CASE STUDY: IDENTIFICATION OF DESERTIFICATION IN THE YEARS 1999, 2006 AND 2011 IN MOSSORÓ-RN

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Abstract

Desertification is defined as a process of destruction of the productive potential of the land by means of the pressure exerted by human activities on fragile ecosystems, whose regeneration capacity is low. The UN classifies desertification just the damage in range located in climates semiarid, arid and sub-humid dry. This process causes three types of impacts: environmental, social and economic. The objective of this study was to evaluate the efficiency of application of the Surface Energy Balance Algorithm for Land (SEBAL) model in estimating surface albedo, temperature and vegetation index, indicators those used to assess desertification in the city of Natal, Rio Grande do Norte, making a comparison between years 1999, 2006 and 2011, having as parameter data of TM / Landsat-5. The variables studied are important weather and climate parameters in meteorological studies. The results showed that the surface albedo is increasing, temperature and vegetation index had similar behaviors in 2006, in which these two corresponded to higher values than in 1999 and 2011.
Keywords: Remote sensing, desertification, semiarid.

Introduction

Remote sensing is an effective tool for management and natural resource management. With the improvement of algorithms for estimating biophysical parameters relevant to the spatial variability of spectral components and results of soil-vegetation-atmosphere interactions, it has become increasingly more advanced in research regarding the process of desertification and land reclamation.

The United Nations (UN) indicates conducting research involving remote sensing to detect biophysical parameters (vegetation indices) and physical (albedo, temperature, emissivity) to identify areas at risk of desertification. The NDVI or IVDN is a variable that has been widely employed in the estimation of dry areas and is closely correlated to climatic variables in the region (BARBOSA et al., 2006). Also is an indicator of vegetation used to highlight occurring vegetation in an area, this is given by the ratio of the bands highly correlated with each other and serves to highlight the targets of interest, the plant biomass (ARAÚJO et al., 2010).

Thus, vegetation is a key parameter in the process, after reducing the mass of the savanna is directly related to the degradation of soils of areas with less vegetation cover, these two conditions tend to increase the albedo of surfaces subject to degradation. The albedo is defined as the fraction of the energy received

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in the solar spectrum range (0.3 to 3.0 μm) which is reflected by a surface (MONTEITH & UNSWORTH, 1990). Physically, the albedo is inversely proportional to the ability of a surface has to absorb solar radiation. Thus, when an area has a high albedo, a large portion of shortwave radiation (Rs) is reflected back to the atmosphere (MESQUITA, 2012).

In ecological systems albedo controls the microclimate conditions of crops and absorption of radiation, affecting physical and physiological aspects, such as energy balance, evapotranspiration, photosynthesis and respiration (WANG et al., 2001).

Regarding the areas susceptible to desertification in Brazil, analyzed as Nuclei of Desertification, regarded with the highest level of severity of this degradation process, they are distributed into four sections and all are located in semiarid portion of the Brazilian Northeast. In mid-1998/1999 the Ministry of the official the identification of four nuclei of desertification, which came to be known as

Centers of Gilbués-PI, Irauçuba-CE, Seridó-RN and Cabrobó-PE. Based on this the present work aims to identify areas that suffer from the desertification process in Mossoró-RN, using the Landsat-5 satellite images, applying the SEBAL as a way to process the images in 1999, 2006 and 2011.

