Watershed Modeling to Inform Jordan Lake Nutrient Management

Jordan Lake One Water/NCDWR
Stakeholder Meeting
2 November 2023

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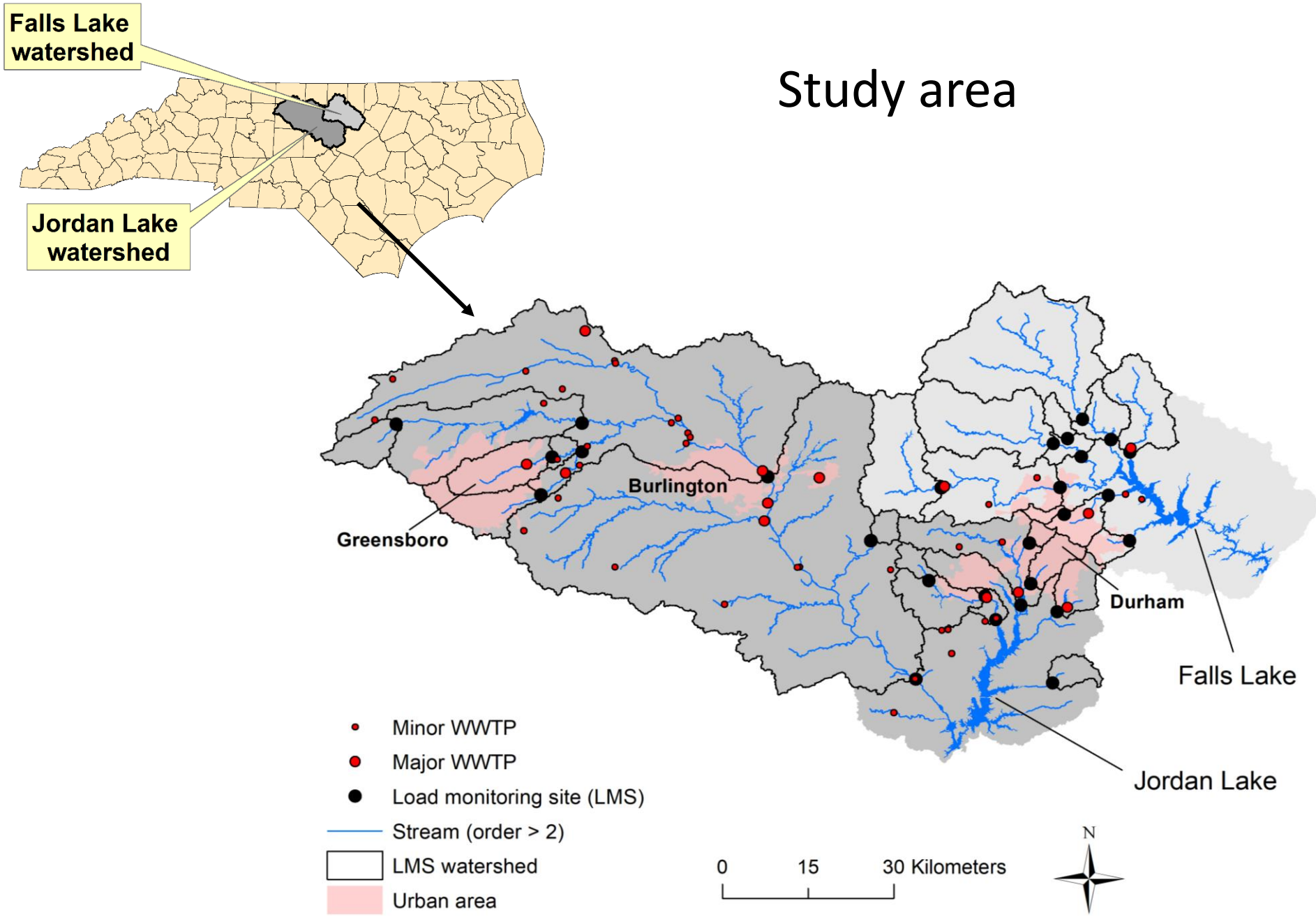
NC STATE UNIVERSITY
COLLEGE OF ENGINEERING

Research/Management Questions

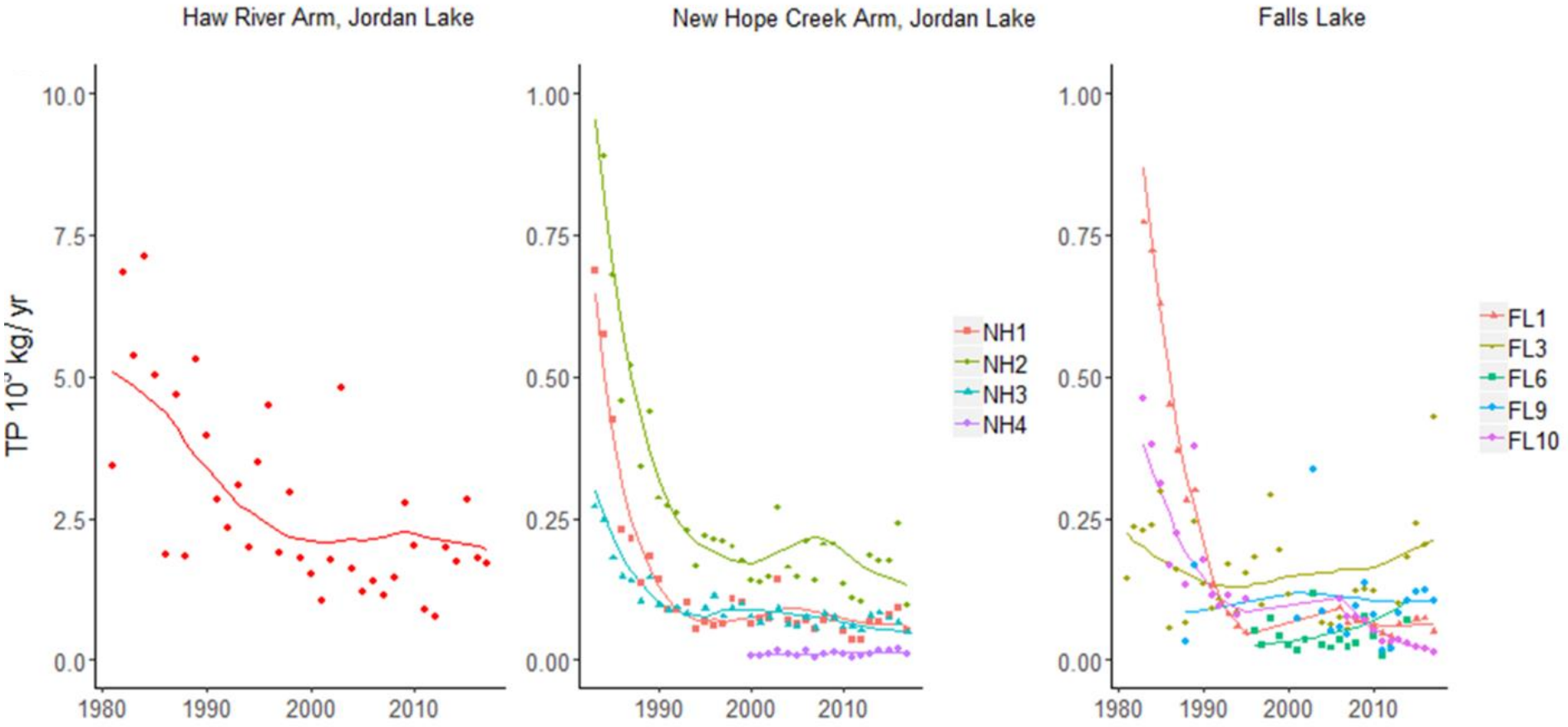
a) What are the source-specific contributions of N and P in the watershed?
   1) How much does urban nutrient export exceed natural and agricultural export?
   2) Do newer development practices reduce nutrient export?
   3) How do these contributions vary across wet/dry years?

b) What percent of N and P export is reaching downstream reservoirs?

