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Dynamics of changes in the structure of the forest edge in Slovakia

Introduction

The current situation in the landscape structure of Slovakia results from the long lasting development of anthropogenous factors influence. Land usage in the past was related to its natural potential, and the natural resources of copper ore, silver ore and wood substance were typical for the Starohorské Mountains. The elements of historical landscape structures occurring everywhere are a significant part of the current landscape structure, and they profile its overall character. They are represented by many mining forms of relief, the specific character of settlement, the deforested top sites of ridges due to expanded grazing, and others. The deforestation of territory conditioned the origination of the system of anthropogenic forest edges. It is the aim of the paper to compare their structure, dynamics and typization in several localities of the Starohorské Mountains.

Methods of research

We consider the edge of the forest area between the line of the diameter of crowns with respect to shrub edge or growth cover (trees and bushes cover more than 40% of area) and the line of the first tree trunks in the main level of forest. The value of 2.5 m was added to the measured values at both sides of ecotone, and the edge zone of forest originated. It became the subject of our research. When selecting the locality, it was very important to select such that would best represent the types of forest edges with respect to georelief, vegetation, structure, the way of origination, age, etc. Forest edge transect (10 m wide) was divided into four (or three) zones (non-forest area, bush edge, growth mantle, forest) for the purpose of more detailed analysis. Within this framework, we executed phytosociological relevés according to Zürich-Montpellier school in spring and summer 2008 and 2009 on the area of 25 m^2. Flora was described with the help of the combined scale of abundance and dominance according to Braun-Blanquet (1964).

Data processing is represented by the identification of the types of forest edges (with the use of the leading factor method) and the processing of phytosociological

data. Besides species data, we acquired a lot of data concerning the factors of surroundings, and then we used the selected data for analyses and tests. The phytosociological relevés were evaluated with the programs JUICE 7.0 (Tichý, 2002) and CANOCO (Ter Braak, Šmilauer, 1998). With respect to the number of records, the selected monitored environment variables were such as altitude, rock chemism, the type of forest edge with respect to the form of relief, the average inclination of relief, soil type, the age of forest growth, the position in transect and the intensity of the anthropic use of non-forest transect area. The impact of individual environment variables on the overall variability of vegetation were then quantified and tested with the help of direct unimodal ordinance method (CCA). The factors were selected with the method of gradual selection. The Monte Carlo permutation test was used to ascertain the significance of individual factors. The genetic analysis represents the evaluation of development and change with respect to forest edge lines through monitoring changes in the landscape structure of individual researched localities in three time intervals.

The characteristics and development of forestation in the researched localities

The collection of data was executed in four model localities in the area of Starohorské Mountains. The locality of **Laskomerská Valley** is situated in the upper part of the Laskomerský brook at the boundary of the Starohorské Mountains and Bystrické Stream, at the altitude of 450 m asl. This area represents an example of degradation of original forest ecosystems in the 17th and the 18th centuries, as well as their demanding restoration. The locality of **Špania Dolina** is situated 11 km north from Banská Bystrica, with altitude from 722 up to 1100 m asl in the valley of the Banský brook. The purposive use of forest manifested itself in extensive interventions into the landscape as early as during the 12th and the 13th centuries during German colonisation, but it was specifically due to the development of mining technique during the 15th up to 17th centuries. The meadow-forest character of the area with many mining forms of relief and the specific character of settlement is at present modified with the successive sprouting of unused meadows and pastureland. Beech and fir-beech growth with a significant admixture of spruce and spruce cultures are mostly represented in forest vegetation. The third locality is represented by the deforested surroundings of **Donovaly** that belongs among the highest located villages in Slovakia (988 m asl). It is located in erosion saddleback at the fault line between the Veľká Fatra Mountains and the Starohorské Mountians. The village developed in the beginning of the 18th century from coal settlements of the Mining Chamber. The structure of forest growth was influenced during the previous 400 years by constant activities of woodcutters and charcoal burners, who supplemented these activities with sheep and goat grazing. The part of forest growth was again forested with spruce cultures that significantly differed from the original species, mostly beech forests.

