RESEARCH ARTICLE

FLORISTIC COMPOSITION AND DIVERSITY IN THE FOREST FRAGMENTS OF DRY AND MOIST TROPICAL FOREST

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Abstract: The stand attributes in terms of structure and diversity across the forest fragments by forest types have been poorly investigated previously. Therefore, in the present investigation stand attributes i.e., floristic composition, structure and diversity of vegetation growing into two different forest types viz., dry tropical forest (DTF) and moist tropical forest (MTF) of the Chhattisgarh, India is examined. By using field data, collected through random sampling techniques from forest fragmented landscape in the dry and moist forests of Chhattisgarh, India, we were able to visualize the effects and influence on tropical forests. We observed changes in species composition, stand structure and diversity of concerned forest types. The most diverse families were Leguminosae (10), Anacardiaceae (7), Euphorbiaceae (4), Combretaceae (3), Myrtaceae (3), Rhamnaceae (3), Rubiaceae (2) and Rutaceae (2). In the present study a total of 8120 trees ha^{-1} in all the forest sites representing 50 species and 23 families were encountered. The total density of trees varied from 390-2130 trees ha^{-1}, being highest in DTF I while least in MTF II. The diversity indices values reflected that Shannon index recorded for various forest fragments ranged from 2.39-3.62, equitability from 0.75-1.25, species richness from 2.65-6.61, beta diversity from 6.02-20.0 and concentration of dominance from 0.12-1.0, respectively. The present reports highlights the sites conditions for phytosociological attributes at stand levels, which may enriched the information towards sustainable strategies, plan and management of these resource in addition to conservation priority.

Keywords: Biomass, C stock, Diversity, Forest fragments, Structure, Tropical forest

INTRODUCTION

Plants are the basis of life, assets in the landscape and central to people's livelihoods. They deliver natural conservation, ecological balance and benefits in addition to aesthetic values on earth, and people are closely associated to their ecosystem and live in harmony with nature (Kumar et al. 2017; Yadav et al. 2017; Jhariya 2017a; Jhariya et al. 2019). Biodiversity is key aspect for human survival, economic well-being, ecosystem functioning and stability (Singh 2002). The local, regional and global biodiversity of the natural ecosystems is under threat due to forest fragmentation (Wu 2013). The process of forest fragmentation is detrimental and has been under alarming situation worldwide, especially in tropics (Yadav et al. 2017). Fragmentation leads towards reduction of habitat into smaller patches beside loss of forest cover and biodiversity (Collinge 2009). Naturally some habitats are patchy due to site conditions, but biotic interferences have laid noticeably fragmented world's landscapes (Haddad et al. 2015). Consequently, knowing the origin and consequences of fragmentation is critical for biodiversity conservation and appropriate ecosystem functioning.

On a global scale 90% of tropical forests situated outside protected areas (WWF 2002), and it experienced with loss of forest cover as well as biodiversity due to biotic disturbances even within protected woodlands (Majumdar and Datta 2015; Oraon et al. 2014 & 2015; Jhariya and Yadav 2016; Yadav et al. 2019). The alteration in land-use is a determining factor which have key impact on vegetation, site conditions, ecosystems structure and functions (Pimm and Raven 2000; Bihn et al. 2008; Jhariya 2010, 2014; Jhariya et al. 2012, 2014; Kagezi et al. 2016; Jhariya 2017b). India houses nearly 47,513 species of plant (Singh and Dash 2014), which represents 11.40% of global flora (Arisdason and Lakshminarasimhan 2016). Tropical ecosystems are perceived to be rich biodiversity reserves due to diverse environmental and ecological conditions (Apguaua et al. 2015; Gandiwa et al. 2016). Species diversity differs from site to site in tropics due to variation in bio-geography and disturbance regimes (Sundarapandian and Karoor 2013; Kumar et al. 2017; Jhariya 2017a). In India, habitat destruction, over-exploitation, deforestation and species introduction are identified as major causes of diversity loss (UNEP 2001; Panda et al. 2013; Mutiso et al. 2015), and nearly 3.5% annual loss of forest is reported for India (Puyravaud et al. 2010).

Increasing fragmentation resulted in the loss of a valuable portion of the forest ecosystem. Tree species with small populations, will be the first to be lost in the process of forest fragmentation. Information on vegetation structure is important key to understand the forest ecosystems (Naidu and Kumar 2016) and it correspondingly respond to

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alteration governed by natural or anthropogenic means (Sundarapandian and Karoor 2013; Jhariya et al. 2014; Yadav and Jhariya 2017; Yadav et al. 2019). The floristic composition of the forests stand depicts the health of these ecosystems (Krishnamurthy et al. 2010; Jhariya et al. 2012; Thinh et al. 2015; Yadav and Jhariya 2017). The assessment of stand biomass and vegetation carbon is key determinant which defining the role and function of vegetation stands towards global climate (Jhariya and Yadav 2018). In Indian perspectives, the precise estimation of vegetation attributes and ecological services assist by different vegetation in different forest types are limited. Measures of community structure and diversity may better inform how fragmentation affects these biotic communities (Haddad et al. 2015). Here, we present the forest fragments study related to its impact on structure and diversity in different sites by forest type in Chhattisgarh, India.

MATERIALS AND METHODS

Study Site

The study was carried out at Barnawapara wildlife sanctuary (North Raipur, Raipur Forest Division) and Achanakmar-Amarkantak biosphere reserve (Achanakmar, Bilaspur Forest Division). The study includes five site viz. DTF I (Bar), DTF II (Ravan) and DTF III (Lavan range) of Barnawapara wildlife sanctuary (BWS), and MTF I (Game range, Paschim Chaparawa) and MTF II (Shiv Tarai range) of Achanakmar-Amarkantak biosphere reserve (AABR).

BWS is located between $21^0$20‟0” to $21^0$25‟47” north latitudes and $82^0$21‟17” to $82^0$26‟27” east longitudes. The general topography of area is undulating and the area adjoining Nawapara forest village has a number of hillocks scattered all over the area. Dry deciduous forest, grasslands, agriculture lands and human habitations surround the study area. The climate of study area is dry humid tropical. The average annual rainfall in the study area ranges from 1200-1350 mm. The mean monthly maximum temperature ranges from 27.3^0C in January to 41.8^0C in May and mean monthly maximum temperature ranges from 12.7^0C in December to 27.3^0C in May. Soils of study area are grouped into three classes *viz.*, *Inceptisols, Alfisols* and *Vertisols*. The teak forest, sal forest, mixed dry forest and bamboo brakes are major vegetation types found in this region (Champion and Seth 1968).

AABR lies between 22^0 15' to 22^0 58' north latitude and 81^0 25' to 82^0 5' east longitude, having an area of 3835.51 km^2, partly falling in Madhya Pradesh and partly falling in Chhattisgarh state. This region comprised by varying topography, geology and variety of landforms are major attributes of AABR. The area has source of origin of Narmada, Sone and Johilla major river system. The biosphere area has a typical monsoon climate. The forest area of the AABR represents tropical deciduous vegetation and can be classified into Northern tropical moist deciduous and Southern dry mixed deciduous forests (Champion and Seth 1968).

Experimental Details

The study was conducted after repeated reconnaissance survey of BWS and AABR. The stratified random sampling procedure was adopted for characterization of vegetation. The phyto-sociological analysis in each forest fragment was carried by randomly laying sample plots of 10 x 10 m^2 in size. In each quadrate, GBH (Girth at Breast height) of each individual was measured at species level. The vegetation data in each forest fragment was quantitatively analyzed for frequency, density and abundance by using following expressions (Curtis and McIntosh 1950). Basal area of trees was calculated as cross sectional area of stem at breast height i.e. at 1.37 m from the ground level. The relative density, relative frequency, relative basal area, relative abundance was calculated. The Importance Value Index (IVI) was determined as the sum total of relative frequency, relative density and relative dominance (Phillips 1959). The diversity indices were calculated following Sagar and Singh (1999). The data thus generated were synthesized and diversity of each fragment was characterized and correlated with the structure parameters (IVI, basal area, density, etc.).

