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Deforestation and Forest Degradation in the Amazon - Update for year 2023 and assessment of humid forest regrowth

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Abstract

The Amazon rainforest, a vital global ecosystem, is facing significant threats from the loss of intact forest through deforestation and degradation. This report provides an overview of recent forest changes in the Amazon, focusing on Brazil, the country with the largest portion of the Amazon.

Based on the JRC cloud-computed, remote sensing – based, large-scale tropical forest monitoring approach, maps and statistical estimates on forest cover changes from 1990 – 2023 are provided in this report for the whole region as well as for the different Amazon countries. The report contains a discussion about the drivers of deforestation, such as agricultural expansion, and forest degradation (e.g. illegal or unsustainable selective logging, forest fires). These activities have severe consequences for biodiversity, climate regulation, and the livelihoods of millions of people. In addition, a dedicated chapter on forest regrowth in the Amazon biome shows its spatial distribution and its changes over time, and provides a detailed analysis of its growth dynamics and their value regarding biodiversity and carbon storage.

Understanding the changes in the forest is crucial for developing effective strategies to protect the Amazon. By identifying vulnerable areas and understanding the underlying drivers of deforestation, forest degradation and regrowth, informed and targeted interventions can be planned and implemented to mitigate these threats.

Foreword

The Amazon rainforest biome is a vital ecosystem that supports 10% of global biodiversity and 47 million people, including 2 million indigenous people. However, this ecological marvel faces unprecedented threats. Since the 1970s, road construction and agricultural expansion have led to the loss of 17% of the forest. This loss is accompanied by widespread degradation of remaining forests, caused by factors such as illegal or unsustainable selective logging, forest fires, edge effects and droughts.

The Amazon's ecological significance is profound. As a vast carbon storage, it plays a critical role in mitigating climate change by absorbing vast amounts of carbon dioxide from the atmosphere. It also regulates regional and global weather patterns, thereby influencing rainfall distribution and air temperature across South America and beyond. Moreover, the Amazon is a biodiversity hotspot, harbouring countless plant and animal species, many of which are endemic to the region.

To address these challenges and safeguard the future of the Amazon biome, it is imperative to have accurate and timely information about its condition. Earth observation technology has emerged as a powerful tool for monitoring forest cover changes. By analysing satellite imagery, scientists can track deforestation rates, identify areas of forest degradation and regrowth, assess the impact of human activities on the ecosystem, and guide effective forest restoration strategies.

Within the Neighbourhood, Development and International Cooperation Instrument Global Europe, the AMAZONIA+ programme includes action plans to be implemented in the Amazon Basin countries: Bolivia, Brazil, Colombia, Ecuador, Guyana, Peru, Suriname and Venezuela. As a part of its response to this mounting crisis of the Amazon forest, the European Commission and its member states launched a Team Europe Initiative (TEI) for the Amazon to address some of the key drivers of deforestation and forest degradation. The AMAZONIA+ programme seeks to strengthen the conditions and ability of the Amazon Basin countries to combat deforestation, forest degradation and its main drivers through the promotion of ambitious and effective policy-making and implementation, improved statistics, effective forest monitoring systems, and inter-sectoral, multi-level, multi-actor and regional articulation. The Amazon Fund, currently containing more than USD 700 million donated by the EU, Norway, Germany, and others, has been reactivated in 2023 and now supports a large number of activities related to environment, bio-economy and society, mostly located in the Brazilian Amazon.

The European Union's Joint Research Centre (JRC) has been at the forefront of using satellite data to monitor the Amazon rainforest for more than 30 years. Through its Tropical Moist Forest dataset, the JRC provides detailed information on changes in forest cover, including deforestation, degradation and regrowth. This dataset offers valuable insights into the drivers of deforestation, such as agricultural expansion, infrastructure development and land grabbing. In parallel, the JRC develops the ‘EU Observatory on Deforestation and Forest Degradation’ that aims to provide scientific evidence with regard to global deforestation and forest degradation and related trade.

This report presents updated forest cover change statistics for the Amazon region up to the end of 2023, including country-specific trends and historical context. For the Brazilian Amazon, data is also included on deforestation and degradation for the first ten months of 2024. An analysis of the occurrence of secondary forests in the entire Amazon biome rounds up the report. Secondary forests regrow on abandoned deforested lands. They have an important role in carbon sequestration, reversing soil degradation, biodiversity recuperation and reconnecting isolated forest patches, and act as buffer for intact old-growth forests.

We hope the report will provide information to various stakeholders on the status of deforestation, forest degradation trends and forest regrowth in the Amazon region.

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Executive Summary

In 2023, the JRC-TMF dataset on Tropical Moist Forests reports a 19% decrease in forest disturbances in the Pan-Amazon region compared to year 2022 (25,685 km^2 of new disturbances in 2023 vs. 35,480 km^2 in 2022) - disturbances including both deforestation and forest degradation. The Amazon countries show different trends in forest cover change. Forest disturbances in the Guiana Shield countries (Guyana, Suriname and French Guiana) and Venezuela increased in 2023 compared to 2022 (by 90% and 49%, respectively), while Bolivia showed only a slight increase in 2023 (2%). In all other countries, forest disturbances decreased in 2023, ranging from 17% (Peru) to 32% (Ecuador), with Colombia and Brazil being slightly below (32% and 24%, respectively).

The overall annual new disturbed forest area in the Brazilian Legal Amazon decreased by 26%, from 22,074 km^2 in 2022 to 16,455 km^2 in 2023, according to JRC-TMF. The reported decrease was supported by statistics from DETER, the near-real-time deforestation and forest degradation detection system from the Brazilian National Space Research Institute (INPE), that also showed a decrease of forest disturbances of 27%, from 28,291 km^2 in 2022 to 20,669 km^2 in 2023 (yearly accumulated deforestation and forest degradation alerts).

This report also provides an overview regarding forest disturbances in the Brazilian Legal Amazon for the first ten months in 2024, as reported by the INPE-DETER alert system. DETER shows a decrease of 18% and an increase of 376% between 2023 and 2024 (January-October period) for deforestation and forest degradation (by illegal or unsustainable selective logging and forest fires), respectively. The huge increase for forest degradation alerts is due to the large areas of forest fires, specifically in September and October 2024. The DETER forest fire alerts have skyrocketed by 928% in the first ten months of 2024, compared to the same period in 2023, favoured by the intense drought in the region. It is notable that in 2024 the DETER deforestation alerts decreased considerably while forest degradation alerts surged. A second, independent deforestation alert system for the Brazilian Amazon, IMAZON-SAD, reports 8% deforestation decrease between 2023 and 2024 (period January to October).

Secondary tropical forests in the Amazon play an increasing role in mitigating soil degradation, carbon sequestration, and biodiversity recuperation and as protection buffer for adjacent intact old-growth forest. JRC-TMF maps in 2023 show ~84,000 km^2 of secondary forest in the Pan-Amazon, including forest regrowth on previously abandoned pastures or crop fields and after severe wildfires. While 75% of the secondary forests in 2023 were less than 10 years old, only 6% were 20 or more years old. More than 3/4 (78%) of secondary forests were still standing in 2023, whereas 22% were re-deforested or burned after 2013. A large part of the secondary forests regrows naturally, i.e. through natural seed dispersal from the neighbouring forest. The natural forest restoration success depends on many factors like e.g. the distance to the next forest patch and its floral and faunal ‘intactness’ and the past land use and intensity. An alternative is the assisted forest restoration by direct seeding, or seedling planting, or e.g. by the installation of establishing artificial perches for frugivorous birds to help the natural seed dispersing process. However, areas of assisted forest restoration are still very limited.

The current Brazilian Government has shown important steps towards a progressive environmental policy, like the re-strengthening of forest monitoring and environmental law enforcement institutions (that lead to the curbing of Brazilian deforestation in 2023 and 2024), the immediate reaction to the Yanomami humanitarian crisis at the beginning of 2023 and the creation of a Ministry of Indigenous Peoples. However, with the new conservative Brazilian Congress in place since 2022, the implementation of new or stronger environmental policies has become more difficult. The Congress is launching important law proposals (PLs) that would, if passed, hamper Brazilian environmental protection and indigenous rights. The current government has expressed to be in favour of projects in the Amazon, e.g. asphalting of the BR-319 Highway, oil and gas exploration, the Ferrogrão railway line, which are seen by many as at least ‘problematic’ in relation to Amazon environmental protection.

About this report

The focus in this report is on the scientific findings concerning forest cover changes in the Amazon in a local, regional or global context. It is published in the context of the European Commission's Amazonia+ Programme and the EU Forest Observatory on Deforestation and Forest Degradation, which was established at the end of 2023 and is managed by the Joint Research Centre. One of the aims of the Observatory is to support the implementation of the new Regulation (EU) 2023/1115 of the European Parliament and of the Council of the EU[2] on the making available on the Union Market and on the export from the Union of certain commodities and products associated with deforestation and forest degradation. This Regulation aims to prevent that the Union's consumption and production of commodities causes deforestation and forest degradation within or outside the EU.

As in the previous reports of this series [1–3], a specific focus is given to Brazil (in particular in sections 3 and 5), the country in the region with the largest share of Amazon rainforest and the largest country of the South American Mercosur region.

After the introduction (Section 1), Section 2 presents the JRC-TMF statistics updated up to year 2023 for all countries of the Amazon region and the comparison with data from INPE's Deforestation Monitoring Project (PRODES)[3] for the Brazilian Amazon. Furthermore, the latest available statistics of the INPE-DETER[4] alert system (January to October 2024), regarding deforestation and forest degradation in the Brazilian Amazon, are presented in Section 3, including a comparison with the statistics from the deforestation alert system SAD[5], run by the Brazilian NGO Instituto do Homem e Meio Ambiente (IMAZON)[6].

Section 4 reports on the occurrence and dynamics of secondary forests in the Amazon region. How is secondary forest defined, where are forests regrowing and what were the causes of forest loss before its regrowth, what are the factors that obstruct or enable forest regrowth and what has shifting cultivation to do with it? Secondary forest data from JRC-TMF is compared with other available datasets regarding forest regrowth in the Amazon region.

Section 5 deals with recent and new Brazilian environmental policies. What are the related actions that the Government has taken to the strengthening of institutions dealing with environmental protection and how does the conservative Congress act in the environmental policy context? Proposed laws (PLs) that have been introduced by the Congress (with a potential effect on the Amazon forest) are discussed in this chapter, as well as Government plans to develop the Brazilian Amazon region with controversial infrastructural projects that might have positive effects for the region's economy, but at the same time might have negative consequences for the Amazon forest.

Annex 1 describes the impacts of using the completely re-processed historical collection (Collection 2) of satellite imagery of Landsat 4,5,7 and 8 and new Landsat 9 imagery for the whole period of 1990-2023 on the JRC-TMF results, in comparison with the TMF statistics before the reprocessing (Collection 1). The improvement in number of 'valid observations' due to the addition of new (historical), reprocessed imagery into the USGS archive is discussed and its effect on this addition for the forest cover change statistics.

Annex 2 reports new scientific findings that have been published between the second half of 2023 and the first half of 2024, and which have not been cited in the main text. The findings deal with many aspects related to forest, deforestation, forest degradation and forest regrowth in the Amazon region.

[2] https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32023R1115
[3] http://terrabrasilis.dpi.inpe.br/app/dashboard/deforestation/biomes/legal_amazon/rates
[4] http://terrabrasilis.dpi.inpe.br/app/dashboard/alerts/legal/amazon/aggregated/
[5] https://imazon.org.br/en/imprensa/understanding-the-imazon-monitoring-system/
[6] https://imazon.org.br/en/

1 Introduction

The carbon uptake of intact tropical forests is not the solution to mitigate climate change, but is an important part of it [4,5]. Three measures to increase the carbon uptake of tropical forests are of importance, i.e. stopping further deforestation and forest degradation, preserving secondary forests and the re-establishments of forests on already deforested areas [4,6]. The preservation (and re-establishment) of tropical forests are also an important way to mitigate the dramatic impact forest loss or degradation has on tropical floral and faunal biodiversity [7,8] and on people that live in and from the forest [9]. In general, the preservation and restoration of deforested tropical regions has multiple social and environmental benefits [10–12].

Climate change contributes to the increased frequency and intensity of wildfires globally, with significant impacts on society and the environment [13]. The hydrological cycle of the Amazon is changing, due to continuous deforestation and forest degradation (specifically due to forest fires), causing decreased precipitation, longer dry seasons, higher temperatures and droughts [14–16]. Negative synergies between deforestation, climate change, and widespread use of fire indicate a tipping point for the Amazon system to flip to non-forest ecosystems in eastern, southern and central Amazonia at 20-25% deforestation, according [17]. However, the authors propose to halt Amazon forest loss and degradation at less than 20% for the common-sense reason “that there is no point in discovering the precise tipping point by tipping it”.

Around 16% of the Pan-Amazon’s original forest cover have been deforested by 2023 (according to JRC-TMF combined with data from Mazur et al. 2024 [18]), while between 17 and 38% are estimated to be degraded [19,20], mostly by illegal or unsustainable selective logging, fire, edge effects and drought-induced mortality [21]. While deforestation has decreased in 2023 in the Amazon region by almost 19% compared to year 2022 (see chapter 2), forest degradation has skyrocketed mostly due to forest fires. In the first 10 months of 2024 the area of forest fire alerts in the Brazilian Amazon has increased by more than 900% compared to the same period in 2023, according to the INPE-DETER alert system, and is by far the largest annual area of forest fire alerts since the beginning of the DETER program in 2016. Forest fires are in 2024 the most important cause for forest degradation in the Brazilian Amazon, covering more than 47,000 km^2 in the first ten months of the year[7]. Even if Amazon forests are not adapted to fire, they have the ability to recover after burning [22,23]. However, the effect of severe or recurrent fires can be devastating for the forest, leading, in the extreme case, to a total loss of tree cover without a change of land use [21], i.e. to a conversion to grass- or shrublands. In addition, forest fires significantly affect air quality, posing health and environmental risks to the population [24–27], and can cause ruinous habitat loss for the region’s flora and fauna.

As a means of mitigating the effects of deforestation and forest degradation, the interest in the concept of rewilding as a tool for nature conservation has been increasing in the past years. Rewilding exists on a continuum of scale, connectivity, and level of human influence and aims to restore ecosystem structure and functions to achieve a self-sustaining autonomous nature [28–30]. It encompasses a large number of terrestrial, freshwater and marine ecosystems[8], like wetlands, boreal and tropical forests, grasslands, freshwater and coral reefs, to name a few. In the context of tropical forest restoration, secondary forests play a crucial role as a buffer for adjacent primary forests (mitigating edge effects), for carbon uptake [31–34], and for the recovery of biodiversity [30,35–37]. In addition, secondary forests can create connectors for previously unconnected forest patches in fragmented forest landscapes. Soil, climate, topography, seed-dispersing fauna, former land use of the secondary forests patch, distance to and type of surrounding forests, adjacent land

[7] https://terrabrasilis.dpi.inpe.br/app/dashboard/alerts/biomes/amazonia-nb/aggregated/
[8] https://global-ecosystems.org/

use intensity, assisted or unassisted natural forest regeneration (among others) are factors that determine the 'success' of forest restoration [33,38–43].

The magnitude of deforestation, forest degradation and forest restoration depend on the various national, regional and local political contexts in the Amazon. While deforestation alerts in the Brazilian Amazon have decreased in 2024, forest degradation has skyrocketed due to extensive forest fires[9,10]. The progressive environmental politics of the current Brazilian government are hampered by the conservative National Congress and recent municipality elections, when in the Amazon region a large number of agribusiness-related and climate denier candidates were selected[11]. However, the Brazilian President's view on Amazon environmental protection is ambiguous. On one hand he supports the country's forest monitoring and related law enforcements efforts, on the other hand he expressed support for major infrastructural operations, which are seen by many as environmentally problematic: the asphalting of the BR-319 [44] and possibly other roads, the Ferrogrão railway[12], and oil and gas exploration in the Amazon region[13].

As mentioned before, the Amazon country's forest cover change statistics are variable. The Colombian Amazon has shown the lowest figures of deforestation and forest degradation in 2023 since 1995 according to TMF data, potentially due to the progressive environmental politics of the current government. Forest disturbances 2023 in the Guiana Shield countries (Guyana, Suriname and French Guiana) are at the highest levels since 1990, possibly due to an intensification of illegal selective logging and gold mining in the region (see [45])[14] and due to a severe drought in the region.

Currently, the Amazon region sees a significant increase of environmental and social violence [46,47]. The poverty rate is high, while public health care and opportunities for employment and income are scarce in the Brazilian Amazon [48], but the same is likely to be true for the whole region. Drug cultivation, trafficking and crimes that affect the environment are surging in large parts of the Amazon Basin due in part to an abundance of natural resources alongside a limited State presence, persistent corruption and structural factors related to informality, inequality and unemployment. Organized criminal networks in the region are not just exacerbating deforestation but are also accelerating convergent crime ranging from corruption, tax and financial crimes, to homicide, assault, sexual violence, exploitation of workers and minors, and the victimization of those defending the environment, including Indigenous Peoples[15]. However, illegal activity is not always directly connected to organised criminal groups. Often, illegal logging and mining are a result of the corrupt award of licences and permits by elected public officials and senior bureaucrats [49,50].

[9] https://news.mongabay.com/2024/10/deforestation-remains-low-but-fires-surge-in-brazils-amazon-rainforest
[10] https://terrabrasilis.dpi.inpe.br/app/dashboard/alerts/biomes/amazonia-nb/aggregated/
[11] https://news.mongabay.com/2024/10/amazon-voters-elect-environmental-offenders-and-climate-denialists-in-brazil/
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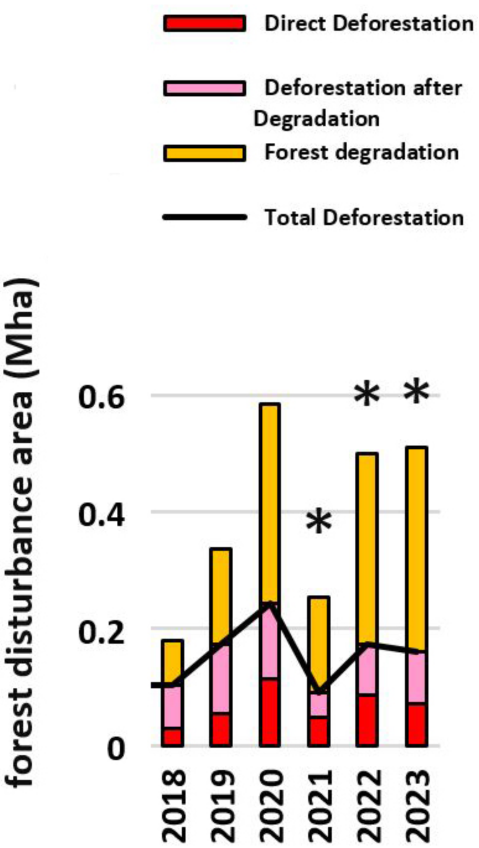
[14] https://learn.landcoalition.org/en/resources/saamaka-vs-suriname-case/
[15] https://publicacoes.forumseguranca.org.br/items/c86febd3-e26f-487f-a561-623ac825863a

2 Deforestation and forest degradation in the Pan-Amazon between 1990 and 2023 - estimates from the JRC-TMF dataset

We report here the trends in national deforestation and forest degradation rates for the six countries in the Pan-Amazon region (Brazil, Colombia, Venezuela, Peru, Bolivia and Ecuador) and the countries of the Guiana Shield (Guyana, Suriname and French Guiana) from year 2000 up to year 2022. The two regions are defined by 'Amazonia sensu stricto' and 'Guiana', according to Eva and Huber (2005) [51] [16].

Figure 1. Subset of JRC-TMF humid forest disturbance statistics for Peru for the past six years. The stars (2021-2023) indicate that the distribution of forest degradation and total deforestation within the yearly overall forest disturbances is an "educated guess"



Source: JRC

The JRC-TMF classification process starts out by mapping disturbances in the forest canopy, regardless of their permanence, from 1984 onwards on a yearly basis (Jan-Dec) with Landsat satellite imagery. The distinction between deforestation and forest degradation is made three years after the forest disturbance occurs by measuring the permanence of the disturbance over time. If the forest canopy is disturbed permanently, i.e. shows no signs of forest regrowth over the three years following the disturbance, the 'forest disturbance' pixel falls into the deforestation class. If a 'forest disturbance' pixel shows clear signs of forest regrowth within the three years following the disturbance, it is classified as forest degradation.

As a consequence, the distribution of yearly deforestation and forest degradation areas within the detected yearly overall disturbed forest areas are consolidated until 2020, but are estimated for the years 2021-2023 by applying a 10-year average (2011-2020), indicated by stars in **Figure 1**.

All statistics are based on the JRC-TMF dataset [52][17] [18]. Figures 12-18 report on forest cover changes of the moist forest in Amazon countries, thus the statistics do not include the changes in e.g. the seasonal or dry forests and savannas of Venezuela, Colombia, Peru and Ecuador, in the Brazilian Caatinga and Cerrado biomes and in the Bolivian Chaco. For comparison, the corresponding statistics of "tree cover loss" from the Global Forest Change (GFC)[19] dataset are displayed in the

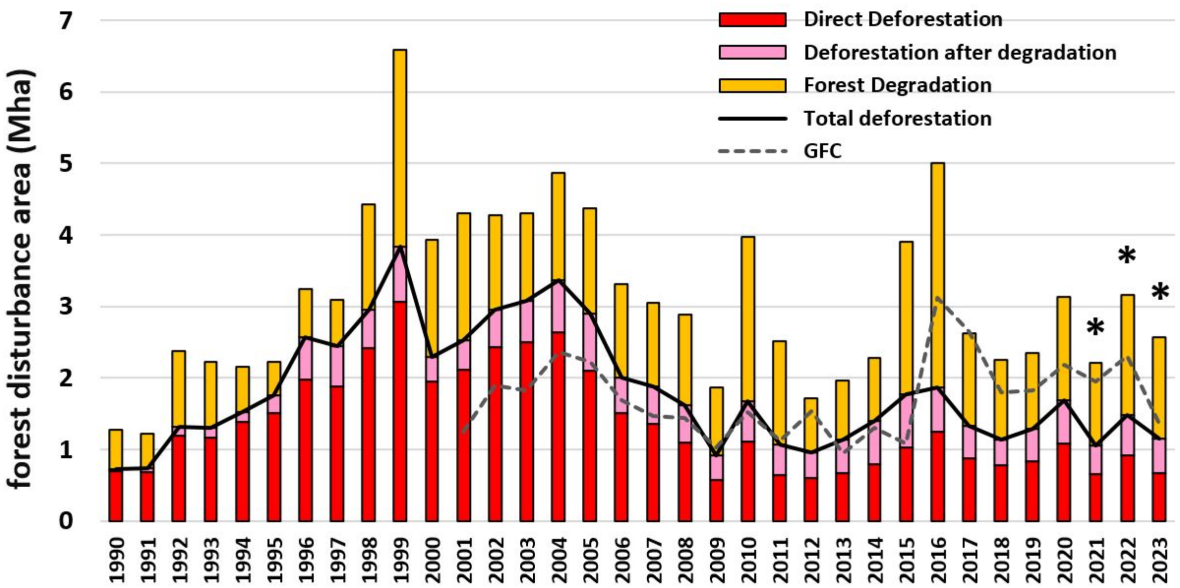
[16] https://forobs.jrc.ec.europa.eu/amazon
[17] https://forobs.jrc.ec.europa.eu/TMF/
[18] https://forobs.jrc.ec.europa.eu/TMF/data#stats
[19] https://glad.earthengine.app/view/global-forest-change

mentioned figures as a grey dashed line. We extracted both JRC-TMF data and GFC data for the Pan-Amazon and the Brazilian Legal Amazon (BLA), based on the area definitions of Eva and Huber (2005) [51] and PRODES, respectively. For country statistics comparison, we extracted both JRC-TMF and GFC data based on the GAUL Level 0 country borders[20] and the year 2000 JRC-TMF humid tropical forest extent as reference layer. For the three datasets JRC-TMF, PRODES and GFC data for the Brazilian Legal Amazon, the INPE-PRODES forest mask defining the humid forest within the BLA has been used additionally to ensure maximum comparability.

2.1 Pan-Amazon

Brazil drives the trend of forest cover change over the past 20 years in the Pan-Amazon, as it covers the largest part of the Amazon forest within the Pan-Amazon region and is the major contributor of deforestation and forest degradation area in the region.

Figure 2. Forest disturbances in the Pan-Amazon humid forest from 1990-2023. The geographic basis are the areas of "Amazonia *sensu stricto*" and "Guiana", according to Eva and Huber [51]. GFC statistics appear as grey dashed line.



