Non-Destructive Method for Estimating Log Volume for *Melia Azedarach* L. Trees in Erbil-Iraqi Kurdistan Region

Talat M. Amin

College of Agriculture, Salahaddin University
Zanko Street, Kirkuk Road, Erbil, Kurdistan Region - F.R. Iraq

***Abstract*—The accuracy of four traditional formulas (Smalian, Huber, Bruce and Newton) to calculate log volumes was compared and tested against volumes determined by the water-displacement technique (xylometer). 150 standing trees were measured in a Sami Abd-Alrahman Plantation Park in Erbil governorate on 1 May, 2012. The accuracy of these four procedures was analyzed considering merchantable outside bark volumes of logs of large, mid-and small diameter. The results showed that Newton's formula was superior for all volumes and log lengths considered. Thus, Newton's formula could be used in the majority of circumstances for log lengths of *Melia azedarach* trees. Applying the Newton formula to the tree volumes, DBH and height presented the best fit regression equation which for use in predicting the log volume of *Melia azedarach* trees in Erbil Governorate.**

***Index Terms*— Erbil of Iraq, *melia azedarach*, volume table.**

I. INTRODUCTION

Methods of deriving log volume are still important, although weight measurement is being used increasingly for sale of logs. Stem volume is a function of a tree's height, basal area, shape and bark thickness. It is therefore one of the most difficult parameters to measure, because an error in the measurement or assumptions for any one of the above factors will affect the volume estimate. There are different tree volumes: *biological volume,* which is the volume of stem with branches trimmed at the junction with the stem, but usually excluding irregularities not part of the natural growth; *merchantable volume* that excludes some volume within irregularities of the bole shape caused by normal growth in addition to those irregularities not part of natural growth; *gross volume* estimates, which include defective and decayed wood, and finally *net volume* estimates, which exclude defective and decayed wood (Cris, 2006).

The development of a volume table requires volume equations for the species in question. There are three types of volume equations based on the number of variables and objectives. Each type is formulated by means of regression analysis. These volume equations are: Local volume equation**,** Regional volume equation and General or Standard volume equation**,** and we used the third equation type was used in this research. Also for preparation of volume tables there are two methods available to generate volume tables, namely the destructive and the non-destructive method (Adhikari 2005). In the destructive method, 40-50 individuals of a particular species, representing all diameter classes of interest are selected randomly and felled. While the second method, used here, called the Non-destructive method which is similar to the destructive method but the trees are not felled.

Hakki (1999) used Centroid Sampling for testing 21 logs of Ash (*Fraxinus angustifolia* subsp. oxycarpa), 38 logs of Spruce (*Picea orientalis* (L.) Link.), and 33 logs of Beech (*Fagus orientalis* Lipsky.). The volume of each log was estimated using Huber's, Smalian's, Newton's, Riecke's and Hosfeld's formulas and Centroid Sampling. These estimates were compared with the "true" volume of each log which was determined by aggregating the volumes of measured short sections (1 m) using Smalian's formula. The mean error of the Centroid estimate of the log volumes was not significant for *Fraxinus angustifolia* subsp. oxycarpa, *Picea orientalis* (L.) Link. Or *Fagus orientalis* Lipsky. And was less than those derived from Huber's, Smalian's, Newton-Riecke's, and Hosfeld's formulas. When the three species were combined, the Centroid estimate was clearly more accurate, and its mean error was not significant at 0.05 probability.

Filho, et al. (2000) prepared log volume tables by testing the accuracy of log volume calculation procedures against water displacement techniques (xylometer). Three traditional formulas to calculate log volumes (Smalian, Huber, and Newton) and three recent methods (cubic splines, centroid sampling, and overlapping bolts) were compared and tested against volumes determined by the water-displacement technique (xylometer). Fifty-two felled trees were measured in a Pinus elliottii Engelm. Plantation. The accuracy of these six procedures was analyzed considering total and merchantable

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Corresponding author's e-mail: Talat_1952@yahoo.com

outside bark volumes with 1, 2, 4, and 6 m log lengths. The results showed that Huber's formula was superior for all volumes and log lengths considered. Centroid and Newton had a similar performance to Huber but with some higher errors.

Ozcelik, et al. (2006) compared the Centroid, Center of Gravity, Newton, Bruce, Huber, and Smalian formulas for predicting log volumes of three species in Turkey showed the Newton, Center of Gravity, and Centroid methods were clearly superior to the other formulae. The accuracy of all the methods, as indicated by Chi-square accuracy tests, ranged from Newton, Center of Gravity, Centroid, Huber, Bruce to Smalian's formula which performed the poorest.

