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Variation of botanical composition, forage production and nutrient values along a grassland degradation gradient in the alpine region of Qinghai-Tibet Plateau

Variación de la composición botánica, producción de forraje y valor nutritivo a través de un gradiente de degradación de pastizales en la región alpina del Plateau Qinghai-Tibet

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Abstract. The alpine grassland in the Qinghai-Tibet Plateau is an extensive rangeland ecosystem sustaining a sparse population of traditional nomadic pastoralists in China. However, global climate change and anthropologic disturbances have severely degraded the alpine grasslands, and the consequences of this degradation are largely unknown. Forage is the only food source for livestock in the alpine region, and livestock is the major income source for nomadic herders. Therefore, it is critical to assess the forage quantity and quality along the current grassland degradation gradient. In this study, we examined the botanical composition, biomass of different functional groups, and forage grass nutritive values, and classified forage grasses according to their biological condition: lightly degraded, moderately degraded, heavily degraded and severely degraded grasslands. A sharp reduction in vegetative production and variations in botanical composition, plant coverage and nutritive values were associated with increasing degrees of degradation of the alpine grassland. Changes in botanical composition resulted in lower nutritive values in more than in less degraded alpine forage grasses. Given the productive importance of the alpine grassland, urgent action is extremely essential to protect it from degradation.

Keywords: Aboveground biomass; Alpine grassland; Degradation gradient; Forage nutrient; Qinghai-Tibet Plateau; Vegetation composition.

Resumen. El pastizal alpino en la meseta del Tibet-Qinghai es un ecosistema de pastizales extensivo que alimenta a una población desparramada de pastores nómades tradicionales en China. Sin embargo, el cambio climático global y los disturbios antropológicos han degradado severamente los pastizales alpinos, y las consecuencias de esta degradación son mayormente desconocidas. El forraje es la única fuente de alimento para al ganado en la región alpina, y la ganadería es la principal fuente de ingreso para los pastores nómades. Por lo tanto, es crítico medir la cantidad y calidad de forraje a lo largo del actual gradiente de degradación del pastizal. En este estudio, examinamos la composición botánica, biomasa de diferentes grupos funcionales, y valor nutritivo del forraje de gramíneas, y clasificamos a las gramíneas forrajeras de acuerdo a su condición biológica: pastizales poco degradados, moderadamente degradados, muy degradados y severamente degradados. Una fuerte reducción en producción vegetativa, y variaciones en la composición botánica, cobertura vegetal y valores nutritivos se asociaron con mayores grados de degradación del pastizal alpino. Cambios en la composición botánica resultaron en menores valores nutritivos en gramíneas forrajeras alpinas más *versus* menos degradadas. Dada la importancia productiva del pastizal alpino, se necesita hacer algo de inmediato para protegerlo de la degradación.

Palabras clave: Biomasa aérea; Pastizal Alpino; Gradiente de degradación; Nutriente de Forraje; Meseta Quinghai-Tibet; Composición de la vegetación.

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INTRODUCTION

Natural grasslands are extremely important for cattle rising, and especially for the agro-pastoralist and nomadic herders that depend almost exclusively on these ecosystems (Dong et al., 2011). Native forage is the only nutrient and energy source for livestock because stored hay or concentrated livestock feed are unavailable. The nutritive value of the forage not only determines its nutritive composition, but also provides an estimate of its quality (Burns, 2011). However, grassland degradation has already been threatening sustainable development of pastoralism in recent years (Harris, 2010). It is necessary to assess the productivity and nutritive value of native forages to restore the vast rangelands. Current research assessing the productivity and nutritive value of forages is sparse, with inadequate studies focusing on the nutrient requirements of grazing animals (Feng, 2004).

Especially for Qinghai-Tibet Plateau (QTP), the highest and largest plateau in the world with a mean altitude higher than 4000 m.a.s.l. (Feng et al., 2010; Zhang et al., 2010), it is extremely critical to assess the nutritive value of forages. In this region, over 85% of vegetative cover is composed of alpine grasslands, where livestock grazing is regarded as the major form of land use and source of income (Dong et al., 2010; Harris, 2010). With a carrying capacity of 30 million sheep and goats, and 12 million native yaks, the QTP supports the livelihoods for about 5 million agro-pastoralists and nomadic herders without degradation (Miller, 2005). However, growing demand for food and rising affluence have intensified grazing and accelerated the degradation of the QTP (FAO, 2005). Consequently food availability and pastoral livelihood in the QTP have been adversely affected by the degradation of the alpine grassland. This has been the result of biotic causes such as overgrazing, and abiotic causes such as the increased frequency of extreme droughts because of global climate change (Harris, 2010). The annual rate of degradation has been reported to be from 6.64 to 34.45% in this area during the past 40 years (Wang & Chen, 2001). As a result of grassland degradation, vegetation composition changed and native forage productivity declined (Zhou et al., 2005; Wang et al., 2006; Zhang et al., 2006; Wang et al., 2008).

