Acta Biológica Catarinense
2017 Jul-Set;4(2):54-59

Canopy cover and invasive grasses effects in distinct ecological restoration technologies: 5-y monitoring in a Brazilian subtropical forest

Cobertura de dossel e gramíneas invasoras em diferentes tecnologias de restauração: monitoramento de 5 anos em uma floresta subtropical no Brasil

Dionatan **GERBER**[1,3]; Tatiene Yumi **KIWARA**[2]; Patricia Ramos de **SOUZA**[2]; Marcos **LUBKE**[2]; Edgar de Souza **VISMARA**[2] & Fernando Campanhã **BECHARA**[2]

Recebido em: 22 jun. 2017
Aceito em: 18 set. 2017

ABSTRACT
The establishment of canopy and the following elimination of invasive exotic grasses are among the main barriers towards the restoration of subtropical forests. We compared canopy initial cover and biological invasion by exotic grasses in different restoration technologies, up to 5-y, in Paraná State, southern Brazil. We tested three treatments in four randomized blocks as follows: T1 – passive restoration; T2 – nucleation; and T3 – high diversity plantation. We sampled 117 points per plot (54 x 40 m). We registered the presence or absence of invasive grasses cover and canopy cover percentage (using a spherical crown densiometer). The high density of fast-growing trees plus dense crowns was probably responsible for the highest shadowing and faster elimination of grasses in the plantation, while nucleation and the passive restoration showed the lowest canopy cover followed by the highest invasion by grasses. We recommend managers to use plantations to make a fast covering, although with higher inputs, or use nucleation in a long-term shadowing basis project.
Keywords: neotropical forests; nucleation; passive restoration; plantation.

RESUMO
O estabelecimento de dossel e a decorrente eliminação de gramíneas exóticas invasoras constituem algumas das principais barreiras para a restauração de florestas neotropicais. O objetivo deste estudo foi comparar a cobertura inicial de dossel e invasão biológica por gramíneas sob diferentes tecnologias de restauração, aos cinco anos de idade, no sul do Brasil. A área foi dividida em quatro blocos casualizados sob três tratamentos: tratamento T1 – restauração passiva; tratamento T2 – nucleação e tratamento T3 – plantação em linhas de preenchimento e diversidade. Foram avaliados 117 pontos por parcela (54 x 40 m), em que foram registradas a porcentagem de cobertura de gramíneas invasoras (presença ou ausência) e a cobertura de dossel (por meio de densitômetro tipo espelho convexo). A alta densidade de árvores de rápido crescimento e a copa densa da plantação em linhas provavelmente foram responsáveis por seu maior sombreamento e eliminação mais rápida de gramíneas, ficando a nucleação e a restauração passiva com menor cobertura de dossel, e consequentemente maior invasão por gramíneas. Recomenda-se aos restauradores o uso de plantações em linhas para fins de rápido recobrimento mas com altos insumos, ou optar pela nucleação num projeto de longo prazo para sombreamento.
Palavras-chave: floresta neotropical; linhas de preenchimento e diversidade; nucleação; restauração passiva.

[1] Pós-Graduação em Engenharia Florestal, Universidade do Estado de Santa Catarina (Udesc), Centro de Ciências Agroveterinárias, Avenida Luís de Camões, n. 2.090, Conta Dinheiro, Lages, SC, Brasil.

[2] Departamento do curso de Engenharia Florestal, Universidade Tecnológica Federal do Paraná (UTFPR), *campus* Dois Vizinhos, Dois Vizinhos, PR, Brasil.

[3] Autor para correspondência: dionatan_gerber@hotmail.com.

INTRODUCTION

Canopy cover can be used as an indicator of the forest structural restoration since it controls the amount, quality, and distribution of light by conditioning the forest internal microhabitat, interfering with growth and survival of seedlings, and determining the composition of the understory community (LAMB *et al*., 1997; GANDOLFI *et al*., 2007; VIANI *et al*., 2010).

A closed canopy influences the temperature and the relative humidity of air and soil. These parameters may determine recruitment of species and dynamic of regeneration in the forest understory.

The fast canopy cover formation may control invasive exotic grass dominance; however, the commitment of the continuity of formed canopy during the restoration process in places where invasive exotic grasses were historically found can also jeopardize the development of regenerating native individuals, such as native shrub and tree species (HOLL, 2007, 2012). Since the closed canopy will act as a filter for the species which attempts to regenerate under it, each canopy species can determine the structure and composition of the understory plant community (BUGMANN, 2001; PETERS *et al*., 2004; GANDOLFI *et al*., 2007).