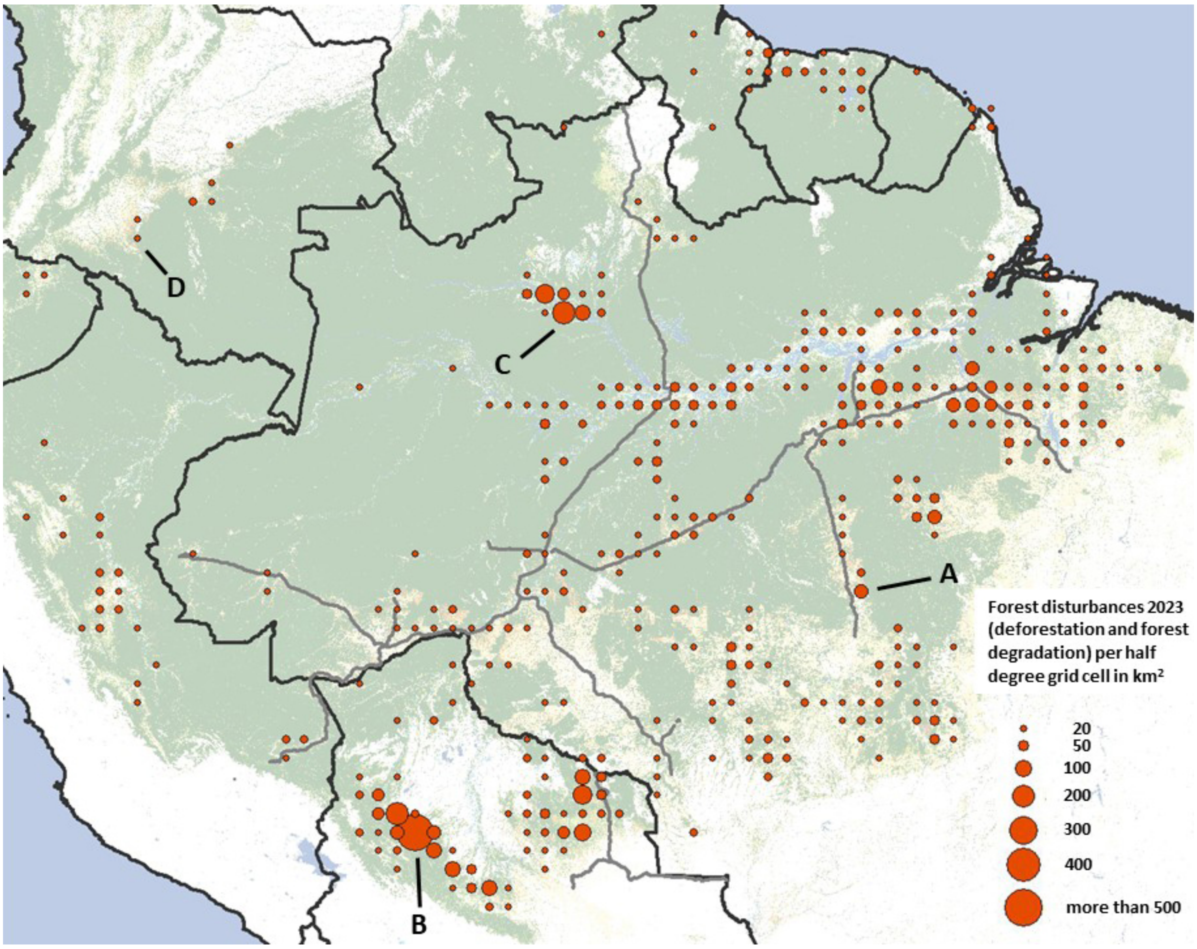
Source: JRC

Altogether, 25,685 km^2 of forest were either deforested or degraded in the Pan-Amazon in 2023, constituting a decrease of 18.8% with respect to 2022. In the past 34 years, the Pan-Amazon has lost 15.8% of its intact humid forest of 1990 (563.0 Mha), either by deforestation (11.0%, or 61.7 Mha) or forest degradation (4.9%, or 27.5 Mha).

The deforestation and forest degradation areas of the single countries do not add up to the Pan-Amazon statistics, as for the country statistics also humid forest areas outside the Amazon region are considered by JRC-TMF data, as e.g. the Choco Forest on the Colombian Pacific coast or the Mata Atlântica in Brazil.

[20] https://developers.google.com/earth-engine/datasets/catalog/FAO_GAUL_2015_level0

Figure 3. Distribution of accumulated JRC-TMF forest disturbances during 2023, i.e. the sum of deforestation and forest degradation (above an area of 20 km²) within 50 km X 50 km grid cells in the Pan-Amazon humid forest (red circles). The Country borders are shown as black lines, major roads as grey lines. Background: TMF forest cover change map, status 2023. Image width ca. 3,500 km.



Source: JRC

For the countries other than Brazil, the forest disturbances mostly occur close to the borders of the Amazon biome, e.g. showing the deforestation hot spot at the Northern border of the Colombian Amazon and some forest cover change activities on the western Amazon borders in Peru and Ecuador (**Figure 3**). Specifically, in Brazil and Peru, new deforestation frontiers are created along the mayor highways cutting through the Amazon forest (e.g. the BR-319, BR-230, BR-163 and BR-364 in Brazil, and the 30C in Peru), i.e. forest disturbances often occur along these transport corridors and along big rivers. In the Southern and Eastern Amazon multiple access routes to the forest exist, thus the forest disturbance areas are more widespread rather than being concentrated along single major roads. An exception in 2023 is the area of drought on the Rio Negro, which is not bound to road or river access. Examples of different types of Amazon forest disturbances in 2023 are shown in **Figure 4**, **Figure 5**, **Figure 6** and **Figure 7**.

Figure 4. (Figure 3 A) Examples of large-scale deforestation 2023 near the town of Cachoeira da Serra on the BR-163, Left: Sl-2 image from 2022, centre: S-2 image from late 2023, right: TMF mapping of 2023 forest cover change. Image width: 35 km

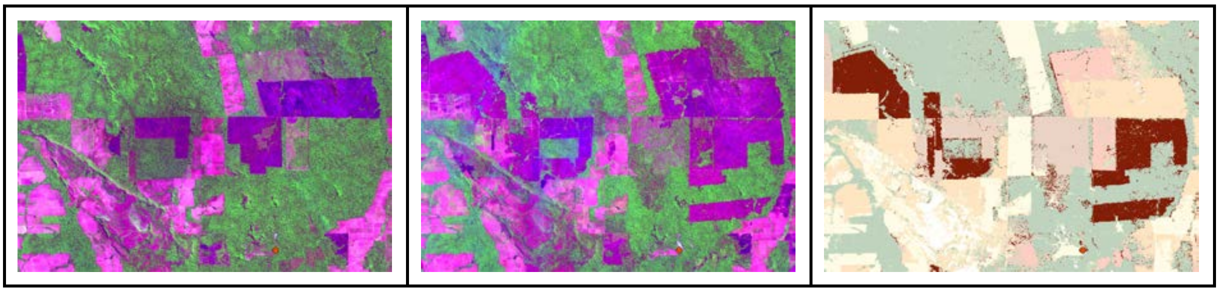


Figure 5. (Figure 3 B) Example of burned forest 2023 in Bolivia near the town of Yukumo, Left: Sl-2 image from 2022, centre: S-2 image from late 2023, right: TMF mapping of 2023 forest cover change. Image width: 35 km

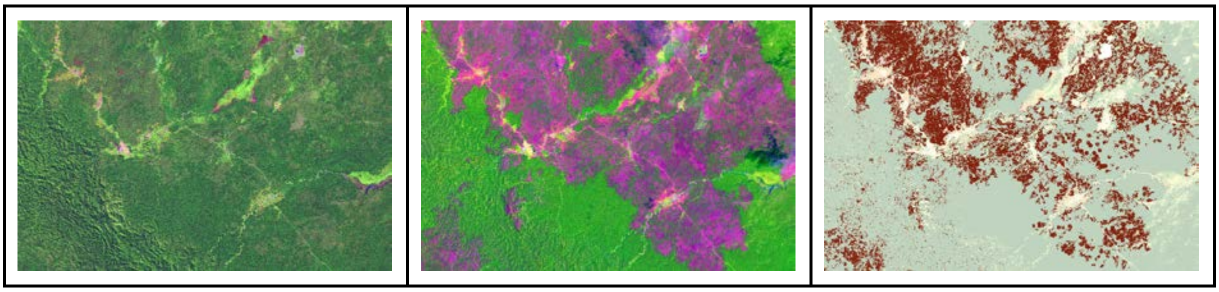


Figure 6. (Figure 3 C) Example of extreme drought 2023 in the Brazilian Amazon, near the town of Barcelos on the Rio Negro, Left: Sl-2 image from 2022, centre: S-2 image from late 2023, right: TMF mapping of 2023 forest cover change. Image width: 35 km

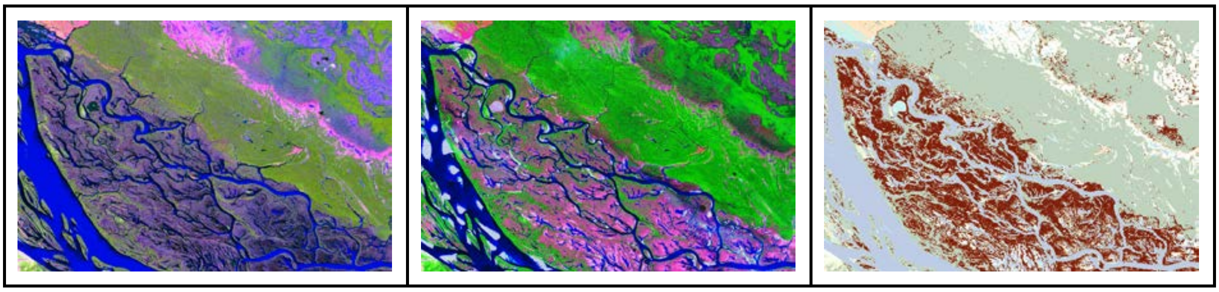
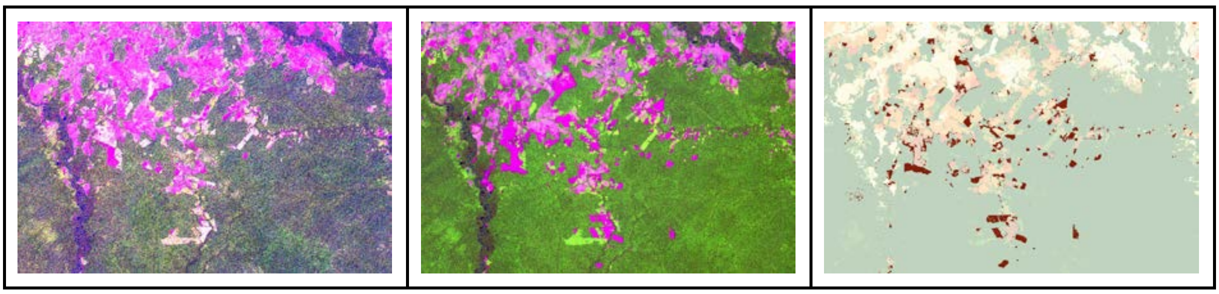


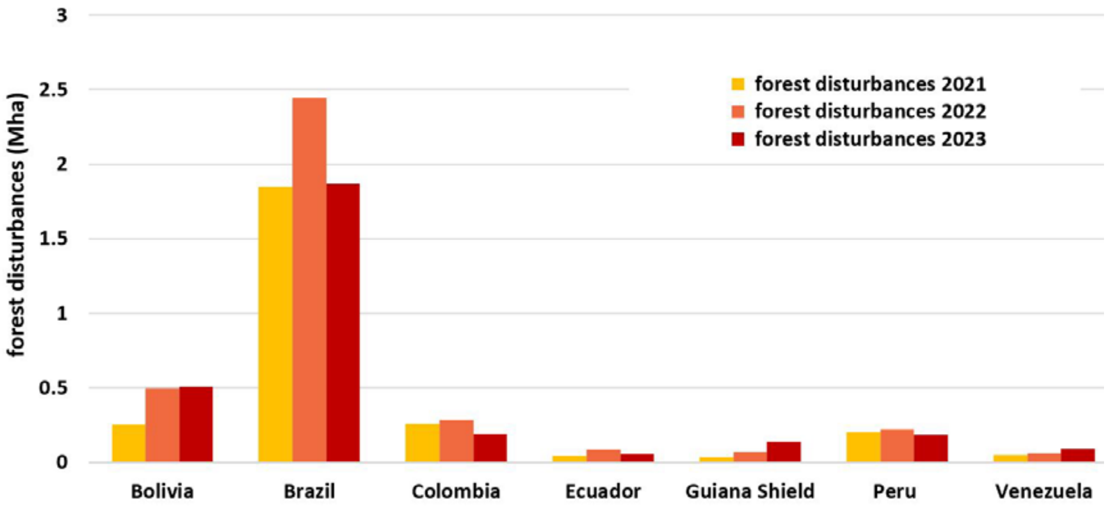
Figure 7. (Figure 3 D) Example of small-scale deforestation 2023 in the Colombian Amazon, near the town of Calamar, Left: Sl-2 image from 2022, centre: S-2 image from late 2023, right: TMF mapping of 2023 forest cover change. Image width: 35 km



Source Figures 4-7: USGS/JRC

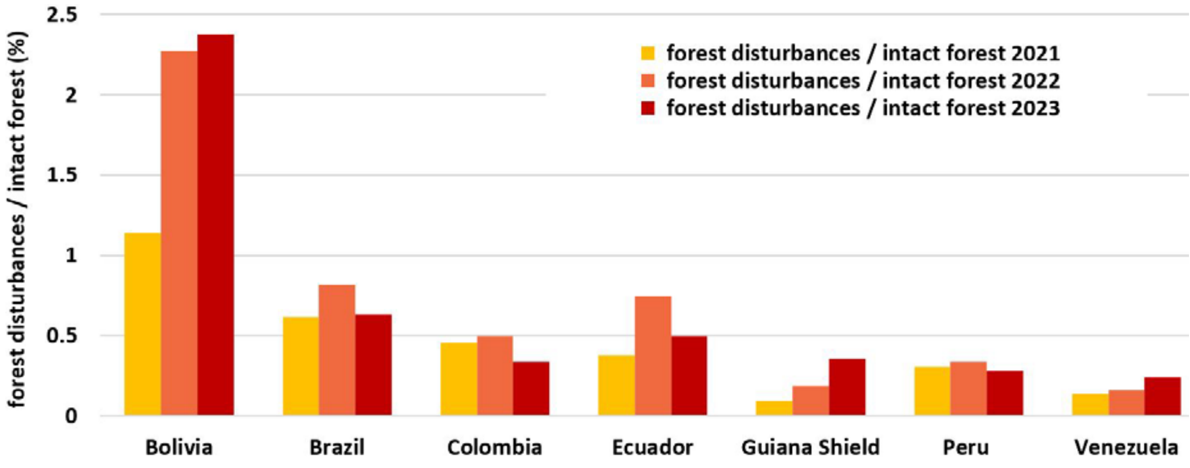
The Amazon basin country statistics regarding the forest disturbance areas in 2021-2023 show that Brazil was highest in absolute values (according to the JRC-TMF data), which is not surprising, given the country's large share of the Amazon forest and current forest disturbance dynamics (**Figure 8**). However, if the areas of forest disturbances are related to the country areas of remaining intact humid forest (**Figure 9**), Bolivia has the highest incidence by far in all three years, with a distance to the other countries that is specifically high in 2022 and 2023. At the same time, disturbances in the Guiana Shield are constantly rising, overtaking Peru and Colombia in 2023. The country statistics cover the countries' rainforests, including humid forest outside the Amazon region.

Figure 8. Disturbed humid forest area (deforestation and forest degradation) during years 2021, 2022 and 2023 for Amazon countries, according to JRC-TMF data.



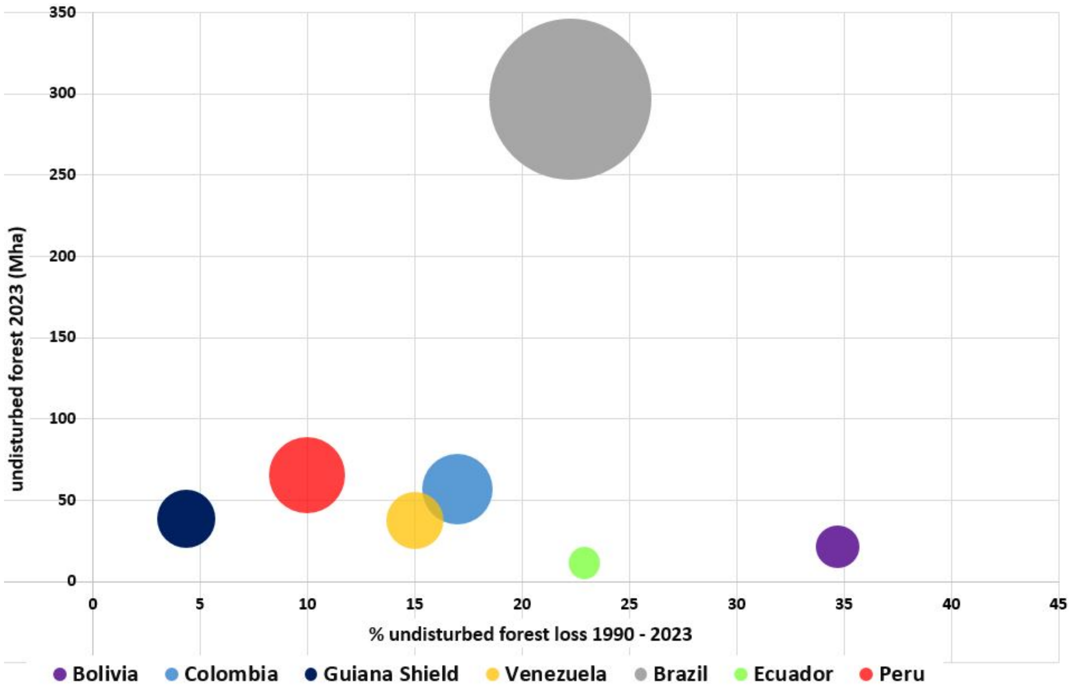
Source: JRC

Figure 9. Percentage of disturbed forest area (deforestation and forest degradation) during years 2021, 2022 and 2023 in relation to remaining intact moist forests for Amazon countries, according to JRC-TMF data.



Source: JRC

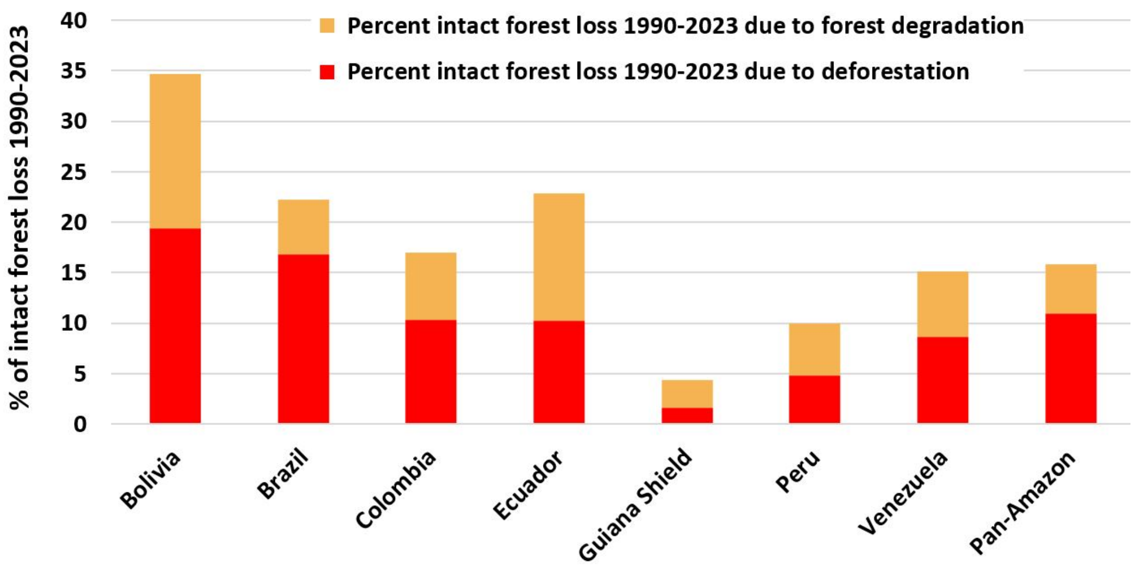
Figure 10. Area of undisturbed moist forest 2023 in the Amazon countries and regions (Guiana Shield, Pan-Amazon) and the percentage of forest loss from 1990-2023. The circle size is proportional to the countries' area of undisturbed forest 2023.



Source: JRC

Bolivia shows with 34.7% by far the highest percentage of intact humid forest loss in the past 34 years, followed by Ecuador (22.9%) and Brazil (22.3%). The smallest percentages are found in the Guiana Shield countries (4.4%) and Peru (10%) (**Figure 10**). The whole Pan-Amazon region shows a 15.8% loss of intact humid tropical forest. Overall, Bolivia and Ecuador have the highest loss of intact forest over 34 years of mapping. The Guiana Shield countries, Ecuador and Peru have the highest average percentage of forest degradation on a year-by-year basis from 1990-2023 (**Figure 11**).

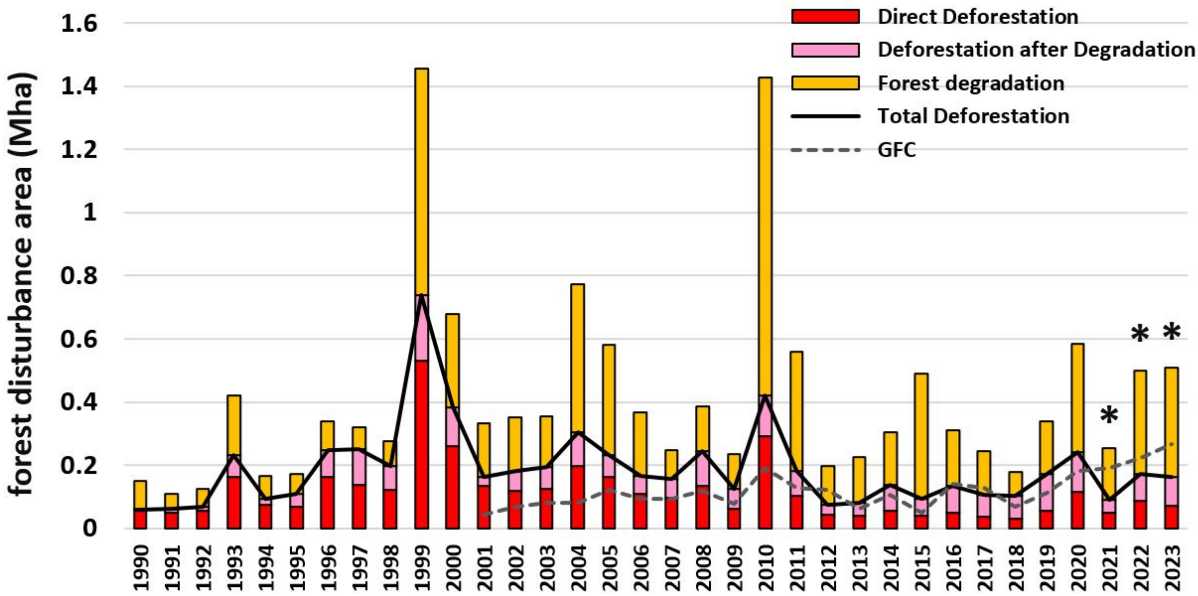
Figure 11. Overall percentage of intact forest loss 1990-2023, with average yearly forest loss class for Amazon countries and regions due to deforestation and forest degradation.



Source: JRC

2.2 Bolivia

Figure 12. Forest disturbances in the Bolivian humid forest from 1990 to 2023, according to JRC-TMF. Tree cover loss estimates from GFC appear as grey dashed line.



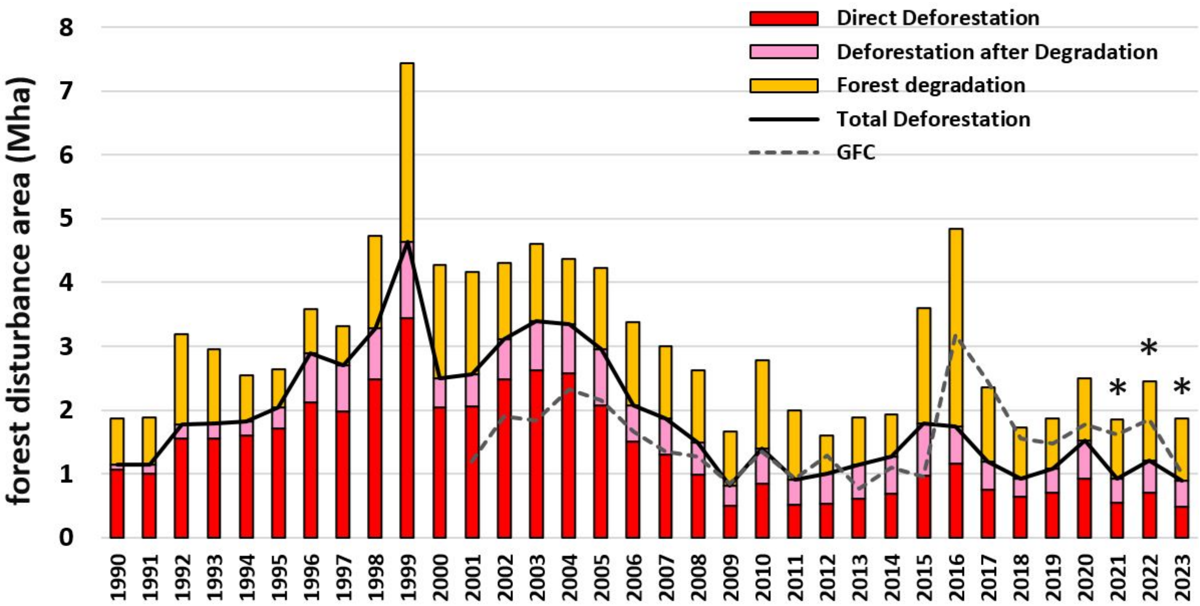
Source: JRC

The forest disturbances for Bolivian humid forests in the last 34 years show the highest peaks in years of severe forest fires, as for the years 1999 and 2010 [53,54]. In 2023, altogether 5,097 km^2 of humid forest were either deforested or degraded, which constitutes an increase of 2.1% compared to 2022.

In the past 34 years Bolivia has lost 34.7% of its intact humid forest in 1990 (328,056 km^2), either by deforestation (19.4%, or 63,736 km^2) or forest degradation (15.3%, or 50,048 km^2).

2.3 Brazil

Figure 13. Forest disturbances in the Brazilian humid forest from 1990 to 2023, according to JRC-TMF. Tree cover loss estimates from GFC appear as grey dashed line.



