UNIVERSITY OF BRASILIA
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CERRADO NATIONAL PARKS BEYOND BIODIVERSITY CONSERVATION: CULTURAL ECOSYSTEM SERVICES AND ENVIRONMENTAL RISKS

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A thesis submitted to the faculty at the University of Brasília in partial fulfillment of the requirements for the degree of Master of Science in the Graduate Program in Environmental Sciences.

Area of Concentration: *Structure, Dynamics and Environmental Conservation*

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UNIVERSIDADE DE BRASÍLIA
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PARQUES NACIONAIS DO CERRADO PARA ALÉM DA CONSERVAÇÃO DA BIODIVERSIDADE: SERVIÇOS ECOSSISTÊMICOS CULTURAIS E RISCOS AMBIENTAIS

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ARIANE DE ALMEIDA RODRIGUES

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ABSTRACT

Buffer zones around protected areas can minimize negative human impacts and stimulate the sustainable use of natural resources. Conversely, land-use in these zones can potentially deteriorate ecological processes and biodiversity conservation inside the area under protection. In this study, we address human-environment interaction in the buffer zones of 13 Brazilian Cerrado National Parks, with a twofold perspective: as vulnerable ecosystems under land-use change pressure, and as important sources of services that sustain human wellbeing. Two analyses were conducted. The first one was aimed at revealing opportunities to expand and complement the touristic attractions around eight Cerrado National Parks opened for visitation, by taking advantage of their scenic views. The methods were based on remote sensing derived landscape biophysical attributes, three key categories related to visual and ecological qualities and six indicators. Results identified profiles of the selected parks, relating their biophysical characteristics to their main touristic potential. Strong hilly topographies, in general, were associated with wide visual scale and high complexity while flat topographies favored water related recreational services. The second analysis investigated protected areas more sensitive to land use and land cover change disturbances carried by hydrologic flows. Three factors that influence natural areas sensitivity, encompassing soil and hydrologic natural characteristics, and measures of exposure from land use and land cover change in the buffer zone were obtained from remote sensing data. The results revealed three groups of parks to be targeted for prevention and mitigation measures. The group classified as high risk sustains high rates of conversion in their buffer zones and additional characteristics that aggravate potential impacts. The group classified as high land-use exhibited the highest rates of conversion in their buffer zones, and should also be prioritized for adaptive management. Another group of parks exhibited high sensitivity to disturbances from hydrologic flows and should be targeted for prevention of land use and land cover change in the buffer zone. Although our research focused on National Parks located in the Brazilian Cerrado, the studied area is representative of tropical ecosystems with relevant specie richness and high land use conversion pressure.

Keywords: scenic view, tourism, erosion, savanna, contamination.

RESUMO EXPANDIDO

As zonas de amortecimento no entorno de unidades de conservação podem minimizar os impactos antrópicos negativos e estimular o uso sustentável dos recursos naturais. Por outro lado, o uso da terra nessas zonas pode potencialmente deteriorar os processos ecológicos e a conservação da biodiversidade dentro da área protegida. Neste estudo, abordamos a interação homem-ambiente nas zonas de amortecimento de 13 Parques Nacionais do Cerrado Brasileiro, sob dupla perspectiva: como ecossistemas vulneráveis sob intensa pressão de conversão do uso da terra e como importantes fontes de serviços que sustentam o bem-estar humano. Foram realizadas duas análises. A primeira teve como objetivo apontar oportunidades para expandir e complementar as atrações turísticas em torno de oito Parques Nacionais abertos para visitação, aproveitando suas vistas panorâmicas. Os métodos foram baseados em atributos biofísicos derivados de sensoriamento remoto, três categorias principais relacionadas à qualidade visual e ecológica e seis indicadores. Os resultados identificaram perfis para os parques selecionados, relacionando suas características biofísicas com seu principal potencial turístico. As topografias mais acidentadas, em geral, foram associadas a maior amplitude de escala visual e complexidade, enquanto topografias planas favorecem serviços recreativos relacionados à água. A segunda análise investigou áreas protegidas mais sensíveis a distúrbios de mudanças do uso e cobertura do solo transportadas por fluxos hidrológicos. A partir de dados de sensoriamento remoto, foram identificados três fatores que influenciam a sensibilidade ambiental, abrangendo características naturais pedológicas e hidrológicas, bem como medidas de exposição à conversão do uso e cobertura do solo na zona de amortecimento. Os resultados revelaram três grupos de parques a serem priorizados para aplicação de medidas de mitigação e prevenção. O grupo classificado como de alto risco sustenta altas taxas de conversão em suas zonas de amortecimento e outras características que agravam os impactos potenciais. O grupo classificado como de alto uso da terra mostrou as maiores taxas de conversão em suas zonas de amortecimento e também deveria ser priorizado para manejo adaptativo. Outro grupo de parques exibiu grande sensibilidade a perturbações nos fluxos hidrológicos e deveria ser direcionado para prevenção de mudanças de cobertura e uso da terra na zona de amortecimento. Embora o estudo tenha focado em Parques Nacionais localizados no Cerrado brasileiro, a área de estudo é representativa de ecossistemas tropicais com relevante riqueza de espécies e alta pressão de conversão do uso da terra.

Palavras-chave: vista cênica, turismo, erosão, savana, contaminação.

To my supporting and loving family,

To my dear husband,

To my brilliant advisors,

To all the friends from the University of Brasília,

Thank you!

I am deeply grateful to have you in my life.

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SUPPLEMENTARY MATERIAL

LIST OF ABBREVIATIONS

ALOS	Advanced Land Observing Satellite
ANA	Brazilian National Water Agency (Agência Nacional de Águas)
BA	Bahia State, Brazil
CDB	Convention of Biological Diversity
CES	Cultural Ecosystem Service(s)
CONAMA	National Environmental Council (Conselho Nacional de Meio Ambiente)
DEM	Digital Elevation Model
DF	Distrito Federal, Brazil
DSM	Digital Surface Model
ES	Ecosystem Services
FUNATURA	Fundação Pró-Natureza (Fundação Pró-Natureza)
GO	Goiás State, Brazil
IBGE	Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística)
ICMBIO	Chico Mendes Institute for Biodiversity Conservation (Instituto Chico Mendes de Conservação da Biodiversidade)
IUCN	International Union for Conservation of Nature
JAXA	Japan Aerospace Exploration Agency
LULCC	Land Use and Land Cover Change
MA	Maranhão state, Brazil
MATOPIBA	Maranhão, Tocantins, Piauí and Bahia Cerrado region
MEA	Millennium Ecosystem Assessment
MG	Minas Gerais state, Brazil
MMA	Brazilian Ministry of Environment (Ministério do Meio Ambiente)
MODIS	Moderate-Resolution Imaging Spectroradiometer
MS	Mato Grosso do Sul state, Brazil
MT	Mato Grosso state, Brazil
NASA	National Aeronautics and Space Administration
NP(s)	National Park(s)
PA(s)	Protected Area(s)
PI	Piauí State, Brazil
SNUC	National System of Conservation Units (Sistema Nacional de Unidades de Conservação)
SRTM	Shuttle Radar Topography Mission
TNC	The Nature Conservancy
TO	Tocantins State, Brazil
UNEP-WCMC	United Nations Environment World Conservation Monitoring Centre

CHAPTER 1
CONTEXTUALIZATION

Societies are not isolated systems, they are connected to broader ecological systems from which they withdraw goods and services for their maintenance. The benefits that people obtain from natural systems are ecosystem services (ES) (MEA 2005a), characterized by stocks and flows of matter and energy. Although demands of society for ES are often determined by political and socio-economical decisions, the capacity of ecosystems to supply these services is governed by the laws of thermodynamic and mass conservation (Burger et al. 2012).

The supply of ES corresponds to the ecosystem's ability to provide a group of services and products beneficial to society in a given location and period (Burkhard et al. 2012). The calculation of the current supply depends on the demand, which corresponds to the total services consumed by the social group in a given area, in the same period (Burkhard et al. 2012). In general, there is a separation between places that produce ES and places where these services are consumed. In globalized markets, this separation includes international displacements of nutrients, biomass, and extensive socio-environmental impacts, that feedback reducing the capacity of ecosystems to sustain the production in the long term (Foley et al. 2005, Burger et al. 2012, Austin et al. 2013, Godar et al. 2016). The scenario in Brazil is illustrative of that vicious circle. Brazil is a leading exporter of agricultural products (Martinelli et al. 2010), a position sustained with high levels of land concentration and deforestation (Lapola et al. 2014). There is a current focus on shot-term over long-term needs that produces extensive environmental imbalances worldwide, representative of our current era, the Anthropocene (Foley et al. 2005).

The Anthropocene is characterized by deep human influence on the planet, including the lithosphere, atmosphere, hydrosphere and biosphere (Crutzen 2002, Zalasiewicz et al. 2011, Richter et al. 2015). Human activities have pushed the planet outside the expected range of variability for key ecological processes and increased the risk of abrupt planetary environmental changes (Rockström et al. 2009). Land use and land cover change (LULCC) is one of the human-determined environmental modifications that have scaled from local to global influence. LULCC is a driver of global environmental change with cascading effects. It impacts climate, water balance, air quality, biogeochemical cycles, biological diversity, transmission of diseases and many other ecological processes, with possible long term decline in human wellbeing (Foley et al. 2005).

Nevertheless, among the subset of global ecosystem boundaries, land-use change is below the zone of high risk (Steffen et al. 2015). This perspective on LULCC boundaries, however, considers major tropical, temperate and boreal forests controls over climate (Steffen et al. 2015). Non-forest ecosystems are underestimated, encompassing some of the biodiversity hotspots, Earth's most biologically rich and threatened areas (Myers et al. 2000). This is the case of the Cerrado, the Brazilian savanna biome, one of the 36 current world hotspots for biodiversity conservation (Critical Ecosystem Partnership Fund 2017).

The Cerrado is Brazil's second largest biome, after the Amazon. It occupies an area of over 2 million km^2 (IBGE 2004) which is comparable to the combined area of England, France, Germany, Italy and Spain (Lahsen et al. 2016). The heterogeneity of relief, soils, climate and fire regimes along the Cerrado create a vast array of vegetation cover or plant physiognomies, establishing a gradient of grasslands, savannas and forests (Eiten 1972, 1977, Ribeiro and Walter 1998, Oliveira-Filho and Ratter 2002). Climate variability is one of the major controls over the ecosystem processes. Cerrado's climate is characterized by strong seasonality, with five to six months of water deficit throughout the year (from April/May until September/October) (Eiten 1972, Silva et al. 1998).

The heterogeneity of habitats sustains the most biologically rich savanna in the world (Klink and Machado 2005). The Cerrado concentrates one third of Brazilian biodiversity (Silva and Bates 2002, Klink and Machado 2005), with high endemism for some groups, such as lizards (45%), upper plants (44%), amphibians (50%) and herbaceous plants (70%) (Machado et al. 2008). The biological diversity is highly threatened by the loss of habitats. The intense LULCC process in the Cerrado started in the early 1970s, to make way for the expansion of Brazilian agricultural production, driven by the demands of the international markets (Klink and Moreira 2002, Mueller and Martha Júnior 2008). About 43% of its original natural vegetation cover was suppressed in a very short time span and converted to cultivated pasture (25.5%), annual (8.5%) and perennial (3.1%) crops (MMA 2015).

Nowadays, the Cerrado remains highly threatened. Despite the tendency towards decoupling agricultural production and LULCC (Lapola et al. 2014), deforestation still advances around 6,000 km^2 per year in the Cerrado (MMA 2015). Native vegetation loss is higher in the northern region, in areas suitable for agriculture that still hold large extents of Cerrado, mostly in the states of Maranhão, Tocantins, Piauí and Bahia, a region known as MATOPIBA (Spera et al. 2016). The accumulated and ongoing LULCC in the Cerrado threatens not only the rich biodiversity, but also the far-reaching benefits that societies obtain from this ecosystem (MEA 2005b) and that have been overlooked (Lahsen et al. 2016).

