# EXPLORATORY ANALYSIS OF RECURRENT DEFORESTATION WARNINGS IN SÃO FÉLIX DO XINGU - BRAZILIAN AMAZON

*Alber Sánchez Ipia*[1], *Guilherme Mataveli*[1], *Aline Pontes-Lopes*[1] *Sulimar Munira Caparoci Nogueira*[2], *and Luiz Aragão*[1]

[1]Earth Observation and Geoinformatics Division - DIOTG, National Institute for Space Research - INPE, Av. dos Astronautas, 1758 - São José dos Campos - SP - Brazil alber.ipia@inpe.br, guilherme.mataveli@inpe.br, aline.lopes@inpe.br, luiz.aragao@inpe.br; [2]IDGeo - Inteligência Agrícola, suli.nogueira@gmail.com

***ABSTRACT***

*Identifying forest degradation is as import as identifying deforestation, but even more challenging. Due to the role of tropical forests in the Earth System, it is imperative to discover new ways to improve and characterize our knowledge about forest degradation. This includes finding alternative uses for already existing data such as the warnings issued by the DETER system. In this paper, we explore the DETER warnings in São Félix do Xingu from 2016 to 2021 and compute their frequency over the same areas. We found forest areas with up to 4 warnings 4 years apart and their mean time between the first and second warnings is two years and one year between the second and the third. Our results are important because they point to DETER as a source of data for analyzing the development of deforestation by recurrent degradation.*

***Key words –*** *Degradation, Deforestation, DETER.*

## 1. INTRODUCTION

The Amazon forest plays an important role in the current climate crisis. Besides hosting a large number of species and regulating the water and carbon cycles, the forest works as a large carbon storage and it is frequently cited as one of the tipping points, which —if mishandled— could potentially cause an abrupt and irreversible change in the climate system [1, 2].

Advances in the areas of Ecology, Remote Sensing, and Computer Science have fostered regional, continental and even global deforestation monitoring systems (e.g. PRODES, Global Forest Watch). However, detecting forest degradation is more challenging than detecting deforestation [3, 4].

Due to the importance of what is at stake, we seek new ways to improve degradation characterization which could alleviate the difficulties associated to detection of forest degradation. For this reason, in this manuscript, we explore the possibilities of using DETER warnings for understanding forest degradation. DETER constantly issues deforestation warnings on the Brazilian Amazon forest, and these warnings capture forest degradation at different stages of development. This information has many potential applications, such as for example, providing quality training data for Machine Learning algorithms able to process massive amounts of satellite imagery.

To test the feasibility of our approach, we processed 5 years of DETER warnings in the municipality of *São Félix do Xingu*, estimating the areas and number of days between warnings on the same area.

## 2. MATERIAL E METHODS

For our analysis, we selected the municipality of *São Félix do Xingu* in the Brazilian state of *Pará* as our area of interest in the period from August 2016 to July 2021. This municipality extent is 82 square kilometers and it is consistently reported as one of the most deforested in Brazil by the PRODES system [5].

We prepare a dataset of degradation and deforestation warnings produced by the Brazilian National Institute for Space Research (INPE) and its DETER system. DETER is a Geographic Information System which produces a fast assessment of forest degradation and deforestation in the Brazilian Amazon since 2004 [6]. DETER is the backbone of law enforcement efforts in the Brazilian Amazon and Cerrado Biomes. Since 2015, DETER uses remote sensing imagery captured by the WFI camera on board of the CBERS 4 & 4A satellites, producing warnings with a minimum area of 3 ha organized into classes: Wildfire scar, mining, deforestation with either exposed soil or vegetation, degradation, and selective cut with either disordered or geometric pattern [5,7]. To spot deforestation, DETER employs human experts which use image composition of red, near-infrared, and green along with a Linear Mixture Model [8] (soil fraction) and the criteria of tone, color, shape, texture, and context. These experts draw DETER warnings on top a computer screen fix on a scale 1:100,000 using as background the latest PRODES primary forest mask and previous DETER warnings [9].

Our data set consists of the warnings issued in our area of interest during the aforementioned period downloaded from the TerraBrasilis portal [5]. After downloading the data, we convert them into a GeoPackage; [1] this helps us overcome the limitations [2] of the traditional Shapefile format available from INPE.

Then, it was used the self-intersect operation (union operation) on the warning polygons and after that, we projected them to the coordinate reference system UTM 22s; later, we removed duplicated vertices and enforced the right-hand-rule of polygons; then we applied successive geometry fixing, and finally we filtered out polygons smaller than 3 ha. These operations were applied using the software QGIS version 3.28.0 [10]. We also converted the warning year to what we call PRODES year, which is time period from August to July. Each PRODES year takes the year number from the last month of its period (July).

It is important to note that DETER warnings overlap over time but not completely. That means, some segments of

[1]GeoPackage Encoding Standard `https://www.ogc.org/standards/geopackage`

[2]Switch from Shapefile `http://switchfromshapefile.org/`

a warning partially overlap with some other segments of other warnings at other dates. We call the result of the self-intersect operation *subareas* and they correspond to segments of DETER warnings which, if overlap other subareas, they do have the same spatial properties (position, area, shape, and centroid).

