Estimated Changes in Nitrogen Export Under Future Climate Hydrology

Modeling Workgroup Quarterly Review
8 October 2019

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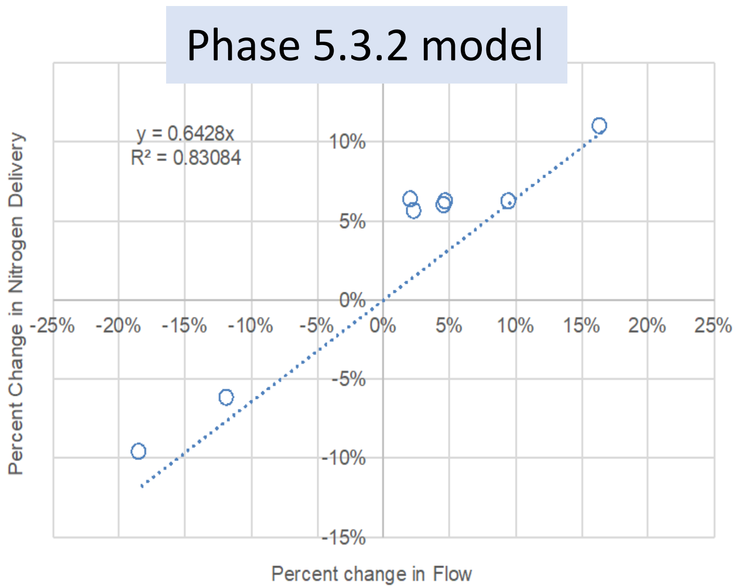
Estimated Changes in Nitrogen Export Under Future Climate Hydrology

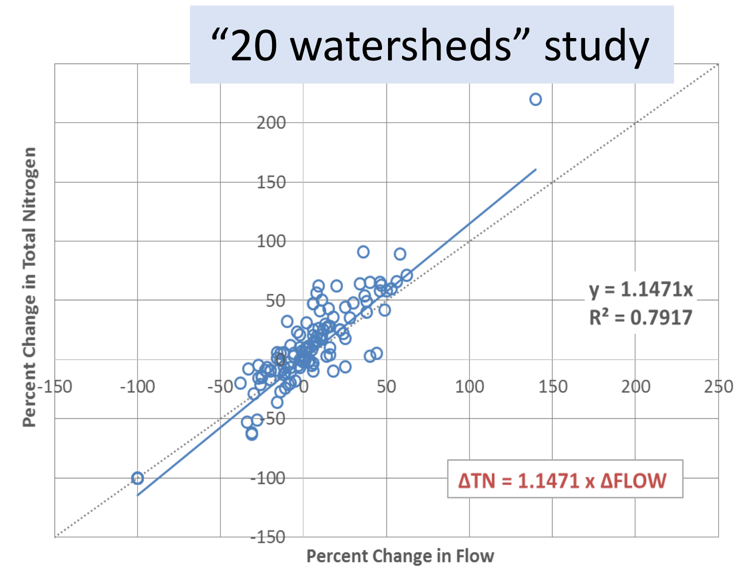
2019 Climate Change Documentation:

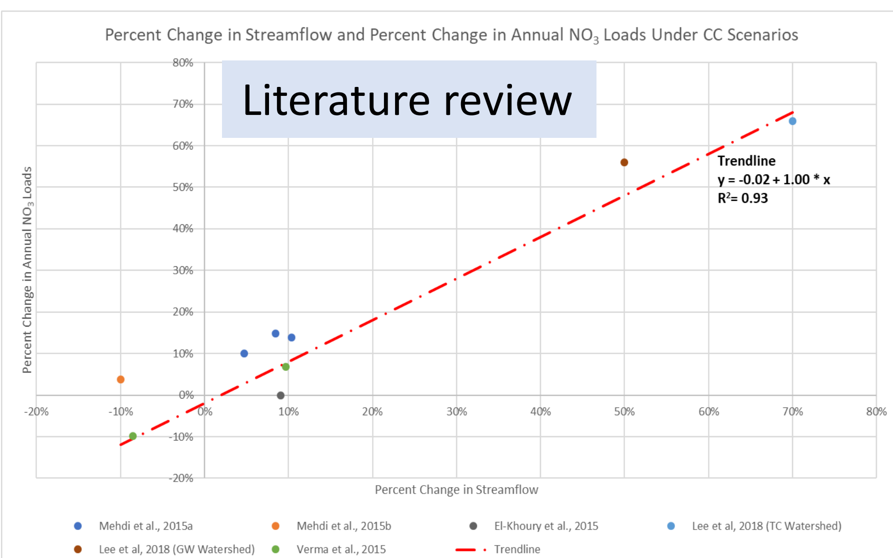
Section **4.4** - Nitrogen Loss Sensitivity to Climate Change

Estimated Changes in N Export Under Future Climate Hydrology

Analyses Used in 2017 Climate Assessment







Assumption:

X% change in flow

=

X% change in TN load

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2018 STAC CC Workshop Recommendation:

Spatially vary the relationship between nitrogen and flow

"The assumed proportional relationship between change in flow and change in nitrogen output from a land use is supported at the large scale, but ***there may be significant differences between land use types and between geographic settings****. It is suggested that the CBP undertake additional literature review to investigate these different responses. Published small-scale modeling efforts may be particularly useful. The CBP should also investigate using the existing P6WM responsiveness to groundwater recharge and available water capacity."*

