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Impact of spatial factors on climate variables and species distribution in forest ecosystems under sea influence of Eastern Black Sea Region, NE Turkey

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Abstract

The distribution and characteristics of forest ecosystems are largely under the influence of climate. Climate directly affects the growth, leaf area and form, fenology and plant life, from seed to seedling formation. Climate varies from global scale to regional and local scales. Climate also has feedback mechanisms that can revert the changing vegetation back to its original state, through the changes it can create on vegetation. In this study, it was aimed to investigate the relationships between the distribution of tree species in the highland which is under the influence of the sea in Canik-Giresun Mountains, Trabzon Mountains and Rize-Kaçkar Mountains sites in the Eastern Black Sea Region, and spatial factors (altitude, distance from sea and latitude) and climate variables. The climate data, such as precipitation, temperature (average, minimum and maximum) and number of foggy days, of meteorological stations at different altitudes in coastal and mountainous areas under the influence of the sea were used in the study. 100 m increase in altitude led to a decrease in 26.9 mm precipitation in the Canik-Giresun Mountains, a decrease in 87.0 mm precipitation in the Rize-Kaçkar Mountains, and an average temperature decrease of 0.4°C in sites. The decrease in annual precipitations reaches 70 mm in Trabzon Mountains, 100 mm in Canik-Giresun Mountains and 290 mm in Rize-Kaçkar Mountains at a distance of 10 km away from the coast. Statistical increases were determined in the number of foggy days depending on the altitude and distance from the sea.

In the research area, at 3rd altitude step where the distance from the sea and altitude are extreme, Scots pine, Oriental Spruce and Fir are spread in Canik-Giresun Mountains, Oriental Spruce and Scots pine are spread in Trabzon Mountains, and Oriental Spruce, Oriental Beech and Fir are spread in Rize-Kaçkar Mountains. Despite the decreasing amount of precipitation along with the increase in altitude and distance from the sea, the fog cloud in high mountainous areas plays an important ecological role in the conservation and distribution of these species.

Key words: Sites, altitude, latitude, distance from the sea, precipitation, temperature

Özet

Orman ekosistemlerinin dağılımı ve özellikleri büyük ölçüde iklimin etkisi altındadır. İklim, tohumdan fidan teşekkülüne, büyümeyi, yaprak alanı ve formunu, fenolojiyi ve bitki hayatını doğrudan etkiler. İklim, küresel ölçekten bölgesel ve yerel ölçeğe farklılık gösterir. İklimin, vejetasyon üzerinde meydana getirebileceği değişiklikler yoluyla, değişen vejetasyonu tekrar orijinal haline döndürebilecek geri besleme mekanizmaları da vardır. Bu çalışmada, Doğu Karadeniz Bölümü'nde Canik-Giresun Dağları, Trabzon Dağları ve Rize-Kaçkar Dağları yetişme ortamlarında deniz etkisi altındaki dağlık arazide ağaç türlerinin yayılışı ile konum faktörleri (yükselti, denizden uzaklık, enlem) ve iklim değişkenleri arasındaki ilişkilerin araştırılması amaçlanmıştır. Çalışmada, deniz etkisi altında kıyı ve dağlık alanlarda farklı yükseltilerdeki meteoroloji istasyonlarının yağış, sıcaklık (ortalama, minimum ve maksimum) ve sisli günler sayısı gibi iklim verilerinden yararlanılmıştır.

Yükseltideki 100 m artış Canik-Giresun Dağları'nda 26.9 mm, Rize-Kaçkar Dağlarında 87.0 mm yağışta düşüşe; yetişme ortamlarında ortalama olarak 0.4 ºC ortalama sıcaklık düşüşüne sebep olmuştur. Yıllık yağışlardaki düşüş, sahilden 10 km uzaklaşıldığında, Trabzon Dağları'nda 70 mm, Canik-Giresun Dağlarında 100 mm ve Rize-Kaçkar Dağlarında 290 mm'ye ulaşmaktadır. Yükselti ve denizden uzaklığa bağlı olarak sisli gün sayısında istatistiksel olarak artışlar belirlenmiştir.
Araştırma alanında, denizden uzaklığın ve yükseltinin ekstrem olduğu III. yükselti basamağında, Canik-Giresun dağlarında Sarıçam, Doğu Ladini ve Göknar, Trabzon dağlarında Doğu Ladini ve Sarıçam, Rize-Kaçkar Dağlarında Doğu Ladini, Doğu Kayını ve Göknar yayılış göstermektedir. Yükselti ve denizden uzaklığın artması ile düşen yağış miktarına rağmen, yüksek dağlık alanlardaki sis bulutu bu türlerin korunmasında ve yayılışında önemli ekolojik bir rol üstlenmektedir.
Anahtar kelimeler: Yetişme ortamları, yükselti, enlem, denizden uzaklık, yağış, sıcaklık

