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

*M. H. Obeyed(1)  Z. M. Akrawee(2)  Y. T. Mustafa(3)
Assist. Prof.   Prof.   Assist. Prof.

1Dept. of Forestry, Coll. of Agric., University of Duhok, Kurdistan Region, Iraq
2Dept. of Economics, Coll. of Economics, University of Duhok, Kurdistan Region, Iraq
3Dept. of Environ. Science, Faculty of Science, University of Zakho, Kurdistan Region, Iraq

zeki.akrawee@uod.ac

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, 31.38121 and 249.9924 Mg ha⁻¹ respectively.

Keywords: Fresh Weight, Dry Weight, Allometric equation, Carbon sequestration, Tree diameter.

*part of Ph.D. Dissertation of the 1st author

Received: 22/5/2019, Accepted: 29/8/2019
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 (CO₂) due to the photosynthesis process that performs by forests. This leads to reducing the amount of CO₂ 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 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 determine FW, DW and the amounts of carbon in individual tree and stand.

MATERIALS AND METHODS
Measurement of harvested trees
Fieldwork was conducted for three months in 2016 (end of July until the 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 locations with 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 ≥ 5 cm 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 d0.3 m, diameters at breast height (D =1.30 m), diameter above breast height at one-meter intervals beginning at d2.3 to d6.3, 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 d0.3 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. Randomly one 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).

\[ DWC = \frac{FWC \times DWs}{FWs} \]  

Where DWC is DW of each component of the tree, FWC is FW of each component 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) | Stem | Branch | Leaves | TREE | DW and its Components Kg. |
|----|--------|------|--------|--------|------|----------------------------|
| 1  | 14.6   | 56.4000 | 30.6000 | 14.8500 | 101.8500 | Stem | 37.7761 | 20.5613 | 8.7615 | 67.0989 |
| 2  | 11.7   | 38.1500 | 23.6000 | 12.0500 | 73.8000 | Branch | 26.0968 | 15.7637 | 6.2058 | 48.0663 |
| 3  | 20.7   | 120.8000 | 56.8000 | 39.3000 | 206.9000 | Leaves | 80.5819 | 38.5731 | 19.3380 | 138.4930 |
| 4  | 9.7    | 28.4000 | 11.8500 | 7.6500 | 47.9000 | TREE | 19.9189 | 7.2716 | 5.2020 | 32.3925 |
| 5  | 10.3   | 31.0000 | 16.3500 | 8.0000 | 55.3500 | Stem | 26.4675 | 13.9490 | 4.9600 | 45.3765 |
| 6  | 13.3   | 47.3000 | 25.7500 | 14.2000 | 87.2500 | Branch | 39.8113 | 21.8875 | 9.3720 | 71.0708 |
| 7  | 21.5   | 125.4850 | 59.2850 | 32.8300 | 217.6000 | Leaves | 94.2645 | 43.7348 | 22.9810 | 160.9803 |
| 8  | 15.6   | 61.8650 | 33.2000 | 15.4000 | 110.4650 | TREE | 45.3797 | 24.2927 | 9.8560 | 79.5283 |
| 9  | 16.3   | 72.7750 | 36.8400 | 21.3800 | 130.9950 | Stem | 60.1399 | 29.1556 | 17.1040 | 106.3995 |
| 10 | 17.3   | 78.8500 | 48.7000 | 24.8000 | 152.3500 | Branch | 57.9271 | 33.9380 | 15.8348 | 107.6999 |
| 11 | 28.3   | 210.4500 | 87.9500 | 43.4000 | 341.8000 | Leaves | 169.6155 | 73.3376 | 28.8610 | 271.8141 |
| 12 | 10.8   | 35.1250 | 18.3500 | 8.6500 | 62.1250 | TREE | 27.2637 | 14.4577 | 5.7090 | 47.5204 |
| 13 | 19.4   | 94.6500 | 50.2000 | 27.6000 | 172.4500 | Stem | 75.1454 | 37.6500 | 18.7680 | 131.5634 |
| 14 | 26.5   | 182.6500 | 76.6000 | 38.6000 | 297.8500 | Branch | 144.6888 | 60.2173 | 24.7040 | 229.6101 |
| 15 | 16.8   | 72.8500 | 38.4500 | 20.4500 | 131.7500 | Leaves | 54.8313 | 28.6490 | 12.2700 | 95.7503 |
| 16 | 22.6   | 143.7500 | 71.4000 | 36.3450 | 251.4950 | TREE | 115.8327 | 56.4471 | 23.0791 | 195.3589 |
| 17 | 34.1   | 261.5500 | 125.3600 | 51.7800 | 438.6900 | Stem | 221.3380 | 112.1193 | 38.3172 | 371.7744 |
| 18 | 36.4   | 324.8350 | 143.5000 | 56.8000 | 525.1350 | Branch | 229.5380 | 106.6845 | 35.2160 | 371.4385 |
| 19 | 37.6   | 338.6500 | 171.8000 | 66.4000 | 576.8500 | Leaves | 248.1034 | 130.1099 | 49.1360 | 427.3492 |
| 20 | 36.8   | 332.1250 | 160.6000 | 63.6500 | 556.3750 | TREE | 228.7886 | 106.1862 | 44.5550 | 379.5298 |
| 21 | 41.8   | 390.3500 | 188.4000 | 73.8170 | 652.5670 | Stem | 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:

\[ AGB_h = \frac{A}{a} \]  

Where: A is the area Mg ha⁻¹, and a is an area of our sample plot 400 m²

**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 (R²), 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 (R² 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**

After selecting 208 trees for data analyzing, the non-destructive method was used to estimate AGB and its component using allometric regression equations. Trees were classified into 8 diameter classes, starting from 5 cm to 45 cm based on what has been found in the study area. The distribution of trees classified and found that the majority of the trees are small in diameter classes. This is clearly shown 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 cm 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 diameter classes**

**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 their statistical criteria. This is reported in Tables (3 and 4).
Table 3. Allometric equation and its criteria used to estimate FW of oak and its components

| NO  | Equations                                           | $R^2$ adj | S.E OF Est. | MAE    |
|-----|----------------------------------------------------|-----------|-------------|--------|
| $A_1$ | $FWS = 0.578721 \times D^{1.72425}$             | 98.5029   | 0.10641     | 0.07897 |
| $A_2$ | $FWS = \exp(2.76121 + 0.082755 \times D)$     | 94.9747   | 0.19548     | 0.1607  |
| $A_3$ | $FWS = -302.243 + 96.304 \times \sqrt[3]{D}$  | 89.8839   | 35.42110    | 27.8935 |
| $A_4$ | $FWS = -97.2582 + 10.6371 \times D$           | 95.6622   | 23.19480    | 18.0004 |
| $A_5$ | $FWB = 0.442825 \times D^{1.58169}$            | 97.9014   | 0.11592     | 0.08386 |
| $A_6$ | $FWB = \exp(2.20072 + 0.0767495 \times D)$    | 96.4691   | 0.15036     | 0.12334 |
| $A_7$ | $FWB = -43.1076 + 4.94173 \times D$            | 94.5749   | 12.11940    | 9.39845 |
| $A_8$ | $FWB = -97.2582 + 10.6371 \times D$           | 95.6622   | 23.19480    | 18.0004 |
| $A_9$ | $FWL = \frac{1.0506 + 0.194824 \times D}{D}$  | 99.0227   | 0.59625     | 0.47385 |
| $A_{10}$ | $FWL = -60.6939 + 20.4103 \times \sqrt{D}$   | 93.4826   | 5.90905     | 4.55902 |
| $A_{11}$ | $FWL = -94.5234 + 42.7296 \times \ln(D)$     | 85.3313   | 8.84967     | 6.97838 |
| $A_{12}$ | $FWL = \exp(5.19573 - 22.0145/D)$            | 81.8496   | 0.34171     | 0.27632 |
| $A_{13}$ | $FWT = (1.49926 + 0.586057 \times D)^2$     | 99.0227   | 0.59625     | 0.47385 |
| $A_{14}$ | $FWT = -168.845 + 18.664 \times D$          | 95.8345   | 39.84550    | 30.83760|
| $A_{15}$ | $FWT = \exp(6.58656 - 24.1472/D)$           | 84.3773   | 0.34171     | 0.27632 |
| $A_{16}$ | $FWT = -799.848 + 350.871 \times \ln(D)$   | 80.8496   | 85.43500    | 67.17090|

