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Research Letters

AMACRO: the newer Amazonia deforestation hotspot and a potential setback for Brazilian agriculture

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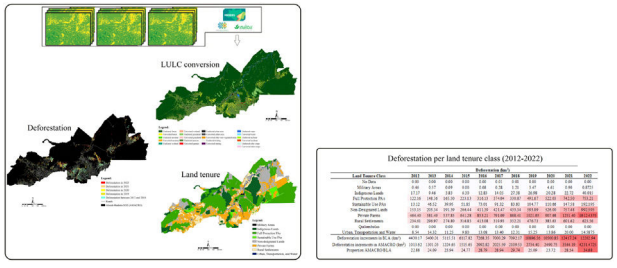
HIGHLIGHTS

- A deforestation hotspot emerges in a region planned for agricultural development in the - Amazon rainforest.
- Deforestation grows in all land tenure classes, especially after the project became widespread, in 2018.
- Forest loss increased in protected areas after 2018, except in Indigenous Lands, which resist as protective shields.
- Contrary to economic development, it can trigger socioeconomic losses and affect essential edaphoclimatic conditions for agricultural activity.
- Environmental impact studies need to be concluded before establishing the zone for agricultural development.

GRAPHICAL ABSTRACT



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ABSTRACT

Brazil can provide ecosystem services, food, and combat climate change-related vulnerabilities. However, this possibility is obliterated by the increasing deforestation in the Brazilian Legal Amazon derived from illegalities and political incentives to a business-as-usual economic development model that clears land for real estate speculation or extensive agro-livestock. Recently, the state governments of Amazonas, Acre, and Rondônia, supported by agro-livestock-related institutions, proposed a zone for economic development in a region of confluence accounting for 23.37% of these states' total area. Formerly "Sustainable Development Zone between the States of Amazonas, Acre, and Rondônia" (AMACRO), it was renamed to "Abunã-Madeira Sustainable Development Zone (SDZ)" to meet sustainability criteria; however, environmental impact studies regarding its implementation still lack. By integrating land tenure and official deforestation datasets from 2012 to 2022, we assess whether this region is becoming a notable deforestation hotspot. Results showed growing deforestation trends for all land tenure classes, alarmingly in protected areas, since 2018, when the project was announced. Unlike possible economic gains,

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deforestation in this region affects essential edaphoclimatic conditions for Brazil's agro-livestock, worsening environmental and socioeconomic vulnerabilities. Effective territorial planning, environmental impact studies, and law enforcement are urgently needed before establishing the zone to avoid a regional hecatomb.

Introduction

Brazil has the agri-environmental conditions to be a protagonist in providing ecosystem services and food (Strassburg et al., 2014). This characteristic makes the country a key player in combating climate change-related environmental, economic, and social vulnerabilities (Metzger et al., 2019; Leite-Filho et al., 2021). At least two attributes support this condition: (i) vast biodiversity, which generates global benefits and is a reserve for biotechnological development, and (ii) the structured and productive agricultural chain, characterized by high yield capacity (Rajão et al., 2020). Consequently, Brazilian agri-environmental policies should focus on innovative economic development models following sustainability principles. However, rising deforestation rates oppose these principles, especially in the Brazilian Legal Amazon (BLA).

The weakening of environmental policies in Brazil started in 2012, including several setbacks from Brazilian Federal Governments (BFG), such as the approval of controversial changes in the Forest Code and the discontinuation of the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm) (Soares-Filho et al., 2014; Silva Junior et al., 2021). More recently, the Bolsonaro presidency stimulated a development model that employs land clearing for real estate speculation or increasing crop area and extensive livestock instead of maximizing production in already-cleared areas (Vale et al., 2021). Under this scenario, deforestation rates in the BLA have consistently increased in the last ten years, surpassing the alarming mark of 10 thousand hectares in 2019 (10,129 km^2), 2020 (10,851 km^2), 2021 (13,038 km^2, the highest rate since 2006) and 2022 (11,594 km^2), according to the official Brazilian deforestation monitoring program (PRODES) (INPE, 2023). Annual deforestation rates averaged out at 6,390 km^2 during the 2013–2017 period but increased to 10,630 km^2 during the 2018–2022 period. In 2023, the BFG administration led by Lula retook the PPCDAm and expanded it to other biomes (PPCDAm+). PRODES preliminary data shows that deforestation rates in Amazonia reduced by 22% in relation to 2022 (INPE, 2023).

Reducing deforestation and bringing socio-economic development to the local population is challenging. About 44% of the 449 municipalities of the Brazilian Northern region have a low Municipal Human Development Index (MHDI) (<0.600) (UNDP Brazil, IPEA, FJP, 2020). Also, deforestation and fires linked to the practices of slash-and-burn and other forest degradation processes are, erroneously, considered suitable to promote regional economic development by many civic associations and local politicians. These actors defend, for example, opening of Protected Areas (PAs) for agribusiness and mining to achieve regional development (Pereira et al., 2020). Neglecting the importance of PAs for the agri-environmental balance (Leite-Filho et al., 2021), they propose the creation of zones for agro-livestock development within the BLA (SUDAM, 2021; SUFRAMA, 2021).

