

**Governance and Infrastructure in the Amazon Project
Tropical Conservation and Development Program**



**Spatiotemporal analysis of the Southern Amazonas/Northern
Rondônia Mosaic: Socio-economics, infrastructure, land cover and
land-use change**

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Table of Contents

1. Introduction	1
2. Methods	2
3. Results.....	4
3.1. Political boundaries, population and economy	4
3.2. Infrastructure.....	7
3.3. Public land tenure allocation	9
3.4. Land tenure regulation.....	13
3.5. Deforestation	15
3.6. Land cover and land use	20
3.7. Mining	22
4. Conclusions	23
5. References.....	24



1. Introduction

This document presents a spatiotemporal analysis of land-use change, socio-economic and infrastructure development in Southern Amazonas/Northern Rondônia Mosaic region. The mosaic was defined in collaboration with the GIA Community of Practice and Learning (CoP-L) during the workshop in July 2019 in Candeias do Jamari –RO. It encompasses Southern Amazonas and Northern Rondônia states in the southwestern Brazilian Amazon, comprising 14 municipalities distributed equally in each state (Figure 1).

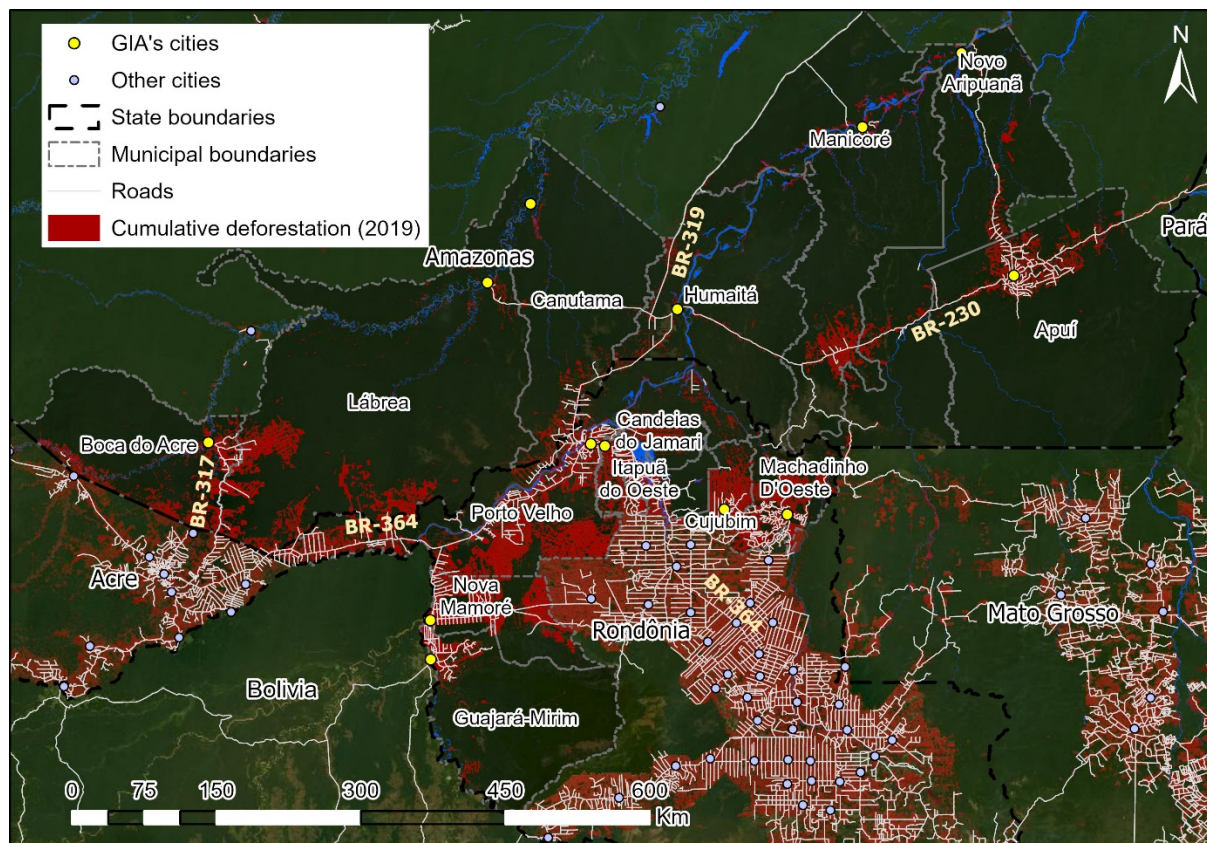


Figure 1. GIA Southern Amazonas and Northern Rondônia Mosaic.

This vast territory, with over 394,000 km², is located in the interfluvial area of the Madeira and Purus rivers that hosts diverse forest and water ecosystems. Several challenges and threats are affecting this region of great importance for the conservation of Amazonian socio-



biodiversity. Among these is the uncontrolled encroachment of the agricultural frontier, illegal logging, forest fires, illegal mining, land tenure insecurity and land grabbing, low government presence and services, and lack of governance with regard to major infrastructure projects, such as the creation or paving of half of the 2,687 km of Federal highways (BR-319, BR-230, and BR-364), and the Santo Antônio and Jirau hydroelectric dams, among others.

The data presented here serve as a source of information for the CoP-L to understand the region's land tenure, socio-economic, and infrastructure development configuration. It is a valuable input for discussion and planning strategies and tools to improve governance and social and environmental outcomes. It can be used in research and practice by the University of Florida, its graduate students and the organizations of the CoP-L. Data prepared for this product can be found in tabular file and the geospatial information organized in a database¹.

2. Methods

I used the datasets in Table 1 and processed all geospatial data in a Geographical Information System environment (ArcGIS Pro v.2.5.2) using datum SIRGAS 2000, projected planar coordinates UTM zone -20S. I merged data from all seven municipalities in each state to assess the total area covered, and summarized information in tables, graphs, and maps per municipality and state.

¹ Link to data: <https://drive.google.com/drive/folders/1p1kVJ-WjV5Y7DK7HnnuR-qYxODwVyU1y?usp=sharing>



Table 1. Datasets used in the analysis.

<i>Description</i>	<i>Spatiotemporal resolution</i>	<i>Periods-dates</i>	<i>Content/type</i>	<i>Source</i>
Infrastructure (Ports, dams)	NA	NA	point shapefile	Brazil's Ministry of Energy, IIRSA compiled.
Deforestation	6.25ha/yr	2008-2019	Polygon shapefile	National Institute of Spatial Research - INPE
Roads	1:100000	2013	Line shapefile (primary and secondary)	Management Center of the System for Protection of the Amazon - SIPAM, ANTT
Mining operations		NA		Departamento Nacional de Produção Mineral (DNPM)
Land Tenure		2020	polygon shapefile	Atlas Agropecuario
Municipal boundaries	1:100000	2016	Polygon shapefile	Brazilian Institute of Geography and Statistics - IBGE
State boundaries	1:100000	2016	Polygon shapefile	
Population (rural-urban)	longitudinal	1970-2019 every ~10 years	Tabular data	
GDP by sectors	longitudinal	1990;2000;2010	csv table format	
Land cover	Longitudinal, 30m	Every 5 years 1985-2018	Raster: Land cover classes	Mapbiomas

I manipulated all tabular data in R v.4.01 (R-project) and exported summary tables. For the land tenure categories, I used the Atlas da Agropecuária Brasileira (Atlas Agropec). I combined land tenure sub-classes of Atlas Agropec datasets with deforestation polygons from the Project for Monitoring Deforestation in Amazonia - PRODES (INPE 2020). I used ArcGIS's identity function to combine the three datasets, generating the frequency and area that overlapped each of the land tenure categories of Atlas Agropec and its associated deforestation.

Atlas Agropec presents the land tenure regulation for Brazil. It organizes and integrates different public datasets on rural private properties and possessions from SIGEF, Terra Legal, settlements, protected areas, and CAR registries. It is useful because it removes the spatial overlap among different land tenures using a hierarchical approach based on the level of juridical security of the rights, the geospatial precision, and the likelihood of changing the nature of the land (from public to private) (Reydon et al. 2018).

