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Yanai, A.M., M.A. Isaac Júnior, J.N. da Silva, M.A. dos Santos Junior, P.M.L.A. Graça & P.M. Fearnside. 2025. **Brazil's Trans-Purus region: Simulating the impact of planned highways associated with BR-319 on Amazon deforestation**. XXII *Simpósio Brasileiro de Sensoriamento Remoto (SBSR), 13 a 16 de abril de 2025, Salvador, BA.* Instituto Nacional de Pesquisas Espaciais (INPE), São José dos Campos, SP (no prelo).

BRAZIL'S TRANS-PURUS REGION: SIMULATING THE IMPACT OF PLANNED HIGHWAYS ASSOCIATED WITH BR-319 ON AMAZON DEFORESTATION

Aurora Miho Yanai [1], Marcos Antonio Isaac Júnior [1], Jonathas Nunes da Silva [2], Marcelo Augusto dos Santos Junior [3], Paulo Maurício Lima de Alencastro Graça [1], Philip Martin Fearnside [1]

[1]National Institute for Research in Amazonia (INPA); Av. André Araújo n° 2936, Manaus, Amazonas, Brazil, yanai@inpa.gov.br; maisaacjunior@gmail.com; pmlag@inpa.gov.br; pmfearn@inpa.gov.br; [2]Center for Analysis, Research and Technological Innovation Foundation (FUCAPI); Av. Governador Danilo de Matos Areosa n° 381, Manaus, Amazonas, Brazil, jonathas.water@gmail.com; [3]National Institute for Space Research (INPE), Av. dos Astronautas n° 1758, São José dos Campos, São Paulo, Brazil, brasa.bio@gmail.com

ABSTRACT

Despite the Brazilian government's efforts to combat deforestation, conflicting infrastructure policies, particularly the proposed construction of highways, pose a threat to undesignated public forests (UPFs) in a critical area of Brazilian Amazonia: The Trans-Purus region. This region is currently inaccessible by road and therefore less attractive to land grabbers, but it could evolve into a new deforestation hotspot. We simulate the potential impact of the planned highways on deforestation and illegal land occupation up to 2070 in this region and its surrounding areas. The simulation showed a substantial deforestation with planned highways in the Trans-Purus region, mainly in UPFs, demonstrating the role of highways in facilitating the access of actors from Brazil's "arc of deforestation" and threatening forests that play a crucial role in biodiversity conservation, water cycling, carbon sequestration, and the survival of local communities. The magnitude of potential impacts implies that government policies on infrastructure need to be rethought.

***Keywords* —** land grabbing, public forests, deforestation, undesignated public forests, environmental modeling.

1. INTRODUCTION

Up to now, most deforestation has been concentrated in the "arc of deforestation" in the southern and eastern portions of Brazil's Amazon rainforest, but recent trends show the emergence of new hotspot areas, pushing the cattle-ranching frontier to the northern part of the region. The impact of existing highways and planned networks linked to BR-319 (Manaus – Porto Velho) could promote significant deforestation and forest degradation [1, 2].

Deforestation actors from arc of deforestation would gain access not only to the BR-319 highway route itself but also to all areas already connected to Manaus by road. In addition, planned highways would open the vast intact forest area in western Amazonia – the "Trans-Purus" region to the west of the Purus River that runs parallel to BR-319 [3, 4]. This area has an enormous stock of carbon [5] and is the most critical area for water recycling that supplies São Paulo [6].

Agribusiness interests in the AMACRO region are already planning to expand their operations to the Trans-Purus region [7]. Decisions are pending on the highway projects modeled in the present study, and these need to be based on the best possible information on likely impacts. The enormous global and national consequences of these decisions add urgency to the development of reliable models of deforestation in the vast area that would be affected, and the present study contributes to this effort.

This study aimed to simulate the impact of planned roads on deforestation and illegal land occupation in the last large remaining block of Brazil's Amazon rainforest. We project these processes up to 2070 considering undesignated public forests (UPFs), protected areas and settlement projects in a key region Amazonas state.

2. MATERIAL AND METHODS

The study area encompasses 429,442.1 km^2 of Brazil's Amazon rainforest and covers 26.5% (415,305.5 km^2) of Amazonas state and 6.0% (14,136.6 km^2) of Rondônia state (Figure 1).

