Chapter 21
The Brazilian Atlantic Forest: A Shrinking Biodiversity Hotspot

Milton Cezar Ribeiro, Alexandre Camargo Martensen, Jean Paul Metzger, Marcelo Tabarelli, Fábio Scarano, and Marie-Josee Fortin

Abstract The Neotropical Atlantic Forest is one of the world's top biodiversity hotspot. Originally, the forest extended over 1.5 million km^2 along the South American Atlantic coast, covering tropical and subtropical climates across highly heterogeneous relief conditions, which led to outstanding levels of endemism and species richness. Unfortunately, the Atlantic Forest has been historically altered by

M.C. Ribeiro (✉)
Departamento de Ecologia, Instituto de Biociências, Universidade de São Paulo, Rua do Matão, 321, travessa 14, 05508-090 São Paulo, SP, Brazil

Department of Ecology and Evolutionary Biology, University of Toronto, 25 Harbord Street, Toronto, ON M5S 3G, Canada

Taki Ambiental, Estrada da Lagoa 3606, 18315-000 Ribeirão Grande, Caixa Postal: 45, SP, Brazil

Present address: Laboratório de Ecologia Espacial e Conservação – LEEC, Departamento de Ecologia, UNESP – Rio Claro. Av. 24A, 1515, Bela Vista, 13506-900 Rio Claro, Brasil
e-mail: mcr@usp.br

A.C. Martensen
Departamento de Ecologia, Instituto de Biociências, Universidade de São Paulo, Rua do Matão, 321, travessa 14, 05508-090 São Paulo, SP, Brazil

Taki Ambiental, Estrada da Lagoa 3606, 18315-000 Ribeirão Grande, Caixa Postal: 45, SP, Brazil

J.P. Metzger
Departamento de Ecologia, Instituto de Biociências, Universidade de São Paulo, Rua do Matão, 321, travessa 14, 05508-090 São Paulo, SP, Brazil

M. Tabarelli
Departamento de Botânica, Universidade Federal de Pernambuco, 50670-901 Recife, PE, Brazil

F. Scarano
Conservation International, Rua Barão de Oliveira Castro 29, 22460-280 Jardim Botânico, Rio de Janeiro, RJ, Brazil

M.-J. Fortin
Department of Ecology and Evolutionary Biology, University of Toronto, 25 Harbord Street, Toronto, ON M5S 3G, Canada

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humans, which has resulted in severe habitat loss and fragmentation. The forest cover is now reduced to around 12% of its original extent, including regenerating areas and degraded forests, which are mostly spread in small fragments. As a result, many species are currently threatened to global extinction, with populations collapsing on local and regional scales. In this chapter, we reviewed the state of the art of Atlantic Forest biodiversity knowledge, pointing out the main achievements obtained by several research groups during the last decades. Additionally, we (1) propose a new sub-division of biogeographical sub-regions into 55 sectors considering 2,650 sub-watersheds, using niche theory and bioclimatic data; (2) describe the original and present distribution of the Atlantic Forest; and (3) relate the forest distribution to elevation and geomorphometric information (aspect and terrain orientation). Forest protection and restoration efforts, and potential ecosystem services are also examined as key topics driving the future of the Atlantic Forest biodiversity.

21.1 Introduction

The Atlantic Forest is the second largest rain forest of South America, once covering around 1.5 million km along the Brazilian coast, and extended westward into smaller, inland areas of Paraguay and Argentina (Galindo-Leal and Câmara 2003; Ribeiro et al. 2009). Stretching over extensive latitudinal (3°S to 30°S), longitudinal (35°W to 60°W), altitudinal (0–2,900 m asl), and soil-climatic gradients (e.g., 1,000–4,200 mm annual rainfall), Atlantic Forest is in fact extremely heterogeneous and encompasses large blocks of evergreen to semi-deciduous forests (the bulk of Atlantic Forest), but also deciduous forests, mangroves, swamps, *restingas* (coastal forest and scrub on sandy soils), inselbergs, high-altitude grasslands (*campo rupestre* and *campo de altitude*), and mixed *Araucaria* pine forests (Scarano 2002; Câmara 2003). This diversified mosaic of habitats is currently home of nearly 20,000 species of plants, 263 mammals, 936 birds, 306 reptiles, and 475 amphibians (Mittermeier et al. 2005). Moreover, outstanding levels of endemism make the Atlantic Forest one of the most distinctive biogeographic unit in the entire Neotropical Region (Müller 1973; Prance 1982).

The evolutionary history of the Atlantic Forest has been marked by periods of connection with other South American forests (e.g., the Amazon and Andean forests), resulting in biotic interchange, followed by periods of isolation that led to allopatric speciation (Silva et al. 2004). As a consequence, its biota is composed of both old (pre-Pliocene) and young (Pleistocene-Holocene) species (Silva and Casteleti 2003), which probably evolved within forest refuges that persisted in isolation during periods of drier climates (Silva et al. 2004). Such dynamic evolutionary history produced a very distinct biota consisting of five well-defined species centers (Silva and Casteleti 2003), with endemism rates ranging from 30% in birds to 44% in plants (Mittermeier et al. 2005).

Despite its extraordinary biodiversity and high levels of endemism, the Atlantic Forest has long experienced relentless habitat loss since the arrival of European colonists in the sixteenth century. A massive agricultural expansion in the colonial period, followed by industrialization and urban development, have profoundly affected the Atlantic Forest, which is now confined to only ~11.7% (163,377 km^2) of its original extent in Brazil (Ribeiro et al. 2009, hereafter, original will refer to pre-European period), 24.9% (11,618 km^2) in Paraguay (Cartes and Yanosky 2003; Huang et al. 2007, 2009), and ~38.7% (9,950 km^2) in northern Argentina (Chebez and Hilgert 2003; De Angelo 2009), so that 12.59% of the Neotropical Atlantic Forest remain today. Furthermore, habitat loss has reached more than 90% in some centers of endemism (Ribeiro et al. 2009), making the Atlantic Forest a global priority for biodiversity conservation, i.e., a biodiversity hotspot sensu Mittermeier et al. (2005). Overall, the Atlantic Forest has been converted into human modified or anthropogenic landscapes, which are typically agromosaics with a dynamic combination of small old growth forest remnants, early to late secondary forest patches on abandoned cropland or pasture, small patches of assisted regenerating forests, agroforestry patches, and plantations of exotic trees such as *Pinus* and *Eucalyptus*. Forest clearing is frequently associated with other human disturbances (e.g., hunting, logging, collection of non timber forest products), which has driven a fraction of the Atlantic Forest's unique biodiversity to nearly complete extinction (Tabarelli et al. 2005). In fact, few tropical biodiversity hotspots are "hotter" than the Atlantic Forest in terms of both existing threats and conservation value (Laurance 2009), despite its 700 protected areas (Galindo-Leal and Câmara 2003), which however protect only 1.62% of the region (Ribeiro et al. 2009).

In this chapter, we first document the environmental variability across the Atlantic Forest region, in order to better delimitate the bioclimatic distribution along its original extent. We overlapped bioclimatic data and the biogeographical sub-regions (Silva and Casteleti 2003) and proposed a refined new sub-division considering environmental variability within its 2,650 subwatersheds. Land use and historical and current habitat cover is examined at the biome scale in terms of both ecological/geographical distribution and landscape structure. We analyze the historical and present relationship between elevation and geomorphometric parameters (terrain orientation) and forest distribution. Forest conservation efforts, including Brazilian environmental legislation, are summarized, as well as key topics regarding ecosystem services and forest restoration. Finally, we examine potential perspectives, threats, and opportunities for Atlantic Forest conservation, and offer some general insights into the prospects for the persistence of biodiversity in human modified tropical forest landscapes worldwide.

21.2 Refinement of Biogeographical Sub-regions Using Bioclimatic Data

To characterize the Atlantic Forest region and refine the already well established biogeographical division of the Atlantic Forest (Silva and Casteleti 2003), we used bioclimatic and elevation data. Using data on birds, butterflies, and primates distributions, Silva and Casteleti (2003) proposed the partition of Atlantic Forest into eight biogeographical sub-regions (hereafter BSR), five as centers of endemism (Bahia, Brejos Nordestinos, Pernambuco, Diamantina, and Serra do Mar) and three as transition zones (São Francisco, Araucaria, and Interior Forests; see Fig. 21.1). Although this sub-division documents the major patterns of biodiversity distribution, with clear consequences for conservation planning, here we advocate for its refinement.

