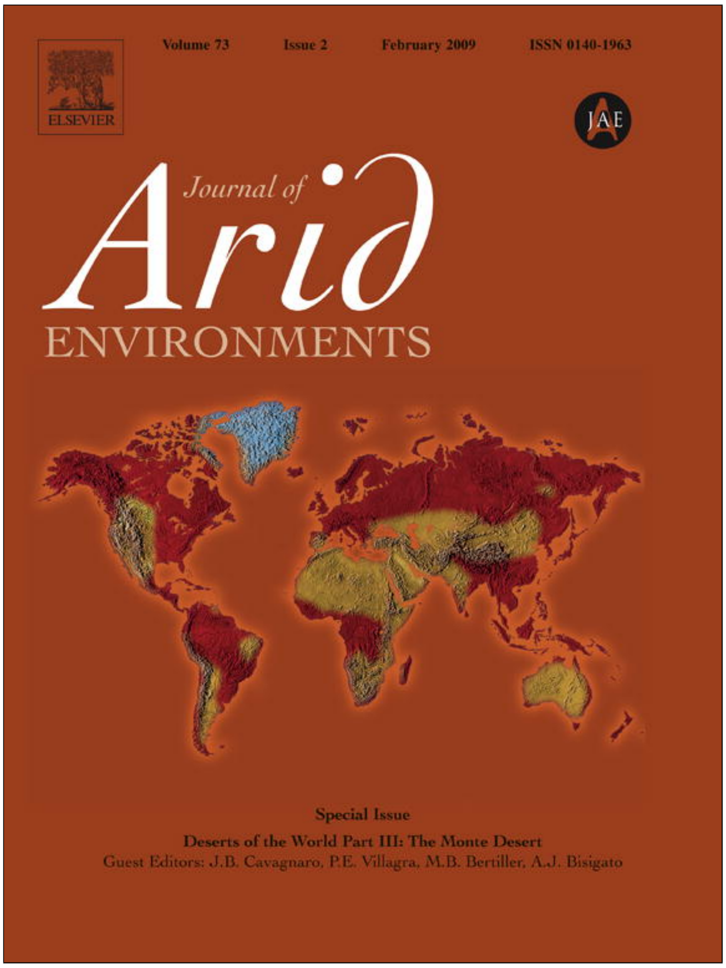
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Range and livestock production in the Monte Desert, Argentina

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A B S T R A C T

This article reviews and analyzes the available information on range and livestock production in the Monte Desert. Cow–calf operations, goats for meat, and sheep for wool are the dominant production systems under continuous grazing. Rest-rotational grazing systems improved the efficiency of the current cow–calf production. Forage resources are primarily composed of perennial grasses and woody species. Rain-use efficiency for the total vegetation ranged from 3.9 to 4.8 kg DM ha^{-1} year^{-1} mm^{-1}. Carrying capacity showed a broad range: 18.7, 4.5–64.5, and 21.6–89.3 ha AU^{-1} in the north, central, and south portions of the Monte, respectively. Mean crude protein (CP) content of grasses varied from 8.4 to 10.3 (wet season) and 7.1–3.7% DM (dry season) in the central west and Patagonia, respectively. Grasses predominated in the cattle diet, while the sheep diet was highly diverse because they ate most of the available plant species, and there was no unanimity as to the fact that goats are strictly browsers. Livestock diseases have lower prevalence indices than those recorded in other areas of the country. The high variability in carrying capacity values could be attributed to differences in rangeland condition and to the different methods used for its estimation. The CP levels in forage could meet cattle requirements provided that a proper-stocking rate were used. The most promising species for land rehabilitation are *Opuntia*, *Atriplex* spp., *Eragrostis curvula* and *Cenchrus ciliaris*. Priorities for future research should include topics such as assessment of the carrying capacity for most of the areas and nutrient content of the components of livestock diet, the livestock intake values, the economic feasibility of the use of complementary feeds and the development of seeding technology for valuable forage resources as *Trichloris crinita*, among others.

1. Introduction

Demand and supply patterns for meat and the external economic and institutional environment in which the livestock sector operates are rapidly changing at the global level. In the next two decades the livestock sector is projected to become the world's most important agricultural subsector in terms of added value and land use. The growing, increasingly urban and more affluent population in the developing world is likely to demand a richer, more diverse diet, with more meat products. As a result, global demand for meat is set to grow from 209 million t in 1997 to 327 million t in 2020. The developing world is projected to be the major supplier of this growing market (De Han, 2001). In addition, crop expansion into drier areas is forcing pastoral livestock production systems to moving into even drier lands, and this is a global trend that includes the Monte region. New pressures on the environment are at work or could emerge as a result of these changes, which should therefore be of concern (Sere et al., 1995). This paper reviews the available information (obtained from Scopus and Scholar Data Bases and regional experts) on range and livestock production for the Monte region, the widest arid region of Southern South America.

The Monte Desert extends from north to south in central and western Argentina, comprising about 50 million ha. The Monte region (Fig. 1) has three geographical portions, north, central (west and east) and south (Patagonian Monte). The northern portion presents a typical landscape of intermountain depressions, valleys,

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and slopes belonging to the Pampean hills. Rivers are intermittent and large salt flats are frequent. The central portion is an undulating to depressed loess plain of fluvial, lacustrine, and Quaternary eolian origin. The third, southernmost region, occurs on a plateau landscape and forms a wide ecotone with northern Patagonia. The Monte is the most arid rangeland of Argentina; it has a dry climate, warm in the north and gradually becoming cooler towards the south. Aridity in the northern portion is related to its position between the Andes to the west and the Pampean hills to the east, both of which intercept the humid winds coming from the Pacific and Atlantic oceans, respectively. Rains occur mainly in summer, ranging from 80 to 200 mm (see isohyets in Fig. 1), and annual potential evapotranspiration decreases from 1000 mm in the west to 700 mm in the east. Annual mean temperature ranges from 15 to 19 °C. The marked continental climate of the central region is influenced by warm and dry winds from the west. The summers are very warm, absolute maximum temperatures may reach 40–45 °C, and absolute minimum temperatures in winter may be as low as −15 to −20 °C. Rainfall ranges from 250 to 400 mm year^{-1}, and annual potential evapotranspiration is about 800 mm. The Patagonia has a colder climate. Its mean annual temperature is 12–14 °C and rainfall is scanty, with 200–300 mm year^{-1} concentrated in

