EFFECTS OF ELEVATION ON THE ABOVEGROUND BIOMASS AND CARBON STOCK IN THE ORIENTAL BEECH (*Fagus orientalis* Lipsky) FORESTS OF THE SINOP REGION, TURKEY

KAHYAOĞLU, N.[1*] – KARA, Ö.[2] – GÜVENDI, E.[1]

[1]*Department of Forestry, Kürtün Vocational High School, Gümüşhane University, 29810 Gümüşhane, Turkey*

[2]*Faculty of Forestry, Department of Forestry Engineering, Karadeniz Technical University, 61080 Trabzon, Turkey*

[*]*Corresponding author*
e-mail: nkahyaoglu@gumushane.edu.tr; phone:+90-0-456-233-1018; fax:+90-0-456-233-1006

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Abstract. In this study it was our aim to assess the amount of aboveground biomass and carbon stock of beech stands based on elevation. To achieve this, in the research area, 55 trial sites were chosen by selective sampling method depending on elevation climatic zones (400–600 m, 600–800 m, 800–1000 m). In these trial areas, 55 trees were cut down and the weights of their bark, leaves, stem and branches were determined. The carbon content of each component was calculated. The results of the study showed that, in all elevation zones, the stem wood had the highest average biomass and carbon stock values of all the tree components (for the 400–600 m, biomass was 199.19 kg and carbon stock was 95.82 kg; for the 600–800 m, biomass was 378.75 kg and carbon stock was 182.49 kg; for the 800–1000 m, biomass was 372.56 kg and carbon stock was 183.39 kg). This was followed by the branches, bark and leaves in descending order. The aboveground biomass in the single tree components of leaves, branches, stem and total biomass, all except the biomass of their bark varied with elevation in oriental beech stands, which are economically significant species in Turkey.
Keywords: *biomass, carbon stock, elevation zones, stem, branches, leaves*

Introduction

The most important geomorphological features affecting the spread of beech forests are elevation, aspect and slope. The effects of climatic factors such as light, temperature, precipitation and evaporation change according to these factors and habitat type (Atalay, 1983). Beech forests are more widespread in shady environments on the northern slopes of mountains that are foggy during the vegetation season. There are also beech forests on the southern slopes where fog is observed and on the upper parts of foggy southern slopes (Atalay, 1992).

The optimal conditions for beech tree growth are low temperature and high precipitation. These conditions are related to elevation from the sea (Atalay, 1992). As the elevation increases, the temperature and the relative humidity to water vapor ratio decrease while precipitation, evaporation and radiation intensity increase (Atalay, 1983). Beech forests can grow on areas at 150–200 m elevation, as well as at 1200 m and mostly at 1800 m. Generally, above 1600 m, the proportion of beech decreases and instead coniferous trees (fir and spruce) are observed (Atalay, 1983, 1992).

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Various factors affect the aboveground biomass. The most important ones include the age and density of the stand, precipitation, temperature, latitude, physiographic factors (elevation, slope, aspect, relief) and soil factors.

In a study performed in the Himalayas, Sharma et al. (2018) investigated the differences in the growth behavior of tree species at different elevations in terms of diversity, regeneration dynamics, biomass and carbon stock. Depending on the elevation, the total biomass density was found to be the greatest between 1600–1900 m and 3100-3400 m. Accordingly, the total carbon density varied at different elevation ranges. Thus, it was concluded that *A. pindrow*, *A. spectabilis*, *A. acuminatum*, *B. utilis*, *Cedrus deodora*, *Q. semecarpifolia* and *R. arboreum* species found in the high regions of the Himalayas had more carbon stock potential and thus could be recommended for carbon management in afforestation works.

Fehse et al. (2002) performed a study in tropical forests and surprisingly found that the total aboveground biomass and annual biomass production were higher at high elevations, considering the assumption of biomass decrease with increasing elevation. These results were attributed to different forest systems, tree species, soils, parent materials and climatic conditions. This study concluded that the positive characteristics of tree species, rapid growth, productive nitrogen and phosphorus compatibility, the suitability of climatic conditions at high elevations, might be the reasons for the increased levels of biomass at higher elevations.

In a study by Zhu et al. (2010) in Northeast China, vegetation cover, eroded material and the amount of carbon stored in the soil were determined in 22 different sites, depending on elevation (700–2000 m). The authors concluded that the carbon density in the vegetation decreased with increasing elevation.

Nagar et al. (2017) reported that biomass and carbon amounts at different elevations and aspects in the humid, temperate Western Himalayan ecosystems were the highest on the northern aspect and in the 2101–2400 m elevation belt. In a study of 444 sample areas performed in the Agarta region of India, it was revealed that the biomass and carbon content of a tree are related to tree diameter and are not dependent only on the number of trees (Majumdar and Selvan, 2018). In a study conducted in Poland, it was found that there was a significant relationship between tree species diversity and aboveground biomass (Gazda et al., 2015).

