Brazil's 2024 fires drove historic emission levels

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Highlights

- Brazil saw its territory burn at an unprecedented rate in 2024, when more than 30.5 million hectares were burned.
- Native vegetation and pasture together represent 93% of the total area burned in the country in 2024.
- In 2024, 42% of the burned area occurred in fire-sensitive ecosystems, which include forests, wetlands and marshes.
- While CO_2 accounts for most (average of 93%) of the emissions, in 2024, the proportional contribution of methane in the Amazon increased due to more fires occurring predominantly in forests.
- It is recommended to prioritize the full implementation of the National Integrated Fire Management Policy, controlling fire use and strengthening monitoring, fighting and governance mechanisms.

Context

In 2024, Brazil saw its territory burn at an unprecedented rate. According to MapBiomas Fire Monitor, more than 30.5 million hectares were burned, with most of this area (95%) comprising native vegetation and pastureland. Between these two land cover types, wildfires in the native vegetation accounted for the majority of the burned area (74%), while fires in pasture accounted for about 10%. Out of the total burned area in Brazil, 12.8 million hectares (42%) comprised fire-sensitive ecosystems (forests and wetlands).

The occurrence of wildfires in Brazil primarily concentrates in the dry season from August to October, with a peak in September, which is a strong indication that they are human-driven, whereas natural fires are caused by electrical discharges associated with storms, which naturally serve as a limiting factor for fires (Ramos-Neto and Pivello 2000; Cochrane 2003).

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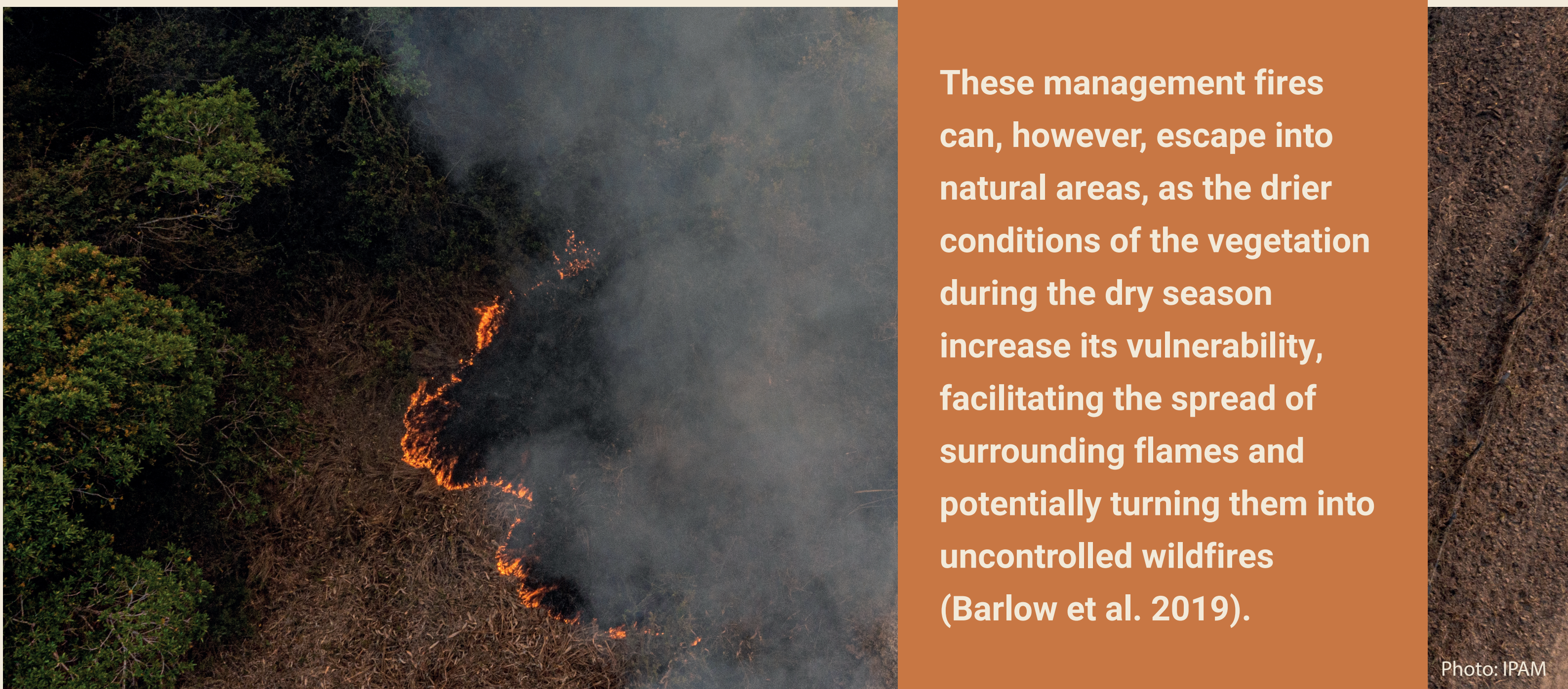
Such naturally occurring fires are found in specific biomes, such as the Cerrado, Pantanal, and Pampa (Pivello et al. 2021). Although these ecosystems are adapted to periodic burning, recent years have seen shifts in their fire regimes, marked by higher intensity and frequency than would naturally occur (Gomes et al. 2024). On the other hand, predominantly forest biomes, such as the Amazon and the Atlantic Forest, exhibit extremely rare natural fire events, are ecologically sensitive to fire, and tend to have high post-disturbance tree mortality rates (Silva et al. 2018).

