Google Earth Engine as an instrument of temporal analysis of NDVI: A case study in banana culture.

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Abstract: Remote sensing is widely used for agricultural monitoring, as crop forecast and agriculture planning, and associated with the computational technological advances, it allows to process and to analyze big data in a more agile way. This study case aimed to develop a script using the Google Earth Engine platform, and the objective was to obtain a NDVI time series in an area of banana plantation. Five cycles were identified, each one with an average of 9 months of banana established in the field. The minimum and maximum NDVI values were -0.6 and 1, respectively. The average annual value of NDVI occurred in 2017.

Introduction

Agriculture plays an irreplaceable role in all countries, being the main supplier of food, fibers and raw materials for energy (FORMAGGIO; SANCHES, 2017). Souza and Gomes (2017) explain that in global level, agricultural management is subject to several types of uncertainties, such as institutional government regulations, market uncertainties, such as prices, exchange rates and international trade, in addition to climate changes, biological factors, among others. Recently, some international studies have designed scenarios for future decades that shows that it is necessary to double the current levels of agricultural production to attend the demand for food security and environmental sustainability until the year 2050 (FOLEY et al., 2011; THE ROYAL SOCIETY, 2016).

Therefore, a good agricultural production forecasting is essential for planning, avoiding losses and delays in the harvest. There are an increasing number of studies aimed at estimating productivity developed by integrating agrometeorological data together with remote sensing images, through mathematical models (RUDORFF; BATISTA, 1990, 1991; FONTANA et al., 1998). According to Liu (2007), the dynamics of forecasting agricultural crops involves environmental factors and management practices that affect productivity at all stages of plant development, from the growth stage to the harvest.

Agricultural crops monitoring through satellite images is widely carried by the use of vegetation indices (MOREIRA, 2000), such as Normal Difference Vegetation Index (NDVI). According to Ponzoni (2007), NDVI is a method that calculates the difference between the reflected values of the Near Infrared (NIR) and the Red (R) bands, normalized by the sum of the same values. This index is associated with biophysical parameters of vegetation cover, such as biomass and leaf area index. Although NDVI is widely used, there are several other vegetation indices, such as Enhanced Vegetation Index (EVI) that was developed as an optimization of the signal enhancement of vegetation, looking for greater sensitivity for locations with high phytomass, with the characteristics of reducing the influence of the signal coming from the soil and atmospheric influences (HUETE et al., 1997).

New remote sensing techniques and methodologies are constantly emerging. The processing of a large volume of data in a long time interval increases considerably the necessary computational resource for processing geospatial data. However, the Google Earth Engine (GEE) cloud platform enables large-scale analysis of environmental data for using Google's servers. In addition, GEE is a free platform that allows the user to develop algorithms and create a fast cycle of tests and improvements for large data processing (GORELICK et al., 2017).

This paper aimed to develop a computational routine in the GEE Platform capable of extracting data of NDVI from MODIS daily products. In this case study, we presented a time series from 2014 to 2018, in a banana plantation area located in the municipality of Santo Antônio do Tauá, state of Pará, Brazil.

Material and methods

Study area

The study area (Figure 1) is located in the geographic coordinates 48°07'48.0"W and 1°10'56.1"S, in the margin of the state highway PA-140. The area is composed of two plots of banana planting, presenting a total area of 4.4380 ha and it is located in the municipality of Santo Antônio do Tauá (SAT), State of Pará, Brazil. According to the state political-administrative division, SAT is inserted in the Belém Metropolitan Mesoregion and Castanhal Microregion, presenting a population about 31 thousand individuals (IBGE, 2020).

