Available online at http://www.journalcra.com

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

International Journal of Current Research
Vol. 13, Issue, 05, pp.17373-17377, May, 2021

DOI: https://doi.org/10.24941/ijcr.41365.05.2021

ISSN: 0975-833X

RESEARCH ARTICLE

OPEN ACCESS

THE ROLE OF RUBBER (*HEVEA BRASILIENSIS*) PLANTATION IN CARBON STORAGE AT BANDARBANS HILL TRACT, BANGLADESH

A.K.M. Abul Kalam Azad[1], Md. Najmus Sayadat Pitol[2*] and Yonosuke Hara[3]

[1] Bangladesh Planning Commission, Ministry of Planning, Agargoan, Dhaka
[2]Bangladesh Forest Research Institute, Ministry of Environment, Forest and climate change, Bangladesh
[3]National Graduate Institute for Policy Studies (GRIPS), Tokyo, Japan

ARTICLE INFO

Article History:
Received 09th February, 2021
Received in revised form
14th March, 2021
Accepted 20th April, 2021
Published online 20th May, 2021

Key Words:
Above-Ground Biomass, Below-Ground Biomass, Carbon Sink,
Carbon Trading,
Tree Farming.

ABSTRACT

The study appraised rubber tree plantations at Bandarbans Hill Tract in Bangladesh, to measure the biomass in plantations of different ages and to determine the organic carbon content and CO_2 equivalence.The DBH and biomass growth were increased with the age of the plantations so as the carbon storage and carbon-di-oxide equivalence (CO_2e). All of them were sharply increased upto 15th year from the beginning and become slower after 15th year. The average DBH, above-ground biomass, below-ground biomass, total biomass, carbon storage and carbon-di-oxide equivalence for rubber plantation were 15.15cm, 160.12 Mg ha^{-1}, 27.41 Mg ha^{-1}, 187.54 Mg ha^{-1}, 93.97 Mg ha^{-1} and 344.14 Mg ha^{-1} respectively. The highest DBH (1.54 87cm ha^{-1} yr^{-1}) and biomass (53.29 Mg ha^{-1} yr^{-1}) growth were found between 10 to 15 years of rubber plantation where the average growth of DBH (1.01cm ha^{-1} yr^{-1}) and biomass (23.71 Mg ha^{-1} yr^{-1}). An average 11663.42 Tk $ha^{-1}yr^{-1}$ earn for rubber plantation in Bandarban hill tract only for keeping the tree in field. Three types of DBH based models were developed with strong mean R^2 (Power = 0.99; Polynomial = 0.98 and Linear = 0.90) and all were highly significant ($P < 0.05$). The result will be explored the value of rubber plantation and helped the policy maker for advancing the management of forest in hilly area of Bangladesh.

Citation: A.K.M. Abul Kalam Azad, Md. Najmus Sayadat Pitol and Yonosuke Hara. "The role of Rubber (*Hevea brasiliensis*) plantation in carbon storage at Bandarbans Hill Tract, Bangladesh*", 2021. International Journal of Current Research, 13, (05), 17373-17377.*

INTRODUCTION

Global Warming and climate change, the most talked issues in the present world. These are the consequence of raised greenhouse gases mainly CO_2 (Kumar 2011, Zhang *et al*. 2011). The combustion of fossil fuel, deforestation, agricultural and industrial processes are responsible for raising the amount of CO_2 in the atmosphere (Sharma *et al*. 2010, Detwiler and Hall. 1988, Pfaff *et al*., 2000).The atmospheric carbon dioxide (CO_2) growth is varying (Wayburn, 2000; Munishi *et al*., 2000; Munishi and Shear,2004) and theterrestrial ecosystems playing a major role in carbon sink (Brown, 1997, 1999; Dixon, 1996; Munishi, 2001; Munishi and Shear, 2004).Forests are giant sponges that soak huge amounts of carbon dioxide (Corpuz et el. 2014) but deforestation proceeds faster than forest re-growth (Houghton *et al*., 1987). Fortunately, tree farmingcover 396108 ha in 2005, and still 2% expanding annuallythroughout the world,while about halfof the total increased through tree plantations (Dijk and Keenan, 2007).

Corresponding author: *Md. Najmus Sayadat Pitol,
Bangladesh Forest Research Institute, Ministry of Environment, Forest and climate change, Bangladesh.

