



Remote sensing applied to the monitoring of macrophytes in the Santa Cruz reservoir – Apodi/RN

Sensoriamento remoto aplicado ao monitoramento de macrófitas no reservatório de Santa Cruz – Apodi/RN

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Abstract: This study aimed to evaluate the spatial and temporal distribution through remote sensing techniques and the quantification of the existence of aquatic macrophytes in the water mirror of the Santa Cruz dam in Rio Grande do Norte, in 2015, 2016 and 2017. The study was developed during the period of low rainfall, using geoprocessing techniques, more specifically the NDVI (Normalized Difference Vegetation Index) and supervised Minimum Distance classification. For the preparation of maps and graphics, the following actions were carried out: selection of images from the LANDSAT-8/OLI satellite, radiometric calibration, atmospheric correction, reprojection, definition of the boundary, area cut, NDVI and supervised classification. The products obtained through the supervised classification, subsidized by the NDVI maps, indicated an increase of 32% in the area occupied by aquatic macrophytes in 2015 and 2016, while a decrease of 38% was observed between the years 2016 and 2017.

Keywords: Spatial and temporal distribution; Supervised classification; Satellite Images.

Resumo: Este trabalho objetivou avaliar a distribuição espacial e temporal por meio de técnicas de sensoriamento remoto e a quantificação da existência de macrófitas aquáticas no espelho d'água na barragem de Santa Cruz no Rio Grande do Norte, nos anos de 2015, 2016 e 2017. O estudo foi desenvolvido no período de baixa pluviosidade, por meio do uso técnicas de geoprocessamento, mais especificamente do NDVI (Normalized Difference Vegetation Index) e classificação supervisionada Minimum Distance (Distância Mínima). Para elaboração dos mapas e gráficos, foram realizadas as seguintes ações: seleção das imagens do satélite LANDSAT-8/OLI, calibração radiométrica, correção atmosférica, reprojeção, definição do limite, recorte da área, NDVI e classificação supervisionada. Os produtos obtidos através da classificação supervisionada, subsidiada pelos mapas de NDVI, indicaram para um aumento de 32 % na área ocupada por macrófitas aquáticas de 2015 e 2016, enquanto que foi observada uma diminuição de 38 % entre os anos de 2016 e 2017.

Palavras-chave: Distribuição espacial e temporal; Classificação supervisionada ; Imagens de Satélite.

1. Introduction

Macrophytes or hydrophytes are plants that live in continental aquatic systems, with immersed, floating or emerged leaves (APARÍCIO; BITENCOURT, 2015). They, by inhabiting aquatic systems prone to human interference and using nutrients dispersed in the water to increase their biomass, can reproduce to the point of positively or negatively interfering in some aquatic systems. An example of positive interference is the use of macrophytes for sewage treatment, as they remove nutrients that are in excess (SCHILLER et al., 2016; FRANÇA et al, 2014; CAMARA et al., 2013). Negative interference occurs when there is too much reproduction of macrophytes, for example in reservoirs built for different purposes, where one of the usual problems is eutrophication.

In this context, the human action in damming water bodies, associated with the release of domestic and industrial effluents, in addition to the erosion of arable soils, has caused the eutrophication of water bodies. Thus, one of the changes caused is the increase in the area occupied by macrophytes, in view of a greater amount of nutrients available in the environment and thus compromising the multiple uses of water resources.

However, Luo et al. (2015) note that, in large reservoirs, monitoring aquatic macrophytes, addressing distribution dynamics and typologies, is a time-consuming and costly operation if carried out using conventional research methods. In addition, these organisms can occupy places that are difficult to access, which increases even more the difficulties in mapping their distribution and monitoring their growth (ZHAO et al., 2012).

Given this, Silva et al. (2011) state that monitoring through remote sensing in places of difficult access, such as flood plains, becomes a very important tool for studying and monitoring the growth of aquatic macrophyte communities.

