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Topographic controls in the distributions of tree species on the Karadağ Massif, NE Turkey

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Abstract

In this study, it was aimed to reveal the relationships between the distribution of tree species in the mountainous land on the Karadağ massif located in the transition zone of the Canik-Giresun mountains and the Trabzon mountains sites, and topographic variables. Results of independent *t*-test and PCA (Principal Component Analysis) indicated that *Carpinus orientalis* and *Quercus petraea* showed high ecological tolerance to humid-drought sites, whereas it limited the distribution of *Castanea sativa* in more humid areas. Although *Alnus glutinosa*, *Fagus orientalis* and *Picea orientalis* show similar ecological characteristics, it is likely that these species will be affected by the rainfall on the Canik-Giresun mountains along with the increasing fog in the upper altitudes of the Trabzon mountains. With increasing urbanization in sub-altitudes close to the coast, negative interventions may limit forests to steep slopes that are unsuitable for agriculture and settlement. Therefore, the drought-resistant *Pinus sylvestris* that can go down to the coast, the drought-resistant naturalized *Robinia pseudoacacia*, and *Pinus pinea* that is characteristic tree of the Mediterranean climate, which are distributed in the sub-altitudes of the Trabzon mountains site, are remarkable in terms of the impact of environmental variables. Given the current social-ecological dynamics, particularly in mountainous areas, which are highly fragile landscapes; understanding these relationships can help to guide appropriate future management strategy in the area and around.

Keywords: Eastern Black Sea region, environmental variables, sites, independent *t*-test, PCA

Introduction

High mountains, which cause different climates due to their topography, are also important places in determining the natural boundaries of site regions. These areas may contain more humid ecosystems with strong winds, and on the other hand, more drought ecosystems despite their sheltered (natural harbour) structures.

Topography has strong effects on tree species distribution. High mountains may change airflow and are a significant barrier to atmospheric circulation, resulting in different temperature and precipitation climate conjunction with the mountainous aspect (Efthymiadis et al. 2007). Moreover, different aspects of the mountain are exposed to different amounts of solar radiation. For this reason, at the mountain and mountain chains scale, especially the mountainous aspect of topography factors, different environments affecting species distribution and plant growth are presented. At this point, considering the local scales, the aspect of the neighbouring environment also affects the site conditions by influencing the microclimate (Deng et al. 2007, Suggitt et al. 2011). Research have indicated that highly complex topographies may produce suitable conditions for plants depending on changing environmental conditions, such as climate change (Dobrowski 2011, Scherrer and Körner 2011).

Species distributions are closely linked to changes in topographic and environmental conditions (Ruiz-Labourdette et al. 2012, Pauli et al. 2014). Thus, patterns of plant species distributions may be affected by the mountainous aspect and local aspect. In addition, most studies revealing relationship between mountainous plant species distributions and topography were realized at local and micro-environment scales, rarely accounting for mountain-scale effects (Qiu et al. 2012). In particular, the mountainous aspect of topographic variables is often ignored in relevant research that should be worth considering (Wu et al. 2018).

Topography is directly related to drainage regimes and soil characteristics associated with the distribution of tree species in a forest (Bourgeron 1983, Johnston 1992). For the mountain ecosystems, aspect, elevation, and slope degree are the three main topographic factors that affect the species distributions indirectly (Huang 2002). The features such as slope, aspect and location cause significant changes in a forest composition (Beaty and Taylor 2001). In many directions, elevation determines the microclimate that affects the spatial patterns of species distribution (Johnson 1981, Allen and Peet 1990, Sang 2009).

In this study, it was aimed to reveal the relationships between the distribution of tree species in the mountainous land on the Karadağ massif, and environmental variables. For this purpose, statistical relationships between topographic variables (altitude, slope, topographic solar-radiation, northern exposure, eastern exposure, topographic position index, site exposure index) and the distributions of tree species in the mountainous land were investigated. The altitude of the mountainous massif on the Black Sea coast reaches 2,000 meters. The Karadağ massif supports different climatic effects and tree species distribution in its western and eastern parts due to its location. Transportation to the upper altitudes of the Karadag massif for the purpose of transhumance and tourism is mostly provided from the Söğütlüdere valley between Trabzon province and Akçaabat district on the east side. In consideration of the population density, Söğütlüdere valley is under the pressure of intensive grazing and agriculture from past to present.

Materials and methods

Study area

The study area is the mountainous Karadağ massif in the Canik-Giresun mountains and Trabzon mountains site transition zone in Trabzon province in the Eastern Black Sea region (Figure 1). These sites are the site sub-regions formed by Kantarcı (1995) "On the Land Under the Sea Effect" based on earth-climate relationship for the Eastern Black Sea region.

The Karadağ massif is located on the Black Sea coast between 39°14'N–39°17'N latitude and 41°05'E–41°07'E longitude. There are the Foldere and Söğütlüdere rivers on both sides of the Karadağ massif. The distance at which the Foldere and Söğütlüdere rivers get closer to each other (2–3 km) forms the southern border. The Canik-Giresun mountains and the Trabzon mountains sites cover areas of 279.48 km² and 206.62 km², respectively. The study area is a total of 486.10 km².

