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ASSESSING VOLUME OF *Quercus aegilops* L.TREES IN DUHOK GOVERNORATE, KURDISTAN REGION OF IRAQ

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ABSTRACT

Valonia oak (*Quercus aegilops* L.) is the dominant tree species in Kurdistan Region of Iraq. It covers the landscape of the region's mountains and has an important role in the life of rural inhabitants besides its vital environmental protection functions. This species tends to develop a decurrent growth pattern, therefore, its wood is distributed over tree trunk and tree branches. As the wood of these two components is utilized for different purposes, separate equations were developed to assess the volume of each component in addition to the total volume. Furnival Index was utilized to select the best equation for estimating volume of each component. The selected equations were then examined to ensure that the error term is homogenous, normally distributed, and not autocorrelated. Finally, one entry and two entry volume tables were constructed for each component and for total volume.

KEYWORDS: Branches volume, Furnival's index, Kurdistan region of Iraq, Valonia oak, Volume equation

INTRODUCTION

Any management plan should take in account yield and growth of stands and these in turn need a mean to estimate tree volume. There are direct methods used in determining tree volume. These methods, however, are expensive and time consuming. Hence, it is customary to resort to equations developed to estimate tree volume as a function of tree attributes that are easy to measure such as tree diameter, height and a measure of form. Diameter explains most of the variation in tree volume and equations developed using diameter as the only predictor variable are called local volume table (one entry volume table) because it is intended to be used for a limited area. Tree height is the second most important variable and equations developed to estimate tree volume using diameter and height as independent variables are called standard volume table (two entry volume table) because it is more general and intended to be used for an extended area. Stem form comes in third place, but it is rarely used because it is expensive to measure and slightly improve the equation (Philip, 1994).

To develop a volume equation, data should be taken from felled trees but, such data might be expensive if it is not collected during stand harvesting operation. It is also resorted to optical dendrometers to collect the required data, such data, however, are not accurate and results require correction factor (Pillsbury and Stephens 1978). In addition to that, this instrument is mostly used for deciduous trees during fall and winter seasons. This is because of the difficulty of measuring stem diameter at various heights due to obstruction by leaves and twigs that make it impossible to get the required measurements. It is also possible to gather the required data by taking measurements through climbing trees. This procedure is also expensive, time consuming, risky, and requires skilled technicians to climb and take the required measurements.

In Kurdistan Region of Iraq, oak trees constitute about 90% of region's forest, of which 70 % are Valonia oak tree (*Quercus aegilops*) (Shahbaz, 2010). Shahbaz (2005) states that Valonia oak lives up to 200 years, and its attributes, diameter, height, and crown width may reach 100 cm, 20 m and 7m respectively. In addition to its environmental benefits, it has many socioeconomic values, For instance, its wood is utilized for producing many tools, its leaves are used as fodder for livestock during winter season, and its branches are exploited for building shelters during summer season. This reflects the importance of this species and the need for developing equations that estimate volume of

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each of trunk and branches in addition to total volume.

In general, this species tends to have decurrent growth pattern (Does not have a main stem from ground to the top of the tree) and the base of the live crown tends to occur at a rather low height, especially for open grown trees. Therefore, branches volume constitutes a large proportion of total tree volume especially for big trees. Since branches are utilized for purposes different from those of tree trunk, it would be beneficial to estimate their volume separately in addition to total volume.

Mohammad (2010) developed volume equations for Valonia oak in four locations in Erbil governorate. The developed equations were for the main stem (assuming that there is a single main stem for tree from ground to the top of the tree). This work aims at developing separate volume equation for the trunk (from stump height to the base of live crown), branches (to 4 cm top diameter), and total volume which is the sum of the above two components. This work will provide indispensable information to carry out investigations regarding growth, yield, stocking and inventory for stands of this species.

MATERIALS AND METHODS

Four locations were selected to collect the required data; Chamanke, Baroshke, Atrosh, and Kezo (Fig. 1). The sampled trees were taken from a wide range of sites, topographic, and other environmental conditions. In literature, a broad range of sample size has been used to develop tree volume equations. It has been found that a sample of 40 trees is adequate in developing equation's coefficients if it is carefully selected (Pillsbury et al., 1978; 1984; 1988). Other authors have used larger sample size for this purpose. Since Valonia trees have large crown and since measurements were taken by climbing trees which is time consuming, this work relied on only 81 trees.