Rosa (2003) emphasizes that the use of remote sensing as a tool for visualizing land data allows checking flood control and assessing environmental impacts. In the same way as for different targets on the earth's surface, variations in the spectral response of water can be recorded in remote sensing images, acquired by sensors installed on land, air or orbital platforms (CRUZ; GALO, 2005).

In view of the above, this study aimed to evaluate the spatial and temporal distribution through remote sensing techniques and the quantification of the area occupied by aquatic macrophytes in the water mirror at the Santa Cruz dam in Rio Grande do Norte.

2. Methodology

The present work was developed in the Santa Cruz reservoir (Figure 1) which is inserted in the Apodi/Mossoró River Hydrographic Basin, section of the Santa Cruz Dam, occupying an area of approximately 4,264 km² and distant about 20 km from the municipality of Apodi-RN covering about 32 of the 62 municipalities in the West Potiguar mesoregion. With a water storage capacity of 599.7 hm³, the Santa Cruz reservoir, built in 2002, is located at the basin outlet (ANA, 2017).

The predominant climate in the region is hot and dry – B'Swh' type, according to the Köppen climate classification (ALVARES et al., 2014), with an average annual rainfall of approximately 700 mm, the soils of the region are predominantly shallow and derived from sedimentary rocks. (IDEMA, 2008).

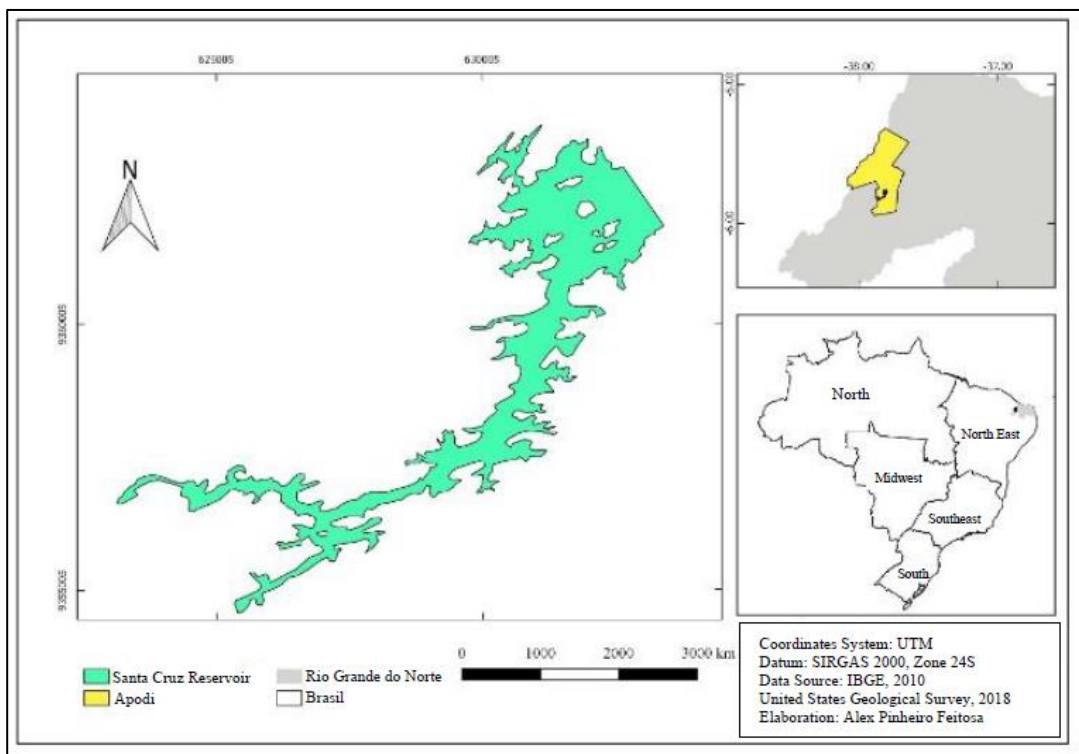


Figure 1 – Location of the Santa Cruz Reservoir
Source: Feitosa, (2018).

