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Spatial-temporal evolution analysis of the vegetation in the Chapadinha microregion (Maranhão, Brazil) through remote sensing

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Abstract

The Chapadinha microregion, located in the eastern part of the state of Maranhão, Brazil, maintains a large agricultural production, especially soybeans, causing beyond largesse of the economy, which promotes a degradation of large areas of native forests. The analysis of space - temporal with remote sensing images can be a tool for understanding the area and possible decision making of allocated mandates. The objective of this study is to analyze spatial and temporal variation of the micro-Chapadinha, Maranhão, Brazil by remote sensing technique called Normalized Difference Vegetation Index - NDVI for the years 2007, 2010 and 2014. It is used Lands at 5 images - TM and 8 - OLI orbits 220 / 62-63 months of 22/07/2007, 15/08/2010 and 25/07/2014and it being applied processing equations of radiometric radiance, reflectance and NDVI. The NDVI for micro-Chapadinha vegetation indicated a fall of the years 2007 to 2010 and at the same time, an increase in agricultural activity; low NDVI areas that are not exposed in 2007 were observed in 2010, one of the causes of this advent can be the event El Niño in the Northeast. In 2014, vegetation indices showed high in much of the micro-region; the response of this increase may be the reaction of trees was once under water stress the great rainfall that year. The municipalities of Brejo, Milagres of Maranhão and Buriti are the most affected by farming, they still come extending and have propensities to leave the micro limits. Remote sensing responded with great efficiency, but the complexity of the natural environment make it necessary that there interconnections with other indices therefore resulting in a more efficient monitoring and analysis.

Keywords: Agricultural expansion, remote sensing, NDVI.

1. Introduction

The development of Brazil in recent decades has provided for the Northeast visible changes as population, economic and social growth. We can point out the main causes of this development public policies of redistribution of industries, increasing investors in the country and the expansion of agricultural activity. In the same context, we include Maranhão region, one of the largest in the Northeast, which obtained enormous changes in the landscape due to human actions resulting from this economic growth.

The state of Maranhão corresponds to 3,9% of national territory and 21.3% of northeastern, which is situated in the transition zone between the semi-arid Northeast and the equatorial zones of the North, making limits with the states of Piauí, Tocantins and Pará (Montes, 1997; SETEC, 2004). It has varied edaphoclimatic standards such as plains, dunes and plateaus. The different precipitation rates and the high temperatures turn this region rich in biodiversity, with vegetation cover comprising Amazon rainforest environments, cerrado (savannah), forest of Coca Crops, fields and wetlands (El-Robrini et al., 2006). It is noteworthy that large areas are in preservation being a great tourist potential for the area.

The privileged strategic location turned it reference in logistics multimodal transport; this region keeps direct contact with the Brazilian North, is integrated with the Tocantins agriculture zones and its wide coast near to north American and European markets allowed the setting up of ports complex of high cargo handling. The charactericts in the logistic of cargos boosted the economy in the sectors of manufacturing industry, timber industry and agribusiness. We emphasize the agricultural sector, in which fertile soils, the lowest price of the land and the proximity to the ports provided the planting of soybean cultivars, rice, cotton, corn and vegetable extraction activities (Cuenca and Mandarino, 2007; Nogueira et al., 2012).

Relevance in Maranhão agricultural sector is widely observed in the micro region of Chapadinha, since that planting like corn, cotton and rice are commonly grown. The expansion and the incorporation of Cerrado areas for the high profitability of soybean farming are gaining space in this region, generating income and causing gradual increase in the economy (Cuenca and Mandarino, 2007; Rodrigues and Mesquita, 2012). Presoti (2008) investigating the area, points out that factors such as pluviometric regime, flat land, near the port, enabling quick flow and favorable soil favored the increase in planted area by 60 times compared to its beginning in 2000. However, the economic advances arising from soybeans production not only brought blessings to society. Botelho and Diniz (2012) studied the agribusiness social conflicts against family farmers. Already Rodrigues and Mesquita (2012) studied the risk environmental order in the micro-region, as the indiscriminate use of pesticides, which contributed significantly to the pollution of rivers; the devastation of large native vegetation areas for soybeans monoculture and the changes in the natural landscape.

