Spectral analysis for identification of plant ecosystems in Brazilian Atlantic Forest

Análise espectral para identificação de ecossistemas vegetais na Mata Atlântica Brasileira

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ABSTRACT
The creation of the Guadeloupe EPA aimed to protect natural ecosystems and promote sustainable development in atlantic forest fragments existing in Pernambuco, Brazil. However, even with the State Decree formalizing these objectives, the ecosystems of the Atlantic Forest Biome present at the site suffered serious data by anthropic actions. For the study of these ecosystems, spectral analysis was an excellent channel of connection between geotechnologies and phytogeography of the site, allowing to study the location and type of vegetation in the extension of the Conservation Unit. From this perspective, the present research aimed to differentiate the atlantic forest ecosystems through spectral analysis. The

results of spectral analysis allowed to indicate that in the identification of the Dense Ombrófila Forest the best specific combination is Atmospheric Penetration (PA) in its Pixel (PI) α. Mangrove in turn can be better identified in Infrared Vegetation (IVV) - Ranging from 150 to 220 Ash Levels (NC) - in pi α and also in PI β and PI γ varying in values very close to 50NC. Regarding restinga it is estimated that it can be accurately identified in Agriculture (AG), especially in pi γ, and also in Enhanced Vegetation Index (EVI) and Normalized Difference Water Index (NDWI), in all its Pixels.

Keywords: pixel reading, remote sensing, mangrove, ambrosiphile forest, restinga.

RESUMO

A criação da APA de Guadalupe teve o objetivo proteger os ecossistemas naturais e promover o desenvolvimento sustentável em fragmentos de Mata Atlântica existentes em Pernambuco, Brasil. Todavia, mesmo com a Decreto Estadual formalizando esses objetivos os ecossistemas do Bioma Mata Atlântica presentes no local sofreram sérios dados pelas ações antrópicas. Para estudo desses ecossistemas a Analise Espectral foi um excelente canal de conexão entre as geotecnologias e a fitogeografia do local, possibilitando estudar a localização e o tipo de vegetação na extensão da Unidade de Conservação. Nessa perspectiva, a presente pesquisa teve o objetivo de diferenciar os ecossistemas de Mata Atlântica por meio de Análise Espectral. Os resultados da Análise Espectral permitiram indicar que na identificação da Floresta Ombrófila Densa a melhor combinação específica é a Penetração Atmosférica (PA) em seu Pixel (PI) α. O Mangue por sua vez pode ser melhor identificado no Infravermelho de Vegetação (IVV) - Variando de 150 a 220 Níveis de Cinza (NC) - no PI α e também nos PI β e PI γ variando em valores muito próximos aos 50NC. No que se refere a restinga estima-se que a mesma possa ser identificada de forma precisa em Agriculture (AG), sobretudo no PI γ, e também em Enhanced Vegetation Index (EVI) e Normalized Difference Water Index (NDWI), em todos seus Pixels.

Palavras-chave: leitura de pixel, sensoriamento remoto, mangue, floresta ombrófila, restinga.

1 INTRODUCTION

This research had as study area the Environmental Protection Area (EPA) of Guadeloupe on the Southern Coast of the State of Pernambuco. The creation of the Guadeloupe EPA took place through State Decree Number 19,635, on March 13, 1997, and aims to conserve and protect natural systems essential to biodiversity, as well as protect natural ecosystems and promote sustainable development.

However, even with the institutionalization of these objectives, the ecosystems of the Atlantic Forest Biome, especially the ecosystems of dense ombrófila forest, mangrove and restinga suffered serious data by anthropic actions, corroborated by the neglect of their protection by the competent authorities.

What happens to the Guadeloupe EPA is not a new or isolated historical fact, the fragmentation of the Atlantic Forest comes from the colonial period, especially on the Brazilian coast, and represents a limiting factor for the survival of a number of species and

for the maintenance of biodiversity and ecosystems. In the country, even in these circumstances, the Atlantic Forest has a great resilience capacity and there are fragments of its ecosystems that have been preserved. An example of these fragments of preserved ecosystems are those found in the West of the Guadeloupe EPA and which are our object of study from the perspective of phytogeography in conjunction with spectral analysis.

It is worth remembering that the importance of recognizing the type of vegetation of a given locality results not only from the particular history of evolution and migration of the species that make up the plant formation, but also from the adaptation of these species to climatic conditions and local biological interactions, allowing better protection and conservation of these ecosystems.

It is important to differentiate and spectrally characterize these ecosystems in order to build graphics that provide tools for the conservation of the APA of Guadalupe and other protected areas, in the present and in the future.From this perspective, the present research aimed to differentiate the atlantic forest ecosystems through spectral analysis.

2 THEORETICAL RATIONALE

One circumstance to be weighed is that the spectral signature of a target can be defined as a cluster of the successive values of the object's reflectance along the EME, also known as the spectral signature of the target. Thus, the spectral signature of the object defines the features of the object, and the shape, intensity and location of each absorption band are what characterize the object (Steffen and Moraes, 1993).

The targets interact spectrally differently with the incident electromagnetic energy, because the objects have different physical-chemical and biological properties, that is, it is a fact that the different ecosystems will have a different behavior between them. These different interactions allow the distinction and recognition of the various remotely sensing terrestrial objects, as they are recognized due to the variation in the percentage of energy reflected in each wavelength (Steffen and Moraes, 1991).

2.1 SPECTRAL BEHAVIOR OF VEGETATION

According to Veiga (2004) since the discovery that vegetables extract from electromagnetic radiation (ER) emitted by the Sun part of the energy they need to live, the interaction between this radiation and vegetation began to be studied in detail. Thus, remote sensing is the technology that has contributed the most and has also contributed and stimulated the advancement in the knowledge of how vegetation processes this electromagnetic radiation.

The Spectral Behavior of Vegetation is often used to represent the reflectance characteristics of The ER, by leaves, individual plants and plant set.