Metodology

Study area

Mossoró is located in the state of Rio Grande do Norte, there are 281 km of Natal, the state capital. With an area of 2099.36 square kilometers. Mossoro is the largest municipality in area of Rio Grande do Norte, and is limited to the municipalities of Aracati (Ceará), Tibau e Grossos (north), Governador Dix-Sept Rosado e Upanema (south), Areia Branca, Serra do Mel e Assu (east) and Baraúna (west), according to Figure 1 below..
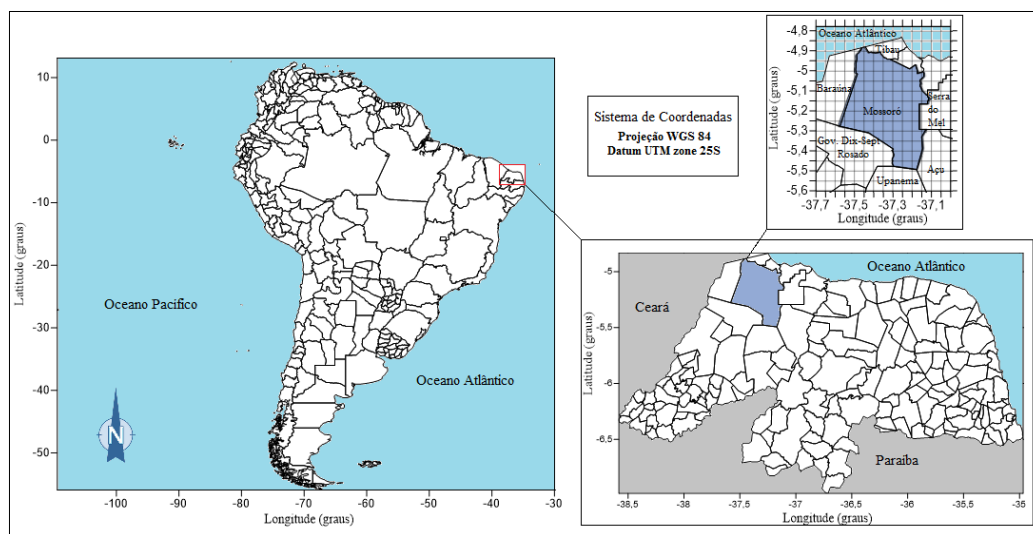

Figure 1 – Location of the study area

The city has all its territory situated in the watershed of the Rio Apodi / Mossoró. The vegetation of the municipality is formed by the savanna, made up of small size plants adapted to drought, as well as vegetation with species adapted to the high degree of salinity. Mossoró, along with Baraúna, home to the Cavern National Park Ugly, environmentally protected area with an area of 8,494 hectares in order to preserve the local biome caatinga.

The scenes used were acquired for free from the USGS site (http://glovis.usgs.gov/), the years of the images were taken in 1999, 2006 and 2011. The images were selected due to present low cloud cover.

Was based on the *Surface Energy Balance Algorithm for Land* algorithm (SEBAL), using the software *ERDAS IMAGINE 2014*. The image processing was done using the *Model Maker* tool and for the preparation of thematic maps was used *QGIS*

2.8.2 program, that the following variables were generated: Radiometric Calibration, monochrome reflectance, planetary albedo and surface vegetation index (NDVI, SAVI and LAI), thermal emissivity and surface and the surface temperature (inverted Planck equation).

The radiometric calibration ($L_{\lambda i}$) it was obtained according to Equation I, as indicated by Markham & Baker (1987):

$$L_{\lambda i} = a_i + \frac{b_i - a_i}{255} DN \qquad (I)$$

where a_i e b_i are the minimum and maximum spectral irradiance ($Wm^{-2} sr^{-1} \mu m^{-1}$), DN is the intensity of the pixel, whose values range from 0 to 255 in the case of Landsat satellite, will correspond to the bands (1, 2, ..., 7). The $L_{\lambda i}$ unit is $Wm^{-2}sr^{-1}\mu m^{-1}$. The calibration coefficients were used to Landsat those proposed by Chander & Markham (2003).

The reflectance of each band ($\rho_{\lambda i}$) it was obtained by applying Equation II according to Allen et al., (2002):

$$\rho_{\lambda i} = \frac{L\lambda i \pi}{K\lambda i \times \cos\theta \times dr} \qquad (II)$$

where $L_{\lambda i}$ it is the spectral radiance of each band, $K_{\lambda i}$ is the solar constant monochrome associated with each band sensor, θ is the zenith angle of the sun and dr is the inverse square of the relative distance Earth-Sun. d_r calculation was obtained according to Equation III:

$$d_r = 1 + 0{,}033 \cos \left(JD \frac{2\pi}{365}\right) \qquad (III)$$

where JD is the order of day of the year when we obtained the radiometric data (satellite images), whose values correspond to the day of the generation of images.

