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Environmental Damages in the Atlantic Forest Biome

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Abstract

We identified the main impacts, drivers, and restoration projects for Atlantic Forest in Northwest of the Rio Grande do Sul State, Brazil. The objective was to analyze the quantity, distribution, and causes of the environmental crimes in 2000-2014. To verify differences between degraded and restored areas, we performed a *t-test*; ANOVA for the municipalities with more quantity of crimes, simple linear regression analysis for the relationship between sizes of degraded areas and quantity of seedlings planted, and Principal Component Analysis (PCA) for environmental damages categories and population of the municipalities. The main environmental damages found were deforestation outside permanent preservation area (20%) and those related to Permanent Preservation Area (37%). Environmental crimes in these areas fall into two categories: native and exotic vegetation removal (17%), and impediment to natural regeneration (20%). The average size of the degraded areas was 5,359±526 m^2, while for restored areas was 3,337±255 m^2. The sizes of the degraded fragments were similar among the five municipalities with the higher number of environmental crimes (ANOVA: $p>0.05$, F=1.24; df=241). The number of seedlings planted was positively related to the sizes of the degraded fragments ($p<0.001$, R^2=0.53). Segregation between the less and the most populous municipalities was found with the PCA analysis along PC1 (51.7%), while PC2 represented 19.2% of the total variation. The most populous municipalities showed the highest number of environmental crimes, and the majority of degraded areas were recovered by planting native seedlings. Atlantic Forest fragments need to be recognized and preserved as an ecosystem with a unique ecological function by the population and public administration.

Key Words: environmental degradation, forest ecosystem, permanent preservation areas, forest management

Introduction

Among the environmental damages caused by human over-exploitation are deforestation and forest degradation. Causes of deforestation are land clearing for agriculture, logging, fuelwood collection, population growth, and world timber trade (Kamlun et al. 2016). Forest fires and selective logging destroy capacity carbon stocks, contribute to the greenhouse gasses emissions, have impacts on forest function, change freshwater biodiversity, stream flow and nutrient retention on watersheds, and cause vulnerability to human populations (Dolný et al. 2012; Valiela et al. 2013; Valente-Neto et al. 2015; Fugère et al. 2016; Morris et al. 2016; Osone et al. 2016; Tsujino et al. 2016). In subtropical forest, logging disturbance changes the diversity and dynamics throughout time, while undisturbed areas can re-

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main steady for decades (Aukema et al. 2017). In Brazil, the Atlantic Forest is considered a hotspot of biodiversity, showing 48% of endemism for vascular plants (Duarte et al. 2014). The forest stretches along the coast of Brazil and extends to Paraguay and Argentina, but due to deforestation, it is currently distributed in ~245,000 fragments in the Brazilian states (Ribeiro et al. 2009). The remnant forests fragments continue to be degraded by illegal land use in protected areas leading to loss of biodiversity and nutrient stock (Tabarelli et al. 2005; Villela et al. 2006; Oliveira et al. 2017). Proposed activities for sustainable land use in the Atlantic Forest include rural tourism, natural regeneration or matrix restoration with structural and functional connectivity (Uriarte and Chazdon 2016; Wheeler et al. 2016; Alves-Pinto et al. 2017). The aim of this study was to identify the impacts, drivers, and restoration projects for Atlantic Forest in the last 14 years. Two research questions were defined: 1) Is the number of environmental crimes related to population of the municipalities?; 2) Are the sizes of the degraded fragments related to the restored areas? We hypothesized that the most populous municipalities have more records of environmental crimes, and that degraded forest fragments have been recovered through restoration projects.

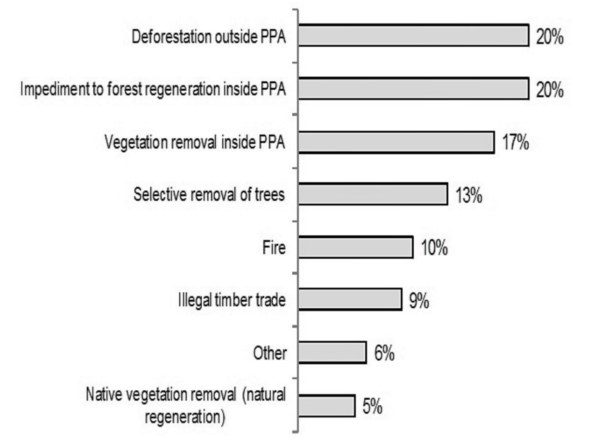

Fig. 1. Categories of environmental damages found in the Northwest Rio Grande do Sul State/Brazil from 2000 to 2014. *Other (tree felling without a licence in urban areas, improper waste disposal).