Introduction

There are many different factors that affect the climate of a place in the world. The climate of a region is determined by the interaction of some important natural controls such as latitude (proximity to the equator), altitude, distance from the sea, aspect, slope, ocean currents, orographic effect, warming and cooling characteristics and air pressure. It has been recently accepted that human activity also affects the climate (Scott, 2004). The changes in altitude may cause big differences in temperature even at similar latitudes. For this reason, high mountain and plateau stations are much colder than the low-altitude stations at the same latitude (Apaydın et al., 2011). In many parts of the world, mountains are open to the effects of a rapidly changing climate and are interesting places for early detection and analysis of the signals of climate change and their effects on hydrological, ecological and social systems (Beniston, 2005). Although the mountains are very different from region to region, their common characteristic is the complexity of their topography. Orographic characteristics affect the rapid and systematic changes especially in temperature and precipitation conditions at very short distances in climate parameters (Becker and Bugmann, 1997; Arnbjerg-Nielsen et al., 2013), directly developing flow and erosion, the systematic change of other climate variables (e.g., radiation), and the environmental factors (such as the differences in soil types). Orographic effect is the lifting effect on winds passing over the mountain peaks or ranges. The air rises as it approaches a mountain barrier, and it typically generates clouds and precipitation usually on the windward side of the mountains. The wettest parts of the world are located on the windward side of high mountain ranges (Clarke and Wallace, 1999; Jackson, 2000; Scott, 2004; Espinoza et al., 2015). These factors are the spatial functions, and the accurate determination of spatial distribution of meteorological variables is as important as their measurements (Apaydın et al., 2004).
The climate factors, such as temperature, potential evapotranspiration, growing season length, moisture, air pressure, presence of nutrients, ultraviolet radiation and precipitation, vary depending on the altitude (Funnell & Parish, 2001). The range of change of tree species spreading in this change is determined directly or indirectly by the inappropriate extremes of these climate factors. The upper limit of the distribution of a species can be determined by a combination of climate and biotic factors (MacArthur, 1972; Ehrlén and Morris, 2015). For this reason, the distribution and characteristics of forest ecosystems are largely controlled by climate. At the individual level, climate directly affects the reproduction of seeds and seedling formation (Renard et al. 2016), the growth (Carrer & Urbinati, 2004, 2006), the leaf area and form (Fisher et al. 2007; Yang et al., 2015), the fenology (Petrotelli et al. 2005), and the lifespan of the plant as an individual (Goulden et al., 1998). The influence of climate in nature varies from global scale to regional and local scales. Climate also has feedback mechanisms that can revert the changing vegetation back to its original state, through the changes it can create on vegetation (Bonan et al. 1992; Lynch et al., 1999; Anderson-Teixeira et al. 2013).
In this study, it was aimed to reveal the relationships between the spatial factors affecting the distribution of forest-building tree species in the highland which is under the influence of the sea in the

sub-regional sites in the Eastern Black Sea Region and climate variables. For this purpose, the statistical relationships between spatial factors (altitude, latitude and distance from the sea) in the highland under the influence of the sea and the climate variables were investigated, the distribution of spreading tree types was evaluated according to spatial factors.

Methods

Study Area

This study was carried out in the ecological units which are under the influence of the sea of Ordu, Giresun, Trabzon, Rize and Artvin provinces that are geographically located in the Eastern Black Sea Region of the Black Sea Region. The sub-regional sites formed by Kantarcı (1995) in the "Site under the influence of the sea", based on the earth-climate relationship for the Eastern Black Sea Region were taken into account while determining the study area. These site regions are Canik-Giresun Mountains, Trabzon Mountains and Rize-Kaçkar Mountains (Figure 1).

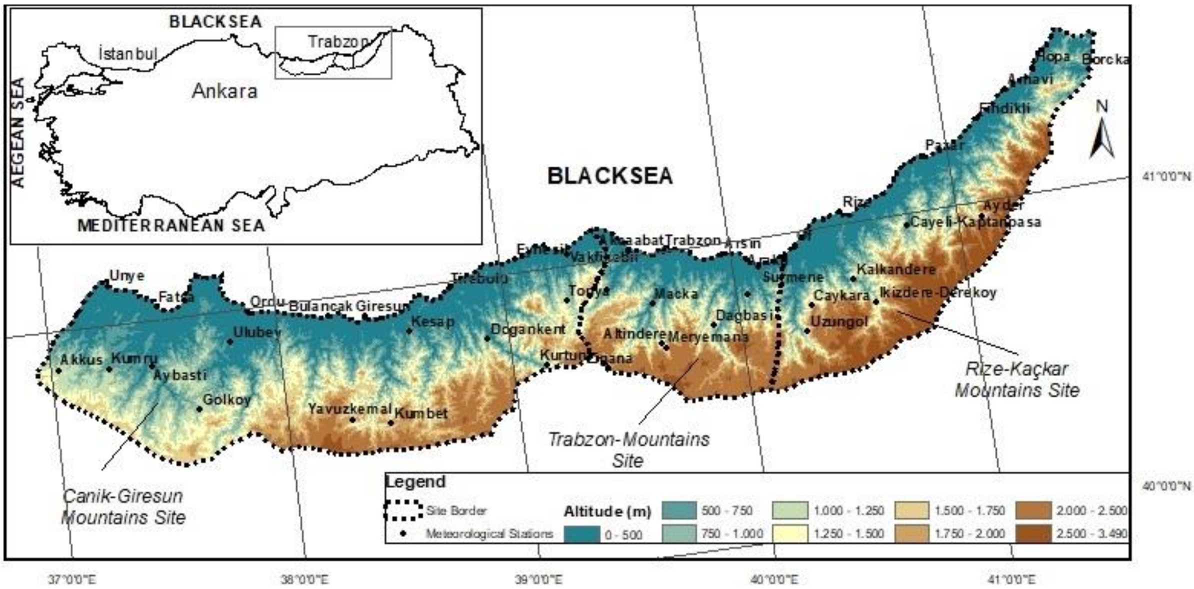

Figure 1. Location of the study area and DEM map

The study area is located between 40°30'42"N - 41°31'2"N latitudes and 36°56'11"E - 41°43'11"E longitudes. In the site which is under the influence of the sea, Canik-Giresun Mountains cover an area of 10149.54 km^2, Trabzon Mountains cover an area of 3362.49 km^2, and Rize-Kaçkar Mountains cover an area of 5869.24 km^2. The study area is a total of 19381,27 km^2.

The study area is located within A6-A8 squares of the Euro-Siberian floristic region among 3 floristic regions identified for Turkey. Euro-Siberian region is represented by Auxin province in Turkey. This site extends to the western part of the Caucasus, involving the whole northern Anatolia. A leafy forest formation merged with coniferous species at higher altitudes spreads in the Auxin province. In the auxin vegetation areas, there is no significant summer drought due to summer rains. The annual amount of precipitation exceeds 1000 mm in many places (Davis, 1971).

