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INSTITUTO DE CIÊNCIAS BIOLÓGICAS
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EM ECOLOGIA E EVOLUÇÃO

AVALIAÇÃO DE RESULTADOS EM PESQUISA E POLÍTICAS PÚBLICAS PARA CONSERVAÇÃO NO BRASIL

Raísa Romênia Silva Vieira

Goiânia, fevereiro de 2019.

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Raísa Romênia Silva Vieira

Orientador: Prof. Dr. Rafael Loyola
Co-orientador: Prof. Dr. Robert L. Pressey

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Prof. Dr. Rafael Dias Loyola
Presidente da banca
ICB/UFG

Prof. Dr. José Alexandre Felizola Diniz Filho
ICB/UFG

Dra. Paula Hanna Valdujo
WWF-Brasil

Prof. Dr. Ricardo Bomfim Machado
UnB

Dra. Katia Torres Ribeiro
Instituto Chico Mendes de Conservação da Biodiversidade

“A utopia está lá no horizonte. Me aproximo dois passos, ela se afasta dois passos. Caminho dez passos e o horizonte corre dez passos. Por mais que eu caminhe, jamais alcançarei. Para que serve a utopia? Serve para isso: para caminhar.”

– Fernando Birri, citado por Eduardo Galeano em ‘Las palabras andantes?’

Dedico esta tese às pessoas que sonham e lutam para transformar a realidade

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SUMÁRIO

RESUMO

O número de ações voltadas para a conservação da biodiversidade e de ecossistemas tem crescido no Brasil e no mundo. Além de políticas locais, pactos internacionais têm sido firmados, visando proteger a diversidade biológica global. Apesar dos avanços, a maior parte das ações conservacionistas implementadas baseiam-se em opiniões ou métodos usuais, não em evidências que indicam a eficácia dessas ações. Não só as políticas para conservação devem ser fundamentadas em critérios adequados, mas também devem ser planejadas de forma que seja possível avaliar seu êxito. Nesta tese, tivemos como objetivo avaliar a eficiência de iniciativas de conservação em preservar a biodiversidade, com enfoque no Brasil. No primeiro capítulo, fizemos uma revisão da literatura sobre degradação e perda de habitat para mensurar a lacuna entre a teoria e prática da conservação. Encontramos que, apesar do crescente número de publicações científicas, ainda existe um hiato entre o saber o fazer que pode implicar em programas de conservação ineficazes. Sugerimos que pesquisadores e tomadores de decisão se aliem para superar essa lacuna. No segundo capítulo, mostramos que o sistema de unidades de conservação possui vieses de criação marcantes e que não é representativo para cerca de metade dos habitats presentes no Brasil. Esse cenário é resultado de uma proteção projetada preponderantemente para não gerar conflitos com interesses extrativistas ao invés de planejamento estratégico e sistemático. Discutimos as razões que acarretaram nesse cenário e caminhos a serem seguidos. No terceiro capítulo, estimamos as prováveis perdas e ganhos de biodiversidade e serviços ecossistêmicos caso o novo Código Florestal brasileiro seja cumprido na íntegra. Também discutimos os desafios associados ao cumprimento da lei e apresentamos oportunidades para sua implementação.

Palavras-chave: biodiversidade, Código Florestal, conservação, política ambiental, SNUC, unidades de conservação.

ABSTRACT

The number of programs aimed at biodiversity and ecosystem conservation has grown in Brazil and in the world. Besides local policies, international agreements were also established to protect the world biological diversity. Despite this progress, most conservation initiatives were made based on opinions and usual methods instead of evidences of effectiveness. Not only conservation policies must be based on appropriate criteria, but they should also be planned to produce outcomes whose success can be assessed. In this thesis we aimed to evaluate the efficiency of conservation initiatives in preserving biodiversity, focusing on Brazil. In the first chapter we reviewed the literature on habitat loss and degradation to measure the gap between conservation theory and practice. We find that despite the growing number of scientific publications, there is still a gap between knowing and doing that can lead to ineffective conservation programs. We suggest that researchers and practitioners come together to bridge this gap. In the second chapter we show that the protected areas system has strong biases and that is not representative for about half of the existing habitats in Brazil. This scenario is the result of protection aimed at minimizing costs and conflicts with extractive uses instead of strategic and systematic planning. We discussed the reasons that led to this scenario and the paths to be followed. In the third chapter we estimate the probable losses and gains of biodiversity and ecosystem services if the new Brazilian Forest Code is properly enforced. We also discuss the challenges associated with law enforcement and present conservation opportunities.

Key-words: biodiversity, conservation, environmental policy, Forest Code, protected areas, SNUC.

INTRODUÇÃO

Nas últimas décadas, as atividades humanas impactaram severamente os habitats naturais e os diversos ecossistemas globais, tanto terrestres quanto marinhos. Cerca de 20% da floresta Amazônica já foi perdida (Nobre et al., 2016) e em menos de 30 anos o planeta perdeu metade dos recifes de corais de águas rasas (Van Hooidonk et al., 2013), podendo chegar a perder 90% até a metade do século (Van Hooidonk et al., 2016). Em relatório recente, a WWF aponta que as populações de vertebrados reduziram, em média, cerca de 60% nos últimos 40 anos e que as principais causas são a superexploração e a agricultura, ambos ligadas ao consumo humano (WWF, 2018). O relatório aponta que a forma que a humanidade se alimenta e sustenta sua economia está empurrando a natureza e os serviços fornecidos por ela para um colapso, que só poderá ser revertido se repensarmos a forma que valorizamos e protegemos o meio ambiente.

A atenção dada à conservação da biodiversidade tem crescido em todo o mundo, em parte pelas taxas alarmantes de extinção e perda de habitat, mas também pelo reconhecimento de que a diversidade biológica é vital para o desenvolvimento econômico e social das gerações atuais e das futuras (Pascual et al., 2017). Os seres humanos dependem da natureza para o fornecimento de água (Vörösmarty et al., 2010), para a manutenção dos recursos pesqueiros (Cinner et al., 2018) e madeireiros (Duncker et al., 2012), para aumento da produtividade de plantações (De Marco and Coelho, 2004; Ricketts et al., 2004), e, globalmente, a natureza fornece serviços cujo valor gira em torno de $125 trilhões de dólares por ano (WWF, 2018).

Apesar da preocupação humana com a conservação da natureza datar de séculos atrás, apenas no final do século XX que a comunidade internacional se organizou para debater a questão. Em 1992, foi criada a Convenção de Diversidade Biológica (CDB), um tratado internacional multilateral da

Organização das Nações Unidas que se baseia em três pilares: a conservação da diversidade biológica, o uso sustentável da biodiversidade e a repartição justa e equitativa dos benefícios provenientes da utilização dos recursos genéticos (www.cbd.int/). A CDB estabelece uma série de normas e princípios para orientar os países signatários sobre como reger o uso e a proteção da diversidade em seus territórios e é a principal referência ambiental mundial (CBD, 2010). No Brasil, a CDB foi ratificada pelo Decreto Federal nº 2.519 de 16 de março de 1998.

O sucesso dessas ações depende que a implementação seja feita de forma concreta e eficaz, tendo como foco alcançar os objetivos determinados. Governos e organizações precisam saber onde melhor investir os escassos recursos destinados à conservação, porém, a maior parte das decisões não é tomada com base em evidências que orientem corretamente a implementação da prática (Pullin et al., 2004; Sutherland et al., 2004). Os tomadores de decisão usam como principais fontes a experiência de experts, planos de ação existentes e práticas de gestão tradicionais ao invés da literatura científica (Karam-Gemael et al., 2018; Pullin et al., 2004). Por outro lado, ainda há pouca evidência compilada sobre as consequências das práticas de conservação executadas, bem-sucedidas ou malsucedidas, e os resultados existentes não são rotineiramente revisados (Sutherland et al., 2004). Essas informações levantam a preocupação de que muitas iniciativas de conservação podem não estar cumprindo adequadamente seus papéis de reduzir a perda de habitat e de biodiversidade.

Os recursos para conservação da biodiversidade são bastante limitados, portanto, é essencial avaliar a eficiência das intervenções feitas para garantir que esses escassos recursos atinjam os melhores resultados e que sirvam de base para intervenções futuras. Cada vez mais tem crescido o alerta que as decisões voltadas para a conservação da natureza devem ser tomadas com base em evidências e que os investimentos já feitos devem ter seus resultados avaliados (Baylis et al., 2016; Ferraro and Pattanayak, 2006; Rose, 2015; Sutherland et al., 2004). Na área da medicina, a avaliação empírica dos impactos de programas de saúde e a prática baseada em evidências se tornou a abordagem dominante, reduzindo mortes e a incidência de doenças, e essa área apresenta modelos a serem seguidos pela biologia da conservação (Ferraro and Hanauer, 2014; Ferraro and Pattanayak, 2006; Miteva et al., 2012; Pullin and Knight, 2001).

No Brasil, as diversas políticas públicas e de Estado voltadas para conservação e recuperação ambiental sofrem dos mesmos problemas de falta de avaliação. O Brasil é um país megadiverso e ainda é um dos principais líderes ambientais do mundo, apesar dos recentes retrocessos ambientais (Ferreira et al., 2014; Loyola, 2014). Algumas políticas ambientais brasileiras já tiveram seus resultados avaliados usando o método científico, como a Moratória da Soja (Gibbs et al., 2015), as Unidades de Conservação no Cerrado (Carranza et al., 2014) e o Plano de Ação para Prevenção e Controle do Desmatamento na Amazônia Legal (Arima et al., 2014), mas essa ainda é uma área de estudo incipiente no país. É essencial construir um conjunto de evidências sobre quais iniciativas de conservação da natureza tiveram êxito e quais falharam para aprimorar as existentes e para o delineamento de programas que realmente façam a diferença na preservação do meio ambiente.

Diante disso, nesta tese tivemos como objetivo avaliar a eficiência de iniciativas de conservação em preservar a biodiversidade, com enfoque no Brasil. No primeiro capítulo, realizamos uma revisão para investigar qual a proporção da literatura científica sobre degradação e perda de habitat conecta o conhecimento sobre esse problema ambiental com a prática para resolve-lo. Abordamos em que medida a literatura aborda as questões sobre conhecimento teórico e ações de conservação, chamada de lacuna entre o saber e o fazer, e medimos quais os vieses dos artigos em relação à geografia, ao sistema ecológico, ao nível de organização biológica e taxonomia. Ao final discutimos as razões para as lacunas e vieses encontrados e possíveis formas de eliminá-las.

No segundo capítulo, trabalhamos com uma política pública específica, o Sistema Nacional de Unidades de Conservação (SNUC). Até então não existia uma avaliação sobre a natureza residual das unidades de conservação (UCs) brasileiras, ou seja, sobre o viés de estabelecimento de UCs em paisagens com baixa adequabilidade para usos extrativistas e, em muitos casos, sob menor ameaça à biodiversidade. Apresentamos o primeiro panorama sobre o caráter residual das UCs terrestres no Brasil, examinando os vieses de proteção em relação ao relevo e a intensidade do uso do solo e se eles variam entre biomas. O estudo contribui com a recente análise global sobre reservas residuais e sua limitação em proteger a biodiversidade, apresentando caminhos para o Brasil abordar essa lacuna.

No terceiro capítulo, apresentamos uma análise dos impactos do Novo Código Florestal brasileiro (CF - Lei nº 12.651/2012) sobre a biodiversidade e os serviços ecossistêmicos. O CF foi aprovado em 2012 sob muitas críticas da sociedade civil e acadêmica e nós avaliamos as prováveis perdas e ganhos esperados de biodiversidade (riqueza de espécies ameaçadas de extinção) e serviços ecossistêmicos (estoque de carbono e provisão de água) no bioma Cerrado caso a lei seja cumprida integralmente. Também discutimos os desafios associados ao cumprimento da lei e apresentamos oportunidades de conservação diante da implementação da lei.

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CAPÍTULO 1

THE SPACES BETWEEN CONSERVATION THEORY AND PRACTICE: A REVIEW OF HABITAT LOSS AND DEGRADATION LITERATURE

THE SPACES BETWEEN CONSERVATION THEORY AND PRACTICE: A REVIEW OF HABITAT LOSS AND DEGRADATION LITERATURE

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1. Introduction

People engagement with nature conservation dates back centuries ago. In the classical work published in 1985, Soulé conceptualized Conservation Biology as a new field of research, characterized as a crisis discipline aimed at preserving biological diversity. It was not just a subset of biology as it reached beyond as an integrative discipline, incorporating aspects of economy, sociology and philosophy (Barry and Oelschlaeger, 1996; Soulé, 1985). Over three decades later, the framing of conservation biology has undergone changes, incorporating new ideas with the final goal to inform conservation policy (Kareiva and Marvier, 2012; Robertson and Hull, 2001).

Although the number of scientific publication in the field has consistently grown, surveys of conservation research papers identified that most studies did not led to on the ground actions (Knight et al., 2008; Prendergast et al., 1999; Pullin et al., 2004). Current practice has been informed mostly by personal experience and common sense rather than evidence of successful initiatives (Pullin et al., 2004; Sutherland et al., 2004; Karam-Gemael et al., 2018). This is the well-known knowing-doing gap or implementation space, i.e. the lack of translation of theory into practical action (Habel et al., 2013; Toomey et al., 2017).

The thematic gap, which is the gap between subjects addressed by scientists and the issues faced by practitioners, and the disciplinary gap, the lack of cooperation between different fields of science, are other types of gaps impeding science to provoke a positive impact in biodiversity conservation (Habel et al., 2013). Still, the space between the translation of theoretical knowledge to practice has been most studied and emphasized in different areas of conservation, such as conservation planning (Knight et al., 2008; Prendergast et al., 1999), biological invasion (Esler et al., 2010) and policy making (Karam-Gemael et al., 2018).

Habitat loss and degradation have been the main drivers of biodiversity loss over the last century on land (Brooks et al., 2002; Fahrig, 1997; Haddad et al., 2015) and sea (Munday, 2004). It is identified as a threat to 85% of all species included in the IUCN Red List (IUCN, 2018) and, though occurring in every region of the world, it is mostly concerning in biodiversity-rich regions facing high rates of habitat loss (Haddad et al., 2015).

The literature on habitat loss and degradation is vast and continues to grow (Fardila et al., 2017), however, no review has been done regarding the implementation spaces between theory and practice. Here, we present a review to investigate what proportions of the scientific literature on habitat loss and degradation (HLD) connects the knowledge about this conservation issue and the actions proposed to solve it. Specifically, we address two questions:

1. To what extent the scientific literature on habitat loss and degradation comprises the subjects about theoretical knowledge and conservation action – in other words: how wide is the knowing-doing gap?
2. What are the biases of papers in terms of geography, ecological system, level of biological organization and taxonomy and how they vary between the research categories we assigned?

2. Methods

The study protocol followed established guidelines for systematic review (Pullin and Stewart, 2006) to efficiently select relevant data. To measure the extent of the knowing-doing gap, we divided the sampled papers in research categories regarding theoretical knowledge and conservation actions, following Esler et al. (2010): “Knowing” papers develop a purely intellectual knowledge on habitat loss and degradation, used to inform policy and other conservation actions; “Doing” papers address specifically conservation actions, regarding their management, implementation or impact. We included a third category, called “guidelines”, for papers that provide detailed guidelines on how to properly implement and evaluate actions targeted at halting HLD and obtain the expected outcomes recommended by “knowing” papers. “Guidelines” papers are in-between the “knowing” and the “doing” literature.

2.1. Literature selection and data extraction

We searched on August 2018, peer-reviewed articles indexed by Thomson Reuters Web of Science Core Collection from 1945 to 2018, restricting the search to Biodiversity & Conservation research area. We used three sets of keywords to search the Web of Science topic field. The first one was related to HLD, which is the conservation problem focused in this study:

#1 "Habitat loss and degradation" OR "Habitat loss" OR "Habitat degradation"

The second set of words was related to types of conservation actions employed to solve conservation problems or words related to those actions:

#2 policy OR management OR "decision making" OR "conservation practice" OR intervention OR implementation OR impact

The third set of words was related to the main field of research of this study:

#3 "bio conservation" OR "conservation bio*" OR "conservation scien*"*

Finally, we combined all three sets of keywords to obtain the final result:

#1 AND #2 AND #3

Eligibility assessment was undertaken independently by one reviewer. I screened the abstract looking for information that met the criteria and, when there was not enough information, I screened the full text. The criteria to include a paper in the review were:

1. the focus of the study must be HLD, alone or combined with other conservation subjects;
2. the study must address conservation actions to halt HLD or recommend conservation actions to halt HLD.

Studies that mentioned habitat loss and degradation but did not address the theme were excluded. Studies that addressed HLD but did not inform any action to tackle the problem were excluded. Beside categorizing as “Knowing”, “Doing” or “Guidelines”, for each paper in the sample we recorded information on the study focus in terms of geography (geographic scale, biogeographical realm and focused countries), ecological system, level of biological organization and taxonomy, following Di Marco et al. (2017) (see Table 1).

Table 1. Categories used to describe the focus of conservation research about habitat loss and degradation.

