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Tree species diversity of natural mixed stands in eastern Black sea and western Mediterranean region of Turkey

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Abstract: *Differences in tree species diversity of natural mixed stands were compared between the eastern Black sea region (EBSR) and western Mediterranean region (WMR) of Turkey, to clarify the effects of differences in forest structure, focusing on the tree species occurring in each. Species diversity, with special reference to stand structure, of natural mixed stands was quantified by Shannon-Wiener index (H'), equitability index (J'), and species richness index (R). All species diversity indices were significantly higher in EBSR than in WMR. According to the coefficients of homogeneity (CH), stands in EBSR are generally have uneven-aged stand structure, but in WMR even-aged stand structure is more common. Uneven-aged stands have more tree species diversity than even-aged forests due to complex vertical forest structure and species composition. According to Pearson's coefficients, species diversity indices and richness are closely related the average stand diameter (Ds) in uneven-aged stands of EBSR, but average stand diameter (Ds), age (A), and stand density (SDI) are the most important stand parameters in even-aged stands of WMR in Turkey.*

Key words: *Natural mixed stands, Species diversity, Stand parameters, Stand structure*
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Introduction

Biological diversity is a key issue of nature conservation and species diversity is one of important components of biological diversity (Wilson, 1992; Itô, 1997). The diversity of tree species is fundamental to total forest biodiversity, because trees provide resources and habitats for almost all other forest species (Cannon, *et al*., 1998; Lexerød and Eid, 2006; Pandeya *et al*., 2007; Ozcelik *et al.,* 2008). Terradas *et al*. (2004) indicated that among factors that influence tree species diversity are climate, stand structure, species composition, and geomorphology. Forest stand structure is a key element in understanding forest ecosystems and also an important element of stand biodiversity (Kint *et al*., 2004).

One of the major goals in the modern and sustainable forestry is preservation and maintaining of biodiversity (Nilsson *et al*., 2001). Natural old and natural mixed stands are very important in protection, maintaining, and monitoring of biodiversity. Mixed stands are also considered to have a high resistance against a multitude of natural damage such as that caused by storms, snow, fungi and insects as well as against anthropogenic damage like air pollution and its consequences. Mixed stands not only best meet the calls for greater biodiversity within the forest but have high economical and multiple use value than pure stands (Knoke *et al*., 2005).

Turkey has a total of 21.188.747 ha forest area, about 46.1% of which are natural mixed stands cover and the biggest parts are found in EBSR and in WMR (General Directorate of Forestry-Turkey, 2006).

Numerical quantification of biological diversity and/or its elements can be of great value because that kind of evaluation is more objective and enables a comparison of current biodiversity status to be made between similar ecosystems. During the last century, a great number of different methods quantifying species diversity were developed (Patil and Taillie, 1982; Alatalo, 1981; Magurran, 2004). However, while using any of the proposed measures one has to be aware of the fact that diversity changes in space and time as it is influenced by abiotic and biotic factors, and disturbances (Frelich *et al*., 1998; Spies and Turner, 1999; Nagaraja *et al*., 2005; Misir *et al*., 2007; Ucler *et al*., 2007). Parameters affecting plant growth and resource availability, *e.g.* climate and stand structure are regarded as primary influencing factors (Pausas, 1994; Terradas *et al*., 2004), while the terrain characteristics, *e.g.* elevation, are considered indirect factors because they themselves have no direct impact on plant growth, but are correlated with the primary factors (Pausas, 1994; Pausas *et al*., 2003).

We determine the composition, stand structure, and the tree species diversity in two bio-geographic regions in Turkey. Our specific objectives were (1) to examine whether or not there are differences between EBSR and WMR, where there were different climatic region, with respect to tree species diversity and stand structure, (2) to clarify the relationship between stand parameters and tree species diversity.

