Assessment of Stream Flow and Nutrient Load in a Highly Tiled Watershed using SWAT+: A Case Study of the Le Sueur Basin

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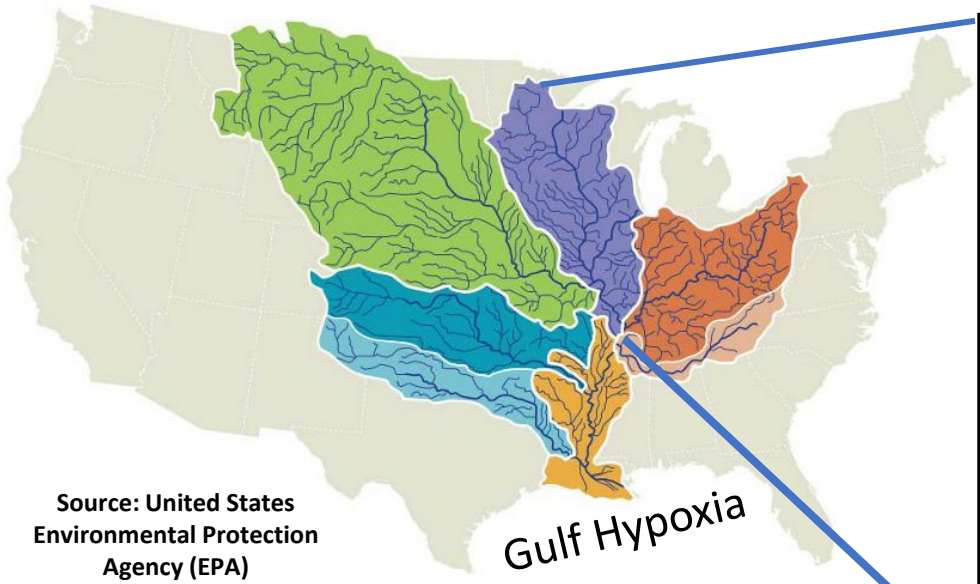
Introduction

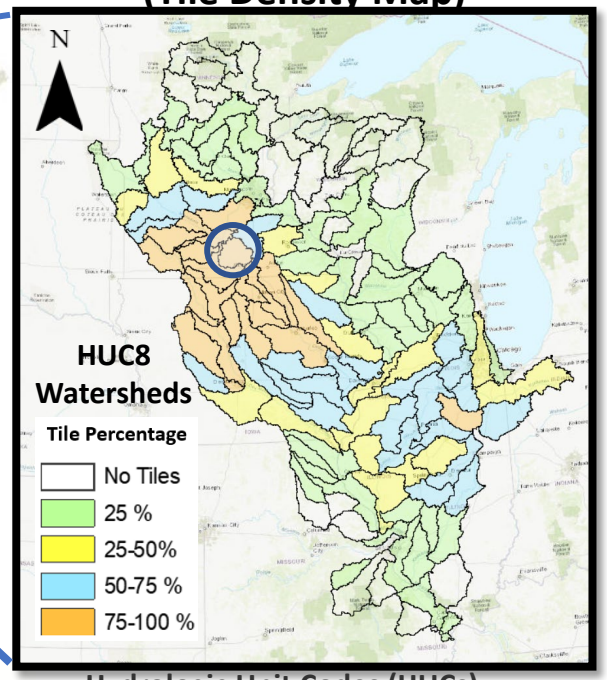
Mississippi River Basin

Drains 41% of Contiguous United States



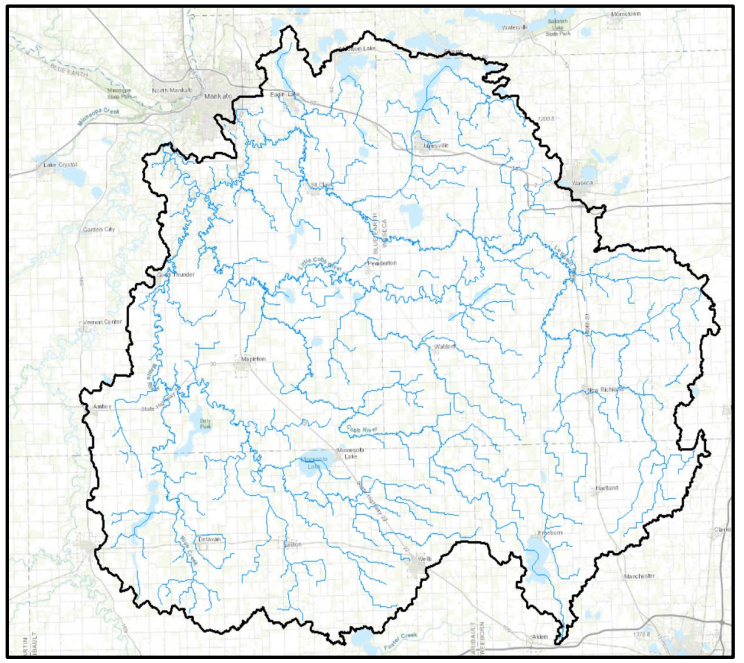
Source: United States Environmental Protection Agency (EPA)

Upper Mississippi River Basin (Tile Density Map)



Hydrologic Unit Codes (HUCs)
Source: USGS 2013; Federal Standards and Procedures for the National Watershed Boundary Dataset (WBD).
doi.org/10.3133/tm11a3

Le Sueur River Basin



Minnesota Pollution Control Agency

- Located in South-Central Minnesota
- Quantify the effect of conservation practices on reducing nitrate load by 20 %.

Objectives

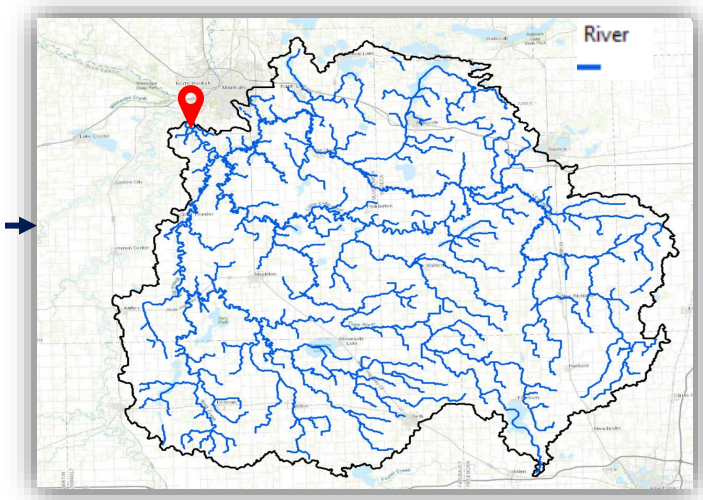
- Explore the interaction between surface and subsurface hydrologic processes accounting for the tile drainage.
- Analyze spatial and temporal dynamics of nutrient fate and transport processes.
- Assess various crop management strategies in reducing nutrient load to achieve conservation goal.

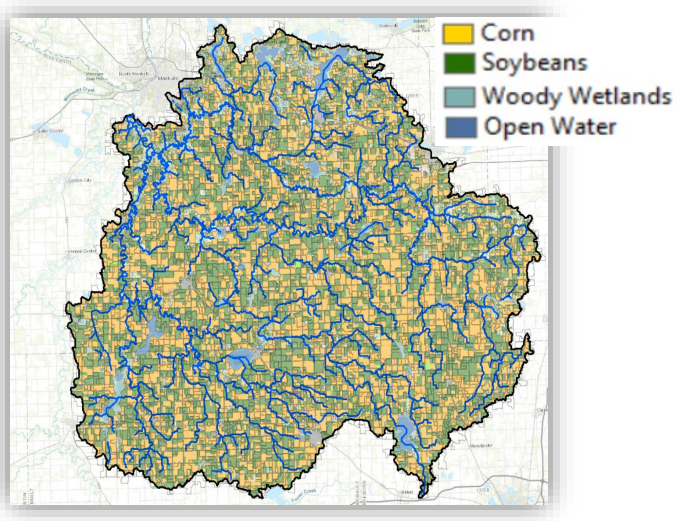
SWAT+ Model Setup

National Agroecosystems Model (NAM)

The NAM is a field-based, national scale hydrologic model to aid in conservation planning and policy.

Jeffery Arnold and Mike White (USDA-ARS)





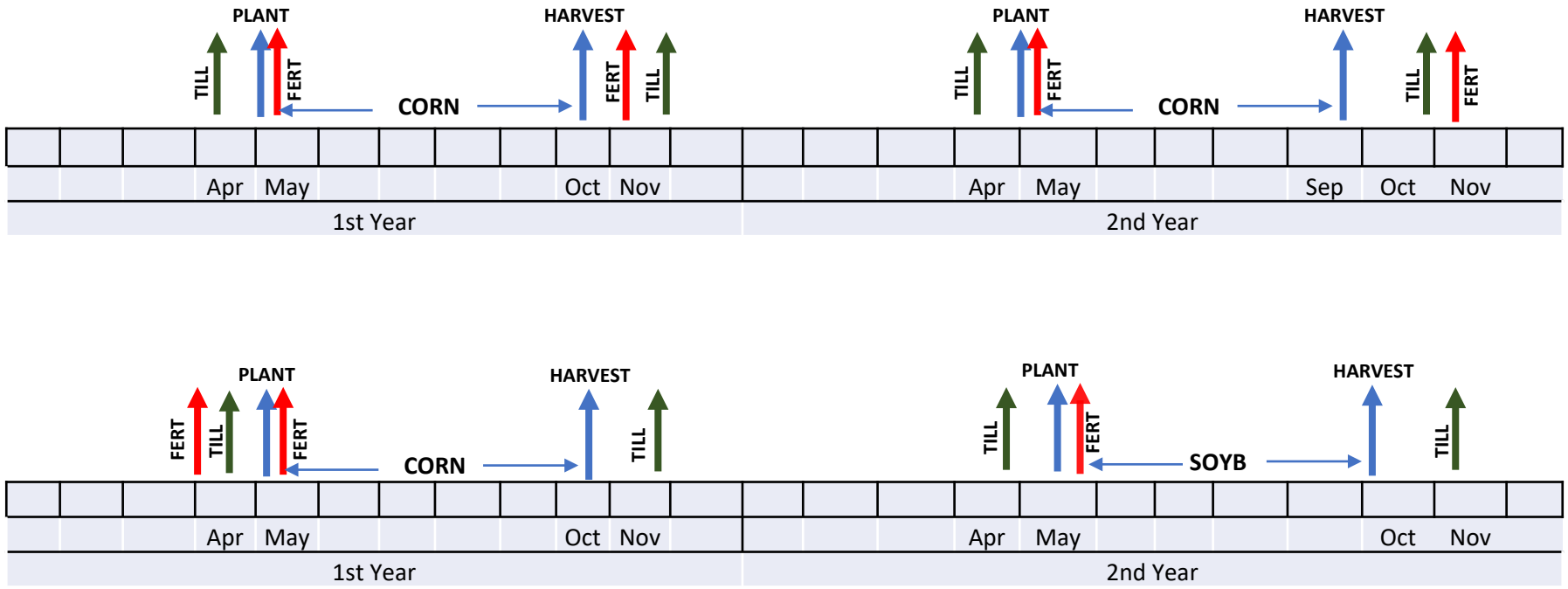
Gauges	Data	Duration
	Flow	2000-2018 daily
	Nitrate	2008-2018 Weekly

