

## Characterization NDVI space-time and surface and analysis phytosociologic albedo for São João do Cariri

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### Abstract

This study aimed to determine the spatio-temporal evolution of two indicators of desertification obtained through remote sensing: surface albedo and NDVI based on spectral bands of TM - Landsat 5, to the city of São João do Cariri, semi-arid Paraíba, which presents severe levels of degradation lands (84%). We used Landsat satellite - 5 TM, orbit 215 point 065 between the years 1990 and 2005 acquired at the USGS website. Using ArcGIS software 9.3 and ERDAS Imagine 9.3. The images were validated with field research and conducting this survey vegetation in the area (7 26'57.12 "S and 36°30'25.85" O). The structure of the vegetation was carried out in two installments of 10 x 20 m, lying 50 cm, with a total area of 0,04ha. the shrubby-arboreal extracts with (CAP)  $\geq 3,5$ . Verificou is this temporal analysis of biophysical parameters were used for the analysis, when the value of albedo declined in class 0.10-0.15 there was an increase in classes 0.4-0.6 and  $> 0.6$  NDVI, in reverse the 0.15-0.20 and 20-30 albedo classes showed an expansion in these areas and therefore a decrease in the area that corresponds to class 0, 2 to 0.4 NDVI. According to the survey of vegetation, we found 30 individuals, with 9 species contained in 5 families. The families with the highest number of species were: *Mimosaceae* with 12 individuals, *Cactaceae* 8 individuals and *Fabaceae* with 4 individuals, they are typical of anthropogenic environments showing enough tolerance to high levels of disturbance.

Keywords: vegetation, desertification, human actions, semiarid region.

### 1. Introduction

The United Nations Convention to Combat Desertification defines desertification as "the process of degradation of land in arid, dry semi-arid and sub-humid areas resulting from various factors, including climatic variations and human activities", resulting in negative impacts on the quality of life of the population.

Further states that 250 million people are directly affected and that vulnerable dry

land desertification cover 45% of Earth's land surface (Lal, 2012).

Moreover, it is a dynamic process of degradation in dry lands, involving physical, chemical and biological, such as erosion by water and wind, deforestation, overgrazing, salinization and fires.

Finally, is a process of complex environmental degradation and global dimensions characterized by an interaction of different natural factors and man-made, as well as socioeconomic factors and political, as

these determine soil management and interact with the different organizational levels (Geist and Lambin 2004; Bisaro et al., 2013).

The Brazilian semiarid region corresponds to 969,589.4 km<sup>2</sup>, is the most populous semi-arid region in the world - covering parts of the states of Pernambuco, Paraíba, Ceará, Rio Grande do Norte, Bahia, Alagoas, Sergipe and Piauí, including still municipalities in the north of Minas Gerais and of the Holy Spirit (SUDENE, 2015)

The physiographic characteristics of the Brazilian semi-arid region are held responsible for natural vulnerability of the region to the desertification process, and due to its climate, edafobiológicas and sociocultural the study area consists of the city of São João do Cariri, Paraíba semi-arid, presents stage Severe desertification with values close to 84%. Since the erosion in various forms (laminar, ridges and gullies) are shown present everywhere (Sousa, 2008).

In Brazil, 62% of the areas susceptible to desertification are in areas originally occupied by scrub, vegetation that occurs exclusively in Brazil, and many are already quite changed. Therefore, usually causes the process is attributed to climate characteristics and the existing soil types. However, it is observed that the main causes of desertification are linked to human action, because of inadequate management of natural resources especially the savanna. (Soares, 2010; Feitosa and Araújo, 2013)

For environmental studies that address the reality of semi-arid regions such as the study area of this research, remote sensing and GIS are effective tools for survey of natural and monitoring of environmental and anthropogenic resources, allowing the estimation of various biophysical indicators, as they assess the dynamics of the physical and natural factors that directly interfere in the process of desertification.

Therefore, the analysis of several landscape indicators provides an integrated study of the environment, taking into account natural aspects (physical) as social, thus favoring the understanding of the society/nature. Emphasizing that combination of physical elements (geology, semiaridez, the irregular rainfall, shallow soils, topography,

etc.) that enhance the erosion and the different social relationships influence land use and report directly by origin the process of desertification.

For planning and environmental monitoring understanding of vegetation, soil and vegetation dynamics obtained from NDVI indices and albedo, combined with remote sensing and geographic information systems (GIS) are key indicators in areas degraded by the process of desertification.

Regarding the vegetation studies in degraded areas in Brazil still have gaps, mainly in the Caatinga, because it takes an understanding of the existing ecological processes and in its maintenance, using the fitossociologia can get much closer results of ecological processes, as the purpose of it is to define the importance of each plant species and their distribution in a sample. The great Brazilian vegetation floristic area, the caatinga is one of the most unknown (Alcaforado-Filho et al., 2003).

