

## Impact of Land Use Changes on Species Structure, Biomass and Carbon Storage in Tropical Deciduous Forest and Converted Forest

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### ABSTRACT

Impacts of land use change on species structure, biomass and carbon storage were studied in a tropical deciduous forest and a converted forest. Total of 2740 trees representing 23 species and 18 families were recorded in the study area. Density and basal area of trees in different forest plots ranged from 480 stems ha<sup>-1</sup> (32 years old converted forest) to 920 stems ha<sup>-1</sup> (natural forest) and 12.04 m<sup>2</sup> ha<sup>-1</sup> (15 years old converted forest) to 25.16 m<sup>2</sup> ha<sup>-1</sup> (natural forest). Diversities in these forest plots were 0.79 to 2.72 (Shannon index), 1.77 to 4.03 (Species richness), 0.44 to 1.18 (equitability), 0.78 to 1.0 (concentration of dominance) and 8.21 to 13.53 (beta diversity). The beta diversity was highest at disturbed forest plot, respectively

The total biomass recorded among the different forest plots was 192.933 Mg ha<sup>-1</sup> in natural forest followed by 95.64 Mg ha<sup>-1</sup> in 32 years old converted forest, 85.78 Mg ha<sup>-1</sup> in 23 years old converted forest and 92.05 Mg ha<sup>-1</sup> in 15 years old converted forest. The total above ground biomass in different forest plots ranged from 71.94 to 162.91 Mg ha<sup>-1</sup> with highest in natural forest and lowest in 23 years old converted forest. The below ground biomass varied from 13.97 to 30.02 Mg ha<sup>-1</sup> with the highest in natural forest and lowest in 23 years old converted forest. Carbon storage was also maximum in natural forest (96.44 Mg ha<sup>-1</sup>) followed by 32 years old converted forest (47.801 Mg ha<sup>-1</sup>), 15 years old converted forest (46.25 Mg ha<sup>-1</sup>) and 23 years old converted forest (42.88 Mg ha<sup>-1</sup>). The higher proportion of above ground carbon was allocated to bole followed by branch and root in different forests. The above ground carbon in different forests ranged between 35.88 to 81.43 Mg ha<sup>-1</sup> with highest in natural forest and lowest in 23 years old converted forest. The below ground carbon in different forest varied from 6.98 to 15.01 Mg ha<sup>-1</sup> and was highest in natural forest and lowest in 23 years old converted forest. Study revealed the changes in structure, diversity, biomass and carbon storage due to changes in land use practices in tropical deciduous forest.

*Key Words:* Tropical Deciduous Forest , Converted Forest, Biomass, Carbon Storage, Species Diversity

### INTRODUCTION

To understand the carbon budget of forests, we should also understand their structure and dynamics, because about half of the plant biomass and soil organic matter are composed of carbon. Forests are influenced by natural and human causes, including harvesting, over-harvesting and degradation, large-scale occurrence of wildfire, fire control, pest and disease outbreaks, and conversion to non-forest use, particularly agriculture and pastures. These disturbances generally cause forests to become sources of CO<sub>2</sub> because net primary productivity is exceeded by total respiration or oxidation of plants, soil, and dead organic matter. Globally land-use change is estimated to release about

0.9 Gt C yr<sup>-1</sup> to the atmosphere. This consists of an estimated loss of 1.65 Gt C yr<sup>-1</sup> in the tropics, but gains in temperate and boreal regions are due to forestation and increase in the average size of existing forests (Brown et al. 1996). FAO reported that natural forests in the tropics were lost at a rate of 14.6 Mha yr<sup>-1</sup> between 1980-90 and at 12.9 Mha yr<sup>-1</sup> between 1990-95 (FAO 1997). This constituted a loss of about 0.7% yr<sup>-1</sup> of the remaining forest area.

Forests play an important role in regional and global carbon cycles because they store massive quantities of carbon in vegetation and soil, exchange carbon with the atmosphere through photosynthesis and respiration, are sources of atmospheric carbon when they are disturbed by human or natural causes,

become atmospheric sinks during regrowth, and can be managed to sequester or conserve significant quantities of carbon on the land.