Estimated Changes in N Export Under Future Climate Hydrology

1. Literature review

2. Analysis of WRTDS data from Chesapeake Bay Nontidal stations

Estimated Changes in N Export Under Future Climate Hydrology

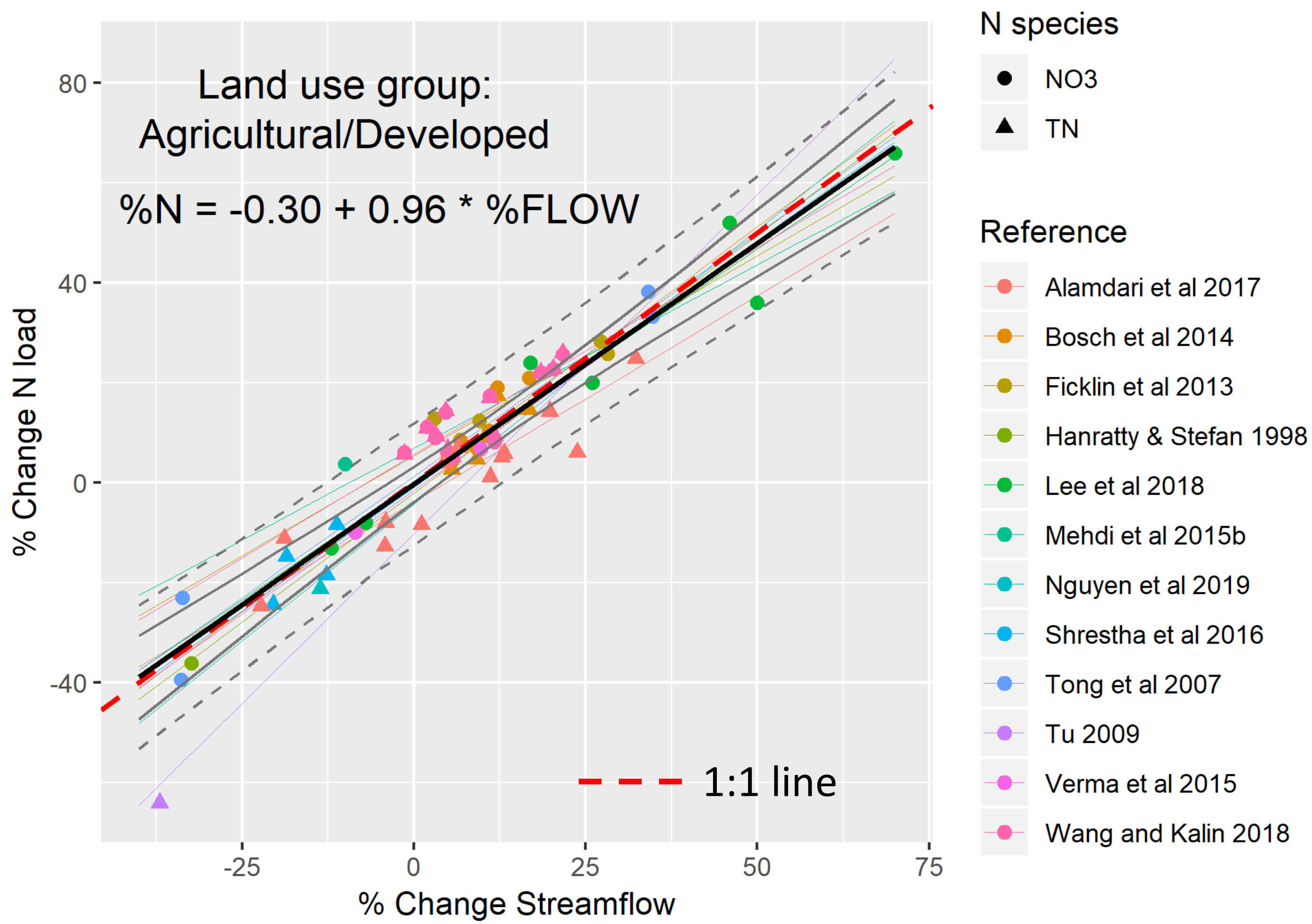
1. Literature review

Estimated Changes in N Export Under Future Climate Hydrology - Literature review

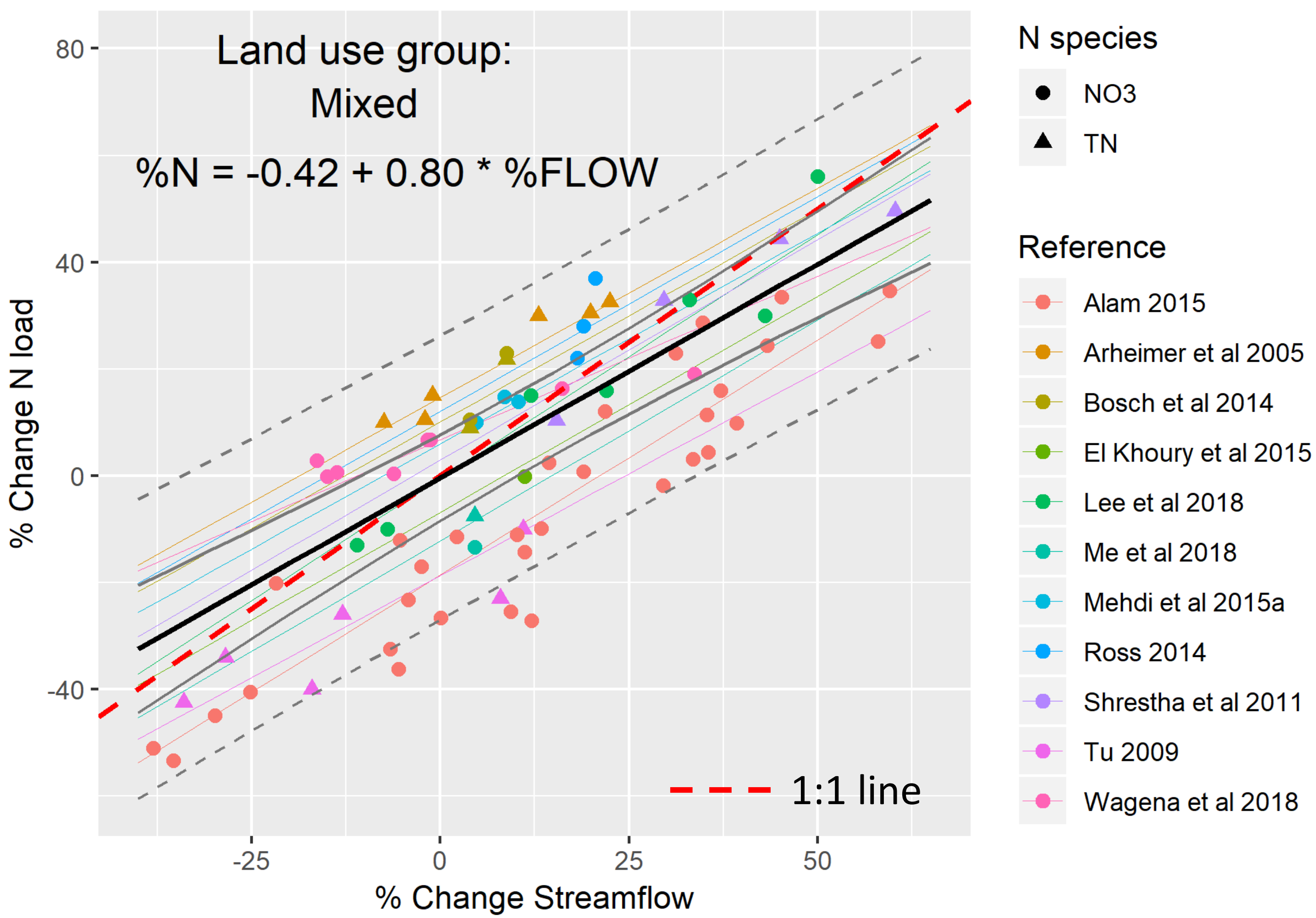
27 studies across 40 watersheds

Land use group	Land use description	Watershed area (km^2)	Model	N species	# studies
Predominantly agricultural or developed	>60% agricultural, pasture and/or developed	64.7 - 23300	AVGWLF; SWAT; SWMM	TN, NO_3	12
Predominantly forested	>60% forested	0.4 - 78500	SWAT; AVGWLF; LSPC; Regression	TN, NO_3	7
Mixed	Neither agricultural/developed nor forested land uses > 60%	7.3 - 13500	SWAT; AVGWLF; SOILNDB + HBV-N	TN, NO_3	11

