EXPLORATORY ANALYSIS OF RECURRENT DEFORESTATION WARNINGS IN THE BRAZILIAN AMAZON

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ABSTRACT

Given the role tropical forests play in the Earths ecosystem, we need to take advantage of already existing datasets and use them in innovative ways to deepen our understanding of it. In this study, we analyzed the deforestation alerts in the Brazilian Amazon from 2016 to 2021 to assess the spatial distribution of deforestation by recurring degradation. Our findings show that the number of alerts aligns with the well-known deforestation arc and includes forest areas with up to five alerts spaced five years apart, with an average gap of two years between the first and second alerts, and one year between the second and third. These results highlight DETER's potential as a valuable data source for monitoring the progression of deforestation through repeated degradation events.

Key words – *Degradation, Deforestation, DETER.*

1. INTRODUCTION

The Amazon rainforest plays many roles in controlling the climate and avoiding the current climate crisis. Not only it is home to countless species, but also regulates both the water and carbon cycles. Besides, it is a massive carbon reservoir, and it is one of the potential tipping points at which poor management could trigger catastrophic and irreversible changes to the climate system.

The current advances in Ecology, Remote Sensing, and Computer Science have enabled the development of regional, continental and global deforestation monitoring systems (e.g., DETER, MapBiomas, Global Forest Watch). However, detecting and monitoring forest degradation remains more challenging than detecting deforestation [1, 2].

Given the importance of this issue, in this paper we present the spatial distribution of recurrent forest degradation in the Brazilian Amazon, which could help address the challenges in detecting it. We think that deforestation real-time forest monitoring systems, such as DETER that continuously issues deforestation alerts, inadvertently captures forest degradation processes at various stages. The findings presented here are the results of processing 5 years of DETER alerts.

This paper extends the findings introduced in [3].

2. MATERIAL E METHODS

For our analysis, we employed DETER data from August 2016 to July 2021. DETER is a real-time deforestation detection system developed by the National Institute of Space Research that is at the forefront of Brazil's efforts to control deforestation. DETER has produced fast assessments of forest degradation and deforestation in the Brazilian Amazon since 2004 [4].

DETER mainly uses remote sensing imagery from the WFI camera on board of the CBERS satellites, producing alerts of at least 3 ha which are tagged as wildfire scar, mining, deforestation with either exposed soil or vegetation, degradation, and selective cut with either disordered or geometric pattern [5, 6].

Degradation and deforestation spots are identified by human experts on images enhanced with a color composition (red, near-infrared, and green) and a Linear Mixture Model [7] (soil fraction) and the criteria of tone, color, shape, texture, and context. These experts draw DETER warnings (polygons) on top of a computer screen fix on a scale 1:100,000 using as background the latest primary forest polygon mask and previous DETER warnings [8]. DETER data is publicly available at the TerraBrasilis portal [6].

After downloading, we self-intersected the data (union operation) and re-projected them to the coordinate reference system UTM 22s. We also removed duplicated vertices and enforced the right-hand rule for polygons. Then we fixed geometry errors, and finally we removed alerts smaller than 3 ha. This processing was applied using QGIS version 3.38.0 [9]. We also computed the alerts' warning year using the PRODES calendar, which is the period from August to July; each PRODES year takes the year number from the last month of its period (July).

DETER alerts don't spatially match over time. This means that it is only possible to match alert subareas consistently along the time dimension. This is the reason for the data self-intersection mentioned above. The *subareas* resulting from this self-intersection correspond to polygons on which DETER alerts were issued on different dates, and are the base on which our analysis is founded.

Our analyses were carried out using the GNU's R language and environment for statistical computing and graphics to estimate statistics analysis [10]. Our source code is available online. [1]

3. RESULTS

DETER data show an abrupt fall in during PRODES year 2019 followed by an increasing trend in the area covered by its alerts. It is worth noticing that the distribution by area in homogenous for each year, particularly for 2021 (see Figure 1).

