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Tree species diversity and its relationship to stand parameters and geomorphology features in the eastern Black sea region forests of turkey

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Abstract: *We studied the effects of stand parameters (crown closure, basal area, stand volume, age, mean stand diameter, number of trees, and heterogeneity index) and geomorphology features (elevation, aspect and slope) on tree species diversity in an example of untreated natural mixed forest stands in the eastern black sea region of Turkey. Tree species diversity and basal area heterogeneity in forest ecosystems are quantified using the Shannon-Weaver and Simpson indices. The relationship between tree species diversity, basal area heterogeneity, stand parameters and geomorphology features are examined using regression analysis. Our work revealed that the relationship between tree species diversity and stand parameters is loose with a correlation coefficient between 0.02 and 0.70. The correlation of basal area heterogeneity with stand parameters fluctuated between 0.004 and 0.77 (R^2). According to our results, stands with higher tree species diversity are characterised by higher mean stand diameter, number of diameter classes, basal area and lower homogeneity index value. Considering the effect of geomorphology features on tree species or basal area heterogeneity, we found that all investigated relationships are loose with $R^2 < 0.24$. A significant correlation was detected only between tree species diversity and aspect. Future work is required to verify the detected trends in behaviour of tree species diversity if it is to estimate from the usual forest stand parameters and topography characteristics.*

Key words: *Tree species diversity, Mixed stands, Stand structure, Geomorphology*
PDF of full length paper is available with author ***(*ramazan@orman.sdu.edu.tr)***

Introduction

Nature conservation priority was rated, using rarity, species richness, stratification, site age, and area of the habitats (Evrendilek, 2003). Biological diversity is a key issue of nature conservation, and species diversity is one of important components of the biological diversity (Ito, 1997). Forest lands extend over a great number of ecosystems, harboring a rich diversity of species and genes. Thus, within the biodiversity conservation debate top priority was given to forests. 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; Pandeya *et al.,* 2007). To study tree species diversity of untreated, natural mixed stands is a key to conserving biodiversity of forest ecosystems.

Biodiversity assessment is often restricted in the red listing of threatened species and clarification of their habitat demands in forest practices and forest management plans. However, good data and appropriate indicators are necessary to assist policy making and monitoring to understand the causes of changes in biodiversity and to better implement protection strategies (Puumalainen *et al*., 2003).

Numerical quantification of biological diversity and/or its elements can be of great value because that kind of evaluation is 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 (Ludwig and Reynolds, 1988; Patil and Taillie, 1982; Merganic and Smelko, 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; Nagaraja *et al*., 2005; Misir *et al.,* 2007; Ucler *et al.,* 2007). Parameters affecting plant growth and resource availability, *e.g*. climate, are regarded as primary influencing factors (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 *et al*., 2003; Bhattarai *et al*., 2004). The indirect factors are often used in the analysis when information about the primary factors is not available (Pausas and Saez, 2000). Most often, the relationship of diversity to elevation is investigated (Grytnes and Vetaas, 2002; Bhattarai and Vetaas, 2003; Bachman *et al*., 2004), while the effects of other topographic features are rarely examined (Johnson, 1986; Palmer *et al*., 2000). In addition, most of the published works analyse environmental factors only with regard to species richness, representing just one component of species diversity (Merganic *et al*., 2004).

This research aims to address tree species diversity (expressed by the Shannon-Weaver and Simpson indices) in untreated natural mixed stands of the eastern Black sea region forests of Turkey. This study also aims to clarify the relationship of the calculated tree species and basal area diversity with selected stand

