

Brazil's climate targets impaired by the potential cessation of the Amazon carbon sink

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Abstract

In accordance with the recommendations of the Intergovernmental Panel on Climate Change (IPCC), countries utilize the "managed land" proxy for their national greenhouse gas (GHG) emission inventories. This implies deducting "passive" carbon removals from countrywide gross GHG emissions. Long-term forest plots indicate that the carbon sink in structurally intact Amazon forest has weakened by roughly 30% since the 1990s, as CO₂-driven growth is increasingly offset by warming. This matters for accounting, given that the majority of the carbon removal reported by countries such as Brazil is passive uptake on managed land. That carbon sink is now being eroded by the same warming it is expected to help limit. Statistical extrapolation of that observational evidence indicate the Amazon carbon sink may cease by mid-2030s. Here we evaluate the impact of this potential cessation of the Amazon carbon sink in the mid-2030s on Brazil's future emissions, in the context of its Nationally Determined Contribution (NDC) to the Paris Agreement. This is achieved by rescaling the forest carbon removal term embedded within Brazil's NDC target, which was determined with the support of an integrated-assessment model scenario. Our results indicate that the potential cessation of carbon removals by structurally intact Amazon forests will imply in an increase of 21% to 26% in Brazil's total (economy-wide) net emissions in 2035, in comparison with its NDC pledge. This finding may be relevant also for other regions, e.g. Africa, where comparable reductions in the carbon sink of their forests are also predicted to occur in the subsequent decades. It is crucial that Brazil and other forest nations that rely on currently strong passive sinks adjust their climate targets, for example by anticipating the timing of their net-zero pledge (currently set to 2050 in Brazil), and increasing its GHG emission cuts in sectors such as energy and transport.

Keywords: carbon removal, tropical forest, Paris Agreement, managed land, national greenhouse gas inventories

Introduction

Global scenarios of greenhouse gas (GHG) emissions highlight the critical role of land use, land-cover change and forestry (LULUCF) processes in meeting climate change mitigation goals (Riahi *et al* 2023, Dooley *et al* 2024). Brazil was the top emitter of LULUCF-related GHG in the 2016-2024 period (Friedlingstein *et al* 2025), and is a reference to other tropical countries, particularly regarding land-based mitigation of climate change in the tropics. The country emitted a total annual average of 1.71 PgCO₂e in the 2014-2023 period, with 64% of these emissions stemming from LULUCF and agriculture/livestocking processes (Brasil 2025b). A considerable amount of Brazil's total gross emissions (including all sectors) is offset by carbon removals that take place in large expanses of "managed" mature forests inside protected areas (the majority of which is located in the Amazon) (Brasil 2025b, Brazil 2024). Despite the absence of substantial recent human disturbance in these forests, their designation as "managed" is permitted under the Intergovernmental Panel on Climate Change (IPCC) guidelines (Eggleston *et al* 2006), given the presence of indigenous and traditional communities or their designation as nature conservation areas. The concept of managed land is formally defined as "land where human interventions and practices have been applied to perform production, ecological or social functions" (Eggleston *et al* 2006).

While the Paris Agreement signatories were expected to submit revised, more ambitious Nationally Determined Contributions (NDCs) by February 2025, Brazil announced its updated NDC a few months earlier at COP29 in Baku, Azerbaijan. The revised NDC commits the country to reducing its GHG emissions by 59% to 67% by 2035, relative to 2005 levels (2.56 PgCO₂e), targeting absolute emissions of 0.85 to 1.05 PgCO₂e in 2035 (Brasil 2026). The achievement of that target relies heavily on the reduction of deforestation (63%) and forest restoration (15%) (Brasil 2026). A number of other countries also rely on their standing forests (e.g. Russia and Canada) or on the regeneration of their forests (e.g. USA) to achieve their NDCs (Dooley *et al* 2024, Roman-Cuesta *et al* 2025).

