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CARBON STOCK IN FRAGMENTS OF THE BRAZILIAN ATLANTIC FOREST THROUGH VEGETATION INDEXES

[ver artigo online]

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ABSTRACT

Today, the fragmentation of the Atlantic Forest represents a limiting factor for the survival of several species and for the maintenance of the biodiversity and functionality of this ecosystem. Despite this, the Atlantic Forest has a great capacity for resilience and carbon stock, which justifies its successive self-regeneration and vigor. Understanding this ability to stockpile carbon is extremely important to assist in the conservation actions of forest remnants. In this perspective, the spectral calculation of CO2Flux translates the integration of the photochemical reflectance index (PRI and SPRI) that spectrally reproduces the efficiency of the use of light in photosynthesis and in turn the NDVI that spectrally describes the vigor of the vegetation synthetically active. One circumstance to be considered is that the CO2Flux methodology is not destructive, that is, it is not necessary to cut trees to estimate aspects related to carbon stock. In addition to the bibliographic research, to perform the spectral calculation methodology of CO2Flux, images of the Landsat 7 and Landsat 8 Satellite scans of the years 2000, 2005, 2010, 2015 and 2020 of the Environmental Protection Area of Guadalupe, in the state of Pernambuco, Brazil, were acquired, and through these was calculated the Vegetation Indexes: NDVI, PRI and SPRI and finally the CO2Flux thus translating the carbon stock on site. The results of the calculations can be seen through the maps and graphs, generated in the QuantumGis software and Statistical Language R, the potential of the Carbon Stock for the Guadalupe EPA in the years 2000, 2005, 2010, 2015 and 2020 corresponding to an area of 30231ha, 30876ha, 29515ha, 29997ha and 28811ha - respectively. Thus showing not only the carbon stock on site and effectiveness of the CO2Flux methodology to estimate the carbon stock, but also showing the increase in deforestation of the Atlantic Forest as a consequence of disordered urban occupation and selective deforestation. It is concluded the indispensability of making use of the methodology of spectral calculation of Carbon Stock and also of technologies such as Remote Sensing with the purpose of quantifying carbon sequestration from vegetation indexes in the Atlantic Forest, not only in the EPA of Guadalupe-PE as in all the native vegetation of the Preserved Atlantic Forest Biome of Brazil and the world.

Keywords: CO2flux, spectral calculus, vegetation indices, atlantic forest.

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RESUMO

Hodiernamente, a fragmentação da Mata Atlântica representa um fator limitante para sobrevivência de várias espécies e para manutenção da biodiversidade e funcionalidade desse ecossistema. Apesar disso, a Mata Atlântica possui uma grande capacidade de resiliência e estoque de carbono, que justifica a sua sucessiva auto-regeneracao e vigor. Compreender essa capacidade de estocar carbono é de extrema importância para auxiliar nas ações de conservação dos remanescentes florestais. Nessa perspectiva, o cálculo espectral do CO_2Flux traduz a integração do índice de reflectância fotoquímica (PRI e SPRI) que reproduz espectralmente à eficiência do uso da luz na fotossíntese e por sua vez o NDVI que descreve espectralmente o vigor da vegetação fotossinteticamente ativa. Uma circunstância a ser ponderada é que a metodologia CO_2Flux não é destrutiva, ou seja, não se faz necessário cortar arvores para estimar aspectos referentes ao estoque de carbono. Além da pesquisa da bibliográfica, para executar a *metodologia de cálculo espectral do CO_2Flux,* foi adquirido imagens do Satélite Landsat 7 e Landsat 8, dos anos de 2000, 2005, 2010, 2015 e 2020, da Área de Proteção Ambiental de Guadalupe, no estado de Pernambuco no Brasil, e através destas foi calculado o *Índice de Vegetação* NDVI, PRI e SPRI e por fim o CO_2Flux traduzindo assim o estoque de carbono no local. Como resultado dos cálculos pode-se vê através dos mapas e gráficos, gerados no software QuantumGIS e Linguagem Estatística R - respectivamente, a potencialidade de Estoque de carbono para a APA de Guadalupe nos anos de 2000, 2005, 2010, 2015 e 2020 que correspondem a uma área de 30231ha, 30876ha, 29515ha, 29997ha e 28811ha - respectivamente. Mostrando assim não apenas o estoque de carbono no local e eficácia da metodologia CO_2Flux para estimar o estoque de carbono, mas também mostrando o aumento do desmatamento da Mata Atlântica como consequência da ocupação urbana desordenada e desmatamento seletivo. Conclui-se à indispensabilidade de fazer uso da metodologia de cálculo espectral de Estoque de Carbono e também de tecnologias como o Sensoriamento Remoto com a finalidade quantificar o sequestro de carbono a partir de índices de vegetação na Mata Atlântica, não apenas na APA de Guadalupe-PE como em toda a vegetação nativa do Bioma Mata Atlântica preservada do Brasil e do mundo.

Palavras-chave: CO_2flux, calculo espectral, índices de vegetação, mata atlântica.

INTRODUCTION

The present research was carried out in the EPA (Environmental Protection Area) of Guadalupe on the South Coast of the State of Pernambuco. An area of 44,799 ha was analyzed, with central geographical coordinates: 8°42'22.75" 35°07'17.08". In the article in question, the Atlantic Forest Biome and its ecosystems of Dense Ombrophilic Forest, Mangue and Restinga were studied.

The creation of the EPA de Guadalupe by State Decree No. 19,635 took place on March 13, 1997 and aims to conserve and protect natural systems essential to biodiversity, especially water resources, protect ecosystems and sustainable development. However, on this date the Kyoto Protocol was not yet drawn up, which deals with studies on carbon sequestration and fixation.

Thus, it is understandable because State Decree 19,635/1997 makes no mention in any of its articles on Carbon Fixation in the EPA's forestry systems. And even with the revision of the Management Plan approved on December 13, 2017, through Ordinance No. 196/2017, Carbon Fixation actions were not commactized.

