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Changes of vegetation and soil cover in alpine zone due to anthropogenic and geomorphological processes

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Abstract: The paper presents the results of studies of geomorphological processes in the surroundings of tourist paths with an effect on vegetation and soil conditions in the subalpine and alpine zones of the Tatra Mts. Hiking paths at the local level represent a significant factor for increasing efficiency of sheet wash and concentrated runoff and subsequent intensive deep erosion. They can interrupt continuous surface runoff and operate as the local base of erosion base for a part of the slope over them, with gravitational effect of surface runoff from rainfall and melting snow water, which increases the effect of slope denudation. The base of erosion of the paths increases the potential of gravitational failures and decreases the soil-debris cover stability. In these conditions, the development of slope movements accelerated evidently. Morphologically, hiking path can influence the accumulation of snow layers and creates the conditions for persistent snowfields. Blocking effect of the paths is also reflected in a slowdown and the subsequent accumulation of snow mass by snow creep, snow sliding and snow mass gliding. Hiking paths may be a part of areas with development of aeolian-deflational processes and associated destructions of the soil-debris cover.

Key words: High Tatras Mts., geomorphological processes, soils and vegetation cover, natural hazards, tourist paths

Introduction and objectives

Most of the high mountains of Europe, including the Tatras, represent areas with significant human impact to the last remnants of natural ecosystems that are preserved in the alpine climatic conditions. In this paper, we point out the spatial aspects of soil destruction and vegetation disturbances occurrence in the subalpine zone with dwarf pine growth and alpine meadows. Characteristic features of destructive processes in the extreme climatic conditions are cumulative effects of overlapping man-induced and natural processes. The effects of destruction are increased in numerous instances, even if limited to certain positions in the georelief (Kotarba *et al.*, 1987). Indirectly, geomorphological processes may significantly affect the vegetation cover and create completely new conditions in habitats (Rączkowska, 1995, 2006). Barančok (1996) and Barančok & Varšavová (1996) suggested the anthropogenic influence on species changes of vegetation near the touristic paths in the Belianske Tatry Mts. Another important contribution of the geomorphological processes is their impact on the biogeochemical cycle at the local level. According to field experimental measurements of Tappeiner *et al.* (2008), we can consider plant biomass declination that can sequestrate a number of important elements, but primarily reside in the ecosystem carbon stocks and the same applies to humus of the soil. Another feature of the destruction of soil and vegetation is the scale and magnitude of impact. Some current and historical human impacts are visible only locally, while the concentrated disturbance has a large-scale and long-term impact.

The aim of this contribution is to highlight the conditions and factors of the unpredictable destruction of soil and vegetation cover along the touristic paths, which determine trends of sensitive alpine environment. In previous contributions, we addressed the spatial distribution and dynamics of individual geomorphological processes of the alpine environ-

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ment in the Tatra Mts. (Hreško, 1994; Hreško *et al.*, 2005; Hreško *et al.*, 2008). We want to show the interaction of geomorphological processes and man attacking touristic trails in relation to the destruction of soil and vegetation, as shown by Hrnčiarová (1996) and Hrnčiarová & Altmannová (1999). The most visible signs of man-made destruction of the soil and vegetation cover are noticeable on the paths and in their immediate surroundings, where several morphodynamic processes were identified. These destructions are caused by water-gravitational, slope-gravitational, aeolian, nivational, and snow-gravitational processes.

The methodological approach is based on previous studies on the evaluation and measurements of recent geomorphic processes realised in the Tatra Mts. since the 1990s (Hreško, 1994; Hreško *et al.*, 2005, 2008).

Geomorphological processes and their connection with touristic paths

Nivation-gravitational processes

Snow cover performs several functions and acts as an important ecological factor in the alpine environment. Preserving and thermal effect of snow and a function of the associated accumulation of water in the winter and spring times are evident. Extreme properties of the topography, the effects of wind and a whole range of other variables created from snow cover major natural hazard and major morphodynamic process with destructive effects on land and denudation of high mountain relief. Touristic trails at the valley slopes that cross the juvenile valleys and troughs are often endangered by avalanches, snow creep, snow gliding, and very often they are modified by snow thawing effect in the surroundings of snow fields.