The management practices follow the NRCS crop management Template and US Agricultural Census data.

Arnold et al., 2021. Conceptual Framework of Connectivity for a National Agroecosystem Model Based on Transport Processes and Management Practices. Journal of the American Water Resources Association57 (1): 154–169. Doi.org/10.1111/1752-1688.12890.

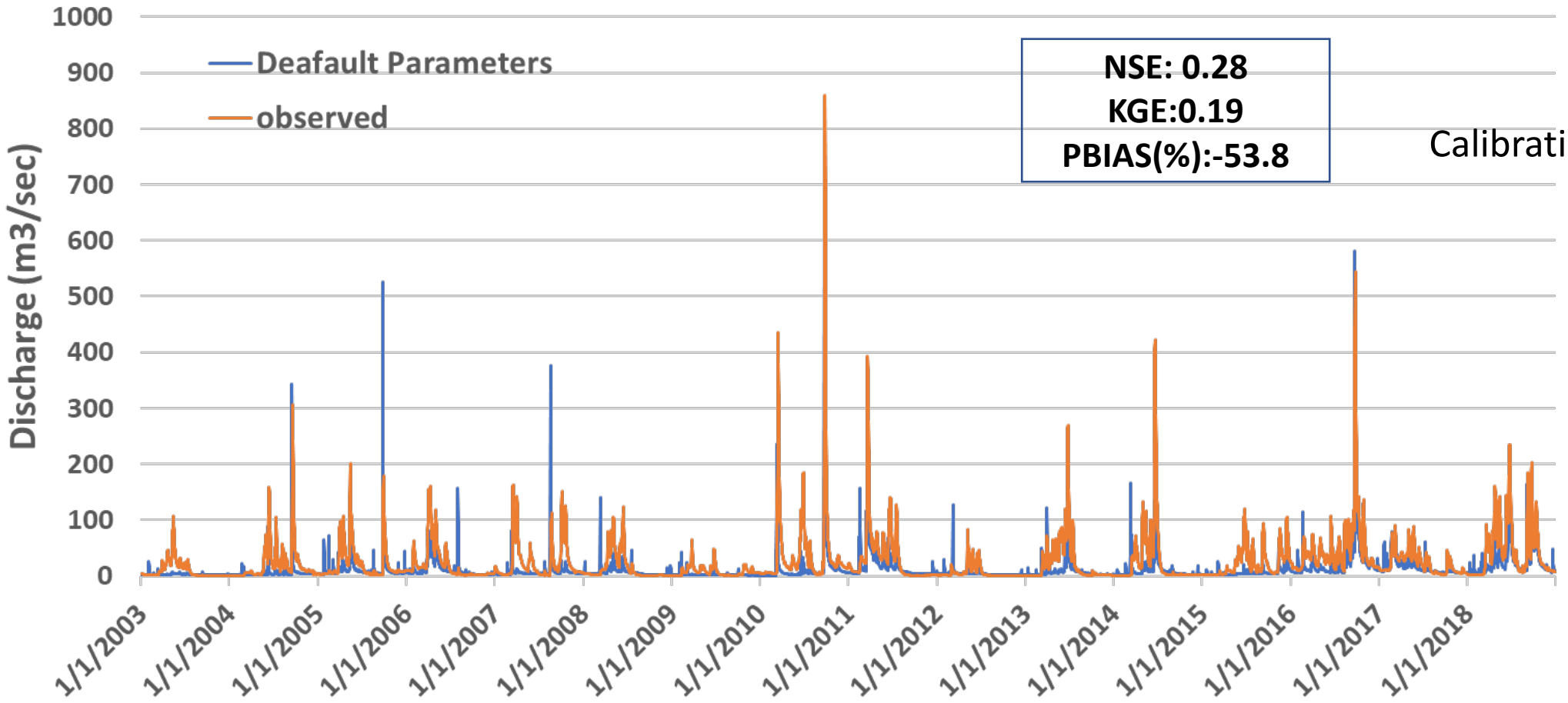
NRCS: Natural Resources Conservation Service