Study area

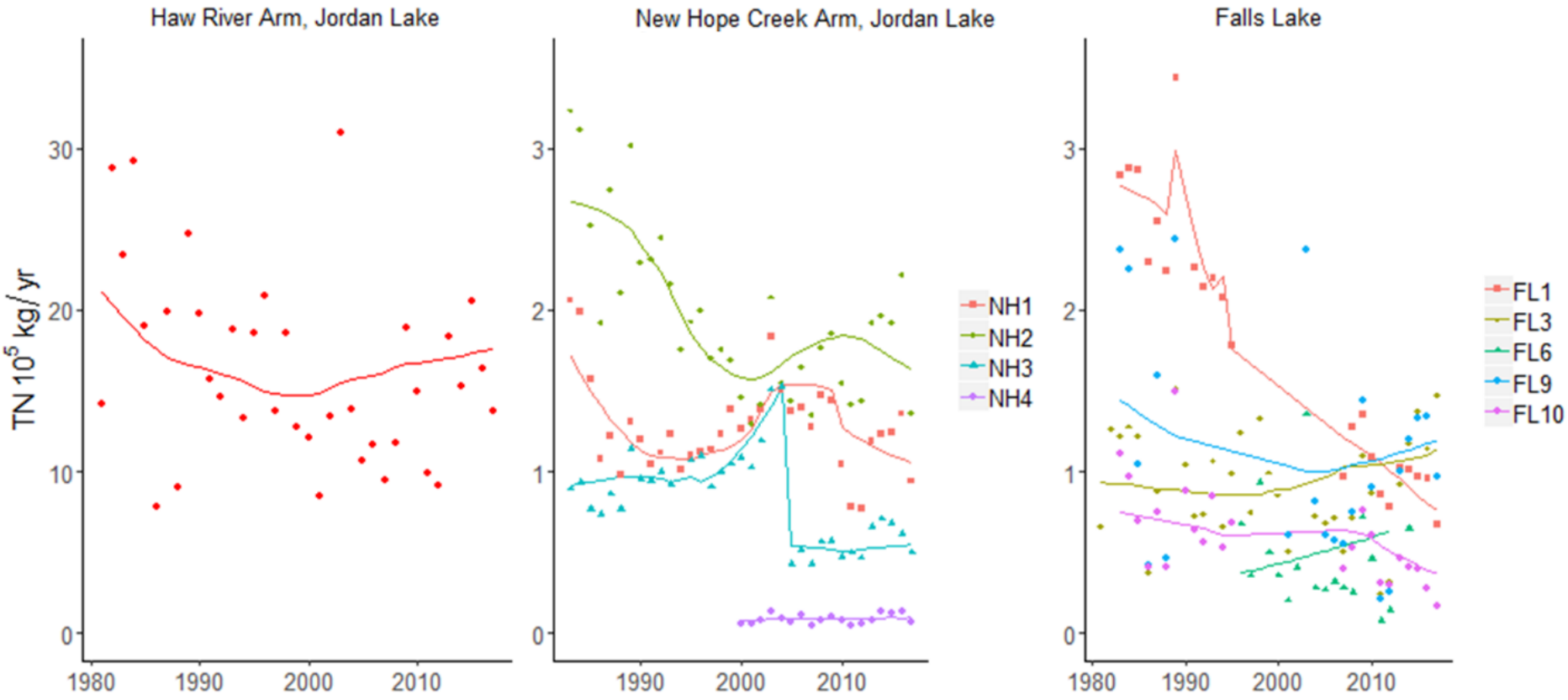

Falls Lake watershed
Jordan Lake watershed
Burlington
Greensboro
Durham
Falls Lake
Jordan Lake
Minor WWTP
Major WWTP
Load monitoring site (LMS)
Stream (order > 2)
LMS watershed
Urban area
0
15
30 Kilometers
N

Watershed P loading estimates (calibration dataset)



Note: loads estimated using USGS WRTDS

Watershed N loading estimates (calibration dataset)



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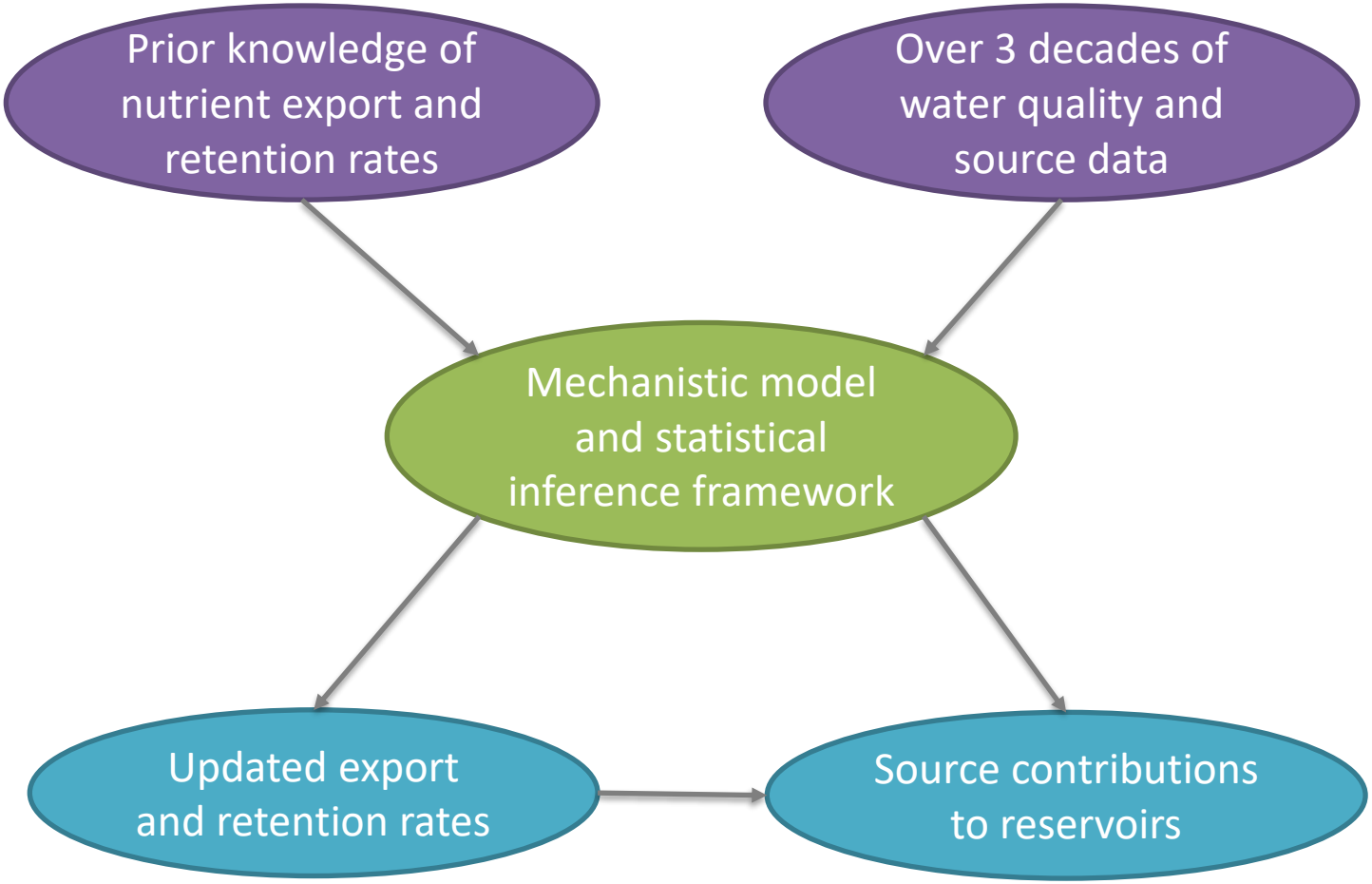
Modeling approach