In the Eastern Black Sea Region, precipitation increases slightly with the increase in longitude, in other words, from west to east. Two reasons can explain this increase: location of mountains and coastline configuration. From west to east, the Eastern Black Sea mountains become higher and closer to the coastline. The location of the Trabzon mountains site is northeast-oriented, has the feature of a sheltered natural harbour and receives less precipitation compared to the Canik-Giresun mountains sites. In the study area, there are significant precipitation differences between both sites (TSMS 2020). As regards Thornthwaite's method, the climate type of the Canik-Giresun mountains is "humid-very humid", the climate type of the Trabzon mountains site is "semi humid, semi humid-semi drought" (Thornthwaite 1948) (Table 1).

Data processing

The data used were a DEM (Digital Elevation Model) produced by the Shuttle Radar Topography Mission (SRTM GL1, Global 30, Publication Date: 08/01/2013) (SRTM 2013). DEM had a resolution of 30 m. These spatial resolutions determined the scale at which the analysis was carried out, and the types of patterns and processes that could be distinguished. DEM were geo-referenced by the supplier. The elevation values of the DEM were rounded to integers, resulting in 1-m intervals (GLCF 2006). The DEM was used to derive the topographic variables (altitude, slope angle, aspect, topographic solar-radiation, eastern exposure, northern exposure, topographic position index and site exposure index) (Table 2, Figure 2).

The stand maps (1/25,000) of the management plans (Anonymous 2008) of Akçaabat, Düzköy, Vakfıkebir and Tonya in the ArcGIS database were used as data. The areas covered by dominant species in normal crown closure (11– 100%) and degraded (0–10%) stands were considered in the distribution of trees. Stand maps are made with data obtained directly from the sample points by systematic sampling of 300 × 300 m on the land. In this study, a total of systematic (100 × 100 m) 19,222 points were marked on the Karadağ massif using the GIS. Dominant species, altitude, slope angle, aspect, topographic solar-radiation, eastern exposure, northern exposure, topographic position index and site exposure index of these points were derived.

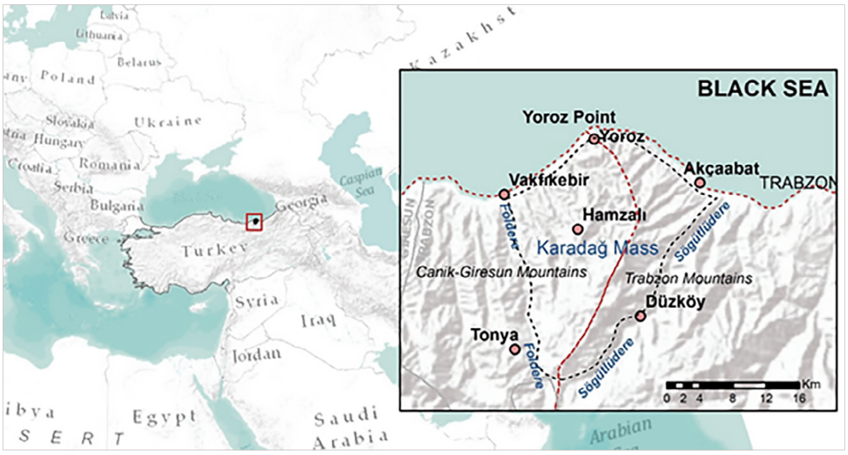

Figure 1. Location of the study area

Table 1. Climate data of the meteorological stations on the study area (Akkaş 1990, Karadeniz 1999, TSMS 2020)

Site / Stations	Climate parameters						
	AvT (°C)	MinT (°C)	MaxT (°C)	AnnP (mm)	Foggy days *	Climate type	PWD
			Canik-Giresun Mountains				
Vakfıkebir (25 m)	14.4	11.2	18.2	1150.9	5.4	Humid	WNW
Hamzalı (845 m)	11.8	8.5	16.0	1457.8		Very Humid	WSW
Tonya (900 m)	9.4	4.8	15.0	1047.0	48.7	Humid	SW-SE
Yoroz Point (370 m)	14.2	11.7	17.3	1194.1		Humid	WSW
			Trabzon Mountains				
Akçaabat (3 m)	14.6	11.7	18.3	621.5	8.7	Semi-Humid/Semi-Drought	WNW
Düzköy (850 m)	11.1	7.1	16.0	628.0	89.6	Semi-Humid	SW

Abbreviations: Precip. – Precipitation, PWD – Prevailing Wind Direction, AvT – Average Temperature, MinT – Minimum Temperature, MaxT – Maximum Temperature, AnnP – Annual Precipitation.

Table 2. Ecological meanings of the topographic variables

Acronym	Variables	Ecological Importance	Description
ALT	Altitude	Temperature, moisture, CO_2 pressure	Altitude above sea level (m)
SL	Slope	Solar radiation, terrain stability, soil moisture	Slope angle in degrees
TRASP	Topographic Solar-Radiation	Solar radiation and precipitation	North- northeast (the coolest and wettest), south-southwest (the hotter-dryer). From 0 to 1
NORTH	Northern exposure	Summer vs. winter solar radiation	Relation to north (1 to –1)
EAST	Eastern exposure	Morning/afternoon solar radiation, wind, moisture	Relation to east (1 to –1)
TPI	Topographic Position Index	Soil moisture and erosion, wind exposure	tpi > 0 (ridge), tpi < 0 (valley), tpi ~0 (constant slope, flat area, or saddle)
SEI	Site Exposure Index	Soil moisture, solar radiation	From –100 to 100 from the coolest to warmest locations

