International
Journal of
**Biological
and Natural
Sciences**

DETAILED MAPPING OF THE LANDSCAPE IN A "HOTSPOT" OF FOREST DIVERSITY ON THE SOUTH COAST OF BAHIA

Gil Marcelo Reuss-Strenzel
Universidade Estadual de Santa Cruz - UESC
Ilhéus - BA, Brazil

Deborah Faria
Universidade Estadual de Santa Cruz - UESC
Ilhéus - BA, Brazil

Abstract: The ``Costa do Cacau``, located on the south coast of Bahia, is one of the forests stretches with great emphasis on conservation, considered a forest diversity hotspot and an endemic center for several species of fauna and flora native to the Atlantic Forest, with the stretch of most representative forest still present in northeastern Brazil. One of the peculiar characteristics of the forest cover of the landscape in the cocoa region is that it is composed of native forests in different successional stages inserted in an anthropized matrix with forest characteristics, formed by shaded cocoa and rubber plantations. Due to the high structural complexity of the mosaic, there are serious difficulties in mapping these forest categories by remote sensing, despite the strategic importance of a detailed cartography in proposing conservation strategies. In this context, aiming to fill this gap by producing a detailed map of vegetation cover and land uses on a 1:10,000 scale in two landscapes with different occupation histories and levels of anthropization, in addition to carrying out a comparative diagnosis of forest fragmentation native in two landscapes totaling 303,807 ha. The mapped surface of the northern landscape (N), most of which is located in the municipalities of Una and Ilhéus, covers 101,899.2 ha, partially protected by two Conservation Units (CUs): the Una Biological Reserve (RBU) and the Refuge of Una's Wild Life (RVSU). the mapping of the southern landscape (S) covers 201,908.4 ha inserted mainly in the municipalities of Belmonte and Mascote. The cartography was performed by visual interpretation and vectorization of high-resolution images obtained by the QuickBird, WorldView-1, WorldView-2 and RapidEye sensors and covered a surface of 303,807.7 ha. ArcMap's V-Late extension was used to calculate fragmentation and isolation indicators of patches of native forest vegetation in the medium and advanced stages of regeneration. Although both landscapes show similar fragmentation indicators, the landscape to the north, partially protected by the UCs, has larger spots and a lower degree of isolation, compared to the landscape to the south, where there is no protection.

Keywords: Atlantic Forest, ``Costa do Cacau``, Una Biological Reserve, Una Wildlife Refuge, landscape.

INTRODUCTION

The southern region of Bahia is known for harboring one of the most distinctive and rich flora and fauna in the world, which together comprise an important center of endemism (Dietz et al. 1996). The original vegetation is classified in a subtype of Atlantic Forest called "Dense Ombrophylous Forest of Lowlands", which accompanies the entire Brazilian tropical coast and is locally associated with the Coastal Plain and outcrops of the Barreiras Group. It is a vegetation of high structural complexity, with a closed canopy and the formation of rainforest environments (Mori et al. 1983). Despite suffering an intense process of deforestation over the centuries, the South Coast of Bahia still harbors the largest continuous area of forests in this biome in northeastern Brazil (Ribeiro et al., 2009).

The remaining forest cover is composed of a complex mosaic that includes native forests in different successional stages and agroforests, formed mainly by shaded plantations of cocoa (Theobroma cacao) and rubber tree (Hevea brasiliensis). Cocoa cultivation employs a shaded agroforestry system, known locally as cabruca, in which the understory of the native forest is completely replaced by cocoa trees and part of the native canopy trees are maintained to shade the crop. It is a crop that serves as habitat for a significant part of the native species of fauna by maintaining the forested aspect of the landscape. Without harboring, however, the same biodiversity

as the original Atlantic Forest. Even so, the cabruca contributes to the connection of forest remnants, due to its structural characteristic analogous to a forest (Schroth, et al., 2011).