Tree farming like rubber (*Hevea brasiliensis)* cultivation opens new opportunities to the small-scale farmers andenvironmentally suitable compared to shifting cultivation. In contrary, create new plantation near natural forest decreases the diversity of forest (Rahaman et al. 2020), but the growing demand for rubber and rubber product insisted on the commercial plantation of rubber in Bangladesh. It will be an excellent tool to cope with the food, wood, energy, ecology, poverty crises and lessen the deforestation rate of forestlands in Bangladesh.Rubber (*Hevea brasiliensis)* is one of the cash crops that is the source of natural latex and also used in furniture industries (Arokiaraj *et al*., 2002; Tissari, 2002). Large-scale rubber plantations were established in the central and eastern hilly parts of Bangladesh (BFIDC, 1995). At present, both the governmental and private sectors 18,954 ha plantation of *H. brasiliensis*has been developed and planned to expand its further 1214 ha during 2020(BFIDC, 2015; Hossain, 2016). Rubber trees are storing a huge amount of carbon from the environment with latex production. The leaves of rubber trees are used as fodder, seedsare the ingredient in poultry feed and seed cakes (Akhter *et al*., 2013). Rubberwood has also used for making furniture, plywood, particleboard, chemical pulping and packing cases (Sattar, 1991; Sattar, 1995; Das, 1995). Presently, rubber plantation meets only 30% of the total current domestic raw rubber demand (ADB, 1997). Kyoto protocol, REDD+ and carbon trading allagreements try to reduce the emission of CO_2 and enhancing the role of conservation of forest (Gardner *et al*. 2011). Bangladesh has already ratified the Kyoto protocol, REDD+ and included herself in carbon trading mechanisms. Some studies revealed that the rubberplantations in southern Braziland Asia accumulated a largerange of carbon ranges from 1.4 to 6.7 MgC ha^{-1} yr^{-1}(Cunha *et al*., 2000; Cotta *et al*., 2006; Wauters *et al*., 2008; Dey, 2005; Yang *et al*., 2005). Some studies were done about the prospectus and economic feasibility of rubber plantation (Ali 1985, Rakkibu *et al*. 2003; Sattar, 1995; Sarkar 2006) but study about rubber biomass and carbon measurement is still rare in Bangladesh.However, Islam (2017) and Mahmood *et al*. (2021) developed allometric biomass models for rubber plantation recently. So, it is essential to evaluate the biomass or carbon stock of the rubber plantations for getting the carbon trading facilities. Thisstudy calculated the amount of carbon that can be sequestered by a rubber tree plantation through biomass measurements in rubber tree stands of different ages in Bandarbans hill tract, Bangladesh.

MATERIALS AND METHOD

Study area: Bandarban district is the most remote district of the country with a 4,479 km^2 area where 2,15,934 Bengalis and 1,42,401 indigenous people in the district (BBS, 2011).It lies between 22°11' and 22°30' north latitudes and between 92° 04' and 92° 41' east longitudes(BBS, 2011).The religious composition of the population in 2011 was 50.8% Muslim, 31.7% Buddhist, 10.1% Christian, 3.4% Hindu and 4.0% others(BBS, 2011). There are more than fifteen ethnic minorities including Marma, Rakhine, Mru (Mro/Murong), Bawm, Khyang, Tripura (Tipra/Tipperah), Lushei (Lushei), Khumi, Chak, Kuki, Chakma and Tanchangya (Tenchungya) living in the district besides the Bengalis. Forestry, fisheries, and livestock are the main source of household income and both shifting cultivators and rubber cultivators were found in the study area (BBS, 2011).This study area has tropical climatic conditions and is moist, warm and equable. Likeother parts of the country, this area also experiences three seasonssuch assummer, monsoon, andwinter season. There is rain during the monsoon and little or norainfall during the winter season.The average temperature was 26.10°C, and the minimumand maximum temperatures were recorded as 10°C in December-January and 34.8°Cfrom May to March to June (BBS, 2011).

Sample design and size: The distribution of rubber plantations in this region was uneven and discrete. So, purposive sampling was used fordata collection.The plantationswere selected through snow-ball methods during the reconnaissance survey.A total twenty-eight sample plots from different ages plantations were selected. The size of each sampling plot was 10m × 10 m. Diameter less than 3cm was castoff purposively.

Biomass and Carbon measurement: DBH is the most significant and easily measured variable from other variables for biomass accretion in forest sector (Haygreen and Bowler, 1989; Jackson, 1992; Malimbwi *et al*., 1994; Munishi *et al*., 2000, Munishi and Shear, 2004)**.** For wide graphical and diameter range, Chave *et al*. (2005) was developed a set of allometric equation for tropical trees that used frequently.By using Chave's(2005) allometric equation above ground biomass of the rubberplantations wasestimated and below ground biomass wascalculated using the most cost effectiveand practical method suggested by Cairns *et al*. (1997). Appraised biomass was multiplied by the woodcarbon content (50%) because almost all carbonmeasurement projects in the tropical forestassume that all tissues (i.e., wood, leaves and roots) consist of 50% carbon on a dry mass basis (Chave et.al. 2005, Haygreen and Bowler, 1989; Munishi and Shear, 2004). The total carbon stock can be converted to CO^2e by multiplying carbon stock by 3.67 (Kauffman and Donato, 2012). One tonne (Mg) of $CO_2$is equal to one CER (Certified Emission Reduction) as per the remaining carbon trading mechanism andat present the market price of one CER is $0.4 (UNFCCC, 2017). To attain the economic value of CO_2 sequesteredthe total CO_2e is multiplied with CER where 1 US Dollar ($) = 84.72 Tk, Date: 30/04/2021. Statistical analysis was done in Microsoft OfficeExcel 2019.

