Nitrogen and phosphorus dynamics in restored riverine floodplains in intensively managed watersheds

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Floodplain Restoration

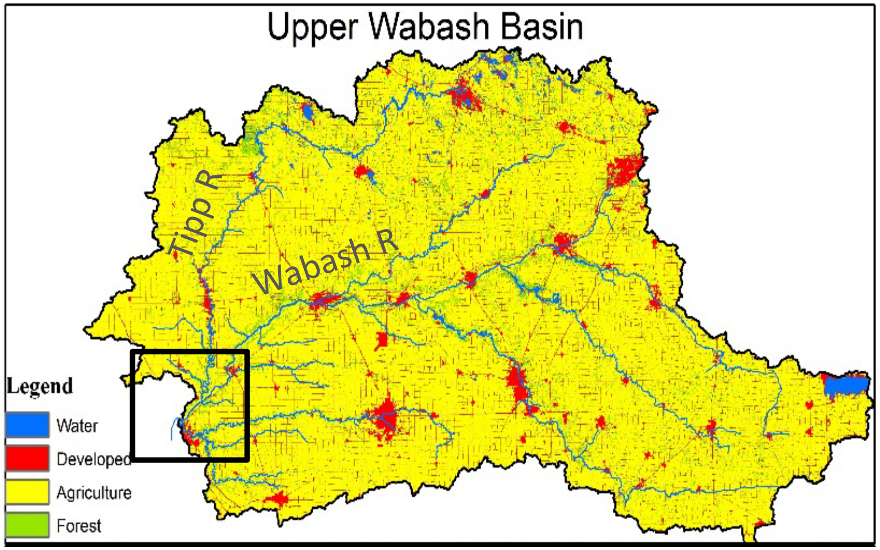
- Exchange between floodplain and river -> gradients in moisture, soil properties, vegetation and nutrient cycling
- Floodplain restoration through reconnection seeks to reestablish these gradients and improve function
- Potential consequences (+/-)
  - *Increased inundation creates anoxic conditions that increase N removal via denitrification BUT can also facilitate P release*
  - *Connectivity leads to greater sedimentation and particulate nutrient trapping BUT the net effect on dissolved constituents is unclear*

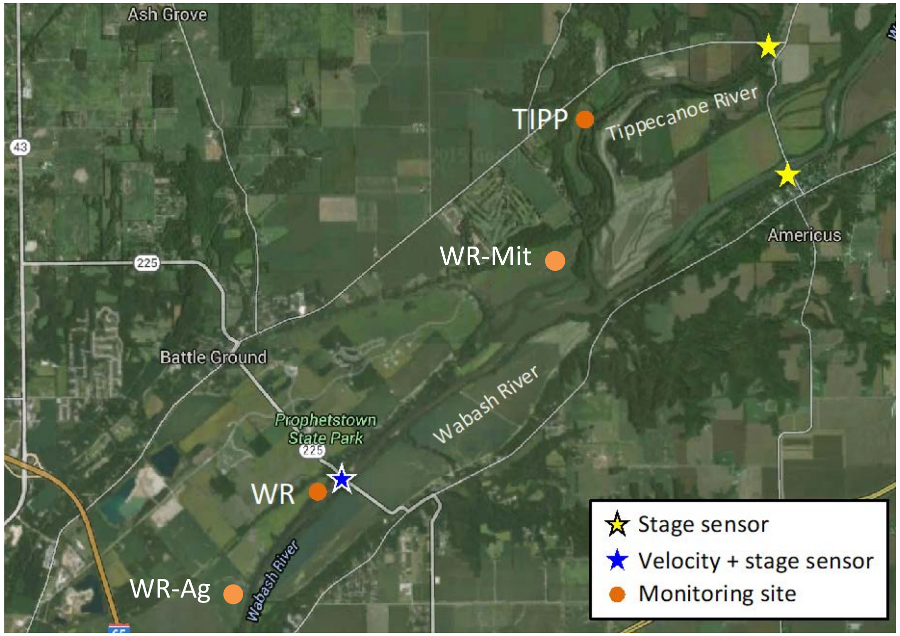
GOAL: Determine the functional relationships between sources and sinks of nutrients