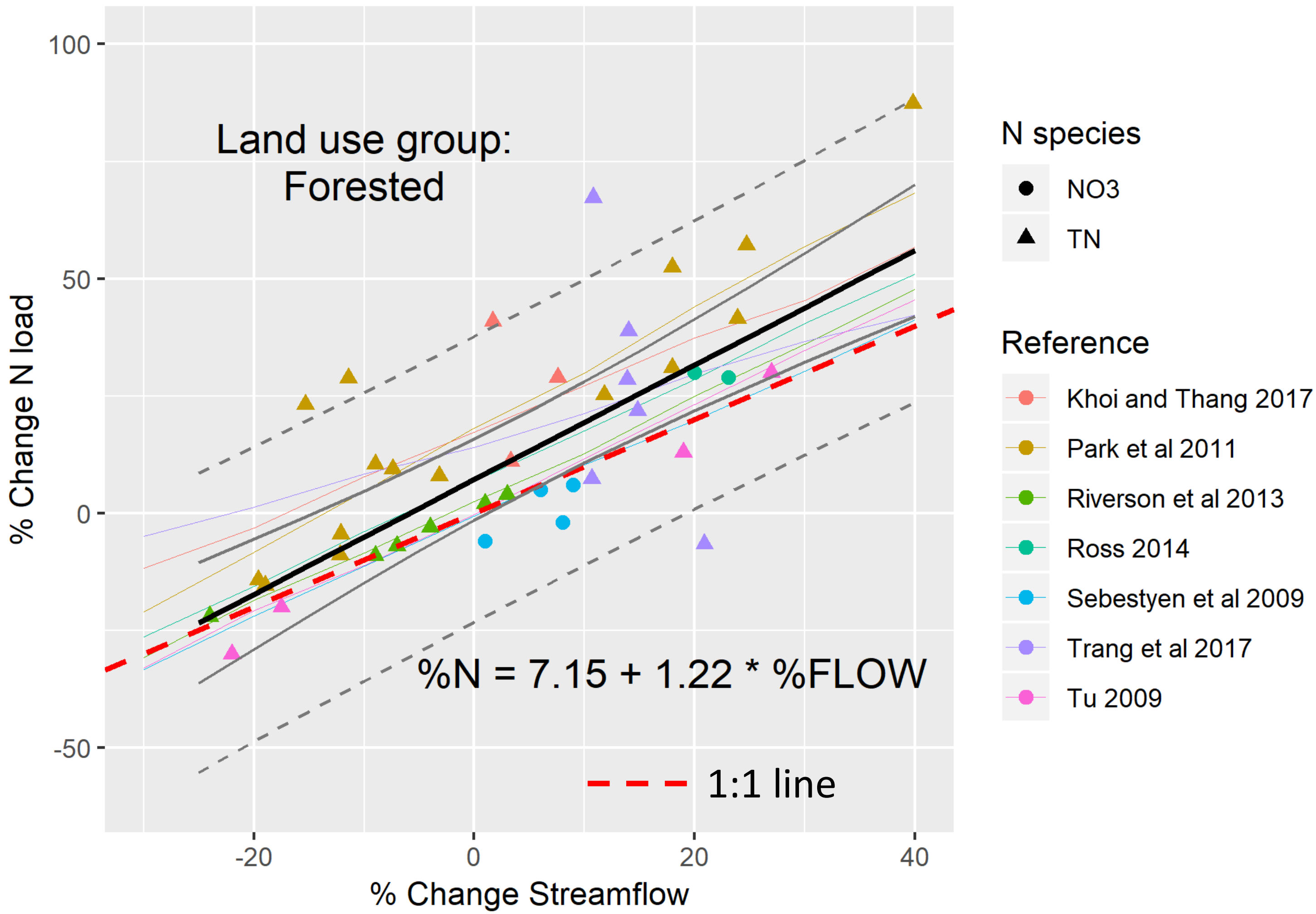
Estimated Changes in N Export Under Future Climate Hydrology - Literature review



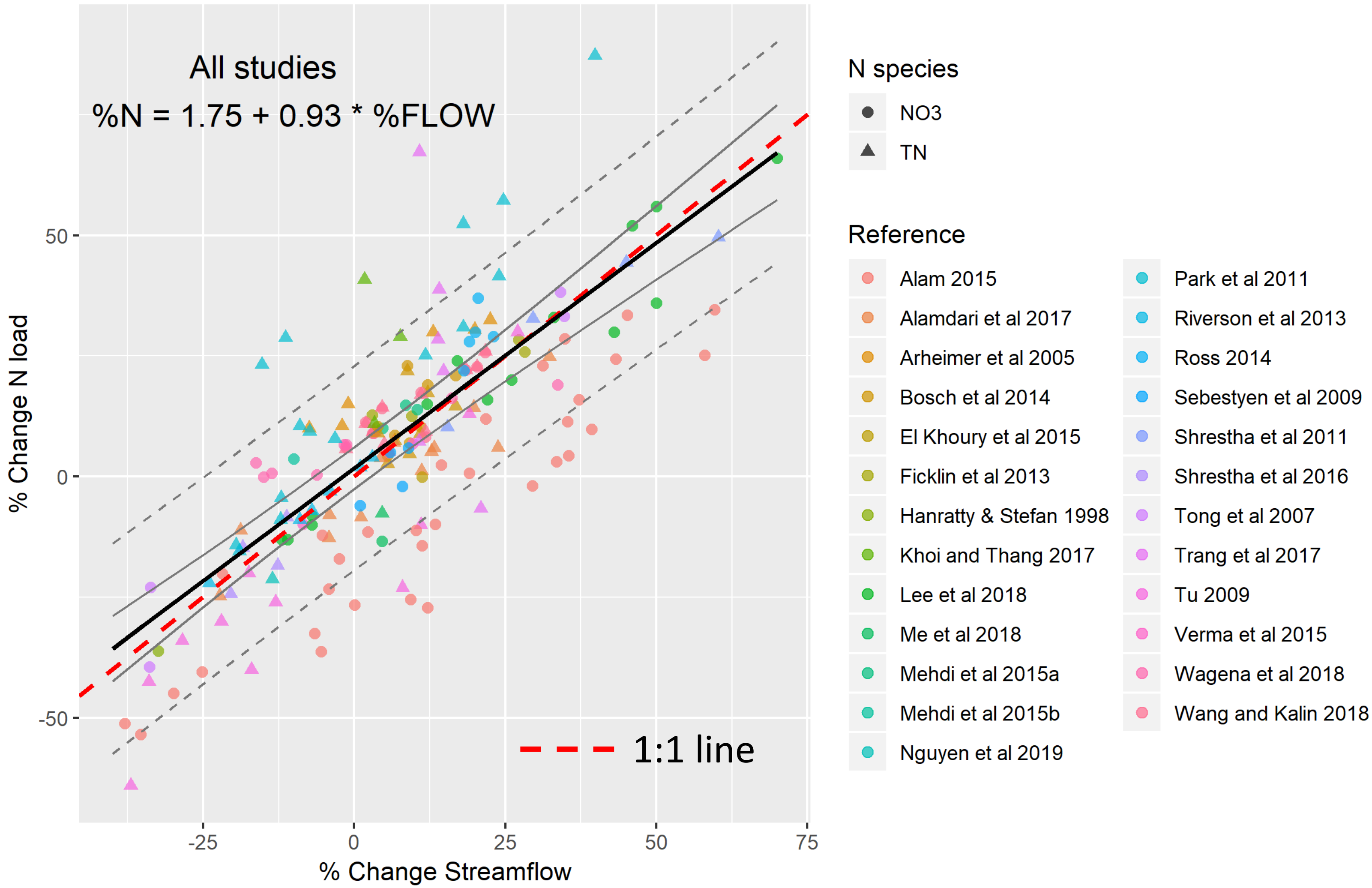
Estimated Changes in N Export Under Future Climate Hydrology - Literature review