RESULTS

It was found that the rotation period played a vital role in the rubber plantations. With the increase in the age of the plantations the average DBH, biomass, carbon storage and carbon-di-oxide equivalence (CO_2e) were increased. All of them were sharply increased up tothe 15^{th} year and the highest average DBH (30.38 cm),above-ground biomass (617.61 $Mgha^{-1}$), below-ground biomass (98.01 $Mgha^{-1}$),total biomass (715.69Mg ha^{-1}), carbon storage (357.84 Mg ha^{-1}) and carbon di-oxide equivalence (1313.30 Mg ha^{-1}) were found for 30-years of rubber plantation (Table-1). The growth was slower after the 15^{th} years so as DBH, above-ground biomass, below-ground biomass, total biomass, carbon storage and carbon-di-oxide equivalence. The average DBH, above ground biomass, below ground biomass, total biomass, carbon storage and carbon di-oxide equivalence for rubber plantation were 15.15cm, 160.12 Mg ha^{-1}, 27.41 Mg ha^{-1}, 187.54 Mg ha^{-1}, 93.97 Mg $ha^{-1}$and 344.14 Mg ha^{-1} respectively (Table-1). The result has explored the value of rubber plantation in carbon trading mechanism because of storing a higher amount of carbon in its body parts.As per theexisting carbon trading mechanism, a single rubber plantation of one year can earn 258.68Tk $ha^{-1}yr^{-1}$ where a 30-year plantation simply earns 45557.82 Tk $ha^{-1}yr^{-1}$ only for keeping the tree in the field. An average of 11663.42 Tk $ha^{-1}yr^{-1}$ earn for rubber plantation in Bandarban hill tract (Table 1).

Yearly DBH and Biomass Increment: The analysis showed that the DBHand Biomass growth wasfollowed the zigzag (natural) manner in the Bandarban hill tract. The average DBH and Biomass growth of 30-year rubber plantation was1.01cm ha^{-1} yr^{-1} and 23.71Mg ha^{-1} yr^{-1} respectively. The DBH gradually increase upto the3^{rd} yearand certainly decrease in the 5^{th}year (Fig 1). The highest DBH (2.6 cm yr^{-1}) growth was found between 7-year to 8-year. The biomass growth sharply increased up to the 6^{th} year from the beginning and suddenly decreased in the 7^{th} year (Fig 2). After the 10^{th} year, the biomass growth touches the pick and the value was 53.29Mg ha^{-1} yr^{-1}. The growth of biomass in 5-year, 6-year and 7-year plantations were 15.27 Mg ha^{-1} yr^{-1}, 16.67 Mg ha^{-1} $yr^{-1}$and 1.35Mg ha^{-1} yr^{-1}respectively. After the 7^{th} year both DBH and biomass were increased slowly but decreased in the 10^{th} year (Fig 1, Fig 2).The growth of biomass in 8-year, 9-year and 10-year plantations were 40.49 Mg ha^{-1} yr^{-1}, 51.50 Mg ha^{-1} $yr^{-1}$and 22.87Mg ha^{-1} yr^{-1}respectively. The highest biomass (53.29Mg ha^{-1} yr^{-1}) growthwerefound between 10 to 15 years (Fig 2). From 15 to 20 years of plantation, the biomass growth was 36.06 Mg ha^{-1} $yr^{-1}$and from 20 to 30 years, the biomass growth was 9.2 Mg ha^{-1} yr^{-1} (Fig 2).

Diameter at Breast Height (DBH) based carbon measurement Equations: Three types of models were developed for carbon assessment from the plot level mean DBH(Eqs. (1) to (3)). A strong mean R^2 value (Power = 0.99; Polynomial = 0.98 and Linear = 0.90) and significant ($P < 0.05$) relationship were found between mean biomasscarbon and mean DBH for rubber plantations (Fig. 3).

Biomass Carbon (C) = 0.0562 $(DBH)^{2.5471}$ (1)

Biomass Carbon (C) =y = $0.557x^2 - 6.4241x + 24.567$(2)

Biomass Carbon (C) = 13.718 (DBH) - 109.44(3)

DISCUSSION

The average DBH and Biomass growth of 30-year rubber plantation at Bandarban was 1.01cm ha^{-1} yr^{-1} and 23.71 MgC ha^{-1} yr^{-1} respectively. The highest biomass (53.29 MgC ha^{-1} yr^{-1}) growth was found between 10 to 15 years of plantation and the highest DBH (2.6 cm yr^{-1}) growth was found between 7-year to 8-year of plantation (Fig 2). The rubber plantations in Brazil and Asia also accumulated a large range of carbon ranges from 1.4 to 6.7 MgC ha^{-1} yr^{-1} (Cunha *et al*., 2000; Cotta *et al*., 2006; Wauters *et al*., 2008; Dey, 2005; Yang *et al*., 2005).