Humboldt and Bonpland (1807) recognized the importance of climate on species and biodiversity distribution, which later on, merged with the ecological niche concept (Grinnell 1917) defined as the range of ecological conditions under which a

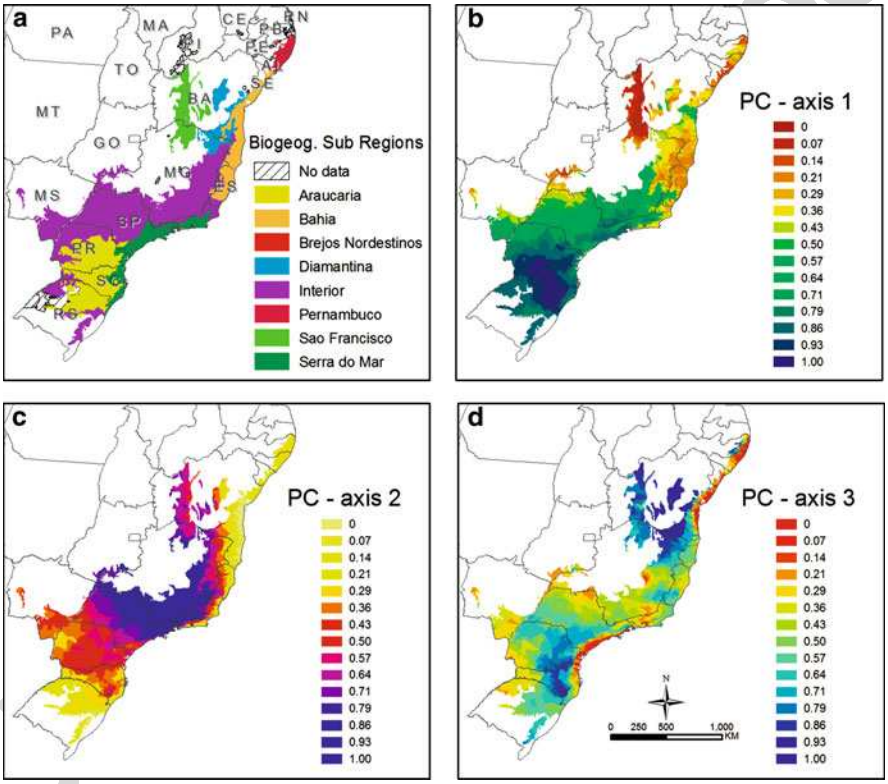

Fig. 21.1 (**a**) Biogeographical subregions (BSRs) proposed by Silva and Casteletti (2003); (**b**), (**c**), and (**d**) are PC axes obtained from the analysis of 19 layers from Worldclim 1.4 and an elevation map. Axis 1 (**b**) was mainly correlated with annual mean temperature and mean temperature in the coldest quarter; the warmer colors represent higher annual mean temperatures. Axis 2 (**c**) was more influenced by elevation, precipitation in the wettest month, precipitation seasonality, and precipitation in the wettest quarter; the cooler (*bluer*) colors indicate higher elevations, while *yellow* represents the lower elevations. Axis 3 (**d**) was mainly correlated with annual precipitation and precipitation in the warmest quarter; *warmer colors* represent higher annual precipitation, and *cooler colors* represent lower annual precipitation

species can occur spatially. Hutchinson (1957) clarified how species and environment are interrelated, using his multi-dimensional "hyper-volume" theory. Specifically, his concept merged autecology and predictive geographical modeling. Ecological niche models basically depict the relationship between species records and a set of environmental conditions, building mechanistic models that allow the extrapolation of potential biodiversity patterns and species occurrences (Guisan and Zimmermann 2000; Guisan and Thuiller 2005).

Environmental or spatial subdivisions can be determined at different spatial and temporal scales (Fortin and Dale 2005; Wagner and Fortin 2005). For macro-regional (>1 million ha) and continental scales, several datasets are now freely available from the Internet, particularly bioclimatic information. The most commonly used database is WORDCLIM 1.4 (http://biogeog.berkeley.eu, Hijmans et al. 2005; Ramirez and Jarvis 2008), which covers the entire globe with a ~900 m spatial resolution. Although the main applications of these map databases are in modeling species distributions, we used the bioclimatic information to refine the biogeographical divisions of the Atlantic Forest. We searched for a unique congruence of climate conditions that could disclose some particular environmental circumstance that might be distinct within the biogeographical region. Based on the results, we proposed to fine tune the Atlantic Forest subdivision.

21.2.1 Proposed Subdivision for BSRs

We used 19 environmental layers of WORDCLIM 1.4 (Hijmans et al. 2005; Ramirez and Jarvis 2008), and an elevation map to characterize the environmental niche amplitude of the region, as was previously used to model species distribution in the Atlantic Forest (Durães and Loiselle 2004; Acosta 2008; Torres et al. 2008; Murray-Smith et al. 2009; Fernandez et al. 2009; Marcelino et al. 2009; Siqueira et al. 2009; Loiselle et al. 2010). However, due to the high colinearity between the environmental and elevation variables, we conducted a PCA analysis to reduce dimensionality (for details of the method, see Loiselle et al. 2010). The first four PCA axes accounted for 92% of the variance, with the first two axes covering 71%. Axis 1 was mainly correlated with the annual mean temperature and the mean temperature in the coldest quarter of the year, while axis 2 was more influenced by elevation, precipitation in the wettest month, precipitation seasonality, and precipitation in the wettest quarter. Axes 3 and 4 (accounting for 21% of the explained variance) were mainly correlated with annual precipitation, precipitation in the warmest quarter, and the annual temperature range.

To map different environmental gradients (see Fig. 21.1b–d for Principal Components – PCs 1, 2, and 3, respectively), we plotted the bioclimatic derived PCA axis on a fifth-order subwatershed division (hereafter SWS; Pfastetter 1987). The SWS were selected because they allowed us to divide the entire Atlantic Forest into ~2,650 parcels, with a size ranging widely between the extremes of fine size for modeling and management (38% are <10,000 ha, and 60% <50,000 ha). Few SWS

($n = 25$) are >500,000 ha in size. The most common sizes of SWS (<50,000 ha) are ideal for regional planning, mainly because they allow the incorporation of landscape level features that are important for conservation and restoration planning. Moreover, the SWS units have been adopted by several Brazilian national agencies (ANA, IBAMA, and EMBRAPA) as the base unit for regional analysis and strategic planning. Therefore, we superimposed the SWS with PC axes on the BSRs proposed by Silva and Casteleti (2003), and produced scatter-plots of paired PC1–PC4. Although the BSRs can be clearly identified as forming groups, Fig. 21.2 shows that there is considerable overlap between the analyzed BSRs on the bioclimatic (PCs) space.

Because our objective in this analysis was to generate a more detailed subdivision of the Atlantic Forest, we combined a cluster analysis with the BSRs suggested by Silva and Casteleti (2003). The results of this superposition are shown in Fig. 21.3. We divided the Atlantic Forest into 55 small sectors, and the number of divisions was proportional to the sizes of the BSR (Table 21.1), which means that the BSRs contain similar heterogeneity within them.

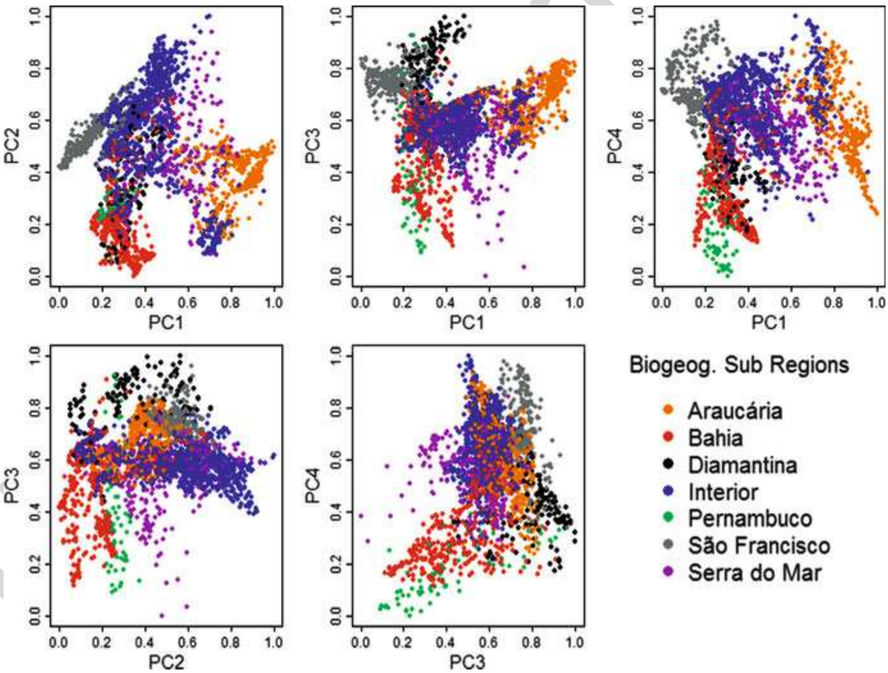

Fig. 21.2 Standardized principal components (PCs) for the first four axes obtained from the analysis of 19 layers from Worldclim 1.4 and an elevation map, of the Brazilian Atlantic Forest bioclimate environmental space. Each point ($n = 2{,}650$) represents a different sub-watershed of order 5a. Biogeographical subregions are identified by *colored dots*, not including the Brejos Nordestinos BSR given its size

