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Height-Age Growth Curve Modelling for Different Tree Species in Drylands of North Karnataka

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HEIGHT-AGE GROWTH CURVE MODELLING FOR DIFFERENT TREE SPECIES IN DRYLANDS OF NORTH KARNATAKA

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Height-Age Growth Curve Modelling for Different Tree Species in Drylands of North Karnataka

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Abstract - Among 24 tree species tested for height and age relationship under agroforestry systems of northern dry zone of Karnataka, Gompertz model fitted well for 9 species, Weibull model for 7 species, Exponential model found well suited for 5 species and Richards model for 3 species respectively. Among the different models tried in predicting height growth for 24 different species Gompertz was found better for Acacia auriculiformis (R^2 = 0.9974), Acacia nilotica (R^2 = 0.9981), Bahunia purpurea (R^2 = 0.9971), Butea monosperma (R^2 = 0.9992), Casuarina equsitifolia (R^2 = 0.9914), Cassia siamea (R^2 = 0.9986), Inga dulce (R^2 = 0.9968), Samanea saman (R^2 = 0.9995), and Tamarindus indica (R^2 = 0.9976). Hence, Gompertz model can be best adopted while predicting height growth of native species grown under dry land situation.

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I. Introduction

Tree height and diameter relationship is an important component in yield estimation, stand description, and damage appraisals (Parresol, 1992). Many height and diameter equations have been developed for various tree species (Wykoff *et al.,* 1982; Huang *et al.,* 1992). Among the variety of mathematical equations, sigmoidal or non-linear growth functions are widely used in developing tree height and diameter equations. Foresters often use height-diameter models to predict total tree height (c-I> based on observed diameter at breast height (DBH) for estimating tree or stand volume and site quality. Therefore, estimations of tree or stand volume and site quality rely heavily on accurate height-diameter functions. There is no standard height/age relationship for trees because of the influence of both internal and external factors on height growth but the basic pattern is sigmoidal.

Growth models assist forest researchers and managers in many ways. Some important uses include the ability to predict future yields and to explore silvicultural options. Models provide an efficient way to prepare resource forecasts, but a more important role may be their ability to explore management options and silvicultural alternatives. For example, foresters may wish to know the long-term effect on both the forest and on future harvests of a particular silvicultural decision, such as changing the cutting limits for harvesting. With a growth model, they can examine the likely outcomes, both with the intended and alternative cutting limits, and can make their decision objectively. The process of developing a growth model may also offer interesting and new insights into the forestry. Growth models may also have a broader role in forest management and in the formulation of forest policy. The same could be used as an advantage and in conjunction with other resource and environmental data, to make prediction, formulate prescriptions and guide forest policy decisions into stand dynamics. Hence looking to the importance of growth models in forestry, the present study was carried out to develop growth models for different tree species under dryland conditions of north Karnataka.

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II. Materials and Methods

The experiment was conducted at Regional Agricultural Research Station, Bijapur of University of Agricultural Sciences, Dharwad, Karnataka from 1990-2000. The soils of the experimental site were analyzed for various physico-chemical properties (Sand 25%, Silt 23%, Clay 52%, bulk density 1.43 g/cc, pH- 8.5, EC- 0.34 dSm^{-1}, $CaCO_3$ 18.5% and soil depth 30-35 cm). The average rainfall of the site is 594 mm with 39 rainy days. 24 tree species *Viz*., *Acacia auriculiformis, Acacia catechu, Acacia nilotica, Leucaena leucocephala, Albizzia lebbeck, Azadirachta indica, Bahunia purpurea, Butea monosperma, Casuarina equsitifolia, Cassia siamea, Dalbergia sissoo, Delonix regia, Emblica officianalis, Eucalyptus citriodara, Eucalyptus hybrid, Hardwickia binata, Anogeissus latifolia, Inga dulce, Peltoferrum ferrugeneum, Pongamia pinnata, Prosopsis juliflora, Samanea saman, Syzygium cumini* and *Tamarindus indica* were planted in 1990 at RARS Bijapur and data were collected at one year interval till 2000. The experiment was laid out in Randomized Complete Block Design (RCBD) with 2 replications. The trees were planted at a spacing of 2m x 2m and examined for 11 consecutive years. For developing growth curves the average height (m) of trees was measured using marked poles were recorded.

