CASE STUDY 6

# Postponing the Amazon Tipping Point

Daniel Nepstad

The Amazon forest is a giant from any perspective. It is the planet's largest tropical forest drained by the largest river—the source of one-fifth of all freshwater that reaches the oceans. It is the greatest cornucopia of biological and indigenous cultural diversity.

The Amazon forest is also a giant in shaping the Earth's climate. Like an enormous planetary cooling system, it influences the global circulation of air and vapor by evaporating vast amounts of water into the atmosphere—converting the equatorial Sun's intense radiant energy into latent heat. Even where long dry seasons are the norm, the deep root systems of Amazon trees allow the forest to absorb soil water stored many meters beneath the soil surface to supply the leaf canopy high above the ground (Nepstad et al. 1994). When patches of Amazon forest are replaced by cattle pasture, the amount of vapor pumped into the atmosphere declines.

The wood of Amazon forest trees is another reason this ecosystem shapes global climate. An amount of carbon equivalent to nearly a decade's worth of global emissions from human activities is stored in Amazon wood—that is, outside of the atmosphere, where it would contribute to global warming. This biological carbon leaks into the atmosphere during and after droughts that are severe enough to kill big Amazon trees, such as the droughts of 2005, 2007, 2010, and 2016. It also leaks out when humans deliberately fell the forest to grow crops or livestock, when they degrade the forest to harvest timber, or when the fires they set to manage the land escape into neighboring forests, killing trees (Nepstad et al. 2008).

Positive feedbacks in the Amazon forest-rainfall-fire system could be important in determining the future of this ecosystem in the face of climate change and further expansion of land-use activities. First, the Amazon rainfall system itself depends on the forest. The same year-round forest evapotranspiration that shapes global circulation patterns sustains rainfall patterns in the Amazon region (Salati and Vose 1984). Simply stated, the large-scale conversion of forest to pasture and cropland along the eastern flank of the Amazon forest means that there is less vapor to supply rainfall systems to the west and southwest. A potential “tipping point” could be reached if forest clearing becomes extensive enough to suppress rainfall below the minimum amount that is necessary to sustain closed-canopy forests (Lovejoy and Nobre 2018).

A second positive feedback is between forest degradation and forest fire: once a forest burns, the chances of subsequent fires increase. In pre-Columbian times, Amazon forests appear to have caught fire a few times every millennium, when severe droughts occurred. Then, as now, during years of normal rainfall, most of the forests of the Amazon extended like giant firebreaks across the landscape; the dense shade of the lofty tree canopies supplied with water by deep root systems kept the forest floor too damp to carry a fire. Today, forest fire is a frequent occurrence along the agricultural and livestock frontiers partly because forests have become more susceptible to fire, either because they were already subjected to an earlier fire or through logging operations that punch holes in the forest canopy, allowing light to penetrate to the forest floor. They have also increased in frequency because there are more ignition sources—more people using fire to clear the land and kill shrubs and trees that invade cattle pastures. If Amazon forests burn repeatedly, they can eventually be invaded by flammable grasses and herbs, further increasing the likelihood of recurring fire—in a second tipping point (Balch et al. 2015).

With our knowledge of Amazon forest feedbacks and tipping points we can assemble two plausible scenarios for the future of this globally significant ecosystem—one in which the Amazon forest becomes a major source of added carbon emissions to the atmosphere as the forest-rainfall-fire system drives regional degradation. In a second, the Amazon forest becomes a major sink of atmospheric carbon, figuring prominently in our success in keeping the planet below a 1.5°C average temperature increase, as expressed in the 2015 Paris Agreement.

In the first "business as usual" future scenario, deforestation accelerates, reversing the recent slowdown in deforestation of the Brazilian Amazon (Nepstad et al. 2014), as forest degradation through logging and fire increases. Major droughts continue to become more frequent and severe, increasing the occurrence of forest fires in vast swaths of primary and degraded forests. The expansion of forage grasses, crop fields, and scrub vegetation further inhibits rainfall. The “scrubification” of Amazon forests that have been degraded by drought, logging, repeated burning, and invasion by highly flammable grasses and fires begins to appear across the eastern and southern Amazon regions (Figure CS6.1)—this is accelerated when deforestation frontiers expand along the newly paved highways from Porto Velho to Manaus, Brazil; from Santarem to Cachimbo, Brazil; and from Pucallpa, Peru, to Cruzeiro do Sul, Brazil.

