Title: Forest degradation is undermining progress on deforestation in the Amazon

Running title: Degradation Undermines Amazon Gains

Abstract: The 30th Conference of the Parties (COP30) of the United Nations Framework Convention on Climate Change (UNFCCC), to be held in Belém, offers Brazil a unique opportunity to reaffirm its commitment to protecting the Amazon and leading global climate efforts. Recent progress in reducing deforestation is promising, as preliminary data show that the 2024 deforestation increment in the Brazilian Amazon reached 5,816 km² - a 27.5% drop from 2023 and the lowest in a decade. This success is largely linked to the reinstatement of the PPCDAm, Brazil's plan to prevent and control deforestation. However, forest degradation remains a major, often overlooked, threat. Unlike deforestation, which involves total forest removal, degradation refers to changes that diminish forest function and resilience without full canopy loss. Nearly 40% of Amazon forests are degraded due to fires, logging, edge effects, and drought. In 2024, degradation alerts surged to 25,023 km² - 44% higher than in 2023 - driven by a severe drought and widespread wildfires, which alone accounted for two-thirds of degradation alerts. Alarmingly, degradation is also driving deforestation. Since 2022, Brazil's monitoring system has tracked deforestation caused by successive degradation events. In 2024, this accounted for over 27% of all deforestation - more than triple the share in 2022. This trend threatens the Amazon's role as a global carbon sink, risking the release of massive carbon stocks and accelerating climate change. To address these threats, Brazil must integrate forest degradation into climate and conservation policy, improve monitoring, hold actors accountable, and invest in fire management, restoration, and sustainable land use. Linking these actions to carbon markets could provide critical incentives. Tackling degradation is essential for Brazil to meet its climate goals and showcase leadership at COP30, protecting both the Amazon and the planet's future.

Keywords: Amazon; Tropical forests; Forest degradation; Deforestation; Wildfire; Climate change; Environmental policy

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The 30th Conference of the Parties (COP30) of the United Nations Framework Convention on Climate Change (UNFCCC), to be held in Belém, provides a unique opportunity for Brazil to affirm its commitment to protecting Amazon forests and to showcase leadership in aligning ambitious climate action with global conservation goals. Encouraging progress has been made in controlling deforestation in the Amazon (Figure 1a-1d). The 2024 preliminary Brazilian Amazon official deforestation increment estimate was 5,816 km^2, 27.5% below 2023 and a staggering 54.2% below 2022 (INPE, 2025). This is the lowest annual deforestation increment in a decade and 26.4% below the average of the 2008-2024 period (INPE, 2025). Such achievement is closely tied to the restoration of command and control in the Amazon, highlighted by the reinstatement of the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm) (MMA, 2023). Nevertheless, deforestation is not the only threat facing Amazon's forests[3].