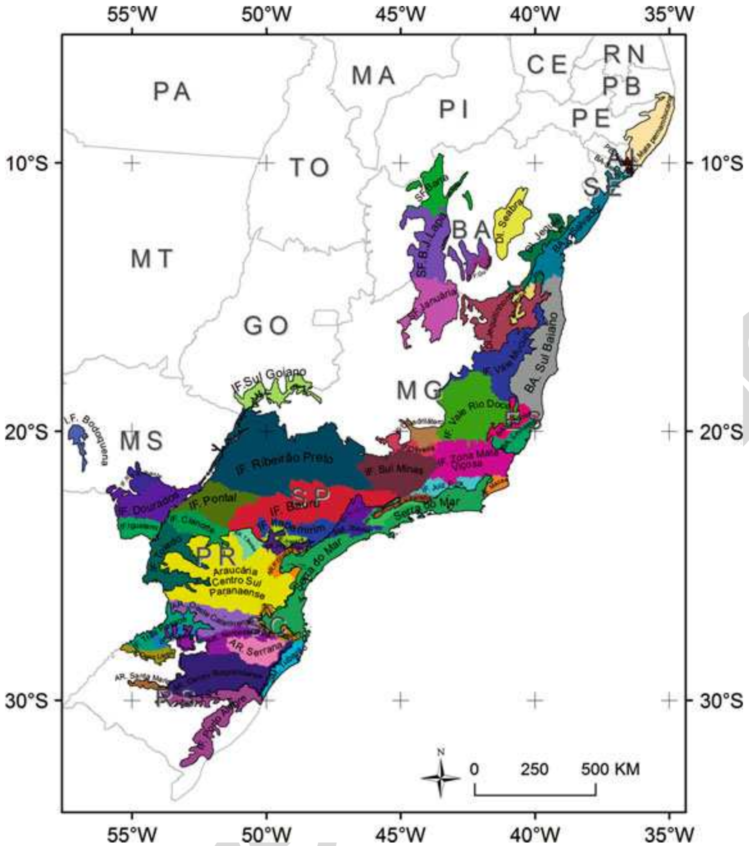

Fig. 21.3 Proposed subdivision of the Brazilian Atlantic Forest by biogeographical subregions [BSRs; Silva and Casteleti (2003), excluding the Brejos Nordestinos], considering clusters derived from 19 environmental layers (Worldclim 1.4) and an elevation map. The first two letters for new subdivisions identify the BSRs: *AR* Araucaria; *BA* Bahia; *DI* Diamantina; *IF* Interior Forest; *PE* Pernambuco; *SF* São Francisco; *SM* Serra do Mar

Table 21.1 Summary information for internal subdivisions proposed for the biogeographical sub-regions (BSRs; Silva and Casteleti 2003), excluding the Brejos Nordestinos, which were already too small

Biogeographical sub-region	Number of subdivisions	Area in ha			
		Minimum	Mean	SD	Maximum
Araucária	9	823,781	2,926,777	9,193,929	9,379,519
Bahia	6	200,941	2,223,135	2,197,306	5,575,259
Diamantina	3	1,645,058	3,598,382	1,691,630	4,577,447
Interior	25	50,713	2,848,668	3,309,680	14,805,211
Pernambuco	2	281,664	1,798,296	2,144,842	3,314,928
São Francisco	5	291,418	2,508,833	2,236,126	5,934,037
Serra do Mar	5	820,619	2,610,988	3,586,569	9,018,947

The subdivisions were generated based on bioclimate (14 environmental layers of Worldclim 1.4) and altitudinal variation data for the Brazilian Atlantic Forest

Most of the sub-divisions have less than 10% of forest remaining, thus below the target minimum percentage for biodiversity conservation (Secretariat of the Convention on Biological Diversity 2002). Type of forests, rain fall and temperature varied greatly between sub-divisions, from evergreen to deciduous forests, following an also extreme gradient of rain fall (varying between 800 and almost 2,000) and temperature (Table 21.2).

This new sub-division allows a better representation of the Atlantic Forest region considering the biogeographical data of Silva and Casteleti (2003), as well as information on bioclimatic and altitude. Field studies should now be conducted to understand the amount of biodiversity variation between subunits, to properly categorize the Atlantic Forest biota in order to support conservation and restoration plans.

21.3 Altitudinal Ranges and Geomorphometric Parameters Across the Atlantic Forest Distribution

Deforestation is recognized worldwide as a process that follows non-random patterns (Seabloom et al. 2002). Soil fertility, economic interests, proximity to urban settlements and roads are among the important factors that drive forest loss and fragmentation in tropical regions (Laurance et al. 2001; Gardner et al. 2009). In the Atlantic Forest, deforestation and regeneration processes are clearly influenced by altitude, topography, land use, and urban areas (Silva et al. 2007; Teixeira et al. 2009; Freitas et al. 2010).

21.3.1 Elevation Ranges

Recently, Tabarelli et al. (2010) quantified the original and present forest distribution across elevation ranges for the entire Atlantic Forest. Originally, more than 80% of the forest occurred at elevations from 200 to 1,200 m, and particularly between 400 and 800 m (Fig. 21.4). The original trends of the proportion of forest distribution between elevation ranges are still perceptible in the present remnants, but the percentage of forest remaining within each elevation range has changed dramatically (Fig. 21.4). Higher altitudes (>1,200 m) retain more than 20% of the original cover, reaching more than 40% for elevations above 1,600 m; whereas at altitudes from 400 to 800 m, only about 10% of the original forest still exists.

21.3.2 Relief Aspect Orientation

Aspect is a circular landform parameter that varies between 0 and 360^{o} and indicates the flow line direction (Hengl and Evans 2009; Olaya 2009). This parameter is obtained from digital elevation models, and could be a good surrogate for

Table 21.2 Characterization of the proposed sub-divisions within each biogeographical subregion (BSR)

Biogeog. subregions[a]	Sub-divisions	Vegetation	Area (km^2)	Forest (%)	Elevation (m)		Precipitation (mm)		Temperature (°C)		Precipitation seasonality (%)
					Mean	SD	Mean	SD	Mean	SD	
Perna	PE-Mata pernambucana	Semidecidual forest/open forest	33,149	14.5	245	215	1384	363	23.5	1.3	60
Perna	PE-Alagoas	Semidecidual forest/Restinga	2,817	6.9	105	71	1107	202	24.6	0.5	66
Bahia	BA-Sul baiano	Evergreen forest	59,561	20.7	153	126	1209	198	23.9	0.6	32
Bahia	BA-Salvador	Evergreen forest	40,867	18.4	173	177	1466	336	23.7	1.3	36
Bahia	BA-Linhares	Evergreen forest	12,423	18.8	459	397	1223	91	22.0	2.3	52
Bahia	BA-Aimorés	Evergreen forest	11,020	9.2	375	276	1210	52	22.8	1.6	61
Bahia	BA-Itambé	Evergreen forest	7,459	10.2	638	202	864	94	21.5	1.3	48
Bahia	BA-Sergipe	Savanna/restinga	2,009	10.4	70	60	1101	182	25.2	0.4	63
S.Fran	SF-Bom Jesus da Lapa	Decidual forest	59,340	6.8	589	187	873	93	24.1	1.3	89
S.Fran	SF-Januária	Decidual forest	36,025	2.2	559	107	891	93	23.8	0.8	94
S.Fran	SF-Barra	Semidecidual forest/ecological transitional zones	20,904	3.2	526	133	855	101	24.6	0.9	87
S.Fran	SF-Guanabi	Decidual forest	9,172	9.6	852	272	783	121	21.6	1.6	81
Diam	DI-Seabra	Decidual forest/semidecidual forest	45,726	20.2	666	232	794	102	21.8	1.3	47
Diam	DI-Jequitinhonha	Decidual forest	45,590	12.6	659	252	857	78	21.9	1.3	71
Diam	DI-Jequié	Decidual forest	16,451	6.8	448	260	853	202	21.9	1.5	36
Inter	IF-Ribeirão Preto	Semidecidual forest/ecological transitional zones	145,235	4.9	540	196	1308	135	22.0	1.3	70
Inter	IF-Bauru	Semidecidual forest/ecological transitional zones	67,022	4.8	645	218	1327	132	20.2	1.3	59
Inter	IF-Vale do Rio Doce	Semidecidual forest	60,740	10.6	552	267	1268	141	21.8	1.7	78
Inter	IF-Zona da Mata/Viçosa	Semidecidual forest	42,484	9.9	530	331	1288	147	21.1	1.8	71
Inter	IF-Porto Alegre	Semidecidual forest	42,109	5.0	81	101	1425	104	18.8	0.7	12
Inter	IF-Vale Mururi	Semidecidual forest	41,885	12.9	519	248	1034	112	22.6	1.3	63
Inter	IF-Sul de Minas	Semidecidual forest	41,880	6.6	993	175	1525	103	19.2	1.2	75

