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High mountain landscape environment and its vulnerability for tourist activities on the selected area of Vysoké Tatry Mts.

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Abstract
The paper presents results of the landscape-ecological research, which has been realized in 2000-2014. The Velická valley situated in the southern part of Vysoké Tatry Mts was chosen for study area as it represents a suitable model area of alpine zone. The main aim of the research was the mapping and evaluation of the actual state of the landscape components and elements of the area with low impact on the landscape. Further on the basis of biotic and abiotic factors assess the level of the vulnerability resistance to a set of the destructive processes. Although there are current studies dealing with abiotic components of the high mountain landscape in the Vysoké Tatry Mts none of those presents the detailed and complex study at such a large scale as 1:10 000, as is presented in this paper.

Key words: vulnerability, tourist activities, high-mountain, landscape, Vysoké Tatry Mts.

Introduction
Landscape-ecological evaluation is becoming again very actual problem. It is linked mainly with its application in legislation and various methodological procedures. Our study concentrates on evaluation of vulnerability of a high-mountain landscape in the Vysoké Tatry Mts, particularly the alpine zone of Velická dolina valley. It is a territory with high diversity of geomorphologic, pedologic, but above all, biotic conditions. This area is attractive for tourists and therefore it is highly visited.

Materials and methods
Vulnerability of landscape is a special landscape property, used for implicit reaction of the landscape to external factors. Mostly it is used for expressing the landscape sensitivity, or resistance to destructive (stress) natural and anthropic impacts.

The reaction of landscape elements on artificial impulses varies. Some elements are more vulnerable than others (Hrnčiarová, 1999).

Vulnerability of high-mountain landscape is given by the utilizable environmental properties making some territories more prone to the origin of erosion (destruction), than other. To design the activities optimization, which will not support the mentioned destruction, but will have positive decelerating effect it is necessary to recognise the natural attributes of particular landscape.

Vulnerability of natural environment is retrieved by potential and real influence of destructive factors (processes and man) to the landscape. The influences could develop and to acquire destructive to catastrophic effect. Attributes of biotic and abiotic environment could be used for understanding of the high-mountain environment reaction to external impulses (Hrnčiarová, 1996).

Some of the most important studies estimating the vulnerability of the natural environment at the territory of the Tatry Mts. And other mountains are the papers of Drdoš (1989), Varšavová, Baranček (1999) and others. These studies were used as a part of the resources for presented paper.

We based our vulnerability evaluation of the study area on:
- vulnerability assessment of abiotic complexes (AK) of the natural environment based on the set of destructive processes
- vulnerability assessment of biotic complexes (BK) of the natural environment based on the set of destructive processes, continuity and/or discontinuity of vegetation cover
- total vulnerability assessment of landscape-ecological complexes (KEK).

Vulnerability evaluation of study area - the alpine zone of Velická dolina valley is to the certain extent a subjective method. It is based on assigning a value of vulnerability to studied attributes of the individual components and elements of the environment.

According to detailed scale of the map (1:10 000) a five-degree vulnerability scale of a given territory was used for vulnerability evaluation. We defined following areas:
- critically vulnerable areas (total environmental degradation by destruction processes, extensive areas without vegetation, unstable ecosystem, etc.)
- very vulnerable areas (consistently affected by environmental degradation, impaired vegetation cover, regeneration of the area is very slow, etc.)
• middle vulnerable areas (medium to moderate environmental degradation, vegetation cover is often discontinuous, regeneration of area takes longer, etc.)
• moderate vulnerable areas (moderate environmental degradation)
• slightly vulnerable areas (relatively low degradation).

Vulnerability of abiotic complexes
In evaluation of abiotic complexes were used numerous studies (Varšavová, Barančok, 1999; Drdoš, 1989; Lukniš, 1968, 1973; Linkeš, 1980; Nemčok et al. 1994; Hreško et al. 2009).

