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Biomass and Carbon Stock Assessment in the Sub-Tropical Forests of Manipur, North-East India

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ABSTRACT

The study was undertaken to assess biomass and carbon stock in three sub-tropical forest ecosystems in Churachandpur district of Manipur, NE India located at 93° 15' to 94° 00' E longitude and 24° 00' to 24° 30' N latitude with an elevation ranging from 900 m to 1100 m above mean sea level. Forest sites I and II was dominated by *Phoebe hainesiana* and *Gmelina arborea* whereas site III by *Schima wallichii* and *Ficus cunia*. Aboveground biomass was calculated using allometric regression model and aboveground carbon stock was determined considering 48% of carbon in the total aboveground biomass. All the forest sites exhibited high tree density in 10-15cm diameter class (sapling stage) and decreased in subsequent diameter classes. Carbon stock was recorded to be highest in 10-15 cm diameter class and declined with the increase of diameter classes in all the forest sites owing to high density of tree species in the lower diameter classes. Small trees (10-20cm diameter class) contributed 80 to 87% of total carbon stock across the forest sites. The carbon stock was estimated to be minimum in site-III (81.17 Mg C ha^{-1}) dominated by *Schima wallichii* - *Ficus cunia* and minimum in site-I (118.24 Mg C ha^{-1}) dominated by *Phoebe hainesiana* - *Gmelina arborea*. Thus, *Phoebe hainesiana* - *Gmelina arborea* community dominated forests will play important role in carbon sequestration in high altitude sub-tropical forest of Manipur, North East India.

Key Words: Biomass; Carbon Stock; Diameter at Breast Height; North East India; Regression Model; Sub-tropical Forests.

INTRODUCTION

Forest plays a vital role to mitigate climate change being a source and sink of carbon. Beside this it provides a wide range of goods, services, economic and social benefits such as employment, forest product and protection of sites of cultural value (FAO 2006). The tropical forest spread over 13.76 million km^2 area worldwide which account for 60% of the global forest (FAO 1988, 2006) and plays a key role in global C-cycle both in term of C-flux and volume of C-store. The tropical forests store large quantity of carbon C in vegetation and soil, exchange C with the atmosphere through photosynthesis and respiration. These forests account for 37% of the total 90% of the world's terrestrial C that is stored in the forest (Houghton 1996).

Biomass of forest account for 85-90% of terrestrial vegetation biomass (Whittaker and Liken 1973, Olson et al. 1983, Dixon et al. 1994) and its stock changes significantly from harvesting, land use, climate variability and disturbance (Canadell et al. 2007, Luyssaert et al. 2007). Therefore forest plays an important role in global C-cycle (Dixon et al. 1994, Goodale et al. 2002, Houghton 2003, 2005, Canadell et al. 2007). Aboveground biomass and carbon stocks have been studied in several parts of the world (Chave et al. 2001, Terakunpisut et al 2007, Guo et al. 2010, Metzker et al. 2011, Hoover et al. 2012, Tang et al. 2012). Estimating broad scale biomass C-stocks has been a focus of global C-cycle studies and attracted the interest of researchers for several decades since the time of the International Biological Programmed (IBP 1965-75). Appropriate methods for estimating regional forest biomass are critical for accuracy of the estimation, which in addition to enriching our understanding of the global C-cycle may also be used to estimate the forestry part of national greenhouse gas inventories reported to the United Nations (IPCC 2006).

A number of studies have been reported on carbon stock in India on basis of growing stock volume data of forest inventories using conversion factors (Rabindranath 1997, Chhabra et al. 2002, Lal and Singh 2002, Dadhwal et al. 2009, Patil et al. 2010). Several workers have reported the aboveground biomass and carbon stock in different forests of India (Murali et al. 2005, Jana et al. 2009, Chavan et al. 2010, Gairola et al. 2011, Kumar et al. 2011) Limited information is available on the carbon stock and sequestration in the natural forests of North-East India (Baishya et al. 2009, Yadava 2010).Carbon storage potential of forests has not been fully well understood in North-East India. The forests in this region are spread over 6,90,899 km^2 in different altitudinal ranges. In Manipur, forest cover an area of 17,280 km^2 (2007-2009) which is 77.4% of the total geographical area. However very dense and moderately dense forest comprises of 3.14% and 24.52% of total forest cover of Manipur (FSI 2011).