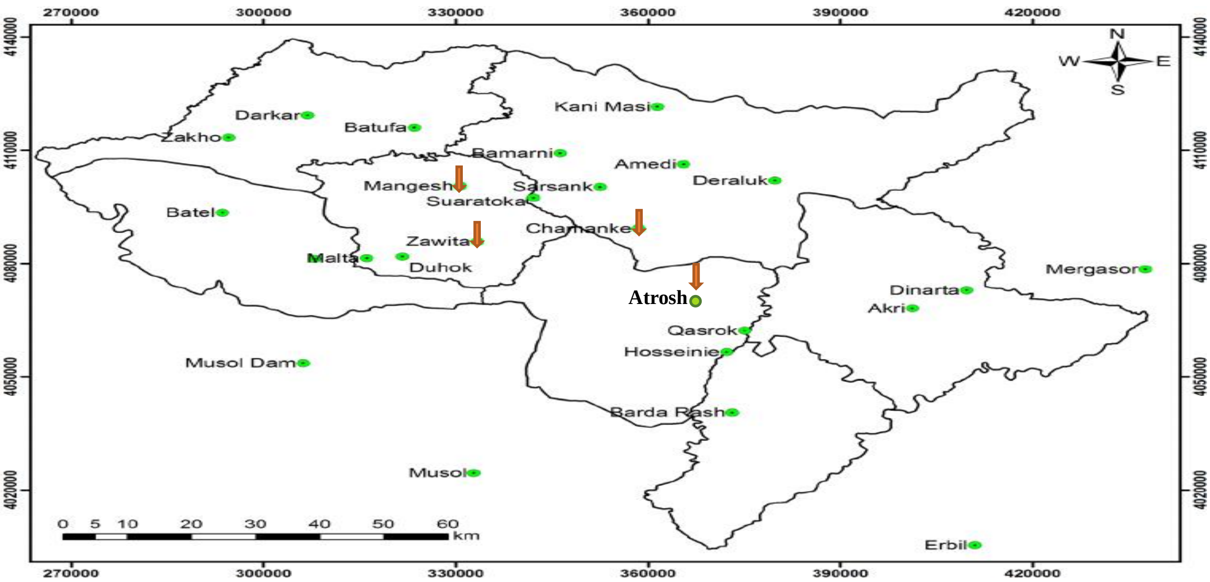

Fig. (1): Locations of the study

The sampled trees were both open grown and stand grown trees. In order to boost equations' precision, the sampled trees were subjectively selected to ensure that they are free from defects and to cover the full range of diameter classes, and for each diameter class it was strived to obtain as many heights classes as possible (Pillsbury et al., 1988). For each tree the following measurements were taken; diameter at breast height, diameter at stump height (at 0.3 m above ground), total height, trunk height (from the ground to the base of live crown), crown length (from base of live crown to the tip of the tree), crown width, number of primary branches, bark thickness (at breast height), and diameter along the trunk and branches at at most one meter intervals. With respect to branches, segments between forks were frequently less than one meter long.

Caliper and Vernier caliper were used for diameter measurement, the average of two perpendicular measurements was taken to nearest 1 mm for this purpose. A ladder was used for

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measuring diameters of small trees and climbing was used for measuring bigger trees where measurements could not be taken by ladder. Diameter at irregular shapes along the trunk and branches were avoided, instead measurements were taken either above or below the irregular area. Height was measured using pole and measurements were taken to nearest 0.05 m. Crown width was obtained by averaging two perpendicular measurements using measurement tape. Bark thickness was measured using bark gauge and the average of two perpendicular measurements was taken for this purpose. Table 1 presents descriptive statistics regarding the selected sample. Live crown ratio is obtained by dividing crown length over total tree height and volumes of trunk and branches segments were calculated using Smalian's formula. Since branches and trunk of Valonia oak trees have different uses, it will be advantageous to develop separate equation for each product, therefore, in this work total tree volume was divided into two components;

1. Trunk volume which is the volume of the main stem from stump height (30 cm above ground) to the base of live crown.

2. Branches volume which is the volume of all branches up to 4 cm diameter.

Least square method was employed to develop equations that relate each of trunk volume, branches volume, and total volume on one hand, and dbh on the other hand (one entry volume equations). To develop more general models, same dependent variables were regressed on diameter, total height, trunk height, crown length, live crown ratio, crown width, and number of primary branches. SAS software package (9.4, 2012) was used for this purpose. Neither single volume equation nor single mathematical model can be utilized to explain the variation in tree volume of different tree species (Cao et al., 1980; Clutter et al., 1983; Mahairwe, 1999). Therefore, relationship between each response variable (in original form and in logarithmic form) and diameter (in logarithmic form and raised to power two and three) were explored for one entry model. With respect to the general model, relationship between same response variables, on one hand, and all the selected predictor variables on the other hand (total height, trunk height, live crown ratio, crown length, crown width, and number of primary branches) were also explored. The explorations were accomplished using scatter plot analysis (Picard et al., 2012) and regression stepwise procedure. In the stepwise procedure all the dependent variables in their original forms, transformed to logarithm, raised to power two and three, and all possible interactions among these variables were tested.