Amin (2010) estimated merchantable volume and total tree volumes, used the centroid method and depended on it as a dependent variable with DBH and height (pole) as independent variables to make a regression equation connecting these variables for *Quercus agilops* L. trees in Erbil Governorate for total and merchantable volume tables.

The objective of this research is to prepare a *Melia azedarach* log volume table for the first time in Kurdistan region and Iraq, by comparison between more than one methods of estimating tree volumes in order to use it in forestry researches.

II. Material and Method

Data were collected from Sami Abd-Alrahman Park in Erbil Governorate on 1 May, 2012 to supply the empirical side of this research. The data about the diameters and height of the trees are listed in appendix A.

When using the formulas which are less common, a mid-length log diameter is required. Bruce (1982) derived a formula using only end diameters and length that was popular in some places in forested countries. These formulae are shown below:

Huber: $V = M . L$

Smalian: $V = (B + S/2)\ L$

Newton: $V = ((B + 4M + S)/6)\ L$

Bruce: $V = (0.25B + 0.75S)\ L$

Where: B = cross-sectional area at large end of log); M= cross-sectional area at mid-length of log; S = cross-sectional area at small end of log; L = log length (m).

From the application of the above formulas the volume of each tree in the sample was found, depending on the data collected. After calculating the cross-sectional areas of large, mid-and small ends of log length, the volumes of the trees were as follow in Table I.

TABLE I

Volumes of sample tree estimating by using volume formula

No.	Plot	Huber	Smalian	Newton	Bruce
1	1	1899.7	1397.3	1732.2	769.3
2	1	1275.2	918.5	1156.3	522.8
3	1	1020.9	805.8	949.2	466.5
4		2077.1	1441.3	1865.2	805.4
5		750.6	630.9	710.7	375.5
6		314	386.6	338.2	249.8
7		188.4	301.7	226.1	203.8
8		356.2	341.5	351.3	223.7
9		1020.8	880.1	973.9	503.6
10		500.1	436.5	478.8	264.2
11		17.6	98.1	44.4	84.3
12		56.5	78.5	63.8	67.5
13		395.6	401.1	397.4	250.1
14		339.1	325.2	334.5	205.1
15		480.4	542.1	500.9	331.1
16		255.1	352.3	287.5	222.1
17		206.6	393.2	268.8	242.5
18		113.1	181	135.7	122.3
19		1557.8	1257.5	1457.7	692.3
20		2279.6	1931.1	2163.4	1050.3
21		1884	1616.1	1794.7	892.8
22		2918.6	2152.2	2663.1	1153.8
23		2077.1	1801.5	1985.2	985.5
24		1004.	1020.5	1010	580.9
25		954.5	776	895	455.1
26		1191	1117.3	1166.5	632.9
27		1644.3	1140.9	1476.6	637.6
28		3114.5	2413.9	2880.9	1312.9
29		356.2	362.4	358.2	234.2
30		1134.3	1042.2	1103.6	591.7
31		907.4	782.2	865.7	447.6
32		1191	1311	1231	729.7
33		794.8	805.8	798.4	466.5
34		596.9	651.8	615.2	389.5
35		803.8	732.5	780	422.7
36		846.2	962.9	885.1	559.1
37		803.8	716.3	774.6	414.6
38		1899.7	1609.2	1802.8	875.2
39	2	729.6	1122.5	860.6	638.9
40	2	1004.8	1086.3	1031.9	613.8
41	2	846.2	1321.2	1004.5	738.2
42		1972.5	1635.1	1860	884.6
43		427.4	487.9	447.5	307.5
44		2279.6	2275.5	2278.2	1222.5
45		618.2	655.3	630.5	377.1
46		461.5	490.1	471	287.4
47		907.4	684.5	833.1	398.8
48		452.2	510.3	471.5	311.6
49		356.1	529.9	414.1	317.9
50		883.1	855.7	873.9	498.5
51		2512	2235.7	2419.8	1230.9
52		1059.8	725.9	948.4	447.7
53		576.9	490.9	548.3	298.5
54		1474.6	1500.7	1483.3	842.2
55		923.5	1074.5	973.5	622
56		1406.7	1489.8	1434.4	843.8
57		1558.6	1269.8	1462.3	712.6
58		1256	1330.2	1280.7	753.4
59		1247.8	1098.9	1198.1	627.1
60		1558.6	1426.9	1514.7	791.1
61		3114.5	2173.2	2800.7	1192.6
62		2267.1	1921.7	2151.9	1073.9
63		1361.2	1413.1	1378.5	791.3
64		3046.7	2951.9	3015.2	1719.7
65		1038.6	1236.1	1104.4	713.4
66		1306.2	1561.3	1391.2	872.5
67		1000.1	1112.3	1037.5	648
68		546.1	895.9	662.8	529.2
69		510.3	829.1	616.5	506.4
70		522.4	941.2	662	548.3
71		846.2	1029.7	907.3	592.6
72		971.4	1219.6	1054.2	687.5
73		1727	1537	1663.7	846.2
74		2250.2	1951.7	2150.7	1067.7
75		621.7	984.9	742.8	570.1
76		1474.6	1654.6	1534.6	919.2
77	3	508.7	668	561.8	397.6