The region, therefore, is of great importance for conservation, since it is a hotspot of biodiversity and endemism of tree species of the Atlantic Forest (Thomas et al., 2008), partially protected by two Conservation Units: The Biological Reserve of Una and the Una Wildlife Refuge. Efforts to map vegetation cover and land use at a scale of 1:100,000 were carried out using Landsat TM images (Landau et al., 2003). However, cartography is not current and independent field verifications have shown that its accuracy is reduced. Recently, the MapBiomas project tried to map the ``Costa do Cacau`` at a scale of 1:100,000, using the Google Earth Engine (GEE) platform. However, the first version of the mapping has proven to be poorly suited to support studies at a local scale (Fonseca et al., 2023).

Considering such gaps and with the aim of supporting the design and execution of experiments capable of answering questions related to the preservation of biodiversity and management of the UCs, we elaborated a cartography in detail scale of the vegetation cover and land uses, in addition to a diagnosis of the state fragmentation of native forest vegetation.

METHODOLOGY

Two landscapes located on the south coast of Bahia were mapped. The northern landscape (N), delimited by the coordinates 15°2'S to 15°23'S and 39°W to 39°18'W, covers part of the municipalities of Una, Ilhéus, Buerarema and Santa Luzia, including the surroundings of two important Conservation, the Una Biological Reserve (RBU) and the Una Wildlife Refuge (RVSU). The landscape located to the south covers part of the municipalities of Mascote, Canavieiras, Belmonte, Camacã, Potiraguá and Itapebi, being delimited by the coordinates 15°30'S to 16°S and 39°15'W to 39°38'W (Figure 1).

Mapping was carried out in a GIS environment by vectorizing polygons, based on the visual interpretation of high-resolution orbital images, using the ArcMap software, through the following steps: (a) search and acquisition of images of the areas of interest available in the catalog ; (b) preparation of a geographic database including images and field truth points; (c) definition of a classification system (legend) for the identified thematic classes; (d) training of technicians responsible for vectorization; (e) identification of continuous spots observed in the 1:10,000 scale images by visual interpretation, based on characteristics of the spots such as: coloration, texture, shape, position and context; (f) delimitation and classification of patches by editing polygonal vectors; and (g) validation of the classification based on field truth.

The vectorization process was performed using QuickBird, WorldView-1 and WorldView-2 (4-band mode) images, obtained in 2011, for the northern landscape, and RapidEye images, obtained in 2010, for the southern landscape. To facilitate the visual interpretation of the images, true color compositions were created using bands in the visible range and false color using bands in the visible and near infrared range. The classification was based on the system proposed by IBGE (2006), for purposes of comparison with similar cartography, such as the map proposed by Ribeiro et al. (2012) for the extreme south of Bahia (Table 1).

Once the mapping was completed, the ArcMap Vector-based Landscape Analysis Tools Extension (V-Late) (Lang and Blaschke, 2007), available on the ArcGis Hub (https://hub.arcgis.com), was used to estimate fragmentation and connectivity indicators

of forest vegetation patches in advanced and medium stages of regeneration (Table 2). The purpose was to verify the role of the UCs in the preservation of the original structure of the landscape

The estimated fragmentation and isolation indicators were: number of patches, total area of patches (ha), area of the largest patch (ha), average area of patches (ha), total area of patch cores (ha), proportion of area -nucleus (%), average area-to-perimeter ratio, average nearest neighbor distance (m), average nearest neighbor area (ha).

RESULTS AND DISCUSSION

The total surface mapped was 303,807.7 ha, divided into 101,899.2 ha in the North landscape (N) and 201,908.4 ha in the South (S) (Figure 1). The thematic classes mapped are described in Table 1 and a comparison of their representativeness is presented in Figure 2. Table 2 presents the results of the analysis of fragmentation and isolation.

