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The ability of carbon storage of Acacia auriculiformis in different forest areas of Rangunia upzila under Chattogram district, Bangladesh

Mohammed Mukhlesur Rahman
Bangladesh Forest Research Institute, P. O. Box, 273, Chittagong-4000, Bangladesh

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ABSTRACT
Acacia auriculiformisA.Cunn. ex Benth.is the most popular and massive planted in different regions of Bangladesh due to its fast-growing feature and timber quality.The study was conducted on the total of 450 ha plantation areas in four Forest Ranges under ChattogramNorth Forest Division during 2020-2021. Non-destructive and systematic sampling methods were used to determine the total biomass carbon. The average diameter and mean annual increment of diameter values were 6.80 cm and 1.01 cm tree-^{1} year^{-1} in 11 years and 3 years old plantation. The average height and mean annual height increment were 6.44 m and 0.93 m in 11 years and 3 years old plantation.The highest carbon 11.04 t ha^{-1} was found in 11 years old and the lowest carbon 0.70 t ha^{-1} was found in 3 years old plantation. The average carbon and mean annual increment carbon stocks were 5.36t ha^{-1} and 0.77 t C ha^{-1}yr^{-1}in 11 years and 3 years old plantationrespectively. The correlation indicated that positive relationships(r=0.98) among ages, biomass and carbon.The statistical analysis showed that total biomass and carbon differed significantly ($p<0.05$) among different ages. The results also focused thatAcacia auriculiformiswas more adapted and capable of storing carbon than other forest tree species.The results of this study will provide important information on the plantation of Acacia auriculiformis,which will be utilized in massive plantation programmes implementation in differentregions of Bangladesh.

Keywords: Carbon, storage, fast-growing, exotic species, forests,

I. INTRODUCTION

Forests vegetation reduce the global atmospheric carbon di-oxide through the photosynthesis process and deposit carbon in various parts of the organs. Forest resourcesplay a vital role to mitigate the global warming. But both natural and planted forest resources are declining at an alarming rate in Bangladesh due to the increase of population and indiscriminately harvesting.For this reason, the government and NGOs sectors take the initial steps to develop the forest resources with the help of plantations by fast-growing indigenous and exotic forest tree species. Among them, Acacia auriculiformis A. Cunn.ex Benth.is an evergreen and exotic forests tree species (Turnbull, 1997).It is planted in artificial forests, homesteads forests, roadsides, avenue, embankment of the river sides, denuded areas and other places in the country. This species is popular in tropical and subtropical countries due to its high adaptation capacity, fast-growing and wood quality. It fixes nitrogen and tolerant of infertile, shadow, acid, alkaline, saline or seasonally waterlogged soils and a long dry season. It is a strong light demander and is fire sensitive (Jackson, 1994).Acacia auriculiformis is endemic to Australia, Papua New Guinea and Indonesia and planted widely in tropical South and Southeast Asia, with extensive plantings in China, Vietnam, Indonesia, India and Bangladesh. It is cultivated in Africa and South America. There are some indications that the species was first imported by tea planters as a shade and ornamental tree about 40-50 years ago (Das, 1986). Hossain et al (2004) reported that the Australian variety is introduced in Bangladesh. The sapwood is whitish and the heartwood is light brown to dark red. The timber is fine-grained, often attractively figured and finishes. Timber is moderately heavy, strong and stable. Wood has a high density and became the substitute for teak wood and its heartwood, grain, colour and polish. Wood is suitable for

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attractive furniture, construction work, wood turning and carving. The heartwood is typically hard, durable and is also used for making paper and hard board. The excellent growth rate and mean annual increment are found in Acacia auriculiformis than other faster species of Albizia procera, Albizia lebbeck, Samanea saman, Eucalyptus camaldulensis, Leucaena leucocephala and Pinus roxburghiietc. The plantation of this exotic species is increasing at a geometrical ratein the whole country because of itswell-adapted, high growth rate and good timberproperties. But research paper on the estimation of carbon sequestration of Acacia auriculiformis has not yet to publish. So it is an urgent need to estimate the biomass and carbon stock for emphasizing of Acacia auriculiformisplantation in different parts of Bangladesh. Keeping this point in mind, the present study was takenan attempt to estimate the biomass and carbon stock of Acacia auriculiformis in four Forest Rangesunder the Chattogram North Forest Division.