Similar rangeland ecosystems exposed to the effects of grazing animals have been studied for their productivity and nutritive management. Some scholars focused on the influence of different grazing managements on forage quality. García et al. (2008) compared a complementary forage rotation (CFR) *versus* a grass pasture in Australia to investigate if the CFR treatment could increase the total supply of feed resources and improve feed quality. Čop et al. (2009) examined the effects of cutting and fertilization on forage nutrients in southern Ljubljana of Slovenia in central Europe. Verlinden et al. (2010) evaluated the effects of humic substances on vegetative production and nutritive values of sown grass pastures. Arzadun & Mestelan (2009) found that forage nutritive value of the lowland natural grasslands of the Salado River Basin in Argentina was negatively impacted by grass defoliation. There were also some scholars who paid attention to the variations of forage quality with vegetation composition. Rosenbaum et al. (2011) investigated the influence of invasive weeds on nutritive value of tall fescue (*Festuca arundinacea)* sown in pastures in Missouri. Deak et al. (2007) examined the nutritive value of mixed forage under grazing in the northeast USA, and found that nutrient quality was very influenced by the proportion of legume in the mixture. Other scholars investigated the effect of grazing on grass nutrients. Nave et al. (2010) stated that different grazing strategies would influence the grass nutritive value in Brazil. Wang et al. (2011) analyzed forage availability in Inner Mongolian steppes of China; they concluded that the (1) crude protein of forage decreased and (2) neutral detergent fiber increased along an increasing gradient of grassland degradation, causing a decrease in dry matter intake.

However, limited information is available on nutritive value of alpine grasslands in the QTP. Dong et al. (2003) investigated the productivity and nutritive values of an artificial establishment of mixed perennial grasses in the Tibetan Plateau. Guo et al. (2007) analyzed the seasonal dynamics of nutritive value on native forages in 2005. Little is known on the effects of different degradation conditions on forage nutrient content.

Many researchers concluded that the current productivity of plateau grasslands is approximately 30% lower than two decades ago (Zhou et al., 2005). In 1997, the fresh biomass production from alpine grasslands was about 400 kg/ha, which represents only 13% of the biomass on non-degraded grassland in the plateau (Wang et al., 2008). However, literature concerning the changes in nutritive value of the vegetation along a grassland degradation gradient in the alpine region of the QTP are insufficient and inadequate. Also, the impacts of degradation on grazing animals native to the QTP and the traditional pastorals whose livelihoods depend on their production have been poorly investigated. It is critical to examine the dynamics of forage production and nutritive value along environmental degradation gradients to improve grazing management for the alpine grassland on the QTP. Therefore, our hypothesis is that forage productivity and nutritive value decrease as grassland degradation, increases in the vast Qinghai-Tibetan Plateau. Chemical composition and forage yield are standard analyses for estimating forage availability of different grasslands (Norland et al., 1985; Wang et al., 2003). Thereafter, we analyzed forage dry matter yield, and forage content of crude protein (CP), crude fat (CF), organic matter (OM), neutral-detergent fiber (NDF), and acid-detergent fiber (ADF) on four study areas in the alpine grassland, each having a different degree of degradation. The aims of this study were: (i) to investigate the variation of botanical composition, forage yield and nutritive value in the grasslands exposed to different degradation levels; (ii) to examine the relationships between botanical composition, forage production and nutritive value along grassland degradation gradients. This is very important to (1) better understand the variations of forage quality with grassland degradation, (2) estimate the carrying capacity based on the forage production and quality, and (3) propose feasible restoration interventions for improving forage quality.

MATERIALS AND METHODS

Study area. The study was conducted at Dawu village (34º 30' - 33° 34'N, 100° 29'- 99° 54' E), which is located in Maqin country Golog national municipality of Tibetan of Qinghai Province, China (Fig. 1). The average altitude of this area is 4500 m.a.s.l. The annual climate typically has one rainy period between July and September, which is the peak growing time for alpine grasses, and a long dry season without any frost-free period (Guo et al., 2007). The mean annual temperature is -1.7 °C, and mean annual precipitation is 600 mm. The plateau, the largest alpine grassland ecosystem in China, sustains herds of unique livestock like the grazing yak (*Bos mutus)* and the Tibetan sheep (*Ovis ammon)*. In this area, livestock prefers to eat *Polygonum macrophyllum* and *P. umviviparum*. *Ligularia virgaurea* and *Leontopodium nanum* are highly unpalatable forbs. In this study, we examined forage production, botanical composition and nutrient content of vegetation across a degradation gradient in the alpine grasslands from July to August.

