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Vegetation response to fire and roller-chopping in the south-west of Buenos Aires, Argentina

Respuesta de la vegetación al fuego y rolado en el sudoeste de Buenos Aires, Argentina

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Abstract. The objective of this work was to study the effect of a controlled fire and/or roller-chopping on foliar cover and density of the most conspicuous woody and forage perennial grass species in the south of the Phytogeographical Province of the Monte, Argentina. All control treatments reduced the woody species mean percentage cover. This reduction persisted during the whole study period. Nevertheless, the woody species tended to recover their percentage cover towards the end of study. At the end of the study period, significant differences (P<0.05) were only detected between the control and controlled burn plus roller-chopping treatment. No significant differences (P>0.05) in woody species mean density were detected among treatments throughout the study period. At the end of the study period, the foliar cover and density of desirable perennial grass species was higher (P<0.05) in the experimental units exposed to woody species control than in the control treatment. No significant differences (P>0.05) were detected in intermediate perennial grasses foliar cover and density among treatments. Our results suggest that the reduction of the woody species cover might encourage increased the foliar cover and density of desirable perennial grass species. The use of the controlled fire and/or roller-chopping, with proper grazing management, may be the key factor to reduce woody species influence and improve rangelands condition in the Monte region.

Keywords: Controlled fire; Roller-chopping; Woody control; Desirable grasses; Monte region.

Resumen. El objetivo de este trabajo fue estudiar el efecto de la quema controlada y/o el rolado sobre la cobertura foliar y densidad de las especies leñosas y gramíneas perennes forrajeras más conspicuas en el sur de la Provincia Fitogeográfica del Monte, Argentina. Todos los tratamientos de control redujeron el porcentaje de la cobertura media de las especies leñosas. Esta reducción persistió durante todo el período de estudio. Sin embargo, las especies leñosas tendieron a recuperar su porcentaje de cobertura hacia el final del estudio. Al final del período de estudio, sólo se detectaron diferencias significativas (P<0,05) entre el control y el tratamiento de quema controlada más rolado. No se detectaron diferencias significativas (P>0,05) entre tratamientos en la densidad media de las especies leñosas a través del período de estudio. Al final del mismo, la cobertura foliar y densidad de las gramíneas perennes deseables fue mayor (P<0,05) en las unidades experimentales expuestas al control de especies leñosas que en el tratamiento control. No se detectaron diferencias significativas (P>0,05) entre tratamientos en la cobertura foliar y densidad de las gramíneas perennes intermedias. Nuestros resultados sugieren que la reducción de la cobertura de las especies leñosas podría favorecer el incremento de la cobertura y densidad de las gramíneas perennes deseables. El uso de quemas controladas y/o rolados, con un apropiado manejo del pastoreo, puede ser el factor clave para reducir la influencia de las especies leñosas y mejorar la condición de los pastizales de la región del Monte.

Palabras clave: Fuego controlado; Rolado; Control de leñosas; Gramíneas deseables; Región del Monte.

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INTRODUCTION

The presence of woody species results in competition for water, light, nutrients, and space, and thus reduces herbaceous forage production for domestic livestock. The complexity of woody infestations, especially where the shrub problem is a combination of many, rather than one or two species, results in an uneven susceptibility to control treatments. Control implies keeping the woody species at a density that minimizes its interference with the production and utilization of range forage. Control of undesirable plants (i.e. shrubs) will be effective only when desirable species (i.e., forage grasses) are present to respond to the control treatments (Vallentine, 1989). Controlled and/or prescribed fires have been suggested as a mechanism for slowing woody vegetation expansion, preventing catastrophic wildfires, and restoring understory vegetation quantity and quality (Wright & Bailey, 1982). In addition, a variety of mechanical control treatments were developed to reduce the cover and/or density of shrubs in rangeland. Mechanical shrub control with roller choppers can be a relatively economic way to control shrubs and increase rangeland production in semiarid regions. A roller chopper consists of a heavy metal drum with blades mounted across the drum surface. These blades are perpendicular to the direction of pulling the drum. It can be filled with water or oil to increase its weight. The weight of the unit crushes the scrub, and the blades chop up the plant material and scarify the soil surface (Hamilton & Hanselka, 2004). Both control methods, burning and mechanical, may be combined to accomplish the desired shrub control treatment.

