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Authors: Thapa, Sunita, All, John, and Yadav, Ram Kailash Prasad

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Effects of Livestock Grazing in Pastures in the Manaslu Conservation Area, Nepalese Himalaya

Sunita Thapa*[1]*, John All*[2]*, and Ram Kailash Prasad Yadav*[1]**

** Corresponding author: rkp.yadav@cdbtu.edu.np*

[1] Central Department of Botany, Tribhuvan University, Kirtipur, Kathmandu, Nepal
[2] Department of Environmental Science, Western Washington University, Bellingham, WA 98225, USA

Livestock herding is a widespread practice in the mountains of Nepal, and grazing in the forest and pastures within protected areas is a main source of cattle fodder. Given the implications of grazing on biodiversity conservation and the need for sustainable management of pastures in the Manaslu Conservation Area of Nepal, we assessed grazing intensity along an elevational gradient following the Budhi Gandaki valley. The data set consisted of grazing intensities recorded every 250 m along a transect from 1400 to 5200 m above sea level and farmer interviews, after an initial satellite data analysis. Grazing and herd size were found to increase with increasing elevation, reflecting local livelihood dependency on cattle herding. Species richness was then analyzed along a grazing disturbance gradient at 7 goths *(summer cattle shed) in heavily grazed areas. Disturbance was found to be moderate at intermediate distances, where species richness was found to be higher; the results agree with the generally accepted intermediate-disturbance hypothesis. The plant species not affected, even at the locations with highest grazing, were unpalatable species. These results can be useful in decision making related to management of forests and pastures in the Manaslu Conservation Area as well as in Himalayan forests and grasslands in general.*

Keywords: *Grazing; pasture; disturbance; species richness; grazing preference; Manaslu Conservation Area; Himalayas; Nepal.*

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Introduction

The keeping of livestock has been practiced for millennia in many parts of the world, and it is an important biotic factor that influences grassland ecosystems (Wray 1998; Mayer et al 2006). Grazing affects vegetation by defoliation through consumption by animals and by causing physical damage through trampling, dung pat deposits, and urine (Palmer et al 2004; Mayer et al 2006; Vandenberghe et al 2007). The most important aspect of grazing that affects vegetation composition is selection of some plants and avoidance of others by herbivores, together with intensity and frequency of grazing (Aryal 2009). Grazing can also be regarded as an agent with distinct and interactive effects on the plant community rather than a general disturbance mechanism. Indeed, classical studies define grazing in grasslands as a disturbance (Grime 1979; Collins 1987), relying on a definition of disturbance standardized by White and Pickett (1985: 7): "any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment."

Considerable empirical and theoretical work has been done on grazing, with contrasting results on its impact on vegetation structure and diversity. Grazing has been found to have major effects on species composition as well as on vegetation height, standing biomass, dead biomass, and sward structure (Hodgson 1990). Livestock grazing has been reported to increase (Rambo and Faeth 1999; Humphrey and Patterson 2000; Mountford and Peterken 2003; Pykälä 2004), as well as decrease (Mcintyre and Lavorel 1994; Landsberg et al 2003; Mayer et al 2006) plant diversity. Highest plant diversity has also been reported at intermediate levels of grazing (Taddese et al 2002; Bhattarai et al 2004; Bustamante Becerra 2006). This further substantiates the intermediate-disturbance hypothesis (Connell 1978; Grime 1979; Huston 1994), which argues that a high number of species with lower biomass but higher productivity results from disturbed vegetation. However, this hypothesis has not been confirmed everywhere, for example, not in desert rangelands (Gamoun 2014). Grazing disturbance gradients may develop in areas with different degrees of livestock activity. In an alpine ecosystem with a long history of grazing, plants are expected to respond to grazing gradients (from heavy to low grazing pressure), and plant species abundance is expected to differ between heavy and reduced grazing regimes (Evju et al 2009).

Grazing in pasture management is a matter of major debate in mountain areas, particularly in developing countries: The effects of grazing on species diversity are still being explored, and both moderate grazing (Bhattarai et al 2004) and heavy grazing are mentioned as a source of increased diversity (Perelman et al 1997). The moderate-grazing recommendation is based on the assumption of higher herbaceous species diversity (Grime 1973); the demonstration that heavy grazing results in greater species diversity is usually specified in the sense that palatable woody plants and perennial herbaceous species are replaced by unpalatable woody species and annuals (Landsberg et al 2003; Todd 2006). On the other hand, where grazing is excluded, the less competitive species have been shown to recede, leaving only a few dominant species (Gillson and Hoffman 2007; Schultz et al 2011).

