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Analysis of the evolution of deforestation in the state of Acre, in the Acre riverbasin, in buffer and in its APP, from 1997 to 2017.

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Abstract [use this style font, Calibri 13 point, for 1st level headings]

The goal of this article is to quantify the area deforested up to 2017 and the evolution of deforestation over the last 20 years (1997-2017) in the state of Acre, with a closer look atthe categories of the Acre River basin, alluvial forests buffer and legally protected riparianforests (APP) along the Acre River as well as the territorial categories of public areas and private or unincorporated areas. The Acre River Basin has great socioeconomic and environmentalrelevance for the state of Acre, concentrating 66.6% of the state's total population. It is connected by road with the Pacific, and contains 49 family farm settlement projects and has 36% of its area in protected areas. The results of the comparisons between the percentages of deforested areas and the evolution of deforestation in these categories shows that the APP and buffer of alluvial forests had the highest percentage of deforestedareas, with 48% and 45%, respectively. The evolution of deforestation in these areas nearthe Acre River also shows that it acted as a vector of deforestation, with private or unincorporated areas as the main drivers. Smallholder farmers in settlement projects had a deforestation pattern that increased with distance from the river, while the traditional populations of the Chico Mendes Extractive Reserve and the indigenous populations of the Acre River Headland Indigenous Land had a pattern of greater deforestation closest to the river.

Keywords: Amazon, Public and Private Areas, Riparian Forests, Vector ofDeforestation.

Introduction, scope and main objectives

The process of occupation of the territory of the State of Acre, which started with rubber extraction and, later, with the advance of cattle raising and the current forms of use of natural resources, has accumulated a forest liability that must be measured for the purposes of vegetation recomposition, especially in the areas defined by law, such as the Permanent Preservation Areas (APPs). (ACRE, 2006; TOCANTINS, 1961).

When considering the Acre River basin as the study area, its environmental relevance is characterized by the presence of four important protected areas, the Indigenous Territories - TIs Cabeceiras do Rio Acre and Mamoadate; the Ecological Station - ESEC Rio Acre and the Extractive Reserve - RESEX Chico Mendes. To highlight its socio-economic relevance, it has the presence of 49 Settlement Projects - PAs within the Acre River basin, aimed at small-scale family production, with eight of these rural settlements having part of their limits on the banks of the Acre River.

The objective of this chapter was to compare the evolution, trend, and increment of deforestation in the period from 1997 to 2017 in four distinct spatial settings: the State of Acre, the Acre River basin, the 2,000-meter buffer on each bank of the Acre River, and the APP of the Acre River (100 meters on each bank).

Within each spatial cutout, the evolution, trend, and increment of deforestation was also compared. These areas were classified as four land use categories, namely: Indigenous Territories - TIs, Conservation Units - UCs, Settlement Projects - PAs; and Private or Undesignated Areas - APSDs, considered as a single category.

From this diagnosis it will be possible to size the area and identify the main players responsible for the current situation of forest liabilities and to understand how these liabilities have evolved in the geographic space.

Methodology/approach

1.1.1. Study Area:

The analysis of the evolution of deforestation considered different spatial cutouts, and within these cutouts, territorial categories, in the period 1997-2017. At the first level of analysis, we considered the evolution of deforestation in the State of Acre, the Acre River basin, the 2,000-meter buffer on each bank of the river, and the APP. For illustration purposes, the maps with the 2017 deforestation classification from PRODES/INPE are presented in Figure 1.

At the second level of analysis, the spatial cutouts of the Acre River basin, buffer, and APP were applied to the following land use categories: TI; UC; PA (without distinction between directed, extractive, sustainable development, or forestry settlements); and the areas that are not part of these categories were classified as APSDs.

1.1.2. Numerical Analyses:

A one-way ANOVA was applied to assess the significance of differences between deforested areas across spatial cutouts and within spatial cutouts, across time periods. The Tuckey test was applied when there were significant differences ($p <= 0.05$), between the relative values (LEGENDRE; LEGENDRE, 1998).

For the analysis of the growth rate and the trend of deforestation for the spatial clusters and for the territorial categories within the spatial clusters, the semilogarithmic model was used. By multiplying r by 100, we obtained the percentage growth rate per year for each of the spatial cutouts and land use categories within the spatial cutouts. The linear trend model was used, where the angular coefficient β_2, if positive, the variable Y presents an increasing trend, if negative, the trend will be decreasing, and the value of the coefficient will represent the absolute variation of the variable Y (deforested area) for each feature.

