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Above-Ground Biomass, Nutrients and Carbon in *Aegiceras corniculatum* of the Sundarbans

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Abstract

Aegiceras corniculatum **grows as single-stemmed evergreen shrub or small tree in the Sundarbans mangrove forest of Bangladesh. The objectives of this study were to derive the allometric models for estimating above-ground biomass, nutrients (N, P and K) and carbon stock in *A. corniclatum.* A total of 8 linear models (y = aX + b, $\sqrt{y} = a\sqrt{X} + b$, y = aLogX + b, Logy = aX + b, Logy = aLogX + b, y = alnX + b, Lny = aX + b and Lny = alnX + b) with 64 regression equations were tested to derive the allometric model for biomass of each plant part; and nutrients and carbon stock in total above-ground biomass. The best fit allometric models were selected by considering the values of R^2, CV, R_{mse}, MS_{error}, S_a, S_b, F value, AICc and Furnival Index. The selected allometric models were Logbiomass = 0.76LogDBH^2 − 1.39; Biomass = 0.07DBH^2 − 0.49; Logbiomass = 1.04LogDBH^2 − 1.80; Logbiomass = 1.04LogDBH^2 − 0.99; $\sqrt{\text{Biomass}}$ = 0.48DBH − 0.13 for leaves, branches, bark, stem without bark and total above-ground biomass respectively. The selected allometric models for Nitrogen, Phosphorous, Potassium and Carbon stock in total above-ground biomass were $\sqrt{\text{Nitrogen}}$ = 0.67DBH + 0.11; $\sqrt{\text{Phosphorus}}$ = 0.94DBH + 0.08; $\sqrt{\text{Potassium}}$ = 1.06DBH − 0.18; $\sqrt{\text{Carbon}}$ = 0.33DBH − 0.09 respectively.**

Keywords

Allometry, Biomass, Carbon, Nutrient, Sundarbans

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1. Introduction

Mangroves are various trees and shrubs that grow in saline muddy habitats in the tropical and subtropical sheltered coastline (Tomlinson, 1986). About 35% of the total mangrove area of the world was destructed within 20 years from 1980 to 2000 (MA, 2005) through the conversion to agriculture, aquaculture, urbanization, tourism and over exploitation of resources (Alongi, 2002; FAO, 2007). Presently this forest covers about 181,377 km^2 and distributed in 124 countries (FAO, 2005). Mangrove ecosystem is one of the most productive ecosystems with a mean production of 2.5 $g \cdot Cm^{-2} \cdot day^{-1}$ which contributes about 11% of global total export of organic carbon to the aquatic ecosystem (Jennerjahn & Ittekkot, 2002). Mangrove ecosystem provides wood and fuel, protection from cyclones and tsunamis, nursery and breeding sites for many aquatic organisms. It also reduces coastal erosion, flooding, and maintains nutrient cycling and water quality (Lugo & Snedekar, 1974; Dinerstein et al., 1995; Mahmood et al., 2005; Ellison, 2008; Mahmood et al., 2008a). Biomass estimation has many applications like timber extraction, estimation of productivity, tracking changes in carbon stocks of the forest and global carbon and nutrient cycle (Komiyama et al., 2008; Mahmood et al., 2008b; Mahmood, 2014). The allometric method estimates the whole or partial weight of a tree using regression equations, which is a useful and non-destructive method for estimating forest biomass from the independent variables (Like diameter and height) (Golley et al., 1975; Ketterings et al., 2001) and has widely been used for estimating biomass of mangroves e.g. Tamai et al. (1986); Komiyama et al. (2002); Clough et al. (1997); Fromard et al. (1998); Mahmood et al. (2012); Siddique et al. (2012); Peters et al. (2014); Mahmood et al. (2015).