Developing height growth curves for 24 different tree species was done by selecting five non-linear models to compare fitness of these models to data (Thornley and France, 2007). The rationality behind the use of these growth models lies in the fact that these models have some important parameters enabling to comment on the growth process.

1. Gompertz model	Y = a*exp (-exp(b^-cx)) Where a, b, c are the parameters in the model.
2. Exponential model	Y=a*exp (-b/(x+c)) Where a, b and c are the parameters.
3. Weibull model	Y = a(1-b*exp (-c*x^d)) Where a, b, and c are the parameters.
4. Richards model	Y=a*(1-exp (b*x))^c Where a, b and c are the parameters in the model y is age and X is diameter.
5. Korf model	Y=a*exp (-b*x^-c) Where a ,b and c are the parameters in the model

III. Results and Discussion

Among the different models tried in predicting height growth for 24 different species Gompertz was found better for *Acacia auriculiformis* (R^2 = 0.9974), *Acacia nilotica* (R^2 = 0.9981), *Bahunia purpurea* (R^2 = 0.9971), *Butea monosperma* (R^2 = 0.9992), *Casuarina equsitifolia* (R^2 = 0.9914), *Cassia siamea* (R^2 = 0.9986), *Inga dulce* (R^2 = 0.9968), *Samanea saman* (R^2 = 0.9995), and *Tamarindus indica* (R^2 = 0.9976) and Weibull model for *Leucana leucocephala* (R^2 = 0.9987), *Dalbergia sissoo* (R^2 = 0.9978), *Eucalyptus citriodara* (R^2 = 0.9982), *Hardwickia binata* (R^2 = 0.9889), *Anogeissus latifolia* (R^2 = 0.9982), *Peltoferrum ferrugeneum* (R^2 = 0.9998) and *Pongamia pinnata* (R^2 = 0.9991).

Exponential model found suitable for *Acacia catechu* (R^2 = 0.9921), *Emblica officianalis* (R^2 = 0.9991), *Eucalyptus hybrid* (R^2 = 0.9933), *Prosopsis juliflora* (R^2 = 0.9966) and *Syzygium cumini* (R^2 = 0.9927) and Richards model was found better for *Albizia lebbeck* (R^2 = 0.9994), *Azadirachta indica* (R^2 = 0.9989) and *Delonix regia* (R^2 = 0.9984) (Table 1 and Figure 1).

Among 24 different tree species tested for height and age relationships Gompertz model fitted well for 9 species showing faster early growth but slower approach to asymptote with a longer linear period about inflection point (Thornley and France, 2007). Arid conditions of the experimental site might also impart such slow approach to the asymptote. Weibull model better fitted for 7 species with highest R^2 and lesser standard error and parameters with asymptote t-values. But overall performance of model is better in which all models were showed R^2 between 0.98 and 0.99. Despite considering initial years of growth of all tree species which are characterized by exponential growth period, the exponential model did not show robustness in predicting in all species. Somez (2009) also reported that Gompertz model fit well in height estimation of *Picea orientalis*.

Among the five growth models tested in this study, Korf model showed least fit in almost every species hence considered to be least robust for all species. Among other four models, Gompertz model showed best fit with highest R^2 value and least standard error for 9 species. Interestingly the fast growing introduced species *Prosopsis juliflora* (a ubiquitous introduced species) showed best fit with respect to exponential model. Hence, it may be preliminarily concluded that Gompertz model can be best adopted while predicting height growth of native species. Mean prediction error, standard deviation and R^2 served the criteria for comparing model prediction performance of growth functions. In this Gompertz function showed superiority over other models for 9 species in height – age relationship.

Typically the asymptotic coefficient is the least stable parameter in non-linear growth functions. The least-squares of these growth functions may result in biologically unreasonable upper asymptotes, especially when there are few data observations near the asymptote. Extrapolation, using the models beyond the data range, may produce overestimation or underestimation for large-sized trees. To circumvent the problem some researchers constrained the growth functions by fixing the asymptote at a constant value, such as an available big tree record, while estimating all other parameters in the models (Brewer et al., 1985, Zhang, 1997).

