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Research Article

Modeling Develops to Estimate Leaf Area and Leaf Biomass of *Lagerstroemia speciosa* in West Vanugach Reserve Forest of Bangladesh

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Leaf area and leaf biomass have an important influence on the exchange of energy, light interception, carbon cycling, plant growth, and forest productivity. This study showed development and comparison of models for predicting leaf area and leaf biomass of *Lagerstroemia speciosa* on the basis of diameter at breast height and tree height as predictors. Data on tree parameters were collected randomly from 312 healthy, well-formed tree species that were considered specifically for full tree crowns. Twenty-four different forms of linear and power models were compared in this study to select the best model. Two models (M_{10} and M_{22}) for the estimation of leaf area and leaf biomass were selected based on R^2, adjusted R^2, root mean squared error, corrected akaike information criterion, Bayesian information criterion and Furnival's index, and the three assumptions of linear regression. The models were validated with a test data set having the same range of DBH and tree height of the sampled data set on the basis of linear regression Morisita's similarity index. So, the robustness of the models suggests their further application for leaf area and biomass estimation of *L. speciosa* in West Vanugach reserve forest of Bangladesh.

1. Introduction

Leaf area (A_1) and leaf biomass (B_1) estimation are significant basics of studying gas-exchange processes and modeling ecosystems. It is key traits in ecophysiological studies that determine assessing photosynthetic efficiency, evapotranspiration, atmospheric deposition, biogenic volatile organic emissions, light interception, and other ecosystem processes. Leaf area is valuable for the evaluation and understanding of individual tree growth models [1], biogeochemical models [2], and gap models [3]. It is defined as the one-sided projected surface area which is an important consequence for the interception of radiant energy, the absorption of carbon dioxide, and the circulation of water between the foliage and the atmosphere [4]. Leaf biomass constitutes one of the most important pools of essential nutrients, which is vital for forest nutrient cycling [5], including carbon cycling in a forest ecosystem. Leaf biomass estimates were considerably improved when additional biometric information relating to crown structure was added, whereas canopy B_1 is the product of leaf dry matter content and leaf area index [6]. Interspecific variation in A_1 and B_1 has been connected with climatic variation, geology, altitude, or latitude, where heat stress, cold stress, drought stress, and high-radiation stress all tend to select relatively small leaves. Within climatic zones, leaf-size variation can also be linked to allometric factors (plant size, twig size, anatomy, and architecture) and ecological strategy [7].

Measurement of the destructive (direct) method of A_1 and B_1 is very time consuming, labour intensive, and ecounfriendly and depends on very small samples. But, nondestructive (indirect) methods were found user friendly and less expensive and can give accurate A_1 and B_1 estimates [8, 9]. To quantify the A_1 and B_1 of individual trees, the relationship between A_1 and B_1 with DBH (diameter at breast height) and height are widely used [10]. This relationship differs between tree species and to some degree also within a tree species [11, 12] and needs to be established for each species in question. For the development of models, the power function ($y = ax^b$) form is widely used in biological sciences particularly

