Effects of Ovine Grazing as a Estrategy for the Control of Privet (*Ligustrum lucidum* W.T. Aiton)

Vique, L. [1]; Blumetto, O. [2]

[1]*Universidad de la Empresa, Facultad de Ciencias Agrarias, Montevideo, Uruguay* ROR

[2]*Instituto Nacional de Investigación Agropecuaria (INIA), Canelones, Uruguay* ROR

Abstract

Invasive species have spread, overcoming dispersion and adaptation barriers. These invasions affect ecological functions and economic activity, especially in areas close to urban centers. In Uruguay, species such as *Ligustrum lucidum* (privet) threaten native forests, highlighting the need for research and collaboration for their control. Directed grazing is suggested as a potentially effective tool to control invasive species. To evaluate the effectivity of livestock grazing as a strategy for privet control, a study was conducted at Las Brujas Experimental Station of the National Institute of Agricultural Research (INIA) in Canelones, Uruguay. Six plots of 0.04 hectares each were established in an area invaded by privet, divided into two blocks with different tree coverages. Using a completely randomized block design, the effects of sheep grazing on privet control were evaluated. Variables such as plants number, height, number of leaves, presence of apical bud and cut buds were recorded before and after the grazing period. At the end of the experiment, grazing reduced the total number of plants and apical buds, especially in plants less than 25 cm tall. Sheep grazing emerges as a promising alternative for privet control by reducing chemical use and costs. However, a single grazing period is not enough to drastically reduce the privet seedlings population. Further research is needed to examine the effects of higher stocking rates or different breeds and to assess the long-term impacts of sustained grazing on the same area.

Keywords: invasive exotic species, restoration, sheep grazing, native forest

Efectos del pastoreo ovino como estrategia para el control de ligustro (*Ligustrum lucidum* W.T. Aiton)

Resumen

Las especies invasoras se han propagado, superando las barreras de dispersión y adaptación. Estas invasiones afectan las funciones ecológicas y la actividad económica. En Uruguay, especies como *Ligustrum lucidum* (ligustro) amenazan los bosques nativos, lo que subraya la necesidad de investigación y colaboración para su control. El pastoreo dirigido es una herramienta potencialmente eficaz para controlar las especies invasoras. Para evaluar la efectividad del pastoreo de ganado en el control del ligustro, se realizó un estudio en la Estación Experimental Las Brujas del Instituto Nacional de Investigación Agropecuaria (INIA), en Canelones, Uruguay. Se establecieron seis parcelas de 0,04 hectáreas cada una en un área invadida por ligustro, divididas en dos bloques con diferente cobertura arbórea. Mediante un diseño de bloques completamente aleatorizado, se evaluaron los efectos del pastoreo de ovejas en el control del ligustro. Se registró: número de plantas, altura, número de hojas, presencia de yemas apicales y yemas cortadas antes y después del pastoreo. Al finalizar el experimento, el pastoreo redujo el número total de plantas y yemas apicales, especialmente en plantas de menos de 25 cm de altura. El pastoreo de ovejas se presenta como una alternativa prometedora para el control del ligustro, al reducir el uso de productos químicos y los costos. Sin embargo, un solo período de pastoreo no es suficiente para reducir drásticamente la población de plántulas de ligustro. Se requiere investigación adicional para estudiar los efectos de mayores densidades de animales o diferentes razas y los impactos a largo plazo del pastoreo sostenido en la misma área.

Palabras clave: especies exóticas invasoras, restauración, pastoreo ovino, bosque nativo

Efeitos do pastoreio ovino como estratégia de controle de ligustro (*Ligustrum lucidum* W.T. Aiton)