Instream (incremental) loads

(i = watershed t = year)

$$\hat{y}_{i,t} = L_{i,t,ur1} + L_{i,t,ur2} + L_{i,t,ag} + L_{i,t,und} + L_{i,t,ps} + L_{i,t,ch} + L_{i,t,h} + L_{i,t,cw} - U_{i,t} * r_{i,z} + \varepsilon_{i,t}$$

Land cover-
Pre-1980 Urban (ur1),
Post-1980 Urban (ru2).
Ag, Undeveloped

Dischargers-
Major and minor WWTPs

Livestock-
chickens, hogs, cows

Upstream load retention
(streams and lakes)

$$L_{i,t,x} = \beta_{ec} (p_{i,t}^{\gamma_{pic}}) * A_{i,t,x} * (1 - r_{i,t,x})$$

β_{ec} = **export** coefficients

γ_{pic} = **precipitation impact** coefficients

$p_{i,t}$ = scaled precipitation

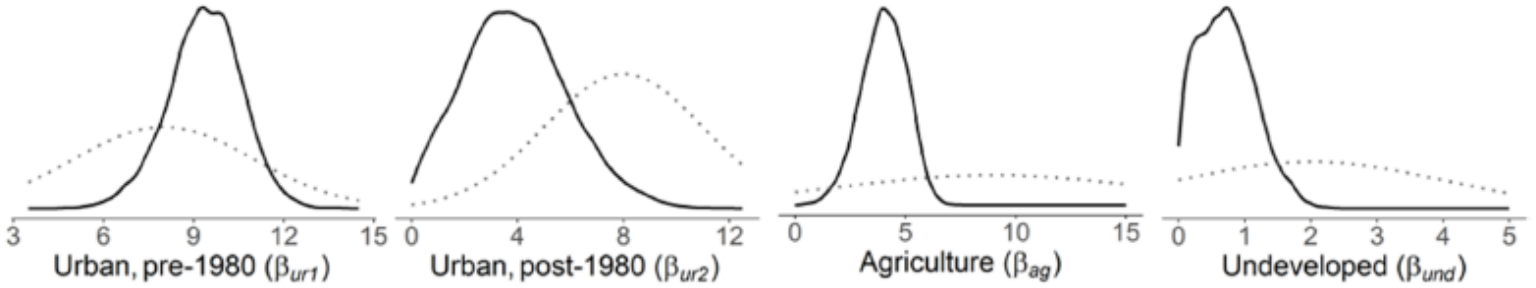
$A_{i,t,x}$ = **Area** of land cover (ha)

$r_{i,t,x}$ = Stream and lake **retention**

Calibration: N and P export rates

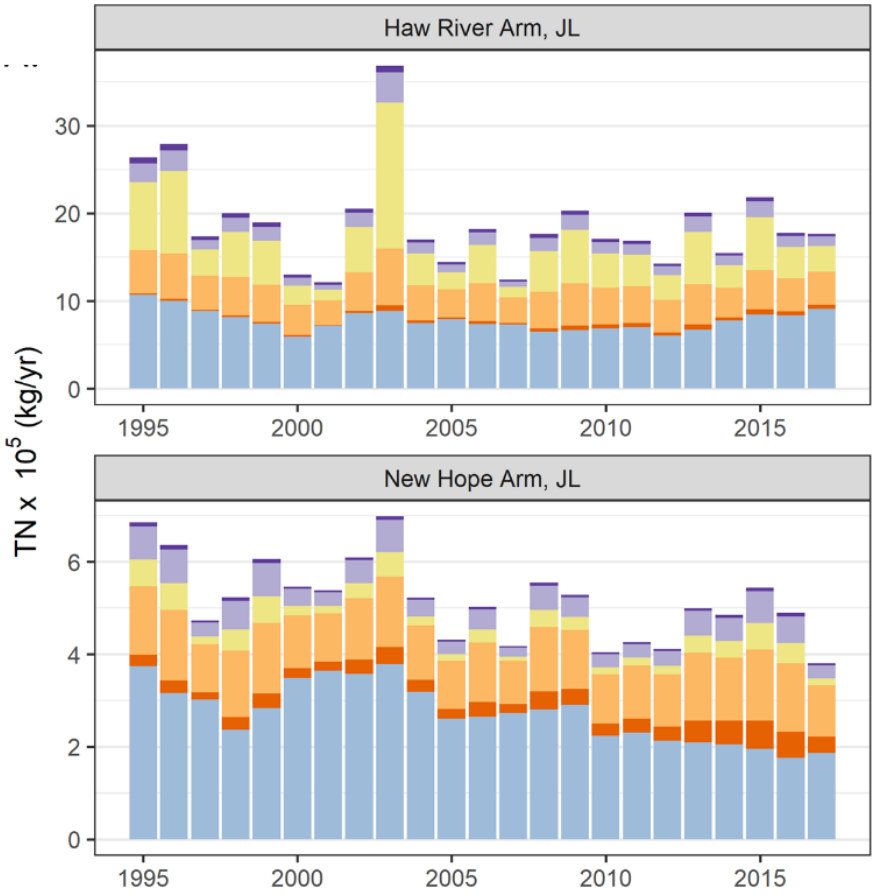
Table 3.2: Mean parameter estimates for the TN and TP models along with 95% credible intervals (CI). Units are kg/ha/yr.