Calculating the albedo at the top of the atmosphere is performed through linear combination of the monochromatic reflectance obtained by Equation IV:

$$\alpha_{toa} = 0{,}293\rho_1 + 0{,}274\rho_2 + 0{,}233\rho_3 + 0{,}157\rho_4 + 0{,}033\rho_5 + 0{,}011\rho_7 \qquad (IV)$$

where, ρ_1, ρ_2, ρ_3, ρ_4, ρ_5 e ρ_7 they are the reflectance of the bands 1,2, 3, 4, 5 e 7.

The surface albedo was calculated by Equation V:

$$r_0 = \frac{\alpha toa - \alpha path\_radiance}{\tau 2sw} \qquad (V)$$

where, α_{toa} it is the planetary albedo, $\alpha_{path\_radiance} = 0{,}03$ is the portion of solar radiation reflected from the atmosphere (Bastiaanssen, 2000) and τ_{sw} it is the atmospheric transmittance (Allen et al., 2002).

The atmospheric transmissivity was computed as a function of the local altitude (z) according to Equation VI:

$$\tau_{sw} = 0{,}75 + 2 \times 10^{-5} \times z \qquad (VI)$$

To calculate the Vegetation Index (NDVI) was used the following equation (Allen et al., 2002):

$$NDVI = (\rho_4 - \rho_3) / (\rho_4 + \rho_3) \qquad (VII)$$

The adjusted vegetation index for the purposes of soil (Soil Adjusted Vegetation Index - SAVI) proposed by Huete (1988) was obtained by Equation VIII:

$$SAVI = (1+L) (\rho_4 - \rho_3) / (L + \rho_4 + \rho_3) \qquad (VIII)$$

where $L = 0{,}5$ it is the soil adjustment factor.

The Leaf Area Index (LAI) was measured by empirical expression suggested by Allen et al., (2002) by applying the Equation IX:

$$IAF = - \frac{ln\left(\frac{0{,}69 - SAVI}{0{,}59}\right)}{0{,}91} \qquad (IX)$$

The inverted Planck's equation was used. Since each pixel does not emit electromagnetic radiation as a black body, it must enter the emissivity of each pixel in the field of thermal spectral band ε_{NB}. According to Allen et al., (2002), the emissivities ε_{NB} (Equation X) and ε_0 (Equation XI) may be obtained as:

$$\varepsilon_{NB} = 0{,}97 + 0{,}0033 \times IAF \qquad (X)$$

$$\varepsilon_0 = 0{,}95 + 0{,}01 \times IAF \qquad (XI)$$

It was considered $\varepsilon_{NB} = \varepsilon_0 = 0{,}98$ when $LAI \geq 3$ and $NDVI < 0$. For water bodies $\varepsilon_{NB} =$

0,99 e $\varepsilon_0 = 0,985$ according to Allen et al., (2002).

Obtaining the Surface Temperature (T_s) it is determined by the spectral radiance of band 6 (thermal) and thermal emissivity (Equation X) by the following expression (Allen et al., 2002):

$$T_s = \frac{K2}{\ln(\frac{\varepsilon NB.K1}{L\lambda 6}+1)} \qquad (XII)$$

where $K_1 = 607{,}76$ Wm^{-2} sr^{-1} μm^{-1}, $K_2 = 1260{,}56$ Wm^{-2} sr^{-1} μm^{-1}, $L_{\lambda 6}$ is the spectral radiance of band 6, ε_{NB} it is the emissivity of each pixel in the portion of the thermal band of the TM / Landsat-5.

This study included the images dated 02/June/1999, 08/Aug/2006 and 06/Aug/2011

to assess the gradual impact of environmental and urban area in the municipality of Mossoró / RN, over a period of 12 years.

