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The Footprint of Tourism:

Ecological sensitivity and hiking trail assessment at selected protected areas in Iceland and Hokkaido

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Cover picture: Askja in Vatnajökull National Park, Iceland and Daisetsuzan National Park, Hokkaido, Japan. 2011.

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INTRODUCTION

This project is part of a PhD focusing on sustainable tourism management at Vatnajökull National Park [VNP]. The overall aim of the PhD is to increase knowledge and understanding of management challenges to sustainable tourism in ecologically vulnerable protected areas [PAs], like the Vatnajökull National Park. The challenges of the park management revolve around the balancing of the conservational and recreational aims of the park's establishment.

This report will help conservation efforts by showing areas of degradation by presenting the results of field measurements and a data analysis on sensitivity of trails towards physical impacts. The results will inform the management of VNP about the areas of high degradation risk, and the areas which already show severe degradation. This report will provide an overview of the research on ecological sensitivity and hiking trail assessment and focus on mountainous PAs in Iceland and northern Japan, which represent subarctic (Dfc on the Köppen-Geiger climate classification) and hemiboreal (Dfb) environments (*cf.* Peel, Finlayson, & McMahon, 2007). The intention is to draw upon the comparison of the two sites in order to give a more informed perspective to the discussion in Iceland. It will also aid the discussion on research methods and widen the perspective providing research based on comparing case studies.

This report would not have been possible without outside help, for this I would like to extend my thanks and acknowledgement. The data collected for this project originated in a research project on Vatnajökull by Dr. Rannveig Ólafsdóttir and was funded by the Friends of Vatnajökull. The data from Japan was collected by Harald Schaller and was funded by the Watanabe Trust Fund of the University of Iceland and the University of Iceland Travel Fund. This project is based on the collaboration with Dr. Rannveig Ólafsdóttir at the University of Iceland and Dr. Tetsuya Aikoh of the Hokkaido University (Japan). It was supported by Dr. Michael Runnström and Kristín Rut Kristjánsdóttir from the University of Lund (Sweden) and the area managers of the Vatnajökull National Park. Gratitude for their valuable comments to the researchers from University of Iceland, University of Lund, Hokkaido University and University of Akureyri. Also thanks to William Shane Swearson for its review and support.

The results of this study will contribute to the discussion on current and future developments of the natural environment for tourism consumption in Iceland and in Japan. Therefore, this study will benefit organizations involved in the management of Vatnajökull National Park, as it helps to identify areas of possible degradation. The results also support the ongoing discussion about the future of the tourism industry in Iceland and its impact on the natural environment. It also contributes to the discussion about the factors influencing ecological sensitivity and degradation of hiking trails, as well as suitable methods for their assessment. The overall research project aims to help formulate management processes that will shape a sustainable tourism management framework for protected areas in Iceland.

This report is organized into six sections. The first section introduces the background of this study providing context and focus on issues regarding natural resource use for tourism in Iceland. Second, a literature overview will shed light on a specific approach to assess the ecological sensitivity of an area using GIS and measuring hiking trail degradation and give reasoning for the proposed methods for assessment. Third, the research sites are introduced, followed by an outline of the methods used for the collection and assessment of the data. Fifth is a presentation of the results. Finally, the report closes with the discussion of the results and examines the applicability and value of the data for protected area management and its impact in the current discussion of tourism management in Iceland.

1 PROJECT INTRODUCTION

With a worldwide increase in the number of protected areas, it appears that the natural environment has never been more protected. But the recent growth (WDPA, 2011) is not necessarily a sign of increased appreciation of the natural environment. As Moran (2006) argues, this is rather a sign of its rapid disappearance (Moran, 2006). Often, PAs are spaces characterized by delicate ecosystems and are thus sensitive to human impact. However, in the example of Iceland, the designation of a national park [NP] has been welcomed by local businesses in order to promote tourism (Benediktsson & Þorvardardóttir, 2005; Benediktsson & Waage, 2005). With consistent increases in tourist numbers - especially for hiking - in these sensitive areas, the threat of land degradation increases, making proper management of nature-based tourism critical. The natural environment in Iceland and Hokkaido are by far the most valuable marketing assets for tourism in these regions (Hiwasaki, 2000; Icelandic Tourism Board, 2014c; Ministry of Economic Affairs, 2011; Sæþórsdóttir, 2010a, 2010b; Sæþórsdóttir & Ólafsson, 2010). The tourism industry in both of these places uses images of wild and natural environments in order to attract visitors from abroad. Nevertheless, the natural resources are sensitive to external physical impacts. With increasing tourism there is a higher risk for negative environmental impacts, due to degradation in the most popular natural areas.

On a global scale, tourism is among the most important industry, creating one out of eleven jobs (UNWTO, 2013). The number of tourists grew within the last decade steadily, though the recent economic crisis of 2008 dampened the growth for a short while. Tourism picked up again in 2010 and is expected to continue to grow within the decade (*op. cit.*). Tourism in Iceland and Hokkaido aren't exempt from this development (Icelandic Tourism Board, 2014c; Hokkaido Government, 2015; Ministry of Economic Affairs, 2011). Both islands have areas of attractive natural environments where, tourism is an important economic factor and source for employment. Iceland is an interesting example as it shows a tremendous increase in number of foreign visitors and rocketing economic importance. At the end of 2014, the amount of foreign visitors through the Keflavik International airport approached nearly 1 million visitors (Icelandic Tourism Board, 2015) (see Figure 1) and with it tourism in Iceland has become an important economic sector (Boston Consulting Group, 2013; Icelandic Tourism Board, 2014c; OECD, 2014). In 2009, tourism in Iceland accounts for about 5,9% of the GDP (STATICE, 2011) and in 2013 it generated about 26,8% of the export revenues of Iceland (Icelandic Tourism Board, 2014c), placing tourism third after aluminium production and the export of marine products. However, there is criticism on the data about international visitors presented in official statistics, as all travellers with foreign passports are counted as tourist, regardless residency, when leaving Iceland (Icelandic Tourism Board, 2014b), which obscures the count of foreign visitors (Frenț, 2014). But even though tourism is of importance for Iceland and Hokkaido, its significance is shadowed by seasonality and migration of workers (*cf.* Marcoullier & Green, 2000; Seaton, 2010). Tourism in Hokkaido has seen a similar increase in the number of foreign visitors (figure 1). During the last 20 years, the number of foreign tourists increased tremendously and reaches now over 1 million foreign tourists (Hokkaido Government, 2015; Ministry of Economic Affairs, 2011).

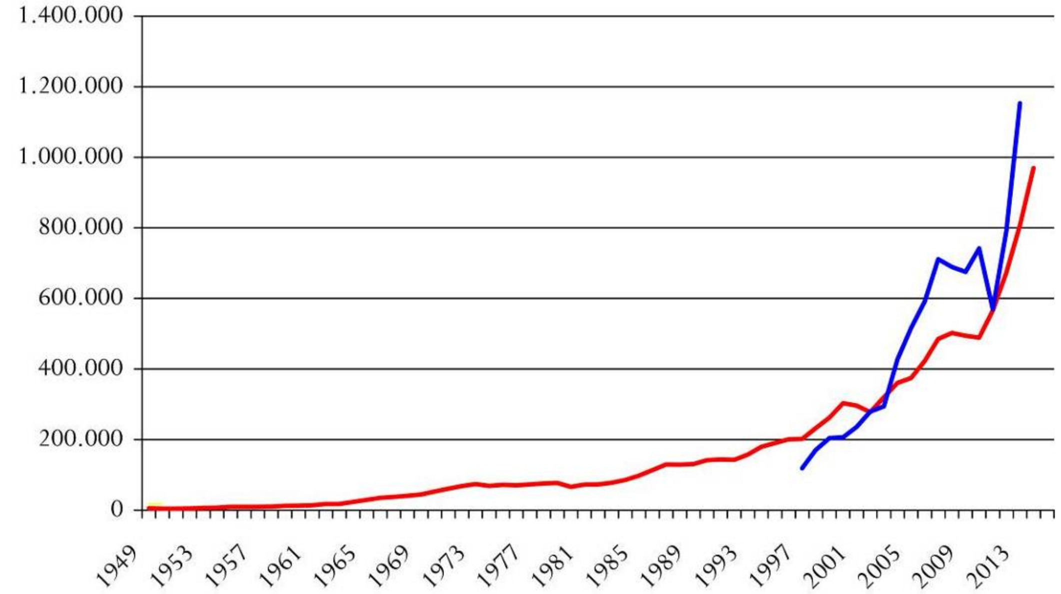


Figure 1: Development of number of foreign visitors: (red) through KEF airport from 1949 to 2014 (Icelandic Tourism Board, 2014a, 2014d, 2015) and (blue) to Hokkaido 1997 to 2013 (Hokkaido Government, 2015)

Currently, there is discussion in popular media about the risk of rapid environmental degradation due to increased tourism in Iceland (Árnadóttir, 2014; Sykes, 2014). As tourism in Iceland and Hokkaido can be described as nature-based tourism, it is important to consider the sensitivity of the natural environment. Research in Iceland and Hokkaido demonstrated that the natural environment in these mountainous areas is very fragile (Arnalds, Gísladóttir, & Sigurjonsson, 2001; Ólafsdóttir & Runnström, 2009; Þórarinsdóttir, 2010; Yoda & Watanabe, 2000; Aikoh, 2008; Watanabe, 2008). The impact of visitors on the natural environment can manifest in different forms and therefore its monitoring requires close attention being paid to maintain a sustainable use of the natural environment (*cf.* Aikoh, 2008; Shoji, Yamaguchi, & Yamaki, 2008). Due to the fragility of these territories, especially mountainous PA in Iceland and Hokkaido, it is of vital importance to increase the knowledge and understanding of its sensitivity to different types of use (*cf.* Þórhallsdóttir, 2007; Ólafsdóttir & Júlíusson, 2000).

With consistent increases in tourism use - especially by hiking - in these sensitive areas, the threat of land degradation increases, making proper management of nature-based tourism and conservation critical. Tourism use of PAs has multiple dimensions and the management of PAs relies on the ability to assess different aspects describing the capacity of the natural environment to withstand tourism impact (Marion, Leung, & Nepal, 2006). Suitable techniques for this assessment have to be reliable yet simple enough to not demand much time and resources to make decisions balancing conservation efforts and enabling tourism at PAs. This report describes a technique using map data and field measurements to assess the environmental sensitivity of an area and assess hiking trails within that area.

The output of this report will be a series of maps showing possible hot spots of ecological sensitivity of the natural environment at Vatnajökull NP (Iceland), the Daisetsuzan NP and Shikotsu-Toya NP (both Hokkaido). In addition to this, the maps will give reference to the current state of hiking trails and show their degradation in these areas. These maps will be of great help to managers of the national parks in the study sites, and support the development of management guidelines for hiking trails and the maintenance of natural sites in Iceland and Japan. Because of its application to natural resource management at national parks, this report is important for tourism studies in northern peripheral and cold climate mountainous PAs.

2 LITERATURE OVERVIEW

The combination of different spatial data is common practice within geography. The combination of data using a computer based Geographic Information System [GIS] has become increasingly popular as computer systems became more widespread in the 1980s (*cf.* Ólafsdóttir & Runnström, 2009). The strength of GIS is that it enables the storing, combination, transformation, and displaying of a varied set of spatial data for specifically defined purposes (Burrough, 1986; van Deursen, 1995).

The methodological approach of this report will combine existing techniques of the assessment of ecological sensitivity with the analysis of hiking trails, but exclude climate factors. Environmental sensitivity and the assessment of hiking trails are established techniques in practice and research regarding physical impact of hiking (*cf.* Leung & Marion, 1999a; Marion & Leung, 2001; Ólafsdóttir & Runnström, 2013; Tomczyk, 2011; Yoda & Watanabe, 2000).

2.1 Ecological Sensitivity

Ecological sensitivity can be, in general, defined by its internal and external ecological parameters, as the parameters either inherit properties which define sensitivity (e.g. chemical composition of soil) or are defined by outside circumstances (e.g. amount of precipitation) (*cf.* Bakr, Weindorf, Bahnassy, & El-Badawi, 2012; Geneletti, 2008; Rossi, Pecci, Amadio, Rossi, & Soliani, 2008; Tomczyk, 2011). Research techniques in ecological sensitivity analysis relies on the assessment of existing data to describe sensitivity by combining different ecological factors (pedological, topographical, and ecological factors – see Figure 2). The quality of the resulting analysis is dependent on the resolution of the input data. The data used to describe ecological sensitivity is often comprised data about *e.g.* vegetation type, vegetation cover, topsoil type, particle size, slope, and aspect. However, these techniques only partly incorporate climate factors. When combining the ecological parameters with hydrological and climatological factors, it is possible to create a more holistic notion of environmental sensitivity (*cf.* Bakr et al., 2012; Tomczyk, 2011). Incorporating these factors has been discussed in various publications (for methods see: Fu & Rich, 2002; Jianchao, Guangfa, Junming, & Liping, 2010; van Deursen, 1995), and research suggests the importance of different climate factors for the description of sensitivity (*cf.* Li, Wang, Liang, & Zhou, 2006; Liu & Liu, 2010; Tomczyk, 2011). It is of importance to mention, that the resolution and scale of data is defining for the outcome of the analysis (*cf.* Kosmas, Ferrara, Briasouli, & Imeson, 1999).