Shrub encroachment in many regions of the world has been attributed primarily to the combined effects of grazing, drought and alteration of the fire regime (Busby & Noble, 1986). Since the introduction of domestic livestock in the south of the Phytogoegraphical Province of the Monte (Cabrera, 1976; known locally as the Monte), many decades of overgrazing have occurred. This may have triggered the abundance increase of woody vegetation in this ecosystem. Grazing may reduce competitive ability of grazed plants, favoring woody species growth. At the same time, this will produce an alteration of the fire frequency, due to the reduction of fine fuels (Bóo et al., 1997). In the south of the Monte, wildfires are common during the hot and dry summer months (Busso, 1997). These fires often occur under hot, dry and windy climatic conditions, and may cause undesirable effects on the ecosystem. However, controlled fires of moderate intensity can control woody plants, increase forage production and facilitate cattle management. There is some information about the effects of controlled fires on the vegetation in the Monte (Peláez et al. 2010). However, although the rolling brush chopper has been successfully used in other parts of Argentina (Adema et al., 2004; Kunst et al., 2008), the impact of this control method on the vegetation has not been studied in the region. The objective of this work was to study the effect of a controlled fire and/or roller-chopping on foliar cover and density of the most common woody and perennial forage grass species in the south of the Monte region.

MATERIALS AND METHODS

Study site. Research was conducted in a representative site of the Phytogeographical Province of the Monte (Cabrera, 1976). The study site is within the Experimental Farm of Patagones (40° 39´ S, 62°54´ W; 40 m.a.s.l.) located at the south-western part of the Buenos Aires province (Argentina). Climate, soil characteristics and vegetation of this temperate, semi-arid region have been described elsewhere (Giorgetti et al., 2000). Long-term (1981-2005) average annual precipitation is 434.6 mm, concentrated mainly during fall and spring. Annual water deficit oscillates among 400 to 800 mm. During the study period, annual precipitation is shown in Figure 1. Average annual temperature is 14.6 °C, being July the coldest month (6.2 °C) and January (21.9 °C) the warmest one. The absolute maximum and minimum recorded temperatures are 41.4 °C and -9.9 °C. The region is a typical plain. Soil texture ranges from loamy and loam-sandy to loam-clay-sandy.

The vegetal community is characterized by an open shrub-by layer which includes herbaceous species of different grazing value (Giorgetti et al., 1997). Dominant woody species are *Condalia microphylla*, *Chuquiraga erinacea*, *Larrea divaricata*, *Schinus fasciculatus*, *Geoffroea decorticans*, *Brachyclados lycioides*, *Prosopis alpataco* and *Prosopidastrum globosum*. The herbaceous layer is dominated by perennial grasses as *Nassella tenuis*, *Piptochaetium napostaense*, *Poa ligularis* and *Nassella clarazii*. Other common perennial grasses in the region include *Pappophorum vaginatum*, *Sporobolus cryptandrus*, *Stipa ichu*, *Jarava plumosa* and *Aristida pallens*.

Controlled fire and roller-chopping application. The study comprised four treatments replicated four times: (i) unburned and non-roller-chopping (control), (ii) controlled burn (CB), (iii) roller-chopping (RC) and (iv) controlled burns and roller-chopping (CBRC). Treatments were randomly assigned to 13-ha experimental units enclosed within the Experimental Farm of Patagones and were separated by 20-m firebreaks one from each other. During the study period, experimental units were grazed using a rotational grazing and one herd. Stocking rate was 7.8 ha/animal unit.

Controlled burns were conducted in accordance with a safe fire prescription guide (Wright and Bailey, 1982). Air temperature, relative humidity, and wind speed were measured with field instruments before and immediately after each burn. Mean values were 28-26 °C, 25-35 % and 8-11 km/h, respectively. On 8 March 2004, controlled burns were conducted as headfires starting 2:00 pm. Prior to the controlled burns, each experimental unit was sampled to determine the

amount of fine fuel with ten 0.5 x 0.5 m quadrats. Fine fuel was considered as all material on the ground, including litter, less than 3mm in diameter. Fine fuels averaged a dry matter (DM) content of 890 kg/ha. The roller-chopping was carried out in November 2012 with a rolling shrub cutter (filled with oil) of 8000 kg, pulled by a tractor (180 HP) equipped with a straight heavy-duty pushing blade.