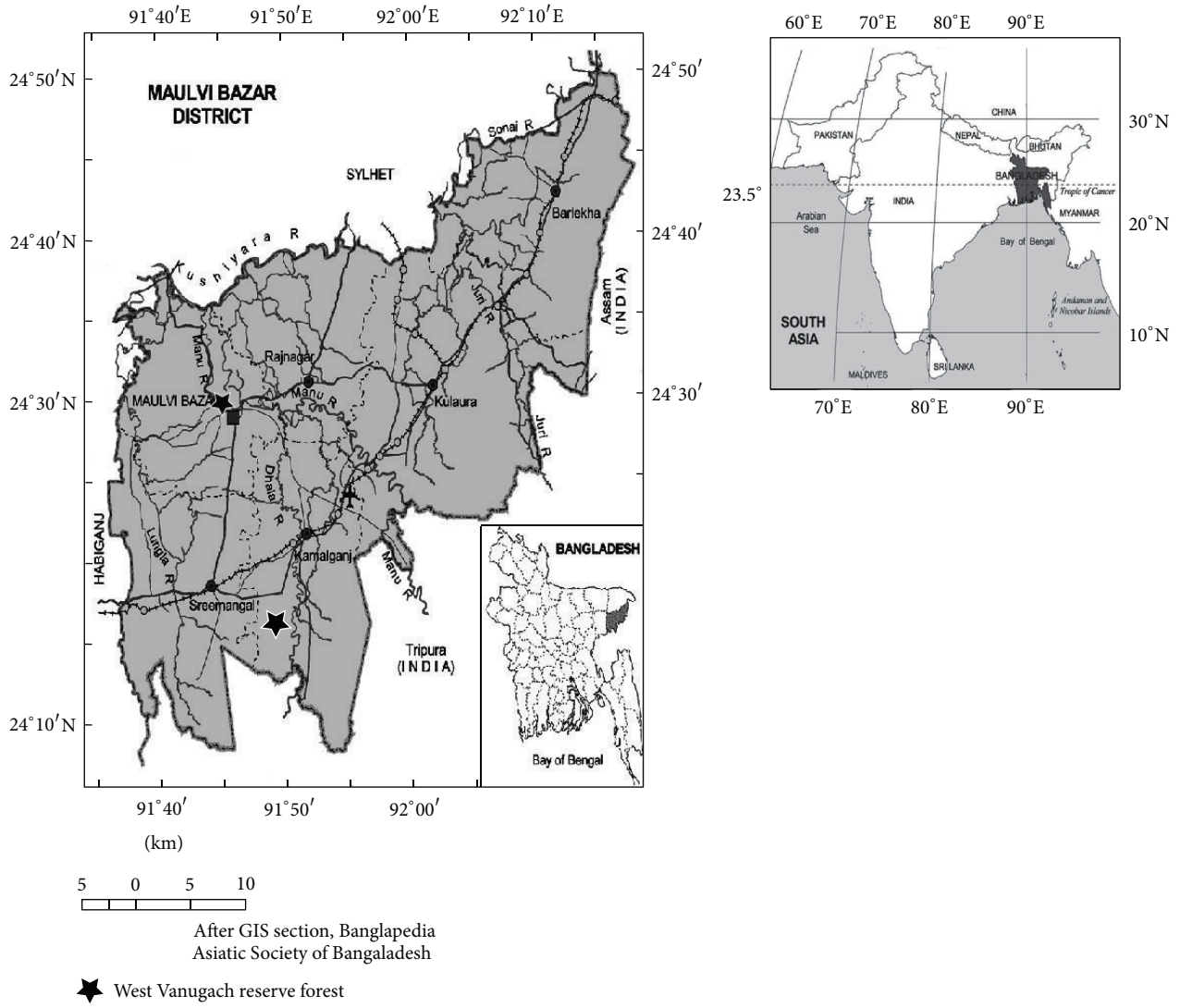


Figure 1: Study site in West Vanugach reserve forest of Bangladesh.

for these relationships [13]. But, in practice, the default nonlinear technique assumes homogeneity of errors that cannot be safely assumed with most model data. At present, models are developed by fitting a linear relationship between log-transformed diameter and leaf data. Although the log-transformed linear equation is mathematically equivalent to the power equation, they are not identical in the statistical sense [14]. However, many model characteristics of organisms are multiplicative by nature and thus fitting models to log-transformed data is perfectly acceptable because accounting for proportional rather than absolute variation is most important [15].

Lagerstroemia speciosa (L.) is the dominant tree both spatially and vertically in the forests of Bangladesh. It is well distributed in natural forests as well as in plantation forests [16]. It is also found at low to medium altitudes in comparatively open habitats, in disturbed or secondary forest and grassland. The habitat may vary from well drained to occasionally flooded but not peat soil and it is resistant to fire. *L. speciosa* is the most important wood species in parts of South and Southeast Asia [16], but to estimate A_1 and B_1 relationships of this species is not available. So, the main goal of my study was to develop and compare models of *L. speciosa* that will help to estimate $A_1$and $B_1$of the species in reserve forest of Bangladesh.

2. Materials and Methods

2.1. Site Description. The field work was conducted at the West Bhanugach Reserved Forest (2,740 ha) on the Moulvibazar Forest Range (24°19′11″ N, 91°47′1″ E, altitude of 45 m) in tropical semievergreen forest, Bangladesh (Figure 1). The soil of this forest is alluvial brown sandy clay loam to clay loam. Average annual rainfall is 4,332 mm and January is the coldest month (minimum temperature around 11°C), while May and October are the hottest months (average maximum temperature around 33°C). The relative humidity is about 75% during December and over 92% during July-August [17].

This forest stand is a mixed forest stand and its vegetation is recognized as old growth plantation forest. It includes 78 species of trees, 14 species of shrubs, 42 species of herbs, and 25 species of climbers [18].

2.2. Species Description. Lagerstroemia speciosa (L.) is a medium-sized tree growing to 20 meters tall, much branched deciduous tree, with smooth and flaky bark [16]. Its leaves are opposite, elliptic, or oblong-lanceolate, 8.5–20.0 cm long and 3.0–7.5 cm broad, acuminate at the apex, acute to rounded at the base, and glabrous and finely reticulate on both surfaces, have lateral nerves 8–12 on either half, prominent beneath, and petioles 5–9 mm long, and are stout. Its wood is strong and fairly durable and is used for carts, furniture, and house posts. The root is considered as an astringent, stimulant, and febrifuge and due to the tree's dense and wide spreading root system, it is used in erosion control. Its extracts have been used as traditional medicines and are effective in controlling diabetes and obesity. A leaf poultice is used to relief malarial fever and is applied on cracked feet. It is planted in forests, edges of forest streams, swamps, ditches, and river banks. It is growing in South East Asia, Bangladesh, India, and Philippines and it is also widely cultivated as an ornamental plant in tropical and subtropical areas [19].

