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Relation between selected indicators of forest stand diversity and quality of timber production in managed Central European forests

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ABSTRACT: The present study examines the relationship between the quality of timber production and the species and structural diversity of forest stands. The data used came from a regional forest inventory of the University Forest Enterprise "Kostelec nad Černými lesy", Czech Republic. The inventory was performed from 2009 to 2011 on 1,188 sample plots that represented 86 strata defined by the combination of three variables: site (5 categories), age (12 categories) and canopy cover (5 categories). On each sample plot, we quantified 171 partial biodiversity indicators that represented species or structural diversity. The quality of timber production was specified by four indicators quantified using local assortment tables. In total, we analysed 58,824 univariate linear regressions describing the relationships between diversity indicators and timber quality in individual strata. The results revealed that their relationship changes with stand age. The proportion of the best-quality assortments increases with the increasing species richness in all age categories.

Keywords: assortment; species diversity; structural diversity; timber quality

Recent trends in central European forestry show that the traditional economically oriented forest management is being transformed to multipurpose sustainable forest management (Schmithüsen 2007). This shift results from multiple reasons including the loss of species diversity (Johann 2004), reduced forest stability (Spiecker 2003), climate change (European Environment Agency 2014), increasing occurrence of disturbances (Schelhaas et al. 2003), changes in human perceptions of forests (Glück, Weiss 1996; Eland, Wiersum 2001) and in human demands on forests (Schmithüsen 2007), and adverse effects of some plantations on soil properties (Fritz 2006). Such an approach favours mixed structurally more diverse forest stands over homogeneous even-aged plantations.

There is ample evidence about the ecological advantages of diversified forests (Fritz 2006). They are more resistant to biotic and abiotic disturbances (Knoke et al. 2008), more efficient in using available sources of space, light and nutrients (Rothe, Binkley 2001), they provide diverse habitats for wildlife (Honnay et al. 1998, 1999). They also tend to be more aesthetically pleasing (Guldin 1996; Liang et al. 2007), which enhances their recreational values (Lawesson 2004). Hence, such forests provide multiple non-timber benefits that justify their promotion from the ecological point of view.

However, demands for timber and timber products are often considered to be in conflict with demands to maintain biodiversity and ecosystem processes (Fox et al. 2006), although some works indicated the contrary. For example, Liang et al. (2007) reported that stands with a higher species and structural diversity also contained a higher percentage of high-quality timber. Nevertheless, economic evaluation of the shift towards ecologically more feasible forests is still rare (Knoke et al.

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2008). Forest production research has mostly dealt with the effect of species and structural diversity on productivity (e.g. Pretzsch 2005; Lei et al. 2009; Long, Shaw 2010; Belote et al. 2011; Wang et al. 2011). Although productivity and assortment structure are closely interconnected, higher productivity does not necessarily generate better timber quality. The quantity and quality of wood assortments that can be obtained from a forest depend on the tree habitus and the occurrence of timber faults (Prka 2012). Thus, the assortments produced from the trees of the same dimensions may differ in their quality (Prka 2012) due to stand characteristics such as density (Liang et al. 2007), and species or structural diversity.

Therefore, the goal of this study was to analyse the relationships between the indicators of tree species and structural diversity and the quality of timber production in Central European forest stands. We searched for the answers to the following questions: (1) how is the quality of timber production influenced by stand diversity?; (2) is the effect of diversity on the quality of timber production constant over time and stand development or does it change with stand age and stand structure?

MATERIAL AND METHODS

The data used in this study were collected during a regional forest inventory of the University Forest Enterprise "Kostelec nad Černými lesy" of the Czech University of Life Sciences (Fig. 1). The total area of the enterprise is 6,581 ha, 95.4% of which is covered with forests. The elevation ranges from 220 to 560 m a.s.l. The average length of the growing season is 153 days. Mean annual temperature varies from 7 to 7.5°C, mean temperature in the growing season ranges between 13 and 13.8°C. Mean annual precipitation fluctuates from 600 to 650 mm. Five forest altitudinal zones as defined by Zlatník (1976) occur within the

