

PASTORALISM IN PARAMO ENVIRONMENTS: PRACTICES, FORAGE, AND IMPACT ON VEGETATION IN THE CORDILLERA OF MERIDA, VENEZUELA

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ABSTRACT An analysis of cattle farming and its impact on vegetation between 3,000 and 4,500 m was conducted in paramo farming communities dedicated to cultivating tuber crops in the Cordillera of Merida, Venezuela. Spatial variation of natural forage, vegetation selection by cattle, the grazing range, and farming practices were studied. The short-term impact of grazing on natural vegetation was investigated using experimental plots in short grassland and rosette-shrub communities. In the highlands of the paramo, the grazing patterns were characterized by intensive use of short grassland on the valley floor and extensive use of rosette-shrub communities on the hillsides which, in turn, were related to the spatial distribution of forage and acceptable ecological conditions for the cattle. The greatest impact on the vegetation was the concentration of grazing in short grasslands and the current grassland composition and distribution may be due to these grazing patterns. However, long-term studies are necessary to evaluate the magnitude of this impact. There is little forage available for recently introduced cattle in the high paramo, especially in the dry period, and fodder is acquired from diverse alternative sources in the agricultural belt. This factor and the need for animal labor in agriculture result in grazing patterns characterized by a great variety of animal movements between ecological zones depending on the resource availability of each family which confers greater spatial-temporal dynamics on grazing patterns. Finally, it is recommended that emphasis is placed on cattle management rather than on the elimination of pastoralism, in order to conserve these fragile ecosystems and to maintain the economy of the agropastoral communities.

RÉSUMÉ. *Pastoralisme dans les environnements du paramo : Pratiques, affouragement et impact sur la végétation de la Cordillère de Merida, Venezuela.* Une étude de l'élevage du bétail et de son impact sur la végétation entre 3 000 et 4 500 mètres a été menée dans des collectivités agricoles du paramo cultivant des plantes tubéreuses dans la Cordillère de Merida, Venezuela. La variation spatiale du fourrage naturel, la sélection de la végétation par le bétail, le terrain de parcours et les pratiques agricoles ont été étudiées. L'impact à court terme du pâturage sur la végétation naturelle a été étudié à l'aide de parcelles expérimentales dans la prairie à herbe courte et des communautés d'arbrisseaux rosette. Dans le haut paramo, les habitudes de pâturage sont caractérisées par l'usage intensif de la prairie à herbe courte au fond de la vallée et par l'usage extensif des communautés d'arbrisseaux rosette à flanc de coteau. Ces habitudes sont liées à la répartition spatiale du fourrage et aux conditions écologiques acceptables pour le bétail. Le plus fort impact sur la végétation réside dans la concentration du pâturage dans la prairie à herbe courte, et la composition et la répartition actuelles de la prairie peut découler de ces habitudes de pâturage. Néanmoins, des études à long terme sont nécessaires pour évaluer l'amplitude de cet impact. Peu de fourrage est disponible pour le bétail récemment introduit dans le haut paramo, en particulier pendant la saison sèche, et le fourrage est obtenu à partir d'autres sources de la bande agricole. Ce facteur et le besoin de bêtes de somme en agriculture a mené à des habitudes de pâturage caractérisées par une grande variété de déplacements d'animaux entre les zones écologiques dépendant des ressources disponibles à chaque famille, ce qui donne une dynamique spatiale-temporelle accrue aux habitudes de pâturage. Finalement, il est recommandé de se concentrer sur la gestion du bétail plutôt que sur l'élimination du pastoralisme, afin de préserver ces écosystèmes fragiles et la fondation économique des collectivités agro-pastorales.

ZUSAMMENFASSUNG *Weidewirtschaft im Paramo-Hochland: Praktiken, Futterarten und Auswirkungen auf die Vegetation in den Cordilleren von Merida in Venezuela.* Eine Analyse der Rinderzucht und ihrer Auswirkungen auf die Pflanzenwelt in 3000 bis 4000 m Höhe wurde in ländlichen, hauptsächlich von Wurzelgemüsezücht lebenden Gemeinden im Paramo-Hochland in den Cordilleren von Merida in Venezuela durchgeführt. Räumliche Variationen in natürlich vorkommenden Futterpflanzen, Vegetationsselektion durch die Rinder, Beweidungsraten, Ausmaß der Weideflächen, sowie landwirtschaftliche Praktiken wurden untersucht. Kurzzeitige Auswirkungen der Beweidung auf die heimische Vegetation wurde in experimentellen Flächen mit Kurzgras- und mit Rosettenbusch-Pflanzengemeinschaften untersucht. Im "Paramo"-Hochland wird die Beweidung durch intensive Nutzung der Kurzgrasflächen am Talgrund und durch extensive Nutzung der Rosettenbusch-Gemeinschaften an den Hängen gekennzeichnet. Dies wiederum steht im Zusammenhang mit der räumlichen Futterpflanzenverteilung und akzeptablen ökologischen Bedingungen für die Rinder. Die konzentrierte Beweidung der Kurzgrasflächen hatte die größten Auswirkungen auf die Vegetation, und die heutige Artenzusammensetzung und -verteilung innerhalb der Kurzgrasgemeinschaften ist möglicherweise auf diese Beweidungsmuster zurückzuführen. Um das Ausmaß ihres Einflusses zu beurteilen werden jedoch Langzeitstudien benötigt. Futterpflanzen für die erst vor kurzem in das "Paramo"-Hochland eingeführten Rinder sind vor allem in der Trockenzeit knapp. Daher werden zusätzlich alternative Futterquellen in der landwirtschaftlichen Zone genutzt. Dieser Umstand, sowie der Einsatz der Rinder bei der Feldarbeit, führt zu Beweidungsmustern die vom vielfältigen Umtrieb der Tiere zwischen verschiedenen ökologischen Zonen geprägt sind. Dies hängt wiederum von den jeder Familie zur Verfügung stehenden Ressourcen ab, was zu verstärkter räumlicher und zeitlicher Dynamik in den Beweidungsmustern führt. Abschließend wird empfohlen die Aufmerksamkeit mehr auf effektiv geplante Viehhaltung als auf die Aufgabe der Weidewirtschaft zu lenken, um so sowohl die leicht zu zerstörenden Ökosysteme als auch die wirtschaftliche Grundlage der weide- und landwirtschaftlich orientierten Gemeinden zu erhalten.

RESUMEN *Pastoreo en ambientes de páramo: Prácticas, forraje e impacto sobre la vegetación en la Cordillera de Mérida, Venezuela.* En comunidades campesinas de páramo dedicadas a la agricultura de tubérculos se analiza el manejo de la ganadería vacuna y su impacto sobre la vegetación entre los 3,000 y 4,500 m en la Cordillera de Mérida (Venezuela). Se investigan las variaciones espaciales del forraje natural, la selección de vegetación que realizan los vacunos, los movimientos en pastoreo extensivo y las prácticas campesinas. Mediante parcelas experimentales instaladas en céspedes y rosetales-arbustales se estudia a corto plazo el impacto del pastoreo sobre la vegetación natural. En las altas tierras de páramo los patrones de pastoreo, caracterizados por uso intensivo en céspedes de fondos de valle y muy extensivo sobre rosetales arbustales de laderas, se relacionan a la distribución espacial del forraje y a las condiciones ecológicas adecuadas para los vacunos. El mayor impacto sobre la vegetación se produce como consecuencia de la concentración de los animales en zonas de céspedes, cuya composición y distribución actual podrían deberse a los patrones de pastoreo. Sin embargo, se requieren estudios a largo plazo para conocer la magnitud del impacto debido al pastoreo. La ganadería vacuna de reciente introducción debe afrontar la escasa disponibilidad de forraje en estos ambientes, especialmente en la época seca, que es superada por diversas fuentes alternativas en el piso agrícola. La búsqueda de estos forrajes alternativos y los requerimientos de fuerza animal para la agricultura configuran patrones de pastoreo caracterizados por una gran variedad de movimientos de animales entre pisos ecológicos. La elaboración de estas prácticas de acuerdo a la disponibilidad de recursos de cada familia, le confiere una mayor dinámica espacio-temporal a los movimientos de los animales. Finalmente, para una conservación mas efectiva del ambiente, especialmente sobre algunas regiones frágiles del piso Altandino, que no perjudique a las economías agropastorales, se recomienda hacer mas énfasis sobre el manejo del ganado que sobre la eliminación del pastoreo.

