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RESEARCH ARTICLE OPEN ACCESS

INTEGRATION OF FOREST MONITORING DATA TO ASSESS THREAT AND ANTHROPIC PRESSURE IN JAMANXIM NATIONAL FOREST

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ABSTRACT

Jamanxim National Forest is a protected area located in the Amazon biome, created in 2006, with the aim of mitigating the foreseen deforestation with BR-163 paving, a highway that crosses portions of the native Amazonforest. The highway paving was completed in a process that ran from 2016 to 2020. Since then, the region has emerged as the leader in deforestation rankings. This research analyzed several georeferenced data referring to anthropic phenomena that occurred in the region in the period from 2008 to 2019, generating a mapping of deforestation and use dynamics in the region, pointing out vulnerabilities and potentials of the protected area in the control of forest degradation. The results showed that the highway is, in fact, the main vector of environmental pressure in the region. Also, its proximity to other protected areas that create a sort of shield strengthens the forest conservation.

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INTRODUCTION

Almost 70% of the Amazon biome belongs to the Brazilian territory, with an extension of nine states (FERREIRA *et al.,* 2005). It is a biome that offers a series of environmental services with values that are superior to any anthropic use that can be given to this area, indispensable services for the well-being and maintenance of human and other species survival, such as: water cycle, biodiversity, food chain and carbon stocks (FEARNSIDE, 2006). The byproducts of the Amazon occupation process have profound impacts on native ecosystems, deforestation being the most common expression of them. Deforestation process in the Amazon has increased over the years and recorded a 279% growth from 2019 to 2020 and almost 20% of the detected deforestation areas were in protected areas (FONSECA et al., 2020). Official data from the National Institute for Space Research of Brazil (INPE) indicated that 8 of the 10 most deforested protected areas in the Brazilian Amazon are in the state of Pará: the first on the list is the Jamanxim National Forest, next to the second place, Tapajós Environmental Protection Area (INPE, 2021). Considering the expressive environmental pressure in the southwest region of Pará, indicated by deforestation data, the objective of the research was to map the threat and anthropic pressure in the conservation unit that presented the highest deforestation values in the legal Amazon, in Jamanxim National Forest, through the calculation of forest cover conversion values, quantifying the transition of land use and fire hotspots incidence, in order to generate a diagnosis

pointing out the main threat vectors and pressure to reduce forest cover to the interior and surroundings, up to 10 km from Jamanxim National Forest.

MATERIALS AND METHODS

Area of Study: Jamanxim National Forest (Figure I) is a protected area for sustainable use, which means, in Brazilian environmental legislation, that it allows the occupation and use by populations committed to the sustainable development of the territory (BRASIL, 2000).

It was created in 2006 (BRASIL, 2006), simultaneously with other protected areas that were delimited in order to preserve forest areas concentrated in the facilities of the newly paved BR-163 highway (ICMBio, 2010). As shown in the map below, Jamanxim National Forest is located in the southwest region of the state of Pará, in the Brazilian Amazon, close to other protected areas that together form a shield around the road. The growing deforestation data in Jamanxim National Forest indicate that the paving of this road caused an environmental impact on the surrounding forests. In this region, deforestation has historically given way to bovine raising pastures and neighboring areas were opened, coming from BR-163 highway and, along with them, pasture areas were included in forest portions

