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A NOTE ON THE TERRITORIAL BOUNDARIES OF THE ATLANTIC FOREST

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ABSTRACT

The geographic delimitation of a biome encompasses questions that involve environmental factors such as climate and vegetation characteristics as well as political aspects. Consequently, a variation on biome delimitation is recurrent. The Atlantic Forest is one of the most important biodiversity hotspots in the world, and historically several territorial boundaries have been proposed for this biome. Here we aim at 1) discussing the four main delimitations and, 2) based on the existing boundaries, discuss their union (Integrative boundary) and Intersection (Consensual boundary). The main boundaries present consensual and integrative areas of 1.01 and 1.62 million km^2, respectively. Five regions of divergence must be carefully evaluated. Finally, we suggest a debate about the use of boundaries in ecological studies and their application in biodiversity conservation studies.

Keywords: biodiversity hotspot; biome; geographic distribution; historical biogeography; tropical forest.

After the first mentions by Whittaker (1962), the concept of biome was widely debated from the ecological and biogeographic perspectives. The term emerged as an effort to define a spatial unit that was used in bio-ecology studies, but was also appropriate to understand the distribution of flora and fauna (Clements & Shelford 1939). Since then the term has been used from different perspectives, whether referring to flora, fauna, relief, vegetation type or combinations of these elements (Coutinho 2006). Biomes can present diverse spatial delimitations, which vary according to environmental, ecological, political or management interests of their proponents. This is the case of the Atlantic Forest biome, a biodiversity hotspot that presents more than 90% of its original distribution in Brazil and also occurs in parts of Argentina and Paraguay (Mittermeier *et al.*, 2004).

Although different territorial boundaries of the same biome can be used for different purposes, the lack of a single delimitation can create confusion. In addition to ecological and environmental issues, the delimitation of a biome is also politically debated and defined, as it may affect the determination or limitation of possible territorial uses by different social actors, which is the subject of frequent conflicts of interest (Steinberger & Rodrigues 2010).

In this article, we treat a biome as an extensive geographic area that presents a specific community of plants and animals, with a particular vegetation type, that is influenced directly by the climate (Whittaker 1970). Although the Atlantic Forest presents different vegetation types - such as the dense ombrophilous forest, mixed ombrophilous forest, seasonal forests, restingas, as well as countryside, coastal and ecotone formations, it is treated as a biome by several authors (Morellato & Haddad 2000, Olson *et al.* 2001, IBGE 2016, Tabarelli *et al.*, 2010). This variety of phytophysiognomies is mainly due to the wide latitudinal (8 - 28 ° S), longitudinal (32 - 58 ° W) and altitudinal (0 - ~ 3,000 m) gradients, combined with large climatic variations, geomorphological formations and types of soil (Oliveira-Filho & Fontes 2000, Eisenlohr & Oliveira-Filho 2015). These changes, combined to the geographic expansions and retractions suffered as a result of past climate changes, have led to the evolution and specialization of several vegetation formations in the Atlantic Forest (Carnaval *et al.*, 2009, Joly *et al.*, 2014, Sobral-Souza *et al.* 2015, Sobral-Souza & Lima-Ribeiro 2017).

Different geographic delimitations for the Atlantic Forest due to climate changes occurring over the last 21 thousand years have been proposed (see Sobral-Souza *et al.*, 2015). The present Atlantic Forest extends over most of the Brazilian coast, reaching the southern interior of the continent, where it covers regions of Paraguay and Argentina (Morellato & Haddad 2000, Ribeiro *et al.* 2009). Large compilations of species abundance and distribution have been made (see the growing ATLANTIC series of data papers at https://esajournals.onlinelibrary.wiley.com/doi/toc/10.1002/(ISSN)1939-9170.AtlanticPapers), leading us to realize that the Atlantic Forest is one of the most well-known biodiversity hotspots on the planet. The Atlantic Forest is considered a priority region for the conservation of biodiversity (Myers *et al.*, 2004). In addition, the Atlantic Forest is considered a priority region for biodiversity conservation (Myers *et al.* 2000).

