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Private reserves in Brazil: Distribution patterns, logistical challenges, and conservation contributions

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Abstract

Traditional strategies to stem declines in biodiversity include the establishment of public protected area networks. However, private lands are an increasingly important component of contemporary reserve networks. Despite the increasing recognition of the value of private lands for conservation little is known about these areas. Consequently, this study aimed to re-evaluate the changes in private reserves in Brazil since 2005. Brazil's private reserve system is represented by 1,182 reserves, recognized under federal law and created to protect nature in perpetuity. These reserves protect 7,502 km^2 of land and are distributed across seven terrestrial biomes. This is an overall increase of 35% in the number of reserves (n=753) and 3,265 km² of protected land (<0.05% of Brazilian terrestrial extent) since 2005. Forty-eight percent of the reserves (n = 572) are each smaller than 0.5 km². While 749 (67%) of all private reserves (n=1,182) are located in the Atlantic Forest biome, 38% of the overall area protected under the private reserve system is in the Pantanal biome, which has only 10 reserves. For landowners, the establishment of these reserves is a costly and bureaucratic process. Few economic incentives to establish reserves are available and comprise mostly tax breaks and funding from NGOs to assist with the establishment and management activities. The private reserve network provides valuable contributions to watershed and species conservation in Brazil, despite their limited size and challenges to create and manage these areas. Greater funding opportunities to landowners can be a catalyst for the establishment of reserves beyond the Atlantic Forest biome.

Keywords: landowners; RPPNs; endangered species; private lands; economic incentives

1.1 Introduction

Traditional global approaches to stem the ongoing loss of biodiversity centre around the establishment of public protected area (PA) networks (Chape et al., 2008; Butchart et al., 2010; Hoffmann et al., 2010). Globally, more than 196,000 PAs (Protected Planet, 2013) protect approximately 13% of the planet's terrestrial biomes (World Database of Protected Areas [WDPA], 2012). Public protected areas are, however, inadequate in fully protecting global biodiversity (Rodrigues et al., 2004) with many threatened species being found only on private lands (Richardson, 1998; Knight, 1999; Krug, 2001; Figgis, Humann & Looker, 2005; Fisher and Dills, 2012). Consequently, failure to account for private lands in conservation can bias assessments towards restricted sets of habitat types leading to underrepresentation at the landscape-scale (Hilty & Merenlender, 2003). The inclusion of private reserves into global PA measures is therefore required to provide a more comprehensive assessment of conservation benefits and management strategies to better evaluate biodiversity loss.

The varied contributions of private reserves to conservation are widely reported (Fitzsimons & Wescott, 2008; Gallo et al., 2009; Pasquini et al., 2010; Pasquini et al., 2011; Fitzsimons & Carr 2014; Holmes, 2015). One of the primary conservation values associated with private reserves is the additional areal extent that supplements existing public reserve networks (Fitzsimons & Wescott, 2008; Wallace et al., 2008; Gallo et al., 2009; Pasquini et al., 2010). Like public protected areas, private reserves also contribute to biodiversity conservation by acting as catalysts for broader land management practices that support conservation goals (Taylor et al., 2011; IUCN/WCPA, 2012; Miller et al., 2012). They can help to establish wildlife corridors and buffer zones (Vieira & Mesquita, 2004; Ribeiro et al., 2009; Worboys et al., 2010; ICMBio, 2012), provide economic returns via payments for ecosystem services (PES) (Alderman, 1991; Langholz et al., 2000; Kareiva, 2010; Swift et al., 2004) and tourism (Buckley, 2009; Pegas & Castley 2014), and help to mitigate the environmental impacts of climate change (Heller & Zavaleta, 2009).

Private reserves in many countries are, however, based on informal land management systems characterized by the lack of a legally binding contract or only short-term contracts, restricted land use practices, and are typically small in size (Theulen et al., 2003; Watson, 2005; Sims-Castley et al., 2005; Morsello, 2008; Kareiva, 2010). Elsewhere, such as in Australia, binding conservation covenants systems form part of national level conservation policy (Fitzsimons & Carr, 2014), while in Chile, neoliberal conservation approaches facilitate private landowner engagement with private conservation efforts (Holmes, 2015). Furthermore, few countries have detailed inventories of these reserves making assessments of their environmental and economic contributions a challenging endeavour. Previous studies have often adopted case-study approaches when assessing the potential value of private reserves (e.g. Langholz et al., 2000; Sims-Castley et al., 2005; Buckley, 2009) but few consider national comparisons of conservation parameters (e.g. size, distribution, biome representation, and ownership).

Brazil is widely regarded as a country of global conservation significance (Dirzo & Raven, 2003; Lewinsohn & Prado, 2005), containing 40% of the world's remaining tropical forests (Peres, 2005), the world's largest floodplain (Pantanal) and eight Ramsar sites (Chape et al., 2008). Much of the Brazilian landscape is also contained within two large global biodiversity hotspots, the Atlantic Forest and Cerrado regions (Myers et al., 2000). Furthermore, the country contains 50% (WDPA, 2012) of the world's largest biosphere reserves (MMA, 2010). Brazil's biomes support approximately 104,500 animal and 43,900 plant species and an estimated 20% of global biodiversity (SECOM, 2014).

In Brazil, initiatives to protect ecosystems and species are also generally dependent on the establishment of public protected areas (PA). The public PA network covers approximately 18.1% or ~1.54 million km^2 of the country, while indigenous reserves cover an additional 12.8% or ~1.09 million km^2 (MMA, 2010). This places Brazil first among the top five nations with the largest acreage of land classified as public PAs followed by China, Russia, the United States and Greenland (WDPA, 2005). Brazil's public PA network comprises 1,620 PAs divided into 310 federal, 621 state and 689 municipal PAs and 522 indigenous reserves (MMA, 2010). Most of the public PAs are, however, poorly funded and staffed, and are threatened by a myriad of legal and illegal activities (Dirzo & Raven, 2003; Lewinsohn & Prado, 2005; MMA, 2010; CBD, 2012). Pressures to biodiversity conservation in Brazilian public protected areas include deforestation in the Amazon for beef production and logging; soy, beef, and charcoal production in the Cerrado; and urban and coastal development in the Atlantic Forest biome (Fearnside, 2001; Brandon et al., 2005; Soares-Filho et al., 2006; Sparovek et al., 2010). These activities severely challenge, and often pose barriers, to conservation efforts.