Table 1 : Comparison of the Observed values of tree height (m) with that estimated by best-fit model and coefficient of determination, standard error, Mean Prediction Error (MPE), Standard Deviation (SD) with respect to different tree species under semi-arid regions of north Karnataka

T_{1}- *Acacia auriculiformis*

Age (years)	Estimated values	Observed values	Growth model
1	0.196	0.52	Gompertz model
2	0.841	0.81	
3	1.994	1.41	
4	3.326	2.41	R^2=0.9974
5	4.505	3.19	
6	5.392	3.70	SE=0.1279
7	5.998	4.50	
8	6.390	5.32	MPE= -0.7250
9	6.633	5.90	
10	6.782	6.40	SD = 0.6462
11	6.872	6.80	
15	6.988		Y=7.005*exp (-6.034*exp (-0.523*X))
20	7.004		
25	7.005		
30	7.005		
35	7.005		
40	7.005		
45	7.005		
50	7.005		

T_{2}- *Acacia catechu*

Age (years)	Estimated values	Observed values	Growth model
1	0.647	0.46	Exponential model
2	1.665	0.61	
3	2.437	1.23	
4	2.994	1.85	
5	3.406	2.51	
6	3.720	2.92	R^2=0.9921
7	3.967	3.49	
8	4.166	3.91	SE=0.1516
9	4.329	4.16	
10	4.465	4.21	MPE = -0.6113
11	4.581	4.3	
15	4.907		SD = 0.4095
20	5.149		
25	5.301		Y=5.966*exp (-3.0001/(X+0.3501))
30	5.405		
35	5.481		
40	5.539		
45	5.585		
50	5.621		

T_{3}-*Acacia nilotica*

Age (years)	Estimated values	Observed values	Growth model
1	0.900	0.48	Gompertz model
2	0.891	0.68	
3	1.549	1.23	
4	2.341	1.75	R^2=0.9981
5	3.187	2.71	
6	4.013	3.24	SE=0.0882
7	4.767	3.83	
8	5.420	4.40	MPE =-0.7304
9	5.967	4.70	
10	6.410	5.22	SD =0.4096
11	6.763	5.44	Y=7.9211*exp (-2.9119exp (-0.2918*X)
15	7.541		
20	7.831		
25	7.900		
30	7.916		
35	7.920		
40	7.921		
45	7.921		
50	7.921		

T_{4}-*Leucaena leucocephala*

Age (years)	Estimated values	Observed values	Growth model
1	0.183	0.38	Weibull model
2	0.712	0.63	
3	1.536	1.66	
4	2.582	2.72	
5	3.764	3.81	R^2=0.9987
6	4.997	4.91	
7	6.200	5.72	SE=0.1648
8	7.312	7.61	
9	8.291	8.64	MPE= 0.0372
10	9.114	9.2	
11	9.777	9.60	SD= 0.2358
15	11.137		
20	11.444		Y=11.465*(1-exp (-0.0161*X^1.993))
25	11.464		
30	11.465		
35	11.465		
40	11.465		
45	11.465		
50	11.465		

T_5-*Albizzia lebbeck*

Age (years)	Estimated values	Observed values	Growth model
1	0.161	0.15	Richards model
2	0.816	0.83	
3	1.791	1.81	
4	2.835	2.81	
5	3.793	3.72	R^2=0.9994
6	4.600	4.69	
7	5.244	5.30	SE=0.0635
8	5.742	5.72	
9	6.118	6.01	MPE =0.000393
10	6.398	6.44	
11	6.604	6.63	SD =0.05685 Y=7.1478*(1-exp (-0.3316*X))^2.9981))
15	7.001		
20	7.120		
25	7.143		
30	7.147		
35	7.148		
40	7.148		
45	7.148		
50	7.148		

T_6-*Azadirachta indica*

Age (years)	Estimated values	Observed values	Growth model
1	0.083	0.34	Richards model
2	0.521	0.83	
3	1.271	1.26	
4	2.146	1.89	
5	2.995	2.53	R^2=0.9989
6	3.738	3.29	
7	4.350	3.88	SE=0.0553
8	4.834	4.21	
9	5.206	4.56	MPE =-0.305522
10	5.487	4.97	
11	5.696	5.21	SD =0.33923
15	6.108		
20	6.236		Y=5.2672*(1-exp (-0.3253*X))^3.3731
25	6.261		
30	6.266		
35	6.267		
40	6.267		
45	6.267		
50	6.267		

