UC SANTA BARBARA

THE Current

April 6, 2023
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US forests face an unclear future with climate change

When you walk through a forest, you are surrounded by carbon. Every branch and every leaf, every inch of trunk and every tendril of unseen root contains carbon pulled from the atmosphere through photosynthesis. And as long as it stays stored away inside that forest, it's not contributing to the rising concentrations of carbon dioxide that cause climate change. So it's only natural that we might want to use forests' carbon-storage superpower as a potential climate solution in addition to reducing human greenhouse gas emissions.

But climate change itself might compromise how permanently forests are able to store carbon and keep it out of the air, according to a new paper by researchers at University of Utah and UC Santa Barbara. The study considered how different regions and tree species will respond to climate change. The authors found a wide range of estimates for the amount of carbon that forests in different regions might gain or lose as the climate warms. Importantly, the researchers found that regions most at risk of losing forest carbon through fire, climate stress or insect damage are precisely those regions where many forest carbon offset projects have been set up.

"Forest health and carbon-storage potential is evolving rapidly due to climate change," said co-author Anna Trugman, an assistant professor at UC Santa Barbara. "The balance of increasing productivity from higher CO_2 levels and accelerating losses from disturbances will determine the fate of forests as a carbon sink."

But the models also revealed significant risks of losing carbon from forests through the triple threat of fire, climate stress and insect damage. Without these stresses, forests might be able to pack away 9.4 petagrams of carbon nationwide by the end of the 21st century. A petagram is equal to a quadrillion grams — about 25 times the mass of all humans on Earth. However, with these risks, the models projected a net gain in forests of between 3 and 5 petagrams.

The study appears in Nature Geoscience. The authors also created an interactive tool showing aboveground, live carbon storage potential in forests across the contiguous United States by the end of the century.

“This tells us there’s a really urgent need to update these carbon offsets protocols and policies with the best available science of climate risks to U.S. forests,” said University of Utah’s William Anderegg, the study’s senior author.

A multi-perspective modeling approach

The researchers hoped to forecast changes in the amount of aboveground carbon storage in forests of different regions in the U.S. Aboveground carbon refers to any living parts of a tree that are above ground, including wood and leaves or needles.

Scientists can look at the future of forests under climate change in a few different ways. They can consider historical and future projections of the climate, or examine datasets from long-term forest plots. They can also use machine learning to identify which climate niches different tree species most prefer. Or they can use complex models that include interactions between the ecosystem and the atmosphere.

Anderegg and colleagues, including first author Chao Wu, chose all of the above. “Each different method has inherent advantages and limitations,” said Wu, a postdoctoral scholar at University of Utah. “No model is perfect.”

“By bringing in many different approaches and different model types and comparing them,” Anderegg said, “we can get a sense of what the different models are telling us and how we [can] learn to improve the models. And we might have much more confidence if all of the models and all of the approaches tell us the same story in a given region.”

The researchers found that, although the models' forecasts differed in some ways, they showed some consistency in predictions of how different regions' carbon storage might change in the future. The Great Lakes and Northeastern U.S., for example, as well as parts of the Southeastern U.S. and the northern Rockies, consistently showed carbon gains in future projections.

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The researchers also applied their analysis to 139 current projects aiming to offset carbon emissions by increasing the carbon stored in forests. "For carbon offsets to be effective," Anderegg said, "they have to store carbon for a pretty long amount of time — multiple decades to centuries. So if fire's burning them down or insects are wiping out different areas, it could vastly undermine their effectiveness as climate change solutions."

Depending on the model method and the climate scenario, the researchers found that large numbers of carbon offset forest projects, particularly in the Southeastern U.S. and on the West Coast, are projected to lose carbon by the end of the century.

What we still need to know

The results highlight that different climate and ecological models have different strengths and weaknesses, and considering them together reveals the areas of research needed to improve climate projections.

Tree demographic models, for example, include simulations of forest dynamics as old trees die and new trees grow. "But these current models didn't consider the disturbance-vegetation feedback," Wu said, referring to the different types of vegetation besides trees that appear following a disturbance like a forest fire and how they might influence the odds of another disturbance. "Also they didn't consider CO_2 fertilization," or the potential for rising carbon dioxide levels to actually improve

plant growth.

The authors identified three research questions that could help elucidate the situation. First is the extent to which plants and trees might benefit from rising CO_2 concentrations, as the compound is vital for photosynthesis. Second is a need for better data on climate-driven tree mortality from fire, climate stress and insects to inform their understanding of these threats. Last, scientists need a better account of how biomes will shift. For example, some forests may be able to grow back after a disturbance, but others may transition to grasslands and be lost entirely. “These are some of the biggest unknowns that the field is really racing to tackle,” Anderegg said.

In the meantime, while science works to understand how climate change affects forests, society can help by slowing the pace of climate change. “Working to tackle climate change as quickly as possible and move to a lower carbon future massively decreases the risks that forests are likely to face in the 21st century,” Anderegg said, “and increases the potential benefits that we might get from forests.”

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draw inspiration from the beauty and resources of our extraordinary location at the edge of the Pacific Ocean.