The phytosociological research in Brazil have been gradually carried out only from 1970, according to the sort order coming from English and American school, obtaining a statistical representation of quantitative attributes of the community, such as density, frequency and coverage, along with method installations arising from Europe.

Therefore, studies fitossociológicos performance key role in environmental management of degraded areas, mainly by the desertification process. The studies shall be under quantitative perspectives of the floristic composition, structure, function, dynamics, distribution and environmental relationships of the community. (Martins, 2013).

It is noteworthy that the conditions imposed by the change in the environment pose a great challenge for the vegetation, reducing photosynthesis efficiency and limiting carbon supply, because these remain fixed to the ground by increasing the level of adaptation and many small individuals and fine indicates the occurrence of severe disturbances.

In this context, it is important to note that the indexes obtained using remote sensing represent efficient indicators in the analysis of the vegetation and the environment, because

the spectral response of the coming of the interaction vegetation with radiation directly depends on the characteristics of individual leaves or plant canopies such as , chemical composition, water, photosynthetic pigments, internal morphology and structure of tissues, finally allowing the researcher to infer increase in cases, reduction or removal of vegetation cover.

The main bands adopted for the vegetation refers absorption which comprises the region of red (R) and near infrared (NIR) due to the different spectral responses of the vegetation. So they are generated dark images representing the absorption and infrared which corresponds to the density of vegetation obeying various shades of gray, so the denser vegetation presents darker color, with shades of gray next to black, the opposite way and due to the greater interaction with the soil, the less dense is represented in various shades of light gray.

Finally, the contrast between these images provides new images showing different behavior between exposed and ground vegetation. The images of NDVI the vegetation characteristics have maximum reflectance in dense vegetation (mainly forests), maximum absorption in areas devoid of vegetation (bare soil) and intermediate behavior in vegetated relatively areas (Welch et al., 2005; Ponzonie and Shimabukuru, 2009).

Thus, considering the importance of desertification, the present work using remote sensing and GIS consisted an development of digital maps of vegetation through the Difference Index standardized NDVI and surface albedo for the period 1990 to 2005 for the city of São João do Cariri. Satellite have been validated through field research and phytosociological survey images to determine which plant species present in the study area.

Thereby proving the importance and efficiency of the use of Geographic Information Systems (GIS) as an aid for monitoring of desertification especially in areas of semiaridez.

## 2. Material and Methods

### 2.1 Study Area

The municipal district of São João do Cariri, latitude: 7 ° 23 '27' 'South and longitude: 36 ° 32' 2 " West, is located in the micro-region of Eastern Cariri and Greater Region of Borborema in Paraíba, 458 m of altitude and area of 702 square kilometers, with 1.2% of the state, 0,045% in the Northeast and 0.008% of the Brazilian territory (IBGE, 2010).

According to Köppen the climate of the study area is considered the hot Bsh-type semi-arid, predominantly rainfall below 600mm and lower temperature due to the effect of altitude.

As for the physiographic features, is located in geoenvironmental unit of the Borborema Plateau, formed by massive and high hills, with altitude of 400 m a600. Relief features generally flattened, with narrow valleys and dissected for a considerable density drainage network (Pereira, 2006).

With respect to geology, the municipality of São João do Cariri is housed in the complex granite-gneiss-migmático of Pernambuco, Alagoas, main elements of the geology and structure of the province of Borborema, where the crystalline basement is the Precambrian, with features impermeability to facilitate runoff (Pires, 2009).

Generically, the entire area in question has steppe vegetation formation of the savanna, called the savanna of Brazil, with dominant shrub and some sparse arboreal individuals, as well as a large concentration of cacti, differing only in their density. (Souza, 2004).

Given the classification of the savanna low type and dense savanna low, thin and low scrub and sparsely where the most frequent species are: jurema (*Mimosa tenuiflora* WilldPoiret), marmeleiro (*Croton sonderianus* MuellArg), pereiro (*Aspidospermapyrifolium* Mart.) mandacaru (*Cereus jamacaru* P. DC.) and xique-xique (*Pilosocereusgounellei* Weber Byl. EtRowl.).

