Understanding Links Between Water, Nitrogen, and Greenhouse Gases in Green Infrastructure

Basic Information

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Principal Investigators:	John Harrison, Kevan B Moffett

Publications

1. Norton, R. (2016) Effects of Storm Size and Frequency on Nitrogen Retention, Denitrification, and Greenhouse Gas Production in Bioretention Mesocosms, M.S. Thesis, Washington State University.
2. Norton, R., J.A. Harrison, C.K. Keller, and K. B. Moffett (Accepted pending minor revisions) Effects of storm size and frequency on nitrogen retention, denitrification, and N2O production in bioretention swale mesocosms, Biogeochemistry.
3. Norton R., J. Harrison. Effects of storm size and frequency on N retention, denitrification, and greenhouse gas production in bioretention mesocosms. 2016. Proceedings of the Society of Wetland Scientists.
4. Kintner, S. (In preparation) Quantifying Denitrification in Bioretention Swales under Unsaturated Conditions, M.S. Thesis, Washington State University.
5. 2016 WSU School of the Environment Graduate Research Symposium (Poster): Effects of Heavy Precipitation Events on NO3- Dynamics in Conventional vs Low Impact Development Stormwater Catchments Reed A. Norton and John A. Harrison.
6. Kintner, Sarah E., Moffett, Kevan B., Harrison, John A. (2017). Understanding Stormwater Nitrogen Pathways in Bioretention Swales. Poster presented at Washington State University Vancouver s Research Showcase, Vancouver, WA.
7. Kintner, Sarah E., Moffett, Kevan B., Harrison, John A. (2017). Understanding Stormwater Nitrogen Pathways in Bioretention Swales. Poster presented at Washington State University Vancouver s Graduate Research Symposium, Vancouver, WA.

Progress Report for USGS 104b project: Understanding Links Between Water, Nitrogen, and Greenhouse Gases in "Green" Infrastructure

Low impact development (LID) structures (rain gardens, bioretention swales) are widely regarded as a cost-effective way to reduce flooding and pollution associated with urbanization. Within the past decade, Portland, OR, alone has spent more than $145 million implementing LID. Plans are proposed to implement green infrastructure across Washington State and in cities nation-wide. The Portland/Vancouver area is a leader in the installation of LID, with over 1,500 individual local LID projects, a nationally recognized "green streets" program, and award-winning installations near the WSU Vancouver campus. These factors ideally place WSU Vancouver, in collaboration with the Washington Stormwater Center of WSU Puyallup and other interested parties, to grow a research hub focused on LID functionality, natural and human costs and benefits, and value within the context of urban resilience to climate change. Cities across the U.S. have already committed to spend billions of dollars on green stormwater infrastructure in coming decades, but scientific understanding of these systems is still quite rudimentary. Little is known about how these systems actually work to retain water and pollutants, and even less about how they will respond to climate change. The scale, accessibility, and diversity of LID systems also make them wonderful laboratories in which to test established theories and develop new basic science linking hydrologic and biogeochemical processes.

Despite their design goals, the efficacy of installed LID systems for reducing flooding and removing pollutants is seldom tested post-construction. These dual services are linked by the control that soil water saturation and residence time exert on oxygen availability, and so on biogeochemistry. One important pollutant thought to be mitigated by LID is reactive nitrogen (N). High levels of N are common in urban runoff, sourced from industrial and vehicular fossil fuel emissions, fertilizer (farms, lawns, gardens), and septic/sewage effluent. When present in excess, N can damage aquatic ecosystems and risk human health via harmful algal blooms, hypoxia, and degraded drinking water quality. The N retention documented in LID systems is highly variable, from 85% N reduction to 650% N enrichment in runoff. This variability is not well understood, nor even whether the key controls are biogeochemical or hydrological; this hinders further advancements in LID design, investment, and management. Furthermore, since microbes in these systems produce potent greenhouse gases (GHGs; e.g., N_2O, CO_2, CH_4), it is unknown to what degree LID systems may trade one environmental problem (water pollution) for another (GHG production).

Better understanding how water and N processing in LID structures respond to storm events of varying size and frequency will become increasingly important in coming decades as Washington State experiences progressive climate change and urbanization. Regional mean annual runoff is projected to increase as much as 34% by the 2080s and the frequency of heavy precipitation events (>5 cm/day) is also expected to increase, as already evident in recent rainfall records. Heavy precipitation on urban impervious areas exacerbates N delivery to aquatic environments and provides a substantial fraction of total annual runoff to LID systems (~20% according to one estimate) and an even greater fraction of the annual N inflow (>40%). An improved understanding of the relationships between storm intensity, LID hydraulics, water retention, aeration, and N cycling are required before we can predict how urban stormwater systems will respond to the co-occurring stresses of N loading, urbanization, and climate change, and so better help planners scale LID investments to meet future water quality goals.

To address these critical gaps in basic understanding of LID function, we have been working to address the following research questions: 1) *How do bulk LID denitrification, N retention, and GHG production respond to different storm intensity and frequency?* and 2) *How is storm rainfall of different intensity and frequency partitioned within an LID into soil moisture storage, deep drainage, and evapotranspiration, and how does this partitioning and patterns of percolation alter the transient biogeochemically-relevant (i.e., moisture, temperature, oxygen) soil conditions?* This research has focused on generating key data from experiments in established LID mesocosms while we have worked toward the process-based numerical models and extensions to the field settings across regional urbanization and climate gradients that are intended to be the foci of subsequent external funding proposals.

To address these research questions, six bioretention column mesocosms at WSUP have been, and will continue to be, used to emulate full-scale LID bioretention facilities in replicate, with experiments in two stages. In Stage 1, experimental focus was on understanding the mesocosms as bulk ("black box") biogeochemical reactors; in particular, on quantifying the magnitude of overall denitrification (using novel methods) and GHG production under different storm intensities and frequencies. In Stage 2, focus is on "opening the black box" to understand the spatially and temporally variable internal linking of hydrological and biogeochemical functions of LID bioretention structures under varied storm intensities and frequencies. Stage 1 was carried out largely by project M.S. student Reed Norton and has resulted in a M.S. thesis, several poster presentations, and a manuscript currently accepted pending minor revisions at *Biogeochemistry*. Stage 2 is currently underway and makes up the bulk of M.S. student Sarah Kintner's thesis research. Support from this grant was instrumental in getting Ms. Kintner started on her research, and we anticipate she will finish her M.S. thesis and submit a manuscript for publication in fall of 2018.

A final report will be submitted to the State of Washington Water Research Center by 15 December, 2017.