Original Article

PHYSICAL ATTRIBUTES OF THE RIVER BASIN OF RONCADOR RIVER ASSOCIATED TO THE LANDSCAPE CHANGE IN THE MUNICIPALITY OF MAGÉ, RIO DE JANEIRO-BRAZIL

ATRIBUTOS FÍSICOS DA BACIA HIDROGRÁFICA DO RIO RONCADOR ASSOCIADOS A MUDANÇA DA PAISAGEM NO MUNICÍPIO DE MAGÉ, RIO DE JANEIRO-BRASIL

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ABSTRACT: The objective of this study was to conduct a temporal analysis of biophysical attributes of the river basin of Rio Roncador, located in the municipality of Magé, Rio de Janeiro. SRTM data were used for the determination of the river basin morphometry and two images of the orbital platform Landsat5 TM sensor (01/28/1986 and 02/15/2010) applied the SEBAL algorithm to characterize the landscape dynamics. The results indicate that The river basin has a drainage area equivalent to 186.21 km2, perimeter 101.78 km, circularity index equal to 0.22, form factor 0.26 and compares index 2.09. These results indicate that the river basin is not prone to flooding, mainly due to its elongated form. It was possible to verify that in the interval of 24 years, degradation occurred in the region beyond the change in the coverage of the soil of the river basin. The results indicated a tendency of reduction in the areas of permanent preservation -13.4% of the river basin. It is concluded that anthropogenic actions were able to alter the surface cover of the soil and that, by the way, may have influenced the water dynamics of the river basin.

KEYWORDS: Geoprocessing. Water availability. Environmental disasters. Image processing.

INTRODUCTION

The present Brazilian scenario has been facing several environmental crises, cited as the main source of water issues, a large part of these problems arises from the inadequate management of soil in river basins (COUTINHO et al., 2013; ALVES et al., 2015), due to the removal of the vegetation cover, there is the change of the forest into the urban areas and pastures; these modifications of the landscape, without planning, generate the hydrological and drainage problems in the hydrographic regions (BORGES et al., 2011), the use of agriculture and efficient irrigation systems and in urban areas has been used as a tool to reduce the risk of flooding in the Amazon basin, which are exacerbated due to lack of consistent and reliable information on the basin's morphometry (SILVA et al., 2015).

Environmental disasters have been observed in river basins by factors related to water resources. Due to these problems associated with extreme events, there has been an increase in the number of fatalities, mainly due to floods (59% of records) and landslides (14%) (COUTINHO et al., 2013). These disasters are mainly due to the extreme indexes of rainfall (COUTINHO et al., 2013). For these reasons, studies have been carried out considering the physical attributes of the river basins (Santos et al., 2014) and their relationship with ecosystemic characteristics in their surroundings, in particular the vegetation cover.

The studies of Pereira et al. (2014) indicate that the maintenance of the vegetation cover influences on soil conservation, local microclimate, rainfall, albedo, variables that can be used to better understand the dynamics of the hydrological cycle (CARDOSO et al., 2006), to propose mitigation actions for the problems found in the river basins, especially in the South and Southeast regions, which are subject to the greatest atmospheric adversities (CEPED, 2012).

In general, to make decisions for the agricultural planning and forest sector of the municipalities are necessary to obtain information that serve as mechanisms for the municipal managers, but they do not have collections of detailed information such as maps and planialtimetric charts that can assist in the studies of the physical characterization of the river basins in

Received: 03/12/16
Accepted: 20/12/17

their respective regions and consequently for the urban and rural planning.

There are free options provided by the Topodata project, which offers the Digital Elevation Model (MDE) and its basic local derivations in national coverage, now elaborated from the SRTM (Shuttle Radar TopogranphyMission) data made available by the USGS in the global computer network (EHSANI et al.; CECÍLIO et al., 2013). Recent studies have used this source for studies of hydrographic basins (SILVA et al., 2014; FRAGA et al., 2014), for better inference on the management and in the processing of automatic delimitation of these (MENDONÇA et al., 2007).

The use of Remote Sensing and Geoprocessing techniques serve as primordial technological tools for the use of MDE data and environmental parameters (ALMEIDA et al., 2014; BEZERRA et al., 2014; SANTOS et al., 2014; SILVA et al., 2014; SILVA et al., 2015).

