# Chapter 206

## The use of NDVI derived from Pléiade images in the analysis of the vegetation structure in two forest fragments

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**ABSTRACT**
The vegetation index generated through satellite images is one of the most used data in monitoring the structural parameters of vegetation in different ecosystems existing in Brazil. In this work, the characterization of the NDVI was carried out using Pléiades images with a spatial resolution of 2 meters with four spectral bands, in two forest areas corresponding to the municipality of Moju-PA whose location is 3º03'14,85409" south latitude and 48º59'36,15357" west longitude and another in the city of Belém-PA located at 1°26'30" S latitude and 48°27'0" W longitude. Image processing was done through the Global Mapper software. The maximum value of the NDVI for the densest vegetation reached 0.654 while the average value was 0.500 for managed forest area located in Moju-PA. In the other forest fragment located within Embrapa Amazônia Oriental, the maximum value of the NDVI indicated a reflectance value of 0.849, and the average value reached approximately 0.790. The profile of the vegetation curve generated through Pléiades images showed a positive behavior for the two forest fragments, being in the range of (0.401 to 0.654) for f forest managed from Moju-Pa and from (0.736 to 0.849) for the secondary forest of Belém-PA. Based on the observed results, it can be concluded that the NDVI, derived from Pléiades satellite images, can be used reliably in the analysis and determination of the NDVI.

**Keywords:** Images, Pleiades, Vegetation Structure, NDVI.

## 1 INTRODUCTION

In general, forests stand out in the global environmental panorama because they perform an important ecosystem service, that is, forests can store carbon in their biomass, aerial and underground, in quantities greater than those existing in the atmosphere (Vieira *et al.*, 2008; Ipcc, 2000).

With the advancement of technology in the area of remote sensing and image processing, there has been an improvement in the association of the characteristics of the structure and dendrometric parameters of vegetation with reflectance data, as well as the development of vegetation indices from satellite images that have helped in the estimates of the desired parameters (Watzlawick *et al*. 2009).

According to Watzlawick (2003), when compared to the usual methods, the use of images with the high spatial resolution is a more economically viable alternative, less harmful to the environment, and with good accuracy to estimate the biomass of plant communities, since the reflectances have a good relationship with the content of dendrometric parameters.

The increased availability of Remote Sensing data, along with the development of Geographic Information Systems (GIS), has led to new possibilities for geographic analysis, both on a local and global scale (Nielsen, 2015).

The simple obtainment of NDVI and its direct relationship with the photosynthetic capacity of vegetation is an intermediate for studies related to essential plant characteristics and functions such as photosynthetic radiation fraction absorbed by the canopy, leaf area, gross primary productivity, with numerous applications in agriculture, forestry, ecology, biodiversity, environmental analysis, such as nutrient cycling, net primary productivity, evapotranspiration, change of environmental components, among others (Ponzoni, *et al.*, 2012; Robinson *et al.*, 2017).

It is worth mentioning that the vegetation indexes from satellite images can indicate the environmental quality of a region. The indexes were created to highlight the spectral behavior of the vegetation to the terrain and facilitate the monitoring of preserved areas or even the efficiency of recovery techniques for degraded areas (Moreira, 2011).

Vegetation indices are correlated with various vegetation parameters, such as volumetry and biomass (Huete, 1988). Although several vegetation indices have already been developed, numerous studies approve the efficiency of the Simple Ratio (SR) and the Normalized Difference Vegetation Index (NDVI), widely used (Brandão *et al.*, 2005). NDVI is the abbreviation of the English expression for Normalized Difference Vegetation Index, which is equivalent in Portuguese to Normalized Difference Vegetation Index. It serves to analyze the condition of natural or agricultural vegetation in the images generated by remote sensors.

NDVI is successfully used to classify global vegetation distribution, infer ecological and environmental variability, biomass production, active photosynthetic radiation, and crop productivity (Liu, 2007).