Images captured by the LANDSAT-8/OLI satellite were used, referring to the years 2015 (10/04/2015), 2016 (09/20/2016) and 2017 (10/25/2017), being chosen only in the low period rainfall during the dry period, as according to Minhoni et al. (2017) during the dry season there is a greater proliferation of aquatic macrophytes. For image processing, the QGIS Software Version 2.14 Essen was used, as it produces satisfactory results and, above all, it is free software. All images were made available free of charge by the USGS (2015). Table 1 presents the main characteristics of the selected images, with orbit/point 216/64 and spatial resolution of 30 meters.

Table 1 – Characteristics of the LANDSAT-8 satellite OLI sensor images: NASA (2015)

Features of OLI sensor images		
Band	Spectral Range	Wave-length (µm)
Band 2	Blue	0,45-0,51
Band 3	Green	0,53-0,59
Band 4	Red	0,53-0,59
Band 5	Near Infrared	0,85-0,88
Band 6	shortwave infrared 1	1,57-1,65
Band 7	shortwave infrared 2	2,11-2,29
Band 8	panchromatic	0,50 – 0,68

The methodology used in the work follows the recommendations of the main sequences until obtaining the final products indicated by Minhoni, et al. (2017). Figure 2 presents a Flowchart of the same.

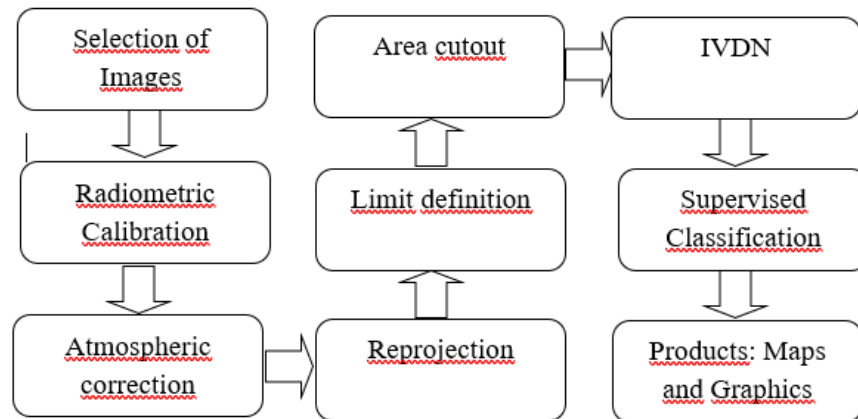


Figure 2 – Flowchart of the methodology used.
Source: Minhoni, et al. (2017)

According to Soares et al (2015), the particles present in the atmosphere, such as aerosols, dust, molecules of different gases with different sizes, interfere with the radiation that reaches terrestrial targets or the sensor. Therefore, atmospheric correction processes are considered essential for the processing of orbital images, as it seeks to minimize the influence of the factors that make up the Earth's atmosphere, improving the quality of the information contained in the images (BATISTA & DIAS, 2015). In addition, Novo (2008) states that when comparing images from different dates, it is important to perform atmospheric correction.

Thus, as the present research performed the comparison between satellite images from different years, atmospheric correction was performed using the Dark Object Subtraction (DOS1) method, developed by Chavez Jr. (1988). This step was performed concomitantly with the radiometric calibration step, which first consists of converting digital numbers (ND) to radiance and, later, to reflectance (SOARES et al., 2015).

As the images obtained are projected to the northern hemisphere, it was necessary to reproject them to the southern hemisphere. After this phase, the images were merged with the panchromatic band of 15 m of spatial resolution, in order to obtain a better result in the delimitation of the reservoir area, considering that in the other bands the spatial resolution is 30 m. In addition, the NDWI (Normalized Difference Water Index) was also used, this index is calculated according to the following equation (MCFEETERS, 1996):

$$NDWI = (Green - IVP) / (Green + IVP)$$

where: 'green' corresponds to the spectral range of band 3 (green range of the visible spectrum) and IVP, the spectral range of band 5, near infrared region.