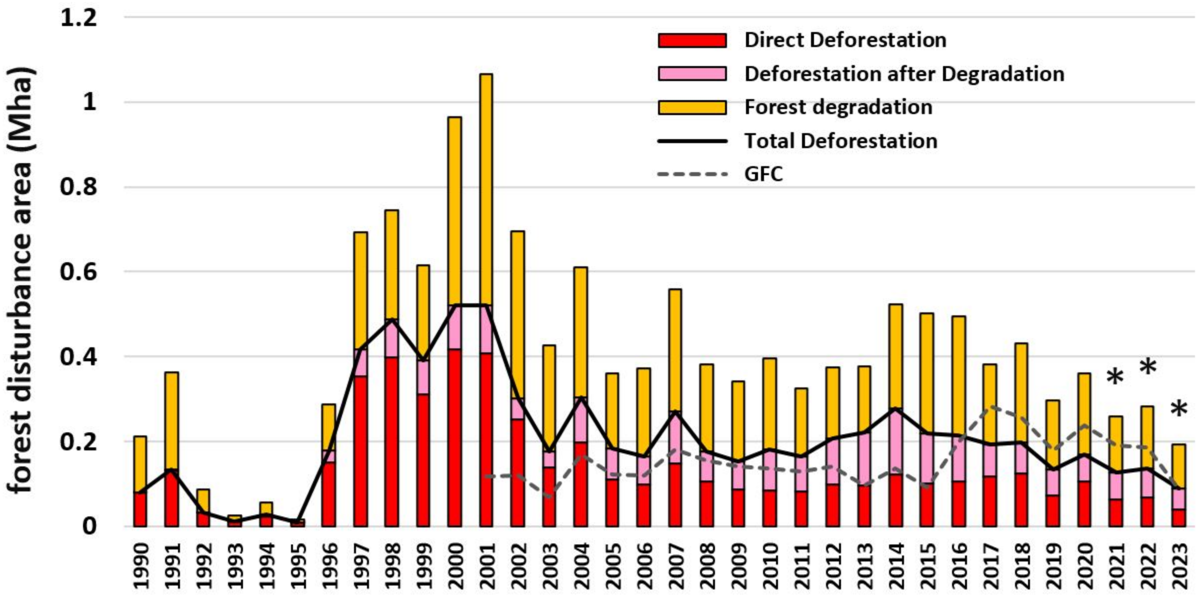
Source: JRC

The Amazon being the Brazilian region undergoing most changes in humid forest cover, its forest dynamics clearly drive the overall Brazilian humid forest cover change statistics reported by JRC-TMF data. The decrease of the Amazon deforestation after 2004 and the peaks in forest degradation, mostly due to forest fires of 1999, 2010 and 2015-2017, are visible in the Brazilian Legal Amazon and the Brazilian statistics from JRC-TMF.

According to JRC-TMF statistics, 18,701 km^2 of forest were either deforested or degraded in 2023 in the Brazilian humid forest (i.e. Amazon and Atlantic forests), constituting a decrease of 23.5% compared to 2022. In the past 34 years Brazil has lost 22.3% of its intact humid forest in 1990 (3,816,270 km^2), either by deforestation (16.8%, or 642,683 km^2) or forest degradation (5.4%, or 207,330 km^2).

2.4 Colombia

Figure 14. Forest disturbances in Colombian humid forest from 1990 to 2023, according to JRC-TMF. Tree cover loss estimates from GFC appear as grey dashed line.

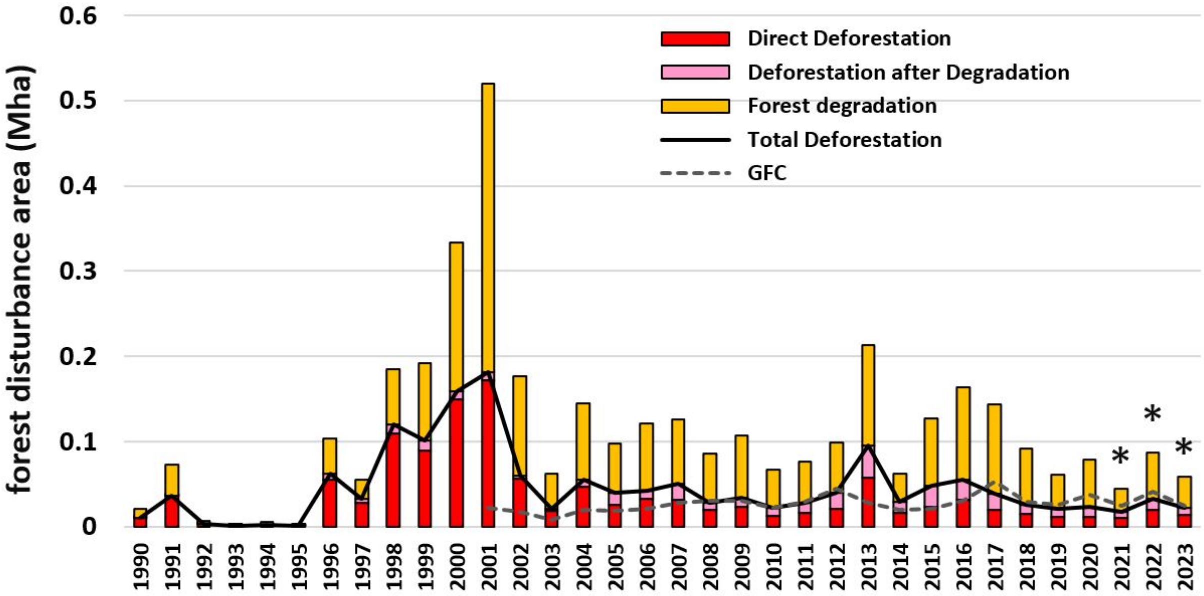


Source: JRC

The Colombian humid forest disturbance area of 2023 is 1,927 km^2, which constitutes a decrease of 32% in comparison with 2022. The overall forest disturbance area 2023 is the lowest since 1996. In the past 34 years, Colombia has lost 17% of its intact humid forest in 1990 (681,183 km^2), either by deforestation (10.4%, or 70,675 km^2) or forest degradation (6.6%, or 45,110 km^2).

2.5 Ecuador

Figure 15. Forest disturbances in Ecuadorian humid forest from 1990 to 2023, according to JRC-TMF. Tree cover loss estimates from GFC appear as grey dashed line.

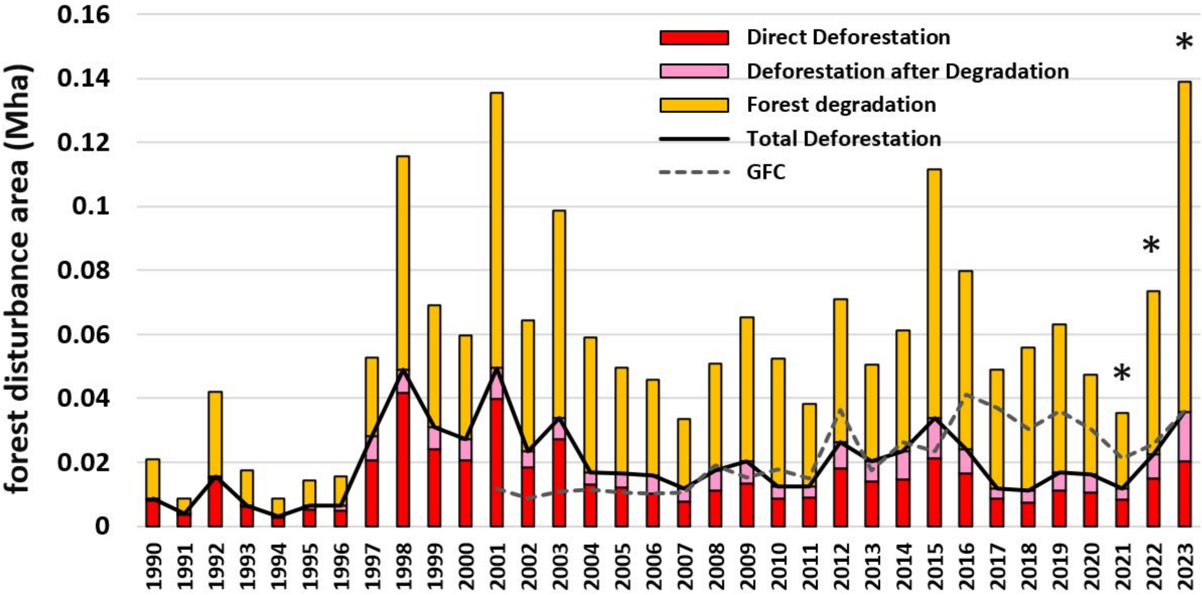


Source: JRC

The Ecuadorian humid forest disturbance area in 2023 decreased by 33.1% compared to the previous year. Altogether 581 km² of forest have been either deforested or degraded. In the past 34 years Ecuador has lost 22.9% of its intact humid forest in 1990 (149,534 km²), either by deforestation (10.3%, or 15,361 km²) or forest degradation (12.6%, or 188,649 km²).

2.6 Guiana Shield (Guyana, Suriname and French Guiana)

Figure 16. Forest disturbances in the Guiana Shield's humid forest from 1990 to 2023, according to JRC-TMF. Tree cover loss estimates from GFC appear as grey dashed line.



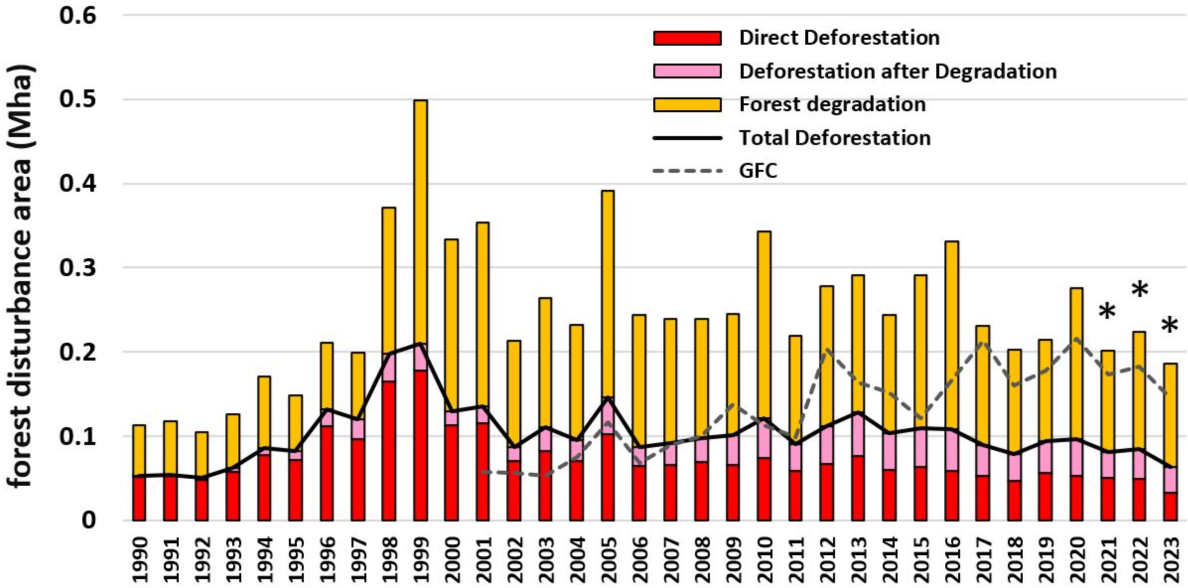
Source: JRC

In 2023, forest disturbances in the Guiana Shield (Guyana, Suriname and French Guiana) show an increase of 89.6%, compared to 2023, adding up to 1,388 km^2. In the past 34 years the Guiana Shield countries have lost 4.4% of their intact humid forest in 1990 (403,527 km^2), either by deforestation (1.7%, or 6,695 km^2) or forest degradation (2.7%, or 11,015 km^2). This substantial increase of forest disturbances in 2024, particularly in Guyana (+133%) and Suriname (+73%), may be partially attributed to illegal logging and mining activities in Indigenous territories[21]. The relative increase of forest disturbances in the past two years is the highest of all Amazon countries or regions.

[21] https://learn.landcoalition.org/en/resources/saamaka-vs-suriname-case/

2.7 Peru

Figure 17. Forest disturbances in Peruvian humid forest from 1990 to 2023, according to JRC-TMF. Tree cover loss estimates from GFC appear as grey dashed line.

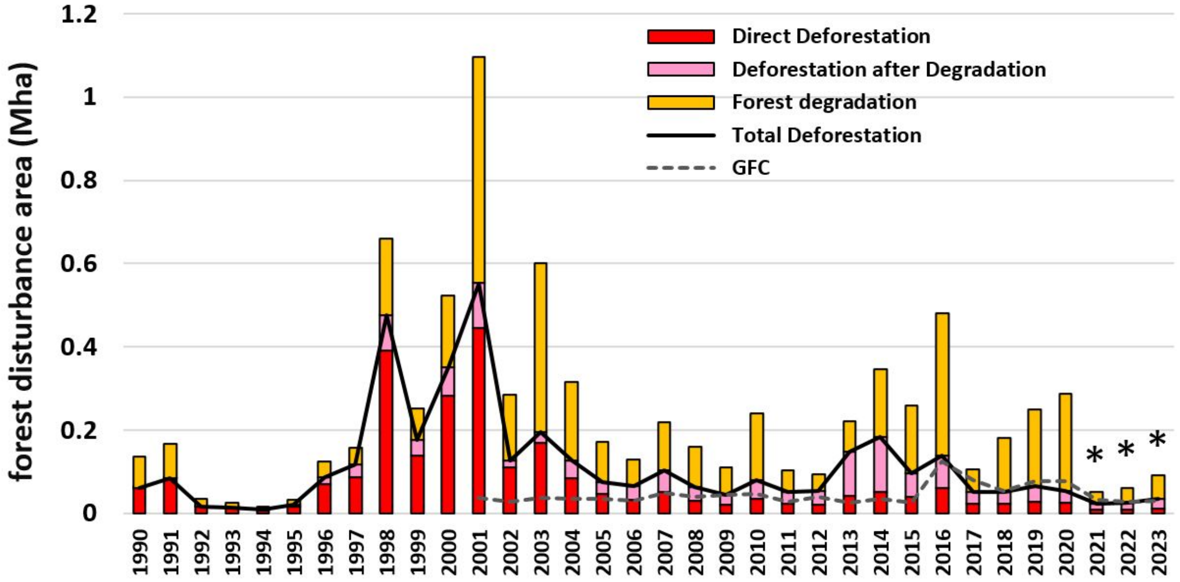


Source: JRC

The decrease of the 2023 forest disturbance area, compared to 2022, is 16.9% (1,857 km^2 in 2023 vs. 2,233 km^2 in 2022). In the past 34 years Peru has lost nearly 10% of its intact humid forest in 1990 (726,587 km^2), either by deforestation (4.8%, or 34,849 km^2) or forest degradation (5.2%, or 37,810 km^2).

2.8 Venezuela

Figure 18. Forest disturbances in Venezuelan humid forest from 1990 to 2023, according to JRC-TMF. Tree cover loss estimates from GFC appear as grey dashed line.



Source: JRC

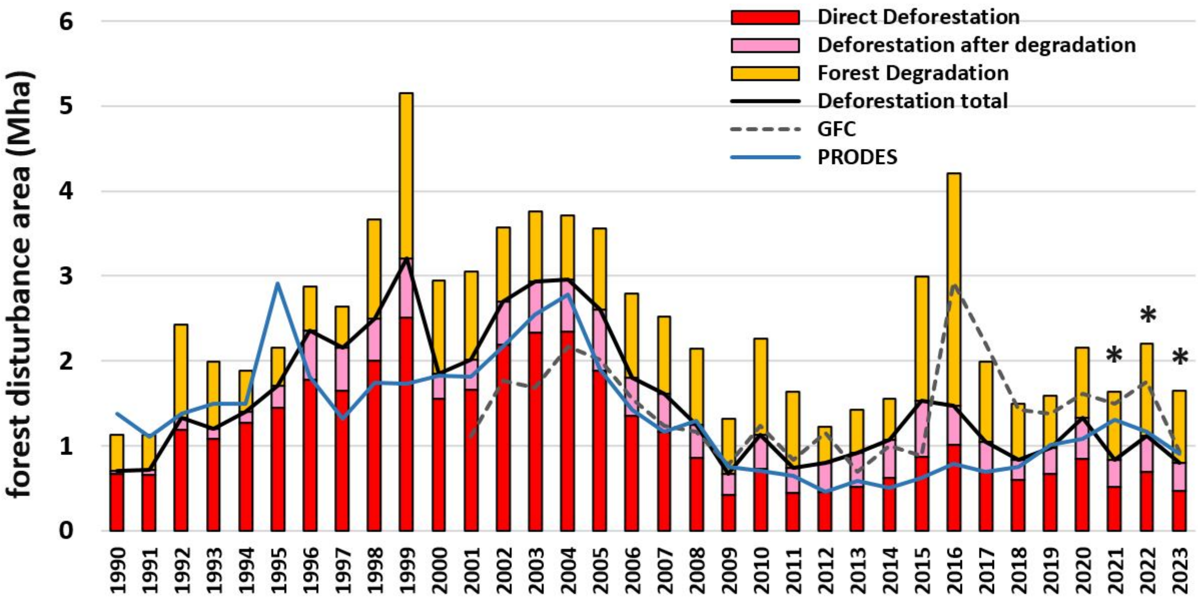
Venezuela showed an increase of forest disturbance areas in 2023 on a relatively low level, compared to the other Amazon countries (see also **Figure 9**), with 901 km^2 of humid forest having been either deforested or degraded. Compared to 2022, forest disturbances increased by 49.4% in 2023. In the past 34 years, Venezuela has lost 15% of its intact humid forest in 1990 (441,151 km^2), either by deforestation (8.6%, or 38,133 km^2) or forest degradation (6.4% or 28,039 km^2).

2.9 Comparison of JRC-TMF and INPE-PRODES deforestation estimates for the Brazilian Legal Amazon

The overall annual new disturbed forest area in the BLA decreased by 25.5% from 22,074 km^2 in 2022 to 16,455 km^2 in 2023.

As mentioned before, the distinction between forest degradation and deforestation events for 2023 can only be done three years from now, once a potential forest regrowth can be assessed and confirmed from satellite imagery. At the beginning of 2024, the consolidated attribution of the two classes was made for year 2020 for the first time. The relative class distribution within the overall disturbed forest areas for years 2021 to 2023 (red + pink bars in figure 19) is based on a 10-year historical average.

Figure 19. Annual deforestation and forest degradation in the BLA from 1990 to 2023, according to JRC-TMF data. Direct deforestation appears in red, deforestation after degradation in pink, while forest degradation appears in pink. For comparison, INPE-PRODES and GFC deforestation estimates appear as blue and grey dashed lines, respectively.



Source: JRC

In the past 23 years the Brazilian Legal Amazon has lost 19.5% (or 68.5 Mha) of its intact humid forest of 1990 (351.3 Mha), either by deforestation (14.9%, or 52.2 Mha) or forest degradation (4.6%, or 16.3 Mha). The numbers given here are not directly related to the bars in Figure 19, as many areas of forest degradation (yellow bars) in early years have been deforested at a later stage.

The current JRC-TMF report's estimates of deforestation and forest degradation in the Amazon region from 1990-2023 are different to a certain extent, compared e.g. to last year's estimates [3]. This is due to the complete reprocessing of the USGS' Landsat archive [55], i.e. different satellite imagery inserted into the JRC-TMF processing chain results in different forest cover change statistics. More information on this topic is found in Annex 1.

3 Monitoring deforestation and forest degradation in the Brazilian Legal Amazon: estimates from PRODES and DETER for 2023(/24)

3.1 INPE-PRODES

The PRODES consolidated statistics on the deforestation of humid forest in the Brazilian Legal Amazon (BLA) showed 6,288 km^2 for the period of August 2023 until July 2024 [22], which constitutes a decrease of 30.6%% in comparison with the corresponding period in 2022/23 (**Figure 20**). For the Cerrado biome, which partly lies in the Brazilian Legal Amazon, the deforestation area given by INPE for the same period was 8,174 km^2, a decrease of 25.8% compared to 2022/23 [23] (**Figure 21**).

Figure 20. Yearly consolidated deforestation estimates for the Brazilian Legal Amazon reported by INPE-PRODES.

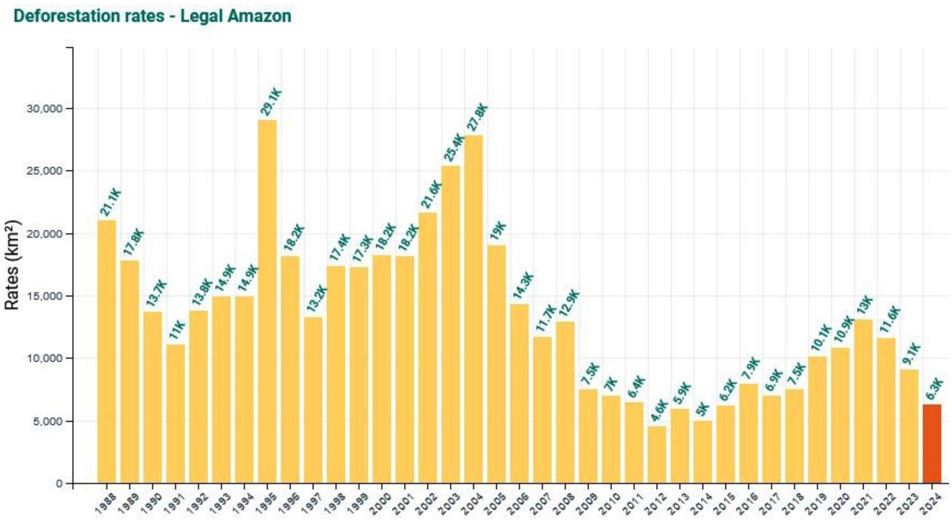
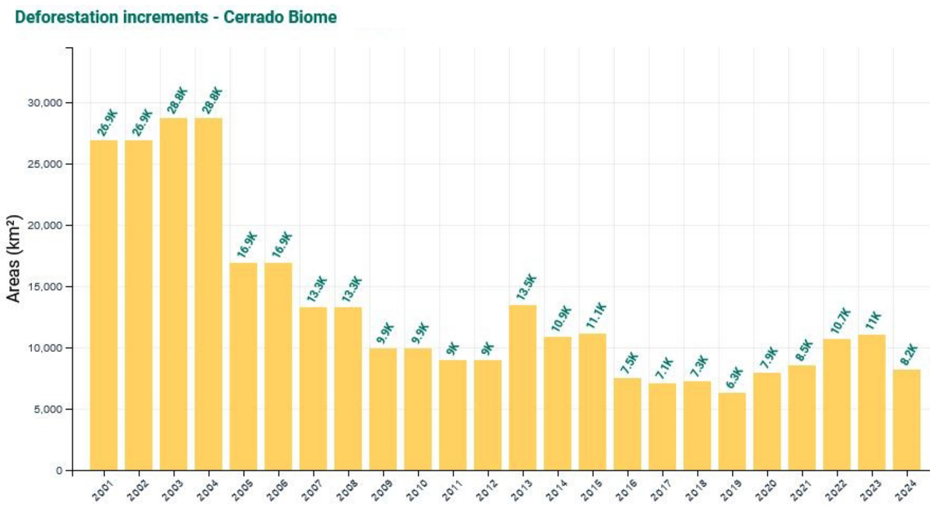


Figure 21. Yearly consolidated deforestation estimates for the Brazilian Cerrado biome reported by INPE-PRODES.



Figures 20 and 21: Source: INPE

[22] http://terrabrasilis.dpi.inpe.br/app/dashboard/deforestation/biomes/legal_amazon/rates
[23] http://terrabrasilis.dpi.inpe.br/app/dashboard/deforestation/biomes/cerrado/increments

3.2 INPE-DETER deforestation and forest degradation alerts

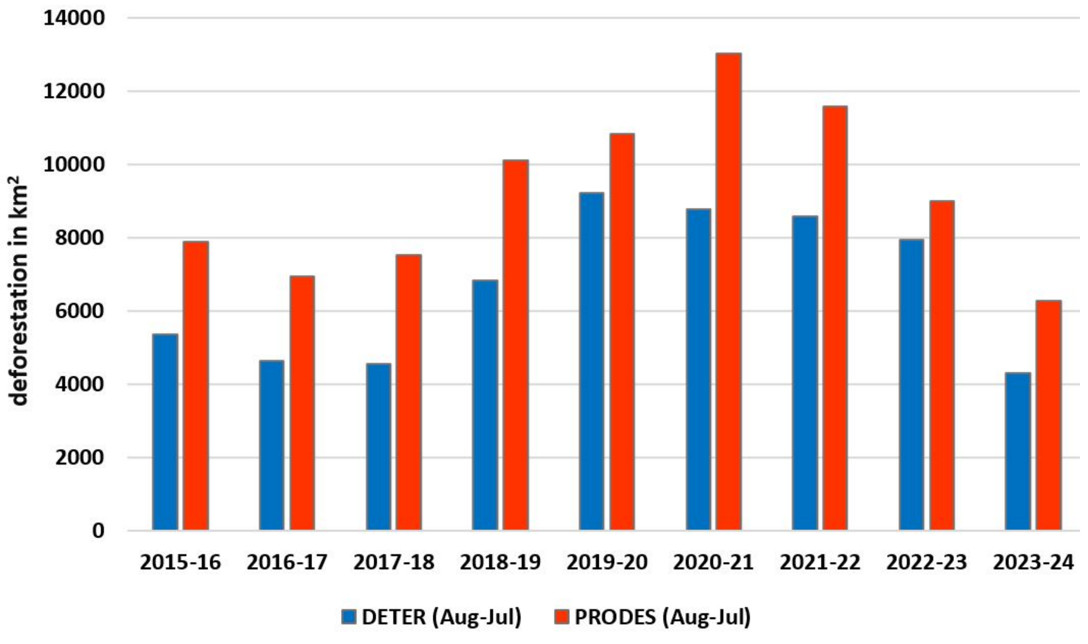
3.2.1 INPE-DETER deforestation alerts 2023(/24)

The INPE-DETER near real-time deforestation detection system produces deforestation alerts (for the Brazilian Amazon and Cerrado biomes separately) and forest degradation alerts (Amazon biome only), based on daily low-resolution satellite imagery. The system gives first trends about decrease or increase of monthly forest cover change in the two regions and provides substantial input to the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), responsible for the surveillance and control of deforestation in the Amazon [56].

