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NDVI AND TERRESTRIAL SURFACE TEMPERATURE ANALYSIS USING THE GOOGLE EARTH ENGINE PLATFORM IN THE AMAZON SAVANNA AND SECONDARY FOREST AREA, IN VIGIA - PA

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Abstract

The Amazonian Savanna is an ecosystem in need of scientific studies on the effects of changes in land use and the temperature of the earth's surface. Moreover, secondary forests in the Amazon are areas that can be affected by land use changes, given their border relationship with the savanna. Therefore, this study aimed: i) analyze the Normalized Difference Vegetation Index (NDVI) in regions of amazonian savanna and secondary forest and ii) verify the behavior of the surface temperature of the land in the municipality of Vigia, State of Pará using the Google Earth Engine (GEE) platform. The choice of the municipality of Vigia is justified due to its territory containing savanna and secondary forest ecosystems and suffering human pressure due to the inflection of agricultural activities over the years. The results of the study revealed that the Earth's surface temperatures in Vigia revolve around 28.91 °C (minimum) and 31.71 °C (maximum). In addition, NDVI close to 1 in secondary forest areas, except for the year 2014 (0.23) show that despite human changes in the land, ecosystem conserve a good part of their vegetation, where the GEE platform is able to assist in planning and monitoring of savanna and secondary forest areas.

Keywords: Forest; Google Earth Engine; Savanna; Temperature.

ANÁLISE DE NDVI E TEMPERATURA DA SUPERFÍCIE TERRESTRE UTILIZANDO A PLATAFORMA DO GOOGLE EARTH ENGINE EM ÁREA DE SAVANA AMAZÔNICA E FLORESTA SECUNDÁRIA, NO MUNICÍPIO DE VIGIA – PA

Resumo

A Savana Amazônica é um ecossistema com carência de estudos científicos sobre os efeitos das mudanças de uso da terra e da temperatura da superfície terrestre. Além disso, as florestas secundárias na Amazônia são áreas que podem ser afetadas pelas mudanças de uso da terra, haja vista o seu relacionamento fronteiriço com a savana. Neste sentido, o presente estudo teve como objetivo: i) analisar o Índice da Vegetação por Diferença Normalizada (NDVI) em regiões de Savana amazônica e floresta secundária e ii) verificar o comportamento da temperatura superficial da terra no município de Vigia, Estado do Pará utilizando a plataforma Google Earth Engine (GEE). Justifica-se a escolha do município de Vigia devido o seu território comportar ecossistemas de savana e floresta secundária e sofrer pressões humanas devido à inflexão de atividades agropecuárias ao longo dos anos. Os resultados do estudo revelaram que as temperaturas da superfície terrestre em Vigia giram em torno dos 28,91°C (mínima) e 31,71°C (máxima). Além disso, os NDVI próximos de 1 em áreas de floresta secundária, exceção do ano de 2014 (0,23) mostram que apesar das mudanças antrópicas na terra, o ecossistema conserva boa parte de sua vegetação, onde a plataforma GEE se mostra capaz de auxiliar no planejamento e monitoramento de áreas de savana e floresta secundária.

Palavras-chave: Floresta; Google Earth Engine; Savana; Temperatura.

ANÁLISIS DE NDVI Y TEMPERATURA DE LA SUPERFICIE DE LA TIERRA UTILIZANDO LA PLATAFORMA GOOGLE EARTH ENGINE EN UN ÁREA DE LA SABANA AMAZÓNICA Y EL BOSQUE SECUNDARIO, EN EL MUNICIPIO DE VIGIA – PA

Resumen

La sabana amazónica es un ecosistema que necesita estudios científicos sobre los efectos de los cambios en el uso del suelo y la temperatura de la superficie terrestre. Además, los bosques secundarios en la Amazonía son áreas que pueden verse afectadas por los cambios en el uso de la tierra, dada su relación fronteriza con la sabana. En este sentido, el presente estudio tuvo como objetivo: i) analizar el Índice de Vegetación de Diferencia Normalizada (NDVI) en regiones de sabana amazónica y bosque secundario y ii) verificar el comportamiento de la temperatura superficial de la tierra en el municipio de Vigia, Estado de Pará utilizando la plataforma Google Earth Engine (GEE). La elección del municipio de Vigia se justifica debido a que su territorio contiene sabanas y ecosistemas forestales secundarios y sufre la presión humana debido a la inflexión de las actividades agrícolas a lo largo de los años. Los resultados del estudio revelaron que las temperaturas de la superficie de la Tierra en Vigia giran alrededor de 28.91 ° C (mínimo) y 31.71 ° C (máximo). Además, los NDVI cercanos a 1 en áreas de bosque secundario, excepto en 2014 (0.23) muestran que a pesar de los cambios antrópicos en la tierra, el ecosistema conserva una buena parte de su vegetación, donde la plataforma de GEI puede asistir en la planificación y monitoreo de sabanas y áreas de bosque secundario.