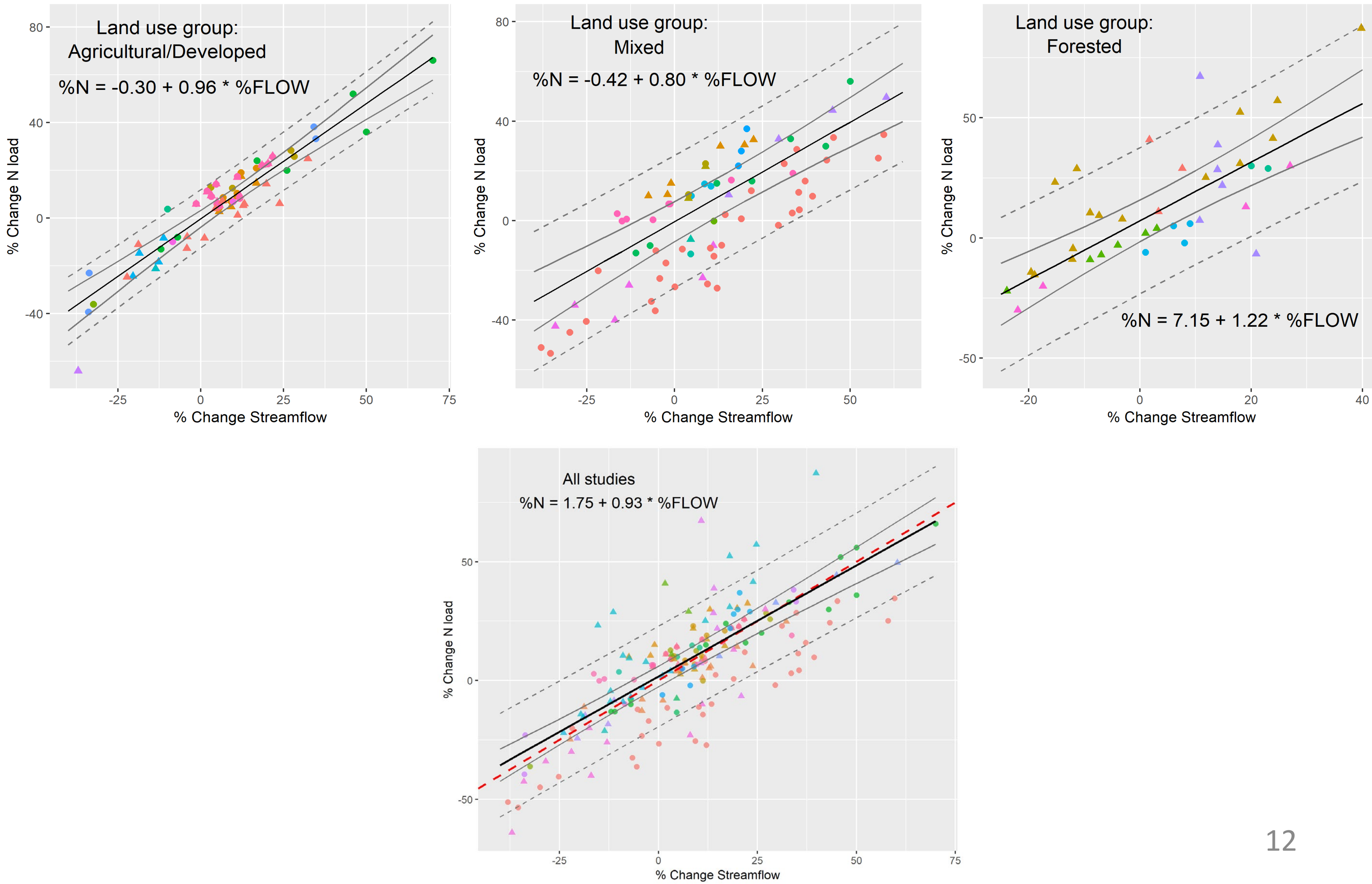
Estimated Changes in N Export Under Future Climate Hydrology - Literature review



Estimated Changes in N Export Under Future Climate Hydrology - Literature review



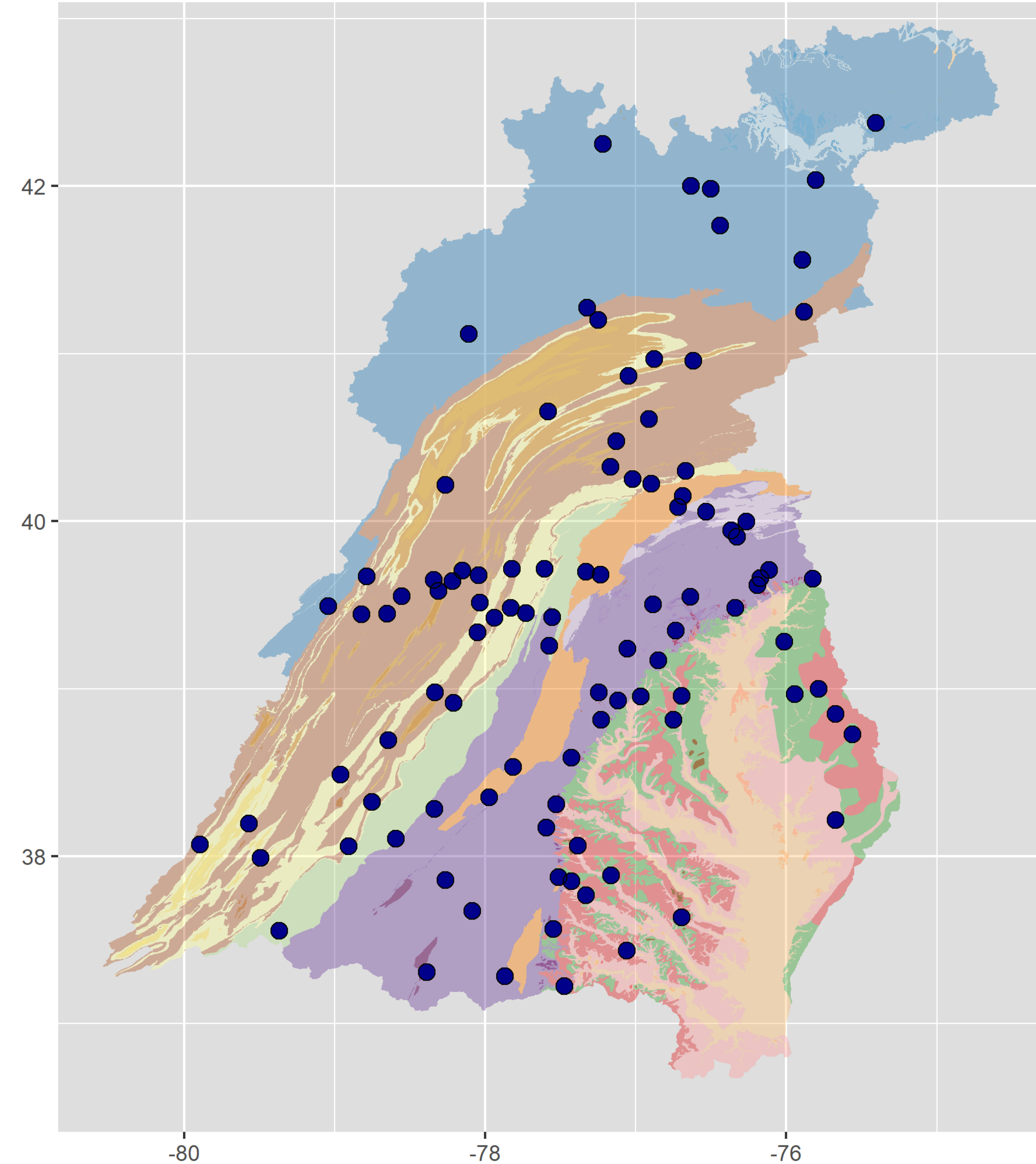
Estimated Changes in N Export Under Future Climate Hydrology - Literature review



Estimated Changes in N Export Under Future Climate Hydrology

2. Analysis of WRTDS data from Chesapeake Bay Nontidal stations

Chesapeake Bay Nontidal Network



Annual flow and WRTDS-estimated **TN loads** from 101 Chesapeake Bay Nontidal Network stations over 1985-2017