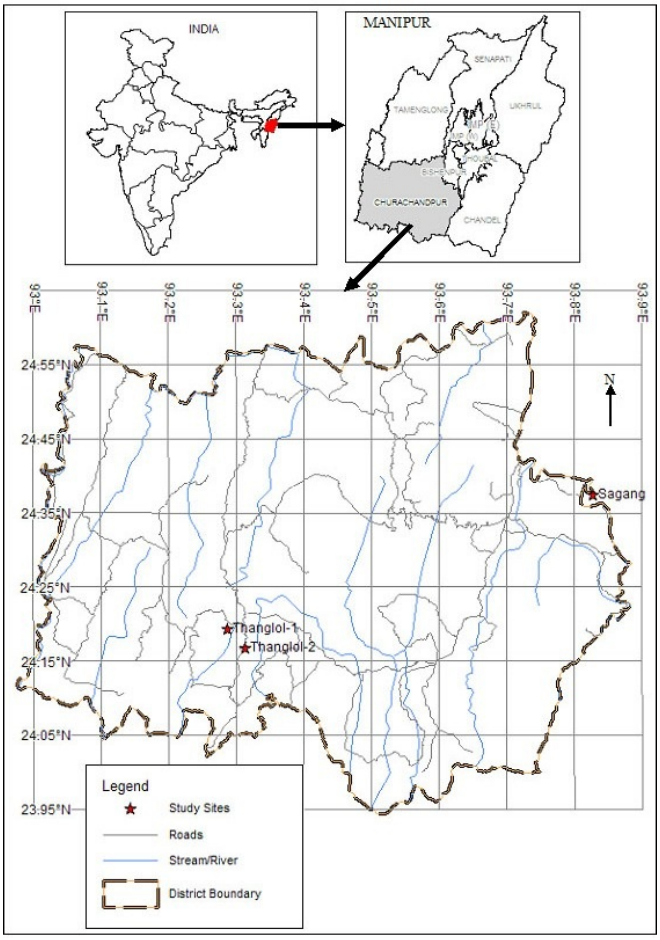
In this study a non-destructive approach is adopted to assess the biomass/carbon. Tree wood volume is estimated using volumetric equation and a product of volume species specific gravity gives the biomass. However the present study is a part of Indian Space Research Organization-Geosphere-Biosphere Programmed (ISRO-GBP), National Carbon Project (NCP-VCP) undertaken at national level in India. Therefore we estimated aboveground biomass and carbon stock in the sub-tropical forest ecosystem of Churachandpur (Manipur) to understand the role of these tropical forests in carbon sequestration and to mitigate climate change at regional and global level.

STUDY SITE AND CLIMATE

The study area is located at Churachandpur district (93° 15' to 94° 00' E Longitude 24° 00' to 24° 39' N Latitude) in Manipur, NE India and has geographical area of 4570 km^2 but southern forest division with the latest reorganization has a geographical area of 4525 km^2. The district is bounded on the North by Tamenglong and Bishnupur district to the East by the district of Imphal and Chandel to the South by Myanmar and Mizoram and to the west by the state of Assam and Mizoram (Figure 1). The topography of is gently hilly with an elevation ranging 110 m from to 1915 m above mean sea level.

The climate of the area in general is monsoonic with warm moist and dry winter. There are three distinct seasons of summer, rainy and winter. Rainy season starts from May and continues up to October. The average temperature ranged from 5 °C (January) to 35 °C (August). The average annual rainfall is about 1800 mm. The western part of the district receives less rainfall compared with the eastern northern part. Humidity is high ranging from 67 to 100%.

Soil of the study area is alluvial red sandy and acidic in nature. It is mostly composed of the rocks such as siltstone, shale and sandstone and middle or central portion is made up of sandstone and sand shale whereas the eastern part is made up of shale, slate and shale sandstone rhythmite.



METHODS AND MATERIALS

Three experimental study sites were earmarked randomly at different altitudes in the forest area for the present study. *Phoebe hainesiana* Brandis and *Gmelina arborea*

Table 1. Geographical coordinates of the study area and forest types.

