ESTIMATING ABOVEGROUND BIOMASS AND CARBON SEQUESTRATION FOR NATURAL STANDS OF *QUERCUS AEGILOPS.* IN DUHOK PROVINCE

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ABSTRACT

The study was aimed to develop above ground biomass(AGB) and its component models for an individual tree and stand of *Quercus aegilops* The benefits of this study are to know the amount of forest biomass to help us to estimate the amount of the lost or emitted carbon during deforestation and will give a clear idea of the forest capacity in capturing and storing carbon C in the forest ecosystem.. The study was conducted in six locations in the northeastern Duhok province in Kurdistan region of Iraq. Twenty-one trees were selected according to their diameter classes and felled to measure fresh weight (FW) and dry weight (DW) from different organs, including (stem, branches, leaves, and whole tree). In addition to, all trees with diameter at breast height (D ≥5 cm) in 89 plots of 0.04 ha, each was measured. Allometric equations of individual trees were used for estimating AGB and its component depending on D only. The DW of AGB and its components were converted into C by multiplying it on a half. The AGB estimated for FW and DW of the entire study area are 157.5285, 115.1153 (Mg ha^{-1}) respectively. The results showed that Csequestration in the stands for stems, branches, leaves and the whole tree are 146.005, 73.9333, 31.38121and 249.9924 Mg ha^{-1} respectively.

Keywords: Fresh Weight, Dry Weight, Allometric equation, Carbon sequestration, Tree diameter.
*** part of Ph.D. Dissertation of the 1[nd] author**

تقدير الكتلة الحية واحتباس الكاربون للمشاجر الطبيعية لاشجار البلوط في محافظة دهوك

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المستخلص

تهدف هذه الدراسة الى تطوير نماذج الكتلة الحية للأشجار ومكوناتها كشجرة مفردة وللمشاجر لنوع أشجار البلوط . تكمن فوائد هذه الدراسة في معرفة كمية الكتلة الحيوية للغابات لتقدير كمية الكربون المنبعث أثناء عمليات إزالة الغابات.أجريت الدراسة في ستة مواقع في محافظة دهوك في إقليم كردستان العراق.تم اختيار 21 شجرة حسب فئات أقطارها وقُطعت لقياس الوزن الطري (الوزن الثابت) والوزن الجاف. ل 89 قطعة من مساحات 0.04 هكتار ، وتم اخذ القياسات لكل منها. ثمتم استخدام المعادلات Allometric للأشجار الفردية والمشاجر لتقدير الكتلة الحية. الكتلة الحية المحسوبة والمقدرة للوزن الجاف والوزن الرطب لمنطقة الدراسة بأكملها كانت 157.5285، 115.1153 (Mg ha^{-1}) بالتعاقب.أوضحت النتائج أن احتباس الكربون في مكونات الأشجار في المشاجر من الساق، الأغصان، الأوراق، وجميع الشجرة كانت 146.005 و 73.9333 و 31.38121 و 249.9924 Mg ha^{-1} على التوالي.

الكلمات الدالة: الوزن الرطب، الوزن الجاف، معادلة Allometric ، احتباس الكاربون، قطر الشجرة.
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INTRODUCTION

Forests are one of the most important natural resources of wood products. It provides direct and indirect benefits to human beings from economic and environmental aspects (1). Moreover, forests are a basin of carbon dioxide (CO_2) due to the photosynthesis process that performs by forests. This leads to reducing the amount of CO_2 from the atmosphere which ultimately diminishes the rate of global warming (15). Carbon is a major global concern Hassoon (6). For that reason, the process of storing carbon in the tree is directly related to its biomass.The AGB estimation becomes a basic necessity for forest management and evaluation (4). Consequently,several studies have been conducted to determine forest production and growth that are concerned with the quantitative output of trees biomass (2) Field-based estimation of biomass is generally performed with two different methods. They are destructive and non-destructive methods (16). The first method is usually achieved by dropping a tree and separating its parts (main stem, branches, leaves, and whole tree) after that, weigh each part separately. The non-destructive method is the most widely used in the estimating above/below-ground biomass also known as allometric equations (7). This procedure does not request to cut down the trees in the forest. Allometric equations are developed through making relationships between different parameters of trees as diameter at breast height, total tree height, tree form, crown diameter, etc.These variables can be used either individually or in combination with each other to estimate AGB. Most models for biomass estimation have been developed and used by the forestry or ecology community. These models normally divide aboveground components into main stem, branches, and leaves parresol (19). In Iraq, Mohammed (12) was the first researcher used allometric equations to estimate AGB of poplar trees in the warso village- Zakho district-governorate of Duhok northern Iraq. More recently, Khalaf (10) was published in his thesis, estimating AGB of *Pinus brutia*Ten. Performed for three areas (Acre, Atrush and Zaweta) located in Duhok governorate northern Iraq. However, so far there are no equations have been developed to estimate AGB of *Quercus aegilops*in Kurdistan region of Iraq. This is the first attempt to develop allometric equations to estimate AGB and its component of oak.Therefore, this study was aimed to determineFW, DW and the amounts of carbonin individual tree and stand.

