Deforestation Increases Within Full Protected Areas of the Brazilian Amazon

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Abstract. *Since 2012, deforestation rates have been increasing within the Brazilian Amazon. This situation undermines the mitigation efforts against global climate change and stresses our need for both accurate identification of deforestation hotspots and promotion of law enforcement. It also implies a permanent need to explore the deforestation data, looking for patterns that enable the public, the academia, and authorities to anticipate and prepare for deforestation outburst. For this reason, we analyzed data of the Brazilian deforestation monitoring program (PRODES) to find deforestation patterns within Full Protected Areas of the Brazilian Amazon. Our aim is to identify and quantify deforestation from 2008 to 2021. We applied a trend analysis to find FPAs with significant increments and we found that approximately 15% of FPAs have statistically significant deforestation growth according to the Mann-Kendall test at 5% significance. Furthermore, we found that only four FPAs accounted for 67.6% of the deforestation increments during 2021, making them good candidates for closer monitoring and law enforcement. Besides, our results also show the role of FPAs as forest safeguards, although deforestation within them is increasing.*

1. Introduction

Deforestation is a major global anthropogenic disturbance [Seymour and Harris 2019; Wade et al 2020], even when intact forests offer important ecosystem services [Watson et al. 2018] such as climate regulation. Therefore, the preservation of natural undisturbed forests is of utmost importance for human well-being. The declaration of Protected Areas (PAs) is the most effective tool for reducing deforestation since deforestation rates are lower within PAs than in neighbor unprotected areas [Johnson et al. 2017; Fuller et al. 2020]. However, even while PAs are crucial for protecting standing forests, many of them remain vulnerable to illegal activities, such as deforestation and mining, due to their dependency on government and law enforcement [Nolte et al. 2013].

The Brazilian Amazon (BA) is an example of this situation. The BA has been facing a deforestation resurgence since 2019, mostly associated with the weakening of environmental laws occurring in Brazil. Deforestation rates over the last three years have surpassed 10,000 km^2 in the BA [INPE, 2022]. After a historical deforestation reduction of 84% in 2012 compared to 2004, the deforestation rate in 2021 has reached the highest value during the last 15 years [INPE, 2022]. Unfortunately, this recent deforestation increase is not restrained to unprotected areas but is also occurring within PAs: (i) the annual average deforestation rate within Indigenous Lands (ILs) of the BA in 2021 was 52% above the average annual rate from 2008 to 2021, and (ii) the deforestation rate within Conservation Units (CoUs) of the BA in 2021 was the highest since 2008 [INPE 2022].

When referring to CoUs, they are classified as Environmental Protection Areas (EPAs), where occupation is allowed with settlers having to follow specific regulations, or Full Protection Areas (FPAs), where human occupation is banned. The increase in deforestation within FPAs is the most concerning threat to the preservation of BA standing forests. Due to the extension of the FPAs within the BA (more than 430 thousand km^2), orbital remote sensing is the most cost-effective way to monitor deforestation within them all. In this study, we have used the openly available PRODES dataset [INPE 2022], the Brazilian official deforestation monitoring data, to identify and quantify, temporally and spatially, the increase in deforestation within FPAs of the BA from 2008 to 2021. Moreover, we have also identified the FPAs where deforestation is concentrated in the current period (the year of 2021), which are the ones where legal authorities must focus on the counteraction measurements to curb deforestation. A trend analysis was also performed to identify in which FPAs of the BA the increase in deforestation was statistically significant during the 2008-2021 time series.

2. Materials and Methods

2.1. Full Protection Areas

FPAs are the most protected type of CoUs in Brazil. They act as a barrier against human disturbances to the standing forests. The constant undermining of the Brazilian environmental policy has been linked to the increasing deforestation within FPAs because it encourages and legalizes illegal activities, reduces environmental fines, and decreases law enforcement actions [Artaxo 2019; Conceição et al. 2021].

The BA includes 95 FPAs, accounting for approximately 10% of its total area (431,448 km^2). FPAs are classified into 5 subcategories: ecological station, park, natural monument, biological reserve, and wildlife refuge. Parks are the predominant FPAs in the BA. Although the increasing anthropogenic pressure over FPAs, they are primarily covered by forest formations [MapBiomas 2022].

