Effect of fire and grazing on vegetation dynamics in the Himalayan landscape

Project progress report

Submitted to the

Himachal Forest Department

Foundation for Ecological Research, Advocacy and Learning

Pondicherry, India

January 2013

Suggested citation;

Nayak, R.R., M. Gangal and A. Sood 2013. Effect of fire and grazing on vegetation dynamics in the Himalayan landscape. Technical report submitted to the Forest Department, Himachal Pradesh. Project funded by The Rufford Small Grants Foundation, London, Foundation for Ecological Research, Advocacy and Learning, Pondicherry.

Principal Investigator
Rajat Ramakant Nayak
Foundation for Ecological Research
Advocacy and Learning (FERAL)
Pondicherry

Project supported by

The Rufford Small Grants Foundation
www.ruffordsmallgrants.org

FERAL

EFFECT OF FIRE AND GRAZING ON VEGETATION DYNAMICS IN THE HIMALAYAN LANDSCAPE

Abstract

Fire and grazing are the two important factors that have played a major role in determining the structure and composition of the Himalayan landscape. It is important to understand the role of these two elements in determining the vegetation characteristics for a better management and conservation of these biologically rich landscapes. The effectiveness of already existing management practices and strategies are greatly limited by the lack of such information on fire-vegetation-grazing dynamics. The aim of our study was to understand the role of fire and grazing in structuring Himalayan landscapes in order to develop long term conservation initiatives. Great Himalayan National Park Conservation Area is a part of the Himalayan Biodiversity hotspot. It provides a unique opportunity to study the vegetation dynamics across different grazing and fire gradients through its diverse land-use types. We used a combination of remote sensing, GIS-tools, village level questionnaire surveys and field sampling techniques to understand the grazing-vegetation-fire dynamics in this landscape. This report summarizes the results obtained for a period between July 2011 and Nov 2012.

Introduction

Fire and grazing have played a major role in determining the structure and composition of many of the world's ecosystems (Bond & Keeley, 2005, Nayak et al. *under review*). The Himalayas experience high levels of livestock grazing and fire (Tandon, 1997). Both these factors are considered as anthropogenic disturbances and there is not much information available on the role of grazing and fire in determining the ground vegetation composition and structure (Singh & Rawat, 1999; Rawat & Sathyakumar, 2002).

The Western Himalayas is part of the Himalayan biodiversity hotspot. Here, people have traditionally been pastoralists depending on the mountainous grasslands for their livelihood (Pandey & Wells, 1997; Tucker, 1997). They regularly burn forested lands in the drier months to encourage a new flush of grass for their livestock. Thus, fire and grazing are two integral parts which together have reshaped these landscapes. However, the growing concern about over-grazing and increasing fire-frequency as a cause of serious disturbance and a threat to biodiversity (Kala, Singh, & Rawat, 2002, Pandey, 2008) has resulted in restriction on grazing and costly protection measures from fire in several areas over the last few decades. These restrictions are based on general perceptions and do not consider the complex fire-vegetation-grazing dynamics in the landscape.

The responses seen in vegetation characteristics to fire suppression and/or grazing exclusions are not consistent. An increase in herbaceous diversity has been observed in areas where fire and grazing have been excluded (Belsky 1992), whereas, a loss in herbaceous diversity and an increase in woody cover are evident as a response to recent exclusion of livestock grazing and fires in other parts of the world (Bond & Keeley, 2005, Silva et al., 2001). In this study we aimed at a better understanding of the fire-vegetation-grazing relationships which could help in developing better management practices and conservation initiatives in the western Himalayan landscape.

Our objectives were:

1. To document the traditional grazing and fire management practices and spatial extent of grazing and fire in the landscape.
2. To determine the effects of over grazing and increased fire frequency on ground vegetation composition.
3. To analyze the effects of protection measures on vegetation characteristics.
4. To determine the acceptable levels of human activities by way of grazing and/or fire from the point of view of biodiversity conservation.
5. To develop strategies involving local people for long term monitoring and ensuring the persistence of existing biodiversity.

The results from our one year study are presented in this report. These results suggest a need for long term experimental studies as well as a need to revisit our present conservation strategies in the landscape.

Study area

The study is being conducted in the Great Himalayan National Park Conservation Area (GHNPCA) in the state of Himachal Pradesh, India. GHNPCA consists of one National park, the Great Himalayan National Park, and two sanctuaries, Tirthan and Sainj (Fig. 1). The National Park is provided with complete protection with no grazing inside the park, whereas the two sanctuaries form the 'eco-zone' around the park where grazing and other anthropogenic activities are allowed. GHNPCA is a part of the Himalayan biodiversity hotspot and is abode for a large number of unique flora and fauna. The climate is sub-tropical to temperate with the vegetation varying from sub-tropical broad leaf forests to high altitude alpine scrubs and grasslands. The area experiences higher levels of grazing and fire (Tucker, 1997). The mosaic of topographical features, variations in pastoral practices and legal and community restrictions at a local-scale (Chhatre & Seberwal, 2005) have resulted in gradients in grazing intensity and fire incidences across the landscape providing us a unique opportunity to study the vegetation along the grazing and fire gradients.