Vegetation sampling. Three 20-m permanent transects were randomly placed in each experimental unit and were used to estimate foliar cover and density of perennial grass species at the end of each growing season (i.e. December) throughout the study period (i.e. from 2012 to 2016). These data were collected with the canopy-cover method of Daubenmire (1959) and by counting the number of individuals whose base was more than half included in each of 20 quadrats (20 by 50 cm) along each transect. Perennial grass species were classified following Cano (1988), according to their degree of preference by livestock as desirable and intermediate (Table 1). Woody species cover and density at the end of each growing season (i.e. March) was also estimated using the same transects. Woody species cover was estimated by the line intercept method (Canfield, 1941). Density data were collected by counting the number of individuals whose canopy was more than half-included in a quadrat (2 by 20 m) centered along each transect.

Statistical analysis. Statistical analysis was restricted to compare the treatments (control, RC, CB, CBRC) within each sampling date. Perennial grasses and woody species data were analyzed following a completely randomized design using a one-way ANOVA. Differences among density (transformed to square root) and cover means (transformed to arcsin) were determined with Duncan´s test (Snedecor & Cochran, 1980). All statistical analysis were performed with the InfoStat version 2015 (Di Rienzo et al., 2015).

Table 1. Perennial grass species classified according to their degree of acceptance by livestock.
Tabla 1. Gramíneas perennes clasificadas de acuerdo a su grado de aceptación por el ganado.

Desirable perennial grasses	Intermediate perennial grasses [1]
Bromus brevis	*Aristida pallens*
Koeleria permollis	*Aristida trachyanta*
Nassella tenuis	*Aristida spegazzinii*
Nassella clarazii	*Jarava ichu*
Nassella papposa	
Piptochaetium napostaense	
Poa ligularis	
Poa lanuginosa	
Sporobolus cryptandrus	

[1] Perennial grasses grazed when desirable perennial grasses are not available
[1] Gramíneas perennes pastoreadas cuando las gramíneas perennes deseable no están disponibles

RESULTS

In the first period of evaluation (2013), mean percentage cover of woody species in the RC, CB, CBRC treatments was significantly lower (P<0.05) than in the control treatments (Fig. 2A). This reduction persisted during the remainder of the entire study period; however, differences were only detected significant (P<0.05) between the CBRC treatment and the control treatment (Fig. 2A). At all sampling dates, the lowest percentage cover of woody species was recorded in the CBRC treatment, but did not show significant differences (P>0.05) with the RC and CB treatments (Fig. 2A). At the end of the study period, the woody species tended to increase their percentage cover in all treatments (Fig. 2A). Mean density of woody species was similar (p>0.05) among treatments throughout the study period. The lowest density of woody species was recorded in the CB treatment (Fig. 2B). Contrarily, in general, the density of woody species was slightly greater in the RC treatment (Fig. 2B).

At the first sampling date, the percentage foliar cover of desirable perennial grass species in the CB treatments was higher (P<0.05) than in the control, RC and CBRC treatments (Fig. 3A). At the same time, the lowest percentage foliar cover of desirable perennial grass species was recorded in the RC treatment (Fig. 3A). The percentage foliar cover of desirable perennial grass species in the control treatment was

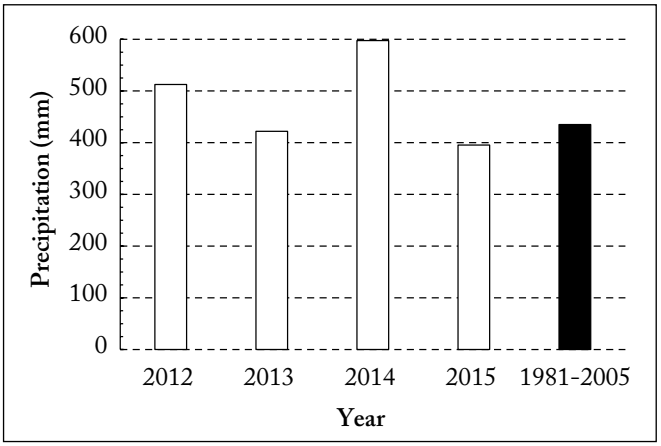

Fig. 1. Annual precipitation recorded during the study period and average precipitation recorded for the 1981-2005 period in the study site.
Fig. 1. Precipitación anual durante el período de estudio y precipitación promedio registrada para el período 1981-2005 en el sitio de estudio.

