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Effects of soil and environmental factors on the site productivity of pure Oriental beech forests in Akkuş region of Turkey

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Abstract

Oriental Beech grows naturally in the Eastern Caucasus, Northern Iran and, Crimea, from the west of the Balkans towards Anatolia. Akkuş Region of Turkey is one of the moist ecosystems where this tree species spread optimally. In this spread area, the change in local site factors affects site productivity. In this study, the correlations between the height growth of pure Oriental beech forests between 1200-1500 m altitudes in Akkuş region and some soil characteristics and location factors were investigated. 40 sample plots were taken from normally covered Oriental beech stands. In the sample plots, soil profiles were dug and soil sampling was performed according to genetic soil horizons. The location factors of the sample plots in the field were determined, and $d_{0.30}$ diameter, $d_{0.30}$ age, and upper height were measured in 4-6 trees with upper stand height. The site productivity (site index) was determined based on the correlation between standard age and upper stand height. Physical and chemical soil analyses were performed in the soil samples taken.

The correlations between the productivity indexes (site index) of the sample plots and the local ecological characteristics of the site were tested by correlation analysis. Positive correlations were determined between site index and the land slope degree and altitude (respectively $p<0.05$, $r=0.438$; $p<0.05$, $r=0.211$) . There are negative correlations between soil properties of the average amount of clay ($p<0.01$, $R=-0.206$) the average amount of silt($p<0.01$, $R=-0.247$), field capacity ($p<0.01$, $R=-0.500$), fine soil weight ($p<0.05$, $r=-0.179$), soil reaction ($p<0.01$, $r=-0.575$), and site index, while there are positive correlations between horizon A_h's organic matter ($p<0.05$, $r=0.340$), the average amount of sand ($p<0.01$, $r=0.258$), physiological soil depth ($p<0.01$, $r=0.212$), skeleton weight ($p<0.01$, $r=0.197$), and site index.

Keywords: Site index, moist ecosystem, slope, altitude, soil physical properties, Akkuş

INTRODUCTION

The growth of forest stands depends on their location in the stand and numerous factors including basic resources such as light, water, and nutrients the actual physical sizes of which can be reached. All these factors interact and change in space and time to be expressed together with the observed growth rate (Cienciala et al. 2016). This interaction and change take place in the form of a series of dynamic events different from its surroundings (matter and energy circulation and transformations) within the boundaries of an ecological unit called site. The effects of the factors that constitute the site on the formation of the characteristics of the site and site productivity are not similar.

The silvicultural practices to be performed in forest ecosystems and the management plans require safe site productivity. The estimation of growth and product in forest ecosystems can be achieved by the accurate assessment of productivity. Despite the suitability of site productivity estimations developed for tree species in forest management (Fernández et al. 2004), the change of local ecological conditions species (edaphic, topographic, climatic) for the same tree may show a correlation contrary to estimations. Although the change of site productivity is determined depending on certain environmental conditions, it can also be evaluated within the conceptual framework of site quality as the characteristic vegetation production capacity of the field (Hägglund, 1981). Most of the site quality studies were carried out in even-aged stands (planted or naturally regenerated) (Herrera and Alvarado, 1998).

There are various methods to estimate the site quality/productivity, including those based on the measurement of the forest (Daubenmire, 1976; Clutter *et al*., 1983 ; Shafer, 1989; Schönau and Aldworth, 1991; Vanclay, 1994). However, the most frequently used method in even-aged stands is the estimation of the site index as a measure of productivity. The most commonly used and mostly accepted method to evaluate the actual site productivity and the growth reaction of trees in forestry is the measure of upper stand height reached at a certain age, which is known as site index (SI). The forest trees and undergrowth in forest ecosystems tend to be shaped according to (climate and soil conditions etc.) (Cajander 1949; Childs and Flint 1990; Sims et al. 1996; Wang and Klinka 1996; Salemaa et al. 2008). Therefore, the nutrition, thermal and hydrological regimes of the soil significantly affect the site productivity. The hydrological conditions of sites depend not only on the physical characteristics of the soil but also on the topographic position and ambient weather conditions (Childs and Flint 1990; Nyberg 1996; Mäkitalo 2009; Campbell et al. 2013). For forestry management, the effect of location factors (slope, aspect, altitude, topographic position) on the characteristics and productivity of forest areas cannot be ignored.

Site productivity is largely determined by the physical and chemical properties of the soil, however, it is also affected by climate factors such as precipitation, temperature and the length of the growing season. Both physical and chemical soil properties are used in soil-site methods to estimate the site productivity (Fontes et al. 2003, Stape et al. 2004, Sampson et al. 2008, Almeida et al. 2010,Vega-Nieva et al. 2013). When the physical, chemical and biological properties of the soil are used, site productivity/site quality is generally better estimated (Subedi and Fox, 2016).