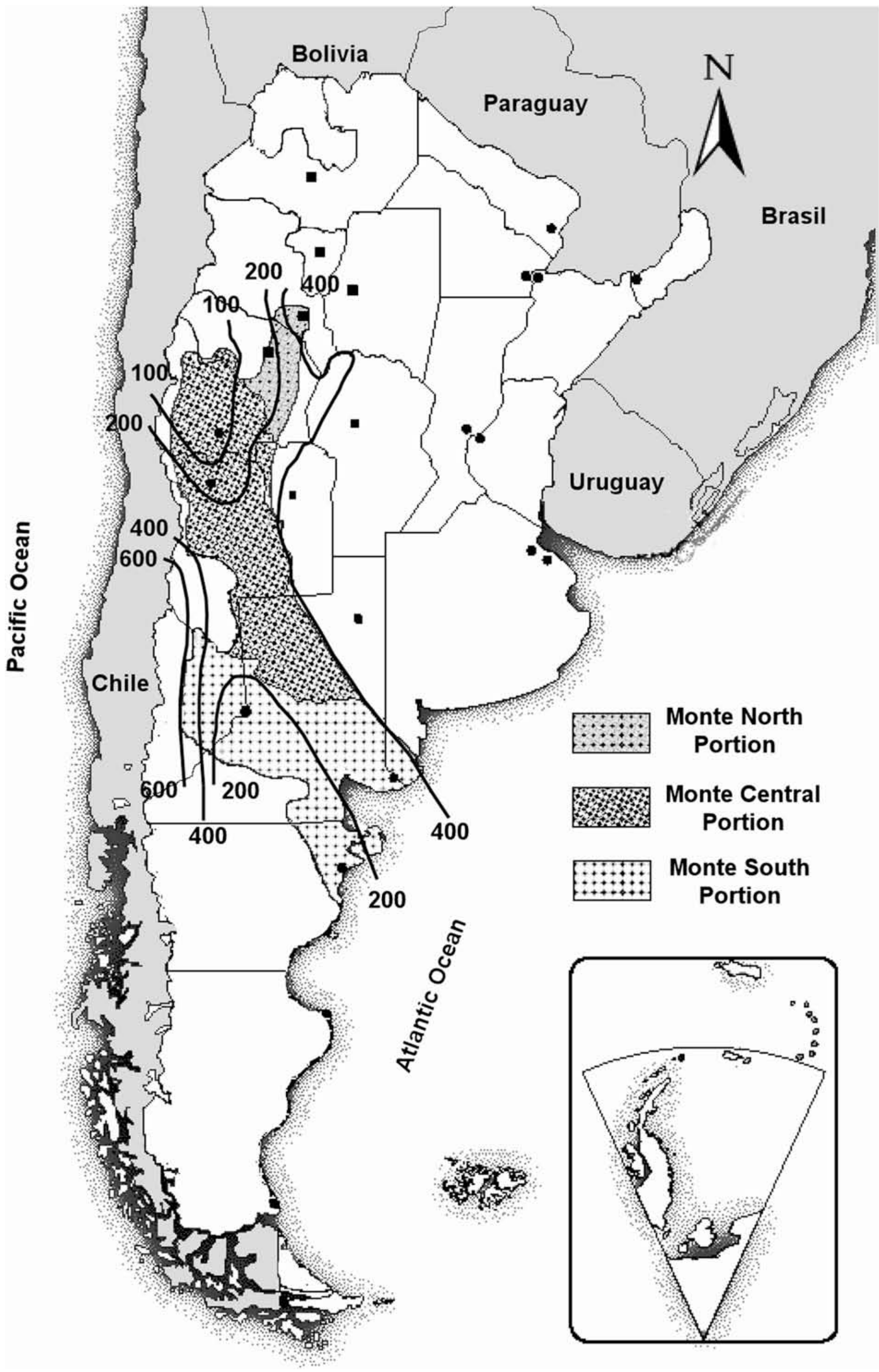

Fig. 1. Location, geographical portions and isohyets of the Monte Desert.

winter and spring; average annual evapotranspiration is similar to that in the north and central portions (Fernández and Busso, 1997; INCYTH, 1994).

Monte vegetation occupies some areas in nine Argentinean Provinces, although none of these provinces is exclusively occupied by this type of vegetation. It may have different physiognomy depending chiefly on its degradation status: dense thickets of small trees, open woodlands and savannas with isolated trees, tall shrublands, low shrublands and bare lands, Close to pristine stands, it typically includes four main structural layers: small trees, tall shrubs, low shrubs and herbaceous layer. Flora and vegetation are reminiscent of the Sonoran formations of NW Mexico and SW USA; one notes several vicariant species in many shared genera; but there are few species (5.6%) in common. Almost pure stands of 'jarillas' are physiognomically identical to those of *Larrea tridentata* in the Sonoran, Chihuahuan, and Mojave Deserts, and nearly as poor in grazing value. This vegetation also somewhat recalls that of the 'Caatinga' in NE Brazil, but under different climatic conditions, since the latter undergoes no cold-weather stress (Guevara et al., 1997).

2. Livestock numbers

The nine Argentinean provinces including Monte vegetation had about 1.3 million cattle, 1.2 million sheep and 1.1 million goats (INDEC, 2002, Table 1). This region supported 3.5% of the cattle, 10.0% of the sheep and 31.6% of the goats in Argentina. About 92% of sheep and 51% of goats were in the Patagonian Monte (Provinces of Neuquén, Río Negro and Chubut), whereas about 67% of cattle were in the other Provinces. The mean stocking rate (37.0 ha AU^{-1})[1] did not include other animals present in the Monte such as horses, donkeys, and species of the Camelidae family (*Lama glama*, *Vicugna vicugna*, and *Lama pacos*).

