Multitemporal analyses of the vegetation cover of coastal sand dune ecosystems in Natal/RN, based on NDVI index

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Abstract. This paper presents a discussion of vegetation monitoring and a temporal analysis of the patterns of vegetation cover of coastal sand dune ecosystems in Jenipabu's APA (RN State) through NDVI index. The initial idea of this study was that the earlier cover of Atlantic Rainforest decreased due to the great pressure for urban use and tourist activities, which are cited as the major causes of losses of vegetation cover, biodiversity and impairment of ecosystem services performed by these environments. TM/Landsat-5 images of the period from 1986 to 2007 with a seven years time intervals, were used to calculate the NDVI values. A vegetation map was created for each one of this four years (1986, 1993, 2000 and 2007) and the degree of change was verified by the visually analysis of the NDVI images. All analyses were done with the GIS softwares ENVI 4.4 and ArcGIS 9.3. We observed that NDVI values of the study showed increased in vegetation cover from 1986 to 1993, a small decrease from 1993 to 2000 and finally increased again from 2000 to 2007. The results indicated that, apparently, the vegetation cover in coastal sand dune ecosystems was undergoing an ecological succession process during the study period, achieving a more dense coverage in 2007. Despite our results have not indicated an decreased of vegetation cover along the time, it is imperative to monitoring and implementing of a field ecological restoration program to maintain that vegetation cover and the ecosystem functions performed by these environments.

Key words: GIS, Idrisi Andes, Jenipabu's Environmental Protection Area (APA), Landsat 5, "restinga" vegetation; SIG, Idrisi Andes, APA de Jenipabu, Landsat 5, vegetação de restinga.

1. Introduction

The coastal sand dunes are ecosystems of great scenic and aesthetic value, which play very important environmental functions (Nordstrom *et al.*, 2002). Coastal sand dunes may be mobile or fixed due to the presence or absence of vegetation (Zuo *et al.*, 2008). These ecosystems are able to protect adjacent areas, urban or naturals, of high tides, strong winds and the invasion of sand, functioning as a natural barrier against the infiltration of saltwater into groundwater, due to the large amount of freshwater that stores (Clark, 1977).

Dunes are fragile ecosystems by natural conditions, because in the most of times suffer stress conditions such as strong winds, movements of sand, high salinity and limited availability of macronutrients (Greipsson, 2002, Randall, & Scott, 1997). This biome is among the most degraded biomes of Brazil due to pressure of real estate and tourist cars traffic that destroy the vegetation down the dunes. Given the importance of this biome and its increasing level of degradation, it becomes urgent to reverse this situation by implementing ecological restoration programs and by understanding the processes and the reasons of degradation in this environment.

In the coastal region of Rio Grande do Norte sand dunes ecosystems occur as a way of accumulation, comprising several dune fields resulting from the sand carried by wind, whose training did not occur in one period, but originated from the relocation together forming successive sand during distinct periods (Trindade, 1991). Jenipabu dunes, located on the east

coast, sand displaced by the tourist cars transit is accelerating the grounding of ecosystems that are behind the dunes. Any management plan, therefore, is contingent on maintaining the free flow of sand and vegetation fixing the dunes, which in many cases it is fragile and susceptible to human action. However, the dunes are part of a mosaic of ecosystems and protection of the areas in question necessarily requires an integrated management of all of them, especially in maintaining the ecological mechanisms associated with existing high biodiversity, such as connectivity and heterogeneity.

As for the remote sensing technique, it is essential for the registration of land use over time, because allows to evaluate changes in the landscape. An interdisciplinary study is necessary to characterize targets on the surface with the technique of sensing due to the complexity of analyzing various environmental factors interacting simultaneously, however, one of the most important of these factors is the vegetation cover, for which were created various vegetation indices with the purpose of enhancing the spectral response of the same in relation to land use and other targets. Although there are a great number of vegetation index in this study we used only the NDVI, since it is one of the most employed for such analysis.

Therefore, this study aims to evaluate the degree of degradation of coastal sand dunes ecosystems in Natal and Extremoz (municipalities of the state of Rio Grande do Norte – Brazil) and evaluate the actual state of vegetation cover trough of a multitemporal analysis of the period from 1986 to 2007 using the remote sensing techniques.

2. Work Methodology

2.1. Study Area

The Jenipabu's Environmental Protection Area (APA – Jenipabu / Figure 1) is located in the State of Rio Grande do Norte, between the cities of Natal and Extremoz (5 º 40'40 "S and 35 º 12'56" W), has a total area of 1881 ha and was established by State Decree 12620 of 17/05/1995. It is composed of various ecosystems and their creation has as objective to direct the use, protect and preserve coastal ecosystems of the Atlantic forest, mangroves, lagoons, dunes, rivers and other water resources (Torres *et al.*, 2009).

