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Detection of burned regions in the state of Tocantins-Brazil through image segmentation

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Abstract**—*Burns in the Cerrado biome are recurrent problems in the state of Tocantins, located in northern Brazil. It is possible to observe, through satellite images, large areas that were destroyed by fire. This paper proposes an algorithm that automates the detection of burn regions in satellite images. In this algorithm, image segmentation techniques are used in order to detect regions that most resembles burned regions, considering color information. The results showed that the method can be effectively used to detect burned regions in satellite images.*
Keywords—Image segmentation, satellite images, burnings.

I. INTRODUCTION

The Tocantins state suffers from intense burnings every year, especially in the period from May to September, due to a severe drought. Throughout 2017, there were 22.531 fire outbreaks in the state, placing the state in 4th place in a national ranking of fires [1]. In 2018, the Tocantins state even declared risk of environmental disaster due to forest fires [2]. In addition, a large forest fire devastated several farms, killing over 1.000 animals and causing one person to die [3].

These statistics highlight the need to act, since Tocantins is a state that has different biomes and is considered a region of ecotones. It is noteworthy that forest fires affect nature in various ways, such as compromising the quality of soil, water, and air. In addition, the smoke generated can be toxic and aggravate respiratory diseases. Thus, combating burning can reduce public spending in other areas, such as health.

Currently, the monitoring of burned areas is not done effectively, because it basically consists of searches carried out by inspection teams, who act through complaints and try to find the responsible person so that they can adopt the appropriate administrative procedures [4]. Due to the difficulties encountered in controlling fires, their consequences are almost inevitable, and it is necessary to adopt other means to address the problem, to bring benefits to society and mitigate its consequences.

One way to help the public authority to take more efficient action to combat the burning of the Cerradobiome would be to map the areas hit by the fire outbreaks by processing and segmenting high resolution satellite images and measuring the damage caused by the fires, supporting the government in making decisions that seek to make the population aware. The Figure 1 taken from the Nature Institute of Tocantins (NATURATINS)[1]presents an example of satellite image that recorded areas of destruction generated by burnings. It is possible to observe that the burned areas are highlighted with a red outline.

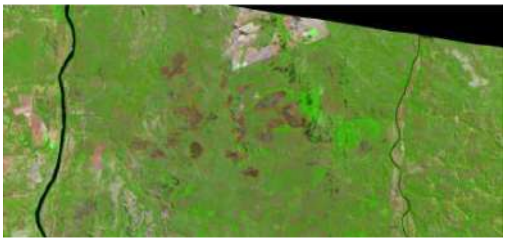

Fig 1: Satellite image example of a region near the city of Palmas, capital of Tocantins, whose burnings caused destruction.

Based on the facts presented, this paper aims to propose a method that can detect areas affected by burning by computationally analyzeof satellite images of the Tocantins state. For this purpose, digital image processing techniques, specifically image segmentation, will be used to detect the areas affected by burnings and to automate their mapping in order to help the government to make the population aware of the prevention and combat of burnings.

Image processing is an area of computer science that enables the manipulation of digital images such as photographs or video frames on a computer to visually enhance the image (to facilitate human interpretation) or to perform the processing of image data (storage,

[1]Available at: https://naturatins.to.gov.br/protocolo-e-servicos/diretoria-de-protecao-e-qualidade-ambiental/gerencia-de-monitoramento-e-gestao-de-infomacoes-ambientais/banco-de-imagens-/

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transmission and representation) to facilitate machine automatic perception. Depending on the purpose, it is only possible to pre-process the image or extract attributes from the image, allowing recognition of individual objects within a scene.

One of the most important steps in image processing is image segmentation, as all the following steps are influenced by your result. Image segmentation refers to the process of dividing a digital image into regions or objects, in order to simplify or change the representation of an image for easier analysis [5]. Based on this context, this work will focus on the detection of areas affected by burning in the state of Tocantins through the segmentation of satellite images. It is noteworthy that these images have several important information that can help identify various aspects of the region, such as lakes, forests, plantations, deforestation and regions affected by burning.

The proposed method uses an image segmentation technique in order to find a better range within the gray scale, which determine which pixels belong to the burned region and which do not belong. After the segmentation process, the image goes through a process called opening, which is responsible for removing noise in the resulting image, that is, small components left over from the previous step that are not interesting to the final result.