INTRODUCTION

The biogeographical region of the paramo is characterized by its insular distribution close to the equator extending throughout regions of high elevation in the northern Andean Cordillera (11° North–8° South). The paramos, in conjunction with the puna, form the largest pasture complexes of the Andean Cordillera (Brush, 1982), utilized for the most part by agropastoral communities who have settled in these areas. These regions are differentiated by their climate and biogeography, as well as by the history of land use (Murra, 1979; Monasterio and Vuilleumier, 1986; Sarmiento, 1986).

Unlike the puna, the vegetation of the paramo evolved in an environment with less climatic seasonality and with abundant and almost continuous rainfall, relative annual isothermy, and low temperatures (Sarmiento, 1986). In the paramo of Colombia and Venezuela the vegetation, dominated by giant rosettes, microphyl shrubs, cushions, and tussocks of grasses, was not exposed to high levels of herbivory by domestic animals for many thousands of years, in contrast to the puna. Human settlements did not attain the dimensions and characteristics of the high puna plains during the Pre-Colombian era. Before the Spanish conquest, human impact in the high-elevation paramo was so low that the pollinic registers began to show human activity only around the year AD 1200 (Van der Hammen, 1968).

Cultures that developed in the paramo were exclusively dedicated to agriculture, and differed from those of the puna where pastoralism has existed for thousands of years (Engel, 1976; Kent, 1988; Wheeler, 1988). The introduction of new crops and technologies, and the use of grazing cattle in high-elevation regions where cultivation was not possible accompanied the arrival of the Spaniards in the sixteenth century. These highlands that had previously been utilized by indigenous communities for hunting and collecting became sources of forage for extensive grazing only a few hundred years ago (Wagner, 1979). The different agro-pastoral strategies developed for the use of resources in the highlands, especially with respect to the use of pastures for grazing, are well documented in the puna (Brush, 1976, 1982; Thomas and Wintherhalder, 1976; Flores-Ochoa, 1977, 1988; Merlino and Rabey, 1983; Brush and Guillet, 1985; and others). In the paramo, pastoralism is relatively new and little is known about the grazing practices, grazing resources offered by the vegetation, or the environmental impact of grazing.

This study analyses the management of cattle farming within the framework of tuber and cereal cultivation in the paramo of the Cordillera of Merida. Spatial and temporal variation of natural forage, selection by animals, grazing distribution, management practices, and vegetation changes related to grazing are discussed.

STUDY AREA AND METHODOLOGY

The study area was the catchment of the Paramo El Banco, between 3,000 and 4,300 m, in the Sierra La Culata, Cordillera of Merida (Figure 1). The vegetation is dominated by rosette-shrub communities of *Espeletia schultzei* (Compositae) which constitute the most important association within the Andean paramo (Monasterio, 1980 a). The highest sector of the catchment (above 3,500 m) is utilized for extensive bovine and equine grazing by a small farming community that cultivates land below

3,500 m. The El Banco catchment area, within the Andean belt (3,000–4,000 m) and High-Andean belt (above 4,000 m), was considered as a single unit for evaluation. Vegetation as a forage source, vegetation selection by grazing animals, carrying capacity, farming practices, and vegetation changes in relation to grazing were determined in this study area.

Physiognomic units of vegetation were determined and mapped using air photographs and field studies. In each

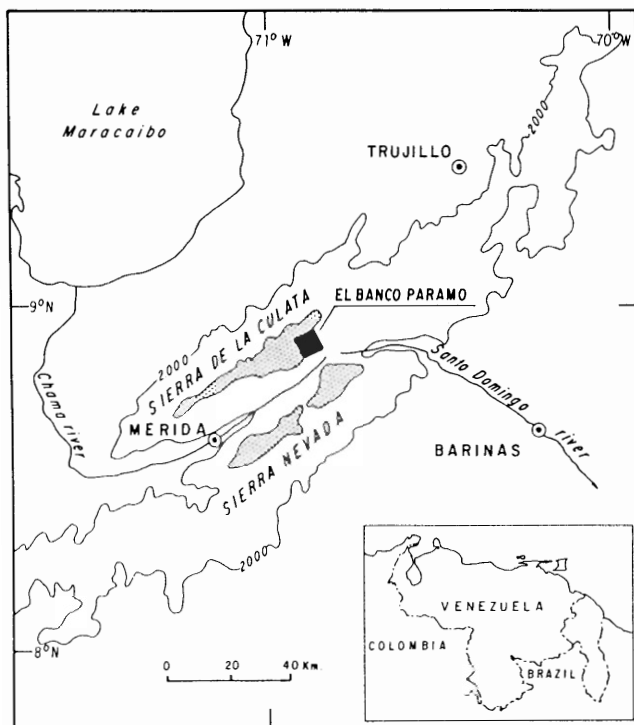


FIGURE 1. Location of the study area in El Banco Paramo in the Cordillera de Merida. The dotted areas represent elevations above 4,000 m.

unit, the dominant species and forage resource were determined by sampling vegetation using randomly placed quadrats. The number of grazing animals was also determined throughout the year in order to calculate the actual load and ascertain the grazing distribution. The selection of plants by grazing animals, and vegetation changes in relation to the elimination of grazing, were analyzed using experimental plots. Three situations were

compared: exclusion of grazing; actual extensive grazing; and experimental grazing with different loads. These were compared in rosette-shrub communities (500 m² plots) and in paramo grassland (180 m² plots) at 3,900 m in the Andean belt. Animals were eliminated from the area for a year and a half (from October 1990 to March 1992) before the effects of excluding grazing animals were evaluated. In each plot 20 fixed quadrats of 1 m² and 0.25 m² were chosen for the rosette-shrub and grassland communities respectively. In each quadrat, samples were taken every three months and before and after each treatment in the experimental grazing plots. The number of species, basic relative cover (Mueller-Dombois and Ellenberg, 1974), and biovolume were calculated. Biovolume was measured by counting the number of contacts made with the vegetation using ten randomly placed needles, and this was used as an indirect measure of biomass (Passera *et al.*, 1986). To determine the species of plants selected by the grazing animals three indices were used: an index of herbivore damage; an index of vegetation selection in free grazing areas (Holechek *et al.*, 1982); and an index of preference (Krueger, 1972). The latter includes the participation of each forage species in the animal diet and the floristic composition of the vegetation unit. An approximate scale of palatability, based on information from farmers and bibliography (Tapia-Nuñez and Flores-Ochoa, 1984; Passera and Borseto, 1986; Canales and Tapia-Nuñez, 1987), was also constructed. The approximate values of the carrying capacity were obtained by measuring the cover and the vigor of the most palatable species and the percentage composition of the fodder species in the vegetation units. These factors combined expressed an index of forage quality which was related to established ranges of carrying capacity (Tapia-Nuñez and Flores-Ochoa, 1984). Grazing practices and animal movements related to agricultural practices were evaluated in a survey of farmers from the community 'Toma Alta.'

THE PARAMO IN THE CORDILLERA OF MERIDA

The paramo in the Cordillera de Merida is situated in the upper altitudinal belts (Andean and High-Andean belts). It is characterized by abundant rainfall and low temperatures, with almost isothermic regimens. Formations of Andean paramo and paramo grassland extend throughout the Andean belt (Monasterio, 1980 a). The former is a heterogeneous plant formation that includes rosettes (principally species of the genus *Espeletia*) and shrubs (including *Hypericum*, *Stevia*, and *Hesperomeles*) in different associations characteristic of the mountainous area between 2,800 and 4,000 m. The paramo grassland, on the other hand, is composed of gramineae (*Bromus*, *Agrostis*, and *Stipa*, amongst others) of varying composition that occupy slopes and glacial valley floors above 3,000 m. The High-Andean belt extends from 4,000 m upwards and is covered by formations of desert paramo, such as high and open rosettes (*Espeletia timotensis* and *E. lutescens*), and the formation of periglacial desert, patches

of vegetation (such as *Draba*, *Arenaria*, and *Azorella*) that are separated by areas of bare substrate.

Humans were late to settle in this region, arriving during the prehistoric era. These communities were dedicated to cultivating (potatoes, corn, oca, and ullucu) and developed on the fringe of the agropastoral cultures of the Central Andes. Populations and agriculture were limited to the lower Andean belt and the highlands of the paramo were used for pathways, hunting, and religious ceremonies (Wagner, 1979). From the sixteenth century onwards, the Spanish Conquest brought new uses for the highlands. The cultivation of cereals practiced in the Iberian Peninsula, accompanied by its infrastructure and technologies (animal traction, threshing, plowing, and milling), was transferred to the Andes. The traditional potato crops continued to be cultivated on the terraces and alluvial cone terraces, whilst the new cereal crops expanded along the steep slopes of the high valleys (Mon-

asterio, 1980 b). The animals that were used for agricultural labor (normally cattle) started to consume the vegetation of the highlands as a source of natural forage. Since then cattle farming has been closely related to agriculture.

