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Perennial grass response to 10-year cattle grazing in the Mendoza plain, mid-west Argentina

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Basal area ($cm^2\,m^{-2}$) and density ($plants\,m^{-2}$) for total, undesirable, intermediate and preferred perennial grasses were monitored in 1990 and in 2000 in response to two grazing strategies (yearlong continuous and rotational) and four grazing intensities (ungrazed; light, moderate and heavy grazing). Grazing intensity had a significant effect on basal area of perennial grasses. Basal area and density for all the grass groups tended to be higher in 2000 than in 1990 for all grazing intensities but the grazed treatments did not show significant differences in basal area and density increases from 1990 to 2000 for all the mentioned grass groups. Several hypotheses could be advanced to explain the limited grass response to treatments. The stocking rates applied may have been too light to cause significant effects. Grasses appear to be resistant under the grazing intensities used and the annual drought occurring during 7 of the 9 last years of the study. Given the history of heavy grazing in this environment, it is possible that what has been observed is natural temporal variation in basal area and plant density.

Keywords: perennial grasses; grazing strategies; grazing intensities; basal area; plant density; cattle selectivity groups

Introduction

Most of mid-west Argentina, *ca.* 500,000 km^2, is subjected to yearlong continuous overgrazing (Marchi *et al.*, 1993). The formulation of sustainable long-term grazing management strategies requires a sound understanding of the effect of domestic livestock on rangeland vegetation (Smit & Rethman, 1992).

Grazing strategies and stocking rates may alter the botanical composition of rangeland vegetation by altering the frequency and intensity of defoliation of individual plant species (Hart *et al.*, 1993). In the particular case we are interested in, i.e. the grass response to continuous and four-pasture, one-herd rotation systems, Pieper *et al.* (1978) found that the production of *Bouteloua curtipendula* (Michx.) Torr. and other grasses was greater under this rotational system than under the continuous system when both grazing strategies were stocked at the same rate.

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On the other hand, the selection of the correct stocking rate is the most important range management decision (Holechek *et al.*, 1999). Stocking rate studies from different locations in the south-western United States have indicated that a conservative stocking involving 30–35% use of average forage production is a reliable way to increase forage production and improve vegetation composition on degraded rangelands (Holechek *et al.*, 1994, 1999; Winder *et al.*, 2000). Similarly, Oliva *et al.* (1998) have demonstrated for the Patagonia Argentina that plant communities under moderate stocking did not lose diversity or highly palatable species after a 10-year grazing trial.

Our previous study (Gonnet *et al.*, unpublished) analysed the response of perennial grass basal area to a grazing intensity gradient around a watering point in the site in which the present study was conducted. Plant basal diameters and plant density were estimated along a 4·6-km transect originating from a watering point after 9 years (1990/91–1998/99) of cattle grazing. Grass groups, according to selectivity by cattle, were coincident with those considered in the present study. Another study (Guevara *et al.*, 2001), conducted on the same site as the previous one, analysed the response of perennial grass biomass to cattle grazing intensity gradients around watering points. Maximum standing crop of perennial grasses was estimated along a 4·5-km transect at the end of the growing seasons 1990–91, 1991–92 and 1999–2000. Classification of grasses according to their selectivity by cattle slightly varied with respect to the previous study, i.e. secondary preference and desirable grasses were distinguished within intermediate grasses.

The objective of this study was to evaluate the effect of two grazing strategies (yearlong continuous, and four-pasture, one-herd rotation system) and four grazing intensities (ungrazed; light, moderate, and heavy grazing) on basal area per area unit and its components (plant density and individual plant basal area) of perennial grasses in the Mendoza plain after a 10-year grazing trial.

