Effect of anthropogenic disturbances on biomass and carbon storage potential of a dry tropical forest in India

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Abstract The forests of Chhattisgarh ares very well known for its species richness, diversity, biomass, carbon stock and productivity**.** The present study was carried out at Katghora forest division under Bilaspur circle of Korba district, Chhattisgarh considering three sites viz., least, moderately and highly disturbed site to estimate biomass and carbon storage in relation to anthropogenic disturbances. For collection of data quadrats were selected under stratified random sampling design. For enumeration of tree and saplings ten quadrats of 10 m × 10 m were laid and each species counted separately. The tree density varies from 100-510 stems ha^{-1} across study sites. Total biomass in the present study was between 127.69 t ha^{-1} and 227.71 t ha^{-1}. Total above ground biomass was between 111.20 t ha^{-1} and 199.42 t ha^{-1}, whereas total below ground biomass varied from 16.49-28.29 t ha^{-1}, respectively. The total carbon storage across the sites were ranged from 55.125 to 98.548 t C ha^{-1} found higher under least disturbed site and lowest under medium disturbed site. Carbon storage pattern according to girth class followed the similar trend of distribution as was in the case of biomass. It has least proportion in small girth class and maximum storage under the higher girth class. It is evident from the study that disturbances have significant impact on density, vegetation diversity, biomass accumulation and carbon storage pattern. Conservation affords are required to control on disturbances and for the natural recovery of forest ecosystem.

Keywords: Biomass, Carbon storage, Diversity, Species richness, Tropical forests

INTRODUCTION

The tropical forests have well known for its vegetation diversity, species richness as well as important role in biomass accumulation and in carbon cycle. Anthropogenic disturbance can change the successional pattern of stand, subsequent diversity and biomass of forest. Quantification of biomass is required to better know the structure and functions of the ecosystem (Ovington, 1962; Brown *et al.*, 1999) and for evaluate the status and trends of forest ecosystems along the wide range of environmental gradients. The structural and functional processes have to be quantified for thoroughly understanding the vegetation dynamics. On the other hand, woody biomass is also necessary for determining the status and flux of biological materials in an ecosystem (Anderson, 1970). Understanding the patterns of storage and production of organic matter in forests in relation to the disturbances is critical for management purposes and an essential aspect of studies of carbon cycle (Keller *et al.*, 2001; Ketterings *et al.*, 2001; Cairns *et al.*, 2003) which can also be used to understand changes in forest structure resulting from succession or to differentiate between forest types (Cairns *et al.*, 2003). In the last few years, there has

been increasing interest in the quantification of the biomass of forest ecosystems and its potential C fixation (Usuga *et al.*, 2010; Jhariya, 2014; Jhariya *et al.*, 2014). Live tree biomass pool is an important source of uncertainty in C balance from the tropical regions in part due to scarcity of reliable estimates of tree biomass and its variation across landscapes and forest types (Alves *et al.*, 2010).

In developing countries, protected forests are facing high anthropogenic disturbance due to fire, grazing, lopping, felling, fuel wood extraction and collection of non - timber forest products (NTFPs) for livelihood of forest dwelling populations (Jhariya *et al.*, 2014). The total forest cover of India is 21.05% of the geographical area and have the total carbon stock in India's forests is to be 6663 m tones (FSI, 2011). In Chhattisgarh biotic interference are more frequent in tropical deciduous forests and limited work has been done in these forests in relation to different anthropogenic disturbance gradient (Singh *et al.*, 2009; Jhariya, 2010; Pawar *et al.*, 2012; Jhariya *et al.*, 2012; Jhariya *et al.*, 2014; Kittur *et al.*, 2014). These factors causing great loss to biodiversity and ultimately destructing the natural vegetation and habitat of the region. However, there is severe ongoing anthropogenic pressure on the tropical forests which calls for sustainable forestry to

reduce poverty, integrating forests into sustainable economic development and protecting local and global forest values. Understanding vegetation changes following the disturbances caused by different factors is essential for developing management practices involving natural regeneration and to maintain the overall biodiversity, productivity and sustainability. Presently there is a dearth of information on the effect of anthropogenic disturbances on biomass, carbon storage potential of such forest. So, present study was carried out to fill the knowledge gap regarding this attributes.

MATERIALS AND METHODS

The study was carried out at Katghora forest division under Bilaspur circle of Korba district (Chhattisgarh) during the year 2010-2011. The area was located between 22°26'49" to 22°28'74" North latitudes and 82°19'30" to 82°22'97" East longitudes. It comprises about 4187.371 sq. km of which 2834.968 sq. km was protected forests area and 1352.403 sq. km was unclassified forests. Physiographically the area comes under Satpura and Maikal Mountain ranges and generally the topography was undulated. The climate of study area was sub humid to humid and the average annual rainfall of area ranges from 1000-1250 mm. Three types of soils are found in study area i.e. red soil, literate soil and mountain soil. Different types of forest vegetation occur in the study area.