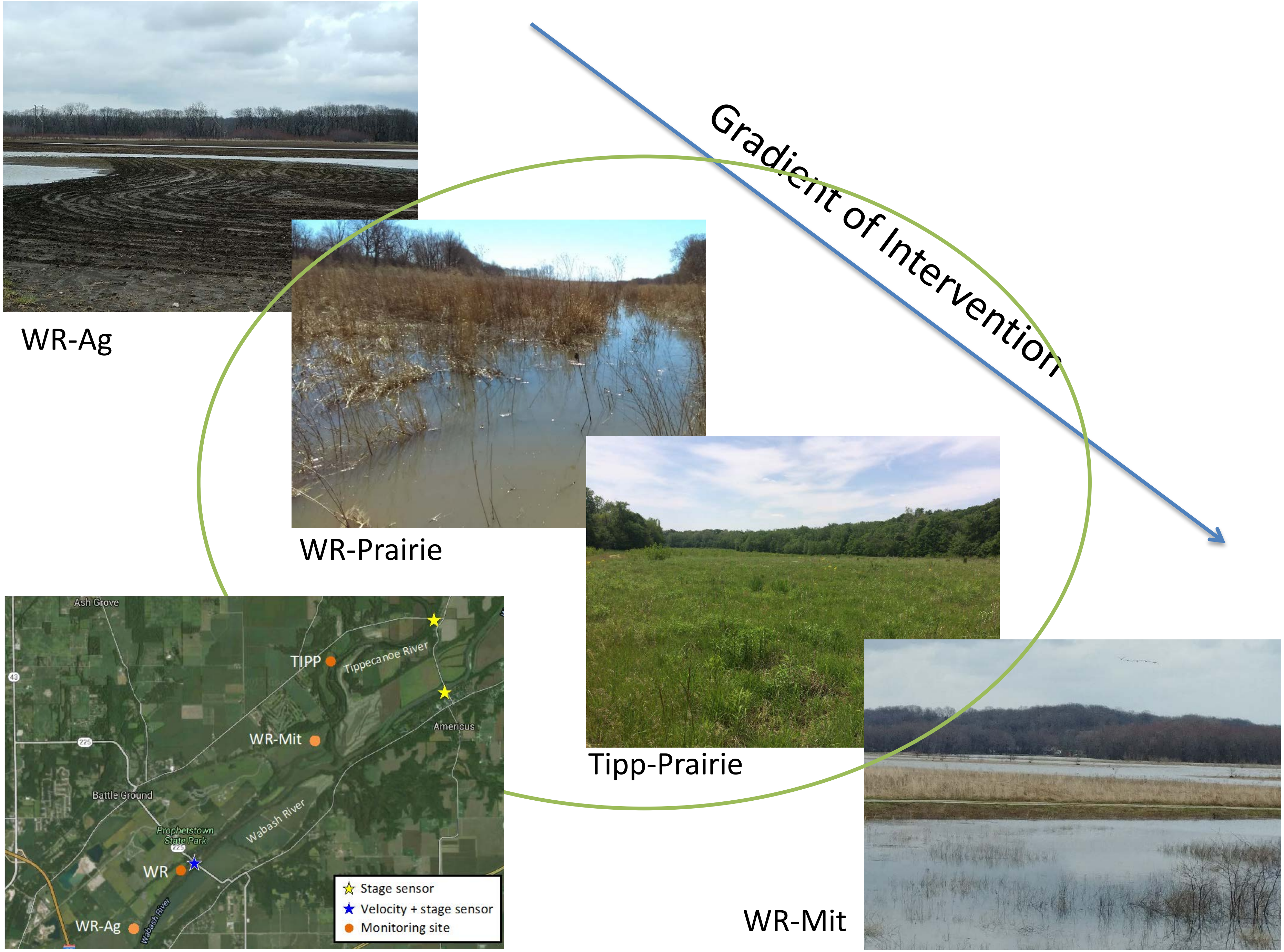
1. Quantify how hydrologic connectivity varies across spatial and temporal scales
2. Characterize the relative role of hydrodynamic versus biogeochemical processes on the N & P biogeochemistry
3. Determine the cumulative effect on the retention or release of N & P at the system scale

Wabash-Tippecanoe River Confluence

- Upper Wabash River Basin is intensively managed for row crop agriculture
- Project site is located at Prophetstown State Park: restored prairies and floodplain wetlands on the western side
- Floodplain restoration (completed ~2003) removed drainage tile, seeded with native prairie species, fire management.

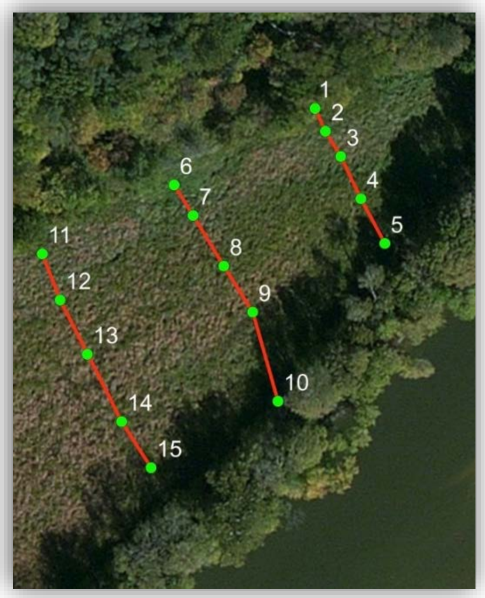





Gradient of Intervention
WR-Ag
WR-Prairie
Tipp-Prairie
WR-Mit
Ash Grove
TIPP
Tippecanoe River
Americus
WR-Mit
Battle Ground
Prophetstown State Park
Wabash River
WR
WR-Ag
Wabash River
Stage sensor
Velocity + stage sensor
Monitoring site