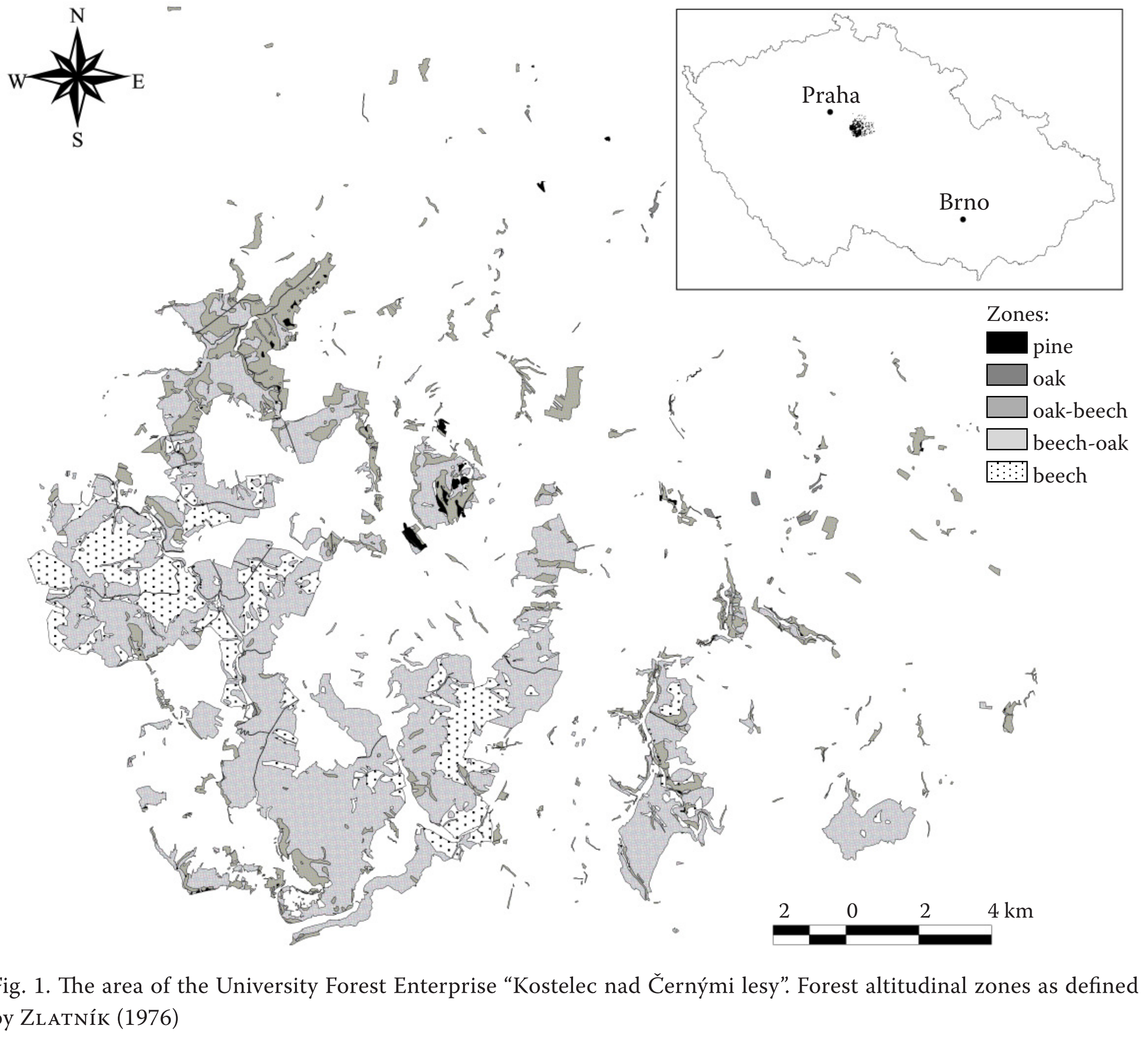

Fig. 1. The area of the University Forest Enterprise "Kostelec nad Černými lesy". Forest altitudinal zones as defined by Zlatník (1976)

enterprise: pine zone (0.8%), oak zone (0.5%), oak-beech zone (18.6%), beech-oak zone (61.5%) and beech zone (18.5%).

Forest inventory was performed from 2009 to 2011 using a stratification sampling design. The area of the enterprise was stratified on the basis of three variables: site (5 categories), stand age (12 categories) and canopy cover (5 categories) in order to ensure that the whole gradient of ecological conditions and stand development would be covered in the data. The suitability of the applied stratification design for these purposes was confirmed by the validation analysis of the inventory data (Merganič et al. 2012).

