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Integrating strict protection and sustainable use areas to preserve the Brazilian Pampa biome through conservation planning

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ABSTRACT

Biodiversity conservation planning must be ecosystem-specific and take into account human needs as food production. The Pampa biome is a temperate grassland with high species richness and with an important role in food production in South America. Here we present the first formal Systematic Conservation Planning for the Brazilian part of the Pampa, which is the least protected biome in Brazil. We aimed to build conservation scenarios where at least 17 % of the biome area were protected, following the 11th Aichi target for terrestrial lands protection according to the Convention on Biological Diversity. Our conservation targets were the vegetation types of this biome. Three scenarios were built varying in their proportions of strict protection (SP) and sustainable use areas (SU): Permissive scenario (5 % SP, 12 % SU); Intermediate scenario (10 % SP, 7 % SU) and Restrictive scenario (15 % SP, 2 % SU). Urban and rural areas, as well as bovine and ovine density, were used as prioritization costs, aiming to minimize possible conservation conflicts. Four main clusters of priority areas to protect the vegetational diversity can be observed in all scenarios and should be considered when implementing future protected areas in this threatened biome. Sustainable use areas are suitable for low-density livestock raising, combining biodiversity protection and food production, but strictly protected areas are still important to species most affected by livestock. The combination of strict protection and sustainable use areas can be effective in similar biomes. It should be considered in future international negotiations, such as the 2020 Conference to be held in Beijing, opening new strategies to achieve the 17 % of land protection. We expect that this Systematic Conservation Planning reinforces the recently started scientific discussion regarding the conservation of non-forest ecosystems in Brazil.

1. Introduction

Conservation science aims to provide principles, strategies and approaches for preserving biological diversity allowing for long-term viability of species and ecosystems (Soulé, 1985; Kareiva and Marvier, 2012). However, investments in conservation are scarce, compelling conservationists and stakeholders to identify priority conservation areas with higher return on investments (i.e. greatest benefit per unit of cost). Protected areas are among the most effective strategies to prevent species extinction and to promote biological conservation (Adeney et al., 2009; Crouzeilles et al., 2013; Geldmann et al., 2013). In this scenario, Systematic Conservation Planning (SCP) emerges as an important approach to analyze and improve the effectiveness of networks of protected areas, and to define priorities of further resource investments. Through SCP, biodiversity representativeness in protected areas can be analyzed and priority areas can be indicated to ensure biological conservation in each specific socio-environmental context (Margules and Pressey, 2000; Watson et al., 2011). SCP can be particularly useful to achieve the 11th Aichi Biodiversity Target, set on The Convention on Biological Diversity in 2010, at Nagoya, Japan, which aims to protect at least 17 % of the terrestrial ecosystems. This protection is expected to be accomplished specially through ecologically representative and well connected network of protected areas, integrated into the socio-environmental landscapes (http://www.cbd.int/sp/targets).

SCP have been widely used to identify priority areas for conservation in forests (eg.: Soares-Filho et al., 2006; Venter et al., 2013; Crouzeilles et al., 2015; Vale et al., 2018) and coral reefs (eg.: Almany

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et al., 2009; Ban and Klein, 2009; O'Leary et al., 2012; Ban et al., 2014); yet it has been rarely applied in temperate grasslands. Temperate grasslands lost more than 46 % of their original extent worldwide and have less than 5 % of their area under protection (Hoekstra et al., 2005), hence a geographical region urging the expansion of the network of protected areas. A key example of temperate grassland under high threat is the Pampa biome in the south of Brazil, Uruguay and Argentina. Overbeck et al. (2016) argue that this is the most endangered Brazilian biome because it has the highest rate of converted areas in comparison to its protected areas. This biome has one of the smallest networks of protected areas in the world and the smallest in Brazil, with only 2.9 % of its Brazilian portion under any level of protection, and only 0.4 % under strictly protected areas (Jenkins et al., 2015), being pointed as the most important biome to fulfill spatial conservational gaps in Brazil (Fonseca and Venticinque, 2018). As a consequence of this critical situation, the Pampa biome lost the largest proportion of mammal populations in South America, together with the Atlantic Forest (Ceballos and Ehrlich, 2002) and has the highest number of threatened species of terrestrial vertebrates that are not represented in protected areas in Brazil (Torres and Vercilio, 2012). The minor coverage and effectiveness of the actual protected area network in Pampa biome makes its expansion imperative. This is not a new perception among scientists and environmentalists as the expansion of the network of protected areas in the Pampas was already pointed as a priority by many (Pillar et al., 2006; Overbeck et al., 2007; Pillar and Velez, 2010; Torres and Vercilio, 2012). Still, a SCP approach remains needed for the Pampa (Pinto and Grelle, 2009).