Avalanches

Avalanches, as is widely known, have the largest impact on the high mountain landscape prevailingly in human impacted areas, where scrub vegetation and upper timber line were largely reduced. Frequently, it was the source parts of the avalanche paths and the avalanche troughs, which were used as well as migratory grassland areas to achieve higher altitudes of the species-rich alpine meadows. Large-scale removal of dwarf pine growths has opened and expanded the field for the potential emergence of avalanches and the effects of increased snow in the starting zone, where permanent expansion of destructive vegetation and soil patches are observed. Although grazing impacts can be considered as historical, not current, the impact of these activities exceeds far into the present time. The most intensive impact of avalanches is connected with breaking of soil and vegetation cover and subsequent accumulation in the slope foots and valley bottoms. Other type of destruction of vegetation and soil is also connected with the uprooting of trees and scrubs in the transport and accumulation parts of the avalanche paths. However, it should be added that the man-affected avalanche paths create the conditions for decreasing of dwarf pine growths to the lower positions, and thus contribute to its spread in valley bottom positions. We can assume the gradual formation of local vegetation inversion in these parts. The slower snow mass sliding has a negative effect on the grasslands, scrubs and forests as well. The character of this process is similar to avalanches, however, the transportation zone is relatively short and the snow mass usually remains on the slope and does not reach the valley bottom. Initial stages of the snow mass sliding can also be likened to the snow gliding of some centimetres to tens of centimetres per day (Leitinger *et al.*, 2008, Höller *et al.*, 2009). Snow mass sliding and small avalanches can be induced by rapidly shifting tourists over a relatively unstable snow cover. On the other hand, slower movement of the snow layer may be blocked and stabilised by step-shape touristic paths in some cases (see Fig. 1).

Nivation

An effect of snow melting represents a significant phenomenon of alpine environment in relation to vegetation and soils (Hreško *et al.*, 2005). However, very significant are short-time snow melting effects of the snow patches drift on touristic paths and concave forms of slopes. Subhorizontal surface of passes creates suitable conditions for retaining of snow mass as a factor of solid particle washing and starting conditions of mass movements. These are indicated

Fig. 1. Dwarf pine vegetation have been influenced by man and grazing heavily in the past and have created favourable conditions for the increasing number of avalanches and snow mass sliding. Here, we can see a breaking effect of the touristic pass to the small avalanche slide. Photo: J. Hreško, October, 11th 2008

Fig. 2. Snowfield above the tourist path creates favourable conditions for soil and vegetation cover destruction and increases the instability of the slope. Photo: J. Hreško, October, 11th 2008

by visible tension cracks and by slope deformation mosaics along the paths. Most frequent slope failures and soil-vegetation cover degradation correspond with debris mantles of granites, carbonates and metamorphic rocks.

Fig. 3. Fresh erosion furrow after intensive rain precipitation on hiking trails in the Zadné Meïodoly Valley. Photo: J. Hreško, June, 16th, 2008

Fig. 4. Tourist trail crosses a relatively narrow slope with the occurrence of surface soil erosion and debris mantle slides accelerated by permanent attacks of tourists. Photo: J. Hreško, October 12th, 2005

Water-gravitational processes

Water-induced processes associated with the touristic trails have generally hill wash and sheet wash character, which transmit both soil particles as well as the substrate fragments of soil parent rocks. The most

Fig. 5. Slow creep of soil and vegetation cover accelerated by a decrease of the local erosional base of tourist trail. Photo: J. Hreško, June, 13th, 2006

Fig. 6. Debris cover slides above the tourist trail on the SW slope in Zadné Meďodoly Valley (Belianske Tatry Mts.). Photo J. Hreško, October 13th, 2006

Fig. 7. Parallel paths and uncovered substrate formed by wind deflation on the ridge of the Nízke Tatry Mts. Photo: J. Hreško, November, 16th, 2008

Fig. 8. Destruction of vegetation and soil cover by aeolian deflation on the tourist path in the Západné Tatry Mts., Photo: J. Hreško, September, 2003

frequent occurrence of this destruction was limited to the direct part of the slopes, where destruction patches are observed around touristic paths or gravitate to them. Even though the disturbed layer is relatively small there is not coming vegetation succession in relative long-term aspect. Hill wash patches are permanently attacked by rainfall water, partially by thawing water of snow fields as well as by disturbance connected with trampling effects. Concentrated hill wash takes various forms: from erosion rills and furrows to the form of gully erosion.