The reduction of deforestation and forest degradation is still a major challenge considering that Brazil hosts the world's largest area of tropical forest, critical for global climate regulation, and despite current numbers (INPE 2026), yet faces persistent illegal deforestation and degradation, economic pressures for agricultural expansion and severe limitations in the enforcement of environmental regulations. These challenges pose serious implications for the durability of carbon removals by the Amazon forest, possibly compromising climate targets that depend on such process (Brunner *et al* 2024).

The "managed lands" proxy

The concept of "managed lands" entered the United Nations Framework Convention on Climate Change (UNFCCC) debate after the IPCC recognized that indirect anthropogenic effects on land, namely CO₂ fertilization and nitrogen deposition, are deeply intertwined with direct anthropogenic influences or even natural processes. This recognition underscores the impracticality of separating these direct and indirect effects through the forest inventory methods employed in national greenhouse gas inventories (NGHGI), since they track physical changes in the landscape, rather than tracking out the root cause of every molecular flux (IPCC 2024). Countries therefore have some flexibility to define where human interventions and practices have altered the background GHG fluxes within their territories, and must report all LULUCF emissions and removals occurring on these so-called "managed lands". This includes emissions from direct human actions, such as from deforestation or harvest. An

unmanaged forest that is deforested becomes managed land, and its emissions are reported from then on. The IPCC guidelines recommend that forest land, wetlands and grasslands be separated into two distinct categories: “managed” and “unmanaged” (Eggleston *et al* 2006). No obligation is placed upon countries to report GHG fluxes in unmanaged lands. Furthermore, the IPCC Guidelines allow countries flexibility in their implementation of the “managed land” proxy definition to their forests. Some countries, like New Zealand and China, and those in the European Union, consider their entire or nearly entire forest extent as managed land (Ogle *et al* 2018, Grassi *et al* 2018, Melo *et al* 2026). Brazil adopted the concept differently and considers only forests within protected areas (biodiversity conservation units and legally recognized indigenous territories) as “managed lands”, in addition to other forest-land uses like secondary forests, forest plantations, forests under selective logging regime, croplands, pasture, mining, bare soil, settlements and water reservoirs (Ogle *et al* 2018, Grassi *et al* 2018, Melo *et al* 2026). Total managed land in 2025 in Brazil, including all those land uses, is estimated as 502,000,000 ha, with roughly 50% of that land being protected areas (IBGE 2026a, 2026b). As explained later, nearly 90% of those protected areas are in the Amazon. In this study the focus is exclusively on the carbon removals occurring within Amazon protected areas, the majority of which are characterized by well-preserved vegetation within their boundaries. These areas are of particular significance as they are expected to be the most adversely affected by the cessation of the Amazon forest carbon sink. At present, 54% of the Brazilian Amazon is within protected areas (IBGE 2026a), the majority of which contain well-preserved forest vegetation. These areas contribute to GHG fluxes primarily by removing additional carbon from the atmosphere due to CO₂ fertilization (Hubau *et al* 2020), which is an indirect human-induced effect, also called “passive sink” (Allen *et al* 2025). Following the country's first national communication in 2004, the extent of protected areas in the Amazon had grown by 81% in 2025 (**Fig. 1**), leading to the inclusion of considerably more carbon removals in subsequent inventories (Roman-Cuesta 2025).

<<Place Fig. 1 here>>

The declining Amazon forest carbon sink

Field data reveals a reduction of 31% of the Amazon carbon sink in structurally intact forests since the early 1990s (**Fig. 2**), apparently attributable to rising temperature and more frequent droughts (Hubau *et al* 2020, Pan *et al* 2024), compromising future carbon removals by these forests. These data demonstrate that the world's largest tropical forest is also subject to the effects of climate change itself. Statistical projection on the evolution of that carbon sink indicates that structurally intact Amazon forests, both within and outside protected areas, should become a source of carbon to the atmosphere sometime by mid-2030s (Hubau *et al* 2020). The Congo basin forest, the world's second largest expanse of tropical forest, is projected to undergo an average reduction of 48% in its carbon sink capacity by the 2030's in comparison with the 1990's (Hubau *et al* 2020).