The trend derived from the monthly INPE-DETER deforestation alerts over annual periods are usually consistent (increase or decrease) with the trend reported through the official consolidated annual deforestation figures for the BLA from INPE-PRODES. The comparison between 12 months of DETER accumulated monthly near-real-time alerts (August-July period) and official PRODES deforestation statistics from 2015/2016 to 2023/2024 periods shows significant differences but with an overall consistent trend (**Figure 22**). The yearly aggregated DETER deforestation alert areas (Aug-Jul period) represent 68.7% of the PRODES estimate for the corresponding period in 2023/2024. This is a middle-range percentage (the lowest being 60.7% in 2017/18, the highest 88.3% in 2022/2023) with an 8-year-average of 71.8%. For the Cerrado biome, the DETER deforestation alerts capture in average (over a 7-year period) 65.7% of the PRODES deforestation estimates.

In 2024 ("calendar year", i.e. Jan-Dec) INPE-DETER deforestation alerts for the Brazilian Legal Amazon[24] recorded an area of 4,321 km^2, which constitutes a decrease of 45.7% compared to 2023. If the PRODES "reference yearly period" (Aug-Jul) is taken into account, the estimates show a decrease from August 2022 – July 2023 of 7.4%, compared to the previous reference year period (**Figure 22, Figure 23**).

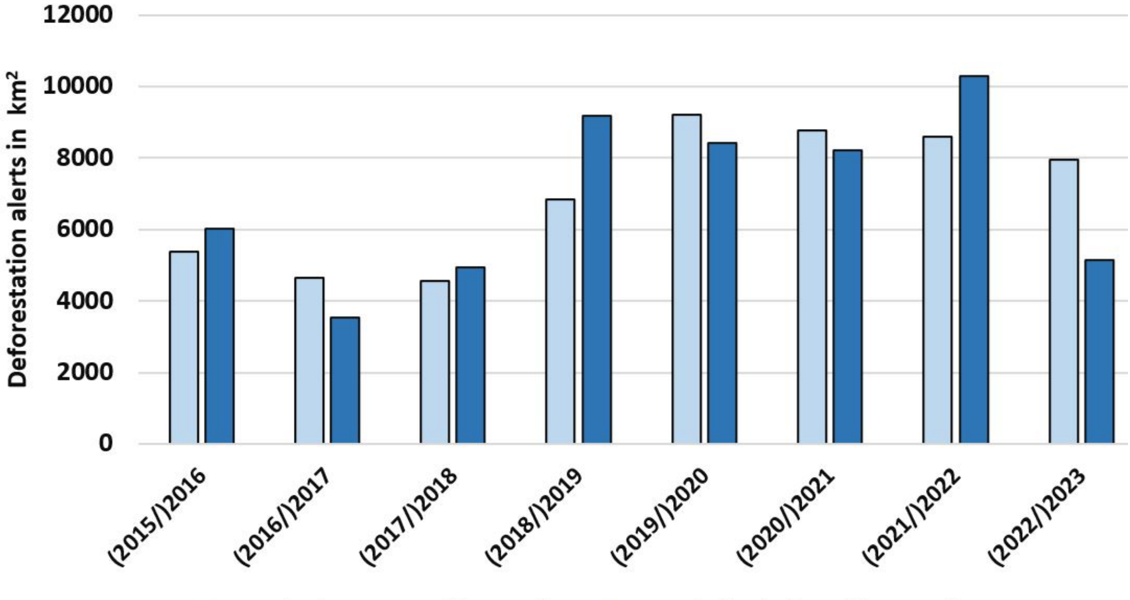
Figure 22. INPE-DETER yearly aggregation of deforestation near-real-time alerts (blue bars) and INPE-PRODES official consolidated deforestation estimates (red bars) from 2015/16 – 2023/24 (August-July) for the BLA



Source: INPE/JRC

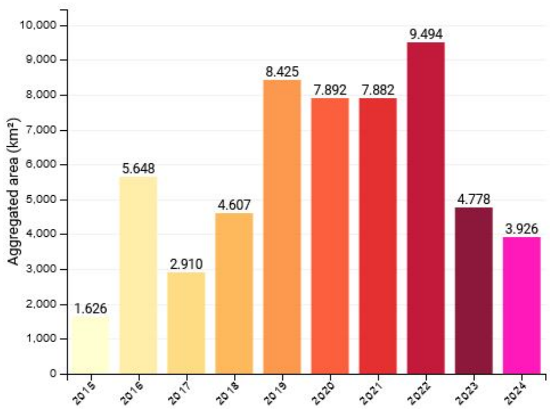
[24] http://terrabrasilis.dpi.inpe.br/app/dashboard/alerts/legal/amazon/aggregated/

Figure 23. Difference between ‘reference year’ (August-July) and ‘calendar year’ (January-December) accumulation of INPE-DETER monthly deforestation alerts.



Source: INPE/JRC

Figure 24. Monthly statistics of INPE-DETER deforestation alerts 2015-2024 for the BLA (January – October)



Source: INPE

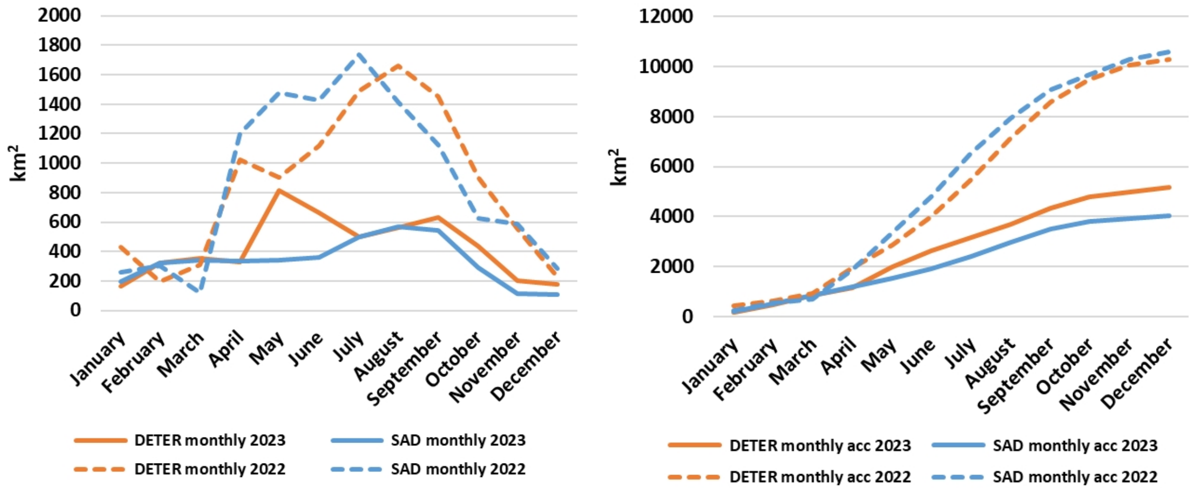
In the first ten months of 2024, the alert areas of deforestation in the Brazilian Legal Amazon decreased by 17.8% in the first ten months, compared to the same period in 2023 (4,778 km^2 in 2023 vs. 3,926 km^2 in 2024), according to INPE-DETER. The effects of a more progressive Brazilian environmental policy and the strengthening of institutions dealing with environmental protection (INPE, IBAMA, ICMBio) can be observed when comparing the years of 2023 and 2024 with the four precedent years.

For the Cerrado biome, a decrease of 24.5% in deforestation alert area is recorded by INPE-DETER for the first ten months of 2024, compared to the same period in the previous year.

3.2.2 INPE-DETER deforestation alerts vs. IMAZON-SAD deforestation alerts 2023 and first ten months of 2024

While INPE is a governmental agency, IMAZON, as a non-governmental organisation, tracks deforestation independently of the Brazilian Government. Their deforestation tracking systems have a similar scope and area of interest, but use different data and image analyses techniques. INPE uses optical imagery with a spatial resolution of 64 m from the WFI sensor on board of the CBERS-4A satellite with a 3-day repetition rate[25] to detect newly deforested areas in near-real time. IMAZON uses different optical and radar satellite data (Landsat 8, Sentinel-1 and Sentinel-2)[26]. Both systems report deforestation alerts on a monthly basis, while DETER has the mandate to provide deforestation detections on a daily basis to law enforcement entities like IBAMA or ICMBio. In 2023, DETER reports 27.9% more than SAD (5154 km^2 vs. 4030 km^2), while both systems show a clear overall decrease of deforestation alert areas. While DETER reports a decrease of 49.9% for 2023 (10278 km^2 reported in 2022), SAD numbers of 2023 decrease by 61.9% (10573 km^2 reported in 2022) (**Figure 25**).

Figure 25. Monthly deforestation alerts from January – December 2022 and 2023 (left), according to INPE-DETER and IMAZON-SAD, with accumulated monthly deforestation alerts of both systems (right)

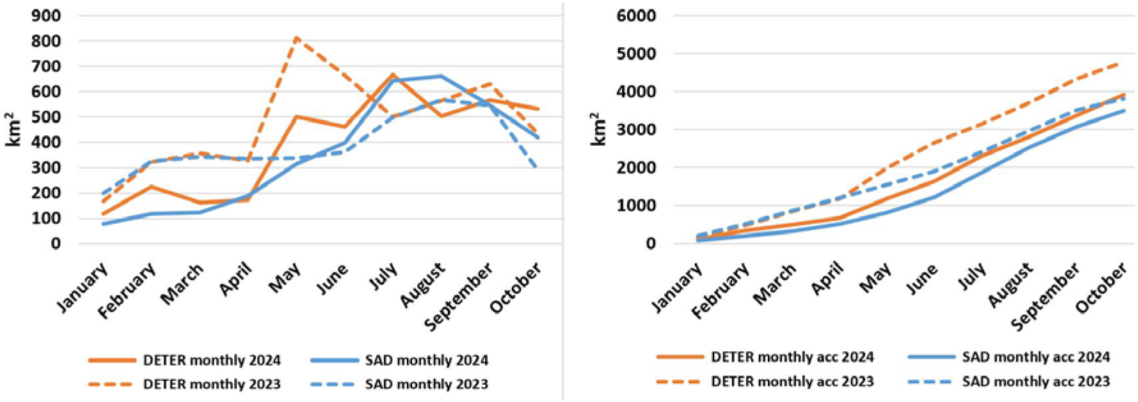


Source: INPE/IMAZON/JRC

Both systems report a decrease in deforestation alerts for the first 10 months of 2024, compared to the same period in 2023 (**Figure 26**), with 17.8% for DETER and 8.3% for SAD. DETER reports accumulated 3,926 km^2 of deforestation alerts, while SAD reports 3,409 km^2.

[25] www.obt.inpe.br/OBT/assuntos/programas/amazonia/prodes/pdfs/Metodologia_Prodes_Deter_revisada.pdf
[26] https://imazon.org.br/publicacoes/faq-sad/

Figure 26. Monthly deforestation alerts (left) from the period January – October for year 2023 and 2024, according to INPE-DETER and IMAZON-SAD, and monthly accumulated monthly deforestation alerts of both systems (right).



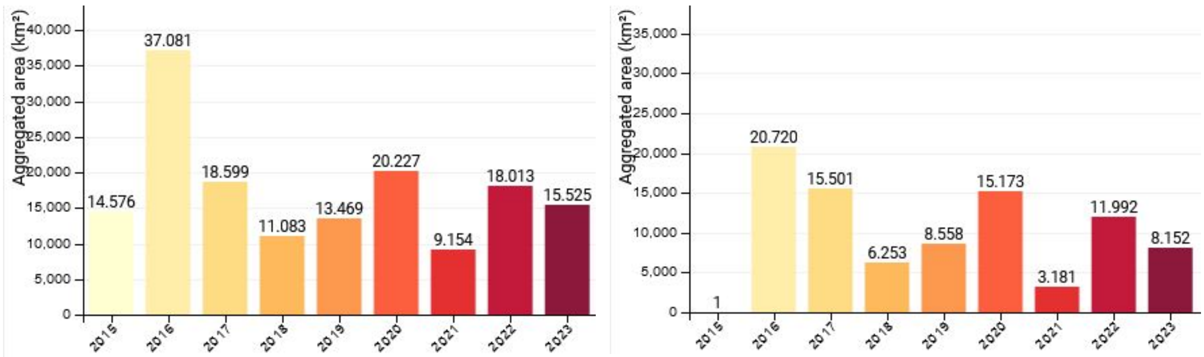
Source: INPE/IMAZON/JRC

3.3 INPE-DETER forest degradation alerts

3.3.1 INPE-DETER forest degradation alerts 2023

The INPE-DETER alerts on forest degradation areas comprise the classes ‘selective logging’, ‘forest fires’ and ‘unspecified forest degradation’. The statistics for 2023 show a decrease of overall BLA forest degradation of 13.0% (**Figure 27**). The driver of this reduction is the decrease of forest fires by 31.3% between 2022 and 2023 (Jan-Dec)[27], while both selective logging and “unspecified degradation” alerts increased in 2023 (21.2% and 27.4%, respectively).

Figure 27. left: INPE-DETER forest degradation alerts for the BLA 2016-2023, right: INPE-DETER forest fire alerts 2016-2023 for the BLA (forest fire being a sub-class of the forest degradation alerts).



Source: INPE

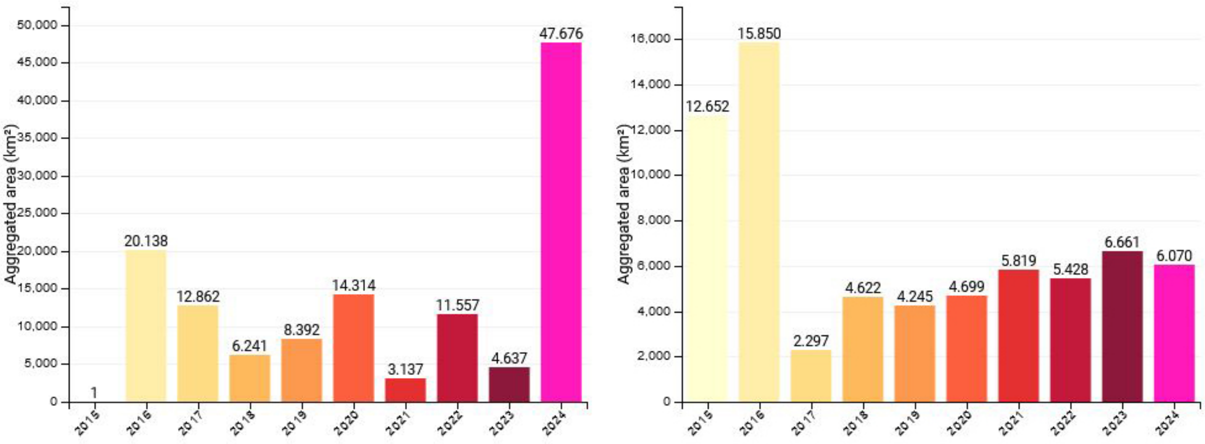
3.3.2 INPE-DETER forest degradation alerts 2024

In the first ten months of 2024, the areas of deforestation in the Brazilian Legal Amazon decreased by 17.8% compared to the same period in 2023 (4,778 km^2 in 2023 vs. 3,926 km^2 in 2024), while the area of forest degradation increased by 375.7% (11,299 km^2 in 2023 vs. 53,748 km^2 in 2024), according to the INPE-DETER alert system. In this context, it is important to note that monthly alert estimates have a high uncertainty in particular due to persisting cloud cover that can limit the detection of forest cover changes during specific months (rainy season) and attribute such changes later during following drier months. In consequence, comparing monthly figures has limited meaningfulness, while observing trends in accumulated figures over yearly periods gives more robust estimates.

Specifically in the months of September and October, DETER measured forest degradation alerts (in purple) that were unprecedented since 2016. Forest degradation alerts add up different causes of degradation, from different types of selective logging, fire and ‘unspecified forest degradation’.

[27] http://terrabrasilis.dpi.inpe.br/app/dashboard/alerts/legal/amazon/aggregated/

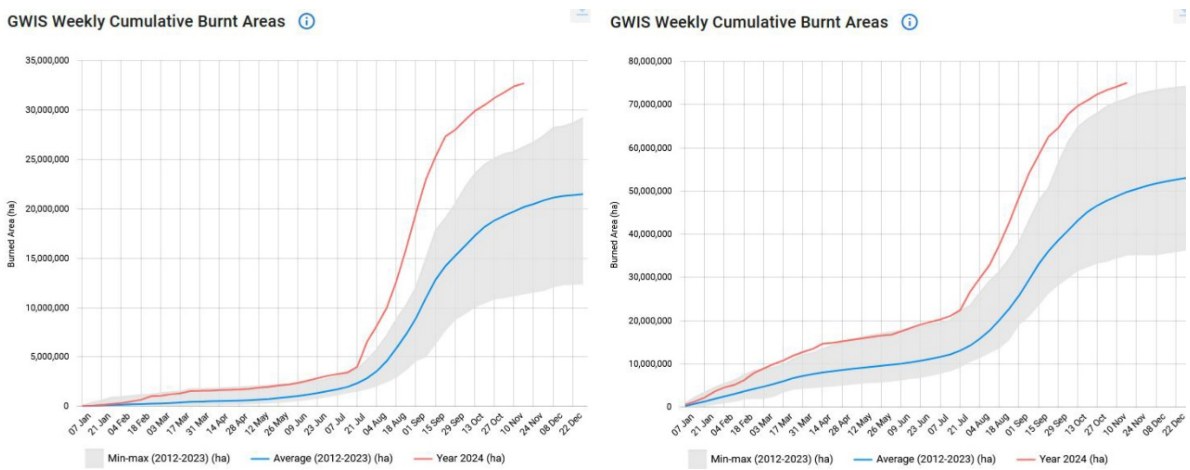
Figure 28. left: INPE-DETER accumulated forest fire alerts 2016-2024 for the BLA (Jan – Oct)[28], right: INPE-DETER accumulated alerts of selective logging and 'unspecified forest degradation' 2016-2024 for the BLA.



Source: INPE

When differentiating the Amazon accumulated monthly degradation alerts for specific degradation causes, it becomes clear that forest fires are the main cause for the sharp increase in the first ten months of 2024. Forest fire alerts increase by 928% compared to 2023, while the other causes of forest degradation (selective logging and 'unspecified forest degradation') roughly stay on the same level over the years (decrease of 8.9% between 2023 and 2024). The huge increase of fires in the region is confirmed by GWIS[29] that maps burned areas globally, for the Brazilian Amazon as well as for South America the red line representing 2024, burned areas are way above the maximum from 2012-2023.

Figure 29. GWIS burned areas, left: for the Brazilian Legal Amazon, right for South America.



Source: JRC

[28] http://terrabrasilis.dpi.inpe.br/app/dashboard/alerts/legal/amazon/aggregated/
[29] https://gwis.jrc.ec.europa.eu/apps/gwis.statistics/seasonaltrend

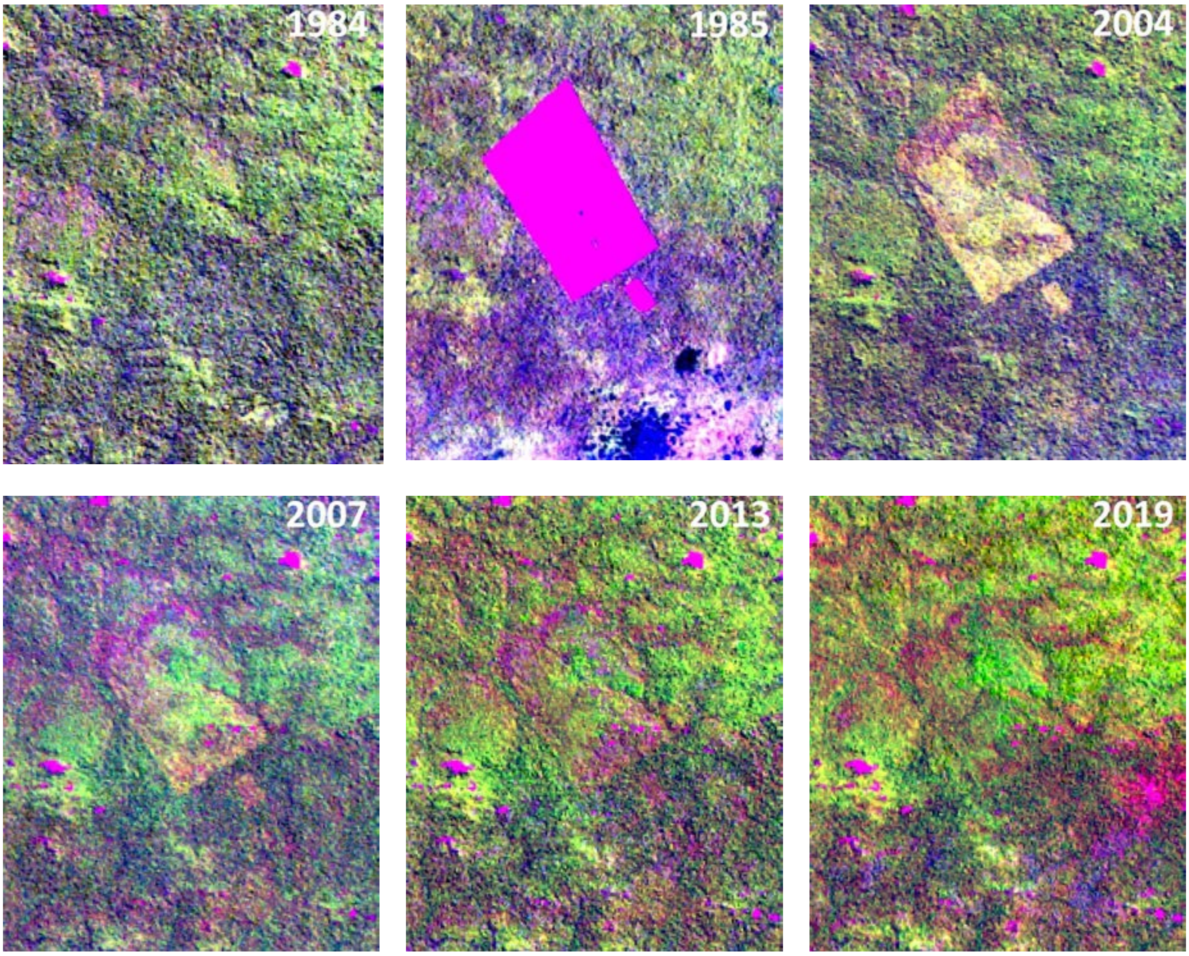
4 Secondary forests in the Amazon

4.1 Introduction

Secondary forests are new forests that grow in places where the original forest had been removed, often due to the expansion of pastures or crop fields [57,58]. In many tropical countries, including parts of the Amazon, these secondary forests are becoming more common as they reclaim areas that were once deforested [59].

Secondary forests have a lot of potential to help mitigating climate change by capturing carbon dioxide (CO_2) from the atmosphere [60–62]. They also play a crucial role in supporting wildlife, improving water regulation, and protecting soil [63]. While secondary forests are incredibly valuable, within policy relevant timeframes they can never fully replace the original, primary forests [64,65] in terms of their biodiversity, structure and composition.

Figure 30. Transition from primary to secondary forest as observed by Landsat satellites. From left to right, above: primary forest, deforestation, usage as cattle pasture, below: signs of pasture abandonment, young secondary forest, consolidated secondary forest. The acquisition year is indicated at the top-right of each panel. Image width ~6 km, at 58.22°W 10.92°S.



Source: USGS

Secondary forests are also important for preserving and restoring tropical ecosystems. They help buffer the negative effects of forest disturbance along old-growth forest edges and can act as natural corridors that connect different patches of forest [66,67]. Connectivity is vital for maintaining and rebuilding biodiversity and ecosystem health.

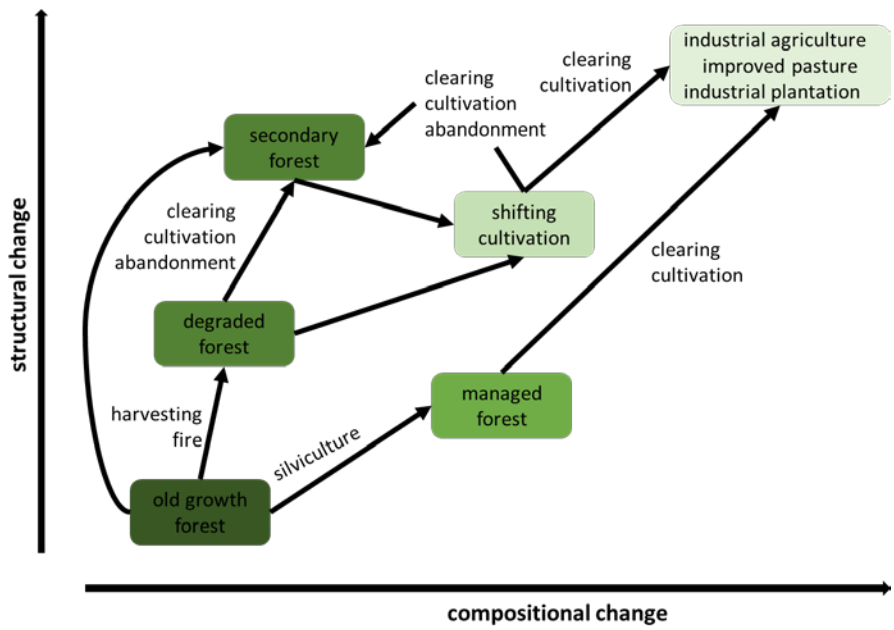
Secondary forest can be detected on satellite imagery only by taking into account the history of the forest through time series analysis (**Figure 30**), where a primary forest is deforested (1985), and converted to another land use (2004), which after some time is subsequently abandoned, allowing the regrowth of vegetation that with time will evolve into a (secondary) forest.