Most fire activity occurs during the dry season because fire remains a key land management tool across much of Brazil. Anthropogenic use of fire is closely associated with agricultural practices adopted by cattle ranchers, smallholders, and indigenous and traditional people, primarily to clear newly deforested areas, renew pastures, or manage fallow systems (Barlow et al., 2019). Among these practices, the management of mainly planted exotic pasturelands, using fire to remove weeds and stimulate grass regrowth, represents the primary agricultural use of fire, particularly in the Amazon and Atlantic Forest biomes (Alencar et al. 2024a).



These management fires can, however, escape into natural areas, as the drier conditions of the vegetation during the dry season increase its vulnerability, facilitating the spread of surrounding flames and potentially turning them into uncontrolled wildfires (Barlow et al. 2019).

Photo: IPAM

In fire-sensitive ecosystems, such as forests and wetlands and marshes, drier and hotter climate conditions intensify the spread and severity of fire events in areas that wouldn't normally burn (Brando et al., 2019). In the Amazon, intense droughts can be a strong predictor of forest fire occurrence (Alencar et al. 2015; Aragão et al., 2018). While fire has historically shown a close relationship with deforestation, given its widespread use to clear recently deforested areas, this coupled occurrence has recently begun to weaken in the Amazon, indicating a new fire dynamics (Alencar et al. 2024b). Between 2022 and 2024, fire incidence increased despite a decline in deforestation rates. In 2024, the area affected by wildfires was 15 times larger than the deforested area, according to the MapBiomas Fire Monitor (Table 1). The severe drought that year also contributed to the spread of accidental fires in pastures and croplands not intended to burn, emphasizing the need to account for these undocumented greenhouse-gas emissions in national inventories and climate-mitigation strategies.

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Despite the importance of these fires, the National Emissions Inventory (Fourth National Communication to the UN Framework Convention on Climate Change: MCTI 2020), only reports fire emissions related to deforestation and from the burning of agricultural residues from cotton and sugarcane crops, leaving out emissions from fires in native vegetation and pastures, with the argument that the recovery of the vegetation will offset emissions from fire in these land cover types. Furthermore, although carbon dioxide (CO_2) emitted by biomass burning might be partially reabsorbed during vegetation regrowth, the same does not apply to methane (CH_4) and nitrous oxide (N_2O), potent greenhouse gases that persist in the atmosphere and are not offset by regrowth (Brando et al., 2019; van der Werf et al., 2017). This omission in national reporting frameworks leads to an underestimation of Brazil's fire-related emissions, hindering the design of more accurate and effective climate mitigation strategies.

The aim of this policy brief was thus to estimate gross greenhouse gas emissions caused by the 2024 fires in Brazil and highlight the relevance of this component in the country's emission profile. To this end, we disaggregated the analysis of fire-affected areas by biome and vegetation type, including native vegetation and pasture, which together represent 93% of the total area burned in the country in 2024 (Table 1).

Table 1. The total burned area detected by the MapBiomas Fire Monitor for 2024, and the amount considered for this study (and their relative proportion), including native vegetation and pastureland.