Resumo

Espécies invasoras se espalharam, superando barreiras de dispersão e adaptação. Essas invasões afetam funções ecológicas e a atividade econômica. No Uruguai, espécies como Ligustrum lucidum (alfeneiro) ameaçam florestas nativas, destacando a necessidade de pesquisa e colaboração para seu controle. O pastejo direcionado é uma ferramenta potencialmente eficaz para o controle de espécies invasoras. Para avaliar a eficácia do pastejo de ovinos no controle do alfeneiro, um estudo foi conduzido na Estação Experimental Las Brujas do Instituto Nacional de Investigación Agropecuaria (INIA) em Canelones, Uruguai. Seis parcelas de 0,04 hectares cada foram estabelecidas em uma área invadida por alfeneiro, divididas em dois blocos com diferentes coberturas arbóreas. Utilizando um delineamento em blocos casualizados, os efeitos do pastejo de ovinos no controle do alfeneiro foram avaliados. Os seguintes parâmetros foram registrados antes e depois do pastejo: número de plantas, altura, número de folhas, presença de gemas apicais e gemas cortadas. Ao final do experimento, o pastoreio reduziu o número total de plantas e gemas apicais, especialmente em plantas com menos de 25 cm de altura. O pastoreio de ovelhas parece ser uma alternativa promissora para o controle da ligustrina, pois reduz o uso de produtos químicos e diminui os custos. No entanto, um único período de pastoreio não é suficiente para reduzir drasticamente a população de mudas de ligustrina. Mais pesquisas são necessárias para estudar os efeitos de densidades animais maiores ou de diferentes raças, bem como os impactos a longo prazo do pastoreio contínuo na mesma área.

Palavras-chave: espécies exóticas invasoras, restauração, pastoreio de ovinos, mata nativa

1. Introduction

Biological invasions, understood as the arrival, colonization and expansion of species beyond their natural biological ranges due to human action, are considered one of the main components of global ecosystem change. The transportation of people and goods is the main vector of dispersion of these species, which can be

transported outside their native distribution ranges voluntarily or accidentally (Vilá et al., 2008). To become invasive, species must overcome barriers such as transportation, adaptation to new conditions and expansion into the new territory. According to Williamson and Fitter (1996), only 10% of species overcome those barriers. The success of exotic invasive species over native ones is due, in part, to the absence of natural enemies or disease, which facilitates their rapid growth and establishment in the ecosystem (Correia et al., 2016; Sala et al., 2000; Shigesada & Kawasaki, 1997; Vilá et al., 2008; Williamson & Fitter, 1996). Biological invasions, unlike other environmental problems, worsen over time and hinder the natural recovery of the affected ecosystems (Aslan et al., 2012; Lowe et al., 2004; Martino, 2006; Montaldo, 2000; Nebel & Porcile, 2006; Westbrooks, 1998).

Several invasive species have high reproductive potential that allows them to rapidly invade the local community, with profuse reproduction by seeds or vegetative structures, wide range of pollinators, seed production under adverse conditions, seed dormancy and dispersal adaptations that increase their reproductive success (Cronk & Fuller, 2001; Godoy et al., 2008; Medina & Rachid, 2004). Many invasive alien species have characteristics that make them difficult to control, such as long-lasting seeds, high production and early reproductive maturity. Furthermore, they spread efficiently through various vectors and with the help of specific structures. These capabilities allow them to disperse over long and short distances, colonizing new sites and increasing the existing population (Cronk & Fuller, 1995; Fernández et al., 2014). They can often develop protective mechanisms against herbivores, such as toxins and defensive structures, and sometimes show tolerance to extreme environmental conditions and disruptive events such as fire and herbicides (Bryson & Carter, 2004; Mack et al., 2000; Shea & Chesson, 2002). Disturbances (wood harvesting, fire, tillage, etc.) make available new niches that can be exploited by these species (Banchero-Ferrari, 2013; Huston et al., 2000; Medina & Rachid, 2004; Sher & Hyatt, 1999).

The invasion of exotic species is a complex process that varies considerably depending on the plant's biological characteristics. While herbaceous and annual species often colonize new habitats quickly, their response to disturbances like grazing or mechanical control tends to be less resilient. In contrast, woody or perennial species, such as privet (*Ligustrum lucidum*) and blackberry (*Rubus constrictus*), have more robust survival and resprouting strategies (Aranda, 2014). These species invest in energy storage structures and deep root systems, which allows them to resist or recover from defoliation and other forms of stress. Therefore, developing effective control strategies for these species requires a specific approach that considers their capacity for resprouting and their long-life cycle, unlike the methods used for more ephemeral species (Padovani, 2015).

In Uruguay, invasive alien species such as *Ligustrum lucidum* and *Gleditsia triacanthos* represent a serious problem for native forests, becoming perhaps the greatest threat to these ecosystems (Olivera & Riaño, 2022). Despite the lack of monitoring and scientific knowledge at the national level, priorities for a strategic action plan on invasive species were identified by the National System of Protected Areas (Aber et al., 2012). In this context, the importance of research and collaboration between institutions to comprehensively address this problem is highlighted (Nebel & Porcile, 2006). It is also essential to prioritize the study of species such as *Ligustrum lucidum* and *Ligustrum sinense*, categorized as dangerous species that require integrated control at the national level (Banchero-Ferrari, 2013). The *Ligustrum* genus is considered highly invasive in the region's forests. These species are native to Asia, produce a large number of viable seeds and are dispersed mainly by birds and water runoff. Their rapid spread in riparian forests has made privet one of the most aggressive invasive species in the native forest.