		Export coefficients			
		TN		TP	
	Parameter	Mean	95% CI	Mean	95% CI
Agriculture	$\beta_{,ag}$	4.0	2.3-5.7	0.6	0.4-0.8
Pre-1980 Urban	$\beta_{,ur1}$	9.5	7.4-11.4	1.5	1.1-1.8
Post 1980 Urban	$\beta_{,ur2}$	3.9	0.7-7.3	0.6	0.03-1.4
Undeveloped	$\beta_{,und}$	0.7	0.1-1.5	0.05	0-0.13

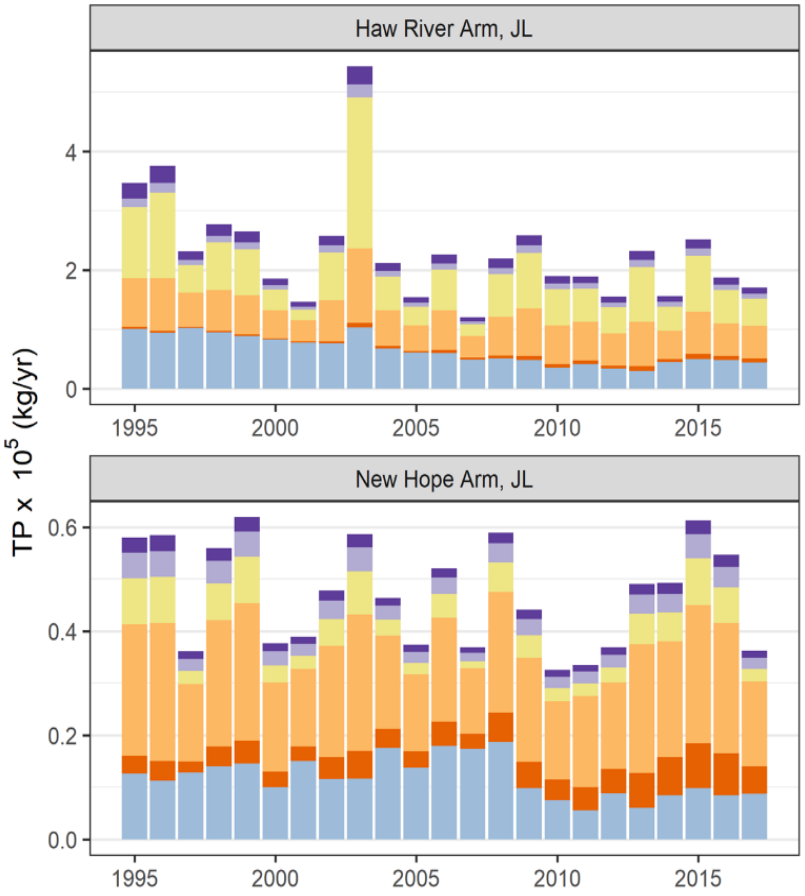


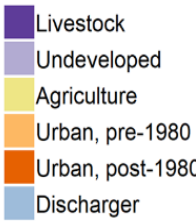
Results summary by year

Nitrogen

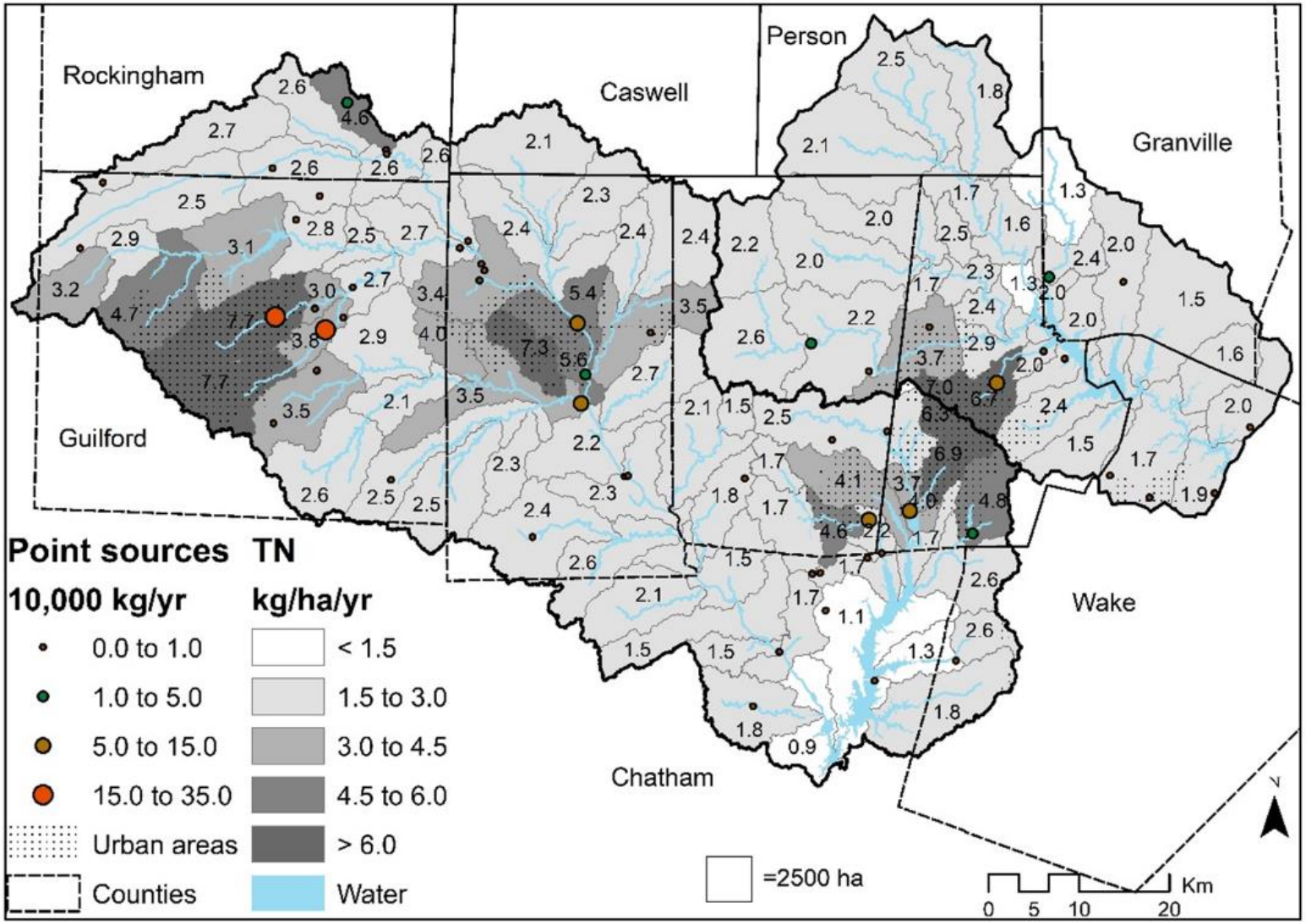


Phosphorus

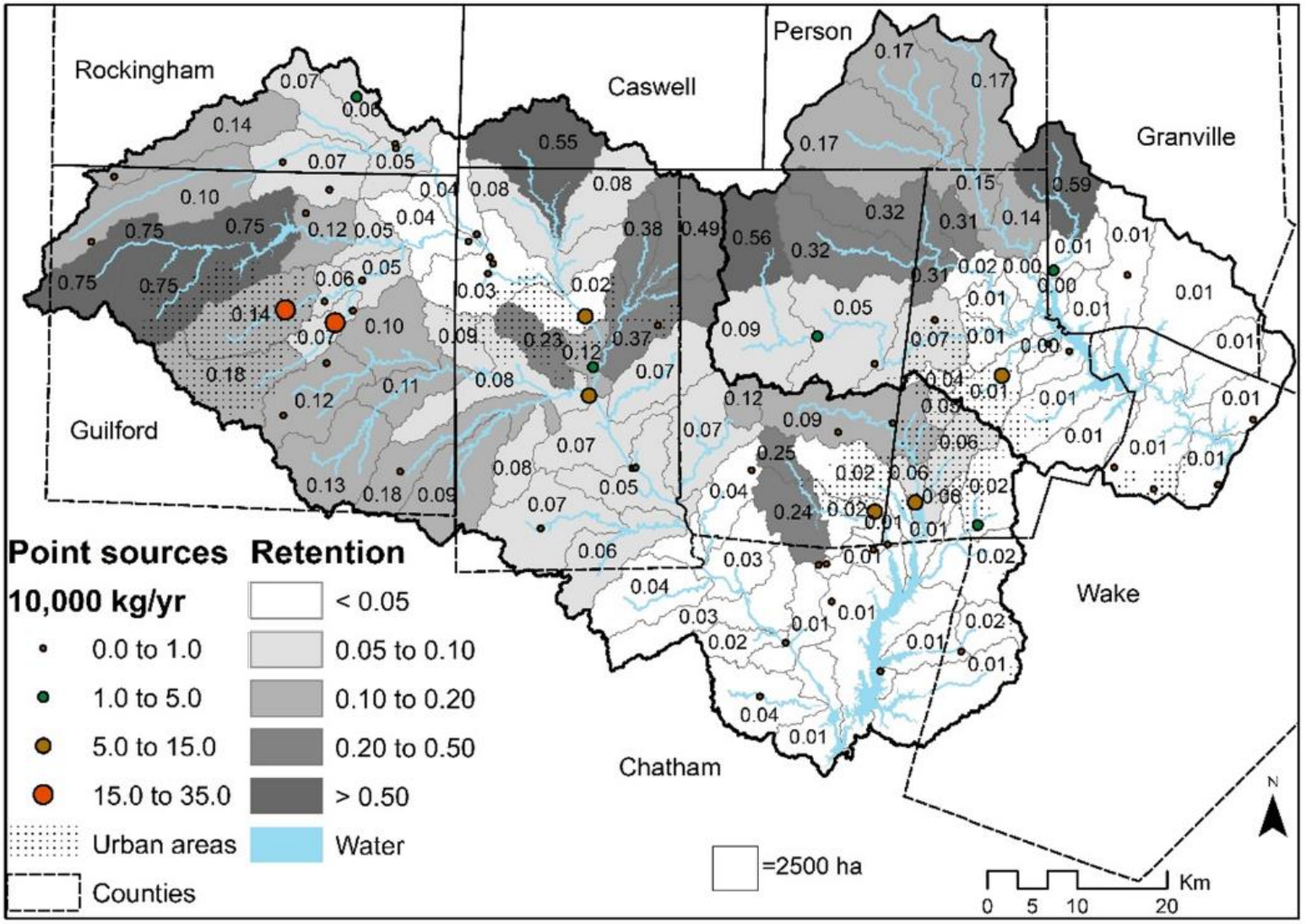




N export by subwatershed



N retention rates (***13% average***)



Watershed Modeling - Key Takeaways:

- Point source dischargers make up about 44% of N and 26% of P loadings to Jordan Lake.
- Lands urbanized before 1980 are hot spots for diffuse nutrient export. They release more than double the N and P newer urban developments (per unit area).