Management Practices



Model Evaluation

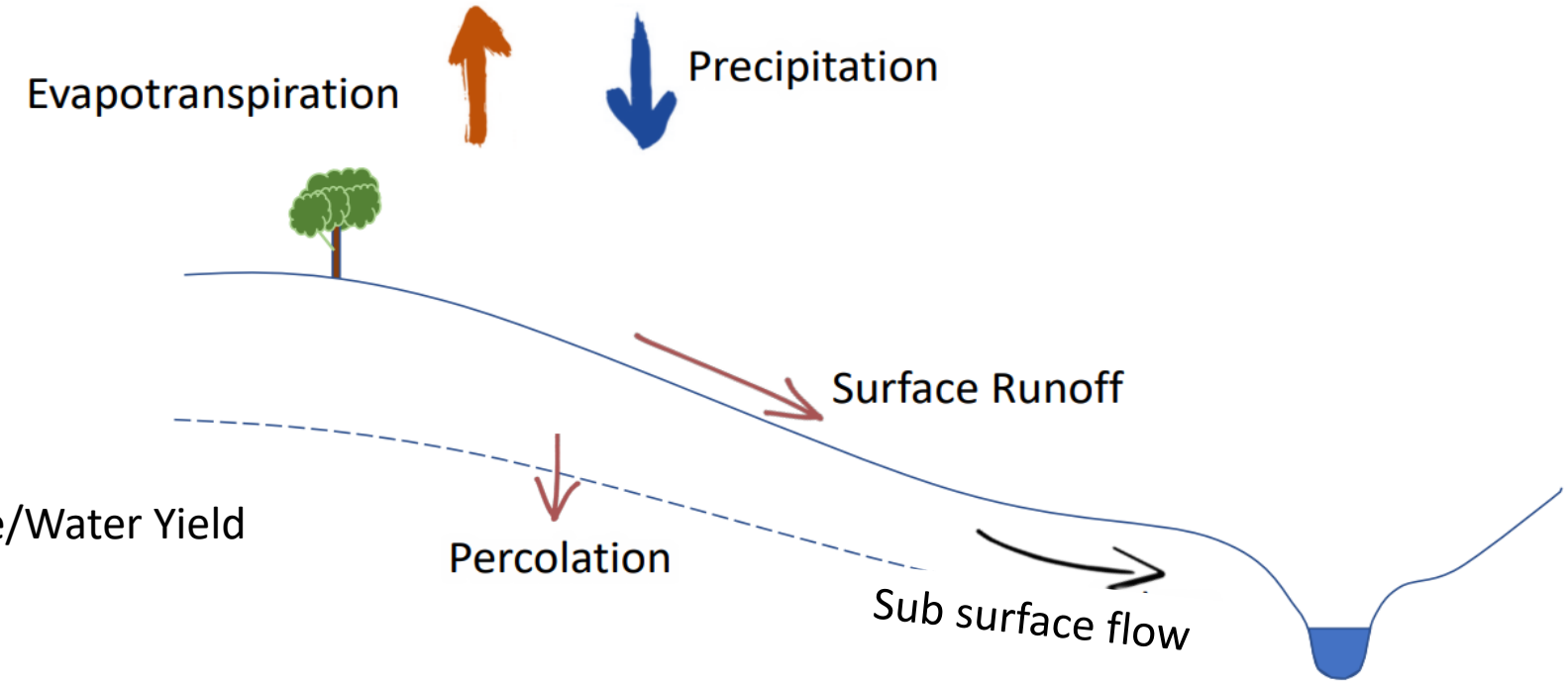
- Default hydrological parameters



Calibration is required

Calibration

Soft-Calibration:
Hydrologic Mass Balance Calibration

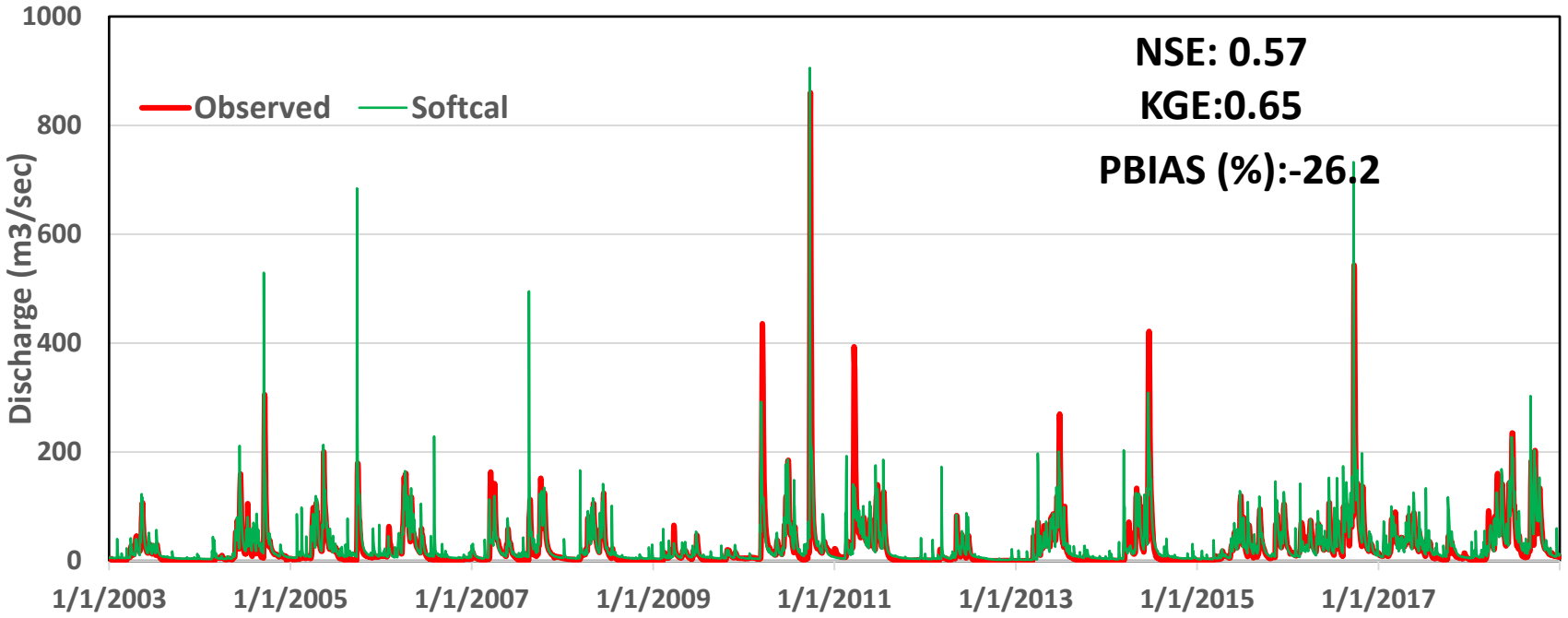


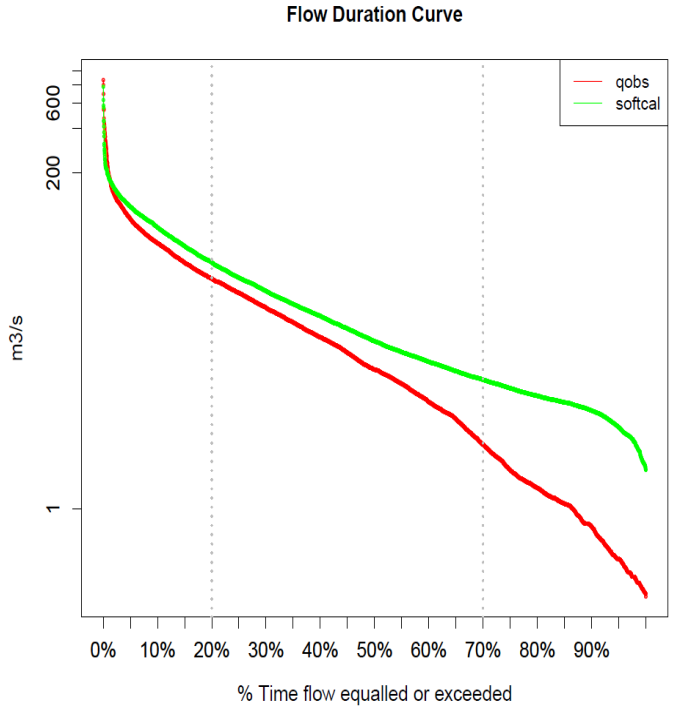
Water Yield/Precipitation	Sub surface/Water Yield
33%	56%

Source: Reitz et al., 2017. Annual Estimates of Recharge, Quick-Flow Runoff, and Evapotranspiration for the Contiguous U.S. Using.... Journal of the American Water Resources Association. 53(4): 961-983. https://doi.org/10.1111/1752-1688.12546.

Calibration

Soft-Calibration:



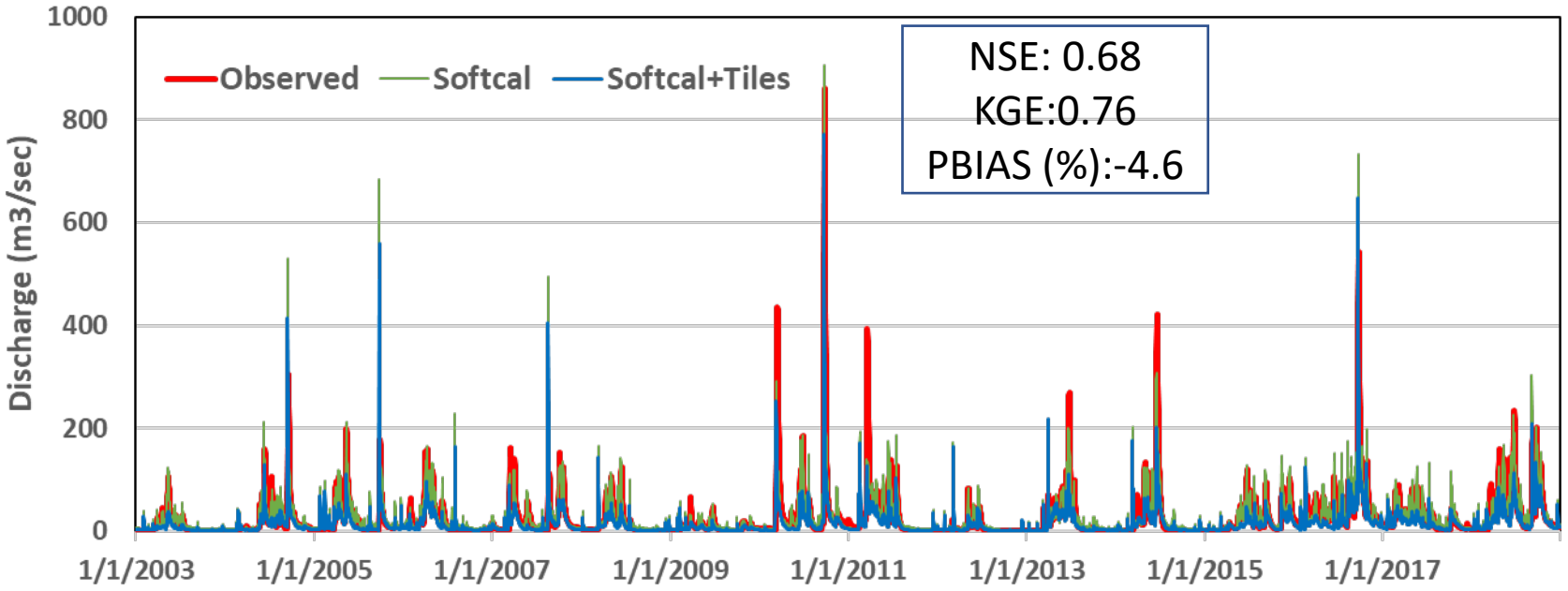


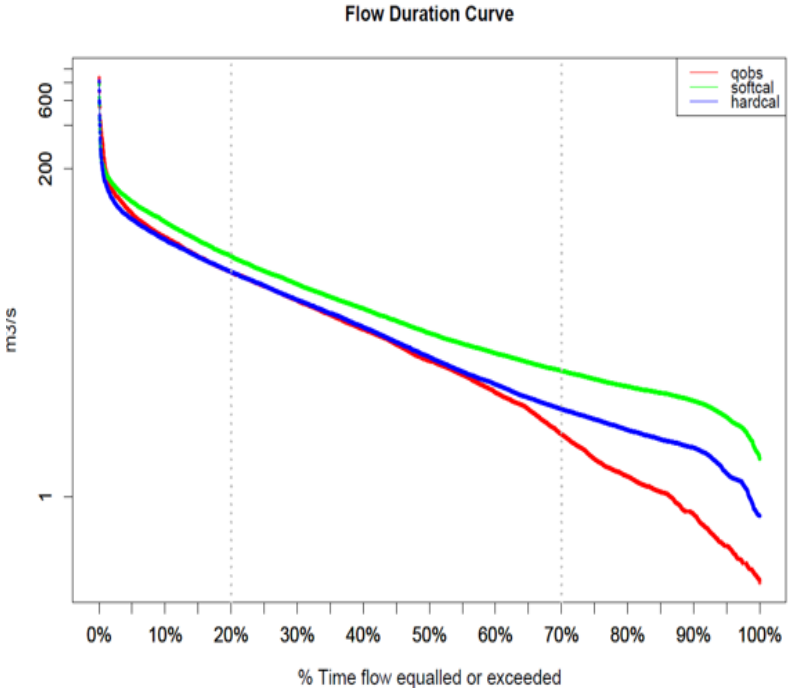
- Satisfactory prediction
- Over predicted flow → Overestimation of nutrient load