Finally, we used the GNU's R language and environment for statistical computing and graphics to estimate statistics and carry on further analysis [11]. The source code of our analysis is available online. [3]

## 3. RESULTS

*São Félix do Xingu* has a growing trend of DETER warnings from August 2016 to July 2021, where 2018 presents a particularly worrying peak. There are increases in the warning areas of DETER along all sizes (see Figure 1).

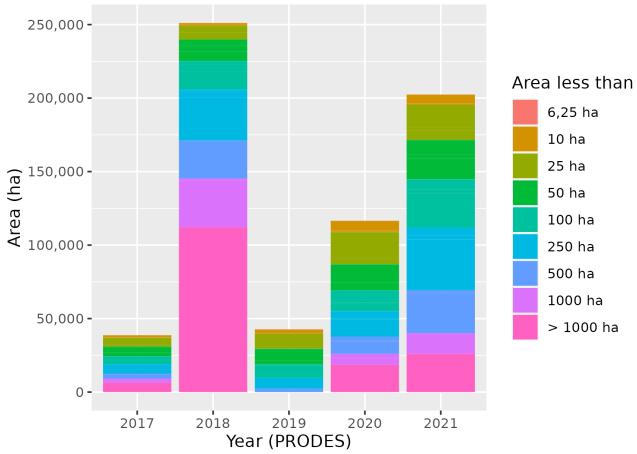


**Figure 1: Area of DETER warnings by year and size. The area covered by warnings peaked in 2018. Note the increasing trend since 2019 and how their distribution is homogeneous along the size brackets in 2021.**

Meanwhile, the number of DETER warnings displays the same growing trend except for the 2018 peak that isn't very prominent, indicating an increment not only in the number of DETER warnings, but also in their size (see Figure 2).

The month where most DETER warnings are issued in the area of interest during the study period is September (the end of the 2-month dry season in half of the Amazon [12]), followed by October and August. The yearly increasing trend is also found inside September and October (even the 2018 peak), the months with the most warnings, (see Figure 3).

Our analysis also shows that most subareas in the area of study receive only one DETER warning (see Figure 4) and those which receive a second one, they receive it two or three years after (see Figure 5 and Table 1). The remaining subareas, which receive a third or even a fourth waning, receive their last warning between three and four years after the first one (see Figure 5).

Besides, subareas smaller than 50 or 100 ha and two DETER warnings tend to receive their second waning two years after the first while larger subareas tend to receive them

[3] File sbsr_2013.R available at `https://github.com/albhasan/treesburnareas`

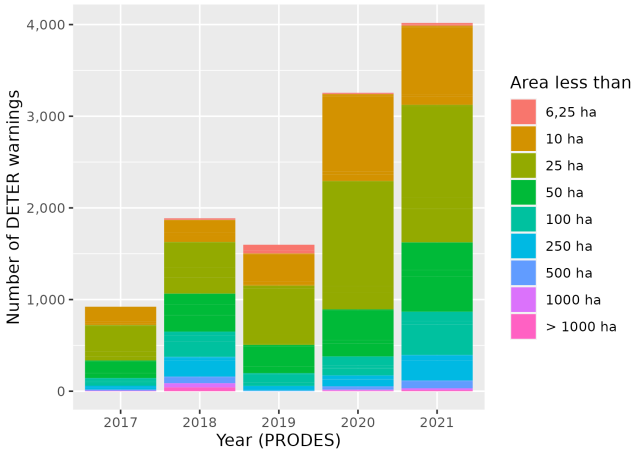


**Figure 2: Number of DETER warnings by year and size.Note the increasing trend since 2017. The increase in warnings in 2018 corresponds to a large increase in area, implying an increment in the size of each warning.**

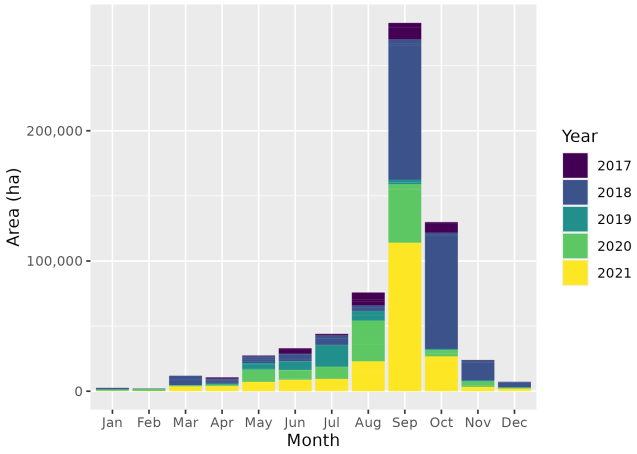


**Figure 3: DETER warnings by month. Between August and October is when most of the warnings are issued. Note how September presents an increasing trend along the years on which 2018 is comparable to 2021.**

after three years (see the medians in Figure 5). Something similar happens to subareas with 3 warnings, where subareas smaller than 25 ha receive their last warning approximately one year before than larger subareas.