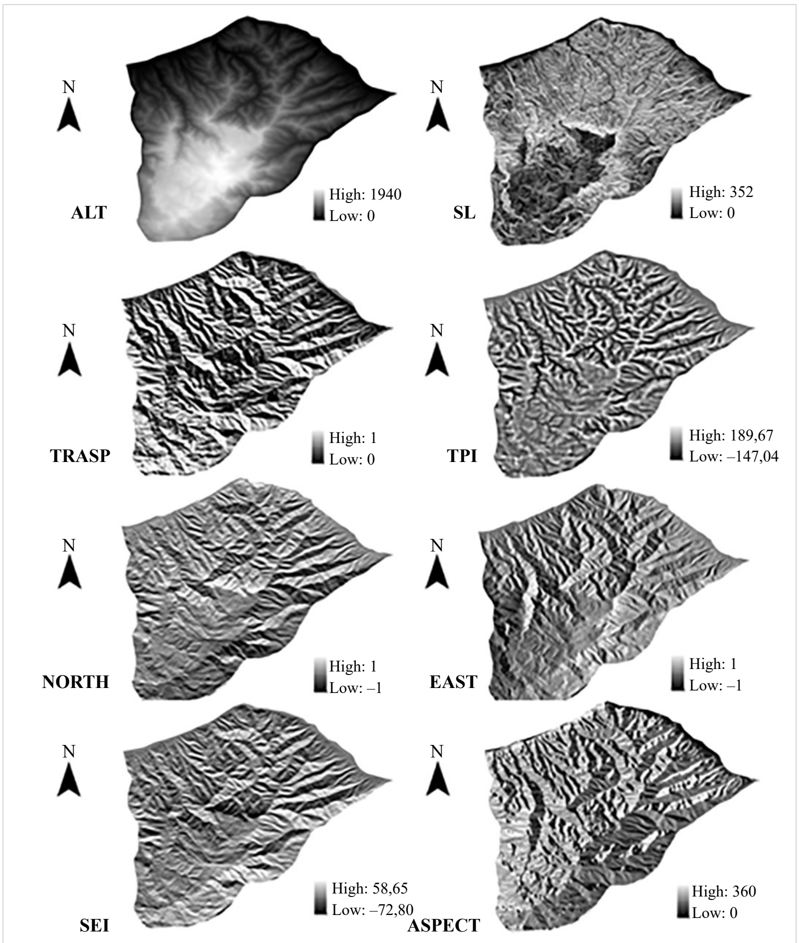

Figure 2. Topographic variables

Statistical analyses

An independent samples *t*-test was used to determine whether there was a significant difference between the means of topographic factors of the Canik-Giresun and the Trabzon mountains ($P < 0.05$). PCA analysis, which is one of the multiple analysis methods, was applied to all dependent and independent variables for the relationships between topographic variables and the distributions of species in the Canik-Giresun and the Trabzon mountains sites on the Karadağ massif. All statistical analyses were performed using the IBM SPSS software platform (IBM 2015).

Results

Descriptive statistics of the topographic factors used in the study are given in Table 3. The skewness and kurtosis of all data sets for the Canik-Giresun and the Trabzon mountains sites showed that the topographic factors data had a normal distribution (Table 3).

In this study area, the Canik-Giresun mountains were represented by 6 tree species, whereas the Trabzon mountains were represented by 9 tree species. Tree species that are different according to the sites are *Robinia pseudoacacia* (*Bl*), *Pinus*

Table 3. Descriptive statistics for variables in both sites

	Descriptive Statistics										
	Mean		MIN	MAX	RANGE	SD	VAR	Skewness		Kurtosis	
	STA	SE						STA	SE	STA	SE
	Canik-Giresun Mountains										
ALT	881.7	7.7	5.0	1894.0	1889.0	488.0	238138.4	0.026	0.039	–1.157	0.077
TPI	–4.3	0.6	–128.0	148.0	276.0	36.9	1359.4	0.115	0.039	0.588	0.077
SL	26.3	0.1	1.0	67.0	66.0	9.0	81.5	–0.117	0.039	–0.167	0.077
SEI	–5.6	0.2	–66.2	45.8	112.0	15.6	242.7	0.037	0.039	0.333	0.077
NORTH	0.1	0.0	–1.0	1.0	2.0	0.3	0.1	0.014	0.039	0.521	0.077
EAST	–0.1	0.0	–1.0	1.0	2.0	0.3	0.1	0.293	0.039	0.523	0.077
TRASP	0.5	0.0	0.0	1.0	1.0	0.3	0.1	0.166	0.039	–0.800	0.077
	Trabzon Mountains										
ALT	796.7	7.5	0.0	1832.0	1832.0	467.9	218944.1	0.258	0.039	–1.059	0.079
TPI	–5.5	0.7	–129.0	172.0	301.0	44.9	2018.1	0.228	0.039	0.089	0.079
SL	28.6	0.1	0.0	66.0	66.0	9.3	86.3	–0.406	0.039	–0.139	0.079
SEI	–1.6	0.4	–55.0	50.7	105.7	23.1	533.0	–0.014	0.039	–1.046	0.079
NORTH	0.0	0.0	–1.0	1.0	2.0	0.5	0.2	0.025	0.039	–0.888	0.079
EAST	0.1	0.0	–0.8	1.0	1.8	0.3	0.1	–0.080	0.039	–0.348	0.079
TRASP	0.4	0.0	0.0	1.0	1.0	0.3	0.1	0.263	0.039	–1.158	0.079

Table 4. Averages of topographic factors of some tree species in the Trabzon mountains

	Altitude (ALT)	Topographic Position Index (TPI)	Slope (SL)	Solar Exposure (SEI)	Topographic Solar Radiation (TRASP)	East Exposure (EAST)	North Exposure (NORTH)
Bl *	346.95	8.52	61.23	22.20	0.68	0.26	–0.44
Sp *	378.44	17.50	56.90	22.09	0.70	0.25	–0.43
Scp *	342.18	–12.38	51.17	–10.50	0.36	–0.05	0.21

* These species do not exist in the Canik-Giresun mountains site. *Bl*: *Robinia pseudoacacia*, *Sp*: *Pinus pinea*, *Scp*: *Pinus sylvestris*.

pinea (*Sp*) and *Pinus sylvestris* (*Scp*). The averages of the topographical variables for these species were given in Table 4.