I found inconsistencies in the subclasses of land tenure and 2.09 Million ha of overlapped areas, totaling 1900 polygons. I used the same hierarchy rules presented in Reydon et al. (2018)



to remove overlapped polygons except for three entries, for which I assumed the hierarchy does not apply². Besides, there were 1.54 Mha without information (gaps) in Atlas Agropec, which I considered designated public lands in the analysis. I reclassified inconsistencies of the subclass COM (Community Areas) to subclasses Indigenous Territories (TI_H), Agricultural Settlements (ARU), or Conservation Units (UCUS and UCPI) according to the column Name, which had the name of the protected area or settlement classified in the COM subclass. Similarly, some entries marked as ARU were reclassified to Protected Areas when the Name column so indicated. Finally, as the purpose of this study is to present public lands under someone's possession, I grouped areas with no information on land tenure with five Atlas sub-classes representing undesignated public lands. The five sub-classes are CAR registries (CARpr and CARpo) in public lands, undesignated public lands registered in SIGEF (ND_I), undesignated public forests from the Brazilian Forestry Service (ND_B), and untitled public lands from Terra Legal (TLPC). I kept areas under private property regimes such as SIGEF and Terra Legal Titled (TLPL) separated to represent what is legally considered private lands.

3. Results

3.1. Political boundaries, population and economy

The southern Amazonas – northern Rondônia mosaic's total area is 39.34 million hectares, 77% in Southern Amazonas, with Lábrea and Apuí being the largest municipalities representing 31% of the entire territory. Northern Rondônia has much smaller municipalities, with the smallest being Cujubim (0.39 Ma) and Itapuã do Oeste (0.41 Mha) representing around 1% of the territory. The total population in the mosaic is estimated to be 963,122 individuals in 2019,

² Terra Legal titled (TLPL) is a higher hierarchy than Settlements and Conservation Units. However, I chose to keep three entries duplicated entries that the wrong one seemed to be the Terra Legal Titled. They are 927,236 ha of PAE Aripuanã-Guariba, 423,814 ha of Parque Nacional do Acari, and 221,970 ha of Resex Baratiri.



being 74% in Northern Rondônia. Porto Velho has 529,544, or 55% of the total population (Fig. 2A). When using the rural population of 2010, density per km² is higher in Rondônia, with Machadinho D'Oeste and Itapuã do Oeste being around two persons per km² (Fig. 2B).

Table 2. Area for the municipalities of Southern Amazonas and Northern Rondônia.

Municipality	State	Area (ha)	Percent
Guajará-Mirim	RO	2,485,478	6%
Machadinho D'Oeste	RO	850,511	2%
Porto Velho	RO	3,409,187	9%
Nova Mamoré	RO	1,007,197	3%
Candeias do Jamari	RO	683,877	2%
Cujubim	RO	386,110	1%
Itapuã do Oeste	RO	407,836	1%
Apuí	AM	5,441,181	14%
Boca do Acre	AM	2,209,084	6%
Canutama	AM	3,362,905	9%
Humaitá	AM	3,308,910	8%
Lábrea	AM	6,838,201	17%
Manicoré	AM	4,831,486	12%
Novo Aripuanã	AM	4,122,932	10%
Amazonas		30,114,701	77%
Rondônia		9,230,195	23%
Total		39,344,896	100%

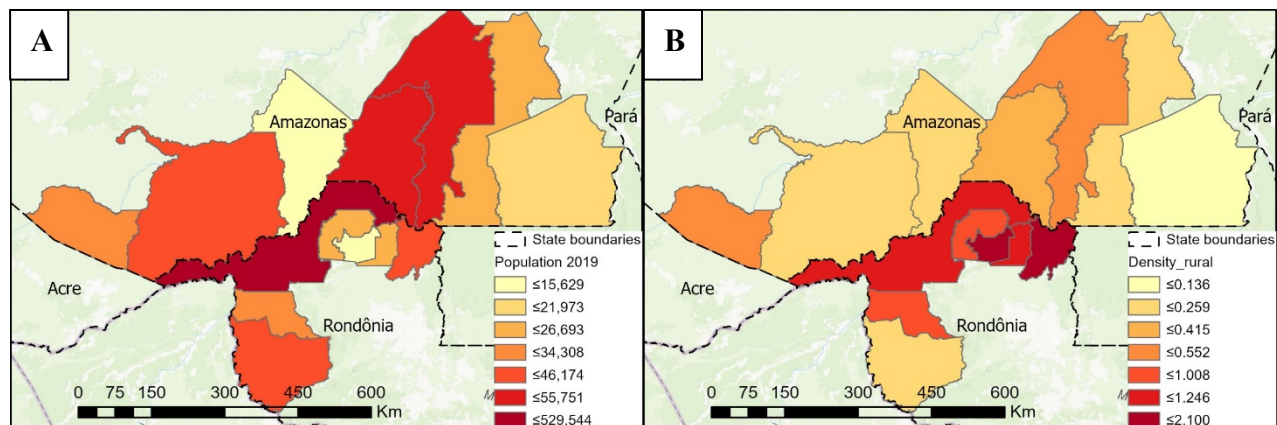


Figure 2. Total Population 2019 (A) and rural population density (person. Km²) 2010 in Brazil's mosaic. Source: IBGE 2020.

Although Apuí, Novo Aripuanã, and Manicoré were created from Maués and Borba municipalities, the number of municipalities covering the mosaic in Southern Amazonas had no drastic divisions since 1950. In contrast, Northern Rondônia's municipalities increased from 2 to 7 by the division of Porto Velho and Guajará-Mirim (Fig.3A). The creation of new districts follows the population increase since the 1970s when the military plan to colonize Rondônia was set up with the construction of BR-364. Massive spontaneous migration to Rondônia



in the 1980s resulted in a population increase of more than five-fold, whereas Southern Amazonas was less than three-fold (Fig. 3B).

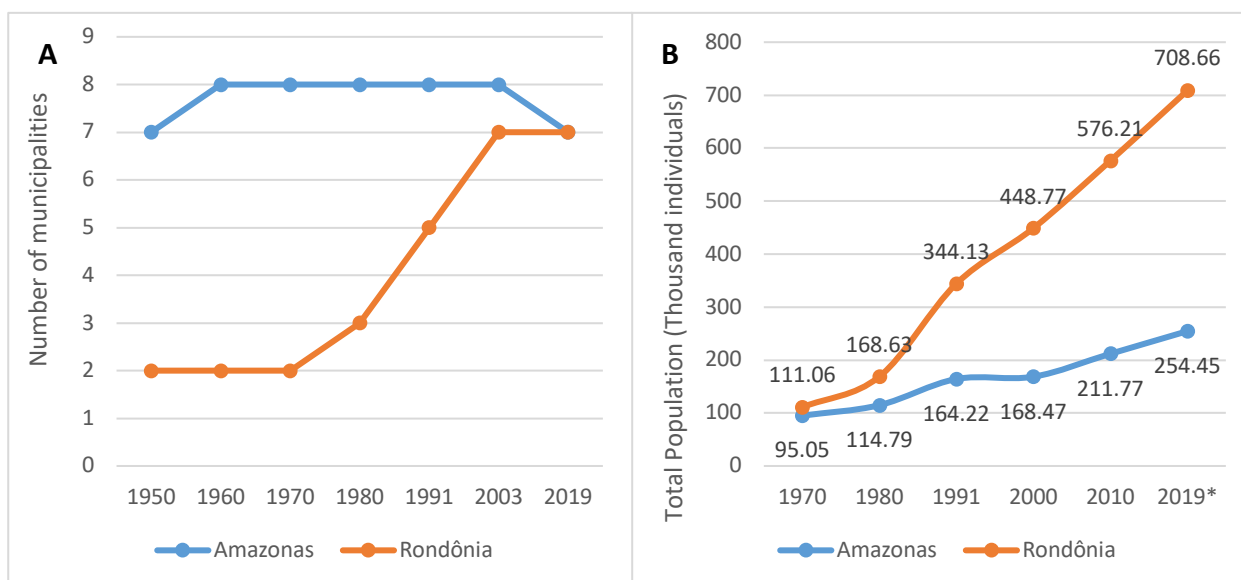


Figure 3. Number of municipalities since 1950 (A) and total population increase (B) over time in Southern Amazonas and Northern Rondônia's GIA Mosaic. (Source: IBGE 2020).

