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THE AMAZON IN FLAMES
FIRE AND DEFORESTATION IN 2019 - AND WHAT'S TO COME IN 2020

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Summary

- The 2019 fire season in the Amazon was clearly related to the increase in deforestation and not to a drier climate;
- Command and control interventions curbed the worst-case scenario for fires in 2019, but not for cutting down the forest;
- The increase in deforestation in 2020, added to the vegetation felled in 2019 which was not burned down, leads us to believe there will yet another season of intense fire events;
- There has been an increase in land grabbing in public forests that are not designated and lack information; to avoid the worst, the federal government and states must act quickly.

Introduction

With the most intense season of deforestation in the Amazon approaching, it is time to evaluate what happened in the region in 2019. It is also time to put strategies in place to combat deforestation, which in the first three months of this year increased significantly and indicates a worrying scenario ahead. To avoid repeating the 2019 fires, we need to make the right choices. And now.

Two-thousand-nineteen (2019) was definitely atypical for the Amazon in terms of fire and deforestation. In the region, the dry season usually extends from May to October and, with it, come tractors with chains and matches to set it on fire. Last year, for example, the first half of August revealed a significant increase (60%) of hotspots in relation to the average for the same period in the previous three years (Silvério *et al*., 2019), although the average volume of rainfall was considered normal.

This fact sparked a warning among experts: the following two weeks would be markedly worse, since the peak of fire in the region, normally September, had not yet arrived. In parallel with the increase in fire, the deforestation curve was also moving upward in the period.

This worsening scenario was confirmed with the imponderable. A dark cloud of smoke, formed by the Amazonian fires, arrived in São Paulo in the same

month of August. The day became night. Repercussion in the media worldwide was significant and immediate and the phenomenon drew the attention of all Brazilians and the international community to the Amazon. The implications were so great that it led the federal government and the states to take measures to contain the problem, which avoided the worsening of the fire scenario predicted by specialists.

Both the factors that led to the increase of hotspots and the responses given to the challenge provided us with numerous lessons on the dynamics of fire in the Amazon. Some of them are explained in this technical note. Here, we consolidate the main results of the analyzes carried out by IPAM for last year's fire season, thus complementing the two previously released technical notes (Silvério *et al*., 2019; Alencar *et al.*, 2019).

Based on this information, we hope to contribute to better strategies for curbing deforestation and fire in the region in 2020. As mentioned, the first three months of this year registered a significant increase in deforestation compared to the previous year. We need to act fast. Otherwise, the situation of large fires, with massive smoke production, can seriously damage the region's biodiversity, the climate and, in particular, the health of the local population, already greatly affected by the new coronavirus pandemic.

Methodology

As in the previous analyzes, forest clearing was quantified based on the monthly deforestation alert polygons of the Deter program, between January 2019 and March 2020. These data, produced by the National Institute for Space Research (INPE), are available at the TerraBrasilis website[1]. For these analyzes, only the Deter data related to deforestation with vegetation, deforestation with exposed soil and mining were used. Other classes, such as degradation, forest fires and selective logging, were not considered. Deter's deforestation data, despite not representing the total deforested area in the year, demonstrate the trend of deforestation and present a good correlation with the total deforested area data produced by the Prodes program, also led by INPE. It is worth remembering that, over the past three years, the deforested area recorded by Prodes was, on average, 52% greater than that recorded by Deter for the same period.

Data on fire events or hotspots were obtained from the MODIS sensor placed on the Aqua M-T satellite, with daily orbits over the Amazon in the early afternoon. These spots do not represent the area affected by fire, but the existence of active fire. Such outbreaks are based on the surface temperature of an area of 1km x 1km. With this approach, the sensor is able to record the heat of a fire front of at least 30 meters in length and 1 meter in width.

Both deforestation and hotspot data were then distributed based on land tenure category. The land tenure information used was organized by IPAM based on official data. For conservation units, indigenous lands and rural settlements (state and federal), we used information from ICMBio,

1. Available at: http://terrabrasilis.dpi.inpe.br/app/dashboard/alerts/legal/amazon/aggregated/.

Funai and Incra, respectively. For private properties[2], the database used was that of SIGEF/INCRA and SICAR/CAR. For non-designated public forests, the source of information was the Public Forest Registry, which is covered by the Brazilian Forest Service. Also included were areas that do not have any registry information. These can be public or private land, which is not in any formal register (see annex 1).