In this study, we analyze the potential consequences of the hypothetical termination of the Amazon carbon sink in the mid-2030s on the Brazilian committed target within the Paris Agreement, with insights valid to other tropical forest countries. It has previously been demonstrated that the weakening of natural carbon removal by the world's forests would have consequences for global climate target ambitions (Gidden *et al* 2023). However, the present analysis focuses on the specific case of Brazil, determining precisely how much it would have to raise its emission targets (or change timing of its commitments) to stay in line with its promised NDC.

<<Place Fig. 2 here>>

Methods

The impact of the declining Amazon carbon sink on Brazil's carbon emission targets is estimated by means of the following calculations:

$$\Delta C_{REM-Hist} = A_{ML} \cdot 10^{-9} \lambda_{REM} \quad (1)$$

Where $\Delta C_{REM-Hist}$ denotes the total gross carbon removal by structurally intact forests (in PgCO₂e yr⁻¹) in a given part year (2005) or average for a past period (2014-2023), A_{ML} is the area considered as managed land (in hectares) from which carbon removals are accounted in the NGHGI, λ_{REM} is the carbon removal rate of structurally intact forest used in NGHGI (in MgCO₂e ha⁻¹ y⁻¹) in the historical period, and 10^{-9} is an unit conversion factor.

The total gross carbon removal by structurally intact forests reported in the Brazil 2035 NDC emission target, $\Delta C_{REM-NDC}$, is estimated by introducing the declining rate of λ_{REM} , τ (in 0-1 fraction):

$$\Delta C_{REM-NDC} = A_{ML} \cdot 10^{-9} (\lambda_{REM} \cdot \tau) \quad (2)$$

The impact of future Amazon forest carbon removals is considered within three scenarios:

- (a) the official 2035 NDC,
- (b) 2035 NDC with no forest carbon sink in managed lands (protected areas) of the Brazilian Amazon,
- (c) 2035 NDC considering no forest carbon sink in managed and unmanaged lands (forests within and outside protected areas) of the Brazilian Amazon.

The factors used in equations (1) and (2) are summarized in Table 1 and explained in depth in the next sections.

<<Place Table 1 here>>

The contribution of $\Delta C_{REM-Hist}$ in comparison to the historical nationwide total net CO₂ emissions ($\Delta C_{TNet-Hist}$) or the contribution of $\Delta C_{REM-NDC}$ considering the total carbon emissions predicted in Brazil NDC for 2035 ($\Delta C_{TNet-NDC}$) is realized through the simple division:

$$\psi_{C+REM} = \Delta C_{REM} / \Delta C_{TNet} \quad (3)$$

Eq. (3) provides a direct estimate of the reliance of the country on the carbon removals by its forests (in this case the Amazon forest) when reporting its emissions, both in its NGHGI and NDC.

And the estimate of potential forgone forest carbon removals (σC_{REM}) due to the cessation of the Amazon forest carbon sink is calculated by multiplying the 2035 NDC carbon removals by the complement of τ :

$$\sigma C_{REM} = \Delta C_{REM-Hist} \cdot (1 - \tau) \quad (4)$$

Managed lands in the Amazon

As previously outlined, the “managed land” proxy is applied in Brazil to protected areas (biodiversity conservation units and legally recognized indigenous territories), as well as to other land uses like secondary forests and plantations (Ogle *et al* 2018). In the year 2023, when Brazil’s NDC was calculated, the total protected area in the Brazilian Amazon was 226,220,000 ha, including biodiversity conservation areas (conservation units) and legally recognized indigenous territories (**Fig. 1**) (IBGE 2026a, MMA 2026). No expansion of protected areas is predicted in Brazil’s NDC. This information is not included in the country’s NDC documentation, but it was corroborated by a specialist who participated in the NDC definition process (G. Angelkorte, *pers. comm.*). Consequently, A_{ML} is maintained at a constant level of 226,220,000 ha in all projections presented herein, except in scenario (c). In that case an area of 193,474,300 ha is added to the managed land area (protected areas) of the Brazilian Amazon, totalizing 419,694,300 ha.