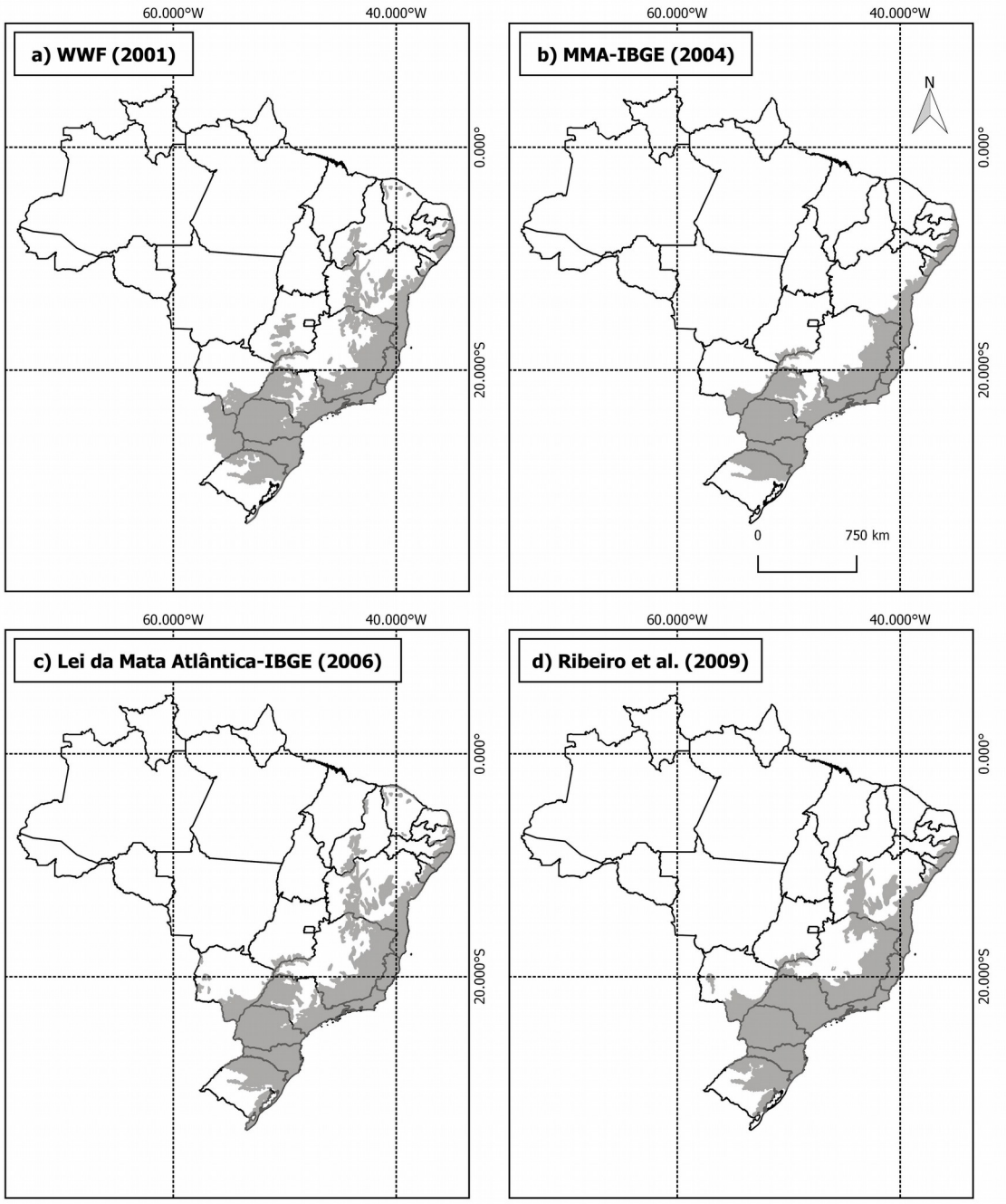

Figure 1. Four Atlantic Forest boundaries according to different maps widely used and available online: a) "World Wildlife Fund-WWF (2001)" (Olson *et al.*, 2001); b) "Ministry of Environment (MMA) - Brazilian Institute of Geography and Statistics (IBGE) (2004)" (IBGE 2016); c) "Atlantic Forest Law" (IBGE 2018, Silva *et al.*, 2016); d) Ribeiro *et al.* (2009).

Although several studies have described the geographic delimitation of the Atlantic Forest (Morellato & Haddad 2000, Oliveira-Filho & Fontes 2000, Silva & Casteleti 2005), establishing the boundaries of the Atlantic Forest is not a trivial task. Ecotones with the other

biomes (e.g., Cerrado, Caatinga and Pampa) may be gradual and of complex classification in certain regions. For example, the transition between the Atlantic Forest and the Cerrado may extend for hundreds of kilometers and be composed of different combinations of savanna, pasture and forest vegetation, with a prevalence of species representative of both biomes (Oliveira-Filho & Fontes 2000, Löbler *et al.* al. 2015). Thus, in spite of its practical implication for the conservation and development of public policies, the establishment of well-defined boundaries for the Atlantic Forest may present inconsistencies with the real world, especially when considering the complexity of plant formations, climate, and fauna associated to ecotones (Eisenlohr & Oliveira-Filho 2015).