Palabras-clave: Bosque; Google Earth Engine; Sabana; Temperatura.

1. INTRODUCTION

The Savanna is conceptualized as a xeromorphic vegetation, which occurs in different climatic conditions. This floristic formation presents a characteristic vegetation of the Amazonian forest, adapted over time to the aluminum Oxisols and even to the Quartzarênic Neossols, through the migration of xeromorphic forest species that were changing through new leached environments (IBGE, 2012; TOGNON et al., 1998). Savanna is subdivided into four training subgroups: Forested, Arborized, Park and Grassy - woody (IBGE, 2012).

This ecosystem is dispersed throughout the Amazon biome in the middle of the vast forest, inserted mainly in the states of Amapá, Amazonas, Pará and Roraima, being named Amazonian Savannahs. These areas are mosaic-shaped, interrupted by natural forest fragments (FEITOSA et al., 2016), having an important role in the functioning and maintenance of natural resources.

Despite their importance for the Amazon biome, savanna areas have been disturbed due to the dynamics of land use associated with the expansion of agricultural activities, and the increase in population (SILVA; OLIVEIRA, 2018). This process took place from the end of the 1980s and is linked to the development model adopted by the states of the Brazilian Amazon that stimulated economic growth by making the use of natural resources in the region more flexible (DINIZ, 1998).

In the same way, secondary forests have also been affected by human changes, as they border the savanna. These changes can compromise the various environmental services offered by the forest, such as the removal of atmospheric carbon responsible for the greenhouse effect and the supply of organic matter and food for the local fauna (NOBRE; NOBRE, 2002).

In this scenario, digital image processing tools have facilitated spatial studies that involve changes in land use and coverage, detecting and preventing inappropriate land use in forest regions. The Google Earth Engine (GEE) fits into these tools, being an innovative remote sensing processing platform, developed by the company Google (HOROWITZ, 2015). This tool allows multitemporal and spatial analysis in a fast and efficient way through JavaScrit and Python programming languages (FERREIRA et al., 2017).

Concomitantly, the Normalized Difference Vegetation Index (NDVI) is being used to measure the chlorophyll activity of the vegetation, analyzing the forest cover for various periods of time through satellite images. This index is a model resulting from the combination of reflectance levels in satellite images, which come from the equation composed of the responses of the spectral bands of red and near infrared (RAMOS et al., 2010).

In addition to vegetation cover, technologies aimed at the processing of satellite images have been useful for monitoring the Earth's surface temperature (PIRES, 2015). The surface temperature, refers to the heat flow given as a function of the energy that reaches and leaves the target, being an important variable for understanding the interactions between the atmosphere and the Earth's surface (FERREIRA et al., 2017). Through the use of remote sensing and geoprocessing techniques it is possible to detect changes in the spectral responses of surface targets, as well as to evaluate the temperature in the most diverse natural resources (water, soil, vegetation) in order to carry out an appropriate regional planning (PEREIRA et al., 2015).

In general, understanding the changes in land cover, with emphasis on vegetation and the mutual benefits between ecosystems (savanna and secondary forest) are fundamental to improve the management of local natural resources. Therefore, this article aims to analyze the Normalized Difference Vegetation Index (NDVI) and to verify the behavior of the land surface temperature (LST) in an area of Amazonian Savanna and secondary forest through the Google Earth Engine (GEE) platform in the municipality of Vigia - PA.

2. METHODOLOGY

2.1. Study area

The Amazonian Savanna and Secondary Forest areas investigated are located in the municipality of Vigia-PA (Figure 1). The municipality has an area of 539.1 km² (IBGE, 2019) and has a municipal headquarters with the following geographical coordinates: 0º 51 'south latitude and 48º 08' west longitude (SEPOF-PA, 2010).