Methods

The study was divided into two phases. The first phase involved informative questionnaire surveys to identify traditional grazing and fire management practices and gradients in grazing intensities and fire frequencies across the landscape. Second phase involved sampling for ground vegetation, mainly for species composition and abundance, in areas with different fire-frequencies and grazing-intensities using vegetation transects. We also used remotely sensed data to understand the distribution of fire in the landscape.

Questionnaire surveys- We carried out informative questionnaire surveys between July 2011 and September 2012. In this survey we covered more than 25 villages within the study area. We documented traditional and current grazing and burning practices by the local people in the study area. We mapped the local grazing grounds and collected information on the intensity of use of these grazing grounds by various villages. We recorded people's perceptions and observations on changes in vegetation due to the restrictions imposed on grazing and burning practices after the declaration of National Park.

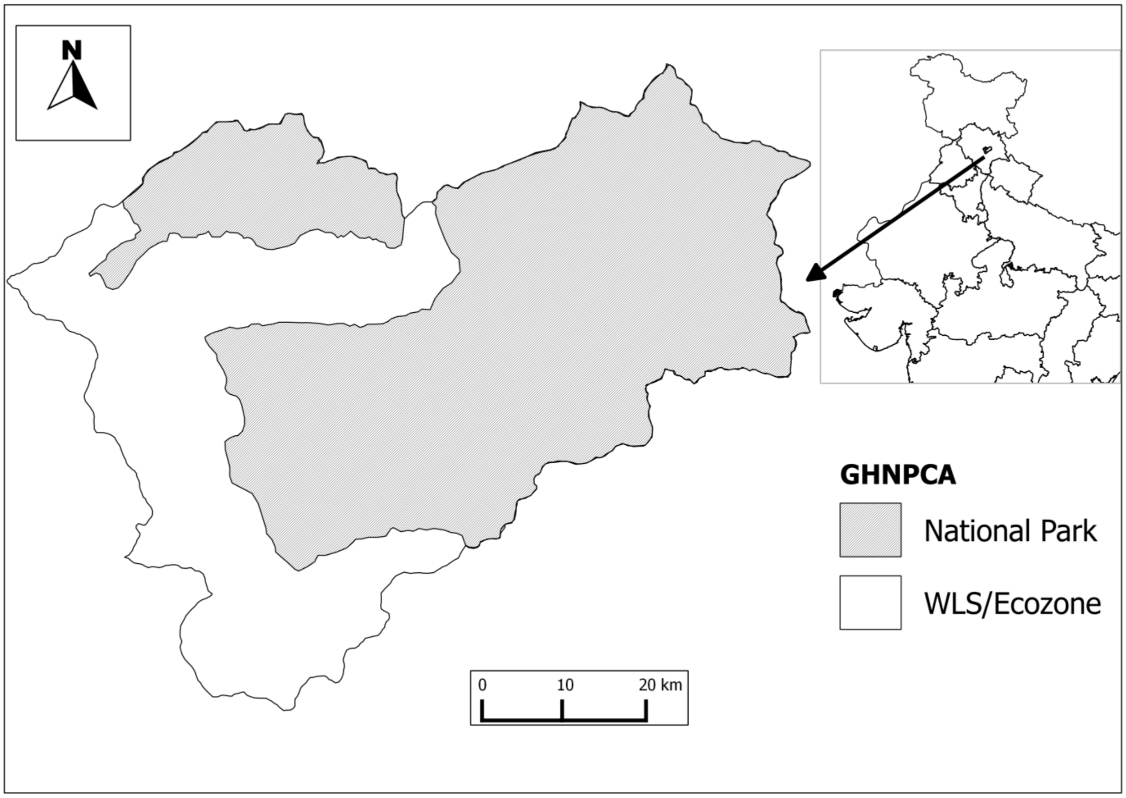

Figure 1. The Great Himalayan National Park Conservation Area (GHNPCA).

With the help of the information obtained during this phase of the survey we identified areas with different grazing intensities and burning practices, which were later used for the field sampling.

Field sampling- The field work was spread across two seasons; pre-monsoon and post-monsoon. The data on pre-monsoon vegetation composition was collected between March 2012 and July 2012. The data for post-monsoon was obtained between October 2012 and November 2012. We collected data across the grazing gradients covering the areas both inside the protected area, where legal restrictions are imposed, and outside the protected, where there are no legal restrictions, using point intercept method along the vegetation transects. A total of 11 high altitude grasslands (*tach*), covering an altitudinal gradient between 2900 m to 3900 m from mean sea level were sampled across four grazing gradients; no grazing (NG), moderate grazing (MG), high grazing (HG) and very high grazing (VHG). The grazing gradients were identified based on the number of livestock visiting the grassland, their duration of stay and number of villages visiting the area. Out of 11, five *tach* were inside the protected area (no grazing; Chakreda, Dhel, Ghumatarao, Nada, Shilt), and two each were in the moderate (Dupanga, Palni), high (Dushmani, Kundri) and very high (Bakhadi, Marhoni) categories of grazing. The number of transects in each *tach* ranged from 4 to 34, and the total number of transects laid were 170.

