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Carbon Concentrations of Some Shrub Species Involved in Understory Vegetation in Istanbul-Durusu Sand Dune Afforestations

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Abstract: Forests are one of the most significant carbon pools in terrestrial ecosystems. Forests store carbon not only in the tree biomass that composes them but also in pools such as dead wood, litter, and soil. Similarly, vegetation elements, which are components of forest ecosystems and are referred to as understory in forestry practice, are also constituents of the forest ecosystems' primary living biomass pool. On the carbon accumulation in forest ecosystems in Türkiye a substantial number of studies have been or are being conducted but this is still insufficient. However, the vast majority of these studies involve tree biomass (particularly above-ground biomass). Some subsequent studies have focused on carbon in litter and soil. But as stated previously, studies attempting to ascertain the amount of carbon stored in the understory biomass, which is a component of the living biomass pool and a part of the forest vegetation, are almost nonexistent. Consequently, the aim of this study is to determine the carbon concentrations of the shrub part of the vegetation on a coastal dune (Durusu (Terkos) Sand Dune) that had zero carbon stock prior to 60 years ago afforestation. During the biomass inventory of the maritime pine and stone pine plantations in Durusu Sand Dune, the carbon content of the shrub species was determined by collecting samples from a total of 18 sample plots. Both the above- and below-ground portions of the plants were sampled independently for shrubs. During the inventory investigations, the following species of shrubs were identified: arbutus (*Arbutus unedo*), heather (*Erica arborea*), cistus (*Cistus creticus*), laurel (*Laurus nobilis*) and broom (*Sarathommus scoparius*). Using the LECO TruSpec 2000 C/N Analyzer, the carbon concentrations of the leaves, branch/stem wood and root organs of these shrub species were determined via the dry burning method. The carbon contents of the leaf, branch/stem wood, and root components of arbutus species were measured and found to be 48.37%, 47.77%, and 47.47%, respectively. The carbon contents in heather species were found to be 51.62%, 50.26%, and 50.64%, while in laurel species, they were revealed to be 51.27%, 48.43%, and 48.28%. The carbon factors of the three biomass components in the broom species are 48.59%, 47.54%, and 48.98%, respectively. The present study investigated the biomass components of the cistus species, specifically classifying them into above-ground and below-ground categories. Additionally, carbon ratios were found for these components. The carbon ratio of the above-ground organs of the cistus species was found to be 48.96%, whereas the carbon ratio of the below-ground organs was determined to be 47.97%.

Keywords: *Arbutus unedo*, *Cistus creticus*, *Erica arborea*, *Laurus nobilis*, *Sarathommus scoparius*.

1. INTRODUCTION

Forests play an important role in the global carbon cycle and are globally valuable due to the services they provide to society (Denman et al., 2007; Pan et al., 2011). Because forests are pools that can reduce the carbon concentration in the atmosphere by storing carbon in their sub-pools (living biomass, dead organic matter and soil) (Pehlivan, 2017). Carbon dioxide (CO_2) has the most significant share of greenhouse gases in the atmosphere. Research shows that increasing concentrations of greenhouse gases (especially CO_2) in the atmosphere is one of the main reasons for climate change (Schimel et al., 2000; Nowak & Crane, 2002; Çömez, 2010).

Forests are the primary reservoirs where the most carbon accumulates among the terrestrial ecosystems in the world. Approximately 20-25% of the amount of carbon released into the atmosphere between 2000 and 2008 was stored in these ecosystems, which is very close to the amount of carbon stored in the oceans (Helin et al., 2013; Liu et al., 2012). Carbon pools on Earth are classified as atmosphere, terrestrial biosphere and oceans. The movement of carbon between these pools due to various processes is called the global carbon cycle (Le Quéré et al., 2012; Sabine, 2014). In forests, there are generally 5 sub-carbon pools classified as above-ground vegetative mass, sub-soil vegetative mass, dead wood, dead cover and soil (IPCC, 2003; IPCC, 2006; Özturna, 2022). Table 1 provides explanatory information regarding the sub-carbon pools found in forests. The information is provided in the given format.