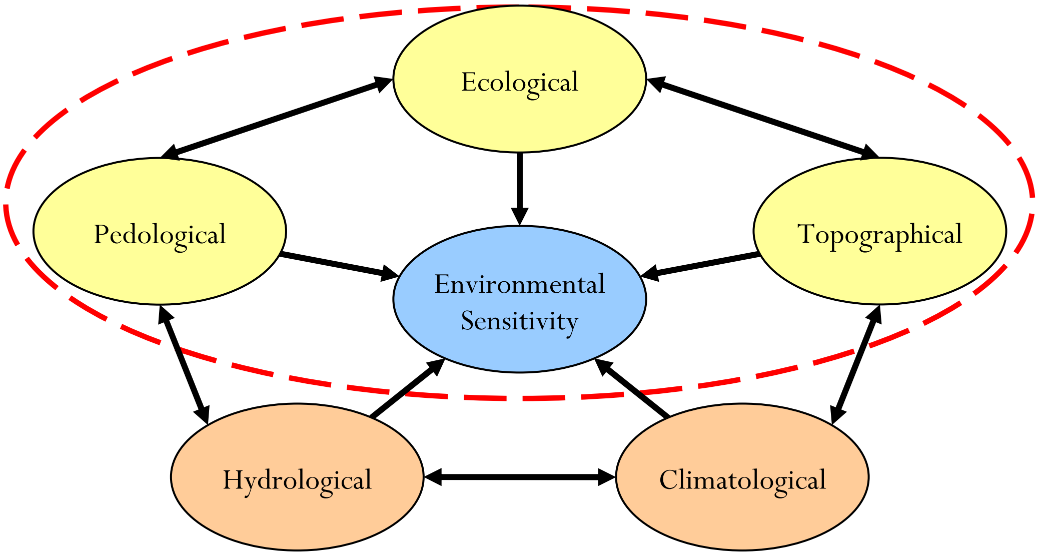


Figure 2: General model of environmental sensitivity (adapted from Tomczyk, 2011), dashed red circle indicating the factors included in ecological sensitivity

The use of climatological and hydrological factors appears to be challenging (*cf.* Fu & Rich, 2002; Jianchao et al., 2010; Lakshmi, Hong, Small, & Chen, 2011), as the modelling of these factors relies either on meteorological observations of sparsely distributed weather stations and the averaging of data over large areas or the computer modelling by using digital elevation models [DEM] and therefore on topographic data. Both are inefficient as the over-representation of DEM models in an analysis can bias the data and create "gap-data" between weather stations which needs to be bridged by interpolation of data. Moreover, relying only on weather stations can be especially problematic as they do not represent micro-climates, which are apparent in topographically heterogeneous mountainous landscapes. Hence, this study will be limited to internal ecological factors and the classification of them as the physical impact of individual tourists (Ólafsdóttir & Runnström, 2009, 2013).

2.2 Hiking Trail Assessment

The techniques to assess hiking trails are diverse and methods employed are dependent on various conditions (*cf.* Leung & Marion, 2000; Marion et al., 2006). The choice is mainly dependent on cost and time efficiency, without compromising resolution and precision of the result of the degradation assessment.

In general techniques are grouped into methods utilizing either field measurements or remote sensing (*cf.* Dixon, Hawes, & McPherson, 2004; Marion et al., 2006). With regards to remote sensing (or reconnaissance), aerial photographs (satellite data or referenced aerial photographs taken by observation planes) are used to cover a vast area of land without taking measurements on the ground. This method often has a disadvantage as the resolution of data is dependent on the method of colleting the photographs. Remote sensing is not as accurate as field measurements, without appropriate areal data.

The methods including field measurements are diverse but can be grouped into two main categories: census-based and sampling-based methods. Census-based methods are employed when specific problems or changes in the trail need to be assessed. Sampling-based methods on the other hand are interested in acquiring an overview of the state of a trail.

Most dominant techniques in hiking trail assessment are field measurements either sampling-based or census-based (Marion et al., 2006). Sampling-based approaches usually employ either systematic point sampling or stratified point sampling. Here the measurements are executed alongside the trail, either using a fixed interval between points, or a sampling adjusted due to the strata of the chosen data. The aim is to get an overview of the trail in its entire length. Census-based approaches, on the other hand, focus on either sectional evaluation or problem assessments. Here the focus is to assess a defined problem within a section of the trail. Often specific points are defined in the trail where a sectional evaluation of the trail takes place. The sections are evaluated repeatedly (*ibid*). Figure 3 gives an overview of the techniques used in hiking trail assessment.

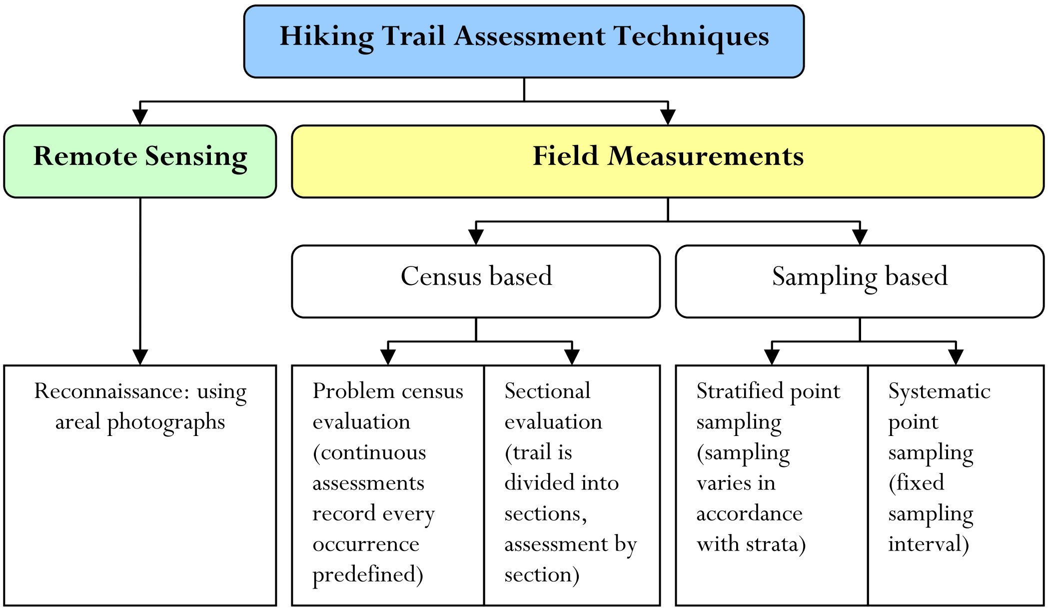


Figure 3: Chart of different hiking trail assessment methods used (derived from Dixon et al., 2004; Marion et al., 2006; Marion, Wimpey, & Park, 2001; Yoda & Watanabe, 2000)

If characteristics of a trail are continuous (e.g. its width or depth) or frequent (e.g. exposed roots or soil), continuous point sampling methods provide more accurate and precise measurements of the trail (Marion & Leung, 2001) whereas a sectional evaluation of the trail gives a good overview of trail changes in a long time series (Yoda & Watanabe, 2000). Most trail assessments evaluate the degradation of a trail according to the following variables: trail width, trail incision depth, trail erosion, the existence of multiple treads, and soil compaction. (Leung & Marion, 1996).

The strength of the results is dependent on the measurement accuracy and the interval of the measurement points. There is a lot of discussion about the most appropriate interval between measurement points. On the one hand shorter intervals (less than 100m between points) seem to have the most accurate results (Hawes, Candy, & Dixon, 2006; Leung & Marion, 1999b). On the other, intervals between 100-500m are recommended to achieve an appropriate balance between estimate accuracy and efficiency of field work (Leung & Marion, 1999b). Often the chosen distance between measurement points is dependent on the resources available for the research.

3 Research Sites

Iceland and the northern island of Japan, Hokkaido, were the selected study sites. This selection is based on pedological similarities, geography (e.g. island of relatively recent volcanic origin), as well as similarities in climate (e.g. cold winters with extended snow cover). Both islands are rich in natural features which are interesting for conservation and nature-based tourism. Hiking is a popular recreation activity in national parks on both islands. Japan has especially experienced an increase in tourism use over the last decades (*cf.* Hokkaido Government, 2015; Ministry of Economic Affairs, 2011). The field measurements in the selected sites have been conducted in the northern part of the Vatnajökull National Park in Iceland, Daisetsuzan National Park, and Shikotsu-Toya National Park in Hokkaido.

This chapter is divided into three sections. The first two sections will describe the characteristics of Iceland and Japan, respectively. It will highlight the geographic features of each region and describe the selected case sites. The third section will present the reasons for the comparison of the two case studies.

3.1 Iceland

Iceland is an island of approximately 103.000km^2 just south of the Article Circle in the North Atlantic. Settled by Norse men from western Scandinavia around 871 (Ogilvie & Pálsson, 2003). Iceland is one of the most sparsely populated countries in Europe with population density at approximately 3 inhabitants/km^2 (STATICE, 2009). Straddling the Mid-Atlantic ridge where the Eurasian and American tectonic plates are drifting apart, Iceland is known for its volcanic activity. Icelanders have experienced several recent volcanic eruptions, including Eyjafjallajökull in the beginning of 2010, Grímsvötn in May 2011, and Holuhraun/Nornahraun in 2014-2015. It is one of the most volcanically active countries in the world and thus rich in diverse geological features. Volcanoes, avalanches, vast black deserts, and long dark winters characterise Iceland. Iceland is rich with many natural resources such as extensive fishing grounds and low and high-temperature geothermal fields, widely utilized for energy production (Þórhallsdóttir, 2007). Icelandic soils represent a special case in Europe, as they mainly consist of Andosols, Vitrisols, and organic Histosols, which are volcanic in origin (Arnalds, 2004, 2008). Iceland, as a subarctic territory, has vegetation that is characterized by sparsely vegetated areas and grassland.

Vatnajökull National Park [VNP] is mainly in the central highlands of Iceland, towards the east (see Figure 4) and covers about 13.920 km^2 or 14% of the landmass of the country (Vatnajökull National Park, 2014a). Though VNP is planned as a single coherent NP it has been divided into four operating areas each of which is assigned a so called 'regional committee' or 'area council'. The main feature of VNP is the Vatnajökull ice cap, which covers approximately 8.000 km^2. The park has mountainous landscapes, many volcanoes, waterfalls and indigenous forests. For this study, the northern area of Vatnajökull NP has been selected. This area stretches from the central part of the Vatnajökull ice cap around Grímsvötn, incorporating Askja, Dettifoss and Ásbyrgi. Some of the areas of VNP receive a high number of visitors and the numbers have been rising over the recent years (Vatnajökull National Park, 2014b). In 2013, 295.000 visitors were registered at VNP (*ibid*). In particular, the southern area of the park receives 264.000 visitors, which is the majority of all guests coming to VNP. But also the area of Ásbyrgi and Askja show a similar trend with about 141.000 visitors (*ibid*).

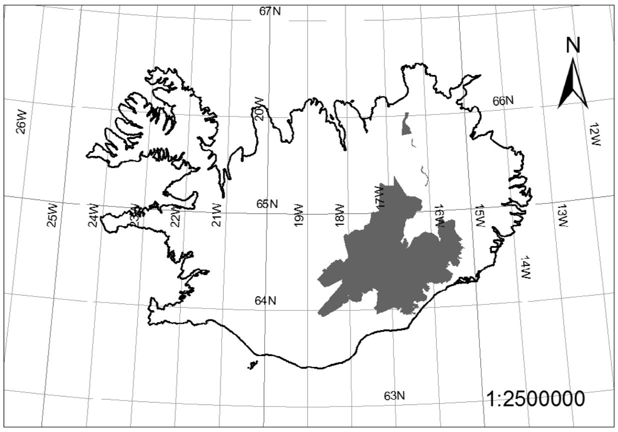


Figure 4: Location of the Vatnajökull National Park (dark gray: Vatnajökull NP, including Vatnajökull glacier)

Previous sensitivity research in Iceland focused on the growing concern about soil degradation and desertification (*cf.* Arnalds, Þórarinsdóttir, et al., 2001). The most recent and comprehensive assessment of soil erosion identified several hot spots, especially in the interior of the country and north of the Vatnajökull ice cap (*cf.* Arnalds, 2000; Arnalds, Þórarinsdóttir, et al., 2001). These surveys assessed the soil properties with regards to their soil classifications and presented an overview of the potential for erosion in sandy deserts and described the country in different erosion classification (Arnalds, Þórarinsdóttir, et al., 2001). Much of the erosion of the natural environment and its degradation can be traced to human use, where sheep grazing and tourist trampling are the most prominent examples (G. Gísladóttir, 2001, 2006). But the erosion of the Icelandic landscape is also shaped by natural processes. Retreating glaciers and the microtopography of the mountainous landscape is suspect to erosion processes (*cf.* F. O. Gísladóttir, Arnalds, & Gísladóttir, 2005).

Man made structures and the ecological sensitivity is another area of recent research on tourism in Iceland. The research by Ólafsdóttir and Runnström (2009, 2011) focused on the changes in Icelandic landscape and their effects on the perception of “wilderness”. As far as hiking trail research at protected areas is concerned, there is no complete assessment done in Iceland. However there has been research on popular hiking trails in the south highlands of Iceland. There Ólafsdóttir and Runnström (2013) analysed hiking trails in the Fjallabak Nature Reserve and at Þórsmörk and demonstrated how these are showing first sights of degradation. Their research shows that in some areas, the up to 30% of the trails are in bad or very bad condition (*ibid*). The decisive factor is the use by tourists (historic and current use), which is of importance to describe the difference in erosion in both sides. Other than that not much research has been done and research is still fragmented (e.g. assessment at Þingvellir National Park by Huber, 2014). However, there has been the discussion about the need for a national assessment and a harmonized standard for trail restoration and maintenance is needed (*cf.* Landvernd, 2014).

3.2 Japan

Japan is a collection of various islands of relatively recent volcanic origin on the Pacific coast of Asia and extends over approximately 378.000 km^2. The four main volcanic islands of Japan are Hokkaido, Honshu, Shikoku, and Kyushu. Its interior mainland is mostly mountainous and covered with forests. The Japanese population lives mainly on the low flat lands around the islands' coast as in Iceland. However, it is much more densely populated than Iceland with approximately 337 inhabitants/km^2. Japan is on the Pacific Ring of Fire which results in ongoing volcanic activity, as the eruption of Shinmoedake in the south of Kyushu in January 2011 or Mt. Ontake on Honshu in September 2014 indicates. Geological formations, continuous earthquakes, and the abundance of hot springs also indicate volcanic activity. Hokkaido as the northern island has an area of about 78.000km^2 and a population of about 5.600.000, which makes it much less densely populated than the rest of Japan (72/km^2).

