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Protected Areas of the Pampa biome presented land use incompatible with conservation purposes

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ABSTRACT

Currently, only 40% of Brazil's Pampa still is covered by original vegetation; however, there is a clear underrepresentation of regional biodiversity in protected areas (PA). Herein, we assessed the extent to which 13 PAs for the Integral Protection in the Brazilian Pampa are effective in conserving samples of the natural attributes and biodiversity of the Pampa. Of all 13 PAs analysed, 11 showed human land uses (range: 0.8–39%) in the legally defined area. Only six PAs had natural land cover above 90%, and abandoned agricultural fields were present in most of the PAs. All buffer zones surrounding PAs for Integral Protection had human land uses. Half of the buffer zones had human-related uses in more than 40% of area. Agricultural mosaics were the most common land uses in the buffer zones. Our study shows that most Pampa PAs are not immune to anthropogenic pressures both inside and around them.

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Buffer zone; grasslands; management plan; agriculture; forestry

Introduction

Protected areas (PA) are of essential importance for biodiversity conservation in today's world where agricultural activities, often for global markets, are responsible for 70% of natural habitat losses (Andam et al., 2008; Sala et al., 2000; Watson et al., 2016). Although the total number of PAs over the world has practically doubled since 1992, only 14.7% of the Earth surface falls into any category of protection (Jones et al., 2018). This percentage is below what has been agreed upon in the Aichi goals that established the goal to protect, until 2020, 17% of terrestrial areas, and 10% for marine areas per countries and territories (Butchart et al., 2015). However, only 40% of the countries over the world achieved these goals. The protection rate is largely unbalanced among the world biomes, and although Latin America has large areas under legal protection, the PAs network is biased towards forest ecosystems with steep slopes and unfertile soils (Butchart et al., 2015; Monteiro et al., 2018; Vieira et al., 2019). Furthermore, 8% of the PAs are under indirect and direct human pressures, such as spread of invasive species, hunting and climate change (Jones et al., 2018; Watson et al., 2016). Additional difficulties in assessing these threats are the lack of scientific baseline information in many PAs and deficient/unrealistic management plans (B.R. Ribeiro et al., 2018; U. Oliveira et al., 2017).

In tropical countries, non-forest ecosystems are commonly overlooked in the environmental agenda, despite their high biodiversity species that can be similar or even higher to that of tropical forests (Ministério do Meio Ambiente (MMA), 2014; Nabinger et al., 2000; Overbeck et al., 2007,

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Overbeck et al., 2015). Conversion of non-forested areas (e.g. grasslands and savannas) to agricultural land has occurred at alarming rates when compared to forests (Brandão et al., 2007; Goldevwjk, 2001). In Brazil, grassland areas are even more threatened, because they are underrepresented in PAs and current land use policy encourages grassland loss (Bonanomi et al., 2019; Overbeck et al., 2015).

Since 2000, the Brazilian National System of Protected Areas (Portuguese acronym: SNUC) establishes rules for implementation and management of PAs under two groups: Integral Protection and Sustainable Use (Brasil, 2000). Both Integral Protection and Sustainable PAs including several categories, but the main difference between them is that the former group has constraints on economic extractive activities, while the latter allows the sustainable use of part of natural resources jointly with nature conservation. Indigenous Lands and Legal Reserves also play important role in conservation, but they are covered by different legislation in Brazil (Brasil, 1996, 2012). Currently, 20% of Brazilian territory is in PAs at federal, state, and municipal levels (Brasil, 2018), and an additional of 13.8% is encompassed by Indigenous Lands (ISA, Freitas Lima & Ranieri, 2018) and 10% by Legal Reserves (Guidotti et al., 2017). However, spatial distribution of PAs and the proportion of both groups (Integral Protection and Sustainable Use) are biased towards forest ecosystems (Overbeck et al., 2007). For example, while 28.5% of the Brazilian Amazon is within PAs, only 3.23% of the Brazilian Pampa is within PAs (Palazzi, 2018). Such bias jeopardizes the ability of the PA network to safeguard grassland habitats in Brazil.