SEI, TRASP, EAST and NORTH values of *Bl* and *Sp* were very close to each other. Except for EAST, according to SEI, TRASP and NORTH, *Bl* and *Sp* increased its distribution in more drought sites, whereas *Scp* increased its distribution in more humid sites. Compared to *Bl*, *Sp* preferred hillier areas (TPI). The average altitude and slope degrees of the species were close to each other (Table 4).

In the study area, independent *t*-test was performed for common species that distributed in both sites and significant differences were determined (Table 5).

According to topographic variables, statistically significant differences were determined in all common species ($p < 0.001$, $p < 0.01$, $p < 0.05$). While statistically significant differences were found in all topographic variables of *Fagus orientalis* (*Ob*) and *Picea orientalis* (*Os*) between the two sites, ALT, SL and EAST variables of *Quercus petraea* (*O*) differed. In general, the topographic variables (TPI, SEI, TRASP, EAST and NORTH) of *Carpinus orientalis* (*Hb*), *Alnus glutinosa* (*Ba*) and *Castanea sativa* (*Ac*) showed similar differences between the two sites. These species preferred lower slopes and valleys (TPI), low insolation (SEI) and high humidity (TRASP, EAST and NORTH) sites in the Trabzon mountains compared to the Canik-Giresun mountains. *Ob* and *Os* indicated similar differences in all topographic variables. Compared to the Canik-Giresun mountains, these species preferred lower altitudes (ALT), higher slopes, near the upper hillside (TPI), high insolation (SEI) and less humid (TRASP and NORTH) areas in the Trabzon mountains. Average EAST was higher in the Trabzon mountains and *Ob*. *O* preferred higher slope (SL), average altitude (ALT) and more humid (EAST) areas in the Trabzon mountains compared to the Canik-Giresun mountains (Table 5). Independent *t*-test could not be performed for *Sp*, *Bl* and *Scp* species that show distribution only in the Trabzon mountains. These species were evaluated by mean values and PCA analysis.

The principal component analysis, which is one of the multiple analysis methods, was applied to all variables for the relationships between topographic variables and the distributions of species in the Canik-Giresun and the Trabzon mountains sites on the Karadağ massif. As a result of the principal component analysis, the eigenvalues, variance percentages and cumulative variance values of the components were obtained (Table 6).

According to the analysis, in the Canik-Giresun mountains and the Trabzon mountains site, the first two axes of PCA explained 62.28% and 61.58% of the total data variance, respectively. In two sites, the contribution of the topographic variables to each component extracted is summarised in Table 6. In the Canik-Giresun mountains, the relative importance of the topographic variables for the first axis in decreasing weight order are: SEI, NORTH, TRASP and EAST. For the second axis, the variables are: ALT, SL, EAST and TPI, also decreasingly ordered.

Table 5. Topographic factors of common species in the investigated sites

Index	Site	Sp *	Mean	SE	Effect	Mean Diff. *	Sp	Mean	SE	Effect	Mean Diff.
ALT	CAN	*Carpinus orientalis*	440.47	9.24	.969	–0.47	*Alnus glutinosa*	812.47	4.32	.000	–76.80
	TRA		440.00	7.89				735.67	9.01		
TPI	CAN		–0.90	1.90	.001	–8.04		–6.24	0.61	.000	–7.96
	TRA		–8.94	1.55				–14.21	1.21		
SL	CAN		54.75	0.35	.372	–0.91		55.89	0.13	.000	3.46
	TRA		53.84	0.29				59.35	0.21		
SEI	CAN		–2.72	0.81	.000	–5.68		–8.21	0.27	.534	0.37
	TRA		–8.41	0.74				–7.84	0.60		
TRASP	CAN		0.54	0.01	.000	–0.17		0.45	0.00	.000	–0.10
	TRA		0.37	0.01				0.35	0.01		
EAST	CAN		–0.17	0.01	.000	0.20		–0.09	0.01	.000	0.23
	TRA		0.03	0.01				0.14	0.01		
NORTH	CAN		0.06	0.02	.000	0.11		0.17	0.01	.664	–0.01
	TRA		0.17	0.01				0.16	0.01		
ALT	CAN	*Fagus orientalis*	1176.32	7.10	.000	–115.39	*Picea orientalis*	1525.27	3.40	.000	–113.50
	TRA		1060.93	8.02				1411.77	7.64		
TPI	CAN		–3.92	0.95	.001	5.56		4.15	0.52	.000	4.82
	TRA		1.63	1.41				8.97	1.05		
SL	CAN		47.61	0.24	.000	16.76		31.64	0.16	.000	5.47
	TRA		64.37	0.27				37.11	0.29		
SEI	CAN		–6.69	0.43	.000	14.46		–2.81	0.26	.000	8.27
	TRA		7.77	0.75				5.45	0.50		
TRASP	CAN		0.46	0.01	.001	0.04		0.49	0.01	.024	0.03
	TRA		0.51	0.01				0.52	0.01		
EAST	CAN		–0.11	0.01	.000	0.37		–0.08	0.00	.000	0.21
	TRA		0.26	0.01				0.13	0.01		
NORTH	CAN		0.14	0.01	.000	–0.29		0.05	0.00	.000	–0.16
	TRA		–0.16	0.02				–0.10	0.01		
ALT	CAN	*Castanea sativa*	301.15	8.84	.146	26.50	*Quercus petraea*	249.29	18.87	.000	274.93
	TRA		327.64	8.28				524.22	16.50		
TPI	CAN		–16.51	1.99	.014	–10.74		–14.33	6.16	.550	4.87
	TRA		–27.25	3.55				–9.46	3.20		
SL	CAN		47.18	0.39	.000	7.66		52.26	1.31	.009	8.73
	TRA		54.84	0.70				60.99	0.55		
SEI	CAN		–6.37	0.79	.000	–11.04		–10.19	2.92	.087	6.92
	TRA		–17.41	1.60				–3.27	1.59		
TRASP	CAN		0.43	0.02	.000	–0.16		0.44	0.05	.664	0.02
	TRA		0.27	0.02				0.46	0.02		
EAST	CAN		–0.04	0.02	.700	0.02		–0.19	0.04	.001	0.16
	TRA		–0.02	0.03				–0.03	0.02		
NORTH	CAN		0.13	0.02	.000	0.22		0.21	0.06	.092	–0.14
	TRA		0.35	0.03				0.07	0.03		