According to Melo (2018), the "appearance" of the vegetation cover in a given Remote Sensing product comes from a complex process that involves many parameters and environmental factors. What is effectively measured by a remotely located sensor, derived from a given vegetation, cannot be explained only by the intrinsic characteristics of this vegetation, it also includes the interference of several other parameters and factors such as:

• The radiation source, which includes spectral irradiance, the location of the zenital angle and solar azimutal;

• The atmosphere, characterized by a number of properties and parameters, including spatially dependent concentrations and the selective absorption and scattering properties of the various wavelengths by the constituents of the atmosphere, such as water vapor, ozone, aerosols, etc.;

• Canopy characteristics are based on various optical properties and parameters (reflectance and transmittance), structural (geometric shapes and positioning of vegetation components such as leaves, branches, fruits, flowers, etc.), plant geometry and environmental parameters (temperature, relative humidity, wind speed and precipitation);

• Soil, which is also characterized by a number of properties and parameters such as reflectance, absorbance, surface roughness, texture and moisture.

Therefore, vegetation is perhaps the most complex target of Remote Sensing (EPIPHANIO et al., 1996); presenting varied properties of leaf reflection in the same plant, multiple reflective components, non-uniformity of inter and intraplant structure, besides settling on a substrate consisting of soil or plant residues that, in turn, have own reflection properties, contributing to the measurement process for modulation of vegetation reflection properties.

It is worth mentioning that the way a plant or plant community is seen, either by the human eye or by a multispectral sensor, depends fundamentally on the interaction of this plant or plant community with radiation (NASCIMETO, 2014).

Thus, the characteristics that occur in the spectra of reflectance, transmittance and absorbance of a leaf are caused nods, pigments, structure and water in solution.

According to Melo (2018), the leaf undoubtedly deserves special attention among the plant components, because this is where photosynthesis takes place. The entire organization of the leaf (its shape, position, structure, etc.) is adapted for better use of the sun's rays, air and water, necessary to carry out the photosynthesis process.

3 METHODOLOGY

3.1 PIXEL READING SPECTRAL ANALYSIS

The spectral analysis by pixel reading, used in the present research, allows us to know the values of the gray levels of a given pixel and its neighbors. Such spectral reading of the gray level of a band is important not only for understanding the spectral behavior of a given target, but also useful for verifying the values of lighter or darker pixels, differentiating the values of a feature (MELO et al., 2018). Moreover, this technique allows studies of the spectral behavior of targets in different spectral bands.

3.2 PARAMETERS AND PROCESSES USED IN PIXEL READING SPECTRAL ANALYSIS

Using the Spring geoprocessing software it was possible to make the spectral analysis by reading the pixels of the band(s) used. To be used, the Pixel Reading tool, you must first create a project following all the data and geographic systems appropriate to the objective use; create a data model in the image category and also the thematic classes of the points to be targeted; select the files of the Image Category, correct and adjust your geographic data, and thus enable the tools of the same. Finally, click Image and then Pixel Reading. The patterns of spectral analysis were based on authors of the area and in the phytogeographic study, confirm the table below:

Parameter	Standard/Measure Used	Reasons
Pixel Sample Dimensions - The dimensions of a sample in the Spring pixel reading can range from: 3x3, 5x5, 7x7, and 21x21.	5x5 - Best suited for spectral analysis of landsat satellite line images.	MELO et al., 2018
Location/Point analyzed in pixel-by-ecosystem sample.	Points were chosen where their location was the maximum centered within the ecosystems fragment to avoid inesgency of spectral responses of anthropic targets.	BANON; BARRERA, 1998. NASCIMENTO, P. H. O. et al., 2014
Number of points per ecosystem.	An analysis point was chosen for each ecosystem. It is worth mentioning that each of the points responds to an area of 30x30 square meters, ie 900 meters.	NASCIMENTO, P. H. O. et al., 2014 CANDEIAS, A. L. B, 1997
Periodicity of Images	A total of 7 years was analyzed in a time space of 32 years.	MELO et al., 2018
Conduct snares on standard errors.	When the Spectral response is 0 (Zero): on this occasion the number 0 is put in the dice. Example.	MELO et al., 2018
	When the spectral response is ND: it means that the software for some reason has not picked up any response. In the Result Table is represented by nd.	

3.3 COMBINATIONS OF USED BANDS AND VEGETATION INDICES

For methodological purposes it is important to describe the combinations and vegetation indices used in this research:

Natural Color (RGB)	Landsat5, Landsat7	$RGB = (B3 + B2 + B1)$
	Landsat8	$RGB = (B4 + B3 + B2)$
Infrared Vegetation (IVV)	Landsat5, Landsat7	$IVV = (B4 + B3 + B2)$
	Landsat8	$IVV = (B5 + B4 + B3)$
Normalized Difference Vegetation Index (NDVI)	Landsat5, Landsat7	$NDVI = \dfrac{(B4 - B3)}{(B4 + B3)}$
	Landsat8	$NDVI = \dfrac{(B5 - B4)}{(B5 + B4)}$
Vegetation Index Soil-Adjusted (SAVI)	Landsat5, Landsat7	$SAVI = 1{,}5 * \dfrac{(B4 - B3)}{(B4 + B3 + 0{,}5)}$
	Landsat8	$SAVI = 1{,}5 * \dfrac{(B5 - B4)}{(B5 + B4 + 0{,}5)}$
Enhanced Vegetation Index (EVI)	Landsat5, Landsat7	$EVI = 2{,}5 * \left(\dfrac{(B4 - B3)}{(B4 + 6 * B3 - 7{,}5 * B1) + 1)}\right)$
	Landsat8	$EVI = 2{,}5 * \left(\dfrac{(B5 - B4)}{(B5 + 6 * B4 - 7{,}5 * B2) + 1)}\right)$
Normalized Difference Water Index (NDWI)	Landsat5, Landsat7	$NDWI = \dfrac{(B2 - B4)}{(B2 + B4)}$
	Landsat8	$NDWI = \dfrac{(B3 - B5)}{(B3 + B5)}$
Atmospheric Penetration (AP)	Landsat5, Landsat7	$PA = (B7 + B5 + B4)$
	Landsat8	$PA = (B7 + B6 + B5)$
Index Stack (PI)	Landsat5, Landsat7	$PI = \left(\dfrac{(B2 - B5)}{(B2 + B5)} + \dfrac{(B4 - B3)}{(B4 + B3)} + \dfrac{(B2 - B4)}{(B2 + B4)}\right)$
	Landsat8	$PI = \left(\dfrac{(B3 - B6)}{(B3 + B6)} + \dfrac{(B5 - B4)}{(B5 + B4)} + \dfrac{(B3 - B5)}{(B3 + B5)}\right)$
Agriculture (AG)	Landsat5, Landsat7	$AG = SWIR1 + NIR + B1$
	Landsat8	$AG = SWIR1 + NIR + B2$

