



The forest question

Trees are supposed to slow global warming, but growing evidence suggests they might not always be climate saviours.

When it comes to fighting global warming, trees have emerged as one of the most popular weapons. With nations making little progress controlling their carbon emissions, many governments and advocates have advanced plans to plant vast numbers of trees to absorb carbon dioxide from the atmosphere in an attempt to slow climate change. But emerging research suggests that trees might not always help as much as some hope.

Forest schemes got a big boost from the 2015 Paris climate accord, which for the first time counted all countries' efforts to offset their carbon emissions from fossil-fuel use and other sources by planting or protecting forests. China aims to plant trees over an area up to four times the size of the United Kingdom. California is allowing forest owners to sell credits to CO₂-emitting companies, and other

BY GABRIEL POPKIN

US states are considering similar programmes, which could motivate projects that establish new forests and protect existing ones. The European Union is moving towards allowing countries to include forest planting in their plans to fight climate change; some nations in the bloc have also pledged billions of dollars to tropical forest programmes.

Many scientists applaud the push for expanding forests, but some urge caution. They argue that forests have many more-complex and uncertain climate impacts than policymakers, environmentalists and even some scientists acknowledge. Although trees cool the globe by taking up carbon through photosynthesis, they also emit a complex pot-pourri of chemicals, some of which warm the planet. The dark leaves of trees can also raise

temperatures by absorbing sunlight. Several analyses in the past few years suggest that these warming effects from forests could partially or fully offset their cooling ability.

Such concerns have prompted vigorous debate among scientists about how forests in different regions have warming or cooling effects. Nobody denies that trees are good for the environment; after all, forests provide a host of benefits, and harbour much of the world's terrestrial biodiversity. And no researchers are suggesting cutting down existing forests or curtailing efforts to combat deforestation. But as governments, corporations and non-profit organizations advance ever-more ambitious programmes to slow climate change, some scientists warn against relying on forests as a solution to global warming until a better understanding emerges. Researchers are involved in major campaigns to collect data

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using aeroplanes, satellites and towers in forests to sample the full suite of chemicals that trees emit, which can affect both climate and air pollution.

At the same time, some researchers worry about publishing results challenging the idea that forests cool the planet. One scientist even received death threats after writing a commentary that argued against planting trees to prevent climate change.

The questions are multiplying as more scientists enter the debate. At the same time, increasingly dire warnings about climate change — and the potential for huge amounts of money to go towards planting forests — have made working out how trees affect climate a matter of urgency. “People want an answer; they want to be able to say, ‘this is what we should do,’” says Gordon Bonan, a geoscientist at the National Center for Atmospheric Research in Boulder, Colorado. When it comes to forests and their ability to cool the climate, he says, “there are a lot of misstatements or overplaying of what can be done.”

CARBON SPONGES

If tree-planting programmes work as advertised, they could buy precious time for the world to reduce its reliance on fossil fuels and replace them with cleaner sources of energy. One widely cited 2017 study¹ estimated that forests and other ecosystems could provide more than one-third of the total CO₂ reductions required to keep global warming below 2 °C through to 2030.

Although the analysis relies on big assumptions, such as the availability of funding mechanisms and political will, its authors say that forests can be an important stopgap while the world tackles the main source of carbon emissions: the burning of fossil fuels. “This is a rope that nature is throwing us,” says Peter Ellis, a forest-carbon scientist at The Nature Conservancy in Arlington, Virginia, and one of the paper’s authors.

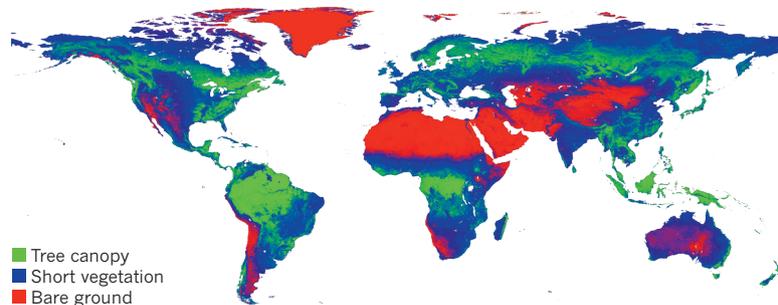
The first inkling that plants suck CO₂ from the air dates back to the 1780s, when Swiss pastor Jean Senebier grew plants under different experimental conditions. He suggested that plants decompose CO₂ from the air and incorporate the carbon, an idea corroborated by subsequent discoveries about the mechanisms of photosynthesis.

More than two centuries later, Senebier’s insights form a key component of plans to combat the accumulation of CO₂ in the atmosphere.

