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

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Keywords : *height, age, model, species, growth.*

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

Strictly as per the compliance and regulations of :

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

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Keywords : height, age, model, species, growth.

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-l> 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. The general diameter/age relationship is represented by the cumulative growth curve (CGC) which is sigmoidal for biological systems.

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.

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 officinalis, 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.

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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 diameter at breast height (DBH) (cm) using vernier caliper were recorded.

Developing diameter 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 diameter growth for 24 different species, Gompertz model was found better for *Acacia auriculiformis* (R^2 = 0.9956), *Acacia catechu* (R^2 = 0.9972), *Acacia nilotica* (R^2 = 0.9938), *Bahunia purpurea* (R^2 = 0.9950), *Butea monosperma* (R^2 = 0.9968), *Casuarina equsitifolia* (R^2 = 0.9979), *Cassia siamea* (R^2 = 0.9986), *Dalbergia sissoo* (R^2 = 0.9944), *Delonix regia* (R^2 = 0.9953), *Emblica officinalis* (R^2 = 0.9944), *Eucalyptus citriodara* (R^2 = 0.9983), *Eucalyptus hybrid* (R^2 = 0.9988), *Hardwickia binata* (R^2 = 0.9969), *Anogeissus latifolia* (R^2 = 0.9962), *Inga dulce* (R^2 = 0.9931), *Peltoferrum ferrugeneum* (R^2 = 0.9978), *Prosopsis juliflora* (R^2 = 0.9989), *Samanea saman* (R^2 = 0.9982), *Syzygium cumini* (R^2 = 0.9976) and *Tamarindus indica* (R^2 = 0.9953).

Exponential model found suitable for *Leucana leucocephala* (R^2 = 0.9958) and *Pongamia pinnata* (R^2 = 0.9987). Whereas, Richards model was found better for *Albizia lebbeck* (R^2 = 0.9986) and Weibull model for *Azadirachta indica* (R^2 = 0.9983) (Table 1 and Figure 1).

Among five growth models tested in diameter and age relationship study, Korf, Richards and Weibull models showed least fit in almost every tree species. Among other two models Gompertz model showed best fit with highest R^2 and lest standard error. Among 24 different tree species, Gompertz model showed best fit for 20 species among which sixteen species were native to semiarid conditions. Gompertz model showed faster early growth but slower approach to asymptote with a longer linear period about inflection point (Thornley and France, 2007) and reported to be more accurate than any other models of forest growth (Zhang, 1997). Arid conditions of the experimental site might also impart such slow approach to the asymptote. Exponential model better fitted for two species with highest R^2 and lesser standard error and parameters with asymptote t-values. Richards model showed best fit for one species *i.e. Albizia lebbeck* and Weibull model for one species *i.e., Leucana leucocephala* which is an introduced fast growing tree species. 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. But overall performance of models was better in which all models were showed R^2 between 0.98 and 0.99 except Korf and Weibull model. Mean prediction error, standard deviation and R^2 were adopted as criteria for comparing model prediction performance of growth functions. The apparent reason for high R^2 values associated with linear models is that the data set usually belongs to the second phase of tree growth and which is linear in nature (Srivastava and Ajit, 2002). In this Gompertz function showed superiority over other models for 20 species in DBH – Age relationship.

Table 1 : Comparison of the Observed values of tree diameter (cm) 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	1.068	0.82	Gompertz model
2	1.788	1.55	
3	2.631	2.51	
4	3.515	3.34	
5	4.367	4.21	
6	5.140	4.99	R^2=0.9956
7	5.807	5.5	
8	6.363	5.91	SE=0.2652
9	6.815	6.21	
10	7.175	6.89	MPE=-0.28976
11	7.457	7.01	
15	8.071		SD =0.15321
20	8.299		
25	8.354		
30	8.367		
35	8.370		
40	8.371		
45	8.371		
50	8.371		