The northern landscape is characterized by a greater representation of native tree-sized forests, with almost half of the area (48%) occupied by forests in the initial, medium and advanced stages of succession, in addition to tree sandbanks. On the other hand, native forests occupy a reduced area in the southern landscape (34%), where around 60% of the coverage is made up of pastures, resulting in the predominance of open areas. If we compute the areas occupied by cabrucas and rubber trees, the forest cover of the northern landscape reaches almost 63% of the mapped total. On the other hand, in the southern landscape, eucalyptus monocultures represent only 5% of the mapped area. Therefore, although they are environments with forest characteristics, they do not significantly contribute to an increase in the forest mosaic in this sector. However, it must be noted that the proportion of native forests remaining in

the southern landscape is greater than what is generally found in the Atlantic Forest as a whole (Ribeiro et al. 2009).

Most of the patches of native vegetation in both landscapes are composed of medium and advanced stage forests, which draws attention to the importance of this region as one of the last representatives stretches of this Atlantic Forest biome in northeastern Brazil. Particularly in the northern landscape, the large representation of anthropic environments, however with relatively complex forest structure such as cabrucas (11%) and rubber trees (5%), consist of habitats with high potential for use by species of native fauna, giving the landscape a greater structural continuity, which favors the movement of biodiversity (Schroth et al., 2004; Faria et al. 2007; Cassano et al. 2009; Pardini et al. 2009).

The biota uses different forest types in an idiosyncratic way. Structural differences between forest categories, important to determine the potential use of each habitat by the different species that make up biodiversity, are often too subtle to be detected during mapping. Native forests in early stages of succession and cabrucas harbor together a great wealth of native species, which are also present in mature forests. However, a significant portion of biodiversity is only found in forests with greater structural complexity (Cassano et al., 2009).

Therefore, a precise interpretation of the degree of fragmentation and isolation and the representativeness of different categories of forest in this mosaic is of paramount importance for us to understand characteristics such as availability and spatial distribution of habitats that are important for the persistence of native species. On the other hand, such structural similarities of the forest mosaic make its mapping extremely difficult, since many of the spectral responses of
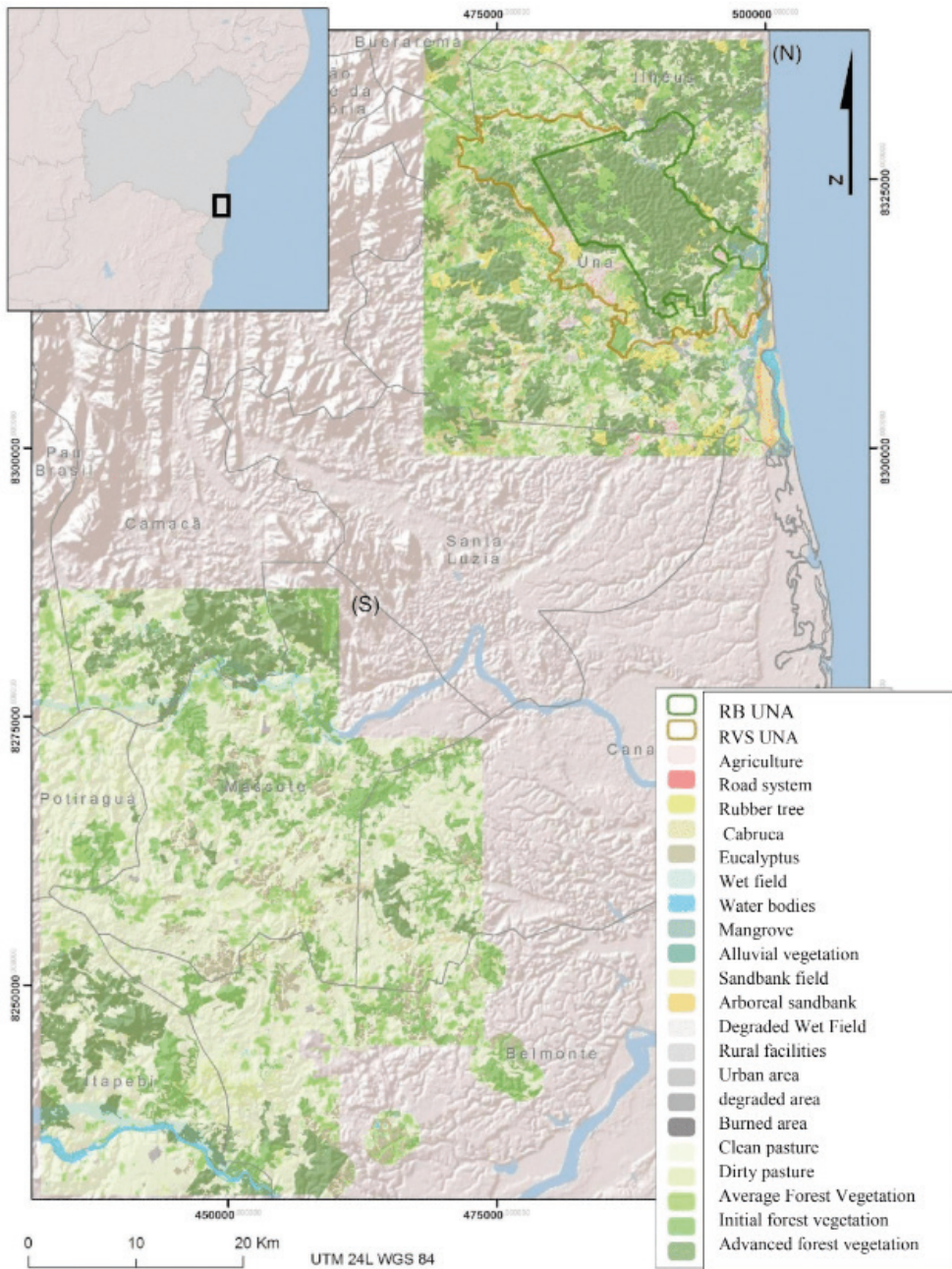
Figure 1: Maps of vegetation cover and land use in the north (N) and south (S) landscapes, superimposed on a shaded relief model and the political map of the municipalities of Bahia.