The hydrological services provided by the Cerrado for freshwater recharge and distribution are critical for Brazil and South America. The biome feeds water for eight of the 12 major Brazilian hydrologic basins, contributing to 94% of the São Francisco, 71% of the Tocantins-Araguaia and 71% of the Paraná-Paraguai basins (Lima and Silva 2005). The extensive presence of deep and well-drained Oxisols (46% of the Cerrado) (Reatto and Martins 2005), along with native vegetation root systems, provide an essential service to recharge national aquifers (Oliveira et al. 2005). Cerrado's vegetation deep roots reach the water table in deep soil horizons and return water to the atmosphere through evapotranspiration, maintaining the water balance in the dry season and in dryer years (Oliveira et al. 2005, Bucci et al. 2008, Cabral et al. 2015). Agricultural expansion replaces the Cerrado with shallow rooted vegetation, reducing evapotranspiration and changing the water balance (Arantes et al. 2016, Spera et al. 2016), while producing increased runoff and erosion (Oliveira et al. 2015). Albedo and surface roughness are also modified, with predicted impacts of higher temperature and longer dry periods in the future (Hoffman and Jackson 2000).

The Cerrado also maintain substantial carbon stocks, with a high fraction of its biomass stocked underground (Miranda et al. 2014). Original carbon stocks in the biome are estimated to be around 21.3 ± 7.5 PgC (Leite et al. 2012). Although savannas can be accounted as carbon sinks under undisturbed conditions (Grace et al. 2014), Cerrado's carbons stocks have been quickly mobilized, mainly through LULCC and increased fire regimes (Grace et al. 2006). Carbon emissions from LULCC vary considerably depending on the management practices adopted, that may include the use of fire (Bustamante et al. 2012), crop rotations and tillage practices (Batlle-Bayer et al. 2010, Bustamante and Ferreira 2011). Nevertheless, deforestation and agriculture activity have historically been the largest contributors to Brazilian CO_2 emissions (Fig. 1).

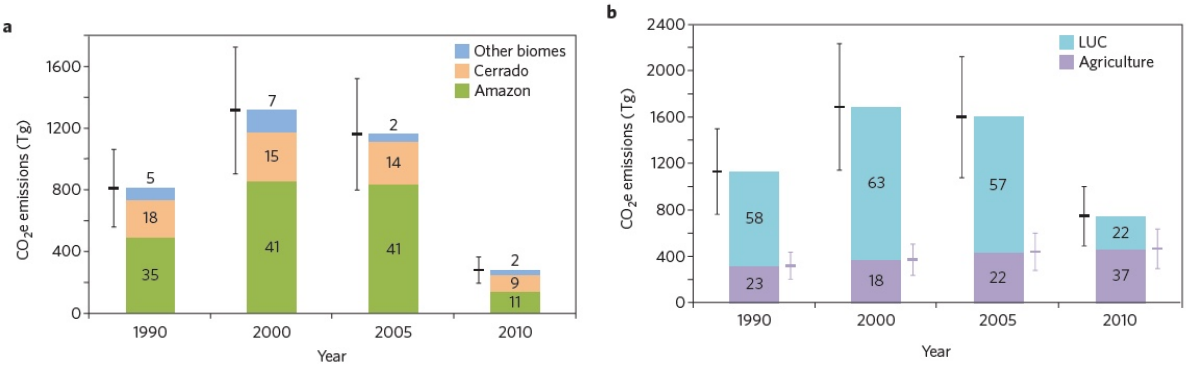

Fig. 1. Greenhouse gas emissions associated with land use in Brazil. **a,** Emissions from land-use change (deforestation) in the Brazilian biomes. **b,** Emissions from agriculture (enteric fermentation, manure decomposition, fertilizer use and other sources) and LUC (deforestation). Numbers inside the bars denote percentage share relative to nationwide total CO_2e emissions (all sectors) in a given year. Error bars represent estimated uncertainty intervals for the LUC sector **(a),** with the agricultural sector indicated in purple and agriculture plus LUC shown in black **(b).** Agriculture includes emissions from the application of limestone over topsoils and from energy use for agriculture-related transport. The 100-year global warming potential method was used for conversion of CH_4 and N_2O to CO_2e, where 1 CO_2e = 21 CH_4 = 310 N_2O. Source: Lapola et al. (2014).

Food provision is another important ES provided by the Cerrado. According to Rudorff et al. (2015), in 2013/2014, the Cerrado was responsible for 51.9% of the Brazilian cultivated soy area (15.66 Mha) (Fig. 2). Pasturelands occupied 26.4% of the Cerrado area In the beginning of the 2000's (Sano et al. 2010). Crop farming and cattle ranching contributed with 23% of 2016 national gross domestic product (GDP) (Oliveira and Cieglinski 2016), but social equity and environmental degradation outcomes are excluded from the economic equation (Lahsen et al. 2016).

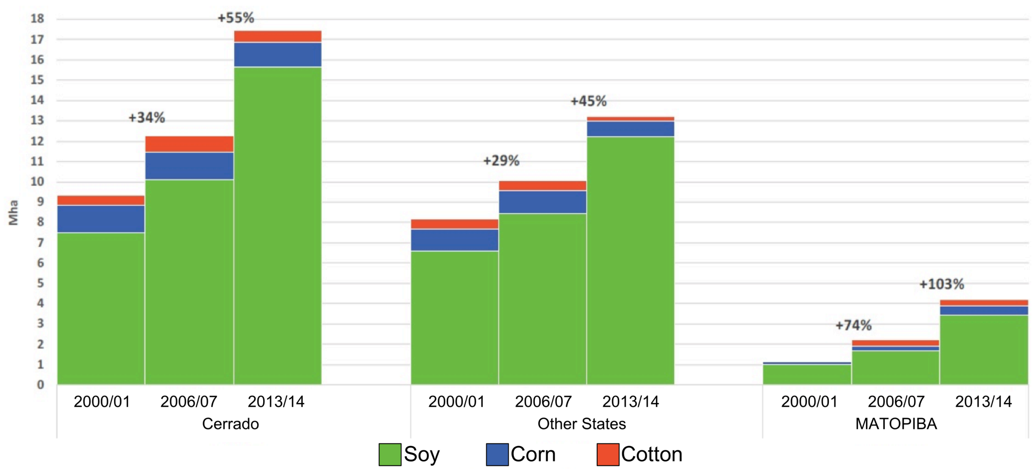

Fig. 2. Cultivated area (in Mha) with soy, corn and cotton in the Brazilian Cerrado. The values refer to the first harvest, in three different periods (2000/2001, 2006/2007 and 2013/2014), in the whole Cerrado (first), and separately for the MATOPIBA region and other states within the Cerrado. Source: Rudorff et al. (2015), with adaptations.

On top of being severely threatened, the biome is poorly protected, since strictly protected areas (PAs) cover approximately 3% of the Cerrado, and that proportion is possibly lower if taken into account the deforestation inside PAs (Françoso et al. 2015). Brazil defines PAs according to the National System of Protected Areas (SNUC in Portuguese), that has similarities with the International Union for Nature Conservation (IUCN) system (Table 1). The terrestrial protected area network cover 28,94% (2.5 million km^2) of the Brazilian territory (UNEP-WCMC and IUCN 2016). Those areas, however, are unequally distributed along the country (Fig. 3). Compared to the Amazon, the Cerrado contains fewer PAs with smaller average sizes (Overbeck et al. 2015).

Table 1. Correspondence between protected areas categories according to the Brazilian system (SNUC Category) and the International Union for Nature Conservation system (IUCN Category). The area covered by each category in the Brazilian territory is also showed, according to governance type (Federal Government or State Government). Source: ISA (2017), with adaptations.

<table>
<tr><th>Type</th><th>SNUC Category</th><th>Management objectives</th><th>IUCN Category</th><th>Federal (km^2)</th><th>State (km^2)</th></tr>
<tr><td rowspan="5">Strictly protected</td><td>Ecological Station</td><td>Research</td><td rowspan="2">Ia</td><td>73,902.68</td><td>46,402.79</td></tr>
<tr><td>Biological Reserve</td><td>Biodiversity protection</td><td>43,390.86</td><td>12,616.50</td></tr>
<tr><td>National/State Park</td><td>Ecosystems protection and recreation</td><td>II</td><td>269,384.28</td><td>70,524.52</td></tr>
<tr><td>Natural Monument</td><td>Unique natural features protection</td><td rowspan="2">III</td><td>447.34</td><td>324.10</td></tr>
<tr><td>Wildlife Refuge</td><td>Wildlife protection</td><td>2,697.81</td><td>1,107.40</td></tr>
<tr><td rowspan="8">Sustainable use</td><td>Environmental Protection Area</td><td>Human occupation ordering</td><td>V</td><td>106,916.48</td><td>210,887.85</td></tr>
<tr><td>Natural Heritage Private Reserve</td><td>Biodiversity conservation in private area</td><td rowspan="2">IV</td><td>Not available</td><td>Not available</td></tr>
<tr><td>Area of Relevant Ecological Interest</td><td>Local ecosystems protection</td><td>450.79</td><td>250.00</td></tr>
<tr><td>National/State Forest</td><td>Sustainable use of forest resources</td><td rowspan="4">VI</td><td>165,044.01</td><td>134,945.01</td></tr>
<tr><td>Extractive Reserve</td><td>Maintenance of sustainable traditional communities</td><td>124,209.03</td><td>30,796.17</td></tr>
<tr><td>Fauna Reserve</td><td>Sustainable economic management of wildlife resources</td><td>0</td><td>0</td></tr>
<tr><td>Sustainable Development Reserve</td><td>Maintenance of traditional cultures</td><td>1029.12</td><td>113,760.87</td></tr>
<tr><td></td><td></td><td></td><td>TOTAL</td><td>787,472.40</td><td>622,615.21</td></tr>
</table>

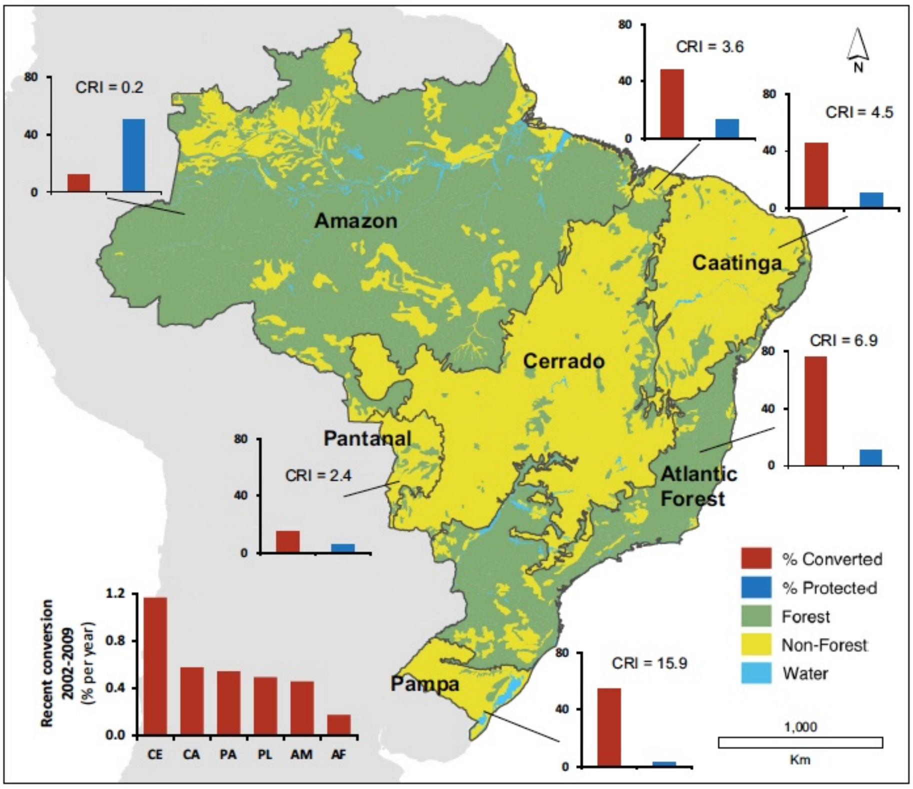

Fig. 3. Map of original vegetation cover in the Brazilian biomes. Original forest area is depicted in green and original non-forest vegetation area in yellow. Small inset graphs indicate the proportion of converted (red) and protected (blue) areas until 2009. Protected areas include IUCN categories I–VI and Indigenous Reserves. The Conservation Risk Index (CRI) given for each biome is the ratio of converted to protected percentages. At the bottom left, recent conversion rates (2002–2009) for each biome are shown (CE = Cerrado, CA = Caatinga, PA = Pampa, PL = Pantanal, AM = Amazon, AF = Atlantic Forest). Source: Overbeck et al. (2015).

