South-Eastern European Journal
of Earth Observation and Geomatics

Issue
Vo3, No2S, 2014

Long-term human impact on Alpine Tundra - 25 years of changes assessed by aerial photography

Jana Müllerová*, Michaela Vítková
Institute of Botany, Academy of Sciences of the Czech Republic, Průhonice, Czech Republic
*Corresponding author: Email Address. jana.mullerova@ibot.cas.cz

Abstract: In our study we assessed the long-term effects of alkaline gravel used for trail stabilization upon adjacent alpine tundra vegetation on nutrient poor sub-alpine plateau of Krkonoše Mts National Park, Czech Republic, using a series of aerial MSS (1986, 1989, 1997) and CIR imagery (2012), GPS mapping, and repeated soil and vegetation surveys. Aerial imagery was analyzed using both pixel and object-based approach. During the study period of 25 years, the area of roadside vegetation more then doubled, showing high rate of spread. In terrain depressions leading down the slope from alkaline stabilized roads it formed extensive lobes reflecting the nature of the terrain and reaching far into undisturbed vegetation (up to 156m). The spread of roadside vegetation was spatially examined to determine its driving forces, and was found to be significantly related to the type of the stabilizing material and the position relative to the road (slope position, distance from the road), indicating the effect of runoff water. The latest imagery of 2012 documented reconstruction of trails (started in 2005). The conservation measure stopped the ecosystem alteration although the damage during reconstruction was extensive and ability of arctic-alpine tundra to recover in the extreme climatic conditions very slow. Longer time lag is therefore needed to record the recovery process.
Keywords: CIR Aerial Imagery, Change Detection, Environmental Monitoring, Historical Analysis, Remote Sensing, Road Disturbances, Vegetation Changes.

1. Introduction

Roads represent an important landscape element affecting both biotic and abiotic components. Disruption of the chemical environment (alteration of chemical soil properties) along roads affects plant growth and species diversity and composition (Cape et al., 2004). The impact is especially profound if alkaline gravel is used in predominantly nutrient-poor environment dominated by stress tolerant plants (Hill and Pickering, 2006). Such processes facilitate colonization by more competitive, often non-native species with greater nutrient uptake efficiency and higher biomass (Dulière et al., 1999). The alpine tundra represents an extremely fragile ecosystem sensitive to human disturbances. In such nutrient poor environment, adding nutrients (alteration of soil properties along roads) is assumed to have very strong impact on vegetation structure.

