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Aboveground Biomass and Carbon Stock of Tropical Deciduous Forest Ecosystems of Madhya Pradesh, India

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ABSTRACT

Tropical dry deciduous forests contribute about 41.87% to the total forests in India. Data on biomass and carbon storage in these forests are scanty. The present study deals with the tree biomass and carbon stock in tropical deciduous forests in Madhya Pradesh. The biomass stocks of four different types of forests *viz.*, mixed non-teak forest (MNTF), dry mixed non-teak forest (DMNTF), teak-dominated forest (TDF) and dry teak forest (DTF), were estimated at twelve different sites. Indicator species for dry conditions considered in the study were *Acacia catechu*, *A. nilotica*, *Aegle marmelos* and *Ziziphus* sp. At each site, 0.1 ha permanent plots were laid in Damoh, Katni, Raisen, and Sagar districts. Biomass and carbon were estimated by non-destructive method and tree allometric equations. Measurements for basal area and tree height were converted into volume using regional species-specific gravity. Since most of the forests in Madhya Pradesh fall under tropical dry deciduous type, sites were demarcated on the basis of species composition and dominance, and the moisture regime. Mean basal area of forest trees ranged from 4.33 to 9.0 m^2 ha^{-1} being maximum in MNTF. MNTF contributed a higher above ground biomass and the carbon stock. Significant positive correlations were observed between basal area and the aboveground biomass. Significant positive correlations were observed between basal area and the aboveground biomass. Comparison with studies done using destructive sampling methods showed that non-destructive allometric equations give reasonably accurate estimate of aboveground biomass and carbon stock. The carbon stock of four typical dry deciduous forests were estimated at 25-54 Mg ha^{-1} (MNTF), 13-42 Mg ha^{-1} (DMNTF), 33-53 Mg ha^{-1} (TDF) and 16-24 Mg ha^{-1} (DTF).

Key Words: Tree Carbon; Aboveground Biomass; Forest Types; Non-destructive Approach; Allometric Equations.

INTRODUCTION

Biomass of vegetation is usually defined as the mass of living plants like trees, shrubs, grasses and herbs, however, sometimes dead plant material is also included (Baccini et al. 2008). Large quantities of carbon are stored in the forest vegetation on account of sequestration and storage through photosynthesis. Due to human intervention, land use changes and other activities, carbon is released in to atmosphere (Haripriya 2000). Tropical forests are considered as having great carbon sequestration potential and therefore now gaining attention for mitigation of climate changes particularly the global warming (Hunter et al. 2013). Deforestation, particularly in developing countries has become an intense activity in recent years and considered on an issue of global environmental agenda. In the tropics as well as in other parts of world, natural forests are shirnking along with its valuable biodiversity (Hossain 2012). Additional pressures such as high rate of population growth and infrastructure development are leading to increased release of CO_2 into atmosphere. Forest ecosystem are the major store of atmospheric carbon and they mitigate the green house effect and contribute to climate stability (Dixon et al. 1994, Binkley et al. 2004, Mohanraj et al. 2011). Tropical secondary forests need to be worked out to fill the gaps for carbon stocking, quantification of carbon pool, rates and patterns of loss of biomass due to land cover change (Kauffman 2009). In India studies related to the above aspects in relation to critical disturbances are sporadic (George et al. 1990, Negi et al. 1990, 1995, Ranawat and Vyas 1975, Singh 1975, Singh and Singh 1981, Roy and Ravan, Dhadwal 2009, Bhat and Ravindranath 2011). According to Sheikh et al. (2011) carbon stocks in Indian forest are continuously decreasing since 2003. Madhya Pradesh (M.P.) is a centrally located state of India which comprises a forest cover of 76,013 km^2 which is 24.66 % of its total geographical area (FSI 2011). Major parts of these forests are surrounded by large numbers of villages and most of the tribal populations depend up on forests for their livelihood security (Pande 2005). Hence, large area of forests remains under threat due to disturbances. There is a need to gather sufficient systematic data on quantitative and qualitative analysis of forest particularly the density, biomass, and carbon storage. In view of this, the present study was carried out to quantify the existing volume, biomass, and carbon storage status of forests.