In total, 1,188 inventory sample plots were established in 86 strata. The sample plots were of circular shape with an area of 500 m^2. On each plot approximately 100 variables describing site conditions (e.g. slope, aspect, soil moisture), stand development (e.g. canopy cover, level of tree aggregation and mixture) and tree status (e.g. tree species, tree diameter at breast height, tree height, stem quality, health condition) were assessed. For further analyses, trees were divided into three groups: (1) young trees with diameter at breast height below 7 cm (hereinafter as ML); (2) old trees with diameter at breast height above 7 cm (hereinafter as ST); (3) all trees, i.e. young and old trees together (hereinafter as SP). Overall, 29 tree species were identified within the inventory. Norway spruce (*Picea abies* L. Karst.) was the most common tree species in both young and old stands (26% and 53% calculated from the number of young trees and stand volume of old trees, respectively).

Biodiversity was quantified by the following basic indicators that describe species and structural diversity: (*i*) indices of species richness: N0 (Hill 1973), R1 (Margalef 1958), R2 (Menhinick 1964); (*ii*) indices of species evenness: BP (Berger, Parker 1970), E1 (Pielou 1975, 1977), E3 (Heip 1974), E5 (Hill 1973), D (McIntosh 1967); (*iii*) indices of species heterogeneity: Si (Simpson 1949), H (Shannon, Weaver 1949), HB (Brillouin 1956); (*iv*) indices of similarity: QS (Sørensen 1948), BC (Bray, Curtis 1957), ED – Euclidian distance, BUB (Baroni-Urbani, Buser 1976), Y (Boyce 2003), DF – Canberra distance (Lance, Williams 1966), PS – proportional similarity (Czekanowski 1909); (*v*) other indicators: absolute and relative range of tree heights, species aggregation and mixture assessed in the field, volume of fine and coarse woody debris on a plot, number of vertical layers according to Zlatník (1976), number of shrub species, number of moss and lichen species.

Indicators of species diversity were calculated for the above-mentioned three groups of trees. Structural diversity indicators were quantified for the group of all trees only. If possible, the indicators were calculated using one of the four stand parameters: total number of trees, sum of tree heights, average tree height and total growth area. Partial biodiversity indicators were defined by combining basic indicators with groups of trees, and stand parameters. For example, from the basic indicator H, which is an index of species heterogeneity (Shannon, Weaver 1949), 12 different partial indicators were derived, because this index could be calculated for each of the three groups of trees and four stand parameters (3 × 4 = 12). The abbreviation of each partial indicator is composed of three parts, where the first part represents the basic diversity indicator, the second part indicates the group of trees, and the third part represents the stand parameter from which the indicator was calculated. An example of a partial indicator is H_ML_Nr, i.e. it is H index of species heterogeneity (Shannon, Weaver 1949) that was calculated for young trees with diameter below 7 cm (ML), while tree species composition was derived from tree number (Nr). In total, 171 partial biodiversity indicators were quantified on every plot.

Tree volume was calculated according to Petráš and Pajtík (1991). Wood assortment was performed using assortment tables of Petráš and Nociar (1990, 1991) that quantify the proportion of six different quality assortment classes from high quality assortments to fuel wood. For the purposes of this study, six quality assortment classes defined in tables were aggregated to four assortment classes as follows: (1) timber of the highest quality used for veneer, musical instruments, sport equipment, and barrels; (2) timber of high quality used for construction purposes (sawn timber); (3) construction sawn timber of lower quality; (4) pulp wood and fuel wood. Four indicators of the quality of timber production (QTP) were quantified for each sample plot as volumetric proportions of each of the four timber quality classes, i.e. as the ratio between the volume of wood in a particular timber quality class and the total volume of wood on a sample plot.

The relationship between QTP and diversity indicators (DI) in each stratum was examined using a univariate linear regression, below as Eq. (1):

$$QTP = a + b \times DI \quad (1)$$

where:
a, b – regression coefficients of the linear regression.

In total, 58,824 linear regressions (86 strata × 4 indicators of the quality of timber production × 171 diversity indicators) were derived for each combination of stratum, diversity and quality indicators. This was performed in order to test the hypothesis if the trend and the strength of the relationship change in individual strata due to different ecological conditions and stand development.

Correlations coefficients of the derived linear regressions were statistically tested by Student's *t*-test to identify their significance at 95% significance level. The null hypothesis was that the correlation coefficient of the regression is equal to zero. The frequency of significant relationships ($P \leq 0.05$) from all analysed relationships was calculated and the average correlation coefficient of significant relationships was determined for each diversity indicator. In order to analyse the overall influence of the diversity indicator on the quality of timber production, the absolute values of correlation coefficients of each diversity indicator in all strata were summed up. The diversity indicators were ranked with regard to the calculated sum in descending order to identify the indicators with the highest correlations to the quality of timber production. A similar approach was applied by Holubec and Halounová (2015).