It is important to highlight that one of the challenges of this work is due to the high computational cost of working with satellite images, since these images are composed of bands with predefined spectral resolution based on the experience gained with the reflectance of more common types of satellite coverage. such as vegetation, water, soil and others [6]. Thus, it is necessary to use appropriate image segmentation techniques to work with high resolution images, which demand high computational cost.

This paper is divided into four well-defined sections: section 2 will address the theoretical foundations of the proposed approach, section 3 will present the methodology used to detect the burned regions in satellite images, section 4 will detail the results and, finally, section 5 will present the conclusion.

II. THEORICAL FOUNDATIONS

Modern digital technology has made it possible to manipulate multi-dimensional signals with systems ranging from simple digital circuits to advanced parallel computers. The purpose of this manipulation comprises three main categories: image processing, image analysis and image understanding[7].

Image analysis can be understood as a set of techniques used to extract meaningful information from digital images. When used properly, image analysis can be a powerful tool that can provide important data about an image, but when misused, image analysis can produce misleading results[8].

Image understanding refers to techniques that attempt to interpret an image in terms of the "physics" of the imaging system, that is, a process that aims to understand the content of images. Generally, the process input is an image or sequence of images, and the output can be decisions, descriptions, actions, among others[9].

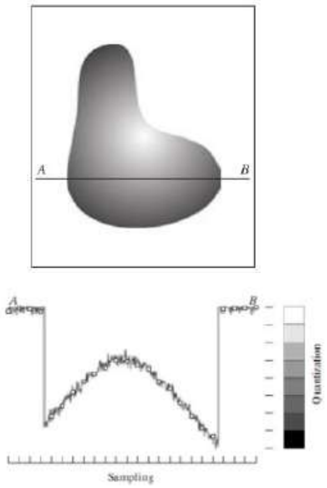
Image processing is used as a form of data processing, in which input and output are images such as photographs or video frames. This area of computing has two main applications: 1) Enhance visual information for human interpretation and 2) Perform image data processing for new processing, such as machine learning or pattern recognition.

In this work, image processing will be used in order to improve the image and automate the process of detection of areas affected by burns to facilitate the work of theinvolved people. The section 2.1 summarizes the concepts related to digital image processing.

2.1 DIGITAL IMAGE PROCESSING

An image can be defined as a two-dimensional function, *f(x,y)*, where *x* and *y* are spatial coordinates(plane), and the amplitude of *f* at any pair of coordinates *(x,y)* is called intensity or gray level of the image at this point. When *x, y* and the intensity values of *f* are finite and discrete quantities, the digital image is defined.

To convert continuous data to discrete data, two processes are performed: *sampling* and *quantization*. Sampling is a process in which image coordinate values are digitized. Amplitude digitization is called quantization. The basic idea behind sampling and quantization is illustrated in Figure 2.



Source: Gonzalez [5]

Fig 2: Process of acquiring a digital image. (a) Continuous image. (b) Sampling and quantization.

According to Gonzalez [5], the field of digital image processing refers to the processing of digital images by a digital computer. For ease of understanding, this section has been divided into subsections. The subsection 2.1.1 addresses the steps that constitute image processing and the subsection 2.1.2 addresses the concepts of image segmentation and their variations.

2.1.1 IMAGE PROCESSING STEPS

The image processing area is divided into several distinct fields, but these can be synthesized into three main categories according to similar subjects:

1. Digitization and encoding: This is the process of image acquisition, in which a continuous image is converted to the discrete form with its subsequent compression to maintain storage capacity and the transmission channel.
2. Enhancement and Restoration: This area is concerned with enhancing certain important image features, as well as recovering images that have been degraded.
3. Segmentation and description: It consist of converting images into simplified maps with measures of characteristics and properties.

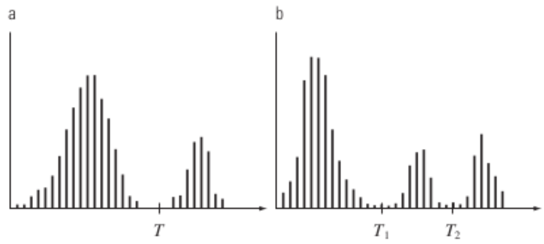
It is in the field of image segmentation and description that this work is focused. Through segmentation techniques it will be possible to map the regions of the Tocantins state that suffered damage caused by burning.