The frequency of burning was used to define fire gradient. We had only two categories in fire gradient, burnt every year and not burnt every year. Questionnaire surveys and remotely sensed data revealed that fire was mainly restricted to village surroundings and village grazing grounds (*ghasni*) and we did not find any data to support occurrence of fire in the high altitude grasslands.

A total of six *ghasni*, three each in burnt (burnt every year) and un-burnt (not burnt every year) categories were sampled for ground vegetation. In each *ghasni* 10 transects were laid for vegetation sampling.

Data analysis. Species richness, diversity and evenness were estimated for each of the sites sampled and for different grazing and fire categories. Species accumulation curve, scaled for the variation in number of vegetation transects, was used to compare species richness across the grazing categories. Renyis diversity and evenness profiles were used to compare the diversity and evenness across the sites.

We looked at the effect of grazing intensities on the pooled species richness across the sites using generalized linear regression models, with a log link and Poisson distribution of variance. We tested the effects of other covariates, elevation, aspect and area of the grassland using the same models. The additive effects with all possible combination of these covariates along with grazing categories were also tested. The models were compared using Akaike Information Criteria with bias adjustment (AICc), to determine the best model and the most plausible explanatory variables for the observed species richness counts.

The heterogeneity, also termed as beta diversity, in species composition across the sites was calculated using Bray-Curtis distance measures. We used mantel test to determine the correlation between species composition and other environmental factors, elevation and aspect and the size of the sampled grasslands. Correlation between species composition and grazing categories was measured using Analysis of Similarity (ANOSIM) test.

We looked at the effect of grazing intensities on the diversity and abundance of annual plants, herbs and grasses, using linear regression methods. Single variable models and additive models were constructed using other covariates, elevation, aspect and area of the grassland. The best model was selected based on the AICc results.

We tested the effect of over grazing on soil by testing the correlation between percentage bare-ground and grazing intensity using box and whisker plots.

Results

Fire information for the area- Fire maps developed using remotely sensed data suggested that fire was mainly concentrated along the PA boundary and the north-eastern part, characterized by inaccessible rocky terrain, was free from any fire. The maximum fire frequency observed was 12, suggesting the presence of annual fires. Although fire was restricted in its distribution, the frequencies observed were much higher than that reported for similar ecosystems from other parts of the world (Fig. 2).

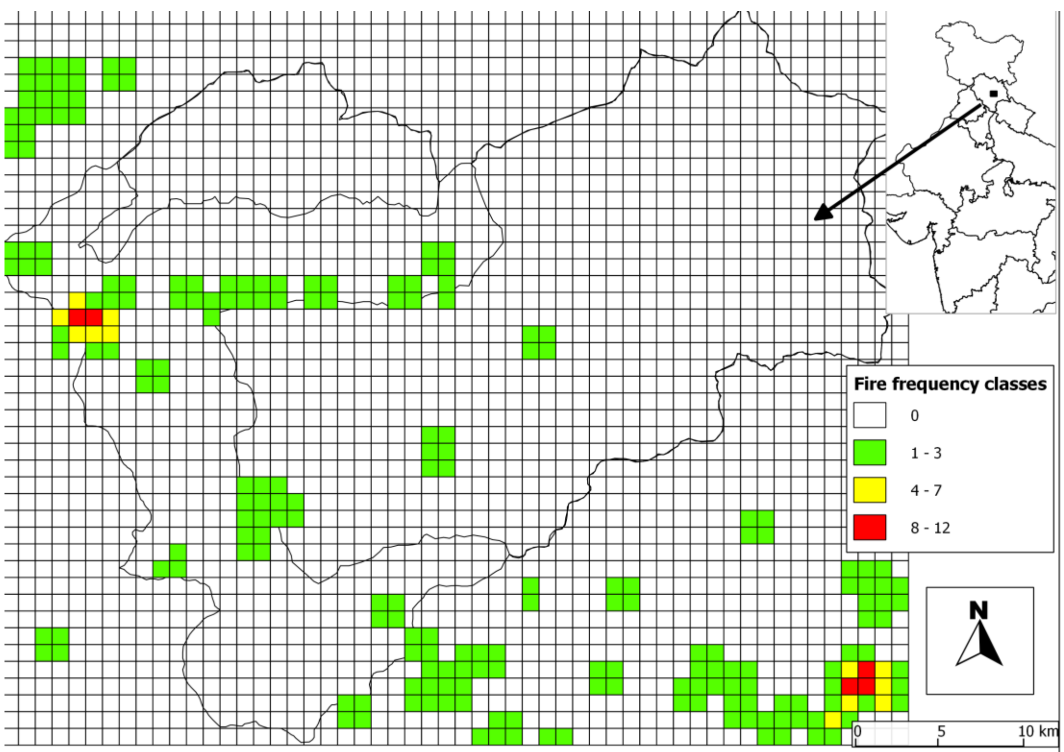

Figure 2. A 1x1 km grid showing the distribution of fire and fire frequency at different cells in the study landscape. Points indicate the distribution of alpine pastures (*thatches*).