(continued)

Table 21.2 (continued)

Biogeog. subregions[a]	Sub-divisions	Vegetation	Area (km^2)	Forest (%)	Elevation (m) Mean	Elevation (m) SD	Precipitation (mm) Mean	Precipitation (mm) SD	Temperature (°C) Mean	Temperature (°C) SD	Precipitation seasonality (%)
Inter	IF-Dourados	Semidecidual forest	38,979	4.8	372	93	1471	100	22.8	0.5	39
Inter	IF-Toledo	Semidecidual forest	34,091	9.0	395	119	1643	156	20.1	1.0	24
Inter	IF-Pontal	Semidecidual forest	30,817	5.6	414	92	1259	73	21.6	0.9	43
Inter	IF-Sul goiano	Semidecidual forest	21,158	5.2	554	126	1392	112	24.0	0.9	78
Inter	IF-Cianorte	Semidecidual forest	18,865	4.9	413	114	1381	87	20.8	1.0	31
Inter	IF-Itapemirim	Ecological transition zones	18,187	7.1	634	88	1246	88	19.5	0.8	48
Inter	IF-Três Passos	Decidual forest	16,944	6.0	363	137	1844	76	19.8	0.6	10
Inter	IF-Juíz de Fora	Semidecidual forest	12,358	16.0	608	302	1440	109	20.4	1.6	72
Inter	IF-Iguatemi	Semidecidual forest	11,774	5.5	350	59	1569	47	21.9	0.2	30
Inter	IF-Cerro Largo	Decidual forest	10,814	3.0	294	108	1800	35	20.1	0.6	11
Inter	IF-Rio brilhante	Semidecidual forest/ecological transitional zones	10,455	5.0	345	42	1435	26	23.5	0.2	42
Inter	IF-Oliveira	Semidecidual forest	8,761	8.0	936	112	1444	58	20.0	0.7	82
Inter	IF-Quadrilátero	Semidecidual forest	8,027	17.1	955	156	1426	65	20.1	1.1	86
Inter	IF-Seberi	Decidual forest	6,908	8.1	433	139	1823	40	19.6	0.6	10
Inter	IF-Itararé	Ecological transition zones	6,358	4.9	671	132	1261	49	19.5	0.9	42
Inter	IF-Macaé	Semidecidual forest/restinga	5,404	8.2	20	44	1083	41	23.2	0.3	48
Inter	IF-Vale do Paraíba	Semidecidual forest	5,341	13.1	630	300	1467	162	19.8	1.7	70
Inter	IF-Bodoquena	Decidual forest	5,214	14.8	278	183	1276	45	24.4	1.1	52
S.Mar	SM-Contínuo da Serra Mar	Evergreen forest	88,594	45.5	418	378	1636	333	19.9	2.3	43
S.Mar	SM-Tubarão	Evergreen forest	12,850	20.0	143	198	1442	89	19.0	0.9	21
S.Mar	SM-Ibíuna	Evergreen forest	10,384	17.8	826	91	1622	347	17.5	0.7	54
S.Mar	SM-Bragança	Evergreen forest	8,910	9.1	941	252	1476	166	17.7	1.4	65
S.Mar	SM-Mantiqueira	Evergreen forest	8,206	14.1	776	270	1469	184	18.4	1.5	66
Arauc	AR-Araucária Centro Sul paranaense	Mixed forest	101,587	10.8	822	192	1632	179	17.5	1.2	23

Arauc	AR-Centro riograndense	Mixed forest/decidual forest	56,696	15.3	540	277	1656	182	17.7	1.3	14
Arauc	AR-Oeste catarinense	Mixed forest	23,747	10.3	841	219	1907	170	16.8	1.4	13
Arauc	AR-Noroeste riograndense	Mixed forest	22,511	5.7	702	177	1726	104	17.6	1.4	13
Arauc	AR-Serrana	Estepe savanna	17,672	15.1	1033	191	1651	76	15.5	1.0	13
Arauc	AR-Telemaco Borba	Mixed forest	8,475	8.3	790	114	1438	66	18.4	0.6	27
Arauc	AR-Jaguariaiva	Mixed forest	8,238	8.9	851	166	1339	80	18.1	1.2	39
Arauc	AR-Rio do Campo	Mixed forest	7,460	46.8	679	202	1554	79	17.2	1.0	21
Arauc	AR-Ponta Grossa	Mixed forest	7,167	23.5	825	160	1498	144	18.0	1.0	32
Arauc	AR-Santa Maria	Decidual forest	5,875	8.8	290	92	1760	30	18.9	0.4	7

BSRs are ordered from north to south, and sub-divisions within each of them, were ordered by their sizes. Predominant vegetation cover of each subdivision was obtained from vegetation map available from IBGE (2004). Elevation was obtained from SRTM DEM. Mean annual precipitation, mean annual temperature and precipitation seasonality were obtained from Worldclim database

[a]BSRs abbreviation: *Arauc* Araucária, *Bahia* Bahia, *Diam* Diamantina, *Inter* Interior Forest, *Perna* Pernambuco, *S.Mar* Serra do Mar, *S.Fran* São Francisco

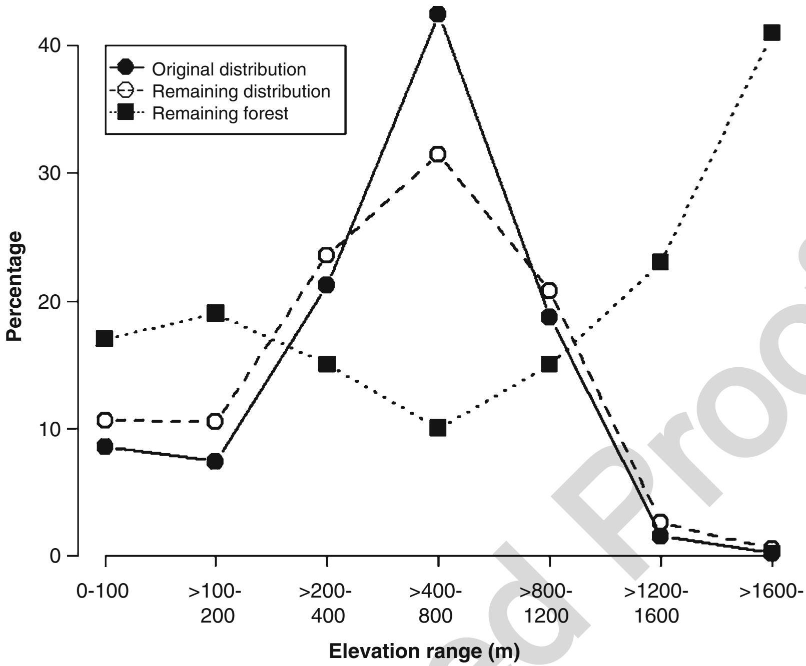

Fig. 21.4 The *circles* indicate the percentages of original and remaining Atlantic Forest distribution across elevation ranges. *Squares* indicate the percentage of remaining forest within each elevation range

solar energy irradiance, net primary production, biomass accumulation (Lu et al. 2002), species distribution (Kappelle et al. 1995), and land cover (Silva et al. 2008; Silva 2010). Since biodiversity is related to vegetation biomass and energy intake, understanding the spatial distribution of a forest in different terrain aspects can help to comprehend forest dynamics, as well as to support restoration programs. The Atlantic Forest relief is not equally distributed, and the aspect parameters vary widely along the biome. Here, we analyzed how the original and present Atlantic Forest remnants are distributed, when considering terrain aspect.

We extracted the terrain aspect parameter from the SRTM 1.4 data. We reclassified the original aspect data according to the eight cardinal directions, and quantified the amounts of original and present forest cover. We also combined this information with elevation data in order to understand how these two variables are influencing Atlantic Forest remains jointly.