From the growth rate and trend it was possible to estimate the relative and absolute growth of deforestation per year over the time series for each spatial cutout and land use category within the spatial cutouts. Non-significant values represent the absence of a trend (GUJARATI; PORTER, 2011).

To illustrate the dynamics of deforestation within the Acre River basin between 1997 and 2017 and its proximity to the river area, a hotspot analysis was performed, an ArcGIS tool that creates a new feature by identifying statistically significant spatial clusters, called hotspots and coldspots. In the presentation of the results the hotspots with 99% probability were highlighted.

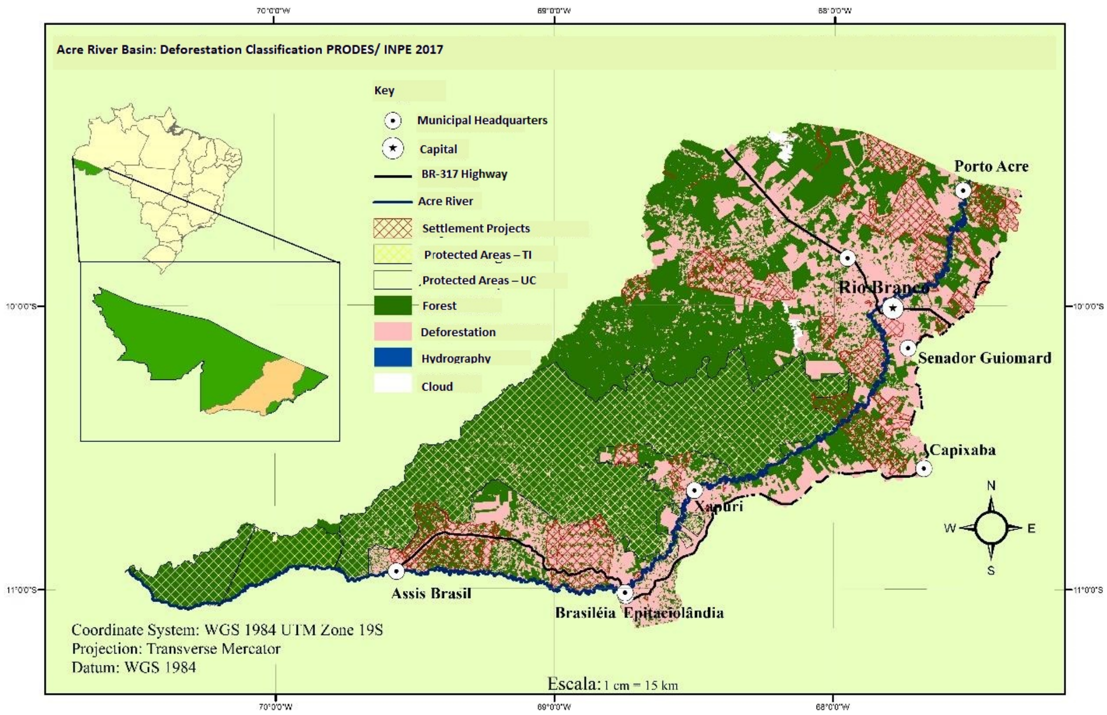

Fig. 1: Map of the Acre River basin with the deforested areas, according to the classification of the PRODES/INPE 2017.

Results

As Table 1 shows, when we reduce the area of analysis, bringing it closer to the riverbank, the greater were the percentages of deforested area in all the periods examined. This pattern has been maintained over the last 20 years. On the other hand, significant differences were found between the averages of the spatial cutouts, where the percentages of deforested areas in the buffer and APP were higher than in the basin and the State. This result is compatible with the result found in forest areas in APPs in the eastern Amazon (NUNES et al., 2015). Forests in APPs that have greater degradation strongly affect the vegetation structure and its ecosystem function of soil protection and stabilization of erosive processes. (SILVA et al., 2017).

Table 1: Percentages of deforested areas, at five-year intervals, in the different spatial cutouts, with 1997 as the base year

Years	Up to 1997	Up to 2002	Up to 2007	Up to 2012	Up to 2017
State	7,7% a	10,3% a	12,1% a	12,6% a	13,7% a
Acre River Basin	20,8% b	25,9% b	30,0% b	31,9% b	34,2% b
Buffer 2000	26,1% bc	35,4% bc	40,2% bc	42,2% bc	44,8% bc
APP	29,4% c	41,6% c	46,0% c	46,5% c	48,0% c

Source: Based on the PRODES/INPE classification. Tuckey test for significant differences ($p<=0.05$). When lower case letters differ, the values are significantly different.

