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The current state of non-forest land in the Czech Republic and Slovakia – forest cover estimates based on the national inventory data

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Abstract

We present the state and the development of forests on non-forest land in the area of the Czech Republic (CZ) and Slovakia (SK). The forests have a different origin, and are currently outside the interest of forest management, nor the whole forestry related legislation is applicable to them. The national forest inventory (NFI) was performed in CZ in the years 2001–2004 and 2011–2014, while in SK in the years 2005–2006 and 2015–2016. The NFI sampling was applied to all forests, i.e. to those growing on both forest and non-forest land. According to the NFI data, the current proportion of forests on non-forest land was not negligible, since in CZ it reached almost 10%, and in SK even more, 13%. While in CZ they were more evenly spatially distributed, in SK they occurred mainly in the central and eastern parts. Broadleaved tree species accounted for approximately two thirds of their growing stock. Their tree species composition was more diverse than the one on forest land. Carbon stock in tree (aboveground and belowground) biomass of forests on non-forest land was 28.5 ±1.6 million tons in CZ and 20.3 ±2.9 million tons in SK, which represented 7.7 ±0.4% and 7.7 ±1.1% of the total tree biomass in CZ and SK, respectively. Hence, it is important to take the forests on non-forest land into account, to see their current state positively, to include them to other forests and to try to maximise the use of their functions by society.

Key words: national forest inventory; forests on non-forest lands; carbon in tree biomass; tree species composition; territory of former Czechoslovakia

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1. Introduction

A man has been influencing natural environment for millennia. Land has long been used for agriculture and forestry, while the proportion of agricultural and forest land has been changing continually. For example, since 14th century forest complexes in the area of current Slovakia were substantially reduced due to the so called Wallachian colonisation (clearing of forests to form pastures; Vladár et al. 1982). Approximately at the same time, the intensity of mining and subsequent deforestation driven by timber demands for mining activities was increasing in the areas of the former Czechoslovakia (see e.g. Veľký et al. 1977; Špulák & Kacálek 2011; Lenoch 2014). Later, as population density was increasing, the demands on food production were growing. As a result, in the Middle Ages as well as in modern times, some parts were deforested to increase the area of agricultural land. In the 18th century, the largest portion of landscape was agricultural land (Demek et al. 2012).

In the territory of the former Czechoslovakia, organised forestry based on sustainability principles and forest legislation have a several-centuries-long tradition. The first legislative decisions focusing on forest registration and protection are known from the Middle Ages (e.g. the Maximilian Forest Regulations from the year 1565). The first comprehensive solution was presented by the Theresian Forest Regulations in the Czechia and Moravia (1754), Silesia (1756) and Slovakia (1769). Forests were protected to ensure the supply of wood resources and sustainable forest management, and to avoid deforestation. Moreover, some degraded deforested land

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could not be used for agriculture any longer, and hence, some locations were systematically afforested (the first afforestation of drifting sands in the Záhorie region is known from 17th century). Surprisingly, the first legislative regulations for planting seedlings did not refer to forests but to non-forest land to increase wood production in the areas, where wood supply was insufficient. It did not always result in forest establishment, but also in planting of tree species along roads, rivers, settlements (Theresian Forest Regulations 1769, paragraphs 48-50). Regeneration planting in forests has been used since the 19th century. Since the middle of 20th century, several research and practical afforestation activities of abandoned land in the areas of the Slovak Karst, Brezovské Carpathians, Krupinská planina and others have been ongoing (Zachar 1965).

Modernisation and intensification of agricultural production significantly increased hectare yields of main crops, which reduced the pressure on the size of agricultural land. The original pressure on forests turned into gradual reduction of demands on agricultural land. At a national level, the changes in land use were solved also administratively, in the Land Register. For example, in the years 1955-59, the General plan to enhance agriculture, forestry and water management (GP ZVL) was prepared in Czechoslovakia, in which land delimitation was proposed with the goal to afforest or to administratively change the land category to forest land of more than 250 thousand hectares in Slovakia and several million hectares in the Czech Republic (Špulák & Kacálek 2011). The intention was fulfilled to about a half. In the year 1994, the Government of the Slovak Republic approved the Afforestation Programme of agriculturally unusable land, but due to the lack of finances the programme was cancelled in 1999. Within the short time, approximately 4 thousand ha of land were settled. According to the data in the Green Reports of Slovakia, the total area of forest land increased from 1.78 mill. ha in the year 1960 to 1.98 mill. ha in the year 2000, and the total area of forest stands increased from 1.77 mill. ha in 1960 to 1.92 mill. ha in 2000. According to the data of the Czech Statistical Office, the area of forest land in the Czech Republic increased from 2.58 mill. ha in the year 1960 to 2.67 mill. ha in 2016.

After the year 1989, a new phenomenon, namely abandonment of agricultural land, occurred (Zaušková & Midriak 2008; Midriak et al. 2011; Zaušková et al. 2012). Many agricultural cooperatives collapsed because of political changes, restitution and globalisation of food market, due to which farming at a number of less fertile sites stopped (Kozak 2003). Hence, over the last 20 years the proportion of agricultural land in the Western Carpathians decreased (Raczkowska et al. 2012). Abandoned meadows, pastures, fields, and orchards were gradually overgrown by different succession stages of bush and tree vegetation (Plesník 1987; Kozak 2003; Kuemmerle et al. 2008; 2009; Boltižiar & Olah 2013) or were artificially afforested (Kulla & Sitková 2012; Jaskowiec 2013; Merganičová et al. 2013). In Slovakia, such sites were named "white areas" (Zaušková et al. 2012). White areas encompass also other land that was not used for farming in the past, nor was registered as forest land, but which is currently overgrown with forests.

In the Czech Republic, many forests on non-forest land occur also in military training zones, which were abandoned or the intensity of their utilisation was reduced after the year 1989. This resulted in overgrowing of non-forest land by woody vegetation and their gradual transition to forests.

A small part of white areas is covered with older forest stands, which were historically incorrectly classified, and this incorrect category has been recorded in the Land Register. Currently, in the Czech and Slovak Republics as well as in the majority of post-communist countries (e.g. Pachova et al. 2004), there are two types of forest stands: (i) those growing on forest land, (ii) those growing outside the registered forest land, i.e. above mentioned white areas. While the first group of forest stands conforms to the forest law and forest management register, and their basic characteristics have been assessed, recorded and made available to professionals (data presented in the so-called Green reports, which are annually published by the Ministry of Agriculture), the second group represents a certain "black hole" in the register (Zaušková et al. 2012). Thus, until recently no exact quantification of forest stands covering these areas existed in the Czech and Slovak Republics.

National forest inventories (NFI) are special systems of data acquisition, which provide us with up-to-date and objective information on forest state and development of large areas (the whole country or regions) for management, decision making, control and forecasting at a level of central organs of forestry, wood-processing industry, environment and other sectors (Šmelko et al. 2008; Šebeň 2017). In the former socialistic countries, in which state ownership dominated, direct sampling on inventory plots was not used, but the data were acquired at a stand level using forest taxation surveys during the preparation of forest management plans (FMP), and were subsequently summarised (the so-called *stand-wise* or *stand-level inventory*). The main objective of FMP differs from NFI, and a simple summing up of such data has several disadvantages (different methods of data acquisition, unknown final accuracy, varying updating, etc.). Thus, after the change of the political regime, sampling data acquisition started to be applied in the majority of post-communist countries, namely in Lithuania from the year 1998, in Estonia from 1999, in Slovenia and former Eastern Germany from 2000, in the Czech Republic from 2001, in Latvia from 2004, in Slovakia, Croatia, and Romania from 2006, in Russia from 2007, and in Poland from 2009 (Šebeň 2017).

NFIs are based on a sampling method applied to representatively distributed inventory plots over the whole country. On these plots, forest state is precisely assessed, and the information representing the national level is derived using mathematical statistical methods (more in the Method chapter). The established network of permanent inventory plots allows us to assess and evaluate the forest state on the same plots repeatedly using the same approach also in the future in arbitrarily selected intervals (usually 10 years). Their "invisibility" reduces the risk that they would be intentionally managed in a different way as other parts of forest stands. This makes the comparison of forest states over a longer time more objective, and brings information on real changes in all assessed characteristics (Šmelko et al. 2008). An advantage of NFI is the fact that all forested land is subjected to data acquisition, i.e. forests on forest land registered in the Land Register, and forests on non-forest (agricultural and other) land. Unlike the data from FMP, they also provide us with the information about the forest state on non-forest land. Nowadays, it is the only source of detailed information about these forests in Slovakia. In the Czech Republic, the information about woody vegetation on non-forest land is available from NFI CZ as well as from the CzechTerra project, which is also based on the statistical field survey. In the Czech Republic, NFI recorded also other land categories covered with tree and shrub vegetation, such as Other Wooded Land (OWL) and Other Land with Tree Cover (OLwTC), which were not included in the presented analysis. The area of older forest stands on forest and non-forest land can be derived using remote sensing methods (Bucha et al. 2014; Hlásny & Sitková 2010; Jaskowiec 2013), but unlike NFI they are not able to provide us with other information about them, e.g. their tree species composition, stand structure, volume, etc., with sufficient accuracy.