The data to measure the intensity of drought in the period in the region, in turn, were based on consecutive days with precipitation below 1mm and obtained from the CHIRPS satellite (Climate Hazards Group InfraRed Precipitation with Station Data).

Results

What feeds the Amazon fires

The Amazon rainforest is not the most propitious natural environment on the planet for fire. It is, by definition, a rainforest. Its ecological and physiognomic characteristics naturally place it as a barrier to fire (Alencar *et al.*, 2015). However, there are three fundamental elements that, when combined, invert this natural order of the biome, creating conditions for wildfires and fire events to thrive.

These fundamental elements are organized in what we can call the "triangle of fire" (Bond and Keane, 2017). They are: *oxygen*, essential in any burning process; higher than normal *temperatures*; and the significant accumulation of *fuel* available to burn. In isolation, these elements mean little to the advance of the flames. Together, however, they form the recipe for combustion.

An adaptation of this "fire triangle" (Figure 1) to the Amazonian reality explains how a humid and evergreen forest becomes susceptible to fire during certain periods of the year.

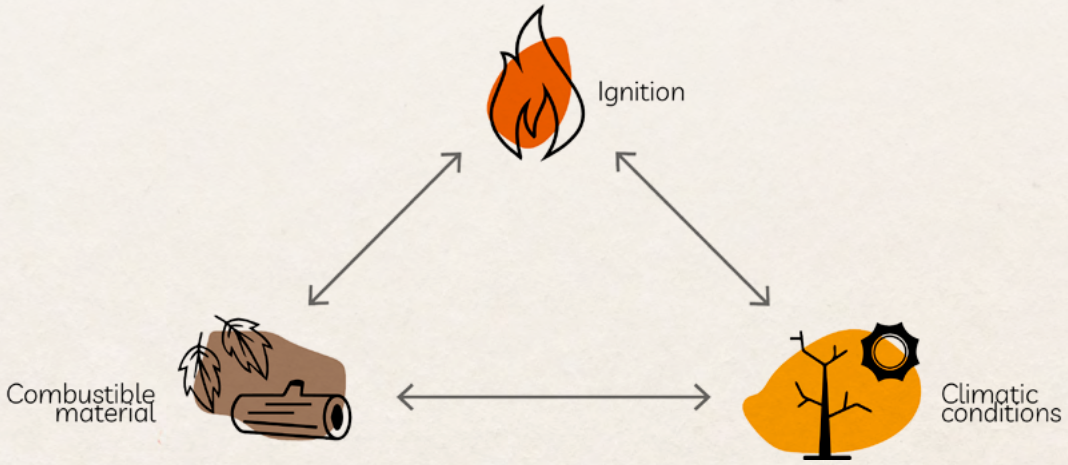

Figure 1. Amazonian fire triangle and the elements which, combined, feed wildfires and fire events in the region. *Source: IPAM*

2. By private properties, we consider the description available at (in Portuguese): http://www.cadastrorural.gov.br/perguntas-frequentes/propriedade-rural/o-que-e-imovel-rural.

The first of the three ingredients of this triangle is the existence and quality of the combustible material (*what burns*). The second is climatic conditions (*when it burns*). And, finally, the third is the source of ignition itself (*who or what causes the burning*).

The quantity and quality of combustible material for fire in the Amazon varies. It can consist, for example, of many dry leaves and branches on the forest floor, which enables the spread of fire under the treetops, characterizing forest fires (Balch *et al*., 2008). This fuel can also be composed of the trunks, branches and leaves of trees felled after forest clearing, constituting what we can call "deforestation fire".

The second ingredient, climatic conditions, in turn influences the quality and quantity of the combustible material. In drought, forests lose more leaves; it is a strategy adopted by the trees to avoid excessive water loss via evapotranspiration (Ray et al., 2010). The result is an increase in the amount of combustible material on the ground, at the same time that the canopy becomes more rarefied or open - which, in turn, allows greater exposure to sunlight within the forest. This leads to a change in the forest microclimate, leaving the organic material deposited on the ground less humid and more flammable.

