Arid conditions limit the forest restoration potential of many regions of Australia.

Edited by Jennifer Sills

Forest restoration: Overlooked constraints

In their Report "The global tree restoration potential" (5 July, p. 76), J.-F. Bastin *et al.* use machine learning to derive the carbon storage potential of global tree restoration, which they identify as the most effective climate change mitigation option. However, the study likely overestimates the actual potential by identifying opportunities for increasing canopy cover in environments with obvious environmental or socioeconomic constraints.

In high-latitude regions of Russia, Scandinavia, and North America, permafrost and short growing seasons (*1*) impair tree growth. In large parts of Australia and other arid and hyperarid regions, salinity, sodicity, hardpans, and moisture limitations prevent tree establishment (*2*, *3*). In African grasslands, infertile soils, grazing animals, water constraints, and wildfires maintain patchy shrub-grass environments (*4*). In areas with severely degraded soils and biodiversity loss in the Americas and in Asia (*5*, *6*), prospects of restoring pre-degradation canopy cover are limited. In grazing lands and production forests, abandoning current uses implies staggering absolute opportunity costs. Finally, Bastin *et al.* excluded areas classified as urban, but the data set they used (*7*) fails to recognize some major urban centers and many towns and villages in rural areas (*7*); more than 2.5 billion people live in areas that Bastin *et al.* considered eligible for restoration (*8*), including entire cities, such as Kinshasa, the capital of the Democratic Republic of Congo.

Bastin *et al.* introduced further overestimation by multiplying tree cover expansion potential by total ecosystem carbon. This operation lowers the baseline by assuming that carbon stock is proportionally related to canopy cover—i.e., that land with no trees contains no carbon. The use of biome-level carbon stock averages, without considering spatial variation, also adds considerable error, especially in alleged high-potential areas, where these averages (154.7 to 282.5 Mg ha^{-1}) are approximately 5 times greater than what has been reported in site-specific assessments (*9*, *10*).

We appreciate the need for benchmark estimates of carbon storage and restoration potentials, but realistic predictions require tapping expert knowledge to ensure relevant constraints are considered, as well as more rigorous quality control, such as mapping how model validation errors are spatially distributed. Overly hopeful figures produced by models without necessary supervision may misguide the development of climate policy (*11*, *12*).

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REFERENCES AND NOTES

1. J. Obu *et al.*, *Earth-Sci. Rev.* **193**, 299 (2019).
2. FAO and ITPS, "Status of the World's Soil Resources (SWSR)—Main Report: Food and Agriculture Organization of the United Nations and Intergovernmental Technical Panel on Soils" (Rome, Italy, 2015).
3. S. R. Morton *et al.*, *J. Arid Environ.* **75**, 313 (2011).
4. M. Sankaran *et al.*, *Nature* **438**, 846 (2005).
5. M. A. Stocking, *Science* **302**, 1356 (2003).
6. IPBES, "The IPBES assessment report on land degradation and restoration," L. Montanarella, R. Scholes, A. Brainich, Eds. (Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany, 2018).
7. O. Arino, Global Land Cover Map for 2009, European Space Agency (ESA) & Université Catholique de Louvain (UCL), PANGAEA, 10.1594/PANGAEA.787668 (GlobCover 2009).
8. Center for International Earth Science Information Network, Columbia University, Gridded Population of the World, Version 4 (GPWv4): Population Density, Revision 11. (2018); https://sedac.ciesin.columbia.edu/data/set/gpw-v4-population-density-rev11/metadata.
9. D. D. Shirima *et al.* *African J. Ecol.* **49**, 332 (2011).
10. M. B. Siewert *et al.* *J. Geophys. Res. Biogeosci.* **120**, 1973 (2015).
11. M. D. Mastrandrea *et al.*, "Guidance note for lead authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties" (IPCC, 2010); https://wg1.ipcc.ch/AR6/documents/AR5_Uncertainty_Guidance_Note.pdf.
12. C. M. Anderson *et al.*, *Science* **363**, 933 (2019).

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