Materials and Methods

The forests of EBSR are called "humid forests", because the region is characterized as the rainiest location of Turkey with average annual precipitation of 1500 mm. Average annual temperature is 14°C, with an average of 4°C in winter and 25°C in summer. The soil conditions of EBSR are characterized by red podzolic soils and brown forest soils (Oakes, 1958). The climate of

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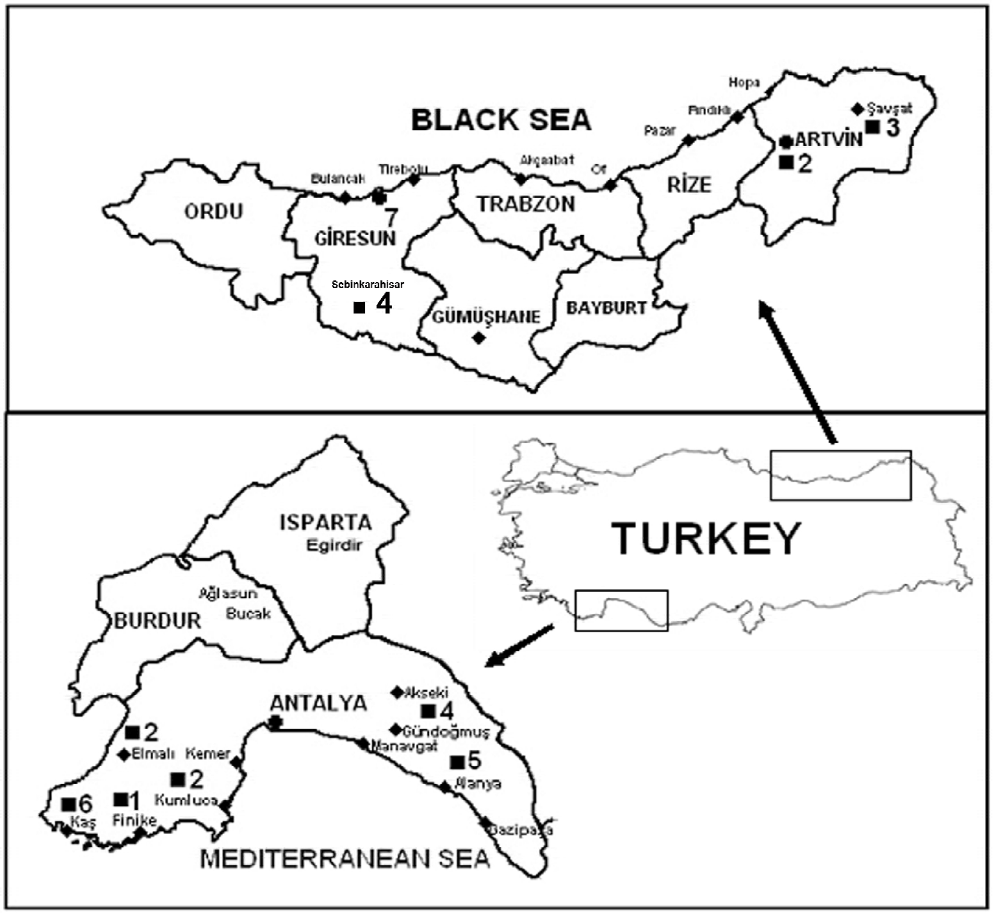

Fig. 1: Location of the sample plots in EBS and WM regions. The number at the particular point represents the number of plots establishment in the area

WM region are called "Mediterranean climate". The most important characteristics of this climate are dry and hot summer and moist and cool autumns and winter (Scarascia-Mugnozza *et al*., 2000). Forests of this region are called "semi-arid forests" for Mediterranean region has long dry period. Average annual precipitation is 600-1200 mm relating to elevation. Average annual temperature is 18°C, with an average of 10°C in winter and 28-30°C in summer (Ozcelik and Eler, 2009). Bedrock is generally calcareous character. Soil conditions of WMR are characterized by red or reddish brown Mediterranean forest soils (Kantarci, 1991; Boydak, 2003).

For this study, the data collected on 16 sample plots taken by Kapucu (1988) in EBSR were natural mixed stands composed by oriental spruce (*Picea orientalis* L.), nordmann's fir (*Abies nordmanniana* (Link.) Spach.), scotch pine (*Pinus sylvestris* L.), oriental beech (*Fagus orientalis* Lipsky.), and of a small admixture of other broad-leaved species (*Fraxinus and Alnus*). In WMR, 20 sample plots were used. Main tree species are brutian pine (*Pinus brutia* Ten.), cilician fir (*Abies cilicica* Carr.), black pine (*Pinus nigra* Arnold. ssp. *pallasiana* (Lamb) Holmboe), oak (*Quercus* L.), cedar (*cedrus libani* A. Rich.) and juniper (*Juniperus* L.) (Fig. 1). In the EBSR, plots were located at an elevation of 1.100 to 1850 meters above sea level. In the WMR, plots were located at an elevation of 950 meters to 1900 meters above sea level.