Therefore, this Project aims to add to the Management and Management Plan of the EPA de Guadalupe: initiatives related to the mitigation of climate change through the kidnapping and fixation of atmospheric CO_2 in native forest systems and reforestation; present alternatives to the Carbon Market and Clean Development Mechanisms for the continental area of the EPA, contributing to the reduction of deforestation and its emissions; encouraging the recovery and maintenance of ecosystem services and social benefits associated with good non-timber forest management practices.

General objective

Estimate the Carbon Stock in the Natural Forests existing in the EPA of Guadalupe in the time space from 2000 to 2020.

Specific goals

- Map the natural vegetation of the EPA of Guadalupe;
- Develop maps and graphs with carbon inventory estimation data;
- Indicate management and sustainability actions associated with ecosystem

services aimed at Carbon Fixation.

1 THEORETICAL FOUNDATION

1.1 The Atlantic Forest Biome

Biome is defined as a set of life consisting of the grouping of contiguous and identifiable vegetation types on a regional scale, with similar geological and climatic conditions in addition to its shared history of change, which results in its own biological diversity (IBGE, 2004). Presented by IBGE (2004), the Vegetation Map of Brazil reconstitutes the probable situation of vegetation at the time of discovery, mapping cartographically the scope of the six Brazilian continental biomes (Amazon, Cerrado, Caatinga, Atlantic Forest, Pantanal).

As explained in Federal Decree 750/93 is considered Atlantic Forest "the associated forest formations and ecosystems inserted in the Atlantic Forest domain, with the seguindes delimitations fixed by ibge's Brazil Vegetation Map: Atlantic Dense Ombrophilic Forest, Mixed Ombrophilic Forest, Open Ombrophilic Forest, Dense Ombrophilic Forest of Lowlands, Semideciduous Seasonal Forest, Deciduous Seasonal Forest, Mangroves, Restingas, Altitude Fields, Inland Swamps and forest encraves of the Northeast." According to Rizzini (1979) to distinguish well a plant formation it is necessary to take into account the structural (physiophilic) and floristic (compositional) aspects without leaving aside the characteristics and aspects of habitat.

However, unfortunately, there is not always clear, concise and secure information about many regions of the national territory, generating doubt in the attribution of categories. The Atlantic Forest is present both in the coastal region and in the plateaus and mountains from the interior of Rio Grande do Norte to Rio Grande do Sul, along the entire Brazilian coast. Its central area is in the great Serras do Mar and Mantiqueira, covering the states of São Paulo, Minas Gerais, Rio de Janeiro and Espírito do Santo (Rizzini, 1997). In the Northeast East, the Atlantic Forest occupies the restingas and, mainly, the formation of coastal boards, from Rio Grande do Norte to Alagoas. It is noteworthy that in the south of Pernambuco and in Alagoas, it also covers the coasts of the low mountains near the coast.

In the scenario placed by Leitão Filho (1987), the coverage of the Atlantic Forest was almost continuous, covering the coastal strip of varying width, going from Ceará to Santa Catarina. Moreover, Silva (1980) and Ogawa et al. (1990) say that this forest stretched along the coast from Rio Grande do Norte to Rio Grande do Sul. In turn, IBGE (1994) places that, in addition to being located along the Brazilian coast, the Atlantic Forest penetrated the interior of the country, covering almost all the states of Espírito Santo, Rio de Janeiro, São Paulo, Paraná and Santa Catarina, as well as parts of the states of Minas Gerais, Rio Grande do Sul and Mato Grosso do Sul. In this perspective, the Atlantic Forest presents a variety of formations, and encompasses a diverse set of forest ecosystems with very differentiated flower structures and compositions, following climate characteristics and Geographical.

It is a fact that in the places where there is the presence of this forest, there are great distinctions and edaphic and geological specifications, and the common element is exposure to humid winds blowing from the Atlantic Ocean.

The Atlantic Forest encompasses several forest ecosystems, with non-forest profiles. Because of this it occurs associated with the coastal ecosystems of mangroves, in the coves, mouth of large rivers, bays and lagoons of tidal influence; restingas, in the sandy coastal lowlands; mixed forests with araucarias, paraná and Santa Catarina; and the fields of altitude and rock, located at altitudes above 900 m, on the summits of the Serras da Bocaina, in Mantiqueira, caparaó, among others. Due to latitude, longitude, relief and climate, it presents variations in plant formations without losing, however, a certain floristic homogeneity (Barbosa & Thomas, 2002).

In this sense, it is explicit that the high biodiversity of the Atlantic Forest is a consequence of the environmental variations of the biome. This factor is corroborated by the variation is its extent in latitude, which covers 38º. Added to this, altitudinal variations are another important factor that contributes to the occurrence of high biological diversity, since the forests extend from sea level to an altitude of 1,800 meters. In addition, the forests of the interior differ considerably from the forests of the coast, providing a greater variety of habitats and niches. These factors together result in a unique diversity of landscapes, which are home to extraordinary biodiversity (CEPF, 2001).

Moreover, historically, it was the first forest to receive colonization initiatives, since it came out the first wealth to be exploited by the colonizers. Since the time several activities have developed in their territory or domain. The result of all the economic cycles that the Atlantic Forest went through was the almost total loss of the original forests and the continuous devastation and fragmentation of existing forest remnants, which puts the Atlantic Forest in a poor position of highlight, as one of the world's most endangered ecosystem sets. Mori et al. (1981), already believed to be this forest the tropical ecosystem, worldwide, in a more critical state of degradation.

According to cepf (2001), in the states that are part of the Central Corridor (Bahia and Espírito Santo) and serra do Mar (Rio de Janeiro, part of Minas Gerais and São Paulo), the proportions of remaining forests range from 2.8% in Minas Gerais to 21.6% in Rio de Janeiro. It is urgent to note that, unfortunately, deforestation rates are much more severe in the states of northeastern Brazil, where only 1 to 2% of the original coverage remains, with the majority remaining in the southern state of Bahia.

1.1.1 The Atlantic Forest in The State of Pernambuco

Soon as the process of settlement began the beginning of the Zona da Mata de Pernambuco, the sugarcane monoculture developed the basis of large deforested areas. In turn, with the progress of sugar production, the passage of banguês mills to plants, at the end of the 19th century and early 20th century, corresponded to an even more intense advance on native forest formations, since the greater production capacity required a greater supply of sugarcane. It also records in this period the development of rail transport that not only promoted new deforestation to give way to railways, but demanded the supply of wood for power generation (BEM et all, 2019).