Challenges in learning about the relationships that occur in ecosystems have limited public policy decision-making, in which these relationships are very complex due to physical interactions, chemical and biological interactions contained. It is known that through understanding these processes the conservation of natural environments and biodiversity, which has been the target of daily human activities can be preserved. In this case, according Barbosa and Vecchia (2009) and Cunha et al. (2012), the remote sensing is shown highlighted in the environmental nature research, helping to establish conditions of use and sustainable soils occupations through the monitoring of biophysical parameters of the areas under study. Vegetation indices, leaf area and soil promoted by remote sensing are the result of spectral responses obtained from satellite images, being used to control harvests, estimate biomasses and study the temporal development activities and anthropogenic changes, allowing comparisons between years as quotes Jensen (2009).

Given the above, this work aims to use the remote sensing parameter called Normalized

Difference Vegetation Index- NDVI for analysis and monitoring of vegetation that occurred between the years 2007-2014, in the area of agricultural influence of micro-Chapadinha (Maranhao) since the last few years many changes in land use were observed due to the population growth and agricultural expansion.

2. Materials and methods

According to IMESC (2010), the micro-Chapadinha (Figure 1) has the following coordinates: north, 02º 58 '26.90' '- 43 28' 51.59 " in the municipality of Belágua; south, in the municipality of Chapadinha: 04 ° 13 '22.63' '- 43 ° 35' 52.77 "; to the east, in Milagres do Maranhão: 03 ° 33 '19.40' '- 42 ° 33' 43.17 " and; finally, to the west, more precisely, in São Benedito do Rio Preto: 03 ° 18 '06.94' '- 43 ° 48' 20.49 ". It is located approximately 230 km from the Atlantic Ocean, where in their mediations are areas of the Amazon forest, savannahs and major agricultural fields, especially soybeans. These cities are recognized as urban, technological and agricultural development hub on Maranhenses Chapadas, a micro-region comprising the municipalities of Brejo, Mata Roma, Anapurus, Buriti, Milagres do Maranhão, São Benedito do Rio Preto, Belágua and Urbano Santos (Nogueira et al., 2012).

According to Pinheiro et al. (2005), the vegetation predominantly characterized up of semi-deciduous forest and Cerrado vegetation. It is observed in the region two well defined seasons: the rainy season in the first semester and drought in the second semester; climate sub humid, the rainfall totals range between 1.600 to 2.000 mm, with irregular rainfall throughout the year.

