OPEN JOURNAL SYSTEMS
ISSN: 2237-2202

Available on line at Directory of Open Access Journals

Journal of Hyperspectral Remote Sensing v.6, n.4 (2016) 195-204
DOI: 10.5935/2237-2202.20160020

Journal of Hyperspectral Remote Sensing
www.ufpe.br/jhrs

Behavior ground cover space-time in the of Paraíba state

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Received 07 may 2016; accepted 23 may 2016

Abstract

Studies on the use and land cover are very important and report on changes in the earth's surface, often caused by human action. In this context, this study aimed to characterize the use and land cover in the state of Paraiba. A time series of products (MCD12Q1) the sensor Moderate Resolution Imaging Spectroradiometer (MODIS) for the period 2003 to 2012. We used the classification of the type 3, which takes into account the leaf area index was used (LAI) and photosynthetically active radiation fraction (fPAR). An adaptation of the product classification was made, which is global, for the types of vegetation in the state of Paraiba. The results show a predominance of Savannah coverage (Caatinga) comprising the mesoregions the Sertão and Borborema. The mesoregions do Agreste and Litoral presented in the first three years of the series, a denser vegetation of broadleaf crops (wet forest), Grasses / cereals (transition vegetation) and shrubs (Caatinga tree). In addition, urban areas increased over the study period. The product used can be useful for monitoring the soil cover of the organs of state environmental management.

Keywords: remote sensing, vegetation, climate

1. Introduction

The characterization of the use and occupation is related to various processes and interactions ranging from the natural aspects of anthropogenic interventions. The processes of change of land cover and use are part of the global environmental discussions for some decades (Anderson and Shimabukuro, 2007). Thus, information on land cover are very useful for environmental planning, identification of degraded areas (desertified) and use in climate models, among others. However, this information is not always available, and when obtained through field measurements have a very high cost.

Remote sensing satellite is recognized as a tool that helps in detecting the use and occupation in temporal and spatial scale, relatively low cost and considerable precision. According to Eckert et al. (2015), on a national or even continental scale, remote sensing needs to be, and has been widely used as a means of detecting and classifying changes in the earth's surface condition over time. In addition, geographic information systems (GIS) have shown support and capacity needed to manage this information. One of the most recent advances in remote sensing area is the Moderate Resolution Imaging Spectroradiometer (MODIS) that is ideal for monitoring large-scale changes in the biosphere. The use of its products (reflectance and surface temperature, vegetation index, leaf area index, soil cover, net primary production and fraction of photosynthetically active radiation absorbed by vegetation) assists in the identification and monitoring of processes in the earth's surface (Senna et al., 2007).

Studies have been conducted to cover analysis and land use, such as: Huttich et al. (2011) to the northeast of Namibia; Gibson et al. (2015) agricultural land in Iraq and Eckert et al. (2015) in areas of degradation and regeneration in Mongolia. In Brazil, Wagner et al. (2013) used the vegetation index normalized difference (NDVI) and the enhanced vegetation index (EVI) to detect temporal variations in the Pampa biome vegetation in Rio Grande do Sul and Uruguay; Schucknecht et al. (2012) used EVI data time series to study the variability of vegetation cover in the state of Paraiba, correlated with rainfall and Santos (2015) used the MCD12Q1 product for land cover classification in the middle region of Paraiba Agreste.

Land cover information is scarce for the state of Paraiba and, where they exist, do not include the aspect of temporality as necessary for understanding and monitoring of terrestrial phenomena. Recognized before the land degradation process (desertification) in most municipalities of micro-regions of East and West Cariri (PAE-PARAÍBA, 2011) and suppression of native vegetation in every state, the spatial and temporal quantification of soil cover becomes indispensable. In this context, this study aimed to characterize the soil cover in the state of Paraiba, from a time series of MODIS images.