The municipality of Vigia has high rainfall of about 2,770 mm per year as a climatic characteristic. The first six months of the year are the rainiest and the months of September and October are the least rainy, coinciding with the period of the Amazonian summer. The region of the municipality as a whole has an average temperature of 27ºC (tropical-equatorial climate) (IDESP, 2011).

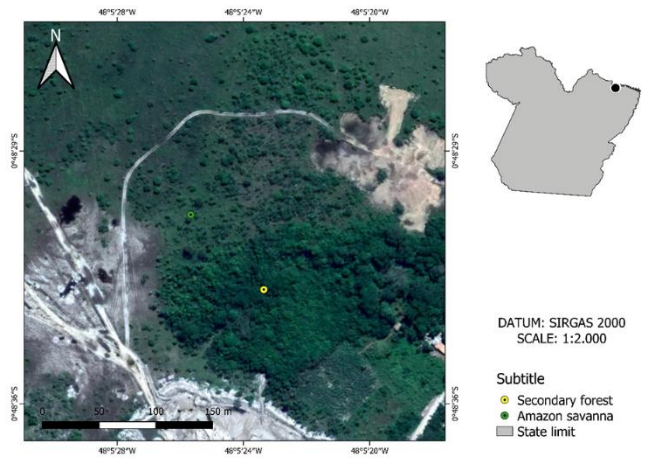

Figure 1 - Location map of the study area. Source: Authors.

2.2. Development and Use of LANDSAT-8 and MODIS images

Landsat 8 satellite images (LANDSAT / LC08 / C01 / T1_TOA) were used for the NDVI analysis, from 2013 to 2018. For the analysis of the surface temperature, MODIS satellite images were used (MODIS / 006 / MOD11A2 - LST_Day_1km), from 2009 to 2018. Both collections available on the Google Earth Engine (GEE) platform. The choice of different satellites aimed to present different sources of environmental data, which can be applied in different modalities of analysis of land use (agriculture, pasture, urbanized area, etc.).

The points used as samples for the survey of the Normalized Difference Vegetation Index (NDVI) and the land surface temperature (LST) of the soil are: 0 ° 48'32.77 "S 48 ° 5'23.43" W for secondary forest and 0 ° 48'30.63 "S 48 ° 5'25.50" W for Amazonian savanna.

The research also included a field visit to the study area (municipality of Vigia) that allowed for the prior recognition of the characteristics of the areas of the Amazonian Savannah and secondary forest, both of which are close and which are around the municipality. In this field visit, the coordinates of the site and photographic records that helped in the development of the research were collected. The NDVI and LST analysis procedures were performed using the Google Earth Engine - Google © (GEE) platform.

2.3. Processing on the GEE platform

Processing on the Google Earth Engine platform enabled the development of the code to obtain the NDVI and LST values in the areas of Amazonian Savanna and secondary forest. In the LST analysis, the code adapted by Ferreira et al. (2017). Firstly, the band “LST_Day_1km” was selected and its value was converted from Kelvin to Celsius. The script prepared to obtain this data is contained in the link: https://code.earthengine.google.com/a01fe12f8fb669889b21f0936e86a92b.

To obtain the NDVI value, equation 1 was used. First, the bands of Red (RED) and Near Infrared (NIR) were selected, then the equation was applied. The script prepared to obtain this data is contained in the link: https://code.earthengine.google.com/e915aad6c53e5eb367f0d7fd834f752d.

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

The results obtained are shown in the form of graphs prepared in Excel and in the GEE platform, as well as in the form of maps. To obtain the NDVI and LST values of the areas in each month and year, he used arithmetic mean. The raster (matrix data) generated (NDVI and LST) on the GEE platform were later exported to the QGIS Software v. 3.6.2 (QGIS TEAM, 2015) for purposes of preparing the layout.

3. RESULTS AND DISCUSSIONS

The Amazonian Savanna (Figure 2a) in this region is close to the secondary forest (Figure 2b), characterized as a mosaic of the Savanna area, that is, isolated patches. The region is characterized by the extraction of minerals (Figures 2c, d), including sand and gravel, used in civil construction.

