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# Species structure and diversity in Achanakmar-Amarkantak Biosphere reserve, Central India

**D. K. Yadav**

Department of Farm Forestry, Sarguja University, Ambikapur-497001 (C.G.), INDIA
E-mail**:** dheerajforestry@gmail.com

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**Abstract:** The present study was aimed at quantifying the species structure and diversity in Achanakmar-Amarkantak Biosphere Reserve. Four sites characterized by varying vegetation attributes and representative of the region were selected. One-hectare, permanent plot was established on each of the site and enumeration was carried out by stratified random sampling techinique. The forest sites are characterized by poor species composition. A sum of 2440 trees representing 23 species and 17 families were encountered. Tree, sapling and seedling density (stems $ha^{-1}$) ranged between 260 - 810, 7500 - 35000 and 25000 - 67500, respectively while the basal cover ($m^2$ $ha^{-1}$) ranged between 9.96 - 41.6, 0.86 - 5.07 and 0.28 - 0.96, respectively. Species diversity was highest on the dense site and low on medium site. Beta diversity was highest on degraded site. The presence of a large number of seedlings indicates the great potential source for future sustainable regeneration, provided by appropriate management regime to protect the forest from degradation and conserve the biodiversity.

**Keywords**: Composition, Permanent plot, Species diversity, Structure, Vegetation

## INTRODUCTION

Biosphere Reserves (BR) are living examples of co-existence of human beings and nature. The Achanakmar-Amarkantak Biosphere Reserve is notified as the 14th National Biosphere Reserve of India by Government of India on 30th March, 2005. Tropical forests are characterized by high species richness, standing biomass and productivity (Jordan, 1983) and their diversity has attracted much attention in recent years (Sagar *et al*., 2003; Sahu *et al*., 2008). In most developing countries, including India, even protected forests experience extensive anthropogenic disturbance due to grazing, extraction of fuelwood and collection of non-wood forest products which contribute to the livelihood of forest dwelling populations (Singh *et al*., 1997; Hegde and Enters, 2000; Pattanayak *et al*., 2003). The degree of anthropogenic disturbance may differ in different parts of a conservation area (Kolongo *et al*., 2006) and it is argued that continuing biomass extraction activities may thwart the very goal of biodiversity conservation (van Schaik *et al*., 1997).

Over the past century virtually all ecosystems on earth have come under increasing human influence. This has been through direct contact and transformation (e.g. for farming, through hunting or the use of fire), the effects of habitat fragmentation, the production of pollutants or the substantial alteration of major biogeochemical cycles, such as the global C, water and N cycles (Vitousek *et al.*, 1997; Ramanathan *et al.*, 2001; Galloway *et al.*, 2002; Malhi and Wright, 2004). However, for tropical forests that are far from most direct human impacts, the question as to whether these ecosystems have been substantially altered and what may be causing these changes is actively debated (Clark, 2004; Lewis *et al.*, 2004).

Disturbances result in changes in species composition and vegetation structure. Altered disturbance regimes tend to cause marked changes in simulated forest composition and to accelerate the rate of forest response to climate change (Overpeck *et al*., 1990). In the dry tropical region, gradual forest destruction results in savannization. The functional importance shifts from the woody canopy to the herbaceous ground stratum where C-4 grasses predominate. This may lead to altered carbon storage/flux relationships and therefore will have implications for global carbon budget (Singh *et al*., 1991). Over the past 50 years, humans have converted and modified natural ecosystems more rapidly and over larger areas than in any comparable period of human history (Steffen *et al*., 2004). These changes have been driven by the rapidly growing demands for food, fish, freshwater, timber, fibre and fuel (Vitousek *et al*., 1997) and have contributed to substantial net gains in human well-being and economic development, while resulting in a substantial and largely irreversible loss of biodiversity and degradation in ecosystems and their services (Reid *et al*., 2005). Biodiversity is a valuable asset, which provides insurance and investment to sustain different ecosystems. India is one of the 12-mega biodiversity regions of the world sharing 8% of the world's total biodiversity. There are increas-

  

ing demands of forest resources in India because majority of people are dependent on forests for livelihoods. Biodiversity in biosphere reserve is threatened due to various anthropogenic disturbances. Understanding the species composition, structure and diversity are important for assessing the forest ecosystems. There is need for conserving biodiversity of tropical deciduous forest ecosystems keeping in view their highly fragmented distribution. These forests are rich in medicinally important plants, minor forest produce and wildlife. There are only a few studies on plant diversity in forest ecosystem of Achanakmar Amarkantak Biosphere reserve. Therefore, the present investigation was carried out to study the species structure and diversity in Achanakmar-Amarkantak Biosphere Reserve, Central India.

