VOLUME ESTIMATION OF *Azadirachta indica* A. JUSS., *Berrya cordifolia* (WILD.) BURRET SYN. AND *Chloroxylon swietenia* DC. IN THE DRY ZONE OF SRI LANKA

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Summary

Volume estimation for locally available timber species is not readily available. Therefore developing volume tables are very useful for the land owners, timber merchants and to the officers who are involved in the legal procedures of felling. Therefore a study was undertaken to estimate the merchantable timber volume of three dry zone timber species Azadirachta indica, Berrya cordifolia *and* Chloroxylon swietenia.

Data were collected from the Range Forest Offices in Kurunegala District of Sri Lanka on the information based on trees felled in that district. After removing the outliers 334 observations for Azadirachta indica, *365 observations for* Berrya *cordifolia and 356 observations for* Chloroxylon swietenia *were considered for final volume estimation. A number of non-linear models were used to identify the best fitted model for volume estimation using STATISTICA software. Coefficient of determination (R^2) and residual plots were used to identify the appropriate model. Linearized of Schumacher model was found to be the best model for estimating the merchantable volume of* Chloroxylon swietenia, Berrya cordifolia *and* Azadirachta indica *grown in the dry zone of Sri Lanka.*

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INTRODUCTION

Timber is an integral part of the lives of Sri Lankan people as their livelihoods are predominantly based on agriculture. With the increase of living standards, use of timber is expected to rise as in other countries. Population growth, coupled with industrial development will result in increasing demand for forest-based products. Population in Sri Lanka is still growing at a rate of 1.1% (Central Bank of Sri Lanka, 2006). In the meantime, sources of wood supply have been shrunk due to the ban on exploitation of natural forests for timber due to the strong lobby from environmentalists (Chokkalingam & Vanniarachchy 2011). According to the Forestry Sector Master Plan prepared in 1995, the gap between the demand and sustainable supply of round wood will continue to grow. Shrinking of sources of timber supply and the increasing demand has lead people to change their attitude towards maximizing the usage of this scarce resource. Therefore, accurate estimation of timber volumes has become very important in present day context.

At present major contributors to wood supply in Sri Lanka are homesteads, rubber and forest plantations and they account for 42, 18 and 11 percent respectively (FAO 2009).There are more than 400 different woody species in homegardens (Ariyadasa 2002). However, widely used timber species differ between climatic zones of Sri Lanka. Among them *Azadirachta indica* A. Juss., *Berrya cordifolia* (Wild.) Burret syn. and *Chloroxylon swietenia* DC are very popular timber species in dry zone of Sri Lanka.

Azadirachta indica, Berrya cordifolia and *Chloroxylon swietenia* are major timber species which fulfill the requirements in the dry zone of Sri Lanka in addition to *Tectona grandis* which is grown predominantly in plantations. *Chloroxylon swietenia* is well known as Buruta (in Sinhala), Muthirai (in Tamil) and Satin wood (in English). It is a light demanding, large but very slow growing deciduous tree. This species is easily recognized by its spreading, light feathery crown with glaucous green, pinnate aromatic leaves (Koelmeyer 1954). It can grow upto 30 m in height and 0.5-0.7 m dbh. It is mainly distributed in the natural forests of dry zone where South-west monsoon is absent. However recent generations are willing to have it in their homegardens for various reasons. Timber from this tree is considered as 'Luxury Grade' by the State Timber Corporation (STC). Sapwood grayish or yellowish-white in colour, heartwood cream to golden-yellow colour having a fine satiny luster and silver grain on the radial face (Fernando 1959). Modulus of elasticity (poundals per sg. inch) (Nm^{-2}) and extreme fiber strength in bending and tension along grain (poundals per sg. inch) (Nm^{-2}) is 53.13×10^6 and 80,500 respectively (Seneviratne 1981). Wood is very strong and hard, generally immune to borer or termite attack.

Berrya cordifolia is also a popular tree species among the people in the dry zone. This is also known as Halmilla (in Sinhala), Savandallai (in Tamil) and Trincomalee wood (in English) and it is native to Sri Lanka. STC has classified it into the timber class 'luxury grade'. It is a deciduous tree, can grow upto the height of 18-27 m and dbh of 0.6-0.8 m. The stem is cylindrical or slightly fluted bole, free of branches up to 9-11 m with a restricted, rounded crown of apple green (Koelmeyer 1953). The sapwood is brownish white, the heartwood is dark red to brown with darker lines which often from partridge mottlings on the tangential face. Modulus of elasticity (poundals per sg. inch) (Nm^{-2}) and extreme fiber strength in bending and tension along grain (poundals per sg. inch) (Nm^{-2}) is 61.18 x 10^6 and 86,940 respectively (Seneviratne 1981). Since it is a very hard wood (1,040 kg/m^3), it has been used for ship building. Due to its hardness, it has been used as tool-handles, ploughs, draught-poles and other agricultural implements (Basta, 1988).

Azadirachta indica is called as Kohomba, Vembu and Neem locally, and widely distributed in the dry zone especially in the North and East of Sri Lanka. According to STC, timber is categorized as special grade. Also timber of this tree has been considered as holy in Hinduism and most of the believers design their 'Pooja' room door with neem timber. In addition, it has been identified as a popular garden and roadside tree in these regions. Sapwood yellowish white in colour and heartwood dark red when exposed fading to reddish brown, resembles mahogany (Goonewardene, 1959). Since this tree has a repellent to the insects, the timber is preferred by most of the people. Tree could grow upto 7-8 m in height and 0.8-1 m in dbh (Pearson and Brown, 1981). Since it keep off moths and other insects, it has different uses in the timber industry mainly with furniture.

METHODOLOGY

The data were collected from the Range Forest Offices in Kurunegala District. These data were gathered from the people of the Kurunegalla District who have come to obtain the transport permit. For a particular tree, number of logs, mid-girth of each log and log length were recorded. From this information volume for each log were calculated and then added to get the total merchantable volume for each tree separately. Then the outliers were removed from all three data and further used for statistical model fitting. Diameter at breast height (dbh), merchantable tree height and volume of the respective trees were used to identify appropriated model for *Chloroxylon swietenia*, *Berrya cordifolia* and *Azadirachta indica* using STATISTICA software (StatSoft, 1995). A number of non-linear models commonly used for other species have been tested. Normal probability plot and frequency distribution of residual plots of fitted models were used to identify the most appropriate model to estimate merchantable timber volume of *Chloroxylon swietenia*, *Berrya cordifolia* and *Azadirachta indica*.

RESULTS AND DISCUSSION

Different non-linear models which have been used to develop the volume tables for *Michelia champaca* and *Toona ciliata* (Sivananthawerl and Premakantha 2011) have also been used to get the best fit. Table 1 shows ten different