Site Name		Location	Altitude (m)	Forest Type
Forest Site-I	Thanlon range	$24^0$11'37.20″N; $93^0$17'13.37″E	1048	Sub-Tropical Moist Semi Evergreen Forest
Forest Site-II	Thanlon range	$24^0$10'07.26″N; $93^0$18'50.85″E	1021	Sub-Tropical Moist Semi Evergreen Forest
Forest Site-III	Sangang range	$24^0$22'31.50″N; $93^0$49'37.17″E	890	Sub-Tropical Deciduous Forest

Roxb. dominated in the forest site-I and site-II whereas *Schima wallichii* (DC.) Korth. and *Ficus cunia* Buch-Ham ex. Roxb. in forest site-III. Other associated species were *Tetrameles nudifora* R.Br., *Terminalia myriocorpa* Van Heurck and Müll. Arg., *Albizia procera* (Roxb.) Benth., *Pterospermum acerifolium* Linn. and *Rhus semi-alata* Murr. The geographical coordinates of the study sites are given in Table 1.

Field Sampling

Sampling design for field inventory is based on the approach followed in ISRO-GBP/NCP-VCP. The forest inventory was carried out in the Churachandpur district during September 2009 to December 2009. Four sample plots of 0.1 ha (31.61 × 31.61m) were laid down at each site of 250×250m which is equivalent the size of MODIS SR PIXEL with 250 m spatial resolution. Coordinates of all the plot centre as well as site centre were recorded using GPS. All individual trees above 10cm DBH were measured in all the sampling sites. Aboveground biomass (AGB) was obtained using volumetric equation and specific gravity for each tree species growing in the study site. The overall methodology adopted for the present study has been depicted in Figure 2.

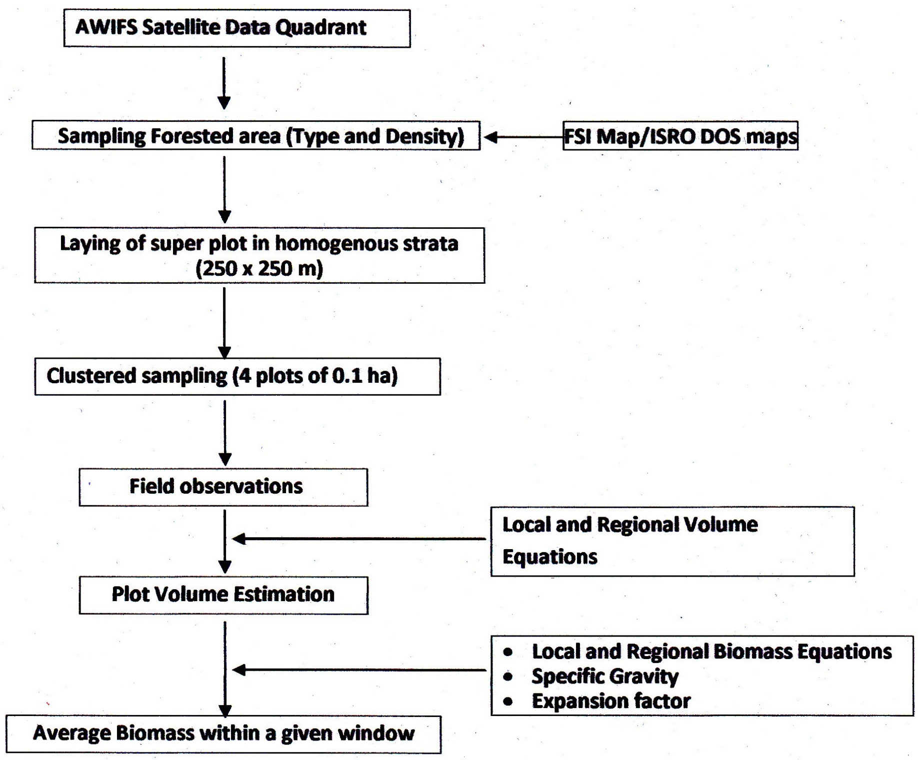


Figure 2. Flow chart showing the field data collection for biomass estimation

Aboveground Biomass Estimation

Sampling is carried out within systematic identified location in the study sites. Diameter at breast height (1.37m above the ground) is measured for all the tree species growing in the site. Specific volume or biomass equations available in the literature (FSI 1996) were used to estimate the volume. To obtain biomass local volume equations were developed for each tree species with only one independent variable i.e. diameter (DBH). Volume of each tree is multiplied by specific gravity to give biomass. The biomass of each tree obtained is summed up to give the plot biomass.