In the Northeast Region,(CPRH, 2011) referred to the existence of only 2% of the original extension of the Atlantic Forest and reported that unfortunately the remaining vegetation area of centro Pernambuco represents 3.76% of the original vegetation.

A data of utmost importance for understanding the subject was published in 2007, this is the Final Report of the Survey of Native Vegetation Cover of the Atlantic Forest Biome (IESB, 2007) carried out from the scale mapping of 1:250,000, using images of the Landsat 7 satellite, ETM+ sensor (spatial resolution of 30m). The base year selected for mapping was 2002, with a easing of about a year. For the Northeast, due to the constant concentration of clouds, a 2004 SPOT 4 scene and 5 CCD/CBERS scenes from 2005 were also used, all with spatial resolution of 20m. This work had among its main conclusions that Pernambuco has 1,245.93 km² of forest remnants, representing 8.57% of the original domain of the Atlantic Forest (estimated at 17,104.48km²) and 198.18km² of pioneering formations (formations with marine or fluviomarine influence, i.e. mangroves and restingas), equivalent to 1.36% of the extent of the dominance of Atlantic ecosystems in the state (IESB, 2007).

But it is a fact that this estimate is overoptimistic, considering that many areas with tree cover in the domain of the Pernambuco Atlantic Forest are known to be exotic, cultivated or subspontaneous fruit trees, whose differentiation in relation to the original vegetation would be extremely difficult considering the resources employed (BEM et all, 2019).

With regard to the types of forests that are part of the Atlantic Forest in the Coastal-Forest Zone of Pernambuco, they present themselves as small and isolated fragments, with remnants corresponding to the following phytoecological regions, sensu IBGE (1992): Obrophilic Forest of the Lowlands and Submontana and Semideciduous Seasonal Forest of the Lowlands and Submontana. The subclasses of Ombróphilic and Seasonal formation are differentiated according to the climate (rainfall ratio x temperature) and the consequent adaptation of plants to soil water deficit. As for the formation itself is determined by the type of environment (form of relief) (IBGE, 1992). Restingas and mangroves are classified by IBGE (1992) as Pioneer Formations with marine influence (restinga) and fluviomarinha (mangroves).

On the South Coast, more specifically the Microregion of the Southern Forest, where the municipalities of Sirinhaém, Rio Formoso, Tamandaré and Barreiros are located, dominated the obrophilic forests, which unfortunately with the advance of anthropoization were reduced to fragments in areas of more difficult access, where the topography prevented the advance of sugarcane, in addition to the pioneering coastal formations.

According to Andrade-Lima (1970), pernambuco's coastal forests remained only a few relics, devastated, because they ended up being opened to housing areas or plantations of coconut trees, in sandy soils. In addition, this author reports as native species of this environment Manilkara salzmanni (maçaranduba), Tabeubia roseo-alba (pau d'arco or peroba), Andira nitida (Angelim), Ocotea gardneri (laurel), Licania tomentosa (beach oiti), Cou (goiti), Schinus terebinthifolius (beach tree), Talisia esculenta (pitombeira), Eschweilera ovata (embiriba), Birsonima sp (murici), some of them possible to be observed in the remaining fragments, in addition to the important forming element of these matas, the Anacardium occidentale (cashew), today much found as a cultivated species or as a result of natural regeneration in anthropized area.

Through studies carried out by the vegetation and flora of the EPA de Guadalupe, it was indicated the presence of remnants of natural vegetation with high biological richness, finding 252 plant species from 95 families in fragments of ombróphilic forest, restinga and mangrove (CPRH, n.d).

The CPRH (n.d) found in the forest surveys carried out in the fragments, that the most numerous tree species most of the remnants were Tapirira guianensis; Thyrsodium schomburgkianum; Byrsonima sericea; Vismia guianensis; Eschweilera ovata; Himatanthus phagedaenicus and Pera glabrata. The occurrence of Tabebuia cf. avellanedae (purple arch stick) stood out; Manilkara salzmanni (maçaranduba); Sloanea obtusifolia (mamajuda); Lecythis pisonis (sapucaia) and Bowdichia virgilliodes (sucupira) as species of high logging value found in these fragments, with different densities.

Moreover, a relevant aspect addressed in the above-mentioned study was the composition of vegetation, forming small riparian forests – as will be shown further in this work, consisting mainly of Symphonia globulifera (milk bulandi), Richeria grandis (bulandi-de-jaca), Inga sp (ingás), Henrietia succosa and Simarouba amara (praíba), as well as several species of Araceae and Bromeliaceae, this phytophysonomy restricted to small stretches.

One of the main fragments visited in the research was Saltinho Biological Reserve, between Rio Formoso and Tamandaré, where the presence of Tapirira guianensis (cupiúba or pigeon stick), Buchenavia capitata (embiridiba or mirindiba), Protium hepthaphyllum(amescla), Himathantus sp (parrot banana), Thyrsodium chomburgkianum (milk caboatã), Cupania racemosa (rego caboatã), Eschweilera ovata (embiriba), Vismia guianensis (lacre), Casearia sp (coffee), Pogonophora schomburgkiana (cocão), Pouteria sp (dairy), Manilkara dardanoi (maçaranduba), Saccoglotis mattogrossensis (bat oiti), Byrsonima sericea (murici), Pera glabrata (seven hooves) and Parkia pendula (visgueiro) among many others, almost always surveys of secondary formations of the Atlantic forest of the Pernambuco South Forest.

1.2 The Electromagnetic Spectrum

For the complete understanding of Sensing as a science, it is essential to know that there are regions of the Electromagnetic Spectrum (EME) where the atmosphere hardly affects electromagnetic energy, that is, the atmosphere is "transparent" to The REM from the Sun or the earth's surface. These regions are known as atmospheric windows. In these regions are placed the REM detectors, and therefore where remote sensing of terrestrial objects is performed (Steffen and Moraes, 1993).