Abbreviations: Sp: Species, CAN: Canik-Giresun Mountains, TRA: Trabzon Mountains, Diff.: Difference.

Table 6. Descriptive statistics for variables in both sites

	F1	F2	F3	F4	F5	F6	F7
			Canik-Giresun Mountains				
Eigenvalue	2.979	1.380	1.102	0.871	0.559	0.107	0.001
Variability (%)	42.56	19.72	15.74	12.44	7.99	1.53	0.02
Cumulative %	42.56	62.28	78.02	90.46	98.45	99.98	100.00
			Trabzon Mountains				
Eigenvalue	2.986	1.325	1.062	0.992	0.558	0.077	0.001
Variability (%)	42.65	18.93	15.18	14.17	7.97	1.09	0.01
Cumulative %	42.65	61.58	76.76	90.93	98.9	99.99	100.00

Table 7. Component 1–2 relationship coefficients (r) of the topographic variables

Sites / Axes	ALT	TPI	SL	SEI	TRASP	EAST	NORTH
			Canik-Giresun Mountains				
F1	0.193	0.050	–0.382	0.951	0.918	–0.387	–0.947
F2	0.786	0.433	–0.612	–0.030	-0.230	0.384	0.021
			Trabzon Mountains				
F1	0.262	0.078	–0.088	0.567	0.507	0.140	–0.565
F2	0.550	0.539	0.152	-0.088	–0.291	0.533	0.088

In the Trabzon mountains, for the first axis in decreasing weight order are: SEI, NORTH and TRASP. For the second axis, the variables are: ALT, TPI and EAST, also decreasingly ordered (Table 7). In the Canik-Giresun mountains, analysis of Figure 6 revealed that the gradient expressed by axis 1 was defined primarily by abundance differences of *Os* on the positive side, and *O*, *Ac* and *Ba* on the negative side.

Os showed a tendency to increase abundance towards the increase of SEI and TRASP and the decrease of EAST and NORTH, whereas *O* and *Ba* showed the opposite tendency. The gradient expressed by axis 2 was defined primarily by abundance differences of *Ob* on the positive side, *Ac* and *Hb* on the negative side. *Ob* indicated a tendency to increase abundance towards the increase of EAST, ALT and TPI and the decrease of SL, whereas *Ac* and *Hb* showed the opposite tendency (Figure 3).

In the Trabzon mountains, analysis of Figure 7 revealed that the gradient expressed by axis 1 was defined primarily by abundance differences of *Sp* and *Bl* on the positive side, and *Ac* and *Ba* on the negative side. *Sp* and *Bl* showed a tendency to increase abundance towards the increase of SEI and TRASP and the decrease of NORTH, whereas *Ac* and *Ba* showed the opposite tendency. The gradient expressed by axis 2 was defined primarily by abundance differences of *Ob* and *Os* on the positive side and *Hb*, *O* and *Scp* on the negative side (Figure 3). *Ob* and *Os* showed a tendency to increase abundance towards the increase of TPI, SL, EAST, and ALT, whereas *Hb*, *O* and *Scp* showed the opposite tendency (Figure 4).