Conservation focus	Categories
Geographic scale	National or sub-national (local) Regional Global
Biogeographical realms	Afrotropic Antartic Australasia Indomalaya Neartic Neotropic Oceania Paleartic
Ecological system	Terrestrial Freshwater Marine
Level of biological organization	Genetic Species Ecosystem
Taxonomic group	Vertebrates: amphibians, birds, fish, mammals, reptiles Invertebrates Plants

3. Results

A total of 169 records returned after the search combining all three sets of keywords and 108 remained after eligibility assessment. The sample papers came from 22 different scientific journals. The most prevalent journals were Biological Conservation (25%), Biodiversity and Conservation (14.8%), Diversity and Distributions (10.2%), Conservation Biology (9.3%) and the Journal of Applied Ecology (6.5%). Ecological Indicators and Conservation Genetics had each 4.6%. Tropical Conservation Science and Global Change Biology had 2.8% of publications, each. All other journals had less than 2% of publications (Table 2).

Table 2. Number and percentage of analyzed papers about habitat loss and degradation published in each scientific journal.

Journal	Number of papers	Proportion of analyzed papers (%)
ANIMAL CONSERVATION	1	0.9
ANNALS OF THE NEW YORK ACADEMY OF SCIENCES	1	0.9
AVIAN CONSERVATION AND ECOLOGY	1	0.9
PROCEEDINGS OF THE LINNEAN SOCIETY OF NEW SOUTH WALES	1	0.9
URBAN ECOSYSTEMS	1	0.9
CONSERVATION LETTERS	2	1.9
ECOGRAPHY	2	1.9
ENVIRONMENTAL CONSERVATION	2	1.9
GLOBAL ECOLOGY AND CONSERVATION	2	1.9
JOURNAL OF INSECT CONSERVATION	2	1.9
NATURE CONSERVATION-BULGARIA	2	1.9
NATUREZA & CONSERVACAO	2	1.9
ORYX	2	1.9
GLOBAL CHANGE BIOLOGY	3	2.8
TROPICAL CONSERVATION SCIENCE	3	2.8
CONSERVATION GENETICS	5	4.6
ECOLOGICAL INDICATORS	5	4.6
JOURNAL OF APPLIED ECOLOGY	7	6.5
CONSERVATION BIOLOGY	10	9.3
DIVERSITY AND DISTRIBUTIONS	11	10.2
BIODIVERSITY AND CONSERVATION	16	14.8
BIOLOGICAL CONSERVATION	27	25.0

3.1.Research categories

More than half of the analyzed studies were categorized as “Knowing” research (62%). “Doing” and “Guidelines” categories were less frequent, with 21.3% and 16.7% of analyzed studies, respectively (Fig. 1a). “Knowing” research had a substantial increase over the years, doubling the number of published papers in less than five years (Fig. 1b). Despite their lower percentages, studies focusing on conservation actions are becoming more common (Fig. 1b). The dominance of “Knowing” research is a pattern observed for all conservation focuses we analyzed.

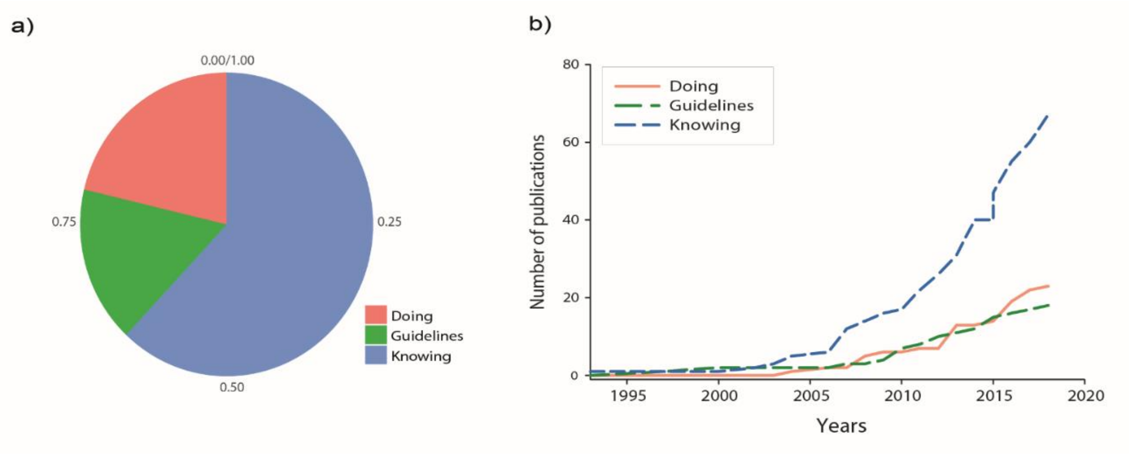

Figure 1. a) Proportion of papers published in each research category; b) Temporal variation of publications of each research category

3.2.Conservation focus on geographic scale and geographic location

Local (national or sub-national) studies were those most common in our sample of the HLD literature, totaling almost three quarters of all papers analyzed ("Knowing" 46.3%, "Guidelines" 12%, "Doing" 14.8%; Fig. 2a). Global studies were the second most common for "Doing" and "Guidelines" (3.7% each), while "Knowing" category had more regional studies (10.2%; Fig. 2a).

The regional scale was the least focused for "Doing" and "Guidelines" categories (2.8% and 0.9%, respectively). Despite the global scale being the least examined in "Knowing" category, it still comprises a reasonable amount of the total number of analyzed studies (5.6%; Fig. 2a). Papers focusing on regional or local scale were based in 57 different countries. Among these papers, 26 were categorized as "Doing", 6 were "Guidelines" and 50 were "Knowing" (considering that some countries were targeted by more than one research category and some studies focused on more than one country) (Table 3).

There was a small difference among studies examining biogeographical realms mostly tropical (56%), and realms mostly temperate (44%, Table 3). Most studies focused on the Neotropics (35.4%) and this was the biogeographical realm with the highest number of analyzed countries (21). This was also the trend for "Knowing" and "Doing" categories, but not for "Guidelines" (Table 3). However, the number of "Guidelines" studies was similar among the realms targeted by this research category.

Despite the great amount of countries studied on the Neotropics, most papers came from Brazil (Fig. 3). Australasia was examined by a significant percentage of studies (16%), but most of them were focused in Australia (Fig. 3). Those patterns are also observed when we analyze the research categories (Table 3, Fig. 3). A considerable percentage of studies were conducted in the Paleartic realm (18.3%), all of them in the categories “Knowing” and “Doing”. European countries were well represented in the “Knowing” category, but not in the “Doing” category. Africa, most part of Asia, and eastern parts of Europe were the least represented regions in my sample. There were no studies conducted in the Caribbean Island, Northern Africa and Central Asia.

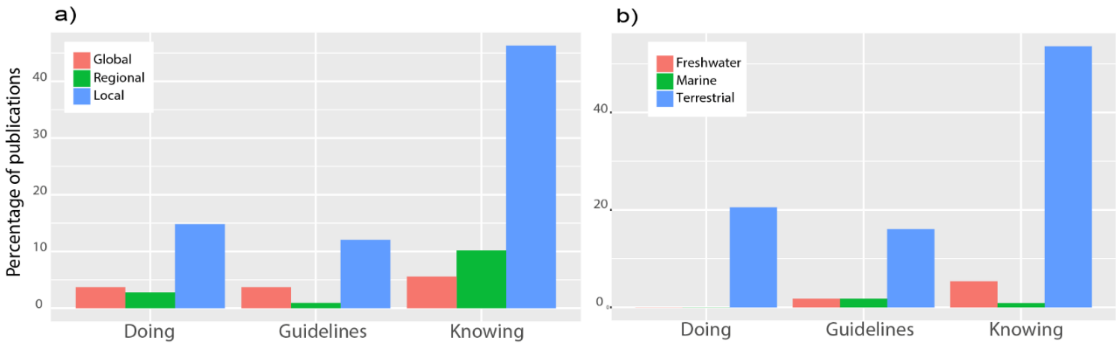

Figure 2. Percentage of publications of each research category considering a) geographical scale and b) ecological system.

Table 3. Number of countries studied, number of publications analyzed and percentage of publications in each research category in each biogeographical realm. *Biogeographical realms with tropical or subtropical climate.

Realm	Countries	Publications	Knowing (%)	Doing (%)	Guidelines (%)
Afrotropic*	7	13	4.57	1.14	1.71
Australasia	5	28	11.43	2.86	1.71
Indomalaya*	5	13	5.14	1.14	1.14
Neartic	3	17	8.00	0.57	1.14
Neotropic*	21	62	24.57	9.71	1.14
Oceania*	2	10	5.71	0	0
Paleartic	14	32	13.71	4.57	0
Total	57	175	73.14	20.00	6.86

1.1.Conservation focus on ecological systems

The focus on ecological systems is where I found the highest disparity. Over 90% of studies focused on terrestrial systems ("Knowing" 53.6%, "Guidelines" 16.1%, "Doing" 20.5%; Fig. 2b). In the "Doing" category all studies focused on terrestrial systems and it is a significant part of analyzed studies. Freshwater studies are divided in "Knowing" (5.4%) and "Guidelines" (1.8%). Marine studies represent less than 3% of the totality ("Knowing" 0.9%, "Guidelines" 1.8%).

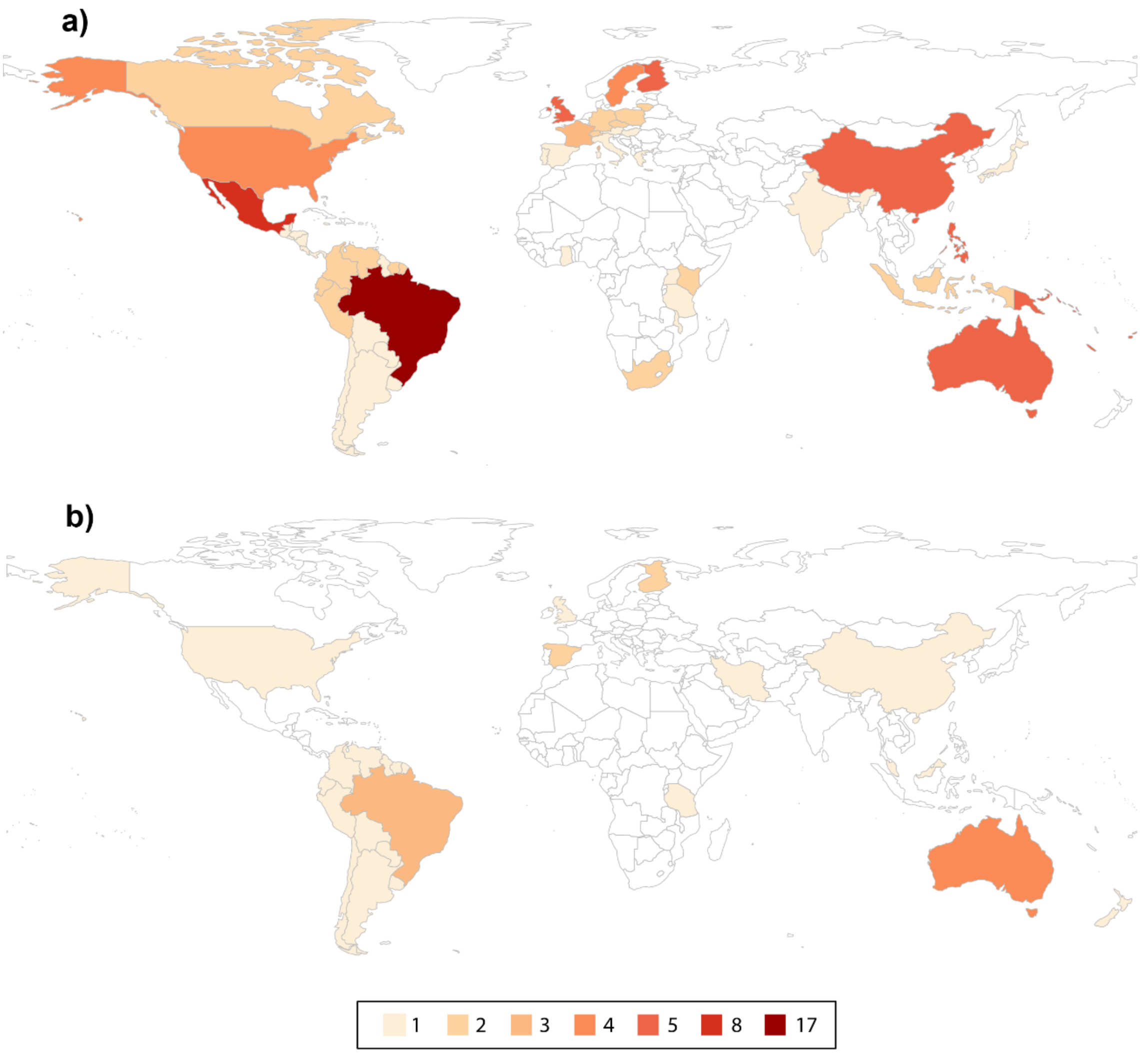

Figure 3. Number of regional or local research papers per country according to research study area a) "Knowing" category; b) "Doing" category. "Guidelines" studies were not included because most of them did not focus on any specific country or used modeled landscapes.

1.2.Conservation focus on level of biological organization

The majority of studies focused on the species level (63%), but with different degrees among research categories (Fig. 4a). At the species level there was a substantial number of studies at the "Knowing" (47.2%) and "Doing" (13%) categories, while for "Guidelines" category there was a low proportion of studies (2.8%). The ecosystem level was the most frequent in the "Guidelines" category and a significant proportion of all studies (12%), whereas it is less representative in the "Knowing" (11.1%) and "Doing" (6.5%) categories. The genetic level presented the lowest percentages for all research categories, being absent at the "Guidelines" category ("Knowing" 3.7%, "Doing" 1.9%).

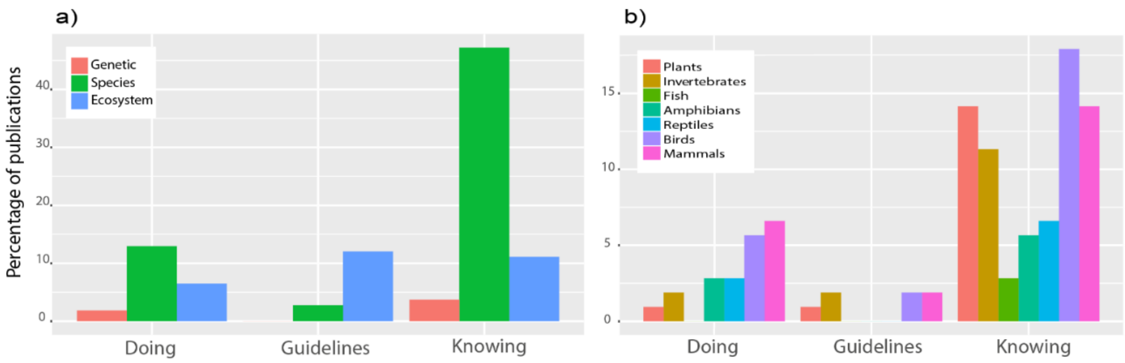

Figure 4. Percentage of publications of each research category considering a) level of biological organization and b) taxonomic group.

1.3.Conservation focus on taxonomic groups

There was a strong taxonomic bias in the HLD literature and research categories, with nearly 70% of articles focusing on vertebrates ("Knowing" 47.2%, "Guidelines" 3.8%, "Doing" 17.9%; Fig. 4b), and only 15.1% focusing on invertebrates and 16% on plants. Studies in categories "Guidelines" and "Doing" presented the same percentages for invertebrates and plants: 1.9% and 0.9%, respectively. "Knowing" studies presented a higher percentage for plants (14.1%) than invertebrates (11.3%). There was only one paper focusing on fungi species and it was in the "Knowing" category.

Within the vertebrates group the results depicted a bias towards birds and mammals (25.5% and 22.6%, respectively), which was found in "Knowing" and "Doing" categories (Fig. 4b). Fish was the least studied group (2.8%). Birds and mammals were the only vertebrate groups focused by "Guidelines" category (1.9% each).

2. Discussion

The amount of research on HLD has increased consistently over the years. This reflects its important role in global change and the considerable amount of resources allocated to reduce its damage (Fardila et al., 2017; Haddad et al., 2015). However, we found implementation spaces between the conservation science ("knowing") and practice ("doing") body of research regarding HLD. A possible cause is that Web of Science does not cover gray literature. Although it is hard to incorporate gray literature using a systematic approach we must acknowledge that important information about conservation practice is being left out because most of the "doing" information is probably available on technical reports or other types of gray literature. Practitioners were questioned about what sources of information were used to inform conservation management plans and the most used sources were existing management plans, expert opinion, published reviews, books or handbooks and documentation of traditional management practices (Pullin et al., 2004). Published scientific papers were one of the least frequently used sources of information. Another study with a similar approach found that a relatively high number of legislators and conservation managers used scientific literature as a source of information, but few have often consulted it (Karam-Gemael et al., 2018).