Material and methods

Study site

This study was conducted on El Divisadero Cattle and Range Experiment Station (33° 45′ S, 67° 41′ W, elev. 520 m), in the north central Mendoza plain, mid-west Argentina. Daily mean minimum and maximum temperatures annually range from −3·8°C to 15·6°C and 14·2°C to 33·0°C, respectively. Mean annual rainfall (July–June) from 1987–88 to 1999–2000 was 322·8 mm (S.D. = 127·1) with nearly 80% occurring during the growing season (October–March). Potential evapo-transpiration (PET) at annual and growing season scales during the study period was computed as 68·64 t and 34·32 t, respectively (Le Houérou, 1989), where t is the mean annual or growing season temperature (°C). Drought was defined by P (precipitation) $<$0·35 PET during the year or the growing season.

Soils are Torripsamments with greater silt content in interdunal depressions. The vegetation is an open xerophytic savanna and shrubland of *Prosopis flexuosa* DC. Eight warm-season perennial grasses dominate the herbaceous vegetation.

The grazing history of the range was not well known until 1980 when the Experiment Station was established. The grazing by livestock appears to have began after 1910 (Guevara *et al.*, 2001). During the 1930s the range was heavily grazed (11 ha AU^{-1}), mainly by cattle. Although vegetation changes were not documented, this heavy stocking rate probably led to vegetation degradation. Data obtained in 1976 (Guevara *et al.*, 1981) showed that stocking rate had been reduced from 11 to 15 ha AU^{-1} and the contribution of goats to livestock population had been increased from 0·6% in 1930 to 10% in 1976.

Treatments

Two grazing strategies, yearlong continuous grazing and four-pasture, one-herd rotation system, and four grazing intensities, ungrazed, light: 25 ha AU^{-1}, moderate: 12·5 ha AU^{-1} and heavy: 7·8 ha AU^{-1} were continued without interruption from 1990 to 2000. The grazed treatments were originally designed to obtain 20%, 50% and 80% use of the average annual production of perennial grasses, respectively. The recommended sustainable stocking rate is about 20 ha AU^{-1} (Guevara *et al.*, 1997).

Paddocks sizes were 100, 50 and 31 ha (yearlong continuous) and 25, 12·5 and 7·8 ha (rotation system) for light, moderate and heavy grazing intensities, respectively. Two livestock exclosures, 1·5 ha each, were established in a site with similar soils and vegetation, adjacent to the grazing treatments. Grazing strategies and grazing intensities were replicated twice. Each pasture was stocked with Angus steers. The number of animals varied through the study according to the annual forage production to obtain the planned use rates.

Eight 30 m fixed line transects were randomly located on each of the grazed paddocks and exclosures in winter 1990. Ten permanent 1 m^2 plots were systematically placed at 3-m intervals along each transect. Within each plot, live basal diameter of each perennial grass and grass density were recorded. Basal diameter was taken as the average between the longest diameter and the greatest perpendicular to this longest diameter. The basal area for each individual plant species was derived from this average basal diameter. For plant density estimation, each tussock or each tiller was counted as an individual for the bunchgrasses and the rhizomatous grass, respectively. Basal area ($cm^2 m^{-2}$) was calculated from the density of each grass species and the individual basal area. Plots were read at the beginning of the study (1990) and at the end of the 1999–2000 growing season.

In examining changes in basal area per unit area, plant density and individual plant basal area, the eight grasses were grouped according to their selectivity by cattle (Guevara *et al.*, 1996) as: preferred, *Chloris castilloniana* Lillo & Parodi, *Digitaria californica* (Benth.) Henr., *Pappophorum philippianum* Roseng. and *Sporobolus cryptandrus* (Torr.) A. Gray; intermediate (including desirable, *Panicum urvilleanum* Kunth and secondary preference, *Setaria leucopila* (Scrib. & Merr.) Schum. species); and undesirable, *Aristida inversa* Haeck. and *Aristida mendocina* Phil. *Panicum urvilleanum* is a rhizomathous species and the others are tussock grasses. Data for all grass species were also added to generate measures of basal area per area unit and plant density for total grasses.