Calibration

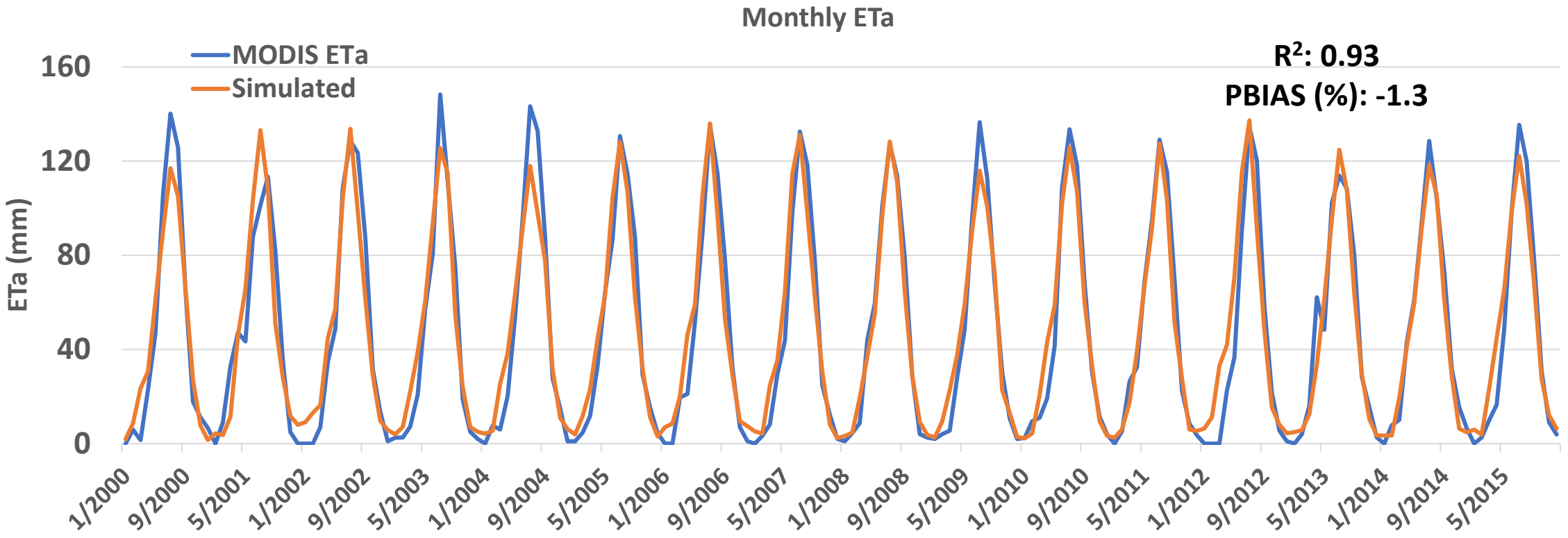
Soft Calibration + **Tile Parameters**

Tile depth
Tile drainage coefficient
Tile lag





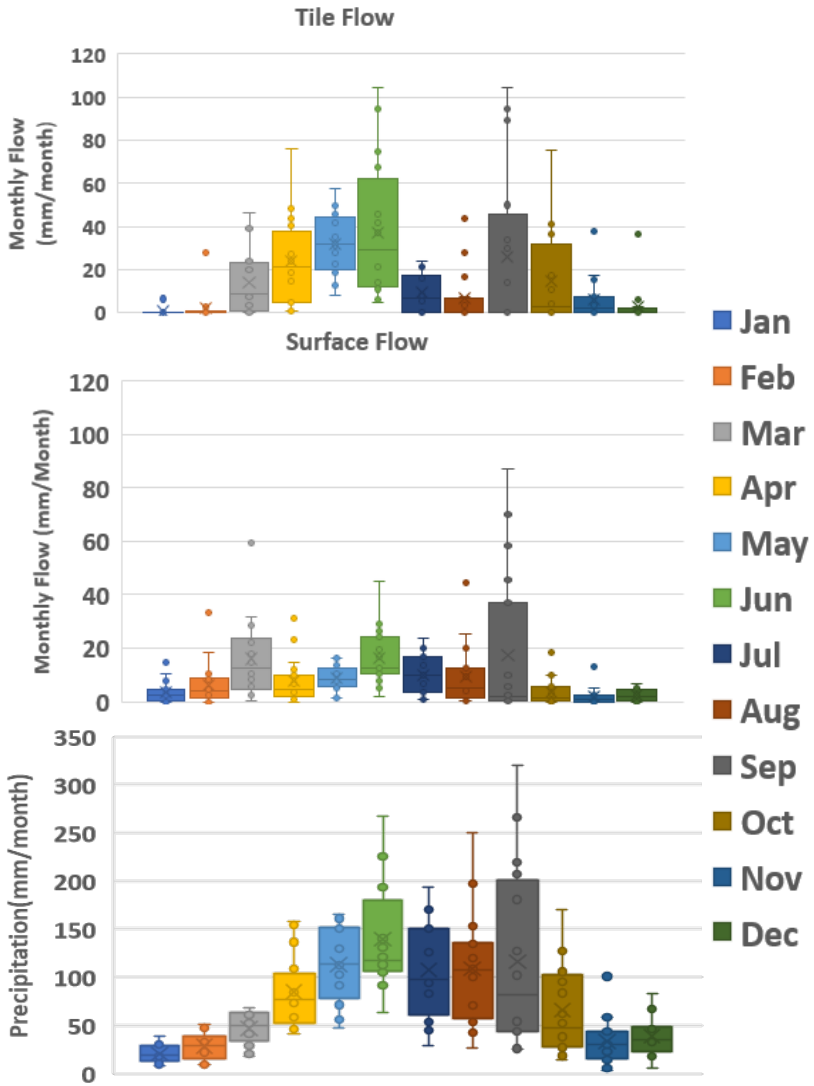
Water Balance

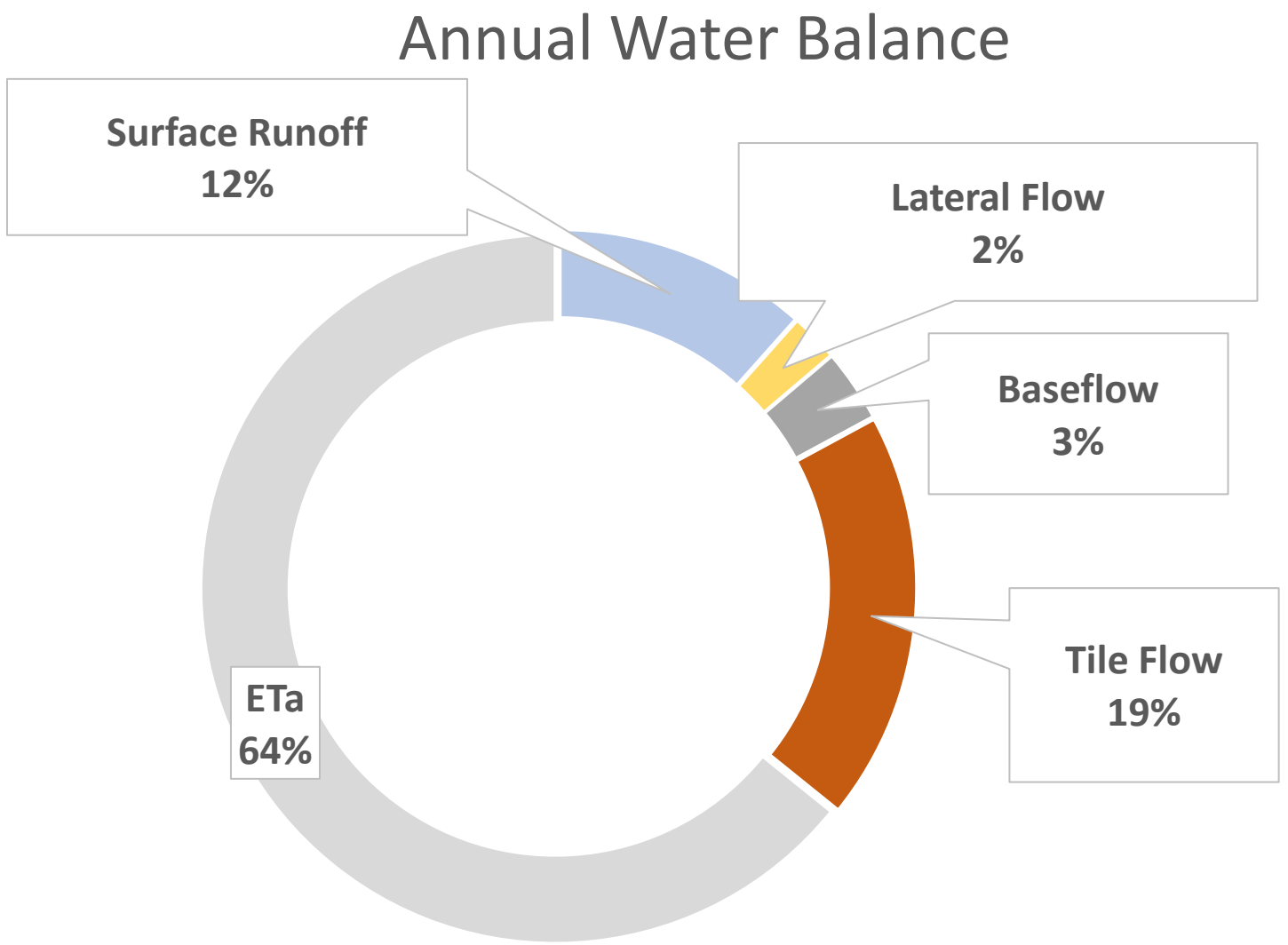


- Simulated monthly watershed scale ET closely follows the trend of MODIS (satellite product) ET.