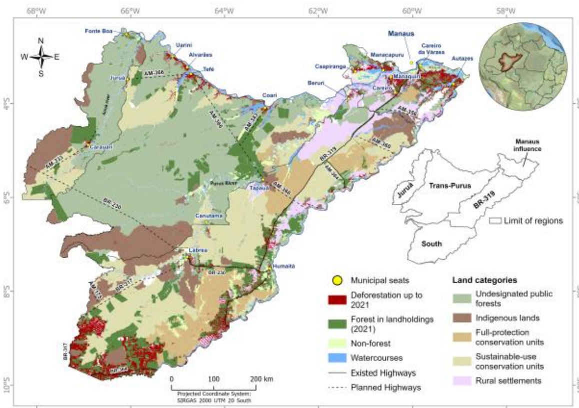

Figure 1. Distribution of existing and planned highways, landholdings (2021), land categories and land cover change up to 2021 in the study area.

As of 2021, 89.1% (382,622.3 km^2) of the total study area remained under forest. Out of this total, 43.1% (164,997.8 km^2) was in UPFs. Additionally, 12% (46,099.9 km^2) of the forest in 2021 was in landholding areas that appear to be overlapping with other land categories (e.g., protected areas and UPFs). The study area is divided into five regions: Trans-Purus, BR-319, Manaus influence, Juruá and South. Here, we focus on presenting the results related to the total area and to the Trans-Purus region.

The Trans-Purus region is the largest (170,282.0 km^2), covering 39.7% of the study area, but the total deforestation in the Trans-Purus region up to 2021 represented only 1.4% (2361.8 km^2) of the Trans-Purus region and 0.5% of the total study area (Figure 1).

2.1. Trans-Purus model

The Trans-Purus model produces spatially explicit simulations designed to project the potential impact of planned highways on deforestation and illegal land occupation, considering the forests in landholdings and in land categories (e.g., UPFs and protected areas). In each simulation time step, the model generates an annual map showing predicted deforestation. When highways are constructed during the simulation, there is an increase in landholdings in forest areas, representing the attraction of land grabbers from the arc of deforestation to forest near highways. Therefore, new landholdings that emerge during the model simulation are treated as illegal land occupations that have a high risk of being cleared, contributing to the spread of deforestation. The occurrence of deforestation in these landholdings depends on their locations within the land categories, the probability map of deforestation and the deforestation rates associated with the region and the land categories.

The Trans-Purus model was developed in Dinamica-EGO software. The model is based on cellular automata that follow transition rules. The transition of a cell (pixel) from one class (e.g., forest) to another (e.g., deforestation) depends on the state of the neighboring cells.

To project the future impact of highway-construction decisions on deforestation and illegal land occupation, a business-as-usual (BAU) scenario was run to show the deforestation trajectory from 2022 to 2070.

In the BAU scenario, it is assumed that (i) the planned federal and state highways are built following the construction schedule used in this study, (ii) UPFs surrounding the planned highways and the secondary roads connected to these highways will be highly attractive to land grabbers, encouraging illegal land occupation and deforestation and contributing to a deforestation pattern similar to that observed in regions with high deforestation pressure (i.e., the South and BR-319 regions of the study area), and (iii) the recent trends in deforestation rates will continue, with an anticipated increase as forest areas near roads become occupied, mainly in UPFs.

2.2. Deforestation rates

Deforestation rates were estimated annually for each region in the study area. Therefore, both the deforestation trend in each region and the assumptions of the BAU scenario will influence the simulated deforestation rates.

In the case of the Trans-Purus, Juruá and Manaus influence regions, we assumed that, before the beginning of illegal land occupation due to the planned highways, the rates would be similar to the average historical trend observed in the region from 2010 to 2021, and that subsequent trends in deforestation rates would be similar to the BR-319 and South regions (2016-2021), with an anticipated increase as forest areas near planned highways become occupied by landholdings. The BR-319 and South regions are hotspot areas that represent the way illegal land occupation and road networks contribute to deforestation.

An equation adapted from the anthropogenic pressure equation developed by Soares-Filho et al. [8] was used to estimate the deforestation rates in the BR-319 and South regions. This equation was also applied in the Trans-Purus, Manaus influence, and Juruá regions when simulated land occupation begins due to highway construction. Thus, deforestation is expected to accelerate in the BAU scenario.

2.3. Model calibration and validation

In the calibration step, we used the initial (2009) land-cover map to run the model up to 2015. In the validation step, we used the land-cover map for 2015 and ran the model up to 2021. One relevant task in calibration is the selection of variables that explain future deforestation and the tuning parameters that control the transition from forest to deforestation [9]. In our study, we ran the model using biophysical variables such as slope, altitude, soil types, and vegetation types. However, we found that the spatial pattern of deforestation produced by the model was more realistic when the variables considered were restricted to distance to existing deforestation, proximity to roads and rivers, deforestation hotspot areas in the BR-319 and South regions, and land categories (e.g., protected areas, settlement projects and UPFs).