The forest carbon cycle accounts for over 90 Gt of annual carbon flux out of a total of 110 Gt annually for all terrestrial ecosystems. The global carbon content of forest systems, above and below ground, is about 1400 Gt within a worldwide terrestrial pool of about 2200 Gt. (Dixon et al. 1991). Forest biomass is a function of its successional state; direct human activities such as silviculture, and harvesting; natural disturbances caused by wildfire or pest outbreaks; and changes in climate and atmospheric pollutants. Biomass is, also, a useful measure for assessing changes in forest structure and for comparing the status and trends of forest ecosystems across a wide range of environmental conditions (Brown et al. 1999).

Forests of the world sequester and conserve more C than all other terrestrial ecosystems and account for 90% of the annual C flux between the atmosphere and the earth's land surface. Forests are a major sink for carbon and play an important role in the global carbon cycle. Not only do forests contain huge amounts of carbon, they exchange it very actively with the atmosphere. Expanding the world's forests, therefore, may present an opportunity to increase the terrestrial carbon sink, and slow the increase in atmospheric CO<sub>2</sub> concentration. The tropical zones of the world seem particularly attractive for forestation because of the high rates of productivity that can potentially be attained there, and because there appear to be large areas of land that would benefit from tree planting.

However, studies on structure, composition, diversity, biomass and carbon storage in tropical dry deciduous forest of Barnawapara is unavailable hence in the present study an attempt has been made to inventories the information on structure, composition, diversity, biomass and carbon storage in tropical dry deciduous forest of Barnawapara in relation to land use change. Structure, composition, diversity, biomass and carbon storage in tropical dry deciduous forest of Barnawapara

## STUDY AREA

The study was conducted in Barnawapara wildlife sanctuary (North Raipur Division) situated in North corner of Raipur district. It is located between 21° 20' 0" to 21° 25' 47" North latitudes and 82° 21' 17" to 82° 26' 27" East longitudes. The general topography of

area is undulating due to formation of rockout crop. The area has three distinct geological formations viz. Chhattisgarh super group, Late Precambrian and Early Precambrians. Dry deciduous forest, grasslands, agriculture lands and human habitations surrounds the study area. Soils of study area are grouped into three classes viz., Inceptisols, Alfisols and Vertisols. The climate is dry humid tropical consist of three seasons viz. rainy, winter and summer. The average annual rainfall ranges from 1200-1350 mm. Champion and Seth (1968) have classified forest of the study area into four major forest types viz., (1) Southern tropical dry deciduous teak forest, (2) Northern tropical dry peninsular deciduous Sal forest, (3) Northern tropical mixed deciduous Sal forest (5B/C2); and (4) Dry bamboo brakes (5/E9).

## METHODS

The stratified random sampling procedure was adopted for characterization of vegetation. The phytosociological analysis in each forest plot was carried by randomly laying 10 sample plots of 10 x 10 m<sup>2</sup> in size. In each quadrat, gbh (girth at breast height) of each adult individual ( $\geq 30$  cm gbh) was measured at 1.37 m. from the ground. Thus, all individuals were enumerated by species and the girth of all the individuals was measured.

The vegetation data in each forest plot was quantitatively analyzed for frequency, density and abundance (Curtis and McIntosh 1950). An Importance Value was calculated as the sum of relative frequency, relative density and relative dominance (Phillips 1959). The diversity indices for each forest plots were calculated following Sagar and Singh (1999). For the measurement of tree biomass, allometric equations relating tree circumference to biomass developed earlier by Singh and Mishra (1979) for the dry deciduous forest species were used.

Carbon content in each plant part was estimated assuming 50% of the plant biomass / plant part as carbon.