T_2- *Acacia catechu*

Age (years)	Estimated values	Observed values	Growth model
1	0.587	0.76	Gompertz model
2	0.963	0.99	
3	1.450	1.41	
4	2.033	1.89	
5	2.687	2.44	
6	3.382	3.12	R^2=0.9972
7	4.090	3.88	
8	4.783	4.51	SE=0.0622
9	5.444	5.11	
10	6.057	5.67	MPE =-0.20924
11	6.615	6.01	
15	8.269		SD =0.2115
20	9.315		
25	9.750		Y=10.03*exp (-3.44*exp (-0.192*X))
30	9.922		
35	9.988		
40	10.014		
45	10.024		
50	10.028		

T_3-*Acacia nilotica*

Age (years)	Estimated values	Observed values	Growth model
1	1.293	0.89	Gompertz model
2	1.574	1.43	
3	1.884	1.89	
4	2.219	2.35	R^2=0.9938
5	2.577	2.66	
6	2.955	3.01	SE=0.0567
7	3.347	3.44	
8	3.750	3.8	MPE =-0.004601
9	4.161	4.2	
10	4.574	4.61	SD =0.14957
11	4.988	4.99	Y=12.331*exp (-2.471*exp (-0.0193*X))
15	6.579		
20	8.283		
25	9.583		
30	10.511		
35	11.144		
40	11.565		
45	11.840		
50	12.018		

T_4-*Leucaena leucocephala*

Age (years)	Estimated values	Observed values	Growth model
1	0.314	0.81	Exponential model
2	0.902	1.21	
3	1.722	1.81	
4	2.664	2.55	
5	3.649	3.44	R^2=0.9958
6	4.627	4.49	
7	5.571	5.53	SE=0.2121
8	6.467	5.99	
9	7.309	6.09	MPE =-0.4726
10	8.096	6.34	
11	8.829	6.69	SD =0.85675
15	11.290		
20	13.550		Y=25.3495*exp (-13.881/(2.1612+X))
25	15.206		
30	16.464		
35	17.448		
40	18.238		
45	18.886		
50	19.427		

T_5-*Albizzia lebbeck*

Age (years)	Estimated values	Observed values	Growth model
1	0.377	0.46	Richards model
2	1.051	1.01	
3	1.816	1.86	
4	2.584	2.55	
5	3.314	3.21	R^2=0.9986
6	3.983	4.01	
7	4.584	4.76	SE=0.1186
8	5.116	5.89	
9	5.582	6.79	MPE =-0.4359
10	5.987	7.99	SD =0.6092
11	6.337	8.88	Y=8.324*(1-exp (- 0.17225*X))^1.6 8031
15	7.300		
20	7.885		
25	8.138		
30	8.245		
35	8.291		
40	8.310		
45	8.318		
50	8.321		

T_6-*Azadirachta indica*

Age (years)	Estimated values	Observed values	Growth model
1	0.361	0.330	Weibull model R^2=0.9983
2	0.983	0.780	
3	1.728	1.560	
4	2.529	2.410	
5	3.342	3.290	SE=0.11055
6	4.138	4.110	
7	4.894	4.760	MPE =-0.15801
8	5.596	5.550	
9	6.237	6.110	SD =0.14015
10	6.812	6.420	
11	7.320	6.880	Y=9.954*(1-exp (- 0.0369* X^1.4948))
15	8.752		
20	9.568		
25	9.847		
30	9.928		
35	9.948		
40	9.953		
45	9.954		
50	9.954		

T_7-*Bahunia purpurea*

Age (years)	Estimated values	Observed values	Growth model
1	0.386	0.510	Gompertz model
2	0.935	0.880	
3	1.741	1.550	
4	2.697	2.490	
5	3.669	3.560	R^2=0.9950
6	4.556	4.410	
7	5.305	5.220	SE=0.05654
8	5.905	5.790	
9	6.366	6.310	MPE =-0.09723
10	6.712	6.620	
11	6.967	6.830	SD =0.088346
15	7.447		
20	7.582		Y=7.61*exp (- 4.24*exp (-0.352*X))
25	7.605		
30	7.609		
35	7.610		
40	7.610		
45	7.610		
50	7.610		