## MATERIALS AND METHODS

The present study was carried out at Achanakmar-Amarkantak Biosphere Reserve. The study sites are located in 22º 15' - 22º 58' N latitude and 81º 25' - 82º 5' E longitude having an area of 3835.51 sq. km. Climate is tropical and is influenced by monsoon conditions. The mean monthly temperature varies from 17.2$^{o}$C (January) to 31.8$^{o}$C (May) and the total annual rainfall average 1383 mm, of which 85 % occurs in the rainy season. The soils of the area are generally lateritic, alluvial and black cotton type, derived from granite, gneisses and basalts. The forest is seasonally dry tropical and includes extensive tracts of old growth *Shorea robusta* forest. Forest is classified into Northern Tropical Moist Deciduous and Southern Dry Mixed Deciduous forests (Champion and Seth, 1968). The former type predominates in the Biosphere Reserve area.

Four sites (Dense, Medium, Regenerating and Degraded) characterized by varying vegetation attributes and representative of the region's vegetation were selected. On each site one-hectare permanent plot was established and within the permanent plot ten quadrats (10 × 10 m) was randomly placed for enumeration of tree species. In each quadrat, GBH (girth at breast height) of individual (≥ 30 cm girth) trees was measured. In the center of each 10 × 10 m quadrat, a 2 × 2 m area was marked for enumeration of saplings (individuals > 10 cm - < 30 cm girth) and seedling (individuals < 10 cm girth but ≥ 30 cm height). Thus, all the individuals were measured by species and the diameter of all the individuals was recorded. Species area curve was used to determine minimal sample area which is based on quantitative variation of vegetation in terms of species number (Mullor-Dombios and Ellenberg, 1974). The vegetation data were quantitatively analysed for frequency, density and abundance (Curtis and McIntosh, 1950). An importance value was calculated as the sum total of relative frequency, relative density and relative dominance (Phillips, 1959). Species diversity parameters were determined using basal cover values.

## RESULTS AND DISCUSSION

**Species composition:** In the present study a total of 2440 trees in all the forest sites representing 23 species and 17 families were encountered. The most diverse family was Combretaceae (3) followed by Anacardiaceae (2), Euphorbiaceae (2), Caesalpiniaceae (2), Fabaceae (2), Myrtaceae (1), Rhamnaceae (1), Sapotaceae (1) and Ebenaceae (1). The Dipterocarpaceae family was represented by 131 individuals followed by Combretaceae (39), Anacardiaceae (16) and Ebenaceae (13). In the dense forest a total of 810 stems ha$^{-1}$ representing 16 species and 13 families were encountered. The dipterocarpaceae was represented by 34 individuals followed by 14 individuals of combretaceae, 8 individuals of anacardiaceae and four individuals of euphorbiaceae, annonaceae and ebenaceae, respectively. It is evident from the data presented in the table 1 that *S. robusta* was the most dominant tree followed by *T. tomentosa* and *M. tomentosa* in tree layer. Highest density was recorded in *S. robusta* followed by *T. tomentosa* and *M. tomentosa, D. melanoxylon, B. lanzan* and *E. officinalis.* Lowest density was recorded in case of *S. oleosa, C. graveolena, G. pinnata* and *B. racemosa*. Highest basal area (m$^2$ ha$^{-1}$) was observed for *S. robusta* (20.54) followed by *T. tomentosa* (4.21) and *M. tomentosa* (1.42). Lowest basal area was observed for *B. racemosa* (0.18 m$^2$ ha$^{-1}$). Basal area and density of individual tree species varied from 0.18 m$^2$ ha$^{-1}$ to 20.54 m$^2$ ha$^{-1}$ and 10 to 340 stems ha$^{-1}$, respectively. *S. robusta* showed highest IVI value (123.88) followed by *T. tomentosa* (36.79) and *M. tomentosa* (17.80). The total density and basal area of dense forest was 810 stems ha$^{-1}$ and 34.15 m$^2$ ha$^{-1}$, respectively. Sapling density and basal cover were 27500 stems ha$^{-1}$ and 5.02 m$^2$ ha$^{-1}$. Among the sapling, density (20,000 stems ha$^{-1}$) and basal cover (3.46 m$^2$ ha$^{-1}$) of *M. philipensis* was highest. Among the seedling layers, seedling of *S. robusta* and *D. melanoxylon* was abundant.