T_7-*Bahunia purpurea*

Age (years)	Estimated values	Observed values	Growth model
1	0.493	0.64	Gompertz model
2	0.912	0.83	
3	1.445	1.485	
4	2.039	2.005	
5	2.639	2.51	R^2=0.99711
6	3.200	3.21	
7	3.698	3.76	SE=0.0943
8	4.120	4.19	
9	4.467	4.55	MPE =0.004599
10	4.745	4.71	
11	4.965	4.885	SD =0.08428
15	5.447		
20	5.626		Y=5.6821*exp (-3.265*exp (-0.4934*X))
25	5.669		
30	5.679		
35	5.681		
40	5.682		
45	5.682		
50	5.682		

T_8-*Butea monosperma*

Age (years)	Estimated values	Observed values	Growth model
1	0.105	0.109	Gompertz model
2	0.313	0.29	
3	0.650	0.69	
4	1.060	1.01	
5	1.469	1.502	R^2=0.99924
6	1.827	1.84	
7	2.114	2.105	SE=0.0289
8	2.330	2.31	
9	2.487	2.49	MPE =-0.000145
10	2.598	2.59	
11	2.674	2.69	SD =0.02582
15	2.803		
20	2.831		Y=2.836*exp (-4.932*exp (-0.4029*X))
25	2.835		
30	2.836		
35	2.836		
40	2.836		
45	2.836		
50	2.836		

T_9-*Casuarina equsitefolia*

Age (years)	Estimated values	Observed values	Growth model
1	0.765	0.95	Gompertz model
2	1.114	1.14	
3	1.506	1.335	
4	1.918	1.78	
5	2.327	2.3	R^2=0.9914
6	2.718	2.81	
7	3.077	3.12	SE=0.1197
8	3.399	3.5	
9	3.680	3.72	MPE =0.003605
10	3.923	3.9	
11	4.129	4.04	SD =0.10707
15	4.660		
20	4.932		Y=5.0717*exp (-2.3623*exp (-0.2219*X))
25	5.025		
30	5.056		
35	5.067		
40	5.070		
45	5.071		
50	5.072		

T_{10}-*Cassia siamea*

Age (years)	Estimated values	Observed values	Growth model
1	0.616	0.69	Gompertz model
2	0.951	0.91	
3	1.356	1.375	
4	1.813	1.805	
5	2.299	2.23	R^2=0.9986
6	2.793	2.75	
7	3.276	3.365	SE=0.0604
8	3.732	3.715	
9	4.152	4.19	MPE =0.00174
10	4.531	4.57	
11	4.867	4.805	SD =0.05406
15	5.814		
20	6.372		Y=6.721*exp (-2.918*exp (-0.2002*X))
25	6.590		
30	6.672		
35	6.703		
40	6.714		
45	6.718		
50	6.720		

T_{11}-*Dalbergia sissoo*

Age (years)	Estimated values	Observed values	Growth model
1	0.360	0.52	Weibull model
2	0.902	0.85	
3	1.493	1.49	
4	2.077	2.01	
5	2.626	2.65	R^2=0.9978
6	3.123	3.13	
7	3.560	3.51	SE=0.0147
8	3.936	3.99	
9	4.255	4.31	MPE =-0.01784
10	4.519	4.42	
11	4.736	4.51	SD =0.09959
15	5.248		
20	5.458		Y=5.5179*(1-exp (-0.0675*X^-1.4036))
25	5.506		
30	5.516		
35	5.518		
40	5.518		
45	5.518		
50	5.518		

T_{12}-*Delonix regia*

Age (years)	Estimated values	Observed values	Growth model
1	0.110	0.16	Richards model
2	0.412	0.31	
3	0.810	0.69	
4	1.230	1.21	
5	1.630	1.63	R^2=0.99841
6	1.987	1.93	
7	2.296	2.31	SE=0.0464
8	2.555	2.52	
9	2.769	2.73	MPE =-0.046169
10	2.944	2.81	
11	3.085	3.02	SD =0.0571543
15	3.416		
20	3.564		Y=3.627*(1-exp (-0.2439*X))^2.284
25	3.608		
30	3.621		
35	3.625		
40	3.626		
45	3.626		
50	3.627		