At present, the agricultural belt of the Cordillera of Merida forms a mosaic of agro-ecological activity. The most accessible regions are utilized by agro-ecosystems in different phases of modernization, highly dependent on agro-chemical and consumer demands. The less accessible zones, on the other hand, still maintain some of the systems utilized during colonial times. The land is still mainly plowed by animals, and tractors are rarely used. Oxen and bulls are generally used for sowing, plowing in preparation for seeding (several months before), and for harvesting potatoes. These animals are reared specifically for agricultural use and are fed on forage from the Andean and High-Andean belts. Although this form of extensive cattle farming is associated with the agricultural practices which dominate the Cordillera of Merida, commercial cattle farming that is independent of agriculture

also exists. Cattle rearing for meat and cheese production is found in the wet paramos with abundant supplies of forage.

The highlands of the paramo are mainly used for extensive grazing and are managed as communal lands. Each family has the right to use the natural fodder according to established legal titles (Egaña, 1983), commonly known as "Rights to the Paramo." This type of tenancy permitted access to large areas for pasturing and favored the development of cattle farming in locations with low quality forage. However, since the constitution of the National Parks Service in the highlands of the Cordillera of Merida, first in the Sierra Nevada (1952) and later in the Sierra La Culata (1990), conflicts have developed between the State and farmers. The State argues that pastoralism has a negative impact on the paramo and should be eliminated, and that land use should be limited to tourism, recreation, education, and research favoring the conservation of these environments (Inparques, 1991).

PASTORALISM IN THE EL BANCO PARAMO

The lower half of the catchment of the El Banco Paramo is used for cultivation by the farming community of the 'Toma Alta.' The middle and upper sectors are composed of plant formations of the Andean paramo, paramo grasslands, periglacial desert, and desert paramo (Figure 2) that are used as sources of natural forage for extensive cattle grazing. The farming community, composed of more than 150 people, is dedicated to the production of potatoes, carrots, and recently, garlic. These crops are sold to the regional markets by an intermediary. Wheat, oats, and barley are cultivated for family use. The land unit for cultivation is approximately five hectares per family, including vegetable plots (in the lower and middle sections of the agricultural belt) and cereal plots (in the upper agricultural belt). Each family owns 10–15 cattle, in addition to small numbers of farm animals such as horses, pigs, and sheep. Horses and cattle are pastured in the extensive lands of the Andean and High-Andean belts for most of the year and are only brought down to the agricultural belt for farming purposes. Extensive pastoralism is not controlled. Cattle are dispersed throughout the highlands that are communally managed, and once a month the farmers round up the cattle, feed them salt, and check their health. Settlements, even temporary ones, are rarely found in these regions. Farmers generally leave their cattle in highland areas where they are permitted to pasture a few hours' walk from their communities. In the agricultural belt the land is divided into properties, including fallow which is used as fodder in the dry period. The agricultural plots are protected from cattle by stone walls.

FODDER AND NATURAL VEGETATION

The slopes of the Andean belt (between 3,500 and 4,000 m), covered with rosettes (*Espeletia schultzei*) and

shrubs (*Hypericum laricifolium*), are subject to extensive cattle grazing, especially in the wet period (March–August). The most appetizing species are found in the herbaceous layer, 80 percent of which is composed of good quality forage (*Stipa philippii*, *Calamagrostis* sp., *Poa petrosa*, *Muehlenbergia* sp., and *Festuca* sp.). In the upper layer the good quality forage diminishes. The high biovolume of less palatable shrubs (*H. laricifolium*, *Hinterhubera* sp., *Stevia* sp.) and caulirosetta species (*E. schultzei* and *E. floccosa*) causes the cattle to move seasonally in search of certain species in the herbaceous layer.

The glacial valley floors in the paramo highlands are covered by grasslands. Unlike the rosette-shrub communities, this vegetation is green during the dry period and this is an important grazing area throughout the year. More than 80 percent of the total biovolume is good quality forage and is composed for the most part of the grass species *Eleocharis acicularis*, *Calamagrostis mulleri*, and *Muehlenbergia ligularis*. Other fodder species that are found are *Carex albolutescens*, *Agrostis breviculmis*, and *Lachemilla* sp.

The desert paramo extends up to the vegetational limit on the slopes and highest parts of the High-Andean belt, alternating with the periglacial desert at the most extreme altitudinal limits. Herbs and cushions are the principal forms of plant life in the herbaceous layer within the rosette community of *E. timotensis* and the association of *Arenaria* sp., that characterizes the desert paramo. Forage of mediocre quality constitutes 70 percent of the biovolume of the herbaceous layer and is composed for the most part of *Rumex acetosella*, *Agrostis* sp., and *Calamagrostis* sp. The latter species is the only one that is good quality forage, although it contributes only 10 percent to the total palatable biovolume. Most species are unpalatable or less palatable, such as *Arenaria* sp., *Lupinus* sp., *Gnapha-*

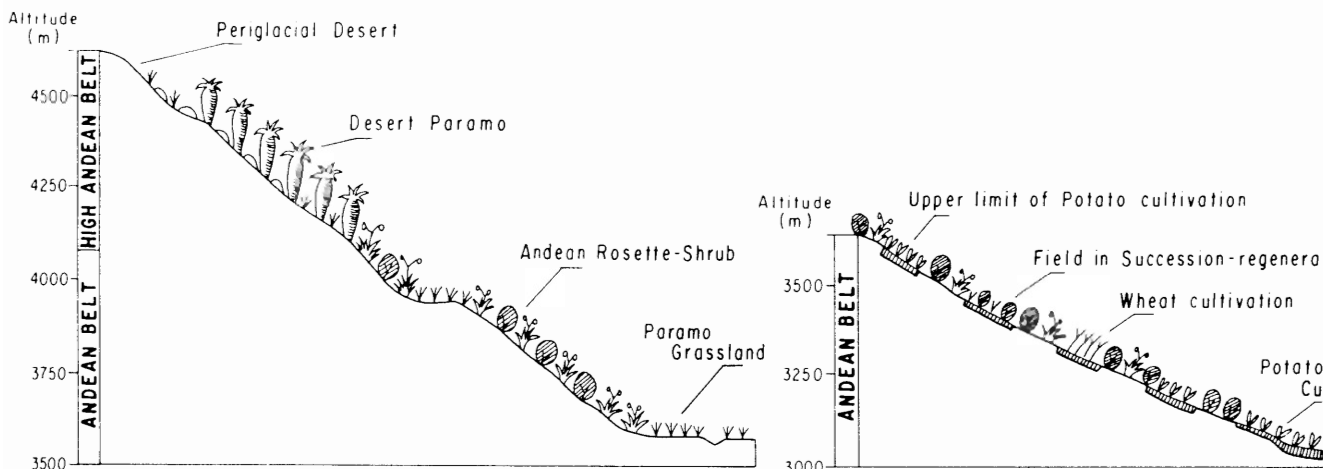


FIGURE 2. Profile of the vegetation in the catchment area of El Banco Paramo. To the left, a profile of the highlands above the limit for cultivation dedicated to extensive grazing and, to the right, the profile of the agricultural belt.

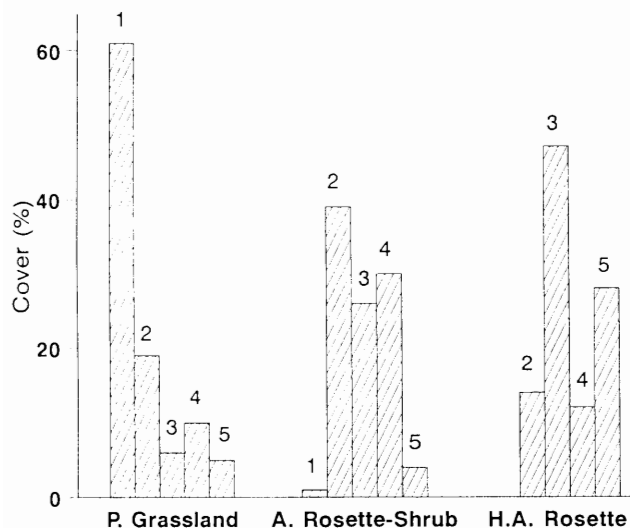


FIGURE 3. Cover of the main fodder species according to their palatability in the vegetation units of paramo grassland, Andean rosette-shrub, and High-Andean rosette-shrub communities in the El Banco Paramo. The numbers indicate approximate palatability:

1-preferred; 2-good; 3-regular; 4-insufficient; 5-rejected.

lium sp., and *Calandrina* sp. Apart from the short grassland and the marshes, the rest of the vegetation of the High-Andean belt does not offer sufficient forage during the dry period.