In this chapter, we will cover i) an overview of secondary tropical forests, including how quickly they grow and build up biomass; ii) the relationship between traditional farming practices and the development of secondary forests; iii) where secondary forests are found, how they change over time, and their extent; iv) how secondary forests are represented in JRC's Tropical Moist Forest (TMF) dataset.

4.2 The Amazon basin, secondary forests, and how fast they grow

The Amazon Basin is a massive region, covering about 7 million km^2 across South America [68]. It spans several countries: Brazil (58%), Peru (13%), Bolivia (8%), Colombia (7%), Venezuela (6%), Guyana (3%), Suriname (3%), French Guiana (1%), and Ecuador (1%). While the Food and Agriculture Organization (FAO) has a single definition of forest, namely any area over 0.5 hectares with at least 10% tree canopy cover and trees taller than 5 meters. However, forests are much more complex. Within a forest there are numerous structural and compositional changes that occur in space and time, leading to a dynamic forested landscape [69]. The authors describe old-growth forests as those with large trees, multiple layers of canopy, and diverse species. Meanwhile, secondary forests show rapid structural change but initially have low compositional change (**Figure 31**).

Figure 31. Changes in ecosystem states from tropical old-growth forests. This diagram shows the main ways that tropical old-growth forests can change over time. It highlights key drivers of these changes but does not include every possible transition. For simplicity, it omits the back transitions that might occur due to natural regrowth, afforestation, reforestation, forest management, and other restoration efforts.



Source: JRC, adapted from Putz and Redford (2010) [69].

Managed vs. degraded forests

Managed forests[30] are carefully tended for timber or other resources, leading to lower densities of valuable species and higher densities of plants that need more light. These forests are managed to be sustainable, though this depends heavily on the practices used. Unlike plantations, managed forests regenerate naturally. On the other hand, degraded forests suffer from uncontrolled or unsustainable pressures like excessive harvesting, conversion to other land uses, or fires. Degradation can range from minor damage to total conversion into non-forest areas. The line between managed and degraded forests can be blurry. Timber logging that does not follow sustainable practices often leads to irreversible damage, making it difficult to distinguish between managed and degraded forests.

Secondary forests and their growth

Secondary forests grow in areas that were completely deforested, often for cropland or pastureland. Traditional farming methods like shifting cultivation (where land is cleared with fire and used for 3-10 years before being left fallow) or low-vegetation cultures (such as grasslands or pastures) can be maintained for years before abandonment. Regrowth typically involves local species and follows a process of natural succession, which depends on factors like the period of active land use, proximity to seed sources, size of the regenerating area, and soil conditions. These lands can sometimes be converted into industrial agriculture or plantations, which use soil fertilizers and pest management, significantly altering nutrient cycles, especially for nitrogen and phosphorus.

The rate of secondary forest growth

Research shows that secondary forests in tropical regions can grow relatively quickly. Across the tropical moist biome in South America, aboveground carbon accumulation rates range from 1.5 to 4.5 tons of carbon per hectare per year in the first 30 years of regrowth [61]. This is about 11 times faster than old-growth/primary forests in quasi-equilibrium [70]. Brown and Lugo (1990) [71] found that it takes forests 60-80 years to reach a state of equilibrium. Generally, there is high variability of forest biomass regrowth rates reflecting a mixture of abiotic and biotic factors as well as human decision to let the forests grow.

Secondary forest growth rates depend on several factors, including climate, soil fertility, prior land use, and distance from remaining mature forests [59,72]. Carreiras et al. (2017) [73] conducted a comprehensive analysis of aboveground biomass productivity in secondary forests. The median growth rate for secondary forests older than 20 years is circa 2.5 tons of carbon per hectare per year. In younger forests, growth rates can vary widely, reflecting greater dependence on initial conditions. Overall, the average growth rate in secondary forests is about 3 tons of carbon per hectare per year. In the Eastern Amazon, Lennox et al. (2018) [65] noted that biomass in these forests recovers at a rate of 2.25 tons per hectare per year, whereas species richness and composition recover at annual rates of 2.6% and 2.3%, respectively. In contrast, other studies, such as those by Uhl et al. (1982) [74] and Saldarriaga et al. (1988) [75], observed that biomass accumulation in western Venezuela continues even after 150 years post-abandonment. While much of the aboveground biomass recovers within 100 years, complete recovery can be slower due to the slow growth of dominant canopy species. This highlights the need to consider dynamics beyond 80 years in tropical forest recovery (Robinson et al., in review[31]).

[30] Here we are not referring to IPCC Good Practice Guidance definition of managed forest, but rather the active management of forest for resources

[31] https://www.researchsquare.com/article/rs-4659226/v1

4.3 Shifting cultivation in the Amazon and its connection to secondary forests

Shifting cultivation is an age-old farming practice that has supported millions of people in developing countries [76]. This method typically starts with clearing wooded areas, such as forests or savannas. Farmers then grow crops for a period, followed by a rest or "fallow" period during which the land is left to recover. Depending on how long the land is left to rest, it can eventually regrow into a secondary forest.

Global Estimates and Patterns

Two major studies have estimated the extent of shifting cultivation around the world. Silva et al. (2011) [77] used the Global Land Cover 2000 dataset to estimate that, in 2000, around 258 million hectares were used for shifting cultivation. Of this, 43% was in Central and South America, 29% in Africa, and the rest in Asia. Another study by Heinimann et al. (2017) [78] used satellite data from 2000 to 2014 to detect shifting cultivation patterns. They estimated that by around 2010, about 280 million hectares were used for this practice globally, with 41% in Central and South America, 37% in Africa, and the remainder in Asia. While both estimates are similar, Silva et al. (2011) [77] noted that land cover maps might not fully capture land use practices, a point further emphasized by Heinimann et al. (2017) [78].

Ecological benefits and challenges of shifting cultivation

The ecological benefits of secondary forests that arise from shifting cultivation, such as carbon storage and biodiversity recovery, are still not fully understood [79]. Mertz et al. (2021) [79] conducted a review of studies comparing the benefits of secondary forests with other types of land use in shifting cultivation areas. They found that while old-growth forests generally support more biodiversity and store more carbon, secondary forests still provide significant benefits, especially when compared to areas with perennial crops. Furthermore, the authors observed that secondary forests tend to accumulate carbon over time, but old-growth forests usually have higher carbon stocks. Comparisons between secondary forests and perennial plantations showed mixed results, with no clear pattern. However, secondary forests typically have soil carbon levels equal to or higher than perennial plantations, while areas used for annual crops or pasture generally have lower carbon stocks [79]. In two-thirds of comparisons, secondary forests had higher soil carbon than areas used for annual crops or pasture, though one-third showed no difference.

Shifting cultivation in the Amazon basin

Approximately 111 million hectares in Central and South America were used for shifting cultivation in 2000, with most of this area (64%) in Brazil [77]. Colombia follows with 16%, and Venezuela, Ecuador, and Peru each have about 5% or less. The length of cropping and fallow periods varies widely across the Amazon Basin. Crop cycles can last from just one year to eight years, while fallow periods can extend up to 20 years. Longer fallow periods allow the land to regrow and often achieve forest cover. The growth rates and species composition of this regrowth depend on factors such as previous land use, soil quality, and climate [80].

4.4 The extent, location and dynamics of secondary forests

Early research tracking secondary forests

Understanding where secondary forests are located and how they change over time in the Amazon basin has been a major focus for researchers since the early 1990s. Most studies have concentrated on the Brazilian Legal Amazon (BLA). In the 1990s and early 2000s, scientists used remote sensing technology with relatively coarse resolution to map these forests. For example, Lucas et al. (2000) [81] used data from 1-km NOAA AVHRR satellites to map secondary forests across the BLA. They estimated that about 160,000 km^2 of secondary forests were present, mostly in north-eastern Brazil and along major highways like the Trans Amazonian Highway. Large areas of secondary forest were also observed near regional centres like Manaus and Santarém. In contrast, regions such as Rondônia and Acre had less regeneration, with younger secondary forests being more common there. Carreiras et al. (2006) [82] used 1-km SPOT-4 VEGETATION images to map around 140,000 $km^2$of secondary forests in the BLA, showing concentrations in the Brazilian States of Pará, Amazonas, Mato Grosso, and Maranhão.

Recent advances in monitoring

In the early 2010s, advancements in geospatial technology, particularly the Earth Engine platform by Google, revolutionized land cover assessments. Silva Junior et al. (2020)[83] in the scope of the MapBiomas project (https://mapbiomas.org) mapped ~150,000 $km^2$of secondary forests in the Brazilian Amazon biome in 2018 using as basis a time-series of land cover maps obtained from classification of annual high-resolution 30-m Landsat data between 1985 and 2018. However, no formal accuracy assessment of the secondary forests class is provided, only the overall and class-specific accuracies (omission and commission errors) of the original land cover maps.

Wang et al. (2020) [84] used a time-series of land cover maps of the Brazilian Amazon in the period 2000-2014 (TerraClass) [85] to assess the spatial distribution and dynamics of secondary forests. Wang et al. (2020) [84] identified two phases of secondary forest loss: i) from 2000 to 2008, secondary forest loss declined significantly, paralleling the reduction in primary forest loss; however, ii) between 2008 and 2014, secondary forest loss surged from approximately 6,000 km^2 to ~10,000 km^2 per year, despite primary forest loss stabilizing. This last period saw increased pressure on forest ecosystems, primarily affecting secondary forests. Consequently, total forest loss (primary and secondary) rose by more than 100% from 2008–2010 to 2012–2014, reversing the previous downward trend. The share of total forest loss due to secondary forest clearance grew from 37% in 2000–2004 to 72% in 2012–2014. The widespread preferential cutting of secondary forests was evident. From 2000 to 2004, secondary forest loss primarily surpassed primary forest loss in the far northeast of the Brazilian Amazon, an area with historically high primary deforestation and limited remaining primary forest. By 2012-2014, secondary forest loss had outpaced primary forest loss across nearly the entire Brazilian Amazon. In terms of the extent of secondary forest in the Amazon, Wang et al. (2020) [84] estimated ~200,000 km^2 in 2000, ~220,000 km^2 in 2004, ~211,000 km^2 in 2008, ~234,000 km^2 in 2010 and ~233,000 km^2 in 2012.

Nunes et al. (2020) [86] conducted a similar assessment to that in Silva Junior et al. (2020) [83], examining its extent, age, and dynamics, including annual changes in forest cover and carbon stocks. Net gains and losses of secondary forests were determined using the FloreSer monitoring system, which utilized MapBiomas Collection 3.1 land cover data at 30 m resolution from 1985 to 2017 [83]. In 2017, patches of secondary forests were found along the arc of deforestation, the trans-Amazon highway, and main river corridors in the Brazilian Amazon, with higher concentrations in older areas like eastern Pará state. Various factors, such as abandonment or rotational management of pastures and agricultural fields, influence the distribution and size of secondary vegetation. Forest restoration and plantations also contribute to these estimates. However, Nunes et al. (2020) [86] did not distinguish between forest plantations and natural regeneration, and the 'planted forest' class mapped by MapBiomas (865 km^2) was excluded from the analysis, reducing the impact of monocultures on the results. From 1985 to 2017, the extent of secondary forests in the Brazilian Amazon increased, reaching over 120,000 km^2 in 2017. The net increase was consistent each year, except for 1999-2000. The time series shows three distinct periods: rapid growth from 1986 to 1993, stabilization from 1994 to 2002, and accelerated expansion from 2003 onwards, likely due to surplus pasturelands from high deforestation rates between 2000 and 2004. By 2001, about 50% of secondary forests were 5 years old or younger, and by 2017, 65% were 10 years old or younger, with only 13% being older than 20 years. The study found uncertainty in the development of early-regenerating secondary forests into older forests, with 35% of young secondary forests potentially being fallow fields – secondary forests older than 5 years are more likely to indicate stable regeneration.

Collaborative efforts

The 2ndFOR network[32], involving researchers from 25 countries, is one of the key collaborations studying secondary forests. Rozendaal et al. (2019) [87] found that while secondary forests quickly regain species richness, they take much longer to recover their full species composition. It takes about 50 years for secondary forests to reach 80% of the species richness found in old-growth forests, but centuries for full recovery. Chazdon et al. (2016) [60] modelled the carbon storage potential of secondary forests in Latin America, estimating that in 2008, these forests covered 2.4 million km^2 and could accumulate 8.48 billion tons of carbon over 40 years. They also projected that if 40% of degraded pastures were allowed to regenerate naturally, an additional 2.0 billion tons of carbon could be sequestered.

Promoting natural regeneration

To help secondary forests thrive, several strategies can be employed:

1. Protection from further degradation: Preventing additional damage by controlling activities like logging and fire helps natural regeneration processes [88]. In the Brazilian Amazon, secondary forests have no protective status until they are at least 20 years old, and this protective status is only in some states, e.g., Pará.
2. Assisted natural regeneration: Actively managing the land by removing invasive grass species [89] and lianas [90] and protecting young trees from grazing animals can support regrowth [66]. Tropical forests forest regeneration can be un-assisted, i.e. through natural regrowth [91], or through assisted forest recovery, i.e. by active seeding or seedlings planting [10,41,92]. However, areas of assisted forest restoration are still very limited.
3. Community involvement: Engaging local communities in conservation efforts ensures sustainable management and protection of these areas. Local knowledge and practices play a crucial role in promoting natural regeneration [93,94].

4.5 Secondary forests in the JRC-TMF dataset

Definition and spatial distribution

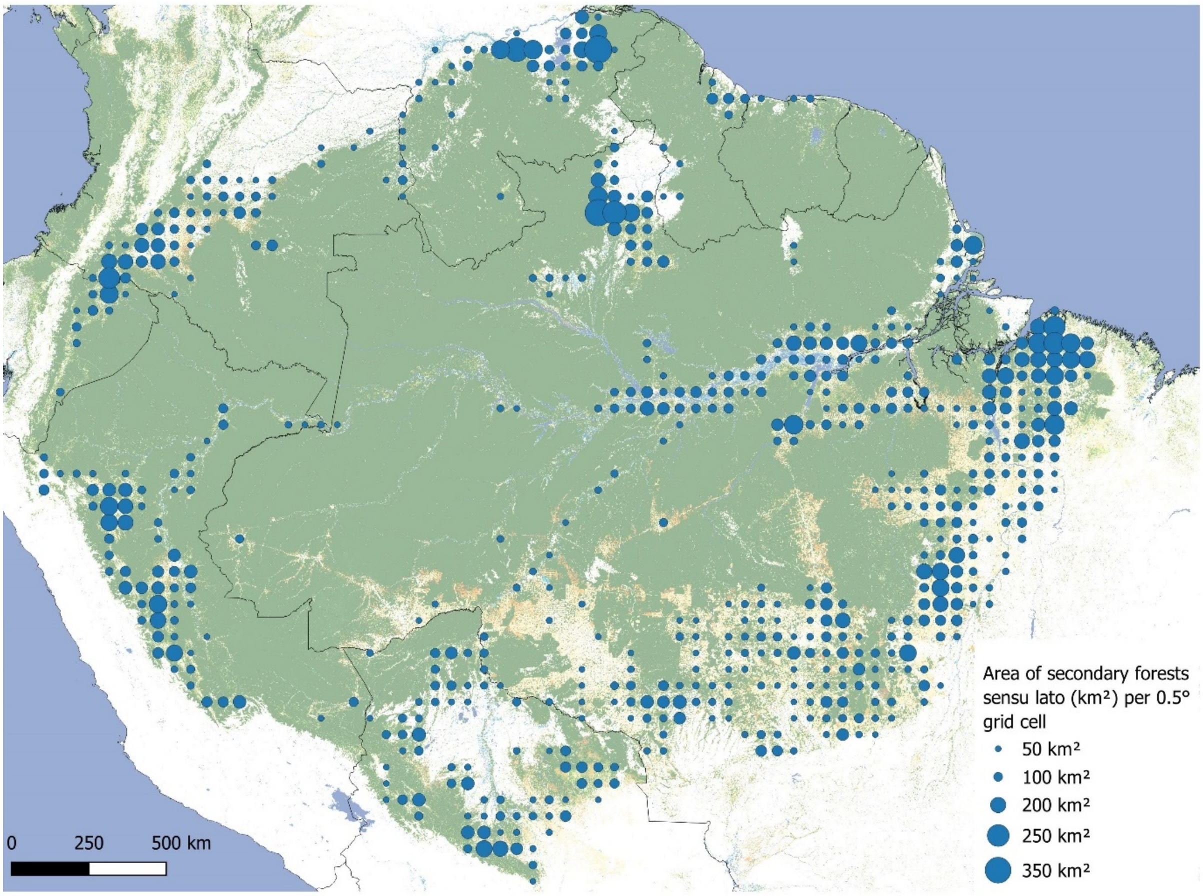
Secondary forests in the JRC-TMF dataset (termed forest regrowth) are mapped by looking at the transition between land cover classes. Any given pixel is classified as forest regrowth only if two conditions are met: i) deforestation signal must be a long-duration disturbance, i.e., detection of the absence of tree cover for more than 900 days, or, alternatively, at least four short duration disturbance events (less than 365 days) must be observed, and ii) regrowth must be observed for at least 3 years. For this chapter, we required a minimum of 5 years of consecutive classification as deforested land before considering the area as forest regrowth. The disturbance signal is evidence of an alternative land use (pastureland or cropland) during the period between primary and secondary forests.

According to the JRC-TMF dataset, there were 4.9 million km^2 of undisturbed forests, 0.38 million km^2 of degraded forests and 0.08 million km^2 of forest regrowth in the Amazon basin in 2023.

[32] https://sites.google.com/view/2ndfor

Regenerating forests after forest disturbances (degradation or deforestation) represent therefore 0.46 million km² or 8.6% of total forest area (regenerating and undisturbed). **Figure 32** depicts the spatial distribution of the 0.08 million km² of secondary forests *sensu lato* in the Amazon region in 2023. Regions where the area of secondary forests *sensu lato* are greater than 200 km² per 0.5° grid cell include NE and SE Pará, Roraima (all in Brazil), significant areas in Eastern Venezuela, Colombia, Peru, and Bolivia. In Brazil, there are also significant areas mapped as secondary forests *sensu lato* along the Amazon river East of the Tapajós river.

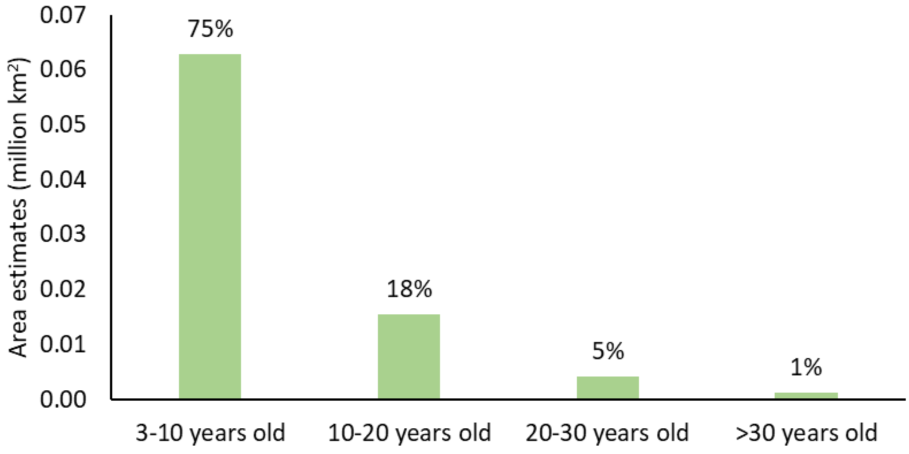
Figure 32. The spatial distribution of secondary forests *sensu lato* in the Amazon basin in 2023. Country boundaries are delimited by black lines. The background dataset refers to the JRC-TMF Transition map, where is mostly visible the extent of undisturbed tropical moist forest (in green).



Source: JRC

According to the TMF-secondary forest dataset, the dominant age class is < 10 years, with 75% of mapped secondary forest below this age (**Figure 33**). Only 6% of the secondary forests are between 20-34 years old. Information on age dynamics is extremely useful to prioritize areas that should be put under protection status. Assuming a constant biomass growth rate of 6 tons per hectare per year, the biomass stock in the 3-10 year age class is only 1.8 times that in the 10-20 year age class, even though the area covered by the latter is 4.2 times larger than that covered by the former.

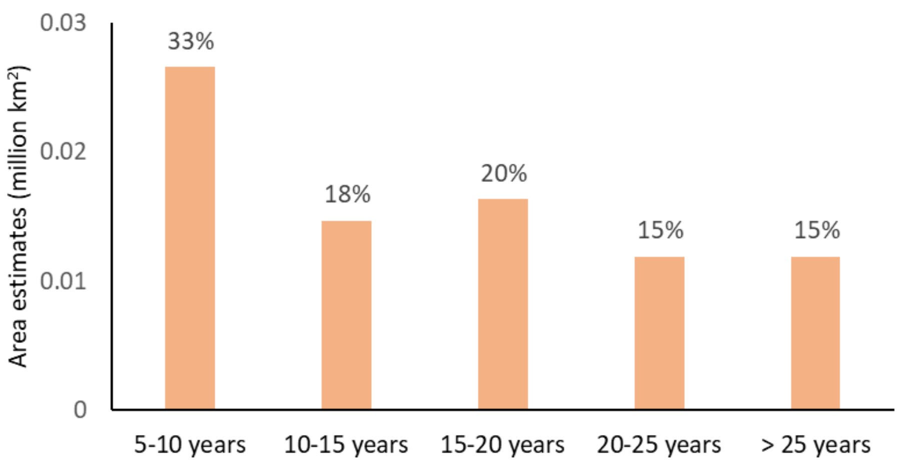
Figure 33. The fate of forest regrowth *sensu lato* in 2023. Area of forest regrowth (in million km²) by age class.



Source: JRC

The duration (and intensity) of disturbance, i.e., the number of years any given deforested land was under active land use (either cropland or pastureland), has implications for the type and rate of vegetation recovery. **Figure 34** shows that 1/3 of the area of forest regrowth *sensu lato* had a period of active use less than 10 years. The remaining 2/3 were evenly distributed by other classes of duration of disturbance.

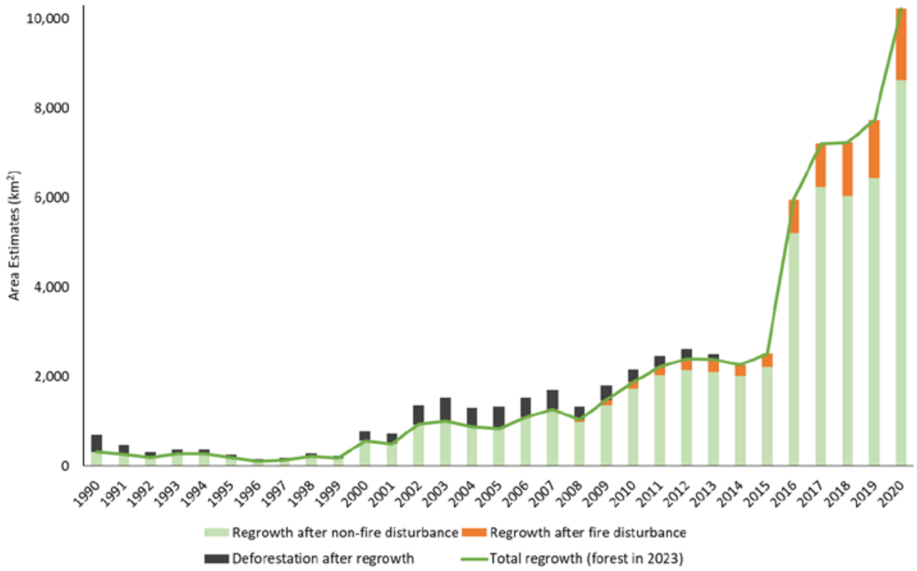
Figure 34. Distribution of the area of secondary forests *sensu lato* by class of previous deforestation duration.



Source: JRC

The JRC-TMF dataset allows also disentangling the contribution of different disturbance-recovery processes to the annual dynamics of forest regrowth *sensu lato* (**Figure 35**). The majority (78%) of new forest regrowth between 1990 and 2013 are still standing in 2023, whereas the remainder was followed by deforestation/disturbance. We observed a four-fold increase of new forest regrowth after 2015 (2,000 km² per year in 2011-2015 compared to 8,000 million hectares per year in 2016-2020). This is partially correlated with a four-fold increase in forest regrowth after fire disturbance (300 km² per year in 2011-2015 vs 1,200 km² per year in 2016-2020).

Figure 35. Annual dynamics of new forest regrowth according to different disturbance-recovery processes.

