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Monitoring land cover changes and desertification process in Rio Grande do Norte (NE Brazil) with MODIS time series

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Abstract: This study presents the result of joint efforts by the Lageoma - Geomatic Laboratory of the Federal University of Rio Grande do Norte (Brazil), and the Institute of Geography, Dept. of Cartography, GIS & Remote Sensing, Univ. of Gottingen (Germany), with the purpose of to devise a methodology and to test the usefulness of spatial analysis methodologies in MODIS scales on images from Feb. 2000 to May 2005 (121 full scenes of MOD13Q1 data), for to quantify the desertification severity and land degradation hazard in the Rio Grande do Norte State (NE-Brazil) taking into account both natural and anthropogenic factors. The target of this study was to evaluate and delineate the current status of land degradation using remote sensing. Classification and interpretation of desertified land mapping areas was accomplished the following stages of treatment of the images MODIS (i) Acquisition of MODIS original data (MOD13Q1, 250 m); (ii) Batch import and subsetting of NDVI, EVI and QA channels. Using the script (PCI Geomatica easi script) and creates a subset for NE-Brazil; (iii) Cloud masking of MODIS data. Use the PCI Geomatica Modeler for cloud flagging.(iv) Export data to IMG format and Import of data to ENVI / save as meta file; (v) Conversion of map projection and (vi) Filtering of time series data.

KeyWords: Desertification, Change Detection, MODIS, Landsat, Vegetation Data, Seridó, Brazil

1 Introduction

The process of desertification began to be studied in Brazil in the decade of the 1970's. The majority of scholars of the subject agree that the most widely accepted definition of desertification is, at present, the one given by the United Nations Convention to Combat Desertification (http://www.unccd.int). It defines desertification as "land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities". They begin with the destruction of the natural vegetation covering and by their interaction of the human activities with the variations of climate and weather, the material conditions are created for the establishment of the processes of desertification.

In the areas submitted to the processes of desertification in the Brazilian Semi-Arid regions, the vegetation shows a reduced size, some species showing symptoms of dwarfing (Pereiro, *Aspidosperma sp*), and diluted concentration, that is with greater permeability than in the remaining areas, generally coinciding with the presence of hyperxerophyte caatinga. In this type of caatinga and soil, desertification can arise spontaneously, existing thus, the possibility of its preexistence in the Northeast, before the appearance of the colonizer. All the hyperxerophyte caatinga is an area presumably weakened with the process of desertification, which becomes more accentuated with each annual cycle and, principally after each drought. When the rainy season returns, one sees an effort to recuperate which is not always totally recovered. And thus, in this uncertain balance between recuperation and degradation it is difficult to discover, the condition which will prevail. But if man interferes negatively, then it is certain that the desertification prevails. (**Table 01**-PAN Brazil, 2005).

TABLE 01: Pilot areas for Investigation about the Desertification in the Brazilian Semi-arid Region . Our target area is on the number 3

AREAS	STATES	NATURAL AND/OR HOMOGENEOUS REGIONS	MUNICIPALITIES
1	Piauí	Caatinga and Cerrado	Gilbués, Simplício Mendes, Cristino Castro, Ribeiro Gonçalves, Correntes, Bom Jesus and neighboring municipalities
2	Ceará	Inhamuns	Tauá, Arneiroz, Mombaça, Aiuaba, Catarina, Saboeiro, Irauçuba and neighboring municipalities
3	Rio Grande do Norte	Seridó	Currais Novos, Acari, Parelhas, Equador, Carnaúba dos Dantas, Caicó and Jardim do Seridó
4	Paraíba	Cariris Velhos	Juazeirinho, S. João do Cariri, Serra Branca, Cabaceiras and Camalaú
5	Pernambuco	Sertão Central	Salgueiro, Parnamirim, Cabrobó, Itacuruba, Belém do São Francisco, Petrolina, Afrânio, Ouricuri, Araripina and neighboring municipalities
6	Bahia	Sertão do São Francisco	Uauá, Macururé, Chorrochó, Abaré, Rodelas, Curaçá, Gloria, Jeremoabo, Juazeiro and neighboring municipalities

Source: Vasconcelos Sobrinho, J. Desertificação no Nordeste do Brasil. Recife: Fadurpe / UFRPE. 2002

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The targets of this study are (i) to evaluate and delineate the current status of land degradation using remote sensing and GIS; (ii) to identify the mechanism and causes of land degradation through field investigation and systematic analysis of the natural settings and socioeconomic background in the study area; (iii) to establish the differentiate regional levels of desertification and land degradation in regional level, and (iv) to analyze and integrate some geo-environmental variables with the creation of environmental indicators associated with the development of the desertification process.