2.1.2 IMAGE SEGMENTATION

Image segmentation is an important step in Image Processing, which aims to divide an image into regions or objects, according to a certain criterion, which may be color, shape or texture. Often the result is not an image but a set of regions or objects. The accuracy of the segmentation phase determines the success or failure of image analysis procedures. Thus, segmentation becomes an important step in the attempt to detect the areas in which burnings occurred.

There are several image segmentation algorithms, each having their advantages and disadvantages, depending on the type of application in which the algorithm will be used. These algorithms are categorized according to two basic properties of intensity values: discontinuity and similarity. In the first category, the approach consists in divide an image based on sudden changes in intensity, such as the edges. The main approaches in the second category are based on dividing an image into regions that are similar according to a predefined criterion. Thresholding, region growth, and region division and fusion are examples of methods in this category. To achieve the best performance in image segmentation, it is often necessary to combine methods from different categories, such as techniques whose edge detection is combined with thresholding [5].

In this work, the proposed method for image segmentation is based on similarity, since a range of gray intensity values is found, which is responsible for identifying the regions that suffered burnings. The similarity segmentation process is based on the similarity between pixels according to a given criterion. Examples of techniques include thresholding and region growth. In this work, itwas considered the thresholding technique, which aims to separate the objects from the image considering the analysis of their histogram. A single threshold or multiple thresholds, as shown in Figure 3 can divide intensity histograms.



Source: Gonzalez [5]

Fig 3: Image histogram. (a) Single Threshold and (b) Multiple Threshold.

One of the difficulties of "thresholding" an image is determining the threshold value, i.e., separation point of the pixels. The simplest thresholding technique consists of partitioning the image histogram by a singlethreshold (**T**). With this, the segmentation is performed by scanning the image pixel by pixel and labeling each pixel as the object or background, depending on whether the gray level of that pixel is higher or lower than **T**. The success of this method depends entirely on how well the histogram can be partitioned.

2.1.3 MATHEMATICAL MORPHOLOGY

Mathematical morphology is an area of image processing that is concerned with the geometric structure of images. Through information from an unknown set related with topology and morphology, along with a defined completely set, called a structuring element, morphology is capable of segmenting, contouring, skeletonizing and eliminating noise from an image [10].

Erosion and dilation are the elementary operations of mathematical morphology and form the basis for the construction of the most complex transformations. In the morphological study of image processing, we have many operators, all of them defined from these elementary functions. Erosion combines two sets using subtraction vectors and can be denoted by equation 1:

$$A \ \theta \ B = \{x \mid (B)_x \subseteq A\} \quad (1)$$

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The effects obtained by erosion are the reduction of particles, the elimination of areas smaller than the size of the structuring element, the increase of "holes" and the separation of nearby areas. Already dilation combines two sets using vector addition, being denoted by equation 2:

$$A \oplus B = \{ x \,|(B)_x \cap A \neq \emptyset \qquad (2)$$

The effects obtained by dilation are the filling of small holes and small particles and connecting nearby areas. From these two elementary operations in the morphological study, the opening process is obtained. The opening process is intended to eliminate unwanted particles from the images without abruptly changing the size of other areas. This process consists of erosion and then dilation of the erosion result, and can be denoted by equation 3:

$$A \circ B = \{(A \,\theta\, B) \oplus B\} \qquad (3)$$

The purpose of morphological processing is primarily to remove imperfections added during segmentation, highlight shapes, extract components, among others. Through elementary operations (dilatation and erosion), it is possible to achieve more advanced operations and achieve very different results. Opening will be an important process used in the proposed method, as it is responsible for eliminating some noise from the images.

III. METHODOLGY

The images used in this paper were acquired from a satellite image bank provided by the Nature Institute of Tocantins (Naturatins). These images cover the entire territory of Tocantins and were obtained from Landsat 5, Landsat 8 and Resourcesat satellites.