T_8-*Butea monosperma*

Age (years)	Estimated values	Observed values	Growth model
1	0.803	0.86	Gompertz model
2	1.1598	1.21	
3	1.584	1.76	
4	2.063	2.29	
5	2.581	2.71	R^2=0.99681
6	3.121	3.19	
7	3.667	3.71	SE=0.03183
8	4.203	4.26	
9	4.719	4.88	MPE =0.10029
10	5.206	5.29	
11	5.658	5.71	SD =0.06277
15	7.081		
20	8.102		Y=9*exp (-2.85*exp (-0.165*X))
25	8.595		
30	8.820		
35	8.921		
40	8.965		
45	8.985		
50	8.993		

T_9-*Casuarina equsitefolia*

Age (years)	Estimated values	Observe d values	Growth model
1	0.859	0.86	Gompertz model
2	1.333	1.39	
3	1.882	1.95	
4	2.469	2.61	
5	3.055	3.19	R^2=0.9979
6	3.613	3.72	
7	4.121	4.22	SE=0.0251
8	4.570	4.69	
9	4.957	4.99	MPE =0.0891
10	5.284	5.37	
11	5.556	5.69	SD =0.0454
15	6.227		
20	6.541		Y=6.68*exp (-2.61*exp (-0.241*X))
25	6.638		
30	6.667		
35	6.676		
40	6.679		
45	6.680		
50	6.680		

T_{10}-*Cassia siamea*

Age (years)	Estimated values	Observed values	Growth model
1	0.805	0.86	Gompertz model
2	1.266	1.31	
3	1.813	1.92	
4	2.411	2.56	
5	3.022	3.17	R^2=0.99865
6	3.615	3.88	
7	4.167	4.28	SE=0.02165
8	4.664	4.73	
9	5.099	5.1	MPE =0.09001
10	5.474	5.49	
11	5.790	5.82	SD =0..76942
15	6.594		
20	6.991		Y=7.18*exp (-2.76*exp (-0.232*X))
25	7.120		
30	7.161		
35	7.174		
40	7.178		
45	7.179		
50	7.179		

T_{11}-*Dalbergia sissoo*

Age (years)	Estimated values	Observed values	Growth model
1	0.622	0.910	Gompertz model
2	0.966	1.260	
3	1.508	1.710	
4	2.129	2.380	
5	2.780	2.810	R^2=0.9944
6	3.418	3.530	
7	4.011	4.190	SE=0.04591
8	4.540	4.620	
9	4.997	5.090	MPE =0.15335699
10	5.382	5.460	
11	5.700	5.780	SD =0.093458
15	6.466		
20	6.805		Y=7.94*exp (-3.29*exp (-0.256*X))
25	6.902		
30	6.929		
35	6.937		
40	6.939		
45	6.940		
50	6.940		

T_{12}-*Delonix regia*

Age (years)	Estimated values	Observed values	Growth model
1	0.846	0.56	Gompertz model
2	1.148	0.99	
3	1.495	1.38	
4	1.88	1.76	
5	2.293	2.19	R^2=0.99536
6	2.725	2.69	
7	3.165	3.26	SE=0.03124
8	3.604	3.68	
9	4.033	4.12	MPE =-0.0638
10	4.447	4.45	
11	4.841	4.7	SD =0.12016
15	6.159		
20	7.229		Y=8.44*exp (-2.65*exp (-0.142*X))
25	7.821		
30	8.129		
35	8.286		
40	8.363		
45	8.402		
50	8.421		

T_{13}-*Emblica officianalis*

Age (years)	Estimated values	Observed values	Growth model
1	0.757	0.61	Gompertz model
2	1.213	1.19	
3	1.774	1.62	
4	2.410	2.33	
5	3.086	3.01	R^2=0.9944
6	3.767	3.61	
7	4.424	4.39	SE=0.0508
8	5.037	4.99	
9	5.592	5.43	MPE =-0.1098
10	6.085	5.99	
11	6.513	6.28	SD =0.0656
15	7.671		
20	8.303		Y=8.65*exp (-3.02*exp (-0.215*X))
25	8.530		
30	8.609		
35	8.636		
40	8.645		
45	8.648		
50	8.649		