1.2 The Brazilian private reserve system

Private reserves in many countries are frequently voluntary without any legal standing, but also include those established using contractual arrangements and binding obligations (Figgis et al., 2005; Fitzimons & Wescott, 2008; Von Hase et al., 2010; Fitzsimons & Carr, 2014). In contrast, private reserves in Brazil are legally binding agreements enacted by the federal Decree 98.914 of 1990 and termed Private Natural Heritage Reserves or simply RPPNs (*Reservas Particulares do Patrimônio Natural*) (Rambaldi et al., 2005). In 2000, RPPNs were recognised as Conservation Areas of Sustainable Use by Brazil's federal environmental agency, which today is the *Instituto Chico Mendes de Biodiversidade* (Chico Mendes Institute of Biodiversity Conservation [ICMBio]), under federal law No. 9.985 (Souza & Corte, 2009). This law was later amended (Article 21, Law 9.985/2000) to prohibit any direct use of the natural resources within RPPNs (Ficangna, 2009). According to existing legislation, RPPNs are created to conserve biodiversity in perpetuity, have conservation as their primary goal, and can only be used for research, conservation, education and ecotourism. Therefore, while RPPNs can be freely traded by landowners their boundaries cannot be

altered (Rambaldi et al., 2005). However, unlike the conservation easement model or other market based incentives used elsewhere (Figgis et al., 2005; Fizsimons & Wescott, 2008; Farmer et al., 2011), RPPN landowners are poorly incentivised. Brazilian landowners receive modest tax breaks as incentives to establish private reserves in their land. Among these incentives, government schemes provide priority access to government funding sources, and, in some areas and on a biome-basis, may gain access to financial support from conservation NGOs.

Conversely, there is incentive for local governments to support private conservation efforts through existing PES schemes. In Brazil, the principal PES scheme is known as the E-ICMS (*Ecológico Imposto sobre Operações relativas à Circulação de Mercadorias e Prestação de Serviços de Transporte Interestadual e Intermunicipal e de Comunicação*) ("Tax on the Circulation of Goods and Services across interstate lines"). In short, the ICMS is the Brazilian state taxation system with the "E" specifically linked to ecologically related tax revenues. At the county scale, the larger the area officially classified as "protected" (i.e. including RPPNs), the larger the economic return. So far, however, E-ICMS economic benefits are paid to municipalities and may not be passed on to individual landowners (ICMS Ecológico, 2014).

1.3 RPPNs in Brazil: The 2005 assessment

To our knowledge, the 2005 study conducted by Rambaldi et al. (2005) provided the first nationwide overview of the RPPN system, which was represented by 411 RPPNs at the time. There has been substantial growth in the private reserve network since 2005 and a review of the nationwide contribution of private lands to conservation is warranted. For instance, little is known about the nationwide distribution, tenure, extent of RPPNs, or the threats facing them. Only recently has a comprehensive study on tourism development in RPPNs at the national scale been conducted (Pegas & Castley, 2014). Therefore, this paper aims to reduce some of the existing knowledge gap by re-evaluating changes to the RPPN system since the last assessment by Rambaldi et al. (2005). In doing so we aim to determine whether (a) the pattern of private land distribution has changed over the past decade and (b) what the potential implications for biodiversity conservation may be.

Aside from the work by Rambaldi et al. (2005), previous studies investigating the RPPN system are largely published in Portuguese and have been case study investigations (e.g., Melo, 2004) or provided general information about the RPPN system (Mesquita & Leopoldino, 2002; Theulen, Milano & Nunes, 2003; Müller, 2011). Previous studies also focused on specific states (Machado, 2007; Marquest & Ranieri, 2012), biomes (e.g., Santos & Costa, 2008), or species (e.g., Palmuti et al., 2009; Marçal et al., 2009) rather than incorporating these themes into a national analysis. Given the relatively narrow focus of many previous studies as well as the concentration in Portuguese literature, our paper provides a widely accessible comprehensive nationwide summary.

1.4 Methods

Information about the regional distribution, size, ownership, location, biome representation, and land ownership of RPPNs was gathered between July 2012 and July 2014. Most of this information is from two publically available free of charge online data sources published in Portuguese: *SIM*RPPN and CNRPPN. The ICMBio manages the *SIM*RPPN database, which is limited to federal-enacted reserves (SIMRPPN, 2014) while the CNRPPN database is managed by the National Confederation of RPPNs. The CNRPPN database includes information about local, state and federal-enacted reserves. Data availability and level of detail was inconsistent within and across these databases. These data gaps constrained our ability to accurately quantify key variables (e.g. year of establishment) for the reserves as a whole. Access to reserve coordinates (e.g., spatial register of each reserve) was also problematic and the lack of such information prohibited a better understanding of the extent to which RPPNs contribute to the establishment of wildlife corridors and buffer zones in fragmented habitat areas. Despite these limitations we are confident that data presented here provide a general reflection of the current state of the Brazilian private reserve system, albeit at the county level.

To ascertain the overall number of reserves, we aggregated both databases and removed duplicate records by cross referencing RPPN names, county location and state. Data were captured into ArcGIS to facilitate spatial representation and analysis of distribution patterns by municipality throughout Brazil. These analyses were completed by using spatial joins to assign biome and municipality parameters to each individual RPPN prior to summarising data. The visual illustration of the location of these reserves at the municipality level across Brazil was not possible because of scale challenges. We also compared patterns within the RPPN network with the public protected area estate (PAs) using WDPA Protected Planet data from 2015 (www.protectedplanet.net). For these comparisons we restricted our analysis to only IUCN Category I-IV classes. As for private reserves, the number of PAs in each county was determined using spatial joins. The relationships among counties with RPPNs and PAs were quantified by enumerating the number of PAs in 100km buffers placed around each county. Neighbourhood relationships were also determined by calculating the distance from RPPN counties to all PAs within this 100km buffer. These PA patterns were then summarised by biome for comparison with the RPPN data.