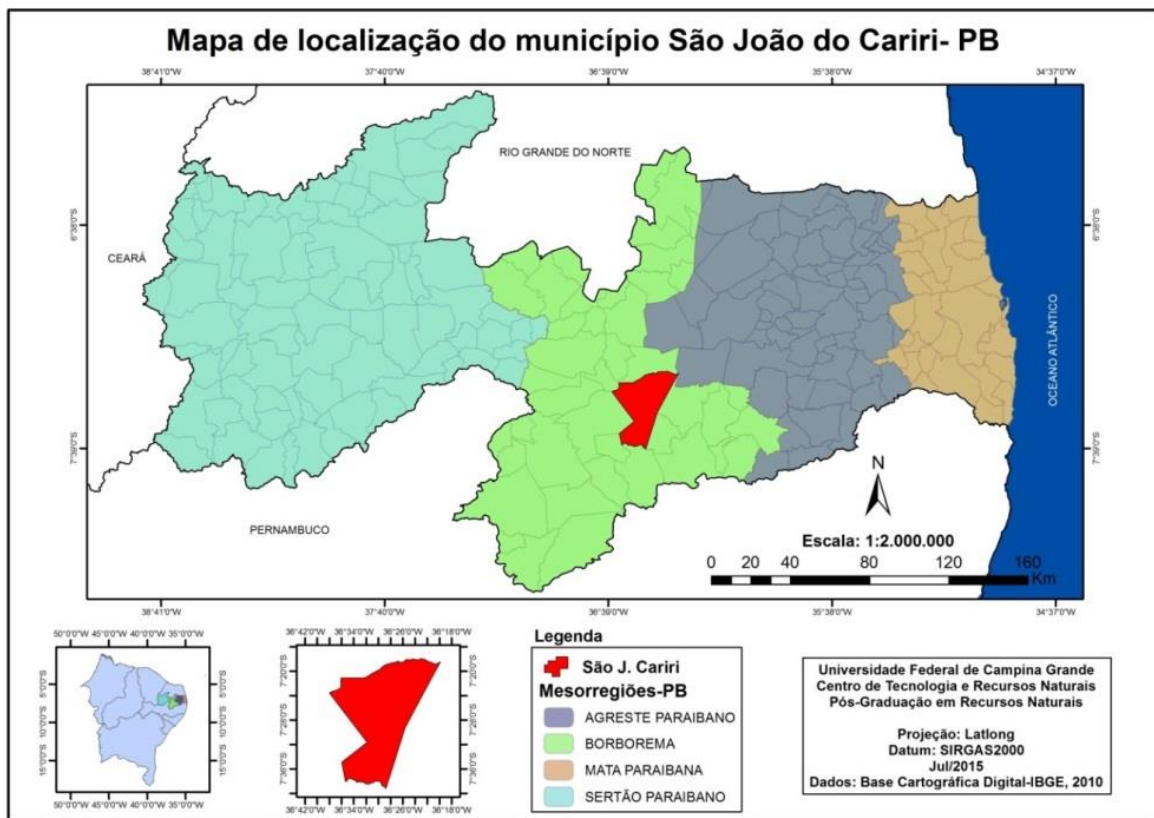


Figure 1 - Location of São João do Cariri.

All vegetation cover has been exploited irrationally, supporting cattle and goat herds, which has led some areas, especially those most exploited, to a rather sharp desertification process. (Sousa, 2008)

The soil conditions are more varied, encompassing various types of soil, every bit thick, gravel or stony. A hydrology of semi-arid regions is quite different from the hydrology of humid and arid regions, erratic rainfall, infrequent, occasional dry periods, climate and land use change add complexity to the semi-arid hydrology. (Montenegro and Ragab, 2012).

It is noteworthy that the erosion of the semi-arid areas, as in the Cariri Paraibano, are much more intense, because erosion is a natural process and its cause is related to environmental characteristics, such as the amount and distribution of rainfall, soil characteristics, land slope, type of natural cover and poor management of land that can accelerate the erosion. (Guerra, 2012).

## 2.2 Material

To conduct this study, images from Landsat - 5 TM, orbit 215 point 065 between

the years 1990 and 2005 acquired the site of the United States Geological Survey - USGS. Software ArcGIS 9.3 and ERDAS Imagine 9.3 geoprocessing laboratory of the meteorological department of the Federal University of Campina Grande - UFCG.

## 2.3 Methods

Initially the geometric correction was performed, using 6 control points and permissible error of 2 pixels (60m). After this correction, the images were converted to reflectance of the surface, consisting of two steps: conversion of the digital number (ND) values for spectral radiance and then to reflectance. The first step SEBAL model used in the processing is the radiometric calibration, the calculation of the spectral radiance of each band (). This step converts the digital number (ND) of each pixel of the image in monochrome spectral radiance that is the solar energy reflected or emitted by each pixel. As calculated by the following equation obtained by Markham & Baker (1987):

$$L_{\lambda i} = a_i + \frac{b_i - a_i}{255} ND \text{ (Wm}^{-2}\text{ster}^{-1}\mu\text{m}^{-1}\text{)}$$

where  $L_{\min}$  and  $L_{\max}$  are the minimum and maximum spectral radiance;  $ND$  is the intensity of pixel (0 to 255 shades of gray); It corresponds to bands (1, 2, ..., 7) Landsat 5 - TM. The planetary reflectance of each band is defined as the ratio of the reflected radiation flux, and the incident radiation flux, SEBAL model being computed by using the following equation:

$$\rho_{\lambda_i} = \frac{\pi \cdot L_{\lambda_i}}{k_{\lambda_i} \cdot \cos Z \cdot d_r}$$

where  $L_{\lambda_i}$  is the spectral radiance of each band,  $k_{\lambda_i}$  is the spectral solar irradiance in each band on top of the atmosphere,  $\theta$  and the solar zenith angle is the inverse of the square of the relative distance Earth-Sun.

