RELATIONSHIPS BETWEEN SOIL SEED BANK AND VEGETATION DIVERSITY ON DIFFERENT GRAZING PRESSURE

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ABSTRACT

In a case study, the main objective was to compare three sites with different grazing pressures in Hvitarsida, W-Iceland in relation to current vegetation, seed bank composition and the correlation between those. Our results show that there were significant difference in species composition in above and belowground, giving very little similarity in species composition between seed bank and current vegetation composition. The only exceptions were Agrostis capillaris and Bistorta vivipara that had close similarity between current aboveground vegetation and soil seed bank. Agrostis capillaris had a great abundance in all the sites and Bistorta vivipara proliferates mostly with bulbils that most likely were numerous in the soil. The results of our study agree with current theories on seed bank composition and similar studies, that the similarity between current aboveground vegetation and soil seed bank depends on current dominant species (annual or perennial) and the productivity (high or low) of the site.

KEY WORDS: Species composition, grazing pressure, correlation

INTRODUCTION

In recent years, many researchers have stated the importance of above and belowground interactions to better understand succession in plant communities and state and transition dynamics in rangelands. Studies indicate that improved knowledge the soil´s seed bank is a key element in understanding above and belowground interactions and plant community dynamics in grazed rangelands. Especially grazing processes affect the legacy of plant roots in the soil, due to the poor dispersal capacity and long survival of many soil organisms (Kalamees et al. 2012).

Study area

The study was conducted at Hvitarsida, W-Iceland, on a hillside along the glacier river Hvita (64°42'.N, 02°106 – 02°115'W). An average temperature of 3.9°C, and mean annual precipitation is 996.6 mm. The site is divided up into sections by fairly deep canyons running up and down the hillside formed by melting water from the edge of the contracting glacier during last Ice age (Anna Gudrun Thorhallsdottir, pers. communication 28.08.2012).

Vegetation analysis

In all the three sites, A, B and C, one transect were lied out from randomly selected GPS point at the same height in the hillside of 25th of July 2012. On each transect, floristic compositions within 10 50x50 cm frames divided into 5 x 5 cm small frames were recorded – total of 3 transects with 30 frames. Within each 5 x 5 cm frame, plant species were identified to be either present or not present, giving a possible total of 100 if a species was present in all small frames. Individual plants were counted to determine the diversity of each species.

Soil seed bank

Soil seed bank sampling was performed of same day, just prior to natural germination of seeds. Thirty soil cores (5cm diameter x 5 cm depth) were sampled and placed in a soil bag. The soil cores were kept refrigerated until transported to Gunnarsholt and put on trays on 29th of July 2012. Seed banks were determined using the germination method (Warr et al. 1993), the soil from each core was spread thinly on a tray covered with a thin layer of sterile organic peat. All trays were randomly arranged in the outside and allowed to germinate under natural conditions. Also all trays were kept moist once or twice daily to keep the surface moist by hand for 6 weeks outside in a sheltered place. After 6 weeks, emerged seedlings were analyzed i.e. Species composition determined and counted.

Statistical analysis

We applied analysis of variance ANOVAs, with abundance of plants as the variable to study the effect of different grazing pressure on the correlation in species composition between aboveground vegetation and soil seed bank. Difference between sites in the mean number of germinated seedlings in the soil seed bank were analysed using two-way ANOVA by SAS.

RESULTS

Species composition in aboveground vegetation and soil seed bank

In the vegetation survey, a total of 39 species were recorded on site A (non grazing pressure-Hvammur), 41 species on site B (light grazing pressure- Samsstadir) and on site C (heavy grazing pressure-Haafell), 38 species were recorded. Whereas the total of 24, 21 and 23 species, respectively, emerged in the soil seed bank (Fig. 1).