Also, according to Brenner and Guasselli (2015) this index allows highlighting water features and minimizing the rest of the targets. The water mirrors of the reservoir were used for each year of the study, in order not to overestimate the results, in the case of considering a single mirror, that is, considering the full reservoir for all years.

In order to improve the supervised classification, the Normalized Difference Vegetation Index (NDVI) was inserted in the methodology of this work. It should be noted that the classification was not performed on the NDVI image, being the same processed on the image stacked by the bands, the same serving only as a subsidy to the classification, contributing to the identification of the classes. The NDVI is an appropriate index for the study of vegetation, ideal for estimating its quantity, quality and humidity, as well as monitoring these characteristics over time (NOVAS, 2008).

The NDVI is calculated from the normalized ratio between the near-infrared bands and the red band, varying between -1 and 1 (TUCKER, 1979). Its formula is presented below (Equation 1):

$$NDVI = (\rho_{NIR} - \rho_{RED}) / (\rho_{NIR} + \rho_{RED})$$

where: ρ_{NIR} and ρ_{RED} are the bidirectional surface reflectance factors for the near infrared (NIR) and red (RED) bands, respectively.

Before performing the supervised classification process of each LANDSAT-8/OLI satellite image, six spectral bands (B2, B3, B4, B5, B6 and B7) were stacked to generate a single layer representative of the study area, process called Layerstack. Thus, the classification was processed based on the spectral information of the six bands.

Layer stacking is commonly used to combine separate bands into a single multispectral image, which can be used in further analysis (VEERENDRA; LATHA, 2012).

In the supervised classification, the Minimum Distance classification algorithm was used, in order to obtain two satisfactory groups, corresponding to the water classes with possible presence of macrophytes and water. This method calculates the spectral distance between the measurement vector for the candidate pixel and the average for each class signature (VALE et al., 2018).

3. Results and discussion

The spectral signature of macrophytes and water, in an image formed by bands 2, 3, 4, 5, 6 and 7, can be seen in graph 1. To obtain this graph, the selection of pixels with presence of macrophytes and absence of them, in order to distinguish the spectral difference of these surfaces. Vegetation has an average spectral behavior that will always make it possible to distinguish it from other objects (NOVO, 2008). In graph 1, the distinction between vegetation and water was easily observed, since for regions with greater presence of macrophytes, a typical spectral signature of vegetation was found, that is, absorbing electromagnetic radiation in the visible spectrum and an apex of reflectance in the near-infrared spectrum. While, in regions where the presence of macrophytes were not detected, the spectral signature was typical of water bodies, where there is an absorption behavior of electromagnetic radiation at all wavelengths.

