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CONTAMINATION OF SOIL AND VEGETATION AT A MAGNESITE MINING AREA IN JELŠAVA-LUBENÍK (SLOVAKIA)

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Abstract

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This paper is focused on the impacts of alkaline and metal deposition on soil and vegetation in the immission field of magnesium factory Jelšava-Lubeník (Slovakia). Soil samples and the foliage of vegetation were obtained from the Jelšava-Lubeník area with specific alkaline pollutants. The examined area is one of the most devastated regions of Slovakia. From the point of view of environmental regionalization, it belongs to an environmentally damaged area of Category 3. The total content of heavy metals in the soil and vegetation (Pb, Zn, Cr, Mn, Mg) were determined by atomic absorption spectrometry and X-ray fluorescence spectrometry. Soil reaction was determined in a solution of 0.01 M $CaCl_2$. Vegetation was assessed by the Braun-Blanquet scale. In conclusion, we can say that spray particles of free magnesium oxide (MgO) strongly influence soil reaction, diversity, and vegetation cover. The research showed that the investigated sites were mostly strongly alkaline; the contents of Cr, Mn and Mg were over the toxicity limit, while the measured values of Pb and Zn did not exceed the limits set by the law. The values that measured significantly above the set limit show contamination that can be considered harmful and toxic. In the monitored species, that is, *Agrostis stolonifera*, *Elytrigia repens* and *Phragmites australis*, an over-limit content of Pb and Zn and toxic contents of Mg and Mn were found.

Key words: magnesium, manganese, soil reaction, *Phragmites australis, Elytrigia repents, Agrostis stolonifera*.

Introduction

Anthropogenic activities, such as fossil fuel burning, mining and smelting of ores, domestic mobile sources (automotive industry) and industrial waste, organic and mineral fertilizers, liming and pesticides, and sludge from sewage treatment cause serious pollution of the biosphere by releasing toxic heavy metals that often have toxic effects on the environment (Mahmood, 2010; Adriano, 2001). Soil does not emerge as a passive acceptor of heavy metals; polluted soil is a source of pollution of the other components of environment and food chain (Singh et al., 2006). In relation to nature, the results of economic activities of anthropogenic activities are acidification, alkalization and metallization elements of the environment (Hronec et al., 2008; Fazekašová et al., 2014; Minďáš, Škvarenina, 1995). Heavy metals can accumulate in various plant parts, depending on the plant species, soil condition, and the type of heavy metal (Barman et al., 2001). Plants' ability to cope with an excessive amount of heavy metals varies. Some plant species have mechanisms that impose heavy metals on cell walls or bond them chemically in the vacuole, thus reducing their toxicity. Others impede penetration of heavy metals from the roots to the above-ground parts. Accumulators are such plants species that accumulate a large amount of specific metals in their tissues (Pant, Tripathi, 2014). *Agrostis capillaris, Calamagrostis epigejos, Deschampsia flexuosa* and *Agrostis stolonifera* are capable of forming tolerant ecotypes. *Elytrigia repens* and *Taraxacum officinale* are also characterized by a high ecological valence and resistance to heavy metals (Banásová, 2004; Boguská et al., 2013). *Phragmites australis* is considered as a plant with a high detoxification and phytoremediation potential and has been widely used in wetlands for the treatment of industrial wastewater containing heavy metals. Therefore, much attention has recently been focused on the response of this plant to heavy metal stresses (Jiang, Wang, 2008). Some plants possess super-accumulative properties with regard to heavy metals: they can accumulate up to 5% of heavy metals (nickel, zinc or copper) in their leaves (as dry mass), which is more than tenfold higher than the values for ordinary plants (Gladkov et al., 2011). Soil parameter such as soil reaction, the organic matter content and quality, soil sorption complex, soil granularity, and oxidation-reduction potential influence the availability of heavy metals in plants (Wang et al., 2015). Soil alkalinity is conditioned by the presence of alkaline salts, which are easily hydrolysed and allow the formation of alkalinity. The fundamental reason of soil alkalinity is the presence of exchangeable sodium and the content of Na_2CO_3 or $NaHCO_3$ in soil solutions that worsen some soil processes like soil acidity. A strong alkaline reaction of $pH/CaCl_2 > 7.7$ is created by air alkaline pollutants from a magnesium factory. Magnesite air pollutants are a mixture of MgO and $MgCO_3$, due to which a soil reaction can move above pH 8 (Baluchová et al., 2011).

This paper examines the impacts of alkaline and metal deposition on soil and vegetation in the immission field of magnesium factory Jelšava-Lubeník (Slovakia).

Material and methods

Study area

Jelšava and Lubeník lie in the south-central part of the Slovak Ore Mountains in the Muran valley, in the district called Jelšava podolie. Jelšava podolie, geomorphologically, belongs to the Revúca Highlands (Mazúr, Lukniš, 1980). Geologically, the area belongs to the Central Western Carpathians. The area is built mainly by Palaeozoic and Mesozoic rocks. Palaeozoic rocks are found in a wide belt between Jelšava and Lubeník, and consist of phyllites, sandstones, shales, limestones and conglomerates. The soil type of Cambisol evolved on this bedrock—it is lightly skeletal, mostly of medium depth (60–120 cm), and the steeper slopes are prone to erosion. The original reaction soil pH of about 5 was changed to a pH of about 7.2 to 8.5 due to magnesite dust contamination. The second largest group of rocks consists of limestone, dolomite, and slate limestone, which we categorize as Mesozoic rocks. The developed soils are mostly shallow (15–20 cm), loam to loamy clay, predominantly strongly skeletal, and classified as Rendzinas. The third group consists of rocks of the upper Pliocene sediments—they are clays, sands, and gravels with overlays of quaternary clays, in which there were developed Luvisols. Fluvisols and their various subtypes are developed in the alluvium of the river Muran (Hronec et al., 2010).

Jelšava and Lubeník belong to a warm climatic region with 50 and more summer days (a summer day has a maximum air temperature 25 °C). The climate is warm, moderately humid with a cold winter. The average temperature in January is -3 to -5 °C and in July 14.5 to 16.5°C. Annual precipitation is 600–800 mm (Climate Atlas of Slovakia, 2015). Based on the values of the Gorczynski index, the study area belongs to the transitional maritime climate (Vilček et al., 2016), where the actual evapotranspiration value reaches 400–450 mm per year (Škvarenina et al., 2009).

Twelve research sites of the problem area Jelšava (N48°38'39.1" E20°13'02.7") and Lubeník (N48°39'18.3" E20°11'48.9") were monitored in the agrarian country (Fig. 1). Soil samples were collected from the permanent research sites, which are used as permanent grasslands and are in the immission field of the magnesium factory, Jelšava-Lubeník (Slovakia), from the A horizon to the depth of 0.05 to 0.15 m.

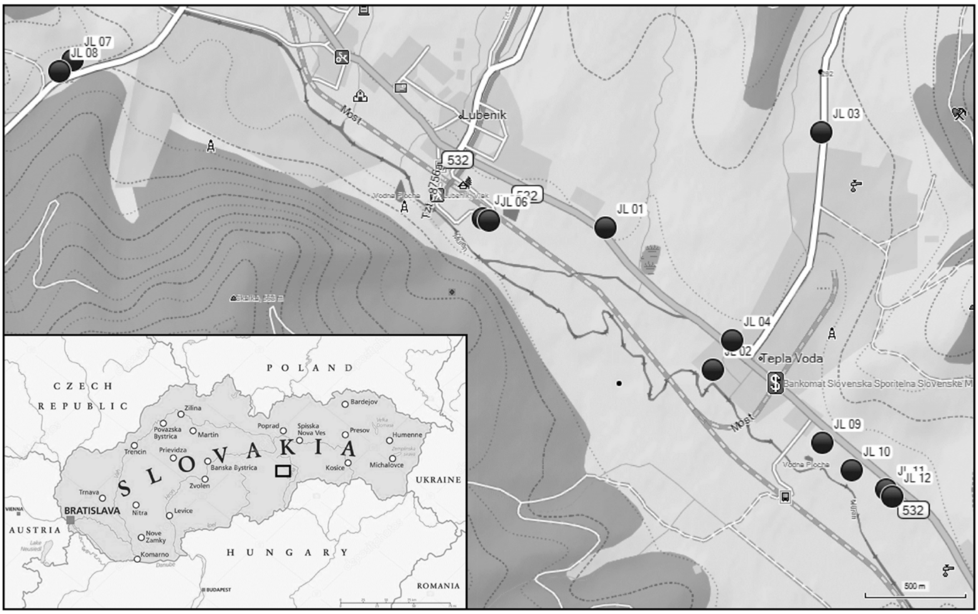

Fig. 1. Location of research sites in the investigated areas of Jelšava and Lubeník (Slovakia).

Soil assays

After homogenization, the soil samples were manually crumbled, dried at room temperature, sieved (< 2 mm) and stored in polyethylene bags until the analysis. We studied and evaluated the soil reaction in a 1N solution $CaCl_2$ (5 g of soil mixed with 25 ml of 0.01M $CaCl_2$) using the Mettler Toledo pH meter. The total content of Pb, Zn, Cr, Mn and Mg was determined by X-Ray fluorescence spectrometry following the methodology as devised by Fiala et al. (1999). The assessed values of heavy metals in soils were compared to the limit values of Slovak soils (Act No. 220/2004).

Vegetation assays

The foliage of *Pragmites australis, Elytrigia repents* and *Agrostis stolonifera* was collected to determine the heavy metal content. Vegetation samples were dried at 40°C, homogenised to the fraction < 0.09 mm, burned in a furnace at 550°C and decomposed with a mixture of HCl and HNO acid. The concentration of heavy metals was (Pb, Zn, Cr, Mn, Mg) determined and the measured values of heavy metals were compared with the threshold values of plants determined by law (Act No. 220/2004). The samples were analysed by atomic absorption spectrometry, and X-ray fluorescence spectrometry following the methodology devised by Fiala et al. (1999).

The diversity of grassland communities was monitored in the form of plots on the field of 16 m^2 during the 2016 growing season. Vegetation was assessed by the Braun-Blanquet scale (Braun-Blanquet, 1964). The terminology is given in accordance with Marhold, Hindák (1998). The determination of the species diversity of the sites was done according to the Shannon index:

$$H' = -\sum_{i=1}^{s} \frac{xi}{N} log2 \frac{xi}{N}$$

which is sensitive to the different characteristics of plant communities, particularly the number and significance of the coefficient of all kinds. The results were evaluated on the basis of scales: 1 extremely low (< 0.5), 2 very low (0.5–1), 3 middle low (1–1.7), 4 low (1.7–2.5), 5 low to moderate (2.5–3.3), 6 medium (3.3–4), 7 half-height (4–5), 8 high (5–7), 9 very high (7–10) and 10 extremely high (> 10).

Statistical analysis

The obtained data were processed statistically with the Statistica 13 software and PAST 3. The level of significance between soil properties was calculated using the Spearman's correlation coefficient. The data were LOG-transformed prior to the analysis.

Results and discussion

Soil reaction

Soil reaction is considered to be one of the main chemical properties because it affects all biochemical reactions in the soil environment (Hohl, Varma, 2010). The mobility, translocation, and toxic effects of risk elements are affected by some soil properties, the content of the clay, organic matter, and soil reaction (Song et al., 2006). The soil reaction in the alkali-contaminated areas of Jelšava and Lubeník ranged between 7.95 ± 1.03 (median ± standard deviation) (Table 1, Fig. 2). Mg flings with significant reactive caustic magnesite are aggressive in natural environments, as even small quantities coming into contact with the soil and crop moisture form saturated solutions with a high alkaline pH value (Baluchová et al., 2011).

Heavy metal pollution in soil

The content of lead (Pb) and zinc (Zn) in the studied area did not exceed the values set by the law (Act NO. 220/2004). The average values of Pb on the examined area were under the limit, ranging from 17–45 mg kg^{-1}. The average content of Zn varies in the region around 32 mg kg^{-1}, a value under the limit. The chromium content in the soil of the investigated area, Jelšava and Lubeník, was in the range of 140.00 ± 279.49 (median ± standard deviation), considerably exceeding the values determined by the law (Table 1, Fig. 2). The median level

T a b l e 1. Variance analyses of heavy metals (mg kg^{-1}) and soil reaction of the investigated areas in Jelšava and Lubeník (Slovakia).

Parameter	Mean	Median	Min	Max	Std. Dev.	*Limit value
pH/$CaCl_2$	7.63	7.95	6.20	8.80	1.03	
Pb (mg kg^{-1})	32.42	32.00	17.00	45.00	8.16	70
Cr (mg kg^{-1})	231.08	140.00	83.00	1055.00	279.49	70
Zn (mg kg^{-1})	88.33	88.50	48.00	108.00	15.17	150
Mn (mg kg^{-1})	1575.00	1600.00	800.00	2300.00	517.20	
Mg (mg kg^{-1})	49841.67	26150.00	7000.00	197000.00	59039.25	

Note: *Act No. 220/2004 Coll. of Laws.

of chromium in the soil of Slovakia was 85 mg kg^{-1} in the A-horizon (Ševčík et al., 2008). However, the data presented by Čurlík, Šefčík (1999) indicate high Cr levels (up to 6096 mg kg^{-1}) in both A and C horizons of soils from the Outer Carpathians. The major part of Cr was in a little mobile form in the soil. The mobility depended on the pH, the content of clay particles, and the redox potential of the soil. Chromium, cobalt and nickel are considered as metals that come from a geogenic load (Takáč et al., 2008). Hexavalent chromium (Cr^{6+}) is classified as one of the most important environmental contaminants (Kafka, Punčochářová, 2002). Readily soluble Cr^{6+} in soils is toxic to plants and animals. A dose of 0.5 g chromium dioxide kills a man and is classified as a human carcinogen (Melichová et al., 2017). Therefore, the variability in the oxidation states of Cr in soils is of a great environmental concern (Kabata-Pendias, 2011). Chromium is a heavy metal of high environmental impact (Vaiopoulou, Gikas, 2012), as it can severely affect the behaviour of micro- and macroorganisms (Gikas, Romanos, 2006; Shanker et al., 2005).

Magnesium is considered the fifth major nutrient in plant nutrition and is not present within the hygienic limits set by the Slovak Republic. The Mg content highly significantly correlates with soil texture, soil reaction, soil potassium content, and soil sorption capacity (Fazekašová et al., 2014). It is located in several primary and secondary minerals. The content values of the magnesium found in the topsoil of agricultural land in Slovakia are in the range of 200–400 mg kg^{-1}, showing a high content of this element in the soil (Kobza et al., 2010). Therefore, the values over 500 mg kg^{-1} can be considered as higher to high, or over the limit (over 1000 mg kg^{-1}). In the studied area, we found significant contamination of soil by magnesium with values within the range of 26150.00 ± 59039.25 (median ± standard deviation), which is, on average, 18 to 493 times in excess (Table 1, Fig. 2). From the measured data of Mg content in the soil, it is possible to conclude the presence of a considerable heterogeneity, which is confirmed by a significant difference between the minimum and maximum values. The highest concentrations of Mg exceeded the high content of this element 492.5 times, which is comparable with Wang et al. (2015). The Mg content above the limit has a toxic influence on plants, causing their gradual necrosis and loss of soil vegetation cover.

The measured levels of manganese had a similar pattern and contents in the range 1600.00 ± 517.20 (median ± standard deviation) (Table 1, Fig. 2). The average content of manganese in the soil of the Slovak Republic is in the range of 0.85 to 112.90 mg kg^{-1}, indicating a significant spatial heterogeneity of the elements, but a medium supply of this element

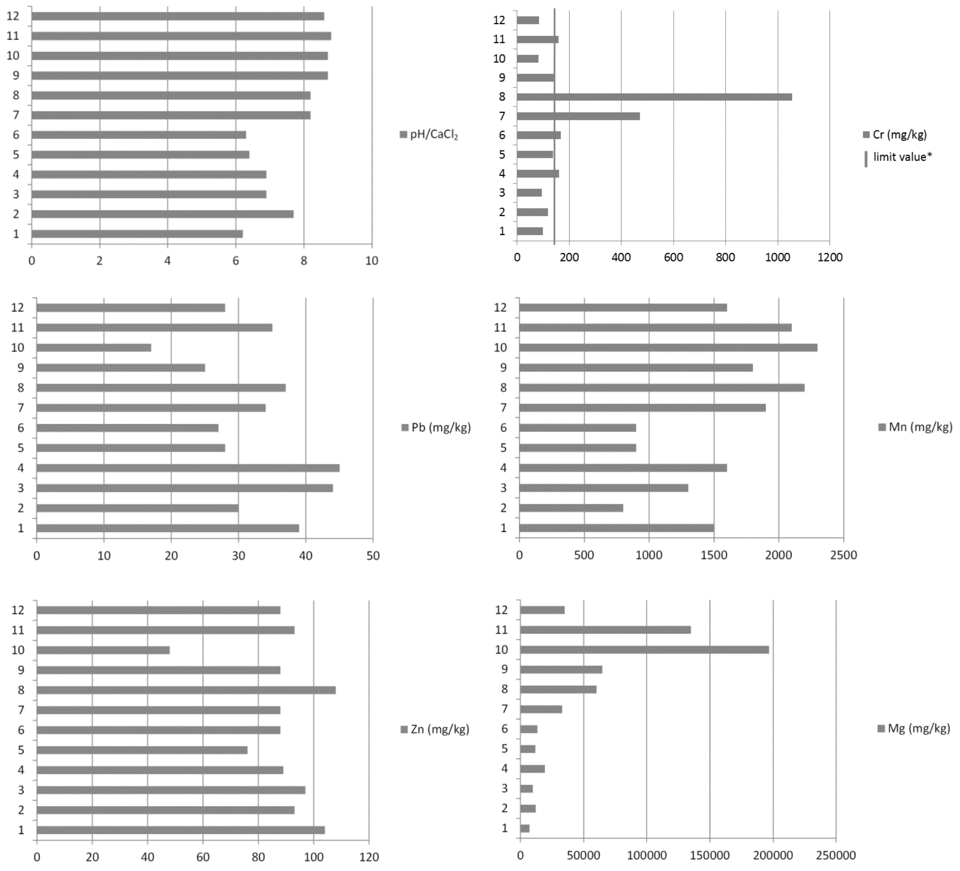

Fig. 2. Values of soil reaction and heavy metal content in soil measured in the investigated areas of Jelšava and Lubeník (Slovakia).
Note: *Act No. 220/2004 Coll. of Laws.

dominates the soil. Kabata-Pendias (2011) referred to the value of 1500 mg kg^{-1}, which shows the symptoms of manganese toxicity. The most toxic compounds of manganese are in the oxidation No. III. The lethal dose of potassium permanganate ($KMnO_4$) for an adult human is 5 g. Some manganese compounds are potential carcinogens (Melichová et al., 2017). Based on the obtained results, it can be stated that the Pb, Zn contents are below the toxic level but that does not apply to Cr, Mn and Mg. They significantly exceed the limits, pointing to contamination that can be considered toxic and harmful.

The relationships between heavy metals are listed in Table 2. Spearman's correlation coefficients confirmed a negative correlation between Pb-Mg and only Zn-Mg was significant. A significant positive correlation ($p < 0.05$) between soil pH-Mn and pH-Mg was determined in this study. Positive correlations were detected between Mn and Mg.

T a b l e 2. Correlations between heavy metals and soil reaction (pH) of the investigated areas in Jelšava and Lubeník (Slovakia).

Parameter	Pb	Zn	Cr	Mn	Mg
pH/CaCl$_2$	0.409	0.239	0.211	0.718*	0.696*
Pb		0.723*	0.210	0.066*	-0.519*
Zn			0.411	0.154	-0.615*
Cr				0.417	0.004
Mn					0.740*

Note: $p < 0.05$*.

T a b l e 3. Variance analyses of heavy metals in the plant species (*Pragmites australis, Elytrigia repents, Agrostis stolonifera*) of the investigated areas in Jelšava and Lubeník (Slovakia).

Parameter	Mean	Median	Min	Max	Std. Dev.	*Limit value
Cd (mg kg^{-1})	0.09	0.10	0.09	0.10	0.01	0.10
Pb (mg kg^{-1})	1.77	3.30	1.00	3.30	1.33	0.10
Zn (mg kg^{-1})	39.63	85.00	7.80	95.00	48.13	2.00
Cr (mg kg^{-1})	2.13	4.30	1.00	4.30	1.88	-
Mn (mg kg^{-1})	206.67	78.00	78.00	400.00	170.46	-
Mg (mg kg^{-1})	11162.33	21.21	5419.00	21208.00	8729.59	-

Note: *Act No. 220/2004 Coll. of Laws.

Diversity of vegetation and heavy metal pollution

We found alkaline to strongly alkaline soil reactions in seven investigated sites. This greatly affected the variability of species. Characteristic wild solanaceous such as *Elytrigia repens, Chenopodium album, Equisetum arvense* were present on farmlands. Permanent grasslands were represented by species typical of wet and waterlogged sites such as *Alopecurus pratensis, Lychnis flos-cuculi, Cirsium rivulare, Acetosa pratensis, Archangelica officinalis, Agrostis stolonifera* and competitively strong species *Elytrigia repens, Phragmites australis,* creating monoculture in four locations (9–12) (Fig. 1). Ruderal communities of *Tanacetum vulgare, Chenopodium album, Silene vulgaris* and rampant invasive taxon *Solidago canadensis* were recorded in Sites 1 and 5 near arable land and also on permanent grasslands.

Species diversity of flora was investigated in localities evaluated by the Shannon index H', which is sensitive to the different characteristics of plant communities, particularly the coefficient of significance of all kinds (Špulerová et al., 2011, 2016; Barančoková, Barančok, 2015; Barančoková et al., 2017). Based on the results of the Shannon index, we can conclude that the diversity on the investigated sites is extremely low (0.0) to middle low (1.5).

The species were selected on the basis of their significance coefficients at individual sites. Pb, Zn, Cr, Mn and Mg were analysed in the plant species. The highest contamination compared to the threshold values was found in *Elytrigia repens* in which the zinc content exceeded the threshold by 47 times and the lead content by 33 times. Excessive values of zinc were also found in dry matter such as *Phragmites australis* (Table 3, Fig. 3)**.**

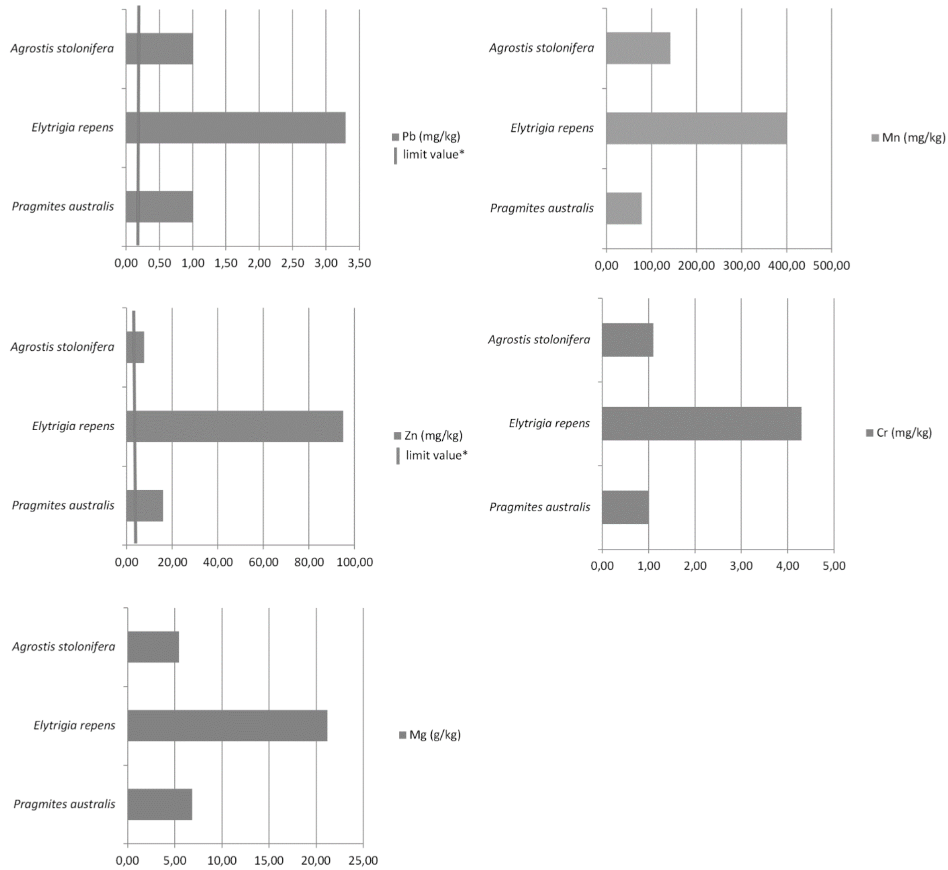

Fig. 3. Heavy metal content in the plant species (*Pragmites australis, Elytrigia repents, Agrostis stolonifera*) of the investigated areas in Jelšava and Lubeník (Slovakia).

The concentration of magnesium in the sampled plants showed a very high content (Table 3, Fig.). The highest content of the element was found in *Elytrigia repens* (21208 mg kg^{-1}) >*Phragmites australis* (6860 mg kg^{-1}) > *Agrostis stolonifera* (5419 mg kg^{-1}). A high-level of manganese concentration was also found in *Elytrigia repens* (400 mg kg^{-1}) > *Agrostis stolonifera* (142 mg kg^{-1}) > *Phragmites australis* (78 mg kg^{-1}). Most plants are affected by a Mn content above 400 mg kg^{-1}. The accumulation above 1000 mg kg^{-1} has also been often reported for several more resistant species or genotypes. The hyperaccumulator plants (*Phytolacca americana* L.) absorbed Mn from the contaminated soil up to 13,400 mg kg^{-1} in leaves (Kabata-Pendias, 2011). Excess magnesium induced some toxicity symptoms. The plant that received 10,000 mg of Mg^{2+} kg^{-1} died on the 20th day after the treatment, and the plants that received 5,000 mg of Mg^{2+} kg^{-1}, died on the 45th day (Venkatesan, Jayaganesh, 2010).

Phragmites australis can tolerate many types of habitats and grow in areas with wide ecological amplitude, including wetland and soil. Many studies reported *P. australis* as one of the best plant organisms for the detection and adsorption of harmful contamination by heavy metals (Wang et al., 2015). *P. australis* is not a hyperaccumulator; however, this is a fast-growing and high-biomass producer, has a deep root apparatus, and can tolerate and/or accumulate a range of heavy metals in their aerial portion. Given this, this is often utilized to reduce the metal concentration of soils, sediments and waters (Bragato et al., 2006). *P. australis* has also been used to identify the presence of Cd, Cu, Pb and Zn in estuaries, suggesting that it can be used as a bio-indicator (Cicero-Fernandes et al., 2017). *Agrostis stolonifera* and *Elytrigia repens* are capable of forming tolerant ecotypes and are also characterized by a high ecological valence and resistance to heavy metals (Banásová, 2004; Boguská et al., 2013; Fazekašová et al., 2016). *Elytrigia repens* is the most resistant to contamination by Pb, Cr, Zn, Mn, Ni, and Cu and is characterized by low contents of the elements under study compared to the other plant species (Minkina et al., 2017). Ranieri et al. (2013) reports that *Phragmites australis* has a high potential for adsorption of Cr from contaminated soils. Charlesworth et al. (2016) state that *Agrostis stolonifera* has a high accumulation potential for heavy metals. These findings will assist in selecting the best grasses to address the pollution of the urban environment by contaminant particulates.

Conclusion

The magnesium industry has a negative impact on the basic elements of the environment. The effects of mining and processing activities are physical changes in a surrounding country, holes and craters after surface mining, heaps, waste dumps as well as dustiness caused by the emission of solid particles. A high deposition of dust is accompanied by soil and water contamination with alkali elements. The area Jelšava-Lubeník is one of the most devastated regions of Slovakia, with an alarming degree of environmental damage. The major component of environmental pollution in Jelšava-Lubeník is magnesite powder belonging to aerosol particles. The result is secondary salinization by Mg, chemical intoxication, and soil devastation. A continuous magnesite crust covers a part of the soil; the vegetation cover is considerably eliminated, reducing a landscaping and environmentally aesthetic function and ecologically important soil functions. The research showed that the investigated sites were mostly strongly alkaline, the contents of Cr, Mn and Mg are over the toxicity limit, the measured values of Pb and Zn did not exceed the limits set by the law. Their significant surpassing of limits points to contamination, which we consider harmful and toxic. In the monitored species, *Agrostis stolonifera*, *Elytrigia repens* and *Phragmites australis*, over-limit contents of Pb and Zn and toxic contents of Mg and Mn were found. Based on the results of the Shannon index, we can conclude that the diversity on the investigated sites is extremely low (0.0) to middle low (1.5).

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SUMMER HABITAT SELECTION OF REINDEER (*Rangifer tarandus*) GOVERNS ON THE UNPROTECTED FOREST AND HUMAN INTERFACE IN CHINA

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Abstract

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The habitat selection by animals depends on different environmental and anthropogenic factors such as the season, climate, and the life cycle stage. Here, we have presented the summer habitat selection strategy of reindeer (*Rangifer tarandus*) in the unprotected forest area from the northern arctic region of China. In summer 2012, we investigated a total of 72 used and 162 non-used plots in the reindeer habitat to record habitat variables. We found that the reindeer used significantly higher altitude, arbour availability, and vegetation cover area as compared to the non-used habitat variables. Principal component analysis (PCA) showed that six principal components (68.5%) were mainly responsible for the summer habitat selection of reindeer such as the slope position, concealment, anthropogenic dispersion, arbour species, distance from the anthropogenic disturbance area (> 1000 m) and water quality (Wilks' Lambda = 0.12; P = 0.0001). The local people are largely dependent on forest product resource in these regions, such as bees herding, collecting wild vegetables, hunting, poaching, and grazing. These activities highly influenced the reindeer habitat and its behaviours. This study thus confirmed that reindeers are forced to choose poor habitat in unprotected forest area with high human disturbance or interference. These factors should be considered by the concerned authority or agency to manage reindeer population in the wild.

Key words: reindeer (*Rangifer tarandus*), summer, habitat selection, effective factor.

Introduction

Habitat selection by animal is a process of long-term evolution and function adopted by the animal to survive in the existing environment, based on the natural selection theory (Manly et al., 2002; Boyce et al., 2002). Habitat selection of species is also dependent on habitats and animal behaviour (Aryal et al., 2013a, 2014b) and the ongoing changes in the environment may also affect the habitat selection by an animal (Aryal et al., 2013b). Habitat selection by an animal differs with season, climate, and the animal life cycle (Jiang, 2004; Aryal et al., 2014a).

