



A Specific Segmentation Approach to Measure Deforestation from Satellite Images

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Abstract. The intention of this work is to show a simple and efficient way to compute the deforestation area using Landsat 8 satellite images. It considers only its best band and segmentation based on thresholding. The described approach is simple to be used in public available images of this type (<http://www.dgi.inpe.br/catalogo/>), can be easily implemented in any computed language or downloaded in this public repository: <https://github.com/rmparanhos/analise-imagens>. Maybe the most complex aspect on processing this type of imaging is due to the great numbers of pixels and band (or channel) that compose each mosaic and each real area to be studied. The presented material can be useful due to the difficulty of finding benchmarks to allow comparison among results.

Keywords: Deforestation · Landsat 8 · Segmentation

1 Introduction

In 2021, the Amazon Deforestation Monitoring Project by Satellites (in Portuguese: Projeto de Monitoramento do Desmatamento na Amazônia por Satélites: PRODES), using 45% of the monitored area, estimated an increment of deforestation of 11,088 km² of the Amazon Rainforest, a rate of 47% when compared to 2018 and 9.5% when compared to 2019. These rates are the highest in the decade (Silva Jr. et al. 2020) and show the need for more frequent monitoring of data, rapid measurement of the deforested area of the Amazon and maybe effort to have more techniques focusing in an autonomous way to verify independently this devastation as much as possible.

In this article, we propose a technique to measure the deforested area from segmentation of Earth observation satellite images. It will be shown how to get the images, what preprocessing is needed and our implementation results with multiple segmentation methods for later comparison.

The observer satellite chosen is the Landsat 8, the eighth generation of the Landsat program: a collaboration project between the National Aeronautics and Space Administration (NASA) and United States Geological Survey (USGS). This satellite has two sensors, the Operational Land Imager (OLI) which produces images in 9 bands and the Thermal Infra Red Sensor (TIRS) imager which produces images in 2 bands, both with spectral bands of long wave infrared. For this work, only the 9 bands produced by OLI

sensors are chosen to be studied, because it is an initial research in Universidade Federal Fluminense (UFF); we would like to have the intuitional assistance of the visible spectrum; and the main objective is to inviting other Brazilians who intend to work with this subject in image processing to join us. In this aspect the main contribution of this work is to put focus on this problem as much as possible, making it popular and bringing it to the status of a usual exercise, which could be made for any person with a minimum computer acknowledgement.

2 Used Image Types

The 9 OLI bands are distributed as follows: band 1 (Coastal/Aerosol) is used to locate bodies of water, the 2, 3 and 4 visible bands correspond to the visible Blue, Green and Red light bands, band 5 (Near Infrared) comprises the wavelengths close to infrared light, in bands 6/7 (Short-Wavelength and Infrared) there are the shortwave and infrared light, band 8 is panchromatic and band 9 (Cirrus) is used to identify cirrus clouds.

The first set of bands used to illustrate this paper represents an area of about 36,000 km² from north of the state of Mato Grosso (Fig. 1, blue marker). It is centered on the coordinates of -11.56909 of Latitude and -56.23546 of Longitude. Each band has $7,631 \times 7,781$ pixels and is available in TIFF format from the National Institute for Space Research (in Portuguese: Instituto Nacional de Pesquisas Espaciais - INPE), more specifically from the INPE's Imaging Division (<http://www.dgi.inpe.br/catalogo/>).

We also have obtained two other images (Fig. 1, red and yellow markers), from the same source, to validate our process. In addition, it's important to note that the Amazon Rainforest biome extends across all the northern states of Brazil to the center west, ending in the state of Mato Grosso (IBGE 2019).