2. Materials and methods

2.1 Characterization of the study area

The Paraiba of State is divided into six mesoregions, so called, according to the classification established by the IBGE: Paraibana Mata or Litoral, Agreste, Borborema and Sertão (Figure 1). For its location in the equatorial belt, the State of Paraíba is subject to the incidence of high levels of solar radiation and high number of hours of daily sunshine. This condition determines a warm climate, annual average temperature of 26 ° C, low intra-annual variation and spatial distribution of relief highly dependent on temperature. According to the climatic classification of Köppen, the state of Paraiba is characterized as a humid tropical region along the coast. The central sector, covering the micro-regions of the Plateau of Borborema and Hinterland, as well as the region located to the northwest, have dry weather. In terms of rainfall, has high spatial variability of rainfall, with average annual rates of 300 mm in Cabaceiras located in Cariri and 1,700 mm in João Pessoa, located along the coast (AESA, 2005).

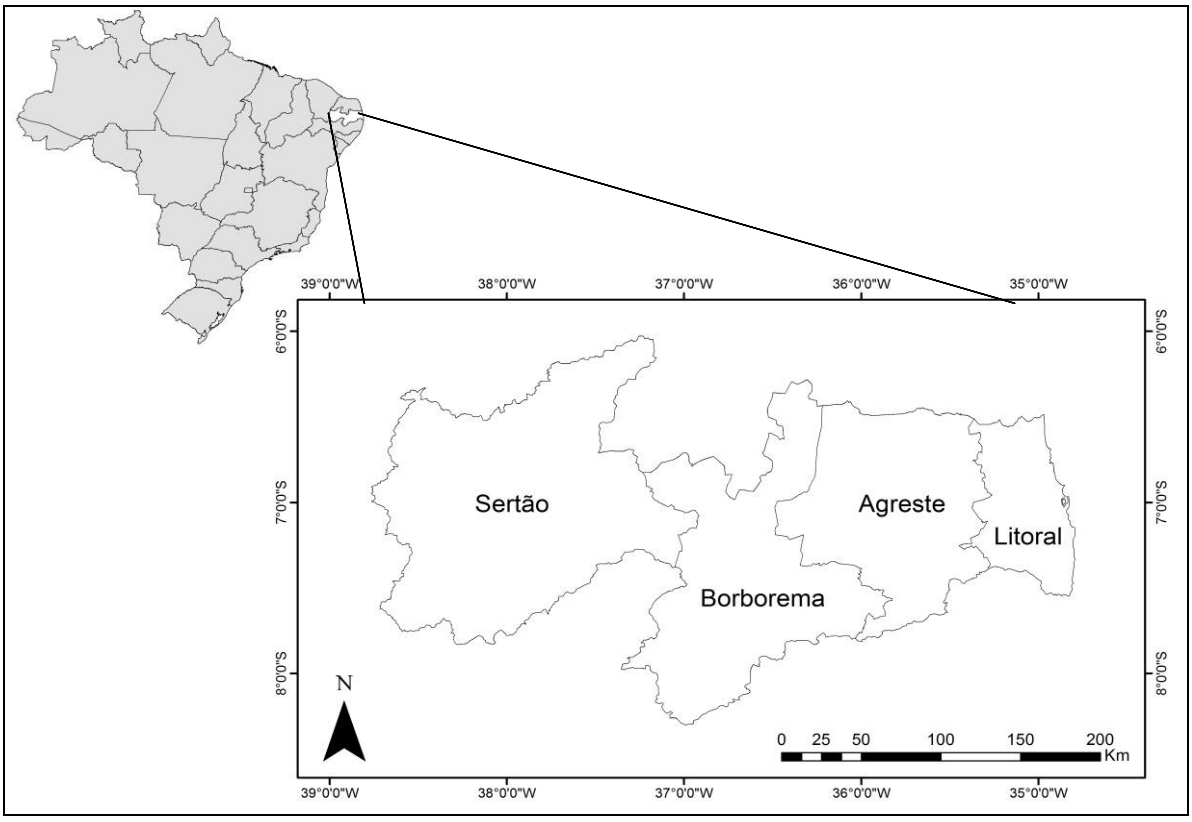


Figure 1- Paraiba of State area location and its mesoregions in Brazil.