Table 1. Plantation age, DBH, above ground biomass, below ground biomass, total biomass, carbon storage, carbon di-oxide equivalence and price of carbon di-oxide of rubber plantation

Plantation Age	Avg. DBH (cm)	Avg. AGB (Mg/ha)	Avg. BGB (Mg/ha)	Avg. Total Biomass (Mg/ha)	Avg. Carbon (Mg/ha)	Avg. CO_2e (Mg/ha)	Tk/ha/yr
1 Year	4.15	3.21	0.94	4.15	2.07	7.62	258.68
2 Years	5.31	6.15	1.67	7.82	3.91	14.36	487.36
3 Years	6.74	12.74	3.23	15.97	7.98	29.31	994.60
4 Years	8.75	23.16	5.39	28.55	14.27	52.39	1777.53
5 Years	10.14	35.94	7.88	43.82	21.91	80.41	2728.30
6 Years	12.04	49.93	10.57	60.50	30.25	111.03	3767.07
7 Years	12.13	51.07	10.78	61.85	30.92	113.50	3851.07
8 Years	14.73	85.38	16.97	102.35	51.17	187.81	6372.04
9 Years	17.14	129.38	24.47	153.85	76.92	282.31	9578.44
10 Years	17.94	149.09	27.64	176.73	88.36	324.29	11002.65
15 Years	26.47	380.41	62.80	443.21	221.60	813.29	27593.38
20 Years	29.21	537.44	86.08	623.52	311.75	1144.15	38818.98
30 Years	30.38	617.68	98.01	715.69	357.84	1313.30	45557.82
Average	15.15	160.12	27.41	187.54	93.77	344.14	11663.42