II. MATERIALS AND METHOD

STUDY AREAS

The study areas lies at 22°.10´ to 22°.34´ N latitudes and 92°.10 ´to 92°.58 ´E longitudes. It is located at Pomra, Hosnabad, Rajanagar and Parua Forest Range under the Chattogram North Forest Division. The whole study area was 450 ha in four Forest Ranges and under their beat offices. The landscape of the study area is flat to gentle slope sandy, sandy loam and acidic soil. The elevation of the study area ranged between 7 and 52 meter mean sea level.

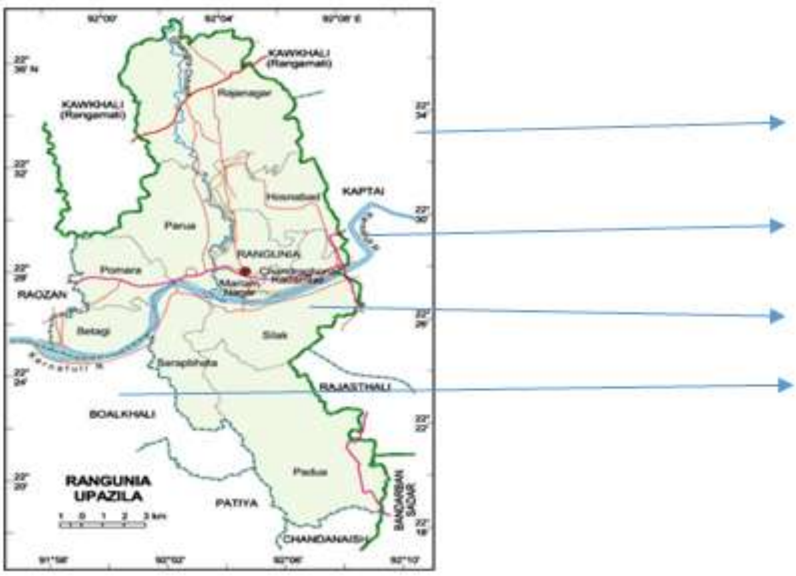

Figure 1. Map showing the location of the study area.

CLIMATIC CONDITION

The summer comes from March and continues up to the end of May. The rainy season starts in June and continues up to October. About 74% of rainfall occurs during this season. The main rainfall starts in the middle of June and continues up to the middle of July and an average 2500 mm rainfall occurs during this time. The climate is tropical in nature. The climate is pleasant and balanced. Winter begins in the middle of November and lasts until the end of February. From October to February the weather is mild with low rainfall. The minimum and maximum mean temperature vary from 19.20° to 32.50° C in December and May respectively. In June, the highest humidity is 82%, while the minimum humidity is 60% in February (Chattogram Weather Station, 2021).

SELECTION OF PLOTS

The study was based on sites selection, measurement of growth parameters of trees as well as determining carbon contents in different ages of Acacia auriculiformis. Field studieswere done from January 2020 to December 2021. There were two hundred fifty eight (258) plots distributed throughout the whole study areas. The plots were situated in varying locations, elevations and different age's forests. The coordinates were recorded using the Global Positioning System (GPS). A systematic sampling method was used for the selection of each plot with the help of global

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positioning system which is recognized all over the world. (Pearson et al., 2007). The whole study area was divided into 1032 sub- plots which were 500 meters apart from each other. Four sub -plots (10 m radius) were set at 100 m intervals from the centre of each plot in north-south and east-west directions. The total numbers of the plots were two hundred fifty eight plots (258). So, there were 1032 sub-plots. Figure 2 shows the schematic representation of the arrangement of plots.