[1]R code available at `https://github.com/albhasan/treesburnareas`

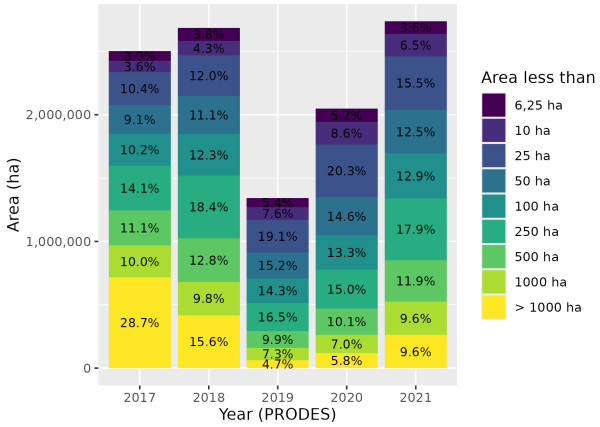


Figure 1: Area of DETER alerts by year and size. The area covered by alerts peaked in 2018 and 2021. Note the increasing trend since 2019 and how their area distribution is relatively homogeneous along in 2021.

Moreover, the number of DETER alerts during the same period shows a somewhat similar pattern, characterized by the fact that half of yearly DETER alerts are issued for small areas (Figure 2).

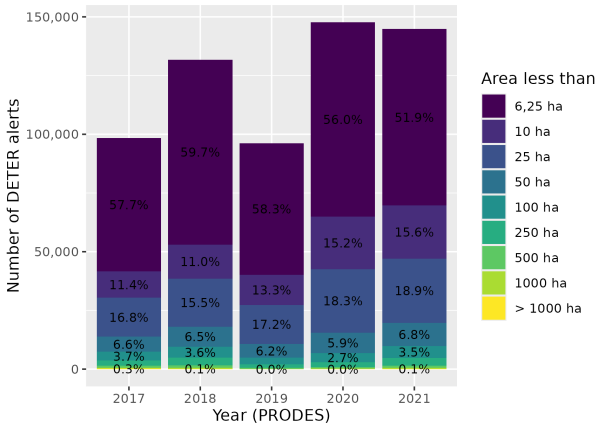


Figure 2: Number of DETER alerts by year and size. Note the increasing trend since 2017. Note how DETER issued a similar number of alert in 2020 and 2021 but Figure 2 shows a larger extent of alerts in 2021.

From August to October is when most DETER alerts are issued, and September, the peak month, presents an increasing trend in area, reaching its maximum in 2021. This period corresponds to the fire season in most of the Brazilian Amazon [11] (see Figure 3).

Most DETER subareas are issued a single alert and never more than five, following an exponential decay pattern.

The time period between DETER alerts in the same subarea is one year, except for subareas with two alerts, when it is two years (Figure 5).

The map in Figure 4 shows the distribution of recurrent deforestation warnings, that is, a surface interpolation of the number of DETER alerts.

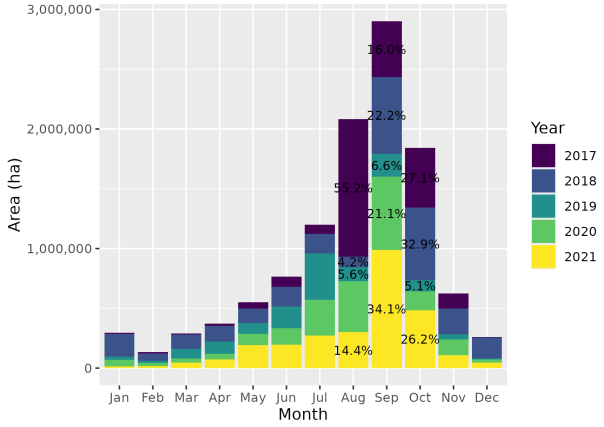


Figure 3: DETER warnings by month. Between August and October is when most of the warnings are issued. Note how September presents an increasing trend along the years which peaks in 2021.