Table (1): Statistical description of the sample

Variables	Number of trees	Mean	Standard Deviation	Minimum	Maximum
Diameter (cm)	81	23.0	12.9	5.4	55.5
Total height (m)	81	7.25	2.21	3.62	13.04
Trunk height (m)	81	2.07	0.75	1.3	4.7
Crown width (m)	81	5.73	2.61	1.65	11.66
Crown length (m)	81	5.17	1.94	1.72	10.49
Live crown ratio	81	0.7	0.095	0.42	0.888
Bark thickness (cm)	81	0.94	0.4	0.3	1.8
Number of Primary Branches	81	2.48	0.96	1	6

Based on this examination, several functional forms were selected to be tested. These equations were simple, combined, logarithmic, and weighted. Double loge function has extensively been used for developing both one entry and two entry volume equations because this model has the potential to remove or alleviate the problem of heteroscedasticity inherent in the data of one and two entry volume equations in their original form (Husch et al., 1982). With respect to weighted models, and in order to properly employ weighted equation, one must know the proportionality of change in variation of error as the tree gets bigger in size. Most of the authors have used D^2, and D^2H for this purpose. All the explanatory variables were tested for their significance in explaining the variation on response variables. Furnival Index (FI) has been used by many authors to rank candidate models among them (Segura et al., 2006; Naing, 2014; Mohammed H. et al., 2018). This criterion is used for ranking equations when the response variables have different forms. The merit of this criterion stems from its consideration to the coefficient of determination, and the departure of error term from normality and homogeneity (Furnival, 1961). As the value of this index reduces as the model gets better. This index was used to select the best equation for each response variable and for each of one entry volume equation and for the general case. Then the best equations were scanned to ensure they do not violate the assumptions of the least squared procedure regarding error term. Heteroscedasticity in the error term reduce the precision of the model, but the model's coefficients remain unbiased (Studenmund, 2006). Heteroscedasticity in the models was detected using White test. In this test, first, error squares of the model is regressed on independent variables in their original form, their squares, and all the interaction as given in the following equation for the case of three independent variables;

$$e^2_i = \beta o + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X^2_1 + \beta_5X^2_2 + \beta_6X^2_3 + \beta_7X_1 X_2 + \beta_8X_1X_3 + \beta_9X_2X_3 + U_i$$

Second, Coefficient of determination obtained from this equation is multiplied by sample size to obtain the test statistic for the null hypothesis which states that the error term is homogenous. This test statistic has a χ^2 distribution with number of β minus one degrees of freedom. This test statistics is then compared to tabulated χ^2 of equivalent degrees of freedom to test the homogeneity of the error term. The merit of this test stems from its consideration of a variety of possible proportionality factors (Studenmund, 2006). Graph of distribution of error term along the observed values was also considered for this purpose. Departure of error term from normality was explored graphically because of the difficulty in testing violation of this assumption (Neter et al., 1996). Autocorrelation of the error term is a problem associated with time series data not cross sectional one. Despite the data of this work is a cross sectional one, yet data were sorted according to trees' diameter, then autocorrelation problem was detected using Durbin Watson (DW) test. It was also ensured that all explanatory variables were significant in explaining the variation in the response variables at at most 0.05 significance level.

Bark factor, which represents the proportion of under bark diameter to over bark diameter, was calculated using the following formula;

$$K = \sum (d_{ub} * d_{ob}) / \sum (d_{ob})^2$$

Where K is bark factor, d_{ub} is diameter under bark, and d_{ob} is diameter over bark. Then bark factor was used to calculate volume under bark and volume of bark using the following formulas respectively;

$$V_{ub} = K^2 * V_{ob}$$

$$V_b = (1 - K^2) * V_{ob}$$

Where V_b is bark volume (Husch, et al., 2002). These formulas assume that bark factor is constant along the stem and branches.

RESULTS

One Way Entry Volume Equations

In one entry volume equations, diameter at breast height (D) was the only explanatory variable in the models. Relationship pattern revealed by scatter plots and stepwise procedure of each dependent variable; trunk volume (V_{Tr}), branches volume (V_B), and total volume (V_T) on one hand, and tree diameter on the other hand were utilized to develop models that were expected to best fit each data set. The following model's attributes; coefficient of determination (R^2), root mean square of error (RMSE), Durbin Watson statistic (DW), and Furnival Index (FI) for each model and for each dependent variable were obtained. Then Furnival Index criterion was employed to select the best model for each dependent variable. Table 2 presents the coefficients of the best equation (the one with lowest FI value) for each of trunk volume, branches volume and total volume along with p-values associated with each model's coefficients, R^2, RMSE, DW, and FI.

Double log function prevailed for both total volume and trunk volume. Logarithmic transformed equation had the edge for branch volume as well, but the model contained D^3 with negative coefficient as explanatory variable. This indicates that the increase in branches volume diminishes as tree size gets larger. The p-values associated with all the independent variables indicated that all the explanatory variables were highly significant. According to white test, all the three models were free from heteroscedasticity problem, figures 2a, 2b, and 2c support this conclusion. Figures 3a, 3b, and 3c do not reflect that the error term for all the selected models considerably depart from normality.