Biome	Total burned area detected (Km²)	Total area deforested (Km²)	Burned area compared to deforestation (%)	Burned area considered in this study (Km²)	Burned area considered in this study compared to total (%)
Amazon	175,119	6,289	2,785%	170,235	97%
Cerrado	97,040	8,175	1,187%	88,071	91%
Pantanal	18,580	723	2,607%	18,400	98%
Atlantic Forest	10,754	765	1,406%	4,545	42%
Caatinga	3,296	3,170	104%	3,037	92%
Pampa	34	655	5%	32	95%
Total	**305,093**	**19,776**	**1,543%**	**284,320**	**93%**

The estimates of emissions from combustion for the different land use classes were calculated based on the fire scar mapping from MapBiomas Fire Monitor, the average carbon stock values in fuel compartments from the Fourth National Inventory (FNI; MCTI, 2020), and combustion and emission factors from the IPCC (2006). The extraction of the burned area in each class considered (forests, savannas, grasslands, wetlands, and pasture) was done by crossing the fire scar maps with the land cover and land use maps from MapBiomas Collection 9. The detailed methods applied here can be found in the at the end of this document.

Fire emissions patterns in 2024

The time series of fire-related emissions by class and biome (Figure 1) reveals that, in 2024, emissions reached their highest levels in the Amazon and the Atlantic Forest. In the Amazon, all types of land cover classes showed a positive trend in 2024 in relation to 2023 (193% increase), with emissions driven mainly by forest fires (375% increase). In the Atlantic Forest, the surge in emissions caused by fire was primarily seen in wetlands, which also experienced a twelvefold increase compared to 2023. However, positive trends between 2023 and 2024 were also detected in forests (300% increase) and pasture (279%) in this biome

Wetlands (281% increase) and grasslands (211%) also drove an emission surge in 2024 in Pantanal, whereas emissions in 2020 were mostly derived from burning grasslands (Figure 1). The Cerrado exhibited a 218% increase in fire-related emissions in forests, grassland, and wetlands compared to 2023 (Figure 1). Only the Caatinga and Pampa saw a decreasing trend of emissions due to fire from 2023 to 2024 (47 and 39% decrease, respectively). Pampa had seen a record high of fire-related emissions in grasslands and wetlands in 2022 (Figure 1).