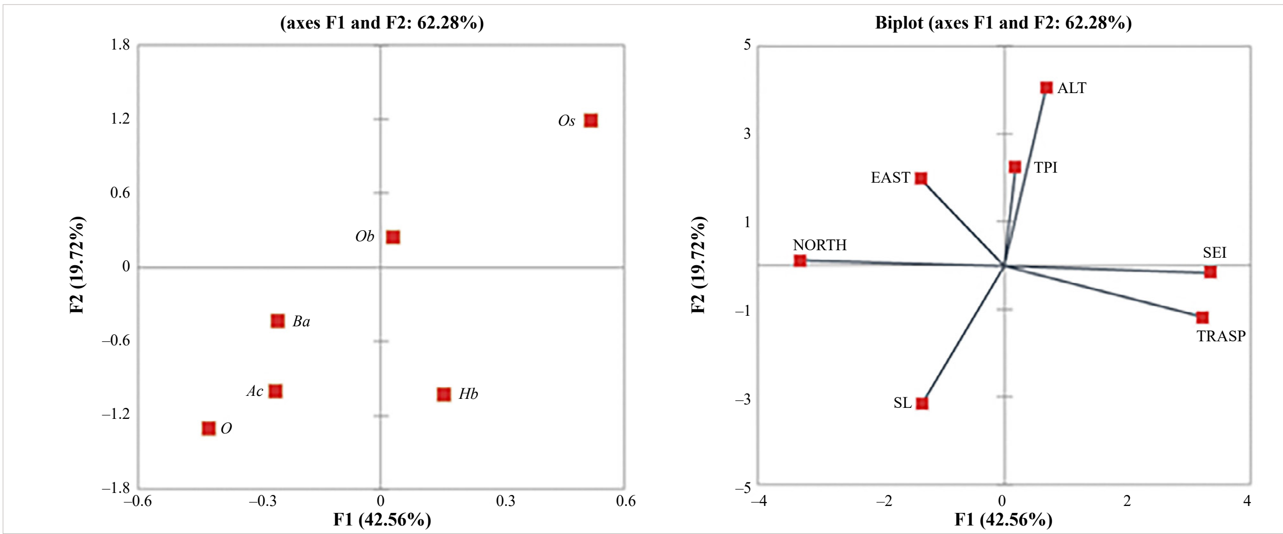

Figure 3. Ordination of the species-topographic variables on the axes in the Canik-Giresun mountains (*Os*: *Picea orientalis*, *Ob*: *Fagus orientalis*, *Hb*: *Carpinus orientalis*, *Ac*: *Castanea sativa*, *Ba*: *Alnus glutinosa*, *O*: *Quercus petraea*)

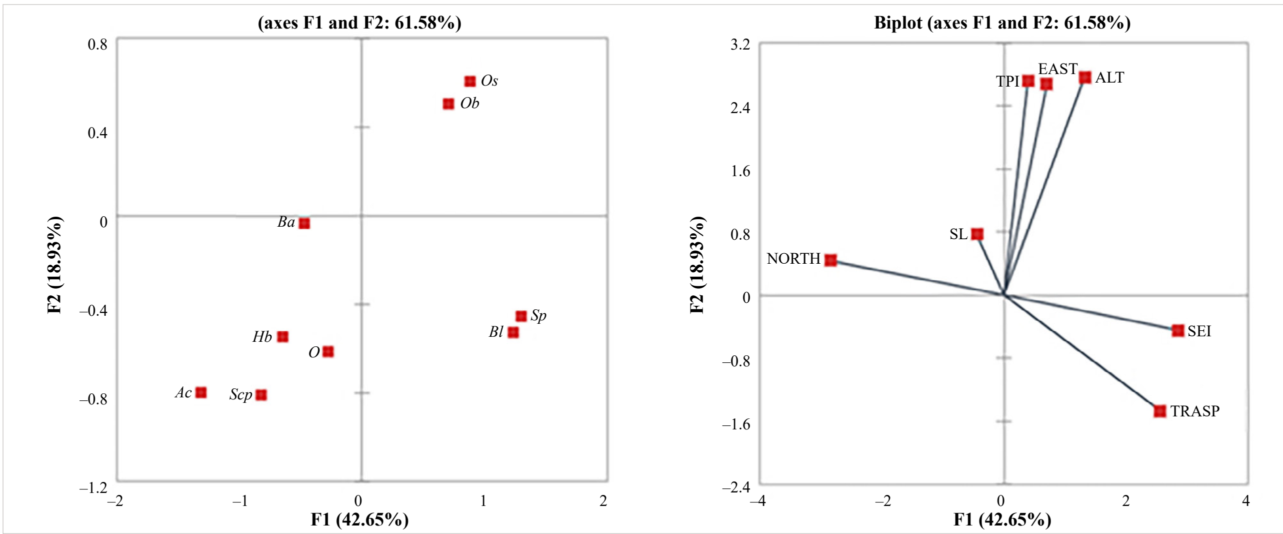

Figure 4. Ordination of the species-topographic variables on the axes in the Trabzon mountains (*Os*: *Picea orientalis*, *Ob*: *Fagus orientalis*, *Hb*: *Carpinus orientalis*, *Ac*: *Castanea sativa*, *Ba*: *Alnus glutinosa*, *O*: *Quercus petraea*, *Sp*: *Pinus pinea*, *Scp*: *Pinus sylvestris*, *Bl*: *Robinia pseudoacacia*)

Discussion and conclusions

The Karadağ massif is located in the transition zone between the Canik-Giresun mountains and the Trabzon mountains sites. This topography is a natural barrier to the dominant western and northern winds carrying moisture. The east-west direction of the massif and its openness to humid air masses coming from the Black Sea affect the orographic precipitation and cloudiness on the northern slopes of the mountains. While the precipitation difference on the coast (Vakfıkebir-Akçaabat) is approximately 530 mm, this difference reaches 830 mm in Hamzalı (845 m) and Düzköy (850 m) at close altitudes.

