Modelling reduction and enrichment effects of urban stormwater best management practices on phosphorus at the watershed scale

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Motivation & Objectives

- Phosphorus (P) export with urban stormwater runoff increases eutrophication risks in receiving surface water bodies;
- Both traditional and low impact development (LID) stormwater best management practices (BMPs) are being implemented to control quantity and quality of urban surface runoff;
- BMPs' effects on urban stormwater P export are highly uncertain under different BMP system, watershed and climatic conditions;
- Traditional methods to estimate watershed-scale BMP effects on urban stormwater P export are oversimplified by assigning a single reduction efficiency → need more robust modelling tool.

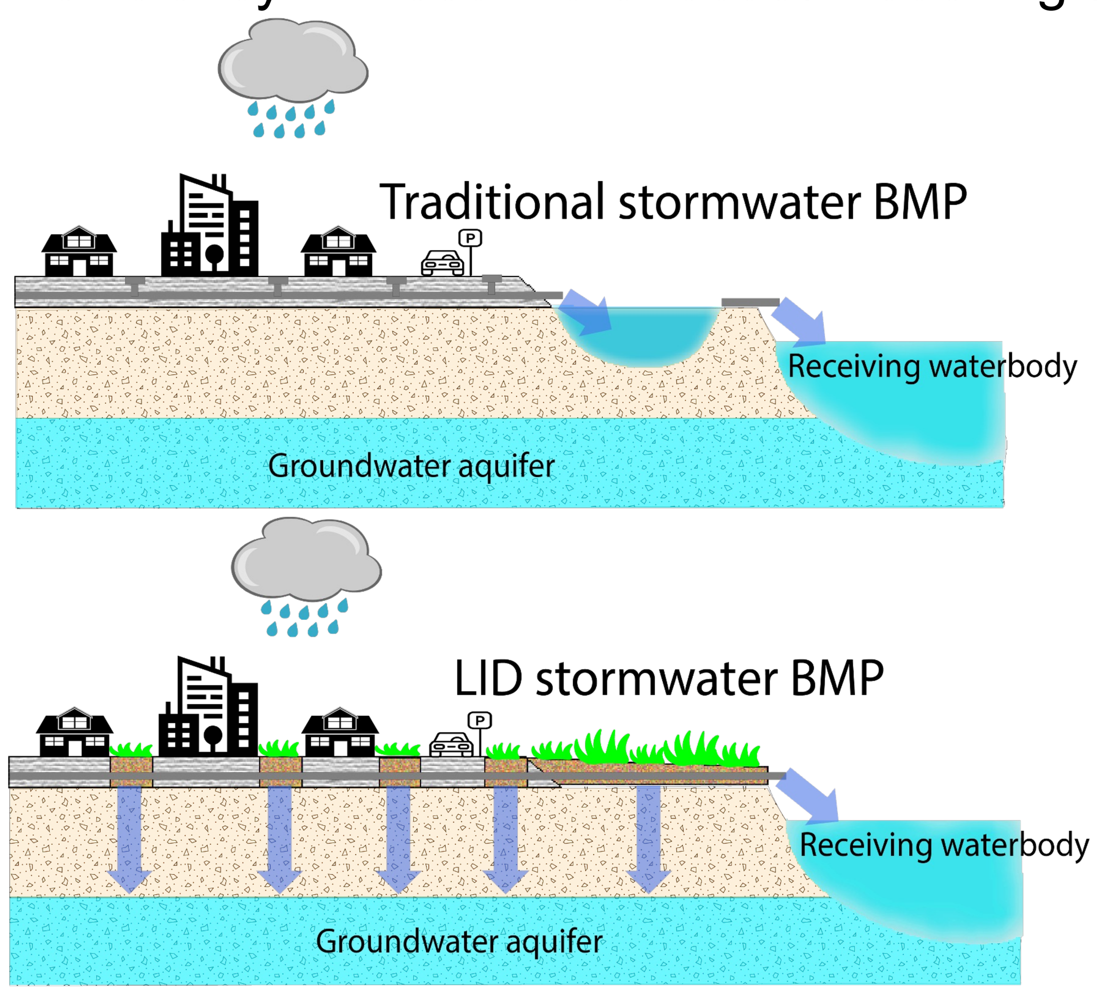

Figure 1. Up: Diagram of urban area with traditional stormwater BMP (centralized retention-based system, e.g., retention pond). **Bottom**: Diagram of urban area with LID stormwater BMP (decentralized infiltration-based system, e.g., bioretention cell).