For collection of data quadrats were selected under stratified random sampling design considering three sites viz., least, moderately and highly disturbed site as strata. In order to understand the effect of different sites on various variables viz., density, biomass and carbon storage. At each site, the vegetation was sampled in ten randomly placed quadrats. For enumeration of tree and saplings a quadrats sized 10 m × 10 m were laid, while for seedling 2 m × 2 m quadrats were laid and each species counted separately for quantify their density, biomass and carbon storage. For the measurement of tree biomass, allometric equation relating tree circumference to biomass developed earlier by Singh and Mishra (1979) and Singh and Singh (1991) for the dry deciduous forest species were used. The tree individuals in each quadrate were categorized into different girth classes. The mean circumference at breast height value for each species for a girth class was used in the regression equation to get an estimate of biomass (by component i.e. bole, branch, foliage and root) for that girth class. Then this value was multiplied by the density of trees in that girth class. The girth class values were summed to obtain the biomass estimate for each of the quadrates in each site. The Carbon concentration was analyzed using CHNOS-Auto Analyzer "Elementar Vario EL". Carbon storage in the vegetation was calculated by multiplying biomass and carbon concentration of different component separately for respective species (Sahu *et al.*, 2013).

RESULTS AND DISCUSSION

Effect on density and biomass in different sites: Across the study sites (Table 1) in tree layer 10 species was found on least disturbed site, 12 species on moderately disturbed site and 6 species on highly disturbed site, whereas in the case of sapling layer it was 9 species in both least disturbed and moderately disturbed site and 2 species on highly disturbed site, respectively. A total of 14 species of seedlings were recorded on least disturbed site, 8 species on moderately disturbed site and 4 species on highly disturbed site. The tree density on least disturbed, moderately disturbed and highly disturbed sites varied greatly and it was highest on least disturbed site (510 stems ha^{-1}) followed by moderately disturbed site (310 stems ha^{-1}) and lowest on highly disturbed site (100 stems ha^{-1}). The sapling density was highest on moderately disturbed site (610 stems ha^{-1}) followed by least disturbed site (490 stems ha^{-1}) and lowest on highly disturbed site (30 stems ha^{-1}) while seedling density was highest on least disturbed site (39500 stems ha^{-1}) followed by moderately disturbed site (26000 stems ha^{-1}) and lowest on highly disturbed site (7750 stems ha^{-1}). The total basal area of tree layer across the site varied from 11.47-26.67 m^2 ha^{-1}, highest under least disturbed site and lowest in moderately disturbed site.

Total biomass (Table 2) in the present study was between 127.69 t ha^{-1} and 227.71 t ha^{-1}. It was highest on least disturbed site (227.71 t ha^{-1}) followed by highly disturbed site (183.20 t ha^{-1}) and lowest on moderately disturbed site (127.69 t ha^{-1}). Total above ground biomass was between 111.20 t ha^{-1} and 199.42 t ha^{-1}, whereas total below ground biomass was between 16.49 t ha^{-1} and 28.29 t ha^{-1}, respectively. The total biomass for least disturbed site (Table 2) was 227.71 t ha^{-1} of which 199.42 t ha^{-1} was above ground and 28.29 t ha^{-1} was below ground biomass. The distribution of biomass in the different components was 117.25 t ha^{-1} in bole, 74.84 t ha^{-1} in branch, 7.32 t ha^{-1} in leaf and 28.29 t ha^{-1} in coarse root. The bole, branch, leaf and root constitute about 51.49, 32.86, 3.21 and 12.42%, respectively of the total biomass. Among the individual species *Shorea robusta* constitutes the highest biomass (110.31 tha^{-1}) followed by *Madhuca latifolia* (43.70 t ha^{-1}) and *Syzygium cumini* (30.82 t ha^{-1}), which contributed 48.44, 19.19 and 13.53% of the total biomass. The total above ground biomass for moderately disturbed site was 111.20 t ha^{-1} and 16.49 t ha^{-1} was below ground biomass constituting about 127.69 t ha^{-1} of total biomass of site (Table 2). The distribution of biomass by components was 53.21% in bole, 30.13% in branch, 3.57% in leaf and 12.91% in coarse root. The bole, branch, leaf and root constitute about 67.95 t ha^{-1}, 38.48 t ha^{-1}, 4.56 t ha^{-1} and 16.49 t ha^{-1} biomass, respectively of the total biomass. Among the individual species *Terminalia alata* constituted the highest biomass (48.71 t ha^{-1}) followed by *Lannea*

Table 1. Density of species in different life form among the sites.