The terrain aspect for the original Atlantic Forest distribution varied from 11 to 16% among the eight directions (Fig. 21.5a). No directional trend was observed for the original forest distribution (Rayleigh test, $t = 0.0076$; $p = 0.9445$), although it was slightly skewed towards west. In contrast, the remaining forest differs from the original one (Rayleigh test, $t = 0.5842$; $p = 0.000162$) by having

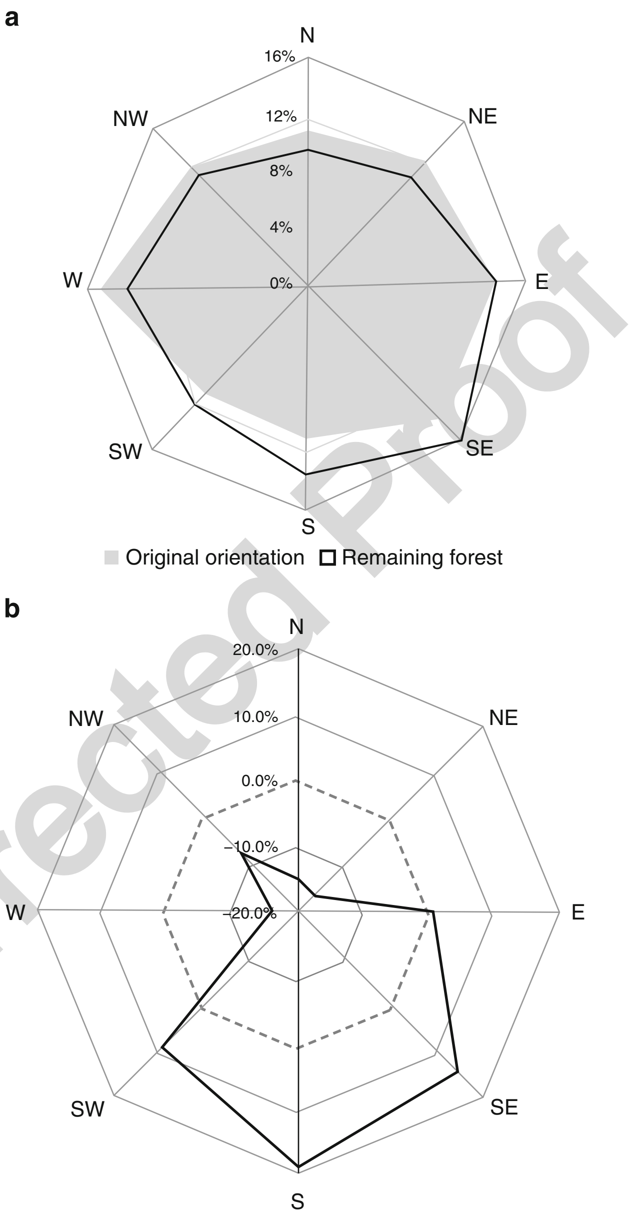

Fig. 21.5 (**a**) Aspect orientation in percentage for the original (*shaded gray*) and remaining (*solid line*) Brazilian Atlantic Forest (summing to 100%). (**b**) difference (in%; *solid line*) between the original and remaining forest distribution within aspect orientation, where positive values indicate less deforestation and negative values more deforestation in relation to the original distribution. *Dashed line* in (**b**) indicates zero difference between the original and remaining forest aspect orientation. Radar graph axis legend: *N* north; *NE* northeast; *E* east; *SE* southeast; *S* south; *SW* southwest; *W* west; *NW* northwest

20% more forests in the South compared to the average remaining Atlantic Forest. The Southeast and Southwest, respectively, show 14% and 9% more forests than on average in the entire Atlantic Forest, corroborating the pattern of more remaining forests southwards (Fig. 21.5b). These results are influenced by the Serra do Mar continuum (more than 1 million ha), which has a large fraction of its terrain facing

South and Southwest. However, and more important, these results reflect a land-use pattern that avoids the south-facing slopes (Mello 2009) due to the lower light intensity, which is less favorable for agricultural production (Silva et al. 2007). This leads to a higher amount of second growth forests given lower land use intensity in these areas.

Superimposing the present remaining forest, to the terrain aspect, and to the elevation zones, the South to Southwest orientations were the most represented for the two elevation ranges that include more forest (401–800 m and 801–1,600 m). In contrast, the elevation range of 0–100 m showed a slight tendency to include more forest in the West aspect direction. This elevation range is largely composed of coastal lowlands with mountains covering their west side that shade them in the evenings, particularly from the central part of the state of Rio de Janeiro toward the southern part of the Atlantic Forest. Other ranges of elevation did not show a predominant direction of terrain aspect.

21.4 The Remaining Forest and Its Spatial Distribution

The Atlantic Forest of eastern Brazil is essentially a complex mosaic of different ecosystems, each of them with a distinct species pool and patterns of human occupation, requiring different conservation and restoration efforts. This complexity and idiosyncrasies need to be clearly considered when conservation measures are to be taken, since precise actions will be extremely beneficial in terms of time and financial needs.

A shortcut to consider these particularities is to analyze the landscape structure, which has been widely used as a biodiversity surrogate in conservation planning (Williams et al. 2002; Lindenmayer et al. 2008), especially where inventory data and ecological information are not available (Fairbanks et al. 2001). Here, we review the available literature on the landscape structural patterns of Atlantic Forest remnants, particularly based on the findings of Ribeiro et al. (2009). We added new analyses and local examples to determine the importance of considering the fine scale in defining regional conservation and restoration planning (Ranta et al. 1998; Teixeira et al. 2009; Barreto et al. 2010). We mainly focused on describing the distribution of forest habitat patches, and did not include information about forest quality and degradation, which would demand a different approach.

21.4.1 Forest Amount

Although the overall amount of remaining Atlantic forest is around 12%, in some regions such as the São Francisco BSR and the Transition Forests the remaining habitat is very limited, as little as 4.7% in the case of the São Francisco (Table 21.3). In contrast, the Serra do Mar BSR has 36.5% of its original extent covered by

Table 21.3 Area of Atlantic Forest (ha and%) remaining in each biogeographical sub-region (BSR) according to Ribeiro et al. (2009)

	Remaining forest		Remaining restinga/mangrove		Total remaining Atlantic forest	
BSR	Area (ha)	%[a]	Area (ha)	%[a]	Area (ha)	%[a]
Araucaria	3,202,134	12.6			3,202,134	12.6
Bahia	2,047,228	16.7	115,059	0.9	2,162,287	17.7
Brejos Nordestinos	13,656	16.0			13,656	16.0
Diamantina	1,109,727	13.5			1,109,727	13.5
Interior	4,807,737	7.0	32,451		4,840,188	7.1
Pernambuco	360,455	11.5	19,363	0.6	379,818	12.1
Serra do Mar	3,678,534	32.2	491,263	4.3	4,169,797	36.5
São Francisco	499,866	4.7			499,866	4.7
TOTAL	15,719,337	11.26	658,135	0.47	16,377,472	11.73

[a]Percentages proportional to BSR area

forests, which makes it by far the best protected BSR. All other BSRs have 12–18% of forest cover (Table 21.3).

Overall, the percentage of forest within the fifth-order SWS is particularly low (Fig. 21.6). SWS with larger proportions of forest (>55%) been found along the coastal mountain ranges of the state of São Paulo, and particularly in the south-coastal region of São Paulo and the coastal region of Paraná. Outside the Serra do Mar BSR, only a few highly forested SWS occur on the south coast of Bahia, in the Iguaçu region in the Interior Forests, and also in the state of Rio de Janeiro (Fig. 21.6).

Landscapes with small amounts of forests (<15%) have been suggested to have biodiversity patterns that are more related to fragment size, since the overall connectivity is generally low to allow forest species to move among fragments (Martensen 2008). Therefore, we expect that in most of the SWS, fragment size would be a good surrogate for species diversity, and the larger patches should be a clear conservation priority. Regions with intermediate proportions of forests (~30%) have been shown to be highly influenced by connectivity patterns (Martensen et al. 2008; Dixo and Metzger 2009; Dixo et al. 2009). Such regions should therefore be targeted to increase connectivity, particularly between large remnants and the surrounding smaller forest fragments, and also to allow connectivity between larger blocks of forests, such as conservation units. Riparian forests, which are legally protected, are especially important and have proved to effectively protect riverine systems (Silvano et al. 2005; Roque et al. 2010), as well as terrestrial ones (Lees and Peres 2008).