It is worth mentioning the study produced by Bernardes (1996), who used vegetation indices to characterize forests in the Flona de Tapajós, another study that deserves to be highlighted was by Amaral *et al.*, (1996), where they related vegetation indices with secondary growth stages in the Amazon Rainforest in Rondônia.

Knowledge of the structure of the forest canopy is essential to improve understanding of forest structure, both for ecological purposes, the distinction of habitats, as well as to analyze functional variables (Korhonen *et al.*, 2006). In this sense, remote sensing data has played an important role in the monitoring of forest areas, as it enables the mapping of large areas (Devries *et al.*, 2015).

In this sense, forest ecosystems need to be preserved and researched, a study produced by Costa *et al.*, (2021), points out the need for the expansion of Conservation Units to mitigate the impacts on Amazonian ecosystems. Given that biodiversity patterns require techniques that capture the complexity and dynamics of communities and ecosystems (Magurran, 2013). Therefore, these ecosystems need to be conserved and studied more often.

For Ravazzano *et al.*, (2021), the application of satellite monitoring of the forest protection zone and the application of the use of NDVI in the analyzed images, can generate information for the public power, about the real dimensions of deforestation and illegally occupied areas, as well as of the local biotic quantity, and the health of plants, being possible a rapid response of the State, in the prevention of illicit acts, consequently, avoiding that the destruction of the ecosystem is too extensive and contributing to the maintenance of the primary protection zone.

In this sense, to contribute to the knowledge of the structure of the forest cover where several forest species are inserted, in particular the copaibeiras, this study aims to understand the behavior of the vegetation through the NDVI images derived from the Pléiades images in the forest fragments.

## 2 METHODOLOGY

### 2.1 LOCATION OF THE STUDY AREA

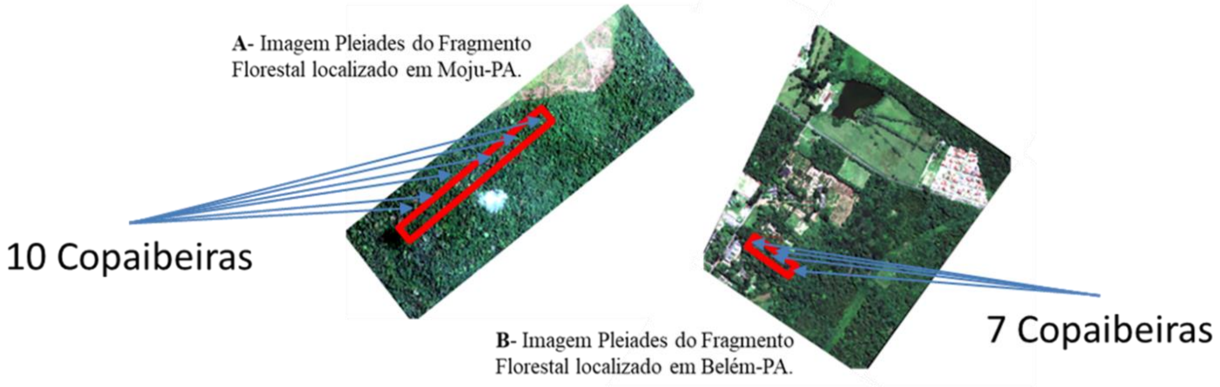
The study was conducted in two fragments of forest areas, the first fragment is located on the São Roque Agroecological farm, between the geographical coordinates 3º03'14.85409" south latitude and 48º59'36.15357" west longitude, in the municipality of Mojú-PA associated with the Managed Forest (Figure 1). Despite being located in this municipality the farm Agroecológica São Roque is bordering the municipality of Thailand with entrance by the right bank (direction Belém / Marabá of PA-150), vicinal 18, northeast of Pará.

The climate is of the Ami type (humid hot) according to the Köpen classification, with average annual temperature ranging between 25ºC and 27ºC and the average annual precipitation ranging from 2,000 mm to 3,000 mm.