Table 1. Carbon pools in forests (IPCC, 2003; IPCC, 2006; Özturna, 2022).

Main Pools	Sub-pools	Basic Components
Living Biomass	Above-ground	Stems, stumps, branches, leaves, bark and seeds above ground
	Below-ground (Roots)	All living roots of the living biomass, except roots less than 2 mm in diameter
Dead Organic Matter	Dead Wood (Planted dry)	All woody biomass found at the base or in the soil in a dry, planted state. It includes wood lying on the surface, standing leaves, dead roots and roots thicker than 10 cm.
Soils	Litter	On top of mineral and organic soil; It consists of all dead woody biomass, debris, humus and fumic layer that can form a layer of at least 10 cm in diameter. Living very small roots are also counted in this section.
	Soil Organic Matter	It contains organic carbon in minerals and organic soils. Living coarse roots are considered soil organic matter.

In recent years, there has been a growing body of research focused on quantifying the carbon sequestration potential of forest vegetation in Türkiye. While the primary focus of these studies pertains to quantifying the carbon sequestration potential of forest vegetation, a comparatively lesser emphasis is placed on assessing the carbon storage capacity of litter and soil. Nevertheless, it is evident from the data presented in Table 1 that there exists a scarcity of research endeavors focused on quantifying the quantity of carbon sequestered by the living cover. This particular component is an integral part of the "Living Biomass" reservoir, which is recognized as a crucial carbon pool within forest ecosystems. The forest component known as understory serves as both a reservoir of biodiversity, housing many plant species, and as a carbon sink, owing to the substantial amount of vegetative mass it generates.

The objective of this study is to determine the carbon levels in the shrub component of the vegetation in Istanbul-Durusu (Terkos) Kumulu maritime pine and stone pine afforestation. The study focuses on an area that was previously assumed to have no carbon content, namely 60 years after the afforestation took place.

2. MATERIALS AND METHODS

The research was carried out in Istanbul-Durusu (Terkos) Sand Dune maritime pine (*Pinus pinaster* Ait.) and stone pine (*Pinus pinea* L.) afforestation. The total area of Durusu (Terkos) Sand Dune is 3106.7 ha. 1647.2 ha of this area has been afforested. Afforestation started in the 1960s and has a history of approximately 60 years today (Tolunay et al., 2017). Durusu Sand Dune, located in the west of the Bosphorus and on the Western Black Sea coast, is located between Karaburun from the east, Kocaçeşme-Çayırburun from the west, Durusu Lake from the south and the Black Sea from the north (Figure 1) (OGM, 2013). It is a slightly rugged terrain where parallel ridges extending in the east-west direction rise and progress towards the south (Saraçoğlu & Bozkuş, 1996). Irmak et al. (1980) in the forest habitat classification of Thrace, Lake Durusu and its surroundings were evaluated as "Terkos Region" within the western part of the Çatalca Peninsula. The average elevation of the dune is 20 m and the highest point is Kabakum hill (70 m elevation) located in the east of the dune.

According to the data obtained from Kumköy Meteorology Station, which is the closest meteorological station to the study area, the lowest monthly average temperature was measured in January with -7.5 °C, and the highest monthly average temperature was measured in July with 41.4 °C. The annual average temperature was determined as 14.7 °C (Pehlivan, 2017; Tolunay et al., 2017). The period between April and December, called the vegetation period, when average monthly temperatures exceed 10 °C. The average annual total precipitation in Durusu Dune is 836 mm, and a significant part of this precipitation falls between September and March (Tolunay et al., 2017). The water deficit between June and October was calculated as 31.4 mm by some researchers (Saatçioğlu et al., 1978; Saraçoğlu & Bozkuş, 1996). In the study area, where the annual average relative humidity is around 77-78%, the dominant winds blow from the northeast with an average annual speed of 9.2-107 km/h (İMP, 2009).