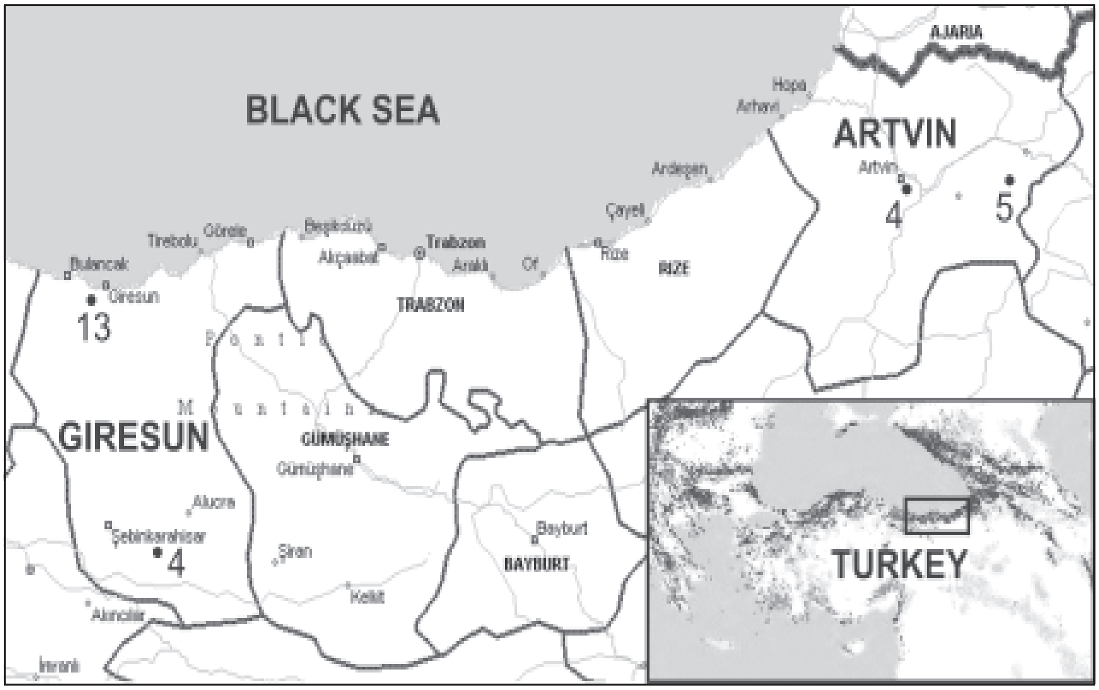

Fig. 1: Location of the sample plots in the region of interest. The number at the particular point represents the number of plots established in the area

parameters and three geomorphology features: elevation, aspect and slope. These relationships, if found to be significant, could be used for estimating the actual species diversity from usual forest stand parameters and/or topography characteristics. This could simplify the integration of biodiversity into forest management plans or models applied for the management of natural resources.

Materials and Methods

In this study, the data collected on 26 sample plots taken by Kapucu (1988) in the eastern Black sea region were used (Fig. 1). The forests of this region were called "humid forests", because the region is the rainiest location of Turkey with an average annual precipitation of 1,500 mm. The average annual temperature is 14°C, with an average of 4°C in winter and 25°C in summer. The soil conditions of the eastern Black sea region are characterised by red podzolic soils and brown forest soils (Oakes, 1958).

All sample plots were located in mixed, natural, untreated stands. The forest stands are mainly composed of oriental spruce (*Picea orientalis* L.), nordmann's fir (*Abies nordmanniana* Link. Spach.), oriental beech (*Fagus orientalis* Lipsky.), scots pine (*Pinus sylvestris* L.), and of a small admixture of other broadleaf species (*Fraxinus, Alnus* and *Populus*). Sample plots were located at an elevation of 1,100 metres to 1,900 metres above sea level. The positions of the sample plots were selected randomly. The size of the plots varied (Table 1) due to the condition for their establishment as they had to encompass a minimum of 100 trees. The plots were of a rectangular shape. On each plot, breast height diameters were measured on trees with height of at least 1.30 m. For each tree, tree species, diameter at breast height determined in the field. Tree height was measured only on 3-5 dominant trees in every sample plot. Similarly, approximate stand age was determined from the increment cores taken from the dominant trees for each tree species. Stand volume in the sample plots was obtained from the local volume tables (Kapucu, 1988). Homogeneity index was calculated from the Lorenz curve which is a suitable tool for graphical representation and for comparison of stand structures. Heterogeneous stands have a low index of homogeneity, while homogeneous stands a higher one (Bachofen and Zingg, 2001).