A part of the area remained non-forested and it is used for mowing and grazing, and currently also for sport, recreation and tourist purposes. The locality of **Kozí hogback** (1330 m asl) represents the most east part of the Starohorské Mountains main ridge, with considerably sharp slopes. In the past, the original vegetation cover

consisted of beech forest. During the period of Vlach´s colonisation, forest growth was removed in top localities. Deforested areas were enlarging starting from spring areas to the ridge, and thus they conditioned the origination of the so called anthropogenic "hoľa" (anthropic deforested mountain) and the upper forest edge. This fact also resulted in the origination of mountain paths, erosion basins and, with respect to bigger declination, also erosion furrows. At present, the area is not used for grazing (grazing was ended in 1990), and the processes of secondary succession occur.

Results

The acquired data comprise phytosociological relevés from the individual zones of forest edge transect, structural characteristics of forest edges and the values of the properties of their abiocomplexes. Within the overall complex of data that we acquired from 31 transects and 99 relevés areas with the size of 25 m2, differences occurred due to not only ecological factors or their combination, but specifically due to anthropic impact. The existence and preservation of forest edge is caused by the mechanism and factor of their origination, i.e. human activity, its intensity and the length of impact.

Sheep, goat and cattle grazing were specifically influenced by the origination of upper anthropic forest edge in the locality of Kozí Hogback, partly Donovaly, and in the locality of Laskomerská Valley on the slopes of Laskomer. The line of forest edge depends on the intensity and length of grazing. On the slopes, where intensive grazing has been lasting for several centuries, it occurs markedly low, and forest usually ends suddenly. In the locality of the Kozí ridge, the edge of forest was pushed to beech zone; and due to peak conditions, there appeared growths that are physiognomically similar to those occurring at the natural upper edge of forest. In the locality of Laskomerská Valley, in the part of Podlavické Potholes, soil was degraded because of pothole erosion resulting from excessive grazing. At the turn of the 20th century, large part of the area was subject to a demanding process, forestation with Pinus nigra. The felling of trees together with mining and charcoaling manifested themselves in the character of forest growth in all the localities (with the exception of the Kozí Hogback). At present, these effects on the structure of forest edges are not recognizable; they are replaced with current reasons of felling such as cableways, ski slopes, chalet areas, the lines of road network and others. The growing of agricultural crop influences and keeps the line of forest only in the southern part of the Laskomerská Valley locality. The construction of houses, gardening, grazing, the construction of roads and quarrying required more wood material and space. As forest growth means the source of seed, the forest edges represent the initial zones of secondary succession immediately after the end of the use of the neighbouring deforested areas. The expansive species of high grass and wood from the seedage of the surrounding growth are applied quite fast and to a larger extent. This is the way in which the edge of forest is moved behind forest soil fund, and what originates are lobately enlarging and moving forest edges. This process can be observed in the localities of Laskomerská Valley, Špania Dolina and Kozí Hogback.

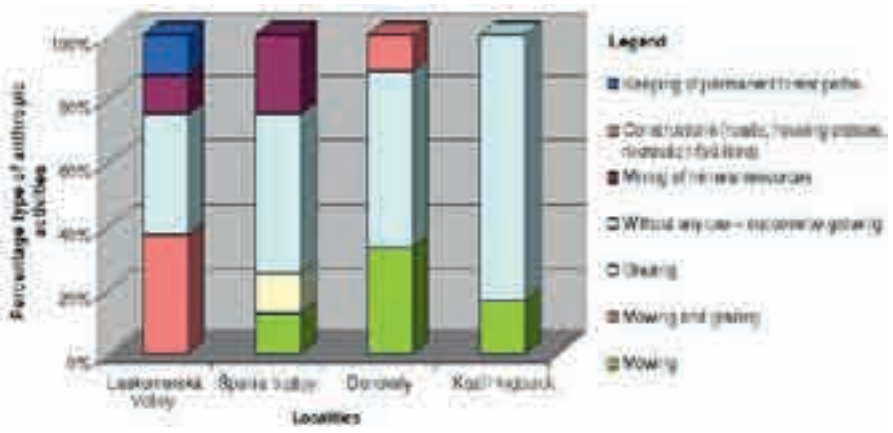

Fig. 1. The graph of proportional occurrence – the type of anthropic activity in the individual localities of the researched forest edge and their percentage

