Image analysis to assess hiking impact in Icelandic vegetation communities

***Micael Runnström**, Department of Physical Geography and Ecosystem Science, Lund University, Sweden, micael.runnstrom@gis.lu.se*
***Rannveig Olafsdottir** Department of Geography and Tourism, Faculty of Life and Environmental Sciences, University of Iceland, ranny@hi.is*

Outdoor recreation in scenic landscapes seems to be rapidly increasing worldwide and in Iceland hiking has long been one of the most popular outdoor recreations. The increasing number of people hiking every year is of concern regarding the environmental impact hikers pose on the country's fragile ecosystems, as well as how to best manage the bulk of visitors, especially during the short high peak period. Research show (i.e. Gísladóttir, 2006; Ólafsdóttir and Runnström, 2009; 2013; 2015) that high trampling pressure in some of Iceland's most popular recreational hiking areas is triggering soil erosion and land degradation. In Iceland, the vegetation and soil cover are extremely fragile and susceptible to external pressure partly due to the soils high content of Andosols (e.g. Arnalds, 2008; Ólafsdóttir and Guðmundsson, 2002). Furthermore, with abundant wind and rainfall surface run-off water follow the trails and scars causing severe and rapid soil erosion that affects both hikers' safety as well as their natural scenery experience.

The objective of this research is to study the correlation between hiking impact (number of hikers) and resilience of different vegetation types in some common Icelandic vegetation communities; moss, moss-heath and grassland. Experimental plots were established in two popular areas of nature-based tourism in Iceland, i.e. Þingvellir National Park located in the lowlands, and Fjallabak Nature Reserve in the highlands (Figure 1). Each experimental plot was designed to encompass five separate walking lanes, each 20 meters long, and with a randomly designated hiking pressure; 0 (control), 25, 75, 200, or 500 hikers, number based on Cole and Bayfield (1993). In subplots (0.6 * 0.6 m in size) along each lane, parameters on soil and vegetation were assessed to analyse to what degree the different vegetation types was affected by different trampling intensity.

In order to assess vegetation cover, high resolution digital RGB-photographs were acquired from 1.7 meters height above each subplot and classified using algorithms common by the Earth Observation Science (EOS) community. Each photograph was split-up into three separate images (Red, Green, Blue), each containing information of ground reflection in separate parts of the electromagnetic spectrum. This facilitates better possibilities to perform an automated classification to separate vegetation from non-vegetation in the images (Richardson et.al. 2007). Thus the vegetation coverage in each subplot was assessed using two methods; i) Supervised maximum likelihood, and ii) Green chromatic coordinate (Sonnentag et al. 2012).

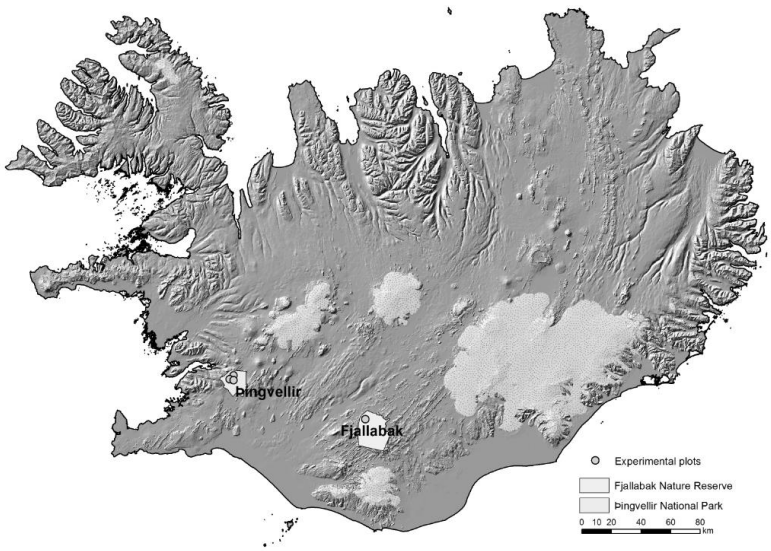

Figure 1. Location of the study sites in Iceland

The difference in resilience (resistance to hiking impact) between the lanes (trampling intensity) and between the different vegetation types, and additionally between highland/lowland moss-heath vegetation is evaluated through analysis of variance (ANOVA) providing statistical correlations. The current experiment was performed in July/August 2014 and the plots re-visited and photographed in 2015, 2016, and 2017. The images thus convey a time-series of recovery for the different vegetation types as the trampling has ceased, a parameter that can be highly relevant in the planning and management of protected or sensitive natural areas.

Initial statistics show good correlation between hiking intensity and loss of vegetation. The physical impact of the trampling breaks down the vegetation, and subsequently decreases the amount of live biomass and vegetation coverage. The moss cover shows to be the most sensitive vegetation community to trampling pressure and already 25 hikers cause a severe trail/scar in the moss layer. The recovery rate of the moss is moreover slow and still after three years, the impact from 25 hikers is still clearly visible. The moss-heath vegetation have more resistance compared to moss. Statistics show that moss-heath in the highlands are more disturbed compared to the lowlands. The grasslands have clearly the highest resilience of the evaluated vegetation types. A dense and thick inter-twined root system of the grass is a probable cause. One year after the trampling experiment, it is *just* possible to distinguish where the 500 hikers-intensity lane was located; the other lanes have blended with the surrounding grassland.

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