The rapid transformation in the structure and urban physiognomy, in the municipality of Magé / RJ, occurred in the last decade, due to the works of the Petrobrás gas pipeline, has led to intense environmental changes in the river basin of Roncador River, being a phenomenon observed by the municipality and records found in the city office for protection of Magé Civil Defense, which point to an increase of natural disasters.

Given the above, the objective of this study was to evaluate the landscape dynamics in the 24-year interval and the river basin morphometry of Roncador River, located in municipality of Magé, in Rio de Janeiro, using SRTM and Landsat 5 TM data.

MATERIAL AND METHODS

Study area

The study area comprises the river basin of the Roncador River (BHRR), located in the municipality of Magé/RJ (Figure 1), is bordered to the north by Serra dos Órgãos, where its main source upstream is located; To the south by the Guanabara Bay and the river basin of Iriri river. The BHRR is located between the co-ordinates 22°39′10″ south latitude and 43°02′26″ west longitude, presents vegetation of Submontane Dense Ombrophylous Forest, whose remnants are in different successional stages (IBGE, 1994).

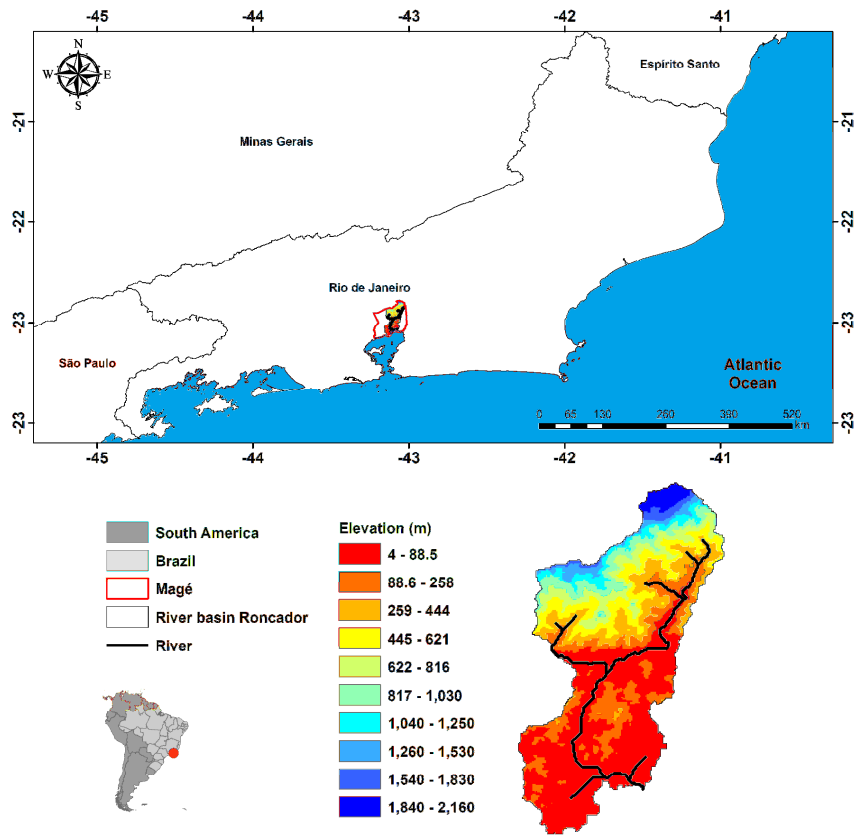

Figure 1. Digital Elevation Model (MDE) to the River Basin of Roncador River.

Land use and coverage and climate

The hydrographic region of Guanabara Bay, which is part of the BHRR, has a typical microclimate of tropical coastal region, influenced by factors such as latitude and longitude, proximity to the sea, topography, nature of the vegetation cover and, above all, actions of large-scale atmospheric circulation, such as cold fronts and sea breezes (ROBERTO et al., 2009).

The study area is comprised of the intertropical climate, with a hot and rainy climate. According to Roberto et al. (2009), in the region of Magé, the rainfall varies between 1000 mm and 2200 mm and the climate of the area can be characterized according to Köppen as hot and humid, with an average annual temperature of 20ºC. As for geology, the area is located on the crystalline basement, which extends from the North of the State of Rio de Janeiro (Serra do Mar) to the Cabo de Santa Catarina (AMADOR, 1996).