21.4.2 Land Use Types

Since most of the Atlantic Forest is very close (<150 m) to forest edges, and thus to human modified ecosystems, land use has a very important influence in biodiversity conservation. Sugarcane, for instance, was the first crop to be planted extensively

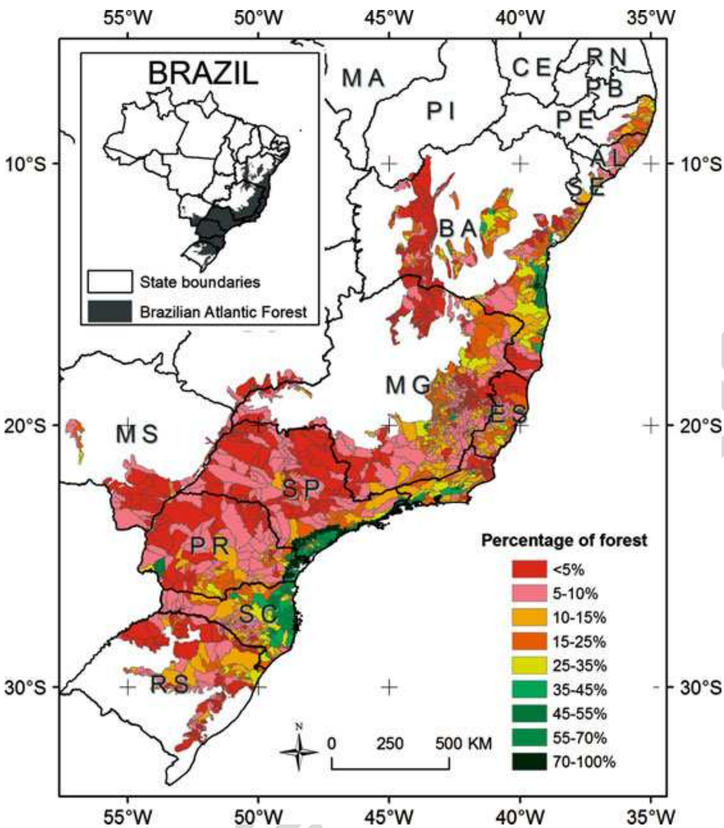

Fig. 21.6 Percentage of remaining Brazilian Atlantic Forest within the 2,650 sub-watersheds of order 5a, as proposed by Pfastetter (1987)

in the Atlantic Forest, beginning early in the sixteenth century and starting an intensive forest conversion process. Later, coffee plantations in the states of Rio de Janeiro, São Paulo, and Paraná pushed the logging frontier forward. Today, sugarcane, pastures, *Eucalyptus* and Pine plantations share the landscapes that were formerly covered by the rich Atlantic Forest. Farm sizes vary according to the region, and are usually larger in favorable sites for modern agriculture. Oliveira Filho and Metzger (2006) observed that for Amazonian regions, large properties, usually present larger and more isolated fragments, when compared to smaller ones, which present fragments of smaller size and more connected by corridors or by close proximity to others, a pattern which is usually corroborated elsewhere. Since the early economic cycles in Brazil, the general agricultural pattern has been based on large monoculture properties and even today, this pervasive system continues, with high land concentration, since 15% of the properties cover more than 75% of the country's farmland (IBGE 2006). Large landowners usually occupy the best farmland, flat or gently sloping (<15%), leaving the steep hills for the small farming families. Small farms comprise more than 84% of the properties, but cover only around 24% of the agricultural land (IBGE 2006). Although occupying less than one-fourth of Brazilian farmland, small family properties are responsible for around 80% of the country's food base, sustaining the country food sovereignty (IBGE 2006). However, in flat areas where mechanization is possible, sugarcane plantations have taken over the land for biofuel (Lapola et al. 2010), which should actually be termed agrofuel (Altieri 2009a, b), also accompanied by soybeans and other large scale crops, including outsized pasture lands.

Following this general deforestation pattern, different types of matrix (i.e., non-forest; Gascon et al. 1999) were established in the Atlantic Forest region (Ribeiro et al. 2009 suppl. material). Cattle ranching and agriculture are the two predominant matrices found in the biome, and particularly cover a large part of the Interior Forest sub-region. In the Araucaria and southern Bahia sub-regions, forestry plantations (*Pinus* and *Eucalyptus*; Fonseca et al. 2009; see also Ribeiro et al. 2009 suppl. material) are among the most important types of matrix, although agriculture and ranching are predominant. The state of São Paulo is particularly covered by sugarcane plantations, which still expanding (Rudorff and Sugawara 2007; Nassar et al. 2008), pastures (Brannstrom 2001; Durigan et al. 2007), and a growing number of *Eucalyptus* plantations. The Pernambuco sub-region is also dominated by pastures and agriculture fields, with dominance of sugarcane plantations (Trindade et al. 2008; Kimmel et al. 2010; Silva 2010). AU1

Traditional sugarcane harvesting is based on burning the crop, which causes problems of air pollution and also accidental spread of fire into the surrounding forest fragments (Durigan et al. 2007). The mechanization of sugarcane harvesting, while diminishing previous impacts, including the reduction of inhumane working conditions (which caused deaths and severe health problems, Silva 2008), has also caused a reduction in the connectivity between forest fragments, since isolated trees have been cut down to facilitate mechanical harvest. Isolated trees considerably increase the connectivity between fragments (Harvey et al. 2004), and thus their loss should be properly compensated by additional connectivity features such as corridors, which can compensate the homogenization caused by sugarcane plantations, especially in the state of São Paulo. Similar recommendations for conservation can be made elsewhere, especially when forest fragments are already interspersed among the plantations or pastures.

Recently, vast *Eucalyptus* plantations are gaining ground, based on huge well-capitalized corporations from other economical fields that possess the financial power to acquire vast landholdings. These corporations have focused on acquiring the cheap small hilly properties, as forestry technologies evolve to operate on steeper terrains. This process has contributed to urban growth through intensifying migration to urban areas. Forestry has proved to be the "beauty" in some cases where good ecological management practices are employed (Fonseca et al. 2009). In other cases, unfortunately more common nowadays, is proved to be "beast," where management is only focused on high productivity not always sustainable in social and environmental aspects (Zurita et al. 2006). Large plantations of a few clones, short cycle rotation, understory cleaning, and intense chemicals use are among the most common practices employed in modern forestry, which are detrimental to environmental conservation.

Another large fraction of the farmland in the Atlantic Forest is covered by pastures. Most of them are lightly managed, and still containing scattered trees that sometimes form small forest patches in different early successional stages. Intense debate is occurring about the conversion of these areas into intensively managed fields, especially sugar cane, with claims that this will allow higher production and economic gains. Besides, the clear positive financial advantages of these proposals, negative aspects such as decreasing matrix permeability, increasing dependency on non-renewable resources, and increasing the use of chemical products, as well as the far-reaching social impacts of these agricultural practices will occur in the Atlantic Forest region, while the benefits will be felt mostly elsewhere, such as lowering habitat conversion in the Cerrado and Amazon, since habitat conversion in the Atlantic Forest is already low. From another side, in order to access water, cattle cause large impacts in riparian forests and riverine systems, which could reduce their potential to promote corridor connections between fragments. Moreover, fire is also commonly employed as a management technique in pastures, which, in combination with cattle occurrence in the surrounding fragments, results in the degradation of nearby forests.

21.4.3 Number of Forest Fragments and Their Size

The Atlantic Forest is patchily distributed in 245,173 forest fragments of varying size. Although some large fragments still exist, such as those that extend along the coastal mountains of southeast Brazil, especially in the states of São Paulo, Paraná, and Santa Catarina, most of the forest fragments (83.4%) consist of patches smaller than 50 ha, which is expected to severely compromise biodiversity conservation (Lindenmayer et al. 2006; Laurance et al. 2007). Only 77 fragments (0.03% of the total fragments) are larger than 10,000 ha, which highlights the very poor conservation condition of the unique Atlantic Forest biota.

In all BSRs, small fragments (<50 ha) were by far the most numerous ones. The most distinct pattern occurs in the Serra do Mar region, which in addition of having the largest fraction of fragments smaller than 50 ha, similarly to the other regions, has more than half of its forests in large fragments (>50,000 ha). Moreover, this region is the only one that contains a forest fragment larger than 1 million ha, and also contains the second and third largest fragments of the entire remaining Atlantic Forest. In all other regions, the largest fragments are <250,000 ha, and only the Araucaria Forest ($n = 4$) and the Interior Forest ($n = 1$) also contain fragments >50,000 ha, respectively, the inland forests of Santa Catarina, including the São Joaquim National Park, and the Iguaçú National Park in Paraná. In the Bahia BSR, the largest patch has approximately 29,000 ha, while in the São Francisco and Pernambuco none exceeds 10,000 ha, and in Diamantina none is larger than 25,000 ha.

21.4.4 Forest Core and Edge Area

Landuse patterns in the Atlantic Forest region have generated intensive fragmentation, resulting in an impressive amount of forest edges. Today at least 73% of the remaining forest is located less than 250 m from any forest edge and 46% is less than 100 m apart from any edge. Only 7.7% is located farther than 1,000 m, and around 12 km is the longest distance that one can penetrate into the forest from any edge. The pattern is similar for every BSR, again with the exception of the Serra do Mar. Whereas all BSRs have edge forests (100 m from edges) in amounts of at least 40% to as high as 60% in Pernambuco, Serra do Mar has only 25% of its remaining forest less than 100 m from forest edges. This relatively small edge effect is reflected in the higher proportion of core areas, i.e., more than 256,000 ha farther than 2.5 km and almost 57,000 ha farther than 5 km from edges. The largest block in the Atlantic Forest is located in the Serra de Paranapiacaba, in the state of São Paulo, Serra do Mar BSR, which together with the Iguaçú National Park in the Interior BSR are the only two fragments that have forests deeper than 12 km from any edge.