2.3. Field Measurements. Leaf, DBH, and tree height data were collected for three hundred twelve sampled healthy well-formed *L. speciosa* tree species with full crown by maintaining the protocols for standardized and easy measurement of plant functional traits worldwide developed by Cornelissen et al. 2003. Field sampling occurred in the rainy season during which A_1 and B_1 were maximum. Diameter at breast height (DBH; at 1.3 m height from ground level) and tree height (H) was measured with Suunto clinometers (Suunto PM5-360, Vantaa, Finland) and tree calipers (Haglöf Graduated Aluminum Tree Caliper, Ben Meadows, Janesville, Wisconsin, USA). Data on tree parameters are usually measured and collected after harvesting for improving data accuracy [6, 20]. Though using nondestructive methods is a highly reliable option [21] where whole tree removal is not possible, as is the case in Bangladeshi reserve forests [22], leaf data were collected manually (by climbing the tree). To retain high data accuracy, stratified random sampling was used for calculation of the leaf number per individual tree. Thereafter, the following steps were performed to count the leaves of each sampled tree: (I) the diameter of all of the main branches was measured; (II) the diameter of the main branch closest to the mean diameter was selected as the model main branch (MMB); (III) subbranches of all main branches were counted; (IV) three subbranches were selected randomly from the MMB; (V) twigs of each subbranch were counted and the mean twig number per subbranch was calculated; (VI) three twigs were selected randomly from each selected subbranch; (VII) the average number of leaves per twig was calculated; (VIII) the leaf number per subbranch was calculated by multiplying the mean twig number per subbranch and mean leaf number per twig; and (IX) the total leaf number per tree was calculated by multiplying the total number of subbranches and estimated leaf number per subbranch [9]. The leaves were categorized into small, medium, and large size and fifteen leaves of each category were collected according to different directions and heights of a tree. A total of forty-five samples of leaves were taken from each sampled tree and packed in a plastic bag. The leaf area of each leaf sample was measured with a leaf area meter (CI-202, CID, Inc., Vancouver, Washington, USA) for small and medium leaves and Adobe Photoshop CS5 software for large leaves. Data of DBH, height, leaf samples, and total leaf number per tree from additional 40 trees were collected and used as a test data set for validating the models. The projected leaf area for each sample tree (A_1, m^2) was calculated by multiplying the average leaf area and total leaf number. Thickness of each sample leaf was estimated with digital caliper (Absolute Digimatic CD-6″ CS, Mitutoyo Corporation, Kanagawa, Japan) and the fresh mass of each leaf was measured with a balance meter. Measured leaves were oven-dried at 65°C for 72 h and weighed to determine fresh mass: dry mass ratios. Total leaf volume per tree was estimated by multiplying total leaf area and leaf thickness. Leaf density was calculated by dividing by the average leaf fresh mass and the leaf volume of forty-five sample leaf in a tree. Total leaf biomass (B_1, kg) per tree was estimated by multiplying the total leaf volume and leaf density.

2.4. Statistical Analysis. Regression analysis was used to evaluate the appropriateness of each of the two independent variables (x): height (m) and DBH (cm), as estimators of total A_1 and B_1 (dependent variables = y) for *L. speciosa* by using R statistical software version 2.15.2 and SPSS 17 software (SPSS, ver. 17, Chicago, IL, USA). The data with two regression models (linear and power) was analyzed. At first, scatter plots were used to see whether the relationship between independent and dependent variables was linear. Secondly, given the presence of heteroscedasticity, power models transformed the data for linear regression using natural logarithmic. A total of twenty-four models were developed using DBH and height for the best model selection (Table 2). The performance of the developed models was evaluated by examining the goodness of fit (R^2 and adjusted R^2), root mean squared error (RMSE), corrected akaike information criterion (AICc), Bayesian information criterion (BIC), and Furnival's index (FI). Thus, to select between models, the corrected akaike information criterion (AICc) for each model was then computed as

$$\mathrm{AICc} = 2k - 2\ln(L) + \frac{2k(k+1)}{n-k-1}, \quad (1)$$

where n is the sample size, k is the number of parameters in the statistical model, and L is the corresponding likelihood [23]. The formula for the BIC (Bayesian information criterion) is

$$\mathrm{BIC} = n \cdot \ln\left(\widehat{\sigma_e^2}\right) + k \cdot \ln(n), \quad (2)$$

where $\widehat{\sigma_e^2}$ is the error variance [23]. For models with different dependent variables using R^2 to compare them could sometimes produce false results [24]. So, Furnival's index

[25] which is able to compare models of different dependent variables or weights was used to compare the logarithmic and nonlogarithmic models. The index is calculated as follows:

$$\mathrm{FI} = \frac{1}{[f'(Y)]}\sqrt{\mathrm{MSE}}, \quad (3)$$

where $f'(Y)$ is the derivative of the dependent variable with respect to A_1 and B_1, MSE is the mean square error of the fitted model, and the square bracket ([]) is the geometric mean. After that, the three regression assumptions were used to judge the consistency of the models for the residues: (I) no outlier, (II) the distribution of these residuals should be normal with mean = 0 and a constant variance and (III) the data points must be independent [26]. The Durbin-Watson test was used to check for autocorrelation. Though logarithmic transformation is reported to increase the statistical validity of regression analysis by homogenising variance, it introduces a slight downward bias when data are back-transformed to arithmetic units [27]. To account for the bias, the back-transformed results from logarithmic unit are usually multiplied by a correction factor. Consequently, a correction factor (CF) was calculated for all logarithmic models. The CF is given by the following [28]:

$$\mathrm{CF} = \exp^{((\mathrm{SEE}*2.303)^2/2)}, \quad (4)$$

where SEE is the standard error of the estimate.