Species	Least disturbed site			Moderately disturbed site			Highly disturbed site		
	Tree (stems ha⁻¹)	Sapling (stems ha⁻¹)	Seedling (stems ha⁻¹)	Tree (stems ha⁻¹)	Sapling (stems ha⁻¹)	Seedling (stems ha⁻¹)	Tree (stems ha⁻¹)	Sapling (stems ha⁻¹)	Seedling (stems ha⁻¹)
Anogeissus latifolia Roxb. ex DC	10	-	-	10	-	-	10	-	-
Bauhinia variegata	-	-	250	-	-	-	-	-	-
Boswelia serrata Roxb. ex Colebr	-	-	-	10	-	-	-	-	-
Buchanania lanzan Spreng	40	70	4500	-	-	-	10	-	-
Butea monosperma (Lamk) Taub.	-	-	-	-	-	-	-	-	-
Casearea graveolens Dalz	-	-	250	-	80	1000	-	-	1750
Cassia fistula Linn	-	-	-	10	-	-	-	-	-
Cassine albeus	-	-	250	-	-	250	-	-	-
Chloroxylon sweitenia DC	-	-	-	10	20	1000	-	-	-
Cleistanthus collinus Roxb.	-	-	-	-	-	-	-	-	-
Diospyros melanoxylon Roxb	-	90	7000	10	30	-	-	-	-
Ficus bengalensis L.	10	-	-	-	-	-	-	-	-
Flacourtia indica Burm.f.	-	-	-	-	10	-	-	-	-
Holarrhena pubescens Buchi.Ham	-	-	-	100	250	19000	-	10	3000
Lagerstroemia parviflora Roxb.	-	-	-	90	160	2750	10	20	2000
Lannea coromandelica Houtt.	-	-	500	20	10	-	10	-	-
Madhuca indica J.F. Gmel	130	130	6750	10	-	-	-	-	-
Miliusa tomentosa Roxb.	-	-	-	10	40	750	-	-	1000
Ougeinia oojeinensis Roxb.	10	-	-	-	-	-	-	-	-
Pterocarpus marsupium Roxb	-	10	750	-	-	-	-	-	-
Schleichera oleosa (Lour.) Oken	-	-	-	-	-	750	-	-	-
Semecarpus anacardium Linn. f	30	10	250	10	10	-	-	-	-
Shorea robusta Roxb.ex Gaertn.f.	170	100	13500	-	-	-	20	-	-
Symplocos racemosa Roxb.	-	60	500	-	-	-	-	-	-
Syzygium cumini (L) Skeels	60	10	4250	-	-	-	-	-	-
Terminalia alata Heyne exRoth	30	10	500	20	-	500	40	-	-
Terminalia chebula Retz	20	-	250	-	-	-	-	-	-
Total	510	490	39500	310	610	26000	100	30	7750

Table 2. Biomass (t ha^{-1}) of different tree components on different sites.