Numerous soil-site studies attempted to associate the measured soil properties with the site index (SI) (Carmean 1975, Hagglund 1981, Bravo and Montero 2001, Fontes et al. 2003) Nevertheless, it is quite difficult to measure the site productivity/site quality from soil properties in forest ecosystems due to the complex correlations between stand productivity and soil properties. The site quality and stand productivity can be approached from a different perspective, and site factors can be considered as a function of geoclimatic variables (Pokharel and Froese 2009; Bontemps and Bouriaud 2014).

In soil-site studies, regression techniques were frequently used to estimate site productivity from the topographical and edaphic characteristics of a site (Carmean 1975, Baker and Broadfoot 1979, Wang 1995, Beaulieu et al. 2011). To estimate the SI by developing a regression equation only with soil properties is also another method. Along with the genetic characteristics and climate characteristics, soil as the source of both water and nutrients is the most important factor affecting the growth of trees. Both physical and chemical soil properties may affect tree height depending on the site conditions.

There are many studies investigating the correlations between the height growth of trees and site factors, in other words, the correlations between SI and site factors. In these studies, the correlations between the site factors of both naturally grown species (Klinka and Carter 1990; Kayhara et al. 1997; Günlü et al. 2006; Johansson 2006; Özkan and Kuzugüdenli 2010; Karataş et al. 2013;) and the species brought to the area by planting (Curt et al. 2001; Sanchez –Rodriguez et al. 2002; Louw and Scholes 2005; Tüfekçioğlu et al. 2005; Yilmaz et al. 2008; Güner et al. 2011; Karataş and Özkan 2017) and site productivity was investigated. In this study, in the natural sites of oriental beech, which is one of the important tree species of Turkey, in Akkuş region of the Eastern Black Sea Region, the correlations between SI and site factors were investigated at altitude levels (1200 -1500 m) where unique ecological conditions are dominant. Oriental beech ranks number two in terms of spread area and ranks number one in terms of the amount of growing stock among leafy species (1.96 million hectares). Approximately 41% of leafy normal high forests in Turkey consist of Oriental beech forests (Anonymous, 2015).

MATERIAL AND METHOD

The research area is geographically located in the Eastern Black Sea Section of the Black Sea Region. The sample plots were selected from Ordu-Akkuş region, from the west of the Eastern Black Sea section where pure Oriental beech (forests are spread. Akkuş region, which is one of the places where the beech is optimally spread, is located within the fields that are under the influence of the sea and within Canik-Giresun Mountains Site region (Kantarcı, 2005a) (Figure 1). Within the scope of the study, 40 sample plots were taken from Akkuş region (20 sample plots were used from Yılmaz 2005).

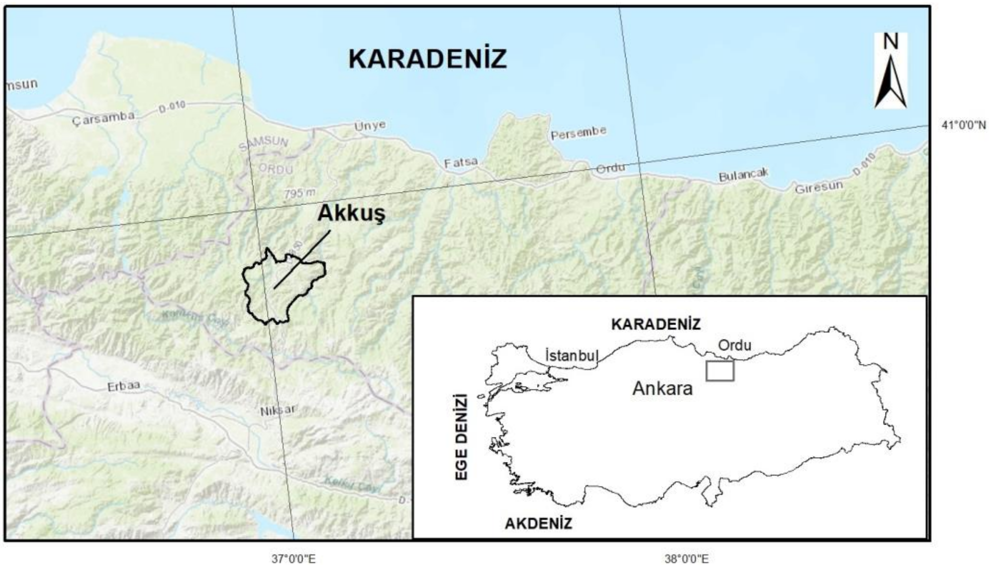

Figure 1. Location of the research area.