Unlike agro-livestock development, such unproper actions including the establishment of zones of interest, have expanded the local environmental vulnerability to climate change, affecting essential edaphoclimatic conditions for the entire Brazil's agricultural activity (Metzger et al., 2019; Spera et al., 2020). Consequently, Amazonia is currently a carbon source linked to deforestation and fires (Gatti et al., 2021). Moreover, climate changes associated with deforestation contribute to delaying the onset and reducing the duration of rainy seasons (Smith et al., 2023), essential for double-cropping systems largely practiced in the main agricultural frontiers Brazil (Abrahão and Costa, 2018; Leite-Filho et al., 2019). This affects crop yield, configuring an agro-suicidal practice (Leite-Filho et al., 2021).

This situation is happening again, among Amazonas, Acre, and Rondônia states. Recently, the governments of these states, with the strategic coordination and technical cooperation of the Superintendence for the Amazon Development (SUDAM), the Manaus Free Trade Zone Superintendence (SUFRAMA), and the Brazilian Agricultural Research Corporation (EMBRAPA - research unit EMBRAPA Territorial), proposed a zone for agro-livestock development in a region covering 32 municipalities that accounts for 23.37% of these states' total area. Formerly named "Sustainable Development Zone between the States of Amazonas, Acre, and Rondônia" (AMACRO), this zone was renamed to "Abunã-Madeira Sustainable Development Zone (SDZ)" to meet sustainability criteria (SUDAM, 2021). However, environmental impact studies and public policies regarding its implementation and protection of local populations are still lacking.

Considering that most of the Brazilian crop-producer regions are directly influenced by the rain produced in the Amazon rainforest (Leite-Filho et al., 2021), we argue that a mere definition of zones for agrarian development without proper socioenvironmental impact assessments and public policies can trigger more setbacks than advances for the agri-environmental sector. By analyzing land use and land cover (LULC) conversion, land tenure, and official deforestation datasets, we expose a devised and underlying deforestation process in the municipalities planned to integrate the Abunã-Madeira SDZ, arguing that land grabbers are potentially clearing, subdividing, and occupying this region as real estate after the announcement of the intention to create the zone. Based on the expectation of a land regularization law authenticating selling the land, they mischaracterize PAs and under-exploit the regional environmental and socioeconomic potential in exchange for a deceptive *Eldorado*.

The emergence of deforestation hotspots: Abunã-Madeira SDZ

New deforestation hotspots are emerging in the BLA. A concerning region is in the confluence of Amazonas, Acre, and Rondônia. For example, this region embraces the direct and indirect influence zones of the BR-319 highway, the only road connection between Manaus and Porto Velho, state capitals of Amazonas and Rondônia, respectively. The highway crosses a region with 63 Indigenous Lands (ILs) and five other areas containing indigenous communities (Ferrante et al., 2020). Despite this, the BFG led by Bolsonaro has opened bidding notices for paving it, which increased deforestation and fires (Mataveli et al., 2021).

Locally, there is a historical cycle of deforestation formed by the pressure of livestock coming from Rondônia and now the eased access resulted from paving and improving the BR-319 highway (Ferrante and Fearnside, 2022). The region is a potential vector for a new deforestation frontier and is now facing a new threat. The project for creating the Abunã-Madeira SDZ, officially launched on December 14, 2020, has been heavily discussed since 2018 and