Due to the complexity inherent to the delimitation of biomes, in this study, we discussed the four main geographical delimitations of the Atlantic Forest. Our objectives were: 1) to make available, describe and present the criteria used in each of the delimitations, quantifying their similarities and differences; and 2) discuss the most extensive form of boundaries evaluated as an "integrative boundary" and its intersection as a "consensual boundary". Thus, we propose here a reflection on the different extents and concepts used to define the Atlantic Forest, and on the implications for its use in ecological, biogeographic and conservation studies.

Although there are exclusive delimitations to the regions of Argentina, Brazil and Paraguay (e.g. Huang *et al.*, 2007), we discuss here both the delimitations that cover the Atlantic Forest in the three countries in which it occurs (Olson *et al.*, 2001) and the Brazilian Atlantic Forest only (IBGE 2016, 2018, Ribeiro *et al.*, 2009, Silva *et al.*, 2016, Table 1). To quantify the differences between the boundaries, we transformed the vector maps to rasters with a spatial resolution of 1 km and extent spanning all boundaries (maximum and minimum latitudes and longitudes among the different boundaries). For each of the boundaries, we assigned codes to the cells of their respective raster files separately. Then, we added the maps and created a new raster to distinguish the similarities and differences between the boundaries at three different levels: (1) cells with unique values, (2) cells with combined values for two maps and (3) cells with values for three and/or four maps. The calculation of the total area of the boundaries was based on the shapefile files within the environment R (R Core Team 2015;

Table 1) using the equivalent conical projection of Albers and the horizontal datum SAD69. The boundaries, as well as additional information, are available at https://github.com/LEEClab/ATLANTIC-limits-shapefiles.

Table 1. *boundaries of the Atlantic Forest used and their respective areas, references and data source.*

Boundary	**Area (km^2)**	**Reference**	**Source**
MMA-IBGE (2004)	1.117.862	IBGE (2016)	http://mapas.mma.gov.br/i3geo/datadownload.htm; http://www.ibge.gov.br/home/presidencia/noticias/21052004biomashtml.shtm
Lei da Mata Atlântica-IBGE (2006)	1.291.000	Federal decreet nº 6660/2008 Lei nº. 11.428/ 2006, IBGE (2018), Silva *et al.* (2016)	http://www.planalto.gov.br/ccivil_03/_ato2004-2006/2006/lei/l11428.htm http://www.mma.gov.br/biomas/mata-atlântica_emdesenvolvimento
World Wildlife Fund-WWF (2001)	1.335.416	Olson *et al.* (2001)	http://www.worldwildlife.org/publications/terrestrial-ecoregions-of-the-world
Ribeiro *et al.* (2009)	1.366.000	Ribeiro *et al.* (2009)	https://github.com/LEEClab/ATLANTIC-limits-shapefiles
"Integrating Boundary" (Union)	1.620.000	This article	https://github.com/LEEClab/ATLANTIC-limits-shapefiles
"Consensual Boundary" (Intersection)	1.018.241	This article	https://github.com/LEEClab/ATLANTIC-limits-shapefiles

*1. Boundary from "*World Wildlife Fund-*WWF (2001)" (Olson et al. 2001)*

The non-governmental organization World Wildlife Fund (WWF) has established unified boundaries for terrestrial ecosystems around the world. The product divides the planet into 867 ecoregions, each one defined as an extensive piece of land or water that shares common species and environmental conditions (Olson *et al.*, 2001), and 14 biomes. Biomes and ecoregions aim to represent the distribution of animal and plant species and communities better than units based on models derived from bioclimatic characteristics (such as temperature and rainfall, vegetation structure, or derived products from remote sensing spectral signatures), since these models do not emphasize endemic genera. According to this definition, the Atlantic Forest is classified as part of the tropical and subtropical moist rainforest, and dry and subtropical rainforest biomes, and we consider the Atlantic Forests and Atlantic dry Forests classes (column G200_REGIO) from the shapefile of terrestrial ecosystems (Terrestrial Ecoregions of the World, Olson *et al.*, 2001). In Brazil, the boundary advances for transitions with the Cerrado, as in the states of São Paulo, Minas Gerais, and Bahia, and Caatinga in the Brazilian Northeast,

and enters the forest vegetation in Paraguay and Argentina as well (Figure 1). The construction of this division was made based on the knowledge and collaboration of more than 100 researchers.

