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Remnant Vegetation Analysis of Guanabara Bay Basin, Rio de Janeiro, Brazil, Using Geographical Information System

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1. Introduction

The importance of tropical forests and the surrounding environment has been increasing, as specific threats and problems (e.g. deforestation, timber logging, infrastructure development, and mining) are generating increased atmospheric carbon dioxide concentration, with severe present and future consequences in climate (Schulze in Carreiras et al., 2006).

Rio de Janeiro is a Brazilian state that presents the greatest diversity of ecosystems, including major portions of Atlantic Forest (Mata Atlântica in Portuguese), considered a hotspot for its importance and relevance in terms of natural resources and biodiversity. The high biodiversity in this biome is a function of the extreme variations in environmental conditions, and great differences in altitude, ranging from sea level to over 1800 meters.

The Atlantic Forest domain has the following delimitations established by the Brazilian Vegetation Map of IBGE (Veloso *et al*., 1991): ombrophilous dense Atlantic Forest; mixed ombrophilous forests; open ombrophilous forests; semidecidual stational forests; decidual stational forests; the countryside swamps, the northeastern forest enclaves (regionally called "brejos") and the associated ecosystems - mangroves and restingas.

According to publication of SOS Atlantic Forest Foundation and the Brazilian National Institute for Space Research (2009) between 2005 and 2009, there was a loss of 1,039 hectares of Atlantic Forest in the state of Rio de Janeiro. The Forest is now fragmented in isolated remnants scattered throughout a landscape dominated by agricultural uses. According to Grimm *et al.* (2008), ecosystem responses to land changes are complex and integrated, occurring on all spatial and temporal scales as a consequence of connectivity of resources, energy, and information among social, physical, and biological systems. As terrestrial landscapes become increasingly fragmented, so do hydrologic connections between landscape elements (Pringle, 2001).

The extensive deforestation at the Basin took place over a historic period. The colonization process of the area, specially of dense ombrophilous forest, was initially with sugar cane, coffee and orange plantations, followed by cattle raising and annual crops (CIBG, 2010), which favored the formation of erosive processes as well as silting of water bodies. The only area with significant forest remnants is found in high slopes, inappropriate for agriculture, especially within the limits of Três Picos State Park. According to Freitas et al (2010), roads and topography can determine patterns of land use and distribution of forest cover, particularly in tropical regions.

Many factors have affected negatively and contribute to degradation of Baia de Guanabara Basin such as the growth of unplanned cities, mining areas, exotic monocultures planted without planning, industries, oil refinery, among others. According to Bidone & Lacerda (2003), there are 12 municipal districts, 7.8 million inhabitants and around 12,500 industries distributed unevenly over the drainage basin area (4,000 km2).

With the increasing deforestation, there were created several protected areas to conserve natural resources and biodiversity existing within it. The National System of Conservation Units (SNUC) was created in Brazil by the Federal Law No. 9985/2000, establishing criteria and standards for the creation, deployment and management of protected areas. The Brazil's conservation units such as parks, reserves and APAs (Environmental Protected Areas) are grouped into two categories: "sustainable use" and "integral protection."

Integral protection conservation units are protected areas which main purpose is the conservation of biodiversity. Only the indirect use of natural resources is permitted and natural processes shall take place without human interference. The following conservation units according to International Union for Conservation of Nature (IUCN) - management category I - III) fulfill this purpose: biological and ecological reserves/stations (I), national and state parks (II), natural monuments and wildlife refuges (III).

Sustainable use conservation units were created with the idea of combining the conservation of biodiversity compatible with the rational use of the natural resources, while respecting the legislation that applies to such resources. The following conservation units (IUCN - management category IV- VI) fulfill this purpose: areas of relevant ecological interest (IV), environmental protection areas (V), extractive/fauna/sustainable development reserves (VI).

Bidone et al. 1999 as cited in Bidone & Lacerda (2004), in accordance with land use criteria, classified the watersheds of the Guanabara Bay region into three types: (1) the pristine type, without anthropogenic activities, which generally belongs to legal environmental protection areas, with Mata Atlântica (i.e., a mountainous tropical rainforest type) and/or similar abundant vegetation on the slopes and natural coastal vegetation in the lowlands (grasses, savannas, ''restingas''); (2) the weakly impacted type with well-preserved Mata Atlântica and/or other remnant vegetation on the slopes, and lowland sectors with human activities (small-scale farming, tourist-urban activities); and (3) the highly impacted watersheds, densely populated and/or industrialized.

Geographic Information System is a tool for evaluating and monitoring of environmental impacts (IBAMA, 2002) and has been widely used in watershed management, environmental zoning, support for studies of biogeography, monitoring animals, management of protected areas, evaluate deforestation, among others. GIS applications are tools that allow spatial analysis of landscape patterns and the consequences of human activities on these patterns (Tuominem et al. 2009). Though imagery resources can provide a reliable basis for measuring the amount and spatial configuration of forest clearing and exploitation.

2. Objectives

This chapter aims to provide information on land-cover in the Guanabara Bay Basin for monitoring its changing through time; to integrate remote sensing data aiming to provide a diagnose of the distribution of vegetation remnants at Baia de Guanabara Basin among three periods ; to calculate the remaining areas of Atlantic Forest at the basin and correlate them with the altitude and slope; to use map algebra to combine raster maps of vegetation class and some other maps as the different conservation units at the basin to predict the remnant vegetation amount; to provide useful information for decision-making purposes.

3. Study area

The Guanabara Bay Basin is located in southeastern Brazil in the state of Rio de Janeiro, and its geographical coordinates are Latitude -22°20'S and - 22°59'S and Longitude - 42°32'W and - 43°34'W (Figure 1). This Basin is located in the tropical zone, with a typical hot and dry climate (Amador 1997). The annual average temperature reaches 24°C in the coastal plain and 20°C in the mountainous regions. The precipitation annual averaged 2,000mm in the Serra do Mar and oscillated between 1,000 and 1,500mm in the Baixada Fluminense (Amador op cit).

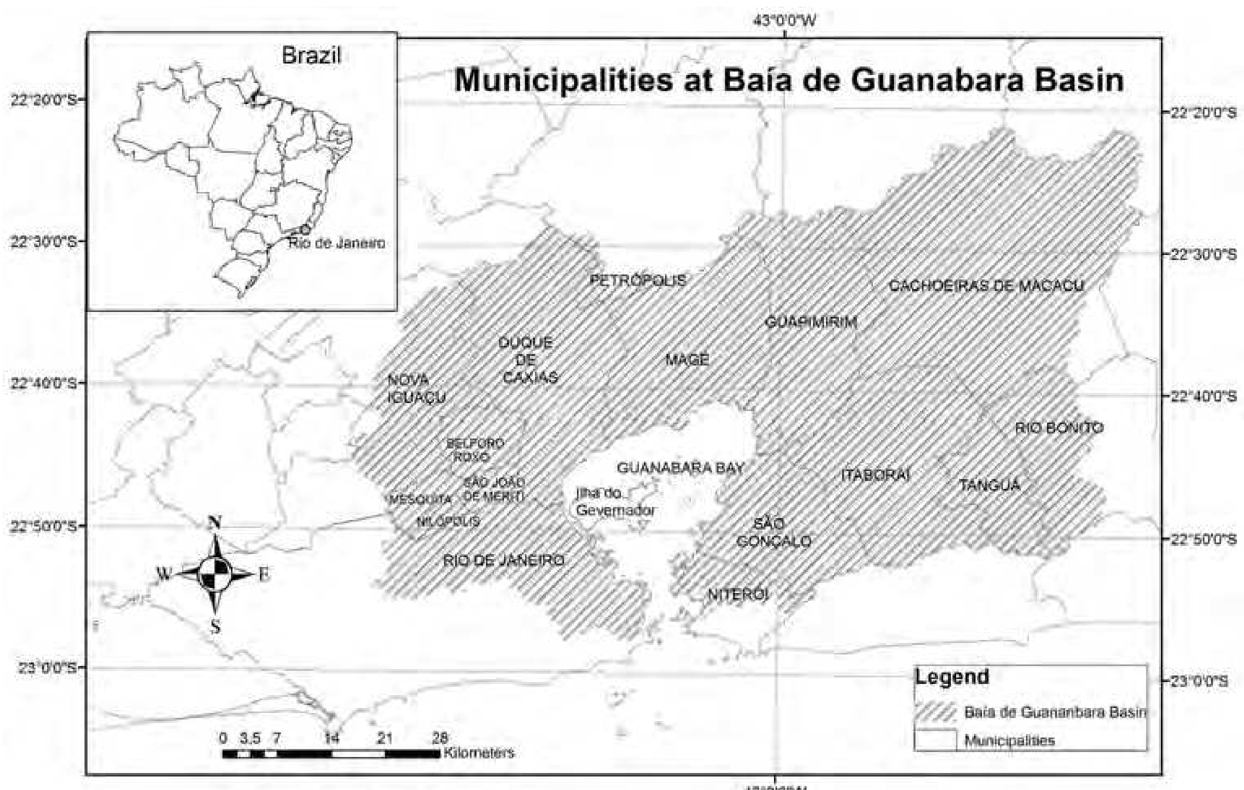


Fig. 1. Study Area

It covers an area of 4,198 km² and includes 16 municipalities that constitute part of the Metropolitan Region of Rio de Janeiro (IBG, 2010). Part of the Basin is located in the mountain range "Serra do Mar", mainly mountainous region and of rough relief, with steep slopes and small valleys. The western part of the Guanabara Bay is called "Baixada Fluminense", located in plain relief that belongs to the urban region of Rio de Janeiro. The Baixada encompasses especially the municipalities of Duque de Caxias, Nova Iguaçu, São João de Meriti, Nilópolis, Belford Roxo, Queimados and Mesquita.

4. Methodology

4.1 Data acquired

4.1.1 Landsat images

Image mosaics from Landsat 5 (Thematic Mapper) and Landsat 7 ETM+ (Enhanced Thematic Mapper plus) were obtained at INPE (Brazilian Institute of Spatial Research) and at USGS (United States Geological Survey's Earth Resources Observation and Science - EROS) websites.

The two images of three periods (1985, 2001 and 2010) were mosaiced to cover the area of Baia de Guanabara Basin, as below:

1985- Landsat 7 ETM+ scenes 217/75 and 217/76 from July 04 and August 05, respectively, obtained at websites of INPE and USGS;

2001- Landsat 7 ETM+ scenes 217/75 from September 04 and 217/76 from October 28, obtained at USGS website;

2010-Landsat 5 TM scenes 217/75 from May 06 and 217/76 from February 15, obtained at INPE website.

4.1.2 SRTM

Images of the Shuttle Radar Topography Mission V. 4.1 (SRTM) in 1-degree digital elevation model (DEM) were obtained at the site of CGIAR- Consortium for Spatial Information (Jarvis *et al*., 2008), for the elaborations of maps of altitude and slope classes.

4.1.3 Shapefile data

Vector format at a scale of 1:50,000 relating to municipalities, hydrography and the conservation units, were obtained from government agencies like the Brazilian Institute of Geography and Statistics (IBGE); National Environment Institute (INEA), Guanabara Bay Remediation Program (PDBG), *Mata Atlântica* Biosphere Reserve (RBMA), Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) and from municipalities.

4.2 Images processing and classification

This step is based on the application of techniques from digital image processing and visual interpretation of images to the acquisition of cartographic features. An image registration requires control points, a point whose coordinates reference is known. The three spectral bands of ETM+ and TM sensor with 30 meters spatial resolution (bands 3, 4 and 5) were registered through planimetrically correct maps. It was used the Universal Transverse Mercator (UTM) projection with longitude origin at 45º00'00"W and datum SAD69. All image pre-processing procedures were done in SPRING 5.1.7 (Georeferenced Information Processing System), a state-of-the-art GIS developed by Brazil's National Institute for Space Research (Camara, 1996) and available for free on the web. It was also made a datum transformation for integrating the different data.

The intent of the classification process is to categorize all pixels in a digital image into one of several land cover classes, or "themes". The software SPRING 5.1.7 was used to develop a statistical characterization of the reflectance for each information class for producing thematic maps of the land cover present in an image. It was made supervised classification (Atkinson, 2004; Foody, 2002; Richards, 1993), using Maximum Likelihood algorithm to extract the information and allow the mapping of land use and vegetation remaining (Waleed and Grealish, 2004). The area was classified into five major thematic categories as following: 1)vegetation - tropical rainforest (ombrophilous forest), forested wetlands include mangrove swamps and pioneer formations and reforestation; 2- fields – including deforested areas, fields of altitude called "campos rupestres"; agriculture and pasture; 3) anthropogenic (Urban or Built-up Land)- including urban and industrial areas and 4) exposed areas (Transitional Areas) including nonforest, temporarily bare areas as construction is planned for such future uses as residences, shopping centers, industrial complexes. and 5)water –representing Guanabara Bay.