In many regions, environmental deterioration due to the invasion of exotic species is extreme (Brazeiro et al., 2024) and it is necessary to implement restoration processes, with the control of exotic species being the first step.

Several academic studies have focused on identifying effective techniques to control invasive exotic plants with minimal impact on the native ecosystem. The use of herbicides, although common, is controversial due to its

risks and costs. Mechanical treatments, such as logging, have shown mixed results, being considered to have a lower impact (Valfré-Giorello et al., 2019). In studies carried out in Argentina and Uruguay, different mechanical and chemical control methods were evaluated, highlighting the effectiveness of logging with the application of polyethylene to reduce survival of plants such as *Ligustrum lucidum* (Blumetto et al., 2007; Delgado, 2010; Valfré-Giorello et al., 2019).

Privet control is difficult due to its rapid growth, its ability to regenerate from shoots and roots, its abundant production of easily dispersed seeds, its tolerance to diverse conditions, and the creation of dense stands of vegetation that displace native species, impacting biodiversity.

Grazing is an important shaper of ecosystem structure and functioning (McNaughton & Sabuni, 1988). In the Río de la Plata grasslands region, diverse responses of plant species to grazing have been observed, with variable effects on vegetation composition. The use of cattle for grazing can delay the growth of invasive plants, such as privet, suggesting that grazing could be an effective long-term control tool (de Santiago et al., 2019).

Grazing with small domestic ruminants to target the problematic plant species has been applied in what is commonly called "directed grazing" (Havstad, 1994). Sheep grazing has been used as a tool to effectively attack weeds such as *Centaurea stoebe* L. (Mosley et al., 2016); thistle species (Holst & Allan, 1996) and *Oxytropis sericea* Nutt (Goodman et al., 2014); shrubs such as *Flourensia cernua* DC (Estell et al., 2016), and grasses such as *Bromus tectorum* L. (Mosley, 1996). However, there are not many references of its use for the control of tree species.

The present work evaluates the effect of sheep grazing as a tool for the control of privet (*Ligustrum lucidum*), which is invading park forest environments. The main research question was: how much sheep grazing impacts the number of privet seedlings? And complimentary, how does it affect the integrity of the plants, considering defoliation, bud loss, and reduction in plant size?

2. Materials and Methods

The field study was conducted at Las Brujas Experimental Station of the National Institute of Agricultural Research (INIA), Las Brujas (34°39'18.29" S and 56°20'12.57" W), southwest of the Department of Canelones, Uruguay.

The predominant environment in this region is the park forest, a community containing a variable density of isolated trees dispersed in a grassland matrix.

The experiment lasted for a 3-month period, starting in November 2022. An area of approximately 0.24 hectares was selected within the park forest invaded by privet, divided into 6 plots of 0.04 hectares each. These plots were grouped into two blocks, one with a woody cover close to 60% and the other with 40% woody cover, with the rest occupied by herbaceous vegetation. A completely randomized block experimental design was used, where the plots were delimited with a 1.2 m high mesh and 3 sampling points were established within each one. Each sampling point consisted of two contiguous microplots of 1 m^2, one exposed to grazing and the other as a control area without grazing. The control microplots had a metal mesh cage as protection to exclude grazing (Figure 1).

To carry out the experiment, a flock of 24 Milchschaf Friesian breeding sheep was used. These sheep were individually identified and randomly assigned to the plots. The treatment consisted of assigning the same stocking rate of 4 sheep to each plot. The measurement focused on the state of the aerial organs and the survival of privet plants in their juvenile stages.