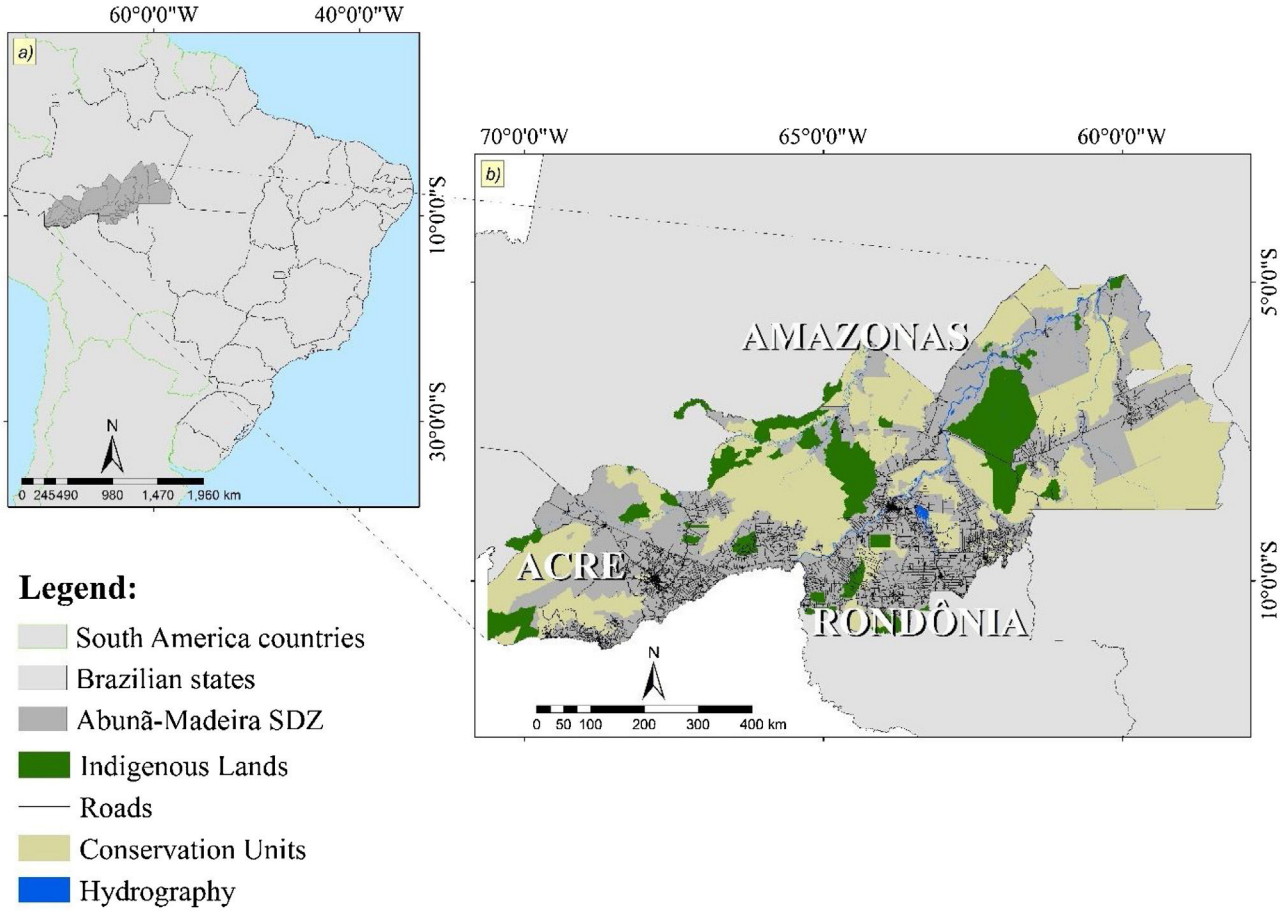

Fig. 1. Location of the intended Abunã-Madeira SDZ.

intends to serve as the Amazonian version of the MATOPIBA agricultural frontier, which is at the forefront of crop production in the Cerrado biome (Chaves et al., 2023a). This planned zone (Fig. 1) has 454,220 km^2 of area and 1.7 million inhabitants (SUDAM, 2021).

Arguing that agribusiness is the regional vocation, politicians from these states seek this zoning to stimulate a collective strengthening that could attract investments and solve farmers' difficulties related to obtaining rural credit and compliance with environmental requirements (SUFRAMA, 2021). They consider that climatic conditions, proximity to the Pacific Ocean, and waterways logistics will trigger the region's agricultural expansion (Barros et al., 2021a). Particularly, Amazonas wants funding to potentialize municipalities with an aptitude for agricultural development in its Southern region. Acre aims to explore export transport corridors in the axes of the BR-317 (connection to the Pacific Ocean through Peru) and BR-364 (connection to the rest of Brazil) highways. Rondônia expects to strengthen its production chains. In common, they aim to explore Asian markets through oceanic routes and Pacific ports (Barros et al., 2021b).

Since the communication of the intention to create this zone, in 2018, the region faces land speculation, an increase in deforestation rates, and subsequent conversion of forests into pasturelands and croplands (Carrero et al., 2022; Silva et al., 2023a; Vilani et al., 2023). This growing pressure is observed from remote sensing-based official data (Supplementary material). The municipalities planned to integrate Abunã-Madeira SDZ accounted for 76.48% of the total deforestation rate in Amazonas, Acre, and Rondônia from 2018 to 2022 (INPE, 2023). Consequently, public lands such as extractivist reserves and ILs, which account for a major portion of the proposed area for the zoning, are under exponential pressure and threat. In 2021, 64.08% of the deforestation in this area occurred within public lands. Also, land tenure conflicts and violence against Indigenous peoples have been raising, reinforced by the permissive political scenario (IPAM, 2021). This situation is risky as this region covers 86 Conservation Units, 49 ILs, and 94,199 km^2 of Non-designated public forests. Moreover, the absence of environmental impact studies and socioenvironmental public policies to protect the human capital embodied in traditional communities before creating the zone is concerning.