The Pampa biome plays an import role in food production (Pallarés et al., 2005; Guilhoto et al., 2007; Oliveira et al., 2017), which cannot be ignored when planning its protection. Cattle raising was first implemented in the 17th century, and since then meat and dairy are important food products of this biome (Litre, 2010; Overbeck et al., 2007). Posteriorly, large croplands were also implemented, especially soybean, rice, wheat and cultivated forests, reducing the grassland cover (Oliveira et al., 2017). These agricultural activities already converted 60 % of Pampa's area (Hasenack et al., 2006) and the original vegetation that remains is mostly used as pasture for livestock species (Nabinger et al., 2000; Overbeck et al., 2007). Nowadays, there are approximately 12,000,000 cows and 4,000,000 sheep on the Brazilian extent of the biome (IBGE, 2006), feeding mostly on native grasslands (Nabinger et al., 2000). This food production is also economically vital in Rio Grande do Sul state, which has the second largest food generated GDP in the country (Guilhoto et al., 2007), only after São Paulo state.

The conciliation between food production and biological conservation is one of the most important challenges of humanity (Tilman et al., 2002; Green et al., 2005) and protected areas of sustainable use can be very useful in this task. This regime of protection can be particularly important in the Pampa, where low-density livestock raising is considered a good opportunity to protect biodiversity and maintain food production (e.g.: Boldrini and Eggers, 1996; Oliveira and Pillar, 2004; Overbeck et al., 2007; Develey et al., 2008; Carvalho and Batello, 2009). Additionally, the conservation of current vegetation patterns can be threatened by shrub/wood expansion in strictly protected areas without fire or grazing in the north of the Pampa biome (Pillar and Velez, 2010). In this context, the more traditional SCP that considers only strictly protected areas is not suitable. We need to go beyond this traditional SCP and propose mixed strategies, where strictly protected areas, which are easier to control by environmental agencies, are combined with areas of sustainable use, allowing protecting for biodiversity while producing low-impact food products. This mixed strategy can be useful in other grassy ecosystems, as shrub/wood expansion is an actual threat in many grasslands and savannas worldwide (Archer, 1990; Moleele and Perkins, 1998; Laliberte et al., 2004; Overbeck et al., 2007; Baldi and Paruelo, 2008; Fernandes et al., 2016).

One of the main difficulties in any conservation planning for the Pampa is the poor knowledge of its biodiversity. For example, this is the Brazilian biome with the smallest number of publications about mammal species (Prevedello et al., 2008; Brito et al., 2009) and it has a similar position regarding invertebrates (Renner et al., 2018a). However, this lack of basic scientific information may be surpassed by using surrogates for biodiversity knowledge, which are measures/indicators or categories with close relationship with species occurrence (Margules and Sarkar, 2007; Carwardine et al., 2008; Watson et al., 2011). In this regard, vegetation types and land use in general are reliable biodiversity surrogates, as satellite images allow for accurate mapping of different types of vegetation cover and land use. Additionally, most species are strongly related to these variables, as it is the case at least for Odonata (Renner et al., 2018b) and dung beetles (Silva and Cassenote, 2019) in the Pampa biome. In South Africa, vegetation types were used to plan for the conservation in the Cape Floristic Region (Cowling and Heijnis, 2001), in the Subtropical Thicket Biome (Pierce et al., 2005) and in Maputaland (Smith et al., 2006). Many conservation plannings focused on marine ecosystem also used habitat types, as we can see on the review presented by Leslie (2005) where biogeographic regions and habitat types were the second most common conservation targets. More recently, Wedding et al. (2013) also used habitat types for marine conservation planning. In addition, there are examples on Brazilian ecosystems: in Pantanal, Lourival et al. (2009) used vegetation classes as surrogates for regional biodiversity and Crouzeilles et al. (2015) used habitat types when planning for restoration in Atlantic forest.

Considering the critical conservation situation of the Pampa, we present the first SCP for its Brazilian portion. Spatial planning respecting political borders is important because conservation actions are mostly implemented individually by each country. Our SCP has as conservation target to protect the main vegetation types of the biome, aiming to reach the 11th Aichi target by planning for the protection of 17 % of the Pampa biome area. Three scenarios with different proportions of native vegetation under strict protection and sustainable use areas are proposed. Aiming to minimize possible conflicts between biodiversity conservation and human activities, we integrated in our analysis socioeconomic variables as prioritization costs related to human occupation and land use activities.