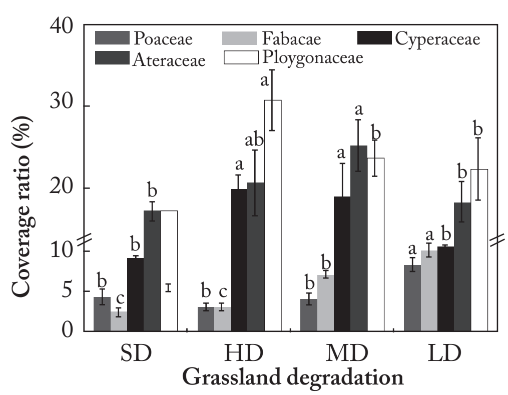

Fig. 1. Plant cover of five families (Poaceae, Fabacae, Cyperaceae, Asteraceae, Polygonaceae) in the degraded QTP alpine grasslands. SD, HD, MD and LD represent severe degradation, heavy degradation, moderate degradation and light degradation. Different lower-case letters indicate significant differences among different study sites by the t test ($p<0.05$).

Fig. 1. Cobertura vegetal de cinco familias (Poaeceae, Fabaceae, Cyperaceae, Asteracae, Polygonaceae) en al pastizal alpino degradado QTP. SD, HD, MD y LD representan degradación severa, alta degradación, degradación moderada y poca degradación. Diferentes letras minúsculas indican diferencias significativas entre diferentes sitios de estudio por el test de t (p<0,05).

Experimental procedure. In this study, a chronosequence approach (space-for-time substitution) was used to obtain integrated information, including vegetation composition (VC), plant coverage (PC), density (PD) and weight (PW). Four types of degraded grasslands were identified in the study area based on Ma et al's (2002) criteria of alpine grassland degradation during June 2008. They were categorized as: lightly (LD), moderately (MD), heavily (HD) and severely (SD) degraded. For each type of degraded grassland three patches were randomly selected. In each patch, three 1 m × 1 m quadrats were randomly placed for sampling vegetation and measuring PC, PD and PW. All species in each plot across the degraded gradient were recorded and identified based on their morphological, structural and floral characteristics. The importance value (IV) of each species was calculated by the following formula (Ren, 1998):

$$IV = (C' + D' + B') / 3$$

Where C' represented the relative cover of each species (defined as the percent cover of a selected species to the total cover of all species); D' represented the relative density of each species, and B' represented the relative dry biomass of each species. In this study, we define the species with an IV greater than 20 as a dominant species, and those with an IV between 10 and 20 as subdominant species.

Aboveground mass was obtained by cutting with hand-scissors at ground level in each quadrat, and sorted by species. The total fresh weight of forage grasses in each plot was measured immediately after harvesting using a 0.01 g sensitive balance. The vegetation in each plot was further classified into five different botanical families (Poaceae, Fabacae, Cyperaceae, Asteraceae and Polygonaceae). The botanical samples were oven dried separately at 65 °C for 48 h until constant weight and then weighed. Then dried forage samples were grounded in a mill with a 1 mm mesh sieve before analyzing dry matter (DM, %), crude protein (CP, %), organic matter (OM, %), crude fat (CF, %), neutral-detergent fiber (NDF), and acid-detergent fiber (ADF).

VC is defined as the ratio of the cover of different botanical families (Poaceae, Fabaceae, Cyperaceae, Asteraceae and Polygonaceae) to the total herbaceous cover of the study site. Biomass weight composition was calculated for each botanical family as the ratio between the weight for that family (Poaceae, Fabaceae, Cyperaceae, Asteraceae and Polygonaceae) to that of the total herbaceous biomass weight of the study site.

Chemical analyses. Nitrogen (N) was determined by using the Kjeldahl method (AOAC, 1990). Organic matter was measured by the chromic acid titration method (spontaneous heating) (Walkely & Black, 1934). CP was calculated as N percentage multiplied by 6.25. NDF and ADF concentrations were determined following Van Soest et al. (Van Soest et al., 1991). CF content was measured using an auto fat analyzer (SZF-06).

Statistical analyses. All data sets were subjected to one-way analysis of variance (ANOVA) to test for statistical differences along the degradation gradient (Steel & Torrie, 1980). Correlation analysis was conducted to test the relationship between production, nutrient value and botanical composition at the significant level of α=0.05 and α=0.01. The statistical analyses were carried out using SPSS 16.0 software for Windows (SPSS Inc., Chicago, IL, USA). The graphs were drawn by the Origin 8.0.