Despite the boom after 2018, deforestation has been increasing in this region since 2012 - coinciding with a period of economic crisis, changes in political forces, and a weakening of environmental regulation in Brazil (Soares-Filho et al., 2014; Azevedo-Santos et al., 2017), when environmental agency budgets decreased, the number of fines issued dropped, and on-field operations collapsed (Pereira et al., 2020). From 2012 to 2020, 5.23% of the Abunã-Madeira SDZ area suffered conversion from forest formations to anthropogenic land-uses, according to MapBiomas data (MapBiomas, 2021) (Fig. 2), mostly from forest to pasture (78%). Recent studies have pointed out that land use conversion in this region is mainly linked to land grabbing, logging, and fires (Andrade et al., 2021; Ferrante et al., 2021; Mataveli et al., 2021), factors that lead to forest degradation, deforestation, and the expansion of the arc of deforestation to preserved forestlands (Silva et al., 2023a; Vilani et al., 2023).

Still regarding land conversion, data from PRODES (INPE, 2023) for the same period corroborates the process of transforming the region into a notable deforestation hotspot - like the Southeastern Pará and the Upper Xingu River Basin (Fig. 3).

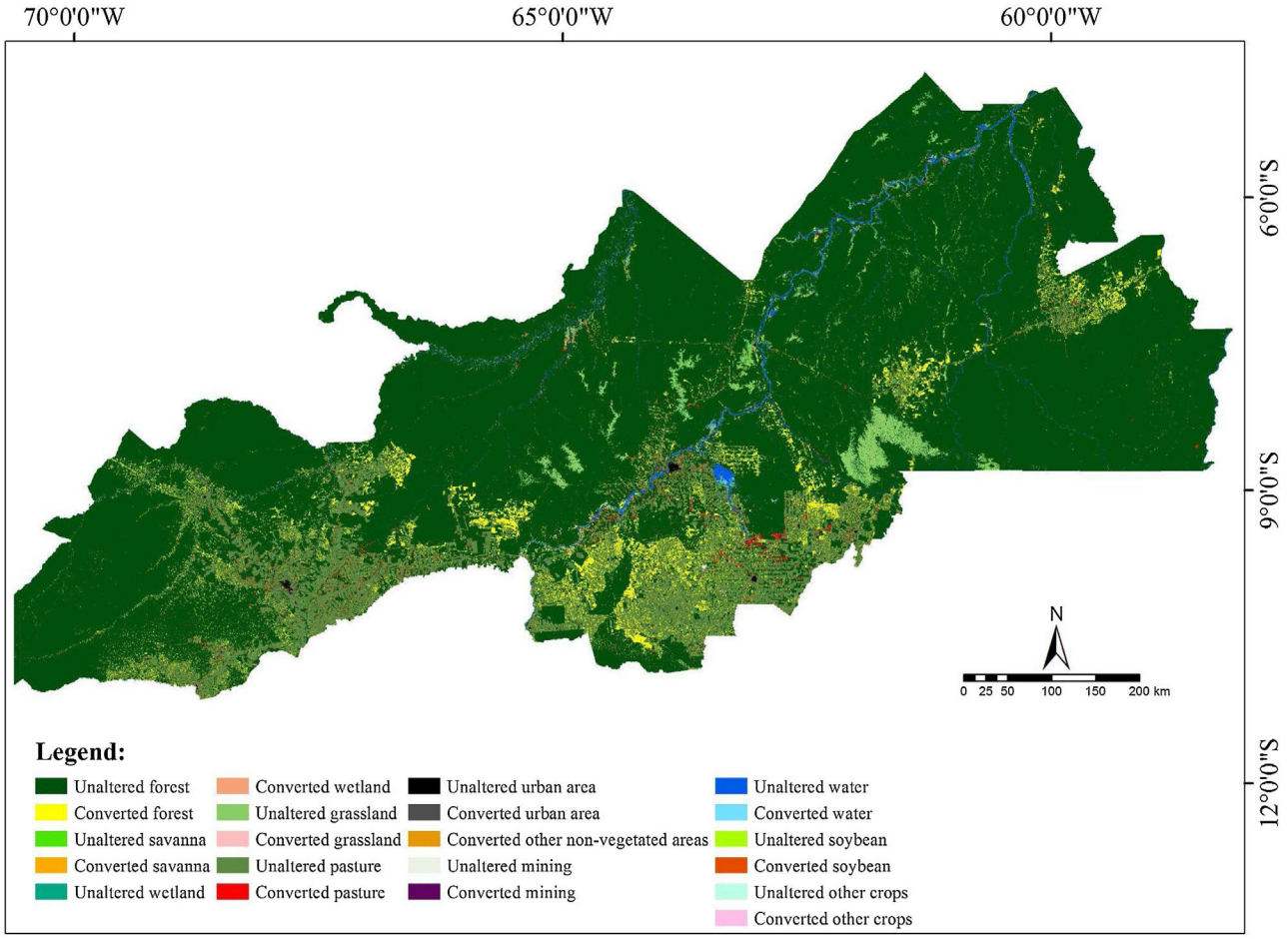

Fig. 2. LULC conversion in Abunã-Madeira SDZ proposed area of implementation from 2012 to 2020, according to MapBiomas data.