The goal of our work was to analyse the state of forest stands growing on non-forest land in the Czech and Slovak Republics. In the case of the forested area, we quantified its state and the change between the two NFI cycles (10-year-long time interval), while in the case of other parameters we focused on the state determined in the 2nd NFI cycle. Next, the work evaluated the spatial distribution of white areas (in administrative units and vertical zones), tree species composition on the base of tree biomass, as well as carbon stock in living dendromass. On the base of the calculations we evaluated the importance of these forest stands from the point of carbon sequestration, and we made a rough estimate of their contribution to tree species diversity of forests at a national level. Finally, we outlined the perspective of these forest complexes with regard to their further management and in the context of necessary legislative changes.

2. Material and methods

To evaluate the currents state of forests on non-forest land we used the data from the terrestrial NFI surveys in the Czech Republic (CZ) and Slovakia (SK). The official term in SK is the National Forest Inventory and Monitoring (NFIM) of the Slovak Republic (Šmelko et al. 2008). Apart from the data assessed within NFI, we also used other basic administrative data (area of countries and regions, population density, etc.) representing CZ and SK taken from other official sources (primarily statistical yearbooks).

The first NFI cycle was performed in CZ and SK in the years 2001–2004 (NFI1), and 2005–2006 (NFIM1), respectively, and the second NFI cycle in 2011–2015 (NFI2) and 2015–2016 (NFIM2), respectively. Hence, the data from both cycles are available. In this paper we evaluated the state in the second cycle and the change between the cycles. The data refer to the middle of the field assessment intervals, i.e. in the case of CZ they refer to January 1st 2003 and 2013, while in the case of SK they refer to December 31st, 2005 and 2015.

2.1. Forest definition and selection of land categories

The forest state was assessed at all inventory plots (hereinafter as IP), which fulfilled the criteria of being covered by a forest, while we applied the international definition of a forest according to FAO (Food and Agriculture Organization of the United Nations) classification, specifically: "A forest is a land covered by tree vegetation with an area exceeding 0.5 ha, a minimal width of 20 m, and a canopy cover of more than 10%. Trees should reach the minimum height of 5 m in situ" (Adolt et al. 2013; Šmelko et al. 2006; Šebeň et al. 2015). Temporarily deforested stands, currently regenerated clearings, and young stands are also considered to be forests. The stands less than 20 m wide and the stands or land with predominantly agricultural or urban use are not considered to be forests.

The category of forest land was taken from available administrative GIS layers (Land Register, forest land, land designated to fulfil forest functions). In this study we included all non-forest land, also land which is not registered as forest land (e. g. cropland, grassland, orchards, gardens, water areas and settlements). In the case of CZ, the whole inventory plot (IP) was classified to the category on the base of the overlap of the plot centre with the map layer. In SK, the land category was assigned to individual sub-plots.

2.2. Network and IP design

Forest inventories are based on the measurements of selected parts of forests using representatively distributed IPs. Their size is adjusted to assessment goals and optimised with regard to the accuracy of results and economic demands of measurements. A very similar sampling methodology was applied in both countries.

The basic area of a circular IP, within which field data acquisition was performed, was set to 0.05 ha (a radius of 12.61 m). Plot density differed between the countries.

2.2.1 Design in the Czech Republic

NFI inventory plots are distributed in a square 2×2 km grid with a randomly chosen beginning, and a north-south, east-west direction. Two inventory points (duplex) are placed inside each inventory square, and these points represent the centres of inventory plots. Within each IP, all trees with a diameter of at least 12 cm are measured and assessed, while trees with a diameter exceeding 7 cm are assessed in circles with a radius of 3 m. Site conditions, regeneration occurrence and other components listed in the supplement of the Government Regulation are also assessed. All plot centres were stabilised by the geodetic harpoon to ensure that they could be found again and re-measured. During the first inventory, 14,220 IPs classified as forests were assessed in the field.

2.2.2 Design in Slovakia

From several density variants (from 1×1 to 8×8 km), a relatively sparse density of 4×4 km was selected due to the economic constraints and available financial sources, which enables sufficiently accurate results at a country level or at a level of large regions. The same design was applied in both cycles. The information spectrum of data and the assessment methodology was very similar to the Czech one. At each IP categorised as a forest, all trees with a diameter above 12 cm were measured, while trees with a diameter from 7 to 12 cm were assessed at a smaller circle with a radius of 3 m placed in the plot centre. The smallest regenerated individuals at least 10 cm high with a diameter at breast height $d_{1.3}$<7 cm were assessed at a variable circle (more details in the methodology of NFIM, Šmelko et al. 2006; Šebeň et al. 2015). In total, there are 3,069 IP in the whole country. Since the second cycle, the plots have been stabilised with an iron stake.

2.3. Field measurements

2.3.1 Working protocol in the Czech Republic

Field measurements of NFI2 were performed by 20 three-member measuring crews, two groups were performing control activities. In the years 2011 to 2014, 15,426 plots were visited, out of which 14,521 plots were classified as forests. From this number, 1,527 plots occurred outside the land designated to fulfil forest functions. For the evaluation of NFI2, the data from 315,249 plots, on which photogrammetric interpretation of airborne and satellite images was performed, were also used.

2.3.2 Working protocol in Slovakia

Field measurements were performed by 5 three-member inventory crews. In the first cycle of NFIM, 1,486 IPs were established between March 2005 and October 2006, out of which 209 IP were identified as forests on non-forest land. During the second cycle from May 2015 to September 2016, 1,498 IPs were revisited, and out of them 219 IPs represented forests on non-forest land. The number of IPs on non-forest land could have been greater, but the category of some IPs changed to forest land during the period between the two cycles.

2.4. Biomass and carbon calculations

Biomass and subsequently carbon stock can be determined using several different approaches. In our case, biomass (above-ground and below-ground) was calculated separately for each tree. Biomass of trees with a diameter of at least 7 cm and those below 7 cm was estimated using a different approach. The total tree biomass was determined using available models separately for above-ground (bark, stem, stump, branches, foliage) and in Slovakia also for below-ground (roots, a part of stump) biomass. Carbon content was derived from biomass for all trees in the same way: in SK a coefficient of 0.5 was used, while in CZ the coefficients equal to 0.51 and 0.49 were used for coniferous and broadleaved tree species, respectively. As documented below, the applied approaches of biomass calculation differed between the examined countries because if possible they were based on national material, but the results are comparable because both are based on representative data and on correct statistical approaches.

2.4.1 Trees with diameter at breast height above 7 cm

2.4.1.1 Approach applied in the Czech Republic

National allometric equations derived for the four main tree species: spruce, pine, beech, and oak, were used for the calculation of tree biomass. These tree species account for more than 80% of the total growing stock. Biomass of other tree species was calculated by applying one equation of the four species on the base of tree species similarity. Tree diameter $d_{1.3}$ and height h were used as input variables in the case of Norway spruce *Picea abies* Karst. (Vejpustková et al. 2017) and sessile oak *Quercus petrea* L. (Cienciala et al. 2008), while tree diameter $d_{1.3}$, tree height h and elevation z were used as independent variables for Scots pine *Pinus sylvestris* L. (Cienciala et al. 2006) and European beech *Fagus sylvatica* L. (Vejpustková et al. 2013). The parametrised equations did not include stump and below-ground biomass. Stump biomass was determined using dendrometric models of stump volume (Pařez 1990), which was converted to biomass using average wood density for each of the four above-mentioned main tree species. The models for beech and oak did not include foliage biomass, which was calculated using the model by Petráš et al. (1985). Below-ground biomass was not accounted for in the basic NFI outputs, hence for the goals of this work we calculated below-ground biomass by multiplying summary values of aboveground biomass with an average coefficient (derived from the Slovak NFI data) equal to 0.25.

2.4.1.2 Approach applied in Slovakia

The applied approach was based on volume calculation and its subsequent conversion to biomass using species-specific wood density. We used national volume equations derived for 11 tree species: Norway spruce, Silver fir (*Abies Alba* Mill.), Scots pine, European larch (*Larix decidua* Mill.), European beech, sessile oak, hornbeam (*Carpinus betulus* L.), birch (*Betula pendula* L.), alder (*Alnus glutinosa* L.), European ash *(Fraxinus excelsior* L.), poplar (*Populus* sp.), by several authors on the base of the experimental data from CZ and SK (Petráš & Pajtík 1991). First, tree volume outside bark was calculated. This was subsequently multiplied with the coefficients of density of dry matter of living wood for individual tree species according to the NFI methodology (Šebeň 2017), and the above-ground biomass was calculated in mass units (kg). Stump and below-ground biomass of living trees was estimated using allometric equations (Drexhage & Colin 2001) for four main tree species (spruce, fir, beech, oak), while the equations for spruce and beech were applied to other coniferous and broadleaved tree species, respectively. This biomass was then added to above-ground biomass. The allometric equation for spruce determines biomass excluding the stump, the biomass of which was calculated using a national model (Šmelko, in Šebeň 2017) similarly as in the case of CZ data. The differences in the density of bark and wood in different components (stem, roots, branches) were not accounted for. Foliage biomass was also added. National models of foliage biomass (Petráš et al. 1985) derived for three tree species (spruce, pine, beech) were used, while the equations for spruce and beech were applied to other coniferous and broadleaved tree species, respectively.

