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Funding deficits of protected areas in Brazil

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ABSTRACT

Protected areas (PAs) are the most effective public policy instruments to protect natural ecosystems and the services these ecosystems provide. Nevertheless, several PAs present a funding deficit because governments allocate fewer financial resources than those required to cover PA management costs. The variation in funding deficits within countries is not well documented because information about PA public investments and management costs are seldom available. We describe the variation in funding deficits across Brazilian federal PAs and propose a model that explains such variation by using PAs' characteristics and their zones of influence as predictors. We estimated that the 282 Brazilian federal PAs needed US$ 468 million to cover their management costs in 2016. However, the Brazilian government allocated only 15.5 % of these costs. Approximately 76.5 % of the PAs had funding deficits. Our model showed that: (1) funding deficit is negatively associated with PA age and the human development index but positively associated with PA size, (2) PAs in the Atlantic Forest and the Savannas and Drylands have lower funding deficits than PAs in the Amazon, and (3) PAs in the Atlantic Forest have lower funding deficits than PAs in the Savannas and Drylands. We found that the proportion of PAs with a funding deficit in Brazil is high and is comparable to the high percentage of PAs (75 %–100 %) with a funding deficit found in sub-Saharan Africa. Moreover, there is evidence that the total annual funding deficit in the Brazilian PAs increased in the last decade. New policies, public-private partnerships, and innovative funding mechanisms need to be set to close the large funding gap in the Brazilian federal PA system.

1. Introduction

In a world where social and environmental transformations are occurring faster than ever before, and societies are struggling to adapt to such changes (Steffen et al., 2011), setting aside protected areas (PAs) continues to be the most effective public policy instrument to protect biodiversity and provide the ecosystem services that nations need to prosper (Pimm et al., 2014; Watson et al., 2014). In the last three decades, global agreements, such as the United Nations Convention on Biodiversity, and financial mechanisms, such as the Global Environmental Facility, have fostered an unprecedented expansion of PAs worldwide (Lewis et al., 2019; Watson et al., 2014). Currently, there are more than 238,563 PAs covering 20 million km^2 of terrestrial ecosystems and 6 million km^2 of marine ecosystems (UNEP-WCMC et al., 2018). Most of these PAs are managed by public agencies and have national budgets as their primary source of income (Hein et al., 2013; Silva et al., 2019; Watson et al., 2014). Because governments allocate fewer financial resources than those required to cover PA management costs, PAs frequently present funding deficits.

Funding deficits are considered a major obstacle to the proper management of PAs worldwide (Coad et al., 2019). Without sufficient resources, agencies responsible for PA management cannot hire staff, build necessary PA infrastructure, engage with local stakeholders, design PA management plans, or enforce PA regulations. Without enforcement, PAs can be degraded by illegal human activities (e.g., Kauano et al., 2017), defeating the purpose for which PAs were initially designated. Currently, at least one-third of global protected land is under intense human pressure, and there is no sign that such a burden will be reversed soon (Jones et al., 2018). Thus, reducing or eliminating PA funding deficits is one of the most important topics for the next round of discussions of the Convention on Biological Diversity.

Designing financial mechanisms that secure the current and future

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global PA estate requires high-resolution PA financial data (Coad et al., 2019; Waldron et al., 2013). Such data would make it possible, for instance, to estimate the actual magnitude of PA funding deficits at different spatial levels (from individual PAs to global PA systems), and to put in place financial instruments that are appropriate to each context (Waldron et al., 2013). However, financial information about PAs is not always available because most governments and agencies that support PAs (including non-profit organizations) do not make their investments in PAs publicly accessible for scrutiny (Lehrer et al., 2019; Silva et al., 2019). Furthermore, information documenting PA management costs is scarce and is not comparable because there are no global standards for collecting it (Iacona et al., 2018).

Studies on PA funding deficits have shown that they are influenced by ecological, social, and political factors (Bruner et al., 2004; Lehrer et al., 2019; Waldron et al., 2013). Such studies have found that although PA funding deficits are found everywhere, they are more pervasive in tropical countries (Coad et al., 2019). Several studies compared PA funding deficits across countries (Bovarnick et al., 2010; Bruner et al., 2004; Lindsey et al., 2018; Waldron et al., 2017), but few analyzed the variation in funding deficits within a country (Lehrer et al., 2019). Therefore, comprehensive studies examining funding deficits within tropical countries are a gap in the literature.