- Undeveloped lands export about an order of magnitude (~10x) less N and P than agricultural and urban lands (per unit area).
- The majority of land in the Falls/Jordan watersheds remain undeveloped.

Enhancements (1/2):

- Annual vs. summer export rates (TP results)

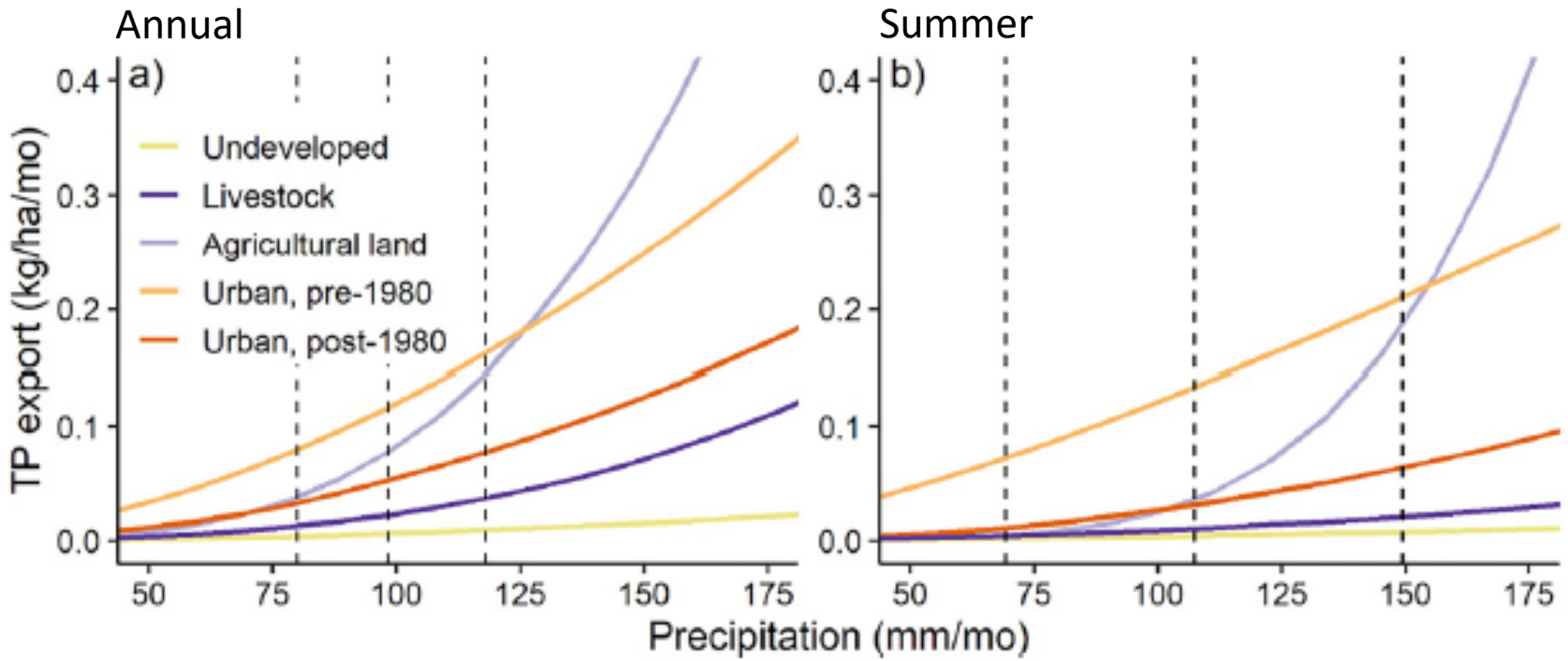


Figure 4. Source-specific export rate variability due to precipitation in annual (a) and summer (b) models. Dashed vertical lines represent the 10th, mean, and 90th percentiles of historical (1982–2017) precipitation.

Karimi, K., Miller, J. W., Sankarasubramanian, A., & Obenour, D. R. (2023). Contrasting annual and summer phosphorus export using a hybrid Bayesian watershed model. *Water Resources Research*, *59*(1), e2022WR033088.