2.4.2 Biomass of trees with diameter at breast height below 7 cm

2.4.2.1 Approach applied in the Czech Republic

The above-ground biomass of thin trees (with minimum height equal to 0.1 m and maximum diameter of 6.99 cm) was estimated using regression models by Konôpka et al. (2010) derived for four main tree species – spruce, pine, beech, and oak. Other tree species were assigned to one of the main species with regard to the habitat similarity (e.g. hornbeam according to beech, fir according to spruce, etc.). The model with a tree height as an independent variable was applied. Similarly, as in the case of thick trees, below-ground biomass was estimated using a coefficient of 0.25 derived from the Slovak NFI data, and was added to above-ground biomass.

2.4.2.2 Approach applied in Slovakia

We applied national allometric regression models derived for eleven tree species (Pajtík et al. 2018): spruce, pine, larch, beech, oak, hornbeam, European ash, Sycamore (*Acer pseudoplatanus* L.), Goat willow (*Salix caprea* L.), Rowan (*Sorbus aucuparia* L.), and common aspen (*Populus tremula* L.). Other tree species were assigned to similar tree species (more in the methodology of Šebeň 2017).

2.5. Statistical analyses

NFI is a sampling method, and thus all mentioned characteristics A, $\overline{y}$, Y, p are sampling characteristics, and their particular values represent only one of many possible values, which could be obtained if the inventory with the same design was repeated several times. Sampling characteristics estimate real values of parameters valid for the whole population (the whole inventoried area). They were estimated statistically from the sampling set (NFI database) following the NFI methodology (Adolt et al 2013; Šebeň 2017). A confidence interval (CI), within which a particular parameter lies with confidence P (we used 95%), was determined. Hence, the result is a sampling characteristic ± a sampling error (in the case of 95% CI we used a sampling error multiplied by 1.96).

3. Results

3.1. Forest area on non-forest land by administrative units

The total forest area on non-forest land derived from NFI2 was equal to 287 ±15 thousand ha and 288 ±39 thousand ha in the Czech Republic and Slovakia (Tables 1a and 1b), respectively. In both countries we recorded a slight (statistically insignificant) increase in their area since the time of NFI1 (when the forest area on non-forest land was 283 ±15 thousand ha and 273 ±41 thousand ha in CZ and SK, respectively). The proportion of the total area of CZ covered by forests on non-forest land was 3.6 ±0.2%, while in SK it was 5.9 ±0.8%. The share of forests on non-forest land in the total forest area was 9.9 ±0.5% and 13.0 ±1.7% in CZ and SK, respectively.

Table 1a. Area of forests on “forest land” (FL) and non-forest land (NFL) in the regions of the Czech Republic derived from the data of both National Forest Inventory cycles.

Name of region (acronym)	NUTS 3	Area of region	NFI1(2001–2004)			NFI2(2011–2014)		
			Forest FL	Forest NFL	Proportion NFL/(FL+NFL)	Forest FL	Forest NFL	Proportion: NFL/(FL+NFL)
	Code		[ths. ha]		[%]	[ths. ha]		[%]
Hlavní m. Praha (PR)	CZ010	50	4 ±2	1 ±1	20.0 ±17.3	4 ±2	1 ±1	25.9 ±18.8
Středočeský (ST)	CZ020	1 101	308 ±17	31 ±5	9.2 ±1.5	308 ±17	32 ±5	9.5 ±1.5
Jihočeský (JH)	CZ031	1 006	362 ±17	51 ±7	12.4 ±1.7	374 ±17	43 ±6	10.2 ±1.4
Plzeňský (PL)	CZ032	756	294 ±15	31 ±5	9.5 ±1.5	296 ±15	28 ±5	8.6 ±1.5
Karlovarský (KA)	CZ041	331	141 ±10	19 ±4	11.7 ±2.5	142 ±10	22 ±4	13.2 ±2.6
Ústecký (US)	CZ042	533	157 ±12	23 ±4	12.6 ±2.5	156 ±12	28 ±5	15 ±2.6
Liberecký (LI)	CZ051	316	134 ±10	17 ±4	11.5 ±2.4	131 ±10	19 ±4	12.4 ±2.5
Královéhradecký (KR)	CZ052	476	156 ±12	11 ±3	6.3 ±1.7	156 ±12	11 ±3	6.7 ±1.8
Pardubický (PA)	CZ053	452	135 ±11	11 ±3	7.5 ±2	133 ±11	13 ±3	9 ±2.2
Vysočina (VY)	CZ063	693	196 ±13	18 ±4	8.5 ±1.8	196 ±13	18 ±4	8.3 ±1.7
Jihomoravský (JM)	CZ064	707	189 ±13	21 ±4	9.8 ±2.1	194 ±14	19 ±4	9.1 ±1.9
Olomoucký (OL)	CZ071	516	180 ±13	11 ±3	5.8 ±1.6	180 ±13	13 ±3	6.5 ±1.7
Zlínský (ZL)	CZ072	396	162 ±11	18 ±4	9.8 ±2.2	161 ±11	18 ±4	10 ±2.1
Moravskoslezský (MO)	CZ080	554	190 ±13	21 ±4	10.1 ±1.9	187 ±13	23 ±4	10.8 ±2
Czech Republic	CZ	7 887	2 607 ±47	283 ±15	9.8 ±0.5	2618 ±47	287 ±15	9.9 ±0.5

Explanatory note: The NUTS3 code is administrative identification for EUROSTAT (Nomenclature des Unitées Territoriales Statistiques).

Table 1b. Area of forests on “forest land” (FL) and non-forest land (NFL) in the regions of Slovakia derived from the data of both National Forest Inventory cycles.

Name of region (acronym)	NUTS3	Area of region	NFI1 (2005–2006)			NFI2 (2015–2016)		
			Forest FL	Forest NFL	Contribution NFL/(FL+NFL)	Forest FL	Forest NFL	Contribution NFL/(FL+NFL)
	Code		[ths. ha]		[%]	[ths. ha]		[%]
Bratislavský (BA)	SK011	205	75 ±18	2 ±4	2.8 ±4.7	76 ±21	2 ±3	2.1 ±3.9
Trnavský (TT)	SK021	415	62 ±18	3 ±4	4.9 ±6.6	62 ±19	3 ±4	4.9 ±6.7
Trenčiansky (TN)	SK022	450	221 ±27	24 ±12	9.7 ±4.5	222 ±35	27 ±11	10.9 ±5.0
Nitriansky (NR)	SK023	634	85 ±22	5 ±6	5.5 ±5.9	86 ±22	11 ±7	11.7 ±8.2
Žilinský (ZA)	SK031	681	351 ±33	54 ±18	13.4 ±3.9	358 ±44	43 ±14	10.8 ±3.9
Banskobystrický (BB)	SK032	945	450 ±39	57 ±19	11.2 ±3.3	447 ±49	78 ±18	14.8 ±4.0
Prešovský (PO)	SK041	897	403 ±43	84 ±25	17.2 ±4.5	411 ±47	86 ±18	17.4 ±4.4
Košický (KE)	SK042	675	253 ±28	46 ±14	15.3 ±4.2	262 ±38	37 ±13	12.4 ±4.8
Slovakia	SK	4 903	1 901 ±86	273 ±41	12.6 ±1.7	1 924 ±54	288 ±39	13.0 ±1.7

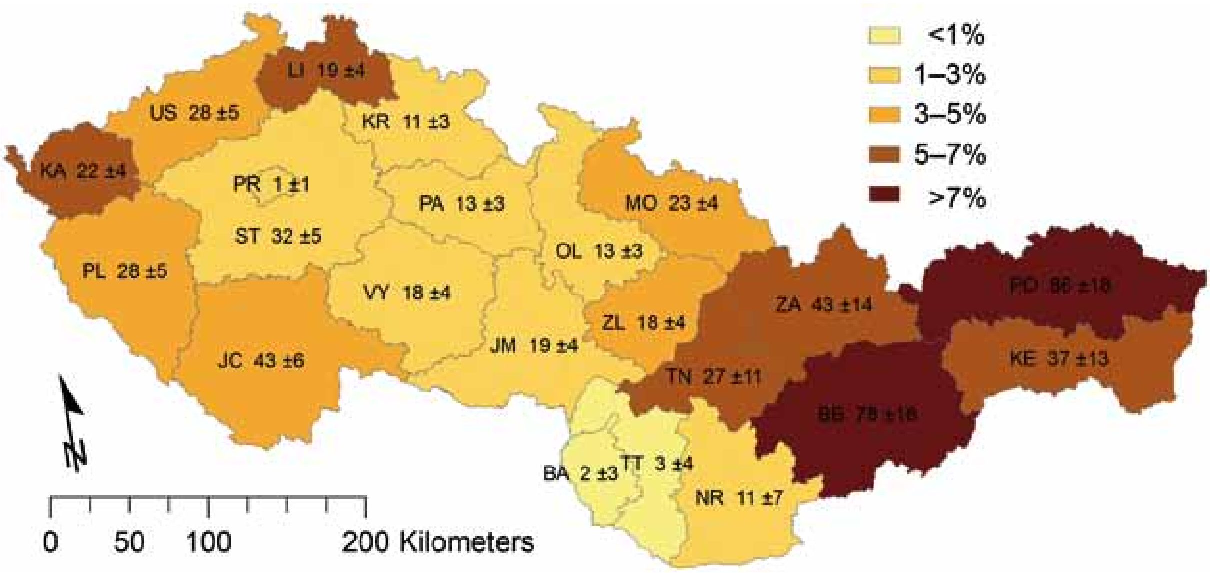

Fig. 1. Area (ths. ha) and share (%) of forests on non-forest land from total area of the individual regions in the Czech Republic and Slovakia.