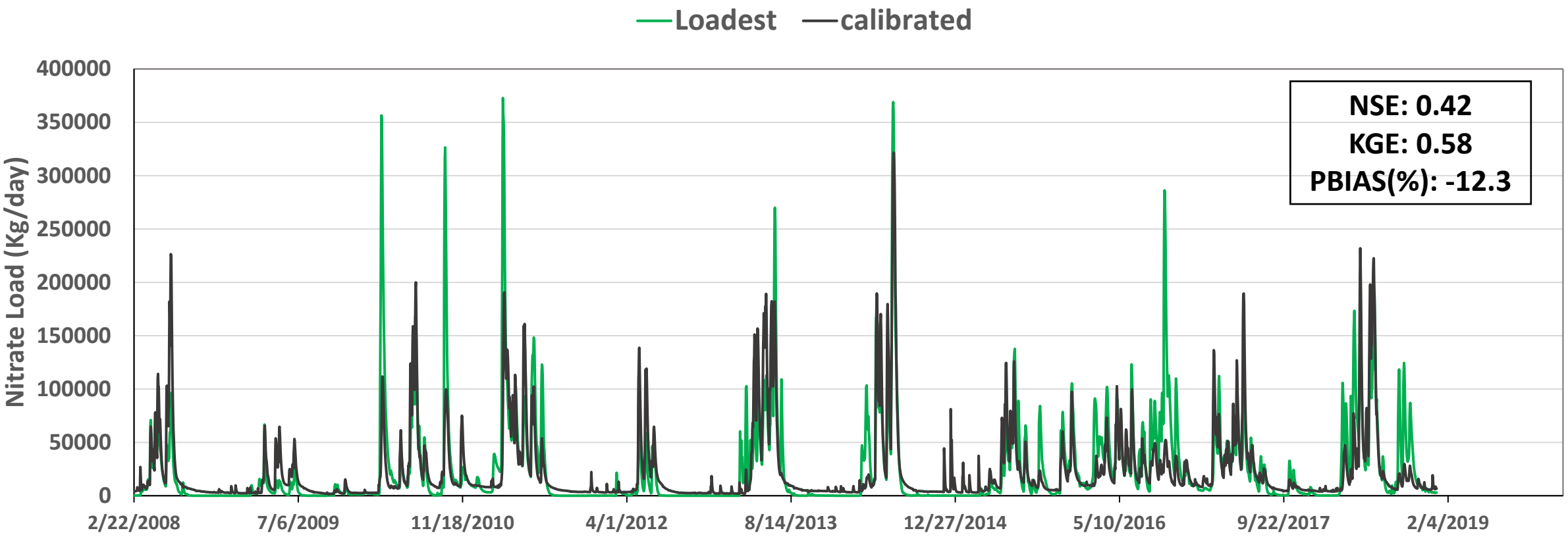
MODIS (Moderate Resolution Imaging Spectroradiometer)