## RESULTS

### Species Composition

A total of 2740 trees representing 23 species and 18 families were encountered in the study area. Density of

Table 1. Species structure of tree layer of converted and natural forest at Baranawapara Wildlife Sanctuary

Species	32 yr old converted		23 yr old converted		15 yr old converted		Natural forest	
	BA	IVI	BA	IVI	BA	IVI	BA	IVI
<i>Tectona grandis</i> Linn. f.	9.712	160.68	14.79	234.49	5.04	133.44	-	-
<i>Semecarpus anacardium</i> Linn. f.	-	-	0.19	10.14	0.58	16.33	-	-
<i>Schleichera oleosa</i> (Lour) Oken.	0.127	6.90	0.55	18.17	-	-	-	-
<i>Pterocarpus marsupium</i> Roxb.	1.74	25.46	0.20	8.65	-	-	1.28	9.89
<i>Madhuca indica</i> J.F. Gmel.	0.491	27.65	0.93	20.40	3.36	39.44	0.35	7.28
<i>Cleistanthus collinus</i> (Roxb). Benth & Hook.	0.49	27.65	0.12	8.14	0.58	31.39	9.24	113.11
<i>Ougeinia oojeninensis</i> (Roxb). Hochr.	-	-	-	-	0.22	8.35	-	-
<i>Buchania lanzan</i> Spreng.	-	-	-	-	0.63	20.33	-	-
<i>Lagerstroemia parviflora</i> Roxb.	0.10	6.79	-	-	0.255	10.04	1.10	23.10
<i>Embllica officinalis</i> Gaerth.	-	-	-	-	0.68	12.19	1.41	10.42
<i>Syzygium cumini</i> (Linn.) Skeels.	-	-	-	-	0.16	7.87	-	-
<i>Diospyros melanoxylon</i> Roxb.	-	-	-	-	0.28	8.87	-	-
<i>Cassia fistula</i> Linn.	-	-	-	-	0.24	11.75	0.51	11.62
<i>Bombax malabaricum</i> Linn.	1.60	22.48	-	-	-	-	-	-
<i>Ventilago calyculata</i>	0.22	7.54	-	-	-	-	-	-
<i>Acacia catechu</i>	0.10	6.78	-	-	-	-	-	-
<i>Garuga pinnata</i> Roxb.	0.15	7.10	-	-	-	-	-	-
<i>Butea monosperma</i> (Lamk) Taub.	0.33	8.22	-	-	-	-	-	-
<i>Ficus glomerata</i>	0.32	8.20	-	-	-	-	-	-
<i>Gentiana kurroo</i>	-	-	-	-	-	-	3.95	60.96
<i>Anogeissus latifolia</i> Wall. Ex Bedd.	-	-	-	-	-	-	1.67	16.23
<i>Adina cordifolia</i>	-	-	-	-	-	-	1.23	14.49
<i>Terminalia tomentosa</i> Wt & Ang.	-	-	-	-	-	-	4.30	32.87
Total	15.57	300	16.81	300	12.04	300	25.16	300

BA = Basal area ( $\text{m}^2 \text{ha}^{-1}$ ), IVI=Importance value index

trees in different forest plots ranged from 480 stems  $\text{ha}^{-1}$  in 32 yr-old converted forest to 920 stems  $\text{ha}^{-1}$  in natural forest. The basal area in these forests were  $12.04 \text{ m}^2 \text{ha}^{-1}$  in 15 yr-old converted forest and  $25.16 \text{ m}^2 \text{ha}^{-1}$  in natural forest (Table 1).

### Species Diversity

Diversities in these forest plots were 0.79 to 2.72 (Shannon index), 1.77 to 4.03 (Species richness), 0.44 to 1.18 (equitability), 0.78 to 1.0 (concentration of dominance) and 8.21 to 13.53 (beta diversity). The beta diversity was highest at disturbed forest plot, respectively (Table 2).

### Biomass

The total biomass ( $\text{Mg ha}^{-1}$ ) recorded among the different forest plots was  $192.933 \text{ Mg ha}^{-1}$  in natural

forest followed by  $95.637 \text{ Mg ha}^{-1}$  in 32 yr-old converted forest (Table 3),  $85.78 \text{ Mg ha}^{-1}$  in 23 yr-old converted forest (Table 3) and  $92.05 \text{ Mg ha}^{-1}$  in 15 yr-

Table 2. Diversity parameters in tropical deciduous forest and converted forest

Parameters	32 yr old converted	23 yr old converted	15 yr old converted	Natural Forest
Species richness	4.0	1.77	4.03	2.70
Shannon index	2.3	0.79	2.46	2.72
Concentration of dominance	0.89	1.00	0.98	0.78
Equitability	0.92	0.44	1.03	1.18
Beta diversity	9.20	13.53	8.21	8.52

old converted forest. The total above ground biomass in different forest plots ranged from 71.94 to 162.91 Mg ha<sup>-1</sup> with highest in natural forest (Table 3) and lowest in 23 yr-old converted forest. The below ground biomass in different forest plots varied from 13.97 to 30.02 Mg ha<sup>-1</sup> and was highest in natural forest and lowest in 23 yr-old converted forest.

