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OPINION

Tropical forests are crucial in regulating the climate on Earth

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Tropical forests are critically important for the global climate because of their impact on the radiation, hydrology, and biogeochemical cycles [1]. Tropical forests are large pools of global carbon, with about 360 Pg of carbon in forest vegetation, that with soil carbon adds up to 800 PgC, almost as much as is stored in the atmosphere [2]. In addition, forests are responsible for much of the carbon removal by terrestrial ecosystems, removing about 29% of annual CO_2 emissions or 15.6 Gigatons of CO_2 each year [3]. Tropical forests have a critical role in supporting biodiversity, storing carbon, regulating the water cycle, influencing the radiation balance via albedo, and having an important role in human well-being. Biogenic volatile organic compounds (BVOC) emitted by forests produces secondary organic aerosols (SOA) that are one of the main sources of cloud condensation nuclei (CCN), which are critical to nucleate cloud droplets [4]. Organic aerosols (OA) scatter solar radiation, cooling the surface and compensating for part of the heating produced by the greenhouse gases. When acting as CCN, OA increases cloud albedo, leading to additional biophysical cooling and increased diffuse radiation, which favors carbon uptake by the vegetation. Most of the aerosols over tropical forests are organic and, due to strong deep convection, are transported to the upper troposphere [5].

By the process of evapotranspiration, tropical forests provide water vapor to support cloud formation regionally as well as in interconnection with other parts of the globe. Deep convection is frequent due to the higher convective available potential energy (CAPE). The vertical distribution of latent heating released by convection over tropical forests impacts the Earth´s climate.

However, when forest cover and structure change due to land use and climate change forcings, shifts in biophysical processes occur, affecting ecosystem services related to water, carbon, and energy balances. While tropical forests contribute to climate regulation, global climate change is impacting forest ecosystems. Climate extremes are increasing significantly in tropical regions. Tropical forest temperatures are in sharp increase, in some regions, by more than 1.5˚C. In Southeast Amazônia, the dry season has expanded from four to five months during the past 50 years. Severe droughts have hit Amazonia three times since 2005. At the same time, since late 1990, nine extreme floods have occurred, the last one in 2021. Tropical forests have evolved under a relatively stable climate, and the increase in droughts and extensive floods could be enhancing tree mortality [1].

Recent findings show that climate change strongly impacts Amazonia's carbon balance, showing that non-deforested areas could soon become a carbon source for the atmosphere. Hubau et al., 2020 [6] compared Amazonian with African forests showing that Amazonia is decreasing the carbon uptake because of tree mortality, with no detectable multi-decadal trend in Africa and a long-term increase in Amazonia. A statistical model including carbon dioxide, temperature, drought, and forest dynamics accounts for the observed trends and indicates a long-term future decline in the African carbon sink, whereas the Amazonian sink continues to weaken rapidly [6]. This saturation and ongoing reduction of the tropical forest carbon sink has consequences for policies intended to stabilize Earth's climate. Similar findings with a long-term decreasing trend of carbon accumulation attributed to an increase in tree mortality are reported by Brienen et al., 2015 [7]. Another way to look at the climate-forest interaction changes is by observing vapor pressure deficit (VPD), where recent works observed a systematic increase in VPD over tropical South America [8]. They argue that the observed increase in VPD cannot be explained by greenhouse-gas-induced (GHG) radiative warming alone. We know that the warmer the atmosphere, the higher the atmospheric moisture content. There is a negative trend in the evaporative fraction in the southeast Amazon, where changes in atmospheric moisture, reduced precipitation, and higher incoming solar radiation influence the partitioning of surface energy fluxes towards less evapotranspiration. The VPD increase combined with the decrease in the evaporative fraction is an important indication of positive climate-forest feedback mechanisms, amplifying forest degradation. Another remote sensing study analyzing the spatial-temporal dynamics of above-ground biomass (AGB) concludes that carbon loss from forest degradation (73%) exceeds that from deforestation (27%) in the Brazilian Amazon [9]. This indicates that forest degradation has become the largest process driving carbon loss in Amazonia. Complementing these remote sensing analyses, in situ measurements using small planes shows that the net biome exchange from 2010 to 2018 in southern Amazonia is a net source of +0.11 PgC y^{-1} when considering fire emissions and carbon uptake by the undisturbed forest [10]. The increase in the dry season duration associated with an increase in deforestation can promote ecosystem stress and increase fire occurrence, resulting in higher carbon emissions in the eastern Amazon.

Protection, expansion, and improved management of the world's forests are important initiatives to keep global warming below 2 degrees [11]. Tropical deforestation leads to strong net global warming because of both CO_2 emissions and biophysical effects (albedo, evapotranspiration, and canopy roughness) [12]. Models show that completely deforesting the tropics could result in global warming equivalent to that caused by the burning of fossil fuels since 1850, with more warming and considerable drying in the tropics, with Amazonia responding more strongly than Southeast Asia or Central Africa [13]. Besides the commitments of several countries to achieve zero deforestation, tropical forests are still being cleared at a high rate, especially in Brazil, the Democratic Republic of Congo, and Indonesia.