2. Material and methods

2.1. Study area

The Brazilian extent of the Pampa biome covers approximately 170,000 km^2 (Fig. 1a), mapped in detail by Hasenack et al. (2006), which identified 14 native vegetation types, rural and urban anthropogenic areas. This map scale was 1:250,000 and all fragments that had their major axis greater than 250 m were mapped. Although there are vegetation maps of the biome based on more recent images (MapBiomas, 2018), they do not present the vegetation types as detailed as Hasenack et al. (2006). The Lowland Dense Ombrophilous Forest and the Submontane Dense Ombrophilous Forest were excluded from our prioritization because both are Dense Ombrophilous forests typical of the Atlantic Forest biome. They occur in the very border with Atlantic forest biome, on Maquine municipality, covering 2320 and 550 ha, respectively. To execute the SCP, the extent of the Brazilian part of the Pampa biome was divided in 1510 hexagonal planning units of approximately 10,000 ha each.

2.2. Scenarios

The 11th Aichi target aims to protect 17 % of land ecosystems by 2020, but it is not established whether this protection should be achieved through strictly protected areas (IUCN categories I to IV) or sustainable use protected areas (IUCN categories V and VI). We chose to compromise between these two possibilities presenting three complementary and comprehensive scenarios with different proportions of

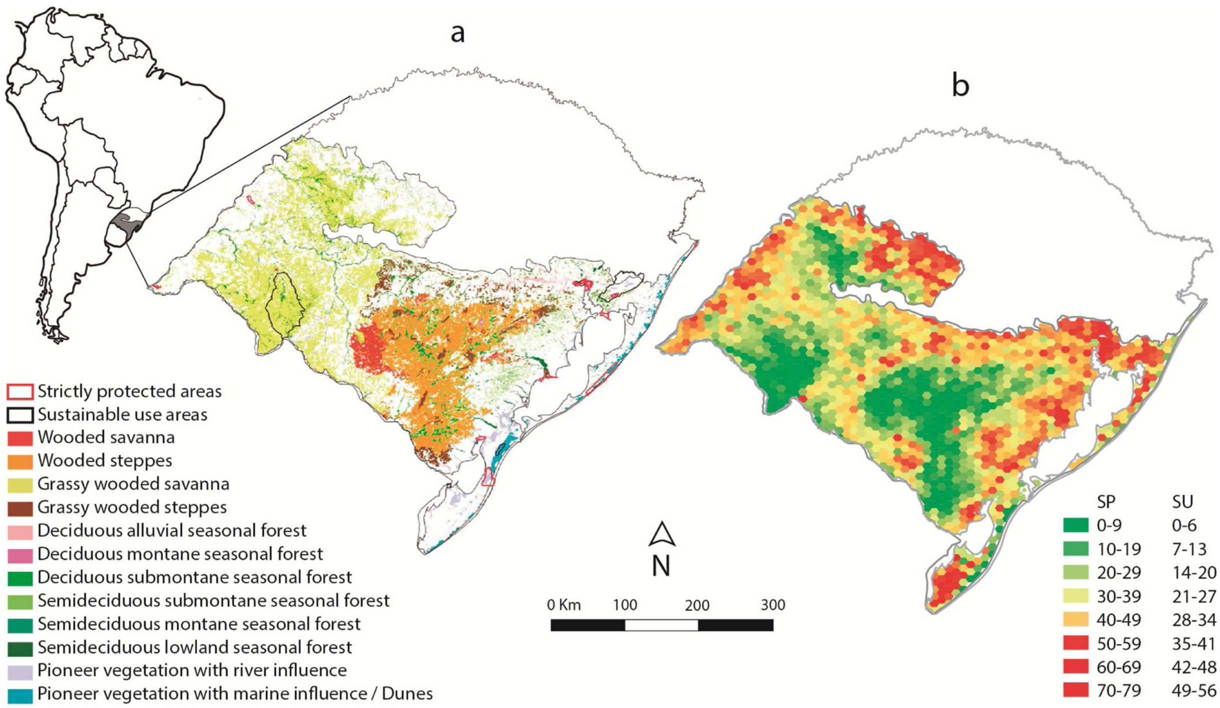

Fig. 1. Location of the Brazilian portion of the Pampa biome on South America. (a) Distribution of the 12 native vegetation types used in this prioritization as conservation targets. (b) Synthetic map of the prioritization costs (a dimensionless estimate). These prioritization costs were obtained throw a socioeconomic index considering urban area, agricultural area, bovine density, and sheep density in each planning unit. SP = prioritization costs for strictly protected areas; SU = prioritization costs for sustainable use areas.

strict protection and sustainable use for each vegetation type, but all protecting 17 % of the Pampa.

Permissive scenario: 5 % of the protected area allocated to strict protection and 12 % to sustainable use (corresponding to ca. 30 % and 70 % of total protected area, respectively).

Intermediate scenario: 10 % allocated to strict protection and 7 % to sustainable use (ca. 59 % and 41 % of total protected area, respectively).

Restrictive scenario: the least permissive to human use, allocates 15 % to strict protection and 2 % to sustainable use (ca. 88 % and 12 % of the total protected area, respectively).