MATERIALS AND METHODS

Measurement of harvested trees

Fieldwork was conducted for three months in 2016 (end of July untilthe ending of October). A total of 89 sample plots of 20 m×20 m were set up and covers an area of 3.56 ha. Plots were distributed in six locationswith different stand density. There were 17 plots in Bady, 19 plots in Rashaur, 12 plots in Banasur, 5 plots in Kamala, 17 plots in Barushka Sadeen and 19 plots in Bilijank.Within these plots, 1322 trees with D $\geq$ 5cm were measured using diameter tape. Randomly 208 trees were selected for analyzing data and used to estimate AGB with its components. Whereas the rest was used for the purpose of prediction.

Estimating AGB and its components

The first essential step of using the destructive method in the current study was tofelled down 21 trees from the stands with different D. The diameter at the stump $d_{0.3}$ m, diameters at breast height (D =1.30 m), diameter above breast height at one-meter intervals beginning at $d_{2.3}$ to $d_{6.3}$, total tree height, crown diameter and crown height were measured directly in the field. This is implemented for the purpose of estimating FW, DW, moisture content, and the amount of carbon.The latitude, longitude, and altitude of trees were determined using a GPS device. Trees were sampled in 5 cm diameter classes, starting at 5 cm up to the maximum diameter found in the area. The main stem was cut into sections at one-metre intervals starting at $d_{0.3}$ m above the ground to the top of a tree that were weighed directly in the field. Cumulative weights of logs were added to obtain total FW of the main stem. From the large end of each log, a disc was cut to a thickness of 3-5 cm. These sub-samples were directly measured in the field.The crown length was divided into three equal sections: upper, middle and lower(9). Branches were cut into 1 m and then assembled and weighed directly in the field. Asub-sample of each section with a length of 20 cm was taken randomly (5), and then weighed using a scale with a precision of 0.05 g.The leaves were assembled and placed in plastic bags and weighed directly in the field. Randomlyone kg. of these leaves were taken and transferred to the laboratory for drying purposes.The total FW of each individual tree AGB was calculated as the sum of the weights of each tree component (17).

Dryweight (DW): Sub-samples of each component of a tree dried at 105°C ±2. Equation (1) used to determine the components DW Jayaraman (10).

$$DWC = \frac{FWC * DWs}{FWs} \quad (1)$$

Where DWC is DW of each component of the tree, FWC is FW of eachcomponent of the tree, DWs is DW of each sub-sample, and FWs is the fresh weight of each sub-sample.The descriptive statistics of the data used for modeling are given in Table (1).

Table (1). Data of FW, DW and its component of individual tree of oak in Duhok province

No	D (cm)	FW and its Components Kg.				DW and its Components Kg.			
		Stem	Branch	Leaves	TREE	Stem	Branch	Leaves	TREE
1	14.6	56.4000	30.6000	14.8500	101.8500	37.7761	20.5613	8.7615	67.0989
2	11.7	38.1500	23.6000	12.0500	73.8000	26.0968	15.7637	6.2058	48.0663
3	20.7	120.8000	56.8000	29.3000	206.9000	80.5819	38.5731	19.3380	138.4930
4	9.7	28.4000	11.8500	7.6500	47.9000	19.9189	7.2716	5.2020	32.3925
5	10.3	31.0000	16.3500	8.0000	55.3500	26.4675	13.9490	4.9600	45.3765
6	13.3	47.3000	25.7500	14.2000	87.2500	39.8113	21.8875	9.3720	71.0708
7	21.5	125.4850	59.2850	32.8300	217.6000	94.2645	43.7348	22.9810	160.9803
8	15.6	61.8650	33.2000	15.4000	110.4650	45.3797	24.2927	9.8560	79.5283
9	16.3	72.7750	36.8400	21.3800	130.9950	60.1399	29.1556	17.1040	106.3995
10	17.3	78.8500	48.7000	24.8000	152.3500	57.9271	33.9380	15.8348	107.6999
11	28.3	210.4500	87.9500	43.4000	341.8000	169.6155	73.3376	28.8610	271.8141
12	10.8	35.1250	18.3500	8.6500	62.1250	27.2637	14.5477	5.7090	47.5204
13	19.4	94.6500	50.2000	27.6000	172.4500	75.1454	37.6500	18.7680	131.5634
14	26.5	182.6500	76.6000	38.6000	297.8500	144.6888	60.2173	24.7040	229.6101
15	16.8	72.8500	38.4500	20.4500	131.7500	54.8313	28.6490	12.2700	95.7503
16	22.6	143.7500	71.4000	36.3450	251.4950	115.8327	56.4471	23.0791	195.3589
17	34.1	261.5500	125.3600	51.7800	438.6900	221.3380	112.1193	38.3172	371.7744
18	36.4	324.8350	143.5000	56.8000	525.1350	229.5380	106.6845	35.2160	371.4385
19	37.6	338.6500	171.8000	66.4000	576.8500	248.1034	130.1099	49.1360	427.3492
20	36.8	332.1250	160.6000	63.6500	556.3750	228.7886	106.1862	44.5550	379.5298
21	41.8	390.3500	188.4000	73.8170	652.5670	285.9262	143.5227	60.7514	490.2003