T_{14}-*Eucalyptus citriodara*

Age (years)	Estimated values	Observed values	Growth model
1	0.813	0.970	Gompertz model
2	1.604	1.760	
3	2.625	2.530	
4	3.753	3.580	
5	4.864	4.810	R^2=0.9983
6	5.871	5.890	
7	6.729	6.880	SE=0.03955
8	7.429	7.340	
9	7.983	7.990	MPE =-0.00771
10	8.409	8.310	
11	8.733	8.670	SD =0.11633
15	9.387		
20	9.597		Y=9.65*exp (-3.41*exp (-0.321*X))
25	9.639		
30	9.648		
35	9.650		
40	9.650		
45	9.650		
50	9.650		

T_{15}-*Eucalyptus hybrid*

Age (years)	Estimated values	Observed values	Growth model
1	0.755	0.910	Gompertz model
2	1.490	1.610	
3	2.443	2.360	
4	3.501	3.410	
5	4.550	4.630	R^2=0.9988
6	5.507	5.610	
7	6.328	6.390	SE=0.03191
8	7.001	6.990	
9	7.536	7.210	MPE =-0.05821
10	7.952	7.580	
11	8.268	7.990	SD =0.18594
15	8.914		
20	9.125		Y=9.18*exp (-3.43*exp (-0.3173*X))
25	9.169		
30	9.178		
35	9.180		
40	9.180		
45	9.180		
50	9.180		

T_{16}-*Hardwickia binata*

Age (years)	Estimated values	Observed values	Growth model
1	0.676	0.950	Gompertz model
2	1.277	1.360	
3	2.043	2.120	
4	2.892	2.910	
5	3.739	3.780	R^2=0.9969
6	4.521	4.610	
7	5.202	5.290	SE=0.1366
8	5.771	5.820	
9	6.231	6.310	MPE =0.099634
10	6.595	6.780	
11	6.877	6.990	SD =0.07222
15	7.474		
20	7.684		Y=7.744*exp (-3.299*exp (-0.3022*X))
25	7.731		
30	7.741		
35	7.743		
40	7.744		
45	7.744		
50	7.744		

T_{17}-*Anogeissus latifolia*

Age (years)	Estimated values	Observed values	Growth model
1	0.589	0.86	Gompertz model
2	1.186	1.29	
3	1.971	2.06	
4	2.854	2.99	
5	3.734	3.65	R^2=0.9962
6	4.541	4.61	
7	5.236	5.41	SE=15316
8	5.807	5.91	
9	6.261	6.29	MPE =0.078329
10	6.613	6.55	
11	6.882	6.92	SD =0.10077
15	7.429		
20	7.607		Y=7.654*exp (-3.524*exp (-0.3183*X))
25	7.644		
30	7.652		
35	7.653		
40	7.653		
45	7.653		
50	7.653		

T_{18}-*Inga dulce*

Age (years)	Estimated values	Observed values	Growth model
1	0.492	0.810	Gompertz model
2	1.074	1.260	
3	1.868	1.910	
4	2.768	2.550	
5	3.659	3.620	R^2=0.9931
6	4.461	4.510	
7	5.134	5.230	SE=0.29147
8	5.672	5.710	
9	6.089	6.020	MPE =0.02059
10	6.402	6.310	
11	6.635	6.550	SD =0.14686
15	7.081		
20	7.210		Y=7.239*exp (-3.789*exp (-0.3429*X))
25	7.234		
30	7.238		
35	7.239		
40	7.239		
45	7.239		
50	7.239		