RESULTS

Botanical composition. A total of 71 herbaceous species were identified in all the experimental plots. Of these, 7 were of the family Poaceae, 3 were legumes and 61 were forbs belonging to 21 distinct families. A majority of plants were low palatable perennial forages, whereas only 6 annual forages were found to be palatable.

Degradation resulted in significant changes in the structure of plant communities in the QTP (Table 1). It is clear that unpalatable forages increased in botanical composition among plant communities along the increasing grassland degradation gradient.

PC of five botanical families varied at different degradation levels of the alpine grassland (Fig. 1). The PC of Fabaceae decreased the most along the degradation gradient, while other families showed variable trends. The PC of Gramineae in the LD grassland was significantly higher (α=0.05) than all remaining grasslands in the study. For Cyperceae, the PC in the LD and SD grasslands were significantly lower than values in the HD and MD grasslands. HD grasslands, Polygonaceae was the most dominant of all botanical families in terms of coverage. Asteraceae reached higher values of PC under MD than under LD and SD (Fig. 1).

Forage production. Along the increasing grassland degradation gradient, fresh matter yield (FMY), dry matter yield (DMY) and PC decreased (Table 2). The FMY, DMY and PC were significantly lower (α=0.01) in the SD than in the other grasslands. All of these parameters were greater (α=0.01) in the LD grassland than in other grasslands. Forage yields significantly decreased proportionally to the severity of degradation in the alpine grasslands. No matter the level of degradation, both FMY and DMY of different families varied greatly (Fig. 2a, 2b). With increasing severity of degradation, biomass weight composition of Gramineae and Fabaceae decreased. The dynamics of biomass weight compositions in both the Cyperaceae and Asteraceae were similar along the grassland degradation gradient, significantly (α=0.05) increasing at first, but decreasing thereafter. For Polygonaceae, biomass weight composition of forage plants in the HD, MD and LD grasslands was significantly (α=0.05) greater than that in the SD grassland. The weight composition in biomass of Polygonaceae in the HD grassland was the highest, irrespective of the desertification level.

Nutritive value. Figure 3 shows that organic matter (OM), crude protein (CP), crude fat (CF), neutral-detergent fiber (NDF) and acid-detergent fiber (ADF) concentrations varied greatly among forages at different severities of grassland degradation. Forage organic matter increased significant-

Table 2. Plant cover and forage production in differently degraded grasslands.
Tabla 2. Cobertura vegetal y producción de forraje en pastizales con distinto grado de degradación.

	Plant cover (%)	Fresh matter yield (g/m²)	Dry matter yield (g/m²)
SD	55 ± 3.1 C	345.5 ± 63.5 C	134.0 ± 8.0 D
HD	101 ± 0.5 B	651.5 ± 26.9 B	198.9 ± 10.1 C
MD	131 ± 5.2 B	776.2 ± 27.2 B	240.0 ± 6.0 B
LD	187 ± 6.8 A	867.7 ± 66.7 A	280.9 ± 8.0 A

Note: SD, HD, MD and LD represent severely degraded, heavily degraded, moderately degraded and lightly degraded grasslands; means with different capital letters are significantly different (α=0.01).
Nota: SD, HD, MD y LD representan pastizales severamente degradados, muy degradados, moderadamente degradados y poco degradados, respectrivamente. Promedios con letras mayúscula distintas son significativamente diferentes (α=0,01).

Table 1. Vegetation characteristics of the study sites.
Tabla 1. Características de la vegetaciòn de los sitios de estudio.

SD	IV	HD	IV	MD	IV	LD	IV
Ligularia virgaurea	26.0 ± 2.4	*Ligularia virgaurea*	16.3 ± 2.1	*Polygonum macrophyllum*	22.6 ± 1.3	*Polygonum macrophyllum*	24.1 ± 1.1
Leontopodium nanum	13.0 ± 1.1	*Polygonum viviparum*	14.6 ± 1.6	*Ligularia virgaurea*	16.3 ± 1.6	*Ligularia virgaurea*	15.4 ± 1.7
		Polygonum macrophyllum	10.1 ± 0.9				

Note: SD, HD, MD and LD represent severe degradation, heavy degradation, moderate degradation and light degradation, respectively. IV represents the importance value of each species.
Nota: SD, HD, MD y LD representan pastizales severamente degradados, muy degradados, moderadamente degradados y poco degradados, respectivamente. IV representa el valor de importancia de cada especie.

