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Projected effects of climate change on the carbon stocks of European beech (*Fagus sylvatica* L.) forests in Zala County, Hungary

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Abstract
Recent studies suggest that climate change will lead to the local extinction of many tree species from large areas during this century, affecting the functioning and ecosystem services of many forests. This study reports on projected carbon losses due to the assumed local climate change-driven extinction of European beech (*Fagus sylvatica* L.) from Zala County, South-Western Hungary, where the species grows at the xeric limit of its distribution. The losses were calculated as a difference between carbon stocks in climate change scenarios assuming an exponentially increasing forest decline over time, and those in a baseline scenario assuming no climate change. In the climate change scenarios, three different sets of forest management adaptation measures were studied: (1) only harvesting damaged stands, (2) additionally salvaging dead trees that died due to climate change, and (3) replacing, at an increasing rate over time, beech with sessile oak (*Quercus petraea* Matt. Lieb.) after final harvest. Projections were made using the open access carbon accounting model CASMOFOR based on modeling or assuming effects of climate change on mortality, tree growth, root-to-shoot ratio and decomposition rates. Results demonstrate that, if beech disappears from the region as projected by the end of the century, over 80% of above-ground biomass carbon, and over 60% of the carbon stocks of all pools (excluding soils) of the forests will be lost by 2100. Such emission rates on large areas may have a discernible positive feedback on climate change, and can only partially be offset by the forest management adaptation measures.

Key words: climate change; mortality; silviculture; forest carbon balance; European beech

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Introduction

Climate change has been repeatedly shown to be unequivocal, and it continues globally at unprecedented rates and with already observed widespread and consequential effects (IPCC 2013, 2014a). Evidence on observed impacts as well as projections of potential effects of climate change on terrestrial ecosystems are mounting (e.g., Allen et al. 2010; Lindner et al. 2010; Vayreda et al. 2012; IPCC 2014a; Lindner et al. 2014) suggesting significant vulnerability of forest ecosystems.

The effects of climate change at the species level are closely related to the fact that, compared with herbs and animals, the maximum speed of trees to move in order to follow climatic changes is much lower than the average climate change velocity (IPCC 2014a). Over time, this may lead to large-scale dieback (Thuiller et al. 2011; Hanewinkel 2012), and even species displacement (Millennium Ecosystem Assessment 2005). While changes in regional temperature and precipitation patterns may also create better growing conditions for forest ecosystems in large areas (Lindner et al. 2010, 2014), the local extinction of certain species from severely affected areas may lead to large losses of carbon and associated emissions of CO_2.

The issue of large-scale displacement of habitat suitability was recently analyzed by studies showing that climate change sensitivity of 38 European tree species in Europe is rather complex and has significantly different patterns over climatic (temperature and precipitation), geographic and temporal (e.g. winter vs summer) dimensions (Zimmermann et al. 2013a). The range of species such as beech (*Fagus sylvatica* L.) and Norway spruce (*Picea abies* L.) is likely to shrink, sometimes dramatically. More drought-tolerant species such as Sessile oak (*Quercus petraea* (Matt.) Liebl) can, however, be expected to become more abundant (at least at lower altitudes, Zimmermann et al. 2013b). Species displacement and local extinction may also depend on pre-climate change conditions, weather extremes and an increase in climate variability, resulting in even more severe extremes (Zimmermann et al. 2009). Such extremes have also been shown to affect the health status of forests (e.g. Jung 2009).

One of the countries of Europe where local extinction might become a serious problem is Hungary where, until recently, the mean annual temperature was about 10 – 11 °C and the mean annual precipitation was about 500 – 750 mm which already represented a limiting factor for many tree species. These species, including beech and sessile oak, occur at the xeric limit of their distribution (Mátyás et al. 2010; Czúcz et al. 2011). Additional climatic vulnerability due to climate change is expected to be more expressed in Hungary than in many parts of Europe as the increase of regional mean temperature is projected to be 1.4 °C relative to each 1 °C of global temperature increase, whereas precipitation is projected to considerably decrease in summer and increase in winter (Bartholy et al. 2007, 2014). The level of tree mortality has so far been low, mainly expressed by a density-related self-thinning, and extreme weather events such as ice-breaks,

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snow-breaks and windbreaks (Hirka 2013) and droughts (Jung 2009) were small scale only.

This situation may, however, be dramatically changed under recent assumptions concerning possible rates of global and regional warming. The results of the REMO regional climate model simulations (Jacob et al. 2007) suggest that mean temperature will increase by 3.7 °C by 2100 relative to the average of 1961–1990. If this temperature increase will take place, trees will have to stand repeated and increasing drought and heat stress. Beyond certain levels of warming, however, an increasingly occurring tree mortality, referred to below as extinction mortality, may affect the Hungarian forests, potentially leading to the extinction of several or many species from certain sites. Czúcz (2011), Móricz et al. (2013), Rasztovics (2014) and others have recently projected that beech forests will almost entirely disappear from Hungary by the end of the century, whereas sessile oak will only be found along the southwest border of the country and in higher mountain regions.

Extinction mortality may lead to carbon-dioxide emissions first from the biomass, and later also from other pools of the affected forests. Such large emissions due to various disturbances have already been shown to be a serious problems if it occurs on a large scale (e.g., Kurz et al. 2008; Seidl et al. 2014).This study is an attempt to project forest carbon stock changes due to climate change-induced mass mortality of trees. Based on the projected forest decline by 2100 by Móricz et al. (2013), extinction mortality, the expected main driver of future carbon emissions, was assumed to increase exponentially for the beech forests of the Zala County, South-Western Hungary, for the period from 2015 to 2100. Using models or assumptions, the effects of climate changes on tree growth, root-to-shoot ratio, and decay rates were estimated, too. Finally, the effect of forest management options such as species replacement and harvesting was also estimated in forest management adaptation scenarios. The projections were developed using the open access carbon accounting model CASMOFOR.

2. Methods

2.1. Study area

With its forest area of 114,602 ha, the hilly (200 – 400 m a.s.l) Zala County located in south-western Hungary (Fig. 1) has the highest forest cover (32%) in the country. The native beech is well adapted to both local pre-climate change site conditions (Table 1) and predominantly deep forest soils. However, considering the climate envelope of beech in Europe using long term (1950–2000) climatic average of annual precipitation and mean July temperature (Mátyás et al. 2010), this species is close to its xeric limits in the Zala County. The mass mortality event of 2003–2004 which followed the drought period from 2000 to 2004 in the region was also taken as an indication of the existence of these limits (Lakatos & Molnár 2009; Mátyás et al. 2010). Nevertheless, similar symptoms were also recorded in the eastern part of the Carpathian basin in the 1880s (Lakatos & Molnár 2009).

The area of all 6406 pure and beech dominated forest stands in the County, identified by the nation-wide stand-wise continuous forest inventory, shows relatively large uneven distributions by both age and yield class (Fig. 2). The yield class of a stand was taken from standard local yield tables (Mendlik 1983) based on the age and the measured mean stand height of the stands. These yield tables employ six yield classes of equal height differences where class 1 is

Table 1. Ranges of key climatic data in the Zala county (mean values for 1981–2010 based on data of the Hungarian Met. Office, Gálos & Vigh 2014).

Climate characteristics	Value for months				
	I–XII	I	IV–IX	VII	X–III
Mean temperature [°C]	9.8 – 11.0	−0.9 – 0.2	16.2 – 17.6	19.6 – 21.2	3.4 – 4.5
Total precipitation [mm]	611 – 770	27 – 34	363 – 472	75 – 94	248 – 301

Fig. 1. The forests of Zala County as situated in the county map of Hungary (Source: National Forestry Database).

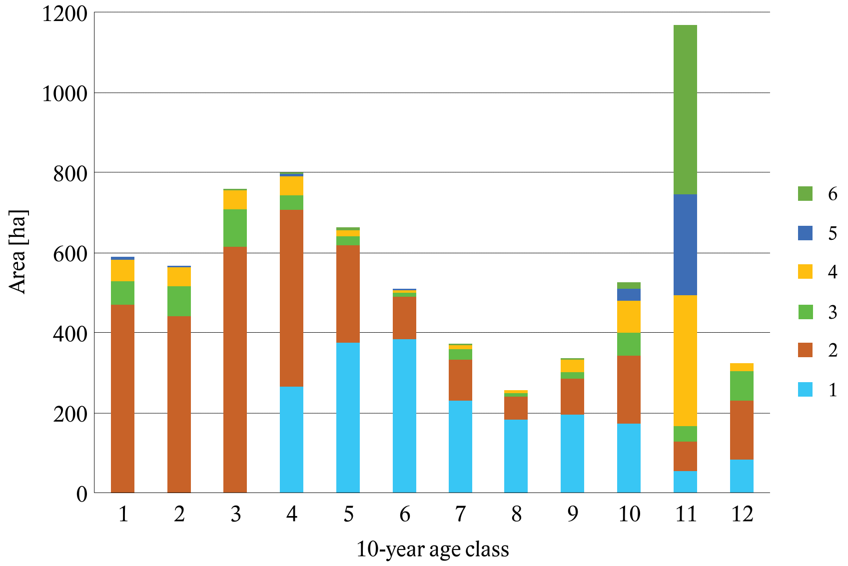

Fig. 2. The area of beech forests in the Zala County in 2012 in 10-year age classes and six yield classes. Yield class, shown on the right, ranges from 1 for the fastest growing stands to 6 for the slowest growing stands. (Source: National Forestry Database by the Forestry Directorate of the National Food Chain Safety Office, Budapest.)

assigned to the fastest and class 6 is assigned to the slowest growing stands, respectively. All forests in both the Zala County and the entire country have been rather intensively managed for several centuries.

2.2. Modelling framework

This study estimates using model CASMOFOR (see below) how much the carbon storage will change in the study area (i.e., the entire area that was covered by beech in Zala County in 2012) due to forest decline and other effects of climate change. Annual changes of carbon stocks were calculated as differences between carbon stocks projected for a baseline (BL) scenario assuming a stable climate (left box in Fig. 3) and those projected for climate change scenarios (right box in Fig. 3, see also below). For all climate change scenarios, extinction mortality rates based on the projection of Móricz et al. (2013) were used. The differences were calculated for the period 2015–2100.

Carbon stocks in each scenario were estimated using the open access forest carbon accounting model CASMOFOR (Somogyi 2010, www.scientia.hu/casmofor). This model is an MS Excel based system of carbon accounting functions which was mainly designed to estimate, by yield class and species, carbon stocks in annual steps as a function of forest

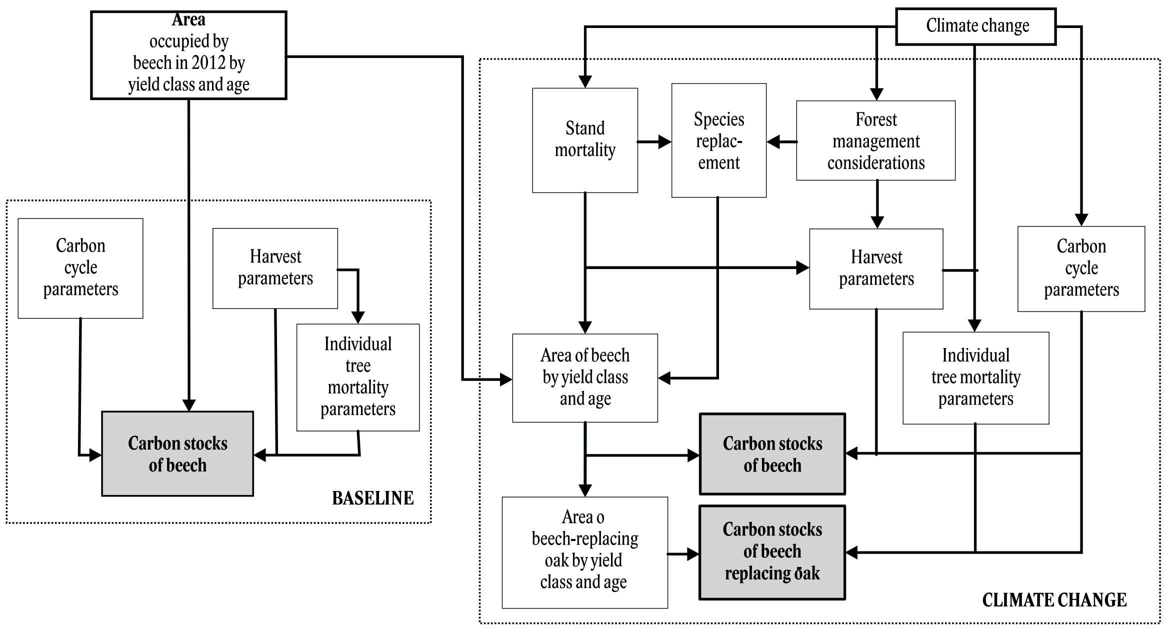

Fig. 3. The scheme of estimating changes of carbon stocks due to climate change as the difference between projected carbon stocks of beech in a baseline scenario (left box) and those of beech and oak in a climate change scenario (right box) for the area that was covered by beech in Zala County in 2012. “Parameters” are those applied in model CASMOFOR (see below).

area and age class structure. Estimates are developed for the forest carbon pools defined by IPCC (2006) based on their respective dynamics. For biomass, the gain-loss method by IPCC (2006) is used. Tree growth is modelled using standard yield tables, whereas thinning and density-dependent mortality (i.e., self-thinning) are modelled using country-level silvicultural models. The dead organic pools are modelled using exponential decay functions. The harvested wood products (HWP) pool is modeled based on the latest methodological guidance by IPCC (2014b). Soils are excluded from this analysis due to knowledge gaps. The model, together with its accounting functions (accessible at http://www.scientia.hu/casmofor/equationsE.php) as well as the parameters used for 19 species of the country (mainly age-dependent data in yield tables and silvicultural models, http://www.scientia.hu/casmofor/creditsE.php, and age-independent ones, (http://www.scientia.hu/casmofor/parametersE.php#flowchart), are described in detail at www.scientia.hu/casmofor.

2.3. Extinction mortality

Mortality (both density-dependent and density-independent) under the current ("no climate change") site conditions is included in the silvicultural models. To develop rates for the expected extinction mortality, the rather strong correlation between the current distribution of the tree species and climatic factors was considered. This correlation is modelled in the forestry practice in Hungary by applying four forest climatic types (Borhidi 1960; Járó 1966; Mátyás & Czimber 2004) that were identified by the dominant occurrence of respective indicator species. These climate types can also be characterized by historical temperature and precipitation data (Table 2), but the occurrence of climate types is also affected by local site factors such as soil type, aspect, hydrological conditions and others.

The above system of climate types indicates that, in general, and subject to variability due to other factors mentioned above, mean annual temperature differences of about 1 °C together with differences of precipitation of about 50 mm are enough in the long term for different tree species to become dominant in the different climate types and disappear from others. As the projected warming of the mean July temperature of about 3.7 °C during this century (Jacobs et al. 2007 is several times the difference between adjacent climate types, it is reasonable to expect this warming to cause a shift in the bioclimatic niche. This shift, in terms of temperature, from the current Beech climate type to the Turkey oak or Forest steppe type may even lead to the local extinction of beech from the Zala County especially if also reduced summer precipitation is considered.

Extinction mortality can take many forms and can occur either directly due to droughts or other weather-related effects such as extreme winds, floods etc., or indirectly due to exacerbating biotic agents, forest fires (due to mortality-driven fuel accumulation) and others. Currently, it is not possible to model these events, only assume the final outcome. Czúcz et al. (2011) projected that, as early as 2050, 56 – 99% of present-day beech forests might be outside their present bioclimatic niche, whereas Móricz et al. (2013) projected that most sites will become intolerable for beech by 2100. These projections were based on the results of the REMO regional climate model simulations by Jacob et al. (2001) and Jacob et al. (2007) assuming the A1B IPCC-SRES emission scenario.

Based on these projections, the main assumptions of this study are that (1) extinction mortality of beech will increasingly appear, (2) all beech stands will disappear from Zala country by around the end of the century, and (3) mortality starts and terminates earlier on sites of yield class 6, and later on sites of yield class 1 that have more potentials to support the trees with water. It was also assumed that, at lower intensities, extinction mortality only affects individual trees. This effect could be seen equivalent to a self-thinning so that, up to a certain level, dead trees can be harvested as part of regular thinnings. Stands affected this way do not need to be regenerated, and the remaining trees of these stands continue to grow at least until more severe mortality ensues. This mortality is referred to below as *individual tree mortality*. In contrast, higher rates of mortality that will result in the dieback of entire stands or their part(s) so that they need to be harvested and regenerated (if that is possible at all), will be referred to below as *stand mortality*. The occurrence of this mortality triggers CASMOFOR to simulate the harvesting and regenerating of the area.

Considering all the above, the rate of extinction mortality over time was modelled to increase along yield class-specific exponential curves for both individual mortality (Fig. 4a) and stand mortality (Fig. 4b). Extinction mortality is simulated to occur in each stand each year, irrespectively of the age of the stand, assuming that the causes of mortality may be mostly age-independent. For individual tree-level mortality, it is further assumed that, beyond a threshold of a cumulative mortality of 0.5 relative to the standing volume, individual tree mortality rate is not increased, and any mortality becomes part of stand mortality.

Table 2. Main characteristics of the forest climate types applied in Hungary based on data of the Hungarian Meteorological Office and the forest climatic types as defined by Borhidi (1960), Járó (1966) and Mátyás & Czimber (2004).

Forest climate type	Indicator species	Occurrence of beech	1961–1990 mean annual temperature [°C]	1961–1990 mean annual precipitation [mm]
Beech	European beech	Dominant	6.5 – 8	>700
Oak-hornbeam	Sessile oak and Hornbeam (*Carpinus betulus* L.)	Mixing	8 – 9	650 – 700
Turkey oak	Turkey oak (*Quercus cerris* L.)	Rare	9 – 10	600 – 650
Forest steppe	None	Practically extinct	10 – 11	<600

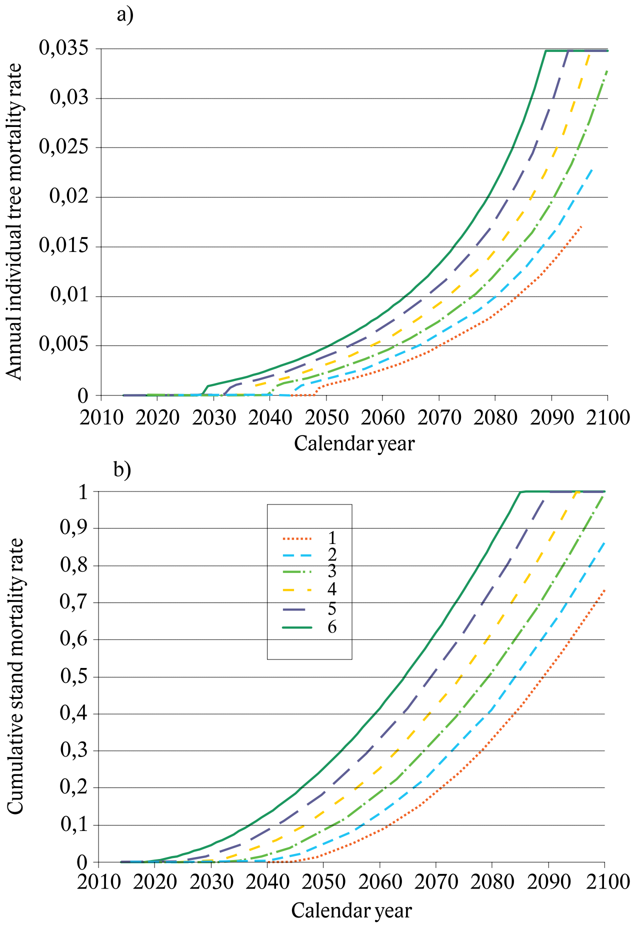

Fig. 4. Assumed (a) annual individual tree and (b) cumulative stand mortality rates in beech stands by yield class (1 is best, 6 is poorest).

2.4. Tree growth, root-to-shoot ratio, and decay of wood and litter

In the baseline scenario, the growth of beech was modelled using the area and yield class of the beech stands as estimated by the National Forest Database for 2012.

In order to estimate volume growth as accurately as possible, the country-level yield tables for beech (by Mendlik 1983) were adjusted by Veperdi (2013) using the local height growth curves over age that were developed from the most recent statistical forest inventory data. First, yield data of Mendlik (1983) was adjusted for each yield class using height values from these local height growth curves and the strong relationship between height and yield as represented in the country-level yield tables. Then, volume growth rates were calculated from the adjusted yield curves. Growth rates for ages not covered by the yield table (i.e., 1 – 10 years) were developed by linear interpolation.

For the estimation of annual volume growth over age, the annual height growth rate was used which was assumed to change over time due to climate change. The expected change was modelled using the evidence by Somogyi (2008a) who showed that, for sites of the same characteristics except for climate type, the mean height of beech stands in the "Beech" and "Turkey oak" climate types at the age of 80 years amounts to 25 m and 18 m (i.e., 0.31 and 0.23 myr^{-1}), respectively. The difference, i.e., 7 m, is attributed to differences between the mean annual temperature of the two above climate types, which is about 2 °C. If such a temperature is to occur by 2100, it might induce a reduction of mean tree height (at the age of 80 years) of a bit over 0.1 m per year. The expected rate of temperature increase will be larger, however, a shift from the Beech climate type to the Turkey oak climate type would also involve a reduction of the annual precipitation of about 100 mm. Considering that no decrease of the total annual precipitation is projected (although summer precipitation is projected to decrease), a slower linear decrease of growth of 0.05 m per year was assumed.

For sessile oak, the country-level yield table by Béky (1981) was used for the entire projection period, assuming that the sites will not deteriorate for this species. As only the yield class of beech is known for forests currently under predominantly beech cover, the yield class of sessile oak (YC_{SO}) had to be estimated from the current yield class of beech (YC_B). This was done using the following regression equation:

$$YC_{SO} = p_1 + p_2 x\, YC_B \qquad [1]$$

The parameters of the equation were estimated using data of stands with each species having a species ratio of at least 33%.

Consistent with empirical studies (e.g., Usoltsev 2001), root-to-shoot ratios in CASMOFOR are larger by 50% for yield classes 5 and 6 than for yield classes 1 and 2 in the baseline scenario. In the climate change scenario, this relationship was used to gradually increase the root-to-shoot ratio of beech under the changing climate scenario as the yield class changes due to growth decline. For oak, consistent with the assumption that its growth will not decline, the ratio was kept constant.

For decay rates for both beech and sessile oak, it is assumed based on available (unpublished) local evidence that they will first gradually increase due to warming (until the middle of the century, by maximum 1.4 times relative to current rates), then gradually decrease by the same rate due to dry conditions.

2.5. Regeneration, preventive species replacement and forest area

Sustainable forest management requires that forest areas are maintained as far as possible by regenerating all areas that have lost their forest cover due to either harvest or natural disturbances. In Hungary and elsewhere in Europe, it has been a general practice for a long time to regenerate stands of indigenous species using the species of the mature stand that are adapted to local conditions. The expected large-scale dieback of beech may require to change this practice, and to use more drought-tolerant species (even despite some adverse implications like higher costs) to avoid climate change induced mortality in the regenerated beech stands. Therefore, as a preventive measure in the "maximum adaptation" climate change scenario (see below), beech is assumed to be gradually regenerated with sessile oak. The replacement was assumed to occur in the first few years if a stand is disturbed and must be harvested. Later, however, replacement is projected to increasingly become a practice at regular final harvests (Fig. 5). It was additionally assumed that sessile oak may not only be able to regenerate but also survive until 2100. Also assuming no afforestations in the region, the total area of all forests will thus assumed to remain constant during the simulations.

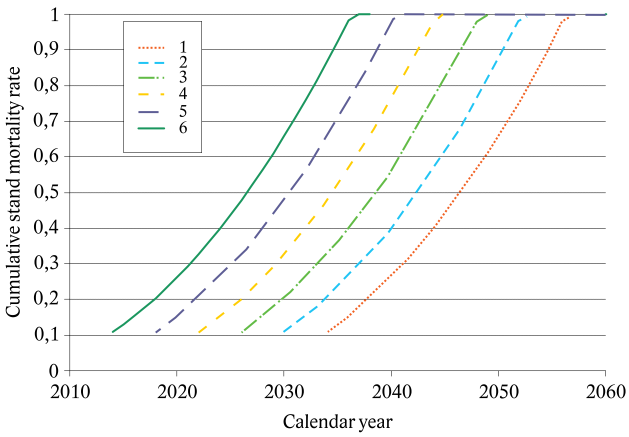

Fig. 5. The assumed fraction of beech that may be replaced by sessile oak in preventive regenerations (applied in the "maximum adaptation" scenario, see below) at the time of final harvest by yield class (1 is best, 6 is poorest).

2.6. Silviculture

For the mostly pure stands of the country, CASMOFOR's built in silvicultural model assumes a species-specific and yield-class dependent system of timing and intensity of thinnings (3 – 5 times over the rotation period, depending on yield class) and final harvest (at the age of 120 years). This silvicultural system, which is used in the baseline scenario without modification, assumes that density-dependent self-thinning may also occur but only at very low rates in the year before thinnings.

For the climate change scenarios that involve salvage cutting (see below), it is assumed that additional thinnings will be necessary between or in the years of standard thinnings whenever the rate of mortality exceeds the level of a light thinning, i.e., 15% of standing volume. One reason to conduct salvage cuttings is to avoid subsequent disturbances such as fire due to fuel accumulation. Small trees (i.e., those below 5 cm of DBH) and trees in stands with a mortality rate below the above threshold are, however, assumed to be left in the forest so that their dead organic matter decomposes.

When stand mortality occurs (at any age), all wood in the stand is harvested, and then the stand is artificially regenerated. Wood utilization rates (i.e., the amount of timber utilized in thinnings and final harvests relative to the amount of wood harvested) as set in CASMOFOR are assumed to be constant over time, and are age-dependent.

Finally, the age of final harvesting may be reduced in practice, for example in order to avoid mortality and any loss of valuable timber in the future. However, for practical modeling reasons, such reduction is not modelled in this study, and the same rotation period (i.e., 120 years) is used in both the baseline scenario and in the climate change scenarios unless stand mortality occurs and harvest and regeneration need to be applied.

2.7. Summary of forest management adaptation scenarios

In the baseline scenario ("BL"), CASMOFOR was run using the time-independent default parameter set of the model. This includes parameters of the standard silvicultural model, the assumptions that all stands are harvested at the age of 120 years, and that harvested stands are regenerated with beech. In the climate change scenarios, model parameters of individual and stand mortality, growth rate, root-to-shoot ratio and decay rates were modified by climate change as described above. To compare the effect of possible forest management adaptation measures, three management adaptation scenarios were identified. In the non-action ("NA") scenario, which is unlikely to happen, it was assumed that thinnings are done according to the standard model, but climate change affects the natural processes, final cuttings are done at standard rotation age or when stand mortality makes it necessary, and regenerations are only done using beech. In the "salvage cutting" scenario ("SC") the dead wood that appears due to the extinction mortality, is assumed to be salvaged in additional thinnings. Finally, the maximum adaptation scenario ("MA"), which is expected to be the best approximation of what is going to take place in practice, involves salvage cutting but also assumes that the preventive replacement of beech with sessile oak will also take place as described above (Table 3).

3. Results

The adjustments of the standard country-level beech yield tables to the conditions of Zala County resulted in an increase of the yield of about 18 – 20%, depending on yield class.

Table 3. Parameters of biophysical processes and forest management adaptation measures used in the various scenarios. Abbreviations: BL – baseline scenario, NA – no-action scenario, SC – salvage cutting scenario, MA – maximum adaptation scenario.

Scenario	Tree growth, root-to-shoot ratio, decay of wood and litter	Thinnings	Age of final harvest	Preventive species replacement
BL	Standard	Standard	120 years	No
NA	Modified by climate change	Standard	120 years or whenever necessary due to stand mortality	No
SC		Salvage cutting is enabled		No
MA				Yes

The estimated parameters of the Equation 1 were p_1 = 1.2418 and p_2 = 0.4155 with statistics $R^2 = 0.2037$, $N = 394$, $p << 0.05$. As a consequence, replacing beech with oak, and considering differences in their growth, yield and wood density, will affect the area-specific mean annual biomass carbon increment at age 80 years: it will decrease by about 1.77 $tCha^{-1}yr^{-1}$ (from 7.6 $tCha^{-1}yr^{-1}$) in beech yield class 1 and increase by about 1.77 $tCha^{-1}yr^{-1}$ (from 2.3 $tCha^{-1}yr^{-1}$) in beech yield class 6.

The total carbon stocks projected for BL demonstrate variation over time around a long-term average (Fig. 6a). The variation is due to the combined effect of the age-specific yield and harvest dynamics and the dynamics of the distribution of the area of the individual stands by yield class. Because all model parameters have fixed values and the length of the rotation period is the same (i.e., 120 years) for each yield class, the total carbon stocks vary in a cycle whose length is equal to that of the rotation period.

Relative to the BL, significant differences are projected in the "MA" scenario in areas that remain occupied by beech (Fig. 6b): the biomass and the litter pools are projected to lose 86% (Fig. 7a) and 70% of their carbon stock, respectively, whereas the deadwood pool is projected to gain 58% carbon by 2100. In total, the forest carbon pools (excluding soils, and again, relative to the baseline) are projected to lose 64% of their carbon stocks (Fig. 6b). In areas where sessile oak is expected to replace beech, all pools are projected to slowly but steadily increase after regeneration (Fig. 6c). Note that Figures 6b and 6c demonstrate annual changes in carbon stocks due to both changes in area covered by the respective species and specific processes (i.e., mortality, tree growth, harvest etc.) in any given year in the areas covered by these species.

Concerning the effect natural processes (i.e., the "NA" scenario) on the carbon balance (relative to the BL scenario, Fig. 7a–b), individual tree mortality seems to have a very small effect. The changes of root-to-shoot ratio and decay rates first have a slightly increasing combined effect, but then lead to a small carbon loss. The decline of volume growth is more expressed and leads to steadily increasing losses. Stand mortality is not a concern for decades, but then becomes by far the most important factor leading to large carbon losses. The effect of all natural processes and harvest (i.e., the "SC" scenario) was also found to be very small (to the point that it was not practical to include it in the figures). A replacement of beech with sessile oak (i.e., the "MA" scenario), however, moderately improved the situation concerning the total carbon stocks (Fig. 7a) and offset a bit more than the half of the loss from the above-ground biomass (Fig. 7b).

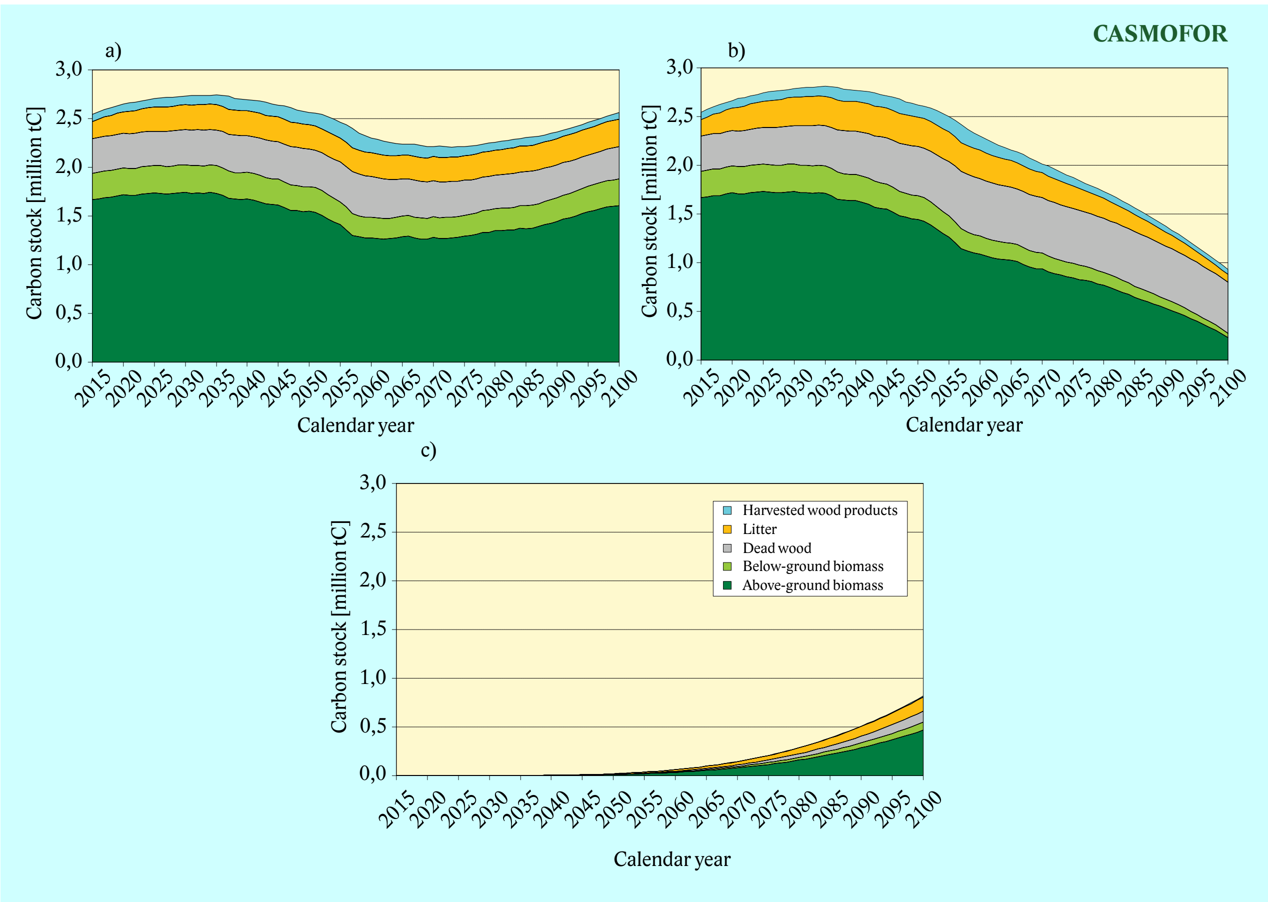

Fig. 6. The simulated evolution of carbon stocks in Zala County in the area currently occupied by beech by carbon pool (excluding soils): (a) for the BL scenario; and for the "MA" scenario: (b) for the area that at any time point in future remains covered by beech and (c) for the area where sessile oak replaces beech. The graphs represent direct outputs from CASMOFOR. The same scale is applied on the y-axis on all graphs.

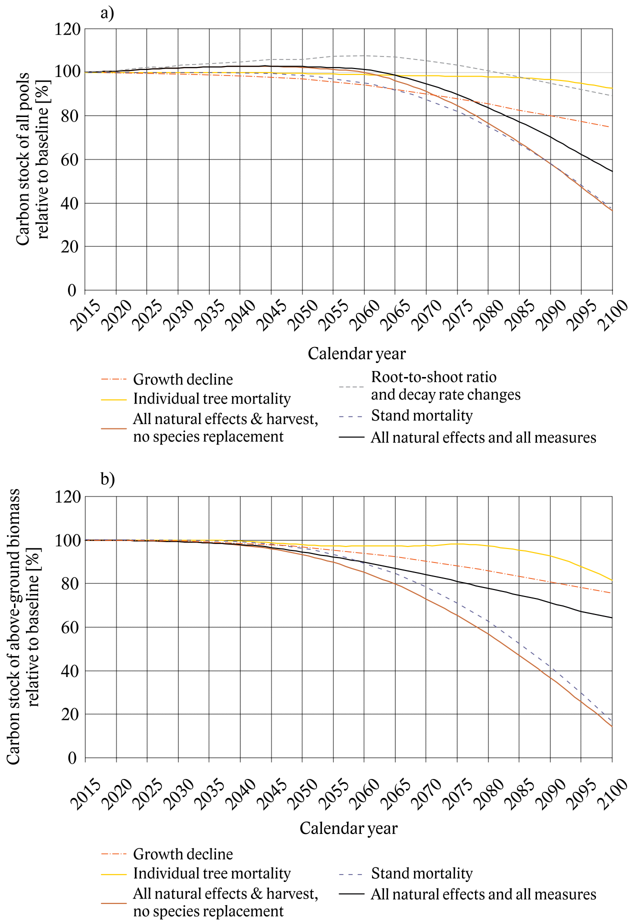

Fig. 7. The carbon stock of (a) all pools (excluding soil) and (b) the above-ground biomass pool over time, relative (%) to the BL, reflecting the partial and combined contribution of various natural and/or human-induced effects under climate change.

4. Discussion

Forest carbon balance has so far been projected under rather different conditions: mainly without assuming climate change (e.g., Zang & Xu 2003; Schmid et al. 2006; Chen et al. 2010; Krankina et al. 2012; Pilli et al. 2013); only considering some biophysical effects (such as change of growth rate) of climate change but excluding possible mass mortality (e.g., Matala et al. 2005; Morales et al. 2007; Eggers et al. 2008; Jansson et al. 2008; Rötzer et al. 2009; Tatarinov & Cienciala 2009; Wamelink et al. 2009; Hurteau et al. 2014; Smyth et al. 2014), assuming a low level tree mortality (Hlásny et al. 2014a), and/or the possible and necessary forestry measures (e.g., Birdsey et al. 1993). Also, projections differ with respect to scale from the stand level (Hlásny et al. 2014a) to large areas (Kurz et al. 2008).

This study reports on a comprehensive integrated assessment of the impact of some major possible effects of climate change, including an assumed mass mortality, for a large forest area. The assessment includes effects on tree growth, root-to-shoot ratio and decomposition rate, but excludes the effects of CO_2 fertilization and N-deposition. Non-CO_2 emissions are not considered, either. The results show that, if tree mortality will take place as projected, rather high CO_2 emissions from forests can be expected due to losses of forest carbon stocks. If upscaled to the country level using a simple ratio of total forest area in the country (1,933,604 ha) and the beech forest area in Zala County in 2012 (i.e., assuming the same average rate of forest decline all over the country, subject to large regional variation), these emissions may reach a level in the second half of the century that is about 50% of the current (2012) total emissions of the country (i.e., 57.6 million tCO_2 equivalent, NIR Hungary, 2014). These emissions might offset a significant portion or even all of the positive effect of future mitigation efforts, thus risking a positive discernible climatic feedback.