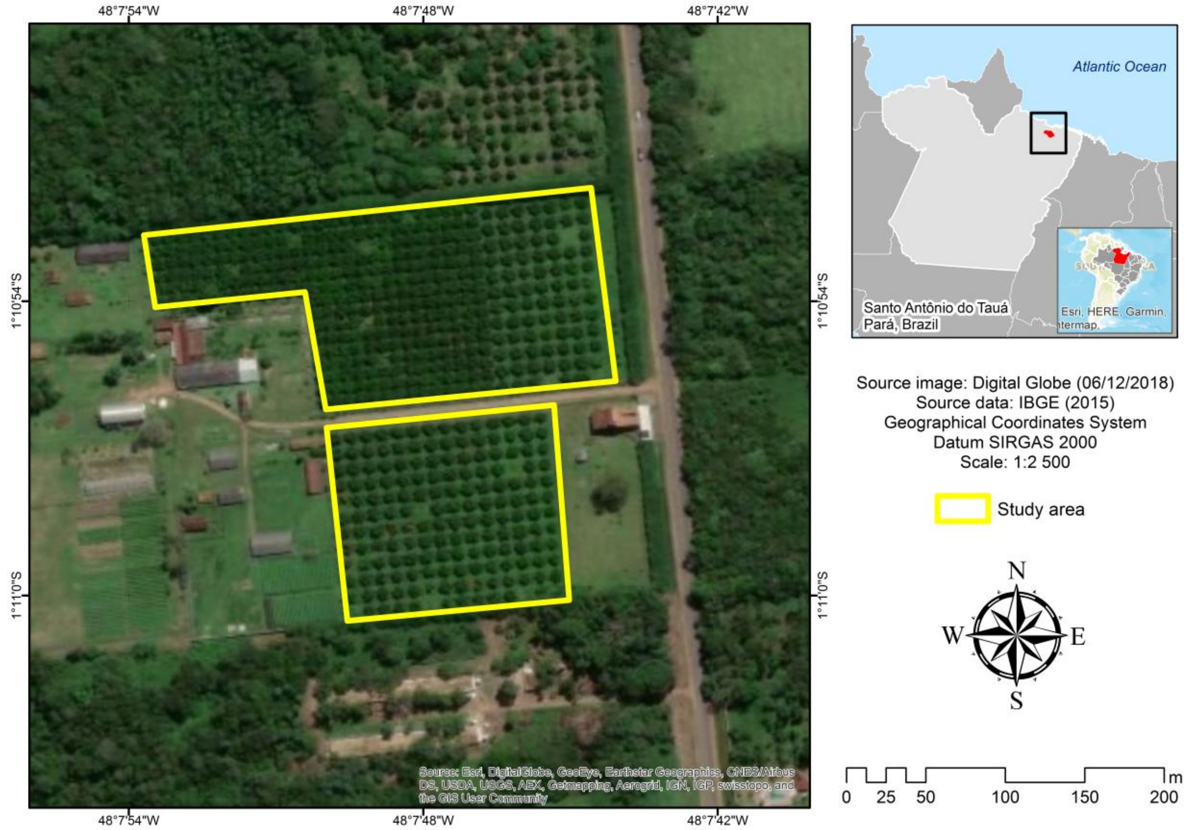


Figure 1 – Study area location map.
Source: Authors (2020).

Familiar agriculture can be considered an important feature in the history of the municipality of SAT. According to Carvalho (1984), 2020 units of families were estimated and between the years of 1980 and 2001, there was a considerable expansion of oil palm monoculture areas, characteristic of medium and large properties, suggesting that the growth of family units has been happening discreetly. In addition, SAT stands out for the production of various fruits, vegetables, palm oil, and for the creation of chickens and their products (PARÁ, 2014).

Normalized Difference Vegetation Index

The vegation index used was NDVI (ROUSE at al., 1973) and it is calculated according to equation 1. NDVI considers the reflectance values from spectral bands of red (0.6 µm) and near infrared (0.8 µm) wavelengths. The data of NDVI were obtained from the product MODIS Terra Daily NDVI (MOD09GA_006).

$$(NIR - Red) / (NIR + Red) \qquad \text{Equation (1)}$$

NIR and Red refer to the regions of Near Infrared and Red from electromagnetic spectrum, respectively.

Moderate Resolution Imaging Spectroradiometer – MODIS

The mission of MODIS sensor started in the mid-1999. The data collect started in February 2000 with the first sensor on the board the *Terra* satellite. After, the second sensor went into orbit in the year of 2002 on board the *Aqua* satellite (JUSTICE et al., 2002; RUDORFF et al., 2007).

Several products are generated from MODIS. Among them, there is a daily product called MOD09GA that provides an estimate of the surface spectral reflectance of MODIS Bands 1 through 7, corrected for atmospheric conditions such as gasses, aerosols, and Rayleigh scattering. Provided along with the 500 meters (m) surface reflectance, observation, and quality bands are a set of ten 1 kilometer (km) observation bands and geolocation flags (USGS, 2020). The GEE platform offers a variation from this product, and it is named as *MODIS Terra Daily NDVI*.