The population growth was accompanied by investments in infrastructure and services explained by investments made by the PoloNoroeste (Mahar 1989). These investments also reflect the Gross Domestic Product (GDP) among municipalities and state regions, as illustrated in Table 3.

Table 3. Total and agricultural GDP per municipality in 2017.

State	Municipality	GDP 2017 (Million BRL)		
		Total	Agriculture	Percentage Agric./total
RO	Guajará-Mirim	805	47	6%
RO	Machadinho D'Oeste	607	183	30%
RO	Porto Velho	16,515	590	4%
RO	Nova Mamoré	473	184	39%
RO	Candeias do Jamari	538	85	16%
RO	Cujubim	324	84	26%
RO	Itapuã do Oeste	161	40	25%
AM	Apuí	193	56	29%
AM	Boca do Acre	365	84	23%
AM	Canutama	103	16	16%
AM	Humaitá	555	123	22%
AM	Lábrea	495	214	43%
AM	Manicoré	496	147	30%
AM	Novo Aripuanã	183	47	25%
	Rondônia	19,422	1,214	6%
	Amazonas	2,390	686	29%
	Total	21,812	1,900	9%



Total GDP in Rondônia’s municipalities is relatively higher, especially in the state’s capital Porto Velho, which has the highest agricultural GDP³ as well. However, when we consider the percentage of the agricultural GDP relative to the total GDP, Southern Amazonas municipalities average 29%. Results for Rondônia are biased due to the enormous contribution of Porto Velho. Still, it is possible to see that some municipalities rely heavily on agriculture, such as Nova Mamoré and Machadinho D’Oeste.

3.2. Infrastructure

As expected, infrastructure in Northern Rondônia has developed faster than in Southern Amazonas. For roads, due to the latter area being three times larger, the extension of roads is almost equal at over 5,000 km. However, Rondônia’s portion has more than two-fold of the length of roads paved (nearly 750 km) (Table 4). Southern Amazonas has roughly 600km of Federal highways, whereas Northern Rondônia has more extension of State roads and local feeder roads. It is essential to mention that in both states, the road network geospatial data has not been updated since 2013, meaning there are certainly more roads than reported here. For Amazonas, I used primary data on local roads for Apuí, Manicoré, and Humaitá. Considering that fact, one can expect that the total road length for Northern Rondônia is less well represented.

Table 4. Length of roads (in kilometers) in the southern Amazonas – northern Rondônia mosaic.

Class	Characteristic	Amazonas	Rondônia	Total
Situation	Unpaved	4,794.3	4,019.5	8,813.8
	Paved	245.4	900.0	1,145.5
	No information	309.2	747.8	1,057.0
Jurisdiction	Federal	1,529.0	941.6	2,470.5
	State	373.1	639.9	1,013.0
	Local	3,446.8	4,085.9	7,532.6
Grand Total		5,348.9	5,667.4	11,016.2

³ Agricultural GDP comprises all revenues from the primary sector, agriculture, ranching, logging and non-timber forest products.



Most remarkable are the difference in number and capacity (MWh) of hydroelectrical generation in these two states' regions (Table 5). All three operational dams are in Rondônia (Samuel, Santo Antônio, and Jirau) with estimated capacity of 7,535 MWh, with the Binational Bolivia-Brazil Dam planned to increase this capacity by an additional 6,000 MWh. Amazonas inventoried and planned dams totals 5,761 MWh, with the three planned ones (São Simão Dam in Juruena river, Samaíma and Prainha in Aripuanã river) accounting for 83% of it. Tabajara planned dam in Ji-Paraná river will deliver 350MWh.

Table 5. Hydroelectric dams inventoried, planned and operational in the southern Amazonas – northern Rondônia mosaic.

State/River	Inventoried		Planned		Operational		Total Count	Total Capacity (MWh)
	Count	Capacity	Count	Capacity	Count	Capacity		
Amazonas	8	998	3	4,764			11	5,761
Curuquetê	1	48					1	48
Endimari	2	69					2	69
Ituxi	3	120					3	120
Juruena			1	3,509			1	3,509
Roosevelt	2	761					2	761
Aripuanã			2	1,255			2	1,255
Rondônia	1	14	6	6,361	3	7,535	10	13,909
Beni, Madeira, Mamoré			1	6,000			1	6,000
Candeias			3	NI			3	NI
Jamari					1	217	1	217
Ji-Paraná			1	350			1	350
Machadinho	1	14	1	11			2	25
Madeira					2	7,318	2	7,318
Total	9	1,012	9	11,124	3	7,535	21	19,670

Rondônia also has more ports than Amazonas (Table 6), mostly due to a concentration of 9 out of 14 in Porto Velho, of which five are private, including Cargill Agricola and Cia. Agro-Industrial Monte Alegre that use it for grain exports, mostly soybeans. Amazonas has six operational ports and only one private, a brand-new grain port of Masutti company in Humaitá, Madeira River.



Table 6. Operational and Planned ports in Brazil's Mosaic

State/River	Operational		Planned	Total
	Private	Public	Public	
Amazonas	1	5	2	8
Rio Aripuana		1		1
Rio Madeira	1	3		4
Rio Purus		1	2	3
Rondônia	8	5	1	14
Rio Candeias		1		1
Rio Machado		1		1
Rio Madeira	7	2		9
Rio Mamore	1	1	1	3
Grand Total	9	10	3	22

Given these three types of infrastructure, Rondônia has been leading with bright prospects to keep growing faster than Southern Amazonas. Similarly, the agricultural infrastructure, considering silos for grain storage, slaughter facilities, and other industrial plants, is likely to be more present in Northern Rondônia. Each region has one slaughter facility according to the official data (not updated), one in Boca do Acre-AM (450 head per day), and one in Porto Velho-RO (350 head per day). My research indicates that southern Amazonas has at least two more slaughter facilities operating, Frigonosso in Matupi District (Manicoré) (300 per day), and Frigorífico Amazonas in BR-319 (360 head per day) located 23km distant from Humaitá town, inaugurated at the end of 2019 and on January 2020, respectively.

3.3. Public land tenure allocation

Until the 1970s, the region was home to indigenous and rubber-tapper communities using rivers for transportation, with some titled lands of wealthy rubber merchants registered in public notary offices. The vast majority of the area was considered *terras devolutas* (undesignated public lands). The military plan took off by the mid-1970s to populate and explore the region's natural resources and produce agricultural surpluses to export. It materialized with the construction of federal roads BR-364, BR-230 (Transamazon highway), and BR-319 (PortoVelho - Manaus) in the mid-1970s. Later, BR-317 was opened, connecting to BR-364 that



crosses Rondônia and Acre states and the Pacific Ocean through the Interoceanic Highway in Peru. Figure 4 presents the areas and number of Protected Areas, Indigenous Lands, and Land Reform Settlements created in the southern Amazonas – northern Rondônia mosaic.

