INTERCOMPARISON OF BURNED AREA PRODUCTS IN MATO GROSSO STATE

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ABSTRACT

In 2010, total carbon (C) loss due to fires was responsible for approximately 78% of the Mato Grosso state emissions. As a result of the considerable contribution of fires to C emissions, it is important to properly account them for the fulfillment of climate change mitigation agreements. The first requirement for assessing the fire-related emissions is to quantify the affected area. The main objective of this work is to assess two burned area products (TREES-INPE and JRC), as a preliminary test, on Amazon biome within Mato Grosso state, for the year 2010. Total burned area differs between the products by only 9%. However, there is statistical evidence the products are not similar ($p < 0.01$). This difference was observed only on '*Small'* polygons. Despite the similarities in the total burned area, the JRC product underestimates affected forests. Considering the magnitude of the differences between the products, our results show that JRC burned area product can potentially be used for monitoring the Amazon, as it is automatically generated.

Key words ***— Fires, fire mapping, burnt scar, Amazon.***

1. INTRODUCTION

Fires play an important role in global climate change. They may depreciate carbon stocks, biological diversity, and human health [1], impacting the environment, economy and population [2–4]. Perhaps, the greatest international concern is its contribution to C emissions, removing plant biomass and transferring the associated C to the atmosphere [5]. In 2010, gross carbon emissions due to fires were 0.51 ± 0.12 Pg C yr^{-1} [5], across the Amazon basin, corresponding to 57% of 2010 global emissions from land-use change (0.9 ± 0.7 Pg C) [6]. In the same year, total C loss due to fires in Mato Grosso state was 0.085 ± 0.033 Pg C. Considering the Brazil's National Plan on Climate Change (NPCC), the country established the target of reducing C emission in 1.3 Pg from 2006 to 2017 [7]. It would be expected at least a reduction of approximately 0.11 Pg C per year. The carbon loss in Mato Grosso state represented 77% of the reduction target in 2010 [2]. This numbers highlight the considerable participation of fires to C emissions. If the fire contribution is not properly accounted for the fulfillment of climate change mitigation agreements, the established targets which Brazil has compromised might not be achieved [8].

In order to have C emissions from fires properly accounted for, it is essential to have an adequate estimation of extent, location and land cover affected by fires. Information on these also enable the assessment of the effects of biomass burning on atmospheric chemistry, ecosystem functioning, and human health [1]. In this sense, several methodological approaches have been developed using remote sensing applications for detection and monitoring of fires [1, 2, 9, 10]. Such applications provide a unique source of spatial information which enables burned areas mapping from local to continental and global scales [1].

The area affected by fire, also called burnt scars or burned area, can be mapped using different sensors and in different scales. Most burned area products are developed with coarse spatial resolution (>250 m) satellite data, which offers high temporal frequency [9, 10]. Despite avoiding the cloud cover issue, coarse spatial resolution imagery turns the development of an automatic burned area mapping very challenging, due to variability of the burnt scar spectral characteristics [1]. Shimabukuro et al. [1] presented a sampling approach to assess burned areas with medium resolution Landsat satellite imagery. Although the medium spatial resolution (30 m) imagery gives more reliability to the burned area assessment [1], it is difficult to obtain full coverage over large areas in tropical regions, because both the relatively low temporal resolution and the potential cloud cover [11]. Depending on the data and method used for burned area mapping, the final product can vary considerably, concerning the distribution, size and frequency of fires [12].

Although there are different burned area products, the issue of which product to use arises. In this context, we aim to compare the TREES [2, 13] and the Joint Research Center burned area products, which were developed independently with different methodologies. Our study focused on Amazon biome within Mato Grosso state, for the year 2010. First, we compared the number and total area of burnt scars. Then, we evaluated the spatial distribution of burned areas detected over a forest proportion gradient. Our hypothesis is that the variation between the products increase on forest areas, due to difficult distinction of the burnt scars in this land cover [2].

2. MATERIAL AND METHODS

The 2010 burned area products were spatially compared considering two perspectives: as vector, and as raster. All analyses were performed on R. Details regarding the products and methods are presented on the following sections.

2.1. Study Area

The study area corresponds to the Amazon biome within Mato Grosso state, Brazil (Figure 1). We used the Amazon biome mask to match the burned area products with the remaining forest data provided by TerraClass [14] and Prodes [15].

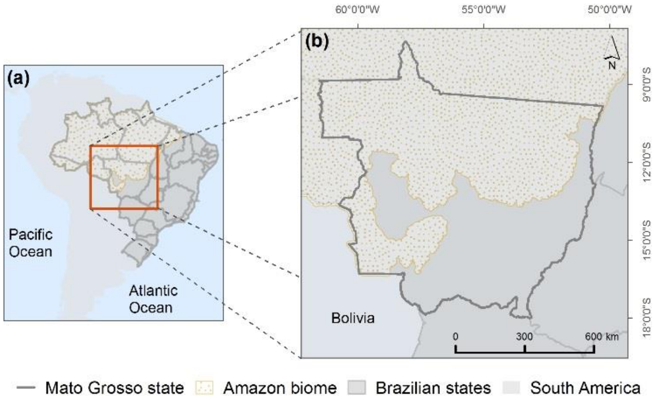

Figure 1. Overview of the study area in (a). (b) highlights the Amazon biome border (area filled with yellow dots) within Mato Grosso state, which is considered the study area.