2.2 Orbital data

Images generated by the MODIS sensor has a satisfactory temporal resolution for analysis related to soil cover and are available for free. The MODIS Land Cover Collection 5 product (MCD12Q1) provides global land cover maps annually, which were derived from MODIS Terra and Aqua (Friedl et al., 2010). This product provides data characterizing five global land cover classification systems, compiled annually at 500 m resolution (Nasa, 2015). The five systems include: classification of the International Geosphere - Biosphere (PIGB); University of Maryland (UMD); leaf area index / fraction of photosynthetically active radiation (LAI / fPAR); net primary production (NPP) and functional plant type (FPT).

The resources used in the MCD12Q1 product algorithm include spectral and temporal information of the bands 1 to 7, complemented by EVI, the surface temperature and adjusted reflectance data - MODIS albedo product. Thus, the algorithm is able to exploit the information related to the phenology and temporal characteristics of the variability of the types of ground cover. Capturing changes in photosynthetic vegetation serves as an indicator for soil degradation processes and regeneration (Eckert et al., 2015).

The data are based on a MODIS product analysis recorded by two sensors aboard the Terra and Aqua NASA platforms, which were launched in 1999 and 2002, respectively. The two satellites are in a near-polar orbit synchronized with the Sun at 705 km altitude and cross the Equator every day at 10:30 local time (Nasa, 2015). MODIS products are supplied in HDF-EOS format (hierarchical data format to the system of Earth observation from NASA). The standard projection system is sinusoidal; The MODIS tile behaves 4800 by 4800 pixels, which corresponds to about 1200 by 1200 km. All MODIS products can be accessed and downloaded from the website at NASA (http://reverb.echo.nasa.gov). The images used in this work were the land cover type 3 product (Table 1) of the MODIS sensor, which the criteria are set by the LAI / fPAR, and have a spatial resolution of 500m. The choice of type 3 classification was made based on Santos (2015) who used this classification to study the middle region of the Agreste of Paraíba, saying it is the most compatible with the field observations.

Table 1- Land cover classification.

Number	**Classification (Type 3) LAI/ fPAR**
0	Water
1	Grasses/Cereal crops
2	Shrubs
3	Broadleaf crops
4	Savana
5	Evergreen Broadleaf forest
6	Deciduous Broadleaf forest
7	Evergreen Needleleaf forest
8	Deciduous Needleleaf forest
9	Non-vegetated
10	Urban

Source: NASA (2015).

2.3 Leaf area index (LAI)

The leaf area index (LAI) is considered a critical parameter for the extrapolation of forest productivity leaf scale to the scale of the canopy within the ecosystem modeling. The understanding of the global carbon cycle depends on the modeling of processes occurring in the interface vegetation - atmosphere, thus requiring measures of spatial and temporal variation of the LAI (Aragon and Shimabukuro, 2007). The LAI expressed the amount of leaf area by land area (dimensionless), determined as Ponzoni et al. (2012):

$$LAI = \frac{Área \; de \; folhas \; (cm^2)}{Área \; do \; terreno \; (cm^2)}$$

The larger a canopy LAI it is expected that its reflectance is lower in visible region and higher in the near infrared.

The photosynthetically active radiation (PAR) comprises the spectral range of solar radiation wavelength of 0.4 to 0.7 µm which is captured by the sensor (spectral reflectance of the vegetation) and has great significance in studies on plant growth rate, photosynthetic rate and stomatal conductance to be radiation that excites the plant chlorophyll molecules, starting the flow of energy during the process of photosynthesis (Frisina, 2003; Anderson et al., 2003). The fraction of photosynthetically active radiation absorbed by vegetation (fPAR) is defined as:

$$fPAR = \frac{APAR}{PAR_{in}}$$

Where: PAR in is the photosynthetically active radiation incident on top of the canopy and APAR is the photosynthetic radiation absorbed by photosynthetic tissues canopy.

