From Urban to Suburban: Evaluating the Effects of Impervious Surfaces on Cobbs Creek and Darby Creek

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Abstract

Urban streams face a multitude of environmental issues today. Land cover change and anthropogenic pollution threaten urban streams and the ecosystems and the human populations they support. One of the biggest obstacles facing urban streams is the overbearing presence of impervious surfaces like roads and sidewalks, which lead to more stream runoff, more polluted runoff, and more severe flooding events detrimental to the health of already-fragile ecosystems. As a part of Dr. Jane Dmochowski's Urban Vegetation Community-Based Participatory Research Project (UrbVeg CBPR), this research will assess the relationships between land cover, vegetation density, and hydrological trends in two Philadelphia watersheds: Cobbs Creek and Darby Creek. Because the Darby Creek watershed contains significantly less impervious surface cover, it is used as a baseline against the much more urbanized Cobbs Creek watershed.

The main hydrologic impacts from urbanization being investigated are peak discharge and the lag time. The lag time is the time between peak precipitation and peak discharge in a stream. Longer lag times are usually indicative of healthier watersheds, with plenty of permeable land cover to allow precipitation to percolate through the earth. This research attempts to analyze the relationship between permeable surface cover and lag time in the Cobbs Creek watershed. Through remote sensing and hydrologic modeling, this research project attempts to assess the hydrologic that impervious surfaces have on nearby urban rivers and streams. According to models run, the Cobbs Creek watershed does display higher peak discharge and shorter lag times in response to precipitation events, as predicted. This is most likely caused by the greater cover of impervious surfaces.

Motivation for Research

Recent research into impervious surfaces has assessed the threats to urban watersheds through remote sensing, hydrologic modeling, and water quality monitoring. Cobbs Creek is a roughly 12-mile-long Pennsylvania stream and tributary of the Delaware River that borders Philadelphia and Delaware counties. It is undergoing an ongoing floodplain restoration project that seeks to limit flooding which has historically presented challenges in the area. The surface area of the watershed contains over 90% impervious surfaces. The geochemistry, ecology, and hydrology of the watershed are all negatively affected by this high percentage of impervious surfaces. Cobbs Creek is a tributary itself to Darby Creek, which is a roughly 26-mile-long Pennsylvania stream and another tributary of the Delaware River. Darby Creek flows almost entirely through Delaware County, which is considerably more suburban. The Darby Creek watershed contains significantly less impervious surface cover and was chosen to assess the impacts of either high vegetation cover or intense urbanization on a watershed.

Over half of the world's population live in cities, and this number is expected to continue to rise throughout the 21st century. Therefore, amidst the backdrop of the global climate crisis, environmental research in urban areas is essential to sustainable living. This research will help inform policymakers on the distribution of permeable surfaces necessary for healthy urban waterways. Green spaces are beneficial for mitigating the Urban Heat Island Effect, improving air quality, and boosting people's mental health, providing further justification for the investment into permeable, green infrastructure in Philadelphia and beyond.

Background

Impact Summary of Urban Areas on the Natural Water Cycle Compared to Undeveloped Catchments

Variable	Urban Impact
Infiltration	Reduction
Evapotranspiration	Reduction
Overall discharge	Increases
Flood magnitude	Increases
Lag time to peak flow	Shorter lag to peak
Recession timing	Reduction
Baseflow	Reduction

Methods

Importing Image Collections

- Landsat 7 (1999 - 2013)
- Landsat 8 (2013 – Present)
- MODIS Land Cover Type Yearly Global 500 m Dataset

Filtering the Image Collections

- Spatially filtered according to USGS Watershed Boundary Datasets
- Temporally filtered from Late Spring to Early Fall
- Clouds removed by masking "pixel_qa" band
- Mean image taken

NDVI and Classification

- Normalized difference of the NIR and Red bands taken
- NDVI value assigned to each pixel on the map

Ratio-Based Impervious Surface Index (RISI)

- Water bodies masked
- 0-1 transformation conducted on the Coastal Band and the NDVI Band
- Transformed coastal band divided by transformed NDVI band to obtain RISI