Published online May 2014

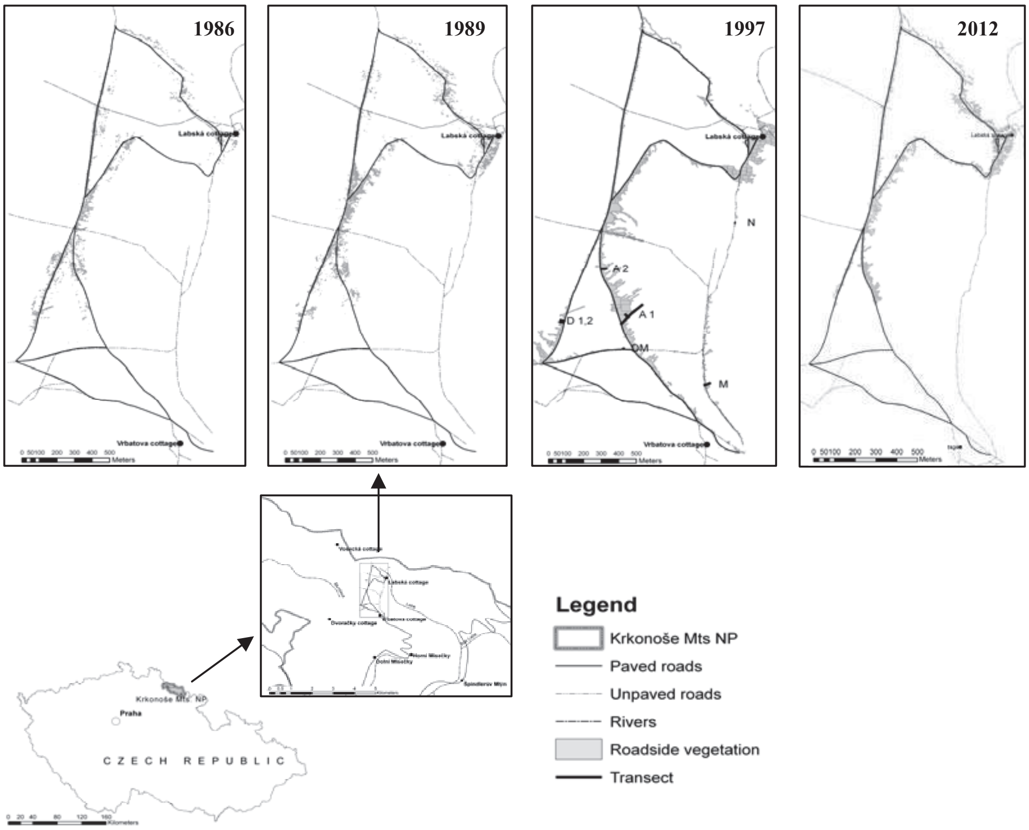

Figure 1. The effect of alkaline road-stabilizing material on tundra vegetation traced from MSS and CIR aerial imagery in Krkonoše Mts., Czech Republic.

2. Methodology

Our study is situated in the Krkonoše Mts National Park and Biosphere Reserve (Figure 1), the highest mountain range in the Czech Republic. Uppermost areas situated above the timberline are covered by a particular ecosystem called "alpine" or "arctic-alpine tundra", displaying affinities to both sub-arctic and high-mountain regions (Gordon et al. 2002), and hosting many endemic, glacial relic and rare species, and unique geomorphologic components (Štursa 1998). Despite the N.P. status, in 1970's to 1980's many paths and roads were stabilized to prevent erosion using unsuitable alkaline material. In this acidic environment, such measure markedly altered both soil properties and vegetation structure along such trails. Whereas normal tundra vegetation is formed by short thin grasses and sessile herbs, along trails paved with alkaline nutrients, the native flora was replaced by meso- to nitrophilous species and species of man-made habitats, mostly herbs with broader leaves and comparable higher biomass. This enabled to recognize the road-altered vegetation on remotely sensed imagery.

Road-related changes were reconstructed using a series of multispectral (1986, 1989, 1997) and CIR aerial imagery (2012), GPS mapping, and repeated soil and vegetation surveys. The roadside vegetation could be traced on the multispectral data because it is much taller, has broader leaves and produces a higher biomass compared to the natural vegetation (Figure 2). It was classified using both pixel based (parallelepiped classification - non-parametric supervised method defining the lowest and the highest values of classes in every spectral band; for details see Müllerová 2004), and object-based approach (a combination of automated hierarchical, iterative, and ruled-based classification). Seven permanent transects following the slope and perpendicular to a road/trail were selected randomly to analyze the effects of different road/trail construction material on vegetation composition (in y. 2000 and 2004) and soil physical-chemical properties (in y. 1998, 2000 and 2001; for details see Müllerová et al. 2011).

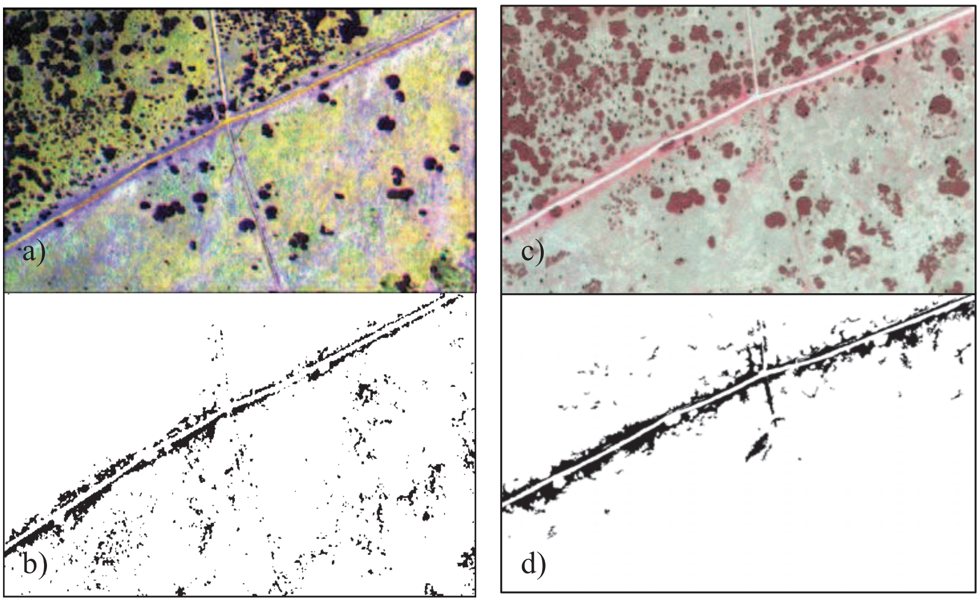

Figure 2. Road-altered vegetation on: a) MSS imagery (histogram equalized, road-altered vegetation in violet), and b) CIR imagery (road-altered vegetation in red). Bottom pictures (b and d) show OBIA classification results.