In the study, independent *t*-test showed significant differences for the sites (Table 5). The average slopes of the tree species in the Trabzon mountains are higher compared to the Canik-Giresun mountains. This may be related to the higher amount of forest destruction in the Trabzon mountains site. Over time increase of destruction, forests may limit to high-slope areas that are unsuitable for agriculture and settlement. Therefore, in the semi-arid regions, the southern slopes are steeper in the northern hemisphere, and the northern slopes are less inclined due to the radiation difference they receive depending on the aspect factor (Goudie 2004). Independent *t*-test results indicated that *Hb*, *Ba* and *Ac* increased the distribution in sites with higher humidity (TRASP, EAST, NORTH, SEI and TPI) in the Trabzon mountains compared to the Canik-Giresun mountains. *Hb* and *Ac* showed a higher increase in moisture requirement from the Canik-Giresun mountains to the Trabzon mountains. *Ac* is highly susceptible to summer droughts caused by the combination of high temperature and deficiency of precipitation and limits distribution (Conedera et al. 2009, Conedera, et al. 2016). Average altitude of *Ac* was lower than 500 m in the two sites. Considering the climate data for these altitudes, the temperatures (average, min and max) of the Canik-Giresun (Vakfıkebir) and the Trabzon mountains (Akçaabat) are close to each other. Annual precipitation is 621.1 mm (semi-humid, semi-drought) in the Trabzon mountains and 1,150.9 mm (very humid) in the Canik-Giresun mountains. In the sites, the average altitude (736 m in the Trabzon mountains, 812 m in the Canik-Giresun mountains) of *Ba* was higher than *Ac* and *Hb*. According to the climatic data at this altitude, the temperatures of sites are close to each other, whereas the annual precipitation (Düzköy: 628 mm, Hamzalı: 1457.8 mm) is quite different. *Ba* is adapted to a wide temperature range and is relatively frost tolerant. It requires a high-water availability combined with atmospheric humidity for growth and development (Savill 2013, Houston Durrant et al. 2016). According to annual precipitations and climate types (Düzköy: semi-humid, Hamzalı: very humid), *Ba* is expected to increase its distribution in more humid sites. In the Trabzon mountains, the number of foggy days is 8.9 day/year in Akçaabat (3 m) and 89.6 day/year in Düzköy (850 m). The altitude of Düzköy station (850 m) and average altitude of *Ba* (735 m) are close to each other. The high number of foggy days in the area can increase atmospheric humidity as well as reduce evaporation by blocking solar radiation. According to PCA, although *Ba* and *Ac* differed in the Canik-Giresun mountains, these two species showed distribution in similar sites in the Trabzon mountains. These species prefer more humid (SEI and TPI) sites against increasing drought in the Trabzon mountains. *Ac* showed distribution in lower altitudes (ALT) with less humid (EAST, SL), while *Ba* showed distribution in more humid areas in the Canik-Giresun mountains. This may be related to the light and temperature requirement of *Ac* that is a thermophile species, with sufficient precipitation (1150.9 mm) in the Canik-Giresun mountains. *Ac* can regenerate in semi-shade conditions but needs light in youth for growth (Bounous 2014). *Hb* showed distribution in the more arid (ALT) lower altitudes in the Trabzon mountains compared to the more humid lower altitudes of the Canik-Giresun mountains. Also, it is interesting that although it prefers west slope (EAST) areas that can increase drought in the Trabzon mountains, it increases its distribution in lower slopes and valleys with higher soil moisture. This can be explained by the high ecological tolerance of *Hb*. Although *Hb* is a thermophilous and xerophilous species, it is also drought-resistant, prefers the poor shallow lands and rocky areas in terms of organic matter (Chiarucci et al. 1996). In addition, it has been stated that *Hb* can exhibit different ecological behaviours in a wide range (Akhani and Ziegler 2002).

According to the independent *t*-test, in the Trabzon mountains compared to the Canik-Giresun mountains, *O* preferred higher slope (SL) and upper altitude (ALT) and east slope (EAST) areas that could increase humidity. Average of *O* is 249 m in the Canik-Giresun mountains, 524 m in the Trabzon mountains. Distribution increase of *O* in upper altitude and with high slope sites may be due to the social pressure in the Trabzon mountains. Agriculture, overgrazing, settlement, and transhumance activities on the Karadağ massif increase the pressure on forests over time. In the 13-year period, the forest area in the Trabzon Regional Directorate of Forestry decreased about 12,500 ha (Kalay et al. 1990). This lost area converted agriculture, pasture, and settlement areas (Karagül 1999). PCA showed that except slope, *O* increased its distribution in lower altitude (ALT) and lower relief-valleys (TPI) that could increase soil moisture and reduce evaporation (EAST) in the sites. In two sites, although the average temperatures were close, the difference in annual precipitation showed that *O* had a high ecological tolerance. *O* has a very large ecological niche because it accepts soil pH from 3.5 to 9 and xeric to humid conditions. It is more tolerant to drought and poor soil. The minor species of sessile oak in south-eastern Europe are well adapted to wide ecological niches from humid to extremely xeric (Ducousso and Bordacs 2004). *O* is drought tolerant and grows in more Atlantic climates on well drained and light, often rocky, soils, generally occurring on hill tops and slopes, and preferring more acidic soil pH (Aas 2012).