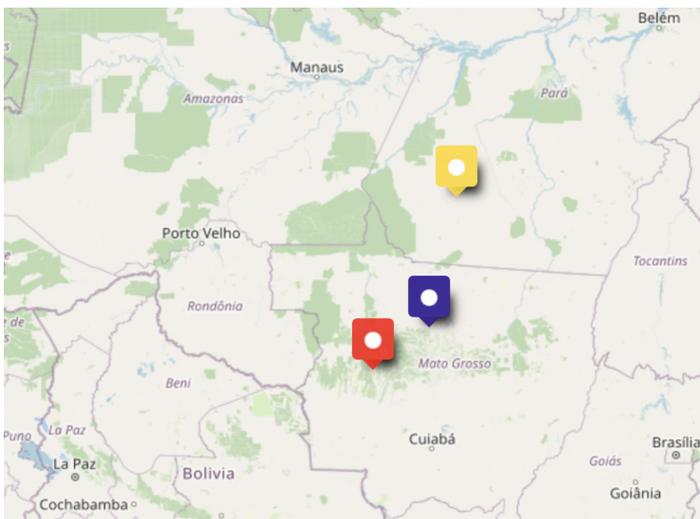


Fig. 1. Markers representing roughly the center of the images used in this experimentation.

To assist in the visualization and qualitative analysis, it is interesting to analyze possible composition of the bands. Using bands 4, 3 and 2 on the normal red, green and blue channels of a computer screen, we obtain an image in true colors (Fig. 2 left), that is, how the region seems to be when observed by a person observing this region. Also, we can obtain false color images by associating non-visible light bands to one of these channels. As an example, using bands 5, 4 and 3, for the red, green and blue channels of a computer screen, we obtain an image with healthy vegetation in red (Fig. 2 center) and, using bands 7, 5 and 3 we get an image with the healthy vegetation in a bright green (Fig. 2 right).

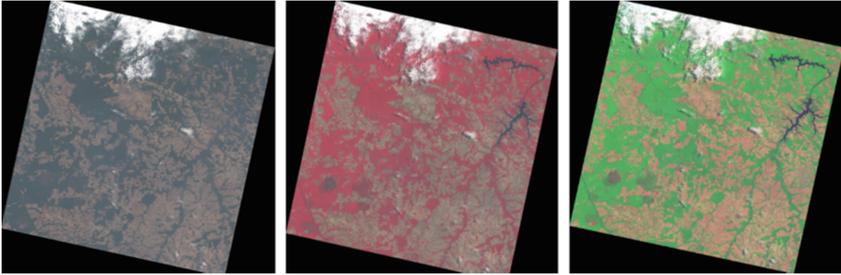


Fig. 2. True color image of the region (left) and same image shown as Blue/Green/Red the 5, 4, 3 channels (center) and 7, 5, 3 channels respectively (right).

After a number of studies and experimentations, band 6 was considered to be used in the presented approach. (Fig. 3 left). This is one of the bands of short infrared and it presents the best amount of light reflected by the healthy vegetation (Price 1992). This statement can be considered as fundamental for this work.

The experiment used the MacOS Monterey 12.1 operating system (Macbook Air M1). The computer language used was Python 3.9.5 64-bit with the libraries scikit-image (0.19.0), scipy (1.7.3), numpy (1.21.4) and matplotlib (3.5.0). The developed code can be consulted at: <https://github.com/rmparanhos/analise-imagens> and is freely available to all interested people.

3 Preprocessing and Processing

Figure 3 shows a general view of the whole process, while Fig. 4 presents the results of these preprocessed steps in the original image used as example. First of all, the image is rotated and cropped to eliminate black areas. Then it is submitted to the histogram normalization function of the libraries resulting in an image with better contrast, as presented in Fig. 4 bottom (left) due the gray level distribution along the possible range. This operation also called Contrast Stretching consists of increasing the contrast by changing the range of intensity values to the maximum limits (Jain 1989). The effect of “stretching” can be seen comparing the Fig. 4 images and the corresponding histogram alterations.