The ecological significance of forest edges is conditioned by their length with respect to the overall area of locality. And this is conditioned by the area structure of forest, to a large extent. The length of forest edge results from the method of cultivation as well as the method and forms of forest growth renewal (Šindelář, 2002). The graph (fig. 2) shows that the highest density of forest edges is in the locality of Laskomerská Valley (72 m/ha in 2009) with respect to increasing altitude, and it decreases with the forestation of area up to the highest locality – Kozí Hogback (48 m/ha in 2009). During the monitored period 1949 – 2009, density of forest edges in the localities with increasing representation of settlement and recreation elements (Laskomerská Valley, Donovaly) increased moderately, and it decreased in less used localities (Špania Dolina, Kozí Hogback).

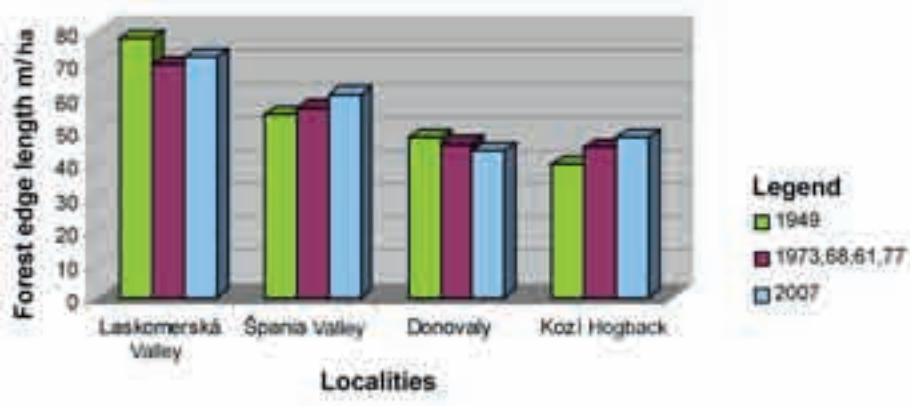

Fig. 2. The graph of the modified density of anthropogenic forest edges (in ha) in the individual researched localities of forest edge

Tab. 1. Types of anthropogenic forest edge in the monitored localities

Type	Description of the forest edge
1	The forest edge is not evident
	– The edge of the forest of coniferous growths – the type of several centuries old forest edge comprising the anthropogenic upper forest edge in the locality of Kozí Hogback
2	The edge of forest comprises trees with normally developed crowns (not thickly branched) without bush zone or only with sporadic shrub in the growth zone
	– It occurs with the cultures such as Pinus nigra in the locality of Laskomerská Valley and Picea in the localities of Špania Valley and Donovaly
3	The edge of forest comprises thickly branched trees with the occurrence of shrub in the growth zone
	3.1 with deciduous and mixed growths – It is the most frequent type of forest edge; the anthropogenous influence reaches the level of growth zone
	3.2 with coniferous forest growths – The type of spruce growths dominant in the locality of Donovaly, less so in Špania Valley. Shrubs occur exceptionally
4	The forest edge comprises thickly branched trees and shrub edge
	– The type of forest edge originating under favourable light conditions (S, SW exposure), mostly with the type of upper forest edge inclination exceeding 20º. The type of forest edge with beech and mixed growths in the locality of Laskomerská Valley and Špania Valley
5	The edge of forest comprises loose and thickly branched trees and herb edge
	– The type of the forest edge of spruce growth in the locality of Donovaly
6	The edge of forest is of roof structure, it grows in lobes
	6.1 with deciduous and mixed forest growth – Growth cover has from loose up to thick cover with crown branches. It occurs on deforested areas that have not been used anymore and are successively growing with wood, and on unused meadows
	6.2 with coniferous forest growth on mounds – The type of forest edge occurring in young coniferous growths on mounds in the locality of Špania Valley
7	The edge of forest is successively enlarged and expands
	– The edge comprising seedage young growth and the successive shift of forest edge. It specifically occurs on side forest edges of old forest growth in the localities of Laskomerská Valley and Špania Valley