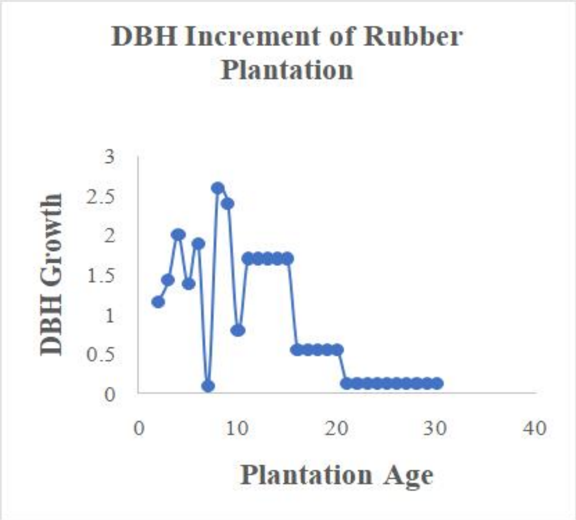

Figure 1. Yearly DBH Increment

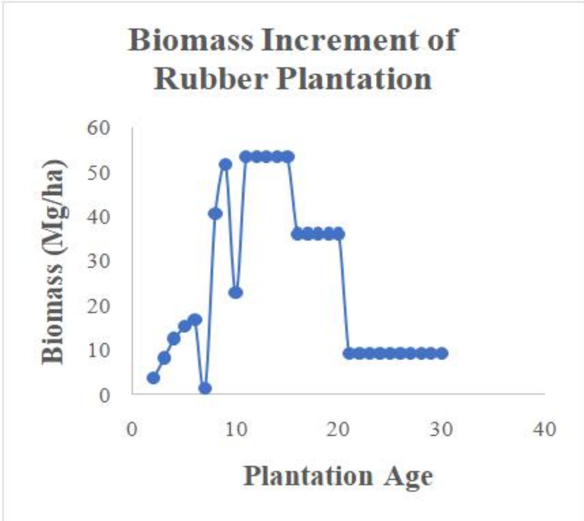

Figure 2. Yearly Biomass Increment

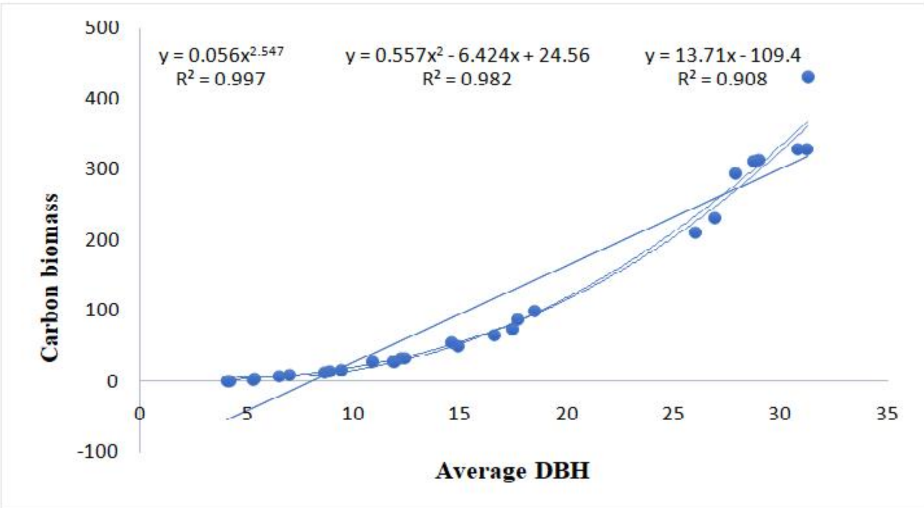

Figure 3. DBH based Carbon measurement model

The established three DBH-based allometric models can be suitable for carbon calculation from the plot level mean DBH as three models exhibited strong relationships in the GLRM analysis (R^2= 0.99, 0.98, 0.90) (Fig 4). It was found that the highest DBH tree has the highest biomass. It indicated that the older the plantation, the higher its DBH and biomass. The finding supports the study on the carbon budget of rubber plantations in ArakanCotabatothe (Corpuz 2014; Corpuz*et.al.* 2011).

It showed that average above-ground biomass (49.93 Mg ha^{-1}), below-ground biomass (10.57 Mg ha^{-1}) and total biomass (60.50 Mg ha^{-1}) for 6-years rubber plantation (Table 1) in Bangladesh were higher than Brazil, India, Philippines and China (Corpuz *et al*. 2014; Cunha *et al*. 2000; Dey 2005; Maggiotto *et al*. 2014; Yang *et al*. 2005).Rubber plantations in Antipas with ages10 and 20 years have total biomass of 110.91 Mg ha^{-1} (46.76 Mg ha^{-1}C) and 573.21 Mg ha^{-1}(257.95 Mg ha^{-1}C) (Corpuz *et al*. 2014) which also lower than this study 176.73 Mg

ha^{-1}(88.36 Mg ha^{-1} C) and 623.52 Mg ha^{-1} (311.75 Mg ha^{-1} C) respectively.Naik *et al*. (2019) also reported total carbon stock in a 10-year-old mango orchard was 3.87Mg ha^{-1}. The rubber plantation of theBandarban hill tract, Bangladesh showed higher above-ground biomass (AGB) (160.12 Mg ha^{-1}), below-ground biomass (BGB) (27.41 Mg ha^{-1}) and carbon (93.77 Mg ha^{-1}**)** storage (Table 1) than many other plantations throughout the world. Chandana *et al*. 2020 stated that mean AGB (51 Mg ha^{-1}) and mean BGB (13.3 tha^{-1}) in *Melia dubia* where similarresultfounded by Saravanan *et al*. (2014) in *M.dubia*. The above-groundbiomass and below-ground biomass of *Mangifera indica* were82.83 Mg ha^{-1} and 21.54 Mg ha^{-1} respectively (Uthappa and Devakumar, 2021). The above-ground biomassranged from 31.8 Mg ha^{-1} to 20.7 Mg ha^{-1}in tropicaldeciduous forests of Central India, (Salunkhe*et al*.2016) and an averagecarbon stock of 31.72 Mg C ha^{-1}estimated in Indian forests(Lal and Singh, 2000). In tropical dryforests of northern India, the above-ground biomass ranged from 38.6- 239.8 Mg ha-^{1} (Singh and Singh, 1991).The average carbon stock in Mahagony (*Swietenia macrophylla*) plantation at Jhenaidah, Bangladesh was estimated to 143.93 ±11.32 Mg ha^{-1} ranging between 26.24 Mg ha^{-1} and 412.22 Mg ha^{-1} (Pitol *et al*. 2019). It also assumed that the rubber plantation received huge amount of CO_2 and stored it as the form of carbon in its body parts. The rubber plantation of Bandarban hill tract at the age of 15, 20 and 30 years sunk 813.29, 1144.15 and 1313.30 Mg ha^{-1} atmospheric CO_2 (Table 1).According to the current carbon trading mechanism, that canearn 27593.38, 38818.98 and 45557.82 Tk ha^{-1} yr^{-1} just for keeping the tree in the field respectively (Table 1). An average 344.14Mg ha^{-1} atmospheric CO_2 absorbed by rubber plantationcan earn an average of 11663.42Tk ha^{-1} yr^{-1}at Bandarban hill tract, Bangladesh (Table 1).The biomass carbon stock in the rubber plantation of Bandarban at the age of 3, 7, 9 years were 7.98, 30.92, and 76.92 Mg ha^{-1} that were much higher than the plantation of Xishuangbanna 2.79, 23.25, 38.65 Mg ha^{-1} (Sun, 2013; Song and Zhang, 2010) respectively but both showed the rapid growth of therubber tree carbon accumulation at early ages.The mean biomass carbon of rubber plantations (93.97 Mg ha^{-1}) in this study was higher than the reported carbon stock 83.72 Mg ha^{-1} (Bonan, 2008) and USA national average urban forest carbon storage (22. 83 Mg ha^{-1}) but lower than 110.94 Mg ha^{-1} (Wang *et al*. 2011).