This process intensifies the drier the climate (Brando *et al.*, 2014). In addition, in forests close to deforested areas, the vulnerability of forest vegetation to fire increases due to the so-called "edge effect": the margin of forests bordering newly opened areas loses moisture, even several meters into the forest, increasing the possibility of a fire burning generating forest fires (Cochrane *et al*., 2002).

The third ingredient is the one that can be more easily controlled: the ignition source (Figure 1). Fire with natural ignition, like lightning, in an ecosystem as humid as the Amazon rainforest is extremely rare - it is estimated to happen only every 500 years or more (Thonicke *et al.*, 2001). Therefore, in the Amazon, all fire is based on a match lit by a human being.

In addition to the fires associated with deforestation, fire is also used to maintain or clear pastures or prepare areas for agricultural cultivation in the region (Barlow *et al*, 2020).

Every year, following the seasonal cycle of the Amazon, these three ingredients correlate to feed the fire season, especially in the months of August, September and October. When one or more elements of this triangle become acute, the season of wildfires and fire events is more intense. That's exactly what happened in 2019.

The 2019 fire season

The first ingredient of the Amazon fire triangle, which is usually observed, is climatic conditions. However, contrary to what the federal government said at the time, 2019 was not an unusually hot and dry year for the region (Silvério *et al*, 2019). The peak of drought, represented by the number of days without rain, was lower than in the previous two years and was delayed by one month (Figures 2A and 2B). The cumulative pattern of rainfall also occurred within the normal

range, despite having fewer days without rain at the peak of the dry season compared to the previous two years. The conclusion was, therefore, that the climate did not represent the fundamental element to explain the increase of hotspots (figures 2A and 2B).

Despite the fact that the climatic ingredient was not acute, the number of hotspots in 2019 was intense and began one month in advance (Figures 2C and 2D). The explanation is in the Deter system deforestation records: there was an increase in deforestation in the previous months, which provided quality raw material in abundance to be burned. Thus, what fueled the fire that year was the significant amount of combustible material from the clearing of the forest, plus the need to clear up the land (Silvério *et al*., 2019).

In September, when the number of hotspots has historically been higher, the scenario changed. The analysis of the dynamics of the hotspots showed a sharp drop. Considering that the rainy season had not yet arrived, and the rate of deforestation remained high, the change was in the third ingredient: ignition. Fewer people lit the match to burn previously cleared forest areas, which can possibly be explained by the two fire control decrees issued by the federal government in late August.

Decree 9,985/19, of August 23rd, 2019, determined that the Armed Forces should curb illegalities and support other enforcement interventions. Decree 9.992/19, published on August 29th, banned fires in the region for 60 days. As a result, there was a reduction in the number of hotspots as of September. The government's response to the crisis only reinforces that the climate component was not fundamental to explain the fire in 2019 and, also, points to the need for the resumption of overt command and control actions in the Amazon. Just as it was fundamental in the early 2000s, when deforestation rates were around 20 thousand square kilometers per year, the continuity of enforcement was essential to curb fire in 2020.

However, government control has not slowed down the rate of forest clearing (Figures 2E and 2F).