Reindeers (*Rangifer tarandus*) are least concerned species distributed in the northern arctic region of China (Ma, 1986; Henttonen, Tikhonov, 2008) as well as in Eurasia and North America (Banfield, 1961; Orians, Wittenberger, 1991). The reindeer population in China is of great interest with the Ewenki community in terms of promoting tourism, providing antler, and also as a food source (Ma, 1986); however, information on the impact of their use on their behaviour, distribution, and response to environmental stress is lacking (Yin et al., 1999; Tang, 2008; Wang, 1995; Li, 1988). The reindeer has seasonal migration in different habitat, and there are very few studies that have reported on the habitat selection of this animal in the other distribution ranges (O'Brian et al., 2006; Skarin et al., 2004). However, specifically, the Chinese reindeer population has not been uniformly managed, and studies on their seasonal habitat preference throughout the distribution range in China is lacking (Ma, 1986; Yin et al., 1999; Tang, 2008; Wang, 1995; Li, 1988). Reindeer in China are distributed outside the protected area, in the unprotected forest. Therefore, we have attempted to study the summer habitat selection strategy of reindeer in the unprotected forest area of the northern China.

Material and methods

Study area

The study was conducted in Aoluguya, Genhe, Inner Mongolia, China (52°10′E, 5′122°N) (Fig. 1). This region is located in northern China and in the western slope of the Great Khingan Range, which is a hilly terrain with plateau-dominated habitat (Ma, 1985). The study area had an altitude ranging from 700 to 1443 m (Fig. 1) and it was covered with larch tree forest including pine, birch, and red spruce trees (Chen, 1985; Feng, Bai, 2011). This forest area has a humid cold temperate climate, which is characterized by cold, wet winter; long, dry, and windy spring; cool short summer; and plunged autumn temperatures with early frost. The annual average temperature and precipitation here is 6.5 °C and 450 mm, respectively (Chen, 1985; Xiang, 2008). This area boasts of about 40 mammalian species including reindeer, musk deer (*Moschus moschiferus*), black brown bear (*Ursus arctos lasiotus*), bear (*Selenarctos thibetanus*), lynx (*Felis*

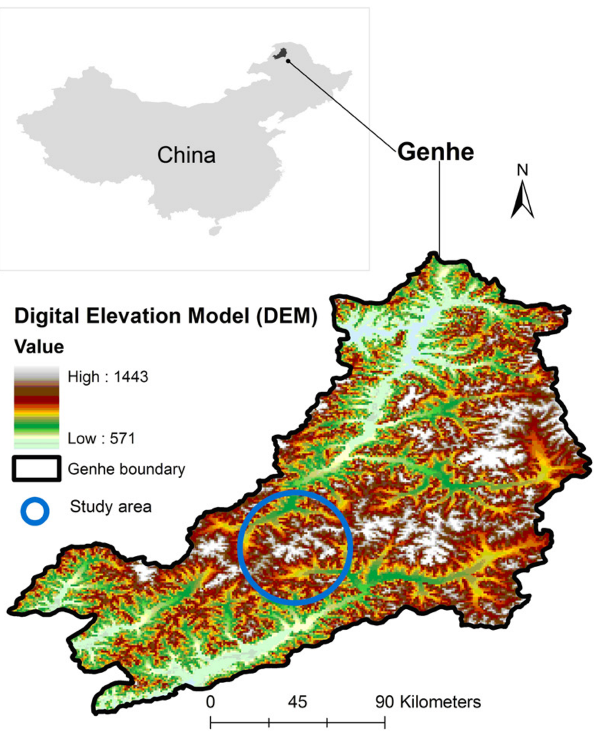

Fig. 1. Illustrated China and study area's digital elevation modelling (DEM) within Genhe district of China.

T a b l e 1. Definition and description of habitat variables of wild reindeer.

Variable	Ecological variables	Variable definition and description
Continuous variables	Altitude (m)	20×20 m altitude of the reindeer fresh activity trace centre within sample area ;
	Arbor canopy (%)	estimate 20×20 m sample centre four directions the upper canopy of vegetation cover on the ground percentage averaged;
	Arbor DBH	20×20 m sample arbour diameter the four directions from the nearest trees to centre sample averages (DBH, roughly 1.3 m height);
	Arbor height (m)	20×20 m sample the four directions from the nearest trees to centre sample height averages (conifers, DBH > 15 cm);
	Arbor density (stems)	20×20 m Arbor quantity (conifers, DBH > 15 cm);
	Shrub height (m)	average value of brush height of five 4×4 m sample area in the 20×20 m sample area;
	Shrub canopy (%)	20×20 m average of Shrub canopy of five 4×4 m sample area in the 20×20 m sample area;
	Ground-plant muscus-lichen cover (%)	the ratio of surface vegetation accounts for the acreage of sample area in the 20×20 m sample area;
	Muscus-lichen cover (%)	estimate the number of eatable plants for reindeer of five 4×4 m sample area in the 20×20 m sample area, average value;
	Stump quantity (stems)	20×20 m sample Stump quantity(conifers, DBH > 15 cm);
	Fallen wood quantity (stems)	20×20 m sample fallen wood quantity (conifers, DBH > 15 cm);
	Withered grass cover (%)	20×20 m sample hay ratio of the total sample area estimated in each 4x4 m quadrat dry plant total coverage;
Discrete Variables	Slope aspect	slope aspect in 20×20 m sample, divided into the east slope (45 ~ 135 °), the southern slope (135 ~ 225 °), the western slope (225 ~ 315 °) and the North slope (315 ~ 45 °);
	Slope gradient (°)	slope gradient in 20×20 m sample, divided into flat slope (≤ 30 °), middle slope (30 ~ 60 °) and steep slopes (≥ 60 °);
	Slope position	20×20 m sample slope position divided into: the lower slopes and valley, mesoslope /mountainside, upslope and ridge;
	Vegetation type	20×20 m sample area vegetation mainly type appearance, divided into conifer forest, conifer and shrub mixed forest, shrub, grassland;
	Concealment	at 1.3 m height (roughly the height of the reindeer head and eye when upright position), sample the average in four direction of the visual range, divided into 3 level, that is good (≤ 10), middle (10 ~ 20 m) and poor (≥ 20);
	Lee condition	sample area affected by the wind, the intrusive is divided into level 3, that is good, middle, bad;
	Water quantity assessment	the size of the bubble water in the sample area and around the sample area, divided into four grade: greatly (diameter of rivers or bubble ≥ 1500cm), big (diameter of river branches or bubbles is ≥ 1000cm), medium (diameter of river branches or bubbles is ≥ 500 cm), small (diameter of bubbles is < 100 cm);
	Soil moisture degree	divided into four grades: very wet (grip will make the water be out of), moist (grip will make dough), moist to some extent (grip will make dough, scattered if loosen the grip), dry;
	Water dispersion (m)	vertical dimension between sample area and source of water (springs and rivers and so on, do not contain snow), divided into three grade: near (≤ 500 m), medium (500 ~1 000 m) and far (≥ 1 000 m);
	Anthropogenic dispersion (m)	from sample area to human disturbance (such as tourism, transportation, agriculture, gathering, grazing and so on. divided into three grade: near (≤ 500 m), medium (500 ~1 000 m) and far (≥ 1 000 m);
	Hunters residential area dispersion (m)	vertical dimension between sample area and settlement, divided into three grade: near (≤ 500 m), medium (500 ~1 000 m) and far (≥ 1 000 m).

lynx), sable (*Martes zibellina*), and snowshoe hare (*Lepus timidus*) (Chen, 1985). The local people largely depend on the forest for their livelihood such as by collecting forest products, grazing, herding bees, collecting wild vegetables as well as by related activities such as tourism and hunting (Chen, 1985; Liao, Xie, 2011).

Data collection

We laid out eights transect lines in the reindeer habitat in summer 2012 (June–July). The transect line were laid from an elevation of 400 to 1400 m with a width of 1000 m between each transect. We walked in each transect line to search for reindeer signs (direct observation, pellets, footprints, resting site, urine deposition site, and mark). Once we encountered any sign, we laid out reindeer use plots of 20×20 m and recorded all habitat information (Table 1). At every 100 m stop, we laid out same-sized plots 50 step to the right and to the left of the transects and searched again for reindeer signs. In case we did not find any signs, we labelled the plot as non-use plot and collected same habitat variables. We used principal components analysis (PCA) and discriminate function analysis (DFA) to analyse the habitat selection function of reindeers in the study area based on the presence and absence of habitat data (Manly et al., 2002). We then performed our analysis by using SPSS (version 16.1) software.

Results

We measured a total of 72 use and 162 non-use sample plots in the reindeer habitat and recorded the habitat variables for summer season (Table 1). Continuous variables of habitat such as higher altitude, arbour availability, and ground cover were significantly different between use and non-use plots (Mann–Whitney U, $P < 0.005$); other continuous variables were not significantly different between the use and non-use plots (Mann–Whitney U, $P > 0.005$) (Table 2).

There was a significant difference in the discrete variables between use and non-use plots such as slope ($\chi 2 = 11.675$, df = 3, $P = 0.009$). Furthermore, the variables such as vegetation type, concealment, lee condition, water quantity assessment, soil moisture degree, water dispersion, and anthropogenic dispersion distance variables were also significantly different

T a b l e 2. Continuous summer habitat variable in use and non-use plots in the study area (Mean±S.E.).

Variables	**(n=72) Use plots**	**(n=162) Non- use plots**	**P Mann-Whitney U test**
Altitude	926.92 ±0.81	913.35 ±1.34	0.000**
Arbor canopy	17.86 ±2.40	9.42 ±1.46	0.000**
Arbor DBH	35.54 ±2.11	15.99 ±1.31	0.000**
Arbor density	8.21 ±0.46	4.30 ±0.37	0.000**
Arbor density	6.94 ±0.49	4.39 ±0.49	0.000**
Shrub canopy	59.38 ±2.38	57.35 ±1.90	0.794
Shrub height	54.16 ±1.98	121.61 ±7.04	0.000**
Ground-plant cover	90.50 ±0.73	91.31 ±0.57	0.023
muscus-lichen	19.37 ±1.69	15.34 ±0.97	0.849
Stump quantity	1.31 ±0.22	0.98 ±0.16	0.000**
fallen wood quantity	1.22 ±0.23	1.31 ±0.20	0.128
Grassland cover	2.57 ±0.36	5.11 ±0.34	0.013*

Notes: * Significant difference (*P*<0.05); **Most significant difference (*P*<0.01).

T a b l e 3. Discrete summer habitat variable in use and non-use plots in the study area.

Factor	Item	Frequency		Percentage (%)	
		Random plots (n=162)	Used sites (n=72)	Random plots (n=162)	Used sites (n=72)
Slope aspect	East	76	39	46.9	54.2
	West	2	0	1.2	0
	South	26	1	16	1.4
	North	58	32	35.8	44.4
	χ^2=11.675 df =3 P=0.009				
Slope gradient	Flat slope (0-20)	108	16	66.7	22.2
	Gentle slope (20-40)	39	32	24.1	44.4
	Steep gradient (>40)	15	24	9.3	33.3
	χ^2=42.731 d*f* =2 P=0.000				
Slope position	Upslope	0	1	0	1.4
	Middle slope	0	59	0	81.9
	down the slope	162	12	100	16.7
	χ^2=181.552 d*f* =2 P=0.000				
Vegetation type	Needle leaved forest	49	17	30.3	23.6
	Mixed forest	77	47	47.5	65.3
	Brush	24	0	14.8	0.00
	Meadow	12	8	7.4	11.1
	χ^2=15.207 d*f* =3 P=0.002				
Concealment	Good	24	0	14.8	0
	Fair	25	3	15.4	4.2
	Poor	113	69	69.8	95.8
	χ^2=20.313 d*f* =2 P=0.000				
Lee condition	Excellent	39	1	24.1	1.4
	Good	38	6	23.5	8.3
	Fair	67	29	41.4	40.3
	Poor	18	36	11.1	50
	χ^2=53.750 d*f* =3 P=0.000				
water quantity assessment	Large	90	70	55.6	97.2
	Quite large	20	2	12.3	2.8
	Middle	11	0	6.8	0
	Small	41	0	25.3	0
	χ^2=40.621 d*f* =3 P=0.000				
Soil moisture degree	Extremely moist	48	0	29.6	0.0
	Moist	81	33	50.0	45.8
	Dry	21	39	13.0	54.2
	Extremely dry	12	0	7.4	0.0
	χ^2=59.848 d*f* =3 P=0.000				
Water dispersion	Far	117	51	72.2	70.8
	Middle	32	21	19.8	29.2
	Near	13	0	8	0
	χ^2=7.741 d*f* =2 P=0.021				
Anthropogenic dispersion	Far	162	43	100	59.7
	Middle	0	29	0	40.3
	Near	0	0	0	0
	χ^2=74.480 d*f* =1 P=0.000				
Hunters residential area dispersion	Far	62	18	38.3	25
	Middle	71	51	43.8	70.8
	Near	29	3	17.9	4.2
	χ^2=16.417 d*f* =2 P=0.000				

Notes: * Significant difference (P<0.05); ** Highly significant difference (P<0.01).

between the use and non-use plots (Table 3, $P < 0.05$). In the summer, the reindeers used more mixed-shrub vegetation type area (65.3%; $\chi 2 = 15.207$, df = 3, P = 0.002), concealment (95.8%; P = 0.001), lee condition (50%; P = 0.001), large amount of water (97.2%; P = 0.021), soil moisture partial drying (54.2%), distance from the nearest water source (≥1000 m, 70.8%; P = 0.001), human disturbance distance (≥1000 m, 59.7%; P = 0.001), distance from the hunter's residential area dispersion (≥500 m, 95.8%; P = 0.001) habitats (Table 3).

Principal component analysis (PCA) revealed that 6 principal components could explain 68.5% of the total variance among all habitat variables (variables in 6 metrics; Table 4). First line of PCA represented arbour (eigen values cumulative 21%); second line represented lichen cover, shrubs height, and canopy (eigen values cumulative 36%); third line represented water quality; and the fourth and fifth lines represented the stump quality and fallen trees (eigen values cumulative 68%) (Table 4).

T a b l e 4. Principal component analysis (PCA) coefficients of 23 reindeer habitat variables in the study area (Variability explained 68.5%).

Variable	**Component**					
	PC1	**PC 2**	**PC 3**	**PC 4**	**PC 5**	**PC 6**
Altitude	-.171	.414	.240	-.284	-.267	.116
Arbor canopy	.771	.178	.369	-.110	.020	.095
Arbor DBH	.809	.036	.387	.020	.085	-.029
Arbor height	.666	.077	.402	.027	-.091	.023
Arbor density	.829	.145	.376	.058	.023	.030
Shrub canopy	-.499	.248	.140	.175	-.154	-.192
Shrub height	-.523	.270	.414	.267	.285	-.075
Ground-plantmuscus-lichen cover	-.108	.673	.249	.077	-.261	.081
muscus-lichen cover	.138	-.544	.053	.287	-.144	.476
Slope gradient	.361	-.125	-.025	-.354	.401	.311
Water dispersion	.396	.332	-.489	.633	-.133	.078
Anthropogenic dispersion	.214	.597	-.424	-.338	.237	.164
Hunters residential area dispersion	.361	.431	-.460	.608	-.021	.143
Concealment	.293	-.481	-.240	-.414	-.397	-.036
Slope aspect	-.210	-.185	-.060	.239	.510	.452
Vegetation type	-.577	-.168	-.342	-.108	-.072	.160
water quantity assessment	-.344	-.382	.671	.074	-.062	.146
Lee condition	.325	-.368	-.286	-.119	-.460	.242
Stump quantity	.470	-.254	-.179	.371	.059	-.461
fallen wood quantity	.278	-.700	-.168	.001	.331	-.316

Our result suggested that 6 variables, namely, the slope position, concealment, anthropogenic dispersion, arbour species, hunter distribution area, and water quality, were significantly responsible for summer habitat selection of reindeer in the unprotected forest habitat (Wilks' Lambda = 0.12; P = 0.0001; Tables 5, 6).

T a b l e 5. Variables in the analysis summer habitat selection model.

Model		Tolerance	F to Remove	Wilks' Lambda
1	Slope position	.993	559.373	.719
	Concealment	.993	33.085	.240
2	Slope position	.955	231.486	.373
	Concealment	.930	45.978	.223
	Anthropogenic dispersion	.894	30.192	.210
3	Slope position	.954	132.159	.223
	Concealment	.914	48.345	.171
	Anthropogenic dispersion	.625	83.337	.193
4	Slope position	.951	129.303	.212
	Concealment	.891	36.075	.156
	Anthropogenic dispersion	.625	79.919	.182
	Arbor DBH	.966	10.908	.141
5	Slope position	.949	111.162	.191
	Concealment	.869	25.964	.143
	Anthropogenic dispersion	.524	95.802	.182
	Arbor DBH	.948	13.510	.136
	Hunters residential area dispersion	.777	12.032	.135
6	Slope position	.947	105.198	.176
	Concealment	.815	13.515	.127
	Anthropogenic dispersion	.524	84.306	.165
	Arbor DBH	.945	14.247	.128
	Hunters residential area dispersion	.580	24.622	.133
	water quantity assessment	.609	15.065	.128

T a b l e 6. Wilk's lambda of governing factors for habitat selection of reindeers.

Model	Number of Variables	Lambda	df1	df2	df3	Exact F			
						Statistic	df1	df2	Sig.
1	2	.210	2	1	232	433.907	2	231.000	.000
2	3	.186	3	1	232	335.891	3	230.000	.000
3	4	.141	4	1	232	347.515	4	229.000	.000
4	5	.135	5	1	232	292.223	5	228.000	.000
5	6	.128	6	1	232	257.307	6	227.000	.000
6	7	.120	7	1	232	236.366	7	226.000	.000

Discussion

Our result habitat features such as the slope position, concealment, and anthropogenic factors mainly influenced the reindeers in selection of their habitat in the summer season in the unprotected forest habitat of the study area (Fig. 2). The animal habitat selection is a compre-

Fig. 2. Showing reindeer and its habitat at study area a) reindeer herd, b) male reindeer in habitat, c) female and newborn, d) female reindeer in habitat (© author: Prof. Xiuxiang Meng, 2013).

hensive countermeasure of animals adapting to the environment. The genetic characteristic and physiological property of an animal, climate, habitat properties, food, shelter, bunker, pressure of predation, and competition, all affect the habitat selection function of animals (Noel et al., 1998; Chu et al., 2009; Aryal et al., 2010, 2013, 2014a). Reindeers avoid the anthropogenic-affected areas, and similar results have been reported in other studies (Nellemann, Cameron, 1996; Vistnes, Nellemann, 2001; Pharo, Vitt, 2000). The study area (i.e., Aoluguya) is a famous tourist attraction, with summer (from June to October) being the peak tourist season with high level of tourism-related activities (Helle, Särkelä, 1993; Nelleman, Cameron, 1996; Dyer et al., 2001; Vistnes et al., 2001). The local people of this area largely depend on the forest product resources such as bee herding, collecting wild vegetables, hunting, poaching, and grazing; these activities highly influence the reindeer habitat and its behaviours, and the reindeers try to avoid such anthropogenic-affected areas.

The availability of feeding species of reindeer such as lichen as the main food source and the rising temperature of this region has largely influenced the forest production and lichen production, as lichen growth is dependent on low temperature and forest canopy (Frid, Dill, 2002). Our study suggested that food availability and canopy cover were significantly greater in the use area as compared to that in the non-use area; therefore, these factors are also responsible for habitat selection of reindeer. Therefore, this study has confirmed that reindeers are forced to choose poor habitat because of their distribution in unprotected areas has high human interference or disturbance. These factors should be considered by the concerned authority or agency to manage the reindeer population in the wild.

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CHANGES IN ALPINE VEGETATION OVER 50 YEARS IN THE WESTERN TATRAS (SLOVAKIA)

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Abstract

Palaj A., Kollár J.: Changes in alpine vegetation over 50 years in the Western Tatras (Slovakia). Ekológia (Bratislava), Vol. 37, No. 2, p. 122–133, 2018.

This paper examines changes in alpine vegetation over 50 years in the Western Tatras part of the Western Carpathians Mountains in Slovakia. We focus on the following most widespread vegetation types: subalpine to subnival grasslands (alliance *Juncion trifidi* Krajina 1933), snow-bed vegetation (alliance *Festucion picturatae* Krajina 1933) and dwarf-shrub vegetation (alliances *Loiseleurio-Vaccinion* Br.-Bl. in Br.-Bl. et Jenny 1926 and *Vaccinion myrtilli* Krajina 1933). The historical 1971–1977 sampling dataset was re-sampled in 2016–2017 and our research is based on a comparison of 40 pairs of these relevés. Herein, we studied (i) changes in species frequencies; (ii) changes in phytodiversity and site conditions using estimates of Ellenberg's eco-indices and (iii) comparison of historical and current relevés over time using the nonmetric multidimensional scaling gradient analysis (NMDS) ordination method. The frequency curves reveal differences; especially in the most frequent species at 37.5–80%, which reach higher values in the current data. The higher 7.5–25% value of medium-frequent species in the historical relevés indicates progressive homogenisation of the examined vegetation. In addition, the Shannon-Wiener index of individual vegetation types revealed no significant differences in diversity or average number of species. The historical relevés included 75 species while 74 were confirmed in the current data. Statistically significant differences were determined in light factor for all three vegetation groups. This was due to the retreat of some light-demanding species. While NMDS indicated changes in *Festucion* and *Vaccinion* relevés over time, the *Juncion* group relevés did not follow this trend, thus confirming their high stability. The observed changes between current and historical data are attributed to changes in climate and altered land use with the cessation of grazing.

Key words: alpine grasslands, snow-bed, dwarf-shrub, changes, environmental factors.

Introduction

Alpine vegetation is typical by its mosaic-like occurrence, the high presence of endemic and relic species and its dynamics (Kliment, Valachovič, 2007). The dynamics are linked to the alpine environment (Lukniš, 1973; Midriak, 1983) and climate changes (Grabherr et al., 1995; Bahn, Körner, 2003; Pauli et al., 2012). The commonly assumed high sensitivity of alpine vegetation to climate change is largely due to invasion processes, and these are most obvious in azonal vegetation types such as snowbeds and at the uppermost limits of plant life (Grabherr, 2003). This paper focuses on alpine vegetation changes in the Western Tatras Mountains influenced also by land use changes that especially include the cessation of cattle and sheep grazing in the mid-1980s when this area was declared a national park (Bohuš, 1994). This is crucial for alpine vegetation changes, since the absence of grazing leads to significant accumulation of plant litter (Virtanen, 2000) and some species are vulnerable to decline or disappearance, especially those with annual life cycles and species that require canopy gaps for recruitment (Erschbamer et al., 2003).

Historical vegetation of the study area was sampled in the 1970s (Horák, 1970, 1971; Turečková, 1974; Dúbravcová, 1976; Dúbravcová et al., 1976; Pietorová, 1977). This inspired our analysis of alpine vegetation changes over the last decades. Herein, we focus on the most widespread vegetation types. These are the subalpine-to-subnival grasslands (alliance *Juncion trifidi* Krajina 1933), snow-bed vegetation (alliance *Festucion picturatae* Krajina 1933) and dwarf-shrub vegetation dominated by *Vaccinium* genus species.

Methods

Study area

The study area covers the 34 km² in the Jamnícka and Račkova valley parts of the Western Tatras Mountains. This area is formed from granite, migmatite and various metamorphic rocks (Nemčok, 1994) and has Podzols soils that follow Cambisols spread at lower altitudes (Šály, 1964). The area also lies in the cold climate region (Plesník, 1974). The 1966–2016 temperature data were recorded at Kasper Peak meteorological station and were supplied by the Polish Institute of Meteorology and Water Management. Situated at 1,959 m a.s.l., this station is close to our study area and it established a mean annual temperature of 0.35 °C, with an average maximum of 7.81 °C in the warmest month and an average minimum of –7.95 °C in the coldest month. The 1966–2016 average monthly temperatures show a fluctuating course (Fig. 1). Long-term measurements from the Skalnaté pleso meteorological station at 1,786 m a.s.l. in the neighbouring High Tatras Mountains revealed a shift from a relatively warmer period in 1941–1960, through mild cooling in 1961–1990 to a warm period after 1990. The registered increase in average annual temperatures was 0.8–1.7 °C in 1991–2012 and 1.2 °C between 2005 and 2012 (Hlavatá, 2013). The highest point in the study area is the Bystrá peak at 2,248 m a.s.l., and this is also the highest peak in the Western Tatras. The timber line at 1,400–1,500 m a.s.l. is affected by historical land use.

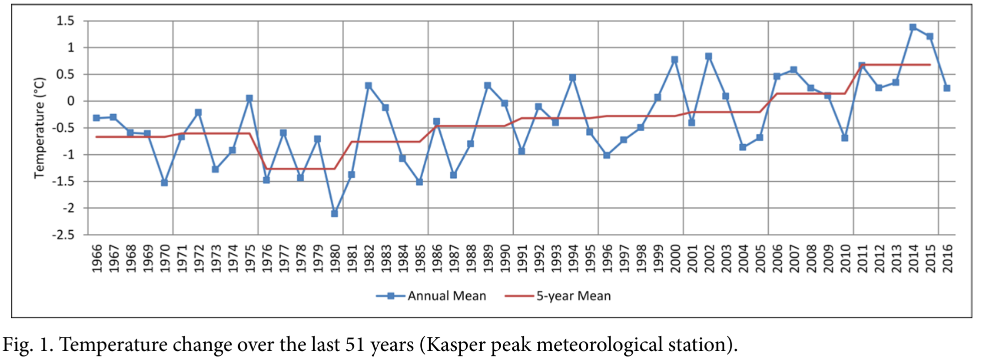

Fig. 1. Temperature change over the last 51 years (Kasper peak meteorological station).

Data sampling and analysis

Relevés were sampled in 2016–2017. The method of generalization of long-term monitoring sites and pair comparison is used to estimate changes in plant communities (Hédl, 2005). We resampled historical relevés of 1971–1977 stored in the Central database of phytocoenological relevés (CDF) (Hegedüšová, 2007; Šibík, 2012). The methods of Zürich-Montpellier School of Phytosociology (Braun-Blanquet 1964) were used to research plant communities. The 7-figure Braun-Blanquet scale was used to estimate species coverage, and while vascular plant nomenclature was modified according to Marhold, Hindák (1998), cryptograms are not included. A major part of the phytocoenological relevés, encompassing alliances *Festucion picturatae* and *Juncion trifidi*, was published in our previous study (Palaj, Kollár, 2017). Our syntaxonomical classification of the studied vegetation agrees with Jarolímek et al. (2008). The only exception here is the dwarf shrub vegetation, which we treated as a single vegetation type under the *Vaccinion* group because this includes communities similar in floristic composition, physiognomy and ecology. Statistical analysis of the phytocoenological relevés is based on comparison of 40 pairs of relevés; *Festucion* has 14 pairs, *Juncion* 17 and *Vaccinion* 9. The analysis included the following: (i) changes in species frequencies; (ii) changes in phytodiversity and site conditions estimated by Ellenberg's eco-indices and (iii) comparison of historical and current relevés over time, using the nonmetric multidimensional scaling ordination method (NMDS). Species frequency is expressed in percentages for all three vegetation groups in both historical and current relevés. The resultant values are depicted in frequency curves for all relevés and the relative frequency change for each group is shown separately (Magurran, 2004). Shannon–Wiener (SW) and evenness indices are calculated for all historical and current relevés and the values compared in box plots. Historical and current site conditions are estimated by bioindication using Ellenberg's eco-indices (Ellenberg et al., 1992) by employing Juice software (Tichý, 2002). The box plots provide results and the paired *t*-test was performed using RStudio software (RStudio Team, 2015). Relevé (di)similarity is estimated by NMDS indirect ordination methods with the RStudio Vegan package (Oksanen et al., 2017). Finally, NMDS is performed on log-transformed data using Bray–Curtis dissimilarity matrix, and species abundances are included in all analysis.

Results

Species frequency changes

Frequency curves (Fig. 2) reveal the differences, especially in species 1–15 where the most frequent species (37.5–80%) occur more frequently in current data and therefore have higher

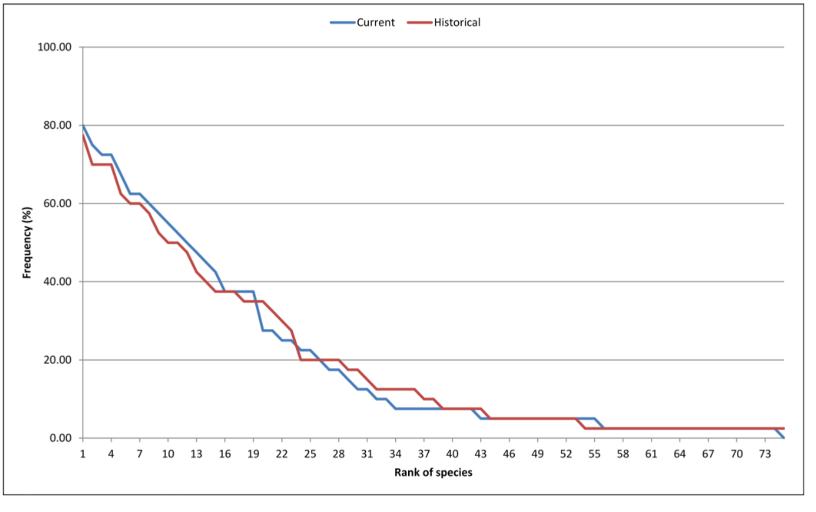

Fig. 2. Frequency curves of all species in the historical and current relevés groups. Species are ranked in descending order of frequency.

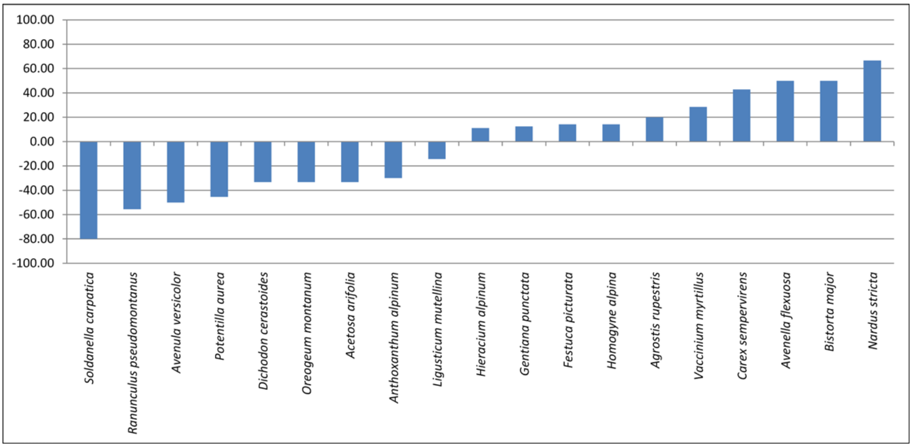

Fig. 3. Relative change in species frequency in the *Festucion* group.