Land use class	Characteristics
Agriculture	Areas dominated by agricultural crops such as coffee, bananas, coconuts and vegetables.
Degraded area	Areas with exposed or degraded soil. E.g. loan boxes, trampling areas, gullies, landslides, slopes, etc. Occasional occurrence of limited scope.
Urban area	Urban centers or residential areas with a concentration of residential and commercial buildings, as well as access roads, among other structures.
Cabruca	Traditional shading cocoa cultivation system, in which the forest understory is removed and the canopy is thinned. Cocoa cultivation in cabruca takes place under the shading of approximately 25 native trees, for hectare.
Sandbank field	Herbaceous vegetation present in sandy ridges characteristic of sandbank formations, originated by the retreat of the sea recorded during the Holocene.
Wet field	Flooded happening in places where there is constantly a vegetation.
Degraded Wet Field	Pioneer herbaceous or shrubby vegetation in flooded areas degraded after clear cutting of alluvial tree communities. Extreme cases of degradation, where the region is dominated by agricultural activity, were classified like clean pasture or dirty pasture.
Tree alluvial community	Tree vegetation occurring in areas subject to flooding in sufficient frequency and duration to restrict the occurrence of species not adapted to such conditions. In general, they present low diversity and high dominance, compared to adjacent dry areas.
Water body	It includes dams, lakes, rivers, lagoons, estuaries and the Atlantic Ocean.
Rural facilities	Small agglomerations of up to three houses. They include farm headquarters and structures related to agricultural production.
Mangrove	Tree vegetation occurring in estuarine tropical intertidal environments. It is characterized by swampy soils and homogeneous forests, adapted to the variable salinity of estuarine waters.
Mussununga	Herbaceous or shrubby vegetation, associated with sandy outcrops located on terraces of marine origin. It is usually associated with quaternary coastal ridges. However, it can occur in patches far from the coastline. current, associated with tertiary marine deposits.
Dirty and clean pasture	Clean pasture is an area submitted to the suppression of vegetation for use in livestock. Dirty pasture, in general, is associated with abandoned agricultural areas, where there is a reestablishment of vegetation in a pioneer successional stage. With a predominance of herbaceous vegetation, the dirty pasture differs from the clean one by the presence of bushes. The activity most frequently associated with this land use is extensive cattle raising.
Burning Area	Burnt vegetation due to fires. It is, most of the times, an agricultural practice, whose purpose is to eliminate the vegetation in order to facilitate its preparation for the farming.
Arboreal sandbank	Tree vegetation occurring over the coastal plain.
Rubber tree	Forestry production areas where rubber tree planting predominates, regions other agricultural crops produced in the shade of the rubber trees were recorded, such as coffee and cocoa.
Road system	It is the set of highways, roads and highways of a region or state.
Initial forest vegetation	Forest formations (Secondary forests, capoeiras) where woody species of low and medium size, varying between 5 and 10 meters in height, predominate. They are fragments often resulting from the natural vegetation succession after the removal or clear cutting of most of the tree species previously existing in the place. They present a little continuous canopy due to the previous environmental changes.
Medium and advanced forest vegetation	These are areas where there has been some kind of anthropic action, these probably suffered pressure from logging activity, with the removal of only species with commercial value, with greater spacing between the treetops. Also included in this category are areas that have been cleared cut, but which have been abandoned for a long time and are already in a medium stage of regeneration, with formation of canopies, being protected by environmental legislation.
	This class features formations ranging from 10 to 25 m in height. Areas of primary vegetation are also included in this class.

