Article

Effects of a Short-Term Trampling Experiment on Alpine Vegetation in the Tatras, Slovakia

Veronika Piscová ¹, Michal Ševčík ², Juraj Hreško ² and František Petrovič ^{2,*}

¹ Institute of Landscape Ecology of Slovak Academy of Sciences, Akademická 2, 949 10 Nitra, Slovakia; veronika.piscova@savba.sk or vpiscova@savba.sk

² Faculty of Natural Sciences, Constantine the Philosopher University in Nitra, Trieda A. Hlinku 1, 949 01 Nitra, Slovakia; msevcik@ukf.sk (M.Š.); jhresko@ukf.sk (J.H.)

* Correspondence: fpetrovic@ukf.sk

Abstract: Over the past decades, outdoor recreation in mountains has become progressively more important and as a result human induced potential damage has increased. Alpine communities are particularly susceptible to human recreational activities, such as tourist trampling. Although there are a number of studies that explicitly assess the effects of trampling on alpine communities, they do not reflect on terrains with a rich topography and the presence of more communities in very small areas. In this study, effects of short-term trampling on some alpine communities in the Tatras, the highest mountains of the Carpathians, were studied experimentally. Vulnerability to disturbance was compared among plant communities in terms of resistance and resilience, which are based on cover measurements. With proximity to trampling intensity, we found a significant decrease in plant cover and abundance of deciduous shrubs, lichens, and mosses. These results demonstrate that human trampling in alpine communities has major negative impacts on lichen and moss abundance and species richness. A short-term trampling experiment required several years of community regeneration. Therefore, management plans should discourage hiking activity off paths and restrict recreational activities.

Keywords: tourist trampling; alpine vegetation; Tatras; resistance of vegetation

Citation: Piscová, V.; Ševčík, M.; Hreško, J.; Petrovič, F. Effects of a Short-Term Trampling Experiment on Alpine Vegetation in the Tatras, Slovakia. *Sustainability* **2021**, *13*, 2750. <https://doi.org/10.3390/su13052750>

Academic Editor: Kyle Maurice Woosnam

Received: 29 January 2021

Accepted: 26 February 2021

Published: 3 March 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

1. Introduction

Alpine ecosystems are generally considered to be sensitive and fragile to disturbance and slow to recover, due to short growing seasons and the harsh climate, in combination with poor soil conditions [1–3]. High-altitude alpine communities provide essential ecosystem functions and services. They are home to highly diverse and endemic flora and fauna that play essential roles in sequestering atmospheric carbon dioxide, facilitating water storage and purification, and provide irreplaceable ecosystem services that sustain human society [4–7].

In recent decades, recreational intensity in protected areas has increased considerably, resulting in growing pressure on wilderness ecosystems [8,9]. Human recreational activities such as walking, hiking, and jogging cause direct mechanical disturbances in natural ecosystems with undesirable effects on vegetation, such as changes in cover, species composition, diversity, plant height and increased risk of invasive species [10–14]. Trampling disturbance alters the morphological and physiological features of individual species by causing direct physical loss or damage to them [15,16] and often leads to changes in vegetation cover and species richness. Its negative impacts might be propagated to higher levels, such as weakening ecosystem stability and functioning due to species loss [17,18]. Even very small numbers of visitors can cause ecological changes [19,20].

Although numerous studies have documented vegetation responses to trampling disturbance, research that thoroughly examines trampling impacts on vegetation at different organizational levels (e.g., species, population, and community levels) is often limited [21].

Most previous studies of human disturbance on vegetation have focused on the impacts on vascular plants [12,14,22–27], while the impacts on plant community composition, bryophytes or lichens are less well documented [13,20,28]. However, bryophytes and lichens at high latitudes play a significant role in terms of species richness [29,30]. Towards higher latitudes, the relative abundance of bryophytes and lichens increases as an indirect effect of the more rapid decline in vascular plant species richness [31,32]. Trampling affects the species' richness and diversity of bryophytes and lichens and their abundance and cover vary [18,28]. Considering the importance of bryophytes and lichens in alpine ecosystems, more studies on the effects of trampling are needed [18].

Previous experimental research has been restricted to forest, scrub, and herbaceous communities [15], coastal plant communities [33], grasslands and heathlands in Norway [34], the UK [35,36], France [37,38] and calcareous grasslands in Poland [39]. Trampling experiments are conducted in temperate grasslands within North America and Europe, and more studies that address the impacts of trampling disturbance on grasslands thriving in different geographic and climatic conditions are needed [27]. Although trampling experiments have examined prolonged trampling and extended recovery [36,40], there are problems with using small experimental plots for such studies.

In Slovakia, we chose research sites within the National Nature Reserve Belianske Tatry and its border with the High Tatras, the most visited part of the Tatras. The High Tatras and Belianske Tatras belong to the Tatra National Park, which was estimated in 1949. Since 1978, the Belianske Tatras have been closed due to excessive visitors and the devastation of the rare natural ecosystems. The mountain massif of the Belianske Tatras is composed of limestones, dolomites, and shales with a clear karst topography, which is fundamentally different from the mostly granite hills of the High Tatras. The Belianske Tatras, as the highest limestone mountains in Slovakia, are characterized by sensitive ecosystems with rare flora and fauna of endemic species and glacial relicts, with a diverse mosaic of unique forms of relief, soil cover and alpine karst. Since 1991, the Belianske Tatras has been under strict protection of the National Nature Reserve Belianske Tatry with the highest degree of protection. The whole area has been closed all year for visitors, since 1993, with the exception of the hiking trail from the valley of Monkova dolina to the saddleback Kopské sedlo (the border).

In this study, we used a simulated trampling experiment according to a standardized experimental protocol developed by [41]. Due to the fact that the alpine relief of high mountains is fragmented and the communities often cover small areas, we have adjusted the layout of treatment lanes, buffers, and measurement of subplots within treatment lanes.

The vulnerability of plant communities subjected to trampling is determined by their ability to resist trampling impact and/or to recover after the cessation of the impact [42,43]. To study recovery processes towards the initial state, we used the approach of experimental trampling over a short period of time with no prolonged disturbance [36,41]. This method allows comparison of the damage to species and communities by specific amounts of trampling [36] as well as the implicit relationship between intensity of use, vegetation deterioration and the vulnerability of plant communities.