Therefore, it is important to analyses to what extent, if at all, forestry can prevent or mitigate these emissions. Of all theoretical (Yousefpour et al. 2013) and more realistic (Susaeta et al. 2014; Nabuurs et al. 2013; Smyth et al. 2014) forest management options, this study focuses on two practical ones.

Concerning salvage cutting, the results of the study demonstrate that it may have rather small effects on net emissions. This result confirms the conclusions by Nabuurs et al. (2007) and Smyth et al. (2014) that the forest management strategy with the largest sustained mitigation benefit is the one that maintains or increases forest carbon stocks.

A much more promising adaptation measure (Koltsröm et al. 2011), although with slow long-term effects, is to significantly speed up artificial species replacement where necessary. Species replacement has been suggested as a potentially successful adaptation measure (e.g., Lindner et al. 2010, 2014; Hlásny et al. 2014b). It has been proven to be possible in Zala County and elsewhere in Hungary at small scales for decades with the aim to improve stand quality in many damaged or degraded forests (Koloszár 2010). Replacing beech with oak can successfully be achieved through the promotion of natural regeneration of oak in mixed stands, or seeding or planting oak seedlings to replace pure beech stands. Favoring oak over beech during thinnings might also be used to replace beech with oak.

However, the availability of propagation material, and competition between tree species and even between trees, herbs and bushes might make such replacements difficult in some places. Also, large areas of the Forest Steppe climate type, or even the Turkey oak climate type in Hungary may become completely unsuitable to support trees as early as the end of this century. The amount of carbon fixed by any forest-replacing ecosystem will likely be very small in any event, only offsetting a fraction of the likely emissions. Finally, although artificial species replacements with the above techniques have been successfully conducted in Hungary from both domestic forestry budget and subsidies from the European Union, such interventions may be prohibitively costly if conducted on large scales (Lindner et al. 2010).

Because all of the above, the assumption that all beech stands will be replaced with oak by 2100 can be considered a "technical potential" scenario. More analysis is needed to explore the optimal speed, method and extent of re-structuring forests at reasonable costs to avoid forest loss as much as possible. Future analyses should also explore more accurate ways to estimate the effects of climate change and the various forest management options. This study was conducted using an open source model with a fully described methodology and database which ensures that calculations can be checked, and that the simulations can be reproduced for any tree species with appropriate data. CASMOFOR ranked highest in a recent comparison of carbon accounting models as it produced the smallest mean square error of biomass estimates among the models compared (Ndalowa 2014). CASMOFOR's prediction of average net annual biomass carbon removals in 2008–2012 by afforestations 1990–2012 of 1.1 $MtCO_2yr^{-1}$ (Somogyi 2006) was also validated by the 1.2 $MtCO_2yr^{-1}$ estimate in 2014 (NIR Hungary, 2014).

Nevertheless, the results of the modelling are subject to uncertainties due to a number of factors. The parameters of the model that can be used under constant environmental conditions have moderate uncertainties, some of which were used as part of a Monte Carlo uncertainty analysis of the model (see NIR Hungary, 2012). Parameters to estimate the effect of climate change (e.g., the change of height growth rate) have higher uncertainties which, in general, could not be estimated. Finally, the results may also be sensitive to the assumptions used.

The single most important assumptions with high uncertainties concern the rate and timing of beech mortality. Projecting future forest decline is rather challenging (Rasztovics et al. 2012). As the findings of both this and several other studies (e.g., Crookston et al. 2010; Hlásny et al. 2014a) confirm, the modeling results are much more sensitive to projections of mortality than to those of tree growth, and that emissions from mass mortality can indeed be large (Kurz et al. 2008).

The assumed mortality in this study is based on climate change scenarios that are consistent with those of IPCC (2013a). However, the projected increase of the temperature by the end of the century (3.7 °C) is much more than the current temperature range in the Zala county (1.5 °C) or the difference between the various adjacent climate types applied in Hungary (about 1 °C), but is by 0.3 – 1 – 7 °C lower than what Bartholy et al. (2014) predicted. Also, European beech is a species favoring cool and humid Atlantic climate (Fang 2006; Mátyás et al. 2010) and extreme droughts may be an increasingly serious limiting factor due to high summer temperature and low precipitation (Rasztovics et al. 2014). Recent beech decline events in the region (Lakatos & Molnar 2009; Mátyás et al. 2010) and other projections (Czucz et al. 2011) also suggest possible large beech decline in the future.

This possibility is further supported by the fact that the projected decline of the amount of water available for the trees during the growing season can be very significant in the light of evidence by Elkin et al. (2013) that a significant decline of forest biomass may occur even due to relatively small climatic shifts at initially warm-dry lower elevations due to the limitation of growth by precipitation, which is clearly the case in Zala County. Crookston et al. (2010) also concur that if climatic shifts go beyond the current climatic range for areas where a species occurs currently, then mortality rates will increase, eventually resulting in the local extinction of the species. The above evidence and assumptions are also in line with the assumption applied in developing the mortality scenarios that mortality will first happen on the poorer sites and start later on better sites.

An important limitation of the assumed mortality scenarios is that, because of their rare and unpredictable nature and the many knowledge gaps reported by Sommers et al. (2014) and others recently, the effects of extreme natural disturbances such as forest fires, droughts, insects and others that produce non-CO_2 emissions could not be fully, and separately, modelled. Also, the rate of disturbances may be overestimated as the current range limits are not always constrained by climate (Lindner et al. 2014).

Considering all the above, the dramatic forest decline assumptions that were developed based on Móricz et al. (2013) and Zimmermann et al. (2013a) and that were the basis for the emission estimation in this study, should be taken as a serious possibility.

Contrary to assumptions in this study, tree growth might, at least in the short run, increase due to increasing temperature (Crookston et al. 2010). However, a temperature increase of only 2 °C was assumed, and the calculated growth reduction rate was further decreased to be conservative, i.e., to underestimate potential emissions. Bošel'a et al. (2014) found that the growth of trees was positively affected at higher altitudes where low temperature is the limiting factor, but it was negatively affected by summer temperatures at lower altitudes where precipitation is the limiting factor. The Zala County is such a low-elevation area for which the above findings are consistent with the assumptions of this study. Hlásny et al. (2011) also reported a drop of about 30% in the growth of beech at elevations similar to those in the Zala Country.

Carbon sequestration may also change after mortality or mortality-induced harvest due to the increased available light through the canopy. However, the average annual rate of ecosystem carbon sequestration over a longer period may not change much, and it was indeed found to be similar in harvested and un-harvested forests (Davis et al. 2009). Battles et al. (2008) reported that tree growth declined under all climate scenarios and management regimes under the conditions of their analysis.

Assuming acclimation to CO_2 effects, Reyer et al. (2013) also estimated lower net primary productivity for the Zala region. However, Reyer et al. (2013) also estimated higher net primary productivity for the Zala region and elsewhere with persistent CO_2 effects. In lack of proper data, the effects of CO_2 or nitrogen fertilization on tree growth could not be included in our analysis. Also, only unverified data and expert judgment could be applied to model changes in less important parameters such as root-to-shoot ratio and decay rates. The allocation of NPP to slow and fast-turnover biomass pools can differ significantly in stands of different species (Konôpka et al., 2013), which indicates that this allocation may change as climate changes. However, for reasons mentioned above, uncertainties in the non-biomass estimation modules are of limited importance with respect to the conclusions of the study.

The modeling of the HWP stocks currently involves fixed parameters, ignoring their sensitivity to climate change or socio-economic processes. Thus, the HWP stock estimates are only indicative. The combination of the assumed half-life time of the various wood products (that are the same as the default values in IPCC 2014b) with their (fixed) utilization rates results in a combined half-life time for the HWP pool that is roughly equal to that applied for the dead wood pool. This implies that salvaging of trees that died due to extinction mortality has only an insignificant effect on reducing net carbon losses.

The current silvicultural model reflects historical practices at the country-level, but such practices will most probably change under increasing rates of mortality. This is partly modelled by including new thinnings and final harvests that become necessary above a given threshold of extinction mortality. However, reducing the age of final harvesting can have a larger effect and should be modeled in more details in future studies.

Finally, the uncertainty analysis shows that estimates of carbon stock changes involve significantly larger uncertainties than those of carbon stocks, especially for the deadwood pool. Clearly, additional evidence is needed to better model the effects of climate change on relevant natural processes (also considering that the effect of the various processes may be different if simulated in isolation or in combination with other processes). In conclusion, none of these uncertainties invalidate the conclusion of the analysis, which is that a discernible positive feedback from very large net emissions might occur from the forests of the Zala County, and maybe also from other forests, in case large-scale mortality occurs as suggested by recent studies.

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Elevated bark temperature in unremoved stumps after disturbances facilitates multi-voltinism in *Ips typographus* population in a mountainous forest

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Abstract

The number of *Ips typographus* generations developed in a year might be indicative of its population size and of risk to Norway spruce forests. Warm weather and unremoved fallen trees after natural disturbances are thought of as key factors initiating large population increase. We studied *I. typographus* development in a spruce forest of the Tatra National Park, which was heavily affected by large-scale disturbances in the last decade. Repeated windthrows and consequent bark beetle outbreaks have damaged almost 20,000 hectares of mature Norway spruce forests, what is a half of the National Park forest area. Current *I. typographus* population size and its response to the environment and to forestry defense measures attract attention of all stakeholders involved in natural resource management, including public. In this paper we analyse the potential *I. typographus* population size in two consecutive years 2014 and 2015, which represented a climatologically normal year and an extremely hot year, respectively. We used bark temperature and phenology models to estimate the number of generations developed in each year. In 2014, the average bark temperature of standing living trees at study sites was 14.5 °C, in 2015 it increased to 15.7 °C. The bark temperature of fallen logs was 17.7 °C in 2014, and 19.5 °C in 2015. The bark temperature of standing living trees allowed to develop one and two generations in 2014 and 2015, respectively. The elevated bark temperature of fallen logs allowed to develop two generations in 2014 and three generations in 2015. The good match between the predicted and observed timing of each generation emergence as well as the large increase in the number of catches in pheromone traps in 2015 indicated a dramatic increase of the *I. typographus* population in the extremely warm year, especially at the unmanaged windthrown site.

Key words: Norway spruce stands; European bark beetle, bark temperature; PHENIPS, disturbances

Editor: Tomáš Hlásny

Introduction

The European spruce bark beetle *Ips typographus* is natural component of Norway spruce forest in Europe. It plays an important role in natural forest cycle by decomposing wood, sustaining nutrient availability and production capacity in long term (Christiansen et al. 1987). On the other hand *I. typographus* is also one of the most important forest pests in Europe (Wermelinger 2004; Blackwell et al. 2013; Schelhaas et al. 2003). *I. typographus* prefers to reproduce in breeding material with non-existing or weak defence such as wind-felled or otherwise damaged trees (Schroeder & Lindelöw 2002). Blow down of entire stands usually provide an excess supply of nutrition and breeding substrate which is a main trigger of mass bark beetle outbreaks (Wermelinger 2004; Netherer & Nopp-Mayer 2005; Faccoli 2009). Mass attack is the strategy of *I. typographus* to overcome the defence mechanism of the trees (Christiansen et al. 1987; Raffa et al. 2008). Large population is able to kill also apparently healthy trees in large numbers. Large-scale windthrows with surplus of food, breeding material and limited defence allow easier colonisation with less dense population. Lower intraspecific competition and consequently stronger and bigger progeny in broken trees stimulates a mass attack on the surrounding healthy trees. To prevent such population increase, removal of wind-felled spruce trees after storm disturbances has been the long practice whenever possible.

Bark beetles are ectothermic organisms, their body temperature depends on the surrounding environmental conditions. Ambient temperature practically controls course of development stages (egg, larvae, pupae, imago), as well as the spring swarming, and population size (Wermelinger & Seifert 1998). Under warmer conditions *I. typographus* is a multivoltin organism. Two generation could emerged in central, or even three, in southern Europe, while in Scandinavia, and mountainous regions, one generation is the most common (Lange at al. 2006). Understanding of *I. typographus* phenology helps to estimate its population size. Close relation between temperature and insect development is a base of phenological models. Baier et al. (2007) developed PHENIPS, model for monitoring generation development and phenology of *I. typographus*. Number of generations per year is one of the key factors for potential tree attack, ranging from tree-wise up to stand or even region-wise (Netherer & Nopp-Mayr 2005). Large *I. typographus* outbreaks in recent

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decade in central Europe (Wermelinger 2004; Berec et al. 2013) and in Scandinavia (Jonsson 2009) attracted broad attention to this bark beetle by analysing and modelling the impact of climate change, stand predisposition, role of natural enemies in population dynamic, winter mortality, population size and other factors controlling the *I. typographus* populations (Hlásny & Turčáni 2009). Warm and dry seasons become more frequent and long elsewhere in mountainous regions due to changing climate and very likely stimulate bark beetle population growth.

Forest in Tatra National Park is naturally dominated by Norway spruce with frequent large-scale wind distubances. During last 10 years the region has been strongly affected by several extraordinary weather events. Windstorm in 2004 flattened 12 000 hectares of spruce forest (30% of total forest cover in National Park) mostly in lower altitudes. Windstorm in 2014 damaged roughly 2500 ha, mostly stands in higher elevations, close to the timber line. According to long-term meteorological observation in the Tatra Mts. region summer temperature is increasing. Eight out of ten last years were warmer than long-term average. The 2015 summer was the warmest in the last 100 years.

Bark beetle outbreaks have always occurred in the Tatra Mts forest, esp. when wind damage coincided with warm and dry seasons. To prevent mass outbreaks sanitary cutting has been used as the standard forest management method for decades in the Tatra National Park. Recently this prevention measure was restricted and allowed only outside the core zone of the National Park. Prognosis for possible forest damage by bark beetle after large-scale disturbances were controversial, spreading from no damage to the total destruction. In reality, since 2007 bark beetle killed more than 7 000 ha of mature spruce forest. Fragmented spruce stands became more sensitive especially to wind disturbances and almost every year several hundreds of ha of mature forest have been fallen. Due to nature conservation rules and partly remoteness of affected sites large areas were left without any controlling measures against bark beetle outbreaks.

Our aim was to describe bionomy of *I. typographus* under normal and extreme weather in the Tatra Mts. The objective was also to estimate potential *I. typographus* population according to contrast post-disturbance management (removed *vs*. unremoved fallen trees). In this paper we interpret number of generation as an indicator of population size and thus potential risk of bark beetle attack on surrounding healthy forest. Specific aim was to estimate phenological development according to directly measured bark temperate and compare it with the model PHENIPS (Baier et al. 2007).

2. Material and methods

2.1. Study site

We studied the *I. typographus* population dynamic on two localities in Tatra National Park, which are part of the international long-term ecological monitoring and research projects (ILTER, EXPEER). The study sites Vyšné Hágy (VH) and Tatranská Lomnica (TL) are located on the edge of the 2004 windthrow and at present are affected by bark beetle outbreaks. Before the disturbances mature seminatural and natural Norway spruce stands dominated on study sites. The sites are fully equipped for continuous measurement of environmental parameters (Fleischer 2008). Terrain on both of the localities is relatively flat, well exposed to incoming solar radiation, with no obstacles from peaks. On the VH site few tall trees remained. Description of the study sites is in Table 1.

We compared *I. typographus* development under contrast weather conditions in 2014 and 2015. The 2014 represents normal temperature and high precipitation, while the 2015 was extremely warm and dry. According to the Slovak Hydrometeorological Institute the 2015 summer in Tatranská Lomnica (830 m a.s.l.) was the warmest since 1898. Average air temperature during growing season (April 1st to August 31st) in 2015 was 15.4 °C what was 1.9 °C above the 1930–1960 average (13.5 °C). In 2014, the average air temperature (13.7 °C) was nearly equal to the long-term normal. Precipitation in 2014 was 572 mm which was 38% above and in 2015 the precipitation sum was 40% below normal (415 mm) and was the second driest in history.

2.2. Phenology of *Ips typographus*

Phenology models describe the beetle´s development stages (egg, larvae, pupae, adult) according to the ambient temperature. We have used threshold values and sum of temperature (so called degree-days, DD) as suggested by Wermelinger & Seifert (1998), shown in Table 2. Phenological development allows to estimate potential number of generations what is crucial for estimation of *I. typographus* population size a thus potential risk for forest. By calculation of DD required for individual stage development we could estimate time of spring swarming, the onset of infestation, the re-emergence of parental beetles, and the number and emergence time of the regular and sister brood as proposed in the PHENIPS model by Baier et al. (2007). Detailed phenological development is needed for estimation of development completeness in late autumn. Since only young adults can successfully survive winter hibernation late autumn developmental stage is crucial for next year population size (Facoli 2002; Netherer 2003). PHENIPS allows to estimate maximum number of

Table 1. Location and characteristic of study sites.

Site name	Alt [m a.s.l.]	WGS E, N	Slope [%]	Orientation	Specific description
Vyšné Hágy – VH-	1200	20° 06´ 30´´ 49° 07´ 30´´	0 – 5	S	Managed zone of NP, in May 2014 50 ha windthrow in vicinity, partly hit the site, fallen wood removed in summer of 2015
Tatranská Lomnica – TL-	1150	20° 14´ 50´´ 49° 10´ 45´´	10 – 15	S	Border between managed and unmanaged zone of NP, continuous IT outbreaks in the site vicinity

generations on regional scale as well as actual state of the bark beetle development on a specific tree level.

Table 2. The lower threshold value and the number of degree-days to complete the development of each developmental stage of *I. typographus* (Wermelinger & Seifert 1998).

Phase	Treshold value °C	ET sum (DD) °C
Egg	10,6	51,8
Larvae	8,2	204,2
Pupae	9,9	57,2
Adult	3,2	245

For sister generation development we add regeneration period defined by 8.3 °C as the threshold and 278 DD as effective temperature sum proposed by Wermelineger & Seifert (1998).

While the phenology model is an estimation of *I. typographus* bionomy, catches in pheromone traps mirror real population dynamic (onset of spring swarming, development of the filial generation and the establishment of sister broods). Every year we have installed 25 traps in the vicinity of each study site. Catches in the traps were sampled every 10 days by local foresters.

2.3. Climate data and bark temperature

Phloem (bark) temperature depends on direct solar radiation and ambient air temperature. Average 60 min radiation and temperature were recorded using a sensor EMS11 (EMS Brno, CZ). Bark temperature was measured with a resistance thermometer Pt1000 (10/1 mm) and recorded by MicroLog SP3 (EMS Brno, CZ) as 60 min average. We drilled 1 mm diameter holes and inserted probes directly into *I. typographus* galleries. We equally sampled both sun exposed and shaded sites of standing live trees as well as fallen logs and for further calculations used average values. The bark temperature was measured in mature trees of representative size for the study sites. For measurement in fallen trees we chose stumps fallen in the previous year (2013 at TL, and 2014 at VH respectively).

Bark temperature is rarely measured in field. Baier et al. (2007) constructed a regression between ambient environmental factors (air temperature and solar radiation) and bark temperature as a part of the PHENIPS model:

$$BT_{avg} = a + b * SR + c * AT_{mean} \quad [1]$$

Where BT_{avg} is diurnal average bark temperature, *SR* is the daily sum of the incoming solar radiation (Wh m^{-2}), AT_{mean} is the daily average air temperature (°C).

3. Results

In phenological models bark temperature serves for calculation of thermal sum needed for completion of developmental stages and estimation of number of generations. Beside climate we found tree health status as another prominent factor controlling bark temperature.

3.1. Air temperature and solar radiation

We measured climate parameters from April 1st to mid-September, a period usually favourable for *I. typographus* development, on study sites in two consecutive, but meteorologically contrast years. In 2015 the average air temperature was higher by +0.8 °C than in 2014 (12.1 °C in 2014 and 12.9 °C in 2015 at TL and 11.1 °C and 11.9 °C at VH, respectively). Sum of solar radiation was higher in 2015 on both study sites (1.15 at TL and 1.43 fold at the VH site). Increase of solar radiation at VH was caused by a windthrow in May 2014 and consequent dieback of individual shading trees at the study site. Diurnal air temperature and solar radiation sum (kWh) for TL and VH sites are shown in Fig. 1.

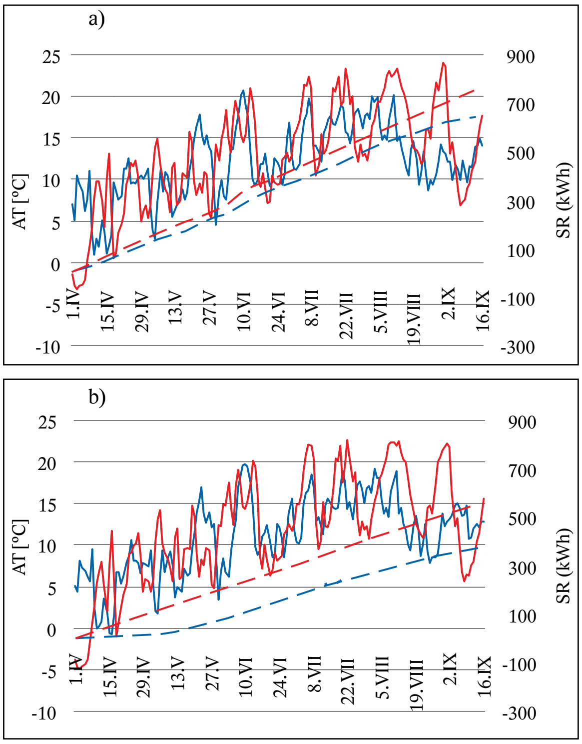


Fig. 1. Average diurnal air temperature (°C) and cumulative solar radiation sum (kWh) in 2014 (dark) and 2015 (light) at (a) Tatranská Lomnica and (b) Vyšné Hágy study sites.

3.2. Bark temperature

Bark temperature was directly measured in phloem of the fallen trees in 2014 at TL (n = 3) and both live (n = 3) and fallen trees (n = 5) at VH in 2015. Missing data for comparison between the years and tree status (live vs fallen) were derived from regression with the air temperature and solar radiation, as proposed by the PHENIPS model. We derived the parameters for equation [1] by the use of multiple linear regression with ordinary least square estimation (Statistica v.7, StatSoft, Inc.) on directly measured bark temperature on both live and fallen trees. In Table 3 we present regression parameters (a, b, c), regression coefficients (R^2) and mean square errors (MSE). For comparison we show also parameters proposed by Baier et al. (2007) and PHENIPS performance with standing live trees at our study sites.

Table 3. Regression parameters for estimation of bark temperature using equation [1].

Model/parameter	a	b	c	R2	MSE	Notes
PHENIPS	−0,173	0,0008518	1,054	95,9	2,41	Baier et al. (2007)
Standing live trees	−0,567	0,0002550	1,031	97,2	0,82	
Fallen trees	−1,811	0,00151	1,079	91,9	1,51	

In Table 4 we show average bark temperature directly measured and modelled at the study sites in 2014 and 2015. Measured data are labelled with an asterix.

Table 4. Bark temperature in °C (L – live, F – fallen trees) at the VH and TL site in 2014 and 2015, * indicates directly measured data.

	TL		VH	
	L	F	L	F
2014	13,9	18,6*	15,0	16,8
2015	15,6	20,7	15,8*	18,3*

Seasonal course of average diurnal bark temperature in live and fallen trees at study sites in 2014 and 2015 is shown in Fig. 2a and 2b.

In 60% of all diurnal averages, the fallen logs were warmer by 2 ÷ 4 °C than standing living trees. The maximum difference in the daily average was 8.7 °C. The maximum hourly values occasionally exceeded 40 °C in logs and 25 °C in living trees.

3.3. Phenology and number of generations

Spring swarming was estimated from the maximum diurnal air temperature. According to Zumr (1982), and confirmed by previous field observations (Tatra National Park forestry evidence, internal data), we used threshold value of 7 °C and 145 °C sum of effective temperature for estimation of first flights. Real flights started after completeness of required sum, in sunny days when daily temperature in three consecutive days exceeded 16 °C.

Differences in bark temperatures between the observed years as well as differences between forest statuses (standing live versus fallen trees) caused remarkably different phenological development. To demonstrate the influence of exceptionally warm weather in 2015 we compare *I. typographus* phenological development in living trees with the 2014 development on both the study sites (Fig. 3). To illustrate the influence of tree status (live versus fallen) we compared phenological development in live and fallen trees in 2014 at TL and in 2015 at VH (Fig. 4).

At the TL site bark temperature in 2014 (Fig. 3a) allowed to emerge one generation and allowed one sister generation to develop up to immature adult stage. In 2015 warmer environment allowed to emerge one parental and one sister generation. First filial generation also fully developed (Fig. 3b), but did not emerge due to the daylight length limit August. Daylight below 14.5 h (Doležal & Sehnal 2007) eliminates *I. typograhus* emergence. At the study sites a critical day is on August 20th.

At the VH site in 2014 also one generation emerged, but sister generation developed only up to the stage of early immature adult (Fig. 3c). In 2015 sister generation fully developed and probably successfully overwintered. The first filial generation developed up to the stage of pupae and chance for successful overwintering was questionable (Fig. 3d).

Contrary to live trees in 2014 at TL bark temperature in fallen trees allowed to emerge also the sister generation. Filial generation reached the stage of immature adult with high chance for successful overwintering. Second sister generation reached the stage of pupae (Fig. 4a). In 2015 under extremely warm weather bark temperature in fallen trees at the VH site allowed 3 generation development. Also 1st and 2nd sister generation fully developed, as well as 1st sister filial generation (Fig. 4b).

3.4. Catches in pheromone traps

Average numbers of *I. typographus* catches by pheromone traps in the vicinity of the study sites in 2014 and 2015 is shown in Fig.5. While in 2014, the catches on the study sites were rather similar, in 2015 the numbers of the insect increased, esp. on TL site, almost two-fold. Remarkable was the increase of late summer catches on both localities.

4. Discussion

Enhanced summer temperature is the driving forces for the spread of bark beetles into higher altitudes and latitudes (Jonsson et al. 2011). Recent warm summers and repeated windthrows stimulated large *I. typographus* populations and vast tree dieback in mountainous Norway spruce forest across the entire Slovakia (Kunca et al. 2015; Vakula et al.

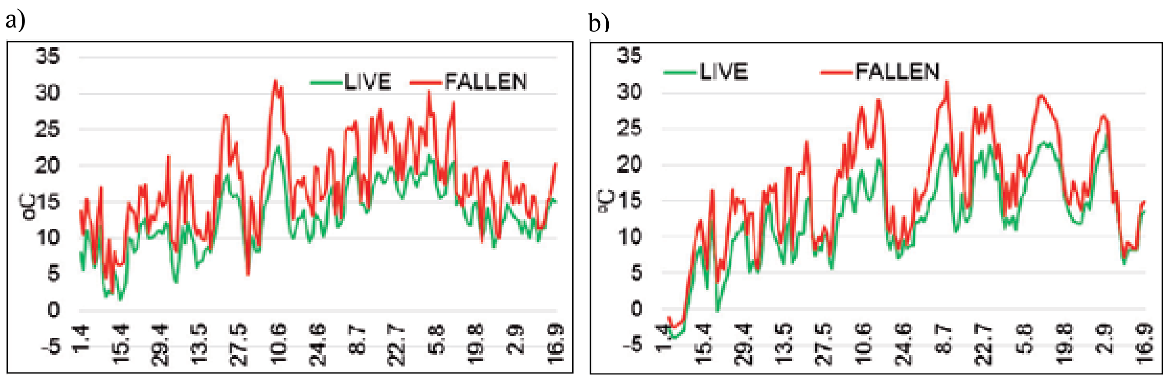
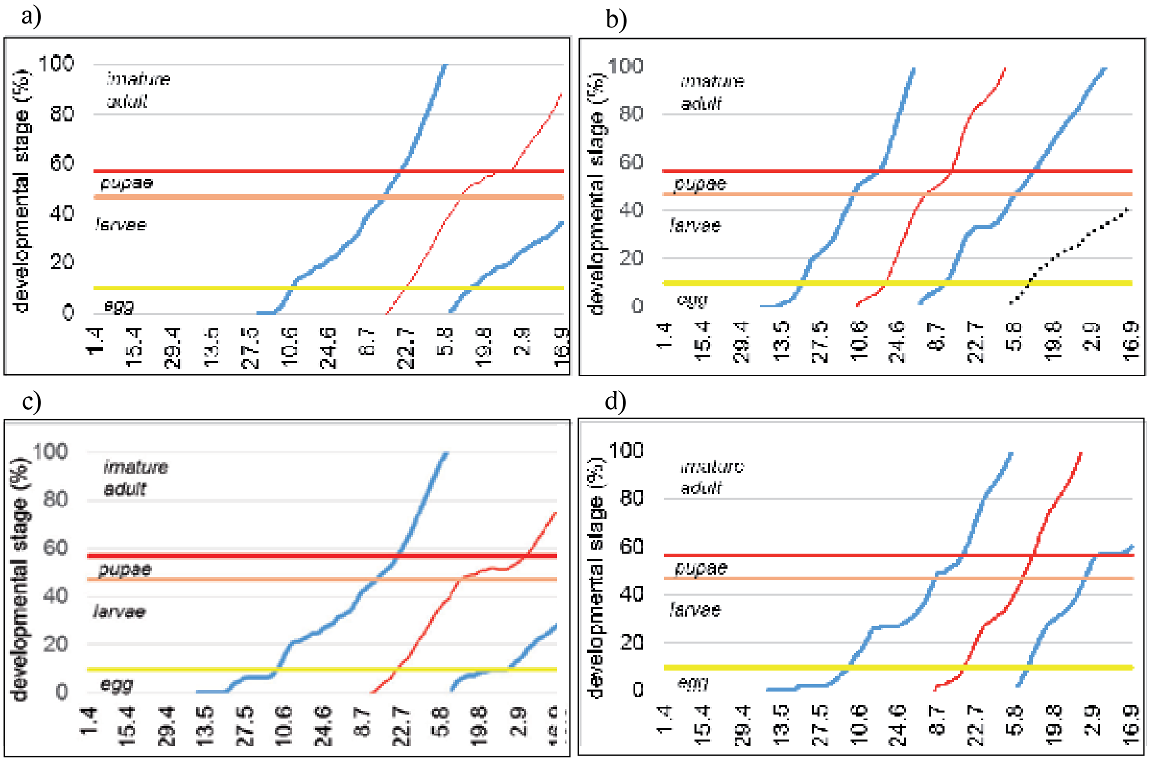
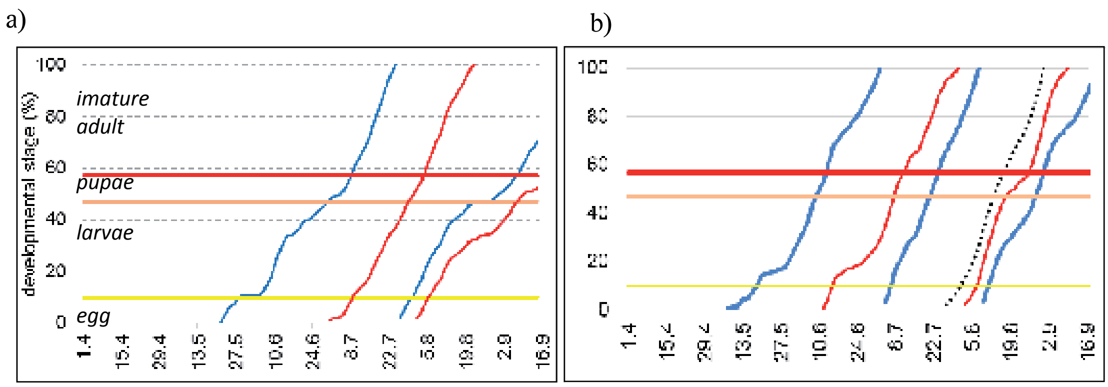


Fig. 2. Average diurnal bark temperature (°C) in live and fallen trees (a) TL 2014, (b) VH 2015.



Legend: blue line: main generations – parental, 1st and 2nd filial generation, red dotted ine: 1st sister filial.

Fig. 3. Comparison in phenology and number of *I. typographus* generations (a) TL 2014, (b) TL 2015, (c) VH 2014, (d) VH 2015 on live trees.



Legend: blue line: main parental, 1st and 2nd filial generation, red line: 1st and 2nd sister, dotted line: 1st sister filial.

Fig. 4. Potential temporal development and number of generations of *I. typographus* fallen trees, (a) Tatranská Lomnica 2014 (b) Vyšné Hágy 2015.

2015; Bucha & Hlásny 2015). In the Tatra Mts. region the 2014 summer was climatologically normal, while 2015 was extremely warm. The average air temperature in Tatranská Lomnica (830 m a.s.l.) was the highest since the regular observation in 1898 started. Study sites established to analyse *I. typographus* development under different environmental and management conditions were located in higher altitude (1,200 m a.s.l.). Naturally, at this height the air temperature was not so high and also the difference between 2014 and 2015, was not as evident as in lower elevations.

We used bark temperature as a predictor for *I. typographus* development. This method based on Baier et al. (2007) PHENIPS model for estimation of potential numbers of generations and thus impact on surrounding forest has been successfully used in the Alps (Blackwell et al. 2013), Bohemian forests (Berec et al. 2013). The PHENIPS model was built for standing trees inside forest stand, where solar radiation was strongly reduced by canopy. Solitaire trees on our study sites were fully exposed to direct radiation. Under these conditions PHENIPS overestimated bark temperature when compared with directly measured in standing live trees (MSE=2.41). Overestimation was also reported Berec et al. (2013). Applying site specific parameters for live and fallen trees improved estimation of bark temperature (MSE=0.82 for live and 1.51 for fallen trees).

In 2014 under normal weather conditions the univoltine *I. typographus* development happened. Second generation was established, but could reach the stage of larvae only. Elevated air temperature in combination with enhanced solar radiation in 2015 allowed one more *I. typographus* generation (filial) to fully develop at the TL site, or to reach the stage of immature adult at the VH site when compared with the

2014. In the warmer 2015 year also 1st sister generation could fully develop and emerge. In the previous year the sister generation reached immature stage only. Fully developed adult beetles have much higher chance to successfully overwinter than earlier developmental stages. Critical stage is "pupae", below this stage (marked by red line in phenological graphs), the chance to survive winter is very low (Faccoli 2009). The bigger the population size in next spring the more extended damage on forest. Large *I. typographus* infestations due to elevated air temperature were recently reported from the Alps (Stadelmann et al. 2013). The temperature was a driving factor also for the damage of more than 14 mil ha of *Pinus concorta* in Canada (Safranyik et al. 2010).

Bark temperature in fallen trees was higher than in standing live trees by 1.8 – 4.9 °C (span of seasonal averages on all sites and years). Such bark temperature increase caused almost bivoltine development in 2014 (first filial generation reached the stage of mid immature adult and sister generation fully developed). In 2015 two main generation fully developed and 3rd reached 90% of full stage. Warm autumn 2015 very likely allowed complete development before winter. Beside two sister also 1st sister filial generation could fully develop.

Unremoved fallen logs after large-scale disturbance are generally thought of as the key risk factor for infestation of the remaining forest (Wermelinger 2004; Wichman & Ravn, 2001). Schroeder & Lindelöw (2002) reported twice as many trees killed by *I. typographus* in southern Sweden after the 1995 windstorm in unmanaged rather than managed stands. Stadelmann et al. (2013) confirmed the importance of salvage logging for reducing *I. typographus* infestation after the large-scale Lothar wind disturbance in Switzerland.

To prevent *I. typographus* population increase, removal of wind-felled spruce trees after storm disturbances has been the long practice also in the Tatra National Park whenever possible. Forest in central part of the Tatra National Park is naturally dominated by Norway spruce. High frequency of severe wind disturbances (Zielonka et al. 2009) prevent forest to became more structurally diversified. Relatively homogenous spruce stands are prone to bark beetle outbreaks, which regularly occur after wind disturbances. Current enormous bark beetle outbreak started 3 years after the 2004 large-scale windthrow (12 000 ha) and so far have destroyed 7 000 ha of mature spruce stands. Majority of remaining mature stands are located in strictly protected zone of the National Park with no control measures against bark beetle outbreaks. Strongly fragmented stands become more susceptible to biotic and abiotic agents. Climate change scenarios expect more wind disturbances in future. As the area of low forestry management approach increases, future forest status becomes very challenging. In the literature, the potential for bark beetle outbreaks from unmanaged windthrow is explained by luxurious food and breeding possibilities in defence-limited and less competitive intraspecific environment (Wermelinger 2004).

Estimated number of *I. typographus* generations is theoretical maximum under existing weather conditions. Despite key role of generation numbers for population size, in reality population might be influenced by numerous external and internal factors and differ significantly from modelling. Comparison of predicted bark beetle emergency dates with catches in pheromone traps confirmed good performance of prediction and usefulness of predicted data for resources managers. Although, the accuracy estimation is difficult due to 10-day collection of catches in pheromone traps and differences among some generation emergence days were sometimes only few days as shown on Fig. 4 and 5.

We found bark temperature on fallen trees to play crucial role in population development. Only little can be found in the literature about fallen tree's bark temperature and population size. One of the reason could be the general opinion about fast drying-out of fallen logs. Dry phloem is no more suitable for establishment and development of new insect populations. Observation from the 2004 unmanaged windthrow confirmed the existence of living uprooted trees even four years after the event. Stadelman et al. (2013) found three years after disturbance as still suitable time for *I. typographus* colonisation in higher altitudes. Higher temperature in fallen logs should be explained by a missing transpiration flux. Also, the reduction of ground level wind speed by surrounding structures might increase the temperature.