The Brazilian Pampa corresponds to the northern portion of the Rio de la Plata grassland region (Andrade et al., 2018), also known as Uruguayan savanna ecoregion (Olson et al., 2001), and encompasses an area of 193.383 km^2 (Instituto Brasileiro de Geografia e Estatística (IBGE), 2019). The landscape consists of a mosaic of grasslands, different types of shrublands and low forests, and gallery forests along rivers. Although many landscapes, especially when dominated by grassland, might appear simple and homogeneous at first glance, the Pampa harbour remarkable biodiversity with more than 2,100 plants only in grasslands (Boldrini et al., 2015), 158 reptiles and 60 amphibian species, most of them endemic of southern Brazil grasslands (Iop et al., 2016; Verrastro & Martins, 2015), more than 95 resident birds (Fontana & Bencke, 2015), and 109 mammal species (Luza et al., 2015). In the last ten years, there was a 14% loss of grassland area in the Brazilian Pampa and an increase of 14% of agricultural lands and 64% of forestry (Souza et al., 2020). However, land use changes in southern Brazil have been poorly documented compared with other regions of the country (U. Oliveira et al., 2017; Overbeck et al., 2007). In addition, management is not always adequate for biodiversity conservation, especially in Pampa PAs. Grazing and fire have shaped the region for millennia (Bernardi et al., 2016; Overbeck et al., 2007), but these disturbances are often suppressed in PAs. The lack of this kind of management may result in woody species encroachment over grassland areas, leading to losses of characteristic ecosystems as well as other processes, such as, fragmentation or original habitat and species extinction (Brandão et al., 2007; Overbeck et al., 2016; Pillar & Vélez, 2010).

Currently, the Brazilian Pampa has 51 PAs, including those under Integral Protection and Sustainable use (Table S1). These PAs represent 3.23% of the Brazilian Pampa area protected *strictu sensu* (Palazzi, 2018). In addition to the clear problem of under-representation of regional biodiversity, many PAs face common problems of mismanagement (e.g. funding, equipment, infrastructure, and issues related to tenure resolution/land rights) and human-related threats, such as biological invasions, external pressures (such as contamination by agrochemicals from agriculture), and climate change (Bellinassi et al., 2011; Overbeck et al., 2007; Watson et al., 2016). Other important shortcomings include the absence of management plans, time lag between PA creation and implementation of actions related to management plan, and lack of incorporation of actions into municipal master plans and other public institutions (Leverington et al., 2010; Neves, 2012).

Here, our objective was to assess the extent to which PAs for the Integral Protection of the Brazilian Pampa are effective in conserving samples of the natural attributes and biodiversity of the Pampa. Specifically, i) we investigated what types of human-land uses occur within legally established PAs and surrounding areas, and ii) evaluated the influence of management indicators and surrounding landscape outside PA on the amount of human-land uses within PA legal area. Our hypotheses are as follows: i) that PAs with fewer tenure problems and older management plans will experience less environmental pressure from human activities in their legally defined area; ii) that land use in the surrounding landscape outside PAs will negatively affect the amount of natural land cover within PA legal area.

Materials and methods

Our study focused on PAs located in the Brazilian Pampa, the Brazilian portion of the Rio de la Plata Grasslands, which extends to Argentina and Uruguay (Andrade et al., 2019). We analyzed only PAs with Integral Protection in federal and state levels (N = 13; Table 1). Integral Protection category allows few uses, and is basically aimed at environmental preservation and education, scientific research and, in some cases, visitation. PAs designed for Sustainable Use were not included, because these areas allow changes in land use both inside and outside of the reserve, such as intensive agriculture, application of agrochemicals, and installation of industrial clusters and wind farms. PAs at the municipal level were not included because data on their limits was not readily available in many cases.