2. *Boundary from "MMA-IBGE (2004)" (IBGE 2016)*

This is the boundary of the Atlantic Forest formalized by the Brazilian Institute of Geography and Statistics (IBGE), made available to the Ministry of the Environment (MMA), and defined with governmental participation, the scientific community and civil society organizations working in the socio-environmental field. The Atlantic Forest was delimited in a map of Brazilian biomes with the boundaries of the Amazon, Caatinga, Cerrado, Pampa and Pantanal. The objective of this boundary is to serve as a reference for the establishment of differentiated public policies and for monitoring the actions implemented in each of them by society. Thus, many remnants of the Atlantic Forest vegetation types that are distributed in ecotones with other biomes are not considered. This boundary is commonly used by studies that compare different Brazilian biomes. According to this boundary, the Atlantic Forest occupies the continental Atlantic strip that borders the east coast and extends inland in the Southeast and South of Brazil, and the main difference in relation to the other boundaries is its narrower range in the Northeast region (Figure 1). Among the criteria used in this boundary, we highlight the "dominant vegetation (forest)" and the "extremely diverse relief" (IBGE 2016). This is the boundary of smaller spatial extent among the four.

3. Boundary from "Atlantic Forest Law-IBGE (2006)" (IBGE 2018, Silva et al. 2016)

This boundary is regulated by Federal Decree no. 6660/2008 and by the Law of the Atlantic Forest (No. 11,428 / 2006, IBGE 2018, Silva *et al.*, 2016). Besides defining the biome's boundary, the law divides the Atlantic Forest into bioregions. The main articles referring to the Decree are clear in the description of the boundary, following the IBGE criteria for the year 2006. Thus, the Atlantic Forest covers the Dense Ombrophilous Forest, Mixed Ombrophilous Forest (*Mata de Araucária*), Open Ombrophilous Forest, Semideciduous Seasonal Forest,

Deciduous Seasonal Forest, Altitude Fields (*Campos de altitude*), Inland swamps (*Brejos interioranos*) and Forest Enclaves, Vegetation Refuges, Areas of Ecological Tension (areas of transition between environments or vegetation types), Pioneer Formation Areas (mangroves, *restingas*, *campos salinos* and alluvial areas), Savannahs, *Savanas-estépicas*, and the Native Vegetation of Islands. The Decree No. 6,660 from November 21, 2008 established the "Map of the Area of Application of Law No. 11,428 of 2006", as well as regulated devices to determine the use and protection of Atlantic Forest vegetation. The application of the law would occur in "remnants of native vegetation in the primary stage and in the secondary, early, middle and advanced stages of regeneration in the area defined in the caput of this article" (article 2, sole paragraph of the Law). This boundary was defined as a result of a long debate between researchers, members of government agencies and civil society activists with different positions (Steinberger & Rodrigues 2010), and is inclusive regarding the interior of the Northeast region of Brazil, in addition to include regions that are in the Pantanal and in the Pampa domains according to other boundaries of the biomes (Figure 1).

4. Boundary from "Ribeiro et al. (2009")

In Ribeiro *et al.* (2009), 94% of the Brazilian Atlantic Forest region defined by the Atlantic Forest Law (nº 11.428, year of 2006, IBGE 2018, Silva *et al.*, 2016) was analyzed, but for some regions the study expanded the boundaries of the law, including the biogeographic regions delimitations proposed by Silva & Casteleti (2005). Therefore, the boundary defines the following biogeographic sub-regions (BSRs): *Araucarias*, *Bahia*, *Brejos Nordestinos*, *Diamantina, Interior*, *Pernambuco*, *Serra do Mar*, and *São Francisco* (see Figure 1 of Ribeiro *et al.* 2009). The delimitation proposed by Ribeiro *et al.* (2009) differs from the others mainly because it includes areas in the interior of the state of São Paulo and parts of the North of the state of Paraná, which are considered as areas belonging to Cerrado by the other three boundaries (Figure 1). The authors incorporated these regions because they present, in addition to savannah areas of the Cerrado domain (such as the Itirapina Ecological Station), plant formations that correspond to Seasonal Semideciduous Forests of the Atlantic Forest, or

transitional areas between the two biomes (Oliveira-Filho & Fontes 2000, Ribeiro *et al.*, 2009). In the Northeast, the boundary covers areas of Semideciduous Forest from Serra do Espinhaço and Brejos Nordestinos. In the South, areas of the Rio Grande do Sul coastal plain are not part of the delimitation. Finally, the boundary does not include small patches of Atlantic Forest on the Northeastern Brazilian coast, in the North of Pernambuco, Rio Grande do Norte, and Ceará (Figure 1).

Comparison between boundaries

From the four boundaries detailed above, we propose two new boundaries: the first refers to the union of the four boundaries - the "Integrative boundary" - and the second consists of the intersection between boundaries - the "Consensual Boundary" of the Atlantic Forest (Figure 2a). By overlapping the four boundaries, it is possible to observe the exclusive regions as well as the areas that coincide for sets of two or three boundaries (Table 2 and Figure 2b). While the union of the existing boundaries comprises an area of more than 1.6 million km^2, the intersection between them presents a coverage of about 1.08 million km² (Table 1 and Figure 2a). We call the "Consensual Boundary" of the Atlantic Forest the intersection of the boundaries, because it is where the four Atlantic Forest boundaries coincide.