As for soils, the Red and Red-Yellow Argisols, Litololic and Regolithic Neosols, Cambisolos Háplicos and Red-Yellow and Yellow Latosols (SANTOS et al., 2013) characteristic of Guanabara Bay (MENDONÇA et al., 2007) predominate. At the bottom of the bay, east of the estuary of Estrela River and west of the Guapimirim Environmental Protection Area are the beaches.

Digital Elevation Model

The MDE was obtained from images of SRTM (Shuttle Radar Topogranphy Mission), with a resolution of 30 x 30 m (Figure 1). The altitude was obtained in the following by letter 22S435. The software used for the preparation of SRTM images was ArcGis 10.2®.

The method used to construct the MDE was subdivided into two stages, the first step to obtain the physical morphometry of the basin from the MDE and the second stage after the delimitation of the basin area to calculate the area and the perimeter, then using the spreadsheet and the equations described by (CARDOSO et al., 2006; SILVA et al., 2014; FARIA et al., 2014), to determine the distinct characteristics of the basin.

The coefficient of compactness (Kc), shape factor (F), circularity index (IC) and drainage density (Dd) were calculated by the Equations 1; 2; 3 and 4, respectively Cardoso et al. (2006):

$$Kc = 0,28 \times \frac{P}{\sqrt{A}} \quad (1)$$

In which:

Kc - compactness coefficient, (dimensionless)

P – river basin perimeter, m

A - drainage area of the river basin, m^2

$$F = \frac{A}{L^2} \quad (2)$$

In which:

F - form factor, (dimensionless)

A - drainage area of the river basin, m^2

L - length of the river basin axis, m

$$IC = \frac{12,57 * A}{P^2} \quad (3)$$

In which:

IC - circularity index (idem)

A - drainage area of the river basin, m^2

P – river basin perimeter, m

$$Dd = \frac{L_t}{A} \quad (4)$$

In which:

Dd - drainage density, km km^{-1}

L_t - total length of all channels, km

A - drainage area of the river basin, km^2

Applying the Equations 5 and 6 described by Fraga et al. (2014), we have:

In which:

$$Cm = \frac{1}{Dd} * 1000 \quad (5)$$

Cm - maintenance coefficient, m^2 m^{-1}

Dd - drainage density, km km^{-2}

I think there is something missing here that calls the equation below.

In which:

$$RN = Hdm * Dd \quad (6)$$

Rn - Roughness coefficient, (dimensionless)

Hdm - mean slope (%)

Dd - drainage density, km km^{-2}

Applying the Equation 7 described by Faria et al. (2014), we have:

$$Dr = \frac{N}{A} \quad (7)$$

In which:

Dr - Density of rivers

N - Number of Rivers

A - drainage area of the river basin, km^2

The hydrological consistency of digital elevation models (MDEHC) was used as input for the altitude and slope generation obtained automatically by the software. In order to classify the slopes in the basin, six different ranges of classes were used, according to the Brazilian System of Soil Classification (SANTOS et al., 2013).

Satellite images

Delimited to BHRR, the processing of the orbital images originated from the TM sensor began. We selected two images of the TM sensor (ThematicMapper) of Landsat 5 satellite (01/28/1986 and 02/15/2010), orbit 217 and point 76 of the historical series made available in the Catalog of Images on the site of the National Institute for Space Research (INPE) (http://www.dgi.inpe.br/CDSR/) in order to obtain concomitantly images with lower cloud cover.

The images were processed in ERDAS IMAGINE 2015 software, using the ModelMaker platform. The algorithm SEBAL (Surface Energy Balance Algorithm for Land) proposed by Bastiaanssen et al. (1998) was used as standard. In the ERDAS IMAGINE 2015 software, the union of the satellite bands, the radiometric calibration (MARKHAM & BAKER, 1987; CHANDER & MARKHAN, 2009), reflectivity (ALLEN et al., 2002) and the Normalized Vegetation Index (NDVI) proposed by Rouse et al. (1973 and 1974) were calculated.

The NDVI of 1986 and 2010 was transformed into ".txt" files for interpretation and quantification of soil cover classes for the period studied according to the method proposed by Santos et al. (2008).