Additional information on land tenure laws and public protected areas was gathered from peer reviewed publications and government reports from publicly available open access literature. With few exceptions, information gathered for this study was only available in Portuguese. The first author, who is Brazilian and fluent in Portuguese, translated this information.

1.5 Results

1.5.1 Distribution and extent of the RPPN system

As of July 2014, the private reserve system of Brazil was represented by 1,182 RPPNs covering 7,502 km² of land across 623 municipalities. Most of the reserves (n=1,088) were listed in

the CNRPPN database with 596 in the *SIM*RPPN database. There are 502 reserves in common between the two databases, with 586 unique to the CNRPPN database and 92 unique to the *SIM*RPPN database. This is an overall increase of 35% in the number of reserves (n=753) and 3,265 km² of protected land since 2005. This represents a 77% increase in the private conservation estate but less than 0.05% of the Brazilian land surface overall.

Sixty-seven percent (n=797) of all RPPNs in Brazil are located within the Atlantic Forest biome with a further 19% (n=222) in the Cerrado biome (Figure 1). All remaining biomes have fewer than 100 RPPNs within their boundaries.

RPPNs cover the greatest overall extent in the Pantanal biome (2678.7 km²), followed by the Cerrado and Atlantic Forest biomes (1896.6 km² and 1627.8 km² respectively). Among the biomes, the Pantanal recorded the greatest gains in protected area extent since 2005 (2174.3 km²). The average size of reserves in the Pantanal biome is also one to two orders of magnitude larger than those in other biomes (Table 1). The greater size of RPPNs in the Pantanal biome is also highlighted by the fact that reserves in this biome only make up 2% of all RPPNs. Overall the average size of the 1,182 reserves is 6.35 km², a fourfold decline since 2005, but substantial variation exists among biomes.

Large reserves (>10 km²) represent only 9% (n=110) of reserves across all biomes, whereas 48% are smaller than 0.5 km² and 75% are smaller than 2.5 km² (Table 2). Notably, 81% of all the land protected by the RPPN system is captured in only the largest reserve size category.

The preponderance of RPPNs within the Atlantic Forest and Cerrado biomes is also reflected in the states with the highest numbers of reserves. Minas Gerais has the greatest number of reserves with these split amongst the Atlantic Forest (n=158), Cerrado (n=100) and Caatinga (n=2) biomes. While Paraná has a lower number of reserves than Minas Gerais overall, a greater number of these fall within the Atlantic Forest (n=206) compared to the Cerrado (n=16). Rio de Janeiro (n=137) and Bahia (n=108) are the only other states with more than 100 RPPNs within their borders. Nine counties have 10 or more RPPNs (n=119 or 10% of all RPPNs) with the greatest number being found in Rio de Janeiro: Silva Jardim (n=20), Nova Friburgo (n=18) and Varre-Sai (n=13); Minas Gerais: Coromandel (n=14), Aiuruoca (n=10); and Bahia: Porto Seguro (n=12). Barão de Melgaço (878.7 km²) (Mato Grosso) and Corumbá (823.9 km²) (Mato Grosso do Sul) are the counties with the greatest acreage under the RPPN system. Conversely, Cubatão (0.70 ha) (São Paulo) and São Fidélis (0.74 ha) (Rio de Janeiro) are the counties with the smallest extent protected under the RPPN system (Figure 2).

1.5.2 Comparisons among RPPNs and public protected areas

A total of 371 Category I-IV public PAs covered almost 490 000 km² with all biomes represented in the public reserve network. The greatest number of PAs was in the Atlantic Forest and Cerrado

Biomes, while those in the Amazon covered by far the largest area (Table 3, Figure 2). Of the 623 counties containing RPPNs only 141 (23 %) also contained public PAs, with this number ranging from one to nine PAs. The majority of counties containing RPPNs had fewer than five public PAs within 100km of county boundaries (58 %), while this number ranged from zero to 34 (Figure 3). The distance from these county boundaries was also significantly greater in the Atlantic Forest and Caatinga biomes than any other ($F = 11.68$, d.f. = 5, 3810, $P < 0.001$).

1.5.3 RPPNs and wildlife corridors

At the time of this study about 200 RPPNs had been established within the Nordeste, Central and Serra do Mar Atlantic Forrest corridors. More specifically, in the Mico-Leão-Dourado, Serra do Mar, Bocaina, Extremo Sul da Bahia (Atlantic Forest biome); Capivara-Confusões (Caatinga biome); Grande Sertão Veredas-Peruaçú, Foz do Rio Doce (Cerrado biome); Baixo Rio Negro (Amazon Rainforest biome); and Serra de Maracaju-Negro and Miranda Serra da Bodoquena (Pantanal biome) corridors. We were unable; however, to gather the specific location of each one of these reserves to identify their relationship to other protected areas and potential contributions to species-specific conservation efforts and this precludes any fine scale analysis of RPPN connectivity within the wider protected area network.

1.5.4 RPPN ownership

We were able to extract ownership information from 90% (n=1,060) of the RPPNs of which 76% (n=808) are owned by private individuals and 24% (n=252) by corporations, industries or NGOs. The state with most reserves owned by private individuals is Paraná (n=189), followed by Minas Gerais (n=146), Rio de Janeiro (n=97), and Bahia (n=74). States with the greatest number of reserves owned by corporations, industries or NGOs are Minas Gerais (n=90), Paraná (n=28) and Mato Grosso do Sul (n=18). There are only a small proportion of RPPNs that conduct ecotourism (4%) as a land use that may be compatible with regional conservation efforts (Figure 2).

1.6 Discussion

Our assessment of Brazil's 1,182 private natural heritage reserves shows that the Brazilian private reserve system is well-established and expanding. There has been an increase of 753 RPPNs since 2005 when these areas were last assessed by Rambaldi et al. (2005) with some patterns clearly in place. Most notably, (a) RPPNs remain mostly clustered within the Atlantic Forest biome, (b) are relatively small in size, and (c) most of the land protected by the RPPN system is within the Pantanal biome. Overall, the average size of reserves has decreased since 2005, which is in response to the greater number of small reserves being established. Notwithstanding the areal increase of 3,265 km², the RPPNs combined still protect only 0.1% of Brazil's terrestrial habitats.