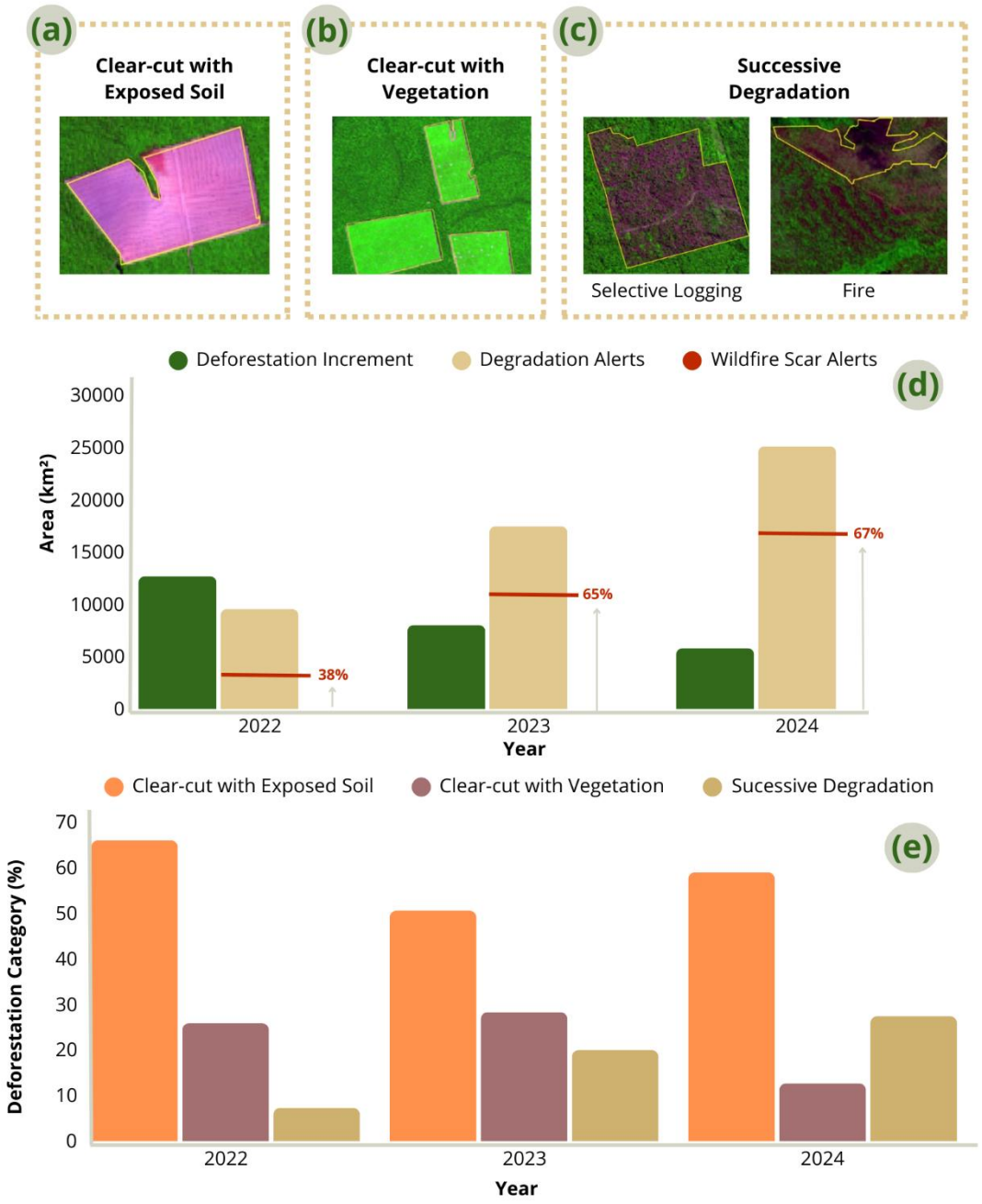
Beyond deforestation, forest degradation represents a significant yet often overlooked threat to tropical forests. While deforestation is a binary process referring to the complete removal of tree cover, leading to a permanent land-use change, forest degradation is the reduction of a forest's capacity to supply ecosystem services, leading to a loss of ecological value, where tree cover remains but undergoes structural and functional changes, ultimately impairing resilience and long-term sustainability (Berenguer et al., 2024; Lapola et al., 2023). Nearly 40% of the Amazon's standing forests are degraded by drivers including fire, edge effect, timber extraction, and extreme drought events, further emphasizing the scale and importance of the issue (Lapola et al., 2023). The 2023-2024 strong Amazon drought, with rainfall deficits of 50–100 mm/month, a +3°C temperature rise, a two-month delay in the wet season, and record-low river levels (Marengo et al., 2024), appears to have compounded a recent rise in forest degradation. Brazil's official forest degradation alerts in the Brazilian Amazon in 2024 - including wildfire scars, selective logging, and other forms of forest degradation that are unrelated to drought - reached 25,023 km^2, an increase of 44% compared to 2023 (17,473 km^2) and 163% compared to 2022 (9,549 km^2) (INPE, 2025) (Figure 1d). In 2024 and 2023, wildfire scars accounted for about 66% of total degradation alerts, compared to just 38% in 2022 (INPE, 2025). Essentially, this means that during the recent drought years the expansion of degraded forest areas has outpaced the promising decline in deforestation in the Amazon.