Materials and Methods

Study area

This work was carried out in the Biodiversity Department of the Rio Grande do Sul State/Brazil. It encompasses 44 municipalities located in the Uruguay River Basin (±348 m altitude), with a population of ~384,000 inhabitants and more than 48,000 rural establishments (Table S1). The seasonal deciduous forest is characteristic of the upper Uruguay River in the North Rio Grande do Sul. Among dominant species are *Peltophorum dubium*, *Ateleia glazioviana*, *Parapiptadenia* sp. (IBGE 1992). The average annual precipitation ranges from 1,500-2,000 mm/year (INMET 2016).

Data and statistical analyses

We analyzed environmental crimes from 2000 to 2014 from fines/infractions of administrative processes. To verify differences between degraded and restored areas, we performed a paired *t-test*; and to verify differences in environmental damage for the five municipalities with more quantity of crimes we performed an analysis of variance (ANOVA), using log transformed data. The relationship between sizes of degraded areas and quantity of seedlings planted to recover them was investigated by simple linear regression analysis on log transformed data. A Principal Component Analysis (PCA) was performed on the main environmental damages categories and the population of the municipalities. All statistical analyses were performed with Statistica Statsoft 7 and Canoco 4.5 for Windows.

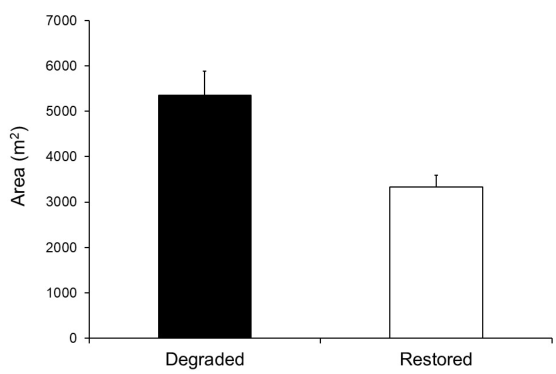

Fig. 2. Degraded and restored areas (mean±SE, n=441) recorded in the processes analyzed.

Results

We analyzed 915 processes containing 1,314 environmental damages. Data were distributed into eight categories (Fig. 1). Thirty-eight percent of the environmental damage occurred inside a permanent preservation area (PPA), vs. 62% that was outside of a PPA. The main environmental damage found were *deforestation outside of a PPA* (20%) and those *related to a PPA* (37%). Environmental crimes inside PPAs fall into two categories: *native and exotic vegetation removal* (17%), and *impediment to natural regeneration* (20%). The latter includes livestock grazing in the riparian forest, crops in riverbanks and wetlands, buildings, and dams. Most of the environmental crimes occurred in 2012 (11%), followed by 2008, 2010, and 2013.

The average size of the degraded areas was 5,359±526 m^2, while for restored areas was 3,337±255 m^2 (mean±SE). The sizes of degraded areas were higher than that for restored areas (*t-test*, $t=2.67$, $df=440$, $p=0.008$, Fig. 2). A total of 682 environmental processes were associated with environmental restoration projects, while 230 did not. The sizes of the degraded fragments were similar among the five municipalities with the higher number of environmental crimes (ANOVA: $p>0.05$, $F=1.24$; $df=241$). The number of seedlings planted was positively related to the sizes of the degraded fragments ($p<0.001$, $R^2=0.53$, Fig. 3). Segregation between the less and the most populous municipalities was found with the PCA analysis along PC1 (51.7%), while PC2 represented 19.2 % of the total variation (Fig. 4).