Aegiceras corniculatum is found to restrict in the indo pacific region and can tolerate comparatively high saline condition (Spalding, 2010). In the Sundarbans, it appears as single-stemmed evergreen shrub or small tree with *Avicennia officinalis*, *Excoecaria agallocha*, *Ceriops decandra*, *Kandelia candel*, *Sonneratia apetala*, *Xylocarpus mekongensis* and *Acanthus ilicifolius* at the moderate to high saline areas. Honey bees produce best quality honey from the nectar of this specie and wood is used for fuel and charcoal production (Siddiqi, 2001). This is a less studied species in the world (Ning et al., 1996; Saintilan, 1997) and there is not a single study on this species in the Sundarbans mangrove forest of Bangladesh. Each mangrove plant species plays a specific role in forest productivity, carbon sequestration and nutrient fluxes (Mahmood, 2004), which helps to understand the contribution of that species in functioning of the mangrove ecosystem (Hutchings & Saenger, 1987). The objectives of the present study were to derive allometric models for estimating above-ground biomass, nutrients (N, P and K) and carbon stock in *A. corniculatum* of the Sundarbans mangrove forest. This outcome will be helpful to estimate the specific role of this species in biomass production and nutrient stock and cycling which can contribute in sustainable management of this species in the Sundarbans.

2. Materials and Methods

2.1. Study Site

The study was carried out at the Sundarbans mangrove forest of Bangladesh which is located between 21˚30'N and 22˚30'N and 89˚00'E and 89˚55'E (**Figure 1**). This forest is almost flat and the maximum ground elevation is about 3 m above the mean sea level and the tidal height varies from 2 m to 6 m. The Sundarbans is dominated by the freshwater flows with high seasonal variation in their discharge. The salinity found to decrease from west to east of this forest and it has been divided into three salinity zones, less saline (salinity <2 dSm^{-1}), moderately saline (2 - 4 dSm^{-1}) and strongly saline (>4 dSm^{-1}). Rainfall varies around 1800 mm per year and the average temperature varies from 28˚C - 30˚C in summer and 18˚C - 20˚C in winter (Siddiqi, 2001). Soil texture is silty to sandy clay loam and pH is around 7.8. Bulk density, particle density and porosity varied from 1.18 to 1.27 gcc^{-1}, 2.31 to 2.52 gcc^{-1} and 46% to 52%, respectively. The major species of the Sundarbans are *Heritiera fomes*, *E. agallocha*, *C. decandra*, *A. officinalis*, *A. corniculatum*, *S. apetala*, *S. caseolaris*, *Nypa fruticans*, *Bruguiera gymnorrhiza*, *B. sexangula*, *Rhizophora apiculate*, *R. mucronata*, *X. granatum* and *X. mekongensis* (Iftekhar & Seanger, 2008).

2.2. Sample Collection and Processing

Twenty nine individual of *A. corniculatum* having Diameter at Breast Height (DBH) from 1 to 15 cm were selected subjectively (avoiding mechanically or insect damaged or infested with disease) from the study area (**Table 1**). DBH and total height (TH) of the selected individuals were measured and felled at the ground level.