For validation of the models, the observed A_1 and B_1 data regressed from a test data set ($n = 40$) against the predicted A_1 and B_1 using linear regression. As a measure of distance between observed and predicted values, Morisita's [29] dissimilarity index (D_M) was calculated as follows:

$$D_M = \frac{(1/n)\sum_{i=1}^{n}\left(y_i - y_i^p\right)^2}{(1/n)\left(\sum_{i=1}^{n} y_1^2 + \left(\sum_{i=1}^{n} y_i^p\right)^2\right)}, \quad (5)$$

where y_i = observed A_1 and B_1 of the sampled data and y_i^p = predicted A_1 and B_1. Note that 1-D_M is essentially Morisita's measure of niche overlap or similarity [30].

Table 1: General characteristics of *L. speciosa* species.

Variables	Mean	SD	Range
DBH (cm)	27.6069	14.4302	7.52–65.16
Height (m)	12.4225	2.8879	3.27–19.01
Validation DBH (cm)	27.0027	12.9432	7.65–64.85
Validation height (m)	11.9863	2.6372	3.24–18.79
Individual leaf area (cm^2)	88.6291	9.3614	36.20–141.31
Individual dry leaf biomass (g)	0.8534	0.0526	0.35–1.26

Table 2: Twenty-four models used in this study.

Model number	Models
M_1	$A_1 = x_o + x_1\mathrm{DBH}$
M_2	$A_1 = x_o + x_1 H$
M_3	$A_1 = x_o + x_1(\mathrm{DBH} \times H)$
M_4	$A_1 = x_o + x_1\mathrm{DBH} + x_2 H$
M_5	$A_1 = x_o + x_1\mathrm{DBH} + x_2\mathrm{DBH}^2$
M_6	$A_1 = x_o + x_1 H + x_2 H^2$
M_7	$\ln(A_1) = x_o + x_1 \ln(\mathrm{DBH})$
M_8	$\ln(A_1) = x_o + x_1 \ln(H)$
M_9	$\ln(A_1) = x_o + x_1 \ln(\mathrm{DBH} \times H)$
M_{10}	$\ln(A_1) = x_o + x_1 \ln(\mathrm{DBH}) + x_2 \ln(H)$
M_{11}	$\ln(A_1) = x_o + x_1 \ln(\mathrm{DBH}) + x_2 \ln(\mathrm{DBH}^2)$
M_{12}	$\ln(A_1) = x_o + x_1 \ln(H) + x_2 \ln(H^2)$
M_{13}	$B_1 = x_o + x_1\mathrm{DBH}$
M_{14}	$B_1 = x_o + x_1 H$
M_{15}	$B_1 = x_o + x_1(\mathrm{DBH} \times H)$
M_{16}	$B_1 = x_o + x_1\mathrm{DBH} + x_2 H$
M_{17}	$B_1 = x_o + x_1\mathrm{DBH} + x_2\mathrm{DBH}^2$
M_{18}	$B_1 = x_o + x_1 H + x_2 H^2$
M_{19}	$\ln(B_1) = x_o + x_1 \ln(\mathrm{DBH})$
M_{20}	$\ln(B_1) = x_o + x_1 \ln(H)$
M_{21}	$\ln(B_1) = x_o + x_1 \ln(\mathrm{DBH} \times H)$
M_{22}	$\ln(B_1) = x_o + x_1 \ln(\mathrm{DBH}) + x_2 \ln(H)$
M_{23}	$\ln(B_1) = x_o + x_1 \ln(\mathrm{DBH}) + x_2 \ln(\mathrm{DBH}^2)$
M_{24}	$\ln(B_1) = x_o + x_1 \ln(H) + x_2 \ln(H^2)$

3. Results

3.1. Model Development. DBH and tree height of sampled individuals of *L. speciosa* ranged from 7.52 to 65.16 cm and 3.27 to 19.01 m, respectively, and the A_1 and B_1 of sampled trees ranged from 36.20 to 141.31 cm^2 and 0.35 to 1.26 g, respectively. In addition, the range of DBH and H data in the model test data set fell within the boundary of the sampled data set (Table 1). Table 3 summarizes the different models derived to predict A_1 and B_1 with DBH and H as the independent variable. For the development of the best model, 24 different model forms were determined (Table 2). Model M_{10} and M_{22} were found to be the best predictor for A_1 and B_1 estimation, respectively. Whereas the RMSE value was the lowest and the goodness of fit (R^2 and adjusted R^2) was highly significant and explained more than 96% variation for the selected models (M_{10} and M_{22}). To compare the models, the AICc and BIC values were calculated and the results are presented in Table 3. The AICc and BIC values for models M_{10} and M_{22} were lower than that of other tested models indicating statistical robustness of the selected models. Based on Furnival's index (FI) of fit, models M_{10} and M_{22} performed better in both A_1 and B_1 estimation, whereas the FI values for both models were lower (0.36 and 0.47, respectively) than that of other tested models.