Objectives:

- Evaluate BMP effects on urban stormwater runoff P concentration and load;
- Develop more robust prediction of BMP effects on urban stormwater P export.

Methodology

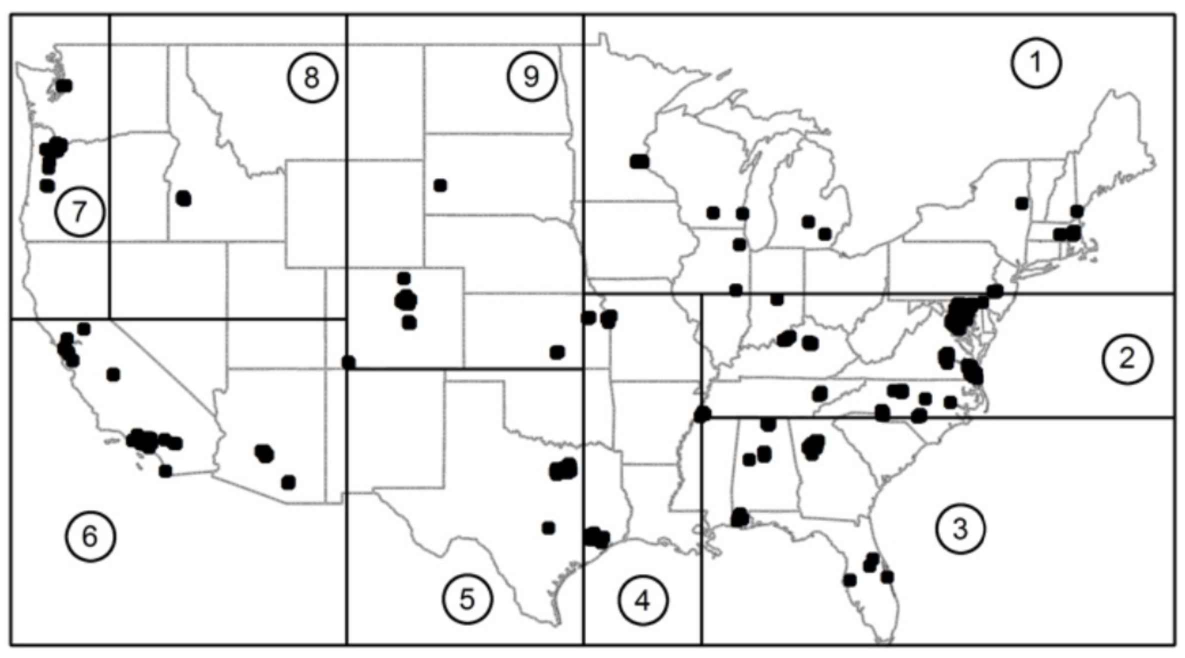

Figure 2. Distribution of stormwater BMPs monitoring data in the International Stormwater BMP Database (International Stormwater BMP Database User Guide (2016)).

Dataset: International Stormwater BMP Database

Online, free-access database with event hydrology and water quality data from stormwater BMPs (most sites are in the United States).

Data analysis & machine learning modelling

- 6 categories of BMPs (traditional: detention basin, retention pond, wetland basin; LID: grass strip, bioretention cell, grass swale);
- Reduction/enrichment factors (REF) with inflow & outflow concentrations and loadings of total P (**TP**) and soluble reactive P (**SRP**):

$$REF = \begin{cases} \frac{\mathrm{IN}-\mathrm{OUT}}{\mathrm{IN}}, & if\ \mathrm{IN} > \mathrm{OUT}\ (reduction) \\ \frac{\mathrm{OUT}-\mathrm{IN}}{\mathrm{OUT}}, & if\ \mathrm{OUT} > \mathrm{IN}\ (enrichment) \end{cases}$$

- Machine learning (ML) models for TP and SRP concentrations. Variables included: BMP system (area and age), watershed (area, imperviousness, land use) and climatic (precipitation depth and intensity, interevent dry period, temperature, month).