The basic statistics of stand parameters and geomorphology features are given in Table 1.

Quantification of tree species diversity: To evaluate species diversity different indicators were formulated. Among them the most common methods are the "Shannon-Weaver Index (SW)" and the "Simpson Index (SI)" (Ludwig and Reynolds, 1988; Merganic and Smelko, 2004). It was stated that the Shannon-Weaver and Simpson indices are successfull tools for the evaluation and quantification of plant and animal diversity, and are easy and practical measures of area diversity (Dale *et al*., 1994). These indices are closely related and they can be derived from the same one-parameter family of diversity indices (Keylock, 2005). Gorelick (2006) stated that both Shannon's and Simpson's indices have stood the test of time and are still generally regarded as the premier measures of ecological diversity.

Shannon-Weaver index (SW)

$$SW = -\sum_{i=1}^{S} p_i \cdot \ln(p_i) \qquad (1)$$

Table - 1: Basic statistics and geomorphology features of sample plots

	Parameters	No. of plots	Min.	Max.	Mean	Standard deviation
Stand parameters	Plot size [m^2]	26	433	2,400	1.563.38	587.02
	Number of trees (N/ha) [pcs/ha]	26	496	2.398	1.179	519.47
	Number of tree species (TS) [pcs]	26	2	4	3	0.74
	Basal area (BA) [m^2/ha]	26	23.85	80.48	58.71	14.55
	Number of diameter classes (DC) [pcs]	26	7	22	13	4.46
	Volume (V) [m^3/ha]	26	205	1,033	619	206.52
	Stand age (A) [yrs]	26	45	150	89	26.52
	Diameter (Ds) [cm]	26	18.1	29.8	26.90	6.53
	Homogeneity Index (HI)	26	1.65	4.81	2.66	0.68
	Tree species diversity (SW)	26	0.339	1.096	0.7566	0.1925
	Tree species diversity (SI)	26	0.179	0.665	0.4849	0.1100
	Basal area heterogeneity (SW)	26	1.8613	2.8702	2.3755	0.3362
	Basal area heterogeneity (SI)	26	0.8314	0.9363	0.8910	0.0345
Geomorphology features	Elevation (m)	26	1,120.00	1,900.00	1,653.27	179.70
	Slope (°)	26	0.00	39.00	23.54	9.83
	Aspect	26		Relative proportion (%)		
	N	11		42.31		
	SW	5		19.23		
	Plain	2		7.69		
	NW	2		7.69		
	NE	2		7.69		
	S	1		3.85		
	W	1		3.85		
	SE	1		3.85		
	E	1		3.85		

Note: Shannon-Weaver index (SW), Simpson index (SI)

Simpson index (SI):

$$SI = 1 - \sum_{i=1}^{S} p_i^2 \qquad (2)$$

Where p_i is the proportion of species i on the sample plot calculated from number of trees N, basal area BA per hectare and S is the number of species.

Using the formulas (1) and (2) of the two species diversity indices SW and SI, tree species diversity values were calculated from two stand parameters: number of trees (N) and basal area (BA). The calculation of the heterogeneity indices using the different stand parameters was performed in order to examine and document the influence of tree dimensions on the index value. The calculation from the number of trees N neglects tree size, while the estimation of heterogeneity from BA accounts for the size of the tree (Merganic and Smelko, 2004).

Basal area heterogeneity: The heterogeneity of basal area was estimated by the indices SW and SI. To determine the basal area heterogeneity of the sample plots, trees on each sample plot were classified to diameter classes of 4 cm width. Basal area of one diameter class was obtained by multiplying the basal area of the mean tree in the diameter class with the number of trees in the particular diameter class. Total basal area of the sample plot was calculated as the sum of the basal areas of all diameter classes. The relative proportion of the basal area of the i^{th} diameter class from the total basal area was taken as the input value p_i for the calculation of the SW and SI indices in the formulas (1) and (2). Note that in this case the variable *S* in the formulas represents the number of filled diameter classes.

