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Original Article

Mechanical recovery of a native forest with shrubs of the Espinal Ecoregion (Argentina)

Espinal Ekolojik Bölgesindeki bir ormanda mekanik müdahele ile çalılar üzerinde sağlanan iyileşme (Arjantin)

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ABSTRACT

The invasion of woody plants in various parts of the world has been a longstanding concern in livestock production due to the expected negative impact on secondary production. Native forests cover 30% of the earth's land surface. A great part of the livestock production of Entre Ríos is developed in these ecosystems, which have been highly degraded due to inadequate cattle management, and the invasion of shrub species. The aim of this study was to evaluate the natural pasture recovery in a degraded native forest, subjected to a mechanical intervention with a frontal roller-chopping, in order to increase the grazing area and improve secondary productivity. The study was carried out in Paraná Department (Entre Ríos, Argentina). On 15/12/2014 a mechanical intervention was carried out with a frontal roller-chopping designed by the Chair Ecology of Agricultural Systems. To evaluate the dynamics of the recovery of the natural grassland of the native forest, seven measurements were made on the following dates: 15/05, 12/06, 28/07, 11/09, 27/10 and 21/12/2015, and 22/02/2016. The vegetation cover was measured with the line intercept method and phytomass production. In each of the evaluations, forage species cover was higher in the mechanically intervened area, presenting significant differences with respect to the control and registering an average relative increase of 47% at the end of the trial. In the section where mechanical intervention had been made, the coverage of *Baccharis punctulata* showed a marked decrease during all the measurements with respect to the control, obtaining an average decrease of 91.8% at the end of the sampling. Mechanical intervention enables the cover of shrubs that compete with natural grassland in a degraded native forest to be reduced, while also recovering forage vegetable species and thus improving primary production, due to a raise in the forage availability because of increased grazing area.

Keywords: Roller-chopping, *Baccharis spp*., shrub control, shrublands, secondary productivity

ÖZ

Dünyanın çeşitli yerlerinde odunsu bitkilerin işgali, ikincil üretim üzerinde beklenen olumsuz etki nedeniyle canlı hayvan üretiminde uzun zamandır devam eden bir endişe kaynağı olmaktadır. Yerli ormanlar dünyanın toprak yüzeyinin %30'unu kaplamaktadır. Entre Ríos'un hayvancılık üretiminin büyük bir kısmı, yetersiz sığır yönetimine ve çalı türlerinin istilasına bağlı olarak büyük ölçüde bozulmuş olan bu ekosistemlerde geliştirilmiştir. Bu çalışmanın amacı, otlatma alanını arttırmak ve ikincil verimi artırmak amacıyla, önden silindirli doğrama ile mekanik müdahaleye maruz kalan, bozulmuş bir ormandaki doğal mera geri kazanımını değerlendirmektir. Çalışma Paraná Bölgesi'nde (Entre Ríos, Arjantin) gerçekleştirilmiştir. 15/12/2014 tarihinde, Ziraat Sistemleri Kürsüsü Ekolojisi tarafından tasarlanan bir önden silindirli doğrama makinesi ile mekanik bir müdahale gerçekleştirilmiştir. Doğal ormanın doğal otlaklarının toparlanma dinamiklerini değerlendirmek için, aşağıdaki tarihlerde yedi ölçüm yapılmıştır: 15/05, 12/06, 28/07, 11/09, 27/10 ve 21/12/2015 ve 22/02/2016. Bitki örtüsünün örtü hattı kesilme yöntemi ve fitoma üretimi ile ölçülmüştür. Değerlendirmelerin her birinde, yem türlerinin örtüleri mekanik olarak müdahale edilen alanda daha yüksek bulunmuş olup, kontrol açısından önemli farklılıklar göstermiştir. Deneme çalışması sonunda ortalama %47'lik bir nispi artış kaydedilmiştir. Mekanik müdahalenin yapıldığı bölgede, Baccharis punctulata'nın kapsamı, tüm ölçümler sırasında kontrol açısından belirgin bir düşüş göstermiştir ve örneklemenin sonunda %91,8'lik bir ortalama düşüş elde edilmiştir. Mekanik müdahale ile bozulmuş otlak alanlardaki doğal otlakla rekabet eden çalı örtüsü azaltılmış, aynı zamanda otları bitki türlerini geri kazanarak, otlatma alanlarındaki yem artışı nedeniyle birincil üretimi iyileştirmektedir.

