UDK 504.7:332.362(549.3)

CARBON SEQUESTRATION POTENTIALITY AND ITS ECONOMIC ANALYSIS OF DIFFERENT LAND USE SYSTEMS IN THE NORTHERN PART OF BANGLADESH

M.S. Bari[1]*; M.B. Abubakar[2] and M.S. Rahman[1]
[1]Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh
[2]Kano University of Science and Technology, Kano, Nigeria
Email: barimdshafiqul@gmail.com (*corresponding author)

This study was conducted to evaluate the carbon sequestration potentiality of different land use systems in the Northern part of Bangladesh. Common land use systems like cropland, roadside, homestead and orchard were used. Data were recorded from both tree growth parameters (height and diameter at breast height) and under storied vegetation (herbs, shrubs and crops) in order to estimate the total land use biomass accumulation. Complete measure of 40 m line transects in cropland, 40×5 m quadrant in roadside, 40×40 m quadrant in both orchard and homestead were used. At every sampling point, under stories biomass sample were taken from 1×1 m quadrant. The results showed that there was significant difference of carbon sequestration potentiality of different land use systems. For the main effect of different land use systems on carbon sequestration, there was significantly difference in respect of tree height (m), dbh (cm), carbon sequestration per tree (t ha^{-1}) and total carbon sequestration by the land use systems (t ha^{-1}). The highest total carbon sequestration (325.33 t ha^{-1}) was recorded from double roadside land use system and the lowest (36.51 t ha^{-1}) was obtained from cropland land use system. However, in case of economic of carbon sequestration, among the six land use systems double roadside gave maximum (4879.95$ t ha^{-1}) monitory returned. So, double roadside tree plantation is a better land use option for reducing atmospheric carbon. Therefore, more emphasis should be given in roadside plantation for mitigating the green house effects.

Keywords: *carbon sequestration, land use, road side plantation, Bangladesh.*

Introduction

Tropical forests play an important role in the global carbon cycle [16]. They contain about 40% of global terrestrial carbon, account for more than half of global gross primary productivity, and sequester large amounts of carbon dioxide (CO_2) from the atmosphere [3, 7, 18]. Carbon is stored in forests predominantly in live biomass and in soils, with smaller amounts in coarse woody debris [15]. In tropical forests worldwide, about 50% of the total carbon is stored in aboveground biomass and 50% is stored in the top 1 m of the soil [6].

The problem of global climate change is considered to be one of the most important to the environment; it has been at the center of scientific debate in recent years. Carbon dioxide (CO_2) emissions from land use and land use changes, predominantly from forested areas, account for 33% of global CO_2 emissions between 1850 and 1998 [4]. Increasing demand for food, fodder, fuel and round wood is rising the pressure on land-use systems, and conservation and sustainable development of land-use systems are critical for meeting those demands sustainably and stabilizing CO_2 concentration in the atmosphere to mitigate global climate change [23].

The carbon storage capacity in agroforestry varies across species and geography [17]. Trees and shrubs in different land use systems act as carbon sinks. They absorb carbon (as CO_2) through photosynthesis and store it in their aboveground and belowground biomass. This process is called ‘carbon sequestration’. IPCC [9] described carbon sequestration as the process of removal of carbon from the atmosphere and stored it in the biosphere. Moreover, the amount of carbon in any land use system depends on the structure and function of different components within the systems put into practice [1, 24]. The developing countries are bearing the maximum brunt of global warming and climate change, although their contribution to greenhouse gas emissions is much less than that of the developed countries.

It is, therefore, important that countries like Bangladesh to take serious steps which contribute in fighting climate change through the role of land use practices to mitigate climate change. The establishment of agroforestry based land use system will help in substantial and productive agriculture and climate change mitigation. However, in Bangladesh, the amounts of carbon sequestration by different land use system are unknown. The study was performed to assess the potentiality of different Agroforestry related land use systems for carbon sequestration in the Northern region of Bangladesh.

