Natural climate solutions, like forest management, do not lessen the need for mitigation from energy and industrial sectors.

CLIMATE CHANGE

Natural climate solutions are not enough

Decarbonizing the economy must remain a critical priority

By **Christa M. Anderson[1], Ruth S. DeFries[2], Robert Litterman[3], Pamela A. Matson[4], Daniel C. Nepstad[5], Stephen Pacala[6], William H. Schlesinger[7], M. Rebecca Shaw[1], Pete Smith[8], Christopher Weber[1], Christopher B. Field[9]**

Stabilizing Earth's climate and limiting temperature increase to well below 2°C per the Paris Agreement requires a dramatic uptick in the rate of progress on reducing greenhouse gas (GHG) emissions. Natural climate solutions (NCS) can be a substantial contributor, while also providing valuable cobenefits for people and ecosystems. Although analyses of NCS have some differences in the GHG fluxes they consider, all include emissions sources (such as deforestation, land-use change, and agricultural practices), emissions sinks (such as reforestation and restoring degraded lands), and non–carbon dioxide (CO_2) agricultural emissions (such as methane from livestock). Some of us have contributed to among the most optimistic assessments of the potential of NCS (*1*), whereas others have been more pessimistic (*2*, *3*). But one thing on which we agree, and which technical literature generally acknowledges, is that the benefits of NCS do not decrease the imperative for mitigation from the energy and industrial sectors (*2*, *4*, *5*). Yet this point sometimes gets lost in public-facing conversations [for example, are forests "our best weapon for fighting carbon emissions" or, more realistically, just one "piece of the puzzle"? (*6*)]. Strategies for incorporating NCS with energy and industrial mitigation in the climate portfolio should not be "either/or" but "yes, and."

Making full use of the potential of NCS is an empowering opportunity, especially in places where large shares of emissions come from the land sector. Recent analyses demonstrate that NCS, including both decreasing sources and increasing sinks of GHGs in ecosystems and agriculture, could be deployed at the scale of billions of metric tons of CO_2 equivalent (CO_2e) per year, at costs below $100 per metric ton CO_2e (*1*, *5*, *7*). Others have been more skeptical about the prospects for implementation of NCS at these massive scales (*2*, *3*), noting a difference between the technical potential and the practical feasibility.

Recent framing of the potential percentage of mitigation that can come from NCS (*1*), as opposed to energy and industry, can be interpreted to imply that climate mitigation is a zero-sum game and that more mitigation in one sector leads to less mitigation effort required in another sector. Although comparing mitigation potential by sector in percentage terms provides context, it tends to downplay the critical fact that, in every analysis to date, getting the required cuts from energy and industry still entails a major increase in the level of ambition and the rate of progress. Dramatically increased mitigation effort across all sectors is imperative, if we are to keep the Paris Agreement goal within the realm of possibility.

BURDEN OF DELAY

Many of the most effective opportunities for NCS will not last. Slowing emissions by preventing tropical deforestation, the preponderant NCS mitigation opportunity (~2 gigatons CO_2e/year) at carbon prices under $10 per metric ton CO_2 (*1*), requires an intact forest as a starting point. Every hectare of forest that is cleared generates a carbon debt that requires decades to centuries for repayment. Halting deforestation provides important cobenefits by preserving existing forests while also avoiding intensive and slow-to-recover carbon emissions.

A major attraction of NCS is the potential

PHOTO: TONY WEST/ALAMY STOCK PHOTO

for cobenefits beyond mitigation, including improved forests, croplands, grazing lands, and wetlands that support human health and well-being. Action to protect, enhance, or restore carbon stocks can improve habitat, reduce the risk of catastrophic wildfires, increase soil fertility and water-holding capacity, and decrease air and water pollution. In some places, the cobenefits of NCS may be more valuable than the carbon mitigation benefit. The prospect for alignment between climate and other goals increases the attractiveness of NCS and the motivation for rapid deployment, especially where governance structures support a reasonable level of monitoring and verification.

But along with the imperative to move quickly on NCS mitigation opportunities is an equal imperative to decrease emissions from energy and industry. Delaying energy and industry emissions reductions, for even a few years, dramatically increases the challenge of meeting the Paris goal. A simple, stylized example illustrates why it is imperative to continue to accelerate mitigation from energy and industry as NCS ambition is also ramped up. In 2018, global CO_2 emissions from energy and industry were about 37 gigatons CO_2 ($GtCO_2$) (*8*). If annual energy and industry emissions begin decreasing from that level at a plausible rate of 1 $GtCO_2$/year in one scenario and decrease at the same rate but after a 10-year delay [as in (*1*)] in another scenario, the extra cumulative emissions in the latter scenario total 370 $GtCO_2$ by the time annual emissions reach zero, a considerable share of the remaining budget of 570 $GtCO_2$ estimated to allow a 66% probability of limiting warming to 1.5°C (*9*).

At 370 $GtCO_2$, a 10-year delay in emissions reductions from energy and industry is substantially larger than the 100 to 200 $GtCO_2$ deployment of NCS in 1.5°- and 2°C-consistent mitigation pathways this century (*9*). Most of the potential NCS mitigation is in the form of negative emissions, which are a critical component of meeting climate goals. Rather than offsetting these negative emissions from NCS with a 10-year delay in energy and industry mitigation, negative emissions from NCS can be paired with no-delay mitigation for maximum cumulative effect. In this way, negative emissions from NCS can instead compensate for especially hard-to-reduce emissions sources in the energy and industry sectors, such as those from aviation and manufacturing (*10*). It is clear, however, that every year of delay magnifies the challenge of holding emissions through the end of the century below the 570 $GtCO_2$ consistent with a 66% chance of holding warming below 1.5°C, or the 1320 $GtCO_2$ required for 2°C (*9*).