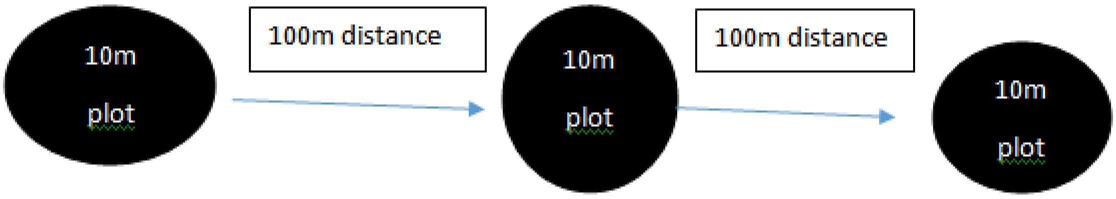

Figure2. Schematic representation of the arrangement of sampling plots.

GROWTH AND BIOMASS MEASUEREMENT OF TREE

After laying out of the plots, the number of trees in each plot were counted and recorded. The trees were measured for height and diameter at breast height (DBH). Each tree was marked and numbered to prevent double counting. A diameter tape was used to measure the DBH (1.30 m above from the ground level) of all the trees in each plot. Height of the trees having DBH equal or greater than 5 cm was measured with a Hega- altimeter. Trees on the border was included in a plot if > 50 % of their basal area fell within the plots and excluded if < 50 % of their basal area fell outside the plot. Trees overhanging to the plots were excluded, but with their trunk inside of the sampling plots, and branches out were included. Care was taken to ensure that the diameter tape is put around the stem exactly at the point of measurement.

ESTIMATION OF TREE BIOMASS

A non-destructive method was used to measure the aboveground biomass of an individual tree. The model of Brown et al. (1989) was used to determine the AGB of each tree from its height and DBH values. This method is taken to be one of the most suitable methods for biomass estimation in tropical forests (Alves et al., 1997; Brown, 1997; Schroeder et al., 1997).

The model for aboveground biomass is as follows.

AGB=exp. {-2.4090+0.9522ln (D^2HS)}

Where,

AGB is the aboveground biomass (kg),

H is the height of the trees (m),

D is the diameter at breast height (cm),

S is the wood density (kg /m^3) for specific species.

Wood density values of the species of the present study were obtained from Sattar et al. (1999).

Aboveground biomass per plot, per track and per hectare were calculated by the following formulas:

AGB per plot = Summation of the AGB values of all the trees in a plot.

AGB per track = Summation of AGB values of all the plots in a track.

AGB per hectare = $\frac{\text{Sum of AGB values of all the plots in a track}}{\text{Total area of all the plots in a track}} \times 10,000$

BGB was considered to be 15 % of the aboveground biomass as suggested by Mac Dicken (1997). The formula is given below:

BGB= AGB × (15 / 100)

The aboveground and belowground biomass was added to get the total biomass of a tree. Total biomass (TB) per plot, per track and per hectare were calculated by the following formulas:

TB per plot = Summation of the total biomass values of all the trees in a plot.

TB per track = Summation of the total biomass values of all the plots in a track.

TB per hectare = $\frac{\text{Sum of total biomass values of all the plots in a track}}{\text{Total area of all the plots in a track}} \times 10,000$

CARBON STOCK IN TREES

The carbon stock of a tree was estimated by assuming that biomass contained 50 % carbon (Brown et al., 1989). Carbon stocks per track and per hectare were also calculated. Carbon stock per track = Sum of carbon stocks of all trees in a track

Carbon stock per hectare = $\frac{\text{Sum of biomass of all the tracks}}{\text{Area of a track, m}^2 \times \text{total number of tracks}} \times 10,000 \times 0.50$

DATA ANALYSIS

Descriptive statistics were calculated to describe biomass and carbon densities in treesand their variations among different ages through a two-factor analysis of variance (ANOVA). Duncan's multiple range tests were used to determine the significance of the variation in mean. Statistical Package for Social Science (SPSS) version 21 was used to perform these analyses.