We compiled management information on PAs from Rio Grande do Sul state secretariat for Environment and Infrastructure–SEMA/RS (SEMA – Secretaria do Meio Ambiente e Infraestrutura do Rio Grande do Sul, 2020) and Chico Mendes Institute for Biodiversity Conservation (Instituto Chico Mendes de Conservação da Biodiversidade-ICMBio, 2020): % area without land tenure issues and time since management plan creation (Table 1). PA polygons were obtained from the SEMA/RS at a scale of 1:250,000 (SEMA – Secretaria do Meio Ambiente e Infraestrutura do Rio Grande do Sul, 2020). We defined a buffer zone of 10 km based on the Brazilian federal act n. 99.274 from 1990 (Brasil, 1990). This act established that in the 10 km radius from a PA should be considered a buffer zone and that any activities that affect the biota need a special license from the local environmental agency. This 10 km radius is proposed for all Brazilian PAs, regardless of their size. Perelló et al. (2012) reviewed the methods for delimiting the buffer zones in Brazil and regarded that the adoption of fixed distances to buffer zones cause great losses in terms of conservation for large PAs. Within the PA and the buffer zone, we re-classified land use/cover classes from the Probio Project for 2015 (Hoffmann et al., 2018) that resulted in maps in the scale 1:250,000 in shape file format based on LandSat images (2015–2016). We used the data from Probio Project for 2015 because its data has been updated since 2007 by Geoprocessing Laboratory of the Federal University of Rio Grande do

Table 1. Management information for 13 PAs under Integral Protection in the Pampa biome. * Parque Estadual Podocarpus consists of two spatially separated units. Data were extracted from Rio Grande do Sul state secretariat for Environment and Infrastructure (https://sema.rs.gov.br/unidades-de-conservacao-estaduais) and Chico Mendes Institute for Biodiversity Conservation (https://www.icmbio.gov.br/portal/unidadesdeconservacao/biomas-brasileiros).

Protected area	Legal area (ha)	Creation of the park	Approval date of management plan	Area without tenure issues (%)
Parque Estadual de Itapuã	5,566.5	1973	1996	100
Refugio Vida Silvestre Banhado dos Pachecos	2,560	2002	-	100
*Parque Estadual do Podocarpus I	163.64	1975	-	0
*Parque Estadual do Podocarpus II	2,193.1	1975	-	0
Parque Estadual Delta do Jacui	14,242.1	1976	1979	0
Reserva Biológica do Maçarico	6,253	2014	-	100
Parque Estadual do Camaquã	7,992.5	1975	-	0
Parque Estadual do Espinilho	1,617.1	1975	2009	58.2
Reserva Biológica de São Donato	4,392	1975	-	0
Reserva Biológica do Ibirapuitã	351.4	1976	-	100
Reserva Biológica do Mato Grande	5,161	1975	-	73.2
Parque Nacional da Lagoa do Peixe	34,400	1986	1999	68
Estação Ecológica do Taim	32,806	1986	-	76

Sul. These data have standardized scales and captions and are responsible for most of the studies related to land use/cover performed in the study region. The Google Earth (2019) high-resolution set was used as auxiliary material. ArcGis 10.2.2 software was used for image analysis at 1:250,000 scale, in the Universal Transverse Mercator (UTM) projection, calculating percentage of every land use/cover classes.

We measured land use/cover classes separately for PA polygons and the buffer zones (percentage cover). Data were grouped into three classes: human land uses, natural land cover, and abandoned agricultural fields, following classifications proposed by Hoffmann et al. (2018). Human land uses encompass forestry (exotic tree plantation), short-term dry crops (such as soybean and maize), irrigated rice fields, mining, degraded forest I (clearing ± 30%), degraded forest II (clearing ± 50%), and agriculture mosaics. Natural land covers encompasses wetlands, native forests, rocky outcrops, water, dunes, and grasslands. Abandoned agricultural fields are areas that were previously used by crops and may have sporadically cattle grazing; they were classified separately because they represent a transitional state between human land use and natural land cover (Forman & Godron, 1986). In PAs, natural regeneration might occur on some of these abandoned areas, even though active restoration may be necessary in many cases (Torchelsen et al., 2018). As many PAs have land tenure problems, abandoned fields might be used for new crops or livestock.