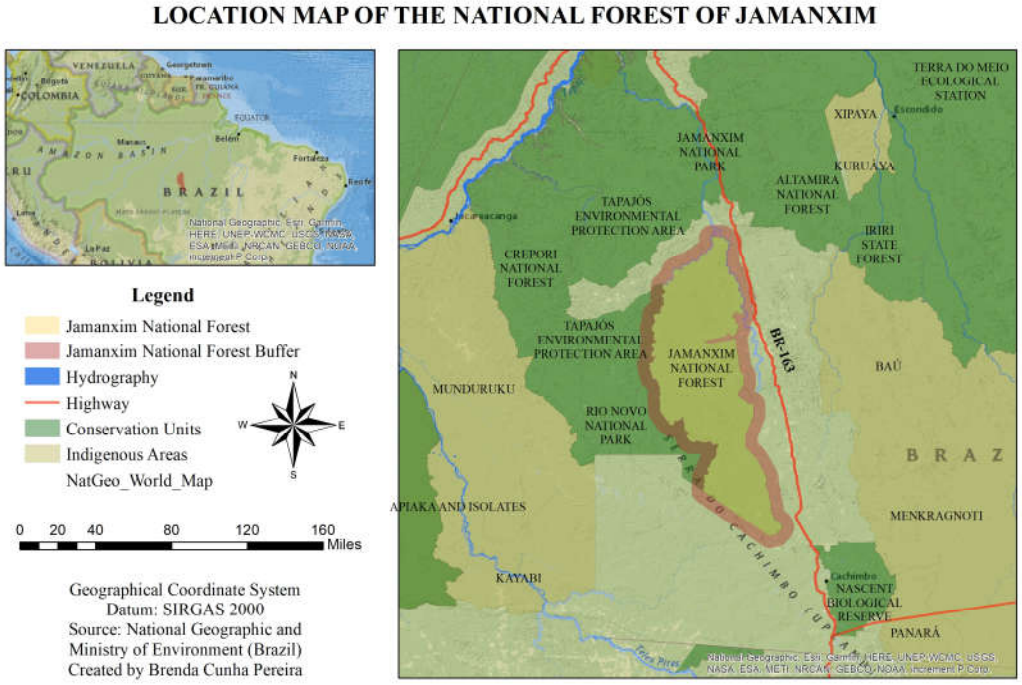

Figure 1. Location map of the area of study
Source: Authors, based on MMA (2021).

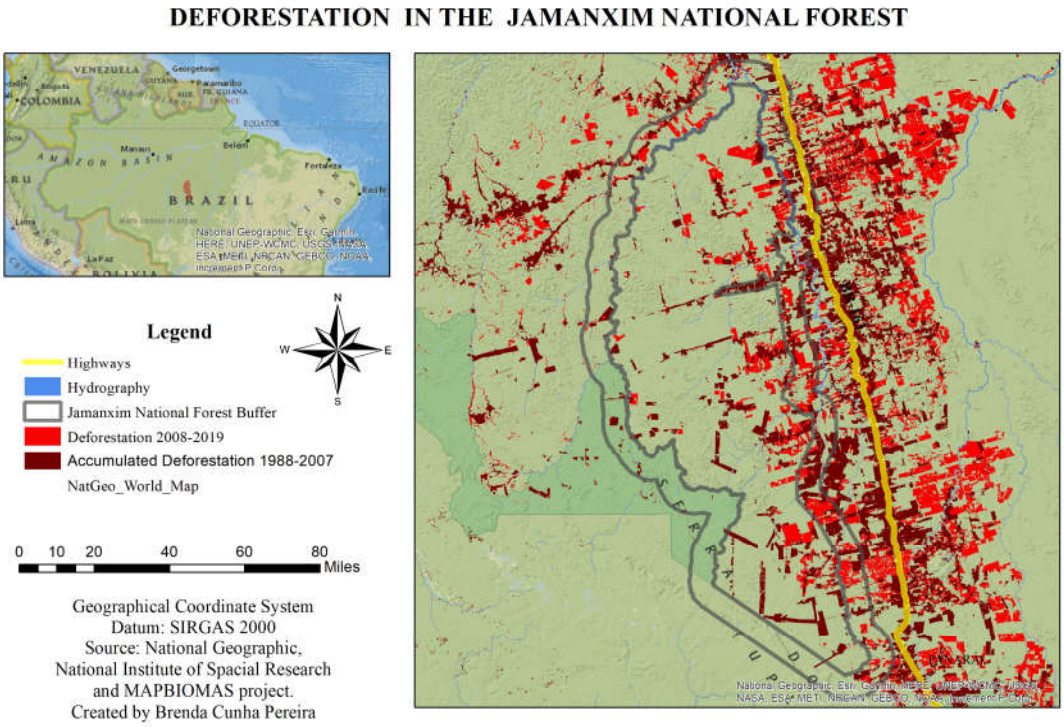

Figure 2. Deforestation map in Jamanxim National Forest Source: Authors, based on MMA and INPE (2021)