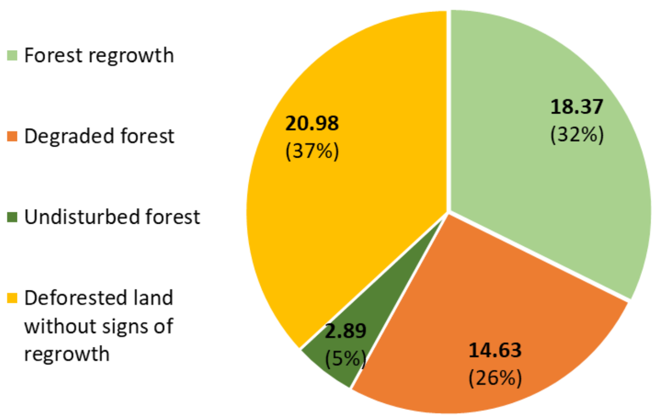


Source: JRC

How forest regrowth from JRC-TMF compares against other datasets

The MapBiomas dataset described above (section 4.4) was compared with the forest regrowth *sensu lato* obtained from JRC-TMF for the year 2023. Overall, Silva Junior et al. (2020) [83] mapped 56,900 km^2 of secondary forest in the Brazilian Amazon moist forest domain (as defined by the JRC-TMF dataset) while JRC-TMF mapped 51,100 km^2. However, there is a strong spatial mismatch between the area mapped as secondary forests by MapBiomas and its correspondence in JRC-TMF (**Figure 36**). Of the 56,900 km^2 of secondary forests in MapBiomas, only 32% were also mapped as forest regrowth in JRC-TMF. Most striking is the fact that 37% of the area mapped as secondary forests by MapBiomas were mapped in JRC-TMF as deforested land without signs of regrowth. The reason for this might be that regrowth needs to have a minimum of 5 years of vegetative regrowth in JRC-TMF, compared to the '1-year recovery' in MapBiomas dataset, or could be linked to the capacity of the JRC-TMF to identify disruptions (i.e. absence of tree cover) at sub-annual timescale, which is key to detect anthropogenic activities.

Figure 36. Breakdown of the area mapped as secondary forests in Silva Junior et al. 2021 (updated to use collection 9 of MapBiomas) by class in the JRC-TMF dataset. The comparison refers to 2023 and only for the Brazilian Amazon within the tropical moist forest biome defined in JRC-TMF. The values in bold refer to areas in thousand km^2.

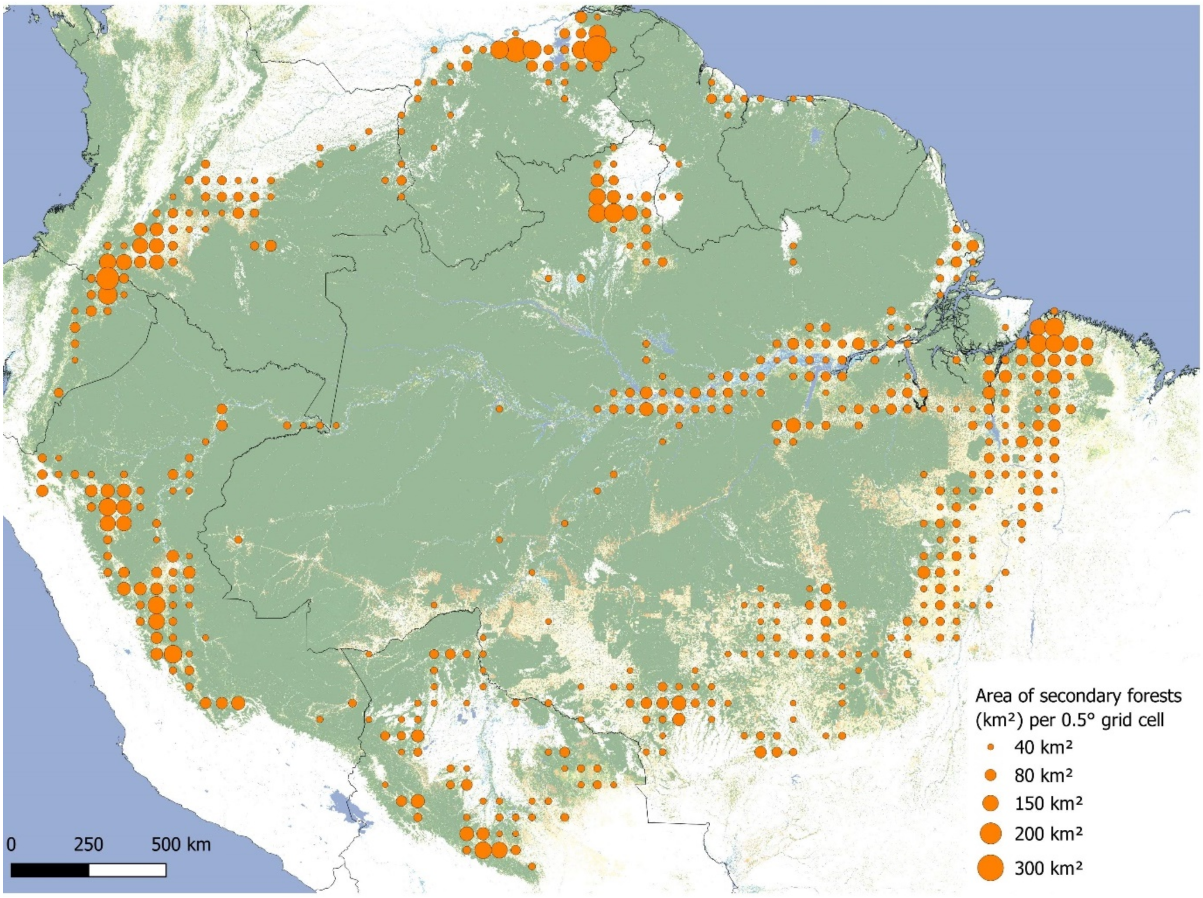


Source: JRC

Improving the detection of forest regrowth

We cannot exclude the possibility that other dynamics or structural characteristics are driving the areas that were mapped as JRC-TMF secondary forests *sensu lato*. Therefore, several ancillary datasets were used to exclude 1) areas whose tree canopy height is lower than 5 meters[33], 2) areas that are covered by tree plantations, and 3) forest areas that were impacted by fire. As a consequence, the area mapped as secondary forest in the Amazon basin in 2023 decreased to ~60,000 km^2 (**Figure 37**), the reduction mostly driven by areas that were impacted by fire (~20,000 km^2), and much less by areas with canopy height less than 5 meters or plantations (together representing only 2,000 km^2).

Figure 37. The spatial distribution of secondary forests in the Amazon basin in 2023. Ancillary datasets about the spatial distribution of areas with canopy height less than 5 meters, plantations, and burnt areas were used to further filter the spatial distribution depicted in **Figure 34**. Country boundaries are delimited by black lines. The background dataset refers to the JRC-TMF Transition map, where is mostly visible the extent of undisturbed tropical moist forest 2023 (in green).

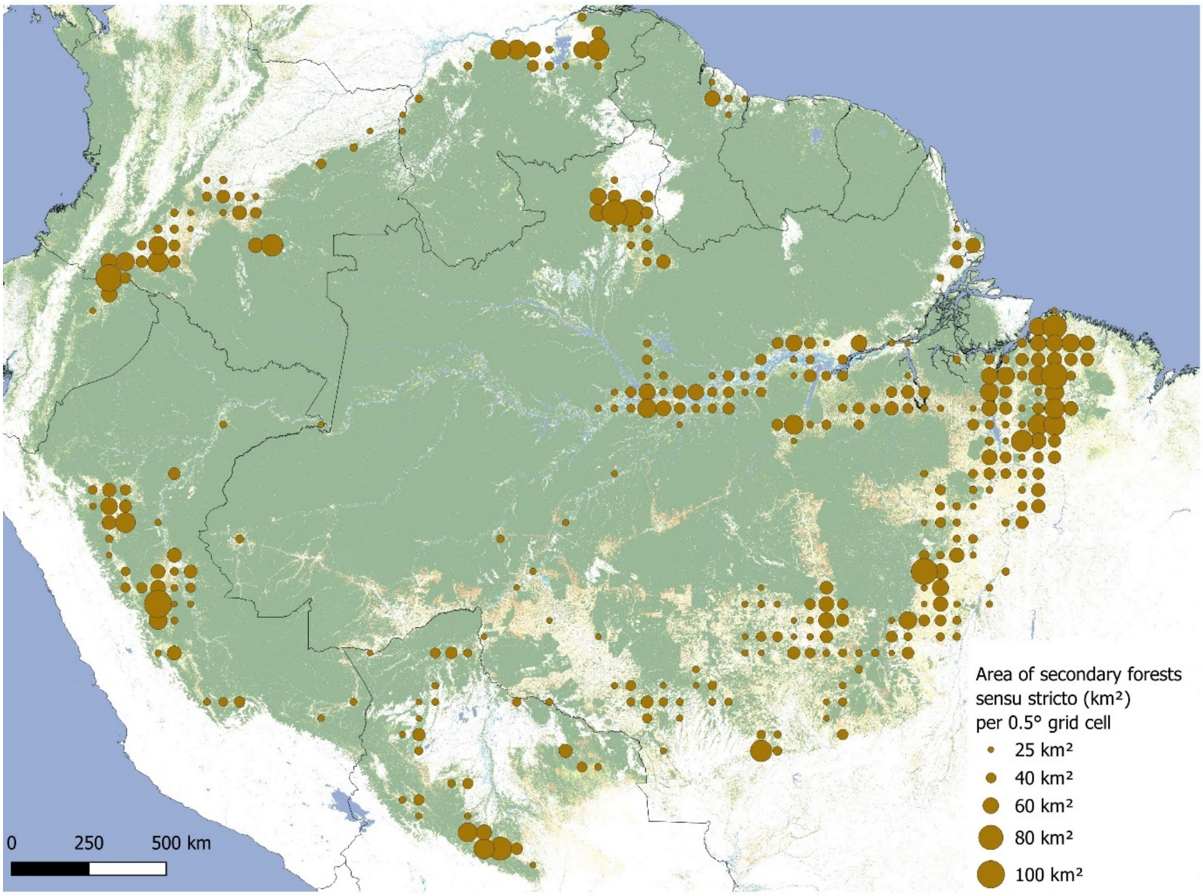


Source: JRC

Some areas that are mapped as secondary regrowth in **Figure 37** might not really be natural regrowth originating from land use change dynamics. Therefore, an additional refinement is proposed leaving only those areas having a pattern of at least 5 years of consecutive disturbance (with at least one disruption detection by year). Applying this condition resulted in an area of ~30,000 km^2 being removed from the area mapped as secondary forests depicted in **Figure 38** shows the spatial distribution of secondary forests *sensu stricto* in the Amazon basin in 2023, which amount to 30,000 km^2.

[33] https://www.google.com/url?q=https://openreview.net/forum?id%3DZzCYOfRver&sa=D&source=docs&ust=1732272634564749&usg=AOvVaw22lXv1jUycictQzD9iOYbP

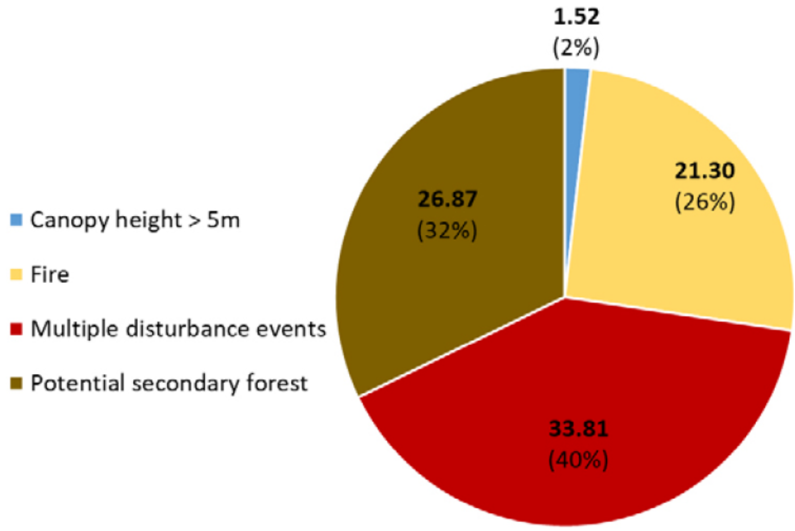
Figure 38. The spatial distribution of secondary forests *sensu stricto* in the Amazon in 2023, further filtered from the spatial distribution depicted in **Figure 37**. Country boundaries are delimited by black lines. The background dataset refers to the JRC-TMF Transition map, where is mostly visible the extent of undisturbed tropical moist forest (in green).



Source: JRC

Figure 39 shows how the ca. 80,000 km^2 mapped as secondary regrowth *sensu lato* are distributed according to the different dynamics mentioned previously. Secondary forests *sensu stricto* occupies essentially certain regions across the Brazilian arc-of-deforestation, areas south of the savannas of Roraima and along the Amazon River east of the Tapajós River. Furthermore, there is also higher incidence of these forests in areas of transition between TMF's moist forest biome and open forests, savannas and dry forests in Venezuela, Colombia, Peru and Bolivia.

Figure 39. Distribution of the area mapped as forest regrowth *sensu lato* by TMF according to different forest dynamics and structural characteristics. The numbers in bold indicate the area of each class (in thousand km^2) with the corresponding proportion indicated in parentheses. The brown area represents the secondary forest *sensu stricto*.

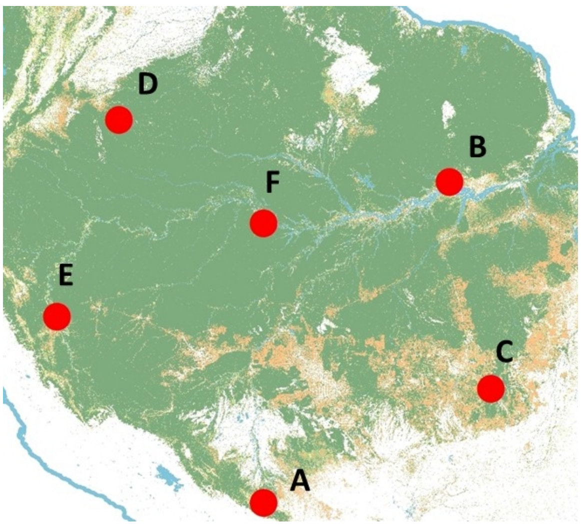


Source: JRC

Case studies of forest dynamics leading to forest regrowth

The reasons for the regrowth of forests after deforestation or natural forest loss are manifold. Human-induced forest loss comprise small-scale and large-scale deforestation (incl. shifting cultivation) and forest fires, while natural causes of forest loss include the change of river courses and windthrow (even if the increase of the latter is often seen as a consequence of human-caused climate change [95]). Here we show six exemplary areas that demonstrate different dynamics related to secondary forest after complete loss of forest cover, according to JRC-TMF data. However, the underlying dynamics of secondary forests are often combined in the same area.

Figure 40. Distribution of the six examples of secondary forest (*sensu lato*) over the Amazon basin.

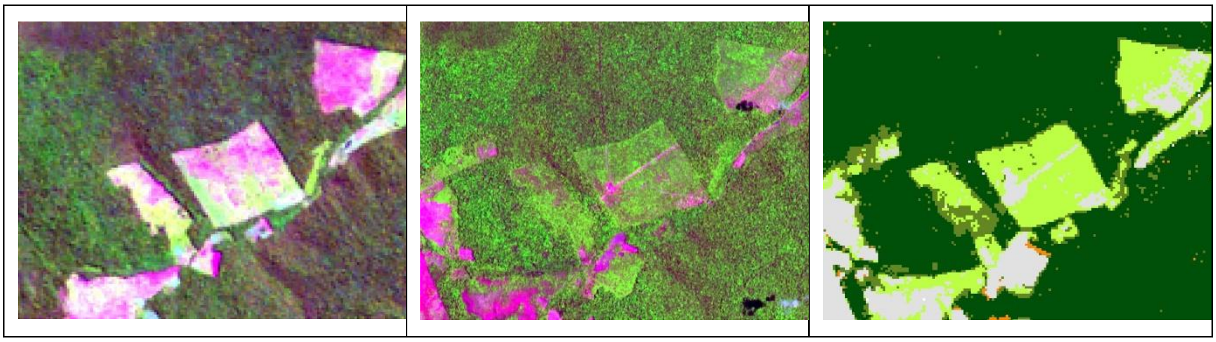


Source: JRC

Figure 41. **A**: Area of small-scale forest loss and secondary forest regrowth (light green) in the Bolivian Amazon (lat: -17.1375 lon: -64.7447) on Landsat imagery 2009 (left) and 2022 (centre) and TMF data (right), image width: 4 km.

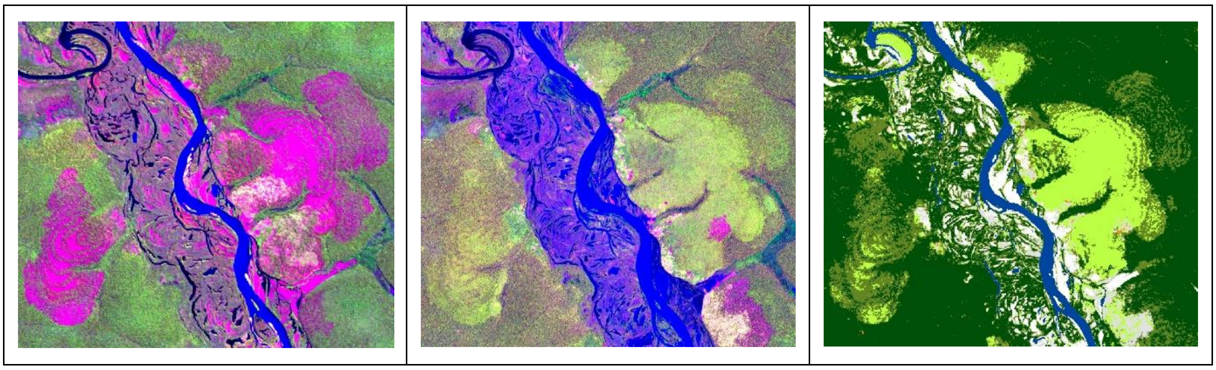
Source: USGS/JRC

Figure 42. **B:** Secondary forest (light green) on abandoned pastures in the Brazilian Amazon (lat: -1.5329 lon: -53.4703) on Landsat data from 2006 (left), S-2 data from 2022 (centre) and TMF (right), image width: 5 km.



Source: USGS/JRC

Figure 43. **C**: Secondary forest (light green) after fire in the Brazilian Amazon (lat: -11.0775 lon: -53.2602) on Landsat data from 2008 (left), S-2 data from 2022 (centre) and TMF data (right), image width: 18 km.

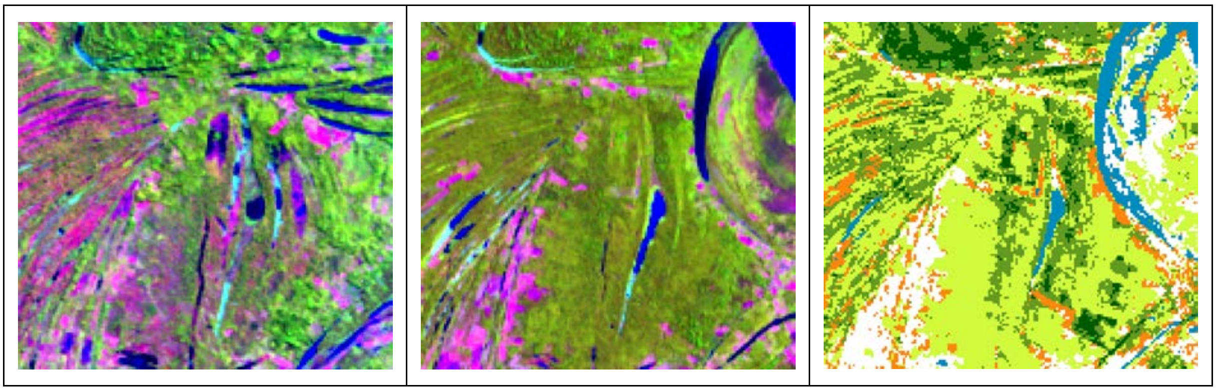


Source: USGS/JRC

Figure 44. **D**: Secondary forest (light green) after small-scale illicit crops abandonment in the Colombian Amazon (lat: 1.4495 lon: -71.8130) on Landsat data from 2004 (left) and 2022 (centre and TMF (right), image width: 10 km

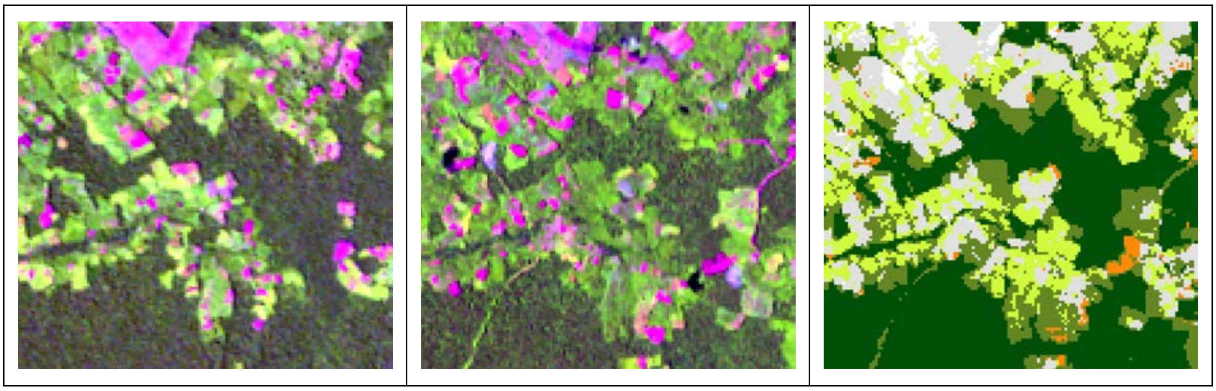
Source: USGS/JRC

Figure 45. **E**: Secondary forest (light green) after the change of a river course in the Peruvian Amazon (lat: -8.2800 lon: -74.5813) on Landsat data from 2008 (left) and 2022 (centre) and TMF (right), image width: 5 km.



Source: USGS/JRC

Figure 46. **F**: Secondary forest (light green) after shifting cultivation in the Brazilian Amazon (lat: -3.4617 lon: -64.7236) on Landsat data from 2009 (left) and 2022 (centre) and TMF (right). Shifting cultivation patterns in this area are well documented in Jakovac et al. (2017) *[96]*, image width: 5 km.



Source: USGS/JRC

5 Update on national Brazilian policies in relation to deforestation and forest degradation in the Amazon (status up to mid-2024)

At the 27th Conference of Parties of the UNFCCC (COP27) the Brazilian president promised to do everything to achieve zero deforestation in Brazil by 2030. Since then, in 2023, Brazilian deforestation in the Amazon region has decreased by 28.1% (compared to 2022), but remains at almost 8,000 km^2 over the full year 2023, according to JRC-TMF data. To pursue further the ambitious goal, strong environmental governance would be indispensable [97]. For this purpose, the new Brazilian government (in office since 1st January 2023) has been re-vitalizing federal institutions like IBAMA, ICMBio (both responsible, amongst other tasks, for environmental law enforcement) and FUNAI (National Foundation of Indigenous People), and created the Ministry for Indigenous People. However, a conservative Congress (Senate and Chamber of Deputies) is setting limits to the current government's progressive approach towards environment and indigenous people [98,99][34].

Brazil is now back on the political world stage after years of isolation. Brazil organised the G20 summit in November 2024 and will be hosting in November 2025 the UN Climate Change Conference (UNFCCC COP30) in Belém in the Brazilian Amazon.

The Amazon Fund, currently containing more than 700 million USD donated by Norway, Germany, and other countries[35], has been reactivated in 2023 and now supports a large number of activities related to environment, bio-economy and society, mostly located in the Brazilian Amazon[36] [37].

Federal Environmental Institutions

The Brazilian National Institute for Space Research (INPE), which amongst other tasks is responsible for the PRODES and DETER Amazon deforestation and forest degradation detection programmes, has seen a revival after years of stagnation and institutional dismantling previous to 2023. INPE is expecting a wave of almost 150 newly created positions in 2024 after having lost almost one third of staff between 2014 and 2023[38].

Brazilian institutions that are responsible for the assignment of research grants (CAPES, CNPq) are struggling with tight budget allocations[39] - with considerable negative impact on Brazil's scientific output [100] - after their budgets had already seen a general downsizing during the years of the previous presidency[40].

With the help of the Brazilian Institute for Environment and Renewable Natural Energy (IBAMA), as environmental law enforcement action, deforestation rates in the Brazilian Amazon has been curbed substantially in 2023 and in the first half of 2024[41]. IBAMA had been revitalised after having been almost paralysed during the former presidency (Pereira 2024). However, IBAMA staff and staff from other institutions dealing with environmental protection (ICMBio, SFB, MMA) went on partial strike for many months in 2024 for better work conditions and wages. During the strike, the number of operations in the field were reduced and, as a consequence, the number of environmental fines

[34] https://www.nature.com/articles/d41586-023-04042-x
[35] https://www.amazonfund.gov.br/en/home/
[36] https://brazilian.report/liveblog/politics-insider/2024/06/17/brazil-amazon-fund-law-enforcement/
[37] https://agenciagov.ebc.com.br/noticias/202402/com-r-1-3-bilhao-para-projetos-e-chamadas-publicas-fundo-amazonia-tem-recorde-historico-em-2023-1
[38] https://www.nature.com/articles/d41586-023-04041-y
[39] https://portal.sbpcnet.org.br/noticias/enquanto-cnpq-e-finep-tem-crescimento-orcamentario-capes-sofre-com-contingenciamentos-e-reducao-de-verbas-para-2024/
[40] https://www.nature.com/articles/d41586-021-02886-9
[41] https://terrabrasilis.dpi.inpe.br/app/dashboard/alerts/legal/amazon/aggregated/

decreased substantially[42]. The strike was called off in August 2024[43]. The reduced field action of IBAMA and the other agencies were specifically problematic in view of the current surge in forest fires in the Amazon and Pantanal biomes in 2024[44] [45]. In addition, operating with a reduced number of effective fire-fighting aircraft hinders tackling the problem, according to the president of IBAMA, Rodrigo Agostinho[46].