As the Pampas' remaining vegetation covers approximately 42 % of the biome extent, we need to protect at least 40 % of the remaining vegetation to protect 17 % of the biome. In the Permissive scenario, where we have 5 % to strict protection and 12 % to sustainable use areas, 12 % of the remaining vegetation was assigned to strict protection and 28 % to sustainable use. In the Intermediate scenario, where 10 % of the Pampa area would be under strict protection and 7 % to sustainable use, 24 % of the remaining vegetation was assigned to strict protection and 17 % to sustainable use. Lastly, in the Restrictive scenario, where strict protection areas would cover 15 % of the Pampa's area and 2 % would be under sustainable use, 35 % of the remaining vegetation was assigned to strict protection and 5 % to sustainable use. One exception was made, because the Seasonal Semidecidual Mountain Forest only covers 3400 ha, this vegetation was 100 % protected in all scenarios. This 3400 ha is smaller than one planning unit and it represents only 0.01 % of the 17 % of land protection goal.

2.3. Socioeconomic costs

Conservation goals will only be achieved if we integrate into conservation plans the highly complex human contexts. We included the socioeconomic aspect in our prioritization by using four variables related to human occupation and land use: proportion of urban area, proportion of agricultural area, bovine density, and sheep density (Fig. 1b).

These four variables were integrated into a socioeconomic index (SEC), a dimensionless estimate. The SEC indicates the overall cost of each scenario by summing the costs of all planning units assigned to protection, both strict protection and sustainable use areas in each scenario:

$$SEC = \sum_{\substack{i=SP \\ j=SU}}^{1510} Uarea_i \times 100 + Aarea_i \times 50 + Bden_i \times 1 + Sden_i \times 0.5 + Uarea_j \times 70 + Aarea_j \times 35 + Bden_j \times 0.7 + Sden_j \times 0.35)$$

where *SP* represents planning units designed to strictly protected areas; *SU* represents planning units designed to sustainable use areas; *Uarea* the proportion of urban area in each planning unit; *Aarea* the proportion of agricultural area in each planning unit; *Bden* the bovine density in each planning unit; *Sden* the sheep density in each planning unit; 1510 represents the total number of available planning units.

To guarantee that the most pristine areas would be indicated to strict protection, SEC attributed higher penalties for planning unities assigned to strict protection than for sustainable use. This induces the algorithm to indicate the planning units with the smaller anthropogenic disturbance for this restrictive zone in order to achieve the smallest total cost for each scenario.

Among the four socioeconomic variables, SEC designated the highest penalty to urban areas because of the severe landscape modification it implies (Savarda et al., 2000; McKinney, 2002), which makes urban areas mostly incompatible with any strategy of protection. The penalty for agricultural areas was specified as half of the urban area. Consequently, a planning unit that has 40 % of agricultural areas will be equivalent in costs to a planning unit with 20 % of urban areas. Urban and agricultural areas were obtained through the same map that was used to obtain the vegetation data (Hasenack et al., 2006).

Bovine and sheep density were used as a second level of prioritization costs, with smaller penalties compared to urban and

Table 1
Vegetation types aimed in this prioritization, their total area of remnants and the area assigned to strict protection (SP) and sustainable use (SU) under three different scenarios. In parentheses the proportion of the target protected for each vegetation type in each scenario under each kind of protection; values greater than 1.00 indicates that the target was meet.

Vegetation type	Available area (km^2)	Permissive scenario		Intermediate scenario		Restrictive scenario	
		SP 5 %	SU 12 %	SP 10 %	SU 7 %	PI 15 %	US 2 %
Wooded savannas	2961	359 (1.01)	832 (1.00)	724 (1.04)	497 (1.02)	1052 (1.01)	179 (1.21)
Wooded steppes	16899	2029 (1.00)	4783 (1.01)	4001 (1.01)	2871 (1.03)	5916 (1.00)	891 (1.05)
Grassy wooded savannas	28087	3376 (1.00)	7866 (1.00)	6615 (1.00)	4654 (1.00)	9836 (1.00)	3883 (2.76)
Grassy wooded steppes	4584	578 (1.05)	1284 (1.00)	1082 (1.00)	757 (1.00)	1605 (1.00)	236 (1.03)
Deciduous alluvial seasonal forest	401	54 (1.12)	114 (1.01)	101 (1.07)	67 (1.02)	141 (1.00)	20 (1.02)
Deciduous montane seasonal forest	180	25 (1.14)	53 (1.05)	42 (1.01)	33 (1.10)	68 (1.07)	9 (1.03)
Deciduous submontane seasonal forest	8484	1020 (1.00)	2379 (1.00)	1995 (1.00)	1400 (1.00)	2970 (1.00)	535 (1.26)
Semideciduous lowland seasonal forest	561	108 (1.61)	160 (1.02)	133 (1.01)	93 (1.01)	205 (1.04)	42 (1.48)
Semideciduous montane seasonal forest	34	10 (1.00)	24 (1.00)	20 (1.00)	14 (1.00)	30 (1.00)	4 (1.00)
Semideciduous submontane seasonal forest	1586	199 (1.04)	445 (1.00)	372 (1.00)	262 (1.00)	558 (1.00)	81 (1.02)
Pioneer vegetation with river influence	3123	522 (1.39)	875 (1.00)	736 (1.00)	516 (1.00)	1092 (1.00)	160 (1.03)
Pioneer vegetation with marine influence / Dunes	1272	384 (2.51)	360 (1.01)	434 (1.45)	251 (1.20)	508 (1.14)	87 (1.37)