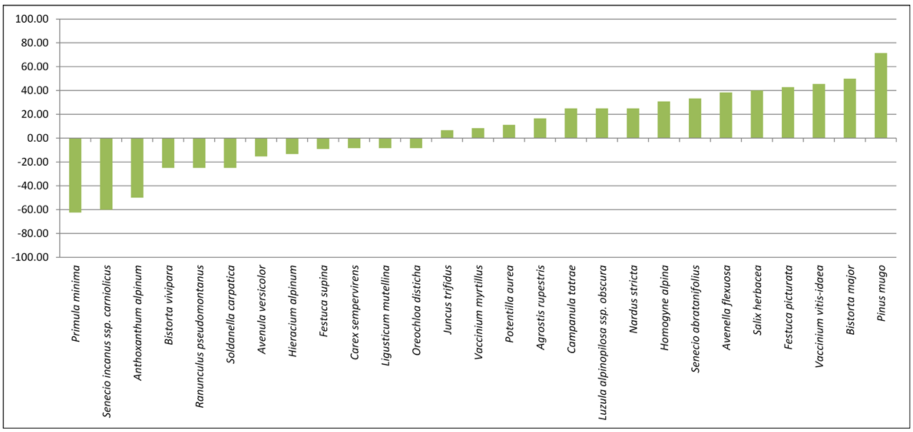

Fig. 4. Relative change of species frequencies in the *Juncion* group.

values. In contrast, species 19–39 has a frequency of 7.5–25% and higher values in the historical relevés. The historical data also included 75 species compared to 74 in our re-sampled relevés.

Relative frequency changes are shown for species with frequency exceeding 10% in the historical and current relevés. There is an obvious decrease in the frequency of current relevés in the *Festucion* group (Fig. 3). This is especially noted in alliance *Festucion picturatae* diagnostic species, including *Doronicum stiriacum* (-80%), *Soldanella carpatica* (-80%), *Ranunculus pseudomontanus* (-55.6%) and *Potentilla aurea* (-45.5%). These species are replaced by contact vegetation diagnostic species (classes *Caricetea curvulae*, *Loiseleurio-Vaccinieta* and *Nardetea strictae*). Important examples here are *Nardus stricta* +66.7%, *Vaccinium myr-*

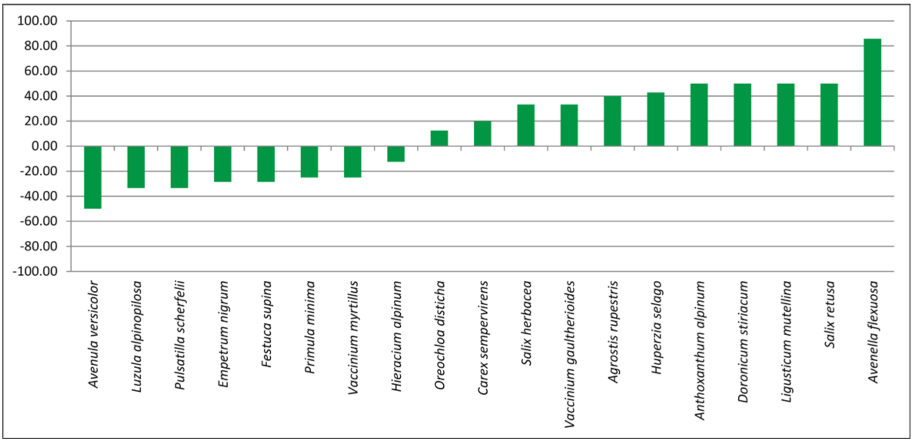

Fig. 5. Relative change in species frequency in the *Vaccinion* group.

tillus +28.6%, *Agrostis rupestris* +20% and *Hieracium alpinum* +11.1%. Additional species noted in current data include *Campanula serrata, Cardaminopsis neglecta*, *Primula minima*, *Juncus filiformis*, *Silene acaulis, Viola lutea* subsp. *sudetica, Achillea millefolium* subsp. *alpestris, Bartsia alpina, Carex nigra, Poa alpina, Pulsatilla scherfelii* and *Vaccinium gaultherioides*. In contrast, the following species recorded in historical relevés are absent in current re-sampling: *Leucanthemopsis alpina, Rhodiola rosea, Poa granitica*, *Campanula tatrae, Adenostyles alliariae, Cerastium fontanum, Omalotheca supina* and *Sedum alpestre.*

Juncion vegetation group (Fig. 4) has an obvious increase in tree species, including *Pinus mugo* (+71.4%) and *Juniperus communis* (+66.7%). *Sorbus aucuparia* (+100%) was also sampled in one relevé. From neighbouring vegetation, especially from tall herb communities, *Gentiana punctata* (+100%), *Bistorta major* (+50%), *Festuca picturata* (+42.9%), *Avenella flexuosa* (+38.5%) and *Luzula alpinopilosa* subsp. *obscura* (+25%) have also penetrated. Current data also established an obvious decrease in the frequencies of *Primula minima* (-62.5%), *Senecio incanus* subsp. *carniolicus* (-60%) and *Anthoxanthum alpinum* (-50%). Additional species were recorded only in current relevés. These included typical alpine species, such as *Carex bigelowii, Gentiana punctata*, *Carex atrata* and *Ligusticum mutellinoides* as well as species inhabiting lower altitudes, including *Calluna vulgaris, Luzula sylvatica, Sorbus aucuparia, Dryopteris filix-mas, Hieracium murorum, Luzula luzuloides* and *Acetosa arifolia.* In contrast, the following species were recorded only in historical relevés: *Euphrasia tatrae*, *Pseudorchis albida, Diphasiastrum alpinum, Antennaria dioica, Carex flava, C. nigra, Phleum rhaeticum, Poa alpina, Pyrola minor, Selaginella selaginoides* and *Tofieldia calyculata*.

The *Vaccinion* vegetation group revealed changes in frequencies for *Avenella flexuosa* (+85.7%) and *Avenula versicolor* (-50%) (Fig. 5). The character and physiognomy of this vegetation is determined mainly by small shrubs, such as *Empetrum nigrum, Vaccinium myrtillus* and *V. vitis-idea*. Their current frequency, however, matches historical values. *Vaccinion* species recorded only in current data include *Nardus stricta, Pinus mugo* and *Veratrum* *album* subsp. *lobelianum* and those sampled historically account for *Calamagrostis villosa, Potentilla aurea, Senecio incanus* subsp. *carniolicus* and *Soldanella carpatica.*

Changes in diversity and site conditions

Differences in diversity and site conditions were analysed by paired *t*-test. The null hypothesis contended that historical and current data are not significantly different (α=0.05) (Table 1), and significant results are presented by box plot (Fig. 6). The *t*-test results revealed no obvious differences in diversity or in the average number of species over the last 50 years. In *Festucion* group the average number of species decreased from 14.8 to 12.9 and the SW index decreased from 1.77 to 1.57, but these changes were not statistically significant. In *Juncion* group, the SW index increased marginally from 1.96 to 2.05 and average species number from 17.02 to 17.51. In *Vaccinion* group, similarly, the SW increased from 1.78 to 1.84 and the average number of species increased by 0.45. In contrast, statistically significant differences were established in light factor

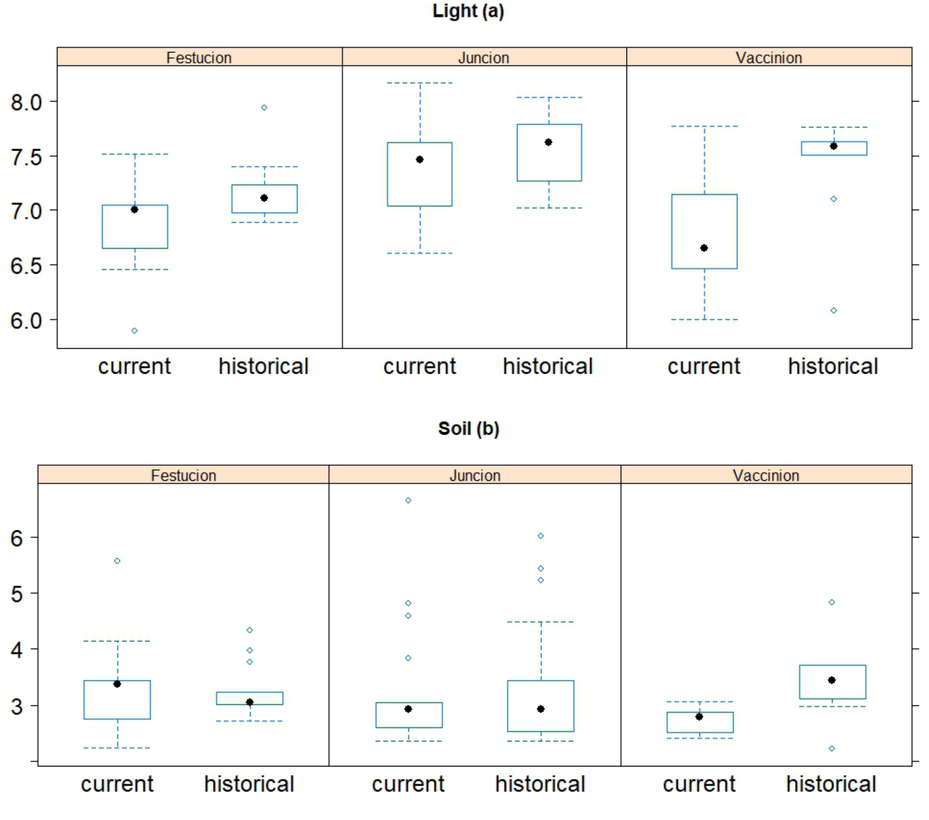

Fig. 6. Comparison of historical and contemporary site conditions estimated by Ellenberg's eco-indices (a, b).

T a b l e 1. Comparison of average values for historical and contemporary site conditions estimated by Ellenberg's eco-indices and results of the Paired t-test. Abbreviations: SW – Shannon-Wiener index, E – evenness index, NOS – number of species, temp – temperature, cont – continentality, mois – moisture, soil – soil reaction, nut – nutrients.

		SW	E	NOS	light	temp	cont	mois	soil	nut
Festucion	Historical	1.768	0.657	14.804	7.194	2.282	2.900	5.617	3.097	2.784
	Current	1.568	0.620	12.899	6.911	2.511	3.063	5.595	3.086	2.838
	t	1.238	0.465	1.738	2.189*	-1.861	-0.912	0.702	-0.482	-0.117
	p-value	0.238	0.650	0.106	0.047	0.085	0.379	0.495	0.638	0.909
Juncion	Historical	1.963	0.713	17.015	7.547	2.146	2.894	4.666	3.485	2.102
	Current	2.050	0.719	17.515	7.371	2.237	2.941	4.671	3.356	2.196
	t	-1.048	-0.656	-0.550	2.515*	-0.989	-0.929	-0.038	0.954	-0.865
	p-value	0.310	0.521	0.590	0.023	0.338	0.366	0.970	0.354	0.400
Vaccinion	Historical	1.781	0.694	13.222	7.388	2.461	3.820	5.129	3.407	2.119
	Current	1.837	0.711	13.667	6.821	2.453	3.768	4.908	2.733	2.272
	t	-0.330	-0.397	-0.222	3.234*	0.081	0.407	2.276	3.094*	-1.311
	p-value	0.750	0.701	0.830	0.012	0.937	0.694	0.052	0.015	0.226
										Significance level: 0.05*

for all three groups. Light-demanding species not found in re-sampled sites included *Antennaria dioica, Diphasiastrum alpinum, Pseudorchis albida, Selaginella selaginoides* and *Tofieldia calyculata*. A significant decrease in soil reaction in the *Vaccinion* group is also observed.

NMDS ordination diagram of historical and current relevés

Figs 7 and 9 illustrate that NMDS ordination distinctly separated the historical and current relevés of *Festucion* and *Vaccinion*. This indicates that these vegetation types experienced a change in the studied period. However, the distribution of *Juncion* group relevés does not follow this pattern, and Fig. 8 highlights its stability in species composition and abundance.

Discussion

Our results on changes in the species *Festucion*, *Juncion* and *Vaccinion* mostly correspond with other authors' findings. With regard to climate change influences, Schei et al. (2015) report a similar pattern in species frequency changes in central Norway. This is explained by climate change, because some species‘ adaptation to gradual climate change is limited by competition with relatively thermophilous species migrating from lower altitudes (Abeli et al., 2012). Here, the *Festucion* group follows snowbed vegetation, which is the most sensitive to climate change, and similar species penetration from adjacent communities has also been observed in the Italian Rhaetian Alps (Carbognani et al., 2014). This phenomenon, and especially the increase in *Vaccinion* dwarf shrub abundance, is attributed to reduced snow cover duration and prolongation of the growth period (Klanderud, Birks, 2003; Cannone et al., 2007; Elmendorf et al., 2012; Grytnes et al., 2014; Vanneste et al., 2017). This increased dwarf shrub frequencies is also reported in other alpine habitats (Körner, 2003; Walker et al., 2006; De Witte, Stöcklin, 2010; Gottfried et al., 2012, Hedenås et al., 2016; Vanneste et al., 2017). Animal grazing is also implicated in frequency changes of species, with recognised trends due to reduction or cessation of grazing (Olofsson et al., 2001). However, the distinct increase in *Nardus stricta*'s frequency in the *Festucion* group is surprising because it does not agree with other authors' findings, which have reported the retreat of this species after a reduction in grazing (Austrheim et al., 2007; Speed et al., 2014; Korzeniak, 2016).

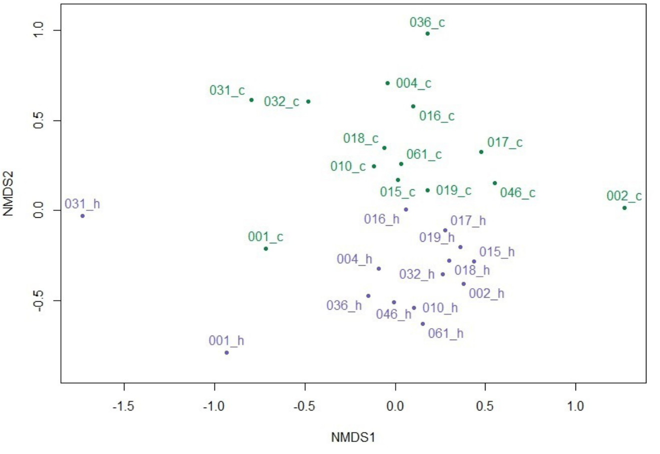

Fig. 7. NMDS ordination diagram (k=3) showing the distribution of current and historical relevés of *Festucion* vegetation group. Suffix _h indicates historical relevés.

The relatively high stability of *Juncion* communities over time, especially the unchanged frequency of dominant graminoids, is supported by the findings of Grabherr (2003) and Dúbravcová and Jarolímek (2007). Here, the increased frequency of reptile chamaephytes (*Calluna vulgaris, Vaccinium myrtillus, V. vitis-idaea*) appears linked to land use and climate changes. The most significant changes were found in dwarf pine stands (*Pinus mugo*) at lower altitudes. These are considered less typical in species composition (Zeidler et al., 2010). Neighbouring dwarf pines also affect both spatiotemporal snow distribution and airflow (Liston et al., 2002) and these altered site conditions gradually change the structure of communities that require strong, permanent winds because of their intolerance to deep snow. Expansion of dwarf pines and other tree species (*Juniperus communis, Sorbus aucuparia*) causes retreat of light-demanding species such as *Primula minima*, *Senecio incanus* subsp. *carniolicus* and *Avenula versicolor*. Similar trends have been reported in the Hrubý Jeseník Mts. alpine zone (Zeidler et al., 2010). The edge-

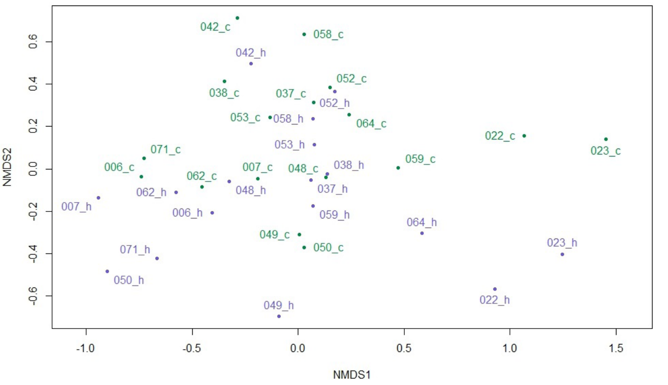

Fig. 8. NMDS ordination diagram (k=3) showing the distribution of current and historical relevés of *Juncion* vegetation group. Suffix _h indicates historical relevés.

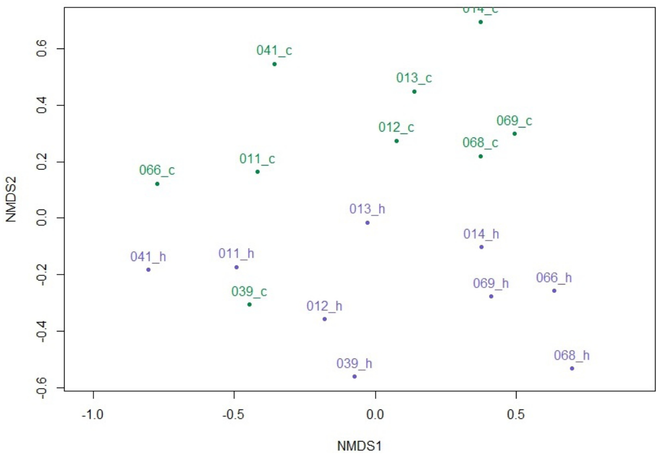

Fig. 9. NMDS ordination diagram (k=3) showing the distribution of current and historical relevés of *Vaccinion* vegetation group. Suffix _h indicates historical relevés.

effect of dwarf pine stands also establishes conditions for nutrient-demanding species from lower altitudes including *Dryopteris filix-mas, Hieracium murorum* and *Luzula luzuloides* (Soukopová et al., 2001).

While there was no change in *Vaccinion* group frequencies of small shrubs that determine stand physiognomy, the results indicate competition with increased *V. gaultherioides* and decreased *V. myrtillus*. Although similar results were reported by Gerdol et al. (2000) these were not confirmed in later research (Brancaleoni, Gerdol, 2006). *Vaccinium vitis-idea* is the most sensitive reptile chamaephyte noted in climate change studies. While Kudo and Suzuki (2003) reported that it is suppressed by other small shrubs, especially *V. myrtillus*, we did not confirm this suppression. Acidophilous small shrub communities are considered very stable at high altitudes, but their succession can lead to dwarf pine stands (Šibík et al., 2007). This trend is indicated in our results by increased *Pinus mugo* frequency recorded in three relevés at lower altitudes, and together with strongly competitive species such as *Avenella flexuosa* and *Veratrum album* subsp. *lobelianum*, it has led to significant changes in Ellenberg indicator value for light. Increased soil reaction is caused by increased frequency of *Agrostis rupestris, Avenella flexuosa* and *Huperzia selago* and abundance at lower altitudes. Šmarda (1963) adds that soil reaction can also be changed by increased frequency of *Nardus stricta*, which strongly acidifies soils.

Although our studied vegetation groups include communities with different ecological demands, all three show significant changes in light conditions. The noted decrease in light-demanding species and those preferring nutrient-poor soils is related to grazing cessation (Witkowska-Žuk, Ciurzycki, 2000; Johansson et al., 2011; Korzeniak, 2016).

While our results show that changes in community structures are not generally reflected in diversity loss, exceptions here are a decrease in the light-demanding species such as *Antennaria dioica, Diphasiastrum alpinum, Pseudorchis albida, Selaginella selaginoides* and *Tofieldia calyculata*. Species competition is also evident in this study. Decrease in small species population density is often caused by competitive increase in taller neighbouring species (Tilman, 1988). Grazing cessation is also accompanied by promotion of expansion of phanerophytes, reptile chamaephytes and tall grasses. Our example of such a good competitor is *Avenella flexuosa* with its distinct 53.1% increase in frequency, and this is supported by similar trend in alpine pastures in the Polish part of the Tatras Mountains (Korzeniak, 2016) and in former alpine pastures in southern Norway

(Austrheim et al., 2007; Speed et al., 2014). The recovery and competitive ability of this species is largely due to cessation of previous vast cattle grazing. Further consequence of grazing cessation is seen in the accumulation of biomass, which has no consumers (Šmarda, 1963), and subsequent decomposition is limited by the harsh alpine climate (Gavazov, 2010). This also suppresses the terophyte and geophyte reproduction confirmed in this research by the decreases in the following species: *Euphrasia tatrae* (-100%), *Veronica alpina* (-100%), *Carex nigra* (-50%) and *Doronicum stiriacum* (-37.5%).

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CHANGES IN WOODLAND COVER IN THE KARVINÁ DISTRICT FROM THE SECOND HALF OF THE 18th CENTURY TO THE BEGINNING OF THE 21st CENTURY

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Abstract

Popelková R.: Changes in woodland cover in the Karviná district from the second half of the 18th century to the beginning of the 21st century. Ekológia (Bratislava), Vol. 37, No. 2, p. 134–151, 2018.

This study analyses the changes in woodland cover from the mid-18th century to the turn of the 21st century in a distinctive region of the Czech Republic – the Karviná district. This region has been substantially affected by the process of industrialisation during the 19th and 20th centuries, which transformed a formerly agricultural landscape into a landscape heavily impacted by underground coal mining and related landscape processes. The occurrence of woodland cover in the Karviná district was determined from historical military maps (second half of the 18th century, first half of the 19th century, second half of the 19th century, first half of the 20th century) and from a colour orthophoto (2017) verified with reference to a contemporary map. The article interprets the occurrence of woodland cover depicted in the abovementioned sources and presents an interpretative key. The vectorisation of the woodland cover and the analysis of temporal–spatial changes in woodland cover were conducted using ArcGIS 10 software.

Key words: industrialization, afforestation, deforestation, military mapping, orthophoto.

Introduction

The contemporary landscape is a result of the action of both natural and anthropogenic factors. Human activity has created a wide range of different landscape types, from natural landscapes through cultural landscapes to anthropogenically transformed landscapes (Van der Zee, 1999). Humans tend to cause short-term, dynamic landscape changes. Anthropogenic effects occur most commonly in areas that are intensively exploited by humans (e.g. for mining, intensive agriculture or forestry) or that are adapted by humans for their own use (e.g. new built-up areas). The social and economic changes that began in Europe in the late 18th century (and subsequently also occurred in other continents) caused a marked acceleration of landscape changes.

Landscape changes can be understood as a modification of landscape structure over the course of time (Leitao et al., 2006). A quantitative analysis of landscape change can be conducted by analysing temporal–spatial changes in land use or land cover; valuable sources of information are historical maps (Hersperger, Bürgi, 2009) and aerial/satellite image time series (Oťahel, Feranec, 1999; Kučera, Guth, 1999; Cooper, Loftus, 1998; Plieninger, 2006; Feranec et al., 2007; Sleeter et al., 2013; Sexton et al., 2013 etc.).

The land-cover change is a main component of global change. Board land change patterns and processes and their main driving forces were examined in Central and Eastern Europe during distinct periods of the past 250 years (Munteanu et al., 2014). A total of 66 papers that were based on spatially explicit data (historic maps, aerial photographs and satellite imagery) and that captured gradual changes since the peak of the Austro-Hungarian Empire up to the accession to the European Union of most of the formerly socialist countries in the study region are analysed. The study is focused on agricultural (agricultural expansion, abandonment) and forest (afforestation, deforestation). In terms of the drivers, institutional and economic factors were most influential in shaping deforestation and agricultural expansion, whilst socio-demographics and institutional shifts were the key drivers of land abandonment. The study highlights the drastic effects that socio-economic and institutional changes can have on land-use and land-cover change and the value of longitudinal studies of land change to uncover these effects. Plieninger et al. (2016) analysed 144 studies that identify the proximate and underlying drivers of landscape change across Europe. They found out that land abandonment is the most frequent driver of landscape change in Europe. In some regions of the world such as the Northern Hemisphere, the abandonment of agricultural land is one of the most widespread forms of land use change. In general, abandonment is followed by colonisation by herbaceous and woody plants. Rühl et al. (2015) analysed afforestation in large areas of southern Italy. Selby et al. (2005) investigated how farmers and rural advisors perceive forests, forestry and afforestation in the context of rural development in three Finnish regions. Abandonment of agricultural land in Europe has been investigated by Lasanta et al. (2017). A general view of the extent of abandoned land, the stages of abandonment and the drivers that manage this process in Europe is presented. Lieskovský et al. (2015) analysed the extent and driving forces of the abandonment of traditional agricultural landscape in Slovakia. One of their findings is that 50% of Slovak traditional agricultural landscapes are partly abandoned or abandoned. Hersperger and Bürgi (2009) quantified the importance of driving forces of landscape change in five municipalities near Zurich in Switzerland from the 1930s to the beginning of the 21st century. Their study is mostly focused on urbanisation and agricultural intensification. Expansion/intensification of forestry using aerial photos from the mid-20th century was observed on two sites in Spain (Plieninger, 2006). The main goal of this study is to provide quantitative information on loss, fragmentation and alteration of holm oak. There was initially a marked decrease in the area of woodland, followed (from the 1980s onwards) by an increase. Plieninger and Bieling (2012) focused on dehesa (it is multifunctional type of agroforestry) landscapes in the part of Spain. Essex and Williams (1992) studied intensive afforestation on Dartmoor (England) from the first half of the 20th century and evaluated its ecological effects.

The research presented in this article focuses on changes in woodland cover in the Karviná district (Czech Republic) and identifies processes of afforestation and deforestation. It characterises the temporal–spatial changes in the distribution of woodland cover between selected points in time, tracing the two abovementioned processes during the intervening periods. Details of preserved original woodlands are also given. The processes of afforestation and deforestation were traced based on the data that captured temporal–spatial changes in woodland cover for a lengthy period of time, from the mid-18th century to the beginning of the 21st century. The multi-temporal analysis was based on the historical military maps (second half of the 18th century, first half of the 19th century, second half of the 19th century and first half of the 20th century) and from a colour orthophoto (2017) verified with reference to a contemporary map.

Study area

The Karviná district (Czech: okres Karviná) is situated in the north-eastern part of the Moravian-Silesian Region (in the easternmost part of the Czech Republic). The district was created in 1960 during a reorganisation of territorial administrative units within Czechoslovakia. It covers an area of 356 km^2 and consists of 17 municipalities, of which 7 have city status. The delineation of the study area is shown in Fig. 1.

The study area consists of flat or gently rolling terrain, without major hills/mountains or terrain breaklines. The land relief falls into two distinct parts; the divide runs approximately along the Havířov–Chotěbuz rail line. The larger northern part belongs to the Ostrava basin. The terrain here is slightly rolling, with numerous bodies of water; there are extensive underground mine workings, and in places, the ground has experienced substantial subsidence. The coal-bearing sediments of the Ostrava basin lie below tertiary and quaternary layers. The smaller southern part of the study area consists of low hills; here the nature of the terrain is more similar to the Beskydy mountains (which lie to the south). There is more variation in elevation in this southern part of the study area, and it is less affected by human activity, with numerous natural structures.

The hydrological system of the Karviná district forms part of the Odra River drainage basin, which belongs to the Baltic Sea catchment basin. The area covered by standing and flowing water bodies is larger than the national average. Two of the main rivers in the district delineate the border with Poland (the Olše River in the north and the Odra River in the west). At the northernmost point in the district is the confluence of these two rivers; the Odra then leaves the territory of the Czech Republic and flows northwards through Poland. There are numerous standing bodies of water in the district, both large and small.

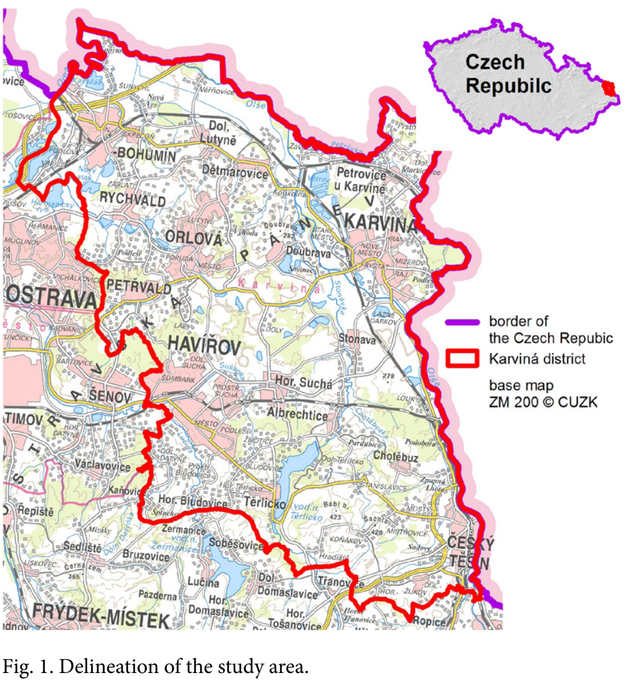

Fig. 1. Delineation of the study area.

The Karviná district has experienced substantial temporal–spatial landscape changes, many of which are immediately visible to the observer. Underground coal mining and the development of heavy industry have had a major effect on changing woodland cover in the Karviná district; part of the Ostrava-Karviná coalfield covers around one-third of the district's total area (Mulková et al., 2016). Originally a developed agricultural region, the study area began to undergo a marked transformation following the discovery of coal in Karviná (1776). During the 19th century, the region became industrialised, with many coal mines and related industrial facilities established. The massive development of heavy industry following the communist takeover in 1948 further contributed to the transformation of the region, bringing major investments in coal mining together with an influx of new workers and the construction of extensive new housing schemes (Havířov, Karviná, Orlová), accompanied by the devastation of large areas of the landscape and some original buildings. During the 1980s, the coal mining industry began to stagnate, as the volumes of coal extracted from the mines in the district decreased because of the progressive exhaustion of the easily workable deposits. The early 1990s brought a rapid restructuring of the economy on a nationwide scale, and heavy industry went into rapid decline. In the Karviná district, this change was manifested in the closure of coal mines that were no longer economically viable (Popelka et al., 2016).

Materials

The sources that help us learn about past land cover/land use are rather wide. Primarily, archive aerial photographs, old maps and cadastral maps belong to such sources. The historical data for the study was taken from the analysis of maps produced for military purposes from the 18th to the 20th century; the current data was taken from a colour orthophoto (2017) verified with reference to a contemporary map.

The first systematic mapping of the Bohemian Crown Lands (i.e. the provinces of Bohemia, Moravia and Habsburg Silesia, which together make up the territory of today's Czech Republic) took place in the second half of the 18th century, in connection with the Wars of the Austrian Succession. In 1763, following the Habsburg Monarchy's military failure in the Seven Years' War, Empress Maria Theresa had military maps drawn up for all the Habsburg provinces. The first complete series of maps – known as the 'military maps' or the 'Josephine maps' after Emperor Joseph II – was completed in 1785 (Semotanová, 2001). The majority of the Monarchy's territory was mapped at a relatively large scale (1:28,800), which was known as the 'simple scale' (Boguszak, Císař, 1961). The province of Austrian Silesia (of which today's Karviná district formed a part) was mapped relatively early, in 1763, because of its strategic location on the border with Prussia. The Silesian maps consisted of 40 sections and covered the Duchies of Teschen (now Těšín/Cieszyn), Troppau (Opava), Jägerndorf (Krnov) and Neisse (Nysa). The original maps were inadequate in terms of both planimetry and topography, so in 1780, a total of 30 sections were remapped, and the remaining 10 sections were corrected. Unlike most of the other military maps, the scale used for the new maps was 1:30,746 (Kuchař, 1967).