Kobler et al. (2019) found that net ecosystem production, aboveground biomass and soil CO_2 emissions were higher on the south-west facing slope rather than the north-east facing slope. They concluded according to these results that there may be changes due to elevation and aspect over small distances in mountainous areas and the forest carbon dynamics in similar complex topographies will not give reliable results on large scales. Similarly, Güner (2019) examined the aboveground biomass and carbon concentrations found in the tree components in different habitats in *Abies nordmanniana* subsp. *equi-trojani* (Bursa-Uludağ and Kastamonu-Ilgaz Mountain). Root, stem, branch, bark and seed samples were taken from 25 sampling points with different elevation, slope and aspect characteristics. As a result of carbon measurements and statistical analyses, significant differences were found in the carbon concentrations. While the lowest carbon concentration was in the roots, the highest was found in the bark. For *Abies nordmanniana* subsp. *equi-trojani* forests, the weighted carbon concentration was found to be 52.31% for aboveground biomass and 52.15% for total tree biomass. They concluded that the carbon concentrations found in this study could be used to calculate the carbon stocks

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stored in the existing tree components in the *Abies nordmanniana* subsp. *equi-trojani* forests at different locations.

In light of the research discussed above, the purpose of this study is to investigate elevation-based changes in the amounts of aboveground biomass and carbon stocks of the components of Oriental beech trees (*Fagus orientalis* Lipsky.) growing in the Sinop region.

Materials and methods

General overview of the research area

This study was conducted in Turkey in 2013. The research was carried out in the pure beech forests on the border between Sinop province and Türkeli district in the Western Black Sea Region (*Fig. 1*). The whole area of its present distribution has a North to South extensions from 41°57’54’’ N to 41°44’42’’ N and East to West extensions from 34°23’32’’ E (Greenwich) to 34°16’25’’ E.

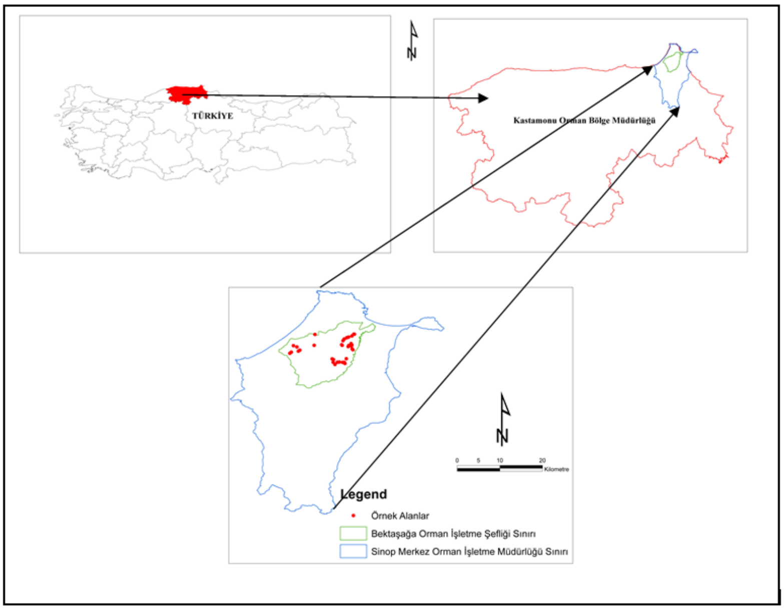

Figure 1. *Overview of the research area*

Climate properties of the research area

In the research area; according to the Thornthwaite method, all of the sample areas the climate is humid, moderately warm, with little or no water deficiency, similar to the oceanic climate.

Soil characteristics of the research area

The soil texture in the sample areas between different elevations (400–600 m, 600-800 m and 800–1000 m) is heavy clay, loamy clay, clay loam, sandy loam, sandy clay and sandy clay loam. The soils of the research area were generally in the clay soil class. Loamy clay soil was dominant in all elevation zones. The soils of the study area have high acidity, low lime content and no salinity (*Table 1*) (Güvendi, 2013).