Despite their limited size our analysis supports the claim that RPPNs make important contributions in global conservation hotpot areas, such as the highly fragmented Atlantic Forest biome and the biodiverse Cerrado biome. However, the RPPN system remains a poorly implemented conservation tool in the Pampa and Coastal biomes despite habitat loss and degradation continuing in these regions (Mesquita, 2004; Overbeck et al., 2005; Roesch et al., 2009; Pillar et al., 2012). As in 2005, conservation contributions in terms of the area of terrestrial biomes protected by RPPNs are greatest in the Pantanal, Cerrado and the Atlantic Forest. Compared to figures from 2005 (Rambaldi et al., 2005), there has been considerable gain in habitat protected in the Pantanal and Atlantic Forest biomes whereas the habitat protected in the Cerrado and Caatinga biomes has remained relatively constant. The Atlantic forest biome has the majority of the reserves but most of these reserves are small and this is an artefact of the historical land tenure characteristic of this biome. The high number of RPPNs in this biome is also related with the presence of NGO funding schemes. The Alliance for the Conservation of the Atlantic Forest (*Aliança para a Conservação da Mata Atlântica*) is one the nation's largest and oldest conservation initiative. One of the tools used by the Alliance to conserve the biome takes place via the Incentive Program for RPPNs of the Atlantic Forest (*Programa de Incentivo às RPPNs*) (CI/SOSMA/TNC, 2012). This program does not provide funding for landowners to purchase land, to acquire court-related documentation, or to pay taxes and fees. Instead, it provides financial assistance for the establishment and management of RPPNs (Ayala, 2010). Since 2003, the program has allocated US$ 1,874,140 and sponsored 553 RPPNs (SOSMA, 2012). Other conservation NGOs that provide support for the establishment of RPPNs are the Golden Lion Tamarin Foundation in Rio de Janeiro and, more recently, Conservation International for the establishment of RPPNs within the Pantanal biome. The former involves initiatives in 21 municipalities within the biological corridors of Serra de Maracaju-Negro and Miranda Serra da Bodoquena (REPAMS, 2013).

1.6.1. Size of reserves and implications for biodiversity conservation

The considerably smaller overall size of RPPNs compared to public PAs in Brazil (~7,500 km² versus 1,5 million km²) seems to be a pattern in other South American countries (Swift et al., 2004) but not as much on the African continent. Here, many private reserves are often greater than 10 km² (Krug, 2001; Sims-Castley et al., 2005; Castley, 2010), and these areas combined exceed the entire conservation contribution of the public protected area estate (Gallo et al., 2009). In Costa Rica, the average size of private protected areas is 0.1 km², but ranges from 0.2 to 220 km² (Langholz et al., 2000). Because of the ecological limitations of small and highly fragmented PAs (e.g. edge effects, ecological functioning, connectivity etc.) within a multi-use landscape matrix, the small size of reserves is considered a weakness by some (Swift et al., 2004; Morsello, 2008). Within the Brazilian RPPN network there appears to be an increasing trend in the establishment of smaller reserves, particularly in the Atlantic Forest, Cerrado and Caatinga biomes where the average size of reserves has declined since 2005. Therefore, while the overall extent has increased in these biomes, the

proliferation of small reserves may have little benefit for ecosystem functioning at a landscape scale. Nonetheless, small reserves do provide important refugia for birds and smaller species (Theulen et al., 2003; Opdam & Wascher, 2004; Pearson & Dawson, 2005; Ferraz et al., 2012). In the Caatinga biome, for example, endangered bird species protected by the private reserve system include *Penelope jacucaca* (white-browed guan) (VU), *Pyrrhura anaca* (Grey-breasted Parakeet) (CE), *Sclerurus scansor cearensis* (Rufous-breasted Leaftosser) (VU) *Xiphocolaptes falcirostris* (VU) and *Carduelis yarellii* (VU) (Farias, Silva & Albano, 2005). In the Cerrado, some of the beneficiary species include *Crax fasciolata* (bare-faced curassow), *Sarcoramphus papa* (king vulture), *Rupornis magnirostris* (roadside hawk) and *Geranoaetus melanoleucus* (black-chested buzzard-eagle) (Lazara, 2011). Most of the reserves, however, remain unassessed.

As noted by Langholz et al. (2000), bigger reserves are also not necessarily better than smaller ones. It depends on the motivations of landowners in establishing these reserves, the overall fragmentation of the region in which these areas are located, the overall biodiversity condition of the reserves and landowner's capacity to manage the area effectively. Therefore, where small areas are well managed and conservation objectives are considered in the context of the larger landscapes, then these areas can make a valuable conservation contribution (Schroth et al., 2011). For example, in Rio de Janeiro, conservation of private land via the establishment of RPPNs has been paramount in the recovery of the threatened golden lion tamarin (*Leontopithecus rosalia*) (Rambaldi et al., 2005; IUCN, 2012; Buckley & Pegas, 2015). Altogether, there are 40 RPPNs protecting some 47 km² within the species' range. Another species that has directly benefited from the establishment of RPPNs is *Brachyteles hypoxanthus* (northern muriqui), one of the world's 25 most threatened primates. The RPPN Feliciano Miguel Abdala, in Minas Gerais, protects the largest known population, which is equivalent to one third of wild population of northern muriquis in Brazil (Fonseca, 2003).

Whilst even small RPPNs provide vital habitat for the tamarin in Rio de Janeiro, size remains a limiting factor for species with large territorial range, particularly if adjacent habitats are degraded. In the case of the jaguar (*Panthera onca*), establishment of large PA networks is needed. Some of the largest RPPNs and public PAs are located within the jaguar's habitat range within the Pantanal biome and could therefore assist in the future conservation of this species. As demonstrated from our own results in the revised Table 1, the overall increase in extent as well as the average size of reserves in this biome is therefore encouraging. As in the Atlantic Forest biome, the larger size of reserves in the Pantanal is linked with Brazil's land settlement history. Unlike in the Atlantic Forest biome, however, land settlement in the Pantanal has been more recent with the *Avança Brazil* government initiative as an important driver (Fearnside, 2002).