Species	Least disturbed site					Moderately disturbed site					Highly disturbed site				
	Branch	Bole	Leaf	Root	Total	Branch	Bole	Leaf	Root	Total	Branch	Bole	Leaf	Root	Total
Anogeissus latifolia Roxb. ex DC	-	-	-	-	-	2.74	11.71	0.66	2.13	17.25	1.84	6.99	0.41	1.38	10.64
Boswelia serrata Roxb. ex Colebr	-	-	-	-	-	2.83	4.54	0.27	1.06	8.70	-	-	-	-	-
Buchanania lanzan Spreng	1.53	0.87	0.22	0.48	3.11	-	-	-	-	-	1.52	2.11	0.21	0.44	4.28
Casearea graveolens Dalz	-	-	-	-	-	0.26	0.11	0.04	0.09	0.52	-	-	-	-	-
Cassia fistula Linn	-	-	-	-	-	0.40	0.37	0.04	0.15	0.98	-	-	-	-	-
Chloroxylon sweitenia DC	-	-	-	-	-	0.36	0.26	0.04	0.13	0.81	-	-	-	-	-
Cleistanthus collinus Roxb.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diospyros melanoxylon Roxb	0.32	0.11	0.04	0.41	0.90	0.73	0.55	0.06	0.47	1.84	-	-	-	-	-
Ficus bengalensis L.	0.22	0.17	0.02	0.08	0.50	-	-	-	-	-	-	-	-	-	-
Flacourtia indica Burm.f.	-	-	-	-	-	0.03	0.01	0.01	0.01	0.06	-	-	-	-	-
Holarrhena pubescens (Buchi.Ham)	-	-	-	-	-	3.99	2.74	0.70	1.55	8.98	0.05	0.04	0.01	0.03	0.13
Lagerstroemia parviflora Roxb.	-	-	-	-	-	5.53	4.92	0.76	2.65	13.88	1.65	1.78	0.20	0.91	4.55
Lannea coromandelica Houtt.	-	-	-	-	-	5.73	9.32	0.53	2.15	17.75	4.21	7.59	0.38	1.58	13.77
Madhuca indica J.F. Gmel	15.63	20.58	1.61	5.86	43.70	-	-	-	-	-	-	-	-	-	-
Miliusa tomentosa Roxb.	-	-	-	-	-	0.40	0.48	0.07	0.22	1.40	-	-	-	-	-
Ougeinia oojeinensis Roxb.	-	-	-	-	-	1.31	1.68	0.13	0.49	3.62	-	-	-	-	-
Pterocarpus marsupium Roxb	0.03	0.01	0.01	0.01	0.05	-	-	-	-	-	-	-	-	-	-
Semecarpus anacardium Linn. f	1.38	1.30	0.16	0.51	3.36	0.75	0.74	0.08	0.28	1.86	-	-	-	-	-
Shorea robusta Roxb.ex Gaertn.f.	33.89	60.55	3.13	12.73	110.31	-	-	-	-	-	17.24	38.34	1.43	6.48	63.52
Symplocos racemosa Roxb.	0.19	0.08	0.03	0.07	0.39	-	-	-	-	-	-	-	-	-	-
Syzygium cumini (L) Skeels	10.33	15.16	1.00	3.88	30.82	-	-	-	-	-	-	-	-	-	-
Terminalia alata Heyne exRoth	4.13	5.55	0.41	1.55	11.66	12.98	29.77	1.07	4.88	48.71	23.75	49.74	2.03	8.93	84.46
Terminalia chebula Retz	6.37	11.22	0.58	2.39	20.57	-	-	-	-	-	-	-	-	-	-
Total	74.84	117.25	7.32	28.29	**227.71**	38.48	67.95	4.56	16.49	**127.69**	50.79	107.68	4.74	19.97	**183.20**

Table 3. Effect of altitude and lopping intensity on plant density, basal area and biomass.

X Y	Altitude (m)			Lopping intensity (%)		
	a	b	r	a	b	r
Seedling density (plants/ha)	-6109**	14.55**	0.7641**	4288**	-36.08**	-0.6921**
Sapling density (plants/ha)	-105.0**	0.242**	0.6396**	64.150**	-0.517**	-0.4979**
Tree density (stems/ha)	-81.88**	0.1915**	0.7197**	59.359**	-0.560**	-0.7696**
Basal area (m²/ha)	-1.068^{NS}	0.0048**	0.3780*	2.439**	-0.013*	-0.3839*
Biomass (t/ha)	9.859^{NS}	0.013^{NS}	0.114^{NS}	19.543**	-0.031**	-0.0919^{NS}

Note: *Significant at p ≤ 0.05, **Significant at p ≤ 0.01, NS Non significant, x = Independent variable, y = Dependent variable, a = intercept, b = Regression coefficient, r = Correlation coefficient

coromandelica (17.75 t ha^{-1}) and *Anogeissus latifolia* (17.25 t ha^{-1}) which constitute about 38.14, 13.90 and 13.50% of the total biomass.

The total biomass for highly disturbed site was 183.20 t ha^{-1} of which 163.23 t ha^{-1} was above ground and 19.97 t ha^{-1} was below ground biomass (Table 2). The distribution of biomass in the different components was 107.68 t ha^{-1} in bole, 50.79 t ha^{-1} in branch, 4.74 t ha^{-1} in leaf and 19.97 t ha^{-1} in coarse root. The bole, branch, leaf and root biomass constitute about 58.77, 27.72, 2.58 and 10.90%, respectively of the total biomass. Among the individual species *Terminalia T. alata* constituted the highest biomass (84.46 t ha^{-1}) followed by *S. robusta* (63.52 t ha^{-1}) and *L. coromandelica* (13.77 t ha^{-1}) which constitute about 46.10, 34.67 and 7.51% of the total biomass.

The Bartlett's test in case of biomass was significant at 5% level this violates the basic assumption of homogeneity of variances of sites for analysis of variance. When the reason was traced it was observed that the highly disturbed site coincidently contained nearly equal quantity of biomass, due to which the variability within site (highly disturbed site) was almost negligible, which forced the heterogeneity of variances among all the sites, which includes highly disturbed site too. It may be noted here that the site variances should be homogeneous before going for analysis of variance of the sites. This is tested by the Bartlett's test. Thus, this problem is not that of the sites, rather it is a coincidental problem in which all the quadrats have similar values. On a larger canvass the quadrat's constituent may not be the same. Therefore, although technically we cannot proceed, having given this caution, we are still proceeding to have an idea about the significance of difference due to sites on the biomass, whose F-test turns out to be non-significant at the 5% level of significance.