The other study area is located in the city of Belém-PA, has an area of 05 hectares of secondary forest, established in the garden of medicinal plants of Embrapa Eastern Amazon, located at 1°26'30" S latitude and 48°27'0" W longitude, with an altitude of 10 meters and average annual temperature of 30°C (Figure 1).

The climate in Belém, according to the Köppen classification (1900-1936) is of the Afi type, i.e. tropical rainy monsoon climate. The average annual rainfall is 2,858.7 ± 76.6 mm/year with the highest volume in the rainy season (December to May), corresponding to 71.2% of the annual total, while the remaining 28.8% is distributed from June to November (Silva Junior *et al.*, 2012).

Figure 1. Clipping of the images Pléiades associated with the Managed Forest vegetation in Moju-PA (Image A) and Image B the secondary forest located in Embrapa Eastern Amazon




(Source: Photo Authors 2021).

The methodology consisted of obtaining data from images generated by the *Pléiades* satellite, with a high spatial resolution of 2 meters and with 4 spectral bands acquired through Engesat with the total dimension of scene 20x 20km. Then for created a buffer around the copaibeiras to identify the profile of the forest structure from the NDVI data through the random 50-point samples in the images.

All procedures were performed in a GIS environment, *using the* Global Mapper software. For NDVI generation, images of orthorectified Pléiades with atmospheric correction were used. Satellite images of this class are offered at the highest levels of processing available.

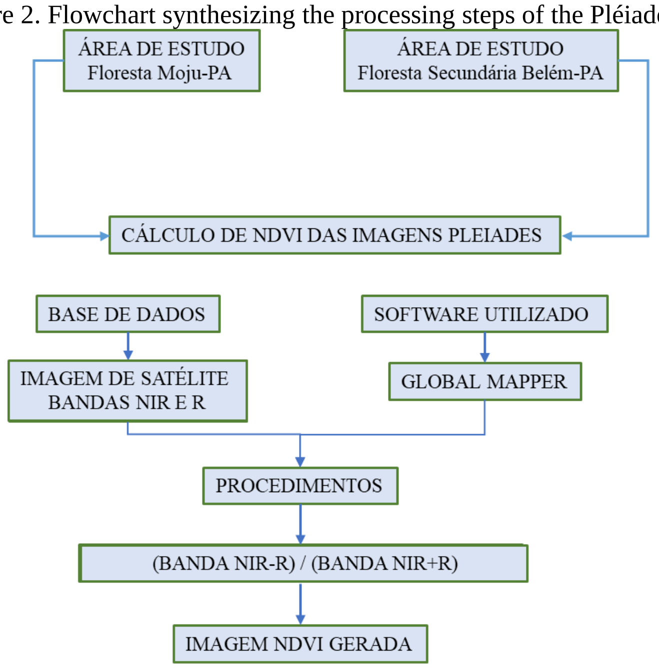
The vegetation indexes were estimated for each image of the *Pléiades* satellite, acquired on May 26, 2021 (Belém-PA) and October 10, 2020 (Moju-PA) for the forest cover fragment located in Moju-PA. Because they are high-resolution images, no type of treatment was performed since the scene used presented high quality for the study performed.

The constellation of the *Pléiades* system is composed of two small satellites of great agility that are capable of acquiring daily images of very high spatial resolution in any region of the planet.

The *Pléiades* satellite has four spectral bands, that is, Blue: 430-550 nm, Green: 490-610 nm, Red: 600-720 nm, and Infra-Red next: 750-950 nm, which has a spatial resolution of 2m, with the pixel covering an area of 4 m² (Embrapa, 2013).

This study has a quantitative approach as Estrela (2018) explains, quantitative research is a research modality composed of variables quantified in numbers that are analyzed statistically. The flowchart below summarizes the processing steps using the images from the Pléiades satellite in the two areas of study (Figure 2).

Figure 2. Flowchart synthesizing the processing steps of the Pléiades images.




(Source: Authors 2021).