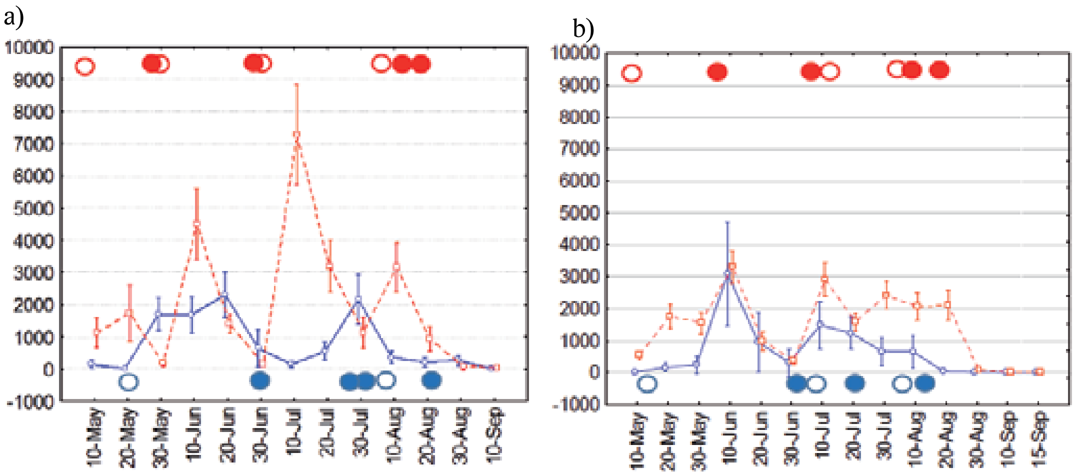


Fig. 5. Number of *I. typographus* individuals in pheromone traps (means and standard errors) in 2014 (blue) and 2015 (red) at (a) Tatranská Lomnica, (b) Vyšné Hágy. Dots represent calculated date of individual generation emergence presented in Fig. 3 and 4: blue circle-emergence from live trees 2014, blue dot-emergence from fallen trees 2014, red circle-emergence from live trees 2015, and red dot-emergence from fallen trees 2015.

5. Conclusion

We analysed the development of *I. typographus* in Norway spruce forest in Tatra National Park affected by strong disturbances, weather extremes and different post-disturbance forest management in recent years. We chose two years representing normal (2014) and elevated air temperature (2015). On two study localities we estimated *I. typographus* development in standing and fallen trees, representing contrast management methods (fallen trees removed vs. left on site). We used effective heat sum to estimate the *I. typographus* phenology, potential number of generations and thus possible risk for the remaining mountainous spruce forest. Heat sums were derived from directly measured and modelled bark temperature. Elevated air temperature increased also temperature in phloem of standing live trees and allowed one more generation to develop. Bark temperature in one year old fallen logs was warmer than bark in standing trees and allowed two generations to develop in climatologically normal and even three main generations in extremely warm year. Catches in pheromone traps confirmed realistic estimation of *I. typographus* generation numbers and their emergence time by phenological models. Accordingly we can conclude that majority of the *I. typographus* population in study sites developed in fallen trees.

The results showed the importance of increasing air temperature on *I. typographus* population. Current extremely high summer temperatures are likely to persist in the future, and bivoltine bark beetle populations might affect adversely also mountainous spruce forests. Our finding on elevated temperature in fallen trees stimulating at least one more generation could explain reasons for enormous bark beetle outbreak 2 – 3 years after the 2004 large-scale windthrow and also might influence further decisions about post-disturbance management in protected area. The results hopefully might attract more attention to study very complex bark beetle population dynamic after natural disturbances and under changing environmental conditions.

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Changes of carbon dioxide concentration in soils caused by forestry machine traffic

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Abstract

Forestry machine traffic causes a number of changes that are not immediately reflected in morphological changes of surface soil. These changes are physical and chemical in nature. The change in subsurface soil CO_2 concentration was one of the parameters of interest. The critical CO_2 concentration is thought to fluctuate around 0.6%. The primary objective of this paper was to determine the impact of forestry machine traffic on subsurface soil CO_2 concentration. We measured CO_2 concentration in the areas undisturbed by machinery and in the ruts in skid trails in eight forest stands. The measurements were performed using a Vaisala MI 70 meter. The results confirmed significant differences in gas concentrations between the individual measurement sites. In the ruts of the skid trails, CO_2 concentrations fluctuated in a range of 0.5 to 2.81% and significantly exceeded the critical concentration. Moisture content and bulk density had a significant impact on the change in gas concentration beneath the surface, which was confirmed by multivariate analysis of variance that revealed that the values of the coefficient of correlation fluctuated in a range of 0.39 to 0.74

Key words: CO_2 concentration; soil disturbance; cut-to-length machines; skidders

Editor: Bohdan Konôpka

Introduction

Soil respiration is one of the most important elements of carbon circulation in forest ecosystems (Hashimoto et al. 2004). Measurements of CO_2 concentrations have been used as proxy for root and microbial activity in soil (Nay et al. 1994). Soil respiration is the result of microbial respiration and the release of CO_2 through plant roots, which may account for 20 – 50% of all CO_2 released from the soil (Bouwmann & Germon 1998). Exact quantification of CO_2 content in soil is problematic, as it is one of the most variable soil parameters; the coefficient of variation may fluctuate between 30 – 150% (Stoyan 2000).

CO_2 released from the soil exhibits daily and seasonal fluctuations and is affected to a significant degree by environmental factors, such as soil moisture content and temperature (Davidson et al. 1998; Howard et al. 1993; Xu & Qi 2001). This effect varies depending on the type of ecosystem. Soil temperature is the primary and decisive factor in respiration in Boreal forests, while instantaneous moisture content only has a minimal effect (Schlentner & van Cleve 1984; Goulden et al. 1998; Rayment & Jarvis 2000; Morén & Lindroth 2000).

Temperature and humidity significantly influence soil respiration in forests of the temperate zone. Soil respiration stops, or is reduced, in the winter months, when temperature decreases and increases when temperature increases during summer (Dong et al. 1998; Fang et al. 1998; Londo et al. 1999; Ohashi et al. 1999). Soil type also significantly affects soil respiration. Large differences exist between fine grained and coarse grained soils and wet or dry soils (Schatschabel et al. 1984). CO_2 concentration in soil reflects biological activity because high concentrations of this gas negatively influence plant growth (Burton et al. 1997). Soil respiration is a major source of CO_2 in terrestrial ecosystems (Schimel 1995).

Soil organisms play a very important role in circulating substances, including CO_2, in terrestrial ecosystems (Paul & Clark 1989; Killham 1994; Roy et al. 1996; Sanders 1996).

Many studies, focused on CO_2 concentration in soil surface layers, are insufficient in terms of providing a correct explanation for CO_2 production in the soil, as the concentration of this gas differs in particular layers as a result of different physical, chemical and biological conditions (Hirano & Kim 2003).

Soil compaction changes the porous system in soil by reducing macro pores. Changes in porosity significantly influence air and water balance in soil, critical for plant growth (Gebauer et al. 2012). Air is a gaseous component of the soil and exists in pores that are not filled with water. It contains less oxygen and more CO_2 (from 0.5 – 5% and higher) compared to atmospheric air (Hillel 1998). Increased levels of CO_2 can be attributed to the root system respiration and the decomposition of organic material in soil. Soils with high CO_2 content and low oxygen content are poorly aerated, which may cause anaerobic conditions to occur (Hillel 1998).

Forest harvesting leads to compaction of surface soil layers, closure of the porous space and a decrease in the exchange of gases between the soil and the atmosphere. Forestry machine traffic may result in a decrease in available freely circulating substances (O_2) or their accumulation (CO_2) in the long term. Root growth may halt as a result of aeration problems. This condition intensifies in soils with

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higher clay content. This lead to greater focus on the soil CO_2 content caused by machine traffic and subsequent effect of forestry machine traffic on the root systems of trees. The use and practicability of this method was described by Neruda et al. (2010) and Skoupý (2011) for example. If CO_2 concentration reaches 0.6%, root growth in soil is significantly affected (Güldner 2002; Gebauer et al. 2012). Other authors, such as Erler and Güldner (2002) state that 1% is the threshold for normal soil recovery. If this threshold is breached, microbial activity is severely constrained and biological recovery takes longer. When CO_2 reaches 2%, all biological activity is halted and soil recovery happens only after physical agents are involved.

Our objective is to identify whether passages of forest harvesting machines cause a build-up of CO_2 in forest soils so severe that microbial activity or root growth is affected in the vicinity of skid trails. Our hypothesis is that CO_2 levels in the disturbed areas are higher than in the undisturbed areas of forest stands. Knowing that CO_2 content in soil air is a highly variable characteristic, we also set a hypothesis that moisture content and bulk density significantly affect CO_2 concentration in soil.

2. Materials and Methods

Measurements were conducted in eight forest stands. Stands n. 2027, 2051, 2052, 187C20, 188, 588, and 574B11 were located in Slovakia and stand n. 805J13 was located in the Czech Republic. Forest stands were different in tree species mix, soil conditions, and various types of harvests were carried out in them by different types of machines (cut-to-length machines – CTL, and skidders). Detailed characteristics of these stands are shown in Table 1. Measurements were conducted from July 2012 to August 2013.

Vaisala MI 70 device was used to measure the CO_2 content in soil. The device was equipped with two Carbocap GMP-70 probes with a measurement range of 0 – 5% CO_2 concentration. Vaisala HMP75B probe with measurement range for relative humidity of 0 to100% and temperatures of −20 to +60 °C was used to measure current air temperature and relative humidity in soil. Measured data was recorded directly onto the device's memory, from which the data was imported into a computer using the Vaisala MI 70 software.

Given that multiple variables concerning soil disturbance and the damage to the parent stand were observed simultaneously, the data were collected using sample plots evenly distributed across the entire stands (Fig. 1a). Dimensions of the sample plots were 20 × 20 m in stands where CTL machines operated (stands n. 2052, 2027, 188, and 187C20), or 20 × 40 m where skidders operated (stands n. 2051, and 588). Square sample plots were chosen for stands where cut-to-length machines operated, because the reach of the harvester's boom enables efficient work up to 10 m to each side. Rectangle sample plots were chosen in stands where skidders operated, because the reach of the winching cable was approximately 20 m to each side. Lukáč (2005) stated that the size of the statistical sample should be sufficient when the sample plots cover 10% of the total area of the stand in stands up to 50,000 m^2 and 5% of the total stand area in stands larger than 50,000 m^2. Within each sample plot we measured soil disturbance on two opposing sides in the direction of skidding.

Stands n. 574B11 and 805J13 were clear-cut, so there was no need to establish sample plots. In these stands we employed the measurement site sampling method as described by Schürger (2012). The measurement sites were located on skid trails with spacing of 5 m (Fig. 1b).

Measurements in the individual stands were conducted throughout the whole day. A total of 256 measurements were performed in all stands. CO_2 concentrations were measured using two Carbocap GMP-70 probes at the same time in: (i) rut of the skid trails; (ii) the undisturbed stand (control measurements). Soil air temperature and relative humidity in soil were entered into the meter before CO_2 was measured in order to regard for changing ambient conditions during the day. CO_2 concentration was measured in the surface soil layer in maximum 10 cm depth. The measurement procedure consisted of multiple steps that were conducted in sequence in order to maximize the accuracy of the CO_2 readings. First, approximately 12 cm deep openings with 2 cm diameter were

Table 1. Basic information on the forest stands where measurements were conducted.

Stand	GPS	Number of measurements	Stand size [ha]	Machine	Volume of harvest [m^3]	Type of harvest	Soil type
2052	48°40'37.95"N 18°5'41.25"E	40	7.9	JDH[a] + JDF[b]	265.87	T>50[i]	luvisol
2027	48°41'19.48"N 18°5'38.19"E	40	8.58	JDH[a] + JDF[b]	232.62	T>50[i]	40% luvisol 60% stagnosol
2051	48°41'9.31"N 18°4'57.79"E	20	16.7	ZTR[c]	95.4	T>50[i]	luvisol
187C20	48°58'6.31"N 18°39'15.40"E	24	5.89	NSS[d] + NVT[e]	90	T<50[j]	rendzic leptosol
188	48°58'5.55"N 18°39'24.47"E	44	12.52	NSS[d] + NVT[e]	190	T<50[j]	rendzic leptosol
574B11	48°35'25.84"N 19°2'41.66"E	44	1.59	HSM[f]	411.3	CC[k]	95% cambisol 5% luvisol
588	48°34'59.62"N 19°3'16.79"E	24	4.12	HSM[f]	215.24	POR[l]	40% cambisol 60% luvisol
805J13	49°49'59.69"N 14°46'25.71"E	20	2.72	PSH[g] + PSF[h]	96.6	CC[k]	modal cambisol

[a]JDH – John Deere 1070D; [b]JDF – John Deere 810D; [c]ZTR – Zetor 7245; [d]NSS – Neusson 132 HVT; [e]NVT – Novotny LVS5; [f]HSM – Hohenloher Spezial-Maschinenbau 805HD; [g]PSH – Ponsse Ergo 6W; [h]PSF – Ponsse Buffalo; [i]T>50 – thinning over 50 years of age; [j]T<50 – thinning under 50 years of age; [k]CC – clear-cut; [l]POR – partial overstory removal.

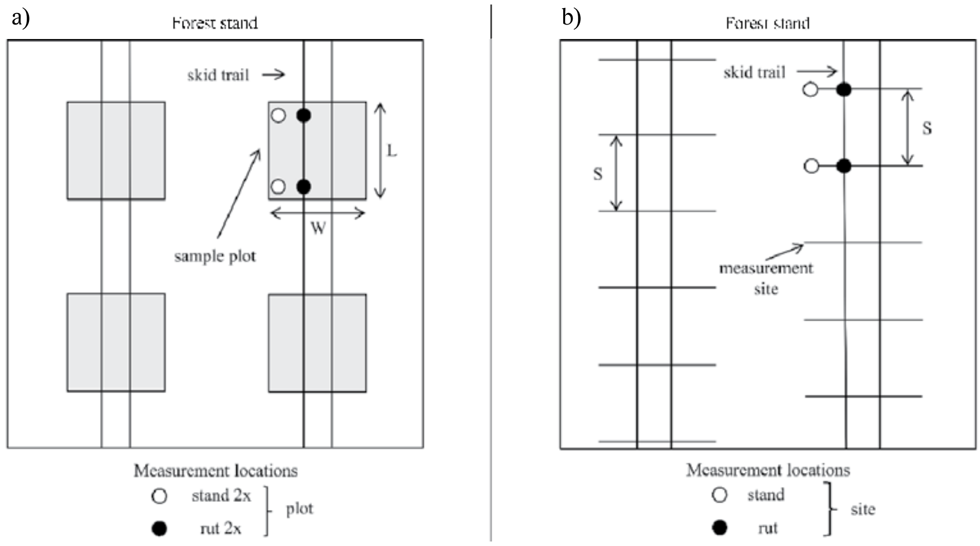

Fig. 1. Layout of the sample plot method of data collection (a) and the measurement site data collection method (b); L – length of the sample plot (20 m); W – width of the sample plot (20 m for cut-to-length machines, 40 m for skidders); S – spacing between two neighboring measurement sites (5 m).

drilled into the soil, then the probes were inserted into the opening so that the top part of the probes with diameter of 2.6 cm would seal the opening. After this, the probes were left in the soil for approximately three to five minutes without recording data into the device's memory so that the ambient air in soil would settle into its original composition (Vaisala 2012a,b). After the interval, the readings were recorded into the device's memory and the probes were taken out of the pre-drilled openings.

Along with CO_2, bulk density and soil moisture content were measured on nearby spots (cca five to ten centimetres away from the CO_2 measurement location) through gravimetric sampling. Soil samples were collected using a set of Eijkelkamp sealable sampling cylinders (volume 100 cm^3, length 50 mm, outer diameter 53 mm). The cylinder was inserted into the soil until it was completely filled with soil, removed from the soil, soil overhanging the cylinder was cut off, and the cylinder was sealed to avoid loss of moisture. Samples were then weighed in laboratory conditions on calibrated laboratory scales with an accuracy of 0.1 g and dried at a temperature of 105 °C for 24 hours, in order to determine the mass of the dry samples. Moisture content at the time of measurement was calculated according to Hraško et al. (1962):

$$w\ \% = \frac{m_v - m_s}{m_s} * 100 \qquad [1]$$

$w\,\%$ – relative soil moisture content [%],
m_v – weight of the raw soil sample [g],
m_s – weight of the dried soil sample [g].

Bulk density and moisture content were used to determine the strength of the relationship between them and the CO_2 concentration.

Before the statistical evaluation we sorted the data according to the forest stands from which they originated. The number of valid cases (number of measurements) in each stand depended on the total area of the stand (Table 1). First, we checked the normality of data through Shapiro-Wilk's test. Subsequently we proceeded to evaluate whether differences between CO_2 content in soil, bulk density of soil, and moisture content in the ruts of the skid trails and the control measurements in the undisturbed stand were statistically significant. We also tested the statistical significance of differences between data from particular stands. Data were evaluated through multivariate analysis of variance (MANOVA) for each stand individually. After testing the significance of differences between the data from individual locations and stands, we tested the relationship between CO_2 content (dependent variable) and bulk density of soil and moisture content (independent variables) through multivariate regression and correlation analysis separately for each forest stand. In this case we also tested the normality of residuals from the model through Shapiro-Wilk's test.

3. Results

Results of this study showed that CO_2 concentration in soil was considerably higher in areas disturbed by machine traffic (i.e. ruts) (Table 2). Fig. 2 illustrates this fact as it depicts the average CO_2 concentration in undisturbed stand soil and in soil from the ruts created by forestry machines. The figure depicts that compressed soil was unable to release excessive CO_2 through its surface into the atmosphere, which lead to the accumulation of CO_2 in the soil. The fluctuations in CO_2 concentrations in ruts indicate that soil compaction and soil moisture content as variables influencing the CO_2 accumulation were not homogenous and varied from one measurement site to another. CO_2 concentrations in ruts exceeded the concentrations from the reference measurement locations, i.e. the undisturbed stand, in all cases.

The overall mean difference in CO_2 concentration between the undisturbed stand and the skid trail rut locations was 0.91% (a relatively large difference). The smallest difference between locations was 0.28% CO_2 content while the largest was 2.22% CO_2 content. The minimum gas con-

Table 2. Changes in CO_2 concentration, bulk density and moisture content in individual stands and in the undisturbed stand and ruts of the skid trail measurement locations.

Stand	2052	2027	805J13	187C20	188	2051	574B11	588
CO_2 concentration [%] stand	0.59	0.72	0.34	0.24	0.28	0.58	0.59	0.30
CO_2 concentration [%] rut	2.81	1.84	0.74	0.52	1.51	1.19	1.73	0.57
Difference in CO_2 [%]	2.22	1.12	0.4	0.28	1.23	0.61	1.14	0.27
Bulk density g cm^{-3} stand	1.21	1.09	1.32	1.05	1.07	0.95	1.43	1.16
Bulk density g cm^{-3} rut	1.64	1.71	1.54	1.34	1.52	1.24	1.79	1.56
Difference in bulk density g cm^{-3}	0.43	0.62	0.22	0.29	0.45	0.29	0.36	0.40
Moisture % stand	25.94	23.04	13.20	28.2	20.4	20.18	39.2	20.41
Moisture % rut	25.48	26.36	11.17	31.5	32.4	18.60	33.6	20.92

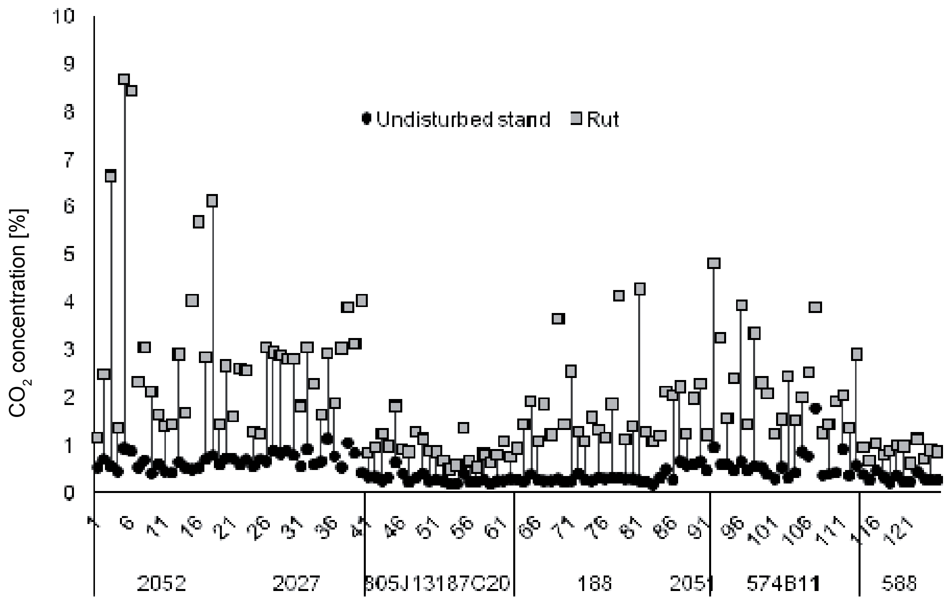

Fig. 2. CO_2 concentrations for each measurement in the undisturbed stand location and skid trail rut location; data from all measurements; vertical lines connect relevant data pairs.

centration in the undisturbed stand was 0.24% CO_2 while the maximum was 0.72% CO_2. Elevated concentrations were noted in the skid trail ruts in all cases, with a minimum value of 0.52% CO_2 and a maximum of 2.81% CO_2. The results from the ruts showed that the critical gas concentration level of 0.6% was exceeded in seven out of eight forest stands. Concentrations in individual stands fluctuated significantly (Fig. 3), which was caused partially by the change of temperature at the time of measurement and partially by the change in natural conditions of the stands. Multiple regression and correlation analysis was used to study the relationship between CO_2 concentration (dependent variable), bulk density of soil, and soil moisture content (independent variables) at the place of CO_2 measurements.

Multiple regression and correlation analysis was conducted for the individual stands given that MANOVA confirmed significant differences between individual stands ($F = 5.26$; $p = 0.00$) and measurement locations (stand, rut) ($F = 32.11$; $p = 0.00$). The value of the correlation coefficient fluctuated in a range of 0.39 – 0.74 (Table 3), which was a moderately strong relationship. Soil bulk density exhibited a significant impact on the change in CO_2 concentration in five forest stands and instantaneous soil moisture content exhibited a significant influence only in one case. The data from all stands were merged into a single database in order to increase the size of the statistical sample; this data was then analysed in the same manner, but separately for the stand and the rut locations.

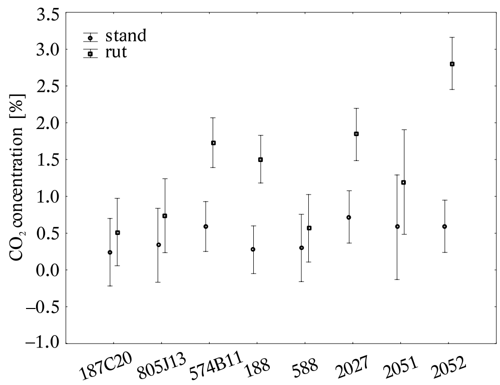

Fig. 3. Mean CO_2 concentration in individual stands for the undisturbed stand and ruts of the skid trails locations; vertical lines indicate 95% confidence intervals.

The results of multiple regression and correlation analysis measured between CO_2 concentration, bulk density of soil, and moisture content of soil in the undisturbed stand location (Table 4) showed a weak relationship with multiple R 0.30; R^2 0,09; $p < 0.003$, caused mainly by the variability of natural conditions. Soil moisture content influenced the

Table 3. Results of multiple regression and correlation analysis between CO_2 concentration, moisture content and soil bulk density in individual stands; Significance of variable: + yes, x no.

Stand	2052	2027	2051	187C20	188	574B11	588	805J13
Correlation coefficient	0.53	0.69	0.74	0.39	0.64	0.50	0.41	0.68
Moisture content	x	x	x	x	+	x	x	x
Bulk density	+	+	+	x	x	+	x	+

Table 4. Multiple regression and correlation analysis between the CO_2 concentration (dependent variable) bulk density of soil, and soil moisture content (independent variables), statistically significant values are marked bold; US – undisturbed stand location, STR – skid trail rut location.

N=125	b*	Std. error of b*	b	Std. error of b	t(122)	p-value
Abs. term			0.130443	0.125308	1.040982	0.299942
Bulk density us	0.121540	0.088211	0.001399	0.001015	1.377821	0.170781
Moisture us	**0.247732**	**0.088211**	**0.007027**	**0.002502**	**2.808386**	**0.005800**
Abs. term			−0.983991	0.940082	−1.04671	0.297303
Bulk density str	**0.233303**	**0.088154**	**0.013894**	**0.005250**	**2.64652**	**0.009205**
Moisture str	0.079206	0.088154	0.011587	0.012896	0.89849	0.370694

CO_2 concentration significantly in the undisturbed stand. Soil bulk density did not exhibit a statistically significant influence on changes in CO_2 concentration.

Multiple regression and correlation analysis of the values from the skid trail ruts showed a similarly weak relationship, with multiple R 0.24; R^2 0.06; $p < 0.03$ (Table 4). An important finding in this case is that soil bulk density exhibited a statistically significant effect on changes in CO_2 concentration in soil. Moisture content in this case did not exhibit a significant influence.

4. Discussion

The results of our measurements confirmed that CO_2 concentrations in compacted soil are higher than in undisturbed soil and that the critical gas concentration value of 0.6% was exceeded in practically all stands in skid trail ruts. The gas concentration fluctuated in a range of 0.28 – 0.72% in the undisturbed stand, compared to 0.52 – 2.81% in the ruts of the skid trail. Gebauer et al. (2012) reached similar conclusions in their work stating that the critical value is exceeded in nearly all skid trails exposed to forestry machine traffic a number of times over (1.2 – 3.4% CO_2 in CTL ruts compared to 0.4 – 0.5% CO_2 in the undisturbed stand).

Kuzyakov (2006) measured CO_2 content with soils compacted to three different densities, specifically: 1.1 g cm^{-3}, 1.3 g cm^{-3}, and 1.5 g cm^{-3}. Dry and wet conditions were examined for precipitation durations of 30 and 90 minutes. The results show a significant correlation between precipitation duration and CO_2 concentration in soil. According to his findings, CO_2 concentration is 42% higher with precipitation lasting 30 minutes and up to 53% higher with precipitation lasing 90 minutes. He found a significant correlation between soil compaction and CO_2. Soil compacted to 1.5 g cm^{-3} retains 32% more CO_2 compared to soil compacted to 1.1 g cm^{-3}.

CO_2 concentration measurements in soil confirm the increase in the content of CO_2 in the soil air as a result of disturbance caused by the heavy forestry machine traffic along skid lines, even if the effects of such forestry machine traffic are not visually apparent (Skoupý 2011). Neruda et al. (2010) confirm a distinct increase in CO_2 concentration on skid trails as a result of a single movement of such forestry machines.

5. Conclusion

One of the drawbacks of measuring CO_2 content in the soil is that it does not provide objective information on to the actual extent of disturbance caused by forestry machine traffic over the soil surface and the fact that CO_2 concentration is unstable and changes depending on natural conditions (time of year, temperature and, as statistically confirmed in our case, humidity and bulk density).

The results of our measurements and the measurements of many foreign authors confirm the hypothesis that forestry machine traffic creates less permeable layers in top soil layers, which hinders gas exchange between the soil and the atmosphere. This was confirmed by the results of our measurements, which correspond to the conclusions of other authors. Changes in gas concentrations are visible after the first passage of forestry machines over soil surface and their negative impact on tree root systems is proven.

Based on these facts, a number of basic recommendations can be determined for forest operations. The most important of these is that the forest managers should restrict movements of the forestry machines to skid trails and prevent any uncontrolled traffic through the stand itself.

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Approaches to the talent management agenda in forestry companies

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Abstract
Professional literature and practice started to focus intensively on the field of talent management. A lack of talented individuals occurred in all sectors worldwide. The war for talents has not faded out, on the contrary, it has been intensifying. The aim of the paper is therefore to analyse the perception of opportunities for development and management of talents in forestry and to specify characteristics of employee/talent support perception in surveyed companies. The analysis is based on a primary survey conducted in 101 forestry companies. The data were obtained through surveys in which one manager and one employee represented a single company. One-dimensional and multi-dimensional statistics were used to evaluate the data. The results showed that employees perceived developmental conditions in companies more positively than what was stated by managers and company representatives. The average difference in the perception was 8.5%; employees perceived the conditions better than company representatives. When negative phenomena were analysed, the perception was quite opposite. The average difference was 9.5%. The limit of the paper is the narrow focus on primary sector companies. The results may help surveyed companies in the primary sector to encourage managers and employees to participate in developmental programmes as their own initiative and willingness to take part in education and developmental activities was found.

Key words: Development; perception; employee; forestry; education

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Introduction

The main source to increase productivity in forestry is particularly the intensification of economic activities as far as qualitatively intensive inputs are concerned, as well as ensuring competent employees and managers of forestry companies (Ministry of Agriculture, 2015; Agriculture Union of the Czech Republic, 2014, Czech Statistical Office, 2014). Therefore research focusing on strategies of human resource management and specifically talent management was made in this paper in order to fill the gap of missing information concerning strategic work with employees in forestry.

Greater attention has been devoted to talent management issues in recent years. Experts in the field of human resource management are of the opinion that in contemporary companies' talent management represents a fundamental and absolutely key element that is able to affect positively the long-term survival of the companies across sectors. A number of factors may be included among these issues, such as demographic changes associated with the general ageing of the population, increased employee mobility, or globalisation, for example (Tarique & Schuler 2010; Beechler & Woodward 2009). According to Schuler & Jackson & Tarique (2011), the success of modern companies is dependent on their ability to identify and manage the up and coming challenges in the area of talent management and to adapt to these challenges. Yapp (2009) adds that companies that practice effective talent management may obtain quite a significant competitive advantage. This topic has also become the subject of a wide range of expert studies and analyses. And yet it still cannot be said that theoretical perspectives on talent management have been sufficiently researched.

Talent may be one of the factors leading to company competitiveness. Therefore this paper focuses on investigating the approaches to the talent management in forestry companies by managers and employees and compare those two views. The paper based upon a primary survey aims to develop a deeper understanding of the support of talents in surveyed companies and to provide underpinning of the area of company's approaches to talent: namely talent support and possibility of development.

The aim of the paper is based on analysis of the perception of opportunities of development and management of talents in forestry to define characteristics of employee/talent support perception in surveyed companies. The first part of the article presents theoretical background of the paper originating from scientific journals. The chapter Results and Discussion includes an analysis and synthesis of the survey targeted at talent management and employees development in forestry companies in the Czech Republic. A comparison of results with results of similar surveys and draft recommendations are also included in last chapter.

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1.1. Theoretical background

Sullivan (2004) defines talent management (TM) as "*the integrated process of ensuring that an organisation has a continuous supply of highly productive individuals in the right job, at the right time*". Collings & Mellahi (2009) define TM as activities and processes that involve the systematic identification of key positions that differentially contribute to the organisation's sustainable competitive advantage, the development of a talent pool of high-potential and high-performing incumbents to fill these roles, and the development of a differentiated human resource architecture to facilitate filling these positions with competent incumbents, and to ensure their continued commitment to the organisation. This is in agreement with results of Collings (2014) and Claussen et al. (2014) which state that TM is a critical driving force in corporate competitiveness and performance. Other definition according to Oosthuizen & Nienaber (2010) states, talent management is an integrated system of recruitment, development and retention of the required human capital at all organisational levels. If organisations refer to talents, they have in mind mostly young people at the beginning of their professional career. Another commonly mentioned group includes employees who have been working for the organisation for some time; their superiors favour them because of their existing performance in order to encourage their further professional growth and promote them to more responsible managerial positions. In conclusion, TM theories have been driven by the assumption that maximizing the talents of employees is a source of sustained competitive advantage (Scullion et al. 2010; Al Ariss et al. 2014). It has resulted in TM becoming extensively linked to human resource management (HRM) practices in organisations (Farndale, Scullion, Sparrow, 2010).

Pascal (2004) specifies the basic definition of talent in the HR field as the capital. Hroník (2007) defines talent itself from the company point of view and this based on two characteristics – performance and respect. If a person features these two characteristics, such a person may be identified as a talented employee according to the author. Waheed, Halim Zalim (2015) state that employees who had high performance and high qualification scores were classified as "stars" in organizations and constituted the talent pool. Employees in other segments needed performance development, qualification development, or both. The employee´s perspective as to development of his or her performance represents another precondition according to Hroník (2007). Similarly, Berger & Berger (2004) believe that a person achieving excellent results is a talented employee. Furthermore, the authors underline the negative consequences of departure of such talented individuals, which specifically means the limited availability of persons with equal qualities which fact makes their substitution even harder and may have negative impacts on the overall results of the company.

Berger & Berger (2004), Lockwood (2006) adds that at the beginning compensation and benefits may attract employees but as the time goes, the top management must start focusing on the development and retention of talented employees. Attention should be paid to the fact that the permanent increase in organizations' demand for talented individuals is logically accompanied by a decrease in their offer. Srivastava & Bhatnagar (2010) the results of which show that the demand for talented and qualified persons greatly exceeds available resources. The war for highly talented employees thus reached all levels of companies and sectors (Frank & Taylor 2004).

Zíková (2010) defines two basic forms of understanding of talent management – narrower and wider. Within the narrower definition, the company focuses primarily on the employees occupying key positions or the employees featuring high potential. It mostly means managerial positions or those filled by experts. The wider definition promotes, on the contrary, the philosophy saying that practically all employees have certain talent and it is up to superiors to discover, develop, deploy it suitably, and last but not least, to be able to make use of such talent.

Iles, Chuai and Preece (2010) identified in more detail four basic perspectives of talent management strategies: the inclusive-people approach (talent = all employees) and the exclusive-people approach (talent = only a specific group of employees). The third perspective focuses on abilities and skills of employees in general (social capital) and the fourth approach deals with specific work positions (exclusive - position). These approaches have been characterized similarly also in the report entitled Asset Skills (2012) which specifies the following five strategies:

1. The inclusive approach – all employees are subject to talent management programs, as it is already mentioned above.
2. The exclusive approach – makes use of the talent pool and the company focuses on managers within talent management.
3. The future-leader approach – all employees throughout the entire company, in whom the potential for managerial positions as been identified, are worked with within talent management.
4. The planned succession approach – key roles are identified and subsequently the employees possessing the required abilities and skills, who are able to fill vacancies when necessary, are identified.
5. The combined approach that makes use of several approaches identified above.

Ready (2009) is of the opinion that if companies are to face the challenges brought up by the 21st century, they should opt for the inclusive approach involving emancipation and development of talents of all employees across the company.

Cannon, McGee (2007) claim that a specific talent management strategy should be always based on the general strategy implemented by the company. Rathod (2014) agrees with that and adds that defining of uniform management criteria in all areas and specifying of specific employee competencies are of equal importance. There are three major objectives of a talent management strategy (Berger & Berger 2004):

– to identify, select, and develop the employees delivering above-average performance and those who inspire other employees in a similar manner;
– to find and correctly appoint highly qualified substitute employees to key positions;
– to allocate resources efficiently (compensation, trainings, work position, couching, etc.).

Already in 2004 the Deloitte company had its own talent management model called Deploy-Develop-Connect Management (Deloitte 2007). Classical linear models focus only on the area of recruitment and retention of employees (Horváthová 2011), but the Deloitte company´s model includes also development of employee abilities, use of talented individuals within various positions in the company, and interconnection with other employees and the entire company, resulting in better communication, cooperation, and higher motivation (Deloitte 2007). According to the results (Siahaan et al. 2016), Waheed & Halim Zalim (2015) it can be summarized that talent attraction and retention to be highly associated with the extent to which the organization is perceived to have a change-, quality-, and technology-driven culture, and characterized by support for creativity, open communications, effective knowledge management, and the core values of respect and integrity.

Hitka et al. (2015) add that continuous monitoring of work performance of employees represents one of fundamental preconditions. Continuing efforts to harmonize the attributes motivating talented employees and the company´s demands and its visions form the basis. According to Siahaan et al. (2016) employees› career development has been well characterized by the presence of career planning and career management provided by the company for the benefit of employees and the organisations.

Similarly important it is to mention the term “employee engagement” that is frequently mentioned jointly with talent management. Robinson et al. (2004) and Stachová et al. (2015) define it as a positive attitude of employees towards the company and values that the company adheres to. According to Falcone (2006), an engaged employee simply shows a high level of engagement and enthusiasm for his/her job. Gibbons (2006) views these issues similarly and according to him it means an increased emotional and intellectual interconnection that involves work performance, company, managers, and co-workers. Robinson et al. (2004) add that the company should develop and foster such engagement and this requires a bilaterally functioning relationship between the employer and the employee.

Schramm (2006) understands retention of talented employees as a strategic opportunity to maintain efficient and competitive labour. In this connection it is equally important to specify the reasons due to which employees leave companies. Kaliprasad (2006) characterizes those reasons as an unsuitable situation as to both tangible (compensation, benefits) and intangible elements such as relationships, the balance between work and personal life, career growth opportunities, trust or the job content itself where the employee believes that those aspects of his/her job may be at a higher level in another company.

Branham (2009) and Buchtová (2002) state that as much as 90% of managers incorrectly believe that the primary reason for departure of employees is the financial remuneration or a better work offer but in fact 80 – 90% of employees leave companies due to various internal factors. Moreover, those factors can be often influenced by the company management. Vronský (2012) includes among those other factors also an offer of better working conditions, dissatisfaction with the overall level of work, and personal reasons. Branham (2004) has already elaborated these issues more specifically and defined the following fluctuation reasons: already mentioned dissatisfactory working conditions, bad relationships with co-workers or superiors, a lack of opportunities to develop talent, absence of the feeling that the job is important for the entire company, or lack of recognition and acknowledgment.