Results

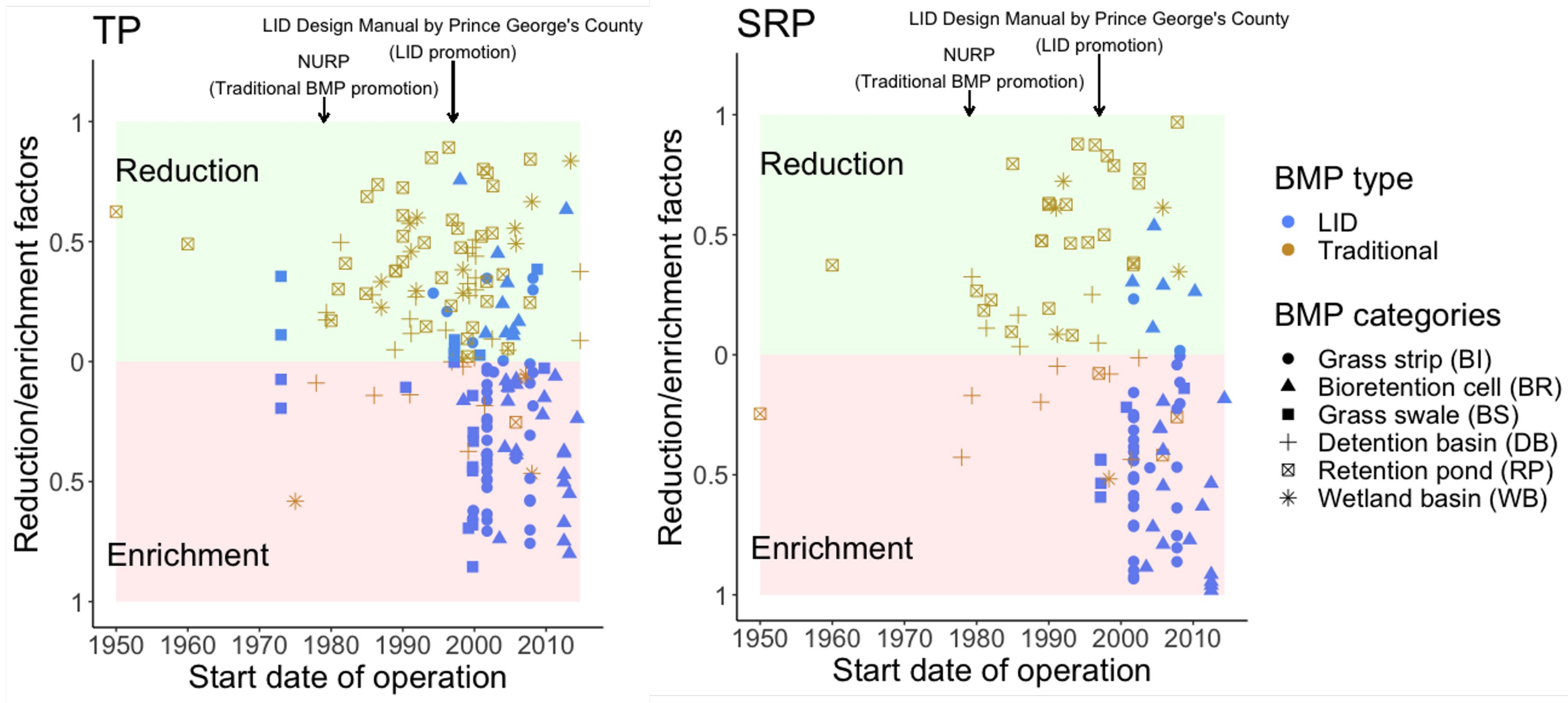

Figure 3. Site-scale TP and SRP concentration reduction/enrichment factors of traditional and LID BMPs along with their start dates of operation.

