

Floristic changes induced by flooding on grazed and ungrazed lowland grasslands in Argentina

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Abstract

Changes in community composition of 2 grassland sites exposed to a flood of unusual intensity and duration were investigated in the Flooding Pampa. These grasslands are subject almost annually to floodings of lesser magnitude. The study sites were adjacent to each other, and differed in vegetation structure and composition. One had been grazed continuously by cattle and was showing signs of intense deterioration. The other had remained ungrazed during 15 years. Basal cover by species was measured in summer, before and after the flooding event. Compositional difference between sites decreased with flooding from 68.9 to 39.1%. In the grazed site the cover of alien forbs was reduced by 48%. After the flooding native graminoids represented 99.7 and 86.7% of the cover, inside and outside the enclosure respectively. Total basal cover was not affected but was redistributed among species already present before the flood. Floristic changes would have led to an improvement of the forage source. We conclude that plant community response to the event was influenced by the previous grazing history of the site. The large flood acted as an overriding environmental factor which partially reverted the effects of grazing upon grassland composition.

Key Words: cattle grazing, community dynamics, disturbance, Flooding Pampa, forage quality, stress

Grazing by domestic ungulates has well-documented effects upon structure and composition of plant communities (Risser et al. 1981, Mack and Thompson 1982, Bakker 1985, Sala et al. 1986). In the grasslands of the Flooding Pampa, Argentina, the introduction of cattle by European settlers added a major causal factor for

vegetational heterogeneity (León et al. 1984). Stands with different grazing history can be viewed as the units of a landscape mosaic widely affected by the pattern of land use (Forman and Godron 1981, León et al. 1984, Urban et al. 1987). The manifold effects of livestock grazing involve changes in grassland floristic composition leading to displacement of native grasses by exotic species and native spreading dicots (Sala et al. 1986, Facelli et al. 1988) of low forage quality.

These grasslands are subject periodically to flooding events of diverse magnitude (i.e., intensity and duration). Flood regime, which is controlled by topographical features, may interact in complex ways with cattle grazing in determining the spatial pattern of vegetation throughout the landscapes of the region (León 1975, Sala et al. 1986). A better understanding of the ecological relationships between these environmental agents, and their influence on community structure, is needed in order to improve the management of the grassland resource.

Within a broad context, floodings have been considered as physical "disturbances" which disrupt the structure of plant communities (White 1979). Since flood tolerance varies widely among species, a substantial impact on community composition might be expected (Kozlowski 1984). There is some evidence suggesting the organization of flood-prone grasslands in the Flooding Pampa can be affected by large, less frequent events (Insausti and Soriano 1988).

Here, we report the changes in grassland composition observed after the occurrence of an unusually large flood on 2 different sites, one subject to continuous grazing, and the other protected by fencing during the last 15 years. Specifically, we addressed the following questions: (1) Does a flood of unusual magnitude alter the floristic composition and dominance relations of the plant community?

(2) How does previous grazing history influence community response to the flooding event? (3) What is the consequence for the grassland as a forage resource?

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Study Area and Methods

The study was carried out in a floodplain rangeland located at the center of the Salado River Basin (36° 30' S, 58° 30' W), the main portion of the Flooding Pampa (58,000 km²). Topographical flatness and absence of integrated drainage systems are the most conspicuous features of the landscape. Soils, predominantly Natraquolls, are poorly drained because of low hydraulic conductivity and lack of slope. The weather is mild with mean annual rainfall around 900 mm, evenly distributed through the year. The area is subject to periodic floods during winter and spring. In summer, droughts are also frequent.

We studied 2 contiguous sites originally occupied by the same vegetation type, the community of *Mentha pulegium*, *Leontodon taraxacoides*, and *Paspalidium paludivagum*¹ (León 1975; the "lowland community" in Sala et al. 1986), which is mostly constituted by perennial forbs and graminoids. One site was a 15-yr-old enclosure (ca. 2 ha) and the other a portion of the surrounding area, year-long grazed by cattle at a stocking rate of 0.5 animal/ha.