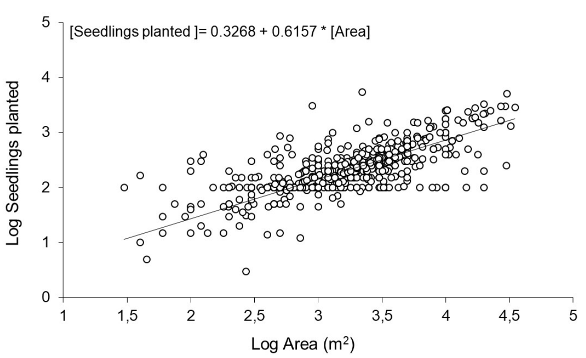

Fig. 3. Relationship between the number of native seedlings planted and sizes of areas to be recovered.

Discussion

Environmental damages

Deforestation drivers both inside and outside of permanent preservation areas can be related to urbanization and agriculture. The majority of rural properties in Northwest Rio Grande do Sul State comprise household farmers and subsistence agriculture, while 8% of the rural properties are non-family farming and are responsible for the production of larger amounts of soybean, wheat, and corn (IBGE 2010). One of the main environmental damages inside of PPAs was removing native and exotic vegetation (*Eucalyptus* sp.) in riparian zones. In the case of protected areas, a licensing is necessary to remove eucalyptus trees, and the area must be recovered by native plants. Watercourses and hilltops up to 1100 m are the most affected permanent preservation areas by interest conflicts and illegal land-use (Ferrari et al. 2015; Santos et al. 2016). Eucalyptus plantations replaced native vegetation in the past decades not only in Brazil, but in some European countries leading to forest degradation and landscapes changes mainly in watercourses (Costa et al. 2014).

Impediment to natural regeneration by native vegetation removal or camping in permanent preservation areas lead to an increase in riverbank erosion and channel destabilization during the rainfalls. Riparian vegetation is the main factor for controlling riverbanks stability, but it depends also of particles sizes of the sediment and biogeomorphologics factors (Corenblit et al. 2007; McMahon et al. 2017). Uruguay River basins have intense irregular rainfalls and

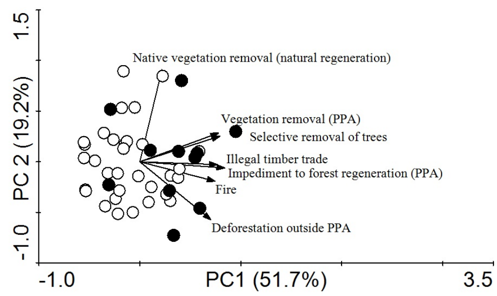

Fig. 4. Principal Component Analysis (PCA) of environmental damages and population of the municipalities of the Northwest Rio Grande do Sul State: dark circles - Municipalities with up to 10,000 inhabitants; white circles -Municipalities with more than 10,000 inhabitants.

frequently floods affect cities and rural populations (Fernández Bou et al. 2015). Furthermore, streams discharges increase solid load fluxes and modify water quality parameters such as turbidity and pH (Colombo et al. 2015). In 2014, 165 rural properties along Uruguay River were surveyed, and in 34% of them was implemented some kind of forest regeneration. Species such as *Croton urucurana*, *Parapiptadenia rigida* and *Helieta apiculata* were the most common from natural regeneration (Bergmann et al. 2011).

