

Seasonality of Vegetation Indices in different land uses in the São Francisco Valley

Cloves V. B. Santos*, Gustavo M. M. Baptista**, Magna S. B. Moura***

* Mestre em Ciências Ambientais; Programa de Pós-Graduação em Modelagem em Ciências da Terra e do Ambiente; Universidade Estadual de Feira de Santana - UEFS. Email: clovesvilasboas@gmail.com (Corresponding author)

**Professor Associado I; Instituto de Geociências; Universidade de Brasília - UnB.

***Pesquisadora; Laboratório de Agrometeorologia; Empresa Brasileira de Pesquisa Agropecuária - EMBRAPA.

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Abstract

Remote Sensing has been used in researches with higher frequency to allow the analysis of the surface without the contact with the targets, allowing to identify biophysical conditions of the vegetation and understanding its photosynthetic dynamics. The objective of this study was to analyze the seasonal behavior of NDVI and EVI2 vegetation indices with and without transforming wavelets in areas with different soil uses in the São Francisco Valley and to verify their relationship with the occurrence of rainfall. The study was carried out in areas of preserved and degraded caatinga, and degraded grassland in the municipality of Petrolina-PE. NDVI was determined on 20 OLI sensor images with dates representing rainy and dry periods between 2013 and 2016. EVI2 data with and without filter were obtained for MODIS pixels. Precipitation data were used to understand the relationship between vegetation indices and rainfall occurrence. The results showed that the studied areas presented similar behavior among vegetation indices, but with different intensities, presenting higher values in January 2014, April 2015 and March 2016, coinciding with the occurrence of higher precipitation records in the region. The relationship between vegetation indices and precipitation was linear. Therefore, it was possible to determine the seasonality of the studied areas, making it possible to understand that through the OLI and MODIS data, it was possible to analyze the dynamics of the vegetation and its relation to the rainfall.

Keywords: Caatinga Biome, NDVI, Rainfall.

1. Introduction

Remote sensing associated with digital image processing techniques has been an alternative for the monitoring of vegetation dynamics. In their applications are the vegetation indices, and through them it is possible to have estimates on the photosynthetic activity of the plants.

One of the most used indices is the Normalized Difference Vegetation Index (NDVI) proposed by Rouse et al. (1973), in which, according to Mascarenhas et al. (2008), permit the visualization of the different phytophysiological of the vegetation.

Remote sensing work on vegetation analysis has been developed. Becerra et al. (2009) analyzed the relationship between this index and rainfall in different land uses in Cerrado areas. Zanzarini et al. (2013) evaluated the variability of NDVI and its relation with soil attributes in agriculture. Lima Junior et al. (2014) analyzed the relationship between the NDVI and the biomass estimated in the Caatinga. Tavares et al. (2015) evaluated different vegetation fragments by verifying the spectral behavior of this vegetation in dry periods.

It is important that remote sensing applied to environmental studies extends to all

regions, including the Biome Caatinga, which is a unique biome, with a territorial extension of approximately 800,000 km², located in the great majority of the Northeast, where it occupies 63% of the area (Oliveira et al., 2006).

According to Rocha et al. (2011), the Caatinga has a great spatial and temporal variability of rainfall occurrence. The biome also has approximately 50% of its area with some kind of degradation.

Due to the extension of the Biome, and its representativeness, it is necessary to develop studies using remote sensing techniques that aim to create models that allow the visualization of space as a whole. Therefore, the objective of the present work is to analyze the seasonal behavior of vegetation indices NDVI, EVI2 without filter and EVI2 with wavelets transformed filter, in areas with different land uses in the São Francisco Valley, and verify their relation with the rainfall occurrence.

2. Material and methods

The study areas are located at the experimental station belonging to the Brazilian Agricultural Research Company / Research Center of the Semi-Arid Tropic (EMBRAPA / CPATSA), located in the region of Vale São Francisco, in the municipality of Petrolina-PE. Three areas with different soil uses were selected: preserved caatinga (PC), degraded caatinga (DC) and degraded grassland (DG) located according to Figure 1.

The study areas were delimited by means of a polygon generated by points using GPS, in a random way and using the criterion of homogeneity of each area within the points. The amount of pixels present in each polygon of the studied areas was 174 for the preserved caatinga, 84 for the degraded caatinga and 113 for the degraded grassland.