Along the Cerrado, the existing PAs are also unevenly distributed, with larger areas in the northwest and small, fragmented and isolated areas in the southeast (Garcia et al. 2011). In addition, most PAs (64.13%) are located in marginal lands, with rugged terrain (Garcia et al. 2011). Protected areas suitable to agricultural activities are under heavy pressure of conversion (Garcia et al., 2011). Large scale activities of mining, dam and road building also submit the PA network to pressing threats (Bernard et al. 2014, Ferreira et al. 2014).

There is a long way ahead to reach the 17% goal of PA coverage in the Cerrado (BRASIL 2000). PA creation policies have stagnated and there is a trend towards downgrading, downsizing, degazettement and reclassification, undermining previous conservation achievements (Bernard et al. 2014, Ferreira et al. 2014). In this rapid-vanishing biome, there is a urgent need to understand the importance of PAs and develop mechanisms to reduce conversion, following the footsteps of the deforestation decrease in the Amazon (Nepstad et al. 2014).

Beyond the well-recognized goal of biodiversity conservation, PAs are identified as cornerstones to ES provision, including provisioning, regulating, cultural and supporting services (Fig. 4). Different studies have demonstrated the role of PA networks in climate change mitigation and adaptation strategies, water supply, protection of wild crop relatives, sustainable fisheries, disaster mitigation and maintenance of cultural diversity (Lopoukhine et al. 2012). Close to a third of the world's largest cities depend on PAs for their freshwater supply (Dudley and Stolton 2003). As a result, the expansion of PA network and improvements in their governance models have gained importance as cornerstones to adaptation and mitigation strategies, in response to global warming and land conversion (Dudley et al. 2010). A better understanding of the ES provided by the Cerrado PAs has potential to highlight social and economic benefits of investing in the expansion and management improvement of *in situ* conservation networks.

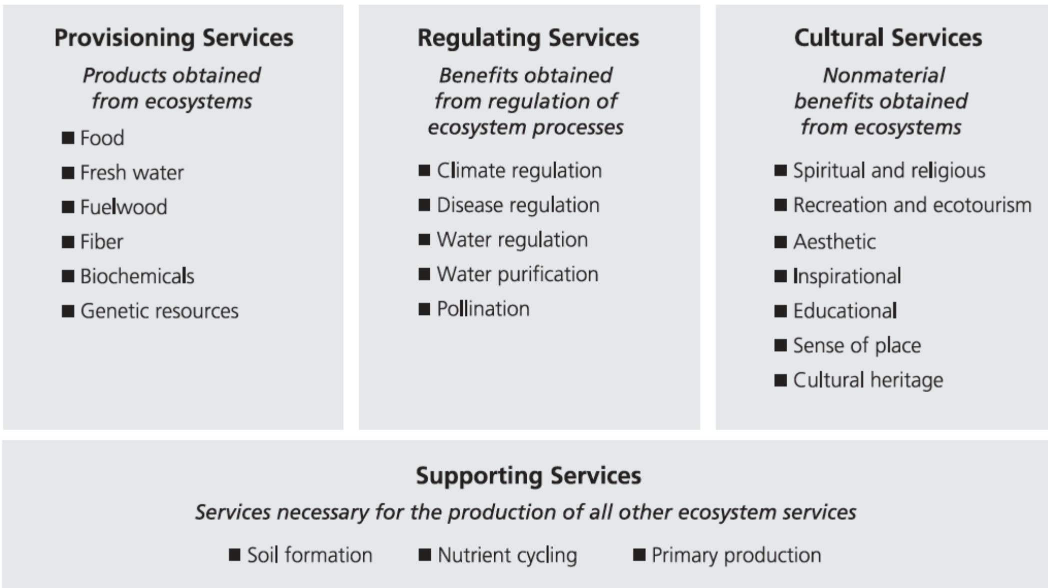

Fig. 4. Ecosystem services categories according to the Millennium Ecosystem Assessment. Source: MEA (2003 p. 57).

PAs offer opportunities for people to interact with nature through various recreational, aesthetical and other cultural ecosystem services (CES) (MEA et al. 2005a, Ament et al. 2016, De Vos et al. 2016). People who experience more frequent contact with nature are more likely to manifest positive feelings, attitudes and behavior toward the natural environment and its value (Soga and Gaston 2016), which may be an essential step towards a more sustainable society. Furthermore, CES can provide revenues to enable the maintenance and expansion of PA networks by means of ecotourism activities (Maciejewski et al. 2015, Souza 2016). Although nature-based tourism has been a long debated issue, only recently it has been integrated in the ecosystem services framework as an activity that encompasses multiple bundles of CES provision (Ament et al. 2016). Studies about CES are limited compared to the number of publications on other ES categories, especially in Latin America (Martín-López et al. 2012).

In this study, we investigated the aesthetic services provided by PAs, a topic not yet well elucidated for the Cerrado. We also identify PAs under higher pressure from anthropogenic activities, considering diverse degrees of sensitivity to these activities. Therefore, we address human-environment interaction regarding the Cerrado biome, with a twofold perspective: (1) as a fragmented and vulnerable ecosystem under land-use change pressure; and (2) as an important natural system that provides services to sustain human wellbeing. The focus lies on the dynamic relationship between PAs and their surroundings, where positive and negative interactions are concurrent. More specifically, our study objective was to evaluate scenic view services, along with sensitivity and exposure to disturbances disseminated through hydrologic flows in Cerrado National Parks and their buffer zones. We tested two hypotheses:

1. Biophysical characteristics can predict different opportunities to obtain benefits from the scenic panoramic views of PAs.
2. Soil and hydrologic characteristics can reveal PAs that are more sensitive to LULCC disturbances transmitted through water flows.

Both hypotheses, concerning scenic view and exposure/sensitivity to disturbance, were applied to Cerrado National Parks. Eight parks were accessed in chapter two and thirteen in chapter three. Since they are common subjects for the analysis carried out in the following chapters, before moving forward it is important to present our study area.

1.1. Study area: Cerrado National Parks

Among the PA management categories, National Park was selected for this study based on its distinguished effectiveness to protect the Cerrado, along with its management objectives to promote ecotourism and protect scenic beauty (Carranza et al. 2014, Françoso et al. 2015). According to Brazilian system, National Parks are strictly PAs, created to promote the preservation of natural ecosystems of great ecological importance and scenic beauty, enabling scientific research and activities of education and environmental interpretation, recreation in contact with nature and ecological tourism (Brazil 2000). Brazilian National Parks are analogous to IUCN-I category (Fig. 3, above) and they constitute the largest proportion of strictly PAs in the Cerrado, with estimated 1.42% coverage (Table 2).

Table 2. Protected areas cover in the Cerrado, by category and jurisdiction. Jurisdiction encompasses federal, state and municipal protected areas. Categories are divided according to land use restriction intensity, between integral protection (IP) and sustainable use (SU). Number, area, cover and natural vegetation remnant for each category is also depicted. Source: Françoso et al. (2015)

Jurisdiction	Remnant (%)	Use	Category	N	Area (ha)	Cover (%)	Remnant (%)
Federal (49)	88.60	IP (22)	EE*	5	1,112,149	0.55	0.54
			PARK*	15	2,891,980	1.42	1.39
			REBIO*	1	3,449	0	0
			RVS	1	128,049	0.06	0.06
		SU (27)	FLONA*	7	29,023	0.01	0.01
			APA	11	1,457,864	0.71	0.45
			RESEX	6	81,621	0.04	0.03
			ARIE	3	2,312	0	0
State (155)	75.19	IP (81)	EE*	25	48,687	0.02	0.02
			PARK*	43	1,326,444	0.65	0.62
			REBIO*	4	10,501	0.01	0
			RVS	5	134,725	0.07	0.05
			MN	4	31,468	0.02	0.01
		SU (74)	FLONA*	10	30,766	0.02	0.01
			RDS*	1	58,780	0.03	0.03
			APA	56	9,057,087	4.44	3.20
			ARIE	7	4,446	0	0
Municipal (81)	29.94	IP (27)	PARK*	16	7,972	0	0
			MN	11	124,806	0.06	0.03
		SU	APA	54	408,579	0.20	0.04
Total				285	16,950,708	8.31	6.50

Remnant (%) = percentage of area not affected by deforestation; Cover (%) = percentage of Cerrado biome covered by each category; IP = integral protection; SU = sustainable use; EE = ecological station; REBIO = biological reserve; RVS = wildlife refuge; FLONA = national forest; APA = environmental protected area; RESEX = extractive reserve; ARIE = area of relevant ecological interest; MN = natural monument; RDS = sustainable development reserve.

* refers to the categories that predict land expropriation.

Our study examines the Cerrado National Parks as representatives of areas with low anthropogenic impact (Françoso et al. 2015), and therefore are expected to provide increased levels of ecosystem services (Lopoukhine et al. 2012). They function as important protectors of water springs, streams and geological and biological diversity. Furthermore, National Parks combine preservation of ecologically important sites with scenic beauty and ecotourism, one of the dimensions evaluated in this study that can possibly fuel social and economical support to the PA maintenance (Souza 2016).

Thirteen National Parks located in the Cerrado were selected (Fig. 5). Lençóis Maranhenses and Serra das Confusões Parks, although located in the Cerrado biome, were not included in this study because vegetation in these parks is not typical of Cerrado. In fact, Lençóis Maranhenses present vegetation from three biomes – Amazonia, Cerrado and Caatinga – and ~2/3 of the park corresponds to sandy dunes. Vegetation from the Serra das Confusões is typical of Caatinga biome. Due to the several difficulties to compare data from different biomes, we also disregarded the Chapada Diamantina and Sete Cidades Parks. They are mostly composed of Cerrado vegetation, but are located outside of the Cerrado biome.

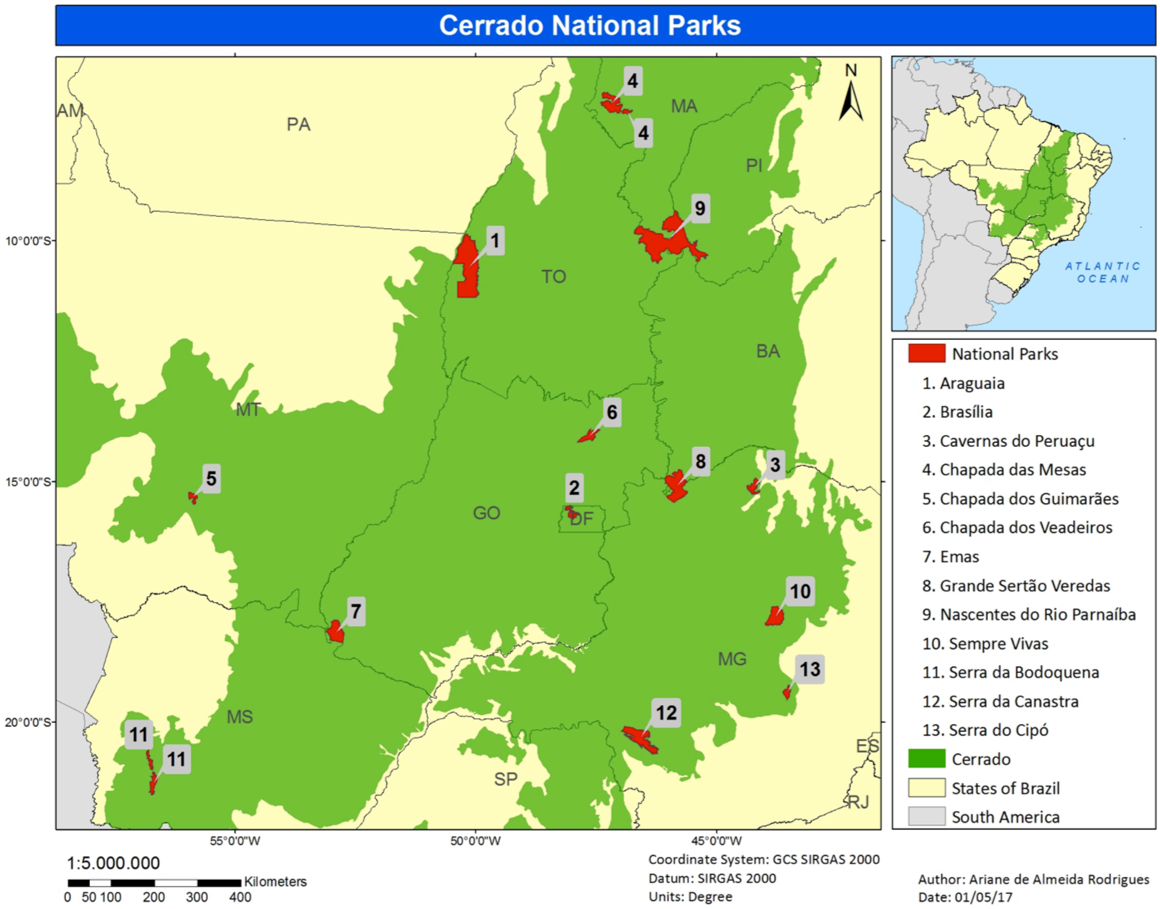

Fig. 5. Map of the study area encompassing 13 National Parks located in the Brazilian Cerrado biome. Sources: Polygon of Brazil and the Cerrado from IBGE (2004) and polygons of parks from ICMBIO (2016a).