Indigenous People

The government of Brazil had, as one of its first activities at the beginning of 2023, put huge effort in solving the humanitarian Yanomami crisis in the North of Brazil. Illegal gold mining in their territories had brought mercury contamination, malnutrition, disease and violence to the Yanomami and other indigenous people [101,102]. However, after driving out most of the illegal intruders in 2023 and successive federal investments into land protection infrastructure[47], illegal gold mining is still menacing the Indigenous territory, as the number of illegal gold miners is reported to be again on the rise[48]. In general, illegal gold mining does not only threaten the Yanomami territory, but is very common also in numerous other Indigenous Lands throughout the Brazilian Amazon[49] and in other Amazon countries [103,104] [50] [51] [52] [53].

Until April 2024, a total of 10 new Indigenous Lands (ILs) have been officialised during the new Brazilian presidency, while in the period of 2017-2022 none had been added to the list of homologated ILs[54]. The bill on the time frame ('marco temporal'[55]) for the demarcation of Indigenous Areas (PL 490/2007) is still under discussion within the Brazilian political entities. If it becomes law, it would deny land rights to Indigenous peoples who had to abandon their traditional territories prior to 1988, the year when Indigenous land rights were established in the Brazilian Constitution. The Brazilian Supreme Court (STF) had cancelled the application of the law by declaring it unconstitutional in September 2023. Since then a battle between the conservative Brazilian Congress, the STF and the progressive Brazilian government is ongoing[56], resulting in a series of conciliation sessions (starting on 5th August 2024) with participants from federal, state and municipal governments, members of society and indigenous organisations and communities, led by the STF[57]. These conciliation sessions in general and the criteria of the participants' selection in particular are highly controversial[58]. The international scientific community has published many

[42] https://www.nature.com/articles/d41586-024-00279-2

[43] https://www.reuters.com/business/environment/brazil-environmental-workers-sign-agreement-end-strike-holding-up-oil-permits-2024-08-12/

[44] https://abcnews.go.com/International/brazil-experiencing-record-breaking-wildfires-persistent-drought-affects/story?id=113688151

[45] https://amazonwatch.org/news/2024/0917-immediate-global-action-needed-to-contain-amazon-fires-emergency-in-collaboration-with-indigenous-and-traditional-communities

[46] https://www1.folha.uol.com.br/internacional/en/scienceandhealth/2024/06/brazil-lacks-firefighting-structure-to-match-climate-crisis-says-ibama-president.shtml

[47] https://www.gov.br/planalto/en/latest-news/2024/01/copy_of_201cwe-will-treat-the-yanomami-as-a-matter-of-state-201d-says-lula

[48] https://g1.globo.com/rr/roraima/noticia/2024/07/18/garimpo-ilegal-avanca-em-novas-areas-da-terra-yanomami-mesmo-com-fiscalizacao-diz-greenpeace.ghtml

[49] https://www.theguardian.com/global-development/2024/nov/28/rise-birth-defects-in-brazil-para-state-illegal-gold-mining-capital

[50] https://digitalcommons.fiu.edu/cgi/viewcontent.cgi?article=1042&context=jgi_research

[51] https://insightcrime.org/news/gold-mining-colombia-increasingly-tied-organized-crime-report/

[52] https://dialogo-americas.com/articles/ecuador-organized-crime-increasingly-turns-to-illegal-gold-mining/

[53] https://www.researchsquare.com/article/rs-4306490/v1

[54] https://www.gov.br/funai/pt-br/assuntos/noticias/2024/governo-federal-anuncia-demarcacao-de-mais-duas-terras-e-reafirma-compromisso-com-os-povos-indigenas

[55] https://verfassungsblog.de/indigenous-rights-and-the-marco-temporal/

[56] https://core.ac.uk/download/595391843.pdf

[57] https://noticias.stf.jus.br/postsnoticias/entenda-as-audiencias-de-conciliacao-do-stf-sobre-a-lei-do-marco-temporal/

[58] https://apublica.org/2024/07/duvidas-e-incertezas-sobre-a-conciliacao-ditada-pelo-stf-no-marco-temporal/

articles that confirm that Indigenous Lands are very effective for the protection of the forest [105–111] [59] [60].

Environmental Laws

Laws proposed by the Brazilian Congress or State governments in relation to Amazon environmental protection hamper the effectiveness of nature conservation. The Proposed Constitutional Amendment (PEC) 12/2022, foreseen to prohibit the creation of new Protected Areas in Mato Grosso State, has been in a process of repeated appeals and counter-repeals, when the Mato Grosso Court of Justice accepted the annulation of a legally created State Park in April 2024[61]. The so-called Cristalino II State Park had been declared as "top conservation priority" for Amazon tree species and vulnerable faunal communities [112].

The "mining bill", or Proposed Law (PL) 191/2020, that would have legalised mining on Indigenous Land, has been withdrawn from further processing by the current Brazilian government [113] [62]. Nevertheless, another proposed law (PL 6050-/2023) is currently underway – to be discussed at the Senate – that would permit mineral extraction and other activities on Indigenous Lands.

The following proposed laws were in the process of being voted for or against in the Brazilian Congress (status 5th May 2024):

The PL 364/2019 would take off protection from all "formations of predominantly non-forest native vegetation", affecting an area of ca. 480,000 km^2. The Pantanal wetlands, the Pampa grasslands and the native grasslands of Amazonia (mostly in Roraima State) would be left without protection [114][63].

The PL 3334/2023 would reduce the legal reserve of the Amazon forest protection, specifically in municipalities that include more than 50% of protected areas on public land. In these areas the legal forest reserve could be lowered from 80% to 50%[64]. In addition, for the reduction of the 'legal forest reserve' an approved ecological-economic planning by the Brazilian States in the Legal Amazon would not be required any more[65]. The proposed law has advanced in the Brazilian Congress in April 2024 and now needs to pass the Constitution and Justice Commission and Senate's Commission of Environment[66].

PL 2374/2020 would extend the amnesty for illegal deforestation from currently July 2008 to May 2012, in addition the Brazilian Ministry of Environment would be excluded from the discussion in the course of any legal process[67].

PL 1282/2019 and 2168/2021: the two proposed laws would liberate the construction of irrigation infrastructure in permanently protected areas (APPs), which could lead e.g. to the suppression of native vegetation, to conflicts related to the water usage, and to changes in the river hydrodynamics and water quality[68] [69].

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[59] https://www.wri.org/insights/amazon-carbon-sink-indigenous-forests
[60] https://www.cifor-icraf.org/publications/pdf_files/infobrief/8387-Infobrief.pdf
[61] https://amazoniareal.com.br/tribunal-de-justica-brasileiro-ameaca-biodiversidade-amazonica/
[62] https://www.camara.leg.br/proposicoesWeb/fichadetramitacao?idProposicao=2236765&fichaAmigavel=nao
[63] https://news.mongabay.com/2024/03/agribusiness-bill-moves-to-block-grassland-protections-in-brazilian-biomes/
[64] https://www12.senado.leg.br/noticias/materias/2024/03/18/ccj-pode-votar-projeto-que-reduz-reserva-legal-na-amazonia
[65] https://observatorioflorestal.org.br/nota-tecnica-wwf-projeto-de-lei-n-3-334-2023-reserva-legal-em-areas-de-florestas-da-amazonia-legal/
[66] https://oeco.org.br/noticias/pl-que-reduz-para-50-reserva-legal-na-amazonia-avanca-no-congresso/
[67] https://www.climatepolicyinitiative.org/wp-content/uploads/2022/05/NT-PL-2374.pdf
[68] https://acervo.socioambiental.org/sites/default/files/documents/n9d00009.pdf
[69] https://observatorioflorestal.org.br/wp-content/uploads/2024/03/ATUALIZADA-24-NT-PL-2.168-2021-OCF_ODA.pdf

PL 686/2022, if finally approved, would cut any control of competent authorities related to the re-clearing of any secondary vegetation in areas of 'alternative land use'. In consequence, in the Amazon and the Mata Atlântica, up to 170,000 km^2 of secondary forest could be re-deforested without any type of control[70].

PL 3179/2004, also called 2159/2021, has been approved by the Chamber of Deputies and awaits the approval of the Senate. It would regulate anew the process of environmental licensing, which is seen an important measure to prevent environmental degradation caused by human activities[71]. Instead of being the rule, environmental licensing would be the exception. The new federal law would be one of the biggest threats to the Brazilian environment [115], because for any larger (e.g. infrastructural) undertaking with potential environmental impact, a mere self-declaration by businesses would be enough, rather than a detailed environmental impact analysis (as it is the rule currently). However, in a decision in April 2024, the STF declared anti-constitutional the proposed change of State (rather than federal) law by Tocantins State, that foresaw the 'flexibilization' (i.e. watering down) the rules for giving out environmental licences[72].

The bills on 'Land Grabbing' ('PL da grilagem'), PL 2633/2020, PL 510/2021 and PL 3915/2021 would extend the amnesty for illegal deforestation from 2008 until the end of 2014 and would permit, through a bidding process, the future regularisation of illegally deforested public land. In addition the bill will make it easier to regularise areas of illegal deforestation without any process of establishing environmental liability[73]. Since many years, organised crime groups ("Brazilian land mafias") are involved in land grabbing operations [116,117]. Two bills await approval of the Brazilian Senate, while PL 3915/2021 currently lies at the Chamber of Deputies.

PL 5822/2019 and PL 2623/2022 (both currently discussed at the Chamber of Deputies) would permit mineral exploration in Conservation Units of Sustainable Use in National Forest areas[74] as well as quarries in National and Nature Parks on federal, State and municipality level[75].

The "Poison Bill" (PL 6299/2002 and 1459/2022) changes significantly the rules for research, experimentation, production, storage, marketing, packaging, transportation, export, usage and disposal of pesticides [118,119] [76]. At the same time the regulatory institutions for the permits of agrochemicals (pesticides etc.) to date, namely the Ministry of Health (through ANVISA) and Ministry of Environment (through IBAMA) were cut out of their responsibilities[77], while, according to the PLs, the Ministry of Agriculture and Livestock now oversees the authorisations. The proposed law was vetoed by the Brazilian president at the end of 2023[78], but the veto was overruled by the Brazilian Congress in May 2024[79] [80].

[70]https://observatorioflorestal.org.br/votacao-de-pls-colocam-em-risco-o-codigo-florestal-e-a-lei-da-mata-atlantica/
[71] https://www.amazonialatitude.com/2024/01/31/licenciamento-ambiental-preocupa-especialistas-pl/
[72]https://g1.globo.com/to/tocantins/noticia/2024/04/11/stf-mantem-decisao-que-declara-inconstitucional-lei-que-flexibiliza-o-licenciamento-ambiental-no-tocantins.ghtml
[73] https://andi.org.br/2024/05/novo-pacote-da-destruicao-ameaca-direitos-socioambientais/
[74] https://www.camara.leg.br/proposicoesWeb/fichadetramitacao?idProposicao=2228130
[75] https://www.camara.leg.br/proposicoesWeb/fichadetramitacao?idProposicao=2335681
[76] https://portal.fiocruz.br/sites/portal.fiocruz.br/files/documentos_2/falacias_pl_veneno.pdf
[77]https://www.uff.br/?q=noticias/09-01-2024/uff-responde-agrotoxicos-e-o-projeto-de-lei-que-flexibiliza-seus-usos
[78]https://www.brasildefato.com.br/2023/12/28/pl-do-veneno-lula-sanciona-com-vetos-lei-que-facilita-uso-de-agrotoxicos
[79]https://agribrasilis.com/2024/05/10/congress-overturns-the-presidents-vetoes-mapa-will-have-exclusive-competence-for-pesticide-registrations-in-brazil/
[80]https://www12.senado.leg.br/noticias/materias/2024/05/09/registro-de-pesticidas-cabera-apenas-ao-ministerio-da-agricultura

- PL 2001/2019, PL 717/2021 and PL 5028/2023 (currently at the Chamber of Deputies for approval) are proposed to prevent the creation of new protected areas (Conservation Units of Indigenous Lands) on public land by setting the rule that all private properties within the defined borders of the protected areas (PAs) must be fully compensated[81] [82]. In practise this will be difficult to apply and, in consequence, the PLs will stop (or slow down considerably) the establishment of new PAs[83].

- PL 6049/2023 (currently at the Senate for approval) would change the legal status for the Amazon Fund (into a civil non-profit association), leading to a less agile Fund due to more bureaucracy and more administrative burden. This would make it more difficult to launch and finance important projects, e.g. related to deforestation control[84].

The State of Mato Grosso passed a law at the end of October 2024 designed to void the Brazilian Amazon Soy Moratorium, a mechanism that significantly reduced Amazon deforestation [120] by abolishing tax benefits for farmers adhering to the moratorium[85] [86] [87]. This disincentive for soy farmers to protect the forest is particularly problematic on the background of the planned grain transport railway Ferrogrão that will start in Sinop, Mato Grosso State, and lead towards the important grain port of Miritituba in Pará State. This railway would make grain transport more effective (thus less costly) and could lead to increased direct or indirect deforestation due to the expansion of soy production in Mato Grosso. At the same time, Mato Grosso State currently tries to change the Forest Code for the Amazon part of the State to reduce the percentage of native forest to be protected by land owners from 80% to 35% per land parcel, by re-classification of the State's Amazon forest as being part of the Cerrado biome (with a lower forest protection level)[88].

Forest concessions

The Brazilian government plans to expand (legal) selective logging concession areas in the Amazon region to more than 50,000 km^2 in the next two years[89], which is more than three times the current concession area defined by the Brazilian Forest Service (SFB). A further, massive increase of concession areas is not to be excluded[90] [91]. According to Renato Rosenberg, the SFB's Director of Forest Concessions, this measure would protect the forest from land grabbing and illegal deforestation, by rather using the forest as a sustainable source of timber and creating jobs and income in the region [121,122] [92]. The logging companies would be able to log six trees per hectare over a 30-year period – with protected species, such as Brazil nuts and older seed-producing trees, strictly off limits, according to the SFB. However, scientific studies question the sustainability of the 30-year repeat cycle, arguing that the Amazon forest will only be able to recover sufficiently if left 'in peace' for a minimum of 60 years [123]. Another question is if the SFB has sufficient means and technical capacity to control large concession areas, i.e. carry out sufficient checks related to extraction area and design, and the type and amount of extracted timber [122,124,125].

[81] https://www.camara.leg.br/proposicoesWeb/fichadetramitacao?idProposicao=2196688
[82] https://www.camara.leg.br/proposicoesWeb/fichadetramitacao?idProposicao=2396529&fichaAmigavel=nao
[83] https://www.oc.eco.br/novo-pacote-da-destruicao-ameaca-direitos-socioambientais/
[84] https://acervo.socioambiental.org/acervo/noticias/novo-pacote-da-destruicao-ameaca-direitos-socioambientais
[85] https://www5.sefaz.mt.gov.br/w/governador-sanciona-lei-contra-empresas-que-aderirem-%C3%A0-morat%C3%B3ria-da-soja
[86] https://www.brasildefato.com.br/2024/11/01/demonstracao-de-forca-dos-ruralistas-mato-grosso-aprova-lei-que-pune-empresas-de-pacto-antidesmatamento
[87] https://www.theguardian.com/environment/2024/dec/03/exclusive-protection-deal-for-amazon-rainforest-in-peril-as-big-business-turns-up-heat
[88] https://oeco.org.br/noticias/mt-tenta-recategorizar-florestas-no-estado-para-que-sejam-consideradas-como-cerrado/
[89] https://revistacenarium.com.br/amazonia-concessoes-florestais-como-estrategia-de-combate-ao-desmatamento/
[90] https://www.itto.int/files/user/mis/MIS_16-31_July2024.pdf
[91] https://apnews.com/article/brazil-amazon-forest-protection-logging-3afaaaf3789d3d2dc19c2d52584676a7
[92] https://woodcentral.com.au/before-eudr-brazils-plan-to-expand-selective-logging-in-amazon/

Infrastructure

Asphalting the BR-319

The most discussed infrastructural project in the Brazilian Amazon is the potential complete asphalting of the BR-319 Highway between Porto Velho in the Western Amazon and Manaus on the Amazon River, cutting through pristine forest between the Purus and Madeira rivers. Some 400 km between the turnoff to the BR-230 in the South and "KM 198" in the North are still without asphalt and are often impassable during the rainy season. The former as well as the current Brazilian government have expressed themselves as being in favour of the asphalting of the yet unpaved so-called "middle part" ("Trecho do Meio") of the BR-319 to provide secure transport on the whole length of the highway all year round [99].

Asphalting the "Trecho do Meio" is strongly contested by scientific institutions, environmental agencies and NGOs. According to their views, pursuing the BR-319 project would create multiple environmental and social problems. A "reliable" road in an up-to-now almost untouched Amazon forest would trigger deforestation [126], attract land grabbers, illegal loggers, illegal miners and hunters and potentially lead to the expansion of the Amazon road network (e.g. the planned state highway AM-366 to Tefé)[93] and to the building of numerous secondary roads [127]. In addition, new access to the undisturbed forest would increase the probability of forest fires [128–132], increase land conflicts [133] and would result in posing multiple health threats for all inhabitants of the region (and beyond), caused by bad air quality due to forest fires [25][94] [95] [96] [97], a higher risk of Malaria transmission [26,134,135] and a higher risk for zoonotic spillover[98] [99] [136–139]. The asphalted road itself would pose no threat to the environment, but the lack of governance (or law enforcement) would make it a spearhead for deforestation and forest degradation and thus highly dangerous to the (up to 18,000) indigenous people and to the forest's vulnerable floral and faunal biodiversity in its vicinity [140,141].

The "PL of the BR-319", PL 4994/2023 passed the Chamber of Deputies at the end of 2023. The PL proposes to use an application of 'urgency' for its political assessment, which would speed up the approval process by leaving out any prior legislative debate, any expert hearings, discussions with affected communities, public bodies etc. [142]. The PL, in addition, should follow the path of a 'simplistic environmental licensing' (rather than an all-encompassing one) by cutting the different parts of the roadworks into single and simplified 'licensing pieces'. This proceeding is possible, but foreseen by the constitution only for "activities or works of little potential for an environmental impact". As the environmental impact of the BR-319 complete asphalting cannot be classified "little", the fragmentation of its environmental licensing in different parts should classified as non-compliant, and, in consequence, the **PL** should be declared as anti-constitutional, as stated by the Brazilian Association of Members of the Ministry of Environment (ABRAMPA)[100].

The juridical battle between promoters and adversaries of the "Trecho do Meio" asphalting is ongoing. On 23rd August 2024, the Federal Regional Court rejected the appeal of the Transport Ministry[101], which had decided to take legal action against the decision of the 7th Environmental and Agrarian Court of the Judiciary Section of Amazonas State, who had stopped in July 2024 the

[93] https://news.mongabay.com/2024/09/brazils-br-319-highway-disaster-yet-another-maneuver-commentary/
[94] https://agenciabrasil.ebc.com.br/en/geral/noticia/2024-08/smoke-amazon-fires-reaches-neighboring-countries
[95] https://www.lemonde.fr/en/international/article/2024/08/21/brazilians-struggling-to-breathe-as-amazon-burns_6719069_4.html
[96] https://www.brasildefato.com.br/2024/08/23/if-the-fires-intensify-we-ll-have-a-period-of-very-unhealthy-air-says-an-environmentalist-about-wildfires
[97] https://www.dnoticias.pt/2024/8/22/417064-nuvem-de-fumo-de-incendios-florestais-na-amazonia-cobre-dez-estados-brasileiros/
[98] https://www.thelancet.com/action/showPdf?pii=S2542-5196%2824%2900163-3
[99] https://www.nature.com/articles/s41591-024-03300-3
[100] https://abrampa.org.br/file?url=/wp-content/uploads/2024/04/NOTA-DE-POSICIONAMENTO-INSTITUCIONAL-DA-ABRAMPA.pdf
[101] https://conexaoplaneta.com.br/blog/suspensao-da-licenca-previa-da-br-319-a-polemica-estrada-na-amazonia-e-mantida-pela-justica/

process of licensing the works for the BR-319 asphalting. The reason for the court was the “environmental unfeasibility of the project until the environmental and land governance is drastically strengthened by different public actors”[102]. However, on 7th October 2024, the Regional Federal Court (TRF-1) suspended this decision, stating that this decision would only establish conditions for the roadworks and not permit the immediate start of the road works[103].

Figure 47. End of the asphalt (in 2024) of the BR-319 highway Manaus – Porto Velho, at the southern End of the “Trecho do Meio”, ca. 25 km north of the BR-230 and BR-319 turnoff

Source: Google Street View

The construction of the Pucallpa – Cruzeiro do Sul road

Since more than four decades a road connection between the Peruvian city of Pucallpa in the Peruvian Amazon and Cruzeiro do Sul in Acre State (Brazil) has been discussed between the two countries. In May 2020 the Peruvian Government approved the road construction up to the Brazilian border, arguing the road to be a “public necessity of national interest”. On the Brazilian side the government of Acre State gave its OK and published the tender for the roadworks. A cost-benefit analysis by the ‘Conservation Strategy Fund’ in 2021 stated that the road would not be sustainable economically, and in addition, would cause deforestation in areas of high biodiversity and affect indigenous people in ‘voluntary isolation’. In consequence, according to the analysis, the environmental and social costs would largely exceed the economic benefits. Notwithstanding the political interest of both countries to build the connecting road, in 2023 the Brazilian Federal Court decided in favour of NGOs and environmental associations that objected to the road construction and stopped the project[104].

Ferrogrão railway line

The planned railway line of almost 1,000 km length that should connect the city of Sinop (as centre of the soy production) in the Southern Amazon with the port city of Miritituba (on Tapajós River in the Central Amazon) is another topic of fierce political debate.

The ‘Supremo Tribunal Federal’ (STF, the highest Brazilian Court) had suspended the start of the railway’s construction in order to allow for the conclusion of environmental impact studies. While

[102] https://oc.eco.br/liminar-anula-licenca-previa-da-br-319/

[103] https://g1.globo.com/meio-ambiente/noticia/2024/10/08/justica-licenca-previa-para-asfaltamento-da-br-319.ghtml

[104] https://www.conservation-strategy.org/sites/default/files/field-file/PB%20Pucallpa%20-%20Cruzeiro%20do%20sul%20PT.pdf

Indigenous leaders of the region have expressed their opposition to the building of the railway line, due to the lack consultancy with indigenous people in the planning process and to their fear of an increase of deforestation related to the production of soy [143] [105]. The STF has to decide at some stage if it is lawful to change the borders of the Jamanxim National Park in order to permit the construction of the railway line[106]. To avoid the STF's potentially negative decision, the Brazilian Government has recently provided an alternative route of the planned train line to reduce eventual impacts for the National Park[107]. Especially in Central and Northern Mato Grosso the railway would considerably cut costs of the grain transport for the export overseas [144], which, as consequence, would make soy production more profitable in the region. At the same time Mato Grosso State is acting to weaken the federal Amazon forest protection laws in order to legalise additional deforestation (see above). Indigenous communities are expressing their opposition against Ferrogrão line[108].

Paraguay-Paraná Waterway Project

The Paraguay-Paraná waterway runs with a length of more than 3400 km from the mouth of the Paraná River at the borders of Argentina and Uruguay up the town of Cáceres in Mato Grosso (Brazil), running through Central Paraguay and along the Bolivian border. It serves, specifically in the Southern part (approx. until Concepción, Paraguay), as important national and international water transport system. In Brazil, starting at the border near the Paraguayan town of San Lázaro, the waterway goes along and partly through the Pantanal biome, the world's largest continuous wetland [145] and key hydrologic resource in South America. After first plans appeared in the 1980s to convert the Paraguay river into a river transport system [146], the Brazilian part of the project was turned down by the government in year 2000, due to concerns about the irreversible, systemic impacts on the Pantanal wetland in particular [147]. Nevertheless, smaller licences, e.g. for river port extensions etc., were issued in Brazil in 2022 and 2023 [148,149], threatening the ecological integrity of the Pantanal wetlands[109]. In addition, a potential 'professionalization' of the northern Paraguay river transport system, up to the town of Cáceres in the South of Mato Grosso State [150], could destroy the fragile river ecology. It could incentivise an increase of soy (or other commodities) production area in the Pantanal, the Southern Brazilian Amazon, in Paraguay and Bolivia and lead to the destruction of wetlands and to direct or indirect deforestation [147].

Energy

Hydropower Dams

Plans related to energy production of the current Brazilian government for the development of the Amazon region have triggered controversial debates. After a decade without new hydropower plants in the Amazon, Brazil has come back to the idea of hydropower from the Amazon region[110], as well as the other Amazon countries [151], with a high number of new dams of different sizes, either in planning or in construction [152]. Due to its favourable physical and hydrological conditions, characterised by a substantial network of hydrographic basins, Brazil's hydroelectric generation plays a crucial role in supplying household electricity demand [153]. Generally, a balance between the energy production, the socio-environmental aspects and multiple uses of water resources should

[105]https://www.reuters.com/world/americas/indigenous-groups-say-brazil-plans-amazon-grain-train-behind-their-backs-2024-07-29/

[106]https://www.cnnbrasil.com.br/economia/macroeconomia/governo-estuda-concessao-casada-de-trilhos-e-estrada-para-tirar-ferrograo-do-papel/

[107]https://climainfo.org.br/2024/09/10/governo-protocola-no-stf-atualizacao-do-projeto-da-ferrograo/

[108]https://www.brasildefato.com.br/2024/11/17/indigenas-de-diferentes-etnias-paralisam-transporte-fluvial-no-rio-tapajos-no-para-contra-ferrograo-e-impactos-da-hidrovia

[109]https://news.mongabay.com/2024/03/projected-pantanal-waterway-threatens-protected-areas-may-render-navigation-impossible/

[110] https://dialogue.earth/en/energy/51950-is-hydropower-making-a-comeback-in-the-amazon/

be reached [154,155]. The building and functioning of dams requires flooding, which, in the Amazon, often results in the destruction of large areas of forest. Newly created islands suffer from forest edge effects and fragmentation (leading to forest degradation), while the island's forest flora and fauna will change considerably due to the lack of terrestrial connectivity [156]. In addition, dams alter river flood regimes that can affect forests a long way away from the reservoir, resulting in large-scale tree mortality [143]. More negative repercussions include fish mortality, loss of aquatic biodiversity, and ecological harm related to the fragmentation of once freely flowing rivers [151]. Despite the concerns of creating substantial socio-environmental problems [157,158], the Brazilian government points at the extension of hydropower plants in the Amazon region [159].