2.2. Burned area products

The two burned area products are based on the Moderate Resolution Imaging Spectroradiometer (MODIS), however they adopt different mapping methodologies. The Tropical Ecosystems and Environmental Sciences (TREES) burned area product was generated by the collaboration between Amazônica, FATE-Amazônia, and Panamazonia projects. Its mapping methodology is based on the application of Linear Spectral Mixture Model on MODIS images [2]. From this model, the shadow fraction image is used to enhance the burned areas, since they are targets that present low reflectance in red, near-infrared and medium-infrared spectral bands. Next, an unsupervised classification and the manual edition are performed for generation of the final product. The manual edition is believed to credit more accuracy on the final product, mainly on forested areas, where the burned target is easily confused or not detected [16–18]. Since the TREES methodology can detect burned areas between January and September, we considered the same time window on both products.

The second burned area product used in our analysis was developed by the Joint Research Centre (JRC). JRC does not detect the burnt pixel, their product is only a post-process of an already done product, in this case MCD64A1, developed by NASA [10]. This post-process is performed to identify individual fire events at global scale [19]. Their final product consists in burned polygons, that contains the initial and final fire dates. Therefore, the total burned area should not be different when compared to the MCD64A1 product. However, the use of JRC product gives the advantage of individualizing burned scars, allowing the comparison of number of polygons and their size distribution.

Hereafter the products are called TREES and JRC.

2.3. Vector analysis

We compared the number of burned area polygons, total burned area, and the mean polygon area for both products. The polygons were classified in *'Small'*, *'Medium'*, and *'Large'*. This classification considered the 75% smallest polygons as *'Small'*, the next approximately 23% as *'Medium'*, and the left 2% as *'Large'*. The thresholds for each class are respectively: $\leq$ 1.16 km^2, $>$ 1.16 and $<$ 27 km^2, and $>$ 27 km^2.

The number of polygons and the total burned area were quantitatively analyzed. The products were statistically compared by Kruskal-Wallis test.

2.4. Raster analysis

We aggregated the burned area products in a 10km regular grid. For each cell, we attributed the proportion of burned area derived from TREES and JRC. We also incorporated into the grid the proportion of remaining forest, extracted from TerraClass 2010 [14] and Prodes [15]. The grid information was used to build the difference map.

3. RESULTS

The burned areas showed a negative exponential behavior for their frequency distribution on both products. This means that a polygon taken at random has a very high chance of being small, and the opposite, the very large burned areas are minority in the data (Figure 2a). The density distribution for both products is similar, approaching a normal distribution (Figure 2b). The smallest burned area detected by TREES has 0.06 km^2, and the highest 17,595 km^2. The size range of JRC polygons goes from 0.23 to 9,714 km^2. 90% of the burned areas from both products are smaller than 4 km^2. The total burned area registered by

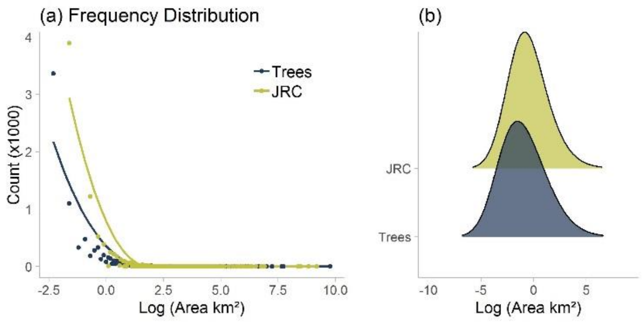

Figure 2. Frequency distribution of the polygons area for both burned area products, (a). Density distribution, (b).

TREES and JRC products is 53,174 km² and 58,810 km², respectively. The products presented a difference of only 9% in area.

Classifying the burned areas into size classes, the biggest difference in number of polygons was observed on the '*Large'* polygons (32%) (Figure 3a). Considering the difference in area, *'Small'* polygons presented the biggest difference (21%) (Figure 3b). In all other cases, the differences did not exceed 11%.

The mean polygon area detected by TREES and JRC is 6.12 and 7.17, respectively (Figure 3c). Statistically, there is evidence that the polygon area distributions from both products are not similar ($p < 0.01$). When considering the size classes, only the 'Small' class presented statistical evidence that suggests difference between the products ($p < 0.01$) (Figure 3d).