Deforestation has been decreasing in all spatial cutouts studied, with the greatest relative decrease in the APP where the average annual reduction was 18.2 hectares per year. However, part of the reduction is due to the fact that the areas subject to legal deforestation were also reduced in the Acre River basin area. (Table 2).

In 1997, deforestation was concentrated near the City of Rio Branco and had its displacement along the margins of highway BR-317, in the direction from Rio Branco to the border with Bolivia and Peru. The pattern of deforestation displacement that has occurred in the Amazon since the 1970s invariably involves the opening of roads for the integration of the region; the implementation of colonization projects; the financing of cattle raising activities with subsidized credits by official banks. Such factors are considered to be the main drivers of deforestation (AHMED et al., 2013; ALVES, 2010). (Figure 2)

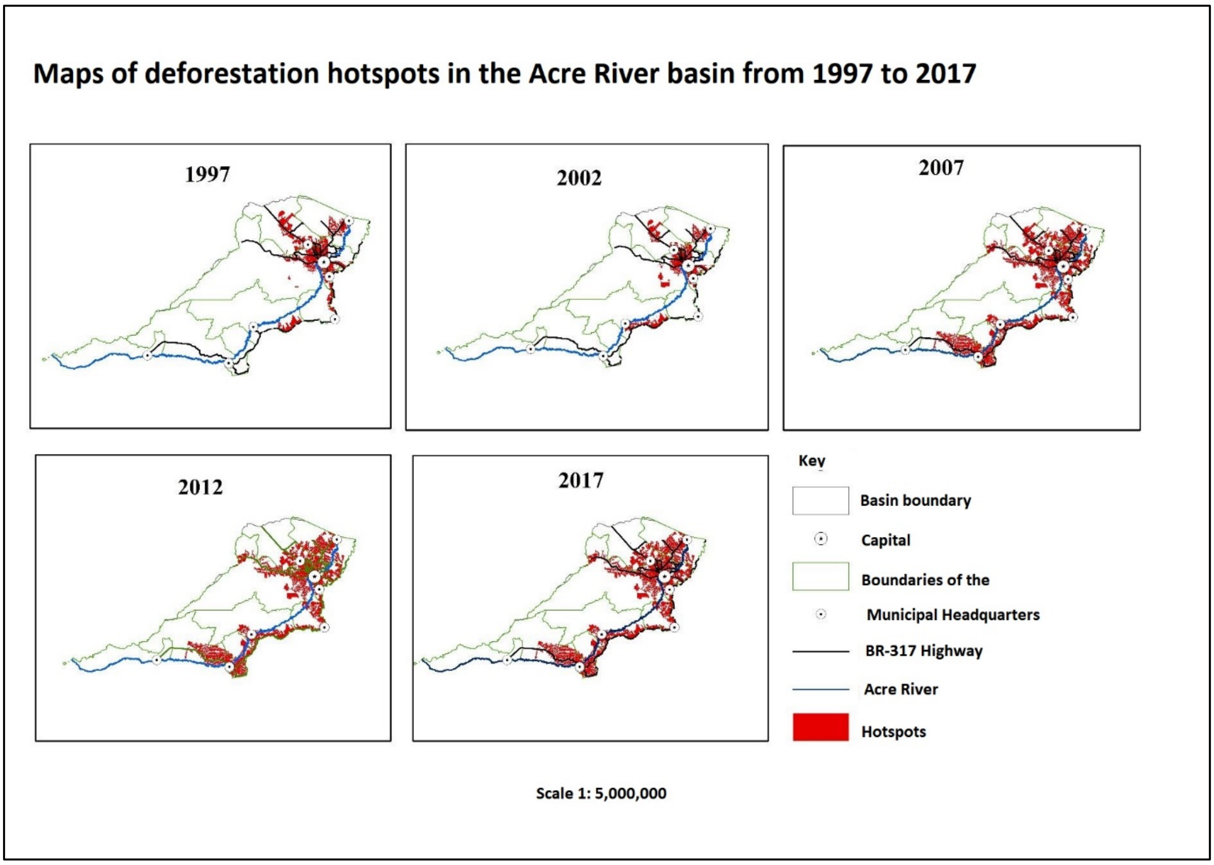

Fig. 2 - Maps of the evolution of deforestation hotspots in the Acre river basin between 1997 - 2017, in periods of 5 years.

Table 2 – Relative growth rate and absolute growth trend of deforestation for the spatial cutouts.