Conservation efforts on public and private lands in the Pantanal biome potentially also face fewer threats from human settlement and associated large urbanization movements in other biomes especially the Atlantic Forest. For example, the small state of Rio de Janeiro (16,000 km^2) in the Atlantic Forest biome has a population of 16 million people (365 people/km^2), whereas Mato Grosso

do Sul (357,145 km^2) in the Pantanal biome has a population of 2.5 million (7 people/km^2). In the Amazon Rainforest biome, illegal and legal land clearing activities continue to threaten biodiversity conservation despite reports of a 24% decrease in deforestation rates over the past 40 years (Gomez et al., 2015). While this biome has the greatest extent under public protection, the representation in RPPNs is relatively poor and presents an opportunity to improve conservation efforts in this region.

Private reserves, regardless of their size or location, can also contribute to the protection of watersheds and the establishment of wildlife corridors (Theulen et al., 2003; Mesquita, 2004; Morsello, 2008; Worboys et al., 2010). In Brazil, the private reserve system also guarantees a greater level of protection due to its restricted land management regulations as imposed by existing legislation.

As presented in a series of case studies noted by Worboys et al. (2010), private reserves, small to large, are complementary conservation tools to public PAs. Their establishment has been vital in the successful implementation of wildlife corridors and minimization of environmental impacts caused by fragmentation and climate change (Heller & Zavaleta, 2009).

As noted in this study, many RPPNs are already achieving these roles and providing a direct contribution to wildlife corridors at the local scale. However, given the lack of accurate RPPN reserve boundary data, there is a need for finer scale analysis of the connectivity within these protected area landscapes to assist in the prioritization of additional conservation lands.

1.6.2 Existing land tenure framework and RPPNs

In Brazil, conservation of private lands, with the exception of the RPPN system, is top-down and government-controlled. Under the current land tenure system, the federal government can allocate private lands to be managed as wildlife refuges, areas of ecological relevance, and as environmental protection areas. Another legal land tenure system that influences conservation in private lands is regulated by the Brazilian Forest Code [BFC]. According to the BFC, a proportion of every rural private property must be set aside as a Legal Reserve (Reserva Legal [RL]), based on current biome representation. Another mechanism is through the establishment of Areas of Permanent Protection (*Areas de Preservação Permente* [APP]). APPs, unlike RLs and RPPNs, are established based on specific landscapes, such as riparian buffer zones. While an estimated 12% of all rural properties are to be set aside as APPs and 30% as RLs, this does not hold true on the ground with a deficit of 35,700 km^2 of land that should be set aside as RLs (Sparovek et al., 2010). Furthermore, 42% of the APPs, 16.5% of the RLs and 3% of the indigenous lands have been illegally deforested (Sparovek et al., 2010).

Due to such inconsistent implementation and land use practice, we propose that RPPNs provide better land tenure security for the following reasons: (a) RPPNs are established in perpetuity while RLs and APPs are not; (b) RPPNs cannot have their boundaries altered while RLs and APPs can; (c) land use practices within a RPPN are limited to conservation, education and research while in

RLs and APPs resource use extraction practices are allowed. Therefore, areas under the RPPNs are managed under more restrictive guidelines and are secured for conservation purposes in perpetuity. These land tenure characteristics fall under the IUCN's category IV (IUCN, 2008) hence should be used to support the recognition of RPPNs as official IUCN protected area categories (Crouzeilles, Vale, Cerqueira & Grelle, 2012). While excluding RPPNs from such category underestimates the acreage of land managed under strict protection, their recognition does not ameliorate some of the existing challenges to create and manage these areas (Pegas & Castley, 2014) and the dissemination of the RPPN system beyond Brazil (Ladle et al., 2013).

Another factor that supports the claim that RPPNs help secure land for conservation purposes is due to what we refer to as to the "use it or lose it" system. Under INCRA (National Institute for Agrarian Reform) land management strategies, private lands not used for agricultural purposes are considered "unproductive lands" and can be confiscated by the federal government and later allocated for the "landless" movement (INCRA, 2012). This includes forested lands that provide suitable habitat for wildlife. Therefore, to avoid having their land confiscated or cleared for agriculture purposes, landowners are obliged by law to "*use*" their land to avoid "*losing*" it. Conversely, the establishment of a RPPN gives landowners the legal right to maintain the area undeveloped and used for conservation purposes only. By 2011, the INCRA confiscated 6,879 rural properties which, combined, extend over 302,380 km^2 of land (INCRA 2013). Hence, anthropogenic actions, both legal and illegal, threaten biodiversity conservation on both public and private lands. As noted by Sparovek et al. (2010), land insecurity as result of Brazil's land tenure framework favours forest clearing not conservation.

Whilst the RPPN system is a well-established mechanism to conserve privately owned land in Brazil, its ability to adapt to social (e.g. population growth), economic (e.g. agricultural development), and legal (e.g. changes in the Brazilian Forest Code) externalities has been key to its survival. Based on our analysis, four main components have helped sustain this conservation strategy over the past two decades: (1) government support through the establishment of laws recognizes RPPNs as official Units of Conservation; (2) support from landowners allows for the private reserve idea to take place on the ground; (3) creation of the E-ICMS as a form of payment for ecosystem services creates incentives for local governments to support the establishment of public and private protected areas, but these benefits do not transfer to landowners; and, (4) development of a NGO-government-private network reduces the financial and bureaucratic burden of creating RPPNs for individual landowners.

1.6.3 Other incentives to establish RPPNs

In nations where the establishment of private reserves generates limited financial returns, the decision to create a reserve may be a risky undertaking for the landowner. In Brazil, while tax benefits exist, they are generally modest for small reserves and are unlikely to surpass the establishment and management costs (Pegas & Castley, 2014). Even if funding is allocated, ensuring adequate

governance of these areas also involves gaining support from local communities, politicians, government agencies and from broader society (Ladle et al., 2013). The successful integration of these components is not always feasible nor sought after by the landowners even if financial and technical support is provided by the government and many conservation NGOs.

Increasing engagement and awareness of corporate social responsibility (CSR) may be another driver for companies to create RPPNs. As noted by Buckley and Pegas (2012), CSR activities also include contributions to conservation and ecosystem services, cultures and community well-being. The linkage between CSR and environmental-related actions as proposed by Buckley and Pegas (2012) is increasingly becoming a sound business strategy and could explain the 25% of RPPNs owned by corporate entities in this study.