The study sites in Hokkaido are Daisetsuzan NP [DNP] and Shikotsu-Toya NP [SNP]. The DNP is one of the first national parks in Japan, established in 1934 (Ministry of the Environment, 2008, p. 48; Ito, 1996; Shiratori & Ito, 2001; Aikoh, 2008). Apart from being one of the first national parks established in Japan, DNP is 2.267 km^2 (Tawara, 2004) and thus, one of the largest national parks. The main feature of DNP is the mountainous landscape between Mt. Asahidake and Mt. Kurodake (*cf.* Simmons, 1973). For SNP the main features are the two lakes - Shikotsu and Toya - and its hot springs. The volcano - Mt. Tarumae - attracts many visitors. DNP is located in the centre of Hokkaido, SNP in the south west (see Figure 5). The selection of these two NP was based on the similarity of topographic features and their accessibility from the largest city, Sapporo. Both NP are also part of the most popular destinations on Hokkaido and subject to most of trips to northern Japan.

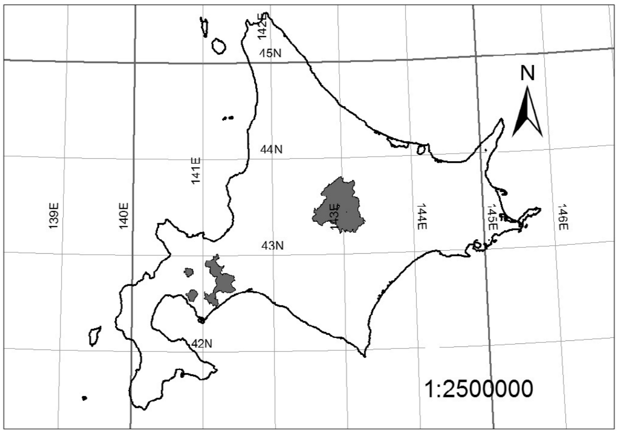


Figure 5: Daisetsuzan National Park (centre) and eastern part of Shikotsu-Toya National Park in Japan.

In Hokkaido, degradation of the natural environment is of concern at protected areas as well. Daisetsuzan NP is one of the oldest, most popular, and extensively researched national parks in Hokkaido (*cf.* Sato & Grabherr, 2004). The flow of visitors to the NP has drastically increased over the last decades (*cf.* Kobayashi, 2004; Yoda & Watanabe, 2000). The influx of visitors at DNP increased from 410.000 in 1960 to 5.240.000 visitors in 1987 (Yoda & Watanabe, 2000). In specific areas of the DNP, the increase of visitors was more than threefold between the years 1997 and 2004 (Shoji et al., 2008). Since this park is popular for hiking, there have been significant changes in the composition and extent of social trails alongside campsites (Aikoh, 2008). The network of social trails expanded considerably over the last decades, which leads to accelerated top soil and vegetation erosion along popular hiking trails and sites. However, no extensive analysis on ecological sensitivity can be found in English.

Research on hiking trails at DNP show a similar picture of ongoing degradation to Iceland. Recent research on trails at DNP described several trails as being one of the most damaged trails in Hokkaido (Watanabe, 2008). Trails in the DNP have been eroding relative to the slope angle and the weather influences on the surrounding (Yoda & Watanabe, 2000). However there has not been any extensive hiking trail assessment available in English.

3.3 Comparability

The most obvious factors describing the comparability of the two research sites are that Iceland and Japan are island nations formed and shaped by volcanic activity. Volcanism in both places formed similar top soils with a high content of volcanic soils. Hokkaido and Iceland are areas with cold winter climates which effects the formation and composition of the vegetation cover and top soil properties. Both island experience extended cold periods in the winter with extended snow exposure. Because of its volcanic origin, the top soil is permeable. This leads to specialized vegetation in this area. This vegetation consists of mosses and snow patch community plants, which are surface extensive, but do not penetrate the soil and are thus sensitive to physical impacts.

It is unique to compare the two islands as it provides insights as to how similar environments react to different amounts of tourism consumption. Iceland is sparsely populated, compared to Japan, but has to cope with a rather recent spike in number of visitors to its PAs. Japan on the other hand, demonstrates what prolonged high numbers of visitors can cause to the state of hiking trails. Hiking in mountains has been a popular recreation in Japan for decades as the book *Nihon Hyakumeizan* (Fukada, 1964) about the 100 mountains of Japan amply demonstrates. Although Iceland and Japan are both areas struggling with hiking trail degradation at PAs, management of PAs in both countries rely on techniques and guidelines of trail management and restoration that have been formulated abroad. The management of PAs and trails is dependent on the collaboration of many locally based stakeholders and location specific topographic qualities. Hence its enactment in reality is quite diverse (*cf.* Schaller, 2011; Watanabe, 2008).

There are limitations to comparing the sites on the two islands. In Iceland and Japan there is almost no data available about the amount of use by visitors within the selected case sites. There is more comprehensive data about the amount of visitors to DNP (*cf.* Shoji et al., 2008) but almost none about the different trails in VNP. Since management of trails is done by different actors and, therefore, the current state of trails is different, it is important to know the current and previous management of hiking trails in Japan. Unfortunately this information is not fully accessible. Lastly, the resolution of data is different from Iceland to Japan. Especially the data in Iceland is still rather coarse, which makes the accuracy of assessment and a definite judgement difficult. This might be influenced by the different resolution of areal observations used to draw the dataset, or historic extent and different methods used in collecting the data. However, the fact that the measurement points are done on 100m interval suggest that these measurements should be able to show a similarity in Iceland and Japan, and provide a high resolution of measurements on the ground. Another aspect is the difference in population density and number of visitors arriving. Hokkaido has a higher population density than Iceland, which leads to a different domestic tourism potential in the area. If the number of international visitor and domestic tourists in both areas are summed up it can be said that Japan has a by far larger number of potential visitors to the selected NPs. However, the numbers of visitors on the selected trails is not easily obtained and thus cannot be verified for comparison. This makes it difficult to say with absolute confidence that the impact at the sites in Hokkaido show a definite response to the increase in tourism, compared to Iceland. Still, the comparison can give an indication of possible development of impacts by recreational use.

4 Methods

This research examines the degradation of trails on the selected field sites by combining excising data through a sensitivity assessment of the natural environment and field measurement of hiking trail conditions. The basis for the assessment of ecological sensitivity and the condition of hiking trail are the methods and sensitivity classifications defined by Ólafsdóttir and Runnström (2009). Using their method and classification will provide the basis for assessment and will help highlight the possible sensitivity of the natural environment towards physical impacts, whereas the hiking trail assessment will give information about the current degradation. The hiking trail assessment has been executed on famous hiking trails, marked on tourist maps within the northern area of Vatnajökull NP (trails between Ásbyrgi and Dettifoss, Askja and Herðubreiðarlindir), Daisetsuzan NP (Asahidake Onsen and Mt. Kurodake), and Mt. Tarumae at the Shikotsu-Toya NP. As the hiking trails are partly located outside the northern area of VNP, the analysis needed to include further land in this analysis. Therefore the surrounding municipalities Norðurþing and Skútustaðahreppur have been chosen, as they incorporate the land of the selected protected areas and the hiking trails. Yet, the analysis excludes the area of the Vatnajökull ice cap as it would not provide enough data for the ecological sensitivity analysis. For Japan, the selected protected areas will omit the western regions of the Shikotsu-Toya National Park, as the hiking trail does not stretch to these areas (see Figure 6 and Figure 7).

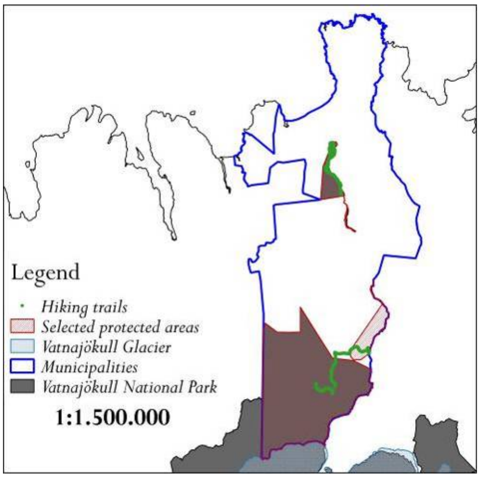


Figure 6: selected focus area and hiking trails in Iceland

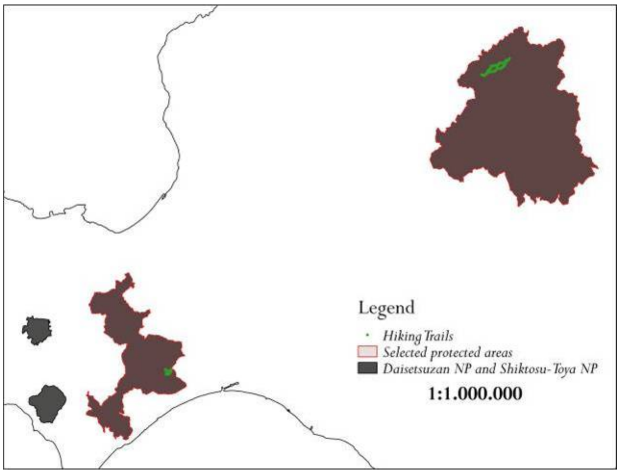


Figure 7: selected focus area and hiking trails in Japan

4.1 GIS data collection

The data necessary for this analysis in Iceland was collected on a national level, whereas the study in Hokkaido was based on data on a regional level. Geographically positioned data to use in the GIS have been acquired from different sources and gathered into a geo-spatial database.

The following geographical data was gathered:

Scale and resolution of data	**Iceland**	**Hokkaido**
Administrative boundaries (vector data)	1:750.000	-/-
Boundaries of National parks (vector data)	1:667.000	1:50.000
Boundaries of Protected areas (vector data)	1:667.000	-/-
Digital Elevation Model	20x20m (vector data)	50x50m (raster data)
Soil type (vector data)	1:250.000	N.A.
Vegetation cover (vector data)	1:500.000	1:50.000
Hiking trails (point data from field)	200m/100m interval	100m interval
Hiking trail condition measurements (field data)	200m/100m interval	100m interval

The digital databases for this analysis were obtained from the Icelandic Institute of Natural History (www.ni.is), the Agricultural University of Iceland (www.lbhi.is), the Environmental Agency of Iceland (www.ust.is), the Ministry of Land, Infrastructure, Transportation, and Tourism (www.mlit.go.jp), the Biodiversity Centre of Japan (www.biodic.go.jp), and the Geospatial Information Authority of Japan (www.gsi.go.jp). The data have been defined, re-projected and transformed if required, to the national coordinate system.

The geographical digital data from Iceland is on a national scale and was obtained from the National Land Survey of Iceland (IS50V3.0 geodatabase). All available data was transformed into Iceland's national coordinate system in a Lambert conformal projection with a central meridian at W19°, latitude of origin at N65°, spheroid WGS84, and standard-parallels at N64.25° and N65.75°. As well as into the Japanese national coordinate system JGD_2000_UTM_Zone_54N projection with a central meridian at E141°, latitude of origin at N0°, spheroid GCS_JGD_2000.

4.2 Ecological sensitivity classification

For the ecological classification data about top soil, vegetation type, and slope angle was used. Each ecological parameter was analysed according to their condition concerning their resistance to physical impact. All parameters have been classified into four individual categories of sensitivity, ranging from 'no sensitivity' (0) to 'high sensitivity' (3) (based on Ólafsdóttir & Runnström, 2009; for further specification of all ecological sensitivity categories see Appendix A).With each physical variable classified into categories of sensitivity, a number of GIS-overlay operations result in the delineation of polygons (spatial regions) where the sensitivity class for each physical variable is stored as attributes. For each polygon the total ecological sensitivity is obtained by summarizing the sensitivity class for the three variables providing a numerical value based on all the physical variables.

The categorization of top soil can vary between countries and requires a unifying categorization to compare the sensitivity of soil. The international soil classification, as described in the World Reference Base for Soil Resources (FAO, 2006) was used to classify the different top soil, with the different soil types described in Iceland (Arnalds & Barkarson, 2003) and Japan (Obara et al., 2011).

The classification of vegetation into the different sensitivity categories is difficult since extensive research about the resistance towards trampling is lacking in Iceland and in Hokkaido. Nevertheless it can be said that different species and types of vegetation react differently to physical impacts, dependent on species-specific factors. More than half of the areas in Iceland are vegetated (F. O. Gísladóttir et al., 2005; Gudjonsson & Gislason, 1998) with a large distribution of moss heath very sensitive towards physical impacts (G. Gísladóttir, 2006). As previous research argues, grasslands are less sensitive than heath lands and wet soils are more likely to be damaged (Pickering, Hill, Newsome, & Leung, 2010). In Hokkaido, the classification of vegetation follows the example in Iceland, and has been adjusted with the help of researchers at the Hokkaido University to accommodate the local setting.

In the case of the slope gradient, a digital elevation model [DEM] with a grid size of 20mx20m (in Iceland) and 50mx50m (in Hokkaido) was used to determine the slope or gradient of slope of each grid cell. The tool included in GIS software calculates the maximum difference in elevation between the grid cell midpoints. It is assumed that the higher the gradient of slope between the different cell midpoints the more sensitive the grid cell is to erosion through gravity. It has to be noted that due to computing constrains at the time of conducting the research, a higher resolution in Hokkaido was used for an area of 20kmx20km around the selected hiking trails, using grid size 10mx10m. The higher resolution of data in this area enables the GIS to represent the actual sensitivity more accurately, which enables a better comparison of GPS point data to the sensitivity of the area.

4.3 Hiking trail measurements

Various techniques are discussed in the literature to assess hiking trails but the methods chosen for this study are based on cost and time efficiency, without sacrificing resolution and precision. In general this research followed a similar study done in Iceland and published in 2013 (Ólafsdóttir & Runnström, 2013; for further specification of all hiking trail measurement classification see Appendix B). Ólafsdóttir and Runnström relied in their study on fieldwork to acquire the necessary data by measuring defined parameters of trails on a continuous interval along the trail. In this research, the measurement of parameters was chosen over trail profiles (transect) because of the flexibility of measurement parameters and the difficulty to select suitable fixed measurement points for profiles at the research sites (e.g. loosening of soil because of seasonal frost and thaw). The trails were hiked and at a regular interval, a Global Positioning System (GPS) point was recorded and five parameters measured: 1) width of trail, 2) impact zone (impact area of hiking trail and used area next to the trail), 3) depth of trail, 4) overall change in vegetation cover (compared to dominant vegetation next to the trail), and 5) severity of erosion visible (example of trail and measured parameters: see Figure 8).