Abiotic environment is represented by the set of abiotic components: geological substrate - relief - soil - climate - hydrologic properties. Abiotic environment can be evaluated by the vulnerability of individual abiotic components based on their properties. Vulnerability of abiotic environment was evaluated on the base of the set of destructive processes in this territory. According to Midriak (1983) there are:
• water processes (processes induced by surface flowing water)
• gravitational processes (landslides, falling rock crumps, climbing down of talus), water-gravitational processes (debris flows, debris shifts), nivation-gravitational processes (snow avalanches), cryo-gravitational processes (solifluxion, frosty climbing down, frosty sliding)
• aeolian processes (aeolian corrosion, deflation)
• cryogenous processes (regelation processes)
• anthropogenic processes (treading and abraving of the surface – surface destruction, destruction and erosion of soils, etc.)

Vulnerability of biotic complexes
In evaluation of vegetation vulnerability of the destructive processes we used studies by: Jurko (1990), Barančok (1996a, b), Varšavová, Barančok (1999), Boltižiar (2000b).

Biotic environment is a superstructure of abiotic environment; its limits are unstable, easily variable not only under the effect of human activities, but also under that of natural processes. The biotic complexes were characterized by vegetation. Evaluation of vegetation according to its vulnerability by external factors is complex because vegetation units are complexes and the interfering factors act also in a complex way.

The vegetation of the alpine zone of the Velická dolina valley is variegated and its structure diverse. The degree of vegetation vulnerability depends not only on the vegetation type, species present, intensity of negative threat, but also on various circumstances that can substantially influence the consequences.

Vulnerability of landscape-ecological complexes
Total vulnerability of landscape-ecological complexes were determined on the base of attributes and degree of vulnerability of abiotic and biotic complexes. Landscape-ecological complexes are characterised by the values of structural stability defined by nature of relation of landscape components and elements. According to its own structure every landscape-ecological complex has different stability and to it related vulnerability to a set of the natural destructive processes and anthropogenic influences.

Natural conditions of the study area
The geological structure of this area is relatively simple. The study area is build by the Palaeozoic metamorphic rocks (gneissess, migmatites, migmatized gneissess), igneous rocks (granodiorites), which represent a crystalline complex. The overlying layers contain Pleistocene and Holocene sediments (glaciofluvial, deluvial-proluvial, etc.).

The geomorphological value of this study area is relatively monotonous (Midriak, 1989). The geomorphological map (Lukniš, 1968) shows that the study area contains the following geomorphological units: forms of removing processes (cliffs and smooth relief on granodiorites, glaciated knobs), forms of accumulation (firm and wūm moraines, talus cones, landslides, rock-aluvial fans, glaciifluvial cones).

On silicate rocks lithosols, regosols, leptosols and podzols are developed. Lithosols occur scattered, most frequently among solid rocks and their stony wastes. Leptosols are spread on base of the slopes. Podzolized leptosols are present mainly in 1600 - 1800 m above sea level (under dwarf pine stands). Humic podzols are distributed on the firm and wūm moraines. Climatologically the studied area can be classified as cold to very cold. The air temperature in the upper dwarf pine line area is 4 to 11.5 °C in July and -7 to 11 °C in January. The mean average annual precipitation totals are 1000 - 2130 mm. Wind conditions are complicated as their directions and speed is much influenced by the relief.

The spatial distribution of single vegetation units (nomenclature after Mucina, Maglocký,
1985) is often determined by the sea level altitude. Alpine zone is represented by alpine grassland communities mostly belonging to the alliances Juncion trifidi, Loiseleurio-Vaccinion, Festucion versicoloris, Calamagrostion villosae, Adenostylion, Trisetion fusc, Cratoneuro filicini-Calthion laeae. Plant communities in higher elevations spread on granodiorites are represented by the alliances of the Androsacicon alpinae, Festucion pictae, Salicion herbaceae alliance and less by the communities belonging to Juncetea trifidi class. Dwarf pine stands (Pinion mughi) are typical for the lowest elevations in the southern part of study area.
Diverse geological substrate, relief and various mezo- or micro-climatic characteristics allowed the development of highly variegated natural mosaics of mentioned plant communities.

Results

Vulnerability of abiotic complexes based on the set of destructive processes

We have compiled partial abio-complexes from geological, relief (geomorphological forms and slopes gradient) and soil conditions of the studied area. After assessing the vulnerability of single indices we proceeded to the assessment of overall vulnerability of the abio-complexes (Fig. 1) and its vulnerability to individual destructive processes.