At each sampling point (1 m² microplot), the total number of plants was recorded, as well as their height, number of leaves, presence of apical bud, other buds and those that had been cut (evidence of apical or secondary buds removed by grazing). These measurements were made at two times: before the animals entered the plots and when they left. In addition, a classification of the plants was made according to their height, dividing them into small plants (height less than 25 cm) and large plants (height greater than 25 cm).
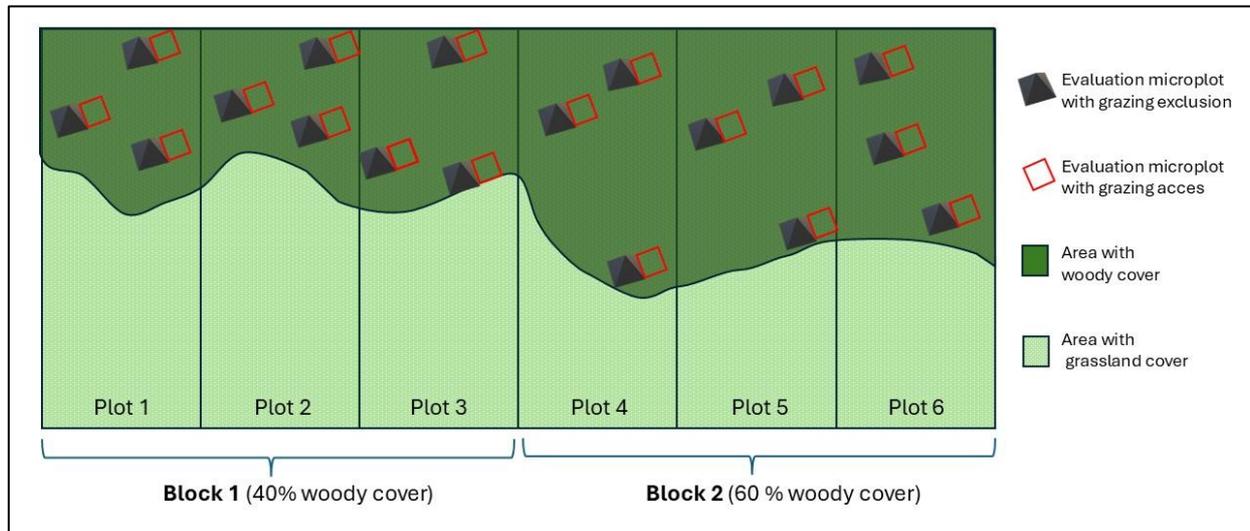

Figure 1. Graphical representation of the experiment design with location of sampling microplots

Forage availability in each plot was estimated using the double sampling method for grassland evaluation (Haydock and Shaw, 1975). For this purpose, 3 cuts of the herbaceous stratum were made per plot (0.50 × 0.50 m quadrants) and the height was measured at 20 different points. The collected forage samples were weighed to obtain the fresh weight and then dried in a forced air oven at 60 °C for 48 hours to determine the dry weight. A similar procedure was carried out with samples of juvenile privet.

For the statistical analysis, the statistical program R version 3.6.3 (R Core Team, 2020) and the ggplot2 package version 3.3.2 (Wickham et al., 2016) were used. Ex ante homogeneity tests between controls and treated were performed using paired t tests.

Initial analyzes of plant characteristics were performed before treatment application, considering variables such as total number of plants, height, number of leaves, and presence of apical buds and other buds. Subsequently, the effect of sheep grazing on privet seedlings was evaluated, examining the presence of significant differences between the microplots before and after treatment.

For data analysis, a mixed linear model approach was used to account for the structure of the completely randomized block design. In this model, the blocks were incorporated as a random effect to control for the inherent environmental heterogeneity among them, which allows for a more precise inference about the effect of grazing. Pre- and post-treatment comparisons were performed using an analysis of variance, evaluating the interaction between the time factor and the treatment.

Additionally, recognizing that count variables like the number of shoots do not typically follow a normal distribution, generalized mixed linear models with an appropriate error distribution for this type of data were used, such as the Poisson or negative binomial distribution, which are more suitable for count variables. This methodological choice allowed us to analyze the effect of grazing on the number of shoots in a statistically rigorous way, without violating the assumptions of normality.

3. Results

Initial analyses showed no significant differences in the variables measured between the microplots that would be exposed to grazing and those that would serve as a control, with the exception of the number of cut buds before the animals entered the plots. This initial homogeneity ensured that any differences observed at the end of the experiment could be attributed to the effect of sheep grazing.

To evaluate the effectiveness of grazing in controlling privet, the effect of grazing on the plant population was examined. At the end of the experiment, a significant reduction was observed in the number of privet plants in the grazed microplots compared to the control plots. The presence of grazing reduced the total number of plants and the number of apical buds.

Plant defoliation was evident, as the number of leaves was reduced in both plant categories (less than and greater than 25 cm), with a more pronounced effect on larger plants. Additionally, the number of apical buds was reduced, with the most relevant reduction (24%) occurring in seedlings less than 25 cm tall.