The selected diversity indicators were analysed on the basis of the calculated averages and sums of correlation coefficients, the frequency and the trend of significant relationships. This was performed first for the whole data set, and then for the four categories of QTP as defined above, and four age classes (young, middle-aged, old, and uneven-aged stands). Young stands were all stands with the mean age below 40 years, middle-aged stands were aged between 40 and 100 years, and the stands older than 100 years were considered old stands. Stands were classified as uneven-aged stands if the crown cover of young trees with diameter below 7 cm exceeded 30%. From 86 strata, young, middle-aged, old, and uneven-aged stands were in 24, 30, 21 and 11 strata, respectively.

RESULTS

The analysis of the relationship between diversity indicators and quality of timber production revealed that the average values of correlation coefficient did not exceed 0.4. Out of the total of 58,824 analysed regressions, 7,413 (12.6%) relationships were significant. The occurrence of species and structural diversity indicators in significant correlations with QTP was balanced with only a slight prevalence of species diversity indicators (53%). The mean correlation coefficient of significant relationships of the first ten diversity indicators with the highest correlation with timber quality fluctuated around 0.6 (0.58–0.65, Fig. 2). The highest average correlation coefficient and the highest frequency (27.3%) of significant relationships were found for R2 Menhinick species richness index that integrates the effect of stand density and number of species. Among the first ten diversity indicators, only one indicator was structural (Euclidean distance ED1, Fig. 2). Three species diversity indicators represented species richness (R2, R1, N0), while evenness and heterogeneity were represented by 2 (BP, D) and 4 (2× Si, H, HB) indicators, respectively. All nine species diversity indicators were calculated for a group of old trees with diameter at breast height above 7 cm.

Next, we analysed the correlations inside the groups of individual indicators of the quality of timber production. We found that R2 Menhinick species richness index was a diversity indicator with the highest correlation with each indicator of the quality of timber production (Fig. 3a). The highest quality of timber production (QTP1) was predominantly correlated with species diversity indicators, as all first five indicators represented species diversity. In lower qualities of timber production, structural diversity indicators also occurred among the first five ones (Fig. 3a). The second and third indicators of the quality of timber production (QTP2 and QTP3) were significantly correlated with Euclidean distance ED1, the structural index quantifying similarity between old and young trees, here in the sums of tree heights. In the case of the lowest quality of timber production (QTP4), the range of tree heights of all trees calculated as a difference between maximum and minimum tree height (Var_SP_Ha) was the structural index ranked among the first five diversity indicators with the highest correlation with QTP (Fig. 3a).

The analysis of the correlations within the individual age categories revealed that the set of the first five diversity indicators with the highest correlations with indicators of the quality of timber production comprised both species and structural indicators, although the actual indicators differed between the categories (Fig. 3b). The greatest similarities were revealed between the groups of middle-aged and old stands, for which the same three basic indicators were ranked among the top five indicators: ED1 Euclidean distance (ranked first in both age categories), E1 Pielou index of species evenness, and E3 Heip index of species evenness (Fig. 3b).

However, E1 and E3 indices were derived for each of the two groups from different data sets: in the case of middle-aged stands, they were calculated for a group of all trees on the basis of the species composition derived from the relative tree height, while in the case of old trees, indices were calculated for the group of old

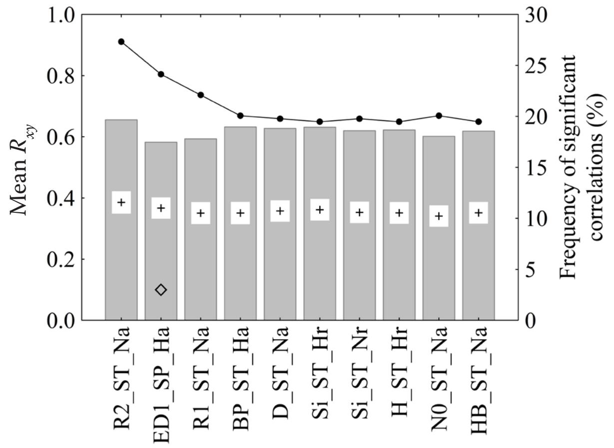

Fig. 2. Top ten diversity indicators with the highest correlation with the quality of timber production in the study area