In the regenerated forest a total of 760 stems ha$^{-1}$ representing 12 species and 8 families were encountered. The dipterocarpaceae was represented by 50 individuals followed by 14 individuals of combretaceae and 5 individuals of fabaceae. It is evident from the data presented in the table 2 that *S. robusta* was the most dominant tree followed by *T. tomentosa* and *O. oojeinensis* in tree layer. Highest density was recorded for *S. robusta* followed by *T. tomentosa* and *O. oojeinensis.* Lowest density was recorded for *C. graveolena, D. melanoxylon, P. marsupium, B. lanzan* and *S. cumini.* Highest basal area was observed for *S. robusta* followed by *T. tomentosa* and *O. oojeinensis.* Lowest basal area was recorded for *C. graveolena.* Basal area and density of individual tree species varied from 0.10 to 12.92 m$^2$ ha$^{-1}$ and 10 to 500 stems ha$^{-1,}$ respectively. *S. robusta* showed highest IVI value (161.16) followed by *T. tomentosa* (62.05) and *O. oojeinensis* (16.53).

**Table 1.** Species structure of tropical deciduous forest on dense forest site.

| Species | Frequency (%) | Density (stems ha$^{-1}$) | BA (m$^2$ ha$^{-1}$) | IVI |
|---|---|---|---|---|
| **Tree layer** | | | | |
| *Miliusa tomentosa* (Roxb.) J.Sinclair | 40 | 40 | 1.42 | 17.80 |
| *Shorea robusta* Gaertn F. | 100 | 340 | 20.54 | 123.88 |
| *Diospyros melanoxylon* Roxb. | 30 | 40 | 0.72 | 13.57 |
| *Schleichera oleosa* (Lour) Oken. | 10 | 10 | 0.35 | 4.42 |
| *Lannea grandis* Engl. | 40 | 40 | 1.07 | 16.77 |
| *Cassia fistula* Linn. | 20 | 20 | 0.27 | 7.61 |
| *Ougeinia oojeinensis* (Roxb.) Hochr. | 20 | 20 | 0.65 | 8.73 |
| *Casearia graveolena* | 10 | 10 | 0.51 | 4.90 |
| *Buchanania lanzan* _ spreng, | 30 | 40 | 0.81 | 13.84 |
| *Emblica officinalis* Gaerth, | 30 | 40 | 0.43 | 12.73 |
| *Garuga pinnata* Roxb. | 10 | 10 | 0.54 | 4.98 |
| *Lagerstroemia parviflora* Roxb. | 20 | 30 | 0.60 | 9.81 |
| *Anogeissus latifolia* _ Wall. ex Bedd, | 30 | 30 | 0.56 | 11.88 |
| *Bauhinia racemosa* Lam. | 10 | 10 | 0.18 | 3.95 |
| *Terminalia tomentosa* Wt & Ang. | 50 | 110 | 4.21 | 36.79 |
| *Madhuca indica* J.F. Gmel. | 10 | 20 | 1.27 | 8.35 |
| **Total** | **460** | **810** | **34.15** | **300.00** |
| **Saplings** | | | | |
| *Miliusa tomentosa* | 20 | 5000 | 1.20 | 75.36 |
| *Casearia graveolena* | 10 | 2500 | 0.36 | 32.99 |
| *Mallotus philipensis* | 30 | 20000 | 3.46 | 191.65 |
| **Total** | **60** | **27500** | **5.02** | **300.00** |
| **Seedlings** | | | | |
| *Casearia graveolena* | 30 | 7500 | 0.26 | 70.67 |
| *Diospyros melanoxylon* | 30 | 10000 | 0.04 | 41.34 |
| *Shorea robusta* | 40 | 32500 | 0.14 | 96.13 |
| *Syzygium cumini* | 10 | 5000 | 0.07 | 24.47 |
| *Buchanania lanzan* | 10 | 5000 | 0.01 | 14.75 |
| *Anogeissus latifolia* | 10 | 2500 | 0.01 | 10.96 |
| *Mallotus philipensis* | 10 | 2500 | 0.11 | 26.72 |
| *Terminalia tomentosa* | 10 | 2500 | 0.03 | 14.95 |
| **Total** | **150** | **67500** | **0.67** | **300.00** |