Our results highlight two major problems regarding the knowing-doing gap. The first is the growing concern that many conservation initiatives may not be fulfilling their mission to reduce biodiversity and habitat loss for trusting intuition and conventional interventions instead of evidence of what works and when (Barnes et al., 2018; Pressey et al., 2017; Sutherland et al., 2004). We must certify that initiatives make a positive difference for biodiversity and that we have the best return for the limited resources devoted to conservation (Ferraro and Pattanayak, 2006).

The second problem is the translation and delivery of existing scientific knowledge. Practitioners informed that there are obstacles that hinder their usage of scientific data, such as technical language, difficulty of access and language barrier for non-English speakers (Karam-Gemael et al., 2018; Prendergast et al., 1999; Pullin et al., 2004). While a great part of scientists affirm their research is relevant for practical *in situ* conservation management and that they give specific management advice (Habel et al., 2013), a certain part of this body of research is not available in appropriate and accessible formats to most practitioners, as was informed. Consequently, practitioners cannot try to execute them and give feedbacks about how practical and feasible recommendations are.

The growing amount of "Guideline" studies signals a concern among conservation scientists in bridging the gap between knowledge and practice, focusing on an evidence-based approach. Although the shape of scientific papers might turn them difficult to be accessed by most practitioners, when writing “Guideline” studies scientists show an attempt to better inform practice with detailed instructions. Nevertheless, there is still much to be done and potential solutions to bridge the identified gap encompass bringing conservation scientists and practitioners closer.

In one side, researchers have a mission to convince practitioners of the benefits of science and evidence-based approaches for decision making with effective outcomes (Pressey et al., 2017). One way to accomplish it is rethinking current publishing format. Publishing papers with additional versions in the conservation focused-area native language is a step closer (e.g. Vieira et al., 2018), but conservation journals should also mind about less technical outputs using accessible language to non-scientists. Developing booklets and science communications courses/seminars on a local scale is a matching strategy to make scientific knowledge more intelligible (Karam-Gemael et al., 2018; Pullin et al., 2004). Walking this path will be more fruitful if collaboration with local practitioners and stakeholders is enhanced throughout the process.

On the other side, practitioners should be more open to scientist’s recommendation (Prendergast et al., 1999) and help them to design feasible strategies to reduce biodiversity and habitat loss. Practitioners are also able to provide valuable information about local conditions that might determine conservation action success, such as public support and potential impact of conservation on social well-being (Leiper et al., 2018; Stephanson and Mascia, 2014). Organizing workshops locally to discuss those matters is a manner to consolidate the partnership between the two sides. An important aspect to be considered is that funding agencies and research institutions should encourage scientists to bridge this gap by changing the reward system and evaluation criteria of their work. Researchers’ work shouldn’t be evaluated only by bibliometric indicators and they should be rewarded for societal engagement and conservation practice, otherwise it is unlikely that they will change their focus on traditional conservation science at the expense of research fund (Knight et al., 2008; Sutherland et al., 2004).

The conservation focuses biases we found are consistent with existing bias in conservation science (Clark and May, 2002; Di Marco et al., 2017; Esler et al., 2010; Martin et al., 2012) and habitat loss literature (Deikumah et al., 2014; Fardila et al., 2017). There are no major differences in conservation focuses among research categories, suggesting that the biases found are due to general conservation literature biases. Among the main conservation focuses biases detected, taxonomic and geographical are the ones most prevalent. Consonant with this review, other studies found a great bias towards vertebrates, especially birds and mammals (Clark and May, 2002; Deikumah et al., 2014; Di Marco et al., 2017; Fardila et al., 2017). This situation is in line with IUCN Red List, in which vertebrates are proportionally more represented than plants or invertebrates, considering both the number of species described or endangered. This cause may also be linked to the bias towards species level of biological organization. The IUCN Red List still is one of the main tools for guiding conservation strategies and policy. Just recently other levels were included in global conservation initiatives, such as the IUCN Red List of Ecosystems (https://iucnrle.org), IUCN Key Biodiversity Areas (Brooks et al., 2015), and Aichi Biodiversity Targets Strategic Goal C, which is aimed to improve the status of biodiversity by safeguarding ecosystems, species and genetic diversity (Convention on Biological Diversity (CBD), 2010).

Another potential bias regards editorial tendency towards certain taxonomic groups, prevailing 'popular' or 'model organisms' study organisms (e.g. endotherms) (Bonnet et al., 2002). For example, amphibians are one of the most imperiled groups, with approximately 40% of the species endangered, 88% of the threatened amphibians are affected by habitat loss and degradation (IUCN, 2018), but they represent less than 9% of the analyzed studies here. Publication bias might also be related to methodological difficulties in working with certain groups compared to others or even public support towards charismatic species (Clark and May, 2002; Pawar, 2003).

Most studies analyzed were conducted in developed countries. However, there is not an overlap with Biodiversity Hotspots (Myers et al., 2000) or countries with the highest rates of habitat loss (Deikumah et al., 2014; Sodhi et al., 2010), which are, generally, developing countries. The Afrotropics have one third of global tropical forest area, the highest percentages of forest cover loss and a deficient forest protection (Deikumah et al., 2014), yet it is the least studied realm, as also shown by previous research (Di Marco et al., 2017; Fardila et al., 2017; Martin et al., 2012). A strong geographical bias entails an imbalanced understanding of habitat loss because certainly there is a lack of knowledge about unique mechanisms from those poorly studies regions. Not only a knowing-doing gap prevails as a result but, more deeply, a general knowledge gap that reduces the capacity of developing initiatives to halt biodiversity threats. One of the main causes is probably the high abundance of researchers and resources in developed countries (Martin et al., 2012).

Researchers in developing countries face many challenges to publish in leading and English written journals. Besides the language barrier, there is also resources and institutional limitations (Salager-Meyer, 2008). International cooperation is a key step to achieve a less biased geographical picture of habitat loss effects and needed actions. Brazil is an exception for being a developing and megadiverse country with high rates of habitat loss and one of the most well studied countries. There is a signal that there is a shift towards a more comprehensive conservation science, although it seems it will be slow (Di Marco et al., 2017). Despite HLD being a generalized threat, the number of papers based on freshwater and marine habitats was scarce. A first though is that humans might be interested primarily in studding the habitat they inhabit and this is translated in the amount of funding available for researches (Levin et al., 2004). Additionally, my search was possibly hindered because research on aquatic habitats are predominantly published on journals more specific in the field instead of conservation journals (Levin et al., 2004).

Considering the focus of this research, it is positive that most studies, in all research categories, were developed at local scales. While global and regional scales allow us to detect system properties, such as complementarity, connectivity, and large-scale ecological processes and threats, planning actions at such broad scales will likely result in failure of designs to guide conservation action (Cheok et al., 2018; Guerrero et al., 2013). Matching actions and appropriate scales results in greater potential to achieve objectives.

A high amount of theoretical knowledge already exists to inform conservation practice in many biogeographical realms to attempt to halt the current levels of habitat loss and degradation. The scientific community should be more cautious about the different bias in current HLD literature and take this into account when designing future projects, aiming to balance the existing conservation biases. In this way we will achieve better results in reducing habitat loss and degradation impacts on biodiversity.

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CAPÍTULO 2

THE RESIDUAL NATURE OF PROTECTED AREAS IN BRAZIL

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The residual nature of protected areas in Brazil

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Highlights

- More than 70% of Brazil’s protected areas (PAs) are in the Amazon biome
- Only the Amazon meets Aichi Target 11 of 17% of land under protection
- The other five Brazilian biomes are poorly protected
- PAs in these other biomes are strongly biased towards lands unsuitable for extractive uses
- Commonly used methods for measuring conservation success can be misleading

ABSTRACT

In recent decades, the number and extent of protected areas (PAs) have increased, covering more than 10% of the Earth. However, protection tends to be residual because PAs have been consistently established on marginal lands that minimize costs and conflicts with extractive uses instead of focusing on places important to biodiversity. Here, we provide a panorama of the current network of PAs in Brazil, examine the biases of protection in relation to slope and land use intensity, and determine whether biases vary between biomes. We measured protection bias by accounting for differences between PAs and the municipalities in which they were established, indicating the direction and strength of bias. Brazil has 18% of its land under protection, but 70% of this is in the Amazon. Brazil's other biomes hardly reach 10% of their territories under protection and have strong protection bias. Generally, PAs are strongly biased towards lands with low intensity of use before they were established compared to their background landscapes. There was a small bias towards high slope, but most PAs had the same slope profile as their background landscapes. Trusting percentages of area under protection as a measure of conservation success risks misdirecting conservation actions to areas of lower biological importance and lower threat. To promote effective conservation actions more evidence-informed strategies should be used, based on appropriate ecological criteria and explicit objectives that allow us to measure the likely conservation impacts.

Keywords: Conservation policy; Convention on Biological Diversity; protected areas; residual protection; systematic conservation planning.

1. Introduction

Protected areas (PAs) are the cornerstone strategy to avert global biodiversity loss. Nations across the globe supported this strategy in committing to the Convention on Biological Diversity's Aichi Target 11 to protect 17% of land and inland water and 10% of marine areas by 2020 (CBD, 2010). Altogether, there are 19.8 million km^2 of terrestrial and inland water areas covered by PAs (14.7% of the earth's surface, excluding Antarctica), with Latin America and the Caribbean having the highest percentages of terrestrial territory under legal protection (24%) (UNEP-WCMC and IUCN, 2016). To reach the 17% target globally, an additional 3.1 million km^2 of PAs are needed (UNEP-WCMC and IUCN, 2016). Marine ecosystems are going through equally rapid and radical transformations but face a different array of threats to biodiversity. In December 2016, 4.12% of the global ocean and 10.2% of coastal and marine areas under national jurisdiction were covered by marine PAs (UNEP-WCMC and IUCN, 2016).

Although the recent growth in global extent of PAs has been impressive, area-based targets such as Aichi Target 11 come with a substantial risk. Target 11's requirements for effective design and management are qualitative, making them impossible to measure and monitor. This limitation shifts the focus of countries to rapid accumulation of sheer extent because it is the only quantitative goal. In turn, in the context of economic forces and political expediency, there is a large risk of expanding PA systems by continuing "residual" reservation. The term residual here refers to the establishment of PAs in landscapes with least suitability for extractive uses and, in many cases, facing least threat to biodiversity. The risk of adding more residual PAs is more than speculation, as demonstrated by many studies on the residual tendency of PAs worldwide (Hoekstra et al., 2005; Joppa and Pfaff, 2009; Nori et al., 2015; Pressey et al., 2015; Scott et al., 2001; Venter et al., 2018), with biases in protection commonly towards steeper, higher, less fertile, more arid, and more remote land. Consequently, area coverage alone is not a good measure of the overall effectiveness of PA networks or conservation success (Pressey et al., 2015).

Brazil is the largest country in Latin America and also holds the largest network of PAs in the world, with more than 250 million ha under protection, covering almost 29.42% of the country's area (UNEP-WCMC and IUCN, 2018). This includes indigenous lands, quilombola territories (settlements founded by escaped slaves now owned by their descendants), military areas, and nature parks and reserves. Protected areas has been the focus of considerable debate in Brazil about their efficiency, location, and legal protection (Carranza et al., 2014; Lemes et al., 2014; Marques and Peres, 2014; Nolte et al., 2013). Many Brazilian PAs have also been subject to downgrading, degazettement, and downsizing (Bernard et al., 2014). Several new PAs were created in the last decade and some studies evaluated country-wide changes in PA boundaries and categories (Bernard et al., 2014), the degree of biodiversity protection and knowledge within Brazilian PAs (Oliveira et al., 2017), and management actions for invasive alien species in Federal PAs (Guimarães and Schmidt, 2017). There were also studies at the biome scale, such as the role of PAs in climate change mitigation (Soares-filho et al., 2010) and avoided deforestation (Nolte et al., 2013) in the Amazon and the Cerrado (Carranza et al., 2014). Other work has evaluated the performance of marine PAs in meeting conservation objectives (Magris et al., 2013).

Even with all this welcome attention to the effectiveness of Brazilian PAs, there has been no assessment of residual biases across the country or within biomes. This is an important gap in knowledge because it concerns the ability of Brazilian PAs to mitigate impacts on biodiversity from extractive land uses. Brazil is signatory to many international commitments and has its own conservation targets (MMA, 2017) but, if Brazil is to make real conservation progress in the coming years, then a thorough understanding of PA biases and how they can be reversed is essential. Here, we provide the first panorama of residual biases of terrestrial PAs in Brazil.

Here, we address three questions: (1) what is the profile of the current system of PAs in terms of extent, coverage of biomes, integral (IUCN categories I to III) versus sustainable categories (IUCN categories IV to VI), and levels of government management? (2) Are PAs biased, relative to surrounding lands, in terms of slope and land use intensity before their establishment?, and (3) How do biases in relation to slope and land use intensity vary between biomes? Our study contributes to the emerging global picture of residual reservation and its limitations for protecting biodiversity. In addition, our methods are likely to have general applicability for extensive assessments of PA biases in other parts of the world.

2. Methods

2.1 Protected areas

We considered federal, state, and municipal PAs. We obtained data from the website of the Ministry of the Environment (MMA - http://mapas.mma.gov.br/) and the National Electricity Agency (ANEEL - http://www.aneel.gov.br/). In our analyses, we excluded PAs that did not fit into categories I-VI according to the International Union for Conservation of Nature (IUCN). Accordingly, we disregarded indigenous lands and quilombola territories because they are covered by different legislation in Brazil and are not compatible with the National System of Protected Areas (SNUC – acronym in Portuguese).

The Brazilian National System of Protected Areas was established in 2000 to unify and standardize management of PAs established and managed with nature conservation as their main goal. Using these sources, we gathered the following information for each PA: name, biome and state in which it was located, area (in ha), year of creation, and category of use (integral protection or sustainable use according to SNUC). The main difference between integral protection and sustainable use PAs is that the first category has stricter constraints on extractive activities, while the latter aims to reconcile nature conservation with sustainable extraction of natural resources. We used data from

Brazil's National Registry of Conservation Units (CNUC, 2017) to complement information about area and biomes of recently created PAs that lack spatial data on boundaries and other attributes.

2.2 Biomes

Brazil is a megadiverse country and houses a great variety of ecosystems ranging from grasslands and savannas to wetlands and dense tropical rainforests. There is a disparity between habitat loss and protection in the world because some biomes are under more pressure for conversion than others and there is a bias in protection towards specific types of biomes and ecoregions (Hoekstra et al., 2005). The six terrestrial biomes identified in this study followed the 2004 habitat classification from the Brazilian Institute of Geography and Statistics (IBGE – acronym in Portuguese).

2.3 Slope

Global protection is typically biased towards locations that minimize conflict with lands suitable for human uses, including steep slopes and low-fertility lands (Joppa and Pfaff, 2009; Pressey et al., 2002). Because slope reflects potential for extractive uses, it is a suitable variable to account for residual bias. We used the Map of Percentage Slope of Brazilian Relief to obtain information about the topographic relief of the PAs. This map was developed by the Brazilian Geological Service from a mosaic of SRTM (Shuttle Radar Topography Mission) images. The SRTM image mosaic was used as the base data and we adopted the slope classification developed by IBGE. Each pixel (approximately 120 m^2 resolution) of the slope layer had an associated value ranging from 1 to 6, according to the degree of the slope (0-3% = 1; 3-8% = 2; 8-20% = 3; 20-45% = 4; 45-75% = 5; > 75% = 6). Analyses of slope were possible for 1483 PAs (70.61% of the total number), excluding marine PAs and terrestrial PAs that lack spatial data on boundaries and other attributes.

We measured protection bias in relation to slope in several steps. As well as the median value of slope for each PA, we calculated the median value of the respective municipality (or municipalities) in which the PA was located (including pixels within the PA). The medians for municipalities gave us a comparative picture of the "background" slope in landscapes surrounding PAs. We acknowledge that median values derived from numerical categories, especially categories with unequal ranges, involve some inaccuracies relative to medians derived from raw, uncategorised values. However, we believe our medians to be adequate for comparative purposes because of the method we used.

We expressed both PA and municipality values as percentages of the range of slope values across the municipality(ies), following the method of Pressey et al. (2000). For each PA, we then subtracted the percentage value for the municipality(ies) from the PA value to estimate its bias. Bias values potentially varied from negative 100% to positive 100%. Differences close to 0 indicated little or no bias in relation to slope. Positive differences indicated that PAs were biased towards lands with higher slope than surrounding unprotected land, while negative differences indicated that PAs had lower slopes than their surroundings. We plotted the distributions of slope bias values only in relation to numbers of PAs. We avoided plotting bias values in relation to extent of PAs because our method did not account for spatial variation in bias within PAs. We also tested whether bias values differed among biomes with Kruskal-Wallis tests.

2.4 Land use intensity

We used data on land use intensity as an indicator of the extractive potential of lands before the establishment of PAs. To evaluate the intensity of land use where the PAs were located, we used the database of agricultural land use in Brazil developed by the Research Group on Atmosphere-Biosphere Interaction (Dias et al., 2016). This is a spatially explicit database (approximately 1 km^2 resolution) of agricultural distribution that includes cropland (total between 1940 and 2012 and soybean, maize and sugarcane planted between 1990 and 2012), pastureland (natural and planted between 1940 and 2012), and productivity (from soybean, maize and sugarcane crops and cattle stocking rates between 1990 and 2012). We combined cropland and pastureland data to obtain a final map of total land use intensity for each decade (1940 to 2010) ranging from 0 to 100%. Analyses of land use intensity were possible only for 1496 Pas (71.23% of the total number), excluding marine PAs and terrestrial PAs that lack spatial data on boundaries and other attributes.