Climate Data

The data of meteorological stations (annual precipitation, average temperature, minimum temperature, maximum temperature and number of foggy days) at different altitudes in coastal and mountainous areas under the influence of the sea were used in the study (TSMS, 2018). The data of a total of 44 meteorological stations, including 19 meteorological stations in Canik-Giresun Mountains, 12 meteorological stations in Trabzon Mountains, and 13 meteorological stations in Rize-Kaçkar Mountains, were evaluated. The location information of meteorological stations (altitude, distance from the sea, latitude, longitude, years with data available) is presented in Table 1.

Table 1. Spatial features of the stations used in the study

Stations in Sites	Altitude (m)	Distance From Sea (km)	UTM		Years with data available
			Latitude	Longitude	
Canik-Giresun Mountains					
Akkuş	1190	38,305	346254	4573001	1989-1992
Aybastı	640	21,433	380413	4574322	1986-1994
Gölköy	925	44,948	398465	4558640	1986-1993
Kumru	600	30,738	364489	4573715	1986-1992
Ordu	5	0,050	416568	4594601	1961-2016
Ulubey	400	13,016	409743	4583550	1986-1993
Ünye	16	0,284	363973	4604414	1986-2016
Doğankent	550	26,690	505472	4584678	1983-1993
Giresun	38	0,030	459753	4593188	1950-2015
Kümbet Yaylası	1730	43,356	469512	4553302	2010-2017
Eynesil-Ören	10	0,384	515286	4614125	1989-1993
Tirebolu	10	0,409	490870	4603605	1986-2000
Yavuzkemal	1711	50,184	455439	4554880	2012-2017
Keşap-Yivdincik	680	7,973	476306	4587419	2014-2017
Kürtün	739	50,249	527504	4575167	1987-1993
Tonya	900	18,791	534633	4599003	1976-1995
Vakfıkebir	215	2,539	535044	4616071	1983-2010
Fatsa	2	0,144	382217	4596669	2010-2016
Bulancak	10	0,020	446371	4593314	1965-1997
Trabzon Mountains					
Akcaabat	3	0,991	557856	4617484	1963-2015
Altindere	1030	39,132	570275	4583113	2011-2015
Arsin	10	0,378	592503	4616168	1984-1995
Arakli	10	0,158	601364	4614415	1983-1996
Duzkoy	850	17,910	549864	4603020	1986-2003
Trabzon	25	1,343	570784	4617511	1950-2015
Zigana	2050	51,281	550001	4573740	2010-2016
Meryemana	1100	41,209	571674	4581544	1976-1986
Dagbasi	1450	29,195	589221	4589929	1989-1998
Macka	265	22,037	566457	4597873	1964-1997
Kucukdere	925	12,277	601969	4601252	1988-1993
Sürmene	50	1,602	606144	4611420	1989-1998
Rize-Kaçkar Mountains					
Of	10	0,566	619393	4619186	1964-1994
Uzungöl	1450	34,059	624271	4587560	1983-2015
Caykara	800	22,404	625690	4597284	1989-1998
Ayder	1354	33,173	689214	4630480	2010-2016
Ikizdere-Derekoy	800	39,811	650024	4598325	1970-1996
Findikli	190	1,004	687173	4666650	1989-2000
Kalkandere	400	26,854	641255	4606754	1986-1996
Cayeli-Kaptanpasa	525	16,703	661119	4626687	1965-1986
Pazar	78	0,472	667314	4652778	1963-2015
Rize	3	0,050	636236	4632061	1950-2015
Arhavi	10	0,071	697598	4677430	1983-1993
Borcka	120	21,893	728786	4684658	1987-2003
Hopa	33	0,267	707918	4685750	1962-2015

In the separation performed by Kantarcı (1995) to determine site regions for the Eastern Black Sea Region, the areas where there are Of, Çaykara and Uzungöl meteorological stations were shown in the Trabzon Mountains site. However, these areas were shifted to Rize-Kaçkar Mountains due to a transition climate between Trabzon Mountains and Rize-Kaçkar Mountains and high amount of annual precipitation (Table 1).

Determination of spatial factors and species distribution in forest sites

In the separation based on the relationship between earth shape and climate, Kantarcı (1995) separated a total of 6 sub-regional sites within two sites in the eastern black sea geography and stated that the boundaries of regional classification complied with the boundaries of forest managements. In the study, the data of the General Directorate of Forestry were used for the distribution of forest trees spreading in the site under the influence of the sea (GDF, 2008; GDF, 2012; GDF, 2015). In the distribution of forest trees, the areas covered by dominant species in normal, degraded and very degraded forest sites were taken into account.

ArcGis/Arcmap software was used in determining the spatial features (slope, aspect, altitude, longitude, distance from the sea) of sites. SRTM 1 Version 3 (Shuttle Radar Topography Mission) satellite data at 30 m resolution with open access were used to obtain the digital elevation model (DEM), which is one of the inputs required for GIS analysis. By performing improvement and updating studies on SRTM data, they are presented with an increased sensitivity at 30 m resolution (Li et al. 2012, Mohd et al. 2014). The altitude, slope and aspect of site regions were generated using the SRTM data. According to the data obtained from the digital elevation model of the study area, the altitude was represented in 3 groups (0-1000 m, 1000 – 2000 m and 2000 – m) and % slope was represented in 5 groups (0-20, 20 – 40, 40 – 60, 60 – 80 and 80<). Furthermore, the systematic points on the study area (representing about 17 ha) were removed to determine the relationship between altitude and distance from the sea.