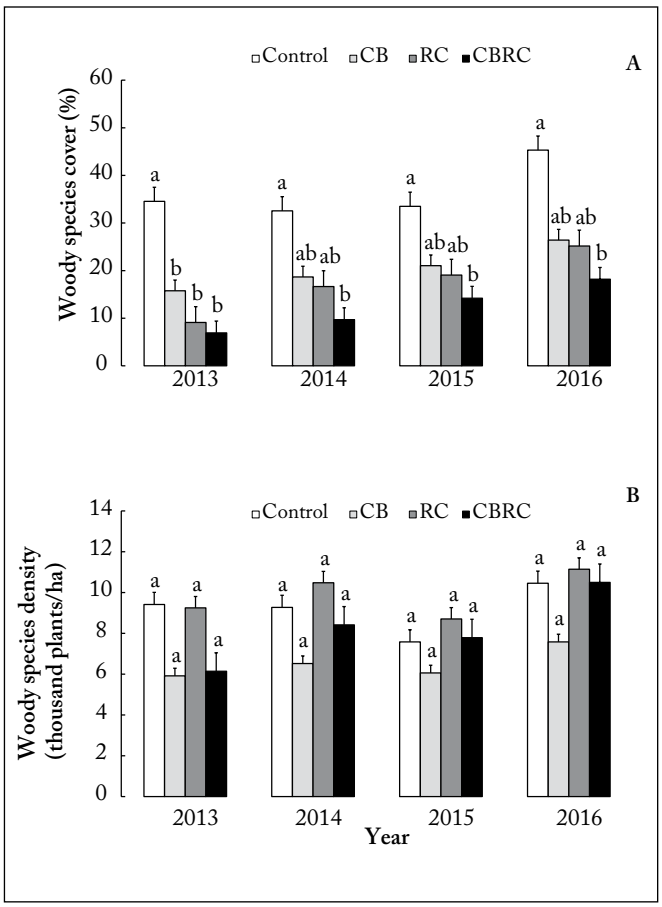

Fig. 2. Woody species mean percentage cover (A) and density (B) in control, controlled burn (CB), chopper-rolling (RC) and controlled burn plus chopper-rolling (CBRC) treatments. In each sampling date, columns with the same letter are not significantly different (P>0.05). Each column is the mean of n=4 and vertical bars represent the S.E.

Fig. 2. Porcentaje medio de la cobertura (A) y densidad (B) de las especies leñosas en los tratamientos control, quema controlada (CB), rolado (RC) y quema controlada más rolado (CBRC). En cada fecha de muestreo, columnas con la misma letra no son significativamente diferentes (P>0,05). Cada columna es la media de n=4 y las barras verticales representan el E.E.