To measure the deforested area, the technique chosen was segmentation. This means to separate the image into two partitions, one containing the pixels that represent the

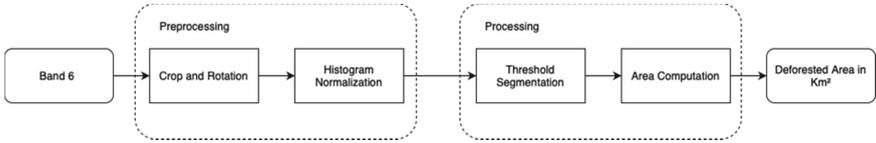


Fig. 3. Flowchart with the steps that result in the calculated deforested area. We use the aforementioned Band 6 of the Landsat 8 as an input, then it goes through the preprocessing and processing steps, which finally give us the deforested area.

deforested area and other containing healthy vegetation. Then measurement of the number of pixels in the partition that represents the deforested area is done. Finally using the relations of pixel per meter the segmented area can be evaluated in physic world units.

There are other segmentation possible approaches: from clustering and edge detection to the use of artificial intelligence techniques and deep learning. In this work, after

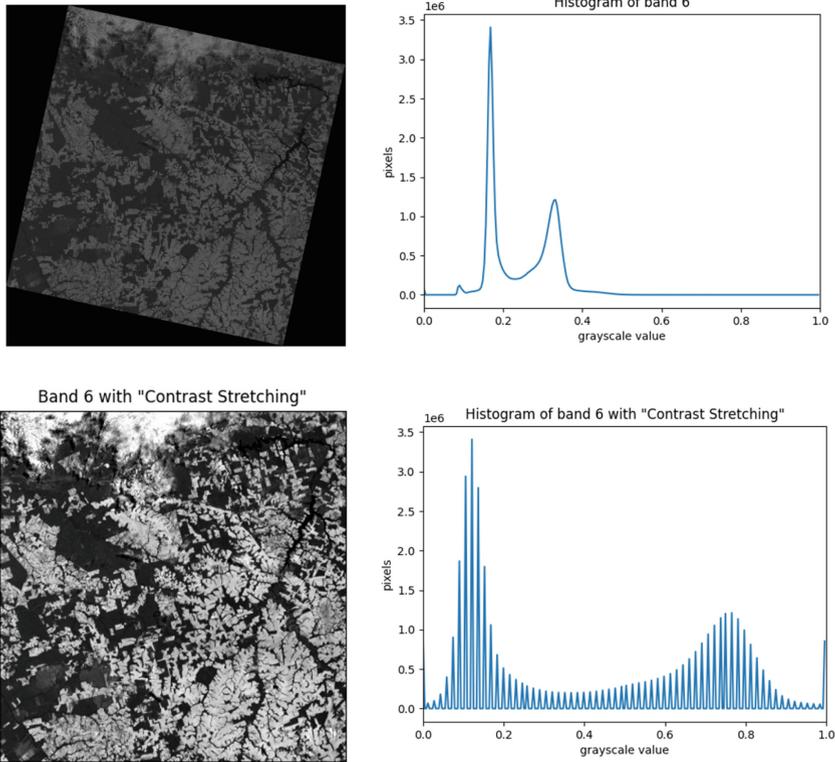


Fig. 4. Using the short infrared channel, from 1560 to 1660 nm wavelength, at 30 m resolution (top left) and its original histogram (top right). Same image after the simple 2 steps preprocessing (bottom left) and its final histogram (bottom right).

some experimentation we considered using thresholding due its simplicity and great multiplicity of techniques already well known and available in programming tools. (Again, as an invitation for continuation of this work for as many people as possible.)

By thresholding, we segment an image by defining a threshold which represents whether the pixel should be considered as belonging to one of the groups according to its intensity being greater than such a value. Consequently at the end of the thresholding there will be a new image version of the original one: a binary image (Fig. 5).

The choice of threshold value can be done through diverse ways. But it is nice to do first a qualitative analysis of the histogram of the image to be segmented. They are bimodal as Fig. 4 shows.

The Otsu's algorithm calculates a global threshold separating the image into two classes, the background and foreground by choosing the threshold value as the one that minimizes variance inside each class and maximizes the variance interclass (Otsu 1979). Another example of a good method for this type of bi modal images is Li's method. This is a variation of the Otsu's algorithm by calculating a local threshold and has better performance than the original one for noisy images (Liu and Li 1993).