Calculations and statistical analyses

Differences in both basal area per area unit and plant density data between 2000 and 1990 were calculated for total, undesirable, intermediate and preferred grasses. Basal area difference data were tested for statistical significance using two-way MANOVA procedure followed by Tukey's HSD test ($p < 0{\cdot}05$) to separate means. Dependent variables in the MANOVA were the grass groups, i.e. total, undesirable, intermediate and preferred. The independent variables used were grazing strategy and grazing intensity. Plant density difference data did not pass homogeneity and normality test and thus, the non-parametric Mann–Whitney test was used to test for plant density differences among grazing intensities. Because estimation of plant basal area was not done on tagged plants in each treatment, we calculated the increase in individual plant basal area for each treatment dividing the basal area ($cm^2 m^{-2}$) by the plant density (plant m^{-2}) for 1990 and 2000. Then, the differences between these values (2000–1990) were calculated. Thus, the individual plant basal area difference data were not statistically analysed.

Results

Precipitation

Precipitation and 0·35 PET at annual and growing season levels during the study period are shown in Fig.1. According to drought definition (see study site), annual and growing season drought occurred in seven and four of the 10 years of the study, respectively. On the other hand, annual and growing season rainfall were lower than the corresponding long-term mean in 6 and 5 of the 10 years of the study, respectively.

The occurrence of annual and growing season drought in the study site was similar to that registered in Ñacuñán (34°02′ S, 67°58′ W, elev. 572 m), the nearest reporting station for long-term climatological data (1972–2000), located 30 km south of the study site. In fact, the analysis of these 29-year precipitation and temperature data indicated that the frequency of occurrence of annual and growing season drought was 71% and 50%, respectively.

Response of grass basal area to grazing strategies and grazing intensities

Grazing intensity had a significant effect on basal area ($cm^2\,m^{-2}$) of perennial grasses. Conversely, neither grazing strategies nor grazing strategies by grazing intensity interaction had a significant effect on basal area. Consequently, the following analysis emphasizes differences in basal area for the different grazing intensities.

Basal area increase for total grasses was significantly lower in exclosures than those from the grazed pastures (Fig. 2(a)). Total basal area increase showed a definite pattern with grazing intensity, i.e. tended to be higher at moderate grazing intensity.

The increase of basal area of undesirable species was significantly lower in exclosures than those from pastures grazed at moderate and heavy grazing intensities (Fig. 2(b)). The pattern of basal area increase from undesirable species was similar to that from total grasses. This result can be explained by the significant contribution of the undesirable species (about 50%) to total basal area increase.

In the intermediate grasses, basal area increase was significantly lower in exclosures than that for pastures stocked at heavy stocking rate (Fig. 2(c)). Grazing intensity did not affect the basal area increase of preferred grasses (Fig. 2(d)) but basal area increase showed a definite pattern with grazing intensity, i.e. this response variable tended to increase as grazing intensity decreased.

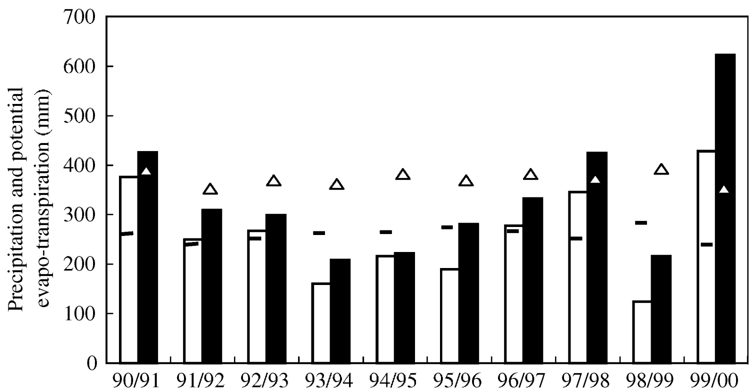

Figure 1. Precipitation (P) and potential evapo-transpiration (PET) at El Divisadero Cattle and Range Experiment Station over the study period. (■) annual P; (□) growing season P; (Δ) 0·35 PET at annual scale; (▬▬) 0·35 PET at growing season scale.