3. Livestock production systems and productivity indices

3.1. Cattle

Cow–calf operations under rangeland conditions are the dominant production system. Investment in both infrastructure and cattle management technology is low. Continuous grazing is the dominant strategy employed (Guevara et al., 2006) and the use of additional food is not a common practice. In the total area of the Provinces included in the Monte, about 18% and 8% of ranchers, used, respectively, time-controlled mating and carried out pregnancy diagnosis (SAGPyA, 2002). Calf crop for the whole Monte was 50.8% (INDEC, 2002). Two main traditional production systems based on cow–calf and goat operations under extensive rangeland continuous grazing are prevalent in the north portion of the Monte. One of them is characterized by a common use of the land, without fencing, and the second by the existence of fenced paddocks (Diez and Calella, 1991). Efficiency measures are low in both systems, mainly due to loss of carrying capacity (CC) and poor animal management (Table 2). In the central east portion of the Monte, the rangelands are in fair or poor conditions. In the current cow–calf production system the range forage supply is lower than cattle forage requirements. Furthermore, the animals are not subjected to a standard sanitary control program (Frasinelli et al., 2002). In the central west portion of the Monte, mean calf crop for the period 1999–2003 was 52% and beef production was 3 kg ha^{-1} $year^{-1}$ (Guevara et al., 2006).

An improved rest-rotational grazing system based on rangelands was developed in the northern Monte for cattle production (Orionte et al., 2001). It consisted of annual adjustment of stocking rate to forage availability and with paddocks being rotationally rested every 2–3 years during the rainy season. In the central east, Frasinelli et al. (2002) proposed the incorporation of low input technologies such as paddocks subjected to half-yearly, annual or biannual rest; herd management reaching a balance between range forage supply and cattle requirements; and application of a strict sanitary control (rest-rotational in Table 2). Improved range management practices were installed in a 5000 ha cow-calf operation demonstration ranch in the central west, stocked at a mean rate of 25 ha AU^{-1}. A four-pasture, one-herd rotation grazing system is used. An average of 70% of calves was weaned, whereas turnover was some 50%. Concerning the prevailing traditional continuous grazing system, beef production was 57% higher (Guevara et al., 1997). At the same time, the range condition was considerably improved, i.e. the number of preferred species in 0.5 m^2-plots significantly increased from 0.57 to 0.81 in 10 years (Guevara et al., 2001).

A rest-rotational grazing with pastures was developed in northern Monte (Ferrando et al., 2005), based on the introduction of buffel grass (*Cenchrus ciliaris*) pastures in 10–15% of the total range area. Frasinelli et al. (2002) proposed for the central east area of the Monte an improved system that incorporated buffel grass seeding in an area equivalent to 13% of the rangeland in poor conditions in the northwestern sector, and to 20% of the rangeland with weeping lovegrass (WL, *Eragrostis curvula*) in the southwestern sector. In the latter sector, *Digitaria eriantha* and *Panicum coloratum* were established for integrating the forage chain with WL and rangeland, improving the productivity of the systems. Paddocks with native vegetation were subjected to annual rest during the summer season. WL seeding in the grazing systems for cow–calf operations in the central west appears to be economically feasible (Guevara et al., 2005a) for most of the analyzed scenarios that combine WL yield (800–2400 kg DM ha^{-1} $year^{-1}$), CC of the rangelands (10–18 ha AU^{-1}) and the cost of prohibited grazing in the area where WL is established (with and without grazing values).

3.2. Goats

Subsistence economy under continuous grazing without fencing is the dominant production system. This activity is the way of life of the stockman who lives in the production site and provides all or most of the necessary labor. Goats are basically fed on rangelands and have been traditionally kept for meat production. The cultural and socioeconomic conditions of the inhabitants have led to overgrazing and its consequent impacts on vegetation, soil and future productivity. Goat herders generally occupy communally or state-owned land.

The mean annual kid crop for the "Criollo" biotype was 1.0 $goat^{-1}$ in the central west, where 8–14 kg liveweight kids are sold at 40–65 days old (Guevara et al., 2006) or at 60–180 days old, with no liveweight specification in the Patagonian Monte (Lanari et al., 2000). Such kid crop was higher than those obtained in the central east for the same biotype: 0.77 (Rossanigo et al., 1995). For the "Colorada" biotype, mean annual kid crop reached 1.9 $goat^{-1}$ in the central east (Bedotti et al., 2003).

3.3. Sheep

The south portion of the Monte is mainly used for sheep production under extensive conditions (Ares et al., 1990). Ranches present a modal size of 10 000 ha, and four paddocks sharing a sole permanent watering point in their center. Sheep, at stocking rates ranging from 0.10 to 0.14 sheep ha^{-1} (Bertiller et al., 2002), graze these paddocks throughout the year. Two paddocks are used by

[1] Animal unit (AU): a cow with 400 kg liveweight; equivalent to 0.16 AU for sheep and goats.

Table 1
Number and distribution of livestock (thousands of adult animal heads and animal units) and stocking rates per province including in the Monte Desert[a]

Province	Cattle		Sheep		Goats		Stocking rate (ha AU^{-1})
	Head	Animal unit[b]	Head	Animal unit	Head	Animal unit	
Catamarca	22.3	20.4	20.6	3.3	28.0	4.5	115.0
La Rioja	73.7	69.2	2.9	0.5	66.3	10.5	32.1
San Juan	30.8	28.9	7.1	1.1	55.6	8.9	230.4
Mendoza	263.3	252.1	35.6	5.7	261.9	41.6	35.9
San Luis	38.6	35.4	0.7	0.1	10.0	1.6	18.5
La Pampa	457.5	398.5	30.4	4.9	90.9	14.5	18.3
Neuquén	67.8	63.4	103.3	16.5	477.6	76.2	60.3
Río Negro	370.4	349.2	495.1	79.2	62.4	10.0	28.8
Chubut	4.0	3.7	462.4	74.3	1.9	0.3	30.2
Total	1328.4	1220.8	1158.1	185.6	1054.6	168.1	37.0

[a] INDEC (2002).
[b] Animal unit (AU): a cow with 400 kg liveweight; equivalent to 0.16 AU for sheep and goats.

ewes, one by castrated males and rams, and the other one by female lambs (A.J. Bisigato, personal communication, 2007). Wool from Australian Merino breed of undefined quality is the most important production item. Meat production is limited to the sale of surplus ewes, refuse castrated males, and lambs with 19–24 kg of liveweight at 70–90 days old (Guevara et al., 2006). Lamb crop ranged from 0.4 to 0.8 sheep^{-1} (Iglesias et al., 2004) and mean wool productivity was 3.6 kg animal^{-1} in the 2001–2002 wool crop (Rimoldi, 2004).