21.4.5 Connectivity Patterns

The capacity of a species to cross open areas is directly associated with its potential to maintain sustainable populations in the present fragmented conditions of the Atlantic Forest. Species that are not able to cross open areas, i.e., obligate forest species, have a functionally connected mean area of only 64 ha, while a species that is capable of crossing 50 m have a mean functional area of around 200 ha. The largest functionally connected cluster for species capable of crossing 100 m comprises the largest fragment of the Serra do Mar and the nearby fragments. All together, this cluster totalizes more than 2.8 million ha (18% of the total remaining forest), and stretches from the state of Rio de Janeiro all the way south to Rio Grande do Sul, comprising the largest "corridor" of the Atlantic Forest. In the Bahia region, species that can cross short gaps such as 100 m can reach a functional area of 50,000 ha (17% of the remaining forest in the region). In the other BSRs, the distances to reach a functionally connected area of this size are always large, up to 400 m in the São Francisco and more than 500 m in the Pernambuco BSRs.

The mean distance between fragments in the entire Atlantic Forest is around 1,441 m, but it varies widely. The importance of the small fragments in reducing isolation is enormous. For example, when fragments $<$50 ha are excluded, the mean isolation increases to 3,532 m, and when fragments smaller than 200 ha are excluded, the mean isolation reaches more than 8,000 m, which highlights the immense importance of these fragments in sustaining viable populations in the region. This is vital in all regions, but it is particularly important in the São Francisco and in the Interior Forest, although of less importance in the Serra do Mar, since most of the remains are clumped in one or a few large fragments.

21.4.6 The Role of Nature Reserves in Protecting Atlantic Forest Biodiversity

Brazil and South America have the world's largest proportion of land in protected areas (Brockington et al. 2008). However, this proportion increased in the last two decades, when the Atlantic Forest biome had already been turned into a myriad of fragments of varying sizes, and thus, beneficiated mainly the Amazonian region. Therefore, the today's total protected area of the Atlantic Forest is approximately 2.26 million ha, which represents only 1.05% of forests of the original cover distribution, way below the 10% recommended by the Global Strategy for Conservation (Secretariat of the Convention on Biological Diversity 2002; Rodrigues et al. 2004). Nature reserves protect 9.3% of the Atlantic Forest remnants, however, differently according to the regions. The Serra do Mar BSR, for example, which is by far the best protected one, has approximately 25% of its remaining forests under some type of restriction. This represents only 8.11% of its original cover, stills lower than the 10% target (Secretariat of the Convention on Biological Diversity 2002). All other BSRs present lower amounts of remaining forest preserved, such as the Interior Forests (6.8%) and Bahia (4.2%), and all others have even less than 4%. Today, restrictive legislation protects all the Atlantic Forest remnants (Lei da Mata Atlântica); however, law enforcement is negligent even in some of the Conservation Units.

Some reserves are contiguous, and thus we could identify seven large protected regions with areas around 100,000 ha. Five of them are in the Serra do Mar region: (1) Serra do Mar State Park, SP and Bocaina National Park, SP/RJ; (2) the former Jacupiranga State Park, SP, which today is a mosaic of Integral Protection and Sustainable Development units, and Superagui National Park, PR; (3) the Paranapiacaba continuum, composed of the PETAR State Park, Intervales State Park, Xituê Ecological Station, and Carlos Botelho State Park, all in the state of São Paulo; (4) the Serra do Tabuleiro State Park, SC; and (5) the Juréia mosaic, composed of the Banhados de Iguape Ecological Station, Juréia-Itatins Ecological Station, Itinguçu State Park, and Prelado State Park (SP). Recently, this last region has been the focus of intense debate between stakeholders, local communities, conservationists, and people involved in urban development, and the limits of the conservation units might be modified in the near future, to accommodate different interests in the region. The two other regions of large blocks of Nature Reserves are in the Interior Forest, the Iguaçú National Park (PR), the most important remnant of the interior forests; and in the Diamantina region, where the Chapada Diamantina National Park encompasses a considerable mosaic of open habitats, more related to the Cerrado biome, and some forest blocks. Together these large blocks of Nature Reserves encompass 1,212,800 ha, which comprises 53.6% of all protected areas. Moreover, 17 reserves range in size from 20,000 to 60,000 ha, also a considerable size in the today's scenario, and represent an additional 26% of the total forest under protection; these reserves are particularly located in the Interior, Serra do

Mar, Bahia, and Araucaria centers. The remaining forest under protection (~20%) is scattered in small reserves in all the Atlantic Forest regions.

Of the remaining forest outside the conservation units, only 22.6% is located within 10 km of any nature reserve, whereas 61% is farther than 25 km. The patterns within the biogeographical regions are similar, again with the Serra do Mar as the sole exception, where almost 60% of the remaining forest is less than 10 km from conservation units, which provides these forest fragments with some connectivity to large blocks of preserved forests.

21.5 Conservation of Marginal Habitats

It has been shown that for conservation purposes, the Atlantic Forest should be treated as a whole; including both rainforest and non-rainforest covers (Scarano 2002, 2009). Marginal habitats are extensions of the core rainforest and also serve as a buffer zone for it, because of the intimate floristic relationships that they maintain and also the animal transit between them, despite marked fragmentation. Since landscape history affects the present distribution pattern of species in fragmented landscapes, this history should be considered in conservation planning (Metzger et al. 2009). Interestingly, as seen in the above data, there is also a strong bias in the distribution of conservation units between forest and non-forest habitats of the Atlantic Forest biome. Rocky outcrops, above the tree line or on inselbergs, are mostly well protected and maintain a fauna and flora that is often relict and highly endemic, but has many close relatives within the neighboring rainforest. Lowlands, conversely, are poorly protected. Restinga vegetation is often replaced by housing and touristic complexes, because of the obvious attractiveness of the Brazilian coast. Swamp forests have been widely affected by drainage, either due to replacement by agriculture or efforts to eradicate tropical diseases in the early twentieth century. The fact that these types of habitats have lower species richness and lower rates of endemism than thus the core rainforest does not help either, and makes them less of a priority, particularly when the conservation currency is merely quantitative, counting the number of species and the number of endemics, and not considering genetic particularities present in this areas. Restingas and swamps are geologically younger, and most species found in these areas are from the rainforest. However, the stressful nature of these habitats has promoted the expression of plastic types of the original rainforest species, which are living evidence of what is perhaps the rainforest's main treasure: its genetic diversity (Scarano 2009).

A sad example of the failure of the legal system to treat the Atlantic rainforest as a whole, i.e., to include non-rainforest vegetation types, has been reported by Sá (2006). The peculiar coastal dry forest found in Búzios municipality in the state of Rio de Janeiro is a relictual vegetation that much resembles physiognomically the *caatinga* vegetation found in the semiarid region of the Brazilian northeast. Previous efforts to classify Brazilian vegetation types have labeled Buzios dry forest as a *caatinga* vegetation type, thus not protecting this highly touristic attractive regiont under the "*Lei da Mata Atlântica*," since it was classified as caatinga. However, Sá (2006) has shown that the floristic similarity between the dry forest and the Atlantic Forest is over 80%.

We make three recommendations for a conservation strategy that is more inclusive of marginal habitats (1) laws must be enforced and government must lead in providing good examples. Brazil has a sad record of not compensating landowners when their lands are seized for protected areas; (2) private protected areas have a successful history in the Atlantic Forest biome, and should be further supported; (3) the design of future protected areas and of future restoration initiatives should aim to promote connectivity not only along the forest–forest axis, but also along the forest-sea axis.

21.6 Ecosystem Services and Forest Restoration

Beyond the conservation of species richness and endemism, the interactions among species and between species and the abiotic environment support, regulate, and provide the services and cultural benefits that people derive from biodiversity (Benayas et al. 2009; McNeely et al. 2009). For instance, although not much is left of the Atlantic Forest biome, the existing remnants safeguard freshwater, climate, and food production, among other securities. The water available for the nearly 50% of the Brazilian population that lives in coastal regions, including large cities such as Rio de Janeiro and São Paulo, either springs from or is bordered by Atlantic Forest. The emerging carbon market indicates that these remnant forests not only ameliorate local climate in an otherwise fully urban landscape, but might also contribute significantly to the global carbon balance. Pollination, pest control, and erosion regulation are all provided by natural remnants of the Atlantic Forest. Furthermore, most of the cities are surrounded by forest fragments, and people use these natural areas for recreation.