Carbon removal rate of tropical forests

Carbon removal rate by primary structurally intact forests used in the last NGHGI of Brazil is $0.48 \text{ MgC ha}^{-1} \text{ y}^{-1}$, or $1.76 \text{ MgCO}_2\text{e ha}^{-1} \text{ y}^{-1}$ (Brasil 2024). This figure is representative of the mid-2000’s carbon sink in the Amazon, and is relatively up to date compared to the value proposed in the IPCC guidelines ($0.59 \text{ MgC ha}^{-1} \text{ y}^{-1}$ or $2.16 \text{ CO}_2\text{e ha}^{-1} \text{ y}^{-1}$ (Eggleston *et al* 2006, IPCC 2019). In fact average observed carbon sink in the Amazon was already as low as $0.25 \text{ MgC ha}^{-1} \text{ y}^{-1}$ ($0.92 \text{ MgCO}_2\text{e ha}^{-1} \text{ y}^{-1}$) by the mid-2010s (Hubau *et al* 2020), but here we employ the same value ($\lambda_{REM} = 1.76 \text{ MgCO}_2\text{e ha}^{-1} \text{ y}^{-1}$) utilized in the latest NGHGI in order to maintain consistency with the elaboration of the country’s NDC. As explained next, a 45% reduction of that figure is considered in Brazil’s NDC target for 2035, which brings the 2035 sink rate closer to the 2010’s estimate.

Declining rate of Amazon carbon sink and Brazil NDC

The Brazilian government opted to use an integrated assessment model (IAM) to support the definition of its new NDC, the Brazilian Land Use and Energy System (BLUES) model (Rochedo *et al* 2018). The definition of the overarching emission target—absolute emissions of 0.85 to 1.05 PgCO_2e in 2035—followed an iterative process with different government sectors, in order to accommodate existing climate policies, allow for more ambitious actions while also considering limitations imposed by political, economic, social and technological factors (Brasil 2025a).

The majority of integrated assessment models (IAM) that are used to explore emissions pathways to slow global warming does not consider passive carbon removals, e.g. through CO_2 fertilization. These indirect effects on forests are generally considered within Dynamic Global Vegetation Models – DGVMs, which are part of Earth System Models (Grassi *et al* 2021). Nevertheless, DGVMs do not reproduce the declining carbon sink of tropical forests, and in fact predict a sustained continuation of CO_2 fertilization throughout the 21st century (Koch *et al* 2021). The BLUES IAM considers passive carbon removals promoted by CO_2 fertilization and anticipates a decrease of 1.5% per year in the carbon removal rate of forests inside Amazon protected areas until 2035. This is less than half the decrease of 3.6% per year obtained from field data for the Amazon forest in the 1990-2010 period (Hubau *et al* 2020), but incurs in a total reduction of 45% of the carbon sink throughout the 2005-2035 period (1.5% times 30 years). Therefore τ (the Amazon forest carbon sink decline ratio considered in Brazil NDC) is equivalent to 0.55 when the total gross carbon removal of Amazon forests within the NDC emission targets for 2035 is taken into consideration. This enables the estimation, utilizing equations (2) and (3), of the extent to which carbon removals by the Amazon forest were embedded in the Brazil NDC targets for 2035. It is then posited that τ is equal to 1.0 specifically when Eq. 4 is applied to scenarios “b” and “c” in which there is complete cessation of the Amazon

forest carbon sink and, as such, of Amazon forest carbon removals from the atmosphere.

Results

The historical absolute carbon removal by Amazon forests within protected areas reported in Brazil's NGHGI ($\Delta C_{REM-Hist}$) is 0.397 PgCO_{2e} y⁻¹. The ψC_{T+REM} factor, defined as the amount of carbon removed from the atmosphere by the Amazon forest in Brazil, represented 16% and 23% of the net countrywide emissions reported in the NGHGI respectively in the base year of 2005 and in the average of the 2014-2023 period (**Fig. 3**). That total historical carbon removal is most probably considerably lower in reality, considering that the carbon sink rate used in the country NGHGI is almost double that measured in field plots in the 2010s (1.76 vs. 0.92 MgCO_{2e} ha⁻¹ y⁻¹) (**Fig. 2**).

