GIS APPLIED TO THE STUDY OF TEMPORAL RECOVERY OF BURNED AREAS IN THE MUNICIPALITY OF PAI PEDRO LOCATED IN REGION NORTH OF THE STATE OF MINAS GERAIS

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Abstract

The northern region of Minas Gerais is considered a transition area between the biomes Caatinga and Savanna, with predominance of the Savanna and its variations. It is common to the occurrence of fires, which can be caused naturally or by anthropogenic actions, resulting in changes in the landscape. In this sense, the study aims to evaluate from time series of LANDSAT-5/TM and MODIS/TERRA images the process of natural recovery of vegetation after the identification of operational pixels corresponding to the burned areas. The results of the research are based on the response of the municipality test of Pai Pedro/MG. We can observe that was detected a hotspots pixel on the day 08/04/2008 through images MOD14A1, which validation was performed from the survey of burned areas conducted by INPE - National Institute of Space Research. From the identification of operational pixel of burned was evaluated the dynamics of recovery of the area through the vegetation index NDVI (Normalized Difference Vegetation Index), generated by images MODIS/TERRA, product MOD13Q. The scars of burned analyzed, approximately 52% were detected. Despite this limitation, much of the area impacted was identified. The errors of omission were considered satisfactory, with a view to the technical limitations of spatial resolution of the sensors used.

Keywords: Burnt areas, NDVI, remote sensing method.

Introduction

The state of Minas Gerais has valuable Environmental Conservation Units and a growing need to eliminate the risk of fires in these areas. The effective control of the sources of risk requires the knowledge of how these operate locally and when and where fires occur more commonly.

These information are linked to an individual record of occurrence and this record is the main source of all the statistics about the quantification of outbreaks of fire. The more frequent data for prevention programs are: the causes of fire; the time, place of occurrence and the extent of the burn area. The northern region of the state is considered a transition

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area between the biomes caatinga and savanna, with predominance of the Savanna and its variations, making it extremely sensitive as the fire action. In large part to the region, can be observed the use of agricultural practices, where it is common the use of fire as a management tool in opening up new areas for farming, as also in the control of pests of pastures, crops, and to eliminate leftovers of pasture aging, bringing the medium and long-term implications. The impacts caused by the action of fire may result, directly or indirectly, major changes in soil and vegetation, mainly due to the reduction of dead plant material, vegetation cover (De Castilhos & Jacques, 1984) and changes in soil moisture, especially when associated with intensive grazing, as Pillar & Tables (1997). According to Coutinho (1990), the burning of vegetation such as practice management for the creation of cattle and one of the main activities associated with the fire in the region, making use of extensive areas of natural pasture in the forms of Cerrado more open, as field clean and dirty field. It is worth noting that there are also cases of burning that occurs by the need for renewal of the same, which is very common in the dynamics of the area. In accordance with Florenzano (2007), the detection and monitoring of the outbreaks of burned transcend to the problem of deforestation and its consequences in themselves, in this way the Remote Sensing can help in the acquisition of spatial information and temporal, which allow the characterization of occurrences of

outbreaks of heat, in addition to the measurement of the area and biomass actually affected by the fire, providing important contributions to studies on this topic, relating these issues to the environment, and their ecological effects, climatic and atmospheric chemistry. The knowledge of the causes and the frequency with which events of fires occur is of paramount importance, especially taking into consideration that the starting point for the preparation of plans for prevention and know who (or what) started the fire (Santos, 2004). In this context, the National Institute for Space Research/INPE since the 1980s has been improving a system for detecting fires from images of sensors on board satellites polar and geostationary. They are the so-called "hotspots", which are geographic points captured by spaceborne sensors on the surface of the soil, when detected temperature above 47°C and minimum area of 900m² (Gontijo et al., 2011). The INPE disclose data derived from polar-orbiting satellites AQUA, TERRA, NOAA's-15, 16, 17, 18 and 19, and the geostationary satellites METEOSAT-02 and GOES-12. Each satellite polar produces two imaging per day, and the geostationary generate some images per hour, and in total the INPE handles more than 200 images per day, specifically to detect outbreaks of burning of vegetation. With regard to outbreaks MODIS (AQUA and TERRA), INPE has developed an algorithm for detection of outbreaks of burning in a conservative way, so as to minimize false alarms associated with

noise and the solar reflection occasional in water bodies and exposed soil in daytime images (INPE, 2010). The accuracy of detection algorithms and the reliability of data generated should therefore be evaluated, to estimate its uncertainty and improve existing products. The information on the accuracy of the algorithms must be constantly updated because, over time, the performance of the sensors and their conditions radiometric characteristics are altered. This analysis can be performed from the mapping of scars burned in scenes of average resolution and the comparison of these with the spatial location of outbreaks of burned in images of spatial resolution low. In this context this paper had as its goal the creation of an algorithm that enables the identification of operational standards and/or scars of fires, from the

association of a geographical information system and temporal data obtained from NDVI/MODIS images and MOD14A1, taking as reference archives of outbreaks of heat released by INPE. To characterize the recovery of the areas burned from used images LANDSTA-5/TM. The use of this methodology could then be used in the monitoring of current areas burned in the northern region of Minas Gerais.