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

The NDVI is an indicator of the strength and quantity of vegetation and its values range from -1 to +1.

The calculation was performed from the ModelMaker in IMAGINE® ERDAS 9.3 software and the results varied between -1.0 and +1.0. To calculate the Difference Vegetation Index Normalized (NormalizedDifferenceVegetation Index - NDVI) is given ratio between the difference of the reflectivity of the band next IV and the band of red, which for the Landsat results in:

$$NDVI = \frac{\rho_4 - \rho_3}{\rho_4 + \rho_3}$$

### Surface Albedo

The albedo is a parameter widely used by various sciences, including remote sensing, atmospheric sciences, climatology and others. The same is the ratio of the reflected energy and the amount of incident electromagnetic energy is central to the understanding of the energy balance of the surface processes and the dynamics of the hydrological cycle.

Arya (2001), albedo variations can cause significant variation in the surface energy balance and thereby promote changes in micro or macro-climate.

The results of the NDVI and albedo represent fundamental information to identify phenomena in a given area, including those related to desertification.

### Calculation of Albedo

To obtain the planetary albedo by the reflectance of the bands, a linear combination of the planetary reflectance, valid for a clear day will be used:

$$\alpha_{toa} = \sum (\rho_{\lambda_i} \cdot \omega_{\lambda_i})$$

where  $z$  is the height of each pixel (m) and can be obtained by the digital elevation model (DEM) to be added in this SEBAL modeling.

$$\tau_{sw} = 0,75 + 2.10^{-5} z$$

Where  $z$  is the height of each pixel (m) and can be obtained by the digital elevation model (DEM) to be added in this SEBAL modeling.

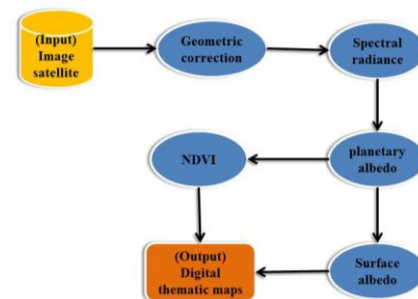


Figure 2 - Flowchart of processing steps.

Where  $\rho_{\lambda_i}$  it is the planetary reflectance and  $\omega_{\lambda_i}$  coefficient for each band, these values follow the low:

$$\alpha_{top} = 0,293 \cdot \rho_1 + 0,274 \cdot \rho_2 + 0,233 \cdot \rho_3 + 0,157 \cdot \rho_4 + 0,033 \cdot \rho_5 + 0,011 \cdot \rho_7$$

### Surface Albedo

The surface albedo is computed by correcting the planetary albedo for atmospheric transmissivity:

$$\alpha = \frac{\alpha_{toa} - \alpha_p}{\tau_{sw}}$$

Where  $\alpha_p$  the solar radiation reflected towards the satellite ranging between 0.025 and 0.04, but for the SEBAL model is recommended to use the value of 0.03, based on Bastiaanssen (2000) and atmospheric,  $\tau_{sw}$  transmissivity is defined as the fraction of incident radiation that is transmitted through the atmosphere and represents the effects of

absorption and reflection to clear sky conditions, is given by:

### Vegetation Survey

To describe the structure of the vegetation we used the manual on floristic studies methods and Phytosociological Ecosystem Caatinga - Botanical Society of Brazil - SBB 2013.

If selected, exclusively, the shrubby-arboreal extracts with (CAP)  $\geq 3.5$ . Were used for the analysis of horizontal structure the phytosociological parameters: absolute density (DA), relative density (RD), absolute frequency (AF), relative frequency (RF), absolute dominance (DoA), relative dominance (DoR) and value importance (VI).

The parameters were calculated by Microsoft Excel 2007 software program.