All the procedures adopted to determine the delimitation of the river basis and its physics, as well as the use of the SEBAL algorithm, are represented in Figure 2.

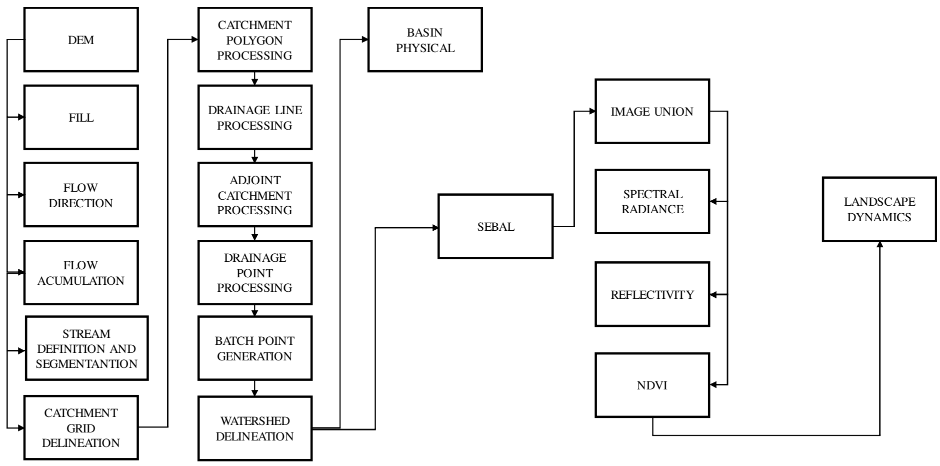

Figure 2. Flowchart of all developed stages.

RESULTS AND DISCUSSION

The morphometric characteristics of the BHRR are presented in Table 1. According to the results obtained, the BHRR has a drainage area of 186.21 km^2, perimeter equivalent to 101.78 km and an axial length 26.79 km, for Cecílio et al. (2013), the basin area serves as an indicator of its hydrological potential, since the larger the area, the lower the tendency for flooding to occur, as the longer the time for all hydrographic networks to contribute at one time to the basin.

Table 1. Characteristics of the river basin of Roncador River.

Geometric Features	**Values**
Drainage area (A)	186.21 km²
Perimeter	101.78 km
Axial length of the Basin	26.79 km
Average width	7.06 km
Compactness coefficient (KC)	2.09
Form Factor (F)	0.26
Circulation Index (IC)	0.22
Relief Features	**Values**
Highest altitude (m)	2160
Lowest Altitude (m)	4
Average altitude (m)	362.33
Altimetric amplitude	2156
Maximum slope (%)	30.40%

Average slope (%)	7.35%
Minimum slope (%)	0%
Roughness index	0.57
Relief Relation	0.0004
Characteristics of the Drainage Network	**Values**
Total length of all Channels	0.049 (km)
Main River length	28.56 (km)
Drainage Density (Dd)	0.00027(km)
Density of Rivers	0.042 km²
Maintenance coefficient	3770.50
Number of drains	8

The Kc, IC and F indexes indicate the geometry of the BHRR and what its standard is like in relation to problems arising from floods, or if the basin is not susceptible to floods. The Kc was 2.08 indicating a basin with an irregular characteristic, the more that value goes away from unit 1, indicates that the flow of the basin is well distributed along the main channel, being, therefore, a basin hardly susceptible to floods accentuated in normal rainfall conditions (SANTOS et al., 2014). The F is another indicative of trends for basin floods, the closer to the unit 1, the greater the rapid flood peaks. The BHRR presented the F value of 0.26 confirming the same pattern observed for the compactness coefficient, indicating a small probability of being submitted to floods. For the IC, which is 0.22, the BHRR shows an elongated shape demonstrating that it is susceptible to slow flow.

According to Villela & Mattos (1975), the river basins with elongated formats have a lower concentration of surface runoff. Considering this characteristic, it can be inferred that BHRR presents a lower risk of extravasation under normal rainfall conditions. Thus, the main channel of the Roncador River will not simultaneously receive contributions from all channels, thus reducing the risk of overflow.

