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High carbon stocks in roadside plantations under participatory management in Bangladesh

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ABSTRACT

Plantations are important REDD+strategies for increasing carbon sequestration while enhancing local livelihoods. Reforestation along roads and highways under participatory forest management in southwestern Bangladesh could contribute to REDD+. This study assessed the diversity and structure of roadside plantations in order to develop a basal area based generalized allometric model for estimating above- and below-ground tree biomass carbon in Southwestern Bangladesh. All woody plants with d.b.h. $\geqslant$2 cm were identified and their diameters measured in 108 systematically selected zigzag plots of equal size (2 × 10 m). A total of 36 species in 17 families were recorded. Leguminosae accounted for 28% of species and 94% of the total estimated biomass carbon. We estimated a mean stem density of 4528 ha^{-1}, basal area of 52.6 m^2 ha^{-1} and biomass carbon of 192.80 Mg ha^{-1}. *Samanea saman, Dalbergia sissoo, Acacia nilotica*, and *Leucaena leucocephala* accounted for most density, basal area, and carbon. We developed and validated three allometric models with equal strength (R^2 0.94–0.98) using generalized linear regression. Roadside plantations in Bangladesh can now surely participate in the UNFCCC's carbon mitigation and adaptation mechanism, but challenges to their long-term sustainability must be addressed.

1. Introduction

Global warming and biodiversity loss are the two important currently debated issues among the world's scientists and policy makers (Zhang et al., 2011), caused mainly by fossil fuel burning and deforestation during the last few decades (van der Werf et al., 2009). The last century finished with an increase in global temperature by 0.74 °C and the atmospheric CO_2 concentration of 379 ppm (UNFCCC, 2007; IPCC, 2013). Furthermore, atmospheric carbon dioxide would be doubled by 2050 if the current rate of increase continues and will lead to the global temperature rise of up to 2–4 °C (IPCC, 2013). A projection by IPCC (2013) revealed that by the end of 21st century the global sea level will rise by 28–98 cm due to melting of polar ice, which would badly alter low-lying coastal countries (e.g. Bangladesh, Maldives, The Netherlands) existence and livelihoods pattern. Forests retention, coupled with various reforestation and afforestation programmes, tropical in particular, can play

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an important role in mitigating global climate change through sequestering atmospheric carbon (see Dixon et al., 1994a,b; Jose, 2009; Kumar, 2011).

Forests in Africa, Latin America, South and Southeast Asia, and the Pacific region have been experiencing the highest carbon emissions due to deforestation (FAO, 2010). In the least developed countries like Bangladesh, 62% of total carbon emissions originate from deforestation (IPCC, 2007). The Kyoto Protocol, the main instrument of the UNFCCC, has introduced the CDM concept among the low-income people who can store carbon through changes in land use patterns (Roshetko et al., 2007; Takimoto et al., 2008). Under the current arrangements, reduced emissions from deforestation and forest degradation, and enhancing forest carbon stocks in developing countries (REDD+) does not consider smallholder trees, but only large scale forests. However, small patches of trees outside forests, if not cut, can contribute towards reducing emissions of carbon to the atmosphere. The only reason why smallholder trees are not a major focus under the REDD+ arrangement is because their contribution towards carbon sequestration is not well documented (Nair, 2012). To improve country negotiations for REDD+ and other carbon market mechanisms, it is necessary to provide evidence about the potential contribution of smallholder trees outside forests to biodiversity conservation, livelihood options and carbon sequestration (Nair, 2012; Jashimuddin and Inoue, 2012).

Yet, globally attention has been given to what extent managed landscapes, such as agroforests, community forests, village woodlots and roadside plantations under participatory management, could hold carbon and contribute to climate change mitigation (see Albrecht and Kandji, 2003; Roshetko et al., 2007; Saha et al., 2010; Kumar and Nair, 2011; Nair, 2012). The global coverage of agroforests is 1023 million ha which represents a carbon sequestration potential of 1.9 Pg of carbon over 50 years at a rate of 94 Mg ha^{-1} in managed landscapes (Dixon et al., 1994a,b; Nair et al., 2009).

Participatory forest management has been practiced in Bangladesh since 1976. Several pilot projects from 1982 to 1987 provided the experience for launching the countrywide participatory forest management project in the forms of restored forests, agroforests, village woodlots, and road and highway plantations in 1989 (Kabir and Webb, 2005). Increasing the supply of forest products, especially fuel wood, to improve rural socioeconomic conditions and reversing the process of environmental degradation through proper soil and water conservation are the main objectives of participatory forest management in Bangladesh. As an outcome, 48,420 ha of roadside plantations, 30,666 ha of woodlots and 8778 ha of agroforestry plantations have been raised during the last 30 years in Bangladesh (Jashimuddin and Inoue, 2012). Members of the poorer sections, with special preference to landless, land-poor and rural women of the surrounding rural communities, are targeted as participants in the roadside plantations. The participants who protect the plantations have the right to harvest and consume or market all intermediate products in the forms of leaves, twigs and dead branches for household fuel. According to Forest Department policy, the participants have a right to receive a pre-determined share of 40% of the receipts from auction of the trees in a local market after the rotation (usually 10–12 years). Yet, commonly practiced roadside plantation under participatory management in Bangladesh has so far received no research attention in estimating its potential contribution to livelihood supplementation and carbon sequestration.

Species-level tree biomass carbon estimation using diameter at breast height (dbh) with a tree density based allometric model is becoming popular (Pandey et al., 2014; Rahman et al., 2014). However, for quick calculation of biomass carbon, a basal area based allometric model could be another important option as both basal area and biomass carbon have a strong relation to dbh (Torres and Lovett, 2012; Rahman et al., 2014). Studies have made significant contributions in estimating ecosystem level aboveground carbon stocks using basal biomass (see Torres and Lovett, 2012; Rahman et al., 2014). The present focus of REDD+ is examining to what extent carbon sequestration through forest restoration and plantation establishment is related to biodiversity conservation, poverty reduction, and carbon sequestration. Therefore, this study aimed to develop generalized allometric equations based on basal area to estimate tree biomass carbon content of the roadside plantations under participatory management in southwestern Bangladesh.

2. Methods

2.1. Study area

Southwestern Bangladesh is primarily a floodplain landmass lying between 21.50° and 23.91°N latitude and 88.55° and 90.35°E longitude (Fig. 1). The region is bounded by India in the west and the Bay of Bengal in the south. Excessive siltation and sedimentation in the upper stream has resulted in phenomenal floods in the plain land areas of the region during the monsoon and severe drought during the dry season. Regular floods and droughts cause enormous damage to the lives and property in the region. The deltaic landscape of this region is a primarily low (<10 m above a.s.l.), flat, and fertile plain. The coastal plain is partly sandy and saline, and varies from 1 to 15 km in width (Kabir and Webb, 2008). Calcareous to non-calcareous soils and peat are the basic soil types extending over the study area. Coastal regions have some areas with acid sulphate and peat soils (Kabir and Webb, 2008).

Thirty-six percent of the study area is cultivable, 9% uncultivable, 37% littoral mangrove forestland, and 18% un-surveyed (BBS, 2013). Rice, wheat, jute, sugarcane, pulses, and potatoes are the principal agricultural crops from the cultivable lands (Kabir and Webb, 2008). Various types of vegetables, spices, fruits, and nuts are also important cultivated crops. There are no primary forests in the study area except the inaccessible littoral Sundarbans mangrove forest. Intensive shrimp (tiger prawn) culture is a newly emerging economic activity along the coastal regions of southwest Bangladesh (Kabir and Webb, 2008).