Growth Rates of Sissoo, Koroi, Akashmoni, Babla, Mahogany and Raintree Planted on Embankments and Roadsides in the Coastal Areas of Bangladesh

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Abstract

Sissoo (*Dalbergia sissoo*), koroi (*Albizia procera*), akashmoni (*Acacia auriculiformis*), babla (*A. nilotica*), mahogany (*Swietenia macrophylla*) and raintree (*Samanea saman*) are the six major species planted on the embankments and roadsides in the coastal areas of Bangladesh. Growth data of these species were collected from the area, and growth models were selected by regression techniques. The selected models may be satisfactorily used for the species in the area.

সারসংক্ষেপ

বাংলাদেশের উপকূলীয় এলাকার রাস্তা ও বাধেঁর পার্শে লাগানো গাছের মধ্যে শিশু, করই, আকাশমনি, বাবলা, মেহগনি এবং রেইনট্রি প্রজাতির গাছই প্রধান। এ ছয়টি প্রজাতির গাছের বৃর্দ্ধির উপাত্ত সংগ্রহ করে রিগ্রেশন পদ্দতির মাধ্যমে বর্ধন হারের সমীকরণ নির্বাচন করা হয়েছে। নির্বাচিত এই সমীকরণ ব্যবহার করে আলোচ্য এলাকার উল্লেখিত ছয়টি প্রজাতির গাছের বর্ধনহার সন্তোষজনকভাবে নির্ণয় করা যাবে।

Key words: Coastal area, embankments, growth rate, roadsides

Introduction

Cyclones and tidal bores cause loss of lives and properties almost every year in the coastal areas of Bangladesh. The loss is comparatively less in the area where there is tree cover along the coastal belt. With these ideas, Forest Department undertook a project, "The coastal greenbelt project", to grow trees in the coastal areas to save the lives and properties of the people in the area. The six important species planted on the embankments and roadsides in the coastal areas of Bangladesh are sissoo (*Dalbergia sissoo*), koroi (*Albizia procera*), akashmoni (*Acacia auriculiformis*), babla (*A. nilotica*), mahogany (*Swietenia macrophylla*) and raintree (*Samanea saman*). There is no volume table for any of these species for these areas. Growth rate is also not known. The volume tables and estimation of growth rates for these species are necessary for their economic evaluation and future management. Therefore, Bangladesh Forest Research Institute undertook the present study to fulfill the need with the financial support of the Coastal Greenbelt Project during the period 1996-1999. The present publication presents the growth rates of the six important species sissoo, koroi, akashmoni, babla, mahogany and raintree planted on the roadsides and embankments in the coastal areas of Bangladesh..

Materials and methods

The plantations raised under the Coastal Greenbelt Project are still young to forecast the future growth rates of different species planted on embankments and roadsides in the coastal areas of Bangladesh. Therefore, necessary data were also collected from the plantations raised in the coastal areas under different Projects like "Thana Banayan

and Nursery Unnayan Project" and others. Generally, the plantations were raised at a spacing of 1.8 m X 1.8 m in two to three lines on the embankments and roadsides. The number of lines of the plantations raised on embankments under Coastal Greenbelt Project was higher. The plot size taken for data collection was of 200 m^2. The girths at breast height (GBH) of all the trees in a plot were measured by measuring tape. The heights of the tallest two trees (100 trees per hectare) per plot were measured by hypsometer as dominant height. The heights of the other trees were estimated by comparing the heights of the trees measured.

The plantations raised under the projects are of mixed species. Small-scale plantations of single species have also been raised. Seedlings of different species in different proportions have been planted. No specific pattern was followed. Therefore, it was not possible to estimate the combined site indices of the plantations. The GBH and heights of all the trees in a plot have been entered into the computer. Then total volume, volume up to 5 cm top end diameter and volume up to 10 cm top end diameter per plot were estimated using volume equations and conversion factors of the respective species (Latif *et al.* 1984, Davidson *et al.* 1985, Latif *et al.* 1995, Latif *et al.* 2000 and Latif *et al.* 2001.) These volumes were then converted to volume yield per hectare. These volumes per hectare were plotted against age in the graphs, and growth trends were observed. Then, volume-age relationships have been estimated by regression techniques. The mean age, GBH, total height and mean volume yield per tree per year of the trees older than 10 years of age were estimated to have an idea about the growth performance of different species planted on the embankments and roadsides in the coastal areas of Bangladesh. The important statistics of the species used for growth estimation are given in Table 1.

