# The Meta-Analysis of Nonpoint Source BMPs: Can We Improve the Empirical Knowledge Associated with BMP Water Quality Improvement?

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Texas A&M AgriLife Research

Texas State Soil & Water Conservation Board

# Introduction

**Purpose**

- Assess scope and scale of published water quality BMP field studies.
- Assess mean reductions in pollutant *concentrations* in BMP studies.
- Methods and results fully detailed in Frontiers article[1]

[1] Schramm, M. P., Kikoyo, D., Wright, J., & Jain, S. (2024).A meta-analysis of the impacts of best management practices on nonpoint source pollutant concentration. *Frontiers in Water*, *6*(1397615). https://doi.org/10.3389/frwa.2024.1397615

# Methods

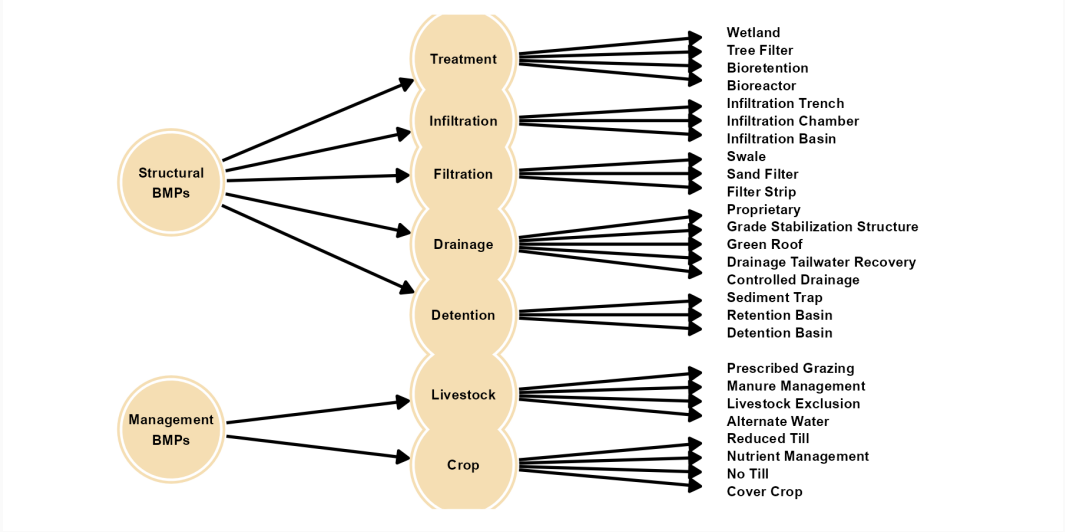
**Systematic Review**

- Followed systematic review guidance in Collaboration for Environmental Evidence[2]
- Review identified **90 studies** and **642 effect sizes**
- Collected data included: *Publication date, measured parameters, runoff source, BMP type, study scale, location, study length, measurement units, control and treatment sample size, standard error, standard deviation, mean concentration, etc.*
- Raw data available on Zenodo[3]

[2]Collaboration for Environmental Evidence. (2018). *Guidelines and Standards for Evidence Synthesis in Environmental Management* (Version 5.0). www.environmentalevidence.org/information-for-authors.

[3]Kikoyo, D., Jain, S., Wright, J., & Schramm, M. P. (2023). *TWRI Non-point Source Best Management Practice Database*. https://doi.org/10.5281/zenodo.8302472

# Methods


Structural BMPs
Management BMPs
Treatment
Infiltration
Filtration
Drainage
Detention
Livestock
Crop
Wetland
Tree Filter
Bioretention
Bioreactor
Infiltration Trench
Infiltration Chamber
Infiltration Basin
Swale
Sand Filter
Filter Strip
Proprietary
Grade Stabilization Structure
Green Roof
Drainage Tailwater Recovery
Controlled Drainage
Sediment Trap
Retention Basin
Detention Basin
Prescribed Grazing
Manure Management
Livestock Exclusion
Alternate Water
Reduced Till
Nutrient Management
No Till
Cover Crop

# Methods

**Meta-Analysis**

- Describe overall effect and heterogeneity
- Weighted multilevel random effects models
  - Weights individual effect sizes based on sampling variance
- Model terms:
  - Influent pollutant concentration
  - BMP category
  - Aridity index: $\frac{\bar{P}}{PET}$ [4]
  - Fixed effect interactions
  - Nested random effects $(Effect|Study)$

[4] Zomer, R. J., Xu, J., & Trabucco, A. (2022).Version 3 of the Global Aridity Index and Potential Evapotranspiration Database. *Scientific Data*, *9*(1), 409. https://doi.org/10.1038/s41597-022-01493-1