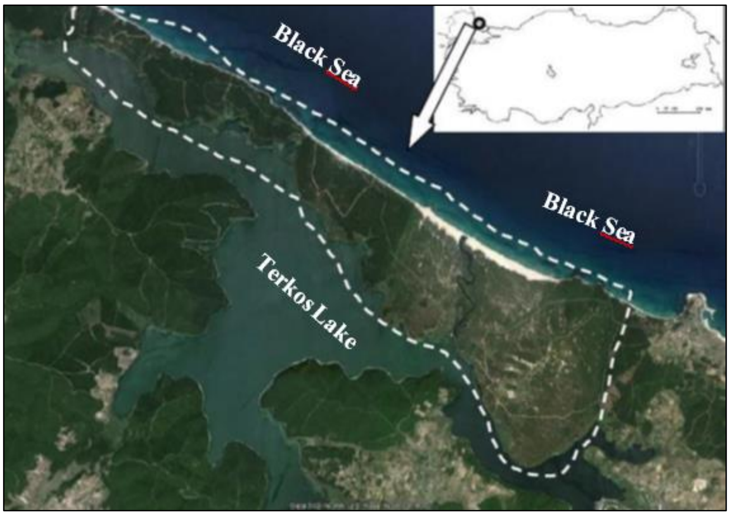

Figure 1. Research area.

Although no bedrock was found in the study area, old soils were found in areas far from the sea and close to Terkos Lake, and excavation depths of 60-70 cm could be reached. As a result of the fact that most of the soil in the research area is of marine origin, the presence of shells and their fragments belonging to marine creatures has been observed. As a result, soils contain significant amounts of lime (Özturna, 2022). Dunes, which have typical sand soil characteristics, have very low water retention capacity due to high water permeability. Abdalmoula et al. (2019) reported that the lime content in the soil of the research area increased up to 30% and the sand content varied between 95-98%. The pH of the soil of the research area can rise up to 8.5 and is slightly alkaline. The electrical conductivity of soils varies between 20-80 µS/cm (Özturna, 2022).

The material of this research consists of shrub species encountered in a total of 18 sample areas during the biomass inventory carried out in maritime pine and stone pine afforestation in Durusu Sand Dune. These shrub species were identified as Arbutus (*Arbutus unedo*), Heather (*Erica arborea*), Cistus (*Cistus creticus*), Laurel (*Laurus nobilis*) and Broom (*Sarathommus scoparius*) (Figure 2).

Sample numbers of shrub species are given in Table 2. These shrub species, which were found in 18 sample areas, were cut and their above-ground and below-ground organs were classified. This classification is made in the form of leaves, branch/stem wood and roots (below-ground) (Figure 3). Then, separate subsamples were taken from the three components of each shrub species.

Table 2. Sample numbers of shrub species.

Species	Number of Samples
Arbutus	2
Laurel	4
Heather	2
Broom	6
Cistus	4
Total	**18**

