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Carbon storage in a bamboo (*Bambusa vulgaris*) plantation in the degraded tropical forests: Implications for policy development

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ABSTRACT

Tropical forests potentially contribute to global climate change mitigation through carbon sequestration, hence a global carbon pool. In order to mitigate the global climate change impact, the Kyoto protocol developed the clean development mechanism (CDM) which supports carbon credits for plantation activities in developing countries. Unfortunately, none of the CDM forestry projects included bamboo as a carbon reservoir. Although bamboo is an integrating part of tropical forest ecosystems, it was overlooked in the initial negotiating process. The present study, therefore, investigated the carbon storage potential of a common bamboo species, *Bambusa vulgaris* at Lawachara forest reserve of Bangladesh. Results showed that five-year-old *B. vulgaris* stand stored in total 77.67 t C ha^{-1} of which 50.44 t C ha^{-1} were stored in the above ground biomass (culms, branches and leaves), 2.52 t C ha^{-1} in the below ground biomass and 24.71 t C ha^{-1} in the soils. This amount of carbon storage is much more promising than the carbon storage of many other tree species considered in the CDM projects. These findings demonstrate the potential of *B. vulgaris* to be considered in CDM projects as a plantation species and thereby mitigate climate change impact more efficiently.

1. Introduction

In recent years, global climate change mitigation has received much more attention of scientists, resource managers and policy makers. The Intergovernmental panel on climate change (IPCC), in order to face climate change challenges, has promoted strategies for climate change mitigation and adaptation (IPCC, 2014). Forests have the potential to reduce carbon from the atmosphere and thus mitigate climate change (Zhang et al., 2007; Jackson and Baker, 2010; Canadell and Raupach, 2008). Considering the carbon sequestration potential of forests, the forestry community perceived the importance of promoting different forestry practices that can provide climate change mitigation benefits (UNFCCC, 2007). Taking this view ahead, the united nations framework convention on climate change (UNFCCC) and the Kyoto protocol have introduced clean development mechanism (CDM), which allows the development of carbon forestry activities in the developing world as a means of mitigating climate change impacts (UNFCCC, 2002).

Under the CDM scheme, industrialized countries finance forestry (reforestation and afforestation) projects in developing countries (UNFCCC, 2004) with a view to provide with two fold benefits. Firstly, it will assist to mitigate climate change impact (Nabuurs et al., 2007) and secondly, it will be a way of potential profitable business (Richards et al., 2006; Sampson, 2004; Ruddell et al., 2006; Helms, 2007). However, the CDM projects mainly focused on the establishment of plantations in the degraded forest land with fast growing species particularly in the tropics. During the selection process of fast growing tree species, bamboos were totally neglected (Lobovikov et al., 2009; Kant, 2010; Buckingham et al., 2011) although all bamboo species are fast growing (Lobovikov et al., 2009) and can act as a potential source of carbon sink (Dewar,

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1990; Lobovikov et al., 2011; Nath et al., 2015a,b). Initially, the main reason of not permitting bamboos in CDM projects was ambiguity to consider bamboos as trees to form forest under afforestation and reforestation projects (Lobovikov et al., 2009, 2011; Kant, 2010). Later on CDM executive board, in its 39th meeting has decided that bamboos can be considered equivalent to trees for CDM afforestation and reforestation projects (Lobovikov et al., 2011) but has left the decision reluctantly to the designated national authorities (DNAs) to include bamboos in CDM projects. Since bamboos are an integrating component of most of the tropical forest ecosystems and are capable of adapting to adverse site conditions, they can be planted in the degraded tropical forests. This will not only sequester carbon from the atmosphere, it will also prevent carbon loss from further degradation of tropical forests because emissions from forests degradation contribute with almost 0.5 Gt of carbons annually into the atmosphere (Achard et al., 2004).

The world has ~850 million ha of degraded forests most of which lies in the tropics (ITTO, 2002). The International Tropical Timber Organization (ITTO, 2002) classified 60% of the world's tropical forest as degraded forest, including secondary forests, degraded primary forests and degraded forest land. Bangladesh is a tropical country having 2.53 million ha area covered by forests (BFD, 2007; FAO, 2011). Nevertheless, the forests of Bangladesh are subjected to high degradation due to population pressure, illicit felling, shifting cultivation, land use change and the conflict between tribal people and settlers. These degraded forest lands and other waste lands provide with the scope of replanting with suitable species like bamboo. In Bangladesh, bamboo is called 'poor man's timber', which is the most important source of non-timber forest products (NTFP), and plays an important role in regional markets (Khan and Khan, 1994; Alamgir et al., 2007; Mukul, 2011; Nath et al., 2011; Rana et al., 2010; Mukul and Rana, 2013). Because of their wide range of site suitability and economic value, bamboos are frequently planted in the degraded forest sites, around homesteads and other wastelands of Bangladesh. Thirty three species of bamboo have so far been identified in the country (Bystriakova et al., 2003; Latif, 2008; Banik, 1998).