3. Results

Both pixel and object-based image classifications enabled successfully analyze road-related vegetation changes. Vegetation along roads paved with alkaline material grew considerably from 2.5 % of the study subset in 1986 up to 4.1 % in 2012 (Figure 1). Both soil and vegetation changes depended significantly on the type of the rod-stabilizing material and position relative to the slope (Müllerová et al. 2011). In terrain depressions leading down the slope from alkaline stabilized roads the roadside vegetation formed lobes reflecting the nature of the terrain and reaching far into undisturbed vegetation, providing evidence of the role of water erosion. Along alkaline roads, soil pH increased from 3.9 up to 7.6, base saturation from 9-30 % up to 100 %, and local stress-tolerant low competitive tundra species disappeared (including rare and protected species), and were replaced by meso- to nitrophilous species and species preferring man-made habitats.

Based on increase between years 1886/97 measured by Müllerová et al. (2011), roadside vegetation was estimated to cover over 7 % in 2012. This prediction was not met and tundra ecosystem alteration slowed down thanks to the conservation measures undertaken by NP Authorities since 2004. Alkaline road material was removed and trails stabilized using local building material. Today, most of the trails are reconstructed except from the asphalt road built with thick layer of dolomite and melaphyre. During the reconstruction, roadsides (ca 2 meters wide) were often disturbed and cleared of vegetation. From the latest imagery, we could document the process of vegetation recovery, although it was not therefore always possible to distinguish from the imagery whether vegetation along roads is damaged by the reconstruction or returns to natural composition of low cover and biomass.

4. Conclusions

Aerial imagery proved to be a good source of information on road-related changes in tundra vegetation, mainly thanks to its different size and biomass compared to native flora. It was even possible to some extend to document the reconstruction of the trails. Although the applied control measures limit expansion of undesirable vegetation, they represent a serious disturbance in this fragile arctic-alpine tundra ecosystem with limited ability to recover in the extreme climatic conditions, and future studies are therefore needed to assess the process of ecosystem restoration in longer time span.

References

Cape J.N., Tang Y.S., van Dijk N., Love L., Sutton M.A., Palmer S.C.F., 2004, Concentrations of ammonia and nitrogen dioxide at roadside verges, and their contribution to nitrogen deposition. Environmental Pollution, Volume 132, Issue 3: 469-478.

Dulière J.F., Carnol M., Dalem S., Remacle J., Malaisse F., 1999, Impact of dolomite lime on the ground vegetation and on potential net N transformations in Norway spruce (Picea abies (L.) Karst.) and sessile oak (Quercus peteraea (Matt.) Lieb.) stands in the Belgian Ardenne, Annals of Forest Science, Volume 56: 361-370.

Gordon J.E., Dvořák I.J., Jonasson C., Josefsson M., Kociánová M., Thompson D.B.A., 2002, Geo-ecology and management of sensitive montane landscapes. Geografiska Annaler, Volume 84 A, Issue 3-4: 193-203.

Hill W., Pickering C.M., 2006, Vegetation associated with different walking track types in the Kosciuszko alpine area, Australia, Journal of Environmental Management, Volume 78: 24–34.

Štursa J., 1998, Research and management of the Giant Mountains' arctic-alpine tundra (Czech Republic). Ambio, Volume 27: 358-360.

Müllerová J., 2004, Use of digital aerial photography for sub-alpine vegetation mapping: A case study from the Krkonoše Mts., Czech Republic, Plant Ecology, Volume 175, Issue 2: 259-272.

Published online May 2014

Müllerová J., Vítková, M., and Vítek, O., 2011, The impacts of road and walking trails upon adjacent vegetation: Effects of road building materials on species composition in a nutrient poor environment, Science of the Total Environment, Volume 19: 3839-3849.

Published online May 2014