Forest degradation is another threat to standing forests that increased in the region, according to forest degradation data from the European Commission Joint Research Centre (JRC) (Vancutsem et al., 2021). To verify the existence of significant differences in the occurrence and intensity of forest degradation as a function of the announcement of the intention to create the Abunã-Madeira SDZ, we compared the SDZ municipalities with its immediate neighbors five years before (2013–2017) and five years after (2018–2022) the announcement, via the Kruskal-Wallis non-parametric hypothesis test (Fig. 4), which evaluates whether different datasets have the same distribution. Results showed that the proportion of Not disturbed areas and Degradation outside of SDZ are statistically equals before and after the announcement ($p = 0.15$ and $p = 0.41$, respectively) but they are different inside SDZ ($p = 0.00014$ and $p = 0.025$, respectively), which represent that the total of non-disturbed forests decreased on a higher pace in the municipalities planned to compose the SDZ and, consequently, forest degradation increased more inside and after the announcement.

This disturb of pristine forestlands in area and proportion potentially occurs in function of land grabbing, logging, and fires (Andrade et al., 2021; Ferrante et al., 2021; Mataveli et al., 2021). This problem led Amazonas, historically preserved, to surpass customary leaders in deforestation due to its southern region - where deforestation rates remained above 80% of the total deforested in the state since 2018 (INPE, 2023).

Regarding land tenure, 50.62% of the region corresponds to Integral Protection PAs and ILs, and 2.80% to Sustainable Use PAs, while 20% corresponds to Private Farms, 17.36% to Non-designated Lands, and 7.42% to Rural Settlements (Freitas et al., 2017). A cross-evaluation between deforestation data from PRODES and land tenure from 2012 to 2022 was performed to show the annual absolute and proportional deforested area per land tenure class (Supplementary material). In absolute values, deforestation increased in all land tenure classes, alarmingly in PAs - especially since 2018, when the Abunã-Madeira SDZ project became widespread. In Rural Settlements, the highest rate registered (625.56 km^2, 2021) was 83.34% above the average between 2012 and 2020 (341.20 km^2). In Private Farms, Military Areas, and Non-designated Lands, for example, the four highest rates were registered in the 2018–2022 interim. This pattern also was found in Integral Protection and Sustainable Use PAs. In ILs, the deforestation pattern changed from 2018 onwards, when all rates exceeded 20 km^2. Proportionally, Private Farms, Non-designated Lands, and Rural Settlements, which had the higher area percentages, began to reach ascending deforestation after 2018. In ILs, deforestation was lower than most classes in absolute values, but increased during the last five years. Details on area and percentages can be observed in the Supplementary material.

This scenario, allied with the continuous deforestation year-by-year (Fig. 3), indicates that, different from consolidated deforestation areas (Pacheco, 2012; Thalês and Poccard-Chapuis, 2014), deforestation was most frequent and increasing in private lands and is concerningly advancing over PAs between 2018 and 2022. The fact that deforestation within ILs is lower than outside is relevant because the occupation timeframe for demarcation is still not decided. While the law bill 510/2021 aims to postpone the so-called timeframe from December 2011 to December 2014, institutionalizing rural leasing in ILs and threatening indigenous