In this research and in the vast majority passive sensor systems where the main source of radiation is the sun, whose radiant energy is distributed along an electromagnetic spectrum (EmSe). Through the atmosphere electromagnetic radiation - REM is propagated, undergoing changes in its intensity and spectral distribution. Reaching the target, the incident REM suffers an interaction process characterized by the phenomena of absorption, reflection and transmission. Anawing in turn the fraction of REM reflected or emitted will again cross the atmosphere, undergo new modifications and reach the sensor, located in earth's orbit (Silva, 1997).

An indispensable term to be mentioned is reflectance spectroradiometry, which consists of a remote sensing technique that records the flow of electromagnetic radiation reflected by objects, in this case the soil, with no physical contact between sensor and target. Thus, the amount of energy reflected by a soil is a function of three factors: the incident electromagnetic energy, which can be coming from the sun or a lamp; the amount of energy absorbed and the amount of energy transmitted (Stoner & Baumgardner, 1986). This relationship is established as follows: $R\lambda = I\lambda - (A\lambda + T\lambda)$, so that R is reflectance at a certain wavelength (λ), I is the incident energy, A is absorbed energy and T is transmitted energy. The amount of reflected radiation (radiance) compared to the incident quantity (irradiance) on the soil provides the measurement of reflectance captured by sensors, called radiometers or spectrometers.

Thus, these sensors detouem the incident radiation at different wavelengths the relative intensity of energy reflected by the object can be measured in a stable manner along the electromagnetic spectrum (Novo, 1992), thus providing a numeric data set or charts known as curves or spectral signatures.

1.2.1 Spectral Signature

One circumstance to be considered is that the spectral signature of a target can be defined as a cluster of the successive values of object 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 is that characterize the object (Steffen and Moraes, 1993).

The targets interact in a differentiated way spectrally with the electromagnetic energy incident, because the objects present different physicochemical and biological properties, that is, it is a fact that the different ecosystems will have a behavior differentiated between them. These different interactions are that they allow the distinction and recognition of the various remotely sensory terrestrial objects, as they are recognized due to the variation in the percentage of energy reflected in each wavelength (Steffen and Moraes, 1996).

1.3 Guadalupe Environmental Protection Area

Created under State Decree number 19,635, on March 13, 1997, the Guadalupe Environmental Protection Area was intentionally made official. Located in the municipalities of Sirinhaém, Rio Formoso, Tamandaré and Barreiros, the EPA covers a total area of 44,799 ha (forty-four thousand, seven hundred and ninety-nine hectares). However, it is noteworthy that there is a part of its territory that is in continental area, corresponding to 32,135 there is, and another stretch corresponding to three nautical miles of the Atlantic Ocean - 12,664 ha.

One circumstance to be considered is that the EPA aimed at the objective of its creation: "protecting and conserving natural systems essential to biodiversity, especially water resources, aiming at improving the quality of life of the local population, protection of ecosystems and sustainable development" (art. 2 of State Decree No. 19,635).

Figure 1 - Location Map of the Environmental Protection Area of Guadalupe, Pernambuco - BR

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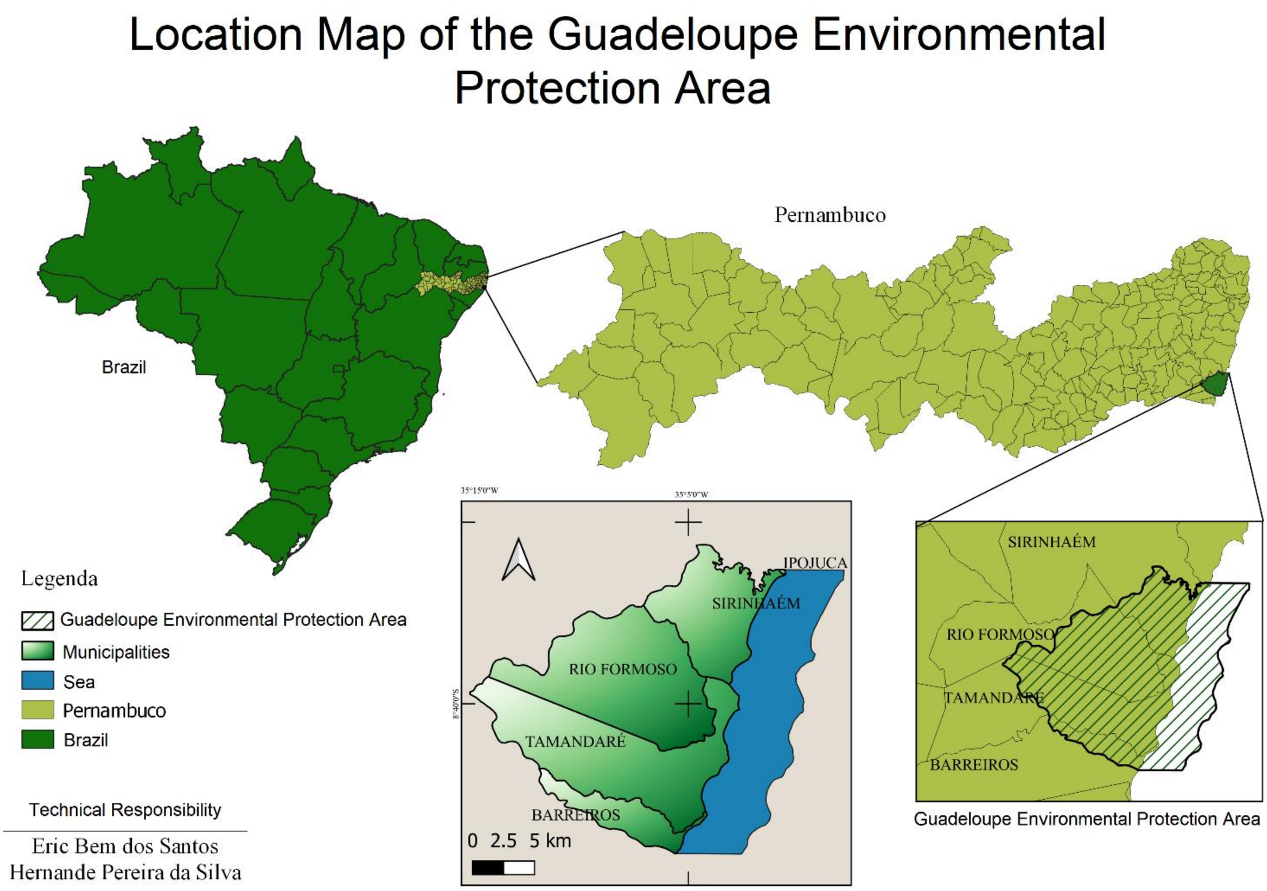