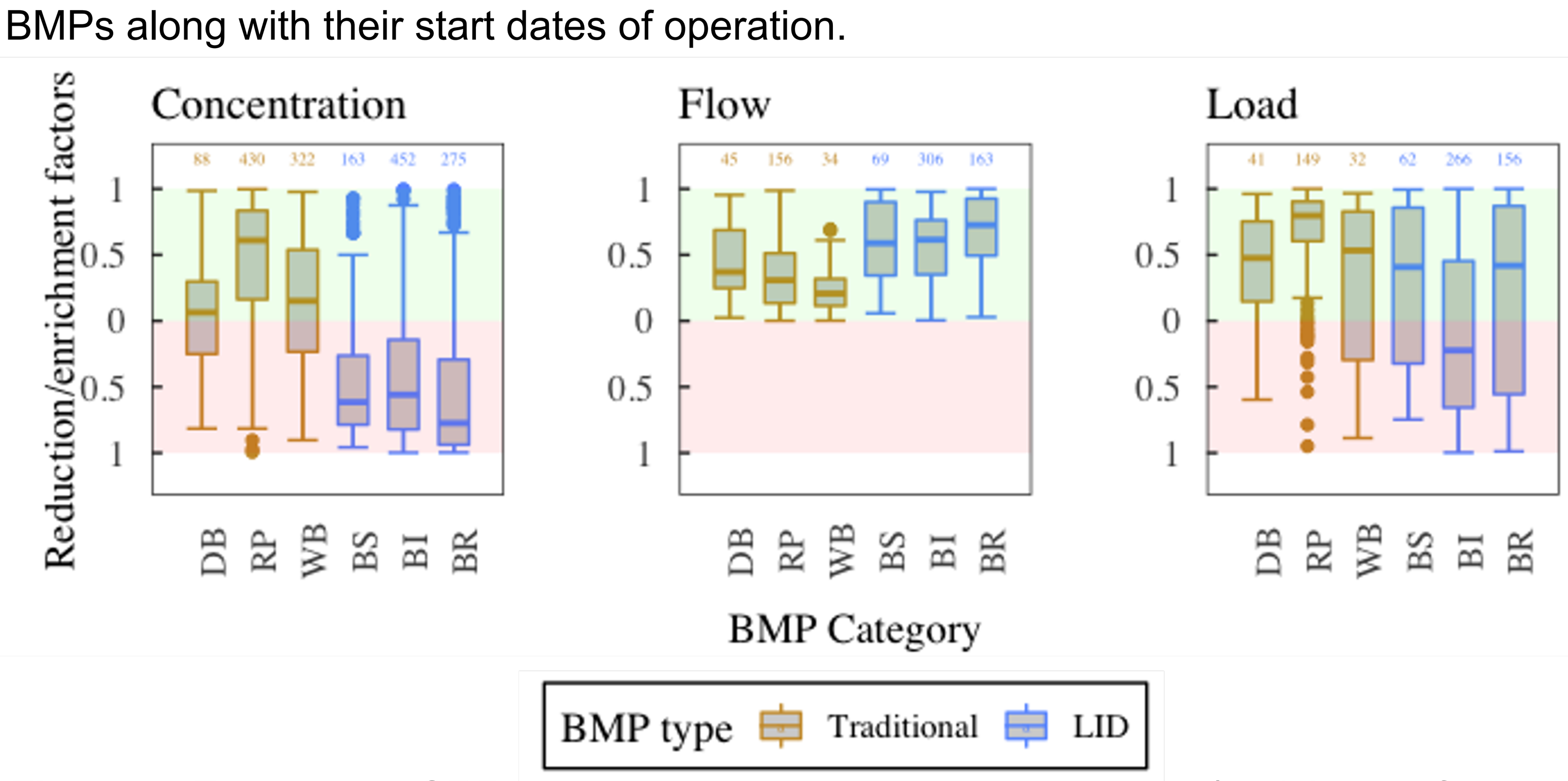

Figure 4. Event-scale SRP concentration, flow and load reduction/enrichment factors for different BMPs.