In this paper, we first describe the variation in PA funding deficits in Brazil's terrestrial federal PAs. Then, we propose a model that explains such variation by using the characteristics of PAs and their zones of influence as predictors. We chose Brazil as a study country because it is a large (8.5 million km^2) megadiverse country (Mittermeier et al., 1997) with high social-environmental heterogeneity (Théry and Mello-Théry, 2014), and one of the world's largest PA estates (Medeiros et al., 2011). Our results contribute to the emerging field of protected area economics that seeks to understand the spatial distribution of the costs and benefits of land use policies aiming to conserve natural ecosystems (Mayer and Job, 2014). In addition, it provides a framework upon which comparative studies on protected area funding deficits across nation-states can be built.

2. Methods

2.1. Protected areas

We studied the funding deficits of 282 Brazilian federal PAs (Fig. 1) that altogether cover 741,782 km^2. These PAs represent 93 % of the PA coverage managed by the country's PA agency (Instituto Chico Mendes de Conservação da Biodiversidade, ICMBIO) and 46.7 % of all the country's terrestrial PAs. We did not include marine PAs or PAs that did not have all of the information required for this analysis.

Information about PA age (in years in 2016), PA size (in km^2), and management groups were collected from the official sites (www.mma.gov.br). In Brazil, there are two PA management groups: strict protection and sustainable use. Strictly protected PAs have conservation of biodiversity as their primary goal, and consequently, have limited human interference. This group includes biological reserves, ecological stations, national parks, and natural monuments. On the other hand, sustainable use PAs aim to conserve biodiversity, while also promoting the use of natural resources within their carrying capacity; thus, they allow different levels of human intervention. This group is represented by relevant ecological interest areas, environmental protection areas, private natural heritage reserves, extractive reserves, sustainable development reserves, and national forests.

Federal PAs are found in all six Brazilian biomes (IBGE, 2004). However, for analytical purposes, we grouped these six biomes into three broad ecological regions: (1) the Amazon; (2) the Savannas and Drylands, an area including Caatinga, Cerrado, Pantanal, and Pampas; and (3) the Atlantic Forest. We assigned individual PAs to each one of these three regions based on the overlap between the PA's boundaries and the regions' boundaries. When the boundaries of a PA coincided with two or more regions, it was assigned to the region that overlapped the most with the PA.

Each PA has its zone of influence, defined here as all municipalities whose official limits overlap with the PA's boundaries. Because Brazil is a socially heterogeneous country, the zones of influence of the PAs differ in their socio-economic indicators. We used two indicators to characterize the zones of influence of each PA: human population density (HPD) and the Human Development Index (HDI; a composite index that measures the standards of human well-being of a population by aggregating indicators of health, income, and education). The HPD is the total population of a zone of influence, as estimated by IBGE (2016), divided by its area (in km^2). In contrast, the HDI of a zone of influence is the average of the municipalities' HDIs in 2016, just as in the estimation of the FIRJAN Municipal Development Index (FIRJAN, 2018). This index annually monitors all Brazilian municipalities' socio-economic development in three areas: employment and income, education, and health. Created in 2008, it is based on official public statistics made available by the ministries of Labor, Education, and Health (FIRJAN, 2018).

2.2. PA funding deficits

The funding deficit is the percentage of the annual management costs that are not covered by the funding available to the PA. In Brazil, funding for a federal PA comes mostly from the national government (Bovarnick et al., 2010). Silva et al. (2019) reported the average amount of public investments made in each federal PA from 2013 to 2016. We used these values as indicators of the resources available for each PA.