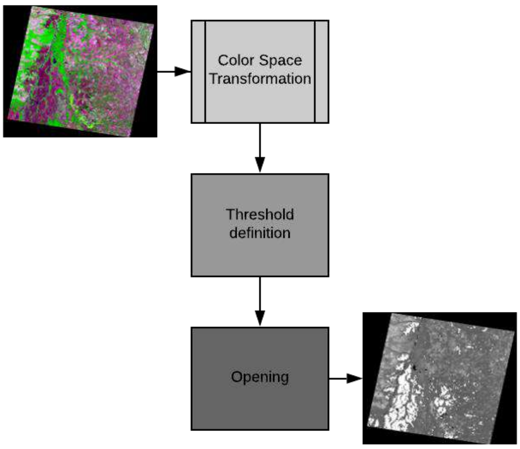

Fig. 4: Methodology of detection of burned regions in satellite images.

Basically, the methodology used to detect the burned regions in satellite images consists of three well-defined steps: color space transformation, definition of the threshold for identifying pixels that make up a burned region and choosing the parameter to perform the opening process, as shown in the flow chart in Figure 4 and detailed in the following subsections.

3.1 COLOR SPACE TRANSFORMATION

In the process of transforming the image from RGB color space to grayscale, the image is simplified to allow analysis of only one parameter: the gray intensity of the pixel. In addition, the results obtained by analyzing the grayscale image were better compared to the results obtained by analyzing a color image in the RGB model. The following equation 4 presents the process of converting a color image to a grayscale image, where *R* represents the intensity value of red, *G* represents green, and *B* represents blue.

$$L = R * \frac{299}{1000} + G * \frac{587}{1000} + B * \frac{114}{1000} \qquad (4)$$

3.2 THRESHOLD DEFINITION

After conversion to grayscale, the image goes through the segmentation process. It is at this stage that all the pixels in the image are analyzed and classified as being from a burned region or not, depending on the gray intensity. The thresholds used are different for the different regions of Tocantins, since the vegetation cover in the state varies due to the transition of biomes. After performing several experiments to obtain the best threshold, it was found that for the region of the Palmascity, capital of the Tocantins state, the best threshold is in the range of 16 to 100, as shown in the following equation:

$$\begin{cases} \textbf{burn}, & pixel[x,y] \in [16,100] \\ \textbf{not burn}, & otherwise \end{cases}$$

For the "Bico do Papagaio" region, located in the north of theTocantinsstate, the gray intensityrangewas from 12 to 85, according to the following equation:

$$\begin{cases} \textbf{burn}, & pixel[x,y] \in [12,85] \\ \textbf{not burn}, & otherwise \end{cases}$$

Finally, for the "Ilha do Bananal",transition region between the Amazon rainforest and the Cerrado biome, the gray intensity range used was 22 to 90, as seen in following equation:

$$\begin{cases} \textbf{burn}, & pixel[x,y] \in [22,90] \\ \textbf{not burn}, & otherwise \end{cases}$$

It is emphasized that experiments were performed with color images, considering the RGB color space, but did not obtain satisfactory results. With this method, each pixel color channel is analyzed separately, considering a certain range of established previously intensity values. If three color channels of the pixel fit within their respective ranges, the pixel is classified as a burn region. However, experiments have shown that using grayscale images yields better results.

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3.3 OPENING PROCESS

After the segmentation process, the resulting image goes through the opening process, which is responsible for removing any remaining noise from the previous step. In this process, the image receives a filter called a "structuring element", which passes from pixel to pixel eliminating small components that do not matter to the result. The size of the structuring element determines the proportion of details removed from the image. Therefore, it returns different results depending on the size chosen.

The choice of the structuring element must be made carefully so that to remove as much noise as possible without impairing the detection of the burned regions. In the experiments, the sizes 2, 3, 4, 5 and 6 were used for the structuring elements. Structuring elements of size 4 and 5 presented the best results, as they were able to remove more details without distorting the final result.

IV. RESULTS AND DISCUSSION

This section presents the results obtained by the proposed method, as well as the image bank used for the experiments. The subsection 4.1 presents the image base and the subsection 4.2 presents the details of the performed experiments.

4.1 IMAGE BANK

The database used is a public repository of satellite images, covering the entire territory of the Tocantins state. This repository was created and is maintained by the Nature Institute of Tocantins (NATURATINS)[2], which has a department called "Management of Monitoring and Environmental Information", responsible for collecting and maintaining these images. In addition, it is committed to "planning, designing and structuring information and data relevant to the issue of loss of vegetation cover, fire/burn scars and environmental emergencies, water use and licensed activities" [9].