In general, the quality of available forage for the cattle in the different vegetation units is distributed heterogeneously. The Andean and High-Andean paramo grasslands are characterized by abundant high quality forage, while dominant vegetation in the rosette-shrub and rosette communities of the Andean and High-Andean belts is mediocre to low quality forage (Figure 3).

GRAZING AND SELECTION OF VEGETATION

The palatability data, indices of herbivore damage, and the indices for the selection of plants during grazing, and the indices for preference produced similar results (Table 1). In the paramo grasslands, *C. mulleri* and *C. albolutescens* were the species that the cattle selected and utilized most, followed by *M. ligularis* and *E. acicularis*. The latter species is not good forage due to its small size. In the Andean rosette-shrub the gramineas *S. philippii* and *P. petrosa* were selected most frequently, followed by *Calamagrostis* sp. and *Muehlenbergia* sp.

The availability and distribution of the forage species directly influenced the grazing patterns. In the experimental plots the limited forage enabled short-term simulation of forage selection by the animals as the availability of forage decreases (Figure 4). In the paramo grassland the cattle first selected *C. albolutescens* and *C. mulleri*, grasses that in abundance greatly favored continuous and intense grazing. When the availability of these grasses was reduced, cattle started feeding on *M. ligularis*. Other species such as *Lachemilla* sp. and *Geranium* sp. were consumed when they were encountered in the grasslands (Figure 4 a). In the Andean rosette-shrub community the isolated distribution of the preferred grasses (*S. philippii* and *P. petrosa*) forced the animals to walk between the shrubs and rosettes in search of forage in the herbaceous layer. This selection of gramineas can be combined with browsing of *E. schultzei*, and occasionally *H. laricifolium*. Other species of grass, such as *Calamagrostis* sp. which has a restricted distribution, were consumed when encountered between the shrubs in the herbaceous layer (Figure 4 b). Data from unrestricted grazing and grazing in the experimental plots showed a marked difference in grazing patterns between the paramo grassland and the Andean rosette shrub. Whilst the former is characterized by good quality forage that forms a continuous carpet and favoring detained and intense grazing, the latter is dominated by poor quality forage species, where the preferred species in the herbaceous layer are spread out and favor extensive grazing.

TABLE 1

Approximate scale of palatability (P), scale of damage (D), and foraging by animals (B), and index of preference (IP=% diet composition/% floristic composition) for the most abundant species in the Andean rosette-shrub communities and the Andean short grasslands

Andean rosette-shrub	P	D	F	IP	Paramo grassland	P	D	F	IP
<i>Stipa philippii</i>	2	2	3	2.9	<i>Calamagrostis mulleri</i>	1	2	3	2.3
<i>Poa petrosa</i>	2	1	3	7.7	<i>Carex albolutescens</i>	1	3	3	7.6
<i>Muehlenbergia</i> sp.	2	3	1	0.5	<i>Eleocharis acicularis</i>	1	1	2	0.6
<i>Calamagrostis</i> sp.	2	1	1	6.7	<i>Muehlenbergia ligularis</i>	2	2	2	0.6
<i>Festuca myurus</i>	3	–	1	0.8	<i>Lachemilla</i> sp.	2	–	1	0.3
<i>Bidens andicola</i>	3	–	1	0.7	<i>Agrostis triclodes</i>	2	–	1	0.3
<i>Geranium</i> sp.	3	–	–	–	<i>Vulpia australis</i>	2	–	–	–
<i>Espeletia schultzii</i>	4	1	1	0.7	<i>Geranium</i> sp.	3	–	1	2.6
<i>E. flocosa</i>	4	1	–	–	<i>Rumex acetosella</i>	3	1	1	–
<i>Rumex acetosella</i>	3	1	–	–	<i>Lucilia venezuelensis</i>	4	–	–	–
<i>Acaena elongata</i>	3	1	1	2.0	<i>Hypochoeris sessiliflora</i>	4	–	1	1.0
<i>Luzula racemosa</i>	3	–	–	–	<i>Gnaphalium paramorum</i>	4	–	–	–
<i>Gnaphalium moritzianum</i>	4	–	1	2.0	<i>Calandrina</i> sp.	4	–	–	–
<i>Hypochoeris setosus</i>	3	–	–	–	<i>Veronica</i> spp.	4	–	–	–
<i>Hypericum laricifolium</i>	5	–	1	0.2	<i>Aciachne pulvinata</i>	5	–	–	–
<i>Blakiella bartisiaefolia</i>	5	–	–	–	<i>Hypericum brathys</i>	5	–	–	–
<i>Hinterhubera ericoides</i>	5	–	–	–	<i>Sisyrinchium</i> sp.	5	–	–	–
<i>Senecio formosus</i>	5	–	–	–					
<i>Stevia lucida</i>	5	–	–	–					

Scale of palatability: 1–Preferred, 2–Good, 3–Regular, 4–Insufficient, 5–Rejected.

Scale of animal damage: 1–Light, 2–Moderate, 3–Severe.

Scale of animal foraging: 1–Little, 2–Medium, 3–Intense.

Index of preference: High values= greater preference.

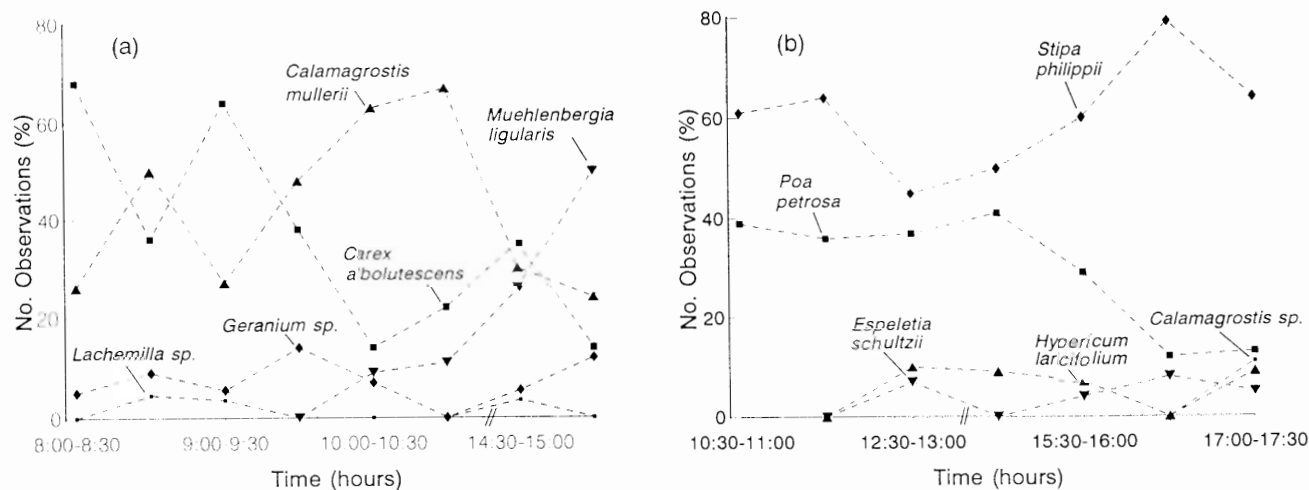


FIGURE 4. Selection of fodder species by cattle in (a) plots of Paramo grassland and (b) in rosette-shrub communities, subjected to moderate grazing loads in the upper Andean belt.

CARRYING CAPACITY AND GRAZING DISTRIBUTION

The approximate carrying capacity for the El Banco catchment area was on average one animal unit per 12 ha in the wet period. If all the animals were utilizing the

natural vegetation in the catchment, the actual load would be one animal unit per 13 ha. These values indicate that the intensity of cattle exploitation (actual load/carrying capacity) would be very high ($I_e=0.91$

TABLE 2
Approximate carrying capacity of the different vegetation units
in the catchment area of El Banco, for the wet and dry periods

Vegetation type	Forage quality		Carrying capacity (A.U./ha)	
	Wet period	Dry period	Wet period	Dry period
Paramo Grassland	good	regular	0.4	0.2
Andean rosette-shrub	poor	very poor	0.1	0.05
High Andean rosette	very poor	very poor	0.05	0.05

The loads are expressed in animal units per hectare (A.U./ha).