Conclusion

The rubber tree is acrucial tree species that sequestrates potential carbon associated with natural latex production. It stored carbon-di-oxide (CO_2) and acts as a carbon sink. Rubber plantation can mitigate the risk to ecologies such as the loss of biodiversity and soil fertility follow the greener rural development.The rubber plantationscan minimize the hazardous effect of shifting cultivation by diminishing the practice.Rubber trees have the potential for food, wood, energy and ecological security would be attained that may slow down poverty and economic crisis in the country. Moreover, based on the result of the study, theGovernment of Bangladesh pays more care and more value to the high-demanding rubber trees that help extenuating CO_2oscillates in the atmosphere.

Conflict of interest: The authors declare no conflict of interest.

Funding statement: This research did not receive any specific grant from funding agencies in the public andcommercial sectors.

Acknowledgement

Authors thanks to SB. Ratul and staff of Bangladesh Cotton Development Board, Bandarban for aiding during data collection. Special thanks to GRIPS, Tokyo, Japan.

REFERENCES

ADB. 1997. *Re-evaluation of the rubber rehabilitation expansion project in Bangladesh.* Asian Development Bank

Akhter S, Rahman MS, Biswas MA, Nath SC. 2013. Suitability of rubber
(Hevea brasiliensis) seed meal as poultry feed. Proceedings of the first International Conference on Bio-resources and stress management held at Science City. Kolkata.

Ali M. 1985. Bangladeshi Rubber Gaser Autit, Bartamanabong Bhabiswat (in Bangla) Rubber Bichitra. *Yearly Journal of BFIDC.* Dhaka, Bangladesh;73:1–3.

Arokiaraj P, Jones H, Olsson*et al.* 2002. Towards Molecular Genetic Improvement of Wood and Latex Production of *Hevea brasiliensis:* Enhancement of the Carbon Sink Capacity. In: Proceeding: Fifth Joint Workshop of the Secretariat of the United Nations Conference on Trade and Development and the International Rubber Study Group on Rubber and the Environment, UK, Glasgow. 2002. International Rubber Study Group, pp. 1-9

BBS.2011. *Bangladesh Census.* Dhaka: Bangladesh Bureauof Statistics, Governmentof the Peoples Republic of Bangladesh.

BFIDC. 1995. Revised Project Proposal for Second Rubber Development Project, Tangail and Sherpur Region, Planning and Development Division, Government of the Peoples' Republic of Bangladesh, 131 pp

BFIDC. 2015. Garden and Industries, Bangladesh Forest Industries Development Corporation. (BFIDC) Government of the People's Republic of Bangladesh. http://www.bfidc.gov.bd/site/ page/ fa 44e5 77-8 362-4cbd-ac31-b0fd58445537/-Accessedon 26 December 2019.

Bonan GB. 2008. Forests and climate change: Forcings, feedbacks, and the climate benefits of forests. 1444-1449

Brown S. 1997. Estimating biomass and biomass change in tropical forests. A primer FAO Forestry Paper No. 134

Brown S. 1999. Guidelines for Inventorying and Monitoring Carbon Offsets in Forest-Based Projects. A Report prepared for the World Bank, Washington, DC, USA, p. 13

Cairns MA, Brown S, Helmer EH, Baumgardner GA. 1997. Root biomass allocation in the world’s upland forests. Oecologia, 111(1): 1-11

Chandana P, Madhavi Lata A, Khan MA, Krishna A. 2020. Climate change smart option and doubling farmer’s income through Melia dubia-based agri-silviculture system. Cur. Sci;118(3):444-448

Chave J, Andalo C, Brown S, Cairns MA, Chambers JQ, Eamus D, Fölster H, Fromard F, Higuchi N, Kira T, Lescure JP, Nelson BW, Ogawa H, Puig H, Rie´ra B, Yamakura T. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests, *Oecologia*, 145: 87-99.

Corpuz OS, AdamZM, SalibioC. 2011**.** Carbon budget of rubber plantation in Arakan, Cotabato. Paper presented during the 1st Regional Conference on Climate Change. June 23-24, 2011. Carlos Domingues Hall, Ateneo de Zamboanga University, Zamboanga City. The Centerfor Sustainable Development CSDi Community. http://www.csd-i.org/read-adapt-climate-change-docs/.

Corpuz OS, Esmael LA, Salibio C. 2014. Potential Carbon Storage of Rubber Plantations. Indian J.Pharm. Biol. Res.; 2(2):73-82.

Cotta MK, Jacovine LAG, ValverdeSR, Paiva HN, Virgens Filho AC, Silva ML. 2006. Análiseeconômica do consórcioseringueira-cacau para geração de certificados de emissõesreduzidas. RevistaÁrvore, v. 30, n. 6, p. 969-979.

CunhaTJF, Blancaneaux P, Calderano Filho B, Carmo CAFS, Garcia NCP, LimaEMB. 2000. Influence of the pedological differentiation on the development of rubber-tree cultivation in the state of Minas Gerais, Brazil. PesquisaAgropecuáriaBrasileira, v. 35, n. 1, p. 145-155.