Statistical Analysis

In the study, the relationships between spatial factors (altitude, distance from sea and latitude) and climate parameters (precipitation, average temperature, minimum temperature, maximum temperature, number of foggy days) in forest ecosystemss were investigated. Regression analysis was used in the prediction of precipitation and average temperature in conjunction with the altitude and distance from the sea in forest ecosystemss. All statistical analyses were performed in the SPSS program.

Results

Relationships between climate parameters and spatial factors

The relationship between spatial factors of the selected meteorological stations and climate parameters was determined by correlation analysis. Significant and meaningful relationships were found between the spatial factors, like altitude, distance from the sea and latitude in sites, and meteorological parameters (Table 2).

Table 2. Correlation coefficients between climate parameters and spatial factors in the sites

Spatial Factors	Climate Parameters				
	Precipitation	Average Temp.	Min. Temp.	Max. Temp.	Foggy Days
Canik-Giresun Mountains					
Altitude	-,621**	-,930**	-,893**	-,917**	,871**
Distance from sea	-,666**	-,884**	-,908**	-,781**	,636**
Latitude	,562**	,861*	,874*	,782*	-,749*
Trabzon Mountains					
Altitude	-,521	-,767**	-,909**	-,705**	,805**
Distance from sea	-,622*	-,742*	-,970**	-,754*	,763**
Latitude	,642*	,897**	,871*	,782*	-,749*
Rize-Kaçkar Mountains					
Altitude	-,812**	-,951**	-,878**	-,896**	,852**
Distance from sea	-,798**	-,769**	-,724**	-,629*	,570
Latitude	,542*	,408	,357	,381	-,368

* Significance at 0.05 probability level.
** Significance at 0.01 probability level

In Canik-Giresun and Rize-Kaçkar Mountains, altitude showed a negative correlation on other climate parameters except for the numbers of foggy days (Table 2). In Trabzon Mountains, altitude once again showed a negative correlation on average minimum and maximum temperatures except for the numbers of foggy days; however, no correlation was found between precipitation and altitude. This shows that the precipitation, average temperature, minimum and maximum temperature parameters decreased along with the increase in altitude in Canik-Giresun and Rize-Kaçkar Mountains, and the number of foggy days increased. In Trabzon Mountains, increase in altitude did not affect precipitation, decreased the average temperature, minimum and maximum temperatures but increased the number of foggy days. The degree of latitude had a similar effect in Canik-Giresun and Trabzon Mountains. The increase in latitude increased the precipitation, average temperature, minimum and maximum temperatures and decreased the numbers of foggy days (Table 2). The increase in the degree of latitude in Rize-Kaçkar Mountains led to an increase in precipitation and a decrease in the number of foggy days. Canik-Giresun Mountains are located between 41°6' N - 40°30'N latitudes, Trabzon Mountains are located between 41°6' N - 40°29' N latitudes and Rize-Kaçkar Mountains are located between 41°31' N - 40°29' N latitudes (Figure 1). Canik-Giresun and Trabzon Mountains are located between approximately same latitudes while Rize-Kaçkar Mountains are located in the further north.

The distance from the sea showed a similar effect to altitude in all sites except for the number of foggy days in Rize-Kaçkar Mountains. However, the distance from the sea in Trabzon Mountains showed a negative correlation on precipitation. Within the scope of the study, regression analysis was performed since a positive correlation was found between altitude and distance from the sea in sites (Table 3). The relationship between altitude and distance from the sea is presented in Figure 2.

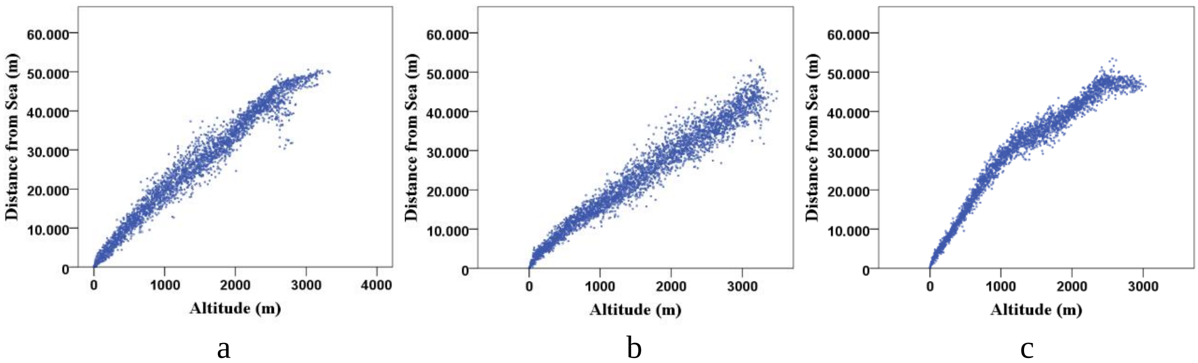

Figure 2. Relationship between altitude and distance from the sea

As a result of the regression analysis performed for the estimation of altitude based on distance from the sea, equations were revealed for each of sites (Table 3). Accordingly, the increase in altitude due to distance from the sea is the highest in Rize-Kaçkar Mountains. For instance, at a distance of 50 km away from the coast, an altitude of 1957.55 m is reached in Canik-Giresun Mountains, an altitude of 2619.45 m is reached in Trabzon Mountains, and an altitude of 3182.17 m is reached in Rize-Kaçkar Mountains.

Table 3. Stepwise multiple regression models for altitude and distance from the sea in the sites

Forest Sites	Min	Max	Mean	Regression Equations	R^2	Adjusted R^2
Canik-Giresun Mountains						
Altitude	107.55	2191.22	1004.16	107.553+0.037*DFS (m)	0.688	0.668
Trabzon Mountains						
Altitude	119.48	2738.72	1370.67	119.451+0.050*DFS (m)	0.815	0.805
Rize-Kaçkar Mountains						
Altitude	82.18	3378.50	1352.25	82.168+0.062*DFS (m)	0.800	0.780

Regression analyses were performed for the estimation of precipitation and average temperature based on altitude and distance from the sea in site regions (Table 4).