4. Composition and productivity of rangelands and their relationships with rainfall and range conditions

Forage resources of native plant communities in the north are mainly composed of perennial grass species (Ferrando et al., 2001). Species composition changes spatially according to a regional aridity gradient (Blanco, 2004; Cabido et al., 1993), topography and soil patterns (Gómez et al., 1993), and range conditions (Blanco et al., 2004). There are also temporal changes strongly related to annual rainfall fluctuations. The relationship between forage productivity (FP, in kg DM ha^{-1} year^{-1}) and rainfall (R, in mm year^{-1}) changes according to range conditions (Blanco et al., 2005a). These authors show that rainfall efficiency, i.e. the slope of the linear regression between FP and R, is significantly higher in good ($FP=-821+4.7R$; $R^2=0.56$; $p=0.001$) and fair ($FP=-553+4.0R$; $R^2=0.58$; $p=0.001$) conditions than it is in poor conditions ($FP=-183+2.2R$; $R^2=0.32$; $p=0.003$).

The vegetation in the central west is an open xerophytic savanna and shrubland of *Prosopis flexuosa*. Warm-season perennial grasses dominate the herbaceous layer. Primary productivity of the latter layer was measured at two sites of this area. The global results were fully comparable when the maximum standing crop at the end of the growing season was considered: 508 and 555 kg DM ha^{-1} year^{-1} for Ñacuñán Biosphere Reserve and for the El Divisadero Cattle and Range Experiment Station, respectively (Guevara et al., 1997). The rain-use efficiency (RUE) factor for grasses, expressed as kg DM ha^{-1} year^{-1} mm^{-1}, was 1.7 for Ñacuñán and 1.9 for El Divisadero. Browse production was estimated to reach 926 kg DM ha^{-1} year^{-1} for Ñacuñán (Braun et al., 1978) and 820 kg DM ha^{-1} year^{-1} for El Divisadero (Guevara et al., 1994, 1996a). Thus, the RUE for both grass and woody species ranged from 4.8 to 4.7, for Ñacuñán and El Divisadero, respectively.

The central east is covered by *Larrea divaricata* open shrublands which are progressively dominated by *Larrea cuneifolia* to the west. The floristic composition of thorny shrubs, the open herbaceous layer and the halophyte-rich shrublands were described in detail by Cano et al. (1980). Precipitation is concentrated between October and March. However, this period also shows the highest values for water deficit due to the associated elevated temperatures (Casagrande and Conti, 1980). Rainfall decreases from northeast (annual: 388 mm; October–March: 204 mm) to southwest (annual: 171 mm; October–March: 111 mm). The productivity of the grass layer varied according to this decreasing rainfall gradient: from 650 to 300 kg DM ha^{-1} year^{-1} in the northern part of the area and from 300 to 100 kg DM ha^{-1} year^{-1} in its southernmost one (Frank et al., 1998). Mean RUE values for the grass layer was 1.2 for the northeast and southwest of the area.

León et al. (1998) highlighted the homogeneity of the Patagonian Monte, although two subunits were identified based on floristic and physiognomic features. The first subunit, called "Typical Patagonian Monte" corresponds to xeromorphic tall shrublands, dominates by species of *Larrea* genus, mainly *L. divaricata* (Ares et al., 1990). Vegetation cover reaches 40–60% (Bisigato and Bertiller, 1997). Most of the cover is composed of tall shrubs although dwarf shrubs are also common. Grass cover is scarce (Bisigato et al., 2005). In the second subunit, named "Eastern Patagonian Monte", plant cover is higher (about 80%) than in the Typical Patagonian Monte, with a sparse tree layer and a shrub layer. As in the Typical Patagonian Monte, the grass layer is dominated by *Stipa tenuis*, but it is also rich in other species typical of the Monte (Busso et al., 2004; León et al., 1998). The main climate difference between both subunits is the annual precipitation. While the Typical Patagonian Monte occurs where precipitation rarely

Table 2
Efficiency measures of the cow-calf production systems in the Monte Desert

Area	Carrying capacity (ha AU^{-1} year^{-1})	Calf crop (%)	Beef production (kg ha^{-1} year^{-1})	Long term vegetation tendency
Continuous grazing				
North[a]	>20	45	4	Negative
Central east[b]	12.6–8.4	61.6–66.3	5.9–10.9	Negative
Central west[c]	15.8–26.3	54.0	3.0	Negative
Rest-rotational grazing				
North[d]	10–12	78–88	12–13	Positive
Central east[b]	10–6.5	85.0–90.0	12.0–19.9	Positive
Central west[e]	25.0	70	4.7	Positive
Rest-rotational grazing with pastures				
North[f]	6.5	85.0	22.0	Positive
Central east[b]	5.9–4.5	90.0	23.5–32.0	Positive
Central west[g]	8.8–10.3	85.0	12.5–14.6	Positive

[a] Diez and Calella (1991).
[b] Frasinelli et al. (2002).
[c] Guevara et al. (1981).
[d] Orionte el al. (2001).
[e] Guevara et al. (1997).
[f] Ferrando et al. (2005).
[g] Guevara et al. (2005a).