MATERIALS AND METHODS

Study Area and Sampling Design

The forests in districts (Damoh: 23º 50' Nm 79º 26' E, Katni: 23º 44' N, 80º 21' E; Raisen: 23º 19' N, 77º 48' E and Sagar: 23º 50' N, 78º 44' E) are tropical dry deciduous type (Champion and Seth 1968). The representative forests were selected on the basis of species composition and magnitude of biotic factors. Four kinds of forests were identified within the tropical dry deciduous type of Champion and Seth (1968). They are mixed non-teak forest (MNTF), dry mixed non-teak forest (DMNTF), teak dominant forest (TDF) and dry teak forest (DTF). All the four district have more or less all the forest types. However, species composition varied with site conditions. Selected sites in different districts were identified for the type on the basis of dominance of Teak and presence of species considered as indicators of dryness. The MNTF mainly contains *Lagerstroemia parviflora*, *Butea monosperma*, *Terminalia alata* without *Tectona grandis* and xerophytic dry species, DMNTF contains *Acacia*, *Aegle* and *Ziziphus* dominance along with above species without *Tectona grandis*, in TDF *Tectona grandis* contribute to dominance and in DTF *Tectona grandis* showed dominance along with dryness indicator species such as *Acacia*, *Aegle* and *Ziziphus*.

Forests were differentiated on the basis of presence / absence of teak (*Tectona grandis*) as well as its dominance. Drier and moisture ends in the vegetation also had great bearing on the species composition. Forest stand of uniform composition were identified and a super plot of 250×250m size was laid at each site (12 sites). Within this super plot, four sub plots each of 31.6×31.6 m (0.1 ha) size were laid in four directions i.e. NE, NW, SW and SE (Figure 1). In all 48 sample plots were assessed for estimation of aboveground biomass. Sites were approached with the help of toposheets of Survey of India and GPS device (Garmin 72).

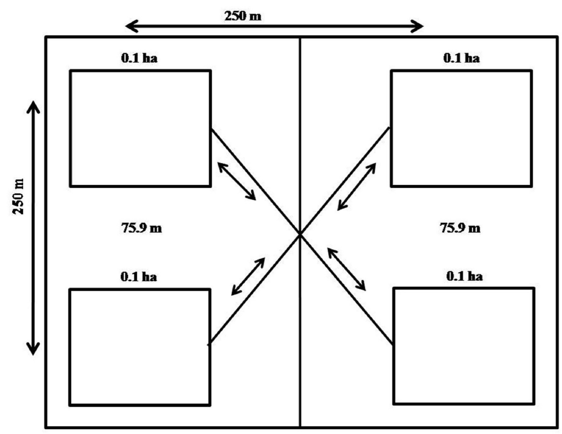

Figure 1. Plot level sampling design of study sites.

The study was carried out during 2011-12. Details regarding the geographical location, climatic conditions and forest cover are given in details earlier (Salunkhe et al. 2016).

Estimation of Biomass and Carbon

Observations were restricted only to the trees. Trunks having more than 10 cm diameter at breast height (DBH; 1.37 m above ground) were considered as trees. Non destructive method was followed for the estimation of aboveground biomass and carbon estimation. All the trees were marked with unique number. The species were identified with the help of herbarium at the Department of Botany, Dr HS Gour University, Sagar, and Flora of M.P. (Verma et al. 1993). Tree height and DBH were recorded by using Hypsometer and measuring tape respectively. The volume of trees was estimated with the help of site or region specific volume equations, procured from State Forest Departments, Forest Research Institute, Dehradun and Forest Survey of India

(FSI 1996, Dadhwal et al. 2009). Species volume equations and species specific gravity of recorded tree species are summarized in Table 1. The biomass was calculated as the product of volume of tree and species specific gravity.

Since carbon in wood varies in between 45% to 50% in different ecosystems, it was assumed that all biomass pool contained about 47.5% of carbon of their biomass (Kotto-Same et al. 1997). Data were analyzed statistically using SYSTAT version 12. Least significant difference (LSD) was used to compare differences.

Table 1. List of volume equations and species specific gravity used in the present study.