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Table 1. *Average soil characteristics of the research area*

Elevation Zones	Sand (%)	Silt (%)	Clay (%)	Soil Texture	SWHC (%)	pH (H_2O)	EC (dS/m)	Organic Substance (%)	Lime (%)
400–600 m (1)	40	19	41	Loamy clay	11.7	5.2	0.07	1.6	0.65
600–800 m (2)	47	19	34	Loamy clay	13.4	5.9	0.14	2.7	0.97
800–1000 m (3)	37	23	40	Loamy clay	11.3	5.7	0.13	2.9	0.85

SWHC: soil water holding capacity; EC: electrical conductivity

Trial areas and determination of sample trees

The research area was divided into three elevation zones (400–600 m, 600–800 m and 800–1000 m). A total of 55 trial areas of 400 m^2 were selected from each elevation zone, in almost equal numbers. In each of these trial areas, one beech tree with representative characteristics of the trial area was cut (Kahyaoğlu, 2017). *Figure 2* shows the cutting of sample trees representing the trial areas, separation into sections and taking cross-section samples from sample trees.

Figure 2. *Taking samples from the research area*

Sample trees in the trial area were selected from trees of different diameters to represent each diameter class. The sample trees were all alive, single stem, healthy, with an intact top and natural branch pruning. Some information about the sample areas is given in *Table 2*.

After measuring the breast height diameters of the determined sample trees, they were cut to the nearest surface and their lengths were measured. The branches of the trees were then separated from their stems and the stem diameters were measured at 0.30 m and 1.30 m above soil level and also at heights above 1.30 m at 2 m intervals; 5 cm thick cross-sections were taken and their fresh weights were determined by weighing with an electronic scale. Following that, the bottom diameters and lengths of all branches of the stem were measured. Then a sample branch was taken to represent the growth and top structure of the trial tree and weighed with its leaves. Subsequently, the branch and fresh leaf weights of the sample branch were determined separately. Following that, a 5 cm cross section of the sample branch wood and all leaves of the sample branch were put into polyethylene bags, then numbered and transferred to the laboratory.

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Table 2. *Summarized data from the sample plot areas*

Plots No.	Coordinates		Elevation Zones (m)	Altitude (m)	Aspect	$d_{1.30}$ (cm)	Height (m)
	x	y					
1	623951	4641842	400-600 (1)	375	N	27	21.3
2	624028	4641571		460	N	32.5	28.3
3	624307	4641696		390	N	21	18.6
4	624508	4641845		410	S	28	25.5
5	624623	4641864		435	N	30	26.3
6	624610	4641566		500	S	21.5	21.1
7	623592	4641586		450	S	28	26
8	623599	4641880		360	S	19.9	17.3
9	623278	4641956		350	N	26.3	25.9
10	623176	4641656		440	N	20	20.1
11	622990	4641943		335	N	21.5	23.6
12	622995	4641651		450	N	21	21.3
13	622711	4641904		330	N	17	18
14	622223	4642053		310	S	29	25.8
15	622423	4641661		400	S	23	16.1
16	621882	4642035		300	S	25	22.8
17	621952	4641706		410	S	19	19.8
18	623356	4641737		375	S	18	18.1
19	623589	4641496		490	S	21	18.8
20	614311	4627415	600-800 (2)	770	S	26	23.5
21	619753	4629219		670	S	30	27.6
22	614075	4627096		790	S	33	28.6
23	619837	4629470		660	S	29	26.2
24	620591	4629528		760	N	25.5	25.1
25	620767	4629236		750	N	31	26.8
26	611248	4629423		780	N	21	16.5
27	611352	4630025		750	N	22	19.6
28	610727	4629577		780	S	20.8	18.7
29	610606	4630079		770	S	16.3	16
30	610237	4630315		790	S	19	19.6
31	612330	4633007		650	N	15.5	16.1
32	612137	4633312		750	N	16.8	14.8
33	612247	4632715		610	N	26	21.3
34	614338	4633365		712	N	23	25.9
35	615000	4632674		770	S	24	25.1
36	611703	4632630		650	N	30	23.1
37	612564	4629611	800-1000 (3)	990	N	29	25.6
38	612970	4628370		1100	N	31	27.9
39	612774	4629192		1012	S	25.5	23.0
40	615713	4634136		975	S	36.5	40.7
41	615332	4634157		990	N	25	29.2
42	615028	4633365		1040	S	21.1	17.6
43	616590	4632263		930	S	20	24.9
44	616059	4631675		872	N	21.8	24.9
45	616562	4631720		915	N	25.5	20.3
46	616719	4631556		940	N	25.5	25.6
47	615616	4631610		860	N	23	29.2
48	611866	4626218		1140	S	26	27.2
49	612007	4626459		1165	S	19	23.2
50	612146	4626745		1182	S	30	25.9
51	612095	4627094		1170	S	29	30
52	611807	4627513		1140	N	24	24.1
53	611499	4627561		1075	N	24	26.4
54	611401	4627732		1005	N	28	25.1
55	611886	4627031		1090	S	18.5	17.4

$d_{1.30}$ (cm): diameter at breast height of tree; Height (m): height of tree

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Determination of tree biomass

In order to determine the fresh and oven dry trunk weights, first the trunk volume of each sample tree was calculated. In the stem volume calculation, the stem was divided into three parts. The bottom stump is between 0 m and 0.30 m and its volume was calculated using the formula for the volume of a cylinder with the measured bottom stump diameter ($d_{0.30}$ m) and a bottom stump height of 0.30 m. The volumes of 2 m long sections from the bottom stump to the top, such as 0.30–2.30 m and 2.30–4.30 m, were calculated using the Huber (median surface) formula by using mid-section diameters such as $d_{1.30}$ and $d_{3.30}$. The volume of the top was calculated by assuming it to be a cone and lastly the volumes of the bottom stump section and the top were added to obtain the stem volume.