The parks are distributed in nine states, 11 ecoregions, under varying environmental conditions (Table 3). Serra do Cipó Park National Park, located in the Minas Gerais State, is the smallest one, with 316 km^2 (Table 2). Conversely, Nascentes do Rio Parnaíba National Park, located in the states of Maranhão, Piauí and Bahia, is the largest one, with 7,497 km^2. Eight parks are officially opened to public visitors according to ICMBIO (2017a).

In 1959, it was created the first National Park in the Cerrado: The Araguaia Park, located in Tocantins State and now in the list of Wetlands of International Importance (Ramsar site). Brasília, Chapada dos Veadeiros and Emas Parks were created in 1961 as part of the project to stimulate economic development in the central part of Brazil. Chapada das Mesas, located in the Maranhão State, is the most recent National Park in the Cerrado, created in 2005. Its creation is coincident with the recent expansion of the agricultural frontier up to the north of the country, to the MATOPIBA region.

Table 3. Main characteristics of 13 Cerrado National Parks selected as study area.

National Park	States*	Ecoregions	Year of creation/ alteration	Area (km²)	Number of visitors in 2015	Main characteristics	Main threats	Touristic attractions
Araguaia	TO	Bananal	Created in 1959, reduced in 1971/1973, with limits defined in 1980	5,555.24	Unregistered	Wetland of International Importance (Ramsar Site), more than 60% of the total area overlaps indigenous territories, located in the Cerrado/Amazon transition	Livestock farming, agricultural expansion, fire, irrigation systems, contamination from agrochemicals, hunting, fishing, roads, waterways	Biggest river island in the world, seasonal river beaches, ponds, extensive river network, fishing, camping, animal observation, indigenous cultures
Brasília	DF	Planalto Central	Created in 1961, extended in 2006	423.56	294,682	Located inside an urban area, contains springs and streams that provide water to the city of Brasília, helps to control the urban climate	Urban expansion, pollution, fire, landfill, biological invasion, fishing, tourism impact, gravel extraction	Natural swimming pools, trails, recreation infrastructure
Cavernas do Peruaçu	MG	Undetermined	Created in 1999	564.49	2,938	Located in the Cerrado/Caatinga transition, characterized by karst topography, and an abundance of caves and archaeological sites	Livestock farming, fire, agricultural expansion, deforestation, wood extraction, invasive species, roads, excessive use of water resources, irrigation systems, dams, erosion, sedimentation, contamination from agrochemicals, sewage disposal	Prehistorical rock paintings, trails, scenic outlooks, archaeological sites, colossal caves, canyons, geological monuments, speleothems, cerrado rupestre (rocky cerrado)
Chapada das Mesas	MA	Bico do Parapagio	Created in 2005	1,599.53	Unregistered	Contains more than 400 springs, located within Legal Amazon limits	Agricultural expansion, steel industry expansion, fire, delay in the expropriation process	Sandstone plateaus, scenic outlooks, waterfalls, archaeological rock paintings
Chapada dos Guimarães	MT	Paraná-Guimarães	Created in 1989	326.46	174,855	Composed by notable landform diversity and geological sites, protects springs of the Cuiabá River (main contributor to the Pantanal), and springs of the Guarani Aquifer	Livestock farming, agricultural expansion, fire, roads, roadkill, delay in the expropriation process, recreational activities	Trails, waterfalls and rivers, scenic outlooks, cycling, sandstone walls, caves, geological sites
Chapada dos Veadeiros	GO	Planalto Central	Created in 1961, extended in 1972, reduced in 1981, extended in 2001 (which was reversed in 2003), extended in 2017	647.26 (new area is 2,406.11)	56,629	UNESCO World Heritage Site, contain a high number of fauna and flora endemic species	Fire, livestock farming, agricultural expansion, roads and urban expansion, tourism expansion, wood extraction, plant gathering, mining, dams	Diversity of Cerrado formations, rivers, waterfalls and rip currents, natural pools, trails, canyons, scenic outlooks
Emas	MS, GO	Paraná-Guimarães	Created in 1961, with limits defined in 1972	1,327.87	1,681	UNESCO World Heritage Site, divide Araguaia and Paraná basins	Agricultural expansion, livestock farming, contamination from agrochemicals, dams, roads, railway, invasive species, fire, erosion, sedimentation, habitat fragmentation and isolation, increased floods	Bioluminescence of termite nests, trails, cycling, car expedition (safari), ponds, tubing
Grande Sertão Veredas	BA, MG	Chapadão do São Fancisco	Created in 1989, extended in 2004	2,308.56	570	Located in the Cerrado/Caatinga transition, contains high biodiversity, abundant water resources and cultural importance	Delay in the expropriation process, fire, agricultural expansion, contamination from agrochemicals, livestock farming, degraded pasturelands, roads, wood and straw extraction	Diversity of Cerrado formations, Veredas formations, scenic outlooks, waterfalls, trails, meeting of rivers
Nascentes do Rio Parnaíba	MA, PI, BA	Chapadão do São Fancisco, Depressão do Paranaguá and Alto Parnaíba	Created in 2002, extended in 2015	7,497.74	Unregistered	Located in the Cerrado/Caatinga/Amazon transition, partially inside the Legal Amazon, in the Cerrado agriculture frontier (MATOPIBA); contains the springs to the Parnaíba river, that supply water to 50 cities in the Northeast	Delay in the expropriation process, fire, livestock farming, wood and straw extraction, wild animals traffic	Waterfalls
Sempre-Vivas	MG	Serra do Cipó	Created in 2002	1,241.55	26	Located in the Mata Atlântica/Caatinga transition, within the Espinhaço Ridge, a biodiversity conservation priority (high endemism); it is a center of genetic diversity of eriocauláceas plant family; contains important springs and streams	Livestock farming, fire, forestry, hunting, fishing, mining, plant gathering for handcrafts, wood extraction, land disputes	Terrain diversity, rivers and waterfalls, diversity of Cerrado vegetation formations, fields of sempre-vivas and other small flowers, animal diversity, historical and cultural human heritage sites (such as archeological rock paintings, caves and historical ruins)

National Park	States*	Ecoregions	Year of creation/ alteration	Area (km²)	Number of visitors in 2015	Main characteristics	Main threats	Touristic attractions
Serra da Bodoquena	MS	Complexo Bodoquena	Created in 2000	769.73	389	Located in the border zone between Paraguay and Brazil (with military presence), in the Pantanal/Mata Atlântica/Cerrado transition, with important springs and streams, inside the Bodoquena-Pantanal State Geopark, due to its high geodiversity	Livestock farming, fire, invasive species, water contamination by cattle, riparian forest suppression, wetlands drainage, springs and streams destruction, sedimentation, hunting, fishing, agriculture expansion, use of agrochemicals (possibly products banned from Brazil, that enter illegally from Paraguay), gravel and limestone extraction, roads, increased population density due to rural settlements	Diversity of Cerrado formations, geosites (including sites with geomorphological, tectonic, stratigraphic, sedimentological, paleontological, speleological, mineralogical and hydrogeological importance)
Serra da Canastra	MG	Serra da Canastra	Created in 1972	1,979.71	52,673	Encompasses main springs for the São Francisco River.	Land use and land cover change in the buffer zone, with livestock farming, agriculture in slopes, use of pesticides, forestry, mining, fire, roads, energy transmission lines, uncontrolled tourism, invasive species, delay in the expropriation process	Archaeological and prehistorical heritage sites, historical buildings, trails, rivers and waterfalls
Serra do Cipó	MG	São Francisco Velhas	Created in 1984 (converted from State Park to National Park)	316.39	53,660	Located in the Mata Atlântica/Caatinga transition, within the Espinhaço Range, which it is a biodiversity conservation priority, with high endemism	Cattle ranching, fire, plant gathering, biological invasion, uncontrolled tourism, fishing, motor biking	Waterfalls, trails, scenic outlooks, ponds, rivers, canyons, cycling, archeological sites

*Abbreviations for Brazilian states: TO - Tocantins, DF - Distrito Federal, MG - Minas Gerais, MA - Maranhão, MT - Mato Grosso, GO - Goiás, MS - Mato Grosso do Sul, BA - Bahia and PI - Piauí.
Sources: IBAMA and FUNATURA (1998, 2003), MMA (2000), IBAMA (2001, 2004, 2005a, 2005b), Arruda et al. (2008), ICMBIO (2009a, 2009b, 2009c, 2013, 2016), Souza (2016).

CONCLUDING REMARKS

The two proposed hypothesis were confirmed by our results. Biophysical measures of visual scale (panoramic view area), topographic heterogeneity (roughness and slope variability) and biological diversity (Shannon's Diversity and Eveness Indexes) proved to be appropriate (in terms of objectivity) indicators of touristic and scenic potentials. We were able to create biophysical profiles to the studied parks revealing differences in their aptitude to offer cultural ecosystem services. Limitations of the proposed model are mostly related to the absence of other variables, such as built infrastructure and socioeconomic factors, that strongly influence visitation potential, and could not be integrated in the analysis.

Additionally, soil (sand content) and hydrologic (drainage density and direction) characteristics were able to define parks under higher sensitivity to LULCC disturbances transmitted through water flows. The indicators provided qualitative measurements of risk to identify areas for priority management, focusing on different land-use degradation drivers and tendencies. Main limitations are the difficulty to rank those aspects and integrate them with other mechanisms that potentially impact protected areas. In order to reach a vulnerability measure, adaptive capacity was the missing component in our analysis.

Our main contributions are methodological, covering two aspects of protected areas rarely mentioned in the scientific literature. Although this study focused only on National Parks located in the Brazilian Cerrado biome, the proposed approaches can be extended to other tropical areas with species-rich ecosystems under high pressures of land use conversion.

REFERENCES

Alexandre, B., R. Crouzeilles, and C. E. V. Grelle. 2010. How can we estimate buffer zones of protected areas? A proposal using biological data. Natureza a Conservacao 8:165–170.

Alin, S. R., C. M. O, A. S. Cohen David L Dettman, M. R. Palacios-Fest Terra, and B. A. McKee. 2002. Effects of land-use change on aquatic biodiversity: A view from the paleorecord at Lake Tanganyika, East Africa. Geology 30:1143–1146.

Allen Consulting Group. 2005. Climate Change Risk and Vulnerability: Promoting an efficient adaptation response in Australia. Page Report to the Australian Greenhouse Office, Department of the Environment and Heritage.

Alonso, M. A., M. P. A. Maqua, A. B. Andray, T. C. Prieto-Lavin, R. M. C. Gonzalez, and G. C. Castellano. 2004. Guía para la elaboración de estudios del medio físico: contenido y metodología. Fifth edition. Ministerio de Medio Ambiente, Secretaría General del Medio Ambiente, Madrid.

Ament, J. M., C. A. Moore, M. Herbst, and G. S. Cumming. 2016. Cultural Ecosystem Services in Protected Areas: Understanding Bundles, Trade-Offs, and Synergies. Conservation Letters 0:1–11.

Andrade, R. G., A. H. de C. Teixeira, J. F. Leivas, G. B. S. da Silva, S. F. Nogueira, D. de C. Victoria, L. E. Vicente, and É. L. Bolfe. 2015. Indicativo de pastagens plantadas em processo de degradação no bioma Cerrado. Pages 1585–1592Anais XVII Simpósio Brasileiro de Sensoriamento Remoto. Instituto Nacional de Pesquisas Espaciais (INPE), João Pessoa.

Arantes, A. E., L. G. Ferreira, and M. T. Coe. 2016. The seasonal carbon and water balances of the Cerrado environment of Brazil: past, present, and future influences of land cover and land use. ISPRS Journal of Photogrametry and Remote Sensing 117:66–78.