In addition, the images analyzed were separated into three different regions, due to the extensive size of the Tocantins state and its peculiarities of vegetation cover. The three regions chosen were: the city of Palmas, the "Bico do Papagaio" and the “Ilha do Bananal”. These three major regions were chosen because they represent very well the different vegetation covers present in the state: the region of the "Bico do Papagaio" represents the Amazon rainforest, the region of Palmas represents the Cerradobiome, and the region of “Ilha do Bananal” represents the transition region between the two mentioned biomes.

[2]Can be downloaded at: http://sinat.naturatins.to.gov.br/arquivos_web/index.php

4.2 EXPERIMENTS

The first experiment performed were made from the color analysis of the RGB channels. When analyzing the value of each color, a threshold range was found that resulted in satisfactory segmentation, as can be seen in Figure 5. In this example we used the intensity ranges of [3,191] for channel *R*, [30,85] for channel *G* and [60,160] for channel *B*.

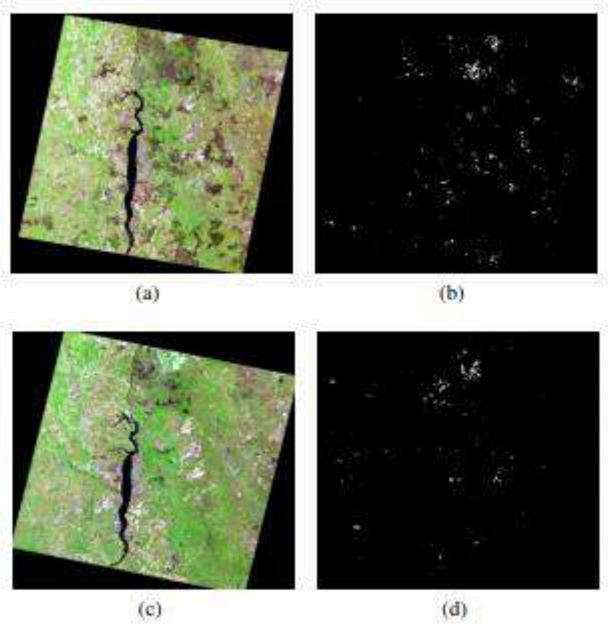

Fig. 5: Result of the Palmas region image segmentation, using the analysis of the values of each RGB channel. (a) Original image of the year 2010. (b) Result of the image of the year 2010. (c) Original image of the year 2014. (d) Result of the image of the year 2014.

Although thresholding range, considering RGB color channels, gives good results for some images, it no longer offers the same for other images. For example, Figure 6 shows an example of a segmentation that did not yield a suitable result, because segmentation identified deforestation regions as being burned regions. It should be noted that this result can be explained by the similarity of colors between some deforestation regions and burn scars.

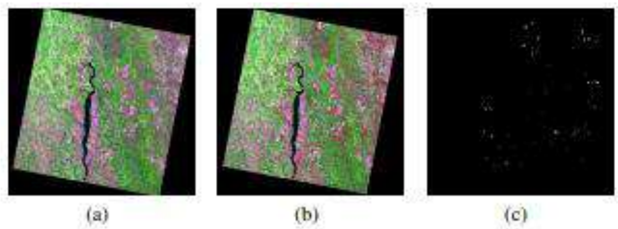

Fig. 6: Result of the satellite image segmentation of the Palms region using the RGB color space. (a) Original image from year 2009. (b) Red dots show pixels identified as burn scar (c) Segmented image after application of opening process of size 3.

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Then, from the difficulty of finding a threshold for each color channel of RGB model that could generalize well to all images, experiments were performed with the images converted to gray scale. Thus, the results obtained were better for allimages in general. Figure 7 presents a comparison of the threshold considering the RGB color channels and the gray scale. Note that the result of using gray scale conversion has less noise, and the identification of pixels that represent burned regions is more accurate.