This first series of military maps is a valuable source of comparative data because it covers the whole of the Bohemian Crown Lands, and the scale of the maps makes them ideal for studying landscape changes. However, the planimetric content of the maps is problematic; the surveyors did not use a single trigonometric network, and different methods were used in the different provinces (Crown Lands). The resulting planimetric deformations make these maps unsuitable for purposes of precise quantitative analysis – although the first military maps are more precise than the previous maps drawn up by Johann Christoph Müller (Boguszak, Císař, 1961; Mikšovský, Zimová, 2006). However, despite these problems, most researchers, nevertheless, consider the first military maps to be an important source of information on the landscape of the Bohemian Crown Lands during the final third of the 18th century (Hauserová, Poláková, 2015). The original hand-drawn sections of the first military maps are held at the Österreichisches Staatsarchiv in Vienna; copies of the maps of the Bohemian Crown Lands are available at the National Archives (Národní archiv) in Prague and also at the Geoinformatics Laboratory of the J. E. Purkyně University in Ústí nad Labem, where the first, second and third series of military maps have been digitalised.

By the turn of the 19th century, the first military maps were no longer able to cope with increased demands on their level of accuracy. In 1806, Emperor Franz I, therefore, ordered an astronomic and geodetic survey to be conducted in order that a trigonometric network could be built (Semotanová, 2001). This enabled cartographers to produce very detailed cadastral maps at a scale of 1:2,880, followed by a second series of military maps (1:28,800), known as the 'Franz maps'. The second series of military maps covering the Bohemian Crown Lands were not produced until the 1830s and 1840s; they were based on the cadastral trigonometric networks. The provinces (Crown Lands) of Moravia and Austrian Silesia were mapped in 1836–1840 (Boguszak, Císař, 1961; Čada, 2006). This second series of military maps is an excellent source of information for tracing landscape changes, for a number of reasons. Their scale is ideal, and the planimetric content of the maps is precise. In addition, the second series of military maps (like the so-called 'imperial prints' of the stable cadastral maps) capture the landscape at a crucial turning point – a time when the modernisation processes associated with the Industrial Revolution and the transformation of society were becoming particularly intense and widespread.

The military defeat of the Habsburg forces in the Austro-Prussian War (1866) ultimately led to the production of a third series of military maps, which were updated and amended (Boguszak, Císař, 1961). Austrian Silesia and eastern Moravia were remapped in 1876, followed by the remaining parts of the Bohemian Crown Lands (completed in 1879). The maps featured the so-called 'simple scale' that used the decimal system (in anticipation of the expected introduction of the metric system) at a scale of 1:25,000; a scale of 1:12,500 was used for areas of particular military interest. The third series of military maps was based on trigonometric points taken from the rectilinear cadastral grid. The graphic planimetric basis for the maps was a reduced-size version of the cadastral maps (reduced from 1:2,880 to 1:25,000). The original topographic sections were produced with 11 colours; the copies were either coloured or (for larger print runs) black and white (Boguszak, Císař, 1961).

This third series of military maps remained the official maps of Czechoslovakia until after the Second World War; they were replaced by new military topographic maps in 1956. The third series of military maps enable the identification of landscape features (commensurate with their scale) for purposes of comparison (Sklenička, 2003).

The surveying for the new topographic maps – which are still used today – was conducted between 1953 and 1957. A total 1736 military topographic map sheets were produced at a scale of 1:25,000. The maps used symbols that had been universally introduced throughout the Warsaw Pact countries. These military topographic maps were followed by topographic maps at smaller scales, which were used as the standard official maps.

To determine the occurrence of woodland cover today, the most recent available orthophoto (2017) was used. In order to maximise comparability with the data from the other maps, data from ZABAGED and the current 1 : 25 000 basic map were used to verify all vectorised areas.

Methods

The relevant sheets from the first, second and third military map series were acquired in digital form from the Geoinformatics Laboratory of J. E. Purkyně University in Ústí nad Labem. The topographic maps from the 1950s were digitalised by scanning. The individual sheets for each of the selected years were then cropped, combined into a single image, and georeferenced. The maps were transformed into the S-JTSK coordinate system via ArcGIS 10 software, using identical ground control points. When georeferencing old maps, it is best to use topographic elements as ground control points, because their position remains stable over the course of time; naturally, if using current reference data, it is essential to select topographic elements that still exist today. These include road junctions, church towers or other buildings that are still standing, pond floodgates and (if no other suitable points exist) river confluences. If older (i.e. non-current) reference data are used, it is easier to identify suitable ground control points.

Georeferencing the first series of military maps is highly problematic. In view of the method that was used to create the maps, the transformation into the S-JTSK system is only approximate. It was also difficult to find suitable ground control points for these maps. The officers from the military surveying authority paid considerable attention to recording roads, rivers and streams and also land use and building use. Road junctions (and occasionally buildings) were used as the ground control points. Despite the problems with georeferencing and accuracy, the first series of military maps represents a rare source of information on the 18th-century landscape, particularly because of their scale and level of detail. For this reason, these maps were included in the analysis of temporal–spatial changes in woodland cover. When georeferencing the maps, affine transformations (first-order polynomial transformations) were used. Currently, the military maps from the second series are available via the map server of the national geoportal INSPIRE. The accuracy of the transformation of the previously georeferenced map sheets from this second series was verified by overlaying them on the same maps displayed via the map server.

It was not necessary to carry out any adjustments to the 2017 orthophoto. It was displayed via the map services of the Czech Surveying and Land Registry Authority (Český úřad zeměměřičský a katastrální, ČÚZK). The orthophoto from the ČÚZK ArcGIS server was displayed using ArcGIS software in the S-JTSK coordinate system.

The occurrence of woodland cover in the 18th, 19th and 20th centuries was determined from the transformed historical maps. The symbol for woodlands in the third series of military maps (at 1:25,000 scale) is not always clearly distinguishable on the maps. For this reason, the location of the woodlands was verified using the special 1:75,000 military maps from the third series, which clearly mark woodland areas in green. The special maps were displayed in ArcGIS via the WMS service of the public administration portal. When determining the occurrence of woodland cover from the military topographic maps, an orthophoto from the 1950s was used to verify the data and provide clarification in disputed cases.

In order to ensure that the 21st-century data are as recent as possible, the current occurrence of woodland cover was determined via a visual photointerpretation of the most recent orthophoto (2017). The maps were generalised at the time of production, whereas the generalisation of the orthophoto to 1:25,000 had to be carried out during vectorisation. The occurrence of woodland cover was verified using ZABAGED data and the current 1:25,000 basic map, displayed via the map services of the Czech Surveying and Land Registry Authority (WMS – ZABAGED® and WMS – ZM 25). The minimum vectorised polygon (1700 m^2) was derived from the minimum size of the vectorised polygons from the historical maps, taking into account the scale (1:25,000). Vectorisation (using ArcGIS software) took place whilst determining woodland cover occurrence from the maps.

Vector layers were created for the woodland cover at each individual analysed point in time. On the basis of the processes under investigation (deforestation and afforestation), the temporal–spatial changes in woodland cover in the Karviná district were determined.

These processes can be defined broadly, including long-term natural processes (geomorphological processes, climate change), difficult-to-predict processes (landscape disturbances) and cultural processes (Marcucci, 2000). The temporal–spatial changes in woodland cover occurrence can be used to characterise the processes of afforestation and deforestation. In the Biopress methodology (2016), the process of afforestation is described as the transformation of agricultural land and other areas (urbanised, natural, semi-natural and aquatic) to natural and semi-natural woodland. Deforestation is the opposite process; woodland cover is lost, transformed into another type of land cover. When evaluating afforestation and deforestation, it is of course essential to take into account the duration of the investigated periods, which depends on the availability of data sources. The second investigated period (1836–1876) is the shortest, at 40 years. The other investigated periods are approximately the same length: the first (1780–1836) covers 56 years, the third (1876–1952) covers 76 years and the fourth (1952–2017) covers 65 years.

Interpretation of woodland cover based on the analysed data sources

The process of interpretation is based on the gradual analytical acquisition of the necessary information from the data source. The interpretation of the data sources (i.e. the military maps and the orthophoto) takes place in three basic phases:

1. Determination of depicted entities based on specific features such as shape, colour, size and structure;
2. Identification of individual entities and their selection on the basis of preselected criteria (interpretative key);
3. Interpretation of the facts determined via the first two phases.

The interpretation of the data from the maps proved to be more difficult than expected. In order to precisely determine the occurrence of woodland cover from the maps, the available legends for the historical maps were studied, as was literature giving information on the depiction of woodland in the maps. On the basis of the map legends and the literature and also on previous experience of deducing landscape structure from historical maps and aerial photographs, the interpretation key shown in Appendix 1 was created. All elements in the key are displayed at a scale of 1:25,000.

The first series of military maps depicted woodland areas in grey-green with a schematic symbol representing a tree (Brůna et al., 2003). It can be expected that the density of the tree symbols corresponded with the nature of the woodland area in question, particularly with respect to its degree of crown closure. Unlike the more recent maps, the first series does not mark clear boundaries between the woodland areas and the other parts of the landscape. The gradual transition from woodland to scattered vegetation or grassland is more accurately representative of the real situation on the ground, but it makes interpretation more difficult and hinders the process of vectorisation (in which it is necessary to delineate the boundaries of spaces). The tree symbols used in the first series of maps enabled the cartographers to capture various degrees of tree density and height, as well as other information (e.g. boggy woodlands). Another advantage of this method is that in hillier areas, the trees are better visible against the background of the dark hatching that represents the terrain relief (Brůna, Křováková, 2006). Larger areas of woodland are named (in black lettering).

The second series of military maps no longer use the tree symbols. Woodland cover is represented by grey-green or brown-green areas with darker borders. In the case of larger areas of woodland, a coniferous or deciduous tree symbol is used to denote the predominant type of vegetation. The boundaries of the woodland areas are easier to interpret than in the first series of military maps, but problems occur in areas of higher elevation, especially with more steeply sloping terrain. The terrain relief is represented by hatching; the increasing thickness of the hatching lines represents a steeper gradient. However, on the steepest slopes, the hatching lines almost run into each other, resulting in a relatively dark surface – sometimes almost solid black – against which it is not possible to identify any other map markings (Brůna, Křováková, 2006). The interpretation of woodland cover can also be problematic in the darker map sheets. Similar to the first series of military maps, the second series also gives the names of larger areas of woodland (again in black), but these are illegible in locations with steep gradients.

The third series of military maps uses grey-green colouring to mark woodland areas, although the use of tree symbols is less prominent. A single coniferous or deciduous tree located in the centre of the woodland area indicates the predominant type of vegetation, but this symbol only appears rarely. In some cases, the symbol is less easily visible, so identifying woodlands is sometimes more difficult than in the maps from the second series. The third series also uses thick hatching to represent steep slopes, which likewise causes problems of interpretation. For this reason, it is advisable to use the special maps from the third military series in order to verify the data. These special maps depict woodlands in bright green, which (besides black and white) is the only colour on the maps, making it very easy to identify woodland areas. The special maps use a scale of 1:75,000, but (especially in the case of larger woodland areas) they offer very valuable data for verifying the interpretations of the 1:25,000 maps from the third series. As in the previous series, the maps in the third series give the names of the larger woodland areas (again in black lettering); in some cases, the Czech name is also given alongside the German name.

The military topographic maps from the 1950s depict woodland areas as bright green surfaces. In the case of the larger woodland areas, the type of vegetation is denoted by a coniferous or deciduous tree (or both in the case of mixed woodlands). In some cases, a more precise identification of the tree species is given (e.g. spruce, oak), and for some woodlands, data is given on the average tree height, trunk diameter or tree spacing.

The visual interpretation of aerial photographs enables us to use direct interpretative features (shape, shadow, size, colour, tone, texture, structure, etc.) and indirect clues (based on our knowledge of the interrelations amongst the direct features) to determine and describe the appearance and properties of entities and phenomena depicted on images (Čapek, 1978; Antrop, Eetvelde, 2000). Certain types of vegetation, bodies of water, rocks and so on reflect solar energy in different ways, giving the electromagnetic radiation a different and clearly distinguishable character. Woodlands are quite easy to distinguish on the colour orthophoto; they are dark green areas, mostly with clearly visible tree crowns (and sometimes entire trees).

Results

In the pre-industrial era, the Duchy of Teschen (now Těšín/Cieszyn) was a region with a relatively low degree of urbanisation (in comparison with other regions of Silesia) and with very diverse land use because of the diversity of geographical conditions. The lowland parts of the Duchy (including the Karviná district) were agricultural, whereas the economy in the Beskydy mountains and their foothills was based primarily on forestry (Pitronová, 1968; Korbelářová, 2005). The development of agriculture and forestry was determined by natural conditions. The Karviná region is largely flat, with minimal variation in elevation. There is sufficient precipitation (with the highest levels in the summer months) and favourable temperatures for agriculture (comparable with the fertile agricultural region of Haná in Central Moravia). The soils in the Karviná region are predominantly of lower quality, mainly podzols and also clay and rendzina soils. The soil conditions are thus less favourable, but the favourable temperature conditions and the use of fertilisers make it possible to grow more demanding crops. In view of the soil quality, the most commonly cultivated crop types are potato/barley and potato/wheat (Havrlant, 1964).

In the pre-industrial era, the Karviná region was primarily an area of arable land. According to the stable cadastre map from the 1830s, arable land occupied more than two-thirds of the area of the current Karviná district. Agricultural exploitation was intensive. According to information collected by valuers for the stable cadastre, the local farmers grew common types of grain, potatoes and sugar beet, cabbages and clover. Data on livestock also confirm that agriculture was intensive. There were relatively large numbers of horses, which was connected with the extensive presence of arable farming. The number of cattle was not higher than the average in neighbouring regions. Sheep farming was also highly developed

T a b l e 1. Total area of forests taken from the source data and their percentage share of the total area of the Karviná district.

Data source	Year	Woodland areas (ha)	Woodland areas (% of total area)
First military mapping	1780	6817.87	19.14
Second military mapping	1836	5416.36	15.20
Third military mapping	1876	4904.84	13.77
topographic military map	1952	4353.57	12.22
orthophoto	2017	7933.05	22.27

until the mid-19th century; sheep were bred for wool on the estates of the local nobility (Popelka et al., 2016).

Woodlands represented an important component in the landscape of the Karviná region. The development of woodlands was influenced not only by natural factors but also – indeed primarily – by human activity. The first existing Silesian cadastre (the so-called Caroline cadastre, compiled in the 1720s) contains data on the extent and type of woodlands in the province. However, the data for woodlands is heavily understated because landowners were keen to avoid paying higher taxes. According to the Caroline cadastre, the main woodland species in the Karviná region were beech, oak, alder, fir and spruce (Nožička 1956). The first reliable data on the extent of woodland areas in the 18th century can be gained by analysing the first series of military maps. This analysis shows that there were just less than ,6818 ha of woodlands in the territory of today's Karviná district, that is, 19.14% of its total area (Table 1). As early as the 18th century, the woodlands were already highly dispersed, scattered over the entire area of the district.

Even before the onset of industrialisation, there was a relatively substantial decrease in the extent of woodland areas in the study area. On the basis of an analysis of the military maps from the second series, it can be stated that by the early 1840s, the total area of woodlands in the study area had decreased to approximately 5,416 ha (i.e. 15.2% of the total area). This process of deforestation affected 11.8% of the total area, counterbalancing the afforestation process that was also taking place at the same time (which affected just less than 8% of the area). The predominance of deforestation revealed by the data corresponds with available information on the loss of woodlands in areas with developed agriculture during the first half of the 19th century: at the outset of the industrialisation process, most woodlands in these areas were relatively long established and consisted mainly of the indigenous mixed populations, with particularly notable populations of beech, oak, alder, fir and, to a lesser extent, spruce (Tichý, 1968). The analysis of species distribution based on the second series of military maps shows that this was also the case in the study area. The majority of woodland was mixed. Coniferous woodlands made up 15% of the total woodland area, and deciduous woodlands were just 4%. However, more than a quarter of the woodland areas marked on the maps (mainly smaller areas of woodland) do not contain any tree symbols. The most likely reason for the decrease in woodland areas was the economic boom that followed the Napoleonic Wars; estate-owners took advantage of the boom to intensify their agricultural production by turning meadows, pastureland, woodland, ponds and unproductive land into arable land (Rodan, 2008: 64).

This trend was accentuated by the industrialisation process. Woodlands were not only cleared to meet growing demand for wood; another factor was damage caused to trees (especially conifers) by industrial air pollution. Other factors in the decline of woodland areas included the development of the mining industry and the increasingly intense process of urbanisation, as well as the need for new agricultural land. According to the data yielded from the analysis of the third series of military maps, the area of woodlands in the Karviná district had fallen to approximately 4,905 ha (13.77% of the study area) since the previous maps, and the process of deforestation during this period had affected 4.5% of the study area. During the period between the second and third military map series, a large area of woodland had become agricultural land. In terms of species distribution, fir trees were in the most precarious position; in the final third of the 19th century, the fir populations in the Ostrava-Karviná coalfield were wiped out by industrial air pollution (Myška, 1989; Popelka et al., 2016). It is not possible to adequately evaluate the species composition of the woodlands based on the analysis of the third military map series, as the symbols for coniferous and deciduous trees occur only occasionally on the maps.

Until the mid-20th century, deforestation – as a result of the factors described above – was one of the most significant landscape formation processes not only in the Karviná district but throughout the entire Ostrava-Karviná coalfield. Woodlands most frequently became agricultural land – a mosaic of fields, meadows and permacultures – or they were abandoned and became overgrown with self-sowing trees, scrub and grass (Popelka et al., 2016).

By the mid-20th century, the area of woodlands in the Karviná district reached a historical minimum. The analysis of the topographic military map shows that woodlands in the study area covered just less than 4,354 ha (12.22% of the total area); the process of deforestation affected 4.65% of the total area during the intervening period. The Karviná district also began to experience widespread mine subsidence, with devastating effects at ground level and the formation of submerged (flooded) ground subsidences (Drlík, 1962; Mareš et al., 1975; Smolík, 1984). By the middle of the 20th century, most of the original indigenous woodlands had disappeared from the landscape and been replaced by artificial plantings. The species composition of the woodlands had also shifted since the mid-19th century. The original fir populations had disappeared entirely and were replaced by spruce. It is easier to identify the species composition of the woodlands from the topographic military maps than from the previous military maps, because most of the woodland areas are marked with the symbols for coniferous or deciduous trees. Almost two-thirds of the woodlands were coniferous, more than one-tenth were deciduous, and less than one-tenth were mixed. Some woodland areas – mainly small in size – were not marked with a symbol showing the predominant type of tree. The most commonly marked species in the maps is spruce (as has been mentioned above), with pine less commonly represented; the most common deciduous species are oak and beech.

The subsequent increase in the area of woodland in the Karviná district was due primarily to two processes: the recultivation of the landscape following the closure of coal mines and the process of deagrarianisation resulting from the collapse of the socialist agricultural planning system.

Research into forestry as a means of recultivating coal mine spoil tips was conducted in the Ostrava-Karviná coalfield from the early 1960s, although pilot projects had already been launched in the late 1950s (Smolík, 1981). From the late 1950s to 1966, the first 1,710 ha of land was remediated or recultivated in the Ostrava-Karviná coalfield as part of efforts to reduce the environmental impact of coal mining; of this, 460 ha were recultivated by tree plantings (Popelka, 2013). After 1967, the area of remediated or recultivated land decreased temporarily because of the application of 1966 legislation on the protection of agricultural land; the new legislation placed much more stringent demands on recultivation and led to the introduction of new, more effective recultivation methods. For this reason, between 1967 and 1972 only approximately 263 ha of abandoned land in the Karviná district was recultivated, 56.9 ha of it via forestry (Popelka, 2013). In terms of species, recultivation used mainly more resilient deciduous trees – especially ash, sycamore, red oak, common oak and elm (Smolík, 1981). During the 1970s and 1980s, priority was given to agricultural recultivation (in line with Act no. 125/1976 on the protection of agricultural land); after negative past experiences, the legislation stipulated that agricultural land that had originally been used for mining purposes was to be recultivated as agricultural land, without exception. However, after 1989, the situation shifted to the opposite extreme. Owing to the de facto collapse of the socialist agricultural planning system, recultivation of mining sites as agricultural land was abandoned, and most sites underwent systematic afforestation (Martinec et al., 2006).

By the beginning of the 1980s, woodland covered 4,651 ha of the Karviná district (13.39%), mainly because of recultivation. However, from the perspective of landscape structure, the new woodlands were only small (none of them exceeded 6 km^2), and they were scattered over a wide area. At this point in time, the Karviná district had 250 separate woodland entities. Woodlands still covered a considerably lower than average percentage of the land – both in comparison with the North Moravia region (38% woodland) and the whole of Czechoslovakia (35%). This made Karviná one of the least wooded districts in the entire country (Plaček et al., 1984).

A substantial increase in the area of woodland in the Karviná district came after 1989. The rapid decline of the mining industry in the Ostrava-Karviná coalfield and the decision to quickly repair the damage caused to the landscape by former mining activity ushered in an era of large-scale recultivation. At the same time, the very rapid collapse of the socialist agricultural planning system led to a decline in agricultural land use, and some agricultural land became woodland; most frequently, woodland areas expanded into adjacent areas with scattered trees, scrub and grasses or into abandoned agricultural land, thus causing a process of partial afforestation. The increase in the area of woodland in the past three decades has been the most dynamic in the investigated history of the study area; woodland currently covers around 7,933 ha of the district (more than 22% of its area), a historical maximum. The process of afforestation has affected 12% of the district's territory during this most recent period – mainly in the central part of the district, as a result of recultivation projects.

On the basis of the data gained from the maps, it is possible to trace not only the changes in the area of woodland as a proportion of the total land cover but also the spatial distribution of woodlands. In order to conduct a temporal–spatial analysis of the individual processes, a map was created for each period under investigation (1780–1836, 1836–1876, 1876–1952 and 1952–2017) showing the areas affected by the processes of afforestation and deforestation within the entire study area (Fig. 2). Table 2 presents the data in percentage.

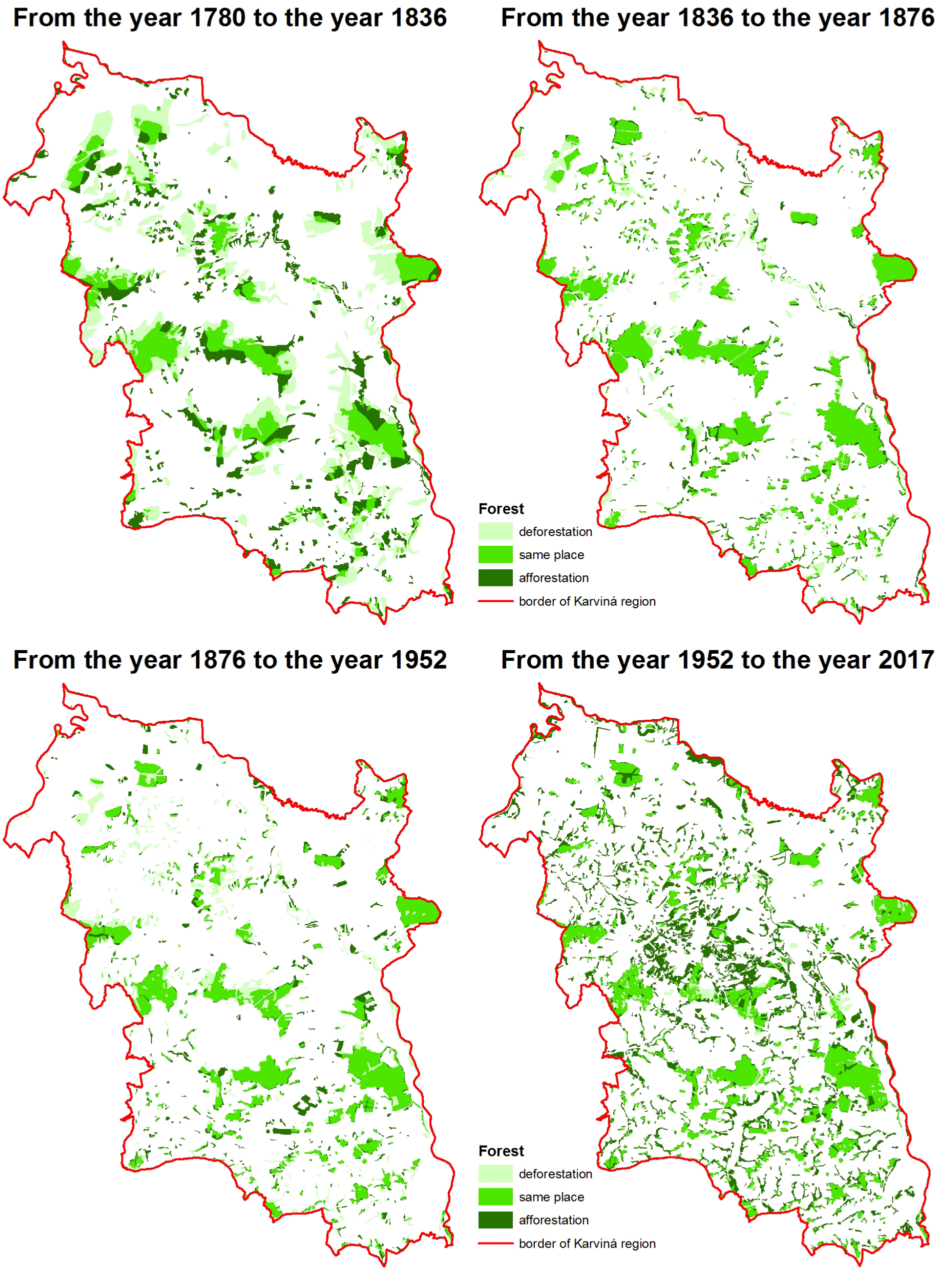

Fig. 2. Woodlands undergoing no change and afforestation/deforestation processes in Karviná district during the years 1780–2017.

T a b l e 2. Percentage of the total area of the Karviná district undergoing all types of afforestation/deforestation processes (and woodlands undergoing no change) during the years 1780–2017.

Process	Area (% from the total area) in the period			
	1780–1836	1836–1876	1876–1952	1952–2017
afforestation	7.86	3.07	3.10	12.04
deforestation	11.79	4.50	4.65	1.99
no change	7.34	10.70	9.12	10.23

On the basis of a multitemporal data analysis, it is possible to identify the locations at which woodlands were present throughout the entire investigated period. A total of 1,413 ha (4% of the territory of the Karviná district) remained as woodland throughout this period. Two-fifths of the woodland identified from the initial data (the first series of military maps) remained intact throughout the entire period. From the perspective of landscape change, some of these woodland areas are of considerable importance for both biodiversity and ecostability. Some of the areas have been granted legal protection in recognition of this fact, whilst others are only now being researched.

One such area is the Černý Les wood in Karviná-Ráj. This is a complex of woodlands located on the north-west slopes of the Ráj hill, which is bisected by the Czech–Polish border. The area has remained intact partly because it was used by the military before 1989 and was thus off-limits to the general public. It consists of indigenous deciduous species, including some rare examples of the European beech and the European spindle.

A similar area, with stable and high-quality populations of indigenous species, is the Krajčok wood in the cadastral area of Orlová. The wood is now used for recreational purposes. It includes 12 protected trees representing the original deciduous populations: 8 European beeches, 2 sessile oaks, 1 sycamore and 1 hornbeam (ages ranging from 110 to 250 years).

An example of natural riparian woodland in the study area is located near the village of Věřňovice, in the north of the Karviná district. The wood is part of a legally protected area classified as a natural monument, covering 4.59 ha and forming a near-natural community on a river terrace. Most of the protected area is riparian woodland, which, in the wetter parts, is dominated by elms and in the drier parts by oak/hornbeam populations. In places, the natural composition of the wood has been disrupted by plantings of non-indigenous species (e.g. the red oak and the European beech). However, large examples of indigenous trees have survived, including oak, ash, white elm, lime (linden) and field maple (Mackovčin, Sedláček, 2004). Adjacent to the protected area is the small Dembina wood (which appears in the maps from the second military series onwards) and meadows separated by avenues of trees. There are willow belts in the former beds of meanders, which, in some places, have been very well preserved. Some parts of the woodlands within the Věřňovice natural monument are recorded as existing in the first half of the 19th century.

The only large legally protected area of woodland in the district is the Velké Doly nature reserve, which covers an area of 30.5 ha between the towns of Český Těšín and Třinec. The reserve consists of mixed woodland with lime (linden) and hornbeam populations and several protected plant species. The original oak and beech populations were destroyed in the

18th century by limestone quarrying and replaced by hornbeam, lime (linden), field maple and sycamore. More than 40 bird species have been observed in the woodland (Mackovčin, Sedláček, 2004).

The Karviná district also has a number of interesting small-scale protected areas along several watercourses, which are bordered by small woodland areas. The natural monument 'Hraniční meandry Odry' (i.e. border meanders of the Odra River) is an 8-km section of the meandering Odra River running along the Czech–Polish border from the Odra/Olše confluence to the town of Starý Bohumín, plus the riparian woodlands adjacent to the river and both temporary and permanent bodies of standing water, and also the 'Meandry Dolní Odry' (i.e. lower Odra meanders), a Site of Community Importance (SCI) forming part of the Natura 2000 system (Mackovčin, Sedláček, 2004). The natural monument also includes Vrbina, a periodically submerged part of the riparian woodland. Common mergansers nest in the old hollow trunks of the black poplars and willows. At some locations adjacent to the Odra River in this natural monument, woodlands existed in the first half of the 19th century.

At south-western extremity of the Karviná district (on the outskirts of the city of Havířov) is the site of the 'Meandry Lučiny' (Lučina meanders) natural monument. The main protected feature is the unregulated course of the Lučina River, which creates natural meanders in alluvial deposits several metres thick. In the vicinity is woodland with hackberry and ash or oak and hornbeam populations, with varied flora and fauna. Gravel terraces have been formed on the right bank of the river, which are home to marsh alder stands (Mackovčin, Sedláček, 2004).

Discussion and conclusion

The data sources – i.e. historical military maps – were chosen because of both the comparability of the map scales and the precision of the maps for military purposes (including details of woodland areas). The most recent orthophoto (2017) was used to capture the current situation; the data from the orthophoto was verified using current maps.