The base diameters and lengths of all living branches of each sample tree were measured and the volumes of all branches were calculated by assuming them to be cone shaped. Then, the volumes of all branches were summed to obtain the total branch volume of the sample tree. The total weight was then calculated by selecting a sample branch to represent all branches and the development of the sample tree. Then, the sample branch was stripped of leaves and the leaf and branch weights were determined separately. The fresh branch weight of a tree was calculated by first calculating the ratio of the volume of the sample branch to the total branch volume, which was then multiplied by the fresh weight of the sample branch. Similarly, the total dry weight of a tree was calculated by using the ratio between the dry and fresh weights of a cross section taken from the sample branch.

In order to determine the total fresh leaf weights of each sample tree, the leaf weight in the sample branch selected to represent the branching of the tree was determined and then multiplied by the total branch volume of the sample tree; the result obtained was then divided by the volume of the sample branch to give the total fresh leaf weight of the sample tree. After that, the total fresh leaf weight of the sample tree was multiplied by the dry leaf weight of the sample branch and then divided by the fresh leaf weight of the sample branch to obtain the total dry leaf weight of the sample tree.

Because the beech tree bark was thin, it was difficult to separate the bark from the trees when they were fresh. The dry bark weight of each tree was calculated from the difference between the total stem weight with dry bark and total stem weight without dry bark. The volumization of the branches taken from the sample trees and the determination of the fresh leaf and branch weight of the sample branch are shown in *Figure 3*.

Figure 3. *Biomass measurements in the research area*

The stem, branch and leaf samples, whose fresh weights were determined in the field, were brought to the laboratory. The stem and branch samples were then dried in an oven

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at 65°C for 7 days while the leaf samples were kept at 65°C for 48 hours (Peichl and Arain, 2007). All samples were completely dried and their weights were determined.

Determination of carbon stock amounts

After completing the required biomass measurements for all components of each sample tree, the stem, branch, bark and leaf samples were crushed and ground into a powder. The amounts of carbon in the tree components forming the ecosystem biomass were then determined. A LECO Truspec 2000 device was used to determine carbon content (C%) by dry combustion method. The amount of carbon stored for all wood components in each sample area was calculated by multiplying the measured biomass values of the wood components by the C% values.

Statistical analysis

One-way analysis of variance (ANOVA) was performed to determine whether there was a difference in the amounts of biomass and carbon of aboveground single tree components depending on elevation at the 5% significance level.

Duncan's post hoc test was performed to identify homogeneous subgroups from the differences obtained from the one-way ANOVA results.

Results

Distribution of the diameter at breast height ($d_{1.30}$) to elevation zones

When the distribution of $d_{1.30}$ diameters of trees representing the study area to elevation zones was examined, it was observed that the trees in the II. elevation zone had a thicker diameter than the trees in the I. and III. elevation zone (*Fig. 4*).