For this study, the four spectral bands mentioned above were used, and based on these bands, the NDVI vegetation indices were estimated. The Normalized Difference Vegetation Index (NDVI) proposed by (Rouse *et al*., 1973, p. 309) is calculated by the following relationship:

NDVI = (NIR – R) / (NIR + R) where,

NIR: Reflectance of vegetation in the near-infrared band;

A: Reflectance of vegetation in the red band.

NDVI values range from -1 to 1, so the closer to 1 the higher the density of vegetation cover, so the lower the density of vegetation the lower the value of NDVI (Polonio, 2015; Ponzoni & Shimabukuro, 2007).

## 3 RESULTS AND DISCUSSION

From the generation of NDVI data derived from the Pléiades images for the two study regions, the reflectance levels of the vegetation of the forest fragments were characterized. The reflectance intervals of the NDVI spatially distributed in Figure 4, associated with the forest fragments of the Moju-PA area, which were generated through 50 samples taken from the NDVI image, reveal that the most representative visual elements are those of positive values, which suggests the presence of vegetation cover, the NDVI values were grouped into four classes and their respective surface targets identified in Table 1.

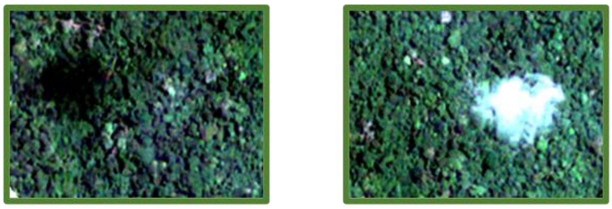
Table 1. NDVI ranges correspond to their respective surface classes.

| Fragment of Managed Forest (Moju-PA) | | |
|---|---|---|
| **NDVI intervals** | **Classes** | **Surface targets** |
| (-0.055 to -0.223) | Class 1 | Areas without vegetation |
| (-0.022 to 0.1019) | Class 2 | Clouds |
| (0.625 to 0.704) | Class 4 | Shadow |
| **(0.401 to 0.654)** | **Class 5** | **Vegetation** |

(Source: Authors 2021).

As suggested by the NDVI intervals, the negative values group the areas without vegetation (Class 1), in the image associated with the forest fragment of Moju-PA, there was the presence of clouds (Class 2) and a shade (figure 3). In this same area, the NDVI of the vegetation showed an average value of 0.500 of reflectance, with a maximum value of 0.654 (Table 1).

Figure 3. Areas with the presence of clouds and shadows on top of the forest fragments are located in Moju-PA.




(Source: Authors 2021).

A study produced by Barros *et al.*, (2020), highlighted the results that the NDVI pointed out for the vegetative coverage of Juazeiro do Norte, with a maximum value of 0.60901. This value close to 1 (one) indicates a good amount of dense vegetation cover. Thus, the application of the NDVI was relevant to identify how the current situation of the municipality regarding its vegetation, since this index can assist in decision-making by public management in environmental planning since it works as an indicator of green areas.

However, when we look at the classes associated with the NDVI intervals corresponding to the forest fragments of the Secondary Forest (Belém-PA), the data indicate a higher reflectance value for secondary vegetation, approximately 0.849 (Table 2). In the image of Belém-PA, there was no presence of clouds and shadows.

Table 3. NDVI ranges correspond to their respective surface classes.

| Fragment of Secondary Forest (Belém-PA) | | |
|---|---|---|
| **NDVI intervals** | **Classes** | **Surface targets** |
| (-0.01338 to -0.0791) | Class 1 | Areas without vegetation |
| (-0.032 to - 0.1039) | Class 2 | Water |

| | | |
|---|---|---|
| **( 0.736 to 0.849)** | **Class 3** | **Vegetation** |

(Source: Authors 2021).

