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Estimation of tree biomass reserves in tropical deciduous forests of Central India by non-destructive approach

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Abstract: The present study deals with the estimation of tree biomass by non destructive method in tropical dry deciduous forest (DDF) and tropical mixed deciduous forest (MDF) in 0.1 ha permanent plots, established at seven sites each in seven districts of state of Madhya Pradesh in central India. Tree volume was calculated using site specific volume equation. The biomass of each species was estimated taking tree volume and species specific gravity. The relationship between basal area and above ground biomass showed positive correlation for all sites and forest types. In general DDF holds higher density, basal area and biomass than MDF irrespective of sites. Significantly higher basal area (m^2 $ha^{-0.1}$) was recorded in DDF (6.45 ± 4.22) MDF (4.53 ± 3.56). Average above ground biomass of both DDF and MDF of all sites were 31.8 t $ha^{-1}$and 20.7 t ha^{-1} respectively. Estimation of above ground tree biomass in the present study provides data for tropical deciduous forests covering a large part (24.66 %) of state for further use.

Key words: Allometric equation, basal area, deciduous forest, non destructive method.

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Introduction

Biomass is a major source of energy for nearly 50 % of world's population (Karekezi & Kithyoma 2006). Wood biomass is a major renewable energy source in developing world, representing a significant proportion of rural energy supply (Hashiramoto 2007). Forest biomass is an important source of food, fodder and fuel, and its exploitation leads to forest degradation (Rawat & Nautiyal 1988). As per the records of Forest Survey of India (FSI 2003), the area under forest was 102.68 m ha in 1880, which has been reduced to 67.83 m ha in 2003. Since 2003, carbon stocks in Indian forests are continuously decreasing (Sheikh *et al.* 2011). The data envisaged that in India, forests are under excessive anthropogenic pressures (Rai & Chakrabarti 2001).

According to Brown *et al.* (1999), the quantity of biomass in a forest determines the potential amount of carbon. Carbon sequestration is a net removal of CO_2 from atmosphere, which includes the uptake of carbon from atmosphere by all chlorophyllous plants through photosynthesis. This carbon is stored as plant biomass in vegetation and organic matter in the soil (Vashum & Jayakumar 2012). Various terrestrial eco-systems such as forests, grasslands and agricultural systems have different potential of carbon storage (DOE 1999). For instance, forest ecosystem contains more carbon per unit area than any other land type (Jaramillo *et al.* 2003). The

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rate of carbon sequestration varies with the species composition, region, climate, topography and management practices etc. (Lal 1999).

Madhya Pradesh (MP) is a centrally located state of India with a forest cover of 76,013 km^2 which is 24.66 % of the total geographical area of the state (FSI 2011). In terms of forest canopy density classes, the state has 4,239 km^2 area under very dense forest; 36,843 km^2 under moderately dense forest; and 34,931 km^2 under open forest. A total of 18 forest types have been identified in MP (Champion & Seth 1968). Broadly, these forest types belong to three groups namely, Type Group 5: tropical dry deciduous forests (88.65 %), Type Group 3: tropical moist deciduous forest (8.97 %) and Type Group 6: tropical thorn forest (0.26 %). Tropical dry deciduous forests are the major forest type in this state. Baishya *et al*. (2009) suggested that tropical forests are more effective in carbon sequestration than other forests.

The rate of forest degradation in the state of MP is very high, resulting in poor regeneration of important tree species and heavy loss of biodiversity and low productivity (Manhas *et al*. 2006). Estimation of biomass enables assessing the amount of carbon loss on account of deforestation and the amount of carbon that forests can store. Large number of villages are located near or within the forests and the tribal populations therein depend on forests for their livelihood (Bahuguna 2000). Hence, large area of forest remains under threat of disturbances. Under present situation, there is an urgent need to reduce the magnitude of disturbances and their impact on the balance of carbon stock. As per the Millennium Ecosystem Assessment Programme, biomass and carbon stock of vegetation are to be estimated in data deficient areas. Biomass assessment is an important facet for national development planning as well as for scientific studies of ecosystem productivity and carbon budgets (Devagiri *et al*. 2013). Therefore, present study focuses on estimation of biomass stored in deciduous forests of MP. In recent times, biomass related studies have become significant due to growing awareness of carbon credit system world over (Kale *et al*. 2004). According to Quirine *et al*. (2001), the estimation of above-ground biomass is an essential aspect in study of carbon stock. Various methods are being employed for measuring biomass/carbon which include destructive, non-destructive and remote sensing methods (Lu 2006). Absolute measurements of biomass can take up only at the time of felling which is not possible in all situations (Murali *et al*. 2005). In India, forest departments follow the selection system for felling where only the marked trees are taken out leaving behind the immature/ unmarked trees. Therefore, biomass estimation on unit area basis of vegetation is not possible. Measurement for basal area, height and species specific gravity in field are good parameters for estimating biomass as non-destructive methods (de Gier 2003). In the present study, the non-destructive method for estimation of biomass was considered, where the basal area, tree height, species specific gravity and volume equations were used as inputs.