Arruda, M. B., C. E. B. Proença, S. Rodrigues, E. S. Martins, R. C. Martins, and R. N. Campos. 2008. Ecorregiões, Unidades de Conservação e Representatividade Ecológica do Bioma Cerrado. Pages 229–270*in* S. Sano and S. P. Almeida, editors.Cerrado: ecologia e flora. Embrapa, Brasília.

Austin, A. T., M. M. C. Bustamante, G. B. Nardoto, S. K. Mitre, T. Pérez, J. P. H. B. Ometto, N. Ascarrunz, M. C. Forti, K. Longo, M. E. Gavito, and L. A. Martinelli. 2013. Latin America ' s Nitrogen Challenge. Science 340:149.

Balla, D., O. G. Varga, and M. Zichar. 2016. Accuracy assessment of different soil databases concerning WRB reference soil groups. Landscape & Environment 10:1–12.

Barbosa, Á. G. 2008. As Estratégias de Conservação da Biodiversidade na Chapada dos Veadeiros: Conflitos e Oportunidades. UnB.

Batlle-Bayer, L., N. H. Batjes, and P. S. Bindraban. 2010. Changes in organic carbon stocks upon land use conversion in the Brazilian Cerrado: A review. Agriculture, Ecosystems and Environment 137:47–58.

Bernard, E., L. A. O. Penna, and E. Araújo. 2014. Downgrading, downsizing, degazettement, and reclassification of protected areas in Brazil. Conservation

Biology 28:939–950.

Birgé, H. E., R. A. Bevans, C. R. Allen, D. G. Angeler, S. G. Baer, and D. H. Wall. 2016. Adaptive management for soil ecosystem services. Journal of Environmental Management 183:371–378.

Bishop, I. D., and D. W. Hulse. 1994. Prediction of scenic beauty using mapped data and geographic information systems. Landscape and Urban Planning 30:59–70.

Bomfim, A. 2004. O ambiente conflituoso do ecoturismo na Chapada dos Veadeiros. Page II Encontro da Associação Nacional de Pós-Graduação e Pesquisa em Ambiente e Sociedade. ANPPAS, Indaiatuba.

BRASIL. 2000. A Convenção sobre Diversidade Biológica - CDB, cópia do Decreto Legislativo n° 2, de 5 de junho de 1992. Brasília.

Brazil. 2000. Lei no. 9985, de 18 de julho de 2000. Casa Civil, Presidência da República, Brazil.

Bucci, S. J., F. G. Scholz, G. Goldstein, F. C. Meinzer, A. C. Franco, Y. Zhang, and G. Y. Hao. 2008. Water relations and hydraulic architecture in Cerrado trees: Adjustments to seasonal changes in water availability and evaporative demand. Brazilian Journal of Plant Physiology 20:233–245.

Burger, J. R., C. D. Allen, J. H. Brown, W. R. Burnside, A. D. Davidson, T. S. Fristoe, M. J. Hamilton, N. Mercado-Silva, J. C. Nekola, J. G. Okie, and W. Zuo. 2012. The macroecology of sustainability. PLoS Biology 10.

Burkhard, B., F. Kroll, S. Nedkov, and F. Müller. 2012. Mapping ecosystem service supply, demand and budgets. Ecological Indicators 21:17–29.

Bustamante, M. M. C., and L. G. Ferreira. 2011. Land use change and the carbon budget in the Brazilian Cerrado. Page *in* M. J. Hill and Niall P. Hanan, editors. Ecosystem Function in Savannas: measurement and modeling at landscape to global scales. CRC Press, Boca Raton.

Bustamante, M. M. C., L. A. Martinelli, J. P. H. B. Ometto, J. B. do Carmo, V. Jaramillo, M. E. Gavito, P. I. Araujo, A. T. Austin, T. P??rez, and S. Marquina. 2014. Innovations for a sustainable future: Rising to the challenge of nitrogen greenhouse gas management in Latin America. Current Opinion in Environmental Sustainability 9:73–81.

Bustamante, M. M. C., C. A. Nobre, R. Smeraldi, A. P. D. Aguiar, L. G. Barioni, L. G. Ferreira, K. Longo, P. May, A. S. Pinto, and J. P. H. B. Ometto. 2012. Estimating greenhouse gas emissions from cattle raising in Brazil. Climatic Change 115:559–577.

Cabral, O. M. R., H. R. da Rocha, J. H. Gash, H. C. Freitas, and M. A. V Ligo. 2015. Water and energy fluxes from a woodland savanna (cerrado) in southeast Brazil. Journal of Hydrology: Regional Studies 4:22–40.

Carneiro, F. F., L. G. da S. Augusto, R. M. Rigotto, K. Friedrich, and A. C. Búrigo. 2015. Dossiê ABRASCO: um alerta sobre os impactos dos agrotóxicos na saúde. Escola Politécnica de Saúde Joaquim Venâncio/Fiocruz, Expressão Popular, Rio de Janeiro,São Paulo.

Carranza, T., A. Balmford, V. Kapos, and A. Manica. 2014. Protected area effectiveness in reducing conversion in a rapidly vanishing ecosystem: The

Brazilian Cerrado. Conservation Letters 7:216–223.

Carvalho, F. M. V., P. De Marco, and L. G. Ferreira. 2009. The Cerrado into-pieces: Habitat fragmentation as a function of landscape use in the savannas of central Brazil. Biological Conservation 142:1392–1403.

Castro, E. V. de, T. B. Souza, and B. Thapa. 2015. Determinants of Tourism Attractiveness in the National Parks of Brazil. Parks 21:51–62.

Cavalcanti, M. M., W. R. Borges, M. P. Rocha, L. S. da Cunha, and E. X. Seimetz. 2011. Investigação Geofísica (Eletrorresistividade e GPR) nos Limites do Lixão da Estrutural e do Parque Nacional de Brasília – DF (Resultados Preliminares). Pages 343–34812th International Congress of the Brazilian Geophysical Society (EXPOGEF). Rio de Janeiro, Brazil.

Chan, K. M. A., T. Satterfield, and J. Goldstein. 2012. Rethinking ecosystem services to better address and navigate cultural values. Ecological Economics 74:8–18.

Critical Ecosystem Partnership Fund. 2017. Where we work. http://www.cepf.net/where_we_work/Pages/default.aspx#.WSiJ-cbOpE4.

Crutzen, P. J. 2002. Geology of mankind. Nature 415:23.

Daniel, T. C. 2001. Whither scenic beauty? Visual landscape quality assessment in the 21st century. Landscape and Urban Planning 54:267–281.

Dellamatrice, P. M., and R. T. R. Monteiro. 2014. Revista Brasileira de Engenharia Agrícola e Ambiental Principais aspectos da poluição de rios brasileiros por pesticidas Main aspects of the pollution in Brazilian rivers by pesticides:1296–1301.

Dramstad, W. E., M. S. Tveit, W. J. Fjellstad, and G. L. A. Fry. 2006. Relationships between visual landscape preferences and map-based indicators of landscape structure. Landscape and Urban Planning 78:465–474.

Dudley, N., and S. Stolton. 2003. Running Pure: The importance of forest protected areas to drinking water.

Dudley, N., S. Stolton, A. Belokurov, L. Krueger, N. Lopoukhine, K. MacKinnon, T. Sandwith, and N. Sekhran. 2010. Natural Solutions: Protected areas helping people cope with climate change.

Eiten, G. 1972. The Cerrado Vegetation of Brazil. Botanical Review 38:201–341.

Eiten, G. 1977. Delimitação do Conceito de Cerrado. Arquivos do Jardim Botânico do Rio de Janeiro XXI:125–134.

Ewers, R. M., and A. S. L. Rodrigues. 2008. Estimates of reserve effectiveness are confounded by leakage. Trends in Ecology and Evolution 23:113–116.

FAO. 2004. Fertilizer use by crop in Brazil. Development Division. Food and Agriculture Organization of the United Nations:64.

Ferreira, J., L. E. O. C. Aragão, J. Barlow, P. Barreto, E. Berenguer, M. Bustamante, T. A. Gardner, A. C. Lees, A. Lima, J. Louzada, R. Pardini, L. Parry, C. A. Peres, P. S. Pompeu, and M. Tabarelli. 2014. Brazil'S Environmental Leadership At Risk. Science 346:706–707.

Fleury, L. C., and J. P. De Almeida. 2009. A conservação ambiental como critério de relações entre grupos e valores: representações e conflitos no entorno do

Parque Nacional das Emas, Goiás. Ambiente & Sociedade 12:357–372.

Foley, J. a, R. Defries, G. P. Asner, C. Barford, G. Bonan, S. R. Carpenter, F. S. Chapin, M. T. Coe, G. C. Daily, H. K. Gibbs, J. H. Helkowski, T. Holloway, E. a Howard, C. J. Kucharik, C. Monfreda, J. a Patz, I. C. Prentice, N. Ramankutty, and P. K. Snyder. 2005. Global consequences of land use. Science (New York, N.Y.) 309:570–4.

Françoso, R. D., R. Brandão, C. C. Nogueira, Y. B. Salmona, R. B. Machado, and G. R. Colli. 2015. Habitat loss and the effectiveness of protected areas in the Cerrado Biodiversity Hotspot. Natureza e Conservação 13:35–40.

Frank, S., C. Fürst, L. Koschke, A. Witt, and F. Makeschin. 2013. Assessment of landscape aesthetics - Validation of a landscape metrics-based assessment by visual estimation of the scenic beauty. Ecological Indicators 32:222–231.

Fry, G., M. S. Tveit, Å. Ode, and M. D. Velarde. 2009. The ecology of visual landscapes: Exploring the conceptual common ground of visual and ecological landscape indicators. Ecological Indicators 9:933–947.

Ganem, R. S. 2015. Zonas de amortecimento de unidades de conservação. Brasília.

Garcia, A. S., H. O. Sawakuchi, M. E. Ferreira, and M. V. R. Ballester. 2017. Landscape changes in a neotropical forest-savanna ecotone zone in central Brazil: The role of protected areas in the maintenance of native vegetation. Journal of Environmental Management 187:16–23.

Garcia, F. N., L. G. Ferreira, and J. F. Leite. 2011. Áreas Protegidas no Bioma Cerrado: fragmentos vegetacionais sob forte pressão. Pages 4086–4093XV Simpósio Brasileiro de Sensoriamento Remoto - SBSR. Instituto Nacional de Pesquisas Espaciais, Curitiba.

Germino, M. J., W. A. Reiners, B. J. Blasko, D. McLeod, and C. T. Bastian. 2001. Estimating visual properties of rocky mountain landscapes using GIS. Landscape and Urban Planning 53:71–83.

Gobster, P. H., J. I. Nassauer, T. C. Daniel, and G. Fry. 2007. The shared landscape: What does aesthetics have to do with ecology? Landscape Ecology 22:959–972.

Godar, J., C. Suavet, T. A. Gardner, E. Dawkins, and P. Meyfroidt. 2016. Balancing detail and scale in assessing transparency to improve the governance of agricultural commodity supply chains. Environmental Research Letters 11:35015.

Grace, J., J. S. José, P. Meir, H. S. Miranda, and R. A. Montes. 2006. Productivity and carbon fluxes of tropical savannas. Journal of Biogeography 33:387–400.

Grace, J., E. Mitchard, and E. Gloor. 2014. Perturbations in the carbon budget of the tropics. Global Change Biology 20:3238–3255.

Grecchi, R. C., Q. H. J. Gwyn, G. B. Bénié, A. R. Formaggio, and F. C. Fahl. 2014. Land use and land cover changes in the Brazilian Cerrado: A multidisciplinary approach to assess the impacts of agricultural expansion. Applied Geography 55:300–312.

Guerra, J. A. T., M. A. Fullen, M. do C. O. Jorge, and S. T. Alexandre. 2014. Soil Erosion and Conservation in Brazil. Anuário do Instituto de Geociências - UFRJ 37:81–91.

Guo, Z., L. Zhang, and Y. Li. 2010. Increased dependence of humans on ecosystem services and biodiversity. PLoS ONE 5.

Gyssels, G., J. Poesen, E. Bochet, and Y. Li. 2005. Impact of plant roots on the resistance of soils to erosion by water : a review. Progress in Physical Geography 29:189–217.

Hansen, A. J., and R. DeFries. 2007. Ecological mechanisms linking protected areas to surrounding lands. Ecological Applications 17:974–988.