Owing to the fact that the first military mapping was conducted 'à la vue', not all the positions of the map elements are recorded with sufficient accuracy; therefore, the precise size and location of the woodland areas cannot be considered entirely accurate. However, this is the only relevant map source from the 18th century that can be used at least to give an approximate indication of the occurrence and extent of woodlands – not only in the study area (the Karviná district) but throughout the Bohemian Crown Lands. In the subsequent military maps, the situation is different; from the second series onwards, the mapping was based on prior astronomic and geodetic surveying. The data yielded by these maps are precise and suitable for a quantitative analysis of changes in woodland cover.

The depiction of woodland areas in the source maps makes it possible to trace primarily the quantitative changes in these areas and to identify processes of landscape change. With regard to qualitative changes (species composition, age, etc.), the maps are less useful. It is difficult to determine the changing distribution of individual types of woodland from the maps; either the predominant species is not marked at all (e.g. in the first series of military maps) or it is only given for the larger areas of woodland (the second series). However, the information on qualitative changes can be obtained from other types of archive materials or historical publications.

When comparing the current distribution of woodlands with the situation in the second half of the 18th century, we can observe a substantial increase in the total area covered by woodlands; this has occurred primarily during the past 50 years, following a long period that had been characterised by a long-term decrease. This basic trend is in line with the trends described in a study by Munteanu et al. (2014), but the Karviná district displays some specific features. In the 1780s, woodlands made up approximately 19% of the landscape in today's Karviná district. This indicates the intensive development of agriculture in the lowland areas of the district. Even at that time, woodlands in the district were widely dispersed. With regard to the age and species composition of the woodlands, historical materials provide information on the predominance of long-established mixed woodlands, consisting mainly of conifer species (especially fir) and partially also of deciduous species (especially beech, oak and alder).

By the 1830s, the first wave of deforestation had already taken place in the study area; this was in line with the general trend throughout the Bohemian Crown Lands. This first phase of the deforestation process was (surprisingly) the most intense deforestation of the entire investigated period – even if we take account of certain inaccuracies in the military maps. The need for new arable land, as well as the need to expand sheep farming, led to the clearance of much existing woodland. The subsequent phase of deforestation, essentially corresponding with the industrial era (from the 1830s to the 1970s), was characterised by a relatively slow yet constant reduction in woodland areas; the less-intensive process of afforestation was not able to compensate for the deforestation. Deforestation during this period was relatively slow because the area covered by woodland was relatively low from the outset of the industrialisation process. The total area of woodland indicated by the second series of military maps (15%) is well below the average figure for the whole of the Bohemian Crown Lands, that is, 29% of their total area (Popelka et al., 2016: 51). By the 1970s, the long-term deforestation of the landscape in the Karviná district meant that (along with neighbouring Ostrava) it was one of the least forested districts in Czechoslovakia.

Some of the reasons for this deforestation were generally applicable to the entire country (such as the intensification of agriculture before 1945 and under the socialist planned economic system). Others, however, were connected with the specific features of the study area (deforestation as a result of coal mining, the influence of air pollution from industry, extensive construction work and the growth of new urban communities). The analysis showed that most woodlands in the Karviná district became arable land and were used for agricultural purposes; this is one of the paradoxes of the landscape changes that affected the Ostrava-Karviná coalfield, especially during the Cold War era.

The species composition of the woodland areas also changed. Firs practically disappeared during the second half of the 19th century, and only the more resilient deciduous populations remained (accompanied by spruce populations). During the second half of the 20th century, the pace of deforestation slowed considerably – a result of the rapid pace with which the process had occurred previously.

The early 1980s marked a turning point at which the predominant trends of the previous period began to change rapidly. The process of afforestation – which had previously been only a marginal feature in the Karviná district – became one of the most significant landscape change processes; this finding is in line with several existing studies (e.g. Plieninger, Bieling, 2012; Plieninger et al., 2016). Woodland areas began to expand – primarily into areas previously affected by the process of abandonment, where there were already scattered trees, scrub and grasses, as well as into abandoned agricultural land. The process of afforestation was also linked to the recultivation of former mining sites by new plantings (a method which became very widespread from the late 1980s) and the collapse of the socialist agricultural system.

The increase in the area of woodland during the past three decades has been the most dynamic in history. It has affected the entire study area – especially the central part of the Karviná district, where it is associated with large-scale recultivation work at former coal mining sites; afforestation has become the most widespread method of recultivation. Another factor is the more rigorous legal protection of the remaining original woodland biotopes, which represent an important source of ecostability in the region.

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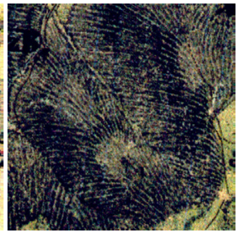
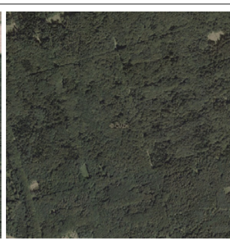
Appendix: Interpretation key.

Data source	The depiction of woodland		
First military mapping			
Second military mapping			
Third military mapping			
Topographic military map			
Orthophoto			

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IMPACTS OF SKI PISTES PREPARATION AND SKI TOURISM ON VEGETATION

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Abstract

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Vegetation of the ski slopes in the Low Tatras National Park in Slovakia was evaluated through the environmental variables and species composition caused by human impact assessment. We compared the grasslands located on pistes, off pistes and on the edge of pistes, and within these we also recorded the grassland management. The results show that the majority of study areas managed by transport of sod clippings has reached the lowest number of species; contrariwise, the grasslands with no management are characterized by the highest number of species. Areas on pistes managed by cutting correlates positively with the bare ground. Cover of mosses positively correlates with the total cover and areas with no management. Total of 17 synanthropic plant species and 2 non-native species as the indicator of human interventions were noticed. They occurred particularly on the edge areas but also in the surroundings of the off piste areas.

Key words: vegetation composition, ski slopes, human influence, management.

Introduction

All human interventions have a strong impact on mountain ecosystems resulting in the destruction of vegetation cover (Wipf et al., 2005), massive changes in soil structure and texture (Ruth-Balaganskaya, Myllynen-Malinen, 2000; Rixen et al., 2003) and threat to the regime of surface and underground water resources (Rixen et al., 2003, 2008). Landscape change is a potentially serious threat to the conservation of the habitats of native species (Rolando et al. 2007), when vegetation reacts with the decrease in biodiversity (Rixen et al., 2003; Wipf et al., 2005; Halabuk et al., 2013), leading to an interruption of successional stages (Urbanska, Fattorini, 2001) and the areas with lack of vegetation cover are likely to be eroded (Ruth-Balaganskaya, Myllynen-Malinen, 2000; Graiss et al., 2005; Barni et al., 2007). The final results are disturbed habitats and non-attractive alpine landscape for tourism which needs to be restored using appropriate management. The environmental damage causes economic losses not only in terms of the cost of restoration measures, but also a decline of interest in tourism in the affected areas (Rixen et al., 2003, 2008).

In the Slovak mountains, human interventions started centuries ago, when the Wallachian colonisers, in the 13th and 14th century, have been changing and destroying the vegetation cover by grazing of cattle and sheep, reducing the upper limit of forests, burning mountain pine and making forest clearings in mountain and alpine areas (Midriak, 1983). Nowadays, these undesirable activities are mainly represented by tourism (Piscová, 2011), construction of sports and relaxation facilities and intense construction of ski lifts and ski pistes (Midriak, 1983; Kizeková et al., 2008). All of these activities require considerable demands on environment of mountain landscape (Kizeková et al., 2008).

Winter tourism today represents one of the most important economic sectors in a great part of the world mountains areas (Elsasser, Messerli, 2001; Rixen et al., 2003). At the same time, the impact of ski runs and other infrastructures related to winter sports may have dramatic effects on the fragile mountainous environments (Argenti, Ferrari, 2009; Pohl, 2009). Construction and winter preparation of the ski pistes by machine grading and increased use of artificial snow are considered as the major factors of environmental degradation in the high-elevation ecosystems (Rixen et al., 2003; Ruth-Balaganskaya, Myllynen-Malinen, 2000; Wipf et al., 2005).

Studied area Jasná Nízke Tatry is a very important ski and tourist centre in the Low Tatras National Park, central Slovakia. History of the first ski pistes in these areas dates back to the 50's of the 20th century (Kulhánek, 1989).

As the destructive impacts on vegetation and soil cover have been very intense in the last couple of years, we decided to summarize the results of our two-years research to analyse the vegetation composition and diversity, compare vegetation composition of ski pistes and the vegetation sampled next to ski pistes or off the ski pistes.

Material and methods

Field data

Total of 94 phytosociological relevés (using 24–30 m^2 plots), based on the standard methods of Zürich – Montpellier school (Braun-Blanqet, 1964), following the modified 9-point Braun-Blanqet cover-abundance scale (Van den Maarel, 1988), were sampled in the montane up to the alpine zone. We focused mostly on grassland habitats, forest plant communities were not surveyed. The relevés were sampled in the areas of three types of positions – directly on the ski piste, on the edge and off piste. Moreover, within each relevé, the method of management (cutting, a combination of cutting and seeding and transport of sod clippings) was recorded in the subalpine and alpine zones. The only off piste subalpine and alpine grasslands and some of the edge grasslands (mainly monotonous plant communities with the dominance of *Rumex alpinus*) were treated with no management.

Data analysis

Before the processing, all relevés were stored into the database program TURBOVEG (Hennekens, Schaminée, 2001). For further modification and analysis, the data were exported to the program JUICE (Tichý, Holt, 2002).

CANOCO 5.0 program (ter Braak, Šmilauer, 2012) was used to analyse the relationships between species composition and environmental variables. Length of gradient was 4.05 using DCA (detrended correspondence analysis), which indicated the use of unimodal method CCA (canonical correspondence analysis) in the next step. Nomenclature of taxa was unified by the Checklist of non-vascular and vascular plants of Slovakia (Marhold, Hindák, 1998).

Statistica 7 (Statsoft, 2005) was used to describe the selected environmental factors of the data set in this study. Box plots were used to evaluate and compare the differences of variables according to the position at the ski piste and management treatments. Univariate test of significance following one-way ANOVA was used to determinate the significant statistical differences between groups (at a significance level of $p < 0.05$). Correlations between the variables of data set were processed by the non-parametric Spearman's rank order correlation test.

Study area

Low Tatras National Park is the largest national park in Slovakia in terms of area. The highest peak is Ďumbier (2043 m a.s.l.). The Low Tatras Mts lie in east-west direction, in the central part of Slovakia (Fig. 1), nearly 100 kilometres in length. The geographical coordinates range within 48°42» – 49°09» of the latitude and 19°16» – 20°17» of the longitude. The Low Tatras Mts consist of the rocks of Crystalline-Mesozoic zone in the West Carpathians (Lacika, 2001).

The overall character of vegetation is determined by the climatic conditions forming vegetation zones from the submontane up to the alpine zone (Vološčuk, 2005). The original vegetation has been greatly changed due to deforestation and new areas of grasslands and pastures were created. Grassland vegetation of the Low Tatras Mts has been highly valuated for its exceptionally rich diversity (Turis, 2007). Our study was carried out on the ski pistes and the areas near the Jasná Nízke Tatry ski resort (Fig. 1). The ski resort ranges from the second highest peak Chopok to the northern as well as the southern slopes (from 943 m a.s.l. up to 2004 m a.s.l.) with average slope up to 40°.

Fig. 1. The map of the study area.

Revegetation

Soil and vegetation are affected by construction of ski pistes, their preparation and especially snowpack compression, machine grading and levelling, when the vegetation and top layer of soil are being removed and compressed (Kangas et al., 2009; Bjedov et al., 2011). In particular, machine grading for winter sports causes environmental degradation such as erosion that has a negative effect on biodiversity. In addition, the common result of these processes is washing out the seeds after repeated rain falls, which prevents the slopes of revegetation (Wipf et al., 2005; Iselin-Nondedu et al., 2007). Vegetation provides protection to the soil and its anti-erosive effect is constant through the whole year. Revegetation of the ski slopes is therefore one of the basic and very important measures that ensures the stability of the mountain landscape and prevents ecological and economic damage. To recover these areas, the degraded ecosystem must be compared with its undisturbed state to determine pre-disturbance soil properties and vegetation cover (Kizeková et al., 2008). The rehabilitation of a disturbed site should aim to minimize the length of time the site is exposed to potential erosion and sedimentation (Behan, 1983; Bjedov et al., 2011), thus rapid reconstruction of the vegetation cover is essential. To establish a stable plant community, it is recommended to use seeds from local natural populations or from species adapted to the disturbed areas using appropriate management methods (Argenti, Ferrari, 2009; Kangas et al., 2009; Bjedov et al., 2011). The preparation of seed mixtures based on the composition of the original vegetation composition is important also because some ski resorts are built within protected areas, national parks and so on, thus preserving the original ecosystems, and prevention of degradation of the original flora has particular importance in these areas (Wipf et al., 2005; Kizeková et al., 2008). In our study area, there are three management methods used for vegetation restoration: 1 – sowing, 2 – aqua sowing, 3 – using jute geotextiles.

Sowing

Seeds are scattered over the land by hands or by machines and are shallowly (5–20 mm) incorporated into the soil. This method should be used during windlesness for maximal possible even distribution of seeds (Marhold, Čunderlíková, 1983).

Aqua sowing

This method of revegetation was created in need of an even distribution of seeds in the large and hard to reach areas. Its application has anti-erosion protection and can be used for the revegetation of slopes up to 60 ° even on slopes affected by water or wind erosion. Seeds are mixed with peat, soil and fertilizers and sometimes with anti-erosive substances in the water tanks (Marhold, Čunderlíková, 1983).

Jute geotextiles

The jute geotextile (or coconut geotextile) is unfolded over the ground before the sowing. The geotextile prevents the seeds from being washed away or removed by the wind, while providing them with nutrition. After a while, this geotextile is decomposed (Marhold, Čunderlíková, 1983).

Results

Results of statistical analysis

To display the comparison of ecological status of grasslands in consideration of the location to the ski slope and type of management, the box plots were used (Figs 2–7). We focused on the following environmental variables – total cover of vegetation, species richness, Shannon diversity index and synanthropization, while only box plots with statistically significant differences are shown (at a significance level $\alpha = 0.05$).

When restoring the ski slope, it is important to re-plant the disturbed areas as soon as possible, not only due to esthetical reasons, but also in terms of stability and biodiversity. Sufficiently developed vegetation that covers over 70% of the soil surface is the only possible way to stabilize the slopes in the long term and reduce soil erosion to an acceptable level (Krautzer et al., 2011). In the Figures 2 and 3, the vegetation cover of study area is represent-

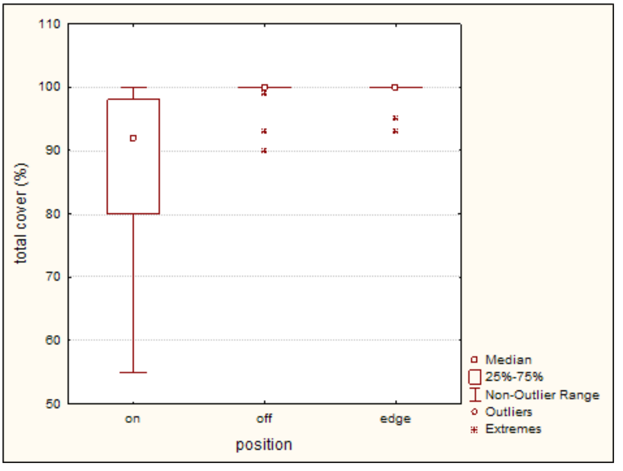

Fig. 2. Box plot of total cover of vegetation in percentage grouped by position on the ski piste.

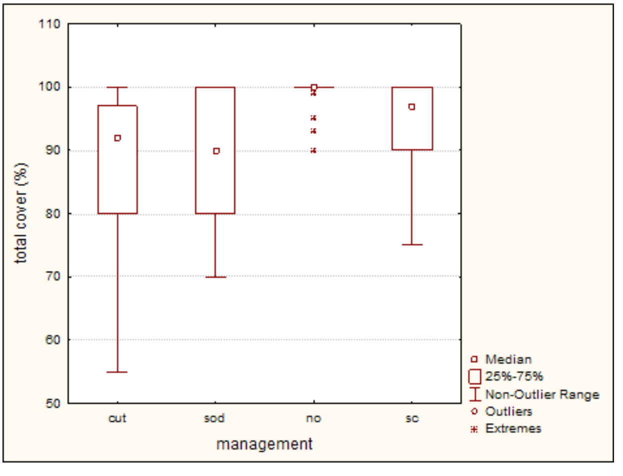

Fig. 3. Box plot of total cover of vegetation in percentage grouped by type of management.
Notes: cut – cutting; sod – transport of sod clippings; no – no management; sc – combination of cutting and seeding.

ed. The total vegetation cover varies depending on the type of management of the ski piste, which reflects conditions of the slopes. The off piste grasslands and edge areas, as well as, areas with no management are mostly with 100% vegetation cover. The combination of cutting and seeding in appropriate conditions (altitude) could turn out as the possibly effective way of management, according to the coverage of vegetation in the study area.

Conditions which occur after the construction and machine grading of ski resorts could result in poor biodiversity and reduced species richness with the following decrease of ecosystem functions (Cole, Bayfield, 1993; Whinam, Chilcott, 2003; Wipf et al., 2005; Rolando et al., 2007; Burt, 2012). In our study, we noticed variances of species richness between the "on" and "off" piste areas (Fig. 4). From areas located directly on piste through the edge to the off piste, the number of species has increased. Variability in species richness on the ski piste reflects the different management practices (Figs 4, 5). The majority of the study areas managed by the transport of sod clippings has reached the lowest number of species; contrariwise, grasslands with no management are characterized by the highest number of species (Fig. 5).

Differences in the Shannon diversity index between areas with different positions on the ski slope and also between the management treatments have not been proven statistically significant. In the study area, we also recorded plant species included in The IUCN Red List of Threatened Species in category vulnerable – *Crepis conizyfolia* and in category of Least Concern – *Carex bigelowii, C. capillaris, Gentiana punctata, Ranunculus pseudomontanus* and *Soldanella carpatica* (IUCN, 2016).

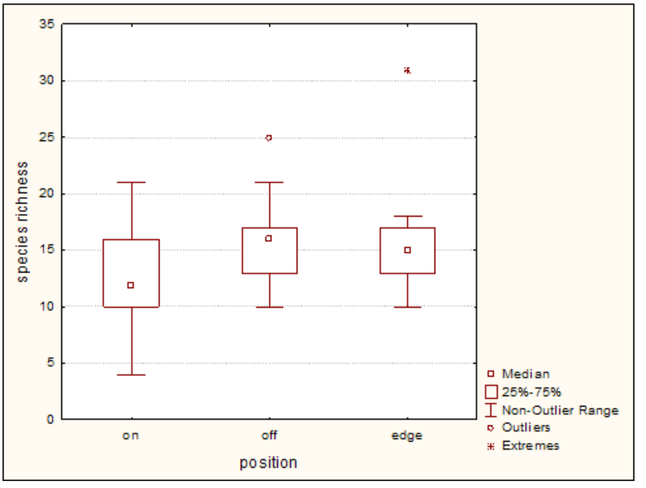

Fig. 4. Box plot of species richness grouped by position on the ski piste.

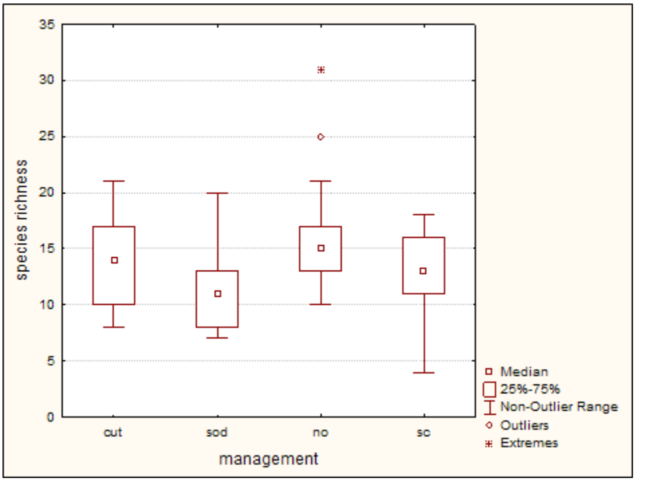

Fig. 5. Box plot of species richness grouped by type of Management.
Notes: cut – cutting; sod – transport of sod clippings; no – no management; sc – combination of cutting and seeding.

Acquaintance of occurrence and representation of non-native and synanthropic plant species in the study site is the requisite condition for grassland degradation assessment. Overall, 17 synanthropic plant species and 2 non-native species (Table 1) have been recorded at the ski slopes in the study area. Differences between percentage of occurrence of these species in the grasslands, in consideration of position and implemented management, are displayed in Figures 6 and 7. The lowest ratio of synanthropization was noticed directly on the areas located on ski piste, where the notable species were – *Plantago major*, *Poa annua, Rumex alpinus, Tussilago farfara* and *Daucus carota.* Some extremes in the spreading of synanthropic species *Aegopodium podagraria* and *Calamagrostis epigejos* with high coverage were noticed on the off piste sites, suggesting that anthropically affected are not only the grasslands and trails on the ski slopes but also the surrounding areas. This could also be a result of the management treatments, when species like *Rumex alpinus* or *Aegopodium podagraria* are doing

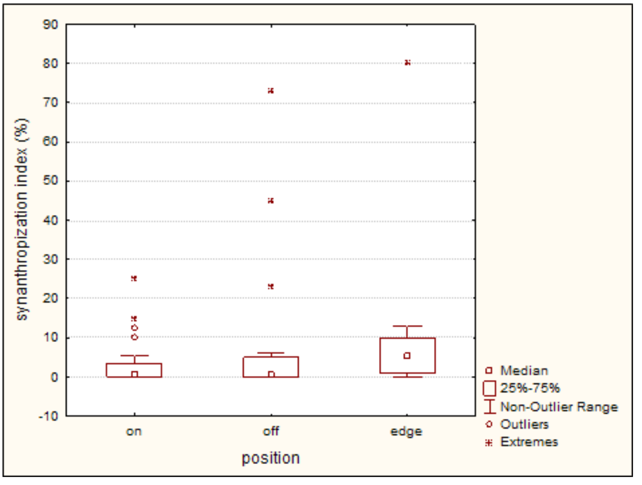

Fig. 6. Box plot of synanthropization index in percentage grouped by position on the ski piste.

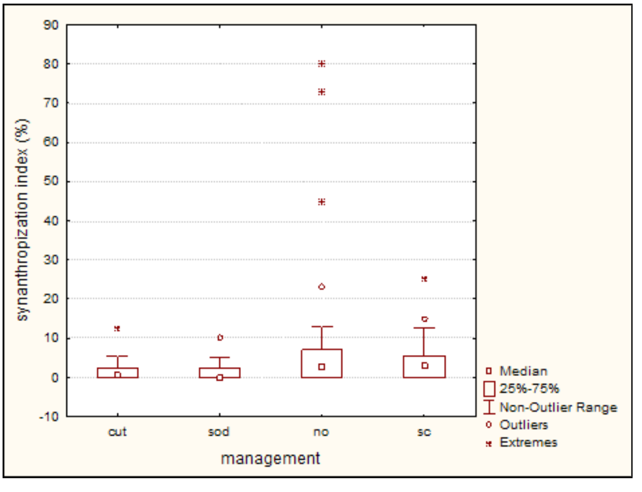

Fig. 7. Box plot of synanthropization index in percentage grouped by type of management.
Notes: cut – cutting; sod – transport of sod clippings; no – no management; sc – combination of cutting and seeding.

T a b l e 1. List of plant species included in synanthropization index of study areas.

Synanthropic species
Aegopodium podagraria
Calamagrostis epigejos
Cirsium vulgare
Daucus carota
Fragaria vesca
Chaerophyllum hirsutum
Chamerion angustifolium
Plantago major
Poa annua
Ranunculus repens
Rumex alpinus
Rumex crispus
Stellaria media
Taraxacum sect. Ruderalia
Tussilago farfara
Urtica dioica
Veronica chamaedrys
Non-native species
Lupinus polyphyllus
Trifolium hybridum

better under no management. Increased percentage of synanthropization on the “edge” areas as compared to the “on” areas is mostly the result of the occurrence of species *Poa annua* and *Urtica dioica*. We also noticed the monotonous grasslands there without the management presented by the species *Rumex alpinus* and *Urtica dioica* with extremely high coverage – up to 65%. This indicates that the soil of these areas contains reserves of phosphorus and nitrogen, which could be the remains after the construction, presence and high activity of workers.

Results of gradient analysis

The canonical correspondence analysis (CCA) was used to test relationships between the environmental variables and the floristic composition of the sampled vegetation in the Jasná Ski Centre, Low Tatras Mts. Along with the environmental factors, we wanted to identify how the factors of management and the positions of individual relevés affect the abundance of species and vegetation richness. The tested environmental variables were: Total vegetation cover, Cover of mosses, Elevation, Slope, Bare ground percentage and Potential annual direct irradiation (Figure 8). Similarly, as in the statistical analysis, we also analysed the variables of management used on the ski slopes (cutting; transport of sod clippings; no management; combination of cutting and seeding) and position of the sampled relevés (on, off, edge of the piste).

Some of the typical species for steep slopes and screes and depressions with long lasting snow cover (*Juncus trifidus*, *Carex capillaris*, *Oreochloa disticha*, *Soldanella carpatica*, etc.) are located along the factors of slope and elevation.

The lower part of the graph belongs to the samples recorded mostly on the edge or off the ski pistes, where no management method was used. As we expected and identically with the statistical analyses, total cover positively correlates with vegetation that is under no management. Species present in this part of the graph (*Myosotis scorpioides*, *Geranium sylvaticum, Dechampsia cespitosa*, *Alchemilla* sp.) are mostly typical for tall herb communities and forests, which have usually very high vegetation cover. Cover of mosses also positively correlates with total cover and areas with no management, as mosses are sensitive to land management and environmental changes (Nelson, Halpern, 2005; Perhans et al., 2009). On the other hand, very few mosses were found in the areas located on ski piste.

T a b l e 2. Spearman rank order correlations between environmental variables

	Shannon diversity index	Species richness	Total cover	Synanthro-pization	Bare ground	Moss and lichens	Elevation	Slope
Shannon diversity index	1.000							
Species richness	**0.683**	1.000						
Total cover	0.058	0.251	1.000					
Synanthropization	0.244	**0.352**	0.281	1.000				
Bare Ground	-0.065	-0.251	**-0.891**	-0.188	1.000			
Moss and lichens	-0.031	0.2	0.121	-0.247	-0.183	1.000		
Elevation	-0.189	-0.259	-0.069	**-0.436**	0.064	0.011	1.000	
Slope	-0.123	-0.325	-0.121	**-0.337**	0.088	0.001	**0.505**	1.000

Marked correlations are statistically significant (at level of significance $p < 0.001$).

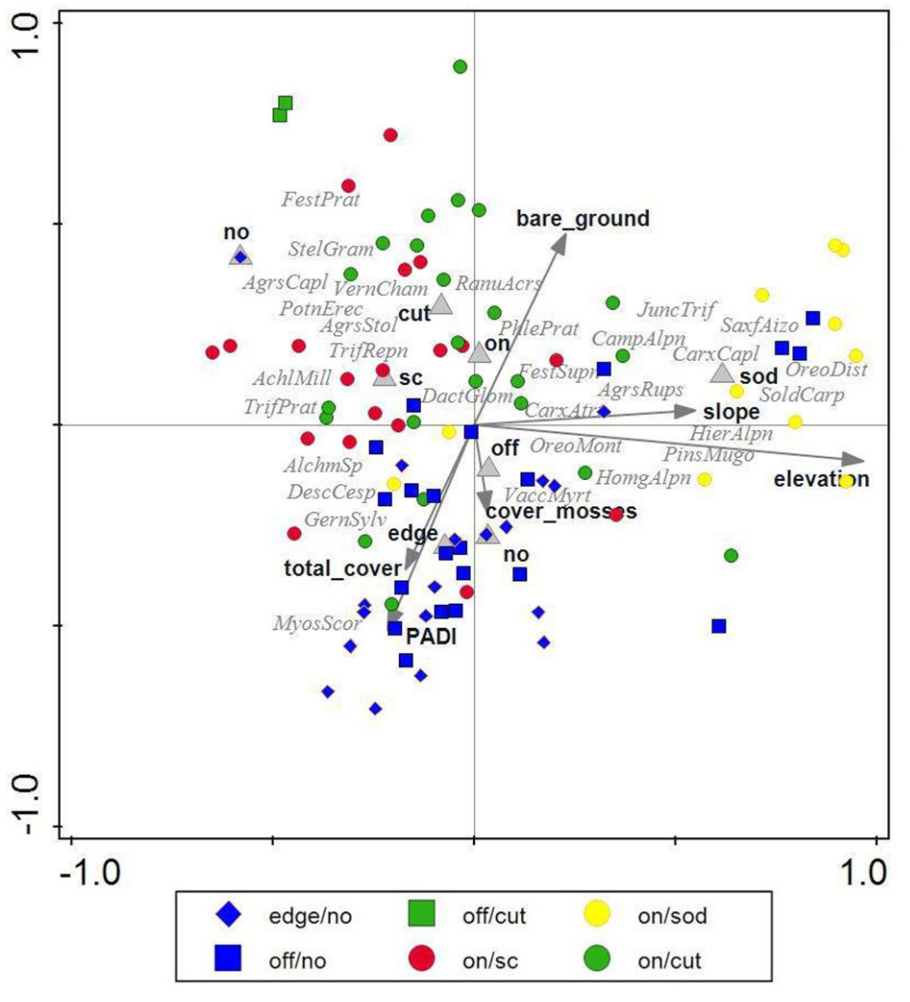

Fig. 8. Canonical correspondence analysis (CCA) ordination diagram of 94 relevés
Notes: cut – cutting; sod – transport of sod clippings; no – no management; sc – combination of cutting and seeding. Abbreviations of the taxa names: *AchlMill – Achillea millefolium*, *AlchmSp – Alchemilla species*, *AgrsCapl – Agrostis capillaris*, *AgrsRups – Agrostis rupestris*, *AgrsStol – Agrostis stolonifera*, *CampaAlpn – Campanela alpine*, *CarxAtr – Carex atrata*, *CarxCpl – Carex capillaris*, *DactGlom – Dactylis glomerata*, *DescCesp – Deschampsia cespitosa*, *FestPrat – Festuca pratensis*, *FestSupn – Festuca supina*, *GernSylv – Geranium sylvaticum*, *HierAlpn – Hieracium alpinum*, *HomgAlpn – Homogyne alpine*, *JuncTrif – Juncus trifidus*, *MyosScor – Myosotis scorpioides*, *OreoDist – Oreochloa disticha*, *OreoMont – Oreogeum montanum*, *PhlePrat – Phleum pratense*, PinsMugo – *Pinus mugo*, *PotnErec – Potentilla erecta*, *RanuAcrs – Ranunculus acris*, *SaxfAizo – Saxifraga aizoides*, *SoldCarp – Soldanella carpatica*, *StelGram – Stellaria graminoides*, TrifPrat – *Trifolium pretense*, *TrifRepn – Trifolium repens*, *VaccMyrt – Vaccinium myrtillus*, *VernCham – Veronica chamaedrys*.