During questionnaire survey, 75% of the villages accepted that they burn grasslands adjacent to them (*ghasni*) every year in order to remove dry and dead material and allow the growth of new, more nutritious grasses. The burning season was November to December and February to March. 25% of villages said that they have stopped burning for the last 5-6 years; the main reason being the loss of shrubs in grasslands which increased the falling risk for shepherds and grass-cutters on these steep terrains.

We did not find any instances of fire in high altitude grasslands in our survey and through remotely sensed data. Hence we sampled for the effects of fire only in village grazing grounds, *ghasni*.

Distinct traditional grazing practices and the recent changes- Grazing in this landscape is characterized by seasonal migration. Livestock is grazed in high altitude grasslands, called *tach*, from summer (April) till the beginning of winter (October). Livestock is brought back to villages during October, and the whole winter is spent in the village grazing grounds called *ghasni*. Every village has its own *ghasni* as well as a favourite *tach*. Since the formation of Great Himalayan National Park in 1999, many of these villages are restricted from entering their allotted/traditional grazing grounds which is now within the National Park. As a result, livestock from these villages are now forced to graze in *tach* belonging to other villages. This has resulted in a very high density of livestock in a few *tach*. Villagers expressed a concern over such kind of grazing, as they believed that it has resulted in over-grazing of these sites leading to deterioration of vegetation.

Vegetation information:

A. High altitude grasslands (tach)- We recorded fewer numbers of species in the post monsoon season than the pre-monsoon season. All the species from post monsoon season were also recorded during the pre-monsoon season survey. As the sampling season for all the sites during pre-monsoon survey is comparable, we used the data only from pre-monsoon season for all our analysis.

Species richness and diversity. A total of 95 species of ground flora – herbs, grasses, sedges and shrubs, were recorded from a total of 170 vegetation transects across different grasslands. Out of 95 species recorded 72 were herbs and 11 were grasses. The species richness observed per grassland ranged from 15 to 39. The minimum number of species, 15, was observed in Dupanga (MG). The maximum number, 39, was observed in Ghumtarao (NG).

Species accumulation curve scaled to account for variation in number of samples (number of transects) showed sites with no grazing (NG, n= 77) to have a very high species richness value (Fig 3). MG showed a species accumulation curve higher than NG. However, care should be taken while interpreting this result, as this could be an artifact of low sampling size (number of transects; n= 9). HG (n= 30) and VHG (n= 54) had the lowest curve, showing poor species richness.

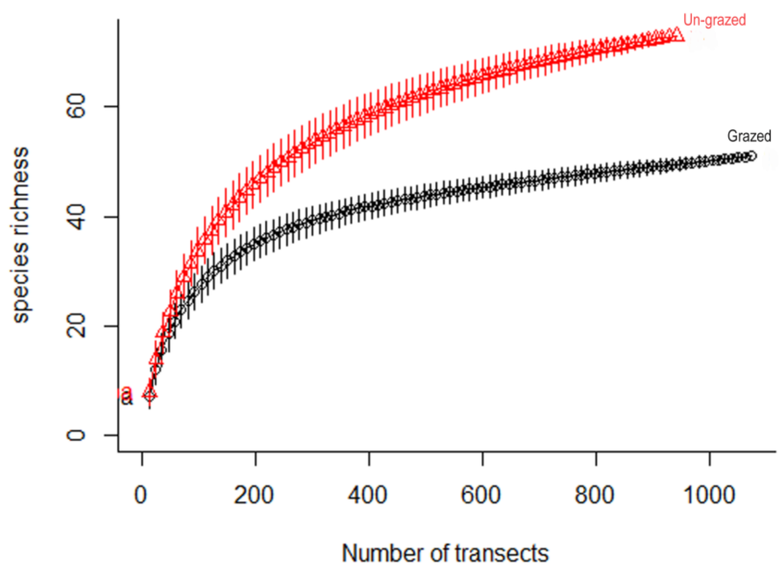

Figure 3. Sampled based species accumulation curve for grazed and un-grazed categories of grasslands. The horizontal axis is scaled by the number of sampled transects in each of the grazing category

Renyis biodiversity profile showed Chakreda and Ghumtarao to have the highest diversity among the sampled plots. The more horizontal curves of for these two sites indicate that the species were evenly distributed, which could have contributed to a higher diversity. Profile curves of all other sites overlapped with each other to a great extent, showing a lesser diversity and evenness in species distribution (Fig 4a). Reneys biodiversity profile showed the highest diversity for NG, followed by VHG. Both MG and HG had a poor diversity profiles (Fig 4b).