As part of a long-term monitoring, in early February 1985 (summer), specific basal cover for living material was measured inside and outside the enclosure by means of 4 permanent intercept-

tion lines, 5 m long each (Brown 1954). Previous studies have shown the structural divergence that arose among sites since the establishment of the fence (Sala et al. 1986, Facelli et al. 1988). Inside the enclosure native tall grasses dominated the community while the grazed site was dominated by forbs, mainly exotics.

Between September and late November 1985 (spring) the study area remained waterlogged with ~ 10 to 40 cm of standing water. This flood had unusual intensity and duration and was the result of intense rainfalls (595 mm) occurring over a 3-month period. Only short-term (1–3 wk) and shallow (<10 cm depth) floods had taken place in the area during the 1980–1985 period.

In late January 1986 we again sampled both sites. These data were compared with those obtained in 1985 when the grazed area showed clear signs of deterioration (Facelli et al. 1988). Although the nature of the study itself precluded the strict use of flooding as a "treatment" (Hurlbert 1984), the unusual magnitude of the event and the short time span between the samplings led us to assume that the flood was the main factor influencing grassland composition during the study period.

Differences in the basal cover of dicots, grasses, and sedges were analyzed for each site. We could not call for a test of significance for differences among dates because sampling units were permanent and, therefore, the observations were not statistically inde-

¹Nomenclature follows Cabrera and Zardini (1978)

Table 1. Changes in percent cover ($\bar{x} \pm SE$, $n = 4$) between Feb. 1985 and Jan. 1986 (before and after the flood respectively) for some of the species recorded in the grazed and ungrazed sites. Species included made up about 95% of the total cover. For the "other species" section, mean cover and species number (in brackets) are shown.

Species	Grazed		Ungrazed	
	Pre-flood	Post-flood	Pre-flood	Post-flood
Dicots				
Warm-season				
<i>Spilanthes stolonifera</i>	0.18 ± 0.06	0.11 ± 0.02		
<i>Aster squamatus</i>	0.05 ± 0.02	0.21 ± 0.07		
Cool-season				
<i>Mentha pulegium</i> ¹	11.14 ± 2.90	0.68 ± 0.26		
<i>Leontodon taraxacoides</i> ¹	2.14 ± 0.30	0.22 ± 0.09		
<i>Plantago lanceolata</i> ¹	1.61 ± 0.74	0.13 ± 0.04		
<i>Phyla canescens</i>	0.31 ± 0.12	0.46 ± 0.08	0.15 ± 0.15	0.02 ± 0.02
<i>Erynqium ebracteatum</i>	0.16 ± 0.04	0.44 ± 0.12	0.02 ± 0.02	0.03 ± 0.02
Grasses				
Warm-season				
<i>Panicum gounii</i>	1.46 ± 0.08	1.04 ± 0.66	0.01 ± 0.02	
<i>Setaria geniculata</i>	0.42 ± 0.13	0.03 ± 0.02	0.02 ± 0.04	0.01 ± 0.02
<i>Panicum milioides</i>	4.36 ± 2.06	2.88 ± 0.23	3.27 ± 1.13	2.92 ± 0.48
<i>Paspalidium paludivagum</i>	0.61 ± 0.10	0.78 ± 0.19	1.49 ± 0.62	3.01 ± 0.66
<i>Leersia hexandra</i>	0.19 ± 0.07	2.56 ± 0.40	0.87 ± 0.78	2.70 ± 1.58
<i>Paspalum dilatatum</i>	0.05 ± 0.10		4.86 ± 2.44	2.99 ± 1.20
<i>Stenotaphrum secundatum</i>			1.28 ± 0.74	0.33 ± 0.29
<i>Deyeuxia viridiflavescens</i>			0.59 ± 0.55	0.25 ± 0.19
<i>Panicum bergii</i>		0.04 ± 0.08	0.45 ± 0.29	0.07 ± 0.06
Cool-season				
<i>Danthonia montevidensis</i>	2.71 ± 0.84	4.64 ± 1.12	1.64 ± 0.82	1.82 ± 1.15
<i>Stipa philippii</i>			5.38 ± 4.62	0.60 ± 0.60
Sedges				
Warm-season				
<i>Juncus microcephalus</i>	0.05 ± 0.05	0.51 ± 0.16		
Cool-season				
<i>Eleocharis viridans</i>	1.50 ± 0.75	5.88 ± 0.66	2.00 ± 0.09	4.28 ± 0.39
Other species				
Dicots	0.33 (11)	0.21 (4)	0.08 (4)	
Grasses	0.59 (4)	0.31 (6)	0.75 (5)	0.20 (3)
Sedges	0.48 (2)	0.05 (2)	0.43 (3)	0.02 (1)
Total basal cover	28.31 ± 1.64	21.60 ± 1.02	23.28 ± 1.74	19.26 ± 2.58