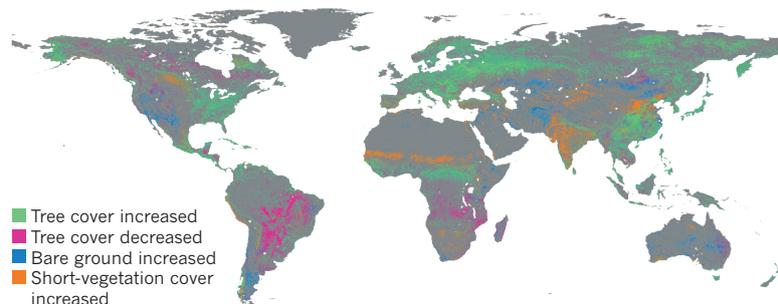
WHERE ARE THE TREES?

Satellite data reveal the different types of land cover across the globe from 1982 to 2016.

AVERAGE LAND COVER



CHANGES IN LAND COVER



The rationale is that trees can lock up carbon in their wood and roots for decades or even centuries. The 1997 climate treaty known as the Kyoto Protocol allowed rich countries to count carbon storage in forests towards their targets for limiting greenhouse-gas emissions. In practice, few nations did so because of the agreement’s unwieldy accounting mechanisms and other factors. Later negotiations laid out a framework for enabling wealthy countries to pay poorer tropical countries to reduce emissions from deforestation and to increase carbon in forests. The framework was formalized under the 2015 Paris agreement, which required countries to commit to reduce greenhouse-gas emissions; more than 50 nations have pledged to add tree cover or protect existing forests (see ‘Where are the trees?’).

Such schemes required firm data on how much carbon is locked up in forests. In the past few decades, scientists have worked to create national estimates of carbon loss and gain from vegetation by studying field plots and by combing through satellite data. In 2011, an international group led by researchers at the US Department of Agriculture’s Forest Service concluded that forests globally are a large carbon sink, taking more carbon out of the air through photosynthesis and wood production than they release through respiration and decay².

That doesn’t mean that all forests cool the planet, however. Researchers have known for decades that tree leaves absorb more sunlight than do other types of land cover, such as fields or bare ground. Forests can reduce Earth’s surface albedo, meaning that the planet reflects less incoming sunlight back into space, leading to

warming. This effect is especially pronounced at higher latitudes and in mountainous or dry regions, where slower-growing coniferous trees with dark leaves cover light-coloured ground or snow that would otherwise reflect sunlight. Most scientists agree, however, that tropical forests are clear climate coolers: trees there grow relatively fast and transpire massive amounts of water that forms clouds, two effects that help to cool the climate.

More-recent studies have branched out to include other ways in which forests can influence climate. As trees live, grow and die, scientists have learnt, they are in constant conversation with the air, swapping carbon, water, light and a bewildering array of chemicals that can interact with the climate.

Atmospheric chemist Nadine Unger, then at Yale University in New Haven, Connecticut, conducted one of the first global studies examining one part of this exchange: the influence of volatile organic compounds, or VOCs, emitted by trees. These include isoprene, a small hydrocarbon that can warm the globe in several ways. It can react with nitrogen oxides in the air to form ozone — a potent climate-warming gas when it resides in the lower atmosphere. Isoprene can also lengthen the lifetime of atmospheric methane — another greenhouse gas. Yet isoprene can have a cooling influence, too, by helping to produce aerosol particles that block incoming sunlight.

Unger ran an Earth-system model that estimated the effects of chemical emissions from forests. Her results suggest that the conversion of forests to farmland throughout the industrial era might have had little overall impact on climate³. Clearing forests liberated carbon stored in trees, but increased Earth’s albedo (leading to cooling) and decreased emissions of VOCs that can both cool and warm.

As a corollary, Unger suggested that reforestation would also have uncertain climate effects. Trees in tropical and temperate zones emit huge quantities of isoprene that is not accounted for in most forestry schemes. Higher-latitude boreal forests emit mostly terpenes, which help to cool the climate by forming aerosols that can block sunlight and promote the formation of cloud particles — although Unger didn’t attempt to quantify this cloud-seeding effect. She acknowledged that her study was a first step, and called for increased monitoring of forest chemicals and

their atmospheric interactions.

She followed up on her research paper by writing an opinion piece in *The New York Times* entitled ‘To Save the Planet, Don’t Plant Trees’, which argued that the large uncertainties around the extent to which forests cool or warm the climate made tree planting a risky strategy for fighting climate change. The article, and especially the headline (which Unger did not write), triggered a tsunami of complaints from researchers, who disputed the science and said the piece threatened to undermine years of research and advocacy. A group of 30 forest scientists wrote a response on the environmental news website *Monogabay*, saying, “We strongly disagree with Professor Unger’s core message.”

Unger says she received death threats, and that some colleagues stopped speaking to her. Some scientists, however, agreed that it was important to look at the impacts of forest VOCs. Subsequent studies have both supported and contradicted Unger’s 2014 analysis. A team led by Dominick Spracklen and Catherine Scott, atmospheric chemists at the University of Leeds, UK, ran a model that included how aerosols from forests can seed clouds, which reflect sunlight. They concluded that the net effect of VOCs from forests is to cool the global climate⁴.