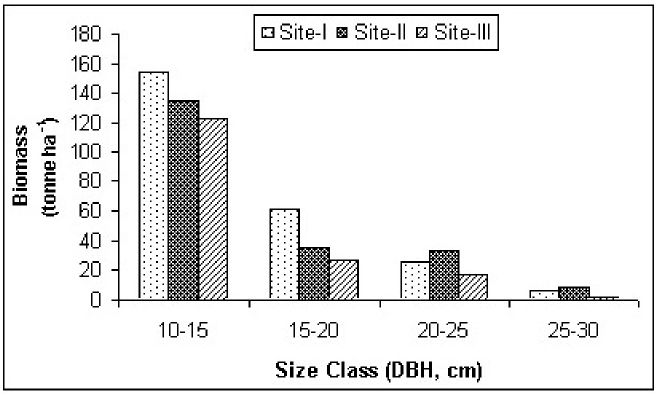


Figure 4. Aboveground biomass in different girth classes in three sub-tropical forests of Manipur.

RESULTS AND DISCUSSION

A total of 29-30 tree species were recorded from the different forest study sites. Total density of tree species was recorded to be highest in site-I (159 trees ha^{-1}) followed by site II (155 trees ha^{-1}) and site III (147 trees ha^{-1}). The density of tree species was found to be highest in 10-15cm diameter class and decreased with increase of diameter sizes across the study sites.

Density of individual tree and aboveground biomass was highest at 10-15 diameter class and subsequently decreased with increase in diameter classes (Figure 3). This shows an inverse relationship between aboveground biomass accumulation and tree diameter class (Figure 4).The decrease in density of trees large diameter class i.e., 20-25 cm and 25-30 cm resulted in low biomass owing to selective logging and shifting cultivation practices in the area by local people. Thus biotic disturbances in the forest area resulted in rapid release of large amount of carbon in the atmosphere that may be recaptured slowly as forest regrowth.

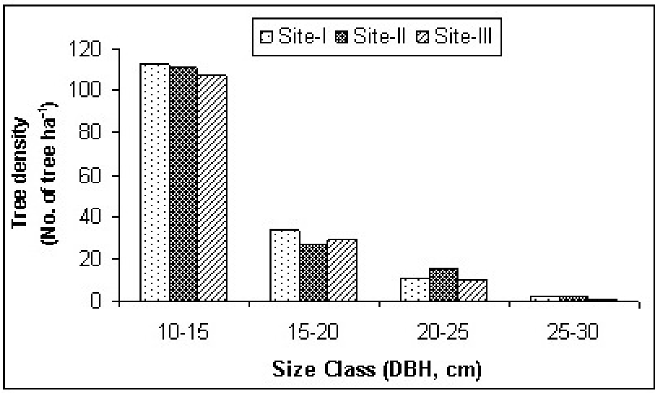


Figure 3. Tree density in different girth classes in three sub-tropical forests of Manipur.

The aboveground biomass varied from 6.45 to 153.8 Mg ha^{-1}, 8.18 to 134.06 Mg ha^{-1} and 2.5 to 122 Mg ha^{-1} in different diameter classes in site I, II and III respectively and reflected marked variation in species composition and tree density and basal area of trees across the study sites (Table 2).

The aboveground biomass was recorded to be highest in forest site I (246.38 Mg ha^{-1}) followed by site II (210.36 Mg ha^{-1}) and site III (179.14 Mg ha^{-1}). Thus, it shows that biomass varied from site to site depending upon different stage of forest type, age of forest and tree density.