A principal component analysis (PCA) based on a correlation matrix was performed with land use/covers in the buffer zone and management information of corresponding PA. This allowed for the formation of correlating variables that represent linear composites of the data without substantial loss of information, avoiding statistical multicollinearity. The first two PCA axes were then used in further analyses as they accounted for most of the variation (75%) in land composition among buffers. Using linear models, we tested if the amount of human land uses inside PAs was influenced by management indicators and surrounding landscape outside PAs. Because all land use/cover used here were represented by proportional data, we used logit transformation prior the analysis, as proposed by Warton and Hui (2011). Analyses were computed using the car Fox and Weisberg (2018) and vegan (Oksanen et al., 2019) packages in R (R Development Core Team, 2020).

Results

Even though the majority of integral PAs in the Pampa region have been established more than two decades ago, to date only four have approved management plans: Parque Estadual de Itapuã, Parque Estadual Delta do Jacui, Parque Estadual do Espinilho, and Parque Nacional da Lagoa do Peixe (Table 1). Only four of them are without tenure issues (Table 1). Integral protected surface area corresponds to 0.6% of the total area of the Pampa (Figure 1), thus representing an extremely low portion of natural cover of the region (Table 2). Roughly 5% of the land currently within integral PAs in the Pampa was occupied by human land uses (Table 3).

Of all 13 PAs analysed, 11 showed human land uses in the legally defined area (range: 0.8–39%). In four PAs, more than 15% of their total area was characterized by human land uses (Parque Estadual do Espinilho, Parque Estadual do Podocarpus I, Parque Estadual do Podocarpus II, and Reserva Biológica de São Donato) and rice fields and forestry were the most common land uses overall (Table 3, Fig. S1). Abandoned agricultural fields were present in most of the PAs, encompassing more than 50% of the area in two PAs: Reserva Biológica do Ibirapuitã and Parque Estadual do Espinilho. Only some PAs had natural land cover above 90%: Parque Estadual de Itapuã, Refúgio Vida Silvestre Banhado dos Pachecos, Reserva Biológica do Maçarico, Reserva Biológica do Mato Grande, Parque Nacional da Lagoa do Peixe, and Estação Ecológica do Taim.

All buffer zones surrounding PAs for integral protection had human land uses (Table 4, Fig S2). Agricultural mosaics and irrigated rice fields were the most common land uses in the buffer zones. Half of the buffer zones had human uses in more than 40% of area. Natural vegetation covered about

Figure 1. Limits of the Brazilian Pampa (light grey) and location of the areas for the Integral Protection (black). 1: Parque Estadual Itapuã, 2: Refugio Vida Silvestre Banhado dos Pachecos, 3: Parque Estadual do Podocarpus I, 4: Parque Estadual do Podocarpus II, 5: Parque Estadual Delta do Jacui, 6: Reserva Biológica do Maçarico, 7: Parque Estadual do Camaquã, 8: Parque Estadual do Espinilho, 9: Reserva Biológica de São Donato, 10: Reserva Biológica do Ibirapuitã, 11: Reserva Biológica do Mato Grande, 12: Parque Nacional da Lagoa do Peixe, 13: Estação Ecológica do Taim.

Table 2. Total area and protected area for each land cover in Pampa biome. Area protected corresponds to the sum all PAs with Integral Protection used in the study.

	Area (km^2)[a]	Area protected (km^2)	Protected (%)
Pampa	193,836	1,176.983	0.61
Remaining natural cover	68,450	1,061.205	1.55
Abandoned fields	23,004	52.80	0.23

[a]data from (Hasenack & Cordeiro, 2006)

45% of the each buffer zone (44.8 ± 21.1) and around 15% of area in the buffer zones was occupied by abandoned fields (16.3 ± 12; Table 4).