Figure 8: Example of a hiking trail condition and impact zone.

The measurements were then linked to the GPS position as attributes and imported into the GIS software. To ensure a high resolution of data it is suggested that the measurement interval has to be around 100m (Leung & Marion, 1999b). Shorter measurement intervals would increase the accuracy for further analysis, but the gained accuracy is achieved by much higher costs (e.g. time for measurement). For this analysis a measurement interval of 100m was used for the trails at Ásbyrgi and for all trails in Askja and Herðubreiðarlindir, but 200m for all other trails in Jökulsárgljúfur, due to bad weather conditions during the hike. For the trails in Askja and Herðubreiðarlindir, as well as the trails in Japan, 100m intervals were used. Using these intervals, a total of 1.255 measurement points were collected within the study areas. However trail junctions can make a measurement point count twice for the analysis. These points were subtracted from the total collection of points. Also additional points which are not on hiking trails have been subtracted, leaving a total of 1.169 measurement points on the total length of 110,8km (771 in Iceland and 398 in Japan). To record the location of a measurement point and to measure the distance to the next measurement point a handheld GPS receiver with approximately 5-10m precision was used. At each measurement point the five parameters were measured using a measurement tape (for width, impact zone, and depth) and general observation (vegetation cover and erosion). For each measurement point the total impact is obtained by summing up the value of the parameter categories for the four variables (except the impact zone) providing a numerical value based on all parameters.

Often, hiking trails show heavy usage as they display a number of parallel trails which extend the total width of the impacted area, and stretch beyond the original trail. Obscure trails, unclear markings, flat areas, and weather conditions can lead to a dispersion of hikers which results in disturbances of a larger area. This additional impact of trampling aside of the trail is in most cases visual and leads to the inclusion of the impact zone as an additional impact factor in the assessment. Only two categories were chosen for the impact zone. If the difference between the classification of the trail width and impact zone was greater than 1, the numerical value for the width was increased by one (e.g. if the trail was 0,6m wide, but the impact zone was more than 3m, the numerical value of the total impact of the trail was “2” instead of “1” as the initial count for the trail width). The inclusion of the total impact zone of the hiking trail leads to better representation of the whole impacted area, rather than classifying the single trail width for the analysis.

During the field measurements, it became apparent that the top soil and vegetation type has an important influence on the current and future state of degradation of the hiking trail. Based on knowledge on ecological sensitivity these two factors can shape the sensitivity of a trail to physical impacts. The top soil conditions, the looseness of the top material and the type of vegetation covering the trail has different properties which can lead to higher or lower impacts than the impact classification would suggest. Therefore, to account for these factors an additional adjustment factor for the top soil properties, the type of vegetation, and the absence of multiple trails is necessary.

Top soil:	"-1" for bedrock or managed trails, "+1" for loose material, and "+2" for multiple trails, since they increase significantly the area of impact
Vegetation:	"-1" for grassland and "+1" for moss heath as the most sensitive

With this adjustment, the range of scores for the impact of hiking trails can vary between "-2" and "+12". With this adjustment an attempt is made not only to bring two important factors into the assessment of hiking trails but also to represent more factors involved in the resistance of hiking trails towards physical impacts. This will balance the points better and align the measurements with the impact classes. However, this report will mention the overall analysis of hiking trails with both classifications but focus then on the level of the individual trail on the classification including this balancing factor.

4.4 Combination of ecological sensitivity and hiking trail measurements using GIS

This report represents the assessment of ecological sensitivity and hiking trail degradation, using a GIS system. For the ecological sensitivity, the existing digital data about top soil, vegetation type, and topography were imputed into the GIS software. After the three layers of data were imported, each layer was classified according to their sensitivity properties using the classifications as described earlier and specified by Ólafsdóttir and Runnström (2009). The layers were then combined in the GIS software and the classification value in each polygon was added up. The resulting layer has the combined values of all three layers, represented in different polygons. The polygons can have a numerical value ranging from "0" to "9", which have been later grouped evenly into 4 sensitivity groups ranging from "no sensitivity" to "high sensitivity".

The degradation of hiking trails was based on field measurement. The GPS points of each measurement point was recorded and linked to the different measurements of the five parameters (width, impact zone, depth, vegetation change, and erosion type). Each parameter was classified as described earlier and specified by Ólafsdóttir and Runnström (2013). All classifications were added up to a total classification value, ranging from "0" to "12", which was later grouped evenly into 4 degradation groups ranging from "no impact" to "severe impact". The GPS points were loaded into the GPS software providing point data, referenced to the GPS location. Each GPS point was then joined in the GIS software with the degradation groups of the classification data. This creates a layer in the GIS software representing the measurement points and their combined classification data (see Figure 9). For further analysis of the hiking trail degradation, the hiking trail was divided into different segments, as represented in the maps, used by hikers (see analogue maps in Appendix C: Jökulsárgljúfur, Appendix D: Herðubreiðarlindir and Askja, Appendix E: Daisetsuzan National Park). Using this division of trails help future analysis and comparison of the data with later research. This divides the trails in Iceland into 34 segments and 16 trail segments in Japan. The trail segments are assessed in the same way as the individual GPS points.

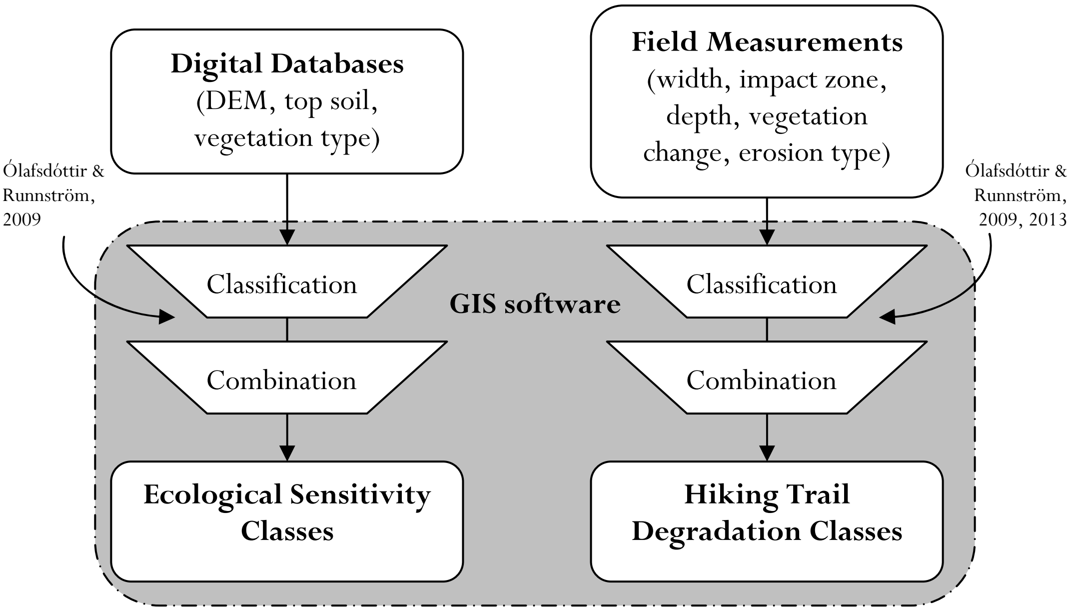


Figure 9: Model of the input of data and methods into GIS assessing the ecological sensitivity and hiking trail

5 Results

5.1 Iceland

After the combination of all layers of digital data and the classification of the combined layer of data, the ecological sensitivity of each area can be assessed. Because the measured hiking trails lie only partly inside the selected protected areas, it is important to assess the ecological sensitivity for the whole of the surrounding municipalities and on the level of the selected protected areas in the case of Iceland (see Figure 10).

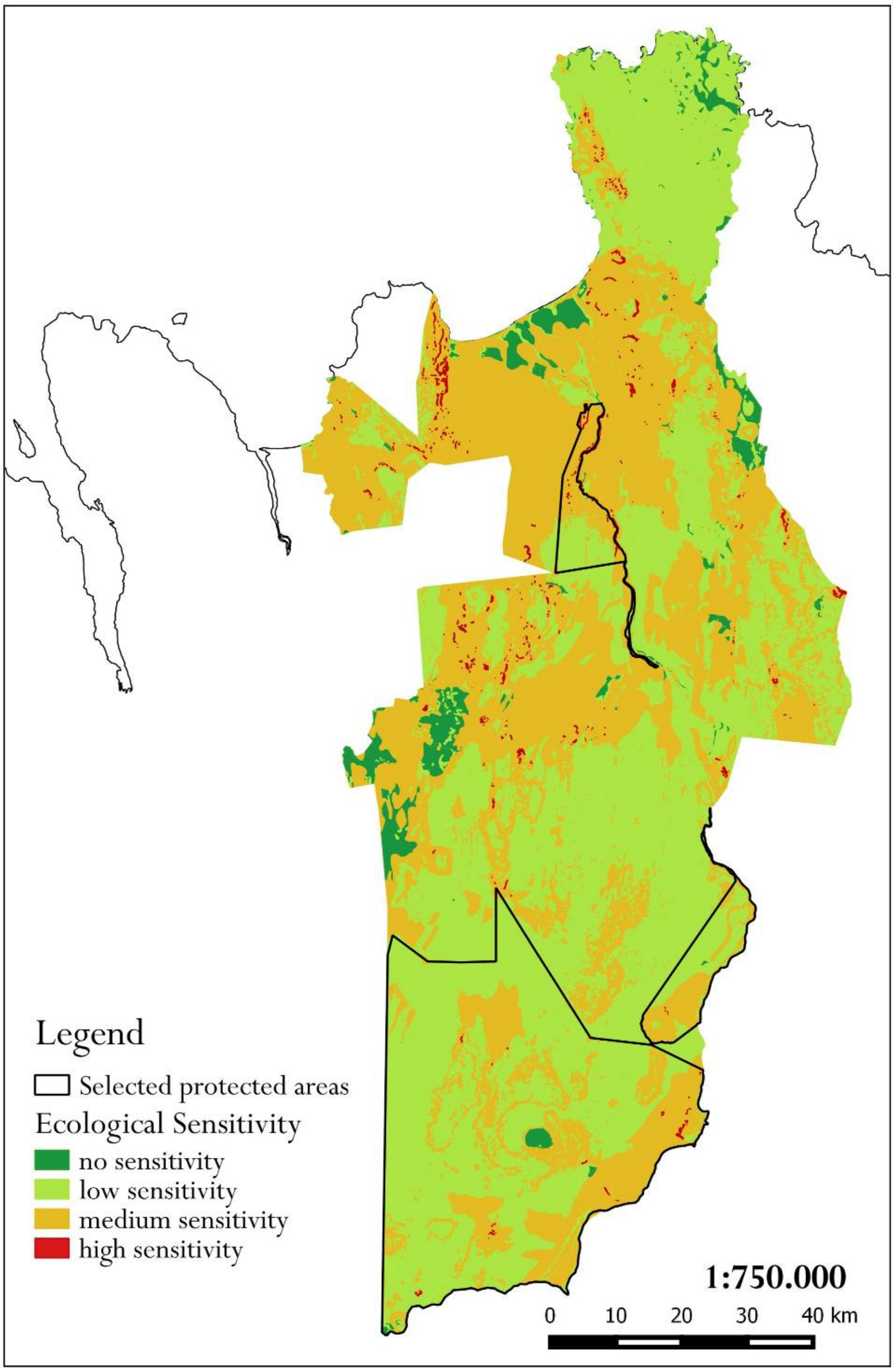


Figure 10: Ecological sensitivity within the municipality boundary in north east Iceland (excluding the area of the Vatnajökull glacier)

The total area for the assessment made in Iceland covers 8.616 km^2, whereas 2.227 km^2 are within the PAs. Statistics of the area and the spatial distribution for each ecological sensitivity class was then extracted. Overall, the majority of the area shows low sensitivity (63,9% on municipality level and 74,9% within the selected protected areas). The areas with no sensitivity or high sensitivity are almost not existent. The areas with high sensitivity, however, highlight areas where special attention needs to be given to degradation. In the case of the selected protected areas, the areas with high sensitivity are mainly on the edges of the Jökulsárgljúfur canyon and the cliff at the southern corner of Ásbyrgi.

Table 1: Ecological sensitivity in Iceland for municipality level and protected area level (see Figure 10)

	Municipality level		Protected Area level	
Ecological sensitivity class	Area (km^2)		Area (km^2)	
no sensitivity (🟩)	81	1 %	13	1 %
low sensitivity (🟩)	5.502	64 %	1.667	75 %
medium sensitivity (🟨)	3.021	35 %	545	24 %
high sensitivity (🟥)	12	~ 0 %	2	~ 0 %
Sum:	8.616	100 %	2.227	100 %

The results of the measurements of the state of hiking trail in the focus area can be examined from the basis of all individual points in two areas: Jökulsárgljúfur and from Herðubreiðarlindir to Askja. The initial measurement, combining the initial parameters (width, impact zone, depth, vegetation change, and erosion) show that the majority of all measurement points along the trails show low impact. Dividing the measurement points to the two areas, it can be said that the trails at Jökulsárgljúfur tend to have low or medium impacts (46% and 48%) whereas the trails at Herðubreiðarlindir and Askja show low impact (see Table 2). Including the balancing of measurement points into the assessment, using balancing factors according to top soil and vegetation type it is possible to see a normalization of all measurements. Table 3 shows how the measurement points align within the impact class. Figure 11 shows an overview of all measurement points on the trails and their impact classification including the balancing factor.

