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Height and diameter at breast height relationship of mangroves in Kerala coast, India

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Abstract

The diameter at breast height in relation to the height (Dbh:H) in mangroves may differ with respect to the region and regions generating large-volume assessments of biomass in the above-ground results in fallacy if these differences in species are neglected. A performance assessment with 11 existing non-linear and linear models were held to pick the optimum solution that resolves the Dbh-h relation in mangroves lying in proximity to the Western coastal line of India using a dataset of heights and Dbh of 1034 trees. To assess the chosen models, we adopt AIC system. As per the inference, monomolecular model with a value of 4933.43 (AIC) was bet fit for pooled data.

Keywords: Height, Diameter at breast height, Nonlinear model, Linear model, Mangrove.

Introduction

Coastline of India is approximately 7516.6 kilometers, having a mangrove spread of 4921sq.km area. This encompasses 3% of the world's mangroves area. Once an area of 700km^2 (until 1957) of mangroves were in Kerala coast, as per the estimations in 1991 it has declined to 17km^2 [1,2]. The districts that house the maximum number of mangrove species are Kannore and Kasargode, and accomodates Ramsarsites, that having abundant mangrove vegetation. The majority of this ecosystem in Kerala are in an inexorable course of deterioration as a result of mangrove felling, shortage of fresh water and deterioration of its quality, development of a number of small dams, discharge of pollutants from different sources, mining of sand etc.

Storage of carbon and sequestration have been identified as major ecosystem service served by this ecosystem[3,4]. According to recent studies, conservation of mangroves could use as an economical option for cut down CO_2 emission[5]. Mangrove soils are recognized as the largest carbon sinks with evaluated burial rates of carbon is 3-10 times greater than peat lands in northern pole[6-8].

Estimation of biomass is a decisive tool in the management of plantations and natural forests. Estimating the growing stock is crucial in better management of particular area. Forest is recognized as the sizable reservoir of carbon, amid the world's ecosystems[9]. The effect of Land-use change, change in climate, and deterioration of forest ecosystems, particularly mangroves with reference to its biomass, is crucial for the sustainability and management of these ecosystems. Felling of mangroves is banned in the south, so we use allometric equations since these relations provide a better chance at estimation of carbon.

Majority of allometric equations may be employed to determine above and below ground biomass, from measurements such as diameter and height of trees or by additionally considering specific gravity and density of wood acquired from each plots. Measuring tree height is a tedious process compared to the Dbh model because of optical hindrances, the shape of the tree's crown, the inclination of trees and slopes could add bias to the assessment of height, even though height is a mandatory predictor in biomass or volume models. Nonetheless, the relationship between height-diameter vary regionally due species composition and local environmental conditions[10]. Establishing a relevant model that describes the relation among height in relation to diameter at breast height of tree across the West coast of India was the major objective of the study.

Methodology

The present study was performed along the Western coastal line of India (10°51'1.8532"N, 76°16'15.8589"E). As per the ISFR, Dehradun-2017, Mangroves in Kerala encompasses an area of 9sq.km and accommodates 18 mangrove species and 54 species of associated species. This area experiences an average annual rainfall of 300cm, and the monthly mean temperature ranging from 28-32ºC[12]. In the time span 2016-17, ten 0.01ha plots were laid at desired sites. The distance measured from bottom to the tree's vertical extremity using a pole was set as tree height. Five species identified from plots were chosen for assessing the height-Dbh relation. 628 mangroves trees were picked for this assessment. An evaluation test of eleven commonly employed nonlinear and linear models were carried out to choose the optimum model that confirms the height-Diameter relation of mangrove trees alongside the Western coastal line of India. Both types of models were adapted using the functions Fitting linear models and Nonlinear Least squares of the R statistical software packages[13]. Akaike Information Criterion (AIC) was employed in the appraisal of the accomplishment of the Dbh and model on various mangroves and to adopt the optimal model[14,15]. AIC = -2 Log (L) + 2p. Here p is the number of factors in this equation and L is the probability of the fitted model. The best of these 11 experimented models from this datum will show the lowest AIC value[14]. Our scrutiny was methodized as follows: i. firstly, we accumulate the subset (employing the datum of 1034 mangroves) to pick the finest model as illustrated above; ii. testing the finest model(s) we equipped optimum site-specific Dbh-h equation and appraised the Akaike Information Criterion value for every species of mangrove iii. ultimately, we choose the equation having the lowest AIC value.

