Supplementary Materials for

Brazil's environmental leadership at risk

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2. Links to full text on legal documents and political debates cited in the main text

PL 1610/96 available at:
www.camara.gov.br/proposicoesWeb/fichadetramitacao?idProposicao=16969

PL3682/2012 available at:
www.camara.gov.br/proposicoesWeb/fichadetramitacao?idProposicao=541161

Campaign in defense of Brazilian PAs by the Federal Public Prosecutor's Office available at:
www.prpa.mpf.mp.br/news/2014/mpf-lanca-estrategia-nacional-para-defesa-das-unidades-de-conservacao

3. Data sources

Georeferenced data on protected areas, indigenous reserves and Brazilian Biomes were extracted from the National Registry of Conservation Units of the Brazilian Ministry of Environment (http://mapas.mma.gov.br/i3geo/datadownload.htm), mining concessions and areas of registered mining interest are from the Mining Geographical Information System (SIGMINE) of the National Department of Mineral Production of Brazil (http://sigmine.dnpm.gov.br/webmap/), the distribution of hydroelectric dams from the Energy Sector Geographical Information System (SIGEL) and the Information Database on Energy Generation (BIG) of the National Agency of Electric Energy of Brazil (www.aneel.gov.br/aplicacoes/capacidadebrasil/capacidadebrasil.cfm). All datasets are made publically available by the Brazilian government according to the 2011 Information Access Law (Law 12.527/2011).

All georeferenced data were originally made available as a shapefile extension (ESRI vector representation file format) with a geographic projection and South America datum. For our analyses we converted the original cartographic configuration to the Albers Conical Equal Area projection (central meridian -54 , first standard parallel -2 , second standard parallel -22 , latitude of origin -12) and SIRGASS 2000 datum.

4. Classification of protected areas

Our analysis only considered protected areas in the category "strictly protected" reserves (*Unidades de Proteção Integral*) and "indigenous lands." "Sustainable use" reserves (*Unidades de Uso Sustentável*) were excluded from the analyses.

According to the National System of Natural Conservation Units (SNUC), from the Brazilian Ministry of Environment (www.mma.gov.br/estruturas/240/_publicacao/240_publicacao05072011052536.pdf), the strictly protected category encompasses Federal, State and Municipal level reserves within five broad classes:

a) **Ecological Station (*Estação Ecológica*)**: area reserved for wildlife and scientific research.

b) **Biological Reserve (*Reserva Biológica*)**: area reserved for preservation of biodiversity, where only activities aiming to restore altered ecosystems, preserve and restore native biological diversity and natural ecological processes are allowed.

c) **National Park (*Parque Nacional*):** area reserved for the protection of natural ecosystems for their ecology and scenic beauty. Recreation, environmental education and scientific research activities are allowed.

d) **Natural Monument (*Monumento Natural*):** area designated with the aim of preserving unique and rare landscapes and areas of outstanding natural beauty. Private properties are allowed within the borders of this reserve type.

e) **Wildlife Refuge (*Refúgio da Vida Silvestre*)**: natural environments designated for the preservation of conditions favorable for the existence or reproduction of species or communities of native flora and fauna, resident or migratory. Private properties are allowed within the borders of this reserve type.

5. Classification of mining areas

Mining areas are separated into two general categories following the Brazilian Mining Code (Law decree n° 227, de 28/02/1967). The first category encompasses those that have received some level of public registration of mining interest (Law decree n° 227, art. 6 I) by whatever process, and includes all areas under different stages of licensing request, areas subject to mineral research, and areas of known mining potential. The categories of such areas under the SIGMINE mining geographical information system include the following: *autorização de pesquisa*, *disponibilidade*, *requerimento de lavra and requerimento de lavra garimpeira*, *requerimento de licenciamento*, *requerimento de pesquisa*, and *requerimento de registro e extração*. The second category includes all those that have been officially approved and licensed for mining activity from the Brazilian Minister of Mines and Energy (Law decree n° 227, art. 6 II) and includes areas classified by SIGMINE as *concessão de lavra, concessão de lavra garimpeira*, *licenciamento,* and *registro de extração.*