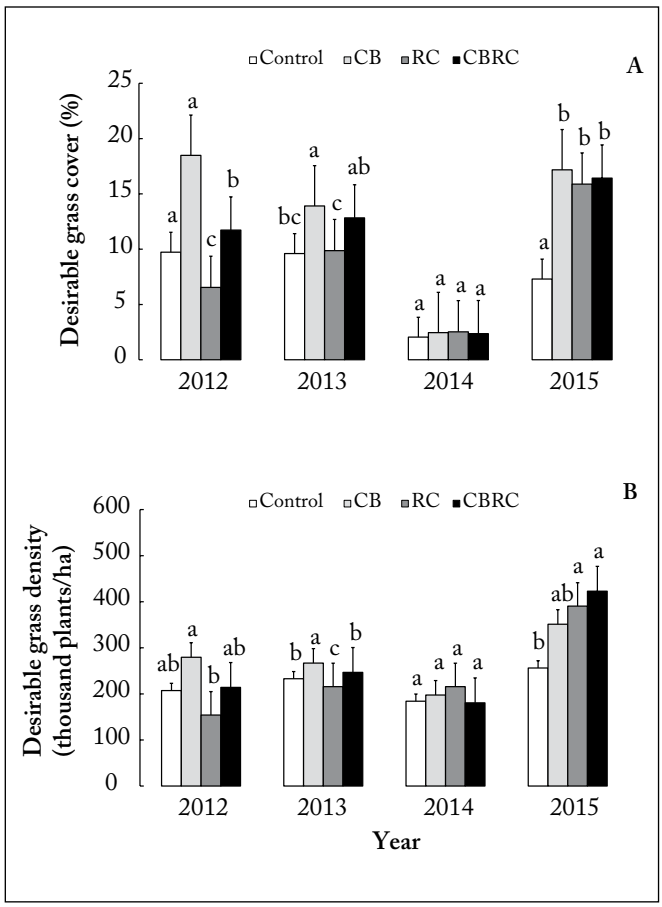

Fig. 3. Desirable perennial grass species mean percentage foliar cover (A) and density (B) in control, controlled burn (CB), chopper-rolling (RC) and controlled burn plus chopper-rolling (CBRC) treatments. In each sampling date, columns with the same letter are not significantly different (P>0.05). Each column is the mean of n=4 and vertical bars represent the S.E.

Fig. 3. Porcentaje medio de la cobertura foliar (A) y densidad (B) de las gramíneas perennes deseables en los tratamientos control, quema controlada (CB), rolado (RC) y quema controlada más rolado (CBRC). En cada fecha de muestreo, columnas con la misma letra no son significativamente diferentes (P>0,05). Cada columna es la media de n=4 y las barras verticales representan el E.E.

lower (P<0.05) than in the CB, RC and CBRC treatments at the December 2014 sampling date (Fig. 3A). However, the foliar cover of desirable perennial grass species was not significantly different (P>0.05) in the CB, RC and CBRC treatments (Fig. 3A). In general, the density of desirable grass species exhibited a similar response to the cover (Fig. 3B).

At all sampling times, the percentage foliar cover of intermediate perennial grass species did not show significant differences (P>0.05) between treatments (Fig. 4A). However, the percentage foliar cover of intermediate perennial grass species was consistently higher in the RC treatment than in the CB and CBRC treatments (Fig. 4A). No significant differences in density of intermediate perennial grass species were detected (P>0.05) between treatments throughout the study period (Fig. 4B). In the first sampling date (2012), the density of the intermediate perennial grass species in the control treatment was markedly higher than in the rest of treatments. However, towards the end of the study period, the density of the intermediate perennial grass species (mainly in RC and CB treatments) had a certain degree of recovery (Fig. 4B).