The total density and basal area of regenerated forest was recorded 760 stems ha$^{-1}$ and 20.47 m$^2$ ha$^{-1}$, respectively. Density and basal cover of sapling was 35,000 stems ha$^{-1}$ and 5.07. *D. melanoxylon* dominate the sapling layer followed by *C. graveolena*. Seedling layer density and basal area were 92,500 stems ha$^{-1}$ and 0.96 m$^2$ ha$^{-1}$. Seedling layer reveals the good regeneration of *D. melanoxylon* and *S. robusta*.

In the medium forest a total of 610 stems ha$^{-1}$ representing 9 species and 8 families were encountered. The dipterocarpaceae was represented by 47 individuals followed by combretaceae (5) and rhamnaceae (3). Data presented in the table 3 revealed that *S. robusta* was the most dominant among tree layer followed by *T. tomentosa* and *Z. xylopyra*. Highest density was recorded for *S. robusta* followed by *T. tomentosa* and *Z. xylopyra*. Lowest density was recorded for *L. pariviflora*, *D. melanoxylon*, *S. cumini* and *A. latifolia*. Highest basal area was observed in *S. robusta* followed by *T. tomentosa* and *Z. xylopyra*. Lowest basal area was observed in *L. pariviflora*. Basal area and density of tree species varied from 0.10 to 33.07 m$^2$ ha$^{-1}$ and 10 to 470 stems ha$^{-1}$, respectively. *S. robusta* showed highest IVI value (200.02) followed by *T. tomentosa* (33.94) and *Z. xylopyra* (19.84). The total density and basal area of medium forest was 610 stems ha$^{-1}$ and 41.60 m$^2$ ha$^{-1}$, respectively. In sapling layer density and basal area was 20,000 stems ha$^{-1}$ and 2.46 m$^2$ ha$^{-1}$. *S. cumini* and *C. graveolena* were dominant in sapling layer. Density and basal area of seedling layer were 32,500 stems ha$^{-1}$ and 0.42 m$^2$ ha$^{-1}$. *S. robusta* and *C. graveolena* showed the highest regeneration on site.

In the degraded forest a total of 260 stems ha$^{-1}$ representing 7 species and 6 families were encountered. The ebenaceae family was represented by 7 individuals followed by 6 individuals of combretaceae and 5 individuals of sapotaceae. Data presented in the table 4 revealed that *D. melanoxylon* was the most dominant tree layer followed by *T. tomentosa* and *M. indica*. Highest density was recorded for *D. melanoxylon* followed by *T. tomentosa* along with *M. indica* and *B. lanzan*, respectively. Lowest density was recorded in case of *A. latifolia*. Highest basal area was observed for *D. melanoxylon* followed by *B. malabaricum* and *T. tomentosa*. Lowest basal area was recorded for *A. latifolia*. Basal area and density of individual tree species varied from 0.22 to 4.07 m$^2$ ha$^{-1}$ and 10 to 70 stems ha$^{-1}$, respectively. *D. melanoxylon* showed high-