Sousa-Poza & Hennenberg (2004) have worked with slightly different categories of departure reasons within their research, i.e. demographic (sex, age, marital status, education), working (working time, membership with trade unions, income amount, benefits, trainings, size of the company), and subjective (satisfaction, security, promotion, labour market opportunities, the company´s pride).

Křečková-Kroupová (2008) specified four basic drawbacks of current talent management concepts. For instance, it means also search for talents in the same and already explored areas and a failure to make use of the opportunities to contact and support talented individuals already during university studies. Furthermore, it includes a lack of willingness to employ older employees or those who want to work part-time. Last but not least, it is important to offer such employees not only good wage but also interesting and demanding work, mutual efficient and open communication, and opportunities for further development and growth.

Rothwell & Kazanas (2003) characterize talent development as changes involving the company, employees, and individual interest groups, while applying both planned and unplanned learning, which may generate, as a consequence, the competitive advantage that has already been mentioned several times. As concerns specific development strategies, Rothwell (2001), for instance, defined the following five basic strategies that are applied especially in respect of leading positions: couching, special work assignment, action learning (a learning process making use of finding solutions to actual issues in order to extend knowledge), work rotation, and various university programs.

Also Armstrong (2006) understands such programs as substantial elements of the entire process of talent development. In his opinion it is possible to secure through such programs acquisition, improvement or extension of usable abilities, knowledge, and skills. Such educational and development activities may play a vital role when increasing engagement and commitment of talented individuals. Luna-Arocas & Morley (2015) added that job satisfaction as a main underlying contributor to job performance, but rather that if we develop and institutionalise a comprehensive talent system, this can affect both job satisfaction (directly) and job performance (indirectly).

Brewster et al. (2005); Dell & Hickey (2002) or Deb (2006) emphasize the interconnections between talent management and building of the employer´s strong and positive image thanks to which talented individuals may be attracted and retained. According to Chapman et al. (2005) the concept of employer image building depends directly on talent management because it represents a combination of various HR approaches influencing the future reputation of the company as an employer. Building of the employer image may thus help resolve the worldwide lack of talented individuals (Jiang & Iles 2011).

As mentioned in theoretical background, there are several studies made focusing on approaches to talent management, respectively work with talents, however its measurement, significance and impact on talent management was not yet analyzed. Therefore this paper focuses on identification of approaches to talent management by employees and company representatives; and on their superordinate factors to support work with talents in forestry.

2. Methodology

The paper focuses on a more in depth discussion of the concept of talent management, as well as investigating the main approaches taken by the participating companies to agendas related to talent management and perception of its use. In addition, the differences between the results of similar studies are discussed.

The article has been based on the analysis of secondary sources, the outcome synthesis and the evaluation of the results of the primary research. The data were mainly extracted from secondary sources and the analysis and discussion is linked to outcome synthesis and the evaluation of international research results. In order to capture all relevant studies, a variety of keywords for talent management was used. The research is descriptive and empirical in nature because the primary data were collected using the survey method through fact finding techniques such as questionnaire and interview.

2.1. Operationalization of variables

The second part of this article analyses and evaluates the results of primary survey. The data for the evaluation of current approaches and perception of talent management, talent development and possibilities for talents (i.e. talent programs) in surveyed forestry companies has been collected in primary quantitative survey by means of questionnaire investigation. The questionnaire had 10 questions on approaches to talent management and 3 identification questions (size, owner and location). The survey did not contain questions regarding respondent´s gender, age etc., because the questions focused on organisational approach towards talent management. The body of the questionnaire contained mostly questions with one possible answer. Only the first question asking on the job positions used for identification of talents and question asking about effects of use of talent management used possible multiple choice of answers. In such cases, respondents could mark maximum 4 answers related to their practices in company in talent management. One question in the questionnaire focused on preferred competencies of talents and used semantic differential (scale 0 – 4, where 0 = not possible to answer, 1 = totally disagree, 2 = partly disagree, 3 = partly agree, 4 = totally agree) to gain respondent´s nuances in answer.

All questions used in the results of the paper were only with one possible answer per respondent (one manager and one employee per company). On behalf of the organisation, the questionnaire was completed by a respondent who holds a managerial position (has at least one direct subordinate). To obtain the results form employees, always one employee without subordinates was contacted to provide a view from employee´s perspective. The two perspectives were used to be able to compare the perception of the situation regarding talent identification and development by employees and company representatives. Each respondent had to choose only one answer which characterized actual situation in the company the most.

2.2. Sample

The sample of companies in forestry was carried out in the Czech Republic as a random sample of companies. The total number of Czech forestry companies on 31st December 2014 was 12,647 according to the Czech Statistical Office. For the purposes of this research presented in the paper, our own database of forestry companies was made based on quota sampling. The quotas used to create the database were specified based on data and sampling of the Czech Statistical Office. The sampling used size of company, number of employees, type of a company (all types were used for the sampling – corporates, cooperatives, state farms and family farms) address and district of the farm or company in the Czech Republic. The database respects the proportion of size and type of companies in the Czech Republic. The database created for the purposes of this survey consists of 680 companies. The companies selected for the survey were contacted based on their registration in the database of forestry companies operating in the Czech Republic. The overall questionnaire return was 14.8%, i.e. 101 companies completed and returned the questionnaire.

Table 1 bellow shows size of surveyed companies.

Table 1. Geographical location of the forestry companies included in the survey.

Size of a company	Relative frequency
large companies (>250 employees)	6.9%
medium sized (50 – 250 employees)	32.7%
small-sized (<50 employees)	60.4%

Source: own survey

2.3. Data Processing

The data was collected by means of using an electronic questionnaire which automatically recorded and pre-categorised respondents' answers (CAWI method – 85 respondents). The telephonic interview [CATI] method was also used with 16 respondents. The sample selection took into account the size of the company (small companies of up to 50 employees; medium-sized companies employing between 51 and 249 people and large companies with more than 250 employees). Only respondents from upper or top management (HR managers were excluded) answered the questionnaire as manager and one employee. This part of the survey took place at the beginning of 2015 (January – March).

All the primary data were evaluated using descriptive statistics. Within the frame of descriptive statistics, the following tools were employed: absolute and relative frequency, the analysis of correlation and association. In addition, dependence among qualitative characteristics was tested for verification of the data which was obtained and their further analyses (Pecáková 2011). To evaluate the data, the IBM SPSS Statistic 22 and MS Excel 2007 were used.

During the research the procedures followed were in accordance with ethical standards and Czech law relating to the use of sensitive information.

3. Results

The chapter presents results of an analysis of the perception of opportunities of development and management of talents in forestry companies included in the survey. The objective of this chapter is to evaluate the results obtained in the primary questionnaires. The results of the quantitative research have been statistically evaluated and outputs have been formulated. The chapter ends with a discussion of results and comparison with other studies that have been undertaken.

3.1. Approaches to the human resources agenda in forestry companies

The research project is dedicated on the approach of forestry companies to human resources and talent management. As the companies both need to manage talents and to create an environment supporting their potential activities and development, the following chapter deals with support of the development of talents in companies, both by representatives (managers) and employees.

Based on the results of the survey, 50 per cent of surveyed companies in forestry are focused on development of their employees. The outputs also show orientation of surveyed organisations on development of their employees; 64% of respondents are being regularly developed on their job position and 12% are being developed for their future position or position on which they aspire. Total 54% of surveyed employees aspire on higher position (managerial or specialist). The impulse to development is mostly own ambition of each employee (58%).

The results presented in Table 2 show characteristics of the forestry companies participating in the survey and their approach to human resources management. The companies hire new employees (54.5%), but unfortunately invest into their development only if the budget permits so (21.8%); however, 16.8% of them have a good reputation and people are interested in working for them.

It is also possible to mention low overall planning in the area of human resources and employee development. Minimum of surveyed companies have specified budget for research and development, the area is usually managed operatively. Research focused on effects of talent management, as attraction of a company for external workers and talents, recruitment of such new employees and creation of innovations. Results in the Table 1 and also Table 2 show partial interest of surveyed companies in this area. On the other hand, employees perceive searched conditions better and show interest in this area.

Table 2. Support of the development of human resources by the forestry companies included in the survey.

Effect	Relative frequencies
Recruitment of new employees	54.5%
External workers are interested in working in company	16.8%
Company is attractive for talents	9.9%
New employees are rarely recruited	36.6%
Company lowers its staff	5.0%
Research and development has own budget – past few years grows	5.9%
Research and development has own budget – past few years stagnates	5.9%
Research and development has own budget – past few years drops	1.0%
Research and development has no budget – it is managed operatively	21.8%
Research and development has no budget – there is no investment	13.9%
Research and development has own budget – past few years grows	14.9%
Innovations are created but not used in praxis	3.0%

Source: own survey.

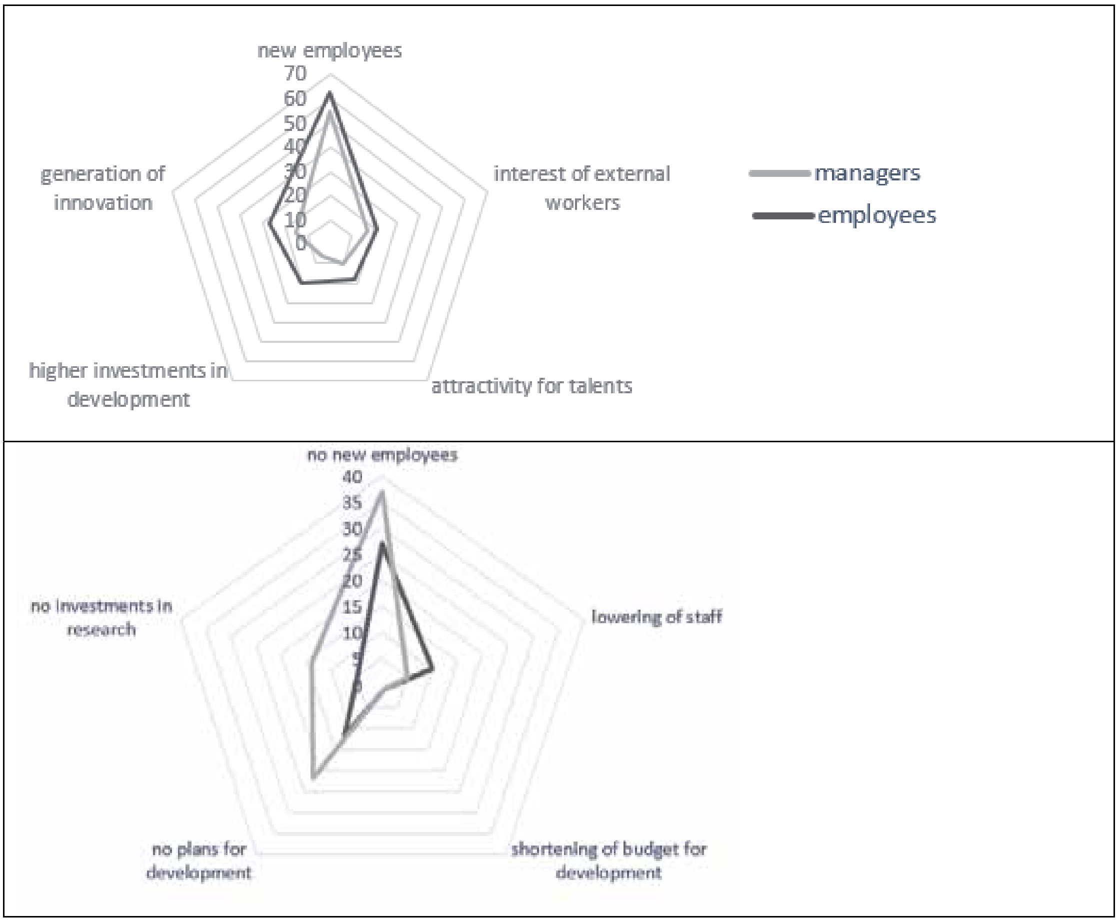
Responses of employees did not dramatically differ from those of representatives of the companies; however, some differences in perception can be identified in them. The employees participating in the survey stated that their company was hiring new employees (63%) and also that it is producing innovations which were subsequently implemented and utilized. The employees feel that people from outside are interested in working for the company (21%). Detailed results are presented in Table 3.

Table 3. Support of the development of human resources by the forestry companies from the viewpoint of employees.

Effect	Relative frequencies
Recruitment of new employees	63%
External workers are interested in working in company	21%
Company is attractive for talents	18%
Research and development has own budget – past few years grows	27%
Research and development has own budget – past few years stagnates	10%
Research and development has own budget – past few years drops	20%
Research and development has no budget – it is managed operatively	7%
Research and development has own budget – past few years drops	1%
Research and development has no budget – it is managed operatively	12%
Research and development has no budget – there is no investment	5%
Innovations are created and implemented	27%
Innovations are created but not used in praxis	6%

Source: own survey.

As shown in the Table 3, employees perceive almost all the areas under examination more positively than representatives (managers) of the companies. They view positively the number of newly hired employees, interest of people from outside in being employed by the company, attraction of the company for talents, investments into education and development, production and implementation of innovations. On the average, the perception of these phenomena by employees is 8.5% higher than that of managers, as indicated in Fig. 1 below.



Source: own survey.

Fig. 1. Comparison of the perception of the development of human resources in the companies included in the survey.

Moreover, Fig. 1 indicates that, insofar as negative phenomena (stagnating number of employees, dropping education/research budgets, inability to produce innovations) are concerned, the difference is reversed – a higher percentage of managers' state that these negative phenomena do occur, while employees do not perceive them as such. The difference in this case is 9.5%. It is possible to notice that employees tend to anticipate better conditions, by 9% on the average, with peak differences being up to 14%.

Employees were asked about specific development opportunities in their companies. It is possible to conclude that most employees of the companies participating in the survey are supported in this respect. These employees stated that their development was focused on the know-how, capabilities and skills they needed in their current positions (64%). 12% of the employees feel the development of competencies will help them improve their current work position. Only 8% of the employees neglect their development (see Table 4).

As shown in Table 4, 6% of employees are formally forced to participate in educational/training programmes and courses. The results indicate that most employees actively educate themselves. Only a negligible percentage of the respondents participate only formally or are without any interest in education. It is obvious that employees themselves are aware of the necessity of development and actively participate in it.

Table 4. Development of individual employees in the companies included in the survey.

Possibilities	Relative frequencies
Development on current job position	64%
Development on aspiring position	12%
Development outside the area of my current job position	22%
Not included in development programme	8%
Development is only formal – necessity in company	6%
Other	7%

Source: own survey.

If results of Tables 2, 3 and 4 are compared, it is possible to see a gap between budget for development and actual development of employees. Almost all searched employees stated they are being educated and/or developed on their current position or on position on which they aspire. Therefore development of employees is particularly managed and organized without any specified conditions, plans, budgets. In some cases employees are even developed by a company´s rule. That means there are internal development programs or courses in surveyed forestry companies. It refers to exclusive approach to talent management in searched area. Companies focus on development of special employees, but there are not specified plans for all staff. This statement is supported by statement of respondents who are developed on aspiring position or outside the area of current job position.

Employees were also asked about reasons of the development in the context of development opportunities. They stated that they themselves wanted to develop (58%), while only 3% of them replied that they were forced to take part in educational/training programmes by the management of the company (Table 5).

Table 5. Development stimuli of individual employees.

Possibilities	Relative frequencies
Personal ambition	58%
Company's rule	3%
Both	27%
Nothing forces me to development	12%

Source: own survey.

The outputs referred to above support the previous result presented in Table 3. The respondents are aware of the necessity of development, and they actively look for development opportunities to fulfil their own ambitions. The positive approach of employees to education and development should therefore make the implementation of educational/training programmes by companies easier.

In order to find overall approach towards employee development in forestry companies, a correlation analysis was used. Those responses of respondents were tested, who stated they apply talent management in their company. Bellow Table 6 shows results of the analysis. Only statistically significant hypotheses are presented in the table.

Table 6. Correlation analysis of approaches to talent management [TM].

Hypothesis	Pearson´s correlation	p-value
Use of TM – interest of workers to work in company	0.344	0.000
Use of TM – list of key talents in company (specialists, managers)	0.341	0.000
Use of TM – development of talents has budget	0.283	0.000
Use of TM – formulated specific development plans	0.292	0.000
Use of TM – TM is part of strategy	0.420	0.000

Source: own survey.

Surveyed companies which use talent management are usually (according to the results of correlation analysis) interesting for workers outside the company and have no problems to hire new staff. This is positive impact of talent management implementation.

Use of talent management concept also correlates with the fact, that talent management is part of company´s strategy and there is a list of key talents in company. Those companies knows their key employees and their strategic importance. And they know it is necessary to further develop them. For this reason there is also a specific budget for talent development of key employees and specific plans are created.

Therefore it is possible to group the results into focus on exclusive talents (exclusive approach) in surveyed companies. Talent management focus on specific and defined key employees, mostly specialists and managers.

As it is possible to see in the Table 6, correlations show that organisations with focus on talents have also unified approach to talent management and clearly defined talent management strategy which is integrated with the strategic goals of the organisation.

Searched companies use some of practices of talent management. The approach is not usually systematic, but necessary development and education of staff were found. As managers of respondent companies stated, they have sometimes problems even to find employees interested to work in forestry and thus they try to retain them and train them, focusing mainly on specialists. The companies surveyed often mentioned necessity to keep quality employees in the future. The main problem in retaining talents is seen in hard seasonal work, low salaries and rewards and challenging work (outside; all kind of weather). Respondent companies try to search for talents between specialists and all employees. On the other hand, the positive impact of talent management is seen by respondents in continuous functionality and development of the whole company, continuity of outputs, improvement of company climate and professional team, stable performance of employees and quality relationships.

4. Discussion

The paper focus attention on talent management practices in forestry companies. The results of the paper indicate there are specific areas of talent management used, but lack of holistic concept was found. Surveyed companies focus mainly on exclusive perspective of talent management (only managers are considered as talents), as it was identified and defined by Iles & Chuai & Preece (2010). Based on this result, it is possible to summarize that forestry companies use mainly exclusive approach to talent management. It is more common approach according to literature and other similar researches. On the other hand, there may be some talents missing when company focus only on development of managers.

On the other hand, most of surveyed employees stated they are part of education and/or development courses or programs. This is in accordance with Ready (2009). Author is of the opinion that companies should opt for the inclusive approach involving emancipation and development of talents of all employees across the company. It is very important to highlight the trend reflected in the results, namely focus on working with strategic talent management, which is a conduit of development and competitive advantage. Overall, half of the sample of companies studied in the given sector is engaged in these areas.

Numerous of authors also mention necessity of employee engagement, which is necessary for successful talent management (i.e. Robinson et al. 2004). In the research conducted it was found that employees are internally motivated for education and development, they knows the need for development and are participating development programs or courses. The positive attitude of employees towards the company and values that the company adheres leads to tendency of employees to stay and grow inside the company. According to Falcone (2006), an engaged employee simply shows a high level of engagement and enthusiasm on the job. Both those findings are supported by the theory.

Gibbons (2006) specified also positive outputs of talent management. According to him it is increased emotional and intellectual interconnection that involves work performance, company, managers, and co-workers. This assumption is in accordance with the results of the survey. Surveyed managers mentioned continuous functionality and development of the whole company, continuity of outputs, improvement of company climate and professional team, stable performance of employees and quality relationships.

Based on gain results, it is possible to agree with Robinson et al. (2004) and Schramm (2006) that the company should develop and foster such engagement and require a bilaterally functioning relationship between the employer and the employee to reach positive impacts of implementing talent management and its practices.

Thus, to retain quality and talented employees, it is possible to recommend the following based on the searched theory and results of the paper:

It is necessary to engage employees/talents in the company. As Kaliprasad (2006) and Branham (2009) states, it is needed to focus on both tangible (compensation, benefits) and intangible elements such as relationships, the balance between work and personal life, career growth opportunities, trust or the job content itself. Additionally, as Buchtová (2002), Branham (2009), Vronský (2012) and Vnoučková (2013) state that as much as 90% of managers incorrectly believe that the primary reason for disaffection of employees and talents is the financial remuneration or a better work offer but in fact 80 – 90% of employees leave companies due to various internal factors, which can be often influenced by the company management. This gap was found also in the presented paper. Searched employees perceive work conditions differently than managers. Luckily, employees perceive conditions better than managers. Companies have thus more possibilities to attract employees and retain them.

To gain new talented employees, Křečková-Kroupová (2008) suggest to search for talents not in the same and already explored areas but to use new opportunities, i.e. to contact and support talented individuals already during their studies (on high school or university), or as respondents mentioned to search between foreigners and also older workers. It includes willingness to employ younger or older employees or those who want to work part-time. Last but not least, it is important to offer such employees interesting and demanding work, mutual efficient and open communication, and opportunities for further development and growth. But as the results of the paper state, employees perceive positive work and development conditions in companies and therefore it is easier to recruit them and subsequently work on their development and retention. Especially it is necessary to work and manage development and retention of those who are key employees and talents.

5. Conclusion

The paper points attention to human resource management and talent management in forestry companies. The research presented in the paper focused on perception of human resource practices by employees and also by company representatives to reveal current situation in this specific companies and to formulate suggestions to practical use of this concept in forestry.

Talent management may be considered a systematic approach to acquiring the right people for the right positions at the right time. The results of the paper show there is lack of specific budget for development of employees in forestry. Employees are being developed, but it does not always correlates with the set budget for development in the searched company (only 13% of surveyed companies have budget for development, other use random financing or there is no investment in this area). Employees included in the survey are mostly developed without specific budget created specifically for research and development purpose. The development of talents is usually random or when it is needed (without specific plans or programs).

Almost all searched employees stated they are being developed on their current job position or on position on which they aspire. Therefore development of employees is particularly managed and organized without any specified conditions, plans or budgets in studied companies. On the other hand it is possible to find some companies where employees are even developed by a company´s rule. That means internal development programs in surveyed forestry companies are being used.

As talent management is implemented in half of studied companies, there are still blind spots in the implementation of the process. Talent management may be seen based on the results of the study as exclusive, because mainly specialists and managers are being developed and are part of talent programs. This statement is supported by responses (both by employees and managers) analysed in the research and correlation analysis. Additionally, the exclusive approach of talent management is supported by the result that surveyed companies develop specific employees on aspiring position or outside the area of current job position.

Another important finding established among the companies and respondents participating in the survey are their own initiative and willingness to take part in education and development programs. The employees themselves are active in the area of development, look for education and training opportunities, and are aware of their importance. The positive and active approach of employees to development therefore makes the implementation of development programs by companies easier.

As a rule, employees perceive opportunities for and conditions of development more positively than managers. Positively are viewed: number of newly hired employees, interest of people from outside in being employed by the company, attraction of the company for talents, investments into education and development, production and implementation of innovations. On the average, the perception of these phenomena by employees is 8.5% better than that of managers. Insofar as negative phenomena (stagnating number of employees, dropping education/research budgets, inability to produce innovations) are concerned, the difference is reversed – a higher percentage of managers' state that these negative phenomena do occur, while employees do not perceive them as such. The average difference in this case is 9.5%.

The relatively narrow focus solely on a primary sector, the forestry industry may be considered a limitation of this article. This sector was nonetheless selected for analysis in view of the conclusions of the National Training Fund (2014), according to which agriculture and forestry ranks in the Czech economy among the industries with not only a higher average age but it also has a great shortage of talented, predominantly young employees, compared to more promising areas, e.g. services. The results and recommendations in this article may assist those companies which were included in the study, in establishing workflows for talent management and employee development.

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Test of airborne laser scanning ability to refine and streamline growing stock estimations by yield tables in different stand structures

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Abstract

Even if stand inventories based on growth tables have been widely discussed over the last years, this method of forest mensuration is still widely applied due to favourable ratio between costs and achievable precision of stand growing stock estimation. The aim of the study was to verify the potential of airborne laser scanning data (ALS) for direct estimation of mean stand height and mean stand density (stocking) as fundamental inputs for forest mensuration based on yield tables. The material from two reference plots with substantially different stand structure was processed by REFLEX software, and confronted with the results of the precise terrestrial inventory. The number of detected tree tops decreased from 100% in the case of super-dominant trees to 30% and 5% in the case of supressed trees at the homogeneous and heterogeneous plot, respectively. The correlation of ALS heights with terrestrially measured heights was R = 0.88 at the homogenous plot, and R = 0.77 at the heterogeneous plot. The tendency to underestimate dominant and to overestimate suppressed trees was revealed at both plots, but was more pronounced at the heterogeneous one. Nevertheless we justified that the mean ALS height calculated from the heights of the detected trees represented the biometric mean stand height linked to the stem with the mean basal area quite well. The stocking estimated by REFLEX software according to delineated crowns´ area was also closer to the real value of stocking than the one obtained by the routine mensuration procedure. The results indicate promising potential of the ALS data processed by REFLEX software to rationalise forest mensuration based on yield tables in even-aged forest structures.

Key words: lidar; stand height; stand density; forest mensuration

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Introduction

Yield tables have been developed for a number of tree species and regions across Europe promoting traditional even-aged forest management (Wiedemann 1949;, Assmann & Franz 1963; Bradley et al. 1966; Marschall 1975, etc). Depending on site conditions, such tables forecast mean stand development (mean diameter at breast height – dbh, mean height) and stocking (basal area, volume and stem number) per hectare for pure even-aged forests. Yield tables operate at a stand level, and therefore only stand level estimation is relevant for simple even-aged forests. Due to the change in silviculture from clear-cuts to an uneven-aged, mixed, small-scale and/or individual tree selective management system, existing yield tables will become increasingly unreliable as the main forest management tool (Hasenauer 2006). However, traditional stand-wise forest mensuration based on yield tables is still widely applied because the costs are substantially lower compared to other inventory methods. Despite the fact that according to the results of the national forest inventory (NFI) more than a half of all forests in Slovakia are more or less uneven-aged, stand inventory using growth tables is currently applied at 88% of the forested area. In Slovakia the national yield tables are used (the last edition by Halaj & Petráš 1998). The required inputs for these growth tables, representing also the subject of stand inventories are: stand age, stand height, site index, stocking, and tree species composition. The accuracy of the growing stock estimation is ±20% at 95% confidence level, and strongly depends on the precision of the determination of input values. Currently the underestimation of the growing stock – 23% obtained by forest mensuration compared to NFI in Slovakia 2005–2006 is under discussion (Šmelko et al. 2008; in the same source Austria – 40%, Czech Republic – 33%).

Remote sensing (RS) is considered one of the promising ways to refine and streamline the acquisition of data on the forests. Especially airborne laser scanning (ALS), which can be combined with aerial photography can provide large amounts of fairly accurate characteristics of the three dimensional structure of a forest in a relatively short time, from which it is possible to derive tree or stand characteristics. Existing practices can be summarised into two categories: individual-tree detection approaches (ITD), and area-based approaches (ABA). Within the first group, tree height is the best directly detectable dendrometric parameter, and the accuracy of its detection is ±9 – 33% (Packalén et al. 2007; Akkay et al. 2009). The resulting growing stock is calculated as the sum of individual trees volumes, using additional inputs derived directly (number of trees) or indirectly (tree diameters) from RS data with lower accuracy than tree height, therefore its detection accuracy is only 10 – 42% (Rossman et al. 2007; Heurich 2008; Maltamo et al. 2009). In the second group of methods, timber stock is estimated using the regression equation between a dendrometric parameter measured in the field, and a specific ALS parameter (e.g. point clouds

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density). The accuracy of growing stock estimates by this approaches reaches ±20 – 33% (Maltamo et al. 2006; Vastaranata et al. 2011).

In this study we applied ITD approach to analyse ALS data by REFLEX software, and subsequently we used the results for the calculation of mean stand values for the purpose of yield estimations on the stand level by yield tables. The aims of the study were:

1) To verify the accuracy of direct determination of mean stand height and mean stand density (stocking) by our own newly developed algorithms of ALS data processing.
2) To assess the usability of ALS data processed in this way for the estimation of the growing stock using domestic yield tables in two different stand structures.

2. Material and methods

2.1. Terrestrial data

Data from two reference plots established in similar geomorphological and growth conditions of Central Slovakia, but with substantially different stand structure and tree species composition were used (48°37'N, 19°04'E). While plot A with an area of 0.95 ha represents a simpler stand structure of a typical even-aged forest, plot B with an area of 0.65 ha is an example of a complex uneven-aged stand structure (Fig. 1). On both plots, full terrestrial inventory was performed by Field-Map technology (IFER 2012). Tree species detection, diameter at breast height (dbh), tree height, and tree position were measured for each tree. Consequently, the volume of each tree was calculated using volume equations (Petráš & Pajtík 1991). These data were taken as a maximally achievable precise base to assess the accuracy of growing stock estimations by yield tables.

2.2. Remote sensing data

Data of aerial photography and airborne laser scanning (ALS) were obtained for each plot. For technical details see Table 1. The data of aerial photography were used for tree species detection, and pairwise individual tree identification after the overlap with outputs of terrestrial measurements and ALS data manually processed by an operator. REFLEX Software (Sačkov 2014a, b) which is being developed by the National Forest Centre was used to analyse ALS data.

2.3. REFLEX software principles

In the first step the initial procedures are applied to transform the point cloud to a regular mesh and to reduce the number of points in the input file. Thus, a point cloud is produced that is further used for an iterative search for treetops detection and tree crowns delineation. A moving-window analysis is

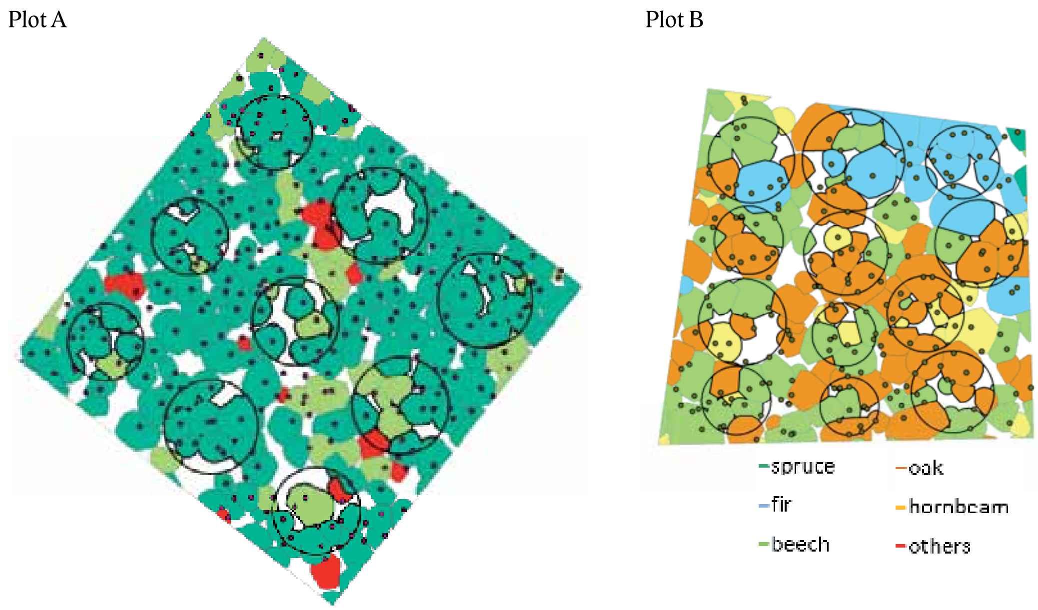

Fig. 1. Sample plots with crown projections of trees derived from ALS data with marked real stem positions according to terrestrial measurements, and circular ten-tree sample subplots for simulated mensuration estimations.

Table 1. Technical description of utilised remote sensing data.

Aerial photography		Airborne laser scanning	
Date	18.04.2012	Date	16. 04. 2012
Used aircraft	Cessna 206G	Used aircraft	Cessna 206G
Imaging camera	UltraCamXp	Scanning camera	Riegl LMS-Q680i
Mean height of flight [m]	2000	Mean height of flight [m]	700
Overlay (H/V) [%]	80/60	Scan angle (DEG)	60
GSD (max)	10 cm (7,2 μm)	Point density	20
Format	*.tiff	Format	*.las

applied to search iteratively for the local maxima. Because there are some reasons to assume that a part of the local maxima identified in the previous operation may not be indicative of real treetops, an additional geo-dendrometric test is applied. The geo-dendrometric test consists of two steps. At first, height differences between the local maxima located in the testing area (radius that represents the mean defined crown semi-diameter) are evaluated. At second, horizontal and vertical distances between all local maxima are evaluated. The horizontal distance is tested to eliminate false treetops situated in the crowns of neighbouring trees. The vertical distance is tested to capture the trees situated under the canopy. Finally, all tested local maxima are classified as true treetops or false treetops. The following procedures are applied to delineate tree crowns. At first, each true treetop was assigned its main crown segment. Then, the peripheral crown segments are repeatedly assigned to the main crown segment. Finally, all crown segments assigned to the true treetop are merged to create a single crown object, and the borderline of such an object is smoothed to create a realistic crown shape. When the treetops identification and crown delineation phase is completed, tree heights are recorded and crown coverage is calculated. Finally, the outputs of all procedures are exported to the point and polygon outputs in ESRI format.

2.4. Determination of stand height

The first step was the pairwise identification of individual trees using the overlap of terrestrially measured positions of trees with the treetops and crown projections derived from ALS data. The orthophotomap and the data on tree height were additionally used for unique detection of the trees. Only the data pairs with no doubt about the identity of the tree were considered as identified. Using these pairs, the correlation between the terrestrially measured heights and heights derived from ALS data was analysed, and the systematic error (BIAS) was examined by t-test. Consequently, the ALS average height (h_{als}) was computed from z-coordinates (heights) of treetops derived from ALS data, and was compared with different types of mean stand height derived from terrestrial measurements. These types of stand height were compared: mean height (h_m) computed as a simple arithmetic mean of heights obtained from terrestrial measurements, Lorey´s height (h_L) computed as a weighted mean of measured heights with basal area used as the weight [Eq. 1], and the upper height ($h_{10}\%$) computed as a mean height of 10% of thickest trees in the examined set of trees.

$$h_L = \frac{\sum_{i=1}^{n} h_i g_i}{\sum_{i=1}^{n} g_i} \qquad [1]$$

Where h_i is the height of tree i, g_i is basal area of tree i, and n is number of trees in the examined set.

To simulate real forest mensuration procedures (Bavlšík et al. 2009), virtual sample subplots each comprising 10 trees were selected within the reference plots (Fig. 1). This approach enabled us to reproduce the variability within the plots for the purpose of the statistical comparison, and it was applied generally for all calculations. Nine subplots were established in the relatively homogenous plot A, and twelve in the heterogeneous plot B.

2.5. Determination of stand density

Stand density (stocking) was estimated from ALS data (st_{als}) as a ratio of the cumulated area of crown projections delineated by REFLEX software to the whole investigated area (in our case to the area of circular subplots) after dissolving of tree crown overlaps. This stocking was compared with the stocking obtained by traditional procedure of forest mensuration based on the estimation of the potential number of missing trees (st_{num}) [Eq. 2], as well as with the precise value of stocking calculated as a ratio of real stand basal area derived from the inventory to the potential maximal basal area according to yield tables (st_{ba}).

$$st_{num} = \frac{n}{n+m} \qquad [2]$$

Where n is number of trees in the examined set (in our case always 10), and m is estimated number of missing trees which would be needed to cover empty space in the set of assessed trees (in our case a circular subplot).

2.6. Growing stock estimation

Finally, the deviations of growing stock estimated by yield tables using either remote sensing (V_{als}) or simulated terrestrial mensuration data (V_{men}) from the accurate growing stock based on full inventory of all trees on the plots (V_{inv}) were assessed. The accurate growing stock represents the sum of individual tree volumes calculated using the set of volume equations $v=f(dbh, h)$ derived for individual tree species, and applied in the National Forest Inventory of Slovakia (Petráš & Pajtík 1991).

The standard national 2-parameter yield tables (Halaj & Petráš 1998) were used for the estimation of growing stock by yield tables. The procedure applied to obtaining two from five necessary inputs for the tables (stand height and stocking) is described above. Regarding the other inputs, the age was taken from the forest management plan, the site index was determined as a function of the age and the stand height, and tree species composition was assessed by visual interpretation of aerial photographs (orthophotomap) in the case of V_{als}, in the case of V_{men} it was calculated from the number of trees, and in the case of V_{inv} it was a relative proportion of a tree species from the basal area of the virtual subplots.

3. Results

3.1. Accuracy of ALS detection of individual tree heights

The pairwise analysis of tree height detection was performed only for identified trees. The proportion of the identified tree crown peaks with the real terrestrially recorded and measured positions of trees strongly depends on the social status of the tree (Fig. 2), and varies from 100% in the case of superdominant trees to 5 – 35% for supressed trees. The proportion of unrecognised under-storey trees is even more pronounced in the multi-layered plot B (Fig. 3). The two factors: the type of stand structure (single- or multi-layered), and the tree species were examined by the analysis of variance, and none of them could be proved to be statistically significant by F-test. The correlation of ALS heights with terrestrial heights was higher at the more homogenous plot A (R = 0.88) than at the heterogeneous plot B (R = 0.77). A tendency to underestimate dominant and to overestimate suppressed trees was observed at both plots, but was more apparent at plot B. This tendency is expressed by the deviation of the dotted line with the intercept equal to zero from the solid line representing the linear regression that fitted the data best (Fig. 4). The distribution of the differences with the results of the test on BIAS is shown in Fig. 5. The values of broadleaved tree species and from the more complex stand structure were more sensitive to BIAS. Generally, dominant trees tended to be underestimated while suppressed ones were significantly overestimated. The positive systematic error (BIAS) of h_{als} in the case of dominant coniferous trees detected at both plots (A + 0.4 m, B + 0.9 m) is difficult to explain.