Despite their increasing adoption with no sign of saturation, the RPPN system remains unevenly distributed across biomes. As noted in our analysis RPPN numbers are heavily skewed towards the Atlantic Forest biome. This overrepresentation in the number of RPPNs in some areas is compounded by the financial support provided to landowners in some regions, but also needs to consider the areal extent added to the conservation estate. For example, the addition of many small areas as in the Atlantic Forest biome over fewer larger areas added in the Pantanal (Table 1), demonstrates a mismatch in conservation gains. The RPPN mechanism fosters a "free ride" payment for ecosystems services (PES) for local government agencies (Pegas & Castley, 2014), who use this as a means to achieve conservation objectives. To substantially increase adoption beyond the Atlantic Forest belt, government agencies should provide landowners with a stable and reliable source of funding to off-set the financial burden associated with these reserves. Without such support and the voluntary nature of the system, many landowners may be hesitant to set aside their land as RPPNs.

1.6.4 Knowledge gaps and future studies

This study increases our knowledge about private reserves in Brazil updating previous assessments to illustrate encouraging trends in the expansion of the private reserve network. We also outline the legal and economic incentives used to promote conservation in private lands more generally. However, an in-depth assessment of the ecological contributions of these reserves is still necessary. Most previous studies have been conducted in the Atlantic Forest biome and remain limited to a relatively few reserves. Our knowledge of actual biodiversity conservation contributions remains scant. We still know little about which species inhabit these reserves, their population numbers, or the threats they face. While threatened species may not all be present in all reserves, an appropriate ecological inventory can contribute to the overall assessment of species-specific habitat suitability and connectivity. This information should be incorporated into the SIMRPPN and CNRPPN database platforms.

There is also limited information about the factors motivating landowners to create their RPPNs and whether these differ from those motivating the corporate business sector, including

NGOs. For example, in the United States conservation easement land remains productive (Fishburn et al., 2009) while Brazilian RPPNs are managed with strong restrictions. Economic gain via tourism does also not appear to be the main driver for the establishment of these reserves with only a small percentage of RPPNs engaged in tourism (Pegas & Castley, 2014). Consequently, if financial incentives and land use practices are limited and the establishment of RPPNs imposes substantial costs to landowners, what drives landowners to establish private reserves?

While the two main databases about private reserves in Brazil provide detailed and updated information, these databases have limitations. At the time of this study, most of the boundary coordinates of these reserves were simply shown as circles on a map with no areas with accurate boundary information. Such data inefficiencies make it almost impossible to reliably evaluate the contributions of RPPNs to biodiversity conservation. Incomplete information relating to the date of RPPN establishment also precludes assessment of temporal patterns in relation to external events such as enactment of specific policies, incentive schemes or other government-driven conservation initiatives. These data are required for finer scale analysis of private sector investment in conservation such as that completed by Fishburn et al. (2009).

1.7 Conclusion

Our study has shown that there has been a widespread increase in the establishment of private protected areas across Brazilian biomes. However, despite the increase in numbers, and an almost two-fold increase in overall extent, the realised contribution to Brazilian conservation efforts remains small. Notwithstanding these relatively marginal contributions, the RPPN network remains important for conservation efforts as there are some Brazilian counties with RPPNs that have little or no representation in the public protected area estate. There are examples of where RPPNs contribute to achieving local conservation goals for either species or habitat conservation, however, a comprehensive assessment of the wider conservation contribution remains a priority. An opportunity exists for greater integration between public and private reserves in Brazil to maximise gains for conservation. The legal foundation for such a system exists, but this may require a more coordinated approach to prioritise areas for conservation in the future. Central to the success of the RPPN system is the continued incentivization of landowners to engage with the program.