Table 2. Values referring to the territorial area (km^2) that incorporates similarities and differences between Atlantic Forest boundaries. * The first value refers to the total area of the rasters, including the international Atlantic Forest; ** The second value was made after a cut of each portion by the current political delimitation of Brazil, based on the Brazilian municipal grid of 2016, available at https://downloads.ibge.gov.br. Boundaries and their sources: a) "World Wildlife Fund-WWF (2001)" (Olson *et al.*, 2001); b) "Ministry of Environment (MMA) - Brazilian Institute of Geography and Statistics (IBGE) (2004)" (IBGE 2016); c) "Law of the Atlantic Forest" (IBGE 2018, Silva *et al.*, 2016); d) Ribeiro *et al.* (2009).

Description	**Boundaries used**	**Area (km^2) total***	**Area (km^2) inside Brazilian current political boundaries****
Area exclusive from one boundary	Exclusive from WWF	148.472	35.992
	Exclusive from MMA-IBGE	1.788	1.766
	Exclusive from Atlantic Forest Law-IBGE	25.197	22.912
	Exclusive from Ribeiro *et al.* (2009)	148.268	146.977
Convergence of 2 boundaries	WWF and MMA-IBGE	1.331	1.311
	WWF and Atlantic Forest Law-IBGE	35.839	34.642
	MMA-IBGE and Atlantic Forest Law	21.758	21.752
	WWF and Ribeiro *et al.* (2009)	16.318	16.093
	MMA-IBGE e Ribeiro *et al.* (2009)	3.177	3.156
	Atlantic Forest Law-IBGE and Ribeiro *et al.* (2009)	27.147	26.856
Convergence of 3 boundaries	WWF, MMA-IBGE and Atlantic Forest Law-IBGE	11.994	11.980
	WWF, MMA-IBGE and Ribeiro *et al.* (2009)	8.250	8.217
	WWF, Atlantic Forest Law-IBGE and Ribeiro *et al.* (2009)	93.663	93.616
	MMA-IBGE, Atlantic Forest Law-IBGE and Ribeiro *et al.* (2009)	51.258	51.253
Consensual boundary/Intersection of the 4 boundaries	WWF, MMA-IBGE, Atlantic Forest Law-IBGE and Ribeiro *et al.* (2009)	1.018.241	1.018.222