We measured protection bias in relation to land use intensity in the same way as for slope, except that we calculated median values for each PA and its municipality(ies) for the decade of the PA's establishment. Using respective historical data had two advantages. First, this approach indicated land use intensity of areas before they were protected. Such data are often missing for protected areas, constraining comparison of protected areas and their surrounding landscapes. Second, it allowed us to measure protection bias in relation to land use intensity at the time of PA establishment. In turn, this allowed us to investigate trends in bias as PAs were added progressively to the system. Bias values for land use intensity, like those for slope, potentially varied from -100% to 100%. Negative differences indicated that PAs were biased towards lands with lower land use intensity than surrounding unprotected land, while positive differences indicated that PAs had higher land use intensity than their surroundings at the time of establishment. We plotted distributions of bias values only in relation to numbers of PAs for the same reason as that for slope bias. We also tested whether bias values differed among biomes with the use of Kruskal-Wallis tests.

We used linear regressions to test the relationship between the decade of establishment of PAs and their bias in relation to land use intensity. We surmised that PAs established earlier might have bias values closer to zero if they were established on land before its full potential for extractive activities was understood, making earlier PAs more representative of their surroundings. In contrast, we guessed that later reserves might be established when land use potential was more fully understood, pushing them toward lands with less extractive interest, which would give them more strongly negative bias values.

2.5 Habitat representation

We obtained spatial data on the different habitats occurring in Brazil using the digital format of RadamBrasil, which is a historical data on the vegetation of Brazil and is considered the biggest project on the level of coverage of natural resources in the country (IBGE, 2015). To update the map for current native vegetation remnants, we overlaid the RadamBrasil map with MapBiomas Land Use and Land Cover map (MapBiomas, 2018). Then, we divided the percentage of each habitat occuring inside PAs by the percentage of land area in Brazil covered by PAs. This procedure allowed us to quantify the extent to which the different habitats are represented by PAs and to compare the representation ration between residual and non-residual PAs (Eigenbrod et al., 2009).

This approach indicates whether the amount of a given habitat is more or less than would be expected for the PA coverage in the country. A value lower than 1 indicates that the PA network contains a lower amount of a specific habitat relative to the area that it covers. A value greater than 1 indicates that the PA network contains a large amount of a specific habitat relative to the area that it covers.

3. Results

3.1 Overall coverage of protection

Brazil had more than 2000 established PAs assigned to IUCN categories I-VI, covering 153 million ha of continental territory and 5.5 million ha of marine territory, totalling *ca.* 18% of the continental territory (Table 1). A period of major investment in the creation of PAs began in the 1980s and continued until the 2000s, when a stagnation period began during which few PAs were created per year (Fig. 1).

3.2 Biomes under protection

In terms of both number and total extent of PAs, there was considerable variation between biomes. The Atlantic Forest, Cerrado, and Amazon were, respectively, the biomes with the highest number of PAs (Fig. 1a, b). Discrepancies between biomes were larger in terms of total extent of PAs. Of the 153 million ha of terrestrial PAs in Brazil, 116 million ha (75% of the national total) were in the Amazon (Fig. 1c, Table 1). The Cerrado had the second largest area protected, but this extent represents only 8.6% of the biome. The Atlantic Forest, despite having the largest number of PAs of all the biomes, had the third largest area protected, covering 10.1% of its territory. The Caatinga was fourth in both number and area protected, with 7.7% areal coverage. The Pampa and Pantanal were the least protected continental biomes, with 2.7% and 4.6 %, respectively, of their areas protected. Brazilian marine ecosystems had the poorest protection, with less than 2% coverage (Table 1).

3.3 Protected area categories

Until the mid-1990s, the number of PAs established for strict (integral) protection was greater than the number of PAs intended for sustainable use. The latest figures indicated that sustainable use PAs were almost twice the number and total extent of strict PAs (Fig. 1e, f).

3.4 Protected areas and levels of government

Investments in PAs have occurred at all levels of government, but those at the state level surpassed the others. In the last few decades, the Brazilian states have increased the number of PAs in their jurisdictions, which is also reflected in the increased total extent of state PAs (Fig. 1g, h). Federal PAs, despite being half the number of state PAs, covered the largest area, with almost 80 million ha. This means that federal PAs had a larger mean area than PAs at the state and municipal levels. In the last 15 years, only a few additional PAs have been established in Brazil. Little investment in PA establishment has been made at the municipal level.

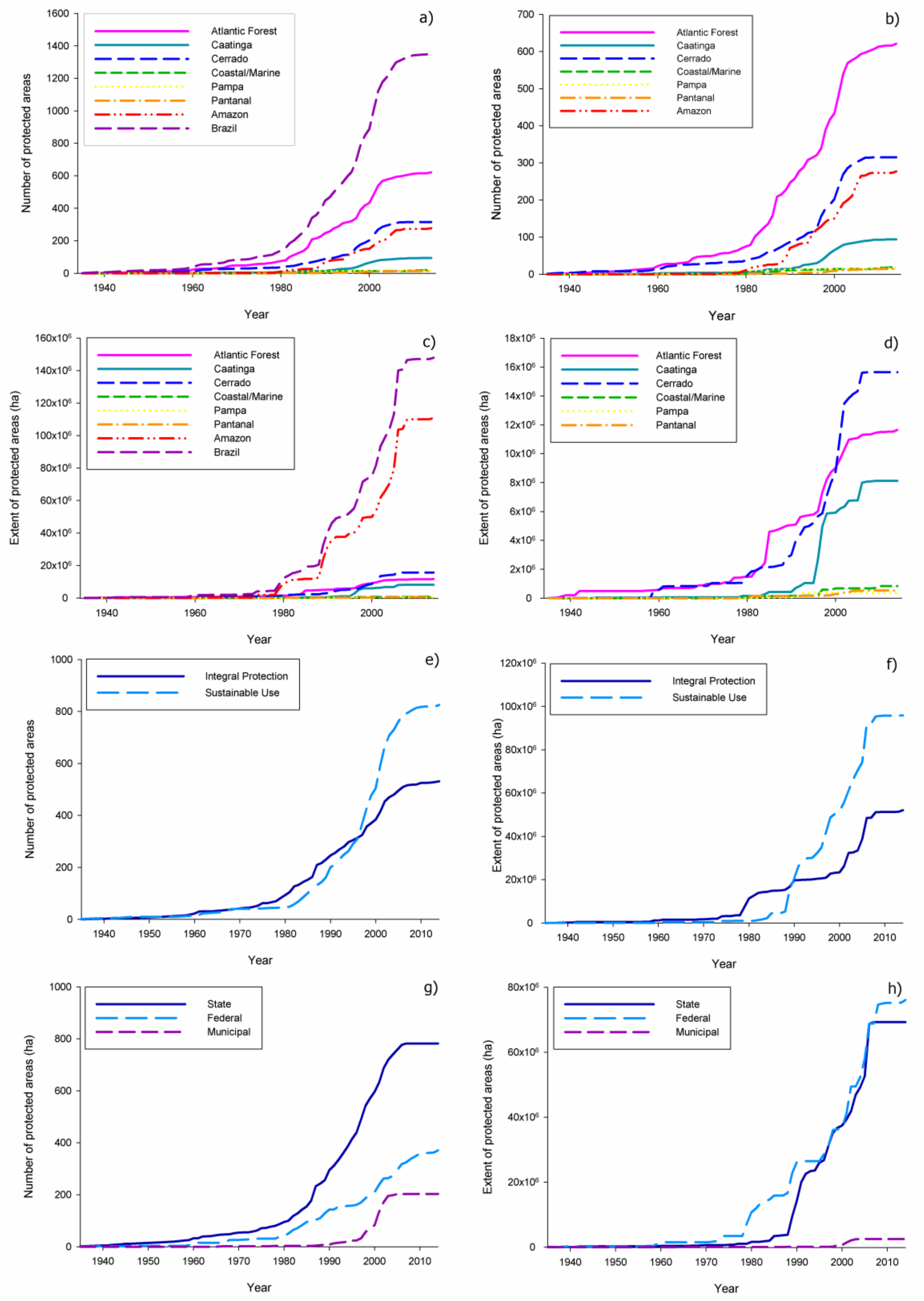

Figure 1. Temporal variation in the establishment of the network of protected areas (PAs) in Brazil: a) Number of PAs in Brazil and in each biome; b) Number of PAs in each biome; c) Total extent of PAs in Brazil and in each biome; d) Total extent of PAs in each biome, excluding the Amazon; e) Number of PAs

by category of use; f) Total extent of PAs by category of use; g) Number of PAs by level of government; h) Total extent of PAs by level of government. Data available for PAs created up to 2014.

Table 1. Total number and area of protected areas (PAs) in Brazil (CNUC, 2017). Numbers of PAs in different biomes should not be added, because some PAs cover more than one biome.

Biome	**Total area (millions of ha)**	**Remaining native vegetation (millions of ha)**	**Number of PAs**	**Area under protection (millions of ha)**	**Percentage of total area under protection**	**Percentage of remaining native vegetation under protection**
Amazon	419.69	356.74	330	116.72	27.8	32.72
Caatinga	84.44	52.86	166	6.36	7.7	12.04
Cerrado	203.64	124.42	388	17.54	8.6	14.09
Atlantic Forest	111.01	30.46	1169	11.24	10.1	36.9
Pampa	17.64	7.28	26	0.486	2.7	6.67
Pantanal	15.03	13.33	24	0.689	4.6	5.17
Continental	**851.57**	**585.11**	**2053**	**153.05**	**18.0**	**26.16**
Coastal/Marine	**355.57**	**-**	**166**	**551.99**	**1.6**	**-**

3.5 Protected area bias in relation to slope

Nationally, most PAs were located on flat to moderate slope (Fig. 2a). This pattern was repeated in most biomes. In the Amazon, no PA had a mean slope greater than 3.5 and, in the Pampas and Pantanal, the average slope in PAs did not exceed 3 and 2, respectively (Fig. 2b, f, g). Although these three biomes have some steep formations, they are mostly flat, and this characteristic was reflected in the PAs. PAs in the Caatinga and Cerrado had more variation in slope, with values varying from 0 to 4 (Fig. 2d, e). The Atlantic Forest had the highest values of slope, and most of its PAs were on moderate to very steep slopes (Fig. 2c).

The largest class of bias values for slope was zero for all biomes and categories of use (Fig. 3a-i), but many PAs were biased toward steeper slopes, especially the Atlantic Forest (Fig. 3e), the

Caatinga (Fig. 3f) and the Cerrado (Fig. 3g). We found no differences among biomes for bias values (H(5)=6.34, $p>0.05$).

3.6 Protected area bias in relation to land use intensity

Across Brazil, the largest class of bias values was zero (Fig. 4a). However, nationally, most PAs were biased towards lower land use intensity, indicating a pronounced residual tendency. Very similar national distributions emerged for both integral and sustainable use PAs (Fig. 4b, c). We found significant differences between the Amazon and the other five biomes (H(5)=246.58, $p<0.01$), but no differences among the Atlantic Forest, the Caatinga, the Cerrado, the Pampa, and the Pantanal ($p>0.05$).

In the Amazon, with the exception of a few PAs with small negative and positive values, there was no bias in protection regarding land use intensity, with more than 70% of PAs in the zero category (Fig. 4d). Given the number of PAs in the Amazon, the influence of this biome's result on the national distribution (Fig. 4a) is apparent. The other five biomes all had obvious residual tendencies, with median bias values varying from -11 in the Pampa to -48 in the Pantanal (Figure 4e-i). Notably, in four biomes, there were small numbers of PAs with positive bias values, indicating that they were established on land with higher use intensity than the municipalities in which they occurred.

Contrary to our expectation, we also found a positive relationship between the the decade of establishment of PAs across Brazil and bias values in relation to land use intensity. In other words, bias values increased slightly through time, indicating a slight lessening of residual tendency over the time-series (R^2=0.015; β=0.123; $p<0.01$). A positive relationship also emerged for integral protection PAs nationally (R^2=0.019; β=0.138; $p<0.01$) but there was no correlation for sustainable use PAs ($p>0.05$). For biomes, there was positive correlation in the Atlantic Forest (R^2=0.023;

β=0.151; $p<0.01$) and a negative one for the Pampa (R^2=0.406; β=-0.637; $p<0.01$). There were no correlations for the other biomes ($p>0.05$). In any case, however, the amount of variance explained was minimal and the temporal trend was clearly weak. The effect size in the case of the Pampa (40.6%) was much larger than for any of the other correlations, indicating a strong tendency for more recent PAs to be established on land with lower land use intensity than their surroundings.

3.7 Protected area bias in relation to both slope and land use intensity

Combining data on bias for slope and land use intensity, we confirmed that land use intensity was more decisive for the establishment of Brazilian PAs. Most PAs were established in lands with lower intensity of use than their background landscapes, but with no bias for slope, even when we excluded the Amazon from the analysis (Fig. 5a-b; S1). Still, a substantial number of PAs were biased towards lands with higher slope and lower land use intensity. These data combined also provide complementary information: slope was not the main reason for low intensity of use, especially because landscapes in Brazil have mostly flat to moderate slopes (Fig. 2), but many PAs were established on steep land with low intensity of use, indicating a marked residual tendency.

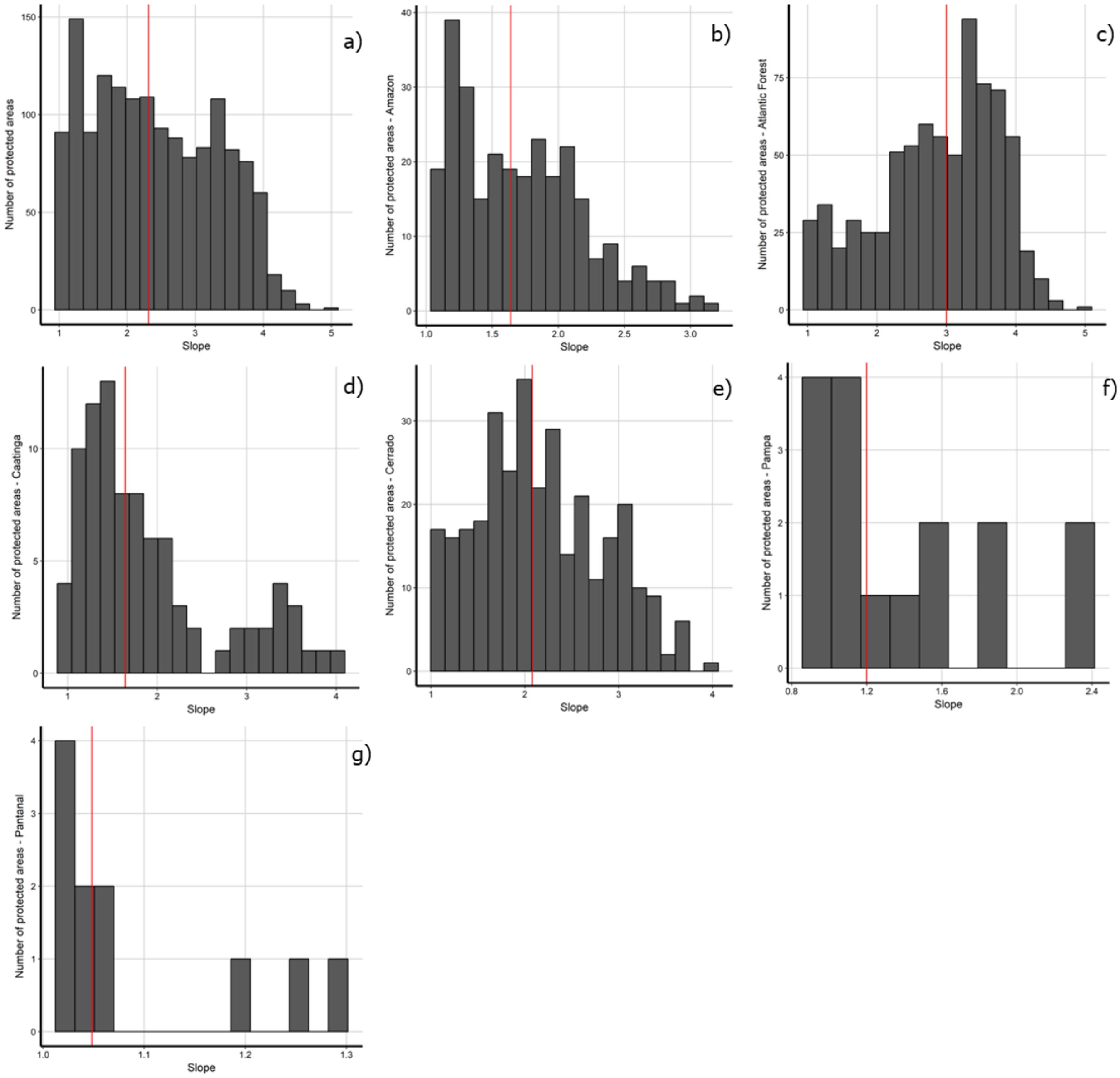

Figure 2. Slope in protected areas. a) Brazil; b) Amazon; c) Atlantic Forest; d) Caatinga; e) Cerrado; f) Pampa; g) Pantanal. Slope values: 1 - 0 to 3%; 2 - 3 to 8%; 3 - 8 to 20%; 4 - 20 to 45%; 5 - 45 to 75%; 6 - > 75%. Red lines indicate median values across all PAs.