For this study, we applied a correction of topological inconsistencies present in the digital map downloaded from the SIGMINE site. These inconsistencies were related to occasional spatial overlap between different categories of registered mining interest—mainly in areas still under consideration (rather than approved). To remove these overlaps we adopted the following protocol:

a) Mining areas classified as "approved" and "under consideration" were separated into two different files and converted from vector to raster format with a 50-m spatial resolution. This grid-cell size was sufficient to represent the smallest area present on the original vector map. This procedure removed all overlap between different categories of mining area that are consolidated within each file.

b) We overlaid the raster map of the category of "approved" mining areas on the map of areas "under consideration" to assess overlap between the two consolidated map layers. These areas of overlap were assigned to the "approved" category. Overlap areas totaled 3,136.6 km^2 of which 2,959.2 km^2 were located outside protected areas, 166.7 km^2 inside "strictly protected" areas, and 10.7 km^2 inside indigenous lands.

6. Overlap between protected areas, indigenous land and mining areas

In Brazil a total of 319,900 km^2 of mining areas that are under consideration fall within strictly protected areas or indigenous land. This is equivalent to approximately 40% of the total area deforested in Amazonia to date (*15*). Full details of overlap between protected areas, indigenous land and mining areas for all six Brazilian biomes are shown in Table S1.

Table S1. Overlap between protected areas, indigenous land and mining areas across six Brazilian biomes. We first report the total area (km^2) and percentage of each Brazilian biome that is protected [sum of the area covered by strictly protected areas (*16*) and indigenous lands (*17*)]. Overlap between protected areas and mining areas refers to the percentage of strictly protected areas and indigenous lands that overlap by at least 5% with mining areas, whether approved or under consideration (Fig. 1, D and E, in the main text).

Biomes	Amazonia	Caatinga	Cerrado	Atlantic Forest	Pampa	Pantanal
Area of each biome	4,196,943	844,453	2,036,448	1,110,182	176,496	150,355
Area of strictly protected areas	411,114	9,699	62,736	27,311	614	4,404
Area of Indigenous lands	991,951	2,185	85,388	5,104	24	2,561
Total area protected	**1,403,065**	**11,884**	**148,124**	**32,415**	**638**	**6,965**
Percentage of biomes protected	**33.4%**	**1.4%**	**7.3%**	**2.9%**	**0.4%**	**4.6%**
Percentage of protected areas overlapping with concessions	**Amazonia**	**Caatinga**	**Cerrado**	**Atlantic Forest**	**Pampa**	**Pantanal**
Strictly protected areas						
Approved	0.07%	0.24%	0.08%	1.31%	0.20%	0.00%
Under consideration	8.30%	3.55%	1.30%	4.83%	0.16%	0.00%
Indigenous lands						
Approved	0.01%	0.01%	0.00%	0.00%	0.00%	0.00%
Under consideration	28.37%	4.39%	1.17%	14.93%	9.58%	0.00%

7. Hydroelectric dams

According to the Brazilian National Agency of Electrical Energy (ANEEL), hydroelectric dams in Brazil are classified by their hydraulic potential:

a) **Hydroelectric generation center (*Central Geradora Hidrelétrica*—CGH)**, which is a unit for energy generation using a hydraulic potential equal to or lower than 1,000 kW (kilowatt), normally with a dam to alter the course of the river, and placed in rivers that naturally impede the passage of fish due to their geomorphology.

b) **Small Hydroelectric Center (*Pequena Central Hidrelétrica*—PCH)**, which encompasses any small hydroelectric plant with a hydraulic potential between 1,000 kW and 30,000 kW and with a reservoir smaller than 3 km^2 (300 ha) or defined by ANEEL in agreement under its resolution nº 652.

c) **Hydroelectric Energy Station (*Usina Hidrelétrica de Energia*—UHE)**, which encompasses all hydroelectric dams with hydraulic potential greater than 30,000 kW, with a reservoir larger than 3 km^2 (300 ha) or as defined by ANEEL.