2.4 Data analysis

Geographic information systems (GIS) have shown support and capacity needed to manage large amount of information. In GIS, the images were converted to the geographic coordinate system, projection WGS, and IMG format. The study area is part of the tile v9_h14. They were analyzed images of the years 2003-2012, with the exception of the year 2011, whose product was unavailable.

3. Results and discussion

For the analysis of land use and land cover time series 2003-2012 images is necessary first to establish the land cover classes corresponding to paraibana vegetation. Based on studies (Ab'Saber, 2003; AESA, 2006; Tabarelli and Santos, 2004) are observed five classes identified by MCD12Q1 product: Atlantic Forest, Caatinga, wet forest, arboreal Caatinga and transition vegetation (Frame 1).

Frame 1- Soil coverage based on the overall ranking MC12Q1 and the corresponding paraibana vegetation.

Ground covers - MCD12Q1	Ground cover (vegetation) paraibana
Evergreen hardwood forest	Atlantic Forest
Savannah	Caatinga
Broadleaf crops	Moist forest
Shrubs	Caatinga arboreal
Lawns / cereal	Transition vegetation

The images of the time series of use and ground cover for the state of Paraiba are shown in Figure 2. We observe a Savannah coverage predominantly comprising the mesoregions the Sertão and Borborema. The meso do Agreste and Litoral presented in the first three years of the series, a denser vegetation of broadleaf crops (wet forest), Grasses / cereals (transition vegetation) and Shrubs (Caatinga arboreal). The areas in red correspond to the urbanized areas, where the largest patch corresponds to the metropolitan area of João Pessoa and the secondary corresponds to the city of Campina Grande.

The results corroborate Santos (2015) where the classification held only for the middle region of the Agreste, presented predominance of Savannah vegetation, followed by broadleaf crops and Grasses / cereals. The product also allowed to observe the difference between the areas investigated in the study, comprising areas of Caatinga in recovery and degraded Caatinga.

According to Ab'Saber (2003) between the nuclear space body of a landscape and ecological domain and nuclear areas from other neighboring areas, there is always an inter-space transition and contact, which affects more sensitively the components of vegetation, soil types and its distribution and, to some extent, the very detail features of the regional relief.