Anahtar Kelimeler: Silindirli-doğrama, Baccharis spp., çalı kontrolü, fundalık, ikincil verimlilik

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INTRODUCTION

Grasslands, shrublands, and savannas, collectively termed 'rangelands', contribute to around 50% of the Earth's land surface (Bailey and Ropes 1998). These areas provide about 30-35% of net terrestrial primary productivity, they contain >30% of the world's human population, and support the majority of the world's livestock production (Safriel and Adeelm 2005, Reynolds et al. 2007). Furthermore, these biomes provide a variety of other ecosystem services, such as carbon sequestration, maintenance and conservation of genetic diversity, among others (Anadona et al. 2014).

The surface occupied by native forests represents 30% of Earth's land surface (FAO 2007). Recent studies by Hansen et al. (2013) quantified that the loss of native forests was 2.3 million km^2 over the period 2000-2012. In such a world context, South America suffered the greatest net forest loss estimated as 0.04 million km^2 (FAO 2007). Argentina is not excluded from this global phenomenon, having an estimated loss of two thirds of its forest patrimony due to agricultural expansion (Cozzo 1979, FAO 2009). In Entre Ríos, at the beginning of the 20th century, the surface occupied by native forests was 2.5 million hectares, and in 2008, in seven departments, Sabattini et al. (2015) determined it to be 1.56 million hectares.

These ecosystems, where a great part of the livestock production of Entre Ríos is developed, have been highly degraded due to inadequate cattle management. The invasion of shrub species because of sub-grazing, soil erosion, and the presence of bare soil by overgrazing has occurred in these ecosystems (Casermeiro et al. 2001, Sabattini et al. 2002). In certain parts of the world the invasion of woody plants has been a long-standing concern in livestock production due to the expected negative impact on secondary production (Scholes and Archer 1997), and control techniques in both private and public areas have been used (Anadona et al. 2014). At present, more than 70% of the Argentine territory has been invaded by woody and semi-woody species, which are characterized by having a great power of adaptation to the environment, as well as great persistence due to the selective effect exercised by animals in grazing. These weeds compete with species of the herbaceous stratum for light, water and nutrients, causing a rapid invasion within a pasture and preventing the management of livestock (Böker et al. 1989).

The invasion of herbaceous and shrub species which are not consumed by cattle in the province of Entre Rios has been verified with the presence of *Baccharis* spp. L., *Eupatorium* spp. L., *Aloysia gratissima* (Gillies and Hook.) Tronc. *Eryngium horridum* Malme, and *Melica macra* Nees. These plant communities cause areas for animal foraging to be restricted since they prevent access. This triggers a vicious circle that brings the development of weed species into that area (Sione et al. 2006). Sabattini et al. (2015) reported that 66.35% of the native forests of the Villaguay Department show a high degree of invasion of shrub species, as well as 50.28% in the Federal Department, 56% in La Paz Department and 18.7% in the Feliciano Department, the most important shrub species being *Baccharis punctulata* L., *Aloysia gratissima*, *Baccharis coridifolia* DC., *Eupatorium bunifolium* RMKing and H.Rob., *Trithrinax campestris* Drude and Griseb., *Baccharis notosergilla* L., *Senecio grisebachii* Baker, and *Opuntia ficus indicus* (L.) Mill. In addition, there are other herbaceous weed species that compete with natural grassland growth such as *Eryngium horridum* and *Melica macra*.

The frequency of closed native forests being overtaken by shrubs or semi-woody plants is considerably higher than in open native forest areas (Sabattini et al. 2015), and the incorporation of mechanical control and management techniques would enhance the secondary production of these environments. A great ecological advantage of these weeds is their great ability to regrow and reseed, thus invading the area easily. In this sense, research in these environments has demonstrated the effectiveness of these practices, revealing a greater coverage of palatable plant species and, thus a favorable trend of natural pasture quality and an increase of 15-20% in the grazing surface (Sabattini et al. 2002).

Techniques for the control of invasive shrub species are very diverse: mechanical (shredder for open field, bulldozers, chains, roller-chopping, chainsaws and line trimmer), biological (grazing of bovine, ovine, equine and caprine), physical (fire-fighting) and chemical (selective herbicides). Mechanical control causes an instantaneous reduction of the vegetal cover of shrubs with high efficiency but presents low efficiency in the months after the intervention due to the seasonal regrowth of vegetation.

In Argentina, roller-chopping is a type of mechanical control used to eliminate the shrub. The technique consists in the passage of a tractor that drags a roller-chopper above the shrub mass, causing the folding of the vegetation and its subsequent cutting. The principle of the operation is based on the kinetic energy of rotation that occurs when the roller is set in motion and, with the presence of blades, the cutting of young trees, shrubs and herbaceous vegetation is generated (Mora and Mercado 2014).

The aim of this work was to evaluate the natural pasture recovery in a degraded native forest, which had been subjected to a mechanical intervention with frontal roller-chopping, to increase the grazing area and improve secondary productivity of a livestock company.