increasingly within the protected area (ICMBio, 2010). In this research, aiming to carry out a broader data analysis, the interior was adopted as the area of study, measuring 1,301,125,679 hectares, and also its surroundings, defined by a 10 km buffer, with an area of 707,807,815 hectares, which will be analyzed separately, since the surroundings do not respond to the same legislation applied to the interior and can be used as a parameter for deforestation advance in the region at portions of protected areas.

Data Analysis: The study used georeferenced data on deforestation, fire hotspots incidence, land coverage and rural properties registered. These data were treated and overlapped in a GIS environment, using the ARCGis 10.8 software, resulting in thematic maps assembled with the aim of generating anthropic activities mapping their dynamics, proportions and spatialities. The choice of this timeline is given by decree 6,514 of 2008, which changes the penalty for environmental crimes since this year (PONTIUS et. al., 2004). Deforestation data were obtained by PRODES project, from the National Institute for Space Research, in shapefile format, showing the deforestation polygons for the analyzed years. Fire hotspots shapefile data were produced by the Brazilian Forest Service and made available through i3Geo platform, indicating the location points of fire hotspots incidences and were applied to Kernel density method, through the tool "Kernell Density" in ArcGis, generating the fire hotspots influence radius (MELO-NETO et al., 2019).

website. The use of these data makes it possible to monitor the relationship between anthropic phenomena related to deforestation and rural properties established in the protected area.

RESULTS

Deforestation: Data showed that, between 2008 and 2019, the interior of the area of study lost a total of 73,446.325 hectares of forest to deforestation. On the other hand, its surroundings lost 60,114,083 ha of forest area (Table I). It represents a conversion of 5.645% of the total area inside the unit into deforested area during a period of approximately a decade, since its surroundings have the proportion of 8.493% deforestation. Between 2010 and 2012 there was a significant drop in the annual rate of deforestation in and around the area. This period converges with the Management Plan of Jamanxim National Forest publication (ICMBio, 2010). From 2009 to 2010 the rate of increase in deforestation reduced 88.687% in the interior and 76.744% in the surroundings. In 2013, deforestation values grew significantly again; this phenomenon accompanied the increase in deforestation values in the Brazilian Amazon as a whole, also having a local influence from the paving of BR-163 and the construction of Itaituba port (FEARNSIDE, 2006; FEARNSIDE, 2007).

Table 1. Annual deforestation data in the interior and surroundings of Jamanxim National Forest (2008-2019) Source: Authors, based on Terra Brasilis (INPE, 2021a).

	DEFORESTATION AREA (HA)		DEFORESTATION AREA (%)	
YEAR	INTERIOR	SURROUNDING	INTERIOR	SURROUNDING
2008	7.915,348	9.953,236	0,608%	1,406%
2009	10.458,732	9.539,680	0,804%	1,348%
2010	1.183,128	2.218,459	0,091%	0,313%
2011	1.345,569	2.148,620	0,103%	0,304%
2012	3.083,621	2.321,484	0,237%	0,328%
2013	7.205,675	8.280,973	0,554%	1,170%
2014	5.648,239	4.074,143	0,434%	0,576%
2015	9.263,987	5.033,745	0,712%	0,711%
2016	7.310,839	3.084,999	0,562%	0,436%
2017	2.523,865	1.612,477	0,194%	0,228%
2018	7.350,551	5.422,255	0,565%	0,766%
2019	10.156,771	6.424,010	0,781%	0,908%
TOTAL	73.446,325	60.114,083	5,645%	8,493%
PROTECTION AREA	1.301.125,679	707.807,815	100,000%	100,000%

Table 2. Annual values of fire hotspots incidence in Jamanxim National Forest (2008-2019) Source: Authors, based on BDQueimadas (INPE, 2021b).