RESULTS AND DISCUSSION

Stand Structure

In the present study a total of 8120 trees ha^{-1} in all the forest sites representing 50 species and 23 families were encountered. The most diverse families were Leguminosae (10), Anacardiaceae (7), Euphorbiaceae (4), Combretaceae (3), Myrtaceae (3), Rhamnaceae (3), Rubiaceae (2) and Rutaceae (2). Out of which 2130 trees ha^{-1} were encountered in DTF I, 1930 trees ha^{-1} in DTF II, 1030 trees ha^{-1} in DTF III, 2640 trees ha^{-1} in MTF I and 390 ha^{-1} trees in MTF II was observed. Results on phytosociological analysis in various forest fragments are given in the table 1. In DTF I total of 25 species representing 14 families were encountered, in the DTF II 22 species comprising 13 families were recorded while in the DTF III total 10 species having 9 families were encountered. In MTF I total of 25 species distributed in 15 families were encountered whereas MTF II showed 11 species representing 8 families were noticed. The MTF I and DTF I were found to be most diverse and rich in terms of species richness and taxonomic family presence.

It is evident that in the DTF I *Terminalia tomentosa* was the most dominant tree followed by *Cleistenthus collinus* and *Lagerstroemia pariviflora.* Highest density was recorded in *Cleistenthus collinus* followed by *Terminalia tomentosa*, *Lagerstroemia pariviflora, Buchanania lanzan* and *Anogeissus latifolia.* Lowest density was recorded by *Ficus hispida, Holoptelea integrifolia*, *Shorea assamica* and *Delonix regia.* In DTF II *Cleistenthus collinus* was the most dominant species followed by *Diospyros melanoxylon* and *Lagerstroemia pariviflora*. Lowest density was recorded by *Syzygium cumini, Bridelia retusa, Pterocarpus marsupium, Emblica officinalis, Dalbergia paniculata, Buchanania lanzan* and *Andidesma acidum*. It revealed that *Lagerstroemia pariviflora* was the most dominant tree followed by *Ougeinia oojeinensis* and *Diospyros melanoxylon* in DTF III. Lowest density was recorded for *Terminalia tomentosa* and *Limonia acidissima*. It observed in MTF I that *Shorea robusta* was the most dominant tree followed by *Terminalia tomentosa* and *Miliusa tomentosa.* Lowest density was recorded by *Ventilago calyculata, Semecarpus anacardium, Zizyphus xylopyra, Garuga pinnata, Cassia fistula* and *Bauhinia racemosa.* In MTF II *Diospyros melanoxylon* was the most dominant tree layer followed by *Terminalia tomentosa* and *Buchanania lanzan*. Lowest density was recorded for *Anogeissus latifolia, Butea monosperma, Tectona grandis, Emblica officinalis* and *Semecarpus anacardium*.

In DTF I highest basal area was observed in *Terminalia tomentosa* followed by *Cleistenthus collinus, Anogeissus latifolia, Emblica officinalis* and *Terminalia chebula.* Basal area and density of individual tree species varied from 0.02-12.72 m^2 ha^{-1} and 10-410 stems ha^{-1}, respectively. In DTF II maximum basal area was observed in *Cleistenthus collinus* followed by *Terminalia tomentosa* and *Diospyros melanoxylon.* Basal area and density of individual tree species varied from 0.02-8.54 m^2 ha^{-1} and 10-850 stems ha^{-1}, respectively. It reflected that in DTF III higher basal area value was observed in *Ougeinia oojeinensis* followed by *Lagerstroemia pariviflora* and *Diospyros melanoxylon.* Basal area and density of individual tree species varied from 0.17-8.76 m^2 ha^{-1} and 10-340 stems ha^{-1}, respectively. MTF I showed that highest basal area was observed in *Shorea robusta* followed by *Terminalia tomentosa* and *Miliusa tomentosa.* Lowest basal area was recorded in *Semecarpus anacardium, Zizyphus xylopyra* and *Cassia fistula*. Basal area and density of individual tree species varied from 0.01-22.77 m^2 ha^{-1} and 10-1460 stems ha^{-1}, respectively. In MTF II highest basal area was observed in *Diospyros melanoxylon* followed by *Terminalia tomentosa and Semecarpus anacardium*. Basal area and density of individual tree species varied from 0.01-3.43 m^2 ha^{-1} and 10 -100 stems ha^{-1}.

In DTF I *Terminalia tomentosa* showed highest value of IVI (53.67) followed by *Cleistenthus collinus* (40.72) and *Lagerstroemia pariviflora* (23.29). In DTF II *Cleistenthus collinus* showed highest value of IVI (81.69) followed by *Diospyros melanoxylon* (33.24) and *Lagerstroemia pariviflora* (27.29). In DTF III *Lagerstroemia pariviflora* showed highest value of IVI (81.58) followed by *Ougeinia oojeinensis* (63.87) and *Diospyros melanoxylon* (63.15). In MTF I *Shorea robusta* showed highest value of IVI (128.23) followed by *Terminalia tomentosa* (21.63) and *Miliusa tomentosa* (13.4). In MTF II *Diospyros melanoxylon* showed highest value of IVI (73.93) followed by *Terminalia tomentosa* (51.75) and *Buchanania lanzan* (47.25).

Tree basal cover in the present study varied from 10.61-50.90 m^2 ha^{-1} for various forest fragments. These basal cover values were higher than the values reported for several dry tropical forest communities in Vindhyan region by Jha and Singh (1990) between 6.58 and 23.21 m^2 ha^{-1} and from 3.84-10.36 m^2 ha^{-1} by Singh and Singh (1991). The present values were comparable with 17-40 m^2 ha^{-1} for dry tropical forest and 20-75 m^2 ha^{-1} for wet forest (Murphy and Lugo 1986a). Basal cover in a Puerto Rican sub-tropical dry forest was 19.8 m^2 ha^{-1} (Murphy and Lugo 1986b). In the present study, tree density ranged between 390-2640 for various forest fragments in dry and moist deciduous forest. Compared to the present study the density of forest in Thailand, of dry *Dipterocarp* forest, was 554-789 (Visaratana et al. 1986); of mixed deciduous forest was 253 (Sahunalu et al. 1979) and tropical rain forest was 818-1540 (Kiratiprayoon 1986). Tree density in the Vindhyan region ranges between 294-627 stems ha^{-1} for several dry tropical forest communities (Jha and Singh 1990; Singh and Singh 1991). However, Rodgers (1990) reported a very high value of basal cover (131 m^2 ha^{-1}) for the forests of Sariska Tiger Reserve.

Inverse relationship between density and GBH showed small structure of the forests where only 28.57% individuals reflecting in the class exceeding 50 cm GBH. This may be related to faster turnover, biotic removal or low capacity of biomass accumulation. Relating tree density with GBH, in Puerto Rican tropical dry forest, Murphy and Lugo (1986b) have found that only 2.3% individual exceeds 10 cm DBH. Singh and Singh (1991) reported that only 3-5% individuals were in the classes exceeding 50 cm GBH. Similarly, Jhariya (2014) reported that forest possessed small structure as 86.37-91.71% individuals represented by ≤10 cm girth class and nearly 8.29−13.63% represented by exceeding 10 cm girth class whereas 1.58-2.18% individuals were found to exceeding > 50 cm girth class.