MATERIALS AND METHODS

Work Area

The study was carried out in 'Establecimiento San Germán', located on Provincial Route No. 32, 3.5 km from Hasenkamp in the Paraná Department (Entre Ríos, Argentina). A section of land with native forest was selected, and a mechanical intervention with roller chopping was carried out on a sector of the same to assess the response of the natural pasture (Figure 1).

The study area has a mild humid plain climate (Plan Mapa de Suelos [Soil Mapping Plan], 1986). Mean annual rainfall during

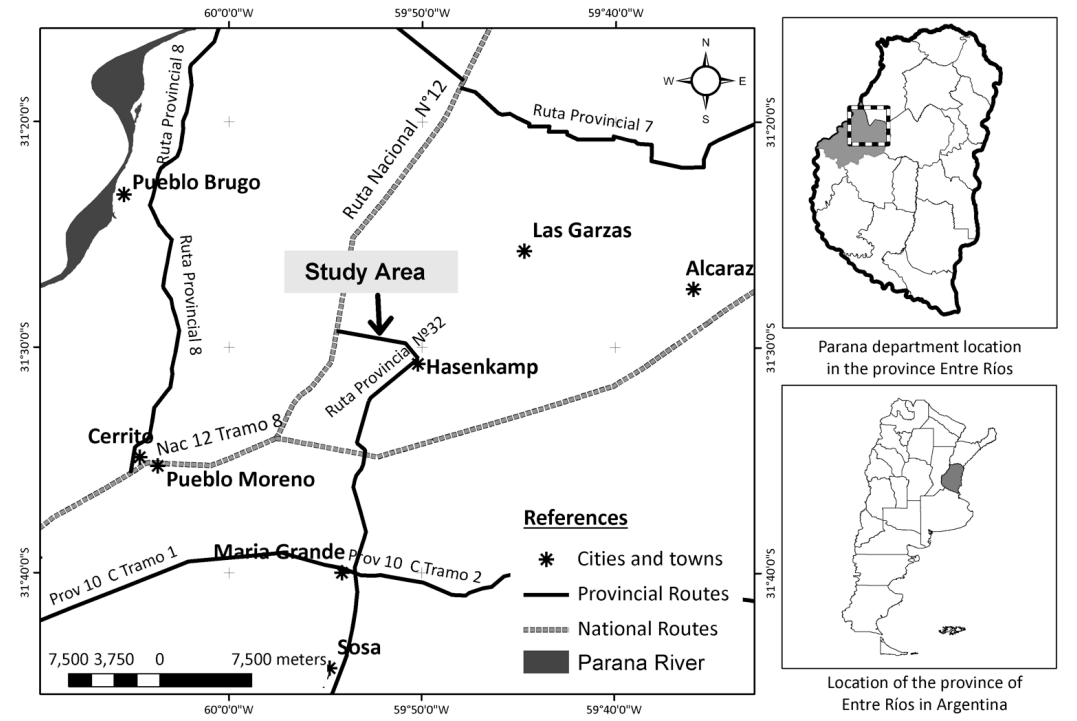

Figure 1. Location of study area

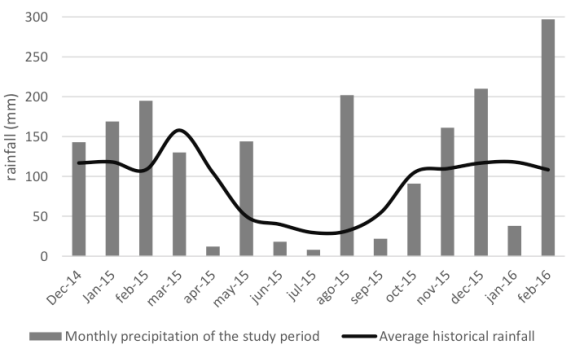

Figure 2. Monthly precipitation of the study period (records of the meteorological station to Bolsa de Cereales de Entre Ríos) and average historical rainfall for the 1934-2010 period (INTA Paraná)

the period of 1934-2010 was 1,025 mm, concentrated between the months October and April. By contrast, in the summer months a situation of water deficit in the soils of the region is expected (Rojas and Saluso 1987). In 2015 annual precipitation in the locality of Hasenkamp was 1586 mm, 54.7% higher than the annual average (Figure 2).

The soil corresponds to 'Las Avispas Consociation', formed by 'Las Avispas' (Peluderte argiacuólico) and 'El Pingo' (Ocracualfe vértico) series, located topographically on a very gently rolling peninsula with gentle slopes. Both soils present physical and chemical limitation of the subsurface horizon owing to their mineralogical composition (Plan Mapa de Suelos [Soil Mapping Plan] 1998).