4.3 Digital Elevation Model (DEM) from the shuttle radar topography mission

It was used the digital elevation model (DEM) from the Shuttle Radar Topography Mission V. 4.1 (SRTM) to create raster maps of altimetry and slope. The altimetry data were sliced into five class intervals: 0-8m 8-50m, 50-500m, 500-1500m and >1500m for generation a raster map. The slope classes was defined into six intervals as followed: 0-3% (plain terrain), 3-8% (gently sloping), 8-20% (sloping), 20-45% (moderately steep to steep), 45-75% (very steep - mountain slope) and >75% (scarped).

The vegetation classes were defined according to the altitude in: mangrove (0-7m), lowland (0-40m), lower montane forest (40-500m), montane forest (500-1500) and upper montane forest (1500-2200).

4.4 Map algebra application

Map algebra uses math expressions to combine raster layers using operators such as arithmetic, relational and boolean logic (Wang & Pulard, 2005). It was used the algebraic language as a tool to estimate the deforestation in the Guanabara Bay Basin using SPRING 5.1.7 software through Spatial Language for Algebraic Geoprocessing (LEGAL). Map algebra creates new features and attribute relations by overlaying the features from two or more input map layers. Features from each input layer are combined to create new output features. The thematic maps of classified images and some other maps of altimetry, slope and conservation units had been manipulated using Boolean algebraic expressions describing the rules and conditions involved in the evaluation and evolution of the deforestation process. Some Conservation Units were cut at the limit of the Guanabara Basin, since the target of this work is to verify the remnant vegetation belonging to the Basin. The integral and sustainable conservation units were overlayed with the maps of land cover classification to create a new map of the remnants vegetation areas in the three study periods (1985, 2001, 2010).

4.5 Maps elaboration

Finally, thematic maps of land cover classification, vegetation remnants according to altimetry and slope classes, vegetation remnants in the conservation units and vegetation fragments were prepared using the softwares Spring (INPE) and ArcGis (ESRI)

5. Results

5.1 Supervised classification of the three Images (1985-2001-2010)

The supervised Classification (Figures 2-4 and Table 1) shows a decrease of vegetated extent in 24.99 percent between 1985 and 2001. The removal of vegetation cover and riparian forest is directly linked to increase in pasture lands and agricultural lands over the three periods, as showed in land cover classification.

In the first time period (1985-2001) the vegetation clearance occurred in 321.989 square kilometers with an increase of agriculture and pasture lands. According to the image classification of 2010 period (Table 1) areas under or pasture use represent the major land-cover type in Guanabara Basin, with 44.91 percent of land-cover classified. Although in the same period, some areas previously occupied by fields became urban and peri-urban areas. The increase of anthropogenic class was probably due to unsustainable land management and city expansion especially in informal settlements ("favelas") with an increase of 1,035.973 square kilometers of total occupation. As geographers and urban sociologists have long observed, topography is a key-element contributing to the heterogeneity of residential segregation (Medeiros, 2009). Rio de Janeiro offers a particularly interesting case, with favelas populating the hills and mountains right next to the high income areas (Medeiros, op.cit). According to Freitas et al (2010) roads and topography are not the current drivers of deforestation, but they act as attractors of land-use change and deforestation. In Guanabara Bay basin the observed linearity is due to the high rates of population growth and to unplanned occupation of watersheds, without the proper infrastructure to cope with their effluents (Bidone & Lacerda, 2004). According to Moraes (2009), escalating drought, deforestation, capitation, irresponsible land use, and pollution are direct consequences that demand an integrated management scheme.

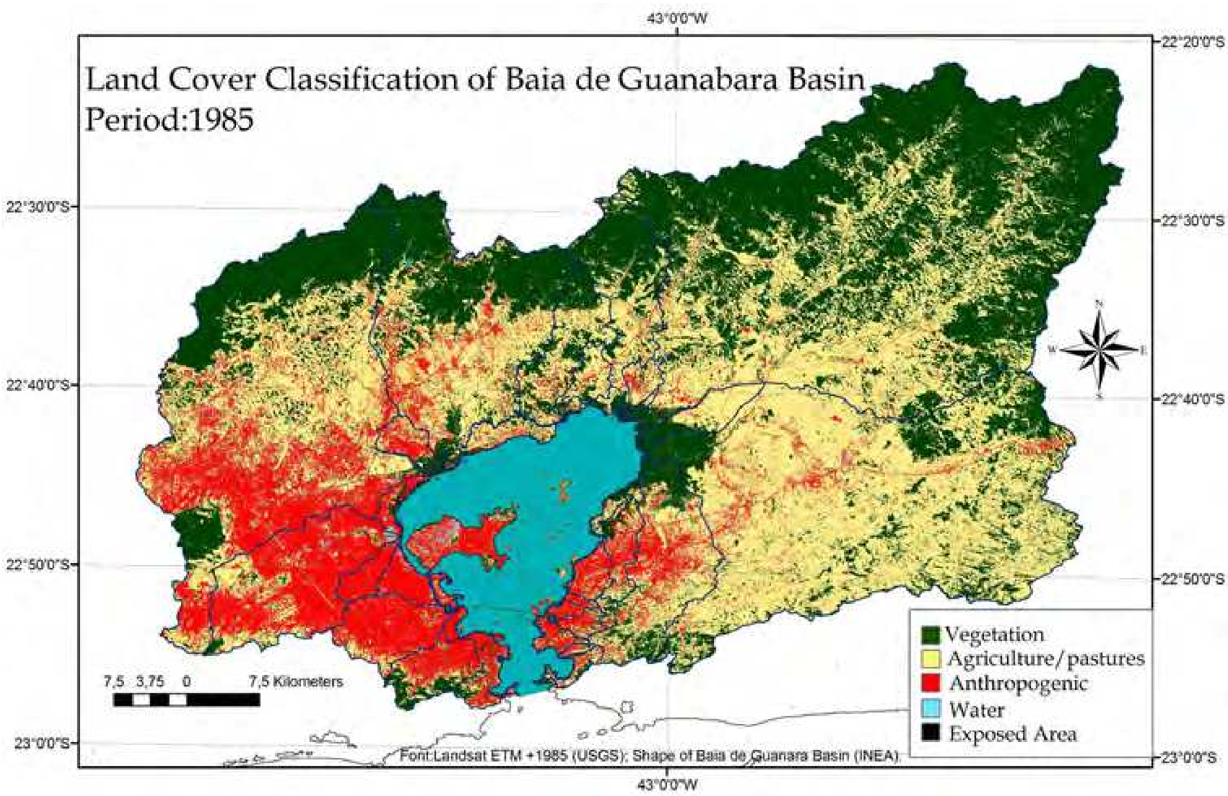


Fig. 2. Land Cover Classification map from 1985 period

Figure 4 of the 2010 period also shows a large exposed area over 10 square kilometers in Guapi-Macacu Basin in the municipality of Itaboraí. The area was exposed due to excavation and earthmoving activities for the implementation of Petrobras Industrial Complex. According to the Environmental Impact Report (EIA), the basic petrochemical unit of COMPERJ will process 150,000 bbl/day of domestic heavy oil to produce thermoplastic resins and fuels (Hernández, 2010). The establishment of petrochemical complex with the magnitude of COMPERJ can lead to an untenable situation due to the increase of the population rate in the Municipality of Itaboraí, which can cause serious damage to riparian vegetation and wetlands remaining in the eastern bay. Attention should be directed to potential social costs and impacts of large-scale projects in the Basin. According to Members of the Committee of the Guanabara Bay Basin (Hernández, 2010) water availability in Metropolitan Rio de Janeiro, considering the water imported from surrounded sub-basins, is no longer sufficient to meet the additional demand generated by the installation of the Petrochemical complex (Pedreira et al, 2009 as cited in Hernández, 2010). Given the tendency toward continued population and Industrial growth, water availability will decline over time, though water availability per se tends to remain fairly constant (in terms of flow, but not in terms of quality) (Hespanhol, 2008).

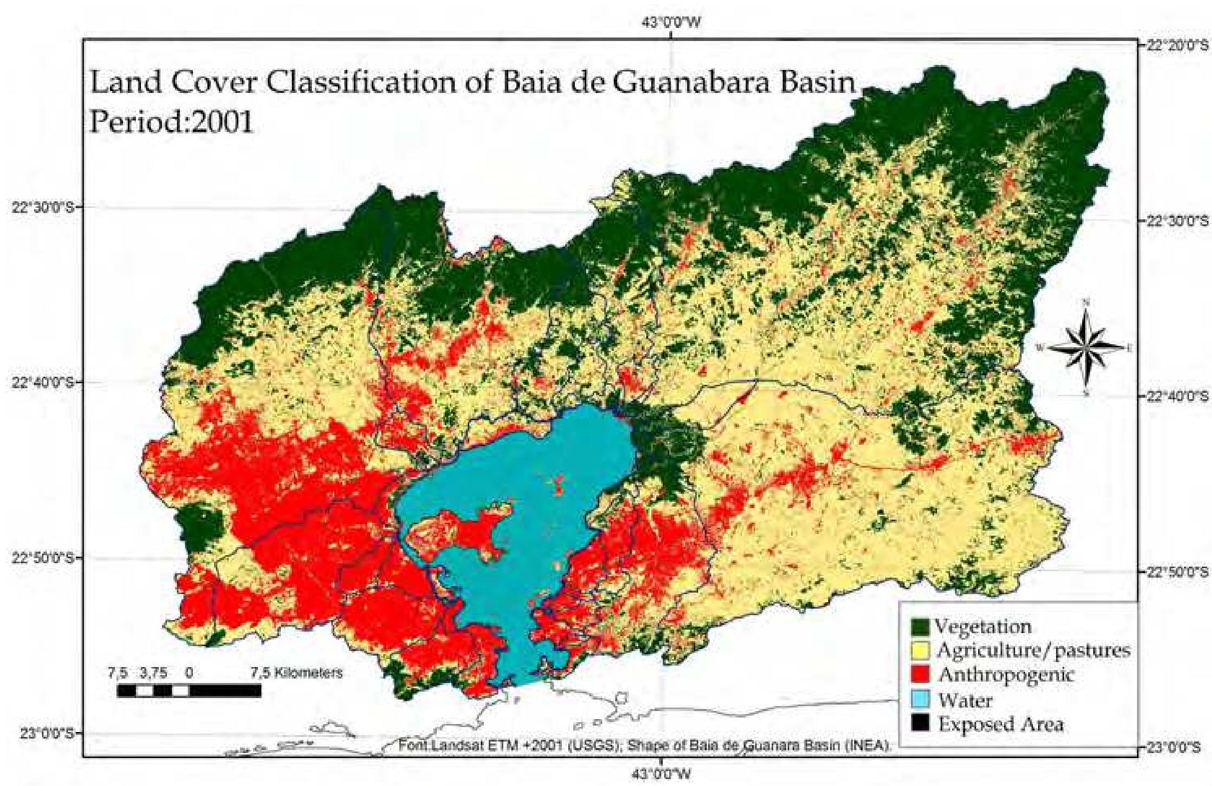


Fig. 3. Land Cover Classification map from 2001 period

According to Hernández op cit. adequate water quality management is necessary for water resource management in a river basin, specifically having a sound water quality monitoring system to indicate the status of water body. Two other large-scale infrastructure projects are undergoing in the Basin: The Metropolitan Arch which will connect Itaguaí municipality to three other major highways: the BR-040 to Belo Horizonte (Minas Gerais) and Brasília (Federal District), the BR-116 to Bahia, and the BR-101 to Espírito Santo and the Gasduct Camboinhas Reduc III with 179 kilometers of extension. The Gasduct was been made in an area of Environmental Protection in Cachoeiras de Macacu Municipality. According to Hespanhol, op cit water conservation in the form of demand management should also be encouraged in industry, pressing for the adoption of modern industrial processes and washing systems with lower water requirements, as well as water treatment stations for public supply through the adequate recuperation and reuse of water used to wash filters and decanters. The Niteroi Municipality Act (Law Nº. 2.856/2011) establishes mechanisms to encourage the installation of collection system and wastewater reuse in public and private buildings. Under the Act, new public or private buildings, with an area over 500m² and water consumption greater than or equal to 20m³ per day are obliged to encourage and promote gray water reuse.