To avoid any confusion, the three regression assumptions were checked to select the best model. A good model should conform to all valid statistical assumptions [26]. First assumption, residual analysis of models M_{10} and M_2, showed that the values of standard residual were 2.93 and 2.48, respectively. A model to be outlier free requires that the value of standard residual must be below 3 [26]. In both models this requirement was fulfilled. The normality of residuals was measured for selected models by histogram and normal

Table 3: Different models tested for the estimation of leaf area (A_1, m^2) and leaf biomass (B_1, kg) with diameter at breast height (DBH, cm) and tree height (H, m) of *L. speciosa* species.

Model	Estimated coefficients			F	RMSE	R^2	Adjusted R^2	FI	AICc	BIC	CF	Durbin Watson
	$x_o \pm$ SE	$x_1 \pm$ SE	$x_2 \pm$ SE									
M_1	2.36383 ± 2.76814	5.33557 ± 0.08891		3602	18.59	0.9452	0.9449	0.64	1836.22	1846.22	—	1.807
M_2	−132.85 ± 13.52	22.74 ± 1.06		460	44.36	0.6877	0.6862	3.21	2203.20	2213.21	—	0.753
M_3	32.165522 ± 1.982558	0.313651 ± 0.004419		5037	15.84	0.9602	0.9600	0.59	1768.75	1778.75	—	1.411
M_4	−44.6109 ± 5.1513	4.4608 ± 0.1128	5.7255 ± 0.5637	2733	15.24	0.9633	0.9630	0.52	1753.26	1766.59	—	1.736
M_5	−11.235989 ± 5.19719	6.465311 ± 0.378365	−0.018144 ± 0.005913	1878	18.23	0.9475	0.9470	0.74	1828.91	1842.23	—	1.767
M_6	−9.5289 ± 34.0715	0.2453 ± 5.8305	0.9602 ± 0.2450	253	42.91	0.7092	0.7064	2.95	2190.20	2203.53	—	0.813
M_7	1.57067 ± 0.05028	1.03390 ± 0.01563		4378	0.1301	0.9544	0.9542	0.53	−257.78	−247.77	1.0084	2.014
M_8	0.03719 ± 0.18967	1.93313 ± 0.07582		650	0.3006	0.7567	0.7555	2.62	95.66	105.67	1.0462	0.854
M_9	0.681579 ± 0.052864	0.736374 ± 0.009257		6328	0.1090	0.9680	0.9679	0.43	−332.53	−322.52	1.0059	1.520
M_{10}	0.93516 ± 0.06836	0.83960 ± 0.02101	0.50296 ± 0.04413	3604	0.1023	0.9720	0.9717	0.36	−358.13	−344.80	1.0052	2.003
M_{11}	1.57067 ± 0.05028	1.03390 ± 0.01563	−0.002271 ± 0.0062	4378	0.1301	0.9544	0.9542	0.68	−257.75	−247.77	1.0084	2.014
M_{12}	0.03719 ± 0.18967	1.93313 ± 0.07582	0.00373 ± 0.05283	650	0.3006	0.7567	0.7555	2.41	95.70	105.67	1.0462	0.854
M_{13}	0.389894 ± 0.240441	0.495224 ± 0.007723		4112	1.615	0.9516	0.9514	0.64	805.08	815.08	—	1.933
M_{14}	−11.0649 ± 1.3503	2.0227 ± 0.1059		364	4.431	0.6358	0.6341	3.33	1231.05	1241.06	—	0.875
M_{15}	3.3471251 ± 0.237553	0.0286013 ± 0.00052		2917	1.899	0.9332	0.9328	0.86	873.37	883.37	—	1.227
M_{16}	−2.23654 ± 0.50829	0.44631 ± 0.01113	0.32012 ± 0.05562	2389	1.503	0.9583	0.9579	0.59	775.93	789.26	—	1.914
M_{17}	−0.411165 ± 0.456914	0.5617675 ± 0.03326	−0.0010687 ± 0.00051	2090	1.603	0.9526	0.9521	0.62	802.87	816.19	—	1.934
M_{18}	−4.26959 ± 3.48979	0.78302 ± 0.59719	0.05291 ± 0.02509	187	4.395	0.6435	0.6400	3.51	1228.62	1241.95	—	0.903
M_{19}	−0.73397 ± 0.05330	1.01654 ± 0.01656		3766	0.1379	0.9474	0.9472	0.54	−233.16	−223.15	1.0095	1.626
M_{20}	−2.22910 ± 0.19082	1.89560 ± 0.07628		617	0.3025	0.7472	0.7459	2.69	98.21	108.21	1.0468	1.062
M_{21}	−1.6049 ± 0.0588	0.7234 ± 0.0103		4938	0.1212	0.9594	0.9592	0.56	−287.66	−277.65	1.0073	1.708
M_{22}	−1.34008 ± 0.07665	0.83123 ± 0.02357	0.47969 ± 0.04948	2768	0.1147	0.9638	0.9634	0.47	−309.79	−296.46	1.0066	1.971
M_{23}	−0.73397 ± 0.05330	1.01654 ± 0.01656	−0.00421 ± 0.00284	3766	0.1379	0.9474	0.9472	0.52	−233.13	−223.15	1.0095	1.626
M_{24}	−2.22910 ± 0.19082	1.89560 ± 0.07628	0.04858 ± 0.03842	617	0.3025	0.7472	0.7459	2.24	98.24	108.21	1.0468	1.062

RMSE: root mean squared error, FI: Furnival's index, AICc: corrected akaike information criterion, BIC: Bayesian information criterion, and CF: correction factor.