black circle – percentage of significant correlations of the diversity indicator with the quality of timber production, grey bar – average value of correlation coefficient R_{xy} calculated from significant correlations of a particular diversity indicator, white rectangle – 95% confidence interval of the average value of correlation coefficient R_{xy} calculated from all correlations derived for a particular diversity indicator, black dagger – average value of correlation coefficient R_{xy} calculated from all correlations derived for a particular diversity indicator, black diamond – structural indicator of diversity, BP_ST_Ha – BP index of species evenness (Berger, Parker 1970) calculated from the sum of tree heights of trees with diameter above 7 cm, D_ST_Na – D index of species evenness (McIntosh 1967) of trees with diameter above 7 cm calculated from the number of trees, ED1_SP_Ha – ED1 index of similarity (absolute Euclidean distance) between the trees with diameter below 7 cm and the trees with diameter above 7 cm calculated from the sum of tree heights per species, H_ST_Hr – H index of species heterogeneity (Shannon, Weaver 1949) of trees with diameter above 7 cm, while the species composition was derived from the sum of tree heights, HB_ST_Na – HB index of species heterogeneity (Brillouin 1956) of trees with diameter above 7 cm, N0_ST_Na – N0 index of species richness (Hill 1973) of trees with diameter above 7 cm, R1_ST_Na – R1 index of species richness (Margalef 1958) of trees with diameter above 7 cm, R2_ST_Na – R2 index of species richness (Menhinick 1964) of trees with diameter above 7 cm, Si_ST_Hr – Si index of species heterogeneity (Simpson 1949) of trees with diameter above 7 cm, while the species composition was derived from the sum of tree heights, Si_ST_Nr – Si index of species heterogeneity (Simpson 1949) of trees with diameter above 7 cm, while the species composition was derived from the number of trees

trees only using the species composition derived from relative growth area (Fig. 3b). In middle-aged stands, four species indicators and one structural indicator were ranked among the first five indicators with the highest correlation with QTP. In old stands, two structural indicators were among the first five indicators. In young and uneven-aged stands, one species diversity indicator and four structural diversity indicators were ranked first, while their types and their order differed between the age categories (Fig. 3b). R2 Menhinick species richness index was ranked among the five species diversity indicators with the highest correlation with the quality of timber production in young and middle-aged stands (Fig. 3b). In the category of uneven-aged stands, the structural indicators were Bray-Curtis index of similarity (BC2) and Canberra index of similarity (DF1) between young and old trees (i.e. trees with diameter below 7 cm and above 7 cm, respectively) calculated from the average tree heights of species, and the ratios of the number of trees with diameter below 7 cm to the number of trees above 7 cm or vice versa (PmM and PmS, respectively). In the category of uneven-aged stands, the only species diversity indicator ranked among the first five indicators was Simpson index of species heterogeneity (Si). This index was among the five most closely correlated with QTP also in the category of old stands (Fig. 3b).

In the next step we analysed the trend of the relationship between particular species or structural diversity indicators to the quality of timber production. Fig. 4 shows the trend for one species and one structural indicator and the best quality of timber production (QTP1) in individual age categories. From the graphs we can see that both species and structural diversity have a positive impact on the proportion of high-quality assortments. Only in the case of young stands, the proportion of best-quality assortments was slightly decreasing with the increasing number of tree layers in stands (Fig. 4b).