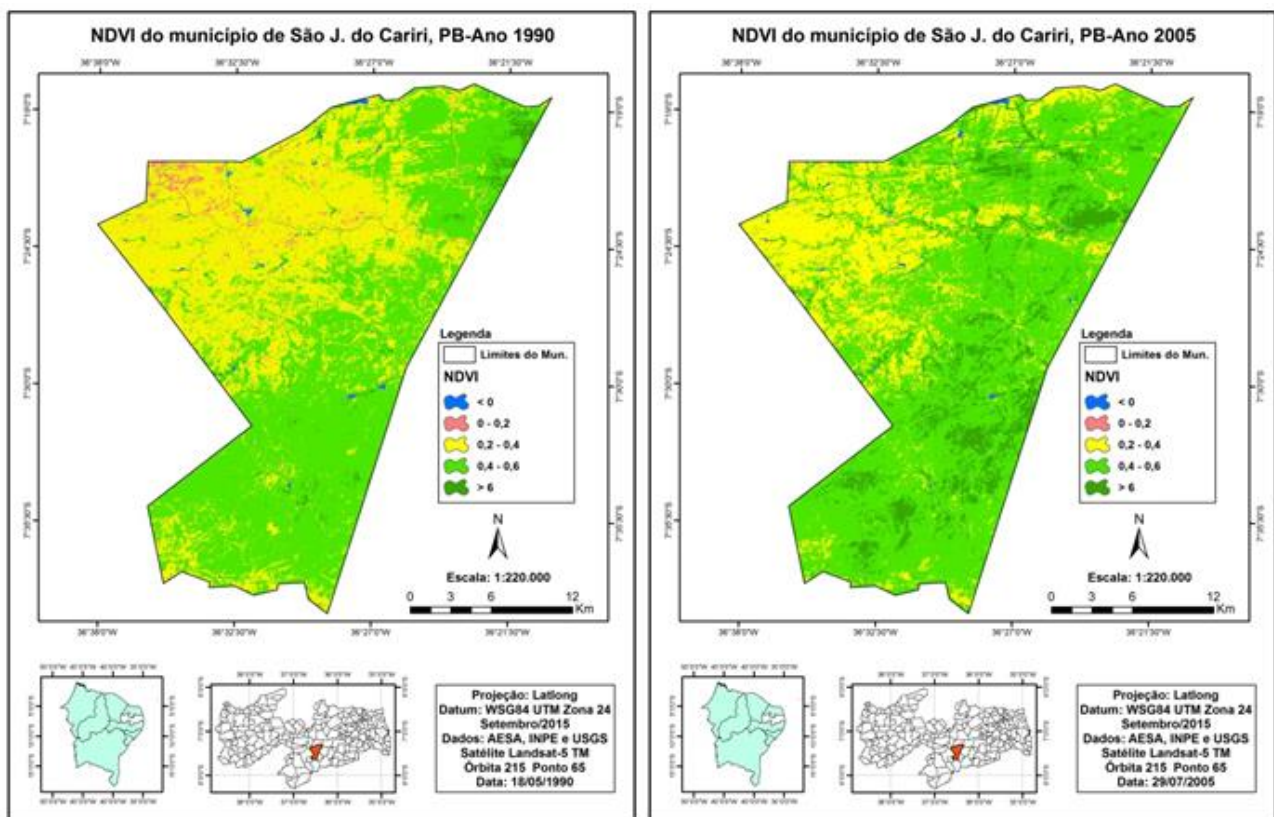
### 3. Results and discussion

The Figures 3 and 4 are represented the NDVI classes between -1 and 1, values below

zero (-0.56 - 0.07) generally correspond to water bodies, near zero values represent in most cases disturbed areas (0 - 0.2) and values above 0.4 indicate a greater force of vegetation, either in secondary succession stage or native vegetation with tree size and density that are different from the others. Map of Vegetation Cover - 1990 – 2005.

The vegetation cover map for the year 1990 (Figure 3), it is observed that the  $<0$  is 1.8 km<sup>2</sup> (0.27% of the area) typical values of areas with water bodies, the classe 0,0 - 0 2 has an area of 12,2 km<sup>2</sup> (1.86% of total area) these values can be found areas with exposed soil and seasonal planting (Graphic 1).

The class 0.2-0.4 it has 282,8km<sup>2</sup> (43.14%) it is an area with anthropic savanna, are generally open areas with shrub extract used for planting of dry land and grassland, the class from 0.4 to 0 6 with 348.8 km<sup>2</sup> represents areas with closed shrub savanna (53.21%), and the class  $> 6$  9,9 km<sup>2</sup> represent with more preserved areas (1.51%) dominated to shrub and tree savanna closed.