The native forests represent the characteristics of the Ñandubay District of the Espinal Ecoregion, which extends from central-south of Corrientes Province and central-north of Entre Ríos Province, encompassing the Departments of La Paz, Federal, Feliciano, Villaguay, Tala and Paraná (Cabrera 1976, Brown and Pacheco 2006). The native forest has the characteristics of high and closed native forest (Sabattini et al. 1999, Sabattini 2015, Sabattini et al. 2015) due to the presence of shrubs such as *Baccharis* spp., *Eupatorium* spp. and *Aloysia gratissima*, as well as other non-forage herbaceous species such as *Melica macra*, *Eryngium horridum*, and numerous young individuals of *Vachelia caven*. This vegetation structure is typical of the Espinal Ecoregion in Argentina, characterized by the invasion of woody and semi-woody species that are adapted to the environment and that compete with the herbaceous species for light, water and nutrients because of bovine overgrazing. The livestock in natural ecosystems has intensified in the last 200 years. During this period, the livestock population rapidly increased exceeding the carrying capacity of natural pastures (Archer 1995). This process was characterized by an intense and continuous grazing that produced changes in the floristic composition of the natural pastures, including the increase in the abundance of undesirable woody species (Walker et al.1981, Cingolani et al. 2005).

Figure 3. Roller-chopping designed by the Chair Ecology of Agricultural Systems (FCA-UNER)

Mechanical Intervention and Sampling Design

On 15/12/2014 a mechanical intervention was carried out with frontal roller-chopping designed by the Chair Ecology of Agricultural Systems (INNOVAR, 2016), on a surface of 250 m^2. The implement developed is a hollow metal cylinder of 2.25 m in width by 0.98 m in diameter that weighs 1,900 kg without water inside and has 19 parallel cutting blades. The roller-chopper is coupled in front of a tractor by means of two hydraulic arms, and in this way, it crushes the plants allowing the tires to advance on clean ground. To attach the hydraulic arms, a 110 HP Massey Ferguson 292 RA double drive tractor was used (Figure 3). The implementation is done by pushing the tractor forwards or backwards in a linear way, supporting the roller-chopper on the ground surface. When changing the working direction, the roller-chopper is lifted with the hydraulic arms and is positioned in a new direction. In addition, it has a particular design in the hydraulic pistons because of irregularities of the ground, while in working position, the transverse movement of the roller-chopper should not be transmitted towards the tractor, thus avoiding possible risks of overturning.

To evaluate the dynamics of the recovery of the natural grassland of the native forest, seven measurements were made on the following dates: 15/05, 12/06, 28/07, 11/09, 27/10 and 21/12/2015, and 22/02/2016. These dates correspond to 151, 179, 225, 270, 316, 371 and 434 days after the mechanical intervention (DMI), respectively.

The line intercept method (Canfield 1941, Kent and Coker 1992) in which the transect line is thought of as a vertical plane that is perpendicular to the ground- was used and modified according to Sione et al. (2006) to quantify the percentage of vegetation cover considering the fraction of herbaceous forage species (monocotyledonous, dicotyledonous and palatable sedges), chaff (senescent plant material), bare soil (without vegetation, with exposed soil), other non-forage herbaceous species, *Baccharis punctulata*, *Aloysia gratissima*, and young individuals of *Vachellia caven*. For the measurements, ten transects of 10 meters length were used at random (five in the mechanical intervened sector and five in the control site). Each transect was divided into ten parts and the coverage of each fraction of both right and left sides was evaluated, obtaining a total of 60 records in the mechanical intervened sector and control site.

The phytomass production was assessed at random in the 10 replicates of each treatment (control and mechanical intervened) by cutting herbaceous forage species, at a height of 5 cm from the ground in an area of 0.25 m^2. The plants were weighed with a portable scale of one decimal precision and then oven drying was performed at 80°C for 48 hours. The dry matter was then weighed to estimate dry matter percentage (%DM) and biomass production in terms of kg DM.ha^{-1}. The availability of forage for bovine consumption was estimated based on the accessibility to the forage by the cover of the shrubs according to the following formula:

Availability forage= (kg DM.ha^{-1})	Phytomass production of herbaceous forage species x (kg DM.ha^{-1})	Accessibility to grazing (100 - % cover of the shrubs) (%)

A controlled and intensive grazing was carried out with breeding cows on 19/09/2015 and 13/01/2016 with high instantaneous animal load according to the forage supply. The lot typically had a rotary type grazing with low stocking in time, because the annual primary productivity of grassland was very low compared to pastoral systems in the region.

Data was then analyzed statistically and the normality of the information was analyzed using the Shapiro-Wilk test. Significant differences between control and mechanical intervention were determined using nonparametric analysis of variance was performed with the Kruskal-Wallis'test for vegetation cover and biomass using InfoStat® software version 2012 (Di Rienzo et al. 2012).