Materials and methods

Benchmark areas

MP is the second largest state of the country with an area of 3,08,245 km^2, comprising 9.38 % of the geographical area of the country. The state lies between 21° 17' N and 26° 52' N latitudes and 78° 08' E and 82° 49' E longitudes. Physiographically, the state can be divided into four different regions viz., the low lying areas in north and north-west of Gwalior, Malwa Plateau, Satpura and Vindhyan Ranges. Like most of north India, it has a hot dry summer (April to June), followed by monsoon rains (July to September) and a cool and relatively dry winter. The average annual rainfall varies from 800 to 1,800 mm. The mean annual temperature ranges from 22.5 °C to 25 °C (FSI 2011).

Present study was carried out in the year 2009 at seven sites in seven different districts of MP, namely Damoh, Katni, Panna, Raisen, Rewa, Sagar and Satna. In each district, two types of forest i.e. dry deciduous forests (DDF) and mixed deciduous forests (MDF) were selected, and sites were marked accordingly. The selection of representative sites in different districts as well as forests was made on the basis of type of forest, crown density and magnitude of anthropogenic activities in the forests. The descriptions of forest sites and the geographical positions of marked sites are presented in Table 1.

Sampling design

In the present study, one super plot of 250 x 250 m size was laid down at each site (i.e. 7 sites). Four sample plots, each of 31.6 m x 31.6 m (0.1 ha) size in all the four directions i.e. NE, NW, SW and SE, respectively were laid in each super plot.

Table 1. Types of forest sites and geographical positions of marked sites.

District	Dry Deciduous Forest		Mixed Deciduous Forest	
	Latitude	Longitude	Latitude	Longitude
Sagar	24 16 49.2	78 33 58.0	23 58 13.0	78 28 19.7
Damoh	23 20 10.7	79 26 08.5	24 03 30.6	79 10 00.9
Katni	23 38 31.4	79 57 30.9	23 43 26.0	79 51 34.2
Satna	24 52 45.3	80 54 02.1	24 54 25.2	80 59 20.4
Panna	24 51 46.3	80 17 50.9	24 55 24.6	80 23 47.8
Raisen	23 03 50.8	78 07 42.2	23 23 38.4	78 07 10.2
Rewa	24 53 31.7	81 10 26.6	24 53 22.6	81 08 33.9

Since, the present study consisted of two different types of forests i.e. DDF and MDF, a total of 56 sample plots were assessed for above ground biomass estimation. During the field visits, topo sheets of survey of India, Google earth images and GPS device (Garmin 72) were used to approach the sites.

Observations

In the present investigation, observations were restricted only to the tree component. Tree trunk having more than 10 cm diameter at breast height (DBH; 1.37 m above ground) was considered as a tree. In each sample plot (0.1 ha quadrat), stratification in the forest was observed and data was recorded in top, first and second order canopies. The categorization of top, first and second order canopy species was done using height of each tree species, i.e. highest as first and second order canopies, respectively. The measurement of tree height and DBH were made by using Blume Leiss Hypsometer (which is based on trigonometric method), digital tree caliper (Haglof, Sweden) and measuring tape, respectively. Trees were categorized on the basis of their girth (m) and classified under different girth classes. All the trees were marked and represented with unique number. The identification of recorded species was done with the help of herbarium section at Department of Botany, Dr H. S. Gour University, Sagar, India, and Flora of Madhya Pradesh (Verma *et al.* 1993).