Table 2: Hiking trail degradation according to initial measurements in Iceland (in percentage of all points)

Impact class	Total	Jökulsárgljúfur	Herðubreiðarlindir to Askja
no impact (🟩)	23 %	2 %	37 %
low impact (🟩)	55 %	46 %	61 %
medium impact (🟨)	21 %	48 %	2 %
high impact (🟥)	2 %	4 %	0 %
Sum:	100 % (771 points)	100 % (321 points)	100 % (450 points)

Table 3: Hiking trail degradation according to measurements including the balancing factor for soil and vegetation

Impact class	Total	Jökulsárgljúfur	Herðubreiðarlindir to Askja
no impact (🟩)	5 %	7 %	4 %
low impact (🟩)	65 %	38 %	84 %
medium impact (🟨)	25 %	43 %	12 %
high impact (🟥)	6 %	13 %	0 %
Sum:	100 % (771 points)	100 % (321 points)	100 % (450 points)

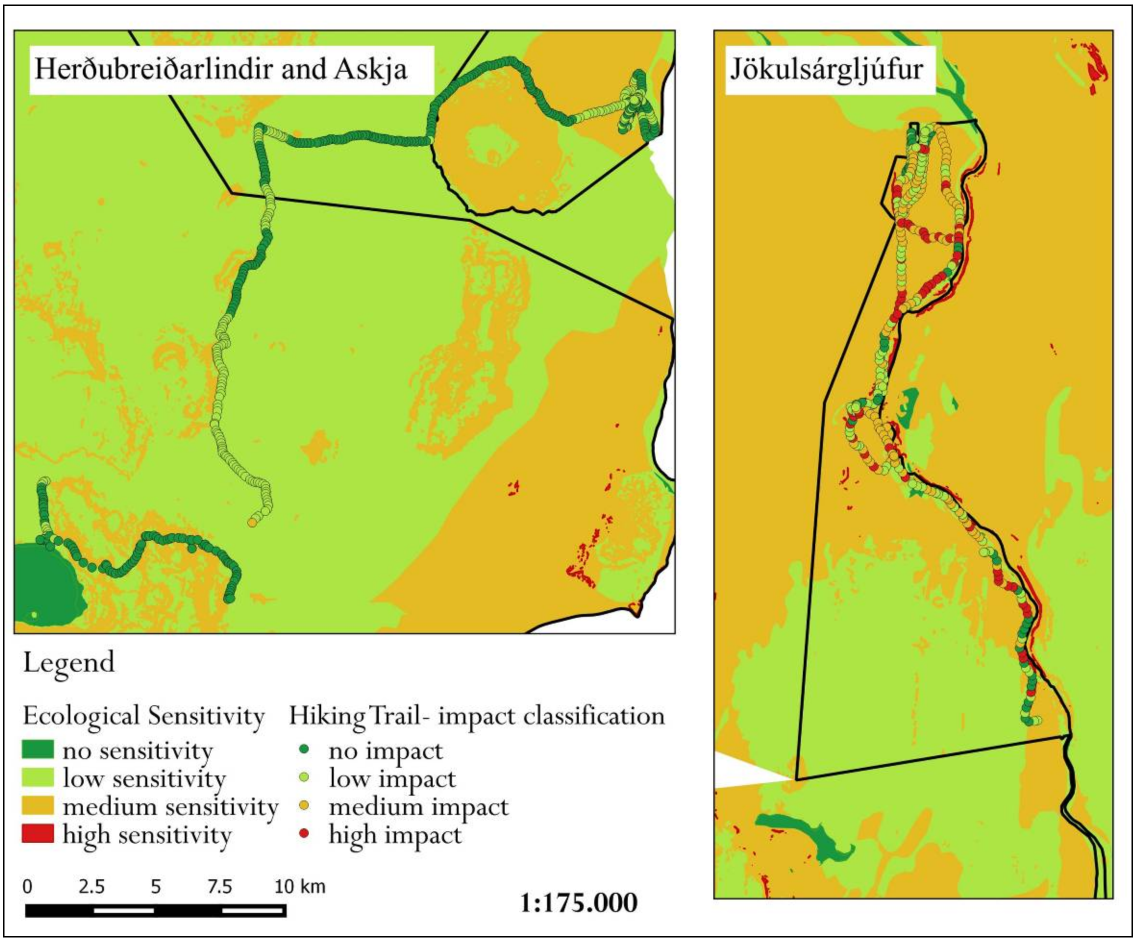


Figure 11: Hiking trails showing the balanced impact classification of all GPS points at research site in Iceland

In addition to the measurement of each individual point on the hiking trail, the different segments of hiking trails have been assessed. The analogue maps (see Appendix C: Jökulsárgljúfur and Appendix D: Herðubreiðarlindir and Askja) of the hiking trails in Jökulsárgljúfur were precise but confusing since some tracks were actually segments of different hiking trails (e.g. trail "Á-8" and "Á-9" between the Wardens Office and the junction at Kvíar, or "D-3" and "L-2" between the northern parking lot at Dettifoss and the junction at Fossvogur). Thus, it is more convenient for a clear analysis to break down the hiking trails into defined segments. Only the mean score for each hiking trail segment was used to classify the trail segments into different impact classifications. Whereas trail segments with "no impact" had an average score of „0", "low impact" segments had a score between „1" and „3", "medium impact" segments scored „4" or „5", and segments with "high impact" showed an average of „6" or higher.

Since some of the trail segments overlapped, it is important to look only at the individual trail segments. In all 35 individual trail segments were identified. However, the trail segment "Á-8" and "Á-9" are the same between the warden's hut at Ásbyrgi and the ruins of Hvammssel, but then continue in different directions. Because these two trails are identical from the ruins at Hvammssel to the hut at Ásbyrgi, only 34 individual trail segments were counted for the assessment. Another confusing trail is "D-3", as it describes the trail from the northern parking lot at Dettifoss towards the junction at Fossvogur, after that the trail continues as "L-2". Overall, there is no large difference between all trail segments, as the majority of all trail segments shows low or medium impact (both 35%), whereas 29% of the trail segments show severe impact (see Figure 12).

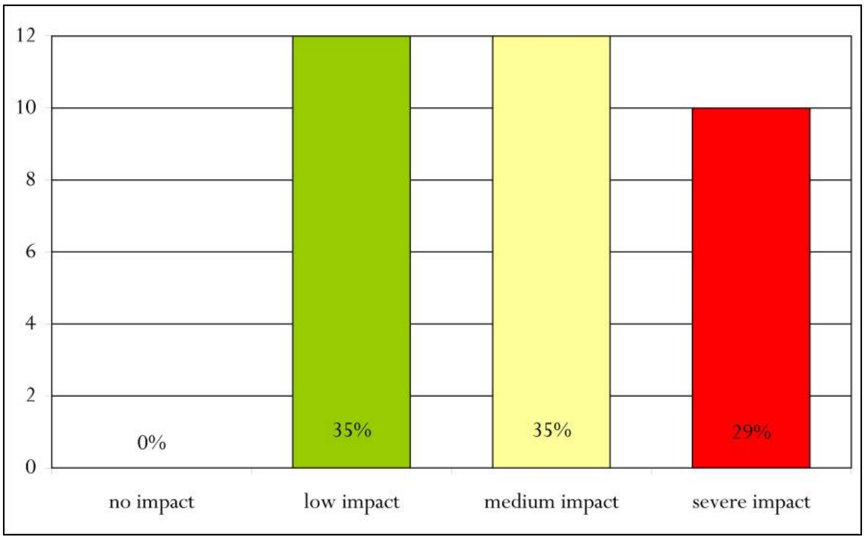
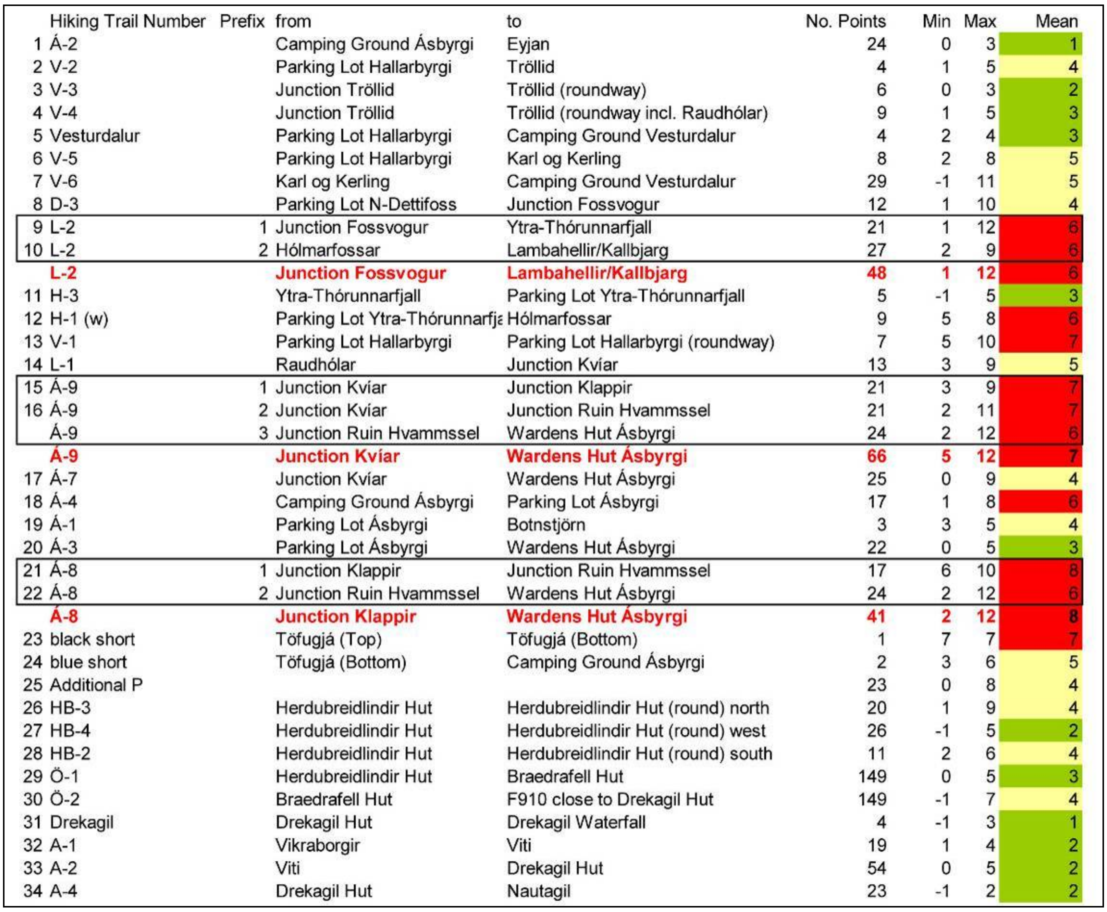


Figure 12: The proportion of trail segments and corresponding trail segment conditions in Iceland

When looking into the results of each individual trail segment (see Table 4), it is possible to see the different impact classifications, including the information about the trail number, the amount of different measurement points along a segment, and the minimum and maximum impact classification. In particular, trails "L-2", "Á-8", and "Á-9" show severe impact. Most of the trails are on the edge of a cliff, either towards the canyon Jökulsárgljúfur or towards the interior of Ásbyrgi.

Table 4: Overview of all trail segments in Iceland, including the amount of measurement points per segment, minimum and maximum impact classification, and mean (grouped into different impact classifications)



	Hiking Trail Number	Prefix	from	to	No. Points	Min	Max	Mean
1	Á-2		Camping Ground Ásbyrgi	Eyjan	24	0	3	1
2	V-2		Parking Lot Hallarbyrgi	Tröllid	4	1	5	4
3	V-3		Junction Tröllid	Tröllid (roundway)	6	0	3	2
4	V-4		Junction Tröllid	Tröllid (roundway incl. Raudhólar)	9	1	5	3
5	Vesturdalur		Parking Lot Hallarbyrgi	Camping Ground Vesturdalur	4	2	4	3
6	V-5		Parking Lot Hallarbyrgi	Karl og Kerling	8	2	8	5
7	V-6		Karl og Kerling	Camping Ground Vesturdalur	29	-1	11	5
8	D-3		Parking Lot N-Dettifoss	Junction Fossvogur	12	1	10	4
9	L-2	1	Junction Fossvogur	Ytra-Thórunnarfjall	21	1	12	6
10	L-2	2	Hólmarfossar	Lambahellir/Kallbjarg	27	2	9	6
	L-2		**Junction Fossvogur**	**Lambahellir/Kallbjarg**	**48**	**1**	**12**	6
11	H-3		Ytra-Thórunnarfjall	Parking Lot Ytra-Thórunnarfjall	5	-1	5	3
12	H-1 (w)		Parking Lot Ytra-Thórunnarfjа	Hólmarfossar	9	5	8	6
13	V-1		Parking Lot Hallarbyrgi	Parking Lot Hallarbyrgi (roundway)	7	5	10	7
14	L-1		Raudhólar	Junction Kvíar	13	3	9	5
15	Á-9	1	Junction Kvíar	Junction Klappir	21	3	9	7
16	Á-9	2	Junction Kvíar	Junction Ruin Hvammssel	21	2	11	7
	Á-9	3	Junction Ruin Hvammssel	Wardens Hut Ásbyrgi	24	2	12	6
	Á-9		**Junction Kvíar**	**Wardens Hut Ásbyrgi**	**66**	**5**	**12**	7
17	Á-7		Junction Kvíar	Wardens Hut Ásbyrgi	25	0	9	4
18	Á-4		Camping Ground Ásbyrgi	Parking Lot Ásbyrgi	17	1	8	6
19	Á-1		Parking Lot Ásbyrgi	Botnstjörn	3	3	5	4
20	Á-3		Parking Lot Ásbyrgi	Wardens Hut Ásbyrgi	22	0	5	3
21	Á-8	1	Junction Klappir	Junction Ruin Hvammssel	17	6	10	8
22	Á-8	2	Junction Ruin Hvammssel	Wardens Hut Ásbyrgi	24	2	12	6
	Á-8		**Junction Klappir**	**Wardens Hut Ásbyrgi**	**41**	**2**	**12**	8
23	black short		Töfugjá (Top)	Töfugjá (Bottom)	1	7	7	7
24	blue short		Töfugjá (Bottom)	Camping Ground Ásbyrgi	2	3	6	5
25	Additional P				23	0	8	4
26	HB-3		Herdubreidlindir Hut	Herdubreidlindir Hut (round) north	20	1	9	4
27	HB-4		Herdubreidlindir Hut	Herdubreidlindir Hut (round) west	26	-1	5	2
28	HB-2		Herdubreidlindir Hut	Herdubreidlindir Hut (round) south	11	2	6	4
29	Ö-1		Herdubreidlindir Hut	Braedrafell Hut	149	0	5	3
30	Ö-2		Braedrafell Hut	F910 close to Drekagil Hut	149	-1	7	4
31	Drekagil		Drekagil Hut	Drekagil Waterfall	4	-1	3	1
32	A-1		Vikraborgir	Viti	19	1	4	2
33	A-2		Viti	Drekagil Hut	54	0	5	2
34	A-4		Drekagil Hut	Nautagil	23	-1	2	2

5.2 *Japan*

After the combination of all layers of digital data and classification of the combined layer of data, we can assess the ecological sensitivity of the selected protected areas. In the case of Hokkaido the ecological sensitivity was examined on a regional level and focused on Daisetsuzan NP and the eastern area of Shikotsu-Toya NP (see Figure 13). The figure shows that areas with no ecological sensitivity are in effect regions containing lakes and fluvial systems that were classified as not being sensitive to tourism impact. The other colours (light green to red) represent a gradient of sensitivity from low sensitivity (green) towards high sensitivity (red) when it comes to physical impacts.