MODIS Terra Daily NDVI

The NDVI is generated from the NIR and Red bands of each scene, and ranges in value from -1.0 to 1.0. This product is generated from the MODIS/006/MOD09GA surface reflectance composites. The snippet of the script to start using this dataset is: *ee.ImageCollection("MODIS/MOD09GA_006_NDVI")* in the GEE platform (EARTH ENGINE DATA CATALOG, 2020).

Satélite Sino-Brasileiro de Recursos Terrestres - CBERS

The CBERS images are used in important fields, such as controlling deforestation and burning in the Legal Amazon, monitoring water resources, agricultural areas, urban growth, land occupation, in education and in countless other applications. The *Câmera Multiespectral Regular* (MUX, in CBERS-3 and 4), for having a good spatial resolution - 20 meters - in four spectral bands, plus a panchromatic (in CCD), it is suitable for the observation of phenomena or objects whose details are detailed important. As it has a 120 km field of view, it helps in municipal or regional studies. Given its 26-day temporal frequency, it can support the analysis of phenomena that have duration compatible with this temporal resolution. This temporal resolution can be improved, as the CCD has the ability to view from the side. Its bands are located in the spectral range of the visible and near infrared, which allows for good contrasts between vegetation and other types of objects (INPE, 2020). The spectral band SWIR (Shortwave infrared) is presented in the sensor IRS (*Imageador Multiespectral e Termal*). The images from CBERS are available for download in: http://www.dgi.inpe.br/catalogo/.

In this study, images from CBERS MUX were used to generate a snapshot of the year 2017, in order to visualize the dynamics of banana planting. The false color RGB composition

NIR-SWIR-RED is widely used in agricultural studies. In this composition, the healthy vegetation appears in tones of red color, providing a better differentiation of agricultural targets by the human eye instead of green tones. In addition, tones of vegetation can vary between brown, red, dark orange, light orange and yellow (FORMAGGIO; SANCHES, 2017).

Google Earth Engine

The Google Earth Engine represents a catalog of information associated with an API (Application Programming Interface) and accessible, through internet, to an interactive development environment (IDE) for generating and visualizing geospatial results on a global scale. The data collection can be accessed in: https://earthengine.google.com, in which can be also found the initial interface, user guide, terms of use and tutorials for beginners in JavaScript language. According to Gorelick et al. (2017), the GEE platform was designed with main objective of studying high-impact social problems such as drought, diseases, food security, water management, monitoring climate, environmental protection, among others.

Chen et al. (2017) describe that GEE uses high-performance computational resources for image analysis and the computational operations performed on the system take place in the cloud, facilitating saving and simplifying information processing. Due to the large volume of necessary data to obtain the time series, it was decided to use this platform for steps related to the calculation of NDVI and generation of charts. The steps of the process performed are shown in Figure 2, where the steps performed on the GEE platform are presented.