TABLE 3
Distribution of animals in different vegetation units in the catchment area of El Banco

Vegetation type	Actual load		Potential load		X ²	
	Wet period	Dry period	Wet period	Dry period	W.P.	D.P.
Paramo Grassland	49	24	60	30	2.0	1.2
Andean rosette-shrub	14	3	67	33	41.9*	27.3*
High Andean rosette	35	17	89	60	32.7*	30.8*

Actual load observed is compared with potential expected load (according to the carrying capacity) for the wet and dry period. Significant differences (*), where $X(t) = 5.99$ and $\alpha = 0.005$.

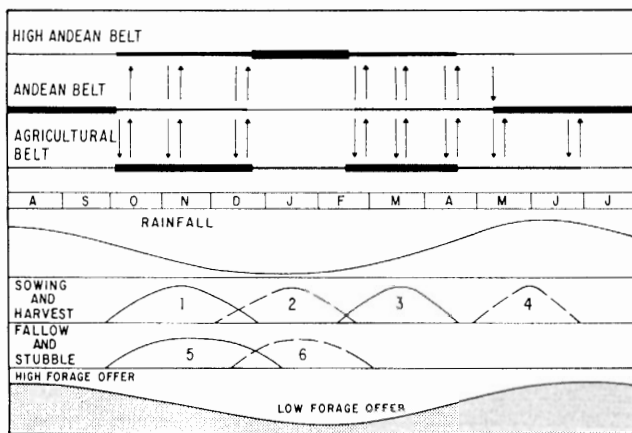


FIGURE 5. Vertical movements of animals throughout the year between the agricultural belt and the highlands of El Banco Paramo. The arrows indicate the direction of movements and the thickness of the horizontal lines indicate the relative number of cattle which are found at each level. The lower curve indicates the forage availability in the highlands. 1-Potato harvest; 2-Wheat stubble; 3-Potato sowing; 4-Wheat sowing; 5-Potato fallow; 6-Wheat stubble.

using the scale of Passera and Borsetto, 1986) if all the animals were utilizing the natural vegetation in the wet period. During the dry period, plant productivity is greatly reduced and a load of one animal unit to 24 ha was estimated: that is, half the load maintained by natural forage in the wet period. However, on account of the

heterogeneous distribution of cattle it was necessary to calculate the carrying capacity per vegetation unit (Table 2). When this was compared with the actual load per vegetation unit (Table 3) a more realistic view of pastoralism in the paramo was obtained. It should be noted that animals were unevenly distributed in the different vegetation units. In both the wet and dry periods the paramo grasslands were intensively grazed, while in the remaining units, grazing was more extensive and animal numbers were below the carrying capacity. Although it is useful to analyze the pressure of grazing on the natural vegetation, the data for actual and potential load are inadequate for explaining the grazing dynamics and the maintenance of large numbers of cattle in these paramos. In the paramo, the movement of animals within the agricultural belt is closely related to agricultural activities and alternative sources of forage. These factors enable the understanding of the dynamics and maintenance of cattle in a system where natural forage is limited.

ANIMAL MOVEMENT AND THE AGRICULTURAL CYCLE

Animals are required for agricultural activities throughout the year. Those that are pastured in the high paramos are brought down to the agricultural belt, establishing a series of movements between the ecological belts which are dependent on the agricultural calendar (Figure 5). The cultivation and harvest of potatoes largely dominates activities in the catchment area. The months of the dry period and beginning of the wet period are times of intense activity that coincide with low availability of natural forage in the paramo highlands. The principal

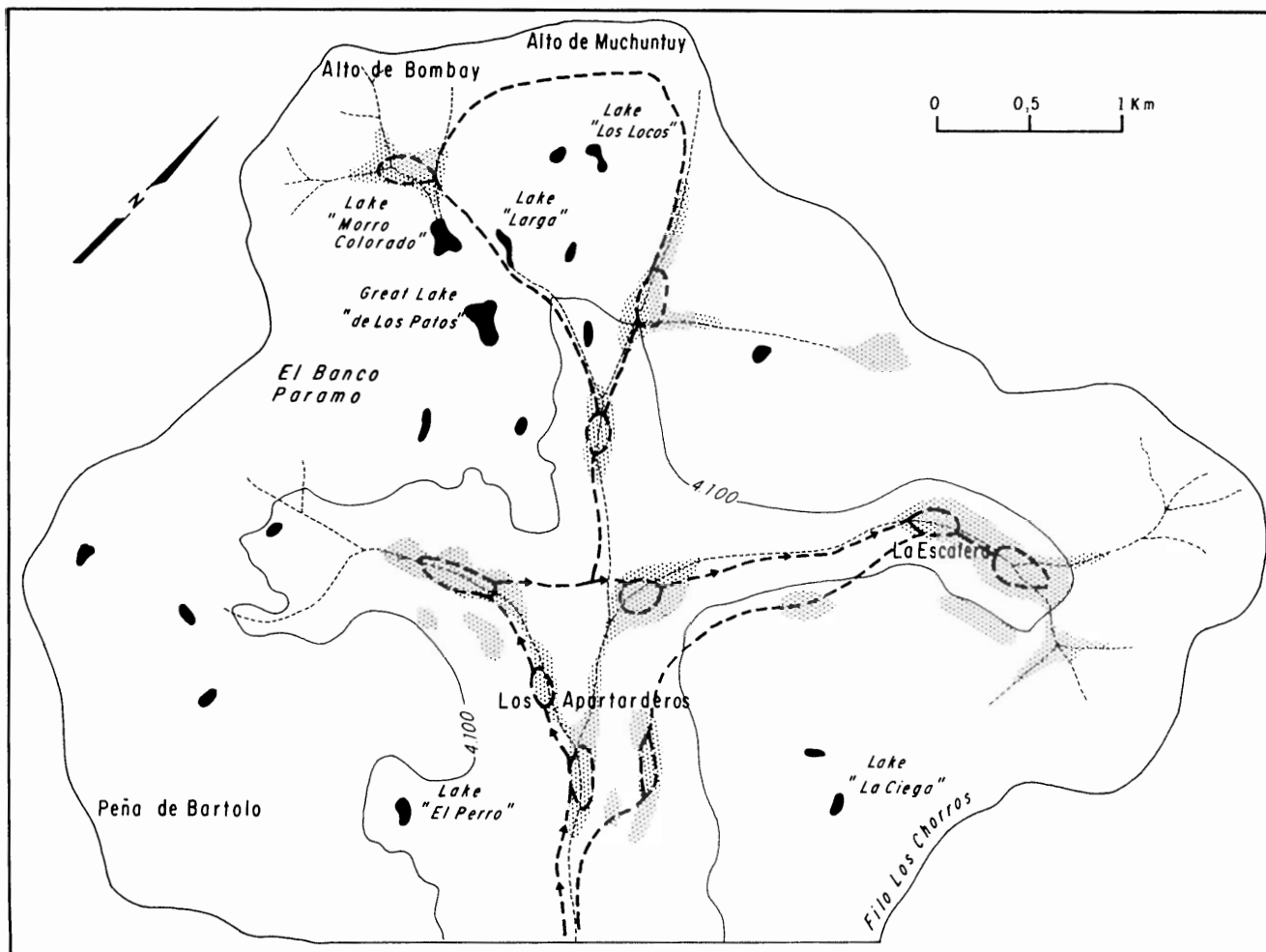


FIGURE 6. Horizontal movements of animals in the highlands of the El Banco Paramo. The dotted areas represent the distribution of the paramo grasslands. The curve of 4,100 m indicates the approximate division between the Andean and High-Andean belts. The dotted lines and arrows represent the movements and directions of the animals. The routes taken by the animals in the High-Andean belt were most frequently used in the dry period. The broken circles indicate the areas of intense grazing.

movements of animals between the highlands and the agricultural belt occur during these months. Between February and May, when potatoes are sown, animals are brought down from the highlands and are maintained in irrigated pastures, in wheat stubble, or in fields of oats cultivated as a food source for the animals. Animal labor is also important during the beginning of the dry period (October–December) when potatoes and occasionally carrots (if watering systems are available) are harvested. Farmers who do not own grasslands within the agricultural belt rent pastures or cultivate oats or barley in sections of their own lands. Animals are taken up to the highlands for the period between the last potato sowing and the potato harvest (May–September), when availability and quality of natural forage is at its highest. At other times also the animals are brought down for the preparation of land a few months before sowing (*barbechadura*), the sowing of wheat, and other agricultural activities which utilize watering systems and are less reliant on climatic regimes.