It is worth mentioning that the results range from -1 to +1 per pixel, so the closer to +1, the higher the density of the vegetation. In the forest fragment located in Moju-Pa, the data showed a maximum reflectance of NDVI of 0.654 (**Table 2**). As this value decreases, the vegetation becomes thinner, and the closer to -1, the greater the evidence of the presence of uncovered soils. (Poelking *et al.*, 2007; Melet *al*., 2011).

When we analyzed the data associated with the mean deviation of the reflectances for the two study areas, we identified a very low deviation value for the vegetation, pointing out that on average the data have low oscillation in the vegetation class (Table 3).

Table 3. NDVI ranges correspond to their respective surface classes.

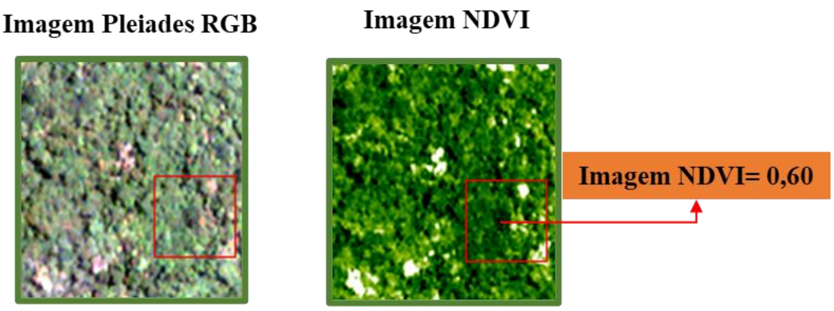
| Forest Fragment | Average | Maximum | Minimum | Mean Deviation |
|---|---|---|---|---|
| Managed Forest (Moju-PA) | 0,500 | 0,654 | 0,401 | 0,049 |
| Secondary Forest (Belém-PA) | 0,790 | 0,849 | 0,736 | 0,025 |

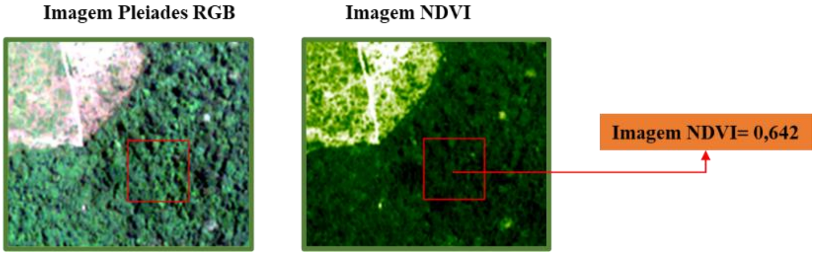
(Source: Authors 2021).

The figure below demonstrates exactly this characterization of positive for areas with forest vegetation (Figure 4) and negative for areas without forest cover (figure 5), collaborating with the studies produced by Barbosa et al., (2017), which recorded the highest values of NDVI, with reflectance values grouped between (0.29 to *0.69*), indicating that sites of high photosynthetic activity, is associated with the presence of denser green vegetation. A study produced by Melo *et al*., (2011) clarifies that the higher the value of the vegetation index, the denser the green phytomass.

Another study produced by Oliveira & Aquino (2020), pointed out that the areas that show negative trends, coincided mainly with those of change of land cover class, indicating a reduction of vegetation and an increase of the exposed soil area respectively. These findings demonstrate that the NDVI analysis is adequate to detect areas of vegetation change and its use in environmental management as a way to achieve sustainability and maintenance of the environment is relevant.

Figure 4. The vegetation cover of the forest fragment located in Moju-PA indicates an NDVI above 0.60.



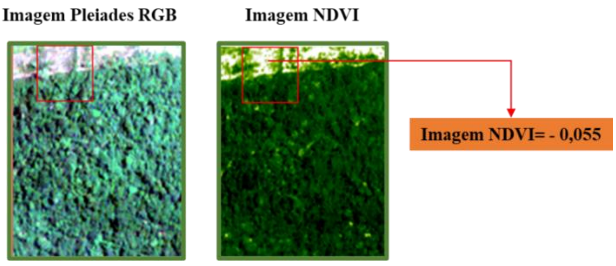



(Source: Authors 2021).