Hengl, T., J. Mendes de Jesus, G. B. M. Heuvelink, M. Ruiperez Gonzalez, M. Kilibarda, A. Blagotić, W. Shangguan, M. N. Wright, X. Geng, B. Bauer-Marschallinger, M. A. Guevara, R. Vargas, R. A. MacMillan, N. H. Batjes, J. G. B. Leenaars, E. Ribeiro, I. Wheeler, S. Mantel, and B. Kempen. 2017. SoilGrids250m: Global gridded soil information based on machine learning. Page Plos One.

Hernández-Morcillo, M., T. Plieninger, and C. Bieling. 2013. An empirical review of cultural ecosystem service indicators. Ecological Indicators 29:434–444.

Hoefel, M. da G., F. F. Carneiro, L. M. P. Santos, M. B. Gubert, E. M. Amate, and W. dos Santos. 2013. Acidentes de trabalho e condições de vida de catadores de resíduos sólidos recicláveis no lixão do Distrito Federal Accidents at work and living of Distrito Federal. Rev Bras Epidemiol 16:774–785.

Hoffman, W. A., and R. B. Jackson. 2000. Vegetation-Climate Feedbacks in the Conversion of Tropical Savanna to Grassland. American Meteorological Society 13:1593–1602.

Hunke, P., E. N. Mueller, B. Schröder, and P. Zeilhofer. 2015. The Brazilian Cerrado: Assessment of water and soil degradation in catchments under intensive agricultural use. Ecohydrology 8:1154–1180.

IBAMA. 2001. Plano de Manejo do Parque Nacional do Araguaia - TO. Ministério do Meio Ambiente, Brasília.

IBAMA. 2004. Plano de Manejo do Parque Nacional das Emas. Ministério do Meio Ambiente, Brasília.

IBAMA. 2005a. Plano de Manejo do Parque Nacional da Serra da Canastra. Ministério do Meio Ambiente, Brasília.

IBAMA. 2005b. Plano de Manejo do Parque Nacional das Cavernas do Peruaçu. Ministério do Meio Ambiente, Brasília.

IBAMA, and FUNATURA. 1998. Plano de Manejo do Parque Nacional de Brasília. Ministério do Meio Ambiente, Brasília.

IBAMA, and FUNATURA. 2003. Plano de Manejo do Parque Nacional Grande Sertão Veredas. Ministério do Meio Ambiente, Brasília.

IBGE. 2004. Mapa Temático - Mapa de Biomas do Brasil. Instituto Brasileiro de Geográfia e Estatística, Rio de Janeiro.

IBGE. 2016. Cidades@. https://cidades.ibge.gov.br/.

ICMBIO. 2009a. Plano de Manejo do Parque Nacional da Chapada dos Veadeiros. Ministério do Meio Ambiente, Brasília.

ICMBIO. 2009b. Plano de Manejo do Parque Nacional da Serra do Cipó. Ministério do Meio Ambiente, Brasília.

ICMBIO. 2009c. Plano de Manejo do Parque Nacional da Chapada dos Guimarães. Ministério do Meio Ambiente, Brasília.

ICMBIO. 2013. Plano de Manejo do Parque Nacional da Serra da Bodoquena. Ministério do Meio Ambiente, Brasília.

ICMBIO. 2016a. Mapa Temático e Dados Geoestatísticos das Unidades de Conservação Federais. http://www.icmbio.gov.br/portal/geoprocessamento1/51-menu-servicos/4004-downloads-mapa-tematicoe-dados-geoestatisticos-das-uc-s.

ICMBIO. 2016b. Plano de Manejo do Parque Nacional das Sempre-Vivas. Ministério do Meio Ambiente, Brasília.

ICMBIO. 2017a. Unidades Abertas a Visitação. http://www.icmbio.gov.br/portal/visitacao1/unidades-abertas-a-visitacao.

ICMBIO. 2017b. Painel Dinâmico de Informações: Banco de Dados sobre Unidades de Conservação Federais. http://qv.icmbio.gov.br/QvAJAXZfc/opendoc2.htm?document=painel_corporativo_6476.qvw&host=Local&anonymous=true.

ISA. 2017. Unidades de Conservação no Brasil (online database). https://uc.socioambiental.org.

Kandziora, M., B. Burkhard, and F. Müller. 2013. Interactions of ecosystem properties, ecosystem integrity and ecosystem service indicators: A theoretical matrix exercise. Ecological Indicators 28:54–78.

Kim, Y. H., S. Rana, and S. Wise. 2004. Exploring multiple viewshed analysis using terrain features and optimisation techniques. Computers and Geosciences 30:1019–1032.

Klink, C. A., and R. B. Machado. 2005. Conservation of the Brazilian Cerrado. Conservation Biology 19:707–713.

Klink, C. A., and A. G. Moreira. 2002. Past and current human occupation, and land use. Pages 69–88*in* P. S. Oliveira and R. J. Marquis, editors.The cerrados of Brazil: ecology and natural history of a neotropical savanna. Columbia University Press, New York.

Lahsen, M., M. M. C. Bustamante, and E. L. Dalla-Nora. 2016. Undervaluing and Overexploiting the Brazilian Cerrado at Our Peril. Environment: Science and Policy for Sustainable Development 58:4–15.

Lapola, D. M., L. a. Martinelli, C. a. Peres, J. P. H. B. Ometto, M. E. Ferreira, C. a. Nobre, A. P. D. Aguiar, M. M. C. Bustamante, M. F. Cardoso, M. H. Costa, C. a. Joly, C. C. Leite, P. Moutinho, G. Sampaio, B. B. N. Strassburg, and I. C. G. Vieira. 2014. Pervasive transition of the Brazilian land-use system. Nature Climate Change 4:27–35.

Leisher, C., J. Touval, S. M. Hess, T. M. Boucher, and L. Reymondin. 2013. Land and forest degradation inside protected areas in latin america. Diversity 5:779–795.

Leite, C. C., M. H. Costa, B. S. Soares-Filho, and L. De Barros Viana Hissa. 2012. Historical land use change and associated carbon emissions in Brazil from 1940 to 1995. Global Biogeochemical Cycles 26:1–13.

Lima, J. E. F. W., and E. M. Da Silva. 2005. Estimativa da produção hídrica superficial do Cerrado brasileiro. Pages 61–72*in* A. Scariot, J. C. Souza-Silva, and J. M. Felfili, editors.Cerrado: Ecologia, Biodiversidade e Conservação. Ministério do Meio Ambiente, Brasília.

Lindemann-Matthies, P., X. Junge, and D. Matthies. 2010. The influence of plant diversity on people's perception and aesthetic appreciation of grassland vegetation. Biological Conservation 143:195–202.

Lopoukhine, N., N. Crawhall, N. Dudley, P. Figgis, C. Karibuhoye, D. Laffoley, J. M. Londoño, K. MacKinnon, and T. Sandwith. 2012. Protected areas: providing natural solutions to 21st Century challenges. S.a.P.I.E.N.S 5:1–16.

Macedo, M. C. M. 1997. Sustainability of pasture production in the savannas of tropical America. Pages 391–400Proceedings of the XVIII International Grassland Congress.

Machado, R. B., L. M. de S. Aguiar, A. A. J. F. Castro, C. de C. Nogueira, and M. B. Ramos Neto. 2008. Caracterização da fauna e flora do Cerrado. Page 1198*in* F. G. Faleiro and A. L. de Farias Neto, editors.Savanas: desafios e estratégias para o equilíbio entre a sociedade, agronegócio e recursos naturais. Embrapa Cerrados, Planaltina.

Maciejewski, K., A. De Vos, G. S. Cumming, C. Moore, and D. Biggs. 2015. Cross-scale feedbacks and scale mismatches as influences on cultural services and the resilience of protected areas. Ecological Applications 25:11–23.

Martín-López, B., I. Iniesta-Arandia, M. García-Llorente, I. Palomo, I. Casado-Arzuaga, D. G. Del Amo, E. Gómez-Baggethun, E. Oteros-Rozas, I. Palacios-Agundez, B. Willaarts, J. A. González, F. Santos-Martín, M. Onaindia, C. López-Santiago, and C. Montes. 2012. Uncovering ecosystem service bundles through social preferences. PLoS ONE 7.

Martinelli, L. A., R. Naylor, P. M. Vitousek, and P. Moutinho. 2010. Agriculture in Brazil: Impacts, costs, and opportunities for a sustainable future. Current Opinion in Environmental Sustainability 2:431–438.

MEA. 2003. Ecosystems and their services. Pages 49–70*in* J. Alcamo, N. J. Ash, C. D. Butler, J. B. Callicott, D. Capistrano, S. R. Carpenter, J. C. Castilla, R. Chambers, K. Chopra, A. Cropper, G. C. Daily, P. Dasgupta, R. de Groot, T. Dietz, A. Kumar, Duraiappah, M. Gadgil, K. Hamilton, R. Hassan, E. F. Lambin, L. Lebel, R. Leemans, L. Jiyuan, J.-P. Malingreau, R. M. May, A. F. McCalla, T. (A. J. . McMichael, B. Moldan, H. Mooney, S. Naeem, G. C. Nelson, N. Wen-Yuan, I. Noble, O. Zhiyun, S. Pagiola, D. Pauly, S. Percy, P. Pingali, R. Prescott-Allen, W. V. . Reid, T. H. Ricketts, C. Samper, R. (Bob) Scholes, H. Simons, F. L. Toth, J. K. Turpie, R. T. Watson, T. J. Wilbanks, M. Williams, S. Wood, Z. Shidong, and M. B. Zurek, editors.Ecosystems and Human Well-being: A Framework for Assessment. First edition. Island Press, Washington.

MEA. 2005a. MA Conceptual Framework. Pages 25–36*in* R. Hassan, R. Scholes, and N. Ash, editors.Ecosystems and human well-being: current state and trends : findings of the Condition and Trends Working Group. Island Press.

MEA. 2005b. Ecosystems and Human Well-being: Synthesis. Page (W. V. Reid, H.

A. Mooney, A. Cropper, S. Doris Capistrano, tephen R. Carpenter, K. Chopra, P. Dasgupta, T. Dietz, A. Kumar, Duraiappah, R. Hassan, R. Kasperson, R. Leemans, R. M. May, T. (A. J. . McMichael, P. Pingali, C. Samper, R. Scholes, R. T. Watson, A. H. Zakri, Z. Shidong, N. J. Ash, E. Bennett, P. Kumar, M. J. Lee, C. Raudsepp-Hearne, H. Simons, J. Thonell, and M. B. Zurek, Eds.). Island Press, Washington.

MEA, R. de Groot, and P. S. Ramakrishnan. 2005a. Cultural and Amenity Services. Pages 457–474*in* R. Hassan, R. Scholes, and N. Ash, editors.Ecosystems and human well-being: current state and trends : findings of the Condition and Trends Working Group. Island Press.

MEA, R. Kasperson, and D. Kirstin. 2005b. Vulnerable peoples and places. Pages 143–164*in* R. Hassan, R. Scholes, and N. Ash, editors.Ecosystems and human well-being: current state and trends : findings of the Condition and Trends Working Group. Island Press.

Merten, G. H., and J. P. G. Minella. 2013. The expansion of Brazilian agriculture: Soil erosion scenarios. International Soil and Water Conservation Research 1:37–48.

Metzger, M. J., M. D. A. Rounsevell, L. Acosta-Michlik, R. Leemans, and D. Schröter. 2006. The vulnerability of ecosystem services to land use change. Agriculture, Ecosystems and Environment 114:69–85.

Miranda, S. do C. de, M. Bustamante, M. Palace, S. Hagen, M. Keller, and L. G. Ferreira. 2014. Regional variations in biomass distribution in Brazilian Savanna Woodland. Biotropica 46:125–138.

MMA. 2000. Cadastro Nacional de Unidades de Conservação. Ministério do Meio Ambiente, Brasília. http://www.mma.gov.br/areas-protegidas/cadastro-nacional-de-ucs/consulta-gerar-relatorio-de-uc.

MMA. 2015. Mapeamento do Uso e Cobertura do Cerrado: Projeto TerraClass Cerrado 2013. Brasília.

Moraes, M. C. P. de, K. de Mello, and R. H. Toppa. 2017. Protected areas and agricultural expansion: Biodiversity conservation versus economic growth in the Southeast of Brazil. Journal of Environmental Management 188:73–84.

Moreira, J. C., F. Peres, A. C. Simões, W. A. Pignati, E. de C. Dores, S. N. Vieira, C. Strüssmann, and T. Mott. 2012. Contaminação de águas superficiais e de chuva por agrotóxicos em uma região do estado do Mato Grosso. Ciência & Saúde Coletiva 17:1557–1568.