Unger, in turn, questions some of Scott and Spracklen’s assumptions. Unger, who is now at the University of Exeter, UK, and Spracklen are discussing using a common experimental design to try to resolve their differences.

They and other researchers say that such studies are hamstrung by sparse data sets on forest emissions. “In my opinion, we still don’t know enough” to say what effect forest VOCs have, says Alex Guenther, an atmospheric scientist at the University of California, Irvine.

The latest findings are piling on even more complexity. Ecologist Sunitha Pangala at Lancaster University, UK, spent much of 2013 and 2014 in the Amazon rainforest, where she placed gas-measuring chambers around the trunks of more than 2,300 trees. “What we were really surprised about was the magnitude at which these trees are emitting methane,” says Pangala. She and Vincent Gauci at the Open University in Milton Keynes, UK, and their colleagues reported in 2017 that trees account for around half of the Amazon’s total methane emissions⁵. Researchers had previously assumed that methane leaked into the air directly from the soil, where it is produced by microbes. The new work suggests that trees could be another conduit for that microbial methane, potentially explaining why more methane has been detected above tropical wetlands than has been measured emanating from soil alone.

In a study first published last October, Gauci and other colleagues added another wrinkle when they found both methane and nitrous oxide, also a greenhouse gas, leaking from trees in upland forests⁶.

The global significance of these findings is

still unclear. Pangala and Gauci both estimate that the cooling effect of trees taking up carbon greatly outstrips the warming from tree emissions of methane and nitrous oxide. But Kristofer Covey, an environmental scientist at Skidmore College in Saratoga Springs, New York, has found methane leaking from non-wetland trees in temperate forests⁷, and argues that such emissions could, in some places, diminish the climate benefits of trees more than researchers and environmentalists realize. “That’s a really painful message,” he says.

The recent explosion of results underscores the need for a full account of the impacts of

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forests, says Unger. “As long as we understand that tropical trees are taking carbon dioxide out of the atmosphere, we must also accept that they’re putting methane and VOCs into the atmosphere.”

ACTION STATIONS

Scientists who champion forests say that although more research is always good, existing results are mature enough to support the use of forests to fight climate change, especially given the urgency of the problem. “We can’t necessarily afford to hold off on those things; we have to begin taking some action,” says Jason Funk, an environmental scientist in Chicago, Illinois, who served as an adviser and observer to the Paris agreement.

Researchers are now turning to sophisticated computer models and using larger and more-comprehensive data sets to nail down exactly what forests in different places do to the climate. In some cases, the results have been sobering. Last October, a team led by ecologist Sebastiaan Luyssaert at the Free University of Amsterdam modelled a variety of European forest-management scenarios⁸. The researchers concluded that none of the scenarios would yield a significant global climate impact, because the effects of surface darkening and cloud-cover changes from any added forests would roughly eliminate their carbon-storage benefits.

To estimate the climate impact of planting forests in different parts of the United States, ecologist Christopher Williams at Clark University in Worcester, Massachusetts, is combining global satellite data collected over more than a decade with carbon-sequestration figures based on data from the US Forest Service. He has found in preliminary work that adding trees to the US west coast and to regions east of the Mississippi River makes sense, climatically speaking. But albedo changes make forest

planting in the Rockies and the southwestern United States a bad deal for the climate in most cases, because the conifers that thrive in those regions are dark and absorb more sunlight than do underlying soils or snow. He hopes to turn this research into a standardized methodology that forest managers can use to assess a project’s climate impact.

Getting planners to adopt such methods could prove challenging, however. Williams has found that some resist considering albedo effects, including representatives of companies hoping to sell carbon credits for forest projects. “Even other scientists sometimes have disbelief in the magnitude of the albedo effect, or even its existence,” he says.

“I have heard scientists say that if we found forest loss cooled the planet, we wouldn’t publish it.”

More data about the climate impacts of forests could come from long-term studies that track the gases and chemicals that trees emit and absorb. Researchers are using a 325-metre tower in the Amazon to monitor carbon, water and other chemical fluxes over a roughly 100-square-kilometre area of intact rainforest northeast of Manaus in Brazil. A companion tower in Siberia does the same.

Teams have erected smaller research towers to collect similar samples at hundreds of sites around the globe amid different types of forest; a tower in Norway, for example, will soon be the first in that country to start taking data in a forest. But many important areas have not yet been covered. Two NASA instruments launched in the past year — the Global Ecosystem Dynamics Investigation and the Ice, Cloud, and Land Elevation Satellite-2 — should soon provide a more consistent global picture of forests’ carbon stores.

Scientists who debate the climate impacts of forests are eager to get their hands on these data. And even those who are firmly convinced that forest projects can fight climate change welcome the added rigour of more-comprehensive studies. Ellis, for one, acknowledges that the analysis he co-authored¹ considered albedo effects only crudely; the team did not consider VOCs and methane emissions from trees.

“We need to more honestly account for these other effects and be more careful about how we strategize,” says Ellis. “We’re using a blunt tool, when it would be much more preferable to use a sharper one.” ■

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