(https://doi.org/10.5066/F7RR1X68)

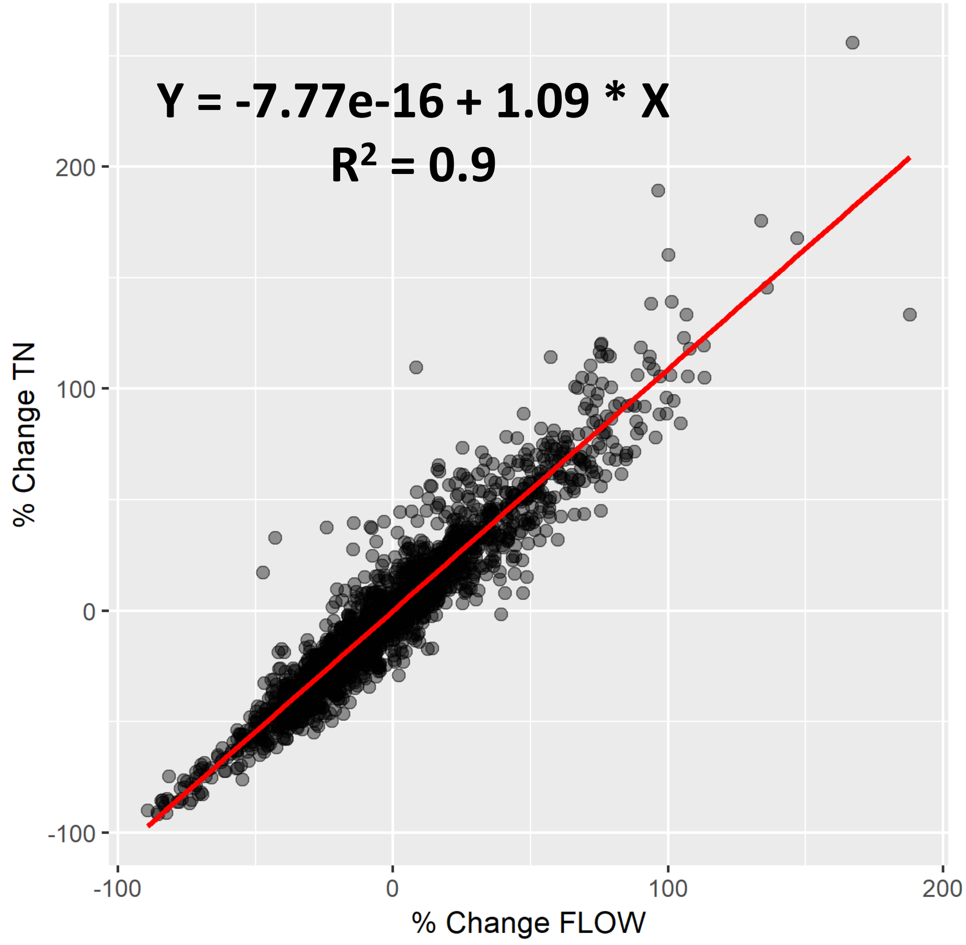
Annual WRTDS data

$$\% \, \boldsymbol{Change\ TNi} = \frac{TN_i - \overline{TN}}{\overline{TN}} * 100$$

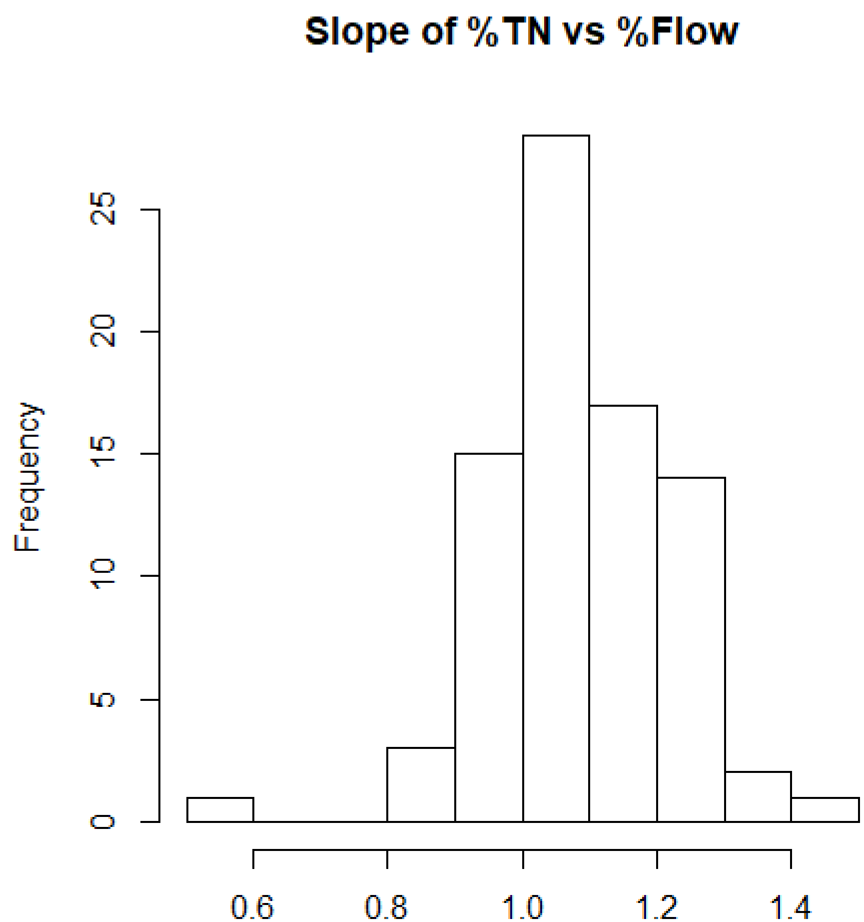
$$\% \, \boldsymbol{Change\ FLOWi} = \frac{FLOW_i - \overline{FLOW}}{\overline{FLOW}} * 100$$