The inverse relationship between density and GBH distribution was found. The relationship between girth class (cm) and number of trees for the different forest fragments are illustrated in figure 1. The relationship followed an exponential model [(y = exp (a-bx)] in DTF I, DTF II and DTF III, Logarithmic model in MTF I (ln y = a–b lnx) and followed by the Linear model (y = a+bx) in DTF III. The relationship for DTF I was y = exp (80.69 – 6.028 x), for DTF II y = exp (51.03-0.026 x) and for MTF II y = exp (6.47 – 0.01 x), respectively. The relationship for MTF I was logarithmic, (ln y = 98.28-20.37 ln x) and in case of DTF III the relationship was linear, y = (17.15 – 0.12 x). In all the forest sites studied most of the trees i.e. 71-90% species comes under middle girth class. This indicates that the forest of this study area is under middle aged. Hence, they should be managed on sustainable basis for the future use.

Small fragments of forests have very different ecosystem characteristics than the large forest fragments, supporting more light loving species, more trees with wind or water dispersed seeds and relatively few understorey species (Laurance 1999). Conservation strategies need to ensure the preservation and restoration of large un-fragmented forest habitats in each region (Aksins 1995). It is argued that if environmental changes produced by disturbance are large; it may become lethal to greater numbers of established species than are, or can be immediately replaced by immigrants. Disturbance such as logging, usually cause an immediate decline in biodiversity followed by a recovery, although not necessarily of the same species (Noble and Dirzo 1997). Species richness of the site experiencing disturbances, therefore, will be cumulative outcome of differential responses of species to disturbance. Some species may tolerate the disturbance and the other may disappear.

Collins *et al*. (2009) reported that forest fragmentation has great impact on populations, communities, ecosystems and suggesting that tract will continue to species loss and declines in ecosystem functions for long time. Pawar et al. (2014) reported that 6-12 species of trees were recorded among different sites. The density of tree varied from 100-510 stems ha^{-1} and value of basal area ranged from 11.47-26.67 m^2 ha^{-1}. Bargali et al. (2014) reported tree density was ranged from 650-1520 trees ha^{-1} in tropical forests of Chhattisgarh. Thakur and Swamy (2012) reported the number of species, tree density and basal area were ranged from 9-26, 324-733 trees ha^{-1} and 8.13-28.87 m^2 ha^{-1}, respectively. Yadav and Jhariya (2017) found a sum of 10 tree species in different site and tree density varied from 520-860 individuals ha^{-1} with the basal area of 19.807-40.21 m^2 ha^{-1}, which supports the present findings.

The presence of maximum number of species with only one or 1 to 10 individuals of all the forest sites may indicate the mixed nature of the forest (Richards 2002) and a marked diversity. In the present study the species represented by a single individual varied from 1-28%. Black et al. (1950) in the Amazonian rain forests found that among trees of at least 10 cm dbh, over one third of the species were represented by single individuals.

Many studies suggested that the heterogeneity of the environment as well as disturbance is the prime cause for patch formation in the forests (Jha and Singh 1990). A small number of unique species on the more disturbed sites and a decrease in the total number of species along the disturbance gradient may reflect high utilization pressure (Bhat *et al*. 2000). The recurrent human intervention for collection of fuel wood and minor forest products and the practice of grazing and trampling may change the habitat fitness for many species.

In the natural environment clumped distribution of vegetation is common whereas in uniform condition random distribution is found. The clumped distribution of individuals of a species may be due to insufficient mode of seed dispersal (Richards 1996), or when death of trees creates a large gap encouraging recruitment and growth of numerous saplings (Armesto et al. 1986; Richards 1996). Vegetative reproduction by sucker and coppice also encourages clustering of species (Lieberman 1979). *Anogeissus latifolia*, *Diospyros melanoxylon*, *Lagerstroemia parviflora*, and *Shorea robusta* are the species, which form coppice and as a result of stem poaching, they either recover or increase in number through coppice when the disturbance is moderate. Of this coppice forming species, only *Anogeissus latifolia* and *Shorea robusta* are able to tolerate high degree of disturbance.

The uniform dispersion pattern of species in tropical forest largely enables the maintenance of high levels of diversity. The changes in the dispersion pattern may reflect the reactions of species to disturbance as well as to changes in the habitat conditions. For example, the stem density of species changing from clumped to uniform dispersion was lower and that of species changing from uniform to clumped dispersion was on the more disturbed sites. Uniform dispersion of species is possible in case of edible fruits by birds and animals e.g. *Ziziphus xylopyrus*, *Diospyros melanoxylon*, *Buchanania lanzan*, *Grewia tiliifolia*, *Terminalia chebula* etc. The study of Ramirez-Marcial et al. (2001) showed decreasing density and basal area with disturbance intensity. Smiet (1992) correlated the basal area with disturbance. Current study also indicated that the stem density declined with disturbance. The decline in stem density along the disturbance gradient may be due to gradual increase in the extraction of firewood, small timbers, insect attack and rotting of boles.

Changes in density and basal area of trees in different forest fragments shows that prevailing biotic factors such as exploitation of forests to meet daily requirements of fuel wood, wood for agricultural implements and house hold construction, for preparation of boundaries along the houses and farm land, unregulated grazing by domestic cattle are the key determinants of structure and function of the forest. These factors in the absence of any viable alternatives defy all regulatory measures. As a result the forest goes on degrading year after year without any hope of rejuvenation without exclusion of these pressures. Variation in vegetation attributes such as IVI, tree density, basal area and distribution of tree species at different sites in the forest indicate the complex plant succession resulting from varying degree of pressures at different sites.

Species Diversity

Species diversity, the number of species in a community is ecologically important. The valuations of species diversity (H') at different sites of same locality are not a good sign for better growth of forest of any area. Species diversity parameters are summarized in the table 2.

Shannon index was found to be variable from site to site in the study area of BWS and AABR. The Shannon index values recorded for various forest fragments were 3.62 for DTF I, 3.42 for DTF II, 2.39 for DTF III, 2.42 for MTF I and 2.99 for MTF II. Equitability (e) values were 1.04 for DTF III, 1.11 for DTF II, 1.12 for DTF I, 0.75 for MTF I and 1.25 for MTF II. Species richness was highest in MTF I (6.61) followed by DTF I (6.12), DTF II (5.80) and MTF II (4.24). However, the lowest value was recorded in DTF III (2.65). Beta diversity was highest in MTF II (20.0) followed by DTF III (11.36), DTF II (7.35) and MTF I (6.33) and the lowest value was recorded in DTF I (6.02). The values recorded for concentration of dominance in different forest fragments were 1.0 for DTF I, 0.12 for DTF II, 0.22 for DTF III, 1.0 for MTF I and 0.17 for MTF II.

Various reports are reflected that fragmentation can substantially modify biodiversity of a region as well as ecosystem functioning (Haddad et al. 2015). Moreover, beta diversity pattern can be changed by forest fragmentation overlaying successional dynamics (Alexander et al. 2012). The diversity parameters of these forests can be compared with the diversity indices reported in different tropical forests (Singh and Singh 1991). The Shannon index in the present study was low (2.39-3.62) in various forest fragments compared to Dry *Dipterocarp* forest and mixed deciduous forest of Thailand (3.75-4.49; Kiratiprayoon et al. 1995), tropical rain forest of silent valley, India (3.8-4.8; Singh et al. 1984) and of Barro Colorado Island (4.8; Knight 1975). In other studies, the Shannon index of Thailand forest was 1.9-4.0 for dry *Dipterocarp* forest (Sahunalu et al. 1979; Nilroung 1986) and 5.0-6.2 for tropical rain forest (Kiratiprayoon 1986).