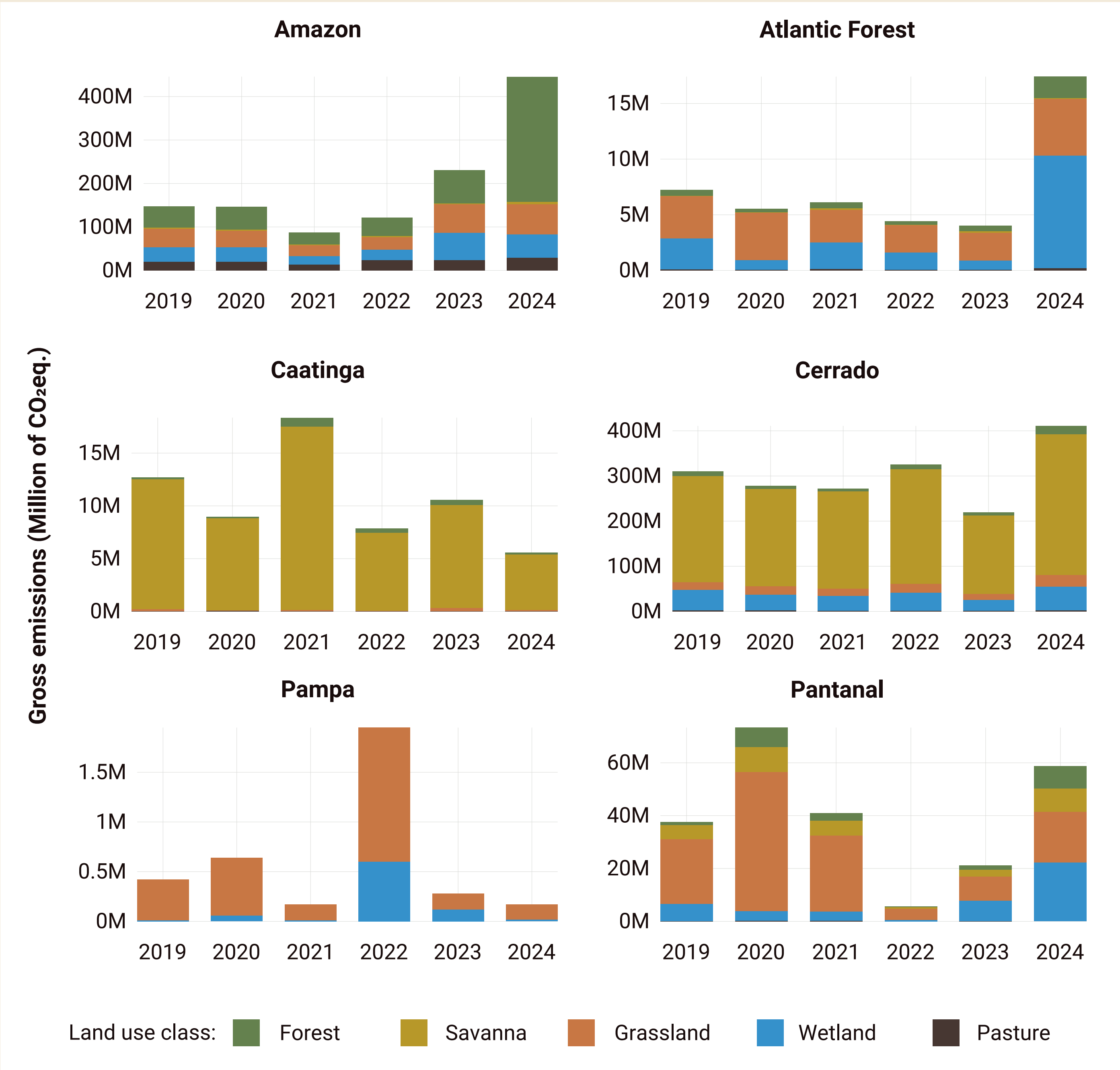

Figure 1. Total gross emissions of CO_2-eq between 2019 and 2024 in the Brazilian biomes and each land cover class.

Most of the emissions produced over the time series are carbon dioxide (93% of the contribution), followed by methane (4%) and nitrous oxide (3%). In the Amazon in 2024, the proportional contribution of methane increased, with carbon dioxide accounting for 87%, methane for 10%, and nitrous oxide for 3% (Figure 2). This is a result of the significant increase in the area of forest burned, given that forests have a higher methane emission factor (see Table 3 in the Methods section).