Results and discussion

Regarding the surface albedo (Figure 2), it is notable that in 1999 had a lower albedo, ie more areas with green color, equivalent to 7%, for the years 2006 and 2011, in the same areas prevailed shades in yellow and orange, representing 10% and 14% respectively in 2011. That is, the albedo is increasing over time, we can say that in Mossoró are finding areas with a greater reflection of energy incident on the surface. An increase in albedo indicates a larger area urbanized / degraded and less vegetated.
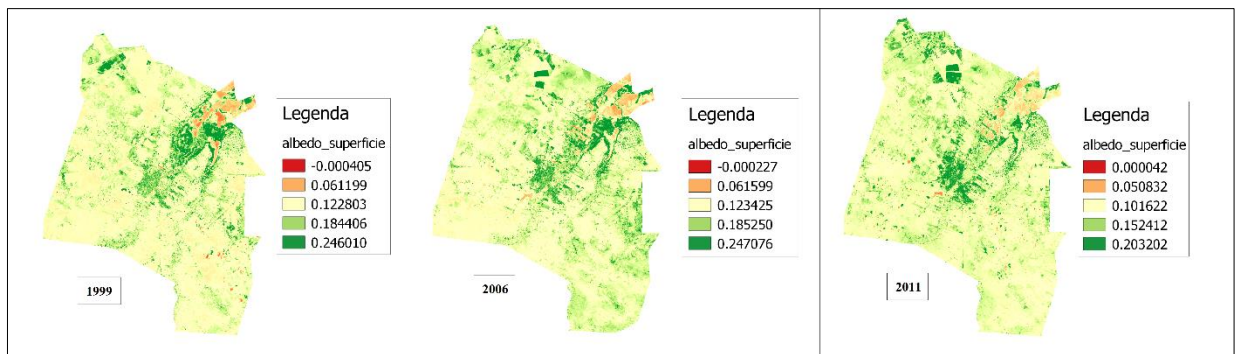

Figure 2 – Albedo for the city of Mossoró in 1999, 2006 and 2011

Temperature is one of the most important variables, but the most important for various environmental studies. In this article we find a variation between the years 1999, 2006 and 2011 (Figure 3). This change was not gradual, however, in 1999 it prevailed little orange areas and reddish, 1999 to 2006 there

was a decrease in temperature in some areas in the city, where you can notice the yellow areas had green nuclei, reaching values 12° C and the maximum temperature of 33° C in other areas, followed by a temperature increase from 2006 to 2011, prevails again with reddened areas.
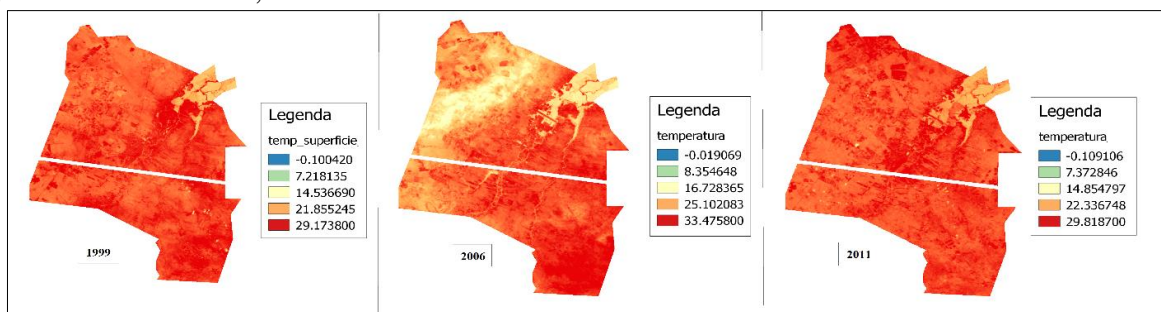

Figure 3 – Temperature for the city of Mossoró in 1999, 2006 and 2011

The values of the vegetation index had a variation throughout the study period, reaching much lower values in 2006, covering

almost the entire municipality values of approximately 0.25, with low NDVI is the