Diversity parameters in the tropical dry forest communities of the Vindhyan region (Jha 1990) had ranges of 0.68-2.08 (Shannon-Wiener index), 0.75-1.75 (equitability), 1.62-7.77 (Simpson's index) and 0.13-4.33 (beta diversity). Diversity in the dry forest of the Vindhyan hill as reported by Singh and Singh (1991) had ranged between 1.93-2.82 (Shannon-Wiener index), 0.83-1.04 (equitability), 0.18-0.39 (Simpson's index) and 0.88-1.4 (Species richness). Prasad and Pandey (1992) in sal and teak forests of Madhya Pradesh found species diversity varying from 0.32-3.76 and concentration of dominance from 0.07-0.63 at different distances from habitation in Bilaspur, Mandla, Balaghat and Jabalpur districts of M.P., India. The forest within habitation recorded lower diversity and dominance compared to forests away from habitation. Sagar and Singh (2003) reported Shannon-Wiener index between 1.398-2.629 for dry tropical forest located along the disturbance gradient.

Singh *et al*. (1984) reported Shannon index value between 3.4-4.8 for tropical rain forests of Silent valley in Western Ghats, India. Similarly, Swamy (1998) reported 1.49-3.67 Shannon index values for tropical evergreen forests of Karnataka, India. It is also evident from the results that Shannon index values were higher than concentration of dominance in different forest fragments. The inverse relationship was found between Shannon index and Simpson's index. These results are in agreement with earlier findings of Singh and Singh (1991) and Swamy (1998). Jhariya et al. (2012) reported the Shannon index value for tropical deciduous forest were ranged from 2.40-3.49, equitability from 0.89-1.28, species richness from 1.62-2.94, concentration of dominance from 0.10-0.32 and beta diversity from 1.35-2.70. Pawar et al. (2014) reported Shannon index ranged from 2.32-2.83, species richness from 1.08-1.91, Cd value from 0.20-0.24, equitability from 1.13-1.29 and beta diversity from 1.50-3.00, respectively which supports the present estimated values. Yadav and Jhariya (2017) found that the Shannon value ranged from 0.159-2.056, Cd from 0.402-0.955, species richness from 0.230-0.936, equitability from 0.148-1.279 and beta diversity from 1.11-5.0 in natural forest and plantation sites of Chhattisgarh, India.

Table 1. Floristic composition and structure of vegetation on different sites

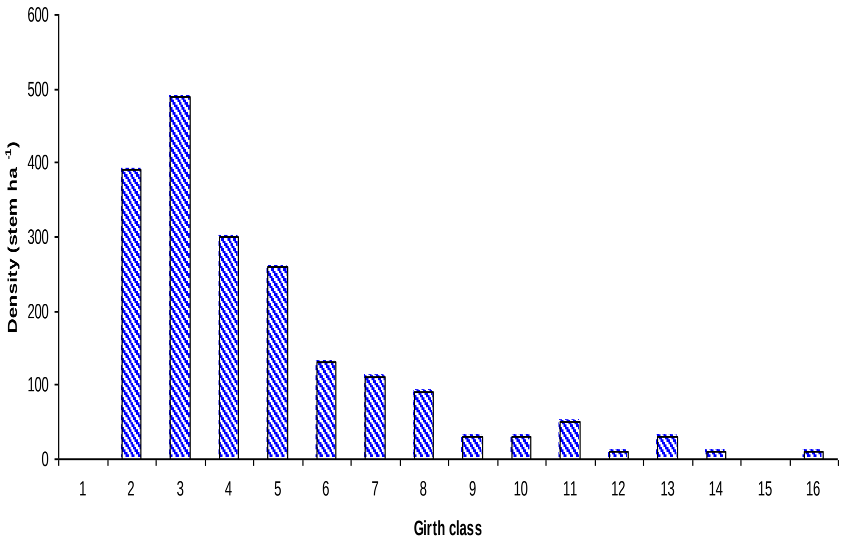
	DTF I				DTF II				DTF III				MTF I				MTF II			
Species	**F**	**D**	**BA**	**IVI**	**F**	**D**	**BA**	**IVI**	**F**	**D**	**BA**	**IVI**	**F**	**D**	**BA**	**IVI**	**F**	**D**	**BA**	**IVI**
Aegle marmelos	10	20	0.12	2.38	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Andidesma acidum	50	80	0.63	11.03	10	10	0.09	2.22	--	--	--	--	--	--	--	--	--	--	--	--
Anogeissus latifolia	60	120	4.51	21.72	50	90	4.18	23.25	--	--	--	--	60	70	0.68	12.04	10	10	0.22	8.67
Bauhinia racemosa	--	--	--	--	--	--	--	--	--	--	--	--	10	10	0.18	2.16	--	--	--	--
Bauhinia variegata	20	20	0.89	5.09	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Bombax malabaricum	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	20	20	0.72	47.25
Bridelia retusa	50	70	1.97	13.18	10	10	0.11	2.29	--	--	--	--	--	--	--	--	--	--	--	--
Buchanania lanzan	70	160	2.64	21.13	10	10	0.38	3.01	--	--	--	--	30	40	0.81	7.45	50	80	1.19	24.37
Butea monosperma	10	20	0.22	2.58	--	--	--	--	--	--	--	--	20	20	0.55	4.71	10	10	0.46	10.89
Caesalpinia sepiaria	--	--	--	--	--	--	--	--	--	--	--	--	60	110	0.21	12.32	--	--	--	--
Careya arborea	10	30	0.98	4.53	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Casearia graveolens	--	--	--	--	--	--	--	--	--	--	--	--	40	60	0.17	7.75	--	--	--	--
Cassia fistula	20	20	0.06	3.47	--	--	--	--	--	--	--	--	10	10	0.01	1.71	--	--	--	--
Chloroxylon swietenia	--	--	--	--	60	80	1.52	17.04	--	--	--	--	--	--	--	--	--	--	--	--
Cleistenthus collinus	60	410	7.25	40.72	100	850	8.54	81.69	70	200	3.68	47.58	--	--	--	--	--	--	--	--
Cordia dichotoma	--	--	--	--	20	20	0.06	4.14	--	--	--	--	--	--	--	--	--	--	--	--
Dalbergia paniculata	--	--	--	--	10	10	0.66	3.76	--	--	--	--	--	--	--	--	--	--	--	--
Delonix regia	10	10	0.16	2	--	--	--	--	10	20	1.05	7.69	--	--	--	--	--	--	--	--
Diospyros melanoxylon	10	30	0.33	3.25	80	160	4.91	33.24	90	200	6.99	63.15	40	150	0.99	13.33	40	100	3.43	73.93
Emblica officinalis	40	90	4.33	17.55	10	10	0.48	3.29	--	--	--	--	60	100	0.65	13.11	10	10	0.23	8.75
Eugenia heyneana	--	--	--	--	--	--	--	--	--	--	--	--	30	30	0.07	5.12	--	--	--	--
Ficus hispida	10	10	0.41	2.49	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Garuga pinnata	50	100	2.63	15.89	--	--	--	--	--	--	--	--	10	10	0.54	3.1	--	--	--	--
Gmelina arborea	--	--	--	--	40	40	0.32	8.8	--	--	--	--	--	--	--	--	--	--	--	--
Grewia tiliaefolia	40	70	1.55	11.14	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Holoptelea integrifolia	10	10	0.02	1.72	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lagerstroemia parviflora	70	200	2.78	23.29	30	280	3.12	27.29	100	340	7.76	81.58	30	100	0.79	9.7	--	--	--	--
Lannea coromandelica	--	--	--	--	50	60	1.65	14.89	20	20	0.31	7.54	--	--	--	--	--	--	--	--
Lannea grandis	--	--	--	--	--	--	--	--	--	--	--	--	60	60	1.18	13.02	--	--	--	--
Limonia acidissima	--	--	--	--	--	--	--	--	10	10	0.17	3.82	--	--	--	--	--	--	--	--
Ixora arborea	--	--	--	--	--	--	--	--	30	40	0.39	12.0	--	--	--	--	--	--	--	--
Madhuca indica	50	120	2.65	16.86	40	40	3.94	18.54	--	--	--	--	20	20	0.56	4.73	20	50	1.0	30.25
Mangifera indica	--	--	--	--	10	40	0.64	5.27	--	--	--	--	--	--	--	--	--	--	--	--
Miliusa tomentosa	--	--	--	--	--	--	--	--	--	--	--	--	50	80	1.53	13.4	--	--	--	--
Mitragyna parviflora	--	--	--	--	--	--	--	--	--	--	--	--	20	40	0.36	4.96	--	--	--	--
Ougeinia oojeinensis	--	--	--	--	--	--	--	--	80	170	8.76	63.87	20	20	0.88	5.59	--	--	--	--
Pterocarpus marsupium	--	--	--	--	10	10	0.51	3.36	--	--	--	--	--	--	--	--	20	20	0.57	18.52
Schleichera oleosa	--	--	--	--	--	--	--	--	--	--	--	--	10	20	0.39	3.08	--	--	--	--
Semecarpus anacardium	--	--	--	--	20	20	0.09	4.22	--	--	--	--	10	10	0.01	1.705	10	10	1.30	18.85
Shorea assamica	10	10	0.03	1.73	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Shorea robusta	--	--	--	--	--	--	--	--	--	--	--	--	100	1460	22.77	128.23	--	--	--	--
Sterculia urens	--	--	--	--	20	30	0.22	5.08	--	--	--	--	--	--	--	--	--	--	--	--
Syzygium cumini	--	--	--	--	10	10	0.02	2.03	--	--	--	--	20	50	0.13	4.75	--	--	--	--
Tectona grandis	10	70	0.32	5.13	20	40	0.44	6.18	--	--	--	--	--	--	--	--	10	10	0.01	6.67
Terminalia chebula	30	30	3.13	11.17	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Terminalia tomentosa	90	380	12.72	53.67	40	80	4.99	23.44	10	10	0.4	4.58	50	110	4.21	21.63	50	70	1.47	51.75
Ventilago calyculata	--	--	--	--	--	--	--	--	--	--	--	--	10	10	0.03	1.76	--	--	--	--

