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Vegetation Structure and Species Composition in Relation to Grazing

In the Andean Cordillera, natural grasslands above 2500 m are used for livestock grazing. Few studies on the effects of foraging natural vegetation have been conducted in the northern Argentinean Andes, although this activity is frequently considered to be involved in the dragging of large amounts of sediment and in soil erosion after summer rainfall. The present study aims to identify and describe floristic composition in main vegetation units, and the potential and susceptibility of these units to foraging within a small catchment in the Andes of northwestern Argentina. Vegetation was sampled for total cover, cover per species, altitude, exposure, slope, and foraging pressure. Data are classified and ordered through multivariate analysis. Species are also classified according to life form (shrubby, gramineous/graminoids, and herbaceous) and palatability. Variance Analysis was applied to detect significant differences among vegetation units. In the study area, differences in the floristic composition of vegetation units are associated with grazing, altitude and slope. Our results allow us to propose different uses of vegetation: sectors fit for foraging, sites severely degraded and in need of strict protection, and sites fit solely for moderate firewood extraction are identified.

Keywords: *Grassland; highlands; foraging potential; susceptibility; southern Andes; Argentina.*

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Introduction

In the Andean Cordillera, natural grasslands above 2500 m are commonly used for livestock grazing (Flores Ochoa 1977; Soto 1995). Extreme temperatures and arid climate result in poor soil development, unsuitable for agricultural practices (Tapia and Ruiz 1985). In these environments vegetation is steppic, distributed in patches among corridors of nude soil as in other arid or semiarid habitats at different altitudinal ranges (Montaña 1992; Bisigato and Bertiller 1996), and consists of rigid pastures, dwarf shrubs, and bushes or fleshy plants (Cabrera 1957; Ruthsatz 1974).

Studies on grazing effects on natural vegetation in the northern Argentinean Andes are scarce. Adler and Morales (1999) consider some structural features of natural grasslands to be related to grazing, and in agreement with Molinillo (1993), these authors find an association with some erosive processes with high temporary livestock concentrations.

In the study area, workshops with the shepherds were held to deal with the main problems of grazing related to availability and forage quality of the natural vegetation. As a result, 2 major vegetation types were distinguished according to physiognomy and use: scrubland, and grassland on high terraces. A grassland sector with a relatively small area but good forage quality was also identified, despite its high proportion of denuded soil. Peasants proposed different hypotheses (eg, "is it possible that animals fatten more there because the vegetation is more exposed to the sun in the morning?") (Sánchez and Quiroga Mendiola 1999).

The study was initiated in this context, given the need to provide answers to intense hydric erosion recorded in the basin. The first part of the study is presented here. The present article aims to identify and describe floristic composition in the main vegetation units described in relation to grazing.