Estimation of AGB in Stand:

Estimating AGB in a stand, need to convert the weight of AGB in an individual tree and its component from Kg. to ton (Mg); then, convert it from ton to ton per hectare (Mg ha^{-1}) using the following formula:

$$AGB_h = \frac{A}{\frac{a}{AGB}} \quad (2)$$

Where: A is the areaMg ha^{-1}, and a is an area of our sample plot 400 m^2

Statistical Analysis

Eight allometric regression equations were used including: linear, exponential, double reciprocal, logarithmic-X, multiplicative, square root-y, square root-X, and s-curve Table (4). Intricate models involving several variables were not considered to predict AGB because the additional variables increase multi-collinearity and reduce strengthening of the biomass equation (5). Also, transformed variables were not included in the dependent variable or returned to their original form

Table (2). Candidate models considered

No.	Type of model	Model form
1	Linear model	y = a + b*X
2	Exponential model	y = exp (a + b*X)
3	Double reciprocal model	y = 1/(a + b/X)
4	Logarithmic-X model	y = a + b*ln(X)
5	Multiplicative model	$y = a*X^b$
6	Square root-y model	$y = (a + b*X)^2$
7	Square root-X model	y = a + b*sqrt(X)
8	s-curve model	y = exp (a + b/X)

The adjusted coefficient of determination (R^2), standard error of estimate (SE of EST) and mean absolute error (MAE) were calculated for purpose of evaluation of the best allometric equation. The appropriate equation with the smaller values of the SE of EST, MAE and higher values of (R^2 adj) were selected. Another important step in evaluating the equations was to perform a graphical analysis of the best-fit equation to assess the appearance of the fitted curves overlaid on the data set.

RESULTS AND DISCUSSION

Trees distribution

Afterselecting 208 trees for data analyzing, the non-destructive method was used toestimate AGB and its component using allometric regression equations. Trees were classified into 8 diameter classes, starting from 5 cm to 45cm based on what has been found in the study area.The Dof trees classified and found that the majority of the trees are small in D classes. This is clearly shows in (Figure, 1)as 8.7% located between 5 and 9.9 cm, 15.4% located between 10 and 14.9 cm, and 19.2% between 15 and 19 cm. Medium trees in D classes with 16.8 % located from 20 to 24.9 and 13% located from 25 to 29.9 cm. Larger trees constitute a smaller percentage of tree composition, with 10% located within a range from 30 to 34.9 cm, 8.7% located with a range from 35 to 39.9 cm, and 8.2% located from 40 to 45 cm of the total number being measured.

