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RESEARCH PAPER

Aboveground biomass and net primary production of semi-evergreen tropical forest of Manipur, north-eastern India

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Abstract: The aboveground biomass dynamics and net primary productivity were investigated to assess the productive potential of *Dipterocarpus* forest in Manipur, Northeast India. Two forest stands (stand I and II) were earmarked randomly in the study site for the evaluation of biomass in the different girth classes of tree species by harvest method. The total biomass was 22.50 $t{\cdot}ha^{-1}$ and 18.27 $t{\cdot}ha^{-1}$ in forest stand I and II respectively. Annual aboveground net primary production varied from 8.86 to 10.43 $t{\cdot}ha^{-1}$ respectively in two forest stands (stand I and II). In the present study, the values of production efficiency and the biomass accumulation ratio indicate that the forest is at succession stage with high productive potential.

Keywords: biomass; net primary production; accumulation; production efficiency

Introduction

Tropical forest plays an important role in reducing atmospheric CO_2, which continues to contribute to global warming of the earth surface. Studies on biomass of forest vegetation are essential for determining storage of the carbon in the dominant tree component and computing the carbon cycling at a regional as well as global level.

Measurement of productivity of dominant tree species in different woodlands is of great importance because the dominant tree species greatly influence the magnitude and pattern of energy flow that is stored in trunks, branches, leaves and roots in the form of various organic substances and material remained in continuous circulation between biotic and abiotic components of the ecosystem. Therefore, it is pertinent to measure the total dry matter production for the efficiency of vegetation to fix energy in the different components of the ecosystem. Net primary production may be considered as the accumulation of organic matter in plant tissue in the excess of respiration during certain specific period (Newbould 1967; Phillips 1970; Lieth 1973). Variability of tree species in net primary productivity has been attributed to numerous factors related to the physiology of the trees, site conditions or structural characteristic of individual tree stands (McMutrie et al. 1994). Van cleve et al. (1983), Bonan and Van cleve (1992) and Reich et al. (1997) suggest that in some regional scale studies, species characteristics (photosynthetic efficiency, carbon allocation strategies) and soil nutrient status have been found to be important. Limited information is available on the biomass dynamics and net primary productivity as especially of *Dipterocarpus* forests from India in general, particularly from Manipur (Devi et al. 2006). Besides it produces resin, *Dipterocarpus tuberculatus* could be used to paint boats in preventing from decay. Therefore, there is a need to evaluate the biomass production to understand the role of these forests in carbon cycle and its rational utilization for various purposes, especially for timber. The present study highlights the total aboveground biomass dynamics and net primary productivity of the *Dipterocarpus tuberculatus* forest in Manipur, Northeast India.

Methods and materials

The study site is located between 23º49'N and 24º28'N latitude and 93º45'E to 94º14'E longitude at an altitude from 300 to 360 m above the mean sea level along the Indo Myanmar border near Moreh town in the Chandel district of Manipur, which is 108 km from Imphal, the capital of Manipur. Two forests stands (stand I and II) were earmarked randomly for the present study. Forest stand I was on hilltop with relatively plain topography. The stand II was situated on the southern hill slope facing Myanmar border. The forest is dominated by *D. tuberculatus* (locally known as Khangra) and represents preclimax state and maintains thin state by frequent felling trees. The present forest is gregarious in nature and occupies an area of 750 km^2, only in Manipur along the Indo-Myanmar border and extends up to South Asian countries.

India *Dipterocarpus* forests were recorded from Western Ghats and northeastern states of India (Champion et al. 1968). Three tree species (*D. tuberculatus*, *Ardisia peniculata*, *Wend-*

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landia wallichii from stand I) and two tree species (*D. tuberculatus* and *A. peniculata* from stand II) with different dbh classes were harvested for the estimating biomass. The fresh weight of all boles, branches, leaves and fruits were determined at the site. The sub-samples of different components were brought to the laboratory in the polythene bags. All the sub-samples were oven dried at 80°C (Singh et al. 1974) to constant weight. Leaf samples of varying size (15 leaves) were also plucked from each tree from different constituent tree species for determining leaf area. The biomass for the standing crop of different tree species was computed using density values (20 quadrats of 10 m ×10 m randomly) along different girth classes (Newbould 1967). The stand biomass was calculated by summing the biomass value across the girth class of all the species. The biomass of herb and shrubs was taken by harvest method (Singh et al. 1974). Average biomass for each herb and shrub species was multiplied by its respective density (individuals per hectare) in the stands. Litter from two stands was collected from 10 permanently laid quadrats of 1m×1m and was oven dried at 80°C to constant weight.