exceeds 200 mm, the Eastern Monte receives more than 250 mm rainfall (Paruelo et al., 1998). Precipitation shows a great inter-annual variability in the Patagonian Monte (Coronato and Bertiller, 1997), which affects plant phenology (Bertiller et al., 1991), establishment of new individuals (Bisigato and Bertiller, 2004a), intra-annual distribution of plant biomass (Paruelo et al., 1998), and forage production (Ares et al., 1990). The above-ground net primary productivity (ANPP) of Typical Patagonian Monte ecosystems ranged from 600 to 730 kg DM ha^{-1} $year^{-1}$, showing the lowest intra-annual variability across Patagonia (Paruelo et al., 1998). These authors ascribed this low intra-annual variability to the dominance of evergreen shrubs of *Larrea* genus. In contrast, Easter Monte ecosystems showed productivity values higher than those of the other subunit, reaching 1110 kg DM ha^{-1} $year^{-1}$. Consequently, the mean RUE was about 3.9 kg DM ha^{-1} $year^{-1}$ mm^{-1} for the Patagonian Monte.

5. Carrying capacity of rangelands

Range receptivity should consider the ANPP, forage quality of vegetation and pasture structure. In the Monte region the methods used for its estimation were mainly ANPP or the Pastoral Value (Point Quadrat method). Nevertheless, none of these methods considered those factors as a whole. The results of both methods differed markedly because none of them integrated quantitative and qualitative aspects. Productivity and forage quality are independent characteristics and, at the same time, the effects of grazing vary according to the physiognomic and botanical characteristics of the pasture (Bottaro, 2007).

For the Northern Monte, in the xerophytic shrubland dominates by species of *Larrea* genus and warm-season perennial grasses, with 300 mm mean annual rainfall, 354 kg DM ha^{-1} $year^{-1}$ and a forage factor use of 50%, CC was estimated as 18.7 ha AU^{-1} (Blanco et al., 2005). In the central west, CC ranged from 64.5 to 16.0 ha AU^{-1} for 135 and 408 mm of mean annual rainfall, respectively. The corresponding FPs were 277 and 1118 kg DM ha^{-1} $year^{-1}$. The mentioned CC values were estimated on the basis of dependable rains (p=0.8), the RUE factor, and a use factor of available forage of 30% (Guevara et al., 1996b). In contrast, in the same area, for the *P. flexuosa* and dune communities, Passera et al. (2006) found that CC, using the closest individual method, ranged, respectively, from 4.5 to 15.6 ha AU^{-1}, under a mean annual rainfall of 150 mm. In Ñangos and dry Pampa, with the presence of *Stipa* spp. and shrubs of the genera *Baccharis* and *Nassauvia*, the mean CC estimated by the point quadrat method was 5.5 ha AU^{-1}, with 296 mm of mean annual rainfall and a mean FP of 2250 kg DM ha^{-1} $year^{-1}$ (Passera et al., 1983). For *Atriplex lampa* and *Bougainvillea spinosa* communities in Guadal Plateau (mean annual rainfall of 346 mm and 50% of forage foliar cover), Passera et al. (2007) found a value of 7 ha AU^{-1} determined by the point quadrat method. In the Patagonian Monte, with 240 mm of mean annual rainfall, the CC determined by the point quadrat method ranged from 21.6 to 89.3 ha AU^{-1} for the subshrub steppe (RUE=1) and shrub and forb steppe (RUE=4) landscapes, respectively (Rimoldi, 2004).

6. Nutrient content of forage species

6.1. Shrub species

In the Northern Monte, shrubs (*Bulnesia foliosa*, *P. flexuosa*, *Atriplex argentina*, *Justicia gilliesii*, *Cordobia argentea*, *Trichomaria usillo*, *Xeroalоysia ovatifolia*, *Lycium ciliatum*, *Acacia aroma*, *Grahamia bracteata*, *Ephedra triandra*) maintained relatively constant values of crude protein (CP), indicating that there was no noticeable influence of precipitation on the content of this nutrient (Ferrando et al., 2003a, Table 3).

Annual mean content of CP, neutral detergent fiber (NDF), acid detergent fiber (ADF) and gross energy were 16.8, 34.6, 21.4% DM, respectively, and 3.6 kcal g^{-1} DM for *A. lampa* (Silva Colomer and Passera, 1990), for samples collected in the central west. We found that there were no significant differences in the above-mentioned parameters among the seasons of the year. Similarly, in the same area, the nutrient content of woody species (*Capparis atamisquea, Ephedra ochreata, Hyalis argentea* var. *latisquama, Lycium chilense* var. *minutifolium, P. flexuosa* var. *depressa*) showed no important consistent variation with precipitation, except in the CP content that was higher in the wet than in the dry season (Van den Bosch et al., 1997). The low intra-annual variability of the shrubs nutrient content may be explained because of the ability of shrubs to complete their phenological phases independently of rains almost every year (Cavagnaro and Passera, 1991). This pattern, in turn, may be associated to the dual root systems of shrubs: a surface system for getting water from upper layers and a deeper one allowing plants to get water from deeper soil layers.

The browse is of paramount importance to livestock production since it constitutes a necessary and adequate supplement to energy-rich grasses in the dry season, mainly providing a source of high protein (Van den Bosch et al., 1997). In contrast, the phosphorus content of browse: 0.13% (Wainstein and González, 1971; Wainstein et al., 1979) and grasses: 0.11% (Guevara et al., 1990) was lower than cow requirements during the dry season (0.17–0.20%). Likewise, the study by Grünwaldt et al. (2005) involving lactating and dry non-pregnant *A. Angus* and *Criollo Argentino* cows and heifers found that 61% of blood samples had phosphorus levels below the optimum range in the dry season.

Deep-rooted evergreen shrubs (*L. divaricata, A. lampa*, and *Junellia seriphioides*) in the Patagonian Monte displayed differences in CP concentrations between green and senescent leaves (Carrera et al., 2000).