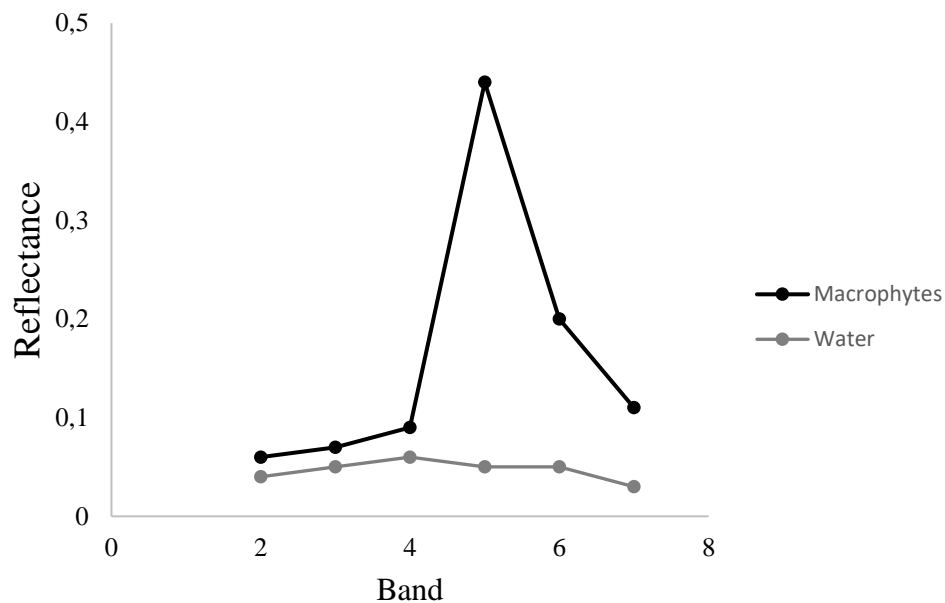


Figure 3 – Graph of the spectral behavior of aquatic macrophytes and water in the Santa Cruz reservoir, RN.
Source: Feitosa, (2018).

In Figures 4 (a), (b) and (c), the images obtained through the NDVI are presented, in which the spatio-temporal dynamics of the values of this index for the reservoir are observed, thus making it possible to identify the increase of the vegetation index in certain areas of the same.