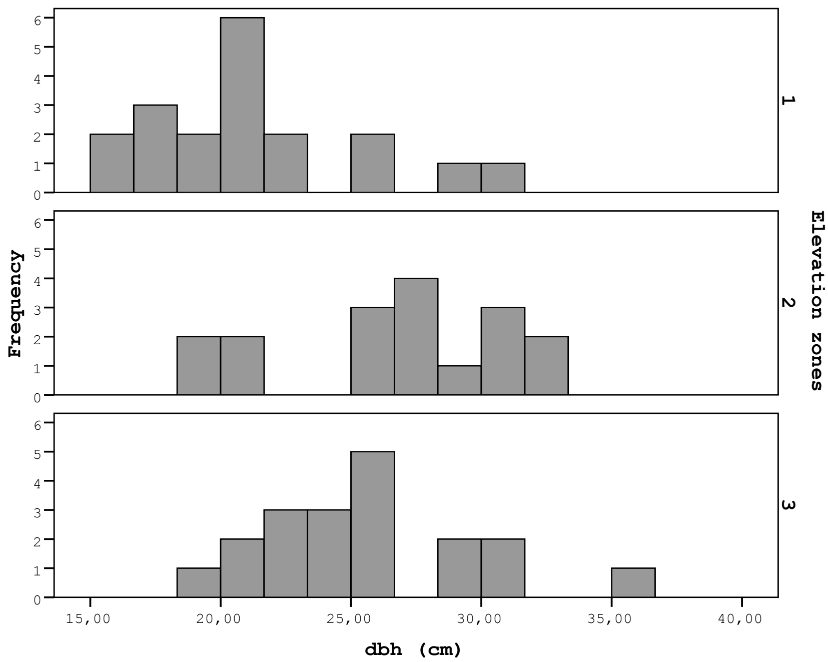

Figure 4. *The diameter at breast height (cm) distributions against elevation zones (1: 0-400, 2: 401-800, 3: 801-1200 m)*

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Biomass amounts in single tree components with respect to elevation zones

As shown in *Fig. 5*, for 400–600 m, the highest average biomass value of Oriental beech tree components was found for the stem wood in a single tree with 199.19 kg. This was followed by branches with 49.27 kg, bark with 22.43 kg and leaves with 7.03 kg. For 600–800 m, the highest average biomass value of Oriental beech tree components was found for the stem wood in a single tree with 378.75 kg. This was followed by branches with 76.48 kg, bark with 38.49 kg and leaves with 10.95 kg. For 800–1000 m, the highest average biomass value of Oriental beech tree components was found for the stem wood in a single tree with 372.56 kg. This was followed by branches with 40.13 kg, bark with 30.84 kg and leaves with 4.94 kg.

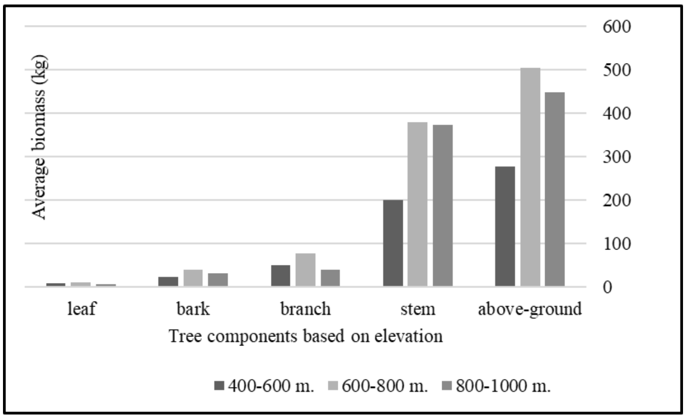

Figure 5. *Measured biomass amounts of sample tree components for elevation zones*

The relationship between diameter at breast height ($d_{1.30}$) and biomass amounts according to elevation zones

When we look at the biomass amounts according to the elevation zones of the trees representing the study area; It is seen that the trees representing the I. elevation zone have lower diameter at breast height and therefore biomass amounts. It is seen that of the trees in the II. and III. elevation zone has higher diameter at breast height and therefore biomass amounts (*Fig. 6*).

Simple variance analysis results showing the change in single tree component biomass with respect to elevation

One-way ANOVA was performed to determine whether the biomass amounts for the aboveground single tree components differed with elevation at the 5% significance level (*Table 3*). According to the one-way ANOVA results, significant differences were found with respect to elevation at the 95% confidence level for the leaf, branch, stem and total biomass amounts, but not for the bark.

Also, Duncan’s post hoc test was performed to identify homogeneous subgroups from the differences shown by the one-way ANOVA results. According to Duncan’s post hoc test results for the leaf biomass, the 800–1000 m (average=4.96 kg) and 400–600 m (average=6.99 kg) elevation zones were in the same group, whereas 600–800 m elevation zone (average=10.77 kg) was different from the other zones with a higher biomass average. For the branch biomass, the 800–1000 m (average=40.25 kg) and 400–600 m (average=48.51 kg) elevation zones were in the same group while the medium elevation

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zone (600–800 m) was found to have a higher amount of branch biomass than the other elevation zones (average=82.05 kg). For the stem component, the 800–1000 m (average=372.64 kg) and 600–800 m (average=378.76 kg) elevation zones were in the same group while the 400–600 m elevation zone (average=198.43 kg) was in another group with significantly lower biomass content. Regarding the aboveground total tree biomass, the 800–1000 m (average=448.90 kg) and 600–800 m (average=503.88 kg) elevation zones were in the same group while the 400–600 m elevation zone (average=276.47 kg) was in another group with significantly lower total biomass (*Table 4*).