Twenty trees and 28 saplings, belonging to three dominant species with different girth classes from forest stand I and II, were marked for the measurement of girth increment. The marked trees were re-measured after one year to assess the increment in girth classes for the estimation of biomass. Then re-measured trees were harvested to compute biomass increment. Aboveground net primary production was estimated by summing up the annual increment in the biomass. The annual biomass increment in different component of tree species was calculated by subtracting the biomass of first year from that of second year.

The production efficiency in terms of net production per unit weight or per unit area of leaf was calculated for the present stands (Johnson et al. 1974). Biomass accumulation ratio (biomass/net production) was calculated to assess the production condition in the forest communities (Whittaker 1966).

Results

Tree layer biomass

Total biomass of all tree species in different girth classes in forest stand I and II was computed by multiplying with the density of tree species per hectare (Table 1). The total biomass of all three species (*D. tuberculatus*, *A. peniculata*, *W. wallichii* from stand I) of each girth class increased with the increase in girth classes. The biomass for *D. tuberculatus* in different girth classes ranged from 1 233.05 kg·ha^{-1} to 3 993.56 kg·ha^{-1} in stand I and 136.01 kg·ha^{-1} to 9 581.80 kg·ha^{-1} in stand II. The biomass for *A. peniculata* was from 255.48 kg·ha^{-1} to 483.49 kg·ha^{-1} in stand I and 163.09 kg·ha^{-1} to 2 388.51 kg·ha^{-1} in stand II. The biomass for *W. wallichii* was 669.27 kg·ha^{-1}.

Table 1. Total biomass of tree species in different girth classes in forest stand I and II

Species	Girth class (cm)	Density (Number·ha^{-1})	Bole (kg·ha^{-1})	Branch (kg·ha^{-1})	Leaf (kg·ha^{-1})	Fruit (kg·ha^{-1})	Total (kg·ha^{-1})
			Stand I				
Dipterocarpus tuberculatus	10.0-20.0	355	833.54	94.21	305.30		1233.05
	20.1-30.0	225	1503.20	312.50	149.62		1965.32
	30.1-40.0	350	5142.50	1188.51	670.00		7001.01
	40.1-50.0	120	2486.40	460.76	1046.40		3993.56
Ardisia peniculata	10.0-20.0	90	218.93	21.33	15.22		255.48
	20.1-30.0	45	387.50	41.09	54.90		483.49
Wendlandia wallichii	10.1-20.0	90	310.46	151.20	47.93	159.68	669.27
Total			10882.53	2269.61	2289.37	159.68	15 601.18
			Stand II				
Dipterocarpus tuberculatus	10.0-20.0	30	86.23	19.23	30.73		136.01
	20.1-30.0	50	198.35	101.55	92.96		392.86
	30.1-40.0	130	1605.50	474.11	678.01		2757.62
	40.1-50.0	270	5437.80	1071.36	3071.92		9581.80
Ardisia peniculata	10.0-20.0	75	121.57	19.83	21.69		163.09
	20.1-30.0	50	303.75	61.31	60.76		425.82
	30.1-40.0	100	1863.00	353.40	172.11		2388.51
Total			9616.20	2100.61	4128.18		15 844.99

The total biomass for the tree species recorded in the different components was in the order of bole > leaf > branch for *D. tuberculatus*. However, the total biomass for *A. peniculata* and *W. wallichii* was in the order of bole>branch>leaf. The total aboveground biomass of tree layer in stand I was recorded to be 15.60 t·ha^{-1}. The biomass of total bole accounted for 90.27% of total aboveground biomass of tree layer in stand I, branch 4.91% and leaf 4.80%, whereas in stand II, the total aboveground biomass of tree layer was recorded to be 15.84 t·ha^{-1}. The biomass of total bole accounted for 60.68% of the total aboveground biomass of tree layer, branch 13.25% and leaf 26.50%. The total aboveground biomass in stand I is higher than that of stand II.