III. RESULTS

The biomass and carbon were measured on the basis of the diameter at breast height, height and specific wood density. Diameter and height play a vital role in the biomass and carbon storage estimation of the forest tree species. The average and mean annual diameter increment were 6.80 cm and 1.01 cm in 3 to 11 old plantation of Acacia auriculiformis.

Table 1. Diameter at breast height (DBH), height, mean annual diameter increment mean annual (MADI) and mean height increment (MAHI) of Acacia auriculiformisin different ages

Ages (yrs.)	DBH (cm)	Height(m)	MADI (cm)	MAHI (m)
11	11.51	10.03	1.05	0.91
10	10.35	9.11	1.04	0.91
9	9.35	8.28	1.04	0.92
8	8.32	7.35	1.04	0.92
7	7.24	6.54	1.03	0.93
6	6.16	5.56	1.02	0.93
5	5.03	4.72	1.01	0.94
4	3.87	3.78	0.97	0.95
3	2.78	2.93	0.93	0.98
Mean	6.80	6.44	1.01	0.93

The highest mean annual diameter increment was found 1.05 cm in 11 years and the lowest mean annual diameter increment was found 0.93 cm in 3 years old plantation respectively (Table 1). Diameter values were increased with the increasing of ages. The present study focused that the growth of diameter was slowly at the early stages and development increased with ages (figure 3).

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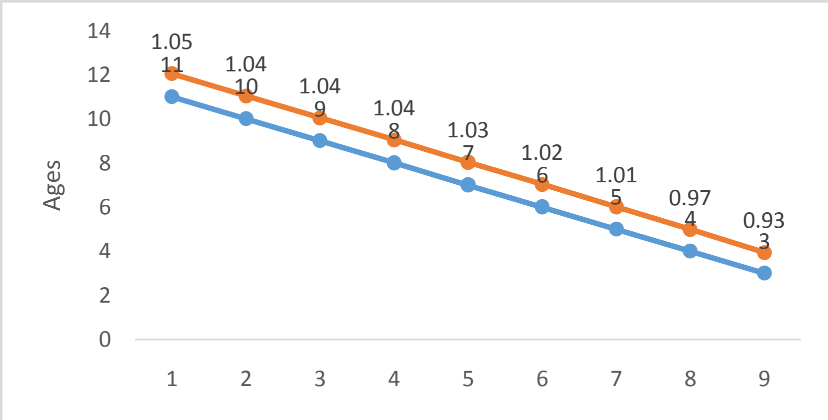

Figure 3.Variation of mean annual diameter increment in difference ages.

There was a positive correlation between mean annual diameter increment and ages. The value of correlation between ages and diameter were 0.95, which indicated that positive correlation and significantly varied at different ages (p<0.05) in the present study.The average and mean annual height increment were 6.44 m and 0.93m in 3 to 11 old plantation of Acacia auriculiformis. The highest mean annual height increment was found 0.98m in 3 years and the lowest mean annual height increment was found 0.91m in 11 years old plantation respectively (Table 1).The study revealed that rapid early growth of height was found in the initial stages and this trend was slightly down with the increase of ages (Figure 4).