In Akkuş region surrounded by beech forests on all sides, the average annual amount of precipitation is 1092,9 mm and the average annual temperature is 7.9 ^{o}C. The average temperature in four summer months is 15.4 ^{o}C (Yılmaz 2005). Since the mountain ranges in the region are parallel to the coastline, moist air masses bring plenty of precipitation in the region. The heights of the mountains and their positions against the prevailing north-west winds are more or less effective on the precipitation regime of the region. Furthermore, the river valleys crossing the mountain chains, which are parallel to the coastline, (Akçay, Cevizdere) ensure that the maritime climate is effective up to the interior parts. The climate analysis of Akkuş region was performed according to the Thornthwaite (1952) method, and it was determined as the "humid, high temperature (mesothermal) climate close to the oceanic climate with little or no water deficient" represented by the "B4 B'1 r b'4" symbol (Table 1).

There are totally 22649 hectares of pure Oriental beech forests in Akkuş region. 7350 hectares of this forest area is between 1200-1400 m altitudes while 8300 hectares of which is between 1000-1200 m altitudes. After 1400 m, the area of beech forests decreases up to 2278 hectares (Anonymous, 2015). The average altitude and average slopes of the sample plots are 1330 m and 36%, respectively, and they were taken from the soils developed from andesite-basalt bedrock. The dominant aspect of the sample plots is in the north aspect direction.

The sample plots were taken from the boundaries of Akkuş Forestry Department Akkuş Forest Sub-district Directorate. The average altitude of Akkuş region from sea level is 1313 meters and the horizontal distance from the sea is 75 km. The district is almost surrounded by beech forests on all sides. There are significant amounts of beech forest areas within the boundaries of Göllüce, Salman and Düzdağ forest sub-district directorate.

Table 1. Climate analysis of the research area.

Climate variables	Months												Vegetation period		
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Inside	Outside	Annual
TEMP (ºC)	-2,6	-1,6	2,6	7,6	10,2	14,5	16,2	15,2	13,3	11,3	7,4	1,1	13,5		7,9
PREP (mm)	74,9	89,1	60,6	136,2	180,8	69,0	51,1	31,6	85,0	84,9	96,4	133,3	502,4	590,5	1092,9
AE (mm)	-	-	13,7	43,0	64,6	92,7	104,8	84,2	70,4	55,2	31,4	4,6	471,8	92,7	564,5
WD (mm)	-	-	-	-	-	-	-	-	-	-	-	-	0,0	0,0	0,0
WS(mm)	74,9	89,1	46,9	93,2	116,2	-	-	-	-	-	-	108,1	116,2	412,1	528,4
ARH (%)	79,2	79	76,1	78,8	78,8	76,8	81,4	81,2	80,4	74,8	72,8	79,6	78,9	77,6	78,2
ACD	11,5	12,5	12,5	16,0	19,5	15,5	18,0	20,5	12,5	8,5	16,5	15,0	92,5	86,0	178,5
AOD*	14,0	13,0	13,5	10,5	9,0	8,5	9,5	8,0	11,5	11,5	8,5	14,0	58,0	73,5	131,5
PD	10,5	9,5	10,0	15,0	15,0	8,0	8,0	5,0	9,5	11,0	8,0	11,0	56,5	64,0	120,5
FD	0,5	1,5	3,0	1,0	0,0	2,0	1,0	0,0	0,5	1,0	0,5	0,5	4,5	7,0	11,5

TEMP: Temperature, PREP: Precipitation, AE: Actual evapotranspiration, WD: Water deficiency, WS: Water surplus ARH: Average relative humidity, ACD: Average cloudy days, AOD: Average overcast days, PD: Precipitation days, FD: Foggy days, * : Fully covered sky

The sample plots were taken by selected sampling, and their sizes vary between 400 and 600 m^2 according to the crown cover. After the boundaries of the sample plots were determined, the trees included in the sample area were numbered in a clockwise direction, and the root collar diameter and chest height diameter of all of them were measured. The height measurement was performed in all trees the diameter measurement of which was performed, and the age of the trees was determined by counting the increment from 0.30 cm height. Carus's (1998) site index yield table for even-aged beech forests was used for the productivity indexes of sample plots.

Method

Soil Properties

In the sample plots, soil profiles were dug and absolute and physiological soil depths were determined (Kantarcı, 2000). In the soil profile, mineral soil horizons were separated and introduced according to genetic soil horizons, and the soil samples were taken in two ways: bag sampling and volume sampling. The fine soil weight (gr/lt) and the skeleton weight (gr/lt) of soil samples were determined using the volume samples taken according to Kantarcı 2005b. 176 soil samples taken from sample plots were ground and sieved following air dried and weighed before and after the skeleton has been removed.