To evaluate the impact of grazing on animal health, the evolution of live weight was analyzed. A significant weight loss was observed in the sheep throughout the experiment. The weight loss was more pronounced in the block with greater forest cover (18%) than in the block with more pasture (11%). Despite this weight loss, the general health of the flock remained stable.

The high nutritional demands of the Milchschaf breed used, combined with its selectivity, likely influenced the results. The weight loss indicates a low preference for privet, as there was still biomass available at the end of the experiment.

Results of the initial analysis comparing the microplots designated for grazing versus the control plots are shown in Table 1. The data, collected prior to the animals' introduction, revealed no significant differences in any of the measured variables, with the exception of the number of secondary buds that had been pruned.

Table 1. Initial homogeneity between grazing and control plots before the start of the experiment

Variable	Would be exposed to grazing	Would be excluded from grazing	Difference	p-value
Number of plants	736.44 (464.93)	656.89 (374.47)	79.56	0.13501
Average height	15.75 (9.67)	15.23 (9.41)	0.52	0.65632
Number of leaves per plant	9.81 (8.09)	9.01 (6.75)	0.8	0.26528
Apical bud presence (%)	53.05 (23.61)	56.42 (22.88)	-3.37	0.26840
Number of other buds	1.66 (2.5)	1.31 (1.85)	0.35	0.11458
Number of cut buds	1.09 (1.69)	0.85 (1.33)	0.24 *	0.01866

Note. ***: p-value < 0.001, **: p-value < 0.01, *: p-value < 0.05, ".": p-value < 0.1 (x)=DE

Table 2 shows the results of the post-experiment statistical analysis, comparing variables between the grazed and control plots. A significant difference was observed for the total number of plants, mean plant height, number of leaves, presence of apical buds, and number of pruned buds. Additionally, Table 3 illustrates the initial and final states of the variables within the treatment groups, specifically highlighting the change in the total number of plants by block.

Table 2. Statistical comparison of measured variables between grazed and control plots at the end of the experiment

Variable	Would be exposed to grazing	Would be excluded from grazing	Difference	p-value
Number of plants	375.1 (285.9)	545.3 (327.8)	-170.2 **	0.00384
Average height	19.9 (13.2)	16.2 (9.6)	3.7 *	0.02544
Number of leaves per plant	4.5 (2.3)	7.8 (5.8)	-3.2 **	0.00332
Apical bud presence (%)	28.8 (21.0)	51.0 (18.7)	-22.3 ***	0.00000
Number of other buds	0.2 (0.5)	0.6 (1.1)	-0.4	0.10039
Number of cut buds	1.9 (2.4)	0.8 (1.0)	1.2 **	0.00461

Note. ***: p-value < 0.001, **: p-value < 0.01, *: p-value < 0.05, ".": p-value < 0.1 (x)=DE

Table 3. Analysis of plant variables by height category: pre-grazing vs. post-grazing comparison

Variable	Differences between plants < 25 cm	Significance	Differences between plants > 25 cm	Significance
Number of plants	-174	**	3.78	
Average height	0.23		0.99	
Number of leaves per plant	-2.01	**	-12.97	***
Apical bud presence (%)	-24.2	***	-6.21	*
Number of other buds	-0.03		-1.36	*
Number of cut buds	0.72	**	1.16	**

Note. ***: p-value < 0.001, **: p-value < 0.01, *: p-value < 0.05, ".": p-value < 0.1

4. Discussion

The absence of significant differences between the main variables measured at the beginning of the experiment reflects a similar starting point for all plots. After the grazing period, the number of plants was reduced and so was the number of apical buds, which shows that there was an effect of sheep grazing. However, if the two differentiated plant strata are considered, the reduction in the number of plants occurs in those of shorter height (less than 25 cm). This implies a difference with that reported by de Santiago et al. (2019), who found no differences in the total number of plants with cattle grazing. However, the magnitude of the decrease is low in accordance with the expectation that it would produce significant reductions in privet seedling populations, according to previous exploratory experiences (Blumetto, 2024). This difference could be attributed to an effect of the sheep breed, since, in this case, animals of the Milchschaf breed were used and in the aforementioned antecedent, Creole sheep were used. The high nutritional demand of dairy breeds such as the Milchschaf (Pulina & Bencini, 2004) and their selectivity may have influenced the results. This clearly affected the animals, as they lost weight when there was still plant biomass available at the end of the experiment. Although the herd was in good health, the animals showed weight loss after experiment period; animals in the block with higher woody cover had a significantly greater drop in liveweight. Based in the breed characteristics, a low preference of sheep for grazing privet and reduction in overall forage consumption is probable.