The forests on non-forest land in CZ were distributed much more evenly than in SK. The lowest proportion of forests on non-forest land from the total regional forested area was found in Královohradecký and Olomoucký regions (7%), and the highest in Ústecký region (15%). The value in Prague (20 ±17%) was not very precise due to its small forested area (4.0 ± 2.3 thousand ha). In Slovakia, substantial regional differences were revealed: minimum regional proportion of forests on non-forest land was found in the south-western part (Bratislavský region 2.1 ±3.9%, Trnavský region 4.9 ±6.7%), while in the central and north-eastern Slovakia their proportion was relatively high (14.8 ±4.0% in Banskobystrický, and Prešovský regions). Greater differences were found in the total forest area on non-forest land. In the Czech Republic, the smallest area of forests on non-forest land equal to 11 ±3 thousand ha was in Královohradecký region, while the largest area of these forests was recorded in Jihočeský region with 43 ±6 thousand ha. In Slovakia, the smallest area of forests on non-forest land (2 ±3 thousand ha) was in Bratislavský region, followed by Trnavský region (3 ±4 thousand ha), while in Banskobystrický and Prešovský regions forests on non-forest land covered 78 ±21 and 86 ±22 thousand ha, respectively.

The comparison of NFI2 to NFI1 showed that the area of forests on non-forest land in CZ slightly but insignificantly increased with time. Similarly, every increase in the area of these forests at a regional level was also insignificant. Likewise, the proportion of forests on non-forest land increased also in SK, but the change was not significant (their NFIM1 proportion was 12.6 ±1.7% compared to 13.0 ±1.7% from NFIM2). The greatest changes were recorded in Nitriansky region (increase from 5 ±6% to 11 ±8%) and Košický region (decrease from 15 ±4% to 12 ±5%). However, the reduction of forests on non-forest area was not caused by deforestation, but resulted from the change of land category from non-forest to forest land.

3.1. Forest area on non-forest land by elevation zones

The analysis of forests on non-forest land showed a decreasing trend with elevation (Fig. 2). Higher proportion of these forests out of the total area was found at lower elevations. In SK, more forests on non-forest land were recorded also at an elevation above 700 m a.s.l., but they were not found above 1,100 m a.s.l.

If we look at their share of the area of an elevation zone (Table 2, available data only for SK), the situation is slightly different. While the share of forests on non-forest land in the zone below 400 m a.s.l. out of the total area was less than 5%, their share in the elevation zone above 400 m exceeded 7%.

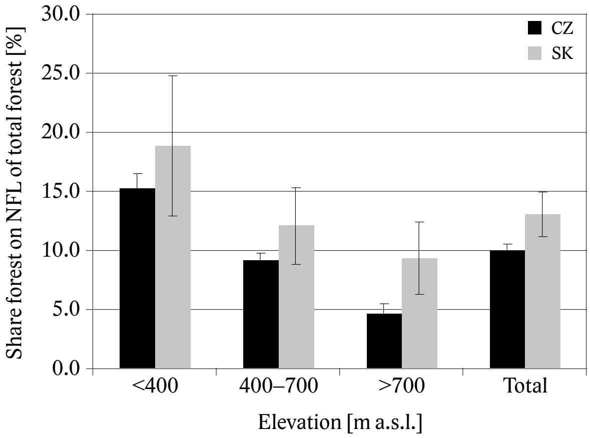

Fig 2. Share of forests on non-forest land (NFL) of total forest area (FL+NFL) by elevation zones in the Czech Republic (CZ) and Slovakia (SK).

3.3. Growing stock and tree species composition

Wood volume of forests indicates their production potentials, but it is also significantly affected by their past development (stand age) and management (performed selective felling). With regard to the relatively lower age of the majority of stands on non-forest land due to the massive abandonment of agricultural land after the year 1989 it is natural to expect lower growing stock than in forests on forest land (Table 3).

In the Czech Republic, the average growing wood stock per hectare in forests on non-forest land was 224 ±10 m^3 ha^{-1}, which was around 60 million m^3 in total. In Slovakia, the average hectare growing stock of these forests was lower, equal to 159 ±22 m^3 ha^{-1}. This was approximately a half of the growing stock of forests on forest land, which equaled to 303 ±12 m^3 ha^{-1} in SK and around 337 m^3 ha^{-1} in CZ. The total stock of forests on non-forest land in Slovakia was 45.5 ±6.7 mill. m^3, i.e.

Table 2. Extent of forests on non-forest land (NFL) and their share of the total forest area (FL+NFL) by elevation zones in the Czech Republic and Slovakia according to the second cycle of NFI.

Elevation [m a. s. l.]	Czech Republic			Slovakia		
	Forest area [ths. ha]	Share [%]	Forest cover [%]	Forest area [ths. ha]	Share [%]	Forest cover [%]
<400	111 ±10	38.7 ±3.3	not available	116 ±20	40.3 ±7.1	4.5 ±0.8
400–700	153 ±11	53.3 ±3.9	not available	103 ±20	35.7 ±6.8	7.4 ±1.4
>700	23 ±4	8.0 ±1.5	not available	69 ±17	24.0 ±5.9	7.2 ±1.6
Total	287 ±15	100	3.4 ±0.1	288 ±39	100	5.9 ±0.5

Table 3. Growing stock and tree species composition of forests on non-forestland.

Species group	Czech Republic NFI2 (2011–2014)			Slovakia NFI2 (2015–2016)		
	Growing stock		Share	Growing stock		Share
	[m^3 ha^{-1}]	[mill. m^3]	[%]	[m^3 ha^{-1}]	[mill. m^3]	[%]
Coniferous	81 ±8	21.8 ±2.5	36.1 ±4.1	48 ±14	13.7 ±3.5	30.1 ±6.1
Broadleaved	143 ±9	38.5 ±3.2	63.9 ±5.2	111 ±19	31.8 ±5.5	69.9 ±11.7
Total	224 ±10	60.3 ±4.3	100	159 ±22	45.5 ±6.7	100

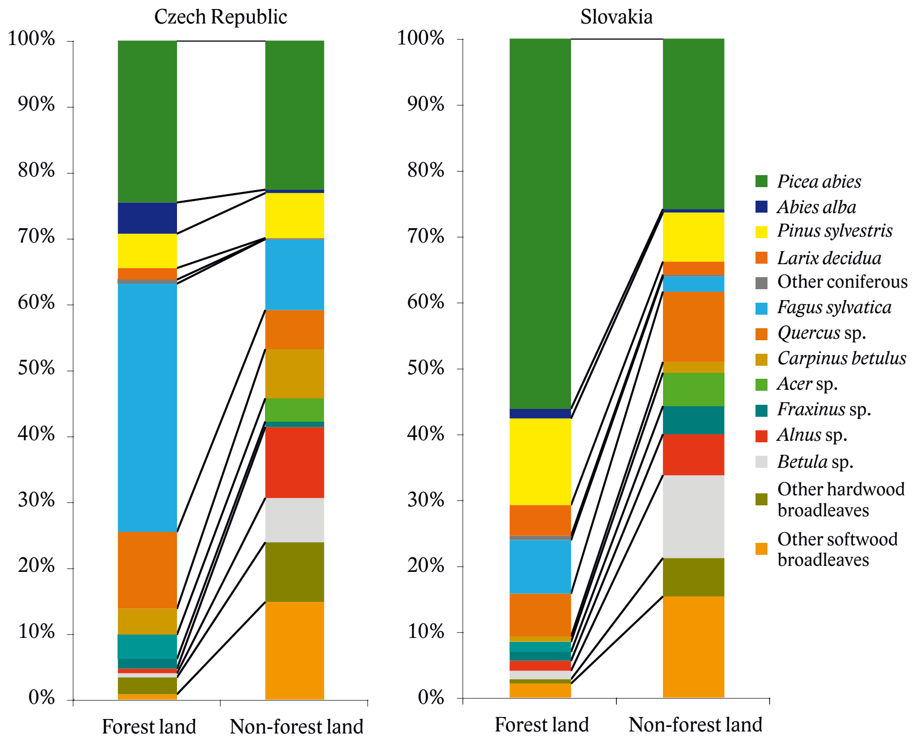

Fig. 3. Comparison of tree species composition (derived from growing stock) between forests on forest-land and non-forest land in the Czech Republic and Slovakia (NFI2 data).

7.3 ± 1.4% of the total stock of Slovak forests according to NFIM2, while their proportion in the Czech Republic was 6.5 ± 0.5%. Approximately 2/3 (in CZ slightly less, in SK slightly more) of the growing stock of forests on non-forest land came from broadleaved species, which are however less productive than coniferous tree species.