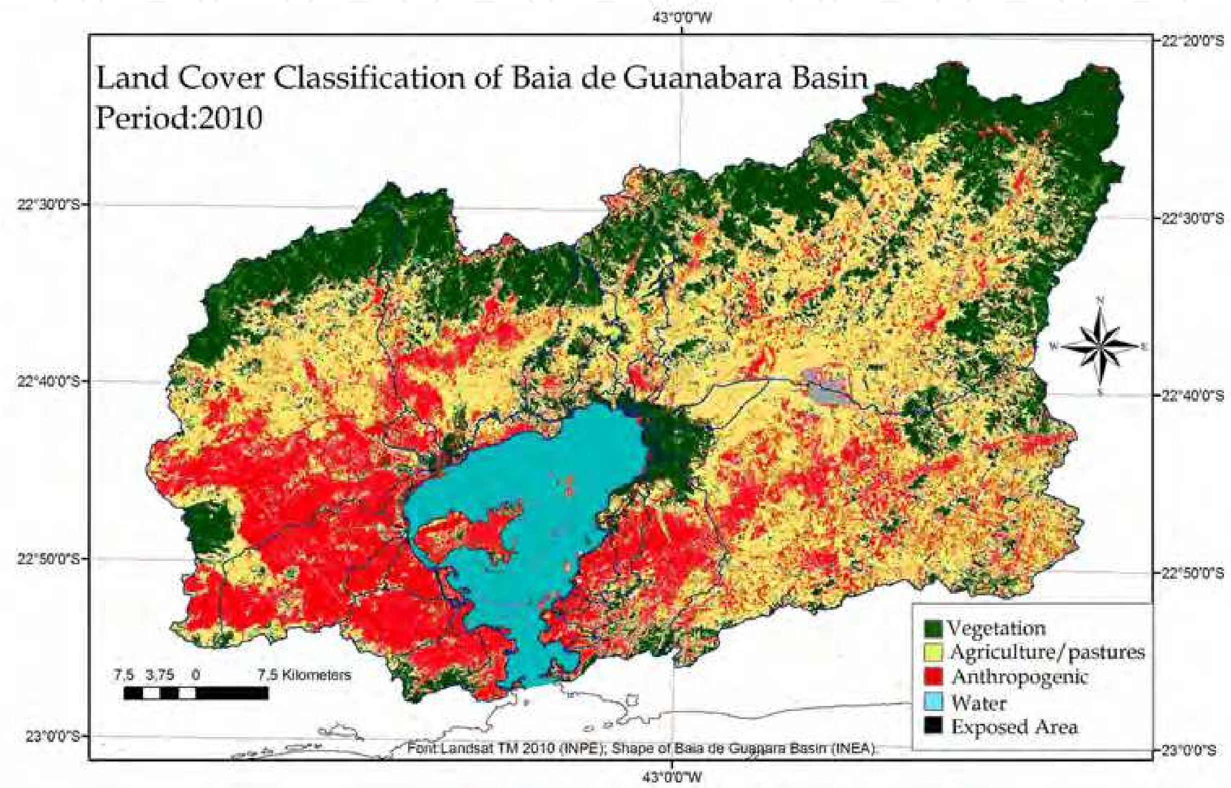


Fig. 4. Land Cover Classification map from 2010 period

Land Cover Classses	1985	2001	2010	Variation (%) 1985-2010
Vegetation	1,590.738	1,268.749	1,193.087	-24.99
Fields	1,791.635	1,985.152	1,833.160	+2.32
Anthropogenic	661.874	829.596	1,035.973	+56.52
Exposed	48.72	1.44	19.16	-60.67

Table 1. Land Cover areas (km²) in the three study periods.

5.2 Conservation units in the Guanabara Basin

The Figure 5, Table 2, shows the delimitation of the major conservation units in the Guanabara Bay Basin according to their uses as strict protection or sustainable use. The units are managed by Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), Chico Mendes Institute for Biodiversity Conservation (ICMBio), National Environment Institute (INEA) and municipalities, among which seventeen Environmental Protected Areas (APAS), five Parks, a Biological Reserve, two Ecological Stations, and an Ecological Reserve. The Atlantic Rainforest Central Mosaic which includes 22 conservation units and the Sambê Santa Fé Corridor which encompasses the mountains regions of Sambê, Santa Fé and Barbosão with well preserved forest stretches.

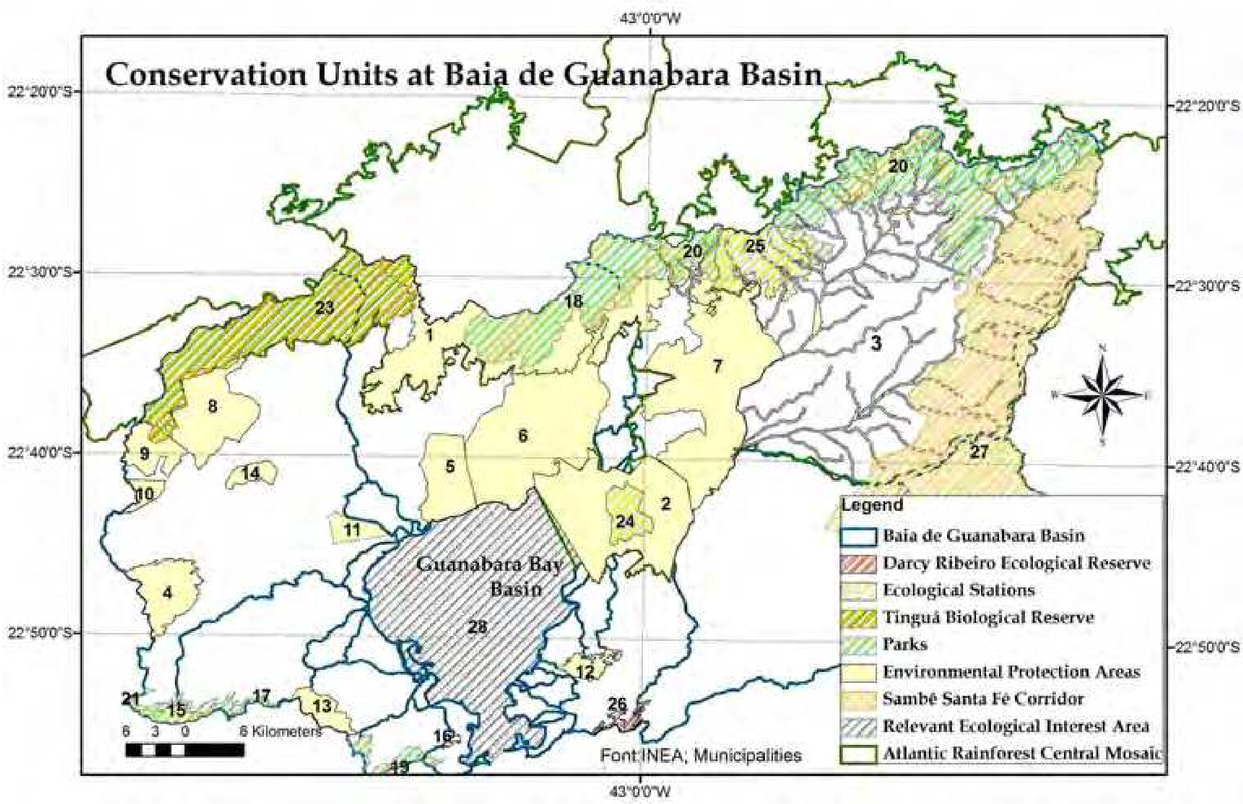


Fig. 5. Main Conservation Units in the Guanabara Bay Basin

The National System of Conservation Units (SNUC) was created in Brazil by the Federal Law No. 9985/2000, which includes the main categories of Protected Areas as follows:

- Area of Environmental Protection (APA): it is a rather large area characterized by a considerable population density and with abiotic, biotic, aesthetic, or cultural features of great importance, above all for the quality of life and human wellness. Protecting biological diversity, regulating the settlement processes, and ensuring the sustainable use of natural resources are among its main aims.
- Biological Reserve: it aims at strictly safeguarding the natural aspects within its borders, avoiding direct human interference or environmental changes, through measures to recover altered ecosystems and management actions necessary to recover or maintain the natural balance, biological diversity, and natural ecological processes.
- Ecological Station: it aims at safeguarding nature and carrying out scientific research activities.
- National Park: it aims at preserving natural ecosystems of great beauty and ecological importance, giving the opportunity to carry out scientific research activities or developing environmental education and interpretation activities, as well as promoting recreational activities at direct contact with nature and ecological tourism.

- Area of Considerable Ecological Interest (ARIE): not very large area, with a scarce population density and extraordinary natural features of great importance at a regional and local level.

Management Responsability	ENVIRONMENTAL PROTECTED AREAS (APAS)
Federal	1. Petrópolis; 2.Guapemirim
State	3. Guapi-Macacú River Basin; 4. Gericinó- Mendanha
Municipal	5. Estrela; 6. Suruí; 7. Guapi-Guapiaçu; 8. Tinguá; 9. Rio D´Ouro; 10. Tinguazinho; 11. São Bento; 12. Engenho Pequeno; 13. Pretos Forros; 14. Retiro; 15. Pedra Branca; 16.São José; 17-Morro do Valqueire
	PARKS
Federal	18. National Park of Serra dos Órgãos; 19. National Park of Tijuca Forest
State	20. State Park of Três Picos; 21. State Park of Pedra Branca
Municipal	22. Municipal Park of Barbosão
	BIOLOGICAL RESERVE
Federal	23. Tinguá
	ECOLOGICAL STATIONS
Federal	24. Guanabara Ecological Station
State	25. Paraíso Ecological Station
	ECOLOGICAL RESERVE
Municipal	26. Darcy Ribeiro Reserve
	CORRIDOR
State	27. Sambê Santa Fé
	ARIE
Municipal	28. Guanabara Bay

Table 2. Main Conservation Units in the Basin

The Brazilian Forest Code (Law No. 4771/1965) defines the limits were set on the use of property, where existing vegetation must be respected and considered of common interest to all, except for the removal of vegetation for public service interests provided there are environmental licenses and compliance with established environmental compensation. According the Brazilian Forest Code and the Resolutions of CONAMA (National Environmental Council) numbers 302 and 303, Permanent Protection Areas (APPs): are protected areas, covered or not by native vegetation, for the purpose of preserving water resources, landscape, geological stability, biodiversity, the gene flow of wild fauna and flora, protecting the soil and ensuring the well being of the human population. The APPs include mangrove swamps, riparian vegetation, sand dune scrubs "restingas", regions above 1,800 meters of altitude and hillsides with slopes above 45 degrees. According to the Brazilian Code Legal Reserves (LRs) are areas located within a farm, with exception to permanent preservation areas, necessary for sustainable uses of natural resources, conservation and rehabilitation of ecological processes, conservation of biodiversity, and the shelter and protection for native fauna and flora. Current Brazilian law provides that the Legal Preservation should be 80% in the Amazon, 35% in savanna regions in Amazonian states, and 20% in other regions in the country. The reforestation should be done with species native to the area.

The new Forest Code in Brazil indicates some changes in regards to the Permanent Protection Areas (APP) and Legal Reserves (WWF, 2011). According to current legislation, at least 30 meters from banks and rivers, steep slopes, hilltops and wetlands should be protected. Thus, those who deforest need to restore vegetation. Under the new code, the minimum protection may be reduced to at least 15 meters, and meadows cease to be considered APP. In relation to Legal Reserves, properties of up to 4 taxed modules (varies among different municipalities) do not need to have a reservation, which will be mandatory only for properties that exceed four modules. The amendments to the Brazilian Forest Code may have an important negative effect on Brazil's capacity to reduce emissions from deforestation and forest degradation. The proposed changes will effectively allow more land to be converted for agricultural purposes in Areas of Permanent Preservation, such as hillsides (inclusively forest land 45% in slope or over) and riversides. In addition, existing cultivation of some products including grapes, apples and coffee will continue to be allowed in areas designated as Permanent Protection Areas (APP). The bill provides an amnesty for some small landowners, and may encourage illicit practices. This new proposal will lead to serious consequences in decreasing of urban and peri-urban water supplies in the face of accelerating population and economic growth. In addition, deforestation and land clearing pose serious problems to the carbon cycling to McPherson (1998), urban forests can reduce atmospheric CO, in two ways. Trees directly sequester CO, as woody and foliar biomass while they grow. Also, trees around buildings can reduce the demand for heating and air conditioning, thereby reducing emissions associated with electric power production (Mc Pherson, op cit).

5.3 Remnant vegetation in the conservation units of strict preservation uses and sustainable uses

Figures 6 to 8 and Table 3 showed the remnant vegetation in Conservation Units of integral protection and of sustainable use in the Guanabara Bay Basin. The greatest loss of vegetated areas was observed in conservation units of sustainable use. In environmental protected areas "APAS", there was a loss of 20.23 percent in vegetation class between 1985 and 2010, the equivalent of 100.371 square kilometers. In the strict protection units as parks it was observed the vegetation loss of 11.27 percent which represents a decrease of 39.43 square kilometers in vegetated areas. The Tinguá Biological Reserve has been decreasing its vegetated in 5.23 percent along the study periods.