Livestock grazing in the pastures of Nepal's mountains is an old practice. Pastures in general are not just a means of rearing livestock for self-consumption, but they are also an important resource for alleviating rural poverty through livestock production (Moktan et al 2008; Buffum et al 2009; Yadav 2012). Pastures are rich in biodiversity and offer many ecosystem services such as production of animal protein for human consumption, carbon sequestration, non-timber forest products, and ecotourism. Of the total geographic area of 14.7 million hectares, about 1.7 million hectares are considered grasslands in Nepal; they are dominated by herbaceous plants (grasses, herbs, shrubs, and thin stands of trees) and are grazed by ruminants. Of the total grasslands, 98% lie in the 2 regions known as Middle Hills and Mountains (Pariyar 2008). Manaslu Conservation Area (MCA), created in 1998, is rich in plant diversity, dominated by herbaceous plants (Chhetri and Bhattarai 2013) that are abundantly distributed in the pastures. Studies about the impact of livestock grazing on vegetation in Nepal's mountain protected areas suggest that moderate disturbance can maintain the biodiversity of the pastures (Bhattarai et al 2004). A study of the impact of grazing in MCA is lacking and is essential for determining adequate measures for pasture management.

The present study assessed the impact of grazing in the MCA by using remote sensing and geographic information system (GIS) methods as well as sampling species richness and household and livestock data along a disturbance gradient. The questions we addressed in this study were: (1) Does the grazing intensity increase or decrease with increasing elevation? (2) How does grazing affect species richness along a disturbance gradient? (3) Is there a difference in the preference of livestock for different plant species?

Methodology

Study area

The MCA is situated in Gorkha District in the western region of Nepal. It is located between 28°20′–28°45′N latitude and 84°29′–85°11′E longitude in the Trans-Himalayan range, extending over an area of 1663 km^2. Situated in the remote northern part of Nepal and bordering with Tibet Autonomous Region (China), the MCA features great variations in elevation, climate, landscape, habitat, vegetation, and culture. Phytogeographically, it forms the meeting ground of the West Himalayan, Indo-Malaysian (southeast Asian), and Oriental (east Asian) flora. The bioclimatic zones vary from subtropical to nival. In our study area, pastures alternate with open-canopy tree sites (because the area is semiarid) up to the tree line at an elevation of about 4200 m, and continue up to about 5000 m. In this park, the elevation rises from a mere 1360 m to the summit of Mt Manaslu (8163 m), the eighth highest peak in the world. The MCA covers 7 Village Development Committees (VDCs): Samagaun, Lho, Prok, Bihi, Sirdibas, Chumchet, and Chhaikampar (Figure 1). The VDCs, except for Sirdibas, border the Tibet Autonomous Region on their northern sides. While formal trade is banned across the border, our interviews revealed that there are extensive trade linkages across the border. These provide a secondary market for timber, cattle, and medicinal plants. The major rivers in the region are Budhi Gandaki, Syar, Daroudi, and Chupe.