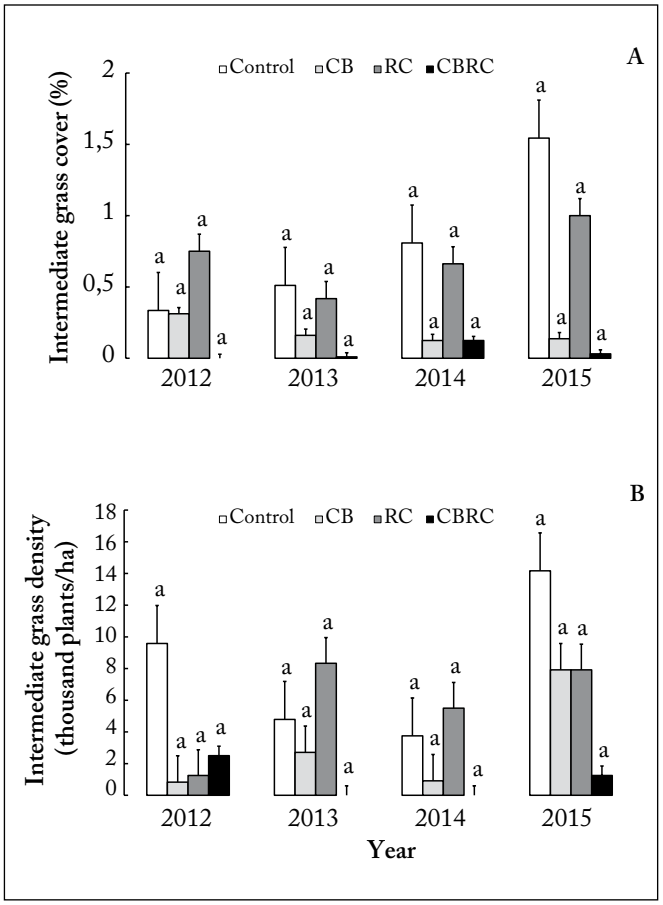

Fig. 4. Intermediate perennial grass species mean percentage foliar cover (A) and density (B) in control, controlled burn (CB), chopper-rolling (RC) and controlled burn plus chopper-rolling (CBRC) treatments. In each sampling date, columns with the same letter are not significantly different (P>0.05). Each column is the mean of n=4 and vertical bars represent the S.E.

Fig. 4. Porcentaje medio de la cobertura foliar (A) y densidad (B) de las gramíneas perennes intermedias en los tratamientos control, quema controlada (CB), rolado (RC) y quema controlada más rolado (CBRC). En cada fecha de muestreo, columnas con la misma letra no son significativamente diferentes (P>0,05). Cada columna es la media de n=4 y las barras verticales representan el E.E.

DISCUSSION

Woody control methods are often only partially effective, and reinfestation frequently requires additional treatment. Although good management may prolong the benefits of woody control on range, the effects are seldom permanent. Subsequent treatments will usually be needed after a few years depending on the regenerative potential of the woody species. Subsequent treatments may be retreatments using the original treatment as supplemental treatments of a different kind inserted to prolong the usefulness of the original treatment. All control methods reduced the woody species mean percentage cover. This reduction persisted during the whole study period. Nevertheless, the woody species tended to recover their percentage cover towards the end of study. Moreover, only significant differences were detected between the control and CBRC treatments until the March 2016 sampling date (Fig. 2A). Bóo et al. (1997) reported a significant reduction in the cover of a group of woody species, *C. microphylla*, *C. erinacea*, *Prosopis flexuosa* and *L. divaricata*, after a wildfire and two controlled fires of different intensities. In general, the effects persisted at least two years after the burns. Similar results were reported by Kröpfl et al. (2007) for *C. erinacea* and *C. microphylla* after a summer wildfire. Repeated controlled burns of moderate intensity, every 3-4 years, permitted to control the cover and the individual height and canopy area of the most common woody species in the south-eastern of the province of La Pampa, Argentina (Peláez et al., 2012). The first year after roller-chopping, in a central Argentina xerophytic woodland, the woody species cover (i.e., *C. microphylla*, *L. divaricata*, *P. flexuosa*) decreased between 26 to 80%. However, after three years, shrubs recovered 70% of their initial cover (Steinaker et al., 2016). When the rolling brush cutter was used to control *Prosopis glandulosa*, retreatment thereafter about every 5 years was necessary, while the rolling brush cutter was ineffective on both *P. glandulosa* and *Larrea tridentata* (Vallentine, 1989).

In general, density of woody species was not affected by the control methods. Moreover, the density of woody species increased slightly through the period of study in the RC treatment (Fig. 2B). This increase might have been due, at least in part, to the decision to consider some clustered plants (i.e., *C. microphylla*) as one individual in the control treatment but as more than one after rolling-chopper. Furthermore, the clustered nature of the woody species in the study site, with no occurrences in several sampling plots, produced a high experimental error. A more intensive sampling or a different sampling design might have produced more conclusive results. Nevertheless, our results are in partial agreement with those obtained by Bóo et al. (1997), Kröpfl et al. (2007) and Peláez et al. (2010; 2012).