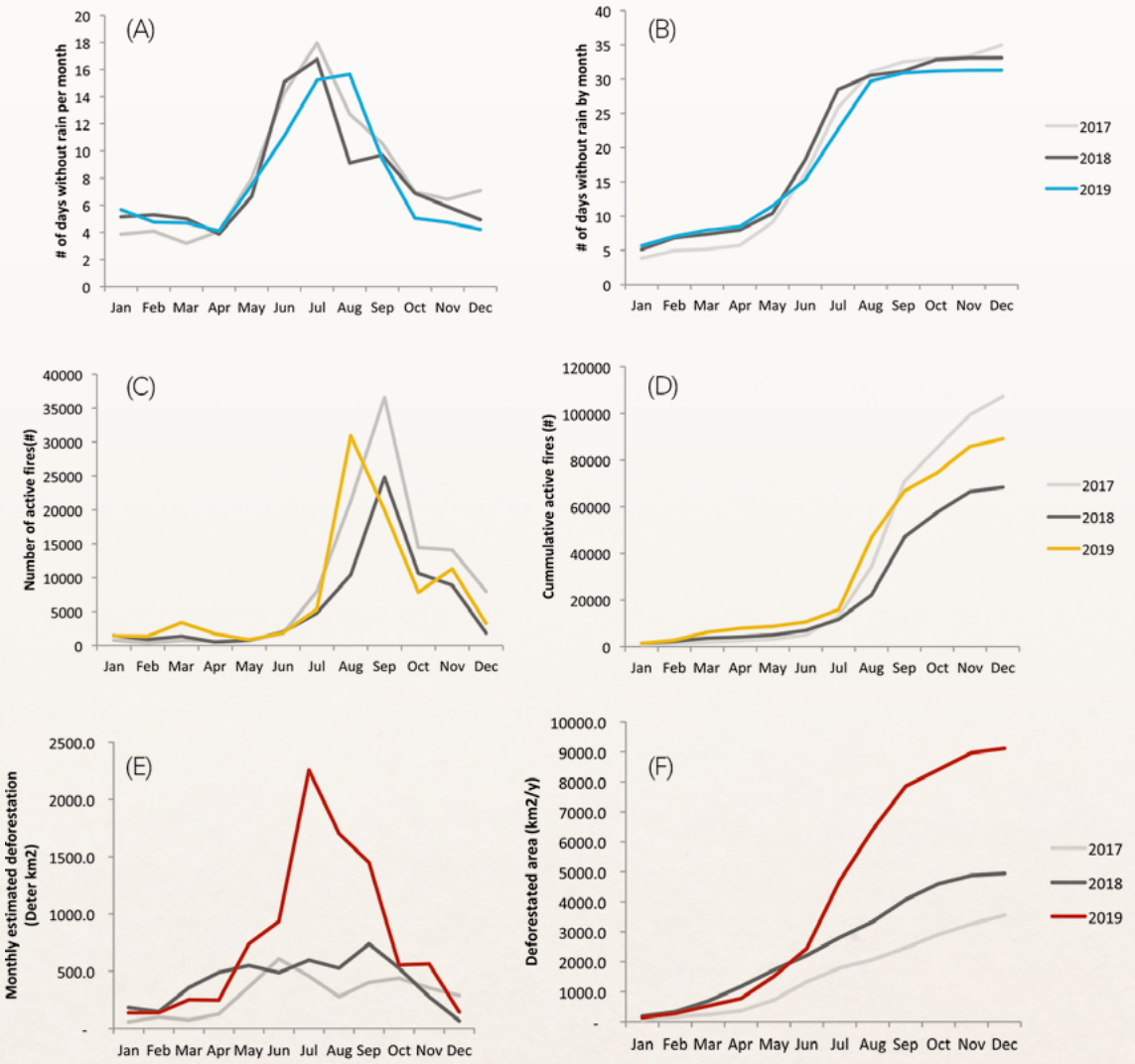

Figure 2. Number of rainless days in the month (A) and accumulated (B); number of hotspots in the month (C) and accumulated (D); and deforestation in month (E) and (F) accumulated in the Brazilian Amazon in 2017, 2018 and 2019. *Source: IPAM, from climatic data from the CHIRPS satellite and from fire and deforestation data from INPE until December 2019.*

The dynamics of the 2019 hotspots distributed by land tenure category reinforces the trend of increased deforestation in recent years (Figure 3) in public lands (public non-designated forests and areas without information). Together with private properties, public lands had the highest rates, 31% and 30% respectively. While in the first category the fire was mainly driven by deforestation and clearing for pastures, in areas that are public and lack information the fire was motivated by deforestation for illegal possession of the area by land grabbers for real estate speculation.

Rural settlements contributed 23% to deforestation and 21% to hotspots, followed by environmental protection areas, protected areas and indigenous lands (Figure 3).