**Table 2.** Species structure of tropical deciduous forest on regenerated forest site.

| Species | Frequency (%) | Density (stems ha$^{-1}$) | BA (m$^2$ ha$^{-1}$) | IVI |
|---|---|---|---|---|
| **Tree layer** | | | | |
| *Terminalia tomentosa* Wt & Ang. | 90 | 120 | 3.53 | 62.05 |
| *Shorea robusta* Gaertn F. | 100 | 500 | 12.92 | 161.16 |
| *Ougeinia oojeinensis* (Roxb.) Hochr. | 20 | 40 | 0.99 | 16.53 |
| *Casearia graveolena* | 10 | 10 | 0.10 | 5.05 |
| *Lannea grandis* Engl. | 20 | 20 | 0.55 | 11.77 |
| *Diospyros melanoxylon* Roxb. | 10 | 10 | 0.11 | 5.10 |
| *Cleistenthus collinus* (Roxb) Benth & Hook. | 10 | 10 | 0.38 | 6.39 |
| *Terminalia chebula* _ Retz. | 10 | 10 | 0.70 | 7.98 |
| *Buchanania lanzan* _ spreng, | 10 | 10 | 0.15 | 5.26 |
| *Anogeissus latifolia* _ Wall. ex Bedd, | 10 | 10 | 0.27 | 5.85 |
| *Pterocarpus marsupium* Roxb. | 10 | 10 | 0.59 | 7.42 |
| *Syzygium cumini* (Linn.) Skeels. | 10 | 10 | 0.18 | 5.44 |
| **Total** | **310** | **760** | **20.47** | **300.00** |
| **Saplings** | | | | |
| *Diospyros melanoxylon* | 60 | 15000 | 2.19 | 135.98 |
| *Casearia graveolena* | 40 | 12500 | 1.55 | 99.63 |
| *Shorea robusta* | 10 | 2500 | 0.68 | 28.90 |
| *Mallotus philipensis* | 10 | 5000 | 0.65 | 35.48 |
| **Total** | **120** | **35000** | **5.07** | **300.00** |
| **Seedlings** | | | | |
| *Diospyros melanoxylon* | 50 | 27500 | 0.47 | 111.92 |
| *Shorea robusta* | 40 | 40000 | 0.20 | 90.95 |
| *Casearia graveolena* | 30 | 10000 | 0.02 | 33.09 |
| *Mallotus philipensis* | 20 | 10000 | 0.26 | 51.72 |
| *Terminalia tomentosa* | **10** | 5000 | 0.01 | 12.33 |
| **Total** | **150** | **92500** | **0.96** | **300.00** |

**Table 3.** Species structure of tropical deciduous forest on medium forest site.

| Species | Frequency (%) | Density (stems ha$^{-1}$) | BA (m$^2$ ha$^{-1}$) | IVI |
|---|---|---|---|---|
| **Tree layer** | | | | |
| *Lagerstroemia parviflora* Roxb. | 10 | 10 | 0.10 | 6.24 |
| *Shorea robusta* Gaertn F. | 100 | 470 | 33.07 | 200.02 |
| *Careya arborea* Roxb. | 20 | 20 | 0.50 | 13.18 |
| *Terminalia tomentosa* Wt & Ang. | 30 | 40 | 5.97 | 33.94 |
| *Diospyros melanoxylon* Roxb. | 10 | 10 | 0.23 | 6.55 |
| *Syzygium cumini* (Linn.) Skeels. | 10 | 10 | 0.44 | 7.04 |
| *Zizyphus xylopyra* Willd, | 30 | 30 | 0.78 | 19.84 |
| *Lannea grandis* Engl. | 10 | 10 | 0.17 | 6.39 |
| *Anogeissus latifolia* _ Wall. ex Bedd, | 10 | 10 | 0.35 | 6.82 |
| **Total** | **230** | **610** | **41.60** | **300.00** |
| **Saplings** | | | | |
| *Syzygium cumini* | 40 | 10000 | 1.08 | 151.04 |
| *Casearia graveolena* | 20 | 7500 | 1.08 | 109.91 |
| *Diospyros melanoxylon* | 10 | 2500 | 0.30 | 39.05 |
| **Total** | **70** | **20000** | **2.46** | **300.00** |
| **Seedlings** | | | | |
| *Diospyros melanoxylon* | 10 | 2500 | 0.02 | 29.18 |
| *Shorea robusta* | 20 | 15000 | 0.01 | 81.83 |
| *Casearia graveolena* | 10 | 10000 | 0.28 | 113.64 |
| *Syzygium cumini* | 10 | 2500 | 0.03 | 31.81 |
| *Lagerstroemia parviflora* | 10 | 2500 | 0.08 | 43.55 |
| **Total** | **60** | **32500** | **0.42** | **300.00** |