Estimation of biomass/carbon

As already mentioned, a non-destructive allometric equation approach was adopted for assessing biomass/carbon, which requires tree measurements (height and DBH), volume equations and species specific gravity of each tree species. Tree volume was estimated by using the site or region specific (phytogeographic/physiographic) volume, general and biomass equations, procured from the State Forest Departments, Forest Research Institute, Dehradun and Forest Survey of India (FSI 1996; Dadhwal *et al.* 2009). Species volume equation and species specific gravity of recorded tree species are summarized in Table 2. The DBH and height for each tree species were used for regression analysis to get an estimate of biomass (Roy & Ravan 1996). The formula used for calculating biomass was as follows: Biomass (t $ha^{-0.1}$) = Volume of tree × Species specific gravity. The tree volume of each species was calculated by using the volume equations as suggested by FSI (1996).

Statistical analysis

All the data were analyzed statistically by using SYSTAT version 12. Least significant difference (LSD) was used to compare differences and the graphs were prepared by SYSTAT.

Results

Observations on density, basal area and biomass of the study sites are presented in Fig. 1. Site wise ANOVA test showed significant differences in tree density ($F_{6, 42}$ = 17.36, $P < 0.05$). Comparatively higher tree density (Stems $ha^{-0.1}$) was recorded at Panna (59.3 ± 19.3), and Sagar (39.3 ± 16.8), and it was minimum at Satna (14.8 ± 4.4). While considering the forest types, the density of trees was significantly higher in DDF as compared to MDF, at most of the study sites. The two-way interaction between study sites and forest types was significant, which suggested that at Panna, density was significantly higher in DDF (74.8 ± 14.3) than MDF (43.8 ± 4.5).

Table 2. Volume equations and wood specific gravity used in the present study. V volume (V; m^3), Diameter at Breast Height (D; m), height (H; m), Square root (SQRT).

Plant	Volume equation[1]	Species specific gravity[2]
Acacia catechu	$V=0.043849-0.552735\ D+2.952386\ D^2+0.334508\ D^{2H}$	0.875
Acacia nilotica	$V=0.043849-0.552735\ D+2.952386\ D^2+0.334508\ D^{2H}$	0.670
Aegle marmelos	$V/D^2=0.0697/D^2-1.4597/D+11.79933-2.35397D$	0.754
Albizia procera	$V=-0.043832+3.262852\ D^2$	0.579
Anogeissus pendula	$V/D^2=0.00085/D2-0.35165/D+4.77386-0.90585D$	0.788
Annona squamosa	$V/D^2=0.0697/D2-1.4597/D+11.79933-2.35397D$	0.619
Bauhinia racemosa	$V=-0.04262+6.09491D^2$	0.619
Bombax ceiba	$V/D^2=0.18573/D2-2.85418/D+15.03576$	0.329
Boswellia serrata	$V=0.00642-0.19774\ D+6.90556\ D2+5.54843\ D^3$	0.498
Buchanania lanzan	$V=0.031-0.64087\ D+6.04066\ D^2$	0.458
Butea monosperma	$V/D^2=0.0697/D^2-1.4597/D+11.79933-2.35397D$	0.465
Cassia fistula	$V=0.066+0.287\ D^2H$	0.746
Chloroxylon swietenia	$V=-0.094+0.376\ D+2.817D^2$	0.458
Clerodendrum viscosum	$V/D^2=0.0697/D^2-1.4597/D+11.79933-2.35397D$	0.619
Dalbergia latifolia	$V=0.04422+2.328465\ D^2+0.309150\ D^2H$	0.754
Dalbergia sissoo	$V/D^2=0.00331/D2+0.000636$	0.669
Diospyros melanoxylon	$V/D^2=0.10426/D^2-1.69816/D+12.29196$	0.678
Elaeodendron glaucum	$V/D^2=0.0697/D^2-1.4597/D+11.79933-2.35397D$	0.619
Ficus recemosa	SQRTV=0.03629+3.95389 D-0.84421SQRTD	0.619
Ficus religiosa	SQRTV=0.03629+3.95389 D-0.84421SQRTD	0.385
Flacourtia ramontchi	$V/D^2=0.0697/D^2-1.4597/D+11.79933-2.35397D$	0.619
Gardenia latifolia	$V/D^2=0.0697/D^2-1.4597/D+11.79933-2.35397D$	0.635
Holoptelea integrifolia	$V/D^2=0.0697/D^2-1.4597/D+11.79933-2.35397D$	0.592
Kydia calycina	$V=0.72892+0.0015117D^2$	0.37
Lagerstroemia parviflora	$V=0.01617-0.66446\ D+9.71038D2$	0.648
Lannea coromendelica	$V/D^2=0.07432/D2-1.75673/D+13.6934-3.31887D$	0.513
Madhuca latifolia	$V=-0.00092-0.55547\ D+7.34460D2$	0.619
Melia azadirachta	$V=-0.03510+5.32981\ D^2$	0.619
Ougennia oojainesis	$V/D^2=0.0697/D^2-1.4597/D+11.79933-2.35397D$	0.704
Phyllanthus emblica	$V=-0.406+3.540\ D-3.231D^2$	0.619
Saccopetalum tomentosum	$V/D^2=0.0697/D^2-1.4597/D+11.79933-2.35397D$	0.619
Stephegyne parvifolia	$V/D^2=0.0697/D2-1.4597/D+11.79933-2.35397D$	0.619
Syzygium cummini	$V=0.08481-1.81774\ D+12.63047\ D2-6.69555D^3$	0.647
Tectona grandis	$V=0.04346-0.26352SQRTD+8.79334D^2$	0.577
Terminalia alata	$V=0.33695-1.23004SQRTD+11.86676\ D^2$	0.694
Terminalia bellerica	SQRTV=-0.14017+3.364233	0.628
Terminalia cuneata	$V/D^2=0.0697/D^2-1.4597/D+11.79933-2.35397D$	0.686
Zizyphus jujube	$V/D^2=0.0697/D^2-1.4597/D+11.79933-2.35397D$	0.597
Zizyphus xylopyra	$V/D^2=0.0697/D^2-1.4597/D+11.79933-2.35397D$	0.597