3.2. ALS stand height versus mean heights applied in forest mensuration

The stand height computed as the mean from all treetops identified by REFLEX software in ALS data generally best responded to terrestrially measured Lorey´s height (Fig. 6). This tendency was even more pronounced in single-layered structure at plot A. The differences between the various types of terrestrially measured stand height were clearly visible. Their values decreased in the following order: top height – Lorey´s height – mean height. The only exception was hornbeam at plot B, where Lorey´s height was the lowest due to the strongly left-skewed diameter distribution of under-story hornbeam population, and ALS height was even higher than the top height because of the overestimation of suppressed tree heights by ALS method as stated before. The variability of terrestrial heights at plot B with the multi-layered stand structure was two to three times higher than at the sinle-layered plot A.

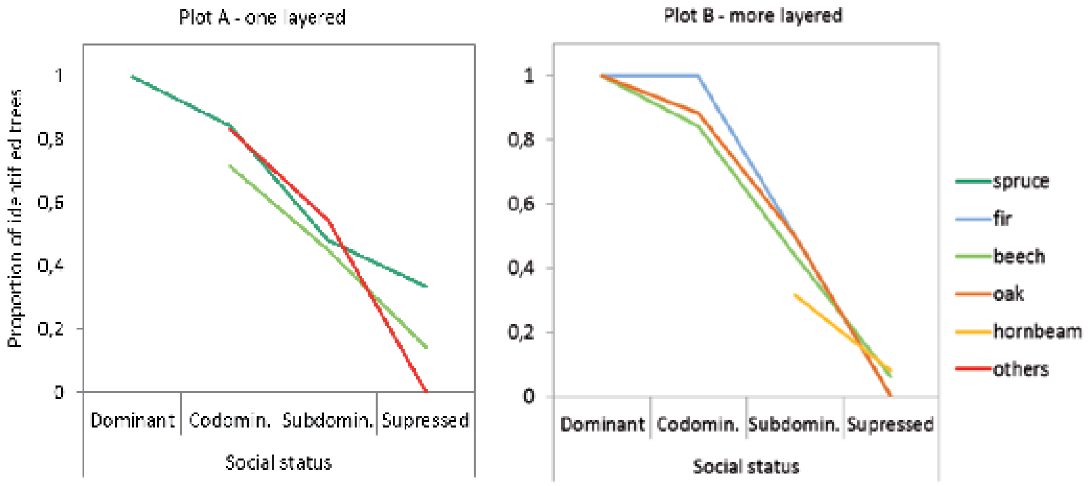

Fig. 2. Proportion of ALS identified trees from all terrestrially recorded trees.

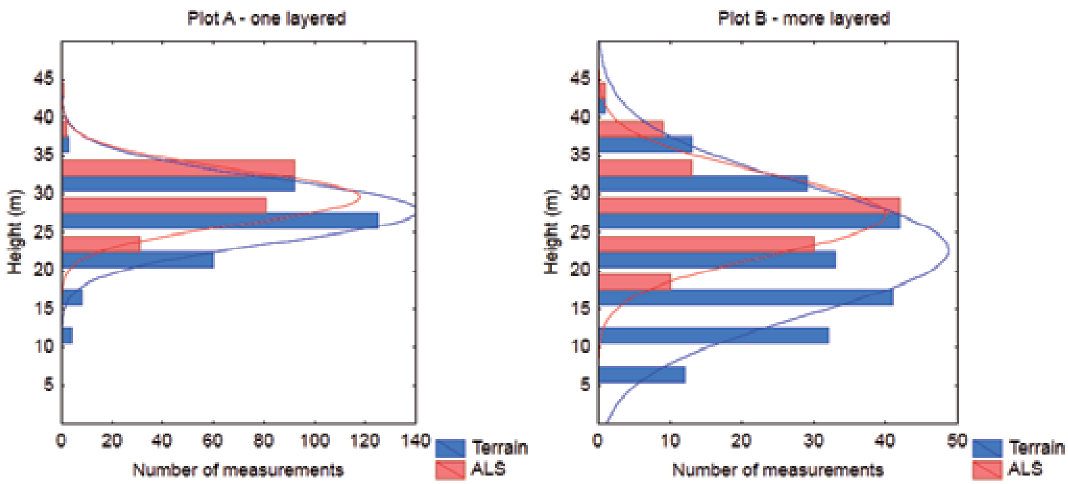

Fig. 3. Height distribution of all ALS identified and terrestrially measured trees fitted with normal distribution.

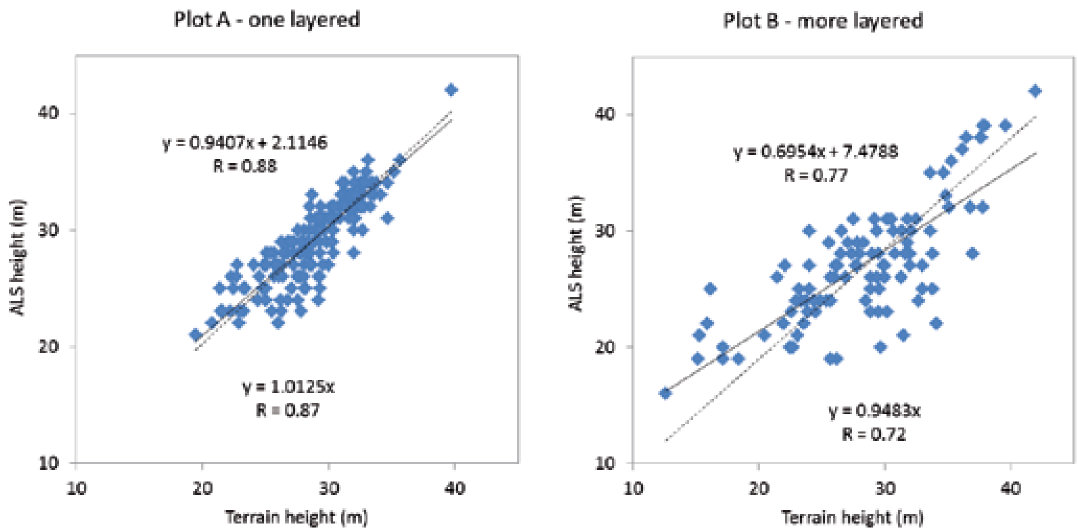

Fig. 4. Pairwise correlation of tree height derived from ALS data and tree height measured terrestrially for identified trees.

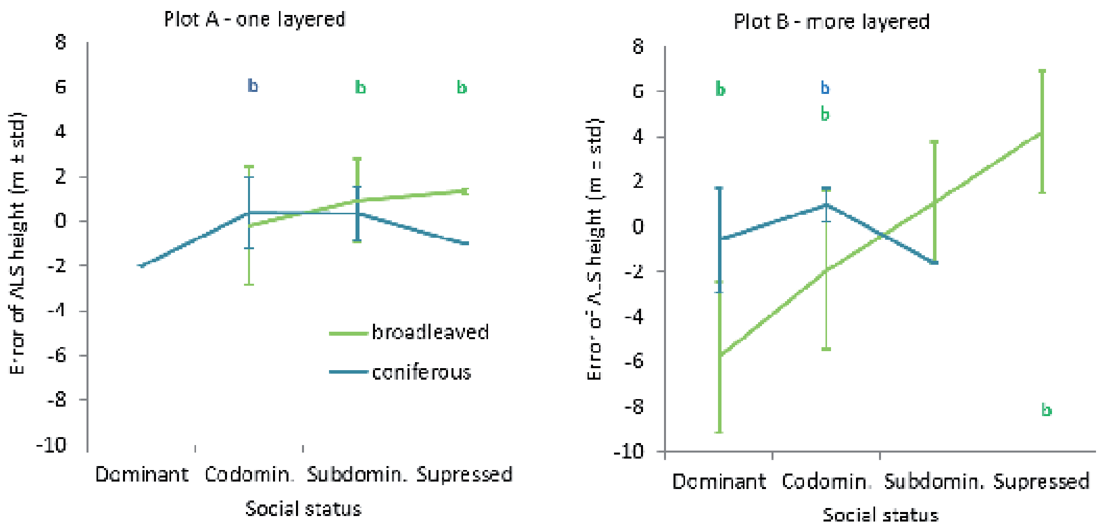

Fig. 5. Distribution of pairwise differences of ALS tree heights from terrestrially measured tree heights of identified trees (standard deviations and BIAS indicated).

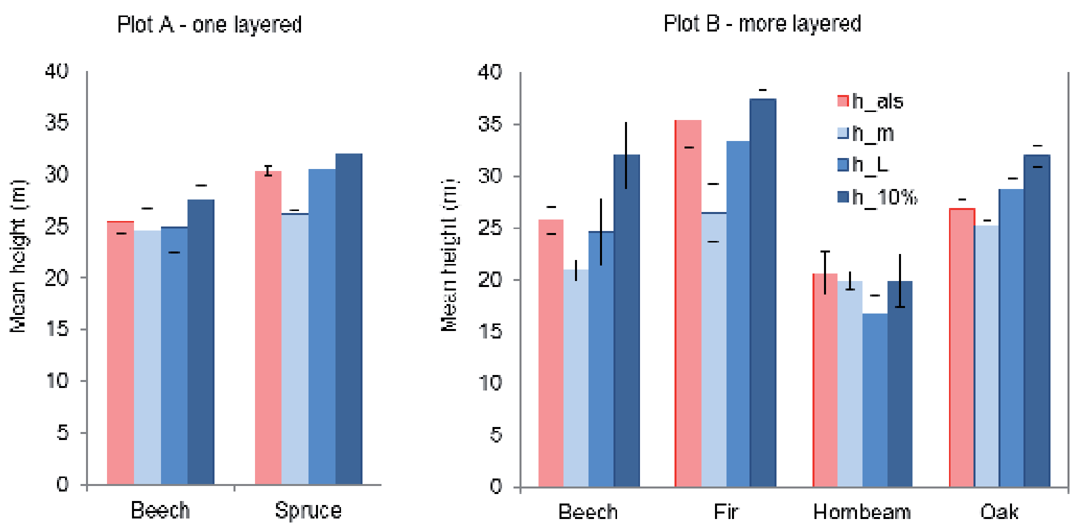

Fig. 6. Comparison of mean stand heights derived from ALS with different types of stand heights computed from terrestrial data (with standard errors at 95% confidence level).

3.3. ALS stocking versus stocking detected by conventional methods

The stocking value assessed from ALS data as a proportion of canopy built from crown projections delineated by REFLEX software was between the values of the other two examined methods at both plots (Fig. 7). We found an interesting (though not statistically significant) tendency to underestimate stocking by nearly 5% using the traditional procedure based on the number of missing trees, when compared with the exact value of stocking calculated from basal area. The variability was highest in the case of stocking calculated from basal area.

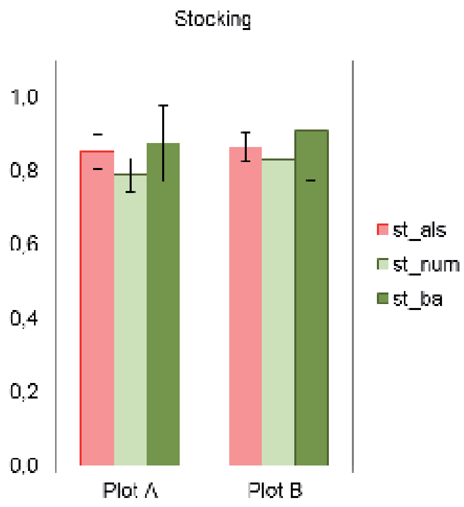

Fig. 7. Comparison of mean stand density (stocking) derived from ALS data with stand densities computed by different ways from terrestrial data (with standard errors at 95% confidence level).

3.4. Impact of remote sensing inputs on growing stock estimation

The results of comparison of remote sensing supported with traditional terrestrially supported estimation of growing stock by yield tables are summarised in Table 2. Finally, confrontation of both methods based on the yield tables with exactly determined growing stock by field measurements of all trees is given. The observed differences are presented in Fig. 8. The results showed good conformity between the estimates of the total growing stock by all examined methods, what is surprising especially in the case of the multi-layered plot B. The differences in the growing stock were −3% and −2% for terrestrially, and +7% and +9% for ALS supported yield table estimates at plots A and B, respectively. Much higher differences (about ±40%) were observed in the case of individual tree species growing stock estimates. Here partial errors of such inputs as the tree species proportion and the tree species mean height played a more pronounced role. Generally, the error of tree species proportion and the error of stocking affect the growing stock estimated by yield tables linearly as a multiplier, while the error of mean height influences the estimated growing stock indirectly through

Table 2. Estimates of stand growing stock based on yield tables derived from remote sensing inputs and from conventional terrestrial inputs, and from fully measured terrestrial data.

Method	Stand	Tree species	Proportion [ratio]	Mean height [m]	Stocking [ratio]	Age [years]	Site index [m]	Volume [m^3 ha^{-1}]
Yield tables – remote sensing inputs	plot A	beech	0.16	25.4	0,85	85	28	58.8
		spruce	0.84	30.3			32	479.1
		total						537.9
	plot B	beech	0.38	25.7	0.87	105	26	155.1
		fir	0.15	35.4			34	111.3
		oak	0.38	26.9			26	131.9
		spruce	0.02	42.0			42	19.2
		hornbeam	0.07	20.6			20	22.5
		total						440.0
Yield tables – terrestrial inputs	plot A	beech	0.24	24.8	0.79	85	28	81.1
		spruce	0.76	30.5			34	419.8
		total						500.9
	plot B	beech	0.27	24.6	0.83	105	24	100.8
		fir	0.16	33.4			32	104.2
		oak	0.46	28.7			28	162.1
		spruce	0.03	29.2			28	17.7
		hornbeam	0.07	16.7			16	17.5
		total						402.3
Terrestrial measurements of all trees	plot A	beech	0.19	23.4	0.88	—	—	95.4
		spruce	0.81	29.2			—	415.5
		total						510.9
	plot B	beech	0.21	20.0	0.91	—	—	108.6
		fir	0.20	33.5			—	104.6
		oak	0.31	28.3			—	157.6
		spruce	0.04	28.2			—	20.5
		hornbeam	0.03	16.4			—	17.1
		total						408.4

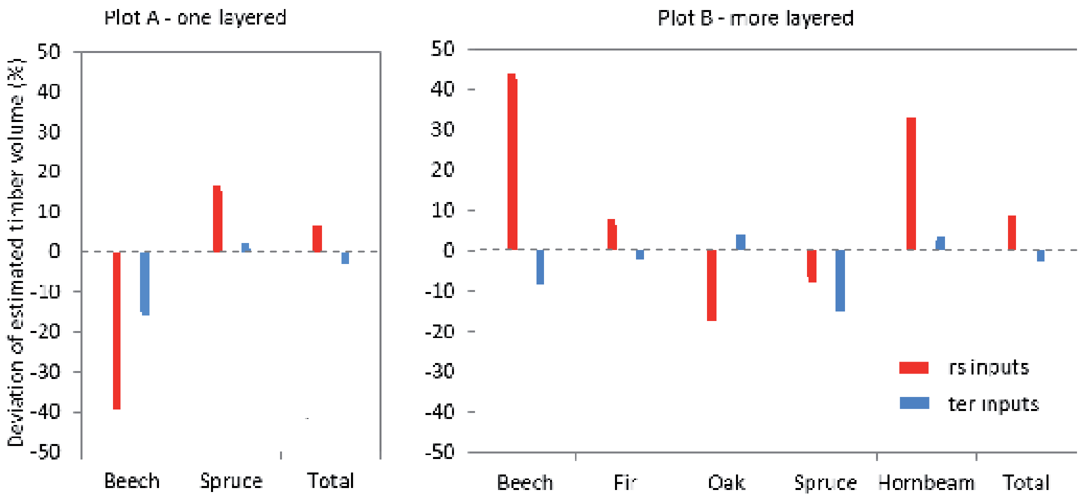

Fig. 8. Differences of stand growing stock estimated by yield tables using remote sensing inputs (rs) and terrestrial inputs (ter), from the real growing stock obtained by full measurement of all trees.

the classification in site index class with a span of 2 m. Hence, a small change of height might sometimes cause relatively substantial differences in the estimated growing stock.

4. Discussion

According to numerous studies focused on individual tree detection using the ALS data it can be stated that in single-layered forest stands individual tree detection results are better than in multi-layered ones. When testing different detection methods in the area of Berner Jura, Eysn et al. (2015) obtained best results in old forest stands with high trees and no understory vegetation. The lowest detection result was obtained in a multi-layered forest with a high amount of trees in different height layers. Only 15% of trees smaller than 10 m could be correctly extracted by the best performing method. Vega et al. (2014) reported an overall performance of 58% for mixed multi-layered mountainous forests in the French Alps, with a 75% detection rate in the dominant tree layer. Between the single-layered coniferous and mixed class, a considerable difference in the matching rates as well as in the commission rates is noticeable (Vauhkonen et al. 2011). Higher commission rates for multi-layered mixed forests can be linked to more complex crowns of broadleaved trees that can have several possible treetops, which results in over performing detection results, while coniferous trees have, in most cases, a clearly defined tree crown shape, and the tree top appears as a clear peak in the canopy height model.

In our study, the detection of 71% of all trees was obtained within the single-layered forest stand, while in the multi-layered stand structure it was only 52%. In both cases, the detection of dominant trees exceeded 80%, and the detection of supressed trees continually decreased with the decreasing relative tree height. Only 6% of trees with their relative height below 1/2 of the main canopy height was detected within the multi-layered structure. No problem with the overestimation of broadleaved crown tops was detected, what might indicate good ability of REFLEX software to delineate also problematic crowns of deciduous trees.

It should be noted that LiDAR studies, similar to other remote sensing studies of individual tree properties, are sensitive to the positional error of both field data and remote sensed data. Potential sources of errors derived from ground-based survey measurements, scanning configuration, position of the tree within the canopy, ground slope effects and crown shape and spacing might affect the predictors extracted from LiDAR, e.g. height (Saremi et al. 2014). Some of these facts might have been reasons for the unexplainable positive BIAS of dominant trees´ heights derived from ALS data when compared with precise terrestrial measurements in our study. Generally, negative BIAS has been documented for ALS height of dominant trees, and positive bias for suppressed trees (Hollaus et al. 2006). Our approach tries to avoid these biometric complications related to individual tree detection method (ITD) by deriving mean stand parameters – mean height, mean stocking directly from ALS data, and using them for growing stock estimations by yield tables at a stand level.

Stand growth tables utilise different types of stand heights to determine site index. Slovak yield tables are based on the mean stand height representing the height of a mean stem, or top height representing the mean height of 10% of the thickest trees in the stand (Halaj & Petráš 1998). The best mean stand height used for this purpose is the height of the stem with mean diameter, mean basal area, or Lorey´s height. These heights are very similar, and are all consistent with the so called Weise´s height widely applied in forest mensuration (for the description of Weise´s rule see Sedmák et al. 2015). In the case of most frequent left-skewed diameter distribution in even-aged stands, they are always higher than the simple arithmetic mean height (Šmelko 2007). Our results showed good consistency of ALS height with Lorey´s height. The decreasing ability of ALS to detect the tops of lower trees has been compensated by the fact that the “mensuration” mean stand height does not represent the arithmetic mean of all heights in the stand, but it is linked to the mean, i.e. a thicker stem.

Numerous automatic algorithms for detecting and delineating individual tree crowns from ALS data are routinely presented with improving performance and computational efficiencies (e.g. Li et al. 2012; Kania et al. 2014; Strimbu et al. 2015). As we documented in our previous studies (Sačkov 2014a, b), the ratio of crown projections delineated by REFLEX software, dissolved, aggregated and related to the whole stand area differed from routine stocking estimates applied in forest mensuration by +6% on average. The results presented in this study are in accordance with previous findings. At both plots, ALS stocking was higher than the stocking obtained by the traditional procedure of forest mensuration, but was lower than the exact value of stocking calculated as a ratio of real stand basal area to potential basal area from yield tables. The recorded tendency to underestimate stocking by routine practice of forest mensuration could be one of the reasons of underestimation of growing stock estimates when compared with forest inventory results.

Stand inventories based on growth tables have been widely discussed over the last years. Nevertheless, this method is still commonly applied not only in Central-Eastern Europe, but also in countries with developed forestry. The main reason is the ratio between the costs and the achievable precision regarding uncertainty (Haara 2005). A mean error of ±20% is declared for stand growing stock estimates by yield tables. A mean error of ±5% is achievable when all trees are measured and individual tree volume functions are applied (Šmelko 2007). Our growing stock estimates obtained from yield tables using remote sensing inputs met the declared accuracy for the whole stand, but not for individual tree species. At plot A, the main reason was the overestimation of the proportion of the dominant spruce and the underestimation of the proportion of the supressed/shaded beech from aerial photographs. At plot B, the overestimation of height and consequently of site index of mostly suppressed beech and hornbeam populations were the main reasons of the observed deviations. The uncertainty of broadleaved tree species detection from aerial photographs, resulting to mutual shifts in oak, hornbeam and beech proportions might be the next reason. The alternative of estimation supported by terrestrial measurements produced very good results, which indicates good accuracy of the yield table model if correct inputs are used.

5. Conclusions

Our study confirmed the existing knowledge about the limited ability of ALS data-processing tools to detect individual treetops of under-storey trees. Hence, individual tree detection (ITD) becomes problematic in more complex, uneven-aged and multi-layered forest structures, and it is necessary to look for other approaches of using ALS data for biometric purposes in such stands.

The tested REFLEX software showed good ability to detect treetops as well as crown shapes of dominant trees in the stand. Although not all trees were identified, we proved that the mean height calculated from the heights of detected trees represented the biometric stand height, linked to the stem with the mean basal area quite well. This height is used in the calculations of site index, thus ALS average height could be directly utilisable instead of terrestrially measured mean height for forest mensuration based on yield tables. Also the stocking estimated according to REFLEX software delineated crown area of the identified trees was closer to the real value of stocking than that obtained by routine mensuration assessment. Since the study was conducted only at two sample plots, the results cannot be generalised, and should be verified on larger data sets. However, they indicate the potential of the ALS data processed by REFLEX software to rationalise forest mensuration based on yield tables in even-aged forest structures. The risk of possible systematic error (BIAS) can be eliminated by checking field measurements and subsequent correction of the results according to the principles of the two-phase survey.

When using ALS and remote sensing data for stand-wise forest inventories it remains challenging: 1) to determine the proportion of individual tree species in the stand, and 2) to estimate the distribution of trees to diameter classes in multi-layered close-to-nature forests.

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Forest certification in Russia: development, current state and problems

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Abstract

The article analyzes the development of voluntary forest certification by the Forest Stewardship Council (FSC) system in Russia. The article is based on the review of diverse information sources, analysis of the reports of timber processing enterprises, personal observations during certification audits, discussions in workgroups, and information collected at training courses. We evaluated the present state of voluntary forest certification in Russia, analyzed non-compliances of the activity of Russian wood processing enterprises with the national standard FSC-STD-RUS-V6-1-2012 and indicated possible reasons for non-fulfillment of the requirements. We also presented problems in the development of forest certification in Russia and possible ways for its further development.

By the end of 2015, about 40 million hectares were certified, approximately 160 certificates were issued on forest management and 440 certificates on chain of custody. The 6th principle of the national forest management standard is the most problematic for logging enterprises. The principle concerns the requirements on the evaluation of impact of enterprise's activity on the environment. About 40% of non-compliances identified by auditors referred to the indicators of the 6th principle.

We argue that the main problems of forest certification development in Russia are contradictions between the principles and the criteria of FSC and the requirements of Russian forest legislation, retention of biodiversity and high conservation value forests, lack of economic incentives for introduction and implementation of certification requirements, and high cost of audits. Despite the existing problems, the certification remains one of the most important instruments for achieving sustainable forest management in Russia.

Keywords: Forest Stewardship Council; non-compliances with the standard requirements; FSC principles and criteria; sustainable forestry.

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Introduction

Forestry must be based on the principles of sustainable forest management. Depletion of natural resources, including forests, during human history has caused crises in many countries and influenced settlement of people, agriculture, industry and international trade, etc.

One of the first notes on the term "sustainability" concerning forest management can be found in a book by Hans Carl von Carlowitz (Carlowitz 1713), who urged land owners to keep and grow forest to provide long-term and inexhaustible use of its resources and asked them not to cut trees every year, so that trees have enough time to grow.

The term "sustainable forest management" began to be widely used in 1992 after the United Nations Conference on Environment and Development (UNCED). The following documents were published based on the results of the conference: "Non-legally binding authoritative statement of principles for a global consensus on the management, conservation and sustainable development of all types of forests" (General Assembly, 1992) and "Agenda 21" (Agenda 21, 1992). These documents specified the foundations of sustainable forest management. Then Ministerial Conference on the Protection of Forests in Europe (MCPFE) and the Food and Agriculture Organization (FAO) defined sustainable forest management as "the stewardship and use of forests and forest lands in a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, vitality and their potential to fulfill, now and in the future, relevant ecological, economic and social functions, at local, national, and global levels, and that does not cause damage to other ecosystems" (MCPFE, 2009).

The conferences and negotiations (Simula & Nussbaum 2005) resulted in the definition of international principles and criteria, observance of which would facilitate development of sustainable forest management. According to the principles of sustainable forest management, we should strive for such a way of conducting forestry in which a forest owner would not only earn an income but would also create conditions for maintenance of social sphere (hunting, fishing, gathering, tourism, employment of population) and would keep ecological values of forest areas. An important condition of sustainability is continuity of forestry processes in a long-term perspective that ensures the next generation to be able to use resources at a forest territory.

Abbreviations: FM – forest management; CoC – chain of custody; PEFC – The Programme for the Endorsement of Forest Certification; FSC – Forest Stewardship Council; SFI – Sustainable Forestry Initiative; CSA – Canadian Standard Association; ATFS – American Tree Farm System; CertFlor – Certification Florestal; EIA – Environmental Impact Assessment, HCVF – high conservation value forests, IFL – intact forest landscapes; SMF – sustainable forest management; CARs – corrective action requests; NGO – non-governmental organization.

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Forest certification is one of instruments that facilitates practical implementation of sustainable forest management (EEM, 2007; Marx & Cuypers 2011). It began to be broadly recognized at the beginning of 1990s. Introduction of forest certification systems was conductive to a new type of sustainable development institutions that differ from traditional processes of implementing policy (Cashore et al. 2004). The authors also reckon that forest certification is "one of the most innovative and startling institutional designs of the past 50 years". It helps to achieve the goals of protecting and managing biodiversity, fighting illegal harvesting and supporting monitoring and certification of carbon absorption in future (EEA, 2008).

Forest certification is a procedure which evaluates the quality of forest exploitation according to the criteria of the standard. If the quality corresponds to the standard, an organization managing forests might receive a certificate proving this. The certification usually focuses on a system of forest management at a certain forest area (FM, forest management) and a chain of custody of forest products to consumers (CoC, chain of custody).

Voluntary forest certification systems started to be developed both at international (FSC (Forest Stewardship Council), PEFC (The Programme for the Endorsement of Forest Certification) and national levels: SFI (Sustainable Forestry Initiative), CSA (Canadian Standard Association), ATFS (American Tree Farm System), CertFlor (Certification Florestal), etc. (Rupert 2000; Simula & Nussbaum 2005). Clark & Kozar (2011) compare three different certification systems (FSC, CSA and SFI) to determine which system meets the goals of sustainable forest management most effectively. They analyzed the literature sources and extracted the indicators required to meet the criteria of sustainable forest management (SFM). The authors came to the conclusion that the FSC certified forests achieve higher level of sustainable forest management than the CSA or SFI. However, they stress that field studies are necessary to collect social and ecological empirical data to check whether the conclusion is true. Rupert (2000) developed a matrix that included about 50 certification schemes and evaluated the credibility of these schemes with respect to various criteria and indicators. The criteria and indicators are based on those agreed by the CEPI Forestry Committee for assessing the credibility of different certification schemes (Rupert 2000). The characteristic feature of the FSC certification is that it is a multi-stakeholder third-party certification system, while other certification systems employ a form of self-regulation (Abbott & Snidal 2009). At present, the most widespread certification standards are PEFC (The Programme for the Endorsement of Forest Certification) and FSC (Forest Stewardship Council), which are compared in Table 1.

The area of forests certified by PEFC makes 268 million hectares in 34 countries, from which Canada, the USA, and Finland are leaders. The number of certificates on FM issued by PEFC system in the world as of November 2015 was 1,260. CoC by PEFC covers 65 countries (the leaders are France, Germany, and Great Britain) and about 10 thousand certificates were issued.

The area of forests certified by the FSC covers about 184 million hectares in 80 countries, from which Canada is in the first position, Russia has the second highest area certified by FSC, and the USA is in the third position. About 1,200 certificates on forest management were issued by the FSC system in the world as of November 2015. About 29,000 certificates were issued on CoC in 112 countries (the leaders are China, the USA, and Great Britain).

Both certification systems (PEFC and FSC) are used in Russia. As of November 2015, the area of forests certified by the PEFC was about 580,000 hectares (3 certificates) and 14 certificates were issued on CoC. At the same time about 40 million hectares in Russia were certified by the FSC system (about 113 certificates for 160 companies) and about 360 certificates were issued on CoC (for 440 companies).

In response to the acceleration of certification by the FSC system in Russia, our goal is to identify problems, which forest enterprises face in their effort to fulfill the requirements of the standard. We set out to address the following tasks:

- To investigate the development of the FSC certification in Russia and to identify the regions with the highest rate of certificates acquisition;
- To analyze the reports from certification bodies and to reveal the indicators, which are most difficult to be implemented in forest enterprises;
- To identify the main problems of certification development in Russia.

Such a research is expected to show the development of the FSC in Russia, to analyze the market of certified timber, and to point out at the problematic indicators while preparing for certification.

2. Material and methods

To study the certification development in Russia we reviewed a number of information sources. We studied the certification development since the beginning of its appearance in Russia from the view of the area of certified forests, the number of issued certificates on FM and CoC, and the number of suspended certificates.

The total area of forests in Russia is about 750 million hectares. The whole territory is divided into 83 regions with regional forest administration bodies. To evaluate the state of certification in the regions, we analyzed documents on

Table 1. Comparison of two international certification systems – PEFC and FSC.

Indicators as of November 2015	Certification on forest management (FM)		Certification on chain of custody (CoC)	
	PEFC	FSC	PEFC	FSC
Number of issued certificates	1257	1357	10625	29522
Number of countries with certification	34	80	65	112
Area of certified forests, million hectares	268	184	—	—
Three leader countries	Canada, USA, Finland	Canada, Russia, USA,	France, Germany, Great Britain	China, USA, Great Britain

forest planning of each region, which contained forest plans, forestry regulations, state reports, etc. We gathered the information on the total area of forests in a region, rented area of forests and certified area. This information allows identifying the leading regions of Russia with a perspective on further development of certification.

Investigation of non-compliances with the standard, which were identified by auditors during the evaluation of forest enterprises on the system of FM, was based on the analysis of the reports of certification bodies collected in the period from 2008 to 2015.

There is a national standard FSC-STD-RUS-V6-1-2012 in Russia (Standard, 2012). In 2013, more than 50 amendments were included into the standard. A number of indicators was excluded from the standard (version of 2012) and one new indicator (4.2.12) on the assessment of living and nutritional conditions of workers at forest logging works according to the requirements of instruction, was added (ILO, 1998). In addition, new guidelines on the use of radioactive wood and prohibition of certification of timber lands that are being used by correctional labor colonies were published. This information is available at the web site of the certification body "Forest certification" Limited Liability Company (LLC) (www.fcert.ru). The last version of the standard includes 10 principles, 56 criteria and 300 indicators. Auditors evaluate each indicator and reveal non-compliance in case of its non-fulfillment. The results of audits are publicly available at http://info.fsc.org.

We analyzed 135 certified companies, which represented 447 reports. Data were compiled in a form of a table with the enterprise name, location of forests, area of forests, date of an audit, type of an audit, certification body and identified non-compliances. This information was used to detect the indicators with the highest number of non-compliances with the FSC standard:

- review of literature on development of certification in the world and in Russia (about 130 sources);
- discussions with concerned parties, which contained 4 non-governmental organizations, about 50 representatives of forest administration bodies, about 70 representatives of the indigenous population, and about 200 specialists employed in forest enterprises;
- personal observations during field inspections of timber companies (personal participation in 57 audits on FM);
- discussions in working groups and seminars;
- information received at four training courses.

3. Results

Currently, 27 bodies of the FSC certification are accredited in the world, of which 16 bodies are active in the Russian Federation. The most active are "NEPCon, LLC", "Forest certification, LLC", and GFA Consulting GmbH. "NEPCon, LLC" is a representative of the US company Rainforest Alliance, and it manages more than 40% of certificates of Russian forest management enterprises. "Forest certification, LLC" is a domestic certification body (28% of certificates were issued). The third most important body is a German company called the GFA, which issued about 11% of certificates. About 70 auditors are involved in the certification bodies. The choice of a certification body depends on the cost of rendered services in the first place. However, as a matter of practice, the prestige of a certification body is also considered. Every year ASI (Accreditation Services International – a company that is in charge of accreditation of auditing companies in the FSC system) evaluates certification bodies on the quality of conducted audits and if there are any non-compliances, accreditation of the respective body can be suspended.

Note: For instance, in 2015 by the decision of ASI an auditing company Bureau Veritas was deprived of the right to sign new contracts on conducting certification, initial certification audits and to issue new FSC FM certificates (certificates on forest management) in Russia. Suspension of the rights of Bureau Veritas was caused by the fact that the company could not correct the most important non-compliances with the standards of accreditation in FSC system, revealed earlier (Report, 2014).

First, we present a graph of certification development of FM and CoC (Fig. 1), a summary table of the state of certification by regions of Russia (Table 2), a summary table of non-compliances revealed by auditors for each principle of the standard (Table 3) and a list of problems in certification development. As can be seen, the first FSC certificate in Russia on FM was granted in 2000.

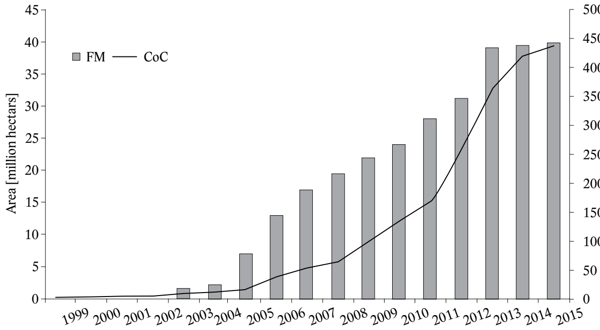

Fig. 1. Development of certification according to the FSC system in the Russian Federation.

The graph shows that an average growth rate of the certification of forest lands is 2 – 3 million hectares a year. The biggest rise was in 2013, when 8 million hectares were certified (25 certificates were issued on FM and about 80 certificates on CoC).

The territory of Russia is divided into 83 constituent territories with the total forest area of about 750 million hectares. The distribution of certification development over the Russian Federation shows that the certification of FM is present in 25 constituent territories and of CoC in 43 constituent territories (Table 2).

Table 2 shows that most certified forest areas are in the Irkutsk Region, the Arkhangelsk Region, and the Republic of Karelia. However, if we consider the ratio of certified forests to the total area of forest land (column F Table 2), the rank of regions will change – the first three places are occupied by the Republic of Karelia, the Primorye territory and the Vologda region. Leased forests are certified in the first place in Russia. Therefore, if we evaluate the relationship between the area of certified and non-certified rented forest lands (column G Table 2), then the Republic of Komi (more than 50% of rented lands), the Vologda region (48%)

Table 2. Analysis of forest management certification in the Russian regions (as of 2015).

No.	Region of Russia	A. f.l.*, mln. hectares	A. rent. *, thousand hectares	A. cert. *, thousand hectares	A. cert./ A. f.l.	A. cert./ A. rent.
A	B	C	D	E	F	G
1	Irkutsk region	69.40	19163	*7040*[1]	10.1	36.7
2	Arkhangelsk region	29.10	14513	*6447*[2]	22.2	44.4
3	Republic of Karelia	14.50	8646	*4080*[3]	*28.1*[1]	*47.2*[3]
4	Khabarovsk Territory	73.70	15560	3309	4.5	21.3
5	Komi republic	36.26	6094	3243	8.9	*53.2*[1]
6	Primorye Territory	11.83	8133	2878	*24.3*[2]	35.4
7	Krasnoyarsk Territory	87.60	16644	2691	3.1	16.2
8	Vologda Region	11.48	5540	2668	*23.3*[3]	*48.2*[2]
9	Leningrad Region	5.68	5300	1245	21.9	23.5
10	Perm Territory	11.98	6501	1006	8.4	15.5
11	Kirov Region	8.10	5824	569	7.0	9.8
12	Tver Region	4.88	2691	429	8.8	16.0
13	Tomsk Region	28.60	4093	363	1.3	8.9
14	Kostroma Region	4.60	1983	312	6.8	15.8
15	Republic of Buryatia	29.63	2730	252	0.8	9.2
16	Novgorod Region	3.90	922	240	6.2	26.0
17	Sverdlovsk Region	15.22	4774	162	1.1	3.4
18	Amur Region	30.52	4204	120	0.4	2.9
19	Omsk Region	5.92	375	77	1.3	20.6
20	Yaroslavl Region	1.52	1077	68	4.4	6.3
21	Ulyanovsk Region	1.03	771	58	5.6	7.5
22	Ryazan Region	0.88	738	56	6.4	7.5
23	Nizhni Novgorod Region	3.81	2509	37	1.0	1.5
24	Udmurt Republic	2.03	496	29	1.4	5.9
25	Vladimir Region	1.46	680	7	0.5	1.1

*A. f.l. – area of forest land; A. rent. – area of rented lands; A. cert. – area of certified forests;
[1,2,3] – indices point out top the three leaders by the corresponding indicators.