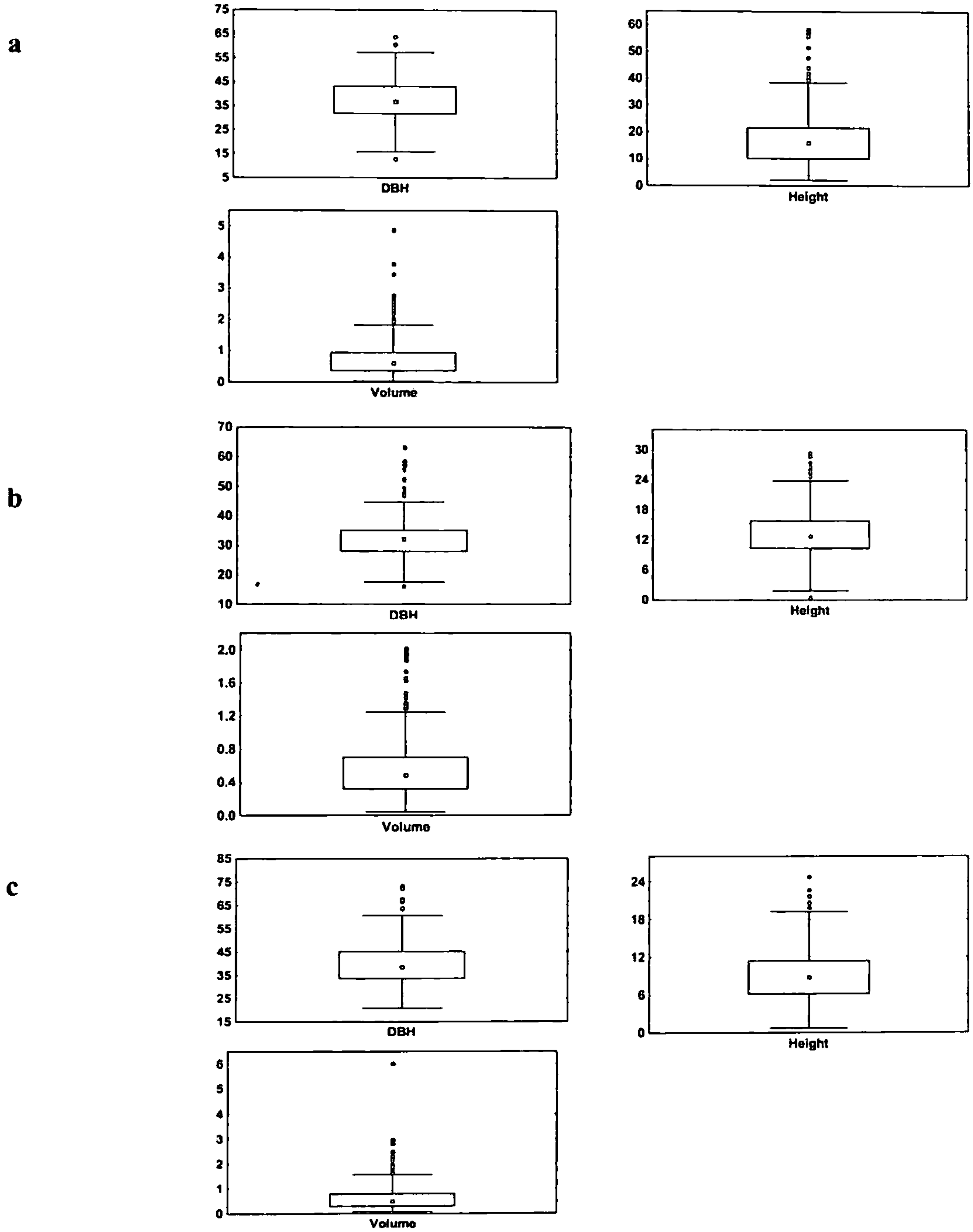


Figure 1: Outliers presented with the Box and Whisker plot for dbh, height and volume; a: *Chloroxylon swietenia* b: *Berrya cordifolia* c: *Azadirachta indica*

models with the fitted coefficient of determination (R^2) values for *Chloroxylon swietenia*, *Berrya cordifolia* and *Azadirachta indica*. When comparing the R^2 values for *Chloroxylon swietenia*, the high R^2 (0.82) was observed when using model F3, F4, F5, F6 and F8, where model F7 (Linearized of Schumacher) showed the highest value of 0.88. Since these six models having the high R^2 value, various plots of residuals for each of these six models were formulated to identify the most suitable model to estimate standing timber volume of *Chloroxylon swietenia*.

Among the models used, *Berrya cordifolia* showed a R^2 value of 0.63 for the models F3, F5, and F8, whereas model F7 showed the highest values of 0.76. Similarly for *Azadirachta indica* F3, F4, F5, F6, F8, and F9 showed a R^2 value of 0.72 whereas in the other species F7 showed the highest R^2 value as 0.79. To select the most fitted model, different residual plots were used.

In addition to the r^2 value, residual plots were used to select the most suitable model. Figure 2 shows the residual plot analysis for *Chloroxylon swietenia*.

According to figure 2, model F7 showed no pattern in the residual values with its predicted values, where all the other five models (F3, F4, F5, F6 & F8) behaved differently i.e. the variance of the residual had increased with the increase of the predicted value.

By considering the r^2 values and the residual plots, residual plot of model F7 found to be more scattered than the rest of the models tested. Therefore, this could be the most suitable model for *Chloroxylon swietenia*.

After examining the residual values for *Berrya* cordifolia in figure 3, similar to *Chloroxylon swietenia*, model F7 showed scattered nature of the residual values with its predicted values and rest of the models (F3, F4, F5, F6 & F8) showed increase in the residual variance with the increase of the predicted value.

Azadirachta indica also showed similar results as in the *Berrya* cordifolia and *Chloroxylon swietenia* i.e. model F7 showed scattered nature of the residual values with its predicted values (figure 4).

Therefore, for all three species, *Chloroxylon swietenia*, *Berrya* cordifolia, and *Azadirachta indica*, the linearized of Schumacher model (F7) was found to be the most best fitted model with respect to r^2 value and the residual plot analysis. The parameter estimates for the best fitted model (F7) were given in Table 2. The standing tree volume of *Chloroxylon swietenia*, *Berrya* cordifolia, and *Azadirachta indica*, could be estimated using F7 model. The error in estimating the volume could range ± 2-4

Table 1: Models with respective coefficient of determination (R^2) for *Chloroxylon swietenia, Berrya cordifolia* and *Azadirachta indica*

Model	R^2		
	Chloroxylon swietenia	*Berrya cordifolia*	*Azadirachta indica*
F 1: Forest Department (1996) $v = a \times dbh^b + c \times ht^d$	76	60	71
F 2: Forest Department (1996) $v = \left[a + \frac{b}{\pi \times dbh}\right] \times \left[\frac{\pi \times dbh^2 \times ht}{40000}\right]$	80	60	71
F 3: Forest Department (1996) $v = a \times dbh^b \times ht^c (1 - d \times dbh^e)$	82	63	72
F 4: Forest Department (1996) $v = \exp[a + b \times \ln(dbh) + c \times \ln(ht)]$	82	62	72
F 5: Forest Department (1996) $v = \left[a - \frac{b}{dbh^2}\right] \times \exp^{[c + d \times \ln(dbh) + e \times \ln(ht)]}$	82	63	72
F 6: Schumacher & Hall (1933) $v = a \times dbh^b \times ht^c$	82	62	72
F 7: Linearized of Schumacher (1933) $\ln v = a + b \times \ln(dbh) + c \times \ln(ht)$	88	76	79
F 8: Scott (1981) $v = a + b \times dbh^c + d \times dbh^e \times ht^f$	82	63	72
F 9: Stoate (1945) $v = a \times dbh^2 + b \times ht + c \times dbh^2 \times ht$	81	61	72
F 10: Böckmann & Kramer (1990) $v = a \times [b \times dbh^2 \times ht + c \times dbh \times ht + d \times ht]^e$	67	48	56
Sample size (N)	356	365	334

Where v = volume, dbh = diameter at breast height, ht= merchantable height, a, b, c, d, e & f = model parameters