### Carbon Storage

The total carbon (Mg ha<sup>-1</sup>) recorded among different forests was highest in natural forest (96.44) followed by 32 yr-old converted forest (47.801), 15 yr-old converted forest (46.25) and 23 yr-old converted forest (42.88). The higher proportion of above ground carbon was allocated to bole followed by branch and root in different forests. The above ground carbon in different forests ranged between 35.88 to 81.43 Mg ha<sup>-1</sup> with highest in natural forest and lowest in 23 yr-old converted forest. The below ground carbon in different forest varied from 6.98 to 15.01 Mg ha<sup>-1</sup> and was highest in natural forest and lowest in 23 yr-old converted forest (Table 4).

## DISCUSSION

### Species Composition

Tree basal cover in the present study varied from 12.04 to 25.16 m<sup>2</sup> ha<sup>-1</sup> for various forest plots. These basal cover values were slightly 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<sup>2</sup> ha<sup>-1</sup> and from 3.84 to 10.36 m<sup>2</sup> ha<sup>-1</sup> by Singh and Singh (1991). These values compare with 17 to 40 m<sup>2</sup> ha<sup>-1</sup> for dry tropical forest and 20 to 75 m<sup>2</sup> ha<sup>-1</sup> for wet forest (Murphy and Lugo 1986a). Basal cover in a Puerto Rican sub-tropical dry forest was 19.8 m<sup>2</sup> ha<sup>-1</sup> (Murphy and Lugo 1986b). In the present study, tree density ranged between 480-920 for various forest plots in dry deciduous forest. Compared to the present study the density of forest in Thailand, of dry Dipterocarp forest, was 554 to 789 (Visaratana et al. 1986); of mixed deciduous forest was 253 (Sahunalu et al. 1979), of teak forest was 262 to 395 (Bunyavejchewin 1983, Dhanmanonda and Sahunalu 1992) and of tropical rain forest was 818 to 1540 (Kiratiprayoon 1986).

Table 3. Biomass (Mg ha<sup>-1</sup>) in tropical deciduous forest and converted forest

Site	Bole	Branch	Leaf	Root	Total
Natural forest	61.06 (31.62)	94.62 (49.04)	7.23 (3.74)	30.02 (15.55)	192.933
32 years old plantation	41.55 (43.44)	31.51 (32.88)	7.41(7.74)	15.19 (15.88)	95.637
23 years old plantation	41.19 (48.01)	19.58 (22.82)	11.17 (13.02)	13.97 (16.28)	85.78
15 years old plantation	29.80 (32.37)	22.59 (24.54)	22.70 (24.66)	16.89 (13.34)	92.05

Table 4. Carbon storage (Mg ha<sup>-1</sup>) in tropical deciduous forest and converted forest

Site	Bole	Branch	Leaf	Root	Total
Natural forest	30.52 (31.64)	47.3 (49.04)	3.61(3.74)	15.01(15.56)	96.44
32 years old plantation	20.76 (43.43)	15.74 (32.92)	3.70 (7.75)	7.596 (15.89)	47.80
23 years old plantation	20.59 (48.01)	9.79 (22.83)	5.50 (12.82)	6.98 (16.27)	42.88
15 years old plantation	14.89 (32.19)	11.28 (24.38)	11.34 (24.51)	8.742 (18.90)	46.25

Tree density in the Vindhyan region ranges between 294 and 627 stems  $\text{ha}^{-1}$  for several dry tropical forest communities (Singh and Singh 1991, Jha and Singh 1990). The forest canopy was three storied in the present forest. The dry tropical forest usually has 1-3 and the wet tropical forest three or more canopy strata (Murphy and Lugo 1986a).