Table 3. Non-compliances with the requirements of the certification criteria.

Characteristics of principles			Number of non-compliances		Problem indicators	
No.	Number of criteria	Number of indicators	Total	Per cent of the total number of indicators	Code*	Number of non-compliances
A	B	C	D	F	G	H
1	6	20	544	27.2	1.6.6	124
2	3	9	149	16.5	2.1.2	48
3	4	22	6	0.3	3.1.1	6
4	5	32	921	28.8	4.2.10 4.2.11	122 135
5	6	27	480	17.8	5.6.5 5.6.3	108 49
6	10	82	2747	33.5	6.7.1 6.3.7 6.2.12 6.7.5	97 89 88 83
7	4	28	655	23.4	7.4.1 7.1.1	138 65
8	5	28	930	33.2	8.5.1 8.2.7 8.2.8	155 130 122
9	4	25	746	29.8	9.2.1 9.4.1 9.3.13	72 70 67
10	9	27	0	0	0	0
Total	56	300	7178	23.9		

* See the description in Appendix.

and the Republic of Karelia (47%) occupy first positions. The geographical position of certified forests can be found at the official website of the Forest Stewardship Council

Next, we present our findings of non-compliances with the standard (Table 3). Most non-compliances (more than 40%) were detected for principle 6. The three leaders (column F Table 3) are principles 6, 8, and 9. The description of problematic indicators (i.e. those for which most non-compliances were revealed) is in Appendix.

In the first principle "Compliance with laws and FSC principles", most discrepancies were detected for indicator 1.6.6 (23% of the total amount of non-compliances for the indicators of the first principle). The requirement of the indicator is connected with teaching the workers of an enterprise the requirements for voluntary forest certification. . This indicator is often fulfilled only formally, i.e., training programs are developed, a report is made, signatures of participants are available, etc. However, a sample interview with the employees and inspection of work in the forest often reveal that required actions were not really taken, and the employees are not aware of the certification requirements.

In the second principle "Tenure and use rights and responsibilities", most non-compliances were detected for indicator 2.1.2 (32% of the total number of non-compliances for the indicators of the second principle). The standard requires that the borders of a timber land are marked in cartographic documents and in forestland. Forest inventory maps and maps describing planned forest management activities are the main cartographic documents of forest harvesting enterprises (Lukashevich & Shegelman 2012). In Russian forestry, timber land of a forest owner is divided into compartments. Borders of compartments must be cleared of vegetation and there must be posts at the corners of the compartments. While these requirements are typically fulfilled by the Russian lumbermen, a big number of non-compliances for this indicator are connected with the requirement to place banners with an enterprise contact information. This allows local population to contact an enterprise to inform about fires, illegal cutting, poaching, etc.

The third principle is connected with the evaluation of interaction of an enterprise with indigenous people. Most comments of auditors were on indicator 3.1.1 (3% of the total amount of revealed non-compliances for the indicators of the third principle). This indicator requires to identify the indigenous people living in a certified territory. The analysis of auditors' comments showed that enterprises do not identify indigenous people sufficiently. For instance, there are no meetings with stakeholders.

The highest number of non-compliances in the fourth principle "Community relations and worker‘s rights" was found for indicators 4.2.10 and 4.2.11 (13% and 15%, respectively, of the whole number of non-compliances for the indicators of the fourth principle). According to indicator 4.2.10, an employer must provide the employees with working clothes and individual protective equipment (IPE), which must satisfy the requirements of the Instruction of the International Labor Organization (ILO, 1998). Besides, workers are obliged to use the equipment in a proper way (indicator 4.2.11). The auditors identified a lot of non-compliances in connection with the absence of first aid kits and fire extinguishers at working places, or with their expired period of validity. A number of non-compliances concerns the fact that many enterprises use outsourcing of forest harvesting works. In such cases, implementing the required criteria is even more difficult as contractors or certificate holders are responsible for the compliance with the standard.

Most non-compliances in the fifth principle ("Benefits from the forest") were revealed for indicators 5.6.5 and 5.6.3 (23% and 10%, respectively, of the whole amount of non-compliances for the principle). Indicator 5.6.5 requires additional information for a technological map such as key habitats, measures for forest conservation and protection and the terms of their implementation, parking area for machinery, area for warehousing of industrial and domestic waste, activities for disposal and recycling of waste. As the analysis of reports showed, this requirement is often not implemented.

In the fifth principle, the noteworthy indicators are 5.6.2 and 5.6.3 that specify the annual harvest level to ensure sustainable use of forests in the long term. An enterprise works in the framework of a lease contract of a forest area and a forest development plan, in which the annual harvest level is given. However, this information is often overestimated during forest planning as there is no up-to-date information on forests in Russia (forest inventory is 15 – 20 years out-of-date). Besides, the established method of annual harvest level calculation does not consider losses of merchantable timber due to fires, forest diseases, outbreaks of phytophagous invertebrates and mass windfalls. An auditor must evaluate how an enterprise considers these factors in its activity.

The highest number of non-compliances was detected for principle 6 ("Environmental impact"), which requires that a certified enterprise has developed and introduced the system of Environmental Impact Assessment (EIA). An enterprise must identify the objects which are important from the point of ecology and which might be influenced by the activity of the enterprise. The extent of the possible impact and recommendations on its reduction must be indicated as well. About 2,800 non-compliances with the standard accounted for the sixth principle (35% of all the detected non-compliances).

Indicators 6.7.1, 6.7.5 are the most problematic (4% and 3%, respectively, of the whole amount of non-compliances for the indicators of the sixth principle). These indicators are connected with the breach of instructions on keeping combustive and lubricating materials and recycling of industrial and domestic waste. Many non-compliances were detected also for indicator 6.2.12 (3% of the whole amount of non-compliances for the indicators of the sixth principle), connected with the training of enterprise employees on the introduced EIA system.

The seventh principle of the standard is connected with the content of a forest management plan of an enterprise. Most non-compliances were identified for indicator 7.4.1 (21% of all non-compliances detected for the principle). The indicator demands that a summary of forest management plan without any confidential information must be accessible to the public (available on the Internet, at administration bodies, sent to the stakeholders, etc.).

A forest management certificate holder must conduct monitoring of his activity based on the indicators that are listed in the standard (principle 8). The organization should have a documented monitoring program, which describes parameters to be monitored (13 indicators are monitored). This information along with the forest management plan must be accessible to the public, which is rarely realized at domestic wood enterprises, and therefore non-compliances are detected for indicator 8.5.1 (17% of the whole amount of non-compliances for the indicators of the eighth principle).

In principle 8, two indicators on monitoring 8.2.7 and 8.2.8 need to be commented as these indicators were found quite problematic for the leaseholders (14% and 13%, respectively, of the whole amount of non-compliances for the indicators of the eighth principle). The indicators imply that an enterprise must collect and analyze basic information on population dynamics of main species of plants, animals and mushrooms that are present at a certified territory. The information on the dynamics of change in the quantity of protected species also needs to be collected and analyzed.

The main non-compliances in the ninth principle ("Maintenance of high conservation value forests") concerned the fact that an enterprise does not consult detection, conservation and management of HCVF (indicator 9.2.1) with stakeholders; it does not include the information on the extent to which HCVF are protected within the network of representative samples of existing ecosystems (indicator 9.3.13); and it does not conduct annual monitoring of HCVF (indicator 9.4.1) (10%, 9% and 9%, respectively, of all non-compliances detected for the principle).

Over the recent ten years the certification by the FSC system has been developing quickly and relatively evenly in Russia. Data analysis shows rapid growth of certification development in Russia. The increase in the certified area presented in this study is likely to be related to the effect of the EU regulations No. 995/2010 and the Revised Lacey Act that put liabilities on importers of forest goods to the markets of the USA and the EU for proving the legal origin of wood products. Importers (operators) are obliged to demand documentary proofs from suppliers that the bought products do not contain wood harvested with violations of the laws of the country from which the wood is exported.

Russia is in the second position in the world by the area of the forests certified by the FSC system. However, a ratio of the certified forest area to the area of managed timber lands provides a different perspective. For Russia the value of this indicator is 5.3, while, for example, for Canada it is 17, for the USA 4.3, for Sweden 39, etc.

A similar situation can also be seen inside Russia. In absolute numbers, the leading regions are the Irkutsk Region, the Arkhangelsk Region and the Republic of Karelia. In the relative terms, the Republic of Komi, the Vologda region and the Republic of Karelia occupy the first positions. Besides the area of certified forests, evaluation by the number of leaseholders is also demonstrative. About 13,000 lease contracts are for harvesting wood, while only 5 – 6% of them are certified. Practically all big enterprises have already certified their rented forests, whereas small and medium-sized enterprises are not interested in the certification procedures. This situation results in an obvious lack of the FSC certified wood in Russia.

Despite Russia's leading positions in certification on FM, the development of CoC is progressing slowly. Russia takes the 19th place by the number of CoC certificates. If we consider the ratio of the number of certificates on CoC to the area of certified forests, the position of Russia decreases to 33.

Since the FSC certification continues developing in Russia, there is a demand for auditors, and their number is expected to grow. Higher educational institutions introduced a subject that teaches the specific requirements of voluntary forest certification. Students get acquainted with certification procedures and can be involved in the work of forest management enterprises as both certification auditors and trainees at audits.

We found that the majority of problems concerned the detection of HCVF, development of EIA, detection of key habitats, and detection and conservation of representative samples of existing ecosystems within the landscape.

The most problematic HCVF for certified lumbermen are intact forest landscapes (Greenpeace, 2014). This type of forests is not considered in the system of Russian forestry and is leased out for harvesting. To fulfill the requirements of the FSC standard, certified leaseholders must voluntarily resign their exploitation of such forests. In fact, forest owners who excluded the HCVF from their management are less competitive than forest owners who did not do this. At the same time, there is no compensation mechanism supporting forest owners to treat HCVF in line with the standard.

Environmental impact assessment is a new and a difficult task for most of leaseholders. This requirement is not included in the Russian forest legislation and lumbermen typically need to consult experts about how to comply with the standard`s requirements.

The organization is expected to establish a network of representative samples of existing eco-systems within the forest area to be certified, which can provide the preservation of the diversity of landscapes, ecosystems, habitat types and local flora and fauna, what also requires experts` support.

Identification and conservation of key habitats is another problem for forest users, mainly because of contradictions between the FSC standard and the Russian forest legislation. Specifically, abandonment of key habitats during clear-cut harvesting is a violation of wood harvesting rules in Russia.

The costs of fulfillment implementation of the FSC standard also hamper the voluntary forest certification. Practically all big timber processing companies of Russia certified their forests, however, for other lumbermen the procedure of certification still remains expensive, and this can drive small enterprises out of the market. This problem can be faced via group certification that unites small leaseholders.

Not only leaseholders of forest areas but also forest owners must participate in the development of certification. A Part of the certification requirements, especially those on the detection of HCVF or the analysis of representativeness of rare eco-systems in a forest area, could be carried out at the expense of the state. This would reduce the expenses on certification, which could be supportive mainly to small enterprises.

There is also a problem with increasing shortage of timber for certified products. In order to raise economic security of a region, it is necessary to analyze the perspectives of development of certification within the region from the following viewpoints: the area of certified forests and volumes of their harvesting, the area of non-rented areas and areas that provide opportunities for harvesting, list of timber processing enterprises, and review of existing and potential consumers. This information will allow to evaluate the progress of certified production in the regions; it will also allow improving economic security of the region by developing recommendations on optimization of supplies between manufacturers and consumers of certified products.

4. Conclusions

Despite the existing problems of development of certification in Russia, certification remains one of the instruments for achieving sustainable forest management, which means carrying out forestry activities with minimization of environmental impact, keeping an opportunity to use all the good that the forests provide to the present-day generations for future generations.

On the one hand, voluntary forest certification favors the growth of ecological (conservation of biodiversity, rational use of forest resources, etc.) and social responsibility of forest users (preservation and security of traditional rights of population). At the same time, certification also supports the economic efficiency. Year by year the demand on certified products is increasing, especially at ecologically-sensitive markets of the USA and Europe. As a result of the survey of the certified companies, the following positive moments of having a certificate were noted: improvement of company's reputation, access to new clients and markets, rise in sale to existing clients, and retention of the market share.

Thus, voluntary forest certification became a quite important factor, defining economic stability of forest exploitation of the country's timber processing regions. In order to increase economic security of a region against the problems with export of forest production it is necessary to develop voluntary forest certification by means of a closer interaction in the field of forest exploitation among the state, business organizations and the public.

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Appendix

The most problematic indicators of the FSC national standard in Russia

Problematic indicator	Number of revealed non-compliances	Percent of all non-compliances
1.6.6. The requirements of the Russian National FSC Standard shall be explained to staff.	124	23
2.1.2. The boundaries of the area shall be mapped and can be identified on site.	48	32
4.2.10. Forest workers shall be provided with personal protective equipment.	122	13
4.2.11. The requirements of health and safety regulations, including the use of relevant tools and machines and work clothing and personal protective equipment shall be adhered to by the staff.	135	15
5.6.3. The annual harvest level shall ensure the sustainable use in the long-term.	49	10
5.6.5. The technological map shall contain at least the following information: location, including district forest management unit, forest group, numbers of blocks, sections, harvest areas; type of management operation (use); type and technique of harvesting or type of resource harvested; grade of harvested timber; size of harvest area; pre-harvest stand composition; area at which young growth shall be retained; AAC for the leased area in terms of timber and/or other forest resources; indication which trees shall and shall not be harvested; timelines for timber harvesting and removal from forest; non-exploitable areas, other retention stands/stand elements; forest protection measures and their timelines; method for clearing the harvest area; peculiarities of harvesting techniques; forest regeneration activities; bays, industrial and household waste disposal sites; waste removal/disposal operations.	108	23
6.2.12. The staff shall be aware of materials about rare, threatened and endangered species of plants, animals and fungi and the list of game species occurring within the certified forest area, their typical key habitats as well as measures for protecting these species.	88	3
6.7.1. Chemicals, their containers, liquid and solid nonorganic wastes, including fuel, oil and highly inflammable liquids shall be stored and managed in line with applicable administrative rules and regulations.	97	4
6.7.5. Industrial and household waste shall be managed in consistency with applicable regulations.	83	3
7.4.1. The primary elements of the forest management plan except confidential information shall be available to public.	138	21
8.2.7. Information permitting to assess the composition of flora and fauna and its changes in relation with the forest management shall be collected and analyzed.	130	14
8.2.8. Information on changes in the populations of rare, threatened and endangered species of plants, animals and fungi shall be collected and analyzed.	122	13
8.5.1. A summary of the monitoring results of parameters, except confidential information, shall be available to the public.	155	17
9.2.1. The organization shall conduct consultations with a wide range of stakeholders to identify, protect and manage HCVF.	72	10
9.3.13. The Public Summary of the forest management plan shall contain information of the extent to which HCVF are protected within the network of representative samples of existing ecosystems.	67	9
9.4.1. The effectiveness of the measures employed to maintain or enhance the characteristics of HCVF shall be determined on the basis of findings of annual monitoring.	70	9

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Species composition and diversity of non-forest woody vegetation along roads in the agricultural landscape

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Abstract

Non-forest woody vegetation represents an important component of green infrastructure in the agricultural landscape, where natural and semi-natural forest cover has only a low land use proportion. This paper focuses on linear woody vegetation structures along roads in the agricultural landscape and analyses them in three study areas in the Nitra Region, Slovakia. We evaluate species composition and diversity, species occurrence frequency or spatial distribution, their structure according to relatively achievable age and origin. For the evaluation of occurrence frequency, a Frequency Factor was proposed and applied. This factor allows a better comparison of different study areas and results in more representative findings. The study areas were divided into sectors based on visual landscape features, which are easily identifiable in the field, such as intersections and curves in roads, and intersections of roads with other features, such as cadastral or land boundaries, watercourses, etc. Based on the species abundance, woody plants present within the sectors were categorised into 1) predominant, 2) complementary and 3) mixed-in species; and with regard to their origin into 1) autochthonous and 2) allochthonous. Further, trees were categorised into 1) long-lived, 2) medium-lived and 3) short-lived tree species. The main finding is that among trees, mainly allochthonous species dominated. Robinia pseudoacacia L. was the predominant tree species in all three study areas. It was up to 4 times more frequent than other predominant tree species. Introduced tree species prevailed also among complementary and mixed-in species. Among shrubs, mainly native species dominated, while non-native species had a significantly lower proportion and spatial distribution. Based on these findings, several measures have been proposed to improve the overall ecological stability, the proportion and spatial distribution of native woody plant species. The recommendations and measures aim at enhancement of native species biodiversity, landscape identity and character, in order to meet the main landscape and biodiversity challenges identified in key biodiversity and landscape policies of Europe.

Key words: biodiversity; climate change; cultural landscape; green infrastructure; landscape architecture

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Introduction

Non-forest woody vegetation structures represent important compositional elements and green infrastructure components in current rural agricultural landscapes. They significantly form the visual and perceptual quality of current landscapes, their structure and character. They make landscapes more diverse and consequently more variable in spatial patterns and mosaics (Rózová 2004; Bell 2005; Demková & Lipský 2013). Current landscape structures can be considered contingent outcomes of past and present land uses, socio-economic and ecological processes and decisions that have shaped land use transitions (Supuka & Štěpánková 2006; Rounsevell et al. 2012). Creation of woodland structures is considered as an important landscape design tool for planning and creating agricultural areas. Planting of new woodlands on farmland changes land use patterns and enhances the appearance of the landscape (Insley et al. 1988; Salašová & Štěpán 2007). The woody component along field edges often provides the only permanent elements of structural and biological diversity in landscapes that have lost much of their naturalness in the process of urbanisation and intensification of agriculture (Sitzia et al. 2013). Non-forest woody vegetation formations are purposefully designed elements in cultural landscapes, which have been created in order to support optimal and efficient land use (Kurz et al. 2011; Supuka et al. 2013; Demková & Mida 2014), they have an indispensable position in our landscape, since they participate in the comprehensive formation of the landscape character, especially in scarcely forested flatlands with dominance of light and dry soils. Furthermore, they protect the landscape against erosion; function as bio-corridors and linkages between landscape sections; regulate the climate, including wind movement; prevent expansion of dust and noise and affect the radiation, temperature and moisture regimes of air and soil (Lampartová et al. 2015).

It is obvious that non-forest woody vegetation has many functions and provides a wide range of ecosystem services as mentioned above. It fulfils the main principle of sustainable and resilient landscapes, which according to Konôpka (2010) consists in their multifunctionality. According to Schaefer (1991) and Kuhn et al. (1991), trees are essential in sustainable agricultural systems to provide continuous and long-term crop and resource protection and a wide range of valuable benefits. Our landscapes are exposed to conti-

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nuously increasing effects of the changing climate (Brandle et al. 2004), including drought risk that threatens not only forests (Hlásny et al. 2014) but also agricultural landscapes (Supuka et al. 2013). Melo et al. (2013) state that climate has become warmer and more arid in the adjacent lowlands of Slovak Carpathians, e.g. in the Danube Lowland, where all the three study areas presented in this paper are situated. Hlásny et al. (2014) expect substantial drying of climate in southern Slovakia, which will require a change in species composition towards a higher proportion of drought tolerant species. The composition and diversity of woody plant species are also tackled by the EU Biodiversity Strategy to 2020 (European Commission 2011), which aims at conservation and protection of Europe´s biodiversity, including native woody plants, which are often displaced or out-competed by alien species. Native species represent according to the EU Biodiversity Strategy the core of the common European natural capital and heritage and their higher proportion in the landscape would significantly contribute to biodiversity enhancement. The literature review has shown that there are many studies on the function and importance of non-forest woody vegetation, however there is a lack of profound knowledge of their current species composition and diversity. The goal of this paper is therefore to assess species composition and diversity of woody plants accompanying roads in the agricultural landscape. The field research has been conducted in three study areas, which are represented by cadastral territories of three rural municipalities in the Nitra Region - Tvrdošovce, Dvory nad Žitavou and Kolíňany. The aims of this study are: 1) to evaluate species composition and diversity of woody plants; 2) to evaluate the ratio of autochthonous to allochthonous woody plant species; and 3) to evaluate the proportion of long-lived, medium-lived and short-lived woody plant species. Based on these findings, specific objectives will be defined, with the aim to increase the existing proportion of native and gradually lower the proportion of non-native woody plant species. This measure aims at improvement of the overall native biodiversity in woodland structures in the agricultural landscape, which at the same time helps to mitigate the impact of the changing climate and to overcome potential drought risks in the future.

2. Material and methods

The study has been conducted in three study areas (cadastral territories of three rural municipalities) – Tvrdošovce, Dvory nad Žitavou and Kolíňany, all located in the Nitra Region, in south-western Slovakia. The three study areas have been chosen based on comparable predominant land use (agriculture), geographical, geomorphological, climate, mean annual precipitation and potential natural vegetation characteristics. The study areas have an area of 55.56 km^2 (Tvrdošovce), 63.85 km^2 (Dvory nad Žitavou) and 12.50 km^2 (Kolíňany). Tvrdošovce is located approximately 30 km from Nitra to south-west, Dvory nad Žitavou approximately 45 km from Nitra to south-east and Kolíňany approximately 10 km from Nitra to north-east.

Tvrdošovce and Dvory nad Žitavou are located in a typical agricultural landscape of the Danube Lowland, with an average altitude of 120 m a.s.l., while Kolíňany is located in a rather hilly upland landscape, with an average altitude of 199 m a.s.l. The woodland cover ranges from 0.04% (Dvory nad Žitavou), through 0.07% (Kolíňany), up to 1.00% (Tvrdošovce). In all three study areas, productive agricultural land (mainly arable land, with a low proportion of orchards and vineyards) has a high land use proportion ranging from 75.30% (Kolíňany), through 82.00% Tvrdošovce, up to 87.58% (Dvory nad Žitavou).

Within each study area, the mapping of non-forest woody vegetation was carried out. In Tvrdošovce, the mapping has been focused on accompanying woody vegetation of side roads in the open landscape connecting the municipality and the surrounding settlements. The mapping in Dvory nad Žitavou has been conducted in the south-eastern (S/E) and north-western (N/W) parts of the study area. The S/E part is mainly covered by agricultural land use, with scattered woodland spots. The N/W part is also covered mainly

Fig. 1. Location of the three study areas in the Nitra Region and Slovakia.

by arable land, orchards and vineyards. In Kolíňany, the emphasis was on linear non-forest woody vegetation elements within the entire study area. The same methodology of data collection has been applied in all three study areas. Non-forest woodlands have been studied along field roads, since these represent a very significant proportion of woodlands in areas where agriculture is the predominant land use.

Woody plant species have been studied along roads in the agricultural landscape in study areas of the three rural municipalities. Tree and shrub species have been analysed and evaluated separately. The linear non-forest woody vegetation structures have been divided into separately assessed sectors – Tvrdošovce (31 evaluated sectors), Dvory nad Žitavou (31 evaluated sectors). Kolíňany (21 evaluated sectors). The sectors have been established based on identifiable physical structures and features in the landscape, such as land, land use, built-up-area or administrative boundaries, intersections of roads or other patterns such as watercourses, railways, changes in direction of roads. The aim of this method was to have easily identifiable and observable physical structures to be mapped and documented in the field. The length of the sectors does not have a significant impact on the presence, distribution and density of non-forest woody vegetation and its species composition and diversity, since the distribution of vegetation is very variable – from sections without woody plants, through sections with individual woody plants or small groups of woody plants, up to semi-dense and dense linear woodland structures. Therefore, division into sectors of the same length would complicate an accurate identification of sectors in the field and lead to unrepresentative results, i.e. the sectors would not have been comparable in terms of vegetation cover. Therefore, the studied sectors could not be of same length. For each sector, the abundance of woody species was visually estimated using three categories: predominant, complementary and mixed-in, described in detail in Table 1.

Table 1. Categories used for the abundance estimation of woody plant species.

Role in species composition	Description
Predominant species	the most frequent species in the assessed sector of non-forest woody vegetation structure, total proportion ranging from 51 to 100%
Complementary species	frequent species, complementing the predominant species, total proportion ranging from 11 to 50%
Mixed-in species	minor or rare species, usually small groups or individual admixture, total proportion up to 10%

Based on the Decree No. 24 of the Ministry of Environment of the Slovak Republic from January 9 2003, which implements the national Act No. 543/2002 on Nature and Landscape Protection, the species were distinguished with respect to their origin and relatively achievable age. For species origin two categories were used, autochthonous and allochthonous. Relatively achievable age was classified within three categories (Table 2).

Table 2. Categories of relatively achievable age of woody plant species.

Relatively achievable age	Description
Long-lived species	high or significantly high relative age, i.e. 200 – 500 or more than 500 years
Medium-lived species	medium age, 100 – 200 years
Short-lived species	very low or low age, up to 50 years or between 50 and 100 years; includes all shrub species

Fig. 2. Division of linear woody vegetation structures into sectors, example from the study area Tvrdošovce.

The frequency of occurrence of species has been evaluated within each study area, based on the following formula:

$$F_o = \frac{S_o}{S_t}$$

Where (F_o) is the Frequency Factor of occurrence of the species as predominant/complementary/mixed-in species; (S_o) is the number of sectors, where the species has been identified as predominant/complementary/mixed-in species and (S_t) is the total amount of assessed sectors in the study area.

The Frequency Factor has been developed by the authors to enable a better comparability of species composition and diversity between the different study areas. The proposed methodology aims to fill the methodological gap in assessing woody plant species composition and diversity in linear woodlands along roads, since currently there is no particular methodology tackling this issue.

The recommendations and measures on species composition enhancement proposed in the results are mainly based on Slovak and European legal political or strategic documents: the Slovak National Act No. 543/2002 on Nature and Landscape Protection, the EU Biodiversity Strategy to 2020 and the European Landscape Convention (Council of Europe 2000).

3. Results

The complete overview of documented tree and shrub species in the three study areas is elaborated in the Appendix 1–3.

3.1. Predominant tree species

Among the predominant tree species (in total 19 species), only *Robinia pseudoacacia* L., *Populus alba* L., *Salix alba* L. and *Populus nigra* L. are classified as predominant within each study area. The highest Frequency Factor in all three study areas has *Robinia pseudoacacia* L. (Tvrdošovce 0.52; Dvory nad Žitavou 0.45 and Kolíňany 0.24), while for other species it is much lower, ranging from 0.19 to 0.03. This clearly shows how widely distributed is this allochthonous medium-lived species.

Predominant tree species occurring in two of the three study areas are: *Fraxinus excelsior* L. ($F_o \leq 0.19$); *Prunus domestica* L. ($F_o \leq 0.19$); *Negundo aceroides* Moench ($F_o \leq 0.07$); *Juglans regia* L. ($F_o = 0.03$).

Predominant tree species occurring in one of the three study areas are: *Prunus cerasifera* Ehrh. ($F_o = 0.13$); *Acer platanoides* L. ($F_o = 0.07$); *Fraxinus angustifolia* Vahl ($F_o = 0.07$); *Gleditsia triacanthos* L. ($F_o = 0.07$) and other tree species with a Frequency Factor of 0.03 (*Acer saccharinum* L.; *Ailanthus altissima* (Mill.) Swingle; *Fraxinus ornus* L.; *Morus alba* L.; *Morus nigra* L.; *Populus x canadensis* Moench; *Tilia platyphyllos* Scop.).

Concerning tree species origin, 58% of species are allochthonous and 42% autochthonous. The most frequent predominant tree species, *Robinia pseudoacacia* L. is allochthonous. The most frequent autochthonous tree species are *Populus alba* L. and *Salix alba* L., followed by *Populus nigra* L. and *Fraxinus excelsior* L. ($0.13 \leq F_o \leq 0.19$). The most frequent allochthonous tree species (excluding *Robinia pseudoacacia* L.) are *Prunus domestica* L.; *Negundo aceroides* Moench; *Juglans regia* L.; *Prunus cerasifera* Ehrh. and *Gleditsia triacanthos* L., descending respectively ($0.03 \leq F_o \leq 0.19$).

Concerning the relatively achievable age, most of the predominant tree species are medium-lived, representing 58% ($F_o \leq 0.52$), followed by short-lived tree species (31.5%; $F_o \leq 0.19$) and long-lived tree species (10.5%; $F_o \leq 0.07$).

Abbreviations used in the figure 3: *Robinia pseudoacacia* (RP), *Populus nigra* (PN), *Salix alba* (SA), *Prunus cerasifera* (PC), *Fraxinus angustifolia* (FA), *Gleditsia triacanthos* (GT), *Fraxinus excelsior* (FE), *Prunus domestica* (PD), *Negundo aceroides* (NA), *Juglans regia* (JR).

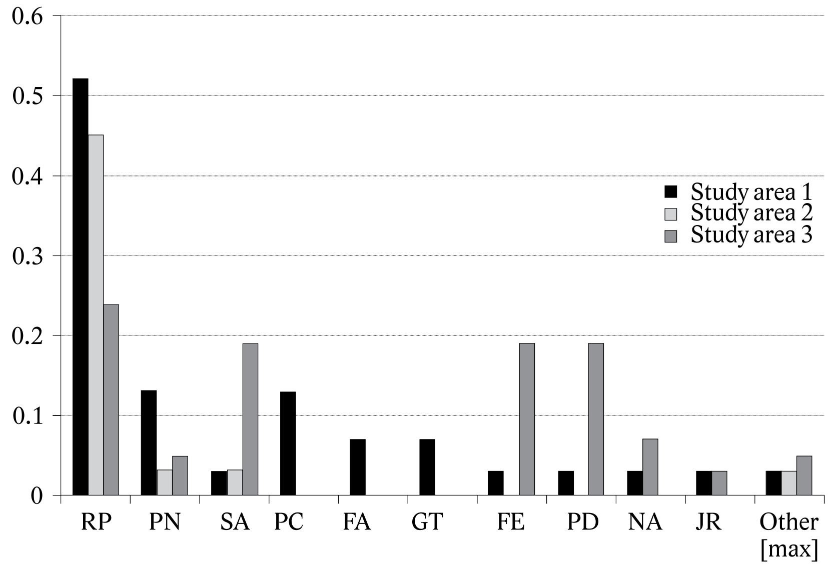

Fig. 3. Overview of the most important predominant tree species in the three study areas based on their Frequency Factor (F_o).

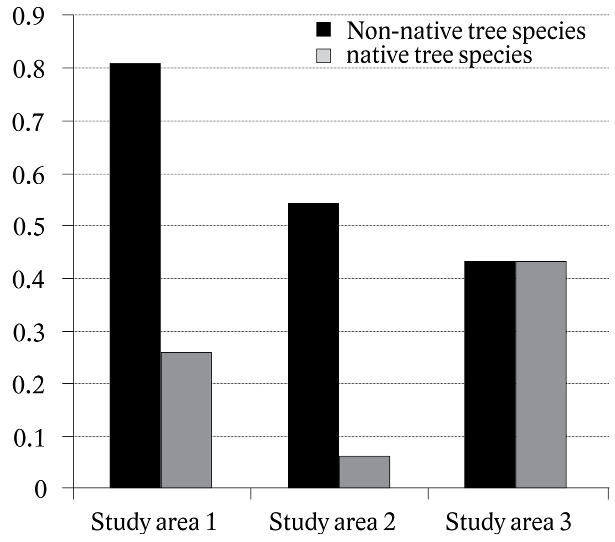

Fig. 4. Overview of the most important predominant tree species in the three study areas based on their origin weighted by their Frequency Factor (F_o).

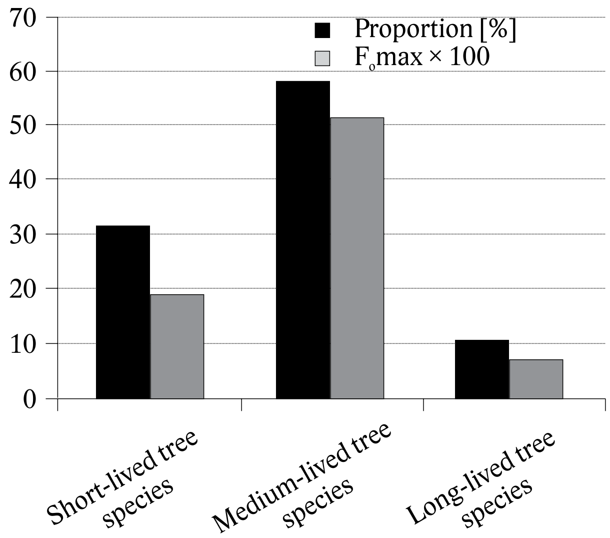

Fig. 5. Overview of the most important predominant tree species based on their relatively achievable age weighted by their Frequency Factor (F_o)

3.2. Complementary tree species

The most frequent complementary tree species (from 22 species in total) are *Prunus cerasifera* Ehrh. ($F_o = 0.32$) and *Juglans regia* L. ($F_o \leq 0.26$), both allochthonous fruit tree species.

Complementary tree species occurring in two of the three study areas are: *Juglans regia L.* ($0.07 \leq F_o \leq 0.26$); *Robinia pseudoacacia* L. ($0.07 \leq F_o \leq 0.16$); *Malus domestica* Borkh. ($0.07 \leq F_o \leq 0.14$); *Prunus domestica* L. ($0.03 \leq F_o \leq 0.10$); *Fraxinus excelsior* L. ($0.05 \leq F_o \leq 0.07$); *Populus alba* L. ($F_o = 0.07$).

Complementary tree species occurring in one of the three study areas are: *Prunus cerasifera* Ehrh. ($F_o = 0.32$); *Fraxinus angustifolia* Vahl ($F_o = 0.16$); *Fraxinus ornus* L. ($F_o = 0.13$); *Populus x canadensis* Moench ($F_o = 0.13$); *Ailanthus altissima* (Mill.) Swingle ($F_o = 0.10$); *Salix fragilis* L. ($F_o = 0.10$) and other tree species with a Frequency Factor ranging from 0.07 to 0.03 (*Acer campestre* L.; *Cerasus avium* (L.) Moench; *Negundo aceroides* Moench; *Populus nigra* L.; *Salix alba* L.; *Acer platanoides* L.; *Acer pseudoplatanus* L.; *Pyrus communis* L. emend. Burgsd.; *Sorbus aucuparia* L. and *Ulmus minor* Mill.).

Concerning origin, 41% of the documented tree species are allochthonous and 59% autochthonous. The most frequent autochthonous tree species are *Fraxinus excelsior* L.; *Populus alba* L.; *Fraxinus angustifolia* Vahl; *Fraxinus ornus* L. and *Salix fragilis* L., descending respectively ($0.07 \leq F_o \leq 0.16$). The most frequent allochthonous tree species are *Prunus cerasifera* Ehrh.; *Juglans regia* L.; *Robinia pseudoacacia* L.; *Malus domestica* Borkh. and *Populus x canadensis* Moench, descending respectively ($0.07 \leq F_o \leq 0.32$).

Concerning the relatively achievable age, most of the complementary tree species are short-lived, representing

50% ($F_o \leq 0.32$), followed by medium-lived tree species (36%; $F_o \leq 0.26$) and long-lived tree species (14%; $F_o \leq 0.07$).

3.3. Mixed-in tree species

The most frequent mixed-in tree species (from 37 species in total) are *Prunus cerasifera* Ehrh. ($F_o = 0.42$); *Juglans regia* L. ($0.10 \leq F_o \leq 0.29$) and *Ailanthus altissima* (Mill.) Swingle ($F_o = 0.29$), all three of them allochthonous species.

Mixed-in tree species occurring in all three study areas are: *Juglans regia* L. ($0.10 \leq F_o \leq 0.29$) and *Populus nigra* L. ($0.03 \leq F_o \leq 0.19$).

Mixed-in tree species occurring in two of the three study areas are: *Cerasus avium* (L.) Moench ($0.14 \leq F_o \leq 0.19$); *Salix alba* L. ($0.03 \leq F_o \leq 0.16$); *Populus alba* L. ($0.13 \leq F_o \leq 0.16$); *Prunus domestica* L. ($0.07 \leq F_o \leq 0.10$) and other tree species with a Frequency Factor ranging from 0.07 to 0.03 (*Acer platanoides* L.; *Robinia pseudoacacia* L.; *Acer saccharinum* L. and *Populus tremula* L.).

Mixed-in tree species occurring in one of the three study areas are: *Prunus cerasifera* Ehrh. ($F_o = 0.42$); *Ailanthus altissima* (Mill.) Swingle ($F_o = 0.29$); *Malus domestica* Borkh. ($F_o = 0.16$); *Morus alba* L. ($F_o = 0.13$); *Negundo aceroides* Moench ($F_o = 0.13$); *Aesculus hippocastanum* L. ($F_o = 0.10$); *Fraxinus excelsior* L. ($F_o = 0.10$); *Morus nigra* L. ($F_o = 0.10$); *Pyrus communis* L. emend. Burgsd. ($F_o = 0.10$) and other tree species with a Frequency Factor ranging from 0.07 to 0.03 (*Catalpa bignonioides* Walt.; *Fraxinus ornus* L.; *Populus x canadensis* Moench; *Pyrus pyraster* (L.) Burgsd.; *Quercus robur* L.; *Ulmus minor* Mill.; *Acer pseudoplatanus* L.; *Carpinus betulus* L.; *Celtis occidentalis* L.; *Gleditsia triacanthos* L.; *Platycladus orientalis* (L.) Franco; *Populus simonii* Carriére; *Tilia platyphyllos* Scop.; *Ulmus glabra* Huds.; *Ulmus laevis* Pall.; *Pinus sylvestris* L.; *Betula pendula* L.; *Picea abies* L.

Concerning origin, 49% of the documented mixed-in tree species are allochthonous and 51% autochthonous. The most frequent autochthonous tree species are *Populus nigra* L.; *Cerasus avium* (L.) Moench; *Salix alba* L.; *Populus alba* L. and *Fraxinus excelsior* L., descending respectively ($0.03 \leq F_o \leq 0.19$). The most frequent allochthonous tree species are *Prunus cerasifera* Ehrh.; *Juglans regia* L.; *Ailanthus altissima* (Mill.) Swingle; *Malus domestica* Borkh.; *Morus alba* L. and *Negundo aceroides* Moench, descending respectively ($0.10 \leq F_o \leq 0.42$).