The greatest contribution of forage in the agricultural

belt coincides with the periods of lowest fodder availability in the highlands. Although alternative forage is available only to animals that are used for labor and for milch cows, it is of great importance for this system. During this period, no animals from neighboring areas are allowed access to fields in succession-regeneration and land with natural vegetation in the agricultural belt. Grazing in fallow plots not only contributes towards colonization by herbs (mainly *R. acetosella*), but also increases the amount of organic manure available from animal excrement.

ANIMAL MOVEMENT IN THE PARAMO HIGHLANDS

Some animals remain in the paramo highlands for most of the year and are not brought down to the agricultural belt; they are reunited with the working cattle once the farming activities are over. The grazing sites and migration routes vary with the seasons. During the wet period the short grassland of the Andean and High-Andean belts, the herbaceous layer of the Andean rosette-shrub, and the dispersed herbaceous vegetation of the High-Andean slopes provide natural forage, and animals

TABLE 4

Comparison of the biovolume of species of the Andean rosette-shrub community in the different treatments. Exclusion of grazing and extensive grazing plots are compared one year later, while experimental grazing plots are compared before and after grazing in June 1991

Species	Exclusion of grazing		Extensive grazing		Experimental grazing	
	Oct. 90	Oct. 91	Oct. 90	Oct. 91	Before	After
<i>Hypericum laricifolium</i>	148	222*	84	154	182	140
<i>Stipa philippii</i>	93	129	54	91	122	75*
<i>Espeletia schultzei</i>	18	38	8	18	14	14
<i>E. flocosa</i>	4	6	6	12	24	17
<i>Geranium</i> sp.	11	21	–	–	–	–
<i>Poa petrosa</i>	5	23	9	21	9	6
<i>Calamagrostis</i> sp.	6	–	–	–	2	2
<i>Muehlenbergia</i> sp.	–	7	2	4	10	7
<i>Festuca myurus</i>	1	1	–	–	2	–
<i>Gnaphalium moritzianum</i>	2	–	2	1	2	–
<i>Aciachne pulvinata</i>	2	2	–	–	–	–
<i>Rumex acetosella</i>	1	5	–	–	–	–
<i>Arenaria</i> sp.	1	–	1	–	–	–
<i>Oxilobus</i> sp.	10	4	–	–	–	–
<i>Luzula racemosa</i>	1	2	–	–	–	–
<i>Bidens andicola</i>	2	2	–	1	2	–
<i>Hypochoeris setosus</i>	–	1	–	–	–	–
<i>Hinterhubera ericoides</i>	–	–	7	13	14	8

Comparisons were conducted using a non-parametric Mann-Whitney test (Sokal and Rohlf, 1979). Significant differences (*), where alpha = 0.05.

move throughout the middle and upper regions of the catchment, concentrating in short grasslands of the valley floor and lightly grazing the Andean rosette-shrub vegetation (Figure 6). The amount of time spent in each 'patch' of short grassland depends on the forage available, the size of the patch, and animal density. Grazing circuits are established where several patches of short grassland are visited throughout the rosette-shrub belt. Such circuits may last for one or two weeks, by which time grass within each patch has rested sufficiently to be intensively grazed again. During the dry period, green fodder is limited to wet short grassland and marshes of the valley floor and high densities of animals graze there. Although movement continues between short grassland patches, time spent within a patch is greater when there are no alternative sources of forage.

GRAZING PATTERNS AND THE DYNAMICS OF LAND USE

Grazing patterns in the paramo show great spatial and temporal variability which is related to resource availability for each family, the type and quantity of crops grown, and the spatial distribution of lands with natural vegetation and crops. In general, families with the most extensive resources use large irrigated fields for cultivating forage, grasslands, natural vegetation or with stubble or fallow, and their animals do not rely heavily on the natural forage of the highlands during the dry period. In some cases the irrigation of short grasslands provides a continual source of high quality fodder throughout the

year, restricting animal movements to the agricultural belt and reducing movements between other ecological belts. For families with few resources, little fodder is available in the dry period; farmers with small holdings with no alternative sources of fodder in the lower part of the catchment area need to graze their animals over extensive areas. These small fodder plots, or short grasslands, are grazed for only a brief period before the animals are taken to the highlands. For these families grazing patterns show great annual variability.

The variability of grazing patterns also depends on the dynamics of land use which is directly related to market demands and the economic situation of each family. During the last few years changes in land use, such as the partition of large areas of short grassland for potato cultivation, the renewed interest in wheat production, the upward extension of the agricultural limit, the reduction in fallow periods, and recent pressures to restrict grazing in the highlands, have altered the grazing patterns. These changes may reduce the amounts of fodder available for cattle.

IMPACT ON NATURAL VEGETATION

The results from the experimental plots demonstrate that for the rosette-shrub communities significant changes occur only with the shrub *H. laricifolium* and the grass *S. philippii* (Table 4). These two species are positively correlated with the primary axes of the multivariate analysis and appear to be responsible for the order of the

Key for species: Sp: *Stipa philippii*;
 Hl: *Hypericum laricifolium*; Es: *Espeletia schultzei*; Ba: *Bidens andicola*; Ca: *Calamagrostis* sp.; He: *Hinterhubera ericoides*; Fe: *Festuca myurus*;
 Ar: *Arenaria* sp.; Ra: *Rumex acetosella*;
 Gn: *Gnaphalium* sp.; Ap: *Aciachne pulvinata*; Mu: *Muehlenbergia* sp.

Key for sampling dates:

In exclusion plots: (I) October 1990;
 (II) June 1991; (III) February 1992.

In extensive grazing plots: (IV) October 1990; (V) February 1991;

(VI) June 1991; (VII) February 1992.

Before experimental grazing:
 (VIII) October 1990; (IX) February 1991; (X) June 1991.

After experimental grazing:
 (XI) June 1991.

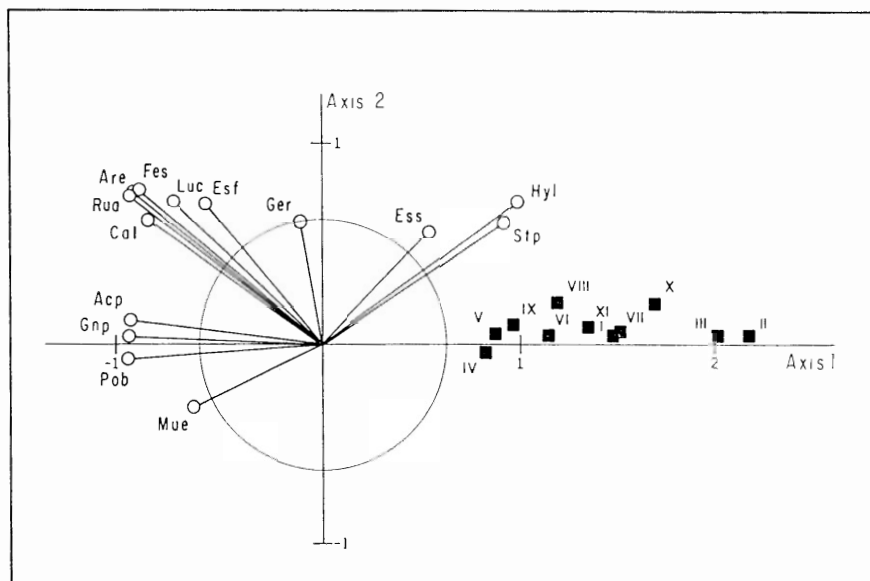


FIGURE 7. Analysis of the principal components of the samples taken from the experimental plots of the rosette-shrub community. A correlation is shown between the dominant species and the samples with the first two axes of analysis. One unit of the graph is equivalent to 10 units in the sampling area and one unit for the species.

TABLE 5

Comparison of the biovolume of species of the short grasslands in the different treatments. Exclusion of grazing and extensive grazing plots are compared one year later, while experimental grazing plots are compared before and after grazing in October 1991.