6.2. Grasses

In the Northern Monte, Ferrando et al. (2003a) determined the nutrient content of the most common grasses (*Setaria pampeana*, *Trichloris crinita*, *Pappophorum philippianum*, *P. krapovickasii*, *Digitaria californica*, *Gouinia paraguayensis*, *Chloris castilloniana*, *Aristida mendocina*) and found that both CP and digestibility are highest at the rainy season (Table 3). In the central west Monte, the CP content of the main native perennial grasses (*Setaria leucopila*, *D. californica*, *Panicum urvilleanum*, *A. mendocina*, *A. inversa*, *P. philippianum*, *C. castilloniana*) ranged from 8.4% DM in the rainy season (October–March) to 7.1% DM in the dry season (April–September). Digestibility and energy were also higher in the wet than in the dry season. Protein and energy levels of these grasses permit a cow–calf operation without nutritional limitations, provided that calving occurs in November or December and forage availability allows for selective grazing (Guevara et al., 1991). Consistent with the CP content of the forage, almost all the animals had blood albumin concentration over the optimum value. These good albumin values implied that dietary protein was not limiting and that liver health was likely to be reasonable (Grünwaldt et al., 2005). In the central east Monte, the green material of *Pappophorum caespitosum* (a summer species) presented CP values ranging from 8.7% to 9.8% (wet season), whereas in the dead material CP ranged from 6.8% to 7.8% (dry season). For a winter grass (*S. tenuis*) CP values ranged from 8% to 14% considering only green material, what makes it a species of high nutritious value at a time when summer species have lower protein content (Chirino et al., 1988). Estelrich and Cano (1996) reported values of potential degradability for *P. caespitosum* of 55.7% and 44.3% for the wet and dry season, respectively. In the Patagonian Monte, Carrera et al. (2000) found that perennial grasses (*S. tenuis*, *S. speciosa* and *Poa ligularis*) showed the lowest CP

Table 3
Mean nutrient content for grasses and shrub species in the Monte Desert

Parameter	Grasses				Shrubs			
	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring
Crude protein[a,b]	13.1	10.8	7.0	5.9	15.8	15.5	15.7	13.5
Crude protein[c,b]	8.6	7.5	6.7	8.2				
Crude protein[d,b]					12.3	11.2	9.7	13.8
Crude protein[e,b] (green leaves)		17.3		5.0		12.0		9.0
Crude protein[e,b] (senescent leaves)		3.3		2.3		8.4		6.2
Dry matter digestibility[a,b]	63.0	55.0	47.0	48.0	64.0	59.0	55.0	48.0
Dry matter digestibility[c,b]	67.6	63.0	59.6	66.0				
Metabolizable energy (MJ kg^{-1} DM)[c]	10.5	9.6	9.2	10.5				
Metabolizable energy (MJ kg^{-1} DM)[d]					6.6	7.0	6.4	6.4
Neutral detergent fiber[a,b]	69.0	79.0	78.0	79.0	52.0	56.0	59.0	63.0
Neutral detergent fiber[d,b]					58.6	56.9	59.9	60.7
Acid detergent fiber[a,b]	46.0	43.0	50.0	51.0	35.0	41.0	43.0	44.0
Acid detergent fiber[d,b]					42.4	40.5	41.6	43.9

[a] Ferrando et al. (2003a): the annual rainfall during the study period (1997–98) was 306 mm in summer, 73 mm in fall, 7 mm in winter and 15 mm in spring.
[b] (% DM).
[c] Guevara et el. (1991).
[d] Van den Bosch et al. (1997).
[e] Carrera et al. (2000).

concentrations in the dry season (late spring) and the highest one in the wet season (late autumn). Shallow-rooted perennial grasses showed high N-resorption efficiency and high N-resorption proficiency (large differences in N concentration between green and senescent leaves and very low N concentration in senescent leaves, respectively).

7. Botanical composition of livestock diet

7.1. Cattle

In the central west, Guevara et al. (1994) found that stocking rate significantly modified the composition of steer diet. Steers were forced to significantly alter their diet selection pattern from beginning to end of grazing periods by consuming less grasses and more woody species. The major shifts in seasonal diet of cows (Table 4) occurred in response to changes in grass phenology, i.e. woody species were consumed in the greatest amount (about 50% of the diet) during the dry season when the grasses were mature (Guevara et al., 1996c). Besides, in the latter season woody species had higher CP content than grasses. Consistent with these results, the study on seasonal specific selectivity by cattle showed that most woody species were undesirable during summer (Guevara et al., 1996a). In contrast, in the central east, proportion of grasses and shrubs in the diet did not show high variability among the seasons of the year, with 83.7% (81–88) and 16.3% (12–19) for grasses and shrubs, respectively (Fernández and Morici, 1999). Furthermore, there was no noticeable relationship between diet botanical composition and CP content of the browse (Troiani and Sánchez, 1990).

7.2. Goats

In the Northern Monte, the highest goat intake of woody species (59.7%) was at the beginning of the rainy season (October), whereas the peak intake of grasses (31.7%) occurred in the middle of the rainy season (January), when both plant strata had the highest nutrient content (Dayenoff et al., 1997). In contrast, Grünwaldt et al. (1994) found in the piedmont of the central west that goats preferred grasses over forbs and shrubs. Despite plant cover was reduced from 62.3% to 23.8% in a 4-year grazing period, there were little changes in the mean chemical composition of the diet (11±2.5% of CP and 42±4.2% of in vitro digestibility). The authors concluded that goats were not primarily browsers and showed the ability to maintain the quality of their diet even though the range condition declined.

Table 4
Botanical composition (% weight) of cow seasonal diet in the central west of the Monte Desert (mean±SD)[a]

Food item	Beginning of rainy season (spring)	Peak of rainy season (summer)	Dry season (fall and winter)
Grasses	65.8±2.9	84.0±3.6	44.9±3.8
Forbs	2.7±2.3	6.4±4.9	6.4±8.6
Shrubs and trees	31.4±2.8	9.6±4.8	48.6±8.2

[a] Guevara et al. (1996c).