T_{19}-*Peltoferrum ferrugeneum*

Age (years)	Estimated values	Observed values	Growth model
1	0.762	0.77	Gompertz model
2	1.295	1.36	
3	1.921	2.09	
4	2.574	2.68	
5	3.199	3.21	R^2=0.99783
6	3.760	3.55	
7	4.240	4.19	SE=0.04753
8	4.635	4.56	
9	4.952	4.99	MPE =0.02788
10	5.202	5.38	
11	5.396	5.47	SD =0.112312
15	5.807		
20	5.953		Y=5.9972*exp (-2.776*exp (-0.2972*X))
25	5.987		
30	5.994		
35	5.996		
40	5.997		
45	5.997		
50	5.997		

T_{20}-*Pongamia pinnata*

Age (years)	Estimated values	Observed values	Growth model
1	0.737	0.810	Exponential model
2	1.321	1.370	
3	1.958	1.880	
4	2.600	2.560	
5	3.221	3.310	R^2=0.9987
6	3.807	3.910	
7	4.355	4.490	SE=0.7327
8	4.862	5.010	
9	5.331	5.540	MPE =-0.56951
10	5.764	5.880	
11	6.163	6.010	SD =0.10793
15	7.485		
20	8.683		Y=14.884*exp (-12.477/(3.1516+X))
25	9.555		
30	10.216		
35	10.732		
40	11.147		
45	11.486		
50	11.770		

T_{21}-*Prosopsis juliflora*

Age (years)	Estimated values	Observed values	Growth model
1	0.709	0.81	Gompertz model
2	1.379	2.06	
3	2.209	3.11	
4	3.085	4.32	
5	3.908	5.61	R^2=0.9989
6	4.620	6.61	
7	5.202	7.35	SE=0.1074
8	5.658	8.26	
9	6.005	8.76	MPE =-0.0217
10	6.263	8.9	
11	6.453	9.13	SD =0.1160
15	6.813		
20	6.916		Y=6.939*exp (-3.221*exp (-0.3449*X))
25	6.934		
30	6.938		
35	6.938		
40	6.938		
45	6.938		
50	6.938		

T_{22}-*Samanea saman*

Age (years)	Estimated values	Observed values	Growth model
1	0.802	1.01	Gompertz model
2	1.403	1.56	
3	2.145	2.38	
4	2.960	2.99	
5	3.779	3.76	R^2=0.9982
6	4.550	4.61	
7	5.238	5.38	SE=0.10406
8	5.828	5.99	
9	6.320	6.41	MPE =0.102446
10	6.721	6.82	
11	7.043	7.01	SD =0.08791
15	7.769		
20	8.058		Y=8.158*exp (-3.0564*exp (-0.2759*X))
25	8.132		
30	8.151		
35	8.156		
40	8.157		
45	8.157		
50	8.157		