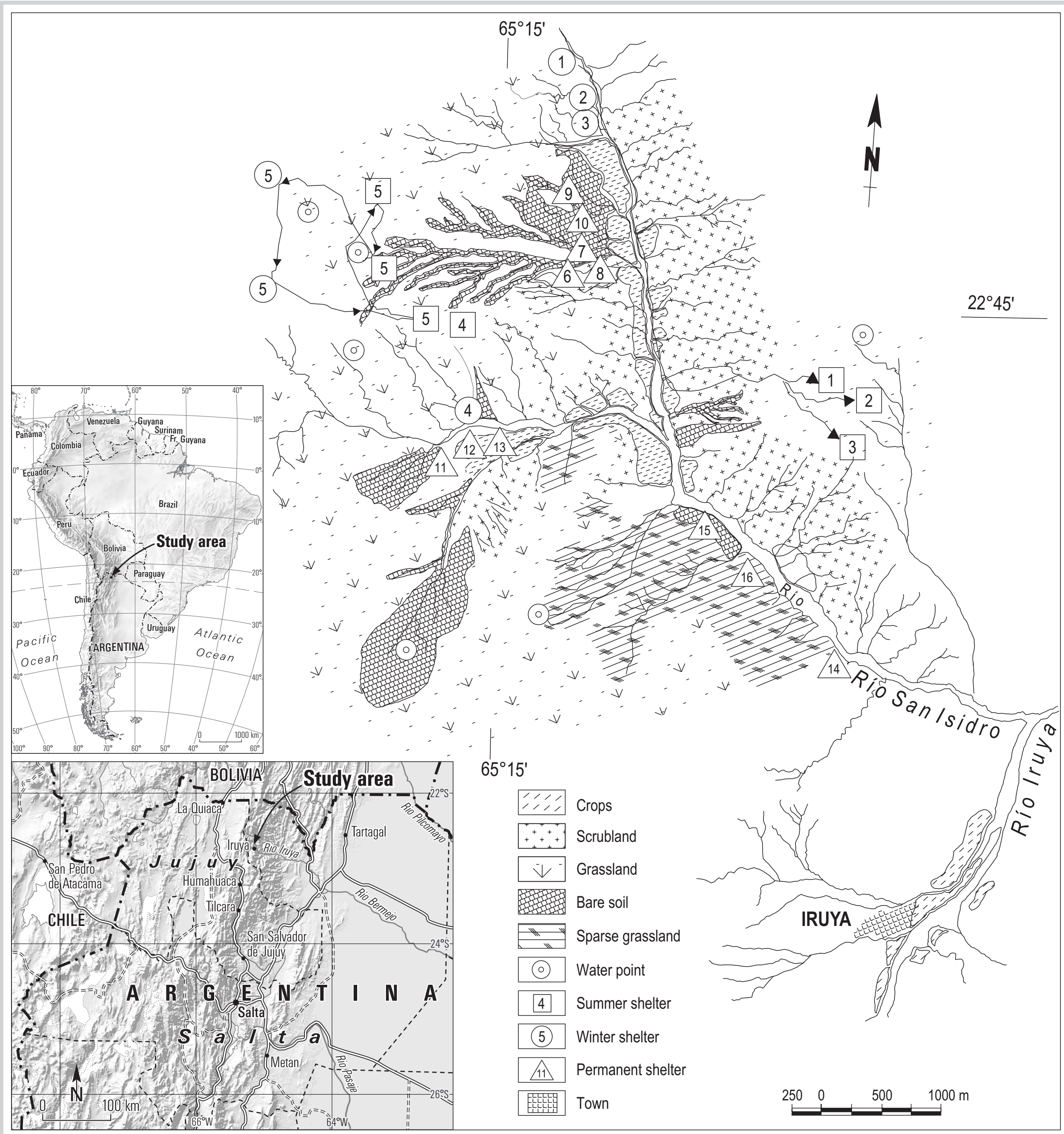
Study area

Santa Victoria Sierra is a mountain range to the east of the Andean Cordillera in northwestern Argentina (Figure 1), including the headsprings of the Iruya River. The main valleys have a north–south orientation, in response to geological structure (Turner and Mon 1979). Topography is irregular, with strong regional slope: from Santa Victoria, with a mean altitude of 4600 m, to the Bermejo River basin, at 600 m, there is a linear distance of 70 km, with a mean slope of 18% (Viera and Menéndez 1981).

The climate is highland semiarid, with different topo-climates caused by relief (Viera and Menéndez 1981). Mean annual rainfall of 300 mm occurs mostly in summer, and temperature shows pronounced daily and annual fluctuations (Bianchi 1981). Soils are rocky and shallow, with low organic content (Nadir and Chafatinos 1990). As a result of these features, the Iruya River contributes a great amount of sediment to the Bermejo River, in the high basin of the Río de la Plata (Konzewitsch 1958).

Local inhabitants are farmers and shepherds with a small livestock and subsistence economy, and sporadic employment as itinerant harvesters in different areas within the country (Quiroga Mendiola 2000). The most important population settlements are on alluvial terraces where soils are suitable for agriculture, irrigated by a wide net of channels. Grasslands and scrublands on mountain slopes are hard to access and non-irrigated.

FIGURE 1 Location of the study area in northwestern Argentina, showing vegetation types and uses. (Modified from Quiroga Mendiola 2000, with overview maps by Andreas Brodbeck)



Land use is therefore limited to rainfed potato crops (*Solanum tuberosum*) and sheep and goat herding (Quiroga Mendiola 2000).

Grazing strategies

Conditions of geographic isolation have favored the persistence of traditional pastoral systems. The small livestock are mainly managed by women and children with dogs, in seasonal shifts, using highland livestock shelters (*puestos*) for 6 to 7 months in the summer, and winter shelters in ravines for 5 to 6 months.