The presented study will address the following questions: (1) How do individual species and communities respond to different intensities of trampling and how do changes arise during the following years? (2) Does short-term human trampling cause a long-term negative effect on the species composition of alpine vegetation and the cover of individual species? With increasing intensity of trampling, we found a significant decrease in plant cover and abundance of broadleaf herbs and less resistant graminoids. The increasing intensity of trampling had a significant negative impact on the species richness of mosses and lichens. As well, the abundance of litter, rock and soil increased depending on the intensity of trampling. Our results demonstrate that human trampling in alpine communities has lasting negative impacts mainly on the abundance and species richness of lichens, mosses, and dwarf shrubs.

2. Materials and Methods

2.1. Study Area

This study was conducted in high-altitude alpine communities located within the National Nature Reserve Belianske Tatry (closed to visitors since 1978, with the exception of one hiking trail open to tourists since 1993) and outside on the border with the High Tatras, the most visited part of the Tatras and the highest part of the Carpathians (Figure 1). Trampling experiments were conducted in three alpine plant communities: *Juncetum trifidi* (49°13.751 N; 20°13.179 E), *Junco trifidi*-*Callunetum vulgaris* (49°13.591 N; 20°13.313 E) and *Seslerietum tatrae* (49°23.467 N; 20°21.780 E).

Figure 1. Location of study area in the Tatras used for experimental trampling of vegetation. Abbreviations: (a) *Seslerietum tatrae*, the site Vyšné Kopské sedlo; (b) *Juncetum trifidi*, the site Kopské sedlo; (c) *Junco trifidi*-*Callunetum vulgaris*, the site Predné Kopské sedlo.

- (1) The community *Juncetum trifidi* (Krajina 1933) is not one of the endangered phytocenoses, although it contains endemic taxa (*Campanula tatrae*, *Leucanthemopsis tatrae*, *Soldanella carpatica*). As a pioneering community, it has an important soil protection function. The community is formed by tufted hemicryptophytes (*Juncus trifidus*, *Oreochloa disticha*, *Festuca supina*) and rosette hemicryptophytes (*Hieracium alpinum*, *Campanula alpina*) with non-dominant shrub chamaephytes (*Vaccinium vitis-idaea*, *Vaccinium myrthillus*). The undergrowth consists of scaly and bushy lichens (*Cetraria is-landica*, *Cladonia rangiferina*, *Cladonia gracilis*, *Cladonia arbuscula*, *Cladonia uncialis*) and mosses (*Polytrichum alpinum*, *Polytrichum piliferum*). The bedrock consists of limestone, dolomites, and shales. The community spreads over rankers on the border of the High and Belianske Tatras. An experimental block was established on the NW site with a slope of 22°, at an altitude of 1754 m. In 2008, the average number of people visiting the path in this community was 298 per day.
- (2) The community *Junco trifidi*-*Callunetum vulgaris* (Krajina 1933) Hadač ex Šibík et al. 2007 with a small-scale and rare occurrence in the Western Carpathians is rare, not yet endangered. The community is formed by chamaephytes (*Calluna vulgaris*, *Vaccinium myrthillus*, *Vaccinium vitis-idaea*) and hemicryptophytes (*Juncus trifidus*, *Avenella flexuosa*, *Hieracium alpinum*, *Campanula alpina*). The undergrowth consists

of lichens (*Cetraria islandica*, *Cladonia gracilis*). The bedrock consists of lime-stone, dolomites and shales. The community spreads over rankers on the border of the High and Be-lianske Tatras. An experimental block was established on the NE site with a slope of 4° , at an altitude of 1778 m. In 2008, the average number of people visiting the path in this community was 249 per day.

- (3) The community *Seslerietum tatrae* occurs in a narrow altitude range 1900–2000 m a.s.l. with long-lasting high snow cover. The community is formed by hemicryptophytes (*Sesleria tatrae*, *Carex tatarum*, *Anthoxanthum alpinum*, *Bastrisia alpina*, *Bistorta vivipara*, *Campanula tatrae*, *Helianthemum grandiflorum*, *Homogyne alpina*, *Pedicularis verticillata*, *Potentilla aura*, *Soldanella carpatica*, *Thymus pulcherrimus*). The mosses reach a cover of 30% (*Pleurozium schreberi*). The bedrock consists of limestone, dolomites, and shales. The community spreads over lithosols in the National Nature Reserve Belianske Tatry. An experimental block was established on the SW site with a slope of 39° , at an altitude of 1924 m. In 2008, the average number of people visiting the path in this community was 86 per day.

2.2. Experimental Design

In each plant community one experimental block was established in uniform vegetation, following the standard procedure according to Cole and Bayfield [41]. Figure 2 shows a modified experimental design for small-scale alpine communities. Each block consisted of three trampling plots (0.5 m wide and 0.5 m long), separated by 50 cm wide buffer zones. This width of plots was selected because: (1) It approximates a common width for a footpath, (2) it occupies an intermediate position in the range of widths that have been utilized and (3) it is wide enough to accommodate a quadrant while minimizing edge effects. Each plot should be divided into 25 subplots, and each subplot should be 0.1 m wide and 0.1 m long. Subplots should be selected by a botanical grid. In a larger plant community, replication blocks can be established. The configuration of plots is not fixed; they can be arranged in a line (where slopes occurred, plots were oriented parallel to contours) or placed irregularly if this suits the site. One plot was a control plot and received no pedestrian pressure while the other plots received successive trampling intensities of 150 and 450 passes. Figure 3 shows the direction of trampling, it should simulate the path, so the trampling should be in two directions.

Figure 2. Experimental block.

2.3. Trampling Treatment and Timing

Each plot should be assigned one of the three trampling treatments: Control (no trampling), 150 passes and 450 passes, where each pass represents one footmark. These treatment intensities were selected because the previous studies in alpine areas had found that these levels can cause damage. The number of passes was also affected by the average number of visitors per day. One trampling procedure should occur on the same day for all treatments, 4 times during the vegetation season, in June, July, August and September.

ber. Trampling all at once eliminates confounding situations such as trampling occurring partly on rainy and partly on dry days. Treatments should be iterative during the time of the vegetation season (we recommend doing treatments during the time of year when vegetative cover is at least half the growing season or near the maximum remains). One block for one plant community was trampled on the same day. A standard protocol for trampling experiments is suggested by Cole and Bayfield [41]. Preliminary experimentation using this procedure suggests that there is no substantial difference in the responses caused by walkers of different weight or shoe type. Standardizing weight and shoe type is not critical. Authors Cole and Bayfield [41] recommended using walkers of moderate weight (75 ± 10 kg). We used a walker with a weight of 65 kg. Trampling was executed in both directions.