Annual management costs are more challenging to estimate because they include personnel salaries, operational costs (e.g., fuel, electricity, services, and meetings), maintenance of infrastructure and equipment, and priority projects (e.g., research, tourism, and environmental education) minimally required to manage a PA (Dias et al., 2016). Because management costs are not collected and made available for all federal PAs, we estimated these costs based on the minimum number of employees required to manage a PA. First, we calculated the number of employees needed in a PA. We did that by using the following procedure: (a) PAs smaller than 100 km^2 need at least five employees (Muanis et al., 2009); and (b) PAs larger than 10,000 km^2 demand at least one employee per 100 km^2; and (c) PAs with sizes between 100 km^2 and 10,000 km^2 need the number of employees estimated by the following formula: number of employees = 5.04 – 0.000404(PA Size). Second, we multiplied the number of employees by US$ 14,000 to estimate the total staff costs for each PA. We used US$ 14,000 because this is the average compensation (including benefits) received by a mid-level employee in Brazil. Finally, we multiplied the total staff costs by two to get the minimum annual recurrent costs for a federal PA in Brazil. We multiplied by two because Dias et al. (2016) found that staff costs are around 50 % of the total annual recurrent management costs of nine PAs in the state of Amapá in the Brazilian Amazon.

2.3. Statistical analyses

We used an ordinary least squares (OLS) regression to model the influence of the attributes of PA attributes (management group, PA age, and PA area) and PA zone of influence (ecological region, HPD, and HDI) on PA funding deficits. The variation inflation factors (VIFs) were examined to ensure that the predictor variables were independent. Because VIFs ranged from 1.0–2.1, we kept all variables in the model (Dormann et al., 2013). To reduce the effects of heteroscedasticity, we report the regression results using robust standard errors that produce unbiased standard errors of the model coefficients. Finally, to estimate each independent variable's importance on the variation of the dependent variable, we used the squared semi-partial correlation. Stata 15 (StataCorp., 2017) was used in all statistical analyses.