The relationship between tree species diversity, basal area heterogeneity and stand parameters or geomorphology features: To examine the relation between tree species diversity and basal area heterogeneity and stand parameters or geomorphology features, linear and non-linear (quadratic and logarithmic) models were used and tested using the SPSS packet (SPSS, 2004) and the Mathcad program (Mathsoft Inc, 2004). The significance of priority in the examined statistical relations was determined according to the coefficient of determinaton R^2, standard error of estimination SE and α-values of treated linear and non-linear regression models. The type of the model was selected not only with regard to its significance but also by accounting for its logical behaviour.

Table - 2: Relationship between tree species diversity, detrended basal area heterogeneity and selected stand parameters according to the Shannon-Weaver and Simpson index

Stand parameter	Model	Tree species diversity												Model	Detrended basal area heterogeneity					
		Shannon-Weaver index						Simpson index												
		N			BA			N			BA				Shannon-Weaver index			Simpson index		
		R^2	SE	α	R^2	SE	α	R^2	SE	α	R^2	SE	α		R^2	SE	α	R^2	SE	α
CL	L	0.177	0.173	0.032*	0.019	0.189	0.506	0.182	0.106	0.030*	0.007	0.098	0.676	L	0.005	0.128	0.741	0.004	0.036	0.752
HI	L	0.062	0.185	0.222	0.291	0.161	0.004**	0.073	0.113	0.181	0.489	0.071	0.000**	L	0.596	0.081	0.000**	0.629	0.022	0.000**
TS	L	0.217	0.169	0.017*	0.438	0.143	0.000**	0.049	0.115	0.278	0.158	0.091	0.044*	L	0.059	0.124	0.232	0.027	0.035	0.424
N/ha	Q	0.068	0.177	0.210	0.132	0.171	0.074	0.053	0.110	0.270	0.105	0.090	0.113	L	0.321	0.106	0.003**	0.282	0.030	0.005**
DC	Q	0.174	0.166	0.038*	0.424	0.139	0.000**	0.099	0.107	0.126	0.374	0.075	0.001**	LN	0.772	0.059	0.000**	0.724	0.018	0.000**
V/ha	L	0.028	0.188	0.412	0.117	0.180	0.088	0.008	0.117	0.662	0.108	0.093	0.102	L	0.538	0.087	0.000**	0.508	0.025	0.000**
A	L	0.004	0.190	0.747	0.067	0.185	0.203	0.016	0.117	0.542	0.084	0.095	0.152	L	0.195	0.115	0.02*	0.216	0.032	0.017*
Ds	Q	0.102	0.174	0.120	0.321	0.151	0.003**	0.040	0.111	0.337	0.252	0.082	0.011*	LN	0.699	0.068	0.00**	0.633	0.021	0.000**
BA/ha	L	0.076	0.183	0.172	0.222	0.169	0.015*	0.025	0.116	0.440	0.202	0.088	0.021*	L	0.407	0.099	0.000**	0.385	0.028	0.001**

Note: Closure (CL), Homogeneity index (HI), Number of tree species (TS) (pcs), Number of trees (N/ha) (pcs), Number of filled diameter classes (DC) (pcs), Volume (V) (m^3/ha), Age (A)(yrs), Diameter (Ds) (cm), Basal area (BA) (m^2/ha), Model: L = linear, Q = Quadratic, LN = Logarithmic, Statistics: R^2 = Coefficient of determination, SE = Standard error. Significance level: ** α <0.01 and * α <0.05

Table - 3: Relationship between tree species diversity, detrended basal area heterogeneity, and selected geomorphology features according to the Shannon-Weaver and Simpson Index