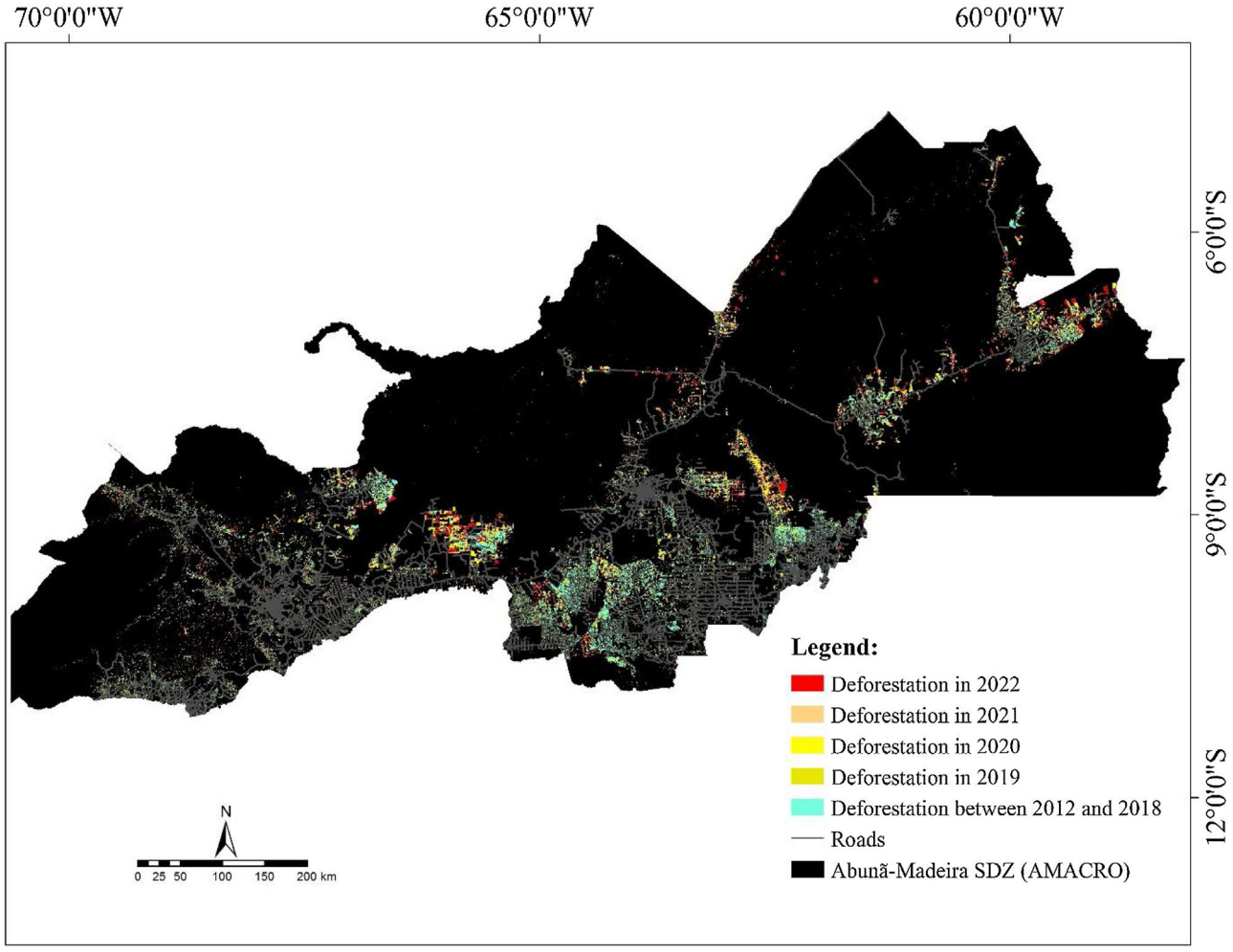

Fig. 3. Deforestation polygons detected by PRODES between 2012 and 2018, and in 2019, 2020, 2021 and 2022.

peoples (Conceição et al., 2021), our results demonstrate that ILs serve as shields to protect environmental integrity in this deforestation frontier. Despite this, deforestation rates above 20 km^2 in the last five years (alarmingly 40 km^2 in 2022) show the need to strengthen the protection of ILs in the region.

Conservation and agro-livestock as a national strategy

Avoiding sanctions

The scenario in the region planned to be the Abunã-Madeira SDZ opposes the national and regional need for preserving the environment. Brazil must increase yield on already-cleared lands amidst combating environmental crimes, such as illegal logging and mining, and the financial flows that sustain them, especially in the BLA. This condition requires end-to-end actions to curb land grabbing under the setback of jeopardizing efforts to boost the national agri-environmental potential, since environmental impacts represent a risk that investors cannot ignore (Chaves et al., 2023b). Worldwide, consumers' demand for only legally-produced goods is growing. Boycott movements emerged pressuring businesses permeated by deforestation. Influenced by concerns for nature conservation and climate change, consumers are avoiding products incompatible with environmental causes (Golob and Kronegger, 2019). These counter-cultural attitudes are rising in Europe and the United States, destinations of many Brazilian exports, requiring the attention of governments and companies. Global investors, associations, former finance ministers, and banks are requesting a pathway to a low-carbon economy. European countries are forcing retailers to ditch meat companies linked to deforestation. In the United States, civil society and NGOs call on Congress to pass bills to prevent commodities produced on illegally deforested land from entering the national market, aiming to rebuild partnerships to tackle the global climate crisis (Rajão et al., 2020). In addition, Brazil's plan to join the Organization for Economic Cooperation and Development (OECD) as a full member mandatorily depends on containing deforestation and fires in Amazonia (OECD, 2022).

A natural reaction to international concerns, economic sanctions on Brazilian commodities are expected if illegal deforestation continues. That would happen during an unfortunate moment, as agribusiness exports are crucial for the Brazilian Gross Domestic Productivity (GDP) (CEPEA and CNA, 2022) and the post-pandemic economic recovery. Recently, institutional investors, global corporations, and foreign governments demanded measures from the Brazilian authorities to curb illegal deforestation (Rajão et al., 2020). European Union (EU) concerns regarding increasing greenhouse gases emissions from deforestation and fires - which could invalidate climate change mitigation efforts - risks Brazilian commodities and the ratification of the EU-Mercosur trade deal reached in 2019 (Retail Soy Group, 2021). In addition, the European Commission proposed a new due-diligence legislation on the import of deforestation-free products (European Commission, 2021).