Materials and Methods

Study Area and observations

The study was conducted in the northern part of Bangladesh located in the districts of Dinajpur. A stratified random sampling method was used in a randomized complete block design (RCBD) with four (4) replications as representative areas where different agroforestry related land use systems like homestead agroforestry, cropland agroforestry, orchard based agroforestry and road side plantation were practiced. Indeed, Dinajpur district includes three Agro-ecological Regions: Old Himalyan Piedmont Plain (AEZ-1), Tista Meander Flood Plain (AEZ-3) and Level Barind Tract (AEZ-25) and the ecosystems vary among the AEZs. Therefore, one site from each of the AEZs was selected. So, the study consist of six (6) land use systems (viz; Boundary crop land, single roadside plantations, double roadside plantations, homestead agroforestry, litchi orchard and mango orchard) and three (3) agro-ecological zones (viz. AEZ 1, AEZ 3 and AEZ 25). So, twenty four observations were recorded from each AEZ having total of seventy two (72) observations. Seven (7) years aged Eucalyptus tree was selected as an experimental tree in cropland and Roadside plantations. Similarly, same age was also considered in case of Orchard. In homestead, age was not used due to high variability and species diversity. Hence, only matured trees with diameter greater than 5cm (dbh) were considered for this experiment. Leaf litter, herb, grass or rice biomass was sampled using 1×1m quadrant method.

Tree Biomass Estimation

The biomass of tree is the sum of aboveground and belowground biomass content. For accurate measure of biomass in tree, it has to be felled. To avoid this, the standing woody biomass has been estimated using important growth parameter such as DBH and height. Tree height and DBH are the most common independent variables needed for the estimation of tree volume [2].

Aboveground biomass estimation (AGB). The aboveground biomass (AGB) has been calculated by multiplying volume of biomass and wood density; the volume was calculated based on diameter and height [19]. In this system, the following allometric equation for estimating biomass (kg per tree) of tree diameter 5–60 cm of different zones developed by [5] was used:

$$(AGB)est = 0.0509 \times \rho D2H,$$

where (AGB)est – Estimated aboveground tree biomass (kg per tree), D – diameter at breast height (DBH) (cm), H – tree height (m), ρ – Wood specific gravity (Mg m^{-3}) [5].

Belowground Tree biomass (BGB). Belowground tree biomass **(**BGTB) of trees was calculated by multiplying the above ground biomass (AGTB) with a default value of 0.26, provided by [8] as a factor of root: shoot ratio. Average root biomass content of all trees was 26% of aboveground biomass:

$$Below\ ground\ biomass = $$
$$= Aboveground\ biomass \times 0.26.$$

Total Biomass. Total tree biomass (TTB) is the sum of the above and below ground biomass [25]:

$$Total\ biomass = AGB + BGB.$$

Estimation of carbon stock in trees (t C/ha). Generally, for any plant species 50% of its biomass is considered as carbon storage [20]:

$$Carbon\ Storage = Biomass \times 0.5.$$

Estimation of carbon stock in Leaf litter, herb, and grass (LHG) or under stories biomass (t C ha⁻¹). The carbon content in under stories biomass (LHG) was calculated by multiplying with IPCC [2006] default carbon fraction of 0.47:

$$LHG\ (kg\ m^{-2}) = Biomass \times 0.47.$$

Estimation of Carbon Sequestered (t ha^{-1}). To estimate carbon sequestration of crops and trees the biomass carbon was multiplied with a factor of 3.67 for all species a formula used by Rajput [22]:

$$Estimated\ Carbon\ sequestration\ (t\ ha^{-1}) =$$
$$= Biomass\ carbon \times 3.67.$$

Total Land use carbon sequestration (t ha^{-1}). In order to achieve the total carbon sequestration by a particular land use system, total of trees and belowground litter fall, shrubs, herbs or rice were summed [21]:

$$Total\ land\ use\ carbon\ sequestration =$$
$$= Tree\ CO_2\ sequestration +$$
$$+ LHG\ CO_2\ sequestration.$$