Species	Volume equations[1]	Equation	Gravity[2]
Acacia catechu (L.f.) Willd.	(0.02471+0.16897*D+1.12083*D*D+2.9328)*(D*D*D)	L	0.875
Acacia nilotica (L.) Willd. Ex Del.	(-0.00142+2.61911*D-0.54703*SQRT(D))^2	L	0.670
Aegle marmelos (L.) Correa.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.754
Albizia procera (Roxb.) Benth.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.579
Annona squamosa L.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.788
Anogeissus pendula Edgew.	(0.00085/(D*D)+(-0.35165/D)+4.77386-0.90585*D)*(D*D)	L	0.619
Bauhinia racemosa Lam.	(-0.04262+6.09491*D*D)	L	0.619
Boswellia serrata Roxb. ex Colebr.	(-0.1503+2.79425*D)^2	G	0.498
Butea monosperma (Lam.) Taub.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.465
Cassia fistula L.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.746
Chloroxylon swietenia DC.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.458
Dalbergia latifolia Roxb.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.754
Dalbergia sissoo Roxb.	(0.04422+2.328465 *(D*D)+0.309150 *(D*D)*H)	L	0.669
Diospyros melanoxylon Roxb.	(0.15581-2.2075*D+9.17559*D*D)	L	0.678
Elaeodendron glaucum Pers.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.619
Ficus racemosa L.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.619
Ficus religiosa L.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.385
Flacourtia indica (Burm.*f.*)Merr	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.619
Gardenia latifolia Ait.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.635
Holarrhena pubescens (Buch.-Ham.) Wall. ex G.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.592
Holoptelea integrifolia (Roxb).Planch	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.37
Kydia calycina Roxb.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.648
Lagerstroemia parviflora Roxb.	(0.01617-0.66446 *D+9.71038*D*D)	L	0.513
Lannea coromandelica (Houtt.) Merr.	(0.14004/(D*D)+(-2.35990/D)+11.90726)*(D*D)	L	0.619
Madhuca latifolia Roxb.	(-0.051-0.034*D+4.542*D*D)	L	0.619
Melia azadirach L.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.619
Mitragyna parvlfolia Korth.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.619
Ougeinia oogeinsis (Roxb) Hochr	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.704
Phyllanthus emblica L.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.619
Saccopetalum tomentosum (Roxb.) Hook. *f.* & Thoms.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.619
Syzygium cumini (L.) Skeels	(0.08481-1.81774 *D+12.63047 *D*D-6.6955*(D*D*D))	L	0.647
Tectona grandis L.f.	(0.04346-0.26352*SQRT(D)+8.79334)*(D*D)	L	0.577
Terminalia alata Heyne *ex* Roth	(0.33695-1.23004*SQRT(D)+11.86676)*(D*D)	L	0.694
Terminalia bellerica (Gaergh.) Roxb.	(-0.14017+3.364233*D)^2	L	0.628
Terminalia arjuna (Roxb. *ex* DC.) Wight & Arn.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.686
Zizyphus jujube Lamk.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.597
Zizyphus xylopyra Willd.	(0.0697/(D*D)+(-1.4597/D)+11.79933-2.35397*D)*(D*D)	G	0.597

D= DBH (m), H= height (m), SQRT= square root, L= Local volume equations, G- General volume equation.[1] FSI (1996), [2] FRI (1999)

Table 2. Tree density, basal area, above ground biomass and carbon at different sites.