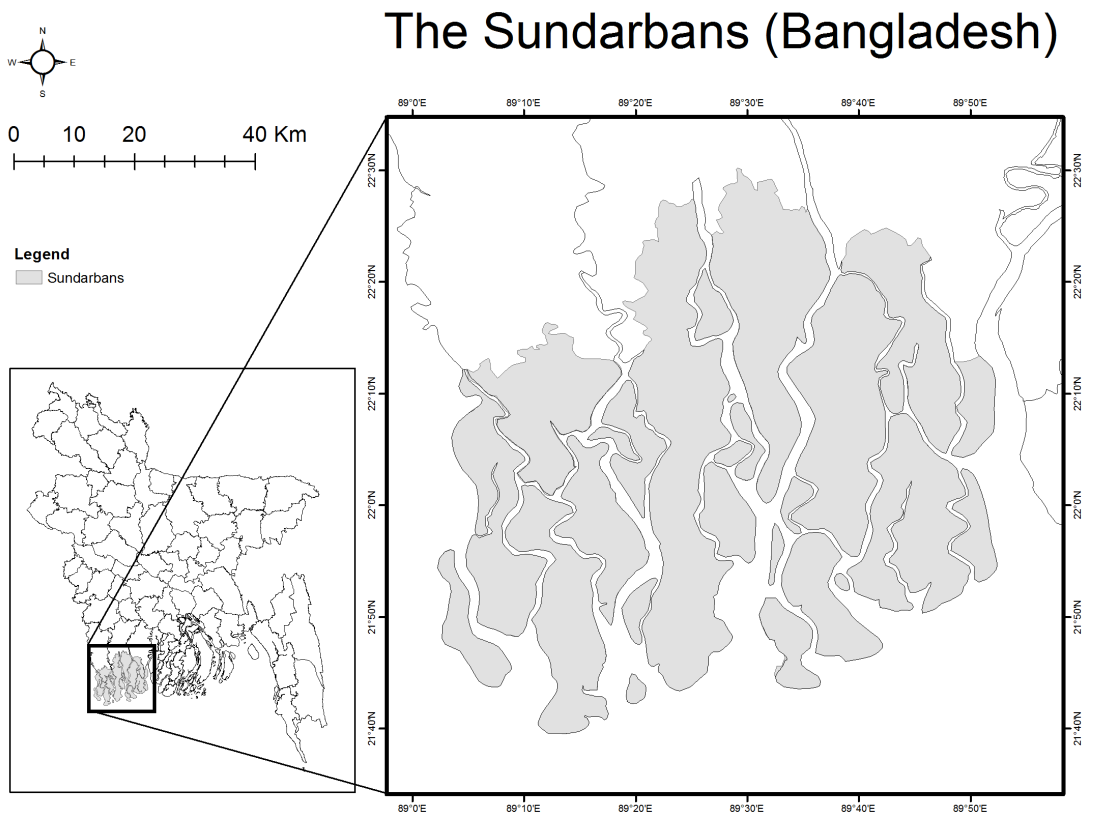

Figure 1. Location map of the study area.

The felled individuals were separated into leaves, smaller branches (diameter <2 cm), bigger branches (diameter > 2 cm) and stems; and all these parts of an individual were weighted (fresh mass) separately in the field and recorded. Ten stem sections of 50 cm in length were collected from the base, middle and upper portion of the stem. These stem sections were then debarked in the field to get fresh mass ratio of bark and stem wood. Five disks (2 cm thick) of stems and bigger branches (for trees) and 10 sub-samples (about 100 g) of each part such as leaves, smaller branches and bark were taken randomly from the sampled plant and brought back to the laboratory. These samples were oven-dried at 80˚C for 10 days to get of fresh mass to oven-dry mass conversion ratio. The oven-dried mass of different parts of individual *A. corniculatum* was calculated from the derived conversion ratio and fresh mass of the corresponding plant part (Mahmood et al., 2004, 2012, 2015).

2.3. Nutrients and Carbon in Plant Part

Ten sub-samples (about 100 g) of each plant part were collected randomly from the selected individual and oven-dried at 80˚C until constant weight for 10 days, crushed and sieved through 2 mm mesh. Kjeldahl digestion for Nitrogen and tri-acid (H_2SO_4, $HClO_4$ and HNO_3) digestion for Phosphorus and Potassium were applied to get the sample extract (Allen, 1989). Nitrogen and Phosphorus in the sample extract were measured calorimetrically according to Baethgen and Alley (1989) and Timothy et al. (1984) respectively using UV-visible Recording Spectrophotometer (HITACHI, U-2910, Japan). Potassium concentration in the sample extract was measured by Flame Photometer (PFP7, Jenway LTD, England). Organic carbon concentration in samples was determined by ignition method (Allen, 1989). Nutrients and carbon concentration in plant parts were compared by one-way analysis of variance (ANOVA) followed by Duncan Multiple Range Test by using SAS (6.12) statistical software. The amount of nutrients and carbon stock in each part of individual tree were estimated from their concentration and the oven-dried biomass of respective plant parts.

2.4. Allometric Models

A total of 8 linear models (y = aX + b, $\sqrt{y} = a\sqrt{X} + b$, y = aLogX + b, Logy = aX + b, Logy = aLogX + b, y =

Table 1. Sampled stems along with their Diameter at Breast Height (DBH), Total Height (TH) and oven-dried biomass of plant parts.