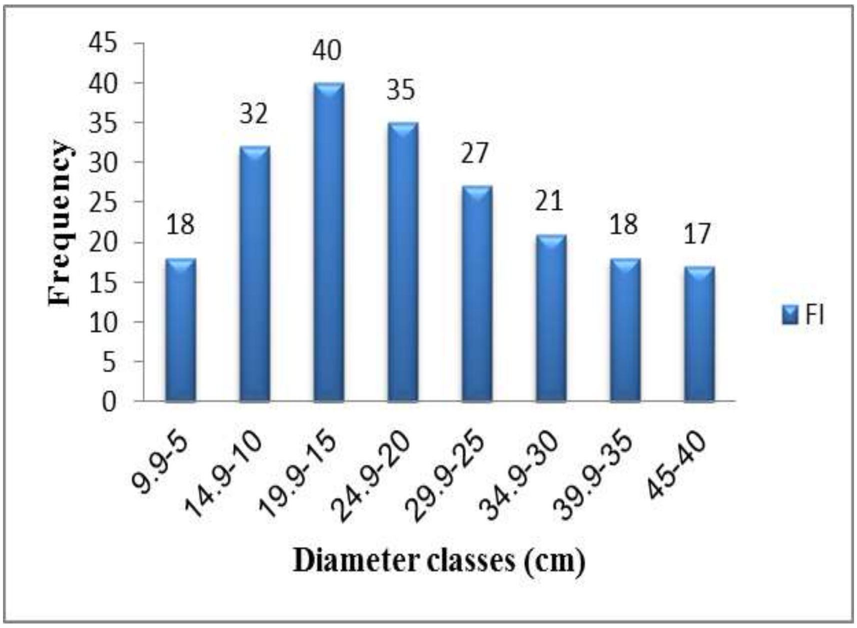

Figure 1. Distribution of trees by diameterclasses

Fresh weight and dry weight (FW and DW)

After analyses AGB of a single tree and its components,using allometric equations. The D was used alone as an independent variable to estimate the FW and DW.From eight allometric regression equations that were used in this study,the best four of them were selected for each component to estimate FW and DW of AGB and its component depending on theirstatistical criteria. This is reported in Tables(3and 4).

Table 3. Allometric equation and its criteria used to estimate FW of oakand its components

NO	Equations	R^2adj	S.E OF Est.	MAE
A_1	$FWS = 0.578721*D^{1.72425}$	98.5029	0.10641	0.07897
A_2	FWS = exp(2.76121 + 0.082755*D)	94.9473	0.19548	0.1607
A_3	FWS = -302.243 + 96.304*sqrt(D)	89.8839	35.42110	27.89350
A_4	FWS = -97.2582 + 10.6371*D	95.66220	23.19480	18.00040
A_5	$FWB = 0.442825*D^{1.58169}$	97.9014	0.11592	0.08386
A_6	FWB = exp(2.20072 + 0.0767495*D)	96.4691	0.15036	0.12334
A_7	FWB = -43.1076 + 4.94173*D	94.5749	12.11940	9.39845
A_8	FWB = exp(5.19573 - 22.0145/D)	81.8494	0.34091	0.27579
A_9	$FWL = (1.0506 + 0.194824*D)^2$	98.6772	0.23101	0.18363
A_{10}	FWL = -60.6939 + 20.4103*sqrt(D)	93.4826	5.90905	4.55902
A_{11}	FWL = -94.5234 + 42.7296*ln(D)	85.3313	8.86497	6.97838
A_{12}	FWL = exp(4.52158 - 22.3167/D)	86.2507	0.29305	0.23570
A_{13}	$FWT = (1.49926 + 0.586057*D)^2$	99.0227	0.59625	0.47385
A_{14}	FWT = -168.845 + 18.664*D	95.83450	39.84550	30.83760
A_{15}	FWT = exp(6.58656 - 24.1472/D)	84.3773	0.34171	0.27632
A_{16}	FWT = -799.848 + 350.871*ln(D)	80.8496	85.43500	67.17090

Source: by the researchers

Where: FWS, FWB, FWL and FWT represent a fresh weight stem, fresh weight branches, fresh weight leaves and fresh weight of whole tree respectively.

Table 4. Allometric equation and its criteria used to estimate DW of oakand its components

NO	Equations	R^2adj	S.E OF Est.	MAE
a1	$DWS = 0.428673*D^{1.73069}$	98.4864	0.10740	0.07955
a2	DWS = -230.305 + 73.2352*sqrt(D)	89.7094	27.19380	21.42390
a3	DWS = exp(5.74402 - 24.3515/D)	84.1588	0.34745	0.28104
a4	DWS = -347.185 + 151.832*ln(D)	80.2948	37.63050	29.56220
a5	$DWB = 0.312628*D^{1.60289}$	97.9014	0.11747	0.08499
a6	DWB = exp(1.89297 + 0.0777779*D)	96.4691	0.15238	0.12499
a7	DWB = -33.6541 + 3.78908*D	94.3954	9.45401	7.34389
a8	DWB = -106.171 + 34.1978*sqrt(D)	88.1380	13.75380	10.77080
a9	$DWL = 1/(-0.0114618 + 3.99296/D^{1.325})$	97.800	0.01157	0.00701
a10	DWL = -47.1523 + 15.2793*sqrt(D)	91.2169	5.19824	4.07289
a11	DWL = exp(1.03851 + 0.0799931*D)	94.4302	0.19893	0.16359
a12	DWL = -71.8774 + 31.7895*ln(D)	82.2282	7.39433	5.82058
a13	DWT = exp(6.18109 - 22.5515/D)	81.8494	0.34922	0.28250
a14	DWT = -119.688 + 13.2857*D	94.2463	33.6133	26.1444
a15	$DWT = 1.02445*D^{1.62028}$	97.9014	0.1187	0.0859
a16	DWT = exp(3.11296 + 0.0786241*D)	96.4680	0.1541	0.1264