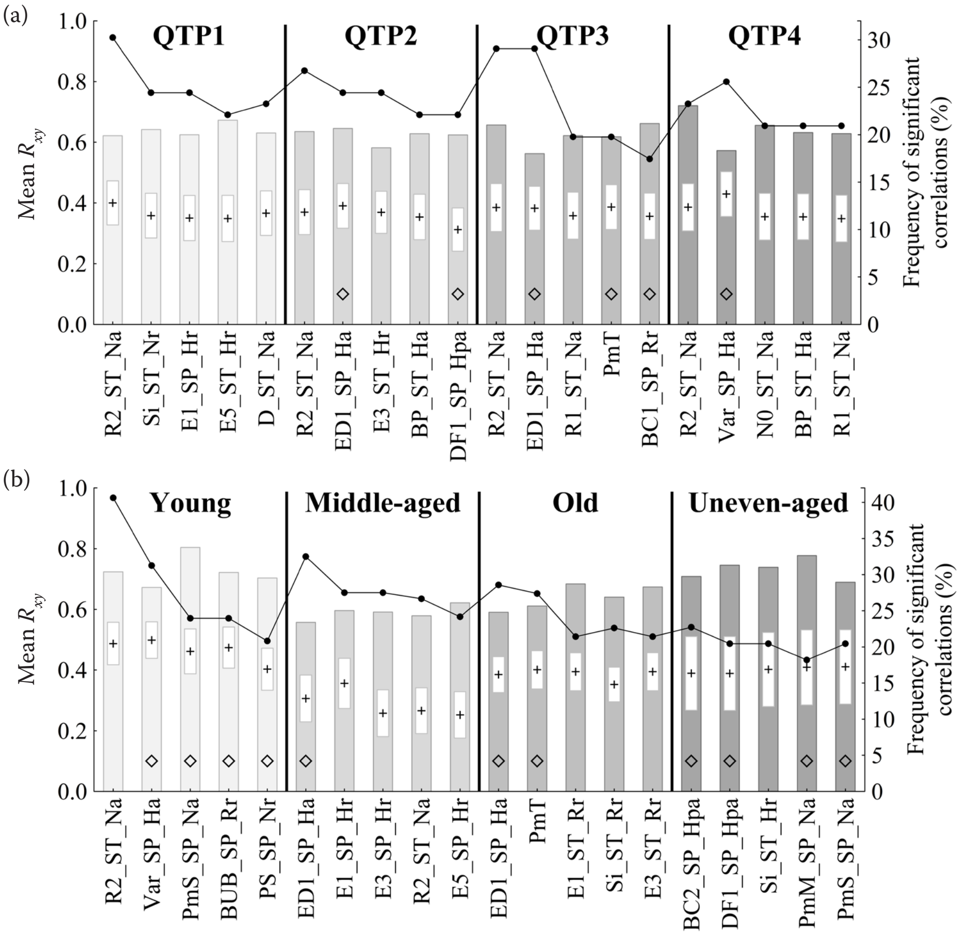

Fig. 3. Top five diversity indicators with the highest correlation: with individual qualities of timber production (a), with individual age categories (b) with the study area

QTP – indicator of the quality of timber production, QTP1 – best-quality timber, QTP2, QTP3 – sawn timber of higher and lower quality, QTP4 – pulp and fuel wood, black circle – percentage of significant correlations of the diversity indicator with the quality of timber production, grey bar – average value of correlation coefficient R_{xy} calculated from significant correlations of a particular diversity indicator, white rectangle – 95% confidence interval of the average value of correlation coefficient R_{xy} calculated from all correlations derived for a particular diversity indicator, black dagger – average value of correlation coefficient R_{xy} calculated from all correlations derived for a particular diversity indicator, black diamond – structural indicator of diversity, BC1_SP_Rr – BC1 index of similarity (Bray, Curtis 1957) between the trees with diameter below 7 cm and the trees with diameter above 7 cm, while the species composition was derived from the growth area, BC2_SP_Hpa – BC2 index of similarity (Bray, Curtis 1957) between the trees with diameter below 7 cm and the trees with diameter above 7 cm calculated from the average tree heights of species, BP_ST_Ha – BP index of species evenness (Berger, Parker 1970) calculated from the sum of tree heights of trees with diameter above 7 cm, BUB_SP_Rr – BUB index of similarity (Baroni-Urbani, Buser 1976) between the trees with diameter below 7 cm and the trees with diameter above 7 cm, while the species composition was derived from the growth area, D_ST_Na – D index of species evenness (McIntosh 1967) of trees with diameter above 7 cm, DF1_SP_Hpa – DF1 index of similarity (Canberra distance) (Lance, Williams 1966) between the trees with diameter below 7 cm and the trees with diameter above 7 cm calculated from the average tree heights of species, E1_SP_Hr – E1 index of species evenness (Pielou 1975, 1977) of all trees, while the species composition was derived from the sum of tree heights, E1_ST_Rr – E1 index of species evenness (Pielou 1975, 1977) of trees with diameter above 7 cm, while the species composition was derived from the growth area, E3_SP_Hr – E3 index of species evenness (Heip 1974) of all trees, while the species composition was derived from the sum of tree heights, E3_ST_Hr – E3 index of species evenness (Heip 1974) of trees with diameter above 7 cm, while the species composition was derived from the sum of tree heights, E3_ST_Rr – E3 index of species evenness (Heip 1974) of trees with diameter above 7 cm, while the species composition was derived from the growth area, E5_SP_Hr – E5 index of species evenness (Hill 1973) of all trees, while the species composition was derived from the sum of tree heights, E5_ST_Hr – E5 index of species evenness (Hill 1973) of trees with diameter above 7 cm, while the species composition was derived from the sum of tree heights, ED1_SP_Ha