• critically vulnerable areas
Critically vulnerable areas are characterised by vulnerable relief accompanied by extreme climatic conditions and very permeable and moving substrate. Here belongs the stands with debris flows (Hrško et al. 2012), talus cones, landslides with very easily or moderately eroded soils (Midriak, 1989). Critically vulnerable is 35 % from the whole territory. These negative natural interferences are intensified by high concentration of tourists.

• very vulnerable areas
Territories consistently affected by environmental degradations. Here belongs cliff, troughs, debris erosional rills with slope gradient over 35°. Very vulnerable is 40 % of the whole territory.

• middle vulnerable areas
The middle vulnerable area is the territory with middle to moderate environmental degradation. Here are included stands, such as glaciated knobs, stands on wits silicate lithosols, with several kinds of destructive processes or a single kind of processes of high intensity. These areas territories occupy 15 % of the study area.

• moderate vulnerable areas
The territory with moderate to low environmental degradation occupies 15 % of the area. It is characterized by the occurrence of at least two kinds of destructive processes (gravitational and cryogeneuse) of moderate to low intensity and higher slope gradient.

• slightly vulnerable areas
Slightly vulnerable area is the area with very slight degradation. Here one kind of low intensity destructive process on small area is either absent or only sporadically occurs. Slightly vulnerable territory (5 %) is linked with glaciogenic gravelly-bouldary-blocky moraine sediments.

Vulnerability of vegetation based on the set of destructive processes

In the investigated area dwarf pine stands and alpine communities such as alpine grassland stands, snow beds, slope debris and springs are present. They vulnerability shows the Fig. 2.

• critically vulnerable vegetation
Here belong the communities of slope debris from the alliance Androsacicon alpinae bound to cliff relief; communities of the snow beds and patches from the alliance Salicion herbaceae and Festucion pictae. They do not form coherent stands and seldom form larger groups of plants. The communities of critically vulnerable vegetation cover 50 % of the territory.

• very vulnerable vegetation
The communities of alpine grass-herb stands (alliances Juncion trifidi, Loiseleurio-Vaccinion, Festucion versicoloris, Calamagrostion villosae, Adenostylion, Trisetion fusc) and azonal communities of springs (Cratoneuro-filicini-Calthion laeae) are characterized as very vulnerable. Vulnerability of vegetation increases also by overall vulnerability of the abio-complex. They form coherent stands and cover 38 % of the territory.

• middle vulnerable vegetation
Here belong communities of coherent dwarf pine stands of alliance Pinion mughi covering 12 % of the territory. Vulnerability of these communities increases near avalanche grooves, long lasting snow is a limit factor.

Vulnerability of landscape-ecological complexes based on the set of destructive processes

On the base of attributes and degree of vulnerability of abiotic and biotic complexes total vulnerability of landscape-ecological
complexes was defined and is presented on the Fig. 3.

Conclusion
The presented vulnerability evaluation of selected abiotic and biotic components and elements of natural environment of the alpine area in the Velická dolina valley is an example of a global solution for nature protection and its synchronization with the possibilities of land use for tourist activities.

In the study area five vulnerability groups were created. The main factors used for the grouping were the destructive processes such as water, gravitational, aeolian, cryogeneic and anthropogenic processes. Three maps of vulnerability for different components were constructed. This paper is a complex study containing important information that might be used in projects or plans for the optimization of the tourist activities in the Velická dolina valley.
Vulnerability of biotic complexes on the base of the set of destructive processes

- Very vulnerable vegetation
- Middle vulnerable vegetation
- Critically vulnerable vegetation

Fig. 2: Vulnerability of vegetation based on the set of destructive processes

References


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**Vulnerability of the landscape structure of landscape-ecological complexes**

- Slightly vulnerable landscape structure
- Very vulnerable landscape structure
- Moderate vulnerable landscape structure
- Critically vulnerable landscape structure

*Fig. 3: Vulnerability of landscape-ecological complexes based on the set of destructive processes*
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