Table 4. Stepwise multiple regression models for some spatial factors and climate parameters in the sites

Climate Parameters	Min	Max	Mean	Regression Equations	R^2	Adjusted R^2
Canik-Giresun Mountains						
Precipitation	606.60	1568.20	1041.62	1175.413-0.269*ALT (m)	0.386	0.352
				1191.123-0.010*DFS (m)	0.444	0.413
Average Temperature	5.80	15.50	11.55	14.317-0.005*ALT (m)	0.866	0.858
Trabzon Mountains						
Precipitation	522.90	1226.50	785.88	909.505-0.007*DFS (m)	0.396	0.336
Average Temperature	4.40	14.90	12.17	14.543-0.003*ALT (m)	0.588	0.536
Rize-Kaçkar Mountains						
Precipitation	817.80	2327.40	1606.17	1981.34-0.870*ALT (m)	0.659	0.630
				2007.66-0.033*DFS (m)	0.637	0.607
Average Temperature	8.30	14.60	12.33	14.020-0.004*ALT (m)	0.904	0.896

In the study, it was observed that precipitation decreased in Canik-Giresun and Rize-Kaçkar Mountains depending on the altitude in the site under the influence of the sea. The decrease in annual precipitation at an altitude of 100 m was 26.9 mm and 87.0 mm in Canik-Giresun Mountains and Rize-Kaçkar Mountains, respectively. The decrease in average temperatures due to altitude was found to be close in sites. The decrease in average temperature in sites was 0.3 – 0.5 ºC at an altitude of 100 m. Decreases were observed in annual precipitation due to distance from the sea. At a distance of 10 km away from the coast, the decrease in average annual total precipitation was 100 mm in Canik-Giresun Mountains, 70 mm in Trabzon Mountains and 330 mm in Rize-Kaçkar Mountains.

Relationships between spatial factors, climate and species distributions in forest sites

It was determined that the average slope was 23% in Canik-Giresun Mountains, 28% in Trabzon Mountains and 32% in Rize-Kaçkar Mountains. The average altitude is 994 m (max. 3037 m) in Canik-Giresun Mountains, 1319 m (max. 3002 m) in Trabzon Mountains and 1389 m (max. 3490 m) in Rize-Kaçkar Mountains (Figure 1). The slope and altitude increase as going from west to east in sites.

In the Eastern Black Sea region, the forest-building tree species in the sub-regional sites are Oriental Beech, Oriental Spruce, Scots pine, Alder, Chestnut, Hornbeam, Fir and Oak. The species involved in mixture with very low quantities were excluded from the study (Figure 3).

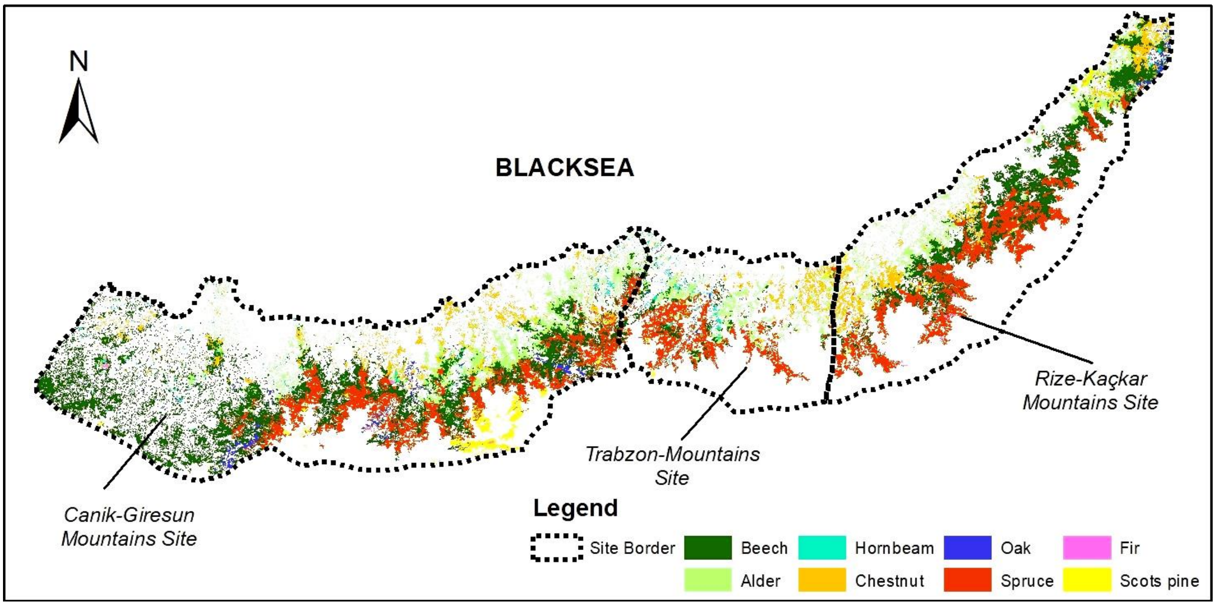

Figure 3. Distribution map of the dominant tree species in Eastern Black Sea region

The areal (%) distributions of forest-building tree species in the forest sites according to altitude steps and aspect groups are given below (Figure 4-6). Oriental Beech is the dominant species in both aspect groups at 0-1000 m (1st altitude step) and 1000 – 2000 m (2nd altitude step) altitude steps in the Canik-Giresun Mountains site. Oriental Beech is followed by Alder at 1st altitude step and Oriental Spruce at 2nd altitude step. At 3rd altitude step, Scots pine is the dominant species in both aspects. Scots pine is followed by Oriental Spruce (Figure 4).