¹exotic species

pendent. Instead, we based the analysis on the confidence intervals of the means ($\alpha = 0.05$). Floristic differences among sites for post-flood observations were examined with the Mann-Whitney U test (two-tailed). Contribution to total cover of native and exotic species, and of cool- and warm-season species were also considered.

The Percentage Similarity index (PS , Gauch 1982) was employed for comparing the overall species composition among sites and between pre- and post-flood conditions. Because our aim was to emphasize the degree of change at 2 different sites, results were expressed as Percent Dissimilarities ($PD = 100 - PS$). The average values of basal cover per species standardized by sample total cover were used in the computations.

The consequences of floristic changes for grassland forage quality were evaluated by the Grazing Value Index (GVI) proposed by Daget and Poissonet (Poissonet et al. 1981):

$$GVI = 0.2 \cdot \sum_{i=1}^n (CS_i \cdot SI_i)$$

where n is the species number GS_i is the relative contribution of species i to the total cover for a given situation, and SI_i is an index of the forage value of the species i , ranking from 0 to 5. The SI takes into account nutritional value, cattle preferences, and some plant traits like growing form, height, and biomass concentration, which contribute to determine the actual forage offered by a species. Tabulations from Cauhépe et al. (1984) were used to assign SI values. This index proved to be suitable in previous works in grasslands and pastures of the region (Cauhépe et al. 1984, Oesterheld and León 1987).

Results

Total basal cover was similar in both sites. Differences (Table 1) were not significant, both before ($U = 2$, $P > 0.1$) and after the flood ($U = 8$, $P > 0.5$). Total cover does not appear to be shifted in either of the study sites (c.i. broadly overlapped between sampling dates, Table 1), although the ranges for the values of the grazed area (1985 = 25.2–31.1, 1986 = 20.2–24.6) would suggest a slight reduction of its plant cover. Floristic changes were primarily related to changes in the cover of species present before the flood.

The floristic composition of the grazed site was substantially modified (Fig. 1a, 2). The basal cover of alien dicots diminished from 14.94 (± 3.82) to 1.07 (± 0.25). Before flooding, *Mentha pulegium*, *Leontodon taraxacoides*, and *Plantago lanceolata*, constituted about 52% of the total cover. Their contribution declined to 5% in 1986 (Table 1). Conversely, the importance of monocots was enhanced by the increased cover of some grasses and sedges (Fig. 1a, Table 1). After the flood, native species became the main component of the grazed site and continued dominating the grassland inside the enclosure. The cover of exotics and forbs remained higher in the grazed area than in the ungrazed one (U -test, $P < 0.05$) (Fig. 1). The cover of cool-season species decreased by 14% in the grazed area (Fig. 1a), although the aforementioned reduction of cool-season forbs was in part compensated by the increase in the cover of *Danthonia montevidensis* and *Eleocharis viridans*, 2 native monocots (Table 1).