Selection of growth models for the six major species

The following models were tested for selection of the best-suited site index guide models:

1. $\log (H) = b_0 + b_1 \log (A)$
2. $\log (H) = b_0 + b_1 / A^K, \quad 0.2 \leq K \leq 2$
3. $H = b_2 * (1 - e^{-b_1 * A})^{b_3}$
4. $H = (A/ (b_0 + b_1 A))^3$

where,

b_0 = intercept,
b_1 = slope,
b_2 = asymptote,
b_3 = inflection point,

Table 1. Parameters used for growth estimation of the species planted on embankments and roadsides in the coastal areas of Bangladesh

Parameter	Range	Babla	Koroi	Mahogany	Sissoo	Akashmoni	Rain tree
Age	Minimum	0.6	0.5	0.5	0.5	0.5	0.5
	Average	8.2	9.8	6.0	5.8	5.1	5.0
	Maximum	20.5	18.0	15.5	18.3	19.6	18.3
Height	Minimum	2.0	0.7	1.0	0.9	0.6	0.4
	Average	7.2	11.0	5.2	6.5	7.2	6.2
	Maximum	12.2	15.5	12.0	15.9	17.8	14.4
GBH	Minimum	2.0	0	0	0.1	0	0
	Average	37.6	65.9	27.8	30.7	36.5	45.3
	Maximum	73.4	117.3	74.7	82.0	122.9	150.0
Site indices	Minimum	8.0	11.0	8.0	9.0	9.0	8.0
	Average	11.2	15.5	13.0	15.0	16.0	14.0
	Maximum	15.0	19.0	20.0	23.0	22.0	21.0
No. of trees per hectare (For all species)		550 - 1692 - 2900 Minimum - mean - maximum					

H = mean total height in metres of 100 dominant and co-dominant trees per hectare

A = age of the plantation in years

The site index model was derived first. Then the model was transformed to estimate the site indices of individual plots. The rotation age of the plantations was considered as 25 years in the project proposal. The age of the oldest plantation was 18 years and as such the age range is well below the proposed rotation age. Therefore, a base age of 15 years was considered for estimation of site indices. This was followed by selection of growth models for estimation of dominant heights (H), mean heights (mht), mean GBH and total mean tree volume of individual trees of the important six species.

Model validation

Statistical validation: Statistical validation was the first step done in validating the models. It included the analysis of variance, minimum residual mean square error and the highest coefficient of determination (R^2).

Biological principle tests: The predicated values were plotted against age for different site indices. The biological requirement is that the yield curves should be sigmoid. It was also observed whether the predicted values fall within the actual data range.

Results and Discussion

Data were collected from a total of 881 temporary sample plots for estimation of growth and yield of the plantations raised on the embankments and roadsides in the coastal areas of Bangladesh. A total of 28857 trees of 34 species were measured and about 83.33% of the total number of trees comprises the six important species sissoo, koroi, akashmoni, babla, mahogany and raintree. The mean annual volume productions per tree per year were estimated to compare the volume production of the major tree species of the plantation. It was observed that among the species, raintree is at the top of the list followed by rajkoroi, koroi, eucalyptus, akashmoni, arjun, sissoo, gamar, minijiri, neem, babla, mahogany and jarul (Table 2). The estimation of volume production was made based on a small number of trees (N<50) for eucalyptus, arjun, gamar and jarul.

The volume yield models of all species combined are given as follows:

Total over bark volume yield per hectare:

$\log (Vt/ha) = 6.96011-6.68958/A^{0.55}$ $R^2 = 0.85$

Total over bark volume yield per hectare up to top end diameter of 5.0 cm:

$\log (V5/ha) = 6.580095-7.94301/A^{0.7}$ $R^2 = 0.80$

Total over bark volume yield per hectare up to top end diameter of 10.0 cm:

$\log (V10/ha) = 6.517235-10.0295/A^{0.7}$ $R^2 = 0.79$

The volume yields of all species combined are given in Table 3 and Fig. 1.