Source: by the researchers

Where: DWS, DWB, DWL and DWT represent dry weight stem, dry weight branches, dry weight leaves and dry weight of whole tree respectively

The dependent variables were used in all the equations, in its original form or returned to its original form, while the independent variable representedby D alone and consisted of these transformations D, D^2, Ln D, exp D, sqrt D, and exp (1/D). All parameters were found to be significant at the 5% level. The best-fit allometric equation for each component of tree was selected based on good tests of largest R^2 adj, least S.E. of Est. and MAE.FWS and FWB multiplicative modelswere selected as a best – fit allometric equation (A_1 and A_5) respectively. Both of them had higher R^2 adj. and smaller S.E. of Est. and MAE 98.5029, 0.10641 and 0.07897, 97.9014, 0.11592 and 0.08386 respectively. Also, FWL and FWT square root-Y modelswere selected as a best-fit allometric equations (A_9 and A_{13}) respectively. This is due to that fact, both of them have highest R^2 adj. and smaller S.E. of Est. and MAE 98.6772, 0.2310 and 0.1836, and 99.0227, 0.5962 and 0.4739 respectively. In addition, DWS and DWB Multiplicative modelswere selected as a best-fit allometric equations (a_1 and a_5) respectively. This is also because both of them had higher R^2 adj. and smaller S.E. of Est. and MAE 98.4864, 0.107401 and 0.079551, 97.9014, 0.117472 and 0.084985 respectively. Moreover, DWL with Double reciprocal model (a_9) was selected because it has a higher R^2 adj. and smaller S.E. of Est. and MAE 97.8000, 0.011572 and 0.00701 respectively. Finally, DWT with Multiplicativemodel (a_{15}) was selected because it has a higher R^2 adj. and smaller S.E. of Est. and MAE 96.6480, 0.1541 and 0.1264 respectively.Significance F-value was then computed and the results tabulated for the best equation in each component of a tree biomass (Table, 5). The P-value of all allometric equation that is selected as fit-test statistics in the ANOVA table is less than 0.01. There is a statistically significant relationship between AGB of the tree and its component as dependent variable and D as an independent variable at the 99% confidence level.

Table 5. Analysis of Variance for FW and DW of AGB and its components

Analysis of Variance for FWS						Analysis of Variance for DWS			
Source	**Df**	**SS**	**MS**	**F-Ratio**	**P-Value**	**SS**	**MS**	**F-Ratio**	**P-Value**
Model	1	154.221	154.221			155.375	155.375		
Residual	206	2.33243	0.01132	13620.74	0.0000	2.37621	0.0115	13469.86	0.0000
Total	207					157.751			
Analysis of Variance for FWB						**Analysis of Variance for DWB**			
Model	1	129.774	129.774			133.275	133.275		
Residual	206	2.76806	0.0134	9657.96	0.0000	2.84273	0.0138	9657.61	0.0000
Total	207					136.118			
Analysis of Variance for FWL						**Analysis of Variance for DWL**			
Model	1	824.045	824.045			1.23236	1.23236		
Residual	206	10.9928	0.05336	15442.21	0.0000	0.0275856	0.000134	9202.89	0.0000
Total	207								
Analysis of Variance for FWT						**Analysis of Variance for DWT**			
Model	1	7456.71	7456.71			137.465	137.465		
Residual	206	73.2347	0.355508	20974.80	0.0000	1.62311	0.007879	17446.53	0.0000
Total	207								

Another important step in evaluating an equation of each component of the tree was to perform a graphical analysis. The best-fit equation was tested to check the performance, especially before putting it into widespread use or practice.Broadly, graphs display that there is a very strong relationship between independent variable as diameter and dependent variable as FW and DW of the tree and its component. Furthermore, graphs show that the data didn't aggregate at a given location from the regression line. Samples are distributed along the line or very close to the regression line(Figure, 2). This is evident when the predicted values correlate with the observed values of each equation.