Of course, reduced and fragmented as it is now, the provisioning of all such essential services for human well-being is under serious threat. Most of the Atlantic Forest is less than 200 m from any forest edge (Ribeiro et al. 2009), and therefore 200 m from a land-use area. More than 100 million people live in the region formerly covered by Atlantic Forests, in both rural and urban areas, including more than 3,000 cities and extensive agricultural fields and grazing land. Moreover, most of the remaining Atlantic Forest was already clear-cut or severely altered by humans, some parts even before European colonization. Finally, almost all of the remaining forests are located on private land; some of them have people living there or somehow related to the area. All of these reasons make it imperative to consider the human perspective in any conservation plan for the Atlantic Forest region.

Recently, Ribeiro et al. (2009) exposed the precariousness of the Conservation Unit System in the Atlantic Forest, which protects around 1% of the original vegetation. The need to expand this system is obvious. However, the efficiency of the existing units is already questionable, since most of them have problems in reaching their conservation targets. The several reasons for this include problems with unit protection and management, and also with the relationships with the surrounding human communities. Moreover, indigenous peoples have been moving to Conservation Units (Cardoso Island State Park and Intervales State Park in the state of São Paulo are two examples), since they are the only places remaining where they can maintain at least some of their original culture, and that are not private lands. This development has posed a challenge to conservationists, to modify their ways to deal with traditional peoples inside conservation units, since both groups have similar goals.

Presently, more than 90% of the remaining forests, including almost all the deforested areas, are located on private land. Therefore, conservation management must be adapted to these conditions. Forest restoration has been suggested as one of the key actions to be implemented in order to achieve Atlantic Forest conservation (Ribeiro et al. 2009; Rodrigues et al. 2009). However, effective means to engage people in landscape management and forest restoration are still lacking (Rodrigues et al. 2009). The estimated amount of forest that must be restored merely to comply with current Brazilian environmental legislation and also to restore agricultural areas that are not prone for adequate land use management (like degraded pastures in steep relief) is immense, and 15 million ha is expected to be restored up to 2050 (http://www.pactomataatlantica.org.br). Except for a few large (hundreds of hectares) restoration projects (see examples and different experiences in Rodrigues et al. 2009), most of the experiments are small and locally focused, and have not published their results and/or properly monitored their programs. This lack of information makes it more difficult to reach appropriate conclusions to help with future restoration actions (Rodrigues et al. 2009). An important rural economy could be enhanced by a massive restoration program in the Brazilian Atlantic Forest, since seed collection (see example in Instituto Refloresta, formerly Ecoar Florestal, www.refloresta.org.br), sapling production in community nurseries, and restoration implementation and maintenance could be conducted by small local farmers as a source of supplementary income. We also suggest that our biogeographical subdivision could be used as an initial surrogate to define regions to collect seeds for restoration projects, since local adaptations could have arisen from local selective pressures for different species.

Large landowners who produce agricultural commodities that are largely exported to Europe and North America as well as used in the local economy, should be obligated to comply with the environmental regulations, including taxation and moratoriums on products that excessively impact the environment. The Amazon Soy Moratorium appears to have had some relative success, and could be even more efficient in regions where the land-use patterns are better established. Small landowners should receive governmental incentives to environmentally improve their properties, including payment for environmental services, abundant technical and financial support for forest restoration, and relaxation of the laws regulating agroecological activities in key areas not yet covered by forests, particularly focusing forest restoration. Areas along the rivers are a main priority, since they can link fragments, allowing populations to maintain themselves in functionally connected fragments (Martensen et al. 2008); as well as protect river systems (Silva 2003).

21.7 Agroecology: Opportunities for Atlantic Forest Conservation

Agroecology, now at the fore of the conservation debate, has proved to enhance food production, biodiversity conservation, and poverty alleviation (Jose 2009). Tropical countries in general are particularly favorable for agroecological production, because of particular social and environmental aspects. Steeper and higher areas usually have larger amounts of forest (see above), and are usually occupied by family raised farms. These areas should be the focus of governmental efforts to make production in agroecological systems viable. The possibility of realizing profits from the multiple gains of this type of system should be explored. For example, ecosystem services such as those related to the maintenance of water quality and quantity, minimization of erosion, and biodiversity conservation (reviewed in Jose 2009 and Benayas et al. 2009) must be evaluated. Also, some effort must be made to aggregate better values to forest products, which are largely free of chemicals and could be produced with low impact. In some cases, restoration methods should be conceived in order to allow economic outputs for farmers, especially in the initial stages of succession, when diminishing costs is imperative to reach the large scale restoration needs in the Atlantic Forest. Moreover, restored forests could be manage to generate incomes out of timber and specially non timber products, including fruits, honey, medicines, seeds, and others. Timber production in diversified plantations of native trees should act as a permeable matrix for forest species, in the same time that reduces the demand of the mostly illegally harvest Amazonian wood.

Changing the common concept of forests as unproductive areas is imperative to protect Atlantic Forest biodiversity. There are many examples of agroforest systems in every region, which stand out as highly productive systems with low environmental impact. Among the better known are the "cabrucas" on the south coast of Bahia (Alvim and Nair 1986; Schroth and Harvey 2007), where shade cocoa is planted and the environmental benefits over other production systems have been largely explored (Pardini et al. 2009). In the Ribeira Valley located in the Serra do Mar BSR in São Paulo (REBRAFE 2007), there are also some very good examples of highly diverse and productive systems, which produce many agricultural goods and fruits, as well as forest products. Examples in the Interior Forests are also abundant, such as in the Pontal do Paranapanema (Cullen et al. 2004). In the Araucaria subregion, systems that mix trees, such as the *Araucaria angustifolia*, and pastures, locally called "faxinais," are widespread. Also in southern Brazil there are some examples that combine timber trees, perennial cash crops, and the South American holly (*Ilex paraguariensis*) (REBRAFE 2007). Some experiments have been indicating a good potential to the use of agroforests as elements to improve connectivity between fragments (Cullen et al. 2004; Uezu et al. 2008; Pardini et al. 2009), to decrease edge effects by functioning as buffer zones (Cullen and Fenimore 2002; Cullen et al. 2004), to reduce soil erosion (Franco et al. 2002), to increase soil fauna (REBRAFE 2007) and biodiversity in general (Schroth et al. 2004; McNeely and Schroth 2006; Jose 2009), and also to increase soil fertility (REBRAFE 2007). Vieira et al. (2009) emphasized the contribution of agroecology techniques as a transition phase that stimulates early forest restoration with a so called "agrosuccessional" restoration strategy, which has been used as a way to induce landowners to restore forests. The social aspects of agroforest systems in the Atlantic Forest are also normally evaluated, and enormous benefits have been reported (Franzen and Mulder 2007; Vieira et al. 2009).

21.8 Conclusions

The Atlantic Forest region is one of the top world's hotspot for biodiversity conservation, and should be a global target for conservation. In this chapter, we explored the characteristics of the biota and the forest distribution, pointing out some weaknesses in its conservation. Most importantly, we presented clear objectives to be aid in its conservation agenda.

A great cause of concern is the rapid expansion of large monocultures, particularly sugarcane and *Eucalyptus* plantations, which could threaten the last forest remnants, in particular by decreasing connectivity between them and causing additional edge effects, especially in the case of agricultural land uses. Moreover, the expansion of these systems had intensified migration of people from rural to urban areas, which has had additional environmental impacts on urban areas.

One key point is that Atlantic Forest conservation is impossible without a clear consideration of the human role, since most of the remaining forest is located on private lands. An effective Atlantic Forest conservation plan should start with making the approximately 110 million people now living in the region aware of its global importance and its present fragile situation. Such a plan should target the preservation of the last large remnants, but should also incorporate agricultural land, within a fragmented landscape management perspective. Small family farms are usually located in steeper areas where forest remnants are usually more abundant, and where low impact agricultural production could be both socially and environmentally beneficial. Restoration should be a clear target, and an immense reforestation effort should be made, focusing on creating clusters of fragments that are functionally connected, particularly by riparian corridors, which can produce multiple benefits. Payment for ecosystem services should be rapidly implemented in certain key conservation regions, which will probably foster conservation on small properties.

Despite the unsatisfactory present state of conservation, the Atlantic Forest still harbors a huge amount of biodiversity, including many endemic species. Urgent conservation actions should be taken focusing on clear targets, in order to promptly implement management plans and avoid massive loss of biodiversity. Some steps are presented here, and we urge that they be taken sooner rather than later.

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Chapter No.: 21

Query Refs.	Details Required	Author's response
AU1	The citation "Rudorff and Sagawara 2007" (original) has been changed to "Rudorff and Sugawara 2007". Please check if appropriate.	