Source: Author (2020)

2 MATERIAL AND METHODS

This research was developed in the Environmental Protection Area of Guadalupe, as previously seen that is located in the municipalities of Ipojuca, Sirinhaém, Rio Formoso, Tamandaré, Barreiros and Ipojuca on the South Coast of the State of Pernambuco. An area of 44,799 ha was analyzed, corresponding to the area of the EPA, with a central geographic coordinate: 8°42'22.75" 35°07'17.08". Composed of the Atlantic Forest biome, in the terrestrial area, and the marine ecosystems in the sea region (FRANÇA et all, 2019).

At first, a bibliographical review was carried out in order to find studies, and thus to become aware of what was scientifically produced about carbon sequestration and carbon stock, especially in the Atlantic Forest areas, and also in the areas of Atlantic Forest, and also on other relevant subjects . The most technical review focused on the methodologies of nondestructively measuring the potential for carbon capture by the biome in question. To this end, documentary research was carried out in academic articles, master's theses and studies

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promoted by state agencies. Thus, it was defined that the "CO_2Flux Methodology" would be used to calculate the estimation of carbon stock in the study area.

Moreover, the acquisition of satellite images of the Landsat series with the lowest percentage of clouds and the years relevant to a correct temporal sive analysis was performed. These images were intended to calculate the vegetation indices that are needed to calculate CO_2Flux and consequently measure the carbon stock of the Guadalupe EPA from remote sensing data. The images used are technically characterized in the table below:

Satellite	Date	Code
Landsat 7	2000/05/29	LE07_L1TP_214066_20000529_20170211_01_T1_B3,B2,B1_M_[-36.5916,-9.6184,-34.5208,-7.734]
Landsat 7	2005/04/25	LE07_L1TP_214066_20050425_20170115_01_T1_B3,B2,B1_M_[-36.6329,-9.6552,-34.5572,-7.7639]
Landsat 7	2010/11/12	LE07_L1TP_214066_20101117_20161212_01_T1_B3,B2,B1_M_[-36.57035,-9.61235,-34.50201,-7.74602]
Landsat 7	2015/04/21	LE07_L1TP_214066_20150421_20161027_01_T1_B3,B2,B1_M_[-36.54847,-9.6122,-34.48007,-7.74637]
Landsat 8	2020/01/21	LC08_L1TP_214066_20200121_20200128_01_T1_B4,B3,B2_M_[-36.5424,-9.72837,-34.47161,-7.63101]

Source: Author (2020)

To generate the data, the following steps were followed: NDVI generation, PRI generation, after pri correction is performed for numerically positive data with SPRI. In possession of the SPRI and NDVI, CO_2flux is elaborated, calculated with the multiplication of these two variables. In this way, the capacity of the Guadalupe EPA as a CO_2 "hijacker" will be quantified. In addition to this process, it was of fundamental importance the field visits (Figure 2 and 3) carried out for the acquisition of GPS points (Global Position System), ratifying the information generated by the calculation of CO_2Flux, in order to attest to the existence of healthy vegetation on site.

Figure 2 - Field visits to the areas indicated in CO_2Flux.

Source: Author (2020)

Figure 3 - Field visits to the areas indicated in CO_2Flux.

Source: Author (2020)

It is of fundamental importance to know a little about the satellites used in the research, i.e. the satellites d Landasat series:

2.1 Landsat Satellites

Undoubtedly one of the main remote sensing programs. In view of their spectral bands, the images can be used for studies of vegetation cover and soil temperature. Thus, the first sensor of this Program was the MSS (Multispectral Sensor Scanner) with spatial resolution of 80 meters. From 1984 came another important sensor of the Program, the TM sensor (Thematic Mapper), whose spatial resolution is much better than the resolution of the Sensor AVHRR/NOAA. The average altitude of LANDSAT satellites is 705 km making an almost polar orbit of 98.2 degrees and heliossynchrony in 98 minutes, performing approximately 14 revolutions per day.

2.1.1 Landsat 7

Like Landsat 5, landsat 7's U.S. artificial ground research satellite comes from a cooperation between NASA and the USGS, both of which are u.S. government research agencies. The present research used only one image of the Landsat 7 satellite to perform the spectral analysis of the year 2001.

Landsat 7 was sent into orbit by the Delta II 7920 rocket on April 15, 1999, at Vandenberg Air Force Base in western California, United States (INPE, 2014).

2.1.2 Landsat 8

In addition to the two satellites mentioned above, Landsat 5 and Landsat 7, Landsat 8 was also used in this research, being more accurate for spectral analysis of the year 2016 (most recent year of analysis). This being an American earth observation satellite as well as the others in its line, is the eighth in the landsat program's satellite succession and the seventh to correctly reach Earth orbit. It was launched on February 11, 2013 (INPE, 2014).

2.2 Vegetation Indices

One of the best known practices of geoprocessing is the analysis of vegetation and detection of changes that are usually used in order to evaluate natural resources and monitor, especially vegetation cover.

Today, the quantification of green vegetation is one of the main applications of Remote Sensing in decision making, environmental management and phytogeographic studies.

From this perspective, it is important to describe the vegetation combinations and indices used in the present study. It is also worth showing the "pure" and pre-processed images acquired for use in the search.

2.2.1 Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI), which in Portuguese means Normalized Difference Vegetation Index is used in various applications such as crop monitoring, drought effects detection, pest infestation, crop estimates, productivity, hydrological modeling, crop mapping and natural vegetation cover monitoring. In this index, the vegetation cover tends to have a green tint and the other targets vary from yellow to intense red (LANDVIEW, 2019).