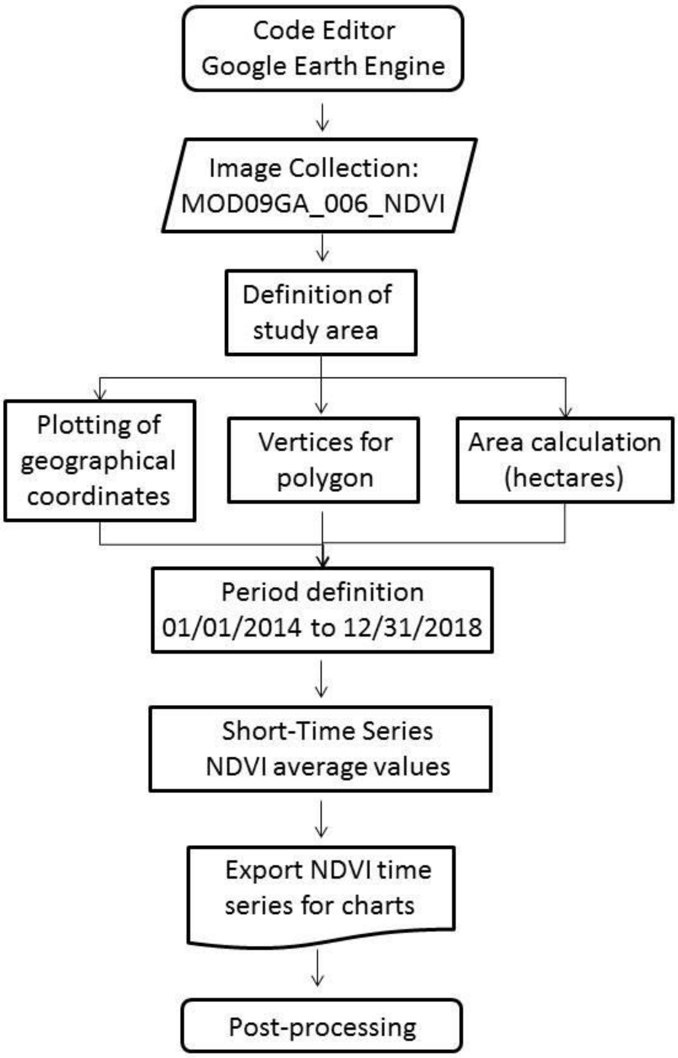


Figure 2 - Flowchart for obtaining NDVI time series in GEE.
Source: Authors (2020).

Post-processing

The post-processing was carried out in the free software *Octave*, which is a powerful tool for mathematical computation and solution for numeric problems, the download is available in: https://www.gnu.org/software/octave/. In this step, the NDVI time series was exported in .csv format from GEE platform to *Octave*, where it was possible to smooth the curve of time series using the Moving Average Filter, which is a simple digital filter using in programming for eliminate the unwanted noises.

Fieldwork

The fieldwork was carried out in October 2017 to obtain the ground truth, where the vertices of the banana plantations were collected with the aid of using GPS of navigation. The geographical coordinates collected in the fieldwork are presented in Table 1.

ID	X	Y
1	-48.131517	-1.181701
2	-48.130669	-1.181615
3	-48.130551	-1.182280
4	-48.128910	-1.182119
5	-48.129049	-1.181025
6	-48.131581	-1.181293
7	-48.131517	-1.181701
8	-48.130547	-1.182383
9	-48.130429	-1.183477
10	-48.129174	-1.183359
11	-48.129260	-1.182254
12	-48.130547	-1.182383

Table 1 - Geographic coordinates collected in the fieldwork.

The points collected were used in GEE platform to generate the polygons and to clip the area of interest. The access to the study area was mainly through the state highway PA-140, according to the sketch presented in Figure 3.

Figure 3 - Access map of the study area.
Source: Authors (2020).

Results and Discussion

The Figure 4 presents a snapshot with images from CBERS comprising different dates during the year of 2017. The plantations of banana are observed in reddish tones. During the rainy season in the region, the high incidence of clouds becomes a limitation for assessing agricultural areas, as seen in the February, April and May images. When observing a time series (one-year) of a banana plantation, there is almost no spectral change and the red color predominate from February to July, it can be deduced that the banana is already established.

In general, the planted area remains almost totally unchanged during the year 2017. From the July image, small changes are noted, as areas of exposed soil (e.g., mowing) begin influencing the spectral response of the crop, appearing in greenish tones, the access road between the two plots becomes visible. In the other months, with the adoption of cultural methods and removal of part of the planting, green tones are more evident.