Community composition of the ungrazed area varied slightly. The cover of sedges increased (Fig. 1b), mainly due to the increment in the basal cover of *Eleocharis* sp. Some grasses also had higher cover values after flooding (Table 1), but the whole of the grass compartment showed a minor reduction from 20.61 (± 2.01) to 14.91 (± 2.47), i.e., 11% over the total cover (Fig. 1b). Grass cover did not differ significantly among sites after the flood ($U = 4$, $P > 0.3$), although its proportion was larger inside the enclosure (Fig. 1). The relationship between the cover of cool-season and warm-season species remained almost unchanged in the ungrazed site (Fig. 1b).

Several rare species recorded in 1985 were not found in 1986. Nevertheless, these species (mostly dicots and annuals) represented a small fraction of the total cover ($< 1.5\%$) in both sites. Those species that appeared in the samples only after the flood (all

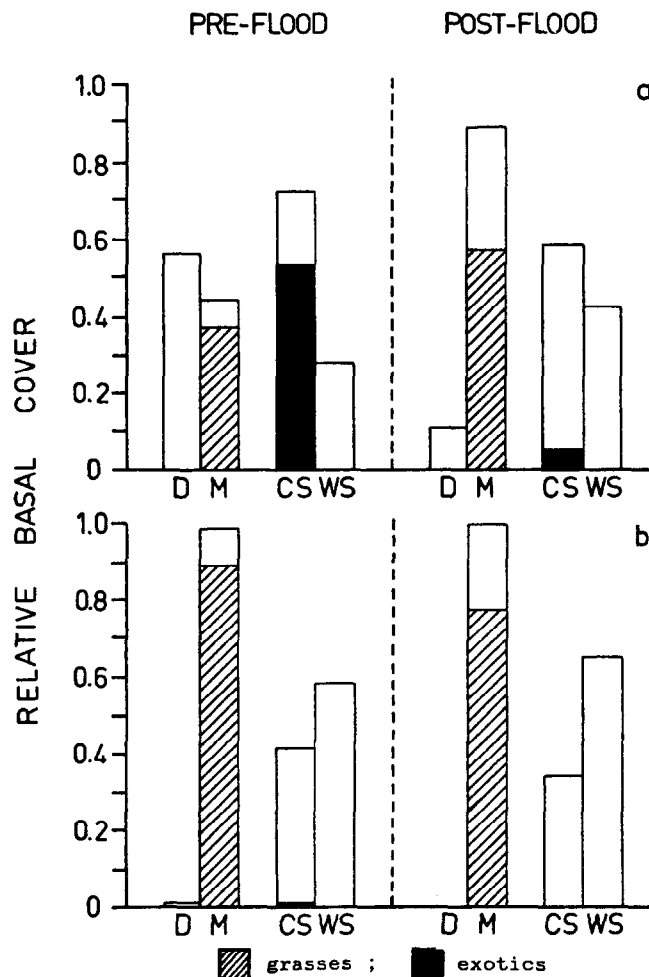


Fig. 1. Proportional basal cover for the grazed (a) and ungrazed (b) areas of dicots (D) and monocots (M), and cool-season (CS) and warm-season (WS) species.

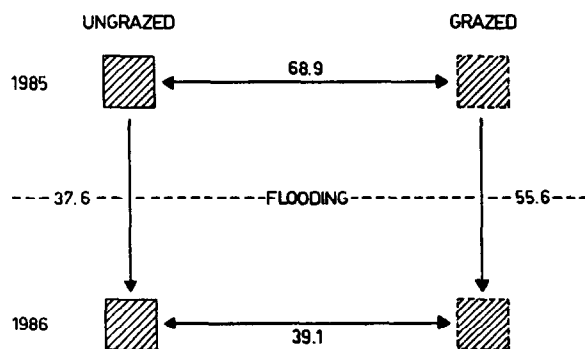


Fig. 2. Comparisons between sites and dates of the overall floristic composition. Values represent Percentage Dissimilarities ($PD = 100 - PS$) (Gauch 1982) for each case.

graminoids) did not show values over 0.06%.