Figure 3. Experimental trampling in two directions should simulate walking on a nearest path.

Parameters to be measured in each subplot are:

1. visual estimates of the top cover perpendicular to the slope angle of each vascular plant species and of mosses and lichens;
 2. visual estimates of the top cover perpendicular to the slope angle of bare ground;
 3. visual estimates of the top cover perpendicular to the slope angle of litter.
- (1) Visual estimates of the coverage (%) of each vascular plant species and of mosses and lichens. Only green photosynthetic material should be included in cover estimates. It is inappropriate to include the cover of surviving stems that had been defoliated by trampling. Cover values are round integral numbers, and if the cover is less than 1% the value 0.5% or 0% can be used, indicating a complete lack of cover.
 - (2) Visual estimates of the cover (%) of bare ground (ground not covered by live vegetation). Bare ground can be either mineral or soil.
 - (3) Visual estimates of the cover (%) of litter (including the litter of recently trampled plants).

2.4. Data Analysis

Relative Cover

Relative cover can be used to characterize the vulnerability of different vegetation types [41]. Vulnerability is the ability of a vegetation type to resist being altered by trampling, and this is also referred to as resistance. Relative cover is based on the sum of the coverage of all species, rather than a single estimate of the total vegetation of vascular plants, mosses, and lichens. Coverage of individual species changed during short-term trampling under the influence of trampling and seasonality. Relative vegetation cover was calculated as follows:

$$RC = \frac{\text{surviving cover on trampled plots}}{\text{initial cover on trampled plots}} \times cf \times 100 \% \quad (1)$$

where cf is the correction factor:

$$cf = \frac{\text{initial cover on control plots}}{\text{surviving cover on control plots}} \quad (2)$$

Relative cover will be 100% in the absence of any change in cover caused by trampling. Therefore, the extent to which relative cover after trampling deviates from 100% provides a measure of the damage response to trampling.

2.5. Loss of Species

Loss of species after trampling was calculated as:

$$\text{species loss} = \frac{\text{number of species before trampling} \pm \text{after trampling}}{\text{number of species before trampling}} \times 100\% \quad (3)$$

2.6. Statistical Processing

A two-way repeated measure ANOVA was performed to evaluate the effect of different trampling intensities and localities over time on the sum of coverages of all species. Although the coverage value for each species was expressed as a percentage, their sum generally exceeded 100% due to stratifications. Due to this absence of an upper limit, it was not necessary to use logistic regression or arcsin transformation to meet the conditions of normality and sphericity. While trampling intensity and location were used as fixed variables, trampling seasons were used as random effects, to capture variability caused by seasonality. Analysis was executed in R environment [44].

3. Results

3.1. Interaction between Trampling Intensities and Sites

Figure 4 shows that there was a statistically significant interaction between trampling intensities and localities on the sum of the coverages ($F_{1,35, 12.12} = 45.6, p < 0.0001$). Therefore, the effect of the trampling intensities was analyzed at each locality. p -values were adjusted using the Bonferroni multiple testing correction method. The effect of treatment was significant at all three localities (for Ks = $F_{1,09, 9.79} = 48.5, p < 0.0001$; PKs = $F_{1,01, 9.06} = 70.3, p < 0.0001$; VKs = $F_{1,1, 9.9} = 44.2, p < 0.0001$).

3.2. Impacts of Trampling Disturbance On Individual Species

Most alpine plants responded similarly to trampling disturbance, with continuous decrease in plant height and leaf size as trampling intensity increased. Particularly, woody chamaephytes were more resistant to the process of trampling than broadleaf hemicryptophytes.

- (1) The Juncetum trifidi community is dominated by hemicryptophytes (88%) and woody chamaephytes (12%). The most damaged were hemicryptophytes *Bistorta major*, *Hieracium alpinum*, *Campanula alpina*, *Campanula tatrae*, and *Juncus trifidus*. Par-

- ticularly, woody chamaephyt *Vaccinium myrtillus* was more resistant to the process of trampling than broadleaf hemicryptophytes.
- (2) The *Junco trifidi*-*Callunetum vulgaris* community is dominated by hemicryptophytes (86%) and woody chamaephytes (14%). The most damaged species were hemicryptophytes *Pulsatilla scherfelii*, *Bistorta major*, *Campanula alpina*, *Campanula tatrae*, and *Juncus trifidus*. Woody chamaephytes *Calluna vulgaris*, *Vaccinium myrtillus* and *Vaccinium vitis-idaea* were more resistant to the process of trampling than broadleaf hemicryptophytes.
 - (3) The *Seslerietum tatrae* community is dominated by hemicryptophytes (67%), woody and herbaceous chamaephytes (26%), annual terophytes (4%), and geophytes (3%). The most damaged species were hemicryptophytes *Sesleria tatrae*, *Carex sempervirens*, *Luzula alpinopilosa* subsp. *obscura*, *Rhodiola rosea*, and *Phyteuma orbiculare*. In this community, the woody chamaephytes of *Salix reticulata* and *Salix kitaibeliana* were severely damaged during the trampling process.

Figure 4. Differences of sum coverages of all species between different trampling intensities for every locality.

3.3. Impacts of Trampling Disturbance on Vegetation Layers, Litter and Bare Ground

Although the average covers of vegetation layers E1 and E0 decreased immediately after trampling, the average covers of leaf litter and bare ground increased. Figure 5 shows detailed changes in average covers of vegetation layers, litter, and bare ground. In the *Juncetum trifidi* community with almost 90% of hemicryptophytes, the bare ground increased significantly.

3.4. Species Loss

Not all plant species survived experimental trampling. Table 1 shows loss of species on trampled plots during the trampling experiment 2008 until 2014. In August 2008, the *Juncetum trifidi* community lacking the species *Primula minima* was missing on the plot with a lower intensity of trampling. During September 2008–September 2010, the species *Campanula alpina* and lichens *Alectoria ochroleuca* and *Cladonia squamosa* were missing on the plot with a higher intensity of trampling. In the *Junco trifidi*-*Callunetum vulgaris* community, some species became extinct, specifically *Campanula alpina* and lichens *Alectoria ochroleuca* and *Cladonia squamosa*, on both trampled plots. As well, in the *Seslerietum tatrae* community, species *Parnassia palustris*, *Ranunculus pseudomontanus*, *Salix kitaibeliana*, *Salix reticulata* became extinct on the plot with a lower intensity of trampling. Other species, *Carex atrata*, *Leontodon pseudotaraxaci*, *Rhodiola rosea*, *Thymus*

pulcherrimus, became extinct on the plot with a higher intensity of trampling. The moss *Polytrichum alpinum* became extinct on both plots.