District	Sites (trees ha^{-1})	Tree Density (m^2 ha^{-1})	Basal Area (Mg ha^{-1})	Biomass (Mg ha^{-1})	Carbon
Damoh	Mixed Non Teak Forest 1	248 ±78^{d}	11 ±4^{a}	54 ±23^{a}	26 ±11^{a}
Katni	Mixed Non Teak Forest 2	338 ±82^{cd}	6 ±3^{b}	25 ±15^{b}	12 ±7^{b}
Katni	Mixed Non Teak Forest 3	238 ±36^{d}	10 ±2^{a}	45 ±7^{a}	21 ±3^{a}
Katni	Dry Mixed Non Teak Forest 1	565 ±148^{ab}	7 ±2^{b}	27 ±10^{b}	13 ±5^{b}
Katni	Dry Mixed Non Teak Forest 2	615 ±52^{a}	10 ±2^{a}	42 ±15^{a}	20 ±7^{a}
Sagar	Dry Mixed Non Teak Forest 3	253 ±96^{d}	3 ±2^{c}	13 ±8^{c}	6 ±4^{c}
Raisen	Teak Dominant Forest 1	293 ±81^{d}	10 ±2^{a}	53 ±10^{a}	25 ±5^{a}
Raisen	Teak Dominant Forest 2	350 ±73^{c}	7 ±1^{b}	33 ±5^{b}	16 ±2^{b}
Sagar	Teak Dominant Forest 3	458 ±200^{bc}	8 ±3^{ab}	39 ±15^{ab}	18 ±7^{ab}
Sagar	Dry Teak Forest 1	193 ±67^{d}	4 ±2^{c}	24 ±16^{bc}	11 ±8^{bc}
Katni	Dry Teak Forest 2	280 ±85^{d}	4 ±2^{c}	16 ±8^{c}	8 ±4^{c}
Katni	Dry Teak Forest 3	370 ±78^{c}	5 ±2^{bc}	16 ±7^{c}	8 ±3^{c}
S. Em. ±		49.58	1.14	6.30	3
$CD_{0.001}$		145	3.29	18.18	8.64

Values with different superscripts differ significantly.

RESULTS AND DISCUSSION

Tree density, basal area, aboveground biomass and carbon measured or estimated at different sites are presented in Table 2. Relatively higher tree density was observed in DMNTF sites. ANOVA showed significant difference among densities of different sites (F=7.18 p< 0.001, df 36). Among the four forest types, the tree density ranged from 193±67 to 615±52 trees ha^{-1} while maximum average tree density was observed in DMNTF (478 trees ha^{-1}) whereas it was minimum in DTF (281 trees ha^{-1}). Significant differences in basal area were also observed at different sites (F= 5.48, p< 0.001, df 36). Average basal area was maximum in MNTF (9 m^2 ha^{-1}) where as it was minimum for DTF (4.33 m^2 ha^{-1}).

Aboveground biomass and carbon follow the pattern of basal area. More or less similar estimates of biomass and carbon were found at MNTF and TDF sites. Significant positive relationship was observed between basal area and biomass irrespective of forest types (Figure 2). However, tree density had no bearing either on basal area or biomass. Regression analysis between biomass and basal area in the four types of forests (Figure 2) showed significantly positive relationship (R^2 = 0.915).

Aboveground biomass and carbon stock varied with the degree of anthropogenic pressure in tropical dry deciduous forests in M.P. Several studies state that human settlements close to forest cause intensive exploitation and degrade forest as compared to remote settlements (Acharya 1999, Sagar et al. 2003, Pande 2005, Ramacharitra 2006, Salunkhe et al. 2016). Reports indicate that the rural populations solely depend upon forest biomass for meeting their livelihood security such fuel wood, fodder, non timber forest products and also for agricultural implements. (Silori and Mishra 2001, Pande 2005, Davidar et al. 2007, Salunkhe et al. 2014). Disturbances cause decline in tree density (Ramirez-Marcial et al. 2001).

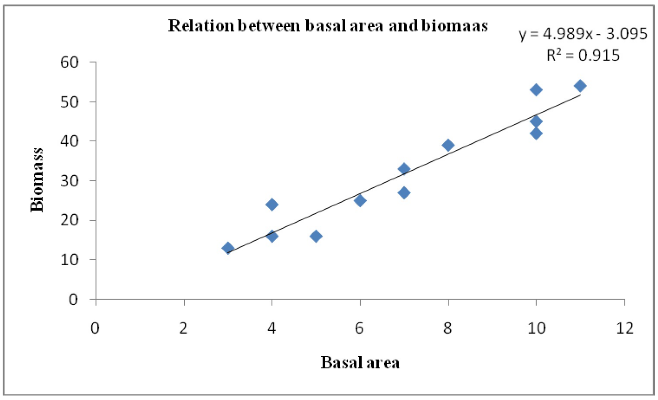

Figure 2. Correlation between basal area and biomass of study area

The lower biomass at DMNTF and DTF of Katni and Sagar districts may be attributed to large numbers of granite and marble mines in forest vicinity and the intensive mining operations responsible for degradation of forests. This could be one of the reasons 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. DMNTF, despite having high tree density had low biomass due to large numbers of trees of young growth in successional stage. High density trees with high girth classes contribute to higher AGB even at disturbed site than with high density of younger trees and less disturbed stand (Pande 2005).