Although the young individuals belonging to seedlings and saplings classes dominated all the three site in terms of density but the total biomass accumulation was greater in the >100 cm girth class (Fig. 1). In least disturbed site the total biomass accumulation was greater in the >100 cm girth class followed by middle girth class while it was minimum in smaller girth classes (Fig. 2). About 52.33% biomass accumulation was in the girth class >100 cm, 37.22% in girth class 60-100 cm, 8.24% in girth class 30-60 cm and 2.18% in smaller girth class 10-30 cm. In moderately disturbed site the total biomass accumulation was greater in the >100 cm girth class followed by middle girth class while it was minimum in smaller girth classes (Fig. 3). About 64.95% biomass accumulation was in the girth class >100 cm, 18.24% in girth class 60-100 cm, 11.62% in girth class 30-60 cm and 5.17% in smaller girth class 10-30 cm. In highly disturbed site the total biomass accumulation was greater in the >100 cm girth class while it was minimum in middle girth classes (Fig. 4). About 89.17% biomass accumulation was in the girth class >100 cm, 10.62% in girth class 60-100 cm and 0.19% in smaller girth class 10-30 cm. Total biomass accumulation in the >100 cm girth class was greater at highly disturbed site followed by least disturbed and moderately disturbed site. While in 60 - 100 cm girth class was greater at least disturbed site followed by moderately disturbed and minimum at highly disturbed site. In 30-60 cm girth class greater at moderately disturbed site followed by least disturbed site and in 10-30 cm girth class greater at moderately disturbed site followed by least disturbed and highly disturbed site.

The correlation analysis indicates that there was a positive influence of altitude whereas, negative influence of lopping intensity on density, basal area and biomass. There was a strong positive influence of altitude on seedling density (r = 7641), sapling density (r = 6396) and tree density (r = 0.7195) while there was negative influence of lopping intensity on seedling density (r = -0.6921), sapling density (r = -0.4979) and tree density (r = -0.7696) at 1% levels of significance. The correlation analysis for basal area indicates that there was a positive correlation (r = 3780) between basal area and altitude while, there was negative correlation (r = -0.3839) between basal area and lopping intensity at 5% levels of significance. It was found that biomass was not significantly correlated with (r = 0.114) altitude and (r = -0.0919) lopping intensity. Regression line indicates that with 1 m increase in altitude the density, basal area and biomass get increased while with 1% increase in lopping intensity the density, basal area and biomass get decreased (Table 3).

Table 4. Carbon (t ha⁻¹) storage pattern of different tree component on different sites.