As a Conservation Unit of Sustainable Use, the Environmental Protected Area of Guapi-Macacu River Basin, established in 2002, contributes to the supply of drinking water to nearly 2.5 million inhabitants living in six municipalities in the State of Rio de Janeiro (Da costa 2007). This basin has suffered several interventions as the built of the Channel of Imunana with the purpose of draining the frequently flooded adjacent areas (Da Costa op cit).

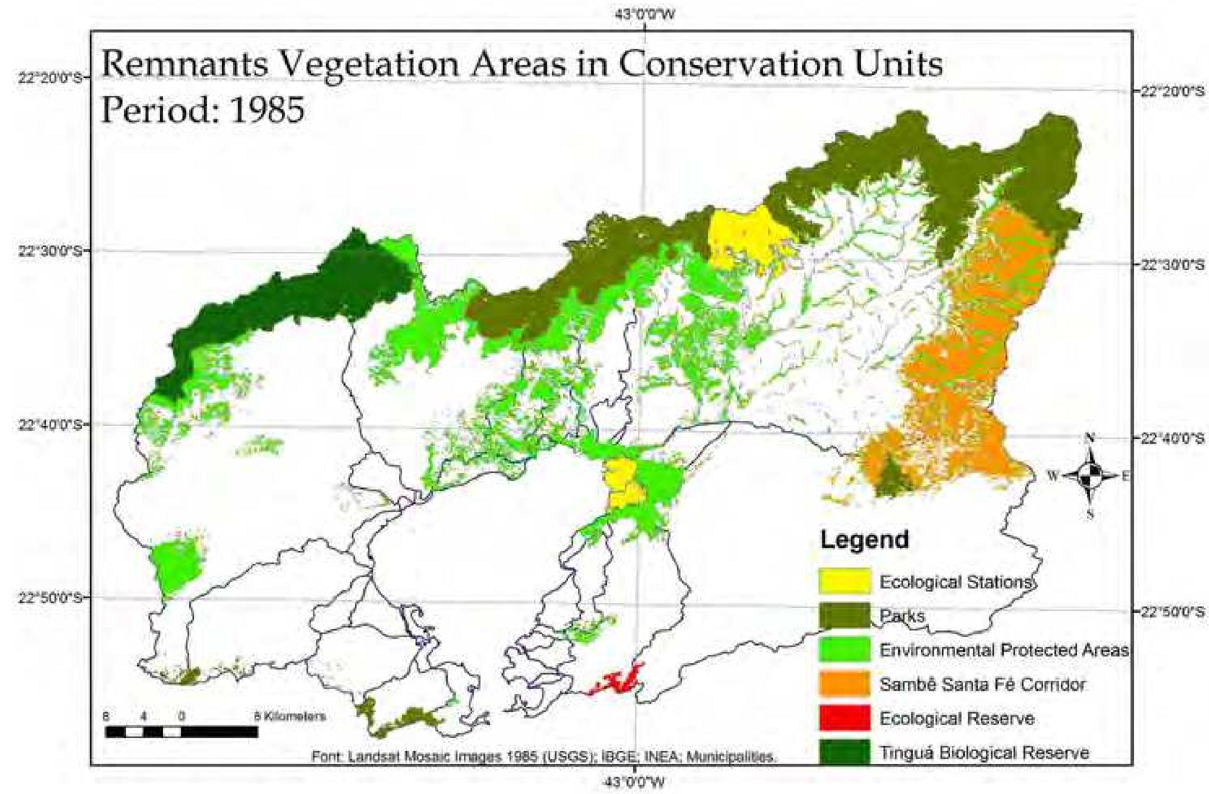


Fig. 6. Remnants vegetation areas in conservation units of Guanabara Bay (1985).

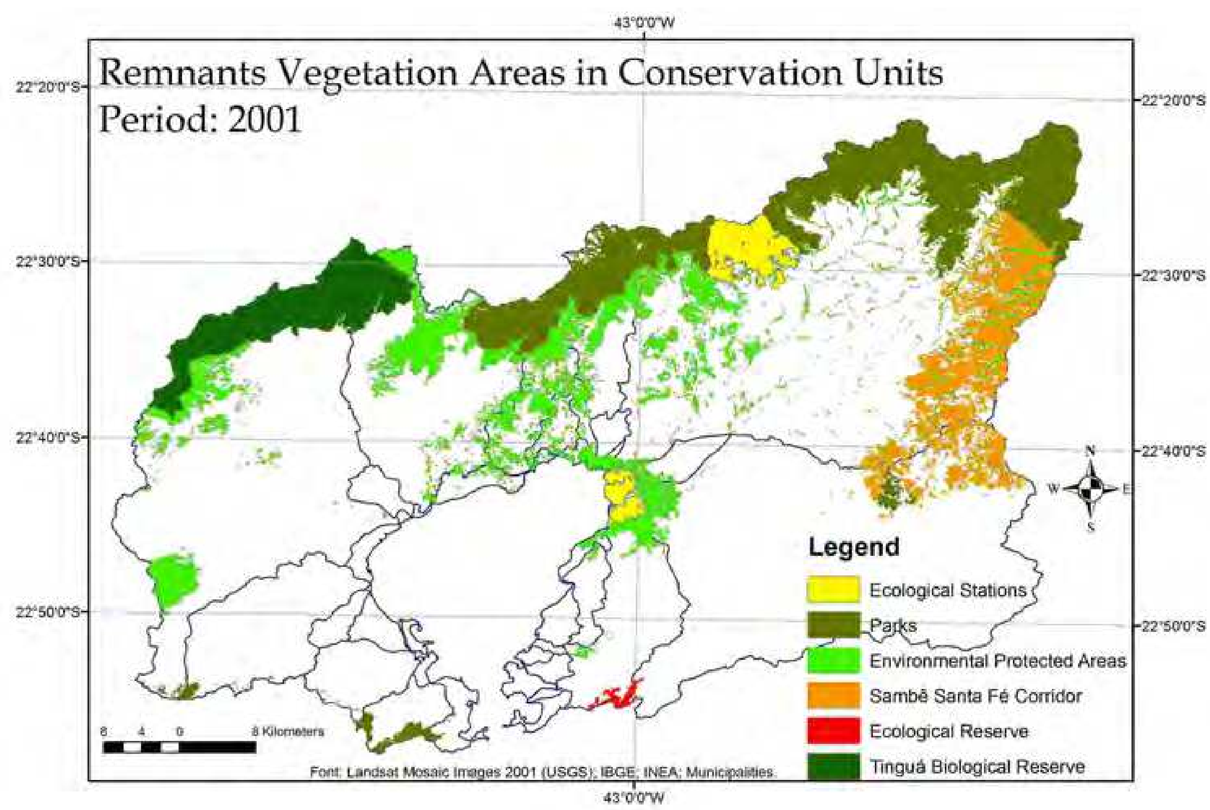


Fig. 7. Remnants vegetation areas in conservation units of Guanabara Bay (2001).

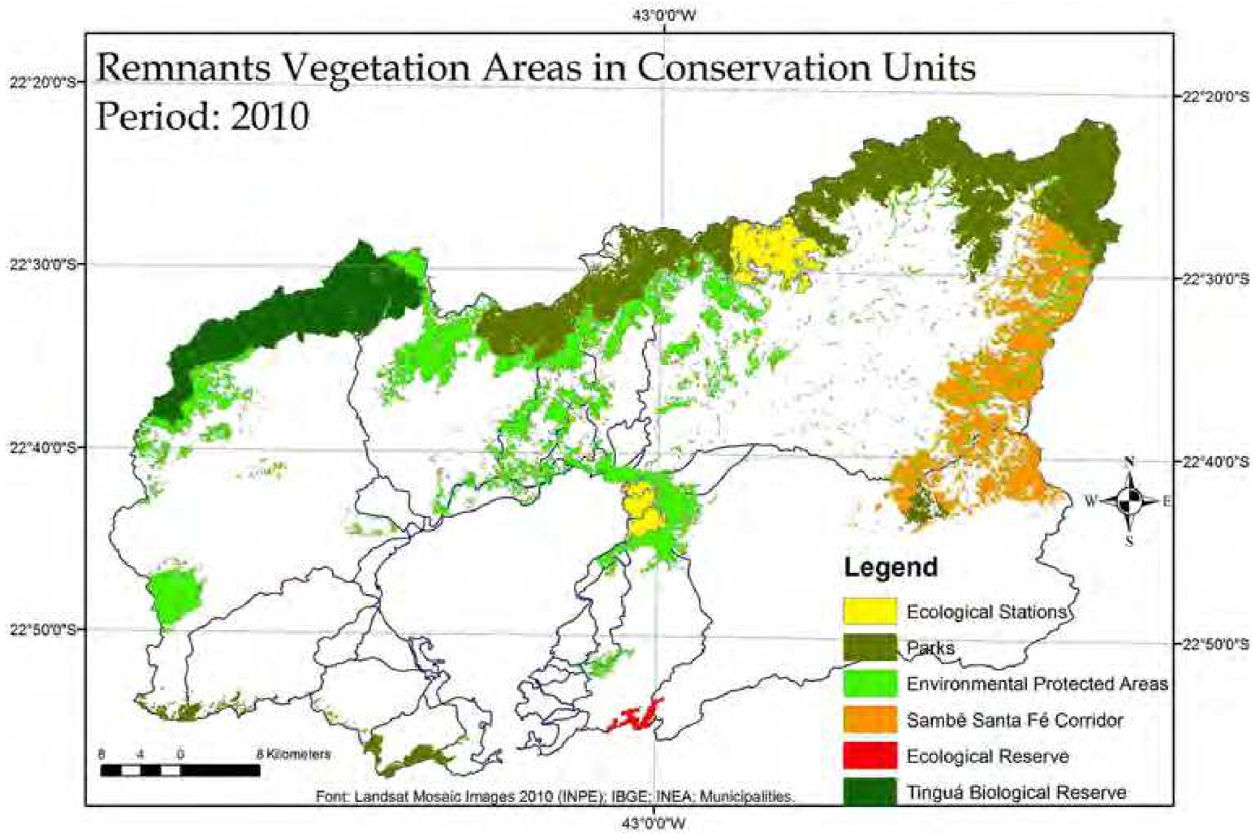


Fig. 8. Remnants vegetation areas in conservation units of Guanabara Bay (2010).

It is evident in the Figures 7 and 8 that the higher forest cover rate is associated with the riparian vegetation along the rivers. Results show the disappearance of large part of riparian vegetation along the Guapi-Macacu river banks. According to CONAMA (National Environmental Council) Resolution No. 9 from 1996, riparian forests are considered corridors linking forest remnants, thus increasing landscape connectivity. In addition, forest fragmentation pattern of Guapi-Macacu river basin appeared to be associated with topography and slope. With the implementation of the Metropolitan Arch and the Petrochemical Complex it is expected a rapid anthropogenic increase moved by the process of building infrastructure networks in urban areas.

The magnitude and extent of human impacts have altered biodiversity, hydrologic connectivity (Pringle,2001), conservation of aquatic ecosystems and also water supplies in the medium and long term. According to Pedreira et al., as cited in Hernández (2010), the main environmental pressures in water quality in the Guanabara Basin are: inappropriate land-use activities, specifically, removal of majority of the original vegetation cover, removal of riparian forest, unplanned urban sprawl, lack of sewage treatment and improper supervision of industrial activities; causing steep erosion and river siltation. Despite the promulgation of wide-reaching legislation, including Law 9,433/1997, which institute the National Water Resource Policy and defined the legal and administrative framework for the National Water Resource System and CONAMA Resolution 357/2005, which established the classification of water bodies and the conditions for effluents discharging, the water pollution is steadily increasing. In critical areas surrounding the Guanabara Bay (particularly along its NW coast), less than 60% of the population has access to adequate sewage treatment, only about 10% of the total sewage is treated before being released into the Bay, the rest being released untreated

into the Bay's tributaries (Bidone & Lacerda, op cit). According to Hespanhol (2008) in terms of water resource management, it is therefore fundamental, especially in urban areas, that we abandon the outmoded orthodox principles and implement a new paradigm based on the key-words of water conservation and reuse, as only thus will it be possible to minimize the costs and environmental impacts associated with the new channeling projects.
In the mountain regions, the most affected areas in terms of vegetated loss in the Guapi-Macacu Basin were observed in National Park of Serra dos Órgãos and also State Park of Três Picos. About eleven percent of the park´s vegetation has been lost between 1985 and 2010, which represents an area of thirty three square kilometers. According to Goncalves et al. (2009) to reconcile conservation and land-use one of the alternatives is to establish buffer zones around protected areas, within which human activities are subjected to specific rules and restrictions. Brazil's Conservation Units National System (SNUC) determines that protected areas should be surrounded by buffer zones where human activity is restrict, but the established size of the buffer seems arbitrary (Alexandre et al, 2010). In 1990, the National Environment Council (CONAMA) Resolution number 13 had already defined a buffer zone of 10 kilometers around protected areas, where any activity that may affect the biota should be licensed (CONAMA, 1990). In 2010 the resolution No. 13 was revoked by Resolution No. 428/2010, which reduced the buffer zone to 3 kilometers for licensing the enterprises of a significant environmental impact , located from the edge of Conservation Units, where the buffer zone is not established with the exception of private reserves (RPPN), the Environmental Protection Areas (APAs) and consolidated urban areas.