## 4. DISCUSSION

Our results show that the number of subareas with more than one DETER warning is low compared to the total number of warnings and there are but a few of subareas with more than three warnings. They also show that most of successive warnings of the same subarea are at most four years apart, two years from the first to the second, and one year from there. We found that DETER warnings provide between two and four warnings to characterize degradation processes in one of the most deforested municipalities in the Amazon.

The number of available subareas seems small for training Machine Learning algorithms, specially those based on Deep Learning that are well-known for requiring large amounts of training data. However, we expect these numbers increase

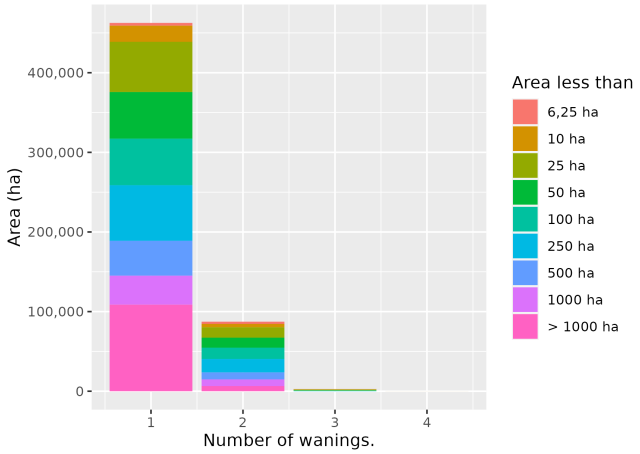


**Figure 4: DETER warning area by number of warnings. Most subareas are issued a DETER warning only once, and never more than four.**

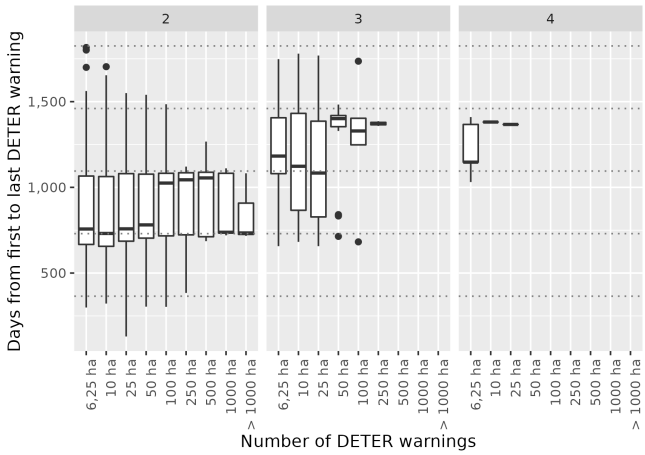


**Figure 5: Number of days between the first and last DETER warning of the same subarea. Note how the difference between 2 and 3 warnings is approximately 365 days (dotted lines). Each Box plot shows the median; the first and third quartiles (hinges); 1.5 times the inter-quartile range from the hinges; and the outliers.**

by extending our analysis to the whole area covered by the Brazilian Amazon since 2016. In addition, we think our results foster new analysis in areas different from Computer Science. Despite this fact, our results are important as they explore a potential new application of the already useful and openly available DETER data.

Our results rely on the assumption that *São Félix do Xingu* is representative of degradation in the Amazon. They also rely on the accuracy of DETER warning polygons and the assumption that subareas larger than 3 ha correspond to actual degradation warnings instead of drawing inaccuracies on a computer screen.

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| N. Warnings | Type | N. Subareas | Total area |
|---|---|---|---|
| 1 | 6.25 ha | 749 | 3468.9 |
| 1 | 10 ha | 2535 | 20277.6 |
| 1 | 25 ha | 4002 | 63098.2 |
| 1 | 50 ha | 1682 | 58496.4 |
| 1 | 100 ha | 847 | 58490.3 |
| 1 | 250 ha | 459 | 69741.0 |
| 1 | 500 ha | 133 | 43890.2 |
| 1 | 1000 ha | 54 | 36388.0 |
| 1 | > 1000 ha | 42 | 108701.0 |
| 2 | 6.25 ha | 617 | 2754.4 |
| 2 | 10 ha | 542 | 4300.3 |
| 2 | 25 ha | 829 | 13016.6 |
| 2 | 50 ha | 356 | 12588.7 |
| 2 | 100 ha | 200 | 14101.6 |
| 2 | 250 ha | 111 | 16949.5 |
| 2 | 500 ha | 25 | 8804.5 |
| 2 | 1000 ha | 12 | 8361.2 |
| 2 | > 1000 ha | 3 | 6444.0 |
| 3 | 6.25 ha | 70 | 331.8 |
| 3 | 10 ha | 48 | 383.2 |
| 3 | 25 ha | 62 | 943.4 |
| 3 | 50 ha | 15 | 528.5 |
| 3 | 100 ha | 5 | 342.0 |
| 3 | 250 ha | 2 | 261.5 |
| 4 | 6.25 ha | 5 | 24.4 |
| 4 | 10 ha | 1 | 8.4 |
| 4 | 25 ha | 2 | 31.4 |

**Table 1: DETER warning subareas by number of wanings, type, number of subareas, and total area. The number and total area decreases as the number of warnings increase.**

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