Estimation of Economic Value of Carbon Credits (US$ t ha^{-1}). One ton of net sequestered or mitigated carbon dioxide from plant biomass in a land use is equal to one carbon credit. Therefore, total carbon credit in a land use systems was calculated from CO_2-eq values of retained biomass in respective land use systems. The carbon credits were calculated from the total land use carbon sequestration from tree and crop biomass using the guidelines of IPCC in 1996. However, according to Vivan [26] the monetary value of one ton CO_2 is equivalent to US$15. In this study, the value of Vivian [26] was used. All data were statisti-

Table 1

Tree biomass and carbon stock of different land use systems

Land Use System	TH (m)	DBH (cm)	AGB (kg per tree)	BGB (kg per tree)	TTB (kg per t ree)	AGCS (kg per t ree)	BGCS (kg per tree)	TTCS (kg per t ree)
Boundary Cropland (T_1)	11.32b	13.52e	63.48cd	16.51bc	79.99cd	31.74cd	8.25cd	39.99cd
Single Roadside (T_2)	14.23a	16.31c	116.75a	30.35a	147.10a	58.37a	15.18a	73.55a
Double Roadside (T_3)	14.53a	15.12d	101.95ab	26.51a	128.46ab	50.98ab	13.25ab	64.23ab
Homestead Plat (T_4)	10.21b	13.02e	53.23d	13.84c	67.07d	26.61d	6.92cd	33.53d
Litchi Orchard (T_5)	5.86c	21.12b	79.81bc	0.75b	100.56bc	39.91bc	10.38d	50.28bc
Mango Orchard (T_6)	6.94c	22.24a	105.49a	27.42a	132.92a	52.75a	13.71a	66.46a
CV%	8.3	7.3	17.4	17.4	17.4	*17.4*	*17.4*	*4.5*

In a column, figures having similar letter(s) do not differ significantly where as figure's bearing different letter(s) differ significantly (as per DMRT)

cally analyzed using computer package R-studio and MS Excel 2007.

Results and Discussion

Tree biomass of different Land use systems. The study found that the total tree biomass (TTB) significantly varied with the land use systems (Table 1). The highest TTB (147.1 kg) per tree was found from Single Roadside (T_2) which was followed by Mango orchard (T_6) and Double Roadside (T_3). On the other hand, the lowest TTB (67.07 kg) per tree was recorded from Homestead (T_4) which was followed by Cropland (T_1) and Litchi Orchard (T_5). Wide variation of total biomass occurs due to heterogeneity of different land use systems. Khaki and Wani [11] estimated maximum total ground biomass (181.34 t ha^{-1}) in *Shorea robusta* pure forest, which was followed by Agrisilviculture system (46.02 t ha^{-1}) and lowest in natural grass land (4.47 t ha^{-1}).

Tree carbon stock of different Land use systems. The trend of carbon stock (TTCS) per tree was also followed as per tree biomass content, as shown in Table 1.

Total carbon sequestration of different land use systems (t C ha^{-1}). The study found that the total carbon sequestrations per hectares (TLUCseq) by the land use systems were highly influenced (Table 2). The highest TLUCseq (325.33 t ha^{-1}) was recorded from Double Roadside (T_3) which was followed by Single Roadside (T_2) and Homestead (T_4). However, the lowest TLUCseq (36.51 t ha^{-1}) was recorded from Cropland (T_1) which was followed by Litchi orchard (T_5) and Mango orchard (T_6). Several studies have been conducted to explore the effects of land use systems on Carbon sequestration and other biophysical factors that affect the systems [13, 14]. Kursten [12] stated that by adding trees in a system, it can increase the C storage capacity of the land use systems.

