Research Article

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Benefits of fire in shrub control in the grasslands of the monte province, Rio Negro, Argentina

Abstract

In the grasslands in the NE of Río Negro province, Argentina controlled burning or mechanical clearing are common practices to reduce the shrub layer and improve the forage supply of the grasslands that constitute the basis of extensive livestock breeding. In one area of the region, we estimated the Aerial Net Primary Productivity (ANPP) and evaluated the quality of the dominant grasses over three years in grasslands subjected to mechanical clearing and burning, through seasonal cuts of biomass and laboratory analysis. We also recorded the phenology of the dominant grasses and shrubs. We obtained higher values of Crude Protein and Dry Matter Digestibility of the grasses in spring, since they were mainly in the vegetative stage, and the differences were significantly greater in the burned site. This effect of fire would be due both to the regrowth and to the increase in the proportion of vegetative material generated by this disturbance. Mechanical clearing had no significant effects on quality, although it increased the ANPP. When analyzing phenological behavior, our results showed better conditions for livestock production in the disturbed sites, with a higher proportion of vegetative growth of the grasses and greater senescence of the shrubs.

Keywords: shrub encroachment, controlled burning, mechanical clearing, crude protein, digestibility, phenology

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Introduction

In Río Negro province, Argentina, the phytogeographical province of the Monte occupies almost 70% of the surface. The main, productive activity in the NE region of the province is livestock breeding on natural grasslands. The available information[1] allows us to infer that a shrub encroachment process has taken place due to an increase in grazing intensity which reduced competition from grasses. The consequence of this has been the lack of fine fuel and, with it, the frequency of fires that took place in this ecosystem, as has also been reported in other similar ones around the world.[2–4]

The technology available for increasing productivity in the eastern Monte, Rio Negro, is scarce and elementary. Tt is fundamentally based on improving the forage supply through the control of the shrub layer by mechanical removal or controlled burning, although the use of fire is a practice limited by the province. However, the exclusion of fire can be a greater disturbance than controlled summer burning,[5] which in our region especially affects shrubs, as they are actively growing in that season.

According to Bond and Keeley,[6] fire has been burning ecosystems for hundreds of millions of years, helping to shape biomes and maintain the structure and functioning of communities prone to burning. It is not only an evolutionary force, but also one of the first tools used by man to remodel his productive systems. On the other hand, the use of machinery is relatively recent in our country and the methods used can vary from clearing with heavy harrows to the use of large cutting rollers.[7–10]

All of these practices affect the primary productivity and physiognomy of the ecosystem; there are numerous citations and reviews on these aspects, showing mixed results.[11,3] However, there is less information regarding how the quality of the forage resulting from the use of such practices is affected.

Our objective was to estimate the net primary productivity and evaluate the quality of the forage present in the Monte grasslands in Rio Negro and so predict to what extent they are affected when the vegetation cover is modified by two practices commonly used for shrub control (mechanical clearing and burning) in comparison to the undisturbed situation and over time.

We hypothesized that controlled fire (which was part of the dynamics of the original ecosystem) is beneficial as it is an easier and cheaper to mechanical clearing if managed properly. It both prevents the generation of a vicious circle of shrub encroachment - soil denudation - erosion, thus contributing to the long-term sustainability of the ecosystem, and improves the quality of the forage supply.

Materials and methods

We carried out this study in a field located in the Pichi Mahuida department (39°40’ S, 64°47’ W), Río Negro province, Argentina, corresponding to the eastern sector of the phytogeographical province of Monte.[12]

The characteristic vegetation of that region is medium to high shrubland, dominated in its shrubby layer by the evergreen shrubs *Larrea divaricata* Cav., in sloping sectors, with *Condalia microphylla* Cav. and *Chuquiraga erinacea* D. Don. ssp. *erinacea,* accompanied by *Prosopis alpataco* Phil. and *Schinus johnstonii* F. A. Barkley on the flat areas, and an important grassy layer dominated by *Nassella tenuis* (Phil.) Barkworth (syn. *Stipa tenuis*) and accompanied by *Poa ligularis* Nees ex Steud. var. *ligularis*, *Piptochaetium napostaense* (Speg.) Hack and *Nassella clarazii* (Ball) Barkworth.[13]