DBH (cm)	Total Height (m)	Oven-dried biomass (Kg) of plant part				Total above-ground Biomass (kg)
		Leaf	Branch	Bark	Stem without bark	
1.10	2.20	0.05	0.12	0.02	0.16	0.35
1.70	1.87	0.06	0.07	0.04	0.28	0.45
1.80	2.37	0.09	0.13	0.05	0.33	0.60
2.00	2.35	0.11	0.15	0.07	0.43	0.74
2.10	2.24	0.12	0.24	0.08	0.50	0.93
2.20	2.77	0.20	0.20	0.10	0.63	1.13
2.40	2.38	0.15	0.18	0.08	0.54	0.95
2.50	3.00	0.20	0.21	0.13	0.85	1.38
3.00	2.70	0.28	0.44	0.18	1.14	2.04
3.10	3.46	0.32	0.41	0.17	1.10	2.00
3.30	2.08	0.42	0.63	0.16	1.01	2.22
3.40	3.05	0.17	0.23	0.16	1.04	1.60
3.60	3.28	0.31	0.61	0.22	1.39	2.52
3.80	3.10	0.20	0.38	0.21	1.37	2.16
4.11	3.34	0.43	0.58	0.27	1.77	3.06
4.30	3.85	0.33	0.35	0.25	1.59	2.52
5.30	4.27	0.72	1.53	0.46	2.99	5.70
6.20	4.93	0.70	1.21	0.78	5.03	7.73
6.30	4.91	0.64	1.84	0.83	5.33	8.64
6.50	4.70	0.47	2.59	0.91	5.86	9.83
7.00	4.40	0.72	1.58	0.91	5.83	9.04
7.30	5.42	0.55	2.91	1.08	6.93	11.46
7.50	4.80	0.93	4.13	1.17	7.56	13.79
8.10	6.00	0.64	2.94	1.47	9.44	14.49
10.40	5.50	1.65	7.24	1.68	10.82	21.40
10.70	6.22	1.87	6.90	2.57	16.55	27.89
10.80	6.46	2.00	8.61	2.63	16.91	30.15
12.50	5.46	2.10	10.39	3.23	20.79	36.50
15.00	6.65	2.03	16.43	3.74	24.06	46.25

alnX + b, Lny = aX + b and Lny = alnX + b) with 64 regression equations were tested to derive the allometric model for biomass of each plant part; and nutrients and carbon stock in total above ground biomass (Mahmood et al., 2015). Significance test of regression equations were tested by using SAS (6.12) statistical software. The best fit regression equations were selected considering the highest R^2 and F-value, with the lowest value of CV, R_{mse}, MS_{error}, S_a, S_b, AICc, CF and Furnival Index and readily measureable independent variables (Furnival 1961; Chave et al., 2005; Soares et al., 2005; Siddique et al., 2012; Mahmood et al., 2015) where R^2 = Coefficient of determination; CV = Coefficient of variation, R_{mse} = Root mean square error; MS_{error} = Mean square error; S_a = Standard error of intercept "a"; S_b = Standard error of regression coefficient "b", CF = Correction Factor (to solve the deformation during calculation back to the original value from $\log_{10}$ and ln transformed value) and

AICc = Akaike's information criterion corrected.

3. Results

The mean biomass proportion of different parts of *A. corniculatum* was varied with DBH classes. Comparatively higher proportion of leaf (13.96%) was observed at the lowest DBH class of 1 to 4 cm while higher proportion of branch biomass (30.22%) was observed for the higher DBH class (10 cm and above). The higher proportion of bark and stem biomass were observed at DBH class of 4 to 7 cm (**Table 2**). Nutrients (N, P and K) and carbon concentration in plant parts varied significantly ($p < 0.05$). Comparatively highest concentration of nitrogen (6.40 mg/g) and phosphorus (1.04 mg/g) were observed in leaf while highest concentration of potassium was observed in both leaf (6.50 mg/g) and bark (6.50 mg/g). Higher concentration (48.59%) of carbon was observed in stem followed by bigger branches (48.22%) (**Table 3**).