[1]FSI (1996), [2]FRI (1996).

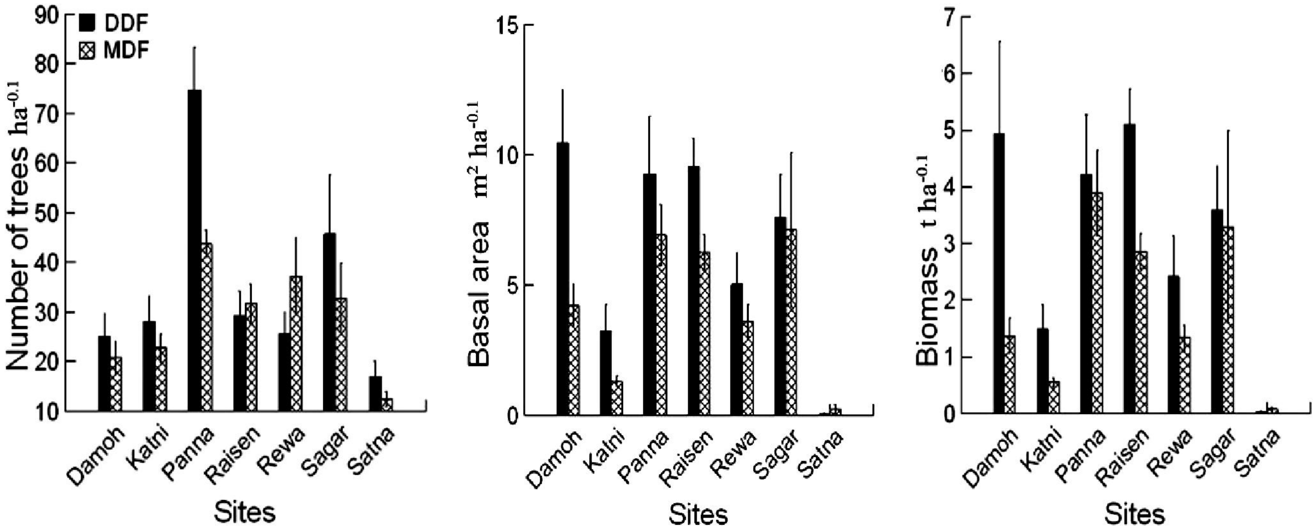

Fig. 1. Density, basal area and biomass of trees in two different type of forests at different study sites.