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

Where:

NIR = near infrared reflectance;

RED = reflectance of the red band of the visible spectrum.

2.2.1 Photochemical Reflectance Index (PRI)

Photochemical Reflectance Index is used to evaluate changes in carotenoid pigments of foliage, being calculated with the relationship between the blue and green bands. Pigments are indicative of the efficiency of the use of photosynthetic light or the carbon dioxide rate stored by foliage per unit of absorbed energy. The values vary between -1 and 1, and common values for healthy vegetation are between -0.2 and 0.2 (GAMON et al., 1992). The rescheduling of the PRI index is necessary to stay on the same scale as the NDVI and thus be combined through a multiplication that will result in CO_2flux (Rahman et al, 2000).

$$PRI = \frac{(B-G)}{(B+G)}$$

Where:

G - is the green band reflectance;

B - is the reflectance blue band.

2.2.1 Rescaled Photochemical Reflectance Index for Positive Values (sPRI)

One circumstance to be weighed is that pri index values need to be rescaled to positive values used in carbon sequestration calculation. This new index is called sPRI and varies between 0 and 1 (BAPTISTA, 2004, 2003)

$$sPRI = \frac{(PRI+1)}{2}$$

3 RESULTS AND DISCUSSION

Today, based on the five acquired and processed images of the Landsat satellite series, the calculations of vegetation indices were performed and it was possible to calculate and map CO_2Flux and thus stretch the carbon stock, with data from 2000, 2005, 2010, 2015 and 2020 of the Guadalupe EPA.

What was evident was the continuous increase in deforestation of healthy floreta areas in 2000 (Ficura 5), the first year measured in the research, the area of carbon stock was 30231ha, already in 2005 (Ficura 6), five years later, this area was with 30876ha of fl healthy oreta, that is, there had been a slight increase that may be related to the water regime of the messes that preceded the image and not directly linked to a reforestation.

However, from 2005 onwards, the decrease was continuous since in 2010 (Figure 7) the carbon stock area of the Guadalupe EPA was already 29515ha. Also, due to hydrological regime, since we have no record of forest regeneration in any of the forest fragments monitoring the area, hears an increase in carbon stock in 2015 (Figure 8) compared to the last year measured previously (2010), with an area of 29997ha.

In turn, in 2020 (Figure 9) we had the lowest value of healthy forest area, capable of storing carbon, 28881ha. These data show the continuous progress of anthropization, whether performing indiscriminate, selective deforestation or allotment of areas with real estate objectives. These previously cited data can be best seen in the following chart (Figure 4):

Figure 4 - Atlantic Forest Area that stocks carbon (2000 - 2020)

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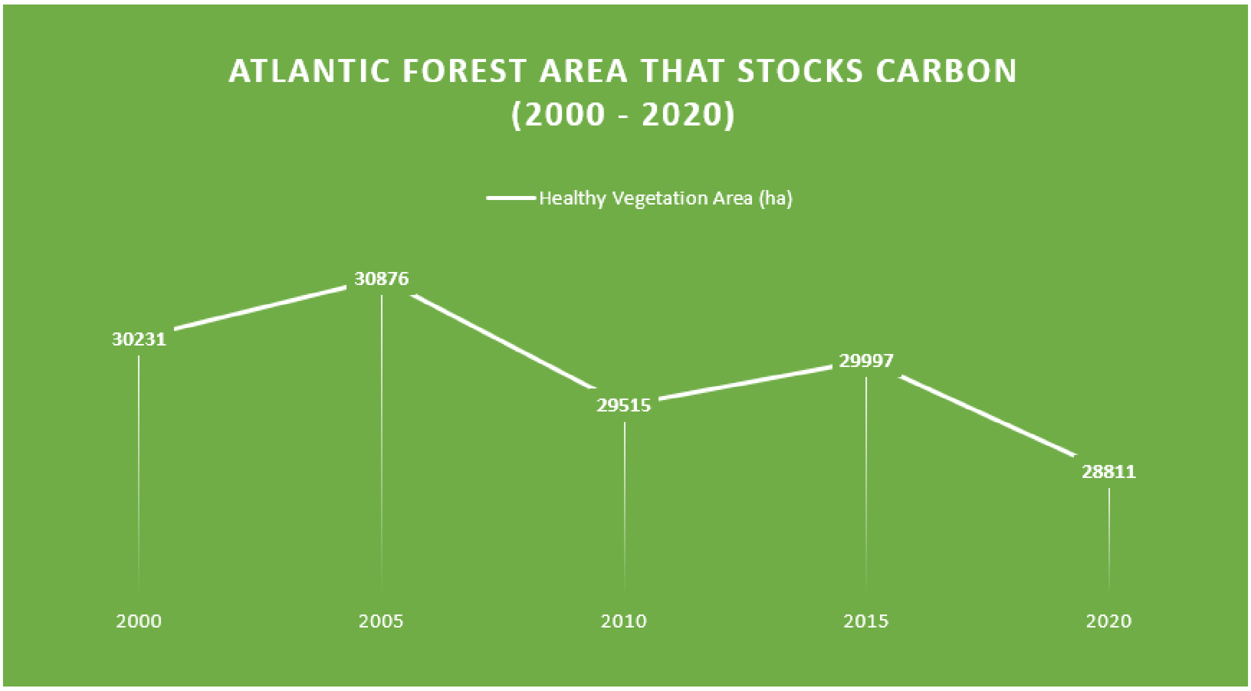
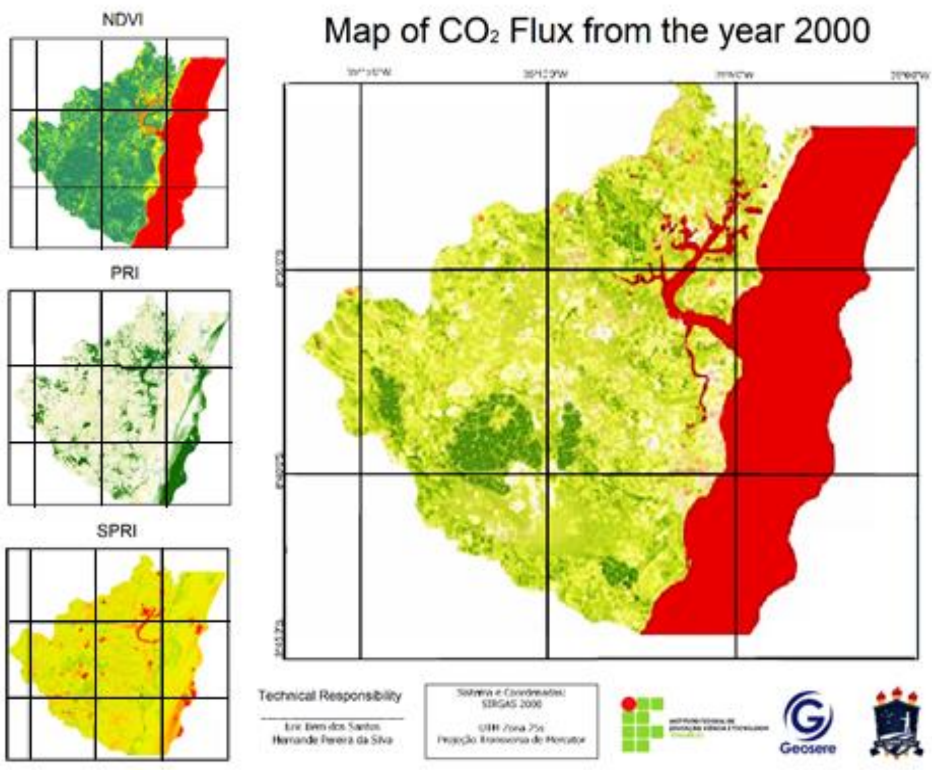