Bovine and equine management is carried out in a transhumance system, based on forage in the forest in winter and highland grasslands in the summer. Integral utilization of the different altitudinal vegetation belts offered by the topography is therefore achieved. Men are responsible for transhumance, in parties united by family bonds (*compadrazgo*) (Quiroga Mendiola 2000).

This activity depends on changes in the demand for manual labor from regional agriculture and precarious land ownership, which limits improvements (fences, forage culturing, etc) (Quiroga Mendiola 1996; Hocsman 2000).

Twenty-four percent of the families in the community raise sheep and goats. This activity represents 40% of the total family income in a productive unit that does not complement its income with sale of manual labor, and 6% of the total income of those who do (Ragno and Quiroga Mendiola 1999a).

Herds are freed daily for 7 hours of grazing. Displacements around a shepherd shelter cover a radius of about 1.2 km and the total distance traveled is about 20 km (Ragno and Quiroga Mendiola 1999b). Hours and distances are a function of low water and pasture availability, and the need to prevent animals from wandering over great distances, in order to avoid losses due to falls from cliffs (Sánchez and Quiroga Mendiola 1999). Thus radial extraction of vegetation declines as distance to the corral increases, along with changes in the composition and condition of natural grassland (Quiroga Mendiola 2000).

Methodology

The catchment area was divided into 3 vegetation units (grassland, sparse grassland and scrubland) based on differential physiognomic features. Pilot sampling to determine *minimum plot size* and *minimum sample size* (Milner and Hughes 1968) was conducted in each unit. Thirty 1-m^2 plots in grassland, 20 1-m^2 plots in sparse grassland, and 11 25-m^2 plots in scrubland were sampled for total cover and species cover. Plots were located left or right along 50-m line transects, and randomly distributed. Altitude, exposure, slope, and grazing pressure were measured on each plot (Krebs 1989).

Grazing pressure was estimated using the following index:

$$\textit{Grazing Pressure} = \frac{(\textit{N}^{\underline{o}}\ \textit{sheep equivalents/hectare}) \times (\textit{N}^{\underline{o}}\ \textit{grazing days/365})}{\log_{10} \textit{distance to the corral}}$$

always taking into account animal density at the site, grazing time within livestock rotation schedules (data from interviews with livestock breeders, and direct observation of the flocks), and logarithm of the distance to the corral (Adler and Morales 1999, modified).

Vegetation units were defined a priori, and a multivariate analysis was performed on a matrix of 60 censuses and 70 species, with cover as the response variable, to explore the association among units and species, and correlate the ordering axes with environmental variables measured independently (grazing pressure, slope, exposition, altitude) (Gauch 1982).

Shrubs, gramineous/graminoids, and herbaceous species were classified according to life form and palatability. Information on species palatability was taken from Bertuche and Vorano (1977), Tapia and Ruiz (1985), Tovar (1988), Braun Wilke (1991), Tichit (1995), and Villca and Genin (1995). When no information could be found for a species, livestock behavior was observed for 1 year. These data were reviewed by interviewing experienced breeders. Species appetizing to sheep over the entire year were classified as "palatable;" those selected only by the end of the dry season when forage availability is lowest as "intermediate;" and species never chosen by livestock as "non-palatable."

Foraging quality among vegetation units (grassland, sparse grassland and scrubland) was analyzed by Variance Analysis, using cover of species grouped by life-form as a variable, and the proportion of different palatability levels with respect to total cover in each census. Tuckey tests (significance level 0.5) were applied a posteriori. The Levene test was used to confirm homocedasticity. Kruskall-Wallis non-parametric analysis was performed for data that did not meet these criteria (Zar 1984).

Results

Floristic groups

Grassland: Groups formed by short grasses among dispersed "straw" bushes. Grassland occurs on ancient alluvial terraces with a 3% mean slope and high mean vegetation cover in the favorable season (Table 1). This unit is mainly composed of *Aristida* spp. and *Eragrostis nigricans,* in a tapestry of short grasses, with herbs such as *Trifolium amabile*, *Alchemilla pinnata*, *Hypseocharis pimpinellifolius* and *Lepechinia meyenii*, very appetizing to livestock; and non-palatable or intermediate species such as *Mitracarpus brevis*, *Richardia stellaris, Hypochaeris meyeniana,* and *Tagetes filifolia*. "Straws" accompany this tapestry of grasses and short herbs: *Stipa neesiana, Piptochaetium indutum*, in patches facing south.