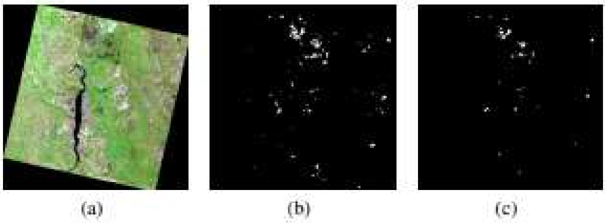

Fig. 7: Result of the satellite image segmentation of the Palmas region. (a) Original image; (b) Color image segmentation (c) Grayscale image segmentation.

Thus, satellite images were segmented after conversion to gray scale and, for each region of the state, a different interval was defined. For the Palmas region, the range of [16,100] was stipulated, the region of Bananal Island has the range of [22,90] and, finally, the region of the "Bico do Papagaio" used the gray level range of [12.85]. The Figures 8, 9 and 10 present the results for the region of Palmas, Bananal Island and "Bico do Papagaio", respectively.

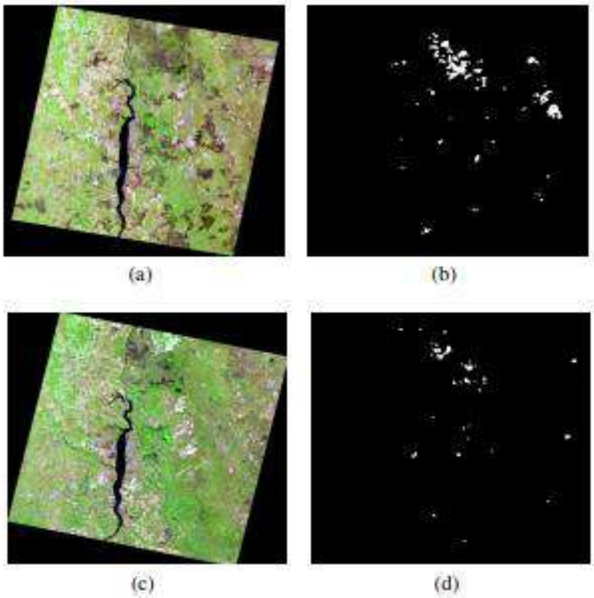

Fig. 8: Segmentation of Palmas region. (a) Original image of the year 2010; (b) Image segmentation for 2010; (c) Original image of the year 2014; (d) Image segmentation of the year 2014.

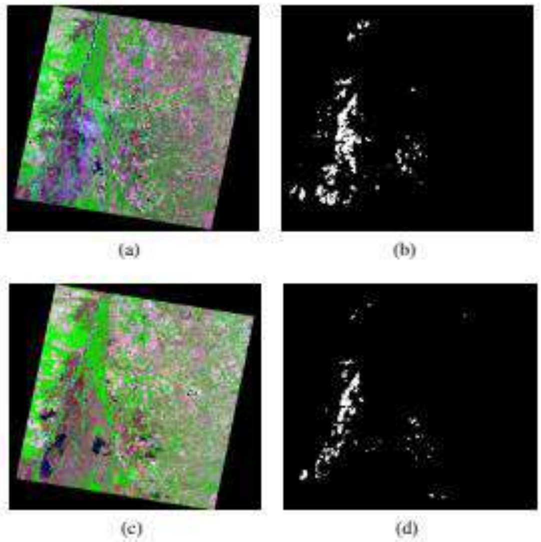

Fig. 9: Segmentation of theBananal Island region. (a) Original image of the year 2010. (b) Result of the image of the year 2010. (c) Original image of the year 2011. (d) Result of the image of the year 2011.