Enhancements (2/3):

- Annual vs. summer retention rates (TP results)

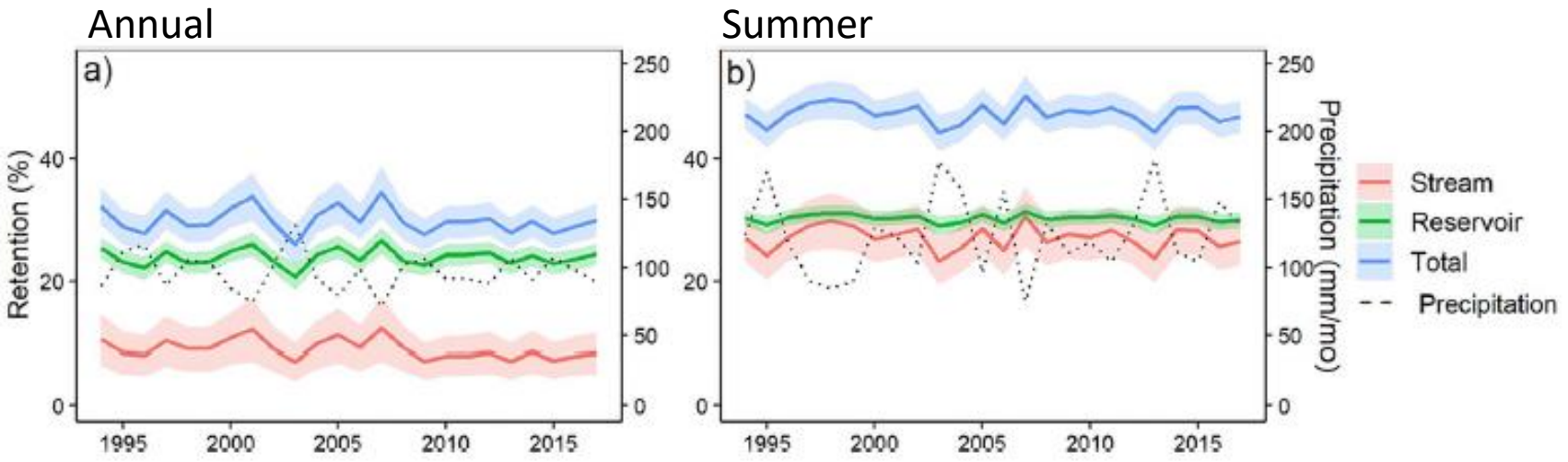
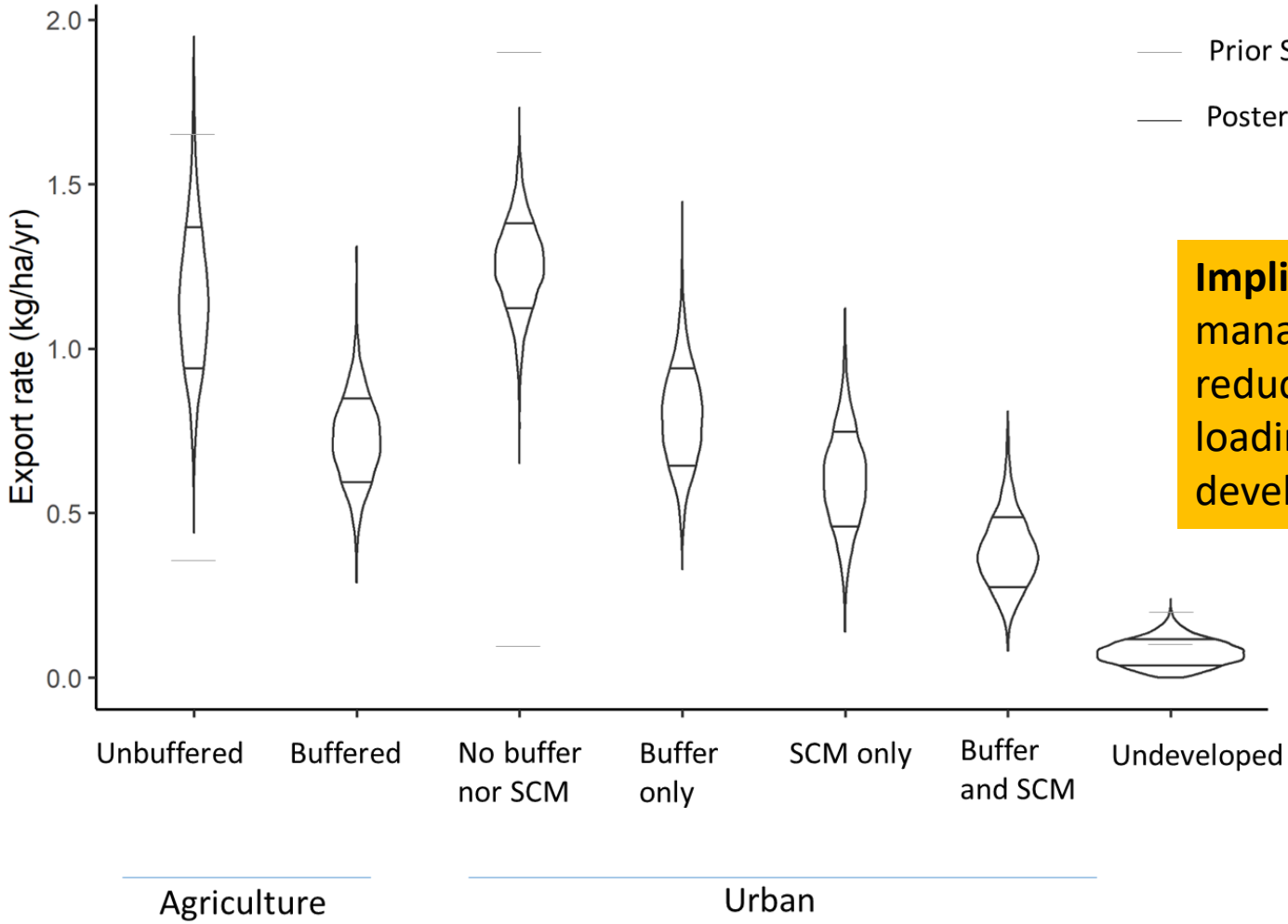


Figure 7. Annual (a) and summer (b) phosphorus retention in streams and reservoirs from 1994 to 2017 along with 95% credible intervals. The dashed black line shows annual/summer precipitation (mm/month).

Implication: Loading is lower in summer due to reduced export **and** increased stream retention. Results indicate that maintaining stream integrity and addressing urban loads are particularly important for managing summer water quality issues.

Enhancements (3/3):