Shrub and herb layer biomass

A total biomass of shrub layer was 6.35 t·ha^{-1} from seven dominant shrub species in stand I and 1.43 t·ha^{-1} from three dominant shrub species in stand II. Of these, *Eleocarpus chinensis* and

Actiphella exelsa have maximum biomass in stand I and stand II, respectively (Table 2).

Table 2. Density and biomass contributed by shrubs and herbs species in forest stand I and II

Species	Stand-I Density (No.·ha^{-1})	Stand-I Biomass (t·ha^{-1})	Stand-II Density (No.·ha^{-1})	Stand-II Biomass (t·ha^{-1})
Shrubs				
Actiphila exelsa	-	-	1260	1.200
Eleocarpus chinensis	200	1.8000	-	-
Albizzia samman	1400	0.0161	-	-
Machillus puthii	220	0.7480	-	-
Quercus sp.	380	0.5580	660	0.082
Desmodium pulchellum	80	0.3440		
Gynocardia odoviata	220	0.6820	60	0.010
Magnolia sp.	220	0.6380		
Others	340	1.5654	760	0.130
Total		6.3500		1.432
Herbs				
Andropogon sp.	-	-	5000	0.014
Axonopus compressus	-	-	7000	0.021
Carex spinosa	61000	0.0183	-	-
Fimbristylis dichotoma	8000	0.0648	-	-
Justica simplex	-	-	995000	0.200
Cardamine sp.	5500	0.0501	-	-
Arundinella setosa	97000	0.0770	-	-
Eragrostis nigra	-	-	108000	0.240
Hetropogon contortus	-	-	69000	0.160
Leucas aspera	9000	0.0400	-	-
Imperata cylindrica	59500	0.0464	118500	0.340
Kyllinga triceps	11500	0.0770	-	-
Sclereria alata	11000	0.0737	-	-
Eulalia fastigiata	1500	0.0144	-	-
Others	9000	0.0936	17500	0.020
Total		0.5520		0.999

Albizia samman and *Gynocardia odorata* have minimum biomass in stand I and II respectively. In herbaceous layer, a total biomass of nine herb species was 0.552 t·ha^{-1} in stand I and 0.99 t·ha^{-1}in stand II. Among the herbs, *Arundinella setosa* and *Kyllinga tricept* in stand I and *Imperata cylindrica* in stand II had maximum biomass. A total forest aboveground biomass was 21.92 t·ha^{-1}, which of tree accounted for 68.51%, shrub 28.96% and herbs 2.5% in stand I. In the forest stand II, a total aboveground biomass was 18.28 t·ha^{-1}, which of tree accounted for 86.69%, shrub 7.83% and herb 5.46% (Table 3). The total forest biomass was recorded in the sequence of tree> shrubs> herbs on the two forest stands (Table 3). The non-photosynthetic/photosynthetic ratio ranged from 2.098 to 7.852 for *D. tuberculatus* and from 6.01 to 15.78 for *A. peniculata* for different girth classes, thereby, *D. tuberculatus* exhibit the higher growth rate in comparison with other species (Table 4).

Litter biomass

Litter biomass attained the peak value in February. The summation of monthly litterfall biomass varied from 5.33 to 6.20 t·ha^{-1}·a^{-1} in two stands, of which *D. tuberculatus* accounted for 89.80%, *A. peniculata* 8.56% and *W. wallichii* 1.63% in stand I, whereas in stand II, *D. tuberculatus* accounted for 96.74% and *A. peniculata* 3.25% (Table 5).

Table 3. Biomass contribution by tree species, shrubs and herbs layers in forest stand I and II

Different layers	Biomass (t·ha^{-1}) Forest stand I	Biomass (t·ha^{-1}) Forest stand II
Tree	15.601	15.8444
Shrubs	6.3500	1.4320
Herbs	0.5520	0.9990
Total	22.503	18.2750

Table 4. Non-photosynthetic to photosynthetic ratio of tree species in forest stand-I and II

Girth class (cm)	Non photosynthetic/photosynthetic ratio Stand-I	Non photosynthetic/photosynthetic ratio Stand-II
Dipterocarpus tuberculatus		
10.1−20	3.038	3.427
20.1−30	4.890	3.225
30.1−40	7.852	3.067
40.1−50	2.098	2.119
Ardisia peniculata		
10.1−20	15.780	6.517
20.1−30	7.782	6.010
30.1−40	-	12.877