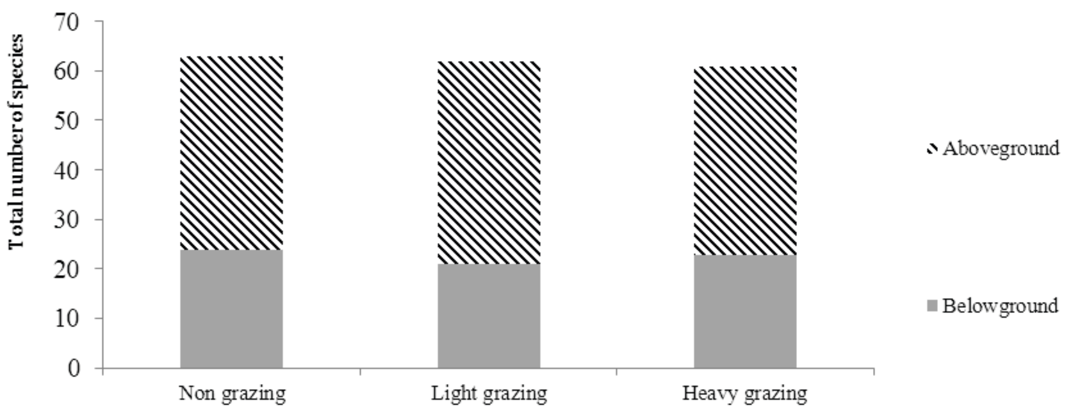

Fig. 1. The total number of species in aboveground vegetation and soil seed bank in different grazing pressure.

Perennial forbs (25 species) and perennial grasses (10 species) dominated in site A, along with three sedge species and 1 small shrub, Salix herbacea. In site B, perennial forbs (25 species) and perennial grasses (12 species) dominated and 4 sedge species occured. Site C was dominated by perennial forbs (25 species), perennial grasses (11 species) and 2 sedge species occured (Fig. 2). There was only found one significant difference in species composition aboveground between the sites; Galium normanii, a small forb, was found in significant ($p = 0.002$) more abundance in the heavy grazed site (C) than in the other two sites (Table 1).

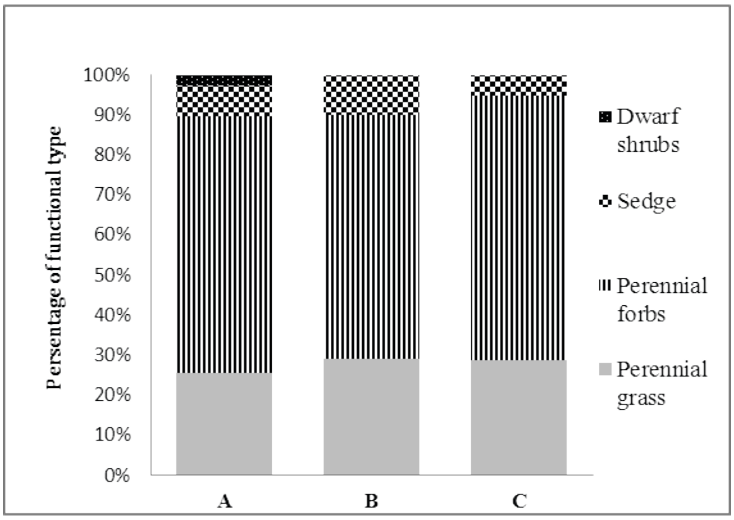

Fig. 2. Relative species abundance of four plant functional types in aboveground vegetation in non grazing (A), light grazing (B) and heavy grazing (C) sites. PG:perennial grasses, PF: perennial forbs, SD: sedge, S: small shrub.

Table 1

The abundance of the selected speciec in different grazing pressure. Within the rows not sharing a same litters differ significantly at $p \leq 0.05$.

	Non grazing	***Light grazing***	***Heavy grazing***
Agrostis venialis	*1.2 ± 0.7a*	*21.8 ± 9.2a*	*16.9 ± 5.0a*
Galium normanii	*2.3 ± 0.8a*	*2.2 ± 1.8b*	*12.2 ± 3.2c*
Vaccinium uliginosum	*4.7 ± 2.0a*	*17.6 ± 8.6a*	*0.7 ± 0.5a*
Kobresia myosuroides	*10.8 ± 2.6a*	*9.7 ± 3.7a*	*22.1 ± 5.3a*