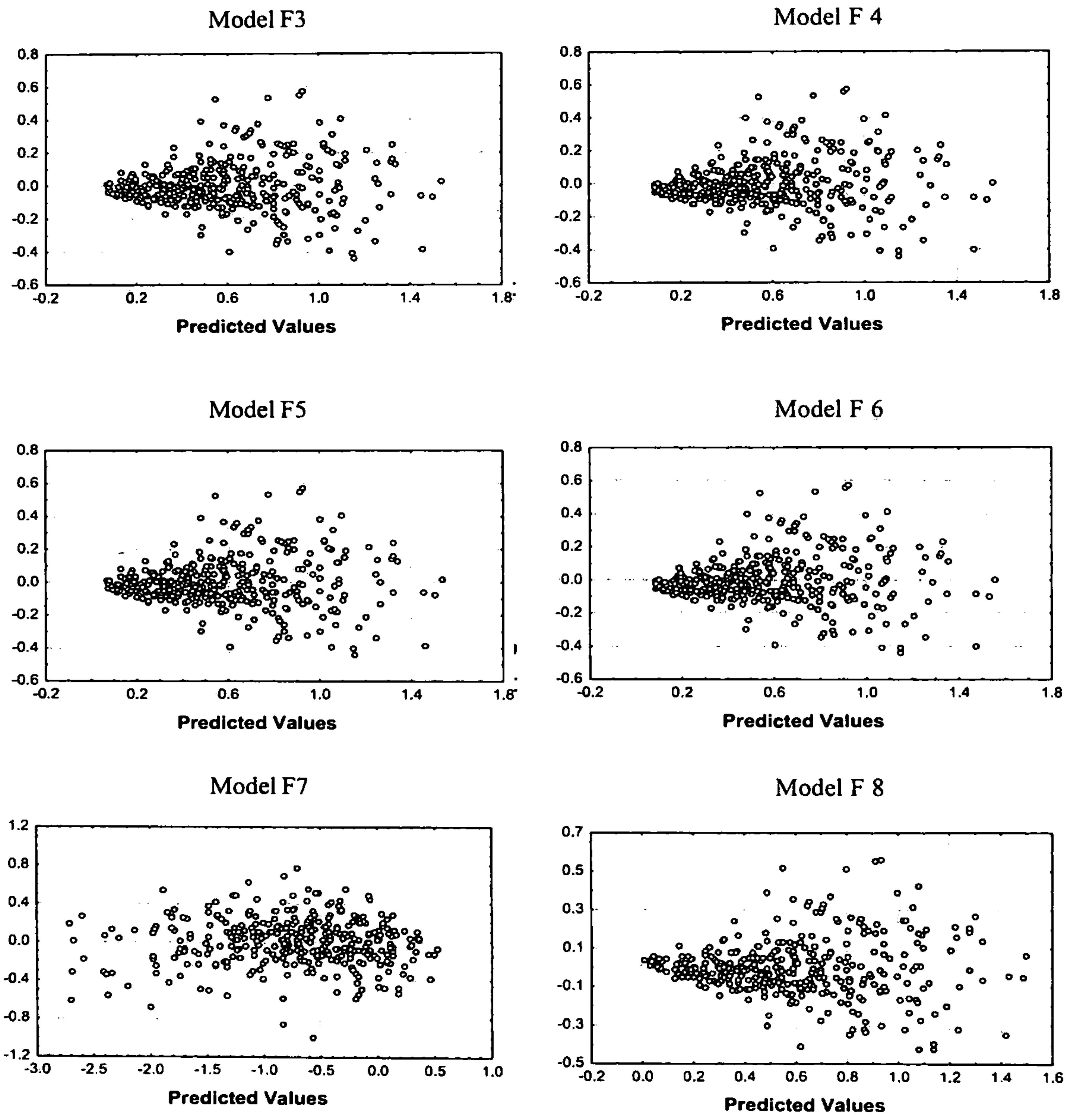


Figure 2: Predicted versus Residual Values of *Chloroxylon swietenia* for Best Fitted Models (F3-F8)