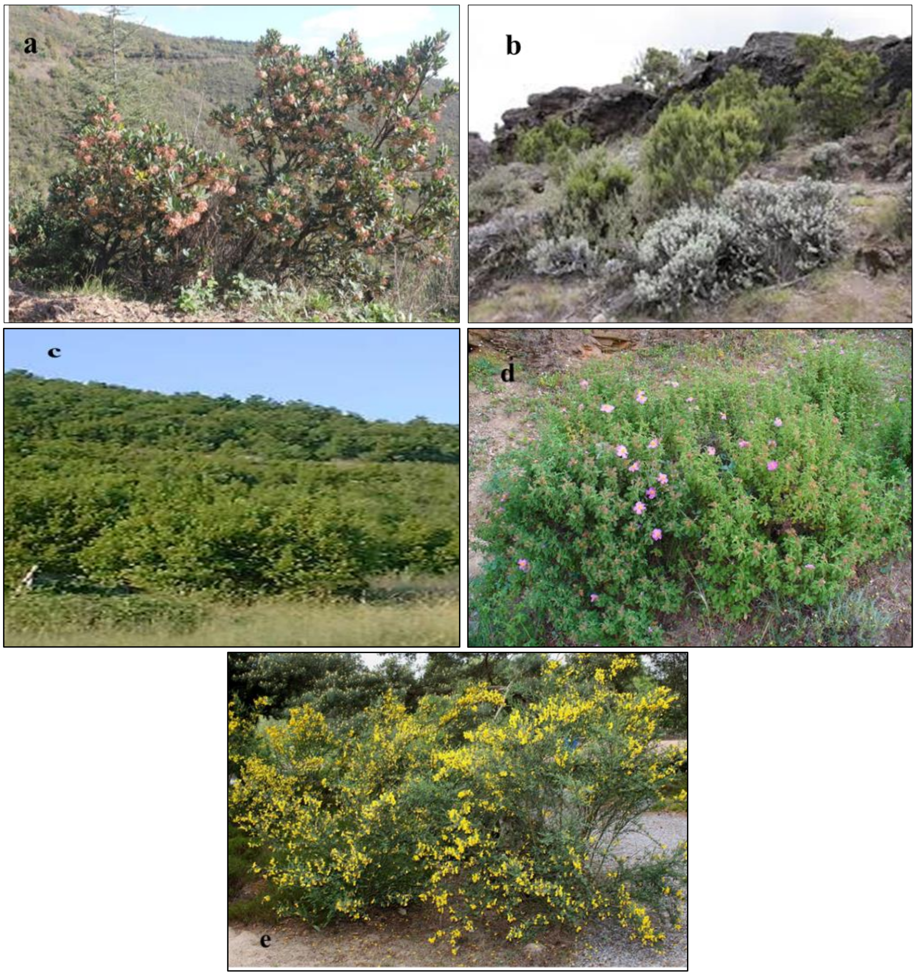

Figure 2. a) Arbutus (*Arbutus unedo*), b) Heather (*Erica arborea*), c) Laurel (*Laurus nobilis*), d) Cistus (*Cistus creticus*) and e) Broom (*Sarathommus scoparius*).

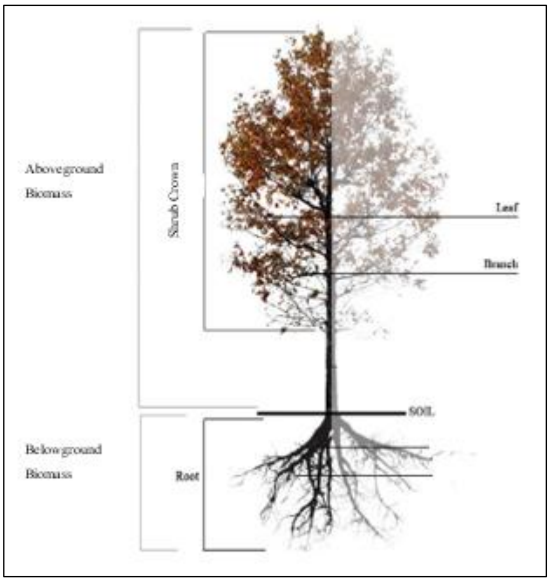

Figure 3. Classification of sap cover subsamples.

The subsamples taken were brought to the laboratory, dried at 70 ℃ until they reached a constant weight, and then ground to prepare for analysis. The carbon concentrations of these ground subsamples were determined by the dry burning method. For this purpose, LECO Truspec2000 C/N Analyzer device was used.

3. RESULTS AND DISCUSSION

3.1. Results

The study involved determining the carbon concentrations of the organs of the shrub species. These concentrations were expressed as percentage values, calculated by taking the arithmetic means (%). This study examined five distinct shrub species, namely arbutus, heather, laurel, broom, and cistus. Carbon concentrations were measured separately for leaves, branch/stem wood, and root organs in the arbutus, heather, laurel, and broom species. However, due to the biological properties of the cistus species, carbon concentrations were determined as above-ground total and below-ground, as it was not feasible to measure them separately. The carbon concentrations were determined and recorded in Table 3.