4 RESULTS

From the pixel reading and these data sheets it was possible to construct graphs for each of the ecosystems in each of the combinations and indexes, configuring the spectral analysis completely, as shown in the following topics. The values presented by this process correspond to the pixels present in the original image, regardless of the scale of the image's on-screen view (MELO et al., 2018).

4.1 RESULTS: NATURAL COLOR (RGB)

In the combination 'RGB' or called Natural Color the results show that the

ecosystems studied were not easily identified showing a variation in terms of gray level especially in the mangrove and Atlantic forest ecosystems, where there were strong sticks especially in 2001, where data for the Atlantic forest reached 0, between an average of 35 for pixel(PI) β , 25 for the PI α and 5 for PI γ. In the mangrove in turn, there was strong variation in a series of years in 1992, 2006, 2011 and 2016 where all pixes were shown not to follow a concise pattern. In the restinga we had the slightest variation for the RGB combination, even though it was not accurate.

Graph 1 - Spectral analysis of the Lowland Anthropic Forest in RGB images at gray (NC) levels

Source: Author (2020)

Graph 2 - Spectral analysis of Restinga in RGB images at gray (NC) levels
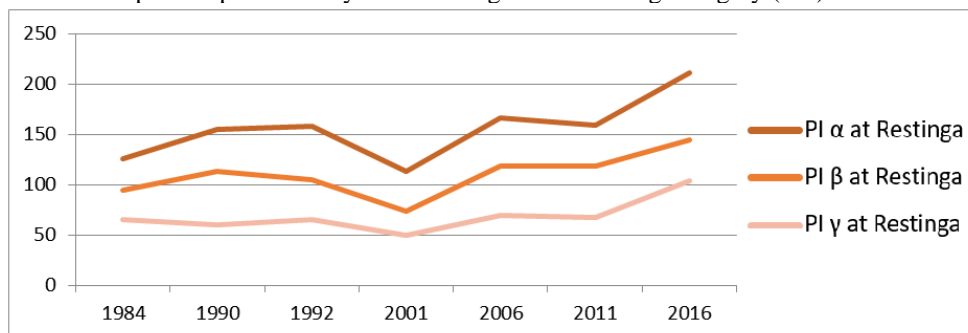
Source: Author (2020)

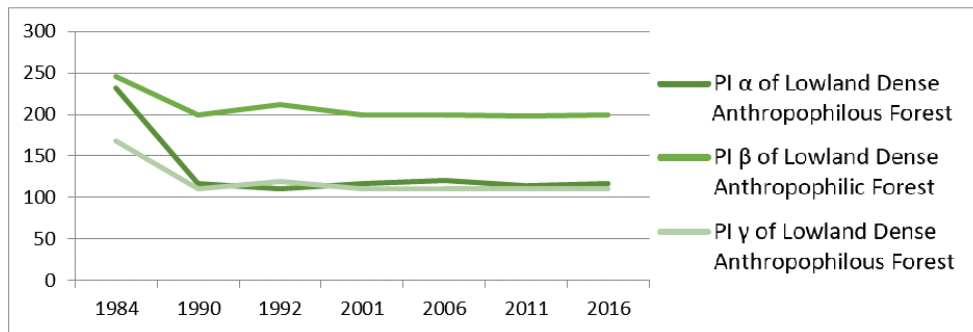Graph 3 - Spectral analysis of mangrove in RGB images at gray (NC) levels
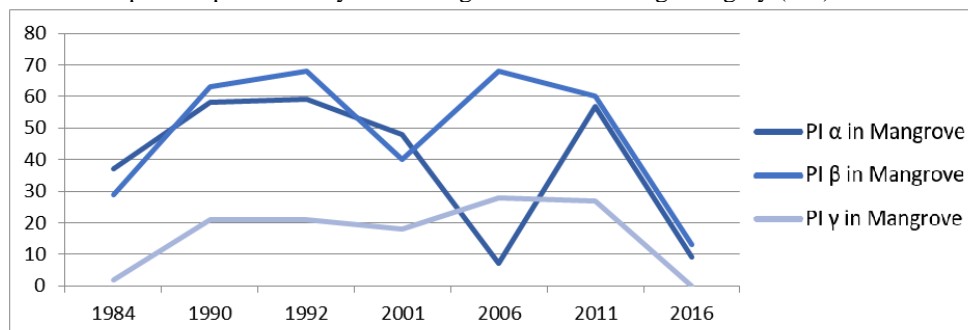
Source: Author (2020)

4.2 RESULTS: INFRARED VEGETATION (IVV)

The results of the Vegetation Infrared (IVV) were extremely promising in the

identification of the Mangue and Restinga ecosystems. One circumstance to be pondered is that this identification of the Mangrove, was shown to be formatted of the spectral signature (ranging from 150 to 220 NC) in the pi α and also in the pi β and PI γ varying in values very close to the 50NC; with regard to Restinga this signature was more pronounced in the α having a constant close to 200NC. The Dense Anthropophilous Forest was not easily identified in ivv.