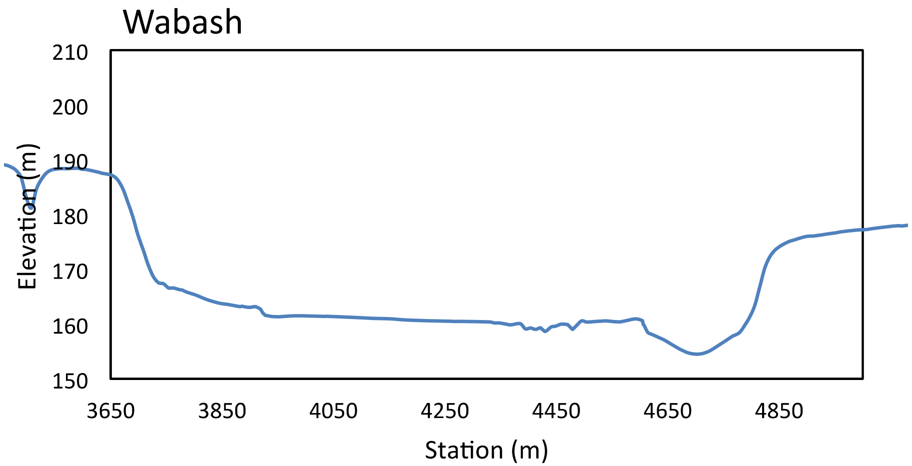
Methods: nutrient biogeochemistry

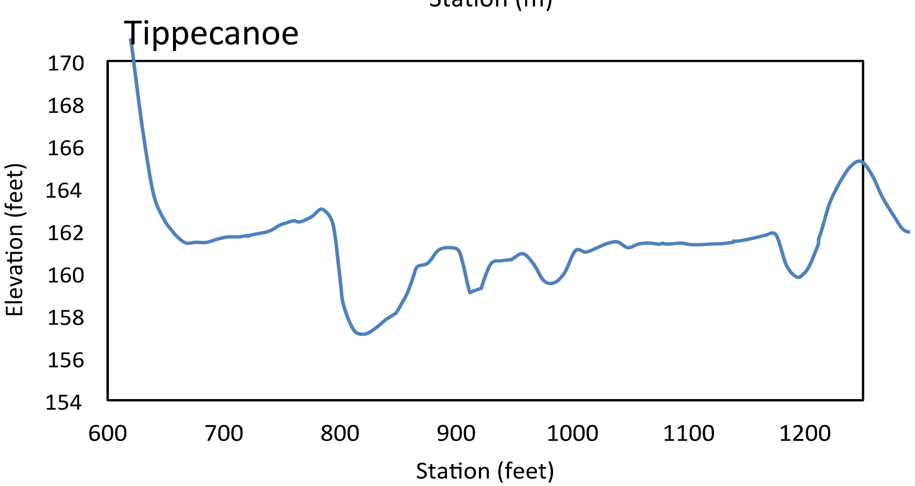
- Seasonal denitrification & respiration
  - P1 & P2: Modified slurry assays using Membrane Inlet Mass Spectrometry (MIMS, Reisinger et al 2016)
- Seasonal nutrient & carbon flux
  - P1: 24-hr intact flow-through cores
  - P2: 21-day core incubations
- P2: Sediment/soil properties: bulk density, TC, TN, microbial P, sequential P
- P2: Sediment & nutrient loading
  - Turf mats (sediment) and resin bags (inorganic nutrients)

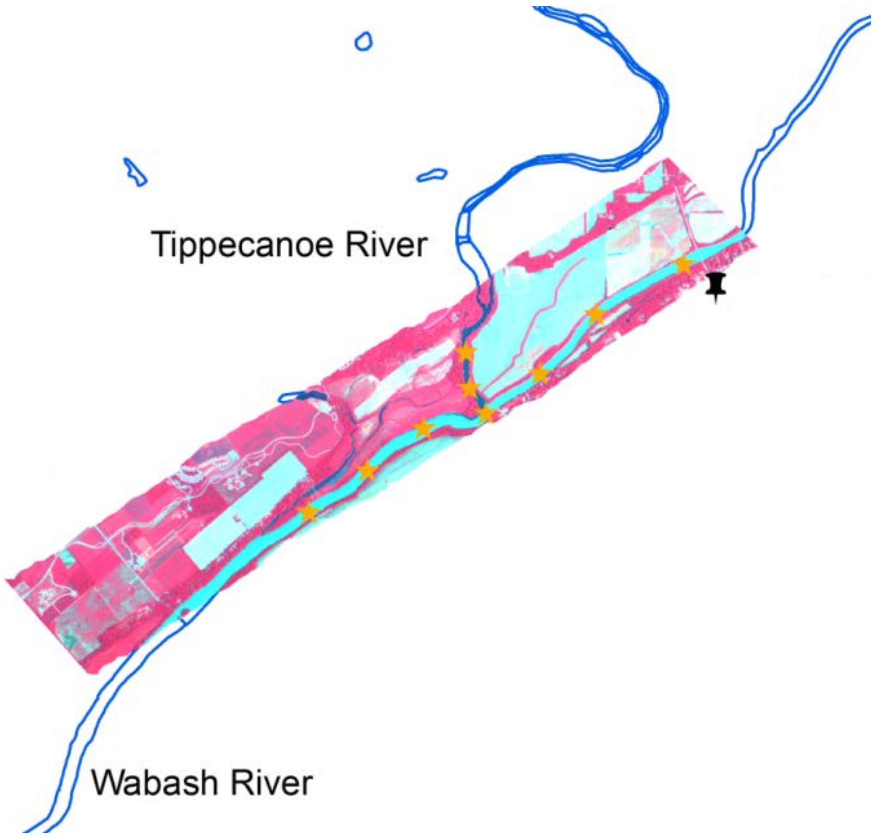


Methods: hydrodynamics

- Hydrodynamic model
  - 2D HEC-RAS model built with detailed bathymetry
  - 3 gaging stations and one high-resolution velocity profiler to calibrate
  - Extract connectivity metrics, velocity profiles through the floodplain and groundwater contributions