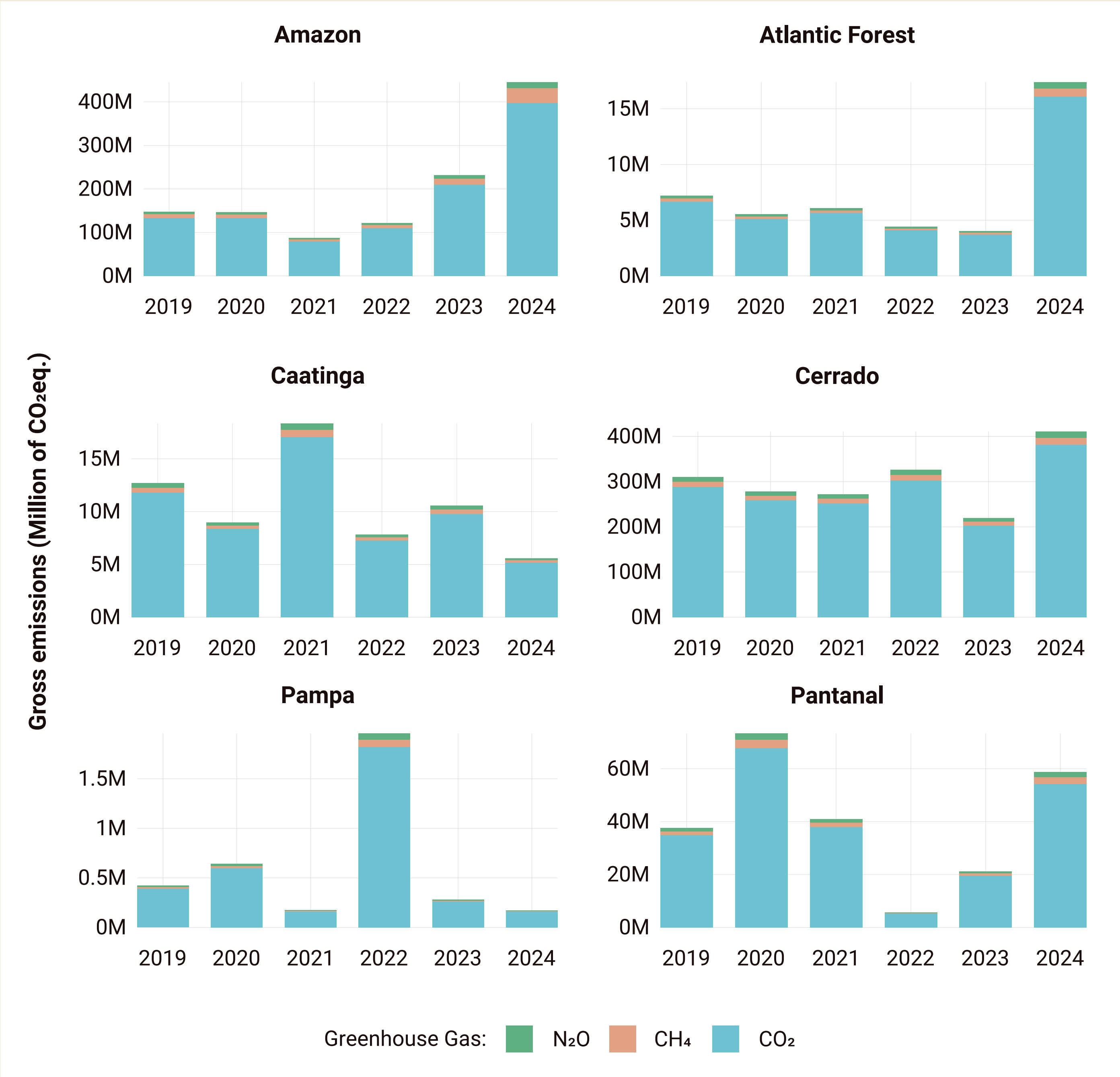

Figure 2. Proportional gross emissions of each greenhouse gas emitted due to fire between 2019 and 2024 in the Brazilian biomes. Gases are compared by their contribution to total gross CO2-equivalent emissions.

Discussion

The record-high fire-related emissions of 2024 reveal how climate stress and human-driven ignitions are reshaping fire dynamics across Brazil. The 2024 fire season in Brazil was unprecedented, especially in the Amazon, Atlantic Forest and Pantanal biomes. Even with deforestation declining, emissions increased sharply, showing that the country's carbon land use GHG emissions were dominated by wildfires and fire use for pasture management rather than deforestation alone.

The five-fold increase in forest fire emissions in the Amazon and the surge in wetlands of the Atlantic Forest and Pantanal illustrate this shift. These results make clear that a mitigation strategy focused mainly on deforestation no longer reflects the reality to reduce fire-driven emissions in Brazil.

Besides, fires beyond deforestation remain largely invisible in the national emissions accounting system. The omission of wildfires and pasture burning from Brazil's National Emissions Inventory results in a consistent underestimation of the country's contribution to global greenhouse gas emissions. While some of the carbon dioxide emitted during fires can be reabsorbed by regrowing vegetation, methane and nitrous oxide persist in the atmosphere for decades, adding to long-term warming, highlighting the importance of reporting these processes since methane is not captured back in the vegetation regrowth process, which is the argument used not to report the emissions from wildfires and burned pasture fields. Including these emissions is essential to ensure transparency in Brazil's reporting to the UNFCCC and to align national mitigation targets with the Paris Agreement.

The severe drought of 2024 made this imbalance even more visible. Climate extremes amplified the spread of accidental and uncontrolled fires, affecting pastures, croplands, and forests alike. These events exposed the challenges of fire prevention, local early warning, insufficient financial and human resources, and the lack of investment in alternatives to fire use. Without strong institutions, early-warning systems, and sustained investment in prevention, prepared and equipped teams on the ground from government institutions, local communities, and the private sector to fight fires in a coordinated way, it will be challenging to face other years such as 2024. Brazil will remain vulnerable to the combined impacts of drought and fire, even under lower deforestation conditions.