Table 5. Annual litterfall and percentage in forest stand I and II

Species	Stand I (t·ha^{-1}·a^{-1})	Percentage (%)	Stand II (t·ha^{-1}·a^{-1})	Percentage(%)
D. tuberculatus	5.57	89.80	5.16	96.74
A. peniculata	0.53	8.56	0.17	3.25
W. wallichii	0.10	1.63	-	-
Total	6.20		5.33	

Annual girth increment

In all the tree species, there is an increment in the girth size in various girth classes. *D. tuberculatus* had 4 increased girth classes, *A. peniculata* had two increased girth classes and *W. wallichii* only one increased girth class in forest stand I. However in forest stand II, *A. peniculata* had three increased girth classes, *D. tuberculatus* exhibited highest girth class and followed by *A. peniculata* and *W. wallichii*. Therefore, the results show that two forest stands are quite young and developed forest through secondary succession. *D. tuberculatus* exhibited maximum girth increment (2.5 cm) in girth class of 20.1−30.0 cm and minimum in girth class of 40.1−50.0 cm (1.26 cm) in two forest stands.

A. peniculata exhibited maximum girth increment (2.00 cm) in girth class (20.1−30.0 cm) and minimum girth increment (1.33 cm) in girth class (10.1−20.0 cm) in stand I, whereas in stand II, the girth increment is comparatively much higher than that of stand I. The increment trend for girth class is in the order of 20.1−30 cm >10.1−20 cm>30.1−40 cm.. The increment in girth classes for *W. wallichii* in stand I is maximum in 13.4-cm girth size and minimum in 11.0-cm girth size.

Net primary production

The total aboveground production was recorded to be 9 282.73, 848.80 and 294.44 $kg^{-1}·ha^{-1}·a^{-1}$ for *D. tuberculatus*, *A. peniculata* and *W. wallichii* respectively in stand I. In forest stand II, total aboveground net production of *D. tuberculatus* and *A. peniculata* was recorded to be 7506.68 $kg^{-1}·ha^{-1}·a^{-1}$ and 1354.37 $kg^{-1}·ha^{-1}·a^{-1}$ respectively (Table 6).

Table 6. Net production in different components of tree species in forest stand I and II ($kg·ha^{-1}·a^{-1}$)

Species	Stand I		Stand II	
	Net production	Percentage (%)	Net production	Percentage (%)
D. tuberculatus	9282.73	89.03	7506.68	84.72
A. peniculata	848.80	8.14	1354.37	15.28
W. wallichii	294.44	2.83	-	-
Total	10425.97		8861.05	
Components of tree				
Bole	1308.84	31.80	1176.37	32.64
Branch	1218.62	29.60	1143.34	31.72
Leaf	1588.93	38.60	1284.21	35.63
Total	4116.39		3603.92	

Out of the total aboveground net primary production, the bole production accounted for 31.80%, branch 29.60% and leaf 38.60% in stand I. In stand II, the bole production accounted for 32.64%, branch 31.73% and leaf 35.63% of the total aboveground net production (Table 6). The distribution of total annual net primary productivity (TANPP) of different components is recorded in order of leaf >branch>bole on two forest stands.

Production efficiency

The production efficiency of leaf ranged from 1.39 to 2.75 on the basis of foliage weight and ranged from 0.40 to 0.45 on the basis of leaf area (Table 7).

Table 7. Production efficiency of tree leaves in forest stand I and II

Production efficiency	Stand I	Stand II
Based on foliage weight *	2.75	1.39
Based on foliage area**	0.45	0.40

Notes: *----ratio of net production(kg) to leaf biomass (kg) per year. **----ratio of net production (kg) to leaf area (m^2) per year.

In two forest stands, the allometric relationship between increase in DBH and increase in biomass of different component had highly significant level except with leaf biomass of *D. tuberculatus* and *A. peniculata* and bole of *W. wallichii* in stand I, and leaf biomass of *A. peniculata* in stand II. Thus it shows that with the increase in dbh, the biomass of the tree is also increased i.e. DBH of the tree species and biomass of the tree components are positive correlation (Table 8).