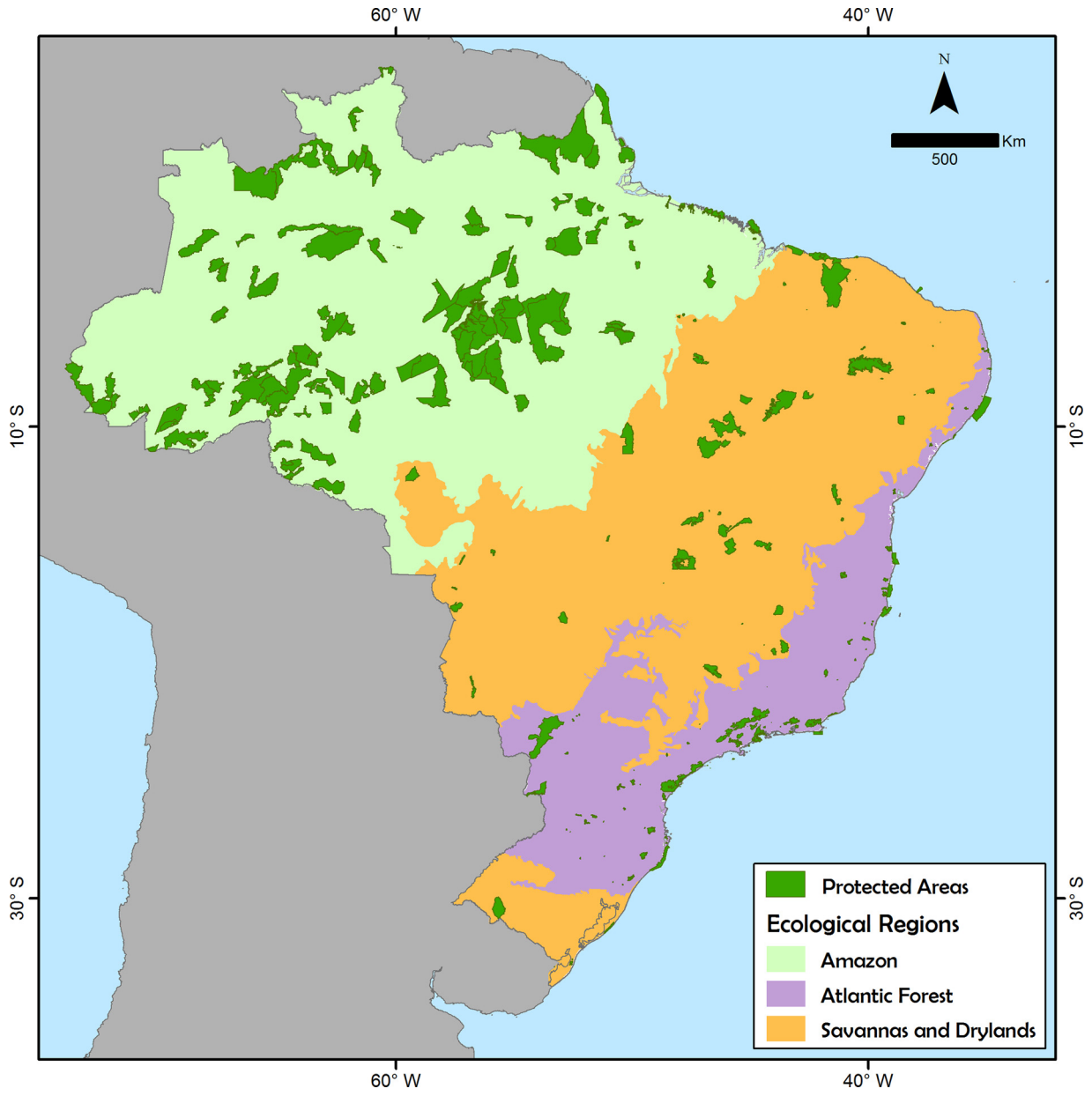

Fig. 1. Distribution of the federal protected areas in Brazil.

3. Results

We estimated that Brazil's 282 PAs required US$ 468 million to meet their recurrent management costs in 2016. However, the Brazilian government invested US$ 72.8 million (15.5 %) (Table 1). PA's funding deficit ranged from 0% to 99.9 % (Table 1), with a national average of 58.5 %. Most PAs showed funding deficits (76.5 %), and those that did are found in all three regions (Table 2). In contrast, the 66 PAs with no funding deficit in 2016 are in the Atlantic Forest or Savannas and Drylands (Table 2).

Federal PAs vary widely in size, age, and in the socio-economic indicators of their zones of influence across ecological regions and management groups (Table 2). The OLS model is statistically significant ($F_{7,274} = 80.8$, $P = 0.000$) and explained 59 % of the variation observed in the dataset. The model showed that funding deficit is negatively related to PA age and HDI but positively related to PA area (Table 3). Moreover, when all variables are considered simultaneously, PAs of the Atlantic Forest and Savannas and Drylands had smaller funding deficits than PAs of the Amazon (Fig. 3), and PAs of the Atlantic Forest had smaller funding deficits than those of the Savannas and Drylands (Wald Test, $F_{1,274} = 24.2$, $P < 0.001$). Furthermore, funding deficits in sustainable use PAs were not different from those in strictly protected PAs (Table 3). Finally, the squared semi-partial correlation between the funding deficit and independent variables revealed that age, size, and ecological regions were the independent variables that explained most of the variation in the dependent variable (Table 3).

4. Discussion

We demonstrated that most (76.6 %) federal PAs in Brazil showed funding deficits in 2016 and that the system's overall funding deficit is substantial (84.4 % of the estimated management costs). Furthermore, we found that the funding deficit varied across PAs and that most of this variation can be explained by a simple linear model that combines attributes of the PAs and characteristics of their zones of influence. In general, our results revealed some general patterns that can be tested by similar studies in other countries.

We found that the proportion of PAs with a funding deficit in Brazil

Table 1
Management costs, funding and funding deficits in Brazilian federal protected areas according to region and management groups.

Regions and management groups	Number of protected areas	Total area (km^2)	Total management costs (US $/year)	Total public spending (US $/year)	Total funding deficit (US $)	Average funding deficit (%)
Amazon						
Strict Protection	38	296,234	141,482,798	10,717,329	130,765,469	90.8
Sustainable Use	79	303,492	199,448,606	10,400,225	189,048,380	89.2
All	117	599,726	340,931,405	21,117,554	319,813,850	89.7
Savannas and Drylands[a]						
Strict Protection	37	52,829	48,515,492	12,188,071	36,327,357	54.4
Sustainable Use	30	44,509	29,002,700	5,990,542	23,012,157	52.4
All	67	97,338	77,518,130	18,178,614	59,339,515	53.5
Atlantic Forest						
Strict Protection	50	10,186	15,725,598	21,236,426	−4,820,249	19.3
Sustainable Use	48	34,530	33,754,552	13,297,222	20,457,329	30.6
All	98	44,716	49,480,151	33,533,648	15,946,502	24.8
All PAs	282	741,782	467,929,686	72,829,815	359,099,869	58.6

[a] This region includes Caatinga, Cerrado, Pantanal, and Pampas.