	Vegetation Remnant Areas (Square Kilometers)			Variation (%)
Conservation Units	**1985**	**2001**	**2010**	**1985-2010**
Environmental Protection Areas	496.193	427. 573	395.822	-20.23
Parks	349.687	338.979	310.257	-11.27
Ecological Reserve	4.141	3.685	4.120	-0.48
Biological Reserve	151.083	149.767	143.172	-5.23
Ecological Station	63.550	61.297	59.185	-6.87
Sambê Santa Fé Corridor	255.330	206.108	198.720	-22.17

Table 3. Vegetation Remnant Areas (km^2) in the Conservation Units at Baia de Guanabara Basin

5.4 Remnant vegetation according to altitude

Guanabara Bay Basin is characterized by a large number of small ponds (over 40), usually <100 km2. The river profiles are characterized by a strong slope change in a few tens of miles to a relief of hills before reaching the coastal plain (Bidone & Lacerda, 2003). The upper part of the basin occurs in the oceanic ridge of the Serra do Mar, a mountain system, with a maximum of 2,000 to 2,200 m and consists of a block of cracks inclined to the north-northeast (Cabral et al, 2007). The southwestern plains, where vegetation has been extensively cleaned, are characterized by plan terrain to gently sloping terrain.
Figures 9 to 11 and Table 4, show the areas of remnant vegetation in relation to altimetry. Between 1985 and 2010 Guanabara Bay Basin lost 382.174 square kilometers of vegetated area. The vegetation is less impacted at higher altitudes ("serras") probably due to difficulty for agricultural purposes.

According to Freitas et al (2010) the highest deforestation and fragmentation occurred in less declivous areas, where there are more roads, and more intensive land use. The results corroborate those previously reported by Freitas op cit, with a significant decrease in 62.01 percent of vegetated areas in the lowlands, the equivalent of an area of 110.689 square kilometers.

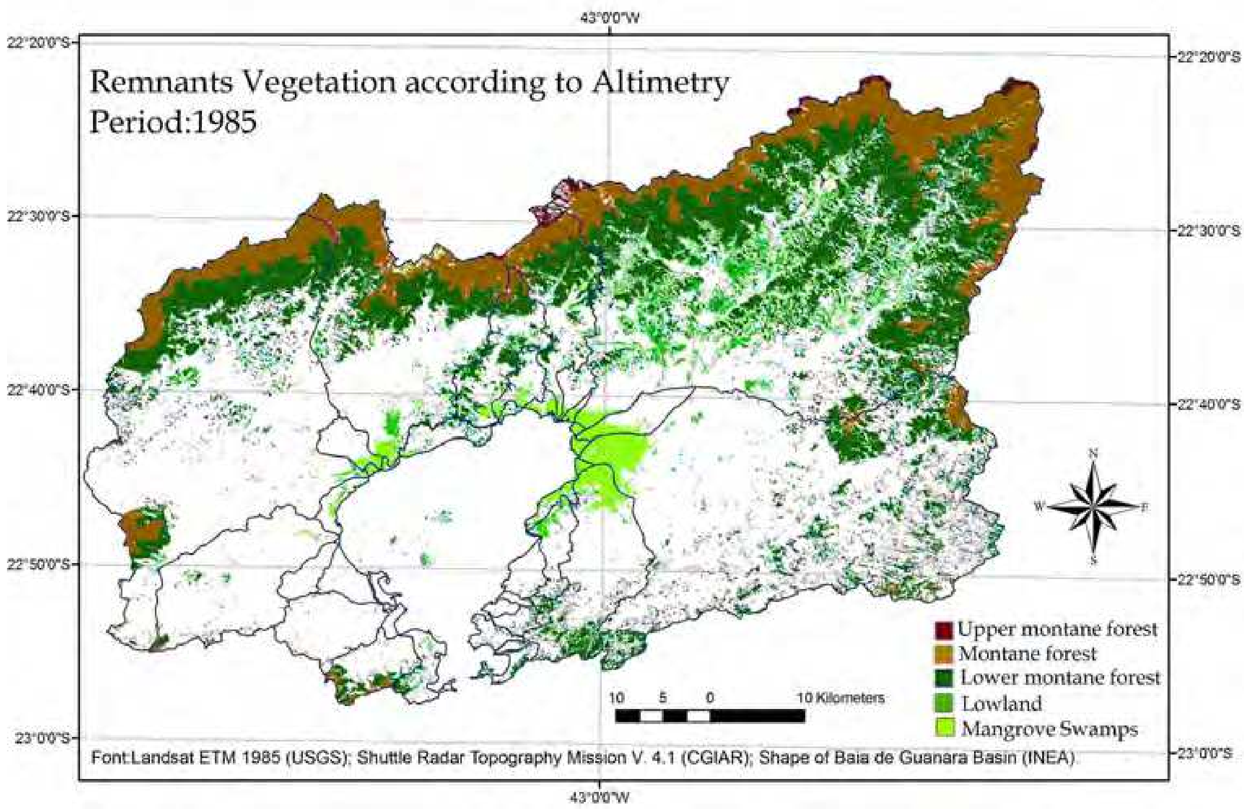


Fig. 9. Remnant vegetation according to altimetry (1985)

The mangrove area has decreased from 86.308 km2 in 1985 to 67.397 km2 in 2010. The main causes of mangrove degradation in the Guanabara Bay Basin include population pressure, agriculture, as well as pollution. On a positive note, between 2001 and 2010 there was a small increase in mangrove area, probably due planting and replanting initiatives. However, the Landsat images do not allow more detailed assessments in relation to degradation stage of mangroves that continually receive different kinds of waste coming from urban, commercial and industrial activities.

The major extension of vegetation remnants was observed in higher altitudes ("serras"). Areas with steep slopes are less used and is much more likely to remain forested (Silva, 2007). Although montane forests and upper montane forests have been losing areas along the study periods, mainly due to intentional fires or those for clearing land for pastures. In September 2010, intentional fires in the State Park of Três Picos destroyed 80 hectares of pasture lands, natural forests and fields of altitude called "campos rupestres". In August 2011 a fire broke out 30 hectares of forest in the National Park of Serra dos Órgãos. The major cause of the vegetation loss in the Guanabara Basin was due to urban development without planning.

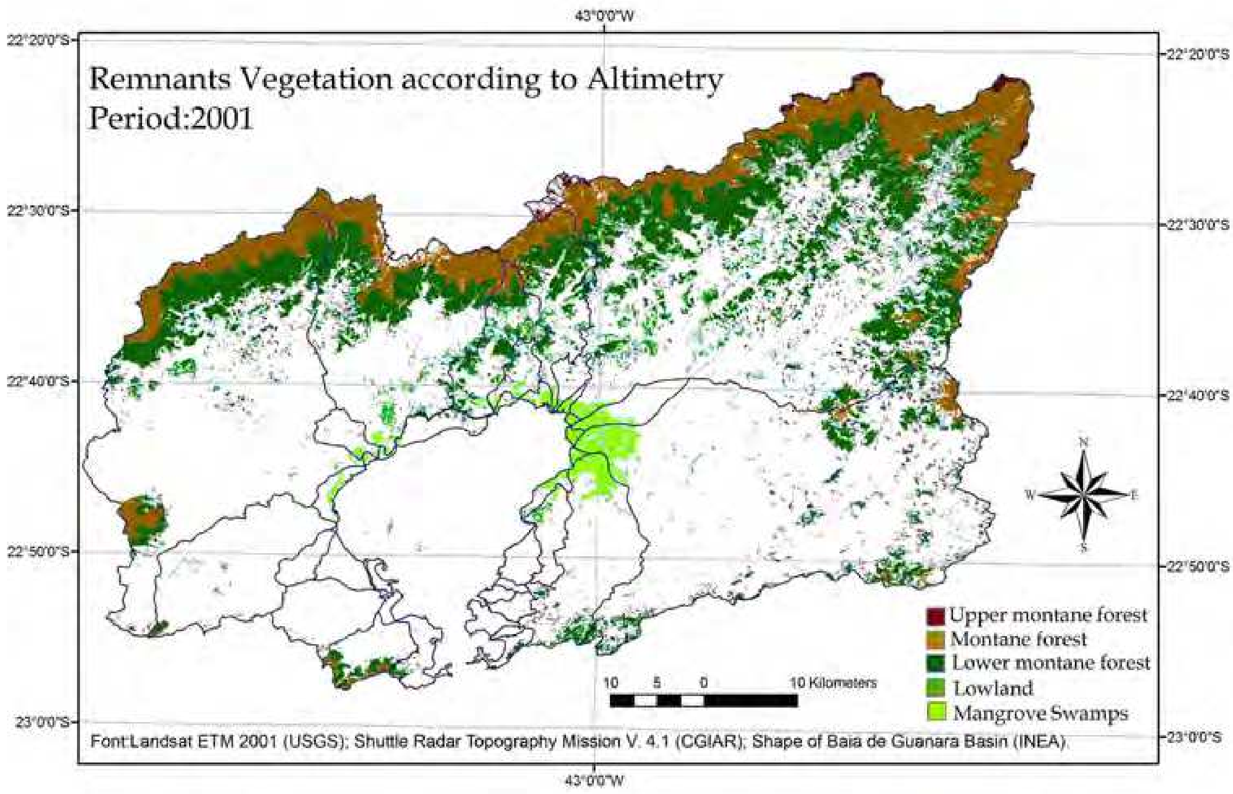


Fig. 10. Remnant vegetation according to altimetry (2001)

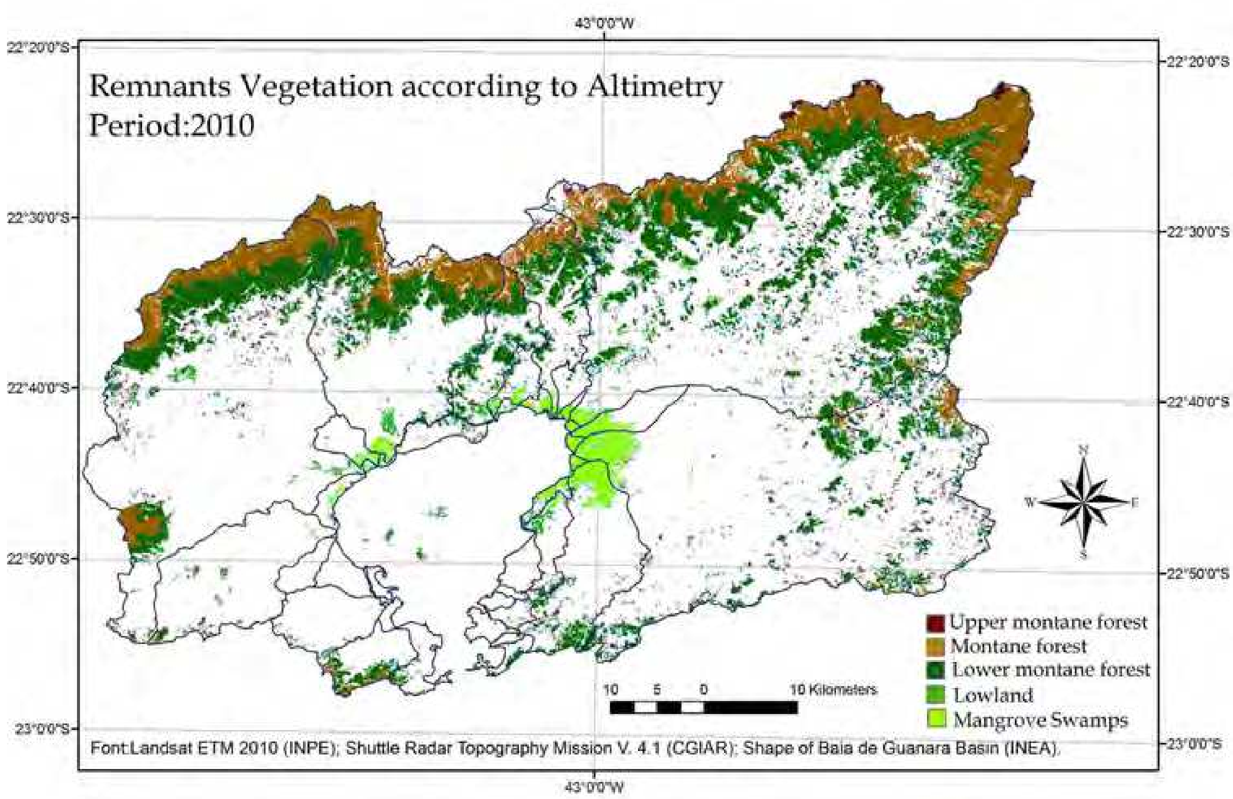


Fig. 11. Remnant vegetation according to altimetry (2010)