T_{13}-*Emblica officianalis*

Age (years)	Estimated values	Observed values	Growth model
1	1.445	0.83	Exponential model
2	2.566	1.35	
3	3.565	1.88	
4	4.413	2.79	
5	5.123	3.43	R^2=0.9991
6	5.722	4.06	
7	6.230	5.11	SE=0.10013
8	6.665	5.68	
9	7.041	6.03	MPE =--1.2767
10	7.368	6.12	
11	7.656	6.24	SD =0.35296
15	8.523		
20	9.218		Y=11.975*exp (-5.674/(X+1.684))
25	9.681		
30	10.011		
35	10.259		
40	10.451		
45	10.604		
50	10.730		

T_{14}-*Eucalyptus citriodara*

Age (years)	Estimated values	Observed values	Growth model
1	0.760	0.79	Weibull model
2	1.769	1.76	
3	2.830	2.83	
4	3.878	3.73	
5	4.878	4.65	R^2=0.9982
6	5.811	5.89	
7	6.667	6.41	SE=0.1373
8	7.443	7.42	
9	8.139	8.12	MPE = -0.104144
10	8.758	8.64	
11	9.304	8.85	SD =0.15763
15	10.871		
20	11.861		Y=12.539*(1-exp (-0.0625*X^-1.2829))
25	12.282		
30	12.447		
35	12.508		
40	12.529		
45	12.536		
50	12.539		

T_{15}-*Eucalyptus hybrid*

Age (years)	Estimated values	Observed values	Growth model
1	0.661	0.82	Exponential model
2	1.325	1.23	
3	2.069	1.84	
4	2.822	2.82	
5	3.545	3.41	R^2=0.9933
6	4.222	4.94	
7	4.849	5.29	SE=0.192
8	5.425	5.72	
9	5.952	5.89	MPE =0.04334
10	6.435	6.21	
11	6.878	6.49	SD =0.32964
15	8.321		
20	9.601		Y=15.879*exp (-11.356/(X+2.573))
25	10.519		
30	11.205		
35	11.737		
40	12.161		
45	12.507		
50	12.794		

T_{16}-*Hardwickia binata*

Age (years)	Estimated values	Observed values	Growth model
1	0.260	0.31	Weibull model
2	0.716	0.73	
3	1.274	1.46	
4	1.893	2.09	
5	2.543	2.59	R^2=0.9889
6	3.204	3.11	
7	3.859	3.55	SE=0.1023
8	4.496	4.78	
9	5.106	5.39	MPE =0.02612
10	5.682	5.62	
11	6.219	5.91	SD =0.20883
15	7.958		
20	9.280		Y=10.403*(1-exp (-0.0253*X^-1.495))
25	9.938		
30	10.227		
35	10.342		
40	10.383		
45	10.397		
50	10.401		

T_{17}-*Anogeissus latifolia*

Age (years)	Estimated values	Observed values	Growth model
1	0.194	0.38	Weibull model
2	0.632	0.62	
3	1.221	1.24	
4	1.892	1.82	
5	2.588	2.39	R^2=0.9982
6	3.262	3.31	
7	3.882	3.88	SE=0.0899
8	4.428	4.46	
9	4.891	4.86	MPE =0.020796
10	5.270	5.19	
11	5.570	5.91	SD =0.14163
15	6.189		
20	6.349		Y=6.366*(1-exp (-0.03101*X^-1.7359))
25	6.365		
30	6.366		
35	6.366		
40	6.366		
45	6.366		
50	6.366		

T_{18}-*Inga dulce*

Age (years)	Estimated values	Observed values	Growth model
1	0.767	0.81	Gompertz model
2	1.208	1.23	
3	1.730	1.79	
4	2.297	2.21	
5	2.874	2.79	R^2=0.9968
6	3.430	3.34	
7	3.945	3.86	SE=0.1023
8	4.406	4.29	
9	4.807	4.61	MPE = -0.08557
10	5.150	4.99	
11	5.438	5.19	SD =0.097399
15	6.162		
20	6.512		Y=6.6737*exp (-2.7339*exp (-0.236))
25	6.624		
30	6.658		
35	6.669		
40	6.672		
45	6.673		
50	6.674		