Location	Growth Rate (%) p.a.	Area (ha/year)	R^2
Acre State	-6,95%	-4.013,70*	0,41
Acre River Basin	-7,72%	-1.763,40*	0,38
Buffer 2.000 m	-9,64%	-193,94*	0,38
Acre River APP	-13,39%	-18,15*	0,30

*Significant values with 95% probability, negative numbers indicating a decreasing trend (GUJARATI, 2011).

The evolution of deforestation in the buffer and APP spatial sections did not present significant differences in relation to the territorial categories, that is, the average percentage of deforestation in the TIs, UCs, PAs and APSDs were similar in the buffer and APP. However, the evolution of deforestation in the TIs, UCs, PAs and APSDs presented significant differences between the average percentages.

In absolute and relative terms, all protected areas presented the lowest percentages of deforestation. This behavior is in line with what has occurred in the Amazon (CAMPOS; NEPSTAD, 2006; SOARES-FILHO et al., 2006). At the same time, the proximity of these protected areas with the advancing frontiers of the agricultural frontier (small and large properties), made them more vulnerable to land invasion (PEDLOWSKI et al., 2005).

Considering the limits of the buffer, there was an increase in the percentage of deforested area in most territorial categories, with the exception of the PAs, where there was a small reduction when compared to what occurred in the Acre River basin. Larger percentage values were found only in the spatial cutouts of the areas of more restricted use, principally in the TI Cabeceira do Rio Acre and in the RESEX Chico Mendes (Table 3)

Table 3 - Territorial categories in the buffer, with respective total areas, deforested areas and percentages, based on the PRODES/INPE 2017 classification.

Territorial Categories	***Bufffer***				
	Area (ha)	**Total Area (%)**	**Deforested Area (AD)**	**AD (%)**	**AD Categ. (%)**
Indigenous Territories - TIs	11.274,9	6,3	594,6	0,8	5,3
Full Protection Conservation Unit - UCPI	8.760,2	4,9	0,00	0,00	0,00
Sustainable Use Conservation Unit - UCUS	20.738,0	11,7	7.139,6	9,0	34,4
Settlement Projects -PAs	54.592,7	30,7	19.927,4	25,0	36,5
Private / undesignated areas - APSDs	82.418,4	46,3	51.995,1	65,2	63,1
Total	**177.784,23**	**100,0**	**79.656,7**	**100,0**	**44,8**

AD = Deforested Area and AD Categ. = Deforested Area considering the area of the land use category.

The fact that 47.4% of the APP area within the Chico Mendes RESEX has already been deforested reinforces the understanding that families are moving closer to the riverbanks. This pattern of deforestation of the APP in the RESEX is similar to that which occurred in the PAs and APSDs, since there was no significant difference between the average percentages of deforestation. The APP is more protected in the ESEC with no deforestation identified and in the TI Cabeceira do Rio Acre, whose percentages were much lower (Table 4).

Table 4 - Territorial categories in the APP of the Acre River, with respective total areas, deforested areas, and percentages, based on the PRODES/INPE 2017 classification.

Territorial Categories	**APP**				
	Area (ha)	**Total Area (%)**	**Deforested Area (AD)**	**AD (%)**	**AD Categ. (%)**
Indigenous Territories - TIs	630,3	5,0	62,4	1,0	9,9
Full Protection Conservation Unit - UCPI	385,4	3,0	0,00	0,00	0,00
Sustainable Use Conservation Unit - UCUS	1.543,0	12,2	731,2	12,0	47,4
Settlement Projects -PAs	3.433,8	27,2	1.174,5	19,4	34,2
Private / undesignated areas - APSDs	6.648,5	52,6	4.097,8	67,6	61,6
Total	**12.641,0**	**100,00**	**6.065,8**	**100,00**	**48,0**

AD = Deforested Area and AD Categ. = Deforested Area considering the area of the land use category.

Significant rates of positive growth of deforestation only occurred in TIs (Table 5). The growth may represent the discontinuity of the classification by PRODES/INPE, where the values are very small and cannot be captured by the satellite, accumulating in certain years. The higher growth observed in the buffer is in agreement with the hypothesis that the communities' plantations were concentrated in this strip, farther from the banks where the villages are located.

In the PAs and APSDs significant decrease rates occurred in all spatial cutouts, with greater decreases in the APP, which in part reflects the better planning of command and control (Table 5).
With a non-significant growth rate within the Chico Mendes RESEX, the accumulated deforestation of 7.13% in the basin area can still be considered within the limits allowed in the unit's management plan. Both in the buffer and in the APP the growth was negative (Table 5).