Illegal timber trade was related to fuelwood harvesting for biomass burning. People of the region consume fuelwood from native forest remnants (dry wood or green wood) and often commercialize it without licensing. Studies found that fuelwood harvesting from Atlantic Forest was associated with poverty, education level, family income and knowledge of the forest species (Ramos et al. 2008; Medeiros et al. 2012). Overall, this forest product consumption was related to impediment of natural regeneration, since forests remnants at early successional regeneration are the most affected (Specht et al. 2015). Illegal timber trade is related also to selective logging, the most common cause of forest degradation at variable levels of destruction of species of plants, which felling of larger trees can be accompanied by the extraction of smaller wood trees (Burivalova et al. 2015). The area of the vegetation damaged, tree fall gaps and edge effects increase in the forest fragments due to higher harvest intensity, reducing biomass and species richness (Panfil and Gullison 1998; Martin et al. 2015). Consequently, the illegal selective tree removal and plantation expansion within (and outside) protected areas lead to natural habitats fragmentations (Zhai et al. 2015). Although the degraded areas in the region analyzed were smaller (~0.10 ha) than those from Cerrado ecosystem (~5.0 ha) (Cintra et al. 2006), rural exodus and urbanization have been following a worldwide trend with great pressures for deforestation and forest degradation (DeFries et al. 2010). Among municipalities with more environmental crimes, Santa Rosa was the most urbanized (IBGE 2010), showing that forest cover loss could be associated negatively with population densities and urban settlements, besides agriculture and global market (Alexander et al. 2015; Hailemariam et al. 2016; Ryan et al. 2017; Tapia-Armijos et al. 2017). Atlantic Forest reserves have shown a trend in change of land use related to human population densities (Marques et al. 2016). Moreover, population growth and densities have experienced changes due to climate conditions and consequences to food production, protected areas, and forest cover at global and regional scales (Aukema et al. 2017). But the urbanization must be seen as a multidimensional process rather than density measurement only, considering lifestyles and social organizations (Clement et al. 2015).

Forest restoration projects

After verification of the damages by environmental agents, land owners or managers should submit a restoration project to the Biodiversity Department of the Rio Grande do Sul State. Overall, forest restoration projects were based on the native seedling plantation, which objective was the recovery of degraded areas considering different species of plants and the functionality of the system. However, the differences between sizes of degraded and restored areas in this work indicated that not all deforested areas were recovered. On the other hand, areas that were recovered showed sufficient number of native tree seedlings (with spacing between the plants of 3×2 or 3×3 m). This seems a good practice regarding to small areas, showing that the efforts of the projects in the Northwest of RS State are effective in areas with vegetation removal. Besides planting of native trees, a common practice in the region is the natural regeneration implementation, even where *Eucalyptus* sp. trees were removed from permanent preservation areas (APPs). We did not measure the compositional levels of diversity of species from this method, but other studies showed that species richness increases with the progress of succession (Adenesky-filho et al. 2017). On the other hand, the mean time for recovery can last 24 years for passive restoration and 15 years for actively restored areas, depending on past land use and type of forest (Meli et al. 2017). In general, the projects at the Biodiversity Department are monitored for at least 3 years, provided there are early indicators of effective recovery. The main indicators employed in the region are related to composition and diversity (richness, similarity) and structure (changes in height, diameter, and vegetation cover), but with little information for function (soil parameters, trophic interactions or functional diversity) (Gatica-Saavedra et al. 2017). Although the role of legal instruments in ecological restoration is controversial for compensation of environmental damages and natural capital losses in Brazil (Aronson et al. 2011), the quality of the assessment of restoration projects in South America tends to increase by use of functional indicators to achieve high levels of effectiveness of forest restoration (Gatica-Saavedra et al. 2017). Nevertheless, a minimum number of species richness as well as priority areas for compensation are not established. Strategies for forest restoration include the cultivation of plants resistant to environmental stresses and to allow connectivity and dispersion of forest fragments (Jacobs et al. 2015). Furthermore, larger areas to be restored require different methods of recovering such as passive (natural regeneration), intermediate (natural succession with applied nucleation and control of fire and invasive species) and active (planting) techniques (Corbin and Holl 2012; Oliveira et al. 2017). At regional scale, restoration projects in the Uruguay River basin should consider the irregular flooding of the streams, adaptation of the trees species to the new climate conditions, the socio-economic conditions of the local populations and industrialization levels of the region. Moreover, a monitoring in the recovery areas could be enhanced to verify functional attributes in the ecosystems.

Conclusions

Deforestation and forest degradation have direct or indirect drivers. The most populous municipalities showed the highest number of environmental crimes, and most of the degraded areas were recovered by planting native seedlings. Our results contribute to the debate on forest degradation at small and regional scales, where an efficient enforcement by forest authorities together with projects of environmental awareness can minimize and prevent these harmful effects on the environment. Atlantic Forest fragments need be recognized and preserved as an ecosystem with a unique ecological function by the population and public administration.

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