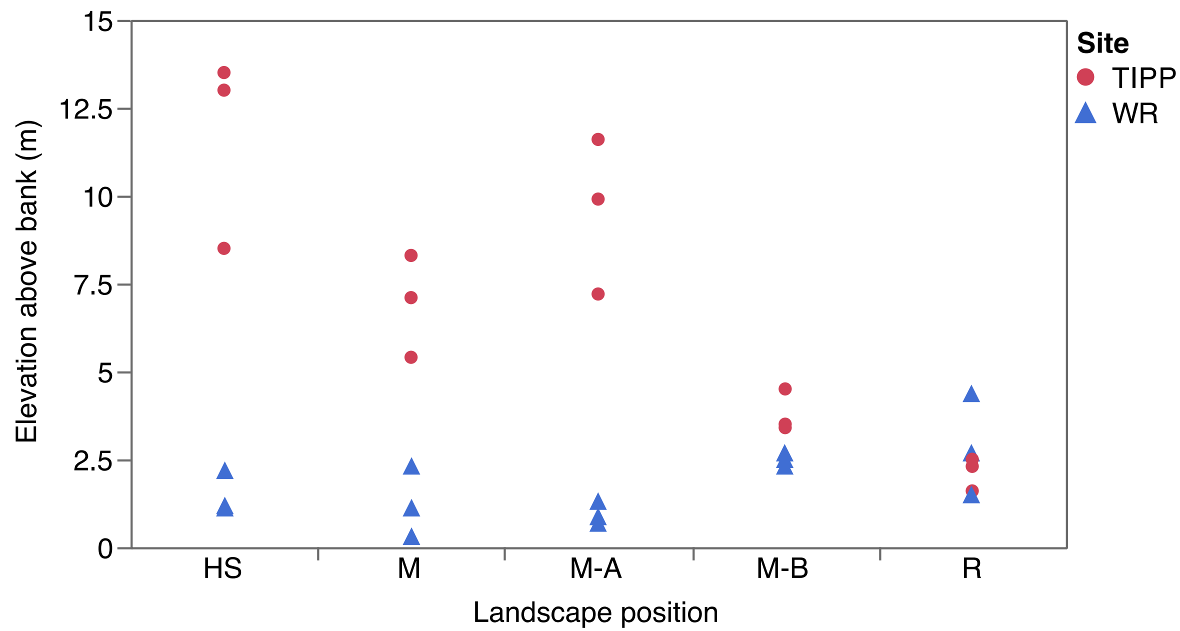




P1: Hydrodynamic connectivity

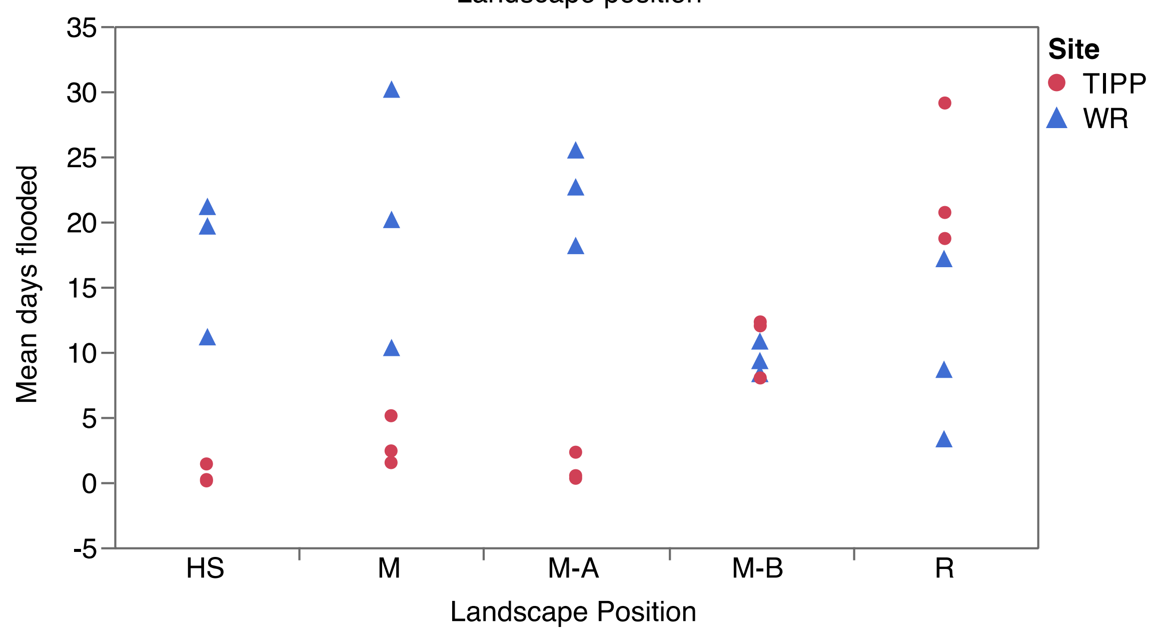
<u>Geomorphology</u>

- More topographic variance at Tippecanoe River site
- Levee/ridge at Wabash River site