Species	Exclusion of grazing		Extensive grazing		Experimental grazing	
	Oct. 90	Oct. 91	Oct. 90	Oct. 91	Before	After
<i>Calamagrostis mulleri</i>	42	286*	34	36	161	51*
<i>Muehlenbergia ligularis</i>	29	109	30	59	183	161
<i>Eleocharis acicularis</i>	87	96*	24	38	107	57*
<i>Carex albolutescens</i>	3	30*	56	87*	93	41*
<i>Vulpia australis</i>	3	6	-	-	9	4
<i>Lachemilla</i> sp.	7	20*	21	43*	32	22
<i>Agrostis trichodes</i>	6	20*	24	23	6	5
<i>Crassula</i> sp.	10	2	-	-	3	1
<i>Geranium</i> sp.	-	-	1	2	11	5
<i>Lucilia venezuelensis</i>	1	6	5	10	2	1
<i>Acaulimalva</i> sp.	-	2	8	7	3	4
<i>Aciachne pulvinata</i>	-	-	3	4	7	2
<i>Azorella crenata</i>	-	1	1	10	1	3
<i>Ophioglossum crotalifloroides</i>	1	1	-	3	3	1
<i>Gnaphalium paramorum</i>	-	-	-	1	-	-
<i>Veronica</i> sp.	2	3	-	2	-	3
<i>Calandrinia</i> sp.	2	3	1	5	1	4
<i>Oenothera</i> sp.	-	-	-	-	4	1
<i>Rumex acetosella</i>	1	2	1	1	4	-
<i>Hypochoeris sessiliflora</i>	-	2	-	1	2	-

Comparisons were conducted using a non-parametric Mann-Whitney test (Sokal and Rohlf, 1979). Significant differences (*), where alpha = 0.05.

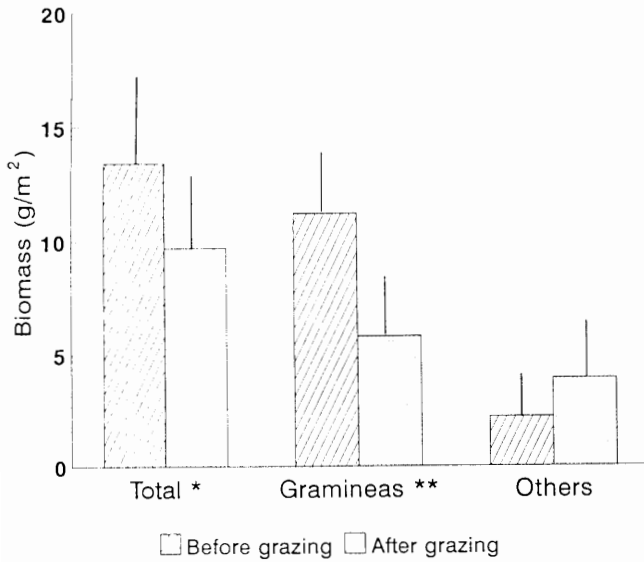


FIGURE 8. Comparison of the aerial biomass of the herbaceous layer of the rosette-shrub community before and after moderate grazing. The grasses are differentiated from the other species (forbs and shrubs). (*) $p < 0.05$, (**) $p < 0.001$.

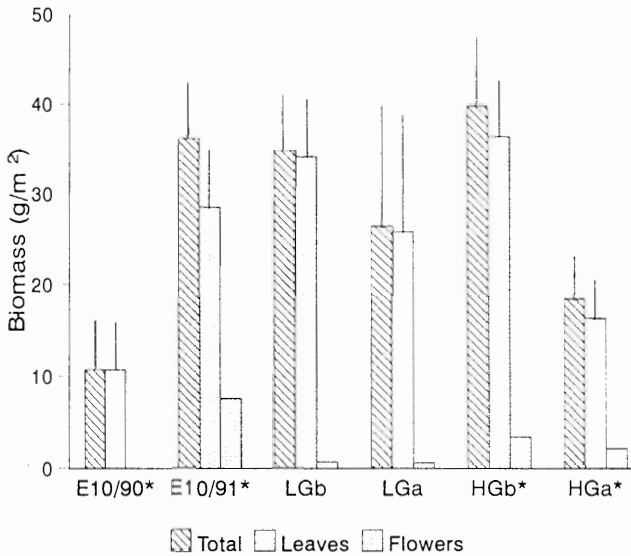


FIGURE 10. Comparison of the aerial biomass of short grassland plots with grazing excluded between October 1990 (E10/90) and October 1991 (E10/91) and with light grazing (LG) and heavy grazing (HG) before (b) and after (a) grazing.

samples taken from the experimental plots along a gradient on the first axis (Figure 7). This is especially noteworthy when comparing the samples taken in the dry period (October 1990–February 1991) with those taken in the wet period (June 1991) where the strong seasonality of the rosette-shrub community appears to be the most important factor for the order of the samples. The change in position of the different samples in the grazing exclusion plots, and the samples before and after experimental grazing, respond to the changes of biovolume of

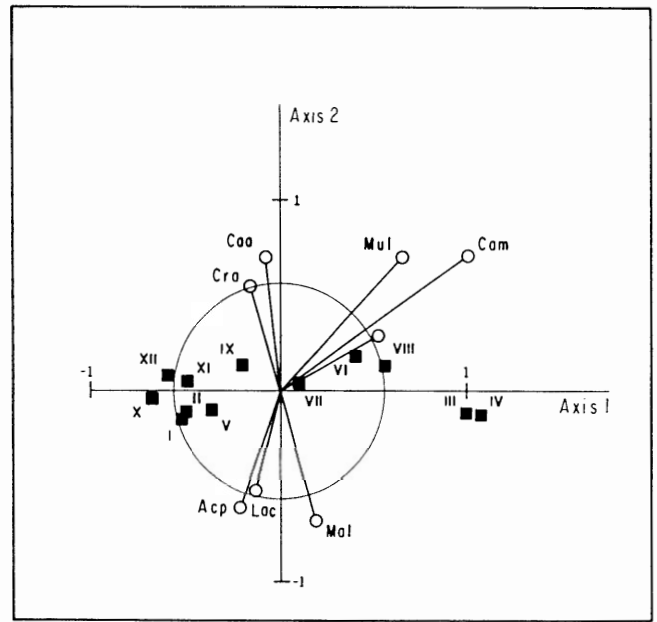


FIGURE 9. Analysis of the principal components of the experimental plots in the short grasslands. A correlation is shown between the dominant species and the samples with the first two axes of analysis. One unit of the graph is equivalent to 10 units in the sampling area and one unit for the species.

Key for species:

Cam: *Calamagrostis mulleri*; Mul: *Muehlenbergia ligularis*; Caa: *Carex absolutescens*; Cra: *Crassula* sp.; Acp: *Aciachne pulvinata*; Lac: *Lachemilla* sp.; Mal: *Malvastrum* sp.

Key for samples:

In grazing exclusion plots: (I) October 1990, (II) February 1991, (III) June 1991, (IV) October 1991.
Before experimental grazing: (V) October 1990, (VI) June 1991, (VIII) October 1991.
After experimental grazing: (VII) June 1991, (IX) October 1991.
In extensive grazing plots: (X) February 1991, (XI) June 1991, (XII) October 1991.

H. laricifolium and *S. philippii*. Both species are affected by grazing. The recuperation of *H. laricifolium* following a reduction in grazing has been observed in other areas of the Cordillera of Merida (Nauman, 1986) and is attributed to the fragility of its branches. The reduction in the biovolume of *S. philippii* is thought to be a direct result of herbivory that generally affects most gramineas in the herbaceous layer of the Andean rosette-shrub (Figure 8).

In the paramo grassland various species (*C. mulleri*, *M. ligularis*, *E. acicularis*, *Lachemilla* sp., and *A. triclodes*) exhibit significant growth when grazing is excluded. These grasses are also affected by moderate loads of experimental grazing (Table 5). Of these grass species, *C. mulleri* and *M. ligularis* are positively correlated with the primary axes of the multivariate analysis and are primarily responsible for the order of the samples on the first axis (Figure 9). These species in particular, and most gramineas and

Cyperaceae of the short grasslands, are affected by grazing and recuperate rapidly in the absence of grazing. The order of the samples from the experiments was a direct result of the changes in grass biomass. The samples taken following several months of exclusion were found at one end of the gradient, while samples taken from extensive

grazing and short periods of exclusion were found at the other gradient extreme. The grasses in the exclusion plots also showed significant differences in aerial biomass, that is only observed in experimental grazing of high cattle loads (Figure 10).

