A tree's response to environmental changes: What can we expect over the next 100 years?

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The many environmental issues facing our society are prevalent in the media lately. Global warming, rainforest devastation, and endangered species have taken center stage. Our ecosystem is composed of a very delicate network of interactions among all species and the non-living environment. Predicting how each component of this complex system will respond to the many environmental changes sweeping the globe is a challenging problem today's scientists face.

A recent article by Dr. Abraham Miller-Rushing and his colleagues at Boston University published in the October issue of the American Journal of Botany explores how increasing concentrations of atmospheric carbon dioxide (CO_2) may be affecting trees and, ultimately, affecting water and carbon cycles.

It is known that increasing concentrations of atmospheric CO_2 affect the physiology and behavior of many organisms, and in plants, changes to the pores (stomata) on the surface of leaves are one example of these effects. Stomata allow air (containing CO_2) to pass into the leaf while water vapor passes out of the leaf. Plants use carbon dioxide to produce sugars during the process of photosynthesis. With increasing concentrations of atmospheric CO_2, stomatal density decreases while rates of photosynthesis increase. The decrease in stomatal density results in decreased water loss through the leaves.

"These changes in stomatal behavior and water use efficiency can, in turn, have large impacts on plants and can alter ecosystem-scale water and carbon cycling," Miller-Rushing said. "For example, soil moisture, runoff, and river flows might increase and drought tolerance in individual plants might improve."

The relationship between atmospheric CO_2 concentrations and stomatal density is so constant over the long term that scientists are able to use stomatal density of fossilized leaves to determine historical atmospheric CO_2 concentrations. However, short-term responses to changes in CO_2 concentrations have previously been found to be much more variable, and very little concrete data exist on how long-lived organisms respond to changing CO_2 concentrations. "We currently do not know how the anatomy and water relations of individual trees will respond to changes in climate and atmospheric concentrations of CO_2 over their lifetimes," Miller-Rushing said. "Understanding these responses will be key to predicting how forests might contribute to changes in carbon and water cycles over the next 100 years."

Miller-Rushing and his colleagues examined the stomatal density on leaves, the length of the cells that surround the stomata (called guard cells), and the leaves' efficiency of water use (a measurement that compares the amount of carbon that is converted to sugar with the amount that passes through the stomata) in 27 trees growing at the Arnold Arboretum in Boston, Massachusetts for the past century. By examining several dried specimens from each plant that had been collected over the past hundred years, they were able to assess these characteristics in a temporal framework. During this period, global atmospheric CO_2 concentrations increased by approximately 29%. Miller-Rushing and colleagues found that stomatal density declined while guard cell length increased in oaks and hornbeams, although these changes were not dependent on the magnitude of changes in CO_2 concentrations. Intrinsic water use efficiency did not change significantly over time, suggesting that it may not respond to changes in CO_2 concentrations over the lifetimes of individual trees, possibly because of compensating changes in stomatal density and guard cell size.

"This finding may have important implications for models that predict changes in future climate, carbon, and water cycles," Miller-Rushing stated. "We also demonstrated a new method that will allow researchers to investigate these questions in greater depth, namely by using herbarium specimens sampled repeatedly from the same trees, as is often done at botanical gardens."

As understanding the rippling impacts caused by various changes to the environment becomes increasingly more important, proper methodology to address these questions has become essential.

More information: The full article in the link mentioned is available for no charge for 30 days following the date of this summary at www.amjbot.org/cgi/content/full/96/10/1779 .

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