To measure the accuracy of model output, the predicted spatial pattern of deforestation was compared to the observed deforestation from 2015 to 2021 using a fuzzy similarity comparison method with a constant decay function in multiple window sizes. Additionally, a null model was run, where all weights-of-evidence coefficients were set to zero, resulting in a random allocation of deforestation in the landscape [10].

The model achieved a minimum similarity of 51% in a 9 × 9 window size (i.e., within a search radius of 2.25 km). In contrast, the null model (in the same area as the calibrated model) had a lower minimum similarity value (25%), indicating that the calibrated model had better spatial performance compared to the null model.

3. RESULTS

3.1. Projection of deforestation

In the BAU scenario, the increment of simulated deforestation (2022-2070) resulted in a reduction by 15.1% (57,817.8 km^2) of the total remaining forest present in the study area in 2021 (382,622.3 km^2). In the Trans-Purus region, the total deforestation by 2070 was 20,979.2 km^2. The presence of planned roads and the increment of simulated landholdings contributed to increased deforestation (Figure 2).

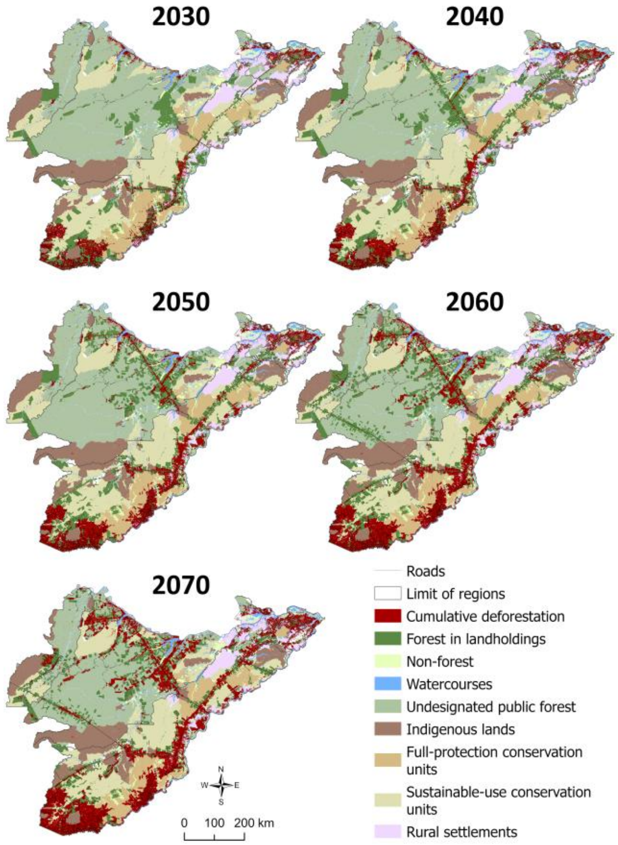

Figure 2. Trajectory of deforestation in the BAU scenario from 2030 to 2070.

Categories in Trans-Purus	Mean deforestation per year (km^2)	
	Planned highways	
	Before: 2022-2032	After: 2033-2070
Region as a whole	22.6	483.4
Landholdings ≤100 ha	1.6	11.5
Landholdings >100 ha	2.2	453.7

Table 1. Mean deforestation per year (km^2) in the Trans-Purus region considering the period before and after planned highways.

In the Trans-Purus region, clearing up to 2021 in landholdings with >100 ha accounted for only 1.5% (205.1 km^2) of the total occupied or claimed area (14,108.9 km^2). Due to the simulation of new landholdings, deforestation up to 2070 in landholdings with >100 ha accounted for 46.5% (17,469.9 km^2) of the total claimed area (37,566.1 km^2). The period following the building of planned highways had higher yearly cleared areas compared to the pre-road period (Table 1).

3.2. Projection of deforestation in land categories

Table 2 shows the total deforestation in each land category present in a total study area and in Trans-Purus region. UPF showed a substantial cumulative deforestation, reaching 4725.3 km^2 by 2021 and 39,139.2 km^2 by 2070. The cleared area in the UPFs in Trans-Purus region represented 42.7% of total deforestation in UPF in the study area. This substantial increase in deforestation is alarming when compared with the initial deforestation (382.4 km^2).