# Methods

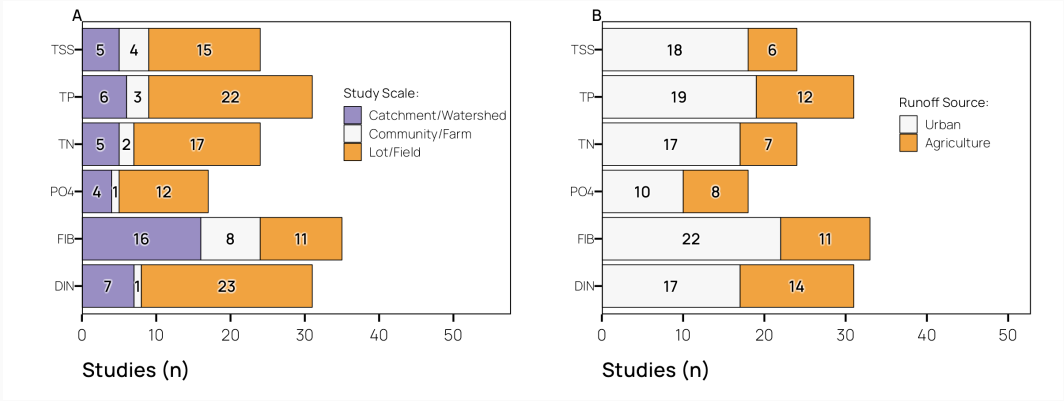
**Meta-Analysis**

- Dependent variable: log ratio of means

$$ROM_i = ln(\frac{x_{i,control}}{x_{i,trmt}}) = ln(x_{i,control}) - ln(x_{i,trmt})$$

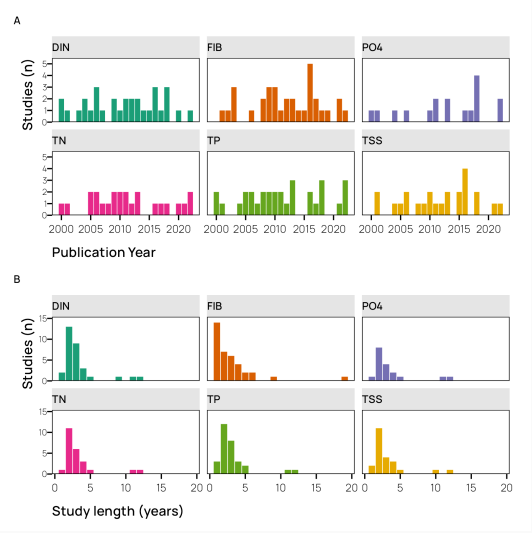
- Separate models for each parameter of interest: **fecal indicator bacteria** (FIB), **total nitrogen** (TN), **total phosphorus** (TP), **total suspended sediment** (TSS), **orthophosphate** ($PO_4$), **dissolved inorganic nitrogen** (DIN).

# Study Scale & Source



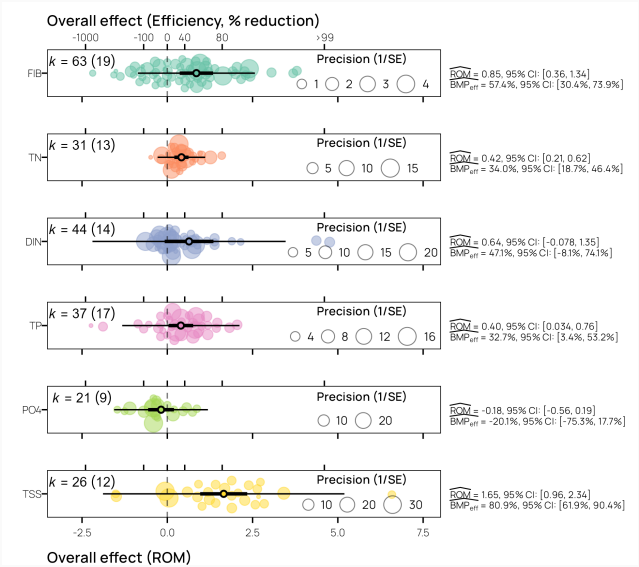

- Most studies were lot/field scale and investigated urbanized runoff.
- FIB studies tended toward larger catchments.