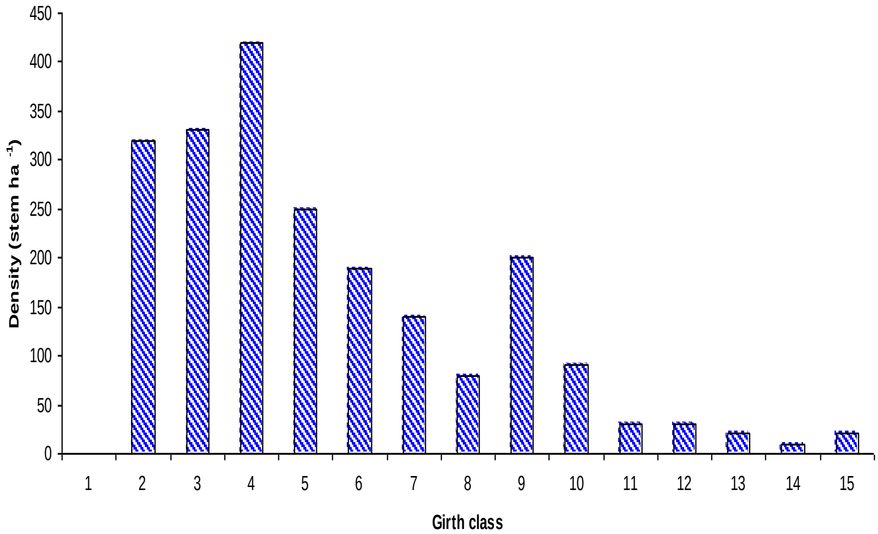
Woodfordia fruticosa	--	--	--	--	--	--	--	--	--	--	--	--	10	40	0.03	2.88	--	--	--	--
Ziziphus mauritiana	20	30	0.33	4.45	--	--	--	--	20	20	0.50	8.15	--	--	--	--	--	--	--	--
Ziziphus xylopyrus	20	20	0.25	3.83	30	30	0.34	6.88	--	--	--	--	10	10	0.01	1.7	--	--	--	--
Total	**830**	**2130**	**50.90**	**300**	**680**	**1930**	**37.21**	**300**	**440**	**1030**	**30.02**	**300**	**790**	**2640**	**37.75**	**300**	**250**	**390**	**10.61**	**300**

Table 2. Diversity parameters of various forest fragments

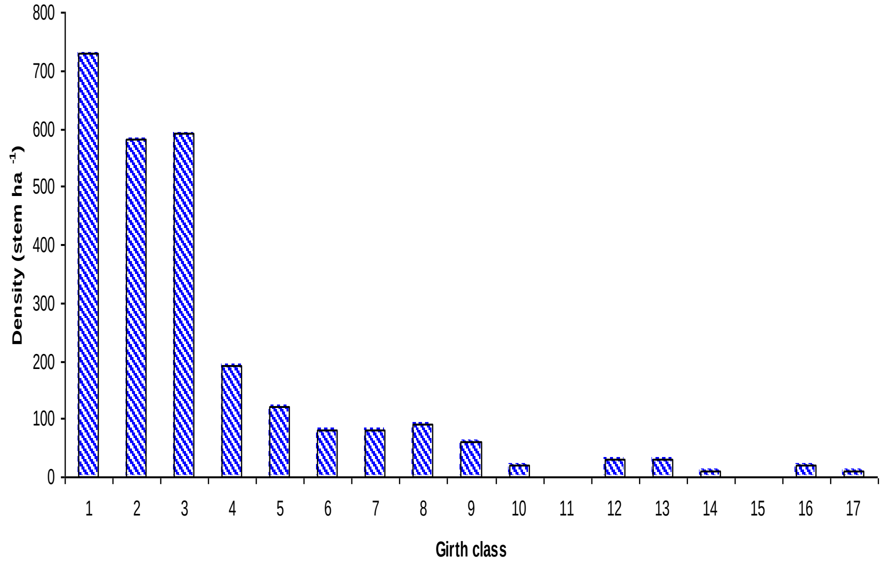
Parameters	**DTF I**	**DTF II**	**DTF III**	**MTF I**	**MTF II**
Species richness (d)	6.12	5.80	2.65	6.61	4.24
Shannon index (H’)	3.62	3.42	2.39	2.42	2.99
Concentration of dominance (Cd)	1.0	0.12	0.22	1.00	0.17
Equitability (e)	1.12	1.11	1.04	0.75	1.25
Beta diversity (βd)	6.02	7.35	11.36	6.33	20.0