2.2. Deforestation Data

The analysis of historical deforestation patterns was performed using the national official deforestation monitoring dataset, the Brazilian Amazon Deforestation Monitoring Program (PRODES). PRODES monitors clear-cut deforestation and provides annual official deforestation rates since 1988 using medium spatial resolution orbital images. The annual estimates of deforestation are based on visual interpretation

of the satellite images. Therefore, it is a reliable dataset to monitor deforestation increases in the BA [Almeida et al. 2016].

PRODES produces deforestation rates corresponding to the period from August 1st to July 31st of the following year. For example, PRODES 2021 was estimated considering deforestation from August 1st, 2020, to July 31st, 2021. An area mapped as deforested by PRODES is not analyzed in the following years, hence the deforestation rate is defined as increment in relation to previous years. The validation of PRODES estimates reached an overall accuracy of 93% [Almeida et al. 2016].

We downloaded the PRODES annual deforestation increments for the 2008-2021 period from the TerraBrasilis platform (http://terrabrasilis.dpi.inpe.br/downloads/) and then clipped the deforestation polygons to the delimitation of the FPAs made available by the Brazilian Ministry of Environment. At the end of this step, we had annual shapefiles quantifying the annual deforestation within the 95 FPAs of the BA.

2.3. Detecting Trends in Deforestation Within Full Protection Areas

Following the 2008-2021 time series, we have identified trends in deforestation of the FPAs within the BA. To this end, we have applied the non-parametric Mann-Kendall trend test, which determines if a trend exists in a time series [Cavalcante et al. 2019; Carvalho et al. 2020]. The Mann-Kendall test was applied to the 62 FPAs of the BA where deforestation is present in at least one year of the time series. Our null hypothesis is that there is no trend in the deforestation time series, while our alternative hypothesis is that there is. If the p-value is lower than the significance level of 5% the null hypothesis is rejected, proving that there is a statistically significant deforestation trend in the time series.

3. Results and Discussions

Figure 1 shows the annual deforestation increments within FPAs of the BA from 2008 to 2021 estimated by PRODES. We observe a reduction in deforestation starting in 2008 and ending in 2014, when the lowest estimate was produced (16.6 km^2). This pattern follows the same one identified for the BA as a whole, explained by the Action Plan for Prevention and Control of Deforestation (PPCDAm) which promoted a severe conservation reform that decreased deforestation specially from 2007 to 2012 [West and Fearnside 2021].

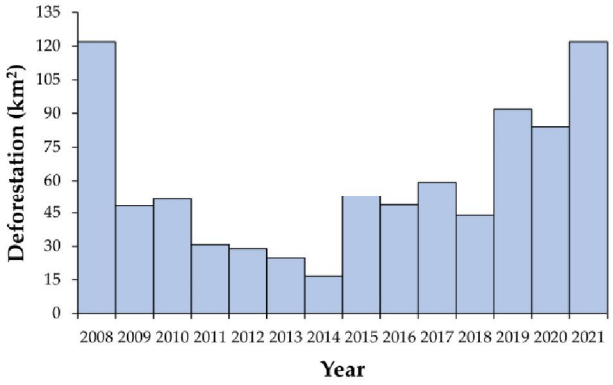

Figure 1. Annual deforestation increments within Full Protection Areas of the Brazilian Amazon during the 2008-2021 period.

Starting in 2015, deforestation increments within FPAs of the BA increased again and reached its highest value in the PRODES digital era in 2021 (121.9 km^2, 634% higher than the lowest estimate found in 2014). The observed increase resulted of several actions taken over the past years that indirectly incentivized land grabbing, such as the possible decriminalization of illegal occupation on public lands and the interruption of the PPCDAm. In 2021, FPAs accounted for 8.6% of the deforestation increment in CoUs of the BA. Still, four FPAs accounted for 67.6% of the deforestation increment in these protected areas in 2021 and therefore are the ones requiring closer monitoring and law enforcement. These are the Terra do Meio Ecological Station (29.5 km^2), the Guajará-Mirim State Park (28.9 km^2), the Jamaxim National Park (13.4 km^2), and the Nascentes Serra do Cachimbo Biological Reserve (10.7 km^2). Three of them are inserted in the center of the "Arc of Deforestation" at the Pará State, while the Guajará-Mirim State Park is located in Rondônia State (Figure 2).