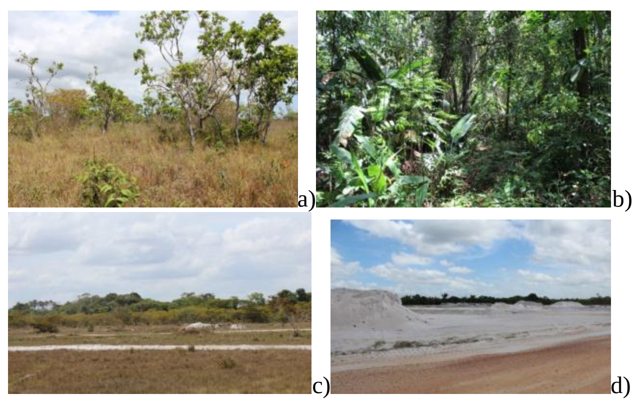

Figure 2 - (a) Amazonian Savannah (b) Secondary Forest in Vigia - PA (c) Transition area between Amazonian Savannah and Secondary Forest (d) Sand extraction area close to the study site. Source: Authors.

The graph generated in the GEE (Figure 3) showed the annual evolution of the NDVI values in the environments selected for the period 2013-2018. Checked thatthe variation in NDVI during the period included declines in vegetative activity in the years 2014 and 2015 and between 2017 and 2018. There was a decrease in NDVI in the second half, the least rainy season in the Amazonian region, and an increase in the first half, the rainiest season. With NDVI peaks in the month of July, a transition period between the “Amazonian winter” and the “Amazonian summer”, when the increased availability of solar radiation begins.

The differences in NDVI between the least and the rainiest periods show the relevance of water availability as a limiting factor for photosynthetic activity. Trentin et al. (2013), in a previous study, observed that savanna areas showed less variation between the minimum and maximum NDVI values, due to the presence of an area of native vegetation. Thus, the NDVI response remains slower compared to anthropized areas.

Different from the study mentioned, in the present work small variations were observed between the periods of the first and second semesters of the year. The same relationship was observed by Teramoto et al. (2018), where the moistening of the root zone made it possible to increase the photosynthetic activity of the vegetation, increasing the NDVI values.

Figure 3 - NDVI time series in areas of Amazonian Savanna and Secondary Forest, 2014 - 2018 through the GHG platform. Source: Authors.

The graphs in figures 4 and 5 show the annual averages of NDVI for savanna and secondary forest areas, respectively. Analyzing the areas separately, both obtained a minimum NDVI value in 2014, with values of 0.20 and 0.25 for the savanna and secondary forest areas, respectively. The maximum NDVI value for the two areas occurred in 2017 with 0.59 and 0.79 for savanna and secondary forest areas respectively. Now observing the arithmetic mean of both areas (Figure 6), the lowest NDVI value was also in 2014, with 0.23, and the highest value in 2017, 0.69.

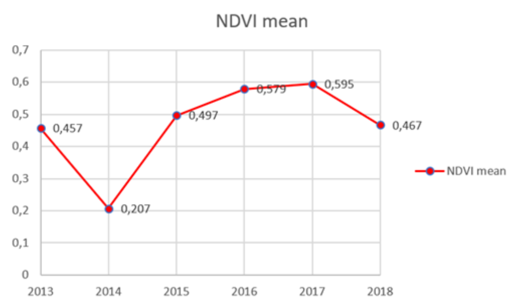

Figure 4 - Average NDVI in the Amazon Savannah area, 2013-2018 (Generated in Excel). Source: Authors.

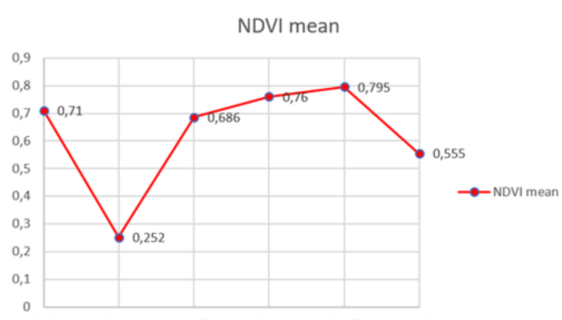

Figure 5 - Average NDVI in secondary forest area, 2013-2018 (Generated in Excel). Source: Authors.