The hydrographic basin is inserted in a region that presents a high altimetric contrast whose spring occurs in Serra dos Órgãos with a maximum altitude of 2160 m in its head and the exutório in Guanabara Bay, whose altitude variation is between 4 m and 362 m. The altimetric range of the area is 2156 m. For (DUARTE et al., 2008), the variation of the altimetric range of a river basin has a great relation with temperature and rainfall, generating significant differences in its average temperature, which consequently can promote variations in evapotranspiration and annual rainfall (SANTOS et al., 2014). Therefore, due to the high variation of the elevation, the basin is subject to extreme environmental variations.

The BHRR presents more than 60% of its area with flat relief, that is, slope values between 0 and 3%, maximum slope of 30,40% and minimum slope of 0% (EMBRAPA, 1979).

In the higher parts, where the slope is higher, there are soils such as Argisols, Cambisols and Nessolos (ECOLOGUS – AGRAR, 2005), due to their physical attributes, such as the presence of a Bt in the Argisols and the small thickness of Cambisols and Neosols, limits the internal flow of water favoring the superficial runoff and consequently the erosive process and landslides.

In a study carried out by Silva et al. (2016), in the Basin of Munique River, MG, the authors verified a high altimetric amplitude in the basin and with a predominance of marked slope, having a high potential for flooding, since it is a high energy basin; presenting a high roughness index in consonance with slope.

Considering the obtained results, it is inferred that the BHRR presents a characteristic similar to that of altimetric amplitude, in comparison with the study by Silva et al. (2014), which promotes a characteristic phenomenon in the region known as floods, the first cause of major natural disasters in the region (ROBERTO et al., 2009). This pattern is different from that one observed in areas of lower slope, which predominate in the basin. In these areas, there is a higher infiltration rate and lower flow velocity (TONELLO et al., 2006), reducing the potential for flooding, even with the large difference in the altimetric range.

However, in a different way, this situation is not observed, the low tide is influenced by the tides, which occur during the intense rains, causing flooding of the flat areas, affected by small channels connected to the Roncador River (SACHETTO, 2012).

The index found for the density of the river was 0.043, which indicates that the basin is extremely human (LIRA et al., 2012), demonstrating the correlation of drainage deficiencies due to the great altimetric amplitude and the high anthropic process that was submitted over time.

The data from the Brazilian Institute of Geography and Statistics (IBGE, 2016) show the rapid growth of the urban area in the municipality of Magé in the last decades and the intense transformation of the green areas into agricultural pasture, aggravating the problems of surface runoff and landslide.

From the images of TM sensor and subsequent quantification of soil cover classes in the study area, it was verified that there were 49.61 km² of dense vegetation cover in 1986 and the same class presented the value 24.72 km² in 2010. Therefore, there was an average reduction of -13.36% of the vegetation cover in the area of the river basin for 24 years. This means decrease in areas classified as very dense vegetation (Table 2). The areas classified as water and shade, non-vegetated areas and fairly sparse vegetation also showed reductions, but with values lower than 1%. The sparse and dense vegetation were areas where they presented significant growth of 1.19% and 13.21%, respectively.

Table 2. Quantification of soil cover classes for 1986 and 2010 at BHRR.

Classes	1986		2010		Difference
	km^2	%	km^2	%	%
Water and shade	1.05	0.56	0.01	0.00	-0.56
Non-vegetated areas	1.27	0.68	1.08	0.58	-0.10
Very sparse vegetation	0.85	0.46	0.15	0.08	-0.38
Sparse vegetation	9.40	5.05	11.62	6.24	1.19
Dense vegetation	124.00	66.60	148.58	79.82	13.21
Very dense vegetation	49.61	26.64	24.72	13.28	-13.36
Total area	186	100	186	100	

According to Almeida et al. (2014) the landscape changes are associated with the types of activities such as agriculture, agriculture, mining and irrigation practices.

In the Municipality of Magé/RJ, several factors cause the non-infiltration of water into the river basin, such as a lack of vegetation cover, replaced by an intense urbanization process in the floodplain that should be protected by APP (Permanent Preservation Areas).

The lowest values of NDVI are located in the eastern and southern portions of the images (1986 and 2010), represented by the non-vegetated areas, very sparse vegetation and sparse vegetation (Figure 3). These areas located to the east and south of the images are the regions where the elevation is minimal, being areas occupied by pastures and urbanization. It can be observed in the image of 2010 (right) that the areas classified with the lowest values of vegetation increase in all directions of the study area.

