Watershed Notes
Knowledge from the Mississippi River Watershed
Technical Research Summary - October 2026

Untangling Urban Growth from Climate Change in Local Watersheds

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Research Highlights

- Botero et al. (2025) examined the unique and combined effects of urban expansion and projected changes in climate on streamflow in the Meramec River watershed in eastern Missouri.
- Projected urban growth, when isolated from climate change impacts, is projected to increase streamflow by up to 26% during some times of the year while decreasing streamflow by up to 16% in other times of the year, further contributing to climate induced increases in flow variability.
- Urban expansion intensified seasonal streamflow extremes, both distinctively and in combination with climate change, with decreases in summer flows and increases in fall flows driven by changes in evaporation, groundwater return flow, runoff, and evapotranspiration.

Introduction

As land surface is converted from vegetated areas to roads, parking lots, rooftops, and other impervious surfaces, rainfall that would have been intercepted by plants or retained by soil instead runs off quickly into waterways, creating dramatic variability in stream discharge and more extreme flooding. This effect is compounded by more frequent and intense precipitation events associated with a changing climate. While climate change and urban expansion are expected to interact and result in more extreme hydrologic events in the coming decades, most stream and river flow forecasts used for water resource planning do not separate these two forces, thus creating challenges for developing targeted and durable mitigation strategies.

Methods

Botero et al. (2025) developed a landscape-scale hydrologic model of the Meramec River Basin in eastern Missouri to simulate projected streamflow through the end of the 21st century under 39 future climate projections. To isolate the effects of both urban growth and climate over time, the model was run twice for each climate projection: once holding land cover fixed at current levels and once allowing urban area to expand according to historically based urbanization rates (Fig. 1).

Results from comparisons of these approaches were used to determine the unique contribution of urban growth to variability in stream flows through the end of the century, independent from climate-driven changes.

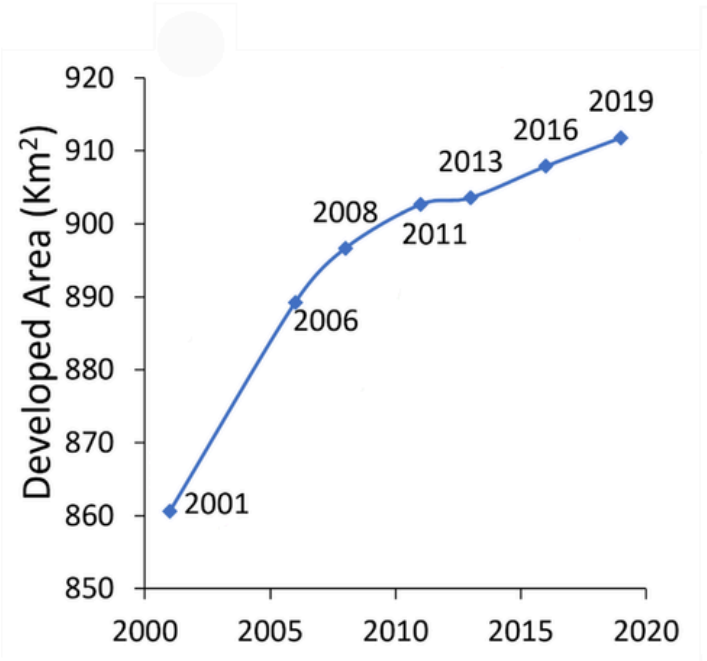

Figure 1. Increases in the amount of urban area in the Meramec River watershed in eastern Missouri from 2001 – 2019. These rates were used to inform future estimates of urban area extent in Botero-Acosta (2025).

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Results and Conclusions

Urban growth resulted in increased projected streamflow by as much as 26% during some time periods and reduced streamflow by up to 16% in other periods compared to what is projected by climate change alone. The largest increases in streamflow are projected to occur in September and October, primarily due to increased precipitation. The largest decreases are projected to occur in July, driven by increased evaporation from paved surfaces and reduced groundwater return flow during the hottest, driest months. Relatively larger rates of urban growth produced more frequent extremes in both directions. The isolated impact of urban growth often resulted in a greater than 10% change in flow, which can impose significant ecological stress on stream ecosystems in addition to flooding events (Fig. 2).

These findings build on previous research in the Meramec River watershed by Chu et al. (2013) in which urbanization alone was found to increase the frequency of high-flow events by more than 140% while decreasing the frequency of low-flow events by over 90%, with low-flow events caused by reduced infiltration that reduces groundwater levels during dry periods. In addition to greater hydrologic variability, research by Wu et al. (2021) in the Meramec River watershed found that climate change-induced increases in runoff during intense precipitation events is projected to increase basin-wide nutrient and sediment yields. However, restoring forested buffers (among other green infrastructure approaches), particularly in urbanized areas, can reduce flow variability and decrease local nutrient and sediment yields. In combination, these studies demonstrate that urban expansion and climate change act as distinct but interacting drivers of hydrologic instability, each independently intensifying streamflow extremes, flood risk, and sediment and nutrient export. Addressing these compounding pressures will require water resource planning that accounts for both forces separately, paired with targeted green infrastructure investments, to build lasting watershed resilience.

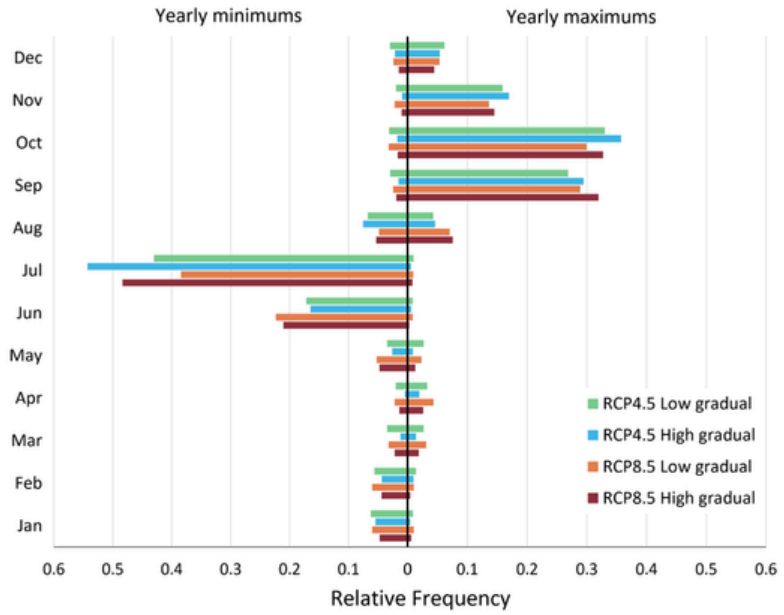

Figure 2. Estimates of the relative frequency of the contribution of the unique effects of urbanization on yearly maximum and minimum flow events based on an array of climate model projections and rates of urbanization. For example, maximum yearly independent impacts of urbanization on river discharge will most likely occur during September and October, while the minimum yearly independent impacts of urbanization will likely occur in July. "RCP4.5" and "RCP8.5" represent hydrological model outputs that were driven by climate estimates from different greenhouse gas concentration pathway ensembles through the end of the 21st century. "Low gradual" and "High gradual" indicate the rates or urban area growth estimates through the end of the 21st century (Low gradual = 1.41 km^2/year; High gradual = 5.28 km^2/year).

Reference(s)

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