Graph 4 - Spectral analysis of the Lowland Anthropophilic Forest in IVV images at gray (NC) levels
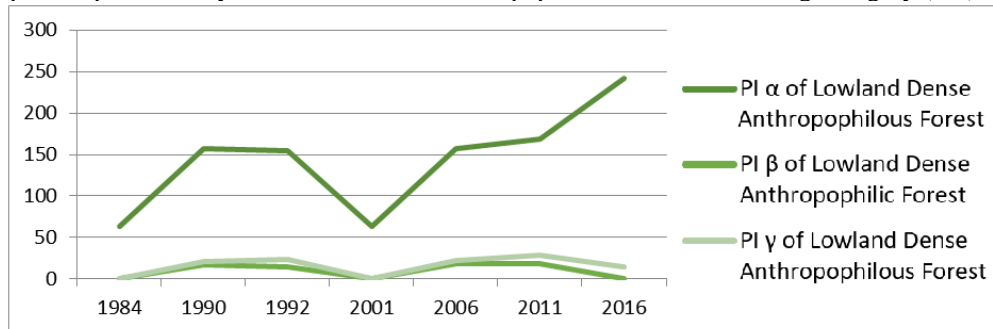
Source: Author (2020)

Graph 5 - Spectral analysis of restinga in IVV images at gray (NC) levels
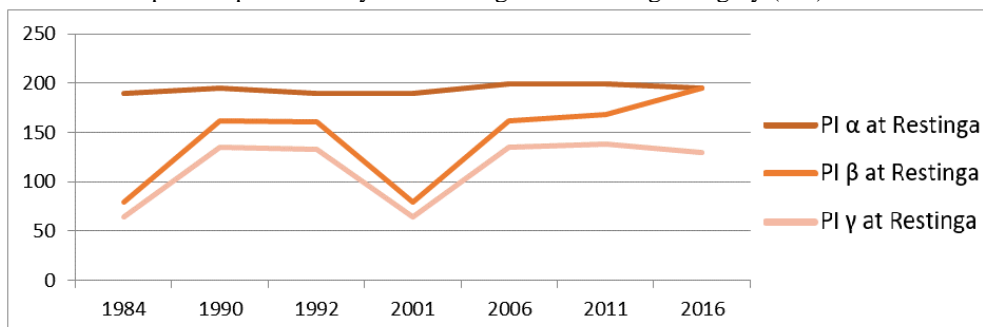
Source: Author (2020)

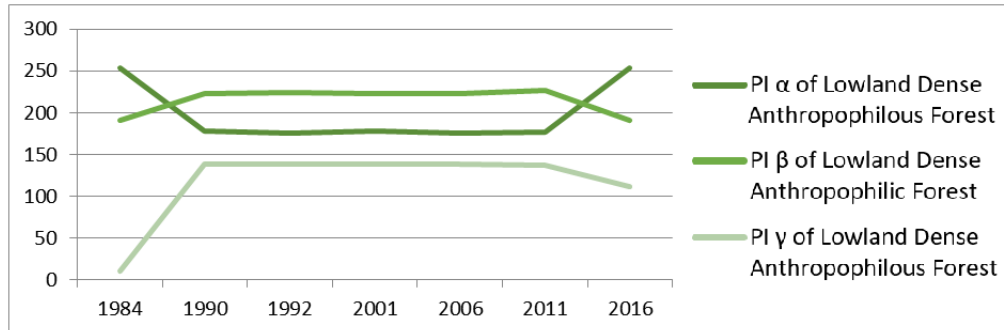Graph 6 - Spectral analysis of mangrove in IVV images at gray (NC) levels
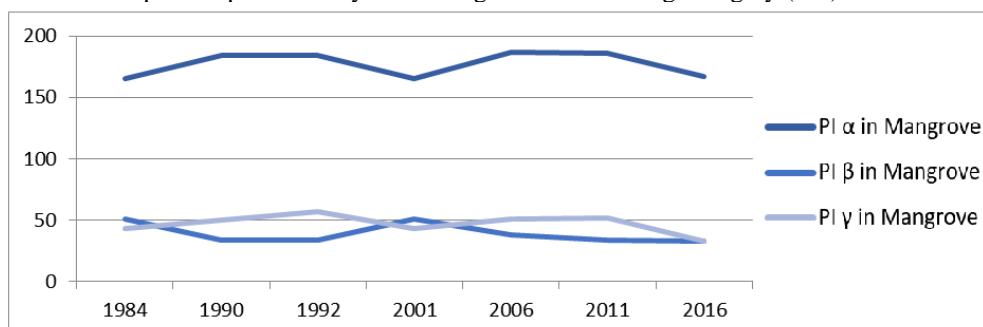
Source: Author (2020)

4.3 RESULTS: NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

In the Normalized Difference Vegetation Index (NDVI), as well as in ivv we noticed a strong potential for identification of the Mangue and Dense Ombrófila Forest ecosystems.

In the Dense Ombrófila Forest chart we noticed a strong stability of pixels α (between 100 and 150), β (in the 200NC range), and γ (between 100 and 150) – with the exception of 1984, an outlier. In Mangrove the graph is stable between 150 and 250, so that in all three PI nc levels did not exceed these values. The restinga in turn was not easily identifiable in ndvi.