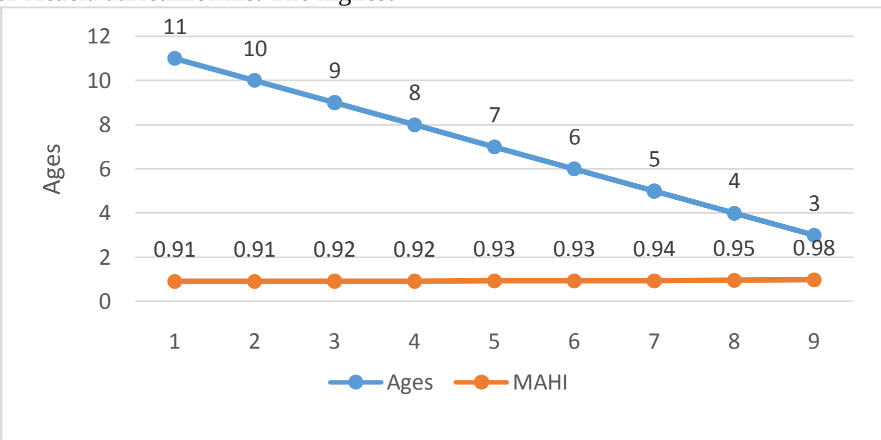

Figure 4. Variation of mean annual height increment in difference ages

There was a positive correlation between mean annual increment of height andages. The value of correlation between ages and height were 0.99, which indicated that strongly positive correlation and significantly varied at different ages (p<0.05) in the present study.

The present study revealed that the maximum and the minimum diameter at breast height (DBH) and height (H) were 11.51 cm and 10.03 m,2.78 cm and 2.93m in 3 to 11 years old Acacia auriculiformis plantation (Table 2). The average values of diameter at breast height and height were 6.80 cm and 6.44 m in 3 to 11 years old plantation. The maximum aboveground biomass and belowground biomass were 53.69 and 8.06 kg/tree found in 11 years old plantation and the minimum aboveground biomass and belowground biomass were 1.10 and 0.16 kg/tree found in 3 years old plantation. The average aboveground biomass and belowground biomass were 19.89 and 2.98 kg/tree found 3 to 11 years old plantation (Table 2).

Table 2. DBH (cm), height (m), aboveground biomass (AGB), belowground biomass (BGB), total biomass(TB) and total carbon(TC) per tree and carbon per ha.

Ages (yrs.)	DBH (cm)	Height (m)	AGB (kg)	BGB (kg)	TB/tree (kg)	TC/tree (kg)	TC/ha	MAI (tC $ha^{-1}yr^{-1}$)
11	11.51	10.03	53.69	8.06	61.75	30.87	11.04	1.02
10	10.35	9.11	44.67	6.70	51.37	25.68	10.27	1.17
9	9.35	8.28	32.25	4.84	37.08	18.54	8.34	1.04
8	8.32	7.35	23.70	3.56	27.26	13.63	6.82	0.94
7	7.24	6.54	11.49	1.72	13,21	6.61	4.62	0.80
6	6.16	5.56	6.63	1.01	7.62	3.81	3.05	0.68
5	5.03	4.72	3.44	0.52	3.96	1.98	2.15	0.56
4	3.87	3.78	2.05	0.31	2.35	1.17	1.21	0.43
3	2.78	2.93	1.10	0.16	1.26	0.63	0.70	0.31
Mean	6.80	6.44	19.89	2.98	22.87	11.46	5.36	0.77

The highest and the lowest biomass were 61.75 and 1.26 kg/tree found in 3 to 11 years old plantation with an average biomass was 22.87 kg/tree. The highest and the lowest carbon were found 30.87 and 0.63 kg/tree in 3 to 11 years old plantation with an average carbon was found 11.46 kg/tree (Table 2). Carbon stock was increasing with the increase of ages. Mean annual increment of carbon was0.77 tC $ha^{-1}yr^{-1}$. There was a positive correlation between ages and biomass growth. The value of correlation between ages and biomass were 0.98, which indicated that strongly positive correlation and significantly varied at different ages ($p<0.005$) in the present study. The maximum, minimum and average carbon stocks were 11.04, 0.70 and 5.36 $tCha^{-1}$ in 11 years and 3 years old plantation respectively (Table 2). It was noticeable that the growth and survival percentage of any tree species were depended on ages, well management and edaphic condition. Over grazing, illicit felling and anthropogenic activities were observed in the study area during the research period. Soil erosion was also occurred by run off in the rainy season. The survival percentage of Acacia auriculiformis was only 25 to 33% in 11 years old plantation areas due to lack of well management and anthropogenic activities.