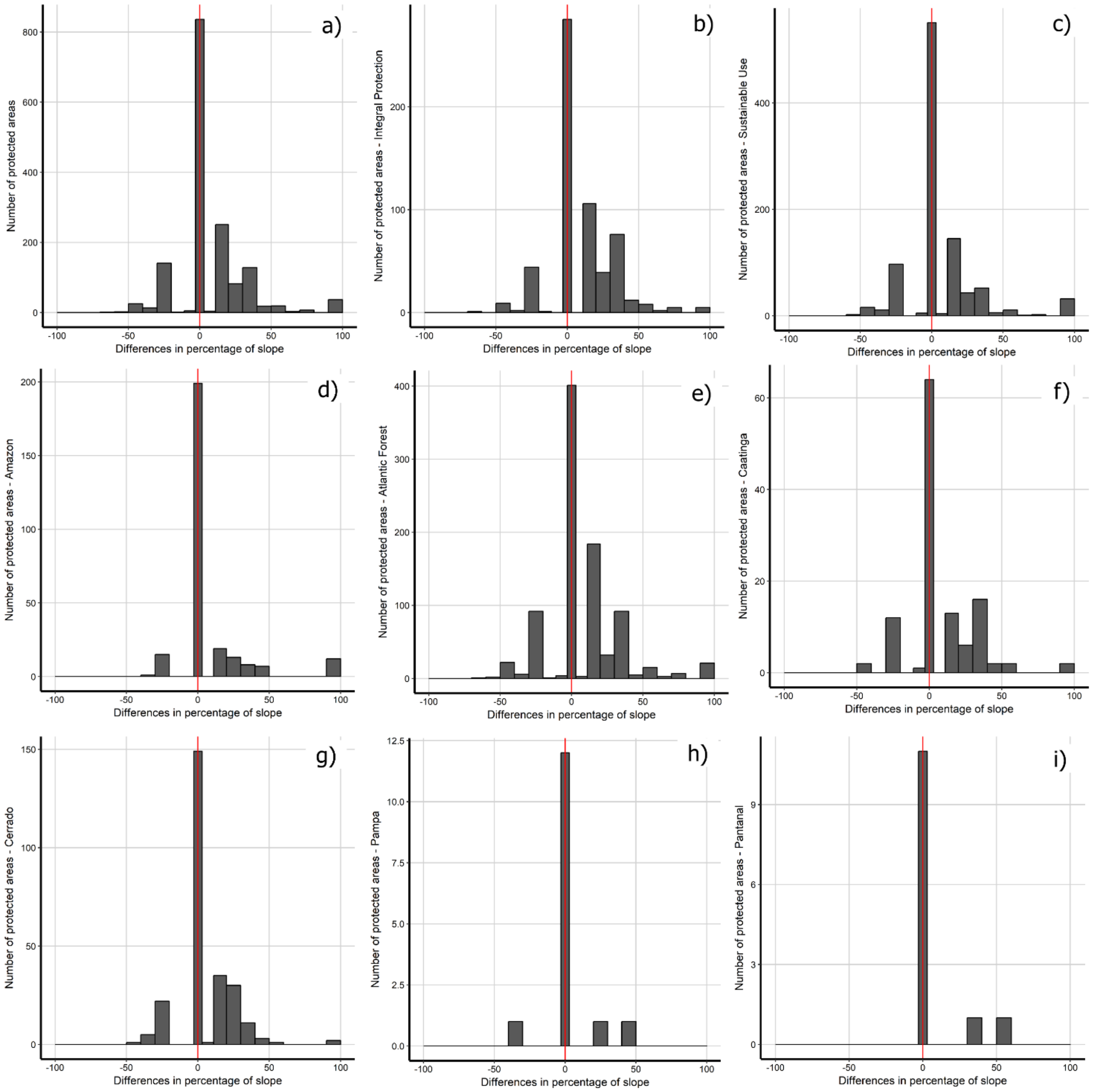

Figure 3. Bias of protected areas (PAs) in relation to slope: a) All PAs in Brazil; b) Integral protection PAs; c) Sustainable use PAs; d) Amazon PAs; e) Atlantic Forest PAs; f) Caatinga PAs; g) Cerrado PAs; h) Pampa PAs; i) Pantanal PAs. Zero values indicate no bias in protection regarding slope; negative values indicate bias towards flatter slope; positive values indicate bias towards steeper slope. Stronger bias values are further from zero. Red lines indicate median values of the distribution.

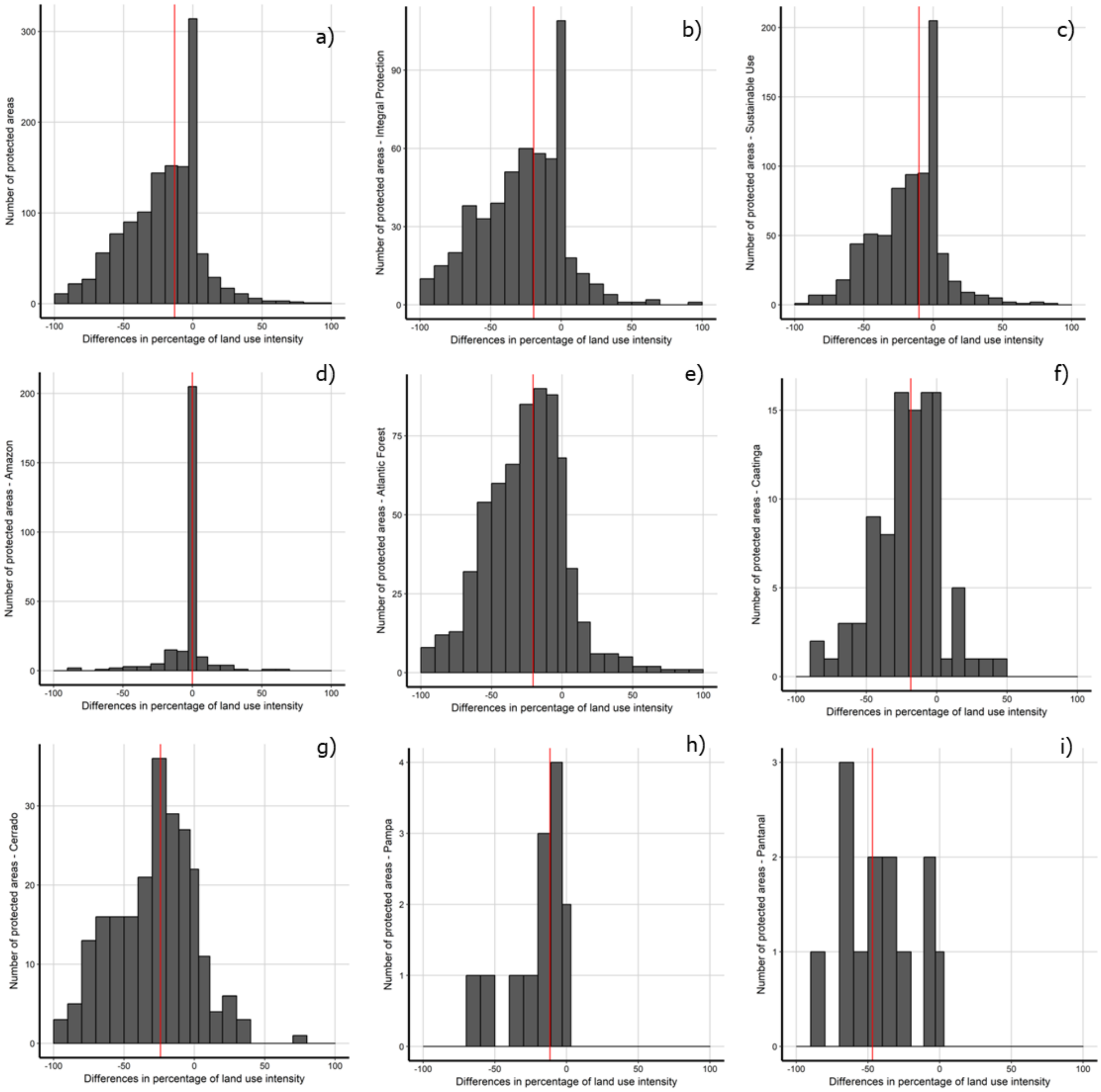

Figure 4. Measure of protection bias in relation to land use intensity in the decade of establishment of protected areas (PAs): a) All PAs in Brazil; b) Integral protection PAs; c) Sustainable use PAs; d) Amazon PAs; e) Atlantic Forest PAs; f) Caatinga PAs; g) Cerrado PAs; h) Pampa PAs; i) Pantanal PAs. Zero values indicate no bias in protection in relation to land use intensity; negative values indicate bias towards lower land use intensity; positive values indicate bias towards higher land use intensity. Stronger bias values are further from zero. Red lines indicate the median values of the distribution.

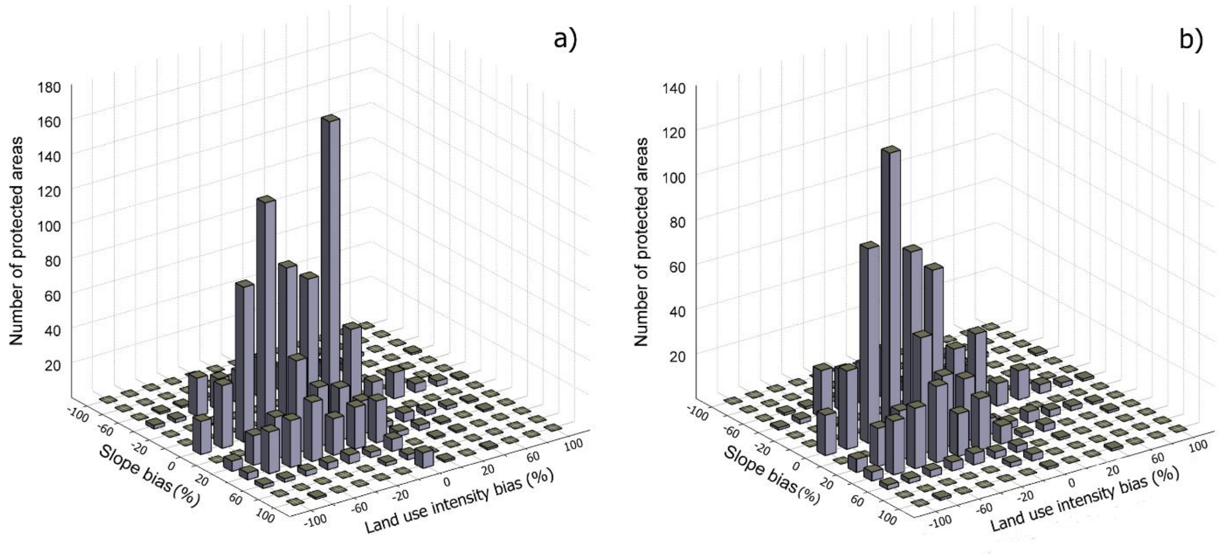

Figure 5. Protection bias in relation to both slope and land use intensity in the decade of establishment of protected areas: a) All biomes; b) All biomes, excluding the Amazon. Zero values indicate no bias in protection for both variables. Negative values indicate bias towards lower land use intensity and flatter slopes; positive values indicate bias towards higher land use intensity and steeper slopes. Stronger bias values are further from zero.

3.8 Protected area bias and habitat representation

Protected areas are relatively well placed to protect Brazil's habitats if we consider all habitats together (Table S1). If we compare PAs classified as residual or non-residual, habitat representation ratios in PAs biased towards steeper slope and lower intensity of use were remarkably lower than expected by the area covered, whereas non-residual PAs presented ratios closer to one. This showed that the residual nature of Brazilian PAs leads to an underrepresentation of habitats. Nevertheless, some habitats were well represented in both residual and non-residual PAs; whereas, others presented a discrepant distribution between biased and non-biased PAs.

The most iconic example is upper-montane vegetation refugee distribution inside residual PAs that was 27.7 times the level of representation expected based on area alone, while the same habitat was underrepresented inside non-residual PAs. The opposite also happened and there were habitats overrepresented in non-residual PAs and underrepresented or even with no representation within residual PAs. It is noteworthy that some habitats had no representation within PAs.

4. Discussion

Percentages of regions under formal protection are not reliable measures of conservation success. A fundamental purpose of conservation planning and the creation of PAs is to intervene in the loss of biodiversity. Despite the global effort to increase the number and extent of PAs, they tend to be residual on land and in the sea (Baldi et al., 2017; Devillers et al., 2015; Joppa et al., 2008; Joppa and Pfaff, 2009; Pressey et al., 2002, 2015; Venter et al., 2018). Terrestrial PAs around the world are biased towards higher elevations, steeper slopes, lower productivity, and more remote locations, mainly to minimize conflict with extractive interests.

Our study demonstrates that, despite considerable expansion of Brazil's PA system in recent decades, the global trend towards residual reservation is repeated in most parts of the country. From the 1990s to 2010s, the area and number of PAs in Brazil increased substantially. Before the due date of 2020, Brazil had partially met the quantitative part of Aichi Biodiversity Target 11 (CBD, 2010) by protecting more than 17% of its land surface. This expansion did not, however, protect Brazilian biomes in equal proportions, with the 17% target achieved only for the Amazon. Part of this unevenness was probably due to differences between biomes in slope and land use intensity and part reflecting a worldwide bias in conservation efforts towards wild, charismatic, and relatively unproductive landscapes (Pressey et al., 2002). Notably, our results demonstrate clearly a residual tendency of PAs nationally and in most biomes, and we found little difference in the distributions of bias values between integral and sustainable use PAs. The exception to the national pattern was the Amazon, which can be explained in two ways. First, most of the Amazon has low values for slope and land use intensity, so that both PAs and the lands surrounding them contain high percentages of natural vegetation (Joppa et al., 2008). Second, our measure of land use intensity did not account for threatening processes such as logging and mining, which are extensive through the Amazon (Asner et al., 2005; Ferreira et al., 2014b; Loyola, 2014).

Differences between protected and unprotected areas in suitability for human uses also mean differences in biodiversity composition, so species, ecosystems, and natural processes associated with unprotected areas remain at risk of reduction or extinction (Devillers et al., 2015; Joppa and Pfaff, 2009). Residual PAs therefore might spell danger for those species and ecosystems overlapping with higher suitability for human uses. The focus of human activities on more productive regions is even more serious for biodiversity where species richness is also correlated with productivity (Luck, 2007). After the expansion of PAs in Brazil in the 2000s there was not a commensurate increase in protection of biodiversity (Oliveira et al., 2017). The Pampa and Pantanal biomes had the lowest percentages of area protected and the lowest percentages of species and lineages protected, but all other terrestrial biomes, even the Amazon, also had a deficit of biodiversity protection (Oliveira et al., 2017). If recent PAs created in the world had been planned to focus strategically on underrepresented vertebrate species instead of favoring low-cost lands, it might have been possible to protect 30 times more species for the same area or the same cost as the actual expansion that occurred (Venter et al., 2018).

Studies of the impact of PAs, in terms of avoiding deforestation that would have otherwise occurred, have shown that PAs have contributed to reducing land conversion in the Amazon (Nolte et al., 2013) and the Cerrado (Carranza et al., 2014). These results are not at odds with ours. For both biomes, we found that some PAs had positive bias values, meaning that they had been established in areas with higher land use intensity than their surroundings and could therefore be expected to reduce land conversion. Importantly, though, our bias results showed that PA impact on conversion could have been higher in the Amazon and much higher in the other biomes. As a complement to this study, it will be very useful to have additional estimates of PA impact across all biomes in Brazil with the aim of understanding how the impact of future PAs can be increased.

Across Brazil and in the Atlantic Forest, we found a slight change over time in bias values related to land use intensity, with later PAs tending to be more similar to their background landscapes, and less strongly residual, than earlier PAs. However, these small changes were insufficient to offset obvious remaining residual biases. The grassland biome, the Pampa, was the exception here, with clearly increasing residual bias over time. This trend suggests that later PAs were established when land use potential was more fully realized and were, therefore, pushed to the margins of suitability. Areas within more strongly residual PAs in the Pampa would more likely have remained unconverted to intensive uses, a possibility that reinforces the Pampa as one of the least protected biomes in Brazil.