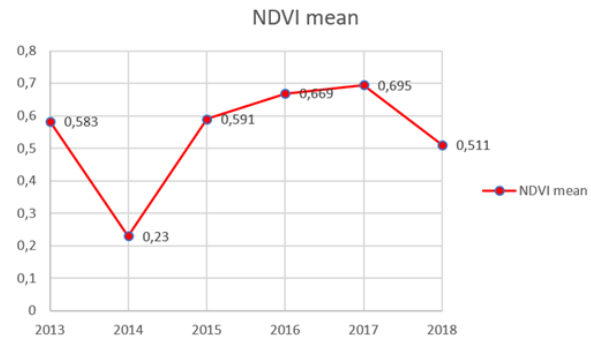

Figure 6 - Average NDVI in the area of Amazonian Savanna and Secondary Forest, 2013-2018 (Generated in Excel). Source: Authors.

The high NDVI values in secondary forest areas are due to the influence of the high photosynthetic activity of dense ombrophilous vegetation. On the other hand, the NDVI values in the Savannah area were lower compared to the secondary forest, which may be due to the influence of the predominance of spaced vegetation of shrub species, according to Trentin, Saldanha and Kuplich (2013). These authors, in their study in the hydrographic basin of São Marcos - GO, observed that the temporal behavior of NDVI in savanna areas was less than in agriculture and livestock areas. This can be explained by the great photosynthetic activity in agricultural areas, as well as by the different grazing phases, from clean to dirty pasture, the latter with high photosynthetic potential. Unlike that,

The minimum NDVI values in the Savanna area (Figure 4) and Secondary forest (Figure 5) were similar to that found by Bayma & Sano (2015) in the municipalities of Jataí (State of Goiás), Luís Eduardo Magalhães (State of Bahia), Mateiros (State of Tocantins) and São Miguel do Araguaia (State of Goias) with minimum values between 0.39 and 0.46 for areas of Savanna and 0.64 for areas of forest formation. The authors observed that the minimum values in areas of savanna and forest formation coincided with the beginning of deforestation events.

The minimum NDVI values may be affected by deforestation caused by the implantation of sand in Savanna areas. These sand extraction areas were observed during a field visit (Figure 2d), where many were abandoned. According to Mechi & Sanchez (2010), this ore removal activity has a significant impact on the environment, as the development of this activity removed from vegetation, soil exposure, among other negative processes, almost always occurs.

The figure 7 shows the average of the NDVI values between 2013-2018, municipality of Vigia - PA. Showing the lowest value in the savanna area and the highest value in the secondary forest area.

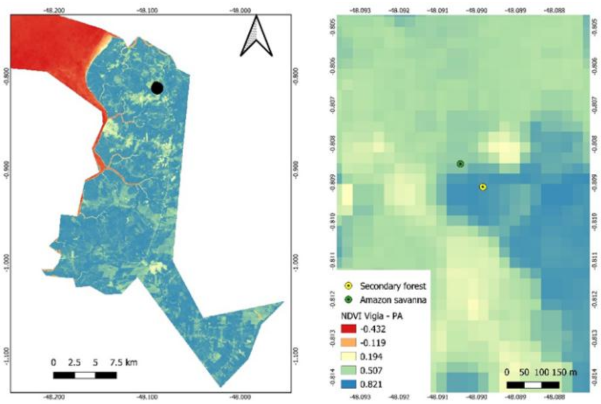

Figure 7 - Map of NDVI values in the municipality of Vigia - PA (2013-2018) processed in QGIS, version 3.6.2. Source: Authors.

Due to the 1000 meter resolution of the MODIS sensor, both areas (Amazonian savanna and secondary forest) obtained the same temperature, as they are close to each other. However, looking at the figure 10, the surroundings of the points studied are between the values 29.38 and 30.63 ºC. Thus, even if the MODIS Sensor is not feasible to detail LST of nearby areas due to its low spatial resolution, it can be used when it is desired to observe the average LST of a region, that is, an entire ecosystem, as well as in areas over longer distances.

The average values of LST over the years, available in the graphs of figures 8 and 9, have minimum and maximum values of 28.91 ° C and 31.71 ° C, respectively. It is also possible to observe minimum temperature values during the first semester, considered to be the highest rainfall in the region and the maximum in the least rainy season in the region, mainly in September and October. On the other hand, observing the average LST between the years analyzed (2009 to 2018), specialized in Figure 10, indicates that the two study areas have a surface temperature in the range of 29.38 ºC.

In addition, other factors may have influenced the results, such as exposed soil, low vegetation, fires and deforestation. Such conditions can contribute to the increase in temperature in the region. On this, Souza et al. (2016) analyzed the changes in land use and its impacts on the surface temperature in João Pessoa (State of Paraiba), noting that the highest temperature values are found in the classes "urban area" and "exposed soil". At the same time, the municipality of Vigia is located in the northeastern mesoregion of Pará, characterized by intense changes in land use due to activities related to agriculture, livestock and plant extraction (ESCADA et al., 2005).