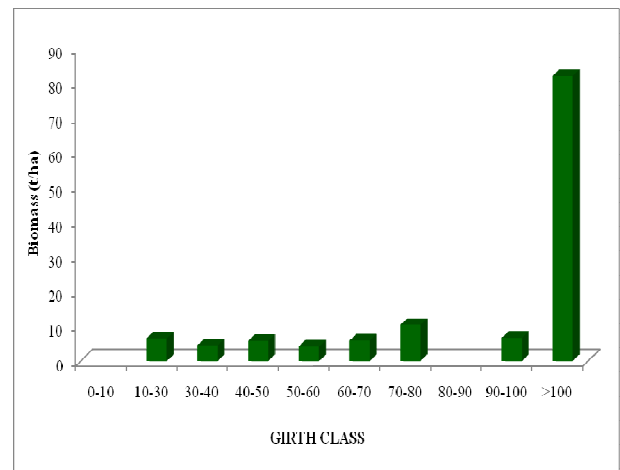| Species	Least disturbed site					Moderately disturbed site					Highly disturbed site				
	Bole	Branch	Leaf	Root	Total	Bole	Branch	Leaf	Root	Total	Bole	Branch	Leaf	Root	Total
Anogeissus latifolia Roxb. ex DC	-	-	-	-	-	1.192	5.348	0.308	0.761	7.609	0.800	3.192	0.191	0.493	4.677
Boswelia serrata Roxb. ex Colebr	-	-	-	-	-	1.231	2.073	0.124	0.379	3.807	-	-	-	-	-
Buchanania lanzan Spreng	0.666	0.397	0.103	0.170	1.335	-	-	-	-	-	0.661	0.964	0.098	0.157	1.880
Casearea graveolens Dalz	-	-	-	-	-	0.113	0.050	0.019	0.032	0.214	-	-	-	-	-
Cassia fistula Linn	-	-	-	-	-	0.174	0.169	0.019	0.054	0.415	-	-	-	-	-
Chloroxylon sweitenia DC	-	-	-	-	-	0.157	0.119	0.019	0.046	0.340	-	-	-	-	-
Cleistanthus collinus Roxb.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Diospyros melanoxylon Roxb	0.139	0.050	0.019	0.146	0.355	0.318	0.251	0.028	0.168	0.765	-	-	-	-	-
Ficus bengalensis L.	0.096	0.078	0.009	0.029	0.211	-	-	-	-	-	-	-	-	-	-
Flacourtia indica Burm.f.	-	-	-	-	-	0.013	0.005	0.002	0.004	0.024	-	-	-	-	-
Holarrhena pubescens	-	-	-	-	-	1.736	1.251	0.327	0.554	3.868	0.022	0.018	0.005	0.011	0.055
Lagerstroemia parviflora Roxb.	-	-	-	-	-	2.406	2.247	0.355	0.947	5.954	0.718	0.813	0.093	0.325	1.949
Lannea coromandelica Houtt.	-	-	-	-	-	2.493	4.256	0.247	0.768	7.765	1.831	3.466	0.177	0.565	6.040
Madhuca indica J.F. Gmel	6.799	9.399	0.751	2.094	19.043	-	-	-	-	-	-	-	-	-	-
Miliusa tomentosa Roxb.	-	-	-	-	-	0.174	0.219	0.033	0.079	0.504	-	-	-	-	-
Ougeinia oojeinensis Roxb.	-	-	-	-	-	0.570	0.767	0.061	0.175	1.573	-	-	-	-	-
Pterocarpus marsupium Roxb	0.013	0.005	0.002	0.003	0.022	-	-	-	-	-	-	-	-	-	-
Semecarpus anacardium Linn. f	0.600	0.594	0.075	0.182	1.451	0.326	0.338	0.037	0.100	0.802	-	-	-	-	-
Shorea robusta Roxb.ex Gaertn.f.	14.742	27.653	1.461	4.548	48.405	-	-	-	-	-	7.499	17.510	0.667	2.315	27.992
Symplocos racemosa Roxb.	0.083	0.037	0.014	0.025	0.158	-	-	-	-	-	-	-	-	-	-
Syzygium cumini (L) Skeels	4.494	7.125	0.467	1.386	13.471	-	-	-	-	-	-	-	-	-	-
Terminalia alata Heyne exRoth	1.797	2.535	0.191	0.554	5.076	5.646	13.596	0.499	1.744	21.485	10.331	22.716	0.947	3.191	37.186
Terminalia chebula Retz	2.771	5.124	0.271	0.854	9.020	-	-	-	-	-	-	-	-	-	-
Total	**32.199**	**52.995**	**3.363**	**9.991**	**98.548**	**16.547**	**30.690**	**2.077**	**5.810**	**55.125**	**21.863**	**48.680**	**2.179**	**7.057**	**79.779**

The total carbon storage across the sites were ranged from 55.125 to 98.548 t C ha^{-1} found higher under least disturbed site and lowest under medium disturbed site (Table 4). In least disturbed site the distribution of carbon was 32.199 t C ha^{-1} in bole, 52.995 t C ha^{-1} in branch, 3.363 t C ha^{-1} in leaf and 9.991 t C ha^{-1} in coarse root, respectively. Out of the total carbon storage the bole constituted 32.67%, branch 53.78%, leaf 3.41% and 10.14% by coarse roots, respectively. Among the recorded species under least disturbed site the higher carbon stored by *S. robusta* followed by *M. indica* and *S. cumini*, which contributed about 82.11% in total, whereas the lowest value were recorded by *Pterocarpus marsupium*, *Symplocos racemosa*, *Ficus bengalensis* and *Diospyros melanoxylon*. The moderately disturbed site had the total carbon storage value of 55.125 t C ha^{-1} out of which 49.315 t C ha^{-1} stored in above ground components and remaining (5.810 C ha^{-1}) in coarse roots, respectively. Among the individual species *T. alata* constituted the highest carbon storage (38.98%) in total C storage. Among different components under the moderately disturbed site followed the order:

branch (55.67%) > bole (30.02%) > root (10.54%) > leaf (3.77%) of the total C storage. Under the highly disturbed site a total of 79.779 t C ha^{-1} were quantified in which 27.40% shared by bole, 61.02% by branch, 2.73% by leaf and 8.85% by coarse root, respectively. Among the all species highest value of carbon storage was recorded under *T. alata* (37.186 t C ha^{-1}) and *S. robusta* (27.992 t C ha^{-1}), while the minimum were found by *Holarrhena pubescens* (0.055 t C ha^{-1}), respectively. Distribution pattern of carbon storage as per the girth class also followed the similar trend as was in the case of biomass distribution. It was found negligible in lowest girth class specially belonging saplings and peak storage was observed in higher girth class.

