RISING CO2 LEVELS ARE CHANGING HOW FAST FORESTS CYCLE WATER

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The leaves of trees process massive amounts of water – worldwide, four times the volume of Lake Superior moves from the soil and is turned into water vapor by plants every year.

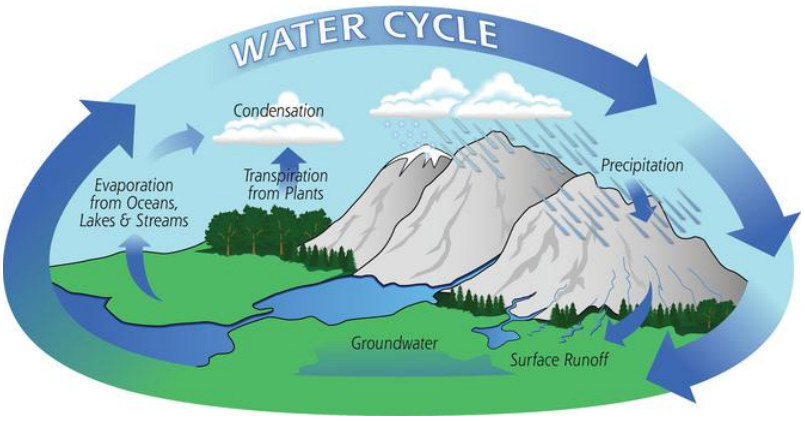
With rising levels of carbon dioxide (CO2) in the atmosphere, scientists have been studying how this process, known as transpiration, may be changing.

In a paper published in Nature Climate Change, we found that plants and how they transpire have indeed been responding to higher levels of carbon dioxide. Using dynamic ecosystem models, we also gained insight into how these changes affect different leaf types and forests overall.

A better understanding of these processes is important to society because changes to the water cycle can affect flooding, soil moisture, river flow, and weather changes linked to climate change.

Stomata

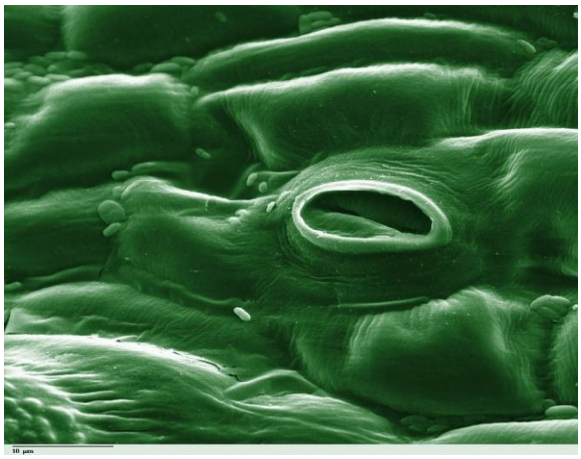
Plants play a key role in the global water cycle by recycling water from the soil to the atmosphere via small openings in leaf surfaces known as stomata.



Each year, massive amounts of water cycle from the atmosphere to the land and ocean in the form of precipitation and evapotranspiration. Of the total land surface evapotranspiration, roughly 60% is directly attributable to plant water losses known as ‘transpiration.' NASA

Each year, approximately 40,000 cubic kilometers of water pass through stomata worldwide through transpiration. Owing to the energy required to convert liquid water to a gas, transpiration provides an important cooling mechanism for plants and contributes to diverse processes and feedbacks in the Earth’s climate system.

Stomata also play a central role in plant growth and the carbon cycle. When stomata are open, they allow atmospheric CO2 to diffuse into leaves. During photosynthesis, the carbon dioxide is converted to sugars. It has been hypothesized that stomata optimize plant performance by simultaneously maximizing carbon gain and minimizing water loss.



Small openings in the leaf surface are called “stomata” and control the movement of CO2 into the leaf used in photosynthesis and the loss of water vapor from inside the leaf to the atmosphere. This is an image taken by an electron microscope of a tomato plant leaf. Dartmouth College

In other words, as the continued burning of fossil fuel increases atmospheric CO2 concentrations (since 1850, an increase from about 280 parts per million to more than 400 parts per million has occurred), stomata may adjust to maintain this optimal relationship with uncertain or surprising consequences for the global water

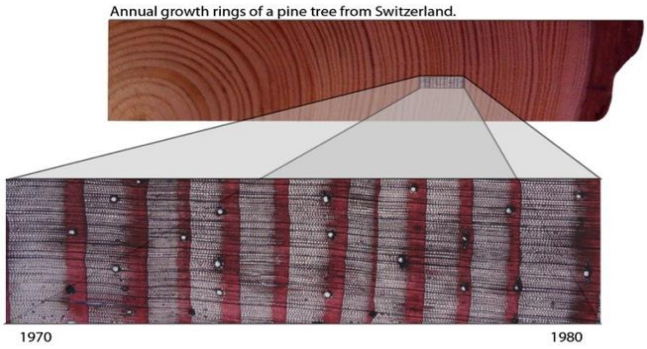
budget and climate system, such as increases in surface runoff and land surface temperature.

