Flood models need to include cities' impact on rainfall, according to study

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Current flood models do not account for cities' impact on local rainfall patterns, an oversight that could lead to significantly underestimating the severity and frequency of floods in urban areas, a Purdue study finds.

Dev Niyogi, Indiana's state climatologist, and collaborators at China's Tsinghua University showed that hard, impenetrable city surfaces such as concrete can dramatically influence the way rainfall spreads across a watershed.

Flood models that do not incorporate the ways cities modify rainfall patterns could underestimate the magnitude of future floods by as much as 50 percent, said Niyogi, who is also a professor of agronomy and earth, atmospheric and planetary sciences.

"Over the last two decades, we've seen an increase in major flooding in urban areas," he said. "Many factors are contributing to that change, including extreme weather, climate change and climate variability. But evidence is also emerging that cities themselves are significantly and detectably changing the rainfall patterns around them."

In rural areas, rainfall seeps gradually into the soil, nourishing plants, flowing into streams and lakes and replenishing underground aquifers. But when a region is urbanized - topped with impervious surfaces such as asphalt - the way water moves over land changes significantly.

Paved roads, sidewalks and roofs can hinder rainwater's ability to filter into the ground, often creating powerful streams by linking water flow paths and sending runoff surging into drains and waterways along with pollutants it picks up along the way. This dual combination of city-altered rainfall patterns and the urban network can modify the strength, timing and duration of floods in cities and damage local water quality.

Previous research by Long Yang, a postdoctoral research associate at Tsinghua University and first author of the study, suggested that covering 5 percent of a watershed with impervious surfaces is the threshold at which local hydrology - the science of how water moves - begins to change. These effects are magnified with increases in impervious surfaces.

Hydrologic engineers make projections about future floods with a liner model that assumes flood magnitude increases at the same rate as impervious coverage and rain. But Niyogi and Yang think this model does not tell the whole story: It treats cities as isolated systems that respond to changes in rainfall but do not affect the outside system, such as the atmosphere.

According to Niyogi, growing evidence shows that cities measurably shift rainfall patterns by sending signals to the atmosphere that can alter how rain accumulates, its intensity, the frequency of downpours and the dynamics of how storms evolve.

By omitting this complex back-and-forth between cities and local rain patterns, the linear model could greatly underestimate flood changes and undermine the effectiveness of flood-control designs, he said.

"Models need to move beyond the traditional approach to consider the feedbacks cities have on local rainfall," he said.

The researchers used a grid-based watershed model to test how urbanized regions surrounded by rural areas, such as grassland, crops and forests, interact with rain and affect how it is spread across a watershed. Hydrology in these "mixed" watersheds can be much more varied than in completely urbanized or undeveloped areas, Yang said. To mimic real rainfall variability, they used a dataset of 30-year daily rainfall typical of an urbanized watershed.

Simulations showed that a region's hydrological response depends on two factors - the amount of impervious coverage and the spatial pattern of rainfall, for example, whether rain falls across the watershed in a random way or is more centralized over impervious areas.

The most notable changes in flood magnitude occurred when the watershed was moderately urbanized, that is, 20-30 percent covered with impervious surfaces. The results indicate that the risk of underestimating flood changes is larger for moderately urbanized watersheds than completely urbanized or undeveloped areas, Yang said.

"Each city is unique," Niyogi said. "There is no single, simple recipe for what urban areas can do to modify rainfall potential and flood risks. Engineering will have to evolve to include multiple factors and feedbacks. Here we've shown that cities create their own rainfall patterns that need to be considered to mitigate flood hazards."

More information: Long Yang et al. A need to revisit hydrologic responses to urbanization by incorporating the feedback on spatial rainfall patterns, *Urban Climate* (2015). DOI: 10.1016/j.uclim.2015.03.001

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