

MULTITEMPORAL ANALYSIS BY REMOTE SENSING OF THE EVOLUTION OF COASTAL LINE OF GUANABARA BAY, RIO DE JANEIRO, BRAZIL

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ABSTRACT

Changes in coastlines are considered one of the most dynamic processes in coastal environments. Therefore, the mapping of such variations has become important in the survey of coastal impacts. In the past years, remote sensing has been used in mapping the coastline. In this research, the coastline of Guanabara Bay, in Rio de Janeiro, Brazil, was mapped in the years of 1938, 1974, 1984, 1997, and 2015, by using geo-referencing software and existing cartographic documents. To map the changes, the bay was divided into four sections, in which maps were produced in graphical format, using ArcGIS, in scales 1:175.000 and 1:250.000. The research used satellite images from Landsat 1 Multispectral Scanner System (MSS), Landsat 5 Thematic Mapper (TM), and Landsat 8 Operational Land Imager (OLI), integrated under geographic information system database, for a visual analysis (qualitative), and statistical observation (quantitative) of orbital images. The data indicate more intense transformations between the years 1938 and 1974, with a total landing area of 15.220.000m². This area corresponds to 69.23% of the amount suppressed during the interval 1938-2015.

Keywords: Historical Mapping; Coastline; Guanabara Bay.

1. INTRODUCTION

Coastal areas present ecosystems that are particularly sensitive and fragile under an environmental perspective, such as estuaries and mangroves. As a result of its peculiar geomorphology and consequent hydrodynamics, they present an ecological complexity and biological richness that are fundamental to the balance of species (Soares et al., 2011). However, in general, the whole seafront is subject to many agents in a fast, developing process of expansion, such as tourism, aquiculture, large industrial complexes, and ports. Such activities have contributed to accelerate the irregular urban expansion and occupation, with all the issues and impacts they generate, such as the emission of domestic and industrial sewage, and the occupation of public and permanent preservation areas.

The coastal area can be defined as a dynamic zone between continents and oceans, subject to continuous morphological changes, resulting from continental and ocean processes (Yanli, 2002; Alesheikh et al., 2007; Selvavinayagam, 2008). The coastlines around the world have quickly changed in recent years due to the result of natural physical phenomenon, as well as due to anthropogenic activity. Natural factors, such as sediment supply, hydrodynamic energy, and sea level are primary causes for changes in coastline. But at the same time, human activity has shown as an accelerating force for these changes (Van and Binh, 2011; Niya et al., 2013) due to landing and industrial installations.

Large-scale landings are common in coastal metropolitan areas, which eliminate significant intertidal areas. Significant examples occur in San Francisco Bay, in the United States of America, in which 96% of the salt marsh area (originally 3,400 km², or more than half of the bay's water surface) was lost (Atwater et al., 1979), and in Holland, where 4,000 km² of estuary marshes were landed (Wolff, 1992). Among Brazilian estuaries, the most severe landing process occurred in Guanabara Bay, where more than 10% of the original area (today at 384 km²) was landed (Amador, 1992).

The coastal integrated management must be understood as an action based on science and technology. Therefore, it demands an understanding that does not come only from its practical implementation, but from a conceptual development, and critical methodology that cannot be built inside research and development institutions (Asmus et al., 2006). The detection and registry of coastline changes are important actions for environmental monitoring and coastal management (Xuejie and Michiel, 2007). The control of sea strip alterations can follow different approaches, with particular advantages and disadvantages. Within this context, satellite images are simple to interpret and easily accessible (Van and Binh, 2011).

Remote sensing is an important tool that uses satellite images, and it has been frequently used to understand and manage natural resources (Sundaravadeivelu et al., 2005). It has the capacity to support studies with basic information for geographical research, with a considerably wide variation. Besides that, the integrated use of remote sensing data and geo-processing techniques represent a powerful instrument to follow and analyze coastal time-space alterations (Zhang, 2011; Zhang and Chen, 2009).

Remote sensing data provides a global perception of a region and a perspective very close to data from other sources, such as maps and geographical information systems, where, according to Centeno (2009), *"the possibility is opened to make use of an integrated way of satellite images, and with other spatial information sources, such as digital models of the terrain generated from GPS or Radar observations"*.

Based on the information mentioned above, this research aimed to evaluate the transformations in the Guanabara Bay coastline, through comparing multi-temporal satellite images in order to evaluate the main modifications that occurred on the water surface of the bay.

2. AREA OF STUDIES

Guanabara Bay is located in the state of Rio de Janeiro, Brazil, between the longitudinal coordinates 43°00'00" and 43°20'00"W, and latitudinal coordinates 22°40'00" and 23°05'00"S. This ecosystem is characterized by an estuary with a total area 346 km², including 59 km² of islands, as seen in Figure 1. The tributary hydrographic basin includes an area of approximately 4,000 km², and contributes through 35 main rivers that are extremely polluted by gross or partially treated domestic sewage, produced by 10 million inhabitants, and industrial effluents, from more than 12,000 industries (Fonseca et al., 2009). The bay touches 15 cities, having a particularly high population density at the west portion of the basin.