Although the Amazon is the most pristine biome in Brazil and is the main conservation focus of the federal government, these characteristics will probably change as the agricultural frontier advances further into the biome (Michalski et al., 2008) and the region is targeted increasingly for mining (Ferreira et al., 2014a; Loyola, 2014) and timber (Asner et al., 2005) enterprises. Indeed, the Amazonian biome has the largest number of events of downsizing, downgrading, and degazettement (PADDD) in Brazil (Bernard et al., 2014). The highest number of PADDD events in Brazil occurred in state PAs, which means that, at the state level, there are more bills and decrees approved to alter PA boundaries and categories (Bernard et al., 2014). This reflects the higher susceptibility of state legislative chambers to local and political extractive interests compared to federal ones. In the Cerrado, Federal PAs are also less deforested than state or municipal PAs (Françoso et al., 2015).

Both formal PADDD events and informal incursions emphasize the need for Brazil’s Ministry of the Environment (MMA) to more closely monitor state and municipal environmental agencies and enforce the integrity of reserves. This would enhance the role of the network of PAs since they would be managed in an integrated manner with other PAs across the country. However, this is only part of the solution, since federal PAs accounted for 70% of the total area lost due to PADDD (Bernard et al., 2014). In the federal sphere, it is much harder to approve controversial bills because there are more members of Congress with different opinions and the country's eyes are on them, even though the environmental agenda is not a high priority for most Congress members. To minimize public exposure, there are efforts in Congress to maneuver to incorporate large adjustments at one time. Early in 2017, the Congress approved a Provisional Measure (MP 756/2016) that reduced the area and conservation status of almost 900 thousand hectares of PAs in the Amazon and Atlantic Forest. The Measure was vetoed by the President at the end, but it demonstrated the potential for one bill to greatly change the extent and conservation status of PAs (Senado Federal, 2017). To halt the environmental shortfall that can lead to irretrievable losses, more political commitments are needed to not only maintain the existing conservation policies but also to enhance the coverage and impact of PAs (Crouzeilles et al., 2017).

Although our focus in this study was on terrestrial PAs, it is timely to review briefly the adequacy of Brazil's marine PAs. The picture in the marine realm is even less satisfactory than on land. Less than 2% of Brazil's marine jurisdiction is within PAs, with marine ecosystems being underrepresented, marine PAs only partially connected (Magris et al., 2013), and PA extent increasing very slowly (Fig. 1a-d). Globally, in the marine environment, there is a similar pattern to that on land. Especially after 2010, many marine PAs have been created in the world, but the emerging trend is to create remote and large marine PAs, far from the main short-term or even long-term threats (Devillers et al., 2015; Giglio et al., 2018; Grech et al., 2017). On land and in the sea, the current practice of creating PAs, besides not protecting areas and features in most need of protection, wastes resources, consumes community goodwill, and establishes a false sense of achievement for conservation (Giglio et al., 2018; Grech et al., 2017; Pressey et al., 2017).

The increase in investments in PAs by the Brazilian government during the 1980s was accompanied by a change in the understanding of the roles of PAs. This change led to the pattern we have today in Brazil, with the sustainable use category representing the greatest number and extent of PAs in Brazil. This is a worldwide trend, especially after the 1992 United Nations Conference on Environment and Development in Rio de Janeiro, when sustainable use initiatives for PAs were prioritised as buffer zones, community-based conservation, and biosphere reserves and bioregional management (Zimmerer et al., 2004). Over 86% of all PAs worldwide allow for some form of human use (Peres, 2011). This reflects an awareness of the necessity to involve local communities in the effort to protect the environment (Zimmerer et al., 2004). Strict protection and sustainable use PAs are created to protect natural areas, but with different specific goals. Therefore, the assessment of PA effectiveness must recognise these different goals. For avoiding deforestation in Brazil, both types have proved to be effective compared to no protection, but strict PAs seem to be more effective (Carranza et al., 2014; Françoso et al., 2015; Nolte et al., 2013). In Latin America and Asia, strict PAs have substantially reduced fire incidence, but sustainable use PAs were even more effective (Nelson and Chomitz, 2011). Clearly, both strict and sustainable use PAs have important roles in conservation. An essential part of any system-wide assessment of effectiveness will be identifying the appropriate mix of these categories.

The national network of PAs currently is not representative for nearly half the habitats because the establishment of PAs has been driven more by opportunity rather than by strategic planning. Although it has been efficient to protect a significant amount of habitats and vegetations types, Brazil's PA network still misses a good part of it. One proposed solution to improve the performance of PA systems is to replace underperforming areas (Fuller et al., 2010). However, in Brazil, this is a dangerous strategy because the reduction of PAs is not offset by the creation of new ones elsewhere and it is likely to lead to an even more precarious reserve system (Bernard et al., 2014; Marques and Peres, 2014). The politics of conservation in Brazil are very unstable, and the balance has often been tipped against conservation when it comes into conflict with some economic sector, such as agriculture, livestock, or mining (Loyola, 2014). Brazilian environmental legislation must be empowered and properly enforced to ensure an efficient management of existing PAs and the establishment of new ones in lands in most need of conservation.

To achieve a more effective reserve system in Brazil will be possible only with a sufficient amount of economic and human resources to define explicit conservation objectives, design PAs to achieve these objectives, and ensure adequate implementation and management. Future PAs must be established not only with systematic conservation planning, but also to maximize the positive difference that PAs make to outcomes for biodiversity and people (Ferraro and Pattanayak, 2006; Pressey et al., 2017, 2015). All of this will be impossible if the government continues to cut resources from the environmental sector (Tollefson, 2016; Wade, 2016; Dobrovolski et al., 2018).The successful implementation of conservation policy also requires public support, so local communities should also be included, not only in decisions about the management plans of PAs but also in the planning beforehand.

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Supporting Information

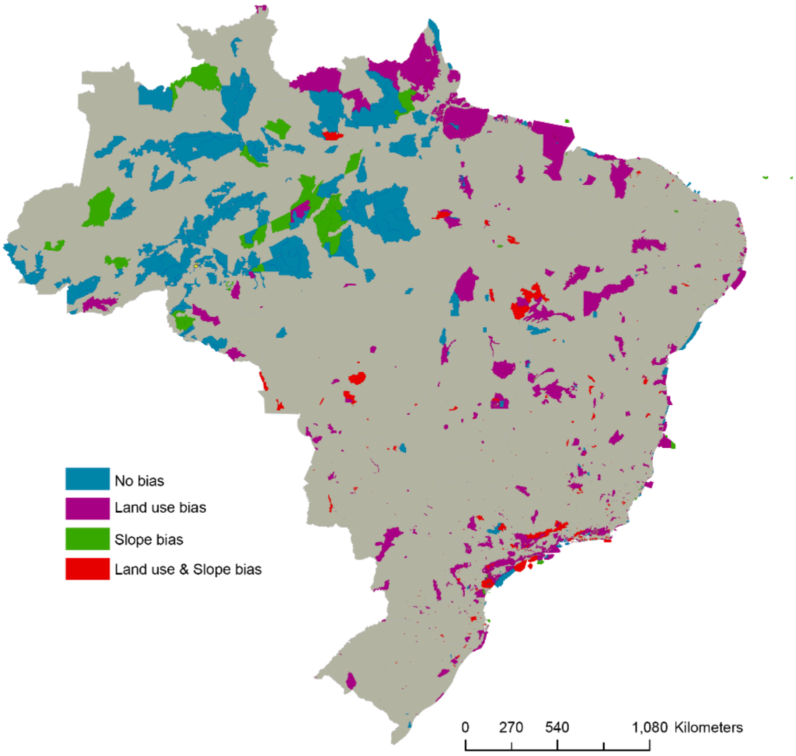

Figure S1. Distribution of protected areas in Brazil and categories of establishment biases.

Table S1. Habitat types in Brazil and their coverage and representation ratio in protected areas (PAs) considered as residual for land use (yellowish columns) or for slope.

Habitat types	Land Use						Slope					
	Residual PAs		Non-Residual PAs		ALL PAs		Residual PAs		Non-Residual PAs		ALL PAs	
	% of total coverage	Habitat Represen-tation Ratio	% of total coverage	Habitat Represen-tation Ratio	% of total coverage	Habitat Represen-tation Ratio	% of total coverage	Habitat Represen-tation Ratio	% of total coverage	Habitat Represen-tation Ratio	% of total coverage	Habitat Represen-tation Ratio
Forest												
Seasonal Decidual Forest	0.33	**0.07**	0.00	**0.00**	0.33	**0.07**	0.01	**0.00**	0.18	**0.04**	0.19	**0.04**
Seasonal Decidual Alluvial Forest	0.34	**0.07**	0.00	**0.00**	0.34	**0.07**	0.00	**0.00**	0.34	**0.07**	0.34	**0.07**
Seasonal Decidual Lowland Forest	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**
Seasonal Decidual Montane Forest	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**
Seasonal Decidual Submontane Forest	0.98	**0.20**	8.27	**1.65**	9.25	**1.85**	0.24	**0.05**	9.01	**1.80**	9.25	**1.85**
Seasonal Semidecidual Forest	6.64	**1.33**	0.08	**0.02**	6.72	**1.34**	0.11	**0.02**	6.14	**1.23**	6.25	**1.25**
Seasonal Semidecidual Alluvial Forest	1.88	**0.38**	17.99	**3.60**	19.87	**3.97**	4.19	**0.84**	15.69	**3.14**	19.87	**3.97**
Seasonal Semidecidual Lowland Forest	6.80	**1.36**	17.84	**3.57**	24.63	**4.93**	0.00	**0.00**	24.63	**4.93**	24.63	**4.93**
Seasonal Semidecidual Montane Forest	0.41	**0.08**	5.71	**1.14**	6.12	**1.22**	0.20	**0.04**	5.91	**1.18**	6.11	**1.22**
Seasonal Semidecidual Submontane Forest	1.28	**0.26**	5.53	**1.11**	6.81	**1.36**	0.03	**0.01**	6.78	**1.36**	6.81	**1.36**
Ombrophilous Open Forest	2.57	**0.51**	0.00	**0.00**	2.57	**0.51**	0.00	**0.00**	2.37	**0.47**	2.37	**0.47**
Ombrophilous Open Alluvial Forest	0.00	**0.00**	6.43	**1.29**	6.43	**1.29**	0.85	**0.17**	5.56	**1.11**	6.40	**1.28**
Ombrophilous Open Lowland Forest	0.02	**0.00**	11.57	**2.31**	11.59	**2.32**	0.80	**0.16**	3.46	**0.69**	4.26	**0.85**
Ombrophilous Semidecidual Montane Forest	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**
Ombrophilous Open Submontane Forest	0.33	**0.07**	3.74	**0.75**	4.07	**0.81**	0.76	**0.15**	3.11	**0.62**	3.87	**0.77**
Ombrophilous Dense Forest	1.07	**0.21**	0.57	**0.11**	1.64	**0.33**	0.16	**0.03**	1.44	**0.29**	1.59	**0.32**
Ombrophilous Dense Upper Montane Forest	76.71	**15.34**	0.05	**0.01**	76.76	**15.35**	0.00	**0.00**	72.04	**14.41**	72.04	**14.41**
Ombrophilous Dense Alluvial Forest	1.17	**0.23**	3.27	**0.65**	4.45	**0.89**	0.54	**0.11**	3.91	**0.78**	4.45	**0.89**
Ombrophilous Dense Lowland Forest	0.10	**0.02**	3.49	**0.70**	3.59	**0.72**	1.24	**0.25**	2.36	**0.47**	3.59	**0.72**
Ombrophilous Dense Montane Forest	0.51	**0.10**	0.69	**0.14**	1.21	**0.24**	0.72	**0.14**	0.43	**0.09**	1.15	**0.23**
Ombrophilous Dense Submontane Forest	0.38	**0.08**	2.83	**0.57**	3.21	**0.64**	0.55	**0.11**	2.65	**0.53**	3.20	**0.64**
Ombrophilous Dense Lowland Forest	0.00	**0.00**	0.08	**0.02**	0.08	**0.02**	0.08	**0.02**	0.00	**0.00**	0.08	**0.02**
Ombrophilous Mixed Forest	1.67	**0.33**	0.01	**0.00**	1.67	**0.33**	0.03	**0.01**	1.45	**0.29**	1.48	**0.30**
Ombrophilous Mixed Upper Montane Forest	32.93	**6.59**	0.00	**0.00**	32.93	**6.59**	1.24	**0.25**	31.65	**6.33**	32.89	**6.58**
Ombrophilous Mixed Alluvial Forest	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**
Ombrophilous Mixed Montane Forest	47.06	**9.41**	0.16	**0.03**	47.21	**9.44**	0.27	**0.05**	46.43	**9.29**	46.70	**9.34**
Ombrophilous Mixed Submontane Forest	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**

Habitat types	Land Use						Slope					
	Residual PAs		Non-Residual PAs		ALL PAs		Residual PAs		Non-Residual PAs		ALL PAs	
	% of total coverage	Habitat Represen-tation Ratio	% of total coverage	Habitat Represen-tation Ratio	% of total coverage	Habitat Represen-tation Ratio	% of total coverage	Habitat Represen-tation Ratio	% of total coverage	Habitat Represen-tation Ratio	% of total coverage	Habitat Represen-tation Ratio
Campinarana **Open Vegetation/ Habitat**	0.00	**0.00**	13.38	**2.68**	13.38	**2.68**	1.43	**0.29**	11.95	**2.39**	13.38	**2.68**
Savanna	1.11	**0.22**	0.01	**0.00**	1.12	**0.22**	0.01	**0.00**	1.12	**0.22**	1.12	**0.22**
Wooded Savanna	3.90	**0.78**	8.33	**1.67**	12.22	**2.44**	0.30	**0.06**	11.57	**2.31**	11.87	**2.37**
Forested Savanna	0.73	**0.15**	3.20	**0.64**	3.93	**0.79**	0.47	**0.09**	3.46	**0.69**	3.92	**0.78**
Wooded Grassland Savanna	46.49	**9.30**	28.30	**5.66**	74.79	**14.96**	1.00	**0.20**	73.66	**14.73**	74.66	**14.93**
Parkland Savanna	4.61	**0.92**	12.01	**2.40**	16.62	**3.32**	2.47	**0.49**	14.15	**2.83**	16.62	**3.32**
Steppe Savanna	3.84	**0.77**	0.03	**0.01**	3.87	**0.77**	0.01	**0.00**	3.30	**0.66**	3.32	**0.66**
Steppe Wooded Savanna	13.95	**2.79**	2.42	**0.48**	16.38	**3.28**	0.05	**0.01**	16.26	**3.25**	16.31	**3.26**
Steppe Forested Savanna	11.75	**2.35**	0.52	**0.10**	12.27	**2.45**	0.01	**0.00**	12.24	**2.45**	12.25	**2.45**
Steppe Wooded Grassland Savanna	9.17	**1.83**	0.00	**0.00**	9.17	**1.83**	0.00	**0.00**	9.17	**1.83**	9.17	**1.83**
Steppe Parkland Savanna	25.56	**5.11**	3.62	**0.72**	29.18	**5.84**	0.00	**0.00**	29.18	**5.84**	29.18	**5.84**
Steppe	15.15	**3.03**	0.00	**0.00**	15.15	**3.03**	0.00	**0.00**	15.15	**3.03**	15.15	**3.03**
Rock outcrop	55.94	**11.19**	9.37	**1.87**	65.32	**13.06**	0.00	**0.00**	65.24	**13.05**	65.24	**13.05**
Dune	10.99	**2.20**	0.01	**0.00**	11.00	**2.20**	0.00	**0.00**	11.00	**2.20**	11.00	**2.20**
Ecotones												
Transition *Campinarana*/Ombrophilous Forest	0.00	**0.00**	0.61	**0.12**	0.61	**0.12**	0.03	**0.01**	0.59	**0.12**	0.61	**0.12**
Transition Seasonal Forest/Ombrophilous Mixed Forest	15.48	**3.10**	0.00	**0.00**	15.48	**3.10**	9.33	**1.87**	5.53	**1.11**	14.86	**2.97**
Transition Seasonal Forest/Pioneer Vegetation Formation	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**
Transition Ombrophilous Dense Forest/Ombrophilous Mixed Forest	60.16	**12.03**	0.00	**0.00**	60.16	**12.03**	15.49	**3.10**	14.32	**2.86**	29.82	**5.96**
Transition Ombrophilous Forest/Seasonal Forest	0.06	**0.01**	0.00	**0.00**	0.06	**0.01**	0.00	**0.00**	0.06	**0.01**	0.06	**0.01**
Transition Ombrophilous Forest/Pioneer Vegetation Formation	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**
Transition Savanna/Steppe	0.08	**0.02**	0.00	**0.00**	0.08	**0.02**	0.00	**0.00**	0.08	**0.02**	0.08	**0.02**
Transition Savanna/Seasonal Forest	47.49	**9.50**	0.51	**0.10**	48.00	**9.60**	0.04	**0.01**	47.96	**9.59**	48.00	**9.60**
Transition Savanna/Ombrophilous Forest	0.01	**0.00**	0.41	**0.08**	0.41	**0.08**	0.00	**0.00**	0.41	**0.08**	0.41	**0.08**
Transition Savanna/Ombrophilous Mixed Forest	2.15	**0.43**	0.00	**0.00**	2.15	**0.43**	0.00	**0.00**	2.15	**0.43**	2.15	**0.43**
Transition Savanna/Pioneer Vegetation Formation	0.00	**0.00**	2.73	**0.55**	2.73	**0.55**	0.00	**0.00**	2.73	**0.55**	2.73	**0.55**