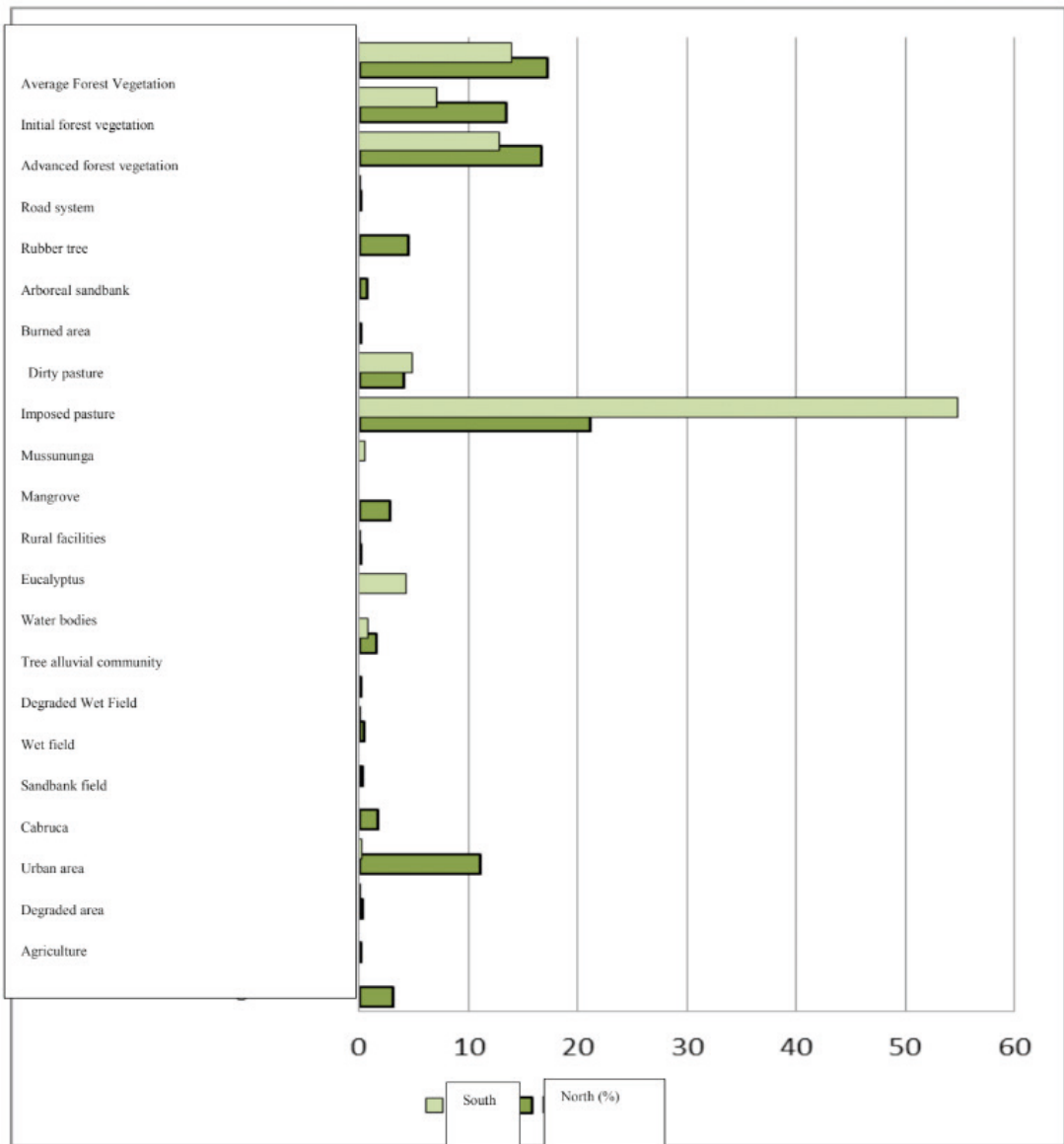Table 1. Description of mapped thematic classes.