Geomorph-ology feature	Model	Tree species diversity												Model	Detrended basal area heterogeneity					
		Shannon-Weaver index						Simpson index												
		N			BA			N			BA				Shannon-Weaver index			Simpson index		
		R^2	SE	α	R^2	SE	α	R^2	SE	α	R^2	SE	α		R^2	SE	α	R^2	SE	α
Elevation	L	0.031	0.180	0.403	0.022	0.182	0.481	0.036	0.111	0.361	0.104	0.090	0.116	Q	0.116	0.116	0.096	0.141	0.032	0.065
Aspect	L	0.230	0.161	0.015*	0.237	0.161	0.014*	0.169	0.103	0.041*	0.137	0.088	0.069	Q	0.144	0.114	0.061	0.141	0.032	0.065
Slope	L	0.148	0.169	0.058	0.058	0.178	0.245	0.181	0.102	0.034*	0.046	0.093	0.303	L	0.042	0.125	0.315	0.055	0.035	0.249

Model: L = Linear, Q = Quadratic, Statistics: R^2 = Coefficient of determination, SE = Standard error, Significance level: ** α <0.01 and * α <0.05

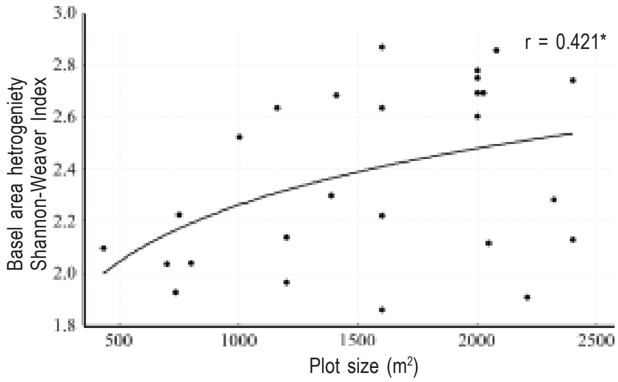

Fig. 2: Influence of plot size on basal area heterogeneity calculated from the Shannon-Weaver index

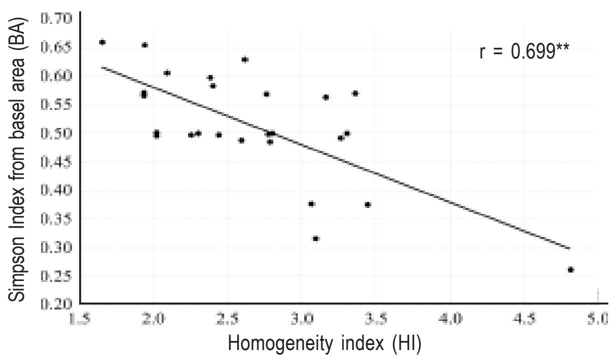

Fig. 3: Relationship between the homogeneity index and tree species heterogeneity derived from basal area according to the Simpson index

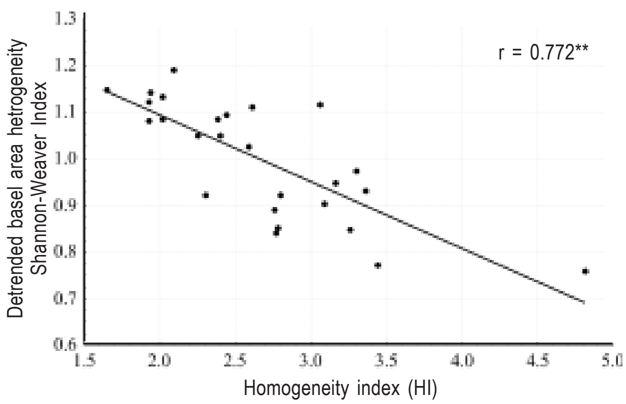

Fig. 4: Relationship between the homogeneity index and detrended basal area heterogeneity calculated from the Shannon-Weaver index. The detrended basal area heterogeneity was obtained by dividing the actual basal area heterogeneity with the value from the regression between the basal area heterogeneity and plot size

From the stand parameters the following parameters were included in the analysis: Crown closure CL, homogeneity index HI, number of tree species TS, number of filled diameter classess DC, and number of trees per hectare N/ha, basal area BA/ha, stand volume V/ha, stand age A and mean stand diameter Ds. When analysing their relationship to tree species diversity, in three cases (for N/ha, DC, Ds), a quadratic model was used, while for the other relationships a linear model was applied. Similarly, the relationship between the basal area heterogeneity values and selected stand parameters was also investigated. Linear regression was applied in the majority cases while the logarithmic model was used to describe the relation between basal area diversity and number of diameter classes DC and mean stand diameter Ds.