The biomass of the stand or forest depends on species their density, size class, age and site condition of the region. The biomass stock significantly changed by disturbances, land use, harvesting and climatic variability (Canadell *et al.*, 2007). The findings present study is more of less close to biomass values reported by many workers. Jhariya *et al.* (2014) have estimated
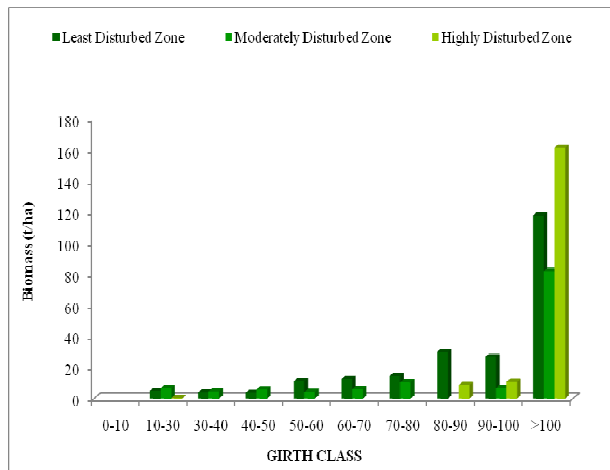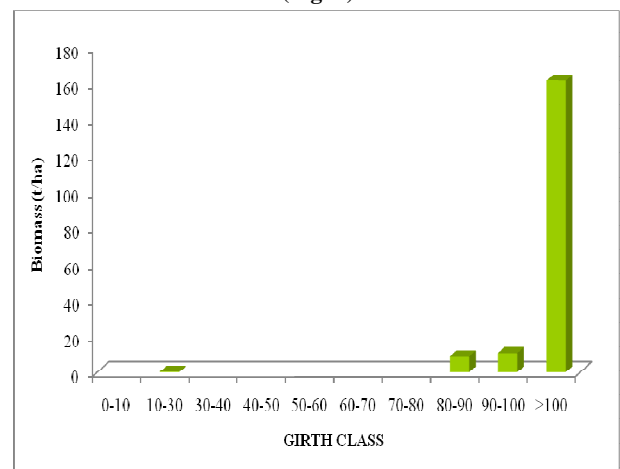

(Fig. 1)

(Fig. 2)
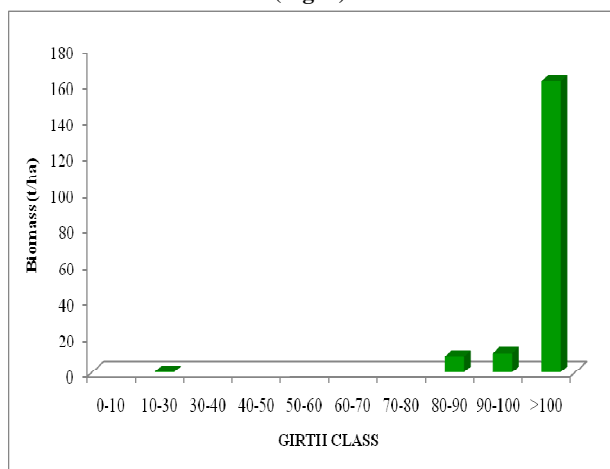
(Fig. 3)

(Fig. 4)

Figs. *(1) Distribution pattern of biomass along the girth classes on three different sites (2) Distribution pattern of biomass along the girth classes in least disturbed site (3) in moderately disturbed site (4) in highly disturbed site.*