Guanabara Bay has reached the present level of impact, starting when the degradation process had intensified during the decades of 1950's and 1960's, due to an elevated urban development, especially in the southern region of Brazil. Another consequence of the occupation after 1950 was the origin, in the bay's hydrographic basin, of one of the largest poles of industrial development in the country.

Population growth and industrial development has brought, besides the pollution generated by this process, physical environmental issues, such as the destruction of peripheral ecosystems to the bay, landings, the uncontrolled use of the soil and its adverse effects, such as aggradation, background aggradation, flood, and landslide (Andreatta et al., 2009).

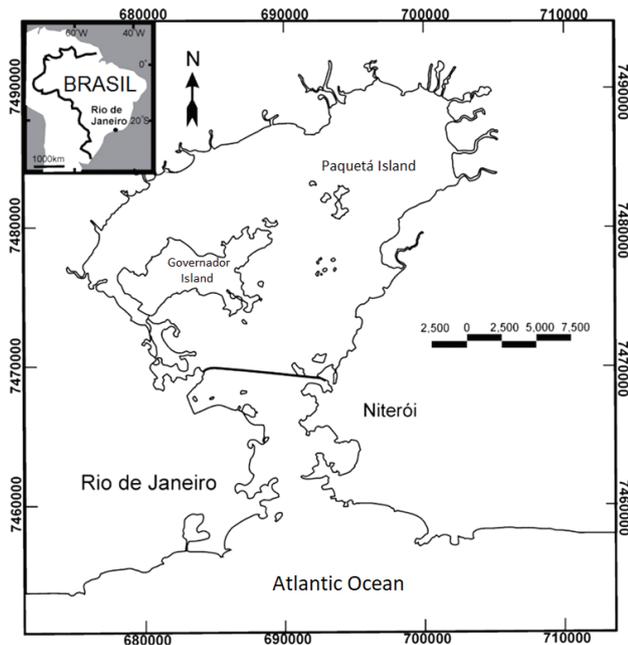


Figure 1. Research area

3. MATERIALS AND METHODS

Initially, the methodology was based on a bibliographical review and a comparative study of cartographic documents and orbital imagery of the selected area. The research was performed in a graphic environment, which aimed to create a databank of geo-referenced information based on maps. Through those data, the indications of the Guanabara Bay coastlines, from 1938 to 2015, were spotted. The maps generated as a result of those observations were integrated to a base of geographical information system (GIS), using as tools the Remote Sensing and the geo-referencing software ArcGis 10.3.1.

During the first stage, the digitalization of the Guanabara Bay coastline was performed in a 1:50.000 scale, on the 1938 historical Nautical Chart No. 1501, acquired at the Brazilian Navy Hydrographical Center. Over this accessed contour, added to the existing cartographic documentation, the data was adjusted under a GIS base from the Brazilian Institute of Geography and Statistics (IBGE, in Portuguese). This adjustment was based on the limitations between the municipalities from IBGE database, as well as the control points under this database, thus leading to the polynomial transformation 1 – nearest neighbor, with average error margin of 0.0345766, corresponding to 1.73 meters.

During the second stage, the images were processed through the software ARCGIS10.3.1. Then, the maps were acquired through the vectorization of orbital images using

the application ArcMap. At this stage, the following satellite images were used: Landsat 1 MSS (1974), orbit point 233/076, Landsat 5 TM (1984; 1997), orbit point 217/076, and Landsat 8 OLI – Operational Land Imager (2015), orbit point 217/076/268 LGN00, acquired from the website of INPE/NASA, with those that presented the best sight because they had less clouds being selected.

Table 1 describes the characteristics of orbital images and sensors used.

Table 1. Orbital images used in the mapping of Guanabara Bay

Image	Sensor	Year	Resolution (in meters)
Landsat 1	Multispectral Scanner System	1974	80 x 80
Landsat 5	Thematic Mapper	1984	30 x 30
Landsat 5	Thematic Mapper	1997	30 x 30
Landsat 8	Multisensors	2015	15 x 15 Panchromatic

From the processing and geo-referencing for the horizontal Datum SIRGAS, 2000, Zone 23S and UTM projection, the images were added to the GIS, by using the software ArcGIS 10.3.1. The colored composition of RGB bands and false color of the orbital images from Landsat satellites was performed with the objective to emphasize the differentiation between water bodies and land (Meneses and Almeida, 2012; Rosa et al., 2011).

Later, the Landsat images were sent to radiometric and geometrical corrections of the distortions related to the sensors of each satellite, through geo-referencing, geometric correction, and cubic interpolation (Silva et al., 1998; D'Alge, 2007).

Aiming to perform the geo-referencing, the first stage was the selection of the reference image, which was previously corrected from the Global Land Cover Facility Catalogue (GLCF). Besides that, it must be ortho-rectified, as both images were presented in TIFF format.

After the previous selection of bands, the organized stacking of such images was performed through the application ArcMap. The same proceeding was done for the bands of the INPE catalogue.