Invasive exotic grasses have come over time, spreading gradually through native areas and threatening ecosystems and local biodiversity in Brazilian Neotropical forests. African grasses have adapted to subtropical conditions and dominate the natural open formations as degraded areas, altering original structure and reducing native species populations. They have a high capacity of vegetative reproduction, forming dense layers of leaves, which may decrease by up to 99% the arrival of light on the ground, hence impeding the germination and recruitment process of native bank seeds (HUGUES & VITOUSEK, 1993; PETERSON & CARSON, 2008; LETCHER & CHAZSON, 2009; PUTZ & REDFORD, 2010; HOLL, 2012).

Exotic grasses invasion can cause several changes in the composition, structure and functioning of natural ecosystems. Some studies have shown that, considering a community scale, one of the effects caused by invasive grasses is the reduction of native plants diversity, especially by the space occupation (DAVIES & SVEJCAR, 2008; FERREIRA & FELIPPI, 2013; SILVA *et al*., 2014). A study conducted by Flory & Chay (2010) had assessed the impact of the presence of invasive exotic grasses (*Microstegium vimineum* (Trin) A. Camus) in an ecological restoration area and reported that in plots with invasive grass, the reduction of native species biomass was 46%, 64% and 58% in three cycles of growth, respectively. These plots with invasive exotic grasses were with 43% lower richness and 38% lower diversity.

According to Holl *et al.* (2000), the absence of canopy closure and the consequent threat of invasion by exotic grasses have been pointed out as a major barrier to the restoration of tropical forests. The invasion of grasses is a key problem for subtropical forest restoration, especially in the first 3-5 years, when the shadowing is still low, thus allowing the recruitment and development of grasses.

The fast formation of canopy closure and coverage has been considered the main responsible one for the elimination of invasive exotic grasses in ecological restoration projects (RODRIGUES *et al*., 2009; MELO & DURIGAN, 2010; RODRIGUES *et al*., 2011).

This study aimed to compare the canopy closure and coverage of invasive exotic grasses under different ecological restoration treatments in the early stages of recovering.

MATERIAL AND METHODS

STUDY AREA

This study was conducted at the farm of the Federal University of Technology - Paraná, municipality of Dois Vizinhos, Southern Brazil, located between the coordinates 25°41’44” – 25°41’49” S and 53°06’23” – 53°06’07” W in a subtropical forest; region of *Araucaria* forest with influence of seasonal semidecidual forest. The region is located on Guarapuava plateau, with an altitude of 495–504 m.

The soil is a Typic Hapludox (Oxisol). The climate is classified as mesothermal humid subtropical (Cfa), according to Köppen classification (ALVARES *et al*., 2013). The study area had been used over decades with annual crops and pastures (*Cynodon nlemfuensis* Vanderyst*, Panicum maximum* Jacq. and *Urochloa decumbens* (Stapf) RD Webster).

The area was all mowed by tractor and then divided into four blocks where three treatments were implemented (in December 2010) in 40 x 54 m plots (spaced about 13 m apart), totalling 0.9 ha per treatment.

Treatment T1 was passive restoration (control: no intervention).

Treatment T2 – nucleation techniques (REIS *et al*., 2010), where six 3 x 40 m strips occupied 1/3 of the total plot area and filled by: 6 artificial shelters, 2 artificial perches, 6 topsoil seedlings nuclei of 1 m^2, 6 seed rain seedlings nuclei of 1 m^2, 12 pigeon beans (*Cajanus cajan* (L.) Huth, Fabaceae) nuclei of 12 m^2, 6 bromeliads (*Bromelia antiacantha* Bertol.) nuclei of 5 seedlings, and 24 native tree islets of 5 seedlings (totalling 4 seedlings of 12 pioneer shade tree species on the sides and 1 seedling of 24 non-pioneer in the centre.

Treatment T3 – high diversity tree plantation (*sensu* RODRIGUES *et al.*, 2009; RODRIGUES *et al.*, 2011) using lines of 10 shade tree species (named "filling species") alternated with 60 non-pioneer (named "diversity species"), in a 3 x 2 m spacing (figure 1).