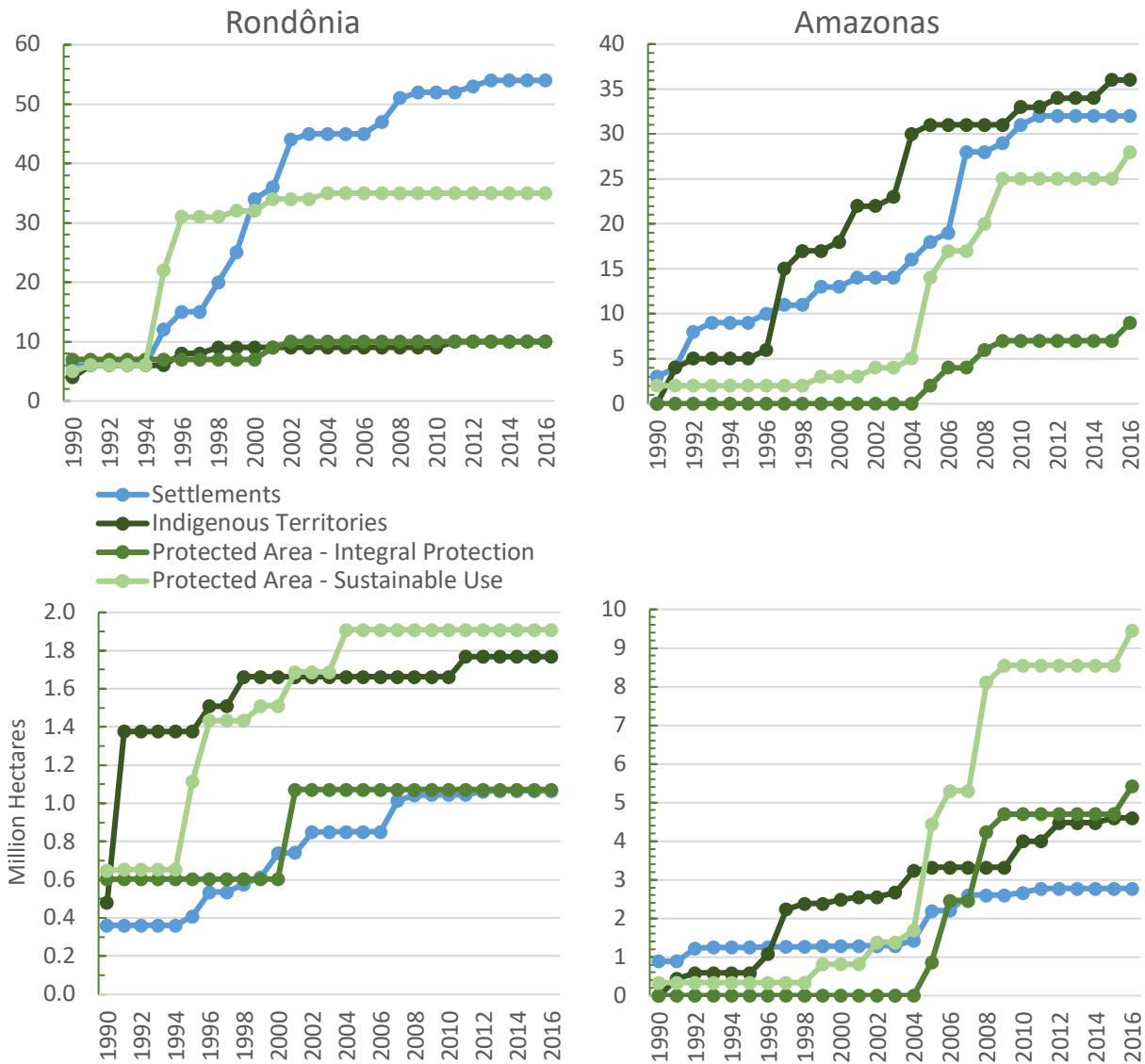


Figure 5. Area (Mha) and number of Protected Areas (Integral Protection, Sustainable Use), Indigenous Territories and Land Reform Settlements created in Southern Amazonas and Northern Rondônia.

The National Institute for Colonization and Agrarian Reform (INCRA), created in 1970, became the federal agency responsible for allocating undesignated public lands for agricultural purposes. At that time, INCRA controlled around 30% of Brazilian lands, including 100km on



each side of any planned and constructed federal highway and 250km from all Brazilian inland borders. INCRA demarcated land parcels alongside these highways, which could be acquired by individuals and enterprises. The military government provided substantial financial incentives for private companies to purchase such lands at meager prices, deemed essential for integrating the Amazon to the national economy. Nevertheless, the dense occupation at that time happened in Rondônia, closer to the economic center of Southern Brazil (Hecht 1985; Mahar 1989).

During the 1980s and 1990s, INCRA created 33 land reform settlement projects totaling 2.02 Mha, 7 in Southern Amazonas, five which are mostly in Acre state (Porto Acre and Acrelândia municipalities) but have a small portion within southern Amazonas, and 21 agricultural settlements in Northern Rondônia. Thirty-one projects are 1 agricultural settlement projects (PAs or PIC) that consist of groups of individual farm lots, each with 50 to 100 ha assigned to colonists. Even though these are considered public lands allocated to agrarian reform, the colonists settled should eventually buy such farm lots at prices lower than market prices and may get the title of private property, which legally allows them to sell or rent. Nonetheless, titled settlement lands are the minority in the region, especially in Amazonas, where for instance, PA Rio Juma has only 18% of lands titled (Carrero and Fearnside 2011). With or without title, these settlement lands have been traded and generated land accumulation in the hands of few large land holders (Carrero et al. 2020, Yanai et al. 2020).

During the government of President Lula, from 2000 to 2013, 48 land reform settlements were created, 29 in Northern Rondônia, 16 in Southern Amazonas, and one in Acre with a portion of it in Amazonas. A total of 26 agricultural settlements encompassing 2.83 Mha were created all in Rondônia and the one in Acre, whereas 22 settlements with special characteristics covering more than 1.84 Mha were created, all in Amazonas. The primary strategy in Amazonas



was creating such “special” settlements such as Sustainable Development Projects (PDSes), Agroforestry Projects (PAFs), and Agroextractive Projects (PAEs) usually to give rights of usufruct for riverine communities. Different than PAs, agricultural conversion in these special settlements should (theoretically) be minimal, and livelihoods should rely more on forest extraction in a regime of communal lands (Yanai et al. 2016). However, what has been reported is that these settlements can present high deforestation rates and contentious conflicts between the legitimate occupants and ranchers’ land appropriation (via violent expropriation or purchasing), as in the case of PAE Antimary in Boca do Acre (Dias et al. 2015).

The National Foundation for Indigenous Peoples (FUNAI) demarcated and homologated 26 indigenous territories encompassing 4.05 Mha until the 1990s, 19 in Southern Amazonas, and 7 in Rondônia. An additional 20 were demarcated from 2000 to 2015, 17 being in Southern Amazonas. The 46 Indigenous Territories sum up almost 6.4 Mha, occupied by 21 ethnic groups and around 56,000 people, with 44,000 in Northern Rondônia (ISA 2020). 82 Conservation Units were created in the region, totaling 17.87 Mha, out of which 14.88 Mha is in Southern Amazonas. 63.6% (11.37Mha) of this area was allocated to sustainable use conservation units that allow dwellers to extract timber and non-timber forest products and perform subsistence agriculture and hunting. Rondônia has dozens of Extractive Reserves, whereas Amazonas has more National and State Forests and Sustainable Development Reserves. The other 6.5Mha (36.4%) of the Conservation Units are for integral protection, only for tourist and research purposes. While no changes in Indigenous Territories’ area have been made via law amendments, Conservation Units had some changes. Seven Conservation Units were enlarged totaling 837,734 ha, out of which Floresta Nacional Balata-Tufari and Parque Nacional Mapinguari, both in Southern Amazonas, represented 58% of this change. Five Conservation



Units, all in Northern Rondônia, had their area reduced, totaling 256,448ha, of which Floresta Nacional de Bom Futuro represented 70%.

3.4. Land tenure regulation

To represent the entire area of the southern Amazonas northern Rondônia mosaic, I used the dataset of Atlas Agropec solved for overlap between different types of public land tenure sub-classes grouped and reclassified. A complete account of the land tenure regulation is presented in Figure 5 and Table 7. Currently, 63% of the mosaic's lands have been allocated by the government under public land tenure regulation. 21.46 Mha of the actual area is under protected areas, already discounting the around 8 Mha of overlap between them and private properties. Southern Amazonas accounts for more than three-quarters of the total area under protected areas, but in relative percentage of total area is only 8% more than Southern Rondônia.