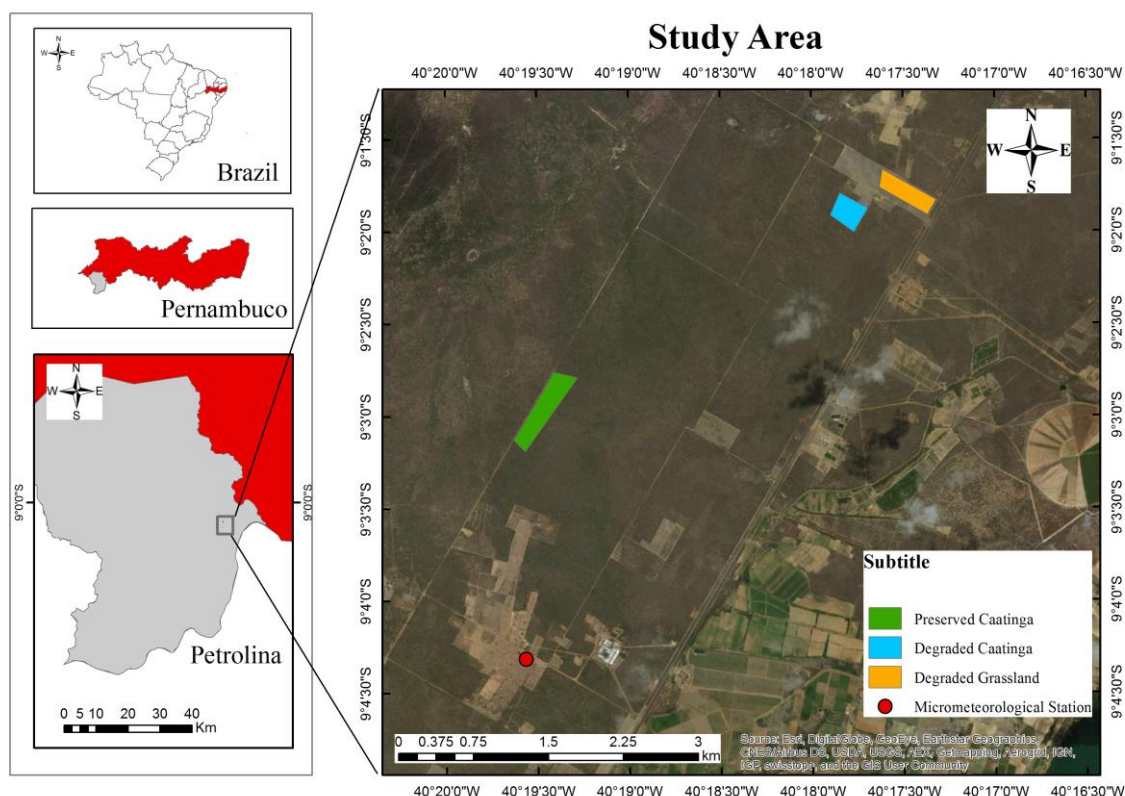


Figure 1 – Study area.

As in the other semiarid regions, the studied area is characterized by high temperatures and low rainfall indices, and this influences the photosynthetic dynamics of the vegetation.

According to Souza et al. (2015), the region has an annual average temperature around 26 ° C, and an annual rainfall of around 510 mm.

As a spatial database, we used 20 images of the Operational Land Imager - OLI (Landsat 8), with spatial resolution of 30 meters, point 217 and orbit 66, obtained through the US Geological Survey (USGS). The scenes represent the rainy and dry periods of the region with dates between the years of 2013 and 2016, selected based on the criterion of absence of clouds in the studied pixels.

The images were preprocessed in the ENVI 5.2 by means of the conversion of the digital numbers (DN) into radiance, and then the correction of the atmospheric effects using the FLAASH module that is based on the MODTRAN4 radiative transference model. For the image processing, the Normalized Difference Vegetation Index (NDVI) was determined, with a process of ratio of difference by the sum, which allows to evaluate the greenness of the

photosynthetically active vegetation. The NDVI was determined by means of equation 1, which generates values in the range of -1 to +1, in which negative values represent non-vegetative or non-photosynthetically active areas (NPA), and positive values represent photosynthetically active vegetation (PAV).