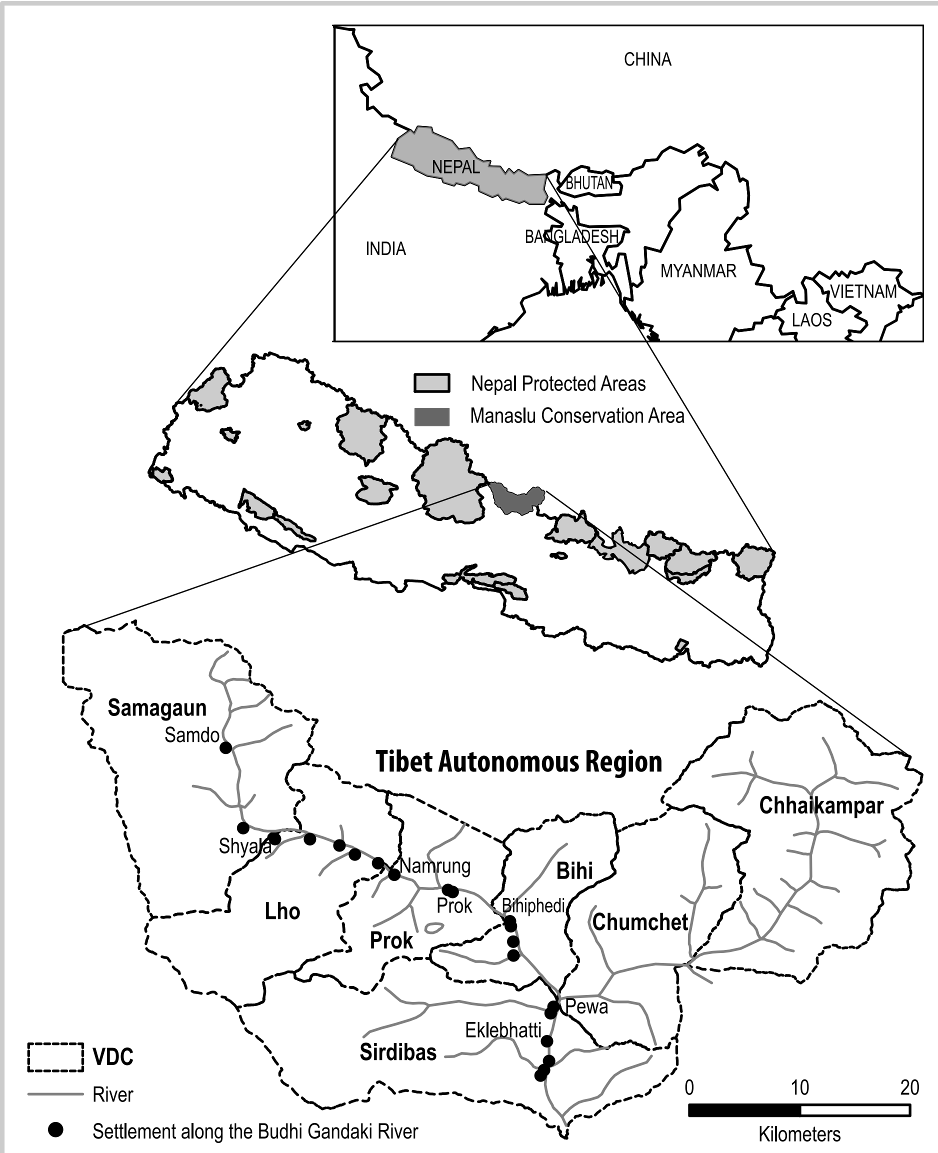
Precipitation falls in the form of summer monsoon rain, usually lasting from June to September. Since the area is surrounded by a series of high mountains, it is protected from the southern monsoon clouds, resulting in partial rain-shadow areas. Maximum and minimum temperatures recorded from 2001 to 2008 (available data) at the nearest weather station (Gorkha, 1097 m above sea level [asl]) are 33.4°C and 2.4°C, respectively. The highest precipitation, averaging 300 mm, has been recorded during the months of June, July, and August (DHM 2010).

Agriculture in general and pastoral livestock rearing in particular are the major sources of people's livelihoods. Cows, sheep, and goats are the main livestock at the lower elevations, whereas cows, yaks, and yak/cow hybrids are reared at higher elevations, with some mixing of herds across the elevations.

Study design

Two field visits were conducted within the MCA. The first, in December 2009, primarily focused on collecting data for GIS analysis of the grazing intensities, after an initial satellite analysis helped us to determine critical areas for analysis. In total, 562 ground control points (GCPs) were recorded within the MCA every 250 m on a transect along the entire Budhi Gandaki valley, beginning at an elevation

FIGURE 1 Location of the Manaslu Conservation Area (MCA). (Map layer source: MENRIS 2010; map by Sunita Thapa)



of about 1400 m and ending at 5200 m. At each point, the intensity of grazing was recorded (see below for details). The second field visit was carried out in November 2010 for the species diversity study. Sampling of vegetation was done above the tree line at 7 summer cattle sheds—called *goths* in the local language. The *goths* were selected based on brief interviews with local people along the Budhi Gandaki transect to find out about the location of the most intensively grazed pastures, mainly grazed by cows and yaks. We selected 6 *goths* in subalpine pastures and 1 in a temperate pasture. Of the 6 subalpine *goths*, 5 were situated in the Hinang pasture at the base of Himalchuli Peak. The 6th subalpine *goth* was selected from the pasture near the Hinang Gompa. These 6 subalpine *goths* lie within an elevational range of 3000–3600 m asl. The 7th *goth* was above Prok at 2400 m asl. All the pastures in these areas consist of grasses, bushes, and rocks.

A household survey in the areas selected for the species diversity study, as well as along the Budhi Gandaki transect, was conducted to record the number of livestock and collect information relating to grazing conditions and livelihood options.