The images acquired as reference from the GLCF are not only available in UTM, but are also found in the Northern Hemisphere. Therefore, an adjustment is necessary for the Southern Hemisphere (Meneses and Almeida, 2012).

After the geometric correction inside a tolerance of 0.5 pixels, the cubic interpolation took place in order to im-

prove the results of the image. This transformation, from a line-column (LC) system, to a UTM (E, N) system allows establishing a mathematical correction between an image and a terrain, through transformation parameters (Antunes, 2002).

The results acquired were maps generated in two scales, 1:175.000 and 1:250,000, in order to enable a visual comparison of the different lines at the historical periods they represent. The methodology was based on visual (qualitative) and statistical (quantitative) interpretation of the geomorphological transformations of the coastline, seen from the orbital images (Kampbel, 2005).

4. RESULTS AND DISCUSSION

The monitoring of the variation of the coastline is extremely important, once it provides basic information that can support actions for coastal management (Makota et al., 2004). The same study permits the forecast of scenarios, as well as it assists geomorphologists to break the code of sedimentary processes existing in a certain region. The present evaluation was also performed through chronologic segmentation of four periods: 1938-1974, 1974-1984, 1984-1997, and 1997-2015 (Table 2).

The water surface area of Guanabara Bay, subtracted by human activity (Table 2), presents continuous growth during the 77 years in which it was analyzed. Within this aspect, the period from 1938 to 1974 was the most intense in relation to the observed modifications onto the coastline, in a total occupied area of 15,22km² of landings. This area corresponds to 69.23% of the total landed area of the bay during the complete analyzed period of this research. For a broader view of this study and the possible consequences, it is plausible to say that, through 77 years, Guanabara Bay has lost water surface losses around 21,980,000 m² (Table 2), which affects intensively whole ecosystems, islands, and rivers by expanding the coastline over landings, rectification of rivers, and uncontrolled urban occupation. The inappropriate use of land has changed the geomorphological characteristics and sedimentation tendencies inside coastal basins, leading to a fast aggradation process, and asphyxia of navigation routes, as for example, at the *Cunha* channel, located between the *Governador* Island and the continent (Sloss et al., 2011).

The losses in water surface area in Guanabara Bay in the historical process of changes of the surroundings from 1938 to 2015, along with the places in which the changes were significant, can be observed in Table 2, Figure 2, and on the map of Figure 3.

Table 2. Places and data of modified areas of Guanabara Bay, from 1938 to 2015

Period	Place	Area Km ²	Percentage %
1938 - 1974	Airport	0.19	0.84
	Guapimirim Environmental Protection Area	1.44	6.55
	Flamengo Landing	1.54	7.01
	Caju	0.96	4.38
	Downtown	0.12	0.55
	Cordovil and Duque de Caxias	0.12	0.56
	Fundão	1.87	8.50
	Governador Island	2.96	13.47
	Maré	0.99	4.51
	Niterói and Downtown	0.51	2.33
	Penha	2.04	9.26
	Ponta da Areia and Conceição Island	0.60	2.73
	Port	0.89	4.03
	Niterói-Manilha Highway	0.94	4.25
São Domingos	0.06	0.26	
Result		15.22	69.23
1974 - 1984	Guapimirim Environmental Protection Area	0.65	2.95
	Caju	0.29	1.32
	Cordovil and Duque de Caxias	1.24	5.65
	Governador Island	1.08	4.89
	Mocanguê Island	0.31	1.43
	Maré	0.45	2.05
	Niterói and Downtown	0.29	1.31
	Port	0.11	0.52
Niterói-Manilha Highway	0.56	2.54	
Result		4.98	22.66
1984 - 1997	Cordovil and Duque de Caxias	1.54	7.02
Result		1.54	7.02
1997 - 2015	Fundão	0.18	0.81
Result		0.18	0.81
1997 - 2015	Port	0.06	0.28
Result		0.06	0.28
Total Result		21.98	100.00