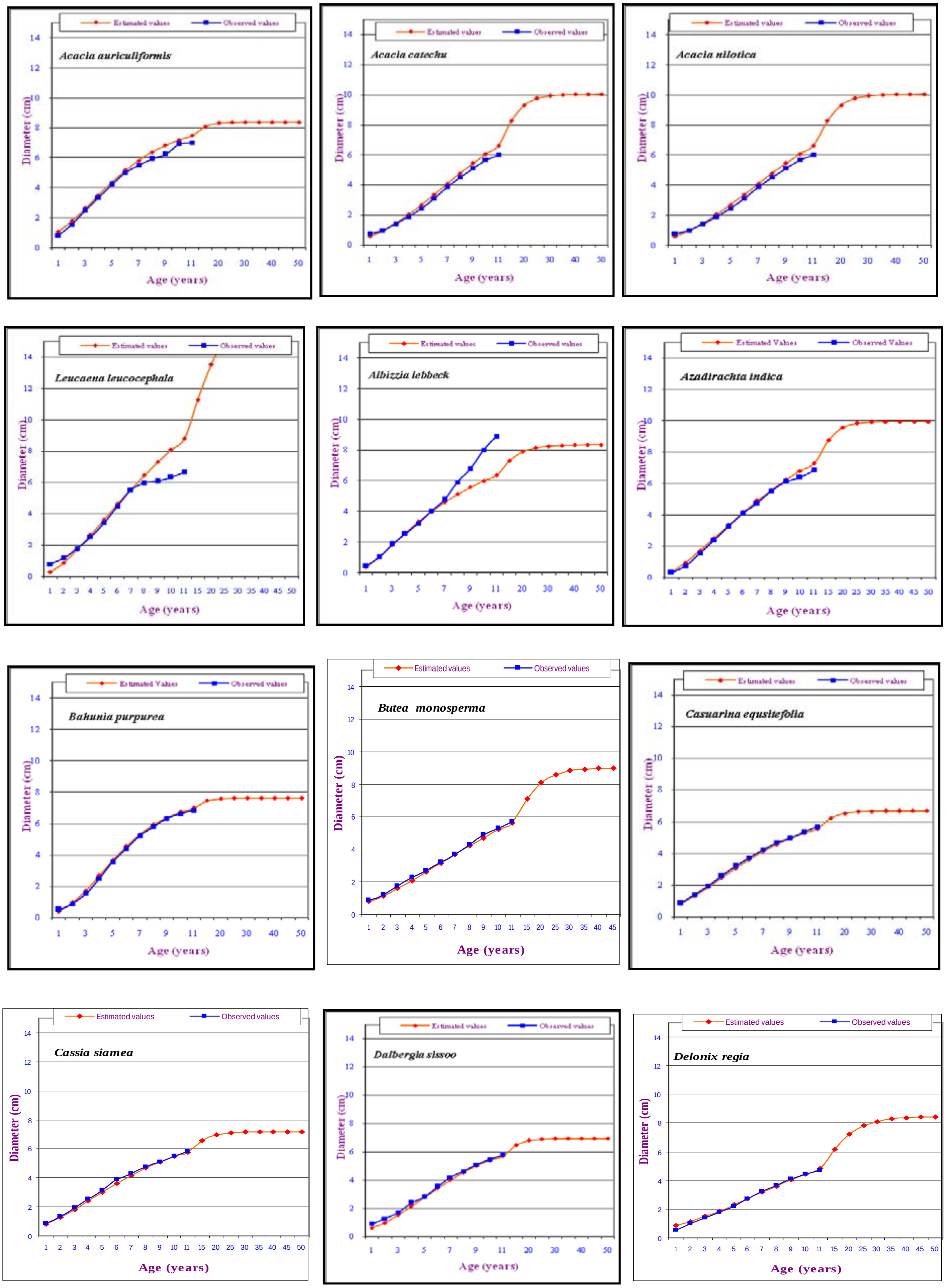
T_{23}-*Syzygium cumini*

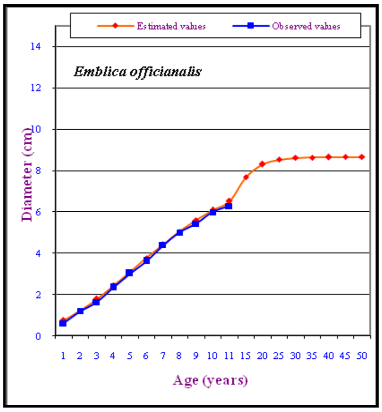
Age (years)	Estimated values	Observed values	Growth model
1	0.736	0.830	Gompertz model
2	1.111	1.210	
3	1.546	1.620	
4	2.014	2.110	
5	2.491	2.560	R^2=0.9976
6	2.952	2.990	
7	3.384	3.420	SE=0.07545
8	3.774	3.810	
9	4.120	4.280	MPE =0.056182
10	4.419	4.460	
11	4.675	4.550	SD =0.07098
15	5.342		
20	5.688		Y=5.8668*exp (-2.591*exp (0.2213*X))
25	5.807		
30	5.847		
35	5.860		
40	5.865		
45	5.866		
50	5.867		