IV. DISCUSSION

Many research works have been done on Acacia auriculiformis for different purposes. A study was conducted by Hossain et al. (1997) in Ramu reserved forests Cox's Bazar. They reported that diameter and height 3.70cm, 8.40cm, 9.90cm, 4.50m, 6.40m and 10.70 m at 3, 5, and 6 years old plantation respectively.Another study was conducted by Kazemi (2005) at Sitakunda degraded hilly areas under Chattogram NorthForests Division, where 4, 5 and 8 year old plantation showed 9.40cm, 9.60cm and 11.10 cm DBH. In this case, the present findings were lower than the above results. Other scientists (Rahman and Kamluddidn,1995; Ahmed,1990) worked on diameter and height of Acacia auriculiformis in Chittagong University campus and their findings were 5.60 cm, 10.60cm, 12.50cm, 4.20 m, 5.30 m and 9.60 m in 3,4 and 8 years old plantation respectively. Maximum diameter values were greater than the present findings of the study.A study was conducted in the Chittagong university campus (Ahmed, 1990) and reported that 2.16 cm, 2.12 cm and 1.88 cm in 8, 5 and 3 years old plantation respectively. Another study was conducted in Karerhat Forest Range under Chittagong North Forest Division (Ahmed et al., 1998) and reported that 1.60cm and 1.74cm in 5 and 4 years old plantation respectively.Hoque et al, (1991) reported that mean diameter increment of Acacia auriculiformis was 1.13cm and 1.66 cm in 4 and 5 years old respectively. The above values of the mean increment of diameter were lower than the present findings of the study. High diameter was found in the trees of different ages of the present study. A study was conducted in the Chittagong university campus (Ahmed, 1990) and reported that 2.32m, 1.68 m and 1.44 m in 8, 5 and 3 years old plantation respectively. Another study was conducted in Karerhat Forest Range under Chittagong North Forest Division (Ahmed et al., 1998) and reported that1.42m and 1.53m in 5 and 4 years old plantation respectively. Hoque et al, (1991) reported that mean height increment of Acacia auriculiformis was 1.55m and 2.55 m in 4 and 5 years old respectively. The above values of the mean increment of height were lower than the present study value's. The height of trees were influenced by different biotic and abiotic factors which were focused on the growth of the present study area. A study was conducted by Miao et al. (1998) in China on the biomass of different forests species in South China and found that total forest biomass in the 5 years old Aegiceras corniculatum, forests was 4.50 t ha^{-1}. Their values were lower than the present study. Yang and Guan (2006) also reported that annual biomass carbon accumulation rate was 4.80 t ha^{-1} in Pinus elliottii plantation in various forests of Pearl River Delta regions in China. The above discussions indicate that Acacia auriculiformisCasuarina equisetifolia is sustainable, adapted and highly capable of storing carbon than other forest tree species in the whole region of the country.

V. CONCLUSION

Massive plantation with Acacia auriculiformis was started from the last century of Bangladesh. Acacia auriculiformis has contributed to restoration of the degraded forest lands through establishing a quick Acacia vegetation cover is successful in both the hill and plain land forest areas. It is well known as fast - growing tree species which has play a vital role for reducing the pressure on teak. The timber quality of Acacia auriculiformis is similar to Tectona grandis and is popular as second teak.But it is the most fast-growing tree species than other timber species of Bangladesh. The study concluded that Acacia auriculiformis plantation could rapidly accumulate large quantities of biomass. The study suggested that these plantation have a greater potential to sequestrate carbon despite of infertile soil. The expansion of Acacia auriculiformis plantation in the whole country can play important role in sequestering of carbon from the atmosphere and contribute the reducing of the global warming.

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