"Delaying energy and industry emissions reductions...dramatically increases the challenge of meeting the Paris goal."

The burden of delay is amplified by the "lock-in" of existing sources and technologies: Every new car, factory, or power plant designed to run on fossil fuels comes with an expectation of lifetime emissions extending over many years or, especially in the case of power plants, decades (*11*). Early retirement increases financial and political costs, reinforcing the pressure to continue to use the product or facility and accept its attendant emissions. The best way to avoid lock-in is to transition rapidly away from the production of new fossil fuel–based products and infrastructure. Doing this also ensures that societies capture cobenefits for air quality and human health that come with reducing energy emissions (*12*).

AVOIDING TIPPING POINTS

Cumulative emissions are much higher in a scenario that uses only early focus on NCS mitigation and delays action on emissions from energy and industry, increasing peak warming. This increases the risks not only to human systems but also to ecosystem function and diversity (*13*) and increases the risks of major and potentially irreversible carbon releases from ecosystem processes, including wildfire, forest die-off, and permafrost thaw (*14*).

To maximize NCS, it is important to act on the full range of possible incentives, policy levers, and remaining barriers. Incentives and policy levers could include regulatory approaches, carbon markets, or payments for cobenefits. Barriers include institutional, technological, political, and cultural factors that need to be addressed, plus fundamental constraints on land available and competing uses of land for food production, conservation, and carbon goals (*4*). Challenges range from inconsistent climate policy in the United States to uncertain land tenure in places like the Democratic Republic of Congo. Implementation of NCS has not been linear, as demonstrated by the case of Brazil's greater than 70% decrease in deforestation (*15*), which has since been followed by political setbacks under a new government.

Capacity for quantifying mitigation is sophisticated but not universally available. Policy levers to manage risks of leakage (shifting emissions outside of project areas) and later carbon releases, and to account for additionality (ensuring that emissions reductions exceed what would have happened anyway in the absence of a particular policy) are available but require robust institutions and governance. Addressing these barriers has been a priority for a wide range of actors interested in NCS, but the agenda is far from complete. All of us who work on NCS must continue to lower these barriers to ensure that NCS makes a maximum contribution to mitigation, while also maintaining a "yes, and" perspective that amplifies the need for policies that implement NCS and energy and industry mitigation. ■

[1]*World Wildlife Fund, Washington, DC, USA.* [2]*Department of Ecology, Evolution, and Environmental Biology, Columbia University, New York, NY, USA.* [3]*Kepos Capital, New York, NY, USA.* [4]*Department of Earth System Science, Stanford University, Stanford, CA, USA.* [5]*Earth Innovation Institute, San Francisco, CA, USA.* [6]*Department of Ecology and Evolutionary Biology, Princeton University, Princeton, NJ, USA.* [7]*Cary Institute of Ecosystem Studies, Millbrook, NY, USA.* [8]*Institute of Biological and Environmental Sciences, University of Aberdeen, Aberdeen, Scotland, UK.* [9]*Stanford Woods Institute for the Environment, Stanford University, Stanford, CA, USA. Email: cfield@stanford.edu*

REFERENCES

1. B. W. Griscom *et al*., *Proc. Natl. Acad. Sci. U.S.A.* **114**, 11645 (2017).
2. National Academies of Sciences, Engineering, and Medicine, *Negative Emissions Technologies and Reliable Sequestration: A Research Agenda* (The National Academies Press, Washington, DC, 2018).
3. W. H. Schlesinger, R. Amundson, *Glob. Change Biol.* **25**, 386 (2019).
4. P. Smith *et al*., in *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, O. Edenhofer *et al*., Eds. (Cambridge Univ. Press, 2014), pp. 811–922; www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter11.pdf.
5. P. Smith *et al*., *Glob. Change Biol.* **19**, 2285 (2013).
6. Science Friday, How much carbon do our forests capture? (2019); www.sciencefriday.com/segments/how-much-carbon-do-our-forests-capture/.
7. United Nations Environment Programme (UNEP), "The emissions gap report 2017: A UN Environment synthesis report" (UNEP, Nairobi, Kenya, 2017); https://wedocs.unep.org/bitstream/handle/20.500.11822/22070/EGR_2017.pdf.
8. Global Carbon Project, The Global Carbon Project, www.globalcarbonproject.org/.
9. The Intergovernmental Panel on Climate Change (IPCC), "Special report: Global warming of 1.5 °C" (IPCC, Incheon, Korea, 2018); www.ipcc.ch/report/sr15/.
10. S. J. Davis *et al*., *Science* **360**, eaas9793 (2018).
11. S. J. Davis, R. H. Socolow, *Environ. Res. Lett.* **9**, 084018 (2014).
12. K. R. Smith *et al*., in *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel*, C. B. Field *et al*., Eds. (Cambridge Univ. Press, 2014), pp. 709–754; www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap11_FINAL.pdf.
13. R. A. Garcia, M. Cabeza, C. Rahbek, M. B. Araújo, *Science* **344**, 1247579 (2014).
14. W. Steffen *et al*., *Proc. Natl. Acad. Sci. U.S.A.* **115**, 8252 (2018).
15. D. Nepstad *et al*., *Science* **344**, 1118 (2014).

10.1126/science.aaw2741

Science

Natural climate solutions are not enough

Christa M. Anderson, Ruth S. DeFries, Robert Litterman, Pamela A. Matson, Daniel C. Nepstad, Stephen Pacala, William H. Schlesinger, M. Rebecca Shaw, Pete Smith, Christopher Weber and Christopher B. Field

Science **363** (6430), 933-934.
DOI: 10.1126/science.aaw2741