est value of IVI (88.81) followed by *T. tomentosa* (59.62) and *M. indica* (39.88). The total density and basal area of degraded forest were 260 stems ha$^{-1}$ and 9.96 m$^2$ ha$^{-1}$, respectively. Density (stems ha$^{-1}$) and basal area (m$^2$ ha$^{-1}$) of sapling layer on this site were 7500 and 0.86, respectively. *S. cumini* was dominant in sapling layer. Seedling density (stems ha$^{-1}$) and basal area (m$^2$ ha$^{-1}$) were 25000 and 0.25, respectively. *C. graveolena* was dominant among seedling layer.

**Species diversity:** Species diversity parameters are summarized in the table 5. Shannon index (H') varied

**Table 4.** Species structure of tropical deciduous forest on degraded forest site.

| Species | Frequency (%) | Density (stems $ha^{-1}$) | BA ($m^2 ha^{-1}$) | IVI |
|---|---|---|---|---|
| **Tree layer** | | | | |
| *Anogeissus latifolia* _ Wall. ex Bedd, | 10 | 10 | 0.22 | 11.36 |
| *Terminalia tomentosa* Wt & Ang. | 50 | 50 | 1.40 | 59.62 |
| *Pterocarpus marsupium* Roxb. | 20 | 20 | 0.57 | 23.99 |
| *Diospyros melanoxylon* Roxb. | 40 | 70 | 4.07 | 88.81 |
| *Buchanania lanzan* _ spreng, | 30 | 40 | 0.58 | 36.96 |
| *Bombax malabaricum Linn*. | 20 | 20 | 2.11 | 39.38 |
| *Madhuca indica* J.F. Gmel. | 20 | 50 | 1.01 | 39.88 |
| **Total** | **190** | **260** | **9.96** | **300.00** |
| **Saplings** | | | | |
| *Syzygium cumini* | 20 | 5000 | 0.64 | 207.88 |
| *Casearia graveolena* | 10 | 2500 | 0.22 | 92.12 |
| **Total** | **30** | **7500** | **0.86** | **300.00** |
| **Seedlings** | | | | |
| *Zizyphus xylopyra* | 10 | 2500 | 0.05 | 44.35 |
| *Diospyros melanoxylon* | 10 | 2500 | 0.01 | 28.49 |
| *Casearia graveolena* | 30 | 17500 | 0.22 | 200.29 |
| *Shorea robusta* | 10 | 2500 | 0.01 | 26.86 |
| **Total** | **60** | **25000** | **0.28** | **300.00** |

**Table 5.** Diversity parameters of tropical deciduous forest on various forest site.

| Parameters | Dense | Regenerated | Medium | Degraded |
|---|---|---|---|---|
| Species richness (d) | 4.2 | 3.6 | 2.14 | 3.9 |
| Shannon index (H') | 2.3 | 1.8 | 1.09 | 2.3 |
| Concentration of dominance (Cd) | 0.38 | 0.43 | 0.65 | 0.25 |
| Equitability (e) | 0.82 | 0.75 | 0.49 | 1.2 |
| Beta diversity (βd) | 5.0 | 7.42 | 10.0 | 12.1 |

from site to site in the study area of Achanakmar-Amarkantak Biosphere Reserve and was recorded 2.3 for dense forest, 1.8 for regeneration forest, 10.9 for medium and 2.3 for degraded forest, respectively.

The values recorded for concentration of dominance (Cd) on different forest sites were 0.38 for dense forest, 0.43 for regeneration forest, 0.65 for medium forest and 0.25 for degraded forest, respectively. Equitability (e) values were 0.82 for dense forest, 0.75 for regeneration forest, 0.49 for medium and 1.2 for degraded forest, respectively. Species richness (d) was highest in dense forest (4.2) followed by degraded forest (3.9), regeneration forest (3.6). However, the lowest value was recorded in medium forest (2.14).Beta diversity (βd) was highest on degraded forest (12.1) followed by medium forest (10.0), regeneration forest (7.42) and the lowest value was recorded on dense forest (5.0), respectively.