The examined geomorphology features were elevation, aspect, and slope. Also in this case, the relationship between them and tree species and basal area heterogeneity was tested using linear and non-linear regression analysis. To apply this kind of analysis to all cases, the aspect as a categorical variable was converted to degree values. The best results were obtained with the quadratic model for all of the examined relationships except the one between basal area heterogeneity and slope, where linear model explained more variability.

Results and Discussion

Tree species diversity and basal area variability: The values of tree species diversity obtained from the SW index fluctuated between 0.339 and 1.096, SI ranged from 0.179 to 0.665 (Table 1). In both cases, tree species diversity was highest if the ratio values of all present tree species were equal or rather similar. Similar results were also obtained for basal area heterogeneity.

How does plot size affect selected diversity quantifiers?: Species diversity is highly dependent on the size of the analysed population. Due to the fact that the sample plots included in this analysis differ in their size (Table 1), it was of great importance to examine the influence of the plot size on the diversity quantifiers. Regression analysis revealed that all relationships between plot size and tree species diversity quantifiers ($SW_{N,BA}$ and $SI_{N,BA}$) are nonsignificant. This result suggests that the plots represent the minimum area, *i.e.* at the microsite level tree species heterogeneity will not increase if the plot is enlarged. Therefore, the data and the tree species diversity values derived from them can be used for further analyses without any modifications.

However, in the case of basal area heterogeneity, the analysis showed a significant correlation between basal area heterogeneity and plot size (Fig. 2). Using these results, the values of basal area heterogeneity were detrended by dividing the actual value with the value from the calculated regression. The following analyses were performed using these detrended values.

Relationship between tree species diversity and stand parameters: In general the relationships between tree species diversity and examined stand parameters are loose, since the correlation coefficient R fluctutaes between 0.02 and 0.70 (*i.e.* R^2 is from 0.00 to 0.49). Nevertheless, some relations were detected to be significant (Table 2). Regarding the use of the different stand variables (N and BA) in the calculation of tree species diversity, higher and significant correlations were obtained if diversity values were derived from the basal area rather than from the number of trees.

If the number of trees N was used as the basis for the calculation of tree species diversity, the analysis revealed three significant relations between the Shannon-Weaver Index and closure,

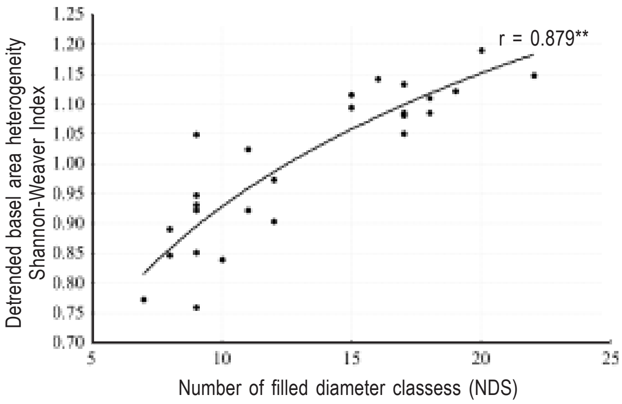

Fig. 5: Relationship between the number of filled diameter classes and detrended basal area heterogeneity calculated from the Shannon-Weaver index. The detrended basal area heterogeneity was obtained by dividing the actual basal area heterogeneity with the value from the regression between the basal area heterogeneity and plot size