Reading the tree rings

Fortunately, tree rings can help provide insights into how plants respond to atmospheric CO2 over these century-long time scales and help predict future changes.

In our paper published in Nature Climate Change, we analyzed the ratio of light (C12) to heavy (C13) carbon isotopes preserved in the wood of annual tree rings.

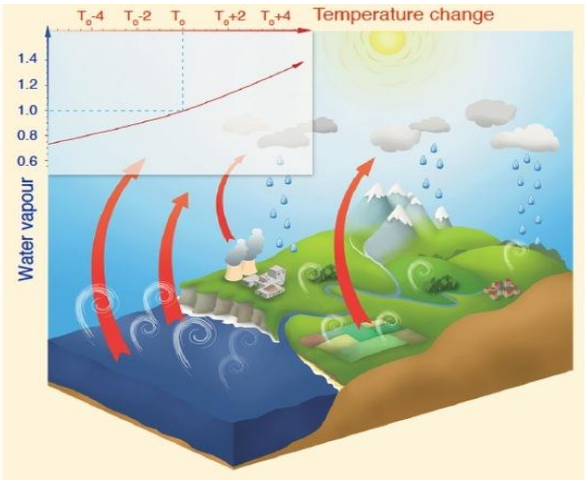
Using principles of plant physiology, plant carbon isotope ratios allow us to reconstruct CO2 concentrations within a leaf, which is determined partly by the behavior and “openness” of stomata. Our analysis of tree ring samples spanning from Morocco to Norway found that plants have a moderately active response to increasing atmospheric CO2 concentrations.



Section of a tree stem showing how each year “tree rings” are formed following the annual cycle of carbon allocation from photosynthesis to cell division and maturation. The cells formed at the beginning of the growing season are large and have thin cell walls and hence a lighter color. In contrast, the dark colored cells formed towards the end of a growing season are small and have thick cell walls. In addition to variation in width, density and anatomical properties, the isotope ratios of wood from the annual tree rings can be measured and provide insights in plant water use efficiency. D. Frank

While the new study confirms a growing body of evidence that plants have actively adjusted to increasing CO2 across the tropical, temperate, and boreal biomes, the study provides two important new insights.

First, the study applied a new statistical technique to account for climatic effects that might also cause stomata to close, such as a drying of the atmosphere. We found that the effects of increasing atmospheric CO2 alone led to broadleaf species increasing the carbon gain per unit water lost by 14%. Needleleaf species increased carbon gain per water lost by 22%. Accounting for climatic effects yielded observations more consistent with physiological theory for maximizing plant growth while minimizing water losses.



Water vapor is an important greenhouse gas that is also intimately coupled with temperature change and also ecosystem behavior. Understanding the hydrologic cycle from leaf to ecosystem to global scales is critical for forecasting how CO2 will affect climate change. (IPCC AR5 Working Group 1, Chapter 8, Figure 8.1; see also Figure 9.43)

Secondly, to find out whether the observed changes at the individual tree level led to reductions in transpiration at the ecosystem scale, we applied dynamic global vegetation models (DGVM) to simulate the hydrologic balance of forest ecosystems. In addition to their role in investigating land surface processes, DGVMs are used in coupled carbon-cycle climate models to make climate change projections and inform earth system science policy.

We found that the DGVM ensemble was able to reproduce the observed tree-ring derived trends in water use efficiency. However, the models showed that the increase in water use efficiency did not translate to a reduction in transpiration.

Instead, a lengthening of the growing season over the same time period, and increases in leaf area contributed to greater annual transpiration that countered any net water savings from plant responses to CO2.

Because water vapor is also a greenhouse gas, this study implies that physiological responses of plant stomata to increasing atmospheric CO2 will not lead to reductions in water-vapor concentrations that may counteract warming. The study is also significant because it demonstrates that small leaf-scale processes of plants have continental-scale consequences.

Source: http://theconversation.com/rising-co2-levels-are-changing-how-fast-forests-cycle-water-40746