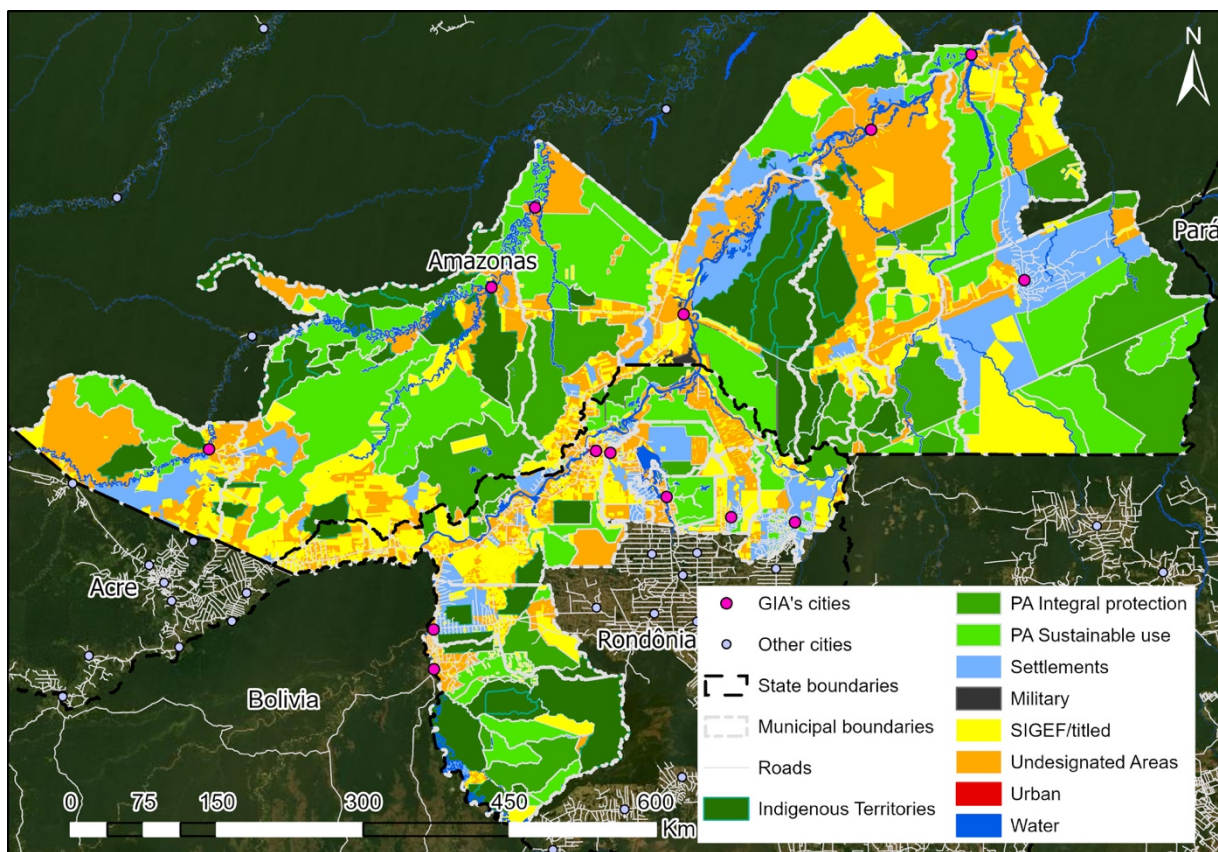


Figure 5. Land tenure regulation in sub-classes in Southern Amazonas/ Northern Rondônia's mosaic.



Table 7. Area and percentage of extension per each class and sub-class of land tenure.

Class	Sub-class	Amazonas		Rondônia		Total	
		Area* (ha)	Percentage	Area (ha)	Percentage	Area (ha)	Percentage
Public - Protected Areas	Conservation Unit- Sustainable Use	8,342,819	28%	1,657,197	18.0%	10,000,016	25.4%
	Conservation Unit- Integral protection	4,735,711	16%	1,076,781	11.7%	5,812,492	14.7%
	Indigenous Territory	3,902,503	13%	1,706,639	18.5%	5,609,143	14.2%
	Military	39,785	0.1%	268	0.0%	40,053	0.1%
	Sub-Total	17,020,818	56%	4,440,886	48%	21,461,704	54%
Public - Settlements	Conventional (PA/PAD)	1,048,597	3%	739,494	8%	1,788,091	5%
	Special (PAE, PDS, PAF)	1,658,724	5%	171,701	2%	1,830,424	5%
	Sub-Total	2,707,321	9%	911,194	10%	3,618,515	9%
Public - Other	Undesignated	5,933,649	20%	1,792,617	19%	7,726,267	20%
Private	SIGEF	3,367,407	11%	1,329,969	14%	4,697,376	12%
	Titled	775,121	3%	565,704	6%	1,340,824	3%
	Sub-total	4,142,528	14%	1,895,673	21%	6,038,201	15%
Water, transportation, urban areas		376,497	1%	189,825	2%	566,321	1%
Total		30,180,813	100%	9,230,194	100%	39,411,008	100%

Sources: Area (Atlas Agropec 2020 - <http://atlasagropecuario.imaflora.org/>)

*The areas were solved for area overlapping (according to Reydon et al. 2018) are smaller than the total areas considered in the creation decree laws.

Conservation Units of Sustainable Use are more widespread in Amazonas because of the creation of many state protected areas during the 2000s, supported by the PPG-7 programs and the ARPA projects. Indigenous Territories cover a larger relative percentage in Rondônia, which was the first front of occupation where indigenous activists played and still play a crucial role in contacting isolated groups and supporting demarcation and homologation of territories. Settlements occupy 9% of the total area. The conventional agriculture type has relatively more area in Rondônia than in Amazonas, which has more under special settlements.

Undesignated public lands occupy 20% of the region, approximately the same relative area in each state. Titled lands and other private properties recognized by law occupy another 15%, although 21% and 14% of the corresponding area of Rondônia and Amazonas parts, respectively. Private Titled lands represented the effort of Programa Terra Legal (Legal Land Program- Law 11.952 of 2009) issuing title for small possessions. SIGEF properties mean those uploaded in the Sistema de Gestão Fundiária (Land Management System), the one that electronically unifies all land registers (titles and possessions), and accepting land possessions



that have a Rural State Cadastre Certificate (CCIR) issued by INCRA. On the other hand, there are many possessions up to 2,500ha that could be considered legal, a size that was extended from 1,500ha by the Law 13,465 of 2017. On 10 December 2019 President Bolsonaro issued a provisional measure (MP-910) allowing titles to be granted for illegal land claims on the basis of a mere “self-declaration.” Provisional measures remain in effect for 120 days, after which their continued validity requires a congressional vote. In April 2020, at the end of the temporary period, the measure was converted to a proposed law (PL-2633/20) known as the “land-grabbers’ law” (*lei da grilagem*) (Fearnside 2020). Approval is likely given the presidential administration’s support and the strong ruralist influence in the National Congress. These undesigned lands could be illegally grabbed through *grilagem*, processes that use forged documents, and often violence. Nevertheless, my estimates using CAR registries for southern Amazonas show that between 36-45% of possession claims within undesigned public lands are smaller than 2,500 ha, the majority (55-64%) considered illegal possessions (Carrero, G. *in preparation*).

3.5. Deforestation

The study area’s total deforestation by 2019 was more than 4.17 Mha, of which around 2.5Mha in Rondônia, and 1.7Mha in Amazonas. Rondônia’s cumulative deforestation reflects its longer agricultural occupation, which started earlier and more intensely due to being closer to the economic center in Southeast Brazil. Table 8 shows deforestation covering the sub-classes of land tenure regulation. Only 7% of total deforestation is within protected areas, whereas 25% is in Settlements (mostly in the conventional type), 36% in Undesignated Public Lands, and 31% in Private Lands. It is not a surprise that appropriated areas have most of the deforestation, as



appropriators must demonstrate productive use through forest clearing, a pre-condition for agricultural use in the rainforest.

Table 8. Deforestation in sub-class of land tenure regulation in the study area.

Class	Sub-class	Amazonas		Rondônia		Total	
		Area (ha)	Relative Percentage*	Area (ha)	Relative Percentage	Area (ha)	Relative Percentage
Public - Protected Areas	Conservation Unit-Sustainable Use	47,998	0.6%	158,566	9.6%	206,564	2.1%
	Conservation Unit-Integral protection	15,483	0.3%	16,670	1.5%	32,153	0.6%
	Indigenous Territory	23,987	0.6%	24,569	1.4%	48,556	0.9%
	Military	1,338	3.4%	0	0.0%	1,338	3.3%
	Sub-Total	88,806	1%	199,805	4%	288,611	1%
Public - Settlements	Conventional (PA/PAD)	385,621	37%	523,906	71%	909,527	51%
	Special (PAE, PDS, PAF)	71,466	4%	50,690	30%	122,156	7%
	Sub-Total	457,088	17%	574,596	63%	1,031,683	29%
Public - Other	Undesignated	633,788	11%	886,706	49%	1,520,494	20%
Private	SIGEF	241,427	7%	443,233	33%	684,660	15%
	Titled	240,228	31%	352,054	62%	592,282	44%
	Sub-total	481,655	12%	795,287	42%	1,276,941	21%
Water, transportation, urban areas		24,284	6%	32,388	17%	56,672	10%
Total		1,685,620	6%	2,488,781	27%	4,174,401	11%

* The percentage of relative deforestation was the total area deforested normalized for the relative size of that land use sub-class in Table 7.