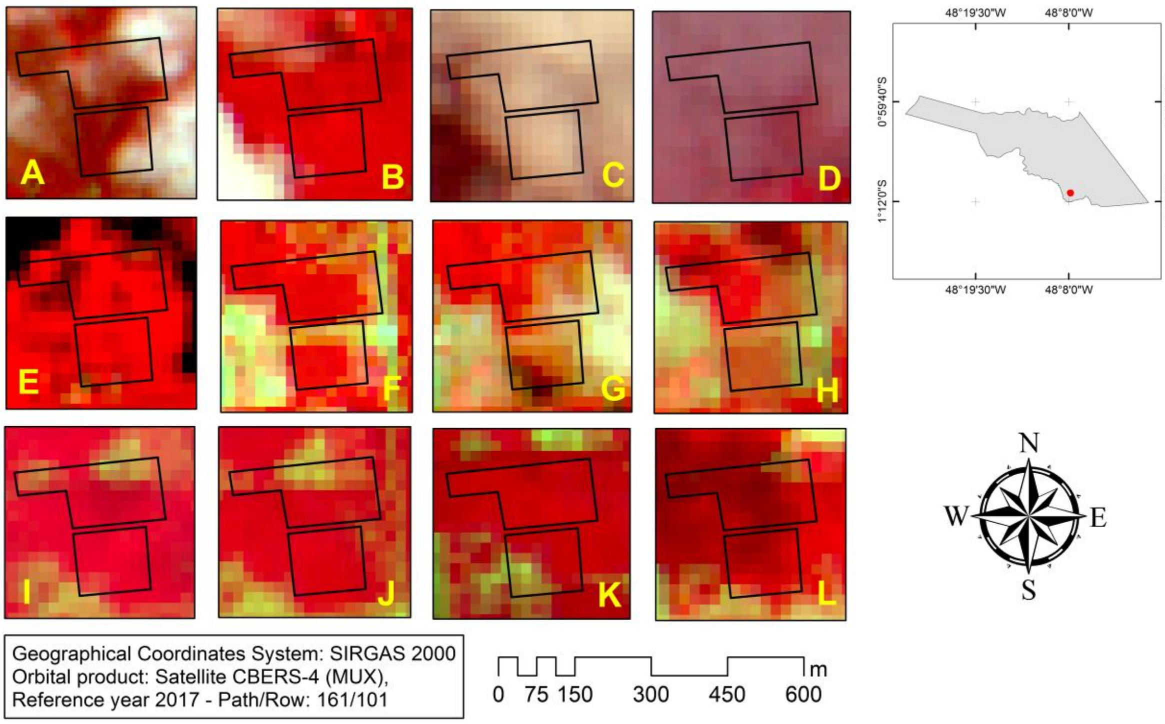
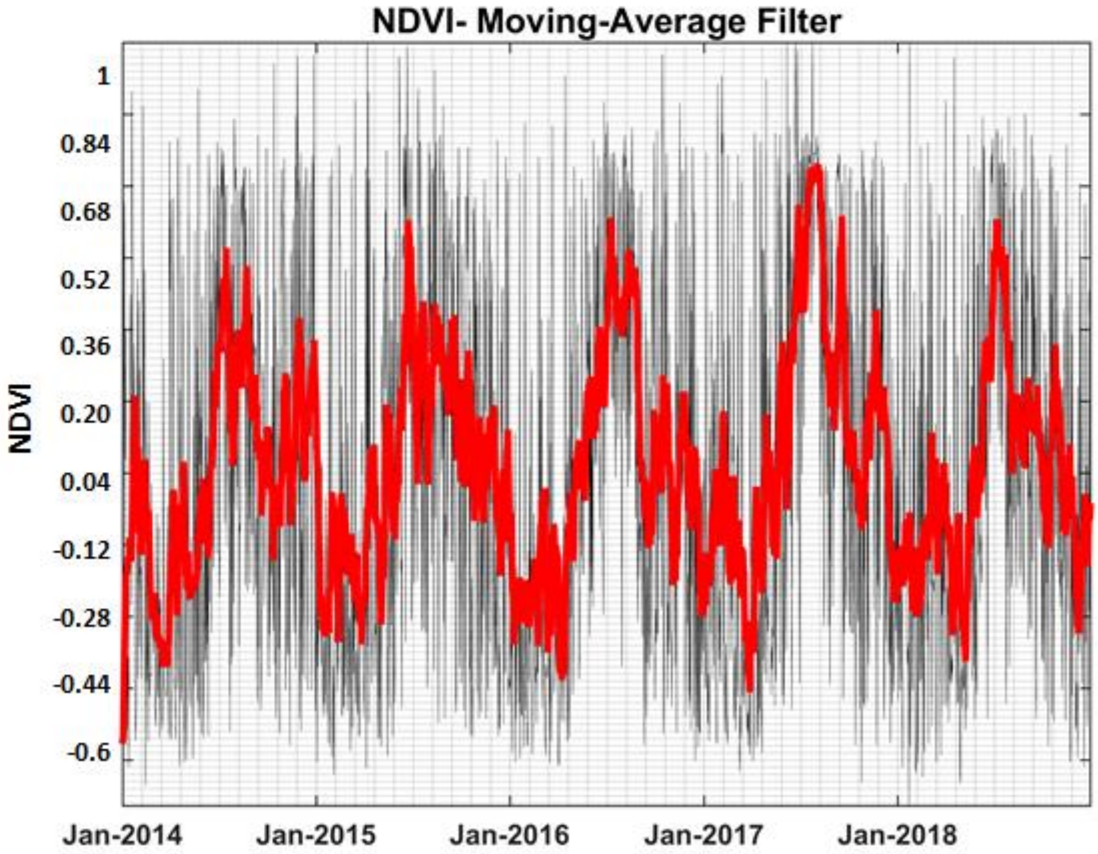