ly from 90.6% in SD grassland to 90.8% in the MD grassland (α=0.05). However, in LD grassland total organic matter was lower than that at the MD grassland. Total organic matter and forage CP concentrations along the grassland degradation gradient showed the same trends; CP concentrations increased from 7.0% in the SD grassland to 12.9% in the MD grassland. CP concentrations of forage in the LD grassland were lower than those in MD grassland. Along the grassland degradation gradient, there was a continuous decline in forage CF concentration, with the maximum CF concentration (5.8%) in the SD grassland, and the minimum (3.6%) in the

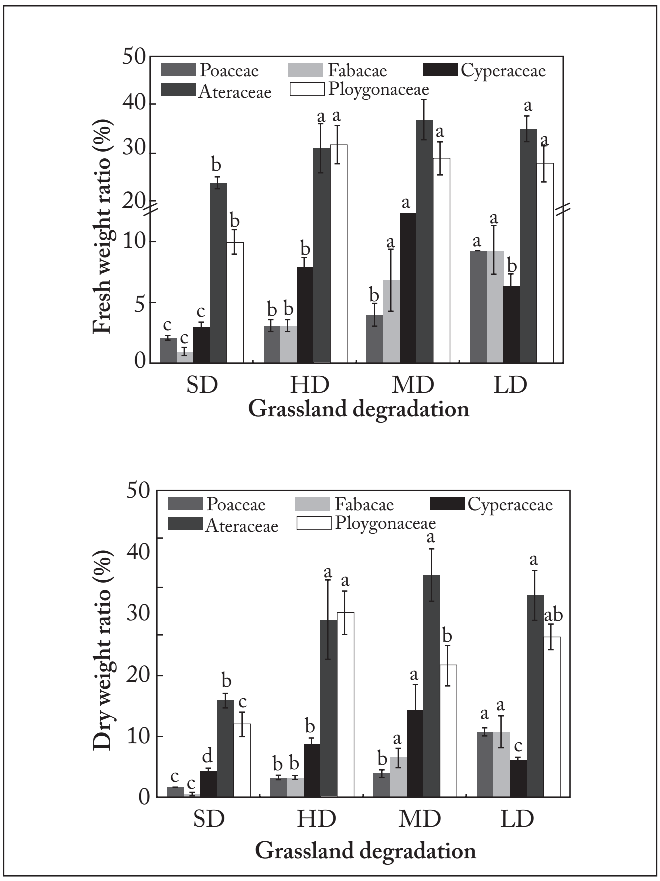

Fig. 2. Biomass weight composition of five different families (Poaceae, Fabacae, Cyperaceae, Asteraceae, Polygonaceae) in the degraded alpine grasslands [(a) for fresh weight ratio and (b) for dry weight ratio]. SD, HD, MD and LD represent severe degradation site, heavy degradation site, moderate degradation site and light degradation site. Different lower-case letters indicate significant differences among different study sites by the t test ($p<0.05$).

Fig. 2. Composición de la biomasa verde de cinco familias diferentes (Poaceae, Fabaceae, Cyperaceae, Asteracae, Polygonaceae) en los pastizales alpinos degradados [(a) para la relación de peso fresco y (b) por la relación de peso seco]. SD, HD, MD y LD representan el sitio con degradación severa, el sitio muy degradado, el sitio con degradación moderada y el sitio con poca degradación. Letras minúsculas distintas indican diferencias significativas entre los diferentes sitios de estudio por el test de t $p<0.05$).