The total area of bamboo forest in Bangladesh is ~491,491 ha (APFSOS, 1998) with a huge pool of existing village and forest bamboos, it can be assumed that Bangladesh can play a vital role in carbon sequestration and thereby contributing to climate change mitigation through bamboo plantations. Many scientists raised such a high expectation of climate effectiveness of bamboos (Henley and Lou, 2009; Widenoja, 2007; Lobovikov et al., 2009; Lou et al., 2009; INBAR Media Release, 2010; Janssen and Lou, 2010) although their limitations in climate change mitigation was also reported (Düking et al., 2011) because of their short life span and CO_2 flux due to respiratory cost. However, after calculating the respiratory cost of leaf culm and branches, the study on an unused *Phyllostachys pubescens* stand in Japan reported an above-ground net production of 18.1 t ha^{-1} y^{-1} which falls within the average range of productivity of forests under similar climate conditions (Isagi et al., 1997). In addition, it is important to note that most tree species need decades to reach maturity, where as bamboos usually mature in 7–10 years which suggest that bamboos might have more potential to mitigate climate change and their possible impacts through durable bamboo product.

Although bamboos have long been thought to have good carbon sequestration abilities (Dewar, 1990; INBAR, 2009a), there has been little published information available to support this (INBAR, 2009b; Dhruba, 2008; Nath et al., 2009; Sultana, 2009; Anon, 2006). Most studies concentrate on biomass production and nutrient cycling (Isagi et al., 1994; Isagi et al., 1997; Embaye et al., 2005; Tripathi and Singh, 1994; Shanmughavel and Francis, 1996; Hunter and Junqi, 2002). The study of the potential roles of different species in carbon sequestration are restricted only in some tree species (Uddin, 2002; Momtaz, 2003; Alamgir and Al-Amin, 2008; Shin et al., 2007; Khan, 2009). Lack of a well established method of biomass estimation of bamboo species, not only for world context but also in the context of Bangladesh, might be another reason of the unavailability of information about the carbon stock potential of bamboo species. Some equations for tree species were developed by researchers (Brown et al., 1989; Negi et al., 1988; FAO, 1997; Alves et al., 1997; Brown, 1997; Schroeder et al., 1997). It is, therefore, necessary to develop models, which can be used for future research in Bangladesh to estimate biomass organic carbon for a matured bamboo species. A complete and detailed study of biomass allocation, carbon concentration and linear regression model for bamboo culm has seldom been done for any bamboo species. The current study was conducted at Lawachara forest reserve of North-Eastern Bangladesh to examine the stand biomass and carbon of *Bambusa vulgaris* plantations, a common bamboo species of Bangladesh. The specific objectives of this study were to:

1. Estimate the above and below ground biomass of *B. vulgaris* stand at Lawachara forest reserve.
2. Determine the carbon stock of *B. vulgaris* stand in above and below ground biomass at Lawachara forest reserve.
3. Determine the soil carbon stock of *B. vulgaris* plantation at Lawachara forest reserve.
4. Develop regression equations for the estimation of biomass organic carbon content of *B. vulgaris* for 5 year bamboo plantation at Lawachara forest reserve.

2. Materials and methods

2.1. Study site

The study was conducted at Lawachara forest reserve (24°30′–24°32′N and 91°37′–91°39′E) (Fig. 1) under Moulvibazar district in Bangladesh. The total area of the reserve is 1250 ha. It is a part of West Bhanugach Reserved Forests of Moulvibazar forest division. Lawachara forest reserve is a mega biodiverse region with many flora and fauna species. Floral composition mainly belongs to evergreen and semi-evergreen tree species (Ahsan, 2000). Among the fauna, Hoolock Gibbon (*Hoolock hoolock*) and Capped Langur (*Trachypithecus pileatus*) are the keystone species (Nishorgo, 2006). Topography is undulating with hillocks of 10–50 m (Riadh, 2007) interspersed with numerous streams flowing through the forest. The soil is alluvial brown sandy clay loam to clay loam dating from the Pliocene epoch (Ahmad, 1970; Hossain et al., 1989). The site experienced a moist tropical climate (Uddin and Hassan, 2010) with long wet (April–October) and relatively short dry (November–March) seasons (Fig. 2). The mean annual rainfall and temperature of the study site were 2344 mm and 24.8 °C, respectively.

The forest serves as the home of several indigenous communities. Members of the Khasia, Manipuri, and Tripura indigenous groups, who reside within and around the forests, depend on the forest resources for their livelihood and subsistence (NSP, 2008; Akhter et al., 2013; Sohel et al., 2015; Mukul, 2014). Because of overexploitation of resources and large-scale selection felling in 1920 and 1950 (Feeroz, 1999) the forests are highly degraded and need immediate restoration. Hence, Lawachara forest is a representative site of degraded tropical forest.

2.2. Above and below ground biomass estimation of B. vulgaris

Bamboo biomass was determined by harvesting randomly selected culms from a five -year-old *B. vulgaris* plantation at Lawachara forest reserve. A total of 12 culms were harvested from