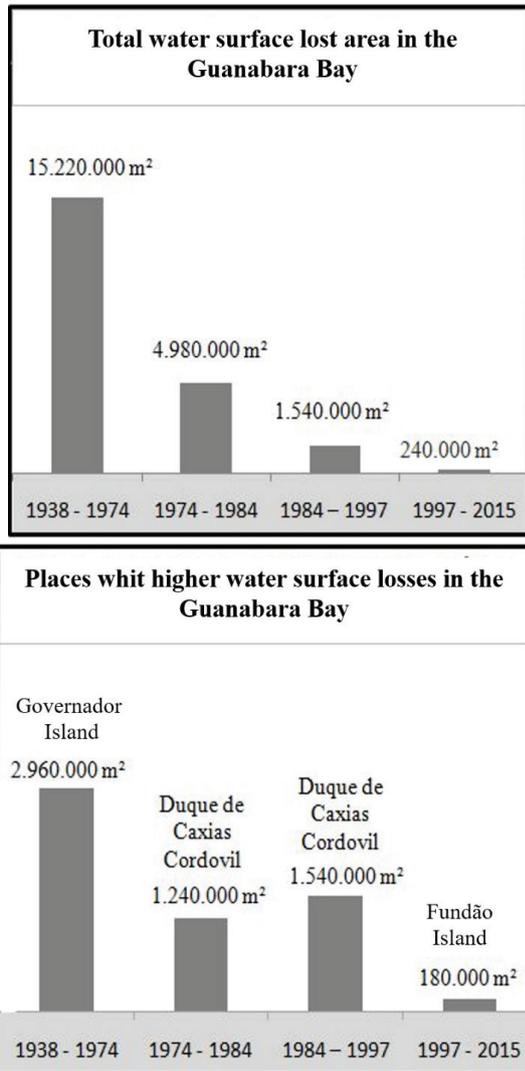


Figure 2. Losses in water surface area in Guanabara Bay, from 1938 to 2015

The total water surface area lost in Guanabara Bay for the studied period (1938-2015) was estimated in 21,980,000 m².

Based on the data acquired in this research, the four areas that presented larger modifications in the coastline were the Northwest (Governador Island), Central-West (Rio de Janeiro Port), Central-East (Niterói Port), and Northeast (Guapimirim Environmental Protection Area) of Guanabara Bay.

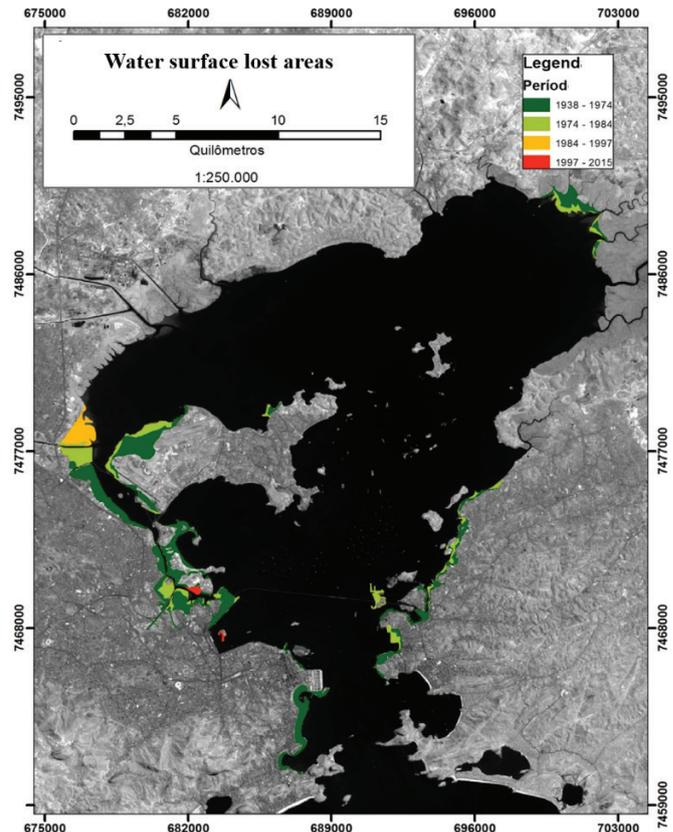


Figure 3. Map of Guanabara Bay, with the total water surface area loss, from 1938 to 2015

In the period observed, the most intense modification was found in Governador Island, with a landing percentage value of 13.47% of the total landed area of the bay (Table 2). The occupation and use of the water surface of Guanabara Bay for industrial oil plants, petrochemical and especially for naval purposes, added to investments in ports and shipyards, have made the coast of Rio de Janeiro the most important and most impacted area of Brazil (Sevá, 2013). In the islands inside the bay, such as Redonda Island, Água Island, and Governador Island, there are oil products loading and unloading terminals, and tank parks with large storage capacity connected to the Duque de Caxias Refinery (REDUC). The recently placed ducts over seabed connect these terminals and REDUC to the new Petrochemical Complex Center of Rio de Janeiro (COMPERJ).

The visual interpretation of the northwestern section of Guanabara Bay, between 1938 and 1974 (Figure 4), shows the changes in coastline for the previously existing group of islands. The multi-temporal analysis for this period indicates the movement of the coastline towards the shore, adding areas by landing, the disappearance of Maria Angú Beach and the incorporation of Ferreiros Island to the continent. Figure 4 permits visualizing the landed area in the complete extension of the shore, from Ferreiros Island to the south of Saravatá Island. It is also observed that, in the period from

1974 to 1984, a crescent movement of the coastal area in the segment that starts from the base of Rio-Niterói Bridge, going southwest towards Fundão Island. The area previously flooded and formed by tidal plains, as seen in Figure 4 map 1, was landed, annexing the Pinheiro Island to the continent.