A climatic classification for the region, according to Köppen (1948) is of type As', characterized by a tropical rainy climate with dry summer and rainy season is ahead for the fall, with an average rainfall ranging between 800 and 1200mm per year (CPTEC, 2007). In the State of Rio Grande do Norte, the area of Atlantic Forest vegetation is comprised by the tropical rain forest, mangroves, "restinga" vegetation, coastal tableland, and riparian forests. This ecosystem, which once occupied the entire coastal area of the Touros/Maxaranguape until Baía Formosa, is now restricted to small fragments due to the accelerated occupation of this region (IDEMA, 2002).

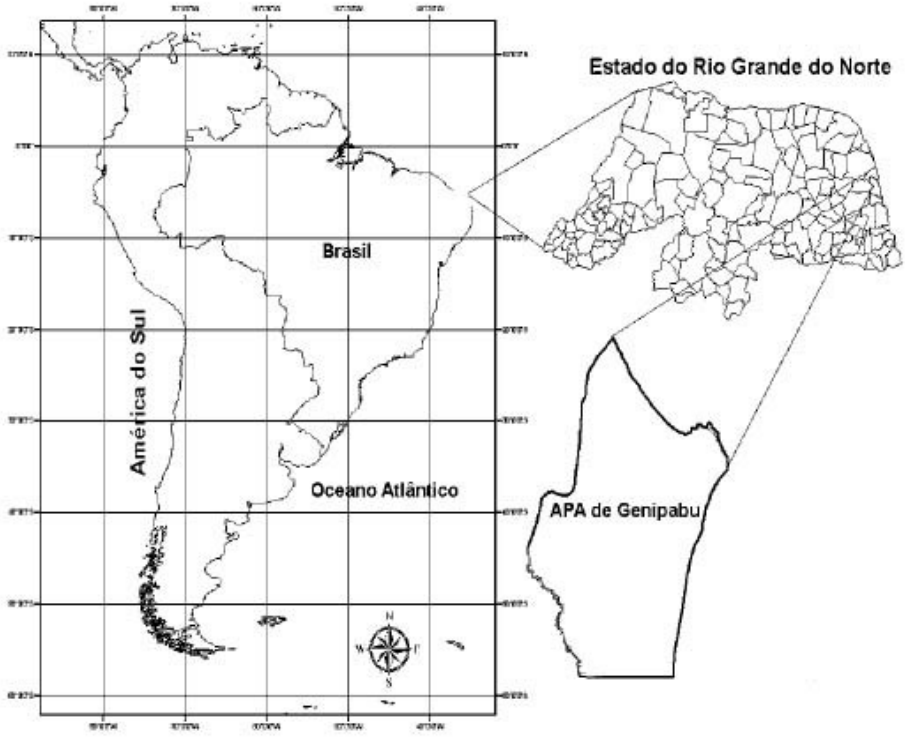

Figure 1. Location of the Environmental Protection Area – APA Jenipabu located in the state of Rio Grande do Norte, Brazil. Figure modified from Torres *et al.* (2009).

2.2. Methods

For this study, were acquired for free in the website of the National Institute for Space Research - INPE (2010) TM/Landsat-5 images corresponding to the period of analysis (1986-2007) in all its spectral channels, nevertheless only the red and infrared channels were used in the NDVI index analysis. All images used correspond to the orbit 214 and the point 64 and were chosen based on its cloud coverage and availability in order to perform a temporal analysis divided into periods of seven years. The dates of passage of the satellite correspond to the days May 15, July 05, September 26 and August 29 for the years 1986, 1993, 2000 and 2007, respectively.

The choice of Vegetation Index (NDVI) to make this work was motivated by the fact that this is a possible automated process and its results will be obtained more rapidly when compared to other ways to detect change in vegetation cover, for example, the supervised classification.

The NDVI index calculates the difference between the values reflected in the near infrared band and red band, normalized by the sum of these values. This index is linked to biophysical parameters of vegetation such as biomass and leaf area index (Pozoni, 2007). NDVI combines the bands of red and near infrared as follows in equation 1 (Eastman, 1995):

$$NDVI = \frac{r_{ivp} - r_v}{r_{ivp} + r_v} \quad (1)$$

Where:
r = reflectance;
ivp = infrared channel of the electromagnetic spectrum;
v = electromagnetic spectrum of the red channel;

For the NDVI index calculating was assumed that the coastal sand dune ecosystems are composed by only one type of vegetation cover, named “restinga” vegetation

The Geographic Information Systems used to perform all analysis and making maps was the ENVI 4.4 (SULSOFT, 2003; 2003b) and the ArcGis 9.3 Desktop (ESRI, 2005).