RESULTS

Forage species cover was higher in the mechanically intervened area in each of the evaluations, presenting significant differences (α=0.05) with respect to the control, registering an average of 47% at the end of the trial. The recorded chaff coverage was significantly lower in the native forest which had been mechanically intervened with respect to the control during the fall (15/05/15 and 12/06/15) and spring (27/10/15 and 21/12/15). In the winter-spring period the results were different, and the chaff coverage was significantly higher in the intervened area compared to the control in July and September ($p<0.0001$ and $p<0.0019$, respectively). Bare soil did not show significant differences (α=0.05) being up to 371 DMI. However, the last sampling performed in February 2016

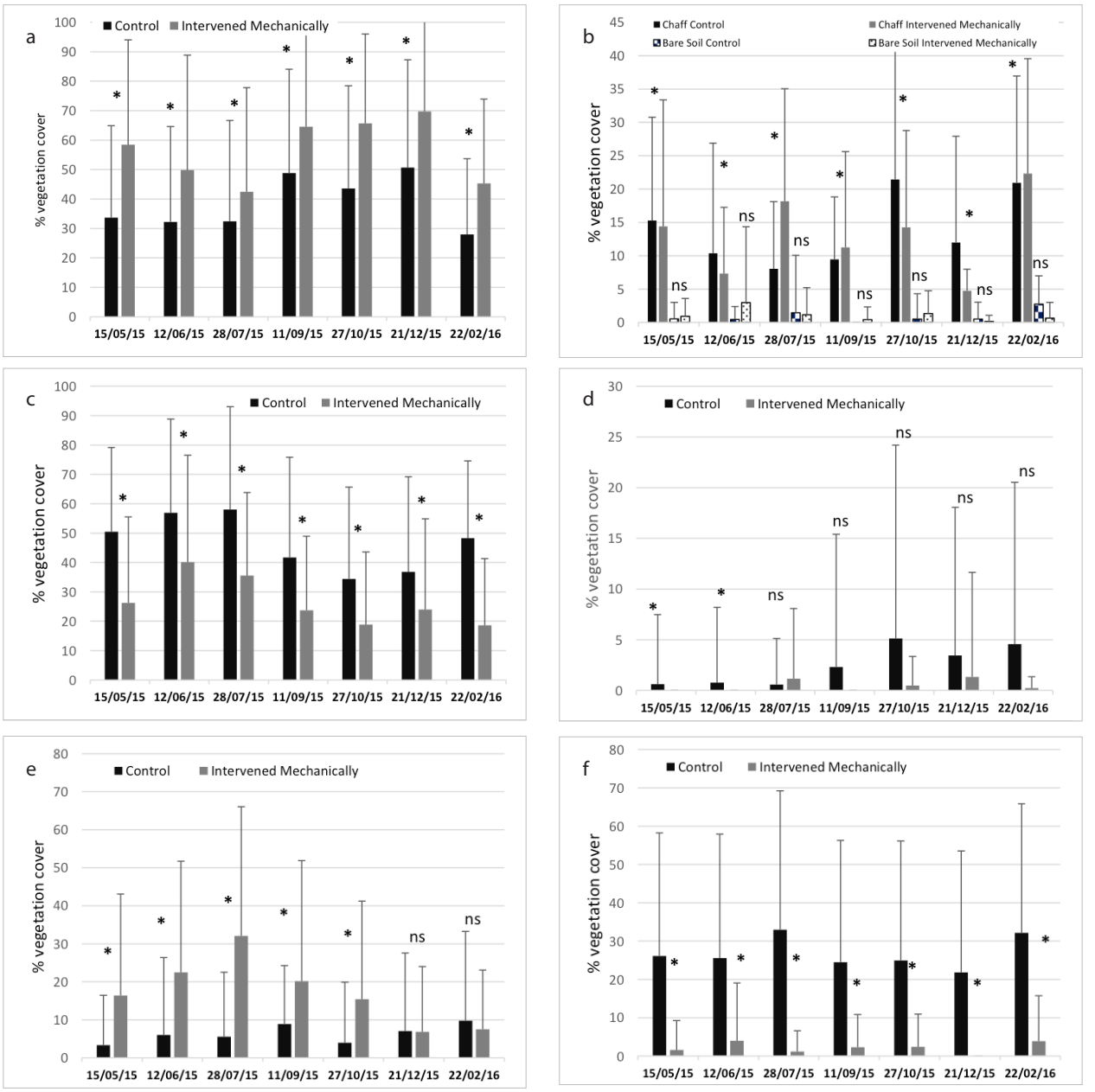

Figure 4. a-f. Dynamics of the coverage of fractions in control and mechanically intervened sectors: (a) herbaceous forage species, (b) chaff and bare soil, (c) other non-forage species, (d) young individuals of *V. caven*, (e) *A. gratissima*, (f) *B. punctulata*. Test Kruskal-Wallis, * means are significantly different (p>0.05) and ns- are not significant

showed significant differences in favor of the control because of adverse weather conditions (Figure 4).