The biosphere reserve is presently influenced by various biotic pressures like grazing, forest fire, illicit felling and land use change. These factors are causing great loss to forest health and biodiversity of the region. Anthropogenic disturbance cause a significant impact on regeneration of species, composition, structure, diversity, biomass and carbon storage of the tropics (Yadav and Singh, 2010; Jhariya *et al*., 2012; Pawar *et al*., 2014a & b). The shifts in species composition in natural forest occur slowly under normal conditions but biotic interference can reduce structural and biological complexity (Jhariya *et al*., 2012 and 2014; Kittur *et al*., 2014a & b).

The structural analysis of vegetation revealed the variation in densities and basal covers of different forest sites. Density varied between 260 and 810 stems $ha^{-1}$ and basal cover between 9.96 and 41.60 $m^2 ha^{-1}$. Number of tree species varied from 7 to 16. The number of tree species, density and basal area values are comparable to other tropical forest ecosystems (Murphy and Lugo, 1986b; Singh and Singh, 1991; Sagar *et al*., 2003; Singh *et al*., 2005 and Pande, 2005; Pawar *et al*., 2012). Density of trees (≥ 30 cm gbh) in tropical forests ranges between 245 and 859 (Ashton, 1975 and Richards, 1996) with intermediate values of 436 stems $ha^{-1}$ in Reserva Forestal de San Ramon of Costa Rica (Wattenberg and Breckle, 1995). The density values of the present study were well comparable and within the range of 255-630 stems $ha^{-1}$ (Jhariya *et al*., 2012); 250-335 stems $ha^{-1}$ (Kittur *et al*., 2014a); 380-880 stems $ha^{-1}$ (Jhariya, 2014).

Tree basal cover in the present study varied between 9.96 and 41.60 $m^2 ha^{-1}$ on four forest sites. These basal cover values were higher than the values reported for several dry tropical forest communities in Vindhyan region reported by Jha and Singh (1990) between 6.58 and 23.21 $m^2 ha^{-1}$ and between 3.84 and 10.36 $m^2 ha^{-1}$ by Singh and Singh (1991). These values compare with 17 to 40 $m^2 ha^{-1}$ for dry tropical forest and 20 to 75 $m^2 ha^{-1}$ for wet forest (Murphy and Lugo, 1986b).

The present estimated values of basal area were well comparable and withing the range of 11.46 to 26.67 $m^2$ $ha^{-1}$ (Pawar *et al*., 2014b); 11.13 to 33.54 $m^2$ $ha^{-1}$ (Jhariya, 2014); 10.11 to 15.71 $m^2$ $ha^{-1}$ (Jhariya *et al*., 2012); 12 to 20 $m^2$ $ha^{-1}$ (Kittur *et al*., 2014a) reported for tropical deciduous forest of Chhattisgarh. Basal cover in a Puerto Rican sub-tropical dry forest was 19.8 $m^2$ $ha^{-1}$ (Murphy and Lugo, 1986a). Basal cover and density varied between 12.8 - 13.7 $m^2$ $ha^{-1}$ and 163 - 298 trees $ha^{-1}$, respectively for sal forest in western terai of Nepal (Timilsina *et al.*, 2007). Pande (2005) reported density for trees between 46.93 and 387.5 stems $ha^{-1}$, for shrubs between 114 and 714.95 stems $ha^{-1}$ and for herbs between 15905 to 102078 herbs stems $ha^{-1}$ in Satpura plateau, M.P. Singh *et al.* (2005) observed the density as 1233 stems $ha^{-1}$ and basal cover as 36.36 $m^2$ $ha^{-1}$ for pure sal forest. The degraded moist deciduous forest sites represent the low density (633 stems $ha^{-1}$) and basal cover (32.82 $m^2$ $ha^{-1}$) of tree in Achanakmar wild life sanctuary, Chhattisgarh, India. Tree density in the Vindhyan region ranges between 294 and 627 stems $ha^{-1}$ for several dry tropical forest communities (Singh and Singh, 1991; Jha and Singh, 1990). The forest canopy was three storyed in the present forest. The dry tropical forest usually has 1-3 and the wet tropical forest three or more canopy strata (Murphy and Lugo, 1986b).