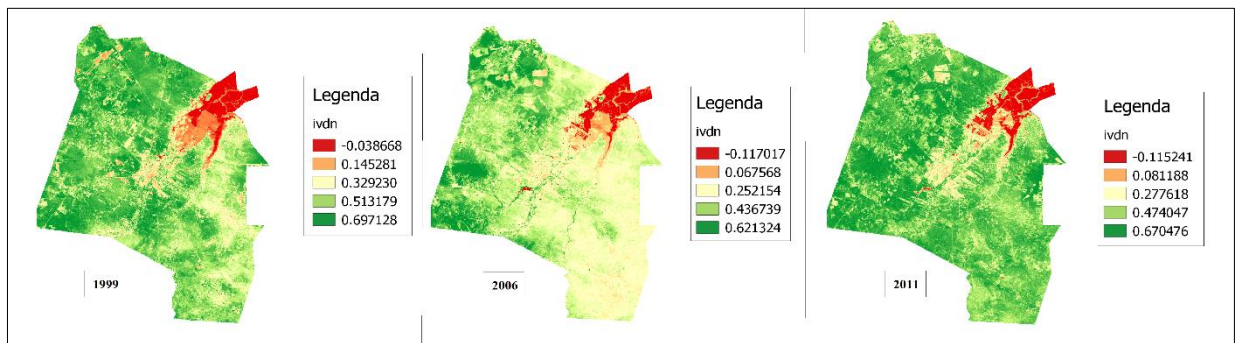temperature increase in degraded areas or no vegetation (Figure 4).

Figure 4 – IVDN for the city of Mossoró in 1999, 2006 and 2011

Conclusions

Although preliminary results show the efficiency of remote sensing in environmental monitoring. It can be concluded that as the surface albedo is increasing over time, in Mossoró are finding areas further reflection of the energy incident on the surface. With the temperature could identify that the change was not gradual, rather, 1999 prevailed slightly orange areas and reddish, followed by a temperature increase in 2006 and areas of lower temperatures and a decrease in 2011, prevails again with areas reddish. Values ranged vegetation index enough, especially in 2006, prevailing values 0.25 in this region. This means the need and implementation of recovery projects to the affected areas.

References

Allen, R. G., Tasumi, M., Trezza, R. 2002. SEBAL (Surface Energy Balance Algorithms for Land) Advanced Training and Users Manual. Idaho Implementation, version 1.0, 97 p.

Araújo, I. R., Silva, H. P., Lopes, A. S.; Alencar, B. P. B., Silva, H. D. B. 2010. Cálculo de NDVI no suporte ao estudo de desertificação no município de Orobó –PE, In: III Simpósio Brasileiro de Ciências Geodésicas e Tecnologias da Geoinformação. Recife – PE.

Barbosa, H.A., Hueti, A.R., Baethgen, W.E. 2006. A 20 - year study of NDVI variability over the Northeast Region of Brazil. Journal of Arid Environments, London, v.67, p. 288-307.

Bastiaanssen, W. G. M. 2000. SEBAL - based sensible and latent heat fluxes in the irrigated Gediz Basin. Turkey. Journal of Hydrology, v. 229, p. 87 – 100.

Chander, G., Markham, B. 2003. Revised Landsat - 5 TM radiometric calibration procedures and post calibration dynamic ranges. IEEE Transactions on Geoscience and Remote Sensing, 41(11), p. 2674 – 2677.

Huete, A. R. 1988. Adjusting Vegetation Indices for Soil Influences. International Agrophysics. 4 (4), p. 367 – 376.

Markham, B. L., Barker, L. L. 1987. Thematic mapper bandpass solar exoatmospherical irradiances. Int. Journal of Remote Sensing, v. 8, nº. 3, p. 517 – 523.

Mesquita, F.L.L. 2012. Monitoramento do balanço de radiação na região metropolitana do Rio de Janeiro. 80 f. Dissertação (Mestrado) - Curso de Meteorologia, Departamento de Instituto de Geociências do Centro de Ciências Matemáticas e da Natureza, Universidade Federal do Rio de Janeiro, Rio de Janeiro.

Monteith, J.L., Unsworth, M.H. 1990. Principles of Environmetal Physics. New York, Chapman and Hall, Inc,

Wang, S.; Grant, R.F.; Verseghy, D.L.; Black, T.A. 2001. Modelling plant carbon and nitrogen dynamics of a boreal aspen forest in CLASS − the Canadian Land surface Scheme. Ecology Modelling.142, p. 135-154.