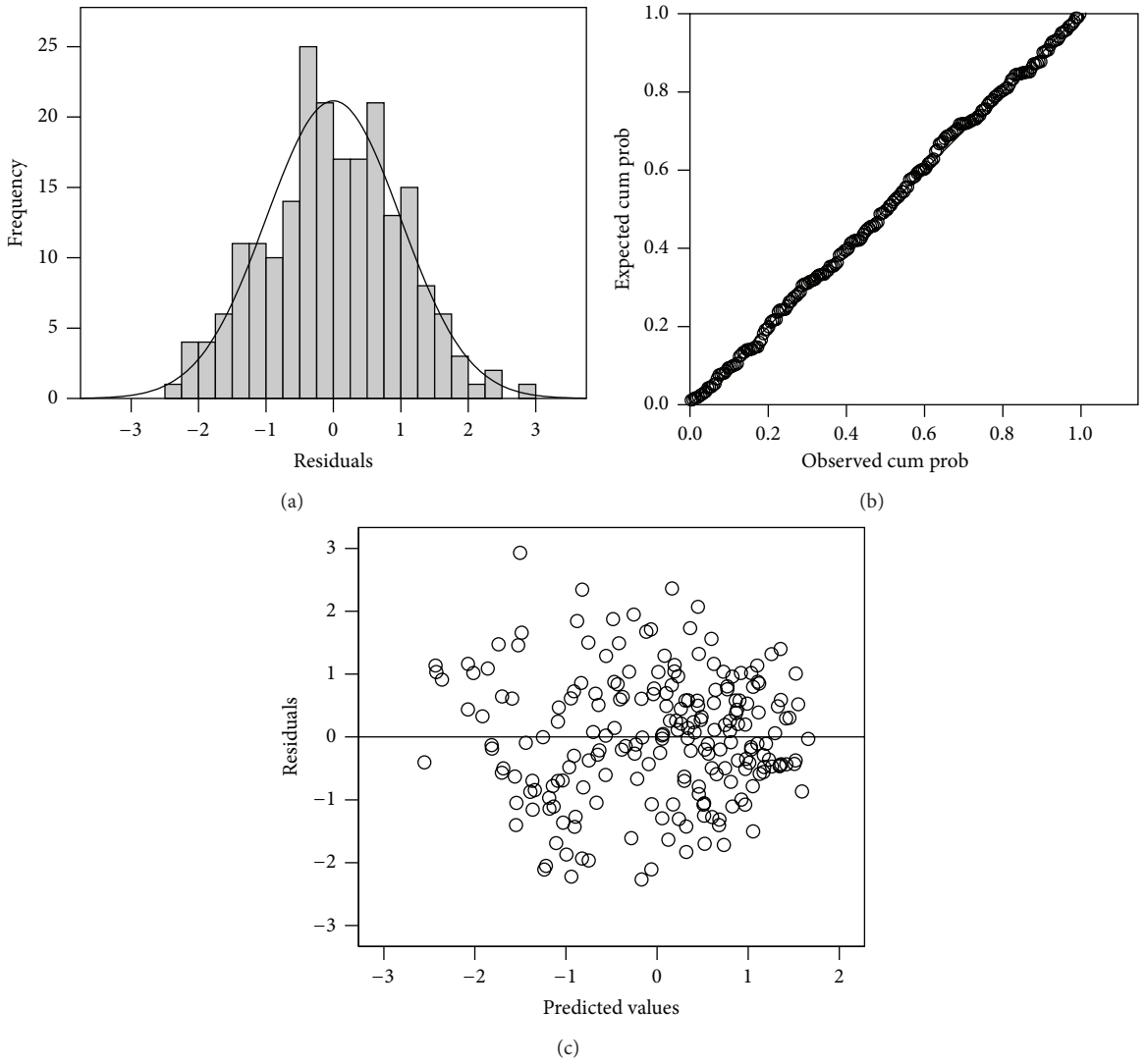


Figure 2: Residual distribution (a), normal P-P plot of regression standardized residuals (b), and scatter plot of residuals (c) for model M_{10}.

probability plot. The distribution of the residual satisfies the normality assumptions for both models M_{10} (Figures 2(a) and 2(b)) and M_{22} (Figures 3(a) and 3(b)). Second assumption, diagnosis for constant variance, was done by plotting the regression standardized residuals and predicted values in a scatter plot. It was shown that the scatter of the residual points was randomly distributed (Figures 2(c) and 3(c)). Thus it can be concluded that the variance was constant for both models. Third assumption, the Durbin-Watson statistic, lies in the range 0.0–4.0. A value of 2 or nearly 2 indicates that there is independence of the data points [31]. This range of the selected models was 2.003 for A_1 and 1.971 for B_1. Thus, the independence assumption was satisfied for both models. However, due to the systematic bias introduced by logarithmic transformation of data, correction factor is normally calculated for logarithmic transformed models so as to account for the bias. Correction factors showed a rather narrow variation for A_1 and B_1 (Table 3).