Figure 2. Representativeness of thematic classes in percentage of mapped area.

	Advanced Forest Vegetation			Medium Forest Vegetation	
	North	South		North	South
Number of spots					
Total area of the spots (ha)	48	31		274	132
Area of the largest patch (ha)	41.271,1	25.954,4		17.641,1	28.362,0
Average	24.307,3	5.105,7		15.867,2	2.588,8
Average distance from Nearest Neighbor (m)	415,7	866,1		227,8	504,0
Neighbor average area Closer (ha)	4.525,3	1.344,7		131,5	398,6

Table 2: Fragmentation and isolation indicators of forest vegetation patches in advanced and medium stages of regeneration, estimated for both analyzed landscapes.

anthropized categories, such as cabrucas, are similar to the spectral responses of fragments of native Atlantic Forest, which are equally similar to each other. These reasons led us to employ mapping by visual interpretation, to the detriment of available automatic classification techniques.

The analysis of fragmentation and isolation of patches indicates that, although both landscapes have similar levels of fragmentation, the landscape protected by the UCs has larger fragments of native forest vegetation, which are less isolated from each other. The largest patch of forest vegetation in an advanced stage of regeneration is found in the northern landscape, associated with the UBU. It presents a continuous surface about five times larger than the largest patch of the southern landscape. The average distance to the nearest neighbor of the same class is about half in the northern landscape and the average neighbor size is about three times larger compared to the southern landscape (Table 2). With this, a lower degree of fragmentation and isolation relative to the northern landscape can be seen, making genetic flows between metapopulations potentially more consistent in the partially protected landscape.

CONCLUSION

Costa do Cacau, located on the south coast of Bahia, is a hotspot of forest diversity and a center of endemism for several species of fauna and flora native to the Atlantic Forest. Detailed mapping of the vegetation cover provides a valuable diagnosis of the landscape structure, capable of supporting the assessment of the effectiveness of the adopted conservation strategies.

Comparison of the fragmentation and isolation of native forest patches between two landscapes on the Costa do Cacau showed a lower degree of fragmentation and isolation in the landscape protected by conservation units, which makes genetic flows between metapopulations potentially more consistent.

THANKS

REFERENCES

Cassano, C. R., et al. (2009). Landscape and farm scale management to enhance biodiversity conservation in the cocoa producing region of southern Bahia, Brazil. Biodiversity and Conservation, 18, 577-603. DOI: 10.1007/s10531-008-9526-x.