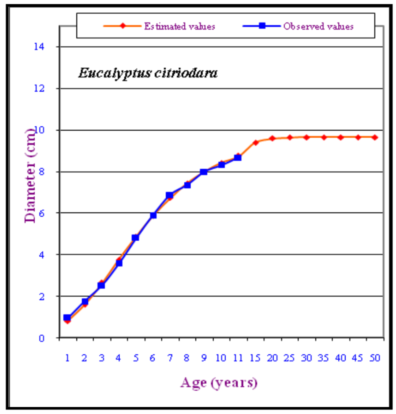
T_{24}-*Tamarindus indica*

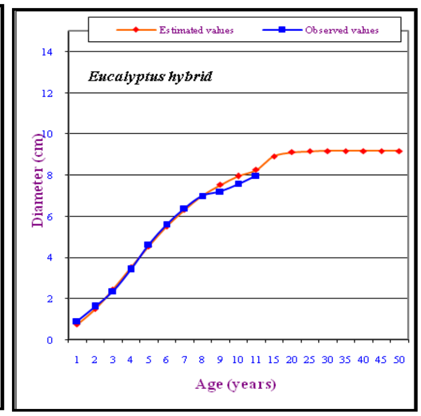
Age (years)	Estimated values	Observed values	Growth model
1	0.893	0.760	Gompertz model
2	1.262	1.560	
3	1.683	2.280	
4	2.137	2.970	
5	2.606	3.310	R^2=0.9953
6	3.073	3.760	
7	3.524	4.010	SE=0.1082
8	3.949	4.420	
9	4.341	4.790	MPE =0.46213
10	4.695	5.010	
11	5.012	5.390	SD=0.25991
15	5.927		
20	6.500		Y=6.904*exp (-2.46*exp (-0.185*X))
25	6.741		
30	6.840		
35	6.879		
40	6.894		
45	6.900		
50	6.903		

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




Estimated values
Observed values
Emblica officianalis
Diameter (cm)
Age (years)


Estimated values
Observed values
Eucalyptus citriodara
Diameter (cm)
Age (years)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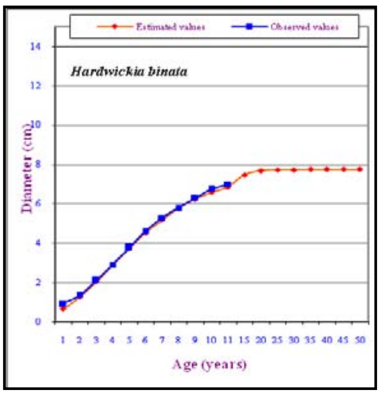
Observed values
Eucalyptus hybrid
Diameter (cm)
Age (years)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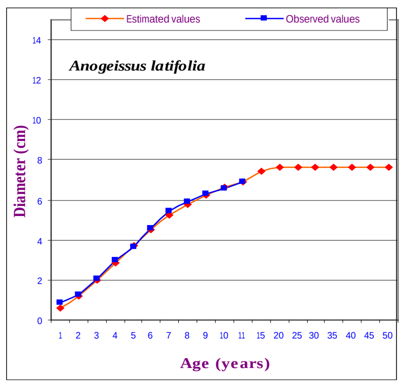
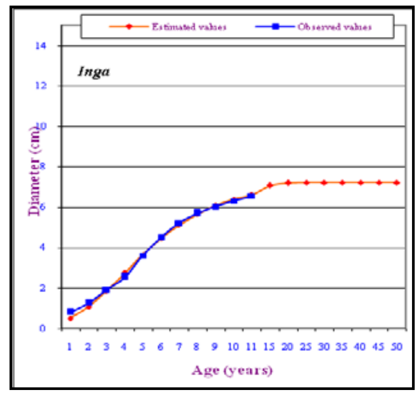
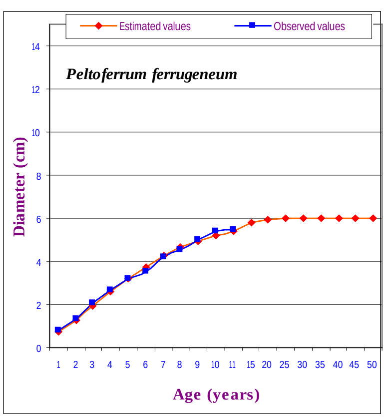
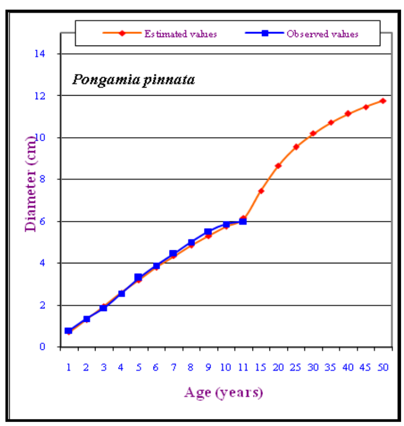
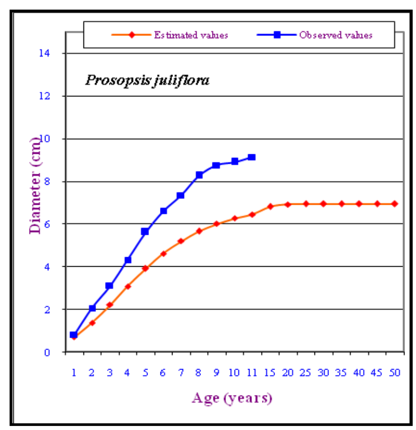
Hardwickia binata
Diameter (cm)
Age (years)