Regarding the qualitative analysis for the period 1984-1997, it is suggested that the pressure on Guanabara Bay has continued due to urbanization, and the successive landings on the northern area of Meriti River set up a new contour of the coastline. The uncontrolled urban growth in the areas of Baixada Fluminense (Fluminense Lowlands) has generated flooding under Tropical Summer rainfall in some of the municipalities around Guanabara Bay (Costa, 2015). Governador Island also had changes in its contour for the construction of the International Airport Tom Jobim, having added areas and larger perimeter at the northwestern side of the island. According to Amador (1980), elevated rates of sedimentation, and the aggradation originated from the deforestation of the channel between the Governador Island and the continent resulted in the loss of water surface. After the 1970s, the successive landings continued to be used by large engineering projects suggested by the economic model used at the time (Amador, 1997).

In the end, for the period between 1997 and 2015, the analysis of Figure 4 shows that there were few changes ob-

served in the scale, if compared to maps in previous periods. A study performed by Gatto et al. (2010) about the present dynamics of the evolution of Fundão Island shows that there is a recuperation project of the environmental reservation area, a decrease in the use of grass, and an increase in the constructed area in some portions of the island. The changes in the northwestern section represented an area of approximately 14,780,000m². Cruz et al. (1996) confirmed in this research that 80% of the landings in Guanabara Bay were found in this area, during the process of urbanization between 1940s and 1960s. As Amador (1997) found, this area was constituted by an archipelago chopped by channels of sandy composition and abundant vegetation, which belonged to these islands and where the circulation of waters by tide currents permitted its renovation. Menezes (2005) suggest a decrease of the water surface of around 2,700,000m², by eliminating eight islands: Fundão, Baiacú, Cabras, Catalão, Ferreira, França, Bom Jesus, and Sapucaia, which were merged to build the University City, today Fundão Island.

More to the south, still on the west coast of the bay, it is possible to spot an accentuated modification which took place during the initial periods analyzed in this research. The stretch of Guanabara Bay where the Rio de Janeiro Port is located is one of the most altered areas since the beginning of the 20th century, where the original coastline was comple-

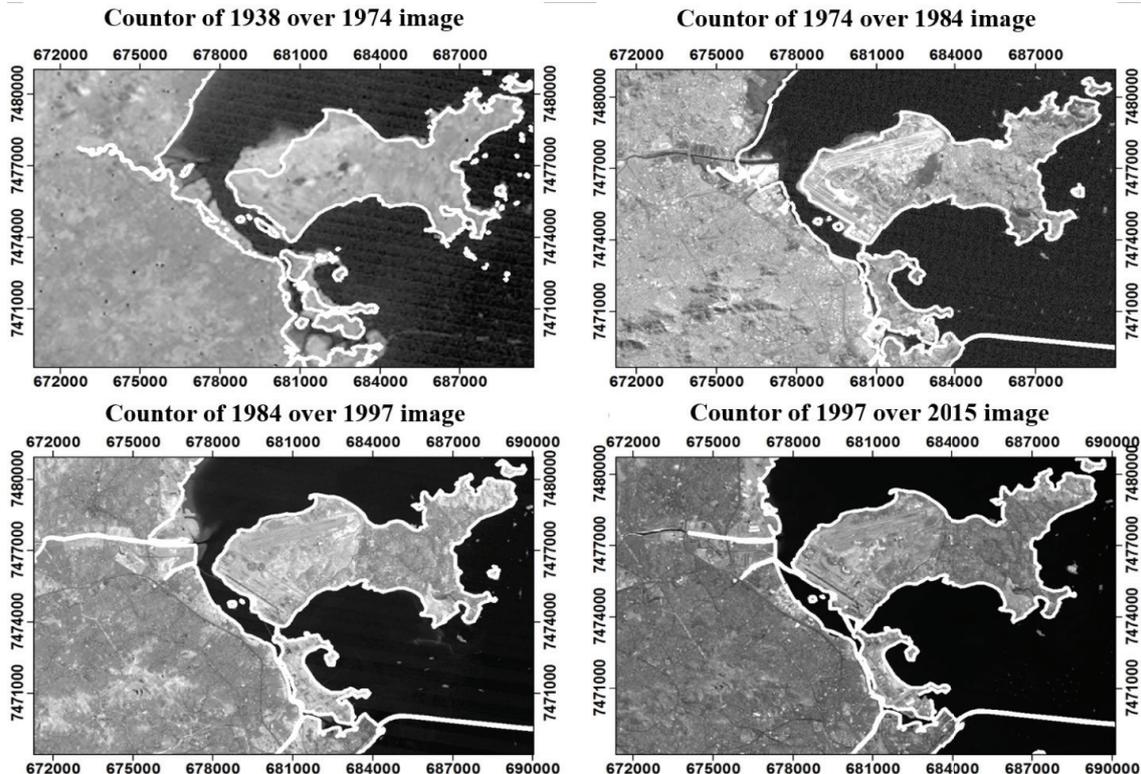


Figure 4. Maps with the historical changes of the contour of Guanabara Bay for the section northwest, in scale 1:175.000, for the period from 1938 to 2015, and panchromatic satellite images: Landsat1 (MSS) 1974, Landsat5 (TM) 1984 and 1997, and Landsat8 (LC8217076) 2015 (Source: www.dgi.inpe.com.br/NASA)

tely modified in order to place the port of the city and, later, to modernize its system (Moscatelli, 2009).