Figure 4 - Plantation of banana: clipping of CBERS images, of path/row 161/101, in RGB composition NIR-SWIR-RED; Legend: A: 02/08/2017-; B: 03/06/2017; C: 04/27/2017; D: 05/23/2017; E: 06/18/2017; F: 07/14/2017; G: 08/09/2017; H: 09/30/2017; I: 10/26/2017; J: 11/21/2017; K: 12/17/2017; L: 01/12/2018.

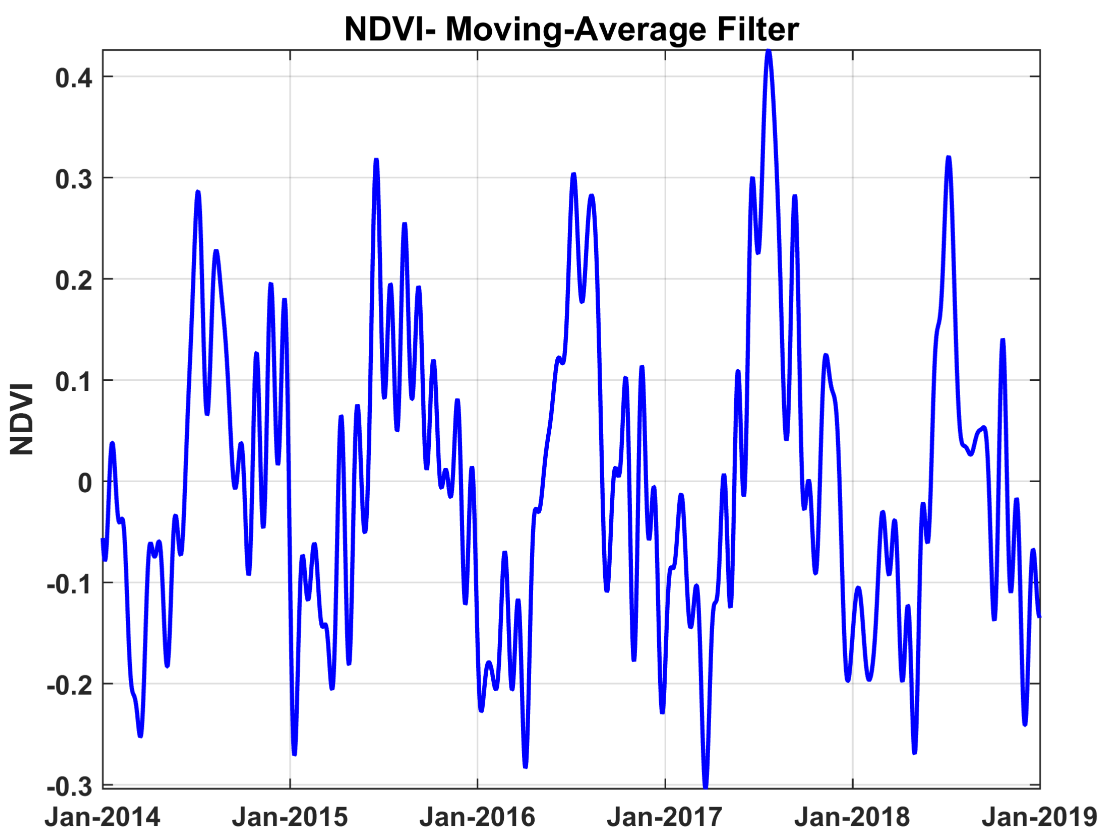
According to Embrapa (2012), the banana cycle can vary between 8 and 10 months for tropical regions with low altitudes, in other conditions, this cycle may last up to 12 months. Satellite images with low and medium temporal resolution can have an impact on NDVI results. Thus, a high temporal resolution allows a more detailed analysis of the dynamics of culture. Figures 5.A and 5.B show the time series without and with the application of the moving average filter, respectively. Among the 1825 data analyzed, 26 had negative NDVI values very far from the average, and after filtering these values were excluded. It is observed a drop in NDVI values between the periods from 01/12/2014 to 27/04/2014; 02/01/2015 to 05/04/2015; 16/03/2016 to 01/04/2016; 09/03/2017 to 03/04/2017; 01/10/2018 to 02/03/2018, and again NDVI values fell from 18/12/2018.