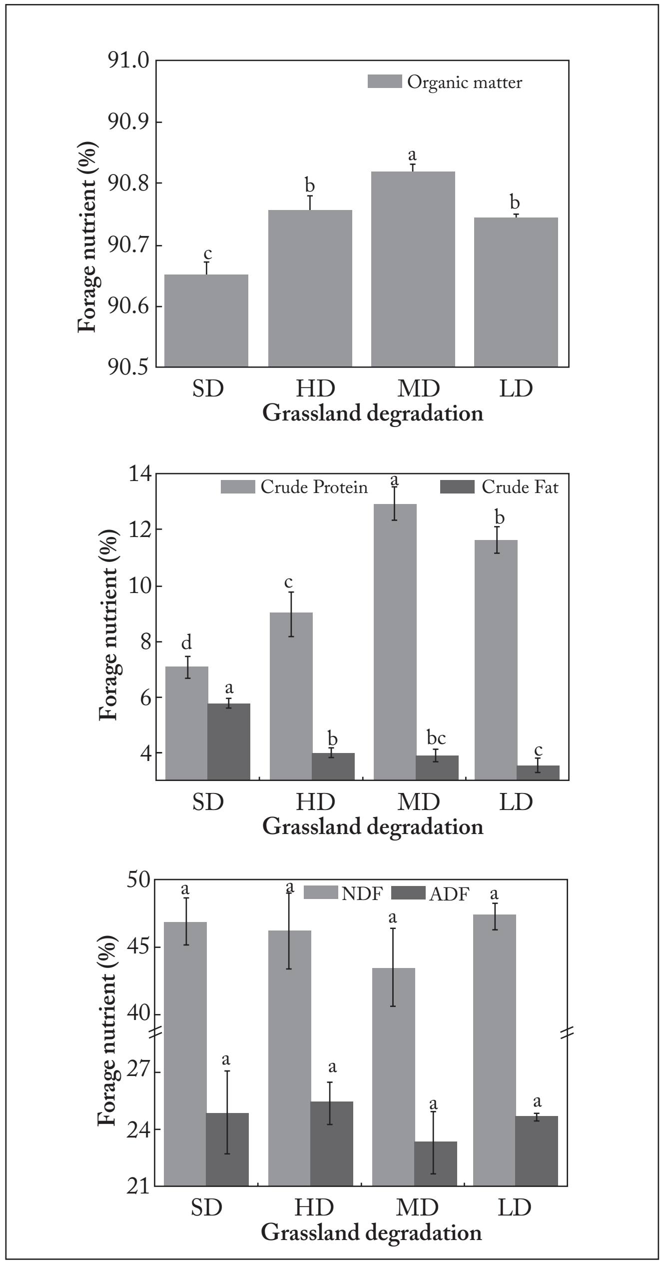

Fig. 3. Nutrient value of forages in the grasslands with different degradation gradients [(a) for organic matter, (b) for crude fat and crude protein, and (c) for NDF and ADF]. SD, HD, MD and LD represent severely degraded, heavily degraded, moderately degraded and lightly degraded grassland. NDF: neutral-detergent fiber, ADF: acid-detergent fiber. Different lower-case letters indicate significant differences among different study sites by the t test ($p<0.05$).

Fig. 3. Valor nutritivo de forrajes en los pastizales con diferentes gradientes de degradación [(a) para materia orgánica, (b) para grasa cruda y proteína cruda, y (c) para NDF y ADF]. SD, HD, MD y LD representan pastizales severamente degradados, muy degradados, moderadamente degradados y poco degradados. NDF: fibra detergente neutra, ADF: fibra detergente ácida. Diferentes letras minúsculas indican diferencias significativas entre los distintos sitios de estudio por el test de t ($p<0,05$).

LD grassland. The lowest concentration of NDF and ADF were found in the MD grassland (Fig. 3c).

Relationships between production, nutrient values and botanical composition. In this study, we used a correlation analysis to check if there was any relation between productivity, nutritive value and botanical composition (Table 3). The results showed a positive relationship (α=0.05) between plant cover and productivity in both DMY and FMY. Correlation analysis showed that organic matter was positively correlated to CP, but negatively related to CF, NDF and ADF. CP was negatively related to CF, NDF and ADF. NDF was positively related to ADF. These changes may be closely associated with the shift in botanical composition (Table 4, Table 5). OM was positively related to plant composition in cover, fresh weight and dry weight of the five botanical families. However, OM content was negatively related to weed composition both in cover and biomass. CF was negatively related to the cover of Fabaceae, Cyperaceae, Asteraceae and Polygonaceae. CP was positively related to the cover of each botanical family and biomass of all botanical groups, except for weed composition. NDF was negatively (α=0.05) related to Asteraceae composition in cover.

DISCUSSION

In rangeland grazing systems, it is critical to evaluate forage quality to know the amounts of protein and energy supplied by forages to sustain livestock. For estimating forage quality, knowledge of the chemical composition and forage yield is necessary (Wang et al., 2003). On the QTP, grasslands are the single source of nutrients for grazing ruminants, since supplement feeds are not available. Therefore, the productivity and quality of grassland forage play an essential role in the alpine region. Both chemical composition and forage yield are main factors used for estimating forage availability of different grasslands. In this study, we examined forage production, botanical composition and nutrient content of vegetation across a degradation gradient in the alpine grasslands during the peak growing time (Guo et al., 2007).

In this study, we found a sharp reduction in forage production, and a great variation in botanical composition, plant

Table 4. Correlations between nutritive value and cover composition of different botanical families.
Tabla 4. Correlaciones entre el valor nutritivo y la composición de cobertura de diferentes familias botánicas.