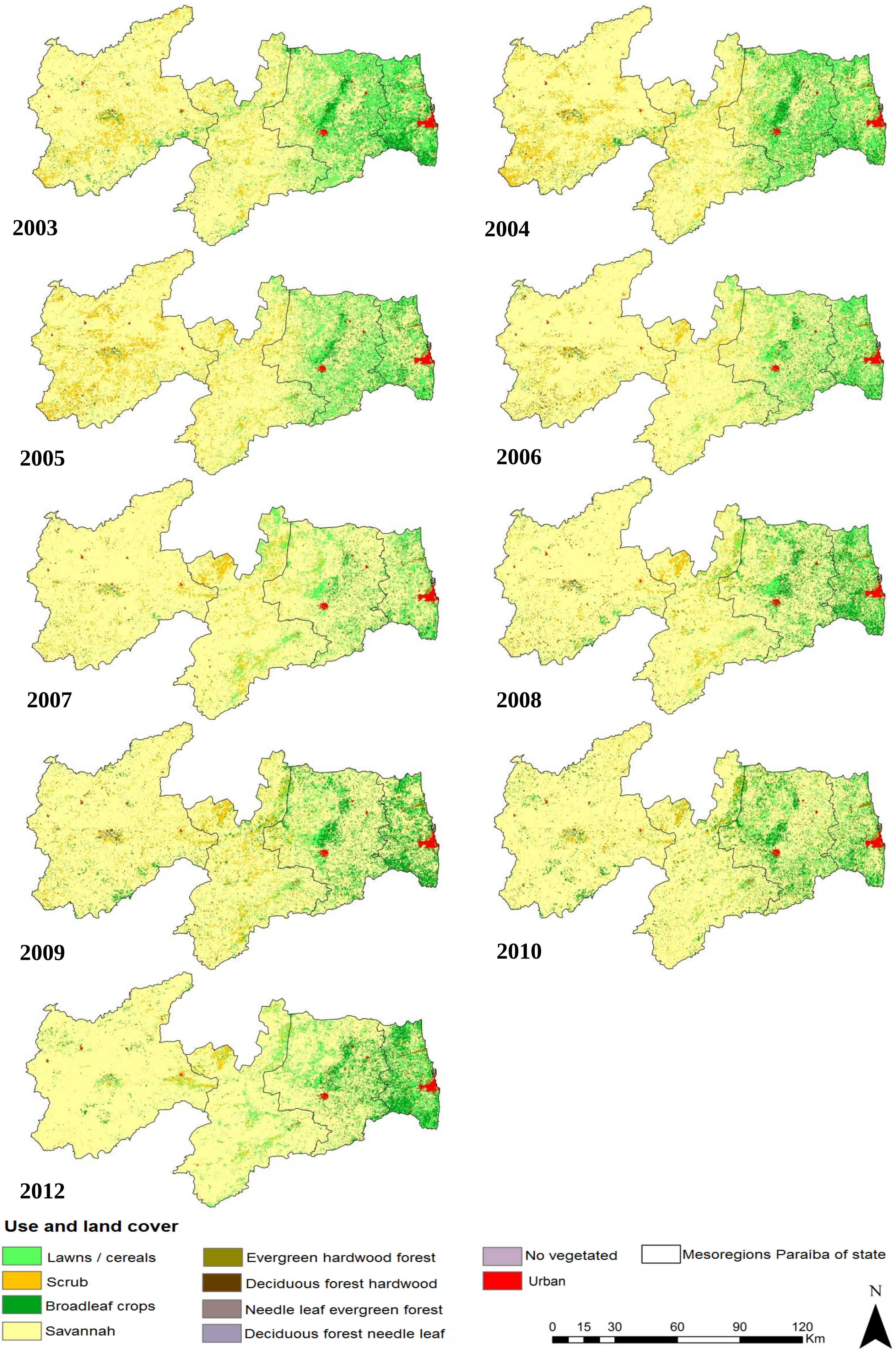
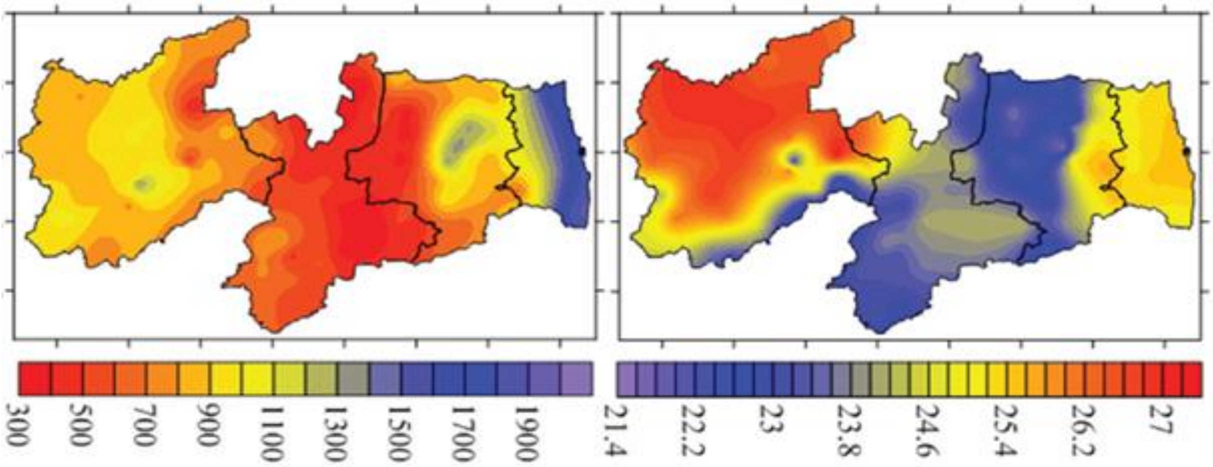