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Figure Captions

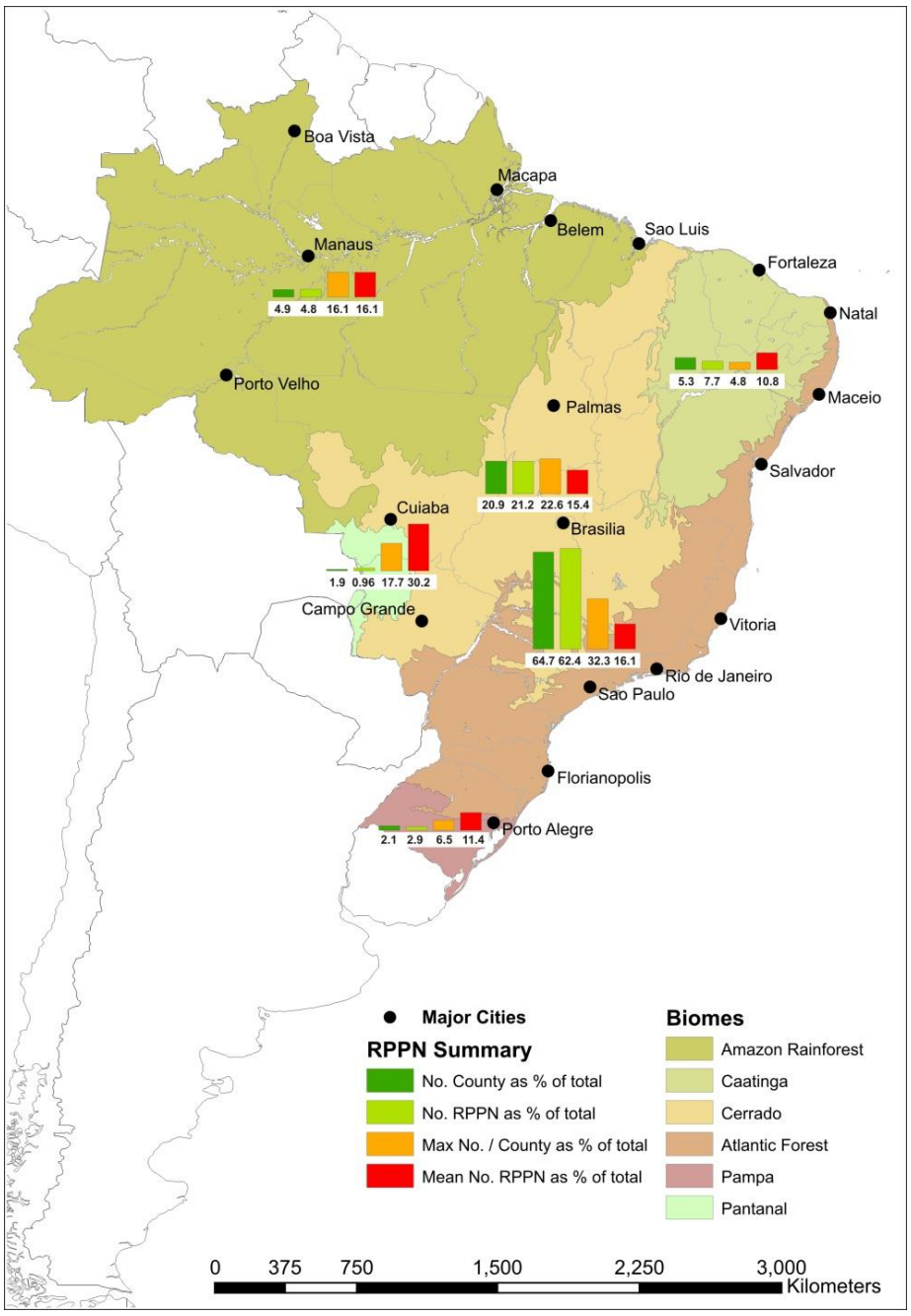

Figure 1. Distribution of private reserves (RPPNs) by biome. Bar charts and values for each biome represent the percentage of the totals for each of the summarised RPPN parameters.

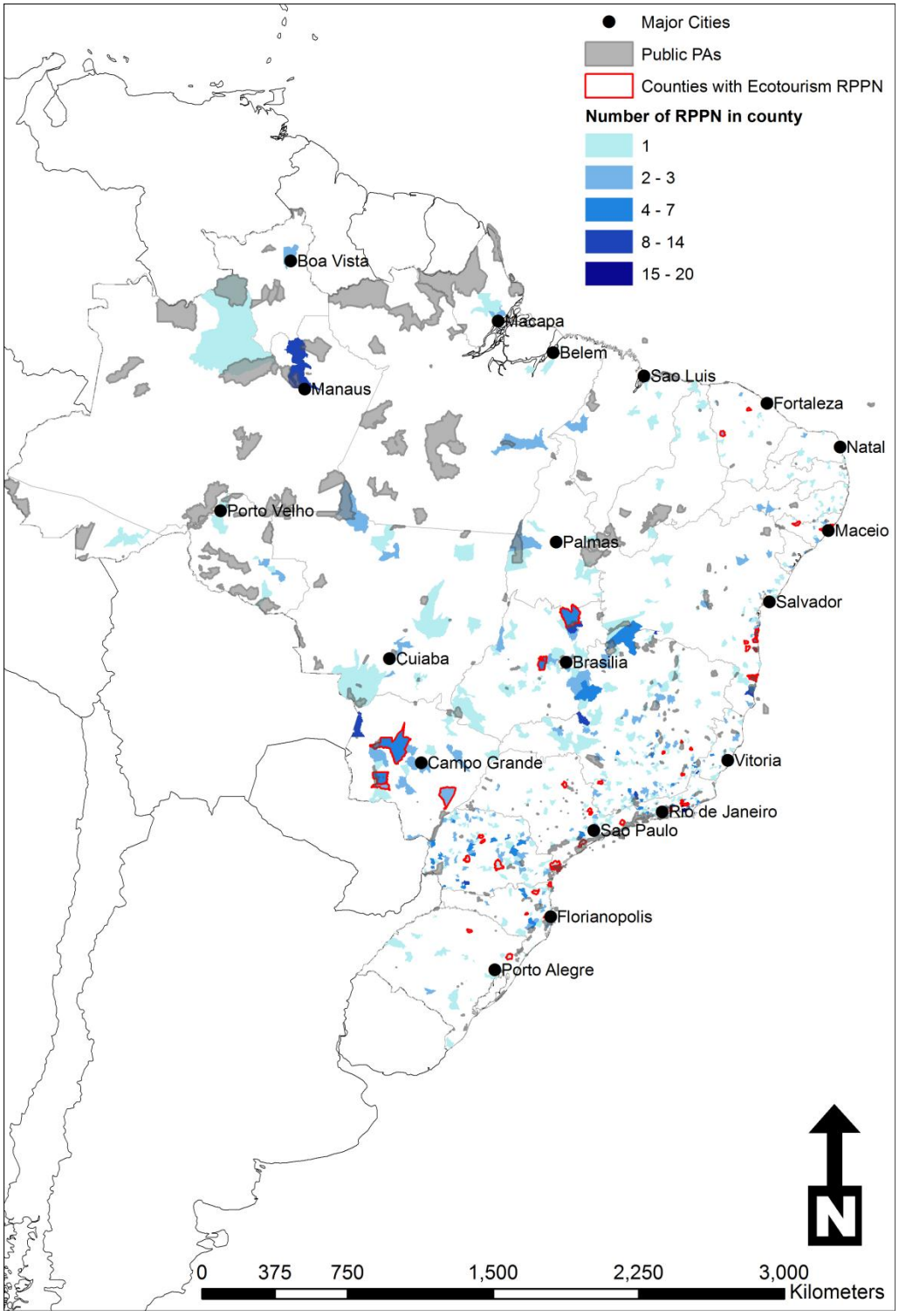

Figure 2: Distribution and representation of Brazilian RPPNs by county depicting those where ecotourism takes place. The RPPN distribution is also compared to public protected areas.