PC1 and PC2 summarized together 77% of the characteristics of the 13 PAs analysed here (Figure 2). The first (PC1) was positively correlated with the % of land uses in the buffer zone (r = 0.59) and negatively correlated to natural land cover in the buffer (r = –0.6). The PC2 summarized mainly changes of abandoned field cover in the buffer zone (r = 0.70). Manage plan age–MANAG (r = – 0.32) and area without land tenure issues–AREA (r = 0.55) have modest association to second axis. Variation in the amount of human land use inside PAs was significantly related with the first PCA axis ($R^2_{adj.} = 0.38$; $F_{1,11} = 8.625$; p = 0.01). Human-related use inside the legal area of the PAs was influenced positively by PC1 (Figure 3). High values of principal component axis indicated higher percentage of human land use in the buffer zones and low values of natural land cover.

Table 3. Landscape composition registered within the legal area of 13 PAs for Integral Protection in the Pampa biome. * Parque Estadual Podocarpus consists of two spatially separated units.

Protected area	Percentage of land use/cover			Use/area
	Natural land cover	Abandoned field	Land uses	(ha)
Parque Estadual de Itapuã	97.8	1.4	0.8	Forestry, agriculture mosaic/ 44.5
Refugio Vida Silvestre Banhado dos Pachecos	93.2	2.3	4.5	Agriculture mosaic, dry crop/ 115.2
*Parque Estadual do Podocarpus I	45.6	15.4	39	Forestry/63.8
*Parque Estadual do Podocarpus II	78	0	22	Forestry/482.4
Parque Estadual Delta do Jacui	88.9	2.6	8.5	Forestry, rice field/1210.6
Reserva Biológica do Maçarico	90.9	9.1	0	
Parque Estadual do Camaquã	80.3	11.9	7.8	Forestry, rice field/623.4
Parque Estadual do Espinilho	34.4	50.3	15.3	Rice field/247.4
Reserva Biológica de São Donato	20	43	37	Rice field/1625
Reserva Biológica do Ibirapuitã	43	57	0	
Reserva Biológica do Mato Grande	93.7	4.3	0.2	Rice field/103.2
Parque Nacional da Lagoa do Peixe	95.2	0.03	4.77	Forestry/1548
Estação Ecológica do Taim	99.2	0	0.8	Rice field, forestry/249.3

Table 4. Landscape composition registered within the buffer zones (10 km) of 13 PAs for Integral Protection in the Pampa biome. * Parque Estadual Podocarpus consists of two spatially separated units.

Protected area	Percentage of land use/cover			Use
	Natural land cover	Abandoned field	Land uses	
Parque Estadual de Itapuã	79.7	7.1	13.2	Forestry, agriculture mosaic, rice field
Refugio Vida Silvestre Banhado dos Pachecos	25	29	46	Agriculture mosaic, mining, degraded forest
*Parque Estadual do Podocarpus I	36.5	18.3	45.2	Forestry, dry crop, agriculture mosaic
*Parque Estadual do Podocarpus II	55	4	41	Forestry, agriculture mosaic, degraded forest
Parque Estadual Delta do Jacui	18.6	10.7	70.7	Urban, rice field, agriculture mosaic
Reserva Biológica do Maçarico	59	16.6	24.4	Rice field, forestry
Parque Estadual do Camaquã	65.8	0	34.2	Rice field, dry crop, forestry
Parque Estadual do Espinilho	21.3	26	52.7	Rice field, agriculture mosaic, degraded forest
Reserva Biológica de São Donato	13	45.3	41.7	Rice field, dry crop, degraded forest
Reserva Biológica do Ibirapuitã	57.2	15.8	27	Agriculture mosaic, rice field
Reserva Biológica do Mato Grande	45.8	25.8	28.4	Forestry, rice field
Parque Nacional da Lagoa do Peixe	39.4	18.4	42.2	Forestry, rice field
Estação Ecológica do Taim	74.4	3.3	22.5	Rice field