Figure 5. Average covers (%) of E1 layer, E0 layer, litter, and bare ground in communities immediately after individual trampling. Abbreviations: Ks—site Kopské sedlo (*Juncetum trifidi*); PKs—site Predné Kopské sedlo (*Junco trifidi*-*Callunetum vulgaris*); VKs—site Vyšné Kopské sedlo (*Seslerietum tatrae*); 150—150 times trampled plot; 450—450 times trampled plot; E1—E1 layer; E0—E0 layer; L—litter; BG—bare ground.

Table 1. Species loss in alpine communities.

Date/Plot	Ks150	Ks450	PKs150	PKs450	VKs150	VKs450
June/July 2008	6.67	0.00	−15.78	−18.12	−13.64	−38.10
June/August 2008	0.00	0.00	−20.89	−33.88	−31.82	−57.14
June/September 2008	6.67	−5.88	−26.89	−41.76	−45.45	−61.90
June 2008/September 2009	6.67	−5.88	−15.44	−35.88	−31.82	−47.62
June 2008/September 2010	6.67	−5.88	−12.33	−31.76	−18.18	−33.33
June 2008/September 2011	6.67	0.00	−6.56	−29.41	−4.55	−23.81
June 2008/September 2012	6.67	0.00	−4.89	−25.41	−4.55	−19.05
June 2008/September 2013	6.67	0.00	−4.00	−26.82	−9.09	−19.05
June 2008/September 2014	6.67	0.00	−3.11	−26.82	−13.64	−19.05

Abbreviations: Ks—site Kopské sedlo (*Juncetum trifidi*); PKs—site Predné Kopské sedlo (*Junco trifidi*-*Callunetum vulgaris*); VKs—site Vyšné Kopské sedlo (*Seslerietum tatrae*); 150—150 times trampled plot; 450—450 times trampled plot.

3.5. Relative Cover of Communities

Relative cover would be 100% in case of the absence of any change in cover caused by trampling. Therefore, the extent to which relative cover after trampling deviates from 100% provides a measure of the damage response to trampling. Relative cover in future years after trampling can be compared with that shortly after trampling to provide a measure of the recovery response. Figure 6 shows the relationship between relative cover and experimental trampling in 2008.

Figure 6. Changes in relative covers of alpine communities in 2008. Abbreviations: Ks—site Kopské sedlo (*Juncetum trifidi*); PKs—site Predné Kopské sedlo (*Junco trifidi-Callunetum vulgaris*); VKs—site Vyšné Kopské sedlo (*Seslerietum tatrae*); 150—150 times trampled plot; 450—450 times trampled plot.

During the experimental trampling in 2008, separate layers of mosses and lichens responded very sensitively to trampling. Table 2 shows the change in their relative covers.

Table 2. Changes in the relative cover (%) of a separate layer of mosses and lichens.

Plot	July 2008		August 2008		September 2008	
	Mosses	Lichens	Mosses	Lichens	Mosses	Lichens
Ks150	61.32	70.57	38.16	65.08	22.47	52.09
Ks450	43.32	59.47	42.06	40.84	31.14	25.26
PKs150	66.6	86.60	55.84	81.09	33.09	78.08
PKs450	56.46	77.59	15.21	66.86	12.28	65.64
VKs150	80.75	96.43	75.69	68.63	60.88	67.9
VKs450	40.65	71.48	34.09	2.91	31.95	0.00

Abbreviations: Ks—site Kopské sedlo (*Juncetum trifidi*); PKs—site Predné Kopské sedlo (*Junco trifidi-Callunetum vulgaris*); VKs—site Vyšné Kopské sedlo (*Seslerietum tatrae*); 150—150 times trampled plot; 450—450 times trampled plot.

In the first year after the trampling experiment, relative cover of the *Juncetum trifidi* community decreased to 14% on the plot with a lower intensity of trampling and 22% on the plot with a higher intensity of trampling (Figure 6). Although the species *Campanula alpina* and *Juncus trifidus* in the community already started the regeneration process during the experiment (Figure 7), in 2014 the community shows only about 50% relative cover on both the plots. Compared to the *Juncetum trifidi* community, the *Junco trifidi-Callunetum vulgaris* community appears to be more resistant to trampling. In 2009, relative cover of the *Junco trifidi-Callunetum vulgaris* community decreased to 50% on the plot with a lower intensity of trampling and 27% on the plot with a higher intensity of trampling. In 2014, the community did not reach the value of the original relative cover, only 57% on the plot with a lower intensity of trampling and 47% on the plot with a higher intensity of trampling. In 2009, relative cover of the *Seslerietum tatrae* community decreased to 45% on the plot with a lower intensity of trampling and 12% on the plot with a higher intensity of trampling. The community already started the regeneration process in 2009, but relative cover of the community shows only 57% on the plot with a lower intensity of trampling and 30% on the plot with a higher intensity of trampling in 2014.

Figure 7. Regeneration of species *Campanula alpina* (details on the top right) and *Juncus trifidus* (details on the bottom right) on the 450 times trampled plot (on the left) in the *Juncetum trifidi* community during the experiment, September 2008.

4. Discussion

Many authors are concerned with the idea of conducting trampling experiments on different types of vegetation. The background to this research is the question of how to reconcile increasing tourism with a sustainable environment [45–52]. Studies are being done all over the world and scientists try to find what influences the response of vegetation to trampling. The responses of vegetation to trampling have been reported to be affected by trampling intensity (number of human trampling passes) [15,21,42,45], frequency (trampling passes per time period [24], distribution (whether trampling passes are dispersed or clumped for a particular trampling frequency [53], season [38], weather [37], habitat [17], species [53], Raunkiaer lifeform (i.e., perennating bud position) and growth-form [22], altitude [54], and soil type [55].