We can see the factor of bare ground in the upper part of the graph, where it correlates negatively with the total vegetation cover. Positively with the bare ground correlates relevés located on ski pistes, which are managed by cutting. Species that are depicted in the upper left part of the graph correspond with the seeding mix used for vegetation restoration (*Trifolium repens*, *T. pretense*, *Dactylis glomerata*, *Phleum pretense, Festuca pratensis*).

Discussion and conclusion

Winter sports became very popular in the last decade and with growing popularity, demands for suitable areas also grew. In order to promote not only national, but also international tourism, the construction and modernization of ski centres is needed. According to Bowker et al. (1999), during the years 1995–2000, winter tourism increased about 6% and it is expected to raise about 122% during the years 2000–2050.

Important factors used in ski centres are artificial snow and use of heavy equipment during the levelling and preparation of ski runs. There are already many studies dedicated to the research on the variety of effects on the ecosystems during the construction and management of ski centres. Roux-Fouillet et al. (2011) analysed the research sites located on the ski pistes and compared the vegetation and soil characteristics with the areas located outside the ski slopes. The result of their study was reduced coverage and overall production of vegetation. Similarly, our analyses are showing that the off piste study sites have much higher coverage of vegetation in comparison with sites located on pistes. At the same time, the study sites that are under no management are characterized by the highest vegetation cover with notable presence of mosses and lichens. Moreover, the off piste sites and unmanaged sites, sites partially managed by cutting, has reached the highest number of species.

During the construction and management of ski centres, the traffic also increases and construction of routes and logging roads is required. These became an appropriate means for spreading of invasive and synanthropic species (Müllerová et al., 2011). Invasive species gained status of one of the largest threats to natural ecosystems of conservation and economic sides in recent years. These species may reduce or replace the original species and can also change the functions of the ecosystem (Eliáš, 2002; Štrba, Gogoláková, 2009). In our study, within the unmanaged sites, the human impact on vegetation is largely manifested through the occurrence of synanthropic plant species, as well as on sites located on ski runs where a combination of cutting and seeding is used as the management method. Transport of sod clippings is implemented in higher elevations and on steeper slopes, and in combination with the harsh environment, the result could be the lowest species richness; nevertheless these sites have the lowest percentage of synanthropization.

Jasná Nízke Tatry ski centre has already been incorporated as the long-term part of environment in the Low Tatras National Park, where several methods of vegetation management are applied these days with varying efficiency due to the environmental factors. Regarding the management methods used in this protected area, several questions remain to see the overall impact on the whole ecosystem (changes in vegetation structure and phenological changes caused by using of artificial snow (Rixen et al., 2003; Wipf et al., 2005) and mechanical damage of chamaephytes from heavy equipment or sharp edges of skis (Kammer, 2002; Rixen et al., 2003; Wipf et al., 2005)).

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TERRITORIAL SYSTEM OF ECOLOGICAL STABILITY AS A PART OF LAND CONSOLIDATIONS (CADASTRAL TERRITORY OF GALANTA – HODY, SLOVAK REPUBLIC)

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Abstract

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A major worldwide problem, especially from the perspective of preserving biodiversity and ecological stability (ES) of the landscape, is the significant gradual degradation and loss of habitats. In the context of ever-changing global conditions, the preservation of healthy ecosystems and their valuable services as well as the interconnection of patches of existing habitats should be encouraged. In Slovakia, conception of the Territorial System of Ecological Stability (TSES) was developed. Biodiversity conservation can be created by means of an integrated approach to management of the landscape and careful spatial planning respecting TSES. Land Consolidation (LC) projects, of which TSES constitutes a key part, are amongst the real planning and implementation tools in the Slovak Republic. Thus, TSES represents a real tool for implementation of landscape changes in order to strengthen ES and biodiversity of the landscape with regard to the current European trends in biodiversity policy. This article describes a Local Territorial System of Ecological Stability (LTSES) project developed as a part of LCs in the cadastral territory of Hody (Galanta, Slovak Republic). The aim was to create a functional proposal of LTSES with all basic types of proposals to strengthen biodiversity and ES of model territory – proposal for establishing new eco-stabilising elements – groups and strips of non-forest woody vegetation (NFWV), proposal for ecologically optimal land use, proposal for eco-stabilising measures in forest ecosystems and proposal for hydro-ecological measures.

Key words: biodiversity, landscape-ecological evaluation, proposals, non-forest land, local level.

Introduction and theoretical and methodological base

The EU Biodiversity Strategy to 2020 (EC, 2011) entitled 'Our life insurance, our natural capital' states the commitment of the commission to create a strategy preservation of biodiversity. Six general targets are defined in the strategy. Target No. 2 states that by 2020, it is necessary to ensure that ecosystems and their services have been preserved and strengthened. Principles are also defined in 'The Revised National Strategy for the Protection of Biodiversity to 2020' (MoE SR, 2013).

Investments in biodiversity enhancing are considered an important step towards the protection of 'natural capital'. Natural capital represents natural resources that provide valuable goods and services. The services of natural capital are referred to as ecosystem services. Protection and enhancement of natural capital are considered the elements leading to long-term sustainability.

In Slovakia, to preserve the biodiversity of the landscape, to restore natural landscape connectivity features and to maintain or enhance the ES of the territory, conception of the Territorial Systems of Ecological Stability (TSES) was created. At the same time, various studies that aimed at role, evaluation and planning of ES and biodiversity, especially the agricultural landscape, have been developed (e.g. Ružička et al., 1982; Brandt, 1985; Selman, 1993).

The TSES plan has been most widely elaborated in the Czech Republic. By the Czech school, the whole-territory approach to maintain the stabilisation of the landscape was proposed (Buček, Lacina, 1979; Buček et al., 1986; Míchal, 1992; Buček, Lacina, 1993; Buček et al., 1996).

In Slovakia, TSES was built based on the Czech principles together with the Institute of Landscape Ecology and other institutions (Jurko, 1986; Miklós, 1986; Miklós et al., 1986). The plan in the Slovak Republic follows up a whole range of international initiatives, for example, NATURA 2000 (European Network of Specially Protected Sites), substantially contributing to the biodiversity maintenance according to the ideas of the Convention on Biological Diversity (National Biodiversity Strategy of Slovakia, including its revisions; MoE SR, 1997, 2013), the Pan-European Biological and Landscape Diversity Strategy (ECNC, 1996), the European Landscape Convention (CE, 2000), AGENDA 21 (MoE SR, 1996) and so on.

TSES conception in Slovakia was built based on the plan of NECONET. The NECONET was based on the concept of the European Ecological Network (EECONET) and drew on the principles of the Dutch National Ecological Network. In foreign studies, the widely used term is 'ecological networks' (Mander et al., 1988; Cook, Van Lier, 1994; Brandt, 1995; Jongman, 1995; Kavaliauskas, 1995; Mander et al., 1995; Kubeš, 1996; Bennett, 1998; Bouwma, Jongman, 1998). Current trends and research confirm the relevance of the theoretical basis for the concept of ecological networks in the landscape (Mackovčin, 2000; Sepp, Kaasik, 2002; Wrbka et al., 2005; Bennett, Mulongoy, 2006; Opdam et al., 2006; Pascual, Dunne, 2006; Boitani et al., 2007; Bonnin, 2007; Ignatieva et al., 2011; Jongman et al., 2011; Buček, 2013; Schilleci et al., 2017).

The establishment of ecological networks has been proposed as a way to counteract the increasing fragmentation of natural ecosystems and as a necessary complement to the network of protected areas (Forman, 1983; Forman, Baundry, 1984; Agger, Brandt, 1988; Hobbs et al., 1990; Hargis et al., 1999).

From the theoretical and methodological point of view, TSES is a modern plan and tool for conservation and organisation of territory based on landscape-ecological approach (Naveh, Liebermann, 1994; Jongman, Kristiansen, 1998; Jongman, Pungetti, 2004; Tardy, Végh, 2006). The strategic principles of the TSES include diversity of conditions and forms of life – geoecodiversity, elimination of spatial isolation of geosystems, broad-based stabilisation of the territory, protection of natural resources, improvement of landscape appearance and the overall quality of the environment (Miklós, 1996). The starting point of the protection strategy of diversity of conditions and life forms is the identification of the geoecosystems that need to be preserved (Bastian, Schreiber, 1994; Bunce et al., 1996; Jongman, Bunce, 2000; Miklós et al., 2006). The critical aspect of the geosystem approach to the landscape for its application in practical activities – and in the process of designing of TSES – is the character of the primary, secondary and tertiary landscape structures and their functions for the spatial planning process (Drdoš et al., 1995; Miklós, Izakovičová, 1997; Renetzeder et al., 2010).

The TSES plan adopted by Resolution of the Government of the Slovak Republic 394/1991 paved the way for the incorporation of the TSES into environmental policy and planning. Several methodological guidelines were produced as part of the development of TSES in Slovakia (SCE, 1992; MoE SR, 1993; Jančura et al., 1994; Izakovičová et al., 2000; Hrnčiarová et al., 2000; SEA, 2009). TSES also became a part of the greening of landscape of Slovakia (Miklós et al., 1990). The process of creating documentation of nature and landscape conservation (including TSES documentation) can be conducted in Slovakia only by people with the required professional qualifications.

The TSES is a binding regulation of various plans and projects as well as decision-making processes on all hierarchical levels (national, regional, local). The TSES produced with the precision of a local level, the Local Territorial System of Ecological Stability (LTSES), represents the most significant incorporation of landscape ecology principles to real environmental policy, spatial planning practice and the promotion and conservation of biodiversity.

The TSES constitutes the central idea of the current wording of Act 543/2002 Coll. on Nature and Landscape Protection as amended (Act on the Protection of Nature). In the Act, §2 defines TSES as an integrated structure of interconnected ecosystems, their components and features, which ensures diversity of conditions and life forms in the landscape, whereby the base of the system consists of bio-centres, bio-corridors and interactive elements of supra-regional, regional or local importance (known as the elements of the TSES skeleton). The Act on Nature and Landscape Protection (§3 Art. 3) stipulates that establishing and preserving the TSES is a public interest. The space (landscape) in which the TSES is implemented, in geosystem terms, understood as a geosystem – 'landscape is a complex system of space, location, geo-relief and other mutually, functionally interconnected, material, natural elements and elements modified and created by man, in particular the geological base and soil creating substratum, water bodies, soil, flora and fauna, artificial objects and the elements of utilisation of territory, as well as their connections determined by socio-economic phenomena in the landscape; the landscape is the living space of man and other living organisms' (Act 50/1976 Coll. as amended by Act 237/2000 Coll., §139 – Building Act).

As defined by §9 Art. 9 of the Act 330/1991 Coll. on Ground Arrangements, Land Ownership, Land Offices, Land Fund and Land Associations (Act on Land Consolidations [LCs]), LTSES is a compulsory landscape-ecological document for general principles of spatial arrangement of the territory (GPFAT). The proposal of TSES skeleton and proposal of anti-erosion measures are ecological optimal variants of spatial arrangement and functional land use. The proposal of GPFAT is a rational variant of spatial arrangement and functional land use. GPFAT proposal is specified based on the more detailed knowledge of designers and comments and requests from participants of LCs.

The LTSES is also a basic document for the proposal of common facilities and measures (roads to make land and buildings accessible, anti-erosion measures and related structures, measures for the protection of the environment, especially to create ES and conditions for biodiversity of the landscape (bio-corridors, bio-centres, interactive elements, accompanying vegetation) water management measures and others (§12 Art. 4 of the Act on LCs).

The inclusion of the TSES concept into LCs enables the real implementation of TSES in agricultural land. Planting the proposed TSES elements – bio-centres, bio-corridors and interactive elements with different NFWV character – is also, albeit sporadically, performed within the process of LCs.

A proposal of new NFWV is based, on one hand, on the abiotic aspects (e.g. slope inclination, skeletality and waterlogging) and socioeconomic demands (e.g. isolation of a plant, dust and noise control, aesthetic aspects etc.) but, on the other hand, also on inadequate representation of biota in the landscape and a need to establish and interconnect present TSES elements. The Ordinance of the Geodesy, Cartography and Cadastre Authority of the Slovak Republic 79/1996 Coll., implementing the Act 162/1995 Coll. on the Real Estate Cadastre and Entering of Ownership and Other Rights to Real Estates (the Cadastral Act), defines NFWV as special-purpose agricultural vegetation or anti-erosion protective strips (as a part of agricultural land) or ecological greenery in case of non-agricultural and non-forest land (Hrnčiarová, 2003).

With respect to practice, it is important to ensure that the designated TSES elements are integrated into the system of protected areas (existing or new) as TSES elements may not always be under legislative protection. This is significant especially from the perspective of strengthening their functionality and merits as elements of the TSES skeleton. The process of the integration of new elements of the TSES skeleton into the network of protected areas is stipulated by the Act on Nature and Landscape Protection (Act 543/2002 Coll.). The Act specifies that a TSES element can be designated as a protected landscape element if it functions as a bio-corridor, bio-centre or interactive element of local or regional importance. Further details regarding the TSES are provided in the implementing rules (e.g. Decree of MoE SR 24/2003 Coll. as amended).

To ensure spatial stabilisation of a territory, TSES includes proposals of eco-stabilising measures. Their importance increases for the purposes of agricultural land. Eco-stabilising measures should, in particular, address the functionality and whole-territory aspect of TSES. They build upon abiocomplexes (ABC) analyses, and, apart from the proposal of ecologically optimal organisation and use of the landscape, it is intended to propose subsequent agrotechnical, agrochemical and agromeliorative measures. The Slovak works authored by Miklós (1989), Húsenicová and Ružičková (1992), Izakovičová and Barančok (1996), Miklós (1996), Izakovičová (1997), Izakovičová (2000), Špulerová et al. (2013) and others also draw on the mentioned principles.

In view of the foregoing, the aim and result of the TSES is, in particular, proposal of TSES elements (bio-centres, bio-corridors and interactive elements) at different hierarchical levels. Thus, the prime objective of the TSES is to promote and preserve biodiversity of territory. In addition, the outputs are also proposals to ensure legislative protection of the TSES elements and the proposals of the framework concept of eco-stabilising measures besides the TSES elements (to ensure landscape stabilisation across the whole territory). The principal objectives of TSES are to maintain the network of ecologically significant landscape segments, not only because of its internal ecological value but also its favourable eco-stabilising effect on the (also ecologically disturbed) adjacent landscape and the protection of such landscape segments – which, based on the standard criteria, are not currently classed in a protective category – although, with respect to the ES of a given territory, their conservation is considered necessary. The TSES plan can be considered the most notable and most visible success of incorporating the landscape-ecological principles into the legislation of crucial planning processes (Miklós et al., 2011). Since its establishment, the TSES has been considered a part of the comprehensive concept of LANDEP landscape-ecological planning (Ružička, Miklós, 1982; Miklós, 1996). An important output of the LTSES is ensuring ecologically optimal land use and providing of whole-territory stabilisation of the landscape. This is due to the fact that TSES follows the LANDEP methodology.

Spatial planning processes are a tool to ensure an ecologically optimal spatial arrangement and functional land use (harmonisation of spatial demands, agricultural and other human activities with the landscape-ecological conditions of a territory, its potential resulting from the landscape structure as a geosystem). The outcome of correctly applied, ecologically optimal spatial arrangement and land use is not only resolution of existing landscape-ecological problems but also prevention of new ones by means of spatial–organisational protection of the landscape, which in an integrated manner ensures the favourable ecological quality of the territory (maintaining ecological functionality, balance, carrying capacity, landscape stability, landscape and biological diversity), especially by securing sufficient areas and spatial structure of ecologically stable landscape elements (forests, greenery, grasslands, wetlands, water areas, i.e. TSES) (Miklós et al., 2011). Currently, the TSES is integrated into binding regulations on landscape planning. It is a mandatory part of LC projects. It has to be taken into account also in water plans, flood protection and the documentation in environmental impact assessments of activities. In Slovakia, the TSES becomes real mainly through the LCs. LCs allows application of a broad spectrum of means and measures aimed at transformation of rural areas (economic, ecological, cultural and social) and are the sole means of restructuring of ownership and land-use rights. A particular focus is on ensuring an adequate level of technical infrastructure. The TSES covers the ecological and environmental aspects of LCs. TSES proposals are focused on optimal land use, on strengthening protection and ES of the landscape and on extension of the TSES skeleton elements.

The problem of TSES for LCs is being addressed by many authors, for example, Dumbrovský and Kolářová (1995), Izakovičová et al. (2000), Zelinka (2001), Ružičková (2006), Muchová et al. (2013), Kocián (2013), Belaňová and Diviaková (2015), Doubrava and Martének (2015) and Julény et al. (2017).

Framework guidelines for creation of LTSES for LCs are methodical instructions for LCs design (MoA SR, 2004) and methodological standards for LCs design (Muchová et al., 2009). By implementation of LTSES proposals to LCs is possible to increase the diversity of the landscape, also improving its ecostabilisation, retention and anti-erosion functions. The realisation of LTSES has a multifunctional and undoubtedly a community importance.

Material and methods

The methodical part of the LTSES project for the studied territory is based on the methodological guidelines for the TSES (Izakovičová et al., 2000), the methodological guidelines for LCs (MoA SR, 2004) and the relevant legislation currently in force, as well as the findings and experience of the authors of the project. It was produced on a scale of 1:5,000.

The process consisted of the following steps:

Step 1: obtaining and homogenisation of the available documents (analyses of the primary landscape structure (PLS), current landscape structure (CLS)) biotic elements (current fauna and flora, tertiary landscape structure (TLS)) and the following socio-economic phenomena (SEP):

- information on geo-relief was obtained by means of visual interpretation of a terrain contour field generated from a digital model of geo-relief (DMR);
- the geological–substrate complex was determined from the geological map of the Podunajská nížina lowland (Pristaš, 2000);
- data on potential natural vegetation was taken from the original field map at 1:50,000 (Michalko et al., 1986);
- ecologically significant segments of the landscape were identified based on the Regional Territorial System of Ecological Stability (RTSES) for the district of Galanta (SEA, 1994);
- a preliminary CLS map was produced from basic topographic maps and orthophoto maps.

Step 2: verification, review and supplementation based on proprietary field surveys with detailed mapping:

- integral collection of data (Minár, 1998) emphasising mapping of soil conditions by means of shallow probing (Dutch type hand drill to a depth of 1.2 m conducted with 36 bores at excavated sites) – determining the soil subtype, depth and skeletality of soil, effects of ground water, soil texture by finger test; examined properties were recorded in field inventory sheet;
- mapping and identification of CLS elements such as land-use elements, actual biota;
- a special botanical and dendrological survey was carried out in order to map the habitats, in particular forest and shrub habitats as well as habitats of flowing and stagnant water and habitats of ruderal and weed communities. The survey was performed to analyse qualitative and quantitative characteristics of individual habitats (species composition, distribution of individual plant taxons and communities, height, width, age, health, etc.), the zoological survey aimed to map selected groups of vertebrates; ecologically significant landscape segments were identified;
- mapping and identification of TLS elements – socio-economical phenomena.

Step 3: synthesis of the information inputs (syntheses):

- information was reviewed and edited in accordance with the field survey and values thus obtained were later inserted into the boundaries of demarcated morphographic-genetic-positional types of geo-relief. The method of gradual superposition of analytical materials was used in parallel with the method of leading element (geo-relief), as well as the method of analogy and method of analysing of basic relationships between elements of the geocomplex; utilising the aforementioned means a map of abiotic complexes (ABC) was produced;
- geo-ecological types were obtained by adding the information on potential natural vegetation.

Step 4: interpretations and evaluation of the collected data (classification, assessment):

- the geo-ecological types were interpreted into representative potential geo-ecosystems (REPGES) (Miklós, Hrnčiarová, 2002);
- based on the characteristics of ABC, relevant potential threats were evaluated: wind erosion (as proposed in Minár, Tremboš, 1994), waterlogging (as proposed in Miklós et al., 1986) as an indication of potential groundwater contamination from agricultural chemicals; the identified threats acted as constraints (limits) on the development of considered activities and the proposal of eco-stabilising measures;
- other selected abiotic properties were interpreted: soil tropism and soil cultivability (machinability);
- a method of two-stage spatial synthesis (Ružička, Hrnčiarová, 1995) was used to determine partial classification of the territory: classification based on abiotic factors, classification based on the CLP elements, classification based on stress factors and overall spatial classification of the territory. The territory was divided into categories as proposed by Löw et al. (1995) and Hrnčiarová and Ružička (1997), which reflect the ES of the territory; SEP were, in terms of the TSES methodology, interpreted in two ways:
- spatial synthesis of 'positive' elements ('threatened' SEP) was conducted by means of superposition of a CLS map and a map of classification of the territory based on the elements of CLS;
- spatial synthesis of 'negative' elements ('threatening' SEP) was conducted by means of superposition of a CLS map and a map of classification of the territory based on the ABC elements.

Step 5: development of proposals for TSES:

- including the proposals of TSES elements (bio-centres and bio-corridors) and protected areas and the design of eco-stabilising measures;
- selection of real habitats to be integrated into the network of bio-centres as well as the proposals and re-evaluations of protected areas was based on REGPES; the selection process was performed by confrontation of species composition of actual habitats and REPGES;
- the proposal of ecologically optimal use of the territory resulted from a comparison of demands of individual activities with respect to landscape properties, and the so-called complex abiotic limitation was used to gauge the suitability of the landscape and its properties for a specific anthropogenic activity.

Basic characteristics of the model territory

The model territory (Fig. 1) is situated in the cadastral territory of Hody extending over 5,385 km^2, and it is a part of the town of Galanta. The territory lies in the Podunajská nížina lowland, subunit Podunajská rovina plain (Mazúr, Lukniš, 1986).

The geo-relief is of erosion-denudation character; it is a monotonous landscape formed by aggradation plains and floodplains (Miklós, Hrnčiarová, 2002). The territory can be characterised as a flat or slightly undulating floodplain. It features more noticeable elongated depressions, which are the remnants of oxbow lakes in the final stages of their existence. Elevation forms are represented by sand dunes and mounds. Depressions and convexity of the geo-relief forms is manifested in seasonal waterlogging and draught. Geo-relief inclination ranges in the intervals from 0.5 to 1° and from 1° to 3. As for geometric geo-relief, forms are defined by a combination of normal and horizontal curvature of geo-relief, linear flat shapes prevail. The altitude of the area is from 116 up to 122.75 m above sea level. The territory is built by the geological units of the Quaternary (Holocene and recent) period, particularly by sediments of fluvial, aeolian, organogenic and anthropogenic genesis of various lithological types (Pristaš, 2000). Fluvial sediments are represented by carboniferous, clay and sandy-loam lithotype. Carboniferous sand drifts of aeolian origin form slight mounds – sand dunes. Organogenic loamy-sludgy, heavily humic sediments deposit on the bottoms of oxbow lakes. Anthropogenic sediments are represented by the material of the railway embankment.

In terms of climate, the territory is not very extensive and thus it does not exhibit more considerable climatic differences. It is in a warm climatic area with a dry or moderately dry lowland climate with mild temperature inversion. The river Šárd runs through the territory. It is covered by soil subtypes typical for large fluvial floodplains – calcaric molic fluvisols, molic gleysols and locally occurring calcaric molic chernozems. Permanently flooded areas are

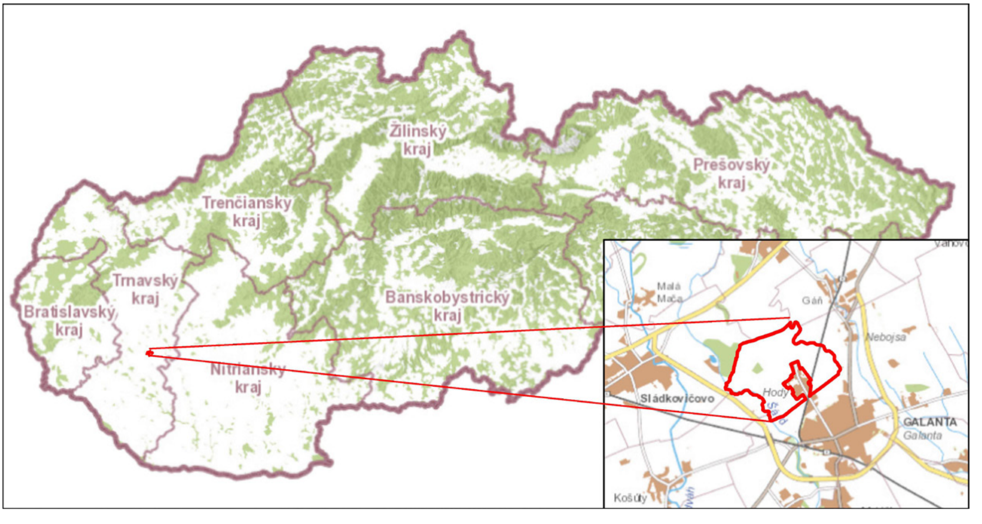

Fig. 1. Cadastral territory Hody in wider relations.

associated with euric to gleyic fluvisols. Heavily humic loamy-sludgy sediments of organogenic character, which fill the bed of oxbow lakes, gave rise to forming organosols (stagnosols). Many original soil subtypes transformed into regosols formed on drifted sand. The embankment is covered by anthropogenic soil – anthrosols and technosols. The aforementioned soil groups (texture) fall predominantly into clay-loam to silty-claim-loam soil texture categories, sandy-loamy and loamy soils are represented less.

Potential natural vegetation is in the mapped territory represented by the following types of communities: willow-poplar floodplain forests (*Salicion albae, S. triandrae*), lowland floodplain forests (*Ulmenion*), Pannonic oak-hornbeam forests *(Querco robori-Carpinenion betuli)*, Pontic-Pannonian xerothermophyllic oak forests *(Aceri-Quercion)* and locally would grow alderfen forests (*Alnetea gutinosae).* With respect to the phytogeographical-vegetation division, the territory falls into the oak zone, lowland subzone, flatland, non-wetland district and floodplain subdistrict. From the zoogeographical point of view, it is a part of terrestrial (province of steppes) as well as limnetic bio-cycle (Pont-Caspian province, county Danubian district, part of Western Slovakia) (Miklós, Hrnčiarová, 2002).

The studied territory has the character of an open agricultural area with predominantly large-block and small-block arable land and also forest communities of hardwood alluvial forests. Almost each dirt road and watercourse is flanked by continuous or discontinuous linear vegetation. As for transport elements, unpaved roads, which prevail, crisscross the whole area. There are also a few isolated buildings: water station, apiary and barn. A bio-corridor of supra-regional significance, the Šárd, runs through the territory and Vincov les bio-centre partly extends into the area, too.

Results

Twenty-five types of ABC (Fig. 2) were designated in the studied territory. The code of an ABC type had the following form: X1 X2 X3 X4 X5, where X1 is the morphographic

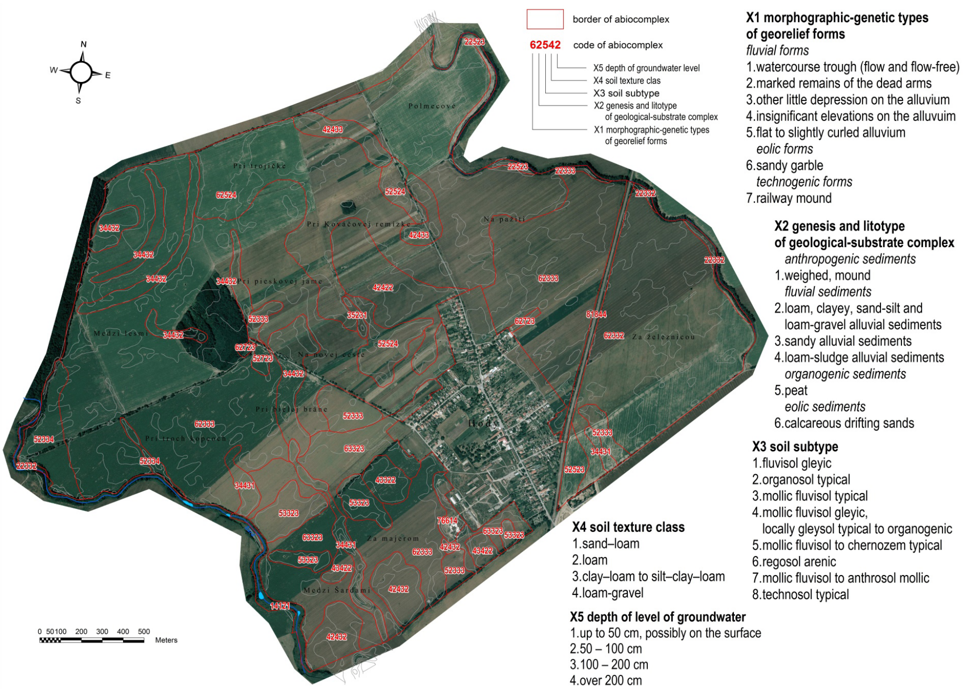

Fig. 2. Types of ABC in the cadastral territory Hody.

genetic type of a geo-relief form, X2 is the genesis and lithotype of geological–substrate complex, X3 is the soil subtype, X4 is the soil texture, X5 is the depth of the ground water level.

Geo-ecological types ware interpreted to 20 REPGES types. These geosystems are considered worthy and require conservation in a particular landscape and at the hierarchical level (Miklós, Hrnčiarová, 2002).

The current landscape structure comprises of 22 types of elements, which were logically classified into 9 categories: forest vegetation, non-forest woody vegetation (NFWV), arable land, permanent cultures, watercourses and water areas, energoducts and pipelines, transport elements, agricultural elements, other areas, isolated buildings.

The territory had precisely delineated forest, shrub and water habitats, habitats of flowing water, habitats of weed and ruderal communities with the presence of plant and animal species, including protected and endangered species, for example, the snowdrop (*Galanthus nivalis*).

The following elements were identified as a part of spatial synthesis of threatened (positive) SEP (Fig. 3): forest stands such as commercial forests, protective forests and special purpose forests; line NFWV continuous and discontinuous such as riparian stands, alleys along dirt roads and vegetation of field baulks; groups of NFWV such as groves, small-block arable land, natural water courses and areas.