In UPF, deforestation in the BAU scenario up to 2070 showed an increase of 728.3% (34,413.9 km^2) compared with PRODES (2021) considering the total area and an increase of 4270.0% (16,328.4 km^2) in the Trans-Purus region.

In the Trans-Purus region, deforestation also increased in environmentally distinctive settlement projects and in the protected areas up to 2070 in BAU scenario. The sustainable-use conservation units (1084.7 km^2) showed the largest cumulative deforestation up to 2070 compared to other protected areas categories.

Land category	Map	Total study area	Trans-Purus
Undesignated Public Forest (UPF)	PRODES	4,725.3	382.4
	BAU	39,139.2	16,710.8
Settlement Projects (PAEs and PDSs)	PRODES	1,417.0	24.6
	BAU	3,764.3	31.4
Indigenous Lands	PRODES	563.4	136.9
	BAU	883.6	140.1
Full-Protection Conservation Units	PRODES	215.5	3.5
	BAU	2,691.6	4.8
Sustainable-Use Conservation Units	PRODES	991.7	335.3
	BAU	8,706.3	1,084.7

Table 2. Cumulative deforestation in km^2 in each land category and region. The PRODES map represents deforestation up to 2021, and the BAU scenarios represent deforestation up to 2070.

4. DISCUSSION

Construction of planned highways in key regions of Amazonas state would promote illegal land occupation, land grabbing and deforestation, especially in the Trans-Purus region. The remaining forest in this region would be threatened by the emergence of a new deforestation hotspot area when roads bring loggers and cattle ranchers from the arc of deforestation.

In the Trans-Purus region, the mean annual deforestation from the beginning of land occupation (2033) to the end of the simulation (2070) was 483.4 km^2 $year^{-1}$. This value represents 30.7% of the mean annual deforestation (1574.4 km^2) estimated by PRODES for Amazonas state from 2016 to 2022, a period marked by the highest deforestation since 2004 [11].

Our modeling approach included a major advance by incorporating landholdings into the simulation, allowing us to distinguish the dynamics of projected deforestation in different landholding types and in areas outside of the landholdings. This approach, coupled with the increment of new landholdings over time, enhances the spatial representation of deforestation actors' behavior, contributing to a more comprehensive understanding of the deforestation process associated with highway construction and illegal land occupation in the Brazilian Amazonia. Thus, although we used a definition of Trans-Purus region similar area to that used by a previous study [12], our study differed in terms of how deforestation rates were calculated and how the spatial distribution of simulated deforestation was allocated. This is particularly important for the Trans-Purus region because the deforestation dynamics, both in terms of rates and spatial distribution, differ from what we expected to occur with the presence of planned roads and the advance of the deforestation frontier.

Regarding the limitations of the modeling, the Trans-Purus model considers the emergence of new highways only based on currently known planned highways. It does not account for the potential development of additional highways that may be proposed in the future, which could significantly influence the allocation of deforestation in certain regions. Additionally, the spatial distribution of landholdings along the roads in the simulation was based on the association of the modelers' prior knowledge of the land-use change and on the local actors in the study area, combined with spatial datasets on landholdings, roads, and deforestation in the BR-319 and South regions, aligned with the BAU scenario assumptions.

5. CONCLUSIONS

This study projected the potential future impact resulting from the construction of planned highways and their role in facilitating access for deforestation actors. The simulation of an increased number of landholdings reflects the way that illegal land invasions in the vicinity of highways contribute to deforestation. We emphasize that the construction of planned highways in key parts of Brazil's Amazon rainforest will promote illegal land occupation and deforestation, especially in the undesignated public lands. The Trans-Purus, a region that encompasses the largest area of UPFs in Brazilian Amazonia, faces an increased risk of deforestation with the construction of planned state and federal roads. The same spatial deforestation pattern observed in the arc of deforestation could be expected to occur in the Trans-Purus region with the presence of planned highways (e.g., AM-366).

The Trans-Purus region provides crucial ecosystem services to Brazil and to the rest of the world. It is also vital for traditional communities and to Indigenous peoples that depend on forest resources for their livelihoods.

6. ACKNOLEDGMENTS

National Institute for Amazonian Research (INPA), FAPEAM (Process 01.02.016301.01073/2023-57); CNPq (Process 150551/2023-1) for financial and logistical support; PMF and AMY thank CNPq (Processes 312450/2021-4, 406941/2022-0) and Rede Clima (FINEP/Rede CLIMA, Process 01.13.0353-00) for financial support.

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