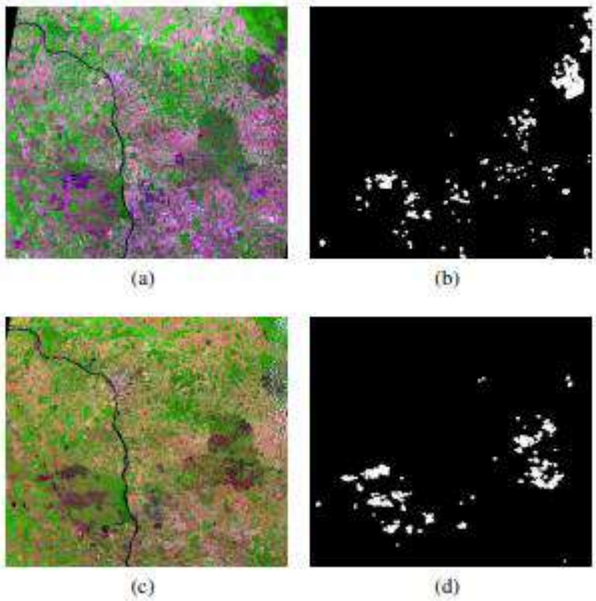

Fig. 10: Segmentation of the "Bico do Papagaio" region. (a) Original image of the year 2014. (b) Result of the image of the year 2014. (c) Original image of the year 2015. (d) Result of the image of the year 2015.

The results were interesting because the algorithm was able to detect the regions where the presence of burn scars is noticeable. The region that obtained the best results was the region of Palmas, where the detection of burn regions was the most accurate compared to the other regions. On the other hand, the region of the "Bico do Papagaio" showed the worst result compared to other regions. This fact can be explained by the greater presence of deforestation, making the process of detection of burns more difficult.

V. CONCLUSION

The proposed method for detecting burned regions from satellite images makes use of image processing techniques, such as color space conversion, color-based image segmentation and noise removal by mathematical morphology, more specifically, the opening process. The results were satisfactory for most images used in the experiments, considering the peculiarities of each region analyzed.

From the visual analysis of the segmentation, the segmentation performed was able to accurately detect most of the burned regions in satellite images. However, the biggest difficulties encountered were in the images, in which the colors of the deforestation regions resemble the colors of the burned regions, that can confuse the algorithm, causing it to segment in a wrong way.

Over the years, by observing the results, it can be concluded that there was an increase in the burned areas and then decreased again. In the region of Palmas, the peak of burns were observed in 2010 and 2015, while in the region of Bananal Island, the years with the most burns were 2009 and 2010, and the region of the “Bico doPapagaio” presented highest burns rates between 2013 and 2015.

In addition, as part of future works, it is intended to measure the burned area detected in the segmentation process to determine the size of the area that was destroyed by fire. This new function could be used to better make the population aware of the large amount of destruction that the burning is causing, as well as to inform another research.

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REFERENCES

[1] Carvalho, Cleide(2017).Brazil ends 2017 with record number of burns since 1999. Available at: <https://oglobo.globo.com/brasil/brasil-termina-2017-com-numero-recorde-de-queimadas-desde-1999-22204556>. Accessed on:May 12, 2019.

[2] Tocantins, G1 (2018). Available at: <https://g1.globo.com/to/tocantins/noticia/tocantins-tem-risco-de-desastre-ambiental-por-causa-de-queimadas-entenda.ghtml>. Accessed on: May 04, 2019.

[3] Tocantins, G1 (2018). Available at <https://g1.globo.com/to/tocantins/noticia/falta-de-manutencao-causou-incendio-que-matou-mil-animais-e-energisa-deve-ser-multada-em-r-45-milhoes.ghtml>. Accessed on: February 16, 2019

[4] Do Pará, Correio. (2017). Availableat<https://correiodopara.com.br/orgaos-publicos-enfrentam-dificuldades-para-combater-numero-crescente-de-queimadas/>. Accessed on: May 13, 2019

[5] Gonzalez, R. C. and Woods, R. E. (2010). “Digital image processing”, Pearson.

[6] De Souza, O. C. and Araújo, M. R.(2001),“Proposal for monitoring MemoraPeregrina,pastry invader using remote sensing”, Available at <http://old.cnpgc.embrapa.br/publicacoes/doc/doc118/03preparacao.html>. Accessed on: February 19, 2019

[7] Young I. T., Gerbrands, J. J. and Vliet L. J. V. (1998), “Fundamentals of Image Processing”,Delft University of Technology.

[8] Smolen A. J. (1990). “Image Analytic Techniques for Quantification of Immunohistochemical Staining in the Nervous Systemunpublished”, Academic Press.

[9] Blackledge J. M. (2005), “Digital Image Processing”,Woodhead Publishing.

[10] Fernandes J. L. (2008) “Mathematical Morphology”. Available at: <http://www.ic.uff.br/~aconci/operadoresBasicos.PDF>. Accessed on: November 16, 2019.