The observed increase in the average height of plants at an aggregate level in such a short period is consistent with the reduction in the number of shorter plants, which determines that the overall average height increased.

Defoliation of plants could also be confirmed with a reduction in the number of leaves in both categories of plants, being similar in terms of proportion, but the effect is greater in absolute terms in plants over 25 cm tall. In the case of apical buds, the average number is reduced, but the most relevant reduction (24%) occurs in seedlings less than 25 cm tall. Regarding seedling control, defoliation and bud cutting do not ensure a reduction

in the number of plants in the short term, but they do ensure slow growth and eventually cause a reduction in the long term.

Compared to other privet control methods, such as chemical or mechanical, sheep grazing is presented as a promising alternative due to its effectiveness and sustainability. On the one hand, it reduces the use of chemical products and their undesirable environmental effects, and reduces costs; on the other hand, mechanical control is almost impossible in this type of ecosystem or must be carried out manually, which limits the scale of work. Clearly, the analysis of the effect of different breeds or biotypes can be relevant. The combination of cattle and sheep under grazing could be a more effective strategy for the control of invasive species. It is vital to consider factors such as stocking rate and environmental conditions in future studies to achieve effective control of invasive plants in a sustainable and efficient manner.

5. Conclusions

The results of this study confirm that sheep grazing is an effective strategy for controlling the invasive woody species *Ligustrum lucidum*. The use of sheep demonstrated a significant reduction in the number of privet plants, as well as their leaf biomass and bud count, which highlights the potential of this tool for managing the invasion.

However, our findings also indicate that the effectiveness of this strategy may be limited by plant size. The sheep showed a greater preference for smaller plants, suggesting that grazing is more suitable for controlling the establishment of new seedlings or managing young populations. For a comprehensive control of the invasion, especially in areas with mature or large plants, sheep grazing might be more effective when used as part of an integrated management approach, in combination with other techniques.

Acknowledgements

Transparency of Data

Data not available: The data set that supports the results of this study is not publicly available.

Author Contribution Statement

	L Vique	O Blumetto
Conceptualization		�
Investigation	▪	
Methodology		▪
Writing – original draft	▪	
Writing – review and editing	▪	▪

References

Aber, A., Ferrari, G., Porcile, J., Rodríguez, E., & Zerbino, S. (Eds.). (2012). *Identificación de prioridades para la gestión nacional de las especies exóticas invasoras*. UNESCO.

Aranda, M. J. (2014). *El papel de la competencia y los disturbios agropecuarios en el establecimiento y crecimiento de una especie leñosa invasora* [Doctoral dissertation, Universidad de Buenos Aires]. http://ri.agro.uba.ar/files/download/tesis/doctorado/2021arandamelinajeanette.pdf

Aslan, C. E., Rejmánek, M., & Klinger, R. (2012). Combining efficient methods to detect spread of woody invaders in urban-rural matrix landscapes: An exploration using two species of Oleaceae. *Journal of Applied Ecology*, *49*(2), 331-338. http://www.jstor.org/stable/41433356

Banchero-Ferrari, R. (2013). *Invasión de especies vegetales exóticas y restauración del monte nativo de barrancas de Melilla: Humedales de Santa Lucía* [Master's thesis]. Universidad de la República.

Blumetto, O. (2024). Manejo de invasiones de especies exóticas en procesos de restauración de Monte Parque en la región sur de Uruguay: Management of exotic species invasions in Monte Parque restoration processes in the southern region of Uruguay. *Brazilian Journal of Animal and Environmental Research*, *7*(1), 764-769. https://doi.org/10.34188/bjaerv7n1-059

Blumetto, O., La Cava, C., & Piñeyro, E. (2007). Control de especies arbóreas exóticas invasoras: Evaluación de diferentes métodos químicos. In *5° Encuentro de Ecoturismo y Turismo Rural y IV Congreso Nacional de Áreas Naturales Protegidas* (p. 35). http://www.seaturtle.org/library/Anon_2007_5EncuentroNacionaldeEcoturismoandTu.pdf

Brazeiro, A., Olivera, J., Betancourt, A., Lado, I., Romero, D., Haretche, F., & Cravino, A. (2024). Disentangling the invasion process of subtropical native forests of Uruguay by the exotic tree Ligustrum lucidum: Establishment and dominance determinants. *Ecological Processes*, *13*, Article 49. https://doi.org/10.1186/s13717-024-00512-w