Table 1 – Models selected for performance test

Models			Ref.
Linear models	(1) $H = a + bD$		16,18
	(2) $H = a + b\ln D$		17,19
Nonlinear models	Hyperbolic models	(3) $H = aD/(b+D)$	17,20
		(4) $H = D^2/(a+bD)^2$	17,21
	Power model: (5) $H = aD^b$		16,17
	Exponential model:(6)$H=e^{a + b/(D+1)}$		17,21
	Chapman-Richard:(7)$H=a(1-e^{-bD})^c$		17,21
	Weibull: (8) $H = a(1-\exp[-bD^c])$		16,17
	Monomolecular: (9) $H=a(1-be^{-cD})$		16,17
	Gompertz: (10) $H=a\exp^{(-b\exp[-cD])}$		16,21
	Logistic: (11) $H = a/(1 + be^{-cD})$		16,21

H=Height of tree in meter; D=Dbh measured in centimeters; a, b, c= variables to be analyzed; e=base of mathematical constant.

Results and discussion

For *Bruguiera cylindrical* species, the Linear model fits the best (Figure-1e), the Logistical model fits best with *Avicenni aofficinalis* (Figure-1b) and *Rhizophora apiculata* (Figure-1d), the Exponential model fits the best with *Rhizophora mucronata* (Figure-1c), and *Avicennia marina* was best appraised by the Monomolecular model (Figure-1a). Monomolecular model was the best option for pooled data (Figure-1f). Non-linear Dbh-h models when conducting anecological analysis proved to be less responsive to independent points, promising more decisive and definitive for data estimation.

Studies have shown that non-linear models are more useful, when comparing with linear model in determining height of tree in connection with diameter at breast height in other tropical forest regions[16,17]. The overall accumulated tree data (Table-2: General species) and *A. marina* (Table-3: Individual species) are better described with the monomolecular equation, whereas the logistical model optimally described the data for *A. officinalis* and *R. apiculata* (Table-4,5) with small AIC's, and *R. mucronata* (Table-6) was best described by the exponential equation.

In accordance with this research, Monomolecular and Logistical equations are the perfect models to describe the 'h' in relation with 'Dbh' in this trees. *A. marina* displays this ubiquitous growth pattern as well.

Table-2: Maximum Dbh and estimated total height range, best fit models with parameter values and AIC values of pooled data.

Model	General species, N=1034						AIC
	DBH max= 88.5cm, H range =1.95-13m						
	a	S.E.	b	S.E.	c	S.E	
Linear model 1	2.96***	0.199	0.456***	0.029			5051.56
Linear model 2	-1.17**	0.382	3.990***	0.213			4972.39
Non Linear hyperbolic model 4	0.803***	0.045	0.273***	0.0069			4968
Power model 5	2.201***	0.134	0.543***	0.0308			5012.84
Exponential model 6	1.499***	0.037	-4.151***	0.226			4954.91
Exponential model 8 (Weibull model)	7.959***	0.222	0.036***	0.016	2.133***	0.2033	4938.42
Exponential model 9 (Monomolecular model)	8.24***	0.268	2.79***	0.577	0.426***	0.057	4933.43✓*

*Notes: (✓) indicates the model with least AIC value, Codes of significance: 0 '***'; 0.001 '**; 0.01 '*'; 0.05 '.'; 0.1 ' '.