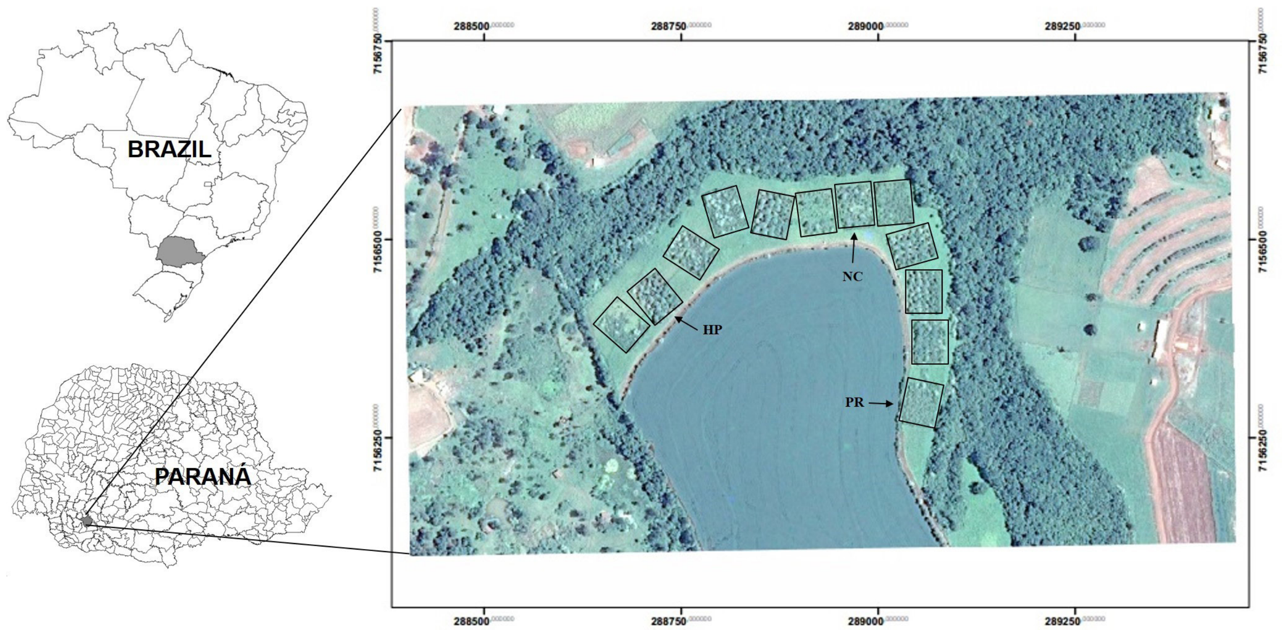

Figure 1 – Experimental area at the Federal University of Technology, *campus* Dois Vizinhos (PR –Brazil). PR: passive restoration; NC: nucleation; HP: high diversity tree plantation.

Silviculture procedures were performed every six months up to the third year, totalling six interventions (except for the passive restoration). Nucleation treatment received mowing followed by chemical weeding (glyphosate) only within the nucleation strips (1/3 area); while the plantation was mowed followed by chemical weeding (glyphosate) in its total area. All seedlings were fertilized (except for passive restoration) and leaf-cutting ants were controlled by 10 g formicide baits (Sulfluramid 0,05%, Fipronil 0,03%) each 5 m, across the entire 7.2 ha experimental area.

DATA COLLECTING

For the evaluation of grass invasion, we marked systematically 117 points in each plot, every 5 x 4.5 m. In each point, we recorded the presence or absence of invasive exotic grasses by touching a topographic pole positioned at the ground level. To measure crown cover, a spherical crown densiometer (24 squares) was positioned 1.30 m above the ground and the same 117 grasses measurements points were taken, recording canopy coverage percentage data.

The results of 5-y monitoring of canopy coverage and grass invasion were submitted to analysis of variance by the statistical software R. The data was compared by Tukey test at 5% level.

RESULTS AND DISCUSSION

The results about exotic grasses cover indicate no statistical difference between the treatments of passive restoration and nucleation in all sampling periods. However, plantation presented, statistically, lower invasion levels from others since 19th to 60th month when there were just 17.40% of grasses (table 1). Comparing the same treatment at different periods, we observed that in both passive and nucleation there was no statistical difference, indicating that these restoration treatments were still not effective in a 5-y basis. On the contrary, plantation gradually decreased grasses invasion in the area since the 19th month and over time.

The invasion of exotic grasses was relatively high (58-63%) in all restoration treatments since the beginning of the experiment. Nevertheless, the highest total average of grasses cover was found in passive restoration (63.35%) and in nucleation (62.58%), followed by high diversity tree plantation that presented the lowest average (38.55%).