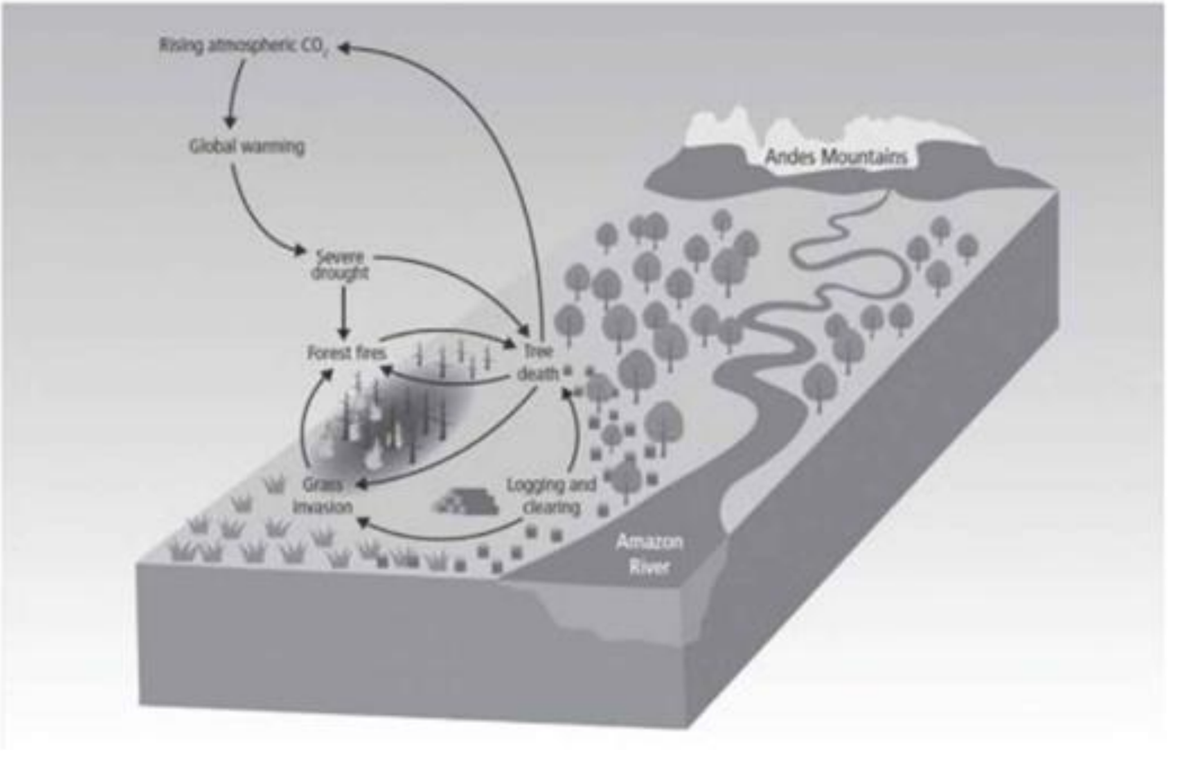


*Figure CS6.1.* The forests of the Amazon Basin are being altered through severe droughts, land use deforestation, logging, and increased frequencies of forest fire. Some of these processes are self-reinforcing through positive feedbacks and create the potential for a large-scale tipping point. For example, forest fire kills trees, increasing the likelihood of subsequent burning. This effect is magnified when tree death allows forests to be invaded by flammable grasses. Deforestation provides ignition sources to flammable forests, contributing to this dieback. Climate change contributes to this tipping point by increasing drought severity, reducing rainfall and raising air temperatures, particularly in the eastern Amazon Basin. (Figure 4-8 from Settele et al. 2014.)

In a scenario of "managed resilience," the slowdown in deforestation that has been taking place in the Brazilian Amazon continues to deepen and spreads to the other Amazon forest nations. Logging continues but through reduced-impact practices; forest fire–control programs established across the Amazon region successfully extinguish forest fires soon after they ignite, and the number of fires needing extinguishing declines through better fire management. This fire prevention program has also allowed forest recovery to take place on nearly half of the forestlands that had been cleared for livestock and crops but were then abandoned because of inadequate soils or infrastructure. This regional forest recovery removes carbon dioxide from the atmosphere as it reestablishes the year-round supply of water vapor to the atmosphere that sustains the rainfall system of the Amazon and that shapes global circulation patterns.

The Amazon forest can be part of the problem of climate change—exacerbating global warming—or it can be part of the solution. Tropical forests could provide a quarter or more of the emissions reductions needed by 2030 to avoid a 2°C increase in global temperature (Griscom et al. 2017). What is remarkable is that the managed resilience scenario is within reach—it is a viable choice that can be achieved with political will, the right market signals, and the right types of financial investments and incentives for landholders. The ecological and climatic integrity of the Amazon can be maintained for decades if Amazon societies secure and deepen the innovations in public policies, law enforcement, and agricultural innovation that already avoided more than 6 billion tons of carbon dioxide emissions from deforestation in Brazil. In the long term, however, the ecological integrity of this giant ecosystem will depend on humanity's success in slowing climate change.

## REFERENCES


Balch, J., P. Brando, D. Nepstad, et al. 2015. "Susceptibility of southeastern Amazon forests to fire: insights from a large-scale burn experiment." *Bioscience* 65 (9): 893–905.

Griscom, B. W., J. Adams, P. Ellis, R. A. Houghton, G. Lomax, D. A. Miteva, W. H. Schlesinger, D. Shoch, J. V. Siikamäki, P. Smith, and P. Woodbury. 2017. "Natural climate solutions." *Proceedings of the National Academy of Sciences* 114 (44): 11645–11650.

Lovejoy, T. E., and C. Nobre. 2018. "Amazon tipping point." *Science Advances* 4 (2): eaat2340.

Nepstad, D., G. Carvalho, A. C. Barros, A. Alencar, J. P. Capobianco, J. Bishop, P. Moutinho, P. Lefebvre, and U. L. Silva Jr. 2001. "Road paving, fire regime feedbacks, and the future of Amazon forests." *Forest Ecology and Management* 154: 395–407.

Nepstad, D., C. Reis de Carvalho, E. Davidson, P. Jipp, P. Lefebvre, G. Hees Negreiros, E. Silva, T. Stone, S. Trumbore, and S. Vieira. 1994. "The role of deep roots in the hydrologic and carbon cycles of Amazonian forests and pastures." *Nature* 372: 666–669.

Nepstad, D, C. M. Stickler, B. Soares-Filho, and F. Merry. 2008. "Interactions among Amazon land use, forests and climate: Prospects for a near-term forest tipping point." *Philosophical Transactions of the Royal Society B—Biological Sciences*. https://doi.org/10.1098/rstb.2007.0036.

Nepstad, D., D. McGrath, C. Stickler, et al. 2014. "Slowing Amazon deforestation through public policies and interventions in beef and soy supply chains." *Science* 344: 1118–1123.

Salati, E., and P. Vose. 1984. "The Amazon: A system in equilibrium." *Science* 225 (4648): 129–138.


## NOTE

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