Different species responded positively (increasing cover) to the flooding event. Some species augmented only in the grazed site (e.g., *Danthonia* sp.), some only inside the enclosed area (e.g., *Paspalum paludivagum*), and others like *Eleocharis* sp. and *Leersia hexandra* increased in both sites (Table 1). The latter response together with the diminution in the cover of dicots for the

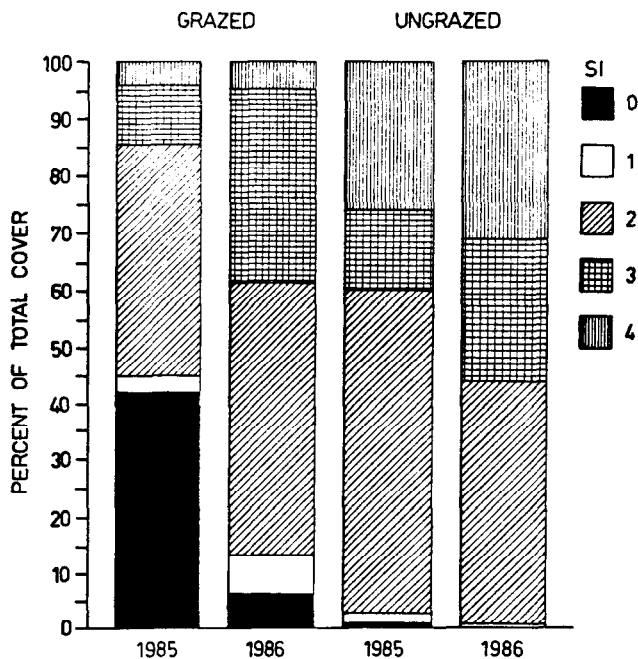


Fig. 3. Percentage contribution to the total cover of the grazed and ungrazed sites in each sampling date (before and after the flood) of all recorded species, grouped accordingly to its forage values (SI). The following are the forage values for some representative species from the study sites in the Flooding Pampa: 4 = *Paspalum dilatatum*, *Paspalidium paludivagum*; 3 = *Leersia hexandra*, *Danthonia montevidensis*; 2 = *Stipa philippi*, *Panicum milioides*, *Panicum gounii*, *Stenotaphrum secundatum*, *Eleocharis viridans*, *Plantago lanceolata*, *Leontodon taraxacoides*; 1 = *Juncus microcephalus*, *Eryngium ebracteatum*; 0 = *Mentha pulegium*, *Phyla canescens*.

grazed area contributed to reduce previous site differences (Fig. 2). The comparison of the overall community composition indicates that both sites converged floristically, i.e., percentage dissimilarity among sites decreased towards 1986 (Fig. 2).

Alterations in grassland floristic composition shifted the *GVI* of the grazed area from 26.2 in 1985 to 44.6 in 1986. The contribution of non-forage species (species with $SI = 0$) decreased markedly as they were replaced by native graminoids of more forage value (Fig. 3). In the ungrazed area, some native grasses having a $SI \geq 2$ reduced their cover (Table 1). The slight variation of *GVI* in this site (53.9 to 57.3) was accounted for by the increase of species with $SI = 3$ or 4 (Fig. 3). Species with very low forage value (0 or 1) were nearly absent inside the enclosure (Fig. 3) thus the ungrazed community always maintained a higher forage quality.

Discussion and Conclusions

The flood altered the floristic structure of the grassland, but the extent of the impact was different in the 2 studied sites. The grazed site was very susceptible to the infrequent magnitude of the flood (Fig. 2).