3. Results and Discussion

The figures 2 - 5 represent the NDVI index analysis applied for the TM/Landsat-5 images acquired for the study period from 1986 to 2007, with time intervals of seven years. However, first we must clarify that the responses obtained by applying the NDVI is indicative of the characterization of the level of green biomass present in the area, it means, the amount of chlorophyll detected. When comparing the images of NDVI for the months of May (1986) and July (1993) or September (2000) and August (2007), we can conclude that the values of vegetation index of the first months are higher compared to the seconds, which confirms the expected result of increased vegetation’s vigour in periods of greatest water supply once the raining season in Natal and Extremoz, located on the east coast of Rio Grande do Norte state (Brazil) comprise the period from June until August.

For this reason and based on the study performed by Durigan (2006) that shows an temporal analysis using NDVI only with the visual aspect of the resulting images, we decided use the same approach in our paper.

The figure 2 shows clearly that the vegetation cover is being influenced by water supply or, maybe, can have being influenced by another parameter which can not be detected visually, such as logging, pasture or other traditional community use, since this area is used to be a region of agriculture and livestock before the regulamentation of the APA by State Decree in 1995.

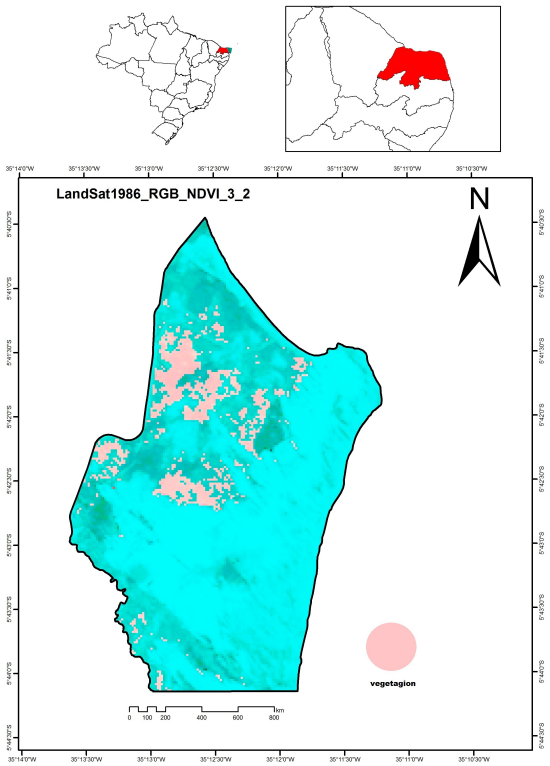

Figure 2. NDVI index resulting for Environmental Protection Area – APA Jenipabu in the image of 1986. The plots with pink hues represent the vegetation cover.

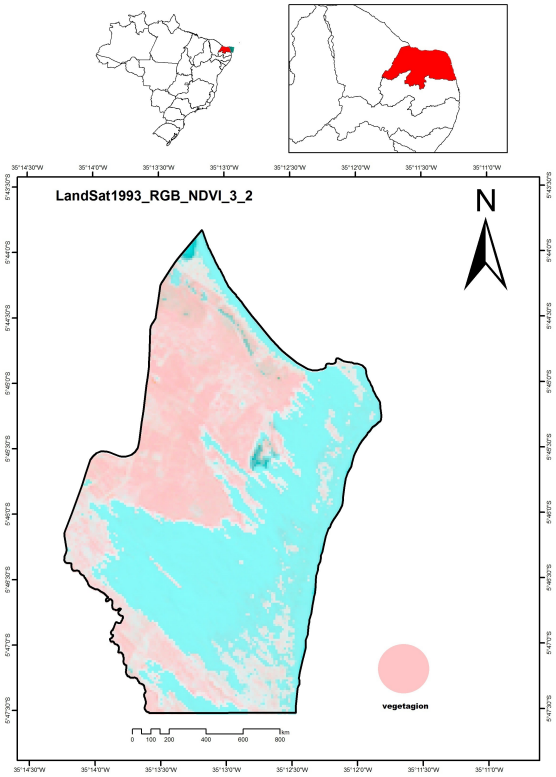

Figure 3. NDVI index resulting for Environmental Protection Area – APA Jenipabu in the image of 1993. The plots with pink hues represent the vegetation cover.

Observing the figure 3 we can see the pattern of most vegetation vigour with availability of water supply and we can hypothesize that are beginning the land use change by traditional communities in this area, due to pressure of necessity to maintain the vegetation cover in this important environment.

However, when we look for the figure 4 we perceived a large decreased in vegetation cover and it is seems to be linked as much the reduction in water supply as the increased tourism activities, once in 2000 Natal is one of the most looked touristic cities in Brazil and your economy seems to be based in this activity. Therefore, we can suppose that the transit of tourist cars in coastal sand dunes environments was bigger than in 1993, due to the high demand for rides on the beautiful beaches of this region.