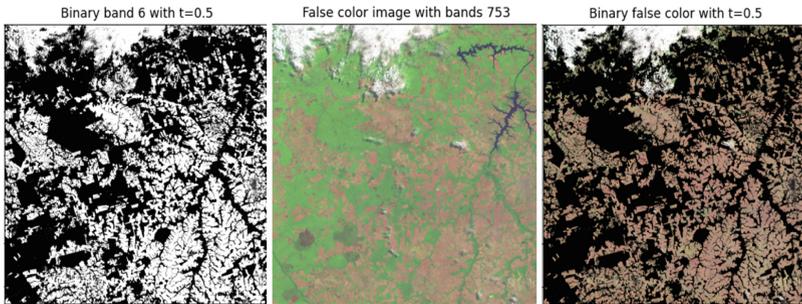


Fig. 5. Band 6 in 2 colors, using a threshold value of 0.5 (left). Original false color image for comparison (center). Binary mask applied over a false-color image, to analysis of selected pixels (right).

The central histogram point after normalization or the medial point between the 2 modes is a good option for segmentation. This plus the results of these 2 automatic approaches were used here for comparison and to evaluate the area versus a human definition of the deforested image regions. These results can be compared in Fig. 5 and 6.

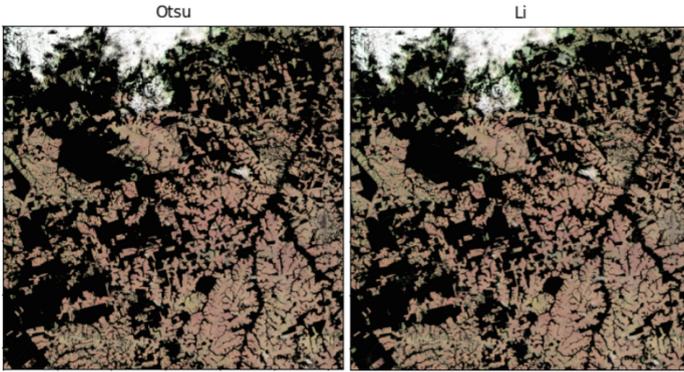


Fig. 6. Binary mask applied over a false-color image, to analyze visually the adequacy of selected pixels using the Otsu (left) and Li methods (right).

4 Results

The area measurement was performed by counting the number of pixels in the binary image, and multiplying by the band resolution. Band 6 of the Landsat 8 OLI instrument, has a resolution of 30 m per pixel, that is, each pixel has a side of 30 m. The area is obtained from the square on the side, so each pixel has an area of 900 m², or 0.0009 km². Using a threshold of 0.5, a deforested area of 15994.2087 was obtained km², about 44% of the total area of the image. For comparison purposes (Fig. 7), the same calculation was performed using the methods of Otsu (deforested area of 16,905.8196 km², about 46% of the total area of the image), and Li (deforested area of 18,019.4679 km², about 49% of the total image area). This shows a convergence to an average value of 17,000 km² and a proposal of using the average values of these 3 approaches.

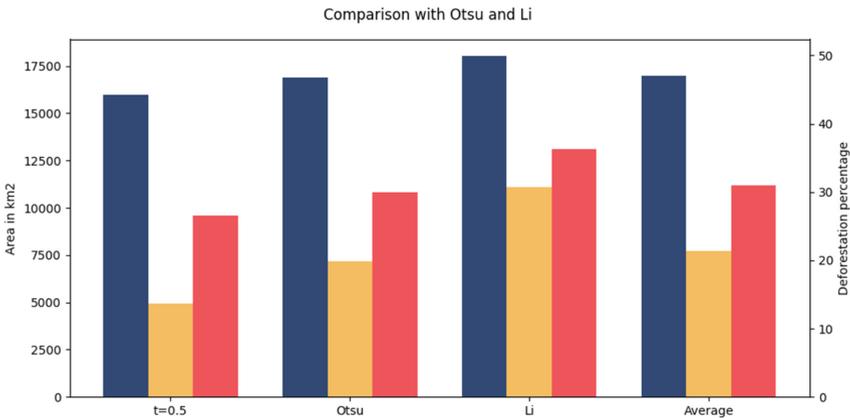


Fig. 7. Total deforested areas by each method in absolute values scale in the left and in percentage scale in the right part of the graph. Each bar corresponds to the image of the same maker color on Fig. 1.