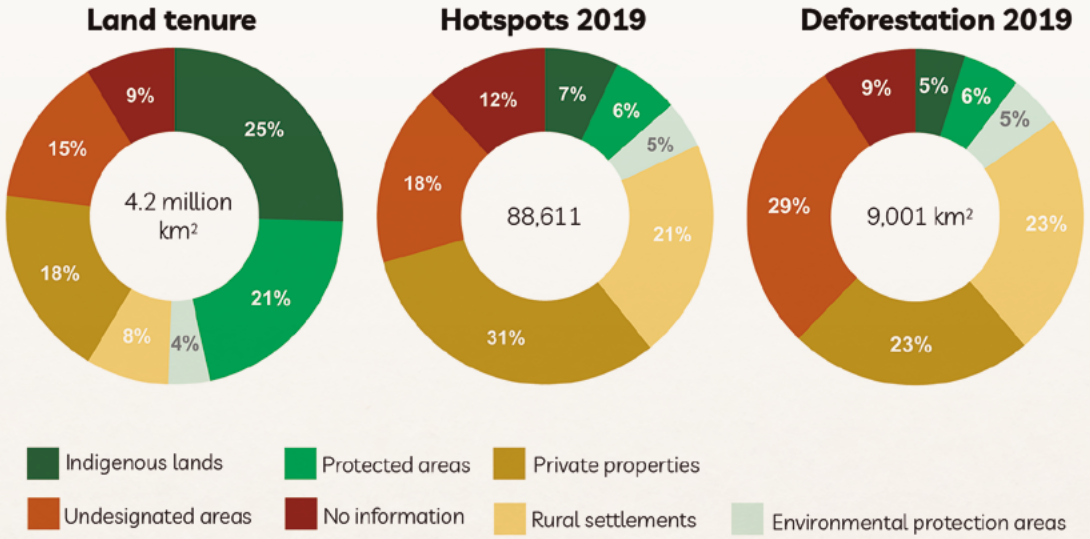

Figure 3. Numbers of hotspots and deforestation in the Amazon in 2019 by land tenure category.
Source: IPAM, based on data from INPE, 2019.

Perspectives for 2020

Without preventive action, this year's fire season could be more severe. This is because a large volume of deforested areas in 2019 was not burned and will probably be added to the deforestation of 2020, creating excessive accumulation of deforestation dry matter. This could be the trigger for a new season full of massive wildfires, forest fires and a lot of smoke in the air (Figure 1).

An analysis of deforestation and the number of hotspots in the first three months of 2020 (Figure 4) shows that, in general, the profile of forest clearing observed in 2019 was repeated in the first three months of this year, but with a crucial difference: both fire and deforestation increased significantly in non-designated public forests and areas without information (Figure 4). In the first quarter of 2019, these two land tenure categories together accounted for 30% of registered deforestation. Now, they account for 46%.

Deforestation remains high at the beginning of the year also on private properties (30%), with a proportional reduction in rural settlements. The other land tenure categories showed little variation between the first quarter of 2019 and that of 2020.