There were, however, found several trends in species abundance between the sites. The abundance of Kobresia myosuroides was found twice as much in the heavy grazing site (C) than in the light and non-grazing sites ($p = 0.07$). The abundance of *Deschampsia caespitosia* was highest in light grazing and *Kobresia myosuroides* in the heavy grazing site compare non grazing site. This trend was the opposite for *Agrostis capillaris, Festuca rubra* and the small forb *Thalictrum alpinum* that all had the most abundance in the non- grazing site and lowest abundance in the high grazing pressure sitse. It is also noticable that Vaccinium uliginosum, a dwarf shrub, is measured with a very low abundance in the heavy grazing site, were the goats graze. All these were, however, non significant differences.

Emerging seedlings from soil seed bank.

Detailed data of the germination test are given in Table D in appendix. A total of 192 seedlings grew from the 30 seed bank samples. Thirty one species were recorded in the all trays. The largest seed bank (number of germinations) was found in the non grazing pressure, and the lowest in the heavy grazing site (Fig. 3). The number of species were the highest in soil seed bank samples from the non grazing sites (24), intermediate in the light grazing (21), and the lowest in soils from heavy grazing pressure (23).

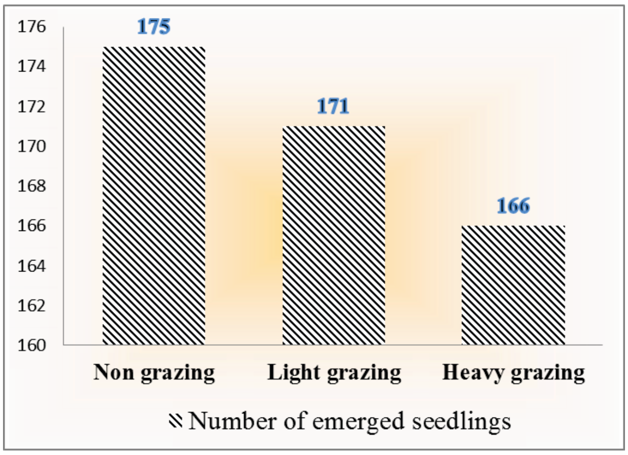

Fig. 3. Total number of emerging seedlings in samples from sites with different grazing pressure.

Perennial forbs (9 species) and perennial grasses (9 species) emerged from the samples from site A, along with 4 sedge species and 2 annual forb species . From the light grazing site B, perennial forbs (9 species), perennial grasses (9 species), 2 annual forbs and one sedge species emerged. From the heavy grazing pressure site C, perennial forbs (11 species), perennial grasses (8 species), two sedge species one annual forb and one low shrub, Betula nana, were counted (Fig. 4). Perennial forb and perennial grass dominanted the seed bank from all three sites, whereas the same annual forb occured from the all sites, which was Poa annua and Stellaria media. There were also site-specific differences. The dominated species in the soil seed bank of the non grazing site were *Agrostis capillaris, Carex capillaris, Poa pratensis* and *Thymus arcticus*, accounting for 51% of the total seedlings for the site, while in the light grazing site most abundance species were *Agrostis capillaris,Poa pratensis, Deschampsia caespitosa* and *Rumex acetosa*, accounting for 60%, respectively, *Agrostis capillaris, Agrostis vinealis* and *Gallium normanii* were emerged, accounting 64% in the heavy grazing site (Table 2). Major high dominant emerged species were *Agrostis capillaris* in most trays in all sites (Table 2).