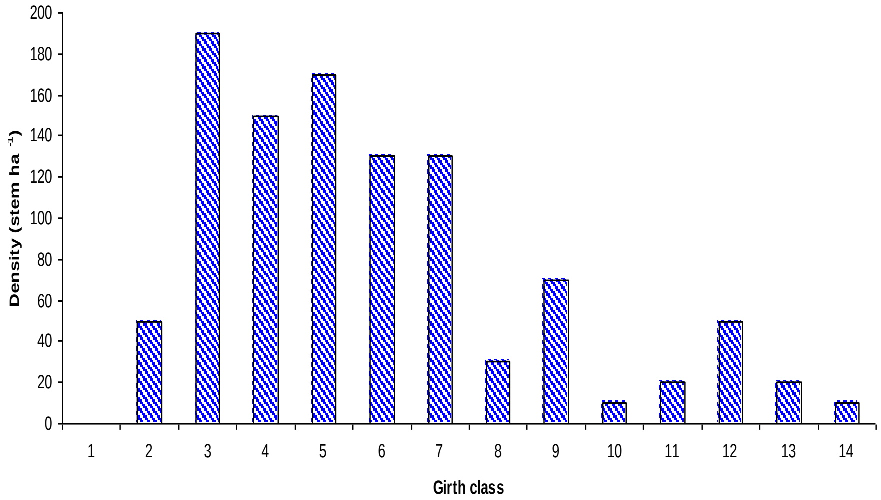
DTF I



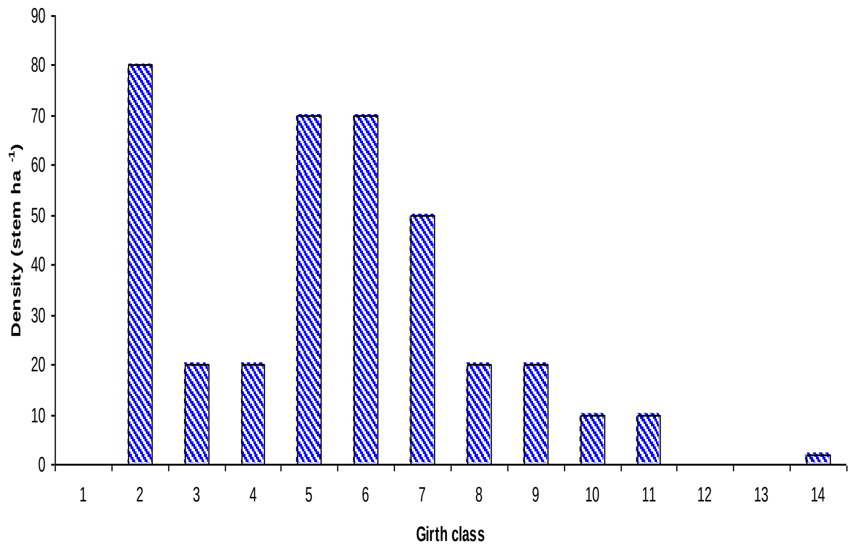
DTF II



DTF III



MTF I



MTF II

Figure 1. Woody species density and mean girth classes (cm) relationship: 1 (≤10), 2(>10≤20), 3(>20≤30)..……… and so on

CONCLUSION

The forest fragmentation significantly influenced the floristic structure, composition and diversity of studied sites. The increasing biotic interferences are degrading these forests and resulting in poor density, basal area and diversity. The changes in community and vegetation structure caused by disturbances have a significant effect on the ecosystem processes. Among the different forest fragments MTF II seems to be more affected as compared to other sites. Some species showed dominate position in forest stands, as revealed by the higher frequency, density and basal cover retained by them. If these species are protected or retained as such then it is possible to obtain long-term ecosystem services on sustainable basis. The study recommends adopting intensive conservation measures especially in degraded areas of the forest. Efforts are needed to regulate the biotic pressure in the vicinity of dwellings and protecting the forests would go a long way in rejuvenating the lost forest ecosystem.

REFERENCES

Alexander, H.M., Foster, B.L., Ballantyne, F. IV, Collins, C.D., Antonovics, J. and Holt, R.D. (2012). Metapopulations and metacommunities: combining spatial and temporal perspectives in plant ecology. *J Ecol*, 100:88–103.

Alone, R.A. (2014). Biomass, carbon stock and carbon sequestration in an age series of teak plantation in tropical environment. Ph.D. Thesis, I.G.K.V., Raipur (C.G.), 240 p.

Aksins (1995). Speciation among tropical forest trees: some deductions in light of recent evidence. *Biol J Linn Soc*, 1:155-196.

Apguaua, D.M.G., Pereira, R.M., Santos, G.C.O., Menino, G.G., Pires, M.A.L.F. and Dyp, T.N.G. (2015). Floristic Variation within Seasonally Dry Tropical Forests of the Caatinga Biogeographic Domain, Brazil, and Its Conservation Implications. *Int For Rev*, 17(S2):33.

Arisdason, W. and Lakshminarasimhan, P. (2016). Status of Plant Diversity in India: An Overview. http://www.bsienvis.nic.in/Database/Status_of_Plant_Diversity in India 17566.aspx.

Armesto, J.J., Mitzel, J.D. and Villagram, C. (1986). A comparison of spatial patterns of trees in some tropical and temperate forests. *Biotropica*, 18:1-11.

Baisya, R., Barik, S.K. and Upadhayay, K. (2009). Distribution pattern of above ground biomass in natural and plantation forests of humid tropics in NE-India. *Tropical Ecology*, 50(2):295-304.

Bargali, S.S., Pandey, V.P. and Bargali, K. (2014). Floral composition and diversity pattern in open and closed dry deciduous forest. *Vegetos*, 27(2):149-157.

Bhat, D.M., Naik, M.B., Patagar, S.G., Hegde, G.T., Kandade, Y.G., Hegde, G.N., Shastri, C.M., Shetti, D.M. and Furtado, R.M. (2000). Forest dynamics in tropical rain forests of Uttara Kannada district in Western Ghats, India. *Current Science*, 79:975-985.

Bihn, J.H., Verhaagh, M., Brandle, M. and Brandl, R. (2008). Do secondary forests act as refuges for old growth forest animals? Recovery of ant diversity in the Atlantic forest of Brazil. *Biol Conserv*, 141:733-743.

Black, G.A., Dobzhansky, T. and Pavan, C. (1950). Some attempts to estimate species diversity and population density of trees in Amazonian forests. *Bot Gaz*, 111:413-425.

Borah, N., Nath, A.J. and Das, A.K. (2013). Aboveground biomass and carbon stocks of tree species in tropical forests of Cachar districts, Assam, Northeast India. *International Journal of Ecology and Environment Sciences*, 39(2):97-106.

Cairns, M.A., Haggerty, P.K., Alvarez, R., De Jong, B.H.J. and Olmsted, I. (2000). Tropical Mexico's recent land use and change: a region´s contribution to the global carbon cycle. *Ecological Applications*, 10:1426-1441.

Cairns, M.A., Olmsted, I., Granados, J. and Argaez, J. (2003). Composition and aboveground tree biomass of a dry semi-evergreen forest on Mexico's Yucatan peninsula. *Forest Ecology and Management*, 186:125-132.

Champion, H.G. and Seth, S.K. (1968), *A revised Survey of the Forest Types of India*. Government of India Publication, New Delhi.

Chauhan, D.S., Singh, B., Chauhan, S., Dhanai, C.S. and Todaria, N.P. (2010). Regeneration and plant diversity of natural and planted sal (*Shorea robusta* Gaertn.F.) forests in the Terai Bhabhar of Sohagibarwa Wildlife Sanctuary, India. *J. American Science*, 6(3):32-45.

Collinge, S.K. (2009). *Ecology of fragmented landscapes*. Johns Hopkins University Press, Baltimore.

Collins, C.D., Holt, R.D. and Foster, B.L. (2009). Patch size effects on plant species decline in an experimentally fragmented landscape. *Ecology*, 90:2577–2588.

Curtis, J.T. and McIntosh, R.P. (1950). The interrelations of certain analytic and synthetic phytosociological characters. *Ecology*, 31:434-455.

Devagiri, G.M., Money, S., Singh, S., Dadhawal, V.K., Patil, P., Khaple, A. and Hubballi, S. (2013). Assessment of above ground biomass and carbon pool in different vegetation types of south western part of Karnataka, India using spectral modeling. *Tropical Ecology*, 54(2):149-165.

Gairola, S., Sharma, C.M., Ghildiyal, S.K. and Suyal, S. (2011). Live tree biomass and carbon variation along an altitudinal gradient in moist temperate valley slopes of the Garhwal Himalaya (India). *Current Science*, 100(10):1-9.

Gandiwa, P., Finch, J. and Hill, T. (2016). Vegetation structure and composition in the semi-arid Mapungubwe Cultural Landscape. *Glob J Environ Sci Manag*, 2(3):235-248.