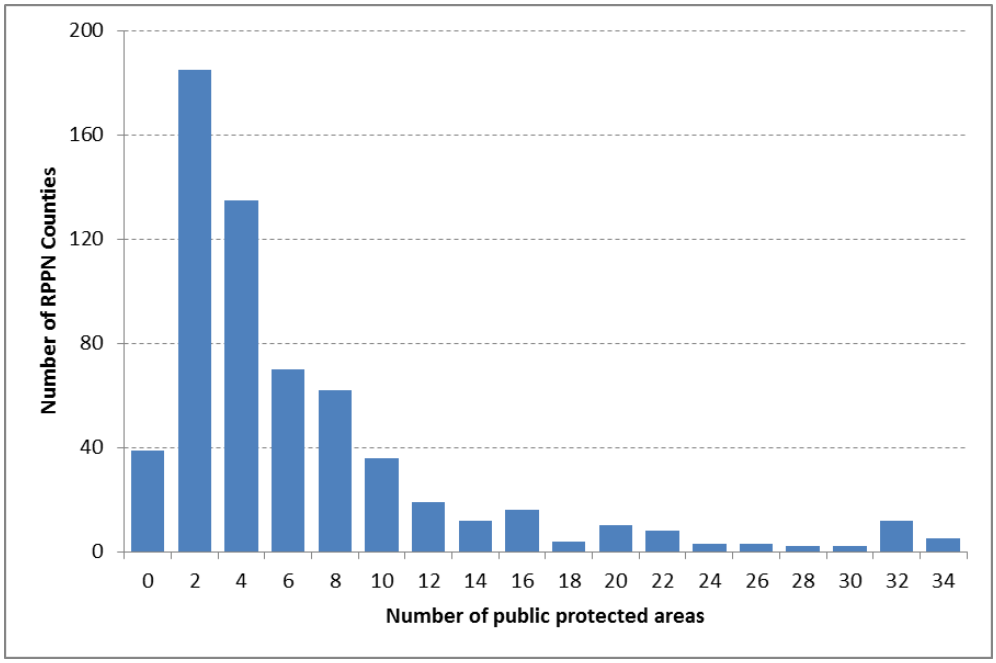

Figure 3. The distribution of public protected areas within 100km buffers around those Brazilian counties containing RPPNs.

Tables

Table 1. Biome areas protected under the RPPN system in 2014 compared to similar figures for 2005 sourced from Rambaldi et al. (2005).

Biome	Number of RPPNs		Total RPPN Area (km²)		Average RPPN size (km²)		Percentage of all RPPNs		Percentage of total area of all RPPNs	
	2005	*2013*	*2005*	*2013*	*2005*	*2013*	*2005*	*2013*	*2005*	*2013*
AF	222	797	869.7	1627.8	3.92	2.04	54.0	67.4	20.5	21.7
CE	114	222	1842.4	1896.6	16.16	8.54	27.7	18.8	43.5	25.3
CA	22	60	816.0	817.9	37.09	13.63	5.4	5.1	19.2	10.9
AR	30	54	172.2	434.3	5.74	8.04	7.3	4.6	4.1	5.8
PT	6	24	504.5	2678.7	84.08	111.61	1.5	2.0	11.9	35.7
CO*	-	15	-	15.2	-	1.01	-	1.3	-	0.2
PA*	17	10	33.1	32.1	1.95	3.21	4.1	0.8	0.7	0.4
Total	411	1182	4237.8	7502.6	24.82	6.35	100	100	100	100

*Coastal areas in 2013 were not considered in 2005. Some RPPNs here were included in the 2005 figures for the Pampa biome. Atlantic Forest (AF); Cerrado (CE), Caatinga (CA), Amazon Rainforest (AR), Pantanal (PT), Coastal (CO), and Pampa (PA).

Table 2. Percentage and number of RPPNs (in parentheses) per size category and biome.

	RPPN Size Category (km²)								
Biome	**<0.10**	**0.1-0.25**	**0.25-0.5**	**0.5-1**	**1-2.5**	**2.5-5**	**5-10**	**>10**	**Total**
AF	83.6 (173)	82.9 (165)	71.7 (119)	70.5 (98)	63.7 (116)	59.8 (61)	49.4 (38)	24.5 (27)	797
CE	9.7 (20)	9 (18)	16.9 (28)	20.1 (28)	22.5 (41)	21.6 (22)	31.2 (24)	37.3 (41)	222
CA	1.9 (4)	1.5 (3)	1.8 (3)	1.4 (2)	8.2 (15)	10.8 (11)	7.8 (6)	14.5 (16)	60
AM	2.4 (5)	4 (8)	6 (10)	6.5 (9)	1.6 (3)	4.9 (5)	9.1 (7)	6.4 (7)	54
PT	0 (0)	0 (0)	0.6 (1)	0.7 (1)	0.5 (1)	1 (1)	2.6 (2)	16.4 (18)	24
CO*	2.4 (5)	0.5 (1)	1.2 (2)	0.7 (1)	2.2 (4)	2 (2)	0 (0)	0 (0)	15
PA*	0 (0)	2 (4)	1.8 (3)	0 (0)	1.1 (2)	0 (0)	0 (0)	0.9 (1)	10
Total	**207**	**199**	**166**	**139**	**182**	**102**	**77**	**110**	**1182**

*Coastal areas in 2014 were not considered in 2005. Some RPPNs here were included in the 2005 figures for the Pampa biome. Atlantic Forest (AF); Cerrado (CE), Caatinga (CA), Amazon Rainforest (AM), Pantanal (PT), Coastal (CO), and Pampa (PA).

Table 3. Public PA (Category I-IV) representation throughout Brazil and the association with the RPPN network at the county scale. PA data derived from WDPA Protected Planet (2015).

Biome	Number of PAs	Total PA Area (km^2)	Mean No. of PAs in RPPN county buffers	Mean distance (km) between RPPN county and PAs
AF	120	13,348	7.4	56.9 ± 0.54
CE	97	52,037	5.1	49.7 ± 1.1
CA	19	5,606	1.9	62.1 ± 3.0
AR	70	401,298	2.4	43.5 ± 3.5
PT	5	3,330	5	42.5 ± 5.3
CO*	54	11,236	-	-
PA	6	254	2.6	50.7 ± 4.2
Total	371	487,109		

*Coastal areas in 2013 were not considered in 2005. Atlantic Forest (AF); Cerrado (CE), Caatinga (CA), Amazon Rainforest (AR), Pantanal (PT), Coastal (CO), and Pampa (PA). Buffers for coastal areas were captured in primary biomes and hence have no relationship calculations.