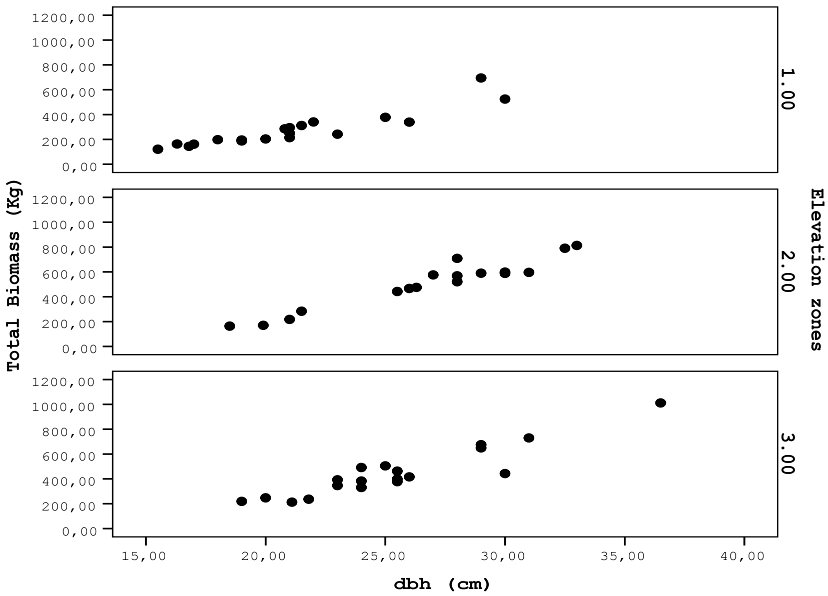

Figure 6. *The relationships between total biomass (kg) and diameter at breast height (cm) distributions against elevation zones (1: 0-400, 2: 401-800, 3: 801-1200 m)*

Table 3. *Simple variance analysis results showing the difference in biomass (kg) amounts of single tree components with respect to elevation*

Tree Components	Sources of Variation	Total of Squares	Degree of Freedom	Average of Squares	F Value	Significance Level (P)
Leaves	Between-groups	310.095	2	155.048	7.106	0.002*
	Within-groups	1134.613	52	21.819		
	Total	1444.708	54			
Bark	Between-groups	2281.292	2	1140.646	2.651	0.080ns
	Within-groups	22377.656	52	430.340		
	Total	24658.948	54			
Branches	Between-groups	17317.995	2	8658.97	6.251	0.004*
	Within-groups	72030.872	52	1385.209		
	Total	89348.867	54			
Stem	Between-groups	390400.52	2	195200.259	9.170	0.000*
	Within-groups	1106946.6	52	21287.434		
	Total	1497347.1	54			
Total	Between-groups	516601.24	2	258300.618	7.843	0.001*
	Within-groups	1712497.8	52	32932.649		
	Total	2229099.0	54			

P: limit probabilities in ANOVA with one factors; *: P<0.05; **: P<0.01; ***: P<0.001; ns: P>0.05

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Table 4. *Duncan's post hoc test results for single tree components and total biomass amounts*

Elevation	N	Tree Components			Total Biomass
		Leaves	Branches	Stem	
400–600 m	19	6.99a	48.50a	198.43a	276.47a
600–800 m	17	10.77b	82.05b	378.76b	503.88b
800–1000 m	19	4.96a	40.25a	372.64b	448.90b

Different letters in each column indicate significant differences (Duncan, P<0.05)

Carbon stock amounts of single tree components with respect to elevation zones

For the 400–600 m elevation zone, the highest average carbon stock value of Oriental beech tree components was found in the stem wood with 95.82 kg, followed by branches with 23.43 kg, bark with 10.48 kg and leaves with 3.22 kg. For the 600–800 m elevation zone, the highest average carbon stock value was found in the stem wood with 182.49 kg, followed by branches with 33.93 kg, bark with 17.86 kg and leaves with 5.06 kg. For the 800–1000 m elevation zone, the highest average carbon stock value was found in the stem wood in a single tree with 183.39 kg, followed by branches with 21.88 kg, bark with 16.58 kg and leaves with 2.32 kg (*Fig. 7*).

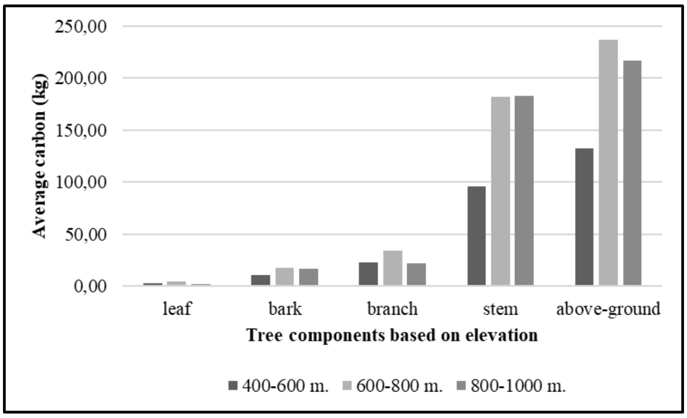

Figure 7. *Measured carbon stock amounts of single tree components by elevation zone*

The relationship between diameter at breast height ($d_{1.30}$) and carbon stock amounts according to elevation zones

When we look at the carbon stock amounts according to the elevation zones of the trees representing the study area; It is seen that the trees representing the I. elevation zone have lower diameter at breast height and therefore carbon stock amounts. It is seen that the trees in the II. and III. elevation zone have higher diameter at breast height and therefore carbon stock amounts (*Fig. 8*).