Sparse grassland: This group covers small areas on very steep slopes in the southern portion of the study area. It is sparse grassland with dispersed shrubs, providing very low vegetation cover (Table 1), with dominant *Pennisetum chilense*, and colonizer species such as *Senecio clivicola*, *Physalis viscosa, Mitracarpus megapotamicus*, *Guilleminea densa*. Short grasses (*Aristida* spp.) and some "tussock grasses" (*Stipa* spp.) are also present.

Scrubland: This group flanks the lower edges of the grassland, between 3000 and 2800 m, on sites with steep

TABLE 1 Environmental parameters and grazing strategies for the 3 vegetation types. (Sources: this paper and Quiroga Mendiola 2000)

Environmental and grazing parameters	Types of cover		
	Grassland	Sparse grassland	Scrubland
Average elevation (m)	3102	2840	2980
Mean slope	3%	40%	40%
Area (ha)	1152	207	487
Richness (number of species)	33	30	44
Total average cover	69%	12%	39%
Most abundant species (% cover)	32%	4%	13%
Number of winter *puestos*	2	0	13
Number of summer *puestos*	15	0	0
Number of permanent *puestos*	0	2	0
Mean grazing pressure (sheep equivalents $\times$ ha^{-1}/log distance)	0.13	0.02	0.004
Mean aereal primary production of palatable species (kg $\times$ ha^{-1})[a)]	976.0	704.0	969.5
Receptivity (sheep equivalents $\times$ ha^{-1}) [a)]	1.1	0.8	1.1
Grazing season	summer–autumn	permanent	winter–spring
Length of grazing season (months)	7–8	12	5–4

[a)] See Quiroga Mendiola 2000.

slopes and low vegetation cover (Table 1). The soil supporting this formation is rocky, with evident signs of erosion. At these altitudes, no snowstorms occur and frosts are milder than on the highland terraces. This group is characterized by shrubby species, with dominant *Viguiera tucumanensis*, and co-dominant *Adesmia cytisoides*, *Stevia* spp. and *Mutisia acuminata*.

Vegetation ordination

Figure 2 presents a DECORANA graph. Sites with a predominance of grasses appear at the left end of Axis 1, and sites with shrubby species at the opposite end. Axis 1 shows high values for sites with slopes over 30% near the river basin (2800 m), characterized by an association of the shrubs *V. tucumanensis* and *A. cytisoides*, and herbaceous plants growing among their branches.

High values on Axis 2 correspond to an increment in nude soil, and plots on sparse grassland, with dominant *Pennisetum chilense* grass and non-palatable shrubs and herbs, are ordered there. The low sector of Axis 2 shows the plots on high terraces (above 3000 m) where most *puestos* (small, simple seasonal stone shelters for shepherds, with corrals for herds) are situated. Typical vegetation on these plots is dominated by palatable gramineous plants, and different herbaceous species also appetizing to livestock.

Axis 1 illustrates two clearly marked groups of censuses, from an association of gramineous/graminoids and herbaceous dicotyledonous species on high terraces used for livestock grazing, to an association of shrubs and herbaceous species sheltered within branches of shrubs, on mountain sides with very steep slopes.

Axis 1 correlates positively with slope ($r = 0.8$; $p < 0.001$), and negatively with altitude ($r = -0.8$; $p < 0.001$) and grazing pressure ($r = -0.8$; $p < 0.001$). Axis 2 shows a negative correlation with total cover ($r = -0.7$; $p < 0.001$).

Vegetation structure and foraging aptitude

Comparison of the vegetation units showed that scrubland is significantly different from the 2 other groups, with a predominance of woody plants (Table 2). Sparse grassland differs from the other groups, particularly in its scarce total coverage (Table 1). Grassland presents almost no cover with shrubby species, but high total cover with gramineous/graminoids and herbaceous dicotyledonous species (Table 2).