The areas without vegetation recorded in Table 1, whose reflectance intervals are in the range of (-0.055 to -0.223), are characterized in the images as being areas without the presence of any forest cover (Figure 5). This negative reflectance information of the NDVI that characterizes the absence of vegetation, was also pointed out by the study of Barbosa *et al.*, (2017), where he states that this spectral behavior corresponds to the presence of uncovered soils, rocks, urbanized areas, and other areas without vegetation.

A study produced by Baptista (2020), pointed out that the NDVI portrayed a reduction in value over the years, which may indicate a lower photosynthetic activity of vegetation cover in the Environmental Protection Area (APA) on the Costa Brava in Santa Catarina.

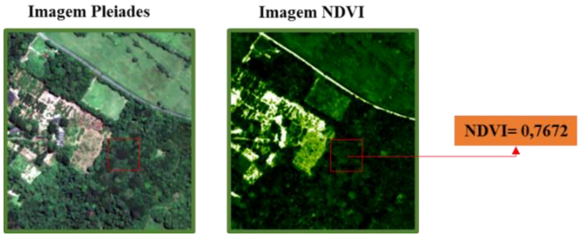
Figure 5. Areas without vegetation are located in Moju-PA indicating a negative NDVI of -0.055 reflectance.




(Source: Authors 2021).

The secondary forest located in Embrapa Eastern Amazon presented a high NDVI, as shown in Figure 6. According to Barbosa *et al.*, (2017), the relationship between NDVI and the aforementioned spectral bands is based on the spectral signature of plants. In this way, the portions absorbed in the red and reflected in the infrared vary according to the conditions of the plants. The greener, nourished, healthy, and well-supplied from a water point of view the plant is, the greater the absorption of red and the greater the reflectance of infrared. In this way, the difference between the reflectances of the red and infrared bands will be greater the greener the vegetation.

Figure 6. Highlighted is a point of the secondary forest (Belém-PA) with an NDVI above 0.767.

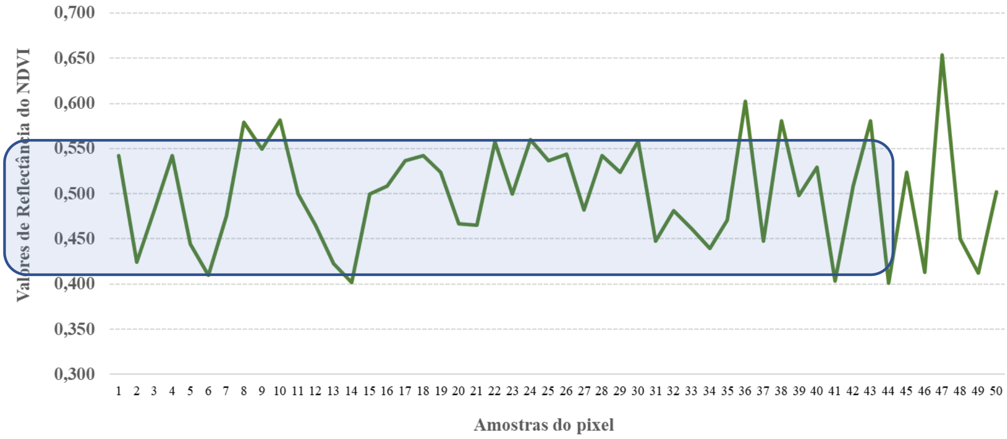



(Source: Authors 2021).

A study produced by Pioltine *et al.*, (2018), which applied the NDVI on the vegetation cover of the Serra da Mantiqueira APA, located overlapping part of the states of São Paulo, Rio de Janeiro, and Minas Gerais, to know the evolution of vegetation cover over 31 years, from 1986 to 2017, the areas that demonstrate a low quality probably due to the intensive agricultural use, contributing to the average values of vegetation quality, as the conservation of vegetation with NDVI close to 0.75 which shows that there is conservation of APA.