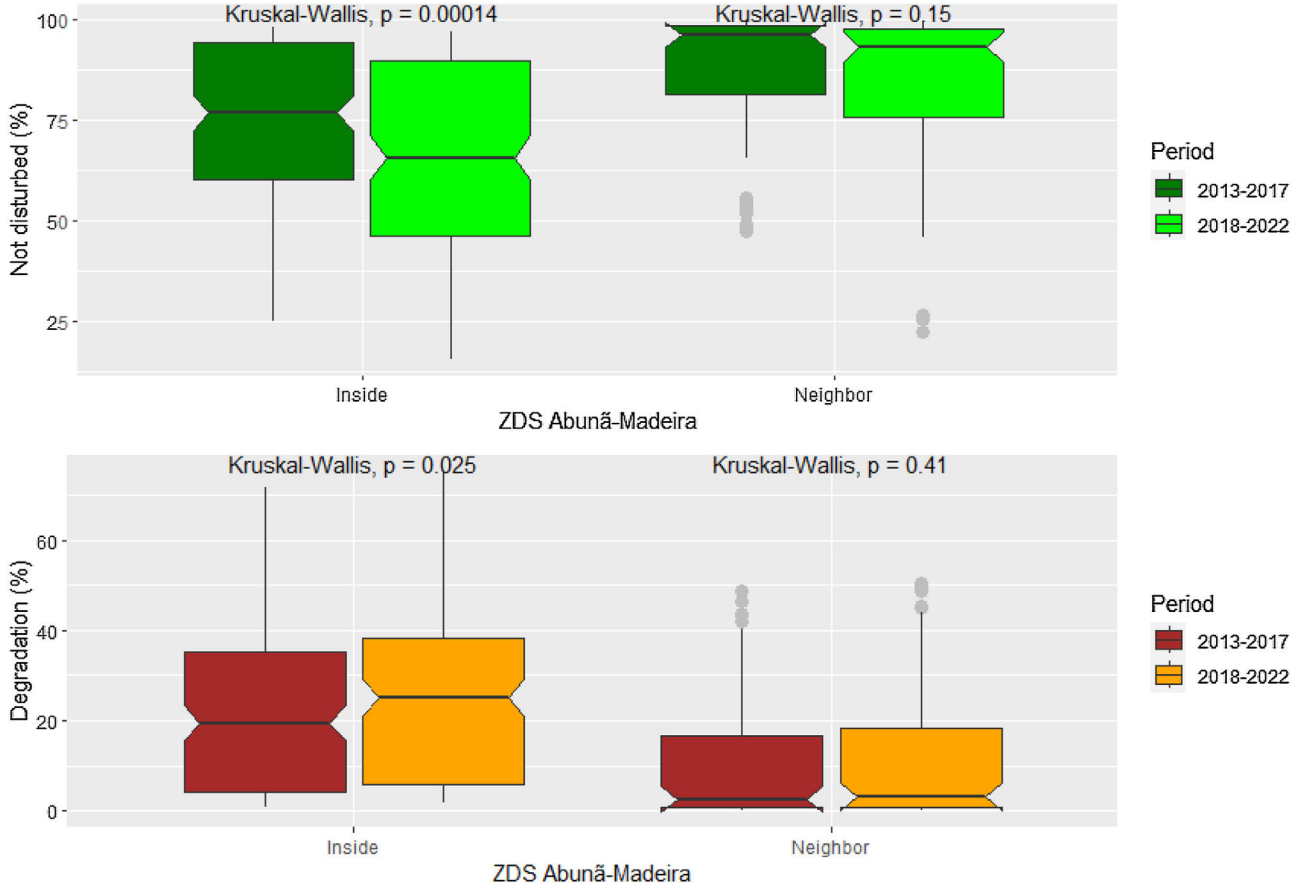

Fig. 4. Proportion of pristine forest and degradation before (2013–2017) and after (2018–2022) the SDZ announcement, inside SDZ and in its surrounding neighbor municipalities.

Using scientific guidelines

Brazil knows the way to revert this situation. A mandatory effort is to foster subnational, national, and international actions for curbing illegalities and prioritizing sustainability, which already started with the reestablished and expanded PPCDAm+. In addition to this, science-based prioritization can strengthen enforcement actions and maximize operational gains (Mataveli et al., 2022). Nowadays, with diffused initiatives on promoting Earth Observation in the agri-environmental decision-making process, this is, unprecedentedly, viable. Brazil has technology and systems for measuring environmental impacts and fomenting territorial planning public policies, such as the CBERS and Amazonia-1 satellite programs (Ferreira et al., 2020). This condition allows reducing uncertainties and risky strategies that can cause opposite effects and recovering the agri-environmental protagonism by deepening the use of technology to ensure environmental certification and transparency in the national supply chain. Also, it can turn Brazil into a unique place for developing innovative early warning systems regarding biodiversity and food production policies.