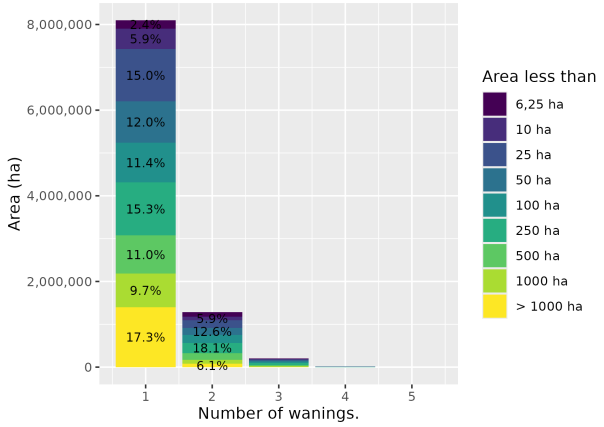


Figure 4: DETER subareas by number of warnings. Most subareas only have one DETER alert and never more than five. The total extent for each number of alerts is homogeneously distributed.

4. DISCUSSION

The data shows that recurrent DETER alerts over the same area are uncommon, and proportionally inverse to the number of alerts. The data also shows that subareas with the most recurrent alerts tend to happen along the east of Amazonia (the deforestation arc) and to the north, in the *Roraima* state (Figure 4 and Figure 6). Also, most of the successive alerts in the same subarea are at most five years apart (that is, the duration of our dataset, from 2016 to 2021), two years from the first to the second, and one year from there.

It must be taken into account that DETER data is produced with for a different purpose than the analysis presented here, and that it acknowledges its under estimation of forest degradation due to its associated challenges [8].

5. ACKNOWLEDGEMENTS

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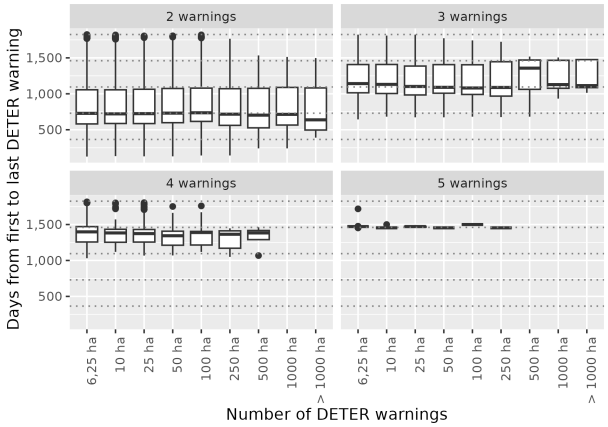


Figure 5: Number of days between the first and last DETER alerts. The horizontal dashed black lines represent intervals of 365 days. DETER subareas with 2 warnings tend to be two years apart and then increase one year with each additional alert. Also note that the distribution by area tend to have long tails towards longer periods between the first and lat DETER alert.

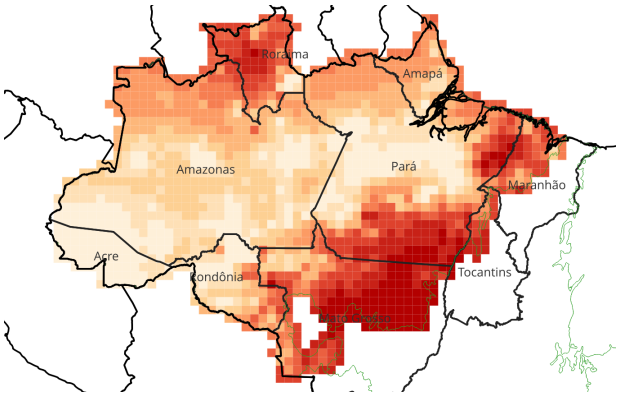


Figure 6: Spatial distribution of recurrent degradation (number of alerts by subarea) in the Brazilian Amazon. Amazon's east front is where most of recurrent DETER alerts area found.

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