Tree species composition of forests on non-forest land differed from the species composition of forests on forest land (Fig. 3). Great differences were recorded particularly in the proportion of commercial tree species. Forests on non-forest land had a more varied tree species composition (calculated from growing stock). In CZ, spruce is a dominant tree species in forests on forest land accounting for more than a half of the total growing stock. Although its proportion was high also in forests on non-forest land, it was only about a half of its proportion on

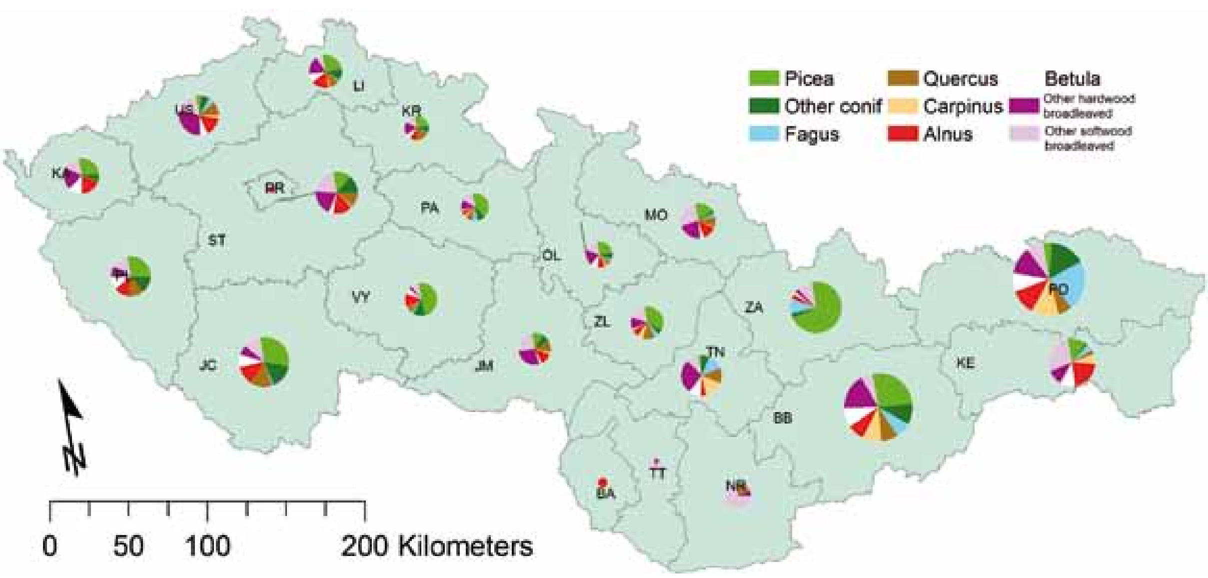

Fig. 4. Tree species composition based on growing stock in forests on non-forest land by NUTS3 regions (NFI2 data), the size of circular charts indicates forest area in the respective region.

forest land (Fig. 3). Softwood broadleaved species, birch, and oaks had substantially higher proportions in forests on non-forest land. In SK, beech and spruce are dominant species in forests on forest land (together they make a half of the total growing stock). On non-forest land, spruce dominated, but its proportion was lower than on forest land. The share of beech on non-forest land was much lower than on forest land (it accounted only for 1/10 of the growing stock). Softwood broadleaved species represented by different poplar, willow, and alder species had higher proportions.

At a regional level, tree species composition in forests on non-forest land varied a lot (Fig. 4). In CZ, spruce and other coniferous species occurred in all regions. In Vysočina region, spruce proportion was almost 50%, while the lowest proportion of spruce was found in Ústecký region and Praha (although the results derived from NFI for Praha are not accurate because of its small forest area, similarly as it is in the south-western part of Slovakia). Hardwood and softwood broadleaves had high proportions particularly in Moravia and Silesia parts. Spruce dominated only in the northern part of Slovakia, Žilinský region, accounting for more than 2/3 of the total stock of forests on non-forest land, while in other regions broadleaved species prevailed. Softwood broadleaves and alder were dominant in the south-western Slovakia. Their proportion was high also in Košický region. Tree species composition in forests on non-forest land of other regions was more diverse and more even, since their proportions did not exceed 1/4.

In the Czech Republic, 67 different tree species and 8 shrub species reaching tree size (i.e. a diameter at breast height of at least 7 cm and a height of 5 m) were identified in forests on non-forest land (and 79 species on forest land) within NFI2, out of which 40 most common species are presented in Appendix table 1. Broadleaved species prevailed, since their proportion from the total stock was 63.9 ± 5.2%. Spruce with the proportion of 26% was the most common tree species in forests on non-forest land. The most common broadleaved species in these forests was the common alder with the proportion exceeding 10%, followed by birch with 5% and the pedunculate oak.

In Slovakia, 50 tree species were identified in forests on non-forest land in comparison to 58 species on forest land, and the 40 most frequent species on non-forest land are listed in Appendix table 2. Broadleaved species prevailed, since their proportion from the total stock reached almost 70%. Spruce was the most common coniferous species, as its growing stock proportion was 23%, while the shares of broadleaved species were more even, the highest was found for beech (11%), followed by alder (9%), hornbeam (8%), and birch (7%), and the other tree species accounted only for less than 5% of the total stock each. The total growing stock of merchantable wood (exceeding a diameter of 7cm) inside bark in Slovak forests on non-forest land was 36.4 ±5.3 mill. m^3 in the year 2005, and 45.5 ±6.7 mill. m^3 in 2015, which means that in 10 years it increased by 1/4.

3.4. Carbon stock in tree biomass

The total (above-ground and below-ground) average carbon stock per hectare in forests on non-forest land in the Czech Republic was 116 ±9 t ha^{-1} (Table 5). The total carbon stock in the forests of non-forest land was 28.5 ±1.6 million tons of carbon. The absolute majority of carbon stock (28.1 ±1.6 mill. t) was cumulated in merchantable wood (i.e. in trees with diameter at breast height over 7 cm). The total (above-ground and below-ground) average carbon stock in all forests of the Czech Republic (on both forest and non-forest land) was 132 ±3 t ha^{-1}. Hence, the average carbon stock of forests on non-forest land was 90% of the average carbon stock per hectare in all forests, and their contribution in the total forest carbon stock of the country was 8%.

In Slovakia, the average carbon stock in forests on non-forest land was 70.8 ±6.6 t per hectare, which is significantly lower than in the Czech Republic, only 61% of the Czech average carbon stock. Three quarters of the total carbon stock were cumulated in broadleaved trees, which is more than their proportion from the growing stock. A dominant part, more than 95% of the carbon stock, was in trees with a diameter of at least 7 cm. In the case of trees with diameters below 7 cm, coniferous tree species contributed to carbon stock less than those with diameters above 7 cm. Carbon stock of forests on non-forest land in Slovakia was approximately a half of the carbon stock of forests on forest land (56%).

Table 5. Carbon stock in forest stands on non-forest land in the Czech Republic and Slovakia (2nd cycle of the NFI).

Tree diameter group	Tree species group	Czech Republic		Slovakia	
		Carbon stock		Carbon stock	
		[t ha^{-1}]	[mill. t]	[t ha^{-1}]	[mill. t]
DBH≥7 cm	Coniferous	27.3 ±4.3	6.7 ±0.6	15.8 ±3.9	4.5 ±1.1
	Broadleaved	87.3 ±9.3	21.4 ±1.4	52.2 ±8.0	15.0 ±2.3
	Total	114.5 ±9.4	28.1 ±1.6	68.0 ±5.0	19.5 ±2.5
DBH<7 cm	Coniferous	0.4 ±0.2	0.1 ±0.0	0.4 ±0.4	0.1 ±0.1
	Broadleaved	1.2 ±0.4	0.3 ±0.0	2.4 ±1.2	0.7 ±0.3
	Total	1.6 ±0.4	0.4 ±0.1	2.8 ±1.2	0.8 ±0.4
Total	Coniferous	27.6 ±4.3	6.8 ±0.6	16.2 ±3.9	4.6 ±1.1
	Broadleaved	88.4 ±9.3	21.7 ±1.4	54.6 ±8.2	15.7 ±2.4
	Altogether	116.1 ±9.3	28.5 ±1.6	70.8 ±6.6	20.3 ±2.9

3.5. Forests on non-forest land in relation to population density

The average area of forests on non-forest land per thousand inhabitants was 25.3 ha in CZ, and 52.8 ha, i.e. twice as much, in SK (Fig. 5). The differences between CZ regions were not big, in the majority of regions the average area fluctuated around 20 ha per thousand inhabitants. The variability in SK was much higher. While in the regions of the south-western part of SK, the area fluctuated around 5 ha per thousand inhabitants, in Prešovský region the area was equal to 100 ha and in Banskobystrický region 120 ha per thousand inhabitants. Green Report for the year 2005 reported only 32 thousand ha of such forests. The first national forest inventory enabled to determine their state and structure in more detail and more precisely. The results showed that the actual area of such stands is much (several times) higher.

The causes and conditions of establishment of these stands have not been clearly identified. Many of these forests originated from the time after the collapse of socialism in the early 90s of the last century when large-scale croplands and pastures had been abandoned (Kuemmerle et al. 2008; Jaskowiec 2013). Such forest expansion was reported also from other countries, e.g. Poland (Kozak 2003), Ukraine (Kuemmerle et al. 2008), Romania (Griffiths et al. 2013). However, NFIM1 data from Slovakia showed that 10% of the forests on non-forest land were older than 60 years old (Šmelko & Šebeň 2009). These older stands on non-forest land indicate historic inconsistencies in the Land Register (for more details see e.g. Midriak et al. 2011). Other parts represent forest areas on agricultural land adjacent to forest land. They are surrounded or placed in the middle of forest land, and cannot be practically visually distinguished in the field.