Table 2
Federal protected areas in Brazil according to funding status, management group, area, age, ecological region, and social context (assessed using the Human Development Index and human population density).

Variables	Ecological Regions		
	Amazon	Savannas and Drylands[a]	Atlantic Forest
Funding status			
Funded	0	15	51
Underfunded	117	52	47
Management group			
Sustainable Use	79	30	48
Strict Protection	38	35	52
Area (km^2)			
Median	2,847	389	66
Lower Quartile	1,337	89	15
Upper Quartile	6,775	1,433	279
Age (years, in 2016)			
Median	15	26	27
Lower Quartile	11	15	15
Upper Quartile	27	35	34
Human development index			
Median	0.48	0.6	0.69
Lower Quartile	0.43	0.54	0.64
Upper Quartile	0.55	0.67	0.74
Human population density (people/km^2)			
Median	1.5	13.3	65.6
Lower Quartile	0.8	4.2	23.5
Upper Quartile	5.3	43.9	190.3

[a] This region includes Caatinga, Cerrado, Pantanal, and Pampas.

is high and is comparable to the high percentage of PAs (75 %–100 %) with a funding deficit found in sub-Saharan Africa (Lindsey et al., 2018). However, most of the African countries have smaller economies and lower governance levels than Brazil. If Brazil is compared only to South Africa, the largest African economy, and thus a better benchmark, Brazil has 3.8 times more underfunded PAs.

The total annual funding deficit found in the Brazilian PAs is substantial, and comparisons with previous studies indicate that it increased over time. Using data produced by the Brazilian government in 2006, Bovarnich et al. (2010) estimated that the total funding deficit for Brazil's federal PA system was between 56 % and 72 % of the total estimated management costs. These values are lower than the one (84.4 %) we found in 2016. Thus, there is support for the hypothesis that the overall PA funding gap in Brazil increased in the last decade. This pattern is possibly due to two factors. The first is the mismatch between the fast expansion of the country's PA coverage in the last three decades (Brazil multiplied its PA estate 13 times from 1980 to 2019) and the slow growth in the allocation of public resources toward these PAs (Medeiros et al., 2011). The second possible factor is that in the last decade, Brazil suffered recurrent fiscal and political crises that have undermined the federal government's capacity to increase its spending in several critical sectors, including the management of its PAs (Silva et al., 2019).

The linear model explained most of the variation in funding deficits among Brazilian PAs and identified five general patterns. First, PA funding deficit was positively related to PA size, indicating that even tough large PAs cost less per km^2 than small PAs (Armsworth et al., 2011; Bruner et al., 2004), they tend to have large funding deficits. Second, PA age was negatively associated with PA funding deficits, indicating that newer PAs receive fewer financial resources than older ones, a pattern reported by Silva et al. (2019). Third, the PA funding deficit is negatively associated with the HDI around PAs. This result is consistent with the finding by Silva et al. (2019) that PAs in areas with high HDI receive more public resources in Brazil. This pattern suggests that the stakeholders of these areas might have more political capital and bargaining power to direct scarce federal funding toward the PAs that they care about most (Silva et al., 2019). Third, the model indicated that PAs in the Amazon have larger funding deficits compared to PAs in the Savannas and Drylands and the Atlantic Forest. This result is surprising because the Amazon is the only region in Brazil with a large-scale funding program (ARPA) dedicated to its PAs. The most likely explanation for this result is that Amazonian PAs are, on average, larger and therefore have higher total management costs than the PAs of other regions. In addition, it seems that ARPA covers only a fraction of the region's PAs' actual management costs. Finally, we did not find statistical difference between the funding deficits of sustainable use and strictly protected PAs, even though the federal government allocates less public funding to sustainable use PAs because they are projected to leverage private funds (through concessions and other mechanisms) to support their management costs (Silva et al., 2019).