Most of the regression equations were significant ($p < 0.05$), but 209 equations were excluded considering the value of co-efficient of determination (R^2) less than 0.93 for leaves, 0.98 for branch, 0.99 for bark, stem without bark and total above-ground biomass. The selected allometric models were Log biomass = $0.76\text{LogDBH}^2 - 1.39$; Biomass = $0.07\text{DBH}^2 - 0.49$; Log biomass = $1.04\text{LogDBH}^2 - 1.80$; Log biomass = $1.04\text{LogDBH}^2 - 0.99$; $\sqrt{\text{Biomass}} = 0.48\text{DBH} - 0.13$ for leaves, branches, bark, stem without bark and total above-ground biomass respectively (**Table 4**). Irrespectively, allometric models for nutrients (N, P and K) and carbon stock in the above-ground biomass were also selected by considering the same principle as followed for the biomass equations. The selected allometric models for Nitrogen, Phosphorous, Potassium and Carbon were $\sqrt{\text{Nitrogen}} = 0.67\text{DBH} + 0.11$; $\sqrt{\text{Phosphorus}} = 0.94\text{DBH} + 0.08$; $\sqrt{\text{Potassium}} = 1.06\text{DBH} - 0.18$; $\sqrt{\text{Carbon}} = 0.33\text{DBH} - 0.09$ (**Table 5**).

4. Discussion

The architecture, morphological characteristics and adaptation ability of mangrove plants varies with species (Hutchings & Saenger, 1987) and stages (seedlings, saplings and trees) which may affect the pattern of biomass allocation in their parts (Mahmood et al., 2004). Stand structure, regional climate, environmental conditions, geographical location, management intervention, along with other abiotic factors may also influence the biomass allocation in plant parts of an individual species (Saenger & Snedaker, 1993; Steinke et al., 1995; Tam et al., 1995; Clough et al., 1997; Mahmood et al., 2004; Peichl & Arain, 2007). Similar to the present study, higher proportion of leaf biomass was observed at lower DBH classes and higher proportion of branch biomass was

Table 2. Biomass proportions in plant parts of *Aegiceras corniculatum* according to DBH classes.

DBH class (cm)	Biomass proportion (%)			
	Leaf	Branch	Bark	Stem without bark
1 to 4	13.96 ± 0.69	21.10 ± 1.52	8.73 ± 0.25	56.21 ± 1.59
4 to 7	9.83 ± 1.30	20.11 ± 1.90	9.42 ± 0.26	60.64 ± 1.69
7 to 10	5.32 ± 0.72	25.20 ± 2.78	9.34 ± 0.46	60.14 ± 2.99
10 to above	6.24 ± 0.56	30.22 ± 1.97	8.54 ± 0.25	55.00 ± 1.62

Table 3. Nutrients and carbon concentration in different parts of *Aegiceras corniculatum* (Similar alphabet along the column are not significant ($p > 0.05$) different).

Plant Parts	Nitrogen (mg/g)	Phosphorus (mg/g)	Potassum (mg/g)	Carbon (%)
Leaf	6.40 ± 0.08^A	1.04 ± 0.01^A	6.50 ± 0.07^A	45.97 ± 0.06^C
Smaller Branch	3.29 ± 0.10^B	0.82 ± 0.01^B	6.05 ± 0.07^A	47.59 ± 0.20^B
Bigger Branch	1.52 ± 0.08^C	0.41 ± 0.02^C	4.69 ± 0.08^C	48.22 ± 0.03^A
Bark	1.97 ± 0.05^C	0.31 ± 0.01^D	6.50 ± 0.14^B	43.10 ± 0.11^D
Stem without bark	1.60 ± 0.08^C	0.26 ± 0.01^D	4.26 ± 0.07^D	48.59 ± 0.17^A

Table 4. Best fit models for plant parts and total above-ground biomass (kg) of *Aegiceras corniculatum.*