Source: Author (2020)

Figure 5 - Map of CO_2 Flux from the year 2000



Source: Author (2020)

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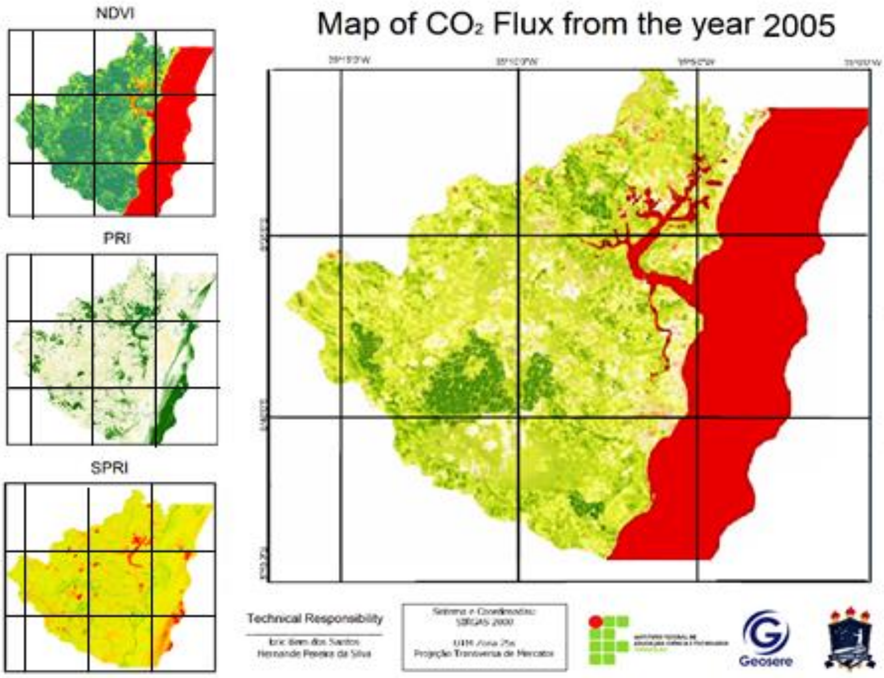
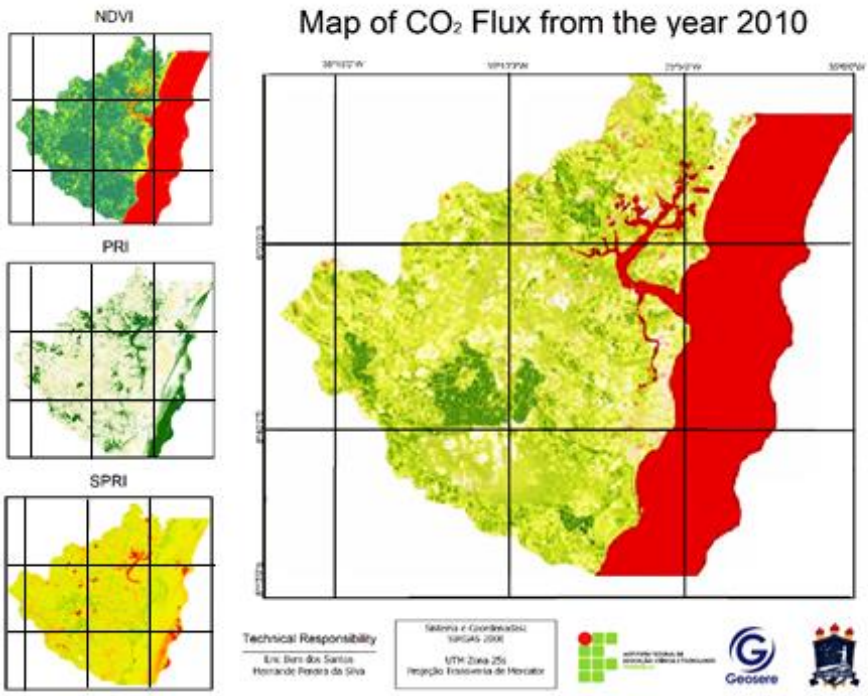
Figure 6 - Map of CO2 Flux from the year 2005



Source: Author (2020)

Figure 7 - Map of CO2 Flux from the year 2010



Source: Author (2020)