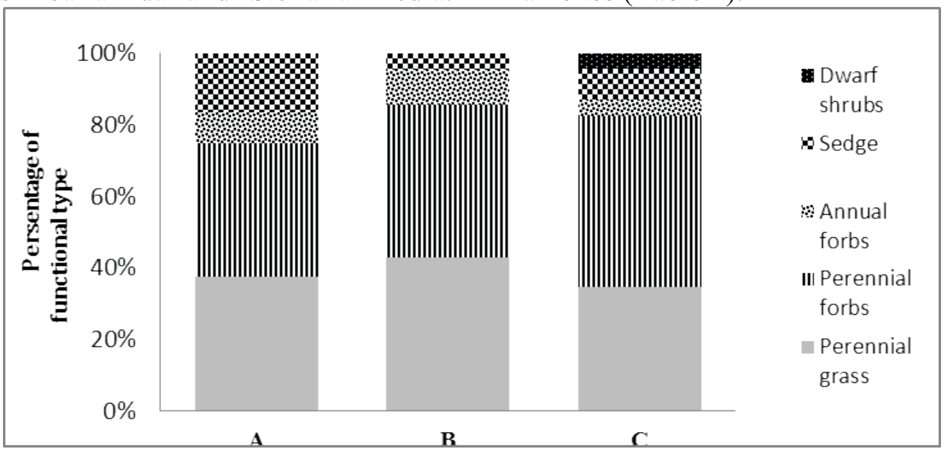

Fig. 4. Relative species abundance of five plant functional types in soil seed bank in non grazing (A), light grazing (B) and heavy grazing (C) sites. PG:perennial grasses, PF: perennial forbs, AF: annual forb, SD: sedge, S: small shrub

Table 2
The a total number of emerged seedlings and abundance of the selected speciec of soil seed bank in the different grazing pressure. Within, persentage of selected species in the emerged seedlings

	Total number of emerged seedlings (n/germinated)	Selective emerged species	Mean.v & St.err	Persentage in emerged seedlings
Non grazing	169	*Agrostis capillaris* *Carex capillaris* *Poa pratensis* *Thymus arcticus*	2.3 ± 0.9 3.2 ± 2.9 1.5 ± 0.4 1.5 ± 0.7	51%
Light grazing	165	*Agrostis capillaris* *Poa pratensis* *Deschampsia caespitosa* *Rumex acetosa*	4.3 ± 1.4 2.0 ± 0.5 1.8 ± 0.6 1.6 ± 0.4	60%
Heavy grazing	164	*Agrostis capillaris* *Agrostis vinealis* *Gallium normanii*	7.7 ± 2.2 1.9 ± 0.5 0.8 ± 0.4	64%

Some species that were recorded in the emerging seedlings from the seed banks were not recorded in the aboveground vegetation (Table 3). *Leontodon autumnalis, Poa annua, Rumex acetosa* emerged from soil seed bank from all sites A, B and C. *Capsella bursa-pastoris, Viola palustris, and Stellaria media* were recorded from seed bank from site A, *Armeria maritima* , *Capsella bursa-pastori* and *Stellaria media* were recorded from seed bank from site B. *Armeria maritima, Betula nana* and *Trifolium repens* were recorded from seed bank from site C. While *Capsella bursa-pastoris*, and *Stellaria media* were found in that of both the non and light grazing site, *Armeria maritima* was found in both of the light and heavy grazing site. Only *Viola palustris* was found in site A, *Spergula arvensis* was found in site B and *Betula nana* and *Trifolium repens* occured in site C.

Table 3
Difference between aboveground and belowground. P values show the significance of the difference between below and aboveground species. Significant differences indicate that the seed bank for that species is different from the above vegetation.

Species name	*Pr > F*
Agrostis capillaris	*0.1204*
Agrostis vinealis	*0.0019*
Bistorta vivipara	*0.4252*
Carex bigelowii	*0.0327*
Deschampsia caespitosa	*0.0199*
Empetrum nigrum	*0.0037*
Festuca rubra	*0.0186*
Galium boreale	*<.0001*
Galium verum	*0.0002*
Galium normanii	*0.0003*

Kobresia myosuroides	*<.0001*
Thalictrum alpinum	*0.0073*
Thymus arcticus	*<.0001*
Vaccinium uliginosum	*0.0188*

Correlation between aboveground vegetation and soil seed bank

The total number of germinated species in the soil seed bank was lower than the total number of species recorded in the aboveground vegetation under different grazing pressure (in appendix). Perennial species are a major common component of the two compartments vegetation. There was a significant difference between species composition of the seed bank and the above species composition, indicating a little or no resemblance between seed bank and above vegetation (Table 4). For individual species, the only species that showed non-significant differences between abundance below and aboveground were *Agrostis capillaris* and *Bistorta vivipara*. These species showed therefore a high resemblance in abundance below and aboveground.