Integrating fire management into Brazil's climate and land-use agenda is therefore urgent. The National Integrated Fire Management Policy (PNMIF) offers a foundation, but its implementation requires greater coordination, funding, and participation of local brigades and communities. Expanding monitoring platforms such as MapBiomas Fire and strengthening prevention networks can help reduce the risk of large-scale fires. Incorporating fire management into the Nationally Determined Contribution (NDC) and subnational climate strategies would increase accountability and reinforce Brazil's credibility ahead of COP 30. Reducing uncontrolled fires is not only essential to protect ecosystems and rural livelihoods—it is central to Brazil's climate leadership and its capacity to present real, science-based solutions for a resilient future.

Recommendations

Addressing the drivers of Brazil's escalating fire emissions demands a comprehensive response that links policy, science, and community action. The measures proposed below point to concrete ways to strengthen prevention, governance, and adaptation across all biomes.

1 **Fully implement the National Integrated Fire Management Policy (PNMIF):** strengthen coordination among federal, state, and municipal agencies and ensure stable funding. Implement the National Integrated Fire Management Policy (Law No. 14.944/2024) with biome-specific strategies and clear operational guidelines. Ensure coordination among federal, state, and municipal levels, while empowering fire brigades, Indigenous peoples, and local communities. Multi-actor governance structures with decision-making power, budgets, and targets should be consolidated at all government levels.

2 **Integrate fire emissions into national climate commitments:** incorporate emissions from wildfires and pasture burning into Brazil's National Greenhouse Gas Inventory and Nationally Determined Contribution (NDC) to ensure transparency and improve climate accountability. Recognizing these currently unreported emissions, especially CO_2 and methane, is essential to provide a more accurate picture of the land-use sector's contribution to national totals. Updating methodologies and datasets will align Brazil's reporting with international standards and strengthen the country's credibility in meeting its climate targets under the Paris Agreement.

3 **Invest in prevention and rapid response:** support local brigades, Indigenous and community-based monitoring networks, and early-warning systems. Integrate hydrometeorological data, vegetation flammability indices, and seasonal risk models into near-real-time monitoring platforms. Create a unified national database combining wildfire, prescribed burning, and emission information to support prevention and rapid response. Early warning systems and priority-area maps should be aligned with local strategies and accessible to all actors.

Photo: Sara Leal

4 **Sustain deforestation reduction and promote fire-free land management:** continue reducing deforestation to limit ignition sources and forest degradation, while investing in fire-free pasture renewal and regenerative agricultural practices. Expand technical assistance and rural extension to scale sustainable systems such as agroecology, direct planting, and integrated crop-livestock-forestry. Strengthen enforcement against illegal burns, hold landholders accountable for prevention failures, and accelerate the allocation of undesignated public forests for protection and sustainable management, proven measures to reduce fire occurrence and enhance landscape resilience.

5 **Regulate and adapt fire use in agriculture:** improve fire use licensing systems and make them transparent and open to society. In recurrent fire zones, establish prevention mosaics and require control and prescribed burn plans. When used, fire must follow ecological and climatic thresholds to conserve biodiversity and soil health.

References

Alencar, A., Martenexen, L., Gomes, J., Morton, D., Brando, P. Entendendo a relação entre o fogo e desmatamento em 2023. 2024a. Nota técnica Amazônia em Chamas n° 12. IPAM, Brasília - DF. https://ipam.org.br/bibliotecas/entendendo-a-relacao-entre-o-fogo-e-desmatamento-em-2023

Alencar, A., Arruda, V., Martenexen, F., Monteiro, N., Silva, W,. Fogo na Amazônia em 2024: um ponto fora da curva? 2024b. Nota técnica. IPAM, Brasília - DF. https://ipam.org.br/bibliotecas/fogo-na-amazonia-em-2024-um-ponto-fora-da-curva/

Alencar, A. A., Brando, P. M., Asner, G. P., & Putz, F. E. (2015). Landscape fragmentation, severe drought, and the new Amazon forest fire regime. Ecological Applications, 25(6), 1493–1505. https://doi.org/10.1017/CBO9781107415324.004

Balch JK, Nepstad DC, Brando PM, Curran LM, Portela O, Carvalho O, Lefebvre PP (2008) Negative fire feedback in a transitional forest of southeastern Amazonia. Global Change Biology, 14, 2276–2287. https://doi.org/10.1111/j.1365-2486.2008.01655.x