Water Balance



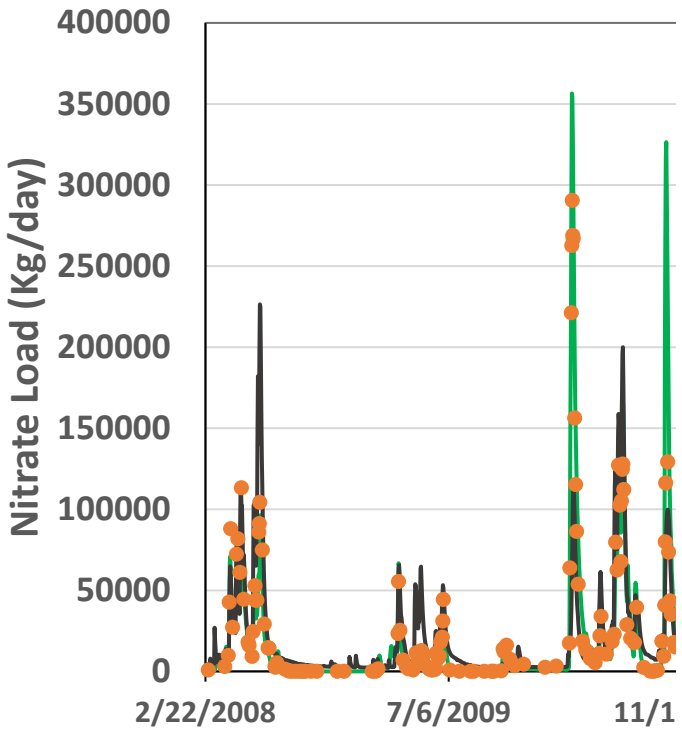


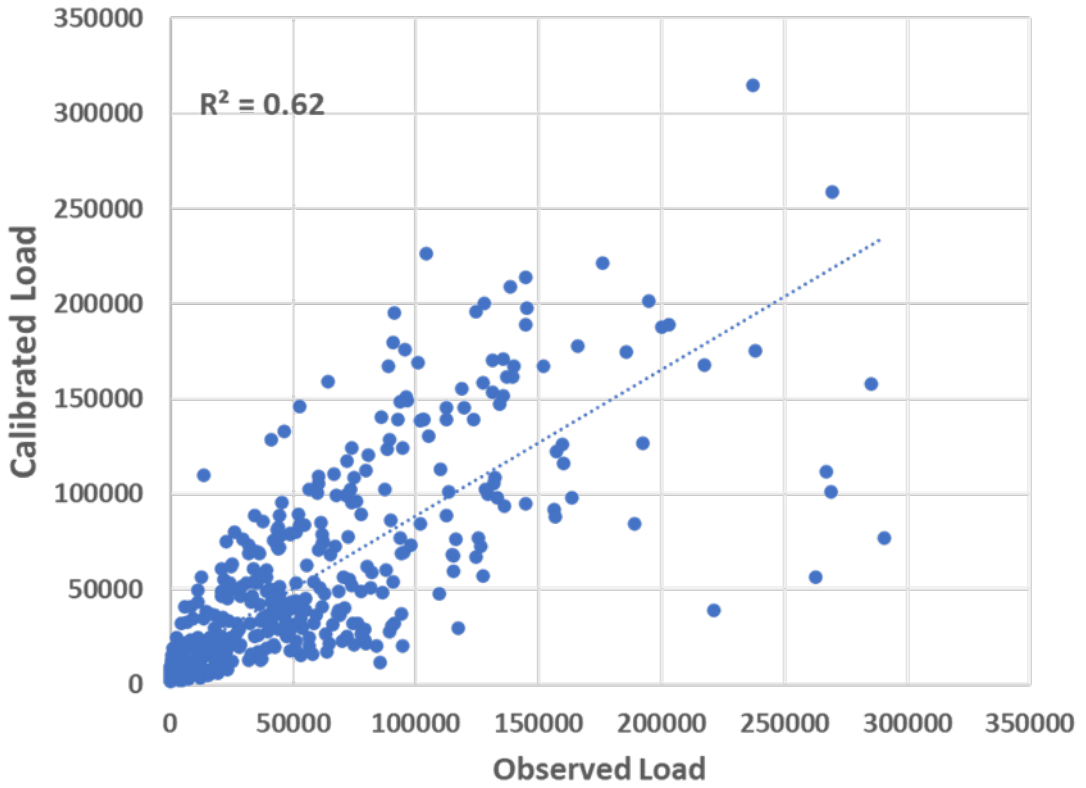
Nitrate Load Calibration

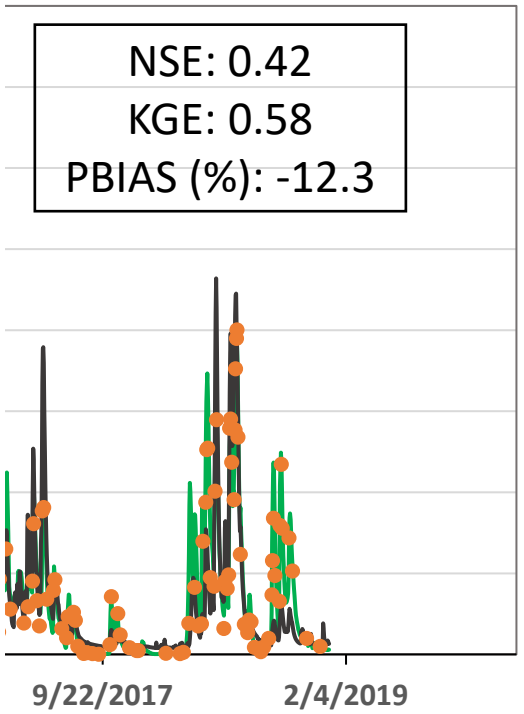


LOAD ESTimator (LOADEST) By USGS

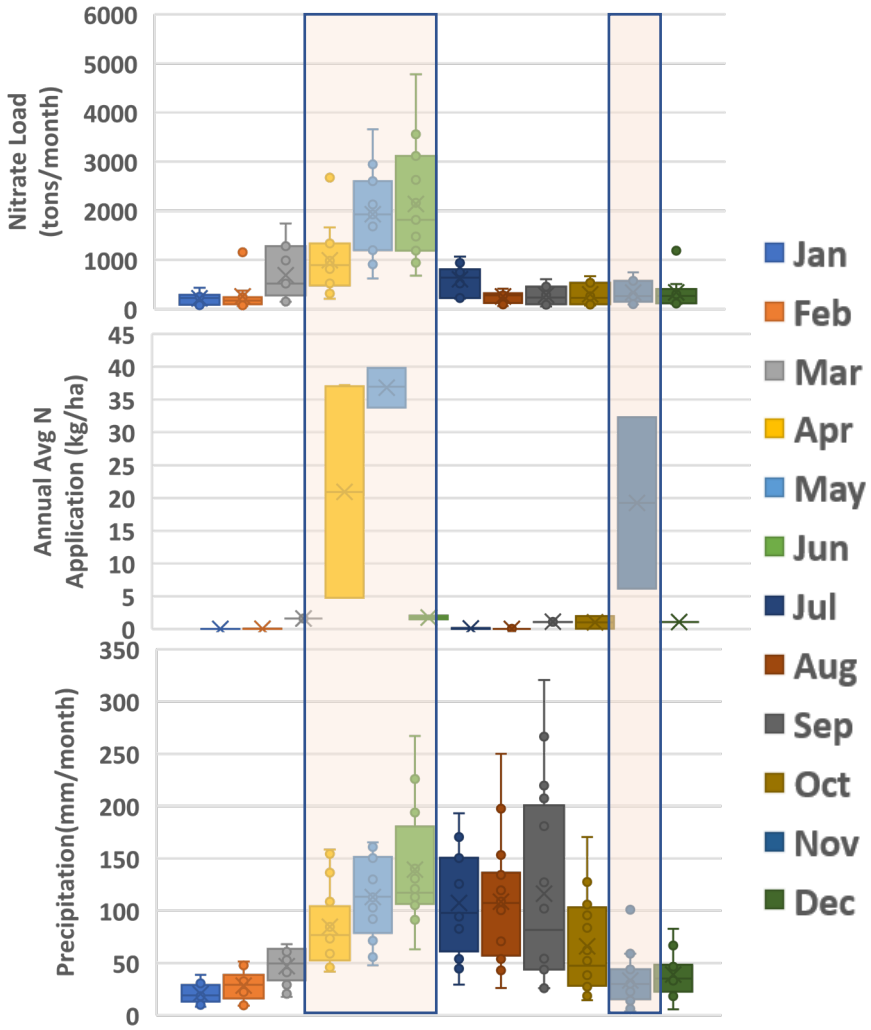
Nitrate Load Calibration







Monthly Load Variation

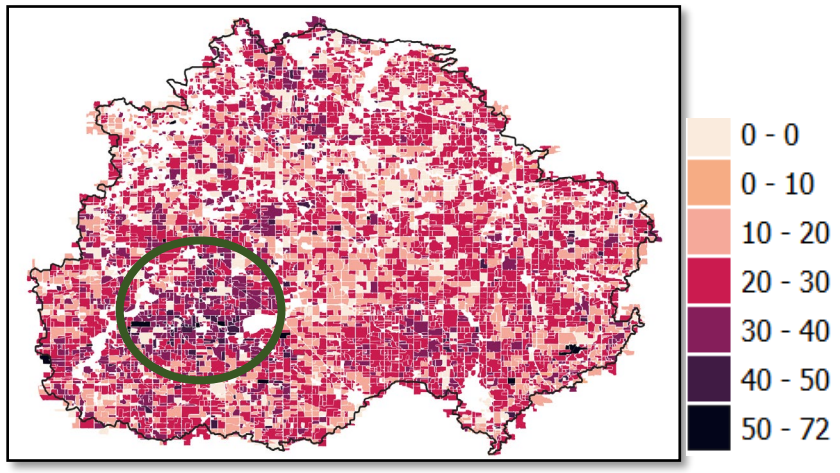


- The nitrate Load reflects the seasonality in precipitation that starts increasing from March and peaks during the month of June.
- Nitrate load also synchronize with the timing of fertilizer application during summer.
- Fall N fertilizer application slowly releases in subsequent months due to snow cover.

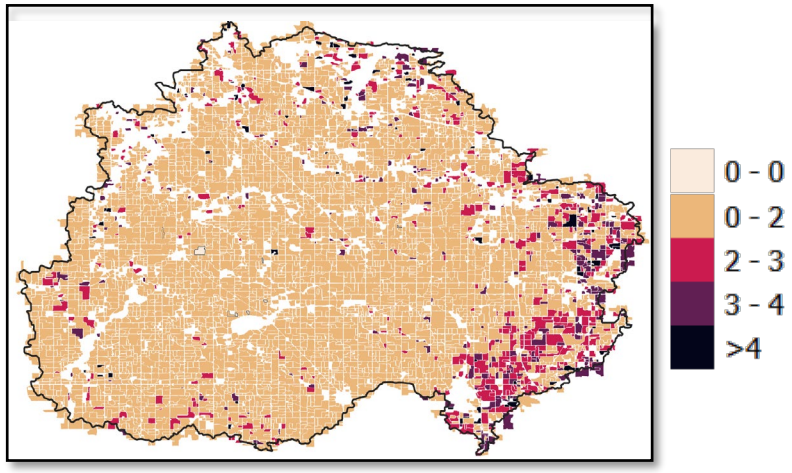
Spatial Variation NO_3-N Loss

Annual Average NO_3-N Loss (2003-2018) at Field scale

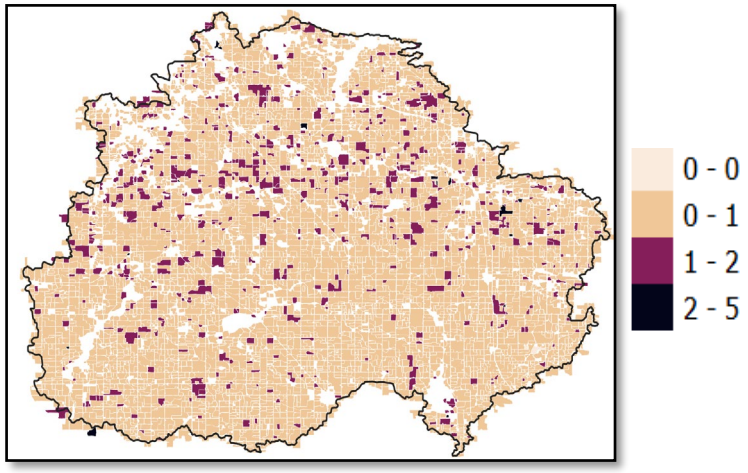
Tile NO_3-N (kg/ha)

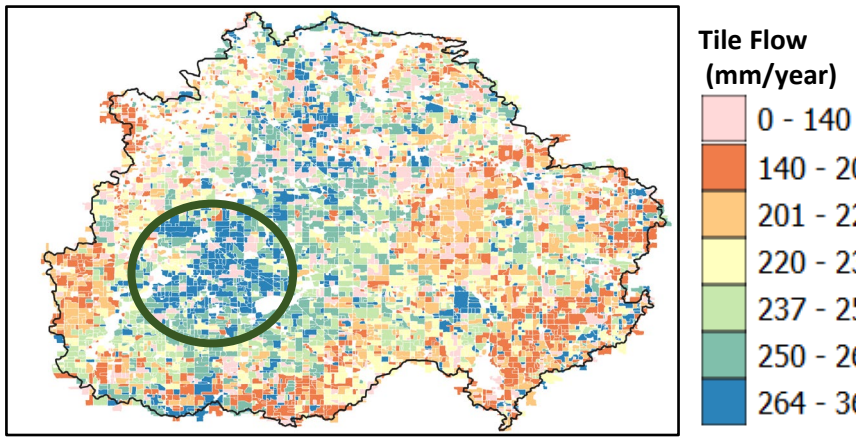


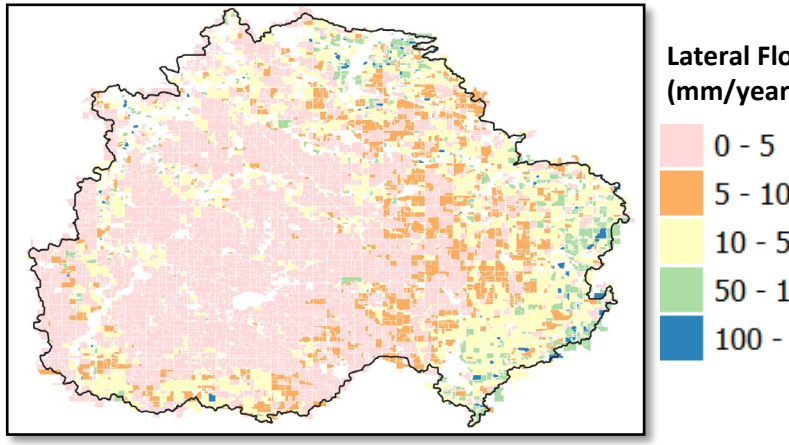
Lateral NO_3-N (kg/ha)

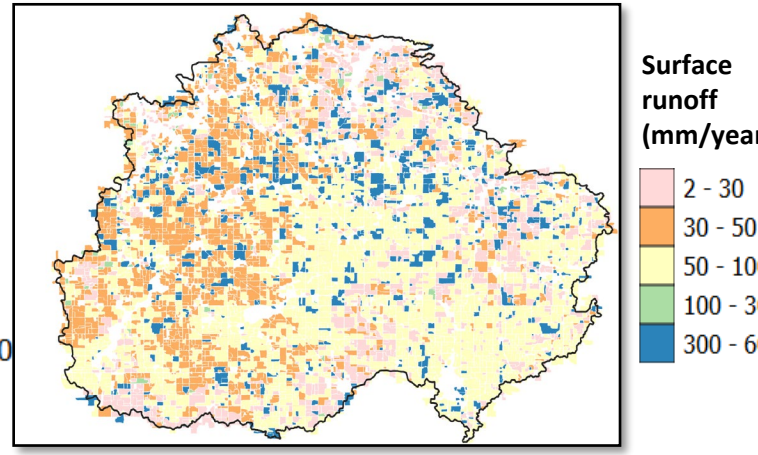


Surface NO_3-N (kg/ha)