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \quad (1)$$

where NIR and RED correspond, respectively, the reflectance values of spectral band 5 (near infrared) and 4 (red) of Landsat 8 OLI sensor.

For the MODIS data, the tool was available at the INPE LAF website (<https://www.dsr.inpe.br/laf/series/index.php>). The selected pixels are presented in Figure 2, with the blue pixel, to preserved caatinga, the red pixel corresponding to the degraded caatinga, and the orange pixel corresponding to the degraded grassland.



Figure 2 - Localization of the MODIS pixels used to obtain the historical series of EVI2 with and without transformed wavelets filter of the studied areas.

The Enhanced Vegetation Index 2, EVI2, (Equation 2) use the near-infrared and the red region spectral bands and is used to indicate vegetative vigor. It is functionally equivalent to EVI, although it is slightly more affected by the aerosol noise, but with continued advances in atmospheric correction techniques, this evidence becomes less significant over time (Jiang et al., 2008).

$$EVI2 = 2.5 \frac{(NIR - RED)}{(NIR + 2.4 RED + 1)} \quad (2)$$

Daily rainfall data for the period 01/01/2013 to 12/31/2016 were obtained at the Caatinga Micrometeorological Station, located near the study areas of the present study. The accumulated rain data of the 30 days prior to the acquisition of the images were summed and analyzed by means of linear regression with the indices of each study area, as well as by the Pearson correlation matrix obtained for the three vegetation indices with the precipitation.

To verify the consistency of the vegetation indices behavior for each soil use, the discriminant analysis was used.

3. Results and discussion

The seasonal profile of the vegetation dynamics of the areas studied from the NDVI analysis for the period from 2013 to 2016 is presented in Figure 3. The average pattern of the indices over the period is similar for all years, however, what differentiates are the intensities.

The behavior of NDVI in the area of preserved and degraded caatinga showed high photosynthetic activity in the rainy periods of the region as April 2015 and March 2016. NDVI peaks coincide with the highest rain values accumulated in the 30 days before the image, with highlight the beginning of 2016, when rainfall of the order of 237 mm was recorded in the month of January. NDVI peaks are identified in the months when rains occurred in the periods before the indices were obtained

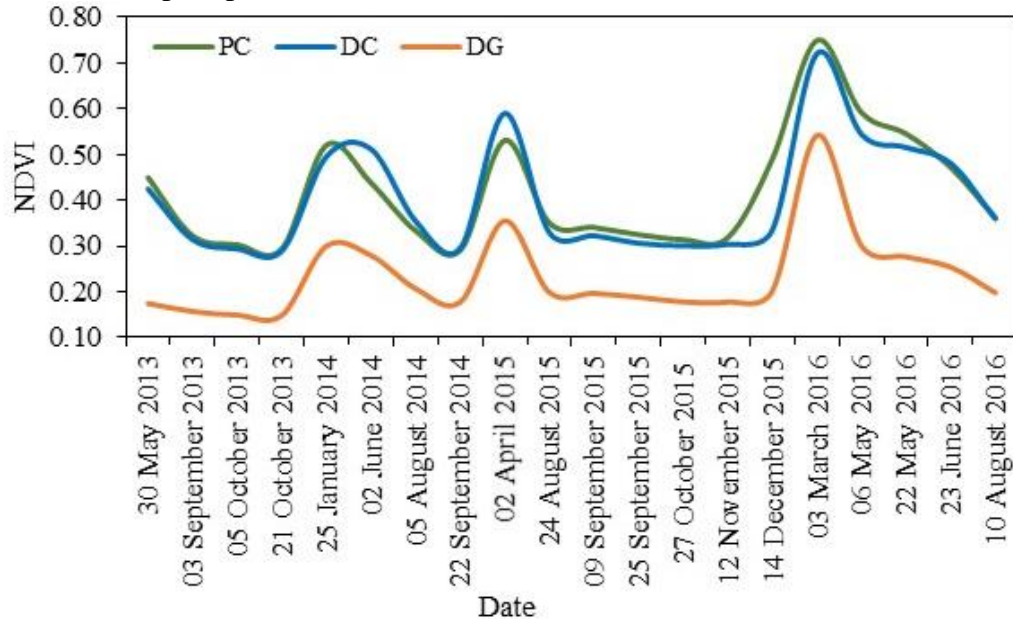


Figure 3 - Seasonality of the Normalized Difference Vegetation Index (NDVI) between 2013 and 2016 for preserved caatinga (PC), degraded caatinga (DC) and degraded grassland (DG) in the São Francisco Valley.