Figure 2- Soil cover in the state of Paraiba, 2003-2012 period.

When comparing the soil cover with climatic variables (precipitation and average air temperature) - Figure 3 identifies that the wetter areas have denser vegetation, the same was not true in relation to the air temperature, as in more vegetated areas occur relatively high temperatures. So there is a dependence of the vegetation in relation to rainfall.



A - Rainfall (mm) **B – Average air temperature (°C)**

Figure 3- Distribution of rainfall (A) and the average air temperature (B) in the Paraiba of state. Source: Bezerra et al. (2014).

When analyzing the two images of the beginning and end of the series (2003 and 2012) it was observed that there was an increase of 16% in areas covered by Savannahs (Caatinga) and reduced (12.5%) Grasslands area / cereals (transition vegetation) – Table 2. Since the algorithm is designed for a global analysis, without much refinement, it is not possible to state with certainty whether this indicates an increase in deforestation of native vegetation.

Table 2: Comparative and area percentage occupied by each land cover class in the Paraiba of state in 2003 and 2012.

	2003		**2012**	
Use and land cover	**Area (km²)**	**%**	**Area (km²)**	**%**
Lawns / cereals	12.227	19.8	4.505	7.3
Scrub	3.761	6.1	1.385	2.2
broadleaf crops	4.072	6.6	4.234	6.9
Savannah	40.977	66.4	50.834	82.4
Evergreen hardwood forest	110	0.2	148	0.2
Deciduous forest hardwood	213	0.3	189	0.3
Evergreen forest agulhosa sheet	4	0.0	16	0.0
Deciduous forest agulhosa sheet	1	0.0	6	0.0
No vegetated	11	0.0	25	0.0
Urban	320	0.5	354	0.6
Total	61.695	100.0	61.695	100.0

Blackman (2003) states that deforestation and land degradation in developing countries are also a major cause of climate change, arguably the most serious global environmental problem as account for one-fourth to one-fifth of total anthropogenic emissions of gases greenhouse. Senna et al. (2007) compared data measured in the field and estimated with the LAI and PAR MODIS products to the region of the Amazon forest and observed approximate values, but came to identify a certain overestimation of the LAI and underestimation of PAR.

Regarding the types of land cover, it can be observed in Figure 4 that there is a decrease in Grasslands / cereal vegetation (transition vegetation) and Shrubs (arboreal Caatinga) over the study period.