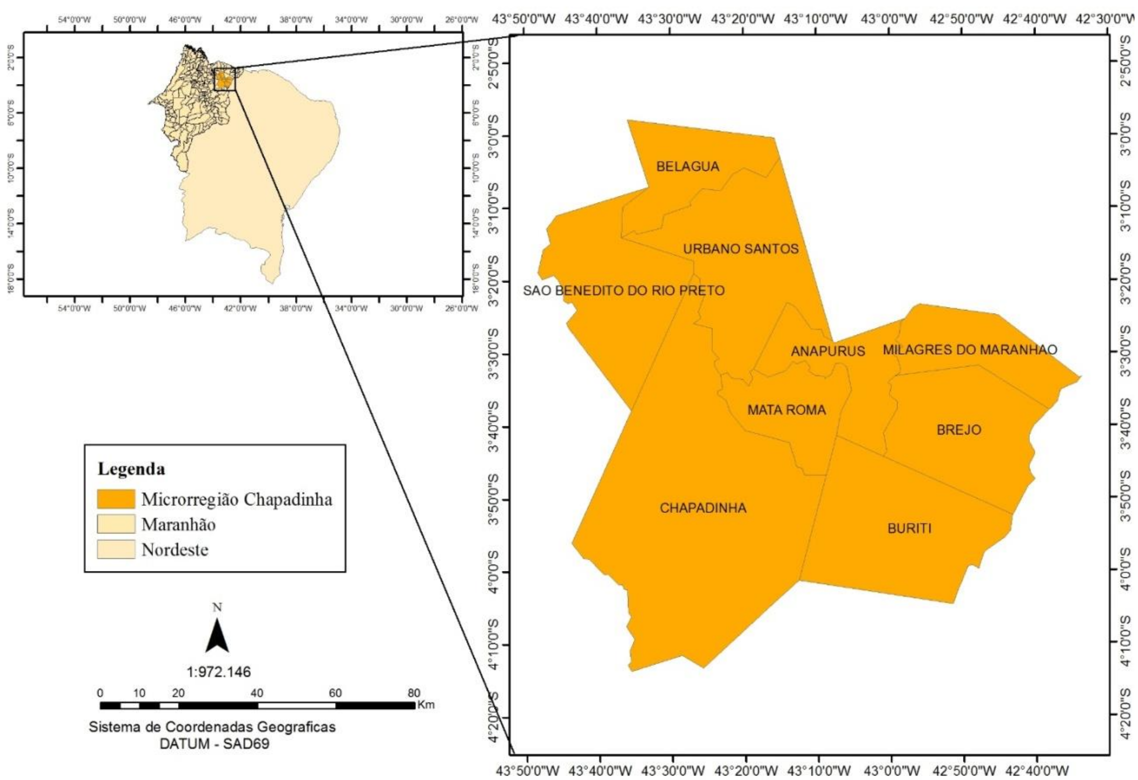

Figure 1– Localization map for study area.

For data collect, were used in this study, images of the years 2007, 2010 and 2014 were obtained from the sensor TM (Thematic Mapper) and OLI (Operational Land Imager), point 220 and orbit 62/63 (22/07/2007), (15 / 08/2010) and (07/25/2014) aboard the Landsat-5 satellite and 8, obtained from the United States Geological Survey - USGS. After data collect, we started the image processing, where the processing of Landsat-5 satellite images were created models using the Model Maker tool ERDAS Imagine 9.3 software and the final assembly of maps was performed using ArcGIS 9.3 software. Both have license from the Department of Geographical Sciences, Federal University of Pernambuco.

Following the steps of image processing we apply the calibration formulas: Radiometric calibration and reflectance. The Radiometric calibration is obtained from the intensity of the radiant flux per unit solid angle. The radiances represent solar energy reflected by each pixel, per unit area, time of solid angle and wavelength, measured at the satellite level Landsat 5 in the bands 1, 2, 3, 4, 5, 6 and 7 (Oliveira et al., 2010). The set of radiance or radiometric calibration is obtained using the equation proposed by Markham and Baker (1987) (Equation 1):

$$L\lambda \mathrm{i} = \alpha \mathrm{t} + \frac{\mathrm{bt} - \alpha \mathrm{t}}{255} . \mathrm{ND} \quad (1)$$

Which **a** and **b** are the minimum and maximum spectral radiance, **ND** is the intensity of pixel (integer between 0 and 255) **i** correspond to the bands (1 to 7) Landsat 5. Chander and Markham (2003) propose the calibration coefficients for TM images.

The reflectance for Landsat 5 images for each band (i) is defined as the ratio between the solar radiation flux reflected by the surface and the solar radiation flux incident obtained by the equation (Allen et al., 2002) (Equation 2):

$$\rho\ \lambda \mathrm{i} = \frac{\pi . L\ \lambda i}{K\ \lambda i\ .\cos(\mathrm{Z})\ .\mathrm{dr}} \quad (2)$$

Where **Lλi** is the spectral radiance of each band, **Kλi** is the spectral solar irradiance of each band at the top of the atmosphere, **Z** is the solar zenith angle and **dr** is the square of the ratio of the average Earth-Sun distance and the Earth-Sun distance on any given day of the year (Oliveira, 2010).