Bryson, C. T., & Carter, R. (2004). Biology of pathways for invasive weeds. *Weed Technology*, *18*, 1216-1220. http://www.jstor.org/stable/3989621

Correia, M., Montesinos, D., French, K., & Rodríguez-Echeverría, S. (2016). Evidence for enemy release and increased seed production and size for two invasive Australian acacias. *Journal of Ecology*, *104*(5), 1391-1399. https://doi.org/10.1111/1365-2745.12612

Cronk, Q. C. B., & Fuller, J. L. (1995). *Plant invaders: The threat to natural ecosystems*. Chapman & Hall.

Cronk, Q. C. B., & Fuller, J. L. (2001). *Plantas invasoras: La amenaza para los ecosistemas naturales*. Nordan-Comunidad.

Delgado, S. (2010). Manejo responsable del bosque nativo del Santa Lucía Chico. In *Conservación y uso sostenible de la biodiversidad* (pp. 29-30). MGAP. http://www.guayubira.org.uy/monte/bibliografia/PPR-Seminario-Biodiversidad.pdf

de Santiago, M. F., Bresciano, R. D., Castagna, A., Del Pino, L., & Blumetto, O. (2019). Evaluación del efecto del pastoreo con bovinos como herramienta de control de ligustro (Ligustrum lucidum) en bosque parque. *Ecosistemas*, *28*(2), 109-115. https://doi.org/10.7818/ECOS.1673

Estell, R. E., Anderson, D. M., & James, D. K. (2016). Defoliation of Flourensia cernua (tarbush) with high-density mixed-species stocking. *Journal of Arid Environments*, *130*, 62-67. https://doi.org/10.1016/j.jaridenv.2016.03.013

Fernández, O. A., Leguizamón, E. S., & Acciaresi, H. A. (2014). *Malezas e invasoras de la Argentina: Vol. 1. Ecología y manejo*. Editorial UNS.

Godoy, O., Valladares, F., Castro, P., & Costa, M. (2008). Características de las plantas invasoras. In M. Vilà, F. Valladares, A. Traveset, L. Santamaría, & P. Castro (Eds.). *Invasiones biológicas* (pp. 53-64). CSIC.

Goodman, L. E., Cibils, A. F., Lopez, S. C., Steiner, R. L., Graham, J. D., McDaniel, K. C., Abbott, L. B., Stegelmeier, B. L., & Hallford, D. M. (2014). Targeted grazing of white locoweed: Short-term effects of herbivory regime on vegetation and sheep. *Rangeland Ecology & Management*, 67(6), 680-692. https://doi.org/10.2111/REM-D-13-00035.1

Havstad, K. (1994). Sheep grazing as a range improvement tool. *Sheep Research Journal*, 10(1), 72-78.

Haydock, K. P., & Shaw, N. H. (1975). Correction-the comparative yield method for estimating dry matter yield of pasture. *Australian Journal of Experimental Agriculture and Animal Husbandry*, 15(76), 663-670.

Holst, P. J., & Allan, C. J. (1996). Targeted grazing of thistles using sheep and goats. *Plant Protection Quarterly*, 11, 271-272.

Huston, M. A., Aarssen, L. W., Austin, M. P., Cade, B. S., Fridley, J. D., Garnier, E., Grime, J. P., Hodgson, J., Lauenroth, W. K., Thompson, K., Vandermeer, J. H., & Wardle, D. A. (2000). No consistent effect of plant diversity on productivity. *Science*, 289(5483), Article 1255. https://doi.org/10.1126/science.289.5483.1255a

Lowe, S., Browne, M., Boudjelas, S., & De Poorter, M. (2004). *100 de las especies exóticas invasoras más dañinas del mundo: Una selección del global invasive species database*. ISSG. https://portals.iucn.org/library/sites/library/files/documents/2000-126-Es.pdf

Mack, R. N., Simberloff, D., Mark-Lonsdale, W., Evans, H., Clout, M., & Bazzaz, F. A. (2000). Biotic invasions: Causes, epidemiology, global 49 consequences, and control. *Ecological Applications*, 10(3), 689-710. https://doi.org/10.1890/1051-0761(2000)010[0689:BICEGC]2.0.CO;2

Martino, A. L. (2006). *Especies exóticas invasoras: Propuestas para la estrategia a nivel del Sistema Nacional de Áreas Protegidas*. SNAP.