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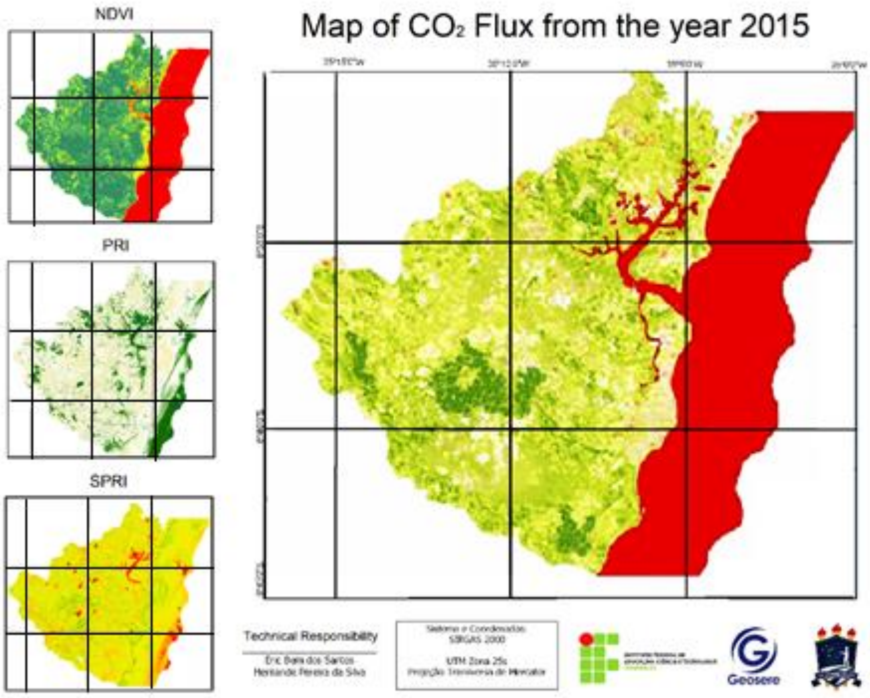
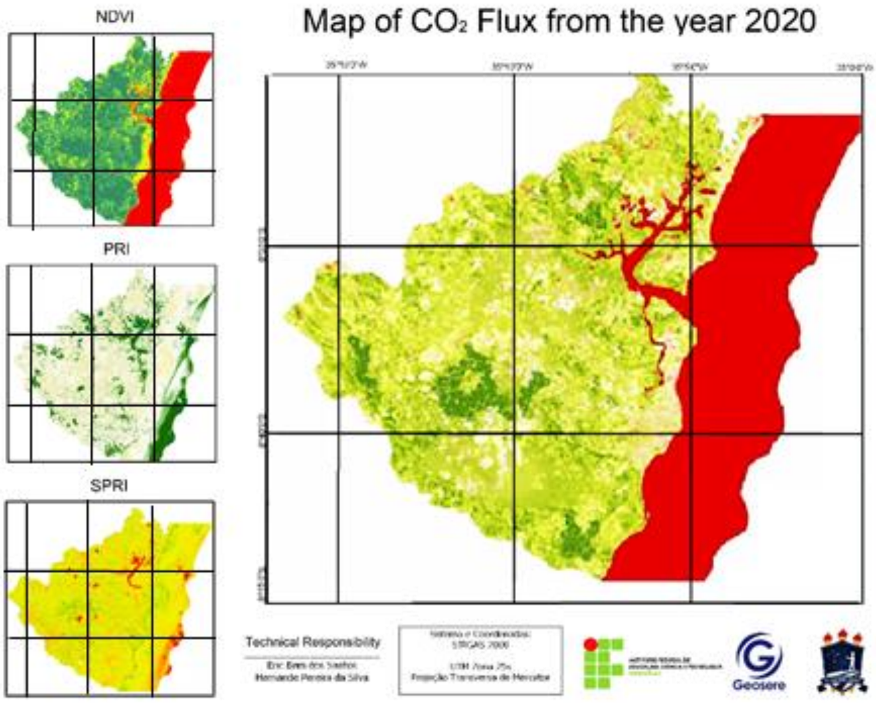
Figure 8 - Map of CO2 Flux from the year 2015



Source: Author (2020)

Figure 9 - Map of CO2 Flux from the year 2020



Source: Author (2020)

CONCLUSIONS

It is concluded that the spectral calculation that integrates photochemical reflectance and photosynthetic vegetation through the Flux CO2 Methodology has been shown to be an extremely important remote sensing product in the evaluation of the spectral behavior of vegetation in relation to its carbon stock conditions, and can be used to not only evaluate the carbon stock potential but also to monitor in a space-time way the fragments of the Atlantic Forest Biome within the Guadalupe EPA, more can also be applied in a multitude of areas, biomes and ecosystems.

Moreover, in this study, using images from landsat 7 satellite and Landsat 8 satellite and respective calculations of Normalized Difference Vegetation Index (NDVI), Photochemical Reflectance Index (PRI) and Rescaled Photochemical Reflectance Index for Positive Values (sPRI), it can be perceived that there was a continuous and marked degradation of the areas of vegetation cover capable of stocking carbon. It is estimated that this degradation is closely related to real estate speculation that occurs intentionally on the South Coast of the State of Pernambuco.

One circumstance to be considered is that this work was of unparalleled value to the Environmental Protection Area of Guadalupe, since this Conservation Unit, like many others, is the result of the CONAMA Resolution that reaffirms the need to proceed to zoning ecological and economic, standardizing the use and occupation of the region, thus protecting and conserving natural systems essential to biodiversity, aiming at improving the quality of life of the local population, the protection of ecosystems and the development Sustainable.

Similarly, together with the concern to protect biomes, concern swelled about global warming, so during Eco-92 in Rio de Janeiro. In this event, an international regime was signed with the aim of stabilizing greenhouse gas emissions.

Thus, the importance of the carbon stock theme by forests and cleaner development mechanisms that reduce gas emissions is more exalted, as well as the importance of this article to successfully apply Remote Sensing and Geographic Information System, in order to quantify the carbon stock from vegetation indices in the Environmental Protection Area of Guadalupe.

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