As a result, the final model of A_1 is

$$A_1 = \exp\left(0.93516 + 0.83960 \times \ln(\text{DBH}) + 0.50296 \times \ln(H)\right), \quad (6)$$

$$\text{or } A_1 = 2.547621 \times (\text{DBH})^{0.83960} \times (H)^{0.50296}.$$

The bias corrected model is $A_1 = 2.547621 \times (\text{DBH})^{0.83960} \times (H)^{0.50296} \times 1.005246 = 2.560986 \times (\text{DBH})^{0.83960} \times (H)^{0.50296}$.

The final model of B_1 is

$$B_1 = \exp\left(-1.34008 + 0.83123 \times \ln(\text{DBH}) + 0.47969 \times \ln(H)\right), \quad (7)$$

$$\text{or } B_1 = 0.261825 \times (\text{DBH})^{0.83123} \times (\text{H})^{0.47969}.$$

The bias corrected model is $B_1 = 0.261825 \times (\text{DBH})^{0.83123} \times (H)^{0.47969} \times 1.0066 = 0.263553 \times (\text{DBH})^{0.83123} \times (H)^{0.47969}$.

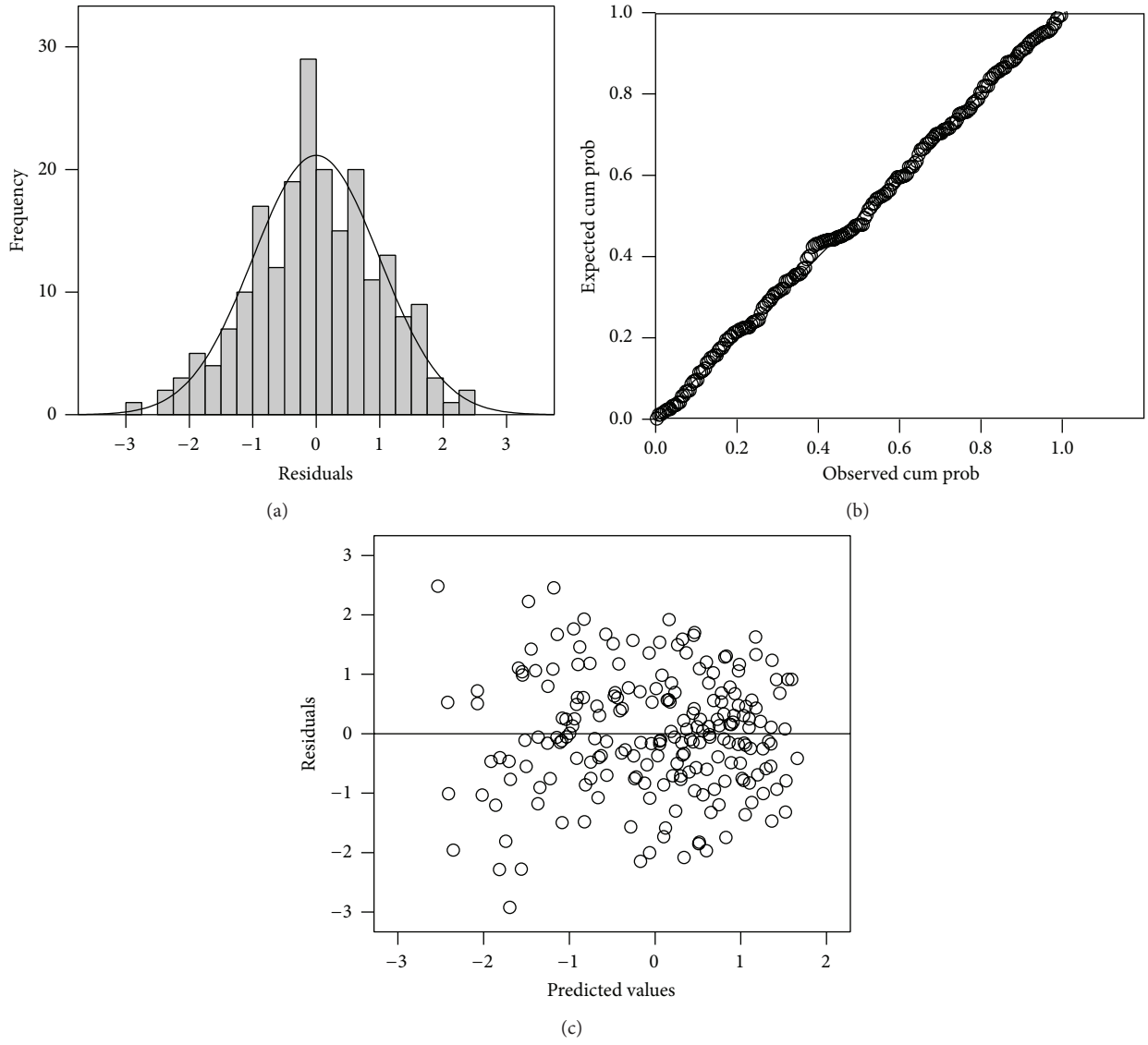


FIGURE 3: Residual distribution (a), normal P-P plot of regression standardized residuals (b), and scatter plot of residuals (c) for model M_{22}.