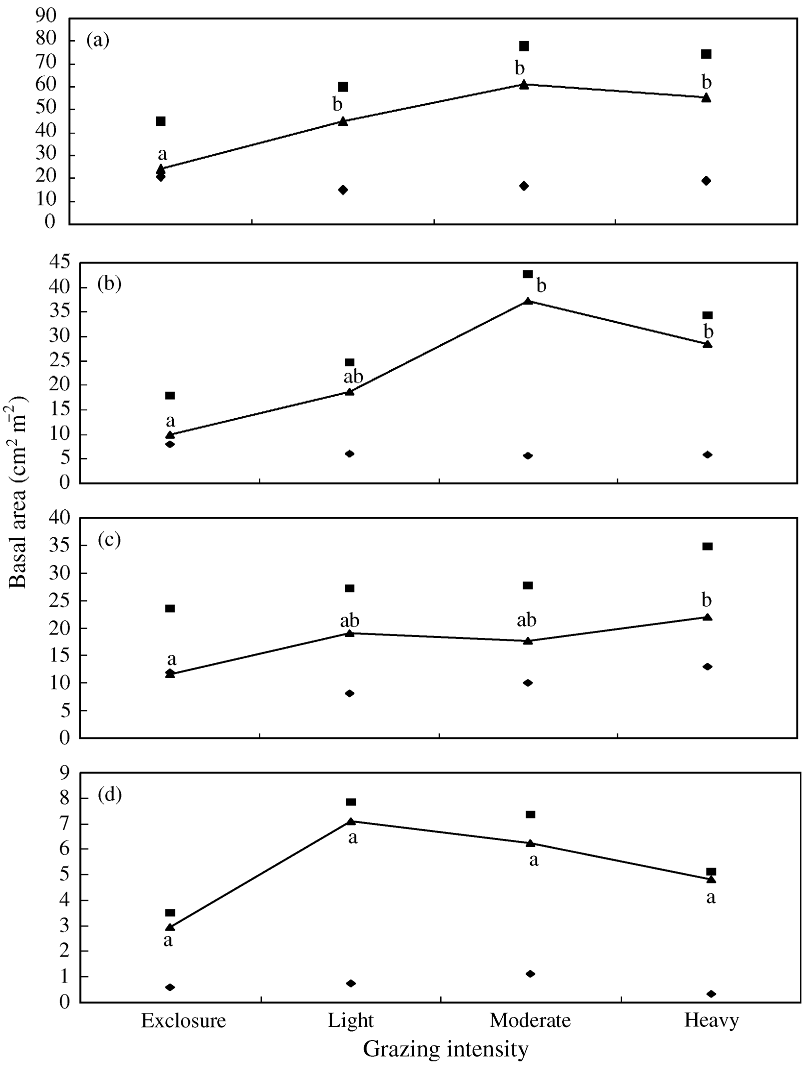

Figure 2. Changes in basal area (cm^2 m^{-2}) of perennial grasses: (a) total; (b) undesirable; (c) intermediate; (d) preferred; (◆) 1990; (■) 2000; (–▲–) 2000–1990. Means followed by the same letter indicate non-significant difference among grazing intensities.

Response of grass density and individual plant basal area to grazing intensities

The increase in grass density for total grasses was significantly lower in exclosures than those for pastures grazed at light and heavy grazing intensities (Fig. 3(a)). This response appears to be principally associated with the response of the intermediate grasses (Fig. 3(c)) whose grass density contributed 86% to total grass density. Grazing intensity did not significantly affect the density increase of undesirable grasses (Fig. 3(b)). Density increase in the preferred grasses was lower in exclosures than those from paddocks grazed at light and moderate grazing intensities (Fig. 3(d)).