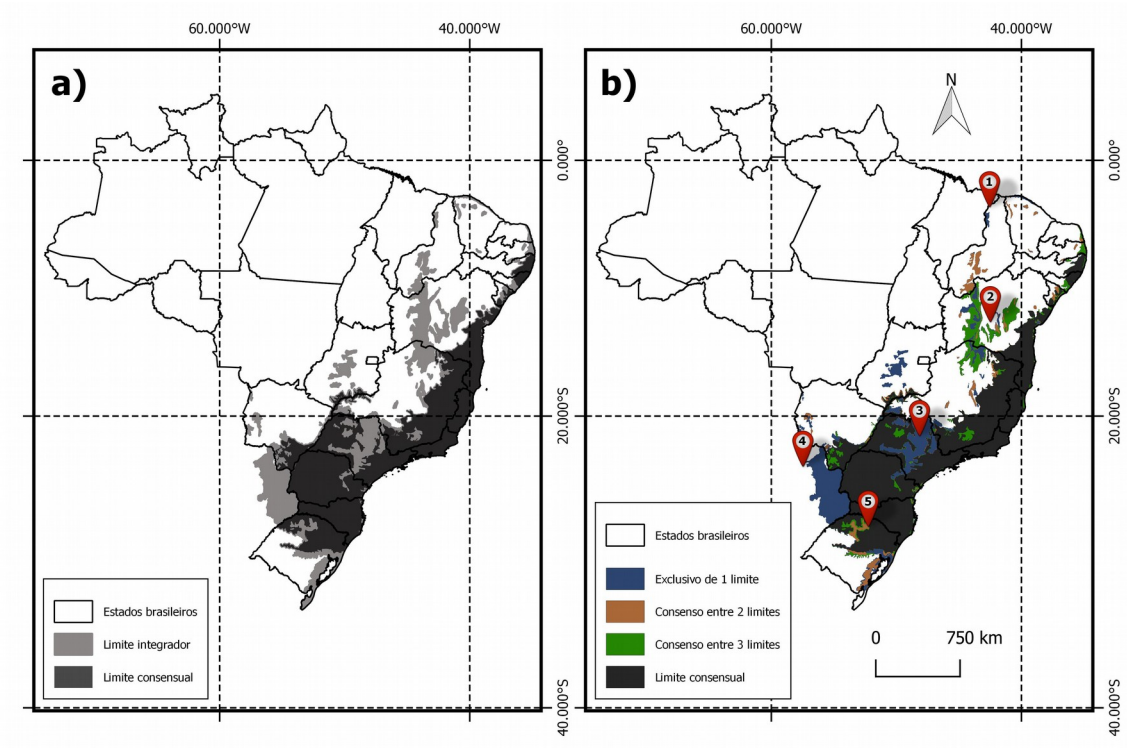

Figure 2. Similarities and differences between the boundaries: a) "Integrative Boundary" (union) and "Consensual Boundary" (intersection) of the Atlantic Forest. b) Similarities and differences between the boundaries of the international Atlantic Forest – WWF (2001), MMA-IBGE (2004), Atlantic Forest Law-IBGE (2006), and Ribeiro *et al.* (2009). Markers in red indicate the main divergences between boundaries.

The union of the four boundaries presented here - the "Integrative Boundary" of the Atlantic Forest - can be considered wide-ranging and inclusive and it encompasses some patterns of historical biogeography. This means that the inclusion of forest remnants in ecotone regions with other Brazilian biomes may be important to highlight the diversity of plants and animals that were part of the Atlantic Forest and are currently distributed in other biomes. Different species may have remained isolated in fragments in ecotone regions with other biomes due to climatic changes that occurred during a geological time and led to the expansion and/or retraction of Neotropical forests in different time periods (Werneck *et al.*, 2012, Sobral-Souza *et al.*, 2015). In addition, recent biodiversity losses are associated with human action intensively changing landscapes. These alterations in the landscapes due to the loss and fragmentation of

habitats suffered in the last centuries are among the main factors causing extinctions and define the period known as Anthropocene (Dirzo *et al.*, 2014). To better understand how changes in the landscape influence the distribution and persistence of species, especially in Atlantic Forest ecotones where the fragmentation process is well advanced, it is important to look at the remnants of the biome as potential refuges of native species where it is important to increase efforts of monitoring and conservation.

From the Northern region towards the South of Brazil, there are five regions that permeate other biomes and are not included in the "Consensual Boundary" of the Atlantic Forest, but where there are exclusive or consensus areas between two or three boundaries: (1) a region in the North of the boundary that includes areas of Caatinga, recognized as *brejos de altitude*, as in Ibiapaba and Baturité in the Ceará State; (2) the region of the São Francisco River, which comprises part of the interior of Minas Gerais and Bahia; (3) the region encompassing a large enclave considered as a Cerrado domain in the state of São Paulo; (4) another Southwestern region that enters parts of the Pantanal and Chaco; and, finally, (5) a region to the South, which permeates the Pampas (Figure 2b). Regions 1, 2, and 4 were described as linking routes between the Atlantic Forest and the Amazon during the process of expansion and retraction of the humid forests along the Pleistocene glacial and interglacial cycles (Sobral-Souza *et al.*, 2015). Sobral-Souza & Lima-Ribeiro (2017) review reinforces the idea of persistence of Atlantic Forest patches in these regions in the past when discussing the genetic and the species composition similarity between the Southern Atlantic Forest and the Western Amazonia, the greater taxonomic similarity between gallery forests of the Cerrado and the Atlantic Forest (in the central portion), and the similarity of species of the Caatinga *brejos of altitude* with species of the North Atlantic Forest.

Regarding the caveats of each boundary, we reiterate the remarks raised by Olson *et al.* (2001), suitable for any biogeographic mapping: 1) no biogeographic delimitation meets all species; 2) boundaries are rarely abrupt, and there are indeed ecotones and mosaics between them; 3) most "ecoregions" (subsets of biomes according to the WWF or other biome-based delimitations, or the biome delimitation itself), contain habitats that are different from the

habitat that defines the biome. In the case of the "Consensual Boundary", which is the most restrictive of the Atlantic Forest, areas of the interior of São Paulo, interior of Bahia and Goiás, as well as areas of Northern Ceará and the Southern coast of Rio Grande do Sul are not considered areas of the Atlantic Forest Biome, as well as the Atlantic Forest in Paraguay and Argentina. It is beyond the scope of this note to propose a single or more adequate delimitation, but we emphasize that the "Consensual Boundary" does not seem to contemplate its real extension, being that it reduces its area in more than 600,000 km^2. It would be interesting to evaluate, for example, how the proportion of protected forest areas varies between the different boundaries, as it was already done for WWF ecoregions (Olson *et al.*, 2001) in Dinerstein *et al.* (2017). In that study, the authors demonstrated that, on average, only 12% of the tropical forests of the World are protected (Olson *et al.*, 2001).