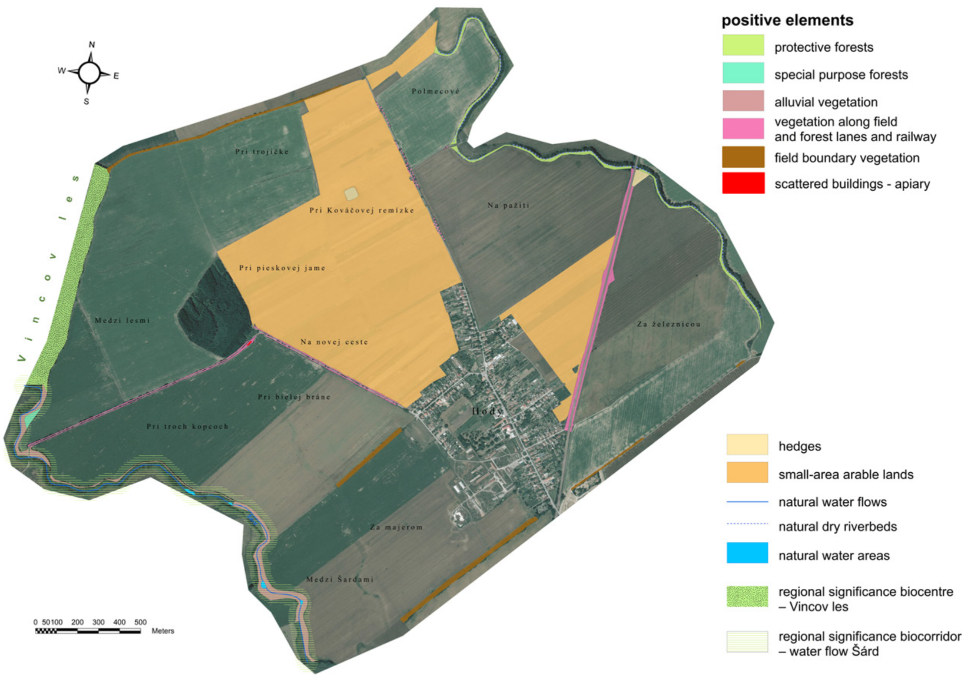

Fig. 3. Spatial synthesis of threatened phenomena in the cadastral territory of Hody.

A regional hydric bio-corridor – the Šárd water course with more or less continuous riparian vegetation runs through the territory. No other legislative or otherwise determined elements are present in the territory. The elements for the proposals of the TSES skeleton were chosen from the ´positive´ phenomena.

The selected abiotic interpretations were assessed in the studied territory such as potential vulnerability of the area to wind erosion (also accumulation) and potential groundwater contamination from agrochemicals (by the interpretation of waterlogging). The identified threats entered the evaluation as negative phenomena and were utilised in the proposals of eco-stabilising measures. Other interpreted properties were evaluated - soil tropism and soil cultivability (machinability). These properties were utilised in creating of the proposals of optimal land use where they functioned as constraints (limits) on the development of activities considered.

The following elements were identified within analyses of threatening (stressing, negative) SEP: clearcut, large-block arable lands, power lines, irrigation systems, transport elements - unpaved dirt roads, rail embankment, field dunghills, landfills, waste, isolated buildings outside residential areas - barn, waterworks, apiary, but also the residential area of the village of Hody.

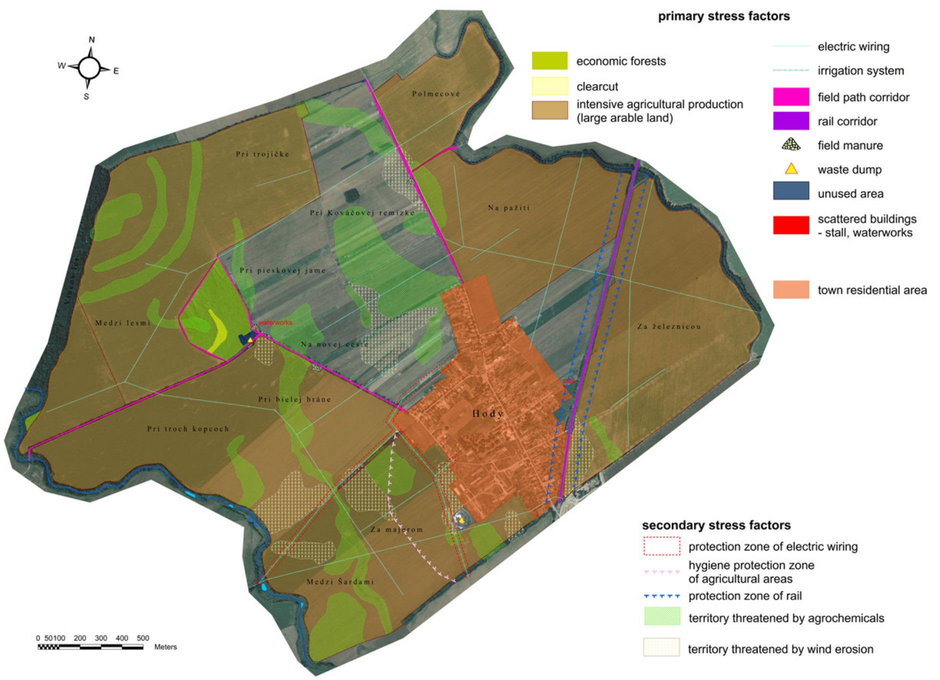

Fig. 4. Spatial synthesis of threatening phenomena in the cadastral territory of Hody.

A separate group of intangible stressors consisted of protection zones (PZ) of technical buildings: PZ of agricultural grounds (300–500 m) to ensure protection against dust, odours and noise; PZ of railway tracks (60 m from the track centre on both sides); PZ of power lines (15 for low voltage power lines). On the basis of the mentioned combination of the stress factors, the Territorial System of Stress Factors (TSSF) was developed and the following types of areas with different combinations of stress factors were proposed: area with multifunctional and monofunctional effect of stress factors and areas with two-pair or three-pair dominating stress factors (Fig. 4).

The outcome of a synthesis of partial classifications was an overall classification of the territory (Fig. 5), which resulted in delineation of individual types of areas with threatened ES: areas with very high ES, high ES, average ES, low ES and very low ES.

The proposals (Fig. 6) aimed to produce a functional TSES in the studied territory. The proposals consisted of the proposal of the TSES skeleton (including re-evaluation of nature and landscape conservation) and the proposal of eco-stabilising measures (including the elimination of stress factors).

The proposals of the TSES skeleton in the studied territory included establishing 11 bio-corridors of local significance, of which 7 were currently present in the territory, 4 bio-cor-

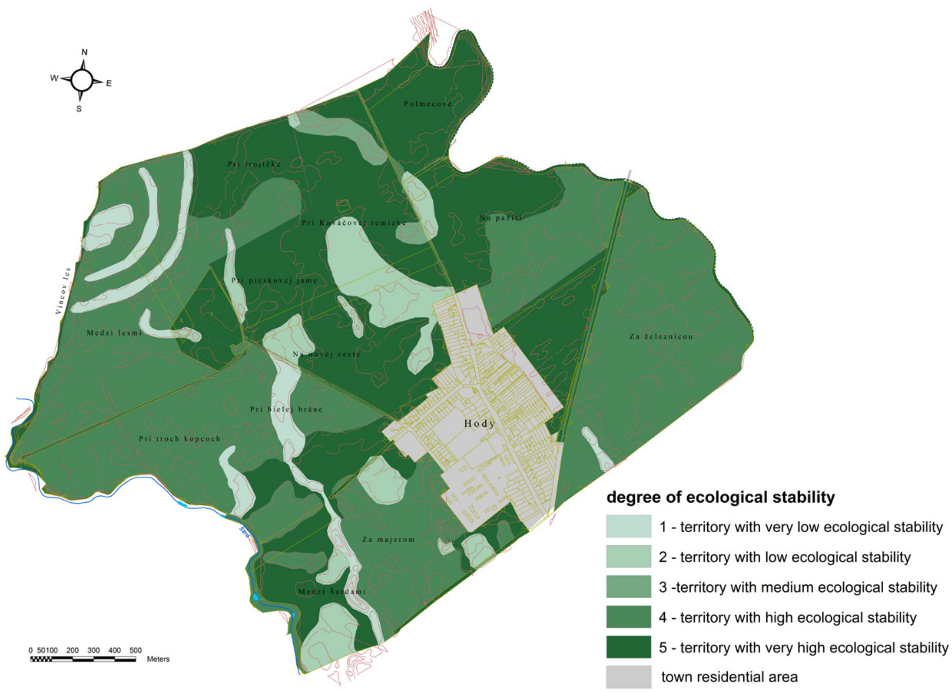

Fig. 5. Classification of the territory based on the ecological stability of the cadastral territory of Hody.

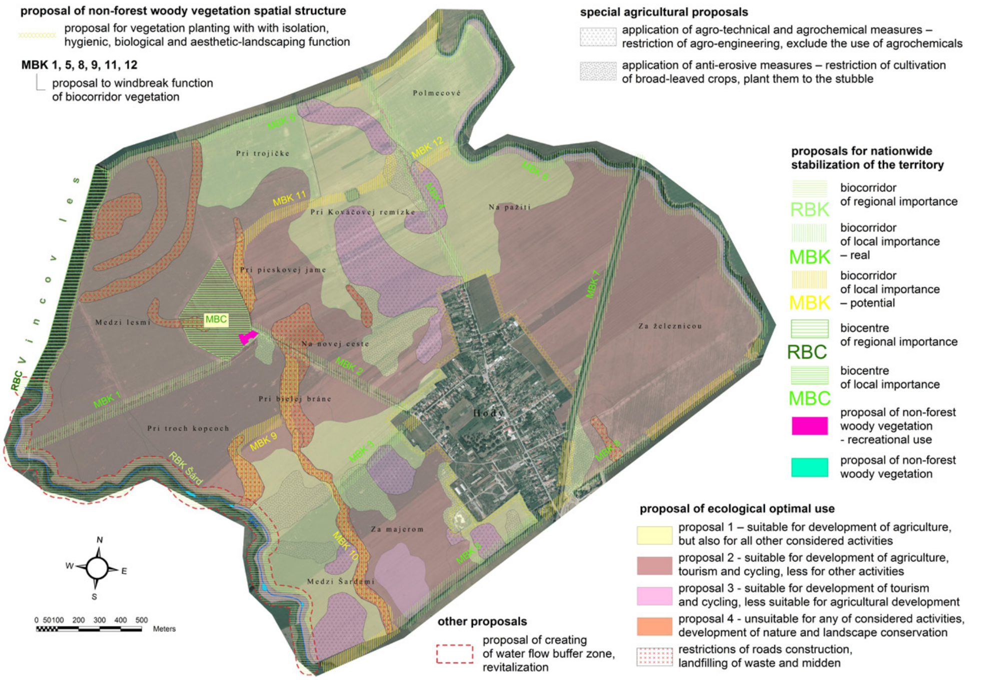

Fig. 6. LTSES proposals.

ridors were proposed to be established and 1 bio-centre of local importance. The proposed TSES elements at local level were functionally and logically interlinked with the ecological networks of higher hierarchical levels.

The proposals for eco-stabilising measures consisted of the following partial proposals:

- proposal for establishing new eco-stabilising elements – groups and strips of NFWV;
- proposal for ecologically optimal land use;
- proposal for eco-stabilising measures in forest ecosystems;
- proposal for hydro-ecological measures.

The objective of the proposal of new NFWV was to safeguard a new ecologically optimal spatial organisation of land and secure several significant ecological and environmental functions in the territory. On the basis of the aforementioned, the following measures were proposed: planting of vegetation around the residential area and landfills, which would primarily fulfil hygienic, biological and aesthetic functions. Furthermore, planting of minimum three-row, semipermeable, aerodynamically homogeneous strips of trees windbreaks were recommended. These should ensure protection against wind and also other ecological functions even without bio-corridors. The proposal also recommended suitable tree species for the territory.

Four types of proposals were formulated within the framework of the proposals of the optimal spatial structure and land use:

- proposal 1 – suitable for agricultural development (arable land, permanent crops, farms, field dunghills) and for all other planned activities;
- proposal 2 – suitable for agricultural development (arable land, permanent crops, farms) and hiking and cycle tourism, less suitable for other activities;
- proposal 3 – suitable for development of hiking and cycle tourism, less suitable for agricultural development;
- proposal 4 – unsuitable for any of planned activities, proposal of development of nature and landscape conservation.

Several regulations were proposed for the forest ecosystems, which need to be taken into account in Forest Management Programme (FMP) (currently Forest Care Programme). The regulations were aimed at the protection of forest stands and land as well as strengthening the biodiversity of the forest ecosystems. The hydro-ecological measures focused on the protection of water resources and aquatic ecosystems.

Discussion and conclusion

In Slovakia, the TSES has a firm position in the modern plan for nature protection, spatial planning processes and environmental legislation, and its importance increases with the current Slovak and EU policies in the field of biodiversity protection (EC, 2011; MoE SR, 2013). The TSES represents one of the most advanced policies, which secures whole-territory nature conservation, biodiversity and stabilisation of unprotected and intensively used land.

The prime objective of the TSES is, amongst other things, to propose establishing the missing TSES elements (e.g. suitable vegetation on arable land and devastated areas).

The content of the TSES draws on the legislation on nature and landscape protection. The concept of the TSES was incorporated into the legislation of the protection of nature and landscape in 1994 (Act 287/1994 Coll. on Nature and Landscape Protection). However, it became a mandatory part of LCs even earlier, in 1993. The legislative basis and principles are provided by Act 330/1991 Coll. (Act on LCs). The content of the LTSES for LCs also principally stems from nature and landscape conservation legislation and was modified for the purposes of LC planning.

The TSES represents a real tool for implementation of landscape changes in order to strengthen the ES and biodiversity of the landscape. It creates conditions to approximate the situation that was successfully created in the Czech Republic. This would be only natural, as our concept of TSES as well as our relevant legislation is based on common Czech–Slovak foundations.

Several projects of LTSES have been solved in Slovakia. Some have become part of the documentation of LCs, for example, in cadastral areas of Vieska nad Žitavou (Mederly et al., 2006), Plavecký Peter (Ružičková et al., 2006), Nováky (Slobodník et al., 2006), Malé Vozokany (Mederly et al., 2007), Lužianky (Muchová, Petrovič, 2007), Tuchyňa (Ružičková et al., 2007), Pravenec (Slámková et al., 2007), Ladice (Mederly et al., 2008), Klasov (Moyzeová et al., 2008), Kanianka (Muchová et al., 2008), Horná Ves (Mederly et al., 2009), Hlboké (Mederly et al., 2010), Kocurany (Diviaková et al., 2012) and Ipeľské Úľany (Králik et al., 2015).

Several projects of the TSES for the LCs were also scientifically published. Few examples are listed as follows:

- Ružičková et al. (2010) have dealt with the fragmentation of natural habitats and with the importance of restoring ecological networks. Through the LTSES designed in LCs, authors compared two geographically distant cadastral areas (Tuchyňa in Western Slovakia, Štôla in Eastern Slovakia).
- Muchová and Petrovič (2010) researched the development of the landscape structure in three time periods on three cadastral areas (Hájské, Veľké Vozokany and Kanianka). Authors pointed to positive changes in the landscape because of the integration of TSES proposals into LCs. Through the LCs, new landscape elements to increase the diversity and stability of the landscape have been created.
- Moyzeová and Kenderessy (2015) solved the creation of an ecological network in cadastral area Klasov. Authors have dealt with the revitalisation of existing and with creation of new fragments of natural habitats. They also solved the system of eco-stabilisation measures and management.
- Muchová et al. (2016) pointed out the problems that currently restrict rural development on the territory of the Žitava basin. Authors pointed to the low ES of the landscape, frequent flooding, increasing soil erosion and so on. They highlighted the main problems in water management and environmental protection.
- Belaňová and Diviaková (2017) presented a proposal of TSES skeleton and anti-erosion measures into proposal of GPFAT. The model territory was cadastral area Kocurany. Authors pointed to insufficient acceptance of the TSES proposals in the LCs. Nonetheless, they considered LCs as a suitable tool to create appropriate conditions for the practical implementation of the TSES.

This article describes an LTSES, which was also developed within the LC project in the cadastral territory of Hody (Galanta). The outputs of the evaluation are the proposals aimed to produce a functional TSES in the studied territory. The proposals consisted of the proposal of the TSES skeleton (including re-evaluation of nature and landscape conservation) and the proposal of eco-stabilising measures (including the elimination of stress factors). The proposed TSES elements at local level were functionally and logically interlinked with the ecological networks of higher hierarchical levels. The proposals for eco-stabilising measures consisted partial proposals – proposal for establishing new eco-stabilising elements – groups and strips of NFWV, proposal for ecologically optimal land use, proposal for eco-stabilising measures in forest ecosystems and proposal for hydro-ecological measures. In the model area, it is possible in certain places to consider all agricultural and also all other activities. In some places, all agricultural activities were appropriate, non-agricultural, tourism and agrotourism were only suitable. In certain places, non-agricultural use is optimal, mainly hiking and cycling. Some locations where nature and landscape protection is optimal are not suitable for any economic use. Different intensity of use is caused by limiting factors that result from the properties of the primary, secondary and tertiary landscape structure. The main objective was to develop a functional TSES. Outputs constitute basis for the GPFAT in the LCs and for the proposal of common facilities and measures in the model territory. Project of LTSES was a key aspect of the 'greening' of the agricultural landscape. Without accepting and implementing LTSES proposals into the LCs, it would not be possible to ensure the integrated protection and the creation of an agricultural landscape.

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QUALITY OF LIFE IN THE CITY, QUALITY OF URBAN LIFE OR WELL-BEING IN THE CITY: CONCEPTUALIZATION AND CASE STUDY

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Abstract

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Quality of life research responds to the growth of urbanization in the world by increasing the focus on the quality of urban life; however, the dominant applied research tends to be without conceptualization of the quality of urban life. The aim of this paper is to answer the question whether the quality of urban life exists as an original, separate part of the concept of quality of life, or whether only the quality of life or the well-being of a certain city exists. The authors argue that the quality of urban life exists as an original category of quality of life and their beliefs are based on the fact that it can be measured separately. The quality of urban life is holistic, co-existing with the quality of life. The city from the point of view of quality of life research is a place, and the quality of urban life is the satisfaction with life in a city and the quality of place in it. This approach is applied to the quality of urban life and its measurement in the city of Liberec. The results are implications for policy-makers and urbanists.

Key words: quality of life, quality of urban life, well-being, quality of place, holistic approach, city of Liberec.

Introduction

Development at present, which is considered the late modern period, is manifested by increased complexity, multidimensionality and interdependence of social and economic processes. The development of cities in its qualitative and quantitative forms is one of the significant parts illustrating these processes. According to statistical data, today's global urban population has exceeded fifty percent; in Europe, it has reached seventy-four percent and in the Czech Republic, it was sixty-nine percent in 2015. Thus, the cities have become the drivers of social and economic development. The flip side of this development is the accompanying growth of the phenomena of social pathology, especially crime accompanied by an increase in mental disorders. Attention is therefore rightly dedicated to the growing cities or to the conurbation with millions of people in different parts of the world, although the dichotomy urban–rural has not lost its justification (Ruiz, 2015). Over the past few years, there has been a rapidly growing city population in the countries of the Global South, while in big cities but also in smaller cities of the countries of the Global North, the qualitative aspect of their development dominates with a strong emphasis on ecology. This is illustrated by the attention paid to the quality of life of urban residents, to the environment in the cities and to the cities as centres of creativity (Landry, 2008). The number of measurements and charts of various aspects of the quality of life in the cities is increasing. Problems associated with urban sprawl pose a great challenge for scientists (Marans, 2012).

What are we talking about when we talk about the quality of life? It refers to the extremely complex and multi-dimensional concept of interrelated variables characterizing the idea of the *good life* and satisfaction with that, and how the life of an individual approaches this notion. If a human is to feel good and secure in life, they need to be engaged in things that lead them to some ideal – to a goal. In the Aristotelian thought conception this is called the final cause (*causa finalis* in Latin), through which not only the ´end of the work` (*causa operis*) but also the ´end of the agent` (*finis operantis*). This way, one then actualizes the endeavor for a ´good life` (Podzimek 2016: 1069). Success of its study is conditional on a multi-disciplinary approach and by accepting the fact that the quality of life is determined culturally and geographically. In connection with the cities, we examine the quality of urban life; as for terminology, we prefer the more often used term *quality of urban life* than the less frequently used term *urban quality of life* (Tiran, 2016). And what are we referring to when we talk about the quality of urban life? Does it differ from ´general` or the quality of life ´as a whole` for people who live in the city? If there is no difference, then for one and the same phenomenon, we use two different names and the quality of urban life and the quality of life of urban residents are synonymous notions. If there is a difference, it is necessary to explain what it is. The quality of life is holistic; it has two dimensions: well-being and quality of place. Therefore, if the quality of urban life exists, it must be holistic and also have these two dimensions.

Quality of urban life research began in the 1960s (Marans, Stimson, 2011). In 1986, the monograph *Quality of Urban Life. Social, Psychological, and Physical Conditions* (Frick et al., 1986) was edited by Dieter Frick. *Investing Quality of Urban Life. Theory, Methods, and Empirical Research* (Marans, Stimson, 2011) is a significant contemporary monograph focused on urban quality of life. In the 1980s, the study of the quality of urban life significantly enriched the development of urban geography and remained significant until the beginning of the 21st century. In urban geography, this development also contributed to developing the idea of ´useful knowledge` in the context of ´applied urban geography` (Pacione, 2003b). In the past, the attention was focused on the material conditions of the quality of urban life, especially living standards (Peil, 1984; Santos, Martins, 2007). At present, the research is oriented towards subjective and objective dimensions of the quality of urban life and their measurement (Marans, Stimson, 2011). Slovak and Czech geographers have paid a great attention to studying quality of urban life: Andráško (2006, 2007, 2016), Andráško et al. (2013), Ira (2005, 2015), Ira, Andráško (2008), Ira et al. (2005), Ira, Šuška (2006), Kladivo, Halás (2012), Rišová, Pouš (2018).

In scientific papers that are dedicated to dealing with the urban–rural dichotomy of quality of life, there is a frequent comparison of life satisfaction in the countryside and in cities. According to Sirgy (2012), in many European countries, Australia and Latin America, life in big cities is detrimental to life satisfaction, and on the contrary, rural life is beneficial to life satisfaction. In regards to the Czech Republic, Murgaš and Klobučník (2016a) have pointed out that the average quality of life in villages measured on Cantril's scale from 0 to 10 is almost the same (5.31) as in the cities (5.14), while the quality of urban life in the smallest towns is the lowest (4.60) and the highest in cities that have a population of over one hundred thousand inhabitants (6.38), which also includes the city of Liberec.

In relation to the quality of urban life, we can say that researchers focus on two different understandings of the city. In the first case, the basic level are districts and on a higher level is the city (Türkoğlu et al., 2011; Kladivo, Halas, 2012). According to Pacione (2003b), most of the geographic studies of quality of life are focused on the intra-urban level. In the second case, the basic level is a ´city as a whole`, and a higher level is a region or a state. Specific works are those which are focused on the assessment of all settlements, i.e. villages and cities in the region (Marans, Kweon, 2011; Stimson et al., 2011) or across the country (Włodarczyk, 2015; Murgaš, Klobučník, 2016b).

For examining the quality of urban life, the attention is focused on large cities or metropolitan areas, and analyses of small or medium-sized cities with populations of up to one million inhabitants (Santos, Martins, 2007; Rezvani et al., 2013; Tiran, 2016). In our paper, we focused on the Czech city of Liberec with a population of 103,000 in 2016, making it the fifth largest city in the Czech Republic. The number of inhabitants in the city of Liberec increases as in only one regional city of the Czech Republic. (The population is also increasing in the capital city of Prague, but the growth is a result of immigrant origin.) The study "Quality of life in municipality of Liberec" (Murgaš, 2016a) has been carried out on the basis of an order placed by the Municipality of Liberec.

The aim of this paper is to answer the question whether there is a quality of urban life as the original, a separate part of the concept of quality of life or if quality of life, possibly the well-being, of a certain city exists. If the quality of urban life exists, it is necessary to outline its conceptualization and measurement. It would also be interesting to know what is the relationship between the quality of urban life in Liberec and the quality of life of its inhabitants. From the above it will be possible to draw implications for policy-makers and urban planners.

Theoretical background and conceptualization

Quality of life has a number of attributes – it is an elusive concept (Budowski et al., 2016), a shibboleth (Rapley, 2008), an umbrella concept. If we accept these claims, then quality of life cannot be conceptualized or measured. The claim that we do not know what a good life is – because for everyone it means something different – is a postmodern understanding of the quality of life. In contrast, according to Bradley (2015, vii), "*well-being has always been a central notion in moral and political philosophy. It plays a role in determining the rightness of action.*"

We can hear quite often the statement that "*often it is difficult to differentiate between the notions of quality of life, well-being, satisfaction, and happiness*" (Marans, 2015: 48), or that these notions are considered to be synonyms. We do not agree with this characterization in our approach; rather we distinguish the quality of life, well-being and happiness (Marans, 2012; Budowski et al., 2016). On the other hand, we value life satisfaction when we examine the quality of life. Therefore, we consider the notions of life satisfaction and well-being as synonyms.

Quality of urban life has been conceptualized by several authors (Izakovičová, 2005; Marans, Stimson, 2011b; Nuvolati, 2014; Marans, 2015; Izakovičová et al., 2017). According to Marans and Stimson (2011), the basis for the conceptualization of the quality of urban life is a holistic understanding of approaches that are focused on well-being and quality of place. The conceptualization of the quality of urban life is based on the following premises:

- Quality of life is holistic. It consists of two dimensions: subjective (well-being) and objective (quality of place) (Murgaš, Klobučník, 2016a). It has two levels – individual and societal.
- A reference point to which the concept of quality of life relates is the concept of the *good life* (Ferriss, 2010; Michalos, Robinson, 2012; Veenhoven, 2013), which is lived in a *good place* (Murgaš, 2016b).
- An important part of a good place in the quality of urban life is its ecological domain. Murgaš and Klobučník (2016) state that the correlation between the emission balance and the Quality of Life Index is 0.34, which means a «moderate» correlation according to the verbal evaluation of the numerical values of the correlations (de Vaus, 2002).
- Quality of life as well as all the current concepts cannot be measured. What can be measured are the variables – the indicators. Well-being is measured by a questionnaire; the results are the primary variables. The quality of place is gleaned from statistical sources; the results are secondary variables.
- Even if well-being is the more important out of the two dimensions, it is not quality of life itself. The meaning of quality of life is ´over` well-being and quality of place, and they are its dimensions.
- Life satisfaction is what one assesses when answering the question of how to evaluate one's life as a whole. Well-being or ill-being is an expression of life satisfaction. Life satisfaction is the content of quality of life; its scale is long term.
- Happiness is short-lived emotional state in which a person can survive the greatest possible fulfilment of their expectations. When we measure life satisfaction on Cantril´s scale from 0 to 10, happiness refers to number 10. As the feeling of happiness fades away, then it translates to life satisfaction.
- The quality of urban life is a societal quality, where the key word is a *place* (Andrews, 2001; Marans, 2012; Murgaš, 2016b). The word ´urban` focuses the notion of quality of life on the quality of life of people living in a certain place, that is, in the city. (Likewise, ´rural` focuses on the quality of life of people living in rural areas.)
- Quality of life and quality of urban life are two notions, and each means something else. Quality of life is the quality of life of the individual, and it is secondary to where the individual lives, whether in the city or village. The quality of urban life in our particular city of Liberec expresses how the inhabitants of the city are satisfied with the life in Liberec and not how an inhabitant is ´generally` satisfied with life. Life satisfaction ´generally` is the quality of life, or its personal dimension.
- The quality of urban life in the city (the city N) is holistic and has two dimensions – life satisfaction of inhabitants of the city N and the quality of place in the city N.

- The city in terms of quality of life research is a *place, and the quality of urban life is the satisfaction with life in the city and the quality of place in it.* This is a key element of its conceptualization.

According to Murgaš (2016b), the quality of life is a *good life*, which is lived in a *good place*. Different opinions on the co-relation between prosperity and its influence on the good life exist (Murgaš, Böhm, 2015).

A good place is a place with high quality of external, tangible and intangible prerequisites of a good life. The quality of life of the individual meets with the quality of life of the community or the societal quality within it. The good life is associated with good company and on the contrary, creating a good society is the key to a good life. In terms of good life, Veenhoven states that the (2014: 5265) quality of life is "the degree to which a life meets various standards of the good life".

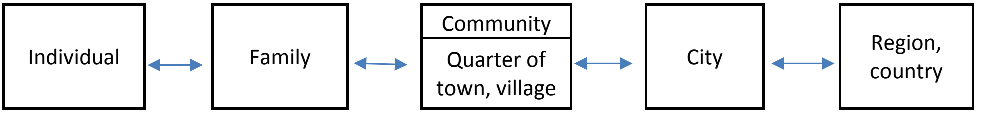

Fig. 1. Levels of quality of place.

The quality of place has five levels (Fig. 1). The dimension of well-being is more important for the quality of life on the individual, family and community level; the impact of the quality of place on well-being is small (Murgaš, Klobučník, 2016b). The dimensions of quality of place are more important for the quality of life on a city district or village, or at the region/state level. The quality of life of the individual turns into societal quality of life and that is from the community, city, district or village level. The terms ´family` (micro-communities) and ´community` have social content, and the terms ´rural settlement` and ´city district`have spatial content. It is natural that if the community lives in one city district, the terms ´community` and ´city district` are merged. From a social point of view, we divide larger and big cities into communities; from an urban point of view, we divide them into city districts.

Psatha et al. (2011) emphasize that the quality of urban life in terms of the societal quality of life cannot be considered as the average life quality of the city residents. It is caused by the fact that indicators on an individual level are not capable of being automatically transferred to a societal level; the reverse is also true. Nuvolati (2014: 6848) defines *"the concept of quality of urban life regards the living conditions in urban areas and mainly in cities."* This definition reduces the quality of urban life to the living conditions because of the absence of well-being. If the quality of life is a subjective assessment of one's own life lived in the spatially differentiated external environment, then *the quality of urban life will be the subjective assessment of life satisfaction lived in a certain city and its quality of place.*

In conceptualization of the quality of urban life besides its holistic determination, the search for an answer to the following questions will be important: (i) if the quality of urban life is the only one of the life quality categories (as it is in the research of quality of life of several age groups or in spatial, hierarchically organized units), or it is an original quality of life. Furthermore, the question (ii) of its differentiation from others arises, meaning the non-urban quality of life. If we accept the hypothesis, that the quality of urban life is the original quality of life, does it mean (iii) that it has its own dimensions?

Pacione (2003a) believes that the quality of urban life is the original quality of life. He considers that the dimension that is specific for it is social groups in the city. In our opinion, the answers to questions asked are the following:

i. The quality of urban life is the original quality of life; it exists together with the quality of life in any city or village. We derive its quality out of the fact that it is possible to ask the question: ´How satisfied are you with living in the city N in general?` and to measure the answers (Murgaš, 2016a). Besides that, it is also possible to ask the inhabitants of the city N the question, ´How satisfied are you with your life in general?` We quantify the answer to the first question ´well-being in the city N` by answering the second question ´well-being generally`. It is natural, that on a regional or state level, only part of the respondents are the inhabitants of cities. But the division of population into urban and rural population is not important in the research of the societal quality of life.
ii. The differentiation of urban from non-urban means that rural quality of life is only semantic. From the content viewpoint, both qualities of life are two kinds of settlement and societal quality of life.
iii. The quality of urban life – in a certain city N – is equal in meaning to the quality of life (in case it is applied to a certain city), and therefore it is divided into dimensions. We will get the holistic quality of urban life in the city N by connecting the well-being of inhabitants in the city N and the quality of place in the city N.

