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The effect of grazing management on plant species richness on the Qinghai-Tibetan Plateau

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Abstract

In Maqu County, Gansu Province, China, there are two types of grazing management. Under multi-household (MH) management, grassland is jointly managed by two or more households without fences between pastures. Under single-household (SH) management, fenced-off parcels of grassland are used. SH management was imposed in the belief that it would alleviate grassland degradation. Comparable land parcels with similar stocking rates subject to MH and SH management were identified and surveyed to determine the species present and species density (m^{-2}). MH land had greater number values than SH but the differences were not significant. A further analysis indicated that the number of households using MH land influenced species richness. There was also evidence to suggest that the quality of the forage available deteriorated under SH management. It was concluded that MH grazing resulted in greater species richness than SH and is perhaps an important contributor to biodiversity conservation and grassland management for the region.

Keywords: multi-household grazing management, single-household grazing management, plant species richness, Maqu County, Gansu Province

Introduction

Anthropogenic land use has transformed large proportion of the planet's surface because the consumption of natural resources generally occurs at the expense of the environment (Foley *et al.*, 2005). Land use can cause a decline in biodiversity (Maurer *et al.*, 2006) and change in vegetation composition (Ao *et al.*, 2008) through the loss, modification and fragmentation of habitats, degradation of soil and water and overexploitation of native species (Pimm and Raven, 2000). At present, land-use change is a major threat to species diversity of grasslands throughout the world (Maurer *et al.*, 2006).

The Qinghai–Tibetan plateau occupies 2·5 million km^2 (approximately 25% of the P.R. China). About 70% is high-altitude, cold, alpine rangeland that has a diverse array of plant and wildlife species. Maintenance of plant-species richness is of national and global importance yet many species are declining because of degradation (Smith and Foggin, 1999). Some researchers (e.g. Gimenez, 2002) have suggested that changes in land use have caused degradation and reduced plant biodiversity, but few field experiments have been conducted to demonstrate these effects. For thousands of years, cold-tolerant livestock grazing by nomadic herders on the Qinghai-Tibetan plateau was the dominant and apparently environmentally sustainable land use (Yan *et al.*, 2005). However, in the late 1970s, policy reform led to settling of nomadic farmers, livestock being divided up and individual family leasing of state-owned pasture (Manderscheid, 2001) in the belief that open access of privately owned livestock to common rangeland had led to rangeland degradation, known as 'the tragedy of the commons' (ToC) (Hardin, 1968; Yan *et al.*, 2005). There is evidence, however, to suggest that theory is not universal (Crépin and Lindahl, 2009) and that common ownership in the right social setting might be environmentally beneficial. After policy reform, there are predominantly two land-management types: single household (SH) and multi household (MH). For MH, grassland is jointly managed by two or more households without boundaries between household pastures, while for SH, grassland is fenced off and managed by one household. If the number of

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households is large enough, MH grassland management is similar to nomadic land use, while SH represents the ideal for the theory of individual ownership. The objective of this research note is to examine the effect on plant-species richness of grazing management under SH (less likely to cause degradation according to ToC theory) and MH ownership (more likely to cause degradation according to ToC theory).

Materials and methods

The Maqu County grassland ecosystem is about 870 000 ha located in the Gansu Province of China on the eastern part of the Qinghai-Tibetan plateau, (101°E; 34°N). The altitude ranges from 2900 m to 4000 m with an annual rainfall of 450 to 780 mm and an annual average temperature of 1·8°C (ranging from minima of −10·7°C in January to 11·7°C in July and growing season maxima of 23·6°C to 28·9°C) with 270 frost days annually. The grassland types include alpine meadow (59%), brushy meadow (33%), woodland meadow <1%), saline meadow (<1%), swampy meadow (6%) and upland grass (1%) (Bu *et al.*, 2006). The estimated number of vascular plant species is over 530, with fifty-seven families and 204 genera.

Since 1995, grassland has been progressively allocated to SH and MH grazing systems. A typical household grazes sheep and yak, with stocking rates of around two animals per hectare. When nomadic grazing stopped, herders usually choose winter grasslands (typically alpine meadow) as their home place because these grasslands are considered more productive under natural conditions and trafficable at most times of the year. The assessment of grassland conditions was carried out on these traditional winter grasslands at the beginning of July. Only land that had been grazed at the same time, had similar stocking rates (two sheep per ha as overseen by Government Agencies) and had the same alpine meadow grassland type was selected. All sampling was performed over 1 week in dry weather on a randomly selected 50 × 50 m plot on winter grazing land of thirty SH and thirty MH areas of rangeland each used by a different family/combination of families. All sampling was conducted within an area of about 36 km^2. Within each representative plot, three quadrats (50 × 50 cm) were laid out at random locations and orientations and the species richness was expressed as the mean species count per m^2 for each plot.

The coverage of individual species was also visually estimated by the same observer for each plot. Land management was classified by the number of households with right of access and a regression analysis of species richness and household pressure (number of households with access to the land parcel) was performed using SPSS 15.0 (SPSS Inc. Chicago, Illinois, USA) statistical software.

Results

The ten most common plant species found on the observation quadrats (Table 1) varied by land management. Under SH management, quality forage typified by *Poa pratensis* (a grass) was no longer common and forbs such as *Ligularia virgaurea, Anemone rivularis var. floor-minore* and *Taraxacum mongolicum* became more common. When summarized, the species richness of MH (22·3 ± 3·9) was marginally higher than that of SH (21·0 ± 3·6), but this difference in species richness was not significant. It was not possible to establish whether this was a progressive trend that might indicate further

Table 1 The 10 most common species found in winter alpine grassland of single-household (SH) and multi-household (MH) management in the Maqu County survey.

