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# Carbon Storage of Alder (*Alnus glutinosa* subsp. *barbata* L.) by Different Stand Structure

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**Abstract:** Forests are one of the important carbon sinks that struggle with the possible negative effects of global climate change. In this sense, it is very important to determine the carbon calculations in forests with the right methods in order to take measures against climate change. In many studies, it has been determined that the carbon stored in forest ecosystems varies according to the forest structure. Therefore, it is important to determine separately the effects of stand establishment, tree species, bedrock and soil characteristics on carbon storage. Features such as age, stratification, closure, density and mixing ratio that make up the stand establishment are effective on the amount of carbon stored and to be stored. For this purpose, carbon storage amounts of Alder *(Alnus glutinosa* L.*)* in different stand establishments were calculated in this study. This study was carried out on the Alder stands affiliated to Trabzon Forest Management Directorate, Düzköy Operation Chief. Since 2008, biomass and carbon calculations of our forest areas have been made with the method mentioned in the Ecosystem Based Functional Forest Management Plans (ETFOP). In this study, BEF coefficients developed based on FRA-2010 within the scope of ETFOP were used. In the study conducted with samples taken from three different sections in the stand, the amount of above-ground carbon storage (TUK) was found to be 1.7233 tons in section 1 with 0.4-0.5 confinement. The amount of TÜK was found to be 2.8208 tons in the 2nd compartment with 0.3-0.4 closure. The amount of TÜK was found to be 2,0557 tons in the 3rd compartment with a clearance of 0.2-0.3. In this context, carbon storage amounts for each stand differed depending on the changes in the factors that make up the stand establishment.

**Keywords:** *Alnus glutinosa* L., Stand structure, Carbon storage, Climate change.

## 1. INTRODUCTION

As a result of increasing population growth, industrialization and urbanization all over the world, there is a rapid increase in the demand for natural resources. While meeting the increasing demand, many problems have emerged such as the destruction of forest ecosystems, desertification, pollution and climate change. Global climate change, one of these problems, is one of the most important problems faced by people in the last century. Within the framework of climate change, it is shown that the amount of CO2 released into the atmosphere is increasing as a result of industrialization and land use differences, which are one of the reasons for global warming (Sivrikaya & Bozali, 2012). In the past, with the industrial revolution, the amount of greenhouse gases and CO2 emissions in the atmosphere increased as a result of the use of fossil fuels as an energy source in industry and heating, people destroying the forest ecosystem and opening new settlements for agriculture and urbanization, and the destruction of forests for fuelwood needs (UN, 1992). The fact that CO2 in the atmosphere as a result of human activities is not among the required reference values is shown as one of the most important causes of global warming (IPCC, 2013). Carbon is held in the trunks, branches, leaves, roots of trees, dead and living cover and forest soil (Brown & Schroeder, 1999; Houghton, 1999; Goodale et al., 2002). Within the terrestrial ecosystem, the forest ecosystem holds approximately 2/3 of the carbon. From this perspective, the forest ecosystem plays a significant role not only in mitigating the adverse effects of global warming but also in maintaining global climate stability (Woodwell et al., 1978; Hashimotio, Kojima, & Satohiko, 2000). arious methods have been developed for calculating carbon and biomass. Biomass is one of the most important parameters that can be used to determine the amount of carbon storage in forest ecosystems (Backeus, Wikström, & Lamas, 2005). One of the best ways to determine biomass is by using inventory data present in management plans. Inventory data is generally accurately determined statistically from forest ecosystems within a national area (Brown & Schroeder, 1999; Brown S., 2002). Based on the calculated stand volumes using inventory data (Birdsey, 1992; Kurz & Apps, 1993; Krankina, Harmon, & Winjum, 1996), biomass is calculated using equations developed based on tree species and ages (Yolasığmaz, 2004; Keleş & Başkent, 2006; Sivrikaya, Keleş, & Çakır, 2007), along with carbon conversion factors, to determine carbon storage capacity. Biomass determination based on tree wealth using inventory data is done in two ways. The first one is the Allometric Biomass Equations (ABE) Method. Determining the weight of each part of felled trees in biomass calculations yields more accurate results. However, when it is not preferred to cut the entire area for the operation, equations determined through samples taken are more commonly used. Allometric Biomass Equations, developed for each tree species with sufficient data, are utilized as a method for biomass models specific to the region (Schroeder et al., 1997; Van Camp et al., 2004; Durkaya, Varol, & Durkaya, 2014; Durkaya, Durkaya, & Ulu Say, 2016).