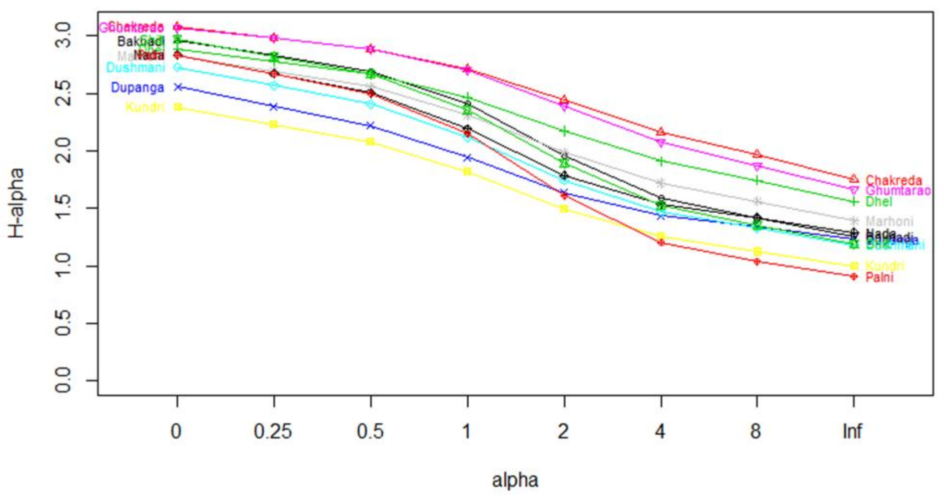

Figure 4a. Renyis diversity profile for different *tach*. Higher the profile curve indicates a higher diversity. The shape of each curve indicates the evenness; more horizontal the curve is higher the evenness

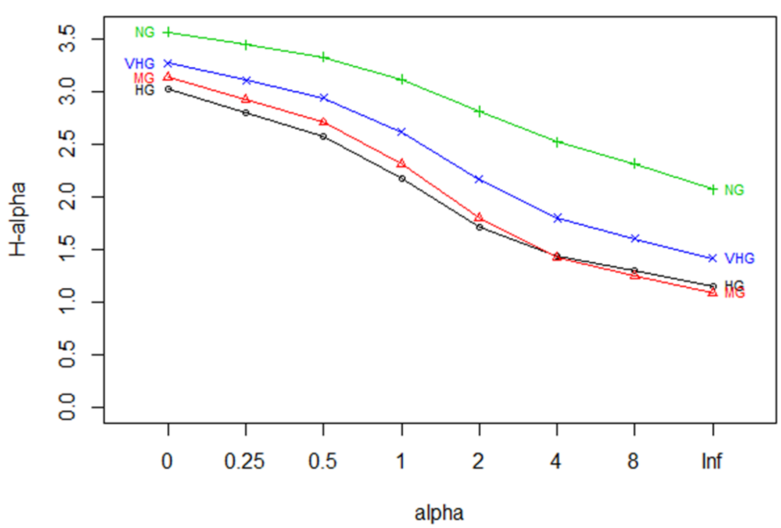

Figure 4b. Renyis diversity profile for different categories of grazing intensity. NG= No grazing, MG= Medium grazing, HG= High grazing, VHG= Very high grazing

Regression models showed elevation to be the most important factor in determining the observed species richness values. Along with elevation, area/ size of the grassland influenced the species richness as it appeared in the top model along with elevation. Grazing intensity did not appear in any of the top models suggesting little influence of grazing intensity in determining the species richness at higher altitudes (table 1, Fig 5). Similarly aspect was found to have little influence on observed variations in species richness.

Table 1. Regression analysis results for different models with species richness (number of species) as the response variable. AIC values were used to select the best model. Weight indicates theprobability of the model being true for the observed data.

Model	B- coefficient	df	AICc	Delta AICc	Weight
Area+Elevation					
Area	0.000001	3	75.3	0	0.384
Elevation	0.000780				
Elevation	0.001130	2	75.8	0.47	0.303
Area	0.000002	2	77.1	1.74	0.161
Aspect+Elevation					
Aspect	-0.00053	3	79.1	3.78	0.058
Elevation	0.001150				
Grazing intensity	+	4	84.1	8.75	0.005
Null			91.9	16.59	0.000

Species composition: No two *tach* had a similarity value of more than 0.6, indicating a unique species composition in each of these *tach*. Mantel test revealed a strong correlation between species composition and elevation (r= 0.44, p= <0.01). Aspect and area of the grassland did not show any influence on species composition (p> 0.1). ANOSIM test showed grazing intensity to have some influence on species composition (R= 0.2, p= 0.07).