Graph 7 - Spectral analysis of the Lowland Anthropophile Forest in NDVI images at gray (NC) levels

Source: Author (2020)

Graph 8 - Spectral analysis of restinga in NDVI images at gray (NC) levels
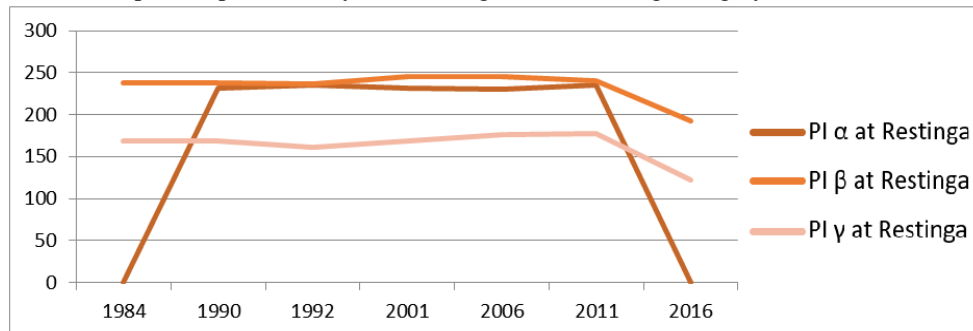
Source: Author (2020)

Graph 9 - Spectral analysis of mangrove in NDVI images at gray (NC) levels
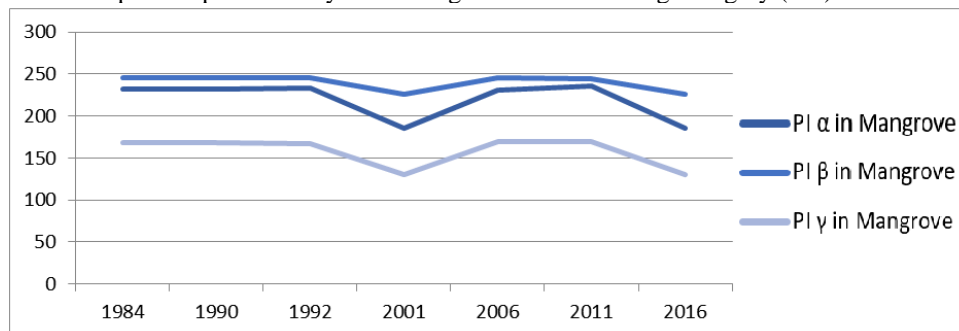
Source: Author (2020)

4.4 RESULTS: VEGETATION INDEX SOIL-ADJUSTED (SAVI)

In the Vegetation Index Soil-Adjusted (SAVI) the Dense Mbrófila Forest was not stable in the graphic results, as well as the Mangrove, which, despite having had a lower variability in the results than the Dense Mbrófila Forest, was also unstable. However,

Restinga was stable in all its pixels analyzed. Thus, we can highlight that SAVI is among the best indexes to identify restinga ecosystems.

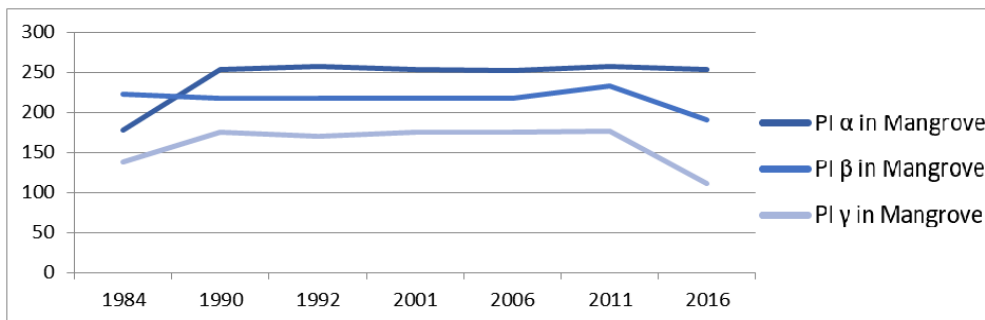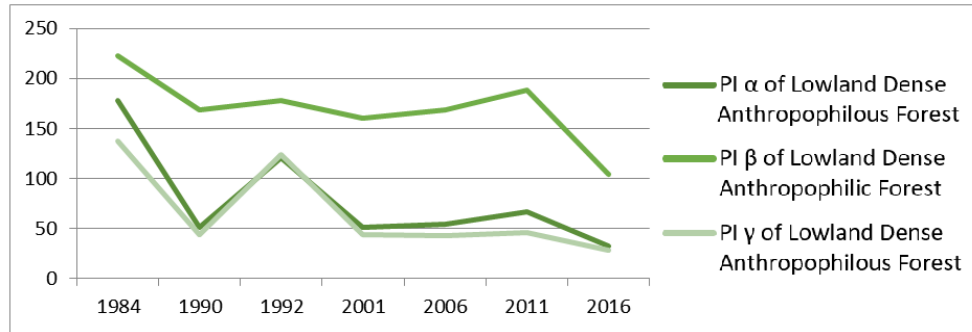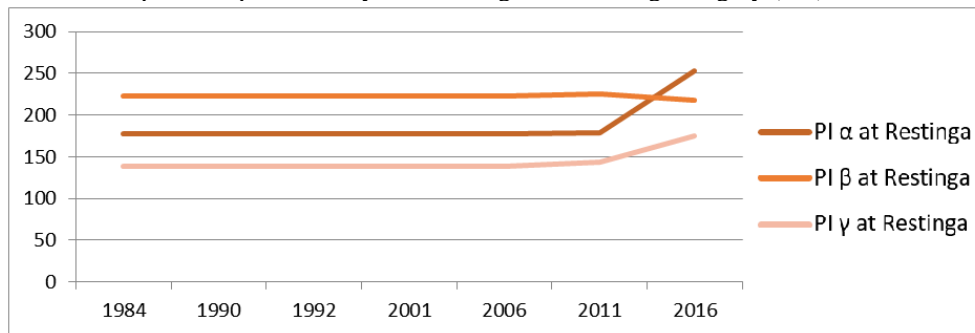Graph 10 - Spectral analysis of the Lowland Anthropophilic Forest in SAVI images at gray (NC) levels
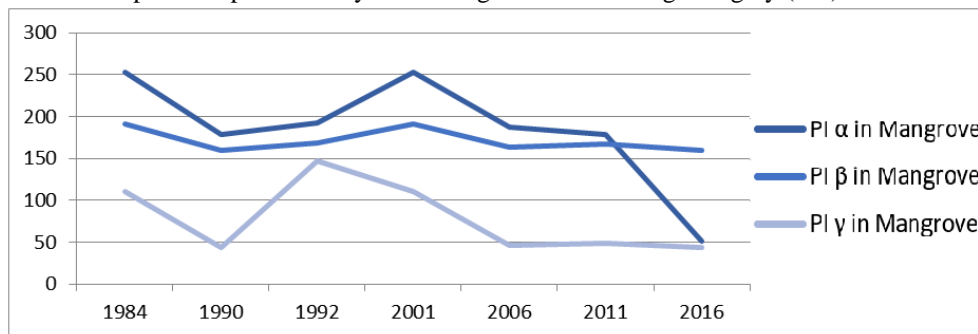