For the Landsat 8 satellite we used bands 2,3,4,5,6,7 and 10 and the following formula promoted by Chander and Markham (2003) for reflectance:

$$\mathrm{rb} = \frac{(Add_{refb} + Mult_{refb} . ND_b)}{\mathrm{Cos\ (Z\ ).\ D_R}} \quad (3)$$

Where, according to Silva et al. (2016), the **Add** corresponds to rescheduling additive factor for each band available in image file metadata, as well as **Mult** corresponding to the multiplicative factor for each band rescheduling. **ND** is the digital number of image values; **Z** is the solar zenith angle and can also be found in the image metadata file. **Dr** corresponds to the square of the ratio between average Earth-Sun distance and the Earth-Sun distance in a given day of the year, and can be calculated using the following equation (Equation 4):

$$\mathrm{Dr} = \left(\frac{1}{\mathrm{D_{TR}}}\right)^2 \quad (4)$$

The Normalized Difference Vegetation Index-NDVI is initially proposed by Rouse Jr. et al. (1973), which significantly indicates the amount and condition of vegetation in the areas under study. Even though an index developed in the 70s, it is still frequently used nowadays which is explored in agricultural, forestry and climate analysis (Ponzoni andShimabukuro, 2009; Boratto and Gomide, 2013). Being calculated from the following equation (5):

$$\mathrm{NDVI/IVND} = \frac{\rho_{4-}\ \rho_3}{\rho_{4+}\ \rho_3} \quad (5)$$

Which: ρ4 e ρ3 are the reflectance values of the bands 3 and 4 of Landsat 5 TM and Landsat 8 OLI.

3. Results and discussion

According to Rosendo (2005), the NDVI values have a range between -1 to 1 where indexes near numbering 1 indicate the predominance of dense vegetation; in contrast, values close to 0 reference soils with great exposure, not vegetated surface. Negative values in the index suggest the presence of water, clouds, or in some cases, little mistakes caused by noise in the image. We have adopted five criteria for the image analysis in which values between -1 to 0 refers to water bodies (blue); 0 to 0.4 for bare soil and / or urban perimeters (red); 0.4 to 0.5; It indicates the transition between bare soil and / or open vegetation / shrub (orange); From 0.5 to 0.7 shrubby vegetation (light green) and 0.7 to 1 for thickets, forested or tree (dark green). The selection of images during the dry season for the micro-region was intentionally so that there is a clearer explanation of agricultural and / or degraded areas through the Normalized Difference Vegetation Index - NDVI.

In Figure 2 are shown the vegetation evolution by NDVI the micro-Chapadinha for three periods: (22/07/2007) (15/08/2010) and (25/07/2014). It is noteworthy that portrayed images are in the transition from rainy season to dry, since, according to Nogueira et al. (2012), the region holds up two well representative periods of rainy and dry seasons, where they comprise the months of December to July and August to November, respectively.