Plant part	Equation	R^2	a	b	Sa	S_b	CV	R_{mse}	MS_{error}	F value	AICc	FI	CF
Leaf	Logbiomass = aLogDBH + b	0.93	1.52	−1.39	0.08	0.06	−29.76	0.12	0.02	366.97	−116.548	0.054	1.042
	*Logbiomass = aLogDBH^2 + b	0.93	0.76	−1.39	0.04	0.06	−29.76	0.12	0.02	366.97	−116.548	0.054	1.042
	lnbiomass = alnDBH + b	0.93	1.52	−3.21	0.08	0.13	−29.76	0.29	0.08	366.97	−67.8263	0.108	1.042
	lnbiomass = alnDBH^2 + b	0.93	0.76	−3.21	0.04	0.13	−29.76	0.29	0.08	366.97	−67.8263	0.108	1.042
Branch	*Biomass = aDBH^2 + b	0.98	0.07	−0.49	.002	0.14	23.02	0.58	0.34	1214.88	−26.588	0.583	
	Biomass = aDBH^2 × TH + b	0.98	0.01	−0.03	0.0002	0.12	21.46	0.54	0.29	1402.70	−27.9736	0.539	
Bark	Logbiomass = aLogDBH + b	0.99	2.08	−1.80	0.04	0.03	−14.46	0.07	0.004	2394.68	−152.179	0.022	1.012
	*Logbiomass = aLog DBH^2 + b	0.99	1.04	−1.80	0.02	0.03	−14.46	0.07	0.004	2394.68	−152.179	0.022	1.012
	Logbiomass = aLogDBH × TH+ b	0.99	1.35	−2.08	0.03	0.04	−14.70	0.07	0.005	2316.43	−149.473	0.024	1.012
	Logbiomass = aLogDBH^2 × TH+ b	0.99	0.82	−1.98	0.01	0.03	−12.18	0.06	0.003	3385.37	−161.231	0.019	1.008
	Logbiomass = aLogDBH^2 × TH^2 + b	0.99	0.67	−2.08	0.01	0.04	−14.70	0.07	0.005	2316.43	−149.473	0.024	1.012
	lnbiomass = aln DBH + b	0.99	2.08	−4.15	0.04	0.07	−14.46	0.15	0.02	2394.68	−104.091	0.049	1.012
	lnbiomass = aln DBH^2 + b	0.99	1.04	−4.15	0.02	0.07	−14.46	0.15	0.02	2394.68	−104.091	0.049	1.012
	lnbiomass = alnDBH × TH + b	0.99	1.35	−4.80	0.03	0.08	−14.70	0.16	0.02	2316.43	−100.035	0.049	1.012
	lnbiomass = alnDBH^2 × TH + b	0.99	0.82	−4.55	0.01	0.06	−12.18	0.13	0.02	3385.37	−111.142	0.049	1.008
	lnbiomass = alnDBH^2 × TH^2 + b	0.99	0.67	−4.80	0.01	0.28	−14.70	0.16	0.02	2316.43	−100.035	0.049	1.012
Stem	Logbiomass = aLogDBH + b	0.99	2.08	−0.99	0.04	0.03	19.09	0.07	0.004	2394.68	−152.179	0.141	1.012
	*Logbiomass = aLogDBH^2 + b	0.99	1.04	−0.99	0.02	0.03	19.09	0.07	0.004	2394.68	−152.179	0.141	1.012
	Logbiomass = aLogDBH × TH+ b	0.99	1.35	−1.27	0.03	0.04	19.41	0.07	0.005	2316.43	−149.473	0.157	1.012
	Logbiomass = aLogDBH^2 × TH+ b	0.99	0.82	−1.17	0.01	0.03	16.08	0.06	0.003	3385.37	−161.231	0.122	1.008
	Logbiomass = aLogDBH^2 × TH^2 + b	0.99	0.67	−1.27	0.01	0.04	19.41	0.07	0.005	2316.43	−149.473	0.157	1.012
	lnbiomass = alnDBH + b	0.99	2.08	−2.28	0.04	0.07	19.09	0.15	0.02	2394.68	−104.091	0.314	1.012
	lnbiomass = alnDBH^2 + b	0.99	1.04	−2.28	0.02	0.07	19.05	0.15	0.02	2394.68	−104.091	0.314	1.012
	lnbiomass = alnDBH × TH + b	0.99	1.35	−2.93	0.03	0.08	19.41	0.16	0.02	2316.43	−100.035	0.314	1.012
	lnbiomass = alnDBH^2 × TH + b	0.99	0.82	−2.69	0.01	0.06	16.08	0.13	0.02	3385.37	−111.142	0.314	1.008
	lnbiomass = alnDBH^2 × TH^2 + b	0.99	0.67	−2.93	0.01	0.08	19.41	0.16	0.02	2316.43	−100.035	0.314	1.012
Total above-ground-biomass	Biomass = aDBH^2 + b	0.99	0.22	−0.20	0.01	0.35	15.99	1.48	2.18	1844.98	27.4388	1.476	
	* $\sqrt{\text{Biomass}}$ = a DBH + b	0.99	0.48	−0.13	0.01	0.06	7.27	0.18	0.03	2591.57	−94.0711	0.684	
	$\sqrt{\text{Biomass}}$ = aDBH × $\sqrt{\text{TH}}$ + b	0.99	0.18	0.38	0.004	0.06	7.77	0.19	0.04	2266.72	−87.4106	0.790	
	Logbiomass = aLogDBH^2 × TH + b	0.99	0.81	−0.90	0.02	0.04	12.62	0.07	0.01	1855.10	−143.001	0.385	1.015
	lnbiomass = alnDBH^2 × TH + b	0.99	0.81	−2.08	0.02	0.09	12.62	0.17	0.03	1855.10	−94.4561	0.666	1.015