7.3. Sheep

The sheep diet in the Southern Monte was highly diverse, since they ate 77.5% of the species present in the community, belonging to 63 genera (Baldi et al., 2004). Taking plant growth forms into consideration, the sheep diet also presented a low seasonal variability, since the relative proportion of grasses, forbs, and woody plants did not vary among seasons. In spring and summer the composition of the sheep diet was similar to the relative availability of plant functional types in the environment, despite the significantly lower proportion of green in summer than in spring for all the functional types forming the herbaceous layer. The authors concluded that sheep were an intermediate feeder able to include both monocots and dicots in its diet. Similar results were found by Siffredi et al. (2005) in the same area.

8. Livestock sanitary aspects

In May 2004, the member countries of the Office International des Epizooties (OIE) approved the creation of an only list of diseases notifiable to the OIE. A new list was approved in May 2005 by the International Committee and came into force in 2006. Many of those diseases (OIE listed diseases) that could affect cattle, sheep and goats have never been verified in Argentina. Others are exotic like Bovine spongiform encephalopathy and Scrapie. In the case of the foot-and-mouth disease, the OIE restored the status of disease free zone with vaccination to all areas north of Parallel 42° in January 2005.

Several diseases affecting livestock were reported for the Monte region (Bedotti and Sánchez Rodríguez, 2002; INTA, 1998; Paloma et al., 1995; Robles and Olaechea, 2001). Moreover, in the central west of the Monte, biochemical and hematological measurements were used to identify some constraints on productivity of beef cattle (Grünwaldt et al., 2005).

Some diseases are still endemic and with high prevalence, such as Brucellosis, Tuberculosis, Enzootic bovine leukosis, Infectious bovine rhinotracheitis/infectious pustular vulvovaginitis. Trichomoniasis and Bovine genital campylobacteriosis have a wide distribution and prevalence and a strong effect on the reproductive indices. *Boophilus microplus* and the associated blood parasites (*Anaplasma*, *Babesia* spp.) are present in the north of Argentina, causing production losses and high control costs. Most of the classical zoonoses such as Tuberculosis, Brucellosis, Anthrax, Leptospirosis, Trichinellosis, Echinococcosis/hydatidosis, Ovine chlamydiosis and Rabies are present in Argentina. The Patagonian Monte has had a particular sanitary status in the past years as a result of the presence of natural barriers such as the Colorado and Barrancas rivers. On the other hand, there are restrictions for introducing livestock from the north to the south of Parallel 42°. This region is considered to be free of foot-and-mouth disease without vaccination.

9. Effects of grazing on vegetation

The Monte vegetation nowadays appears to be degraded by 200 years of overgrazing and 100 years of wood harvesting, which resulted in the dominance of unpalatable and spinescent tall or dwarf shrubs. Concurrently, forage species, in particular perennial grasses, may almost disappear whereas annual unpalatable grasses and forbs thrive in the rainy season. However, the situation in this respect is very variable from one site to another depending on grazing pressure, grazing system and post wildfire dynamic stage (Guevara et al., 1997). For instance, in the central west, with mean annual rainfall of about 300 mm, density of preferred perennial grasses was 0.7 plant m^{-2} in the "sacrifice zone" near watering points (500 m) and 3.0 plants m^{-2} in areas away from water (3600 m). In contrast, densities of undesirable perennial grasses were 3.0, and 1.8 plants m^{-2} in the same areas, respectively (Gonnet et al., 2003).

In the central east, with a mean annual rainfall from 200 to 400 mm, the foliar plant cover of forage species increased from about 6% on sites close to water (50–100 m) to 37% on those far from water (⩾3000 m), and density of forage grasses increased from about 12–64 plants m^{-2} (Morici et al., 2006). In the same area, Cueto and Cano (1988) reported forage mass values of 1100–1500 kg DM ha^{-1} for the ungrazed range condition, and of 650–700 kg DM ha^{-1} for the grazed range condition.

Grazing strongly affected the structure of Patagonian Monte communities. Total plant cover diminished, mainly as a consequence of strong reductions in grass cover (Bisigato and Bertiller, 1997). However, the cover of some dwarf shrub species such as *J. seriphioides* and *Nassauvia fuegiana* increased under medium and/or high grazing pressure (Bertiller and Bisigato, 1998). Managerial practices oriented toward maintaining and increasing the soil seed bank of perennial grasses, such as grazing exclusion during the grass reproductive period, might contribute to promote the re-establishment of perennial grasses (Bisigato and Bertiller, 2004b).

10. Introduction of species for land rehabilitation

Degraded rangelands could be improved through revegetation with native or exotic forage species. Several studies with this goal were conducted in the Monte on both shrubs (Berone et al., 2002; Braun et al., 1979; Buono and Ciano, 2005; Chagra Dib et al., 2002, 2004; Ferrando et al., 2003b; Guevara et al., 1999a, b, 2000, 2003a; Le Houérou, 1999; Lemes, 1992; Reynoso et al., 1998) and grasses (Blanco et al., 2005c; Ferrando et al., 2003b; Guevara et al., 2005a; Ochoa et al., 2002). Table 5 shows shrub and grass biomass production and the corresponding annual precipitation.

10.1. Shrubs

Saltbush (*Atriplex nummularia*) and cactus (*Opuntia ficus-indica*) crops and use were developed as complementary winter feeding strategies for goats and goats–cows, respectively, in the Northern Monte (Berone et al., 2002; Chagra Dib et al., 2002, 2004). Values of RUE factors for saltbush in the central west (Le Houérou, 1999) were consistent with those reported by Le Houérou (1992) for artificial saltbush plantations in rainfed conditions. In the latter area with permanent water table (1.0–1.1 m deep) and 189 mm of mean annual rainfall, the total biomass production of saltbush after three growing seasons was estimated to be 5470 kg DM ha^{-1}, 25% of which was browse biomass (Guevara et al., 2005b). In the Patagonian Monte, native (*A. lampa* and *A. saggittifolia*) and exotic (*A. nummularia*) species were established. Fifty percent of total aerial biomass was browse biomass and it represented 5 times the forage biomass provided by the rangelands in this area (Buono and Ciano, 2005).