Discussion & Conclusion

Our results showed that Integral Protection PAs of the Pampa biome presented large proportions of land use incompatible with their conservation goals when compared with other Brazilian PAS (S. Ribeiro et al., 2020). The high influence of land uses in 10 km radius buffer zones on the amount of land uses within the PAs repeated the pattern found in previous studies about the impact of the buffer zones in other regions (Jusys, 2016; S. Ribeiro et al., 2020; Robinson et al., 2013). With a growing and compelling body of evidence on ongoing biodiversity erosion in South Brazilian grasslands due to land cover change (Oliveira et al., 2017; Saccol et al., 2017; Staude et al., 2018), there is a clear need for more effective biodiversity protection in the region. While PAs are but one component of protection on a landscape scale, in Brazil, for instance, alongside with Legal Reserves (Metzger et al., 2019), Permanent Protection Areas (Perelló et al., 2012) or other areas under management compatible with biodiversity conservation, they are recognized to be of high relevance as they effectively impede conversion of lands within them to human land uses. Nonetheless, our results

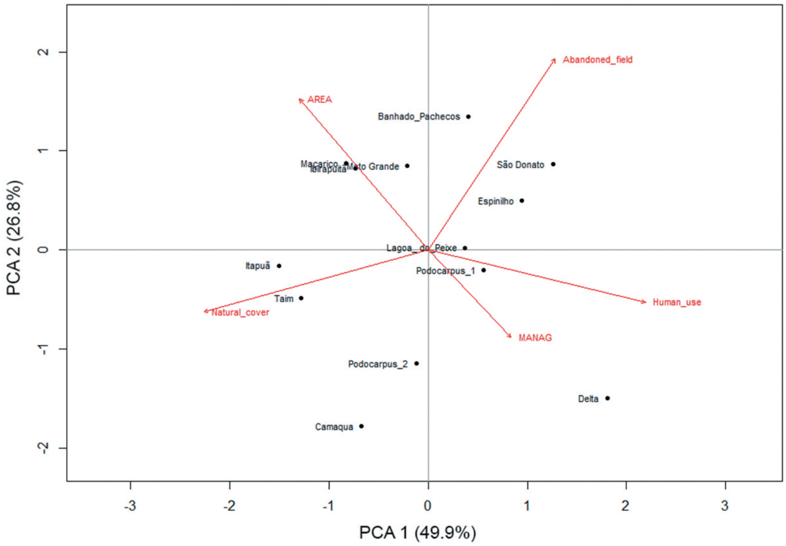

Figure 2. Principal component analysis biplot for land use/covers in the buffer zone and management information of Integral Protection PAs in the Pampa region. AREA–% area without land tenure issues; MANAG–time since management plan creation; Human use–forestry, short-term crops, mining, degraded forest, and agriculture mosaics in the buffer; Abandoned field–areas that were previously used by crops or livestock in the buffer; Natural cover – wetland, native forest, rocky outcrop, water, dune, and grassland covers in the buffer zone.