Another method for biomass determination is the Biomass Expansion Factor (BEF) method. With this method, the appropriate conversion factor is multiplied by the total biomass to determine the accumulated carbon in the stand (IPCC, 2003; Tolunay & Çömez, 2008). BEF coefficients can be used in carbon calculations on a species-specific basis. In reality, it is noted that these coefficients vary based on certain elements in the stand establishment (tree species, age, crown closure, stratification, and mixture ratio) (Lehtonen et al., 2004; Çömez, 2011).

Alder tree (*Alnus glutinosa* L.) is commonly found in Türkiye, especially in Thrace, the Marmara region, Western Black Sea, Eastern Black Sea, Southern Anatolia, and Hatay, particularly along riverbanks. It has a distribution as pure and mixed stands. The Alder generally grows up to 20-30 meters in height with a straight trunk, sometimes also in shrub form. It is a deciduous woody plant that sheds its leaves during the winter season. It has a preference for moist soils but can also grow on poor soils. Through root nodules that fix atmospheric nitrogen and microorganisms in its roots, it enhances soil fertility (Tarrant & Trappe, 1971; Benson & Sylvester, 1993; Yılmaz & Ekici, 2011; Yılmaz, 2020). Due to these characteristics, it is introduced as a pioneer tree in poor sandy soils, and as the soil becomes richer in nitrogen, other trees are introduced to the area (Harrington, 2006).

In this context, this study calculates the carbon storage amounts of Alder (Alnus glutinosa L.) in different Stand Structure. The aim is to reveal the differences in carbon storage amounts based on the characteristics that make up different Stand Structure using Biomass Expansion Factors (BEF), such as age, stratification, crown closure, density, and mixture ratio.

## 2. MATERIALS AND METHODS

### 2.1. Material

This study was carried out on the alder stand belonging to Trabzon Regional Directorate of Forestry, Düzköy Forest Management Directorate, Taşocağı Village, section 59. The study area, its location on the stand map and its location are given below (Figure 1).

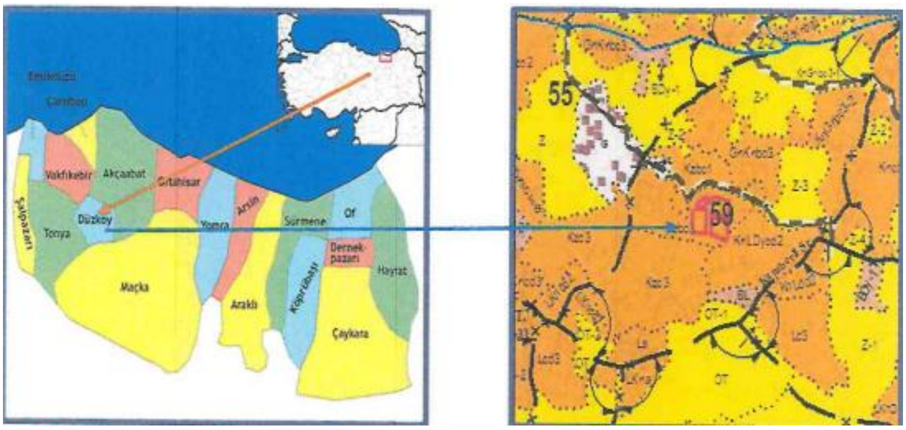


**Figure 1.** Location of the study area and its position on the stand map.

## 2.2. Method

To calculate the biomass and carbon amounts of the Alder stand, three different plots were selected. Within these plots, parameters such as diameter, height, age, crown closure, density, stratification, and branch length in four directions (East, West, North, and South) from the tree trunk were measured, which make up the stand establishment. Based on these measurements, biomass and carbon amounts were calculated by determining the standing volume (DGH) in the field using both the single-entry volume equation and the double-entry volume equation.