Compared with the control, the coverage of *Baccharis punctulata* showed a marked decrease during all the measurements in the section which had been intervened mechanically, obtaining an average decrease of 91.8% at the end of the sampling. Moreover, *Aloysia gratissima* coverage increased significantly in the mechanically intervened area compared to the control until 15/10, whereas on 16/02/2016 no significant differences were found between the treatments. The average increase in the coverage of this section was 170% in the intervened sector with respect to the control. Juvenile individuals of *Vachellia caven* presented an average vegetation cover of less than 5%, and a significant decrease in coverage was observed on 15/05 and 12/06/15. Subsequently, no significant differences were observed between the mechanically intervened area and the control site.

The mechanically intervened native forest showed a significantly decreased coverage of the other non-forage herbaceous species for cattle, and on all the evaluation dates a decreased average of 42.6% was observed with respect to the control.

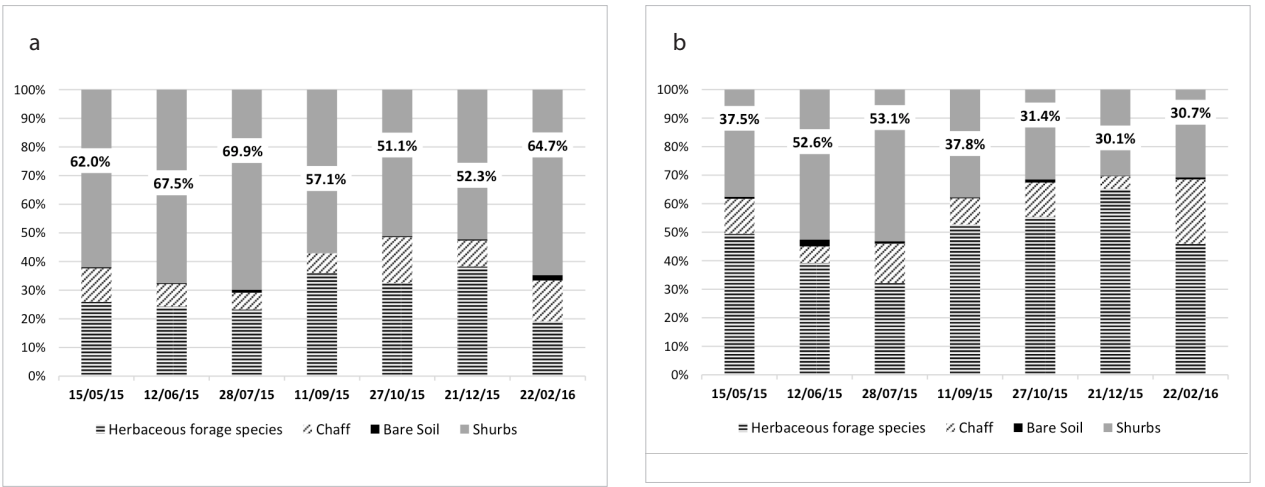

Figure 5. a, b. Relative coverage in the control area (a) intervened mechanically (b) sectors of the fractions: herbaceous forage species, chaff, bare soil and shrub (*Baccharis punctulata* + *Aloysia grattisima*)

Table 1. Values of phytomass production of herbaceous forage species values r (Kg DM.ha^{-1}), cattle accessibility to grazing (%) and forage availability (Kg DM.ha^{-1}) in the control area and section which had been intervened mechanically. Kruskal-Wallis test means between treatments with a common letter are not significantly different (p>0.05)