The selected models suitable for the six species planted on embankments and roadsides in the coastal areas of Bangladesh are given in the next page.

The selected models for babla, akashmoni, koroi, mahogany, sissoo and raintree satisfied all the statistical and biological criteria. The coefficients of determination are high. The predicted values were plotted against age and site indices. The yield curves conform with the ideal attributes of biological yield curve. The yield curves are sigmoid. The slope of the curves increases in the early life of the stand. Then, the rate decreases with yield still increasing until the stand reaches the carrying capacity of the site. Higher yield is obtained at better sites. The selected models could be satisfactorily used for sissoo, koroi, akashmoni, babla, mahogany and raintree planted on the embankments and roadsides in the coastal areas of Bangladesh for site indices and age ranges used for the study.

Koroi is one of the most important species of the coastal areas of Bangladesh. The number of trees in the raised plantations is comparatively low. Local people informed dibbling seeds or planting young seedlings could raise that koroi. Planting of bigger and older seedlings does not give satisfactory result. Another reason is that the trees become leafless in winter when they are cut down, assuming that they are dead. Therefore, it needs special care for raising koroi plantations.

Babla (*Acacia nilotica*)

$\log(H) = 2.765 - 1.6388/A^{0.55}$	$R^2=0.746$, N = 204
$\log(H) = 0.3696 - 1.6388/A^{0.55} + \log(s)$, Base age 15 years	
$\log(mht) = 0.08118 - 1.7364/A^{0.55} + 1.0399*\log(s)$,	$R^2=0.855$
$\log(GBH) = 3.2709 - 3.3906/A^{0.55} + 0.6245*\log(s))$.	$R^2=0.811$
$\log(Vt/tree) = -5.6308 - 8.2612/A^{0.55} + 2.30077*\log(S)$	$R^2=0.847$

Akashmoni (*A. auriculiformis*)

$\log(H) = 3.6394 - 2.62955/A^{0.4}$	$R^2=0.889$, N = 279
$\log(H) = 0.89011 - 2.62955/A^{0.4} + \log(S)$, Base age 15 years	
$\log(mht) = 0.89966 - 2.713733/A^{0.4} + 0.9422*\log(S)$,	$R^2=0.950$
$\log(GBH) = 2.10558 - 3.97967/A^{0.6} + 1.14278*\log(S)$	$R^2=0.810$
$\log(Vt/free) = -7.35069 - 9.1448/A^{0.4} + 2.9054*\log(S)$	$R^2=0.680$

Koroi (*Albizia procera*)

$\log(H) = 3.3472 - 2.36685/A^{0.5}$	$R^2=0.965$, N = 83
$\log(H) = \log(S) - 2.36685/A^{0.5} + 0.611105$, Base age 15 years	
$\log(mht) = 0.08106 - 2.17922/A^{0.6} + 1.06862*\log(S)$	$R^2=0.980$
$\log(GBH) = -1.12274 - 6.07462/A^{22} + 2.14125*\log(S)$	$R^2=0.924$
$\log(Vt/tree) = -14.5002 - 13.502/A^{1.1} + 5.33615*\log(S)$	$R^2=0.993$

Mahogany (*Swietenia macrophylla*)

$\log(H) = 4.6356 - 3.9728/A^{0.24}$	$R^2=0.878$, N=196
$\log(H) = \log(S) - 3.9728/A^{0.24} + 2.0741$, Base age 15 years	
$\log(mht) = 2.4843 - 3.943/A^{0.24} + 0.7364*\log(S)$	$R^2=0.930$
$\log(GBH) = 2.7776 + 0.6181*\log(S) - 4.6171/A^{1.1}$	$R^2=0.863$
$\log(Vt/tree) = -5.4225 - 12.1071/A^{0.8} + 1.9904*\log(S)$	$R^2=0.859$