Table (2): The chosen one entry volume equations and some of their attributes

N	Equations Parameters	R^2	RMSE	DW	FI
1	Ln V_B = -13.82095 + 3.70707 Ln D - 0.00000624 D^3 P-val. (<.0001) (<.0001) (0.0038)	0.96	0.42	1.96	0.0217
2	Ln V_{Tr} = -8.76046 + 1.96678 Ln D P-val. (<.0001) (<.0001)	0.944	0.289	1.88	0.0156
3	ln V_T = -9.84006 + 2.59526 Ln D P-val. (<.0001) (<.0001)	0.985	0.195	1.81	0.0233

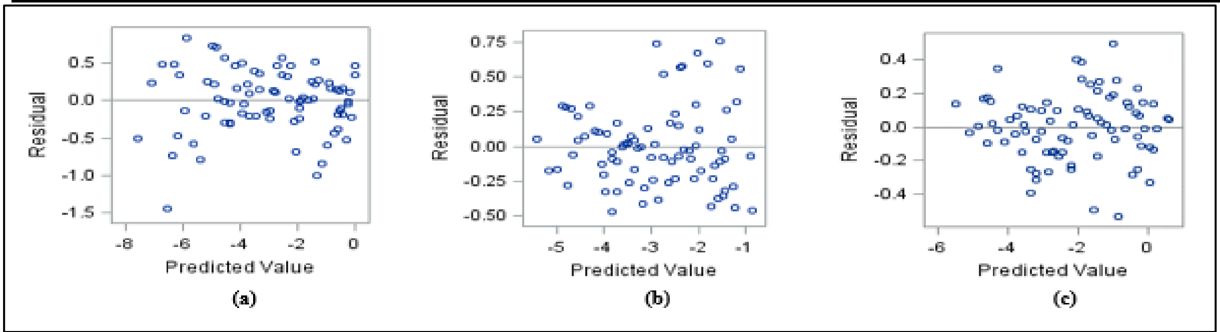

Fig. (2): One entry volume equations' residuals scatter plot for branches volume (a), trunk volume (b) and total volume (c)

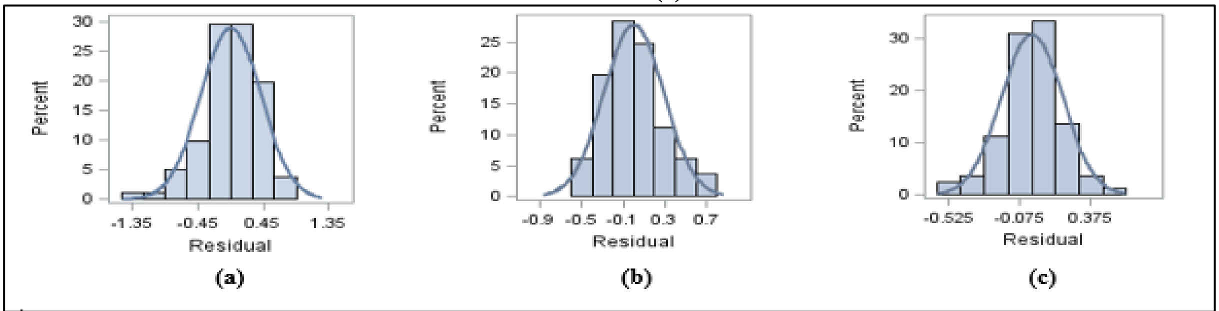

Fig. (3): One entry volume equations' residuals frequency distribution for branches volume (a), trunk volume (b) and total volume (c)

The Durbin Watson statistics for the three models do not indicate that there is significant autocorrelation in any of these three models. The equation that estimate total tree volume has the highest precision, it explained 98.5% of variation in the dependent variable followed by branches volume equation that explained 96% of the variation, while trunk volume equation explained the lowest amount of variation in the dependent variable (94.4%). Table 3 shows the one entry volume table for branches volume (V_B), trunk volume (V_{Tr}), and total volume (V_T). If Furnival Index is considered, this ranking is reversed. Equation estimating trunk volume came in the first place, followed by models estimating branches volume and total volume respectively. One can deduce that trunk volume model outperform the other two models in complying with least square assumptions regarding homogeneity and absence of autocorrelation of error term.

Table (3): One entry volume table for each of total, trunk and branches volume

Diameter (cm)	Branches volume (m^3)	Trunk volume (m^3)	Total volume (m^3)	$V_B + V_{Tr}$ (m^3)	V_T - ($V_B + V_{Tr}$) (m^3)
6	0.0007	0.0053	0.0055	0.0060	-0.0005
9	0.0034	0.0118	0.0159	0.0152	0.0007
12	0.0098	0.0207	0.0336	0.0306	0.0030
15	0.0223	0.0322	0.0600	0.0545	0.0055
18	0.0431	0.0461	0.0964	0.0893	0.0071
21	0.0748	0.0625	0.1438	0.1373	0.0065
24	0.1193	0.0812	0.2034	0.2005	0.0028
27	0.1780	0.1024	0.2762	0.2804	-0.0042
30	0.2513	0.1260	0.3631	0.3773	-0.0142
33	0.3384	0.1520	0.4650	0.4904	-0.0254
36	0.4370	0.1804	0.5828	0.6174	-0.0346
39	0.5433	0.2111	0.7173	0.7545	-0.0371
42	0.6521	0.2443	0.8695	0.8964	-0.0269
45	0.7572	0.2798	1.0399	1.0371	0.0028
48	0.8519	0.3176	1.2296	1.1696	0.0599
51	0.9294	0.3579	1.4391	1.2873	0.1517
54	0.9840	0.4005	1.6692	1.3845	0.2847
Sum	**6.1967**	**2.6325**	**9.2111**	**8.8292**	**0.3818**