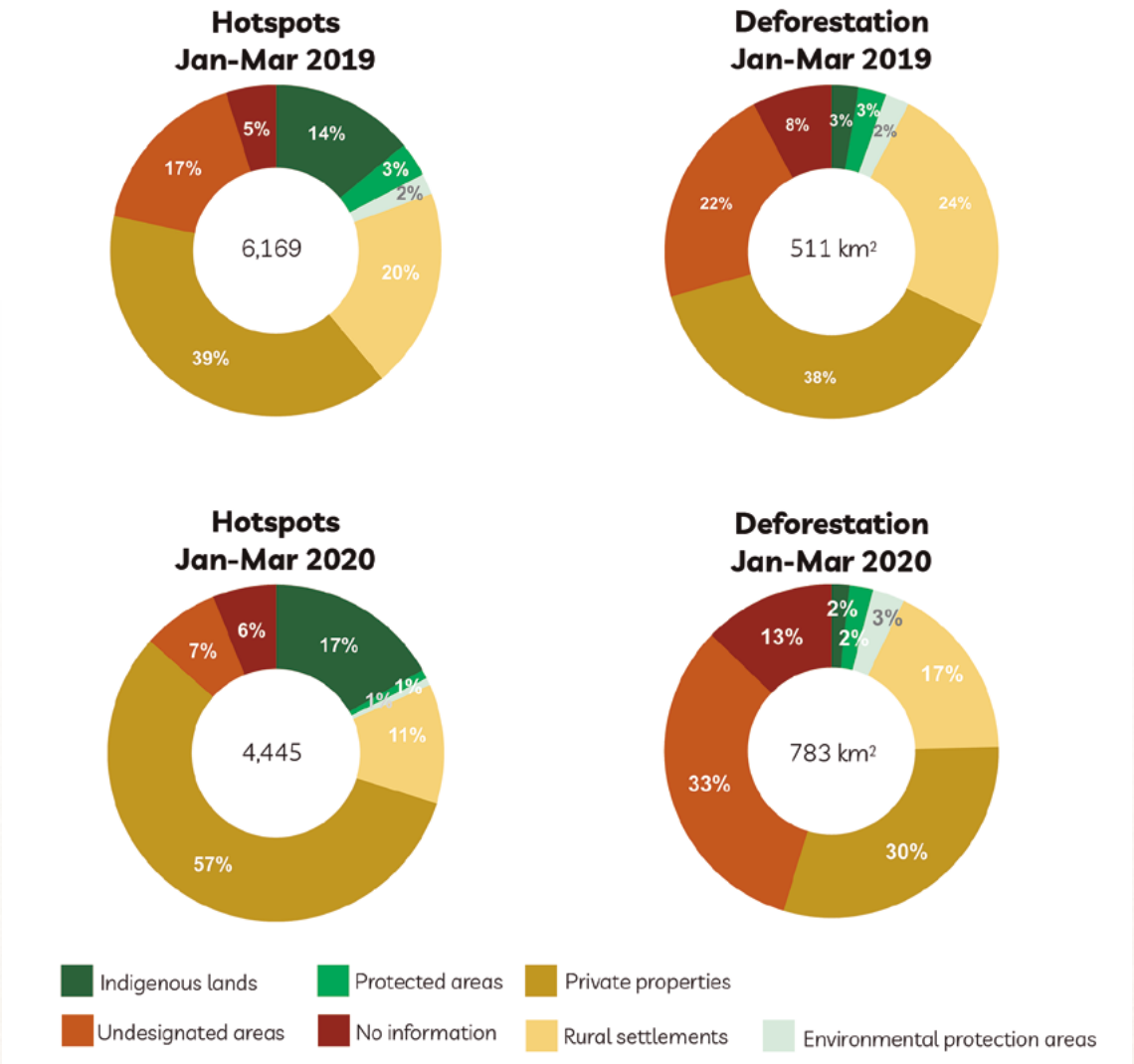

Figure 4. Numbers of hotspots and deforestation in the Amazon, divided by land tenure category, in the first quarter of 2019 and 2020. *Source: IPAM, based on data from INPE, 2019/2020.*

Conclusions

Governance pays off. When there is political will, there is an effective result in reducing forest wildfires and fire events. This is the first lesson learned from managing the 2019 fire crisis.

The analysis of last year's data demonstrates the positive effect of enforcement and control actions on the use of fire in the Amazon, especially during the period of the burning moratorium (September and October 2019). They were necessary before and must be maintained now, especially considering that almost a third of the hotspots registered in 2019 happened on undesignated public lands – i.e., the land grabbing effect -, which intensified in the first quarter of 2020, in what we actually consider to be a theft of Brazilian public assets.

However, contrary to what happened in 2019, on-the-ground efforts should also curb deforestation, since they are two sides of the same coin. Without strategies that address both problems jointly, there is little hope for any government fire control plan in the Amazon.

The fight against land grabbing begins with the police, but it also involves the allocation of public areas for the conservation and sustainable use of forest resources, with respect to the traditional populations that live there, and the consolidation and support of the protected areas system (Stabile et al., 2019). These are actions that must be maintained on a permanent basis, as they are areas under government responsibility.

Half of the deforestation recorded in the first quarter of 2020 wouldn't have taken place if only command and control had been supported and intensified in these locations, curbing illegality.

Another aspect of combating deforestation is the illegal logging of forests within private properties and settlements. For this to happen, it is necessary to invest in a state licensing system for the suppression of native vegetation that works, and with transparency. This situation leads law-abiding producers to be seen as villains of deforestation and to lose ground to those who commit environmental crimes, usually going unpunished.