There are significant differences in the foraging potential of the scrubland and the other 2 groups. Rela-

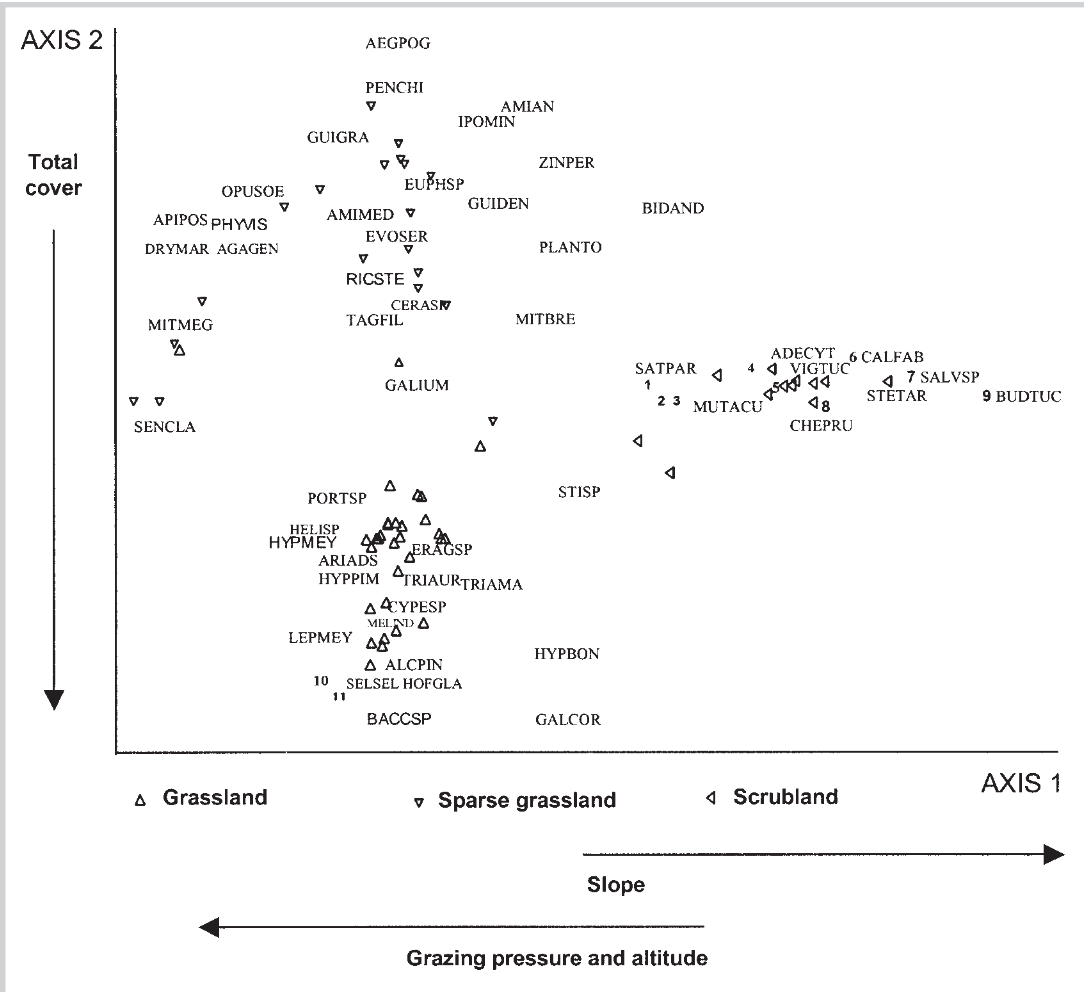


FIGURE 2 Vegetation ordination. DECORANA (PCORD). ADECYT: *Adesmia cytisoides*; AEGOPOG: *Aegopogon* spp.; ALCPIN: *Alchemilla pinnata*; AMIAND: *Amicia andicola*; AMIMED: *Amicia medicaginea*; APIPOS: *Apium postratum*; ARIADS: *Aristida adscencionis*; BACCSPP: *Baccharis* spp.; BIDAND: *Bidens andicola*; BUDTUC: *Buddleja tucumanensis*; CALFAB: *Calceolaria fabrisii*; CERASP: *Cerastium* spp.; CHEPRU: *Cheilantes pruinata*; CYPESP: *Cyperus* spp.; ERAGSP: *Eragrostis* spp.; EUPHSP: *Euphorbia* spp.; EVOSER: *Evolvulus sericeus*; GALCOR: *Galium corimbosum*; GALIUM: *Galium* spp.; GUIDEN: *Guilleminea densa*; GUIGRA: *Guilleminea gracilis*; HELISP: *Heliotropium* spp.; HOFGLA: *Hoffmannseggia glauca*; HYPBON: *Hypericum bonariensis*; HYPMEY: *Hypochaeris meyeniana*; HYPPIM: *Hypseocharis pimpinellifolius*; IPOMIN: *Ipomoea minuta*; LEPMEY: *Lepechinia meyenii*; MELIND: *Melilotus indica*; MITMEG: *Mitracarpus megapotamicus*; MUTACU: *Mutisia acuminata*; OPUSOE: *Opuntia soerensii*; PENCHI: *Pennisetum chilense*; PHYVIS: *Physalis viscosa*; PLATOM: *Plantago tomentosa*; PORTSP: *Portulaca* spp.; RICSTE: *Richardia stellaris*; SALVSP: *Salvia* spp.; SATPAR: *Satureja parvifolia*; SELSEL: *Selaginella sellowii*; STETAR: *Stevia tarijensis*; STISP: *Stipa* spp; TAGFIL: *Tagetes filifolia*; TRIAMA: *Trifolium amabile*; TRIAUR: *Trichocline auriculata*; VIGTUC: *Viguiera tucumanensis*; ZINPER: *Zinnia peruviana*. 1: *Turnera* spp.; 2: *Diplachne dubia*; 3: *Senna* spp.; 4: *Lactuca* spp.; 5: *Polygala mendocina*, *Stevia* spp.; 6: *Peperomia peruviana*, *Tagetes* spp.; 7: *Opuntia* spp., *Stipa neesiana*, *Poa* spp.; 8: *Habenaria* spp.; 9: *Stenandrium* spp.

tive proportions of species with foraging value are high, on both grassland and sparse grassland (Table 3).

Discussion