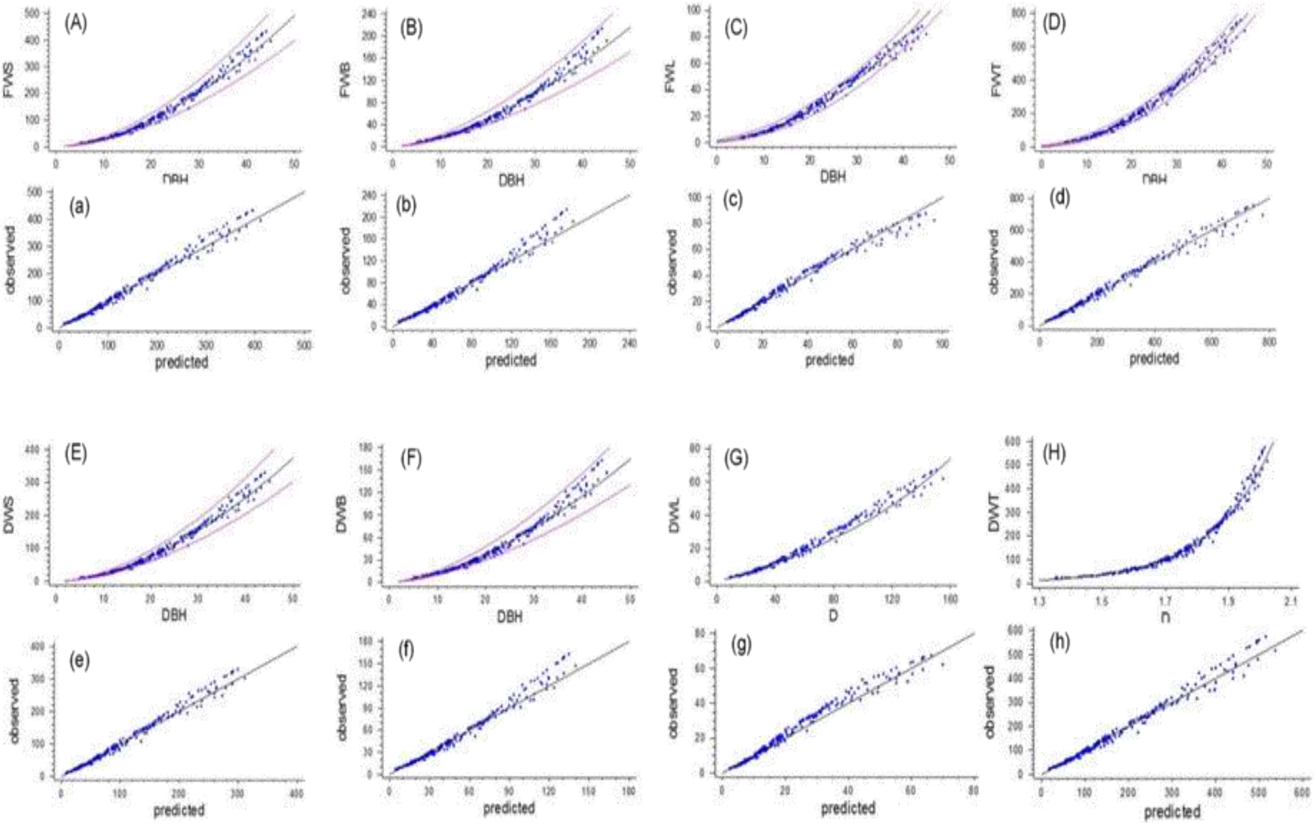

Figure 2. A, B, C, D.Represent the relationship between FWS, FWB, FWL, FWT and (D) respectively, whilea, b, c, drepresent observedvs. predicted for selected equation. Also E, F, G, H represent the relationship between DWS, DWB, DWL and DWT and (D) respectively, while a, b, c, d represent observed vs. predicted for selected equation

AGB of Individual tree

Many conducted biomass assessment studies in forestry were focused on AGB (11, 21). This is due to the fact that AGB accounts for the majority of the total accumulated biomass in the forest ecosystem. This study also focuses on the assessment of AGB of natural oak located in Duhok province. FW and DW were extracted for each individual tree and its component in kg based on their diameter classes. The mid-point of each diameter class, compensate inthe equation that has been selected according to fit test statistic, FW and DW of each individual tree and its component was estimated as shows in (Table, 6).