All sample plots were located in mixed and natural stands. The plots were randomly located on the forest areas. The size of the plots varied due to the condition for their establishment as they had to encompass a minimum of 100 trees (433 - 2500 m^2) and shape of the plots were circular. On each plot only the trees with a diameter at breast height were measured and number of trees in hectare (N) were determined. For each tree, tree species (TS), diameter at breast height (Ds), basal area (BA), and silvicultural status classified using the IUFRO classification system was determined in the field. Similarly, stand age (A) was determined from the increment cores taken from 3-5 dominant trees. Stand volume (V) in sample plots was obtained from the local volume tables. For the estimation of stand density (SDI), the stand density index (SDI) according to Curtis (1982) was calculated. The basic statistics of stand parameters of natural mixed stands are given Table 1.

The species diversity and richness in each plot were quantified using (1) Shannon diversity index (H'), (2) equitability (J'), and (3) the number of species per unit area. The species diversity and equitability indices and , were calculated from frequency of occurrence of each species in each plot (Izsak and Papp, 2000; Nagaike *et al*., 2005). To evaluate species diversity different indicator were formulated. Gorelick (2006) stated that both

Table - 1: Basic statistics of sample plots in EBS and WM regions

Parameters	EBS region				WM region			
	Min	Max	Mean	SD	Min	Max	Mean	SD
Number of tree (*N/ha*) [pcs]	629	1934	1155	381.7	112	575	255.9	108.8
Number of tree Species (*TS*) [pcs]	2	4	2.81	0.750	2	5	3.05	1.05
Basal area (*BA*) [m^2 ha^{-1}]	34.7	79.2	61.72	15.74	8.44	43.6	21.10	9.071
Volume (*V*) [m^3 ha^{-1}]	316	850	594.3	173.6	41.8	389.0	178.4	91.86
Diameter (*Ds*) [cm]	19.1	34.4	29.4	6.120	16.4	43.7	30.80	7.96
Stand density (*SDI*)	4.77	15.57	11.42	2.64	2.02	7.32	3.79	1.45
Homogeneity index (*CH*)	1.65	3.16	2.26	0.334	1.90	3.91	2.71	0.401
Age (*A*) [yrs]	45	150	98.69	26.27	40	196	94.65	43.71
Tree species diversity (*H'*)	0.682	1.090	0.868	0.164	0.325	1.227	0.657	0.287
Equitability (*J'*)	0.663	0.999	0.893	0.129	0.296	0.892	0.619	0.142

SD: Standard deviation

Table - 2: Differences in species diversity index (H'), equitability (J'), and the number of species between EBSR and WMR

	Eastern black sea region		Western Mediterranean region		t-test (p-value)
	Mean	SD	Mean	SD	
Diversity (*H'*)	0.8681	0.164	0.6574	0.287	0.010*
Equitability (*J'*)	0.8934	0.129	0.6198	0.142	0,000**
Species richness (*R*)	2.81	0.750	3.05	1.050	0.452

**p<0.01 ; *p<0.05, SD: Standard deviation

Table - 3: Differences in stand structure between EBSR and WMR

		Eastern black sea region		Western Mediterranean region		t-test (p-value)
	Mean SD	Mean	SD	Mean	SD	
Living trees	DBH (*Ds*) [cm]	29.40	6.120	30.80	7.96	0.567
	BA [m^2 ha^{-1}]	61.72	15.743	21.10	9.070	0.000**
	CH	2.26	0.334	2.71	0.401	0.001**
	SDI	11.42	2.640	3.79	1.45	0.000**

SD: Standard deviation, DBH: Diameter at breast height, BA: Basal area, CH: Coefficient of homogeneity. SDI: Stand density; **p<0.01

Table - 4: Simple correlation coefficients between stand parameters and species diversity indices: H': Shannon-Weiner index, J': Equitability and R: Species richness

Stand parameter	EBS region			WM region		
	H'	J'	R	H'	J'	R
Homogeneity index (*CH*)	-0,295	0,144	-0,228	-0,056	0,079	-0,110
Number of trees (*N/ha*) [pcs]	-0,392	0,060	-0,232	0,306	0,011	0,352
Volume (*V*) [m^3 ha^{-1}]	0,402	-0,016	-0,016	-0,356	-0,597**	0,006
Age (*A*) [yrs]	0,146	0,209	-0,095	-0,369	-0,517*	-0,165
Diameter (*Ds*) [cm]	0,692**	0,070	0,320	-0,552*	-0,426	-0,379
Basal area (*BA*) [m^2 ha^{-1}]	0,457	0,262	0,074	-0,305	-0,620**	0,077
Stand density (D)	0,180	0,251	-0,063	-0,057	-0,548*	0,177