Soil erosion

Soil erosion in the subalpine and alpine belt is clearly linked to areas with the occurrence of hiking trails, which have the role of local erosional bases and dry troughs for concentrated surface runoff. The most significant manifestations of surface and concentrated erosion correspond to the intensive summer rainfalls as we observed. Most commonly, rain rills and furrows were determined on the paths having a depth of 10 to 40 cm. During the formation of rain rills and furrows, the erosional process spreads the original path by undercutting the edge slopes or another processes affecting the soil and debris mantle destruction. Concentrated splash wash obviously helps to the lowering of local base of erosion and raises retrograde gravitational effects on the adjacent slope. Local erosion symptoms are associated with increased surface run-off during a sudden snow melting in autumn and spring time.

Sheet erosion and debris cover slides

Effects of sheet erosion occur in relatively small areas, but they can be very predisposed to more efficient destructions in the form of debris mantle slides, which presents completely destructed vegetation and soil cover, including debris substratum. Debris mantle slides offer only minimal possibility to extending return of the soil and vegetation. Transition from surface erosion to the debris slides is continuous and favours massive transport of material down to the bedrock layers. The process of sudden debris mantle movements relates to all types of rocks, but predominantly to granite, limestone and shale. Along the touristic trails in the areas affected by debris slides, the slower movements of soil-vegetation fragments in the form of moving turfs or walls occur. In some cases, especially on limestones and dolomites, the surface soil layer creep and slides are observed. Primary cause of these relative slow processes are water saturation during the snow thawing.

Measured data of downslope movements show that it is the so-called creep, when the speed of movement reaches several centimetres per year. The acceleration of creep is increased by the erosional base of path as well as the retrograde effect of the slope above the path (see Fig. 3). Other continuous changes are connected with water cutting effects to the path surface or into the bedrock. Thus, consequently, new conditions of local erosional base and runoff of recipient change will occur. Resulting from the surface destruction in these areas, the probability of the vegetation and soil cover stabilisation is very low.

Aeolian deflation effects

The effects of wind are reflected both in the saddle as well as ridge top positions in alpine environment of high mountains in the Western Carpathians (Midriak, 1983; Hreško, 1994, 1997). Destructive effect on vegetation and soil is documented by various landforms: from aeolian patches in the saddle areas to aeolian niches in the lee side of the wide ridges. In relation to the tourist paths, the acceleration of deflation processes was confirmed at several sites of branching or parallel paths. An intensive removal of particles of 2 mm in size and humus layer gradually destroys the vegetation cover, resulting in raw debris surface in extended passages. Paths with inclination above 3° are completely transformed by surface runoff in the form of erosion rills and furrows.

Conclusions

In this paper, we briefly present the geomorphological processes in the surroundings of tourist paths with an effect on vegetation and soil conditions in the subalpine and alpine zones of the Tatra Mts. The results can be summarized as follows:

- hiking paths at the local level represent a significant factor for increasing efficiency of sheet wash and concentrated runoff and subsequent intensive deep erosion,
- paths interrupt continuous surface runoff and operate as the local base of erosion for a part of the slope over them, with gravitational effect of surface runoff from rainfall and melting snow water, which increases the effect of slope denudation,
- the base of erosion of the paths increases the potential of gravitational failures and decrease the soil-debris cover stability. In these conditions, the development of slope movements accelerate evidently,
- morphologically speaking, hiking path can influence the accumulation of snow layers and creates the conditions for persistent snow fields,
- the breaking effect of the paths is also reflected in a slowdown and the subsequent accumulation of snow mass by snow creep, snow sliding, and snow mass gliding,
- hiking paths may be a part of areas with development of aeolian-deflational processes and associated destructions of the soil-debris cover.

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