Species	SH	Rank SH	MH	Rank MH
Anemone rivularis var. folre-minore (F)	5·9 (±3·6)	8		
*Elymus nutans** (G)	13 (±16)	6	19 (±15)	7
*Festuca sinensis** (G)	14 (±8)	4	25 (±11)	2
Gueldenstaedtia diversifolia (L)			22 (±14)	4
Kobresia capillifolia (G)	22 (±21)	1	24 (±20)	3
Kobresia humilis (G)	4·1 (±1·7)	10		
Lancea tibetica (F)			19·3 (±10·7)	6
Ligularia virgaurea (F)	11·9 (±13·7)	7		
*Poa pratensis** (G)			20 (±12)	5
Potentiualfragarioides (F)	15·6 (±11)	3	16·1 (±11·5)	8
Ranunculus angutisus var. capillaceus (F)			12 (±9)	10
*Scirpus distigmaticus** (G)	19 (±17)	2	26 (±15)	1
Taraxacum monongolicum (F)	5·3 (±3·4)			
Thalictrum alpinum (F)	13 (±8·1)	5	15 (±12·2)	9

G, Grass or sedge; F, Forb; L, Legume; *preferred by herders.

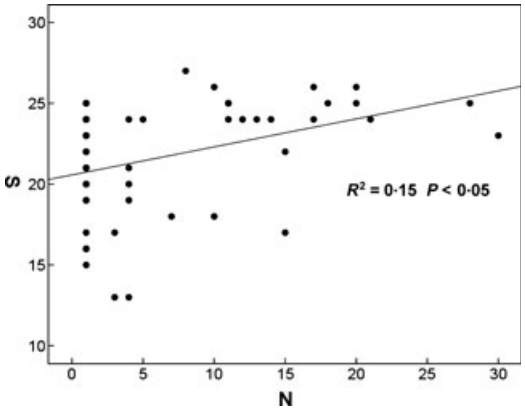

Figure 1 The relationship between plant species richness (S) and the household number (N) found from the Maqu Country survey.

species decline. The regression of species richness and number of households (Figure 1) indicated that the plant species richness increased as the household number increased. The overall coverage of MH (92·4 ± 5·7%) relative to SH (89·2 ± 6·5%) was not significantly different.

Discussion

The results indicated that grassland species richness was linked to household access and the intensity with which animals grazed the grassland resource on a year-round basis. SH management has little access to a range of pasture types (i.e. only alpine meadow as sampled in this study), so the land has to be used at times when it would traditionally be rested (e.g. the shift from winter to summer grazing grounds and *vice versa*), whereas MH landholdings can be managed in a more traditional manner with alpine meadow allocated to the most suitable grazing season. Therefore, there is more sustained grazing pressure on the plant assemblage in SH plots than in MH plots because of trampling (Ao *et al.*, 2008) and non-selective grazing (Milchunas *et al.*, 1998).

Generally, trampling causes grassland degradation when overgrazing occurs (Yang, 2007). In SH land, *Ligularia virgaurea* (9·3 ± 10% coverage), *Anemone rivularis var. floor-minore* (5·4 ± 3·9% coverage) and *Taraxacum mongolicum* (5·3 ± 3·4% coverage) are regarded as indicators of degradation because they are poisonous plants that exploit gaps exposed by grazing pressure (Zhang *et al.*, 2003; Xie *et al.*, 2010). Poisonous plants were observed to be more common on SH land. This suggests that SH might be causing further serious degradation and productive forage species may be declining as these contrasting management systems have been in place since around 1996.

On the MH plots the owners have more management options for optimizing grazing (Gimenez, 2002). It would also appear that the social pressure assumed by the theory of the 'tragedy of the commons' has not applied. Individuals seem not to have taken personal short-term benefits at the expense of neighbours. This presumably reflects a tradition of nomadic cooperation. At the smaller management scale associated with SH, decreased resource heterogeneity may have contributed to decreased niche dimensions leading to the loss of grassland species richness (Olff and Ritchie, 1998; Spiegelberger *et al.*, 2006; Harpole and Tilman, 2007) and to the introduction of new species because of bare soil being exposed. In this case, stocking rate was not an issue because all plots had the same nominal stocking rate as regulated by the government authorities.

Conclusion

The results of this study suggest that having a choice of grazing land associated with natural seasonality, and sufficient area to permit variable grazing patterns through the year, could protect plant diversity on the Qinghai-Tibetan plateau. Under MH (or even nomadic management), livestock can use abundant low-quality food and create frequent but small disturbances, and spatially heterogeneous urine and dung deposition, across the landscape that then aids plant recruitment, (Olff and Ritchie, 1998). To achieve sustainable rangeland management, lessons from traditional management (Yan *et al.*, 2005) could perhaps be adapted to permit controlled development of the resource without unwanted side effects. The results of this study indicate that single-household management will probably cause a decrease in plant diversity by focusing continuous and higher grazing pressure on small areas of grassland unless other tactics are imposed. The grassland policy of the Chinese government should perhaps consider MH management or even group management to maintain plant diversity because communal grazing may not degrade the resource if other factors, e.g. stock density, are appropriate.

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