Barlow, J., Berenguer, E., Carmenta, R. and França, F. (2019), Clarifying Amazonia's burning crisis. Glob Change Biol, 26: 319-321. https://doi.org/10.1111/gcb.14872

Brando, P.M.; L.N. Paolucci; E. Ordway; C. Ummenhofer; H. Hartmann; M. Cattau; L. Rattis; V. Medjibe; M.T. Coe; J. Balch. Droughts, Wildfires, and Forest Carbon Cycling: A Pantropical Synthesis. 2019. Annual Review of Earth and Planetary Sciences 47: 55-581. DOI: https://doi.org/10.1146/annurev-earth-082517-010235

Brunel, Marie et al. When do Farmers Burn Pasture in Brazil: a model-based approach to determine burning date. Rangeland Ecology & Management, [S.L.], v. 79, p. 110-125, nov. 2021. Elsevier BV. http://dx.doi.org/10.1016/j.rama.2021.08.003.

Campanharo, W. A., Morello, T., Christofoletti, M. A. M., & Anderson, L. O. (2021). Hospitalization Due to Fire-Induced Pollution in the Brazilian Legal Amazon from 2005 to 2018. Remote Sensing, 14(1), 69. https://doi.org/10.3390/rs14010069

Catapani, Mariana Labão et al. Manejo do fogo na pecuária pantaneira: percepções e oportunidades para sua gestão sustentável no bioma. Biodiversidade Brasileira, [S.L.], v. 14, n. 4, p. 69-88, 2 dez. 2024. Instituto Chico Mendes de Conservacao da Biodiversidade - ICBBio. http://dx.doi.org/10.37002/biodiversidadebrasileira.v14i4.2551.

Cochrane, M. (2003) Fire science for rainforests. Nature 421, 913–919. https://doi.org/10.1038/nature01437

Maracahipes-Santos, L.; L. Maracahipes; D.V. Silvério; M.N. Macedo; A.C. Silveiro; N. Potter; L.N. Paolucci; B. Starinchak; A.A.C. Alencar; P.M. Brando. Amazonian forest resilience inferred from fire-induced changes in carbon stocks and tree diversity 2025. Environmental Research Letter. http://doi.org/10.1088/1748-9326/ade60d

Pivello, V. R., Vieira, I., Christianini, A. V., Ribeiro, D. B., Da Silva Menezes, L., Berlinck, C. N., Melo, F. P. L., Marengo, J. A., Tornquist, C. G., Tomas, W. M., & Overbeck, G. E. (2021). Understanding Brazil's catastrophic fires: Causes, consequences and policy needed to prevent future tragedies. Perspectives in Ecology and Conservation, 19(3), 233–255. https://doi.org/10.1016/j.pecon.2021.06.005

References

Ramos-Neto, M., Pivello, V. Lightning Fires in a Brazilian Savanna National Park: Rethinking Management Strategies. Environmental Management 26, 675–684 (2000). https://doi.org/10.1007/s002670010124

Santos, Sandra Aparecida et al. Fogo como ferramenta de manejo em pastagens nativas. In: UFRPE. Pastagens tropicais: dos fundamentos ao uso sustentável. Recife: Mércia Virginia Ferreira dos Santos, 2023. Cap. 13. p. 387-403. Disponível em: https://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/1157915. Acesso em: 21 jun. 2025.

Silva, C. V. J., Aragão, L. E. O. C., Barlow, J., Espirito-Santo, F., Young, P. J., Anderson, L. O., Berenguer, E., Brasil, I., Foster Brown, I., Castro, B., Farias, R., Ferreira, J., França, F., Graça, P. M. L. A., Kirsten, L., Lopes, A. P., Salimon, C., Scaranello, M. A., Seixas, M., … Xaud, H. A. M. (2018). Drought-induced Amazonian wildfires instigate a decadal-scale disruption of forest carbon dynamics. Philosophical Transactions of the Royal Society B: Biological Sciences, 373(1760), 20180043. https://doi.org/10.1098/rstb.2018.0043

Van der Werf, G. R., Randerson, J. T., Giglio, L., van Leeuwen, T. T., Chen, Y., Rogers, B. M., Mu, M., van Marle, M. J. E., Morton, D. C., Collatz, G. J., Yokelson, R. J., and Kasibhatla, P. S.: Global fire emissions estimates during 1997–2016, Earth Syst. Sci. Data, 9, 697–720, https://doi.org/10.5194/essd-9-697-2017, 2017.