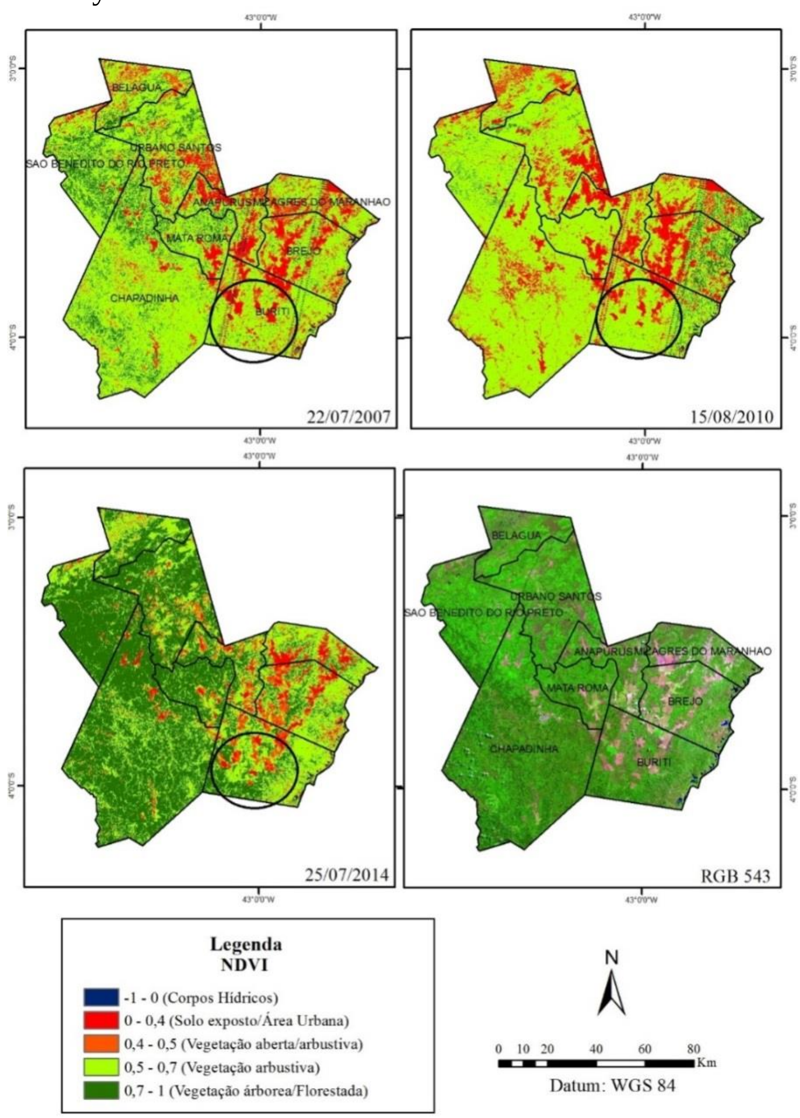

Figure 2 - Temporal evolution of NDVI in the microregion of Chapadinha - MA between 2007-2014 and Satellite Image with bands R (5), G (4), B (3)..

The micro-Chapadinha, according Presoti (2008), produces 78% of all soy east Maranhão, highlight being the municipalities of Anapurus, Brejo, Buriti and Mata Roma, where these together account for 74% of total production. Can affirm the connotations of Presoti on production areas in Figure 2, where the cities of Buriti, Brejo, Anapurus, Milagres do Maranhão and Urbano Santos in 2007 showed the largest plantation areas, listed by the parties in red on map. In the municipalities of Belagua and Chapadinha agricultural areas were also observed, but without much significance. In 2010, the increase is noticed in areas with NDVI between 0 to 0.4 related to exposed soil and / or urban area, it is worth noting that among the municipalities of Buriti Brejo and there is visibly an expansion of these areas. In Chapadinha, where he had previously seen high levels of NDVI in 2007, in 2010 it is observed scattered red spots, may or may not be derived from soybeans or other crops.

It is important to take into consideration the annual rainfall regime of the studied images. From precipitation graphs generated by CPTEC / INPE (2016) (Figure 3) it appears that the crediting period of the 2007 image and 2010 rainfall showed monthly values below the climatology of the region (called by INPE region 32), increasing the accumulated negative anomalies. In 2010 was the year of El Niño in the Brazilian Northeast (Kim et al., 2012), which helped directly in the increase of negative anomalies for that period as seen in Figure 3. The event El Niño determined for the Northeast the drastic reduction in rainfall, resulting in soil with low water availability under stress vegetation and largely with leaves lose (Machado et al., 2010; Silva et al., 2013). It may have intensified the decrease in vegetation indices in 2010 for the area in which were the lowest in all three images analysis.