In the study, independent *t*-test results showed similar changes for *Ob* and *Os* increased its distributions in lower altitude (ALT) and less humid-drought (SL, TPI, SEI, TRASP and NORTH) areas except for the EAST variable in the Trabzon mountains compared with the Canik-Giresun mountains. However, compared to *Os*, *Ob* tended to increased moisture (EAST). In the Trabzon mountains, average altitude was 1,061 m in *Ob* and 1,412 m in *Os*. The climate type is very humid in the Canik-Giresun mountains (Hamzalı, 845 m), and semi-humid in the Trabzon mountains (Düzköy, 850 m). On the other hand, the total number of foggy days in the Trabzon mountains (Düzköy) is quite high (89.6 days). It has been previously stated that the high number of foggy days in the area can increase atmospheric humidity as well as reduce evaporation. *Ob* and *Os* as well as *Ba* are more common in the Eastern Black Sea Region, where the number of foggy days is high. The fog cloud in this region plays an important ecological role in distribution of these species (Usta et al. 2018). Therefore, it is likely to be affected by the high precipitation in the Canik-Giresun mountains due to the high average altitudes (1,000 <) of the *Ob* and *Os* in the Trabzon mountains. According to PCA, *Os* increased its distribution in the more arid areas (SEI, TRASP, NORTH and EAST) in the Canik-Giresun mountains and in the upper altitude (ALT), the higher slope-hilly and east (EAST) slope areas that can increase the humidity in the Trabzon mountains. Accordingly, *Os* preferred more drought sites in the Canik-Giresun mountains. It has been reported that it is rarely encountered in the relatively arid parts of the mountains facing inward, although *Os* prefers high humidity in high mountain climates and with abundant precipitation in summers (Saatçioğlu 1969). *Ob* preferred higher altitudes, hilly areas (TPI) and east slope (EAST) areas that can increase humidity in both sites. It has been stated that *Ob* desires a warm-cool climate zone with a balanced precipitation distribution, high relative humidity, and low temperature extremes (Atay 1982, Atalay 1983, Anşin and Özkan 1997).

Average SEI, TRASP, EAST and NORTH of *Sp* and *Bl* were quite close to each other. *Bl* and *Sp* increased its distribution in very drought (SEI, TRASP and NORTH) areas, except for the EAST variable. The average altitude of these species was lower than 500 m. Although this site is the driest (Akçaabat: semi humid-semi arid) site of the Karadağ massif, according to PCA analysis, *Sp* and *Bl* were observed to increase its distribution in much more drought and sun exposed areas in this site. Increment in SEI and TRASP may increase the sunshine duration and indirectly the loss of water by evaporation in the area. However, it is understood that *Sp* and *Bl* have a higher resistance to these areas, where sunshine duration increases compared to *Scp*. It has been reported that *Bl* adapted successfully to a variety of climate zones such as the dry terrestrial Turkey, subtropical South Africa and cold ocean Patagonia, although natural distribution area has a humid and temperate climate (Li et al. 2014). *Bl*, which is the most significant and aggressive invasive tree found in Turkey, is mostly distributed in open places and sunny slopes of the study area (Uzun and Terzioğlu 2008).

Sp is very tolerant to summer droughts (Carrasquinho and Gonçalves 2013). *Sp* is also known to adapt very well to high temperatures and arid characteristics in the Mediterranean climate (Yılmaz et al. 2010). However, in his report based on the results of a 7-year study in the Southeastern Anatolia region in Turkey, Ürgenç (1986) does not recommend *Sp* for the areas with an annual precipitation of less than 400 mm. It has also been reported that *Sp* is not a suitable species for arid and semi-arid regions (Sayman et al. 2006). It grows mostly in pure stands and is usually renewed by self-seeding/artificial seeding. The stands are found in Mediterranean climate zones characterized by hot, dry summers (up to drought of 5 months) and temperate winters (average temperature of the coldest month is above 0°C and an annual precipitation of 600800 mm) and in semi-humid climates. *Sp* is spread over the northern and eastern Mediterranean, from Portugal to Syria and some coastal regions of the Black Sea (Faddy et al. 2004). Acun (1982) stated that once upon a time, small pine groves remained from 100–200 hectares of *Sp* forests on the sides of Trabzon-Söğütlüdere valley. Although this area geographically has the characteristics of this region, it has the characteristics of Mediterranean climate (Yaltırık 1988).

According to the averages of topographic variables, *Scp* increased its distribution in quite humid (SEI and TRASP) valleys and lower slopes. Average altitude of *Scp* such as *Sp* and *Bl* was lower than 500 m. It was previously stated that this site is the driest (Akçaabat: semi humid-semi arid) site of the Karadağ massif. According to the PCA analysis, *Scp* preferred valleys and lower reliefs that could increase soil moisture despite the drier lower altitudes (ALT) and west slope (EAST) sites. *Scp* is a species that can grow in a wide variety of sites. Although it is a pioneer species that requires light, it can invade recently deteriorating sites if competition and grazing pressure are low in its environment (Mátyás et al. 2004). It usually grows in sunny and partially shaded, generally nutrient-poor (Farjon 2010) areas. In the literature, although it is stated that *Scp* cannot cope with atmospheric pollution or salty sea winds (Savill 2019), its presence in this site indicated that it could cope with salty sea winds. This site is one of the few sites (Akçaabat, Sürmene-Çamburnu, Hopa) in the Eastern Black Sea Region where *Scp* could reach the seaside.

In the study, *Hb* and *O* showed a high ecological tolerance from humid to drought sites. Therefore, *Ac* limited its distribution in more humid areas. Although *Ba*, *Ob* and *Os* show similar ecological characteristics in both sites, these species are likely to be affected by the precipitation in the Canik-Giresun mountains with the increasing fog in the Trabzon mountains. In addition, salty sea winds-drought resistant *Scp*, the drought-resistant naturalized *Bl*, and *Sp* that is characteristic tree of the Mediterranean climate, which are distributed in the Trabzon mountains site, are important in terms of biodiversity. Given the current ecological dynamics, particularly in mountainous areas, which form highly fragile landscapes, results of this study can help to guide appropriate future management strategies in the region.

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