McNaughton, S. J., & Sabuni, G. A. (1988). Large African mammals as regulators of vegetation structure. In M. J. A. Werger (Ed.), *Plant form and vegetation structure* (pp. 339-354). Academic Pub.

Medina, S., & Rachid, C. (2004). *Estudio de una sucesión vegetal en las Barrancas de los Humedales del Río Santa Lucía* [bachelor's thesis]. Universidad de la República.

Montaldo, N. H. (2000). Éxito reproductivo de plantas ornitócoras en un relicto de selva subtropical en Argentina. *Revista Chilena de Historia Natural*, 73(3), 511-524. http://dx.doi.org/10.4067/S0716-078X2000000300015

Mosley, J. C. (1996). Prescribed sheep grazing to suppress cheatgrass: a review. *Sheep & Goat Research Journal*, 12, 74-81.

Mosley, J. C., Frost, R. A., Roeder, B. L., Mosley, T. K., & Marks, G. (2016). Combined herbivory by targeted sheep grazing and biological control insects to suppress spotted knapweed (Centaurea stoebe). *Invasive Plant Science and Management*, 9(1), 22-32. https://doi.org/10.1614/IPSM-D-15-00034.1

Nebel, J. P., & Porcile, J. F. (2006). *La contaminación del bosque nativo por especies arbóreas y arbustivas exóticas*. MGAP. https://www.guayubira.org.uy/monte/Contaminacion_monte_nativo_exoticas.pdf

Olivera, J. M., & Riaño, M. E. (2022). Remote sensing of invasive alien woody species in Uruguayan native forests. *Agrociencia Uruguay*, 26(1), Article e653. https://doi.org/10.31285/AGRO.26.653

Padovani, C. S. M. (2015). *Efecto alelopático de malezas leñosas invasoras sobre la germinación de hierbas pratenses* [Doctoral dissertation]. Universidad Austral de Chile.

Pulina, G., & Bencini, R. (Eds.). (2004). *Dairy sheep nutrition*. CABI publishing.

R Core Team. (2024). *R: A language and environment for statistical computing* (version 4.4.2) [Software]. https://www.R-project.org/

Sala, O. E., Chapin, F. S., 3rd, Armesto, J. J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L. F., Jackson, R. B., Kinzig, A., Leemans, R., Lodge, D. M., Mooney, H. A., Oesterheld, M., Poff, N. L., Sykes, M. T., Walker, B. H., Walker, M., & Wall, D. H. (2000). Global biodiversity scenarios for the year 2100. *Science*, 287(5459), 1770-1774. https://doi.org/10.1126/science.287.5459.1770

Shea, K., & Chesson, P. (2002). Community ecology theory as a framework for biological invasions. *Trends in Ecology & Evolution*, *17*(4), 170-176. https://doi.org/10.1016/S0169-5347(02)02495-3

Sher, A. A., & Hyatt, L. A. (1999). The disturbed resource-flux invasion matrix: a new framework for patterns of plant invasion. *Biological Invasions*, *1*, 107-114. https://doi.org/10.1023/A:1010050420466

Shigesada, N., & Kawasaki, K. (1997). *Biological invasions: Theory and practice*. Oxford University Press

Valfré-Giorello, T. A., Torres, R. C., Barri, F. R., & Renison, D. (2019). Control mecánico del árbol no nativo Ligustrum lucidum (Oleaceae): Supervivencia, regeneración y costos. *Boletín de la Sociedad Argentina de Botánica*, *54*(1), 93-104. https://doi.org/10.31055/1851.2372.v54.n1.23588

Vilá, M., Valladares, F., Traveset, A., Santamaría, L., & Castro, P. (Eds.). (2008). *Invasiones biológicas*. CSIC. https://www.valladares.info/wp-content/uploads/2021/02/Invasiones-biologicas-2008.pdf

Westbrooks, R. (1998). *Invasive plants: Changing the landscape of America*. FICMNEW. https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1489&context=govdocs

Wickham, H., Chang, W., & Wickham, M. H. (2016). *Package 'ggplot2': Create elegant data visualisations using the grammar of graphics* [Software]. https://search.r-project.org/CRAN/refmans/ggplot2/html/ggplot2-package.html

Williamson, M. H., & Fitter, A. (1996). The characters of successful invaders. *Biological conservation*, *78*(1-2): 163-170. https://doi.org/10.1016/0006-3207(96)00025-0