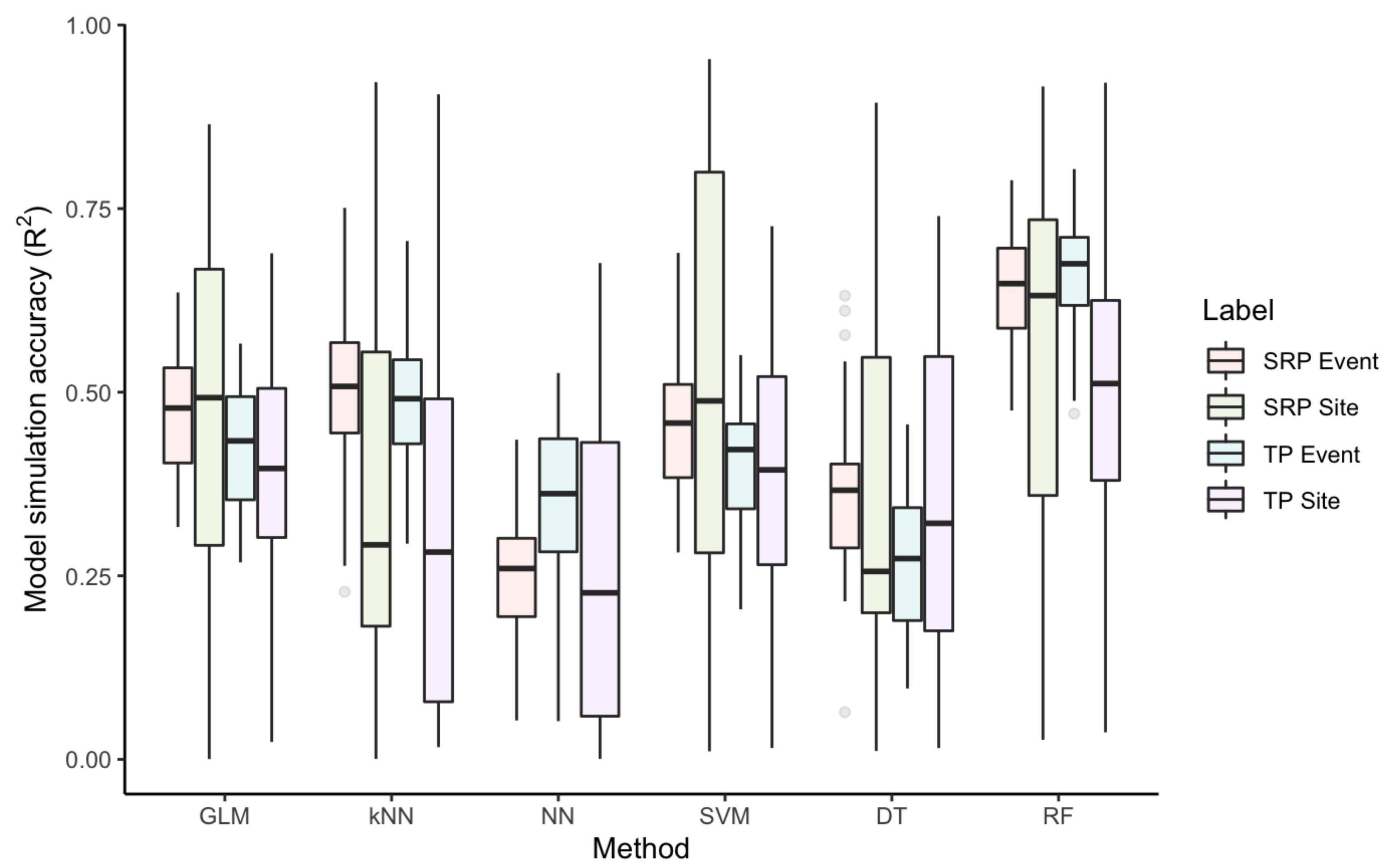

Figure 5. Accuracy (R^2) of TP and SRP event and site scale REF simulation with different ML models (GLM – generalized linear model; kNN – nearest neighbour clustering; NN – neural network; SVM – linear support vector machines; DT – decision tree; RF – random forest).

Conclusions & Future work

Conclusions:

- BMPs can have both P reduction and enrichment effects;
- LID BMPs are more likely to enrich P concentration compared to traditional BMPs → is switching to LIDs really sustainable?
- Random forest model provides more accurate estimation for BMPs' effects on urban stormwater P at watershed scale compared to other ML methods.

Future work:

Couple machine learning BMP P model with urban watershed P model (e.g., SWMM) → estimate watershed-scale BMP effects on P under different climatic conditions.

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