We seek to motivate a discussion on the differences between the Atlantic Forest boundaries already proposed so that they are used with criteria appropriate to the proposed studies, even when it comes to simply represent a study region in an illustrative map. After comparing the four main available boundaries of the Atlantic Forest, we concluded that there is no trivial solution for the choice of the boundary to be used for studies at different scales, whether in biogeographic, macroecological or for the investigation of processes in more restricted geographic extensions. The comparison of the boundaries carried out here allows researchers to consciously decide which spatial delimitation to use when performing ecological studies in the Atlantic Forest and other biomes. The "Integrative Boundary" and the "Consensual Boundary" can be used to investigate issues related to public policy proposition and management of territories and natural resources, even though such applications may be subject to boundaries already implemented for law enforcement and decision making, such as the Boundary of the Law of the Atlantic Forest, since they involve questions of sovereignty and jurisdiction. We do not aim to question the validity of the existing boundaries, but rather to generate discussions about that, so that ecological studies and the application of public policies take into account the complexity of the extent of the Atlantic Forest.

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REFERÊNCIAS

Carnaval, A. C., Hickerson, M. J., Haddad, C. F. B., Rodrigues, M. T., & Moritz, C. 2009. Stability predicts genetic diversity in the Brazilian Atlantic Forest hotspot. Science, 323(5915), 785–789. DOI: 10.1126/science.1166955

Clements, F. E., & Shelford, V. E. 1939. Bioecology. F. E. Clements & V. E. Shelford (Eds.), 1 ed. New York: John Wiley & Sons: p. 425.

Coutinho, L. M. 2006. O conceito de bioma. Acta Botanica Brasilica, 20(1), 13–23. DOI: 10.1590/S0102-33062006000100002

Dinerstein, E., Olson, D., Joshi, A., Vynne, C., Burgess, N. D., Wikramanayake, E., Hahn, N., Palminteri, S., Hedao, P., Noss, R., Hansen, M., Locke, H., Ellis, E. C., Jones, B., Barber, C. V., Hayes, R., Kormos, C., Martin, V., Crist, E., Sechrest, W., Price, L., Baillie, J. E. M., Weeden, D., Suckling, K., Davis, C., Sizer, N., Moore, R., Thau, D., Birch, T., Potapov, P., Turubanova, S., Tyukavina, A., De Souza, N., Pintea, L., Brito, J. C., Llewellyn, O. A., Miller, A. G., Patzelt, A., Ghazanfar, S. A., Timberlake, J., Klöser, H., Shennan-Farpón, Y., Kindt, R., Lillesø, J. P. B., Van Breugel, P., Graudal, L., Voge, M., Al-Shammari, K. F., & Saleem, M. 2017. An ecoregion-based approach to protecting half the terrestrial realm. BioScience, 67(6), 534–545. DOI: 10.1093/biosci/bix014

Dirzo, R., Young, H. S., Galetti, M., Ceballos, G., Isaac, N. J. B., & Collen, B. 2014. Defaunation in the Anthropocene. Science, 345(6195), 401–406. DOI: 10.1126/science.1251817

Eisenlohr, P. V., & Oliveira-Filho, A. T. 2015. Revisiting patterns of tree species composition and their driving forces in the Atlantic Forests of southeastern Brazil. Biotropica, 47(6), 689–701. DOI: 10.1111/btp.12254

Huang, C., Kim, S., Altstatt, A., Townshend, J. R. G., Davis, P., Song, K., Tucker, C. J., Rodas, O., Yanosky, A., Clay, R., & Musinsky, J. 2007. Rapid loss of Paraguay`s Atlantic forest and the status of protected areas — A Landsat assessment. Remote Sensing of Environment, 106, 460–466. DOI: 10.1016/j.rse.2006.09.016

IBGE - Instituto Brasileiro de Geografia e Estatística. 2016. Mapa de biomas e de vegetação. Ministério do Planejamento, Orçamento e Gestão. (Acessado em 12 de janeiro de 2016, em http://mapas.ibge.gov.br/).

IBGE - Instituto Brasileiro de Geografia e Estatística. 2018. Mapa da Área de Aplicação da Lei no 11.428, de 2006. Ministério do Planejamento, Orçamento e Gestão. (Acessado em 28 de maio de 2018, em https://ww2.ibge.gov.br/home/geociencias/recursosnaturais/mapas_doc6.shtm).

