Water Sustainability and Climate
In the Yahara Watershed
UNIVERSITY OF WISCONSIN–MADISON

RESEARCH BRIEF

Understanding a city's urban heat island effect improves preparation for climate-related risks

Summary

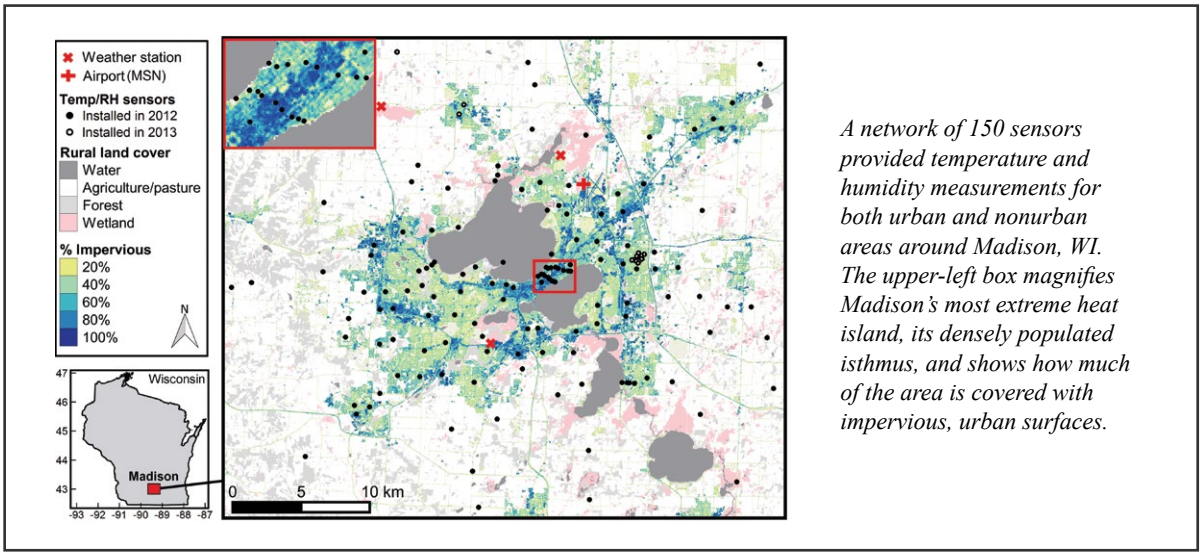
Given climate change and growing urban populations worldwide, cities must factor the potential impacts of their local climates, especially the urban heat island effect, into efforts to prepare for climate-related risks. Urban heat islands tend to be densely populated areas, and certain weather conditions, especially heat waves, can increase the extremity of temperatures experienced in these areas, posing greater public health and economic risks.

Background

Climate and weather are largely determined by factors occurring at the global and continental scales, but local elements, such as land cover, can also influence them. In particular, local land cover affects how people experience temperatures in that place. Notably, cities tend to be warmer than their nonurban surroundings due to the heat retention of urban surfaces, a phenomenon known as the urban heat island effect. While common, the details of how this effect works are not well understood. Since most people—54% globally and 80% of North Americans—live in cities, proportions that are expected to grow, and global warming compounds the urban heat island effect, understanding its mechanics are critical to prepare for higher temperatures and maintain livable conditions for billions of people. This study explores fundamental questions about the urban heat island effect in Madison, WI, USA: where are the city's warmest temperatures in relation to where people live, when is the city the warmest, and how much warmer is the city? Its findings offer implications for how cities across the globe can prepare for climate change.

Research Design

Using a network of 150 sensors, researchers collected and analyzed temperature and humidity measurements from various locations in Madison and its surrounding nonurban areas. The data set includes measurements taken in 15-minute intervals over the course of three years. This urban climate monitoring network is one of the largest deployed to date.



A network of 150 sensors provided temperature and humidity measurements for both urban and nonurban areas around Madison, WI. The upper-left box magnifies Madison's most extreme heat island, its densely populated isthmus, and shows how much of the area is covered with impervious, urban surfaces.