In the study area, differences between floristic composition and vegetation were related to grazing, altitude and slope. Although the sampling design does not reveal the relative importance of these factors, different authors found that grazing may affect the structure and floristic composition of mountain communities (Molinillo and Monasterio 1997; Adler and Morales 1999). The mechanisms involved in these changes are direct and indirect effects of grazing. Among the former, consumption of vegetative tissues can compromise sapling survival (Salihi and Norton 1987; Clements and Young 1996) and adult individuals (McLean and Wikeem 1985; O'Connor 1993). The latter operates through removal of reproductive tissues (O'Connor and Pickett 1992; O'Connor 1993; Bertiller and Coronato 1994)

TABLE 2 Variance Analysis: average cover of shrubs, gramineous/graminoids and herbaceous species for the 3 vegetation types. Different superscripts (a and b) indicate significant statistical differences (P = 0.05) among vegetation groups.

Species type	Average cover (%)		
	Grassland	Sparse grassland	Scrubland
Shrubs	1 [a]	3 [a]	34 [b]
Gramineous/graminoids	36 [a]	5 [b]	3 [b]
Herbaceous	32 [a]	4 [b]	2 [b]
Total cover	69	12	39

TABLE 3 Variance Analysis: Mean cover of palatable, intermediate and non-palatable species for the 3 vegetation types. Different superscripts (a and b) indicate significant statistical differences (P = 0.05) among vegetation groups.

Palatability index	Average cover (%)		
	Grassland	Sparse grassland	Scrubland
Palatable	63.7 [a]	48.7 [a]	22.7 [b]
Intermediate [a)]	11.8 [a]	12.5 [a]	2.2 [b]
Non-palatable	24.5 [a]	38.8 [a]	75.1 [b]

[a)] Kruskall-Wallis test.

and generation of clearings for establishment of new individuals (Oesterheld and Sala 1990).

The effect of grazing on the floristic composition of communities depends not only on grazing pressure, but also on frequency and season (Adler and Morales 1999): pastures produce most of their biomass in spring, and their ulterior development is conditioned mainly by this initial production (Newman 1993). During the reproductive season, intensive grazing also impairs seed production (O'Connor and Pickett 1992; Bertiller 1994), favoring vegetative reproduction strategies (Belsky 1992).