Two Entry Volume Equations

In selecting the best general volume equation for each of the branches, trunk, and total volumes a procedure analogous to that used for developing one entry volume equations was followed, except for explanatory variables, in which several variables were tested. Table 4 displays the functions with lowest FI for each response variable. The p-values associated with all the independent variables indicate that they are significant at a probability less than 0.0001. According to White test and figures 4a, 4b, and 4c, the variance of error term of all the three models were homogenous, and the error distribution of all the three equations do not depart considerably from normality (figures 5a, 5b, and 5c). The equations are also free from autocorrelation problem as this can be detected by the values of Durbin Watson statistics. Again, the equation that estimate total tree volume had the highest precision, it explained 99.7% of variation in response variable followed by trunk volume equation then branches volume equation. With respect to Furnival Index, ranking analogous to that of one entry equations was prevailed, trunk volume equation comes in first place followed by brunches volume equation then total volume equation.

Table (4): The chosen two entry volume equations and some of their attributes

N	Equations Parameters	R^2	RMSE	DW	FI
1	$\ln V_B = -14.84954 + 5.7315 \ln D - 0.46135 (\ln D)^2 + 2.47921 \ln Cr$ P-val. (<.0001) (<.0001) (<.0001) (<.0001)	0.982	0.286	1.988	0.0148
2	$\ln V_{Tr} = -9.23954 + 1.91607 \ln D + 0.92731 \ln Th$ P-val. (<.0001) (<.0001) (<.0001)	0.997	0.065	2.004	0.0035
3	$\ln V_T = -10.35315 + 2.30293 \ln D + 0.7143 \ln H$ P-val. (<.0001) (<.0001) (<.0001)	0.992	0.143	1.709	0.01699

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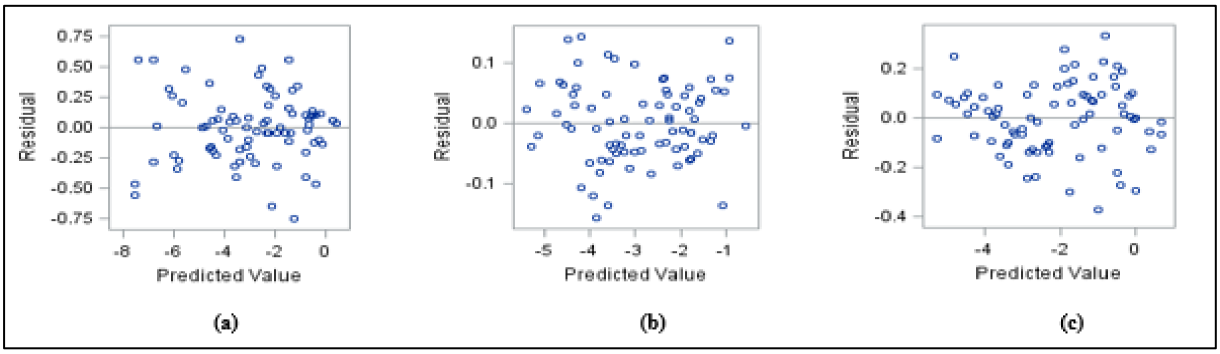

Fig. (4): Two entry volume equations' residuals scatter plot for branches volume (a), trunk volume (b) and total volume (c)

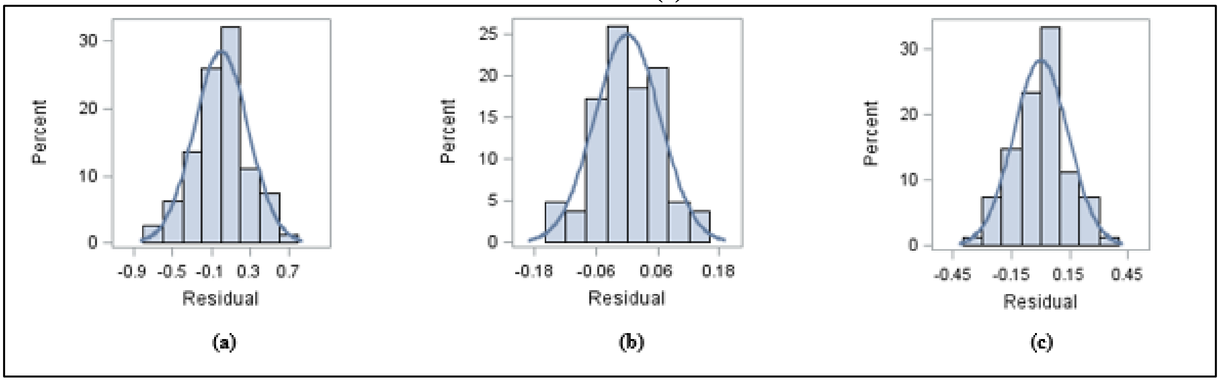

Fig. (5): Two entry volume equations' residuals frequency distribution for branches volume (a), trunk volume (b) and total volume (c)