<<Place Fig. 3 here>>

In a future perspective, the removal of ($\Delta C_{REM-NDC} =$) 0.219 PgCO_{2e} y⁻¹ by Amazon forests was abated from Brazil's countrywide emissions to reach the announced NDC target range of 0.85 to 1.05 PgCO_{2e} in 2035. That passive forest carbon removal, which is not explicitly mentioned in the NDC documents, represents from ($\psi C_{T+REM} =$) 21% to 26% of the 2035 emission targets. As previously outlined, the 2035 NDC emission target projects a 45% diminution in the Amazon carbon sink, leading to a forgone carbon removal of ($\sigma C_{REM} =$) 0.179 PgCO_{2e} y⁻¹. Such a forgone carbon removal of 0.179 PgCO_{2e} y⁻¹, which was already considered in the publicly announced NDC targets, is also taken into account here when calculating the impact of the complete cessation of the Amazon carbon sink on the NDC targets.

The complete cessation of the Amazon carbon sink would therefore imply an increase of 21% to 26% of future Brazilian emissions in relation to the 2035 NDC targets, with additional forgone carbon removals of ($\sigma C_{REM} =$) 0.219 PgCO_{2e} y⁻¹. The sum of that value of 0.219 PgCO_{2e} y⁻¹ and the 0.179 PgCO_{2e} y⁻¹ forgone carbon removals originally predicted in the NDC, would totalize 0.397 PgCO_{2e} y⁻¹ that would not be removed from the atmosphere and incorporated in the forest biomass anymore. In the event of structurally intact Amazon forests ceasing to remove carbon from the atmosphere, it is projected that the country's net emissions would rise to 1.07-1.27 PgCO_{2e} by 2035.

In case the cessation of the Amazon forest carbon removals is considered both in managed and unmanaged lands, the total forgone carbon removal (σC_{REM}) in this case would surmount to 0.737 PgCO_{2eq} y⁻¹, making it increase to 1.41-1.61 PgCO_{2e}. That is the real total emission that would happen in case the Amazon carbon sink ceases by mid-2030s, given that no distinction is made by the atmosphere of whether the forest is within or outside a protected area.

Discussion

Our results suggest that the Amazon is a powerhouse of passive carbon removal in the context of both Brazil's NGHGI and NDC. On the one hand it is evident that the managed land proxy provides an additional reason, among many others, for the preservation and research of these protected areas in the Amazon. On the other hand though, the country is very reliant on the uncertain Amazon forest carbon sink, and the potential cessation of such a sink would exert significant impact on the nation's commitments to the Paris Agreement. These findings are also relevant to other Amazonian and tropical forest countries for a compelling reason. Reductions in the carbon sink of other tropical forests, such as in the Congo basin, are also occurring or

are anticipated in the forthcoming decades, albeit at a slower pace in comparison to that of the Amazon. Delayed action to curb global warming seem to be jeopardizing the capacity of these tropical forests to help in the mitigation of climate change. While tropical forests around the world absorbed 20% of anthropogenic carbon emissions annually in the 1990s, this figure decreased to 9% in the 2010-2019 period, as a consequence of both a lower sink per unit area and a smaller intact forest area (Friedlingstein *et al* 2025, Pan *et al* 2024).

Therefore, when it comes to carbon removal by structurally intact vegetation, countries may not be able to count on tropical forests to mitigate climate change in the future as they are doing now. And carbon emission targets of countries that are heavily reliant on land carbon removals such as Brazil, DR Congo, Canada, China, USA and the European Union (Dooley *et al* 2024) are apparently disregarding the mismatch of timescales of carbon removals to offset other sectors (Brunner *et al* 2024). Furthermore, there is a risk that structurally intact tropical forests will not only halt the removal of carbon from the atmosphere but also begin to emit substantial amounts of carbon stored in their vegetation and soils if the carbon sink of these structurally intact forests becomes a source of carbon to the atmosphere. This would certainly make climate targets more difficult to achieve (Abernethy *et al* 2026). In this regard, it is noteworthy that our estimates are conservative in nature, insofar as they do not encompass the possibility of the Amazon forest becoming a source of carbon to the atmosphere.