Economic value of carbon sequestration (US$ t ha^{-1}). The economic value of carbon sequestration provides market for GHG reduction in monetary val-

Table 2

Total Carbon sequestrations of different land use system

Land Use System	NT/ha	TTCS (tC ha^{-1})	LHG/RCS (tC ha^{-1})	TTCseq (t ha^{-1})	LGCseq (t ha^{-1})	TLUCseq (t ha^{-1})
Boundary Cropland (T_1)	158.9e	6.39d	3.56d	23.47d	13.05d	36.51c
Single Roadside (T_2)	420.0c	30.68b	11.52b	112.58b	42.29b	154.87b
Double Roadside (T_3)	1166.7a	75.43a	13.22a	276.83a	48.51a	325.33a
Homestead Plant (T_4)	988.9b	33.51b	7.69c	122.99b	28.22c	151.27b
Litchi Orchard (T_5)	216.6d	10.74cd	2.19e	39.62cd	8.03e	47.65c
Mango Orchard (T_6)	220.0d	14.64c	2.61e	53.72c	9.58e	63.30c
CV%	21.7	19.9	4.5	19.9	4.5	16.1

In a column, figures having similar letter(s) do not differ significantly where as figure's bearing different letter(s) differ significantly (as per DMRT)

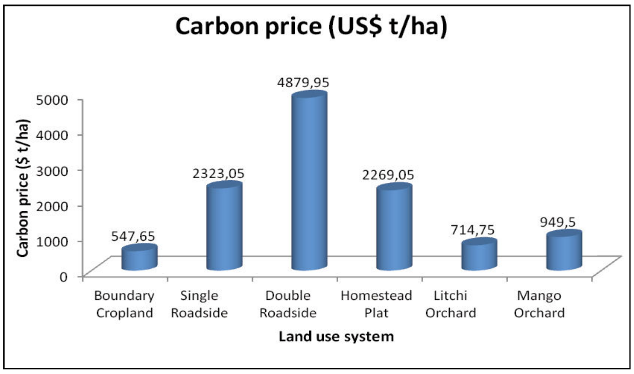

Figure. Economic value of carbon sequestration (US$ t ha^{-1})

ue (Figure). According to Vivian [26] one (1) ton of carbon was sold at US$15. So, the highest carbon price (4879.95 $ t ha^{-1}) was recorded from Double roadside (T_3) which was followed by single roadside (T_2) and Homestead (T_4). On the other hand, the lowest carbon price (547.65 $ t ha^{-1}) was obtained from Cropland (T_1) which was followed by Litchi orchard (T_5) and Mango orchard (T_6).

Conclusions

The finding of this study showed that different land use system had significant effects on biomass and carbon accumulation. Planting of multipurpose tree species in non-forest land like cropland, roadside, homestead etc. can serve a dual purpose by promoting carbon sequestration and production of non timber forest product for local people. The present investigation finds out that seven (7) year old Eucalyptus plantation in double roadside strip gave the highest sequestration ability of CO_2 due to its high biomass stand density. Finally, it may be concluded that since forest plantations cannot be extended to many large areas of Bangladesh due to high population pressure and demand of agricultural land, roadside agroforestry land use system will be a better option for larger tree plantation coverage and reduction in GHGs effects.

REFERENCES:

1. Albrecht A, Kandji S (2003) Carbon sequestration in tropical agroforestry systems. Agriculture, Ecosystems and Environment. Institut de Recherche pour le Développement (IRD), c/o International Centre for Research in Agroforestry (ICRAF), Nairobi, Kenya 99: 15–27.
2. Avery TE, Burkhart HE (2001) Forest Measurements (5th ed.). New York: McGraw-Hill, 456.
3. Beer C, Reichstein M, Tomelleri E, et al. (2010) Terrestrial Gross Carbondioxide Uptake: Global Distribution and Covariation with Climate. Science 329: 834–838. Doi: 10.1126/science.1184984.
4. Bolin B, Sukumar R (2000).Global Perspective. Chapter 1 in Watson RT, IR Noble, B Bolin, NH Ravindranath, DJ Verardo, DJ Dokken (Eds), 2000. Land Use, Land-Use Change, and Forestry. A Special Report of the IPCC.
5. Chave J, Andalo C, Brown S, et al. (2005) Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145: 87–99. http://dx.doi.org/10.1007/s00442-005-0100-x.
6. Dixon RK, Winjum JK, Andrasko KJ, Lee JJ, Schroeder PE (1994) Integrated Systems: Assessment of Promising Agroforestry and Alternative Land Use Practices to Enhance Carbon Conservation and Sequestration. Clim Change 27(1): 71–92. https://doi.org/10.1007/BF01098474.
7. Grace J (2004) Understanding and managing the global carbon cycle. J Ecol 92: 189–202. https://doi.org/10.1111/j.0022-0477.2004.00874.x.
8. Hangarge LM, Kulkarni DK, Gaikwad VB, Mahajan DM, Chaudhari N (2012) Carbon Sequestration potential of tree species in Somjaichi Rai (Sacred grove) at Nandghur village, in Bhor region of Pune District, Maharashtra State, India. Annals Biol Res 3(7): 3426–3429.
9. IPCC (2000) IPCC Special Report on Land Use, Land-Use Change and Forestry. A special report of the Intergovernmental Panel on Climate Change. Approved at IPCC Plenary XVI (Montreal, 1-8 May, 2000). IPCC Secretariat, c/o World Meteorological Organization, Geneva, Switzerland. At http://www.ipcc.ch/..
10. IPCC (2006) Agriculture, forestry and other land use. In: Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (Eds) IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme. IGES, Japan.
11. Khaki BA, Wani AA (2011) Carbon sequestration potential of biomass under different agroforestry land use systems in Poanta area of Himachal Pradesh. Indian Forestry Congress, Conference, New Delhi.
12. Kursten E (2000) Fuelwood production in agroforetry systems for sustainable land use and CO_2 mitigation. Ecol Engineering 16: 569–572.
13. Lal R, Kimble JM, Follet RF, Cole CV (1998) Land conversion and restoration In: The potential of U.S. cropland to sequester carbon and mitigate the greenhouse effect, R Lal et al. (Eds). Ann Arbor Press, Chelsea M. I. p. 35–51.

14. Lal R, Follett RF, Kimble J (1999) Managing U.S. cropland to sequester carbon is soil. J Soil Water Conservation.53: 374–381.
15. Malhi Y, Aragao LEOC, Metcalfe DB, et al. (2009) Comprehensive Assessment of Carbon Productivity, Allocation and Storage in Three Amazonian Forest. Global Change Biol 15: 1255–1274.
16. Masera OR, Garza-Caligans JF, Kanninen M, et al. (2003) Modelling Carbon Sequestration in Afforestation, Agroforestry and Forest Management Projects: The CO_2 FIX V.2 Approach. Ecol Modell 164: 177–199. https://doi.org/10.1016/S0304-3800(02)00419-2.
17. Newaj R, Dhyani SK (2008) Agroforestry for carbon sequestration: Scope and present status. Indian J Agroforestry 10: 1–9.
18. Pan Y, Birdsey RA, Fang J, et al. (2011) A Large and Persistent Carbon Sink in the World's Forest. Science 333: 88–993. Doi: 10.1126/science.1201609.
19. Pandya IY, Salvi H, Chahar O, Vaghela N (2013) Quantitative Analysis on Carbon Storage of 25 Valuable Tree Species of Gujarat, Incredible India. Indian J Sci Res 4(1): 137–141.
20. Pearson T, Walker S, Brown S (2005) Sourcebook for land-use, land-use change and forestry projects. Arlington, 19–35.
21. Pearson TR, Brown SL, Birdsey RA (2007) Measurement guidelines for the sequestration of forest carbon, general technical report, USAID forest service.
22. Rajput BS (2010) Bio-economic appraisal and carbon sequestration potential of different land use systems in temperate north-western Himalayas. PhD Thesis, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP). India.
23. Ravindranath NH, Madelene O (2008) Carbon Inventory Methods: Handbook for Greenhouse Gas Inventory, Carbon Mitigation and Round wood Production Projects.
24. Schroeder P (1993) Agroforestry systems: integrated land use to store and conserve carbon. Clim Res 3: 53–60.
25. Sheikh MA, Kumar M, Bussman RW, Todaria NP (2011) Forest carbon stocks and fluxes in physiographic zones of India. Carbon Balance Manag 6.
26. Vivian JB (2010) Potential economic value of carbon sequestration in Kakamega forest and surrounding farms. A Thesis submitted to graduate school. Egerton University.