From each selected *goth*, a 60-m-long transect was established. This was the maximum horizontal distance accessible along the entire transect reaching out from the door of each selected *goth*, due to rugged topography and the small size of available grazing area within the selected sites. In each transect, the livestock assembly area in the

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TABLE 1 Plant species with importance value index (IVI) >10 (unpalatable species) and <1 (preferred species).

Plant species	Importance value index (IVI)
Saccharum spontaneum L.	36.379
Rumex nepalensis Spreng.	24.273
Fragaria nubicola Lindl. ex Lacaita	21.023
Drymaria cordata (L.) Willd.	20.349
Potentilla microphylla D. Don.	13.878
Gentiana capitata Buch.-Ham. ex D. Don.	11.462
Cotoneaster frigidus Wallich. ex Lindley.	10.464
Trigonella emodi Benth.	10.367
Trifolium repens L.	10.3107
Ipomoea purpurea Linn.	0.828
Taraxacum officinalis Webb.	0.737
Polygonum virginianum L.	0.726
Anemone discolor Royle	0.547
Campanula aristata Wall.	0.498
Lonicera lanceolata Wall.	0.498
Rheum australe D. Don	0.4715

immediate vicinity of each *goth*—affected by higher disturbance and less vegetation than the pasture area to be studied (Riginos and Hoffman 2003)—was excluded for the first 10 m; we split up the remaining 50 m of the transect into 5 segments of 10 m length.

Vegetation sampling and species data

Two plots of 1 m × 1 m—one on either side of the *goth* transect—were established along each 10 m segment, thus making a total of 10 plots per *goth* and 70 plots in total. In each plot, the disturbance (in percentage) caused by grazing was recorded on the basis of a visual assessment of trampled and bare land area and the presence of dung (dry dung and marks of deposit) (Anderson and Currier 1973; Hendricks et al 2005).

All plant species in each 1 × 1 m plot were recorded, and the total number of plant species present in each plot was defined in terms of species richness (Klimek et al 2007). Plant identification was done in the field; for the unidentified ones, herbaria were prepared, and identification was done at the Herbarium of the Central Department of Botany (TUCH), Tribhuvan University, Kirtipur, Kathmandu, Nepal.

To assess livestock preferences for plant species, we used the importance value index (IVI, Table 1), which incorporates frequency and cover together with density (Ambasht 1990). These were calculated for each of the species over the entire sampling plot, since species composition changed according to elevation; those with high IVI values were concluded to be unpalatable species. The IVI was calculated following the relationship $IVI = RD + RF + RC/100$, where RF is the relative frequency, RD is the relative density, and RC is the relative cover (Ambasht 1990).

Data collection for GIS

The effects of grazing intensities can be quantified using the normalized difference vegetation index (NDVI) obtained by the Moderate-Resolution Imaging Spectroradiometer (MODIS) onboard the Earth Observing System Terra Satellite (Kawamura et al 2005). MODIS satellite images from the same time periods as the field visits were examined to assess grazing intensities in the area. For the GIS, 6 categories of grazing intensities were distinguished, ranking from 0 to 6 (0 = no grazing, 1 = 20% grazing, 2 = 40% grazing, 3 = 60% grazing, 4 = 80% grazing, and 5 = 100% grazing); they were evaluated using the procedures described by Anderson and Currier (1973), modified by Holechek and Galt (2000). The same categories were then used for determining disturbance gradients in the *goth* study.

As mentioned above, the GIS ground data were taken at regular 250 m intervals all along the Budhi Gandaki route. At each point, latitude, longitude, elevation, aspect, species data, and the value of grazing intensity within a pixel of 20 m × 20 m were noted. Grazing intensity was assessed by observing the forage removed, stubble height of plant species, number of remnant species numbers, and disturbances by livestock (dung and trampling). These methods were well established in the early part of the twentieth century and have been reviewed by Sharp et al (1994); they are not based on total annual growth but on the percent utilization at the time of sampling, and so this measurement is called "relative utilization." These data gave us the regional picture and were calibrated with the detailed *goth* study.