Table- 3 Maximum Dbh and estimated total height range, best fit models with parameter values and AIC values of *Avicennia marina*

Model	*Avicennia marina* N=327 DBH max (cm) = 59.2 H range (m) = 2-8.2						AIC
	a	S.E.	b	S.E.	c	S.E.	
Linear model 1	0.813 ***	0.058	0.474***	0.009			396.06
Linear model 2	-2.46***	0.1030	3.583***	0.060			306.27
Nonlinear hyperbolic model 4	1.44***	0.0211	0.268***	0.003			280.49
Power model 5	0.886***	0.022	0.800***	0.012			344.97
Exponential model 6	1.362***	0.0165	-5.88***	0.099			336.25
Exponential model 8 (Weibull model)	9.699***	0.501	0.056***	0.0021	1.216 ***	0.044	281.89
Exponential model 9 (Monomolecular model)	10.81***	0.538	1.073***	0.019	0.085***	0.007	279.89 ✓
Exponential model 10 (Gompertz model)	8.90***	0.229	2.967***	0.070	0.188***	0.008	291.37
Logistical model 11	8.319***	0.163	7.195***	0.297	0.296***	0.010	309.32

Codes of significance: 0 ‘***’; 0.001 ‘**’; 0.01 ‘*’; 0.05 ‘.’; 0.1 ‘ ’.

Table- 4 Maximum Dbh and estimated total height range, best fit models with parameter values and AIC values of *Rhizophora apiculata*.

Model	*Rhizophora apiculata* N=10 DBH max (cm) = 23.5 H range (m) = 2.25 – 6						AIC
	a	S.E.	b	S.E.	c	S.E.	
Linear model 1	0.960	1.664	0.661.	0.307			34.033
Linear model 2	-1.96	2.373	3.91*	1.433			31.99
Nonlinear hyperbolic model 4	0.921.	0.443	0.294**	0.0810			32.51
Power model 5	1.3425	0.838	0.725.	0.362			33.60
Exponential model 6	1.315**	0.331	-4.209*	1.768			31.788
Logistical model 11	5.207×10^{00} ***	3.235×10^{-02}	5.633×10^{03}	2.196×10^{04}	2.281×10^{00}.	1.043×10^{00}	23.72✓

Codes of significance: 0 ‘***’;0.001 ‘**’; 0.01 ‘*’;0.05 ‘.’; 0.1 ‘ ’.

Table-5: Maximum Dbh and estimated total height range, best fit models with parameter values and AIC values of *Avicennia officinalis.*

Model	*Avicennia officinalis*						AIC
	N=143						
	DBH max (cm) = 88.5 H range (m) = 2.1 - 12.5						
	a	S.E.	b	S.E.	c	S.E.	
Linear model 1	0.694***	0.0905	0.415***	0.011			282.19
Linear model 2	-2.65***	0.268	3.55***	0.155			383.24
Nonlinear hyperbolic model 4	1.75***	0.0652	0.249***	0.006			355.27
Power model 5	0.702***	0.036	0.852***	0.021			292.89
Exponential model 6	1.421***	0.043	-6.67***	0.293			403.17
Logistical model 11	15.67***	1.415	9.22***	0.707	0.130***	0.008	271.96(✓)

Codes of significance: 0 ‘***’; 0.001 ‘**’; 0.01 ‘*’;0.05 ‘.’; 0.1 ‘ ’.

Table-6: Maximum Dbh and estimated total height range, best fit models with parameter values and AIC values of *Rhizophora mucronata*

Model	*Rhizophora mucronata*						AIC
	N = 499						
	DBH max (cm) = 55.2 H range (m) = 2.5 - 13						
	a	S.E	b	S.E	c	S.E	
Linear model 1	7.475 ***	0.280	0.116 **	0.0389			2191.68
Linear model 2	6.254***	0.534	1.087***	0.284			2186.17
Non Linear hyperbolic model 3	11.25***	0.985	0.653**	0.216			2182.50
Non Linear hyperbolic model 4	0.160***	0.0387	0.321***	0.006			2182.48
Power model 5	6.561***	0.424	0.124***	0.033			2186.83
Exponential model 6	1.266***	0.037	-0.935***	0.221			2182.20(✓)

Codes of significance: 0 ‘***’;0.001 ‘**’; 0.01 ‘*’;0.05 ‘.’;0.1 ‘ ’.