Table 5 - Relative growth rate and absolute growth trend for the land use categories within the spatial clusters.

Territorial Category	Spatial Cutout	Growth Rate (%) p.a.	Area (ha/p.a.)	R^2
TI	Basin	11,27*	25,29*	0,51
	Buffer	22,21*	22,93*	0,51
	APP	13,90*	2,22*	0,42
UC	Basin	0,06 ns	-4,83 ns	0,00
	Buffer	-7,50*	-18,01*	0,30
	APP	-9,66*	-3,01*	0,35
PA	Basin	-5,77*	-881,69*	0,30
	Buffer	-6,69*	-49,70*	0,30
	APP	-19,70*	-5,03*	0,45
APSD	Basin	-9,56*	-1.264,70*	0,50
	Buffer	-15,43*	-120,22*	0,51
	APP	-16,64*	-9,30*	0,46

TI = Indigenous Territory; UC = Conservation Unit; PA = Settlement Project; APSD = Private areas without destination; APP = Permanent Preservation Area. R^2 = coefficient of determination of the regression model. * significant values; ns – non-significant values, p<=0,05. negative numbers indicating a downward trend (GUJARATI; PORTER, 2011).

Discussion

The largest growth in the period 1997-2002 coincides with the paving of the BR 317 highway, which follows the basin of the Acre River, connecting the municipalities of Rio Branco (the Capital) with Assis Brasil, on the border with Peru. Starting in 2002, the adoption of the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon coincided with smaller percentage increases in the two subsequent periods, reaching the lowest values between 2008 and 2012, for all spatial cutouts, with the APP showing the smallest percentage increase (ACRE, 2010; BRASIL/MMA, 2004, 2011).

In the most recent period, from 2013 to 2017, there was a percentage increase in all spatial cutouts, a period that is associated with the economic recession and the lack of investment with public budget resources, affecting the Government's ability to promote enforcement.

The dynamic nature of the causes of deforestation makes it difficult to study more objectively the reasons for the fluctuation found over time, which has been a pattern throughout the Amazon (EWERS; LAURANCE; SOUZA, 2008; FEARNSIDE, 2005). In the State of Acre, deforestation in the last 20 years has shown a downward trend, once the adoption of public policies associated with international cooperation projects may have been a contributing factor to this downward trend.

In the TIs, although the relative increase in deforestation has been large, in absolute terms the area is still very small, and this increase can be explained by the location of the villages and their plantations closer to the banks of the Acre River.

In the UCs, the ESEC Rio Acre has fulfilled its role of full protection, since no deforestation was detected. The Chico Mendes RESEX, however, showed a percentage increase in deforestation in relation to that which occurred in the basin, indicating that the proximity of access roads to the river has influenced this increase, which may also indicate a displacement of families from inland areas to near the riverbank. We emphasize that the buffer of the Acre River within the RESEX, in the municipalities of Epitaciolândia and Brasiléia, is close to the BR-317 highway, a place where greater deforestation pressure may have occurred.

On the other hand, the reduction in the percentage of deforested area in the PAs can be explained by the greater effect of land access routes, such as highways and secondary roads (branch roads) in a "fishbone" format (ARIMA et al., 2013) to the detriment of river access.

Conclusions/ wider implications of findings

The area deforested, up to 2017, in the APP of the Acre River, including consolidated areas that are not subject to forest restoration, corresponds to 48% of its total area, which is approximately equivalent to 6,065.8 hectares. Of this total, 52.6% are in APSDs and 47.4% in public areas, of which 27.2% are in PAs, 12.2% in UCs, and 5.0% in TIs.

The access through the Acre River worked as a vector of deforestation in the areas closest to the riverbank, even after the paving of the BR-317 highway, since the percentage area deforested in this strip was always higher than the percentages presented in the other spatial cutouts studied (state, basin and buffer).

The deforestation migrated from the surroundings of the more urbanized centers, with a greater density of rural settlements and local roads, to the surroundings of the BR-317 highway, paved at the end of the 1990s.

Rural producers in private areas are the most responsible for the deforestation of the APP of the Acre River.

Small farmers had a pattern of deforesting farther from the banks, probably because more families are concentrated near the side roads than near the river banks.

Traditional populations in UCs and indigenous populations in TIs had a pattern of deforestation closer to the riverbank.

Even with decreasing deforestation rates in the APP of the RESEX Chico Mendes, the RESEX Chico Mendes has 47.4% of its area already deforested, demonstrating the effect of the migration of local populations from the interior to the banks of the Acre River.

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