The Seridó Region on the Rio Grande do Norte State **(Fig. 01**) has been selected as the interesting area, and the series of the sensor, Terra/MODIS were utilized in this study according to its spatial and temporal resolutions. A set of five-year period of MODIS images were explored for vegetation and soil study and local analysis of association and variability of spectral data were performed. The integration of the georeferencied data, related to these indicators, allowed the identification of five different levels of susceptibility to desertification (very high, high, moderate, low and very low), and the geographic domain of each class.

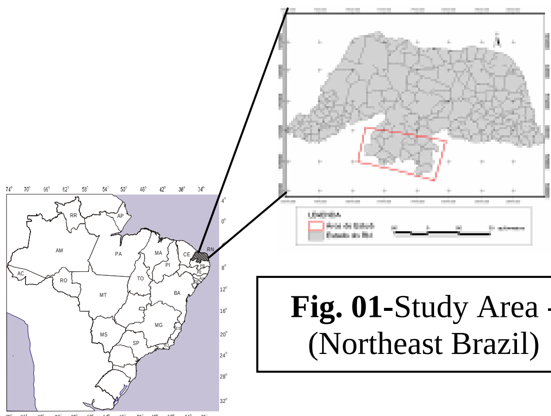


Fig. 01-Study Area - (Northeast Brazil)

2 Characterization of the area

The Seridó Region is located in the Borborema Province (NE Brazil). Although it is one of the oldest areas of northeast of Brazil, in settlement terms, the Seridó presents the more bass index of demographic density and, associate to that, they are the low precipitation indexes, what makes that the agricultural activity suffers the consequences of those climatic limitations. It is therefore an area strongly individualized, for the natural limitations, for the economic activity or for the low demographic density. Seridó includes most of the Rio Grande do Norte State and a small portion of the Paraíba State. This area is characterized by presenting a low vegetation index, very spaced and a soil shallow, sandy and dry, still presented biggest granites outcrops. Those characteristics become decisive to increase the fragility of the ecosystem, favoring the installation of processes of environmental degradation.

In its natural feature, it can stand out the vegetation, which is constituted of savanna arboreal arbustive (*caatinga*). The physiognomy of that sub-formation is marked by a vegetation caducipholic, could be open or close according to the density and distribution of the species, being basically constituted by stratum arbustive and arboreal significant and different. The *Caatinga* is a typical biome of the interior of the Brazilian northeast, was usually distributed in a semi-arid climate area, that it presents heatstroke and high temperatures, low cloudiness, irregular distribution of the rains during the year, and only two defined seasons, a drought with prolonged periods and one with rains, reduced, being like this the whole area subjects to long drought periods, that echo directly in the conditions of permanence certain populations there rooted. Due to all those conditions, that area was delimited by National Brazilian Council of Geography in 1949 and denominated of “Polygon of the Droughts”.

In agreement with statistic accomplished by the DESERT Nucleus, presented in the National Conference of Desertification by FGEB in March of 1994 in Fortaleza-CE (Brazil), the desertification reaches, in their several degrees, about 55,25% of the lands of the semi-arid Northeasterner, affecting direct or indirectly 42,17% of his population. The same study shows that the annual economical loss, in the affected areas for the desertification process, it is esteemed in approximately US$ 470 millions and that the minimum cost for the recovery of these areas is of US$ 4 millions, to be applied in twenty years.