Table 1 – Invasive exotic grasses cover in different technologies of ecological restoration. Averages followed by the same letter do not differ by Tukey test at 5% level: capital letters compare values in horizontal and lowercase letters compare values in vertical. Legend: w = winter; s = summer.

Age (months)	Passive restoration (%)	Nucleation (%)	Plantation (%)
0 (s)	58.55 a A	62.82 a A	59.40 a A
5 (w)	53.21 a A	53.21 a A	51.71 ab A
19 (w)	67.52 a A	70.94 a A	26.28 cd B
36 (s)	69.44 a A	71.16 a A	44.87 abc B
48 (s)	72.01 a A	62.18 a A	31.63 bcd B
60 (s)	71.40 a A	55.16 a A	17.40 d B
Mean	63.35 A	62.58 A	38.55 B
CV (%)	19.28		

Considering the results of canopy cover between technologies, there was no significant difference during and between data collecting periods. However, when the total averages were assessed, plantation presented the highest canopy cover (66.20%) followed by nucleation (51.58%) and passive restoration (45.66%) (table 2).

Table 2 – Canopy cover in different treatments of ecological restoration. Average of treatments with the same letter do not differ among themselves by Tukey test at a significant level of 5%.

Age (months)	Passive restoration (%)	Nucleation (%)	Plantation (%)
0 (s)	0	0	0
5 (w)	0	0	0
19 (w)	36.13 ns	39.23 ns	50.85 ns
36 (s)	36.41 ns	45.29 ns	54.03 ns
48 (s)	45.58 ns	46.70 ns	71.70 ns
60 (s)	64.54 ns	75.12 ns	88.22 ns
Mean	45.66 B	51.58 B	66.20 A
CV (%)	14.86		

The passive restoration and nucleation treatments presented higher rates of biological invasion by grasses and lower canopy cover. One of the factors for a lower invasion of grasses on plantation is that this technology was mowed in its total area in the first three years of the experiment, unlike the passive restoration (no intervention) or nucleation which had been cleaned, only 1/3 of its area. Furthermore, plantation technology includes a high density of trees (1,666.00 ha^{-1}), 50% of fast-growing trees with dense canopy ("filling species") that within the development and the intersection of their crowns provide a continuous shading canopy, which probably inhibited the development of exotic grasses. On the other hand, plantation requires more cleaning and planting inputs which can make the restoration project economically unfeasible.

Plantation presented higher canopy cover and consequently lower levels of invasion by grasses at 5-y old communities. This fact was already expected since this system has more predictability whereas it gets higher density of trees planted in total area, providing a canopy of larger volume and continuity. On the other hand, a more long-term question is whether the understory formed by this system will be open to the arrival of a new community through natural regeneration in an integrated manner with the landscape.

If the restoration project predicts more time to succession development, nucleation may be an intermediate and satisfactory solution. Well-done diagnoses should recommend a technology that is more or less open to stochastic events as natural regeneration that can be either positive, catalyzing the regeneration or negative, allowing the entry of invasive plants.

CONCLUSION

Plantation was more effective in eliminating invasive exotic grasses, even if it seems to be more expensive due to higher levels of mowing inputs in the implementation and maintenance of a high tree density. While there are no more long-term results on the effect of technologies established in their understory along the secondary succession, it is recommended that the managers choose the high diversity tree plantation when the aim is a fast covering and shading.

ACKNOWLEGMENTS

We thank Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq (Brazilian National Council for Scientific and Technological Development) for financial support (Process 575081/2008-2). To COPEL-GET, specially to Dr. Murilo L. Barddal and to Eng. Claudemir D. Silva, for the logistics, seedlings and labor force. To IAP – Instituto Ambiental do Paraná (Environmental Institute of Paraná) and to Sergio M. Bittencourt for the logistics and seedlings. To the internship students Ítalo Amaral, Suzamara Biz, Renã Borineli, Carla Viana e Douglas Porrua for data collecting.

REFERENCES

Alvares, Clayton Alcarde; José Luiz Stape; Paulo Cesar Sentelhas; José Leonardo de Moraes Gonçalves & Gerd Sparovek. Koppen's climate classification map for Brazil. Meteorologische Zeitschrift. 2013; 22(6):711-728. doi: 10.1127/0941-2948/2013/0507.

Bugmann, Harald. A review of forest gap models. Climatic Change. 2001; 51:259-305. doi: 10.1023/A:1012525626267.

Davies, Kirk & Tony Stejcar. Comparison of medusahead invaded and non-invaded wyoming big sagebrush steppe in southeastern oregon. Rangeland Ecology and Management. 2008; 61:623-629.