Dietz, J. M., Sousa, S. N., & Billerbeck, R. (1996). Population dynamics of golden-headed lion tamarins Leontopithecus chrysomelas in Una Reserve, Brazil. Dodo: Journal of Wildlife Preservation Trusts, 32, 115-122. DOI: 10.1159/000492176.

Faria, D., et al. (2007). Ferns, frogs, lizards, birds and bats in forest fragments and shade cacao plantations in two contrasting landscapes in the Atlantic forest, Brazil.

Biodiversity and Conservation, 16, 2335–2357. DOI: Not available.

Fonseca, M. G., et al. (2023). Mapbiomas cacau: avanços e desafios no mapeamento do cultivo sombreado de cacau no sul da Bahia In: XX Simpósio Brasileiro de Sensoriamento Remoto. Anais do XX Simpósio Brasileiro de Sensoriamento Remoto, Florianópolis. INPE, São José dos Campos, 20, 155800.

Instituto Brasileiro de Geografia e Estatística, IBGE. (2006). Manual Técnico de Uso da Terra Manuais Técnicos em Geociências número 7. Diretoria de Geociências, Coordenação de Recursos Naturais e Estudos Ambientais. Disponível em https://biblioteca.ibge.gov.br/index.php/biblioteca-catalogo?id=281615&view=detalhes. Acesso em 31 de maio de 2023.

Landau, E. C., Hirsch, A., & Musinsky, J. (2003). Cobertura Vegetal e Uso do Solo do Sudeste da Bahia, Brasil. Escala 1:100.000, data dos dados: 1996-97 (mapa em formato digital). In: Prado P. I., Landau E. C., Moura R. T., Pinto L. P. S., Fonseca G. A. B., Alger K. (orgs.) Corredor de Biodiversidade da Mata Atlântica do Sul da Bahia.

Publicação em CD-ROM, Ilhéus, IESB/CI/CABS/UFMG/UNICAMP.

Lang, S. & T. Blaschke (2007). Landschaftsanalyse mit GIS, UTB-Reihe. Ulmer Verlag, Stuttgart, 420 pp.

Pardini, R., et al. (2009). The challenge of maintaining Atlantic forest biodiversity: a multi-taxa conservation assessment of specialist and generalist species in an

agro-forestry mosaic in southern Bahia. Biological Conservation, 142, 1178-1190. DOI: 10.1016/j.biocon.2009.01.010.

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.

Ribeiro, M. C., Holvorcem, C. G. D., Marques, A., Martensen, A. C., Metzger, J. P., & Tambosi, L. R. (2012). Monitoramento independente da cobertura florestal das bacias setentrionais do extremo sul da Bahia. Relatório técnico, Porto Seguro-BA. Disponível em https://ib.rc.unesp.br/Home/Departamentos47/ecologia/leec/ibio_monitoramento_final.p df.pdf. Acesso em 31 de maio de 2023.

Schroth, G., Harvey, C. A., & Vincent, G. (2004). Complex agroforests: their structure, diversity, and potential role in landscape conservation. In: Schroth G., Fonseca G., Gascon C., Vasconcelos H., Izac A. M., & Harvey C. (Eds.). Agroforestry and Conservation of Biodiversity in Tropical Landscapes (pp. 227-260). Island Press.

Schroth, G., et al. (2011). Conservation in tropical landscape mosaics: the case of the cacao landscape of southern Bahia, Brazil. Biodiversity and Conservation, 20, 1635-1654. DOI: 10.1007/s10531-011-0042-8.

Thomas, W. W., Carvalho, A. M. V., Amorim, A. M. A., Hanks, J. G., & Santos, T. S. (2008).

Diversity of Woody Plants in the Atlantic Coastal Forest of Southern Bahia, Brazil. Memoirs of the New York Botanical Garden, 100, 21-66.