Annual deforestation from 2008 to 2019 shows that Southern Amazonas has taken the lead over Northern Rondônia after 2016. Rondônia's historical annual deforestation trend steadily increased the entire period, whereas Amazonas had a constant small increase up to 2014, then a sharp increasing trend afterward, reaching almost 130Kha in 2019 (Figure 6A). Such a sharp increase reflects the presumption that deforesters would not be caught due to the paucity of law enforcement' and recent law changes. Such changes signaled that illegal deforesters would again be pardoned in future "amnesties" (as many violators were in 2012 under the new Forest Code).

Figures 6B and 6C show that deforestation polygons of 50-100ha, 100-500ha, and 500-1500ha markedly increased in Southern Amazonas after 2014. This deforestation trend in remote regions like Southern Amazonas represents the agricultural frontier of current land-use change forces in the Brazilian Amazon.

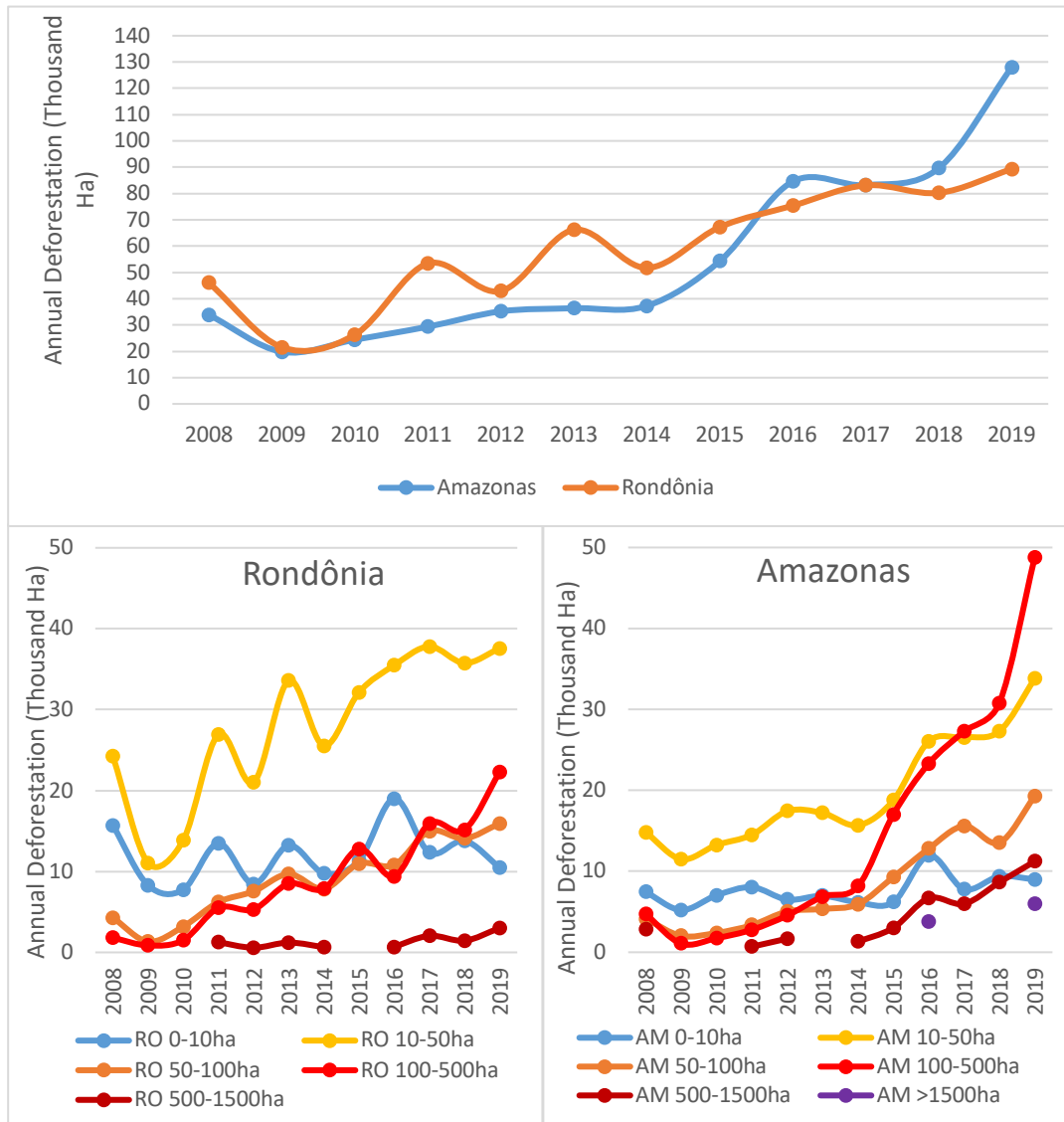


Figure 6. Annual deforestation in Brazil’s Mosaic (A), per class of size in Northern Rondônia (B) and in Southern Amazonas (C).

Illegal land grabbing has had a surge in recent years, which can be explained by the political power of the “ruralists,” a coalition of legislative representatives of large landowners and agribusiness interests. These politicians have taken the lead in the National Congress and since 2012 have been pushing constitutional amendments that weaken environmental protection and



facilitate infrastructure development and agribusiness⁴ (Metzger et al. 2010; Soares-Filho et al. 2014; Fearnside 2016, 2017a,b; Tollefson 2018). The ruralists' impact on legislation has increased substantially since president Jair Bolsonaro took office in January 2019⁵. The resulting changes in the laws undermine the likelihood of future compliance with environmental measures that are preconditions for the many investments in infrastructure being made in the region (Meirelles et al. 2018; Simmons et al. 2018). The infrastructure also prompts more migration (Perz et al. 2010).

Figure 7A presents the Conservation Units with the most cumulative deforestation, except for the two top deforested conservation units (not shown). They were the Extractive Reserves RESEX Jaci-Paraná and the RESEX Rio Preto-Jacundá that have climbed, respectively, from 24,871ha and 1,138ha in 2007 to astonishing 135,938ha and 63,561 ha of cumulative deforestation in 2019. RESEX Rio Ouro Preto and FLONA de Bom Futuro also have steadily increasing deforestation. Instead of riverine communities, family farmers and ranchers occupy these conservation units, and are responsible for the fishbone deforestation pattern. FLONA de Bom Futuro and Parque Estadual dos Picaás Novo show a marked increasing trend since 2014, reflecting similar encroachment of ranching activities.

⁴ The significant moves towards the “flexibilization” of laws, Provisional Measure (MP) 867, would completely dismantle the Forest Code, removing obligations such as the need to restore around 5 million hectares of forests in areas that were illegally deforested (before 2000) outside Amazonia. Unless formally notified, landholders would be exempted from registering in the “Rural Environmental Registry” (CAR) under the Environmental Regularization Program. These measures will not be well received by the 5.6 million landholders who have registered in the CAR Program since it was launched in 2012, as it would reward those who have not registered, pardoning their environmental crimes

⁵ This extreme conservative president has been using authoritarian measures to dismantle environmental protection and education programs and the government's environmental agencies. His government is pushing proposed laws and constitutional amendments that promote resource extraction (minerals, oil, and agribusiness) for export at the expense of environmental destruction (Ferrante and Fearnside 2019; The Guardian 2019a,b).