In recent years, trampling experiments in alpine grasslands have been conducted to address the resistance and recovery of alpine vegetation. Potential reasons for the heterogeneity of experimental results in primary studies are variations in trampling intensity, vegetation resistance and recovery time. Such studies complement previous research, and the findings generally suggest that alpine grasslands are relatively more resistant to trampling, but also are slower to recover than their temperate counterparts [9,21]. In a wide variety of vegetation types, studies follow the protocol described by Cole and Bayfield [41] that can generate reliable relative cover data. These data provide estimates of both damage and recovery that can be directly compared with estimates provided by other studies using the same design. This protocol is a pragmatic approach to obtaining standardized information on vegetation responses to trampling. As the authors have written, it will not work well with some vegetation types. One goal of the experimental trampling research is to provide measures of response of vegetation to different levels of trampling. In a wide variety of vegetation types, studies that follow the protocol described by Cole and Bayfield [41] can generate reliable relative cover data. These data provide estimates of both damage and recovery that can be directly compared with the estimates provided by other studies using the same design.

Short-term effects consist of the mechanical deterioration of plant material, whereas long-term effects of trampling include direct as well as indirect effects on the total system of vegetation and soil, e.g., compaction on root functions [11,56]. The results of the short-term trampling of the *Juncetum trifidi* community correspond with the observations in several plant communities in North America and Europe [15,21], where some communities are initially very prone to trampling. As previously described by Marion and Cole [57], and Whinam and Chilcott [23], this is due to the high amount of sensitive herbal species (Σ cover

72–85%). More than 80% of species are hemicryptophytes (*Bistorta major*, *Campanula alpina*, *Campanula tatarica*, *Hieracium alpinum*, *Juncus trifidus*), which appear to be very sensitive and weak to short-term trampling. The woody chamaephyte *Vaccinium myrtillus* occupies only small coverage. In the *Juncus trifidus*-*Calluna vulgaris* community, species of dwarf shrubs (*Vaccinium myrtillus*, *Calluna vulgaris*) increase the resistance, at least to lower intensity of trampling [58,59]. There, *Calluna vulgaris* is a dominant species (cover 50–68%) with very limited recovery abilities because of its woody habit. This confirms earlier conclusions which stated that more resistant species have less recovery abilities [22,60]. In our study, in contrast to the woody chamaephyte *Vaccinium myrtillus*, all individuals of *Calluna vulgaris* (cover 25%) maintain a limited amount of vital plant tissue even after 450 passes. The woody chamaephyte *Vaccinium myrtillus* suffered major damage in the *Juncetum trifidus* community. Some species of dwarf shrubs appear to increase resistance only at a lower intensity of trampling. This response to trampling intensity is confirmed by *Salix silesiaca* (cover 17%) and *Salix reticulata* (cover 10%). Both willows became extinct after the end of the experiment.

Previous studies show that trampling affects the species richness and diversity of bryophytes and lichens and their abundance and cover vary [18,28,54]. Our experiment shows that all mosses (*Polytrichum*, *Pleurozium*) and lichens (*Alectoria*, *Cetraria*, *Cladonia*, *Thamnolia*) responded very sensitively to short-term trampling. Their relative covers decreased in direct proportion to the intensity of the trampling. In the *Juncetum trifidus* and *Juncus trifidus*-*Calluna vulgaris* communities, mosses responded more sensitively to trampling (Table 2), especially the species *Polytrichum alpinum*. On the contrary, lichens (*Cladonia*) are less resistant in the *Seslerietum tatarica* community (Table 2). Bryophytes and lichens at high latitudes play a significant role in terms of species richness [29,30]. Towards higher latitudes, the relative abundance of bryophytes and lichens increases as an indirect effect of the more rapid decline in vascular plant species richness [31,32]; we consider it important to focus separately on mosses and lichens.

Existing studies also suggest that disturbance may have different effects on the species richness of alpine grasslands, where plants are exposed to adverse environments, abiotic stress and disturbance which could reduce species richness [59,61]. Significant effects of pedaling disorders on taxonomic richness were observed in all experimental localities and species richness decreased with increasing intensity of trampling. Our study shows that species loss is related to the life forms of species in the community. The presence of woody chamaephytes is particularly important. We already recorded species losses in the *Juncetum trifidus* community after the last experimental trampling in September 2008 (with the exception of the plot trampled at a lower intensity, where species losses did not occur). The community later achieved the original number of species in the community since 2011. In the *Juncus trifidus*-*Calluna vulgaris* community, species losses were higher. After the first experimental trampling, species losses decreased to 15% and 18% (intensity of trampling was directly proportional to species losses). At the end of the trampling experiment, these losses reached approximately 30% and 40%. However, even years later, the community did not reach the original number of species. In 2014, species losses decreased to 15% and 36% (Table 1). We noticed that all individuals of the woody chamaephyte *Calluna vulgaris* survived the trampling, even if they were damaged. The most significant species losses affected the community *Seslerietum tatarica* with woody chamaephytes *Salix ketelebeana* and *Salix reticulata*. Even after the first experimental trampling, we recorded species losses of 13% and 38%. After completion of the trampling experiment, the losses increased to 45% and 62%. The community did not include the original number of species even in 2014 and species losses remained at 13 and 19%. The species loss on the less trampled area was already 4% in 2011, but by 2014 it rose again to 13% for unknown reasons. However, the woody chamaephytes *Salix silesiaca* and *Salix reticulata* did not survive.

Researchers studying trampling have divided community responses to trampling into various categories and series with the intention of producing indicators or indices

representing the responses of plant communities [9,62]. The most often used indicators of trampling impact are resistance, the capacity of vegetation to withstand the direct effect of trampling [17], and resilience, the capacity of vegetation to recover from trampling [43]. Other works emphasize the repetition of trampling [53] and also the reactions of the microbial community in the soil to modifications of soil chemistry after trampling [63]. We think that a comprehensive approach is needed in this research. Our study demonstrates that occasional trampling severely disturbs alpine plant communities. This problem has been confirmed by several studies [45,64,65]. Some studies point out that trampling also causes degradation of sidewalks [66] and transformation of slopes within a hiking trail [67]. Other studies emphasize the effects of trampling by tourists and pack animals used for tourism in mountain protected areas [68–71]. For conservation managers and practitioners, the relevance of trampling studies depends on the nature of the managed site, the plant communities contained within, and the type of access in use [39,62]. Some localities may be essentially open access, whilst others may guide or restrict users to paths or delimited areas [9,72]. The attitudes of visitors towards the mountain protected areas also prove to be important [73]. All these experimental studies have meaning and conceptually direct references to management practice.