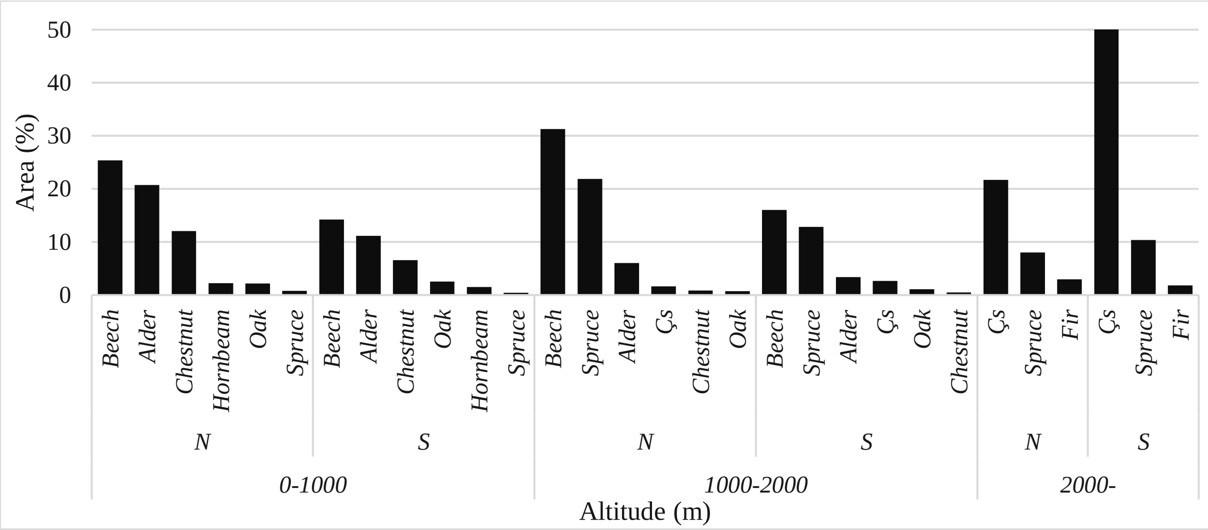

Figure 4. Distribution of dominant tree species in Canik-Giresun Mountains by altitude and aspect

In Trabzon Mountains site, Alder is dominant at 1st altitude step and Oriental Spruce is dominant at 2nd altitude step in both aspect groups. Alder and Oriental Spruce are followed by Chestnut and Alder, respectively. At 3rd altitude step, Oriental Spruce is the dominant species in both aspects. Oriental Spruce is followed by Scots pine (Figure 5).

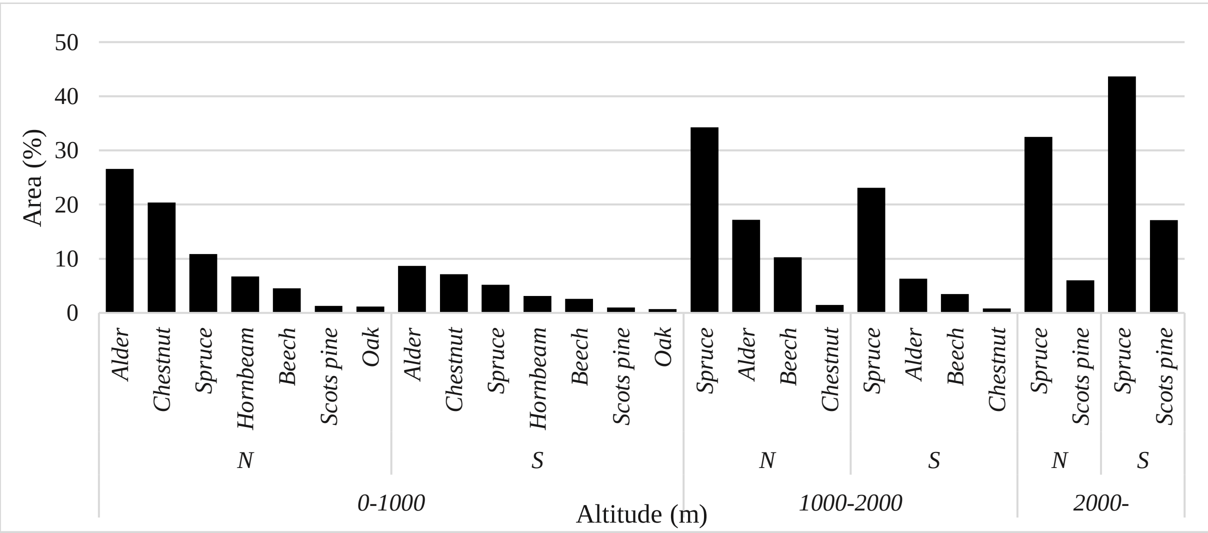

Figure 5. Distribution of dominant tree species in Trabzon Mountains by altitude and aspect

In Rize-Kaçkar Mountains site, Alder is the dominant species at 1st altitude step in both aspect groups. Alder is followed by Oriental Beech. At 2nd and 3rd altitude steps, Oriental Spruce is the dominant species in both aspect groups. Oriental Spruce is followed by Alder at 2nd altitude step and Scots pine at 3rd altitude step (Figure 6).