In the two first sampling dates, the highest foliar cover of desirable perennial grass species was observed in the CB and CBRC treatments. At the end of the study period, the foliar cover of desirable perennial grass species was higher in the experimental units exposed to woody species control than in the control treatment (Fig. 3A). Controlled burns and/or rolling-chopper reduced the percentage cover of woody species (Fig. 2A). Reduced competition from woody species for light, water and/or nutrients after controlled burns and/or rolling-chopper might explain the increase in cover of desirable grass species. Both rolling-chopper and controlled burns generally (i) reduces consumption of water by woody species, (ii) releases plant nutrients in the soil for plant use, (iii) re-

duces temporarily the amount for vegetation that intercepts precipitation from light rains, and (iv) reduces the shrub cover (Anriquez & Albanesi, 2008; Peláez et al. 2012). The results of the present study are in agreement with those obtained by Bóo et al. (1996) and Peláez et al. (2010; 2013), who reported that controlled burns induced an increase in foliar cover in desirable perennial grass species (*P. napostaense*, *N. clarazii*, *N. tenuis*). The cover of grass species (i.e., *Digitaria californica*, *Setaria leucopila*, *Tricloris crinita*) increased (26-80 %) the first year after roller-chopping. After three years, the grass species maintained a relatively high cover (74 %) (Steinaker et al., 2016). On the other hand, Adema et al. (2004) showed that average perennial grass dry matter production (*P. napostaense*, *N. tenuis*, *P. ligularis*, *D. californica*, *T. crinita*) of the 4-year study in the rolled shrub treatment was significantly higher than in the non-rolled treatment (2886 vs 1530 kg dry matter/ha). Those authors suggested a better soil water use by the herbaceous strata in the rolled treatment. At the December 2012 sampling date, the foliar cover of desirable perennial grass species was significantly lower in the RC treatment than in the rest of the treatments. On the following sampling date, the desirable perennial grass species showed some level of recovery of its foliar cover (Fig. 3A). This result suggests that this group of perennial grass would be less tolerant to roller-chopping effects. Therefore, a period of at least one year would be necessary to preserve this grass species. The study period was characterized by near- or above-average annual rainfall (Fig. 1). This suggests that the woody species control may favour an increase in the foliar cover of desirable perennial grass species with normal and well-distributed rainfall (Fig. 1). The lowest foliar cover of desirable perennial grass species was recorded in 2014 (Fig. 3A). This was the result that the experimental units were grazed 45-60 days prior to the date of sampling.

Towards the end of the study period the desirable perennial grass density increase after the control of woody species (Fig. 3B). Bóo et al. (1996) reported that *N. tenui*s increased in density after a controlled fire conducted in autumn. Controlled fire treatments, regardless of frequency, induced an increase in density in desirable perennial grass species such as *P. napostaense*, *P. ligularis*, *N. clarazii* and *N. tenuis* (Peláez et al., 2013). However, Peláez et al. (2010) detected no increases in the density of the desirable perennial grass after a controlled fire carried out at the end of the summer. Roller chopper leave a ridge and furrow effect on the soil surface that holds water and promotes seed germination and seedling establishment (Hamilton & Hanselka, 2004). According to Kunst et al. (2016), the recruitment of new individuals by germination after a low intensity roller-chopping was relevant in the case of perennial native grasses represented by the genera *Setaria*, *Gouinia*, *Trichloris* and *Pappophorum*. Likewise, the improvement in perennial grass standing crop associated to native species may last for 4-5 years and reach an average of 3000-5000 kg dry matter/ha.

No significant differences were detected in intermediate perennial grass foliar cover (Fig. 4A) and density among treatments (Fig. 4B). This group of perennial grass species did not show a consistent response to a controlled burning and/or roller-chopping. Population distribution (as in the case of woody species) and the low intrinsic density of these perennial grass species (Fig. 4B), would be responsible that changes were not found. Our results are similar to those reported by Peláez et al. (2013) after controlled burns, conducted over a 20-year period, for a group of intermediate perennial grass species represented by *Poa lanuginosa*, *Pappostipa speciosa*, *Jarava plumosa* and *Nassella trichotoma*. We found no studies on the effect of the roller-chopping on the density of the intermediate perennial grass species.

Overall, the results of the present study suggest the controlled burning and/or chopper-rolling reduced the woody species cover, which improves access and availability of forage to grazing animals in the dense woody areas. The effect of roller-chopping, alone or in combination with a controlled burn, would keep the woody species cover low at least for four years. This period could be even greater in the case of a controlled burn. Our results also suggest that the reduction of the woody species cover might have favored the foliar cover and density of desirable perennial grass species. The use of the controlled fire and/or roller-chopping, with proper grazing management, may be the key factor to reduce woody species influence and improve grazing in the Monte region.

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