ASSESSING FIRE EXTENT IN PRIMARY AND SECONDARY FORESTS IN RURAL PROPERTIES OF THE EASTERN AMAZON

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ABSTRACT

The state of Pará has concentrated the greatest fire activity in the Brazilian Amazon in the last years, triggering negative impacts on forests. In this study, we assessed the burned area of primary and secondary forests in rural properties in the state in 2018. Primary forests were the most affected, representing almost 80% of the burned area, nearly 35,000 ha. Of this total, large properties concentrated 48%, about 17,000 ha or three times the area observed in small properties. More than 50% (5,713.6 ha) of the secondary burned forests showed ages between 5-20 years. We also found that 15% of secondary forests burned in 2018 could be illegal deforestation occurring after 2008. Considering the causes and origin of burning is fundamental to reducing fire impacts on the Amazon forest. Solutions need to include strengthening environmental enforcement to curb illegal deforestation and ensuring safe practices in using fire for subsistence activities.

Key words **—** CAR. Rural property. Fallow. Forest fires.

1. INTRODUCTION

Avoiding the removal of primary forests and promoting the regeneration of secondary forests is a central issue for protecting the Amazon forest, the largest tropical forest in the world, which plays a crucial role in regulating the global climate. However, forest degradation has been a growing threat to the Amazon, impacting an area twice as large as that affected by deforestation [1]. Fire is one of the main drivers of degradation in the Amazon, causing forest impoverishment and reducing carbon stocks [2].

Protecting this tropical forest on private lands plays a key role in the environmental governance of the Brazilian Amazon since 34% of the biome is under rural properties land tenure [3]. However, the use of fire by landowners as part of rural activities, such as land management, pasture maintenance, and deforestation, threatens the forest, as fires can escape into adjacent native vegetation, resulting in forest fires [4]. The Brazilian Forest Code defines the rules for protecting native vegetation on private lands, including prohibiting using fire on vegetation. The use of fire can only be allowed in specific situations, such as the burning of fallow areas, that is, productive areas of the rural property that have activities interrupted for a maximum of five years. Therefore, to ensure the correct application of the law, it is essential to know the characteristics and ages of the secondary forests exposed to burning events, identifying, for example, if they are being used as fallow areas in rural properties. Pará was the first Brazilian Amazon state to elaborate specific legislation for the protection of secondary forests on private lands, defining rules to classify the regeneration stage [5]. In this state, requests from landowners for the removal of secondary forest, which can include the use of fire for this purpose, will be subject to the rules of this law and prior authorization from the environmental agency.

Record-breaking fires have been increasingly frequent in the Brazilian Amazon, emphasizing the state of Pará, which has led to the number of active fires in the last years in the biome [6]. The Rural Environmental Registry (CAR, an acronym in Portuguese), a mandatory public electronic registry for all rural properties in Brazilian territory, is an important tool to monitor compliance with environmental legislation by rural landowners [7]. Combined with spatial data derived from remote sensing, these data can provide helpful information about fire occurrence in forest areas on rural properties. In this study, we aimed to (i) quantify the area of primary and secondary forest affected by the fire on rural properties in the state of Pará and (ii) stratify the secondary forest affected by fire according to the regeneration stages defined by the state law.

2. MATERIAL AND METHODS

2.1 Study area

The study area covers the state of Pará, the second largest state in Brazil, covering c. 1.25 M km² (Figure 1). In this state, fire seasons are concentrated in the last five months of

the year, with 59% of the fire peaks concentrated between August and September and 41% between October and December [8].

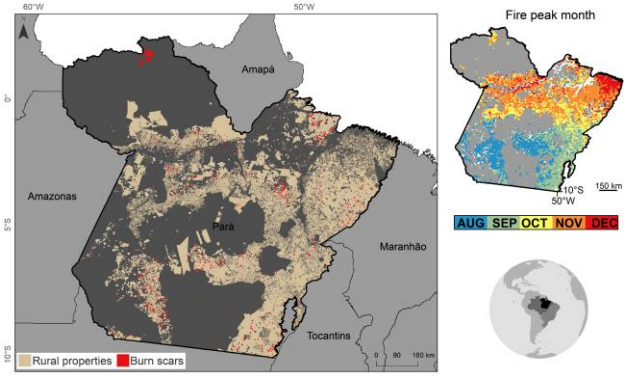

Figure 1. Rural properties and burned area in the state of Pará in 2018. The fire peak months in the state are also shown.

2.2 Data

We used the limits of rural properties enrolled in the Rural Environmental Registry (CAR) of all 144 municipalities in the Pará state, available on the CAR public consultation platform [3]. To obtain the area affected by the fire on rural properties, we used the MCD64A1/Collection 6 product, a global burned area data that provides information per-pixel with 500-m spatial resolution [9].