Fig. 3. to be continued

– ED1 index of similarity (absolute Euclidean distance) between the trees with diameter below 7 cm and the trees with diameter above 7 cm calculated from the sum of tree heights per species, N0_ST_Na – N0 index of species richness (Hill 1973) of trees with diameter above 7 cm, PmM_SP_Na – ratio between the number of trees with diameter below 7 cm and the number of trees with diameter above 7 cm, PmS_SP_Na – ratio between the number of trees with diameter above 7 cm and the number of trees with diameter below 7 cm, PmT – ratio of the volume of fine woody debris to the volume of coarse woody debris, PS_SP_Nr – PS index of similarity (proportional similarity) (Czekanowski 1909) between the trees with diameter below 7 cm and the trees with diameter above 7 cm, while the species composition was derived from the number of trees, R1_ST_Na – R1 index of species richness (Margalef 1958) of trees with diameter above 7 cm, R2_ST_Na – R2 index of species richness (Menhinick 1964) of trees with diameter above 7 cm, Si_ST_Hr – Si index of species heterogeneity (Simpson 1949) of trees with diameter above 7 cm, while the species composition was derived from the sum of tree heights, Si_ST_Nr – Si index of species heterogeneity (Simpson 1949) of trees with diameter above 7 cm, while the species composition was derived from the tree number, Si_ST_Rr – Si index of species heterogeneity (Simpson 1949) of trees with diameter above 7 cm, while the species composition was derived from the growth area, Var_SP_Ha – absolute range of tree heights

DISCUSSION

Stand assortment structure is influenced by a combination of several factors including site conditions (Danilović 2006), silvicultural measures (Danilović 2008; Prka, Krpan 2010), stand density, spatial distribution of trees, species composition (Liang et al. 2007), and diversity of tree habitus (Prka 2012). The results of our analysis confirmed that the quality of timber production is a result of multiple relations because the explanatory power of the univariate linear regressions was low (the average significant correlation coefficients did not exceed 0.7, Fig. 2). Moreover, the analysis also revealed that there was no supreme diversity indicator that could be preferred over others, as the number of different species and structural diversity indicators were significantly correlated with quality indicators (Figs 2 and 3). The R2 Menhinick species richness index that integrates the effect of stand density and species richness occurred seven times among the best indicators, while six times it was ranked first. From structural indicators, Euclidean distance ED1, i.e. a structural index of similarity, was most frequent among the best diversity indicators: it occurred five times (Figs 2 and 3). Similarly, Simpson index of species heterogeneity (Si), which is frequently applied in forestry studies (Pretzsch 1996; Lexerod, Eid 2006; Pretzsch 2009; Zhou et al. 2009; Duduman 2011), also occurred five times among the best diversity indicators. On the contrary, the number of species – N0 index as the most commonly used diversity measure, occurred only twice among the indicators with the highest correlation with quality indicators (Figs 2 and 3). Three other species diversity indicators, i.e. Pielou and Heip indices of evenness (E1 and E3), and Margalef index of species richness (R1) were also more frequent species diversity indicators than the number of species. These results indicate that the