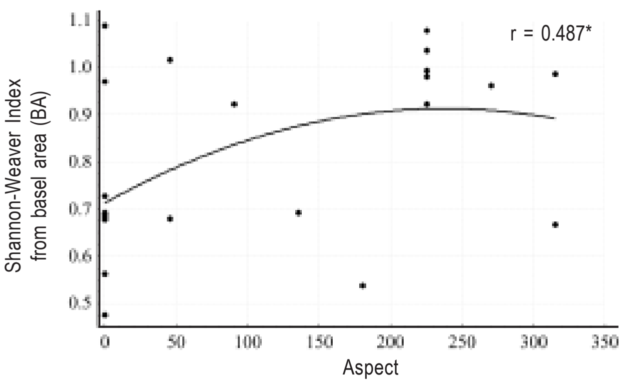

Fig. 6: Relationship between the aspect and tree species heterogeneity derived from basal area according to the Shannon-Weaver index

number of tree species, and number of filled diameter classes, and one significant relation between the Simpson index and closure, although in all cases the correlations are low ($R^2 < 0.22$; Table 2). When tree species diversity was calculated from BA, significant correlations with homogeneity index, number of tree species, number of diameter classes, mean stand diameter, and basal area were found for both indices (Table 2).

The results of the analysis indicate that tree species diversity increases in parallel with increasing stand closure, number of tree species, basal area, stand volume, and age, but decreases with an increasing homogeneity index (Fig. 3). Regarding the three relationships where quadratic regression was used for their description, it was found that tree species diversity first decreases with the increasing number of trees per hectare until it reaches its minimum at approximately 1,400 - 1,600 trees per ha, and then it begins to rise. Similar behaviour was observed for the relationship with the number of diameter classes and mean stand diameter.

Relationship between basal area heterogeneity and stand parameters: The statitical analysis of the relationship between basal area heterogeneity and selected stand parameters revealed that similar relationships between basal area heterogeneity values and all selected stand parameters were obtained by both diversity indices SW and SI. All examined relationships except the ones between basal area heterogeneity and number of tree species and closure, were significant. The highest R^2 value was obtained for the number of diameter classes followed by mean stand diameter, homogeneity index and stand volume (Table 2).

Generally, basal area heterogeneity increases in parallel with increasing age, basal area and stand volume, but decreases with an increasing number of trees per hectare and homogeneity index (Fig. 4). Increasing number of diameter classes DC and mean stand diameter Ds results in higher basal area heterogeneity, but this trend slows down when DC and Ds reach higher values (Fig. 5).

Relationships between tree species diversity and basal area heterogeneity and geomorphology features: The analysis revealed a significant correlation between calculated tree species diversity (SW) and aspect regardless of the stand parameter (N, BA) used for the calculation (Table 3). In the case of SI index, significant correlation with aspect was found only if SI was derived from N. Slope had a significant effect only on SI_N. However, all significant relationships are loose with $R^2 < 0.24$. Elevation did not appear to be significantly related to any of the examined tree species diversity indices (Table 3).

Regarding the performance of tree species diversity both indices, when calculated from N, first decrease with aspect. The lowest tree species heterogeneity is at the aspect of around 90^o (*i.e.* east), after which the diversity begins to increase. If BA was used to calculate tree species diversity, this first increases with aspect, and at 230^o (*i.e.* west) it reaches its maximum (Fig. 6). The same behaviour was observed for the relationship of SW and SI versus slope, whereby the minimum heterogeneity was at slopes of 10^o and the maximum at around 23-30^o. Similarly, with increasing elevation tree species diversity first increases up to approx. 1,800 m above sea level, where it reaches maximum and then decreases.

The relationship between the geomorphology features and basal area heterogeneity was analysed in the same manner. For elevation and aspect, a quadratic model was used, while for slope a linear regression model was applied. According to the results of the analysis, none of the geomorphology features have a significant effect on basal area heterogeneity (R^2<0.5 and α>0.05, Table 3).

Since the analysis of the relationship between the plot size and tree species diversity did not detect any significant correlation, for a better understanding of these values we apply the verbal scale of species diversity suggested by Merganic *et al.* (2004), although he worked with optimally sized sample plots. The scale has four degrees of species diversity (low, medium, high, and very high) determined by the values of the particular index. According to this scale, the calculated values indicate that the evaluated forest stands have a high degree of tree species diversity.

From the examined stand parameters number of filled diameter classes has the highest correlation with tree species diversity (Table 2). Although in our analysis the quadratic model described this relationship best, in general our results correspond with the findings of Huang *et al*. (2003) who found a positive relation between the number of diameter classes and species diversity.