With regard to branches volume, logarithm of diameter in polynomial form and logarithm of live crown ratio were the only significant variables in the best model. The sign of $(\text{Ln d})^2$ was negative, which indicates that the growth of branches volume tends to diminish as tree diameter gets bigger. This is analogous to what had been obtained for one entry branches volume equation. The R^2 of this equation surpasses that of the one entry volume equation by 2.2%. Table 5 shows the volume table for branches volume for different combinations of tree diameter and live crown ratio. With regard to trunk volume, double log allometric equation prevailed and trunk height improved the amount of variation explained by the one entry model by 5.3%. Table 6 presents trunk volume table for different combinations of diameter and trunk height. With respect to total volume, double log allometric equation had the best R^2. Logarithm of diameter and logarithm of total height were superior over other variables in explaining the variation in total tree volume. Logarithm of tree total height slightly increased the R^2 by 0.07% over one entry model. Table 7 shows the volume table for total volume for different combinations of diameter and total height.

Husch et al. (2002) state that bark factor ranges between 0.87 for trees with thick bark and 0.93 for trees with thin bark. The bark factor obtained for Valonia oak was 0.926. This indicates that the bark layer of this species tends to be very thin. Volume under bark for any component of Valonia trees can be obtained by taking the product of over bark volume and bark factor raised to power two.

Table 5: Branches' two entry volume table

	Live crown ratio									
Diameter	**0.4**	**0.45**	**0.5**	**0.55**	**0.6**	**0.65**	**0.7**	**0.75**	**0.8**	**0.85**
6	0.0002	0.0003	0.0004	0.0005	0.0006	0.0008	0.0009			
9	0.0011	0.0015	0.0020	0.0025	0.0031	0.0038	0.0046	0.0055	0.0065	
12			0.0056	0.0071	0.0088	0.0108	0.0130	0.0154	0.0181	

15	0.0119	0.0150	0.0187	0.0223	0.0274	0.0325	0.0382	
18	0.0211	0.0267	0.0332	0.0405	0.0487	0.0578	0.0678	
21	0.0335	0.0425	0.0527	0.0643	0.0772	0.0916	0.1075	
24	0.0491	0.0622	0.0772	0.0942	0.1132	0.1343	0.1576	
27	0.0679	0.0860	0.1067	0.1301	0.1564	0.1856	0.2178	
30	0.0897	0.1136	0.1410	0.1719	0.2066	0.2451	0.2877	0.3343
33		0.1449	0.1797	0.2192	0.2634	0.3126	0.3668	0.4263
36			0.2227	0.2716	0.3264	0.3874	0.4546	0.5283
39			0.2697	0.3289	0.3952	0.4690	0.5503	0.6396
42				0.3905	0.4693	0.5568	0.6534	0.7594
45				0.4561	0.5481	0.6504	0.7632	0.8870
48				0.5253	0.6313	0.7491	0.8791	1.0216
51					0.7184	0.8524	1.0003	1.1626
54							1.1264	1.3091