In the central west of the Monte, biomass of *Opuntia ficus-indica* was 2.1 t DM ha^{-1} $year^{-1}$ under a mean annual rainfall of 294 mm (Guevara et al., 2000), lower than the 3–9 t DM ha^{-1} $year^{-1}$ reported by Le Houérou (1996) for arid lands under mean annual rainfall of 200–400 mm, deep sandy soil and controlled competition. This low productivity may be due to the presence of competition, the greatest single factors affecting productivity of *Opuntia* spp. in forage plantations (Felker, 1995). The experimental *Opuntia* plantation was established in a sand dune in which the native vegetation was not eliminated for controlling soil erosion. Another

Table 5
Precipitation and biomass production for shrubs and grasses in the Monte Desert

Species	Rainfal (mm $year^{-1}$)	Biomass (kg DM ha^{1} $year^{-1}$)	RUE (kg DM ha^{-1} $year^{-1}$ mm^{-1})	Source
Shrubs				
Opuntia ficus indica	300	2464	8.2	Braun et al. (1979)
	362	2776	7.7	Reynoso et al. (1998)
	294	2060	7.0	Guevara et al. (2000)
	390	2030	5.2	Ferrando et al. (2003b)
A. nummularia	250	1700	6.8	Le Houérou (1999)
	350	3300	9.4	Le Houérou (1999)
Atriplex spp.	220	1100	5.0	Buono and Ciano (2005)
Grasses				
Cenchrus ciliaris	425	2198	5.2	Blanco et al. (2005c)
	390	2400	6.2	Ferrando et al. (2003b)
Eragrostis curvula	400	2400	6.0	Guevara et al. (2005a)
	350	1300	3.7	Ochoa et al. (2002)

limitation for cultivating *O. ficus-indica* in the central west is the cold winter temperature (Guevara et al., 2000) which coincides with water shortage. Further attention was given to a frost-tolerant and great water-use efficient cactus species such as *Opuntia ellisiana* (Guevara et al., 2003b; Han and Felker, 1997; Wang et al., 1997).

The economic feasibilities of cactus plantations as a feed supplement for cattle (Guevara et al., 1999a) and goats (Guevara et al., 1999b) and the combined use of *A. nummularia* and cactus as a supplement for goats (Guevara et al., 2003a) were examined for the central west with simulation models. Cactus production for cattle could be feasible in a direct browsing system with 300 and 400 mm rainfall on 100 and 50 ha plantations, respectively. With 400 mm rainfall, 100–200 ha plantations would be needed if the cut-and-carry system was adopted. When cactus is used for goat supplementation, the additional kids per goat required to reach an internal rate of return 12% would range from 0.21 to 0.29 for 200 and 50 does, respectively, if dependable rains ($p_{0.8}$) are considered. A decrease in doe mortality from 10 to 2% and an increase in annual kid crop from 0.17 to 0.32 would economically justify saltbush and cactus plantations for stockmen having more than 50 goats at annual rainfall probabilities from $p_{0.1}$ to $p_{0.8}$.

10.2. Grasses

The seeding of the buffel grass T-4464 cultivar has been a regional strategy for quick restoration of grass cover and cattle grazing capacity of degraded areas in the Northern Monte. Direct sowing using a common roller chopper with an attached seeding device caused an important short-term increase in ANPP, when it was compared to non-treated native degraded shrublands (2198 vs. 704 kg DM ha^{-1} year^{-1}). Generally, buffel grass is used during spring and summer, coincident with the period of mating and calving of cows (Blanco et al., 2005c), but in some situations it is used during winter. Heifers grazing buffelgrass supplemented with 20 kg FM animal^{-1} day^{-1} of cactus, and deprived of water, survived and maintained their initial weight during 65 days (Ferrando et al., 2003b).

The Argentinean Institute of Arid Land Research (IADIZA) created a germplasm bank of native forage species that includes *T. crinita*, *P. caespitosum*, *D. californica* and species of *Setaria* and *Atriplex* genera (Lemes, 1992). *T. crinita* seems to be a suitable species to be used in processes of land rehabilitation. This summer growing perennial grass is well adapted to water stress conditions, tolerant to trampling and grazing by domestic animals and has good quality forage for raising livestock in arid zones in which it has a wide area of distribution (Cavagnaro and Trione, 2007).

Guevara et al. (2005a) demonstrated, for the central west, the ecological and economic viability of WL in the rehabilitation of degraded rangelands. Generally, in cow-calf production systems WL is used during spring and summer; and during fall and winter the cattle is moved from this pasture to the rangelands. This management had an improvement effect on the ecological condition and forage production of the rangeland which is under resting during its growing season.

11. Conclusions

Continuous grazing is the dominant strategy used, however, application of improved grazing systems appears to be a hopeful tool for a sustainable management of rangelands and consequently for the improvement of cattle production. The RUE factors for the total vegetation are consistent with those reported for arid and semi-arid areas of the world. The great variability in CC could be attributed to the different methods used for its estimation and the rangeland condition. The grass nutrient content showed some consistency with rainfall variability, i.e. CP, digestibility and energy were higher in the wet than in the dry season. The CP content of the available forage could meet cattle requirements provided that an adequate stocking rate was used. The forage phosphorus content could be a constraint for cattle production. There is no unanimity as to the fact that goats are strictly browsers. The low stocking rate and the climate conditions act as restrictive factors for the propagation of livestock diseases. Some diseases, although present, show prevalence indices lower than those recorded in other areas of the country. The most promising species for land rehabilitation are *Opuntia* spp., *Atriplex* spp., *E. curvula* and *C. ciliaris*. There is no correspondence between the number of researchers devoted to range and livestock production in the Monte and the scope and future importance of this region for meat production. Among the main knowledge gaps, and thereby the need for future research, we can mention the estimation of: (a) CC for most of the areas of the Monte, (b) nutrient content of the components of livestock diet, (c) livestock intake values and (d) effect of mineral supplementation and other complementary feeds on animal performance and the corresponding studies of the economic feasibility of these practices. There is no seeding technology for native grasses such us *T. crinita* in the region. There is a need for holistic information on livestock-environment interactions.

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