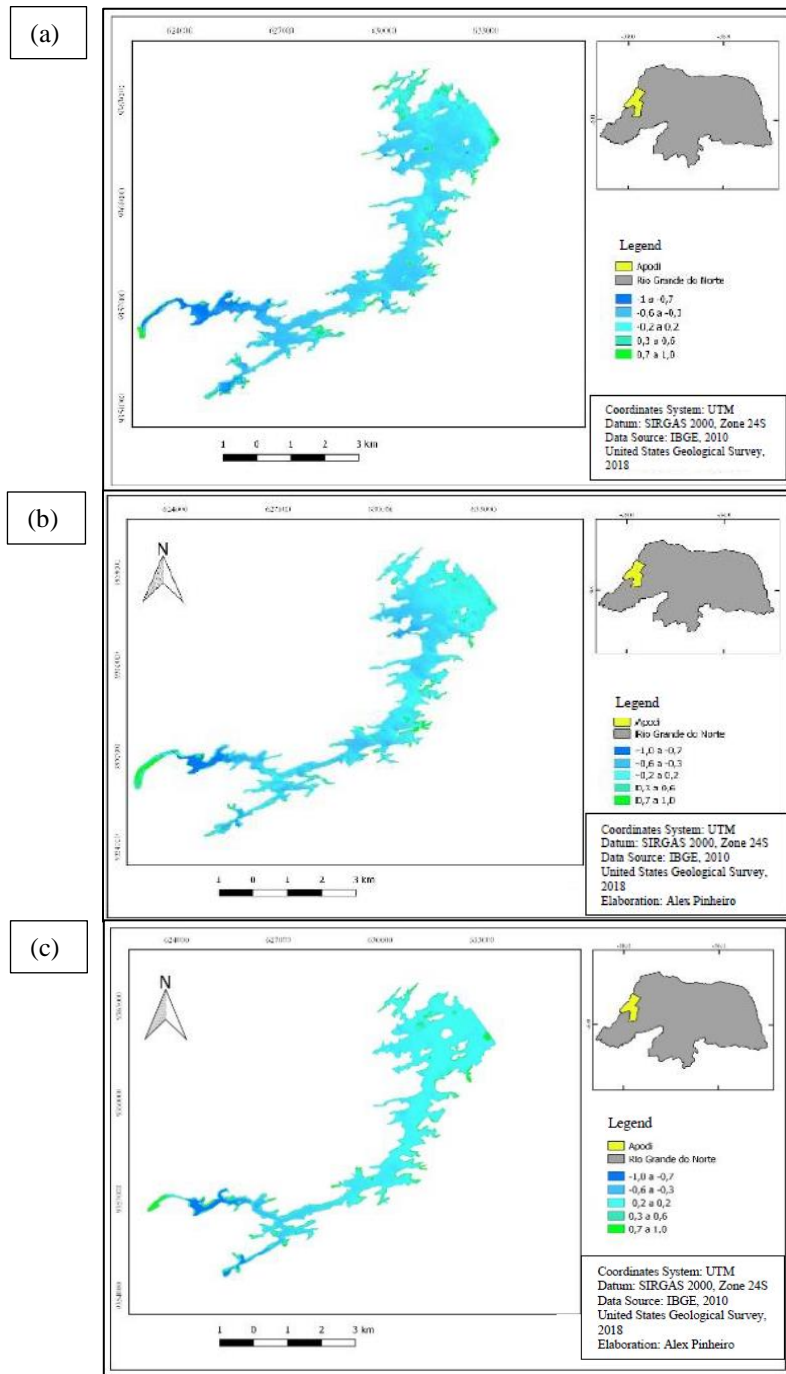


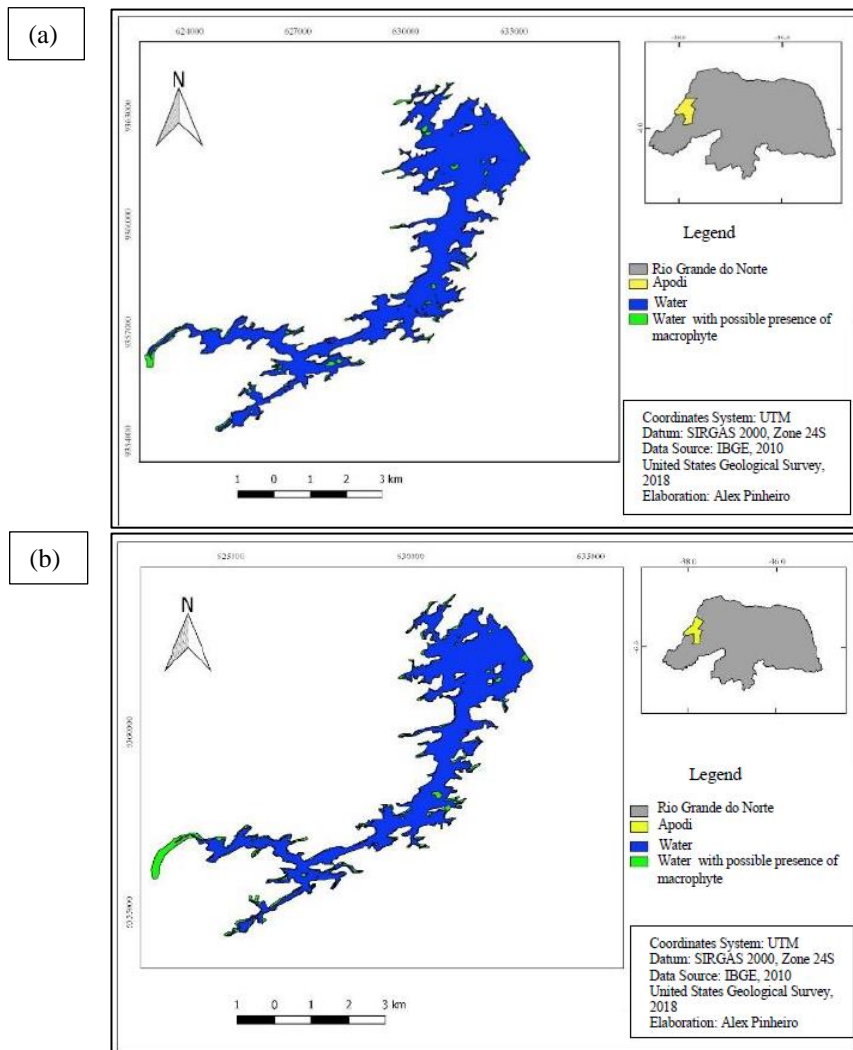
Figure 4 – NDVI vegetation index in the Santa Cruz Reservoir in the years (a) 2015, (b) 2016 and (c) 2017.
 Source: Feitosa, (2018).