Fortunately, PPCDAm contemplates the use of remote sensing technologies to monitor forests and provide environmental compliance. Local initiatives, such as the *Selo Verde* Program in the state of Pará, use it to assess private farms and provide economic and fiscal incentives to farmers who protect forests. To expand this initiative to other states, aiming to ensure environmental certification and transparency in agropastoral supply chains, citizen science, accompanied by policies for the open distribution of satellite data, sharing principles, and intuitive platforms can help to overcome practical and political barriers. This premise must be part of any impact study for implementing the zone.

The wide range of public data for landscape monitoring allows detecting and understanding deforestation, supporting decision-making related to transparent end-to-end supply chains. Hence, public-private policies to stimulate juridical security and sustainable options for economic development would be crucial for Brazil's post-pandemic recovery, as environmental conservation and agro-livestock must be equally prioritized to ensure biodiversity and food security.

Environmental and territorial planning

Initiatives to integrate BLA into profit-making practices without robust long-term planning have no proven effectiveness, instead they cause forest fragmentation and land market speculation (Miranda et al., 2019). Also, previous agricultural development projects without impact assessment and planning failed to avoid reductions in crop cultivation suitability in other Brazilian biomes; in the MATOPIBA, for example, changes driven by agricultural expansion reduced crop cultivation suitability (Marengo et al., 2022) and caused concentration of income and land, deforestation, depletion of natural resources and rural conflicts (Silva et al., 2023b). The Abunã-Madeira SDZ's proponents diffuse the positive rhetoric of preventing illegal deforestation by producing on already-cleared lands. However, scientists and federal prosecutors who handle environmental crimes locally warn that it can legalize deforestation that is already occurring (The Guardian, 2021). Hence, if not well planned, this zone will function as a smoke-

screen for legalizing activities prohibited by environmental laws that encompass land clearing for mining and agro-livestock practices, consequently propitiating more illegal deforestation and fires (Carrero et al., 2022). Moreover, the uncontrolled conversion of forests with pasturelands or croplands (Conceição et al., 2020) contributes to rising temperatures, change precipitation patterns, and intensify extreme weather events. These conditions disturb climate regulation and the water cycle useful for crop production in relevant crop producer states in Brazil, driving losses. As extreme weather events are expected to become more frequent in the upcoming years, crop production is at risk (Chaves et al., 2023a).

As deforestation triggers biodiversity loss and socioeconomic damage that threatens Brazilian post-pandemic recovery, politicians and investors should work on policies to conciliate food production and conservation. Environmental and territorial long-term planning following sustainable development principles is paramount for BLA conservation (Mataveli et al., 2022). Given this, developing strategies for subsidizing landscape monitoring and policies for environmental conservation and food production is a national sovereignty issue.

During the COP-27, Brazil defended that the biofuel market is an alternative for the Amazonian economic development. However, bioenergy developments in the Abunã-Madeira SDZ potentially could increase deforestation, requiring an adequate economic ecological zoning. The current zoning for sugarcane, for example, do not permit the opening of new areas for its cultivation (Manzatto et al., 2009). Hence, a robust ecological and economic zoning of crops for biofuels would be necessary (Ferrante et al., 2021).

Concluding remarks

The growing deforestation in the region increases LULC changes, socioeconomic losses, and the local environmental vulnerability, affecting essential edaphoclimatic conditions for agro-livestock and, consequently, the water-climate-food security nexus. The standard agribusiness model tends to fail in this scenario because of crops suitability and management conditions. Considering the local characteristics, the SDZ project would be interesting if environmental impact studies were made and respected during the years towards agroforestry or integrated crop-livestock-forestry systems, Payments for Ecosystem Services (PES) policies (Law 14,119/2021), as well as investments in the industrialization and value addition of the production of fish, chocolate, and nature-based cosmetics. In addition to being environmentally adequate, this scenario tends to add value to local products and services and generate employment and income. Given this, territorial ordering strategies should contemplate environmental impact studies, safeguard measures, and public policies to protect natural resources and local populations (i.e., 'ribeirinhos' and traditional communities), respect commitments established in climate and biodiversity conventions, and avoid judicial fights. Therefore, consulting traditional peoples and institutions with vast knowledge of the local reality, such as the National Institute for Amazonian Research (INPA), Emílio Goeldi Museum of Pará, Amazon Institute of People and the Environment (IMAZON), and the Mamirauá Institute for Sustainable Development is paramount for a people and standing forest-centered development framework.

To ensure the highly expected turn on conservation policies, the BFG will need science-based law enforcement measures and strategies to curb the spread of deforestation. Territorial ordering and land tenure regularization are complex, systemic, and multi-sectoral. Stimulating sustainable agro-livestock following conservation principles is nearly impossible without law enforcement. A backward initiative involving this zoning may represent the absence of political will to apply science-based plans for sustainable development in BLA, causing a regional hecatomb.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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