The threshold value found by the automatic methods was very close to the value chosen using qualitative histogram analysis (that is that above mentioned in the central range: threshold of 0.5). Considering the percentage of the results, they are for Otsu method of 0.43%, and for Li method of 0.35%. Both are similar to those perceived when comparing the binary masks of each method applied to the false color image.

Figures 8 and 9 show the original aspect and after segmentations using the same process for the other two markers (yellow and red) represented in Fig. 1. They show that such methods choose coherent threshold values, allowing the suggestion of a generalization of the method to other satellite images.

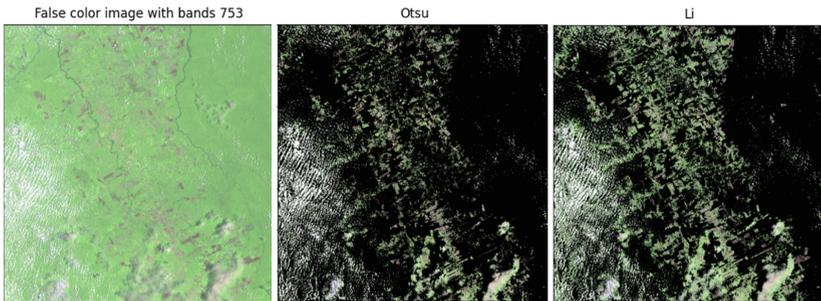


Fig. 8. Yellow marker area: original image and it after segmentation by Otsu and Li thresholds.

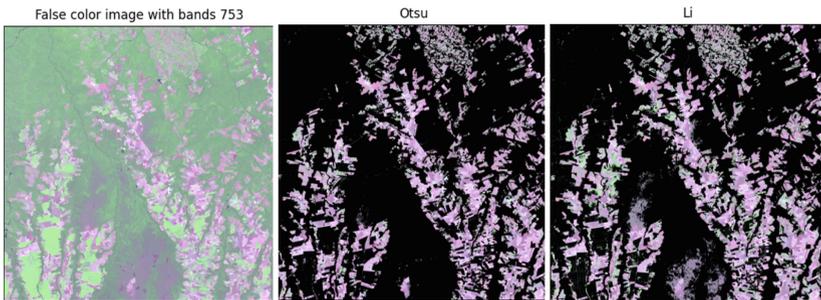


Fig. 9. Red marker area: original image and it after segmentation by Otsu and Li thresholding approaches.

5 Conclusions

By analyzing the masks applied to false-color images, it is possible to realize that the thresholding methods were effective to segment the area deforested. Moreover, despite the facility of using both methods, Otsu and Li, the threshold value found by them allowed a greater spillage of green seen visually, which indicates that the area deforested can be larger. The relation among the methods and the visual deforestation are in a way that the

results of the computed area are always lower than the real one. That is, they represent this quantitative relation: Real > Central point between the modal level > Otsu > Li.

As future work, it is suggested to use other segmentation techniques, for instance the use of texture based edge detection (Rodrigues et al 2016, Araujo et al. 2018). Employment of other ways of preprocessing techniques in order to remove clouds, shadows and other artifacts in the images can also be interesting (Melo et al 2005).

A factor that must be stated is that there is no ground truth available for comparison of the deforested region of Brazil, so that it is not possible to make a fair comparison between the numbers obtained. But as there are a wide variety of possible approaches for segmentation of this type of image, we are here opening a space for comparison and dissemination of a multitude of techniques.

Furthermore, more important than an exact and precise segmentation of the deforested area is the continuous investigation of the rainforest to identify its degeneration year by year. And this can be done using a unique technique, but returning after a time interval in order to investigate how it is increasing.

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