

## **Modelling of trail degradation based on detailed multi-temporal digital elevation models**

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Degradation of trails adversely affects the natural environment as well as the safety and comfort of visitors. Managers of protected areas can directly impact some of the factors related to the degradation, for example, they may regulate the type of use or location of the drainage. On the other hand, they may only have an indirect impact on the other factors, e.g. through the appropriate demarcation of trails. The role of national and landscape parks is both protection of the natural environment and providing recreational opportunities. Hence, the need to obtain accurate information about the current state of the trails and the direction of their transformation is apparent.

Based on multi-temporal detailed digital elevation models (DEMs) generated using topographic surveys, we proposed a simplified model of geomorphological processes which shape the surface of recreational trails. As the basis of our consideration, we adopt the idea that recreational trails and forest roads can be equated with periodic flows in the context of soil loss, transport and accumulation. Our model of trail development and degradation consists of three phases:

- 1) Initial phase: In this phase, anthropogenic processes play the most important role. Destroying of vegetation cover by boots and tires leads to developing of a bare trail tread which becomes vulnerable to the natural processes. When the vegetation cover is removed, soil erosion starts, hence anthropogenic processes such as trampling or damaging vegetation by tires can be regarded as preparatory processes for further development.
- 2) Mature phase: In this phase, natural and anthropogenic processes coexist. All areas of trail tread and its surrounding undergo transformations. Anthropogenic processes impact mainly on trail tread. Trampling leads to soil compaction in case of smooth tread or to soil relocation and loss in case of bumpy tread. Uses of hiking sticks also lead to soil loosening, similar to tires of cycles. Loosening by anthropogenic forces prepare the soil for erosion and transport by water flow. The natural agents are mainly erosion and transport by water flow; however, during autumn and spring seasons the presence of needle ice is also important. It leads to loosening of the soil and similarly to anthropogenic processes that prepare the soil for erosion and transport. Additional natural processes occur on the sides of the trail. In case of significant incision, mass movements (mainly small scale landslides, mass flows, slumps and falls) occur. They destroy steep sidewalls of trails and provide the material for further transport by water. In case of wide trails, deflation also plays some role in transporting the finest particles.
- 3) Senile stage: This stage begins when the trail incision reaches the bedrock. In such cases, processes acting on the trail tread are significantly slowed or even stopped. The only active geomorphological processes occur on trail sides. They are mainly mass movements which destroy steep trail sides and deliver material to the trail tread, from which it is subsequently transported by water.

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