Tree die-off triggered by hotter temperatures

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A team of scientists, led by researchers at Carnegie's Department of Global Ecology, has determined that the recent widespread die-off of Colorado trembling aspen trees is a direct result of decreased precipitation exacerbated by high summer temperatures. The die-off, triggered by the drought from 2000-2003, is estimated to have affected up to 17% of Colorado aspen forests. In 2002, the drought subjected the trees to the most extreme growing season water stress of the past century.

While often not killing the trees directly, the drought damaged the ability of the trees to provide water to their leaves, leading to a decline in growth and increased mortality that has continued for a decade after the drought. The research is published on-line in Global Change Biology. Another related study appeared earlier this year in the same journal.

Until recently, there has been little attention paid to what drought characteristics (seasonal differences, severity, or durations) actually cause trees to die. Scientists additionally have lacked a sufficient understanding of the processes that lead to die-offs, which inhibits the ability to predict how climate change can affect different ecosystems.

The recent study was led by brothers Leander and William Anderegg. William was a Ph.D. student while Leander was an undergraduate at the time of the research at Carnegie. The team looked at the dynamics of water availability to the trees by examining the ratio of oxygen isotopes in the sap contained in the tree "veins" that transport water. Isotopes are atoms with the same number of protons, but different numbers of

neutrons and their ratios are signatures of where and when water originates, among other features.

"Mother nature provides us with natural fingerprints in the ratio of oxygen isotopes," explained Leander. "They tell us about the type of water available to the trees. For instance, summer rain has different isotopic ratios than winter snow. So we can use these markers to figure out where and when the water found in tree veins was taken up, which in turn helps us determine drought impacts."

The scientists examined the isotopes in the aspen sap during natural and experimental drought in an area in Colorado that had heavy tree casualties. It turns out that aspens generally use shallow soil moisture, which evaporated quickly with increased temperatures during the summer drought of 2002. They then looked at climate data finding that these high temperatures were part of a long-term increasing trend, likely linked with climate change, a unique feature of this drought that separates it from earlier less damaging droughts.

"Forests store about 45 percent of the carbon found on land," remarked William. "Widespread tree death can radically transform ecosystems, affecting biodiversity, posing fire risks, and even harming local economies. Rapid shifts in ecosystems, particularly through vegetation die-offs could be among the most striking impacts of increased drought and climate change around the globe."

In a previous study the brothers, with colleagues, looked at two competing theories for how forest trees die during a drought. One hypothesis was that the trees starved due to decreased photosynthesis. Another was that the system for transporting water within a tree was damaged beyond repair. They looked at both carbon starvation and water-transportation stress and found no evidence of significantly decreased carbon reserves. They did find a notable depressed function in the trees'

water-transport systems, especially in the roots—some 70 percent loss of water conductivity.

This study pinpoints the trigger of this loss—summer temperature was the most important climate variable for explaining aspen death by drying out surface soil and stressing the trees' water-transport system. Joe Berry, a co-author and Carnegie staff scientist, noted that understanding how and where the trees get their water was key to unraveling cause and effect in this study.

"Since there is a very strong upward trend in Colorado summer temperatures, they could link tree death to climate change," said Chris Field, director of the Carnegie department. This study is a milestone in linking plant-level physiology measurements with large-scale climate to predict vulnerability to climate change in these forests.

Interestingly, this type of climate-change hot summer drought actually occurred again in 2012, which could indicate more tree die-offs are in the pipeline for the near future.

More information: Published related work includes:

Anderegg, W.R.L., Plavcova, L., Anderegg, L.D.L. Hacke, U.G., Berry, J.A., Field, C.B. (2013) Drought's legacy: multiyear hydraulic deterioration underlies widespread aspen forest die-off and portends increased future risk. Global Change Biology. doi: 10.1111/gcb.12100,

Anderegg, W. R. L. (2012). Complex aspen forest carbon and root dynamics during drought. Climatic Change, 111(3-4), 983–991. doi:10.1007/s10584-012-0421-9.

Anderegg, W. R. L., Kane, J. M., & Anderegg, L. D. L. (2012). Consequences of widespread tree mortality triggered by drought and

temperature stress. Nature Climate Change, 3(1), 30–36. doi:10.1038/nclimate1635.

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