The particle size analysis of soil samples was performed according to the Bouyoucos hydrometer method, and the soil types were determined according to international texture classes (Gülçur, 1974; Karaöz, 1989a).

Soil reaction (pH): was measured by pH meter with a glass electrode. The soils were mixed with distilled water by 1:2,5 for actual acidity, and they were mixed with 1N KCl by 1:2,5 for potential acidity, they were kept overnight and then measured (Gülçur, 1974; Karaöz, 1989b; Kantarcı, 2005b). Organic carbon in the soil was determined by Walkley-Black wet burning method. The organic matter of the soil was calculated based on organic carbon (Gülçur, 1974; Kantarcı, 2005b). The available water capacity

(AWC) of soil samples were calculated based on the differences of field capacity moisture and wilting point moisture values determined in soil moisture device with pressure table (Karaöz 1989a; Kantarcı, 2005b).
Location Factors

The altitudes of the sample plots selected within the scope of the research vary between 1230 m and 1485 m and their slopes vary between 5% and 70%, and the research area was divided into two altitudinal zones and four slope groups.

Slope (%)	Slope Class	Slope group	Altitude (m)	Altitudinal zones
(0 - 16)	Low and moderately sloping	I	1200 – 1350	I
(17 - 35)	Moderately high sloping	II	1351 – 1500	II
(35 - 58)	Strongly sloping	III		
(>58)	Steep	IV		

Statistical analysis
The simple correlation analysis was performed between the SI values of sample plots determined and the physiographical factors and soil properties of the site. SPSS package program was used for this process (SPSS 2015).

RESULTS AND DISCUSSION

60% (24) of the sample plots are located in the 1st altitudinal zone while 40% (16) of them are located in the 2nd altitudinal zone.
The site indexes of the sample plots are significantly positively correlated with altitude despite a low correlation coefficient. In other words, an increase is observed in site indexes along with an increase in altitude in Akkuş region ($p<0.01$, $r=0.211$) (Table 2). In the literature, it is generally thought that there is a decrease in site indexes along with an increase in altitude (Klinka et al. 1996; Klinka and Chen 2003; Yılmaz 2005; Ercanlı et al. 2008; Socha 2008; Özkan and Kuzugüdenli 2010; Öztürk 2012; Yilmaz et al. 2015). Although there is no correlation between the height growth of forest stands and altitude in some studies (Kalay 1996; Yılmaz 2005), there are also positive correlations between altitude and height growth (Özkan et al. 2005; Güner 2008). These differences between altitude and SI values can be explained depending on the altitude variation of the study area and the change of other site factors, as well as the ecological characteristics of tree species. In general, the climatic characteristics changing with increasing altitude also negatively affect the site conditions, and the productivity of forest trees decreases along with the shortening of the growing period. In a part of the study carried out by Yılmaz (2005), no correlation was found between altitude and the SI of Oriental beech in Akkuş region. Within the scope of the study, 30 sample plots were taken between 1230-1550 meters. This study was carried out by taking 40 sample plots from Oriental beech stands between 1200-1500 meters altitudes. These altitudes are the 2nd altitudinal zone where Oriental beech spreads optimally. The 1st altitudinal zone, where Oriental beech spreads optimally within the boundaries of Akkuş Forestry department, is between 1000-1200 meters (a forest area of 8300 hectares). The positive correlation between altitude factor and the SI of Oriental beech stands is specific to the studied altitude climate zone of Akkuş region. The absence of temperature reduction that would shorten the growing period depending on the increasing altitude between 1230 meters and 1485 meters where sample plots were taken, and also the availability of sufficient moisture did not negatively affect the organic and inorganic decomposition. Along with the increase in altitude, the thickness of B horizon (TBH), thickness of A horizon (TAH), physiological soil

depth (PSD) and excavation depth (ED) in soil profiles, and the increase in average amounts of silt and clay and the reduction in average amount of sand of soil samples confirm conclusion (Table 2, Table 3). Along with the increase in altitude, TBH ($p<0.01$, r=203), TAH ($p<0.05$, r=0.157), PSD ($p<0.01$, r=0.480) and ED ($p<0.01$, r=0.339) increased, and increased PSD and ED increased the SI values ($p<0.01$, r=0.212; $p<0.01$, r=0.268).