5. Conclusions

The current study deals with the questions “How do individual species and communities respond to different intensities of trampling and how do changes arise during the following years?” and “Does short-term human trampling cause a long-term negative effect on the species’ composition of alpine vegetation and the cover of individual species?” We tried to find the answer by the experimental trampling of three alpine communities: *Juncetum trifidi*, *Junco trifidi*-*Callunetum vulgaris*, and *Seslerietum tatrae* using a standard short-term vegetation tracing protocol from Cole and Bayfiel [41]. However, we adjusted the design of trampled blocks and also changed the number of trampled areas according to the number of visitors to the site. Our study confirms earlier conclusions which stated that the more resistant woody chamaephytes have less recovery abilities because of their woody habitat. The statement that some communities are initially very prone to trampling due to the high amount sensitive herbal, was also confirmed. The presented work can be of great importance for conservation managers.

Author Contributions: All authors contributed meaningfully to this study. V.P.—research topic; V.P., M.Š., J.H.—methodology, data acquisition and analysis; F.P.—methodology support; writing—original draft preparation V.P.; writing—review and editing M.Š., J.H., F.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences, grant number VEGA 2/0018/19 Ecological Analyses of Landscape Acculturation in Slovakia since Early Prehistory until Today.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: We would like to thank Róbert Kanka and Ján Krajčí (Institute of Landscape Ecology, Slovak Academy of Sciences) and Eva Makovníková (Faculty of Natural Sciences, Comenius University in Bratislava) for their help during field studies).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Körner, C. *Alpine Plant Life: Functional Plant Ecology of High Mountain Ecosystems*, 1st ed.; Springer: Berlin, Germany, 2003; p. 343.
2. Körner, C.; Spehn, E.M. *Mountain Biodiversity: A Global Assessment*, 1st ed.; Routledge: London, UK, 2002; p. 350.

3. Willard, B.E.; Cooper, D.J.; Forbes, B.C. Natural Regeneration of Alpine Tundra Vegetation after Human Trampling: A 42-year Data Set from Rocky Mountain National Park, Colorado, U.S.A. *Arct. Antarct. Alp. Res.* **2007**, *39*, 177–183. [\[CrossRef\]](#)
4. Ram, J.; Singh, J.S.; Singh, S.P. Plant Biomass, Species Diversity and Net Primary Production in a Central Himalayan High Altitude Grassland. *J. Ecol.* **1989**, *77*, 456. [\[CrossRef\]](#)
5. Dhar, U. Conservation implications of plant endemism in high altitude Himalaya. *Curr. Sci.* **2002**, *82*, 141–148.
6. Price, M.F. *Conservation and Sustainable Development in Mountain Areas*; IUCN: Gland, Switzerland, 2004.
7. Wang, X.X.; Dong, S.K.; Yang, B.; Li, Y.Y.; Su, X.K. A comparison of biodiversityecosystem function relationships in alpine grasslands across a degradation gradient on the Qinghai-Tibetan Plateau. *Rangel. Ecol. Manag.* **2014**, *37*, 45–55.
8. Buckley, R. Tourism in the Most Fragile Environments. *Tour. Recreat. Res.* **2000**, *25*, 31–40. [\[CrossRef\]](#)
9. Roovers, P.; Verheyen, K.; Hermy, M.; Gulinck, H. Experimental trampling and vegetation recovery in some forest and heathland communities. *Appl. Veg. Sci.* **2004**, *7*, 111–118. [\[CrossRef\]](#)
10. Scott, J.J.; Kirkpatrick, J.B. Effects of human trampling on the sub-Antarctic vegetation of Macquarie Island. *Polar Rec.* **1994**, *30*, 207–220. [\[CrossRef\]](#)
11. Cole, D.N. Impacts of hiking and camping on soils and vegetation: A review. In *Environmental Impact of Ecotourism*, 1st ed.; Buckley, R., Ed.; CABI Publishing: Oxfordshire, UK, 2004; pp. 41–60.
12. Pickering, C.M.; Growcock, A.J. Impacts of experimental trampling on tall alpine herbfields and subalpine grasslands in the Australian Alps. *J. Environ. Manag.* **2009**, *91*, 532–540. [\[CrossRef\]](#)
13. Crisfield, V.E.; Macdonald, S.E.; Gould, A.J. Effects of Recreational Traffic on Alpine Plant Communities in the Northern Canadian Rockies. *Arct. Antarct. Alp. Res.* **2012**, *44*, 277–287. [\[CrossRef\]](#)
14. Barros, A.; Gonnet, J.; Pickering, C. Impacts of informal trails on vegetation and soils in the highest protected area in the Southern Hemisphere. *J. Environ. Manag.* **2013**, *127*, 50–60. [\[CrossRef\]](#)
15. Cole, D.N. Experimental Trampling of Vegetation. I. Relationship Between Trampling Intensity and Vegetation Response. *J. Appl. Ecol.* **1995**, *32*, 203. [\[CrossRef\]](#)
16. Xu, L.; Freitas, S.M.A.; Yu, F.-H.; Dong, M.; Anten, N.P.R.; Werger, M.J.A. Effects of Trampling on Morphological and Mechanical Traits of Dryland Shrub Species Do Not Depend on Water Availability. *PLoS ONE* **2013**, *8*, e53021. [\[CrossRef\]](#) [\[PubMed\]](#)
17. Liddle, M. A selective review of the ecological effects of human trampling on natural ecosystems. *Biol. Conserv.* **1975**, *7*, 17–36. [\[CrossRef\]](#)
18. Jägerbrand, A.K.; Alatalo, J.M. Effects of human trampling on abundance and diversity of vascular plants, bryophytes and lichens in alpine heath vegetation, Northern Sweden. *SpringerPlus* **2015**, *4*, 95. [\[CrossRef\]](#)
19. Forbes, B.C.; Monz, C.; Tolvanen, A. Tourism ecological impacts in terrestrial polar ecosystems. In *Environmental Impact of Ecotourism*, 1st ed.; Buckley, R., Ed.; CABI Publishing: Oxfordshire, UK, 2004; pp. 155–170.
20. Perterra, L.R.; Lara, F.; Tejedro, P.; Quesada, A.; Benayas, J. Rapid denudation processes in cryptogamic communities from Maritime Antarctica subjected to human trampling. *Antarct. Sci.* **2013**, *25*, 318–328. [\[CrossRef\]](#)
21. Li, W.; He, S.; Cheng, X.; Zhang, G. Short-term effects of experimental trampling on alpine grasslands in Shangri-la, China. *Glob. Ecol. Conserv.* **2020**, *23*, e01161. [\[CrossRef\]](#)
22. Cole, D.N. Experimental Trampling of Vegetation. II. Predictors of Resistance and Resilience. *J. Appl. Ecol.* **1995**, *32*, 215. [\[CrossRef\]](#)
23. Whinam, J.; Chilcott, N. Impacts of trampling on alpine environments in central Tasmania. *J. Environ. Manag.* **1999**, *57*, 205–220. [\[CrossRef\]](#)
24. Cole, D.N.; Monz, C.A. Trampling Disturbance of High-Elevation Vegetation, Wind River Mountains, Wyoming, U.S.A. *Arct. Antarct. Alp. Res.* **2002**, *34*, 365. [\[CrossRef\]](#)
25. Whinam, J.; Chilcott, N.M. Impacts after four years of experimental trampling on alpine/sub-alpine environments in western Tasmania. *J. Environ. Manag.* **2003**, *67*, 339–351. [\[CrossRef\]](#)
26. Bernhardt-Römermann, M.; Gray, A.; Vanbergen, A.J.; Bergès, L.; Böhner, A.; Brooker, R.W.; De Bruyn, L.; De Cinti, B.; Dirnböck, T.; Grandin, U.; et al. Functional traits and local environment predict vegetation responses to disturbance: A pan-European multi-site experiment. *J. Ecol.* **2011**, *99*, 777–787. [\[CrossRef\]](#)
27. Pescott, O.L.; Stewart, G.B. Assessing the impact of human trampling on vegetation: A systematic review and meta-analysis of experimental evidence. *PeerJ* **2014**, *2*, e360. [\[CrossRef\]](#)
28. Gremmen, N.J.M.; Smith, V.R.; Van Tongeren, O.F.R. Impact of Trampling on the Vegetation of Subantarctic Marion Island. *Arct. Antarct. Alp. Res.* **2003**, *35*, 442–446. [\[CrossRef\]](#)
29. Longton, R.E. Bryophyte vegetation in polar regions. In *Bryophyte Ecology*, 1st ed.; Smith, A.J.E., Ed.; Springer: Amsterdam, The Netherlands, 1982; pp. 123–165.
30. Matveyeva, N.; Chernov, Y. Biodiversity of terrestrial ecosystems. In *The Arctic: Environment, People, Policy*; Nuttall, M., Callaghan, T.V., Eds.; Harwood Academic Publishers: Groningen, The Netherlands, 2000; pp. 233–273.
31. Vitt, D.H.; Pakarinen, P. The bryophyte vegetation production and organic components of Truelove Lowland. In *Truelove Lowland, Canada: A High Arctic Ecosystem*; Bliss LC: Edmonton, AB, Canada, 1977; pp. 225–244.
32. Wielgolaski, F.E.; Bliss, L.C.; Svoboda, J.; Doyle, G. Primary production of tundra. In *Tundra Ecosystems: A Comparative Analysis*, 1st ed.; Heal, O.W., Moore, J.J., Eds.; Bliss LC: Cambridge, UK, 1981; pp. 187–226.
33. Andersen, U.V. Resistance of Danish coastal vegetation types to human trampling. *Biol. Conserv.* **1995**, *71*, 223–230. [\[CrossRef\]](#)