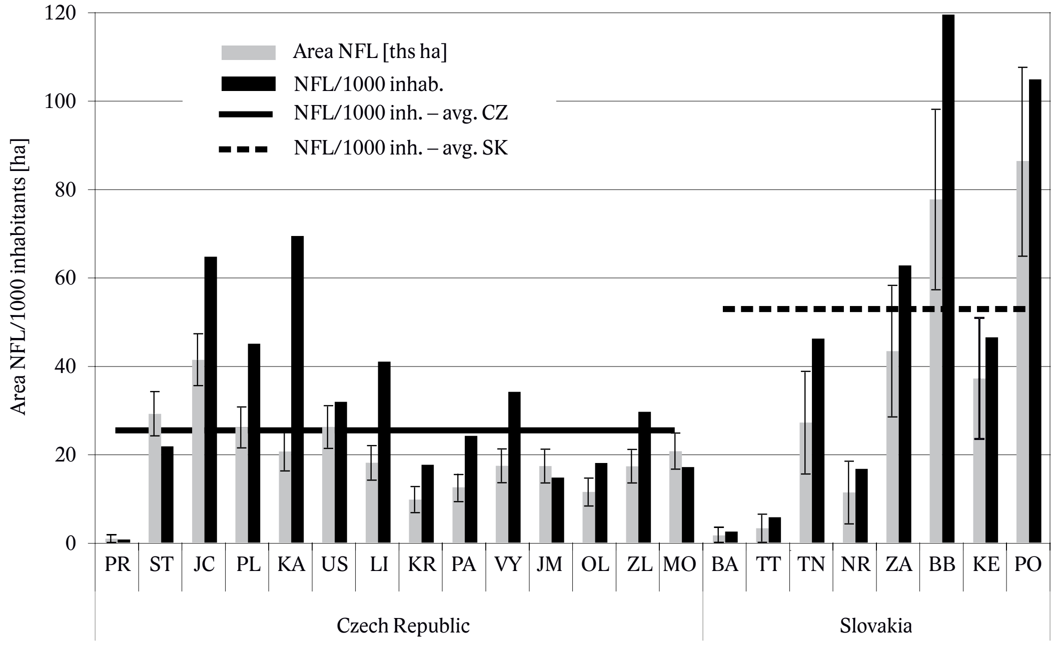

Fig. 5. Forest area on non-forest land (NFI2 data) in relation to population density by administrative units of the Czech Republic and Slovakia (acronyms are shown in Table 1). Human population data sources: www.eprehledy.cz, https://sk.wikipedia.org.

4. Discussion and conclusion

Forests on non-forest land are a specific feature of post-socialistic countries in Europe, and hence also in the Czech Republic and Slovakia. In Slovakia, forest management uses the term "white areas" to refer to them. In other countries of Europe, a forest is understood unambiguously and without any differences. Forests on non-forest land are either not identified separately, or have only a small proportion. The term "forests on non-forest land" is usually not used.

However, the majority of reports about forest state in CZ and SK (e.g. State of Europe's Forests – SoEF, Forest Resource Assessment – FRA) as well as the so-called national Green Reports, presented only the data on forests on forest land (the land registered as forest land in the Land Register). So far, only the area of forests on non-forest land has been presented, and the value is usually substantially underestimated. For example, the Slovak

Such areas occurred in former Czechoslovakia in the second half of 20th century as a result of collectivisation and the establishment of joint farm cooperatives that focused on increasing the efficiency of agricultural land use. If the area of large-scale agricultural land exceeded the area necessary for the production of the expected amount of agricultural crops, management selected more fertile parts accessible for machinery, and the remaining parts were left abandoned. Such forest expansion resulting from centralised agriculture after WW2 was confirmed at local and regional scales by e.g. Merganičová et al. (2013, 2014). The interest for less fertile agricultural land (particularly former pastures) was further reduced after the political changes in November 1989 (Zaušková et al. 2012).

The analysis of land categories revealed that in Slovakia white areas were located primarily on agricultural land, mainly on permanent grassland (75%), followed by other land (13%), and to lesser extent also on arable land, water areas, built-up areas, gardens. The analysis of the ownership structure (Šebeň 2017) showed that 3/4 of the forest area on non-forest land belonged to private owners, and about 1/10 to unknown owners. The remaining minor part was owned by state, municipalities, or church.

Our results showed that in the year 2015, the total area of forests on non-forest land was almost the same in both examined countries (287 ±15 thousand ha in CZ versus 288 ±39 thousand ha in SK). However, considering the total area of the respective country, forests on non-forest land in Slovakia covered almost twice as much of the country area as in CZ (5.9 ±0.5% versus 3.4 ±0.1%). From the point of their distribution with regard to elevation, the highest proportion of forests on non-forest land in CZ was found at elevations 400–700 m a.s.l. (53.3 ±3.9%), while in Slovakia at lowest elevations below 400 m a.s.l. (40.3 ±7.1%). In general, land use of montane areas has been reported to be more stable in comparison to lowlands, where land use intensification was frequently applied (Boltižiar & Olah 2013). Over a period of 2001 to 2009, the most intensive land cover changes in the Carpathians were observed at low elevations (below 200 m a.s.l.), while areas at higher elevations experienced the smallest modifications (Jaskowiec 2013). However, a number of works showed that the real differences in land cover change occur at local or regional levels (Kuemmerle et al. 2008). It has been documented that some areas have remained unchanged since the first Austrian military mapping, e.g. 95% of the forests in the Poľana Biosphere reserve in Slovakia has not changed since 1782 (Boltižiar & Olah 2013), while other areas show high temporal alternations. Thus, we examined the regional distribution of forests on non-forest land. The distribution of these forests by administrative units is more even in CZ, while in SK greater regional differences were found with the smallest share of forests on non-forest land in the south-west and the highest share in the east of the country.

From the point of average growing stocks per hectare (merchantable wood inside bark), the values in CZ forests on non-forest land were by 40% higher (224 ±10 m^3 ha^{-1}) than those in SK (159 ±22 m^3 ha^{-1}). The ratio of the growing stock of coniferous to broadleaved tree species was similar in both countries (1:2). Tree species composition of forests on non-forest land was more diverse than those on forest land. This results from natural forest expansion and is in accordance with ecological succession theory. In both countries, spruce was the most common coniferous species (25.9 ±3.5% in CZ, and 22.6 ±5.5% in SK). From broadleaved species, alder and oak species were more abundant in CZ, while beech and hornbeam prevailed in SK (Fig. 3).

In spite of the fact that forest stands on former agricultural land indicate the trend of reduced systematic land use, their expansion has also positive consequences. Forest expansion is coupled with the increase of forest biomass, and hence also the sequestered carbon stock. Carbon sequestration is considered as one of the main approaches how to reduce CO_2 in the air (the so-called mitigation measure, Lindner & Karjalainen 2007). At the same time, carbon budget of forest ecosystems is substantially better than the one of arable land because of significantly longer rotation period of biomass, greater biomass amount, as well as continuous carbon conservation in soil environment (e.g. Smith et al. 2008). Thus, many European countries claimed extending forest area as a part of their carbon strategy policy. The Czech Republic declared national rural development including afforestation, while Slovakia suggested carbon stock inventory as a key measure in these processes (Forest Europe 2015). In addition, prevailingly mixed forest stands growing on "white areas" may represent species-rich biotopes in both flora and fauna and fulfil a broader range of ecosystem services than agricultural land. Apart from production of high-quality food on agricultural land, this kind of forest stands would positively contribute to human life standard as it was defined for instance by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES; Díaz et al. 2018).

From the point of carbon sequestration, forests on non-forest land have lower biomass amount, and hence lower carbon stock, than forests on forest land. Their positive feature is that they have more active carbon balance (they cumulate more carbon than they emit because of their low age and relatively faster growth). They also have higher tree species diversity and evenness. The four most frequent tree species (spruce, pine, beech, and oak) in forests contribute to biomass amount in forest stands on forest land in the CZ by 79%, while their proportion on non-forest land was only 46%. Similarly, in SK their share on forest land is 84%, but only 46% on non-forest land.

The lack of management, or the lack of optimal management, is the main shortage of the current state of these forest stands on non-forest land. This means that no forest management plans are elaborated for or applied to them. The Forest Europe (2015) document showed that management plans are not mandatory in all European countries, since only 70% of European forests are under management plans. However, this number is assumed to increase in the future. In addition, in both the Czech Republic and Slovakia, "white areas" covered by forests are usually not managed using standard forestry practice. Obviously, restoration and development of forest cover at these areas is spontaneous, without any systematic human interventions, except for the occasional harvest. Forest felling is performed exclusively based on decisions of a land owner often without respecting the principles on optimising yield potential. Low-quality wood originated from these stands is prevailingly utilised for energetic purposes (Oravec & Slamka 2018) that represents "undesirable" carbon emission to the atmosphere (however, see Stockmann et al. 2012 versus Creutzig et al. 2015). Therefore, there are many tasks to be solved in management of forests stands on white areas, and a conceptual approach requires reliable information (such as we have presented in this work) about their actual state.