Simple variance analysis results showing change of carbon stock amounts of single tree components with respect to elevation

One-way ANOVA was performed to determine whether there was a difference between carbon stock amounts of aboveground single tree components and elevation factor according to the 95% significance level (*Table 5*).

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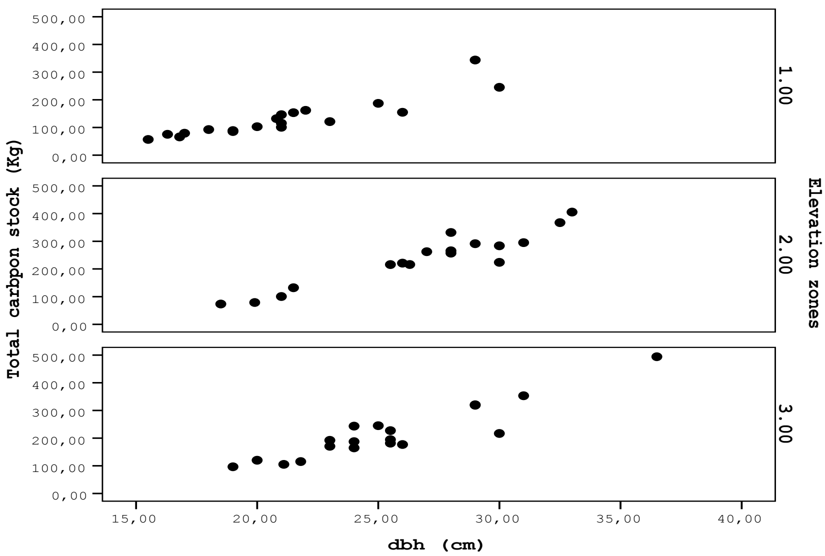

Figure 8. *The relationships between total carbon (kg) and diameter at breast height (cm) distributions against elevation zones (1: 0-400, 2: 401-800, 3: 801-1200 m)*

Table 5. *Simple variance analysis results showing change of carbon (kg) stock amounts of single tree components with respect to elevation*

Tree Components	Sources of Variation	Total of Squares	Degree of Freedom	Average of Squares	F Value	Significance Level (P)
Leaves	Between-groups	66.450	2	33.225	7.119	0.002*
	Within-groups	242.700	52	4.667		
	Total	309.150	54			
Bark	Between-groups	487.963	2	243.982	2.484	0.093ns
	Within-groups	5107.808	52	98.227		
	Total	5595.771	54			
Branches	Between-groups	1984.421	2	992.210	2.839	0.068ns
	Within-groups	1817.699	52	349.533		
	Total	20160.120	54			
Stem	Between-groups	89548.865	2	44774.433	8.724	0.001*
	Within-groups	266872.09	52	5132.156		
	Total	356420.96	54			
Total	Between-groups	113808.10	2	56904.052	7.242	0.002*
	Within-groups	408563.42	52	7856.989		
	Total	522371.52	54			

P: limit probabilities in ANOVA with one factors; *: P<0.05; **: P<0.01; ***: P<0.001; ns: P>0.05

The results of the one-way ANOVA showed that there were significant differences with respect to elevation at the 95% confidence level for the stem, branch and total carbon stock amounts, but not for the bark and branch carbon stocks.

Duncan's post hoc test was performed to identify any homogeneous subgroups from the differences obtained according to the one-way ANOVA results.

According to the results of Duncan's post hoc test for the amount of carbon stock in the leaves, the 800–1000 m (average=2.29 kg) and 400–600 m (average=3.20 kg)

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elevation zones were in the same group while the 600–800 m elevation zone was in another group with a significantly higher carbon stock value (average=4.98 kg). For the stem component, the 400–600 m (average=95.41 kg) elevation zone had a significantly lower amount of carbon in the stem than the other two elevation zones. The 600–800 m (average=179.98 kg) and 800–1000 m (average=180.52 kg) elevation zones were in the same group and had significantly higher amounts of carbon. For the total aboveground total tree components, the 400–600 m (average=132.05 kg) elevation zone had a significantly lower amount of carbon than the other two elevation zones. The 600–800 m (average=236.58 kg) and 800–1000 m (average=217.02 kg) elevation zones were in the same group and had significantly higher carbon averages (*Table 6*).