34. Arnesen, T. Vegetation dynamics following trampling in grassland and heathland in Sølendet Nature Reserve, a boreal upland area in Central Norway. *Nord. J. Bot.* **1999**, *19*, 47–69. [\[CrossRef\]](#)
35. Liddle, M.J.; Greig-Smith, P. A survey of tracks and paths in a sand dune ecosystem II. Vegetation. *J. Appl. Ecol.* **1975**, *12*, 909–930. [\[CrossRef\]](#)
36. Bayfield, N.G. Recovery of four montane heath communities on Cairngorm, Scotland, from disturbance by trampling. *Biol. Conserv.* **1979**, *15*, 165–179. [\[CrossRef\]](#)
37. Gallet, S.; Roze, F. Resistance of Atlantic Heathlands to trampling in Brittany (France): Influence of vegetation type, season and weather conditions. *Biol. Conserv.* **2001**, *97*, 189–198. [\[CrossRef\]](#)
38. Gallet, S.; Rozé, F. Long-term effects of trampling on Atlantic Heathland in Brittany (France): Resilience and tolerance in relation to season and meteorological conditions. *Biol. Conserv.* **2002**, *103*, 267–275. [\[CrossRef\]](#)
39. Kostrakiewicz-Gierałt, K.; Pliszko, A.; Gmyrek-Gołab, K. The Effect of Visitors on the Properties of Vegetation of Calcareous Grasslands in the Context of Width and Distances from Tourist Trails. *Sustainability* **2020**, *12*, 454. [\[CrossRef\]](#)
40. Cole, D.N. Effects of three seasons of experimental trampling on five montane forest communities and a grassland in Western Montana, USA. *Biol. Conserv.* **1987**, *40*, 219–244. [\[CrossRef\]](#)
41. Cole, D.N.; Bayfield, N.G. Recreational trampling of vegetation: Standard experimental procedures. *Biol. Conserv.* **1993**, *63*, 209–215. [\[CrossRef\]](#)
42. Kelly, J.R.; Harwell, M.A. Indicators of ecosystem recovery. *Environ. Manag.* **1990**, *14*, 527–545. [\[CrossRef\]](#)
43. Kuss, F.R.; Hall, C.N. Ground flora trampling studies: Five years after closure. *Environ. Manag.* **1991**, *15*, 715–727. [\[CrossRef\]](#)
44. R Core Team. *R: A Language and Environment for Statistical Computing*; R Foundation for Statistical Computing: Vienna, Austria, 2020. Available online: <https://www.R-project.org/> (accessed on 21 January 2021).
45. Apollo, M.; Andreychouk, V. Trampling Intensity and Vegetation Response and Recovery according to Altitude: An Experimental Study from the Himalayan Miyar Valley. *Resources* **2020**, *9*, 98. [\[CrossRef\]](#)
46. Bates, G.H. The Vegetation of Footpaths, Sidewalks, Cart-Tracks and Gateways. *J. Ecol.* **1935**, *23*, 470. [\[CrossRef\]](#)
47. Speight, M.C. *Outdoor Recreation and Its Ecological Effects: A Bibliography and Review*; University College: London, UK, 1973; Volume 4.
48. Dale, D.; Weaver, T. Trampling Effects on Vegetation of the Trail Corridors of North Rocky Mountain Forests. *J. Appl. Ecol.* **1974**, *11*, 767. [\[CrossRef\]](#)
49. Nepal, S.K. Tourism in protected areas: The Nepalese Himalaya. *Ann. Tour. Res.* **2000**, *27*, 661–681. [\[CrossRef\]](#)
50. Marek, A.; Wieczorek, M. Tourist Traffic in the Aconcagua Massif Area. *Quaest. Geogr.* **2015**, *34*, 65–76. [\[CrossRef\]](#)
51. Barros, A.; Monz, C.; Pickering, C. Is tourism damaging ecosystems in the Andes? Current knowledge and an agenda for future research. *Ambio* **2014**, *44*, 82–98. [\[CrossRef\]](#)
52. Hertlová, B.; Popelka, O.; Zeidler, M.; Banaš, M. Alpine plant communities responses to simulated mechanical disturbances of tourism, case study from the High Sudetes Mts. *J. Landsc. Manag.* **2016**, *7*, 16–21.
53. Lemaufiel, S.; Gallet, S.; Roze, F. Responses of three heathland shrubs to single or repeated experimental trampling. *Environ. Manag.* **2004**, *33*, 821–829. [\[CrossRef\]](#)
54. Grabherr, G. The impact of trampling by tourists on a high altitudinal grassland in the Tyrolean Alps, Austria. *Vegetatio* **1982**, *48*, 209–217.
55. Talbot, L.M.; Turton, S.M.; Graham, A.W. Trampling resistance of tropical rainforest soils and vegetation in the wet tropics of north east Australia. *J. Environ. Manag.* **2003**, *69*, 63–69. [\[CrossRef\]](#)
56. Zachar, D. *Soil Erosion*; Elsevier: New York, NY, USA, 2011.
57. Marion, J.L.; Cole, D.N. Spatial and Temporal Variation in Soil and Vegetation Impacts on Campsites. *Ecol. Appl.* **1996**, *6*, 520–530. [\[CrossRef\]](#)
58. Cole, D.; Spildie, D. Hiker, horse and llama trampling effects on native vegetation in Montana, USA. *J. Environ. Manag.* **1998**, *53*, 61–71. [\[CrossRef\]](#)
59. Monz, C.A. The response of two arctic tundra plant communities to human trampling disturbance. *J. Environ. Manag.* **2002**, *64*, 207–217. [\[CrossRef\]](#)
60. Sun, D.; Liddle, M. Field occurrence, recovery, and simulated trampling resistance and recovery of two grasses. *Biol. Conserv.* **1991**, *57*, 187–203. [\[CrossRef\]](#)
61. Chardon, N.I.; Wipf, S.; Rixen, C.; Beilstein, A.; Doak, D.F. Local trampling disturbance effects on alpine plant populations and communities: Negative implications for climate change vulnerability. *Ecol. Evol.* **2018**, *8*, 7921–7935. [\[CrossRef\]](#)
62. Leug, Y.; Marion, J.L. Recreation Impacts and Management in Wilderness: A State-of-Knowledge Review. In Proceedings of the Wilderness Science in a Time of Change Conference, Missoula, MT, USA, 23–27 May 1999; Volume 15.
63. Li, Z.; Siemann, E.; Deng, B.; Wang, S.; Gao, Y.; Liu, X.; Zhang, X.; Guo, X.; Zhang, L. Soil microbial community responses to soil chemistry modifications in alpine meadows following human trampling. *Catena* **2020**, *194*, 104717. [\[CrossRef\]](#)
64. Cole, D.N. Minimizing conflict between recreation and nature conservation. In *Ecology of Greenways: Design and Function of Linear Conservation Areas*; Smith, D.S., Hellmund, P.C., Eds.; University of Minnesota Press: Minneapolis, MN, USA, 1993; pp. 105–122.
65. Klug, B.; Scharfetter-Lehr, G.; Scharfetter, E. Effects of trampling on vegetation above the timberline in the eastern Alps, Austria. *Arct. Antarct. Alp. Res.* **2002**, *34*, 377–388. [\[CrossRef\]](#)