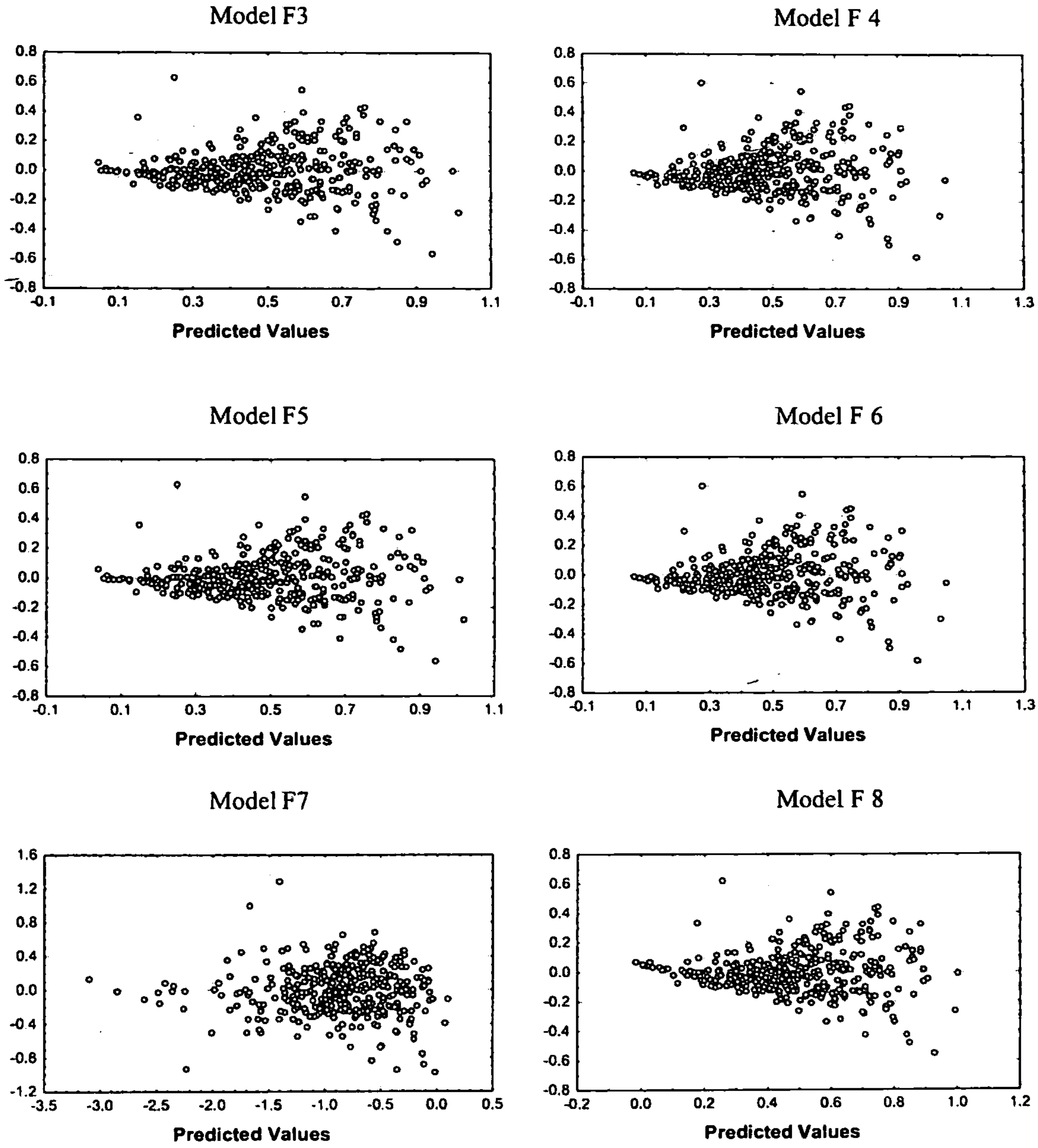
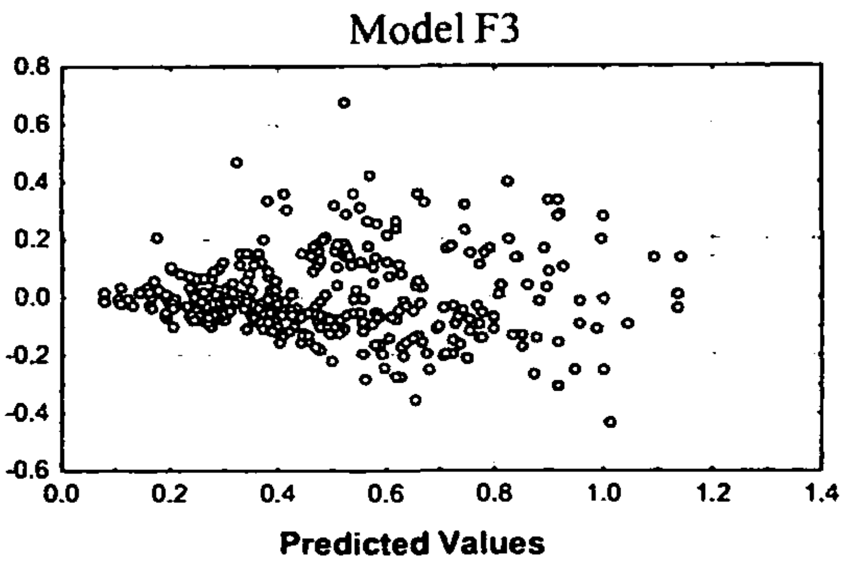
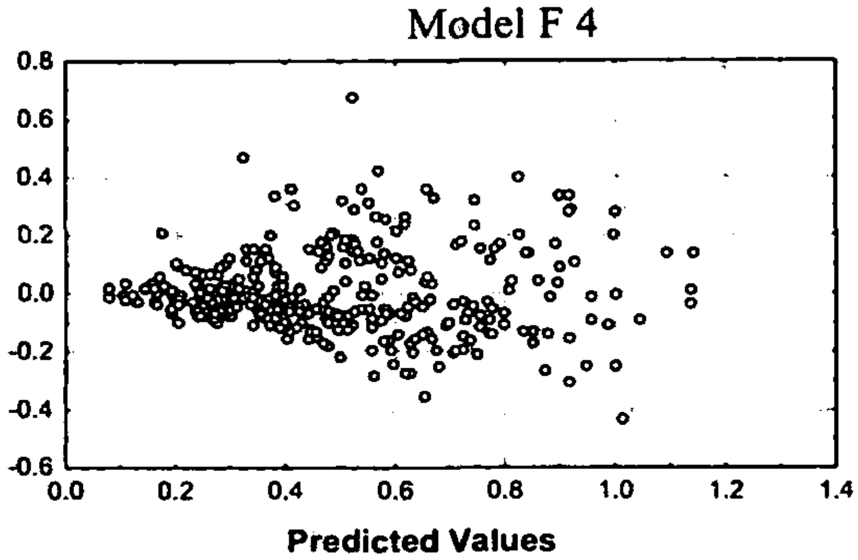
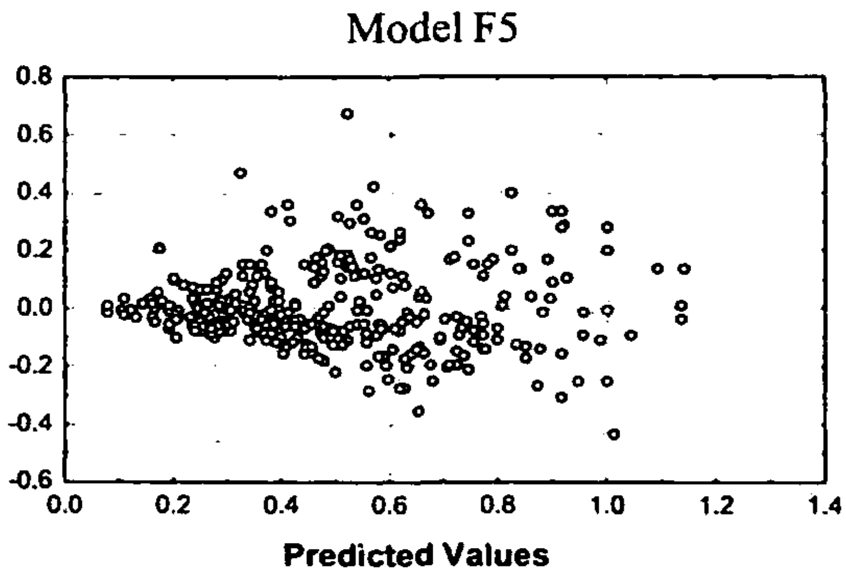
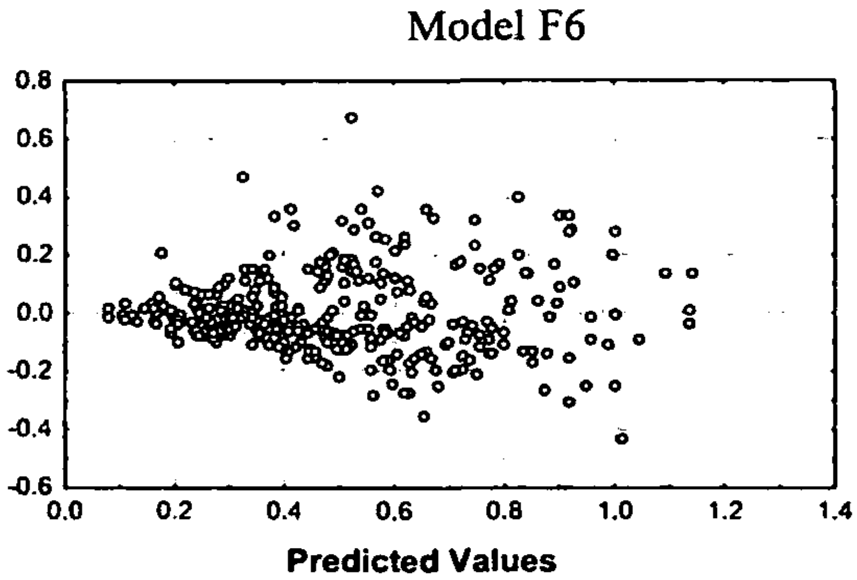


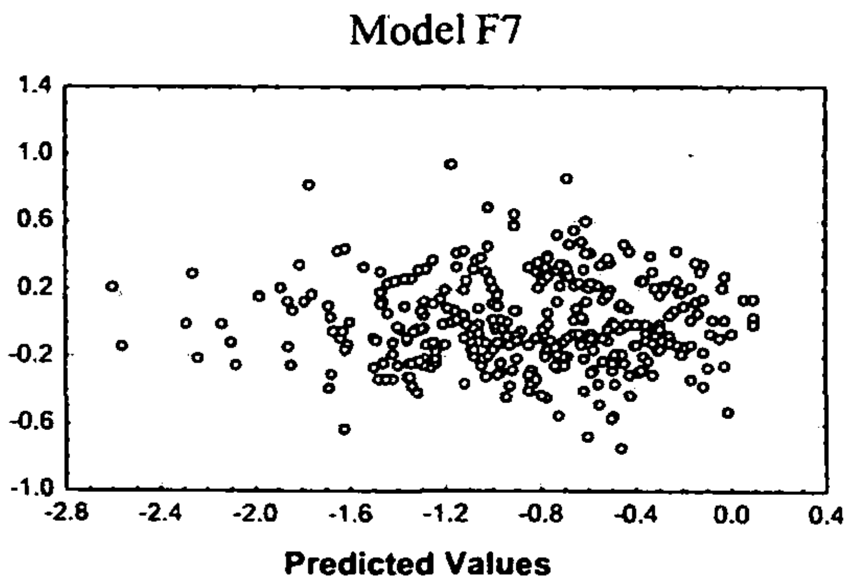
Figure 3: Predicted versus Residual Values of *Berrya cordifolia* for Best Fitted Models (F3-F8)

