New model predicts maximum tree height across the US

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The next time you're outdoors, see if you can spot the tallest tree. If you're in the desert Southwest, this may be an easy task — trees there are few and far between, and tend to hunch low to the ground to conserve resources. In the temperate Northeast, dense forests make the exercise a bit more difficult. And in the rainy Northwest, the towering stands of sequoias often reach higher than the eye can estimate.

Knowing how tall trees can grow in any given region can give ecologists a wealth of information, from the potential density of a forest and size of its tree canopy to the amount of carbon stored in woodlands and the overall health of an ecosystem. Now an MIT researcher, along with colleagues at the University of Maryland and the Santa Fe Institute in New Mexico, has come up with a simple model to predict the maximum tree height in different environments across the United States. The researchers' results have been published in the journal *PLoS One*.

The model takes in basic meteorological data — such as average annual temperature, precipitation, humidity and solar radiation — and computes how tall a tree is likely to grow under those conditions. The concept sounds simple enough, but lead author Chris Kempes, a PhD student in MIT's Department of Earth, Atmospheric and Planetary Sciences, says it took an understanding of plant mechanics, as well as fractal geometry, to accurately link tree height with meteorology.

"The branches of a tree really form a fractal, where if you cut off one of the limbs … and blow it up to the size of the tree, it'll look like the whole tree," Kempes says. "If you nail down that network structure correctly, then you can use it to predict how things change with size."

Kempes describes a tree's network as a vascular "highway system" of xylem and phloem that pumps water and nutrients from the soil up to the leaves, which in turn transport the sugary byproducts of photosynthesis back down to the roots. This pumping capacity, or fluid flow rate, is a bit of a balancing act: Trees of a given size have certain rates of metabolism that pump enough water and nutrients to survive without using up all of the available resources, such as light and water.

The team drew up an "idealized tree" to represent an average model of all tree species in the United States and developed equations to represent the relationships between fluid flow rate, tree size, and meteorological factors such as average temperature, rainfall, humidity and sunlight.

Putting their model to work, the group predicted the height of the tallest trees across the country, using local meteorological data. Kempes compared the team's results with actual measurements from the United States Forest Service. The predictions from the model matched up well with the Forest Service data, except for two geographic regions: the arid Southwest and parts of New England.

In the Southwest, the team found that trees actually grew taller than the model predicted, possibly due to evolutionary adaptation. "Deserts are where you find many specialized trait adaptations," Kempes says. "This is where you have weird traits that can deal with harsh environments."

In New England, trees were a bit shorter than predicted, primarily because the model did not factor in the area's timber and logging history. New-growth forests simply haven't had time to recover, but if left undisturbed, Kempes says they will eventually catch up with the model's predictions.

The group used the same model to predict what would happen to tree height in the event of global temperature changes, and found that with an increase of 2 degrees Celsius across the country, the average height of the tallest trees would shrink by 11 percent. Conversely, a dip of 2 degrees Celsius would spur trees to sprout up by 13 percent.

Going forward, Kempes and his colleagues plan to use the model to "see the forest from the tree," using maximum-tree-height data to extrapolate the heights of other, smaller trees in the forest. They also plan to adapt the model to predict the potential heights of different species of trees; the current model is based on an idealized, or universal, tree structure. Kempes says the team will study traits from different species to draw up a model that predicts which species live where.

"If you take a really small juniper tree that lives in the desert and you put it in the Northwest, it'll grow to perhaps four times as tall," Kempes says. "But it won't grow to be the height of a redwood. And this is what all of ecology is interested in: How much of your existence is determined by the environment versus your genetics? Now we can concretely say this is the environmental side of things, and now we want to go after the species."

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