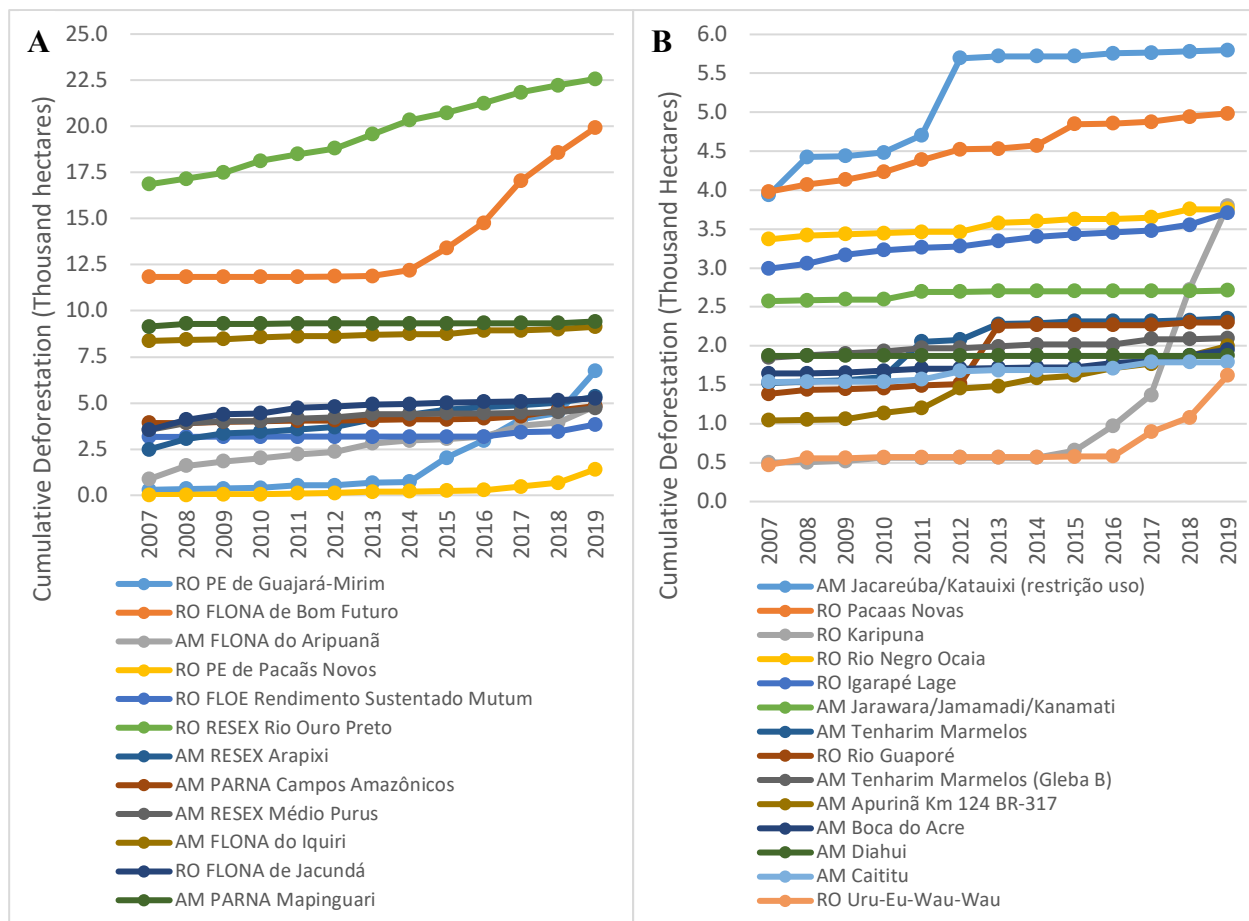


Figure 7. Cumulative deforestation in the most deforested Conservation Units (A) and Indigenous Territories (B)

Figure 7B shows the 14 Indigenous Territories with the most substantial cumulative deforestation. While some of them had a steady increase over time, Jacareuba, Rio Guaporé, Karipuna, and Uru-Eu-Wau-Wau territories show sharp increasing trends, especially the last two. All of these indigenous territories seem more threatened with the latest push of the elected president, which edited a law allowing ranches within indigenous lands (Fonseca and Oliveira 2020, Batista 2020).

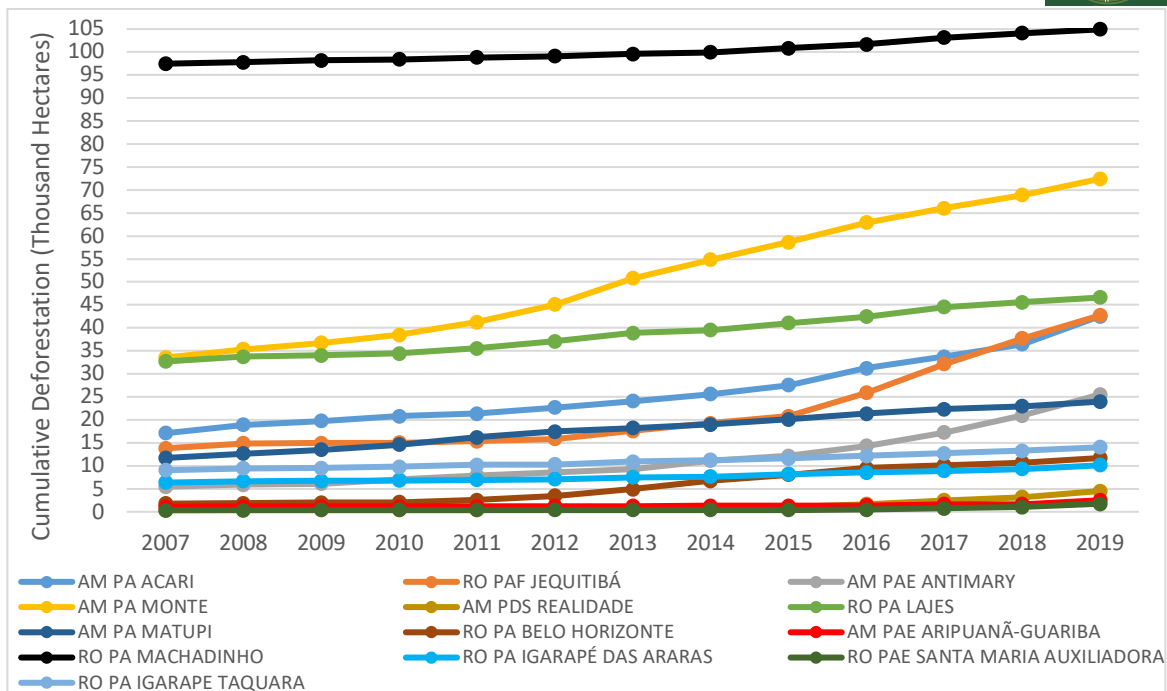


Figure 8. Cumulative deforestation in the 14 most deforested settlements for the year 2019, except for PA Rio Juma. Figure 8 shows the cumulative deforestation of the top 14 settlements with the most

deforestation in 2019, except for PA Rio Juma in Apuí. PA Rio Juma went from 106,691ha to 222,841 ha deforested between 2007 and 2019. PA Rio Juma is the largest conventional settlement in the region with the most extensive annual deforestation in 2019 (24,363ha), where most of Apuí's deforestation occurs. The seven settlements with the most deforestation in 2019 were in Southern Amazonas. It is worth noting that the other settlements with more steep increases are PA Monte, PA Acari, and PAE Antimary in Southern Amazonas, and PAF Jequitibá in Machadinho D'Oeste (RO). Surveillance and better planning should focus on these special settlements that are suffering invasions and deforestation.

3.6. Land cover and land use

Land use in the region is dominated by pastures, as in most of the Brazilian Amazon.

Pastures expanded over 3 Mha since 1985 and occupied 3.37 Mha in 2018 (Table 9).



Agricultural lands (annual and perennial crops) were not identified by Mapbiomas until 2000 and have grown 10-fold to occupy around 20Kha in 2018. All these land-use classes took place in forest lands, which reduced by 3.1 Mha during the period.

Table 9. Land cover and land use classes in Brazil's Mosaic.

Year	Forest	Non Forest			Urban	Non-vegetated area	Mining	River, lake
		Natural Formation	Pasture	Agriculture				
1985	37,688,719	902,039	368,995	0	6,876	0	601	377,374
1990	37,531,688	854,930	478,795	0	9,639	543	601	468,429
1995	37,262,974	853,345	756,183	0	10,284	3	319	461,515
2000	36,857,700	856,735	1,136,856	1,967	12,600	359	263	478,148
2005	36,139,302	816,452	1,897,074	1,709	13,668	1,050	284	475,084
2010	35,639,338	817,287	2,396,945	3,073	15,282	0	348	472,352
2015	35,125,454	827,481	2,829,432	4,705	17,196	0	505	539,850
2018	34,568,771	851,579	3,370,498	19,830	18,166	0	531	515,250
Net change	-3,119,948	-50,460	3,001,503	19,830	11,290	0	-70	137,876

Mining areas varied over time, but did not surpass 601 ha, whereas urban areas almost doubled. It is also noteworthy that the increase of 137,876 ha in the areas of rivers and lakes is attributed to new dam reservoirs and lakes created in rural properties for animal consumption or fisheries. Analyzing the land cover and land use per state (Table 10), most forest loss, pastures, agriculture, and urban areas are in Northern Rondônia, whereas most of the forests, rivers, and lakes are in Southern Amazonas. The areas under crops have increased in Rondônia, as the region has also been a route of grain transportation and has more established family farmers' production, including rice, beans, and coffee.