Haddad, N.M., Brudvig, L.A., Clobert, J., Davies, K.F., Gonzalez, A., Holt, R.D., Lovejoy, T.E., Sexton, J.O., Austin, M.P., Collins, C.D., Cook, W.M., Damschen, E.I., Ewers, R.M., Foster, B.L., Jenkins, C.N., King, A.J., Laurance, W.F., Levey, D.J., Margules, C.R., Melbourne, B.A., Nicholls, A.O., Orrock, J.L., Song, D.X. and Townshend, J.R. (2015). Habitat fragmentation and its lasting impact on Earth's ecosystems. *Sci Adv*, 1:e1500052.

Hoover, C.M., Leak, W.B. and Keel, B.G. (2012). Benchmark carbon stocks from old growth forests in Northern New England, USA. *Forest Ecology and Management*, 266:108-114.

Jha, C.S. (1990). Land use and vegetation analysis of dry tropical forest region. Ph.D. Thesis, Banaras Hindu University, Varanasi, India.

Jha, C.S. and Singh, J.S. (1990). Composition and dynamics of dry tropical forest in relation to soil texture. *J Veg Sci*, 1:609-614.

Jhariya, M.K. (2010). Analysis of vegetational structure, diversity and fuel load in fire affected areas of tropical dry deciduous forests in Chhattisgarh. M.Sc. Thesis, I.G.K.V., Raipur (C.G.), 86 p.

Jhariya, M.K., Bargali, S.S., Swamy, S.L. and Kittur, B. (2012). Vegetational Structure, Diversity and Fuel Load in Fire Affected Areas of Tropical Dry Deciduous Forests in Chhattisgarh. *Vegetos*, 25(1):210-224.

Jhariya, M.K., Bargali, S.S., Swamy, S.L., Kittur, B., Bargali, K. and Pawar, G.V. (2014). Impact of forest fire on biomass and Carbon storage pattern of Tropical Deciduous Forests in Bhoramdeo Wildlife Sanctuary, Chhattisgarh. *Int J of Ecol Environ Sci*, 40(1):57-74.

Jhariya, M.K. (2014). Effect of forest fire on microbial biomass, storage and sequestration of carbon in a tropical deciduous forest of Chhattisgarh. *Ph.D. Thesis*, I.G.K.V., Raipur (C.G.), 259 p.

Jhariya, M.K. and Yadav, D.K. (2016). Understorey Vegetation in Natural and Plantation Forest Ecosystem of Sarguja (C.G.), India. *Journal of Applied and Natural Science*, 8(2):668-673.

Jhariya, M.K. (2017a). Vegetation ecology and carbon sequestration potential of shrubs in tropics of Chhattisgarh, India. *Environmental Monitoring and Assessment*, 189(10): 1-15. 518, https://doi.org/10.1007/s10661-017-6246-2.

Jhariya, M.K. (2017b). Influences of Forest Fire on Forest Floor and Litterfall in Bhoramdeo Wildlife Sanctuary (C.G.), India. *Journal of Forest and Environmental Science*, 33(4):330-341.

Jhariya, M.K. and Yadav, D.K. (2018), Biomass and carbon storage pattern in natural and plantation forest ecosystem of Chhattisgarh, India. *Journal of Forest and Environmental Science*, 34(1):1-11. DOI: 10.7747/JFES.2018.34.1.1.

Jhariya, M.K., Banerjee, A., Meena, R.S. and Yadav, D.K. (2019). Sustainable Agriculture, Forest and Environmental Management. Springer Nature Singapore Pte Ltd., 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore. eISBN: 978-981-13-6830-1, Hardcover ISBN: 978-981-13-6829-5. DOI: 10.1007/978-981-13-6830-1. Pp. 60.

Kagezi, G.H., Kaib, M., Nyeko, P, Bakuneeta, C., Schadler, M., Stadler, J. and Brandl, R. (2016). Impacts of land-use intensification on litter decomposition in western Kenya. *Web Ecol*, 16:51-58.

Khurana, P. (2007). Tree layer analysis and regeneration in tropical dry deciduous forest of Hastinapur. *Indian Forester*, 16(1):43-50.

Krishnamurthy, Y.L., Prakasha, H.M., Nanda, A., Krishnappa, M., Dattaraja, H.S. and Suresh, H.S. (2010). Vegetation structure and floristic composition of a tropical dry deciduous forest in Bhadra Wildlife Sanctuary, Karnataka, India. *Trop Ecol*, 51(2):235-246.

Kumar, A., Jhariya, M.K., Yadav, D.K. and Banerjee, A. (2017). Vegetation Dynamics in Bishrampur Collieries of Northern Chhattisgarh, India: Eco-restoration and Management Perspectives. *Environmental Monitoring and Assessment*, 189(8), DOI: 10.1007/s10661-017-6086-0.

Kumar, J.I.N., Kumar, R.N., Bhoi, R.K. and Sajish, P.R. (2010). Tree species diversity and soil nutrient status in three sites of tropical dry deciduous forest of western India. *Tropical Ecology*, 51(2):273-279.

Laurance, W.F. (1999). Ecology and management of fragmented tropical landscapes - introduction and synthesis. *Biol Conserv*, 91:101-107.

Lieberman, D. (1979). Dynamics of forest and thicket vegetation on the Accra plains, Ghana. Ph.D. Thesis, University of Ghana, Legon.

Majumdar, K. and Datta, B.K. (2015). Vegetation types, dominant compositions, woody plant diversity and stand structure in Trishna Wildlife Sanctuary of Northeast India. *J Env Bio*, 36:409-418.

Metzker, T., Sposito, T.C., Martins, M.T.F., Horta, M.B. and Garcig, Q.S. (2011). Forest dynamics and carbon stocks in Rio Doce state park an Atlantic rainforest hotspot. *Current Science*, 100(12):1855-1862.

Mohanraj, R., Saravanan, J. and Dhanakumar, S. (2011). Carbon stock in Kolli forests, Eastern Ghat (India) with emphasis on aboveground biomass, litter, woody debris and soil. Forest Biogeosciences and Forestry, 4, 61-65.

Murphy, P.G. and Lugo, A.E. (1986a). Ecology of tropical dry forest. *Annual Review of Ecology and Systematics*, 17, 67-88.

Murphy, P.G. and Lugo, A.E. (1986b). Structure and biomass of a subtropical dry forest in Puerto Rico. *Biotropica*, 18:89-96.

Mutiso, F.M., Mugo, M.J., Cheboiwo, J., Sang, F. and Tarus, G.K. (2015). Floristic Composition, Affinities and Plant Formations in Tropical Forests: A Case Study of Mau Forests in Kenya. *Int J Agric For*, 5(2):79-91.

Naidu, M.T. and Kumar, O.A. (2016). Tree diversity, stand structure, and community composition of tropical forests in Eastern Ghats of Andhra Pradesh, India. *J Asia Pac Biodivers*, 9:328-334.

Nascimento, H.E.M. and Laurance, W.F. (2002). Total aboveground biomass in central Amazonian rainforests: a landscape-scale study. *Forest Ecology and Management*, 168(1/3):311-321.

Nilroung, S. (1986). Structural characteristics, Rate of Gap Formation and Turnover Rate in Dry Dipterocarp Forest at Sakaerat. M.Sc. Thesis, Kasetsart University (in Thai).

Nobel, I.R. and Dirzo, R. (1997). Forests as human-dominated ecosystems. *Science*, 277:522-525.

Oraon, P.R., Singh, L. and Jhariya, M.K. (2014). Variations in Herbaceous Composition of Dry Tropics Following Anthropogenic Disturbed Environment. *Current World Environ*, 9(3):967-979.

Oraon, P.R., Singh, L. and Jhariya, M.K. (2015). Shrub Species Diversity in Relation to Anthropogenic Disturbance of Bhoramdeo Wildlife Sanctuary, Chhattisgarh. *Environment and Ecology*, 33(2A):996-1002.