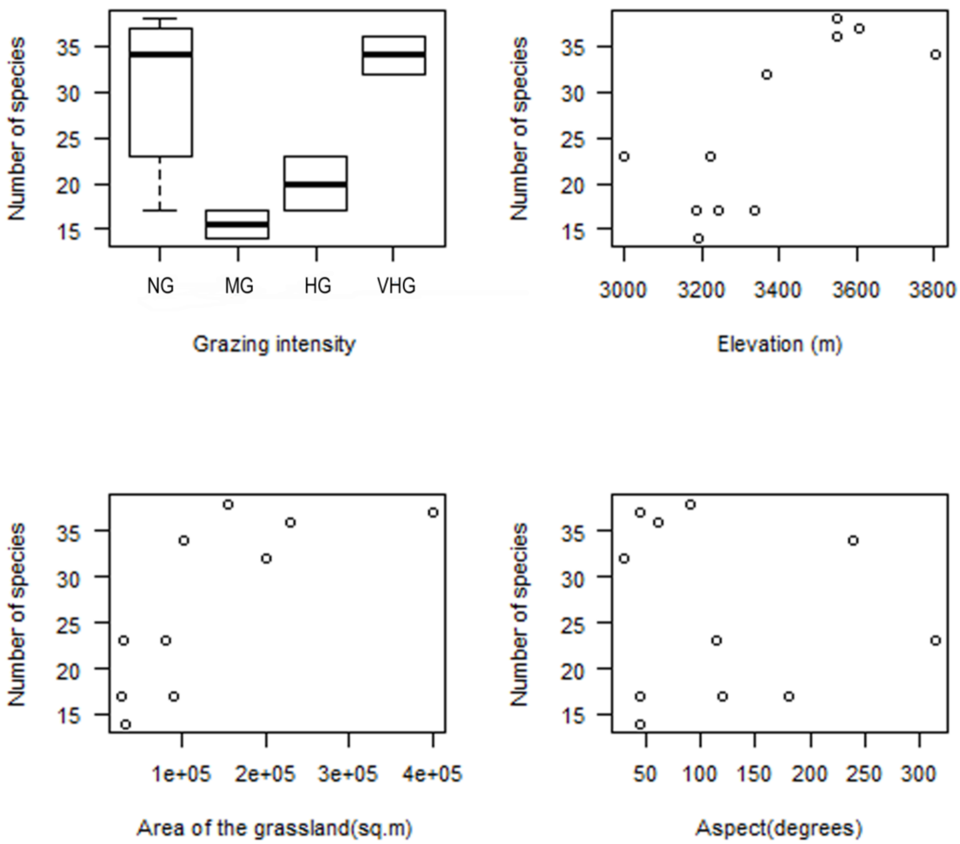

Figure 5. Species richness plotted against different predictor variables; grazing intensity, elevation, area of the grassland and aspect

Diversity and composition of annual plants. Only 26 out of 95 species recorded were annuals. Regression analysis revealed a high correlation between grazing intensity and number of annual species ($p < 0.01$), which explained nearly 87% of the variation observed in the data (Fig 6a). None of the other covariates tested had any influence on annual species richness ($p > 0.1$).

Grazing intensity was also found to be the best variable to explain the abundance of annual species of plants (multiple $r^2 = 0.81$, $p < 0.01$) (Fig 6b). No other covariate tested was found to be influencing the abundance of annual species of plants in the landscape.

Effect on soil. The amount of bare ground observed was lower in NG and MG compared to HG and VHG (Fig 7).

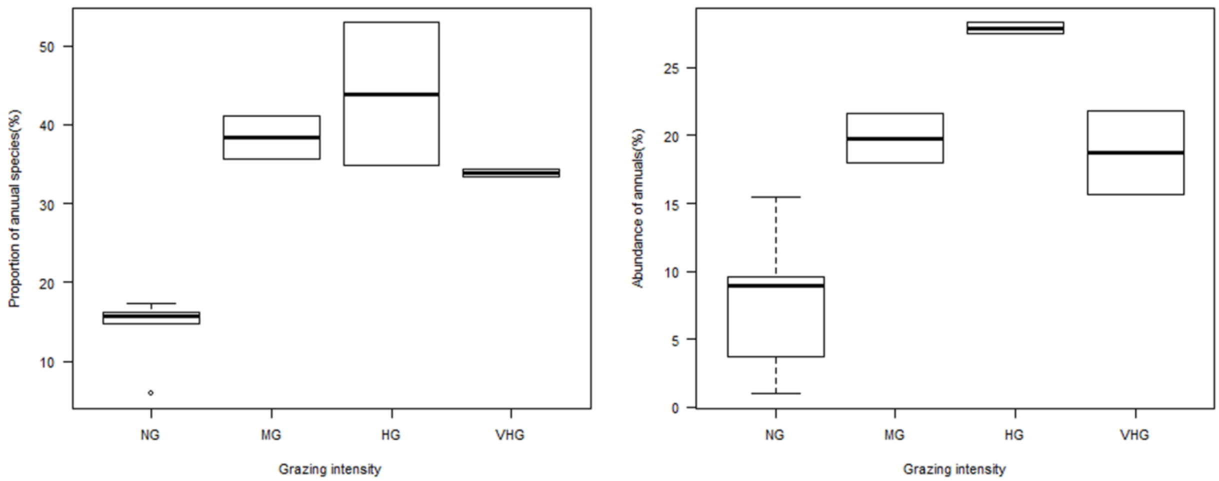

Figure 6.a. Proportional representation of annual species across sites with different grazing intensities. b. Abundance of annuals in each grazing category.