In San Isidro, shrubby chamaephyte or suffruticose species dominate grasslands heavily grazed in spring, which sprout by the end of trimming season. The sites used in summer are mainly composed of grasses and species with rhizomes, bulbs or tuberous roots (Quiroga Mendiola 2000).

Grassland and sparse grassland share the species *Pennisetum chilense*, both with a disperse distribution and low abundance. However, it is the only palatable species that remains on sparse grassland, along with annual colonizing species. Sparse grassland probably belongs to the "grassland" vegetation unit, but in a transitional state of degradation, probably because of excessive use or lack of resting periods. *P. chilense* remains, despite its high palatability and thanks perhaps to its survival strategy through rhizomes.

Good cover recovery has been achieved on 7 artificial 1-year closures on both grassland types (Quiroga Mendiola 1996, 2000). However, grassland did not experience species shifts, but a rise in recruitment and plant height on sites where soil was removed for implanting the closure, suggesting the importance of the trampling effect in a selective process against therophyte species. On the other hand, sparse grassland exhibited different behavior after 1-year closure. Two new species were found: therophyte colonizers and an unusual growth of *P. chilense*. Reappearance of other herbaceous co-dominant species was not recorded, also suggesting the transitional degradation status of this grassland (Quiroga Mendiola 2000).

The effect of altitude, in turn, is a function of frequency and intensity of frost. In the highlands, largely exposed to winds and frost, species with meristems just below or above the soil surface will flourish, a strategy also effective as a defense against browsing (Westoby 1980; Coughenour 1985). This may explain why a heavily grazed unit such as grassland maintains a good cover of perennial palatable gramineous species.

In this study, altitude and slope are related to grazing. Intensive vegetation and steep slopes result in a nude site most susceptible to erosion—sparse grassland. However, environmental factors not measured in this work—such as organic matter content and soil moisture—can also help to explain plant distribution.

Grassland exhibited the greatest coverage with grasses and herbaceous dicotyledonous species. The other 2 communities exhibited lower foraging aptitude: mean coverage in sparse grassland was low, and species with low foraging values are dominant on scrubland. In the closure study, good primary areal annual productivity was found on grassland and scrubland, but it was very low on sparse grassland (Quiroga Mendiola 2000). This foraging aptitude ranking was related to actual land use intensity in the study area, the most productive areas moderately used in summer being those colonized by shrubs with no foraging value in spring, while those with intensive and constant use are practically denuded.

Conclusions

Physiognomic and floristic differences among the vegetation units correlate with altitude, slope, and grazing pressure. However, grazing seasonality, rather than grazing pressure, appears to play a major role in the conformation of floristic composition and vegetation structure, as revealed in analysis of the grazing pressure index in relation to vegetation data. On sites with uninterrupted grazing, annual colonizer species and non-palatable species become permanent. Only 1 palatable species survives thanks to its rhizome system. Grassland and sparse grassland species have good foraging aptitude; however, the second type is affected by permanent grazing, with a decline in species richness and mean cover, as well as in forage quality and soil protection.

The results of the present work make it possible to propose differential use of the 3 communities described. *Grassland* is a good site for pastoral use and does not appear intensely degraded in terms of cover and grass quality. Taking into account the potential effects of grazing on vegetation structure and composition, management practices to favor disseminule generation, such as a resting period during seed production and dispersion stages (rotational grazing use), should be implemented. *Scrubland*—because of the dominant vegetation type and steep slopes—could be used to provide only wood, as long as plants are not uprooted. Features of *sparse grassland* define it as a degraded unit, poorly fit for pastoral use, with high risk of erosion. Recovery measures such as permanent closure, planting of native species, and fertilizing should therefore be applied.

The poverty of the families in the study area, precarious land ownership, and changes in the domestic economy caused by transformations in regional production (Hocsman 2000; Quiroga Mendiola 2000) pose problems that will be difficult to solve when trying to optimize the system. The study team is presently working on implementation of management improvements in pastoral procedures and natural vegetation (soil systematization, emergency community aid with shifting funds, and irrigation systems for intensification of forage production, among other things).

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