Area (Km²)	1985	2001	2001	Variation (%) 1985-2010
Mangrove swamps and wetlands (0-7m)	86.308	67.397	67.792	-21.31
Lowland (0-40m)	178.497	90.401	67.808	-62.01
Lower montane forest (40-500m)	884.356	691.698	672.229	-23.98
Montane forest (500-1500m)	405.536	396.678	364.694	-10.07
Upper montane forest (1500-2200m)	17.90	15.05	10.1	-43.52

Table 4. Remnant Vegetation in relation to altimetry

5.5 Vegetation fragmentation in the Atlantic Rainforest Central Mosaic

Landscape mosaics are described by the landscape components of patches, corridors, and the surrounding matrix (Forman, 1995). Factors such as patch size and shape, corridor characteristics, and connectivity work together to determine the pattern and process of the landscape (Forman, op cit). Franklin et al. (2002) has proposed four requisites for building situational definitions of habitat fragmentation: (1) what is being fragmented, (2) what is the scale(s) of fragmentation, (3) what is the extent and pattern of fragmentation, and (4) what is the mechanism(s) causing fragmentation. According to Franklin op cit., fragmentation at the range-wide scale can affect dispersal between populations, fragmentation at the population scale can alter local population dynamics, and fragmentation at the home range scale can affect individual performance measures, such as survival and reproduction. The topography can also influence patterns of forest fragmentation and forest cover, as previously demonstrated in several regions, including the Brazilian Atlantic Forest region (Silva et al., 2007; Freitas et al., 2010). Fahrig (2003) defined four effects which influence the fragmentation process on habitat pattern:(a) reduction in habitat amount; (b) increase in number of patches; (c) reduction in patch size; and (d) increase of isolation between patches. However, fragmentation measures vary widely; some include only effect (e.g., reduced habitat amount or reduced patch sizes) whereas others include two or three effects but not all four (Fahrig, op.cit). The large connected area (corridor) allows the exchange of genetic material with large populations.

The study area is included in the Atlantic Rainforest Central Mosaic with a large and contiguous corridor observed in mountain region. The figures 12 to 14 show that the six classes of vegetation fragments, varied from very small fragments (<0,03ha) and small fragments (<80ha) to a unique and very large vegetation block of 87,241 hectares observed in mountain region in 1985. This contiguous forest block is composed by different Conservations Units of integral protection and of sustainable use as National Park of Serra dos Órgãos, State Park of Três Picos, Paraiso Ecological Station, Tinguá Biological Reserve and part of Sambê Santa Fé Corridor and Petrópolis Environmental Protected Area. Between 1985 to 2010 the continuous vegetation block has been reduced in 26.44 percent, the equivalent of 23,066 hectares of vegetated area.

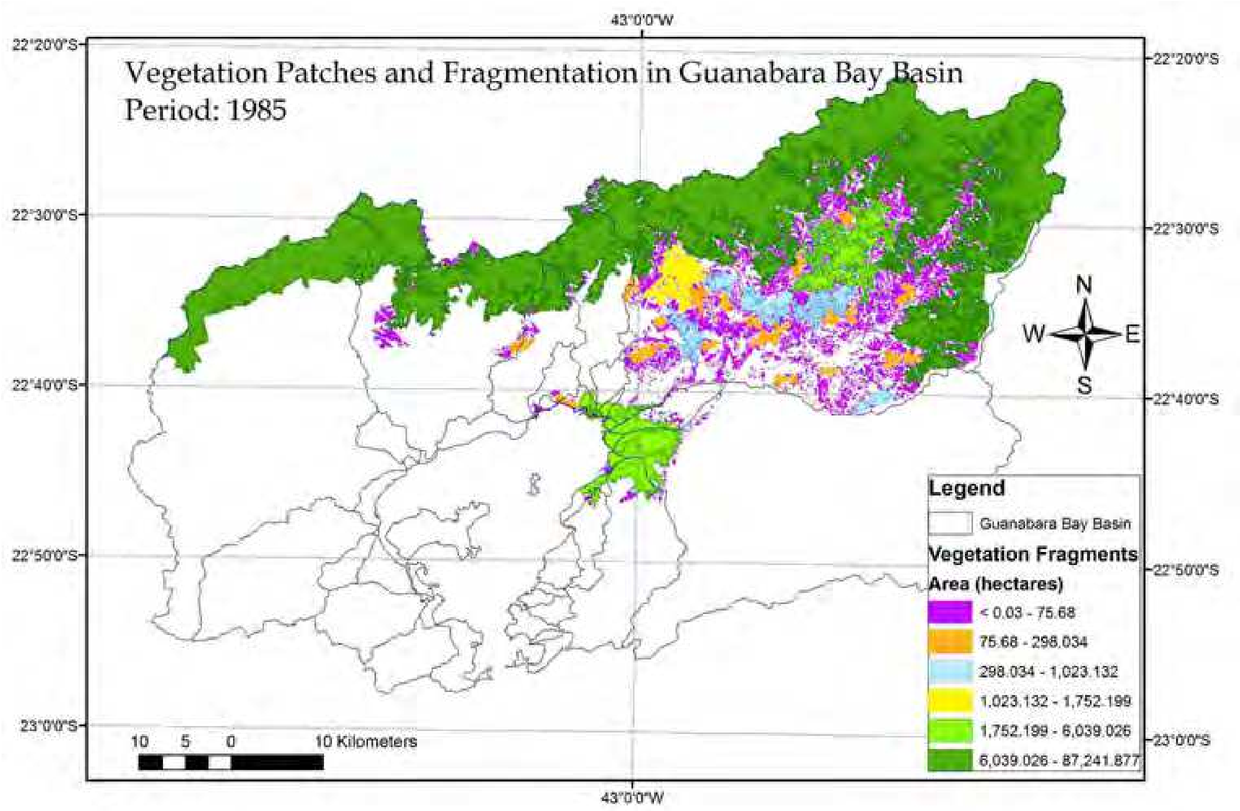


Fig. 12. Vegetation Fragmentation in Guanabara Bay Basin (1985)

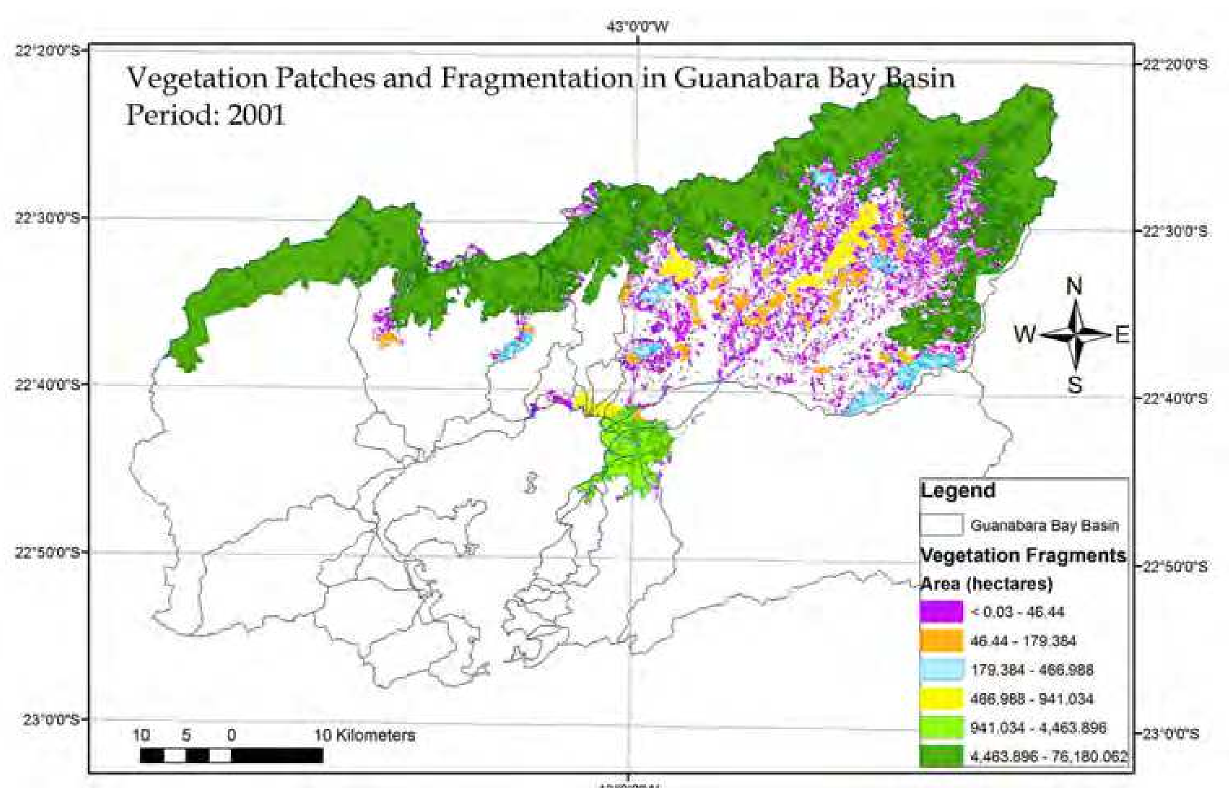


Fig. 13. Vegetation Fragmentation in Guanabara Bay Basin (2001)

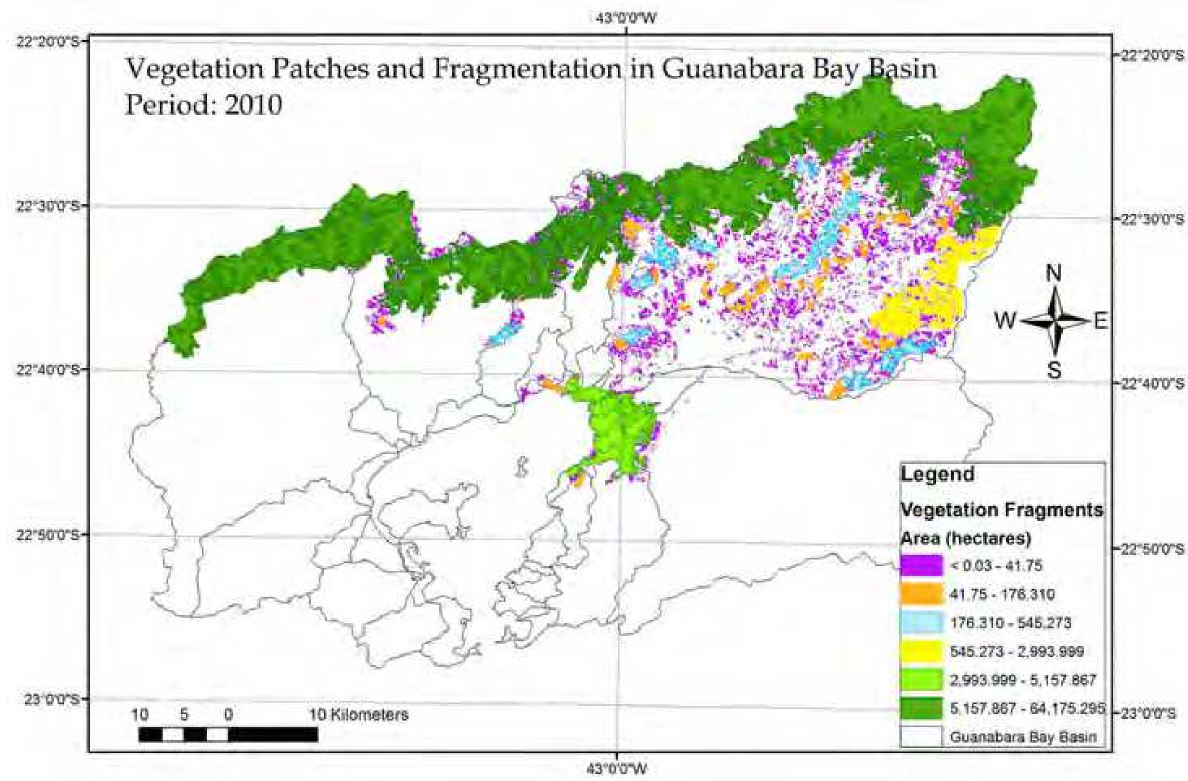


Fig. 14. Vegetation Fragmentation in Guanabara Bay Basin (2010)

In the same period, there was also a lack of continuity between forest fragments that were previously connected. Fragment size and connectivity are among the key landscape factors that affect species survival in fragmented landscapes (Carvalho et al., 2009). Metzger et al. (2009) suggested that fragment size is usually related to the amount and diversity of resources, which directly influence the size and number of resident populations.
The study shows that the largest reduction in size of forest patches was observed on the plains. Although the vegetation patch in lowlands is extremely important to allow connection between highlands, it was observed that vegetation fragments become smaller and more widely spaced. Figure 12 shows a vegetation patch of 4,648 hectares in the central part of the Guapi-Macacu River Basin , which was reduced to some small patches disconnected in 2010. Also, the number of the bigger fragments declined while the smaller ones increased, which means that during that study period a strong fragmentation took place. According to Freitas et al. (2010) higher density of roads is a primary predictor of forest fragmentation and deforestation. As shown in Figure 14, there was a fragmentation in the south and southwest of the Sambê Santa Fé Corridor in some small patches of vegetation. According to the analysis in 1985 the Corridor of Sambe Santa Fé had a large-continuous patch of 188.200 square kilometers. In 2001 this large patch was reduced to 142.117 square kilometers and several fragments of different sizes, which will bring serious problems for the local biodiversity. The National Park of Serra dos Órgãos has lost approximately 20 percent of the vegetated area.