3 Material and methods

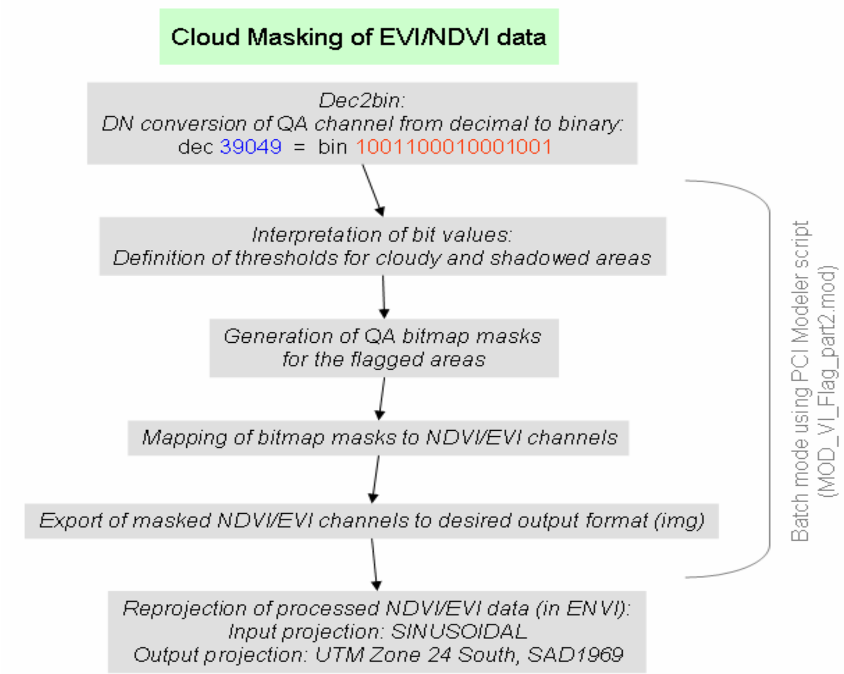
High temporal frequency observations with the Moderate Resolution Imaging Spectroradiometer (MODIS) onboard the Terra Earth Observing System platform offer unique opportunities to study land changes concerning our environment , such as, climate and anthropogenic induced land transformations, in the temporal domain. The MODIS sensor provides both morning and afternoon measurements in support of global change research and applications for at least 15 years, and its characteristics are very useful for assess land desertification applications with a better accuracy and more rapid frequency due to the spatial, spectral and temporal characteristics. So it is very useful to develop the methodology of deriving the data sets of land desertification from MODIS data.

In this research, only the progress of land desertification in Seridó Region area was evaluated by using the 16-day composite Terra/MODIS image during Feb. 2000 to May 2005 (121 full scenes of MOD13Q1 data) downloaded from NASA’s DAAC web site (http://daac.gsfc.nasa.gov/data/). The MODIS image was firstly geo-rectified and resized into 30 m resolution to match with the Landsat TM image, and then, was applied a relatively atmospheric correction to minimize the effect of atmospheric conditions difference between these images.

4 Change in vegetation greenness (NDVI) using MODIS images

Vegetation change has been successfully observed at scales ranging from local to global using the Normalized Difference Vegetation Index (NDVI), derived from satellite data. This index utilizes the reflectance spectra of healthy green vegetation, which is characteristically high in the near infrared. The NDVI minimizes the effects of topography and atmosphere, requires no prior knowledge of ground conditions, and is sensitive to the amount of photosynthetically active vegetation present. The change in the value of the NDVI between 2000 and begin of 2005 obtained from imagery acquired by the MODIS satellite was used for this indicator.

Fig. 02 Processing of MOD13Q1 data



The stages of treatment of the images MODIS were the following ones: **(Fig. 02)** (1) Acquisition of MODIS original data (MOD13Q1, 250 m) from USGS site; (2) Batch import and subsetting of NDVI, EVI and QA channels. Using the script (PCI Geomatica easi script) performs a batch import and subsetting of the original MODIS HDF files to creates a subset for NE-Brazil; (3) Cloud masking of MODIS data. Use the PCI Geomatica Modeler models script for cloud flagging. This script creates masks for the cloudy and shadowed areas within the images. The cloud and shadow values are taken from the QA bit mask. This script applies the masks that have been created in (3.) to the VI channels. The output is stored in separate files for EVI and NDVI; (4) Export data to IMG format (convert_PIX_IMG.mod) and Import of data to ENVI / save as meta file,; (5) Conversion of map projection from Siunosuidal to UTM24S_SAD69 - For further visualization and analysis in ENVI and GIS software, desired subsets of the files can be reprojected to UTM projection (6)Visualization of time profiles and Filtering of time series data (preliminary stage). (**Figures 3 to 8**).

First results of the cloud flagging attempts with 5 masks (3 cloud + 2 shadow) is shown in **Figure 09**, produce large masked areas. Further Investigations have to be carried out using only 3 cloud + 1 shadow mask (shadow2) or using only the cloud masks. Despite of the large coverage of masked areas, these 5 mask cover the cloudy and shadowed areas fits good results.