		Control			Intervened mechanically		
Date	DMI	Phytomass production of herbaceous forage kg DM.ha^{-1}	Accessibility to grazing %	Forage availability kg DM.ha^{-1}	Phytomass production of herbaceous forage kg DM.ha^{-1}	Accessibility to grazing %	Forage availability kg DM.ha^{-1}
15/05/2015	151	675.3±165.9^{a}	38.0	256.6±63.0^{a}	760.1±137.9^{a}	62.5	475.0±86.2^{b}
12/06/2015	179	667.4±152.2^{a}	32.5	216.9±49.5^{a}	781.6±239.4^{a}	46.4	362.7±111.1^{b}
28/07/2015	225	749.0±438.9^{a}	30.1	225.4±132.1^{a}	739.6±167.4^{a}	46.9	346.9±78.5^{b}
11/09/2015	270	1030.2±174.3^{a}	42.9	441.9±74.8^{a}	958.4±380.8^{a}	62.2	596.1±236.8^{b}
27/10/2015	316	405.2±185.2^{a}	48.9	198.1±90.6^{a}	448.0±176.7^{a}	68.6	307.3±121.2^{b}
21/12/2015	371	1838.8±548.3^{a}	47.7	877.1±261.5^{a}	1490.0±361.1^{b}	69.9	1041.5±252.4^{a}
22/02/2016	434	164.4±48.2^{a}	35.3	58±17.0^{a}	224.0±108.9^{a}	69.3	155.3±74.9^{b}

DMI: days after the mechanical intervention

Table 2. Evolution of the percentage of dry matter (% DM) in the mechanically intervened and control sectors. Kruskal-Wallis test, means with a common letter are not significantly different (p>0.05)

Date	DMI	Control	Intervened mechanically	H	p
15/05/2015	151	43.8±5.3^{a}	47.3±5.7^{a}	3.58	0.0585
12/06/2015	179	44.2±3.6^{a}	43.5±2.4^{a}	0.38	0.5379
28/07/2015	225	52.8±7.6^{a}	51.2±4.4^{a}	0.56	0.4545
11/09/2015	270	66.7±10.8^{a}	78.9±9.0^{b}	8.69	0.0032
27/10/2015	316	29.6±4.8^{a}	34.5±3.9^{b}	6.74	0.0094
21/12/2015	371	59.4±16.3^{a}	60.0±5.1^{a}	0.63	0.4284
22/02/2016	434	39.6±8.9^{a}	28.2±6.9^{b}	8.43	0.0037

DMI: days after the mechanical intervention

In general, there was an increase in herbaceous forage species coverage due to a significant reduction of shrubs in the intervened mechanically sector compared to the control in all evaluations (Figure 5a, b). These results would indicate an increase in forage accessibility, thus improving efficiency in grazing. Moreover, an increase in the percentage of chaff in the intervened mechanically sectors was observed due to senescent plant material generated after the intervention.

A greater phytomass production of herbaceous forage species was observed in the mechanically intervened sector compared with the control, but from a statistical point of view the differences are not significant except for the sampling taken on 12/21/2015 (Table 1). In terms of forage availability, significant differences were obtained on all the evaluated dates, except for 12/21/2015. Total forage availability increased to 89.6%, reaching 2200.6 kg DM.ha^{-1} in the mechanically intervened sector and 1160.6 kg MS.ha^{-1} in the control at 434 DMI.

DISCUSSION

The control of shrubs induces a secondary succession of the natural grassland, improving its ability to compete against weeds due to the cover and production of phytomass herbaceous forage. The mechanical intervention with frontal roller-chopping enables a high control of the aerial biomass of the shrubs in this type of native forest and little plant death. For this reason, it would not affect the biodiversity of the intervened systems. These initial results would indicate that the treatment is maintained over time, taking into account observations of other mechanical interventions carried out in the region since 2004 (Sabattini RA, personal communication).

Ecologically, mechanical intervention is an ecosystem disturbance that is applied for agronomic or forestry purposes. It is considered a discrete event given that it occurs in a period of time, is located in space, and modifies ecosystems, communities or populations because it changes the availability of resources and substrates, as well as the physical environment (Kunst et al. 2008). Anthropic disturbances are phenomena that alter the structure of ecosystems and the physical factors, lead to the change of one serial community for another (White and Pickett 1985), and whose magnitude depends directly on spatial size and its temporality (Chapin et al. 2002).

The response in herbaceous forage species coverage in the mechanically intervened sector compared to the control was similar to other research conducted in Argentina, where the researchers presented an increase of 66.8% and a decrease of 38% in shrub cover (Mora and Mercado 2014). This increase generates better conditions for the use of water and soil nutrients by forage species (Adema et al. 2004), caused by the increase in the average percentage of chaff (Figure 4). This condition would allow the soil to be covered with senescent plant material and the infiltration rate to be improved, reducing surface runoff and increasing the organic carbon content in the superficial horizon of soil by reactivating decomposition mechanisms (Adema et al. 2004, Martín et al. 2008). Studies carried out in La Pampa, Argentina, indicate that the total density of grasses in the rolled sectors was higher than in the control, and were directly affected by water stress conditions, indicating a significant loss of plants (Adema et al. 2004). Apart from this, in Entre Ríos, there was a similar response in the increase of natural pasture cover in the sector intervened with a mechanic cut using a motorbike and retouching with a machete (Cottani and Sabattini 2006, Sabattini et al. 2014).