DISCUSSION

Traditional agro-pastoralism is an old and widely used strategy for land use in puna environments, and communities that are dedicated exclusively to pastoralism are rarely found (Browman, 1974; Flores-Ochoa, 1977; Guillet, 1986; McGreevy, 1991). In the agricultural communities of the Colombian and Venezuelan paramos the introduction of cattle during the colonial period allowed access to new resources in the highlands that had not been used previously. Extensive areas of vegetation, divided by natural barriers, that were readily available with no preparation or cutting of forest provided ideal environments for grazing (Hofstede, 1995). This new activity rapidly became incorporated into the agricultural economy during the colonial periods and land above the limits of cultivation was distributed as land for grazing (Wagner, 1979). Since that time, cattle introduced for agricultural activities have become increasingly important in these regions. Cattle farming in the Cordillera of Merida has played an increasingly important role in the agro-pastoral strategies, although it was developed much later than in the puna. Although agro-pastoralism is mainly dominated by the traditional cultivation of tuber crops (Sarmiento *et al.*, 1993) and in isolated regions by cereals (De Robert and Monasterio, 1993), traditional farming is dependent on the complement of cattle. Cattle not only contribute farm labor, but also play an important role in the economy of agriculture-dependent communities. In most cases, animals that are reared at a low cost in the highlands represent savings available for other circumstances. In only a few places has cattle management replaced the economic importance of agriculture, such as cattle and sheep farming in the oldest agro-pastoral economies in some paramos in Ecuador (Hess, 1990; White and Maldonado, 1991).

One of the problems confronted by introduction of European cattle into paramo environments, and Andean environments in general, was the forage quality of the dominant vegetation. In puna environments the low efficiency of European animals for digesting natural forage (San Martin and Bryant, 1989; Genin *et al.*, 1994) limited potential areas for grazing. Thus animals were concentrated in a low number of suitable pasture areas, traditional grazing patterns were altered, or vegetation was modified to improve forage quality (Flores-Ochoa, 1979, 1988 b; Molinillo, 1993). In the wet paramos of Ecuador and Colombia the large proportion of dry material in the highland forage was also an obstacle. Forage palatability and accessibility was improved by burning the pastures (Grubb, 1970; Williamson *et al.*, 1986; Hofstede *et al.*, 1995). In the less humid paramos of the Cordillera of

Merida a close relationship was developed between agricultural activities and cattle management, with grazing in the highlands complementing alternative forage sources in the agricultural belt (crops, stubble, fallow, succession plots). Grazing patterns in this region are characterized by great spatial and temporal mobility of animals between the agricultural belt and other ecological belts. This great diversity and variability of responses was developed at a family, rather than a community, level and largely reflects the difficulty of finding collective solutions for obtaining fodder, especially during the dry period. In some wet paramos in Ecuador the scarcity of forage has also led to the development of relationships between agriculture and cattle farming, although solutions were developed at the community rather than family level (Hess, 1990). As with grazing practices in the puna, it was possible to develop agro-pastoral models at a community level (Brush, 1976; Gunderman, 1988; Molinillo, 1988; Palacios Rios, 1988; Rabey, 1991).

The grazing patterns developed in the highlands of the Cordillera of Merida were in response to both ecological characteristics of the environment and animal requirements. Glacial valleys with good quality forage lie between mountainsides covered in rosette-shrub communities, where cattle prefer to graze in flat areas with accessible water and abundant, fresh fodder (Muegler, 1965; Cook, 1966; Walker and Heitschmidt, 1986). These preferences gave rise to grazing patterns with circuits of intense use of short grasslands and extensive use of rosette-shrub communities. Grazing patterns could strongly influence the composition and spatial distribution of short grasslands of these paramos. In wetter paramos the presence of short pastures among the high grasses has been related to the use of fire and intensive grazing (Hofstede *et al.*, 1995).

In other parts of the world, the formation and maintenance of short grasslands are also closely related to animal movements and preferential grazing zones (Brasher and Perkins, 1978; O'Connor, 1978; Garcia Gonzalez *et al.*, 1990; Molinillo, 1993). The composition and structure of these short grasslands depends principally on grazing pressure (Mack and Thompson, 1982; Milchunas *et al.*, 1988) which affects mainly the perennial grasses, although when grazing is eliminated they are able to recuperate rapidly (Robertson, 1971; McLean and Tisdale, 1972; Smith and Shmutz, 1975; Anderson and Holte, 1981). Grazing pressure of short duration in each 'patch' of grassland favors the maintenance of some perennial grass species but prevents them from becoming permanently dominant. In short-term experiments the exclusion of grazing resulted in changes in the biomass

only in the grasses adapted to this grazing type. Changes in structure and composition of the short grasslands would be expected after several decades of exclusion, with the recuperation of tall grass species, such as those found in wet environments with no history of grazing (Milchunas *et al.*, 1988). On slopes with rosette-shrub communities the type of grazing has produced a dispersed distribution of some palatable grasses below the shrubs in the herbaceous layer (refuges from herbivory). This pattern has also been observed when grazing occurs on grasses growing among less palatable shrubs (Jaksic and Fuentes, 1980). Other changes that result from grazing are an increase in low shrub cover in areas with high animal movement where cattle disperse fruits and create conditions for establishment (Molinillo and Farji-Brener, 1993) and where cattle damage the trunks of giant rosettes in the High-Andean belt (Perez, 1992).

The introduction of cattle into these wet environments with little history of grazing has produced marked changes in the vegetation and long-term studies are necessary to determine the magnitude of these changes. The pollen studies of some Venezuelan paramos indicate an increase in composites and a decrease in grass species during the last 400 years that can be attributed to pastoralism (Salgado-Laboriau, 1980). However, the degree of grazing impact is not only related to the recent introduction of large herbivores, but also to the type of management. In the wet paramos of Colombia large alterations in the structure and composition of the vegetation have been attributed to the repeated use of burning, followed by intensive cattle grazing. In contrast, in places with moderate grazing intensity and no burning, the structure of the vegetation has not altered greatly in comparison to undisturbed areas (Hofstede *et al.*, 1995). In areas subjected to thousands of years of grazing, such as the puna,

severe grazing pressure has changed the vegetation significantly (Wilcox *et al.*, 1987). If management, in addition to grazing history, is an important variable in the determination of vegetative response to herbivory, then pastoralism in the Cordillera of Merida can be analyzed from a different perspective: the question "should grazing cattle be eliminated in order to reduce the impact on paramo vegetation?" may be replaced by "what type of management causes the least impact on the vegetation of the paramo?"

The proposal by the National Parks Service to eliminate grazing cattle (Inparques, 1991) has resulted in confrontations with the agro-pastoral communities and has not reduced grazing pressure. If grazing management rather than elimination of cattle were considered, both the environment and the farming communities would benefit. Controls that should be included within a program are: grazing restrictions in fragile areas such as the periglacial desert in the High-Andean belt; a reduction in the number of animals; an increase in alternative fodder in the agricultural belt; and the generation of alternative agricultural activities for the farming communities. Furthermore, the application of grazing control in this paramo, where cattle farming is closely related to agricultural activities, would also ensure that other problems could be addressed: for example, the altitudinal advance of the agricultural limits; the conversion of short grasslands and marshes into crop land; degradation of the soils; reduction in crop diversity; and the dependence on intermediaries for marketing crops. An emphasis on cattle management, therefore, would form a part of a more participative and global project (Monasterio *et al.*, 1996), compatible with the objectives of the farming communities and the conservation of the biota and environments of the paramo.

CONCLUSIONS

The introduction of cattle to environments with no grazing history is the key to understanding pastoralism in the paramos of the Cordillera of Merida. It led to the utilization of resources that previously had been unexploited in the highlands, and to the development of agro-pastoral strategies in which animals played an important role in agricultural activities and the farming economy. The diversity of practices that were developed in the agricultural belt reflects the decision making of individual families in order to cope with the limited availability of forage. The impact of grazing on the vegetation of the highlands was closely related to the low spatial and temporal availability of good quality forage and suitable ecological conditions for grazing cattle. This led to grazing patterns with intensive use of short grasslands whose distribution and composition could be related to grazing. Long-term studies are required to determine the magnitude of vegetative changes produced by grazing. Finally, a

greater emphasis should be placed on the development of suitable management schemes to be included in a participative and global project that considers both the conservation of the environment and the economy of the farming community.

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