For the degraded grassland area, the seasonal behavior was similar to that observed in

the caatinga areas, but with lower intensity of values due to the presence of exposed soil.

There is also a tendency for a decrease in index values in all analyzed areas, ranging from the rainy season, at the beginning of the year, to the highest rainfall rates, until the dry season, at the end of the year, with the drought. In the grassland area, the seasonal pattern was similar, with the exception in June 2014 of accumulated precipitation in the previous month. This is justified because the caatinga does not maintain a regular rainfall regime, which comes to be natural when it comes to the climatic conditions of that region. Lima Junior et al. (2014), affirm that the irregularity of caatinga rains interferes in the biomass production in these areas, presenting great variations, both spatial and seasonal.

Figure 4 presents the seasonal variation of the spectral indices evaluated for each soil use. It should be noted that, since the EVI2 data are up to June 2016, the NDVI data of the scene of 10/08/2016 was ignored. In all uses NDVI presented higher values than EVI2. This characteristic is observed by Pedroza da Silva and Baptista (2015), and these authors attribute this question to the saturation that NDVI results present in relation to EVI2.

Variation of spectral indices of vegetation for each of the land uses. As of October 2015, there are greater divergences between the observed trends, mainly in the two uses that present degradation.

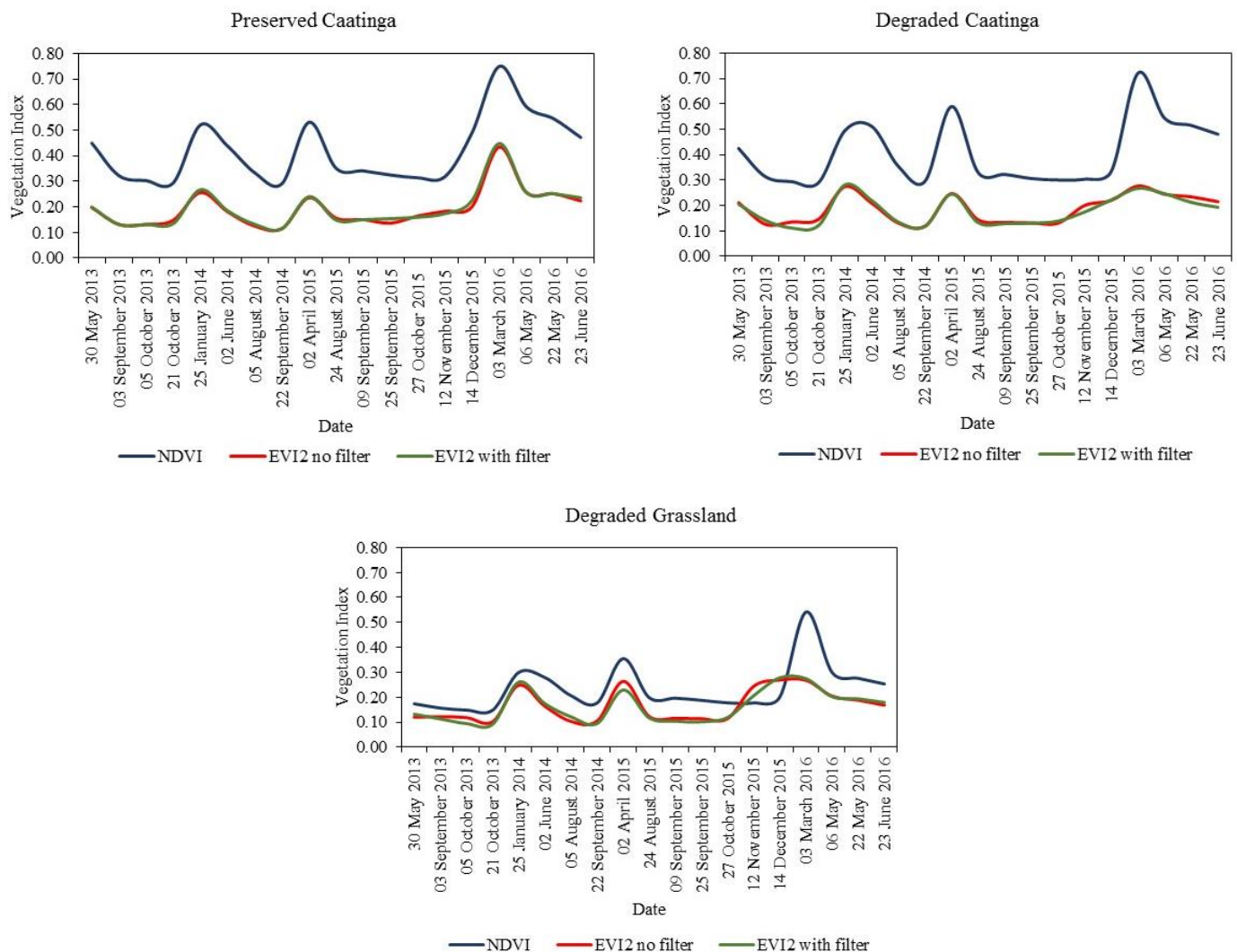


Figure 4 – Variation of vegetation spectral indices for each land use.

Figure 5 shows the total monthly precipitation record from 2013 to 2016, from the Caatinga Micrometeorological Station, located near the studied areas.

It is observed in the same figure, that during the four years of analysis rainfall values were registered below 20 mm in most of the months, but, through the measurements, it was determined that the rainy season comprised the months of November to April, with intensities higher in the months of November and December.

According to Oliveira et al. (2006), based on a series of 30 years of measurement in the region, it was observed an occurrence of concentrated rainfall between the months of November and April, but the authors highlight the irregularity of these rains in their study, presenting a recorded series of July 2004 to July 2005, where extreme rainfall events occurred between January and April, thereby indicating the existence of an intense and enduring dry season.

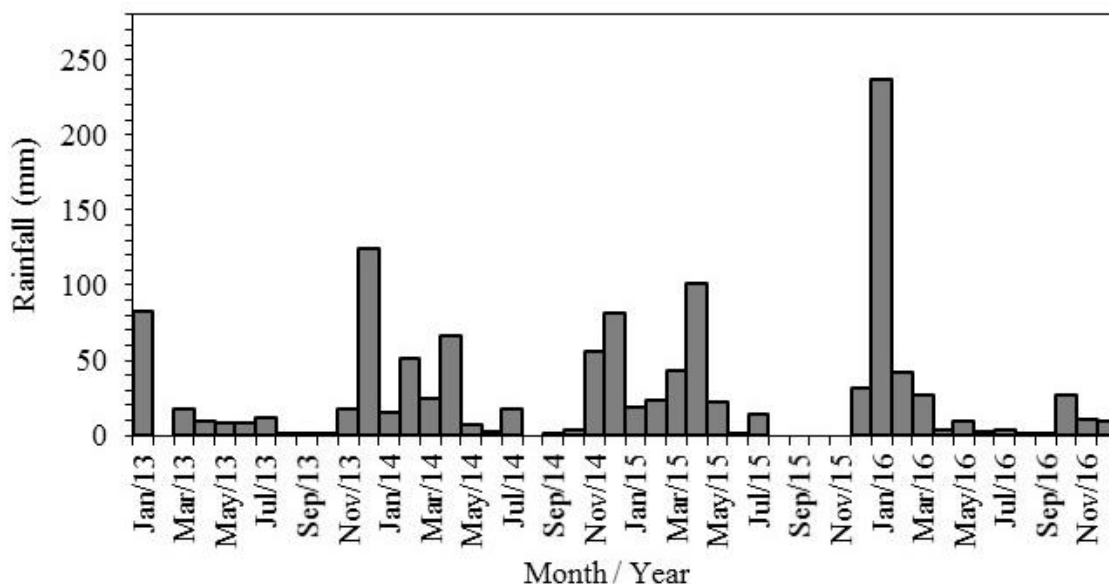


Figure 5 – Total rainfall during the period from 2013 to 2016 in the study area. Data from the Micrometeorological Station of the Caatinga, Embrapa Semi-Arid. The figure shows that the region's highest rainfall volumes are concentrated between November and April.