Cattle grazing deeply affects the structure of the native grassland, disrupting the canopy and promoting colonization by cool-season weedy forbs (Sala et al. 1986, Facelli et al. 1988). These species are able to tolerate light seasonal floodings, yet the large flood of 1985 drastically reduced their cover. The success of exotic species likely depends on the duration and depth of floodings. Recurrent, light floods interacting with continuous grazing might create advantageous conditions for invaders like *Mentha* sp. and *Leontodon* sp., whereas less frequent, more intense events would impair their performance (Panetta 1985). Insausti and Soriano (1988) found a similar response in *Ambrosia tenuifolia*, a common forb of the "upland" communities which is usually avoided by

cattle ($SI = 0$). The aerial and belowground portions of that species were observed to be strongly affected by a prolonged flood (Insausti and Soriano 1988).

Two native cool-season graminoids highly preferred by cattle, *Danthonia* sp. and *Eleocharis* sp. (Cauhépé et al. 1984), were promoted. Regardless that flooding occurred during their period of maximum annual productivity (Sala et al. 1981), these species resisted the stress and dominated the grazed community after the flood (Table 1). The results suggest that the effect of a large flood could not be related to the phenological behavior of the species involved.

The slight changes of dominance recorded within the enclosure were caused by variations in the cover of individual species, not in any particular floristic group. They had the same direction to those observed in the grazed site, indicating that the changes of species abundances in both sites mainly reflected unequal abilities to cope with waterlogging stress. In the ungrazed area, competition and tolerance due to the small-scale light shortages would play an important role in structuring the community (Tilman 1982, Facelli et al. 1988). The inundation caused the depletion of the available oxygen in the soil (Ponnamperuma 1984), temporarily adding a limiting resource to the plant environment. Community composition is thought to reflect alterations in the resource availability (Tilman 1982). Thus, species which endured the new constraint such as *Eleocharis* sp. and non-tussocking grasses like *Paspalidium* sp. and *Leersia* sp., shared the dominance with tall grasses (e.g. *Paspalum dilatatum*, *Panicum milioides*) which dominated before flooding (Table 1).

The community of the ungrazed site was more resistant to compositional modifications. Community response to prolonged waterlogging seemed to be largely influenced by the identity of the dominant species as determined by the preceding management history of the site. The response of a community to external perturbations derives in part from the adaptive properties of its component species resulting from the evolutionary history of the ecosystem (Rapport et al. 1985). Exotic eurasian weeds are more successful on sites disturbed by cattle (Mack and Thompson 1982) probably due to a long history with domestic grazing (Knapp 1979), but they have not developed resistance to floods of large magnitude. On the other hand, native graminoids dominant inside the enclosure presumably have evolved under this constraint but not subjected to grazing by large ungulates (Burkart 1975).

Because of flooding, grazing was suspended for 3 months. However, the changes observed in the grazed area resembled those which usually occur following 4 to 5 years of cattle exclusion (Sala et al. 1986, Rusch and León unpubl.). Floristic changes induced by the flood were the opposite of those shaped by livestock grazing (León et al. 1984). Flooding promoted the replacement of exotics of low forage value by more valuable, native species (Fig. 3). After the flood, a large proportion of the available forage was made up of preferred graminoids, a factor which may influence herbage intake of grazers (Allison 1985, see also Senft et al. 1985). McNaughton (1983) pointed out that many environmental factors may override the effects of herbivores on vegetation. In our case, the unusually large flood functioned as the overwhelming agent (coarse-grain signal sensu Allen and Starr 1982, p. 135), masking the ecological differences among sites and partially reversing grazing effects on grassland composition. A group of indigenous species responded similarly to this factor in both sites leading to floristic convergence (Fig. 2).

In these grasslands, floodings are recurrent events of varying magnitude. Hence it would be appropriate to consider them as a consistent driving force of the system (White 1979, Vogl 1980, Rapport et al. 1985), which constitutes an essential part of the environmental setting as is fire in other grassland ecosystems (e.g., Risser et al. 1981, McNaughton 1983). Moreover, periodic floods may contribute to mitigate the action of continuous domestic grazing upon range condition (Taboada and Lavado 1988). Nevertheless, our results suggest that the outcome of infrequent large

phenomena for a given community would depend on the initial conditions, in terms of the abundance of the species present.

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