Note: Homogeneity index (CH), Number of trees (N/ha) [pcs], Volume (*V*) [m^3 ha^{-1}], Age (*A*) [yrs], Diameter (Ds) [cm], Basal area (BA) [m2 ha^{-1}], Stand density (SD) **p<0.01; *p<0.05

Shannon's and Simpson's indices have stood the test of time and are still generally regarded as the measures of ecological diversity. We chose Shanon's diversity index because it reflects both evenness and richness of species without favoring either dominant or rare species (Liang *et al*., 2007).

Shannon-Weiner Index (H')

$$H' = -\sum p_i \log_2 p_i \quad ....(1)$$

Equitability Index (J')

$$J' = H'/H_{\max} \quad ....(2)$$

where $H'_{\max} = \log_2 S$ ....(3)

Where p_i is the proportion of species i on the sample plot to basal area (BA) in each plot, S is the number of species in each plot.

Stand structure and heterogeneity of a stand can easily be described through the employment of the homogeneity coefficient (CH) of De Camino. CH was developed by Lorenz curve and The Gini coefficient (De Camino, 1976). The Gini coefficient and Lorenz curve were originally developed in the field of economy to be a measure of inequality of income distribution, but Lorenz curve and The Gini coefficient have also been widely used in ecological studies (Knox *et al.,* 1989; Rouvinen and Kuuluvainen, 2005).

$$CH = \frac{\sum_{i=1}^{n-1} SN\%}{\sum_{i=1}^{n-1} (SN\% - SV\%)} \quad ....(4)$$

where SN% represent sum of stem percentages up to $d_{1,3}$ class *i*; SV% is the sum of growing stock percentages up to $d_{1,3}$ class *i*; ΣSN% and ΣSV% are only computed up to the class "u-1", that is up to one class below the highest $d_{1,3}$ class (SN% and SV% of the highest class=100% each). The Lorenz curve is a suitable tool for graphical representation and for comparison of stand structures. It shows the interdependence of the parameters SN% and SV%. For a completely homogeneous stand, the Lorenz curve forms a diagonal between the points (0,0) and (100,100) (Bachofen and Zingg, 2001). The less homogeneous stand, the more the Lorenz curve deviates from this diagonal. Lexerød and Eid (2006) stated that The Gini coefficient and Lorenz curve can be used as an objective measure to compare tree size diversity in different stands, to assess changes in tree size diversity over time at the stands, to quantify the influence of different silvicultural treatment on stand structure, and to describing stand structure.

Data analysis: The group t-test was performed to compare the stand structure parameters (Ds, BA, CH and SDI) and indices of tree species diversity between EBSR and WMR.

Pearson's correlation was calculated to identify relationship between stand variables (Ds, BA, V, SDI, CH and N), indices of species diversity, number, and frequency of occurrence of ecological characteristics of species. All statistical relations tested using the SPSS packet (SPSS, 2004).

Results and Discussion

Tree species diversity and stand structure: Tree species diversity and equitability values were significantly higher EBSR than in WMR, although the difference in the species richness was not significant (Table 2).

To characterize stand structures of natural mixed stands in two bio-geographic regions, as ingle variable is insufficient, and several parameters are needed (*e.g.* Ds, BA, CH, and SDI). Stand structure did differ significantly between natural mixed stands in EBSR and WMR, according to CH, BA, and SDI values (Table 3). Terradas *et al*. (2004) indicated that among factors that influence tree species diversity are climate, stand structure, species composition, and geomorphology. Soil fertility or disturbance history also may be important, but the current structure and composition of the vegetation in part reflect their effects. Therefore, the diversity of tree species diversity seemed to be affected mainly by differences in stand structure rather than by the other primary factors.

Relationship between tree species diversity and some stand parameters: Although the relationships between tree species diversity and some examined stand parameters (*e.g.*, CH, N) are loose in both regions, some relations (*e.g.*, Ds in both regions) were detected to be significant (Table 4).