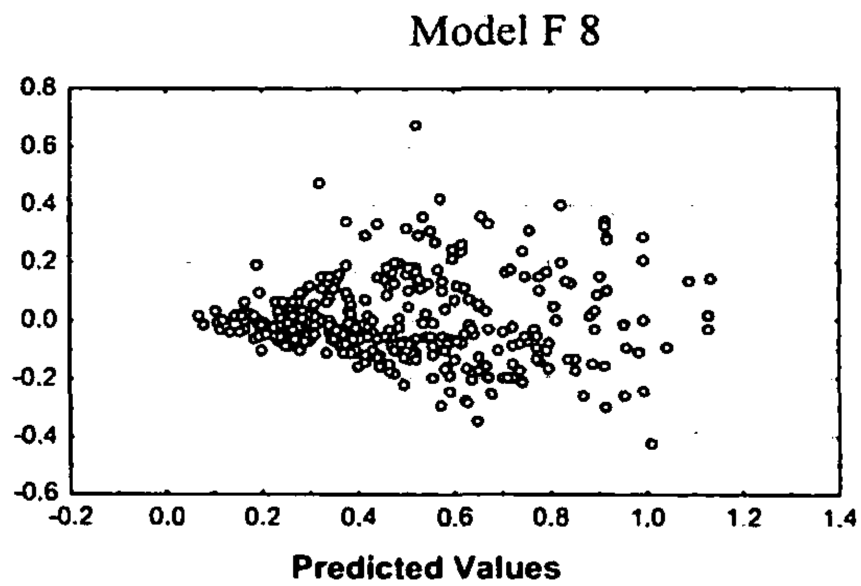












Model F9

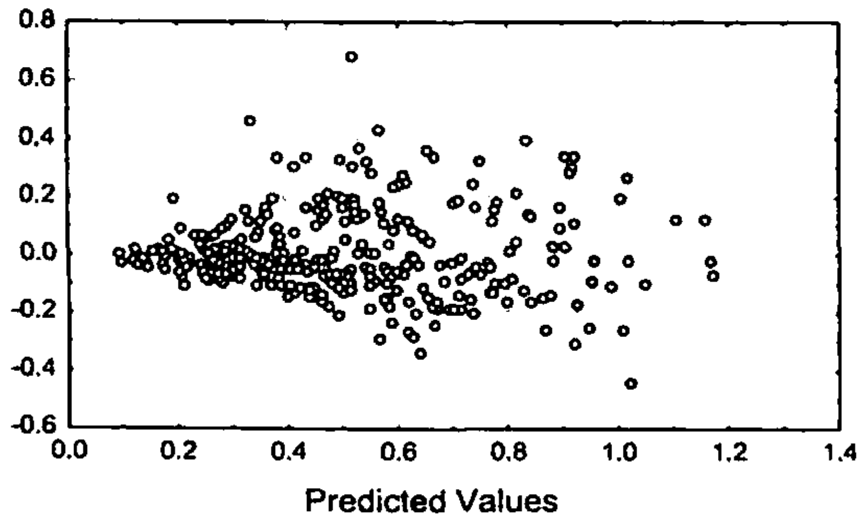


Figure 4: Predicted versus Residual Values of *Azadirachta indica* for Best Fitted Models (F3-F9)

Table 2:Estimated parameter values for the best fitted model.

Parameters	Estimates		
	Chloroxylon swietenia	Berrya cordifolia	Azadirachta indica
A	-6.933070	-8.097910	-7.091150
B	1.125880	1.482923	1.252025
C	0.829166	0.868598	0.816379

CONCLUSION

The merchantable volume of *Chloroxylon swietenia, Berrya cordifolia* and *Azadirachta indica* could be estimated using following 'Linearized of Schumacher' models respectively.

$$\ln v = -6.933070 + 1.125880 \times \ln(dbh) + 0.829166 \times \ln(ht)$$ - for *Chloroxylon swietenia*

$$\ln v = -8.097910 + 1.482923 \times \ln(dbh) + 0.868598 \times \ln(ht)$$ - for *Berrya cordifolia*

$$\ln v = -7.091150 + 1.252025 \times \ln(dbh) + 0.816379 \times \ln(ht)$$ - for *Azadirachta indica*

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Annex 1: Merchantable Volume Table of *Chloroxylon swietenia*

$$[\ln v = -6.933070 + 1.125880 \times \ln(dbh) + 0.829166 \times \ln(ht)]$$

DBH [cm]	Merchantable Height [m]										
	2	3	4	5	6	7	8	9	10	11	12
15	0.037	0.051	0.065	0.078	0.091	0.103	0.115	0.127	0.139	0.150	0.161
16	0.039	0.055	0.070	0.084	0.098	0.111	0.124	0.137	0.149	0.162	0.174
17	0.042	0.059	0.075	0.090	0.105	0.119	0.133	0.146	0.160	0.173	0.186
18	0.045	0.063	0.080	0.096	0.112	0.127	0.142	0.156	0.170	0.184	0.198
19	0.048	0.067	0.085	0.102	0.119	0.135	0.151	0.166	0.181	0.196	0.211
20	0.051	0.071	0.090	0.108	0.126	0.143	0.159	0.176	0.192	0.208	0.223
21	0.053	0.075	0.095	0.114	0.133	0.151	0.168	0.186	0.203	0.219	0.236
22	0.056	0.079	0.100	0.120	0.140	0.159	0.178	0.196	0.214	0.231	0.248
23	0.059	0.083	0.105	0.126	0.147	0.167	0.187	0.206	0.225	0.243	0.261
24	0.062	0.087	0.110	0.133	0.154	0.175	0.196	0.216	0.236	0.255	0.274
25	0.065	0.091	0.115	0.139	0.161	0.184	0.205	0.226	0.247	0.267	0.287
26	0.068	0.095	0.121	0.145	0.169	0.192	0.214	0.236	0.258	0.279	0.300
27	0.071	0.099	0.126	0.151	0.176	0.200	0.224	0.246	0.269	0.291	0.313
28	0.074	0.103	0.131	0.158	0.183	0.208	0.233	0.257	0.280	0.303	0.326
29	0.077	0.107	0.136	0.164	0.191	0.217	0.242	0.267	0.292	0.315	0.339
30	0.080	0.112	0.142	0.170	0.198	0.225	0.252	0.278	0.303	0.328	0.352
31	0.083	0.116	0.147	0.177	0.206	0.234	0.261	0.288	0.314	0.340	0.366
32	0.086	0.120	0.152	0.183	0.213	0.242	0.271	0.298	0.326	0.352	0.379
33	0.089	0.124	0.158	0.190	0.221	0.251	0.280	0.309	0.337	0.365	0.392
34	0.092	0.128	0.163	0.196	0.228	0.259	0.290	0.320	0.349	0.377	0.406
35	0.095	0.133	0.169	0.203	0.236	0.268	0.299	0.330	0.360	0.390	0.419
36	0.098	0.137	0.174	0.209	0.243	0.277	0.309	0.341	0.372	0.402	0.433
37	0.101	0.141	0.179	0.216	0.251	0.285	0.319	0.351	0.384	0.415	0.446
38	0.104	0.146	0.185	0.222	0.259	0.294	0.328	0.362	0.395	0.428	0.460
39	0.107	0.150	0.190	0.229	0.266	0.303	0.338	0.373	0.407	0.440	0.473
40	0.110	0.154	0.196	0.236	0.274	0.312	0.348	0.384	0.419	0.453	0.487
41	0.113	0.159	0.201	0.242	0.282	0.320	0.358	0.394	0.430	0.466	0.501
42	0.116	0.163	0.207	0.249	0.290	0.329	0.368	0.405	0.442	0.479	0.515
43	0.120	0.167	0.212	0.256	0.297	0.338	0.377	0.416	0.454	0.492	0.528
44	0.123	0.172	0.218	0.262	0.305	0.347	0.387	0.427	0.466	0.504	0.542
45	0.037	0.051	0.065	0.078	0.091	0.103	0.115	0.127	0.139	0.150	0.161
46	0.039	0.055	0.070	0.084	0.098	0.111	0.124	0.137	0.149	0.162	0.174
47	0.042	0.059	0.075	0.090	0.105	0.119	0.133	0.146	0.160	0.173	0.186
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49	0.048	0.067	0.085	0.102	0.119	0.135	0.151	0.166	0.181	0.196	0.211
50	0.051	0.071	0.090	0.108	0.126	0.143	0.159	0.176	0.192	0.208	0.223
51	0.053	0.075	0.095	0.114	0.133	0.151	0.168	0.186	0.203	0.219	0.236
52	0.056	0.079	0.100	0.120	0.140	0.159	0.178	0.196	0.214	0.231	0.248
53	0.059	0.083	0.105	0.126	0.147	0.167	0.187	0.206	0.225	0.243	0.261
54	0.062	0.087	0.110	0.133	0.154	0.175	0.196	0.216	0.236	0.255	0.274
55	0.065	0.091	0.115	0.139	0.161	0.184	0.205	0.226	0.247	0.267	0.287