Mueller, C. C., and G. B. Martha Júnior. 2008. A Agropecuária e o Desenvolvimento Socioeconômico Recente do Cerrado. Page *in* F. G. Faleiro and A. L. Farias Neto, editors. Savanas: desafios e estratégicas para o equilibrio entre sociedade, agronegocio e recursos naturais. Embrapa Cerrados, Planaltina.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. da Fonseca, and J. Kent. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853–858.

Nepstad, D., D. Mcgrath, C. Stickler, A. Alencar, A. Azevedo, B. Swette, T. Bezerra, M. Digiano, J. Shimada, R. Seroa, E. Armijo, L. Castello, P. Brando, M. C. Hansen, M. Mcgrath-horn, O. Carvalho, and L. Hess. 2014. Slowing Amazon deforestation through public policy and interventions in beef and soy supply chains. Science 344:1118–1123.

Netto, P. B., V. V. Mecenas, and E. S. Cardoso. 2005. APA de Cafuringa: a última fronteira natural do DF. Secretaria do Meio Ambiente e Recursos Hídricos do Distrito Federal, Brasília.

New7Wonders Foundation. 2007. New 7 Wonders of the World. https://new7wonders.com.

Oliveira-Filho, A. T., and J. A. Ratter. 2002. Vegetation Physiognomies and Woody Flora of the Cerrado Biome. Pages 91–120*in* P. S. Oliveira and R. J. Marquis, editors.The Cerrados of Brazil: Ecology and Natural History of a Neotropical Savanna. Columbia University Press, New York.

Oliveira, K., and A. Cieglinski. 2016. CNA prevê expansão de 2% do agronegócio em 2017. http://agenciabrasil.ebc.com.br/economia/noticia/2016-12/cna-preve-expansao-de-2-do-agronegocio-em-2017.

Oliveira, P. T. S., E. Wendland, M. A. Nearing, R. L. Scott, R. Rosolem, and H. R. da Rocha. 2015. The water balance components of undisturbed tropical woodlands in the Brazilian cerrado. Hydrology and Earth System Sciences 19:2899–2910.

Oliveira, R. S., L. Bezerra, E. A. Davidson, F. Pinto, C. A. Klink, D. C. Nepstad, and A. Moreira. 2005. Deep root function in soil water dynamics in cerrado savannas of central Brazil. Functional Ecology 19:574–581.

Overbeck, G. E., E. Vélez-Martin, F. R. Scarano, T. M. Lewinsohn, C. R. Fonseca, S. T. Meyer, S. C. Müller, P. Ceotto, L. Dadalt, G. Durigan, G. Ganade, M. M. Gossner, D. L. Guadagnin, K. Lorenzen, C. M. Jacobi, W. W. Weisser, and V. D. Pillar. 2015. Conservation in Brazil needs to include non-forest ecosystems. Diversity and Distributions 21:1455–1460.

Paiva, R. J. O., R. S. Brites, and R. B. Machado. 2015. The role of protected areas in the avoidance of anthropogenic conversion in a high pressure region: A matching method analysis in the core region of the brazilian cerrado. PLoS ONE 10:1–24.

Parron, L. M., M. M. C. Bustamante, and D. Markewitz. 2011. Fluxes of nitrogen and phosphorus in a gallery forest in the Cerrado of central Brazil. Biogeochemistry 105:89–104.

Pereira, E. C., L. da S. Alves, E. C. Antunes, and A. Pasqualetto. 2004. Reservas Particulares do Patrimônio Natural como zona de amortecimento do Parque Nacional da Chapada dos Veadeiros. Universidade Católica de Goiás.

Pereira, R. F., I. Karmann, T. D. A. Ferreira, D. De Almeida, and G. Ruy. 2006. Geomorfologia e Hidrogeologia Cárstica do Parque Nacional Cavernas do Peruaçu. Page XLIII Congresso Brasileiro de Geologia. Aracaju.

Peres, F., and J. C. Moreira. 2007. Saúde e ambiente em sua relação com o consumo de agrotóxicos em um pólo agrícola do Estado do Rio de Janeiro , Brasil. Saúde, Ambiente e Agrotóxicos:612–621.

Pignati, W., J. C. Moreira, F. Peres, E. Dores, C. Lourencetti, P. Zeilhofer, O. Weber, A. Pinto, T. Mott, M. Pignatti, and A. B. Silva. 2012. Agrotóxicos, alimentos e impactos na saúde e no ambiente. Brasília.

Pinto, J. R. R., E. E. Sano, C. M. Reino, and C. A. D. Pinto. 2009. National parks in the cerrado and the types of preserved vegetation. Natureza & Conservacao 7:149–163.

Rana, S. 2003. Fast approximation of visibility dominance using topographic features as targets and the associated uncertainty. Photogrammetric Engineering & Remote Sensing 69:881–888.

Reatto, A., and É. de S. Martins. 2005. Classes de solo em relação aos controles da paisagem do bioma Cerrado. Cerrado: Ecologia, Biodiversidade e Conservação:47–59.

Reynolds, J., K. Wesson, A. Desbiez, J. Ochoa-Quintero, and P. Leimgruber. 2016. Using Remote Sensing and Random Forest to Assess the Conservation Status of Critical Cerrado Habitats in Mato Grosso do Sul, Brazil. Land 5:12.

Ribeiro, J. F., and B. M. T. Walter. 1998. Fitofisionomias do bioma Cerrado. Pages 89–166*in* S. M. Sano and S. P. de Almeida, editors.Cerrado: ambiente e flora. Embrapa Cerrados, Planaltina.

Richter, D. deB, A. R. Bacon, Z. Brecheisen, and M. L. Mobley. 2015. Soil in the Anthropocene. Page IOP Conference Series: Earth and Environmental Science (EES).

Rocha, G. F., L. G. Ferreira, N. C. Ferreira, and M. E. Ferreira. 2011. Detecção de desmatamentos no bioma Cerrado entre 2002 e 2009: padrões, tendências e impactos. Rev Bras Cartogr 63:341–349.

Rockström, J., W. Steffen, K. Noone, Å. Persson, F. S. I. Chapin, E. Lambin, T. M. Lenton, M. Scheffer, C. Folke, H. J. Schellnhuber, B. Nyknist, C. A. de Wit, T. Hughes, S. van der Leeuw, H. Rodhe, S. Sörlin, P. K. Snyder, R. Costanza, U. Svedin, M. Falkenmark, L. Kalberg, R. W. Corell, V. J. Fabry, J. Hansen, B. Walker, D. Liverman, K. Richardson, P. Crutzen, and J. Foley. 2009. Planetary Boundaries : Exploring the Safe Operating Space for Humanity. Ecology and Society 14:32.

Rodríguez-Jorquera, I. A., P. Siroski, W. Espejo, J. Nimptsch, P. G. Choueri, R. B. Choueri, C. A. Moraga, M. Mora, and G. S. Toor. 2017. Latin American protected areas: Protected from chemical pollution? Integrated Environmental Assessment and Management 13:360–370.

Rudorff, B., J. Risso, and et al. 2015. Análise Geoespacial da Dinâmica das Culturas Anuais no Bioma Cerrado: 2000 a 2014. Page Agrosatélite.

Ruszkiczay-Rüdiger, Z., L. Fodor, E. Horváth, and T. Telbisz. 2009. Discrimination of fluvial, eolian and neotectonic features in a low hilly landscape: A DEM-based morphotectonic analysis in the Central Pannonian Basin, Hungary. Geomorphology 104:203–217.

Salgado, T. R., J. Lacerda, and R. Viana. 2014. Impactos da atividade turística à economia municipal de Alto Paraíso de Goiás, Brasil. Mercator 13:75–91.

Sano, E. E., R. Rosa, J. L. S. Brito, L. G. Ferreira, E. E. Sano, R. Rosa, J. L. S. Brito, and L. G. Ferreira. 2010. Land cover mapping of the tropical savanna region in Brazil. Environ Monit Assess 166:113–124.

Santana, O. A., J. I. Encinas, R. S. Corrêa, and A. F. C. Júnior. 2008. Soil and “Cerrado” trees nutrients and metals in adjacent sanitary landfill area. CERNE 14:212–219.

Santos, D. B. M., D. M. G. de Sousa, and W. J. Goedert. 2008. Balanço do Potássio em Solo do Cerrado no Sistema Plantio Direto. Simpósio Internacional Savanas

Tropicais 1.

Schirpke, U., F. Timmermann, U. Tappeiner, and E. Tasser. 2016. Cultural ecosystem services of mountain regions: Modelling the aesthetic value. Ecological Indicators 69:78–90.

Schröter, D., L. Acosta-Michlik, A. W. Arnell, M. B. Araújo, F. Badeck, M. Bakker, A. Bondeau, H. Bugmann, T. Carter, A. C. de la Vega-Leinert, M. Erhard, G. Z. Espiñeira, F. Ewert, U. Fritsch, P. Friedlingstein, M. Glendining, C. A. Gracia, T. Hickler, J. House, M. Hulme, S. Kankaanpää, R. J. T. Klein, B. Krukenberg, S. Lavorel, R. Leemans, M. Lindner, J. Liski, M. J. Metzger, J. Meyer, T. Mitchell, F. Mohren, P. Morales, J. M. Moreno, I. Reginster, P. Reidsma, M. Rounsevell, E. Pla, J. Pluimers, I. C. Prentice, A. Pussinen, A. Sánchez, S. Sabaté, S. Sitch, B. Smith, J. Smith, P. Smith, M. T. Sykes, K. Thonicke, W. Thuiller, G. Tuck, G. van der Werf, J. Vayreda, M. Wattenbach, D. W. Wilson, F. I. Woodward, S. Zaehle, B. Zierl, S. Zudin, and W. Cramer. 2005. ATEAM Final report 2004.

SIEG. 2014. Mapa de Aptidão Agrícola das Terras. http://www.zee.go.gov.br.

Silva, F. A. M., E. D. Assad, and B. A. Evangelista. 1998. Caracterização Climática do Bioma Cerrado. Pages 70–88*in* S. M. Sano and S. P. de Almeida, editors.Cerrado: Ecologia e Flora. Embrapa Cerrados, Brasília.

Silva, J. M. C. da, and J. M. Bates. 2002. Biogeographic Patterns and Conservation in the South American Cerrado: A Tropical Savanna Hotspot. BioScience 52:225.

Soga, M., and K. J. Gaston. 2016. Extinction of experience: The loss of human-nature interactions. Frontiers in Ecology and the Environment 14:94–101.

Souza, T. do V. S. B. 2016. Recreation Classification, Tourism Demand and Economic Impact Analyses of the Federal Protected Areas of Brazil. University of Florida.

Spadotto, C. A., and A. J. Spadotto. 2006. Problemas ambientais no manejo de pastagens: uso de pesticidas e fertilizantes e mineralização do rebanho. Pages 425–437*in* C. G. S. Pedreira, J. C. de Moura, S. C. da Silva, and V. P. de Faria, editors.Anais do 23° Simpósio sobre Manejo da Pastagem. Fundação de Estudos Agrários Luiz de Queiroz (FEALQ), Piracicaba.

Spera, S. A., G. L. Galford, M. T. Coe, M. N. Macedo, and J. F. Mustard. 2016. Land-use change affects water recycling in Brazil's last agricultural frontier. Global Change Biology 22:3405–3413.

Steffen, W., K. Richardson, J. Rockström, S. Cornell, I. Fetzer, E. Bennett, R. Biggs, and S. Carpenter. 2015. Planetary boundaries: Guiding human development on a changing planet. Science (New York, N.Y.) 348:1217.

Tavares, M. de F. D., and B. Nakagomi. 2016. Brasília: Utopia Urbana a a Desconstrução da Paisagem Idealizada. Page XIV Coloquio Internacional de Geocrítica Las utopías y la construcción de la sociedad del futuro. Barcelona.

UNEP-WCMC, and IUCN. 2016. Protected Planet: Protected Area Profile for Brazil from the World Database of Protected Areas (WDPA). www.protectedplanet.net.

UNESCO/WHC. 2001. Cerrado Protected Areas: Chapada dos Veadeiros and Emas National Parks. http://whc.unesco.org/en/list/1035/.

Vendramini, J. M. B., M. L. A. Silveira, J. C. B. Dubeux Jr., and L. E. Sollenberger. 2007. Environmental impacts and nutrient recycling on pastures grazed by cattle. Revista Brasileira de Zootecnia 36:139–149.

