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Carbon Sinks in a Changing Climate

Over 65 million years ago, the planet experienced a cooling period, and as a result, temperate forests sprang up around the globe. Today, temperate forests blanket approximately 10 million square kilometers (3.1 million square miles) of the Earth's surface and are the most managed forest type worldwide. In the face of climate change, these forests have emerged as a critical player in absorbing carbon from the atmosphere.

Rising atmospheric carbon dioxide (CO_2) levels warm up weather patterns, which in turn leads to an increase in annual precipitation in some areas and droughts in others. Increased CO_2 also has a direct effect on plant growth. As climate change continues unfurling around us, experts expect the rate of change in atmospheric CO_2 levels and shifts in precipitation patterns to speed up. Understanding if, where, and how a changed water supply helps plants function under higher levels of CO_2 is critical for projecting how ecosystems will respond to climate change. Yude Pan, a research scientist with the Climate, Fire, and Carbon Cycle Sciences group at the USDA Forest Service, Northern Research Station, is leading an international research team that has uncovered new information about ecosystem-scale plant responses to elevated CO_2.

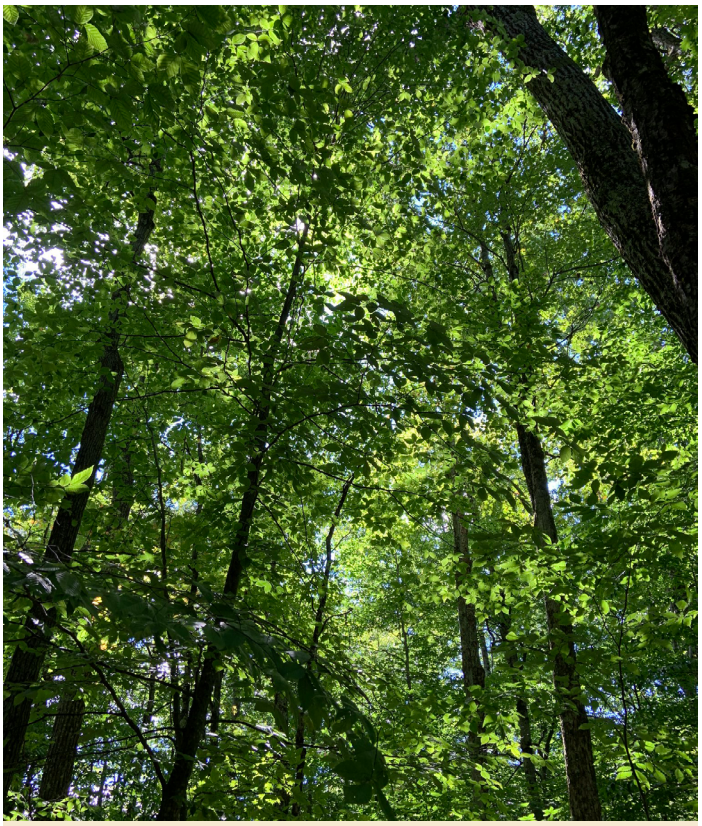
KEY MANAGEMENT CONSIDERATIONS

- Woody ecosystems exhibit better growth than grassland ecosystems under both wetter and dryer conditions, but especially under wetter conditions, when there is more carbon and water to support leaf area expansion.
- Younger forests with less leaf area have a greater potential to respond to increased CO_2 because they have more space to grow their leaves. In addition to developing new forests via afforestation and reforestation efforts, uneven-age forest management strategies can better take advantage of higher CO_2 levels as compared to even-age management. Forest stands with diverse age structures can support large carbon stocks that could make forests into more sustainable and effective carbon sinks.

Room to Grow

The study, published in an article in Nature Ecology & Evolution in January 2022, found that both temperate forests and grasslands ecosystems showed an increased ability to process CO_2 in a drier climate. The team suspects that plants in drier climates benefit more from high carbon dioxide because the plants are able to use water more efficiently.

Both forests and grasslands provide many benefits. New research is offering insights into how these systems vary in response to increased CO_2 levels and changes in precipitation patterns. Licensed photos by Adobe Stock.



Northern hardwood forest canopy. USDA Forest Service photo by Paula Murakami.

Further, the study found that forests in the United States have even more significant growth when they are exposed to increased CO_2 levels in wetter years, while grassland ecosystems experience less growth. Woody plants, the researchers think, gain more from higher carbon dioxide levels in wetter years because of their flexibility in increasing leaf growth. Overall, and across different precipitation regimes, forests had noticeably stronger growth (24 percent) than grasslands (13 percent) when grown in elevated CO_2.

"We try to do adaptive forest management with a changing climate, which includes taking advantage of high CO_2 levels to make a forest healthy, productive, and a good carbon sink. —Yude Pan

"CO_2 directly enhances vegetation growth by increasing CO_2 concentration at the leaf level and increasing water use efficiency. It also indirectly increases leaf area with more available carbohydrates and water from the direct effects" says Pan. "Grasslands are more limited by that because they have different structures—no canopy or height."

Because grasslands do not to grow as high, grassland plants do not appear to benefit from increased CO_2 levels as much as woody plants. Grassland plants can also more easily become crowded in a way that limits their growth potential.

A Tool in the Arsenal

This study offers insights into how terrestrial ecosystems will respond to elevated atmospheric CO_2 levels and changes in precipitation and soil water in the future. But it also helps clarify the ability of terrestrial ecosystems to remove CO_2 from the atmosphere and the potential contributions they could make toward the goal of achieving world-wide net carbon neutrality.

"We try to do adaptive forest management with a changing climate, which includes taking advantage of high CO_2 levels to make a forest healthy, productive, and a good carbon sink," says Pan. "And we think the trees have a better opportunity than grasslands and other systems to be a carbon sink in both wet and dry years."

"A lot of large-scale landscape studies use models," Pan says. "But the real relationship between the high CO_2 and productivity was still unclear." Pan and her team analyzed the relationship between the responses of plant leaf area and productivity under high CO_2 conditions by using data from 14 long-term ecosystem-scale CO_2 enrichment experiments. The model developed from this study could be applied together with remote-sensing data to better estimate plant productivity and carbon dynamics at landscape scales.

To Pan, the quality and amount of data make the study unique, and this was possible because of collaboration. "We have all these experts in different regions and different countries with data and expertise in their regions. So that's why we could put all this data together," she says. "It's unique. We have an excellent group of scientists."

Project Lead

Yude Pan is a research scientist with the Climate, Fire, and Carbon Cycle Sciences group. Learn more about her work at https://www.fs.usda.gov/research/about/people/ypan.

FURTHER READING

Pan, Yude; Jackson, Robert B.; Hollinger, David Y.; Phillips, Oliver L.; Nowak, Robert S. [et al.]. 2022. Contrasting responses of woody and grassland ecosystems to increased CO2 as water supply varies. Nature Ecology & Evolution. 6(3): 315–323. https://doi.org/10.1038/s41559-021-01642-6.

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