13	14	15	16	17	18	19	20	21	22	23	24	25
0.172	0.183	0.194	0.205	0.215	0.226	0.236	0.247	0.257	0.267	0.277	0.287	0.297
0.186	0.197	0.209	0.220	0.232	0.243	0.254	0.265	0.276	0.287	0.298	0.308	0.319
0.199	0.211	0.224	0.236	0.248	0.260	0.272	0.284	0.296	0.307	0.319	0.330	0.342
0.212	0.225	0.238	0.252	0.265	0.277	0.290	0.303	0.315	0.328	0.340	0.352	0.364
0.225	0.239	0.253	0.267	0.281	0.295	0.308	0.322	0.335	0.348	0.361	0.374	0.387
0.238	0.254	0.269	0.283	0.298	0.312	0.327	0.341	0.355	0.369	0.383	0.396	0.410
0.252	0.268	0.284	0.299	0.315	0.330	0.345	0.360	0.375	0.390	0.404	0.419	0.433
0.265	0.282	0.299	0.315	0.332	0.348	0.364	0.379	0.395	0.411	0.426	0.441	0.457
0.279	0.297	0.314	0.332	0.349	0.366	0.382	0.399	0.415	0.432	0.448	0.464	0.480
0.293	0.311	0.330	0.348	0.366	0.384	0.401	0.419	0.436	0.453	0.470	0.487	0.504
0.307	0.326	0.345	0.364	0.383	0.402	0.420	0.438	0.456	0.474	0.492	0.510	0.527
0.320	0.341	0.361	0.381	0.400	0.420	0.439	0.458	0.477	0.496	0.514	0.533	0.551
0.334	0.356	0.376	0.397	0.418	0.438	0.458	0.478	0.498	0.517	0.537	0.556	0.575
0.348	0.370	0.392	0.414	0.435	0.456	0.477	0.498	0.518	0.539	0.559	0.579	0.599
0.362	0.385	0.408	0.430	0.453	0.475	0.496	0.518	0.539	0.561	0.582	0.602	0.623
0.376	0.400	0.424	0.447	0.470	0.493	0.516	0.538	0.560	0.582	0.604	0.626	0.647
0.391	0.415	0.440	0.464	0.488	0.512	0.535	0.558	0.581	0.604	0.627	0.649	0.672
0.405	0.430	0.456	0.481	0.506	0.530	0.555	0.579	0.603	0.626	0.650	0.673	0.696
0.419	0.446	0.472	0.498	0.524	0.549	0.574	0.599	0.624	0.648	0.673	0.697	0.721
0.433	0.461	0.488	0.515	0.541	0.568	0.594	0.619	0.645	0.670	0.696	0.721	0.745
0.448	0.476	0.504	0.532	0.559	0.587	0.613	0.640	0.666	0.693	0.719	0.745	0.770
0.462	0.492	0.520	0.549	0.577	0.605	0.633	0.661	0.688	0.715	0.742	0.768	0.795
0.477	0.507	0.537	0.566	0.595	0.624	0.653	0.681	0.709	0.737	0.765	0.793	0.820
0.491	0.522	0.553	0.584	0.614	0.643	0.673	0.702	0.731	0.760	0.788	0.817	0.845
0.506	0.538	0.570	0.601	0.632	0.662	0.693	0.723	0.753	0.782	0.812	0.841	0.870
0.520	0.553	0.586	0.618	0.650	0.682	0.713	0.744	0.775	0.805	0.835	0.865	0.895
0.535	0.569	0.603	0.636	0.668	0.701	0.733	0.765	0.796	0.828	0.859	0.890	0.920
0.550	0.585	0.619	0.653	0.687	0.720	0.753	0.786	0.818	0.851	0.882	0.914	0.946
0.565	0.600	0.636	0.671	0.705	0.739	0.773	0.807	0.840	0.873	0.906	0.939	0.971
0.579	0.616	0.652	0.688	0.724	0.759	0.794	0.828	0.862	0.896	0.930	0.963	0.996
0.172	0.183	0.194	0.205	0.215	0.226	0.236	0.247	0.257	0.267	0.277	0.287	1.022
0.186	0.197	0.209	0.220	0.232	0.243	0.254	0.265	0.276	0.287	0.298	0.308	1.048
0.199	0.211	0.224	0.236	0.248	0.260	0.272	0.284	0.296	0.307	0.319	0.330	1.073
0.212	0.225	0.238	0.252	0.265	0.277	0.290	0.303	0.315	0.328	0.340	0.352	1.099
0.225	0.239	0.253	0.267	0.281	0.295	0.308	0.322	0.335	0.348	0.361	0.374	1.125
0.238	0.254	0.269	0.283	0.298	0.312	0.327	0.341	0.355	0.369	0.383	0.396	1.151
0.252	0.268	0.284	0.299	0.315	0.330	0.345	0.360	0.375	0.390	0.404	0.419	1.177
0.265	0.282	0.299	0.315	0.332	0.348	0.364	0.379	0.395	0.411	0.426	0.441	1.203
0.279	0.297	0.314	0.332	0.349	0.366	0.382	0.399	0.415	0.432	0.448	0.464	1.229
0.293	0.311	0.330	0.348	0.366	0.384	0.401	0.419	0.436	0.453	0.470	0.487	1.255
0.307	0.326	0.345	0.364	0.383	0.402	0.420	0.438	0.456	0.474	0.492	0.510	1.281