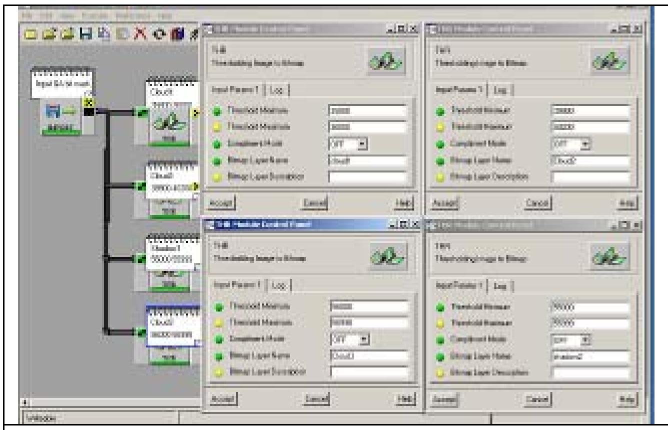


Fig. 3: Thresholds for QA bitmaps (3 bitmaps „clouds“, 1 bitmap „shadow“)

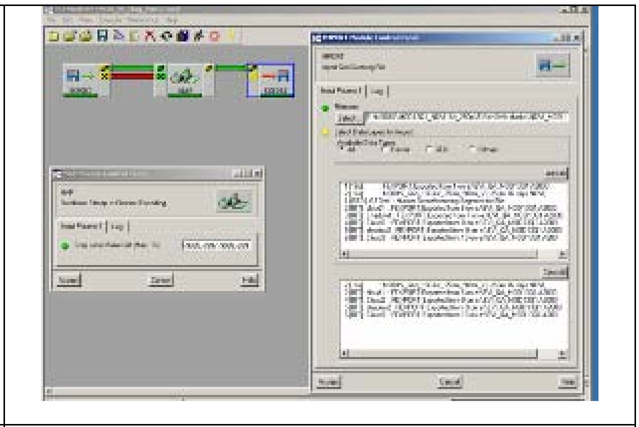


Fig 4: Mapping of the bitmap masks to the VI channels

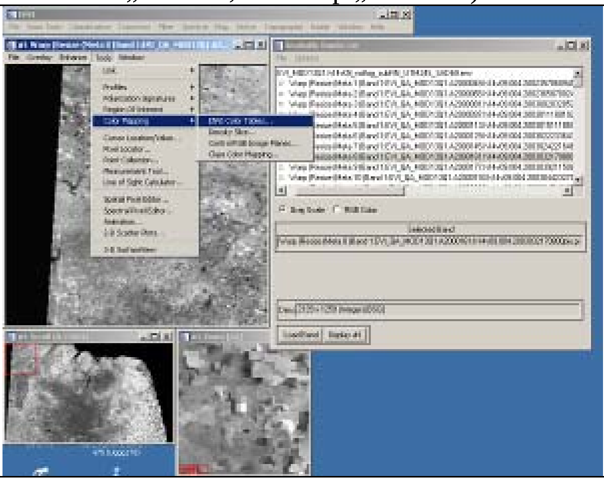


Fig.5: Load one band (here: Band8; read: A2000161 = 09 June 2000), and open the “ENVI color table” dialog

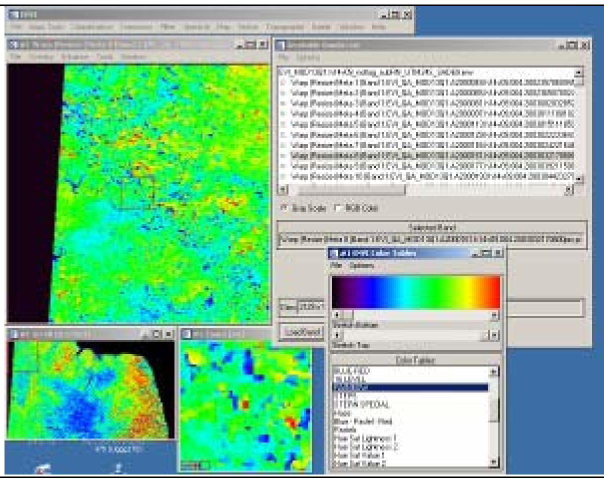


Fig. 6: Apply the “Rainbow” color table to the EVI data (blue = low; green = medium; red = high EVI values)