Measurement and data

There are several indicators used while measuring the quality of urban life (Psatha et al., 2011; Marans, 2015; Włodarczyk, 2015). Most of these variables are secondary data gathered from statistical surveys and they create the quality of space in a certain city. Murgaš and Klobučník (2016a) quantified the quality of life in all settlements, and also in cities in the Czech Republic, using indicators that make up the gold standard of quality of life. The fair values of the indicators were converted to a consistent range <0–1>. If we accept the need for a holistic understanding of the quality of urban life, we have to make two measurements: (i) satisfaction of inhabitants with life in the city – well-being and (ii) the quality of place.

As we have already mentioned, at the request of the Municipality of Liberec, the Technical University of Liberec, Department of Geography conducted a study "Quality of life in municipality of Liberec" (Murgaš, 2016a). The study was based on a questionnaire survey, which drew responses from 505 inhabitants of Liberec (210 men and 295 women). The research was conducted from May to June 2016. A question about the quality of life was a part of the questionnaire: *How would you express satisfaction with your life?* on a scale of 0 to 10. Another issue was about the quality of urban life: *How would you express satisfaction with life in Liberec?* (possibilities for a response on a 5-point scale: very satisfied, satisfied, neither satisfied nor dissatisfied, dissatisfied and very dissatisfied). Liberec reached a 6.4 value on a scale of 0 to 10 from the aspect of quality of place (Murgaš, Klobučník, 2016a).

All data from the questionnaires were grouped into a unitary database from which we created a pivot table. Using our method, we were able to obtain the necessary results – life satisfaction of the inhabitants of Liberec with life in the city and the quality of life of this city, both divided according to demographic characteristics (sex, age and education). We constructed overview charts for a better analysis of the obtained results from which we were able to make several conclusions. It should be noted that the quality of urban life in Liberec and the quality of life of the inhabitants of Liberec were analysed in relative numbers.

Results

In the first step, we constructed a hundred percent pie chart (Fig. 2). We assigned the following weight to the individual answers to questions concerning the quality of urban life on the 5-point scale: very satisfied (9 points), fairly satisfied (7 points), satisfied with some aspects, dissatisfied within others (5 points), fairly dissatisfied (3 points) and very dissatisfied (1 point). We used these points as a comprehensive analysis, when we compared the difference between optimal and gained points within the quality of urban life (9-7-5-3-1 point) and quality of life (Cantril's scale 0–10) according to sex, age and education. The optimal condition would occur if people were "very satisfied" within the question about satisfaction with the quality of urban life and at the same time, when asked to assess the quality of life, gave 10 or 9 points. It would be an ideal combination of the highest quality of urban life with the highest quality of life.

As shown in Fig. 2, the inhabitants of Liberec are very satisfied with the quality of urban life in the city; nearly four-fifths stated that they are very or fairly satisfied. The number of fairly dissatisfied is three percent; very dissatisfied respondents comprise not even one percent.

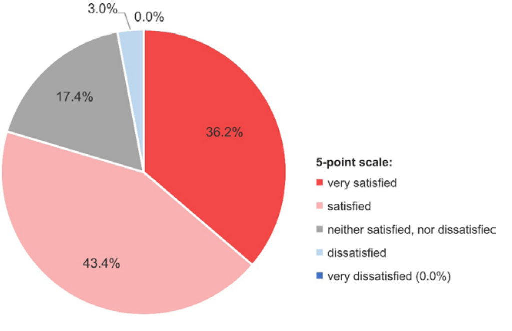

Fig. 2. Quality of urban life in Liberec.

Comparing the quality of life by gender (Fig. 3) does not produce clear results. According to many authors, on the one hand, women report higher quality of life; on the other hand, there are no

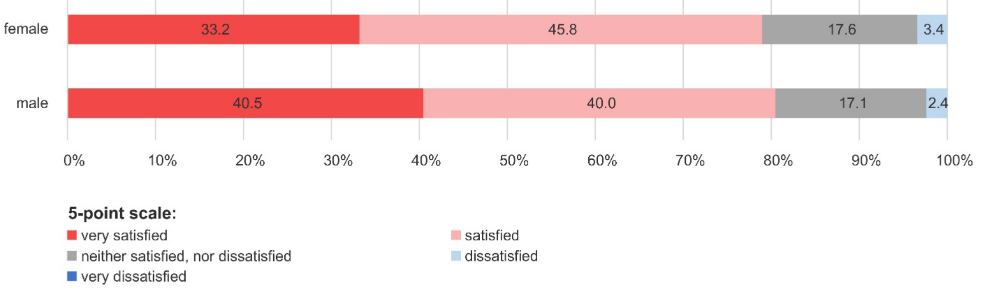

Fig. 3. The quality of urban life by gender.

differences between men and women as per some other authors (Blatný, Šolcová, 2015). In our case, gender differences between men and women are in pentiles with the values very and fairly satisfied. About seven percent fewer women than men reported they are very satisfied, and six percent more women than men are fairly satisfied; the number of undecided is almost the same. Those responding that they are fairly dissatisfied is almost the same number as well. The difference between very or fairly satisfied men and women is small; 80.5 percent of men is slightly more than 79 percent of women.

According to Blatný and Šolcová (2015), the youngest and oldest age groups have a higher level of well-being, whereas people in the middle age have a lower level of well-being. This statement was not confirmed in the case of Liberec. As shown in Fig. 4, the quality of urban life increases with age. By age groups, the quality of urban life in the previous segmentation of women and men is differentiated much more. The most satisfied are the oldest inhabitants of Liberec aged 66 years and older, the value of more than forty percent in points ‹very satisfied` is the highest among surveyed variables of gender, age and education. When we consider these points together with ´satisfaction` in comparison with ´dissatisfaction`, the

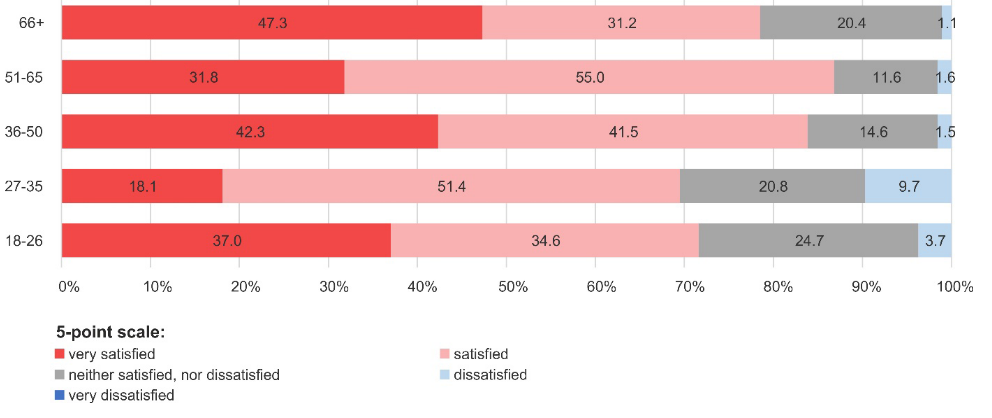

Fig. 4. Quality of urban life according to age groups.

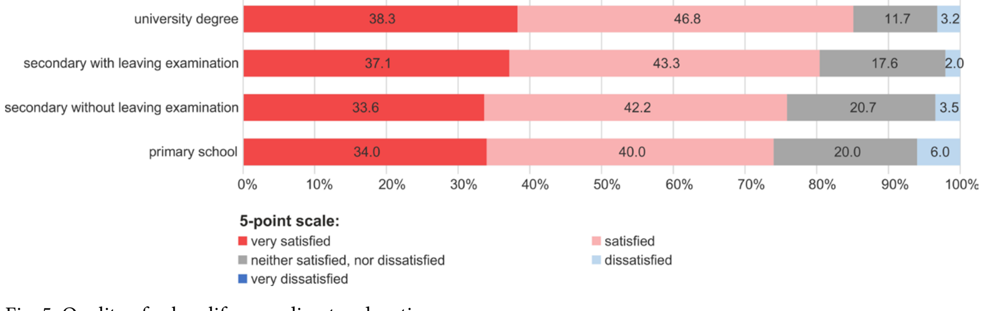

Fig. 5. Quality of urban life according to education.

first dominated in the most remarkable ratio. The pentile ´mostly satisfied` with the value of fifty percent in the age group of 51- to 65-year olds has the highest numerical value of all measurements of quality of urban life and the quality of life in Liberec. The least satisfied are the inhabitants of Liberec in the age group of 27–35 years; they also have the highest proportion in point ´dissatisfied` out of the variables of gender, age, education.

According to Blatný and Šolcová (2015), several surveys point to the increase of well-being together with the increase of education. This finding was also confirmed in our paper (Fig. 5). The quality of urban life rises with gained education; however, the differences in various categories of education are not large.

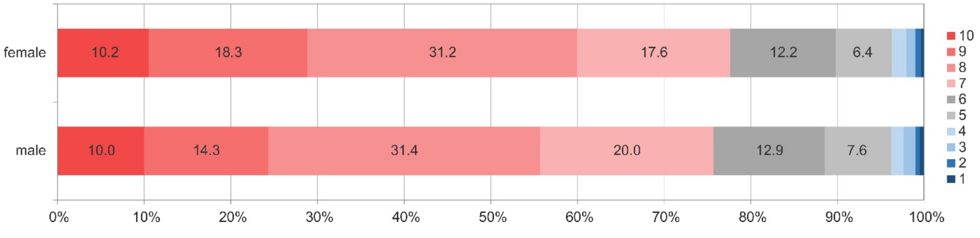

Fig. 6. Quality of life according to sex.
Note: There were no answers in the value ´zero` on a scale of 0–10.

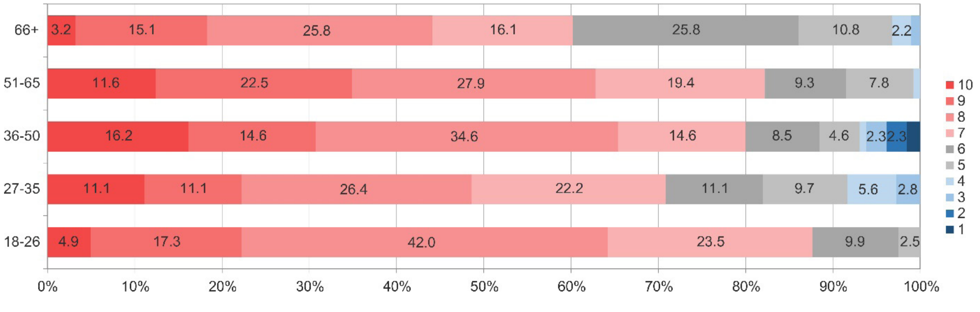

Fig. 7. Quality of life by age group.
Note: There were no answers in the value ´zero` on a scale of 0–10.

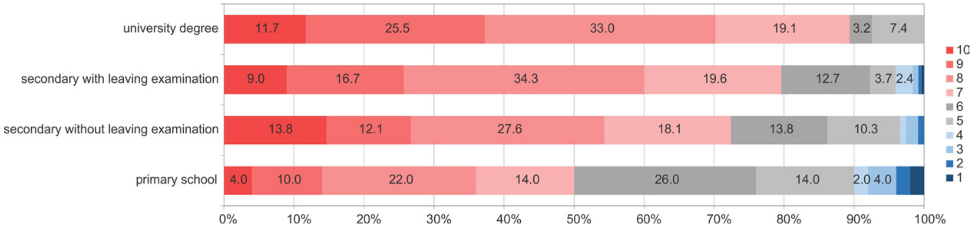

Fig. 8. Quality of life according to education.
Note: There were no answers in the value ´zero` on scale of 0–10.

T a b l e 1. The Pearson correlation coefficient between the quality of urban life and quality of life.

		Dwellers	Pearson´s coefficient	Assessment[a]
Sex	female	295	0.2464	small
	male	210	0.3109	medium
Age	66+	93	0.2078	small
	51–65	129	0.2470	small
	36–50	130	0.4321	medium
	27–35	72	0.0997	very small
	18–26	81	0.3262	medium
Education	university degree	94	0.3268	medium
	secondary with exam (most typically 4 years)	245	0.2861	small
	secondary without exam (most typically 4 years)	116	0.2669	small
	primary school	50	0.1120	small
Total		505	0.2704	small

[a] The word 'evaluation' was based on de Vaus (2002).

The quality of life, which is the answer to the question *´How satisfied are you with your life in general?`* and for which we gave attributes *´generally`* or *´as a whole`* for clarity to distinguish the quality of urban life slightly differ or show no difference at all between women and men in Liberec within Cantril's scale. The satisfaction expressed by the value of 10, the highest within Cantril's scale that we consider to be happiness, was declared by ten percent of men and slightly more women. If we want to compare the quality of life and urban quality of life by gender, we need to convert Cantril's value to the 5-point scale value (9-7-5-3-1). The differences are significant, especially for men. In the point ´very satisfied ` within the quality of urban life, there are more than forty percent of men yet within the quality of life, only more than twenty-four percent of men. In the point ´satisfied` within the quality of life, there is eleven percent more men than in the quality of urban life. In the point ´very satisfied`, within the quality of life, there are less women than in the quality of urban life, but the differences are smaller than for men. Overall, we can say that within the quality of life and quality of urban life, the share of very satisfied and satisfied men and women is nearly the same, around eighty percent (Fig. 6).

We can see a significant differentiation in the quality of life by age group (Fig. 7). A value of 10 in Cantril's scale was declared by a small percentage of the population of Liberec, in the youngest and oldest age range. In the other age ranges, value 10 was declared by a multiple times higher percentage. If we identify the value of 7–10 of Cantril's scale with the points very satisfied and satisfied, the highest quality of life is declared by the youngest population in the age group 18–26 years (87.7%) and an older population in the age group 51–65 years (81.4%). The lowest percentage of the highest quality of life is observed within the oldest inhabitants aged 66 or older (60.2%). On the contrary, the lowest quality of life, value 0–3, can be seen within the age groups 27–35 years and 35–50 years, while in this age group the lowest rating of 1 or 2 is declared.

Within the quality of life according to education (Fig. 8), there is an expected increase from the population with basic education to inhabitants with university education. In our pentile scale, very and fairly satisfied represent almost ninety percent of the population with higher education and on the other hand, only fifty percent of the population with basic education. In this educational category, the most – up to ten percent – are fairly and very dissatisfied.

Together with the identification of the quality of urban life as the original quality of life, the question of its relationship to quality of life comes to the fore. We explored this relationship using previously used variables – gender, age and gained education. The findings are

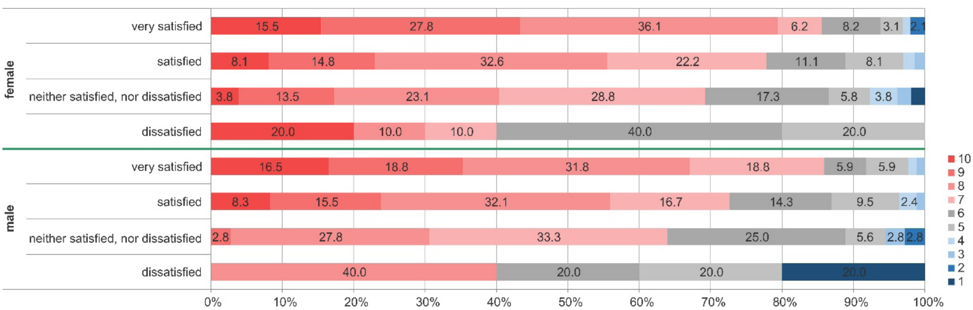

Fig. 9. Relation between quality of urban life and quality of life by gender.
Note: There were no answers in point ´very dissatisfied` as well as in value ´zero` on a scale from 0 to 10 for both men and women.

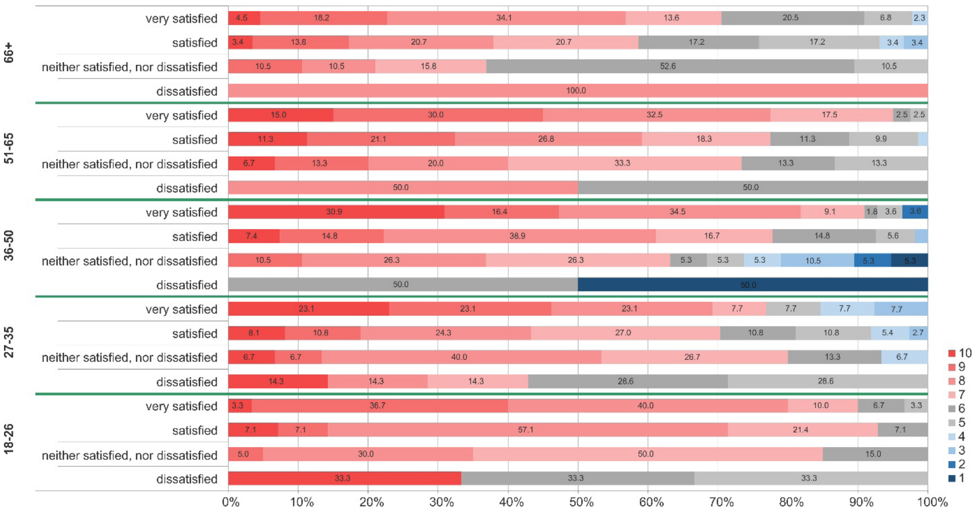

Fig. 10. Relationship between the quality of urban life and the quality of life by age group.
Note: There were no answers at the ´very dissatisfied` pentile, as well as no ´zero` value in the scale from 0 to 10 for both men and women.

surprising. In Figs 9 through 11, the quality of urban life is set by points, with quality of life ranging from 0 to 10 (however, the zero value didn't appear even once in 505 replies). There are differences between the quality of urban life and the quality of life in Liberec (Fig. 9) between men and women. For women, the quality of life at value 10 is a larger percentage of fairly dissatisfied than very satisfied with the quality of urban life. Men dissatisfied with the quality of urban life reported lower values of quality of life. Generally, however, for both men and women, the quality of life improves with the quality of urban life.

There are also differences for the quality of urban life and the quality of life by age group. The quality of life at the value of 10 is rated by 30.9 percent of very satisfied respondents between the ages 36 and 50 years, and 33.3 percent of fairly dissatisfied respondents are 18- to 26-year-olds. The relationship of growing satisfaction with the quality of urban life in Liberec, with increasing quality of life of this city is the most remarkable in the age group 36–50 years. Generally, the satisfaction with the quality of urban life as well as the quality of life of Liberec inhabitants increases with growing age. Extreme values of very dissatisfied in the age groups of 36–50 and 66 years and older are achieved thanks to the small population.

Because the value of the quality of urban life (Fig. 5) and quality of life (Fig. 8) increase with education gained, this is reflected also in relation to each other (Fig. 11). Here again, however, no direct causal connection applies, and so at all levels of education, the most satisfied with the quality of life out of people with primary education are those who are ´dissatisfied` in the point group. Relatively extreme values in this pentile are again due to the small population.

To measure the intensity of the linear relationship between two variables – the quality of urban life and the quality of life – we used the Pearson correlation coefficient. We calculated it for the sex, age and education categories and it achieved positive values within all the

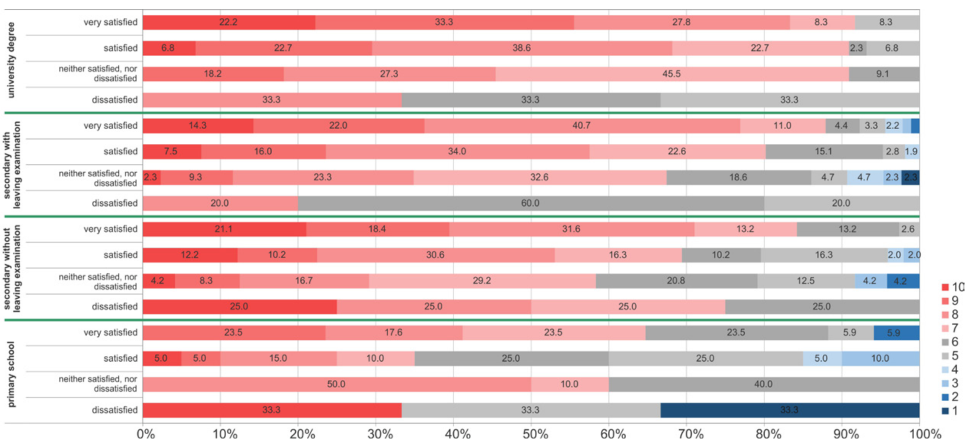

Fig. 11. Relationship between the quality of urban life and the quality of life by education.
Note: There were no answers at pentile ´very dissatisfied`, as well as no ´´null` value in a scale from 0 to 10 for both men and women.

categories. The coefficient reached the lowest and highest value within the age category. The predominant value is small, that is from 0.10 to 0.29 (de Vaus, 2002), and it was achieved in seven out of twelve categories. It is significant that the coefficients depending on sex, age and education differed significantly, as evidenced by the fact that the various groups of the population perceive the range between the quality of urban life and the quality of life differently (Table 2).

T a b l e 2. The difference between optimal and gained points between the quality of urban life and quality of life (by gender, age and education).

The Quality of Urban Life – Quality of Life		very satisfied		satisfied		neither satisfied, nor dissatisfied		dissatisfied		very dissatisfied		Sum ± (absolute value)
The optimal points (The Quality of Urban Life)		9–10		7–8		5–6		3–4		0–2		
Points obtained (in Quality of Life) ± difference from the optimal points		pts.	±	pts.	±	pts.	±	pts.	–	pts.	±	
Sex	female	8.10	**–0.90**	7.49	0.49	7.02	2.02	6.90	3.90	-	-	7.31
	male	7.93	**–1.07**	7.43	0.43	6.72	1.72	5.60	2.60	-	-	5.82
Age	66+	7.43	**–1.57**	6.83	**-0.17**	6.58	1.58	8.00	5.00	-	-	8.32
	51–65	8.30	**–0.70**	7.68	0.68	7.27	2.27	7.00	4.00	-	-	7.65
	36–50	8.33	**–0.67**	7.57	0.57	6.16	1.16	3.50	0.50	-	-	2.90
	27–35	7.69	**–1.31**	7.11	0.11	7.40	2.40	6.71	3.71	-	-	7.53
	18-26	8.10	**–0.90**	7.86	0.86	7.25	2.25	7.00	4.00	-	-	8.01
Education	university degree	8.44	**–0.56**	7.89	0.89	7.55	2.55	6.33	3.33	-	-	7.33
	secondary with exam	8.00	**–1.00**	7.62	0.62	6.84	1.84	6.20	3.20	-	-	6.66
	secondary without exam	8.13	**–0.87**	7.31	0.31	6.63	1.63	7.75	4.75	-	-	7.56
	primary school	7.00	**–2.00**	6.10	**–0.90**	7.10	2.10	5.33	2.33	-	-	7.33

Note: There were no answers in pentile ´very dissatisfied`. Negative values are written in bold numerals.

In addition to the Pearson correlation coefficient, we decided to express the relationship between the quality of urban life and the quality of life in other ways. In order to assess the relationship between these variables in more detail, we recalculated a percentage representation of the responses of individual categories into points. We considered the points of quality of urban life to be optimal and we compared them with points of quality of life, which were divided according to sex, age and education (Table 2). This can be illustrated by the example of women who answered the question of quality of urban life as "satisfied". We assumed that their replies to the questions of quality of life (0–10) would be in the range of 9 to 10 points of the quality of urban life. If these women perceived the quality of urban life and the quality of life almost identically, it would be the optimal situation. This case did not really occur. Therefore, we recalculated a percentage of the occurrence of responses of the quality of urban life within the variables such as gender, age and education. There could be cases where respondents perceived the quality of urban life as more positive than quality of life, and vice versa. From Table 2 it is clear that in all tested categories in which respondents answered the question of quality of urban life with ´very satisfied`, they already perceived the quality of life (in the range from 0 to10) slightly differently, meaning that they didn›t assign points 9 or 10 but lower values. Within respondents who answered ´satisfied`, such a case was only in two categories, namely in the population 66+ and in the population with basic education. In all categories, and within other answers to the quality of urban life, they rated quality of life (0–10 scale) as higher. Absolutely the smallest differences in the perception of the quality of urban life and the quality of life occurred in the response «very satisfied» and the category of 27- to 35-year olds (point difference 0.11). The optimal group within all inhabitants of city of Liberec, who answered the questions, is the category of 36- to 50-year olds. The summary difference in all response categories of quality of urban life is the lowest (reaching 2.90 points), on the contrary, the group with the highest absolute difference is 66 years and older (8.32 points).

Implications for policy-makers and urbanists

As mentioned, the quality of urban life is holistic and implies two dimensions – the personal, which comprises life satisfaction in a certain city, and the spatial, which comprises quality of place. External conditions create the quality of place for living a good life. The sketch conceptualization of the quality of urban life and its measurement in the example of the city of Liberec gives rise to the following implications for the policy-makers and urbanists:

The purpose of public administration, represented by policy-makers on all hierarchical levels, is good governance. Governance is good when it provides services to citizens. In the context of quality of life, it implies the creation and strengthening of already established good places as places for living a good life.

Due to urbanization, good places are mainly cities. Therefore, the quality of urban life should be the focus of all policy-makers and urbanists, who put most of their decisions into concrete form.

The impact of quality of place on quality of life of people in developed countries is generally not large; on the other hand, it is not insignificant (Murgaš, 2016b). Residents of these countries take a high level of personal, religious and political freedoms, social and medical services, education, housing, technical infrastructure and the environment for granted. It can be assumed that this sense of certainty results in the quality of place having a lower value for quality of life. Within the developing countries, there are significant differences in the above criteria. Therefore, people from countries with a lower level of development commute to work or move to countries with higher levels of development, and not the other way around.

Policy-makers on a regional and local level but not on a state level have a greater importance for a specific city and its quality. Local policy-makers should initiate the creation and development of sustainable local partnerships to improve the quality of urban life. From the start, it is necessary to carry out a study describing the status, which can be reached on a city district level, including surveys of citizens' opinions on the development priorities in these city districts. A good example is the progress of the municipality of Liberec.

The experience of the elaboration of the material quality of life in the municipality of Liberec (Murgaš, 2016a) means that in addition to large urban interventions in cities in the form of revitalization of deprived urban areas or increasing its technical facilities, there are mainly minor urban interventions in the form of the planting trees and maintenance of green areas, playgrounds, leisure opportunities and so on, which improve life satisfaction in the city.

In the Czech Republic, as in other countries of Central and Eastern Europe, there is no tradition of moving for work several times in life, as in the USA. However, a new remarkable phenomenon is emerging. It is the effort of some cities to attract mainly young residents to move to their cities. Subsequently, the cities will have higher tax revenue. Cities with higher level of quality of place will undoubtedly have a competitive advantage in this case.

Discussion

According to our findings, we consider the most important fact that the inhabitants of Liberec are very satisfied with the quality of urban life in this city. This correlates with positive assessment of quality of life of citizens of other cities, as Prague (Heřmanová, 2012) or Bratislava (Ira, 2015). Almost eighty percent declared they are very or mostly satisfied. On the contrary, the number of fairly dissatisfied is three percent; very dissatisfied is not even one percent.

Since we wanted to compare the relationship of the quality of urban life in Liberec with the quality of life of the inhabitants of Liberec in a further analysis, we constructed complex pivot charts and calculated the Pearson correlation coefficient.

Other findings are as follows:

- Within the pentiles for all variables, the values in pentiles ´very or mostly satisfied` significantly prevail over the pentiles ´very or mostly dissatisfied`.
- The difference between very or fairly satisfied men and women is small.
- The quality of life rises with age; the most satisfied are the oldest inhabitants of Liberec aged 66 years and over, the pentile ´mostly satisfied` with the value of fifty percent in the age group of 51- to 65-year olds has the highest numerical value of all measurements of quality of urban life and the quality of life in Liberec.
- Within the quality of life measured according to education is an expected increase from the population with basic education to inhabitants with university education.

Two concepts raised from the above mentioned are as follows:

(i) The quality of urban life and quality of life are two different qualities.

(ii) The difference in the quality of urban life and quality of life by sex, age and education is relatively large, especially in the age-based groups (2.90 to 8.32).

The result from measuring the quality of urban life and the quality of life in Liberec is that the quality of urban life on a scale of 0 to 10 is 7.2, the quality of life of the inhabitants of Liberec is 7.5 (males 7.4, females 7.6, Murgaš, 2016a) and within the quality of place, Liberec has a value of 6.41 (Murgaš, Klobučník, 2016b). If we want to compare these values with the average values of the Czech Republic, the average quality of urban life in Czech cities is not known; however, it is known that the average quality of life of the inhabitants in the Czech Republic is 6.2 and the average value of the quality of place in all Czech cities is 5.14.

Conclusion

The aim of this paper was to answer the question whether the quality of urban life exists as an original, separate part of the concept of quality of life, or whether only the quality of life or the well-being of a certain city exists.

If the quality of urban life exists, it is necessary to outline its conceptualization and measurement. It will also be necessary to examine the relationship between the quality of urban life in Liberec and the quality of life of its inhabitants. From the above, it will be possible to draw conclusions for policy-makers and urban planners.

In our opinion, the quality of urban life is the original quality of life. We derive its quality from the possibility to ask the question: ´How satisfied are you with living in the city N in general? ` and to measure the answers (Murgaš, 2016a). Besides that, it is also possible to ask the inhabitants of the city N the question: ´How satisfied are you with your life in general?` We quantify the answer to the first question ´well-being in the city N` and the answer to the second question ´well-being generally`. The quality of urban life – in a certain city N – is equal in meaning to quality of life (in which case, it is applied to a certain city), and it is also divided into dimensions. We will get the holistic quality of urban life in the city N by connecting the well-being of inhabitants in the city N and quality of place in the city N. Measuring the quality of urban life in Liberec supports the claim about the existence of quality of urban life as a separate category of quality of life.

The conceptualization of quality of urban life is based on the following premises:

i. The city in terms of quality of life research is a place, the quality of urban life is the satisfaction with life in the city N and the quality of place within it. At the same time, the quality of urban life is a societal quality. This is a key element of its conceptualization.
ii. Quality of urban life is holistic; it consists of two dimensions: subjective (well-being) and objective (quality of place). In contrast to the quality of life, it has only one level – the societal level.
iii. A reference point to which the concept of quality of urban life relates is the concept of the *good life*, which is lived in a certain city as a *good place*.
iv. Even if well-being is more important out of the two dimensions, it is not a quality of urban life itself. The quality of urban life is semantically ´over` well-being and the quality of place, which are its dimensions.
v. Quality of life and quality of urban life are two notions and each means something else. Quality of life is the quality of life of the individual, and it is secondary to where the individual lives, whether in the city or village.

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