Overreliance on land sinks: are countries aware of the consequences?

The strong reliance of countries like Brazil on passive carbon sinks by forests poses two major risks:

- (1) If the carbon sink stops, which is a possibility in the Amazon and Congo forests, countries will not achieve their emission targets should their NDC remain unchanged;
- (2) In case the carbon sink continues as expected in the NDC, since such passive carbon removals are not comprised in the IPCC emission pathways, if all countries like Brazil follow that approach of relying on passive carbon sinks, it would hamper the assessment of collective progress under UNFCCC Global Stocktake (Grassi *et al* 2021). This issue can be circumvented by “translating” the global model results used by IPCC to make them comparable to NGHGs and NDCs. However this procedure would reduce the remaining global carbon budget (Grassi *et al* 2021, Gidden *et al* 2023), and would also imply that net-zero CO₂ globally would not be enough to halt global warming (Allen *et al* 2025).

The attenuation of risk 1 would require that Brazil and other tropical forest countries should pursue more ambitious GHG emission reductions in sectors other than LULUCF. The reduction of deforestation, forest degradation and the promotion of forest restoration continue to be pivotal priorities for nations like Brazil, the emission matrix of which is predominantly characterized by LULUCF emissions. However, the dependence on uncertain future carbon removals by Brazil’s structurally intact forests can be complemented by more ambitious goals for example in the energy and transport sectors. On the other hand, the consideration of risk 2 would demand these countries to anticipate their net-zero target (Brazil’s is currently set to 2050), while also targeting, in the long-term, for a net-negative emission matrix, or even plan for geological net zero (Allen *et al* 2025).

Moreover, to the extent possible, it would be important that the passive carbon removals that are reported in Brazil’s NGHGI (Brasil 2024a), also get informed in the country’s NDC, according to the paragraph 5(a) from annex I of Decision 4/CMA.1 (<https://unfccc.int/documents/193407>). That said, the calculations performed here for Brazil can be theoretically extrapolated to Congo forest countries under certain

assumptions regarding how carbon removals are considered in their NDCs (Roman-Cuesta *et al* 2025).

In the future, should countries continue to report the carbon flux from these forests, that may mean reporting emissions—and not removals anymore—from forests without any major direct human intervention but rather permanently degraded by climate change (Lapola *et al* 2023). That is because these forests which are now acting as sinks might become sources of carbon to the atmosphere in the future. Our reasoning assumes that the NGHGI should consider the decline of the sink. Brazil's inventory currently applies a constant removal factor representative of the mid-2000s, so a declining or ceasing sink would show up in reported emissions only once that factor is updated with recent field data. The question gets even trickier for countries like Brazil if the notion of reporting carbon fluxes from unmanaged land gains traction, as a way to reflect more precisely the observed increase in atmospheric CO₂ concentration (Nabuurs *et al* 2023). That would keep Brazil's emissions roughly at the same level as the average annual emissions reported in the 2013-2022 period (Fig. 3).

However, one should consider the Amazon carbon sink will certainly not decline or cease at the same time, or rate, in the entire Amazon. Evidence shows that the decline is happening faster in south Amazon (Esquivel-Muelbert *et al* 2019), an area that has been subject to the strongest warming, alterations in the water cycle and severe forest fragmentation (Marengo *et al* 2024).

Other than that, large-scale rational adaptation actions to protect the Amazon and other tropical forests against the ravages of climate change and its effects on many processes alongside carbon storage should be implemented (Brasil 2025b).