Source: by the researchers

Where: FWS, FWB, FWL and FWT represent 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 oak and its components

| NO  | Equations                                           | $R^2$ adj | S.E OF Est. | MAE    |
|-----|----------------------------------------------------|-----------|-------------|--------|
| $a_1$ | $DWS = 0.428673 \times D^{1.75969}$             | 98.4864   | 0.10740     | 0.07955 |
| $a_2$ | $DWS = -230.305 + 73.2352 \times \sqrt{D}$     | 89.7094   | 27.19380    | 21.4239 |
| $a_3$ | $DWS = \exp(5.74402 - 24.3515/D)$              | 90.2227   | 0.59625     | 0.47385 |
| $a_4$ | $DWS = -347.185 + 151.832 \times \ln(D)$     | 80.2948   | 37.63050    | 29.56220|
| $a_5$ | $DWB = 0.312628 \times D^{1.60289}$             | 97.9014   | 0.11747     | 0.08499 |
| $a_6$ | $DWB = \exp(1.89297 + 0.0777799 \times D)$   | 96.4691   | 0.15238     | 0.12499 |
| $a_7$ | $DWB = -33.6541 + 3.78908 \times D$             | 94.3954   | 9.45401     | 7.34389 |
| $a_8$ | $DWB = -106.171 + 34.1978 \times \sqrt{D}$    | 88.1380   | 13.75380    | 10.77080|
| $a_9$ | $DWB = 1/(-0.0114618 + 3.99296/D)^{1.325}$   | 97.8000   | 0.00157     | 0.00701 |
| $a_{10}$ | $DWT = -47.1523 + 15.2793 \times \sqrt{D}$   | 91.2169   | 5.19824     | 4.07289 |
| $a_{11}$ | $DWT = \exp(0.013851 + 0.07999931 \times D)$ | 94.4302   | 0.19893     | 0.16359 |
| $a_{12}$ | $DWT = -71.8774 + 31.7895 \times \ln(D)$    | 82.2282   | 7.39433     | 5.82058 |
| $a_{13}$ | $DWT = \exp(6.18109 - 22.5515/D)$           | 81.8494   | 0.34922     | 0.28250 |
| $a_{14}$ | $DWT = -119.688 + 13.2857 \times D$          | 94.2463   | 33.61330    | 26.14440|
| $a_{15}$ | $DWT = 1.02445 \times D^{1.62028}$           | 97.9014   | 0.1187      | 0.0859  |
| $a_{16}$ | $DWT = \exp(3.11296 + 0.0786241 \times D)$ | 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 represented by 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 models were 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 0.08386 respectively. Also, FWL and FWT square root-Y models were 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 0.5962 and 0.4739 respectively. In addition, DWS and DWB Multiplicative models were 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 0.107401 and 0.079551, 97.9014, 0.11592 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 0.011572 and 0.00701 respectively. Finally, DWT with Multiplicative model ($a_{15}$) was selected because it has a higher $R^2_{adj}$ and smaller S.E. of Est. and 0.011572 and 0.00701 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 | 13620.74 | 0.0000 | 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 |        |          |          |          |          |          |          |          |          |
| 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 |        |          |          |          |          |          |          |          |          |
| Model                        | 1      | 824.045 | 824.045 |          |          | 1.23236 | 1.23236 |
| Residual                     | 206    | 10.9928 | 0.05336 | 15442.21 | 0.0000 | 0.027586 | 0.000134 | 9202.89  | 0.0000 |
| Total                        | 207    |          |          |          |          |          |          |          |          |
| Analysis of Variance for FWT |        |          |          |          |          |          |          |          |          |
| Model                        | 1      | 7456.71 | 7456.71 |          |          | 137.465 | 137.465 |
| Residual                     | 206    | 73.2347 | 0.35508 | 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, while a, b, c, d represent observed vs. 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 in the 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).

| 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 | 7.4555 | 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 | 60.4989 | 29.5299 | 215.6652 | 93.8285 | 45.9650 | 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 were located in the region of Rashaur and Bilijank as 19 plots in each region with diameter means 10.84 - 11.62 cm respectively. While smaller numbers of plots were located in the Kamala region, 5 plots with diameter means 10 cm. The main reason for the differences in the number of trees in each region is 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\(^{-1}\)) | DW (Mg ha\(^{-1}\)) |
|------------|--------------|--------------|-------------|---------------------|---------------------|
| Bady       | 259          | 17           | 9.83        | 8.5517              | 4.5910              |
| Rashaur    | 328          | 19           | 10.84       | 13.3522             | 6.9981              |
| Banasur    | 147          | 12           | 18.42       | 15.3820             | 7.4429              |
| Kamala     | 77           | 5            | 10.80       | 3.1065              | 1.6278              |
| B. Sadeen  | 193          | 17           | 26.00       | 33.9183             | 15.9204             |
| Bilijank   | 318          | 19           | 11.62       | 13.7939             | 7.2681              |
| Total      | 1322         | 89           | 88.1046     | 43.8482             | 22.4887             |

The results show the number of trees in the B. 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.
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 was 29.42%, 12.49% respectively.

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

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

There is a clear differences among diameter means from one region to another that led to differences 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 stand of 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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