the total biomass of the Bhoramdeo wildlife sanctuary of Chhattisgarh ranging from 101.43-192.36 t ha^{-1} which resemble with the present study (127.69-227.71 t ha^{-1}). Cairns *et al.* (2003) have reported that the total above ground biomass of Mexico tropical forest was 225 Mg ha^{-1} which are closer to present estimates (111.2-199.42 t ha^{-1}). The present findings are supported by global pattern of above ground biomass (30-273 t ha^{-1}) and total biomass (78-320 t ha^{-1}) reported by Murphy and Lugo (1986) for the various type of dry tropical forest. Delaney *et al.* (1997) reported 285 Mg ha^{-1} above ground biomass of Venezuela Tropical moist forest. The above ground biomass is very similar to Cairns *et al.* (2000) for the semi-evergreen forest of Yucatan Peninsula (111.2 Mg ha^{-1}), but less than the Veracruz (225.8 Mg ha^{-1}). Brown *et al.* (1995) and Golley *et al.* (1975) estimated biomass of tropical moist forest and it was found that in the present study biomass was 34% less than biomass estimates for Brazil tropical moist forest (306 Mg ha^{-1}) and 57% less than biomass of Panama tropical moist forest (358 Mg ha^{-1}), respectively. Total below ground biomass of present study was between 16.49 t ha^{-1} and 28.29 t ha^{-1}, which resembled with below ground biomass of tropical deciduous forest estimated by Singh *et al.* (2009). Hall and Uhling (1991) estimated the biomass of South and South East Asia's forest using the volume estimates and biomass expansion factors derived from Brown *et al.* (1989). Their biomass estimates for India ranged from 116 Mg ha^{-1} for undisturbed forest for 60-80 years and 35, 66 and 84 Mg ha^{-1} for logged, unproductive and managed forests, respectively. Present finding are supported by Borah *et al.* (2013) where they have reported aboveground tree biomasses in tropical forest of Assam from 32.47 to 261.64 Mg ha^{-1}. Similarly, Thokchom and Yadava (2013) noted the aboveground biomass was in the range of 179.14 to 246.38 Mg ha^{-1} for sub tropical forests of Manipur, North-East India. Gairola *et al.* (2011) reported the wide range of aboveground biomass from 172 to 380 Mg ha^{-1} along an altitudinal gradient in the temperate valley forests of Garhwal. Mohanraj *et al.* (2011) estimated the 372 Mg ha^{-1} aboveground biomass of tropical forests of India which was found higher than present estimates. Pande and Patra (2010) estimated the biomass of sal forest and miscellaneous forest of Satpura (Madhya Pradesh) India. The ranges for aboveground biomass (t ha^{-1}) were 154.9-345. They also reported that disturbances in open forests reduce the stand biomass, which resembled with present findings. Yadava (2010) reported the aboveground biomass of sub-tropical broad leaved forest of Manipur between 130 and 255 Mg ha^{-1}. The present estimates are comparable with the findings of Upadhyay *et al.* (2009), who studied the effect of disturbance on standing biomass in a sal mixed forest of eastern Uttar Pradesh.

Carbon is the key component of plant and they utilize and store it in different components viz., bole, branch, foliage and roots (Kiran and Shah, 2011). In an ecosystem carbon flows and sinks in the form of biomass by photosynthesis and the electron transport chain in plant system (Atkin *et al.*, 2012). The carbon sequesters potential of forests depends on the type of forest, their age and size class of trees (Terakunpisut *et al.*, 2007). The most of biomass accumulation in the higher girth class under natural forest ecosystem reveal the key function of large trees in carbon storage. The tropics are much affected by the different biotic interference, the size class distribution of trees an important determination of carbon stock (Baisya *et al.*, 2009). The amount of carbon stored in the tropical forest of the present study (55.125-98.548 t C ha^{-1}) was similar to the disturbed tropical forests of Sri Lanka (77 MgC ha^{-1}), but lower than the relatively undisturbed matured tropical rain forest of Malaysia (223 Mg C ha^{-1}) reported by Brown and Lugo (1982). Ogawa *et al.* (1965) reported a carbon stock of 60-179 t C ha^{-1} in variety of tropical forest in Thailand. Jhariya *et al.* (2014) have estimated the total carbon value of tropical forest in Chhattisgarh was varied from 50.71 to 96.18 t C ha^{-1} which are similar to present estimated value. The present carbon storage values are comparable with Hall and Uhling (1991), Cairns *et al.* (2003), Sierra *et al.* (2007) and Chaturvedi *et al.* (2011). Metzker *et al.* (2011) reported 48-91 Mg C ha^{-1} for tropical forest of Brazil which is line agreement with our findings. Thokchom and Yadava (2013) reported the aboveground carbon stock varied from 81.17 to 118.29 Mg C ha^{-1} across the forest study sites. Borah *et al.* (2013) reported that the aboveground carbon stock in tree species ranged from 16.24 to 130.82 Mg C ha^{-1} which is well within the range of present forest C stock. The present findings are lower than the value documented by Baisya *et al.* (2009) and Mohanraj *et al.* (2011). Tang *et al.* (2012) reported 155 Mg C ha^{-1} for the tropical forest of SW China, while Hoover *et al.* (2012) 116-125 MgC ha^{-1} in above ground compartment.

Conclusion

The present study reveals that anthropogenic disturbance has a significant impact on regeneration of species, composition, diversity, biomass and carbon storage potential of these tropics. The rise in the anthropogenic disturbances is degrading the forest wealth and quality of the stand. Therefore, there is need of improvement in proper density, stock, species composition and their distribution which can be sink more carbon in their organic biomass. The practice should be opted which disturbs the forest at low scale, maintains the forest composition and structure that are more sustainable for long run.

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