The highest values are observed in the northwest and north portions. These regions present higher elevations or higher percentages of slopes and present a lower percentage of urbanization.

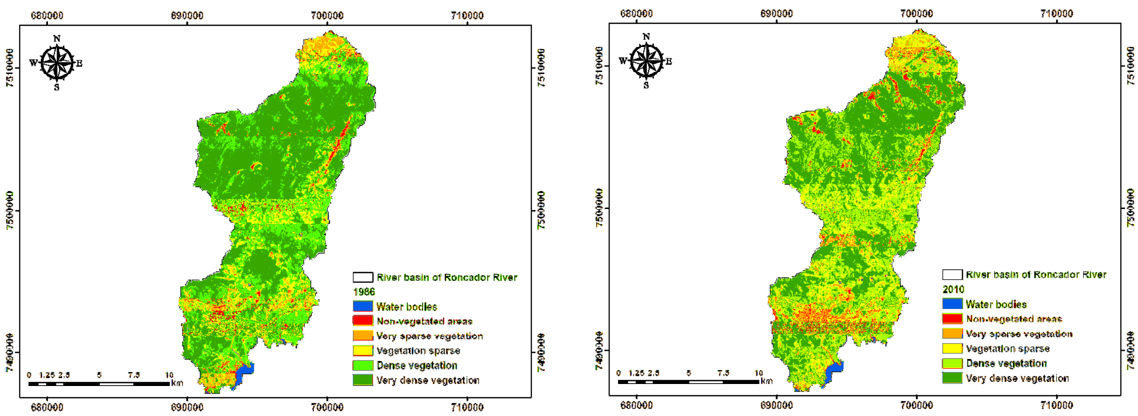

Figure 3. Classification of the NDVI image for 1986 (left) and 2010 (right) of the BHRR.

NDVI values higher than 0.44 - 0.75 (dense vegetation) and 0.75 - 1.00 (very dense vegetation) can contribute in a favorable way to the maintenance of soil moisture, attenuating the heat and stopping the loss of sensible heat by the surface of the soil.

According to Santos et al. (2015) when the vegetation is removed, the soil is consequently exposed to a higher incidence of solar radiation, providing a greater loss of water by evaporation, which is evident in this work, since in 2010, the NDVI values decrease progressively, besides the soil retains less radiation, these areas with lower vegetation imply a smaller interception of rainwater, which accelerates the surface runoff of the basin during flood periods.

CONCLUSIONS

The river basin does not have in its physical morphometry tendency towards processes characteristic of events related to hydrological disasters. However, environmental changes over the last few years have influenced the basin to present serious problems in its hydrological pattern, which indicates the need for careful management in its mediations.

The remote sensing techniques applied to programming software in the Geographic Information System environment, as an analysis tool for the morphometric characterization of river basins, is an effective way to provide data for the management of the hydrographic basin.

RESUMO: O objetivo deste estudo foi realizar uma análise temporal de atributos biofísicos da bacia hidrográfica do Rio Roncador, localizado no município de Magé, Rio de Janeiro. Utilizaram-se dados do SRTM para a determinação da morfometria da bacia hidrográfica e duas imagens da plataforma orbital Landsat5 sensor TM (28/01/1986 e 15/02/2010) aplicado o algoritmo SEBAL para caracterizar a dinâmica da paisagem nesse período. Os resultados indicam que a bacia hidrográfica possui uma área de drenagem equivalente a 186,21 km2, perímetro de 101,78 km, índice de circularidade igual a 0,22, fator forma de 0,26 e índice de compacidade de 2,09. Estes resultados indicam que a bacia hidrográfica não é propícia a enchentes, devido principalmente a sua forma alonga. Foi possível verificar que no intervalo de 24 anos ocorreu degradação na região além da mudança na cobertura do solo da bacia hidrográfica. Os resultados obtidos indicaram uma tendência de redução nas áreas de preservação permanente de -13,4% da bacia hidrográfica. Conclui-se que ações antropogênicas foram capazes de alterar a cobertura superficial do solo e que por sinal podem ter influenciado a dinâmica hídrica da bacia hidrográfica.

PALAVRAS-CHAVE: Geoprocessamento. Disponibilidade hídrica. Desastres ambientais. Processamento de imagens.

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