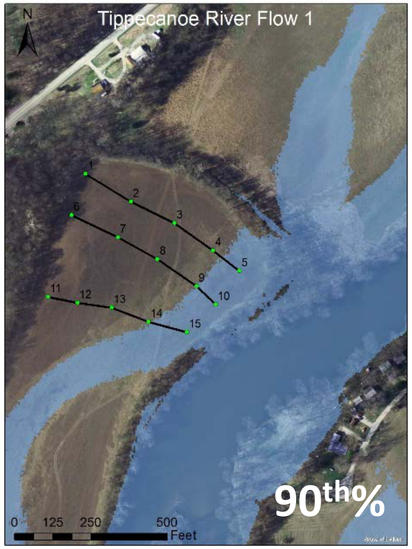
<u>Flood frequency</u>

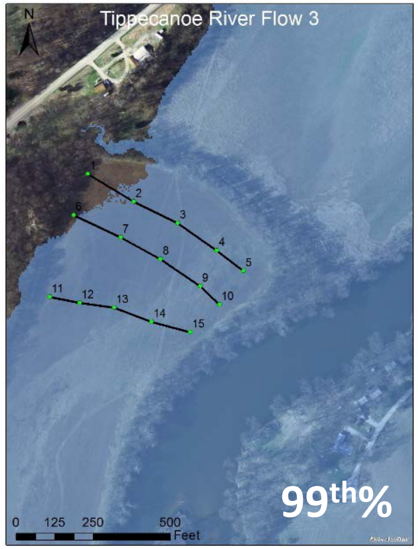
- Threshold for higher frequency of flooding
  - TIPP = near river
  - WR = entire floodplain