	FIRE HOTSPOTS		DENSITY (FOCUS/KM²)	
YEAR	INTERIOR	SURROUNDING	INTERIOR	SURROUNDING
2008	712	284	0,054721847	0,040123886
2009	177	176	0,013603605	0,024865507
2010	976	278	0,07501197	0,039276198
2011	191	133	0,014679597	0,018790411
2012	578	204	0,044423072	0,028821383
2013	181	79	0,013911031	0,011161222
2014	632	220	0,048573325	0,031081883
2015	805	233	0,061869504	0,03291854
2016	506	149	0,038889402	0,021050912
2017	699	244	0,053722712	0,034472634
2018	444	121	0,034124298	0,017095036
2019	711	181	0,05464499	0,025571913
TOTAL	6612	2302	0,508175352	0,325229526

In order to observe the dimensions and dynamics of land coverage in the area of study, the research used raster-type satellite images, referring to land coverage classes generated by MAPBIOMAS project, generating a transition matrix between 2008 and 2019 land coverage and use profile, allowing the observation of predominant uses, their variations and spatial location, facilitating the understanding of deforestation and anthropic processes over the years. Finally, the polygonal shapefile data for georeferencing rural properties registered with the Brazilian Forest Service was obtained from the National System of Rural Environmental Registration

Spatially, deforested areas (Figure II) are more frequent in the eastern portion of the protected area. The portion closest to BR-163 is the only one that does not meet the limits of other protected areas, which indicates that the presence of neighboring protected areas is a mitigating factor for the advance of deforestation (FERREIRA, 2005). The portion most affected by deforestation in Jamanxim National Forest converges with the zone of use stipulated by the management plan. This choice of zoning occurred precisely due to the already existing degradation process of the region (ICMbio, 2010).

Fire Hotspots: According to BDQueimadas (INPE, 2021b) data (Table II), the number of fire hotspots records in the interior region of Jamanxim National Forest presents a variable pattern between periods of decrease and increase of one-year fire hotspots to another, as well as the number of deforested areas previously presented. Its pattern differs from the pattern analyzed in terms of deforestation areas in a period, since deforestation showed a decrease between 2010 and 2013, but the values of fire incidence were relatively high in this period. However, from 2015, the values of fire incidence and deforestation areas occurred in a similar pattern of growth and retraction.

Land Coverage: Land use and coverage mapping in Jamanxim National Forest generated the classification in and around the protected area. By analyzing the natural and anthropogenic classes of use and coverage, it is possible to analyze that the surroundings of the forest (Table III) lost, in the analyzed period, 39,772,857 ha of forest areas, gaining 40,247,246 ha of pasture, 934,894 ha of other crops, 210,170 ha of soybean and 8,042 ha of urban infrastructure.