3.2. Model Validation. In the model validation, the goodness of fit (R^2) showed that there was a highly reliable relationship between predicted and observed data for A_1 and B_1. The R^2 values between them for models using A_1 or B_1 were 0.9716 and 0.9736, respectively (Figure 4). Morisita's [29] index of similarity ($1 - D_M$) was 0.994836 for A_1 and 0.993567 for B_1 (almost 1), which indicated that the models can predict A_1 and B_1, outside the sampled data set, effectively.

4. Discussion

Different combinations and forms of model of diameter and tree height were used to select the best models (M_{10} and M_{22}) that are more than 96% variation and lower RMSE, AICc, BIC, FI value in measuring A_1 and B_1 of *L. speciosa*. After that, logarithmic transformation induces a systematic bias in the estimation, which was corrected using a CF in the final model [27]. Given the paucity of models for this forest, I expect these models to prove valuable in future research that requires estimates of A_1 and B_1 of this species. Burton et al. [32] found that DBH is the best predictor for estimating A_1 and B_1 ($R^2 > 0.90$). Using a nondestructive sampling technique for A_1 estimation, Grace [33] found that DBH could explain 91% variation in A_1 of *Acacia Koa*. Although sapwood area (AS) or sapwood volume has proved a good predictor of tree canopy properties in different temperate in the past [34, 35], it has not been measured in this study or any national forest inventories in Bangladesh. However, Turner et al. [36] found that, in *Pseudotsuga menziesii*, the A_1 estimates based on DBH were more accurate than those on AS. So, I excluded AS from this study. Other studies found higher [37–41] correlations with DBH. Then it provides support for estimation of $A_1$and B_1 which are positively correlated to DBH and H [20]. Sarker et al. [9]

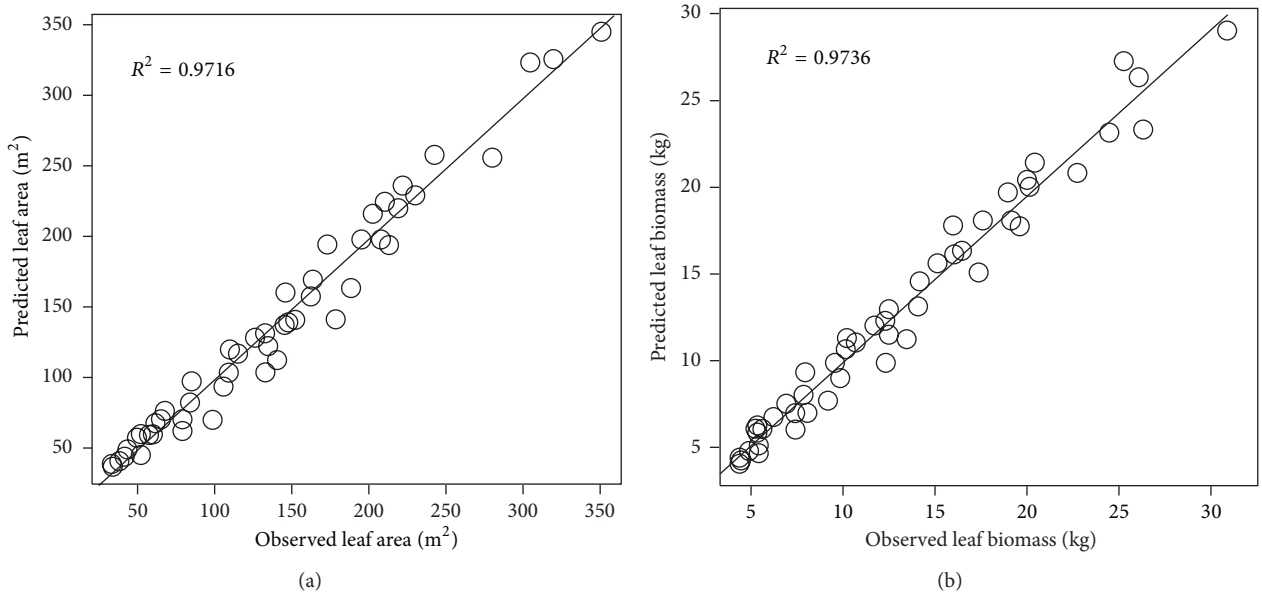


Figure 4: Linear regression between observed and predicted leaf area (a); between observed and predicted leaf biomass (b).

also show that allometric models are explained for more than 95% of the variation based on DBH with A_1 and B_1. *L. speciosa* is the dominant and medium sized deciduous tree species in tropical semievergreen forest of Bangladesh. Thus, this study is important to tree growth models of this species and ecological purposes, including light interception, transpiration rate, biomass estimation, and carbon storage. As a result, I suggest estimating A_1 and B_1 of this species based on available standard inventory measurements such as DBH and tree height in Bangladesh.

5. Conclusion

The consequences of this result showed a strong statistical dependence and best fitted models (M_{10} and M_{22}) between A_1 and B_1 with DBH and H. These models can be used effectively at the stand level for estimation of A_1 and B_1 of *L. speciosa* quickly, accurately, and nondestructively. Therefore, I propose that the models obtained and validated in this study could be employed with confidence by foresters, forest ecologists, and other scientists for estimating leaf area and leaf biomass in Bangladeshi reserve forests.

Conflict of Interests

The author declares that there is no conflict of interests regarding the publication of this paper.

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