To calculate the area of primary forests burned, we used data from the MapBiomas project (Collection 6), which produces annual maps of land-use and land-cover with 30-m spatial resolution for the entire Brazilian territory [10]. To calculate the area and age of secondary forests burned, we used data from [11], which provides information in the same territorial extent and spatial resolution as the MapBiomas project. To identify the year of deforestation of the secondary forests, we also used data from the Brazilian Amazon Deforestation Monitoring Program (PRODES), an annual mapping of clear-cutting of primary forests in the Amazon [12].

2.3 Analysis

We classified the rural properties (RP) according to the number of fiscal modules (FM), in small (RP<4FM), medium (4FM≤RP<15FM), and large properties (RP>15FM). The overlapping areas among the categories of rural properties were classified only in the multiple category. We calculated the total burned area of primary and secondary forests for each rural category. We performed the analysis for 2018 as this was the most recent year with data available for secondary forests.

To calculate the burned area only in primary forest, we used the data produced by [11] to remove the secondary forests in the Mapbiomas mapping. For the secondary forests, in addition to calculating the total burned area, we also classified the regeneration stage as initial (<5 years), intermediate (5-20 years), and late (>20 years), according to the legislation of the state of Pará [5]. In the Pará state, depending on the productive characteristics of the area, location, and regional structure of vegetation, burning may be allowed for secondary forests up to 20 years old.

Finally, we also evaluated the possible illegality of the use of fire in secondary forests. For this, we used the PRODES deforestation data to identify if the clear-cut of the secondary burned forests occurred after 2008. According to the Brazilian Forest Code, the continuity of agricultural activities is allowed in areas illegally deforested before 2008, defined as consolidated areas of rural property. However, areas illegally deforested after 2008 must be fully recovered, that is, even if these areas have secondary vegetation that characterizes them as fallow areas, the use of fire or activities with agricultural purposes is not allowed.

3. RESULTS AND DISCUSSION

3.1 Primary burned forest

In 2018, 45,966.2 ha of forests were burned in rural properties in Pará state (Figure 2). Primary forests represented 77% of the total burned area, with more than 35,000 ha affected by the fire. Large properties concentrated almost half of the primary burned forest, adding 17,023.6 ha, which was equivalent to triple the area observed in small properties (5,427.5) and twice (11,192.2) the area in medium properties (Figure 2).

Large properties accounted for 50% of deforestation on private lands in the Amazon [13], an activity strongly related to fire [14]. As a large number of ignition sources are produced with the burning of biomass from deforestation, there is a greater likelihood that they can spread to other areas of the rural property and accidentally advance into native vegetation, resulting in forest fires. In this case, to reduce the occurrence of forest fires, it is necessary to reduce the deforestation-related fire, which involves not only curbing the burning of biomass, but also strengthening the enforcement of illegal deforestation [4].

3.2 Secondary burned forest

In 2018, more than 10,000 ha of secondary forests were burned in rural properties (Figure 2). According to the regeneration stage, 42% (4,537.9 ha) of the burned area occurred in secondary forests <5 years, 53% (5,713.6 ha) in forests with 5-20 years, and 4% (463.1 ha) in forests>20 years, (Figure 3). The burning of fallow areas (<5 years) accounted for more than half of the secondary burned forest in small (879.8 ha) and medium (1,290.6 ha) properties (Figure 3). In large properties, the largest burned area occurred in secondary forests in an intermediate stage of regeneration (5-20 years), adding 64% (4,073.1 ha), while

burns in the initial stage (<5 years) added 31% (1,985.9 ha), (Figure 3).

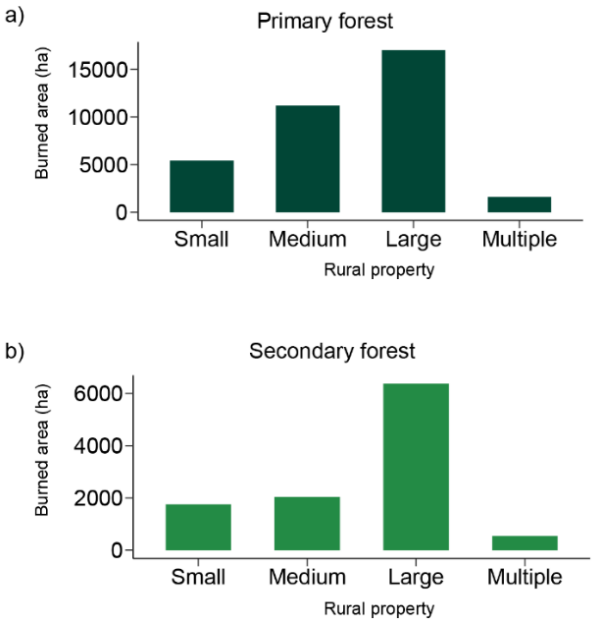

Figure 2. Total burned area of primary and secondary forests on rural properties in the state of Pará 2018.