The region is climatically classified as semi-arid mesothermal, with a marked water deficit in summer and an average rainfall of about 425 mm p.a.[13]

We conducted initial sampling of the forage biomass in two adjacent undisturbed grasslands in February, 2014 and a few days later we burned one of them. We called these sites C (Control) and B_0 (Control to burn). All biomass sampling consisted of cutting to ground level in 30 plots of 40 cm sides per site, which were free of domestic herbivores throughout the entire period.

When spring arrived (October 2014) we compared both sites (C and B) again and in March 2015 we included a site that had been mechanically cleared in 2013 (M), in addition to the previous sites (C and B). In March 2016 we repeated the harvest in all the sites, but we analyzed the results separately, since in December 2015 a natural fire occurred (started by lightning), which covered the entire property, except for the site that we had previously burned (B).

The harvested samples were dried in an oven at 70ºC, and weighed on a precision scale. In the laboratory we determined:

a) Total Nitrogen, by the Kjeldhal method, to estimate Crude Protein (CP), and

b) Acid Detergent Fiber content (Van Soest) to calculate the Dry Matter Digestibility, using the formula: DMD% = 88.9 - (ADF% x 0.779)

We also recorded the phenological stages, seasonally, over the same period (classifying them as "vegetative", "reproductive", or "senescent") of four C3 grass species: *Nassella tenuis, N. clarazii, Poa ligularis*, and *Piptochaetium napostaense*) and four species of shrubs (*Condalia microphylla*, *Prosopis alpataco*, *Monttea aphylla* and *Larrea divaricata*).

Throughout the trial, we recorded the rainfall at a meteorological station located at the same site.

We associated the phenological stages of the grasses with the quality values in a descriptive way, and we observed the development of the grasses and shrubs in the disturbed sites with respect to the control site, in all cases comparing them with the rainfall of the period.

We estimated the Aerial Net Primary Productivity using the biomass cuts in the two springs after burning, because that is the time of peak production in the year.

We analyzed the ANPP and pasture quality data through ANAVAs and *t* tests for comparison of means with the Infostat/P statistical software.[14]

Results

Initially, the CP and DMD values of the grasslands did not differ between the different paddocks, which demonstrated the similarity of the sites chosen to apply the treatments (Table 1).

Table 1 Initial percentages of crude protein and dry matter digestibility of forage grasses, for two adjacent sites C (Control) and B_0 (site to be burned or Burned time 0). Different lowercase letters indicate statistically significant differences between treatments (p<0.05)

Date	Treatment	CP	DMD
February 14	C	3.90^a	58.31^a
	B0	3.61^a	57.87^a

In the following spring, after the end-of-summer burning had been carried out, the values increased in both sites (C and B), although the differences were greater in site B (Table 2).

Table 2 Percentages of crude protein and digestibility of dry matter of forage grasses, for two years and different sites (C, M and B). Different lowercase letters indicate statistically significant differences between treatments (p<0.0)

Date	Treatment	CP	DMD
October 2014	C	8.3^b	66.80^b
	B	10.31^a	72.88^a
March 2015	C	10.35^{ab}	59.53^a
	B	13.43^a	61.05^a
	M	9.46^b	60.81^a

By including site M in the comparisons from 2015 onwards, we were able to observe that, at the same time of year, site B had a higher CP percentage than site M and site C did not differ from either of them (Table 2).

However, towards the end of the following summer (March 2016) these values were inverted, as sites C and M did not differ from each other, exceeding the values of site B (Table 3). This result, however, was also due to the action of fire, since in December 2015 a natural fire occurred in the field that did not affect site B which was in the full vegetative stage, but burned the other two sites, C and M, which resprouted vigorously after that event. Therefore, these values are presented separately from the previous ones.