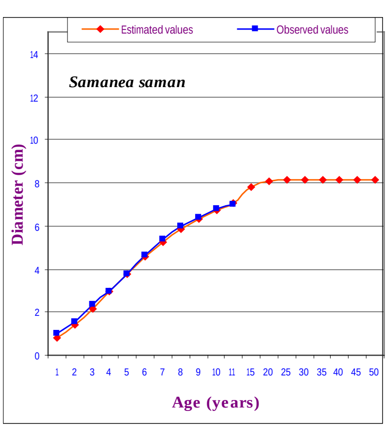

Estimated values
Observed values
Anogeissus latifolia
Diameter (cm)
Age (years)

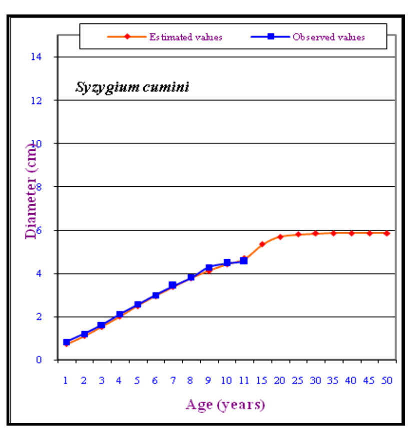

Estimated values
Observed values
Inga
Diameter (cm)
Age (years)

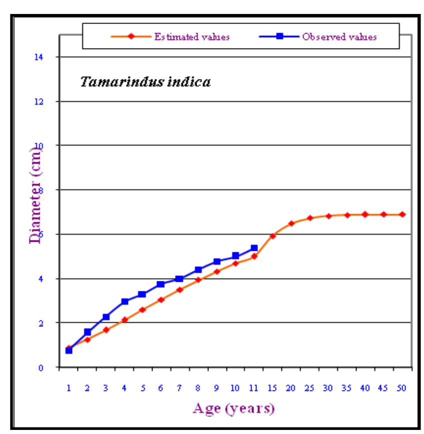

Estimated values
Observed values
Peltoferrum ferrugeneum
Diameter (cm)
Age (years)


Estimated values
Observed values
Pongamia pinnata
Diameter (cm)
Age (years)


Estimated values
Observed values
Prosopsis juliflora
Diameter (cm)
Age (years)


Estimated values
Observed values
Samanea saman
Diameter (cm)
Age (years)


Estimated values
Observed values
Syzygium cumini
Diameter (cm)
Age (years)


Estimated values
Observed values
Tamarindus indica
Diameter (cm)
Age (years)

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