### Species Diversity

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 (0.79 to 2.72) in various forest plots compared to Dry Dipterocarp Forest and Mixed Deciduous Forest of Thailand (3.75 to 4.49, Kiratiprayoon et al. 1995), tropical rain forest of silent valley, India (3.8 to 4.8; Singh et al 1984) and of Barro Colorado Island (4.8; Knight 1975). In other studies, the Shannon–Wiener index of diversity in forests of Thailand was 1.9 to 4.0 for dry Dipterocarp forest (Sahunalu et al. 1979), 3.5 to 3.9 for mixed deciduous forest (Sahunalu et al. 1979); 2.9 for teak forest (Dhanmanonda and Sahunalu 1992) and 5.0 to 6.2 for tropical rain forest (Kiratiprayoon 1986).

### Biomass

Values for biomass are comparable with the estimates made by many workers (Murphy and Lugo 1986b, Singh and Singh 1991, Haripriya 2000). Singh and Mishra (1979) reported 77  $\text{Mg ha}^{-1}$  and Singh and Singh (1991) reported 42-78  $\text{Mg ha}^{-1}$  biomass in dry tropical forests. Total biomass of the different forest communities ranged from 7.42 to 52.41  $\text{Mg ha}^{-1}$  in tropical dry deciduous forests of Madhav National Park, India (Ravan 1994). Hall and Uhling (1991) estimated the biomass density of forests in South and South East Asia using the volume estimates and biomass expansion factors derived from Brown et al., (1989). Their biomass estimates for India ranged from 116  $\text{Mg ha}^{-1}$  for forest undisturbed for 60-80 yr-and 35, 66 and 84  $\text{Mg ha}^{-1}$  for logged, unproductive and managed forests, respectively.

### Carbon Storage

Estimates of carbon stocks and fluxes from several tropical regions provided additional depth to the analysis. Africa, for example, was determined to

contain 50.6 Gt C in all vegetation cover, both above and below ground (Gaston et al. 1998). In the western Hemisphere, Brazil contains the world's largest expanse of tropical forests, with 136- 162 Gt C in above and below-ground vegetation and litter (Schroeder and Winjum 1995a), and net emissions of carbon to the atmosphere of 174-233 Mt yearly (Schroeder and Winjum 1995b) projected for the 20-yr period of 1990 to 2010 (Schroeder and Winjum 1995c). Delany et al., (1998) determined that Venezuelan forests held 300- 500 t/ha C, with 20-37 % of that on and below ground and with turnover time of litter into  $\text{CO}_2$  being very rapid (<2 yrs). Biomass burning in Costa Rica (Helmer and Brown, 2000) contributed to considerable  $\text{CO}_2$  emissions as well, primarily from lowland forest destruction.

In Mexico, like Costa Rica, most carbon stock changes near the end of the 20<sup>th</sup> century (1996), from southern Mexico (Cairns et al., 2000), to the Mexican central highlands (De Jong et al. 1999, 2000). The data from Brazil, Mexico, the U.S. and the former Soviet Union, were combined in several studies, both for comparing overall carbon budgets (Turner et al. 1998, without Mexico), and to compare land use effects (Cairns et al. 1997). The results amplified conclusions reached in earlier analyses, demonstrating the importance of reducing land use impacts on forest biomass in tropical areas, and of applying forest management techniques to enhance carbon sequestration in tropical, temperate and boreal regions. Slowing deforestation, combined with an increase in forestation and other management measures to improve forest ecosystem productivity, could conserve or sequester significant quantities of C. Future forest carbon cycling trends attributable to losses and regrowth associated with global climate and land-use change are uncertain (Dixon et al. 1999). Model projections and field experiments suggest that forests could be carbon sinks or sources in the future (Dixon et al. 1994). To the end, forest carbon conservation and sequestration options have become major policy instruments of the UN Framework Convention on Climate Change Activities (UNFCCC) Implemented Jointly (AIJ) over the past decade (Dixon 1995).

Study revealed that both biotic and abiotic factors significantly influenced the structure, composition, diversity, biomass and carbon storage of dry deciduous forest resulting in poor density, basal area and diversity. The greater the biodiversity of an environment, the greater its ability to withstand environmental stress and produce new and useful forms

of life. In properly managed forest animals and plants may produce more valuable medicine, food, and construction material over the years and decades than can be procured by clear-cutting forests and destroying them in their current form.

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