Source: Author (2020)

Graph 11 - Spectral analysis of restinga in SAVI images at gray (NC) levels
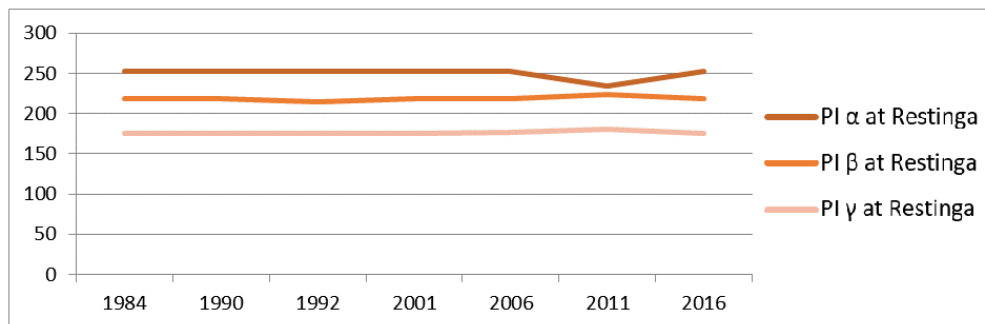
Source: Author (2020)

Graph 12 - Spectral analysis of mangrove in SAVI images at gray (NC) levels

Source: Author (2020)

4.5 RESULTS: ENHANCED VEGETATION INDEX (EVI)

As in the SAVI, in the Enhanced Vegetation Index (EVI) the Dense Mbrófila Forest and the Mangrove were not stable, both showed very marked variability in the different years. However, Restinga was stable, suffering some variations in 2016, i.e., with the image of Landsat 8. Even so, we can highlight that the EVI is among the best indexes to identify restinga ecosystems.

Graph 13 - Spectral analysis of the Lowland Anthropophilic Forest in EVI images at gray (NC) levels

Source: Author (2020)

Graph 14 - Spectral analysis of restinga in EVI images at gray (NC) levels

Source: Author (2020)

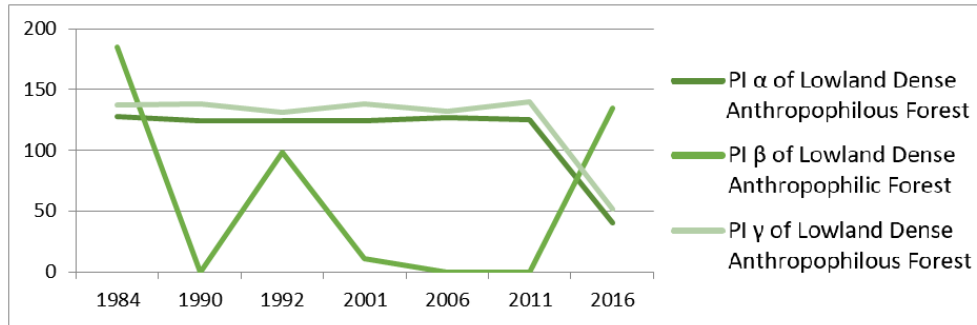Graph 15 - Spectral analysis of mangrove in EVI images at gray (NC) levels

Source: Author (2020)

4.6 RESULTS: NORMALIZED DIFFERENCE WATER INDEX (NDWI)

In the Normalized Difference Water Index, Mangue and Restinga were considerably stable, especially in the α and γ. Both, however, showed variations in the year 2016 with the image of Landsat 8, in the case of Restinga a variation lighter than that occurred in the Mangrove. The Dense Anthropophilous Forest in turn showed no stability, making marked variations.

Graph 16 - Spectral analysis of the Lowland Anthropophilic Forest in NDWI images at gray (NC) levels
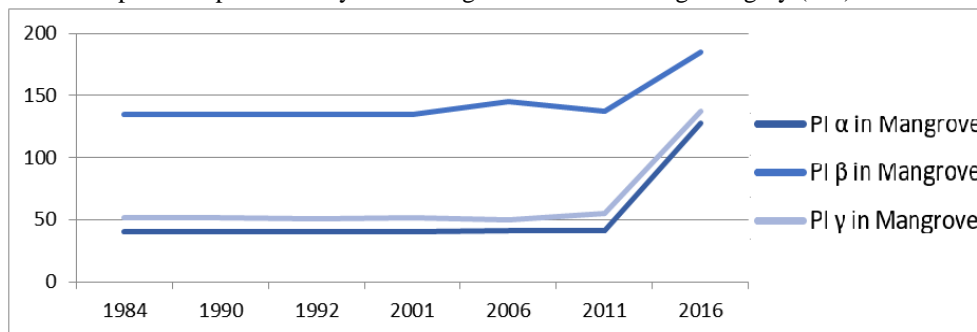

Source: Author (2020)