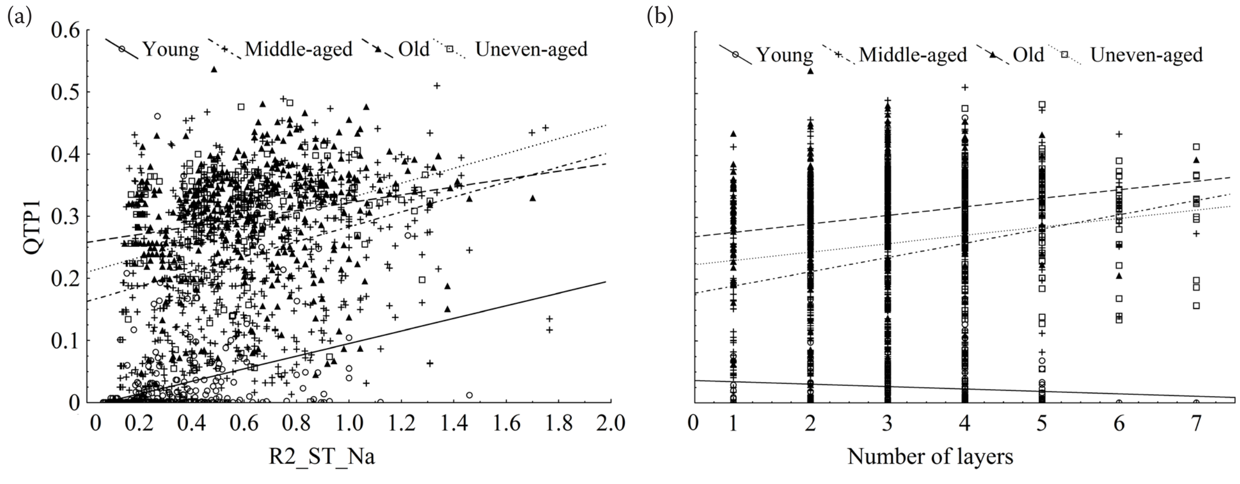

Fig. 4. Correlation of the best-quality timber proportion (QTP1) with R2 Menhinick index of species richness of trees with diameter above 7 cm (a), number of vertical tree layers (b) according to Zlatník (1976) in individual age categories of stands

number of species itself is not a satisfactory indicator, because it does not account for other diversity elements, e.g. species evenness, heterogeneity, and structural diversity. Thus, in order to obtain complex information about ecosystem properties, other metrics of biodiversity than species richness should also be included (Hooper 2014). From the mathematical point of view, the effect of the number of species is included in the above-mentioned species diversity indicators together with other diversity elements.

As seen in Figs 2 and 3a, all species diversity indicators ranked among the first indicators were calculated for a group of old trees, i.e. trees with diameter at breast height above 7 cm. This group of trees is principal for timber production at the actual time. Young trees with diameter at breast height below 7 cm represent the prospective state of forest ecosystems. Their impact on timber quality was found only in the case of middle-aged stands, for which three out of four species diversity indicators ranked among the top five indicators were calculated from the group of all trees (Fig. 3b).

The results of individual age categories indicate that the impact of diversity on timber quality changes with stand age. In young stands (younger than 40 years), structural diversity influences the quality of timber production more, while in middle-aged and old stands the species diversity has a more profound effect on the quality of timber production. In uneven-aged stands, structural diversity seems to be more important for timber quality production than species diversity (Fig. 3b).

The analysis of the trend in the relationship between diversity and the quality of timber production revealed a positive effect of species diversity on the proportion of high quality assortments (QTP1) in all examined age categories (Fig. 4a). This is in accordance with Liang et al. (2007), who found that the proportion of peeler logs was positively correlated with species diversity. This finding can help to promote mixed forest stands in spite of the fact that the yield of mixtures may not always reach the yields of pure stands (Knoke et al. 2008). According to Pretzsch (2012), species composition is the driving parameter that affects the productivity of mixed stands.

The impact of structural diversity seems to be more complex, because in some cases structural indicators showed a positive relationship to high-quality timber assortments, while in other cases the trend was negative (Fig. 4b). After a more detailed analysis of the applied structural indicators we concluded that the selected indices of similarity, e.g. Euclidean distance, do not describe the forest structure to its full extent, but rather quantify differences between the two stand parts, in our case young and old trees. Due to this, we analysed the trend between the quality of timber production and structural diversity using a simple indicator represented by the number of tree layers (Fig. 4b), although this indicator was not ranked among those with the highest correlation with the quality of timber production. We found that in uneven-aged stands and even-aged stands older than 40 years, the proportion of high-quality assortments is greater than in the stands with the greater number of tree layers (Fig. 4b). However, in stands younger than 40 years, the relationship was negative (Fig. 4b). This can be influenced by the fact that the proportion of high-quality assortments is lower in young stands due to their small dimensions. Moreover, the results may also be influenced by a greater error of timber quality estimates in young stands. Since the structure of a forest is the result of natural processes and human disturbances that include forest management practices, such as thinnings, fellings, and plantings (Gadow et al. 2012), the negative trend of the percentage of high-quality assortment with increasing structural diversity may also be caused by the applied silvicultural treatments.

To conclude we can say that the results of the present study indicate that stand diversity and quality of timber production are not in conflict with each other. Hence, promoting diversified stands both from species and structural points of view may enhance the economic value of the final timber products at the same time. According to our knowledge, there is a lack of similar studies dealing with the relationship between the quality of timber production and diversity. However, considering modern forestry concepts aimed at sustainable development and utilisation of forest resources, such studies are highly valuable as they can provide us with objective information that can modify or support the applied forest management.

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