Fire is widely used in the management of fallow areas on rural properties because it is a cheap technique that reduces production costs [15]. However, burning can become uncontrol and reach unwanted areas of rural property, both productive and primary forests. In this case, alternatives to reduce the use of fire in fallow areas should consider the social-economic context of landowners. The use of tractors, fertilizers, and no-tillage systems are some alternatives to the traditional slash-and-burn system. However, the costs of implementing machinery and new technologies in agricultural systems often make using these tools unfeasible for small landowners [16]. On the other hand, using fire by medium and large landowners can be seen as an obsolete technique, representing a misalignment with strategies to ensure sustainable development in the Amazon.

Public policies must consider the origin and cause of the fire on rural properties, using strategies that, while reducing the environmental damage caused by burning, also guarantee agricultural productivity and safe techniques in the use of fire by landowners who depend on it for their livelihood. These actions are essential for states such as Pará, which is primarily responsible for burning activity in the Amazon biome [6].

3.3 Secondary burned forest deforested after 2008

Of the total secondary forest burned in 2018, 15% (1,563.8 ha) presented clear-cutting of primary forest between 2009 and 2018, indicating possible illegal use of fire (Figure 4). According to age, values were higher in secondary forests in the initial regeneration stage. Although the use of fire can be allowed in secondary forests with age <5 years, in 2018, 30% (1,383.3 ha) of the burned area in this category was deforested after 2008, indicating possible irregularities in the fire activity.

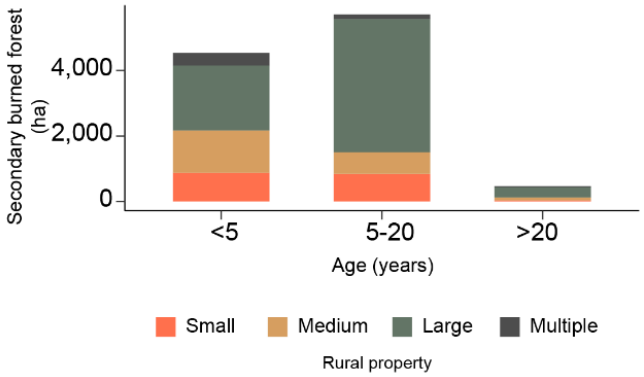

Figure 3. Total area of secondary burned forest in 2018 in each regeneration stage and rural property category

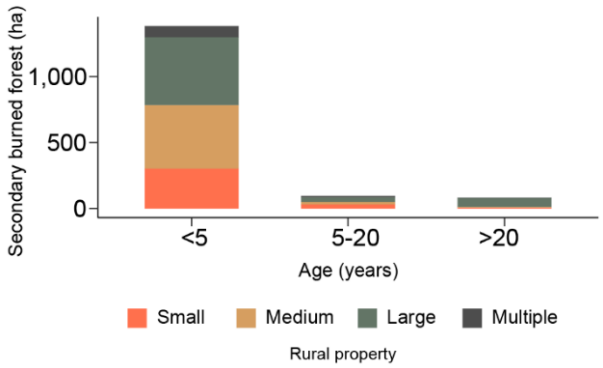

Figure 4. The total area of secondary forest burned in 2018, with clear-cutting of primary forest observed after 2008.

These results showed the non-compliance with the Forest Code by rural landowners in the Pará, highlighting the urgent need to strengthen land and environmental governance in the state. The analysis by environmental agencies of the information declared by rural landowners in the Rural Environmental Registry (CAR) is essential to correctly identify the environmental deficit in rural properties, representing a key strategy to curb illegal deforestation and the irregular use of fire on private lands in the state.

4. CONCLUSIONS

In our study, we assessed the extent of primary and secondary forests affected by the fire on private lands in Pará. Based on the state legislation, we also evaluated the burned area according to the regeneration stage of the secondary forest (initial, intermediate, and late). By identifying the year of deforestation, we also evaluated if the use of fire on the

secondary forests in the rural properties was in accordance with the Brazilian Forest Code.

Our results showed that primary forests were the most affected by fire in the Pará state, with the largest area concentrated in the large properties, which covered 48% of the total. Our results also showed the urgent need to analyse the information declared by the landowners in the CAR, as we observed that fire has been used in secondary forests that were deforested after 2008, areas that, according to the Brazilian Forest Code, must be completely recovered in the rural properties.

The separation of the burned area by forest type and rural property size can provide a clearer view of the fire problem on private lands, which can support and guide public policies aimed at reducing the impacts of fire on forest areas in the state of Pará.

5. ACKNOWLEDGMENTS

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