Now in Figure 5, shows the pattern of increasing forest coverage due to the rainy season and shows plots on which vegetation were not found in any of the other images. This leads us to hypothesize that the vegetation of the coastal sand dunes of Jenipabu may have undergone a process of ecological succession, once we see a pattern that can be explained by thinking about the colonization by pioneer species that are replaced by shrub-arboreal vegetation until it reaches its highest density in 2007. However, further studies and field surveys should be implemented to ensure they conform to the patterns of ecological succession in this environment and this hypothesis is verified.

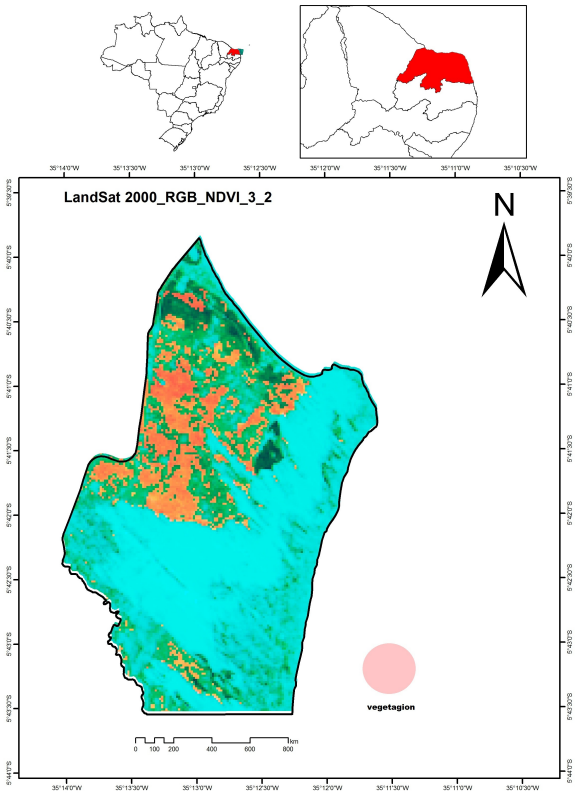

Figure 4. NDVI index resulting for Environmental Protection Area – APA Jenipabu in the image of 2000. The plots with pink hues represent the vegetation cover.

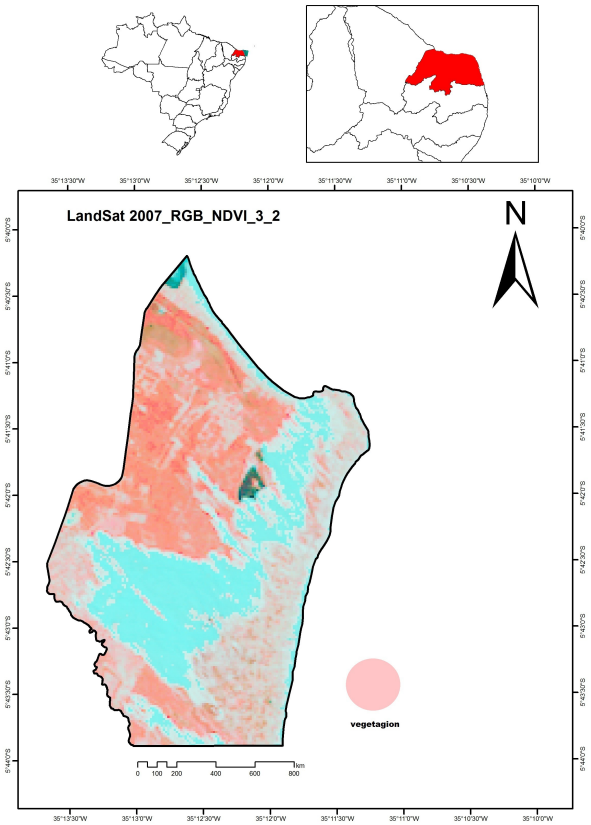

Figure 5. NDVI index resulting for Environmental Protection Area – APA Jenipabu in the image of 2007. The plots with pink hues represent the vegetation cover.

4. Conclusions

Despite our results have not indicated an decreased of vegetation cover along the time, it is imperative to monitoring trough remote sensing data and implementing of a field ecological restoration program to maintain that vegetation cover and the permanency of ecosystem functions performed by these environments. In conclusion, although our results have not corroborated the initial idea of this study, the Normalized Difference Vegetation Index (NDVI) is a good indicator to vegetation monitoring considering its simplicity, costs and likely to be automated by computer and further analysis must be applied to another dataset or in a longer time series.

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