DISCUSSION

Species composition in aboveground vegetation and soil seed bank

The total number of species identified in the soil seed bank was lower than number of species identified in the aboveground vegetation in all the sites. Highest number of species was found in the light grazing pressure site (A) and the lowest in the heavy grazing pressure site (C). The difference between the sites was, however, small. Continuous heavy grazing in rangelands has a negative impact on plant community composition, diversity, and biomass production, thereby potentially limiting the ability of the site to recover following disturbance or stress (Louhaichi et al. 2011). On the other hand, high disturbance, like heavy grazing pressure, can cause the rangeland to undergo retrogression, even to primary successional stages. Besides the lack of the grazing control may have been a consequence of the lack of bare ground and late summer disturbance to facilitate germination and establisment, probably coupled with a lack of new species in the seed bank (Zuo et al. 2012).

Some species, found in all the sites, showed a clear trend with grazing pressure. *Carex bigelowii, Festuca rubra* and *Thalictrum alpinum* had the highest abundance in the non grazing site, *Agrostis vinealis, Galium verum* and *Vaccinium uliginosum* had their highest in the light grazing site, and *Kobresia myosuroides* had highest abundance under heavy grazing pressure. These trends indicate that grazing intensity effects species abundance on aboveground vegetation. However, we did not find not much reduction of species number between the site, we found some indicator species of grazing in each site, so we focused on indicative of such trend.

Carex bigelowii and *Festuca rubra* are both plant species readily grazed by sheep (Thyrhallsdyttir & Thorsteinsson 1993). Their absence (C. bigelowii-heavy grazing) or lower abundance (F. rubra) in the heavy grazing site might indicate that plant community responses to heavy grazing by reduction of palatable species sensitive to heavy grazing and replacement with species of lower palatability (Zhao et al. 2007). Higher abundance of *Kobresia myosuroides* in the heavy grazing site supports this. In hillland ecosystems of the W-Iceland, *Kobresia myosuroides* responds to heavy grazing by increasing abundance and reducing other forage species foliage abundance and biomass under sheep grazing (Thyrhallsdyttir & Thorsteinsson 1993). *Vaccinium uliginosum* had the highest abundance the light grazing pressure site but was nearly absent in the heavy grazing site and has a lower abundance in the non-grazing site. The heavy grazing site was grazed by goat while the light grazing site was grazed by sheep Goats are much more browsers than sheep (Hofmann 1989) and will select more trees and shrubs than sheep. It is possible that the very low abundance of *Vaccinium uliginosum* in the heavy grazing site is due to selective grazing by goats, and the high abundance of the species in light grazing site an avoidance by sheep, as sheep usually do not select *Vaccinium uliginosum* for grazing (Thyrhallsdyttir & Thorsteinsson 1993).

The percentage of funtional types is a good indicator for the health and resilience of the natural plant community (Louhaichi et al. 2011). Results showed high proportion of perennial grasses and perennial forbs in the current vegetation on the all three sites. There was a higher abundance of perennial grasses in the light and heavy grazing sites, whereas perennial forbs were more abundant in the non grazing and heavy grazing sites. The abundance of sedges was higher in the light grazing site. *Salix herbacea* was only recorded in the non grazing site. In indicate of functional type abundance, can be a more direct, mechanistic link to ecosystem processes than individual species (Peco et al. 2012).

Emerging seedlings from soil seed bank

The total number of emerged seedlings was higher from the non grazing site, than from the light and heavy grazing site. The results indicate that grazing had impact on the soil seed banks in the hill of different grazing pressure, with a larger quantity of emerged seedlings at the non grazing sites, indicating that grazing has reduced the species abundance not only in the aboveground vegetation but also in the soil seed banks. Species composition of soil seed bank observed more seedlings of perennial grass species at lightly grazing areas compared with heavy and non-grazing sites, indicating a less seed setting in heavy grazing site and also in the non-grazing site. Heavy grazing has an effect on the inflorescence of the plants, keeping them in a more vegetative stage and reducing seed setting. Heavy grazing therefore leads to smaller seed banks. It is known that the seed production capacity of perennial grasses and their ultimate contribution of seeds to the soil seed bank can be reduced under heavy grazing (Tessema et al. 2012). On the other hand, a thick stand of dead standing biomass reduces the livelihood of the seed to reach the soil which also reduces soil seed bank (Bosy & Reader 1995; Chambers 2000).