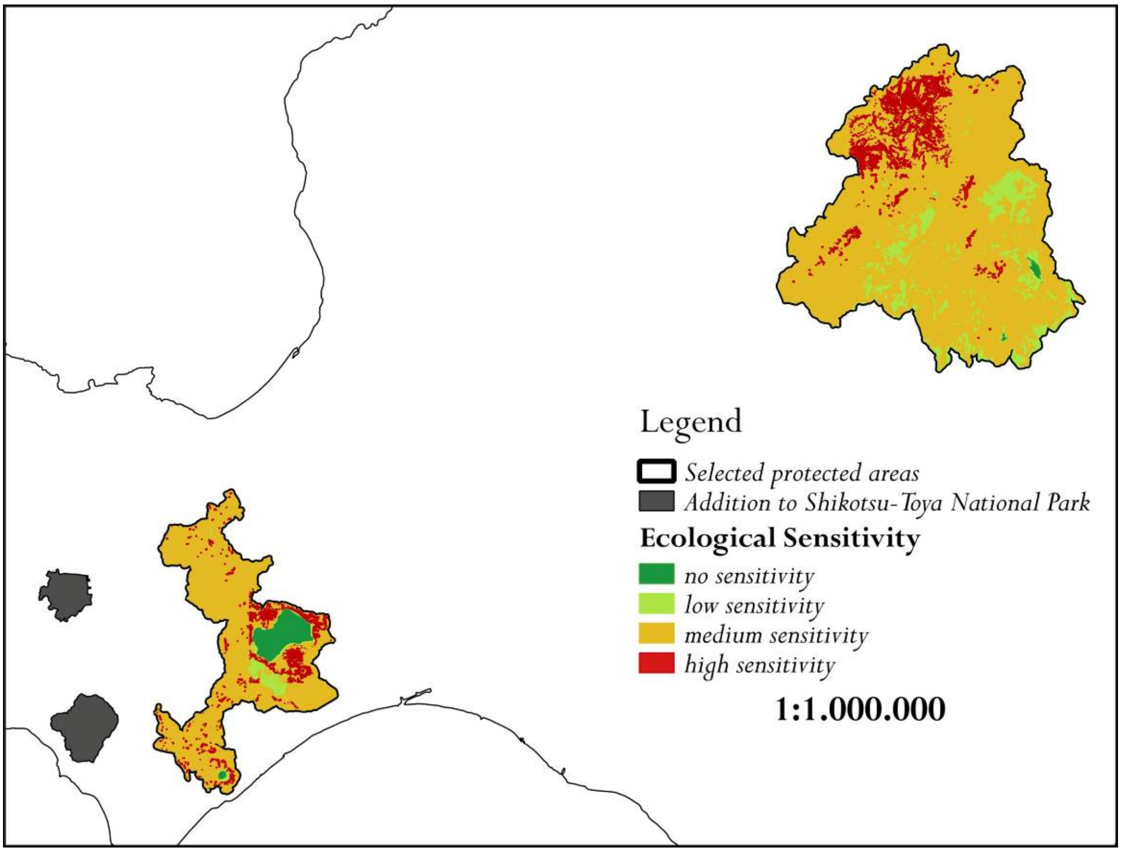


Figure 13: Ecological sensitivity at the selected protected areas in Hokkaido

In Hokkaido, the total area for this assessment covers 3.095 km^2 within the Pas only. Statistics of the area and the spatial distribution for each ecological sensitivity class was extracted using a GIS system (Table 5). It shows that the majority of the study area shows medium sensitivity (67,1% within the selected protected areas). The areas with no sensitivity are almost non-existent (2,7% of the total area) whereas a significant area shows high sensitivity (16,2%). The areas with high sensitivity demand special attention due to degradation.

Table 5: Ecological sensitivity for the selected protected area level in Japan (see Figure 13)

	Protected Area level	
Ecological sensitivity class	Area (km^2)	
no sensitivity (🟩)	84	3 %
low sensitivity (🟩)	433	14 %
medium sensitivity (🟨)	2.076	67 %
high sensitivity (🟥)	502	16 %
Sum:	3.095	100 %

The results of the measurements of the state of hiking trail in the focus area can be looked at from the basis of all individual points and of the two areas: Daisetsuzan NP and Shikotsu-Toya NP. The initial measurements, combining the initial parameters (width, impact zone, depth, vegetation change, and erosion) show that the majority of all measurement points along the trails show low impact. Dividing the measurement points to the two areas, it can be said that the trails at Daisetsuzan NP show higher impacts (29%) whereas the trails at Shikotsu-Toya NP show mainly medium impacts (see Table 6). Using balancing factors according to top soil and vegetation type, it is possible to see a normalization of all measurements. Table 7 shows how the measurement points aligned within the impact class. Figure 14 shows an overview of all measurement points on the trails and their impact classification including the balancing factor.

Table 6: Hiking trail degradation according to initial measurements in Hokkaido, Japan

Impact class	Total	Daisetsuzan NP	Shikotsu-Toya NP
no impact (🟩)	2 %	2 %	0 %
low impact (🟩)	24 %	24 %	24 %
medium impact (🟨)	49 %	45 %	65 %
high impact (🟥)	26 %	29 %	11 %
Sum:	100 %	100 %	100 %
	(398 points)	(318 points)	(80 points)

Table 7: Hiking trail degradation according to measurements including the balancing factor for soil and vegetation

Impact class	Total	Daisetsuzan NP	Shikotsu-Toya NP
no impact (🟩)	1 %	1 %	0 %
low impact (🟩)	27 %	32 %	6 %
medium impact (🟨)	45 %	38 %	71 %
high impact (🟥)	27 %	28 %	23 %
Sum:	100 %	100 %	100 %
	(398 points)	(318 points)	(80 points)

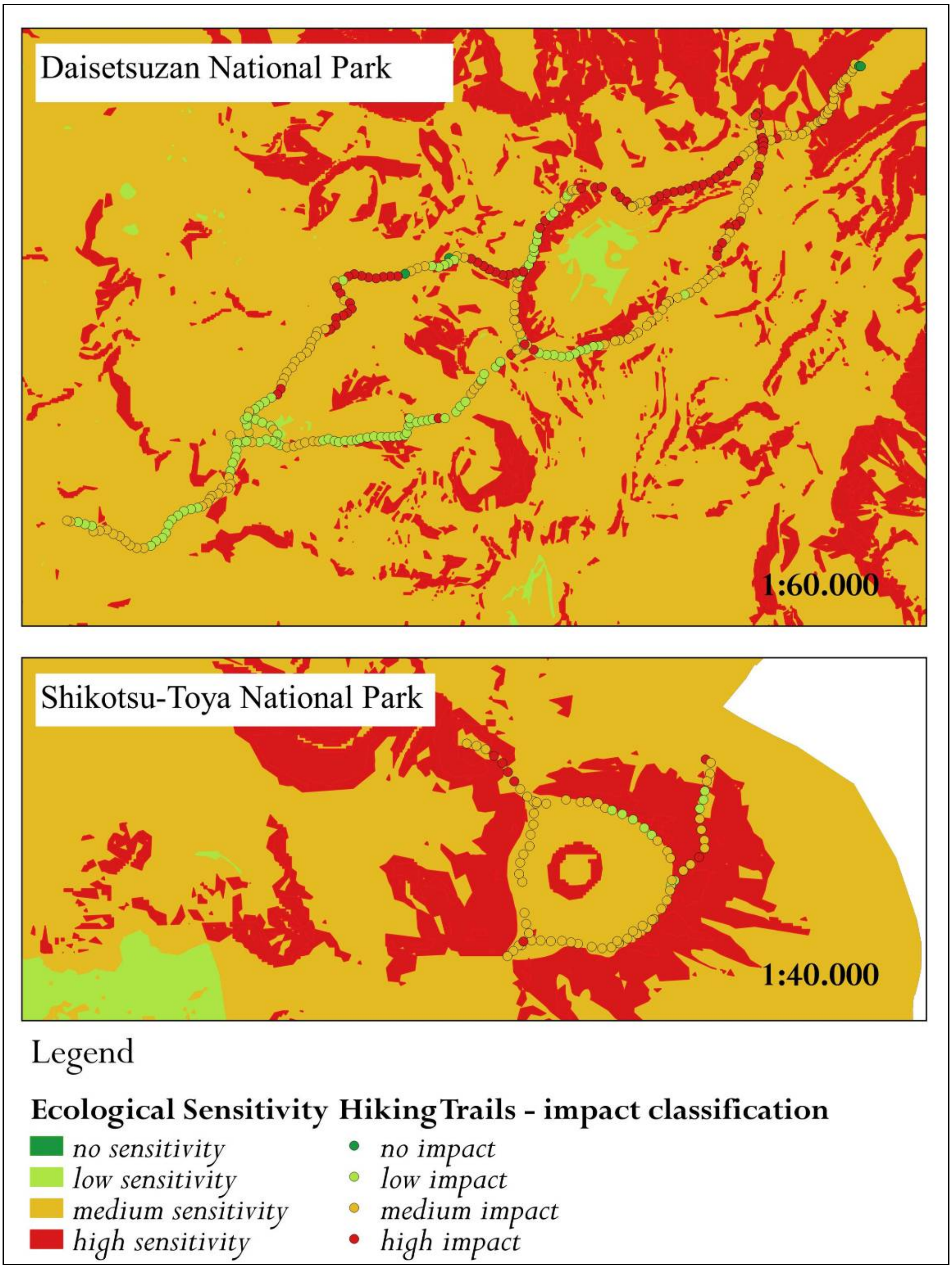


Figure 14: Hiking trails showing the balanced impact classification of all GPS points at research site in Hokkaido

In addition to the measurement of each individual point on the hiking trail, different segments of hiking trails were also analysed. Different to the situation in Iceland, hiking trails in Hokkaido are identified on maps with time markers giving the distance between different junctions or points of interest (see Appendix E). But since different municipalities are responsible for different segments of the total trail, it was difficult to apply the existing numbering and naming system. To represent this, and to ensure consistency with previous research, it was decided to separate trail segments according to specific meeting points, or end points of trails, if needed. The numbers given to the trail correspond to the trail markers in the field. Only the average score for each hiking trail segment was used to classify the trails. Whereas trail segments with no impact had an average score of „0“, low impact segments had a score between „1“ and „3“, medium impact segments scored „4“ or „5“, and segments with severe impact showed an average of „6“ or higher.

For this analysis, 16 trail segments were analysed. The majority of all trail segments show high impact (63%), whereas 31% of the trail segments shows a medium impact, and only one trail (6%) had little impact (see Figure 15). No trail segments were in very good condition.

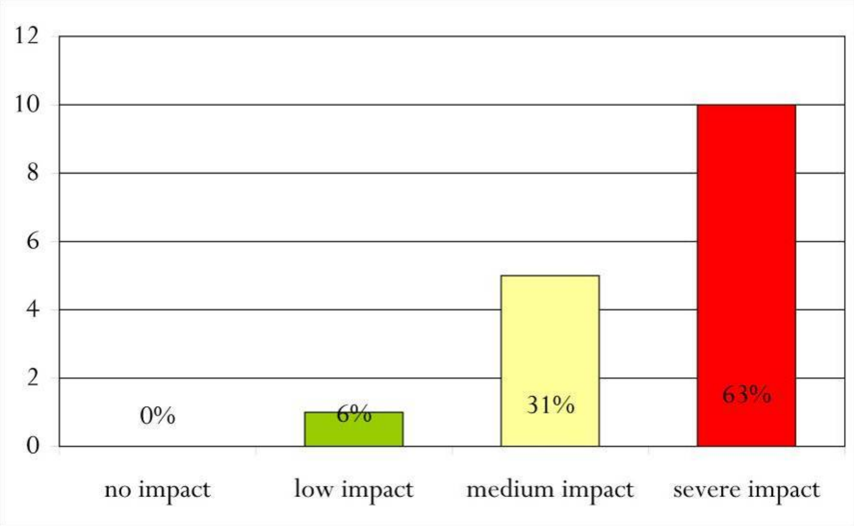


Figure 15: The proportion of trail segments and corresponding trail segment conditions in Hokkaido

When looking at the results of each individual trail segment (see Table 8), it is possible to see the different impact classifications, including the information about the trail number, the amount of different measurement points along a segment, and the minimum and maximum impact classification. However, almost all trails show severe impact, which does not give any further indication if a trail is more or less interesting to tourists.

