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A crucial store of carbon in Australia's tropical forests has switched from carbon sink to carbon source

Publié: 15 octobre 2025, 21:10 CEST

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DOI

https://doi.org/10.64628/AA.evq3c9twr

https://theconversation.com/a-crucial-store-of-carbon-in-australias-tropical-forests-has-switched-from-carbon-sink-to-carbon-source-262955

One approach to help fight climate change is to protect natural forests, as they absorb some atmospheric carbon released by burning fossil fuels and store large volumes of carbon.

Our new research on Australia's tropical rainforests challenges the assumption that they will keep absorbing more carbon than they release.

We found that as climate change has intensified over the past half-century, less and less carbon has been taken up and converted to wood in the stems and branches of the trees in these forests. Woody biomass is a large and relatively stable store of carbon in forests, and acts as an important indicator of overall forest health.

The effect has been so pronounced that the woody biomass of these forests has gone from being a carbon sink to a carbon source. This means carbon is being lost to the atmosphere due to trees dying faster than it is being replaced by tree growth.

This is the first time woody biomass in tropical forests has been shown to switch from sink to source. Our research indicates the shift likely happened about 25 years ago.

It remains to be seen whether Australian tropical forests are a harbinger for other tropical forests globally.

Aboveground biomass of trees in 20 long-term Australian rainforest research sites has gone from carbon sink to source as more trees die and decay. Andrew Ford, Author provided (no reuse)

What did we find?

Since 1971, scientists have tracked around 11,000 trees in 20 tracts of tropical rainforest in Australia's far northeast, now part of the Queensland Permanent Rainforest Plots Network. This 49-year research effort is one of the world's longest and most comprehensive of its kind.

We analysed this long-term data and found a clear signal: woody biomass switched from being a carbon sink to a carbon source about 25 years ago.

Why? One reason: trees are dying twice as fast as they used to.

Tropical rainforest tree species are adapted to generally warm, wet conditions. As the climate changes, they are subjected to increasingly extreme temperatures and drier conditions.These kinds of extreme climate events can damage wood and leaves, limiting future growth and leading to higher rates of tree death.

We also found tree deaths from cyclones reduced how much carbon these forests could absorb. Cyclones in far north Queensland are projected to become increasingly severe under climate change. They are also likely to push further south, potentially affecting new areas of forest.

Isn't carbon dioxide plant food?

Burning fossil fuels and other human activities have increased carbon dioxide levels in the atmosphere. This should make it easier for plants to absorb CO_2 from the air, photosynthesise and grow. Given this, Earth system models predict higher atmospheric CO_2 levels will stimulate plant growth and increase how much carbon tropical forests can take up.

Also, remote sensing shows the canopies of tropical forests on Australia's east coast are about 20% greener than they were in the 1980s. This suggests forest canopy growth has increased due to higher levels of CO_2 in the atmosphere. But this isn't the whole picture.

Our data shows any potential increase in photosynthesis resulting in greener forest canopies has not translated to greater carbon storage in stems and branches.

The reason may be that tree growth can be limited by water, nutrients and heat. Our work suggest that warmer and drier conditions have limited tree growth even as CO_2 concentration has increased.

In a separate study, scientists artificially increased CO_2 and found the extra carbon taken up by leaves wasn't being stored as extra woody growth. Rather, it was quickly released through roots and soil microbes.

Australian rainforest canopies have become greener. But heat, drying and water availability are taking their toll on carbon sink capacity. Alexander Shenkin, Author provided (no reuse)

What about other forest carbon stocks?

It will be challenging to find out whether these forests as a whole (including wood, roots, leaves and soils) have declined in carbon sink capacity.

The use of a specialised research tool known as eddy covariance towers could help, as these measure overall CO_2 movement into and out of ecosystems.

As of yet, only 15 years of this kind of data from three tropical Australian sites is available, which currently limits our ability to describe the fuller impact of climate change.

In any case, we know carbon stored in forest canopies and soils is often broken down and released back to the atmosphere faster than carbon in woody biomass.

So while Australia's tropical rainforest carbon stores remain large, they may be less secure and reliable than in decades past.

Long term datasets are vital

When people visit Australia's tropical rainforests, they can see intact stretches of biodiverse forest and large, carbon-rich trees. It's hard to directly see the changes we have detected – for now, they're only visible in the data.

Without high-quality long-term datasets, this signal would have been almost impossible to detect. Unfortunately, persistent funding shortages for long-term ecological monitoring threaten the continuity of these hugely valuable datasets.

Australia has the potential to assume a globally leading role in tropical ecosystem science. In light of state and national biodiversity and emission reduction commitments, Australian governments should support continued monitoring of vital ecological research sites.

Tropical forests may not be saviours

The fact that woody biomass in Australia's tropical rainforests is now a net source of carbon has major implications.

These findings challenge our future reliance on forests as natural absorbers of extra atmospheric carbon.

We don't know yet whether all tropical forests will respond similarly. Evidence on carbon sink capacity is mixed. Rainforests in South America are showing a decline while African rainforests are generally not.

Overall, the world's tropical forests remain very significant stores of carbon and biodiversity. Their protection remains essential despite the climate risks they face.