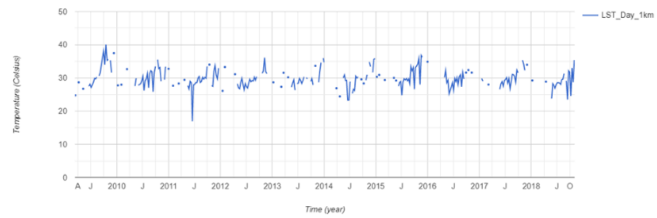

Figure 8 - Average LST in the area of Amazonian Savanna and Secondary Forest, 2009-2018, through the GEE platform. Source: Authors.

Figure 9 - Average LST in the area of Amazonian Savanna and Secondary Forest, 2009-2018 (Generated in Excel). Source: Authors.

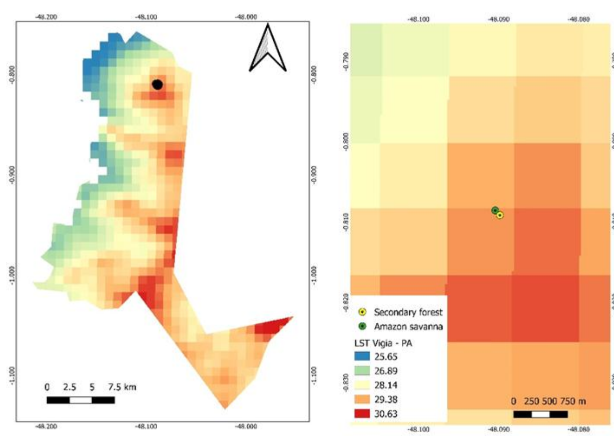

Figure 10 - Map of LST values in the municipality of Vigia - PA. Source: Authors.

The high temperatures (mainly in the second semester) have an inverse relationship with the relative humidity of the air. Fernandes et al. (2018), for example, observed that the hot spots in the municipality of Parauapebas (State of Pará) were concentrated in the less rainy period. Likewise, heat stains intensified in places close to urban centers and highways.

The increase in LST, in this case, may favor the appearance of forest fires and fires. In this sense, Url & Kauffman (1990); Aragão et al. (2007) cite that the appearance of fires is directly related to the processes of conversion of forest cover to other uses (agriculture, livestock and timber extraction) that leave much of the soil exposed, which consequently increases the surface temperature. The intensification of land use activities has made burning and forest fires more frequent in the Amazonian region (ANDERSON et al., 2017).

Specifically in Vigia, changes in land cover have largely been due to the extraction of sand (often illegally) in the vicinity of savanna and secondary forest areas in Vigia, causing increased heat retention in the soil and risk of fire outbreaks. The sand removal process tends to cause soil erosion and degradation and Heberle et al. (2017) state that degradation has impacts both on temperature and on the increase of extreme events (floods and floods). Therefore, it is necessary to pay more attention to extractive activities in the region, given that the indiscriminate use of the soil can lead to climate change and loss of local biodiversity.

4. CONCLUSION

The GEE platform made it possible to process images from the Modis and Landsat sensors, generating LST and NDVI results, respectively, through graphs and maps. The results showed variations of NDVI in the savanna and secondary forest areas of Vigia, according to seasonality and limiting factors in the region (water and radiation). NDVI close to 1 in secondary forest areas show that despite changes in land use, the analyzed vegetation maintains good photosynthetic activity.

On the other hand, in the areas of Amazonian Savanna, the low NDVI indicates the negative effects of changes in land cover on savanna vegetation. Regarding the LST, it was not possible to observe variations between the two areas studied due to the low spatial resolution of the MODIS sensor. However, just like the NDVI, there were changes in LST related to seasonality. With higher LST values in the less rainy semester and lower values in the rainiest semester.

Thus, we suggest further studies on the behavior of NDVI and LST in these two areas (savanna and secondary forest) in the Amazon, given that such ecosystems have a direct influence on the region's macro climate.

Finally, it is concluded that the information generated based on historical data from NDVI and LST can help to understand the behavior of vegetation during rainy and less rainy periods, as well as in the generation of fire and disaster risk models. as a whole in the Amazon region.

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