	C_G	C_F	C_C	C_A	C_P	C_W
Plant Cover	.762	.959*	.042	.199	.529	-.621
Fresh Matter Yield	.514	.865	.359	.469	.736	-.836
Dry Matter Yield	.647	.934	.199	.358	.622	-.732
Organic Matter	-.058	.507	.781	.898	.787	-.934
Crude Protein	.367	.827	.393	.707	.541	-.755
Crude Fat	-.366	-.733	-.507	-.491	-.870	.917
Neutral-detergent Fiber	.496	-.039	-.715	-.960*	-.303	.512
Acid-detergent Fiber	-.075	-.477	-.200	-.717	.024	.279

C_G: Poaceae composition cover; C_F: Fabaceae composition cover; C_C: Cyperaceae composition cover; C_A: Asteraceae composition cover; C_P: Polygonaceae composition cover; C_W: weed composition cover.
* Significant correlations (α=0.05).
** Significant correlations (α=0.01).
C_G: cobertura de la composición de Poaceae; C_F: cobertura de la composición de Fabaceae; C_C: cobertura de la composición de Cyperaceae; C_A: cobertura de la composición de Asteraceae; CC: cobertura de la composición de Polygonaceae; C_W: cobertura de la composición de malezas.

Table 3. Relationships among nutrient value of forages.
Tabla 3. Relaciones entre el valor nutritivo de los forrajes.

	Fresh Matter Yield	Dry Matter Yield	Organic Matter	Crude Protein	Crude Fat	Neutral-detergent Fiber	Acid-detergent Fiber
Plant Cover	.947	.986*	.579	.806	-.873	.013	-.297
Fresh Matter Yield	1	.986*	.801	.895	-.973*	-.241	-.375
Dry Matter Yield		1	.709	.880	-.927	-.143	-.380
Organic Matter			1	.881	-.824	-.746	-.598
Crude Protein				1	-.814	-.574	-.747
Crude Fat					1	.238	.231
Neutral-detergent Fiber						1	.784
Acid-detergent Fiber							1

* Significant correlations (α=0.05), ** Significant correlations (α=0.01).
* Correlaciones significativas (α=0,05), ** Correlaciones significativas (α=0,01).

Table 5. Correlations between nutritive value and biomass weight composition of different botanical families.
Tabla 5. Correlaciones entre el valor nutitivo y la composición del peso de la biomasa de diferentes familias botánicas.

	F_G	F_F	F_C	F_A	F_P	F_W	R_G	R_F	R_C	R_A	R_P	R_W
PC	.936	.981*	.405	.839	.657	-.853	.934	.996**	.217	.805	.596	-.872
FMY	.776	.939	.656	.955*	.845	.778	.778	.928	.486	.949	.729	-.981*
DMY	.863	.980*	.553	.918	.748	.8606	.860	.977*	.376	.894	.644	-.935
OM	.256	.634	.975*	.925	.858	-.905	.251	.558	.907	.949	.613	-.866
CP	.581	.886	.820	.973*	.684	-.903	.560	.818	.718	.942	.426	-.865
CF	-.677	-.837	-.677	-.921	-.941	.981*	-.689	-.835	-.509	-.943	-.862	.995**
NDF	.331	-.129	-.874	-.515	-.350	.402	.356	.001	-.954*	-.525	-.016	.317
ADF	-.107	-.475	-.679	-.591	-.121	.408	-.060	-.355	-.715	-.526	.236	.324

PC: plant cover; FMY: fresh matter yield; DMY: dry matter yield; OM: organic matter; CP: crude protein; CF: crude fat; NDF: neutral-detergent fiber; ADF: acid-detergent fiber.
F_G: fresh weight in biomass of Poaceae; F_F: fresh weight in biomass of Fabaceae; F_C: fresh weight of Cyperaceae biomass; F_A: fresh weight of Asteraceae biomass; F_P: fresh weight of Polygonaceae biomass; F_W: fresh weight of weed biomass.
R_G: dry weight of Poaceae biomass; R_F: dry weight in biomass of Fabaceae; R_C: dry weight of Cyperaceae biomass; R_A: dry weight of Asteraceae biomass; R_P: dry weight of Polygonaceae biomass; R_W: dry weight of weed biomass.
* Significant correlations (α=0.05), ** Significant correlations (α=0.01).
PC: cobertura vegetal; FMY: rendimiento de materia fresca; DMY: rendimiento de materia seca; OM: materia orgánica; CP: proteína cruda; CF: grasa cruda; NDF: fibra detergente-neutra; ADF: Fibra detergente ácida.
F_G: Peso fresco en biomasa de Poaceae; F_F: Peso fresco en biomasa de Fabaceae; F_C: Peso fresco en biomasa de Cyperaceae; F_A: Peso fresco en biomasa de Asteraceae; F_P Peso fresco en biomasa de Polygonaceae; F_W: Peso fresco en biomasa de malezas.
R_G: Peso seco en biomasa de Poaceae; R_F: peso seco en biomasa de Fabaceae; R_C: peso seco en biomasa de Cyperaceae; R_A: peso seco en biomasa de Asteraceae; R_P: peso seco en biomasa de Polygonaceae R_W: Peso seco en biomasa de malezas.
* Correlaciones significativas (α=0,05), ** Correlaciones significativas (α=0,01).