Table 8: of all trail segments in Hokkaido, including the amount of measurement points per segment, minimum and maximum impact classification, and mean (grouped into different impact classifications)

	Hiking Trail Number	Prefix	from	to	No.points	Min	Max	Mean
	5	1	Sounkyo	Kurodake Ropeway				
	5	2	Kurodake Ropeway	Kurodake Skilift				
1	**5**	**3**	**Kurodake Skilift**	**Mt. Kurodake**	**19**	**5**	**8**	🟥 6
2	6	1	Mt. Kurodake	Kurodake Hut	9	0	11	🟥 6
3	6	2	Kurodake Hut	Mt. Keigetsu	8	5	11	🟥 9
4	6	3	Kurodake Hut MP	Mt. Hokkai	31	3	11	🟥 9
5	6	4	Mt. Hokkai	Mamiya Junction S	25	3	12	🟨 5
6	6	5	Mamiya Junction S	Mt. Asahidake	23	2	12	🟨 4
	6		**Mt. Kurodake**	**Mt. Asahidake**	**96**	**2**	**12**	🟥 6
7	7	1	Kurodake Hut	Ohachaidaira Obeservatory	23	7	13	🟥 11
8	7	2	Ohachaidaira Obeservatory	MP Mt. Hokuchindake	19	3	11	🟥 7
9	7	3	MP Mt. Hokuchindake	Nakadake Junction N	9	2	6	🟩 3
	7		**Kurodake Hut**	**Nakadake Junction N**	**51**	**2**	**6**	🟥 8
10	8	1	Mt. Asahidake	Asahidake Rescue Hut	27	2	5	🟨 4
11	8	2	Asahidake Ropeway	Asahidake Spa	38	2	8	🟨 5
	8		**Mt. Asahidake**	**Asahidake Spa**	**65**	**2**	**8**	🟨 5
12	9		Sugatami (Ropeway - Hut)		19	0	6	🟨 4
13	15		Susoaidaira	Sugatami	31	2	12	🟥 8
14	17	1	Mamiya Junction S	Nakadake Junction N	11	2	12	🟥 6
15	17	2	Nakadake Junction N	Susoaidaira	31	0	12	🟥 9
	17		**Mamiya Junction S**	**Susoaidaira**	**92**	**0**	**12**	🟥 8
16	Tarumae				82	4	11	🟥 7

6 Discussion and conclusion

This analysis focused on the combination of existing data and the collection of data in the field to assess the current ecological sensitivity of selected sites in Iceland and Japan and the state of their hiking trails. The comparison of the ecological sensitivity of the selected protected areas in Iceland and Japan demonstrate that the sites in Hokkaido show a higher sensitivity than the sites in Iceland. This is subject to further analysis. However, in terms of vegetation cover type, Iceland shows higher sensitivity due to the fact that the majority of land is classified as sparsely vegetated (41%). In this case the top soil becomes the more defining factor for sensitivity. Much of the areas analysed in Iceland are classified at a medium sensitivity level. In addition to this, large areas in Iceland are rather flat, which also results in a low value for ecological sensitivity. However, many of the trails are also located in areas close to greater slope angles and thus more sensitive. In Japan the sensitivity due to the top soil is more homogenous. The vegetation cover and slope angle are more diverse and, especially in the area of the hiking trails, the most defining aspect of the ecological sensitivity. The slope angle is of particular importance since the hiking trails are located in the very heterogeneous topography of the mountainous landscape.

Comparing the measurements from Iceland and Japan (see Table 9), we see that the majority of hiking trails in Hokkaido show a much higher impact than the trails in Iceland. The majority of trails in Iceland show a low or medium impact (35%), whereas the dominant situation in Hokkaido is severe impact (63%). The reason for this could be in the fact that NPs in Japan have a more prolonged exposure to high visitor numbers as compared to the NPs in Iceland. With the limitation of this research in mind, it can be assumed that most of the development of hiking trail degradation is a result of an increase in use by hikers. The question remains if the degradation is based solely on man-made use, and if the different management styles of the trail have something to do with the current state of degradation. Another interesting factor to explore would be if the measurement points of the hiking trail and their corresponding degradation classification finds its same sensitivity classification in the ecological sensitivity. The accuracy of the dataset in Iceland and Hokkaido are maybe not high enough to provide the foundation for a solid comparison. But it could be argued that the resolution of the digital database (e.g. DEM model has a grid size of 10m x 10m) might higher than the interval of the measurement points (e.g. distance between measurement points is 100m).

Table 9: Comparison of ecological sensitivity and the state of hiking trails segments within the selected protected areas in Iceland and Hokkaido

Sensitivity class / impact class	Ecological sensitivity		Hiking Trail degradation	
	Iceland	Hokkaido	Iceland	Hokkaido
No sensitivity/ impact (🟩)	1 %	3 %	0 %	0 %
Low sensitivity / impact (🟩)	75 %	14 %	35 %	6 %
Medium sensitivity / impact (🟨)	24 %	67 %	35 %	31 %
High sensitivity / severe impact (🟥)	~ 0 %	16 %	29 %	63 %

The statistics on measurement points of the hiking trails show there are several factors with a strong positive and significant correlation (see Appendix F for Iceland and Appendix F for Hokkaido). In Iceland, the hiking trails show some obvious correlations as the impact zone is correlated with the width of a trail and the severity of erosion is related to the overall depth of the trail and the change in the vegetation cover. The correlation between the slope angle and the depth of trails is significant, however just weak. In Hokkaido, the trails show a similar picture, as the impact zone is positively correlated with the width of the trail and the erosion of a trail is correlated with the depth of the trail. However, the depth of the trail is more correlated with the change of vegetation in Hokkaido than it is in Iceland. Even though the slope angle appeared to be a stronger influencing factor in the ecological sensitivity, there seems to be little to no correlation to other factors, however several are significant. The problem with this analysis can be that the GPS measurement points on the trail and the collected measurement of the ecological sensitivity on that point are dependent on the accuracy of measurements in the field and the accuracy of the digital databases.

Hiking trails can be seen as an indicator for the sensitivity of the land underneath and the consumption of natural environments for recreation. The overall picture of the assessment in Iceland and Japan is that the trails in Hokkaido have been impacted more than in Iceland. It is speculative if the difference in degradation of hiking trails could be accounted to the greater use of trails in Hokkaido than Iceland, since sufficient data about hikers are missing in Iceland. However it stands to reason that a greater use of trails will and can lead to higher degradation on the site.

The use of GIS systems can help combine data from different sources, present the data in a visual form, and support the management of a specific area. However, it is dependent on the quality of its input. The results of such exercises are dependent on the accuracy of collected data and the spatial resolution and quality of digital data. The basis for such an assessment in Iceland is limited as much of the digital data is coarse. The field measurements have not been done in a unified form and on a national scale. This makes it difficult to compare sites in the future. With improved quality of such data it would be possible to make stronger claims about the identification of degradation hot spots and the situation of ecological sensitivity.

In addition to this, the methods used for describing the ecological sensitivity and the state of hiking trails are in flux. Discussions are ongoing dealing with the parameters used to identify the sensitivity of an area. The research by Ólafsdóttir and Runnström (2009; 2013) is one example of the development of the discussion on methodology and classifications. The attempt is to represent and model an area as close as possible to the “reality” in order to draw conclusions about its current state and potential future development. Several of the parameters are easy to use, but some of the proposed parameters demand complicated models to create a data layer that represents the essence of it in the GIS. However, the applicability of such methods for the individuals within the management regime of protected areas is of concern. Therefore, the proposed methods have to combine three aspects: 1) they have to be easy-to-use, 2) need for tools and computing power has to be minimal, yet 3) provide a sensible accuracy and resolution of data. Further improvement of the digital data would improve the quality of the assessment, significantly.

In order to move from ecological sensitivity to environmental sensitivity, it would be of interest to incorporate climate factors into the sensitivity model. Temperature and top soil wetness play an important factor in the sensitivity of an area and of trails. Some parameters can indirectly already represent this (e.g. vegetation cover). To incorporate the parameter for temperature and wetness it would be necessary to either generate models to represent these parameters or to use existing tools in the GIS software. There is already research about the accuracy of these tools to present data otherwise collected through field measurements of surface temperature and wetness (*cf.* Fu & Rich, 2002; Jianchao et al., 2010).

Existing tools (e.g. solar radiance and hydrology), however, rely on the input coming from a DEM model. This in return would lead to an over-representation of one source of data in the final GIS model. Another concern is that no extensive research has been done in Iceland or in Hokkaido analysing the impact of trampling on different plant communities. Little is known to what extent different plant communities respond to continuous or single physical stress by the physical impact by hikers, although there are indications (*cf.* G. Gísladóttir, 2006; Marion & Leung, 2001).

This study presents an example of easy-to-use methods with which the ecological sensitivity and the state of hiking trails can be assessed. The strength of them is that they do not require many resources, yet produce reliable data. Therefore, this report supports the management of protected areas by giving them: a) a dataset on which they can base future trail management decisions, and b) describe the process to re-assess the selected sites and include other sites.

Ólafsdóttir and Runnström (2013) stress the point that the management of protected areas is precariously poised when it comes to their use for recreational purposes. The importance for a successful management of such tourism destinations is dependent on the available data. However the necessary data for such a holistic management process is lacking in Iceland.

The current discussion on hiking trails in Iceland stresses the point that many trails are under high pressure from tourism. Future growth of tourism will presumably worsen the situation, unless counter measurements are taken. These are, nonetheless, dependent on a unified national assessment of trail conditions. This study is one additional voice in the ongoing discussion of the current state and the future development of tourism in Iceland. It sheds light on the methods used to identify sensitive areas for tourism consumption and presents an additional status report on popular hiking trails. It comes as no surprise that many popular sites will face an increase in impact due to tourism despite the efforts to manage trails to reduce erosion. This is especially true in Iceland, as the natural environment in subarctic regions is very sensitive to physical impacts, such as trampling. Even low levels of traffic can already have a significant impact (*cf.* Forbes, Monz, & Tolvanen, 2004), which makes the steady increase in visitors to a site even more concerning.

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APPENDIX

Appendix A

Table 10: Sensitivity categories according to the different data sets in Iceland and Hokkaido (partly shortened list)

Sensitivity category	Soil type	Vegetation cover type	Slope angle
'no sensitivity' (0)	Histosol, Histic Andosol	Glacier, lake and fluvial river system, open water	0° ≤ x ≤ 10°
'low sensitivity' (1)	Hydric Andosol, Brown Andosol and Hydric Andosol, Gravel, Gravel and Sandy soil, Haplic Fluvisols, Gray Lowland soils, Andisols	Wetland, sand, gravel and lava, Miscanthion sinensis, Oxycocco-sphagnetea, Moliniopsietalia japonicae, Phragmitetea, Natural bare land	10° < x ≤ 20°
'medium sensitivity' (2)	Brown Andosol, Cryosol and Hydric Andosol, Leptosol, Sandy soil and Leptosol, Rocks, Podzols, Brown Forest Soil	Heath, grassland and agriculture, Alpine scrub and heath land, wind-exposed grassland, plant communities in clear-cut area, natural grassland, deciduous conifers and broad-leaved plants, Paddy-field weed communities, Urban district, various tree plantations	20° < x ≤ 30°
'high sensitivity' (3)	Sandy soils, Regosols (Tephric)	Moss heath, Snow patch community	30° < x

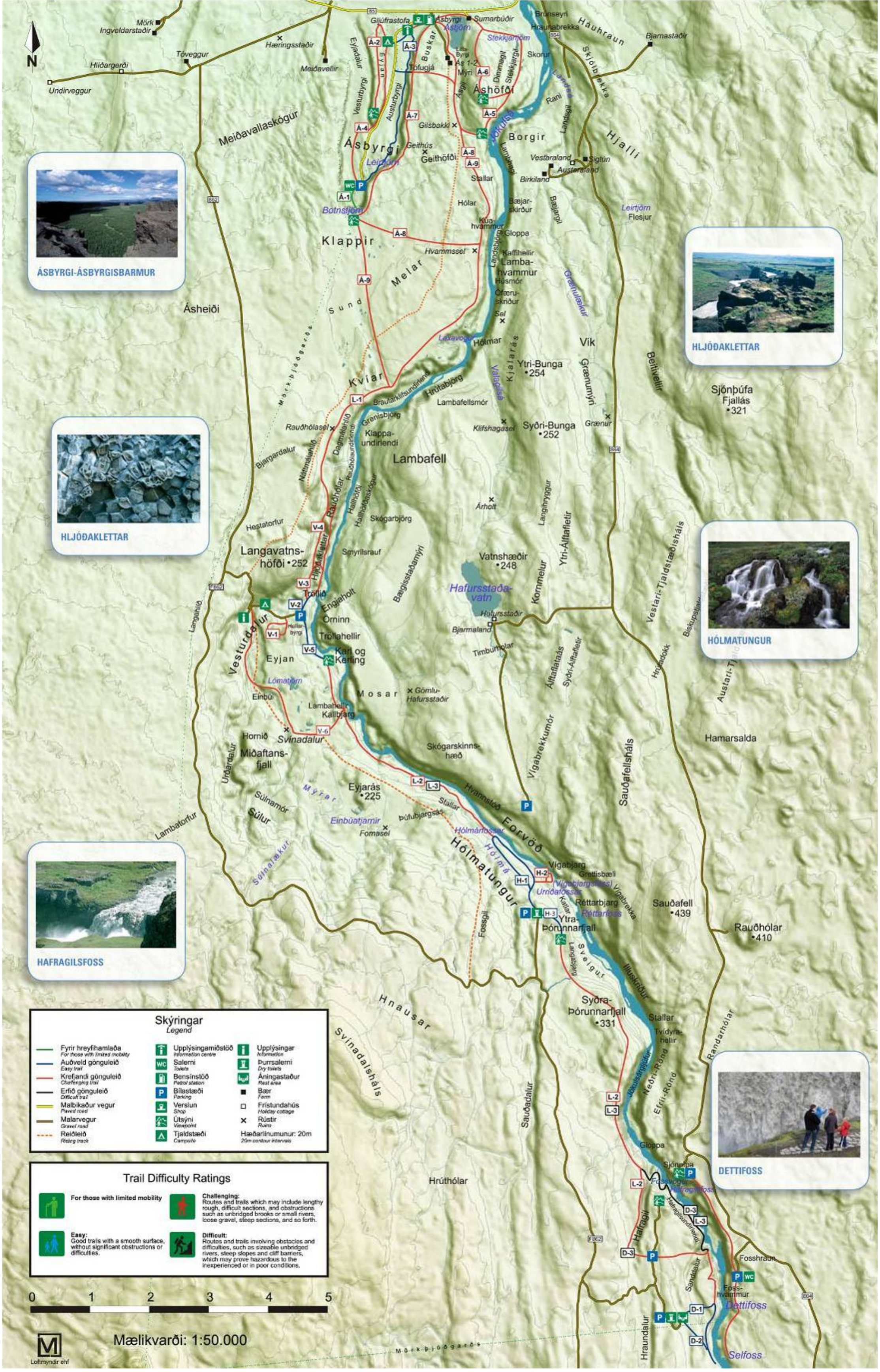
Appendix B

Table 11: Sensitivity categories according to the different data sets in Iceland and Hokkaido

