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Bamboo based family forests offer opportunities for biomass production and carbon farming in North East India

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ABSTRACT

Although neglected in scientific research and development, bamboo based family forests (BBFF) have traditionally been managed on family farms because of their great socioeconomic value in India and other parts of Asia. Recently, there has been increasing interest in their role in biomass production and climate change mitigation. However, our knowledge of the contribution of BBFF at village and landscape level to biomass production and terrestrial carbon is very limited. Therefore, the objectives of this paper are to (1) quantify occurrence of bamboo resources in BBFF,(2) develop appropriate models for estimation of biomass of thick walled bamboos, and (3) estimate biomass and carbon stock in BBFFs in North East India. Occurrence of bamboo resources in BBFF was quantified through survey of 2850 households selected from 95 villages of Barak valley, North East India. Allometric models for biomass estimation were developed through destructive harvesting of 268 bamboo culms from *Bambusa cacharensis*, *B. vulgaris* and *B. balcooa*. The height-diameter relationships and allometric scaling between above-ground biomass (AGB), culm height (H) and diameter at breast height (D) were examined using various models.Culm height, D and AGB were allometrically related in all the three species, but the exponents were significantly larger than those expected under a geometric and stress similarity growth models. The above-ground biomass carbon density in BBFF was estimated at 16.38 Mg ha^{-1} for *B. cacharensis*, 38.42 Mg ha^{-1} for *B. vulgaris* and 19.64 Mg ha^{-1} for *B. balcooa*. In addition to the various ecosystem services provided by village grown bamboo, total biomass (52.8 Mg ha^{-1}) and carbon (25.8 Mg ha^{-1}) storage in BBFFs can offer an opportunity for carbon farming.

1. Introduction

Many bamboo species are important in local economies; their most important economic uses include food, handcraft, fencing, and cottage industry (Ahmad and Kamke, 2003). As such bamboos are a major commodity in domestic trade and subsistence use, generating over US$ 4.6 billion per year globally (Bystriakova et al., 2004). In addition, they contribute to soil and water management, and biodiversity conservation (Sheil et al., 2012). More importantly bamboo plays a crucial role as a carbon sink, thus contributing to climate change mitigation (Nath et al., 2015; Singnar et al., 2017; Yuen et al., 2017).

In India and other parts of Asia, two types of bamboo production practices can be recognized, namely "village bamboos" and "forest bamboos" (Banik, 2000; Nath et al., 2015; Singnar et al., 2017). Village bamboos are mostly thick-walled, tall species, and these are managed either in a pure stand or mixed with other tree species (Nath and Das, 2008) forming bamboo based family forests (BBFFs). Forest bamboos are mostly thin walled and grow in patches. Village bamboos have traditionally been managed with a view to increasing the socio-economic value of the system. Bamboos are used by the rural populace for fencing, construction, roofing and crafts (Nath et al., 2009). The young shoots of some species (e.g. *Bambusa balcooa*) are edible, and shoots are harvested from first week of June to first week of September every year for consumption (Bhatt et al., 2003). There is also an increasing interest in the value of these family forests in climate change mitigation and biodiversity conservation (Nath et al., 2015; Yuen et al., 2017). Management of BBFF offers land owners an opportunity to obtain secondary source of income and environmental co-benefits (Nath et al., 2015). Most of the studies on biomass carbon storage in bamboos have concentrated on forest bamboos (Yen et al., 2010; Yen and Lee, 2011; Yen and Wang et al., 2013; Zhang et al., 2014; Singnar et al., 2017; Yuen et al., 2017) while village grown bamboo species remain little studied (Nath et al., 2009).

The high annual carbon accumulation rates (2–14 Mg ha^{-1} yr^{-1})

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suggest the potential for successful carbon farming using bamboo (Nath et al., 2015; Yuen et al., 2017; Sileshi and Nath, 2017). The clean development mechanism (CDM) promotes carbon forestry activities in the developing world as a means for mitigating climate change impacts (UNFCCC, 2002). However, CDM projects have mainly focussed on the establishment of tree planting in degraded forestland with fast growing species. Although bamboos are characterized by fast growth and high biomass productivity (Scurlock et al., 2000; Nath et al., 2015) they have been neglected in selecting fast growing species for plantation (Sohel et al., 2015). In comparison to the 10–50 years for most timber species, the harvest time for bamboos is 3–5 years (Desalegn and Tadesse, 2014). As a result bamboos possess high potential for biomass production and carbon sequestration (Wang et al., 2013; Zhang et al., 2014; Zhou et al., 2011; Nath et al., 2009; 2015; Yuen et al., 2016; 2017). Initially, bamboos were not considered in CDM projects due to the ambiguity relating to the classification of bamboos as trees under afforestation and reforestation projects (Lobovikov et al., 2012). In its 39th meeting the CDM executive board has decided that bamboos can be considered equivalent to trees for CDM afforestation and reforestation projects (Lobovikov et al., 2012) but the decision has been left to the designated national authorities to include bamboos in CDM projects (Sohel et al., 2015). As a result little progress has been made in the development of biomass estimation models and tools for bamboo-based systems. A recent synthesis has strongly recommended development of equations for predicting carbon biomass for more bamboo species (Yuen et al., 2017) and especially for village grown species for their diverse role in rural life and numerous other ecosystem services (Nath et al., 2015).