Das SA. 1995. Chemical components and water repellent property of rubber wood (*Hebeabrasiliensis*) from Bangladesh. *Bangladesh Journal of Forest Science, 24* (1), 58-61.

Detwiler RP, Hall CAS. 1988. Tropical forests and the global carbon cycle. Science.,239:42-47.

Dey SK.2005. A preliminary estimation of carbon stock sequestrated through rubber (*Hevea brasiliensis*) plantation in north eastern region of India. The Indian Forester, v. 131, n. 11, p. 1429-1436.

Dixon RK. 1996. Agroforestry systems and greenhouse gases. Agrofor. Today, 8(1): 11-14.

Gardner TA, Burgess ND, AguilarAmuchastegui N, Barlow J, Berenguer E, Clements T, Danielsen F, Ferreira J, Foden W, Kapos V, Khan SM, Leesm AC, Parry L, Roman-Cuesta RM, Schmitt CB, Vieiram ICG. 2011. A framework for integrating biodiversity concerns into national REDD+ programmes. Biological Conservation.; 11:0-18

Haygreen GJ, Bowler L. 1989. Forest products and wood science. An introduction, 2nd edition. Iowa State University Press, Ames, Iowa.

Hossain M, Chameli S, Siddique MRH, Abdullah SMR, Islam S, Kumar F, Iqbal M, Akhter M, Henry M. 2021. Development of Allometric Biomass Models for Hevea brasiliensisMüll. Arg. Plantation of Bangladesh: A Non-Destructive Approach. Indian Forester. 147. 366-373. 10.36808/if/2021/v147i4/152964.

Hossain MK. 2016. Plantation forestry- paradign to meet the demand of the forestry resources in Bangladesh. In: Monoculture Farming- Global Perspectives, Ecological Impact and Benefits/Drawbacks (T.K. Nath and Patrick O'Reily, Eds.), New York, Nova Publishers. Edition: 1st, Chapter: 3.

Houghton RA, Boone RD, Fruci JR. 1987. The flux of carbon from terrestrial in land use: Geographic distribution of the global flux. Tellns Ser. B. Chem. Meteorol., 39: 122 – 139.

Islam ZSM, Ullah MR. 2017. Allometric relationships for estimating stem volume of rubber tree (*Hevea brasiliensis*muell-arg.) in Bangladesh. *Open Access J Sci.*;1(1):17–21. DOI:10.15406/oajs.2017.01.00006

Jackson BR. 1992. On estimating agriculture's net contribution to atmospheric carbon. Water, Air and Soil Pollution. 64:121 – 137.

KauffmanJB, Donato DC. 2012. Protocols for the measurement, monitoring and reporting of structure, biomass and carbon stocks in mangrove forests. Working Paper 86. CIFOR, Bogor, Indonesia.

Kumar BM. 2011. Species richness and aboveground carbon stock in the home gardens of central Kerala, India. Agriculture, Ecosystems and Environment.;140:430-440.

Lal M, Singh R. 2000. Carbon sequestration potential of Indian forests. Envi. Moni. & Assess 2000; 60:315-327.

Maggiotto SR, Oliveira de D, Marur JC, Stivari SMS, Leclerc M, Wagner-Riddle C. 2014. Potential carbon sequestration in rubber tree plantations in the northwestern region of the Paraná State, Brazil. Acta Scientiarum. Agro. Maringá, v. 36, n. 2, p. 239-245. Doi: 10.4025/actasciagron.v36i2.17404

Malimbwi RE. 1994. Estimation of biomass at Kitulangalo Forest Reserve Tanzania. J. Trop. For. Sci., 7(2): 230-242

Munishi PKT, Maliondo SM, Msanya B, Malimbwi RE. 2000. Biomass and Carbon Storage of a Montane Rain Forest Ecosystem in Northern Tanzania. Proceedings of the first University-wide Scientific Conference held at the Institute of Continuing Education (ICE), SUA from 5th-7th April, pp. 478-493.

Munishi PKT, Shear T. 2004. Carbon Storage of two Afromontane rain forests in the Eastern Arc Mountains of Tanzania. J. Tr. For. Sci., 16(1): 78-93.