# Publication Date and Study Length



# Spatial Distribution

# Results



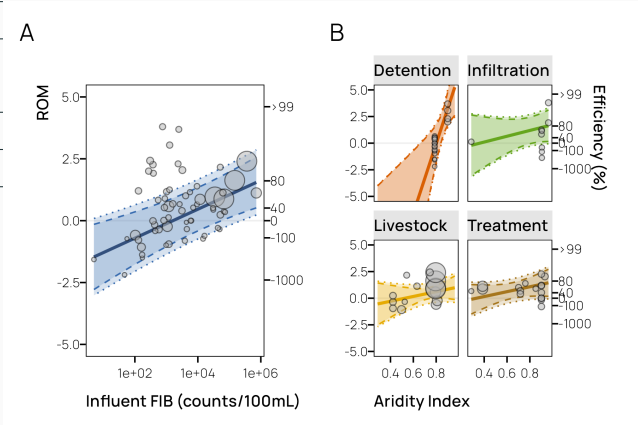

## Overall Effect

- Strong evidence across studies for mean reductions in:
  - **FIB (57%)**
  - **TN (34%)**
  - **TP (32%)**
  - **TSS (81%)**
- Prediction intervals provide low certainty about the performance of future *individual* studies.

# Attempts to Explain Variation in BMP Performance

| Parameter | Moderators |
|---|---|
| FIB | Influent Concentration, Aridity × BMP Subcategory |
| TP | Influent Concentration |
| $PO_4$ | Influent Concentration |

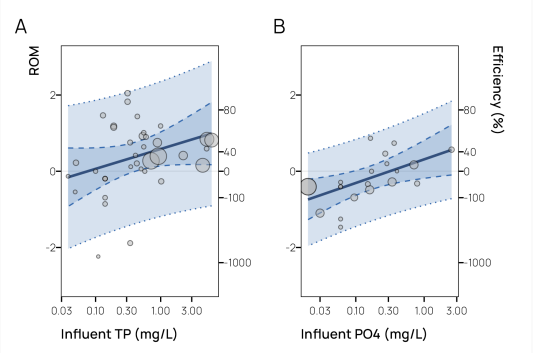
Influent concentration + Aridity×BMP Subcategory explained ~89% of effect size variance in FIB models.



# Attempts to Explain Variation in BMP Performance

| Parameter | Moderators |
|---|---|
| FIB | Influent Concentration, Aridity × BMP Subcategory |
| TP | Influent Concentration |
| $PO_4$ | Influent Concentration |

Influent concentration explained 12% and 35% of effect size variance in TP and $PO_4$ models.



# Overview

- Few long-term studies (>4 year).
- Studies clustered in the mid-Atlantic, low spatial variability.
- Studies demonstrated mean reductions in FIB, TN, TP, and TSS.
- Did not find evidence for mean reductions in DIN, $PO_4$.
- Influent concentration has strong influence on FIB, TP, and $PO_4$ performance.
- Failed to explain majority of variance in nutrient and TSS models. **(Why???)**

**Issues in Published BMP Studies**

- Very inconsistent reporting of non-manipulated study conditions.
- Earlier studies tended to report BMP efficiency only.
- Many studies fail to report sample size, variance, or uncertainty measures (59% of identified effect sizes).
- There is an opportunity to develop reporting protocols for BMP studies. See Eagle et al.[5]
    - Environmental variables, reported metrics, regression model reporting…

[5] Eagle, A. J., Christianson, L. E., Cook, R. L., Harmel, R. D., Miguez, F. E., Qian, S. S., & Ruiz Diaz, D. A. (2017).Meta-analysis constrained by data: Recommendations to improve relevance of nutrient management research. *Agronomy Journal*, *109*(6), 2441–2449. https://doi.org/10.2134/agronj2017.04.0215

# Lessons Learned

**Study/Systematic Review Issues**

- Broad study design (focus on specific BMP types).
- Keyword comprehensiveness.
- *metafor* R package facilitates meta-analysis.[6]
- Developing and training students/staff on data extraction is difficult.
- Data entry interfaces that reinforce data consistency.

[6] Viechtbauer, W. (2010).Conducting meta-analyses in R with the metafor package. *Journal of Statistical Software*, *36*(3). https://doi.org/10.18637/jss.v036.i03

# Thank You

**Contact:** michael.schramm@ag.tamu.edu

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**Paper:** Schramm M, Kikoyo D, Wright J and Jain S (2024) A meta-analysis of the impacts of best management practices on nonpoint source pollutant concentration. Front. Water 6:1397615. doi: 10.3389/frwa.2024.1397615

**Data:** Kikoyo D, Jain S, Wright J, and Schramm M. (2024). TWRI NPS-BMP-DB (v1.05). Zenodo. doi: 10.5281/zenodo.10451303