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Effects of watershed-scale green infrastructure retrofits on urban stormwater quality: A paired watershed study to quantify nutrient and sediment removal

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Effets des rénovations d'infrastructures vertes à l'échelle du bassin versant sur la qualité des eaux pluviales urbaines: Une étude de bassin versant jumelée pour quantifier l'élimination des nutriments et des sédiments

Effects of watershed-scale green infrastructure retrofits on urban stormwater quality: A paired watershed study to quantify nutrient and sediment removal



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Introduction

Urban stormwater is a substantial source of nutrients and sediment to aquatic ecosystems. Green infrastructure (GI), including bioretention and permeable pavement, is an increasingly utilized method to treat stormwater pollutants. **This paired watershed study was conducted to quantify changes in nutrients and sediment resulting from the implementation of GI at the watershed scale.**

Methods

Monitoring followed a paired watershed design in 1 control and 2 treatment watersheds in a residential neighborhood of Columbus, OH, USA over a 3.5-yr period (Table 1; Fig. 1).

Table 1. Watershed characteristics

Watershed Name	Role	Area (ha)	% Watershed Imperviousness Treated by GI
Beechwold	control	111.5	--
Cooke-Glenmont	treatment	11.5	66.5
Indian Springs	treatment	47.8	69.7



Figure 2a. Bioretention installed at Cooke-Glenmont. Figure 2b-c. Bioretention and permeable pavement installed at Indian Springs

Results

Nutrients Significant TN ($p < 0.005$) and TP ($p < 0.05$) concentration reductions were observed at both treatment watersheds. Further reductions could have occurred if bioretention had internal water storage. OP concentrations significantly decreased ($p < 0.001$) by 25.2% at Indian Springs, the only watershed with permeable pavement. Limestone aggregate and native subsoils perhaps allowed for the attachment of OP to iron and aluminum oxides on clay particles.

Sediment TSS concentrations and loads significantly decreased ($p < 0.001$; Fig. 3) by 61.6% and 78.3%, respectively, at Cooke-Glenmont with the installation of GI, which treated 66.5% of the imperviousness area in the watershed. TSS concentrations decreased 67.7% between the pre- and post-GI phases at Indian Springs, where 69.7% of the impervious area in the watershed was treated by GI. At both Cooke-Glenmont and Indian Springs, reductions in TSS concentrations closely paralleled the watershed imperviousness treated by GI.