Precipitation

- Obtained using NASA's Global Precipitation Measurement (GPM) v6 dataset

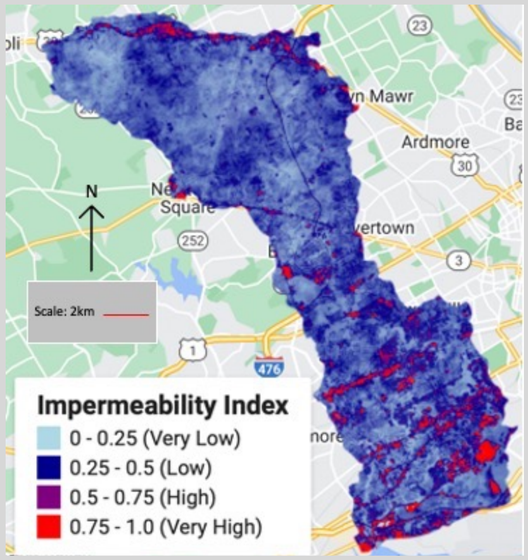
Discharge

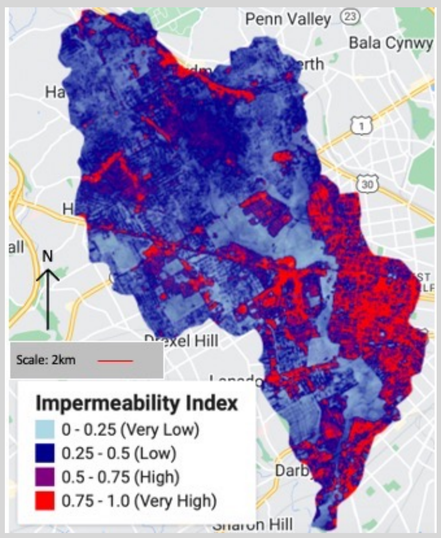
- 2012 - 2021 data taken from USGS stream gages

Constructed Models

- Combined meteorological and discharge data in hydrologic modeling tool, HEC-HMS

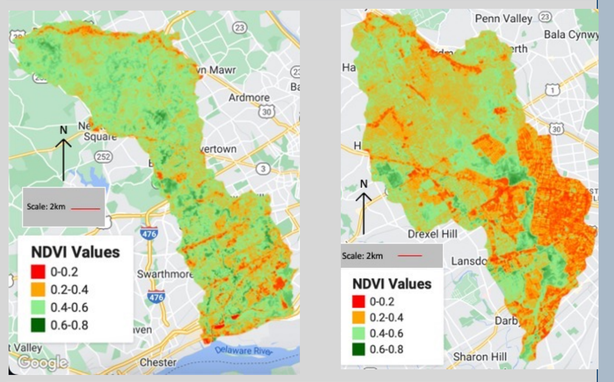
Results



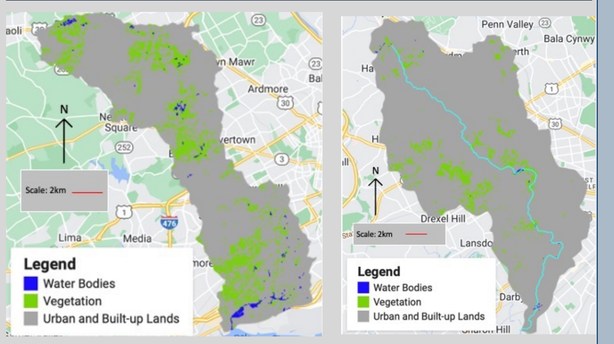


Ratio-Based Impervious Surface Index (RISI) maps for Darby Creek (left) and Cobbs Creek (right). A higher RISI number indicates a greater distribution of impervious surface cover in that area. The RISI method as outlined in Fang et al. (2019) is especially effective at distinguishing impervious surfaces from other similar land cover types, such as bare soil.

Results (continued)



Mean vegetation cover in Darby Creek (left) and Cobbs Creek (right) represented using Normalized Difference Vegetation Index (NDVI) for May – October 2018.



Supervised classifications of Darby Creek (left) and Cobbs Creek (right), displaying land cover types separated into three classes after being trained on 235 data points.

Conclusions and Future Work

Models run using HEC-HMS indicate that Cobbs Creek exhibits excessively flashy behavior in response to precipitation events in comparison to Darby Creek. Cobbs Creek demonstrates a shorter average lag time and higher peak discharge per watershed area. It is hypothesized that this is due, in part, to the disproportionate area of impermeable surfaces in the watershed, with Cobbs Creek being covered in almost 50% more impervious surfaces than Darby Creek.

Cobbs Creek is certainly suffering the detrimental environmental impacts accompanied by excessive impervious surface cover. Future research on this vital green space oasis in West Philadelphia should investigate the extent to which impervious surfaces contribute to flooding, the urban heat island effect, and water pollution. The vegetation in this region contributes to mitigating the impacts of urbanization, however further research into effective means of increasing permeable surface area should be pursued and not limited to only planting trees.

References

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