GIS and numerical analysis

Grazing intensities at each GCP were tabulated, and the table containing grazing intensities was pinned to a shape file containing the GCPs, using the *join and relate* option of ArcGIS. Using the *select by attribute* menu, each specific grazing intensity (0%, 20%, 40%, 60%, 80%, and 100%) was queried, and each intensity class was imported as a separate shape-file layer. Each layer was overlaid above the boundary layer of the MCA (extracted from the Conservation Area layer of MENRIS 2010). Finally, maps containing grazing intensities were prepared in ArcMap. The mean values of the grazing intensities were calculated

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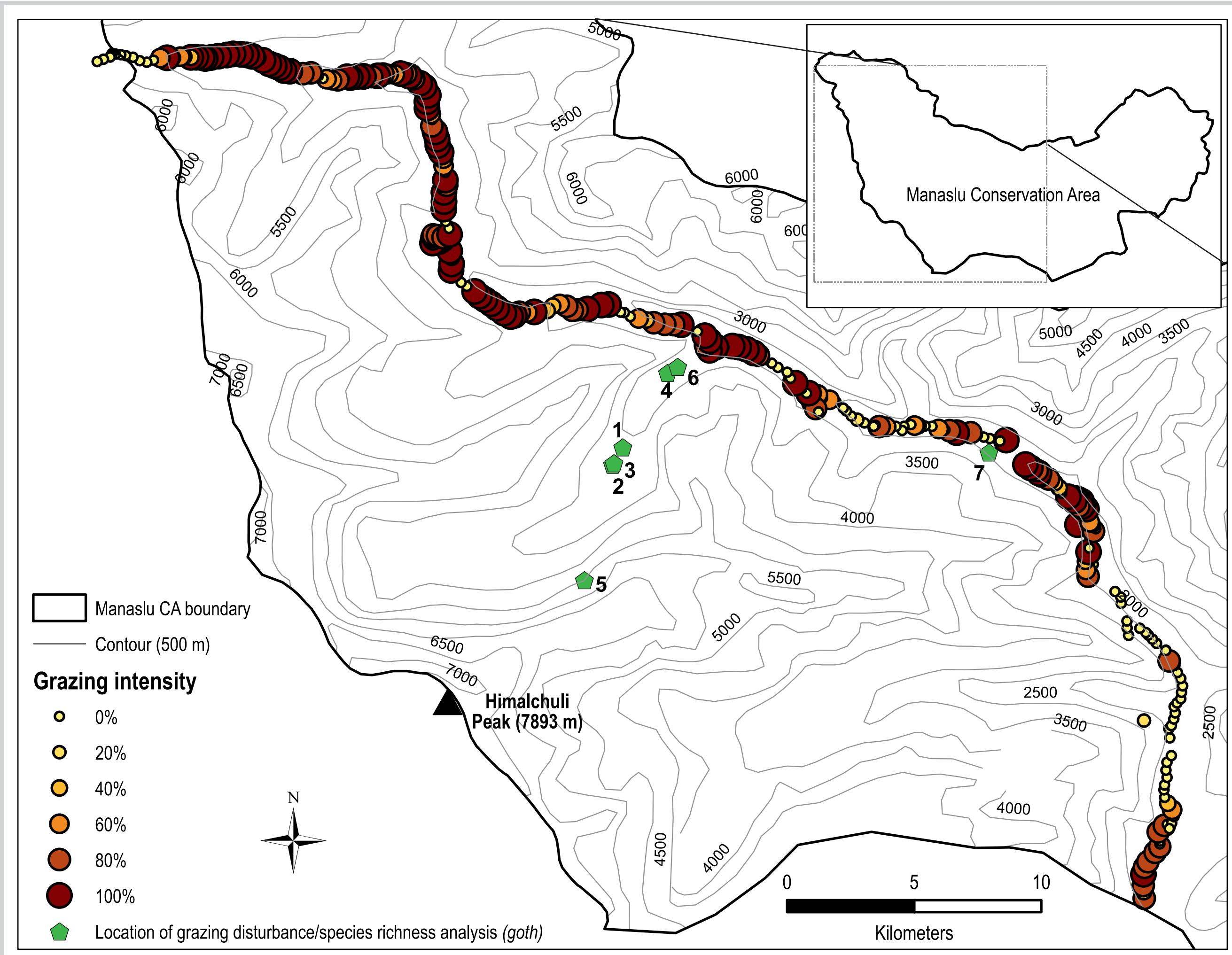
FIGURE 2 Map of MCA transect showing different grazing intensities and location of *goth* study sites.



for each ecological zone, starting from the subtropical zone (from 2000 m asl in this case) to the alpine region (>5000 m asl).