5.6 Anthropogenic occupation in Guanabara Bay Basin in relation to slope classes

The topography determines the expansion of roads and the land use activities, which will impact the forest cover (Freitas et al, 2010). The thematic maps overlay of anthropogenic class and slope layers (Figure 15) showed that the human occupation occurs mainly in the slope classes between 0 and 3 percent, less than 10 meters of altimetry. The anthropogenic class occupied an area over 600 square kilometers in plan terrain, which is subject to risk of flooding, especially in rainy periods. In April 2010, heavy rain caused destruction and death in the State of Rio de Janeiro. The anthropogenic growth is also evident in slopes between 3 to 8 percent, with 268 square kilometers occupancy in gentle sloping terrain. In steep slopes and near streams, where it is difficult to grow crops and accessibility is limited, forest is commonly found (Teixeira et al., 2009). In addition, in most cases the Atlantic Forest region is located in sites where access is difficult (Cabral et al., 2007; Silva et al.,2007). According to Freitas op cit, forests far from land use (buildings and agriculture) and major cities are more likely to be preserved and regenerated. The results corroborate those from authors cited above with low occurence of anthropogenic occupation on slopes between 20 to 45 percent and 45 to 75 percent with higher amount of remnant vegetation. This fact is explained by the difficulty of occupying the higher slopes and the lack of infraestructure which restrict the urban expansion.

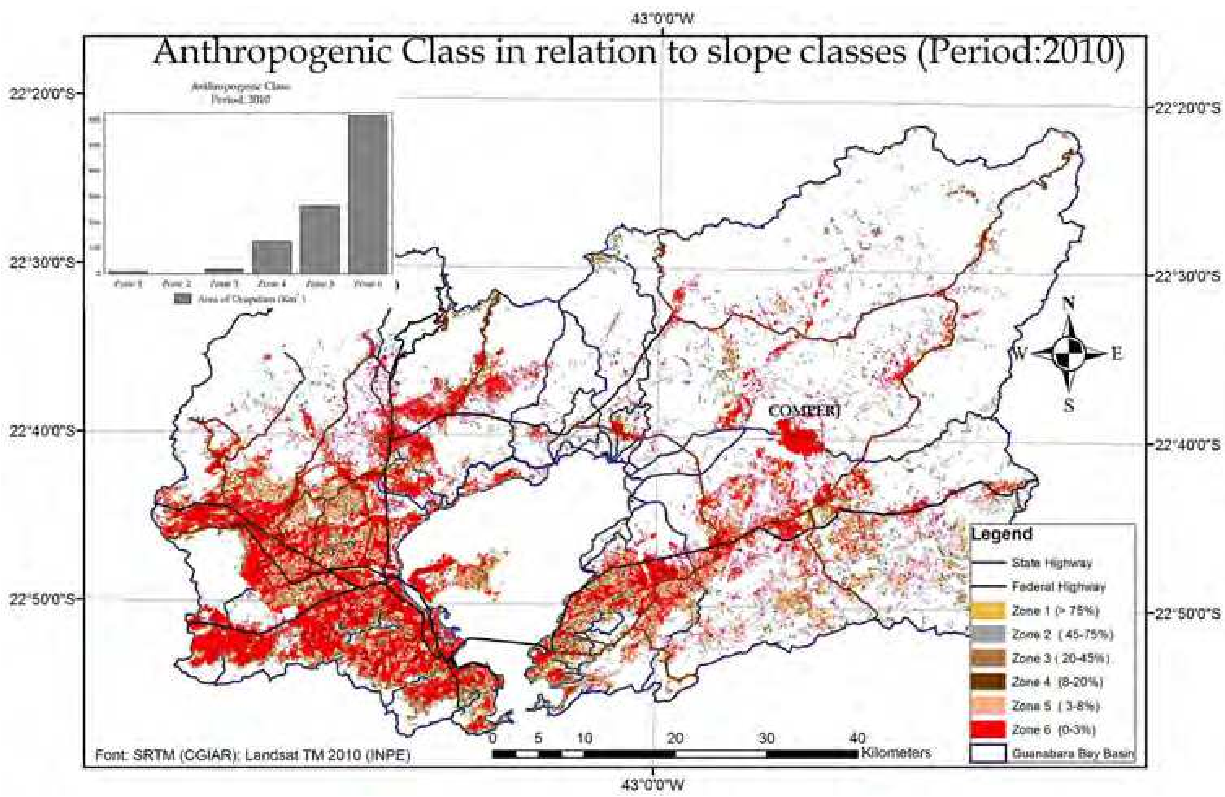


Fig. 15. Anthropogenic Occupation in relation to slope classes.

Figure 16 shows that the anthropogenic occupation in plan terrain also occurs in buffer zones that must be preserved as the Permanent Protection Areas (APP), along the rivers, in the buffer zones of riparian vegetation. According to Naiman & Décamps (1997) riparian zones play essential roles in water and landscape planning, in restoration of aquatic systems, and in catalyzing institutional and societal cooperation for these efforts. Rivers and their adjoining riparian zones are considered to be the most important corridors for movements of animals in natural landscapes (Forman & Godron 1986). Furthermore, human alteration of riverine ecosystems involves not only changes to flow regimes but also simultaneous changes in hydrologic connectivity (Nilsson et al. 2005).

The human occupation is also observed in mountain regions, inside buffer zones of strict protection conservation units as Parks and Reserves. The Figure 16 also shows a drastic reduction of seven kilometers in buffer zones, which may allow the expansion and implementation of large-scale infrastructure projects and also a rapid urban occupation in the eastern part of Guanabara Bay Basin. There is a concern with the rapid urban growth in Itaboraí, Cachoeiras de Macacu and Guapemirim which could bring serious damage to surrounding pristine vegetation, riparian vegetation and also wetlands.

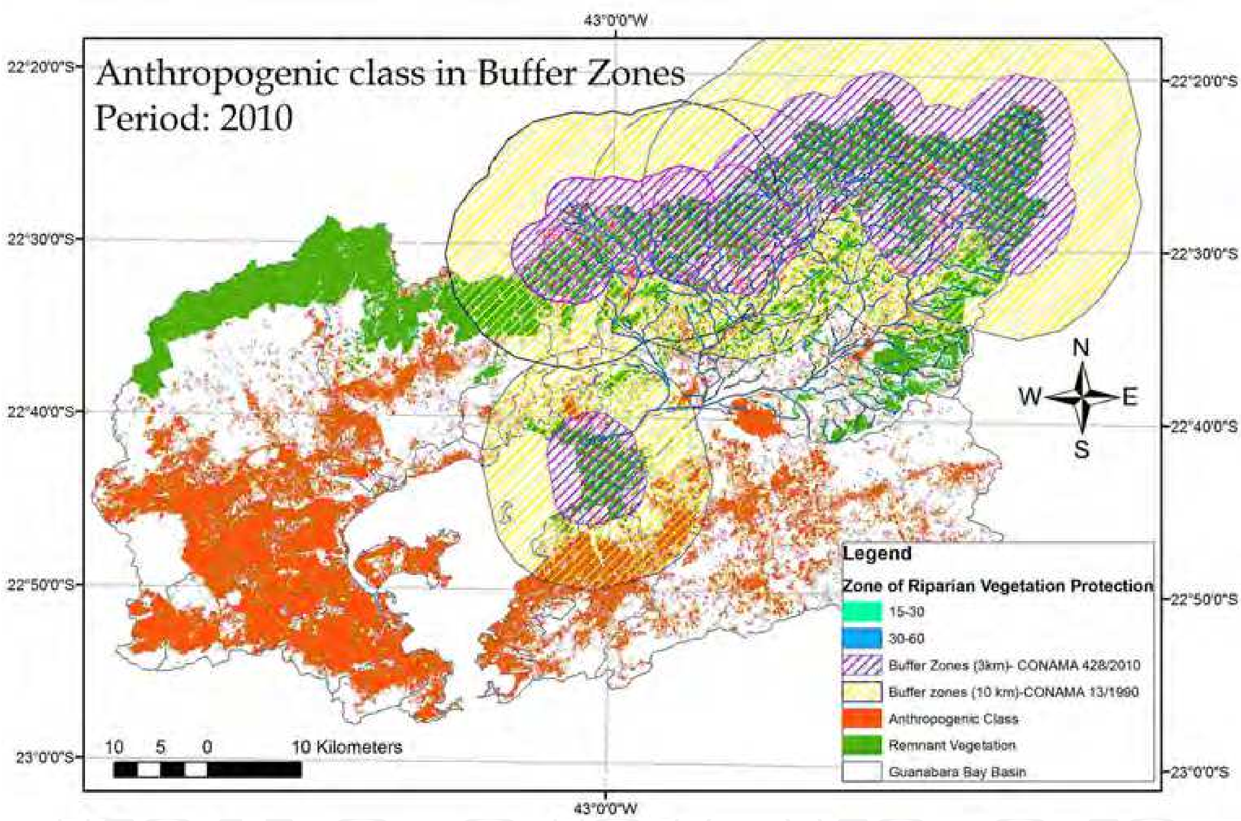
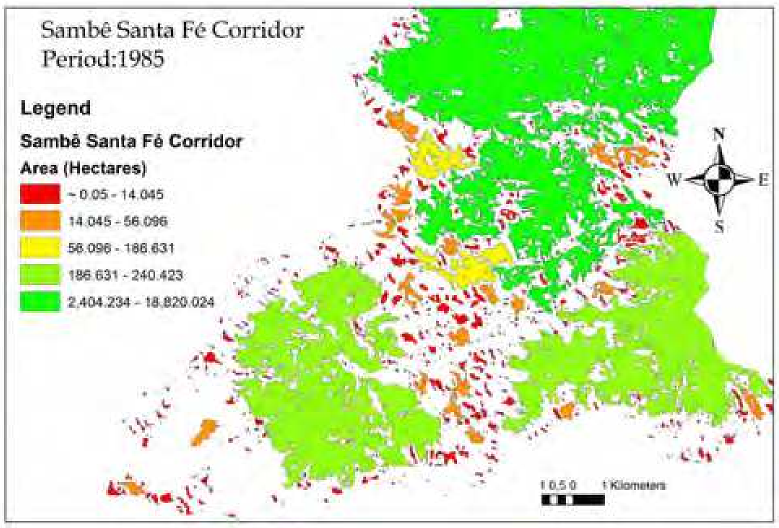


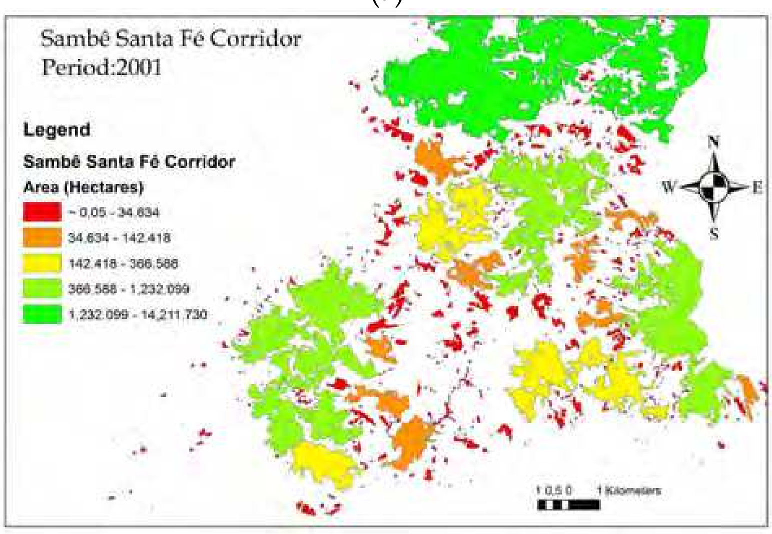
Fig. 16. Anthropogenic occupation in buffer zones