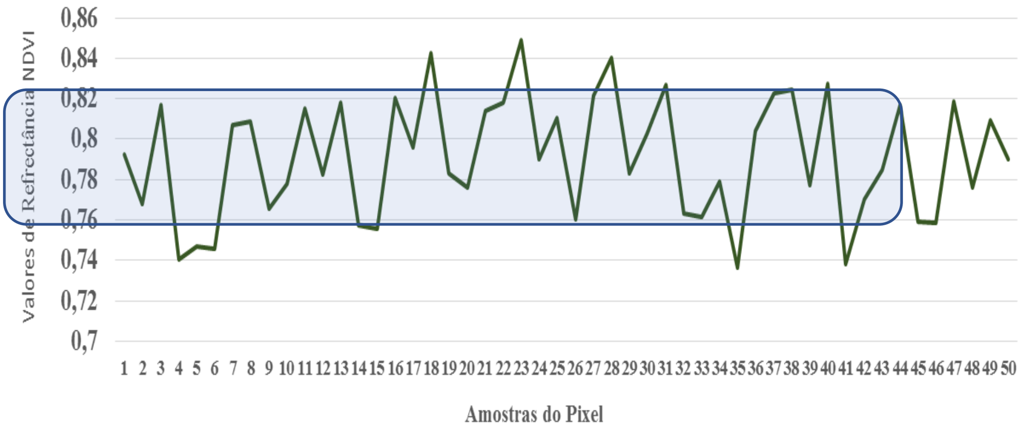
Through the behavior of the profile of the reflectance values (generated through the collections of 50 points) derived from the NDVI of the Pléiades images, they indicate that more than 88% of these values were concentrated in the range of 0.450 to 0.550 in the forest fragment of Moju-PA (Figure 6). Regarding the fragment of secondary forest located in the city of Belém-PA, approximately 86% of the data were concentrated in the reflectance range above 0.76 (Figure 7).

Figure 7. NDVI distribution concentrating 88% in the reflectance range above 0.420 in the fragment of the managed forest of Moju-PA.




(Source: Authors 2021).

Figure 7. NDVI distribution concentrating 86% in the reflectance range is above 0.76 in the fragment of the secondary forest of Belém-PA.




(Source: Authors 2021).

A study produced by Luz *et al.*, (2021), in the fragments of a Seasonal Semideciduous Alluvial Forest located in the Hydrographic Basin of Córrego Padre Inácio in the State of Mato Grosso, pointed out seasonal variations in this type of forest fragment, the NDVI ranged from 0.5 in the driest months, to 0.9 of reflectance in the months of the occurrence of a greater volume of water.

## 4 CONCLUSION

The normalized difference vegetation index (NDVI) applied to the Pléiades satellite images proved to be a simple methodology with wide applicability, besides being extremely useful in studies of environmental analysis of vegetation by remote sensing.

The profile of the vegetation curve generated through the Pléiades images showed a positive behavior for the two forest fragments, being in the range of (0.401 to 0.654) for the managed forest of Moju-Pa and from (0.736 to 0.849) for the secondary forest of Belém-PA.

The classes of surfaces for the fragment of the managed forest were areas without vegetation, cloud, shade, and vegetation, in the second study area the classes of areas without vegetation, water, and vegetation in the secondary forest were identified.

Regarding the data of minimum and maximum reflectance in the two areas of study, the NDVI was higher in the secondary forest, indicating a value of approximately 0.736 and 0.849 respectively with an average of 0.790. Obtaining spatially detailed vegetation information is of paramount importance for sustainable forest management, as it is a number that translates the condition of natural vegetation.

However, we suggest for the next studies the use of a larger time series to monitor seasonal variations over the years, concerning the drier and wetter period of each region associated with its vegetation index.

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