Several studies have hypothesized a possible "tipping point" where Amazonia could be converted to a tropical savannah, partly due to deforestation, losing large amounts of carbon to the global atmosphere [14]. There is now clear evidence that the natural Amazon Forest also experiences increasing mortality and decreasing net biomass due to climate change impacts. Reducing deforestation is the cheapest, easiest, and quickest way to reduce global greenhouse gas emissions. Brazil signed an agreement at COP-26 to achieve zero deforestation by 2028 and must implement public policies to achieve this commitment. Additionally, Brazil is committed to reforesting 12 million hectares to sequester carbon from the atmosphere. These actions are a great opportunity for Brazil and help the global climate. But stopping deforestation alone is not enough to protect tropical forests. We also need to stop fossil fuel burning, otherwise, our tropical forests could not survive further climate change, with a hotter climate and reduced precipitation. It is necessary to create and promote a new vision of tropical forests, one that recognizes that the natural and economic assets of the region must be managed to maintain their essential role in sustaining the health of the planet. It could be challenging to have "net zero emissions" in 2050 if we do not preserve our tropical forests.

References

1. Artaxo P, Hansson HC, Andreae MO, Back J, Alves EG, Barbosa HMJ, et al. Tropical and Boreal Forest–Atmosphere Interactions: A Review. Tellus B: Chemical and Physical Meteorology, 74 (2022), 24–163. https://doi.org/10.16993/tellusb.34.
2. Pan Y, Birdsey RA, Phillips OL, Jackson RB. The structure, distribution, and biomass of the world's forests. Annu. Rev. Ecol. Evol. Syst., 2013, 44, 593–622. https://doi.org/10.1146/annurev-ecolsys-110512-135914.
3. Friedlingstein P, Jones M, O'Sullivan M, Andrew R, Hauck J, Peters G, et al. Global carbon budget 2019. Earth Syst. Sci. Data 2019, 11, 1783–1838. https://doi.org/10.5194/essd-11-1783-2019.
4. Artaxo P, Rizzo LV, Brito JF, Barbosa HMJ, Arana A, Sena E, et al. Atmospheric aerosols in Amazonia and land-use change: from natural biogenic to biomass burning conditions, Faraday Discuss., 2013, 165, 203. https://doi.org/10.1039/c3fd00052d PMID: 24601004
5. Andreae MO, Afchine A, Albrecht R, Holanda BA, Artaxo P, Barbosa HMJ, et al. Aerosol characteristics and particle production in the upper troposphere over the Amazon Basin. Atmospheric Chemistry and Physics, 2018, 18, 921–961. https://doi.org/10.5194/acp-18-921-2018.
6. Hubau W, Lewis SL, Phillips OL, Affun-Baffoe K, Beechman H, Cuni-Sanchez A, et al. Asynchronous carbon sink saturation in African and Amazonian tropical forests. Nature 2020, 579, 80–87. https://doi.org/10.1038/s41586-020-2035-0 PMID: 32132693
7. Brienen RJW, Philips OL, Feldpausch TR, Gloor E, Baker TR, Lloyd J, et al. Long-term decline of the Amazon carbon sink. Nature 2015, 519, 344–348 https://doi.org/10.1038/nature14283 PMID: 25788097
8. Barkhordarian A, Saatchi SS, Behrangi A, Loikith P, Mechoso CR. A Recent Systematic Increase in Vapor Pressure Deficit over Tropical South America. *Sci Rep* 9, 15331 (2019). https://doi.org/10.1038/s41598-019-51857-8 PMID: 31653952
9. Qin Y, Xiao X, Wigneron JP, Ciais P, Brandt M, Fan L. et al. Carbon loss from forest degradation exceeds that from deforestation in the Brazilian Amazon. *Nat. Clim. Chang.* 11, 442–448 (2021). https://doi.org/10.1038/s41558-021-01026-5.
10. Gatti LV, Basso LS, Miller JB, Gloor M, Domingues LG, Cassol HLG. et al. Amazonia as a carbon source linked to deforestation and climate change. *Nature* 595, 388–393 (2021). https://doi.org/10.1038/s41586-021-03629-6 PMID: 34262208
11. Roe S, Streck C, Obersteiner M, Frank S, Griscom B, Drouet L, et al. Contribution of the land sector to a 1.5 C world. Nat. Clim. Change 2019, 9, 817–828. https://doi.org/10.1038/s41558-019-0591-9.
12. Lawrence D, Coe M, Walker W, Verchot L, and Vandecar K. The Unseen Effects of Deforestation: Biophysical Effects on Climate. Front. For. Glob. Change 2022, 5:756115. https://doi.org/10.3389/ffgc.2022.756115
13. Lawrence D, and Vandecar K. Effects of tropical deforestation on climate and agriculture. Nat. Clim. Change 2015, 5:27. https://doi.org/10.1038/nclimate2430
14. Lovejoy TE and Nobre CA. Winds of will: Tipping change in the Amazon. Sci. Adv. 2019, 5, eaba2949.