USDA Forest Service
U.S. DEPARTMENT OF AGRICULTURE

Northern Research Station

Rooted in Research

ISSUE 35 | JULY 2024

The Enduring World Forest Carbon Sink: Key Findings and Policy Implications

Forests play a critical role in mitigating climate change by sequestering carbon dioxide (CO_2) from the atmosphere. A new study led by Yude Pan, research scientist with the U.S. Department of Agriculture, Forest Service, Northern Research Station, provides a unique perspective and a long-term, ground-based benchmark on the recent magnitude, trends, drivers, and locations of Earth's critical forest carbon sinks. The study compiles and analyzes data from extensive ground-based forest inventories and ecological studies as well as commonly used forest area estimates based on remote sensings in national forest inventories and other types of land surveys from 1990 to 2019.

The world's forests have consistently accumulated carbon over the past three decades despite significant changes at regional and continental scales. For example, while temperate and tropical regrowth forests have experienced increases in carbon sinks, boreal and intact tropical forests have experienced declines. Deforestation, timber harvesting, wildfire, drought, reforestation, growth enhancements, and climate change have all affected carbon dynamics in varying ways around the world. But taken together, these activities have—surprisingly—sustained a global forest carbon sink of 3.5 ±0.4 billion metric tons per year, which was enough to absorb not quite half of carbon dioxide emissions from burning fossil fuels from 1990 to 2019. However, two-thirds of the sink's benefit—2.2 ± 0.5 billion metric tons of carbon per year during the same period—has been negated by tropical deforestation.

While the global forest carbon sink has endured undiminished for three decades despite regional variations, aging forests, continuing deforestation, and further intensification of disturbance regime may weaken it. These findings, and with atmospheric CO_2 concentrations now surpassing 420 ppm and climate change approaching tipping points, add urgency to achieving net-zero greenhouse gas emissions by 2050.

KEY FINDINGS

- **Atmospheric CO_2 concentration and climate change:** Atmospheric CO_2 concentration has surpassed 420 ppm, and urgent actions are needed to mitigate climate change as it approaches potential tipping points.
- **Net zero emissions goal:** One of the main challenges to achieving net zero greenhouse gas emissions by 2050 is reaching large-scale negative emissions to compensate for the inability to eliminate all emissions from fossil fuels.
- **Trends in forest carbon sinks:** Different forest biomes show varying trends in carbon sequestration. While temperate and tropical regrowth forests have increased carbon sinks, boreal and intact tropical forests have experienced declines.
- **Threats to forest carbon sinks:** Deforestation, degradation, and disturbances pose significant threats to forest carbon sinks, particularly in intact tropical forests.
- **Importance of mitigation strategies:** Halting deforestation and degradation while increasing large-scale reforestation and afforestation are crucial for sustaining and enhancing forest carbon sinks.
- **Improved forest management:** Strategic forest management practices, such as reduced-impact logging and protecting old-growth forests, are essential for maximizing carbon uptake and co-benefits like biodiversity conservation.
- **Investment in research and monitoring:** Research and monitoring are necessary to reduce uncertainties in forest carbon assessments, especially in tropical regions and regarding belowground biomass and soil carbon.

Trends Across Different Biomes

Despite global stability, there are major biome-level changes.

Boreal forests: The carbon sink declined by 36 percent in the northern hemisphere's boreal forests, which are found in Alaska, Canada, Northern Europe, and Eastern Russia. Increasing disturbances, particularly from fire and soil warming, have contributed to the boreal forest decline. For example, Canada's boreal forests have now become a carbon source.

Tropical forests: In the tropics, loss of intact forest areas due to deforestation caused a 31 percent decline in the carbon sink. However, in tropical regrowth forests that followed the abandonment of agriculture and recovery from logging, regrowing forests brought about increases of 29 percent in carbon sink. Combining both tropical intact and regrowth