One of the most important site factors affecting the productivity of forest trees is the degree of slope. The SI values of forest trees decrease with an increase in the degree of slope (Sharma et al. 2012; Yılmaz 2005; Kalay 1996; Ercanlı et al. 2008; Yilmaz et al. 2015). In this study, the SI values of Oriental beech increased along with an increase in the degree of slope. There is a positive correlation between the degree of slope and SI values ($p<0.01$, r=0.438). This correlation coefficient was found to be r=0.262 in the study carried out by Yılmaz (2005) in the region. However, the author stated that it was not very true to generalize this argument on the grounds that the sample plots in the good productivity class are represented in a small number. The positive correlation between SI and slope resulting from unique ecological conditions of Akkuş region was clarified by increasing the number of sample plots in less sloping areas. The fact that the generally known positive effect of low and moderately sloping bottom lands on productivity was found to be opposite in Akkuş region may be due to the weak and moderate drainage feature of the sample plots taken from low and moderately sloping lands. Since the mountain ranges in the region where the study was carried out are parallel to the coastline, moist air masses bring plenty of precipitation in the research area and its surroundings. Indeed, Akkuş region was characterized by "very humid, low-temperature climate type without water deficiency" (Yılmaz 2005).

There is excess water in the soil during the vegetation period. Furthermore, during the vegetation period, moist and saturated air masses move towards low and moderately sloping fields over high sloping fields and accumulate over beech forests in these areas (Figure 2).

The fact that the soil is saturated with water due to precipitation, low degree of slope and soil characteristics (particle size, skeleton, fine soil weight) and also the fact that transpiration does not occur in the stand the top roof of which is covered with moist air masses adversely affect the nutrition and growth relationships in trees. In these sites, suberization and mossiness occur in trees due to excess moisture (Figure 3) In the fields with high slope and sufficient soil depth, uptake of water and nutrients from the soil is not interrupted since there is less water in the soil and photosynthesis organs are further exposed to the sun. Because Oriental beech prefers high sloping lands with well-drained, deep, permeable soils (Saatçioğlu 1979). There are significant correlations between SI values of Oriental beech and the soil properties of the site. There was a positive ($p<0.01$, r=0.258) correlation between the particle diameter of soils and the average amount of sand and a negative ($p<0.01$, r=-0.206 and $p<0.01$, r=-0.247) correlation between average amounts of silt and clay, respectively. The increased amount of clay and silt and decreased amount of sand in soils lead to the development of finer textured soils. In the sites located in the region where there is adequate precipitation and the slope is low, the increase in silt and clay amounts of soils further worsen the poor drainage conditions. The SI values of the low sloping sample plots, where drainage is blocked and the formation of standing water was observed locally, were low. The fact that the most important factors affecting the productivity of Oriental beech forests in the region are moisture in the atmosphere during the vegetation period, water held in the soil, the blocked drainage and the degree of slope of the land is also supported by the results of other correlation analyses. When the results of the correlation analysis presented in Table 2 are examined, it is seen that there are negative correlations between SI values and moisture content ($p<0.01$, r=-0.500) and fine soil weight (%) of the soils ($p<0.05$, r=-0.180) in the field capacity, and there are positive correlations between skeletal part of the soils (%) ($p<0.05$, r=0.197).

Table 2. Correlations between the SI and site factors

	ALT (m)	Slope (%)	Sand (%)	Silt (%)	Clay (%)	SW (%)	FSW (%)	FC (%)	ED (cm)	PSD (cm)	TAH (cm)	TBH (cm)	pH (KCl)	pH (Water)	AHOM (%)
SI (m)	,211**	,438**	,258**	-,247**	-,206**	,197**	-,179*	-,500**	,268**	,212**	-,212**	-,055	-,575**	-,331**	,340**
ALT (m)		,058	-,377**	,357**	,293**	-,031	,112	-,139	,339**	,480**	,157*	,203**	-,198**	-,289**	-,141
Slope (%)			-,286**	,139	,337**	,212**	-,206**	-,024	,085	-,015	-,321**	-,053	-,406**	-,355**	,099
Sand (%)				-,806**	-,905**	,193*	-,268**	-,416**	-,102	-,101	-,082	-,042	,101	,267**	-,046
Silt (%)					,488**	-,246**	,296**	,372**	,091	,063	,097	,038	-,096	-,378**	-,066
Clay (%)						-,122	,200**	,364**	,056	,090	,025	,041	-,083	-,123	,105
SW (%)							-,952**	-,370**	,042	,015	-,225**	-,048	-,045	,064	,002
FSW (%)								,367**	,008	,085	,167*	,186*	,029	-,072	,005
FC (%)									-,211**	-,262**	,120	-,069	,291**	,134	-,039
ED (cm)										,612**	,372**	,349**	-,139	-,158*	,211**
AWC (cm)											,408**	,597**	-,051	-,019	,298**
TAH (cm)												,184*	,285**	,273**	,200**
TBH (cm)													-,074	,034	,014
pH (KCl)														,825**	-,063
pH(Water)															,040

*: Significance at 0.05 probability level **: Significance at 0.01 probability level. SI: Site index, ALT: Altitude, SW: Skeleton weight, FSW: Fine soil weight, FC:Field capacity, ED: Excavation depth, PSD: Physiological soil depth, TAH: Thickness of A horizon, TBH: Thickness of B horizon, AHOM: Amount of organic matter of A horizon,

Table 3. Variation of the average SI and soil properties of the sample plots according to altitudinal zones.