i = Year

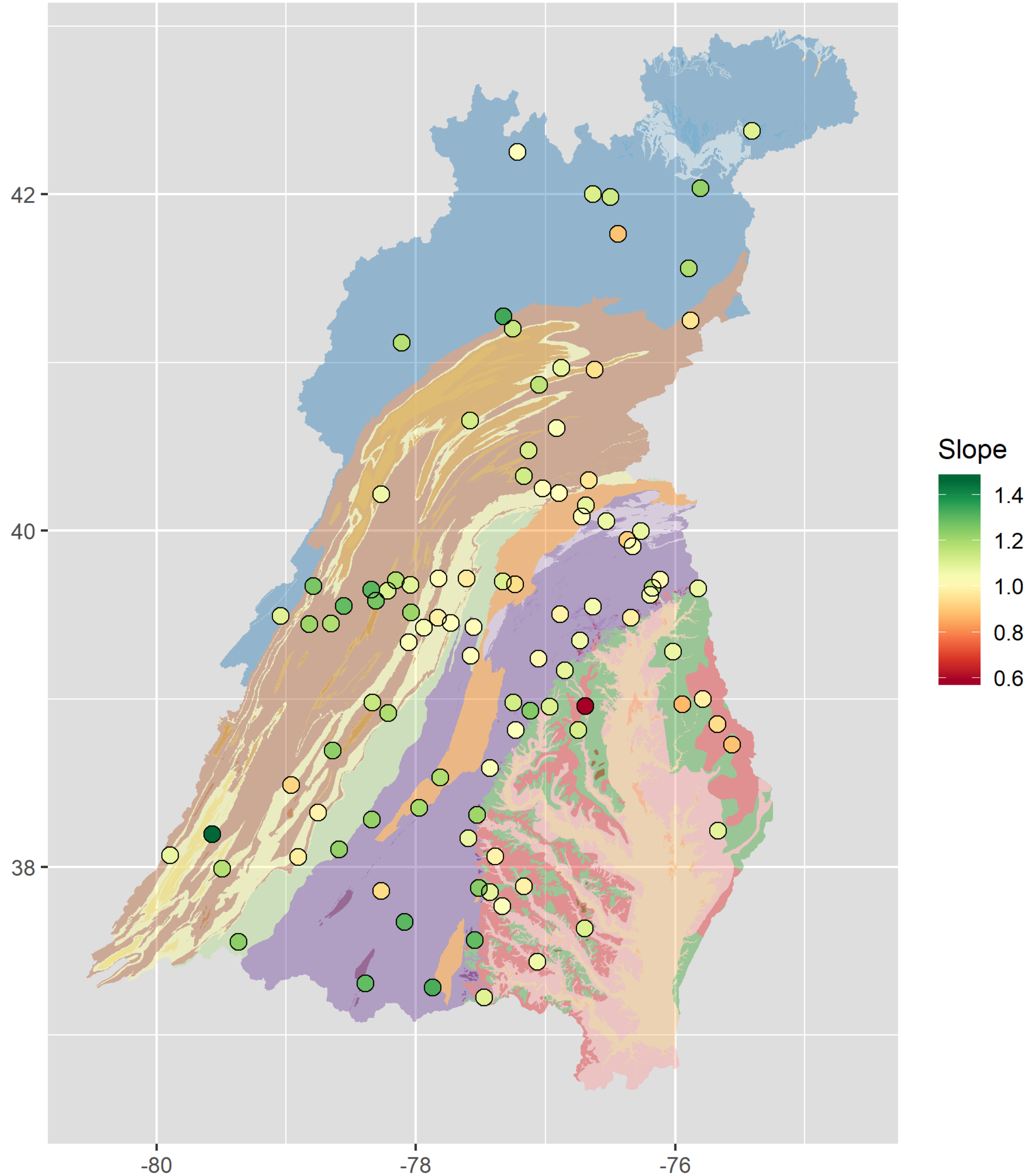
$\overline{TN}, \overline{FLOW}$ = long-term averages at each station



Annual WRTDS data



Annual WRTDS data



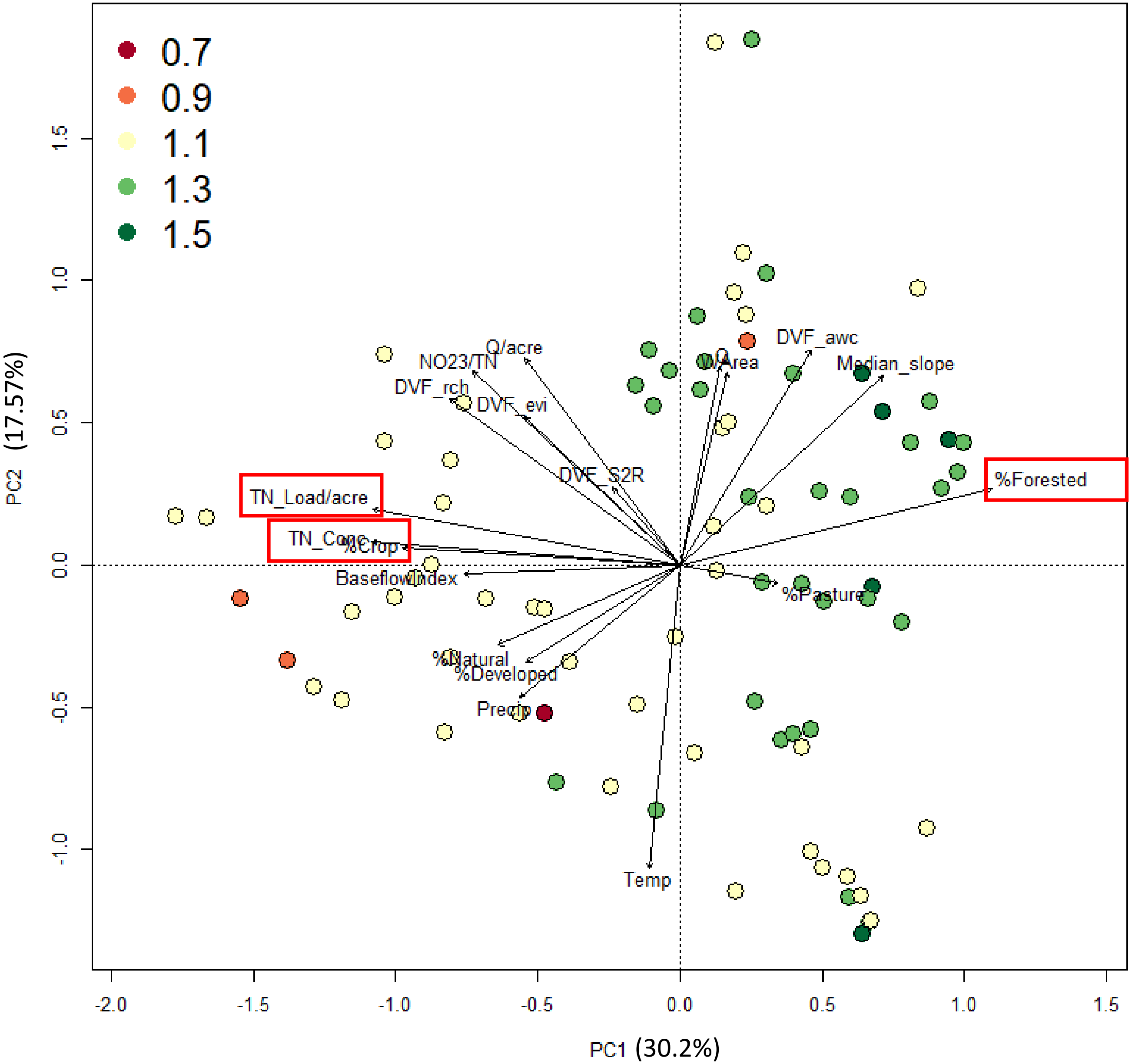
Can we explain spatial variability in slope of %TN vs %FLOW across stations?

Annual WRTDS data

Candidate covariates of %TN vs %FLOW slope

Variable	Description
[TN]	Long-term average annual TN concentration
TN_load/ac	Long-term average annual TN load
%C	Fraction of drainage area occupied by agricultural land uses
DVF_rch	SPARROW Delivery Variance Factor related to groundwater recharge
BI	Long-term average baseflow index
NOx/TN	Long-term average annual NOx/TN ratio
%N	Fraction of drainage area occupied by non-forest natural land uses
DVF_pca	SPARROW Delivery Variance Factor related to Piedmont carbonate
Pcp	Long-term average annual rainfall across the drainage area
Q/ac	Long-term average annual flow normalized by drainage area
DVF_evi	SPARROW Delivery Variance Factor related to enhanced vegetation index
%D	Fraction of drainage area occupied by developed land uses
DVF_S2R	SPARROW average stream to river Delivery Variance Factor
T	Long-term average annual air temperature across the drainage area
Q	Long-term average annual flow
WA	Station total drainage area
%P	Fraction of drainage area occupied by pasture
DVF_awc	SPARROW Delivery Variance Factor related to soil available water capacity
Med_slo	Median slope across the drainage area
%F	Fraction of drainage area occupied by forests

