Using isotopic source partitioning of urban runoff to verify effective impervious area model in a partially forested, partially developed urban watershed

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Highlights

- Urban stormwater management would benefit from improving modelling/prediction of runoff flow paths
- Effective impervious area is
- Urban runoff sources may be distinguishable using stable isotope analysis
- Using stable isotopes as environmental tracers may be useful in modelling how urban runoff delivers nutrient pollutants to streams

Introduction

Hydrologic regimes in urban streams are altered by increased runoff from impervious surfaces in developed areas. Runoff also delivers pollutants that have collected on impervious surfaces during dry periods antecedent to storm events. Urban nutrient loading is considered a nonpoint source pollutant, making targeted mitigation strategies challenging.

Determining the source of stormwater runoff (and thus the associated source of pollutants), is a critical need in urban hydrology to optimize siting of stormwater controls and improve water quality monitoring. This study employs stable isotope analysis to attempt to identify environmental tracers for stormwater partitioning. Three monitoring sites on a unique urban watershed with forested headwaters in the city of Knoxville, TN allowed collection of flow-paced stream samples during the course of various storm events in all four seasons. Water samples were also collected throughout the watershed during dry weather to evaluate a baseflow control.

This project uses stable isotope analysis of nitrogen ($\delta^{15}N$) and oxygen ($\delta^{18}O$) for dissolved nitrate and sulfur ($\delta^{34}S$) and oxygen for sulfate as environmental tracers for stormwater source partitioning. These nutrients are known to have distinctive endmember isotope compositions between groundwater and surface inflow. This study builds on this knowledge by investigating the application of this technique to urban runoff endmembers, such as roadway, rooftop, and grass runoff sources. The results are essential to understanding impervious surface connectivity, and how this effects nutrient sources and transport during storm events.

Methodology

Hydrologic Monitoring

Three hydrologic monitoring sites were strategically established to observe the differences in hydrologic flow between a developed urban watershed and an urban forest watershed.

Table 1. Overview of subcatchments monitored for this study.

	Subcatchment Area (sq. miles)	% Impervious
URBAN	0.33	90.0
FOREST	0.5	19.1
COMBINED	2.3	61.4

Velocity, stream head, and rainfall measurements were recorded at each of the three hydrologic monitoring sites at 1-minute intervals over a 2-year period. These measurements were used to build a stage-discharge relationship to inform an ISCO automatic sampler. Flow paced samples were taken by the autosampler at each of the three sites during three separate seasons.

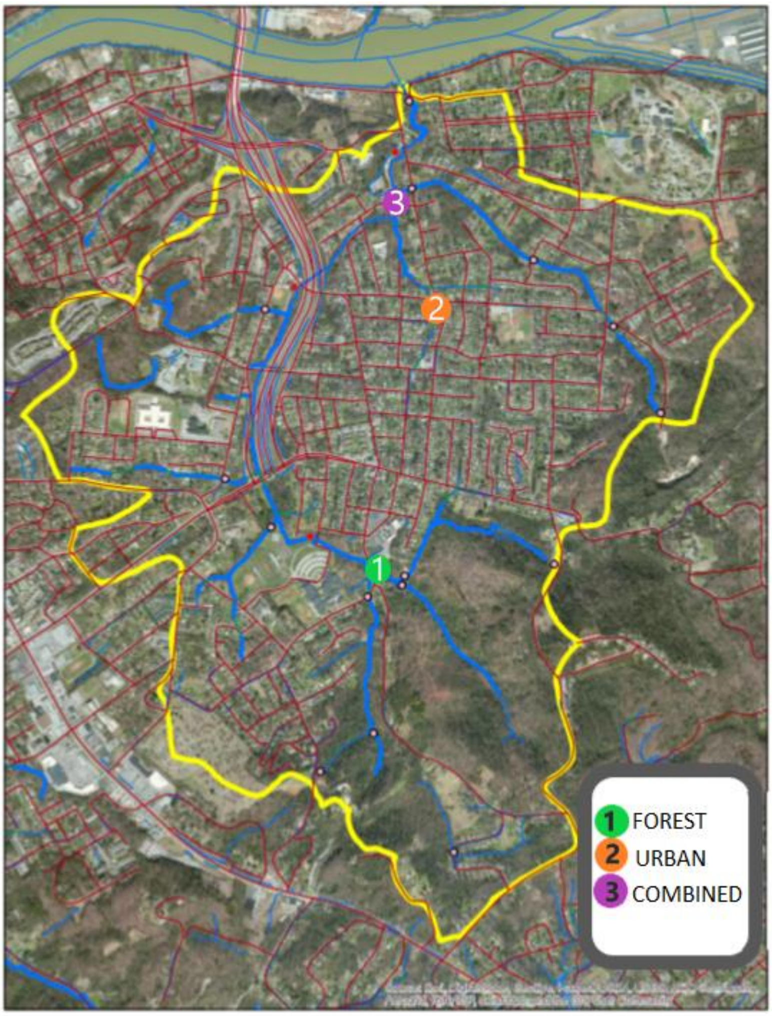

Figure 1. Map of Baker Creek Watershed labelling the three study sites.