agricultural areas. The difference in the cost values between urban / agricultural areas and bovine / sheep density is because these livestock species are usually raised in native grasslands in Pampa biome (Nabinger et al., 2000). Consequently, livestock raising in Pampa biome represent a minor modification of the landscape compared to urban areas and croplands, which imply total clearance of native vegetation. Bovine density received higher penalties than sheep density because of their larger body size, which implies a more intense pasture pressure on native grasslands. The number bovine and sheep per administrative unit (city or town) were obtained through national agricultural census (IBGE, 2006).

2.4. Spatial prioritization

We used the decision support software Marxan with zones (Watts et al., 2009), a multiland use planning version of Marxan, with the objective of identifying the combination of land use strategies and locations that minimize the costs of meeting prespecified conservation targets. In this SCP we had two different zones: strict protection and sustainable use.

Marxan with zones allocates the planning units to each zone aiming to achieve the specified conservation targets (in this paper 17 % of land protection by protecting 40 % of the remaining vegetation) with minimum costs using the simulated annealing algorithm (Watts et al., 2009). In this algorithm, a random network of planning units is selected in each iteration, consequently, in each iteration the total cost changes. In this paper, we conducted 500 repetitions with 100.000.000 iterations in each repetition. For each scenario (different proportions of strict protection and sustainable use), the repetition where the conservation targets were achieved with minimum costs was selected. Before the iterations, the existing protected areas were fixed to their zones (strict protection or sustainable use). When we fix some planning units to a certain zone, part of the conservation target is already achieved and the indication of the other planning units to that zone will consider the conservation target already accomplished.

In addition to present all the planning units selected to strict protection and sustainable use in each scenario, we also present the irreplaceable planning units (Pressey et al., 1994), those with rare biological characteristics making them irreplaceable to achieve the conservation targets. Planning units selected in at least 450 of the 500 repetitions were considered irreplaceable for each scenario.

Besides socioeconomic costs (SEC), the Boundary Length Modifier (BLM) was used as a cost coefficient in this prioritization. BLM tries to minimize the boundary length of the reserve system, considering that a single and larger protected area is better than multiple smaller ones (Possingham et al., 2000). If the BLM is set to zero, the algorithm will ignore boundary length and the resulting network of protected areas is fragmented. Here we tested multiples values of BLM and opted to use BLM = 1, since different values over zero of BLM provided similar aggregation patterns.

2.5. Anthropogenic increase on priority areas

As our SCP used a vegetation map mostly build on 2002 satellite images (Hasenack et al., 2006) and considering that the Brazilian Pampa biome still presents a considerable habitat loss (Oliveira et al., 2017), we analyzed the extent of anthropogenic increase in our conservation priority areas. We compared the increase in the anthropogenic areas (both urban and rural) between 2002 and 2017 (MapBiomas, 2018) among planning units selected for strict protection, planning units selected for sustainable use and planning units not selected for conservation. These analyses were conducted for each scenario separately using analyses of variance.

3. Results

All the three scenarios were able to achieve their conservation goals for all the vegetation types (Table 1). In the Permissive scenario (5 % of strict protection / 12 % of sustainable use protection), 379 planning units were selected, 137 for strict protection and 242 for sustainable use protection (Fig. 2). In the Intermediate scenario (10 % strict protection / 7 % sustainable use) 376 planning units were selected, 230 for strict protection and 146 for sustainable use (see Fig. 2). In the Restrictive scenario (15 % strict protection / 2 % sustainable use) 419 planning units were selected, 338 for strict protection and 81 for sustainable use (see Fig. 2). The higher number of planning units selected in the Restrictive scenario demonstrates how deficient is the current network of protected areas in terms of strictly protected areas. A plan with a higher proportion of land under strict protection requires adding more planning units to the solution than a plan with higher proportion of land under sustainable use, which have a higher number of planning units already protected.

Similarly, we found an increase in the number of planning units considered as irreplaceable from the Permissive scenario to the most restrictive one (Fig. 2). The Permissive scenario had 73 irreplaceable planning units, most of them placed in the sustainable use area (24 strict protection / 49 sustainable use). The Intermediate scenario had 120 irreplaceable planning units, most of them placed within strictly protected areas (96 strict protection / 24 sustainable use). The Restrictive scenario had 203 irreplaceable planning units, most of them placed under strict protection (199 strict protection / 4 sustainable use).