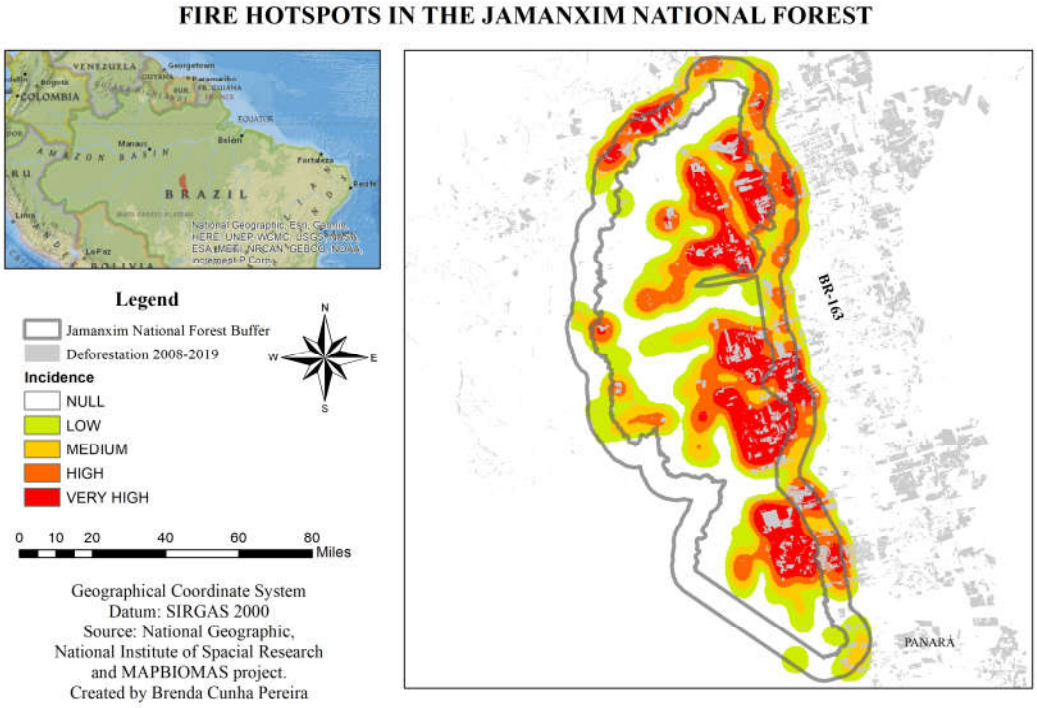

Figure 3. Incidence map of fire hotspots in Jamanxim National Forest
Source: Authors, based on INPE (2021).

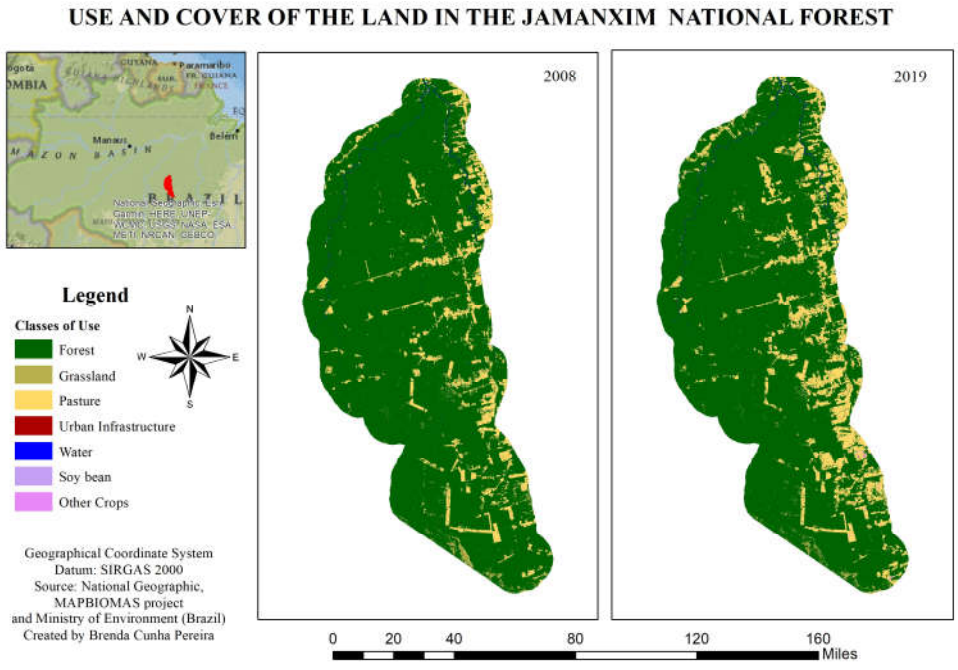

Figure 4. Land use and coverage map in Jamanxim National Forest (2008 and 2019)
Source: Authors, based on MAPBIOMAS (2021).