Sissoo (*Dalbergia sissoo*)

$\log(H) = 3.5683 - 2.54987/A^{0.4}$	$R^2=0.870$, N=316
$\log(H) = \log(S) - 2.54987/A^{0.4} + 0.8631$, Base age 15 years	
$\log(mht) = 1.876535 - 2.85225/A^{0.35} + 0.61884*\log(S)$	$R^2=0.912$
$\log(GBH) = 2.009806 - 4.83801/A + 1.011956*\log(S)$	$R^2=0.800$
$\log(Vt/tree) = -8.05486 - 11.3207/A^{0.95} + 2.77568*\log(S)$	$R^2=0.840$

Raintree (*Samanea saman*)

$\log(H) = 3.59221 - 2.81293/A^{0.4}$	$R^2=0.855$, N=265
$\log(H) = \log(S) - 2.81293/A^{0.4} + 0.9520$, Base age 15 years	
$\log(mht) = 1.151346 + 0.90778*\log(S) - 3.10455/A^{0.4}$	$R^2=0.934$
$\log(GBH) = 1.67299 - 6.17255/A^{1.1} + 31.310865*\log(S)$	$R^2=0.853$
$\log(Vt/tree) = 8.94968 - 22.0456/\log(S) - 14.2572/A$	$R^2=0.850$

Table 2. Species distribution and comparative growth performance of important tree species planted on roadsides and embankments in the coastal areas of Bangladesh.

Species	Species distribution					Growth performance				
	Plot (No.)	% Plots	Tree No.	% trees	Trees (N) measured	Age (yrs)	GBH (cm)	Height (m)	Volume m^3/tree	MAI m^3/yr./tree
Raintree (*Samanea saman*).	265	30.1	3729	12.92	379	13.2	109.1	11.9	0.5968	0.0452
Rajkoroi/chambol (*Albizia richardiana*)	73	8.3	713	2.47	72	15.5	109.7	15.5	0.5847	0.0377
Koroi (*Albizia procera*)	83	9.4	977	3.39	143	14.9	90	12.4	0.4930	0.0331
Eucalyptus (*Eucalyptus camaldulensis*)	11	1.2	95	0.33	8	13.5	82.6	20.8	0.4304	0.0319
Akashmoni (*Acacia auriculiformis*)	279	31.7	5066	17.56	53	12.6	88.3	13.8	0.3581	0.0284
Arjun (*Terminalia arjuna*)	77	8.7	604	2.09	26	12.6	44.6	5.3	0.2418	0.0192
Sissoo (*Dalbergia sissoo*)	316	35.9	6600	22.87	191	14.2	71.3	12.2	0.2528	0.0178
Gamar (*Gmelina arborea*)	25	2.8	190	0.66	16	13.8	69.8	10.7	0.2146	0.0155
Minjiri (*Cassia siamea*)	74	8.4	844	2.92	539	12.9	63.5	11.1	0.1771	0.0137
Neem (*Azadirachta indica*)	22	2.5	138	0.48	133	14.4	70.1	10.4	0.1806	0.0125
Babla (*Acacia nilotica*)	204	23.2	4691	16.26	1910	13.9	52.9	9	0.1316	0.0095
Mahogany (*Swietenia macrophylla*)	196	22.2	2983	10.34	341	13.3	54.8	8.8	0.1009	0.0076
Jarul (*Lagerstroemia speciosa*)	8	0.9	41	0.14	8	12.7	48.8	8.1	0.0871	0.0069
Mangium (*Acacia mangium*)	20	2.3	61	0.21						
Ghoraneem/bakain (*Melia azedarach*)	43	4.9	705	2.44						
Jam (*Syzygium cumini*)	18	2.0	246	0.85						
Aam (*Mangifera indica*)	5	0.6	25	0.09						
Badam (*Sterculia foetida*)	3	0.3	6	0.02						
Champa (*Michelia champaca*)	3	0.3	14	0.05						
Chapalish (*Artocarpus chaplasha*)	4	0.5	15	0.05						
Chickrassy (*Chukrasia velutina*)	4	0.5	17	0.06						
Dhakijam (*Syzygium grande*)	2	0.2	4	0.01						
Golap/Poinal (*Calophyllum inophyllum*)	7	0.5	20	0.05						
Ipil-ipil (*Leucaena leucocephala*)	46	5.2	700	2.43						
Jhau (*Casuarina equisetifolia*)	21	2.4	106	0.37						
Krishnachura (*Delonix regia*).	9	1.0	32	0.11						
Kadam (*Anthocephalus chinensis*)	3	0.3	34	0.12						
Kanthal (*Artocarpus heterophyllus*)	5	0.6	32	0.11						
Khoibabla (*Pithecellobium dulce*)	16	1.8	69	0.24						
Pitali (*Trewia nudiflora*)	4	0.5	25	0.09						
Pitraj/Royna (*Aphanamixis polystachya*)	2	0.2	6	0.02						
Shimul (*Bombax ceiba*)	4	0.5	17	0.06						
Sonalu/Bandorlathi (*Cassia fistula*)	4	0.5	17	0.06						
Teak (*Tectona grandis*)	2	0.2	35	0.12						
Total			28857	100						