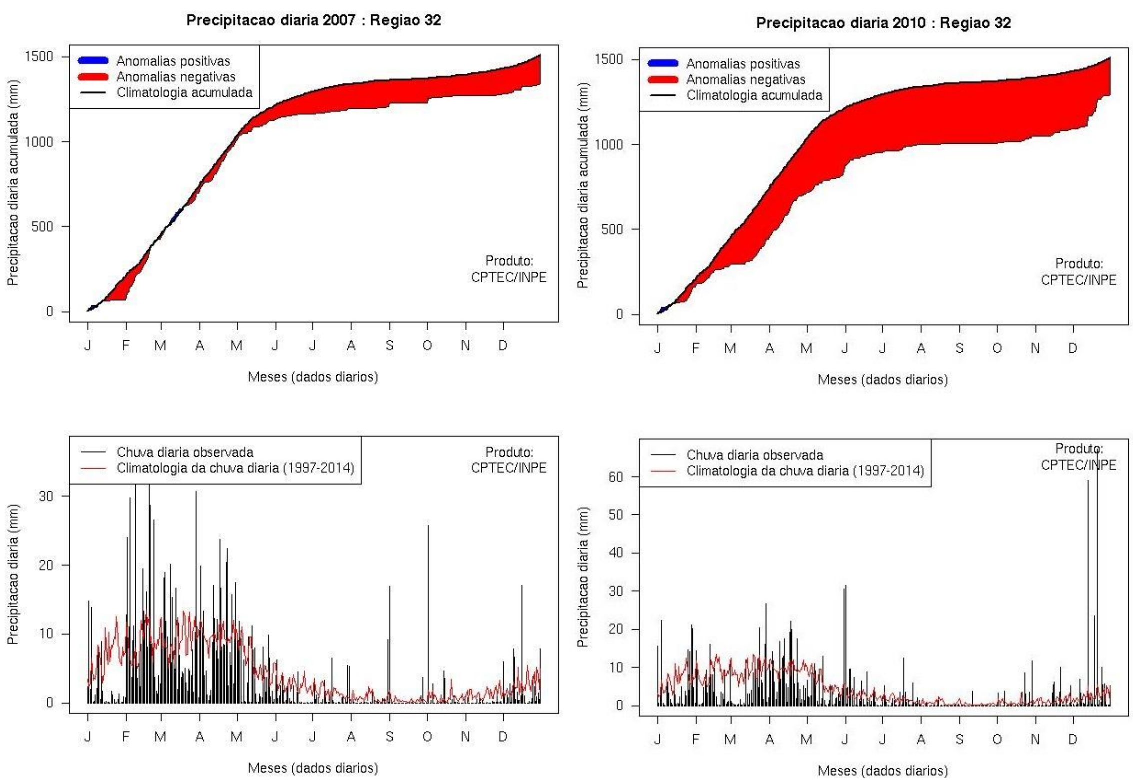

Figure 3 - Climatology and climatic anomalies for micro-Chapadinha (region 32) in 2007 and 2010. Source: CPTEC / INPE, 2016.

In 2014 the values of NDVI presented in large areas values above 0.7. São Benedito do Rio Preto, Chapadinha, Urbano Santos, Belagua and Mata Roma are the municipalities that exhibited such data. Having support of the climatological graphs for the year due and the Probability Density Curve (CDP) from the end of the rainy season in the region (Figure 4), it is observed that between the end of the month of May to the end of August, likely period for final rains, there was a positive anomaly for micro, that is, these months it rained more than expected and may be one of the possible causes of high levels of NDVI to image the response of vegetation before under water stress, the constant rains in the area.