Basal area (m^2 ha$^{-0.1}$) was maximum at Sagar (8.37 ± 3.90), followed by Panna (8.10 ± 3.00), Raisen (7.88 ± 2.26) and Damoh (7.33 ± 4.10). These differences were not significant. Minimum basal area was recorded at Satna (0.15 ± 0.20) which was comparable with Katni (2.27 ± 1.52) and Rewa (4.32 ± 1.67). Irrespective of studied sites, higher basal area was recorded in DDF (6.45 ± 4.22) as compared to MDF (4.53 ± 3.56).

More or less similar trends were also recorded for biomass. Tree biomass (t ha$^{-0.1}$) was maximum at Panna (4.04 ± 1.4), followed by Sagar (4.01 ± 2.16), Raisen (3.97 ± 1.41) and Damoh (3.43 ± 2.62). However, the lowest biomass was recorded at Satna (0.04 ± 0.05). At sites Damoh and Raisen, differences between forest types were significant, where greater biomass was recorded in DDF i.e. 5.49 ± 2.10 (Damoh) and 5.10 ± 1.02 (Raisen) than MDF i.e. 4.45 ± 2.94 (Sagar) and 3.88 ± 1.27 (Panna). While comparing the forest types, similar trends are recorded for tree density and basal area. Significantly higher biomass was recorded in DDF (3.18 ± 2.21) as compared to MDF (2.07 ± 1.92).

Regression analysis between biomass and basal area was performed for both MDF and DDF (Fig. 2). Both types of forest showed more or less similar values of R^2 i.e. 0.959 for MDF and 0.975 for DDF showing positive relationship between biomass and basal area.

Discussion

It is an established that the biomass is a function of tree density, height and basal area at any given location. These parameters contribute to the above-ground biomass which differs with site, habitat, forest successional stage, composition of forest, species variability and varying tree density etc. (Brunig 1983; Joshi & Ghose 2014; Whitmore 1984). Terakunpisut *et al.* (2007) suggested that variation in biomass at various sites can be attributed to some internal and external factors, such as type of forest, site to site variations, disturbances, total annual rainfall and geographical location of the forests. Our results clearly suggested that at Damoh, tree density was less than Panna, but the biomass was very high in DDF at Damoh. This can be due to the occurrence of old and big sized trees of *Ficus benghalensis, Terminalia alata, Boswelia serrata, Lannea coromandelica, Holoptelia integrifolia,* etc., at Damoh and Sagar. Further, the bole sizes of these were comparatively higher as compared to bole size recorded at other sites. This site also had some sacred patches that might play a role in restriction of tree felling. Moreover, a forest police check post located in the boundary of district might have restricted the tree cutting. According to Baishya *et al.* (2009), such types of forest do not add further biomass because most part of the gross primary productivity is either used up in respiration or returned to soil as litter.

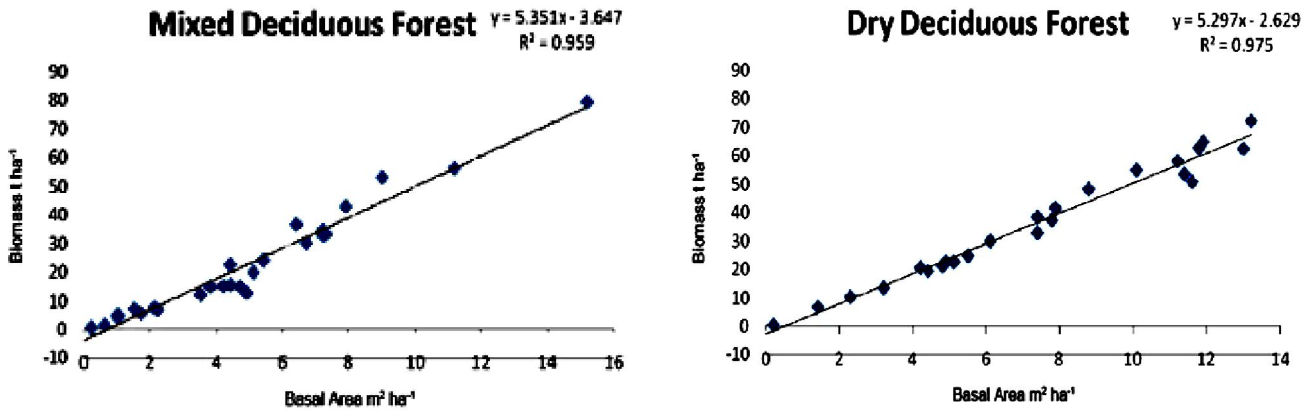

Fig. 2. Regression equation for MDF and DDF for biomass and basal area.