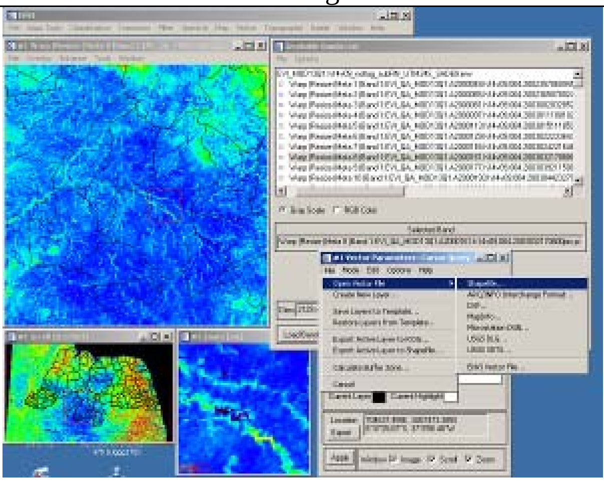


Fig. 7: Vector and load the district boundaries.

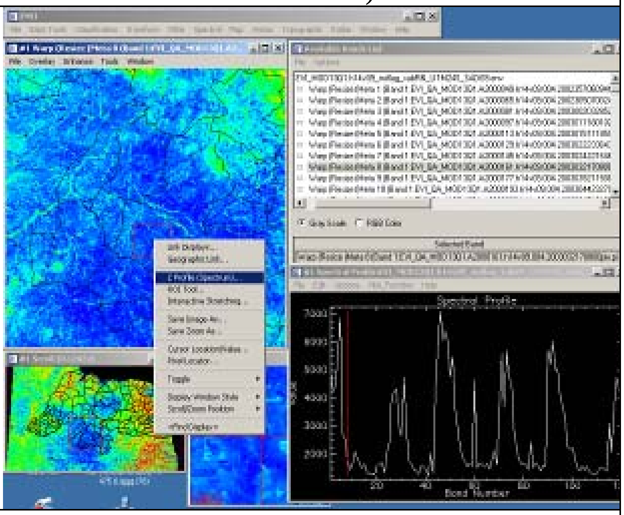


Fig. 8: Activate the “Z Profile” and exported as text files from the File menu and then loaded e.g. in Excel for further visualization and analysis (Save Plot As ASCII).

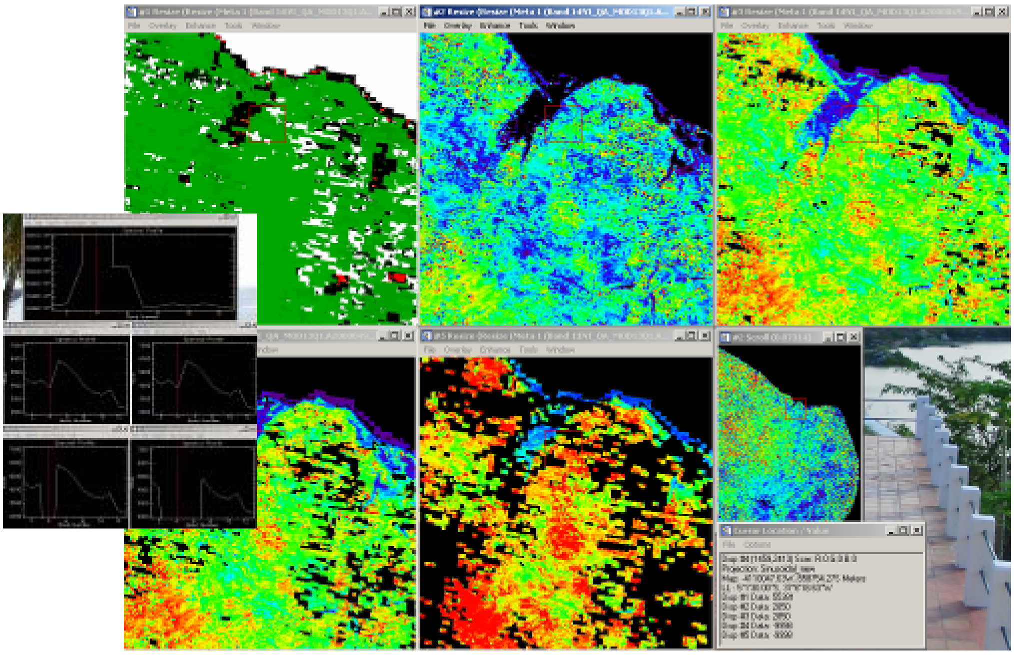


Figure 9: Results of the Results of the cloud masking procedure

After this treatments the EVI data (without cloud mask "noflag", because the flagged data are not yet filtered and only show „holes" where clouds exist) were open and the load one band (here: Band8; read: A2000161 = 09 June 2000), and open the "ENVI color table" dialog **(Fig.6)** and apply the "Rainbow" color table to the EVI data (blue = low; green = medium; red = high EVI values). The displayed channel can be saved as an image file (the "8-bit color table" option saves disk space).