Single-Entry Volume Equation (1)

V1 = -0.0188+7.00423×$d^2$ (Saraçoğlu, 1991) (1)

Double-Entry Volume Equation (2)

$$V2 = 0.404687xd^{1.92886}xh^{0.91382} \quad (2)$$

According to the equation, the calculated volumes need to be multiplied by the correction factor: 1.005689 (Saraçoğlu, 1991).

**Chart 1.** Data for Plot 1.

| Tree Number | d1.30 (cm) | Height (m) | Age |
|---|---|---|---|
| 97 | 23,5 | 14,3 | 18 |
| 36 | 23,4 | 11,2 | 39 |
| 73 | 26,5 | 12,3 | 35 |
| 100 | 35,4 | 14,6 | 49 |
| 92 | 30,9 | 11,7 | 55 |
| 6 | 36,7 | 16,7 | 54 |
| 59 | 21,6 | 15 | 39 |
| 42 | 29,5 | 13,1 | 43 |

**Chart 2.** Data for Plot 2.

| Tree Number | d1.30 (cm) | Height (m) | Age |
|---|---|---|---|
| 12 | 15,1 | 8 | 16 |
| 1 | 41,9 | 23,3 | 80 |
| 84 | 44,1 | 17,8 | 56 |
| 80 | 13,5 | 9,4 | 22 |
| 64 | 38,5 | 15 | 41 |
| 96 | 33,5 | 17,8 | 40 |
| 100 | 46 | 13,8 | 72 |
| 84 | 44,6 | 17,8 | 56 |

**Chart 3.** Data for Plot 3.

| Tree Number | d1.30 (cm) | Height (m) | Age |
|---|---|---|---|
| 83 | 34,5 | 18,1 | 51 |
| 20 | 21,8 | 15,4 | 51 |
| 12 | 41,5 | 22,2 | 46 |
| 7 | 24,7 | 12,2 | 19 |
| 80 | 18,5 | 12,4 | 29 |
| 126 | 46,1 | 17,5 | 73 |
| 182 | 38,1 | 20,2 | 46 |

Since 2008, biomass and carbon calculations for our forest areas have been carried out using the Ecosystem-Based Functional Forest Management Plans (ETFOP) method mentioned. In this study, Biomass Expansion Factors (BEF) coefficients developed based on FRA-2010, which is within the scope of ETFOP, were used (OGM, 2014).

The FRA 2010 method employs the coefficients and calculation method outlined in the FRA 2010 guide prepared by the Food and Agriculture Organization of the United Nations (FRA, 2010). The stages of the method are provided in Table 1.

**Table 1.** Carbon calculation coefficients according to FRA (2010).

| Carbon Pool | | Calculation Method and Coefficient Numbers |
|---|---|---|
| Above Ground Biomass (AGB) | Broad Leaf | DGH x 0,638 x 1,24 |
| Aboce Ground Carbon (AGC) | Broad Leaf | AGB x 0,48 |

In this study, a carbon conversion factor of 0.48 was applied to convert aboveground biomass values to carbon for broad-leaved species (IPCC, 2006; Tolunay, 2011).

The Biomass Expansion Factor (BEF) used has been used to demonstrate changes in carbon stock quantities in different Stand structure through calculations and graphs.