The average coverage of shrubs in the control area of the native forest was higher than 60%, which would represent a high ratio of native shrubland-grassland, equivalent to 2.3: 1. These results provide assurance that the 'arbustization' process generates an imbalance in the natural proportion of shrubs and pastures, provoking a strong competition for ecological resources such as water at the soil surface as indicated by Kröpfl et al. (2002). Semi-woody species such as *Baccharis spp, Aloysia spp* and *Vachellia caven* capture an important solar interception with negative consequences for forage species for grazing. Therefore, their management is central not only to increasing the primary productivity of grasslands, but also to changing the botanical composition of the herbaceous community (Adema et al. 2004). Subsequent to the treatment, a high reduction of the percentage of shrubs was observed (Figure 3), improving the natural shrub-grassland ratio (0.9: 1).

The plant cover of *Baccharis* spp. was significantly reduced by mechanical intervention, being less than 5% in all evaluations. Nonetheless, *Aloysia gratissima* showed a steady increase until the middle of winter 2015, and thereafter it decreased towards the middle of summer 2016. This behavior is attributable to its ecological requirements, since it is a highly invasive species, and its frequency, vegetative cover and the size of the individuals are favored in conditions of high luminosity (Perreta and Vegetti 2004). Due to the reduction of the vegetation cover of *Baccharis punctulata* - a species whose height reaches 2.5 m - light is increased, representing a favorable environment conducive for the development of *Aloysia gratissima* (Burkart 1969). This behavior was observed in the northern region of Entre Ríos (Argentina) in a study of natural pasture recovery through chemical dewatering, where control of *Baccharis punctulata* favored the development of other non-forage species (Sabattini R, com. pers.). The size of *Aloysia gratissima* in an adult state is similar to a woody species, the stem / leaf ratio being very high. After growing, the regrowth is expressed with larger leaf architecture, more coriaceous and with a lower stalk / leaf ratio. These changes cause the shrub to occupy more space in the plant community, exerting greater competitive effect in the natural grassland.

It is important to mention that these shrub species have a very high resilience capacity depending on different environments (Kimmins 2003), allowing them to adapt to periodic disturbance events, regenerating asexually through basal regrowths or seeds (Morello et al. 2012). Several studies on the mechanical control of the shrub stratum argue that, given the rapid recovery of these weeds, another deforestation must be considered whose frequency will depend on the type of invasive species, ecological conditions and livestock management. In this regard, Brassiolo et al. (2008) concluded that, in order to maintain the productivity of the semi-arid Chaco pasture, it is necessary to carry out a cycle of deforestation every five years. Marchesini (2003), on the other hand, emphasizes that the mechanical control of *Baccharis punctulata* is immediate, and that treatment repetition must be performed before the year as these weeds rapidly re-grow using their reserves.

Other non-forage herbaceous species decreased their coverage significantly by mechanical intervention (Figure 4), with an emerging outbreak of *Melica macra, Eryngium horridum, Sida rhombifolia, Senecio grisebachi* and *Baccharis ulicina*. Similar studies have demonstrated the impact of *Melica macra* on the biomass and cover of this weed by frequent cuts (Rupp 1994). However, by reducing *Eryngium horridum* plant cover using a combination of mechanical cutting and the application of specific herbicides it might be possible to improve the natural

grassland, but logistically and economically it would not be a feasible option for livestock production (Lallana et al. 2004).

The reduction of the competition of the shrub species did not result in an increase in the production of vegetal biomass in the sector which had been intervened mechanically with respect to the control, but in terms of forage availability the reduction in shrub cover would allow greater accessibility for cattle to graze (Figure 5). These results were similar to those obtained in other regions of Argentina by Adema et al. (2004) and Mora and Mercado (2014), as well as in the northern center of Entre Ríos (Cottani and Sabattini 2006, Sabattini and Sabattini 2012).

The percentage of dry matter in both sectors did not show a significant variation until the 225 DDR; in contrast a linear increase of the DM% was observed until the 270 DMI, due to the closure to the bovine grazing until 19/09/2015. Subsequently, a significant increase of 34.5% DM in the rolling area compared to 29.6% DM in the control (Table 2) was recorded on 10/27/2015 attributable to changes in the plant cycle due to grazing, which causes a rejuvenation of the plant tissues.

CONCLUSION

Mechanical intervention permits the reduction of the cover of shrubs that compete with the natural grassland in a degraded native forest, and this recovers forage vegetable species, which in turn improves primary production due to an increase in the forage availability of the grazing area. This is directly translated into the secondary productivity of a livestock agroecosystem. These studies should be continued in other productive cycles from an ecological approach and as agronomic studies in order to check if mechanical intervention persists over time.

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