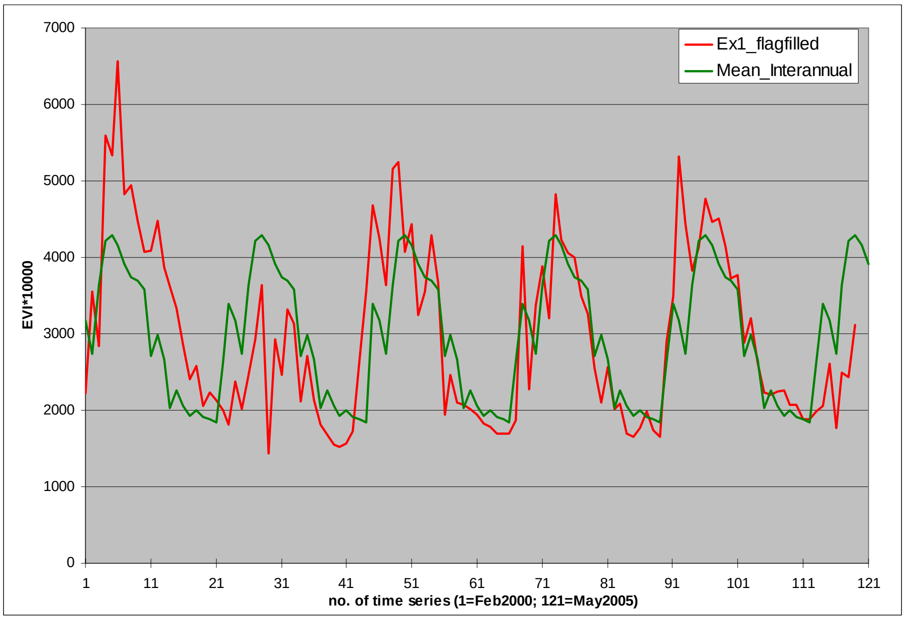


Fig. 09: Filtering of time series data (121 full scenes of MOD13Q1 data),

After repeat this same procedure with all the set of five years images and filtering of time series data **(Fig. 09)**, we have the overview of this period um the different season of dryness and rain. The integration of the georeferenciated data relative to the environmental indices selected has resulted in the identification of five different susceptible levels to Desertification (Very High, High, Moderate, Low and Very Low with color varying from blue to red (**Fig.11**), and the delimited area of geographical domain assumed by the obtained classes. The desertified land classification map is shown in **Figures 11 a,b,c,d**. Because of the vulnerable natural environment and intensive human disturbance, land degradation and desertification is very serious and desertified land distributes widely in the studied area.

The validation of the reached results, starting from the space modeling in regional scale, it was accomplished, in a semi-detail scale, in the pilot area identified as Desertification Nucleus of Seridó, taking as base analyses of the dynamics of the vegetable covering (acted by orbital images) and evaluations of field data (Petta 2004, 2006). The obtained results allowed a direct association between the different susceptibility levels and varied forms of environmental problems. Where, the areas with "Very high susceptibility" they are linked to the practices of recovery of the degraded areas; "High susceptibility", to the practices of recovery of degraded areas, as well as the adoption of techniques and control procedures to combat the desertification; "Moderate susceptibility", to the prevention, control and combat of the processes of Desertification; and "Lowers to Very low susceptibility", to the adoption of prevention measures to the development of desertification processes.