The differences of surrounding abiotic variables and anthropic influences conditioned the differences in the structure and the species variability of forest edge vegetation. The bottom edge of forest prevails in the localities of Laskomerská Valley and Špania Dolina, unlike in the localities of Donovaly and Kozí Hogback, where the upper type of forest edge dominates. Furthermore, we defined seven types and four subtypes of forest edge in the monitored localities according to horizontal and vertical structures (table 1).

With respect to the common set of all the researched edge forest localities, we identified 380 species of vessel plants in 99 records; thereof, 101 species occurred only in non-forested zones of forest edge transects, 55 species only occurred in the edge zone, and 13 species were only relevés in forest. The largest variety in the

common set of data can be explained by the factor of altitude, wood cover (the position in transect), the factor of soil, the age of forest growth and the type of forest edge (its position towards the form of relief).

In the locality of Laskomerská Valley, the intensity of the use of non-forested area by man represents a significant factor. The age of forest growth, altitude and relief inclination proved to be insignificant according to the test of statistical significance. The locality of Špania Dolina differs due to higher variability of ecological factors and vegetation itself. Beside the position in transect, the tests revealed the significant factors of surroundings, such as the impact of anthropogenous elements: mounds or sludge bed, the factor of soil that correlates with the inclination of terrain. The age of forest growth represents a significant factor in the locality of Donovaly. The character of substrate represents the second highly significant variable. The CCA ordination of data from the locality of Kozí Hogback is interesting with respect to the mutual correlations of highly significant factors such as altitude, the character of substrate, the type of forest edge with respect to the form of relief and the age of forest growth that together explain 51% of overall data variability.

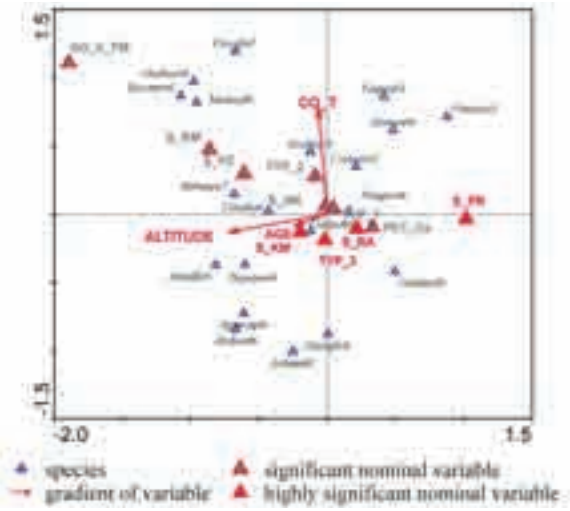

Fig. 3. The ordination graph of CCA analysis with permutation showing significant (P<0,05) and highly significant (P<0,01) nominal and gradient factors of surroundings and plant species with significance above 15% in the common set of all the researched forest edge localities

CO_T – the position in transect (wood cover). Note: INCLIN – relief inclination, SP – sun input, AGE – the age of forest growth, TYPE 1 – the bottom edge of forest, TYPE_2 – the side edge of forest, TYPE_3 – the upper edge of forest, PET_Ca – Ca substrate, S_FS – fluvisols, S_RL – rendzic leptosols, S_CC – calcaric cambisols, S_EC – eutric cambisols, S_UAR – urbi. anthropic regosols, S_PZ – podzols, S_RS – regosols, MANAG – the intensity of the use of non-forest area, Oxalace6 – the abbreviation of genus and species name and level