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78	3	2279.6	1801.6	2120.3	985.6
79	3	1558.6	1122.6	1413.2	638.9
80		1004.8	1020.5	1010	580.9
81		226.1	362	271.4	244.6
82		2077.1	1676.8	1943.7	923.2
83		2163.7	1621.56	1982.9	899
84		1361.2	1330.6	1350.9	750.1
85		508.7	604.4	540.6	365.8
86		2423.3	2489.9	2445.5	1343.8
87		1474.6	1271.2	1406.8	727.4
88		2119.5	1621.4	1953.4	906
89		884.7	1052.9	940.8	607.7
90		1356.5	1320	1344.3	755.4
91		1644.7	1741.5	1677	973.2
92		596.9	842.5	678.8	484.8
93		3581.9	2724.2	3296	1457.5
94		474.9	706.5	552.1	423.9
95		1884	1801.6	1856.5	985.6
96		1531.3	1818.1	1626.9	1004.4
97		2336.7	2323.5	2332.3	1257.1
98		1304.4	1381.2	1330	771
99		1716.8	1886.4	1773.3	1038.6
100		1912.8	1818.1	1881.3	1004.4
101		2564.6	1621.4	2250.2	906.1
102		3189	2349.8	2909.3	1266.8
103		1962.5	1811.02	1912.007	993.8223
104		2564.6	2026.7	2385.3	1108.7
105		1077.6	1140.9	1098.7	637.6
106		2387.7	1788	2187.852	975.2
107		1335.3	1212.1	1294.2	680.2
108		1361.2	1224.6	1315.7	697.1
109		2595.4	2259.4	2483.4	1218
110		3316.6	2759.8	3131	1468.2
111		2599.9	2690.2	2630	1426.3
112		2119.5	1621.4	1953.4	906
113		2699.2	2387.9	2595.4	1285.8
114		2423.3	1816.1	2220.9	1006.9
115		2250.2	2504.2	2334.8	1343.9
116	4	923.2	1074.5	973.5	622
117	4	1361.2	1224.6	1315.7	697.1
118	4	904.3	770.1	859.6	448.6
119		497.4	453.7	482.9	279.8
120		692.4	918.5	767.7	522.8
121		1361.2	1330.6	1350.9	750.1
122		1570	1397.3	1512.4	769.3
123		907.5	1037.8	950.9	575.4
124		284.9	382.7	317.5	233.7
125		1921.7	1876.6	1906.7	998.3
126		84.8	211.9	127.2	148.4
127		883.1	936.1	900.8	538.7
128		1134.3	1108.8	1125.8	625
129		403.6	542.1	449.8	331.1
130		395.6	494.6	428.6	296.7
131		538.5	908	661.7	503.4
132		971.4	857	933.3	506.2
133		1148	1383.4	1226.5	783.5
134		1570	1297.2	1479	719.2
135		1361.2	1330.6	1350.9	750.1
136		2491.6	1931.1	2304.8	1050.3
137		1134.3	1201.1	1156.6	671.2
138		2163.7	2407.9	2245.1	1292.3
139		1192.2	1263.7	1216	727.2
140		1589.6	1501.3	1560.2	838.9
141		1462.5	1491.7	1472.2	827.1
142		1805.5	1606.9	1739.3	884.7
143		884.7	895.9	888.5	529.2
144		653.9	761	689.6	440.5
145		356.1	641.7	451.4	373.8
146		1471.3	1344.6	1429	732.4
147		1306.2	1686.4	1432.9	935
148		2089.7	2020.6	2066.6	1088
149		593.5	898.4	695.1	523.4
150		904.3	842.5	883.7	484.8

The field work also included felling two trees (there was no ability or permission to fall more trees) to find their volumes using water displacement by the xylometer method. The accuracy of four traditional formulas for calculating log volumes was compared and tested against the volumes determined by the water-displacement technique (xylometer). The results showed that the Newton formula was superior for all tree volumes and had the best results. We replied on the tree volumes estimated by this formula in preparing the volume Table for Melia azedarach trees. These results are compatible with the results of Filho, et al. (2000) and Ozcelik, et al. (2006).