Findings

Where and when it is hottest

Warming due to the urban heat island effect was the strongest in Madison's most densely built areas, which are also the city's population centers, where most people live, work, and play. This means that a disproportionally high number of Madisonians experience higher temperatures.

The urban heat island effect is strongest during clear, calm weather conditions, especially at night. For example, summertime temperatures in downtown Madison averaged 3 degrees Fahrenheit warmer in the day and 7 degrees warmer at night compared to rural areas. The higher nighttime temperature difference is the result of heat retention by urban surfaces, whereas the abundant vegetation of rural areas cools them off relatively quickly after sunset. At the seasonal scale, the urban heat island effect is often strongest in the summer, when higher temperatures are generally undesirable.

Heat islands and heat waves

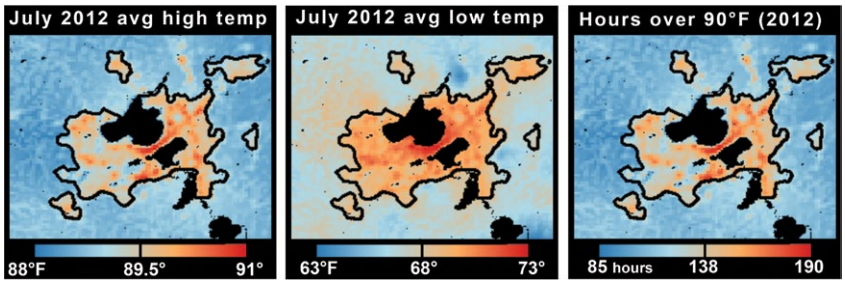
Heat islands are hotter during heat waves, which have favorable weather conditions for strong heat island effects: clear skies and stagnant air. Moreover, urban warming and heat waves tend to reinforce each other, meaning not only can heat waves cause stronger heat islands, but heat islands can also cause stronger heat waves. For example, during the July 2012 heat wave, which was part of Madison's third hottest summer since 1869, urban areas experienced up to twice as many hours over 90 degrees Fahrenheit than rural areas.

Alarmingly, Madison's heat islands prolonged the duration of this heat wave and prevented nighttime relief from the stressful temperatures. The densest urban areas spent over four consecutive nights in temperatures above 80 degrees Fahrenheit, the National Weather Service's nighttime heat advisory threshold. Since prolonged heat exposure, rather than isolated hot days, is what can cause heat stress to humans, long stretches with no nighttime reprieve in densely populated areas pose a greater risk to public health, especially to vulnerable urban populations, such as people living in poverty, the elderly, and individuals with pre-existing health conditions.

Implications

Understanding what climatic conditions a city must be prepared for is fundamental to ensuring its population has access to not just livable conditions but also a sufficient quality of life. Climate change could increase the frequency and intensity of extreme heat, which could, in turn, intensify a city's urban heat island effect and its impacts. As urban populations grow and more people inhabit heat islands, these city-dwellers could face more uncomfortable summers, increased health risks, and potentially higher energy bills from an increased use of air conditioning—although, they may experience lower energy costs in winter.

There are many possible ways a city might address the challenges presented by its urban heat island effect, such as improving building efficiency to lower air conditioning costs. Cooling the entire city would be a difficult undertaking, but focusing on reducing risks for vulnerable neighborhoods or people could be more feasible and cost effective. Moreover, as cities such as Madison consider future growth and development, ensuring they become more livable and resilient requires addressing the impacts of the urban heat island effect.



These heat maps clearly depict Madison's heat islands (in red/dark orange), which experienced warmer average high and low temperatures and more hours of extreme heat during the heat wave of July 2012.

Sources

Schatz, J., and C. J. Kucharik. "Seasonality of the urban heat island effect in Madison, Wisconsin." *Journal of Applied Meteorology and Climatology* 53 (2014): 2371–86. doi: 10.1175/JAMC-D-14-0107.1.

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Research sponsor

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Water Sustainability and Climate Project

The Water Sustainability and Climate Project (WSC) at the University of Wisconsin-Madison is an integrated effort to understand how water and the many other benefits people derive from nature could change over time. The five-year project (2011–2016) is focused on the Yahara Watershed in southern Wisconsin and funded by the National Science Foundation. Visit wsc.limnology.wisc.edu.