Table-7: Maximum Dbhand estimated total height range, best fit models with parameter values and AIC values of *Bruguieracy lindrica*

Model	*Bruguieracy lindrica* N=65 DBH max (cm) = 32.3 H range (m) = 1.95- 8						AIC
	a	S.E.	b	S.E.	c	S.E.	
Linear model 1	0.121	0.1921	0.823***	0.0379			90.80
Linear model 2	-3.13***	0.266	4.71***	0.171			62.68✓
Non Linear hyperbolic model 4	1.229***	0.047	0.233***	0.008			74.10
Power model 5	0.924***	0.0648	0.949***	0.040			89.47
Exponential model 6	1.573***	0.0382	-5.396***	0.193			64.44
Exponential model 8 (Weibull model)	7.647***	0.418	0.044***	0.007	1.861***	0.150	67.47
Exponential model 10 (Gompertz model)	7.845***	0.392	4.505***	0.681	0.418***	0.496	67.04
Logistical model 11	7.489***	0.297	13.64 ***	2.529	0.601***	0.056	70.01

Codes of significance: 0 ‘***’; 0.001 ‘**’; 0.01 ‘*;0.05 ‘.’; 0.1 ‘ ’.

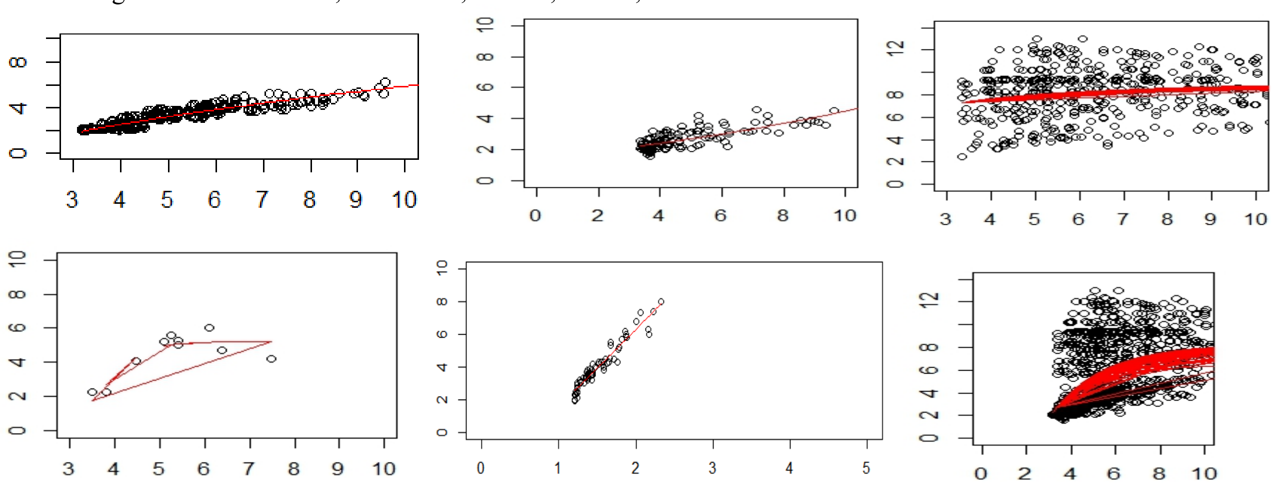

Figure-1: Best fit model of selected mangrove species.
(a). Monomolecular model of *Avicennia marina,* (b). Logistical model of *Avicennia officinalis,* (c). Exponential model of *Rhizophora mucronata,* (d). Logistical model of *Rhizophora apiculata,* (e). Linear model of *Bruguiera cylindrica,* (f). Monomolecular model of General species.

Conclusion

Tree height and diameter assessments in species were palpable and highlight the essentiality of species-specific equations. To measure the biomass of trees, tree height and diameter are significant components using in allometric models. The advancement of local Dbh-h models for every mangrove region will aid in curtailing the struggle of individual tree parameter estimations.

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