Table 3 Percentages of crude protein and digestibility of dry matter of forage grasses, for a post-fire date and different sites (C, M and B). Different lowercase letters indicate statistically significant differences between treatments (p<0.05)

Date	Treatment	CP	DMD
March 16	C	13.81^b	$63.89a^b$
	B	8.95^a	57.45^a
	M	11.05^{ab}	64.65^b

Table 4 and Table 5 show the different dominant phenological stages in each period: towards the end of the first summer, before burning, the C3 grasses are mostly in a senescent stage with a lower forage quality, as they are autumn-winter-spring cycle species: they resume vegetative growth in the autumn (end of March) and the dominant stage is in spring.

Table 4 Vegetative and senescent stages (average values, in percentages) of forage grasses, for two adjacent sites C (Control) and B_0 (site to be burned or Burned time 0). Different lowercase letters indicate statistically significant differences between treatments (p<0.05)

Date	Treatment	Veg.	Sen.
February 14	C	0^a	70.15^b
	B_0	0^a	66.00^b

Table 5 Vegetative and senescent stages (average values, in percentages) of forage grasses, for two years and different sites (C, M and B). Different lowercase letters indicate statistically significant differences between treatments (p<0.05)

Date	Treatment	Veg.	Sen.
October 14	C	68.99^b	12.66^a
	B	89.20^b	0.470^a
March 15	C	76.58^{ab}	10.42^a
	B	84.33^{ab}	8.33^a
	M	72.33^a	16.00^a

The fire occurred in December 2015 induced phenological changes in vegetation at the three experimental sites, that were reflected towards the end of summer (Table 6).

Table 6 Vegetative and senescent stages (average values, in percentages) of forage grasses, for a post-fire date and different sites (C, M and B). Different lowercase letters indicate statistically significant differences between treatments (p<0.05)

Date	Treatment	Veg.	Sen.
March 16	C	95.30^b	4.67^a
	B	92.67^{ab}	4.00^a
	M	87.67^{ab}	11.00^b