In order to further delineate the relationship between grazing and plant diversity, we used the more focused *goth* study. For calculating disturbance due to grazing and species number with respect to distance from the *goth*, the values at respective segments in all 7 *goths* were averaged. Analysis of variance (ANOVA) was applied to calculate variation in disturbance and species richness with distance from the *goth*, and differences in means among distances were compared with the Duncan multiple range test at $p < 0.05$. The relationships between distance from the *goth* and disturbance due to grazing, and distance from the *goth* and species richness were assessed using regression models. All statistical analyses were conducted with SPSS 16.0.

Results

Mapping of grazing intensities

The GCPs with different grazing intensities were analyzed and are presented in Figure 2. In 6 individual grazing intensity maps, 100% grazing had the maximum number of GCPs. The least points (below the average of all points with grazing intensities) were found with 20% grazing intensity. A moderate number of the GCPs had 40% and 60% grazing. Locations with an 80% grazing intensity dominated the data.

Not surprisingly, the areas with no recorded grazing were mostly in areas with rocky surroundings, rivers, settlement areas, and snow (above 5000 m asl). Likewise, very few points (only 2) were found with 20% grazing, 1 in Eklebhatti and 1 in Namrung. The GCPs with 40% grazing were found to be concentrated around Bihiphedi and

TABLE 2 Average herd size and grazing intensity along the elevation gradient.

Elevation range (m asl)	Number of households sampled	Average number of livestock[a] per household	Grazing intensity (%)
1400–2000	32	12	30.44
2000–3000	40	20.5	50.74
3000–4000	38	33	64.16
4000–5000	45	48	71.8
>5000	–	–	0

[a] Main livestock at lower elevations: cows, sheep, and goats; at higher elevations: cows, yaks, and yak/cow hybrids.

above Samdo. Similarly, concentrated numbers of points with 60% grazing were observed to fall around Namrung, Shyala, and Samdo, while 80% grazing was found to be located at almost all the places starting from Pewa up to 5000 m. GCPs with 100% grazing were the most common, and their maximum occurrence was found in the highest elevations.

Disturbance, species richness, and livestock grazing preferences

Grazing intensities varied along the elevational gradient (Table 2). The subtropical region showed the lowest average value of grazing intensity (with a mean of 30.4%), whereas the alpine zone showed the highest grazing intensity (71.8%); hence, we observed a pattern of increasing grazing intensity with increasing elevation, up to 5000 m asl. There was no grazing above 5000 masl. The average number of cattle increased at higher elevations up to 5000 masl, confirming the pattern of increasing grazing intensity (Table 2).

In the areas with reported heaviest grazing—the *goths* selected for detailed study—not unexpectedly, the mean

FIGURE 3 Relationship between distance from *goth* and average disturbance. Each marker represents the mean value; the error bars represent the standard deviation of the mean ($n = 14$). Different letters indicate significant differences at $p < 0.05$.

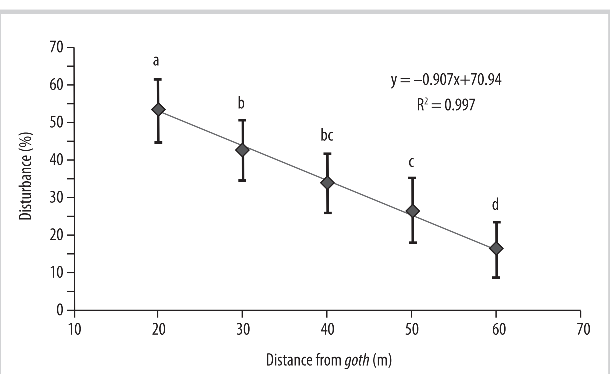
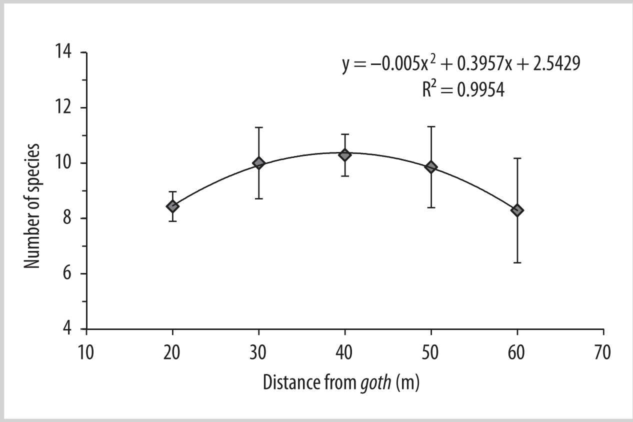


FIGURE 4 Relationship between distance from *goth* and number of species. Each marker represents the mean value; the error bars represent the standard deviation of the mean ($n = 14$).



value of disturbance varied significantly with distance from *goths* ($p < 0.001$) and was found to be the highest (53.6%) at the nearest distance from *goths* and the lowest (16.4%) at the farthest distance (Figure 3). Intermediate disturbance was recorded in the middle of the range. The linear regression analysis revealed a significantly negative relationship between disturbance due to grazing and distance from *goth* ($R^2 = 0.99$, $p < 0.001$).