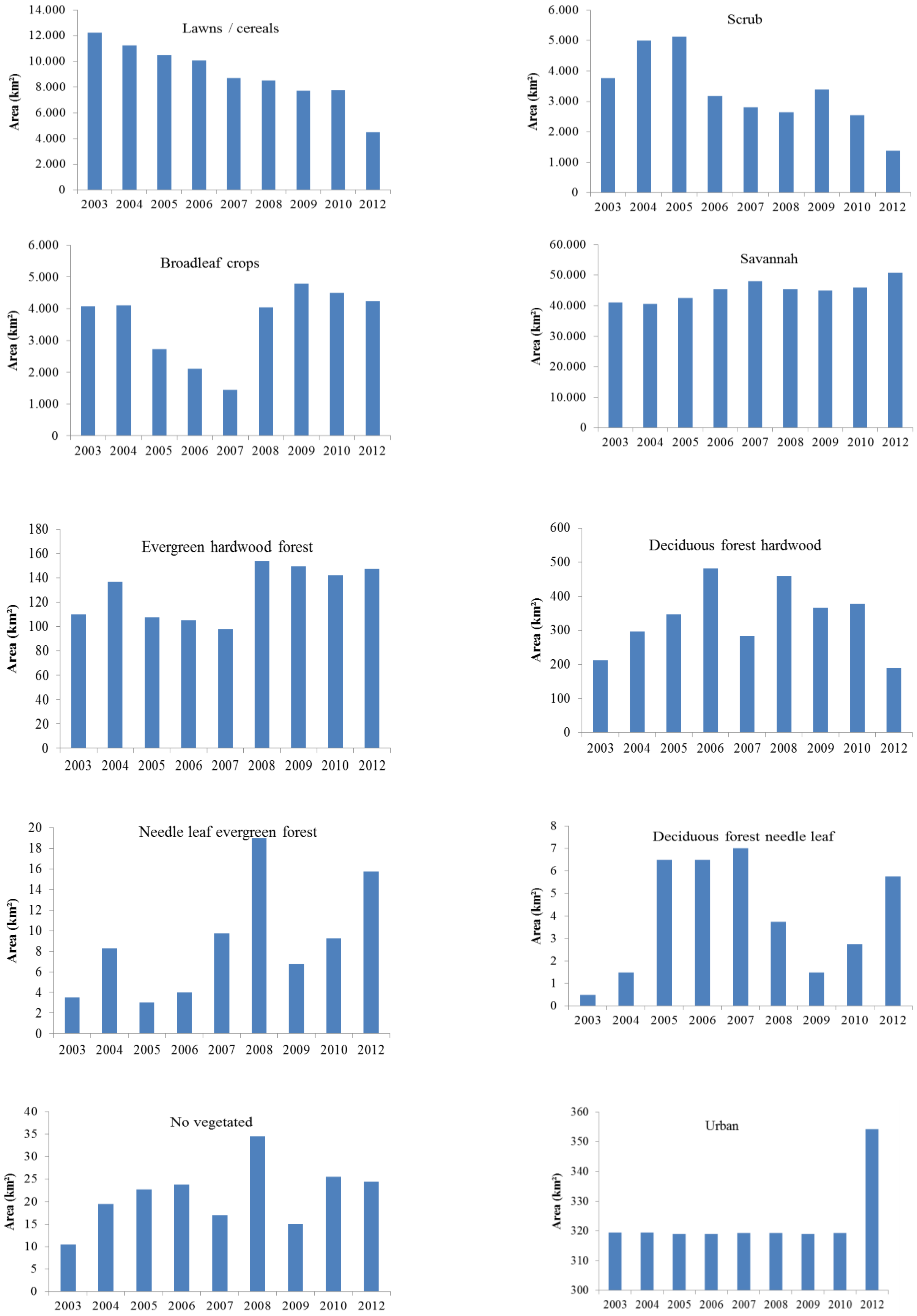


Figure 4- Temporal behavior of soil cover for each product class MCD12Q1, period 2003-2012, Paraiba of State.

There was an increase in the areas covered by Savannah (Caatinga) and the evergreen broadleaf forests, probably indicating a reconstruction of the coastal native vegetation in some areas. The areas identified as hardwood deciduous forest occur around the large water reservoirs in the state: Reservoir de Coremas – Mãe D'água, municipality de Coremas- PB e Reservoir Epitácio Pessoa, municipality of Boqueirão – PB and are indicative of seasonal crops such as banana and coconut trees, for example, have been classified in this range. The same is true for the few areas classified as deciduous and evergreen forest agulhosas leaves. Finally, urban areas increased by over 100% in 2012 compared to the previous year of the series (2010), showing a significant increase in urbanization in the state.