The aboveground biomass in the studied present forest are more or less close to biomass value of Broad leaved forest of tropical America (170 Mg ha^{-1}), tropical Africa (260 Mg ha^{-1}), tropical Asia (215 Mg ha^{-1}) reported by Brown and Lugo (1984) and sub-tropical broad leaved forest of Manipur (130-255 Mg ha^{-1}) reported by Yadava (2010). However the present value of aboveground biomass value is less than the value of 607.7 Mg ha^{-1} reported for tropical evergreen forests of Western Ghats of India by Rai (1981), 406 Mg ha^{-1} for semi-evergreen forest of Meghalaya (Baishya et al. 2009) and 591 Mg ha^{-1} for subtropical pine forest of Manipur (Yadava 2010). However, aboveground biomass value of the forest in the present study is higher than the value of 182 Mg ha^{-1} for primary and 97 Mg ha^{-1} for secondary tropical forests at Rio Doce State Park, Geais, Brazil (Metzker et al. 2011) and 199 Mg ha^{-1} Montane wet temperate forest of Manipur (Yadava 2010). Gairola et al. (2011) reported the wide range of aboveground biomass from 172 to 380 Mg ha^{-1} along an

Table 2. A comparison of tree density (No. ha^{-1}), biomass (Mg ha^{-1}) and carbon sequestration potential (Mg C ha^{-1}) in each diameter class at the 3 study sites.

Diameter	Site-I			Site-II			Site-III		
class (cm)	Tree density	Biomass	C-storage	Tree density	Biomass	C-storage	Tree density	Biomass	C-storage
10-15	112	153.80	73.82	111	134.06	64.34	107	122.32	58.71
15-20	34	60.60	24.08	27	35.21	16.90	29	27.06	12.98
20-25	11	25.53	12.25	15	32.91	15.79	10	17.23	8.17
25-30	2	6.45	3.09	2	8.18	3.92	1	2.53	1.21
Total	159	246.38	118.24	155	210.36	100.95	147	179.14	81.17

altitudinal gradient in the temperate valley forests of Garhwal. However, the present sub- tropical forests have great potential to carry more biomass in the standing crop in comparison to temperate forest. Thus the tropical forest plays a major role in CO_2 reduction as carbon sink.

The aboveground carbon stock was calculated by assuming that carbon content in 48% of the total aboveground biomass (Brown and Lugo 1982, Ravindranath et al. 1997). The aboveground carbon stock varied from 81.17 (site III) to 118.29 Mg C ha^{-1} (site I) across the forest study sites. The lowest value of carbon stock in the forest site III may be due to low density of tree species, species composition and biotic disturbances as compared to study site I and II as later sites were located at highest altitude with limited disturbance.

In our study, young trees (dbh 10-20 cm) comprised of 83%, 80 % and 86 % of total carbon stock in forest sites I, II and III respectively. Thus, it shows that the contribution of large diameter trees is only 14 to 20% of total carbon stock across the study sites. Delaney et al. (1997) also reported contribution of large tree to biomass carbon stock less than 10% in very dry forest to more than 35% in moist forests of Neo-tropical region of South America.

It shows that carbon was stored in the biomass of 10-15 diameter class of tree which will grow to large size in the near future. Therefore young trees will have greater potential for future carbon sequestration if these forests are under appropriate management without human disturbances.

The carbon storage value of present forest was greater than the disturbed tropical forest of Sri Lanka (77 Mg C ha^{-1}) but lower than tropical rainforests of Malaysia (223 Mg C ha^{-1}) reported by Brown and Lugo (1982) and tropical forests of SW China (155 Mg C ha^{-1}) reported by Tang et al. (2012), tropical forest of Brazil (91 Mg C ha^{-1} for primary and 48 Mg C ha^{-1} for secondary forest) reported by Metzker et al. (2011). Hoover et al. (2012) reported higher aboveground carbon stock (116-125 Mg C ha^{-1}) in old growth forest in northern New England, USA and the aboveground carbon stocks are more or less comparable to sub-tropical broad leaved forest (65.1 to 127.6Mg C ha^{-1}) and Montane wet temperate forest of Manipur (93 to 106 Mg C ha^{-1}) reported by Yadava (2010).

CONCLUSION

The present study shows that the aboveground biomass and carbon stock were highest in lower diameter classes and decreased with the increase of diameter class across the sites because of high density of tree in the lower diameter classes. However carbon storage is likely to increase according to age of the trees. Out of total carbon stock in the forest sites, small tree (dbh 10-20cm) contributed 80-86 % of carbon stock across the forest sites. Thus it shows that small diameter classes tree have a greater potential for carbon sequestration than big trees because of slow growth in large trees. The study further shows that forests dominated by *Phoebe-Gmelina* community have greater potential in carbon storage than that of *Schima-Ficus* community in the sub-tropical forest ecosystems of Manipur, NE India.

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