5.7 Critical areas for protection

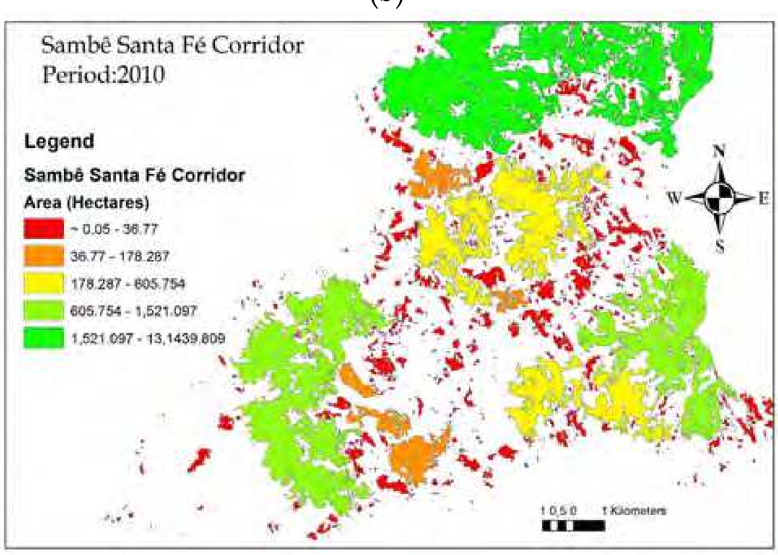
The Conservation Units in the Atlantic Rainforest Central Mosaic are becoming fragmented and have lost a great amount of vegetated areas along the study period. It was identified two critical areas that Conservation or restoration actions become more urgent: Sambê Santa Fé Corridor and Guapi-Macacu River Basin. The major rupture in the continuity of Sambê Santa Fé Corridor is observed in southwestern part of the corridor (Figure 17a,b,c) with highly fragmented landscapes into small and isolated fragments. In 1985 it was observed the close proximity of the patches and also the amount of vegetation areas was higher than in 2010. Figure 17c shows that the patches were reduced in habitat amount, increase in isolation among patches and reduction in patches size.



(a)

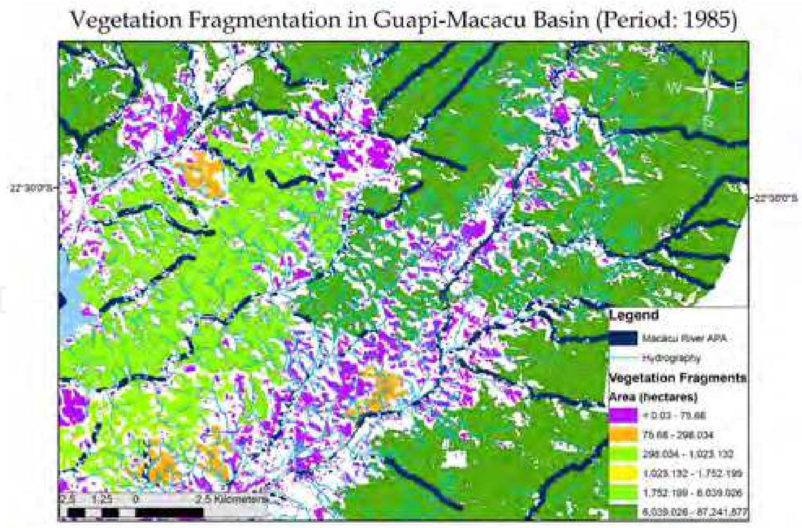


(b)

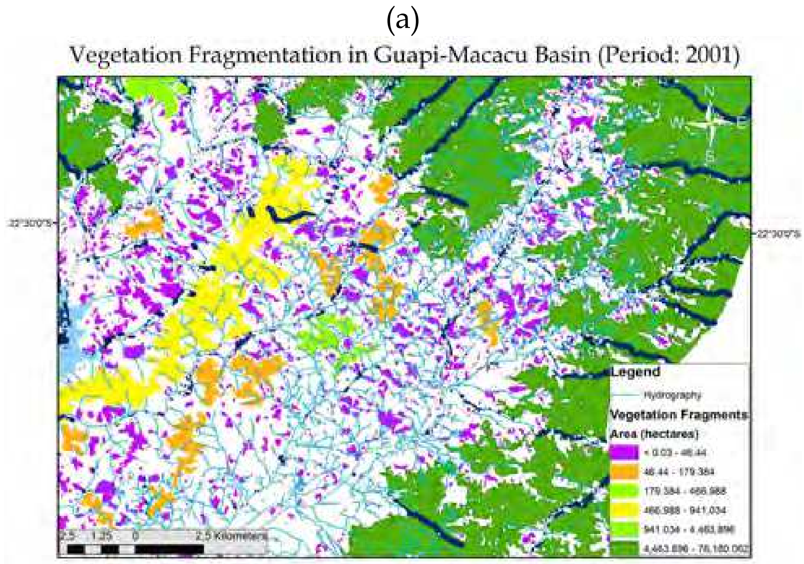


(c)

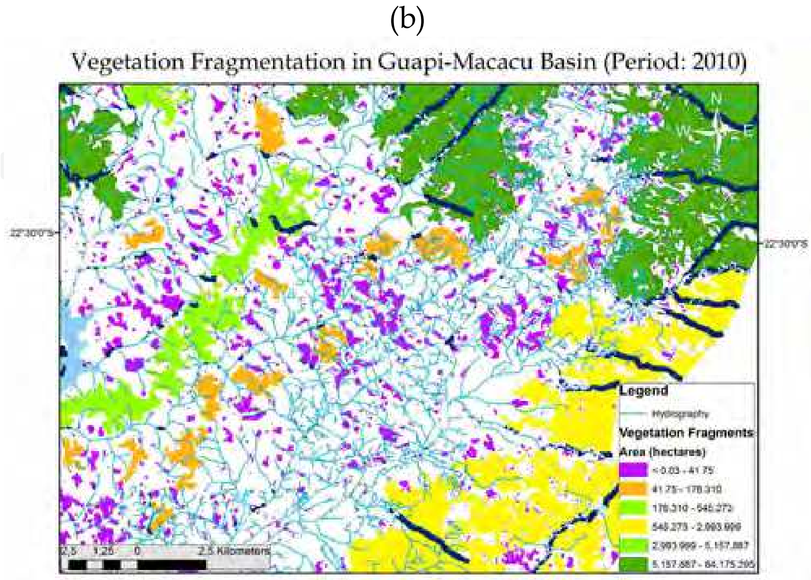
Fig. 17. Sambê Santa Fé Corridor



(a)



(b)



(c)

Fig. 18. Guapi-Macacu River Basin (1985, 2001 and 2010), respectively.

The vegetation patches in Guapi-Macacu River Basin are being fragmented along the years. Figures 18a,b,c shows a decrease in amount of vegetated area among the study periods. In 2010 it was observed that the vegetation fragments became smaller and isolated and the riparian vegetation is much less evident. Fig 18c shows that riparian vegetation had a severe decreasing in the central part of Guapi-Macacu. Human-centered attitudes toward water have deteriorated many riverine ecosystems, implying that the derived benefits have brought considerable environmental and social costs (Nilsson, 2007). Therefore, enhancements of river connectivity require thorough analysis and, ideally, should be carried out in concert with rehabilitation of flow dynamics (Nilsson op cit.).

6. Conclusion

Forests are cleared, degraded and fragmented in the Guanabara Basin. The riparian vegetation in the Guapi-Macacu river basin is disappearing over the years and it may soon affect the water supply in the Guanabara Basin. The most serious threat comes from the disorderly and irregular land occupation without urban planning.

People yet ignore the importance of the riparian vegetation and this negligence will cause in a near future serious problems in the available ground water and consequently in the water supply. Degraded riparian vegetation leaves surrounding ecosystems vulnerable to some disturbances as flood and drought. The existing vegetation in the riparian zone needs to be kept intact or protected by law. There must be strongly enforced laws to limit urban occupation in the river bank and avoid activities which deplete the riparian vegetation.

Despite its water reserves, Brazil now runs the risk of losing their most precious natural resources: water and forests, due to disorderly process of land occupation and irresponsible degradation of the environment. Everything that happens in one point of a river basin will influence the total of the basin. The irresponsible use of natural resources is bringing drought, which is bound to handicap the production of vital resources for sustaining human population, as is already happening in some parts of the world (Moraes, 2009).

There is a need for the stakeholders to establish conservation initiatives and share experiences in order to safeguard the riparian vegetation, mangrove swamps and Atlantic Forest remnants of the Guanabara Bay Basin. The forests are essentials for maintaining a drinking-water provision.

It is necessary urgent efforts to restore the remaining forests, with reforestation initiatives, especially in the headwaters of rivers. And to connect and expand the remnants of forests that are already fragmented which reduces the capacity of species to disperse through the landscape.

The Landsat satellite becomes very useful for working with medium scale maps for distinguishing higher ranks of classification. Moderate resolution remote sensing is widely used in a variety of sectors including land use planning, agriculture, and forestry. However, this approach cannot be applied directly in large scale maps. Thus, it is necessary an integrated study combining high resolution satellite images with data from other sources (thematic maps and numerical data) for providing new possibilities for land-cover analysis of the Basin. The further studies using a large-scale vegetation mapping for verifying with detailed the different succession stages of Atlantic Forest and its biodiversity. According to National Environmental Council (CONAMA) number 6, 1994 and Law n. 11.428 (December,

2006) different types of land use and natural vegetation cover are categorized based on ecological succession.

Water production for life also depends on protected areas. A connected administration (Federal, State and Municipal) of different protected areas is essential. Parks, reserves and environmental protected areas have to plan together and also work together against fires, environmental disasters, irregular occupations, trafficking and poaching of animals. Impacts in higher places affect lower places. So those the opposite. It is very important the interaction between public and private agencies and also non Governmental Organizations NGOs, universities, and research organizations aiming at define land use objectives and restrictions.

The restoration of Guapi-Macacu River Basin is not easy and involves efforts by different sectors of society to the implementation of integrated alternatives such as: technical, ecological, and also environmental education programs and policies. It is also urgent a linking of remnant vegetation of lowlands with that of highlands aiming at guarantee the water supply in the basin and also the integrity of the ecosystem.

Sambê Santa Fé Corridor restoration should be considered a high priority conservation action, since the corridor contributes to maintain the water quality and quantity of Guapi-Macacu watershed.

In Brazil were created some Conservation Units and ecological corridors to preserve biodiversity and restore landscape connectivity. Many units have been established for over 20 years and still do not have a management plan which difficult the environment zoning. Some NGO´s and public and private organs are currently involved with Atlantic Forest conservation efforts. Although, these efforts is not sufficient to preserve/conserve the Protection Areas and its remnant vegetation. This fact is mainly because the political and economic interests have a higher priority than environmental ones.

Urban planning is essential, especially in the areas of influence of Rio de Janeiro Petrochemical Complex (COMPERJ) that are expanding rapidly. The urban expansion in the eastern part of the basin may cause serious damages to remnant vegetation , especially with the reduction of buffer zones, including strict protection in areas as parks and ecological stations. The application of public and private investments in water reuse is also urgent to meet additional population demand.

With the increasing of world population it is necessary a change in way of life in order to seek what is really important for our survival by using different sources of sustainable energy as well as making use of non conventional materials. Humans can no longer continue exploiting and destroying the forests because in the end, we will be no water, no food and no prospect of survival in our planet.

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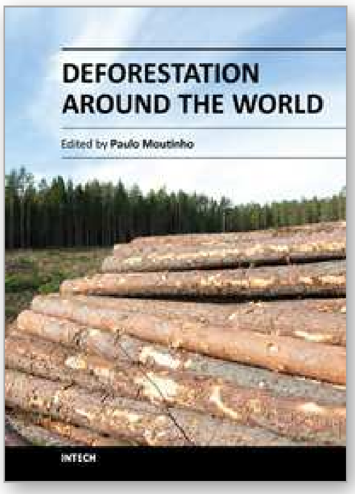

Deforestation Around the World
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Deforestation and forest degradation represent a significant fraction of the annual worldwide human-induced emission of greenhouse gases to the atmosphere, the main source of biodiversity losses and the destruction of millions of people's homes. Despite local/regional causes, its consequences are global. This book provides a general view about deforestation dynamics around the world, incorporating analyses of its causes, impacts and actions to prevent it. Its 17 Chapters, organized in three sections, refer to deforestation impacts on climate, soil, biodiversity and human population, but also describe several initiatives to prevent it. A special emphasis is given to different remote-sensing and mapping techniques that could be used as a source for decision-makers and society to promote forest conservation and control deforestation.