Table 6.AGB and its components of an individual tree of oak

DBH	MP	FW (kg)				DW (kg)			
		FWS	FWB	FWL	FWT	DWS	DWB	DWL	DWT
5—9.9	7.5	18.6764	10.7228	6.309	34.7473	14.0148	7.9005	3.7717	28.6639
10—14.9	12.5	45.0626	24.0549	12.1515	77.8801	33.9264	17.9165	7.7455	60.0154
15—19.9	17.5	80.4966	40.9575	19.8918	138.1861	60.7351	30.7242	12.7317	101.5873
20—24.9	22.5	124.1566	60.9489	29.5299	215.6652	93.8285	45.965	18.8494	153.848
25—29.9	27.5	175.4845	83.7163	41.0658	310.3174	132.7898	63.4045	26.323	217.3505
30—34.9	32.5	234.0637	109.0342	54.4995	422.1427	177.3077	82.8725	35.4981	292.6915
35—39.9	37.5	299.5661	136.7293	69.8311	551.1412	227.1362	104.2382	46.8926	380.4943
40—45	42.5	371.7225	166.6628	87.0605	697.3129	282.0737	127.3961	61.2939	481.4012

Consequently, the weight of AGB and its components can be estimated for all regions that are presented in the study area.It is also, noticed that the weight of the main stem of a tree is approximately twice the weight of branches, whether it is FW or DW. In contrast, weight of branches per tree is roughly double weight of leaves (Figure, 3).

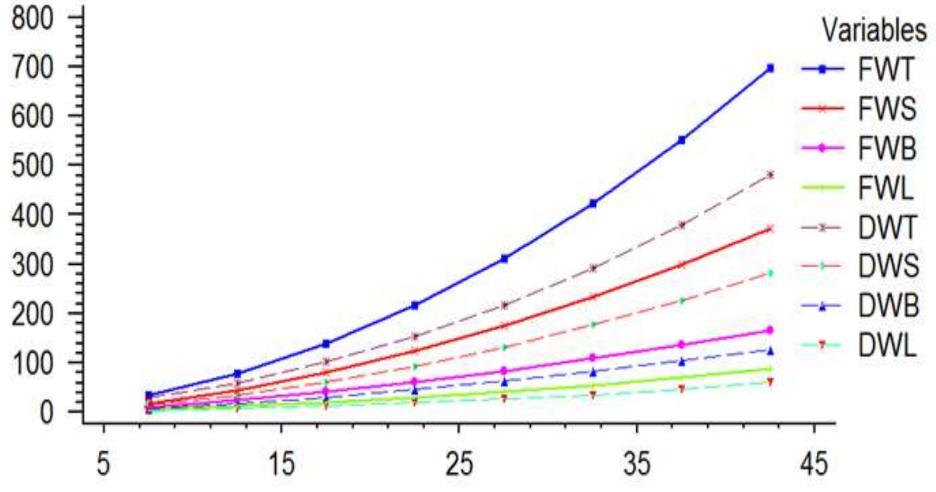

Figure 3. FW and DW of AGB and its components for oak

AGB of Stands

The weight of AGB and its components for each region(Mg ha^{-1}) was estimated based on the total number of trees in that area (Table, 7). There is a clear difference in the number of plots taken from each region. The largest numbers of plots werelocated in the region of Rashaur and Bilijank as 19 plots in each region with diameter means 10.84 - 11.62 cm respectively. While smallernumbers of plots werelocated in the Kamala region, 5 plots with diameter means10 cm. The main reason for the differences in the number of trees in each regionis due to the nature of tree distribution in those areas, as well as to the density of the number of trees in each plot. As a result, this leads to a different weight of each component of the tree. In addition, the differences in the average diameter of trees in each region have led to differences in the biological weight of trees and their components regardless of the number of trees in that area.

Table 7. FW and DW of AGB and its components for stands of oak in six locations of Duhok province

Region	No. of Trees	No of Plots	D (cm) mean	FW (Mg ha^{-1}) FWS	FWB	FWL	FWT	DW (Mg ha^{-1}) DWS	DWB	DWL	DWT
Bady	259	17	9.83	8.5517	4.5910	2.4561	15.2621	6.4373	3.4156	1.5271	11.8597
Rashaur	328	19	10.84	13.3522	6.9981	3.6646	23.7005	10.0620	5.2248	2.2936	18.0161
Banasur	147	12	18.42	15.3820	7.4429	3.7434	27.4628	11.6332	5.6238	2.4163	19.5762
Kamala	77	5	10.80	3.1065	1.6278	0.8569	5.5384	2.3411	1.2153	0.5403	4.2206
B. Sadeen	193	17	26.00	33.9183	15.9204	8.0250	61.3546	25.6862	12.0852	5.3178	42.9749
Bilijank	318	19	11.62	13.7939	7.2681	3.7427	24.2101	10.3919	5.4228	2.3624	18.4678
Total	1322	89		88.1046	43.8482	22.4887	157.5285	66.5518	32.9875	14.4575	115.1153