Sample Analysis

Nine storm events were chosen to prioritize for analysis based on clarity of hydrologic context, including one storm of each sampling site (URBAN, FOREST, and COMBINED) per season sampled. Samples were then analysed for ion concentrations, isotopic ratios of nitrogen and oxygen in nitrate, and for isotopic ratios of sulfur and oxygen in sulfate.

Results and discussion

In plotting $\delta^{18}O$ vs $\delta^{15}N$ and distinguishing by storm site, we see clusters which distinguish isotopic ratios between the 3 sites.

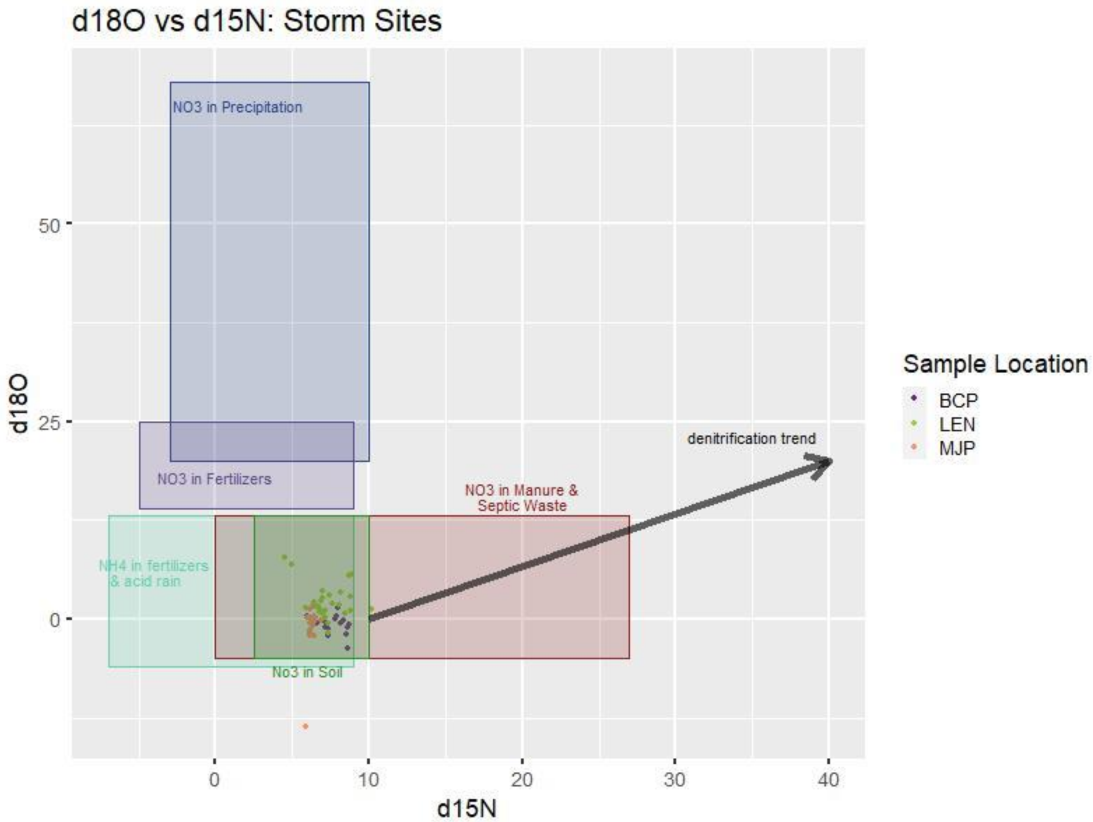

Figure 2. δ^{18}O vs δ^{15}N of spring storm events for the three monitoring sites. The boxes of known nitrate sources has been established in previous literature such as Casciotti (2002) and Dvorak (2014).

Analysis of this data is still ongoing, however through this preview we can see evidence that using stable isotope analysis of nitrate and sulfate may be capable of distinguishing between three hydrologically different sampling locations. More analysis is needed to explain why these isotopic differences occur and if they are repeatable in various watersheds.

Conclusions and future work

Analysis of this data presents that there may be a distinguishable difference in isotopic ratios of nitrate and sulfate between developed and forested urban subcatchments. Further investigation of the data is needed to determine how urban runoff contributes to these differences, whether volumetrically or by delivering pollutants, and if this is quantifiable through either a mass balance calculation or through modelling the effective impervious area of the watershed. Future work will also investigate seasonal variabilities in urban stream geochemistry, specifically of nitrate and sulfate isotopes. Because these nutrient cycles are microbially driven, it is reasonable to expect seasonal variability. Samples will also be analysed for genetic potential using 16S metagenomic analysis, to see how microbial community fingerprint may interact with availability and delivery of nutrient contaminants in stream.

References

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