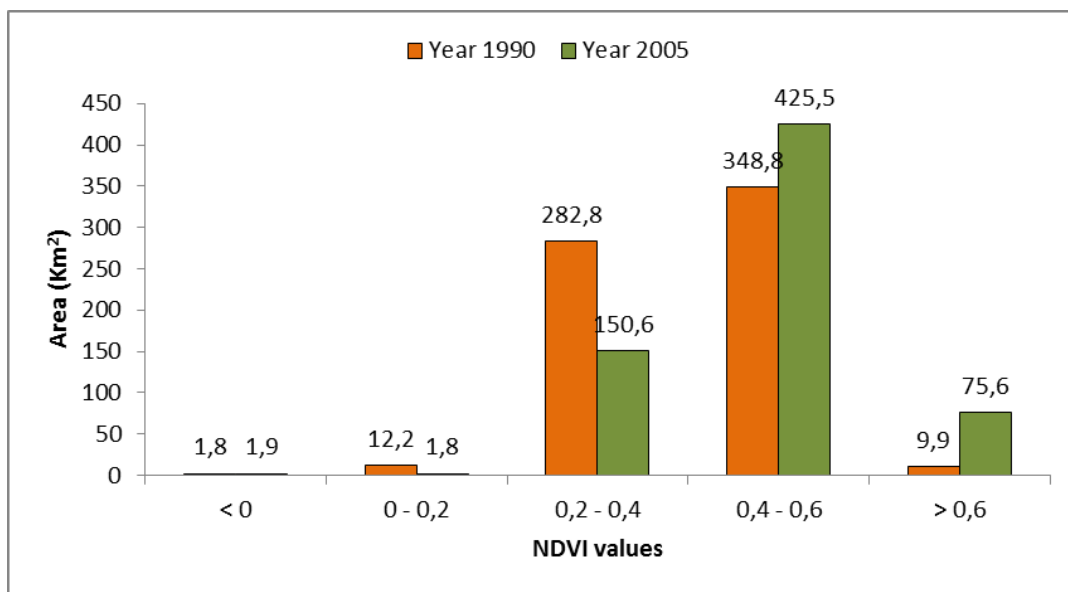
Figures 3 and 4 - Digital map fland cover classes São João do Cariri - PB to 1990 and 2005, respectively.

The vegetation cover map for the year 2005 (Figure 4), it is observed that the  $<0$  has  $1,9 \text{ km}^2$  (0.28% of total area) class 0.0 to 0.2 has an area of  $18 \text{ km}^2$  (0.27% of total area), the class of 0.2 - 0.4 offers  $150.6 \text{ km}^2$  (22.98%), class 0.4 - 0.6 with  $425.5 \text{ km}^2$  (64.9%), and class  $> 0.6$  to  $75.6 \text{ km}^2$  (11.5%) (Graphic 1).

The chart summarizes the changes in vegetation cover from the spatial distribution of data from the Landsat-5 satellite images between 1990 and 2005 (Figures 3 and 4),

corresponding to 15 years of temporality. The spatial variability of this biophysical parameter gives an idea of savanna dynamics over time, taking into account the anthropogenic share, a preponderant factor in landscape modification of the space under consideration.

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Graphic 1 - Spatial distribution of NDVI between the years 1990 and 2005.

Surface Albedo maps between the years 1990 to 2005

The figures 5 and 6 show the surface albedo of space-temporal behavior between the years 1990 and 2005 in São João do Cariri, it is a dimensionless measure and is expressed generally for between 0.0 and 1, or as a percentage. By comparing the two images, there is a significant increase in high values of surface albedo for the year 2005 compared to 1990 image, these high values are concentrated along the drainage network, which are located in agricultural activities with irrigation and without irrigation or area of pasture. One should take into consideration

that the relationship between surface albedo and NDVI is reversed. Thus, removal of native vegetation for carrying out activities aforementioned does that there is a greater increase in reflectivity indicating intensification of processes morphogenetic present in the study area, since the predominant type of soil in this municipality is the Luvisol, susceptible to erosion.

The chart above shows that in areas where the classes correspond to 0.15 to 0.20 and 0.20 to 0.30 it is area and urban areas that may be being used for agriculture, cattle extensively, pasture or as biofuel (Graphic 2).