For total grasses, the individual plant basal area increased in all grazing intensities (Fig. 4 (a)). This increase showed a definite pattern with grazing intensity, i.e. tended

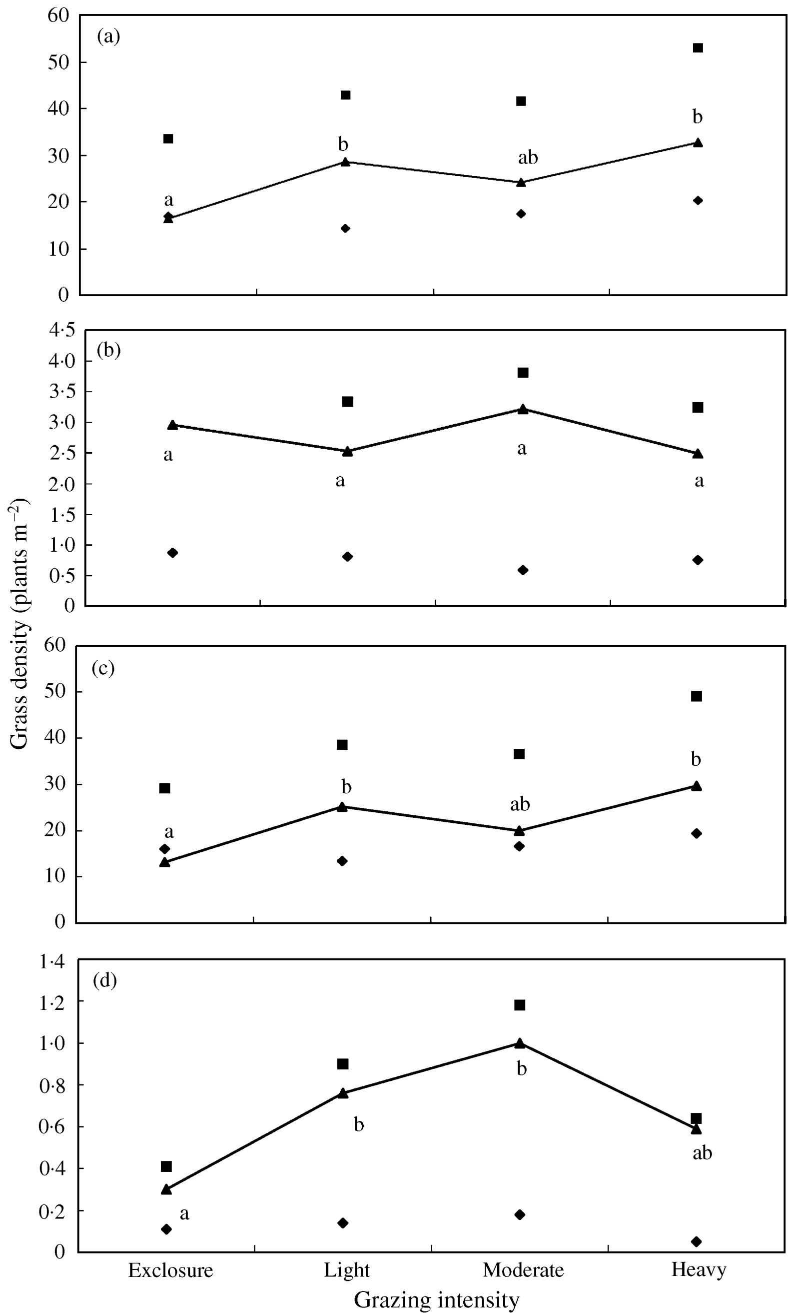

Figure 3. Changes in plant density (plants m^{-2}) of perennial grasses: (a) total; (b) undesirable; (c) intermediate; (d) preferred. Means followed by the same letter indicate non-significant difference among grazing intensities (see Fig. 2 for keys).

to be higher at moderate grazing intensity. On the other hand, individual plant basal area increase tended to be higher in the grazed pastures than that in the exclosures. For the undesirable grasses, the individual plant basal area was lower in 2000 than in 1990 for the exclosures and the pastures stocked at light grazing intensity (Fig. 4(b)).