**Chart 4.** Results of stand stock, biomass, and carbon storage capacity for Plot 1.

| Tree Number | d1.30 (cm) | Height (m) | Age | V1 | V2 | V1 AGB | V2 AGB | V1 AGC | V2 AGC |
|---|---|---|---|---|---|---|---|---|---|
| 97 | 23,5 | 14,3 | 18 | 0,368009 | 0,20415 | 0,291139 | 0,161507 | 0,139747 | 0,077524 |
| 36 | 23,4 | 11,2 | 39 | 0,364724 | 0,161959 | 0,28854 | 0,128129 | 0,138499 | 0,061502 |
| 73 | 26,5 | 12,3 | 35 | 0,473072 | 0,224286 | 0,374257 | 0,177437 | 0,179643 | 0,08517 |
| 100 | 35,4 | 14,6 | 49 | 0,858942 | 0,458566 | 0,679526 | 0,362781 | 0,326173 | 0,174135 |
| 92 | 30,9 | 11,7 | 55 | 0,649971 | 0,28816 | 0,514205 | 0,227969 | 0,246818 | 0,109425 |
| 6 | 36,7 | 16,7 | 54 | 0,924593 | 0,555837 | 0,731464 | 0,439734 | 0,351103 | 0,211072 |
| 59 | 21,6 | 15 | 39 | 0,307989 | 0,181256 | 0,243657 | 0,143395 | 0,116955 | 0,06883 |
| 42 | 29,5 | 13,1 | 43 | 0,590743 | 0,292179 | 0,467349 | 0,231148 | 0,224327 | 0,110951 |
| TOTAL | | | | 4,538042 | 2,366394 | 3,590136 | 1,872102 | 1,723265 | 0,898609 |

**Chart 5.** Results of stand stock, biomass, and carbon storage capacity for Plot 1.

| Tree Number | d1.30 (cm) | Height (m) | Age | V1 | V2 | V1 AGB | V2 AGB | V1 AGC | V2 AGC |
|---|---|---|---|---|---|---|---|---|---|
| 12 | 15,1 | 8 | 16 | 0,140903 | 0,051159 | 0,111472 | 0,040473 | 0,053506 | 0,019427 |
| 1 | 41,9 | 23,3 | 80 | 1,21087 | 0,973025 | 0,957943 | 0,769779 | 0,459813 | 0,369494 |
| 84 | 44,1 | 17,8 | 56 | 1,34339 | 0,839718 | 1,0627825 | 0,664318 | 0,510136 | 0,318873 |
| 80 | 13,5 | 9,4 | 22 | 0,108852 | 0,047764 | 0,086115 | 0,037787 | 0,41335 | 0,018138 |
| 64 | 38,5 | 15 | 41 | 1,019402 | 0,55265 | 0,806469 | 0,437213 | 0,387105 | 0,209862 |
| 96 | 33,5 | 17,8 | 40 | 0,76725 | 0,494128 | 0,606987 | 0,390915 | 0,291354 | 0,187639 |
| 100 | 46 | 13,8 | 72 | 1,463295 | 0,721862 | 1,157642 | 0,57108 | 0,555668 | 0,274118 |
| 84 | 44,6 | 17,8 | 56 | 1,374453 | 0,858179 | 1,087358 | 0,678922 | 0,521932 | 0,325883 |
| TOTAL | | | | 7,428415 | 4,538486 | 5,876768 | 3,590487 | 2,820848 | 1,723434 |

**Chart 6.** Results of stand stock, biomass, and carbon storage capacity for Plot 3.

| Tree Number | d1.30 (cm) | Height (m) | Age | V1 | V2 | V1 AGB | V2 AGB | V1 AGC | V2 AGC |
|---|---|---|---|---|---|---|---|---|---|
| 83 | 34,5 | 18,1 | 51 | 0,814878 | 0,531022 | 0,644667 | 0,420102 | 0,30944 | 0,201649 |
| 20 | 21,8 | 15,4 | 51 | 0,314069 | 0,188998 | 0,248466 | 0,14952 | 0,119264 | 0,07177 |
| 12 | 41,5 | 22,2 | 46 | 0,187504 | 0,913893 | 0,939458 | 0,722999 | 0,45094 | 0,34704 |
| 7 | 24,7 | 12,2 | 19 | 0,408521 | 0,194734 | 0,323189 | 0,153773 | 0,155131 | 0,073811 |
| 80 | 18,5 | 12,4 | 29 | 0,22092 | 0,112972 | 0,174774 | 0,089374 | 0,083892 | 0,0429 |
| 126 | 46,1 | 17,5 | 73 | 1,469746 | 0,900621 | 0,162745 | 0,712499 | 0,558118 | 0,342 |
| 182 | 38,1 | 20,2 | 46 | 0,997941 | 0,710922 | 0,789491 | 0,562425 | 0,378956 | 0,269964 |
| TOTAL | | | | 5,413579 | 3,552803 | 4,28279 | 2,810693 | 2,055739 | 1,349133 |