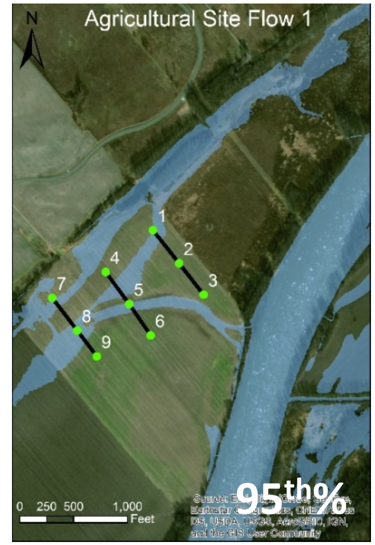
Hydrodynamic connectivity

Tippecanoe – Prairie

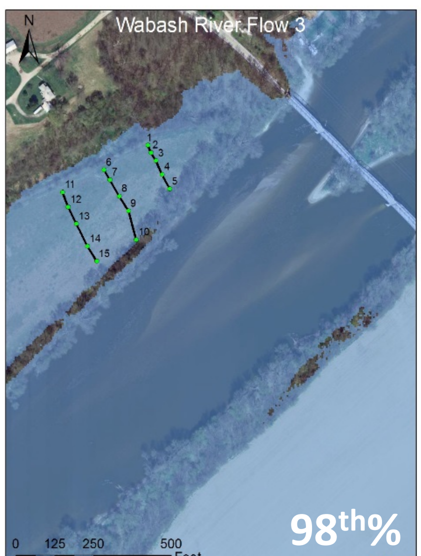




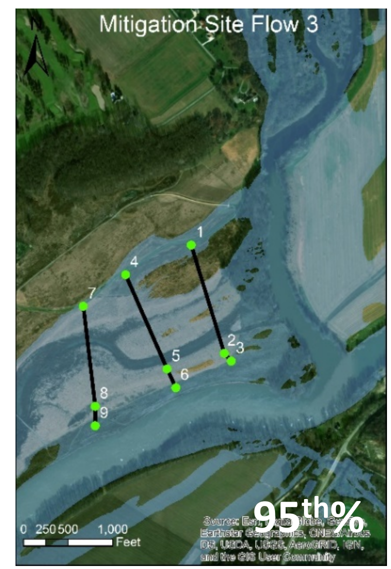
Wabash - Agriculture



Wabash - Prairie

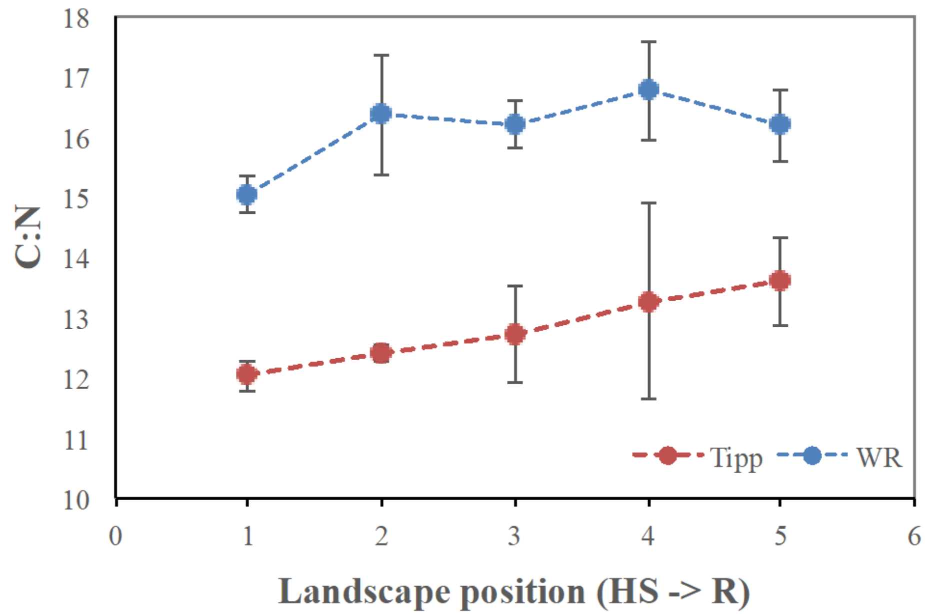


Wabash - Mitigation

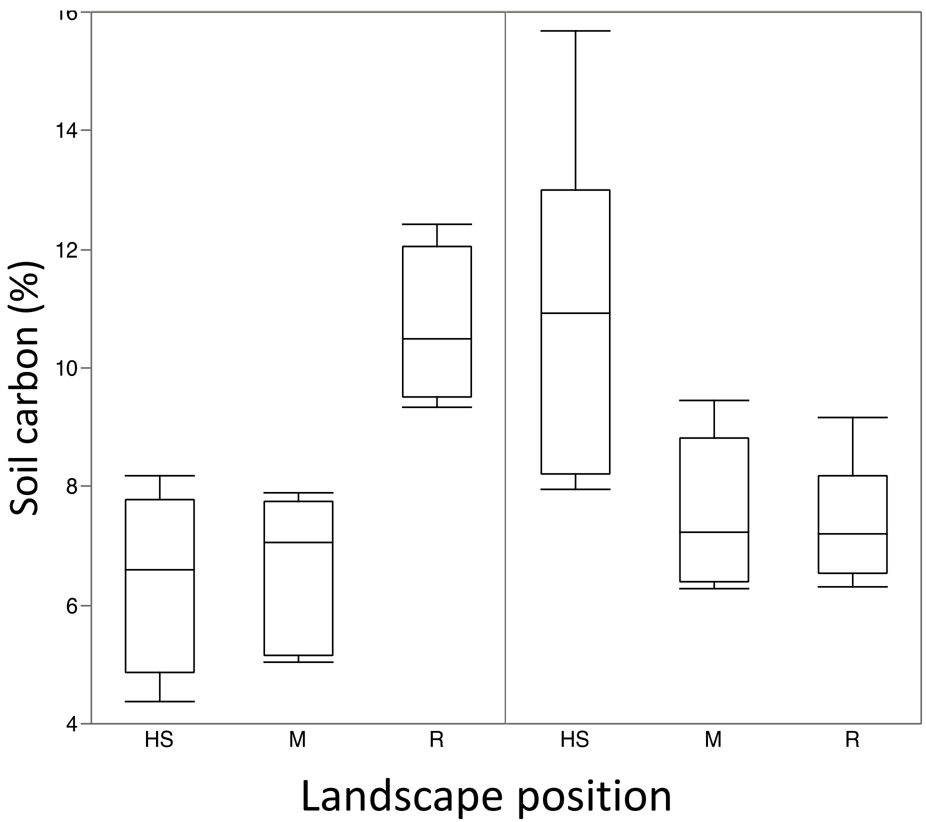


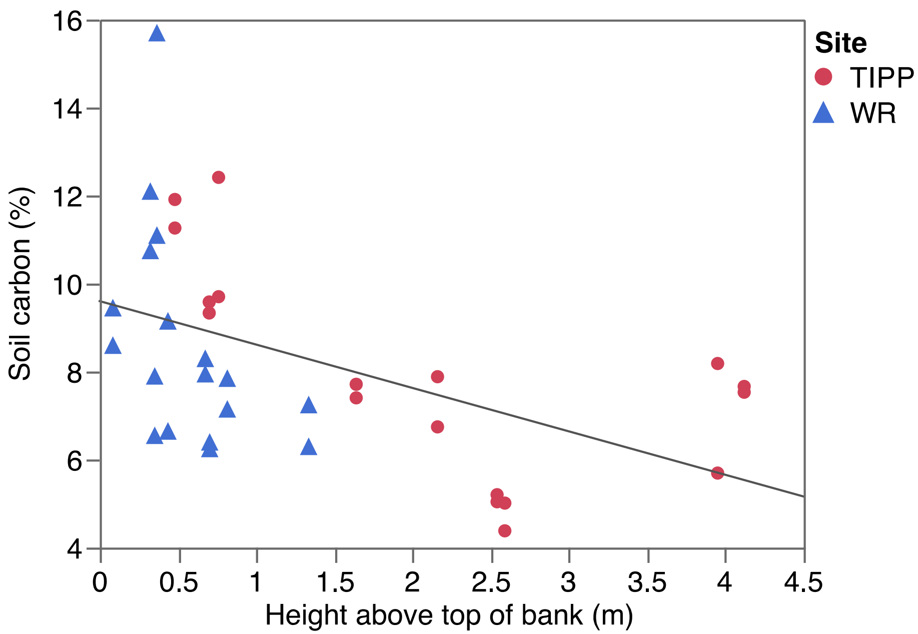
P1: Sediment characteristics

- More bioavailable carbon at Tipp (12.8±0.95) than at WR (16.1±0.82)
- Patterns in total carbon vary laterally
  - Tipp: historical channel near river edge
  - WR: levee + hillslope seep
- Carbon greatest at lower elevation



