ENVIRONMENT

Tropical Forests and Climate Policy

New science underscores the value of a climate policy initiative to reduce emissions from tropical deforestation.

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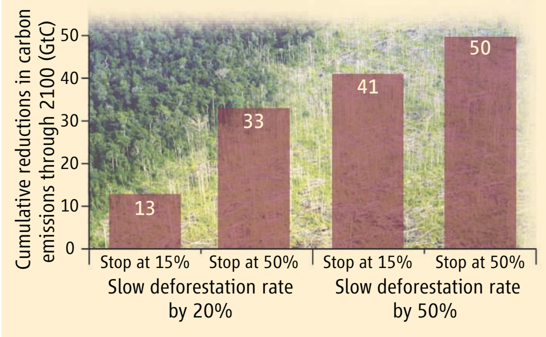
Tropical deforestation released ~1.5 billion metric tons of carbon (GtC) to the atmosphere annually throughout the 1990s, accounting for almost 20% of anthropogenic greenhouse gas emissions (*1*). Without implementation of effective policies and measures to slow deforestation, clearing of tropical forests will likely release an additional 87 to 130 GtC by 2100 (*2*), corresponding to the carbon release of more than a decade of global fossil fuel combustion at current rates. Drought-induced tree mortality, logging, and fire may double these emissions (*3*), and loss of carbon uptake (i.e., sink capacity) as forest area decreases may further amplify atmospheric CO_2 levels (*4*).

A combination of sovereignty and methodological concerns led climate policy-makers to exclude "avoided deforestation" projects from the 2008–12 first commitment period of the Kyoto Protocol's Clean Development Mechanism (CDM) (*5*). The United Nations Framework Convention on Climate Change (UNFCCC) recently launched a 2-year initiative (*6*) to assess technical and scientific issues and new "policy approaches and positive incentives" for Reducing Emissions from Deforestation (RED) in developing countries. This process was initiated at the request of several forest-rich developing nations, an indication of willingness to explore approaches to reduce deforestation that do not intrude upon national sovereignty. Recent technical progress in estimating and monitoring carbon emissions from deforestation (*7*) and diverse climate policy and financing proposals to help developing countries reduce their deforestation emissions (*8*) are currently being reviewed by the UNFCCC Subsidiary Body on Scientific and Technical Advice.

Whether a successful RED policy process can make an important contribution to global efforts to avoid dangerous climate change depends on two issues. First, are the potential carbon savings from slowing tropical deforestation sufficient to contribute substantially to overall emissions reductions? Second, is it likely that tropical forests (and the forest carbon) protected from deforestation will persist over coming decades and centuries in the face of some unavoidable climate change? The available evidence indicates that the answer to both questions is yes, especially in a future with aggressive efforts to limit atmospheric CO_2.



Estimated cumulative reductions in carbon emissions achievable by 2100 through reducing tropical deforestation. Calculations assume (i), deforestation rates observed in the 1990s decline linearly from 2010–50 by either 20 or 50%, and (ii) that deforestation stops altogether when either 15 or 50% of the area remains in each country that was originally forested in 2000 (*1*).

Potential savings for a range of deforestation levels are shown in the figure (above). Reducing deforestation rates 50% by 2050 and then maintaining them at this level until 2100 would avoid the direct release of up to 50 GtC this century (equivalent to nearly 6 years of recent annual fossil fuel emissions, and up to 12% of the total reductions that must be achieved from all sources through 2100 to be consistent with stabilizing atmospheric concentrations of CO_2 at 450 ppm (*1*) (figs. S1 to S5). Emissions reductions from reduced deforestation may be among the least-expensive mitigation options available (*9*). The IPCC estimates that reductions equal to or greater than the scale suggested here could be achieved at ≤U.S.\$20 per ton CO_2 (*1, 10*).

Reducing deforestation not only avoids the release of the carbon stored in the conserved forests, but by reducing atmospheric carbon, it also helps to reduce the impacts of climate change on remaining forests. The experience of the 1997–98 El Niño Southern Oscillation Event (ENSO) demonstrates how climate change can interact with land-use change to put large areas of tropical forests and their carbon at risk. The extended dry conditions triggered by the ENSO across much of the Amazon and Southeast Asia increased tree mortality and forest flammability, particularly in logged or fragmented forests. Globally, increased forest fires during the 1997–98 ENSO released an extra 2.1 ± 0.8 GtC to the atmosphere (*11*).

Even in non-ENSO years, global warming may be putting tropical forest regions at risk of more frequent and severe droughts. Over the last 5 years, a number of Amazon Basin and Southeast Asian droughts have been uncoupled from ENSO events but have coincided with some of the warmest global average temperatures on record.