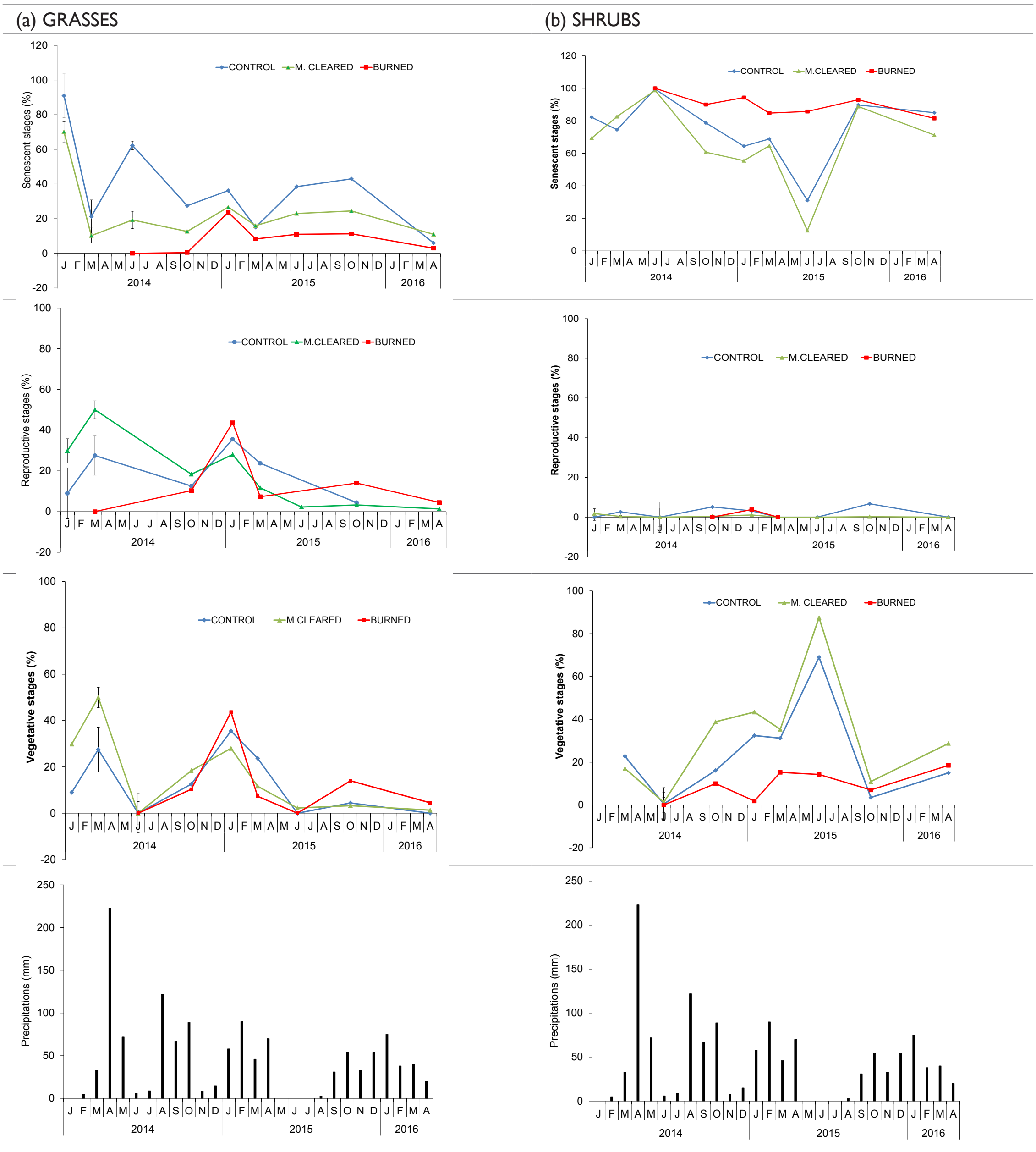
The phenological stages of the grasses accompanied the precipitation events, with higher percentages in the vegetative and reproductive stages at peak times of occurrence (Figure 1a). The lowest senescent percentages were recorded in site B and the highest in site C, except in the last period due to the occurrence of the previously mentioned fire that affected the whole field.

The shrubs did not allocate large resources to reproductive effort at any site, but the highest proportions occurred at site C, and the senescent proportions were always higher than those of grasses. In the case of site B, the fire eliminated the aerial biomass almost completely, although regrowth of the same plants resumed later (Figure 1b). The rainfall of the current year had little effect on the vegetative growth of this functional group.

In general, the peaks of occurrence at each stage did not coincide in the same periods for both functional groups.

Annual precipitation was higher in 2014 (Figure 1) and much higher than the average (649 vs. 439 mm), and all the years showed a basically bimodal distribution, with peaks in spring, but mainly in autumn. This seasonality, normal in the area, would explain the greater proportion of grasses with vegetative stages in autumn, which decrease towards the end of spring and become senescent in the summer.

Figure 1 Phenological stages of (a) grasses and (b) shrubs for a period of three years, in a Control site, one Mechanically cleared and one Burned, and rainfall for the same period.



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The ANPP of the forage species did not differ between C and B in the first spring (perhaps due to the variability in the biomass produced), but it did in the second spring, when C was surpassed by the two disturbed sites (Figure 2).