Table 3. Average carbon concentrations of subsamples of shrub species (%).

Tür	Leaf	Branch/Stem Wood	Below-ground
Arbutus	48.37	47.77	47.47
Laurel	51.27	48.43	48.28
Heather	51.62	50.26	50.64
Broom	48.59	47.54	48.98
Cistus	48.96*		47.97

*It was evaluated as total above-ground.

In Arbutus species, the highest carbon content was detected in the leaves with 48.37%, while the lowest carbon content was detected in the roots with 47.47% (Figure 4). In Laurel species, similar to arbutus, the lowest carbon rate (48.28%) was detected in the below-ground organs and the highest carbon rate (51.27%) was detected in the leaves (Figure 5).

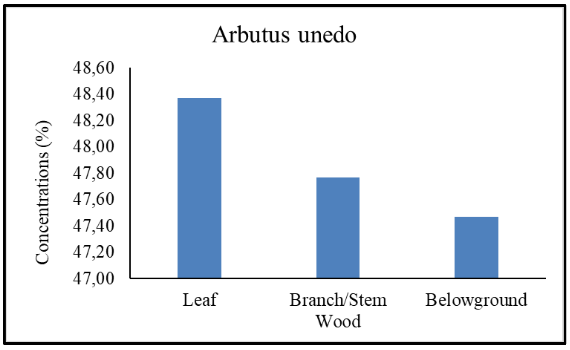

Figure 4. Carbon ratios of Arbutus species.

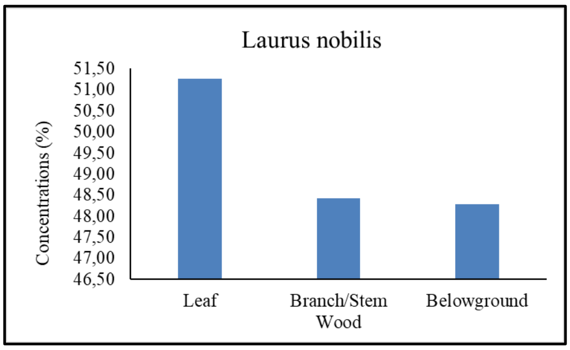

Figure 5. Carbon ratios of Laurel species.

While the roots have the highest carbon content in Heather (Figure 6) and Broom (Figure 7) species, the organs with the lowest carbon concentrations of these species were determined to be branch/stem wood (Table 3).

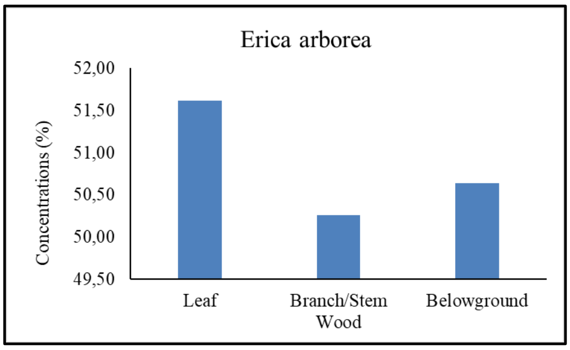

Figure 6. Carbon ratios of Heather species.

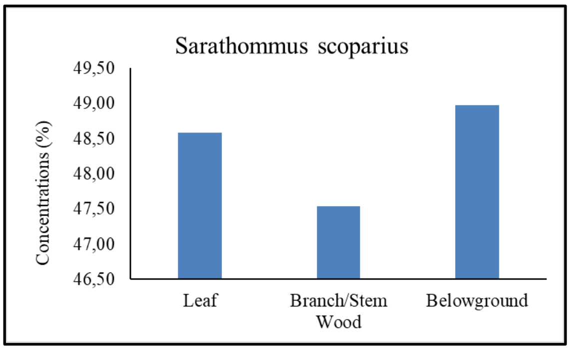

Figure 7. Carbon ratios of Broom species.