## 3. RESULTS AND DISCUSSION

The results obtained from the stand stock, aboveground biomass, and aboveground carbon capacity calculations as described in the methodology section have been compiled into tables (2, 3, 4) based on different Stand Structure and are presented below.

### 3.1. Results

**Table 2.** Above ground carbon storage data for Plot 1.

| Plot 1 | V1 AGC | V2 AGC |
|---|---|---|
| Crown Closure (0,4-0,5)<br>Diameter (20cm-40cm)<br>Age (18-55)<br>Height (11m-17m) | 1,723265 ton | 0,898609 ton |

**Table 3.** Above ground carbon storage data for Plot 2.

| Plot 2 | V1 AGC | V2 AGC |
|---|---|---|
| Crown Closure (0,3-0,4)<br>Diameter (13cm-47cm)<br>Age (16-81)<br>Height (8m-24m) | 2,820848 ton | 1,723434 ton |

**Table 4.** Above ground carbon storage data for Plot 3.

| Plot 3 | V1 AGC | V2 AGC |
|---|---|---|
| Crown Closure (0,2-0,3)<br>Diameter (18cm-47cm)<br>Age (19-73)<br>Height (12m-23m) | 2,055739 ton | 1,349133 ton |

As a result of the measurements taken in the sample plots, the crown closure (0.4-0.5), diameter range (20cm-40cm), age range (18-55), and height range (11m-17m) for Plot 1 are provided in Chart 1. When these values are processed considering the FRA-2010 guide, the aboveground carbon storage capacity is calculated as 1.723265 tons using the single-entry volume equation. When calculated using the double-entry volume equation, the aboveground carbon storage capacity is 0.898609 tons.

For Plot 2, the crown closure (0.3-0.4), diameter range (13cm-47cm), age (16-81), and height range (8m-24m) are provided in Chart 2. The aboveground carbon storage capacity for the plot is calculated as 2.820848 tons using the single-entry volume equation. When calculated using the double-entry volume equation, the aboveground carbon storage capacity is found to be 1.723434 tons.

For Plot 3, the crown closure (0.2-0.3), diameter range (18cm-47cm), age (19-73), and height range (12m-23m) are provided in Chart 3. The aboveground carbon storage capacity for the plot is calculated as 2.055739 tons using the single-entry volume equation. When calculated using the double-entry volume equation, the aboveground carbon storage capacity is found to be 1.349133 tons.

### 3.2. Discussion

Our country is rich in terms of climate structure, and hence, each area will be affected differently by climate change that may occur due to global warming (Öztürk, 2002). Therefore, the results of global climate change, even seen today, emphasize and enhance the importance of carbon storage.

There are several widely accepted methods for calculating biomass and carbon storage capacity both globally and in our country. The most commonly used methods among these are the allometric biomass equation and the biomass expansion factor coefficients that we used in our study (Brown et al., 1989).

As a result of various studies, allometric biomass equations have been developed for some tree species (Schroeder et al., 1997). The fact that an allometric biomass equation has not been developed for every tree species in our country is insufficient for the realistic calculation of carbon storage amounts. Particularly for deciduous species like alder, where there is no specific equation, calculations using biomass expansion factor coefficients cannot clearly reveal the results.

## 4. CONCLUSION

The study shows variations in carbon storage amounts based on stand establishment parameters. Even within species, differences arise in establishment parameters, emphasizing the need for a comprehensive study to create specific equations for each tree. More studies should be conducted at the species level to demonstrate how stand establishment characteristics affect carbon storage capacity and in what direction.

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