As per our results, maximum tree density and biomass was recorded at Panna in both the types of forest but low basal area as compared to Sagar. The correlation between biomass and basal area was positive, which suggest that the basal area is an indicator of biomass. Strong relationships between biomass and basal area have also been reported by several workers in various types of forests (Cannell 1984; Rai & Proctor 1986). Sites like Katni and Satna showed lower tree biomass as compared to other sites. At site Satna, this can be attributed to a number of cement industries in the area and the pollutants from these might affected the productivity. Moreover, the low biomass can also be due to low soil moisture and excessive use of ground water by industries. According to Pande (2005), lower soil depth and poor soil structure of any site can be responsible for low above ground biomass. In addition, Satna district is located at the boundary of other adjoining state i.e. Uttar Pradesh; and inter-state conflicts leading to illegal cuttings of trees affect the wealth of forest. At Katni, large numbers of granite and marble mines are located and the intensive mining operations are degrading the forests. This could be the reason of low biomass recorded during the course of work. Our results corroborated with the findings of Joshi *et al.* (2009). They assessed the effects of industrialization on land use and land cover change in dry tropical region of northern Chhattisgarh with the help of remote sensing data and GIS. They recorded that over the last 30 years, around 22.2 % of forest land has been converted to industries, 25 % is completely cleared, 10 % is degraded and around 4 % of agricultural area is totally affected due to industrial activities. Similarly, Agarwal *et al.* (2010) suggested that industrialization affects the forest resources.

The remaining sites, namely Sagar, Raisen and Rewa showed stable biomass in both types of forest. The stem size at these sites ranged between small to medium, and this type of forest exhibited greater potential for carbon sequestration as compared to the forests having big size trees, due to higher growth rate (Upadhaya *et al.* 2015). According to Baishya *et al.* (2009), in forests where most trees are yet to be mature, there will be a net addition to standing biomass leading to carbon storage, which suggests that conservation and management of small trees can considerably increase carbon sequestration potential in near future (Terakunpisut *et al.* 2007). We also examined the relationship between basal area and above ground biomass. The results suggested that the basal area and biomass strongly associate with the tree architecture, as the growth processes generally take place in lower parts of the tree trunk (Chiba 1998). The comparisons of biomass estimates of study sites with other works are difficult because of variation in the methods employed for estimation of biomass in different studies.

Reports on allocation of above ground biomass are mostly from tropical dry forests of northern India (Ranavat & Vyas 1975; Singh & Singh 1981; Singh 1989; Negi 1995). The biomass ranged from 38.6 - 239.8 t ha^{-1}. Pande (2005) reported the range of biomass as 28.1 - 85.3 t ha^{-1} in disturbed tropical dry deciduous Teak forest of Satpura plateau, Madhya Pradesh. The maximum biomass for the present study was 54.9 t ha^{-1} in DDF and 44.5 t ha^{-1} in MDF.

Species composition of dry deciduous forest (DDF) in the present study showed dominance of

Teak (*Tectona grandis*) with trees having higher girth classes indicating a state of maturity and stabilized status. On the other hand, a dry mixed deciduous forest has considerable proportion of other species than teak. Further this forest type is attributed to relatively low rainfall and lower altitude (Champion & Seth 1968; FSI 2011). Therefore, in the present study, biomass is greater in DDF than in MDF.

Conclusions

Results showed that tree density, basal area and biomass varied with forest type. These were higher in DDF as compared to MDF, at most of the sites. Maximum tree density was recorded at Panna and minimum at Satna; basal area was maximum at Sagar and minimum at Satna; and biomass was maximum at Panna and minimum at Satna. Regression analysis between biomass and basal area showed positive relationship, which suggested that as the basal area increases, biomass will also increase. Lowest biomass was estimated at Satna and Katni among all the study sites. It was concluded that industrialization is responsible for reduced tree density and thus above-ground biomass.

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