Deciduous forests are not considered species rich, but have a diversity of life forms. Still these forests assume unusual significance for conservation since they are the most used and threatened ecosystem, especially in India. Results of diversity parameters revealed that Shannon index (H') values in the present study ranged from 1.09 to 2.3, equitability (e) from 0.49 to 1.2, species richness (d) from 2.14 to 4.2, concentration of dominance (Cd) from 0.25 to 0.65 and beta diversity (βd) from 5.0 to 12.1, respectively. The present study is also comparable with the diversity indices reported in different tropical forests (Singh and Singh, 1991; Pande *et al*., 2002; Singh *et al*., 2005 and Pande, 2005). The Shannon index in the present study was low (1.09 to 2.3) compared to dry *Dipterocarp* forest and mixed deciduous forest of Thailand (3.75 to 4.49; Kiratiprayoon *et al.*, 1995), tropical rain forest of silent valley, India (3.8 to 4.8; Singh *et al*., 1984a) and of Barro Colorado Island (4.8; Knight, 1975). Tripathi *et al*. (2004) reported richness index from 2.25 to 3.94 in humid tropical evergreen forests of Saddle peak area of Andaman Island. Pascal *et al*. (1988) reported the range between 2.1 to 4.3 in different forest ecosystems in Western Ghats. Tripathi *et al*. (2004) reported the species diversity (H) from 2.26 to 3.58 in tropical forests of Andaman. Panchal and Pandey (2004) observed lowest and highest value as 2.034 and 3.53, respectively in tropical forests in Gujrat and sal forest in north India.

Diversity parameters in the tropical dry forest communities of the Vindhyan region (Jha, 1990) had ranges of 0.68 to 2.08 (Shannon - Wiener index), 0.75 - 1.75 (equitability), 1.62 to 7.77 (Simpson's index) and 0.13 to 4.33 (Beta diversity). Diversity in the dry forest of the Vindhyan hill as reported by Singh and Singh (1991) had ranged between 1.93 to 2.82 (Shannon - Wiener index), 0.83 to 1.04 (equitability), 0.18-0.39 (Simpson's index) and 0.88 to 1.4 (Species richness), concentration of dominance from 0.18 to 0.75 and beta diversity was 3.1 for dry deciduous forests of Vindhyan region, India. Sagar and Singh (2003) reported Shannon-wiener index between 1.398 to 2.629 for dry tropical forest located along the disturbance gradient. Diversity of plants in pure sal forest was 2.82 (Shannon index), 4.76 (richness index) and 0.99 (equitability index) as reported by Singh *et al*. (2005).

The Shannon index values of in present study were comparatively lower (3.4 to 4.8 ) than those reported by Singh *et al*. (1984a) for tropical rain forests of Silent valley in Western Ghats, India. De, Aparajita (2007) calculated the diversity values (0.87 - 3.89) from the corridor area of Rajaji Corbett National Parks, Uttaranchal, India. Shannon - Wiener index for tree species was 1.84 - 2.46, 1.39 and 0.53 for Shiwaliks, Doon Valley and outer Himalaya, respectively (Rawat and Bhainsora, 1999). The diversity values obtained in the present study were also comparable to studies conducted in the Corbett National Park (Singh *et al*., 1995), where the values ranged from 1.79 to 3.64. Beta diversity ranged from 5.0 to 12.1, a low index values as compared to those reported by others for communities occurring in different environmental gradients (Adhikari *et al*., 1991). The beta diversity was found to be highest for degraded forests and lowest for dense forest.

## Conclusion

The study suggests that the high level of disturbance due to over exploitation of trees for timber and firewood had critically affected the regeneration status, species structure and diversity of the Biosphere reserve area. This is evidenced by the very low density, diversity and basal area on degraded site. The forest has lost its climax vegetation due to anthropogenic pressure which if increased, may retrogress the succession into a degraded community. Despite the escalating exploitation of the forest, the phytosociological analysis of the Achanakmar Amarkantak Biosphere Reserve indicates that this forest is an extremely important ecosystem by the virtue of high richness and diversity of tree species. The presence of a large number of seedlings in the dense and regenerated sites indicates the great potential source for sustainable regeneration of the forest, provided by appropriate management regime to protect the forest from degradation and conserve the biodiversity.

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