According to Andreatta et al. (2009), in the 1960s, the first governor elected in the period promoted an intense campaign of civil engineering modifications to improve sanitation and urbanization in the city of Rio de Janeiro. The most significant construction of this period was the Flamengo Park, or Flamengo Landing, in 1964, initiated in the previous decade. The celebration of the Eucharistic Congress of 1955, at Glória Cove, was the starting point to create a large landed area. Yet, the same author mentions that the dismantling of Santo Antônio Hill generated necessary material to sustain the landing of large dimensions, and permitted the city of Rio de Janeiro to have a unique park at seaside, modifying the profile of Flamengo and Botafogo beaches. The complete change in this sector represented approximately an additional area of 1,850,000m².

The quantitative analysis for the northeastern portion of the Guanabara Bay shows significant modifications in the surroundings between rivers Magé and Guaxindiba, represented in the first map of Figure 5. According to the data in Table 2, the region of the Guapimirim Environmental Protection Area presented a difference in the coastline, under the polygons of area found, with approximate values of 1.44 Km² in the period 1938-1974. This value corresponds to 6.55% of the area of water surface lost. Such evidence can be associated to the aggradation of the region, due to deforestation to provide resources according to the adopted economic models during the period analyzed (Amador, 1997).

In the following period of 1974-1984, 0.65 Km² were subtracted from the protection area, corresponding to 2.95% of the water surface area lost. In the third and fourth maps of Figure 5, the changes in coastline are not perceptible in the scale used for the research, which can suggest a reduction in the impacts resulting from the pressure of human activities over the water body (Verdonschot et al., 2013). In Moraes et al. (2009), the natural recuperation of mangrove ecosystems located in the limits of the Guapi River can be associated to a wider control of human actions due to the monitoring policies established. An example of such movement is the promulgation of Decree No. 90,225, of September 25th 1984, which created the Guapimirim Environmental Protection Area, and the protection of its mangrove areas.

The deforestation, the rectifying, and the channeling of some rivers that drain into the bay, changing their course and flow rate (Pires, 1986), have influenced in the deposition of sedimentation around the basin of Guanabara Bay (Godoy et al., 1998). With that being said, the mangroves that retain through their roots a large part of the sediments freely carried by the rivers, and which used to work as real filters found in areas between tides, are now inexistent in

places where they used to be abundant (Amador, 1997). The complete modification of the northeastern portion was approximately 2,090,000m².

In the end, the central east region of the bay has also presented great variation in terms of area, more specifically in the area corresponding to the downtown region of the city of Niterói, between the years of 1938 and 1984. According to Kang et al. (2010), the area is characterized by the low dynamic activity of tides and muddy seabed, typical from estuary environments; it has been suffering from anthropogenic actions of soil use, which directly affect the characteristics of hydrographic basins. This area was widely impacted by the port sector, where the Niterói Port was placed, with the goal to initially activate the trade of food kinds, wood, and celluloses; exporting sugar, sardines, and coffee (in the period of 1958-1962). After 1964, with the expansion of the road systems, Niterói Port declined; a situation that was also impacted by the aggradation of the main channel, and the proximity of the port of Rio de Janeiro. In 1967, the channel that allowed access to the port was reduced to an average depth of three meters and a half (out of the eight meters minimum to be used), contributing to scare ship commanders whose vessels were fully loaded, and forcing them to dock in the Rio de Janeiro Port (Azevedo, 1994).

Costa (2014) mentions some significant facts related to the placement of the port region to be taken into consideration: the construction of the Contorno Avenue around the beachfront, heading north, in the decade of 1960, which meant additional landings, and as a consequence, changes in the design of the port cove; and, in 1974, the inauguration of Rio-Niterói Bridge, which accentuated even more the changes of coastline in this area. The many ramps created together with the bridge modified significantly the local landscape and environment, and have become considerably important physical barriers. The complete modification of the center-east section represented a landing area of approximately 3,270,000m².

Several authors have been conducting research in recent years regarding recent muddy sedimentation rates in Guanabara Bay. Amador (1997) divides the siltation rates in the bay into two phases: 1st - represented by geological or natural siltation rates and 2nd - represented by historical siltation. Amador (1997) determines the geological siltation from the relationship between the average thickness of sediments deposited in the bay and the time during which the deposition took place. In 1997, this author considers that the average sediment density currently deposited in Guanabara Bay is 1.256 g/cm³ at 4 m depth, thus assuming a value of 26.9 cm/century of geological or natural siltation. The historical silting rate was determined, according to Amador (1997), by comparative study of nautical charts from different periods. This author determined the siltation of the periods