There are positive correlation between Ds and tree species diversity in EBSR (Table 4). The results of the analysis indicate that tree species diversity increases in parallel with increasing Ds, BA, V, SDI and A, but decreases with an increasing CH, and N in EBSR. There is significant negative correlation between *H'* and Ds, and *J'* and A, V, BA and SDI in WMR. Generally, tree species diversity increases in parallel with increasing N, but decreases with CH, Ds, BA, SDI, V, and A in natural mixed stands of WMR.

De Camino (1976) stated that the coefficient of homogeneity vary between 4.0-10.0 in even aged stands treated with low thinning and 1.3-2.8 in uneven aged stands. Heterogeneous stands have a low coefficient of homogeneity, homogeneous stands a higher one (Bachofen and Zingg, 2001). For two bio-geographic regions, the coefficient lies between 1.65-3.16 in EBSR and 1.90-3.91 in WMR. It is accepted that limit value of homogeneity index can be CH=2.5 for separated uneven-aged stands with even aged stands. If coefficients of homogeneity is CH<2.50, stand is uneven-aged and If coefficients of homogeneity CH>2.50, stand is even-aged (Kapucu, 1988). Mean coefficient of homogeneity of natural mixed stands is 2.26 in EBS region, while 2.71 in WM Region. Therefore, they show the peculiarity of uneven-aged stand structure in EBSR and even-aged stand structure in WMR.

Huang *et al*. (2003) stated that species diversity was significantly influenced by forest structure and species composition. Brokaw and Lent (1999) and Latham *et al.* (1998) indicated that high species diversity is often connected to more complex vertical structure. Tree species diversity values of sample plots in these two bio-geographic region decrease in parallel with increasing CH and there is negative correlation between species diversity value and CH (Table 4). When homogeneity index values are examined in two bio-geographic regions, it is seen that homogeneity index values in natural uneven-aged mixed stand are less than in natural even-aged stand. The results of this study, as indicated earlier, indicate that there is a positive correlation between uneven aged stand structure and tree species diversity.

Jaehne and Dohrenbush (1997) stated that uneven-aged stands have the highest diversity index scores than even-aged stands. Whitmore (1998) stated that tree species diversity in forest ecosystems varies greatly from place to place mainly due to variation in bio-geography, habitat and disturbance, but more importantly, uneven-aged stands are high species diversity than even-aged stands because of species compositions and vertical structure of uneven-aged stands.

According to Pitkanen (1998) the significant stand variables for the classification of biodiversity are the number of tree species, and mean stand diameter, which was confirmed also in the presented analysis (Table 4). Generally, tree species diversity increases in parallel with increasing mean stand diameter (Denslow, 1995). In this study, there is a positive correlation between diameter and tree species diversity in EBSR, but a negative correlation between diameter and tree species diversity (Table 4).

Thus, there are documented positive correlation between species diversity and SDI (Palmer *et al*., 2000; Steege *et al*., 2003). Although Huang *et al*. (2003) stated that significant negative relationship between species richness and tree densities, in our case the negative correlation was very low and nonsignificant with SDI in WMR (Table 4). As Coroi *et al*. (2004) expressed that SDI in uneven-aged stands was generally higher than even-aged stands. Even aged stands are composed of trees almost the same age and the spatial structure is simpler than in uneven-aged stands. Due to the presence of many saplings and trees in various aged and diameter, the average diameter was lower and the average density was higher in uneven-aged stands (Table 1). Generally, species diversity decreases with increasing SDI in WMR; but species diversity increases with increasing SDI in EBSR in this study.

Our findings correspond with those of Fridley (2003) concerning the positive relationship between species richness and above-ground production (here represented by stand volume), in our case the correlation was positive and non-significant in EBSR, but correlation was negative and nonsignificant in WMR (Table 4).

Findings differ on the influence of stand age on tree species diversity varied. Several studies showed a positive correlation (Kirby, 1988; Kiyono, 1990), whereas Sykes *et al*. (1989) demonstrated that species richness of plantations decreased with stand age. While species diversity values of sample plots have uneven-aged stand structure increases in parallel with increasing A, not in even-aged stands in our analysis.

Unsuitable stand structures and silvicultural treatments practiced are related to be the decrease on species diversity in even aged stands. As a result of conversion from the mixed even-aged stands to pure stands, the stands structures were depreciated and ratio of tree species mixture was changed in favor of one of the species found in the original tree mixture. We conclude that more importance should be given to maintaining and protecting natural mixed stands for conserving biodiversity.

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