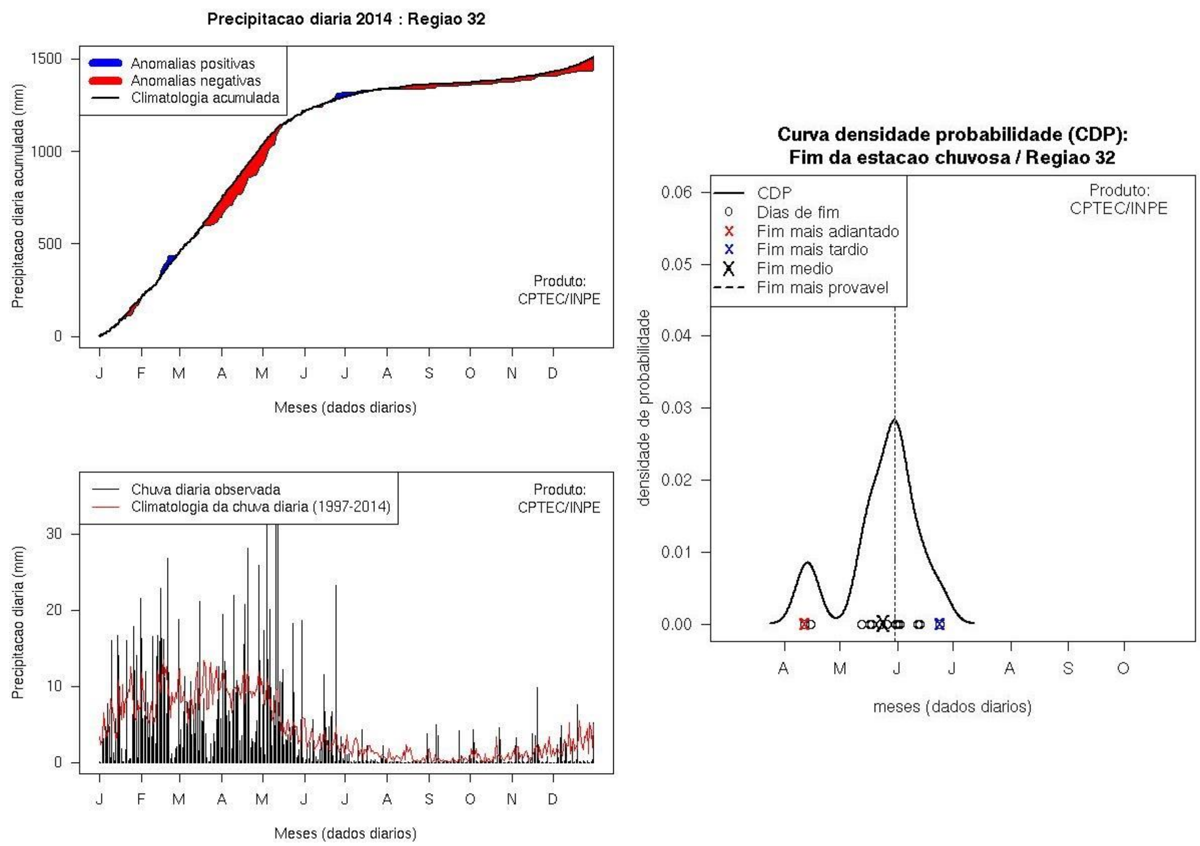

Figure 4 - Climatology and climatic anomalies and curve probability density of the rainy season (CDP) for the micro-Chapadinha (region 32) in the year 2014. Source: CPTEC / INPE, 2016.

In contrast, resident areas in the municipalities of Brejo, Miracles of Maranhão and Buriti maintained scores ranging from 0 to 0.7, with large areas of exposed soil / open or shrub vegetation. Highlight an area in the municipality of Buriti, which was flagged with a small circle in Figure 2, where it is observed that even with high vegetation indices portrayed in the 2014 image, in this environment there are new exposed soil stains, keeping a continuous expansion of agricultural areas to the north of the micro-region. The same stains are also observed in the image cropping area for bands with R (5), G (4) and B (3) in shades of pink.

4. Conclusions

The Normalized Difference Vegetation Index-NDVI for micro-Chapadinha vegetation indicated a fall of the years 2007 to 2010 and at the same time, an increase in agricultural activity; low NDVI areas that are not exposed in 2007 were observed in 2010, one of the causes of this advent can be the event El Niño in the Northeast, which could have contributed to a large negative anomaly of precipitation for the same year. In 2014, the vegetation indices showed high in big part of micro-region; the answer of this increase may be the reaction the tree vegetation was once under hydric stress the great rainfall that year, since the precipitation curve has remained normal for the region, highlighting a positive precipitation anomaly in June / July / August and a long rainy season, with its end in mid-August. The municipalities of Brejo, Milagres do Maranhão and Buriti are the most affected by agriculture, which still come extending and have propensities to leave the micro limits.

Remote sensing answered with great efficiency for what was competed, but the complexity of the natural environment is necessary that there interconnections with other indices, whether climatological, vegetation, hydrological or soil to proceed reliably to a monitoring and analysis efficient comprising facilitation in decision making in public administration.

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