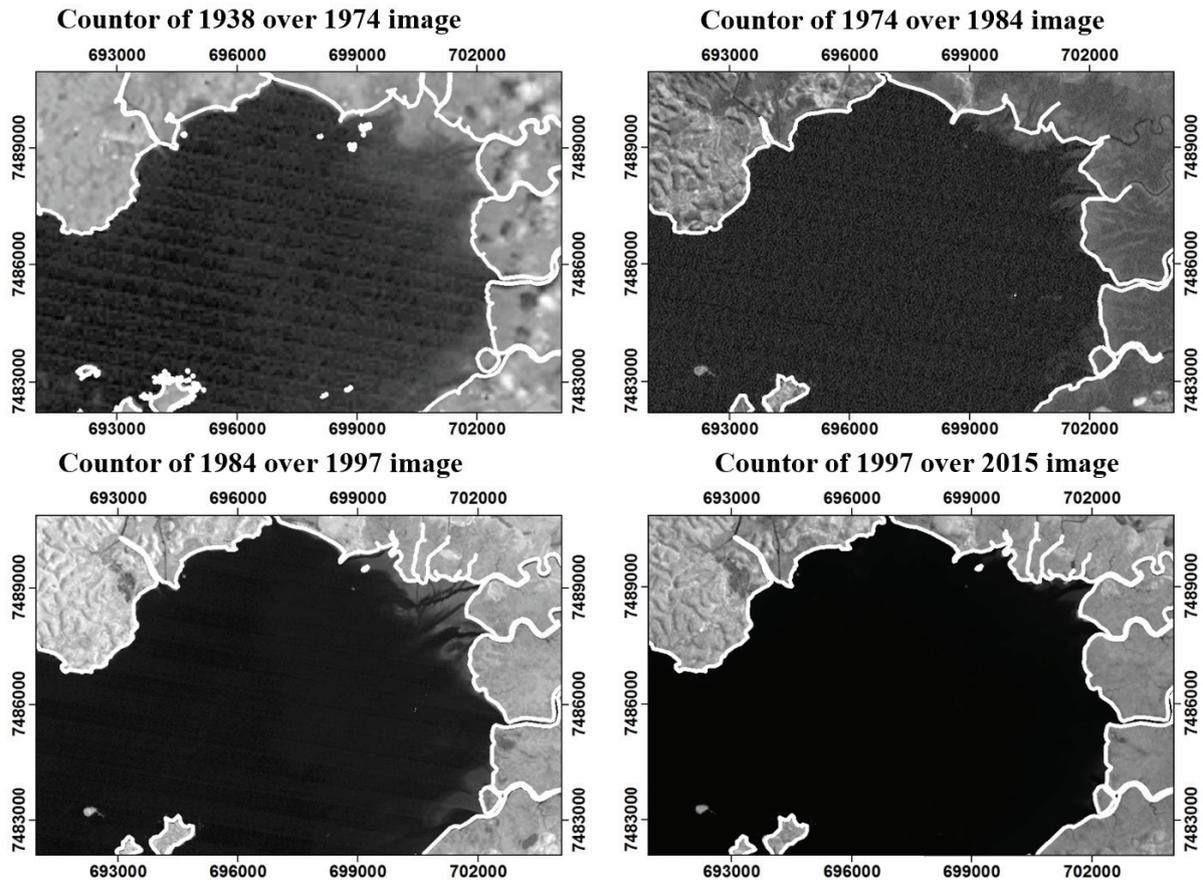


Figure 5. Maps with historical changes of the contour of Guanabara Bay for the northeastern section, under scale 1: 175,000, for the period between 1938 and 2015, and panchromatic satellite images: Landsat1 (MSS) 1974, Landsat5 (TM) 1984 and 1997, and Landsat8 (LC8217076) 2015 (Source: www.dgi.inpe.com.br)

of 1849/1922 and 1938/1962, and, according to Amador (1997), the latter period is mainly related to the anthropic action in the drainage basins of Guanabara Bay, such as the hydraulic engineering works developed in the 1930s, the constant deforestation, landfills, and mangrove destruction that are of great importance in the retention of fine sediments. For the period between 1849/1922 the rates observed by Amador (1980) were 24 cm/100 years. For the period 1938/1962, values of 81 cm/100 years were observed. This period is equivalent to the major urban changes promoted in the city of Rio de Janeiro, the main one being the dismantling of Morro do Castelo and the landfill of the coastal areas of the city (Figure 6).

Godoy et al. (1998) determined siltation rates using the lead isotope technique (^{210}Pb) for the last 100 years, based on shallow cores collected from two stations in the north of Governador Island. In one season, sediments collected at depths below 50 cm from the bottom of the bay, aged 40 to 100 years prior to the present, generated a siltation rate of 0.15 cm/year, while in sediments between the bottom surface and depth of 50 cm, corresponding to the last 40 years, the determined siltation rate was 1.3 cm/year. In the other