Conclusions

Simple calculations on the impact of the potential cessation of the Amazon carbon sink by the mid 2030's reveals an anticipated escalation in total economy-wide Brazil's emissions ranging from +21% to +26% in comparison to the country's latest NDC. This finding has implications for other countries that similarly to Brazil rely on their forests to abate gross GHG emissions in their NGHGI and in their NDCs. This is due to the fact that reductions in the strength of the carbon sink of other forests are also predicted in the subsequent decades. It is important that countries like Brazil are fully aware of the consequences of that reliance on such passive carbon sinks. In case the Amazon carbon sink really ceases, the NDC target will not be achieved and more ambitious targets for other sectors including energy and transport would seem necessary. In case the Amazon carbon sink continues as predicted in the country's NDC, and considering such passive carbon removals are not comprised in IPCC emission pathways, if all countries like Brazil continue following that approach it will hamper the assessment of collective progress under UNFCCC Global Stocktake. In light of that, an anticipation of countries' net-zero target (Brazil's is currently set to reach it by 2050) is recommended, while also targeting for long-term net-negative economy, or even plan for geological net zero.

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Author contributions

DML and JPHBO conceived the research. DML conducted the research. RVA and MRC provided data. All authors contributed to manuscript writing and revision.

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Data Availability

All data used to make the calculations presented in this study are presented in supplementary material to this article.

Declarations

Ethics approval and consent to participate

Not applicable

Consent for publication

Not applicable

Competing interests

The authors declare no competing interests related to the findings presented in this study, as well as related to the funding agencies.

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Figures and tables

Table 1. Key factors used to estimate the impact of the potential cessation of the Amazon forest carbon sink in Brazil's national greenhouse inventories (NGHGI) and future nationally determined emission targets (NDC).

Factor	Abbreviation	Value	Unit	Reference
Managed land area in Brazilian Amazon (2023)	A_{ML}	226,220,000	ha	(IBGE 2026a, MMA 2026)
Amazon forest carbon removal rate considered in Brazil NGHGI	λ_{REM}	1.76	MgCO ₂ e ha ⁻¹ y ⁻¹	(Brasil 2024)
Amazon forest carbon sink decline ratio considered in Brazil NDC	τ	0.55	Unitless (0-1)	(Brasil 2025a)

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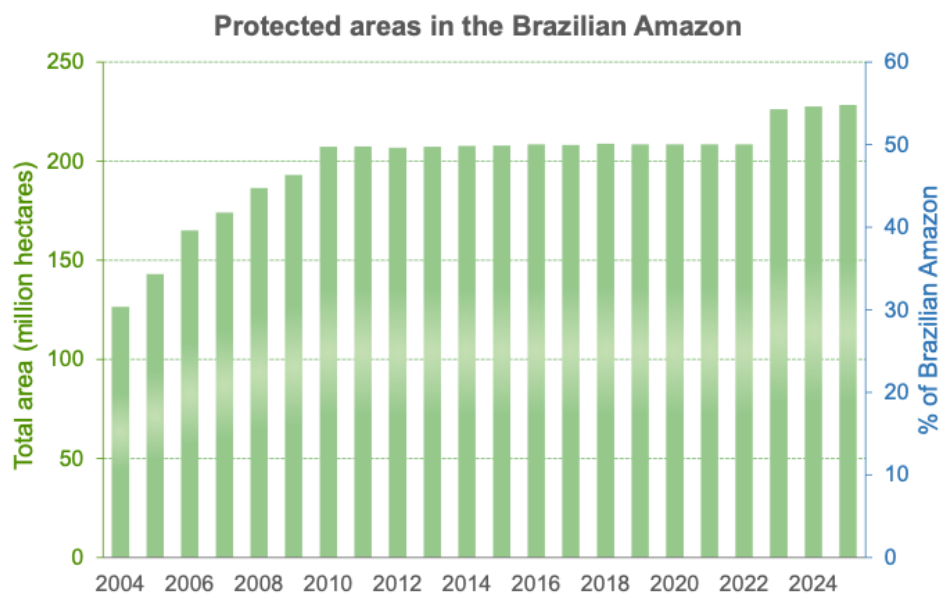


Figure 1. Cumulative area formally designated as protected areas (conservation units and indigenous territories) in the Brazilian Amazon (excluding oceanic areas). Total area of Brazilian Amazon forest is 419,694,300 ha. Sources: (IBGE 2026a, MMA 2026, Veríssimo *et al* 2011, MapBiomas 2026).