Munishi PKT. 2001. The Eastern Arc Mountains Forests of Tanzania: Their Role in Biodiversity and Water Resources Conservation and Net Contribution to Atmospheric Carbon. PhD Thesis, North Carolina State University, Raleigh, NC USA. p. 128

Naik SK, Sarkar PK, Das B, Singh AK, Bhatt BP. 2019. Biomass production and carbon stocks estimate in mango orchards of hot and sub-humid climate in eastern region, India, Carbon Mngt;10(5): 477-487. DOI: 10.1080/17583004.2019.1642043

Pfaff A, Kerr S, Hughes F, Liu S, Sanchez-Azofeifa A, Schimel D *et al*. 2000. The Kyoto Protocol and payments for tropical forests: an interdisciplinary method for estimating carbon-offset supply and increasing the feasibility of a carbon market under the CDM. Ecological Economics.;35:203-221

Pitol MN, Khan MZ, Khatun R. 2019. Assessment of Total Carbon Stock in Swietenia macrophylla Woodlot at Jhenaidah District in Bangladesh. Asian Journal of Research in Agriculture and Forestry, 2(3), 1-10. https://doi.org/10.9734/AJRAF/2018/46922

Rahman MT, Gurung DB, Pitol MNS. 2020. Comparative study of understory between exotic monoculture plantation (*Acacia Sp.*) and adjacent natural Sal (*Shorea Robusta*) forest. European Journal of agriculture and food science 2 (6). DOI: https://doi.org/10.24018/ejfood.2020.2.6.204

Rakkibu MG, KyserMA, Rana R. 2003. Economic potentials of rubber (*Hevea brasiliensis*) monoculture and rubber-agroforestry system: a case study of northern Bangladesh. Khulna University Studies 5(1): 7-9.

Salunkhe O, Khare PK, Sahu TR, Singh S. 2016. Estimation of tree biomass reserves in tropical deciduous forests of Central India by non-destructive approach. Trop. Ecol; 57:153-161

Saravanan V, Parthiban KT, Thirunirai R, Kumar P, Vennila S, Umesh Kanna S *et al*. 2014. Comparative study of wood physical and mechanical properties of Melia dubia with Tectona grandis at different age gradation. Res. J Rec Sci; 3:256-263.

Sarkar MAH. 2006. Bangladesh rubber ChashebongerBhabissat (In Bangali). Bangladesh: Bangladesh Forest Industries Development Corporation. Dhaka. P. 6.

SattarMK. 1991, February 14. Physical mechanical and seasonal properties of Bangladeshi rubber wood (heveabrasiliensis). *Timber Physics Series, 8*(13), pp. 8-12.

Sattar, M. 1995. Utilization of rubber wood: A Timber from the non-conventional source. *Bangladesh Journal of Forest Science, 24* (1), 1-6.

Sharma MC, Baduni NP, Gairola S, Ghildiyal SK, Suyal S. 2010. Tree diversity and carbon stocks of some major forest types of Garhwal Himalaya, India. Forest Ecology and Management.;260(12): 2170-2179.

Singh L, Singh JS. 1991. Species structure, dry matter dynamics and carbon flux of a dry tropical forest in India. Annl. Bot; 68:263-273.

Song Q, Zhang Y. 2010. Biomass, carbon sequestration and its potential of rubber plantations in Xishuangbanna, Southwest China. Chinese Journal of Ecology 29: 1887–1891.(in Chinese).

Sun Y. 2013. Simulation of Carbon dynamic change and accumulation process in Rubber Plantation of xishaungbanna [PhD Thesis]: Xishuangbanna Tropical Botanical Garden, University of Chinese Academy of Sciences. 43 p. (in Chinese).

Tissari J. 2002. Further development of the rubber wood processing industries in producer countries. In: Proceeding: Fifth Joint Workshop of the Secretariat of the United Nations Conference on Trade and Development and the International Rubber Study Group on Rubber and the Environment, Glasgow, UK; 2002. pp. 34-78.

UNFCCC. 2017. CER Demand, CDM outlook and Article 6 of the Paris Agreement 2017.

Uthappa AR,Devakumar AS. 2021. Carbon sequestration potential of different land use systems in semi-arid regions of Karnataka. Journal of Pharmacognosy and Phytochemistry; Sp10(1): 371-376

VanDijk A, Keenan RJ. 2007. Planted forests and water in perspective. Forest Ecology and Management 251: 1–9. doi:10.1016/j.foreco.2007.06.010

Wang W, Lei X, Ma Z, Kneeshaw DD, Peng C. 2011. Positive relationship between aboveground carbon stocks and structural diversity in spruce dominated forest stands in New Brunswick. Canada Forest Science.;57(6):506-515

WautersJB, Coudert S, Grallien E, Jonard M, PonetteQ. 2008. Carbon stock in rubber tree plantations in Western Ghana and Mato Grosso (Brazil). Forest Ecology and Management, v. 255, n. 7, p. 2347-2361.

Wayburn AL. 2000. From theory to practice: Increasing carbon stores through forest management. Ecoforestry, Summer, pp. 40 – 42.

YangJC, Huang JH, Tang JW, Pan QM, Han XG. 2005. Carbon sequestration in rubber tree plantations established on former arable lands in Xishuangbanna, SW China. Acta PhytoecologicaSinica, v. 29, n. 2, p. 296-303.

Zhang Y, Duan B, Xian J, Korpelainen H, Li C. 2011. Links between plant diversity, carbon stocks and environmental factors along a successional gradient in a subalpine coniferous forest in Southwest China. Forest Ecology and Management.;262:361-369.

****