The results shows the number of trees in theB. Sadeen region was 193 with an average diameter of 26 cm and total DW of trees was 42.9749 Mg ha^{-1}. However, the number of trees in the Rashaur region was 328 with an average diameter of 10.84 cm and the total DW of the trees was 18.0161 Mg ha^{-1}. This indicates that the increases in tree diameter mean in B. Sadeen region led to four times increase in the total DW of the tree compared to the DW of a single tree in the Rashaur region

Carbon storage estimation

The amount of carbon in the stem, branches, leaves and whole tree was calculated by multiplying the DW of each component of an individual tree by 50% (Table 8) it represents carbon sequestered in the tree (14). In another word, it refers to the total amount of carbon that is captured from the atmosphere during photosynthesis, as well as the amount of carbon sequestered by the tree.

Table 8. The amount of carbon stored in the tree and its components depending on diameter classes of oak

		WEIGHT OF CARBONkg.			
D-classes	MP	WCS	WCB	WCL	WCT
5—9.9	7.5	7.0074	3.9503	1.8859	14.3319
10—14.9	12.5	16.9632	8.9583	3.8728	30.0077
15—19.9	17.5	30.3675	15.3621	6.3659	50.7936
20—24.9	22.5	46.9143	22.9825	9.4247	76.9240
25—29.9	27.5	66.3949	31.7022	13.1615	108.6753
30—34.9	32.5	88.6538	41.4363	17.7491	146.3457
35—39.9	37.5	113.5681	52.1191	23.4463	190.2471
40—45	42.5	141.0368	63.6981	30.6470	240.7006

The results in (Table, 8)reveal carbon content values for an individual tree, based on their diameter values. Also, shows that the amounts of carbon that stored in older trees are larger than younger trees and this was confirmed by West and Marland(22). The results in (Table, 9)show the weight of carbon stored in the stands (Mg ha^{-1}) for each region. Moreover the weight of carbon stored in the main stem, branches, leaves and whole tree. It was found the largest amount of carbon stock was concentrated in the main stem of the tree and lowest in the branches and the very lowest in tree leaves. Most researchers confirmed that the main stem represents the largest amount of carbon of the total biomass of trees, ranging from 50 to 92% for different species of trees (3, 13, 20). The results of this study fall within the range of 58.10%. While the amount of carbon sequestration in the branches and leaves was29.42%, 12.49%respectively.

Table 9. Weight of carbon sequestrationin the stands and its component for each region Mg ha^{-1} of oak in Duhok province

Region	N/ha.	Mean-D	Area/ha	Carbon(Mg ha^{-1})			
				WCS	WCB	WCL	WCT
Bady	381	9.83	0.68	11.1918	6.0947	2.7502	21.0131
Rashaur	432	10.84	0.76	13.2560	7.1291	3.1582	24.2463
Banasur	306	18.42	0.48	33.1834	16.6770	6.8836	55.1926
Kamala	385	10.80	0.2	13.1714	7.0870	3.1417	24.1143
B. Sadeen	284	26.00	0.68	60.2527	28.9764	11.9603	98.5422
Bilijank	418	11.62	0.76	14.9499	7.9690	3.4872	26.8839

There is a clear differencesamong diameter means from one region to another that led to a differenes in weight of carbon stock in the parts of the tree. Moreover, a differences in the number of trees and the number of plots taken from each region was also observed. The number of trees and their plots were converted into hectares for the purpose of determining the amount of carbon stored in these areas, depending on the difference in the average diameter of trees per region.The results showed that the total carbon weight in these areas was 249.9924Mg $ha^{-1}$with an average diameter of 14.59 cm.The largest amount of carbon sequestration in the standof B. Sadeen 98.5422Mg $ha^{-1}$with an average diameter of 26 cm.Followed by Banasur, Bilijank, Rashaur, Kamala and Bady 55.1926, 26.8839, 24.2463, 24.11433 and 21.01306 Mg ha^{-1}respectively with an average diameter of 18.42, 11.62, 10.84, 10.80 and 9.83 cm respectively

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