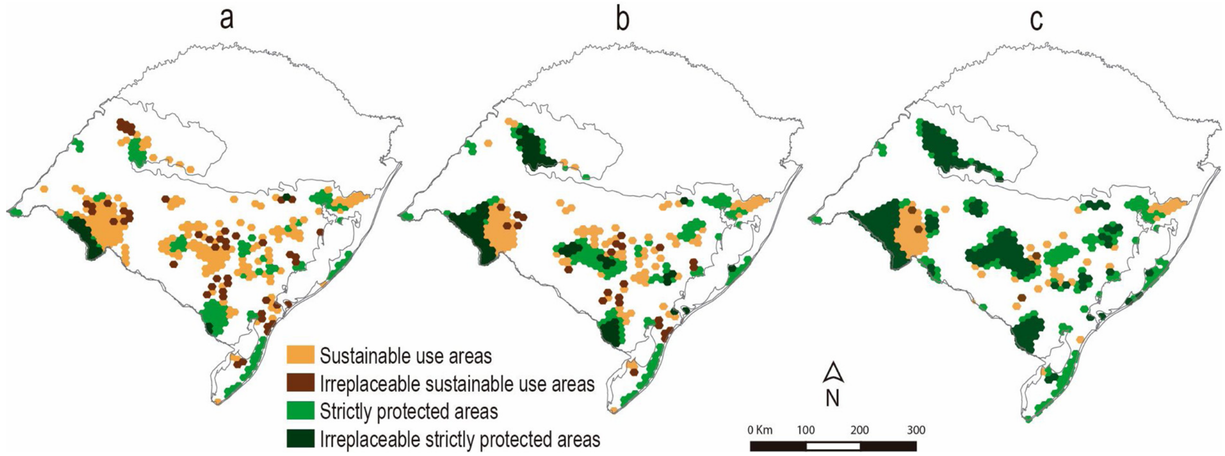

Fig. 2. Spatial zonation of planning units selected for strict protection or for sustainable use and the spatial zonation of irreplaceable planning units - which were selected in at least 450 of the 500 repetition in each scenario for strict protection or for sustainable use in this Systematic Conservation Planning for Pampa biome. (a) Permissive scenario: 5 % strict protection / 12 % sustainable use. (b) Intermediate scenario: 10 % strict protection / 7 % sustainable use. (c) Restrictive scenario: 15 % strict protection / 2 % sustainable use.

The Permissive scenario had the smallest total cost (SEC index = 4590), followed by the Intermediate one (SEC = 4898), and consequently the Restricted scenario had the highest total cost (SEC = 6087). This is an expected pattern, once we set that any planning unit selected to strict protection would add higher costs for the protected area network, and the Restricted scenario had the most ambitious target for this class of protected areas.

Although the selected planning units were spatially scattered, in all three scenarios we found the same four main clusters of selected units to protect the different types of vegetation in the Brazilian Pampas (Fig. 2). These clusters were located (1) at the northwest of Rio Grande do Sul state, (2) on the west face of the current Ibirapuitã Environmental Protection Area - an international border with Uruguay, (3) in the central region of the planning area, and (4) in the southernmost of Rio Grande do Sul, also an international border with Uruguay. These clusters comprised most of the irreplaceable planning units, especially in the Restrictive scenario, where 82 % of the irreplaceable planning units selected where within these four priority clusters.

Planning units selected for strict protection and sustainable use in all scenarios had smaller increase of anthropogenic areas than planning units that were not selected for any kind of protection between 2002 and 2017 (Fig. 3). In the Restrictive scenario, planning units that were not selected had an average increase of anthropogenic areas of 19.84 %; planning units selected for sustainable use had an average increase of anthropogenic areas of 10.15 % and planning units selected for strict protection had an average increase of anthropogenic areas of 9.78 % (Fig. 3a; $F = 70.86$ on 2 and 1507 DF, p-value: < 0.001). In the Intermediate scenario, planning units that were not selected had an average increase of anthropogenic areas of 19.79 %; planning units selected for sustainable use had an average increase of anthropogenic areas of 9.66 % and planning units selected for strict protection had an average increase of anthropogenic areas of 10.37 % (Fig. 3b; $F = 68.54$ on 2 and 1507 DF, p-value: < 0.001). In the Restrictive scenario, planning units that were not selected had an average increase of anthropogenic areas of 19.94 %; planning units selected for sustainable use had an average increase of anthropogenic areas of 8.51 % and planning units selected for strict protection had an average increase of anthropogenic areas of 11.23 % (Fig. 3c; $F = 67.73$ on 2 and 1507 DF, p-value: < 0.001).