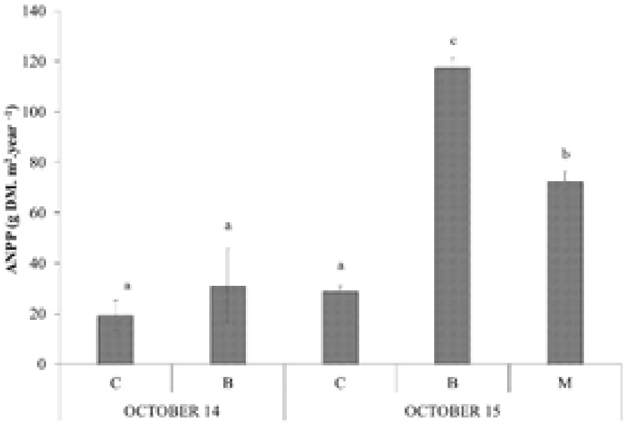

Figure 2 Aerial Net Primary Productivity of a Control site (C) and two sites disturbed by Burning (B) and Mechanically clearing (M), in two consecutive springs (x̄±EE). Lowercase letters on the bars indicate statistically significant differences for the date ($p<0.05$).

Discussion

In this ecosystem of the Monte province, the crude protein values that we obtained were those expected for this kind of environment and which normally satisfy the needs of the herbivores that graze them.[15] In the burned site, partcularly, both quality values that we measured (crude protein and dry mater digestibility) initially increased in a significative way due to the strong rejuvenation of the plants caused by fire, but then they declined. So, as this effect is lost over time, controlled burnings must be repeated periodically (around 5 years[1]).

However, it is not only necessary to consider the quality derived from the use of shrub control practices, but also by how much the quantity is modified, and whether the change in quality compensates or not for it. In our case, in the first year the quantity (ANPP) of disturbed sites not only did not differ from that of the intact site but also the quality was higher, and in the second year, the ANPP was vastly higher (four times) in the disturbed sites, always without grazing. Grazing, in fact, is a large scale disturbance and a driving force in these grasslands and as such it needs to be controlled. Wang et al.[16] suggested that it would be desirable not to graze a burned site until a year after burning. In our case, the highest ANPP would be a direct consequence of the fire and climate, since none of the grasslands were being grazed, and the highest rainfall occurred during the first year.

Fire had a positive effect on the development of grasses and a negative effect on that of shrubs, which showed greater proportions of senescence in that site, while mechanical clearing did not show the same effectiveness. This supports the observations of Vermeire et al.[17] regarding the fact that mechanical treatments cannot replace the ecological effects of fire in grasslands. Mechanical clearing, however, had a positive effect on increasing the ANPP compared to the intact site, although it did not reach the values of the burned site.

The response of the grasses was also strongly influenced by the occurrence of precipitation, especially in autumn, which suggests that the effects of fire would be more beneficial if burning is carried out at the end of summer, as proposed by Wang et al.[16]. This gives the grasses a better chance to resume vigorous growth in the later spring in those grasslands that have autumn-winter-spring cycles.

The phenological responses of shrubs to rainfall were somewhat delayed and did not show any great differences between the intact site and the cleared site, but rather between both these sites and the burned site, which was the most favored one.

ANPP estimates of the herbaceous layer through satellite images in shrub steppes, such as those of the eastern Monte, are quite erratic due to the "noise" produced by the shrub layer in the values. The fact that the peaks of occurrence of the phenological stages are not coincident for the two functional groups could facilitate the discrimination of the group that contributes more to productivity at each time of the year and improve the predictability of the NDVI (normalized difference vegetation index).

This differentiation of the stages would also allow us to identify the best time of the year to carry out prescribed burning without damaging the grassland. The combustible material that accumulates in summer due to grass senescence could provide an opportunity to negatively affect shrubs, which are actively vegetating, without endangering the grasses. As Richburg et al.[18] stated, it would be much less effective to apply a control treatment during the dormancy periods of the shrubs and the costs of applying it would not change.

Conclusion

Our results aim to show better conditions for livestock production in disturbed sites, with a higher proportion of vegetative growth of grasses and greater senescence of shrubs.

Fire would be an economical and valuable tool to improve this ecosystem, since it not only reduces the area occupied by shrubs, but also improves the quality of the grasses that form part of the lower layer of vegetation, without the costs required by mechanical clearing.

We even propose the use of controlled burning to reduce the risk of accidental fires occurring, but without reducing the benefits generated by the rejuvenation of the grassland.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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