2. Material and Methods

The area under study involves the municipality of Pai Pedro located in the mesoregion north of Minas Gerais (Figure 1). The municipality has an area of 839.804km² and according to the census of agriculture has 28.980ha of land for pasture and 5.262ha for practices of crops (IBGE, 2010).

Figure 1. Spatial Location of the municipality of Pai Pedro (A) and LANDSAT-5/TM image composition color RGB-543 09/12/2008 (B).

The spatial area used presents the following limits: 15° 30' 37" to 15° 23' 51" south latitude and 43° 18' 23" to 43° 8' 51" west longitude. The municipality is located in the microregion of Janaúba, and has average annual rainfall around 838.4mm. The months of highest rainfall, november to march, totaling 85% of the total annual precipitation, the driest months are between May and August being the most critical the months of June and July. The average annual temperature is around 28°C; in the colder months, June and July, the average temperature around 24°C; in the hottest month, October, the average is 33°C. To analyze these events were used as reference meteorological data of the municipality of Janaúba provided by INMET (National Institute of Meteorology). For the analysis of burned area were used the following data and steps: 1. LANDSAT-5/TM Images of Path/Row 218/71, obtained from the catalog of images of the INPE of days 05/07/2008, 08/11/2008 and 07/27/2009, being the last date used for the validation of outbreaks of fire and analysis of the regeneration process of burned areas. The choice of the period is directly related to the era of greater occurrence of outbreaks of heat in the year 2008, evaluated from the outbreaks of heat supplied by INPE. 2. MODIS images product MOD14A1 of the day 11/04/2008. This product has an important feature that is the inclusion of the occurrence of fire and the calculation of energy emitted by the burning, in addition to the composition of eight days of its occurrence (Latorre et al., 2007). The

MOD14 product and an algorithm for the detection of thermal anomalies (indicative of burned) developed by the National Aeronautics and Space Administration (Nasa), based on the algorithm for the detection of fires assets of AVHRR/NOAA and the TRMM/VIRS. The algorithm includes several parameters related to fire, as the occurrence of thermal anomalies, grouped into different classes of temperature, based on energy emitted by the burning (Justice, 2006). 3. NDVI images generated by MODIS product MOD13Q1, for the corresponding months the temporal series studied, respectively representing the months of May/2008 to july/2009, for the assessment of temporal recovery of the burned area. This product contains compositions of 16 days in the form of vegetation indexes: NDVI and EVI (Enhanced Vegetation Index), in addition to a surface corresponding to the bands of blue, red, near infrared and medium infrared, at a spatial resolution of 250m (bands of blue and medium infrared, originally obtained with 500m spatial resolution, are resampled for 250m). For each point of the image the algorithm selects the pixel of better quality in relation to the geometry of stamped and atmospheric interference among other passages of the period, which is then used in the generation of composite images (Klering, 2007). 4. Outbreaks of heat, obtained by INPE for days August 04-12nd, 2008, corresponding to the images MOD14A1. The digital processing of images was performed in

SPRING (System of Information Processing Georeferenced) version 5.2, software and the MODIS sensor images converted from format Hierarchical Data Format (HDF) to GEOTIFF, using the application MODIS Reprojection Tool (MRT). The georeferencing of LANDSAT-5/TM images was conducted taking as reference images GeoCover (Nasa, 2001), whereas 30 points distributed spatially in the scene of Path/Row 218/71. The images were converted to UTM projection the datum WGS-84. Has been performed radiometric and atmospheric corrections for bands 3, 4 LANDSAT-5/TM images. The reflectance and radiance are calculated by Equations 1 and 2, respectively.

$$L_{rad} = L_{i, \min} + \left(\frac{L_{i, \max} - L_{i, \min}}{255} \right) \times NC_i \quad (1)$$

Were: L_{rad} and the spectral radiance in band i in $Wm^{-2}sr^{-1}\mu m^{-1}$; $L_{i, \max}$ and $L_{i, \min}$ values of radiance maximum and minimum in band i , respectively, and NC_i the level of ash in band i .