Discussion

The places of transition from forest and non-forest land are understood with respect to different point of views and levels. Forrest edges can be perceived as the ecotones that are boundary clusters, which represent the transition between various

clusters (Šindelář 2002) that touch, overlap and join. Thus, specific edge life conditions originate, which compensates the properties of both neighbouring clusters. In most cases, the forest edge comprises the complex of several specific ecosystems. It is represented by a transitive zone of forest ecosystem, more or less influenced by the proximity of forest edge delimited by growth cover: shrub and herb line that continuously or suddenly changes into non-forest edge (Forman, Godron 1993). The edge of forest comprises a very variable ecosystem. Depending on the ecological factors of surroundings and the impact of men, it can be of various structures (width, density, shape, species diversity, and others). At the same time, it has the properties that are conditioned by time, development and function. The edge of forest can be of sudden or continuous – terraced character (Temple, Flaspohler 1998), or it can consist of the mosaic starting from isolated individuals up to groups of trees. The zone of forest edge can also consist of the heterogeneous mosaic of species – herb, shrub and tree growths, which is typical for successively growing localities.

Several authors tried to present a typology of forest edges according to their structure. Forman and Godron (1993) differentiate three types of anthropogenous edges with respect to the distance of the intrusive impact of anthropic activity from the cover of forest. Pietzarka (1996) describes four types of forest edges. Contrary to the former authors, he also takes into account the impact of the intensity of the deforested area use upon the structure of forest edges. Costa (2001) defines four types of transition from forest to open land according to the line of forest edge. Furthermore, Šindelář (2002) differentiates external and internal forest edges with respect to the surrounding country, and Gajdoš (2005) differentiates the types according to their landscape with respect to the form of relief. He also describes the structure of forest edges in relation to the historical development of forest land.

Conclusion

Predominantly forest land of the Starohorské Mountains is typical for its significant dynamics of forest growth during the last centuries that is specifically related to mining and grazing. All these resulted in the fragmentation of originally continuous forest growth and the origination of anthropogenic forest edges that currently represent a significant part of the forest area. The anthropic influences were different in individual localities of the researched forest edges, they were effective during different periods of time, and with various intensity and continuity. Older forest edges, specifically in contact with unused deforested areas, have roof structure with thick inclusion of crowns. A steep and sharp end of forest indicates a younger boundary. After the end of anthropic activity, gradually repeated transfer of forest edge appears. At present, historical anthropogenous impact on the structure of forest is only recognizable where forest growths have not been renewed due to various reasons, and the method of non-forest land use has not changed significantly. First of all, it is related to original beech and debris growths in the locality of Kozí Hogback. In other places, there are current anthropic impacts on the structure of forest edge. It is necessary to pay close attention to forest edges, a biologically specific phenomenon with the specific concentration of flora and fauna species and landscape function.

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Abstract

Forest edges generally represent a very important element of ecological stability. The goal of this paper is to classify the types of anthropogenic forest edges in the area of Starohorské Mountains and to analyse anthropogenic impacts on the selected attributes of forest edges. We evaluated the attributes of abiocomplex, type of forest edge, its structure, consistence, species composition and other factors. The differences in environment variables and anthropic impact were influenced by singularities in the composition and species variability of vegetation. In the monitored areas we defined seven types and four subtypes of forest edges according to its vertical and horizontal structure. With the help of detrended correspondence analysis (DCA) we also interpreted organization relevés and species by gradients of environment variables, and with the help of canonical correspondence analysis (CCA) we tested their statistical significance. From the results of our research, there is a clear tendency for high diversity of living species in the forest edge. Environmental variables interpreting the highest volume of species variability are the altitude and transect position.

Key words: forest edge, species diversity, anthropogenic activities, Starohorské Mountains

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