For this study, we focused exclusively on the third category (**Hydroelectric Energy Stations (UHE)**). Because of their large energy generating potential (>30,000 kW) and size of their reservoir (>3 km^2), we expect them to have a larger environmental impact. In this context, we only considered hydroelectric dams that have been approved, which excluded additional prospective dam sites that are under consideration. Information on all approved dams was extracted from the ANEEL databases. To consolidate the complete set of approved dams and ensure all hydroelectric plants were represented, the geodatabase, in shapefile format, provided by SINGEL was updated with data from the tables provided by the BIG database.

8. Data Processing and graphic representation

The results shown in Figure 1 presented in the main manuscript were calculated using the GIS software package ArcGis 10.2 by calculating the area of intersection between Brazilian biomes, strictly protected areas, indigenous land and mining areas “under consideration” or "approved."

References

1. WDPA, 2012. World Database on Protected Areas. Database accessed in June 2014 from www.protectedplanet.net.
2. A. Veríssimo *et al*., "Protected areas in the Brazilian Amazon: Challenges and Opportunities" [Imazon, Belém, Brazil; Instituto Socioambiental (ISA), Sao Paulo, Brazil, 2011].
3. D. V. Spracklen, S. R. Arnold, C. M. Taylor, *Nature* **489**, 282 (2012). Medline doi:10.1038/nature11390
4. E. Bernard, L. A. Penna, E. Araújo, *Conserv. Biol.* **28**, 939 (2014). Medline doi:10.1111/cobi.12298
5. Brasil Ministério de Minas e Energia (MME), *Plano Nacional de Energia 2030* (MME, Rio de Janeiro, 2007).
6. MME, *Plano Nacional de Mineração 2030* (MME, Rio de Janeiro, 2010).
7. T. H. Ricketts *et al*., *PLOS Biol.* **8**, e1000331 (2010). Medline doi:10.1371/journal.pbio.1000331
8. F. P. L. Melo, V. Arroyo-Rodríguez, L. Fahrig, M. Martínez-Ramos, M. Tabarelli, *Trends Ecol. Evol.* **28**, 462 (2013). Medline doi:10.1016/j.tree.2013.01.001
9. Business and Biodiversity Offsets Programme (BBOP), Guidance Notes to the Standard on Biodiversity Offsets (BBOP, Forest Trends, Washington, DC, 2012).
10. A. Villarroya, A. C. Barros, J. Kiesecker, *PLOS ONE* **9**, e107144 (2014). Medline doi:10.1371/journal.pone.0107144
11. P. M. Fearnside, *Environ. Sci. Policy* **38**, 164 (2014). doi:10.1016/j.envsci.2013.11.004
12. M. Maron *et al*., *Biol. Conserv.* **155**, 141 (2012). doi:10.1016/j.biocon.2012.06.003
13. J. D. Pilgrim *et al*., *Conserv. Lett.* **6**, 376 (2013). doi: 10.1111/conl.12002

14. B. Soares-Filho *et al*., *Science* **344**, 363 (2014). Medline doi:10.1126/science.1246663
15. INPE (Instituto Nacional de Pesquisas Espaciais). PRODES: Assessment of deforestation in Brazilian Amazonia (2014); www.obt.inpe.br/prodes/index.html.
16. CNUC/MMA (Cadastro Nacional de Unidades de Conservação/Ministério do Meio Ambiente). Consolidaded database (2014); www.mma.gov.br/cadastro_uc.
17. E. E. Miranda, C. A. Carvalho, C. A. Spadotto, M. C. Hott, O. T. Oshiro, W. A. Holler, Alcance Territorial da Legislação Ambiental e Indigenista, Embrapa Monitoramento por Satélite (2008); www.alcance.cnpm.embrapa.br/.