Habitat types	Land Use						Slope					
	Residual PAs		Non-Residual PAs		ALL PAs		Residual PAs		Non-Residual PAs		ALL PAs	
	% of total coverage	Habitat Represen-tation Ratio	% of total coverage	Habitat Represen-tation Ratio	% of total coverage	Habitat Represen-tation Ratio	% of total coverage	Habitat Represen-tation Ratio	% of total coverage	Habitat Represen-tation Ratio	% of total coverage	Habitat Represen-tation Ratio
Transition Savanna/Steppe Savanna	29.72	**5.94**	1.03	**0.21**	30.75	**6.15**	0.00	**0.00**	30.28	**6.06**	30.28	**6.06**
Transition Savanna/Steppe Savanna/Seasonal Forest	39.09	**7.82**	0.00	**0.00**	39.09	**7.82**	0.00	**0.00**	39.09	**7.82**	39.09	**7.82**
Transition Steppe Savanna/Seasonal Forest	3.98	**0.80**	0.11	**0.02**	4.09	**0.82**	0.04	**0.01**	4.05	**0.81**	4.09	**0.82**
Transition Steppe Savanna/Pioneer Vegetation Formation	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**	0.00	**0.00**
Others												
Pioneer Vegetation Formation	1.33	**0.27**	0.04	**0.01**	1.38	**0.28**	0.00	**0.00**	1.38	**0.28**	1.38	**0.28**
Pioneer Vegetation Formation with Freshwater Influence	29.83	**5.97**	22.25	**4.45**	52.08	**10.42**	0.98	**0.20**	51.07	**10.21**	52.06	**10.41**
Pioneer Vegetation Formation with Estuarine Influence	5.11	**1.02**	18.86	**3.77**	23.97	**4.79**	3.51	**0.70**	20.43	**4.09**	23.94	**4.79**
Pioneer Vegetation Formation with Marine Influence	19.51	**3.90**	38.05	**7.61**	57.56	**11.51**	21.43	**4.29**	36.11	**7.22**	57.54	**11.51**
Upper Montane Vegetation Refugee	99.28	**27.69**	0.72	**0.14**	100.00	**27.84**	6.98	**1.40**	93.02	**26.44**	100.00	**27.84**
Montane Vegetation Refugee	62.85	**12.57**	8.51	**1.70**	71.36	**14.27**	7.51	**1.50**	63.28	**12.66**	70.78	**14.16**
Submontane Vegetaion Refugee	34.14	**6.83**	5.08	**1.02**	39.23	**7.85**	0.00	**0.00**	39.23	**7.85**	39.23	**7.85**
Water Body	3.19	**0.64**	1.82	**0.36**	5.01	**1.00**	0.23	**0.05**	4.78	**0.96**	5.00	**1.00**
ALL HABITAT TYPES	**1.24**	**0.25**	**3.72**	**0.74**	**4.95**	**0.99**	**0.63**	**0.13**	**4.27**	**0.85**	**4.90**	**0.98**

CAPÍTULO 3

COMPLIANCE TO BRAZIL'S FOREST CODE WILL NOT PROTECT BIODIVERSITY AND ECOSYSTEM SERVICES

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Compliance to Brazil's Forest Code will not protect biodiversity and ecosystem services

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Abstract

In striking contrast to heartening events in the adjacent Amazon, Brazil's Cerrado biome has seen continued deforestation over the past decade. Though approved in 2012, no study evaluated the impacts of new Brazilian Forest Code (FC) revision on biodiversity and ecosystem services. Here we report the first assessment of the likely loss and gain in biodiversity and ecosystem services expected if the FC is properly enforced across 200 million hectares of the Cerrado. We also discuss the challenges associated to compliance with the law and present opportunities for conservation. Establishing restoration programs in private properties with currently less native vegetation than required by the FC could create habitat for 25% more threatened species than now found in these places and could also increase water security and carbon stock in 56.6 MtC. More important, trading environmental reserve quotas coupled with the strategic expansion of protected areas on private and public land could definitely rescue the Cerrado from the brink.

Keywords

Carbon stock; environmental policy; deforestation; nature's contribution to people; restoration; water provision.

Brazil's environmental legislation is currently under siege by agribusiness lobby and interest to expedite the environmental licensing for infrastructure development (Fearnside, 2016). In 2012, the Congress approved a controversial revision to Brazil's Forest Code (FC), which regulates land use on private properties. Although the impacts of FC revision on vegetation have been addressed (Soares-filho et al., 2014; Brancalion et al., 2016; Strassburg et al., 2017), no study evaluated its impacts on biodiversity. We report the first assessment of losses and gains in biodiversity and ecosystem services (ES) expected if the FC is properly enforced. We project high losses of ES and biodiversity and suggest solutions to address such a dismal scenario.

We focused our analyses on 200 million hectares (Mha) of tropical savanna within the Cerrado, as an example of its likely impacts nationwide. The Cerrado is key for the maintenance of Brazil's biodiversity and the provision of ecosystem services (Overbeck et al., 2015). However, it is also the most vulnerable savanna in the world: 46% of its native vegetation cover has been lost (88 Mha) and just 19.8% remains undisturbed (Strassburg et al., 2017). Roughly, 40% of remaining native vegetation can be legally converted – FC requires that only 20% of private lands be set aside for conservation (Soares-filho et al., 2014; Strassburg et al., 2017). Additionally, weak protection (only 7.5% of the Cerrado is covered by protected areas) puts its huge biodiversity and ecosystem services in jeopardy.

We used data from Brazil's 2014 Red List of threatened plant and animal species (totaling 1029 threatened species), carbon biomass, and the distribution of intermittent water springs (that are no longer protected by the new FC and represent almost 40% of all springs within the Cerrado), to estimate loss and gains in biodiversity and ecosystem services from likely deforestation or restoration on private lands as regulated by the FC (Table S1). We found that 26% of the Cerrado areas are currently in debt with existing legislation having less native vegetation than required by the FC (Fig. 1A).

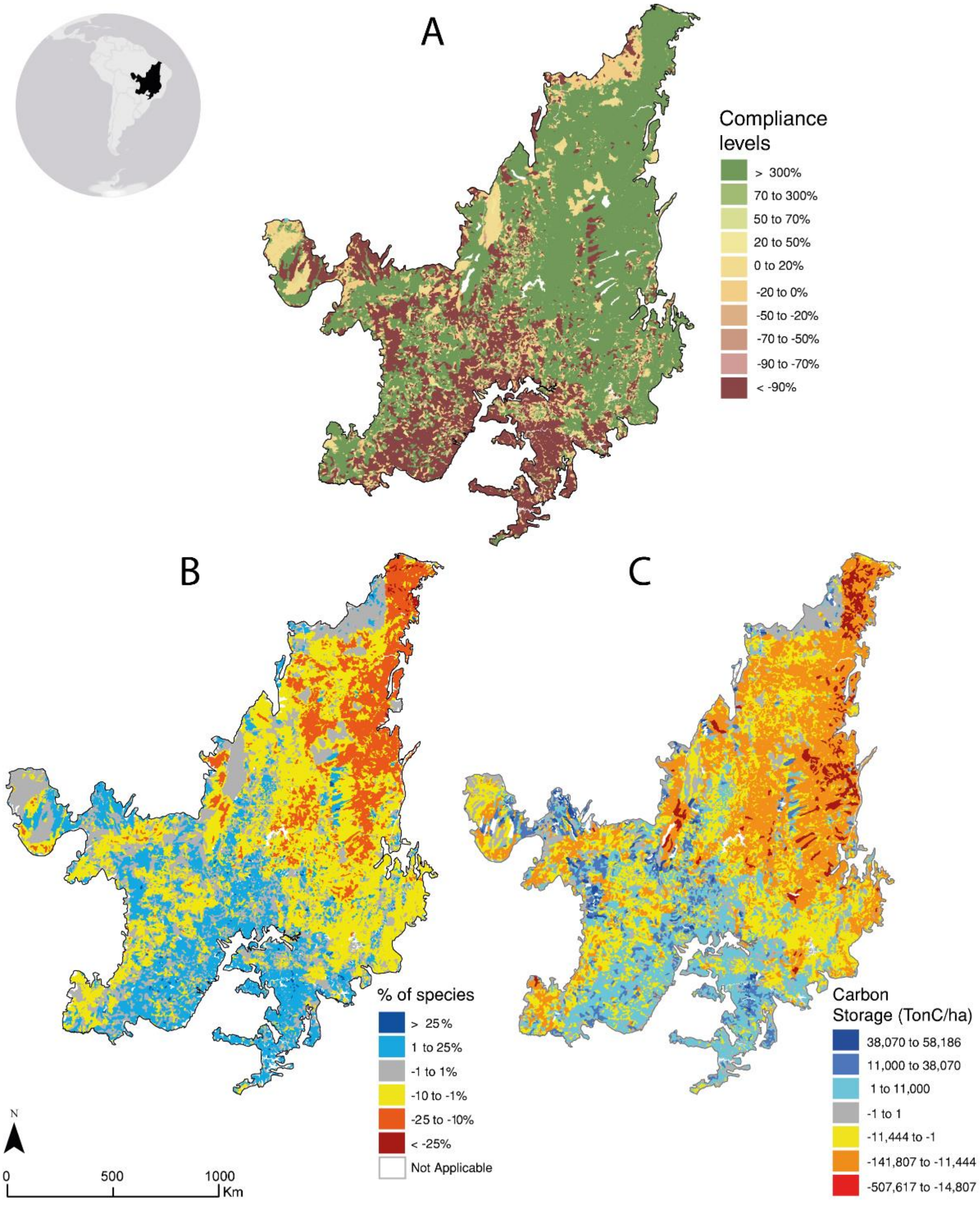

Figure 1. Expected changes following compliance to Brazil's Forest Code in the Cerrado. A – Compliance levels under Brazil's Forest Code. Positive values indicate the percentage of native vegetation that exceeds the conservation requirement of the Forest Code and thus could be legally deforested. Negative values indicate the percentage of vegetation in need for restoration to comply with Forest Code; B – Percent of change in threatened species richness change expected after compliance; C – Changes in carbon storage expected after compliance.

This situation implies that nearly 5 Mha of deforested land would need to be restored (Table S2). Northern Cerrado holds surplus of vegetation, meaning that 39 Mha of native vegetation could be legally deforested because properties have more native vegetation than required by the FC. This figure alone is three times larger than Brazil's national policy to restore/reforest 12 Mha as part of its Nationally Determined Contribution to Paris Treaty (MMA 2017).

Such potential legal deforestation, if realized, would entail an unprecedented species extinction crisis. Our calculations based on species-area relationships (see Supporting Information) indicate that 51.6% of private lands might lose at least one threatened species; 374 (1%) of those might lose up to 221 (Fig. 1B and Fig. S1). Most of the threatened plant species occur only in the Cerrado and thus are likely to go extinct (Strassburg et al., 2017). Loss would be higher in the north and in the southeast, areas in contact with the Brazilian Atlantic Forest.

Compliance to FC also impacts nature's contribution to people, such as climate stability and water availability. If all legal deforestation were realized, nearly 50% of private lands would lose more than one thousand tons of carbon per hectare (Fig. 1C and Fig. S2). Total loss of carbon stock in the Cerrado amounts to 385 million tons of carbon (MtC, Table S2), which is almost the double of the stock secured in all currently established protected areas of the biome (Medeiros & Young, 2011). Loss of vegetation would also threat water supply to urban populations in the Cerrado (currently >29 million people) (IBGE 2010) and elsewhere. Most intermittent springs (72.8%) lie in areas with current surplus of vegetation. Further, 18.3% of intermittent springs lie currently in lands in need for restoration (Fig. 2).

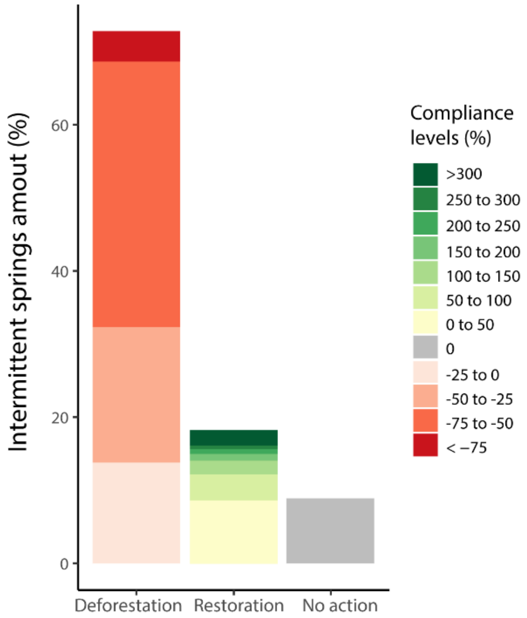

Figure 2. Percent of intermittent water springs in lands under legal deforestation, restoration and no action after compliance to Brazil's Forest Code in the Cerrado.

The picture we found is dismal and will likely preclude the Brazilian society to achieve its international environmental and climate mitigation commitments. In particular, the Aichi Biodiversity Targets 5 (deforestation close to zero), 7 (biodiversity conserved in areas under agriculture), 12 (threatened species away from extinction), and 15 (at least 15% of degraded lands restored) would become impossible to achieve by 2020. This situation reflects a common practice in Brazil in which there is an enormous mismatch between international agreements and in-house conservation decisions and policymaking (Loyola, 2014).

Over the past years, Brazil has witnessed a coordinated systematic attack to its environmental legislation (see discussions in Ferreira et al., 2014; Loyola, 2014; Fearnside, 2016; Azevedo-Santos et al., 2017). The makeup of Congress is dominated by powerful rural lobby (Fearnside, 2016). The political instability that Brazil is facing in the last years threats the reversal of environmental progress. Under pressure to approve other controversial bills and emends (Azevedo-Santos et al., 2017), the Congress often rely on sudden approval of environmentally damaging measures (e.g. undermining the national environmental licensing system and the revision of the Mining Code) in exchange of support by the rural lobby to other controversial political issues, such as the welfare reform.

There is no easy solution to avert loss of biodiversity and ecosystem services in the Cerrado, but enforcement of restoration on private lands below the FC compliance is paramount (Strassburg et al., 2017). Restoring the required 4.7 Mha of these lands would increase carbon stock in 56.6 MtC and would create new habitat leading to an increase in up to >25% the number of species in private lands currently in debt, according to our calculations (Fig. 1B-C, Table 2). It would also increase water security and benefits from 18.3% of intermittent springs that are located in heavily impacted private lands where restoration is demanded (Fig. 2).

Due to deforestation and fires, the Cerrado is a major contributor to national emissions and its protected areas play a pivotal role in mitigating climate change effects in Brazil. Recent studies showed that the network of protected areas established in the Cerrado was effective in avoiding deforestation in areas that would have been converted if not protected (Carranza et al., 2014). However, almost 73% of all intermittent springs in Cerrado are located on lands that could be legally deforested. Intermittent springs and rivers provide ecosystem services and support a diverse biota nearly just like any other water body, however they are neglected by society and have attracted less attention than perennial rivers (Datry et al., 2017). In a biome that contributes to 43% of all freshwater outside of the Amazon, increasing protection and fostering large-scale restoration programs are essential to guarantee water security (Strassburg et al., 2017).

A caution must be made, though: the Cerrado is not a forest-dominated ecosystem. Therefore, proposals of large-scale afforestation for the region have been rejected by the scientific community (Overbeck et al., 2015; Veldman et al., 2015). A sustainable alternative scenario that reconciles agricultural expansion, conservation and restoration is within reach, however. There is no need of further conversion of native vegetation to enhance crop and beef production in Brazil. A right mix of current policies would suffice to achieve such sustainable scenario (Strassburg et al., 2017). These policies involve effective and comprehensive implementation of the FC by federal and state government, land reform, continuity of satellite-based monitoring systems, implementation of the low carbon agriculture plan in the Cerrado, policies for the conservation of threatened species and initiatives from the private sector such as international certification standards and boycotts of agricultural products grown in recently deforested or high-biodiversity areas, such as the soy moratorium (Soares-filho et al., 2014; Strassburg et al., 2017).

The new FC introduced the Environmental Reserve Quota (Portuguese acronym, CRA) as a new mechanism that allows the vegetation debts of one property to be offset with the surpluses of another property in the same biome (Brancalion et al., 2016). CRA can be a new form of fostering Payment for Ecosystem Services (Soares-Filho et al., 2016) and it is estimated to have better economic and conservation outcomes when compared to a scenario of full compliance at the property (Veldman et al., 2015). Although CRA trading will not be enough to prevent legal deforestation in the Cerrado, it is crucial that states and the union counterbalance the FC debts in already established priority areas for conservation, enhancing the effectiveness of protection.