Table 6. *Duncan's post hoc test results for single tree components and total carbon amounts*

Elevation	N	Tree Components		Total Carbon
		Leaves	Stem	
400–600 m	19	3.20a	95.41a	132.05a
600–800 m	17	4.98b	179.98b	236.58b
800–1000 m	19	2.29a	180.52b	217.02b

Different letters in each column indicate significant differences (Duncan, $P<0.05$)

Discussion

According to the one-way ANOVA results, significant differences were found with respect to elevation at the 95% confidence level in the leaf, branch, stem and total biomass values, but not for the bark, as well as in the changes of leaf, stem and total carbon amounts, but not for the bark and branch. The biomass amounts of the tree components were generally found to be higher in the 600–800 m and 800–1000 m elevation zones than in the 400–600 m elevation zone. This may be due to drought at low elevations (400–600 m) because beech trees have high moisture demands. On the other hand, it has been shown in previous studies that as elevation increases (>1000 m), the shortening of the growth period and low temperatures adversely affect the development of beech stands (Wardle, 1984). In terms of biomass production, our results show that the 600–800 m zone has the most suitable habitat conditions for beech stands. Fehse et al. (2002) assumed that the productivity of forests and hence the carbon sequestration, falls as elevation increases and their research results support this assumption. Simard et al. (2006) in their study performed in the mangrove forests in the Everglades National Park (Florida, USA), revealed that most of the biomass were available in medium height forests when they matched the elevation and biomass data. Zhu et al. (2010) found that carbon storage and partitioning of different components in Mt Changbai temperate forests in Northeast China varied substantially with forest type and elevation. Aiba et al. (1999) in their study performed at 700, 1700, 2700 and 3100 m, determined that as elevation increased, average leaf areas and the diversity of tree species decreased. Rajput et al. (2017) revealed that total biomass production increased with increasing elevation from 1100–1400 m to 2000–2300 m. Likewise, the increase in biomass with increasing elevation was supported by studies by Zhu et al. (2010) and Gairola et al. (2011). This can be explained by the fact that large conifers in areas with higher elevations have dominance over those in lower elevations. Also, it was found that the highest biomass and carbon storage were in forest land as compared with other land covers. Chen et al. (2019) in a study conducted to determine the amount of carbon storage in forest ecosystems in Hunan state in southern

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China, found that carbon storage increased over more than 20 years. They pointed out that efforts should be made to prevent negative human effects in young and middle-aged forests and appropriate tree species should be selected in order to maximize the carbon storage potential in forest ecosystems. Numerous studies have reported that stand development changes with elevation. In some studies, stand development decreased with elevation, while in others it increased up to a certain elevation, and then decreased (Kalay et al., 1993). Mankou et al. (2017) concluded that the changes in forest structure were mainly caused by elevation. Lucas-Borja et al. (2012) reported that soil moisture and temperature varied significantly with elevation. Soil respiration, microbial carbon and enzyme activity tended to be lower at low elevations, but no differences were found between pure and mixed pine forests. This study suggested that the soils of the Cuenca Mountains may be more sensitive to changes in tree composition under certain physical and chemical conditions, such as soil temperature and humidity. Bagroo et al. (2017) found that soil organic carbon and nitrogen stocks in mountainous forests were affected by forest diversity, topographic characteristics and climate change, concluding that elevation had a positive effect on soil organic carbon. Ali et al. (2017) reported that soil organic carbon stock values increased with increasing elevation in all land uses (agriculture, forest, pasture) but decreased with soil depth. These results show that in areas of high elevation, the recovery of degraded agricultural land into forests and the decrease in land use intensity may increase soil organic carbon stocks in the study area and in similar mountainous areas.

Conclusion

This study found that for Oriental beech stands, which are economically important for Turkey, the amount of leaf, branch, stem and total biomass, but not bark among aboveground single tree components varied with respect to elevation. When examining the carbon contents of beech specimens, the leaf, stem and total carbon contents significantly varied with elevation. In the study area, the higher biomass and carbon values obtained in the 600–800 m elevation zone are related to the favorable characteristics of this habitat for beech. Particularly, the fact that temperature and humidity conditions are optimal for beech at this elevation zone may cause this difference. The lower zone (400–600 m) is dry and the upper zone (800–1000 m) is cold, which may adversely affect the biomass and carbon content of the beech trees that grow in those zones. In the mountainous habitat where the study was carried out, the mutually complex relations between the location, microclimate and soil properties make generalization difficult. For this reason, in future studies, detailed climate and soil investigations should be done to reveal the factors affecting the biomass and carbon contents of oriental beech with respect to elevation.

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