The overlay map (Figure III) of deforested areas with fire hotspots indicates that the points of high fire incidence are located spatially in the same places as the deforestation areas, which indicates the use of fire as a forest suppression mechanism and maintenance of deforestation areas using burning to prevent the growth of regeneration vegetation (PEDROSO-JÚNIOR; MURIETA; ADAMS, 2007).

The loss of forest portions in this period represents more than 5% of the area's total territory. In the interior (Table IV), the loss of forest areas in the analyzed period is 49,073,847 ha. The addition of anthropized areas is 48,799,341 ha of pasture, 13,056 ha of soybean

and a further 399,876 ha of other crops, totaling an increase of 412,932 ha of agricultural areas. Within the protected area the proportion of forest degradation is lower than in the surroundings and the loss of forest portions in this period represents almost 4% of the unit's total territory.

previously classified as pasture. The matrix of use and coverage of Jamanxim National Forest surroundings (Table VI), shows that the class with the greatest loss of areas was the "forest" class, which lost its areas largely to the "pasture" class (which had the most grew in the analyzed period).

Table 3. Land use and coverage data within Jamanxim National Forest (2008 and 2019)
Source: Authors, based on MAPBIOMAS (2021).

SURROUNDING	2008		2019		2008-2019	
CLASS	ÁREA(HA)	ÁREA (%)	ÁREA(HA)	ÁREA (%)	ÁREA(HA)	ÁREA (%)
FOREST	1.211.356,15	93,101%	1.162.282,310	89,329%	-49.073,847	-3,772%
GRASSLAND	1.459,08	0,112%	1.532,832	0,118%	73,747	0,006%
PASTURE	86.279,06	6,631%	135.078,408	10,382%	48.799,341	3,751%
WATER	1.967,47	0,151%	1.755,307	0,135%	-212,172	-0,016%
SOYBEAN	0,000	0,000%	13,056	0,001%	13,056	0,001%
OTHERCROPS	63,89	0,005%	463,767	0,036%	399,876	0,031%
TOTAL	1.301.125,67	100,000%	1.301.125,679	100,000%		

Table 4. Land use and coverage data in Jamanxim National Forest surroundings (2008 and 2019)
Source: Authors, based on MAPBIOMAS (2021).

INTERIOR	2008		2019		2008-2019	
CLASS	ÁREA(HA)	ÁREA (%)	ÁREA(HA)	ÁREA (%)	ÁREA(HA)	ÁREA (%)
FOREST	594.937,674	84,054%	555.164,817	78,434%	-39.772,857	-5,619%
GRASSLAND	8.820,656	1,246%	7.277,334	1,028%	-1.543,322	-0,218%
PASTURE	99.411,850	14,045%	139.659,096	19,731%	40.247,246	5,686%
URBAN INFRASTRUCTURE	22,531	0,003%	30,573	0,004%	8,042	0,001%
WATER	4.558,502	0,644%	4.474,329	0,632%	-84,172	-0,012%
SOYBEAN	-	0,000%	210,170	0,030%	210,170	0,030%
OTHERCROPS	56,601	0,008%	991,495	0,140%	934,894	0,132%
TOTAL	707.807,815	100,000%	707.807,815	100,000%		

Tabela 5. Land use and coverage transition matrix within Jamanxim National Forest (2008-2019)
Source: Authors, based on MAPBIOMAS (2021).

INTERIOR	CLASS 2019						
CLASS 2008	FOREST	GRASSLAND	PASTURE	WATER	SOYBEAN	OTHERCROPS	TOTAL
FOREST	1.150.728,620	307,680	60.004,272	105,710		209,875	1.211.356,157
GRASSLAND	217,511	1.166,724	44,554	2,229		28,067	1.459,085
PASTURE	11.036,214	18,148	74.980,244	35,541	13,056	195,864	86.279,067
WATER	299,782	39,149	16,603	1.611,827		0,119	1.967,479
OTHERCROPS	0,183	1,131	32,735			29,842	63,891
TOTAL	1.162.282,310	1.532,832	135.078,408	17.553.074,356	130.556,420	463,767	1.301.125,679

Tabela 6. Land use and coverage transition matrix in Jamanxim National Forest surroundings (2008-2019)
Source: Authors, based on MAPBIOMAS (2021).