4. Discussion

The current SCP is distinct from most of the prioritization of protected areas available as it planned both for strict protection and sustainable use areas. This SCP also provides alternative strategies to reach 17 % of land protection in the Pampa biome, the 11th Aichi Biodiversity Target. This approach is important on the north of Pampa, as many consider that low-density livestock raising is a good opportunity to protect biodiversity and maintain food production in the Pampa (e.g.: Boldrini and Eggers, 1996; Oliveira and Pillar, 2004; Overbeck et al., 2007; Develey et al., 2008; Carvalho and Batello, 2009). This view is based on the assumption that livestock species could fulfill the ecological role of native herbivores, avoiding the shrub/wood expansion on this grassy biome, hence protecting native species of the Pampa. In this subtropical portion of South America livestock grazing seems to prevent tree expansion into the grasslands (Bernardi et al., 2016) and the conservation of current vegetation patterns can be threatened in strictly protected areas without fire or grazing in the Pampa biome (Pillar and Velez, 2010). Considering this complex situation, implementing the scenario with larger proportion of sustainable use areas (Permissive

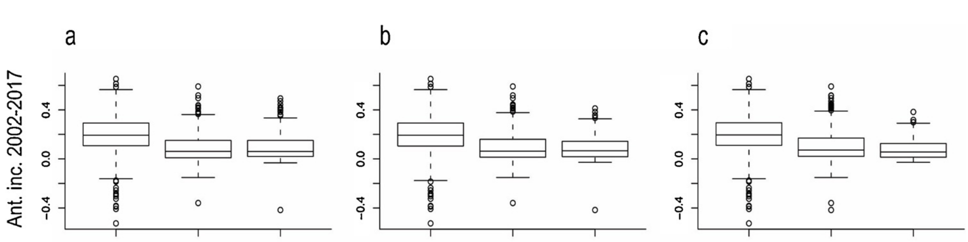

Fig. 3. Comparison of anthropogenic increase between 2002 and 2017 in planning units not selected (NS) for conservation; planning units selected for strict protection (SP) and planning units selected for sustainable use (SU) in this Systematic Conservation Planning for Pampa biome. (a) Permissive scenario; (b) Intermediate scenario; (c) Restrictive scenario. Median values showed on the middle of the box; box length represents the upper and lower quartiles; error bars represent ± 1.5 * inter-quartile range and dots represent observations considered outliers. Ant. inc. = Anthropogenic increase.

scenario), can be more appropriate for Pampa biome, where low-density livestock raising could be implemented as a wildlife-friendly farming technique.

Choosing between the implementation strictly protected *vs.* sustainable use areas is not a simple task and there is no available recommendation from The Convention on Biological Diversity regarding such decision. All the planned scenarios had both kind of protection because we believe that both will bring unique and complementary benefits to biodiversity in Pampa. Sustainable use areas will promote the conservation of the current biological patterns, maintaining the grassland cover, and food production. Strictly protected areas will not have a role in food production and could not preserve the current grassland cover, but these areas will be important to preserve species most affected by livestock grazing, and to preserve the biological diversity of grassland-forest mosaics, favoring higher beta-diversity on Pampa's landscapes (Azpiroz et al., 2012; Luza et al., 2014). For small mammals, it seems to be important to maintain areas with low-density of livestock as well as ungrazed areas (Luza et al., 2018). For birds, ungrazed grasslands are associated with species more dependent on tall grasses, including threatened species, while grazed grassland are associated to species more dependent on short grasses and less dependent on vegetation height (Jacoboski et al., 2017). Therefore, for higher bird diversity it is important to maintain grassland mosaics with plants of different heights, associated to ungrazed and grazed areas (Azpiroz et al., 2012; Jacoboski et al., 2017). Additionally, strictly protected areas use to present stronger control from environmental agencies and to present better conditions to biodiversity conservation than sustainable use areas (Crouzeilles et al., 2013). Considering that strictly protected areas are also important to Pampa's preservation and that Brazilian Pampa biome has only 0.4 % of its area under strict protection (Jenkins et al., 2015), the implementation of this restrictive kind of land protection also should be instigated in the Pampas, along with sustainable use areas.