Note: R^2 = coefficient of determination; S_a = standard error of intercept "a"; S_b = standard error of regression coefficient "b", CV = Coefficient of variation, R_{mse} = Root mean square error; MS_{error} = Mean square error, AICc = Akaike's information criterion corrected; FI = Furnival index; CF = Correction Factor; *Selected equations.

observed at higher DBH classes of *E. agallocha* in the Sundarbans (Mahmood et al., 2015), *B. parviflora* in Malaysia (Mahmood et al., 2004), *R. apicuata* and *R. stylosa* in north-eastern Australia (Clough, 1992).

The rate of nutrient uptake and its distributional patterns in plant parts (leaf, branch, bark and stem) varies with species, stages of plant growth and productive capacity of the site (Alongi et al., 2005; Mahmood, 2007; Krishtensen et al., 2008; Mahmood et al., 2008a). Structural component of plant cell (Kaakinen et al., 2004) physiological age of the tissue, position of the tissue in plant, available form of nutrients in the substrate, concentration of other nutrients, climatic and soil edaphic factors (Mahmood, 2004) may be responsible for the variation in nutrients and carbon concentration in plant parts. The trend of nitrogen, phosphorus and carbon concentration in plant parts of the studied species was similar to that of *E. agallocha* (Mahmood et al., 2015), *C. decandra* (Mahmood et al., 2012), *B. parviflora* (Mahmood et al., 2006), *Avicennia* spp., *Bruguiera* spp. and *Ceriops* spp. (Aksornkoae & Khemnark, 1984) and *R. apiculata* (Ong et al., 1984).

DBH and TH (Total height) are widely used independent variables for allometric equations to estimate above-ground biomass of mangrove species (Lee, 1990; Saintilan, 1997). But, allometric models with DBH as single independent variable might be more practical and user friendly in the field instead of using other independent variable like total height of a tree (Mahmood et al., 2015). The selection of best regression equation is the major concern in allometric modeling for biomass estimation (Grundy, 1995; Steinke et al., 1995; Tam et al., 1995; Mahmood et al., 2015). Therefore, present study recommended DBH as independent variable for allometric models considering the scope of application and different statistical test. In comparison with the present study, common allometric biomass model of Komiyama et al. (2005) and Chave et al. (2005) showed about 4% to 100% and 2% to 40% of over estimation in above-ground biomass respectively with the studied DBH range (1 to 15 cm) (**Figure 2**). Similarly, higher estimation (16% - 60%) of total above-ground biomass was also observed for *Excoecaria agallocha* of the Sundarbans by comparing that common allometric model of Komiyama et al. (2005)