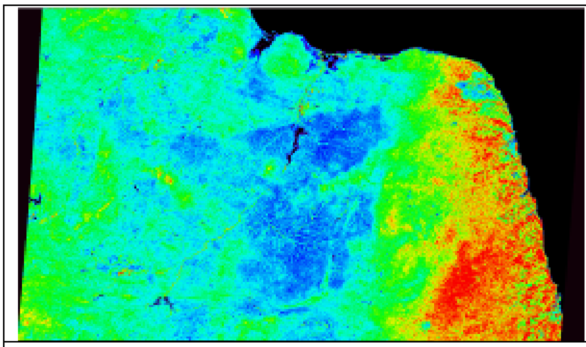


Fig. 11a- EVI 2000 dry season

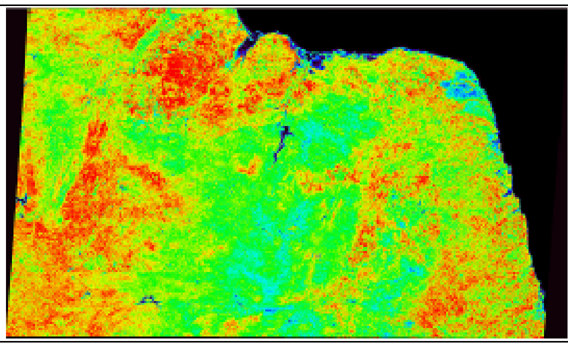


Fig.11b- EVI 2000 wet season

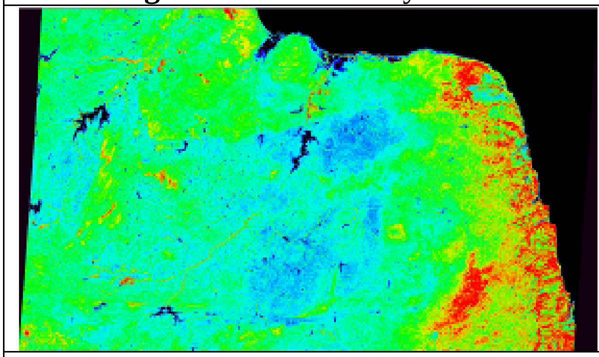


Fig. 11c- EVI 2004 dry season

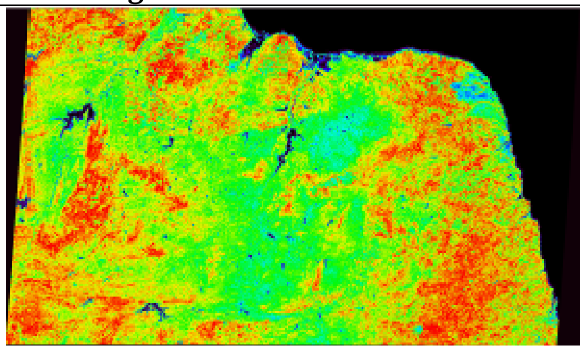


Fig.11d- EVI 2004 wet season

Fig. 11- Examples of Maps for different periods (dry and wet season). The blue color reflect the more low level of vegetation index and the red color reflect the more heights level of vegetation index.

5 Conclusions and discussions

The results presented in this study are part of a larger effort to implement an operational assessing and monitoring system on land desertification for the northeast Brazil. The sensors, MODIS has particular advantages over NOAA AVHRR for land surface biomass estimation. On the other hand MODIS has more finely defined visible and near infrared bands then NOAA AVHRR and it has one of the most accurate calibration subsystems ever flown on a remote sensing instrument.

Although preliminary and not conclusive, the results showed that MODIS daily data is a sustainable remotely sensing source of information for monitoring at regional scale the land desertification in arid and semi-arid climatic zones. The distribution and diversity found could be simply related to climate or land-cover, but for the spatio-temporal patterns of functional units in the study area they are rather complex and there were no patterns behavior. Further analyses are needed to isolate the effects of climate and landscape from the local environmental factors within land-cover types.

The obtained results and the adopted methodology proves the advantage of the use of extracted information of satellite images MODIS for the production and updating of base cartography, focused on types of vegetal covering, for the prevention and combat to the desertification processes, because it allowed a classification and systematic monitoring of the vegetal covering in the study area. The high allied periodicity to the quality of the products makes this a applicable methodology for a constant evaluation and ecological attendance of the bioma "Caatinga" in Rio Grande do Norte State. In the specific case of Seridó region, the products MODIS were shown as potential tools for characterization of the seasonality of NDVI, together with pluviosity data for use of data MODIS in local and regional scale.

The good reached results suggest that the methodology adopted in this work will annually be able to be used before the beginning of the time of the rains to aid the planning of the activities and administration of the necessary resources to the prevention of the desertification processes. In spite of that, it is important to register that this methodology doesn't constitute a substitute to the frequent monitoring and surveillance of the risks.

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