Graph 17 - Spectral analysis of restinga in NDWI images
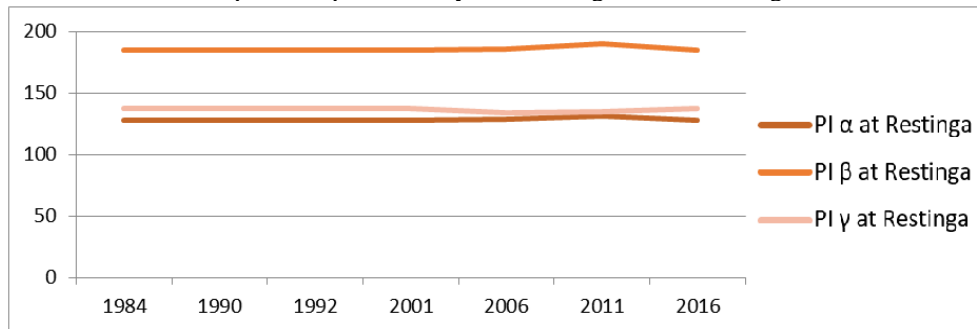
Source: Author (2020)

Graph 18 - Spectral analysis of mangrove in NDWI images at gray (NC) levels

Source: Author (2020)

## 4.7 RESULTS: ATMOSPHERIC PENETRATION (PA)

In Atmospheric Penetration, the Dense Ombrófila Forest proved to be considerably stable especially the Pixel α which was always very close to the 50NC line in all years, even in 2016 - images from Landsat 8. We can also highlight that Mangrove and Restinga proved to be instible, showed variation in the years 1984, 2001 and 2016.

Graph 19 - Spectral analysis of the Lowland Ambrosican Forest in the PA images at gray (NC) levels
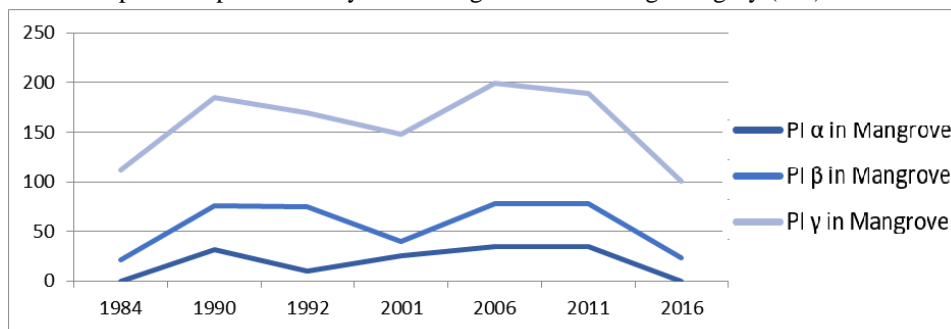

Source: Author (2020)

Graph 20 - Spectral analysis of restinga in PA images at gray (NC) levels
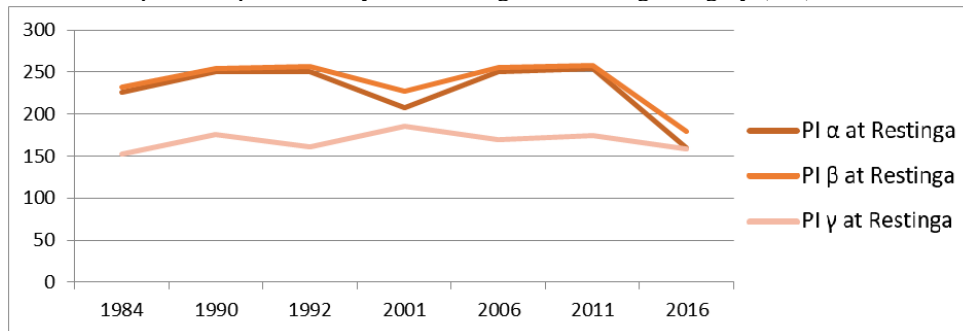
Source: Author (2020)

Graph 21 - Spectral Analysis of mangrove in PA images at gray (NC) levels

Source: Author (2020)

4.8 RESULTS: INDEX STACK (PI)

In the Index Stack, all ecosystems studied were not easily identified, not formulating a spectral identity, that is, varying in the years and consequently in the images of the satellites used.

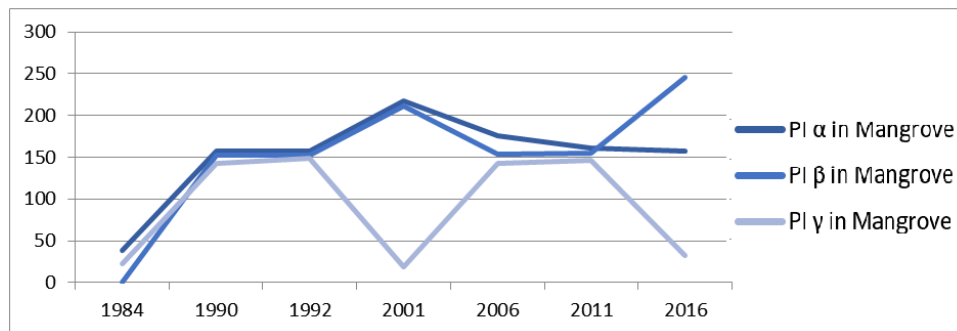Graph 22 - Spectral analysis of the Lowland Anthropophilic Forest in the PI images at gray (NC) levels

Source: Author (2020)

Graph 23 - Spectral analysis of restinga in PI images at gray (NC) levels
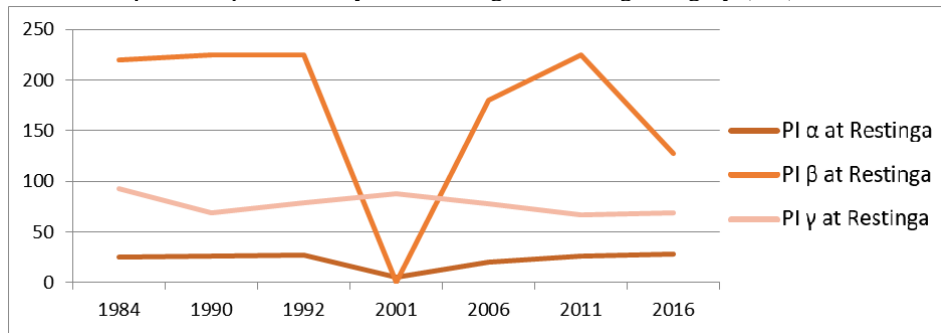
Source: Author (2020)