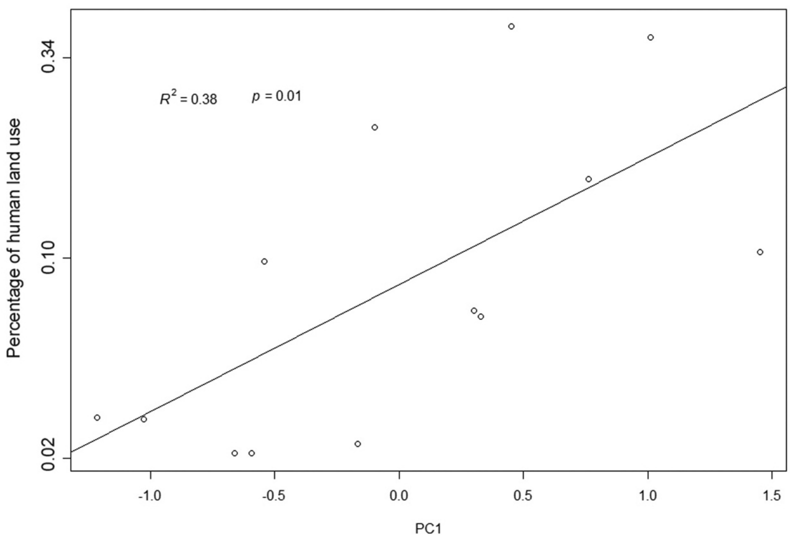

Figure 3. Relationship between human land use inside PAs and Principal Component axis summarizing landscape composition and management indicators in a 10 km radius buffer zone.

demonstrate the need to pay more attention to buffer zones establishment and land management in buffer zones that ideally would be compatible with conservation objectives within the PAs. Results of other assessments have already indicated that buffer zones effectiveness surrounding Brazilian PAs are not sufficient to guarantee good conservation outcomes (Alexandre et al., 2010; Lourival et al., 2009; Paolino et al., 2016; S. Ribeiro et al., 2020), and we now show this for the Pampa biome. Here, land uses related to agriculture (rice fields, agricultural mosaics, and forestry) were the most common human-related uses in PAs and buffers zones. Populations of many species are negatively affected by even modest levels of native habitat loss to agriculture (Dotta et al., 2016; Phalan et al., 2011). Forecasts of agricultural expansion indicate that the proportion of area covered by agriculture may reach 80.4% in the Pampa until 2100, and PAs are expected to be four times more affected by agricultural activities than today (Dobrovolski et al., 2011). For the Pampa, the biome with the lowest cover of conservation units of all Brazilian biomes, this can have severe consequences regarding biodiversity conservation in PAs. Reaching adequate land management now likely will reduce pressures in the future.

More than 70% of rice production, 25% of fuel wood, and 49% of pulpwood in Brazil comes from Rio Grande do Sul state (Instituto Brasileiro de Geografia e Estatística (IBGE), 2019). Studies on the impact of irrigated rice production crops on biota highlighted negative consequences of management practices, crop age, and agrochemicals use on species richness and community structure (Machado & Maltchik, 2010; Maltchik et al., 2011; Moreira & Maltchik, 2014, 2015). The significant amount of tree plantations (sometimes called 'planted forest') observed in the study PAs is due to the expansion of forestry by *Pinus* and *Eucalyptus* (about 477%) between 1985 and 2017 in the Pampa Biome (Mapbiomas 2020). Companies in the forestry sector were attracted to southern Brazil from 2004 with the aim of increasing wood production and improving the region's economy (Binkowski & Filippi, 2009; Dick & Schumacher, 2018). In the south of Brazil, the area of tree plantations currently corresponds to 2.8% of the region surface. Part of these plantations occurs inside PAs, mainly due to the lack of tenure regularization in many PAs (Binkowski & Filippi, 2009; Dick & Schumacher, 2018). While effects of tree plantations on native biota includes species loss and changes in the community composition (Machado et al., 2012; Rolon et al., 2011; Saccol et al., 2017), some studies pointed to unexpected positive results for some species with high plasticity, at least in certain periods (Becker et al., 2007; Marques et al., 2016). At any rate, PAs guarantee the long-term presence of areas with native vegetation in landscapes under high general human influence, and their establishment is extremely important in the Pampa region. Even if we consider other categories, such as sustainable use and federal PAs, total surface area under protection in the Pampa is far below that of other Brazilian regions (only 3.14%).