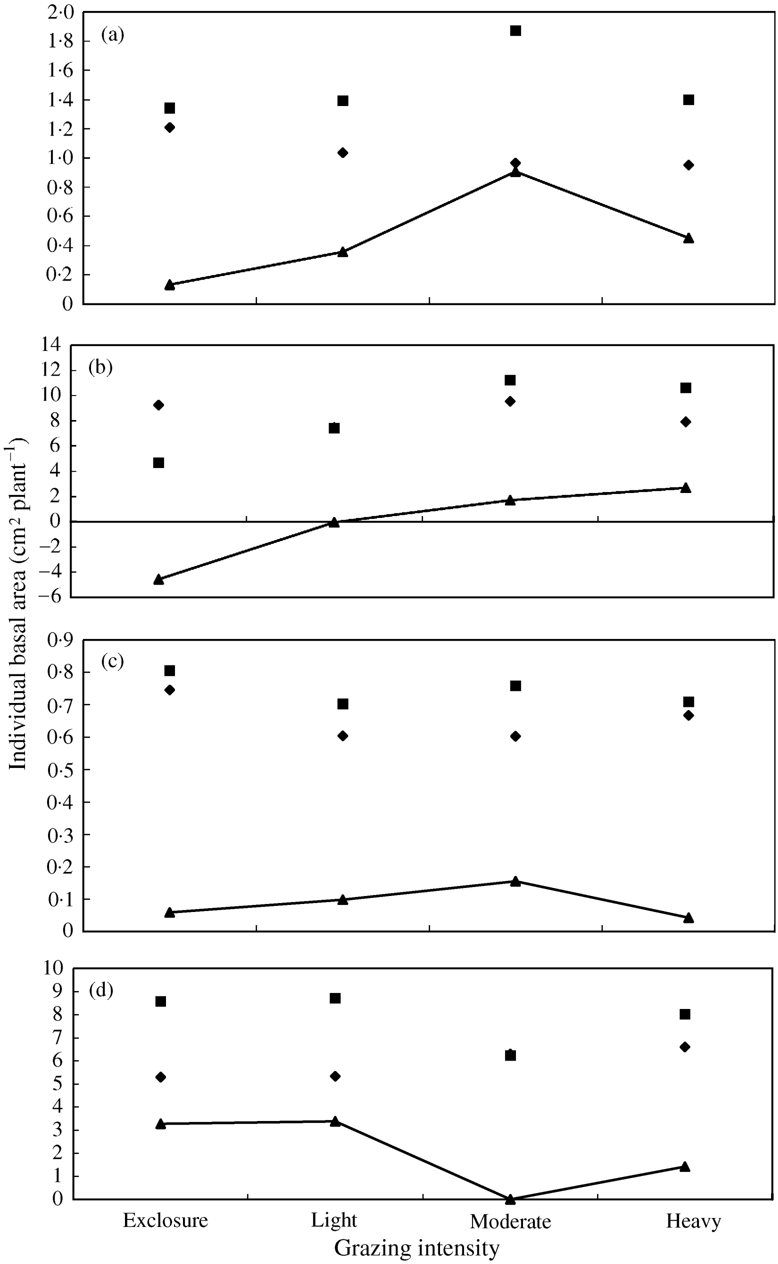

Figure 4. Changes in individual plant basal area ($cm^2\,plant^{-1}$) of perennial grasses: (a) total; (b) undesirable; (c) intermediate; (d) preferred (see Fig. 2 for keys).

On the contrary, individual plant basal area for undesirable species was higher in 2000 than in 1990 in pastures stocked at moderate and heavy grazing intensities. Individual plant basal area of intermediate grasses showed a pattern similar to that for the total grasses (Fig. 4(c)). The individual plant basal area increase in the preferred species tended to be higher in exclosures and pastures stocked at light grazing intensity than those from pastures stocked at moderate and heavy grazing intensities (Fig. 4(d)).