T_{19}-*Peltoferrum ferrugeneum*

Age (years)	Estimated values	Observed values	Growth model
1	0.129	0.22	Weibull model
2	0.435	0.31	
3	0.873	1.72	
4	1.411	3.17	
5	2.020	3.95	R^2=0.9998
6	2.673	4.63	
7	3.346	4.72	SE=0.179
8	4.018	4.57	
9	4.673	4.81	MPE =0.7.02075
10	5.295	5.08	
11	5.874	5.29	SD= 0.925451643
15	7.669		
20	8.808		Y=9.334*(1-exp (-0.0139*X^1.78))
25	9.205		
30	9.309		
35	9.330		
40	9.334		
45	9.334		
50	9.334		

T_{20}-*Pongamia pinnata*

Age (years)	Estimated values	Observed values	Growth model
1	0.160	0.13	Weibull model
2	0.547	0.49	
3	1.085	1.09	
4	1.709	1.82	
5	2.356	2.34	R^2=0.9991
6	2.980	2.89	
7	3.545	3.56	SE=0.0583
8	4.031	4.06	
9	4.429	4.42	MPE = -0.003014
10	4.742	4.77	
11	4.979	4.96	SD =0.052112
15	5.407		
20	5.486		Y=5.5911*(1-exp (-0.0295*X^1.8292))
25	5.491		
30	5.491		
35	5.491		
40	5.491		
45	5.491		
50	5.491		

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T_{21}-*Prosopsis juliflora*

Age (years)	Estimated values	Observed values	Growth model
1	0.084	0.96	Exponential model
2	0.489	1.35	
3	1.106	1.97	
4	1.772	2.62	
5	2.408	3.11	R^2=0.9966
6	2.988	3.62	
7	3.507	3.99	SE=0.0938
8	3.967	4.41	
9	4.375	4.71	MPE = 0.56302
10	4.738	4.92	
11	5.062	5.03	SD =0.30899
15	6.063		
20	6.889		Y=10.295*exp (-8.329(X+0.7335))
25	7.448		
30	7.851		
35	8.155		
40	8.391		
45	8.581		
50	8.736		

T_{22}-*Samanea saman*

Age (years)	Estimated values	Observed values	Growth model
1	0.642	0.68	Gompertz model
2	1.063	1.01	
3	1.562	1.59	
4	2.096	2.06	
5	2.625	2.66	R^2=0.9995
6	3.116	3.13	
7	3.553	3.54	SE=0.0366
8	3.928	3.91	
9	4.241	4.23	MPE =0.000455
10	4.496	4.54	
11	4.702	4.68	SD =0.03281
15	5.173		
20	5.365		Y=8.158*exp (-3.0564*exp (-0.2759*X))
25	5.416		
30	5.430		
35	5.433		
40	5.434		
45	5.434		
50	5.434		