In the Cistus species, only the total above-ground and below-ground values were evaluated, and the carbon rates of these organs were determined as 48.96% and 47.97%, respectively (Figure 8 and Table 3).

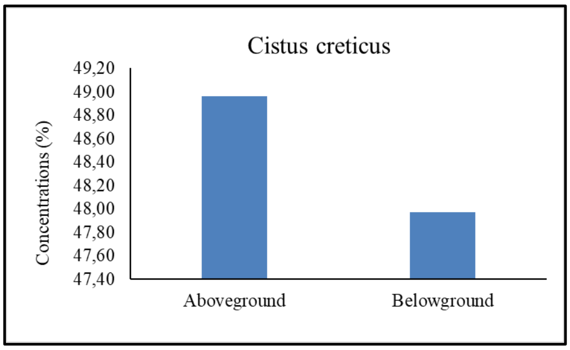

Figure 8. Carbon ratios of Cistus species.

3.2. Discussion

The carbon ratios of the shrub species added to the understory in Durusu Kumulu afforestation vary depending on the plant species and various organs of these species, but vary between 47.47% and 51.62%. The plant species with the highest carbon content in its leaves is heather with 51.62%. The lowest carbon content was found to be the arbutus species with 48.37%. Similarly, the highest and lowest carbon rates of under-ground organs were detected in heather and arbutus species, respectively. Lim (2012) conducted a study in Isparta to ascertain the carbon rates associated with the above-ground organs, namely leaves, branches and stem of Kermes oak exclusively within maquis areas that are predominantly characterized by the presence of Kermes Oak (*Quercus coccifera*). According to the results of the relevant study, the average carbon concentrations of leaves, branches and stem organs of Kermes oak are 50.65%, 49.12% and 48.58%, respectively. In this context, it can be said that the results obtained for Kermes oak are similar to the species detected in Durusu Sand Dune. In a study conducted in pure Scots Pine (*Pinus sylvestris*) stands in Bolu Aladağ, the average carbon rate for all above-ground organs of the understory was determined as 47.64% (Tolunay, 2009). Additionally, Çömez, (2012) determined the carbon rates of understory in Scots Pine stands in Eskişehir Sündiken Mountains. According to the results obtained for the overall understory, the average carbon content of the above-ground parts of the understory is 47.00%. The average carbon concentration of the below-ground parts of the understory in Scots Pine stands in the Sündiken Mountains was determined to be 42.90% (Çömez, 2012). In both studies, separate evaluations were not made for the species that make up the understory. Zheng et al. (2008) measured the understory carbon ratios in stands of different tree species and found it to be 42.08% in the *Camellia oleifera* stand, 42.55% in the *Cunninghamia lanceolata* stand and 44.33% in the *Pinus elliottii* stand. Falkengren-Grerup et al. (2006) measured the carbon contents of *Dryopteris filix-mas*, *Milium effusum* and *Stellaria holostea* species, which they sampled from the *Quercus robur* stand, as 44.2%, 41.5% and 41.6%, respectively. Bing et al. (2006) determined the carbon rates of the stem part in the understory to be between 32.7-46.7%, and the carbon rates of the root part to be between 41.2-46.7%. Both Falkengren-Grerup et al. (2006) and Bing et al. (2006) shows that living carbon concentrations are lower than the results obtained in Durusu Sand Dune. It is considered that the carbon ratios were determined to be low because the understory sampled in these studies consisted mostly of herbaceous species and therefore their lignin content was low (Bert & Danjon, 2006; Çömez, 2012).

4. CONCLUSION

Carbon concentrations of both above-ground and below-ground organs of shrub species participating in the understory vegetation in Durusu Sand Dune afforestation were revealed in this study. In previous studies conducted in Türkiye, carbon ratios of understory components were not examined on a species basis. In addition, studies on determining the carbon ratios of the below-ground organs of the understory are very few both in Türkiye and in the world. This study, in which carbon concentrations are determined both on a species basis and for below-ground and above-ground, will make a significant contribution to the literature with the mentioned features.

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