Assessment factors	*Definition of assessment*
1. Width	**0 score**: Trail is hardly seen (unclear) **1 score**: Simple trail/path – total width of effected area 0,50-0,99 m **2 score**: 1,00-2,99 side paths, on both sides of the main trail/path – total width of effected area 1,00-2,99 m **3 score**: Many side paths – total width of effected area ≥ 3,00 m
2. Depth	**0 score**: < 5 cm **1 score**: 5-24 cm **2 score**: 25-44 cm **3 score**: ≥ 45 cm
3. Vegetation cover	**0 score**: Trail is hardly seen (unclear) **1 score**: Depression seen in the vegetation cover **2 score**: Vegetation dead and/or clear vegetation changes **3 score**: Vegetation has disappeared – trail has reached the parent material
4. Soil Erosion	**0 score**: No erosion **1 score**: Breaking starting at the edges **2 score**: Gullies in the edges – vegetation roots striking **3 score**: Transformation of material due to wind and water erosion both in the trail itself and on both sides

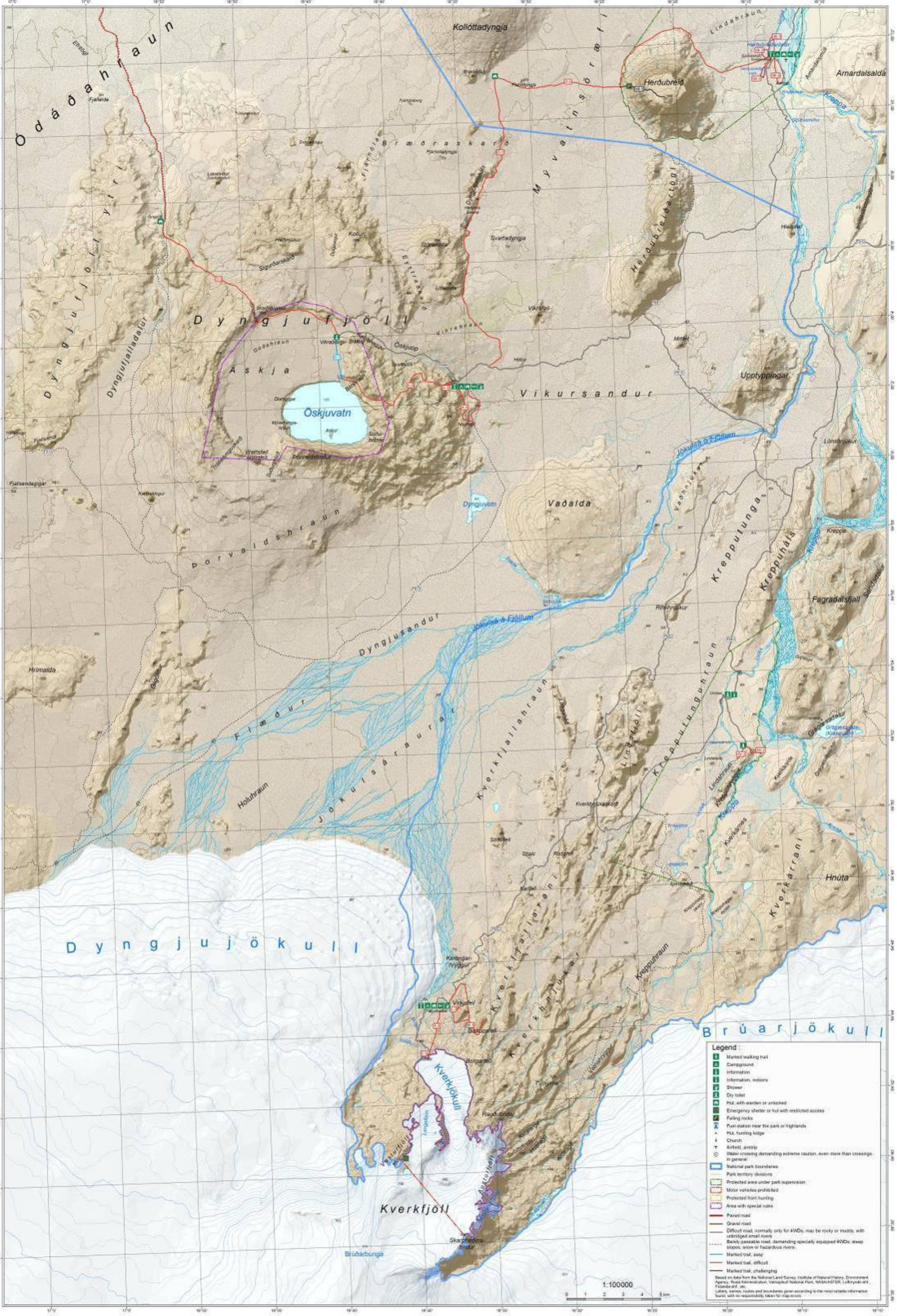
Appendix C

Map of hiking trails at Jökulsárgljúfur, given out by the Vatnajökull National Park



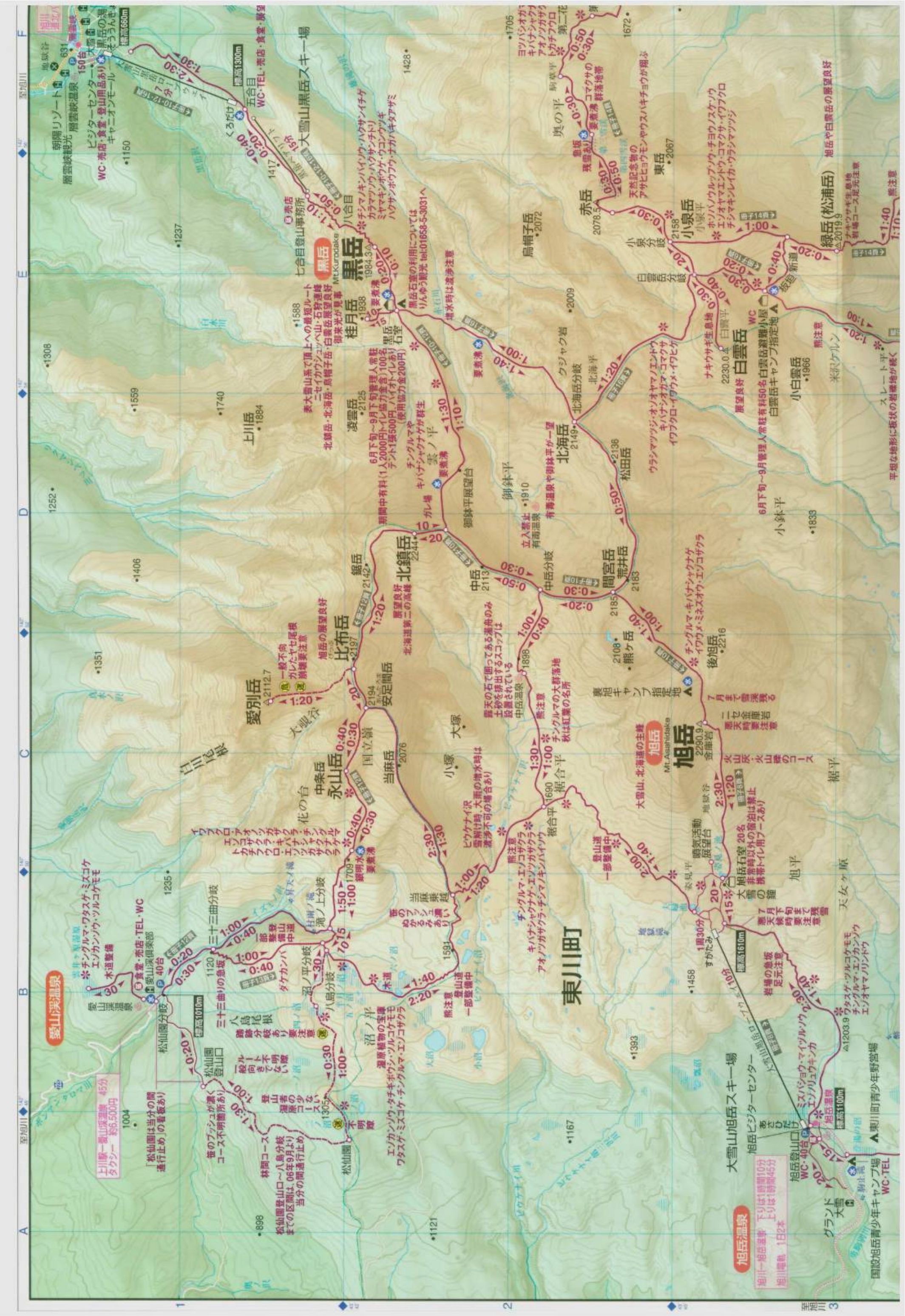
Appendix D

Map of hiking trails at Herðubreiðarlindir to Askja, given out by the Vatnajökull National Park



Appendix E

Map of hiking trails at Daisetsuzan National Park



Appendix F

Iceland
Statistics on parameters for ecological sensitivity and hiking trail degradation:

Descriptive Statistics

	Mean	Std. Deviation	N	
Width	.91	.800	771	Hiking Trail Assessment
Impact zone	1.90	1.070	771	
Depth	.25	.494	771	
Vegetation cover	1.06	1.279	771	
Erosion	.40	.802	771	
Vegetation type	1.25	.589	771	Ecological Sensitivity
Top soil	1.92	.579	771	
Slope angle	.80	.749	771	

Correlations

		Width	Impact Zone	Depth	Veg. cover	Erosion	Veg. type	Top soil	Slope angle
Width	Pearson Corr.		,480**	,170**	,138**	.045	,123**	-,153**	,088*
	Sig. (2-tailed)		.000	.000	.000	.211	.001	.000	.014
	N		771	771	771	771	771	771	771
Impact zone	Pearson Corr.	,480**		-,159**	-,141**	-,261**	-,132**	-,132**	-.012
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.000	.734
	N	771		771	771	771	771	771	771
Depth	Pearson Corr.	,170**	-,159**		,282**	,579**	,177**	-,153**	,136**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000	.000
	N	771	771		771	771	771	771	771
Vegetation cover	Pearson Corr.	,138**	-,141**	,282**		,608**	,295**	,127**	,098**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000	.006
	N	771	771	771		771	771	771	771
Erosion	Pearson Corr.	.045	-,261**	,579**	,608**		,224**	-.010	,091*
	Sig. (2-tailed)	.211	.000	.000	.000		.000	.773	.011
	N	771	771	771	771		771	771	771
Vegetation type	Pearson Corr.	,123**	-,132**	,177**	,295**	,224**		,137**	-.010
	Sig. (2-tailed)	.001	.000	.000	.000	.000		.000	.772
	N	771	771	771	771	771		771	771
Top soil	Pearson Corr.	-,153**	-,132**	-,153**	,127**	-.010	,137**		-,139**
	Sig. (2-tailed)	.000	.000	.000	.000	.773	.000		.000
	N	771	771	771	771	771	771		771
Slope angle	Pearson Corr.	,088*	-.012	,136**	,098**	,091*	-.010	-,139**	
	Sig. (2-tailed)	.014	.734	.000	.006	.011	.772	.000	
	N	771	771	771	771	771	771	771	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix F

Japan
Statistics on parameters for ecological sensitivity and hiking trail degradation:

Descriptive Statistics

	Mean	Std. Deviation	N	
Width	1.74	.726	398	Hiking Trail Assessment
Impact zone	2.24	.584	398	
Depth	.91	.996	398	
Vegetation cover	2.52	.988	398	
Erosion	1.17	1.275	398	
Vegetation type	1.77	.969	398	Ecological Sensitivity
Top soil	2.20	.401	398	
Slope angle	.82	.791	398	

Correlations

		Width	Impact Zone	Depth	Veg. cover	Erosion	Veg. type	Top soil	Slope angle
Width	Pearson Corr.		,479**	-,116*	-,128*	-,172**	,117*	-,163**	-.034
	Sig. (2-tailed)		.000	.021	.011	.001	.019	.001	.500
	N		398	398	398	398	398	398	398
Impact zone	Pearson Corr.	,479**		,137**	.068	.056	,118*	-,134**	.040
	Sig. (2-tailed)	.000		.006	.176	.262	.019	.007	.428
	N	398		398	398	398	398	398	398
Depth	Pearson Corr.	-,116*	,137**		,367**	,714**	,216**	-,183**	-.093
	Sig. (2-tailed)	.021	.006		.000	.000	.000	.000	.062
	N	398	398		398	398	398	398	398
Vegetation cover	Pearson Corr.	-,128*	.068	,367**		,286**	-.037	,200**	-,155**
	Sig. (2-tailed)	.011	.176	.000		.000	.459	.000	.002
	N	398	398	398		398	398	398	398
Erosion	Pearson Corr.	-,172**	.056	,714**	,286**		,223**	-,199**	-,130**
	Sig. (2-tailed)	.001	.262	.000	.000		.000	.000	.009
	N	398	398	398	398		398	398	398
Vegetation type	Pearson Corr.	,117*	,118*	,216**	-.037	,223**		-,606**	-,172**
	Sig. (2-tailed)	.019	.019	.000	.459	.000		.000	.001
	N	398	398	398	398	398		398	398
Top soil	Pearson Corr.	-,163**	-,134**	-,183**	,200**	-,199**	-,606**		,129**
	Sig. (2-tailed)	.001	.007	.000	.000	.000	.000		.010
	N	398	398	398	398	398	398		398
Slope angle	Pearson Corr.	-.034	.040	-.093	-,155**	-,130**	-,172**	,129**	
	Sig. (2-tailed)	.500	.428	.062	.002	.009	.001	.010	
	N	398	398	398	398	398	398	398	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

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