Merchantable Volume Table of *Berrya cordifolia*

$$[\ \ln v = -8.097910 + 1.482923 \times \ln(dbh) + 0.868598 \times \ln(ht)\ ]$$

DBH [cm]	Merchantable Height [m]										
	2	3	4	5	6	7	8	9	10	11	12
15	0.031	0.044	0.056	0.068	0.080	0.091	0.103	0.114	0.125	0.135	0.146
16	0.034	0.048	0.062	0.075	0.088	0.101	0.113	0.125	0.137	0.149	0.161
17	0.037	0.053	0.068	0.082	0.096	0.110	0.124	0.137	0.150	0.163	0.176
18	0.040	0.057	0.074	0.089	0.105	0.120	0.135	0.149	0.163	0.177	0.191
19	0.044	0.062	0.080	0.097	0.114	0.130	0.146	0.162	0.177	0.192	0.207
20	0.047	0.067	0.086	0.105	0.123	0.140	0.157	0.174	0.191	0.207	0.224
21	0.051	0.072	0.093	0.112	0.132	0.151	0.169	0.187	0.205	0.223	0.241
22	0.054	0.077	0.099	0.120	0.141	0.161	0.181	0.201	0.220	0.239	0.258
23	0.058	0.083	0.106	0.129	0.151	0.172	0.194	0.214	0.235	0.255	0.275
24	0.062	0.088	0.113	0.137	0.161	0.184	0.206	0.228	0.250	0.272	0.293
25	0.066	0.093	0.120	0.146	0.171	0.195	0.219	0.243	0.266	0.289	0.312
26	0.070	0.099	0.127	0.154	0.181	0.207	0.232	0.257	0.282	0.306	0.330
27	0.074	0.105	0.134	0.163	0.191	0.219	0.246	0.272	0.298	0.324	0.349
28	0.078	0.111	0.142	0.172	0.202	0.231	0.259	0.287	0.315	0.342	0.369
29	0.082	0.116	0.150	0.181	0.213	0.243	0.273	0.302	0.331	0.360	0.388
30	0.086	0.122	0.157	0.191	0.224	0.256	0.287	0.318	0.348	0.379	0.408
31	0.090	0.129	0.165	0.200	0.235	0.268	0.301	0.334	0.366	0.397	0.429
32	0.095	0.135	0.173	0.210	0.246	0.281	0.316	0.350	0.383	0.417	0.449
33	0.099	0.141	0.181	0.220	0.258	0.294	0.331	0.366	0.401	0.436	0.470
34	0.104	0.147	0.189	0.230	0.269	0.308	0.346	0.383	0.420	0.456	0.492
35	0.108	0.154	0.198	0.240	0.281	0.321	0.361	0.400	0.438	0.476	0.513
36	0.113	0.160	0.206	0.250	0.293	0.335	0.376	0.417	0.457	0.496	0.535
37	0.118	0.167	0.215	0.260	0.305	0.349	0.392	0.434	0.476	0.517	0.557
38	0.122	0.174	0.223	0.271	0.317	0.363	0.408	0.452	0.495	0.537	0.580
39	0.127	0.181	0.232	0.282	0.330	0.377	0.424	0.469	0.514	0.559	0.602
40	0.132	0.188	0.241	0.292	0.343	0.392	0.440	0.487	0.534	0.580	0.626
41	0.137	0.195	0.250	0.303	0.355	0.406	0.456	0.505	0.554	0.602	0.649
42	0.142	0.202	0.259	0.314	0.368	0.421	0.473	0.524	0.574	0.623	0.672
43	0.147	0.209	0.268	0.326	0.381	0.436	0.490	0.542	0.594	0.646	0.696
44	0.152	0.216	0.277	0.337	0.395	0.451	0.507	0.561	0.615	0.668	0.720
45	0.157	0.223	0.287	0.348	0.408	0.466	0.524	0.580	0.636	0.691	0.745
46	0.162	0.231	0.296	0.360	0.421	0.482	0.541	0.599	0.657	0.714	0.770
47	0.168	0.238	0.306	0.371	0.435	0.497	0.559	0.619	0.678	0.737	0.794
48	0.173	0.246	0.316	0.383	0.449	0.513	0.576	0.638	0.700	0.760	0.820
49	0.178	0.254	0.325	0.395	0.463	0.529	0.594	0.658	0.721	0.784	0.845
50	0.184	0.261	0.335	0.407	0.477	0.545	0.612	0.678	0.743	0.807	0.871

13	14	15	16	17	18	19	20	21	22	23	24	25
0.157	0.167	0.177	0.188	0.198	0.208	0.218	0.228	0.237	0.247	0.257	0.267	0.276
0.172	0.184	0.195	0.206	0.218	0.229	0.240	0.251	0.261	0.272	0.283	0.293	0.304
0.189	0.201	0.213	0.226	0.238	0.250	0.262	0.274	0.286	0.298	0.309	0.321	0.333
0.205	0.219	0.232	0.246	0.259	0.272	0.285	0.298	0.311	0.324	0.337	0.349	0.362
0.222	0.237	0.252	0.266	0.281	0.295	0.309	0.323	0.337	0.351	0.365	0.379	0.392
0.240	0.256	0.272	0.287	0.303	0.318	0.334	0.349	0.364	0.379	0.394	0.409	0.423
0.258	0.275	0.292	0.309	0.326	0.342	0.359	0.375	0.391	0.407	0.423	0.439	0.455
0.276	0.295	0.313	0.331	0.349	0.367	0.384	0.402	0.419	0.436	0.454	0.471	0.488
0.295	0.315	0.334	0.353	0.373	0.392	0.410	0.429	0.448	0.466	0.484	0.503	0.521
0.314	0.335	0.356	0.377	0.397	0.417	0.437	0.457	0.477	0.496	0.516	0.535	0.555
0.334	0.356	0.378	0.400	0.422	0.443	0.464	0.486	0.507	0.527	0.548	0.569	0.589
0.354	0.378	0.401	0.424	0.447	0.470	0.492	0.515	0.537	0.559	0.581	0.603	0.625
0.374	0.399	0.424	0.448	0.473	0.497	0.521	0.544	0.568	0.591	0.614	0.638	0.661
0.395	0.421	0.447	0.473	0.499	0.524	0.549	0.574	0.599	0.624	0.649	0.673	0.697
0.416	0.444	0.471	0.498	0.525	0.552	0.579	0.605	0.631	0.657	0.683	0.709	0.735
0.438	0.467	0.496	0.524	0.553	0.581	0.609	0.636	0.664	0.691	0.718	0.745	0.772
0.459	0.490	0.520	0.550	0.580	0.610	0.639	0.668	0.697	0.726	0.754	0.783	0.811
0.482	0.514	0.545	0.577	0.608	0.639	0.670	0.700	0.731	0.761	0.791	0.820	0.850
0.504	0.538	0.571	0.604	0.636	0.669	0.701	0.733	0.765	0.796	0.827	0.859	0.890
0.527	0.562	0.597	0.631	0.665	0.699	0.733	0.766	0.799	0.832	0.865	0.898	0.930
0.550	0.587	0.623	0.659	0.694	0.730	0.765	0.800	0.834	0.869	0.903	0.937	0.971
0.574	0.612	0.649	0.687	0.724	0.761	0.797	0.834	0.870	0.906	0.941	0.977	1.012
0.597	0.637	0.676	0.715	0.754	0.792	0.831	0.868	0.906	0.943	0.980	1.017	1.054
0.621	0.663	0.704	0.744	0.784	0.824	0.864	0.903	0.943	0.981	1.020	1.058	1.097
0.646	0.689	0.731	0.773	0.815	0.857	0.898	0.939	0.980	1.020	1.060	1.100	1.140
0.671	0.715	0.759	0.803	0.846	0.890	0.932	0.975	1.017	1.059	1.101	1.142	1.183
0.696	0.742	0.788	0.833	0.878	0.923	0.967	1.011	1.055	1.098	1.142	1.185	1.227
0.721	0.769	0.816	0.863	0.910	0.956	1.002	1.048	1.093	1.138	1.183	1.228	1.272
0.746	0.796	0.845	0.894	0.942	0.990	1.038	1.085	1.132	1.179	1.225	1.271	1.317
0.772	0.824	0.875	0.925	0.975	1.025	1.074	1.123	1.171	1.220	1.268	1.315	1.363
0.799	0.852	0.904	0.956	1.008	1.059	1.110	1.161	1.211	1.261	1.311	1.360	1.409
0.825	0.880	0.934	0.988	1.041	1.094	1.147	1.199	1.251	1.303	1.354	1.405	1.456
0.852	0.908	0.964	1.020	1.075	1.130	1.184	1.238	1.292	1.345	1.398	1.451	1.503
0.879	0.937	0.995	1.052	1.109	1.166	1.222	1.277	1.333	1.388	1.442	1.497	1.551
0.906	0.966	1.026	1.085	1.144	1.202	1.260	1.317	1.374	1.431	1.487	1.543	1.599
0.934	0.996	1.057	1.118	1.178	1.238	1.298	1.357	1.416	1.474	1.532	1.590	1.647