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Methods

The estimates of emissions from combustion in the different land use classes were calculated based on the fire scar mapping from the MapBiomas Fire Monitor, the average carbon stock values in fuel compartments from the Fourth National Inventory (FNI; MCTI, 2020), and combustion and emission factors from the IPCC (2006). The extraction of the burned area in each class considered (forests, savannas, grasslands, wetlands, and pasture) was done by crossing the fire scar maps with the land cover and land use maps from MapBiomas Collection 9.

The equation used to calculate emissions from fire is also derived from the IPCC guidelines (Equation 2.27; IPCC, 2006), presented as:

$$L_{fire} = A * M_b * C_f * E_f * 10^{-3}$$

Where:

L_{fire}: Emissions of greenhouse gases from combustion, in tonnes;

A: Burned area, in hectares;

M_b : Mass of fuel available for combustion, in tonnes ha-1. The compartments that make up the fuel component varies according to class (see Table 2);

C_f: Combustion factor, dimensionless, which also varies according to class (see Table 2);

E_f: Emission factor, varying per gas and class (see Table 3), g kg-1.

Table 2. Parameters used to calculate emissions in each biome including combustion factors (Cf, adimensional), fuel compartments susceptible to burning (AGB: aboveground biomass; DW: dead wood; LI: leaf litter) and average carbon stock (in tC/hectare).

Classes	C_F[1]	Compartments	Average C stock[2]
Amazon			
Pasture	0.350	AGB	8.18
Grassland	0.866	AGB+DW+LI	11.88
Wetland	0.866	AGB+DW+LI	11.88
Savanna	0.666	0.26*AGB+DW+LI	10.59
Forest	0.663	DW+LI	14.56
Cerrado			
Pasture	0.350	AGB	6.19
Grassland	0.607	AGB+DW+LI	11.81
Wetland	0.607	AGB+DW+LI	11.81
Savanna	0.666	0.26*AGB+DW+LI	27.41
Forest	0.656	DW+LI	12.53

Classes	C_F[1]	Compartments	Average C stock[2]
Atlantic Forest			
Pasture	0.350	AGB	2.13
Grassland	0.769	AGB+DW+LI	25.04
Wetland	0.769	AGB+DW+LI	25.04
Savanna	0.666	0.26*AGB+DW+LI	8.08
Forest	0.663	DW+LI	11.41
Pantanal			
Pasture	0.350	AGB	6.19
Grassland	0.6925	AGB+DW+LI	12.37
Wetland	0.6925	AGB+DW+LI	12.37
Savanna	0.666	0.26*AGB+DW+LI	12.70
Forest	0.656	DW+LI	16.18
Caatinga			
Pasture	0.350	AGB	0.97
Grassland	0.649	AGB+DW+LI	11.56
Wetland	0.649	AGB+DW+LI	11.56
Savanna	0.666	0.26*AGB+DW+LI	7.90
Forest	0.85075	DW+LI	10.72
Pantanal			
Pasture	0.350	AGB	6.19
Grassland	0.944	AGB+DW+LI	15.79
Wetland	0.944	AGB+DW+LI	15.79
Savanna	0.666	0.26*AGB+DW+LI	0
Forest	0.656	DW+LI	4.61

[1]Combustion factors derived from the literature (REF)

[2]Stock values derived from the Brazilian Fourth National Inventory (FNI; MCTI, 2020)

Table 3. Emission factors (g kg-1 dry matter burnt), from Table 2.5 in the IPCC guidelines (IPCC, 2006).

Classes	CO_2	CH_4	N_2O
Pasture	1613	2.3	0.21
Grassland	1613	2.3	0.21
Wetland	1613	2.3	0.21
Savanna	1613	2.3	0.21
Forest	1580	6.8	1.6

The non-CO_2 gases were then transformed to CO_2-equivalent (CO_2-eq) based on the conversion factors available in the IPCC guidelines (IPCC, 2006), which are: 28 for CH_4 and 265 for N_2O.