



Natural climate solutions

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Better stewardship of land is needed to achieve the Paris Climate Agreement goal of holding warming to below 2 °C; however, confusion persists about the specific set of land stewardship options available and their mitigation potential. To address this, we identify and quantify “natural climate solutions” (NCS): 20 conservation, restoration, and improved land management actions that increase carbon storage and/or avoid greenhouse gas emissions across global forests, wetlands, grasslands, and agricultural lands. We find that the maximum potential of NCS—when constrained by food security, fiber security, and biodiversity conservation—is 23.8 petagrams of CO₂ equivalent (PgCO_{2e}) y⁻¹ (95% CI 20.3–37.4). This is ≥30% higher than prior estimates, which did not include the full range of options and safeguards considered here. About half of this maximum (11.3 PgCO_{2e} y⁻¹) represents cost-effective climate mitigation, assuming the social cost of CO₂ pollution is ≥100 USD MgCO_{2e}⁻¹ by 2030. Natural climate solutions can provide 37% of cost-effective CO₂ mitigation needed through 2030 for a >66% chance of holding warming to below 2 °C. One-third of this cost-effective NCS mitigation can be delivered at or below 10 USD MgCO_{2e}⁻¹. Most NCS actions—if effectively implemented—also offer water filtration, flood buffering, soil health, biodiversity habitat, and enhanced climate resilience. Work remains to better constrain uncertainty of NCS mitigation estimates. Nevertheless, existing knowledge reported here provides a robust basis for immediate global action to improve ecosystem stewardship as a major solution to climate change.

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The Paris Climate Agreement declared a commitment to hold “the increase in the global average temperature to well below 2 °C above preindustrial levels” (1). Most Intergovernmental Panel on Climate Change (IPCC) scenarios consistent with limiting warming to below 2 °C assume large-scale use of carbon dioxide removal methods, in addition to reductions in greenhouse gas emissions from human activities such as burning fossil fuels and land use activities (2). The most mature carbon dioxide removal method is improved land stewardship, yet confusion persists about the specific set of actions that should be taken to both increase sinks with improved land stewardship and reduce emissions from land use activities (3).

The net emission from the land use sector is only 1.5 petagrams of CO₂ equivalent (PgCO_{2e}) y⁻¹, but this belies much larger gross emissions and sequestration. Plants and soils in terrestrial ecosystems currently absorb the equivalent of ~20% of anthropogenic greenhouse gas emissions measured in CO₂ equivalents (9.5 PgCO_{2e} y⁻¹) (4). This sink is offset by emissions from land

use change, including forestry (4.9 PgCO_{2e} y⁻¹) and agricultural activities (6.1 PgCO_{2e} y⁻¹), which generate methane (CH₄) and nitrous oxide (N₂O) in addition to CO₂ (4, 5). Thus, ecosystems have the potential for large additional climate mitigation by combining enhanced land sinks with reduced emissions.

Here we provide a comprehensive analysis of options to mitigate climate change by increasing carbon sequestration and reducing emissions of carbon and other greenhouse gases through conservation, restoration, and improved management practices in forest, wetland, and grassland biomes. This work updates and builds from work synthesized by IPCC Working Group III (WGIII) (6) for the greenhouse gas inventory sector referred to as agriculture, forestry, and other land use (AFOLU). We describe and quantify 20 discrete

Significance

Most nations recently agreed to hold global average temperature rise to well below 2 °C. We examine how much climate mitigation nature can contribute to this goal with a comprehensive analysis of “natural climate solutions” (NCS): 20 conservation, restoration, and/or improved land management actions that increase carbon storage and/or avoid greenhouse gas emissions across global forests, wetlands, grasslands, and agricultural lands. We show that NCS can provide over one-third of the cost-effective climate mitigation needed between now and 2030 to stabilize warming to below 2 °C. Alongside aggressive fossil fuel emissions reductions, NCS offer a powerful set of options for nations to deliver on the Paris Climate Agreement while improving soil productivity, cleaning our air and water, and maintaining biodiversity.

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Data deposition: A global spatial dataset of reforestation opportunities has been deposited on Zenodo (<https://zenodo.org/record/883444>).

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