The analysis of NFI data showed that forests on non-forest land cover a relatively high proportion of forested area, specifically around 10% in the Czech Republic and 13% in Slovakia. With regard to such a great extent of "white areas" and landscape management, it would be best to change their land category to forest land. This results also from the Slovak Act No. 220/2004 Coll. on protection and use of agricultural land, according to which an owner, a tenant or a manager of agricultural land is obliged to arrange the land category registered in the Land Register that would coincide with its current state and use.

Considering the national as well as international importance of this land, sufficient amount of financial sources should be allocated to the extensive changes from state (public) resources, or eventually from EU structural funds. Due to the inconsistencies in the Land Register, administrative demands of these changes also increase. A part of these lands (mainly the more fertile ones) could be used for agriculture, particularly when the subsidy agrarian policy is consistently applied. The parts which will obviously not be used for agricultural purposes, should be moved to the forest land category in the Land Register. This requires several steps: identification, mapping and administrative re-categorisation. Currently, this process is explicitly linked to the owner´s request. Apart from the problems with the identification of e.g. unknown owners, the reluctance of owners to make such a change in the land category is a big issue, because at such sites relatively strict forestry legislation does not have to be followed (managing forests following forest management plans). We consider it appropriate to change this process, and to allow the possibility of the administrative re-categorisation of the land that has not been utilised for a long time (e.g. over 10 years) even without the owner's consent.

Out of many necessary steps that need to be performed in this field we would like to mention basic forestry measures, i.e. practical recommendations (see also Šmelko & Šebeň 2009):

– Since forests on non-forest land are positive components of landscape, they should become a part of other forests also from the legislative and management point of view to ensure that they are protected by the Forest Act.
– The land covered by large compact dense forest stands with a sufficient proportion of commercial tree species should be re-categorised to forest land, and should be managed to ensure its prevailing function.
– An effort should be developed (a joint strategy of post-communist countries – current EU members) to ensure that the EU financial support for afforestation of inappropriate agricultural land could also be applied to these forests on non-forested land.

According to us, it is important to take the forests on non-forest land into account, to see their current state positively, to include them to other forests and to try to maximise the use of their functions by society. In addition, we recommend a joint strategy of former post-communist countries – current EU members, to promote financial support for afforestation, or standard management of forest stands on non-forest land from EU sources.

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References

Adolt, R., Kučera, M., Zapadlo, J., Andrlík, M., Čech, Z., Coufal, J., 2013: Pracovní postupy pozemního šetření NIL2. Ústav pro hospodářskou úpravu lesů, Brandýs nad Labem, 657 p.

Adolt, R., Kohn, I., Kučera, M., Kratěna, L., Fejfar, J., Závodský, J.et al., 2016: Výstupy Národní inventarizace lesů uskutečněné v letech 2011–2015. 2. Zásoba dříví; 4. Přírůst dříví. 12. Biomasa. Příloha Lesnické práce, 8 p.

Boltižiar, M., Olah, B., 2013: Land use changes of UNESCO Biosphere Reserves in the Slovak Carpathians since the late eighteen century. In: Kozak, J. (ed.): The Carpathians: Integrating nature and society towards sustainability, Springer-Verlag, Berlin Heidelberg.

Bucha, T. et al., 2014: Satelity v službách lesa. Bratislava: SAP, 202 s.

Cienciala, E., Apltauer, J., Exnerová, Z., Tatarinov, F., 2008: Biomass functions applicable to oak trees grown in Central-European forestry. Journal of Forest Science, 54:109–120.

Cienciala, E., Černý, M., Tatarinov, F., Apltauer, J., Exnerová, Z., 2006: Biomass functions applicable to Scots pine. Trees – Structure and Function, 20:483–495.

Creutzig, F., Ravindranath, N. H., Berndes, G., Bolwing, S., Bright, R., Cherubini, F. et al., 2015: Bioenergy and climate change mitigation: an assessment. Global Change Biology – Bioenergy, 7:916–944.

Díaz, S., Pascual, U., Stenseke, M., Marín-López, B., Watson, R.T., Molnár, Z. et al., 2018: Assessing nature's contributions to people. Science, 359:270–272.

Drexhage, M., Colin, F., 2001: Estimating root system biomass from breast-height diameters. Forestry, 74:491–497.

Forest Europe, 2015: State of Europe's Forests. Forest Europe Liaison Unit Madrid, Madrid, 312 p.

Griffiths, P., Mueller, D., Koemmerle, T., Hostert, P., 2013: Agricultural land change in the Carpathian ecoregion after the breakdown of socialism and expansion of the European Union. Environmental Research Letters, 8 045024.

Hlásny, T., Sitková, Z. (eds.), 2010: Spruce Forests decline in the Beskids. Zvolen, NLC, 182 p.

Jaskowiec, B., 2013: Assessment of Land Cover Changes in the Carpathian Mountains with MODIS Data. In: Kozák, J. (ed.): The Carpathians: Integrating nature and society towards sustainability, Springer-Verlag, Berlin Heidelberg.

Konôpka, B., Pajtík, J., Moravčík, M., Lukáč, M., 2010: Biomass partitioning and growth efficiency in four naturally regenerated forest tree species. Basic and Applied Ecology, 11: 234–243.

Kozák, J., 2003: Forest Cover Change in the Western Carpathians in the Past 180 Years. A Case Study in the Orawa Region in Poland. Mountain Research and Development, 23:369–375.

Kučera, M., Adolt, R., Kratěna, L., Kohn, I., Fejfar, J., Závodský, J. et al., 2016: Výstupy Národní inventarizace lesů uskutečněné v letech 2011J.2015. 1. Plocha lesa. Příloha Lesnické práce, 8 p. In Czech.

Kuemmerle, T., Hostert, P., Radeloff, V. C., van der Linden, S., Perzanowski, K., Kruhlov, I., 2008: Cross-border comparison of post-socialist farmland abandonment in the Carpathians. Ecosystems, 11:614–628.

Kuemmerle, T., Chaskovskyy, O., Knorn, J., Radeloff, V. C., Kruhlov, I., Keeton, W. S. et al., 2009: Forest cover change and illegal logging in the Ukrainian Carpathians in the transition. Remote Sensing of Environment, 113:1194–1207.

Kulla, L, Sitková, Z. (eds.), 2012: Rekonštrukcie nepôvodných smrekových lesov: poznatky –skúsenosti – odporúčania. Zvolen, NLC, 208 p.

Lenoch, J., 2014: Dějiny lesního hospodářství a dřevozpracujícího průmyslu. Učební texty, Mendelova univerzita, Brno, 120 p.

Lindner, M., Karjalainen, T., 2007: Carbon inventory methods and carbon mitigation potentials of forests in Europe: a short review of recent progress. European Journal of Forest Research, 126:149-156.

Merganičová, K., Sitko, R., Merganič, J., 2013: Využitie GIS pre procesne orientované modelovanie vývoja lesa. Praktické využití GIS v lesnictví a zemědělství, 21.–22. 2. 2013, Praha.

Merganičová K., Merganič J., Sitko R., Mistrík M., 2014: Human impact on the land cover in the area surrounded by the centres of past mining. The International Forestry Review, 16: 544.

Midriak, R. et al., 2011: Spustnuté pôdy a pustnutie krajiny Slovenska. Univerzita Mateja Bela v Banskej Bystrici, Fakulta prírodných vied, 2011, 401 p.

Oravec, M, Slamka, M., 2018: The energy intensity of the production of energy chips from dendromass stands on long-term uncultivated agricultural land. Central European Forestry Journal, 64:104–115.

Pachova, N. I., Tikkanen, I., Pajari, B., Nevenic, R., 2004: Introduction: Capacity needs for forest policy in countries with economies in transition. In: Challenges in Strengthening of Capacity for Forest Policy Development in Countries with Economies in Transition. United Nations University, Tokyo, p. 1–16.

Pajtík, J., Konôpka, B., Šebeň, V., 2018: Mathematical biomass models for young individuals of forest tree species in the region of the Western Carpathians. Zvolen, NLC – LVÚ Zvolen, 89 p.

Plesník, P., 1987: Pôvodnosť hlavných lesných drevín na Kysuciach (v oblasti Čadce). Geographica, 26:27–489.

Pernes, J., 2016: Kolektivizace zemědělství v Československu v letech 1948–1960. Forum Historiae, 10:5–34.

Petráš, R., Košút, M., Oszlányi, J., 1985: Leaf biomass of trees in spruce, pine and beech. Lesnícky časopis, 31:121–136.

Petráš, R., Pajtík, J., 1991: Sústava česko-slovenských objemových tabuliek drevín. Lesnícky časopis, 37:49–56.

Raczkowska, Z., Lajczak, A., Margielewski, W., Swiechowicz, J., 2012: Recent landform evolution in the Polish Carpathians. In: Lóczy, D., Stankoviansky, M., Kotarba, A. (eds.): Recent landform evolution: the Carpatho-Balkan-Dinaric Region, Springer Geography.

Smith, P., Nabuurs, G.–J., Janssens, I. A., Reis, S., Marland, Soussana, J.–F. et al., 2008: Sectoral approaches to improve regional carbon budgets. Climatic Change, 88:209–249.