Aboveground biomass of given location differs with site, habitat, forest succession stage, composition of forest, species variability and varying tree density as well as disturbances, total annual rainfall and geographical location of the forests.etc.(Whitmore 1984, Brunig 1983, Terakunpisut et al. 2007). In two forest types of present study namely, MNTF and TDF had higher biomass and carbon on account of maturity of forest with more bole size as compared to bole size recorded at other sites. Long dry conditions and low moisture conditions in DMNTF and DTF also result in low biomass. It is one of the reason that a mixed composition of species exists as in case of MNTF or under more dry conditions, species adapted to that can grow but with fewer dimensions.

Among the four forest types the overall tree density ranges from 193 trees ha^{-1} to 615 trees ha^{-1} and average tree density ranges from 281 trees ha^{-1} to 478 trees ha^{-1}. Basal area of present study ranged from 3±2 to 11±4 m^2 ha^{-1}. These values are well in ranged as compared to earlier reports from tropical dry deciduous forests such as 6.58-23.21 m^2 ha^{-1} by Jha and Singh (1990); 7.66-19.55 m^2 ha^{-1} by Joshi (2012) from tropical dry deciduous forest of West Bengal, India; 13.73 m^2 ha^{-1} by Sahu et al. (2012) at tropical dry deciduous forests of Eastern Ghats, India;0.52 to 5.61 m^2 ha^{-1} by Devagiri et al. (2013) at Southern West part of Karnataka and 0.98 to 22.19 m^2 ha^{-1} by Bhat and Ravindranath (2011) at tropical rain forest of Western Ghat, India.

The biomass and carbon ranged from 13 ±8 to 54 ±23 and Mg ha^{-1} and carbon stock from 6 ±4 Mg ha^{-1} to 26 ±11 Mg ha^{-1} across different study sites. As compared to available estimates of different tropical deciduous forests of India (Ranavat and Vyas 1975, Singh and Singh 1981, Singh 1989), values of AGB in present study lie within those reported eg. 27.6 Mg ha^{-1} by George et al. (1990), from Indian tropical dry deciduous forest, 7.69 to 20.48 Mg ha^{-1} by Devgiri et al. (2013) in tropical dry deciduous forest of Hassan district of Andhra Pradesh, and 28.68 Mg C ha^{-1} by Singh et al. (1991) in dry tropical forest of Kaimur range of Vindhyan hill track, India. According to Pande (2005) in disturbed tropical dry deciduous teak forest of Satpura plateau, Madhya Pradesh, biomass range from 28.1-85.3 Mg ha^{-1} respectively. The mean AGB and C in mixed forest 78.31 and 39.11 Mg ha^{-1} respectively and in Teak mixed forest as 66.34 and 3317 Mg ha^{-1} were reported by Bijalwan et al (2010) at tropical dry deciduous forests of Chhattisgarh region of India; 22.50 and 18.27 Mg ha^{-1} AGB and C were reported by Devi and Yadava (2009) in two strands of tropical forests of North-Eastern India and 27.44 Mg ha^{-1} AGB was reported by Kale et al (2004) in tropical dry deciduous forests of Central India. Dadhawal et al. (2009) recorded phytomass of deciduous forest of Surat district of Gujarat, ranging from 8 Mg ha^{-1} to 211 Mg ha^{-1}. The results of the present study show similarity with above cited works of national level biomass estimation. In the present investigation, the correlation of basal area and biomass shows positive relation indicating the basal area is an indicator of biomass. Strong relationships between biomass and basal area have been reported by several workers in various types of forests (Cannell 1984, Rai and Proctor 1986).

CONCLUSION

The present study furnishes evidences that estimation of biomass and carbon in forests can be accurately estimated taking non-destructive method using allometric equations. Further, the carbon stock in these forests may of importance when dealing with carbon sequestration potential. It was concluded that industrialization is responsible for reduced tree density and thus above-ground biomass.

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