$$P\lambda_i = \frac{\pi \times Li}{Ki \times L \times \cos Z \times dr} \quad (2)$$

Were, Li and the spectral radiance of each band ($Wm^{-2}sr^{-1}\mu m^{-1}$); Ki and the solar irradiance of spectral band at the top of the atmosphere ($Wm^{-2}\mu m^{-1}$); Z and the overhead angle solar; dr , and the square of the ratio between the average distance earth sun (r_0) and the distance earth-sun (r_0) in a given day of the year (DJ). For the atmospheric correction, the values of irradiance measurements were converted to a by the

method of (Dark Object Subtraction), using the histogram of band 1, as reference for the selection the pixel darker second methodology proposed by (Gürtler et al., 2005). The atmospheric correction allows mitigate the combined effects of absorption, scattering and atmospheric, caused by the presence of various gases, water vapor and particles that interact with the electromagnetic radiation as (Rodrigues et al., 2010). The NDVI of the temporal series of LANDSAT-5/TM images was calculated by equation (3).

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}} \quad (3)$$

Were, ρ_{NIR} reflectance near infrared (band 4) and ρ_{RED} reflectance of red (band 3).

To characterize the areas burned was developed an algorithm for automatic detection, in LEGAL/SPRING environment (Language Spatial to Geoprocessing algebraical) capable of: spatially locate the fire through the product MOD14A1 and apply a rule of decision in the area under study, based on the following requirement: *If* the image MOD14A1 have correspondence to the data provided by INPE *then* points of hotspots identified. The algorithm operates in accordance with the following premises: 1. Selection of pixels of the places that were observed the fire spots in image MOD14A1, through the process of slicing, being the class interval corresponding to the grade level of the incidence of burned. For this paper was considered the value of level of gray more than

seven, because in this class is the outbreaks that are detected by MODIS. 2. Weighting of pixels selected images of MOD14A1 with the objective to create a final image that contains only the region of burned with his level of gray classified according to the above item related, i.e. it is attributed to pixels not belonging to this condition a value equal to zero. 3. In the detection of the area effectively burned maps to the extend of vegetation destroyed by fire from the change of spectral characteristics of the images obtained before and after the occurrence of fire, according to the methodology proposed by Rudorff et. al (2007). From the operational identification was performed to validate the focus by displaying the actual area burned, taking as reference images LANDSAT-5/TM.

The procedure adopted was the Boolean operation that performs a test from the result of the operation of the difference of NDVI before and after the process of burned itself. The technique for the detection of changes used was the subtraction images according to the methodology proposed Mather(1999). It was established the following sentence of decision: *If the image difference have a negative value and have pixel corresponding in weighted image MOD14A1 then burned area confirmed and/or detected.* Once identified the burning was carried out the monitoring of surface, through the temporal analysis of the values of vegetation index NDVI. The NDVI/LANDSAT-5 was compared to the NDVI/MODIS in order to

establish a response parameter (consistency) between images, by choosing the resolution of space of 30m as a reference. The pixels were mapped and converted to a vector file, where it was possible to follow the behavior of the surface until the total disappearance of the scar of burned.

3. Results and Discussion

After validation of outbreaks of fire, about 75% of pixels of outbreaks diagnosed by MODIS and 42% of the points of hotspots identified a burned effective in the field. To analyze the points coincident MODIS x outbreaks of heat, the hit was 80% of pixels belonging to the class burned. The amount of outbreaks of heat coming from each detection methodology, carried out by satellites show that the spectral differences, temporal and thresholds of algorithms, interfere with the effective monitoring of the burning of vegetation. This result also highlights the fact that outbreaks of heat are diagnosed by different types of satellites, and then a higher sensitivity when there are sudden changes in temperature, and can be more precise the smaller the area burned, causing also in the incidence of observations from places that there was not a burned of fact. In remarks made by the junction of those files, the dense areas of points of hotspots tended to coincide with the pixels observed by MODIS, characterizing a burned significant that covers a larger area. The results obtained by the junction of the MODIS sensor and points of

hotspots are valid and significantly increases the probability of identifying operational of outbreaks of burned by the algorithm, with a higher margin of safety thus reducing the need for the use of LANDSAT-5/TM images for validation. Time series of NDVI

images/MODIS presented in Figure 2, it is possible to observe the response of temporal evolution of the vegetation in the area burned, taking the month of May/2008, as the beginning of the analysis.