Principal Component Analysis

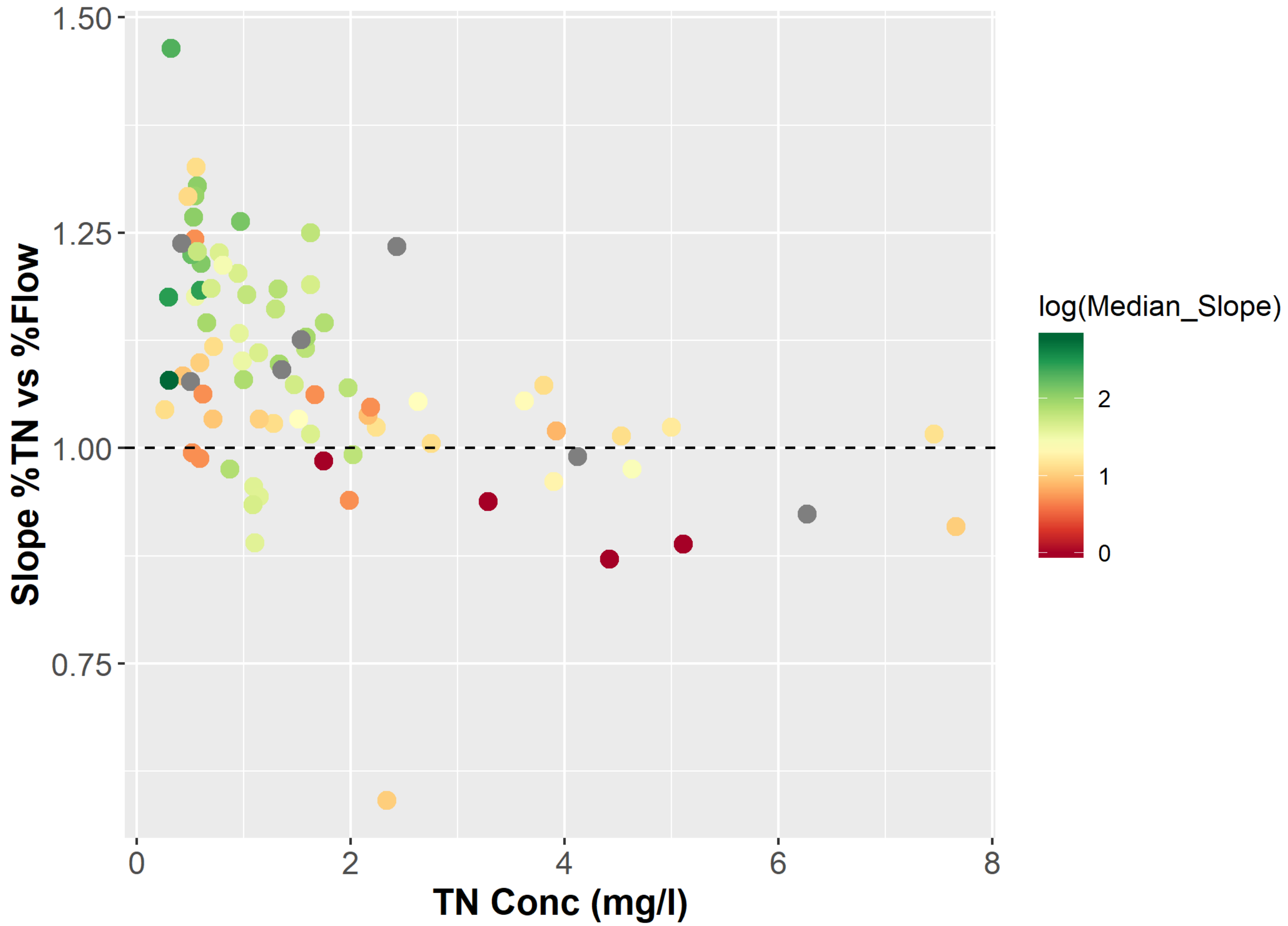


Variable	PC1	PC2
[TN]	-0.368	0.0341
TN_load/ac	-0.3677	0.0837
%F	0.3583	0.1192
%C	-0.3231	0.0231
DVF_rch	-0.2658	0.2501
BI	-0.2524	-0.0156
NOx/TN	-0.2425	0.2928
Med_slo	0.2311	0.2918
%N	-0.2002	-0.1273
DVF_pca	-0.1907	0.0231
Pcp	-0.1834	-0.2048
Q/ac	-0.1779	0.3121
DVF_evi	-0.1773	0.2237
%D	-0.1755	-0.151
%P	0.1061	-0.0245
DVF_awc	0.1509	0.3292
DVF_S2R	-0.076	0.116
T	-0.0348	-0.4632
Q	0.0461	0.3023
WA	0.0544	0.2934

Multiple linear regression

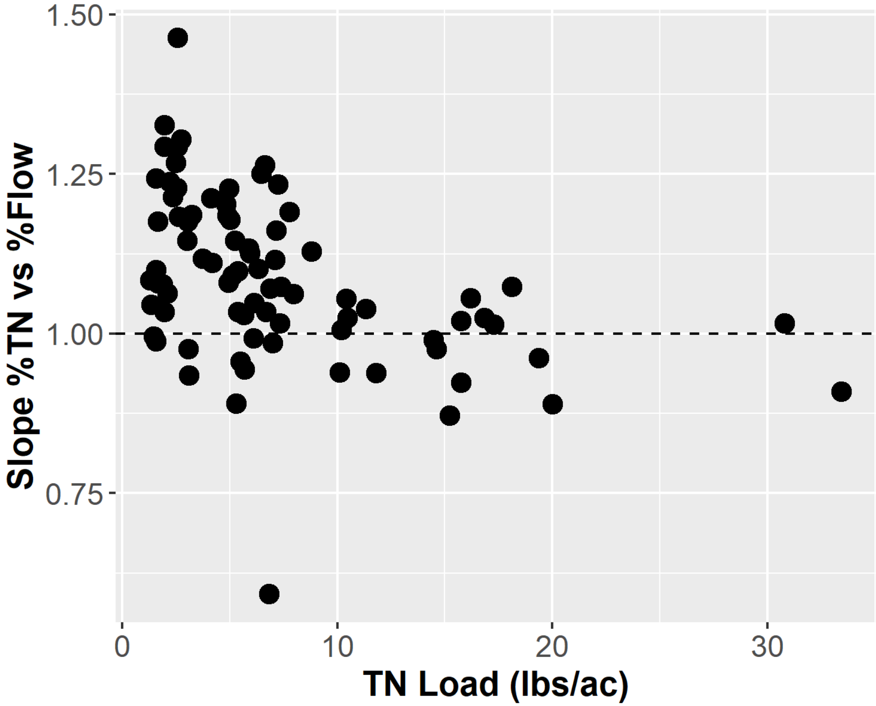
$$Y = 0.99 - 0.07 * \log([TN]) + 0.07 * \log(Median\_catchment\_slope)$$