III. Results and Discussion

Diameters were measured at different heights by climbing the trees. In the Equation Method, while the basic data essentially remain the same as in the graphical method, the relationships between volume as a dependent variable and DBH, hight and form, etc as independent variables are given mathematical expressions by a regression equation. Various workers have developed various equations or models, some of them are: Meyor modified, Austrian, Combined variable, Constant Form Factor, Logarithmic, and others (Chaturvedy and Khanna 2000). The results from using three of these equations and testing them are presented in Table II.

TABLE II
Standard Volume Regression Equations Using Log Tree Volume with Their Measures of Precision Test, From Data of All Sample Plot Trees for *Melia Azedarach* in Erbil governorate

Regression Equations	b_0	b_1	b_2	R²ˆ(adj)%	S.E
$V = b_0 + b_1 D + b_2 H$	-481.665	- 0.00538789	329.358	48.6184	522.585
$V = b_0 + b_1 DH$	-458.44	15.67	-	89.6368	235.484
$V = b_0 + b_1 logD + b_2 logH$	-5557.21	4044.61	2266.86	77.7774	343.677

$V = Tree\ volume$
$D = Tree\ diameter$
$H = Tree\ height$
$bi = Parameters$

According to the value of the adjusted coefficient of determination in Table II we can see that the second equation has the best fit regression equation (the highest R²ˆ value equals to 0.89 and the lowest standard error value equals to 235.48, in comparison with other models or equations). This second equation can be used for preparing a log volume table for *Melia azedarach* trees in Erbil Governorate using different values for diameter at breast height and different values for trees height.

IV. Recommendations

From the results of this research we recommend the use of the regression equation for preparing a volume table for *Melia azedarach* trees by those interested in this field because it is easy to assess the volume of standing trees and easy to use, whilst the calculation is time, money and manpower consuming, and needs extra instruments, whereas, a volume table does not. A volume table is more convenient, easy to apply in the field, and measurements and calculation can be done simultaneously.