Joly, C. A., Metzger, J. P., & Tabarelli, M. 2014. Experiences from the Brazilian Atlantic Forest : ecological findings and conservation initiatives. New Phytologist, 204, 459–473. DOI: 10.1111/nph.12989

Löbler, C. A., Sccoti, A. A. V., & Werlang, M. K. 2015. Contribution to the delineation of Pampa and Atlantic Forest biomes in Santa Maria, RS. Revista Eletrônica em Gestão, Educação e Tecnologia Ambiental, 19(2), 1250–1257. DOI: 105902/2236117016038

Mittermeier, R. A., Gil, P. R., Hoffmann, M., Pilgrim, J., Brooks, T., Mittermeier, C. G., Lamoreux, J., & Fonseca, G. A. B. 2004. Hotspots Revisited: Earth's Biologically Richest and Most Endangered Ecoregions. 1 ed. Mexico City: CEMEX, Conservation International, e Agrupacion Sierra Madre: p. 390. DOI: 10.2744/ccab-14-01-2-10.1

Morellato, L. P. C., & Haddad, C. F. B. 2000. Introduction: The Brazilian Atlantic Forest. Biotropica, 32(4), 786–792. DOI: 10.1111/j.1744-7429.2000.tb00618.x

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

Oliveira-Filho, A., & Fontes, M. 2000. Patterns of floristic differentiation among Atlantic Forests in Southeastern Brazil and the influence of climate. Biotropica, 32(2), 793–810. DOI: 10.1111/j.1744-7429.2000.tb00619.

Olson, D. M., Dinerstein, E., Wikramanayake, E. D., Burgess, N. D., Powell, G. V. N., Underwood, E. C., D'amico, J. A., Itoua, I., Strand, H. E., Morrison, J. C., Loucks, C. J., Allnutt, T. F., Ricketts, T. H., Kura, Y., Lamoreux, J. F., Wettengel, W. W., Hedao, P., & Kassem, K. R. 2001. Terrestrial Ecoregions of the World: A New Map of Life on Earth. BioScience, 51(11), 933–938. DOI: 10.1641/0006-3568(2001)051[0933:TEOTWA]2.0.CO;2

R Core team. 2015. R Core Team. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-Project.org/., 55, 275–286.

Ribeiro, M. C., Metzger, J. P., Martensen, A. C., Ponzoni, F. J., & Hirota, M. M. 2009. The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. Biological Conservation, 142(6), 1141–1153. DOI: 10.1016/j.biocon.2009.02.021

Silva, A. P. M., Marques, H. R., & Sambuichi, R. H. R. 2016. Mudanças no código florestal brasileiro: desafios para a implementação da nova lei. 1ª Edição. Rio de Janeiro: Ipea/IPC-IG: p. 359.

Silva, J. M. C., & Casteleti, C. H. M. 2005. Estado da biodiversidade da Mata Atlântica brasileira. In: C. Galindo-Leal & I. de G. Câmara (Eds.), Mata Atlântica, biodiversidade, ameaças e perspectivas. p. 472. Belo Horizonte: Fundação SOS Mata Atlântica e Conservation International.

Sobral-souza, T., & Lima-Ribeiro, M. S. 2017. De volta ao passado: revisitando a história biogeográfica das florestas neoropicais úmidas. Oecologia Australis, 21(2), 93–107. DOI: 10.4257/oeco.2017.2102.01

Sobral-Souza, T., Lima-Ribeiro, M. S., & Solferini, V. N. 2015. Biogeography of Neotropical Rainforests: past connections between Amazon and Atlantic Forest detected by ecological niche modeling. Evolutionary Ecology, 29(5), 643–655. DOI: 10.1007/s10682-015-9780-9

Steinberger, M., & Rodrigues, R. J. 2010. Conflitos na delimitação territorial do Bioma Mata Atlântica. Revista GEOgrafias, 6(2), 37–48.

Tabarelli, M., Aguiar, A. V., Ribeiro, M. C., Metzger, J. P., & Peres, C. A. 2010. Prospects for biodiversity conservation in the Atlantic Forest: lessons from aging human-modified landscapes. Biological Conservation, 143(10), 2328–2340. DOI: 10.1016/j.biocon.2010.02.005

Werneck, F. P., Nogueira, C., Colli, G. R., Sites, J. W., & Costa, G. C. 2012. Climatic stability in the Brazilian Cerrado: Implications for biogeographical connections of South American savannas, species richness and conservation in a biodiversity hotspot. Journal of Biogeography, 39(9), 1695–1706. DOI: 10.1111/j.1365-2699.2012.02715.x

Whittaker, R. H. 1962. Classification of natural communities. Botanical Review, 28(1), 1–239.

Whittaker, R. H. 1970. Communities and ecosystems. Communities and ecosystems. New York: Macmillan: p. 385.

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