Figure 2. Analysis of the sample mean of the values of NDVI/MODIS of temporal series.

after burning, variations are observed in a of these areas, which are more intense the more severe the source of heat. Fluctuations in the proportion of the vegetation in pixel, resulting from the change in structure and quantity are responsible for these variations (Tanaka et al., 1983; Frederiksen, 1990; Robinson, 1991). According to Pereira et al. (1997), and it's important to know the time interval between the occurrence of fire and the date of acquisition of spectral data due to the changes that will occur in a of these areas, occasioned by the recovery of vegetation affected by fire.

Time series of NDVI/MODIS images (Figure 3) and submitted the response related to the regeneration of the area over the period studied. Note that in the month of

February/2009 (Figure 3D), was observed, greater vegetative vigor of the analyzed area. This response was similar to the month of May/2008 (Figure3A) period before burning. However, the pixels of burned in some regions still had a value well below the expected, which shows that at some points there is presence of the scar of burned, and only in the month of March/2009 there is a complete recovery, i.e. there is no pixel with expected value of a burned area. This dynamics can be observed in Figure 3.

Figure 3. Monitoring of the scar of burned and natural regeneration of the area in the municipality of Pai Pedro/MG. NDVI image from MODIS sensor product MOD13Q1, for the months may/2008 (A), august/2008 (B), january/2009 (C) and February/2009 (D).

Second Kaufman & Justice (1998), small areas being burned, depending on its temperature, has the ability to saturate the pixel, making the same is classified as a source of heat by the algorithm of the product MOD14/MODIS, even if it is only a small fraction of the area of the pixel that is being burned. Another reason for the errors of commission (i.e, those whose allocation on the map of a certain appearance falls on a class to which it belongs) and the change of land cover in the period between the occurrence of burned and the detection by the sensor of average resolution since the agricultural areas are

plowed in after the occurrence of fire. The scattering of ashes in the wind and the regrowth of vegetation in this period may also result in problems in the identification of scars (Pereira JR. & Setzer, 1996). On the criterion of boolean selection, by the algorithm, specifically in the region of burned, there was a satisfactory outcome with regard to the recovery of the local vegetation, and the complete disappearance of pixels of burned corresponds to the time limit of vegetative recovery, as shown in Figure 4. The quantification of the affected areas was based in the scars of fires, i.e. in polygons resulting

from the mapping by means of satellite pictures. These scars were divided into size classes: total area diagnosed, area inside the polygon, the area outside the polygon and percentage of the total area within the polygon, to assess the influence of the size of the burnings and detection by outbreaks of heat, depending on the months studied. In reality,

we attempted to understand the influence of the size of the areas burned in the chances of these being detected, because of the low spatial resolution of the sensors used and/or low energy emitted at these events. Table 1 presents this monitoring by checking the actual area before and after burning.

Figure 4. LANDSAT-5/TM image in May/2008 showing the location of burned (A), and identification of operational scars burned in function of the response of NDVI/MOD13Q1 for the months August/2008 (B), January/2009 (C) and March/2009 showing the final result of the processing performed by the algorithm.

The results demonstrate the advantages of the use of orbital data for the survey and monitoring of the burnings everywhere north of Minas Gerais. In the analyzes it was possible to identify and locate the occurrence

of fires through the points of hotspots of INPE map area by the scar of burning in LANDSAT-5/TM images-and monitoring the recovery of the natural vegetation.

Table 1. Table quantification of areas in hectares, diagnosed by detection algorithm automatically burned areas.

<i>Months of time series</i>	<i>Total area diagnosed (hec)</i>	<i>Area within the polygon (hec)</i>	<i>Area outside the polygon (hec)</i>	<i>Percentage of the total area inside the polygon (%)</i>
AUGUST/2008	1.411,11	185.22	1.225,89	13.13
SEPTEMBER /2008	1.411,11	185.22	1.225,89	13.13
OCTOBER/2008	1.411,11	185.22	1.225,89	13.13
DECEMBER/2008	222	92.43	129.32	41.68
JANUARY/2009	57	23.99	33.01	42.09
FEBRUARY/2009	24.87	11.39	13.48	45.79
MARCH/2009	18.37	0	18.37	0

4. Conclusions

The frequency of outbreaks of heat showed that the differences spectral, temporal and thresholds of the proposed algorithm interfere in the monitoring of the burning of vegetation, which assumes a greater amount of satellites, expanding coverage of information. The scars of burned analyzed, approximately 52% were detected. Despite this limitation, much of the area impacted was identified. The errors of omission were considered satisfactory, with a view to the technical limitations of spatial resolution of the sensors used.

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