Our expectations that PAs with older management plans and few tenure issues would also suffer lower pressures due to human activities were not supported. Surrounding landscape was a better descriptor of the amount of human-land uses with PAs than management indicators. However, we cannot rule out synergistic effects between management indicators and surround landscape. It is clear that larger amounts of natural land cover in the buffer zone reduce the impact of human activities around the PAs. Buffer zones, usually covering private properties, provide important benefits that go beyond buffering negative effects of intensive land use. These may include improving landscape connectivity for some species, complementing habitat protection, and reducing conflicts between local populations and PA managers (Paolino et al., 2016; Perelló et al., 2012). However, our results also show that less than a half of state's PAs in the Pampa have management plans, even though most of them were created over 40 years ago. In Brazilian nature conservation, regulations for buffer zones – where management plans exist – usually are very weak, with recommendations, but no strict rules (Freitas Lima & Ranieri, 2018; Perelló et al., 2012). This is a severe impediment to effective conservation, as conservation goals are not clearly defined and as the natural features as well as anthropogenic pressures on the area are not known or at least not documented sufficiently to guide conservation goals and actions. The Management Plan is a document of the rules of use and management of the Brazilian PAs, and it provides legal security to the manager for his decision making. Management plans (i) ensure that PAs are appropriately managed, (ii) provide a mechanism for consistency over time in management actions and (iii) are to guarantee that a PA is being managed in their best interests and that of future generations (Goosen & Blackmore, 2019).

A critical issue in terms of conservation effectiveness in PAs is the restoration of abandoned agricultural fields or areas formerly used for tree plantations. Existing studies from the South Brazilian grasslands show that areas that originally had been grassland and then were used for agriculture or tree monocultures do not easily return to their original state after abandonment of the more intensive land use, considering both vegetation composition or ecosystem processes (Koch et al., 2016; Leidinger et al., 2017; Torchelsen et al., 2018). This clearly is a problem for meeting conservation goals in PAs, and points to the importance of active restoration. Furthermore, degraded areas can act as source sites for invasive species that may then spread into natural areas (Valkó et al., 2016), also underlining the need of restoration. While considerable knowledge and experience exists in Brazil for restoration of forests (Rodrigues et al., 2009), much of which can be applied to forests in the Pampa where somewhat less experiences exist, restoration of grasslands has only recently become a topic in research and policy (Overbeck et al., 2013). Development of restoration techniques is still in a rather initial phase for South Brazilian grasslands (e.g. P. Thomas et al., 2019a,b). With the development of the 'Plano Nacional de Recuperação de Vegetação Nativa' (Ministério da Educação (MMA, MAPA, MEC), 2017) and recent initiatives on the state level, e.g. the GEF Terrestre Program (MMA, Ministério do Meio Ambiente (MMA), 2019), interest in and potential for restoration of degraded lands in PAs has risen. This is highly relevant as abandoned fields corresponded to nearly 20% of land cover in PAs of Pampa biome, reaching more than 50% of the legal area in some cases. Indeed, the PAs could serve as important sites for testing of restoration techniques that have been shown promising in academic studies on larger areas.

Our study shows that most Pampa PAs are not immune to anthropogenic pressures both inside and around them. Human uses within PAs identify low PA efficiency in minimizing environmental pressures from land use. In the case of PAs with Integral Protection, as evaluated here, the presence of intensive land uses and of degraded areas in PAs conflicts with the main objectives of PAs such as species conservation, scientific research, environmental education and visitation. The implementation of public policies to reduce degradation processes and restore these areas to natural land cover as far as possible is urgent to reach conservation objectives; a first step should be the elaboration of management plan and the solution of land tenure issues. A basis and justification for these efforts, besides biodiversity itself, could be the valuation of natural areas in terms of ecosystem services (Metzger et al., 2019).

At current, the window of creation of large PAs is closing rapidly as agricultural conversion progresses rapidly and as scenarios point to further land conversion (Oliveira et al., 2017), calling for rapid action to reach global conservation aims that support the Sustainable Development Goals (Schultz et al., 2016). The evaluation of representability of PAs in terms of ecosystems covered should guide PA management and, where necessary, i.e. where international goals at current are not met, such as in the Pampa, expansion of the PA network, in all regions of Brazil.

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