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 2). Generally, tree species diversity increases in parallel with increasing mean stand diameter (Denslow, 1995).

Homogeneity index is the only stand parameter with a negative relationship to tree species heterogeneity (Fig. 3) due to its character. Higher values of the homogeneity index indicate evenaged stand structure, whereas the values between 1.3 and 2.8 are characteristic for unevenaged stands (Kapucu, 1988) with a more complex vertical structure. In such stands, high species diversity can be expected (Brokaw and Lent, 1999). Our results support this hypothesis, as the highest tree species heterogeneity was observed on the plots with the lowest homogeneity index (Fig. 3).

Unlike in the number of works, that documented positive correlation between species diversity and stand density (Palmer *et al*., 2000; Steege *et al*., 2003), our results did not reveal a strong significant relationship with the number of trees per hectare. This is due to the different approach of quantifying species diversity: while the cited works dealt with species richness, in the presented work we examined species heterogeneity encompassing both species abundance and species evenness in a studied community (Bruciamacchie *et al*., 1995). Thus, both tested indices reacted not only to the number of species, but also to their equality in species composition, whereas the SW index is mainly sensitive to the level of evenness in species composition, but less to the numberof species. On the contrary, SI index reacts more to species abundance and less to species evenness (Hubalek, 2000; Liang *et al*., 2007).

Similarly, although our findings correspond with those of Fridley (2003) about the positive relationship between species richness and above-ground production (here represented by stand volume), in our case the correlation was very low and nonsignificant (Table 2).

The collected information of the influence of stand age on plant species diversity varied. Several studies showed a positive correlation (Kirby, 1988; Kiyono, 1990; Ohsawa and Nagaike, 2006), whereas Sykes *et al*., (1989) demonstrated a negative correlation with stand age. Nagaike *et al*. (2003) expressed that increasing stand age did not directly contribute to higher species diversity and richness, which was proved also in our analysis (Table 2).

Statistical analysis of the relationship between basal area heterogeneity and stand parameters revealed significant relations between basal area heterogeneity and the number of diameter classes, mean stand diameter, homogenity index and number of trees (Table 2). As expected, basal area heterogeneity is significantly correlated and increases with increasing number of diameter classes (Fig. 5), because this variable enters the calculation of basal area diversity. Nevertheless, to obtain the highest basal area heterogeneity, apart from the high number of diameter classes the ratio values of diameter classes should also be equal or similar, since the calculation of basal area heterogeneity using the SW and SI indices accounts for the number of diameter classes as well as for the level of evenness in the distribution of the trees in the diameter class.

Johnson (1986), who described topographic position by elevation, slope and aspect, also found its strong influence on species composition of the forests. Our analysis revealed that from these three geomorphology features aspect influences tree species diversity at most (Table 3). However, our data do not allow us to state at which aspect the lowest or highest diversity can be expected, since the experiment is unbalanced, *i.e.* the number of plots in individual aspect groups is unequal (Table 1, Fig. 6).

From the topographic characteristics, the effect of elevation on species diversity is most often examined in the scientific literature (Grytnes and Vetaas, 2002; Pausas *et al*., 2003; Bhattarai *et al*., 2004). Very often hump-shaped curves with maximum species diversity at mid-elevations were reported (Bhattarai and Vetaas, 2003; Bachman *et al*., 2004). A similar pattern was observed in our analysis, although the correlation was nonsignificant (Table 3). Such loose relationships between species diversity and elevation with R^2= 0.3 and 0.4 were reported in other studies (Merganic *et al*., 2004).

Biodiversity protection and maintenance is an important issue, which should be integrated into forest management plans or models applied to the management of natural resources. In this context, the main task is to quantify the biodiversity numerically. This study documented how this could be performed using simple index techniques. Another possibility could be to estimate the actual biodiversity status from the usual forest stand parameters and topography. Although our analysis did not reveal any strong correlations, we detected some trends in the behaviour that would require more thorough studies in the future.

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