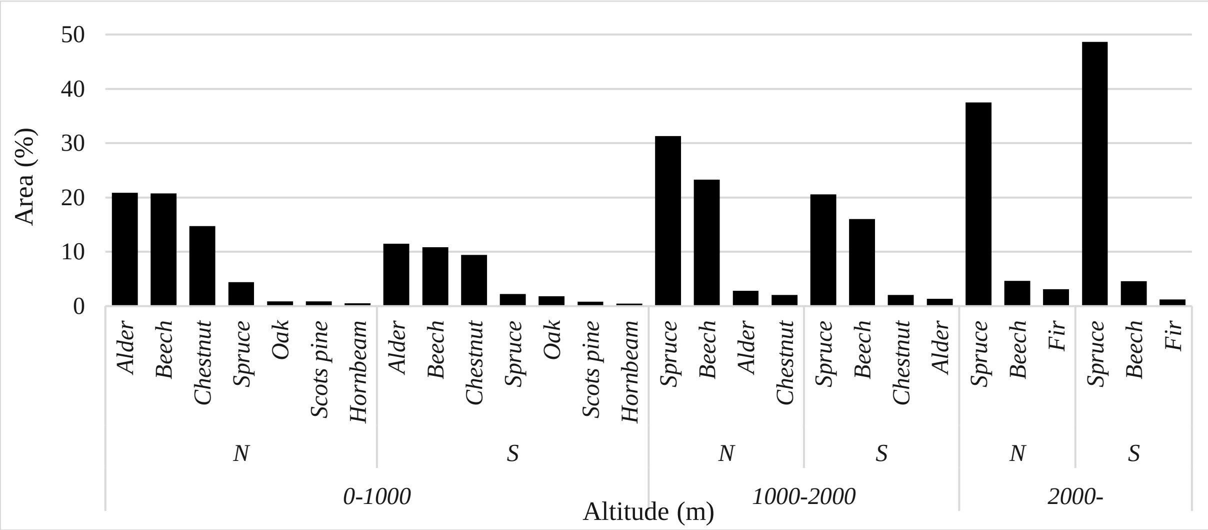

Figure 6. Distribution of dominant tree species in Rize-Kaçkar Mountains by altitude and aspect

When all site regions are evaluated, it is seen that the forest-building tree species at 1st and 2nd altitude steps are mainly present in the North aspect by area (%). However, the South aspect group gets this superiority at 3rd altitude step. Scots pine is the dominant species in Canik-Giresun Mountains and Oriental Spruce is the dominant species in Trabzon and Rize-Kaçkar Mountains. Scots pine is followed by Oriental Spruce in Canik-Giresun Mountains, Oriental Spruce is followed by Scots pine in Trabzon Mountains, and Oriental Spruce is followed by Oriental Beech in Rize-Kaçkar Mountains. At 3rd altitude step in Rize-Kaçkar Mountains, Oriental Spruce is apparently dominant while Oriental Beech is at much lower rates. While the distribution of species in the north aspect is more dominant at 1st and 2nd altitude steps, it is interesting that the south aspect group gets the dominance at 3rd altitude step. When it is noted, Scots pine and Oriental Spruce are more dominant in the south aspect group. It would not be wrong to say that the light demands of tree species come to the forefront at this altitude (2000 m <) where the vegetation period is quite shortened. Indeed, the light demands of Scots pine and Oriental Sprucen are higher compared to Oriental Beech and Fir.

Discussion

Relationships between climate parameters and spatial factors

The Eastern Black Sea Mountains constitute the highest part of the mountain range that surrounds our country from the north. The mountain range starts to rise as going from Central Black Sea Region to the east and reaches the highest level in Kaçkar Mountains. The mountain range with an extension in the east-west direction in Central Black Sea Region changes the direction as going towards the east and has an extension in the southwest–northeast direction. In this section, Eastern Black Sea Mountains rise suddenly at the backshore and exceed 3000 meters at a distance of about 20-30 km (Çiçek et al. 2003).
The effects of topographic factors such as altitude, slope status, orographic mountain ranges and continentality play the most significant role in the classification of habitats and ecosystems. For instance, local climate changes, and the distribution of vegetation cover both at vertical and horizontal distances are controlled by topographic factors (Atalay, İ. et al. 1985).
In this study, in contrast to the studies in which precipitation in mountainous areas is stated to increase typically with altitude (Daly et al., 1994; Park and Singh, 1996; Sevruk, 1997; Marquinez et al., 2003; Naoum and Tsanis, 2004), precipitation decreased along with the increase in altitude in Canik-Giresun and Rize-Kaçkar Mountains sites, except for Trabzon Mountains (Table 2). This decrease corresponds

to a decrease of 538 mm in Canik-Giresun Mountains and a decrease of 1740 mm in Rize-Kaçkar Mountains in the areas above 2000 m. There is no statistically significant and meaningful relationship between altitude and precipitation in Trabzon Mountains (Table 2). The accumulation of humid air masses coming over the Black Sea in front of the high highland leads to a huge amount of precipitation on the coastline. The air with decreasing humidity that rises on mountain slopes and also becomes cold as it rises also enables the formation of precipitation in these parts (Kantarcı 1995). The accumulation of humid air in front of a barrier, its rise, cooling and condensation, and the formation of precipitation are more apparent in Taurus Mountains in the Mediterranean Region (Kantarcı 1982). Warm and humid air masses coming from the Mediterranean need to rise by 600-800 m on the slopes of the Taurus Mountains for their cooling and the condensation of the moisture they contain. Since the winds coming from the Black Sea are cooler, they can be cooled at lower altitudes and cause high precipitations (Kantarcı 1995). The headland (Yoroz) between the Canik-Giresun Mountains and Trabzon Mountains sites decreases the precipitation falling to the Trabzon Mountains site. This topography is a natural barrier to the moisture-bearing dominant west and north winds. Since the headlands located in the coastal region block the west winds, the eastern part of the headlands receives less precipitation than western part. It is reported that the coastline angles are an effective factor in the precipitation of the eastern and western parts of headlands (Eriş, 2011). The choice of western direction at the coastline angle is based on the dominant wind direction in the study area. If the coastline angle is less than 90 degrees, the measurement point is blocked from the west and north winds and receives less precipitation than the areas with an angle greater than 90 degrees (Eriş, 2011). Accordingly, among the measurement stations on the coast of Trabzon, the coastline angles of Vakfıkebir and Of were determined to be above 90^{o} while the coastline angles of Akçaabat, Trabzon, Arsin, Araklı and Sürmene were determined to be below 90^{o}. Even in this study, Vakfıkebir region was evaluated within the boundaries of Canik-Giresun Mountains sites while Of and Çaykara and Uzungöl regions at the same vertical position were evaluated in Rize-Kaçkar Mountains site.