Table 5. Best fit models for nutrients (N, P and K) and carbon stock in total above-ground biomass (kg) of *Aegiceras corniculatum.*

Equation	R^2	a	b	S_a	S_b	CV	R_{mse}	MS_{error}	F value	AICc	FI
$\sqrt{\text{Nitrogen}}$ = a DBH + b	0.99	0.67	0.11	0.02	0.10	8.10	0.31	0.09	1782.12	−63.7732	1.849
$\sqrt{\text{Phosphorus}}$ = a DBH + b	0.98	0.94	0.08	0.02	0.15	8.34	0.43	0.19	1731.83	−43.4436	3.688
$\sqrt{\text{Potassium}}$ = a DBH + b	0.99	1.06	−0.18	0.02	0.14	7.37	0.41	0.17	2434.85	−46.7529	3.657
$\sqrt{\text{Carbon}}$ = a DBH + b	0.99	0.33	−0.09	0.01	0.04	7.28	0.13	0.02	2598.32	−115.167	0.385

Note: R^2 = coefficient of determination; S_a = standard error of intercept "a"; S_b = standard error of regression coefficient "b", CV= Coefficient of variation, R_{mse} = Root mean square error; MS_{error} =Mean square error, AICc = Akaike's information criterion corrected; FI = Furnival index; CF = Correction Factor; *Selected equations.

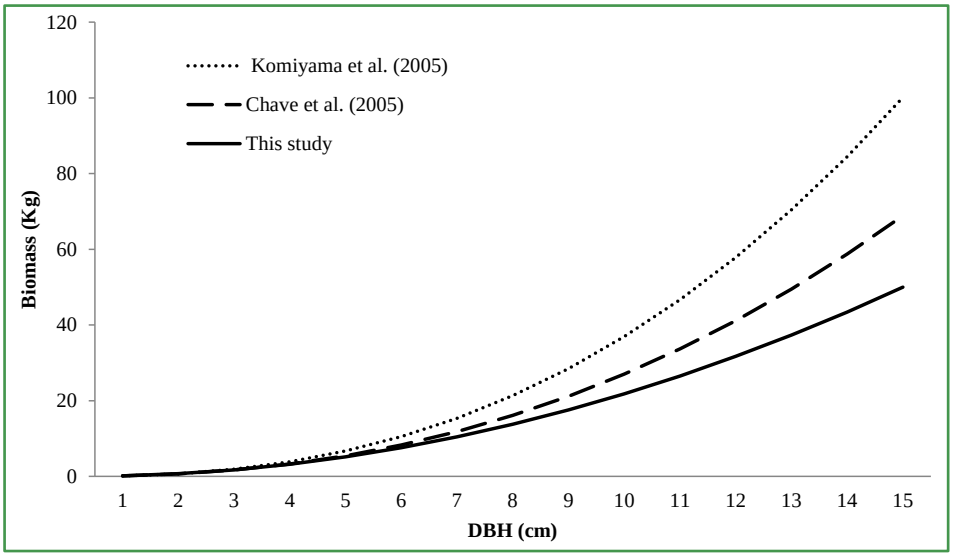

Figure 2. Comparison of estimated total above-ground biomass of *Aegiceras corniculatum.*

(Mahmood et al., 2015). So, the applicability of the common allometric models may not be suitable for biomass estimation of different mangrove species of the Sundarbans. This variation in biomass estimation implies that allometric models should be site and species specific (Ketterings et al., 2001; Chave et al., 2005; Soares & Schaeffer-Novelli, 2005; Mahmood et al., 2004; Kairo et al., 2009; Mahmood et al., 2015).

5. Conclusion

The derived models are simple, more practical and user-friendly by using DBH as independent variable. These allometric models for *A. corniculatum* of the Sundarbans will be helpful in estimating biomass, nutrient and carbon stock which may contribute in broader study on nutrient cycling, nutrient budgeting and carbon sequestration and finally can contribute in planning for utilization and management of this species in the Sundarbans.

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