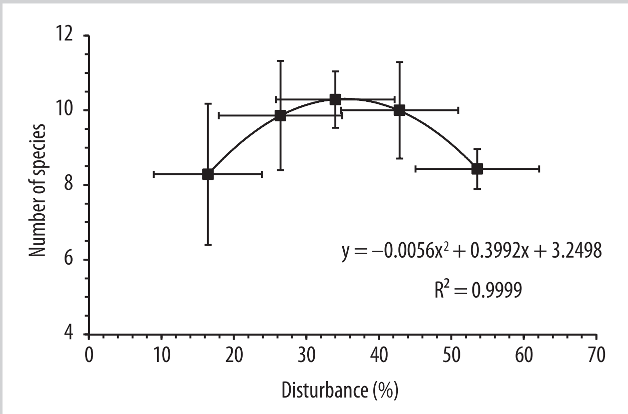
In total, 56 species (*Supplemental material*, Appendix S1: http://dx.doi.org/10.1659/MRD-JOURNAL-D-13-00066.S1), excluding ferns and mosses, were recorded in the 70 sampled plots. In each plot, the number of species varied with each 10 m increase in distance from the *goth*. The mean number of plant species varied significantly from the nearest to the farthest plot ($p < 0.05$). Species number was lowest in plots at 20 m and 60 m distance from the *goth*, while it was highest in middle plots (Figure 4). A polynomial second-order fit revealed a significant relationship between species richness and distance from the *goth* ($R^2 = 0.99$; $p < 0.01$). With regard to disturbance along the grazing gradient, species richness was recorded to be significantly higher ($R^2 = 0.99$, $p < 0.01$) at intermediate-disturbance levels (Figure 5).

Of the 56 species that were recorded, many were greatly preferred by livestock, and some were avoided (Table 1). The IVI of *Sachharum spontaneum* and *Rumex nepalensis* was found to be highest (36.37 and 24.27, respectively), making them the most unpalatable species. *Potentilla microphylla*, *Fragaria nubicola*, and *Drymaria cordata* were also found to be less palatable or unpalatable plants. *Ipomoea purpurea*, *Lonicera lanceolata*, *Polygonum virginianum*, *Anemone tetrasepala*, and *Taraxacum officinalis* were recorded as preferred plants (low IVI).

Discussion and conclusions

Species richness and species composition are related to numerous factors (Löffler and Pape 2008). The present study of the effect of grazing intensity and disturbance on

FIGURE 5 Relationship between disturbance and number of species. Each marker represents the mean value; the error bars represent the standard deviation of the mean ($n = 14$).



species richness in intensely grazed pastures of the MCA was carried out at different elevations along 60 m transects calculated from livestock assembly points (6 *goths* above 3000 m, and 1 at 2400 m), selected after an initial GIS campaign to map grazing intensities in the entire Budhi Gandaki valley. The distance from *goths* to their surroundings was tested as a disturbance gradient.

Our results showed that disturbance decreased with increasing distance from *goths*, while species richness increased, but species richness decreased again on the more distant plots. As distance from the *goth* represents the disturbance gradient, this relation, to some extent, can be interpreted as a response of species richness to grazing intensity (Pandey and Singh 1991; Löffler and Pape 2008). The higher species richness in intermediate-disturbance areas in this study agrees with the intermediate-disturbance hypothesis (Connell 1978; Grime 1979; Huston 1994), which has generally been verified and accepted in various other regions, including in the Himalayas (Vetaas 2002; Shea et al 2004; Bhattarai et al 2004).

There was variation in the grazing intensities at different settlement areas throughout the conservation area, as revealed by the GIS analysis of the Budhi Gandaki valley. While low grazing intensities (20–40%) were generally found at the places where there were less dense villages and households with smaller herd size, higher grazing intensities (60–100%) were found at most of the places, more specifically, in those areas where the herd size was large. Large herd size was primarily the result of animal husbandry being the major source of income in these areas, which have a lack of good cultivable land.