It can be observed in Figure 4 (a) for the year 2015 that, throughout the studied area, there is a greater presence of index values between classes -1 to -0.7 and -0.6 to -0.3, such values are indicative of the absence of vegetation. Regarding the other classes, due to their respective results, they already indicate the presence of macrophytes, with a greater agglomeration of them occurring in the class with higher NDVI values.

Also in Figure 4 (b) it is possible to observe a distribution of values with NDVI between -0.2 and 0.2, which may indicate the presence of suspended solids, as well as a possible infestation of cyanobacteria in the extension of the water body (MINHONI et al., 2017). In the other upper intervals, mainly in the arms of the reservoir, they indicate the presence of a higher concentration of aquatic macrophytes.

In Figure 4 (c) it can be seen that in 2017 there was a higher concentration of macrophytes in the arms of the reservoir, as in the studies by (GALO et al., 2002; MINHONI et al., 2017), which despite the works were developed in a region with different characteristics of the semi-arid, a possible explanation for the results to be similar may be related to the period of the study, in the case of both low rainfall. Comparing with the years 2015 and 2016, macrophytes were observed in greater intensity in the year 2017.

The results obtained with the NDVI, served as a subsidy for comparison with maps prepared with the supervised classification. The maps resulting from the supervised classification for the years 2015, 2016 and 2017 are shown, respectively, in Figures 5 (a), (b) and (c).



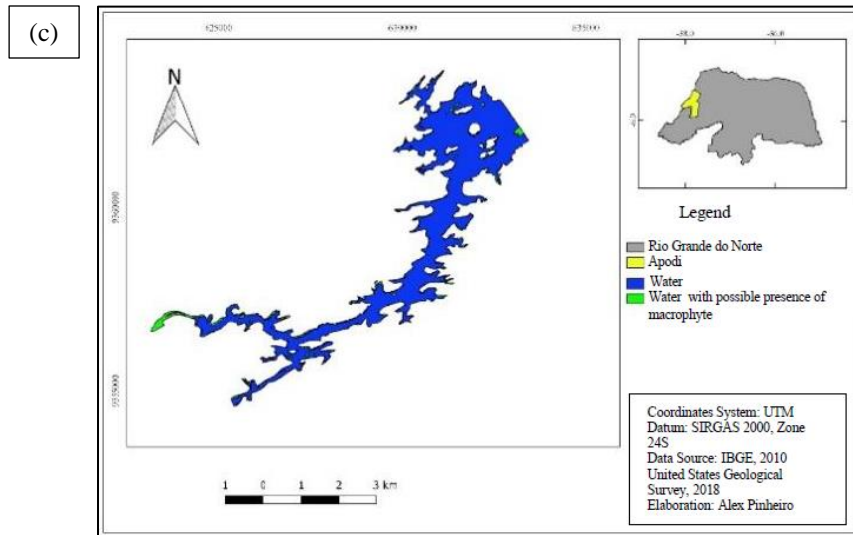


Figure 5 – Supervised classification for the Santa Cruz reservoir in (a) 2015, (b) 2016 and (c) 2017. Source: Feitosa, (2018).

It is observed in the respective figures a high concentration of aquatic macrophytes existing in places with less water volume. A possible explanation for this high number of plants is that in these places there is a greater availability of nutrients, thus making it necessary to characterize the surrounding area so that it can be identified from which source these nutrients originate. Tundisi et al. (2008) points out that the main cause of eutrophication is the increased availability of nutrients, which promotes the disordered growth of algae. It is also observed that, in 2015 Figure 5 (a), there was a lower concentration of macrophytes, while in 2016 Figure 5 (b) there was an increase in the area occupied by them, similar results were observed in the work of Miranda and Costa (2015).