Table 10. Land cover and land use classes per state of the study area.

State	Year	Forest	Non Forest			Urban	Mining	River, lake
			Natural Formation	Pasture	Agriculture			
Amazonas	1985	28,909,873	768,880	163,972	0	1,415	0	270,556
	2018	27,842,968	706,713	1,234,642	1,606	3,190	0	325,576
	Net change	-1,066,905	-62,168	1,070,670	1,606	1,776	0	55,020
Rondônia	1985	8,778,845	133,159	205,023	0	5,462	601	106,818
	2018	6,725,802	144,866	2,135,856	18,224	14,976	530	189,674
	Net change	-2,053,043	11,708	1,930,833	18,224	9,514	-71	82,856



3.7. Mining

Mining areas in all phases of application to operation cover 6.93 Mha within the mosaic.

Figure 9 and Table 11 present information on the phase status, showing that Rondônia has the majority of the regions, including sites in operation. Areas available for mining, under research application, or with research authorization sum up 79.3% (5.06 Mha), meaning that most mining sites are not active yet. The other 20% of the area has already been petitioned for gold mining, mostly in Rondônia municipalities and Apuí. Only 3% (194.5 Kha) is being mined, primarily for metals in Itapuã do Oeste and Cujubim, and for gold along the Madeira riverbed in both states.

Table 11. Area registered for mining and phases of the processes.

Phase	Amazonas	Rondônia	Total	Percent
Availability of sites	92,990	54,992	147,981	2.3%
Research application	1,220,519	1,628,154	2,848,673	43%
Research Authorization	1,201,788	858,597	2,060,385	31%
Gold Mining application	431,504	871,150	1,302,654	20%
Mining Concession	398	128,676	129,074	2.0%
Gold Mining	1,541	59,307	60,848	0.9%
Licensing application	261	1,554	1,815	0.03%
Licensing	709	2,132	2,840	0.04%
Total	2,949,709	3,604,561	6,554,269	100%

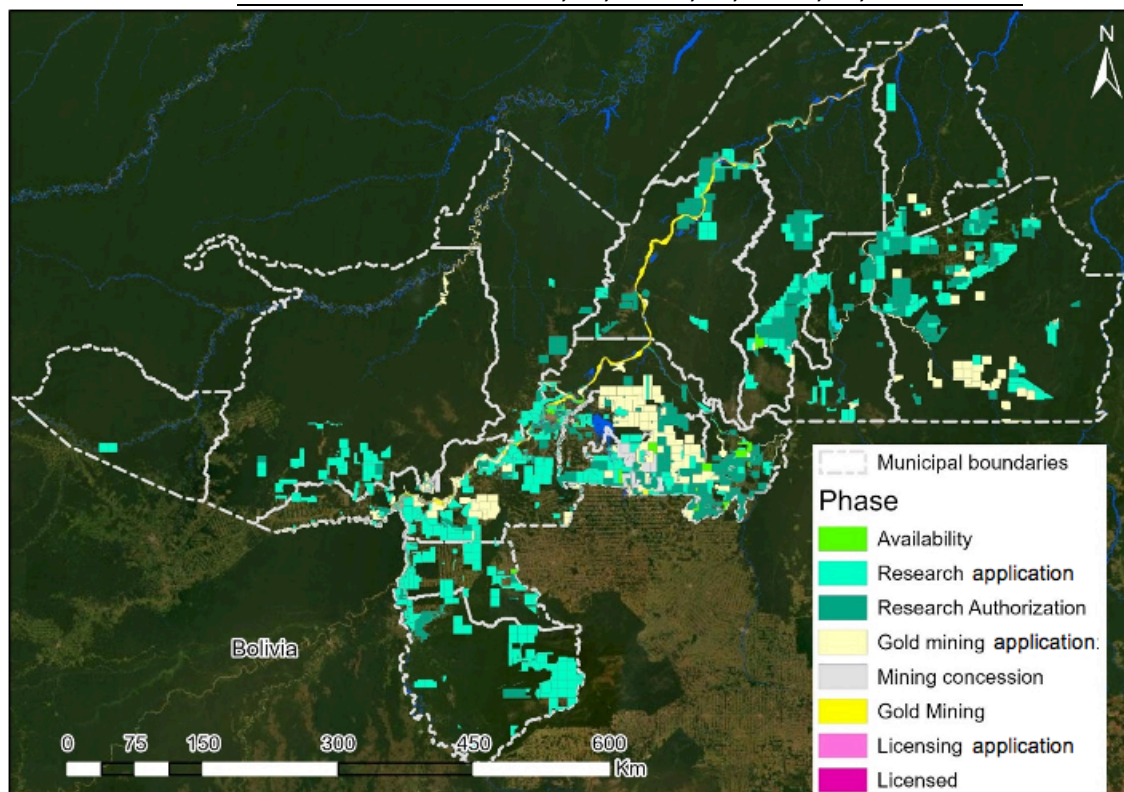


Figure 9. Mining areas according to phase of operation.



Table 12 shows what the mining operations are for, grouped in metals and non-metals.

Metals represent 95.4% of all mining areas, in which metal ores (mostly cassiterite, iron, tin, and copper ores) represent 49.8%, and gold comprise 45.6%. Diamond mining represents 1% of the total area.

Table 12. Mining areas per class of mineral to (be) exploited.

Class	Area (hectares)			Percent
	Amazonas	Rondônia	Total	
metal	88,323	253,138	341,461	4.9%
metal ore	992,634	2,108,718	3,101,352	44.9%
gold	20,000	728,215	748,215	10.8%
gold ore	1,746,142	657,998	2,404,139	34.8%
Metal Subtotal	2,847,098	3,748,069	6,595,167	95.4%
diamond	52,347	14,646	66,992	1.0%
other gems	9,062	99	9,161	0.1%
limestone	982	301	1,283	0.02%
mineral water	50	657	707	0.01%
non-metal igneous	7,427	32,118	39,546	0.6%
non-metal metamorphic	0	150	150	0.0%
non-metal sedimentary	115,855	0	115,855	1.7%
sand/clay/gravel	1,047	81,263	82,311	1.2%
Non-Metal subtotal	186,769	129,234	316,004	4.6%
Total	3,033,868	3,877,303	6,911,171	100%

It is possible to conclude that legal mining in the region is still in its initial phases and could cause severe environmental degradation in the long term, along with the increasing economic growth for the industrial sector. However, illegal gold mining has been happening throughout the region since the roads were built, and it is an important source of income for many people. Gold mining attracts migrants to the region, who then could serve as rural laborers or become rural farmers, another potential source of future environmental degradation.

4. Conclusions

The southern Amazonas – northern Rondônia mosaic covers regions in two Amazonian states with different socio-economic, infrastructure, land cover, and land-use characteristics. Northern Rondônia has experienced a more significant population, economic and infrastructure growth, resulting in the creation of smaller districts and more cumulative deforestation. Most of the



ports, paved roads, mining sites, and dams are also in this state, which covers an area three times smaller than Southern Amazonas. Southern Amazonas, in contrast, has most of the area and forests, the protected areas and indigenous lands, but deforestation rates have been increasing rapidly since 2014. Given new infrastructure enhancements, the magnitude of the area of undesignated public lands, and the dismantling of environmental and land policies, Southern Amazonas is the region that will likely experience high ecological degradation in the next years due to agricultural expansion. In both states, encroachment in protected areas and illegal activities (mining and logging) is worrisome. It could jeopardize traditional livelihoods and provoke more contentious events between ranchers/miners/loggers and indigenous and traditional communities. Tools and strategies that include human rights and support for these vulnerable populations should be a primary concern. Another critical issue is to advocate for policies and programs that regulate land tenure, and secure the conservation of biodiversity and ecosystem services of this unique region.

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