The grazing intensity increased with increasing elevation. Several factors affect grazing, mainly related to the distribution of grazing resources (Coughenour 1991; Adler et al 2001). In pasturelands with good grazing, higher vegetation densities have been found at intermediate elevational range in comparison to the highland and lowland areas (Bühler and Schmid 2001). In the MCA, the disturbance due to grazing was also moderate at intermediate elevations by comparison with the lower and higher elevations, in spite of the fact that grazing intensities increased with elevation. Indeed, at higher elevations, many of the nutrients stored in soil and plants from such a fertile habitat are taken up rapidly, produce fast-decomposing litter, and sustain a greater magnitude of herbivory (Hobbie 1992); high-elevation pastures harbor plants that complete their life cycle fast and are preferred by grazers, resulting in higher rates of grazing at higher elevations.

Another reason for increasing intensity of grazing at higher elevations was socioeconomic: with increasing elevation in such regions, the availability of goods and services decreases, and the dependency of people upon the natural resources like forests and pastures increases (Roder et al 2002). Sources of income other than animal husbandry in MCA are rare, contrary to other mountain areas of Nepal (Moktan et al 2008). Indeed, the number of cattle held by each household increased with elevation up to 5000 m (beyond which there is snow cover), and people extracted as much benefit as they could from their livestock by selling the animals in Tibet, selling meat, milk, and milk products, and using the animals for transportation. Thus, out-migration from the remotest areas, which we have observed in other valleys in the Nepalese Himalayas, has not yet affected the Budhi Gandaki valley, but this may change in the short term, as revealed in the interviews we conducted.

This study further substantiates—though with the limitation of not assessing other features such as biomass and productivity—that moderate disturbance increases species richness along a grazing gradient. Another limitation is that our 7 study sites for species richness were limited to a transect 60 m long, and this may not be enough to generalize a disturbance/species richness pattern. Indeed, Socher et al (2012) mentioned the need for further testing to determine whether the trend they observed was consistent, or whether there was variation beyond this distance, insisting that regional environmental differences impact possible generalizations of findings. Nevertheless, we believe that it is possible to draw implications of these findings for the management of pastures in the MCA, where the severity of grazing in terms of species diversity does not yet exceed capacity. Studies in high-elevation rangelands in the Himalaya show that total available fodder biomass is underutilized, because the total available supply is surplus to the present demand as population pressure decreases (Buffum et al 2009; Bhattarai and Upadhyaya 2013)—which may become the case in the Budhi Gandaki valley. The results of this study could help improve decision making related to sustainable pasture management of the MCA in terms of (1) the number of livestock allowed to graze per season and (2) the location of *goths* at each pasture, because there is clearly an overutilization of local biomass in the settlement and *goth* areas, in spite of a regional excess biomass.

It has been amply shown that selective consumption preferences of grazing animals change species composition (Mcintyre and Lavorel 1994; Brooks et al 2006) and that the response of forage species varies according to plants' ability to regrow after damage (Bryant et al 1991; John and Turkington 1995). Although many plant species are not resilient to grazing, there are reports of plants responding positively to herbivory, showing increased growth compared to the ungrazed state (Paige and Whitham 1987). However, if grazing intensity increases even more, loss of biomass will reach levels that cannot be maintained by regrowth, and productivity will decline. Also, within the study area of the MCA, many plants were found to be highly preferred, whereas some plants were neglected by the grazing animals, leading to an ongoing species transition. Observations during our field assessments showed that unpalatability due to secondary chemical substances, hard and indigestible plant parts, and presence of protective or defense organs of plants, such as spines and thorns, were obvious reasons why livestock were not attracted to those plant species.

To conclude, we have shown that grazing intensity varies in the different ecological zones in the MCA; it is low at lower elevations and increases with increasing elevation, concomitant with increasing herd size at higher elevations. At a smaller scale, disturbance due to grazing decreases with increasing distance from the *goths*, which in turn has an effect on species richness; species richness is highest with moderate disturbance along the grazing gradient. We would like to stress that grazing is still a major environmental challenge in pastures within the MCA, at least in the areas not yet affected by a decrease of the farming community due to the attractiveness of income-generating tourism, or those located along the tourist routes. Our results could be considered as a baseline for more rigorous studies considering larger sample size, more detailed vegetation analysis, carrying capacity analysis for grazing in different seasons, herd size, and other parameters.

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Supplemental material

APPENDIX S1 List of plant species recorded in the sampling plots.

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