Oil and gas extraction

A large section of the current Brazilian government promotes oil and gas production in the Amazon region[111] [112], both within the Amazon forest[113] and at the Amazon River's mouth[114], despite the opposition of the Ministry of Environment and IBAMA[115] and despite serious socio-environmental concerns [160,161]. However, oil and gas production and expansion happen not only in Brazil, but throughout the Amazon region[116] [117] [118]. After a slow start[119] [120] [121], Ecuador has apparently shut down the first oil wells in the Yasuní National Park[122], following a decision of a national referendum in 2023. However, a possible overturn of the referendum is already discussed in the national media[123].

Drugs, crime and violence

The Amazon region has been an epicentre of environmental and social crimes since a long time. Typical activities that lead to violence include land-grabbing, illicit cropping and mining, and enterprise lobbying as well as armed conflict. Actors perpetuating these crimes can be individuals, private organisations, institutions, criminal groups, and even governments, among others [162]. In particular in Brazil, 'land mafias' - often an amalgamation of rural elites, police, and governmental and judicial power holders [116] - have surged in the context of land speculation and deforestation. Organised criminal groups like the "Comando Vermelho' and the 'Comando da Capital' (and others) have been active in the context of drug-trafficking in Central and Southern Brazilian since a long time [163], but have shown a stronger presence in the Amazon since the 2000s [164], drawn by increasing revenues by illegal drug and gold commerce [165]. Their activities related to the nexus of drug and environmental crime, i.e. involvement in illegal mining activities, illicit cropping, illegal wood extraction, drug trafficking, human and animal trafficking, deforestation, land grabbing, arms smuggling, and forest arson[124] [125], have increased significantly in the past decade, making the Amazon one of the most dangerous regions in Latin America [162,166–168], while the often only sporadic presence of law enforcement in the region facilitate these activities [50,169]. At the same

[111]https://www.france24.com/en/live-news/20240612-brazil-s-lula-defends-oil-exploration-near-amazon-river
[112]https://news.mongabay.com/2023/12/brazils-end-of-the-world-auction-for-oil-and-gas-drilling-commentary/
[113]https://sumauma.com/en/cupula-amazonia-sociedade-quer-barrar-petroleo-brasil-tendencia-explorar-mais/
[114] https://www.nature.com/articles/d41586-023-02187-3
[115]https://sumauma.com/en/exclusivo-ibama-recomenda-negar-licenca-para-explorar-petroleo-na-foz-do-amazonas/
[116]https://news.mongabay.com/2024/08/one-year-after-oil-referendum-whats-next-for-ecuadors-yasuni-national-park/
[117]https://assets.takeshape.io/17e2848c-4275-4761-9bf5-62611d9650ae/dev/7f15b84c-7431-4d6f-8742-2de166271f87/PIACI%20Threat%20Assessment_ENGLISH.pdf
[118]https://www.servindi.org/actualidad-noticias/12/08/2024/xpansion-petrolera-amenaza-pueblos-indigenas
[119]https://www.ohchr.org/en/press-releases/2024/08/ecuador-must-respect-will-people-and-halt-oil-drilling-yasuni-park
[120]https://www.therepublic.com/2024/08/28/ecuadors-citizens-voted-to-stop-oil-drilling-in-heart-of-amazon-a-year-later-it-hasnt-happened/
[121] https://insideclimatenews.org/news/21082024/ecuador-oil-operations-ban-vote/
[122]https://amazonwatch.org/news/2024/0829-ecuador-starts-dismantling-yasuni-national-park-oil-block-two-days-before-court-deadline
[123]https://www.climatechangenews.com/2024/02/08/ecuadors-new-president-oil-drilling-referendum-amazon-indigenous/
[124] https://publicacoes.forumseguranca.org.br/items/c86febd3-e26f-487f-a561-623ac825863a
[125]https://www.nexojornal.com.br/expresso/2024/09/21/amazonia-quais-as-dinamicas-do-crime-ambiental

time, the violence of the criminal groups against indigenous people and activists opposed to their illegal activities have risen to extreme levels, especially, but not restricted to, in border areas between Brazil, Peru, Colombia and Venezuela [49,164][126]. While criminal groups collaborate across borders, the security and law enforcement collaboration between the Amazon countries is weak to non-existent [170]. The Brazilian Norther Amazon states of Amazônas, Roraíma and Amapá have the highest murder rates in Brazil [171]. The advocacy group Global Witness ranks Colombia as the most dangerous country in the world for environmental defenders and those defending land rights for Indigenous and other local community groups[127], especially in the Amazon region[128].

[126] https://amazonunderworld.org/

[127] https://www.npr.org/2023/12/06/1214170818/colombia-environmentalists-murders-latin-america

[128]https://www.theguardian.com/environment/2023/sep/13/environmental-activists-killed-at-a-rate-of-one-every-other-day-in-2022-global-witness-report-aoe

6 Conclusions and Outlook

The year 2023 saw a decrease of forest disturbances (incl. deforestation and forest degradation) in the Pan-Amazon region (by 18.8%), with only few countries (or regions) having a contrary trend, like the Guiana Shield countries with an increase of almost 90%. In the first ten months of 2024 the Brazilian Amazon shows a further decrease of deforestation of 17.9%, according to the Brazilian deforestation alert system DETER, while forest degradation saw an increases by 375%, mostly driven by the massive surge (of more than 900%) in forest fires.

The current Brazilian Government has strengthened the institutions dealing with forest monitoring and environmental law enforcement, which has led to the curbing of forest loss due to the conversion to pasture or crop fields. In 2023, the fines issued by IBAMA had increased by 53% in monetary terms, compared to the 2019-2022 average, while the destruction of illegal equipment rose by a factor of 11[129].

However, severe droughts in the Amazon region do not only affect vegetation, animals and people in the region, it also makes the forest more prone to fire and, in general, poses one of the greatest threats to the ecological integrity of Amazon forests [172–174]. The Amazon basin has experienced an extreme drought that started in the austral summer of 2022-2023 that extended well into 2024 [175][130]. Fires in the Amazon region are not part of a natural cycle; they are almost exclusively from anthropogenic origin [176]. The combination of a drought-affected forest, exacerbated by rising temperatures due to climate change, together with the increased criminal action in the region[131] sets a worrying scenario. Indeed, most of the fires raging in the Amazon, leading to "record fires"[132] and the largest area of burned forest ever, are considered to have been started by arsonists, mostly in the interest of illegal loggers and land grabbers [116]. Effective firefighting in such a large area is a difficult (to impossible) task[133].

A countermeasure to Amazon forest destruction or degradation is consisting in preserving areas of secondary forests and forest regrowth. Secondary forests are the new forests that grow in places where the original forest has been removed, often due to activities like logging or agriculture [177,178]. In many tropical countries, including parts of the Amazon, these secondary forests are becoming more common. Secondary forests are a buffer for adjacent primary forests by reducing the forest edge effect that leads to negative impact on the forest structure [179]. In addition, they play an important role as carbon sink [32] and for restoring biodiversity in previously agricultural areas [36]. Amazon secondary forests are mostly located, not surprisingly, in regions of large-scale forest loss, like the Brazilian Arc of Deforestation [180] and the Northern, Western and Southern Amazon forest borders in Colombia, Peru, and Bolivia, respectively, and in the more populated areas along the Amazon River. According to JRC-TMF data, in 2023, the Pan-Amazon is covered by more than 83,500 km^2 of secondary forest, which include a significant area of forest regrowth after severe fire.

The fate of the Amazon rainforest is inextricably linked to the current and Brazilian policies. As the country prepares to host the 30th Conference of Parties (COP30) in Belém in late 2025, the government faces a critical juncture. It must make appropriate choices for a sustainable development of the Amazon region with the imperative of environmental protection. The extent to which the government prioritizes conservation efforts, curbing deforestation and forest degradation,

[129]https://www.gov.br/planalto/en/latest-news/2024/06/marina-silva-presents-overview-of-federal-environmental-protection-results
[130]https://www.g20.org/en/news/wildfires-and-climate-crisis-the-2023-2024-drought-is-the-most-severe-in-recent-history-records-show
[131] https://globalinitiative.net/analysis/criminal-networks-driving-the-amazons-climate-emergency/
[132]https://news.mongabay.com/2024/04/amid-record-high-fires-across-the-amazon-brazil-loses-primary-forests/
[133] https://www.theguardian.com/world/2024/sep/20/amazon-brazil-firefighters

and protecting the rights of indigenous communities, will significantly affect the health of the Amazon and its global ecological importance.

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List of abbreviations and definitions

JRC	Joint Research Centre
TMF	Tropical Moist Forest
EU	European Union
DG-INTPA	Directorate General for International Partnerships
DETER	Brazilian system for near real-time detection of deforestation and degradation
INPE	Brazilian Space Research Institute
IMAZON	Amazon Institute of People and the Environment
PRODES	Brazilian program for monitoring deforestation in the Legal Amazon
PL	Brazilian Law Proposal
SAD	IMAZON Deforestation Alert System
GFC	Global Forest Change
BLA	Brazilian Legal Amazon
IBAMA	Brazilian Institute for Environment and Renewable Natural Resources
CBERS-4A	China-Brazil Earth Resources Satellite 4A
ICMBio	Chico Mendes Institute for Biodiversity Conservation
FAO	Food and Agriculture Organization of the United Nations
NOAA	National Oceanic and Atmospheric Administration
SPOT-4 VEGETATION	Satellite pour l'Observation de la Terre 4 VEGETATION
COP27	27th Conference of the Parties of the UNFCCC
FUNAI	Brazilian National Foundation for Indigenous People
CAPES	Brazilian Federal Agency for Support and Evaluation of Graduate Education
CNPq	Brazilian Council for Scientific and Technological Development
MMA	Brazilian Ministry of the Environment
IL	Indigenous Lands
STF	Brazilian Supreme Court
PEC	Proposed Constitutional Amendment
APP	Permanently protected areas
ANVISA	Brazilian Heath Regulatory Agency
PA	Protected Area
SFB	Brazilian Forest Service
NGO	Non-Governmental Organization
ABRAMPA	Brazilian Association of Members of the Ministry of Environment
TRF	Brazilian Regional Federal Court
AVHRR	Advanced Very High-Resolution Radiometer
WFI	Wide Field Imager
GAUL	Global Administrative Unit Layers
UNFCCC	United Nations Framework Convention on Climate Change
GWIS	Global Wildfire Information System

S-2	Sentinel-2 Satellite

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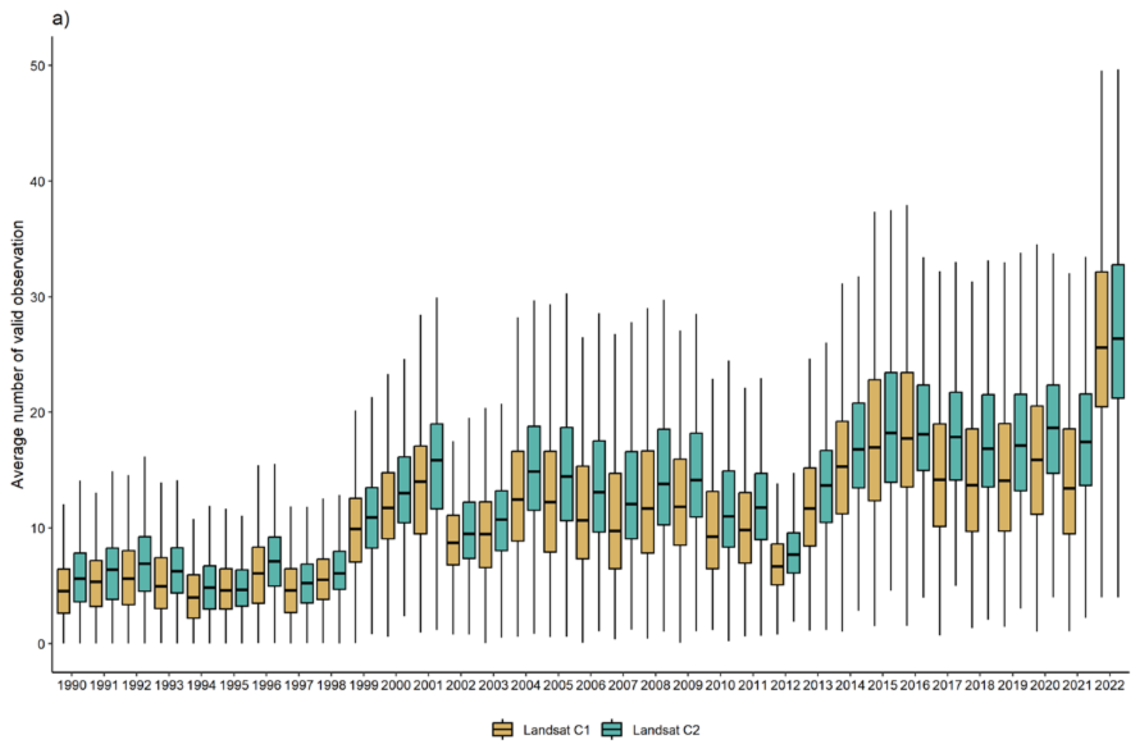
Annex 1: Using ‘Collection-2’ rather than ‘Collection-1’ Landsat imagery for mapping tropical forest change in the Amazon

In 2020, The United States Geological Survey (USGS) reprocessed the whole Landsat archive of 50 years of image collection in order to provide imagery with improved absolute geolocation accuracy. The enhanced Landsat Collection 2 (C2) has now replaced Collection 1 (C1), which has been phased out by USGS in 2022[134]. In the cloud computing space Google Earth Engine, where JRC-TMF is produced, C1 was removed from their servers in mid-2024[135]. The full Landsat Collection 2 has been used to recreate the new ‘TMF 2023’ dataset. The use of Landsat Collection 2 results not only in better quality input data, but also in an increase in the overall number of valid observations (i.e. observations free of cloud/cloud shadow/haze coverage or sensor issue) of 16% in the Pan-Amazon region for the period 1990-2022 compared to Landsat Collection 1. **Figure 48a** show the yearly distribution of valid observations per pixel from Landsat Collection 1 and 2 and **Figure 48b** provides a 5- year average representation. Landsat collection 2 brings an increase of 15% on average in the availability of valid observations and has an even bigger impact for 1990-1994 and 2005-2009 with a 20% increase compared to Landsat Collection 1.

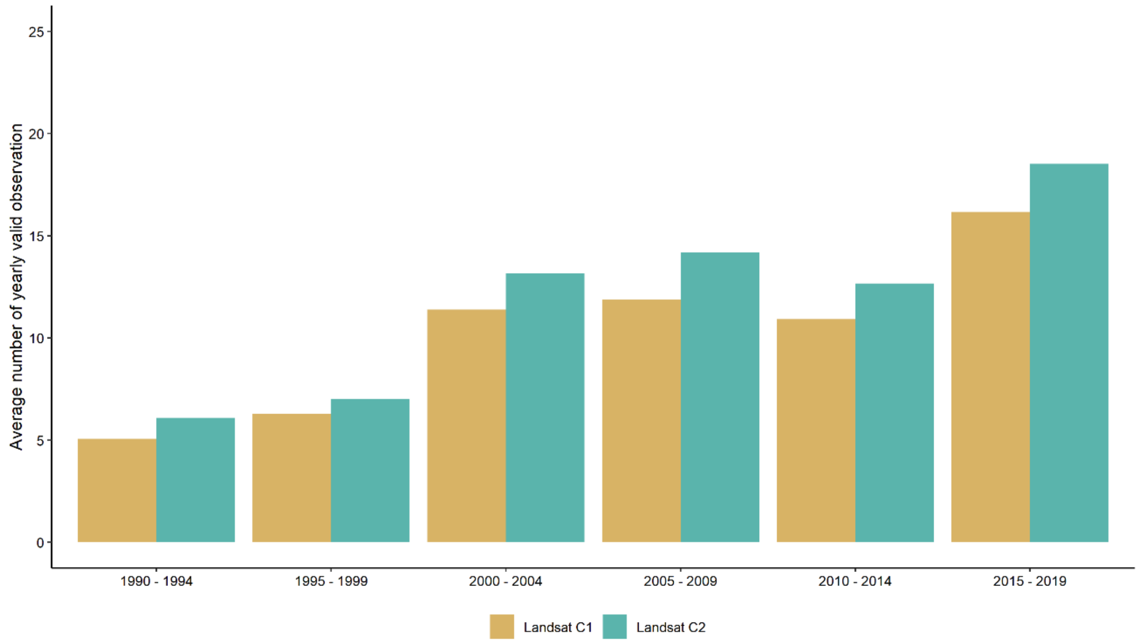
Figure 48. Average number of valid observations per pixel for the Pan-Amazon region between Landsat Collection 1 and Collection 2. Panel a) shows a yearly distribution of valid observations from 1990-2022 (boxplots display the median value as a horizontal bar, the 1st and 3rd quartile as a box and the whiskers drawn within the 1.5 interquartile range). Panel b) is a summary of panel a) and provides a 5 years average value of mean valid observations at Pan-Amazon scale between the two collections.



Source: JRC

[134] https://www.usgs.gov/landsat-missions/news/landsat-collection-1-datasets-be-removed-december-30-2022
[135] https://developers.google.com/earth-engine/datasets/catalog/landsat

b)



Source: JRC

The significant increase of valid satellite observations leads to a more precise assessment of forest cover changes in the tropics, given e.g. the persistent cloud cover in many regions of the tropics and the, sometimes, short time period to detect e.g. short-duration forest disturbances (e.g. detection of selective fire or low-intensity fires). In addition, a better geolocation reduces false positives due to geometric mismatch between images. The increase of valid observations is specifically important for years of long wet seasons (with persistent cloud cover), especially in highly dynamic areas of forest cover change, and for the 1990 years with overall low numbers of valid Landsat observations.

In addition to having an increased number of valid observations, we improved the classification of forest disturbances and recovery periods. First, we applied spatial filters to remove noise or false positives in the detection of short-duration disturbances. Second, we improved the detection of the first year of forest degradation and deforestation events given the enhanced input Landsat C2 data. The following rules based on the duration in days and recurrence of disruption detection (absence of tree cover in a 0.09 Landsat pixel) were applied throughout the time series:

Degraded Forests are defined as pixels with a maximum occurrence of 3 short-duration disturbance events observed between 1990 and 2022. These short-term events have a maximum duration of 900 days (when disruptions, i.e. absence of tree foliage cover within a Landsat pixel, are observed) and need to be separated by at least two years with no disturbance observation. In previous TMF versions, the duration of the first disturbance event was recorded in the number of days whereas the following events were only characterized by their duration in the number of years. In this TMF-v2023 version, the duration in days of the first three disturbance events are recorded. Beyond an occurrence of three short-duration disturbance events, the pixel is classified as deforestation from the starting date of the first observed disturbance event. Note that the distinction between forest degradation and deforestation in the last three years of the analysis (i.e. including year 2023) is always based on the ratio between the number of valid observations and the number of observed disruptions.

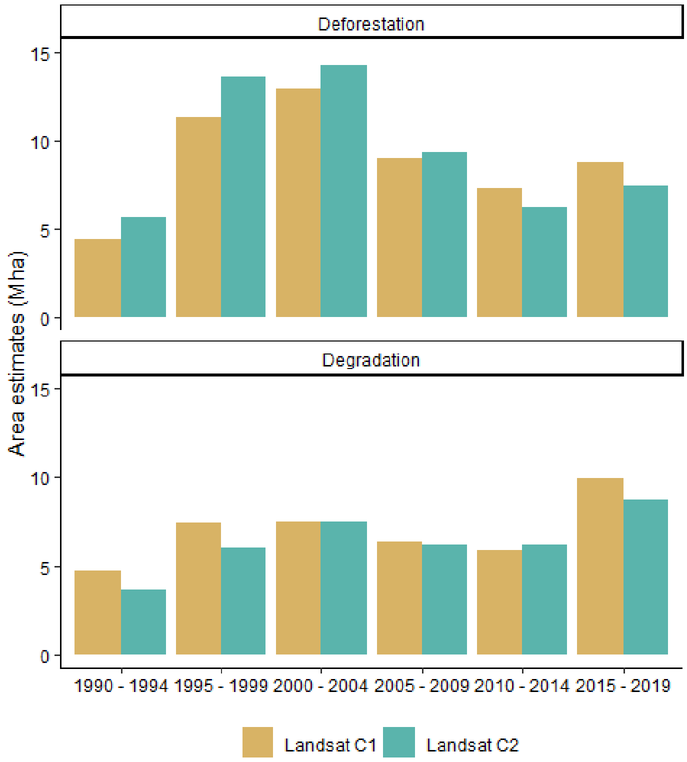
Deforestation refers to conversion of an undisturbed or degraded forest to another land cover type which is characterised in the TMF approach as a long-duration disturbance event (>900 days). The year of deforestation is attributed to the starting year of a disturbance event of more than 900 days duration or to the starting year of the first disturbance event when more than three consecutive short-term disturbance events are detected. In the case of forest conversion to agricultural plantations (e.g. oil palm, coconut or rubber plantations), the year of deforestation corresponds to the year of the first disturbance event if longer than 900 days or to the year of the second disturbance event if the first disturbance event's duration was less than 900 days.

Together, the improvement of the classification rules (for first year detection) and the reprocessing of the full Landsat archive to collection 2 led to updates in the historical dynamic of forest degradation and deforestation. It is important to note that change events that were detected in previous TMF versions are not removed but can be potentially reassigned to a previous year or converted to another class of change (e.g. indirect into direct deforestation). **Figure 49** show a comparison between the area estimates of deforestation (direct and after degradation) and forest degradation (not followed by deforestation) from TMF version 2023 (TMFv2023) with version 2022 (TMFv2022) for five years periods from 1990 to 2019 at Pan-Amazon level.

Deforestation in TMF v2023 is 17% higher in the Pan-Amazon from 1990 to 2004 compared to the previous version v2022. This is due to several combined factors: (1) increase in the overall number of valid observations in particular for historical periods, (2) improvement in the distinction between degradation and deforestation through the more accurate recording of each disturbance event's duration, (3) earlier attribution of the deforestation year in the case of large number of disturbance events, and (4) earlier attribution of the deforestation year in the case of forest conversions to agricultural plantations. We quantify an increase of 5% in total global deforestation in TMF v2023 (56.4 Mha) compared to TMF v2022 (53.6 Mha) for the period 1990-2019.

From 2010, we observed a 15% decrease in deforestation area estimates in TMF v2023 compared to TMF v2022. This can be explained by a decrease in deforestation after degradation after 2010 which either occurred earlier in the time series or was reclassified into direct deforestation. Overall, there is a decrease of 9% in total degradation in TMF v2023 (41.8 Mha) compared to TMF v2022 (38.2 Mha) for the period 1990-2019 but the trends using 5-years reporting periods remain similar between the two versions.

Figure 49. Difference for the Pan-Amazon region in detecting deforestation and forest degradation 1990-2019 by JRC-TMF with Landsat C1 or C2 collections.



Source: JRC

Annex 2: New research on forests, deforestation, forest degradation and regrowth in the Amazon (status October 2024)

Here we provide a comprehensive list of the most recent references about forest dynamics in the Amazon Basin, either land use / land cover change processes, drivers of forest change or effects on the wider climate system. The following table contains those references by major subject.

Subject	References
Air temperature	[1], [2], [3], [4], [5], [6], [7], [8], [9]
Carbon	[10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21]
Deforestation	[22], [23], [24], [25], [26], [27], [28], [29], [30], [31], [32], [33], [34], [35], [36], [37], [38], [39], [40], [41], [42], [43], [44], [45], [46], [47], [48], [49], [50], [51], [52], [53], [54], [55], [56], [57], [58], [59], [60], [61], [62]
Degradation	[63], [64], [65], [66], [67], [68], [69], [70], [71], [72], [73], [74], [75], [76]
Droughts	[77], [78], [79], [80], [81], [82], [83], [84], [85], [86], [87], [88]
Edge effects	[89], [90], [91], [92]
Fire	[93], [94], [95], [96], [97], [98], [99], [100], [101], [102], [103], [104], [105], [106], [107], [108], [109], [110], [111], [112], [113], [114]
Forest	[115], [116], [117], [118], [119], [120], [121], [122], [123], [124], [125], [126], [127], [128], [129], [130], [131], [132], [133], [134], [135], [136], [137], [138], [139], [140], [141], [142], [143]
Health	[144], [145], [146], [147], [148], [149], [150], [151], [152], [153]
Mining	[154], [155], [156], [157], [158], [159], [160], [161], [162], [163], [164], [165], [166], [167]
Protected areas	[168], [169], [170], [171], [172], [173], [174], [175], [176], [177], [178], [179], [180], [181], [182], [183], [184], [185], [186], [187], [188], [189]
Reforestation	[190], [191], [192], [193], [194], [195], [196], [197], [198], [199], [200], [201], [202]
Roads	[203], [204], [205], [206], [207]
Remote sensing methods	[208], [209], [210], [211], [212], [213], [214], [215], [216], [217], [218], [219], [220], [221]

Selective logging	[222], [223], [224], [225], [226], [227], [228], [229], [230], [231], [232], [233], [234], [235], [236], [237], [238], [239], [240], [241], [242]

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