Appendix A

Data Collection for Melia Asedarach Trees in Erbil Governorate

No	Loc.	Plot	do 30 cm	dbh	D at mid	H	hi d6cm
1			26	25	22	8	5
2			22	20	19	7.50	4.50
3			20.50	18.50	17	8.50	4.50
4			24	23	21	9	6
5			18.50	17.50	15	7.75	4.25
6			14.50	12.50	10	7.25	4
7			13	11.50	8	6.75	3.75
8			14	12	11	6.25	3.75
9			21.50	19.50	17	8	4.50
10			17.50	16.50	14	6.75	3.25
11			8	6.50	3	5.50	2.50
12			8	7	6	4.75	2
13			16	14	12	6.25	3.50
14	Erbil	1	15.50	14	12	6	3
15			17	15	12	6.50	4.25
16			15.50	13.50	10	5.75	3.25
17			16.50	13.50	9	6.25	3.25
18			13	11	8	4	2.25
19			26	25	21	8	4.50
20			28	27	22	10	6
21			25.50	24.50	20	9.50	6
22			31	30	26	11	5.50
23			27	24.50	21	9.50	6
24			22	19.50	16	8.50	5
25			19.50	18.50	16	7	4.75
26			22.50	20	17	9.25	5.25
27			24	23.50	21	10	4.75
28			28	25.75	23	10	7.50
29			14.50	13.75	11	8.25	3.75
30			22.25	21.50	17	9	5
31			21.50	20	17	8.25	4
32			24.50	21.50	17	8.50	5.25
33			20.50	18.50	15	8.50	4.50
34			18.25	15	13	7.75	4.50
35			20.75	19.25	16	8	4
36			20.25	17.25	14	9.50	5.50
37			20.50	19.25	16	8	4
38			28	26	22	8.75	5
39			22	18	13	9	5.50
40			22.75	19	16	9.50	5
41			24	19.50	14	9.50	5.50
42			29	27.25	23	9.25	4.75
43			15.50	14	11	8	4.50
44		2	30.50	26.25	22	9	6
45			21	18	15	7	3.50
46			19.50	18	14	6.50	3
47			20	19	17	8	4
48			17	15.50	12	8	4
49			18	16	11	8	3.75
50			20	18	15	8.50	5
51			26	23	20	11	8
52			16.50	16	15	10	6
53			17.25	16.50	14	8	3.75
54			23.50	20	17	12	6.50
55			20.50	16	14	10.50	6
56			22.50	18.75	16	11	7
57			23.50	21	19	9.50	5.50
58			22.50	18	16	11.25	6.25
59			21.75	18.50	17	10.75	5.50
60	Erbil		25	21	19	12	5.50
61			26.50	25.50	23	12.50	7.50
62			24	21.75	19	12	8
63			23.75	18	17	12	6
64			20	18	15	11.50	17.25
65			20.75	17.75	14	11	6.75
66			24	20	16	11	6.50
67			20	19	14	11	6.50
68			19	18	11	10.25	5.75
69			17	15.50	10	10	6.50
70			20	16.50	11	9.50	5.5
71			21	19.50	14	10	5.5
72			23	19	15	10.50	5.5
73			26	24.50	20	10.50	5.50
74		3	27	24.	21	10.50	6.50
75			20.50	19	12	10	5.50
76			24.75	22	17	10.50	6.50
77			18.50	16	12	9.50	4.50
78			27	26.50	22	10.50	6
79			22	21	19	10,50	5.5
80			22	19.50	16	10.50	5
81			13	11.50	8	9.50	4.50
82			26	24	21	12	6
83			25	23	21	11	6.25
84			23	21	17	10.50	6
85			17.50	15.50	12	9.50	4.50
86			29.50	26.50	21	11.75	7
87			21.50	20	17	10.50	6.50
88			24	22	20	11.25	6.75
89			20.75	18	14	10.25	5.75
90			21.50	20	16	10.50	6.75

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No	Loc.	Plot	do 3`0 cm	dbh	D at mid	H	hi d6cm
91			24	21	17	11.25	7.25
92			21	17	13	10.50	4.50
93			31.50	30	26	10.75	6.75
94			18	16	11	9.75	5
95			27	23	20	10.75	6
96			25.50	20.50	17	11.75	6.75
97			29	25	21	10.75	6.75
98			24	21	17	10.75	5.75
99			26	22	18	11.50	6.75
100			25.50	23	19	11.25	6.75
101			24	24	22	10.75	6.75
102			29.75	27.75	25	11.25	6.50
103			26.50	23	20	10.50	6.25
104			27	26.50	22	10	6.75
105			24	22	17	9.50	4.75
106			27.50	26	23	10.50	5.75
107			23.50	21	18	10.75	5.25
108			22	20	17	11	6
109			29.75	27.50	23	11.75	6.25
110			33	29	26	10.75	6.25
111			34	28.50	24	11.25	5.75
112			24	23	20	11.50	6.75
113			30	27	23	10.75	6.50
114			25	24	21	10.50	7
115			30.75	25.75	21	11.75	6.50
116			20.50	19	14	9.50	6
117			22	20	17	9.25	6
118			20	19	16	9.75	4.50
119			16.50	15.5	13	8.75	3.75
120			22	18	14	8.50	4.50
121			23	21	17	9.50	6
122			26	25	20	9.50	5
123			25	22	17	8	4
124	Erbil	4	17	14	11	8	3
125			33	29	24	8.50	4.25
126			12	10	6	6.50	3
127			21	19	15	8.50	5
128			23	21	17	8.75	5
129			17	16	11	7.75	4.25
130			18	15.50	12	7	3.50
131			25	18	14	8	3.50
132			19	18	15	9.25	5.50
133			22.50	18	15	10	6.5
134			25	24	20	9.75	5
135			23	21.75	17	9.50	6
136			28	27	23	10	6
137			24	20.50	17	10	5
138			30.75	25.50	21	10.50	6.25
139			21	19	15	10.75	6.75
140			24	23	18	9.25	6.25
141			25	21	18	10	5.75
142			26	23	20	10	5.75
143			19	18	14	10.75	5.75
144			20.50	19	14	8.75	4.25
145			20	18	11	7.75	3.75
146			27.75	26	21	8.75	4.25
147			25	20	16	10.25	6.50
148			30	27	22	10.75	5.50
149			20	18.50	12	8.75	5.25
150			21	20	16	8.50	4.50

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