season, the sediments below the depth of 20 cm at the bottom of the bay, aged 10 to 80 years before the present, presented a siltation rate of 0.32 cm/year, while sediments between The bottom surface and depth of 20 cm, referring to the last 10 years, presented a siltation rate of 2.2 cm/year. Godoy et al. (2012), based on literature data and additional data presented by them, conclude that, in general, the current sedimentation rate of Guanabara Bay is approximately 1 cm year⁻¹, which represents a five-fold increment higher than the baseline values. According to these authors, these data are consistent with existing data in the literature related to Guanabara Bay sediment dating, using ^{210}Pb . The dating validation was performed based on copper, chromium and lead profiles, and the ^{210}Pb flow and the historical record of the main physical interventions in the last century, such as landfill, main river channeling, and the construction of highways (Godoy et al., 2012). These high siltation rates are responsible for an increasingly fast shrinking of the Guanabara Bay water slide, especially in its innermost portion. According to Pagliosa et al. (2006), this increase in sedimentation rates, observed in the ^{210}Pb flow, corresponds to the urban-industrial expansion, which occurred in the mid-1950s, and promoted rapid urban growth, leading to great environ-

mental pressure, especially in coastal areas. Amador (1997) draws attention to the intense coastal changes in Guanabara Bay through river rectifications, deforestation, and landfills in coastal environments.

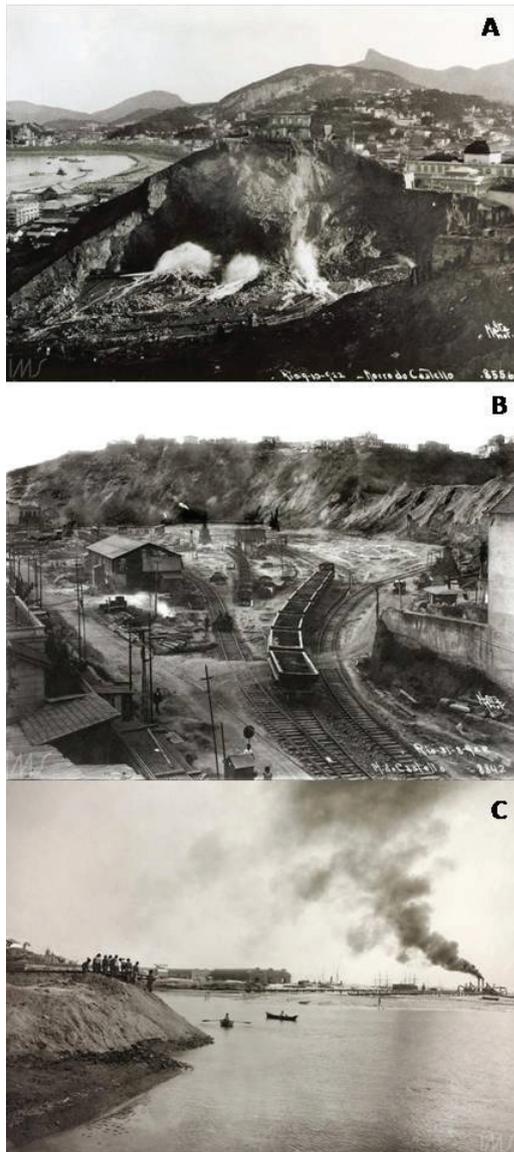


Figure 6. Dismantling of Morro do Castelo (A,B) and the landfill of the coastal areas of the city (C)

5. CONCLUSION

The continuous changes in the coastline of Guanabara Bay, performed specially to support the economic models imposed by governors, resulted in great transformations of the coastline and subtraction of its water surface area. With the evaluation of the transformations of the water surface

through the comparison of multi-temporal satellite images, this research has found that, through the past 77 years, Guanabara Bay has lost approximately 21,980,000m² in water surface area, which generated a significant impact in adjacent ecosystems. The study found that the period between 1938 and 1974 was more intense in the modifications observed in coastlines, totaling an area occupied by 15,220,000m² landfills.

When establishing a comparison between the western and eastern portions of the bay, it can be observed that the largest changes in the contour occurred in the western part of Rio de Janeiro city, where the use of the physical space of Guanabara Bay, whether for industrial, oil, petrochemical, or naval purposes, with investments in ports and shipyards, transformed the shore of Rio de Janeiro into the most important and most impacted region of Brazil. Nevertheless, the detection and register of modifications of coastlines, with a nation-wide zoning, can contribute with policies and actions of environmental monitoring and coastal management of Guanabara Bay.

The low spatial resolution of the TM sensor images, and especially MSS in the multi-temporal study, led to the necessity to interpolate, in order to have images with better brightness and natural-looking results, smoothing the image. Due to the various data sources used in the research, it was necessary to process the images that presented different spatial resolutions, such as by ortho-rectification, to standardize the information, and to integrate them into a GIS databank, notwithstanding the vectorization errors that such studies can generate and the low resolution of images that require a good geo-referencing procedure, adding to this the outdated status of information of the topographic charts of aerial photogrammetric surveys from 1960 and 1970, which, many times, do not correspond to the present reality of the area of study. On the other side, the qualitative and quantitative analysis of the variations of the coastline of Guanabara Bay, indicated in the two maps built in compatible scale to spatial resolution, despite being different from each other, allowed observing the correlation between this research and other studies in the area, being described individually and not influencing in the analysis of results.

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