The command and control tactic alone cannot be sustained, however, beyond a specific moment. In building sustainable solutions for the long-term development of the region - without deforestation and without fire – we must further stimulate the low carbon economy. Rural producers can benefit from alternatives for land replenishment without fire, as the risk of fires escaping in the region has increased with the worsening of climate change. They can also make better use of open areas, which reduces pressure for new land. Without deforestation and fire, with legal production, the reputational risk of agricultural products from the Amazon can decrease considerably. On the other hand, a new fire season in the region in 2020 will put the world's public opinion of agribusiness on the ground, for good.

In times of crisis, such as the one currently experienced by Brazil due to the pandemic,

it is natural to seek to intensify activities that promote a rapid economic recovery. However, the challenges posed by climate change require that traditional methods of land use and cultivation - slash & burn - are quickly replaced by more sustainable ones. The Amazonian natural system, with large forest extensions, is the fundamental element that provides the basic climatic conditions for agricultural production; however, such a system is close to its limit and will no longer provide environmental services if deforestation and associated fires continue to advance.

In a process of economic recovery like the one we will face in the coming months or years, deforestation and fires must be definitively left aside. Otherwise, such a recovery will be neither sustainable nor safe.

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Annex 1. Land tenure categories and their respective cartographic bases used in this technical note.

Land tenure category	Cartographic base used
Private properties (PP)	CAR-SFB, 2018, and SIGEF-Incra, 2018
Rural settlements (RS)	Incra, 2018
Undesignated public forests (ND), type B	SFB, 2018
Indigenous lands (IL)	Funai, 2018
Protected areas (PA) e environmental protection area (EPA)	MMA, 2018
Quilombo areas (QA)	Fundação Palmares, 2018
Military areas (AM)	SFB, 2018
Areas lacking registry information (NI)	Territory that hasn't been registered in any official government database

Annex 2. Absolute number of hotspots registered in 2019 between January 1st and December 31st, 2019 and average number of hotspots in the same months between 2011 and 2018, divided by land tenure category in the Amazon biome, including the proportion of increase in the number of fires in 2019 compared to the average for the period 2011-2018
Source: IPAM, based on data from the AQUA M-T satellite.

Land tenure category	Number of hotspots in 2019	% number of hotspots per category in 2019	Average number of hotspots between 2011 and 2018	% increase in hotspots compared to the 2011 – 2018 average
Indigenous lands	6,274	7%	5,131	22%
Protected areas	5,705	7%	4,559	25%
Environmental protection area	4,032	5%	13,183	27%
Rural settlements	18,782	21%	19,645	-4%
Private properties	27,732	31%	26,856	3%
Undesignated public forests	15,577	18%	11,368	37%
Areas lacking registry information	10,509	12%	10,745	-2%
TOTAL	88,611	100%	81,486	9%

Annex 3. Distribution of hotspots registered between January 1st and December 31st, 2019 by land tenure category and by state. Source: IPAM, based on data from the AQUA M-T satellite..

Land tenure category	AC	AM	AP	MA	MT	PA	RO	RR	TO	Total
IL	144	677	169	178	1,749	1,956	501	900	0	6,274
PA	1,199	392	165	71	267	1,774	1,637	200	0	5,705
EPA	20	93	2	764	0	3,132	0	21	0	4,032
RS	1,858	3,599	214	1,240	1,504	7,071	1,983	1,250	63	18,782
PP	1,652	2,933	341	1,030	10,946	6,836	2,890	949	155	27,732
UD	1,084	3,402	236	51	873	5,743	2,826	1,358	4	15,577
NI	844	1,573	135	911	2,298	3,232	1,383	94	38	10,508
Others	0	7	15	52	0	402	9	12	0	497
TOTAL	6,801	12,676	1,277	4,297	17,637	30,146	11,229	4,784	260	89,107

IL – indigenous land; PA – conservation units except APAs; EPA – environmental protection area; RS – rural settlements; PP – private properties; UD – undesignated public forests; NI/ no info – areas lacking clear information on their land tenure situation; Others – quilombo and military areas. .