Discussion

The definite patterns shown by basal area per area unit increase with grazing intensity for total, undesirable and preferred grasses were coincident with those observed when distance from the water (0·1–4·6 km) was regressed on basal area of perennial grasses (Gonnet *et al.*, unpublished). A quadratic relationship between basal area and distance from water was found by these authors for both total ($r^2 = 0{\cdot}48$, $p<0{\cdot}05$) and undesirable ($r^2 = 0{\cdot}49$, $p<0{\cdot}05$) grasses. This means that the basal area for total and undesirable grasses was higher at intermediate distance from water, about 2·5 and 2·4 km, respectively. Accordingly, a quadratic relationship ($r^2 = 0{\cdot}74$, $p<0{\cdot}05$) between above-ground biomass of undesirable species and distance from water was reported (Guevara *et al.*, 2001) and thus, biomass of undesirable grasses was higher at intermediate distance from water (about 2·1 km). A similar trend was observed by Winder *et al.* (2000). These authors reported that in moderately stocked pastures (40–45% use of key forage species), standing crop of threeawns (*Aristida* spp.) were higher (although non-significantly) than that for conservatively (30-35% use) stocked pasture.

On the other hand, basal area of preferred species increased linearly ($r^2 = 0{\cdot}74$, $p<0{\cdot}01$) along the grazing gradient of decreasing intensity of grazing from the vicinity of watering points to sites far from water (Gonnet *et al.*, unpublished). The same relationship was found by Guevara *et al.* (2001) when distance from water was regressed on above-ground biomass for the preferred grasses ($r^2 = 0{\cdot}59$, $p<0{\cdot}05$).

Because basal area proved to be a good predictor of biomass for the grasses included in the present study (Guevara *et al.*, 2002), similar trends were observed when distance from water was regressed on basal area or above-ground biomass.

A compensatory growth might be suggested as the mechanism creating the pattern observed in individual plant basal area and density for some grass groups when grasses were measured at the end of the growing season and stocked at the rates used in this study. In fact, individual basal area of undesirable grasses increased with grazing intensity but density did not increase. Further, plant basal area for total and intermediate grasses increased from light to moderate grazing intensity while plant density did not increase. Thus, the individual plants remaining would have increased in size (more tillers) to create the greater basal area. Despite the fact that tillers per bunchgrasses were not counted, the significant correlation ($p<0{\cdot}05$) between number of tillers and individual plant basal area that exhibited these grasses (data not shown) supports this statement.

Conclusions

Basal area ($cm^2\,m^{-2}$) and grass density (plants m^{-2}) for total, undesirable, intermediate and preferred grasses tended to be higher in 2000 than in 1990 for all the grazing intensities. However, basal area and density differences between 2000 and 1990 did not differ among the grazed pastures.

Several hypotheses, advanced by Gillen *et al.* (2000) to explain the few impacts of stocking rate on a mixed-grass prairie over a 7-year period, could be applied to our study for explaining the limited grass response to treatments . First, the stocking rates applied in this study may have been too light to cause significant effects. In fact, our grazing pastures and exclosures were built close to an ancient watering point, a zone of extreme herbivore impact. In fact, it has been found that cattle impact is more concentrated close to watering points in dry years (Guevara *et al.*, 2001) whose frequency of occurrence in the study site was 60%. This hypothesis may explain why basal area and density increased still in the heavily stocked paddocks. Second, weather conditions during the study period may have ameliorated the impact of grazing intensity on perennial grasses. Annual drought occurred during 7 of the 9 last years of the study. It is expected that these weather conditions in combination with the heavy stocking rate used to trigger basal area changes but the perennial grasses appear to be resistant under the grazing intensities applied and the weather conditions observed. The third hypothesis refers to the influence of initial conditions. Given the history of heavy grazing in this environment, it is possible that what has been observed is a natural temporal variation, i.e. grazing in this environment resulted in an increase in temporal variation in basal area and grass density. It is not that these grazing treatments increase or decrease cover and density but they make cover and density of these grass groups more variable and less predictable.

This long-term study showed how variable these systems are since they are driven by a number of factors, rather than that they are strongly influenced by one factor such as grazing.

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