coverage and nutritive values in relation to the severity of degradation in the alpine grassland. Plant composition in terms of cover and biomass weight of Poaceae, Fabaceae, Cyperaceae, Asteraceae, and Polygonaceae were sensitive to alpine grassland degradation. For grazing ruminants, forages with high crude protein and low fiber contents are vital for their growth and daily dietary requirements (Schut et al., 2010). Our results showed less plant biomass production, and lower CP and OM contents in SD forage grasslands, and higher CP contents with lower NDF and ADF levels on forages of LD grasslands. This suggests that the quality of forage was the best in the LD grasslands and the worst in those SD. The degradation of alpine grasslands can thus result from both a decline in forage production and a deterioration of forage quality. The reduction of forage production along the increasing grassland degradation gradient is consistent with previous research that demonstrated a decrease in aboveground biomass with greater severities of disturbances (e.g., grazing, land use change) (Niu et al., 2009; Wu et al., 2009; Fan et al., 2010). Changes in forage nutrient contents may be related with changes in soil nutrient contents, botanical composition and interactions among plants. Alpine grassland degradation has been shown to decrease soil quality (Wang et al., 2005; Yang et al., 2009; Malhi et al., 2010; Wu et al., 2010). Forage quality can also be influenced by soil quality (Čop et al., 2009; Malhi et al., 2010; Verlinden et al., 2010). Several previous studies have shown that botanical composition can affect forage nutritive value (Deak et al., 2007; Dong et al., 2007; Biewer et al., 2009; Perbandt et al., 2010). It is known that a greater share of the soil resources will be taken by more than less competitive perennial grass species (Saint Pierre et. al, 2004).

In this study, there were positive and negative relationships between production, nutrient value and vegetation composition in the degradation gradient. Our results are consistent with conclusions from previous researchers (Ainalis et al., 2006; Zarovali et al., 2007; Mijangos et al., 2010) that changes in forage nutrient content were generally correlated with shifts in botanical composition. Thereafter, changes of botanical composition along the alpine grassland degradation gradient may determine shifts in the nutritive values of alpine forages.

There are many reasons that might lead to changes in forage nutrients. The changes in both forage production and quality may be caused by species composition and interactions within and among species (Saint Pierre et. al, 2004; Prins et al., 2008). Doll et al. (2009) reported that about 50% of the variability in forage quality was attributed to burning and grazing. Additionally, global climate change has also affected forage quantity and quality. The general warming and drying trend of the atmosphere in recent decades has changed the depth and cover of the permafrost layer in the Tibet area (Zhou et al., 2005; Oelke & Zhang, 2007; Xu & Liu, 2007; Yang et al., 2007; Wang et al., 2008). Changes in the permafrost depth are directly correlated with fluctuations in rangeland productivity (Zhang, 2007; Harris, 2010). Luo et al. (2009) proved that warming temperatures could significantly increase the dissolved soil organic carbon concentrations in the QTP. The fluctuations of soil carbon concentrations could in turn influence the nutrient content of forages (García et al., 2008; Iker et al., 2010). Not only chemical fertilizers but also additions of organic matter can increase both the quantity and quality of forages (Sheaffer et al., 2006; McFarland et al., 2007; Lawrence et al., 2008; Malhi et al., 2010; McFarland et al., 2010).

We have shown that grassland degradation will no doubt lead to serious consequences for local livestock, herdsmen and pastoralists. Giving the productive role of alpine grasslands, urgent actions are extremely essential to protect the alpine grasslands from degradation. Chinese government launched an ecological restoration program for retiring livestock and restoring pastures since 2003. It was reported by the Ministry of Agriculture of the People's Republic of China that this program promoted an increase in productivity of 43.9%, and an edible forage increase in productivity of 49.1%. Although there is a remarkable improvement on the grassland quality, the degradation situation has not yet changed by nature. Therefore, it is necessary to abase negative disturbances and use a proper carrying capacity to mitigate the degradation of alpine grasslands on the QTP.

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