Vivacqua, M., and P. F. Vieira. 2005. Conflitos socioambientais em Unidades de Conservação. Revista Política & Sociedade:139–162.

De Vos, A., G. S. Cumming, C. A. Moore, K. Maciejewski, and G. Duckworth. 2016. The relevance of spatial variation in ecotourism attributes for the economic sustainability of protected areas. Ecosphere 7.

Wells, M. P., and K. E. Brandon. 1993. The Principles and Practice of Buffe Zones and Local Parlicipation in Biodiversity Conservation. Ambio 22:157–162.

Wherrett, J. R. 2000. Creating Landscape Preference Models Using Internet Survey Techniques. Landscape Research 25:79–96.

Willis, C. 2015. The contribution of cultural ecosystem services to understanding the tourism-nature-wellbeing nexus. Journal of Outdoor Recreation and Tourism 10:38–43.

Zalasiewicz, J., M. Williams, A. Haywood, and M. Ellis. 2011. The Anthropocene: a new epoch of geological time? Phil. Trans. R. Soc. A 369:835–841.

SUPPLEMENTARY MATERIAL

Table S1. Values for scenic view indicators, related to biophysical characteristics in eight National Parks located in the Cerrado, opened for visitors.

Cerrado National Park	Viewshed proportional area (%)	Terrain Roughness (m)	Slope variability (%)	Shannon's Diversity Index	Shannon's Equitability Index	Drainage density (km/km^2)
Brasília	32,48	3,83	68,38	0,93	0,84	1,02
Cavernas do Peruaçu	31,86	3,14	56,70	0,54	0,78	0,94
Chapada dos Guimarães	39,76	5,27	136,59	1,02	0,93	1,01
Chapada dos Veadeiros	34,29	5,86	106,98	0,44	0,40	1,00
Emas	16,25	1,38	23,70	0,94	0,86	1,20
Grande Sertão Veredas	10,93	1,43	23,49	0,41	0,60	1,06
Serra da Canastra	20,52	10,75	139,60	0,83	0,76	0,85
Serra do Cipó	47,62	6,24	141,93	0,69	0,63	1,05

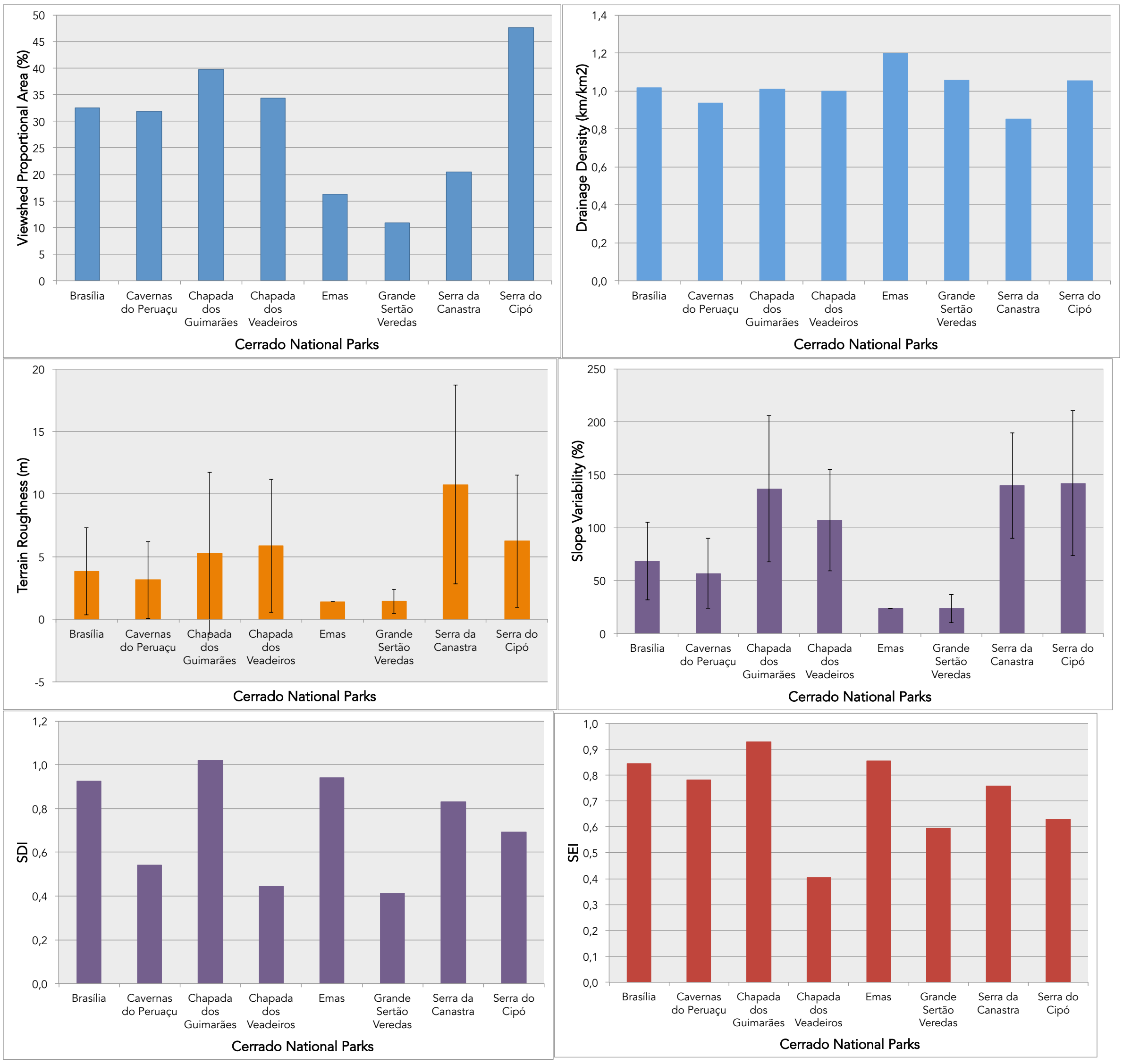

Fig. S1. Bar chart with the values and standard deviation of biophysical scenic view indicators in eight National Parks located in the Cerrado, opened for visitors.

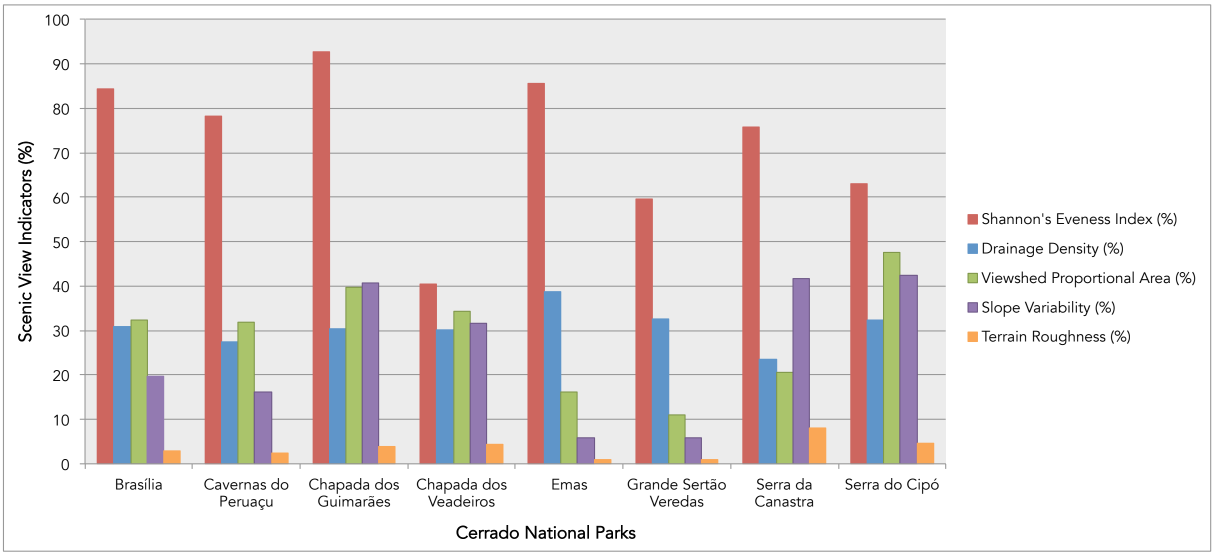

Fig. S2. Stacked bar chart with the bioprofiles of scenic potential in eight National Parks located in the Cerrado, opened for visitors. The objective environmental and ecological indicators depicted in the chart indicate different opportunities to explore touristic activities in each park. Flat parks register higher drainage density and offer more opportunities for water recreational activities, inside the park. Hilly parks can offer panoramic views to viewers in the surroundings of the park.

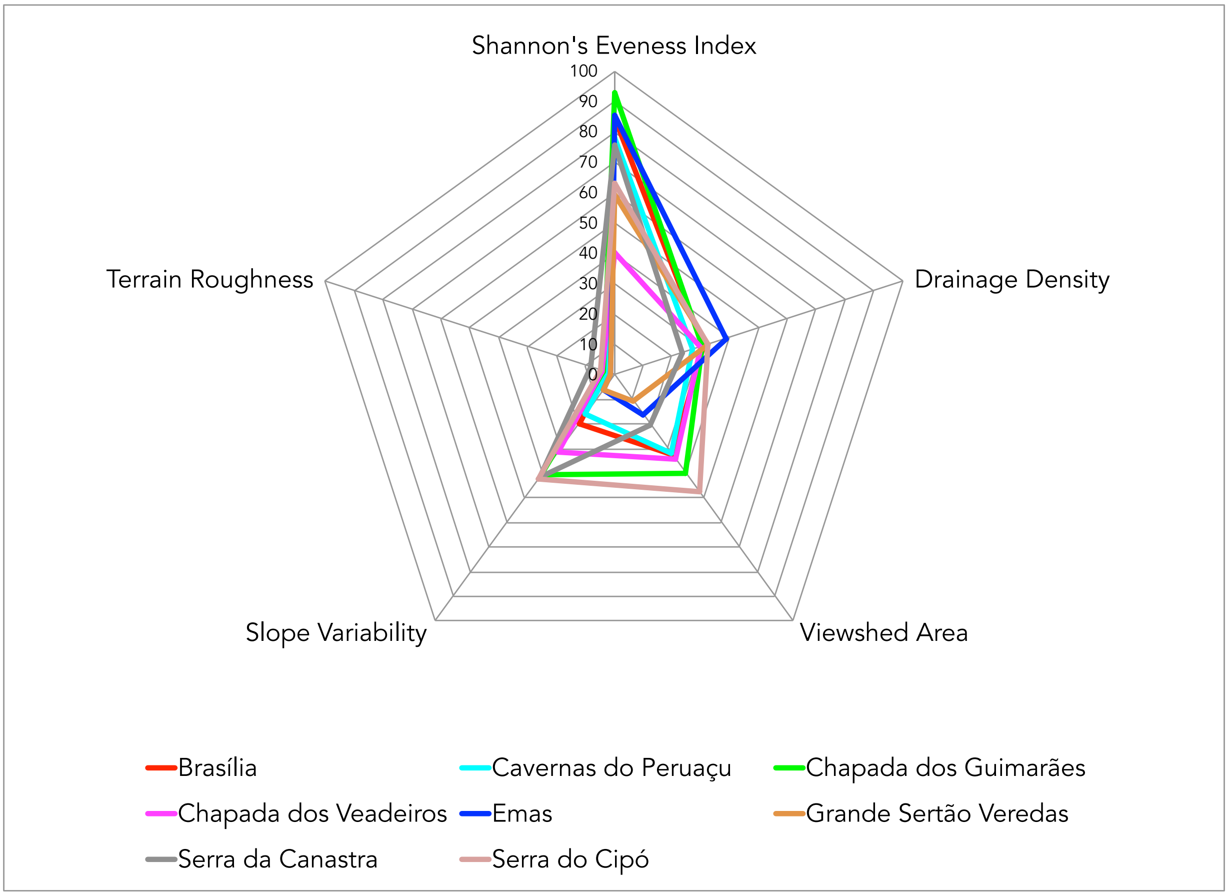

Fig. S3. Variation of radar chart in Fig. 13, displaying the biophysical scenic view profiles for the eight selected National Parks located in the Cerrado biome and opened for visitation. Five visual and ecological indicators can be seen: Shannon Evenness Index (SEI), slope variability, drainage density, terrain roughness and viewshed area.