According to the recorded by the rain gauges in the present study, 88% of the total precipitation was concentrated during the rainy season corresponding to the months of November and April.

This variability in the distribution of rainfall results in a water deficit in most of the year that starts from the less rainy season in May, which is natural for semi-arid environments, and consequently an NDVI presenting a great variability also during this period, as presented in Figure 2, with mean intensities for all areas (preserved caatinga, degraded caatinga and

degraded grassland) with values reaching 0.42 ± 0.04 ; 0.40 ± 0.03 ; and 0.23 ± 0.02 , respectively. For the non-filter EVI2 time series, the mean data presented were, for preserved caatinga, degraded caatinga and degraded grassland, 0.19 ± 0.07 ; 0.19 ± 0.06 ; and 0.17 ± 0.06 , respectively. The EVI2 with filter, mean values were 0.20 ± 0.08 ; 0.18 ± 0.06 ; and 0.16 ± 0.06 , respectively.

Similar results for the caatinga areas were found by Lima Júnior et al. (2014), in the same region with the index generated by the TM sensor, with mean values in April and June 2011 of 0.49 and 0.42, respectively, but found in August of that same year, 0.13, which is a value below in

relation to those found in the present study, is more justified by the water stress of the plants in this period, since in the two months prior to August 2011, the author registered rainfall below 10 mm in each month.

Other results were found by Tavares et al. (2015), studying fragments of native vegetation (semideciduous seasonal forest, secondary vegetation of semideciduous seasonal forest, and secondary vegetation of seasonal forest in contact with savanna), in dry periods, finding NDVI averages of 0.52, 0.48 and 0.39 respectively, which are greater than those found in the present study for the two Caatinga and grassland areas, but which is justified by the difference in vegetation structure in relation to Caatinga patterns.

Zanzarini et al. (2013) determining NDVI an area of agriculture (sugarcane cultivation) in a region of rainy tropical climate, obtained an index value of 0.40.

The NDVI and EVI2 results of the studied areas (preserved caatinga, degraded caatinga and degraded grassland) and their relationship with rainfall are presented in Table 1.

The adjustment of the trend line between the vegetation indices of the different areas with the precipitation was obtained by means of a

coefficient of determination that adjusted the variables to a linear function.

Table 1 - Determination coefficients (R^2) between use and cumulative precipitation in the 30 days prior to scene acquisition.

Soil use	NDVI	EVI2 no filter	EVI2 with filter
Preserved			
Caatinga	0.444	0.3908	0.4432
Degraded			
Caatinga	0.3951	0.3453	0.3761
Degraded			
Grassland	0.4749	0.4091	0.4669

The coefficients mentioned show that for the different types of soil use in the semi-arid region, the seasonal pattern established by the NDVI and the two EVI2 have a relation with the precipitation accumulated in the 30 days prior to the acquisition of the images.

When analyzing the Pearson correlation matrix among the four variables, we obtained the following results (Tabela 2).

Table 2 - Pearson's Correlation Matrix

	PCN	DCN	DGN	PCEN	DCEN	DGEN	PCEW	DCEW	DGEW	AR
PCN	1									
DCN	0.94**	1								
DGN	0.90**	0.94**	1							
PCEN	0.95**	0.90**	0.92**	1						
DCEN	0.90**	0.85**	0.76**	0.86**	1					
DGEN	0.75**	0.65**	0.68**	0.74**	0.86**	1				
PCEW	0.96**	0.89**	0.92**	0.99**	0.86**	0.75**	1			
DCEW	0.90**	0.86**	0.77**	0.82**	0.97**	0.85**	0.84**	1		
DGEW	0.82**	0.70**	0.71**	0.79**	0.90**	0.97**	0.81**	0.91**	1	
AR	0.66**	0.63**	0.69**	0.63**	0.59**	0.64**	0.67**	0.61**	0.68**	1