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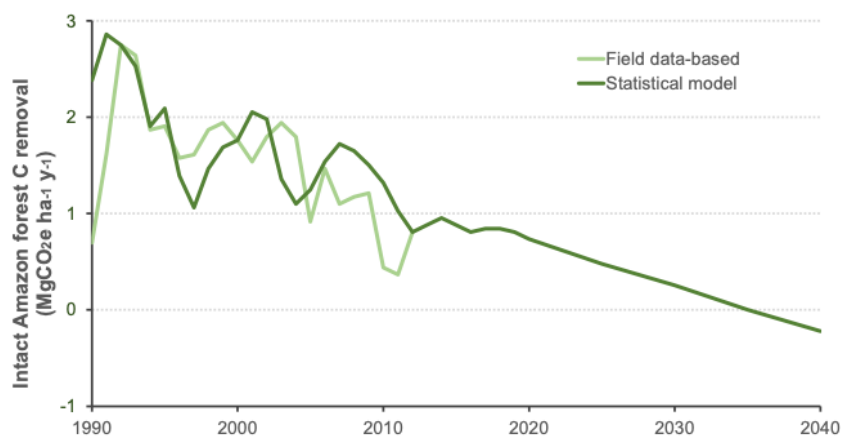


Figure 2.

The declining carbon removal by the Amazon forests. Field data- and statistical model-based estimate of carbon removal rates in structurally intact Amazon forests in the 1990-2040 period [adapted from (Hubau *et al* 2020)].

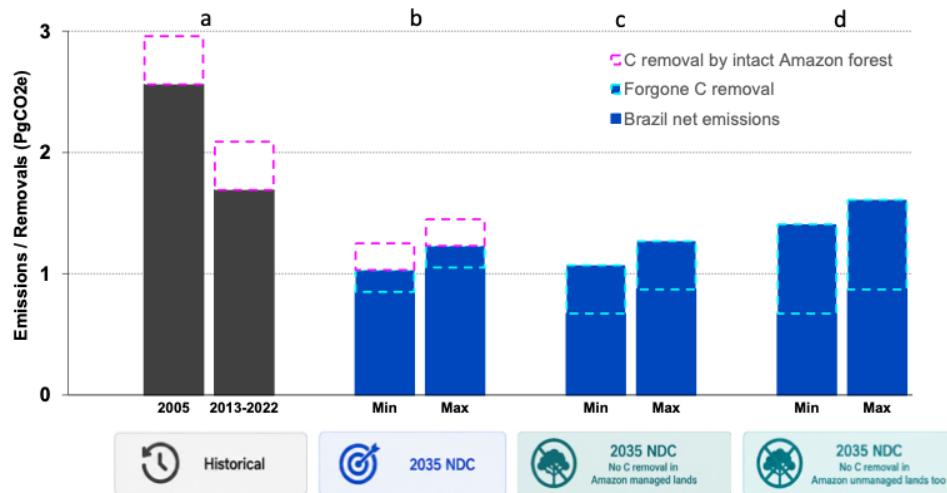


Figure 3.

Amazon forest carbon removals and Brazil climate emissions. **(a)** Historical (baseline year 2005 and 2014-2023 average) emissions reported in Brazil's national greenhouse gas inventories and **(b)** emission targets for 2035 predicted in the country's latest NDC (2035 NDC), considering the minimum and maximum projected emissions reported in the country's NDC; **(c)** the impact on the same targets but considering the cessation of carbon removals by structurally intact Amazon forests inside protected areas; **(d)** the impact on Brazilian emissions in case the termination of carbon removals is reported for both managed (protected areas) and unmanaged lands (non-protected forest areas) in the Brazilian Amazon. Pink-dashed area denotes carbon removals from structurally intact Amazon forest inside protected areas that is deducted from gross emissions in national inventories and in the country's NDC. Light blue-dashed area depicts forgone carbon removals in case the Amazon carbon sink is ceased by 2035.