Merchantable Volume Table of *Azadirachta indica*

$$[\ln v = -7.091150 + 1.252025 \times \ln(dbh) + 0.816379 \times \ln(ht)]$$

DBH [cm]	Merchantable Height [m]										
	2	3	4	5	6	7	8	9	10	11	12
15	0.044	0.061	0.077	0.092	0.107	0.121	0.135	0.149	0.162	0.175	0.188
16	0.047	0.066	0.083	0.100	0.116	0.131	0.146	0.161	0.176	0.190	0.204
17	0.051	0.071	0.090	0.108	0.125	0.142	0.158	0.174	0.189	0.205	0.220
18	0.055	0.076	0.096	0.116	0.134	0.152	0.170	0.187	0.203	0.220	0.236
19	0.058	0.081	0.103	0.124	0.143	0.163	0.181	0.200	0.218	0.235	0.253
20	0.062	0.087	0.110	0.132	0.153	0.173	0.193	0.213	0.232	0.251	0.269
21	0.066	0.092	0.117	0.140	0.163	0.184	0.206	0.226	0.247	0.267	0.286
22	0.070	0.098	0.124	0.148	0.172	0.195	0.218	0.240	0.262	0.283	0.303
23	0.074	0.103	0.131	0.157	0.182	0.207	0.230	0.254	0.276	0.299	0.321
24	0.078	0.109	0.138	0.166	0.192	0.218	0.243	0.268	0.292	0.315	0.338
25	0.082	0.115	0.145	0.174	0.202	0.229	0.256	0.282	0.307	0.332	0.356
26	0.087	0.121	0.153	0.183	0.212	0.241	0.269	0.296	0.322	0.348	0.374
27	0.091	0.126	0.160	0.192	0.223	0.253	0.282	0.310	0.338	0.365	0.392
28	0.095	0.132	0.167	0.201	0.233	0.264	0.295	0.325	0.354	0.382	0.410
29	0.099	0.138	0.175	0.210	0.244	0.276	0.308	0.339	0.370	0.399	0.429
30	0.104	0.144	0.182	0.219	0.254	0.288	0.321	0.354	0.386	0.417	0.447
31	0.108	0.150	0.190	0.228	0.265	0.300	0.335	0.369	0.402	0.434	0.466
32	0.112	0.156	0.198	0.237	0.275	0.312	0.348	0.384	0.418	0.452	0.485
33	0.117	0.163	0.206	0.247	0.286	0.325	0.362	0.399	0.434	0.470	0.504
34	0.121	0.169	0.213	0.256	0.297	0.337	0.376	0.414	0.451	0.487	0.523
35	0.126	0.175	0.221	0.266	0.308	0.350	0.390	0.429	0.468	0.506	0.543
36	0.130	0.181	0.229	0.275	0.319	0.362	0.404	0.445	0.484	0.524	0.562
37	0.135	0.188	0.237	0.285	0.330	0.375	0.418	0.460	0.501	0.542	0.582
38	0.139	0.194	0.245	0.294	0.342	0.387	0.432	0.476	0.518	0.560	0.602
39	0.144	0.200	0.253	0.304	0.353	0.400	0.446	0.491	0.536	0.579	0.621
40	0.149	0.207	0.262	0.314	0.364	0.413	0.461	0.507	0.553	0.598	0.641
41	0.153	0.213	0.270	0.324	0.376	0.426	0.475	0.523	0.570	0.616	0.662
42	0.158	0.220	0.278	0.334	0.387	0.439	0.490	0.539	0.588	0.635	0.682
43	0.163	0.226	0.286	0.344	0.399	0.452	0.504	0.555	0.605	0.654	0.702
44	0.167	0.233	0.295	0.354	0.410	0.465	0.519	0.572	0.623	0.673	0.723
45	0.172	0.240	0.303	0.364	0.422	0.479	0.534	0.588	0.641	0.692	0.743
46	0.177	0.246	0.312	0.374	0.434	0.492	0.549	0.604	0.658	0.712	0.764
47	0.182	0.253	0.320	0.384	0.446	0.506	0.564	0.621	0.676	0.731	0.785
48	0.187	0.260	0.329	0.394	0.458	0.519	0.579	0.637	0.695	0.751	0.806
49	0.192	0.267	0.337	0.405	0.470	0.533	0.594	0.654	0.713	0.770	0.827
50	0.196	0.274	0.346	0.415	0.482	0.546	0.609	0.671	0.731	0.790	0.848
51	0.201	0.280	0.355	0.425	0.494	0.560	0.625	0.688	0.749	0.810	0.870
52	0.206	0.287	0.363	0.436	0.506	0.574	0.640	0.704	0.768	0.830	0.891
53	0.211	0.294	0.372	0.446	0.518	0.588	0.655	0.721	0.786	0.850	0.912
54	0.216	0.301	0.381	0.457	0.530	0.602	0.671	0.739	0.805	0.870	0.934
55	0.221	0.308	0.390	0.468	0.543	0.616	0.686	0.756	0.824	0.890	0.956

13	14	15	16	17	18	19	20
0.201	0.213	0.225	0.238	0.250	0.262	0.273	0.285
0.217	0.231	0.244	0.258	0.271	0.284	0.296	0.309
0.235	0.249	0.264	0.278	0.292	0.306	0.320	0.333
0.252	0.268	0.283	0.299	0.314	0.329	0.344	0.358
0.270	0.286	0.303	0.319	0.336	0.352	0.368	0.383
0.288	0.305	0.323	0.341	0.358	0.375	0.392	0.409
0.306	0.325	0.344	0.362	0.380	0.399	0.417	0.434
0.324	0.344	0.364	0.384	0.403	0.423	0.442	0.461
0.343	0.364	0.385	0.406	0.426	0.447	0.467	0.487
0.361	0.384	0.406	0.428	0.450	0.471	0.492	0.514
0.380	0.404	0.427	0.450	0.473	0.496	0.518	0.540
0.399	0.424	0.449	0.473	0.497	0.521	0.544	0.568
0.419	0.445	0.471	0.496	0.521	0.546	0.571	0.595
0.438	0.465	0.492	0.519	0.545	0.571	0.597	0.623
0.458	0.486	0.515	0.542	0.570	0.597	0.624	0.651
0.478	0.507	0.537	0.566	0.595	0.623	0.651	0.679
0.498	0.529	0.559	0.590	0.620	0.649	0.678	0.707
0.518	0.550	0.582	0.614	0.645	0.675	0.706	0.736
0.538	0.572	0.605	0.638	0.670	0.702	0.734	0.765
0.559	0.594	0.628	0.662	0.696	0.729	0.762	0.794
0.579	0.616	0.651	0.686	0.721	0.756	0.790	0.824
0.600	0.638	0.675	0.711	0.747	0.783	0.818	0.853
0.621	0.660	0.698	0.736	0.773	0.810	0.847	0.883
0.642	0.682	0.722	0.761	0.799	0.838	0.875	0.913
0.663	0.705	0.746	0.786	0.826	0.865	0.904	0.943
0.685	0.728	0.770	0.811	0.852	0.893	0.934	0.973
0.706	0.750	0.794	0.837	0.879	0.921	0.963	1.004
0.728	0.773	0.818	0.862	0.906	0.949	0.992	1.035
0.750	0.796	0.843	0.888	0.933	0.978	1.022	1.066
0.772	0.820	0.867	0.914	0.961	1.006	1.052	1.097
0.794	0.843	0.892	0.940	0.988	1.035	1.082	1.128
0.816	0.867	0.917	0.966	1.015	1.064	1.112	1.160
0.838	0.890	0.942	0.993	1.043	1.093	1.142	1.191
0.860	0.914	0.967	1.019	1.071	1.122	1.173	1.223
0.883	0.938	0.992	1.046	1.099	1.152	1.204	1.255
0.906	0.962	1.018	1.073	1.127	1.181	1.234	1.287
0.928	0.986	1.043	1.100	1.156	1.211	1.265	1.319
0.951	1.010	1.069	1.127	1.184	1.241	1.297	1.352
0.974	1.035	1.095	1.154	1.213	1.270	1.328	1.385
0.997	1.059	1.121	1.181	1.241	1.301	1.359	1.417
1.020	1.084	1.147	1.209	1.270	1.331	1.391	1.450