COULD TROPICAL FORESTS SOON CONTRIBUTE TO GLOBAL WARMING?

Harlyn Ordoñez Cruz measuring photosynthesis. *Credit: Beth Perkins*

Mornings here at La Selva Biological Station, Terry McGlynn counts bugs. McGlynn takes measurements from dozens upon dozens of sites throughout the forest and brings carefully chosen collections of leaf litter—everything that falls from the trees—back to the lab. McGlynn's routine is part of an attempt to understand how animals affect the decomposition of dead plant matter in a tropical rainforest, which, in turn, is part of an effort to understand the way carbon moves through the forest. The project is spearheaded by David and Deborah Clark, who, much to their dismay, may have come up with some really bad news for life on Earth.

Even small changes in the way this type of forest functions can have big impacts on global climate. Tropical forests cover 17% of the Earth's land mass, but account for more than a third of the world's plant growth and store roughly 40% of all the carbon in terrestrial life, plus a third or more of all the carbon stored in soils. "Tropical forests move more carbon in and out of the atmosphere than any other ecosystem," says Alan Townsend, who studies carbon and nutrient cycling in Costa Rica. "They're the United States of carbon dioxide emissions and uptake."

For years, scientists assumed these ecosystems would save us from ourselves: that they'd soak up some of the extra CO_2 we're adding to the atmosphere by driving our cars and powering our houses and cutting down other parts of the forest for wood and crops. It makes sense: If plants use CO_2 to grow, and there's more CO_2 available, then the plants will grow more. This has been demonstrated in short-term experiments. The concept is called CO_2 fertilization, and it was built into many early models that tried to predict the future of the Earth's climate.

"The problem," says Jay Gulledge "is we don't have any strong evidence that there really will be or is a significant CO_2 fertilization effect—it's just assumed. There are certain situations where you can show this in a greenhouse, but whether real ecosystems do this is questionable."

To make a model that can accurately predict the impacts of climate change, it's crucial to know whether tropical forests will in fact be sinks for carbon dioxide—net reducers of CO_2in the atmosphere—or whether they'll be sources, releasing more CO_2 than they absorb. The Clarks' research hints at the idea of rainforests as CO_2 sources, a scary proposition that could speed up the effects of global warming. Armed with decades of data, the Clarks are now showing that enough global warming will slow the growth of tropical trees, which could cause rainforests to emit more carbon dioxide than they soak up, and by century's end, trees in the tropical forests could die. Instead of saving us from the greenhouse effect, the world's rainforests could contribute to it.

The Clarks began their landmark study, called “Trees,” in 1983, measuring more than 2000 individual trees once a year, keeping track of information like the tree’s physical condition, how much light its crown was getting and the status of the immediately surrounding forest.

By the early 1990s, their data began to tell them something strange. “In a totally separate finding we weren’t even particularly interested in at the time,” recalls Deborah Clark “we discovered that adult trees showed big differences in how much they grow from one year to the next. And because they’re different species, what really stood out was they were telling us the whole forest was growing at different rates from one year to the next.”

Several years later, the Clarks’ 16 years’ worth of data—initially intended simply to help shed light on the form and function of trees—yielded even more surprising results, showing a clear relationship between the temperature in a given year and how much the trees grew. Even modest changes made a difference: Although there was only a 2° C difference in average temperature over the decade and a half the Clarks had been taking measurements, the connection between tree growth and temperature was clear. In the hottest year, the trees grew 34% less than the long-term average, and in the coolest year, they grew 33% more. The difference in the amount they grew in the warmest and coolest years was 90%.

The disturbing implication is that global warming caused by increasing levels of atmospheric CO_2 might be impeding the growth of rainforests and initiating a “positive feedback loop”: CO_2 causes warming, which slows growth, which reduces CO_2 uptake, which causes warming.

Even more worrisome, when the Clarks compared their results with data on carbon dioxide levels in the tropics as a whole, the graphs showed a clear correlation. The years the tropics emitted the most CO_2 were the hottest years for the tropical regions overall. And, the Clarks discovered, those were the same years in which the temperatures were highest and the same years in which tree growth slowed down.

“We are now coming to understand that tropical forests may be being stressed by this ongoing climate change we’re causing,” Deborah says, “and if some predictions about this turn out to be true, the stress on tropical forests could, in fact, speed up global warming.” Tropical forests, she says, “may be a very major source of carbon dioxide emissions to the atmosphere. It could be a very big positive feedback. We may be at a point now where this has gone too far.”

Evolution and Possible Engineering

Global food insecurity is already an extremely acute problem, and continued reliance on inefficient food and energy sources is dangerous, especially because we do not know what might happen to those plant cycles as our atmosphere becomes more carbon-rich. The reduction in atmospheric CO2 and the drying of the Earth's climate are thought to have promoted C4 and CAM evolution, which raises the alarming possibility that elevated CO2 may reverse the conditions that favored these alternatives to C3 photosynthesis.

Evidence from our ancestors shows that hominids can adapt their diet to climate change. Ardipithecus ramidus and Ar anamensis were both C3-focused consumers. But when a climate change altered eastern Africa from wooded regions to savannah about 4 million years ago (mya), the species which survived were mixed C3/C4 consumers (Australopithecus afarensis and Kenyanthropus platyops). By 2.5 mya, two new species evolved, Paranthropus who shifted to become a C4/CAM specialist, and early Homo, which used both C3/C4 foods.

Expecting H. sapiens to evolve within the next fifty years is not practical: maybe we can change the plants. Many climate scientists are trying to find ways to move C4 and CAM traits (process efficiency, tolerance of high temperatures, higher yields, and resistance to drought and salinity) into C3 plants. Hybrids of C3 and C4 have been pursued for 50 years or more, but they have yet to succeed because of chromosome mismatching and hybrid sterility. Some scientists hope for success by using enhanced genomics.

Whether It's Possible

Some modifications to C3 plants are thought possible because comparative studies have shown that C3 plants already have some rudimentary genes that are similar in function to C4 plants. The evolutionary process that created C4 out of C3 plants occurred not once but at least 66 times in the past 35 million years. That evolutionary step achieved high photosynthetic performance and high water- and nitrogen- use efficiencies. That's because C4 plants have twice as high a photosynthetic capacity as C3 plants, and can cope with higher temperatures, less water, and available nitrogen. For this reason, biochemists have been attempting to move C4 traits to C3 plants as a way to offset environmental changes faced by global warming.

The potential to enhance food and energy security has led to marked increases in research on photosynthesis. Photosynthesis provides our food and fiber supply, but it also provides most of our sources of energy. Even the bank of hydrocarbons that reside in earth's crust was originally created by photosynthesis. As those fossil fuels are depleted or if humans limit the use of fossil fuel to forestall global warming, people will face the challenge of replacing the energy supply with renewable resources. Food and energy are two things humans cannot live without.