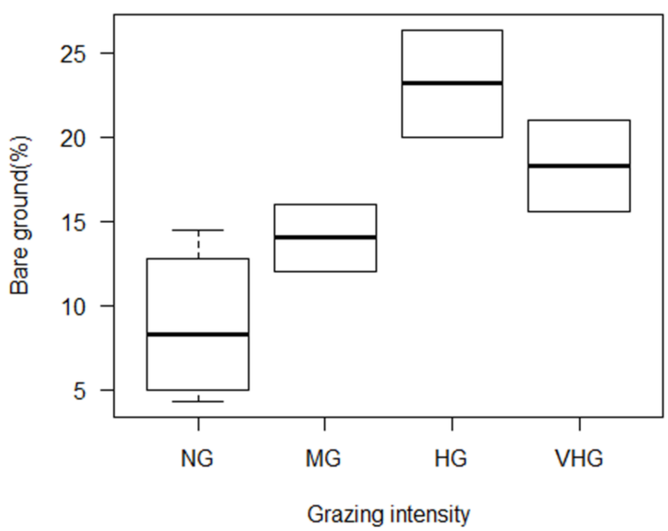

Figure 7. Box and whisker plot showing the percentage of bare ground across different categories of grazing intensity. Median for all the sites which age grazed have a higher proportion of bare ground compared to un-grazed site.

B. Village grazing grounds (ghasni)- We observed a total of ten species of ground flora in the *ghasni*. Analysis of Similarity (ANOSIM) showed that there was no correlation between fire frequency and species composition ($p > 0.5$).

Discussion and conclusion

Grazing by livestock and fire are the two most important factors that been active in the Himalayan landscape for the last several hundreds of years. However, very little is known about their role in structuring the vegetation in the Himalayas. In our study we aimed at understanding the fire-grazing-vegetation dynamics in the Western Himalayas with GHNPCA as the study site.

Over the last few decades there is an increased concern over the impacts of over-grazing on floral diversity in the Himalayas. Our study indicated that the species richness in the high altitude grasslands is mainly influenced by the gradient in elevation and size of the *tach* (Fig 5). Although, species accumulation curve was higher for non-grazed areas, the regression analysis did not show any significant difference between different categories of grazing intensity. Furthermore, the observed higher species richness in no grazing category could be a result of pooling of all non grazed sites into one category. A comparison of species composition across all the sites revealed that each of the *tach* consisted of unique vegetation and no two *tach* was very similar in its composition. Mehra, 2000, in his study also reported similar observations.

Each of these high altitude grasslands are surrounded by thick woodlands and hence are very similar to islands. In such situations, it is observed for a larger island to have more number of species (MacArthur & Wilson 1967). Larger areas of the grasslands can also reduce grazing pressure on a single species and thus reduce extinction threats and help in maintaining higher species richness. The observed influence of elevation and area of grassland is well explained by the fact that all the larger grasslands (> 100000 m^2) occurred at a higher elevation (>= 3400m), this could have resulted in observed patterns of species richness with elevation and area. This result suggests that to know the influence of grazing on species richness it is important to study a single *tach* or few similar *tach* with long term experimental plots simulating different grazing intensities and frequencies.

Grazing and elevation both influenced heterogeneity and species composition. Grazing by selectively removing certain plants and providing space for colonization by others can influence species composition (Hayes & Holl 1983, Adler et al. 2001). We found a strong relationship between grazing and the abundance and richness of annual species. This is an important result as these observed patterns were not influenced by any other variables considered. Grazed areas had relatively higher number of annual plants compared to non grazed areas. Perennials plants are better competitors over the annuals in natural conditions. However, in a grazed ecosystem, annual pants get an opportunity to colonize open spaces and thus result in a higher abundance of annuals and an increased heterogeneity (McNaughton 1985, Noy-Meir 1995, Olff & Ritchie 1998).

Although local people expressed a concern on over-grazing of certain sites, we did not find any influence of over grazing, as we did not find higher number of weeds and shrubs in such sites as expected under over-grazed conditions. The higher number of perennials in un-grazed sites could be an indicator of changes in ground vegetation composition taking place in protected un-grazed areas. There is a need to look at this compositional change carefully, especially, at lower elevations (2900-3400 m) as they are more susceptible to succession by perennial herbs and shrubs, which can reduce the fodder value of these grasslands to larger ungulates.

We found that the percentage of bare ground increased with the intensity of grazing. Several other studies have shown an increase in soil erosion in over-grazed areas. Although we did not find an influence of over grazing in vegetation composition, higher percentage of bare ground could be considered as an indicator of changes occurring in such sites. Hence, there is a need to halt the occurrence of over-grazing outside the National Park and develop alternate strategies to reduce grazing pressure on a single site. The presence of lower number of perennials in grazed areas suggest that to prevent the succession of these high altitude grasslands by woody components, some low intensity grazing may be necessary. As it is not advisable to open up the livestock grazing inside the National Parks, as it carries other threats in the form of poaching and collection of NTFPs along with it, we need to develop alternate strategies, may be clipping, to conserve these grasslands inside the NP.