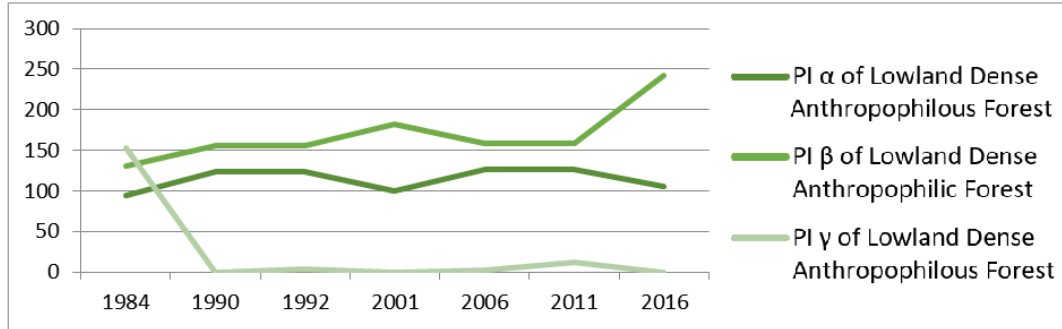Graph 24 - Spectral analysis of mangrove in PI images at gray (NC) levels

Source: Author (2020)

4.9 RESULTS: AGRICULTURE (AG)

In Agriculture (AG) the Dense Ombrófila Forest was not easily identifiable, varying mainly in the years 1984, 2001 and 2016. In addition, the γ had much of its data invalidated by the software, stagnating its values close to zero in the years 1990 to 2016. Just as the PI of the Dense Ombrófila Forest the γ of mangue also had its values close to zero. In Restinga, spectral behavior was stable and potentially identified, especially PI γ.

Graph 25 - Spectral analysis of the Lowland Anthropophilic Forest in ag images at gray (NC) levels
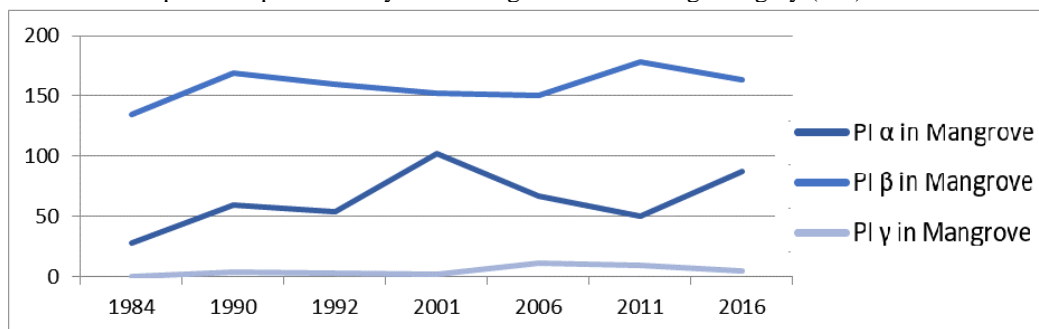

Source: Author (2020)

Graph 26 - Spectral analysis of Restinga in AG images at gray (NC) levels
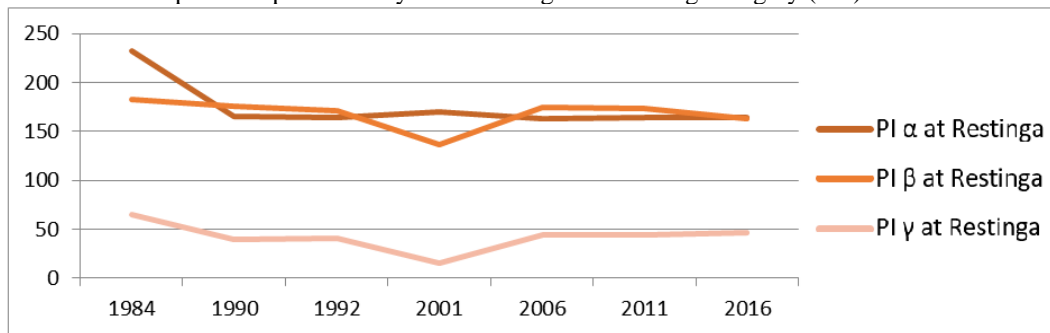
Source: Author (2020)

Graph 27 - Spectral analysis of mangrove in AG images at gray (NC) levels

Source: Author (2020)

5 DISCUSSIONS

The present work allows us to affirm that in the identification of the Dense Anthropophilous Forest the best combination is the PA (Pixel α), but we can also cite ndvi as a good combination.

The Mangrove in turn can be better identified in ivv (ranging from 150 to 220 NC) in the α PI and also in the pi β and PI γ varying in values very close to 50NC. Still in the mangrove we can also cite the NDWI as a good index.

With regard to restinga it is estimated that it can be identified in GA and EVI, but it is in SAVI, especially in the γ PI, which is more easily identifiable, and the NDWI is also extremely accurate in the β PI.

In addition, the development of the present study allowed us to realize that unfortunately it is not only institutionalizing a conservation unit that will preserve its

ecosystems, but it is extremely necessary for public policies aimed at the study of the areas still preserved so that it is possible to recover the degraded areas, as well as policies for monitoring the preserved areas so that they retain their integrity so that there is no decrease but a reduction, but a increase in special and consequently biological terms.

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