INTERIOR	CLASS 2019							
CLASS 2008	FOREST	GRASSLAND	PASTURE	URBAN INFRASTRUCTURE	WATER	SOYBEAN	OTHERCROPS	TOTAL
FOREST	545.479,656	899,526	48.068,864	2,898	368,736	0,005	117,989	594.937,674
	239,809	6.283,208	110,564	0,900	13,135		14,757	8.820,656
PAST	6.853,433	27,962	91.389,406	4,207	75,714	210,165	850,963	99.411,850
URBAN	0,086	0,117	0,162	22,092	0,074			22,531
	433,546	63,347	44,041	0,477	4.016,670		0,421	4.558,502
OTS	0,002	3,175	46,059				7,365	56,601
TOTAL	555.164,817	7.277,334	139.659,096	30,573	4.474,329	210,170	991,495	707.807,815

The map (Figure V) shows land use and coverage in the Jamanxim National Forest (inside and surroundings) in 2008 and 2019, spatially presenting anthropic classes advances in the protected area territory. The map illustrates the growth of pasture class in 2019 over areas previously considered forested in 2008. Pasture is almost always connected by "endogenous" roads and their growth is more due to the expansion of already established areas. For Schneider et al. (2000), the drier climate provided by BR-163 region favors extensive bovine raising and, for Fearnside (2007), the absence of figures of power and order make this region a "lawless" territory. Within the National Forest, the land use and coverage matrix (Table V) indicated that the natural class that lost most areas was the "forest" class, which had most of the lost areas converted into "pasture". Differently from the surroundings, inside the protected area the class "other crops" takes, in the majority, areas previously classified as forest in 2008. However, the class "soybean" follows the pattern of settling in areas

The new anthropogenic class, "soybean", appears in 2019 with most of its areas coming from old pastures of 2008. The "other crops" class, on the other hand, kept few remaining areas, acquiring new areas that previously belonged to the classes "pasture" and "forest". The "urban infrastructure" class has anthropic nature and showed the greatest persistence, kepting most of its remaining areas.

DISCUSSION SECTION

Deforestation and fire hotspots values from INPE (2021b) point to a growing trend of these phenomena. Their spatialization is overlapped, which points to interconnected phenomena: the fires found in Jamanxim National Forest are directly linked with new deforestation areas. The most common pattern observed through the superposition of the different data analyzed is the suppression of vegetation cover in

native forest areas through slash and burn, which generates deforestation, followed by the establishment of pastures (SCHNEIDER, 2000; FEARNSIDE, 2007). This scenario has a new phenomenon at the beginning: the replacement of pasture by soybean areas. However, this phenomenon has not been accompanied by a reduction in "pasture" class, which continues to grow and continues to take over forest areas in both analyzed scenarios (inside and in surrounding areas). When analyzed together, the data indicate that deforestation portions are located in regions registered as rural property. Pressure vectors occur more significantly around the protected area, manifesting themselves as a threat with a clear propagation direction, illustrated by the increase in deforestation and suppression of the native forest. The pressures established in the area have a sense of east-west expansion and are more evident in regions far from other protected areas. Therefore, Jamanxim National Forest would be functioning as a buffer to cushion the impacts of BR-163's direct influence zone on the native Amazon forest. However, its category allows direct sustainable use, which legalizes land registration and its use for economic purposes. Deforestation and fires at the protected area continue to grow, replacing forest with pasture. The proximity to other protected areas reduces deforestation: Jamanxim National Forest has a lower occurrence of deforestation in its bordering portions with other units, but its most affected area, the portion close to BR-163, where there are no other protected areas, advances and enters, through neighboring areas, into the interior of the forest.

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