$$R^2 = 0.40$$

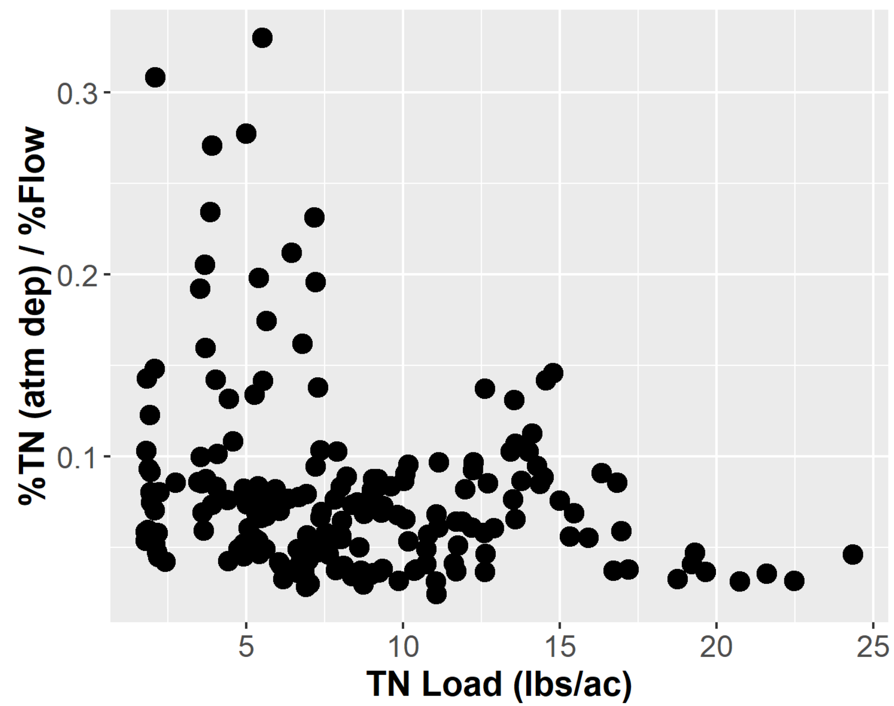


Potential explanation of observed variability in TN response: Relative contribution of atmospheric deposition

WRTDS data



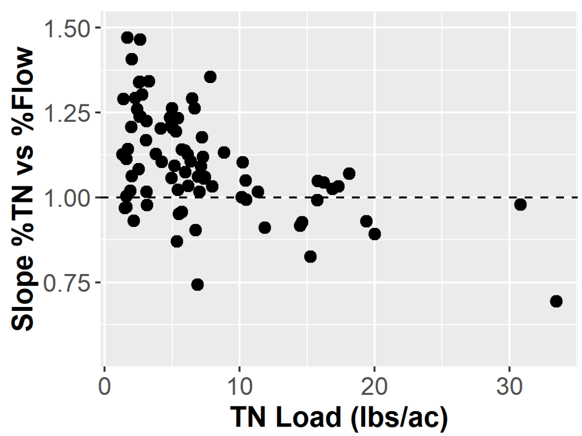
Contribution of atmospheric deposition to %TN (2025 vs 1995) at land segments



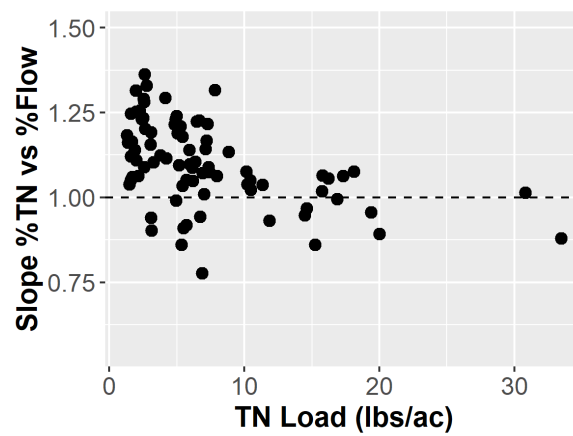
Note: Likely other factors involved , currently not accounted for – focus of future research

Exploring confounding effect of long-term changes in atmospheric deposition and/or other inputs (1/2)

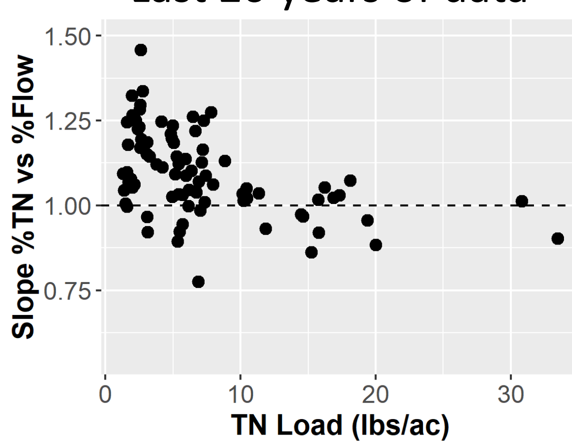
Last 10 years of data



Last 15 years of data

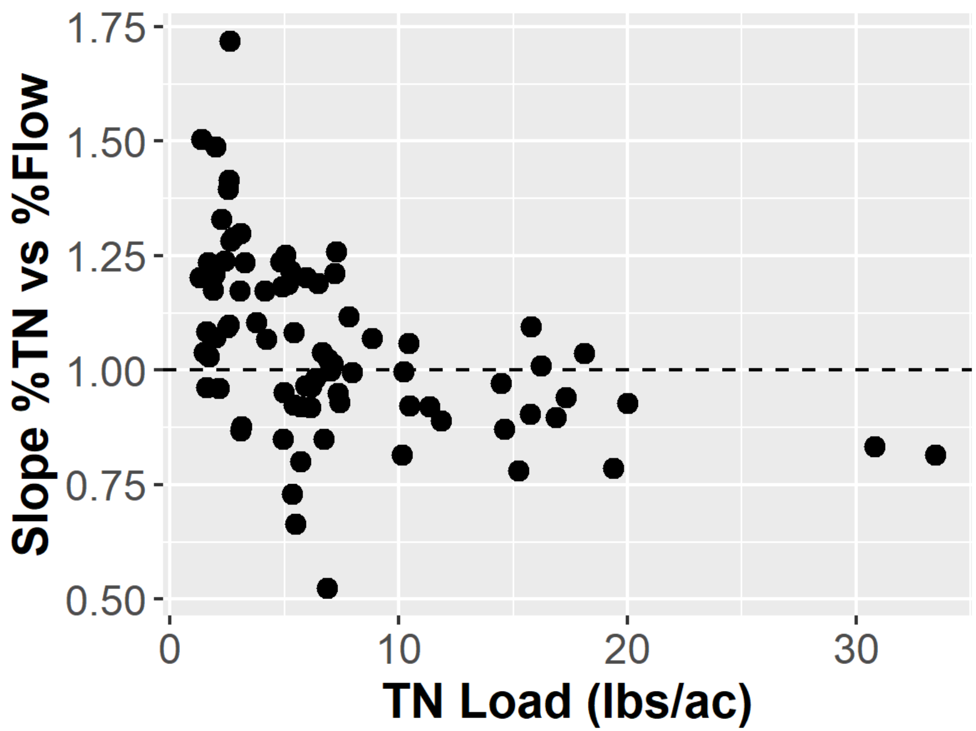


Last 20 years of data



Exploring confounding effect of long-term changes in atmospheric deposition and/or other inputs (2/2)

Time series of TN loads were de-trended based on estimated long-term trends in flow-normalized TN loads at each station



Conclusions

- Literature review and analysis of WRTDS data generally support ~1:1 relationship between % change in TN and % change in flow

- Higher sensitivity observed in forested watersheds likely a result of, among other factors, higher relative contribution of atmospheric deposition in less impacted watersheds (will be accounted for in the model – see Gopal`s presentation after lunch)

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Seeking approval of

Section 4.4 - Nitrogen Loss Sensitivity to Climate Change

of 2019 Climate Change Documentation

Main outcome: Maintain 1:1 relationship between % change in TN and % change in flow in P6 Watershed Model