-
66. Marion, J.L.; Olive, N. Assessing and Understanding Trail Degradation: Results from Big South Fork National River and Recreational Area. US Geological Survey. 2006. Available online: www.pwrc.usgs.gov (accessed on 10 April 2020).
 67. Fidelus, J. Slope transformations within tourist footpaths in the northern and southern parts of the Western Tatra Mountains (Poland, Slovakia). *Z. Geomorphol.* **2016**, *60*, 139–162. [[CrossRef](#)]
 68. Barros, A.; Pickering, C.M. Impacts of experimental trampling by hikers and pack animals on a high-altitude alpine sedge meadow in the Andes. *Plant Ecol. Divers.* **2014**, *8*, 265–276. [[CrossRef](#)]
 69. Barros, A.; Pickering, C.M.; Renison, D. Short-Term Effects of Pack Animal Grazing Exclusion from Andean Alpine Meadows. *Arct. Antarct. Alp. Res.* **2014**, *46*, 333–343. [[CrossRef](#)]
 70. Badía, D.; Martí, C.; Sánchez, J.R.; Fillat, F.; Aguirre, J.; Gomez, D.; Badía-Villas, D. Influence of livestock soil eutrophication on floral composition in the Pyrenees mountains. *J. Mt. Sci.* **2008**, *5*, 63–72. [[CrossRef](#)]
 71. Hiltbrunner, D.; Schulze, S.; Hagedorn, F.; Schmidt, M.W.; Zimmermann, S. Cattle trampling alters soil properties and changes soil microbial communities in a Swiss sub-alpine pasture. *Geoderma* **2012**, *170*, 369–377. [[CrossRef](#)]
 72. Tomczyk, A.M.; Ewertowski, M. Planning of recreational trails in protected areas: Application of regression tree analysis and geographic information systems. *Appl. Geogr.* **2013**, *40*, 129–139. [[CrossRef](#)]
 73. Arnberger, A.; Eder, R.; Alex, B.; Sterl, P.; Burns, R.C. Relationships between national-park affinity and attitudes towards protected area management of visitors to the Gesäuse National Park, Austria. *For. Policy Econ.* **2012**, *19*, 48–55. [[CrossRef](#)]