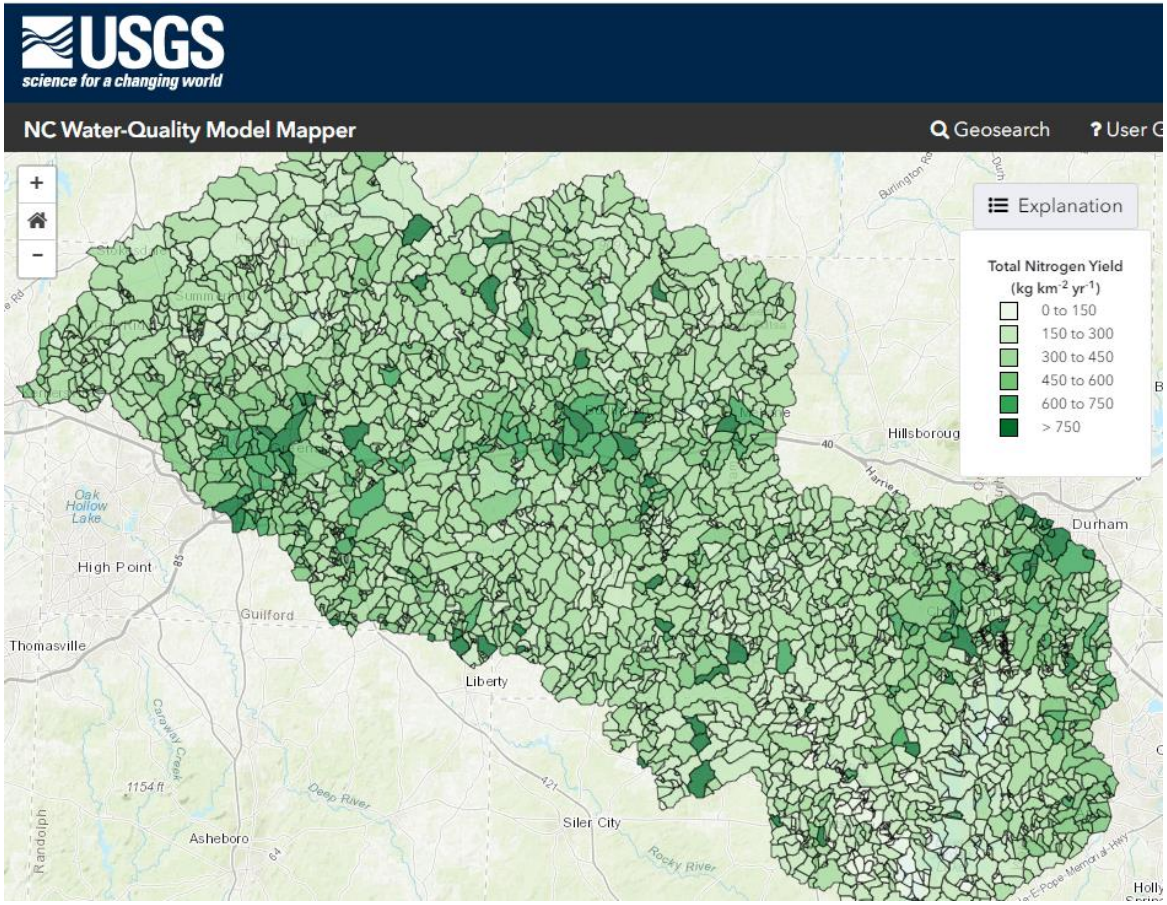
- Stormwater controls and buffers (TP results)



Implication: stormwater management greatly reduces nutrient loading, but not to pre-development conditions.

Obenour, D. R., & Mitasova, H. (2022). Assessing Controls on Nutrient Loading at the Watershed Scale through Data-Driven Modeling. NC WRRI.

Comparisons with other studies



- USGS NC

  SPARROW model:

  – TN export ranges from around 1-10 kg/ha/yr (forested to dense urban catchments).

  – TP Export ranges from around 0.1-0.8 kg/ha/yr (forested to dense urban catchments).

- NCPC Stream Monitoring and Nutrient Loading Study (Delesantro & Riveros-Iregui, UNC)

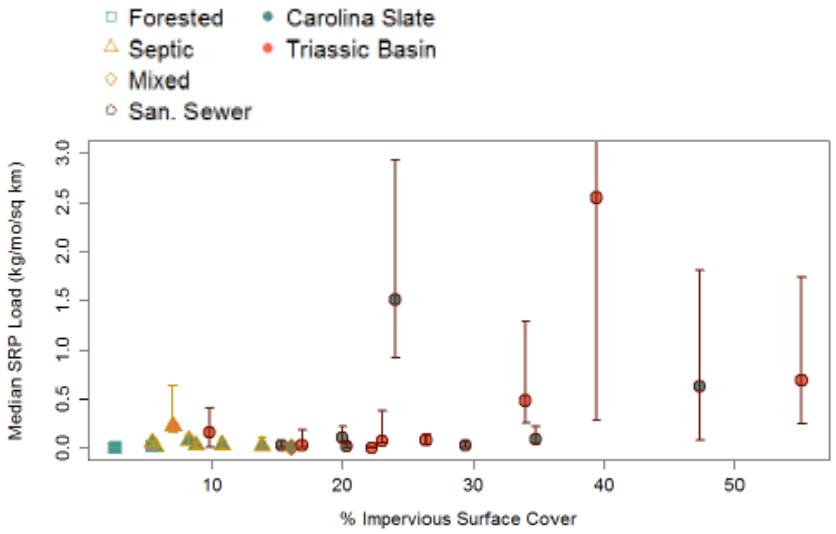


Figure 6. Median SRP concentration and loading with the interquartile range for 31 twice monthly sampled single land-use watersheds. All watersheds have greater than 12 months of sampling covering all seasons. Shapes depict land-use and infrastructure of developed watersheds while the fill col indicates the underlying geologic basin.