Table 8. Allometric relationship between DBH (*X*, cm) and biomass of tree components (*Y*, $kg·tree^{-1}$) in forest stand I and II

Species	Items	Biomass ($kg·tree^{-1}$)	Intercept (a)	Slope (b)	r^2	*t*	Variability
Stand I							
D. tuberculatus	Bole	0.1850	0.4153	0.9183	10.6023	91.83	S
	Branch	-0.1886	0.5716	0.7235	5.1155	72.35	S
	Leaf	0.8254	0.0658	0.0210	0.4640	2.1	Ns
A. peniculata	Bole	-1.9353	1.9313	0.7066	3.1041	70.66	S
	Branch	-1.2301	1.2037	0.5664	2.2861	56.64	S
	Leaf	-0.5897	0.7118	0.3103	1.3417	31.03	Ns
W. wallichii	Bole	-7.3051	4.555	0.4085	0.8312	40.85	Ns
	Branch	-7.1557	4.205	0.7489	1.7273	74.59	S
	Leaf	0.0590	0.085	0.7083	1.0033	50.16	S
Stand II							
D. tuberculatus	Bole	-1.0125	0.7878	0.9339	11.8908	93.39	S
	Branch	0.1186	0.4740	0.8407	7.2648	84.07	S
	Leaf	0.5339	0.3505	0.5031	3.1818	50.31	S
A. peniculata	Bole	0.4071	0.4635	0.5590	2.9792	55.90	S
	Branch	-0.3669	0.5732	0.6470	3.5822	64.70	S
	Leaf	0.2243	0.4126	0.3499	1.9414	34.99	ns

Discussion

The biomass from *D. tuberculatus* in two forest stands with higher girth classes and higher density was higher in comparison with the other two species i.e. *A. peniculata* and *W. wallichii*. The present forest is young i.e. secondary forest and biomass of different tree component as well as total biomass increased with the increasing girth class.

The biomass of *D. tuberculatus* accounted for higher percentage of total biomass in two forest stands due to large leaf area per tree. *D. tuberculatus* had maximum leaf area in comparison with *A. peniculata* and *W. wallichii*.

Though higher value of tree biomass was recorded in forest stand II, the total biomass (tree + shrub + herb) was found to be higher in stand I.

The biomass of present forest stands was lower than that of dry deciduous forest and Sal (*Shorea robusta*) forest (Singh et al. 1992), mixed Oak forest of Manipur, India (Singh et al. 1994) and lowland Dipterocarp forest (Kawahara et al. 1981). The biomass of present forest stands was higher than that of secondary forest (Limand et al. 1985). However, the biomass of present forest stands was lower than that of Sal (*Shorea robusta*) (Misra et al. 1967) and conifers forest (Ovington 1967). The biomass reported for aboveground biomass of several other species ranged from 34.2 to 599.6 kg·tree^{-1} at Yona, Japan (Kawavabe 1977). The biomass of total annual litter in the present forest is consistent with the value reported by Golley et al. (1962) for tropical forests and dry deciduous forest reported by Singh et al. (1992).

All species attained maximum girth increment in girth class (20.1-30.0 cm). *D. tuberculatus* exhibited maximum girth increment and followed by *A. peniculata* and *W. wallichii*. However, in the present forest the girth increment is in conformity with that of the tree species of Oak forest (Monk et al. 1985).

The present net primary productivity is similar to the value reported by Singh et al. (1992) in dry deciduous and sal forest of India and in oak forest and cool temperate deciduous forest (Monk et al. 1985; Ryunosuke et al. 2004). The present net primary productivity had a lower value in comparison with that in Mixed oak forest (Manipur, India) (Singh et al. 1994; Semwal et al. 1999). The net primary production in the present study stand had lower value due to young forest trees at successional stage. However the present value is higher than the value reported by Whittaker and Woodwell (1969) and Art and Marks (1971) reported of temperate deciduous forests of USA (8.59 t·ha^{-1}·a^{-1} and 7.12 t·ha^{-1}·a^{-1} respectively)

The production efficiency of the present forests shows that this forest had higher production efficiency than that of Oak and Pine forest (Singh et al. 1994; Chaturvedi et al. 1987).

In the present forest stand, the biomass accumulation ratio was recorded to be 2.10 and 2.06, which was lower than that of dry deciduous forest (Singh et al. 1992) and intermediate and mature forest (Whittaker 1966). Lower value may be due to different combination of tree size and increment rate of biomass in the dominant tree species (*D. tuberculatus*), which is influenced by abiotic factors and ages of the dominant tree species. Thus the present forest represents the fast growing young forest with high productive potential in this region.

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