One limitation of our analysis is that PA funding deficits were based only on recurrent management costs, one of the three PA cost categories. The other two cost categories are systemwide costs and establishment costs (Bruner et al., 2004). Systemwide costs include the national and sub-national technical and operational support needed for PA management (Bruner et al., 2004). Because these costs remain unconsidered in the conservation literature, estimates from other national-level public systems can be used as benchmarks. For instance, the systemwide costs of effective national health systems are estimated at 15 %–20 % of the total annual management costs (Woolhandler et al., 2003). If these values are used as a reference, then the systemwide costs of the Brazilian PAs are projected to range from US$ 70.2 million to US $ 93.6 million a year. Establishment costs include designation costs,

Table 3
Effects of the characteristics of protected areas (age, size, and management category) and their zones of influence (ecological region, human population density, and human development index) on the funding deficit (measured as the % of total management costs that is not covered by government spending) of 292 federal protected areas in Brazil.

Variables	*Coefficient*	*Robust SE*	*t*	*P*	*Squared semi-partial correlation*	*P*
Intercept	123.54	10.45	11.81	0.000		
Age, in 2016	−0.445	0.10	−4.22	0.000	0.024	0.000
Size, in km^2	0.001	0.0003	3.65	0.000	0.020	0.003
Population density	−0.004	0.003	−1.43	0.155	0.002	0.256
HDI[a]	−68.01	20.01	−3.40	0.001	0.019	0.005
Management group						
Sustainable use[b]	2.92	3.36	0.87	0.439	0.001	0.4257
Ecological Region[c]						
Atlantic Forest	−40.50	5.78	−7.00	0.000	0.093	0.000
Savannas and Drylands[d]	−18.80	4.67	−4.03	0.000	0.024	0.000

[a] Human Development Index.
[b] Compared to Strictly Protected Area.
[c] Compared to Amazon.
[d] This region comprises Caatinga, Cerrado, Pantanal, and Pampas.

investments in infrastructure, and land purchase costs when governments do not own the land to be protected (Bruner et al., 2004; Dias et al., 2016). These costs depend on the region where a PA is placed. Dias et al. (2016) estimated that establishment costs were 1.8 times the annual management costs for PAs without considering land purchase. Using this ratio, establishment costs for Brazilian federal PAs without land purchase are projected to be around US$ 842.2 million. If on top of this value, we add the US$ 3 billion calculated by the Brazilian government as the sum of financial resources required to compensate landowners who have their properties within the existing federal PA system (Tribunal de Contas da União, 2013), then the total establishment costs for the federal PAs are projected to be US$ 3.8 billion. In summary, federal PAs in Brazil need: (1) US$ 3.8 billion distributed over 5–10 years to build their necessary infrastructure and solve all land tenure issues; (2) US$ 531.8–561.5 million a year to cover their systemwide and management costs.

Brazil is the world's ninth-largest economy and is considered one of the world's leaders in biodiversity conservation because of its innovative environmental policies, vast stocks of natural capital, and extensive PA system (Scarano et al., 2012). The country uses these assets to export its commodities worldwide, branding them as more environmentally friendly than those produced by its competitors. Although the official discourse is compelling (but see Ferrante and Fearnside, 2019 for current development), our results show that the Brazilian government is falling short of implementing the most fundamental component of its environmental legislation, that is, to protect a set of strategically selected areas that compose the very core of its green infrastructure (*sensu* Silva and Wheeler, 2017) that the country needs to prosper. New policies, public-private partnerships, and innovative funding mechanisms need to be set to close the large funding gap in the Brazilian federal PA system. Because PA funding deficits are not restricted to Brazil, more studies are required in all countries to produce high-resolution estimates on the actual costs of an effective global PA system.

CRediT authorship contribution statement

José Maria Cardoso da Silva: Conceptualization, Methodology, Investigation, Writing - review & editing. **Teresa Cristina Albuquerque de Castro Dias:** Conceptualization, Investigation. **Alan Cavalcanti da Cunha:** Conceptualization, Investigation. **Helenilza Ferreira Albuquerque Cunha:** Conceptualization, Investigation.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.landusepol.2020.104926.

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