The trees of the plantations get additional space on both sides to spread the crowns. As a result, the trees get more space for growth. Therefore, the actual area occupied by the trees is higher than the estimated area of the plantation. This area is different for different species and again different for different ages of the same species. Hence, the area estimation was done based on the planting spacing.

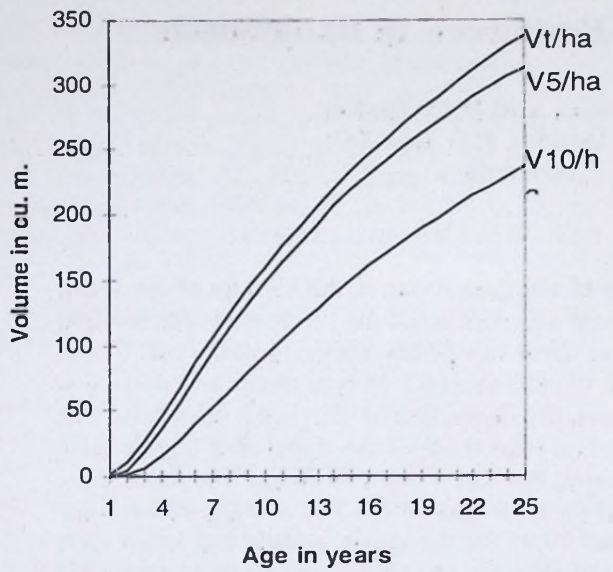

Figure 1. Volume yield of the plantations raised on embankments and road sides in the coastal areas of Bangladesh.

Vt/ha = Total over bark volume yield per hectare

V5/ha = Total under bark volume yield per hectare up to the top end diameter of 5 cm.

V10/ha = Total under bark volume yield per hectare up to the top end diameter of 10 cm.

Table 3. Total volume overbark, underbark volumes per hectare for the combined species planted on the embankments and roadsides in the coastal areas of Bangladesh.

Age (Years)	Vt/ha (m^3)	V5/ha (m^3)	V10/ha (m^3)
1	1.3	0.3	0.0
2	10.9	5.4	1.4
3	27.2	18.2	6.5
4	46.5	35.5	15.1
5	66.7	54.9	26.2
6	86.8	74.7	38.7
7	106.3	94.2	51.9
8	125.0	113.0	65.2
9	142.9	130.8	78.5
10	159.9	147.7	91.5
11	176.1	163.6	104.1
12	191.5	178.6	116.3
13	206.0	192.7	128.0
14	219.9	206.0	139.2
15	233.1	218.5	150.0
16	245.7	230.3	160.3
17	257.7	241.5	170.2
18	269.2	252.1	179.7
19	280.2	262.1	188.7
20	290.7	271.6	197.4
21	300.8	280.7	205.8
22	310.5	289.3	213.8
23	319.8	297.5	221.4
24	328.7	305.3	228.8
25	337.3	312.8	235.9

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