**. Correlation is significant at the $\alpha=0,01$ level (2-tailed).

PCN- Preserved Caatinga NDVI; DCN – Degraded Caatinga NDVI; DGN – Degraded Grassland NDVI; PCEN – Preserved Caatinga EVI2 without filter; DCEN – Degraded Caatinga EVI2 without filter; DGEN - Degraded Grassland EVI2 without filter ; PCEW – Preserved Caatinga EVI2 with filter; DCEW – Degraded Caatinga EVI2 with filter; DGEW - Degraded Grassland EVI2 with filter; AR – Accumulated Precipitation in 30 days.

All correlations presented significance for a confidence interval of 99%. The correlations between the NDVI values between the uses were positive and all with values equal or superior to 90%; those obtained by the unfiltered EVI2 values ranged from about 65% to 95%; and those obtained by means of the filtered EVI2 data, between about 76% and about 97%. Although the coefficients of determination obtained with the vegetation indices data with the accumulated precipitation in 30 days were low, the correlations obtained were all significant for the 99% confidence interval. The highest correlation was filter, with 68.3% and the lowest with degraded caatinga EVI2 without filter, 58.8%.

According to the regression analysis, it can be affirmed that the relationship between vegetation indices and precipitation, for the conditions established for the semi-arid region, has

a linear relationship between the variables analyzed.

The discriminant analysis is presented in Table 3. For each assigned group (preserved caatinga, degraded caatinga, degraded grassland), three variables were evaluated (NDVI, EVI2 without filter, EVI2 with filter), totaling 57 samples. Of these, 41 were correctly classified according to the pre-established groups, representing a 72% accuracy. Analyzing each group individually, the highest proportion of accuracy was obtained by degraded grassland, with 94.7%, which was to be expected, since it occurs in almost all the observed moments with values of vegetation indices ranging from 10% to 30%. But even the preserved caatinga presents hits of the order of 60%. The caatinga degraded in 6 dates presented with spectral behavior of preserved caatinga.

Table 3. Discriminant Analysis

Group	True Group		
	Degraded Caatinga	Degraded Grassland	Preserved Caatinga
Degraded Caatinga	11	0	6
Degraded Grassland	2	18	1
Preserved Caatinga	6	1	12
Total N	19	19	19
N correct	11	18	12
Proportion	0.579	0.947	0.632
N total		57	
N correct		41	
Right proportion		0.72	

These variations in the coefficients of determination, correlation and in the discriminant analysis are explained, therefore, the seasonal dynamics of the caatinga is so marked that, in some moments of the hydrological years, the values of the vegetation indices of the preserved caatinga areas are presented as those found in areas of degraded caatinga or even grassland. This does not mean that they are degraded, but as they dry out, they exhibit similar spectral behavior. An example of this is the NDVI of 03/09/2013 of the portion considered in the field as preserved

caatinga and, through the linear discriminant function obtained was classified as degraded caatinga, in September, whose precipitation accumulated in the thirty days before the acquisition of the scene was only 1.8 mm.

4. Conclusions

Through the vegetation indices, it was possible to determine the seasonality of the studied areas. The pattern established by the indices, allowed the understanding of the dynamics of the

photosynthetic activity of the vegetation in the studied areas.

The presented pattern, it was possible to identify that in the rainy periods, in the first months of the year, the most expressive index values make a direct relation with the photosynthetic activity of the vegetation, making it understood that through the data of both the OLI sensor with 30 meters, and of MODIS, with 250 m, it is possible the analysis of the dynamics of the vegetation and its relation to the rains that occurred.

It was observed that all the studied areas, the response of the vegetation indices is in agreement with the precipitation accumulated in the 30 days in relation to the date of the imaging. Moreover, it is possible to affirm that the variables precipitation and vegetation indices of the three areas investigated presented positive and moderate correlations with level of significance for a confidence interval of 99%.

In addition, the study allowed to verify, through discriminant analysis, that the classes of land use, depending on the season of the year, presents different spectral behavior, which creates confusion between the classes preserved and degraded, either in the caatinga or in the grassland.

New studies should be encouraged to verify the efficiency of these vegetation indices, especially during the dry season, when confusions increase.

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