The experiences gained through the conservation efforts across India over the last few decades and the studies done by us and other researchers clearly suggest that no single strategy is appropriate to conserve a diverse ecosystem like western Himalayas. We need to consider several anthropogenic as well as environmental factors in developing conservation strategies. In GHNPCA, each of the high altitude grassland is unique in its diversity and composition, which is shaped by elevation, colonization and by grazing. Compared to high altitude grasslands, village grazing grounds had very few species. Hence, to develop better management strategies that will ensure conservation and livelihood of local people, long term experimental studies, designed for different elevations simulating traditional grazing practices and different intensities of grazing are necessary. We are designing such long term experimental studies which could then be tested in field to determine any acceptable levels of grazing and alternate strategies both inside and outside the National Park.

Proposed working plan for 2013.

<table>
<tr><th>Activities</th><th>I quarter</th><th>II quarter</th><th>III quarter</th><th>IV quarter</th></tr>
<tr><td>Designing and planning</td><td style="background:#c4bd97"></td><td></td><td></td><td></td></tr>
<tr><td>Setting up of plots and data collection on ground vegetation</td><td></td><td style="background:#c4bd97"></td><td></td><td></td></tr>
<tr><td>Data collection</td><td></td><td></td><td style="background:#c4bd97"></td><td></td></tr>
<tr><td>Data analysis</td><td></td><td></td><td></td><td style="background:#c4bd97"></td></tr>
</table>

Reference

Adler, P. B., Raff, D. A., and Lauenroth, W. K., (2001). The effect of grazing on the spatial heterogeneity of vegetation. Oecologia, 128; 465-479

Belsky, A. J.(1992). Effects of grazing, competition, disturbance and fire on species composition and diversity in grassland communities. Journal of Vegetation Science, 3; 187-200

Bond, W. J., & Keeley, J. E. (2005). Fire as a global “herbivore”: the ecology and evolution of flammable ecosystems. Trends in Ecology and Evolution, 20; 387-394.

Chhatre, A., & Saberwal, V. (2005). Political incentives for biodiversity conservation. Conservation Biology, 19; 310-317.

Hayes, G. E., and Holl, K. D. (2003). Cattle grazing impacts on annual forbs and vegetation composition of mesic grasslands in California. Conservation Biology, 17; 1694-1702.

Kala, C. P., Singh, S. K, & Rawat, G. S. (2002). Effects of sheep and goat grazing on the species diversity in the alpine meadows of Western Himalaya. The Environmentalist, 22; 183-189.

MacArthur, R. H. and Wilson, E. O. (1967). The Theory of Island Biogeography. Princeton, N.J.: Princeton University Press.

McNaughton, S. J. 1985. Ecology of a grazing ecosystem: the Serengeti. Ecological Monographs 55:260-294

Mehra, B. S. (2000). Livestock Grazing and Conservation of Biodiversity in the High Altitude Ecosystem: An Integrated Landscape Management Approach. Ph.D thesis. Saurashtra University

Noy-Meir, I. 1995. Interactive effects of fire and grazing on structure and diversity of Mediterranean Grasslands. Journal of Vegetation Science 6:701-710.

Olff, H., and M. E. Ritchie. 1998. Effects of herbivores on grassland plant diversity. Trends in Ecology & Evolution 13:261-265.

Pandey, S. (2008). Linking ecodevelopment and biodiversity conservation at Great Himalayan National Park, India. Biodiversity Conservation, 17; 1543-1571.

Pandey, S., & Wells, M. P. (1997). Ecodevelopment planning at India's Great Himalayan National Park for biodiversity conservation and participatory rural development. Biodiversity and Conservation, 6; 1277-1292.

Rawat, G. S., & Sathyakumar, S. (2002). Conservation issues in the Himalayan region of India. Wildlife and Protected Areas, 1; 50-56.

Singh, S. K., & Rawat, G. S. (1999). Floral diversity and vegetation structure in Great Himalayan National Park, Western Himalaya. Wildlife Institute of India, Dehradun.

Silva J. F., Zambrano, A., & Farinas, M. R. (2001). Increase in the woody component of seasonal savannas under different Fire Regimes in Calabozo, Venezuela. Journal of Biogeography, 28; 977-983

Tandon, V. (1997). Status of collection, conservation, trade and potential for growth in sustainable use of major medicinal plant species found in the Great Himalayan National Park and Its Environs in Kullu District of Himachal Pradesh. Wildlife Institute of India, Dehradun.

Tucker, R. (1997). The historical development of human impacts on Great Himalayan National Park. Wildlife Institute of India, Dehradun.

A high altitude grassland, *tach*, is an integral part of traditional grazing system; grazed by the livestock during summer

High altitude grasslands act as an important repository for biodiversity in the Himalayas.

Local people being trained in data collection in the field