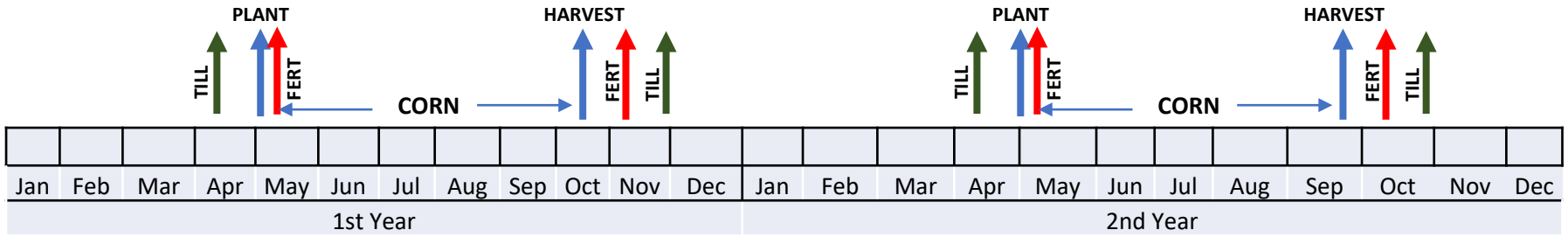


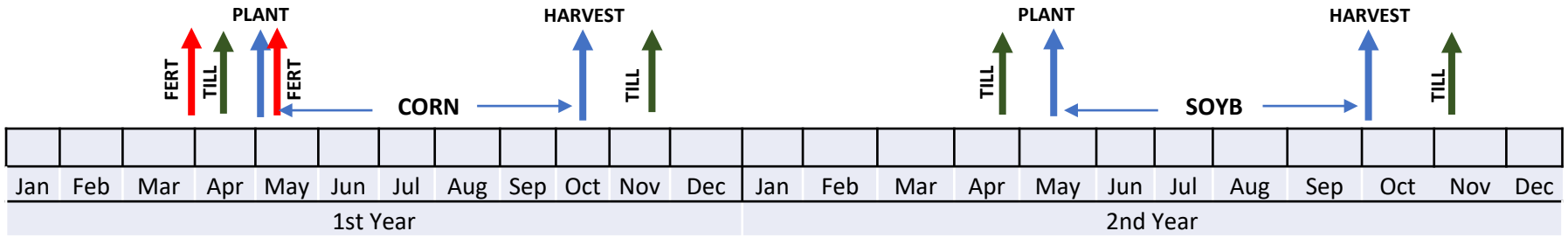


Tested Scenario

Fertilizer Reduction

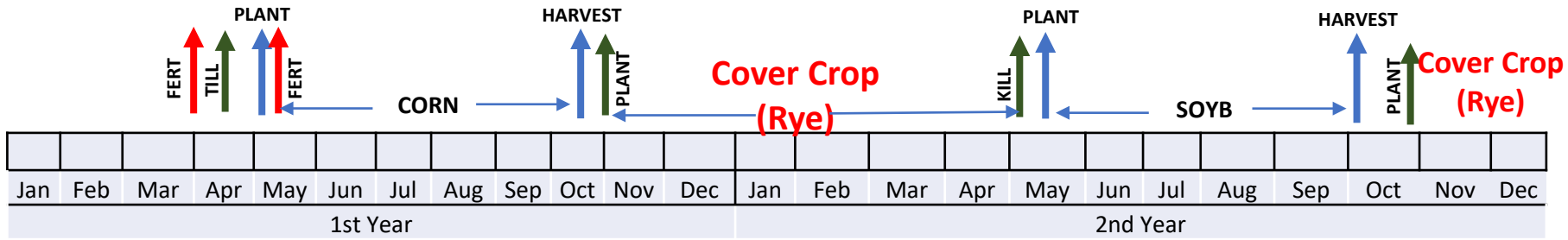
-20%



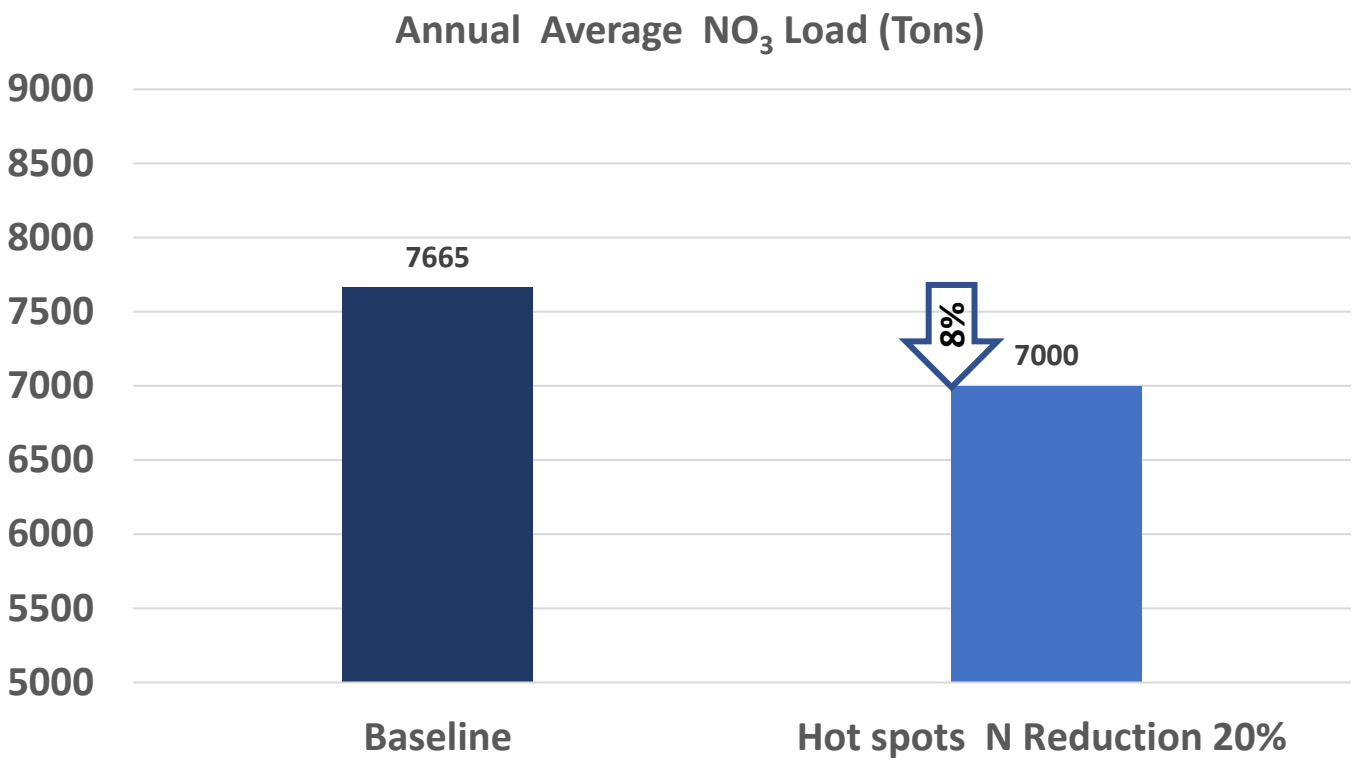


Fertilizer Reduction

-20%

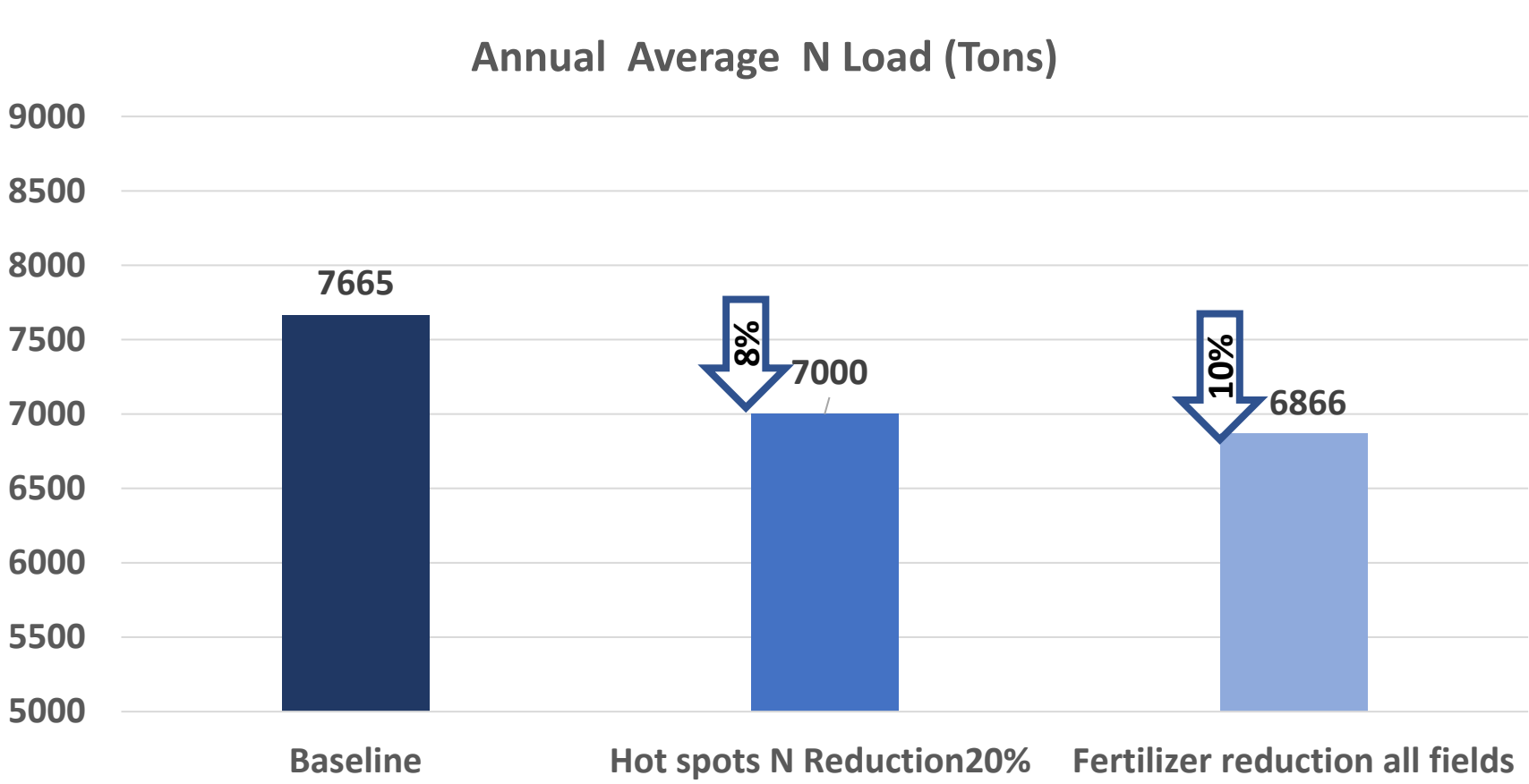


Load Reduction

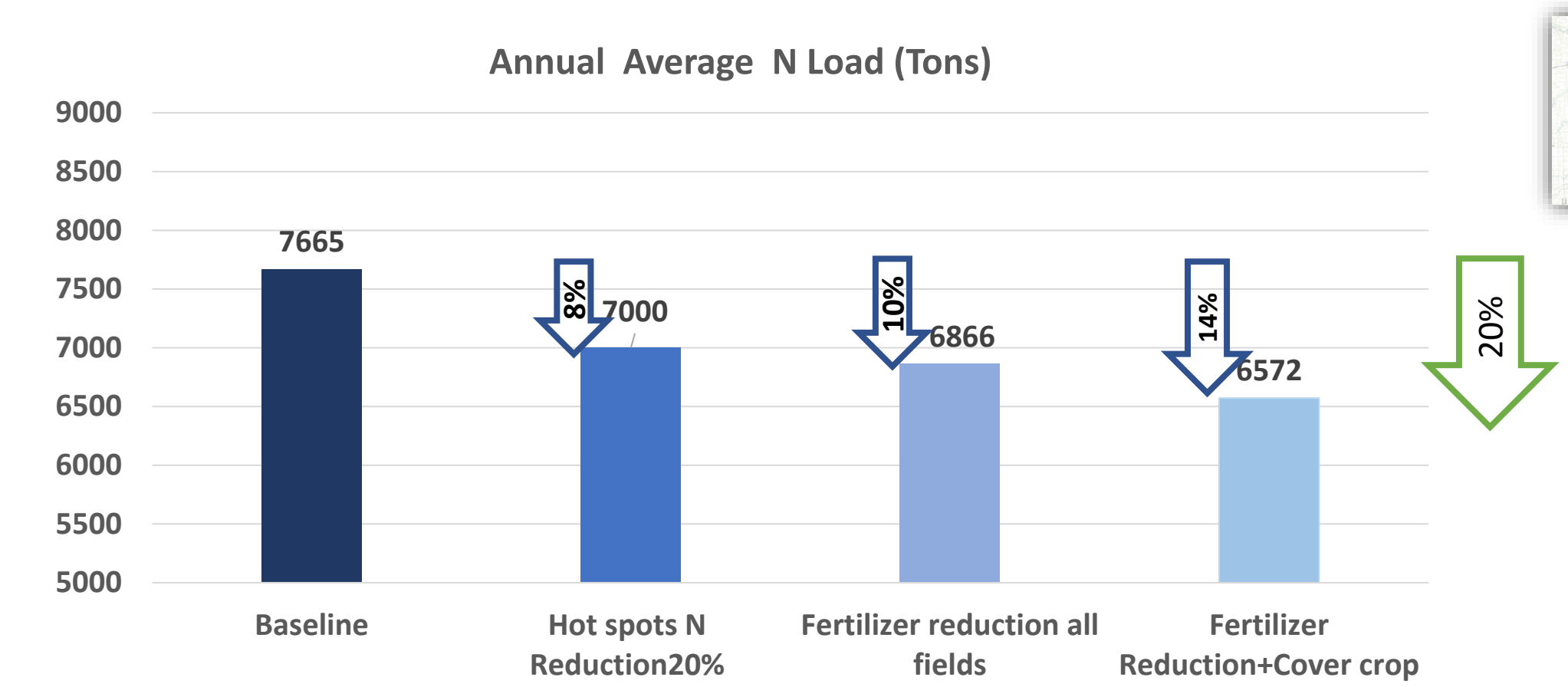


Hot Spots: Fields > 30 kg/ha NO_3-N Loss

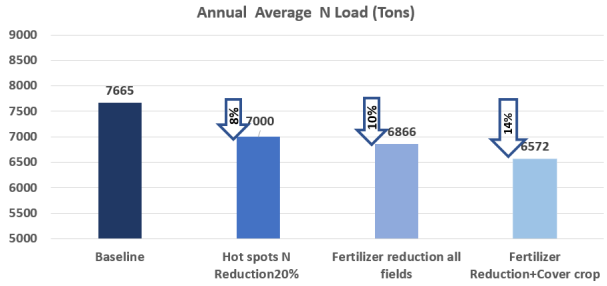
Load Reduction

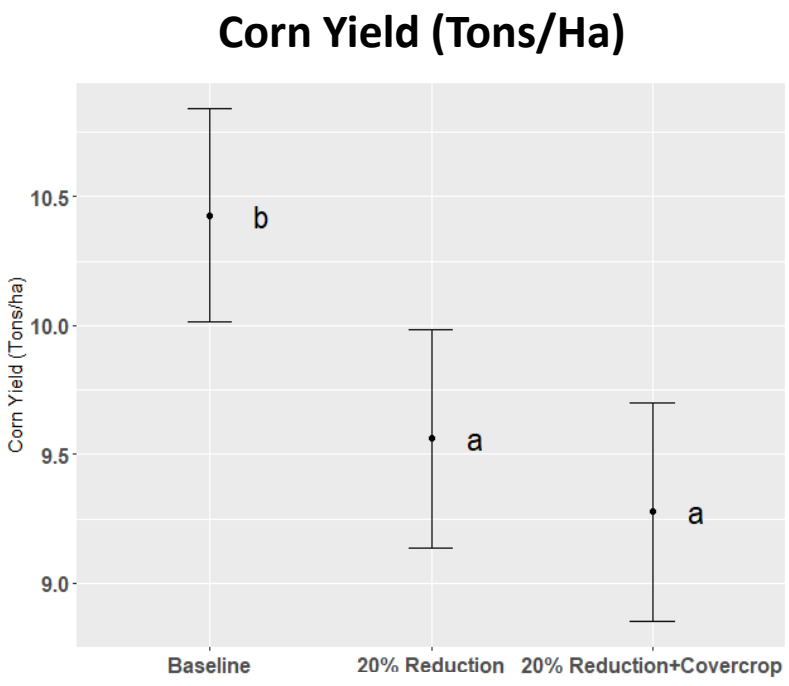


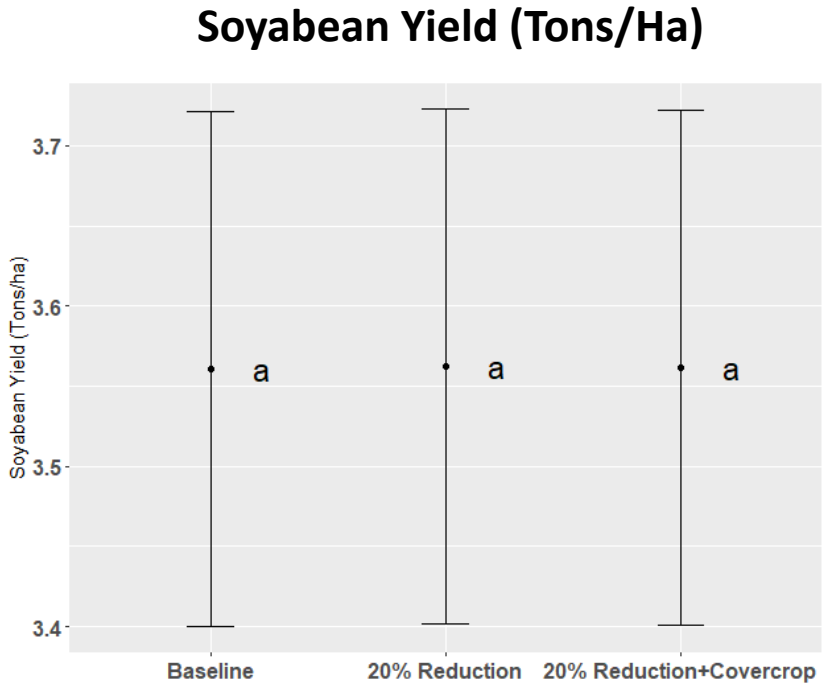
Load Reduction



Load Reduction







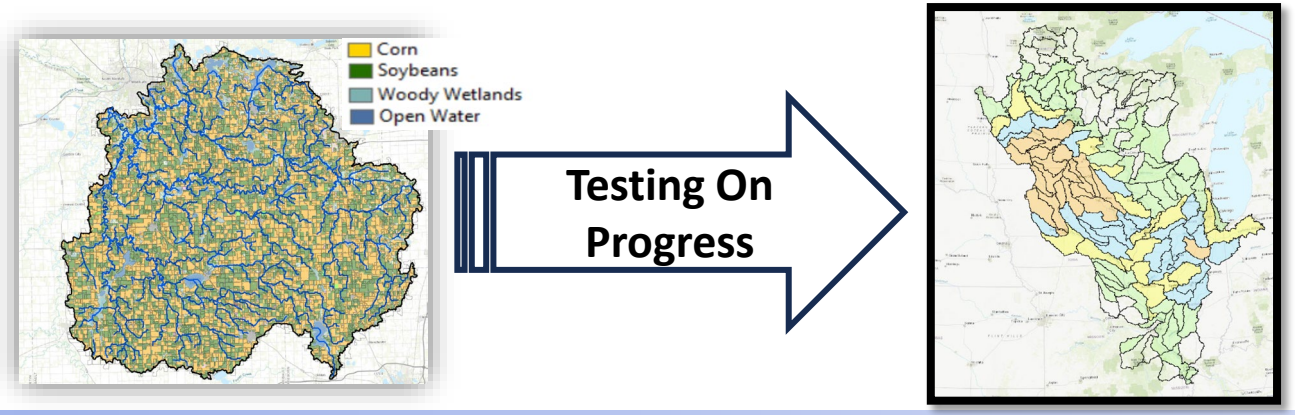
Simulated Corn and Soyabean yield (2000-2018) across basin. Different letters indicate significant differences ($p \leq 0.05$) between scenarios according to Tukey's test.

Take Home Message

- ✓ The implementation of nutrient reduction and cover cropping alone may not be adequate to achieve the conservation goal, and it may come at the expense of compromising economic returns.

Explore additional conservative measures

- Increase Fertilizer use efficiencies (Apply right time and right rate)
- Promote conservation and Reduce tillage practices
- Marketable Cover crops (short seasonal crops)
- Controlled tile drainage practices (manage timing and amount of water discharge)
- Grassed waterways and buffers
- Land use change (convert crop/soyabean fields to hay/ Perennial energy crops)



SWAT+
SOIL & WATER ASSESSMENT TOOL

Thank You

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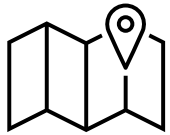

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