Concerning the relatively achievable age, most of the mixed-in tree species are medium-lived, representing 43% ($F_o \leq 0.29$), followed by short-lived tree species (38%; $F_o \leq 0.42$) and long-lived tree species (19%; $F_o \leq 0.07$).

3.4. Predominant shrub species

Among the predominant shrub species (in total 8 species), *Sambucus nigra* L. is the only one occurring in all three study areas ($0.14 \leq F_o \leq 0.65$). The other predominant shrub species reach a Frequency Factor of maximum 0.29, which illustrates very well the wide distribution of this autochthonous species.

Predominant shrub species occurring in two of the three study areas are: *Rosa canina* L. ($0.24 \leq F_o \leq 0.29$); *Salix caprea* L. ($0.07 \leq F_o \leq 0.19$).

Predominant shrub species occurring in one of the three study areas are: *Prunus spinosa* L. ($F_o = 0.23$); *Rhus typhina* L. ($F_o = 0.14$) and other species, such as *Euonymus europaeus* L.; *Lycium barbarum* L. and *Syringa vulgaris* L. ($0.03 \leq F_o \leq 0.07$).

Concerning origin, 37.5 % of the documented shrub species are allochthonous and 62.5 % autochthonous. The most frequent predominant shrub species, *Sambucus nigra* L. ($F_o \leq 0.65$), is autochthonous. The most frequent shrub species are autochthonous ($0.07 \leq F_o \leq 0.65$), while allochthonous species have only a low frequency and special distribution ($0.03 \leq F_o \leq 0.14$).

Abbreviations used in the figure : *Sambucus nigra* (SN), *Rosa canina* (RC), *Salix caprea* (SC), *Prunus spinosa* (PS), *Rhus typhina* (RT), *Euonymus europaeus* (EE), *Lycium barbarum* (LB), *Syringa vulgaris* (SV).

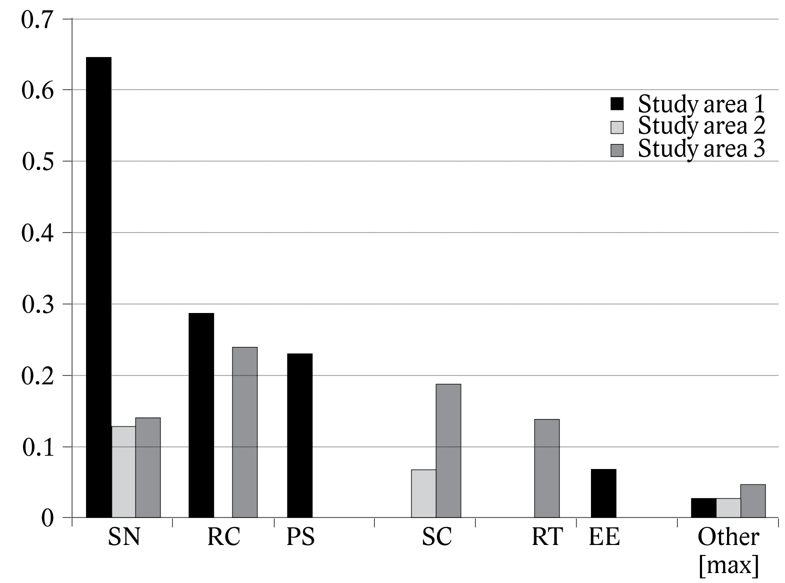

Fig. 6. Overview of the most important predominant shrub species in the three study areas based on their Frequency Factor (F_o).

3.5. Complementary shrub species

Among the complementary shrub species (in total 10 species), *Prunus spinosa* L. is the only one occurring in all three study areas ($0.07 \leq F_o \leq 0.13$).

Complementary shrub species occurring in two of the three study areas are: *Rosa canina* L. ($0.10 \leq F_o \leq 0.39$) and *Sambucus nigra* L. ($F_o = 0.19$).

Complementary shrub species occurring in one of the three study areas are: *Hippophae rhamnoides* L. ($F_o = 0.14$); *Euonymus europaeus* L. ($F_o = 0.13$); *Swida sanguinea* (L.) Opiz ($F_o = 0.13$); *Lycium barbarum* L. ($F_o = 0.10$) and other species, such as *Ligustrum vulgare* L.; *Rubus fruticosus* L. agg. and *Tamarix tetrandra* Pall. ($0.03 \leq F_o \leq 0.05$).

Concerning origin, 30% of the documented shrub species are allochthonous and 70% autochthonous. The most frequent complementary shrub species are all native. Allochthonous species have only a low frequency of occurrence and spatial distribution ($0.03 \leq F_o \leq 0.14$).

3.6. Mixed-in shrub species

Among the mixed-in shrub species (in total 12 species), *Rosa canina* L. ($0.13 \leq F_o \leq 0.26$) and *Prunus spinosa* L. ($0.10 \leq F_o \leq 0.16$) are the only species occurring in all three study areas.

Mixed-in shrub species occurring in two of the three study areas are: *Sambucus nigra* L. ($0.13 \leq F_o \leq 0.26$) and *Ligustrum vulgare* L. ($0.03 \leq F_o \leq 0.07$).

Mixed-in shrub species occurring in one of the three study areas are: *Swida sanguinea* (L.) Opiz ($F_o = 0.19$); *Euonymus europaeus* L. ($F_o = 0.13$); *Crataegus monogyna* Jacq. ($F_o = 0.10$); *Elaeagnus angustifolia* L. ($F_o = 0.10$) and other species, such as *Syringa vulgaris* L.; *Lycium barbarum* L.; *Rhamnus catharticus* L. and *Mahonia aquifolium* (Purch) Nutt. ($0.03 \leq F_o \leq 0.07$).

Concerning origin, 33% of the documented shrub species are allochthonous and 67% autochthonous. The most frequent mixed-in shrub species are all native. Allochthonous species have only a low frequency of occurrence and spatial distribution ($0.03 \leq F_o \leq 0.10$).

3.7. Species composition and diversity – proposed measures and changes

Considering the relatively achievable age, the proportion of long-lived tree species is significantly lower compared to medium-lived and short-lived species and the species diversity is also very low – only two long-lived autochthonous tree species occur, with a very low distribution or frequency. In complementary tree species, the diversity of native species is higher than the diversity of allochthonous species; however native tree species have a much lower spatial distribution and quantitative proportion. Considering the relatively achievable age, the proportion of long-lived trees is very low compared to medium-lived and short-lived species, while the species diversity is also very low – only three long-lived autochthonous tree species occur among complementary species, with a very low distribution.

Based on the findings of the field research and according to several national and international policy documents - the Slovak National Act No. 543/2002 on Nature and Landscape Protection, the EU Biodiversity Strategy to 2020, the European Landscape Convention and authors Kurz et al. (2011), Sitzia et al. (2013), Supuka et al. (2013), it is necessary, that native plant species are enhanced in the landscape, since they significantly impact the regional and local landscape identity, character and visual design. It is therefore highly recommended that regionally suitable native woody plant species are preferred to non-native woody plant species, as required by the Slovak National Act No. 543/2002. However, in our literature review, we have not found any recommendations on exact numbers, percentage or proportion of native and non-native woody plant species. We recommend therefore 50% as the minimum proportion of native woody plant species in the landscape, in order to avoid dominance of alien woody plant species. This results in the following measures and recommendations:

1) To continuously increase the current proportion of native tree species, suitable for the specific area based on the potential natural vegetation (this means an increase by at least 8% for predominant species from 42% to at least 50%). Complementary (59%) and mixed-in native species (51%) have a higher proportion than non-native species; it is therefore recommended to sustain and ideally increase this proportion by future plantings. The aim of this proposal is to have as high proportion of regionally suitable native species as possible, but at least more than the half of the species - this measure would enhance not only the native biodiversity as proclaimed in the EU Biodiversity Strategy to 2020, but also the identity of the local landscapes as proclaimed by the European Landscape Convention.

Native shrub species prevail in all study areas and in all abundance categories (for categories see Table 1) – as in terms of species diversity, as well as in terms of spatial distribution and frequency of occurrence. It is therefore proposed to sustain and ideally increase the proportion of native shrub species, suitable for the specific area based on the potential natural vegetation. This would mean a preference of regionally suitable native species to alien species as required by the Slovak National Act No. 543/2002 on Nature and Landscape Protection.

2) It is recommended to have a proportion of at least 30 % of long-lived regionally suitable native tree species in non-forest woodland structures in the agricultural landscape (Supuka 1992; Supuka et al. 2013). It is therefore recommended to continuously increase the proportion of long-lived regionally suitable native tree species to at least 30% (from the current 10.5% in predominant species; 14% in complementary species and 19% in mixed-in species). The aim of this measure is to enhance long lasting natural features in the landscape, which is important for landscape perception proclaimed in the European Landscape Convention.

3) To continuously increase the spatial distribution (F_o) of long-lived native tree species to at least 0.30 (from the current 0.07 in predominant, complementary and mixed-in species), in order to achieve a balanced vegetation structure in the landscape as suggested by Supuka (1992) and Supuka et al. (2013).

4) To continuously increase the spatial distribution (F_o) of native tree species to at least 0.50 (from the current maximum of 0.16 in complementary species and 0.19 in mixed-in species)

5) To continuously increase the proportion and spatial distribution (F_o) of traditional native fruit tree species to at least 0.30 (from the current maximum of 0.07 in complementary species and 0.19 in mixed-in species). The legal tool to change species composition of non-forest woody vegetation in Slovakia is the Slovak National Act No. 543/2002 on Nature and Landscape Protection, which requires plantations of regionally suitable native woody plant species based on the potential natural vegetation. The practical implementation consists mainly in local actions by the municipal authorities, more precisely their environmental commissions, which have the legal power to implement the proposed measures, i.e. mainly to plant regionally specific native species and where necessary to reduce the spreading of invasive non-native species. The local municipal authority defines the species composition of new or compensatory plantings, thus it has the legal power and the practical implementation tools.

4. Discussion

We found out that *Robinia pseudoacacia* L. dominates in all three study areas. This non-native species has been identified as the main tree species in bio-corridors in south-western Slovakia by Baranec et al. (2015), as well as by Supuka (1992) and Supuka et al. (2013). There is thus a clear evidence of a significantly wide distribution of this species in agricultural landscapes of Slovakia. This is partly the result of inappropriate tree plantings mainly in the previous century and partly also due to vital or in some cases even invasive distribution of this species (Gojdičová et al. 2002).

Baranec et al. (2015) have evaluated also *Populus x canadensis*, which is not of such significance in areas assessed in this paper. This is likely the reason of different management interventions in past decades, where the planting of fast growing tree species in the agricultural landscape was common. They also documented populations of *Prunetalia spinosae*, mainly hybrids of *Prunus spinosa* (*Prunus x fruticans* and *Prunus x fetchneri*), which was found to occur as one of the most frequent complementary shrub species. This justifies a wide distribution of *Prunus spinosa* in agricultural landscapes of south-western Slovakia. Baranec et al. (2015) also identified the problem of superseding native *Prunus spinosa* by hybrids of *Prunus x fruticans*. Similarly to our results, the latter authors found a frequent occurrence of *Populus alba*, *Populus tremula* and *Salix fragilis* in Veľké Úľany and Čechynce. This can be explained by comparable potential natural vegetation. Similarly to Supuka et al. (2013), we found valuable old tree species along roads in the study areas of rural agricultural landscape, such as *Quercus robur* (stem diameter in breast height $d_{1.3}$ = 1.61 m; stem circumference in breast height $c_{1.3}$ = 5.05 m), *Pyrus pyraster* ($d_{1.3}$ = 0.86 m; $c_{1.3}$ = 2.70 m) or *Morus nigra* ($d_{1.3}$ = 0.65 m; $c_{1.3}$ = 2.03 m) in the study area of Tvrdošovce. These trees are very significant in terms of natural and cultural heritage as well as gene pool and biodiversity. Similarly to Kurz et al. (2011) and Supuka et al. (2013), we have documented the occurrence of traditional fruit tree species such as *Prunus sp., Cerasus avium, Juglans regia, Malus domestica, Pyrus sp.* and *Sorbus aucuparia*, but in contrast to Kurz et al. (2011), we have not documented a significant proportion of *Acer sp.* and other long-lived native tree species, which is a result of different management approaches in past decades and can indicate pathways for improvements and biodiversity enhancement in the study areas. In line with Supuka (1992) and Supuka et al. (2013), we have also documented a high proportion and spatial distribution of shrub species *Rosa canina*, *Sambucus nigra, Prunus spinosa, Lycium barbarum* and tree species *Cerasus avium, Fraxinus excelsior, Juglans regia, Malus domestica, Populus nigra, Prunus cerasifera, Prunus domestica, Salix alba, Salix caprea* and *Salix fragilis*. Contrary to Supuka (1992), there is a less significant proportion and spatial distribution of *Populus x canadensis, Acer campestre, Carpinus betulus, Crataegus laevigata, Quercus robur, Tilia cordata* and a much higher proportion and distribution of *Populus alba* and *Salix alba*.

The proposed measures aiming to increase the proportion of native woody plants agree with the approach of Insley et al. (1988), who state that when planning new farm woodlands, the first thing to consider is the existing landscape character and identity of the area, which is partly formed by native woodland species. The main features to consider are the landform, existing vegetation patterns (especially semi-natural vegetation), land use patterns (in particular the prominence of hedgerows and hedgerow tree patterns), and the character of the landscape. Based on this statement, an increase of endemic woody plant species has been proposed, since these enhance the identity and character of current landscapes as proclaimed by the European Landscape Convention. Besides landscape character and identity aspects, also the biodiversity plays a key role in the proposed measures, which is in line with Rey Benayas & Bullock (2015), who propose a widespread strategic re-vegetation to enhance wildlife in European agricultural landscapes by planting woodland islets and hedgerows for ecological restoration in extensive agricultural landscapes. This approach allows wildlife enhancement, provision of a range of ecosystem services, maintenance of farmland production, and conservation of values linked to cultural landscapes. Our approach not only maintains the farmland production, but also supports a multifunctional and efficient land use, since we propose mainly linear woodland structures. Strategic re-vegetation in actively farmed fields can include planting woodland islets, hedgerows and isolated trees. These woodland structures have the potential to enhance wildlife, agricultural production, and other services at the field and landscape scales since they hardly compete for farmland use. In this study and particularly in the proposed measures, a preference has been given to native species, since woodland structures in the agricultural landscape should be only planted by a variety of native shrub and tree species (Thompson et al. 2009; Rey Benayas & Bullock 2015). This agrees with the approach of Cramer et al. (2015), who state that when restoring woodlands in extensive agricultural landscapes, the emphasis should be placed on the development of self-sustaining ecosystems, protecting native biodiversity and according to Cunningham et al. (2015), planting a mixture of native trees and shrubs is best for biodiversity. Thus a significant enhancement of native woody plant species and an active restoration of agricultural landscapes is needed in the study areas, which according to Rey Benayas et al. (2008) should involve large-scale plantings of native trees and tree growth management. The technical implementation of the proposed measures means mainly planting a mixture of native trees and shrubs, which according to Barrett et al. (2008), has become a cornerstone strategy for natural resource management in agricultural landscapes. For the technical implementation of this measure, active planting seems to be the most efficient tool, since many native plant species need to be actively planted, due to a lack of local seed sources (Flinn & Vellend 2005). Planting of native woody plant species in open landscape (non-built-up or non-urbanised areas) is also required by the Slovak National Act No. 543/2002 on Nature and Landscape Protection as well as by the EU Biodiversity Strategy to 2020.

Planting native woody plant species in the agricultural landscape not only enhances biodiversity as argued above, but also provides landscape planning and landscape management with a strategic tool for climate change mitigation and drought risk management. According to Cunningham et al. (2015), in low-rainfall areas (<800 mm year^{-1}), native species are likely to be less vulnerable to drought and climate change and provide higher biodiversity benefits to native wildlife species (Lindenmayer et al. 2003).

The results can be generalised for rural agricultural landscapes in lowlands and slightly hilly upland areas of Slovakia and other Central European countries. A comparison of different case studies from Central European countries would be valuable to compare the current situation and work on collaborative measures at the European or bilateral level.

5. Conclusion

The presented results extend the existing knowledge on species composition, diversity and spatial distribution of non-forest woody vegetation in the agricultural landscape, with a particular focus on trees and shrubs growing along roads in the open landscape. It has been found that among trees, allochthonous (introduced) species dominate, while among shrubs autochthonous (native) species prevail. Moreover a low proportion and distribution of long-lived tree species has been documented. Based on these findings, several measures have been proposed, in order to improve the existing situation of native species diversity, spatial distribution and ecological resilience of rural landscapes. The results can be applied mainly at the local level, in municipal decision making and governance, but it can be a useful tool also in policy making at the regional, national or EU level, since the assessment methodology is in line with the national nature and landscape protection policy. Further research and verification of the applied methodology could help in creating and transferring knowledge on woody plant species in rural agricultural landscapes, their composition, diversity, relatively achievable age and origin.

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Appendix 1: Woody plant species composition in non-forest woody vegetation structures along roads in the agricultural landscape, locality: study area Tvrdošovce.

Growth characteristic	Predominant species	Complementary species	Mixed-in species
Tree species	***Robinia pseudoacacia*** L. (16); *Populus nigra* L. (4); *Prunus cerasifera* Ehrh. (4); *Fraxinus angustifolia* Vahl (2); *Gleditsia triacanthos* L. (2); *Acer saccharinum* L.; *Ailanthus altissima* (Mill.) Swingle; *Fraxinus excelsior* L.; *Fraxinus ornus* L.; *Juglans regia* L.; *Morus alba* L.; *Morus nigra* L.; *Negundo aceroides* Moench; *Populus alba* L.; *Populus* x canadensis Moench; *Prunus domestica* L.; *Salix alba* L.	***Prunus cerasifera*** Ehrh. (10); ***Juglans regia*** L. (8); ***Fraxinus angustifolia*** Vahl (5); ***Robinia pseudoacacia*** L. (5); *Fraxinus ornus* L. (4); *Populus x canadensis* Moench (4); *Ailanthus altissima* (Mill.) Swingle (3); *Acer campestre* L. (2); *Cerasus avium* (L.) Moench (2); *Fraxinus excelsior* L. (2); *Malus domestica* Borkh. (2); *Negundo aceroides* Moench (2); *Populus alba* L. (2); *Salix alba* L. (2); *Acer pseudoplatanus* L.; *Prunus domestica* L.; *Pyrus communis* L. emend. Burgsd.; *Sorbus aucuparia* L.; *Ulmus minor* Mill.	***Prunus cerasifera*** Ehrh. (13); ***Ailanthus altissima*** (Mill.) Swingle (9); ***Juglans regia*** L. (7); ***Cerasus avium*** (L.) Moench (6); ***Populus nigra*** L. (6); ***Malus domestica*** Borkh. (5); ***Salix alba*** L. (5); *Morus alba* L. (4); *Negundo aceroides* Moench (4); *Populus alba* L. (4); *Aesculus hippocastanum* L. (3); *Fraxinus excelsior* L. (3); *Morus nigra* L. (3); *Pyrus communis* L. emend. Burgsd. (3); *Acer platanoides* L. (2); *Catalpa bignonioides* Walt. (2); *Fraxinus ornus* L. (2); *Populus* x *canadensis* Moench (2); *Prunus domestica* L. (2); *Pyrus pyraster* (L.) Burgsd. (2); *Quercus robur* L. (2); *Robinia pseudoacacia* L. (2); *Ulmus minor* Mill. (2); *Acer pseudoplatanus* L.; *Acer saccharinum* L.; *Carpinus betulus* L.; *Celtis occidentalis* L.; *Gleditsia triacanthos* L.; *Platycladus orientalis* (L.) Franco; *Populus simonii* Carriére; *Populus tremula* L.; *Tilia platyphyllos* Scop.; *Ulmus glabra* Huds.; *Ulmus laevis* Pall.
Shrub species	***Sambucus nigra*** L. (20); ***Rosa canina*** L. (9); ***Prunus spinosa*** L. (7); *Euonymus europaeus* L. (2); *Lycium barbarum* L.	***Rosa canina*** L. (12); ***Sambucus nigra*** L. (6); *Euonymus europaeus* L. (4); *Swida sanguinea* (L.) Opiz (4); *Prunus spinosa* L. (4); *Lycium barbarum* L. (3); *Rubus fruticosus* L. agg.; *Tamarix tetrandra* Pall.;	***Swida sanguinea*** (L.) Opiz (6); ***Prunus spinosa*** L. (5); *Euonymus europaeus* L. (4); *Rosa canina* L. (4); *Sambucus nigra* L. (4); *Crataegus monogyna* Jacq. (3); *Elaeagnus angustifolia* L. (3); *Syringa vulgaris* L. (2); *Ligustrum vulgare* L.; *Lycium barbarum* L.; *Rhamnus catharticus* L.

Explanatory note: If the amount of sectors of occurrence (S_o) is higher than 1, it is stated in brackets following the species name. The total amount of assessed sectors is 31. If the (S_o) is 5 or more, the species is bolded.

Appendix 2: Woody plant species composition in non-forest woody vegetation structures along roads in the agricultural landscape, locality: study area Dvory nad Žitavou.

Growth characteristic	Predominant species	Complementary species	Mixed-in species
Tree species	***Robinia pseudoacacia*** L. (14); *Populus alba* (4); *Acer platanoides* L. (2); *Negundo aceroides* Moench. (2); *Juglans regia* L.; *Populus nigra* ´Italica´ L.; *Tilia platyphyllos* Scop.; *Salix alba* ´Tristis´ L.	*Juglans regia* L. (2); *Populus alba* L. (2); *Robinia pseudoacacia* L. (2); *Acer platanoides* L.; *Populus nigra* L.	***Populus alba*** L. (5); *Juglans regia* L. (3); *Pinus sylvestris* L. (2); *Acer platanoides* L.; *Acer saccharinum* L.; *Betula pendula* L.; *Picea abies* L.; *Populus nigra* L.; *Populus tremula* L.; *Robinia pseudoacacia* L.; *Salix alba* ´Tristis´ L.
Shrub species	*Sambucus nigra* L. (4); *Salix caprea* L. (2); *Syringa vulgaris* L.	***Sambucus nigra*** L. (6); *Rosa canina* L. (3); *Prunus spinosa* L. (2)	***Rosa canina*** L. (8); ***Sambucus nigra*** L. (8); *Prunus spinosa* L. (4); *Ligustrum vulgare* L. (2); *Mahonia aquifolium* (Purch) Nutt.

Explanatory note: If the amount of sectors of occurrence (So) is higher than 1, it is stated in brackets following the species name. The total amount of assessed sectors is 31. If the (So) is 5 or more, the species is bolded.

Appendix 3: Woody plant species composition in non-forest woody vegetation structures along roads in the agricultural landscape, locality: study area Kolíňany.

Growth characteristic	Predominant species	Complementary species	Mixed-in species
Tree species	***Robinia pseudoacacia*** L. (5); *Prunus domestica* L. (4); *Salix alba* L. (4); *Fraxinus excelsior* L. (4); *Populus nigra* L.; *Populus alba* L.	*Malus domestica* Borkh. (3); *Prunus domestica* L. (2); *Salix fragilis* L. (2); *Fraxinus excelsior* L.	***Juglans regia*** L. (6); *Cerasus avium* (L.) Moench (3); *Prunus domestica* L. (2); *Populus nigra* L. (2)
Shrub species	***Rosa canina*** L. (5); *Salix caprea* L. (4); *Rhus typhina* L. (3); *Sambucus nigra* L. (3)	*Hippophae rhamnoides* L. (3); *Ligustrum vulgare* L.; *Prunus spinosa* L.	*Rosa canina* L. (3), *Prunus spinosa* L. (2)

Explanatory note: If the amount of sectors of occurrence (So) is higher than 1, it is stated in brackets following the species name. The total amount of assessed sectors is 21. If the (So) is 5 or more, the species is bolded.

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REPORTS

V Prahe sa uskutočnilo zasadanie redakčnej rady časopisu

Redakčná rada Lesníckeho časopisu – Forestry Journal v súčasnom zložení začala činnosť v januári 2014. Vzhľadom k tomu, že je približne v polovici svojho funkčného obdobia, hlavný redaktor doc. Bohdan Konôpka zvolal na 4. 2. 2016 jej zasadanie. Zasadanie sa uskutočnilo na České zemědělské univerzite (ČZU) v Prahe, Fakulte lesnícké a dřevařské (FLD), konkrétne v novootvorených priestoroch drevárskeho pavilónu. Okrem šestnástich členov redakčnej rady (šesť členov sa ospravedlnilo) sa zasadania zúčastnil aj dekan FLD prof. Marek Turčáni.

Členov redakčnej rady privítal prodekan FLD prof. Róbert Marušák. Poďakoval hlavnému redaktorovi a členom redakčnej rady za predošlú prácu. Následne, riaditeľ Lesníckeho výskumného ústavu vo Zvolene (LVÚ) Dr. Tomáš Bucha potvrdil správnosť fúzie dvoch organizácií pri vydávaní časopisu. Vedúci úradu Central-East and South-East European Regional Office of the European Forest Institute (EFICEEC-EFISEE EFI) Dr. Bernard Wolfslehner pochválil ambície časopisu týkajúce sa medzinárodnej spolupráce, hlavne kooperáciu medzi Českom a Slovenskom. Zdôraznil, že bude potrebné postupne sa dostať aj mimo československého priestoru, k čomu môže prispieť aj potenciálna spolupráca časopisu s EFI.

Doc. Martin Lukac z Readinskej univerzity vo svojej prednáške zhrnul niektoré aspekty nevyhnutné pre úspešné napredovanie vedeckých časopisov: zameranie (čo publikovať), skupina čitateľov (kto bude čítať a citovať), vedecká kvalita článkov a aktuálnosť tém. Predstavil štatistiku niektorých lesnícky orientovaných vedeckých časopisov – počet článkov a citácii. V tejto skupine časopisov sa počet príspevkov veľmi nemenil, avšak počet citácii exponenciálne rástol. Pre ďalšie zvyšovanie kvality časopisu je podľa doc. Lukaca dôležité mať jasné zaradenie a účel. Taktiež treba podporovať prípravu kvalitných článkov a orientovať sa na zvyšovanie citovanosti.

Hlavný redaktor časopisu doc. Bohdan Konôpka predstavil históriu časopisu a hlavné body, ktoré sa riešili na zasadaní redakčnej rady v roku 2014. Pripomenul zmeny v časopise počas ostatných rokov a zdôraznil prínos spolupráce NLC - LVÚ s ČZU - FLD. Predstavil tiež štruktúru a fungovanie časopisu počas rokov 2014 a 2015 (Tabuľka 1 a 2). Pripomenul krátkodobé ciele definované na prvom zasadaní redakčnej rady a zhodnotil ich reálne naplnenie. Informoval, že od roku 2013 sú všetky „veľké“ články (t. j. pôvodné vedecké práce a referáty) zobrazené v databáze SCOPUS. Potešujúce je, že sa počas dvoch rokov v časopise objavili aj články z Nemecka, Rakúska, Ruska a Ukrajiny.

Tabuľka 1. Počet článkov v kategórii pôvodná vedecká práca, referát, správa, recenzia a kronika publikovaných v Lesníckom časopise - Forestry Journal v rokoch 2014 a 2015

Ročník	Pôvodná práca	Referát	Správa	Recenzia	Kronika
2014	23	4	9	1	6
2015	21	7	5	4	8

Tabuľka 2. Prehľad počtu článkov v kategórii pôvodná vedecká práca a referát podľa jazyka v rokoch 2014 a 2015

Ročník	Angličtina	Čeština	Slovenčina
2014	18	4	5
2015	19	4	5

Výkonný redaktor doc. Tomáš Hlásny vysvetlil niektoré okolnosti týkajúce sa systému „Emerging sources citation index“, do ktorého sme podali žiadosť o zaradenie časopisu. Predstavil kritériá pre prijatie do databázy Thomson Reuters a pre získanie impakt faktoru. Okrem iných podmienok bude potrebné sa zamerať aj na tieto aspekty: mať naplnené počty článkov aspoň dvoch čísel dopredu, posilniť redakčnú radu o nových členov – uznávaných vedcov, zdôrazniť regionálny charakter časopisu, zvýšiť viditeľnosť pomocou EFI a zlepšovať kvalitu článkov. V ďalšej časti doc. Hlásny predstavil návrh štatútu Lesníckeho časopisu - Forestry Journal. Štatút by mal vytvoriť jasné rámce pre menovanie hlavného redaktora a členov redakčnej rady, ich funkčné obdobie, kompetencie a povinnosti. Ďalej sa definujú kategórie článkov a cieľové vedecké oblasti vhodné pre Lesnícky časopis - Forestry Journal. Taktiež sa vysvetľuje spôsob spracovania a zasielania článkov, recenzný proces a formy financovania časopisu.

K predneseným informáciám a hlavne k predloženému Štatútu Lesníckeho časopisu - Forestry Journal prebehla diskusia. Týkala sa aj spoluúčasti EFICEEC-EFISEE na jeho vydávaní (išlo by konkrétne o propagačnú činnosť). Ďalej sa diskusia zamerala na prípadnú zmenu názvu časopisu. Členovia redakčnej rady sa dohodli, že konečné znenie Štatútu, forma spolupráce s EFICEEC-EFISEE, ako aj zmena názvu časopisu sa doriešia v priebehu najbližších mesiacov. O týchto záležitostiach sa bude hlasovať formou per rollam prostredníctvom e-mailov.

Následne hlavný redaktor doc. Bohdan Konôpka informoval o edičnom pláne pre rok 2016 a predstavil strednodobú víziu zlepšovania vedeckej úrovne časopisu. Hlavnou zmenou je, že počas roka 2016 kategóriu článkov „Referáty (Discussion papers)“ nahradí kategória „Prehľadové práce (Review papers)“. Zároveň pôvodné vedecké práce a prehľadové práce budú do časopisu akceptované výlučne v anglickom jazyku. Kategórie článkov „Správy“, „Recenzia“ a „Kronika“ môžu byť napísané jedným z týchto jazykov: angličtina, slovenčina alebo čeština. Hlavný redaktor navrhol, aby sa upustilo od vypracúvania slovenskej (resp. českej) verzie názvu článku, abstraktu a kľúčových slov v kategórii pôvodné vedecké práce a prehľadové práce. Túto zmenu v hlasovaní podporila väčšina členov redakčnej rady. Hlavný redaktor vysvetlil ďalšie postupné kroky zvyšovania kvality časopisu najmä prostredníctvom práce redakčnej rady, recenznej práce, webovej stránky časopisu, ďalšími formami zviditeľňovania časopisu na internete (napr. cez stránku ResearchGate) a pod. Kľúčový strednodobý cieľ pre časopis je získať impakt faktor. Uskutočnilo sa hlasovanie týkajúce sa uvádzania mena tematického editora na prvej strane každého článku v kategórii pôvodné vedecké práce a prehľadové práce. Návrh redakčná rada jednohlasne odsúhlasila.

Obr. 1. Pohľad na rokujúcich členov redakčnej rady Lesníckeho časopisu - Forestry Journal. S diskusným príspevkom vystúpil prodekan FLD prof. Róbert Marušák

Obr. 2. Členovia redakčnej rady, zľava: R. Marušák, T. Hlásny, M. Barna, M. Bošeľa, J. Fojt, M. Tučáni (hostiteľ zasadania), I. Štefančík, T. Bucha, J. Socha, B. Konôpka, B. Wolfslehner, J. Holuša, J. Konôpka, J. Novák, M. Lstibůrek, M. Lukac

Ďalej vystúpil výkonný redaktor časopisu prof. Jaroslav Holuša. Predstavil plán prípravy špeciálneho čísla Lesníckeho časopisu - Forestry Journal v roku 2016. Prof. Holuša bude zároveň pre toto číslo zodpovedným editorom. Predpokladá sa, že pôjde o číslo 4. Výkonný redaktor uviedol predbežný zoznam článkov do tohto čísla, ako aj možnosti prípravy „nosného článku", ktorý by mal zostaviť medzinárodný kolektív.

Nakoniec sa uskutočnila záverečná diskusia členov redakčnej rady. Týkala sa hlavne návrhov na zlepšovanie odbornej kvality časopisu a spôsobov rozširovania základne prispievateľov, recenzentov a čitateľov. Sekretár časopisu Dr. Michal Bošeľa upozornil na niektoré chyby tematických editorov, recenzentov a autorov pri práci v online systéme časopisu (Editorial Manager). Hlavný redaktor doc. Bohdan Konôpka poďakoval členom redakčnej rady za aktívnu účasť na zasadaní. Navrhol, aby sa ďalšie zasadanie redakčnej rady konalo začiatkom roka 2018 v Banskej Štiavnici. Zároveň to bude v čase končiaceho sa funkčného obdobia súčasného hlavného redaktora a členov redakčnej rady.

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Správa z odborného seminára Aktuálne otázky ekonomiky a politiky lesného hospodárstva SR 2015

Dňa 10. decembra 2015 sa vo Zvolene, v Národnom lesníckom centre - Lesníckom výskumnom ústave, konal pod záštitou Ministerstva pôdohospodárstva a rozvoja vidieka SR a Slovenskej lesníckej spoločnosti, odborný seminár pod názvom *„Aktuálne otázky ekonomiky a politiky lesného hospodárstva SR 2015"*. Tento seminár patrí k najvýznamnejším odborným podujatiam, ktoré NLC-LVÚ každoročne organizuje. Zorganizovali ho riešitelia projektu APVV-0057-11 VYNALES – *Výskum vplyvu neštátneho vlastníctva lesov na politiky súvisiace s lesníctvom* s podporou Agentúry na podporu výskumu a vývoja.

Význam a tradíciu seminára potvrdzuje nielen pravidelnosť konania, aktuálne išlo o 14. ročník, ale najmä podnetnosť príspevkov a ich popularizácia v praxi prostredníctvom zborníka a webových stránok. Prostredníctvom odberateľov výskumu projektu VYNALES sa prednesené myšlienky dostávajú do verejného priestoru, aj mimo vlastníkov a obhospodarovateľov lesa. Rozhodujúci pre organizátorov je záujem z praxe, doložený hojnou účasťou, ktorá bola tentokrát na hranici priestorovej kapacity usporiadateľov. Z celkovo 61 účastníkov tvorili polovicu zástupcovia neštátneho sektora, vysoká účasť bola aj z radov zástupcov MPRV SR a štátnej správy.

Zámerom organizátorov bolo koncipovať program tak, aby priblížil nové poznatky a riešenia problémov, ktorými žije lesné hospodárstvo na Slovensku. Cieľom seminára bolo prerokovať aktuálnu ekonomickú situáciu a politické problémy lesného hospodárstva a lesníctva SR. Osobitná časť programu sa venovala workshopu v rámci projektu VYNALES, zameraného na odporúčania pre neštátny sektor, majiteľov lesa a ich združenia.

V úvodnej časti odzneli referáty z oblasti ekonomiky LH, vplyvu daní a odvodov na hospodárenie lesných podnikov, informácia o výsledkoch 7. ministerskej konferencie o ochrane lesov v Európe, konanej v Madride a postupe vyčíslenia ekonomických dopadov uplatnenia osobitného režimu hospodárenia v lesoch. Program pokračoval workshopom o faktoroch ovplyvňujúcich politickú moc združení neštátnych vlastníkov lesa na Slovensku.

Obr. 1. Ing. Milan Dolňan prezentoval na workshope stanovisko Rady združení neštátnych vlastníkov lesov

Obr. 2. Diskutuje riaditeľ odboru lesníckych stratégií, ekonomiky lesného hospodárstva a spracovania dreva SLSD MPRV SR, Ing. Ivan Wolf

Seminár otvoril riaditeľ Národného lesníckeho centra - Lesníckeho výskumného ústavu Dr. Ing. Tomáš Bucha, diskusiu usmerňovala a workshop viedla Ing. Zuzana Sarvašová, PhD.

Prvý úvodný referát námestníka generálneho riaditeľa Národného lesníckeho centra Ing. Miroslava Kovalčíka, PhD. odznel pod názvom *Ekonomické výsledky lesného hospodárstva SR v roku 2014*. Okrem ekonomických výsledkov LH za rok 2014 predstavil aj vývoj vybraných ekonomických ukazovateľov za obdobie rokov 2005–2014. Ekonomické výsledky LH SR v roku 2014 boli poznačené najmä vyššou ťažbou surového dreva o približne 1 mil. m^3, čo zlepšilo všetky ekonomické ukazovatele. Celkové tržby LH dosiahli v roku 2014 hodnotu 532,9 mil. € a oproti minulému roku vzrástli o 13,2 %. Hodnota dodávok sortimentov surového dreva vzrástla o 11,5 %. Najvýraznejšie sa to prejavilo pri piliarskych guľatinových sortimentoch dreva, kde bol nárast až o 14 %. Pri vlákninových sortimentoch hodnota dodávok vzrástla o 9,6%. Naproti tomu, hodnota dodávok palivového dreva klesla o −14,8%. V roku 2014 dodali subjekty obhospodarujúce lesy na Slovensku na trh 9 168 tis. m^3 dreva a medziročne vzrástli dodávky dreva o 13,7 %. V porovnaní s rokom 2013 boli dodávky dreva na domáci trh o 1 133 tis. m^3 vyššie. Lesné podniky vyviezli priamo 432 tis. m^3 surového dreva v celkovej hodnote 25 mil. €. Priemerné speňaženie dreva v LH SR v roku 2014 bolo vo výške 47,44 €/m^3. Výsledky kapitálového účtu poukazujú stále na nedostatočné zdroje na obnovu investičného majetku, hlavne mechanizačných prostriedkov, ktoré obmedzujú realizáciu nevyhnutných technicko-ekonomických, ale aj ekologických opatrení a následne ovplyvňujú nákladovosť výrobného procesu. V lesnom hospodárstve pôsobí aj silná podnikateľská sféra, ktorá poskytuje služby pre obhospodarovateľov lesa. Ich hodnota dosiahla v roku 2014 výšku 210 mil. €. Lesnícko-drevársky komplex dosahuje ročne tržby zhruba 3,5 mld. €, zamestnáva 40 tis. pracovníkov a tvorí 2,2 až 2,3 % HDP SR.