Some limitations are observed with the use of these images: small changes in ground cover or changes that affect only small areas (eg, an urban development area or a new mining site with vegetation removal) can not be detected by the product MODIS land cover classification, because it does not cause a quite obvious spectral change to be captured via sensor (Eckert et al., 2015). Illogical transitions between pixels are observed in MCD12Q1 product, but are more common in high latitudes, in mountainous areas, or along the coasts of the continents. These areas tend to be the transition zones between different ecological biomes represented by different land cover classes where the classification errors are more common. In particular, it highlights several areas where the pixels have experienced two or more illogical transitions, including the northern United States, Canada, northern, southeastern United States, the Andes, Northern Europe and Eurasia, the mountains of the Himalayas, and Southeast Asia (Cai et al., 2014). It is noteworthy also that the product used offers more areas of identification possibilities with predominant faces, however, the Caatinga is not homogeneous, with vegetation of different sizes and types of settlements in parts due to operating cycles that have occurred.

Some aspects of the vegetation the Paraiba of state of were observed in place in order to validate the classification. Caatinga vegetation with different sizes (tree and shrub / herbaceous) was observed in the state of Cariri (Figure 5).

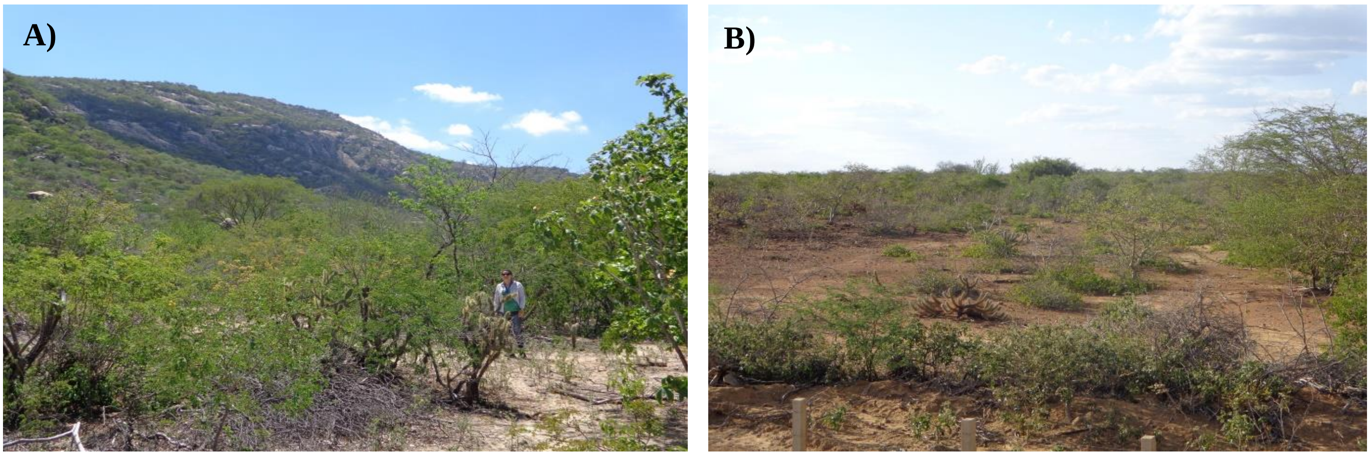


Figure 5- Caatinga tree in the Environmental Protection Area (EPA) of the Jaguars, the municipality of São João do Tigre - PB; Caatinga, municipality of Caraúbas - PB.

4. Conclusions

The use of product and soil cover MCD12Q1 was appropriate for the identification of areas where vegetation has been modified, as well as areas where vegetation was not effectively changed since 2003. Urban areas and its expansion were identified and quantified. In addition, the product allowed the identification satisfactorily the types of vegetation the Paraiba of state, which can help in monitoring the use and soil cover by the bodies of environmental management of the state.

Acknowledgements

The National Council for Scientific and Technological Development (CNPq) for granting the scholarship the first author.

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