Between the five years of analysis, the drop in NDVI values occurred after each 10 to 12 month interval. The values equal to or below zero occurred in an average of 3 months each year, a common period for the fallow land after banana plant withdrawn.



(A)

Figure 5.A - NDVI values (Y axis) in a banana plantation during the period from 01/2014 to 12/2018 (X axis). Black lines in the background: time series without moving average filter.



(B)

Figure 5.B - NDVI values (Y axis) in a banana plantation during the period from 01/2014 to 12/2018 (X axis) after application of Moving-Average Filter.

The Figure 6 shows the average annual profiles of NDVI, this data type is important to evaluate different factors about the vegetation conditions, as biomass concentration, climate influence, irrigation, moistening of the landscape, hydric stress, among others. According to the following figure, the highest average value occurred in the year 2017 (0.448), more specifically in the months of July and August. In addition, there are registers of occurrence of extreme events in 2017, as La Niña. These data can be consulted in: http://enos.cptec.inpe.br/~renos/misc/lanina.html (CPTEC/INPE, 2020). These climate phenomena may have a positive relationship with the increase in the average annual NDVI, since the occurrence of a moderate La Niña event, precipitation tends to be greater than the normal in the Amazon region (SANTOS et al 2012; SANTOS et al 2014).

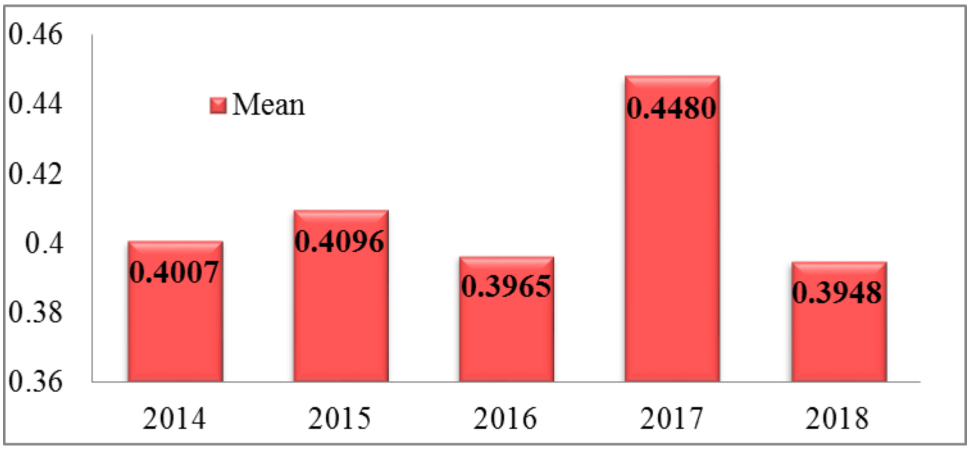


Figure 6 - Average annual NDVI.

The NDVI time series can indicate changes in the crop, such as reform or replacement of the crop, weed growth, cultural methods, among others. In this study, the results show the repetition of the banana cycle in the analyzed period, with maintenance of the crop in the field for around 9 months, consistent with the average banana cycle according to Embrapa (2012).

Conclusions

The previous field knowledge of the area associated with obtaining the excellent results, validate the computational routine developed in this case study. The use of Google Earth Engine platform presented excellent results, and the developed script can be applied to other crops in different regions. Considering the cloud processing, it was possible to run several simulations and quick view of results, also allowed to optimize the processes of extracting refined information from a large volume of data in an agile way and with less demand for computational resources.

For future studies, it is suggested to analyze crops on a large scale, using other vegetation indices in addition to NDVI, and relate them to environmental factors, such as annual precipitation and slope.

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