Table (6): Trunk's two entry volume table

	Trunk height (m)										
Diameter	**1.3**	**1.6**	**1.9**	**2.2**	**2.5**	**2.8**	**3.1**	**3.4**	**3.7**	**4**	**4.3**
6	0.0038	0.0046	0.0054	0.0062	0.0070	0.0078	0.0085	0.0093	0.0101	0.0108	0.0116
9	0.0083	0.0101	0.0118	0.0135	0.0153	0.0169	0.0186	0.0203	0.0220	0.0236	0.0253
12	0.0144	0.0175	0.0205	0.0235	0.0265	0.0294	0.0324	0.0353	0.0381	0.0410	0.0439
15	0.0222	0.0269	0.0315	0.0361	0.0407	0.0452	0.0497	0.0541	0.0585	0.0629	0.0673
18	0.0314	0.0381	0.0447	0.0512	0.0577	0.0641	0.0704	0.0767	0.0830	0.0892	0.0954
21	0.0423	0.0512	0.0601	0.0689	0.0775	0.0861	0.0947	0.1031	0.1116	0.1199	0.1282
24	0.0546	0.0662	0.0776	0.0890	0.1002	0.1113	0.1223	0.1332	0.1441	0.1549	0.1656
27	0.0684	0.0830	0.0973	0.1115	0.1255	0.1394	0.1533	0.1670	0.1806	0.1941	0.2076
30	0.0838	0.1015	0.1191	0.1364	0.1536	0.1707	0.1875	0.2043	0.2210	0.2376	0.2541
33	0.1005	0.1219	0.1430	0.1638	0.1844	0.2049	0.2251	0.2453	0.2653	0.2852	0.3050
36	0.1188	0.1440	0.1689	0.1935	0.2179	0.2420	0.2660	0.2898	0.3134	0.3369	0.3603
39	0.1385	0.1679	0.1969	0.2256	0.2540	0.2822	0.3101	0.3378	0.3654	0.3928	0.4200
42	0.1596	0.1935	0.2270	0.2600	0.2928	0.3252	0.3574	0.3894	0.4211	0.4527	0.4841
45	0.1822	0.2209	0.2591	0.2968	0.3341	0.3712	0.4079	0.4444	0.4807	0.5167	0.5526
48	0.2062	0.2500	0.2932	0.3359	0.3781	0.4200	0.4616	0.5029	0.5439	0.5847	0.6253
51	0.2316	0.2808	0.3293	0.3772	0.4247	0.4718	0.5185	0.5649	0.6110	0.6568	0.7023
54	0.2584	0.3133	0.3674	0.4209	0.4739	0.5264	0.5785	0.6303	0.6817	0.7328	0.7836

Table (7): Total's two entry volume table

	Height (m)									
Diameter	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
6	0.0053	0.0062	0.0071	0.0079						
9	0.0135	0.0158	0.0180	0.0201	0.0222					
12	0.0262	0.0307	0.0350	0.0391	0.0430	0.0468				
15	0.0438	0.0514	0.0586	0.0654	0.0719	0.0783	0.0844			
18	0.0667	0.0783	0.0891	0.0995	0.1095	0.1191	0.1284			
21		0.1116	0.1272	0.1420	0.1562	0.1699	0.1832	0.1961		
24		0.1518	0.1730	0.1931	0.2124	0.2311	0.2491	0.2667		
27			0.2269	0.2533	0.2786	0.3031	0.3268	0.3498		
30			0.2892	0.3228	0.3552	0.3863	0.4165	0.4459	0.4745	0.5024
33			0.3602	0.4021	0.4423	0.4812	0.5188	0.5553	0.5909	0.6257
36			0.4401	0.4913	0.5405	0.5879	0.6339	0.6785	0.7221	0.7645
39			0.5292	0.5908	0.6499	0.7069	0.7622	0.8159	0.8682	0.9193
42				0.7007	0.7708	0.8385	0.9040	0.9677	1.0298	1.0904
45				0.8214	0.9036	0.9829	1.0597	1.1344	1.2071	1.2782
48					1.0484	1.1404	1.2296	1.3162	1.4006	1.4830
51						1.3113	1.4138	1.5134	1.6104	1.7052
54						1.4958	1.6127	1.7263	1.8370	1.9451

Ratio of Branch Volume to Trunk Volume

The ratio branches volume to trunk volume for sampled trees ranged from 0.035 for small trees to 6.76 for big trees and the average was 1.53. This indicates that branches of Valonia oak contribute more to total volume than trunk volume when trees are big in size. The proportion of estimated branches volume to estimated trunk volume obtained from one entry volume equation starts at 0.14 for the smallest tree in diameter (6 cm). In other words, branches volume constitutes only 14% of trunk volume, this attributed to the small crown (branches greater than 4 cm in diameter) of small trees. This ratio consistently increases as tree diameter increases, when diameter reaches 19 cm the volume of these two components equalize. Further increase in diameter leads to consistently increase in this ratio until it reaches its maximum (2.7) at diameter 46 cm then it declines.

Differences Between Estimated Total Volume and The Sum of Its Estimated Two Components

Since Valonia oak trees' volume was broken down into trunk volume and branches volume, the estimated total volume should coincide with the sum of its estimated two components. Divergence or convergence of these two values or existence of a trend in the change in their values as the tree gets bigger in diameter will indicate a problem with at least one equation. Based on one entry volume table,

the difference between the two figures for the sampled 81 trees was only 0.467 m^3 which constitutes only 1.87% of estimated total volume. Table 3 demonstrates the differences between the two figures for the one entry volume table constructed from the three developed equations. There were no consistent differences between these two figures. The sum of the differences was only 0.382 m^3 which constitute only 4.1% of the sum of the total volume of the trees in the table. This outcome advocates that the developed one entry volume equations are precise and unbiased.

The two entry volume equations was even better in this respect, the difference between estimated total volume of the sampled 81 trees and the sum of the estimated branches volume and trunk volume was only 0.24 m^3 which represents only 0.95% of total volume.