Orographic precipitations are mostly observed in these sites that receive the influence of the sea. Orographic precipitation takes place in a mountain range at middle latitudes the axis of which is perpendicular to the wind direction. In the climatological average, the windward side of the mountain range receives more precipitation from the non-windward side reflected by sharp transitions in climate, flora and fauna, known as rain shadow (Roe, 2005). Orographic precipitation is at the center of the interaction between the field surface and the atmosphere. It is not only important for the management of natural ecosystems and drinking water resources but also has important subcomponents for the other physical components of the world system. For instance, on short time scales, natural hazards such as sudden floods, landslides and avalanches are affected by precipitation in mountainous regions (e.g., Caracena et al. 1979, Caine 1980, Conway & Raymond 1993). Finally, for millions of years, orographic precipitation models control the surfacing of rocks moving to finalize erosion and ultimately mountain ranges (e.g., Beaumont et al. 1992, Willett 1999, Montgomery et al. 2001, Reiners et al. 2003, Anders et al. 2004a, Roe et al. 2004).

Relationships between spatial factors, climate and species distributions in forest sites

The Eastern Black Sea region is a geographical area where there are very significant ecological differences between its slopes facing the sea by the effect of steep highland. The forests of the Eastern Black Sea are the forests that strictly reflect the effects of precipitation, one of climate factors, and the altitude and aspect, physiographic factors. This section includes the areas with the highest precipitation values (Rize 2441 mm) of Turkey (Ardel et al. 1969, Erinç 1969). While the maximum level of diversity was reached in the vegetation stages, high slope and aspect differences increased the ecotype richness of Eastern Black Sea forests (Efe and Sönmez, 2006). The location of the mountains against the winds coming over the sea causes significant precipitation differences while altitude causes significant

temperature differences. The change of precipitation and temperature according to the earth's shape has enabled the emergence of significant ecological differences. The presence of a high mountain or mountain ranges located in the climate region enables the formation of one or more separate environments in the vertical direction. The altitude, direction of extension of mountains, direction of the slope, ruggedness and slope conditions that constitute the properties of the earth surface, and some surface features affect the distribution of climate elements such as temperature, precipitation, fog and wind, which plays a significant role on the spread of plants and the biomass efficiency (Atalay, 2014).
In the correlation analyses, it was stated that the precipitation decreased in site regions due to the altitude and distance from the sea in the site under the influence of the sea, but the number of foggy days increased. When altitude and distance from the sea factors are evaluated together, the increase in the number of foggy days against the decrease in precipitation gives us information about the moisture that can maintain the life of high mountain forests despite being far away from the coast.
Fog is considered as an important ecological factor in mountain cloud forests in the world (Cavelier and Goldstein 1989, Schemenauer and Cereceda 1994, Walmsley et al. 1996, Bruijnzeel 2001). The fog droplets on the vegetation cover can serve as an additional water source supplementing the amount of precipitation (Bruijnzeel and Proctor 1995, Hutley et al. 1997, Chang et al. 2002, Gutierrez et al. 2008); however, its contribution to groundwater is limited (Eugster 2007, Ritter et al. 2008). In several previous studies, complete tree transpiration was measured in the cloud forests (Hafkenscheid 1994, Santiago et al. 2000, Motzer et al. 2005). Hutley et al. (1997) reported a 40% decrease in the tree transpiration rate of foggy conditions on a single tree in a small forest land in the southeastern Queensland. Johnson and Smith (2008), when Rhododendron catawbiense Michx and Abies fraser (Pursh) Poiret seedlings were compared with open days, reported an estimated reduction in the leaf transpiration of 83-95% in a 6-day study in the southern Appalachian Mountains.
It has been reported that altitude plays an important role in determining the amount of fog. Provided that there is sufficient moisture support (Zangvil, 1996), it has been reported that altitude may lead to an increase in fog precipitation as a result of low temperatures in higher fields (Levi, 1967; Oke, 1978). The distance from the sea factor was also considered to be a critical factor for dew and fog precipitations. Precipitation is expected to decrease as going away from the sea (Zangvil, 1996). Thus, as going away from the sea, both factors, altitude and distance, may contribute to increasing or decreasing the dew and fog amounts by their geographical locations. The size, shape and structure of the trees that prevent the fog droplets and wind velocity are effective on the amount of fog water that contributes to the ecological system (Parsons, 1960). Furthermore, Went (1955) determined that the leaf surfaces of coniferous species were much more effective on the interception of fog water.

Conclusion

In this study, the relationships between the spatial factors affecting the distribution of tree species in the sub-regional sites which are under the influence of the sea in the Eastern Black Sea Region and climate variables were revealed.
In many parts of the world, mountains are open to the effects of a rapidly changing climate and are extreme places for early detection and analysis of the signals of climate change and their effects on hydrological, ecological and social systems. Furthermore, probably the most significant effect of climate change in mountain ecosystems will be seen in the spatial size of forest ecosystems and in upper forest boundaries. Therefore, when tree species at 3rd altitude step (above 2000 m) where the distance from the sea and altitude are extreme are taken into account, Scots pine, Oriental Spruce and Fir are spread in Canik-Giresun Mountains, Oriental Spruce and Scots pine are spread in Trabzon Mountains, and Oriental Spruce, Oriental Beech and Fir are spread in Rize-Kaçkar Mountains. Despite the decreasing amount of precipitation along with the increase in altitude and distance from the sea, the

fog cloud in high mountainous areas plays an important ecological role in the conservation and distribution of these species.

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