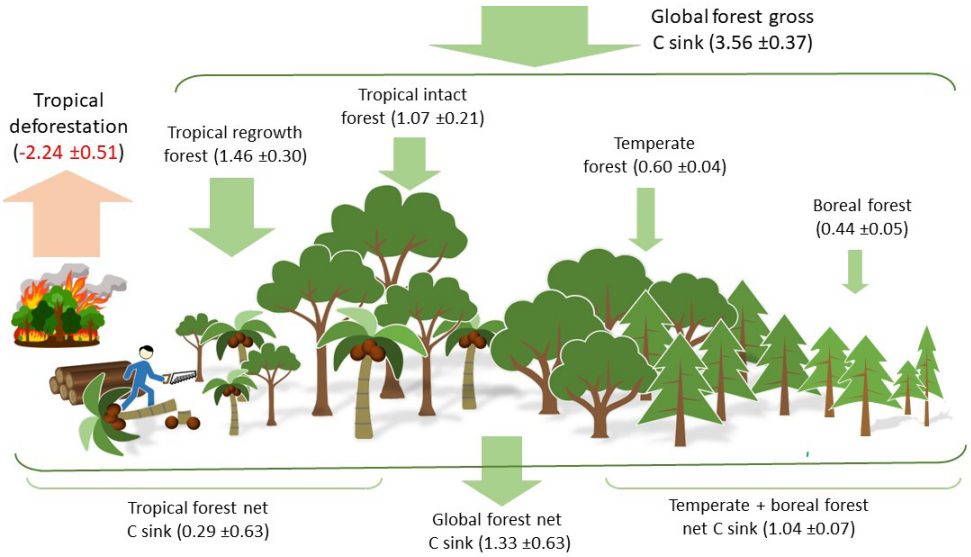

Figure 1.—Carbon sinks and sources in global forests (billion metric tons of carbon [C] per year) from 1990 to 2019. Positive values represent carbon sinks. Negative (red) values represent carbon sources.

forests brought near carbon neutrality, with a small net sink and source that fluctuates with deforestation intensities. In some areas, such as the Brazilian Amazon, drought has reduced growth rates and carbon uptake, which together have reduced the carbon sink.

Temperate forests: The carbon sink in temperate forests increased significantly, by 30 percent, due in large part to increasing forest area in China from massive reforestation efforts. In some areas, such as the continental United States, temperate forests continued to accumulate carbon as middle-aged forests grew older and despite increasing emissions from disturbances, especially insects and fire. Temperate forests in other regions, such as Europe and Japan, have shown declines of carbon sinks due to forest aging.

Interpreting the Findings

Two-thirds of the benefit of the global forest carbon sink has been offset by tropical deforestation that averaged 2.2 ±0.5 billion metric tons of carbon per year between 1990 and 2019, reducing the net carbon sink in the world's forests to 1.3 ±0.5 billion metric tons of carbon per year (Fig. 1). Reduced forest carbon sinks make it harder for nations to reach net greenhouse gas emission targets and increase the risks from climate change impacts and associated disturbances and disasters such as drought, flooding, and wildfires.

Despite the advancements in data collection that made this study possible, the accuracy of carbon estimates varies throughout the world. The study shows that regions with more established forest inventory systems, such as the United States, have smaller uncertainties in carbon estimates, while vast tropical forests—Earth's most productive and diverse biomes—have critical needs for data about changes and climate sensitivities but have limited ground sampling plots and therefore the largest uncertainties in their estimates.

The study issues strong calls for massive investment in long-term, tree-by-tree monitoring of forest biomass, growth, and mortality in tropical forests and other regions that lack forest inventories, which is critical for reducing uncertainty in both forest carbon budgets and the global carbon budget. The study also makes recommendations for sustaining and enhancing the forest carbon sink to help attain global carbon neutrality and effectively mitigate climate change.

Halting deforestation and degradation are important to sustaining and enhancing forest carbon sinks, according to Yude Pan. "In order to maintain the future sink," she says, "land management policies must limit deforestation not only in the tropics but in all forest biomes," noting also the need to promote forest restoration of lands not needed for food production and to improve timber-harvesting practices to reduce emissions from logging and sawmill operations. Because global forests contribute dominantly to the land carbon sink, mitigating and adapting to the climate crisis can only be achieved by protecting the carbon sources and sinks in Earth's forests.

PROJECT LEADS

Yude Pan is a senior research scientist with the Climate and Carbon Cycle Sciences research unit of the Northern Research Station.

FURTHER READING

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