DISCUSSION

Many of developed volume equations addressed in literature have used allometric double log function, among them Pillsbury et al. (1984); Retson and Sochaki (2003); Segura and Kanninen (2006); Magalhaes (2017); Ajayi et al. (2017); and Mohamme et al. (2018). The popularity of this functional form stem from its capability in remove the problem of the heterogeneity of error term besides its capability to depict changes in tree volume as diameter and height varies (Parresol, 1999; Picard, 2012). In this work, this model has prevailed as well for all the selected equations. The two entry volume equations revealed that diameter and height or some form of height were superior over other tested tree attributes in explaining the variation in tree volume and volume of its components. This is in accord with the majority of standard volume equations found in literature such as Pillsbury and Prayor (1989), Masota et al. (2014), and Mohammed et al. (2018).

It has been found that diameter at breast height explains the most amount of variation in tree volume. As a result local volume tables are constructed depending on tree diameter. Total tree height or merchantable height comes in second place; the first one is associated with total volume and the second one is associated with merchantable volume to a given top diameter (Husch et al., 2002). In general, the results of this work are analogous to the above trend. In this work, diameter and height were chosen in the best equation for total volume. While in trunk volume model, trunk height, which is equivalent to merchantable height, was obtained along with diameter. With respect to branches volume, besides diameter, live crown ratio was superior over other tree attributes in explaining the variation in branches volume. Live crown ratio implicitly represents some form of crown length but it presents it as a percentage of total tree height. This form surpassed both crown length in its explicit form and total tree height in explaining the variation in branches volume. For trees with equal diameter, as live crown ratio increase (which means crown covers greater percentage of tree height in other wards bigger crown) volume of branches increases as well. While tree diameter covers the variation in tree size, as tree diameter gets bigger in size branches volume gets bigger too. All the other tested tree attributes could not surpass tree diameter, height, trunk height, and live crown ratio in explaining the variation in total tree volume and its components.

With respect to general volume equations, it was not possible to verify whether the estimated total volume of a given tree will be close to the sum of its estimated branch and trunk volumes from the figures given in the three tables because different explanatory variables were used in these three models. When estimated total volume compared to sum of its estimated two components the differences were arbitrary and small for both one entry and two entry equations. This boosts the adequacy of these developed equations.

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هەلسەنگاندنا پێکهاتا داری یا دارا بەرییا خوارنێ ل پارێزگەها دهوکێ، هەرێما کوردستانێ- عیراق

پوختە

دار بەری(بەرییا خوارنێ) د هێتە هژمارتن ژ جورین گەلەك بەربەلاف ل چیایین کوردستانێ.ڤی جورێ داری گەلەك یا پشکیشی کومەلگەهین ئاکنجیبونا گوندان کرییە دگەل ئەرکین زیندەی د پاراستنا ژینگەهێ دا.ژبەرکو قەدێ ڤی جوری ب رەنگەکێ راست و بەردەوام ناشین بیت دناڤبەرا قەد و چقان. ژبەر کو دارێ ڤان هەردوو پارچان کارئینانێن جوراجور هەنە. لەورا ئەم رابوین ب بەرهەڤکرنا هاوکێشیین تایبەت ژ بو هەر پارچەکێ ژبو ب دەستڤەئینانا قەباری و زێدەباری تێکرایین گشتی ین قەبارەی.مە پیڤەرێ **Furnival Index** ژبو مەرەما بەراوردکرنێ دناڤبەرا تێکرایین بەرهەڤکری و ژێکگرتی ین باشبکار ئینا. و پشتی هنگی ئەڤ هاوکێشە هاتنە تاقیکرن ژبو دووپاتکرنێ ژ هەڤدژ بونا مەرجان برێکا شێوازی **Least square method** ول دوماهیێ ئەم رابوین ب ئامادەکرنا خشتەین قەباری ێن ژلایەکێڤەو ین ژ هەردوو لایانڤە ژبو هەر ئێك ژ قەد و چقان و قەبارێ گشتیێ دارێ.

تقييم محتوى خشب بلوط الاكل في محافظة دهوك، إقليم كردستان العراق

الخلاصة

يعتبر شجرة البلوط (بلوط الاكل) النوع الاكثر شيوعا في تغطية جبال كوردستان العراق. وتقدم هذه الشجرة الكثير للمجتمعات الريفية في هذه المناطق بالاضافة الى وضائفها الحيوية في حماية البيئة. ونظرا لان ساق هذه النوع لا ينمو بصورة مستمرة كساق رئيسي لذا فان خشب هذا النوع يتوزع بين كل من الساق والاغصان. وبما ان خشب هذين الجزئين لهما استخدمات مختلفة, لذا فانه تم اعداد معادلات خاصة بكل جزء على حدا لغرض الحصول على حجومها اضافة الى اعداد معادلات للحجم الكلي. تم استخدام معيار **Furnival Index** لغرض المفاضلة بين المعادلات المشتقة (المعدة) واختيار انسبها. وبعد ذلك تم اختبار هذه المعادلات للتاكد من عدم مخالفتها لشروط **Least square method** . واخيرا تم اعداد جداول الحجوم ذات اتجاه واحد و ذات الاتجاهين لكل من الساق و الاغصان والحجم الكلي للشجرة.