Nevertheless, high costs of proactive restoration (recently estimated in US$ 1000–5000 ha^{-1}) and unclear regulations about what qualifies an area as restored after the allotted 20-year recovery period makes restoration a hard choice to most landowners (Bernasconi et al., 2016). Further, restoration carries uncertainties. First, choice of restoration method in the Cerrado depends on the history of land use in the area. Natural regeneration, assisted or not, is successful only where the subterranean structures of the Cerrado plant species were not destroyed, what happens in most agriculture models (Pellizzaro et al., 2017). Currently, seeding and topsoil methods are pointed out as the best cost-effective methods, with much lower costs than planting nursery-raised seedlings, but they also lead to some problems, like species dominance (Sampaio et al., 2015; Pellizzaro et al., 2017). Further, there is no guarantee that restored areas will recover the same species, their ecological roles and deliver ecosystem services existing in the past; and if they do, there is a huge time lag between the implementation and the perceived outcomes arising from restoration. Hence, averting deforestation in properties holding vegetation surplus is a better strategy for conservation in the short-term as an area of native vegetation remnants is often richer in biodiversity and have higher conservation value than a new planted forest. CRA has as important role to play in this strategy. Given that CRA supply is higher than its current demand (Soares-Filho et al., 2016), CRA market is affordable to most landowners and should be fostered by the government, private sector and the civil society.

More than ever, Brazil needs to decide whether to develop sustainably or in traditional ways that endanger its natural capital (Ferreira et al., 2014; Loyola, 2014). It already has legal (e.g. Plan for Prevention and Control of Deforestation in the Cerrado – PPCerrado; Land Reform policy) and market instruments in place to allow for a green and socially just transition that will safeguard the existence of species and ecosystems in the most biologically diverse country in the world guaranteeing food, water and all other nature's contribution to >200 billion people that depend on nature to thrive. No form of development is sustained in the long run based on highly exploitative activities, excluding people and the environment. We urge our society, national policy-makers and international stakeholders to engage in favor of effective environmental legislation that supports countrywide welfare and sustainable development in all its dimensions.

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Biosketch: Authors are members of the Conservation Biogeography Lab, which is focused on delivering scientifically-validated evidence, analysis, and synthesis to support conservation decision and policymaking, especially in Brazil.

Author contributions: RRSV and RL conceived the study; RRSV, BRR, FB, NM, LPS, FMR, LM compiled and analyzed data; BS-F developed land-use models; RL wrote the first draft; all authors contributed to writing.

Supporting Information

Compliance to Brazil's Forest Code will not protect biodiversity and ecosystem services

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This PDF file includes:

1. SUPPORTING METHODS

Predicted vegetation changes under the Brazil's Forest Code

In the absence of a geo-spatial national database on Brazilian rural properties, we used microwatersheds as surrogate for rural properties, which has also been done in recent works on the Brazil's Forest Code. We calculated net losses and gains (in hectares) on native vegetation within microwatersheds, based on change predictions from the new Brazilian Forest Code. To do so, we used maps of remnant vegetation and information on microwatersheds from Soares-filho et al. (2014), both available in http://csr.ufmg.br/forestcode/ at 250 x 250 m spatial resolution. The microwatershed information file contained the area (ha) of vegetation surpluses and debts associated to each microwatershed where the forest code is enforceable. Those values indicate, respectively, the amount of vegetation that can be legally deforested and those that need restoration. All subsequent analyses refer to a "compliance scenario", in which the new law is fully complied, i.e. all surpluses are deforested and all debts are restored.

Biodiversity changes

One of the objectives of the new Forest Code is biodiversity protection. We used official information from the Brazilian Ministry of Environment (*Ministério do Meio Ambiente – MMA*, in Portuguese), which combines the best biodiversity information currently available. We used spatial data – presence/absence maps – on threatened fauna (312 species) and flora (717 species) found in the Cerrado (Table S1). Fauna data was obtained from ICMBio (*Instituto Chico Mendes de Proteção à Biodiversidade*, in Portuguese), and flora data from CNCFlora (*Centro Nacional de Conservação da Flora*, in Portuguese), which are the Red List Authority for animals and plants, respectively, in Brazil and adopts the standards and procedures recommended by the International Union for the Conservation of Nature – IUCN.

At first, we calculated current species richness per microwatershed. Then, we projected how many species may be lost or gained, in case the new Forest Code is fully complied, based on Arrhenius' species-area relationships. Microwatersheds that will be restored will likely gain species and microwatersheds to be deforested tend to lose species, according to the formula:

$$\log S = \log c + z \log A$$

Where *S* is species richness, *A* is vegetation amount and *c* and *z* are constants. We tested three different values of *z* (0.15, 0.25 and 0.35) that have been suggested to be suitable in different circumstances (Thomas et al., 2004; Strassburg et al., 2017). Because no significant difference was found among them we kept the one most often used in biodiversity assessments (z = 0.25). By doing so, we obtained the expected values of species richness in the compliance scenario, as result of changes in native vegetation cover. We assumed no time-lags on local extinction and recolonization processes. Therefore, extinction immediately follows habitat loss and recolonization prompts restauration in constant proportions defined by the amount of native vegetation lost or gained.

Ecosystem services changes

We estimated the potential impact of the 2012 Forest Code in the carbon stored in native vegetation and water security. Carbon stored in vegetation regulates the climate at global level and land use change is concerned, especially in the Cerrado, where the vegetation loss is responsible for 62% of greenhouse gas emission from land use change in Brazil (MCTi, 2014). In turn, waters from the Cerrado fed rivers from eight of the twelve national major watersheds of the country (Overbeck et al., 2015), being important to sustain the livelihood and economy not only of local people, but also to other regions of Brazil and South America (MCTi, 2014).

We assessed expected changes on the amount of carbon stored in vegetation within each microwatershed using biomass database provided by Leite et al. (2012) Leite et al. (2012), which considers the biomass of the original distribution of the Brazilian native vegetation (http://csr.ufmg.br/forestcode/). We calculated the impact of legal deforestation as the mean carbon storage (in ton C/hectare) of the remaining native vegetation in each microwatershed with vegetation surplus multiplied by the area (in hectares) of the remaining native vegetation in the microwatershed after legal deforestation. Following Soares-filho et al. (2014), we considered 50% of the biomass as carbon (Houghton et al., 2001) and that 15% of the carbon is not emitted to the atmosphere due land use change (Houghton et al., 2000). To calculate the carbon sequestration from restoration, we multiplied the mean carbon storage (in ton C/hectare) of the remaining native vegetation in each microwatershed with vegetation debt by the area (in hectares) of remaining native vegetation included in the microwatershed after restoration.

To illustrate the impact of the 2012 Forest Code to the water security, we evaluated the number and distribution of intermittent springs along the Cerrado (~40% of the total, ~19 thousand springs included in the database to the Cerrado). We obtained the spatial distribution of springs by extracting spring location from the hydrography map available at the Geological Survey of Brazil website *(Serviço Geológico do Brasil* in Portuguese) (www.cprm.gov.br). As intermittent springs are no longer protected by the 2012 Forest Code and so may become endangered or disappear, we only considered them in our analysis excluding permanent springs. We quantified the proportion of intermittent springs included in microwatersheds with vegetation surpluses (i.e. with native vegetation could be legally deforested) and in microwatersheds with vegetation debts (i.e. with required restoration of vegetation). Different levels of legal deforestation or required restoration were also associated to intermittent springs occurrence.

2. SUPPORTING FIGURES

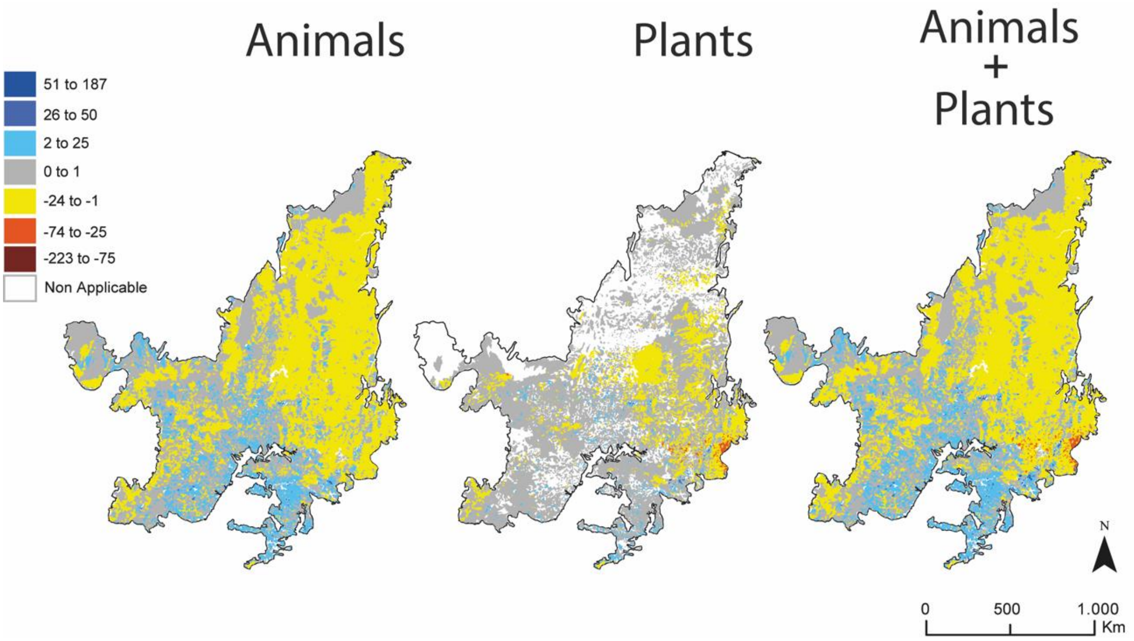

Figure S1 Losses and gains of species richness resulting from revision of Brazil's Forest Code in absolute values.

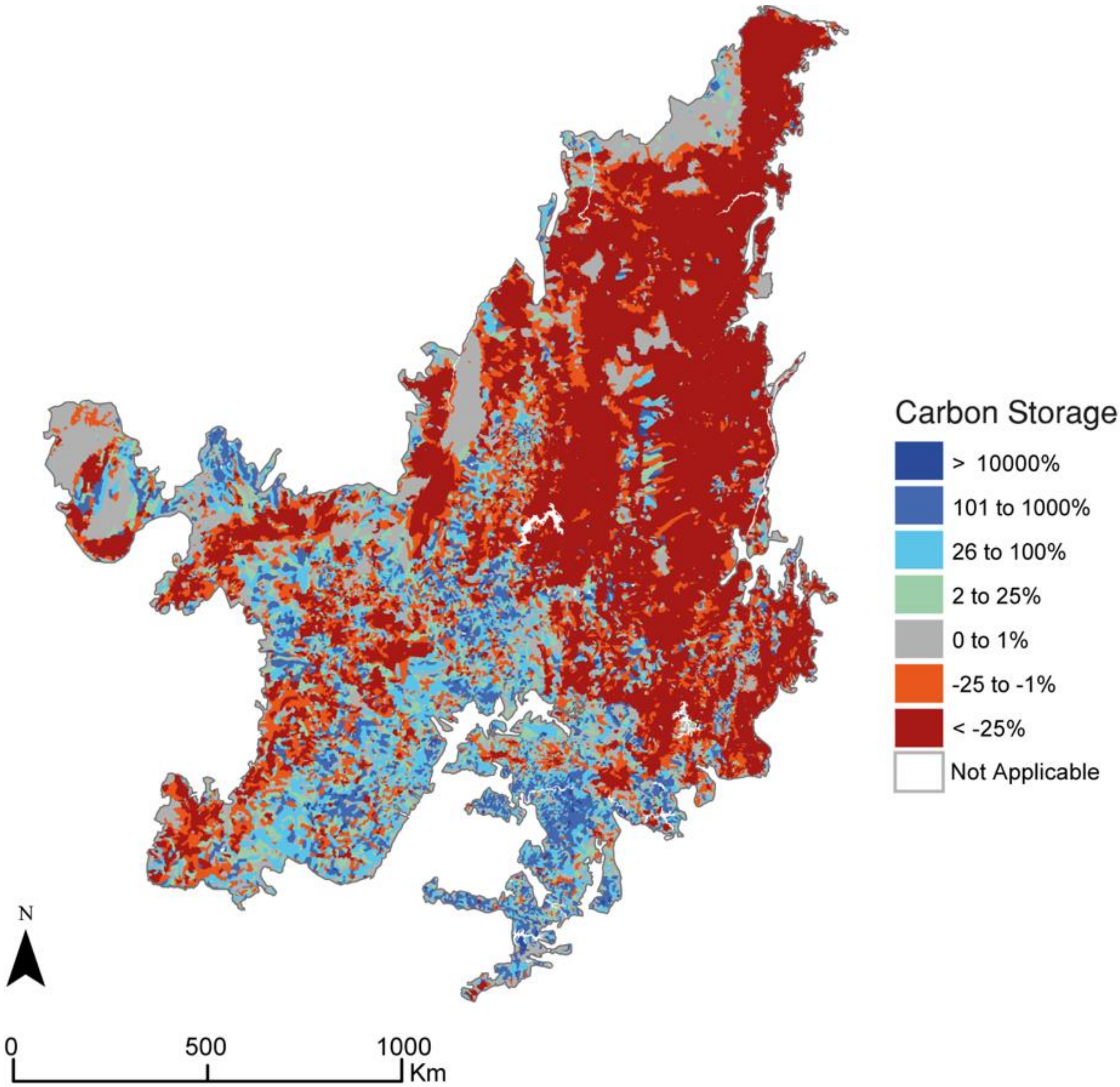

Figure S2 Losses and gains of carbon storage resulting from revision of Brazil's Forest Code in absolute values.

3. SUPPORTING TABLES

Table S1. Number of threatened species in each taxonomic group occurring in the Cerrado.

Taxonomic Group	**Number of Species**
Invertebrates	63
Amphibians	6
Birds	62
Reptiles	22
Mammals	47
Fishes	112
Plants	717
TOTAL	1029

Table S2 Total losses and gains of native vegetation and carbon storage resulting from revision of Brazil's Forest Code.

	Native vegetation (Mha)	Carbon (Mt/ha)
Restoration	4.7	56.6
Legal deforestation	-38.9	-385.4

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CONCLUSÃO

Nesta tese discutimos a eficiência de iniciativas de conservação em preservar a biodiversidade. No primeiro capítulo, avaliamos a lacuna entre a teoria e a prática da conservação, apresentando sugestões de como preenchê-la. No segundo e terceiro capítulos, estimamos os resultados de duas das principais políticas públicas ambientais brasileiras, o Sistema Nacional de Unidades de Conservação e o novo Código Florestal, sugerindo caminhos para corrigir os erros e minimizar as ameaças ao meio ambiente.

No primeiro caso, encontramos que a quantidade de pesquisa sobre degradação e perda de habitat aumentou substancialmente ao longo dos anos, mas existe uma grande lacuna entre a ciência e a prática da conservação. Isso significa que o conhecimento gerado não é usado como principal base das ações de conservação e que estas poderiam ser mais eficazes. Apesar dos vieses encontrados, uma grande quantidade de conhecimento teórico existe em diversos domínios biogeográficos que pode ser usado para informar programas de conservação. Tanto tomadores de decisão quanto pesquisadores precisam se aliar para que os recursos investidos em conservação tenham o melhor resultado possível.

No segundo capítulo, mostramos que o sistema de unidades de conservação (UCs) possui vieses de criação, especialmente em relação à intensidade de uso do solo e aos biomas, e que não é representativo para cerca de metade dos habitats presentes no Brasil. Apesar dos esforços para aumentar o número e a extensão de UCs no território nacional, elas tendem a ser residuais e podem não cumprir um de seus principais objetivos, que é reduzir a perda de biodiversidade. Esse cenário é resultado de uma proteção projetada preponderantemente para não gerar conflitos com interesses extrativistas ao invés de planejamento estratégico e sistemático. A legislação ambiental deve ser empoderada e devidamente aplicada para garantir uma gestão eficiente das UCs existentes e a criação de novas em áreas que mais necessitam de políticas de conservação, trazendo os melhores resultados para a biodiversidade e para a população.

No terceiro capítulo, encontramos que, de acordo com as regras do novo Código Florestal brasileiro (CF), quase 5 Mha de vegetação devem ser restaurados e que 39 Mha de vegetação nativa poderiam ser legalmente desmatados. Essa gigantesca potencial perda acarretaria em uma crise de extinção de espécies sem precedentes e impactaria serviços fornecidos pela natureza, como estabilidade climática e fornecimento de água. Programas de restauração são importantes para minimizar esses danos, mas mais importante é evitar a perda de vegetação nativa remanescente através das cotas de reserva ambiental determinadas pelo CF. Essas ações devem acontecer em conjunto com um planejamento estratégico da expansão de áreas protegidas. O Brasil possui instrumentos legais e de mercado para garantir a preservação ambiental atrelada ao desenvolvimento social e econômico do país e da população. Resta aos tomadores de decisão e ao governo se comprometerem com o cumprimento da legislação do país.

Este estudo se soma aos esforços de criação de uma base científica de evidências sobre os efeitos das ações de conservação. Apesar da crise política que o Brasil passa, somada a uma negação de fatos e da ciência, esperamos que os tomadores de decisão façam uso de trabalhos como este para garantir à população um meio ambiente ecologicamente equilibrado e preservá-lo para as presentes e futuras gerações, como manda a constituição.