In recent decades, carbon losses from tropical deforestation have been partly or largely offset by a tropical sink (*12*). Forest sinks are, however, unlikely to continue indefinitely, and continued warming will likely diminish and potentially even override any fertilization effects of increasing CO_2. Climate change might also adversely impact tropical forests by reducing precipitation and evapotranspiration, making them drier, more susceptible to fires, and more prone to replacement by shrublands, grasslands, or savanna ecosystems (*13*), which store much less carbon. In the Amazon Basin, continued deforestation may disrupt forest water cycling, amplifying the negative impacts of climate change (*1*).

A new generation of coupled climate-carbon models is being used to explore the prospects for the persistence of tropical forests in a changing climate. A widely discussed early

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CREDIT: PHOTO COURTESY OF H.-D. VIKTOR BOEHM study projected that business-as-usual increases in CO_2 and temperature could lead to dramatic dieback and carbon release from Amazon forests (*14*), raising concerns that high sensitivity of tropical forests to climate change might compromise the long-term value of reduced deforestation, with dieback releasing much of the carbon originally conserved. However, of 11 coupled climate-carbon cycle models using the IPCC's mid-to-high range A2 emissions scenario, 10 project that tropical forests continue to act as carbon sinks, albeit declining sinks, throughout the century (fig. S6). The moderate sensitivity indicated by the new results suggests that reducing deforestation can result in long-term carbon storage, even with substantial climate change. Aggressive efforts to reduce industrial and deforestation emissions would likely further reduce the rate of decline and risk of reversal of the tropical sink (*1*) (fig. S6).

While no single climate policy approach is likely to address the diverse national circumstances faced by forest-rich developing countries seeking to reduce their emissions, there are promising examples of countries with adequate resources and political will that have been able to reduce forest clearing (*10*, *15*). In some countries, it may be possible at relatively low cost to reduce emissions from deforestation and forest degradation that provide little or no benefit to local and regional economies. For example, reducing accidental fire and eliminating forest clearing on lands that are inappropriate for agriculture are two promising low-cost options for reducing greenhouse gas emissions in Brazil and Indonesia.

Most deforestation for cattle production in Amazonia yields unproductive pasture but releases hundreds of tons of CO_2 per hectare. Compensating landowners to keep their land in forests instead of creating pastures could be done at relatively low carbon prices (*16*).

Other measures are unlikely to be implemented at large scales without financial incentives that may be feasible only within the framework of comprehensive environmental service payments, such as through carbon-market financing (*16*, *17*). In forests slated for timber production, for example, moderate carbon prices could support widespread adoption of sustainable forestry practices that both directly reduce emissions and reduce the vulnerability of logged forests to further emissions from fire and drought exacerbated by global warming. On forested lands threatened by agricultural expansion, financing could provide significant incentives for forest retention and enable, for example, more effective implementation of land-use regulations on private property and protected area networks (*18*).

Parties to the UNFCCC should consider adopting a range of options, from capacity building supported by traditional development assistance to carbon-market financing to help developing countries meet voluntary national commitments for reductions in forest-sector emissions below historic baselines (*7*). Voluntary commitments, which were put forward by several tropical forest nations (*19*), would substantially address a concern associated with the project-based approach of the CDM that emissions reductions from a site-specific project might simply be offset by increased deforestation elsewhere (*10*).

Key requirements for effective carbon-market approaches to reduce tropical deforestation include strengthened technical and institutional capacity in many developing countries, agreement on a robust system for measuring and monitoring emissions reductions, and commitments to deeper reductions by industrialized countries to create demand for RED carbon credits and to ensure that these reductions are not simply traded off against less emission reductions from fossil fuels.

Beyond protecting the climate, reducing tropical deforestation has the potential to eliminate many negative impacts that may compromise the ability of tropical countries to develop sustainably, including reduction in rainfall, loss of biodiversity, degraded human health from biomass burning pollution, and the unintentional loss of productive forests (*16*). Providing economic incentives for the maintenance of forest cover can help tropical countries avoid these negative impacts and meet development goals, while also complementing aggressive efforts to reduce fossil fuel emissions. Industrialized and developing countries urgently need to support the RED policy process and develop effective and equitable compensation schemes to help tropical countries protect their forests, reducing the risk of dangerous climate change and protecting the many other goods and services that these forests contribute to sustainable development.

References and Notes

1. Further information can be found in supporting material on *Science* Online.
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Supporting Online Material

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