In 2017 Figure 5 (c) it is possible to observe a decrease in the number of plants in the reservoir, a justification for this behavior was that throughout the study period the region faced a drought, where according to data from the National Institute of Meteorology (INMET), point out that during the study period the annual rainfall recorded was 293.0 mm, 522.6 mm and 587.1 mm, respectively for the years 2015, 2016 and 2017, in addition to a poor temporal distribution, or whether the rains occur in a few months of the year.

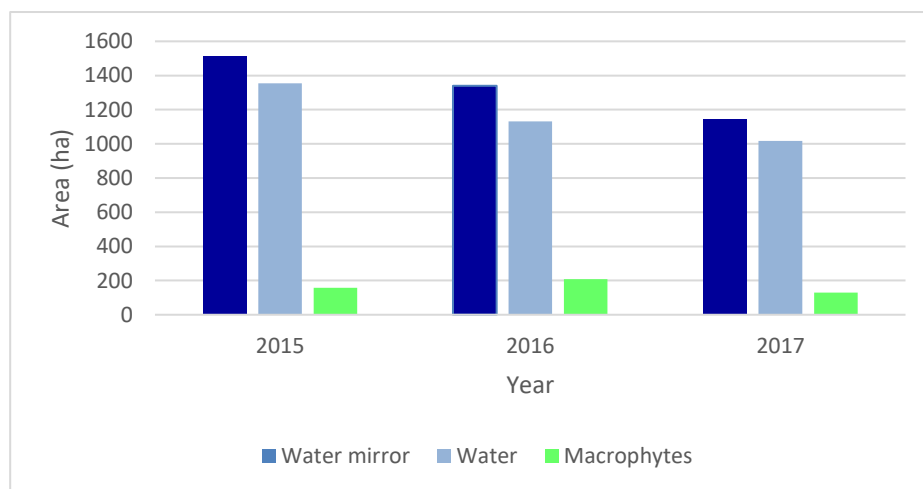


Figure 6 – Graph of the relationship between the areas of the water mirror, water and macrophytes, in the years 2015, 2016 and 2017. Source: Feitosa, (2018).

Figure 6 shows the evolution and growth of the aquatic macrophyte community over the three years studied. In 2015, macrophytes occupied an area of 158 ha, corresponding to 11.67% of the reservoir area. In 2016, they occupied an area of 208 ha (18.37%) and in 2017, 129 ha (12.67%), it is worth noting that the values obtained are based on the reservoir mirror for each year. Thus, between 2015 and 2016, there was an increase of approximately 32% in the area occupied by aquatic macrophytes in the reservoir, while for the same period there was a reduction in the mirror from 1,512 ha to 1,340 ha, which corresponds to 12% of reduction. Between 2016 and 2017, there was a decrease in the number of macrophytes of 38%, in terms of the reservoir mirror there was a reduction from 1,340 ha to 1,147 ha, corresponding in percentage to a reduction of 15%. These results differ from those obtained in the work by Miranda and Costa (2015) and Mesquita et al. (2013), indicating that in the reservoir with the decrease of the water mirror there may be some limiting factor, given that the population of Macrophytes has decreased.

4. Final considerations

In view of the results obtained, it is observed that there was a progressive increase in the amount of macrophytes in the Santa Cruz reservoir between 2015 and 2016, while a decrease was observed between 2016 and 2017, this decrease may be caused by some limiting factor, such as the availability of nutrients.

The use of remote sensing techniques proved to be efficient in the differentiation and identification of macrophytes and water in the occupied areas.

The generated products can serve as a basis for future studies and it is recommended to carry out field research, characterization of the area around the reservoir and water analysis as a way to further corroborate the results.

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