Ferreira, Nadilson Roberto & Eduardo Ernesto Felippi. Reflexos econômicos, sociais e ambientais da invasão biológica pelo capim-annoni (*Eragrostis plana* Nees) no bioma pampa. Cadernos de Ciência e Tecnologia. 2013; 27:47-70.

Flory, S. Luke & Keith Clay. Non-native grass invasion suppresses forest succession. Oecologia Berlin. 2010; 164:1029-1038. doi: 10.1007/s00442-010-1697-y.

Gandolfi, Sergius; Carlos Alfredo Joly & Ricardo Ribeiro Rodrigues. Permeability – impermeability: canopy trees as biodiversity filters. Sciency Agricola. 2007; 64(4):433-438.

Holl, Karen D. Old field vegetation succession in the neotropics. In: Cramer, Viki A. & Richard J. Hobbs (Eds.). Old fields: dynamics and restoration of abandoned farmland. Washington: Island Press; 2007. p. 93-118.

Holl, Karen D. Tropical forest restoration. In: van Andel, Jelte & James Aronson (Eds.). Restoration ecology. Malden: Blackwell Publishing; 2012. p. 103-114.

Holl, Karen D.; Michael E. Loik; Eleanor H. V. Lin & Ivan Samuels. A. Tropical Montane Forest Restoration in Costa Rica: overcoming barriers to dispersal and establishment. Restoration Ecology, 2000; p.339-349.

Hugues, Flint & Peter M. Vitousek. Barriers to shrub establishment following fire in the seasonal submontane zone of Hawaii. Oecologia. 1993; 93:557-563.

Lamb, David; John Parrotta; Rod Keenan & Nigel Tucker. Rejoining habitat remnants: restoring degraded rainforest lands. In: Laurence, William F. & Richard O. Bierregaard Jr. Tropical forest remmants. Chicago: The University of Chicago; 1997. p. 366-385.

Letcher, Susan G. & Robin L. Chazdon. Rapid recovery of biomass, species richness, and species composition in a forest chronosequence in Northeastern Costa Rica. Biotropica. 2009:608-617.

Melo, Antônio Carlos Galvão de & Giselda Durigan. Fire in the seasonal semideciduous forest: impact and regeneration at forest edges. Unasylva. 2010; 61:37-42.

Peters, Halton. A.; Anton Pauw; Miles R. Silman & John W. Terborgh. Falling palm fronds structure Amazonian Rainforest sapling communities. Proceedings of Royal Society of London. 2004; 271:5367-5369.

Peterson, Chris J. & Walter P. Carson. Processes constraining woody species succession on abandoned pastures in the tropics: on the relevance of temperate models of succession. In: Carson, Walter P. & Stefan A. Schnitzer (Eds.). Tropical forest community ecology. Oxford: Wiley-Blackwell; 2008. p. 366-383.

Putz, Francis E. & Kent H. Redford. The importance of defining “forest”: tropical forest degradation, deforestation, long-term phase shifts, and further transitions. Biotropica. 2010:10-20.

Reis, Ademir; Fernando Campanhã Bechara & Deisy Regina Tres. Nucleation in tropical ecological restoration. Scientia Agricola. 2010; 67:244-250.

Rodrigues, Ricardo Ribeiro; Renato Augusto Ferreira de Lima; Sergius Gandolfi & André Gustavo Nave. On the restoration of high diversity forests: 30 years of experience in the Brazilian atlantic forest. Biological Conservation. 2009; 142:1242-1251.

Rodrigues, Ricardo Ribeiro; Sergius Gandolfi; André Gustavo Nave; James Aronson; Tiago Egydio Barreto; Cristina Yuri Vidal & Pedro Henrique Santin Brancalion. Large-scale ecological restoration of high-diversity tropical forests in SE Brazil. Forest Ecology and Management. 2011; 261(10):1605-1613.

Silva, Rosilene Rodrigues; Felipe Tadashi Asao Coelho; Marconi Andrade dos Anjos & Valdenir Vaz Filho. Controle do capim-gordura nas áreas de recuperação ambiental da Mineração Corumbaense Reunida (MCR), Corumbá, MS. Biodiversidade Brasileira. 2014; 3(2):237-242.

Viani, Ricardo Augusto; Giselda Durigan & Antônio Carlos Galvão de Melo. A regeneração natural sob plantações florestais: desertos verdes ou redutos de biodiversidade. Ciência Florestal. 2010; 20(3):533-552.