Stockmann, K. D., Anderson, N. M., Skog, K., Healey, S.,P., Loeffler, D.,R., Jones, G. et al., 2012: Estimates of carbon stored in harvested wood products from the United States Forest Service Northern Region, 1906–2010. Carbon Balance and Management, 7:1–16.

Šebeň, V., 2017: Národná inventarizácia a monitoring lesov SR 2015–2016. Informácie, metódy, výsledky. Lesnícke štúdie 65/2017. Zvolen, NLC - LVÚ Zvolen, 256 p.

Šmelko, Š., Šebeň, V., 2009: Aktuálne informácie o lese na nelesných pozemkoch podľa NIML SR 2005–2006, metodika ich získania a námety na jej využitie v krajinnej ekológii. In: Zaušková, Ľ. (ed.): Pustnutie krajiny – ochrana pôdy – krajinná ekológia. Zborník referátov z vedeckého seminára. Ústav vedy a výskumu Univerzity Mateja Bela, Banská Bystrica, p. 163-175.

Šmelko, Š., Šebeň, V., Bošeľa, M., Merganič, J., Jankovič, J., 2008: Národná inventarizácia a monitoring lesov Slovenskej republiky 2005–2006. Základná koncepcia a výber zo súhrnných informácií, Zvolen, NLC, 16 p.

Špulák, O., Kacálek, D., 2011: History of non-forest land afforestation in the Czech Republic. Zprávy lesnického výzkumu, 56:49–57.

Vejpustková, M., Čihák, T., Šrámek, V., 2017: Kvantifikace nadzemné biomasy smrku ztepilého. Certifikovaná metodika. Lesnický průvodce 3/2017, Jíloviště, VÚLHM, 27 p.

Vejpustková, M., Čihák, T., Zahradník, D., Šrámek, V., 2013: Metody stanovení nadzemné biomasy buku. Certifikovaná metodika. Lesnický průvodce 1/2013, Jíloviště, VÚLHM, 30 p.

Veľký, J. et al., 1977: Encyklopédia Slovenska (A – D). Bratislava, Veda, 719 p.

Vladár, J. et al., 1982: Encyklopédia Slovenska (T – Ž). Bratislava, Veda, 853 p.

Zachar, D., 1965: Zalesňovanie nelesných pôd. Bratislava, SVPL, 229 p.

Zaušková, Ľ., Midriak, R., 2008: Multifunkčné poľnohospodárstvo ako alternatíva trvalo udržateľného rozvoja poľnohospodárskej krajiny. In: Izakovičová, Z. (ed.): Smolenická výzva IV. Kultúrna krajina ako objekt výskumu v oblasti trvalo udržateľného rozvoja. Zborník z konferencie, Bratislava, ÚKE SAV Bratislava, p. 61–67.

Zaušková, Ľ., Midriak, R., Šebeň, V., 2012: „Biele plochy" z pohľadu pustnutia kultúrnej poľnohospodárskej krajiny. Lesnícky časopis – Forestry Journal, 58:121–128.

Appendix tables

Table A1. Tree species composition of forests on non-forest land in the Czech Republic based on the data of the NFI2 (2011–2014).

Group	Tree species	Growing stock [mill. m^3]	Growing stock [%]
Coniferous	*Picea abies*	15.6 ±2.1	25.9 ±3.5
	Pinus sylvestris	4.5 ±0.8	7.5 ±1.4
	Larix decidua	1.2 ±0.4	2.0 ±0.6
	Abies alba	0.3 ±0.2	0.5 ±0.3
	Others coniferous	<0.1	<0.1
	Total	21.8 ±2.5	36.1 ±4.1
Broadleaved	*Alnus glutinosa*	7.1 ±1.3	11.8 ±2.1
	Quercus robur	5.0 ±1	8.3 ±1.7
	Betula pendula	3.7 ±0.6	6.2 ±0.9
	Fraxinus excelsior	2.6 ±0.6	4.2 ±1.1
	Populus tremula	2.3 ±0.5	3.8 ±0.8
	Acer pseudoplatanus	2.1 ±0.5	3.5 ±0.8
	Salix alba	2.1 ±0.5	3.4 ±0.8
	Populus nigra	1.8 ±1	3.0 ±1.7
	Tilia cordata	1.7 ±0.5	2.8 ±0.9
	Fagus sylvatica	1.4 ±0.5	2.3 ±0.8
	Quercus petraea	1.3 ±0.4	2.2 ±0.7
	Robinia pseudoacacia	1.3 ±0.5	2.1 ±0.8
	Carpinus betulus	1.0 ±0.3	1.6 ±0.5
	Salix caprea	0.8 ±0.2	1.3 ±0.3
	Cerasus avium	0.8 ±0.2	1.2 ±0.3
	Acer platanoides	0.6 ±0.3	1.0 ±0.5
	Alnus incana	0.4 ±0.2	0.7 ±0.4
	Populus x.	0.4 ±0.4	0.6 ±0.7
	Acer campestre	0.3 ±0.1	0.5 ±0.2
	Tilia platyphyllos	0.2 ±0.2	0.3 ±0.3
	Sorbus aucuparia	0.2 ±0.1	0.3 ±0.1
	Sambucus nigra	0.2 ±0.1	0.3 ±0.1
	Others hardwood	0.2 ±0.1	0.2 ±0.2
	Coryllus avellana	0.1 ±0.1	0.2 ±0.1
	Pyrus pyraster	0.1 ±0	0.2 ±0.1
	Quercus rubra	0.1 ±0.1	0.2 ±0.2
	Ulmus laevis	0.1 ±0.1	0.2 ±0.1
	Padus racemosa	0.1 ±0.1	0.2 ±0.1
	Malus sylvestris	0.1 ±0	0.2 ±0.1
	Crataegus sp.	0.1 ±0	0.2 ±0.1
	Padus serotina	0.1 ±0.1	0.2 ±0.1
	Prunus spinosa	0.1 ±0.1	0.1 ±0.1
	Acer negundo	0.1 ±0.1	0.1 ±0.1
	Ulmus glabra	0.1 ±0	0.1 ±0.1
	Salix sp.	0.1 ±0	0.1 ±0.1
	Ulmus minor	<0.1	0.1 ±0.1
	Total	38.5 ±3.2	63.9 ±5.2

Table A2. Tree species composition of forests on non-forest land in Slovakia based on the data of the NFI2 (2015–2016)

Group	Tree species	Growing stock [mill. m³]	Growing stock [%]
Coniferous	*Picea abies*	10.3 ±2.5	22.6 ±5.5
	Pinus sylvestris	3.1 ±1.5	6.8 ±3.3
	Abies alba	0.2 ±0.4	0.5 ±0.9
	Larix decidua	0.1 ±0.2	0.1 ±0.5
	Other	<0.1	<0.1
	Total	13.7 ±2.8	30.1 ±6.1
Broadleaved	*Fagus sylvatica*	4.9 ±1.9	10.8 ±4.1
	Alnus glutinosa	4.0 ±1.7	8.7 ±3.7
	Carpinus betulus	3.4 ±1.6	7.5 ±3.5
	Betula pendula	3.1 ±1.5	6.7 ±3.3
	Populus x canadensis	1.9 ±1.2	4.1 ±2.6
	Quercus petraea	1.8 ±1.2	4.0 ±2.6
	Populus nigra	1.1 ±0.9	2.5 ±2.1
	Salix alba	1.1 ±0.9	2.5 ±2.1
	Alnus incana	1.0 ±0.9	2.1 ±1.9
	Populus tremula	1.0 ±0.9	2.2 ±1.9
	Robinia pseudoacacia	1.1 ±0.9	2.4 ±2.0
	Acer campestre	1.0 ±0.9	2.3 ±2.0
	Quercus cerris	0.8 ±0.8	1.7 ±1.7
	Salix caprea	0.9 ±0.8	1.9 ±1.8
	Cerasus avium	1.0 ±0.9	2.1 ±1.9
	Populus euamericana	0.6 ±0.7	1.3 ±1.5
	Tilia cordata	0.6 ±0.7	1.3 ±1.5
	Acer pseudoplatanus	0.5 ±0.6	1.1 ±1.4
	Pyrus pyraster	0.5 ±0.6	1.2 ±1.4
	Fraxinus excelsior	0.4 ±0.5	0.8 ±1.2
	Populus alba	0.1 ±0.3	0.3 ±0.7
	Quercus robur	0.1 ±0.3	0.3 ±0.7
	Padus racemosa	0.2 ±0.4	0.4 ±0.8
	Ulmus minor	0.0 ±0.1	0.1 ±0.3
	Malus sylvestris	0.3 ±0.5	0.7 ±1.1
	Juglans regia	0.1 ±0.3	0.2 ±0.6
	Ulmus laevis	0.1 ±0.2	0.1 ±0.4
	Acer negundo	0.0 ±0.2	0.1 ±0.4
	Prunus domestica	0.1 ±0.3	0.3 ±0.7
	Morus alba	0.1 ±0.2	0.1 ±0.5
	Acer platanoides	<0.1	0.1 ±0.4
	Sorbus torminalis	<0.1	<0.1
	Fraxinus angustifolia	<0.1	<0.1
	Sorbus aucuparia	<0.1	<0.1
	Salix fragilis	<0.1	<0.1
	Tilia platyphyllos	<0.1	<0.1
	Total	31.8 ±2.8	69.9 ±6.1