Od roku 2016 preberá Slovenská republika od Španielskeho kráľovstva na najbližšie štyri roky predsedníctvo *FOREST EUROPE*, ktoré je najvyšším politickým grémiom európskych ministrov zodpovedných za lesné hospodárstvo. Na Národnom lesníckom centre vo Zvolene bude koordinačná jednotka procesu – Liaison unit Bratislava. Aké sú úlohy Laison unit Bratislava (LUB) a čo vyplynulo zo 7. ministerskej konferencie v Madride, ktorá sa konala v októbri referovala Ing. Lucia Ambrušová, PhD. Cieľom FOREST EUROPE je vytvoriť paneurópsku platformu na formuláciu spoločných stratégií k aktuálnym problémom lesníctva a ochrany lesov v Európe v záujme zabezpečenia trvalo udržateľného obhospodarovania lesných zdrojov regiónu a ich ďalšieho rozvoja. Hlavnými úlohami LUB bude organizácia oficiálnych zasadnutí procesu FOREST EUROPE, spravovanie agendy, príprava dokumentácie na tieto zasadnutia, návrh zadávacích podmienok pre činnosť špecializovaných pracovných skupín pôsobiacich v rámci procesu, komunikačné a propagačné aktivity a zabezpečenie tzv. styčného bodu pri komunikácii medzi zainteresovanými stranami procesu. Predsedníctvo v procese FOREST EUROPE, ktoré Slovenská republika prevzala na obdobie rokov 2014–2021, má pre Slovenskú republiku významný propagačno-prezentačný potenciál a to nielen v rámci európskeho geopolitického regiónu, ale aj v medzinárodných inštitúciách a procesoch s globálnou pôsobnosťou. Na základe doterajších skúseností je možné uviesť, že v čase umiestnenia koordinačnej jednotky v meste predsedajúcej krajiny, je toto mesto považované medzinárodnou lesníckou verejnosťou za „hlavné mesto európskeho lesníctva". Pre SR je preto predsedníctvo príležitosťou na zviditeľnenie sa v celkovom medzinárodnom kontexte. Na vnútroštátnej úrovni má predsedníctvo významný potenciál pri zvyšovaní povedomia verejnosti o lesoch a lesníctve, ako aj význame medzinárodnej spolupráce v lesníctve a prínose medzinárodných lesníckych politík pre trvalo udržateľné obhospodarovanie lesov.

Zatiaľ posledná, siedma konferencia ministrov o ochrane lesov v Európe sa konala v Madride v dňoch 20. – 21. októbra 2015. Spolupredsedami konferencie boli Isabel García Tejerina, ministerka poľnohospodárstva, výživy a životného prostredia Španielskeho kráľovstva, a Ľubomír Jahnátek, minister pôdohospodárstva a rozvoja vidieka Slovenskej republiky. Na konferencii sa zúčastnilo približne 220 účastníkov vrátane ministrov zodpovedných za lesy a ďalších vedúcich predstaviteľov 39 európskych krajín a Európskej únie, ktoré sú signatárskymi stranami procesu, a 18 organizácií, ktoré majú štatút pozorovateľa v procese FOREST EUROPE. Predstavitelia signatárskych krajín prijali a podpísali 1 deklaráciu ministrov, 2 rezolúcie ministrov a 1 rozhodnutie ministrov.

Deklarácia ministrov z Madridu: 25 rokov spoločnej podpory trvalo udržateľného obhospodarovania lesov v Európe. Madridská deklarácia zaväzuje signatárske strany procesu FOREST EUROPE posilňovať úlohu lesov a ich trvalo udržateľné obhospodarovanie pri riešení globálnych výziev, akými sú agenda trvalo udržateľného rozvoja po roku 2015 vrátane rozvojových cieľov, boj proti zmene klímy, ochrana biodiverzity a boj proti dezertifikácii. Zároveň deklarácia zaväzuje signatárske strany monitorovať a podávať správy o pokroku pri implementácii strategických cieľov a cieľov pre európske lesy do roku 2020.

Rezolúcia ministrov z Madridu 1: Lesnícky sektor v centre zelenej ekonomiky zaväzuje signatárske strany k ďalšiemu posilneniu úlohy lesného hospodárstva a priemyslu spracovania dreva pri prechode spoločnosti na tzv. zelené hospodárstvo, ďalšiemu posilneniu sociálnych aspektov trvalo udržateľného obhospodarovania lesov podporou zelených pracovných miest, vzdelávania a sociálnej inklúzie a rodovej rovnosti v lesníctve. Rezolúcia ďalej zaväzuje k začleneniu hodnoty lesných ekosystémov do zelenej ekonomiky podporou výmeny skúseností a informácií o metodikách v oblasti oceňovania a platieb za lesné ekosystémové služby, podporou politických prístupov na tieto účely, ako aj zvyšovaním úsilia k lepšiemu zohľadňovaniu hodnoty všetkých služieb lesných ekosystémov, v rámci politík relevantných pre lesníctvo a ich nástrojov, vrátane národných lesníckych programov, trhových nástrojov a platieb za ekosystémové služby.

Rezolúcia ministrov z Madridu 2: Ochrana lesov v meniacom sa prostredí zaväzuje k implementácii opatrení zameraných na zlepšenie ochrany lesov pri zohľadnení meniacich sa podmienok prostredia. Záväzky adresujú vývoj celoeurópskych prístupov v ochrane lesa, zvyšovanie povedomia verejnosti o životne dôležitej úlohe trvalo udržateľného obhospodarovania ochranných lesov a pokračovanie adaptácie lesov na meniacu sa klímu. Na posilnenie spolupráce v celoeurópskom regióne sa signatárske strany zaviazali pokračovať v spolupráci v oblasti lesných genetických zdrojov prostredníctvom Európskeho programu pre lesné genetické zdroje (EUFORGEN). Súčasťou tohto rámca je aj záväzok na výmenu odborných znalostí a posilnenie spolupráce v oblasti prevencie proti prírodným rizikám vrátane lesných požiarov, záplav, invazívnych druhov a dezertifikácie.

Rozhodnutie ministrov z Madridu: Budúce smerovanie FOREST EUROPE potvrdilo postavenie a úlohu FOREST EUROPE ako dobrovoľného politického procesu na najvyššej úrovni pre dialóg a spoluprácu o politikách v oblasti lesov v Európe. Rozhodnutie zdôrazňuje potrebu prehodnotiť proces FOREST EUROPE s cieľom reagovať na súčasné i nové výzvy a príležitosti, zachovať a posilniť jeho príspevok k trvalo udržateľnému hospodáreniu v lesoch v Európe. Signatárske strany sa dohodli preskúmať štruktúru procesu FOREST EUROPE, postupy a pracovné modality s cieľom jeho zefektívnenia a zlepšenia podmienok pre účasť všetkých relevantných strán v ňom.

Dane – téma, aktuálna nielen v roku 2015. Prezentáciu *Daňovo-odvodové zmeny a ich vplyv na výsledok hospodárenia lesných podnikov* mala kolegyňa z Lesníckej fakulty TU vo Zvolene, Ing. Blanka Giertliová, PhD. Daňová sústava Slovenskej republiky je v neustálom vývoji, čoho dôkazom je aj rozsiahly počet noviel dotýkajúcich sa zákonov v daňovej a odvodovej oblasti. Rok 2015 bol významným z hľadiska viacerých legislatívnych zmien v oblasti daní z príjmu fyzických i právnických osôb. Po prvýkrát sa uhrádzala tzv. daňová licencia pre právnické osoby, zmenil sa systém odvodov, došlo k zmene a sprísneniu uplatňovania viacerých skupín daňovo uznateľných výdavkov. Väčšina uvedených skutočností sa dotkla i podnikateľských subjektov z oblasti lesného hospodárstva. Významné zmeny nastali v postupoch odpisovania majetku. Došlo k zmenám počtu odpisových skupín, a tým aj k preklasifikovaniu dlhodobého majetku pre tieto účely, zároveň sa obmedzila možnosť využitia zrýchlených odpisov. Nastali významné zmeny aj pri dani z motorových vozidiel. Výnos z dane nebude príjmom VÚC, ale stáva sa príjmom štátneho rozpočtu. Zmeny realizované v daňovej oblasti možno z hľadiska potreby konsolidácie verejných financií, ako aj z hľadiska zlepšenia výberu daní považovať za pozitívne. Na základe výsledkov analýzy možno konštatovať, že realizované opatrenia mali v prevažnej miere negatívny dopad na výšku daňových povinností analyzovaných subjektov v LH, a teda aj na objem ich disponibilných zdrojov tvorených z výsledku hospodárenia. Táto situácia má z dlhodobého hľadiska negatívny dopad na kreáciu vlastných zdrojov financovania na rozvoj, či na financovanie ekosystémových služieb.

Otázku, *aká je cena osobitného režimu hospodárenia v lesoch,* otvoril Ing. Ladislav Kulla, PhD. V zákone 326/2005 Z. z. o lesoch je osobitný režim hospodárenia zadefinovaný nepriamo v § 14 ods. 1: Lesy osobitného určenia sú lesy, ktoré boli za také vyhlásené a ktorých účelom je zabezpečovanie špecifických potrieb spoločnosti, právnických osôb alebo fyzických osôb, na ktorých zabezpečenie sa významne zmení spôsob hospodárenia oproti bežnému hospodáreniu. Ak návrh na vyhlásenie lesov osobitného určenia predkladá iná osoba ako vlastník lesa, musí tento obsahovať aj súhlas vlastníka alebo správcu s vyhlásením lesov osobitného určenia a dohodu o určení výšky a spôsobe poskytnutia náhrady za obmedzenie vlastníckych práv v dôsledku osobitného režimu hospodárenia. Náhrada za obmedzenie vlastníckych práv sa poskytuje na základe dohody o určení výšky a spôsobe jej poskytnutia. Všeobecne uznávaná metóda ekonomického hodnotenia v lesníctve je metóda čistej súčasnej hodnoty. Na jej základe a s využitím princípu fázových výrobkov bol s pomocou využitia aplikácie modelu SIBYLA predstavený postup ekonomického hodnotenia alternatív hospodárenia. Navrhnutý postup sa odskúšal na modelovom území uceleného komplexu 27 lesných porastov na

Výskumno-demonštračnom objekte Kysuce. Výsledky pilotného overenia metodiky založenej na čistej súčasnej hodnote lesa pri započítaní pestovných nákladov spojených so zakladaním následných porastov naznačujú riziko podhodnotenia dopadov osobitného režimu pri nedostatočne dlhom období hodnotenia, a to najmä v rubne zrelých porastoch vstupujúcich do obnovy. Pre kratšie dohody navrhujú autori využiť zjednodušenú metódu vyčíslenia dopadov, založenú na čistej súčasnej hodnote existujúceho porastu, nezohľadňujúcu operácie spojené so zakladaním následných porastov, a ani ich hodnotu do celkovej finančnej hodnoty lesa. Takýto postup je ľahšie prakticky zvládnuteľný, a aj menej časovo a finančne náročný. Jeho výsledky však prestávajú byť relevantné pre obdobia dlhšie ako 50 rokov, keď následné porasty začnú významne ovplyvňovať hodnotu lesa.

V programe sa pokračovalo *workshopom projektu VYNALES* a formát stretnutia sa zmenil. Na začiatku predstavil doc. Dr. Jaroslav Šálka výsledky výskumu, ktoré viedli k identifikácii faktorov ovplyvňujúcich politickú moc združení neštátnych vlastníkov lesov. Tieto výsledky spolu s teóriami slúžia k návrhu procesného modelu a formulácii odporúčaní pre organizácie neštátnych vlastníkov lesov a štátnu správu na úseku lesného hospodárstva. V snahe zvýšiť relevantnosť výstupov a záverov projektu VYNALES riešitelia pripravili priestor pre hodnotenie jednotlivých faktorov pomocou hlasovania. Prítomní boli rozdelení do troch skupín na základe príslušnosti k sektoru: neštátni majitelia a obhospodarovatelia lesov, reprezentanti štátnej správy a ostatní experti. Z referátu vyplynulo, že požiadavky členov združení a názory ich výkonných predstaviteľov sa neodlišujú v otázkach povinnosti členstva (ktoré odmietajú), požiadavkách na podporu zo strany štátu (ktorú očakávajú) a nejasnosti v riešení financií (nemajú vlastné zdroje a cudzie sú limitované). Závažné rozdiely nie sú medzi štátnou správou a predstaviteľmi neštátnych vlastníkov lesov v otázkach potreby spolupráce. Tá je hodnotená ako potrebná a nedostatočná, tak v rámci lesníckeho sektora ako takého, ako aj vo vnútri neštátneho sektora LH SR. Práca s verejnosťou, využívanie nátlakových aktivít a lobovanie bolo hodnotené ako potrebné, ale okrajové celou vzorkou prítomných.

V následnej diskusii odzneli názory a odporúčania pre zlepšenie fungovania združení vlastníkov lesov a pre štátnu správu v súvislosti s podporou spolupráce s neštátnym sektorom. Výsledky workshopu sa vyhodnotili a sú súčasťou oponovanej záverečnej správy projektu VYNALES. Spätná väzba zo strany odberateľov výskumu je nesmierne dôležitá a posúva lesnícky výskum aj v oblasti ekonomiky a politiky bližšie k požiadavkám praxe.

Všetky prezentácie zo seminára, ako aj ďalšie súvisiace publikácie projektu VYNALES sú k dispozícii na webovej stránke www.ipoles.sk a plné znenia príspevkov sú publikované v zborníku *Aktuálne otázky ekonomiky a politiky lesného hospodárstva Slovenskej republiky 2015*.

Poďakovanie

Táto správa bola podporovaná Agentúrou na podporu výskumu a vývoja na základe zmluvy č. APVV-0057-11.

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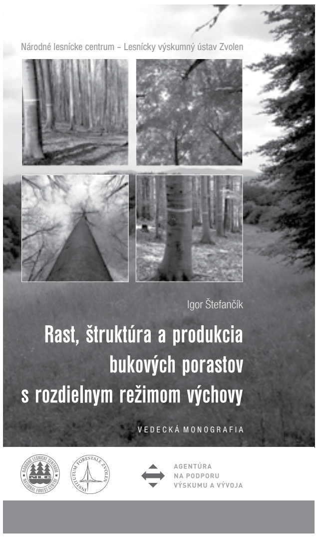
REVIEWS

Štefančík, Igor: Rast, štruktúra a produkcia bukových porastov s rozdielnym režimom výchovy – Growth, structure and production of beech stands with different thinning regimes



The National Forest Centre - Forest Research Institute in cooperation with the Agency for support of research and development by the end of 2015 published a scientific monograph written by Igor Štefančík named "*Growth, structure and production of beech stands with different thinning regimes*" in the extent of 148 pages. Graphic design of the monograph, accompanied with illustrative color and black and white 81 images and 68 well-arranged tables successfully carried out Ľ. Pilná and Ľ. Frič in the Publishing of the National Forestry Centre Zvolen in the edition of 100 copies (ISBN 978-80-8093-202-2). The monograph is dedicated to the memory of Prof. Ing. Ladislav Štefančík, DrSc. (*4. 4. 1929 – † 23. 11. 2002), who was the initiator and leading personality in the research of thinning in beech stands not only in the Slovak Republic and the former Czechoslovakia, but also in Central Europe. He is the author of the original thinning methods – the free crown thinning from above according to Štefančík, which is also included in all modern silviculture textbooks. In addition, this thinning method is already applied in forestry practice for a long time.

This complex scientific monograph is the work of Doc. Ing. Igor Štefančík, CSc., who in the thinning of beech stands follows on the long-term research efforts of Prof. Ing. Ladislav Štefančík, DrSc., which dates back to the 50s of the 20th century. The monograph contains 11 main chapters and a list of references, an English summary and annexes (color photos of the monitored research plots), as is evident from the content: 1. Introduction, 2. Starting points, 3. Objectives of research, 4. Material and Methods, 5. Results, 6. Effect of thinning on quantitative production, 7. Effect of thinning on qualitative production, 8. Discussion, 9. Summary of results of research, 10. Recommendation for forestry practice and 11. Conclusion.

In the **Introduction** it is emphasized that changing natural conditions in the recent decades gave rise to new (innovative) approaches of the forest management. Formulation of their principles is possible thanks to the research on long-term permanent research plots (PRPs) that are an irreplaceable natural laboratory for the management of forest ecosystem based on exact measurements.

In the chapter **Starting points** are presented complex aspects of thinning of forest stands, especially beech stands, which are crucial for their development. This chapter is accentuating that in the thinning of beech stands it is not only important the methodology of applied treatment, but also the age when it is best to start with thinning, with regard to the habitat and stands conditions. More detailed is presented the already mentioned free crown thinning from above according to Štefančík, which was developed in the 50s of the 20th century.

The aim of the study was to evaluate the long-term development of beech stands on the basis of scientific analysis and synthesis of 8 series of PRPs and a total of 28 sub-PRPs with a different thinning regimes based on: diameter and height structures, the number of trees, the basal area and the volume of timber, selected quantitative parameters of production and the total volume of production, the development of superior quality trees (promising and target trees), growing quality of the stem and crown of trees of the main stand, the quality of the main stand and the overall quality of production. The main aim of all attempts were in addition to compare the results of three different thinning methods (the heavy thinning from below – C grade according to the German forest research institutes from 1902, the free crown thinning from above according to Štefančík and area without thinning regimes), as well as evaluation of development of trees with selection quality by the methods of promising, respectively target trees.

In the chapter **Materials and Methods** it is stated that the base material for the writing of this publication was data from PRPs established between 1958–1984 by Prof. Ing. Ladislav Štefančík, DrSc., in naturally regenerated homogenous beech in Slovakia. All investigated stands were at the time of the experiment establishment in the growth phases of small pole stage to pole stage. Up to the establishment of the series of PRPs, the stands were with almost any planned systematic thinning. Each PRP consists of three to five sub-PRPs which are arranged side by side (along level line) and separates them from each other always at least 15 m wide insulating belt of trees. The area of each sub-PRPs is 0.25 ha (50 × 50 m). On all sub-PRPs all living trees with diameter at breast height 3.6 cm and larger were numbered, measured and classified in terms of the standard parameters of growth, structure and quantitative and qualitative production growth. Within each of PRP is always one sub-PRP left without intervention (control). On other areas within each series effects of various thinning methods are monitored and compared. The results were processed using standard techniques of mathematical and statistical methods.

Crucial chapter the **Results** covers 8 series of PRPs: Koňuš, Jalná, Kalša, Štagiar, Žalobín, Zlatá Idka, Lukov and Cigánka. There the results are given more than 50 years of research experiments based on the years 1958–1984, which contain anywhere up to 12 regular repeated complete biometric measurements and evaluations.

Based on a detailed analysis of partial results from individual series PRPs and sub-PRPs were formulated following key results:

- After repeated tending, the thickest individuals (with the highest mean diameter d_g) were on PRPs with the heavy thinning from below and the free crown thinning from above according to Štefančík and thinnest (with the smallest d_g) on the control PRPs.
- The sub-PRPs tended by the free crown thinning according to Štefančík showed the best diameter structure with the highest values of diameter differentiation indices ($TM_d > 0.5$) indicated even high differentiation. The worst diameter structure with the lowest values (TM_d <0.3) characterized by small differentiation were found on sub-PRPs managed by heavy thinning from below.
- The highest values of the mean height (h_g) were found on sub-PRPs with heavy thinning from below and the lowest on all sub-PRPs with the free crown thinning according to Štefančík and control sub-PRPs (without tending). The highest values of height differentiation indices (TM_h) were found always on sub-PRPs with the free crown thinning according to Štefančík (medium to high differentiation) and the lowest on all sub-PRPs managed by heavy thinning from below (small differentiation).
- After repeated tending, the lowest number of trees (N) was found on sub-PRPs with heavy thinning from below (224 to 464 trees ha^{-1}) at stand age from 83 to 105 years (except for PRP Žalobín). On the contrary, the highest N (435 to 1,012 trees ha^{-1}), as well as basal area (G) was found on control sub-PRPs (42.7 – 48.0 $m^2 ha^{-1}$). The sub-PRPs tended by the free crown thinning according to Štefančík showed the lowest G (30.5 – 39.7 $m^2 ha^{-1}$). Merchantable volume was found the lowest on sub-PRPs with the free crown thinning according to Štefančík (468 – 614 $m^3 ha^{-1}$) and the highest on both control sub-PRPs (582 – 846 $m^3 ha^{-1}$) and sub-PRPs with heavy thinning from below (609 – 779 $m^3 ha^{-1}$).
- Total mean annual merchantable volume increment was found the highest on 4 PRPs with heavy thinning from below (10.3 to 10.9 $m^3 ha^{-1} year^{-1}$) and the lowest on 5 control sub-PRPs (6.8 to 10.2 $m^3 ha^{-1} year^{-1}$). Sub-PRP managed by the quality group selection thinning was characterized by the value of 9.8 $m^3 ha^{-1} year^{-1}$, but on PRPs Štagiar it was ranged from 7.1 to 8.1 $m^3 ha^{-1} year^{-1}$.
- The highest number of target (crop) trees was registered on all sub-PRPs managed by the free crown thinning according to Štefančík (68 to 184 trees ha^{-1}) and the lowest on most of control sub-PRPs . It was 190 trees per hectare on the sub-PRP with the quality group selection thinning. On PRP Štagiar it ranged from 156 to 200 trees ha^{-1} at stand age of 68 years.
- The quantitative parameters of target trees (basal area, merchantable volume, current annual periodical diameter increment) achieved the highest values on sub-PRPs managed by the free crown thinning according to Štefančík, with the proportion from 37 to 75% out of basal area of the main stand and/or 39 to 77% out of the merchantable volume of the main stand. On sub-PRPs managed by the quality group selection thinning it was 92% and 93% and/or on PRP Štagiar ranged from 26 to 35% and 29 to 39%, respectively.
- The silvicultural quality of trees at crown level of the stand (1st and 2nd growth class) was found always better in comparison to suppressed level of the stand (3rd to 5th growth class). The worst silvicultural quality of stem was registered on control sub-PRPs (without tending), contrary to sub-PRPs managed by the free crown thinning according to Štefančík and the quality group selection thinning, where the best quality was registered.

Based on a synthesis of acquired knowledge from long-term monitoring and evaluation of PRPs, guiding principles of thinning in beech stands were developed and recommendations generalized for their use in forestry practice, which certainly contribute not only to an increase in the quantity of timber production, but especially the quality of production.

In the **Conclusion** of the monograph it is stated that after more than 50-years of systematic research, heavy thinning from below still comes slightly better (stand age 83–105 years) with respect to total volume production compared to the free crown thinning from above according to Štefančík. However, effective near-natural silviculture of beech stands should be aimed at the quality of production and in this the free crown thinning from above according to Štefančík is the best suited thinning treatment in the conditions of pure beech stands in Slovakia.

This monograph, which summarizes quite exceptional long-term (over 50 years) experimental material, will certainly well serve to managers and employees in forest management, dealing with issues of silviculture. It will also be an inspiration and a repository of knowledge for scientists, whose research addresses various aspects of thinning. However, it will also be used as a teaching tool to forestry faculties in the field of silviculture. Thanks and appreciation for this monograph belong not only to the author Doc. Ing. Igor Štefančík, CSc. and his father Prof. Ing. Ladislav Štefančík, DrSc., but also to the publisher - National Forestry Centre Zvolen and the sponsor – Agency to support research and development.

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CHRONICLE

Spomienka na Františka J. Turčeka – 100 rokov od jeho narodenia

František Jozef Turček sa na rodil 3. 12. 1915 v Badiciach pri Nitre v učiteľskej rodine. Po skončení ľudovej školy študoval na gymnáziu v Nitre. Gymnázium nedokončil, pokračoval v štúdiu v Učiteľskom ústave v Prešove. Po roku začal pracovať v Lesnej správe v Kamenici nad Hronom ako lesný praktikant (1934) a potom dva roky ako lesný adjunkt na Kysuciach (1935–1937). Po ukončení základnej vojenskej služby sa v roku 1942 vrátil do zamestnania ako revírnik komposesorátnych lesov v Nitre. Ďalej bol lesným správcom na súkromnom majetku v Kovarciach pri Topoľčanoch (1944–1946). Na základe toho, že už od roku 1941 publikoval odborno-populárne práce v poľovníckych časopisoch vznikol o neho záujem v Ústave pre pestovanie lesov a lesnú biológiu v Banskej Štiavnici. Sem nastúpil do zamestnania 1. októbra 1946, ako pomocná vedecká sila. V ďalších rokoch, po viacerých organizačných zmenách tohto pracoviska pôsobil v Ústave pre poľovníctvo a najdlhšie v Ústave ochrany lesov, resp. v oddelení ochrany lesov vo Výskumnom ústave lesného hospodárstva v Banskej Štiavnici. V roku 1964 prešiel pracovať do Ústavu biológie krajiny Slovenskej akadémie vied, kde pôsobil až do svojej smrti v roku 1977. Ako z uvedeného veľmi stručného životopisu vyplynulo František J. Turček najdlhšie (18 rokov) pracoval vo Výskumnom ústave lesného hospodárstva v Banskej Štiavnici (teraz Národné lesnícke centrum - Lesnícky výskumný ústav Zvolen).

Pri príležitosti 100 rokov od narodenia Františka J. Turčeka sa konali v roku 2015 viaceré spomienkové podujatia, najmä v Ústave ekológie lesa SAV. Okrem iného pri tejto príležitosti mu odhalili aj pamätnú tabuľu. Taktiež, či už v tlači ako aj masmédiách sa činnosti a dielu Františka J. Turčeka venovala značná pozornosť. Všetkým tým, ktorí sa na tomto podieľali patrí srdečné poďakovanie. Oprávnene sa tu vyzdvihovala záslužná činnosť, ako ekológa, zoológa a poľovníka. Preto aj v našom Lesníckom časopise chceme pri príležitosti 100 rokov od jeho narodenia pripomenúť najmä mladšej generácii jeho činnosť a dielo, hlavne pre rozvoj lesníckej vedy, lesného hospodárstva, zvlášť v odbore ochrany lesov.

Dosiahnuté výsledky možno najlepšie ilustrovať uverejnenými prácami, ktoré napísal v slovenskom, nemeckom, anglickom a maďarskom jazyku. Ide o desiatku knižných publikácií a 400 pôvodných a odborných prác. Ako sme už uviedli zaoberal sa širokou problematikou patriacej do viacerých vedných odborov. Vynecháme problematiku zoológie, ekológie lesa a poľovníctva, pretože jeho prínos v týchto oblastiach sa už uviedol v rámci konaných podujatí v roku 2015, zameriame sa len na ochranu lesov. Aj tu ide o širokú problematiku týkajúcu sa hmyzích škodcov, zveri, drobných hlodavcov, vtákov, požiarov a ďalších škodlivých činiteľov. Pozornosť venoval taktiež kontrole výskytu jednotlivých škodcov a prognóze ich šírenia, ako aj možnostiam využitia jednotlivých metód ochrany a obrany proti škodcom, vrátane biologickej ochrany.

Z hmyzích škodcov sa venoval najmä mníške veľkohlavej (*Lymantria dispar* L.), jej premnoženiu a vplyvu na lesnú biocenózu. Ďalej hromadnému výskytu chrústa a opatreniam na ochranu pred spriadkovačom (priastevníkom) americkým. Ešte aj v súčasnosti sa v zmysle vyhlášky č. 453/2006 Z. z. o hospodárskej úprave lesov a o ochrane lesa ohrozenie lesných porastov mníškou veľkohlavou posudzuje „Turčekovou metódou“ (cit. : Kontrola. Vo zvýšenom stave , keď početnosť samcov v lapačoch presiahne 70 ks, sa začína s kontrolou početnosti pomocou Turčekovej metódy. Za zvýšený stav treba považovať početnosť 0,3 – 2 znášky na strom. V čase kalamitného výskytu sa používa na zisťovanie škodcu Turčekova metóda. Za kalamitný stav sa považuje početnosť 2 a viac znášok na kmeň).

Pomerne veľa prác publikoval o ochrane lesných porastov pred poškodzovaním zverou. Išlo najmä o lesné kultúry, kde riešil ich ochranu pred ohryzom zverou. Ďalej problematiku zodierania kôry drevín srncami pri „vytĺkaní“ parohov. Problematikou poškodzovania lesných kultúr sa zaoberal komplexne, čiže riešil ich ochranu takmer proti všetkými najvýznamnejšími škodlivým činiteľom. Osobitú pozornosť venoval ochrane lesných kultúr na nelesných pôdach. Sem priradíme aj problematiku ochrany lesných semien, siatby a sejby pred škodcami, najmä vtákmi a hlodavcami. Spomenúť treba taktiež ochranu lesných porastov pred požiarmi. Participoval na riešení ochrany lesných porastov proti hubovým chorobám, napr. topoľov.

Podieľal sa taktiež na spracovaní správ o výskyte lesných škodcov na Slovensku, napríklad v rokoch 1947, 1948. Zaoberal sa prognostikou a jej významom v ochrane lesov. Vypracoval prognózu výskytu drobných hlodavcov v lese pre potreby ochrany lesov. Zaoberal sa využitím insekticídov, fungicídov, herbicídov v ochrane lesa, čo riešil aj vo vzťahu k ochrane prírody. Osobitú pozornosť venoval účasti vtákov v biológii lesa. Ďalej využitiu mravcov v biologickej ochrane lesa.

Tým, že sme dielo Františka J. Turčeka zúžili len na výber niektorých prác z ochrany lesov neznamená to, že aj ostatné práce týkajúce sa biologických vied, najmä zoológie, poľovníctva či ekológie neboli významné z hľadiska lesníckeho výskumu. Tvorili veľmi dobré východisko pre riešenie úloh v aplikovanom lesníckom výskume, kde našli mnohé z nich veľmi dobré využitie.

K doposiaľ uvedenému treba dodať, že František J. Turček bol mimoriadnou osobnosťou, s vynikajúcimi tvorivými schopnosťami. Ako samouk sa stal významným odborníkom, výskumným či vedeckým pracovníkom v širokej škále vedných odborov. Ovládal tri svetové jazyky. Dokázal v problematike, ktorú riešil náležite uplatňovať a využívať štatistické metódy. Bol členom viacerých zahraničných spoločností. Zrejme aj preto, či pre nekomfortné postoje k vládnucim štruktúram ho po roku 1958 služobne degradovali.

Nakoniec v roku 1964 odišiel z Výskumného ústavu lesného hospodárstva v Banskej Štiavnici pracovať do Ústavu biológie krajiny Slovenskej akadémie vied. Treba uviesť, že napriek týmto životným peripetiám zostal vždy skromným človekom, ktorý aj pri podlomenom zdraví nachádzal zmysel svojho života v práci.

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Vyhláška č. 453/2006 Z. z. o hospodárskej úprave lesov a o ochrane lesa.

Jozef Konôpka

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K nedožitým 90. narodeninám prof. Ing. Dr.h.c. Štefana Korpeľa, DrSc.

Začiatkom roka 2016 sme si pripomenuli 90 rokov od narodenia významnej osobnosti slovenskej lesníckej vedy, vysokoškolského pedagóga a vynikajúceho človeka prof. Ing. Dr.h.c. Štefana Korpeľa, DrSc., ktorý bol zároveň dlhoročným členom redakčnej rady Lesníckeho časopisu - Forestry Journal.

Prof. Korpeľ sa narodil 8. 2. 1926 v Pohronskej Polhore. Už po skončení meštianskej školy v Brezne sa zameral na lesníctvo, ktorému ostal verný počas celého svojho plodného života. V roku 1945 zmaturoval na Štátnej vyššej lesníckej škole v Banskej Štiavnici. Potom študoval lesnícke inžinierstvo na Vysokej škole technickej v Bratislave, resp. Vysokej škole poľnohospodárskeho a lesníckeho inžinierstva (VŠPLI) v Košiciach, kde bol v roku 1951 promovaný na lesného inžiniera. Po absolvovaní spomínanej školy začal pracovať ako asistent vo vtedajšom Ústave pestovania lesa Lesníckej fakulty (LF) VŠPLI v Košiciach. Po presťahovaní Lesníckej fakulty do Zvolena v roku 1952 v rámci novozriadenej Vysokej školy lesníckej a drevárskej (VŠLD) pôsobil na jej Katedre pestovania lesa takmer 50 rokov, kde prešiel všetkými učiteľskými funkciami od asistenta až po vysokoškolského profesora. Pritom v rokoch 1975–1991 zastával funkciu vedúceho Katedry pestovania lesa LF VŠLD, resp. Technickej univerzity (TU) vo Zvolene. Na sklonku života pôsobil krátky čas aj v Ústave ekológie lesa SAV vo Zvolene.

V rokoch 1956–1961 absolvoval externú vedeckú ašpirantúru na Vysokej škole zemědělskej v Brne a získal vedeckú hodnosť kandidáta poľnohospodársko-lesníckych vied (CSc.). V roku 1967 ho po obhajobe habilitačnej práce vymenovali docentom pre vedný odbor pestovanie lesa. V roku 1984 obhájil doktorskú dizertačnú prácu na tému *„Dynamika prírodných lesov Slovenska“* a získal vedeckú hodnosť doktora poľnohospodársko-lesníckych vied (DrSc.). V rovnakom roku ho prezident republiky vymenoval za profesora pre vedný odbor pestovanie lesa.

Profesor Korpeľ venoval prakticky všetok pracovný i voľný čas lesníckej vede, ktorá mu bola zároveň aj „koníčkom“. Aj preto bola jeho pedagogická a vedecká činnosť neuveriteľne široká a bohatá. Bol vedúcim kolektívu autorov, resp. spoluautorom šiestich celoštátnych vysokoškolských učebníc pestovania lesa. Vychoval nespočetné množstvo diplomantov a pod jeho vedením ukončilo vedeckú výchovu viacero našich i zahraničných ašpirantov (v súčasnom ponímaní doktorandov). Prednášal ako hosťujúci profesor aj na iných univerzitách, napr. Aas v Nórsku (1984), v Zürichu vo Švajčiarsku (1992), v Tharandte a Göttingene v Nemecku (1992, 1994).

Veľmi intenzívne boli aj jeho vzťahy s lesníckou praxou, a to formou exkurzií a školení v teréne, kde bol vyhľadávanou a uznávanou autoritou. Bol autorom, resp. spoluautorom rôznych smerníc a koncepčných materiálov zameraných na obhospodarovanie lesov. Významne sa podieľal aj na usmerňovaní pestovnej činnosti v Školskom lesnom podniku TU Zvolen.

V rámci vedeckovýskumnej činnosti riešil prakticky celú rozsiahlu problematiku pestovania lesov od zakladania, cez výchovu až po obnovu, pričom zahrňovala všetky hlavné dreviny a ich zmiešaniny. Okrem toho svoju pozornosť upriamil aj na vzácnu a raritnú drevinu slovenských lesov – tis obyčajný (*Taxus baccata* L.), spracovaním jedinečnej štúdie *„Význam tisu v lesných ekosystémoch Slovenska a možnosti zlepšenia jeho stavu“* (1995). Osobitnú pozornosť venoval biologickej racionalizácii našich listnatých a zmiešaných lesov. Dôkazom je aj jeho originálna koncepcia tzv. racionalizačnej úrovňovej prebierky, ktorá umožňuje technicky a ekonomicky zracionalizovať výchovu porastov, ktorá všeobecne patrí medzi vysoko nákladové činnosti v rámci existencie lesného porastu. Ťažiskovou a priekopníckou oblasťou jeho výskumu, kde dosiahol aj medzinárodné uznanie bola štruktúra a vývoj regeneračných procesov prírodných lesov. Výsledky 45-ročného výskumu z 25 pralesovitých rezervácií Slovenska spracoval v knižnej publikácii *„Pralesy Slovenska“* (1989), ktorá mala veľký ohlas nielen doma, ale aj v zahraničí, pričom vyšla aj v Nemecku v inovovanej verzii *„Die Urwälder der Westkarpaten“* (1995) vo vydavateľstve Verlag Fischer, Stuttgart-Jena-New York v rozsahu 310 strán. Výsledky svojej bohatej experimentálnej činnosti vyhodnotil v 24 záverečných správach a 148 vedeckých prácach a početných odborno-populárnych článkoch. Veľmi aktívne sa angažoval v rámci Medzinárodného spolku lesníckych výskumných ústavov (IUFRO), osobitne v pracovnej skupine „Prírodných lesov“.

Za jeho mimoriadne významný prínos v oblasti lesníckych vied mu udelili čestný doktorát (Dr.h.c.) na Švajčiarskej technickej univerzite (ETH) v Zürichu (1992), v Lesníckom výskumnom ústave vo Zvolene najvyššie uznanie slovenského lesníctva „Medailu Jozefa Dekreta Matejovie“ (1993) a v Nemecku cenu Wilhelma-Leopolda Pfeila (1997). Ako jednému z mála lesníckych osobností mu na kamennom balvane v území Vysokoškolského lesného podniku TU Zvolen na lokalite Poruba umiestnili pamätník.

Prof. Ing. Dr.h.c. Štefan Korpeľ, DrSc. patril k najvýznamnejším osobnostiam v odbore pestovania lesa uznávaných vo vedeckých kruhoch doma i v zahraničí. Výsledkami svojej práce sa nezmazateľne zapísal do histórie slovenskej lesníckej vedy a praxe.

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