Forests experiencing repeated degradation events become increasingly vulnerable. Over time, this weakening reduces their ability to recover and may ultimately lead to deforestation. Since 2022, Brazil's official deforestation monitoring system has categorized deforestation polygons to identify those caused by successive degradation events. Two processes can lead to this pervasive type of deforestation: (i) selective logging, followed by the removal of lighter woods and ground vegetation, gradual pasture introduction, and recurrent fires that degrade the forest; (ii) recurrent fires alone (Almeida et al., 2022). Both lead to canopy collapse, where the forest loses its ecological functions and self-recovery capacity, resulting in deforestation through gradual decay (Almeida et al., 2022). In 2022, deforestation led by successive degradation events accounted for 928 km^2, or 7.3% of total deforestation in the Brazilian Amazon (INPE, 2025) (Figure 1e). In 2023, this proportion increased to 20% (1,609 km^2) of total deforestation, and in 2024,

27.4% (1,594 km^2) of total deforestation was caused by successive degradation (INPE, 2025). The area affected by successive degradation in 2024 was 72% above 2022 levels. This is particularly concerning given the Amazon's role as a carbon reservoir, storing approximately 55% of the carbon held in tropical woody vegetation (Baccini et al., 2012). Preventing carbon release from the Amazon is critical, as it could amplify the already ongoing impacts of climate change, further exacerbating global warming and disrupting ecosystems worldwide.

The rising impact of both forest degradation and degradation-driven deforestation in tropical areas, such as the Amazon, demands integrated solutions, crucially incorporating forest degradation into conservation policies and forest management practices (Dutra et al., 2024), to address these interconnected challenges and protect standing forests. A critical challenge lies in effectively tracking and quantifying degradation while creating mechanisms to hold accountable those responsible for forest degradation. Efforts like improving fire management, alongside large-scale restoration and reforestation projects, can immediately curb forest degradation. Additionally, explicitly integrating these strategies into both mandatory and voluntary international carbon markets could create financial incentives for landowners, businesses, and communities to adopt sustainable practices.

Controlling forest degradation in the Amazon is essential for Brazil to meet its climate targets, as protecting and restoring these forests would preserve critical carbon sinks, reduce biodiversity loss, mitigate greenhouse gas emissions, and enhance ecosystem resilience. Aligned with Brazil’s updated Nationally Determined Contribution (NDC) commitments under the Paris Agreement, such efforts are crucial to reduce its net greenhouse gas emissions by at least 59% below 2005 levels by 2035 (MMA, 2024). As the world prepares for COP30, concrete steps to curb forest degradation will be key to demonstrating Brazil’s commitment to safeguarding the Amazon and its leadership in global climate action.



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126 **Figure caption:** Forest degradation alerts in Brazil's Amazon in 2024 rose by 163%, and
127 deforestation caused by successive degradation events increased by 72% in relation to
128 2022, despite a 54% decrease in overall deforestation. Panels (a), (b), and (c) represent
129 the categories of deforestation identified by Brazil's official deforestation monitoring
130 system; examples of categories were adapted from Almeida et al. (2022). Panel (d) shows
131 the yearly deforestation increment and degradation alerts, including wildfire scar alerts,
132 in the Brazilian Amazon during 2022-2024; degradation data matched the deforestation
133 increment reference year for comparison - from 1st of August to 31st of July. In panel (e),
134 we have the proportion of the three major deforestation categories during 2022-2024. The
135 "Clear-cut with Vegetation" category includes areas that were deforested and later
136 occupied by herbaceous vegetation, as shown in panel (b). Data were extracted from the
137 yearly increment in deforestation shapefiles. All data are freely available in the
138 *TerraBrasilis* platform (INPE, 2025).

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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