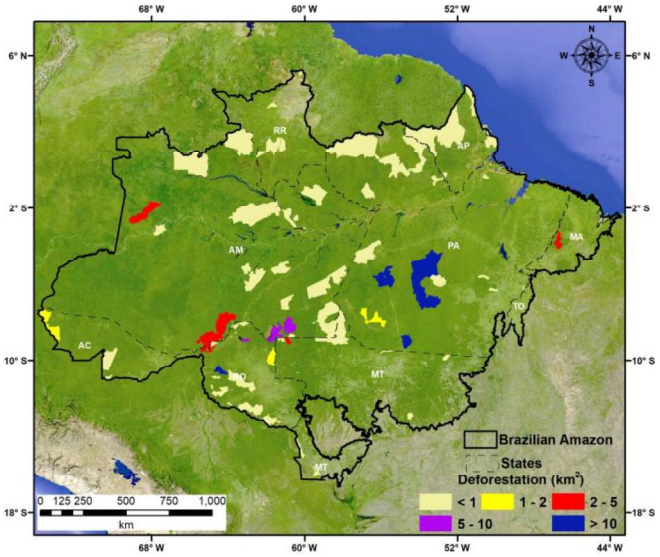

Figure 2. Deforestation increments within Full Protection Areas of the Brazilian Amazon in 2021.

An analysis of Figure 3 shows that 9 of the 62 FPAs of the BA where deforestation was detected in at least one of 14 years analyzed (~15% of them) had a statistically significant increasing trend according to the Mann-Kendall test at 5%. These were located not only at the "Arc of Deforestation", but also in other areas, such as the State of Amapá, which may potentially constitute new deforestation hotspots. Deforestation in these areas is critical and must be counteracted now.

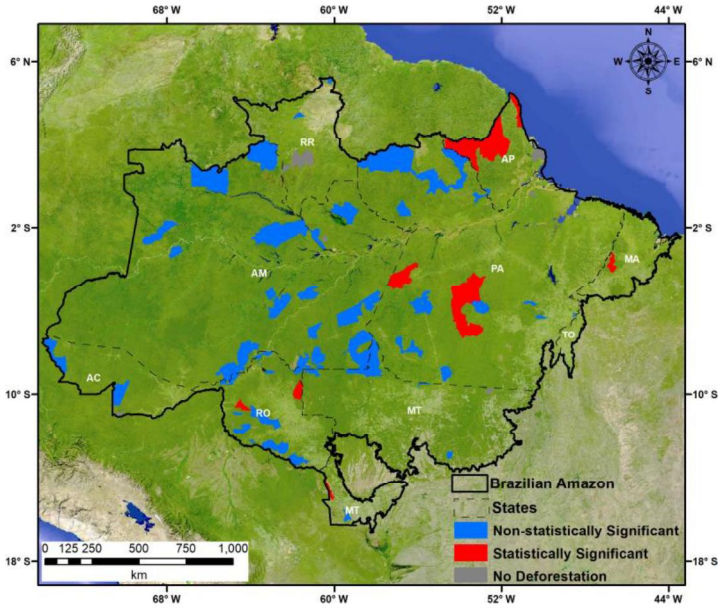

Figure 3. Mann–Kendall test applied to the deforestation time series of the Full Protection Areas within the Brazilian Amazon during 2008-2021.

4. Conclusions

In this work, we have analyzed the increase of deforestation within FPAs of the BA during the 2008-2021 period based on PRODES estimates. In this initial analysis, we observed that despite the recent push to ease environmental regulations in Brazil, FPAs are more effective at avoiding deforestation than unprotected areas. Therefore, law enforcement in these areas is key for maintaining BA standing forests and to stop new deforestation hotspots from appearing. However, we must emphasize that political calculus or lack of a proper monitoring can cancel conservation efforts within FPAs. Finally, PRODES is proven, once again, as a critical tool for legal authorities in curbing deforestation.