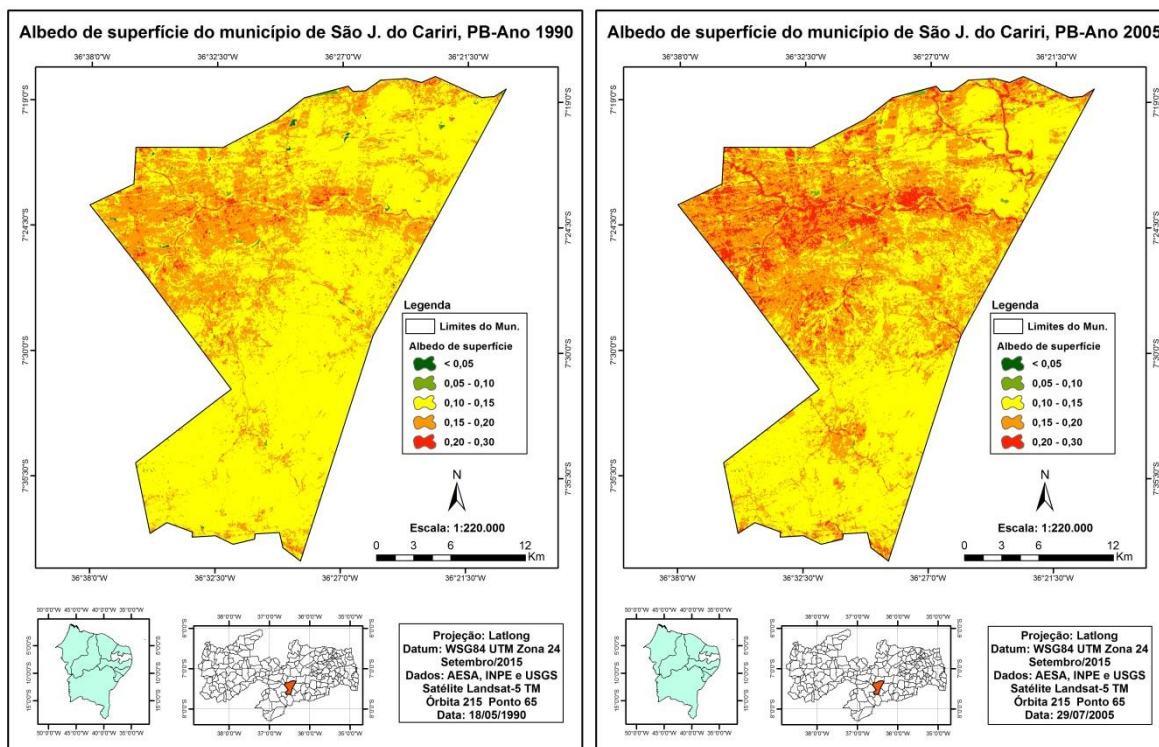
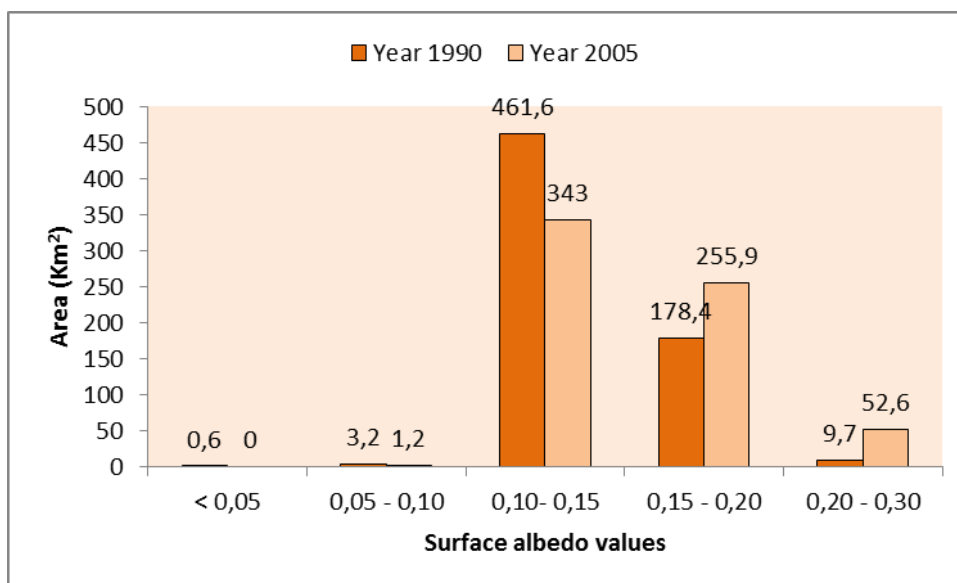


Figure 5 and 6: Spatial distribution of surface albedo between the years 1990 and 2005 for São João do Cariri – PB.



Graphic 2 - Spatial distribution of Albedo between the years 1990 and 2005.

The removal of native vegetation for charcoal manufacture, responsible for provision of bakeries and gift ceramic production plants in Cariri region and in other regions of the state.

Table 2 data show small decrease spatial distribution of albedo values surface corresponding class 0.05-0.10 (0.6 and 2 km<sup>2</sup>).

There has been a considerable decrease in albedo values in the class 0.10-0.15 (118.6 km<sup>2</sup>), before prevailing in 1990 year image, which indicates a significant change of that area, which is now added the classes 0.15-0.20 (77.5 km<sup>2</sup>) and 0.20 to 30 (42.9 km<sup>2</sup>) contributing to a reasonable expansion in the 2005 image.

Table 2 - Summary of the spatial distribution of surface albedo values in km<sup>2</sup>.

Albedo values	Year 1990	(%)	Year 2005	(%)	Difference (Km2)
<0,05	0,6	0,1	0	0	0,6
0,05-0,10	3,2	0,5	1,2	0,2	2
0,10-0,15	461,6	65,8	343	48,9	118,6
0,15-0,20	178,4	25,4	255,9	36,5	-77,5
0,20-0,30	9,7	1,4	52,6	7,5	-42,9

If closely observe the available data we can see that the inverse relationship can be seen from the analysis of graphics with both spatial areas and surface albedo of classes as the NDVI represented on the maps. It was found that when the value of albedo decreased between 0.10-0.15 class (from 1990 to 2005) there was an increase in classes and 0.4-0.6 > 0.6 NDVI of Conversely the 0.15-0.20 and 20-30 albedo classes showed an expansion of this area and consequently a decrease in the area corresponding to 0.2-0.4 class of NDVI.