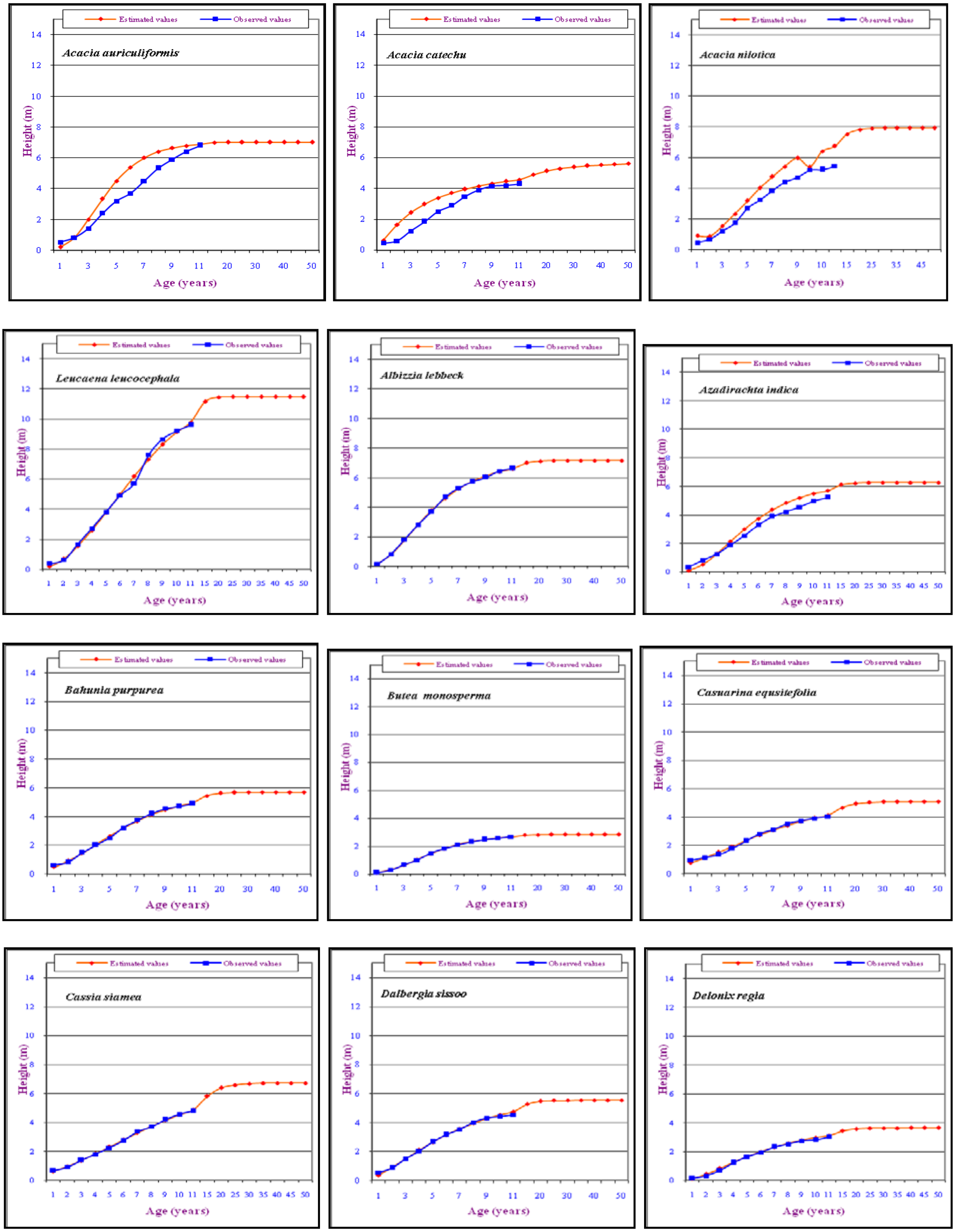
T_{23}-*Syzygium cumini*

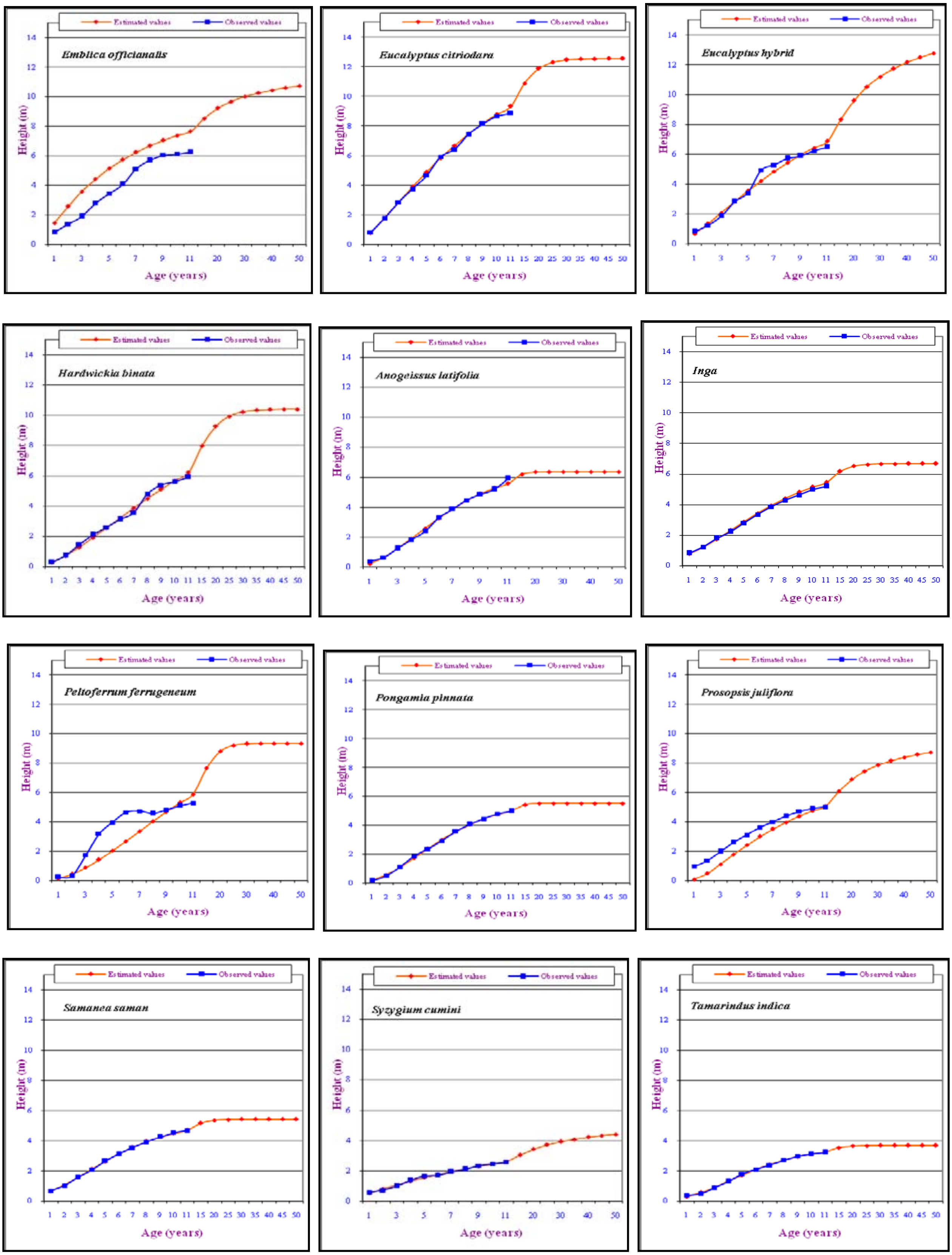
Age (years)	Estimated values	Observed values	Growth model
1	0.520	0.58	Exponential model
2	0.789	0.72	
3	1.056	0.98	
4	1.308	1.36	
5	1.542	1.65	R^2=0.9927
6	1.757	1.72	
7	1.953	1.92	SE=0.0656
8	2.131	2.09	
9	2.294	2.33	MPE =0.0000665
10	2.442	2.46	
11	2.578	2.56	SD =0.05874
15	3.020		
20	3.413		Y=5.381*exp (-10.74/(X+3.595))
25	3.696		
30	3.909		
35	4.074		
40	4.206		
45	4.314		
50	4.404		

T_{24}-*Tamarindus indica*

Age (years)	Estimated values	Observed values	Growth model
1	0.285	0.37	Gompertz model
2	0.555	0.49	
3	0.909	0.89	
4	1.309	1.29	
5	1.713	1.78	R^2=0.9976
6	2.090	2.09	
7	2.422	2.37	SE=0.0528
8	2.700	2.7	
9	2.926	2.96	MPE =0.00197
10	3.105	3.13	
11	3.244	3.21	SD =0.047194
15	3.540		
20	3.644		Y=3.3674*exp (-3.459*exp (-0.3023*X))
25	3.667		
30	3.672		
35	3.674		
40	3.674		
45	3.674		
50	3.674		

Figure 1 : Height-age growth curves of different tree species under semi-arid regions of north Karnataka




Estimated values
Observed values
Emblica officianalis
Eucalyptus citriodara
Eucalyptus hybrid
Hardwickia binata
Anogeissus latifolia
Inga
Peltoferrum ferrugeneum
Pongamia pinnata
Prosopis juliflora
Samanea saman
Syzygium cumini
Tamarindus indica
Height (m)
Age (years)

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