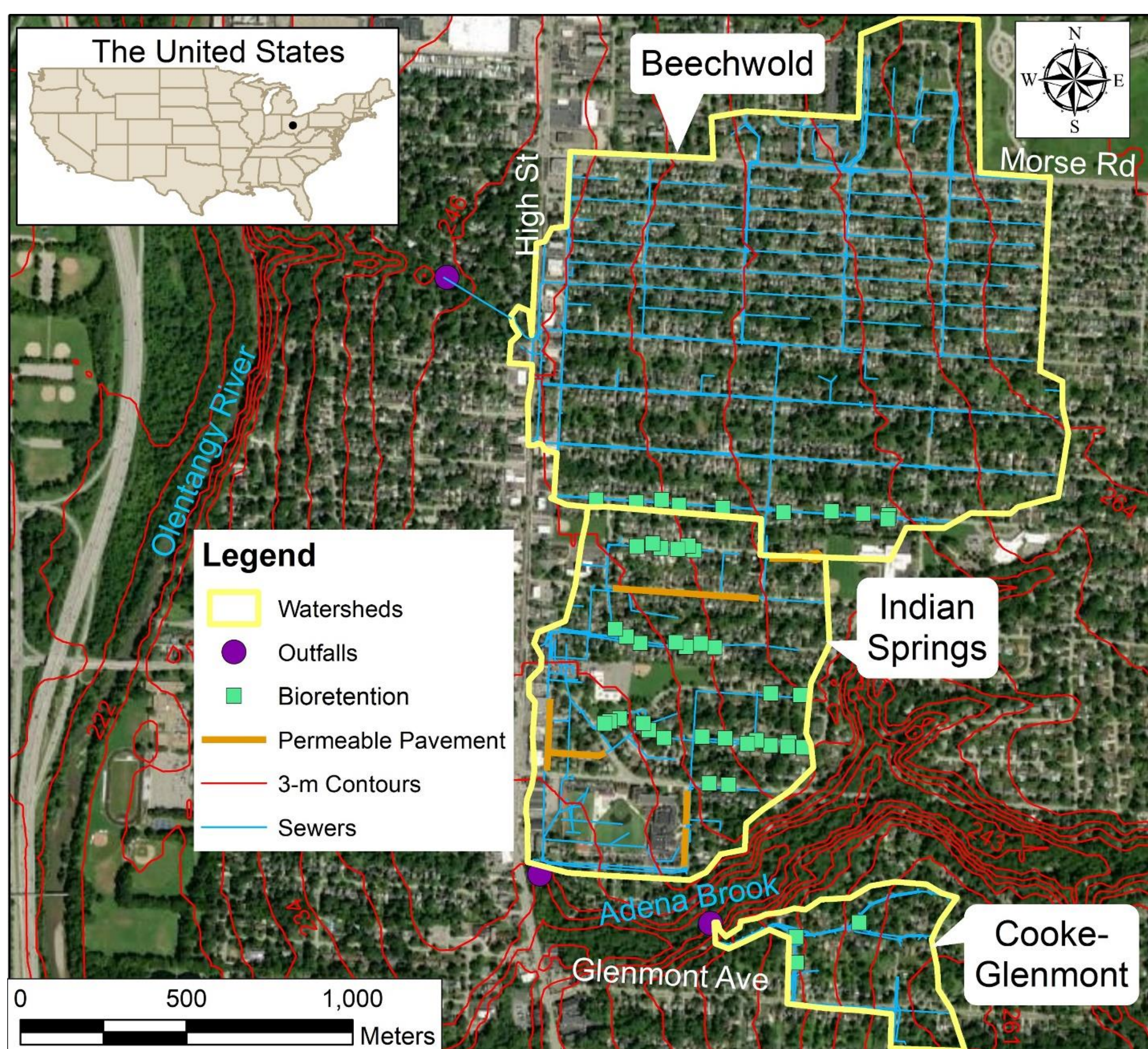


Figure 1. Overview of study area showing control (i.e., Beechwold, no GI) and treatment watersheds where GI was installed (i.e., Cooke-Glenmont and Indian Springs)

Analysis of covariance (ANCOVA) and least squared means analyses were used to quantify water quality changes resulting from GI installation at the watershed scale (Fig. 2). Water quality parameters analyzed include total nitrogen (TN), total phosphorus (TP), dissolved phosphorus (OP), and total suspended solids (TSS).

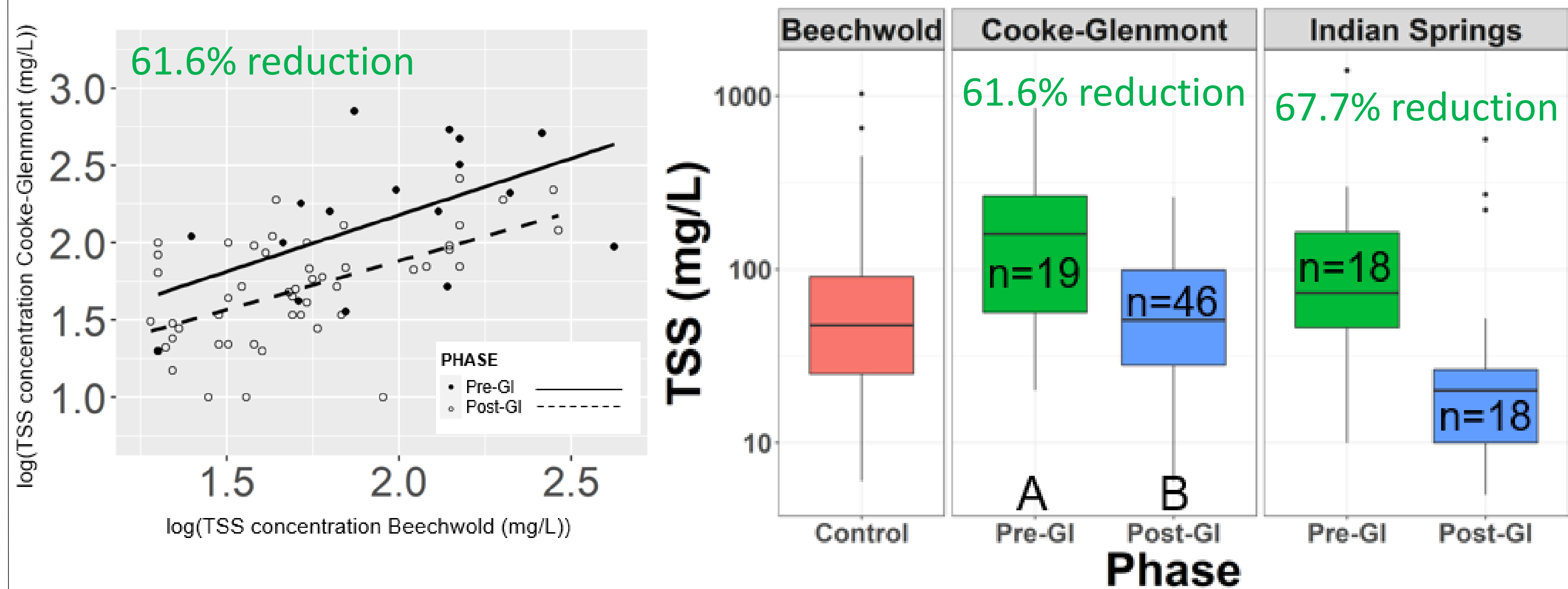


Figure 3. Left: ANCOVA for TSS concentrations at Cooke-Glenmont. Right: TSS concentration boxplots, letters indicate significant reductions by ANCOVA

Conclusions

Results demonstrate that GI was effective in reducing runoff event mean concentrations and loads at the watershed scale. TN, TP, TSS concentrations decreased by 13.7–24.1%, 20.9–47.4%, and 61.6–67.7%, respectively. Runoff attenuation by GI contributed to significant pollutant load reductions of 24.0–25.4% (TN), 27.8–32.6% (TP), and 59.5–78.3% (TSS). OP concentrations and loads significantly decreased. Reductions in TSS concentration were similar (within a margin of 5%) to the percent of the watershed imperviousness treated by GI.