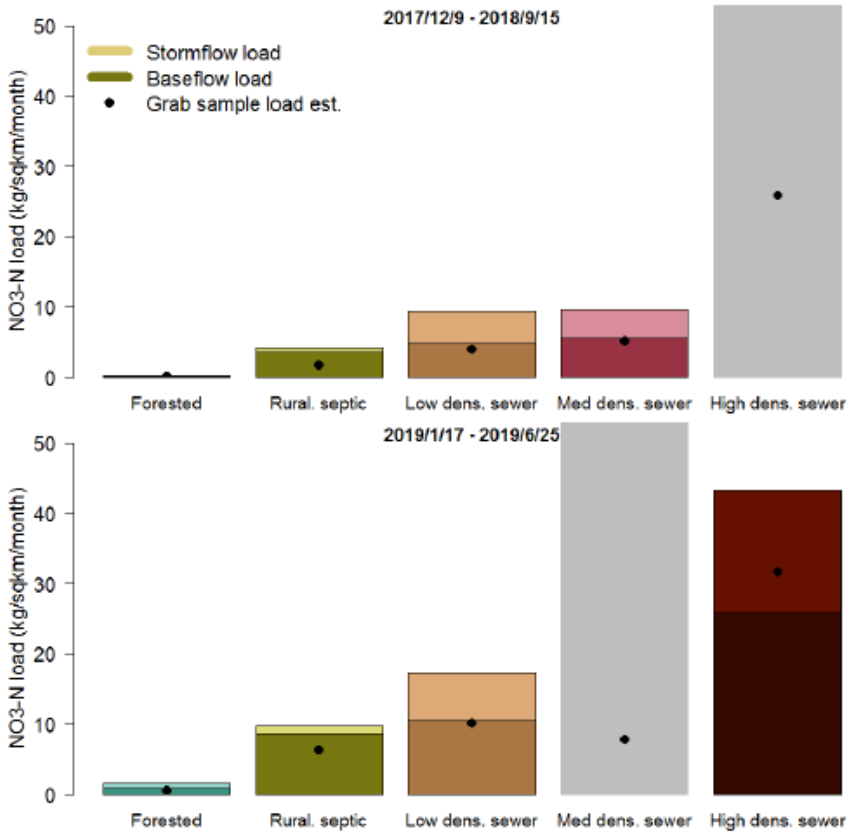


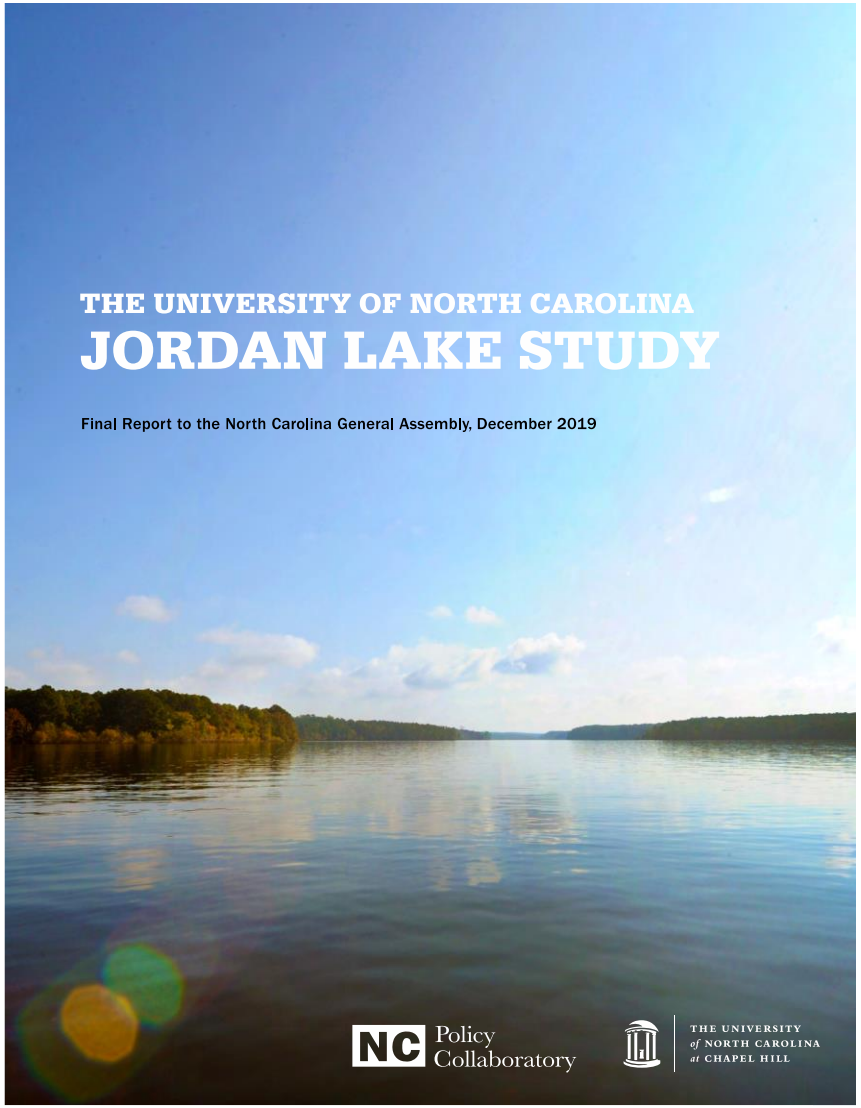
Figure 8. Total loading for two periods of high confidence continuous monitoring data. Study watersheds are TH, RRdev, BG, BT, and TY respectively. Light colors represent stormflow loading while paired dark colors represent low flow (baseflow) loading. Data is missing for the high-density watershed in the first period and 44 days of data have been removed in QA/QC. Data is missing for the medium density watershed in the second period and 6 days of data have been removed for QA/QC. Points represent the grab sampled based estimate for nitrate loading. Peak flow for TY is estimated and therefore TY stormflow loading is a conservative estimate and is likely higher. The 2019 period of data was wetter (127 mm/mo rainfall) than the 2017/2018 period (91 mm/mo rainfall) which started in drought.

Thank you for listening!

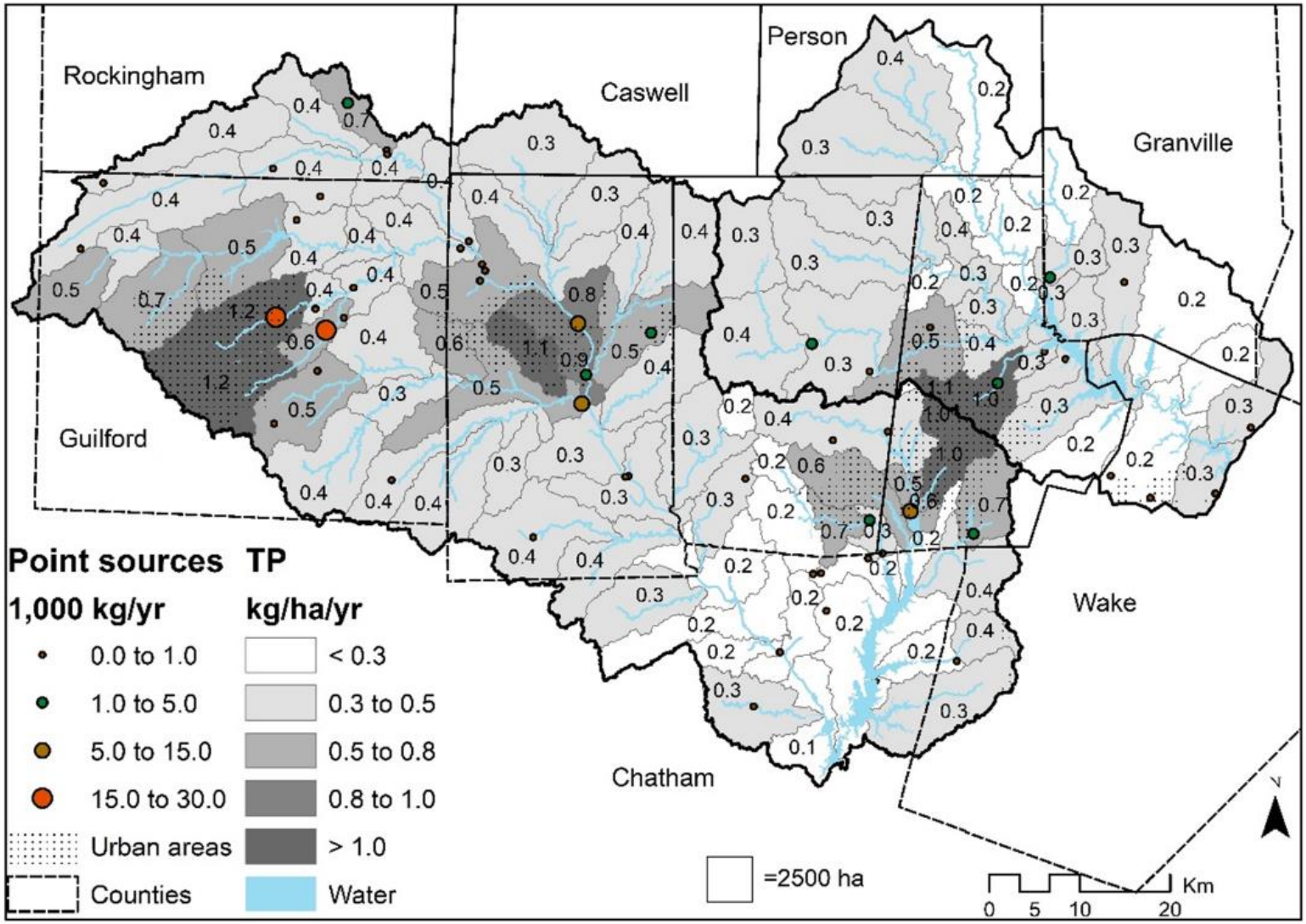
For more details:

http://nutrients.web.unc.edu/resources/

Acknowledgements:
Jonathan Miller, PhD
Sankar Arumugam, PhD
Helena Mitasova, PhD
Kimia Karimi, PhD
Corey White, PhD



P export by subwatershed



P retention rates (*17% average*)