Incorporation of the human context is crucial to diminish the conflict between biodiversity conservation and human activities. Consequently, socioeconomic variables are frequently used as prioritization costs in SCP (Balmford et al., 2001; Chown et al., 2003; Lawler et al., 2003; Pinto et al., 2007). The prior inclusion of potential sources of conflict between human activities and protected area increases the probability that these protected areas will be implemented and successful in protecting the biodiversity (Ban et al., 2013). The inclusion of these socioeconomic variables are probably also related to the smaller rates of anthropogenic increase that our priority areas had in comparison with the non-priority areas, once habitat conversion are often facilitated by historical human use (Müller et al., 2012a,b; Busch and Ferretti-Gallon, 2017). Including bovine and sheep density in our prioritization is also important to diminish any possible productive loss of livestock raising due to implementation of future protected areas. In these new protected areas, livestock species should be eliminated (in strict protection areas) or reduced to very low densities (in sustainable use areas), allowing that native species have some photosynthetic products for their own. Besides minimizing productive loss, it is important to give smaller conservation value for grasslands with high density of livestock, once these areas will probably present higher levels of degradation due to overgrazing and trampling (Overbeck et al., 2007; Carvalho and Batello, 2009; Castilhos et al., 2009).

The four priority clusters indicated in this prioritization comprise most of the remaining vegetation diversity of the biome, with the smallest anthropogenic disturbance levels. One of these clusters is located on the northwest of Rio Grande do Sul, corresponding to the last remnants of native vegetation in an intense agricultural region of the state (IBGE, 2006). Protecting the area under this cluster will be crucial to prevent the expansion of croplands on these last native remnants. Another priority cluster is close to Ibirapuitã Environmental Protection Area, the largest protected area of sustainable use in the Brazilian Pampas. However, because of its large size (ca. 317,000 ha), inefficient surveillance and control, biodiversity are poorly protected in this protected area, where even endangered species are frequently hunted (Peters et al., 2011). For this reason, the biodiversity protection in the area under this cluster would be improved by providing better management in this already implemented sustainable use area and by implementing additional and more restrictive protected areas. The other two clusters indicated as priority areas for the Pampa conservation - central and south regions of planning area - contain a great diversity of relief and soil and consequently contain several vegetation types, ranging from pure grasslands to shrublands, savannas, woodlands and riparian forests. Preserving these two clusters is, therefore, crucial to preserve the vegetation diversity of the biome, the main goal of the prioritization presented in this paper. The great number of planning units considered irreplaceable inside these four clusters is also an indicative that they contain a considerable part of the vegetation diversity in the Pampas, as their protection were projected in almost all repetitions of each scenario. These irreplaceable areas should receive special attention and the expansion of the protected area network should start considering these areas.

This is the first SCP for the Pampa biome, but there are four technical reports that had indicated areas for implementation of protected areas for this biome. The Brazilian Ministry of the Environment elaborated and requested two technical evaluations regarding priority areas for implementation of protected areas in this biome (MMA, 2007; Vélez, 2010). These technical evaluations were elaborated using combinations of automated and non-automated procedures. Although they use diverse methods and targets, they agree with the current SCP, indicating the central and the northwest regions of Rio Grande do Sul as priority for Pampa's conservation. The central region of Rio Grande do Sul was also pointed as priority for Pampa's conservation by Bilenca and Miñarro (2004) and Bencke et al. (2006), which used expert opinion to indicate priority areas for grassland and bird conservation on the Pampa. These four prioritizations did not account for socioeconomic costs neither proposed combination of strict protection and sustainable use areas, but even with very different methods, they agree with the current SCP in most of the presented priority cluster regions, highlighting the biological value of these areas.

5. Conclusion

We presented the first formal SCP proposal for the Pampa biome, a diverse grassland with high biological importance, but insignificant conservation plans and actions. In this biome covered mostly by grasslands, the Permissive scenario is suitable for low-density cattle raising where biodiversity protection would be combined with food production mostly in areas of sustainable use. Although, even the Permissive scenario plans also for strictly protected areas, where species most affected by cattle raising would be protected, into a perspective of conservation of the entire grassland-forest mosaics in this biome. This SCP for the Pampa is an example of optimal combinations between strict protection and sustainable use areas, opening new strategies to achieve the 17 % of land protection (the Aichi target 11). It could be used as a starting point in future international negotiations (eg.: Beijing 2020), considering that we have a very diverse biosphere within different needs and realities. The importance of the present prioritization is also highlighted because it considered important socioeconomic variables as prioritization costs. When including these socioeconomic costs, this SCP incorporated the current conflicts between human activities and biodiversity conservation in the Pampa biome. Consequently, the protected area network presented here, considering any scenario, has a great probability of effectively protect the Pampas' biodiversity. This was confirmed when comparing the anthropogenic increase between priority areas and non-priority areas in the Pampa. We believe this SCP has an important role to play into the recently started scientific discussion regarding the conservation of non-forest ecosystems in Brazil (see Overbeck et al., 2007; Luza et al., 2014 and

Overbeck et al., 2016), offering a powerful conservation strategy.

Author statement

D.O.L worked on study conceptualization, carried out the analysis and wrote the original draft; R.C. carried out the analysis, reviewed and edited the manuscript; M.V.V worked on the study conceptualization, reviewed and edited the manuscript.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.landusepol.2020.104836.

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