	Altitudinal zones	NSP	Mean ± Std. Dev.	Min.	Max.		Mean ± Std. Dev.	Min.	Max.
SI (m)	I	24	25,94 ± 2,34	20,40	29,30	ED (cm)	115,82 ± 20,43	60,00	140,00
	II	16	25,53 ± 2,43	23,10	30,20		119,39 ± 8,2	90,00	130,00
Sand (%)	I	24	62,37 ± 16,36	36,00	91,00	PSD (cm)	91,75 ± 25,11	30,00	120,00
	II	16	48,45 ± 13,76	26,00	86,00		95,00 ± 17,93	60,00	115,00
Silt (%)	I	24	17,09 ± 7,36	5,00	35,00	ASD (cm)	73,76 ± 17,99	15,00	97,00
	II	16	23,27 ± 7,9	5,00	37,00		72,15 ± 17,96	23,00	92,00
Clay (%)	I	24	20,85 ± 10,74	1,00	42,00	TAH (cm)	18,07 ± 4,38	11,00	28,00
	II	16	28,36 ± 10,49	9,00	49,00		18,73 ± 2,85	15,00	23,00
FSW (%)	I	24	84,06 ± 13,11	33,54	99,00	TBH (cm)	29,44 ± 11,94	,00	52,00
	II	16	85,73 ± 13,26	50,91	98,95		33,21 ± 13,02	,00	50,00
SW (%)	I	24	15,94 ± 13,11	1,00	66,46	pH (KCl)	4,50 ± 0,48	3,60	5,40
	II	16	14,27 ± 13,26	1,05	49,09		4,43 ± 0,33	3,80	5,20
FC (%)	I	24	32,24 ± 6,62	14,17	43,20	pH(Water)	5,36 ± 0,57	4,10	6,40
	II	16	32,90 ± 4,71	21,80	42,24		5,14 ± 0,43	4,40	5,90
WP (%)	I	24	21,25 ± 5,3	9,33	31,67	AHOM (%)	7,33 ± 2,99	3,78	14,17
	II	16	23,51 ± 4,38	14,62	30,92		5,61 ± 0,82	4,52	7,45
AWC (%)	I	24	10,99 ± 4,16	2,73	30,14	OM (%)	3,02 ± 2,98	,23	14,17
	II	16	9,39 ± 2,74	4,30	14,76		2,91 ± 1,88	,47	7,45

NSP: Number sample plot, SI: Site index, FSW: fine soil weight, S: Skeleton weight, FC:Field capacity, WP: Wilting point, AWC: available water capacity, ED: Excavation depth, PSD: Physiological soil depth, ASD: Absolute soil depth, TAH: Thickness of A horizon, TBH: Thickness of B horizon, AHOM: Amount of organic matter of A horizon, OM: Organic matter

The moisture content in the field capacity of the soils corresponds to the equivalent moisture retained in capillary pores after leachate leach out of the soil. In fact, it is the moisture equivalent to the upper limit of water retained by capillarity in the soil. While it is considered by some scientists as a value close to the maximum capacity of capillary water and normal capillarity moisture terms (Irmak, 1972), it is considered by some scientists as the maximum moisture content that can be retained in the root zone soil of free-draining soils (Özhan, 2004). The negative correlation between the SI values and the moisture contents in field capacity means a reduction in the productivity of Oriental beech depending on the increase in the amount of water retained in the capillary pores of soils. Oriental beech, which prefers deep and well aired and drained soils, is not well developed in these sites. The fact that capillary pores are saturated with water for a long period of time also negatively affects the aeration in time.

Figure 2. Top roof covering of the stand by moist air masses in the research area.

Figure 3. Mossiness in trees in Oriental beech stands on flat grounds.

The positive correlation between the SI of Oriental beech and the amount of skeleton of soils can be partially explained by the fact that the soil skeleton positively affects the productivity by allowing aeration. Because the percolation of the water is accelerated, drainage becomes easier and aeration increases in the sites where the skeleton part of the soil is more. However, it is usual to expect a negative correlation between the amount of skeleton and the site indexes in the sites where the average skeleton reaches 60-70% (Yılmaz 2005)

Increased fine soil weight in soils slows down percolation, complicates drainage and reduces aeration. In the research area, while the lowest fine soil section varies between 50.91% and 68.47% in the low and moderately sloping sample plots, the lowest fine soil section varies between 33.54% and 45.92% in high and steep sloping fields. In this region, the reduction of the fine soil weight, and the increase in skeleton weight in terms of facilitating aeration and drainage in the soil increased the productivity of forest trees. However, this can be said for the low sloping sample plots of the research area where the soil depth is sufficient, dominated by the moderately fine textured soils with no lack of water and nutrients.