To evaluate the spatial differences between the two products, we plot a difference map, in which the closer to zero the cell value is, the smaller the difference between them (Figure 4a). The TREES product mapped more burned areas on the northeast of the study area in 2010, while the JRC product presented more burned areas on the southern portion. This analysis showed that the difference between the two products is spatially systematic, occurring regions under or overestimating the burned area on each dataset. These regions with greater difference between the products were not coincident with high proportion of forest, indicating that forest presence is probably not the reason of the observed difference (Figure 4b).

4. FINAL CONSIDERATIONS

The two burned area products analyzed in this paper use the same satellite data source to perform the burned area mapping – MODIS imagery. However, there are slight differences between the mapping approaches adopted. The TREES product is developed using MODIS/Terra imagery with 250 m of spatial resolution and image classification process. In contrast, JRC product is based on the burned area dataset developed by NASA, MCD64A1. The MCD64A1 product combines imagery from MODIS/Terra and MODIS/Aqua with 500 m of spatial resolution, along with thermal anomalies.

The spatial resolution difference may be one of the reasons the smallest burned area detected by TREES was almost 4 times smaller than the smallest registered by JRC. Despite of mapping a smaller number of '*Small'* polygons, JRC product presented a greater area mapped in this category. This shows that TREES product was able to detect a larger number of smaller polygons. Improvements on JRC detection algorithm for smaller polygons could minimize this variation. The *'Small'* category was also the only one that presented statistic significant difference between the products, contributing for the significant difference observed on the overall comparison.

Besides this variation on polygons size, the difference between the burned area products varied spatially. This could be explained by the algorithm and image selection used for mapping. Studies that consider a time series could evaluate if the spatial variation is systematic. If so, this variation can be used as guidelines for mapping improvements. The extreme differences did not seem to occur on high forest proportion cells, going against from what we would expect.

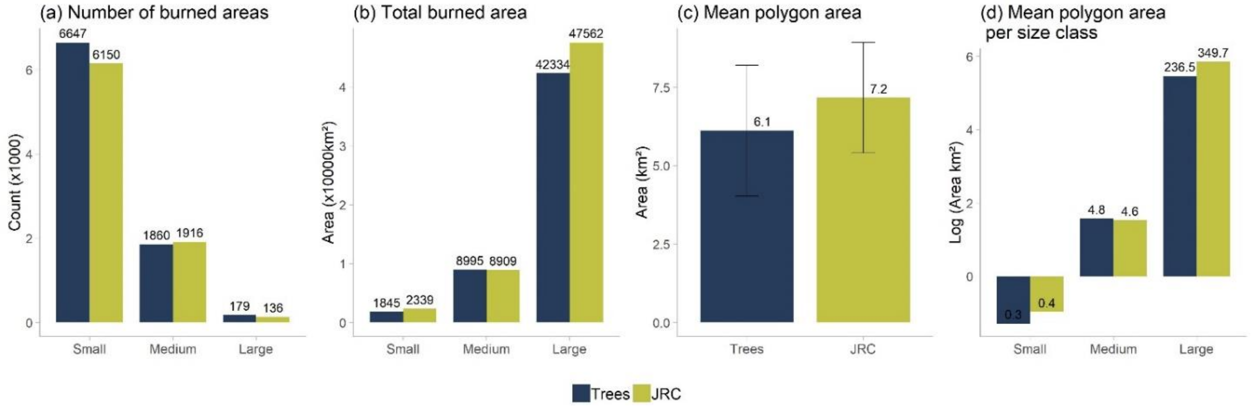

Figure 3. Number of burned area polygons, (a). Total area burned detected, (b). Mean polygon area, (c). Mean polygon area per size class, (d).

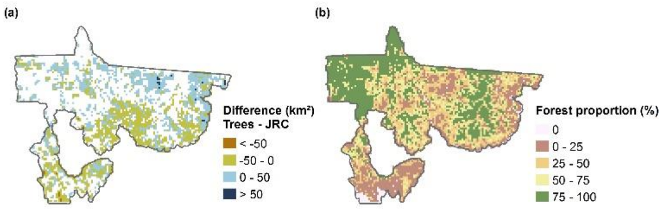

Figure 4. Raster analysis. Difference map (TREES – JRC), (a). Remaining forest proportion, (b). All the information is aggregated in 10x10 km cells.

In general, the total area affected by fire was very similar between the two products. Shimabukuro et al. [1] estimated a difference of 21% between MCD64A1 and a wall-to-wall burned area map built using Landsat TM images, also for Mato Grosso state in 2010. This difference is 2.4 times greater than what we found. Considering the human and time resources necessary to perform the manual edition TREES product applies on its methodology, JRC burned area product could be used as a useful alternative, since it has a considerable time series (2005-2016), and it is automatically generated. Nevertheless, more studies are needed to evaluate if the differences between the products varies when considering a greater extent and longer time series.

Lastly, the variation between the products does not necessarily mean that one is more accurate than another. The decision on what dataset to use depends on the end user needs.

6. ACKNOWLEDGMENTS

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