In India thick walled bamboos are mainly composed of *Bambusa* species. *Bambusa* is a large genus of clumping bamboos and most species are tall and thick (Banik, 2000). This species is widely grown in homegardens in India and Bangladesh (Banik, 2000) forming family forest. In India, the genus *Bambusa* are represented by 37 species (representing 26% of the bamboo species), and are predominantly arborescent bamboos growing in diverse regions and habitats (Sharma and Nirmala, 2015). Our knowledge of the contribution of BBFF at village and landscape level to biomass production and terrestrial carbon is very limited (Nath et al., 2015). Therefore, it is important to develop appropriate biomass estimation models for different species being managed under family forest. In this paper, our main objectives are to: (1) quantify occurrence of bamboo resources in BBFF,(2) develop appropriate models for estimation of bamboo biomass and (3) estimate biomass and carbon stock of BBFFs in North East India.

2. Materials and methods

2.1. Study area

The present study was conducted in the Barak valley (24°08′–25°08′ N and 92°15′–93°15′E) in Assam, North East India. The study area falls within the range of the Himalayan foothills and the Barak River Basin. The Barak valley, in conjunction with Cachar, Hailakandi, and Karimganj administrative districts, covers an area of ∼7000 km^2 (NEDFCL, 2016). The study area is characterized by tropical humid climate. Administrative units of the study area and the number of blocks and villages in the three districts are presented in Table 1. The region has a mean annual precipitation of 3500 mm, temperature range of 13–37 °C, and relative humidity of 93.5% (NEDFCL, 2016). The dominant soil of the region is classified as the Barak series, which is fine, mixed, hyperthermic family of Aeric Endoaquepts(USDA, 1998).

In traditional homegardens of North East India, the land holding is deliberately demarcated into more micro zones or management zones based on the specific needs of the farmer. For example, Das and Das (2005) recognized five major management zones in homegardens based on their function, location and composition: (i) bamboo groves (ii) betel groves (iii) banana groves (iv) vegetable garden, and (v) dense or extended zones. In bamboo groves, bamboo is grown either in pure stands or mixed with dicotyledonous tree species such as *Lagerstroemia*, *Bombax* and *Erythrina* (Nath and Das, 2008) forming a small scale forest. Inventory of village bamboo species in BBFF revealed the dominance of the genus *Bambusa*. Based on their high frequency of occurrence, *B. cacharensis*, *B. vulgaris* and *B. balcooa* have been designated as the priority species in the study area (Das and Das, 2005; Nath and Das, 2008). These three species represents 90% of the total growing stock of BBFF (Nath and Das, 2008). Therefore, this study focussed on evaluating these priority species to represent biomass and carbon storage in BBFF as a whole.

Table 1
Administrative units of Barak valley, North East India and number of villages surveyed for the present study.

District	Cachar	Hailakandi	Karimganj
Block*	15	5	7
Villages*	1047	331	940
Household per village*	297	402	239
Number of villages surveyed	50	15	30
Number of household surveyed	1500	450	900
Average size of BFF (ha)†	0.08 (0.02–0.67)	0.05 (0.01–0.23)	0.04 (0.02–0.42)

Figures in parenthesis are range of mean value from minimum to maximum.
* Source: Statistical Hand Book Assam, Directorate of Economics &Statistics, Govt, of Assam, 2011, BFF: Bamboo Based Family Forest.
† Mean values were calculated over households.

2.2. Selection of villages and representative culm and clump

The selection criteria for villages were to cover 5% of the total villages from each district. Representative villages were selected by surveying at least three or more villages randomly from all the blocks in each district. Therefore, a total of 50, 15 and 30 villages from Cachar, Hailakandi and Karimganj district respectively were selected for the present study (Table 1). Occurrence of bamboo clumps in each village was studied by randomly selecting 30 household from each village. Therefore, a total of 1500, 450 and 900 households from Cachar, Hailakandi and Karimganj district respectively were surveyed. During the field visits, the size (ha) of BBFFs and total number of clumps of *B.cacharensis*, *B.vulgaris* and *B. balcooa* in each household were enumerated. In total 2850 households from three districts were surveyed to estimate the size of BBFFs and clump level information. During household survey, the number of culms of different aged stands viz. 1-yr, 2-yr, 3-yr, 4-yr in each clump of the selected households were counted. The average number of clumps per BBFF in each district and the number of culms per clump in bamboo stands of different ages are presented in

Table 2
Number of bamboo clumps per bamboo family forests (BFFs) in each district and number of culms per clump in North East India.

	District/Age	*B. cacharensis*	*B. vulgaris*	*B. balcooa*
Average number of Clumps in BFFs	Cachar	4.5 (1–37)	2.5 (1–7)	1.2 (1–5)
	Hailakandi	1.8 (1–5)	3.7 (1–18)	1.1 (1–5)
	Karimganj	2.4 (1–15)	1.8 (1–12)	1.2 (1–17)
Number of culms/ clump in different ages	1-yr	28 (12–45)	32 (12–49)	16 (08–27)
	2-yr	34 (16–50)	24 (14–43)	34 (10–48)
	3-yr	17 (9–35)	15 (11–35)	18 (07–32)
	4-yr	18 (10–29)	19 (08–30)	27 (09–38)
Total number of culms/clump		97 (75–127)	90 (65–125)	95 (72–118)

Values are mean; Figures in parenthesis are range of mean value from minimum to maximum.