One of the physical soil properties affecting the productivity of forest trees is the soil depth. Soil depths are known as physiological depth, absolute depth, and excavation depth. In general, the productivity of forest trees increase with increasing soil depths (Çepel ve ark., 1977; Daşdemir 1987; Kalay 1989; Leblanc 1994; Yılmaz 2005; Karataş et al. 2013; Paulo et al. 2014; Güner et al. 2016).

Table 4. Variation of site indexes and soil properties according to slope groups

	SG	NSP	Mean ± Std. Dev	Min.	Max.		Mean ± Std. Dev	Min.	Max.
SI (m)	I	8	25,28 ± 1,32	23,60	27,30	ED (cm)	122,38 ± 4,31	120,00	130,00
	II	12	23,81 ± 2,17	20,40	26,60		112,61 ± 18,67	60,00	130,00
	III	10	27,04 ± 1,45	24,70	28,90		110,95 ± 25,55	60,00	140,00
	IV	10	27,07 ± 2,52	23,10	30,20		122,61 ± 6,81	120,00	140,00
Sand (%)	I	8	69,52 ± 15,58	41,00	91,00	PSD (cm)	93,48 ± 20,44	65,00	120,00
	II	12	48,82 ± 13,31	32,00	86,00		93,04 ± 25,15	30,00	120,00
	III	10	53,19 ± 14,31	36,00	75,00		95,57 ± 18,92	60,00	110,00
	IV	10	57,22 ± 16,86	26,00	87,00		90,04 ± 25,42	50,00	115,00
Silt (%)	I	8	15,90 ± 7,50	5,00	32,00	ASD (cm)	78,14 ± 5,62	70,00	84,00
	II	12	22,41 ± 7,37	5,00	36,00		69,43 ± 26,76	15,00	92,00
	III	10	20,38 ± 7,99	6,00	37,00		68,19 ± 16,58	47,00	97,00
	IV	10	18,96 ± 8,43	5,00	35,00		76,87 ± 13,50	63,00	97,00
Clay (%)	I	8	14,57 ± 9,28	1,00	33,00	TAH (cm)	20,48 ± 4,45	17,00	28,00
	II	12	28,82 ± 11,06	9,00	47,00		18,83 ± 2,54	14,00	21,00
	III	10	26,95 ± 8,73	10,00	42,00		17,50 ± 3,56	12,00	22,00
	IV	10	24,17 ± 10,31	8,00	49,00		16,57 ± 3,73	11,00	23,00
FSW (%)	I	8	89,60 ± 6,54	68,47	96,93	TBH (cm)	35,57 ± 11,34	25,00	52,00
	II	12	86,44 ± 12,47	50,91	98,95		28,04 ± 15,91	,00	50,00
	III	10	83,56 ± 16,17	33,54	99,00		28,05 ± 8,04	19,00	40,00
	IV	10	79,56 ± 13,77	45,92	95,45		31,87 ± 11,55	16,00	50,00
AS (%)	I	8	10,40 ± 6,54	3,07	31,53	pH (KCl)	4,69 ± 0,34	4,10	5,20
	II	12	13,56 ± 12,47	1,05	49,09		4,66 ± 0,40	4,00	5,40
	III	10	16,44 ± 16,17	1,00	66,46		4,18 ± 0,26	3,80	4,80
	IV	10	20,44 ± 13,77	4,55	54,08		4,37 ± 0,47	3,60	5,20
FC (%)	I	8	32,19 ± 7,07	14,17	43,11	pH (Water)	5,58 ± 0,52	4,80	6,40
	II	12	34,31 ± 5,00	21,80	43,20		5,38 ± 0,46	4,40	5,90
	III	10	30,84 ± 4,85	17,14	37,49		4,99 ± 0,46	4,10	5,90
	IV	10	32,53 ± 6,32	17,45	42,24		5,17 ± 0,51	4,40	6,10
WP (%)	I	8	22,22 ± 5,08	11,44	31,67	AHOM (%)	6,73 ± 2,43	4,37	9,32
	II	12	24,13 ± 5,21	13,05	30,30		5,84 ± 0,79	5,09	8,56
	III	10	20,41 ± 2,82	12,36	24,67		7,92 ± 3,81	3,98	14,17
	IV	10	21,63 ± 5,95	9,33	30,92		6,31 ± 1,86	3,78	8,90
AWC (%)	I	8	9,97 ± 3,93	2,73	19,10	OM (%)	2,58 ± 2,53	,32	9,32
	II	12	10,18 ± 4,91	4,51	30,14		3,07 ± 2,20	,47	8,56
	III	10	10,43 ± 3,62	4,30	17,17		3,51 ± 3,27	,57	14,17
	IV	10	10,90 ± 2,20	6,49	15,26		2,77 ± 2,37	,23	8,90