Panda, P.C., Mahapatra, A.K., Acharya, P.K. and Debata, A.K. (2013). Plant diversity in tropical deciduous forests of Eastern Ghats, India: A landscape level assessment. *Int J Biodivers Conserv*, 5(10):625-639.

Pande, P.K. and Patra, A.K. (2010). Biomass and productivity in Sal and miscellaneous forests of Satpura plateau (Madhya Pradesh) India. *Advances in Bioscience and Biotechnology*, 1:30-38.

Pawar, G.V., Singh, L., Jhariya, M.K. and Sahu, K.P. (2014). Assessment of Diversity along the Disturbance Gradient in Dry Tropics of Chhattisgarh, India. *The Ecoscan*, 8(3-4):225-233.

Phillips, E.A. (1959). *Methods of Vegetation Study*. Holt R and Winston, NewYork USA. 105 p.

Pimm, S.L. and Raven, P. (2000). Biodiversity: extinction by numbers. *Nature*, 403:843–845.

Prasad, R. and Pandey, R.K. (1992). An observation on plant diversity of Sal and teak forest in relation to intensity of biotic impact of various distances from habitation in Madhya Pradesh, A case study. *Journal of Tropical Forestry*, 8(1):62-83.

Puyravaud, J.P., Davidar, P. and Laurance, W.F. (2010). Cryptic loss of India's native forests. *Conserv Lett*, 3(6):390-394.

Ramirez-Marcial, N., Gonzalez-Espinosa, M. and Williams-Linera, G. (2001). Anthropogenic disturbance and tree diversity in montane rain forest in Chiapas, Mexico. *For Ecol Manage*, 154:311-326.

Rawat, V.S. (2012). Litter fall and soil nutrient returns in community managed forest in Lamgara block of Uttarakhand. *Nature and Science*, 10(12):38-42.

Richards, P.W. (1996). *The tropical rainforest*. 2nd ed. Cambridge Univ. Press, Cambridge.

Richards, P.W. (2002). Composition of primary rain forest (II). In: Chazdon, R.L., Whitmore, T.C. (Eds.) Foundations of Tropical Forest Biology. The University of Chicago Press, Chicago and London, pp. 538-544.

Rodgers, W.A. (1990). A preliminary ecological survey of Algual spring Sariska Tiger Reserve, Rajasthan. *Journal of Bombay Natural History Society*, 87:201-209.

Sagar, R. and Singh, J.S. (1999). Species diversity and its measurement. *The Botanica*, 49:9-16.

Sagar, R. and Singh, J.S. (2003). Predominant phenotypic traits of disturbed tropical dry deciduous forest vegetation in northern India. *Community Ecology*, 4:63-71.

Sahunalu, P., Chamrenpruk, M., Puriyakorn, B., Dhanmanonda, P., Suwannapin, W. and Prachaiya, B. (1979). Structure of three forest types in the Prom Basin, Chaiyaphum provinance. Forest Research Bulletin No. 63, Faculty of Forestry, Kasetsart University (in Thai).

Sharma, C.M., Baduni, N.P., Gairola, S., Ghildiyal, S.K. and Suyal, S. (2010). Tree diversity and carbon stocks of some major forest types of Garhwal Himalaya, India. *Forest Ecology and Management*, 260(12):2170-2179.

Singh, J.S. (2002). The biodiversity crisis: a multifaceted review. *Current Science*, 82:638-647.

Singh, J.S., Saxena, A.K. and Rawat, Y.S. (1984). India‟s silent valley and its threatened rain forests ecosystem. *Environmental Conservation*, 11:223-233.

Singh, L. and Singh, J.S. (1991). Species structure, dry matter dynamics and carbon flux of a dry tropical forest in India. *Annals of Botany*, 68:263-273.

Singh, L., Yadav, D.K., Pagare, P., Lekha, G. and Thakur, B.S. (2009). Impact of land use changes on species structure, biomass and carbon storage in tropical deciduous forest and converted forest. *International Journal of Ecology and Environmental Sciences*, 35(1):113-119.

Singh, P. and Dash, S.S. (2014). Plant Discoveries 2013 – New Genera, Species and New Records. Botanical Survey of India, Kolkata.

Smiet, A.C. (1992). Forest Ecology on Java: human impact and vegetation of montane forest. *J Trop Ecol*, 8:129-152.

Sundarapandian, S. and Karoor, P.J. (2013). Edge effects on plant diversity in tropical forest ecosystems at Periyar Wildlife sanctuary in the Western Ghats of India. *J Forest Res*, 24(3):403-418.

Swamy, S.L. (1998). Estimation of net primary productivity (NPP) in an Indian tropical evergreen forest using Remote Sensing data. *Ph.D. Thesis,* Jawaharlal Nehru Technology University, Hyderabad.

Tang, J.W., Yin, J.X., Qi, J.F., Jepsen, M.R. and Lu, X.T. (2012). Ecosystem carbon storage of tropical forests over limestone in Xishuangbanna, SW China. *Journal of Tropical Forest Sciences*, 24(3):399-407.

Thakur, T. and Swamy, S.L. (2012). Analysis of land use, diversity, biomass, C and nutrient storage of a dry tropical forest ecosystem of India using satellite remote sensing and GIS techniques. In: Proceedings of the 15th International Forestry and Environment Symposium, 15:273- 278.

Thinh, N.V., Mitlohner, R. and Bich, N.V. (2015). Comparison of floristic composition in four sites of a tropical lowland forest on the North-Central Coast of Vietnam. *J Nat Sci*, 1(8):144.

Tiwari, A.K. (1994). Mapping forest biomass through digital processing of IRS-1A data. *International Journal of Remote Sensing*, 15(9):1849-1866.

Thokchom, A. and Yadava, P.S. (2013). Biomass and carbon stock assessment in the sub-tropical forests of Manipur, North-East India. *International Journal of Ecology and Environment Science,* 39(2):107-113.

UNEP (2001). India: State of the Environment - 2001. United Nations Environment Programme.

Visaratana, T., Pitprecha, K., Kiratiprayoon, S., Kampan, T. and Higuchi, K. (1986). Structural characteristics and species composition of dry Dipterocarp forest (*Dipterocarpus tuberculatus* Roxb. Community type) at Salak Phra Wildlife Sanctuary. Technical Paper No. 10 Forest Ecology Section, FRd (in Thai).

Wu, J.G. (2013). Key concepts and research topics in landscape ecology revisited: 30 years after the Allerton Park workshop. *Landsc Ecol*, 28:1–11.

WWF (2002). Forest management outside protected areas. World Wildlife Fund (WWF), Gland, Switzerland.

Yadav, D.K. and Jhariya, M.K. (2017). Tree Community Structure, Regeneration and Patterns of Diversity in Natural and Plantation Forest Ecosystem. *Research in Environment and Life Sciences*, 10(4):383-389.

Yadav, D.K., Ghosh, L. and Jhariya, M.K. (2017). *Forest Fragmentation and Stand Structure in Tropics: Stand Structure, Diversity and Biomass*. *Lap Lambert Academic Publishing***.** Heinrich-Bocking-Str. 6-8, 66121, Saarbrucken, Germany. Pp. 116. ISBN: 978-3-330-05287-1.

Yadav D.K., Jhariya, M.K. and Ghosh, L. (2019). Vegetation inter-relationship and regeneration status in tropical forest stands of central India. *Journal of Plant Development Sciences*, 11(3):151-159.

Yadava, P.S. (2010). Soil and vegetation carbon pool and sequestration in the forest ecosystem of Manipur, NE India. Pages 163-170, In: Qasim SZ, Goel M. (Editors) CO_2 Sequestration Technology for Clean Energy. Daya Publication House, New Delhi.