The increase or decrease in albedo values can be explained by the influence of meteorological factors (rain irregularity, among others energy balance) on the passage of the satellite, as well as by anthropic actions, one of the main factors responsible for altering the long landscape of the time.

#### Vegetation structure

In the two selected areas were found 30 individuals belonging to 9 species contained in 5 families. The families with the highest number of species were: *Mimosaceae*, with 12 individuals, *Cactaceae* with 8 individuals and *Fabaceae* with 4 individuals. Andrade et al. (2005), found 16 species, 15 genera and seven families in the well-preserved area, and six species, six genera and four families in degraded Cariri Paraibano. Such families are still cited as being most prominent in the work carried out in Caatinga and the results were similar with a predominance of these taxes in disturbed and typical Caatinga areas (Andrade et al., 2005).

By the number of individuals per species, she noticed the predominance of three species, where the most abundant was *Caesalpinia pyramidalis*, 79.16% with 4 individuals, *Croton sonderianus* Müll species. Arg.com three individuals and the third was *Mimosa tenuiflora*, with 12 individuals.

The species of *Mimosa tenuiflora* it presents dominance in floristic succession of the savanna is areas of colonization in a state of degradation and great potential as regenerating of eroded soils, indicative of secondary progressive succession or recovery, when it is about the only present woody species, prone the shortage throughout the process, with drastic reduction in the number of individuals (Maia, 2004; Araujo Filho and Carvalho, 1996).

Table 3 - Phytosociological parameters of the species in both areas in São João do Cariri - PB.

Família	Espécies	NI	P	DAP	FA	AB	DR	FR	DoA	DoR	IVI
<i>Fabaceae</i>	<i>Caesalpinia pyramidalis</i>	4	1	100	100	2,42	13,33	33,33	0,006	32,50	79,16
<i>Cactaceae</i>	<i>Opuntia palm adora</i> Br. et Rose	8	2	20	50	0,65	26,67	16,67	0,002	8,769	52,10
<i>Mimosaceae</i>	<i>Mimosa tenuiflora</i>	12	2	30	50	0,03	40,00	16,67	0,000	0,457	57,12
<i>Eupobiaceae</i>	<i>Croton sonderianus</i> Müll. Arg.	3	1	7,5	50	2,96	10,00	16,67	0,007	39,75	66,41
<i>Apocynaceae</i>	<i>Aspidospermum pyriforme</i>	3	2	7,5	50	1,38	10,00	16,67	0,003	18,53	45,20
<b>TOTAL</b>	<b>30</b>	<b>8</b>	<b>75</b>	<b>300</b>	<b>7,44</b>	<b>100</b>	<b>100</b>	<b>0,018</b>	<b>100</b>	<b>300</b>	<b>300</b>

It has a deep root system, which allows its development in degraded soils, especially

in the initial occupation of degraded and secondary or degradation process areas. Gives

way to the secondary species, with a low share (0.3%) of individual trees in areas of Paraíba backlands, with climax forest cover (Silva, 1994).

The distribution diametricit is an indicator of the growth of the stock structure and serves to evaluate the age of the trees is used to measure diameters, hoping that reflect the size of populations of structure (Daubenmire 1968; Harper1977).

According to Nunes et al. (2003), a lot of small, thin individuals may indicate the occurrence of severe disturbances in the recent past, such as cutting for various purposes, burning or constant attacks of pests and insects.

## Conclusions

According to the results, there was a significant variation in NDVI values between two images over a period of 15 years, to 2005 there was a decline in the index in the fields before with anthropic vegetation with open shrub layer, and an increase the areas of shrub savanna is closed which may correspond directly a regeneration vegetation due to land abandonment.

The surface albedo had a strong variation in their values for the two images considered, indicating a significant change in the municipal land cover studied, this may be related to several factors, including o deforestation for introduction of agriculture and use of vegetation as biofuel must take into account that removal of vegetation contributes to changing the reflectance of the surface, causing the albedo values are high.

The use of the products generated by remote sensing is indispensable in geoenvironmental studies, these techniques have helped in monitoring and management of natural resources in the semiarid region, coupled with the low cost in the preparation of maps and charts, there is a rapid response in biophysical analysis data and spatial distribution of the phenomena that take place on screen.

Regarding the vegetation there was the presence of some species more often, they are typical of anthropogenic environments, showing a strong tolerance to high levels of

disturbance, including: *Caesalpinia pyramidalis*, 79.16% and *Mimosa tenuiflora*, with 12 individuals.

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