SG: Slope groups, NSP: Number sample plot, SI: Site index, FSW: fine soil weight, AS: Amount skeleton, FC:Field capacity, WP: Wilting point, AWC: available water capacity, ED: Excavation depth, PSD: Physiological soil depth, ASD: Absolute soil depth, TAH: Thickness of A horizon, BHK: Thickness of B horizon, AHOM: Amount of organic matter of A horizon, OM: Organic matter

In this study, there were positive correlations between the site index values and soil depths ($p<0.01$, $r=0.212$ with physiological soil depth; $p<0.01$, $r=0.268$ with excavation depth) (Table 2). However, the low correlation coefficient is remarkable. The fact that soil depths show a lower correlation than the other soil properties is specific to this site. For the research area, the average absolute soil depth is 74 cm, the physiological soil depth is 91 cm and the excavation depth is 117 cm (Table 4). There is no restriction related to soil depth in terms of the nutrition of plants.

Another edaphic factor affecting the productivity of forest trees is the soil reaction. Soil reaction may have different degrees of effects on growth of trees depending on tree species, tree age, climatic conditions, and other ecological conditions. In addition to positive correlations between soil reaction and the SI values of trees (Brown 2007; Yilmaz et al. 2015), negative correlations (Yilmaz et al. 2008; Yilmaz et al. 2015) were also mentioned. In natural spread area, Oriental beech forests grow in soils with degrees between 4.1 - 6.0 pH (NKCl) (Çepel 1995) and 3.5 – 6.6 pH (NKCl) (Yılmaz 2005), 4.88 – 5.35 pH (H_2O) (Sariyildiz et al. 2005; Sariyildiz and Küçük 2009). In this study, there was a significant negative correlation between soil reaction (pH) (NKCl) and the SI values of Oriental beech ($p<0.01$, $r=-0.575$), the average soil reaction was 4.47 pH (NKCl), and average limit values varied between 3.60 –

5.40 pH (NKCl). The increase in pH between these limit values decreases the SI values. In the research area, the sample plots where the SI values are low are the low sloping sample plots. It is interesting that the average pH values of low sloping sample plots are higher (Table 4). It is known that Al^{+3} and H^{+} ions in the soil cause low soil pH and that other cation (such as Ca^{+2}, Mg^{+2}) cause high pH. In the research area, the changeable Ca^{+2} and Mg^{+2} amounts of the sample plots with high pH values are lower than those of the sample plots with low pH values and high SI values. The correlation between soil pH and SI may be due to the effect of nutrient uptake. Since transpiration from plant leaves will decrease in the sites with high air humidity like the research area, the groundwater will not be absorbed by plant roots and especially the leaves will not get the cations such as Ca^{+2}. It is reported that fungi develop in leaves that cannot get enough Ca^{+2} (Kantarcı 2000). Since the development of leaves is adversely affected and the leaf surface area will decrease in sample plots with high Ca^{+2} and high pH, photosynthesis will be adversely affected and the SI values will decrease.

CONCLUSION

Site productivity is determined by the local ecological conditions (climatic, edaphic and topographic) of the site, along with the genetic characteristics of species. While site productivity is generally expected to decrease with an increase in some spatial factors such as land slope and altitude, productivity may increase when evaluated together with other local ecological conditions (climatic and hydrological). In this study, a similar correlation was revealed under local site conditions in Akkuş region of Eastern Black Sea Region of Turkey. It is quite interesting that SI decreases along with a decrease in altitude and the degree of slope of the field in Akkuş region, which is one of the optimum sites of Oriental beech in Turkey. It is very important to know the correlations between such sites and productivity for forestry practices to be performed and planned management organizations. The time and forms of the interventions to be performed to forest ecosystem at a limited elevation belt (1200-1500 m) and under certain topographical and edaphic conditions (flat and low slope, fine-textured soils) and the interventions to be performed in the sites with regional ecological conditions (high slope, hillsides and areas with high altitudes) may be different. Because the SI and the amount of above-ground biomass of the same tree species will be different in the two different sites described. Therefore, the time of intervention to the forest ecosystem will change. Furthermore, the areas of usage of forest products to be produced from these sites may also change. For instance, the properties of wood produced in humid sites and the properties of wood produced in very humid-wet sites will be different. To know the local ecological characteristics of the site well in the afforestation and natural regeneration studies in potential areas will provide a basis for the management of similar areas.

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