Acknowledgements

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References

Almeida, C., Coutinho, A. D. A. C., Esquerdo, J. C. D. M., Adami, M., Venturieri A., Diniz, C. G., Dessay, C. G., Durieux, L. and A. R. Gomes. (2016). “High Spatial Resolution Land Use and Land Cover Mapping of the Brazilian Legal Amazon in 2008 Using Landsat-5/TM and MODIS Data”. Acta Amazonica 46 (3): 291–302. doi:10.1590/1809-4392201505504.

Artaxo, P. (2019). “Working Together for Amazonia”. Science 363 (6425): 323. doi:10.1126/science.aaw6986.

Carvalho, S., Oliveira, A., Pedersen, J. S., Manhice, H., Lisboa, F., Norguet, J., de Wit, F. and Santos, F. D. (2020) "A changing Amazon rainforest: Historical trends and future projections under post-Paris climate scenarios". Glob. Planet. Change, 195: 103328. doi: 10.1016/j.gloplacha.2020.103328.

Cavalcante, R. B. L., Pontes, P. R. M., Souza-Filho, P. W. M., and Souza, E. B. (2019) "Opposite Effects of Climate and Land Use Changes on the Annual Water Balance in the Amazon Arc of Deforestation". Water Resources. Research, 55: 3092–3106. doi: 10.1029/2019WR025083.

Conceição, K. V., Chaves, M. E. D., Picoli, M. C. A., Sánchez, A. H., Soares, A. R., Mataveli, G. A. V., Silva, D. E., Costa, J. S., and Camara, G. (2021) "Government policies endanger the indigenous peoples of the Brazilian Amazon". Land Use Policy, 108: 105663. doi: 10.1016/j.landusepol.2021.105663.

Fuller, C., Ondei, S., Brook, B. W., and Buettel, J. C. (2020). "Protected-area planning in the Brazilian Amazon should prioritize additionality and permanence, not leakage mitigation". Biol. Conservation, 248: 108673. doi: 10.1016/j.biocon.2020.108673.

INPE (National Institute for Space Research). (2022). "Deforestation monitoring of the Brazilian Amazon rainforest and Cerrado biome by satellite". https://terrabrasilis.dpi.inpe.br/app/dashboard/deforestation/biomes/legal_amazon/increments

Johnson, C. N., Balmford, A., Brook, B. W., Buettel, J. C., Galetti, M., Guangchun, L., J. M., and Wilmshurst, J. M. (2017). "Biodiversity Losses and Conservation Responses in the Anthropocene". Science 356 (6335): 270–275. doi:10.1126/science.aam9317.

MapBiomas. (2022). "Collection 6.0 of Brazilian Land Cover & Use Map Series". Available online: http://mapbiomas.org/en.

Nolte, C., Agrawal, A., Silvius, K. M., and Soares-Filho, B. S. (2013). "Governance regime and location influence avoided deforestation success of protected areas in the Brazilian Amazon". PNAS, 110 (13): 4956–4961. doi: 10.1073/pnas.1214786110.

Seymour, F., and Harris, N. L. (2019). "Reducing Tropical Deforestation". Science 365 (6455): 756–757. doi:10.1126/science.aax8546.

Wade, C. M., Austin, K. G., Cajka, J., Lapidus, D., Everett, K. H., Galperin, D., Maynard, R., and Sobel, A. (2020). "What Is Threatening Forests in Protected Areas? A Global Assessment of Deforestation in Protected Areas, 2001–2018". Forests 11 (5): 539. doi:10.3390/f11050539.

Watson, J. E. M., Evans, T., Venter, O., Williams, B., Tulloch, A., Stewart, C., Thompson, I., et al. (2018). "The Exceptional Value of Intact Forest Ecosystems". Nature Ecology and Evolution 2 (4): 599–610. doi:10.1038/s41559-018-0490-x.

West, T. A. P., and Fearnside, P. M. (2021). "Brazil's conservation reform and the reduction of deforestation in Amazonia". Land Use Policy, 100, 105072. doi: 10.1016/j.landusepol.2020.105072.