There were a higher percentage of emerged seedlings of perennial forbs counted in the heavy grazing site compare other sites. Annual plants rely on seed setting for survival from one year to the next and have therefore usually a high seed production. With higher disturbance, like heavy grazing, plant rudderless that can tolerate high disturbance gain advantage (Grime 1979). Plant rude reals found in heavily disturbed sites are usually annual pants. Therefore, more abundance of annual forbs in the seed bank of the heavy grazed site is to be expected (Tessema et al. 2012). A few species emerged from the soil seed bank but were not found in the above vegetation, indicating a transfer on to the site from surrounding vegetation, with wind or even grazing animals (DeFalco et al. 2009). These were mostly annual forbs that are often found in openings on disturbed land or weeds. Poa annua, Rumex acetosa and Leontodon autumnalis emerged in all sites while Armeria maritima, Capsella bursa-pastoris and Stellaria media emerged in two of the sites. Only one dwarf shrub, Betula nana, emerged, from the soil seed bank samples, from the heavy grazing site.

This study confirmes that grazing can icrease, decrease or have no effect on the species composition similarity between current vegetation and soil seed bank (Zhao et al. 2011) in a hill site dominated by perennial species and in hight production in Hvitarsida, of W-Iceland.

Correlation between aboveground vegetation and soil seed bank

The similarity in species composition between the soil seed banks and aboveground vegetation was relatively low. The two-way analyses of variance showed that there was, in general, significant difference in species composition on aboveground vegetation and soil seed bank under all grazing pressures. Only three species had non significant differences above and belowground. Galium normanii showed a high similarity between current vegetation and the soil seed bank, especially under heavy grazing. Agrostis capillaris and Bistorta vivipara had also similar abundance above and belowground. Agrostis capillaris sets seed very late in the summer (Gudni Thorvaldsson pers. communication, 15. September 2012). Bistorta vivipara mainly reproduces asexual with bulbils (Thora Ellen Thorhallsdottir, pers. communication 26. September 2012), and therefore it is likely that the emerging seedlings of Bistorta vivipara were from bubils, possibly this years bulbils.

Low similarity in species composition between the soil seed banks and aboveground vegetation was also reported in natural forsests (Lemenih & Teketay 2006) church forests (Wassie & Teketay 2006) in Acacia woodlands (Hopfensperger 2007), in grazed area (Osem et al. 2006) and in a long term grazing exclusion (Zhao et al. 2011). This studies have reported that the similarity between aboveground vegetation and soil seed bank depends mainly on whether the grassland is dominated by annual (Tessema et al. 2012) or perennial plants (Zhao et al. 2011) and on the productivity of the grassland. In general, a high corellation has been found in communities dominated by annuals . Therefore, the lack of correlation found in the current study may be explained by the dominance of perennial grasses in all the sites. Perennial species in arctic environments have, in general a low seed production and rely rather on vegetative reproduction. These plants will only set seeds in in very favorable summers. In arctic, perennial and grazed grasslands, seed production capacity of grasses can therefore be limited and ultimate formation of seeds banks can be reduce, especially under heavy grazing (Martinez-Duro et al. 2012). Previous studies also reported poor correlation between species in the soil seed banks and standing vegetation, with similarity between often not more than 50-60 persent (Tessema et al. 2012). Others, however, report much higher similarity (Osem et al. 2006; Wellstein et al. 2007; Zhan et al. 2007; Agra & Ne'eman 2012; Martinez-Duro et al. 2012).

CONCLUSION

We found very little similarity in species composition between seed bank/belowground and current vegetation/aboveground. In our study argued with current theories and other studies: main effects on aboveground vegetation and soil seed bank similarity depends on the dominance grassland by annual or perennial plants and high or low productivity grassland.

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