3D digital city model analyzes effects of blocking sunlight

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When the summer sun blazes on a hot city street, our first reaction is to flee to a shady spot protected by a building or tree.

A new study is the first to calculate exactly how much these shaded areas help lower the temperature and reduce the "urban heat island" effect.

Researchers created an intricate 3D digital model of a section of Columbus and determined what effect the shade of the buildings and trees in the area had on land surface temperatures over the course of one hour on one summer day.

"We can use the information from our model to formulate guidelines for community greening and tree planting efforts, and even where to locate buildings to maximize shading on other buildings and roadways," said Jean-Michel Guldmann, co-author of the study and professor emeritus of city and regional planning at The Ohio State University.

"This could have significant effects on temperatures at the street and neighborhood level."

For example, a simulation run by the researchers in one Columbus neighborhood found on a day with a high of 93.33 degrees Fahrenheit, the temperature could have been 4.87 degrees lower if the young trees already in that area were fully grown and 20 more fully grown trees had been planted.

Guldmann conducted the study with Yujin Park, who did the work as a doctoral student at Ohio State and is now an assistant professor of city and regional planning at Chung-Ang University in South Korea, and Desheng Liu, a professor of geography at Ohio State.

Their work was published online recently in the journal *Computers, Environment and Urban Systems*.

Researchers have long known about the urban heat island effect, in which buildings and roadways absorb more heat from the sun than rural landscapes, releasing it and increasing temperatures in cities.

One recent study found that in 60 U.S. cities, urban summer temperatures were 2.4 degrees F higher than rural temperatures—and Columbus was one of the top 10 cities with the most intense summer urban heat islands.

For this new study, Guldmann and his colleagues selected a nearly 14-square-mile area of northern Columbus that had a wide range of land uses, including single-family homes, apartment buildings, commercial and business complexes, industrial areas, recreational parks and natural areas. More than 25,000 buildings were in the study area.

The researchers created a 3D model of the study area using 2D land cover maps of Columbus, as well as LiDAR data collected by the city of Columbus from an airplane. LiDAR is a laser sensor that detects the shape of objects. Combining this data resulted in a 3D model showing the exact heights and widths of buildings and trees.

They then turned to computer software that calculated the shadows cast by each of the buildings and trees in the study area over the course of a one-hour period—11 a.m. to noon—on Sept. 14, 2015.

In addition, the researchers had data on land surface temperatures in the study area for the same date and time. That data came from a NASA satellite that uses Thermal Infrared Sensors to measure land surface temperatures at a resolution of 30 by 30 meters (about 98 by 98 feet). That resulted in surface temperatures for 39,715 points in the study area.

With that data in hand, the researchers conducted a statistical analysis to determine precisely how the shade cast by buildings and trees affected surface temperatures on that September day.

Results showed that, as expected, buildings turned up the heat in the area, but that the shadows cast by them also had a significant cooling effect on temperatures, particularly if they shaded the rooftops of adjacent buildings.

The statistical model could precisely calculate those effects, both positive and negative. For example, a 1% increase in the area of a building led to surface temperature increases between 2.6% and 3% on average.

But an increase of 1% in the area of a shaded rooftop led to temperature decreases between 0.13% and 0.31% on average.

Shade on roadways and parking lots also significantly decreased temperatures.

"We learned that greater heat-mitigation effects can be obtained by maximizing the shade on building rooftops and roadways," Guldmann said.

Results also showed the importance of green spaces and water for lowering temperatures. Grassy areas, both shaded and exposed, showed significant heat-reducing effects. However, the impact of shaded grass was stronger than that of grass exposed to direct sunlight.

The volume of tree canopies and the area of water bodies also had significant cooling effects.

In the simulation run in the Columbus neighborhood, the researchers calculated that if the current trees there were fully grown, the temperature on a 93.33-degree F day would be 3.48 degrees lower (89.85 degrees).

But that's not all. The simulation showed that if the neighborhood had 20 more full-grown trees, the temperature would be another 1.39 degrees lower.

"We've long known that the shade of trees and buildings can provide cooling," Guldmann said.

"But now we can more precisely measure exactly what that effect will be in specific instances, which can help us make better design choices and greening strategies to mitigate the urban heat island effect."

More information: Yujin Park et al, Impacts of tree and building shades on the urban heat island: Combining remote sensing, 3D digital city and spatial regression approaches, *Computers, Environment and Urban Systems* (2021). DOI: 10.1016/j.compenvurbsys.2021.101655

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