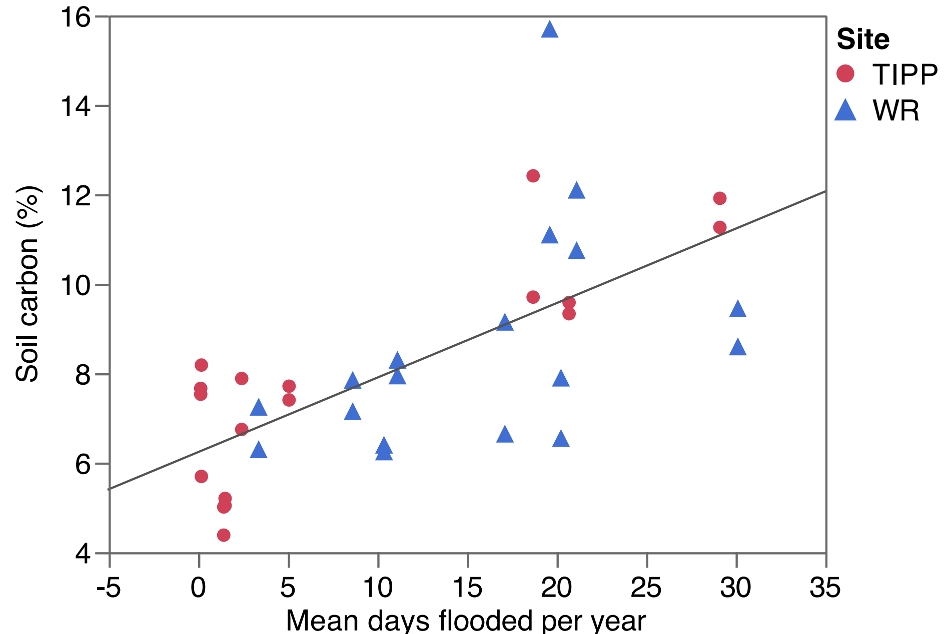
Tippecanoe Wabash

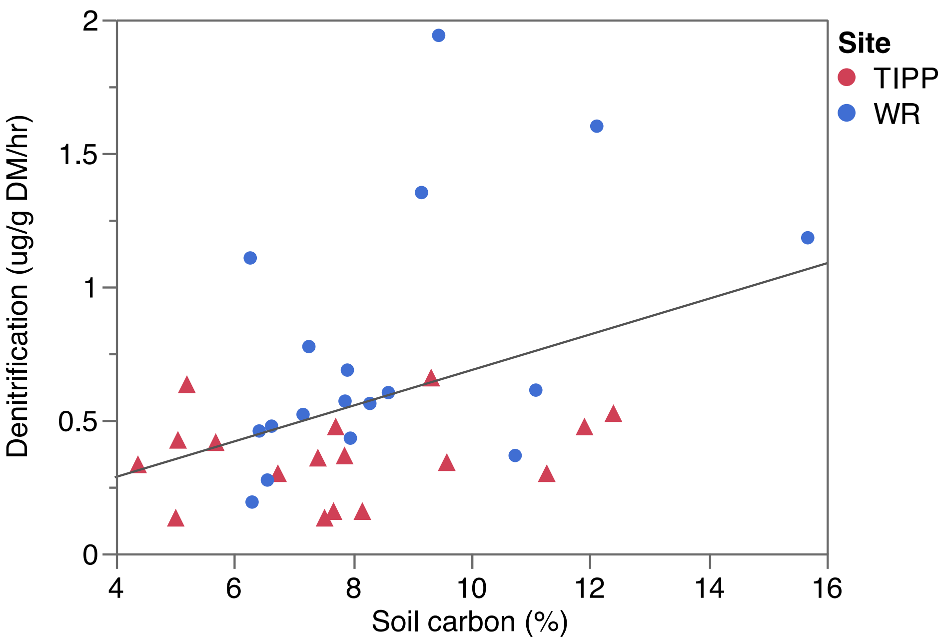


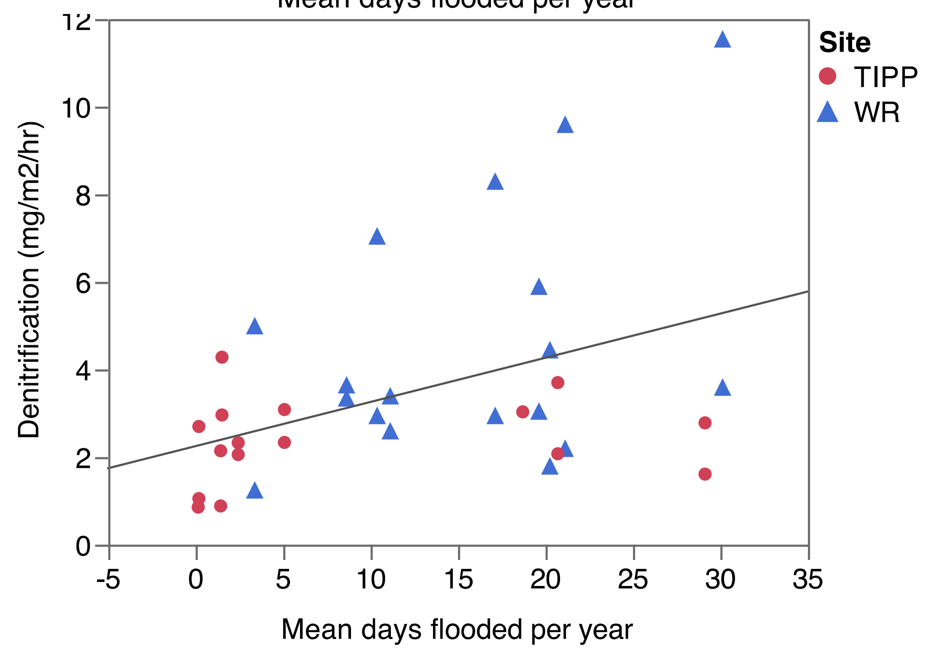


P1: Hydrologic connectivity & biogeochemistry

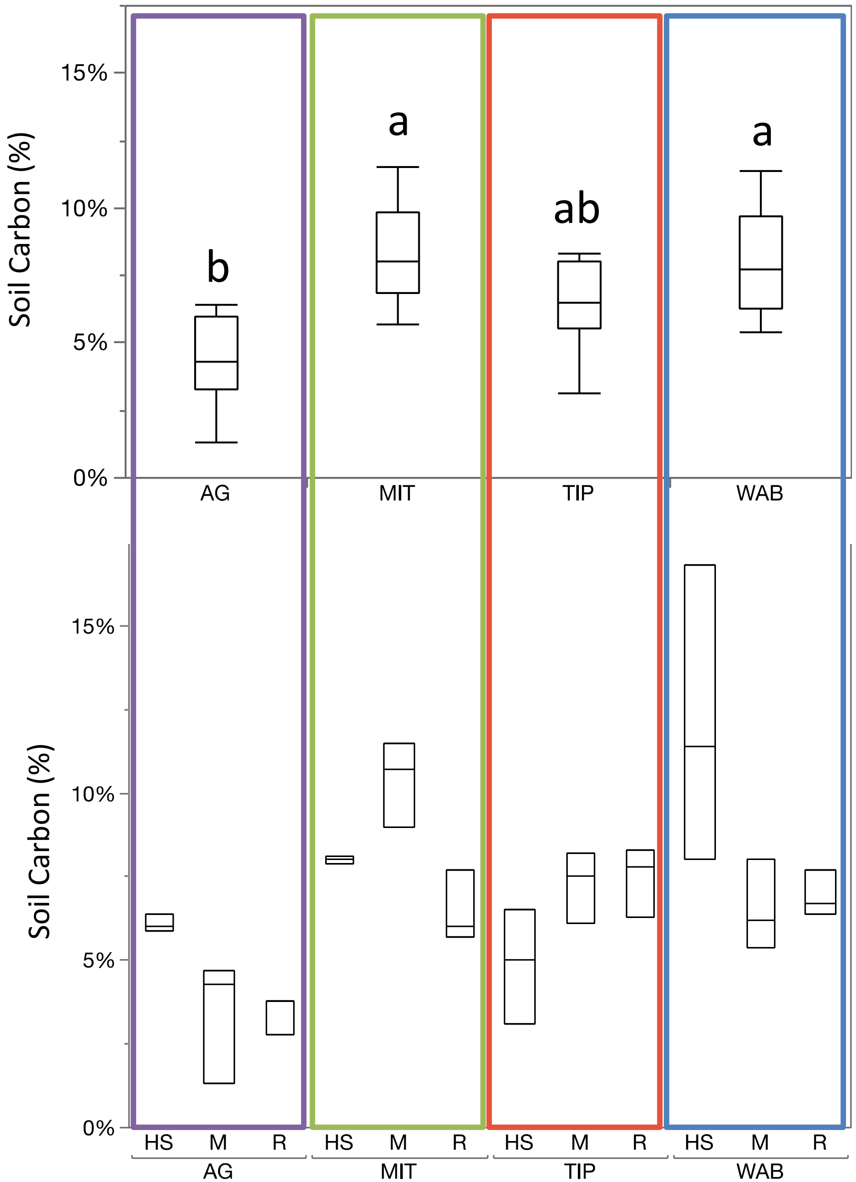
- Flood frequency appears to be important control on carbon quantity (r=0.677, p<0.0001)
- Moderate control on denitrification (r=0.416, p=0.013)
- Soil carbon is a likely process control, but soil, microbial, etc. are also possibilities (r=0.399, p=0.018)
- No control on respiration





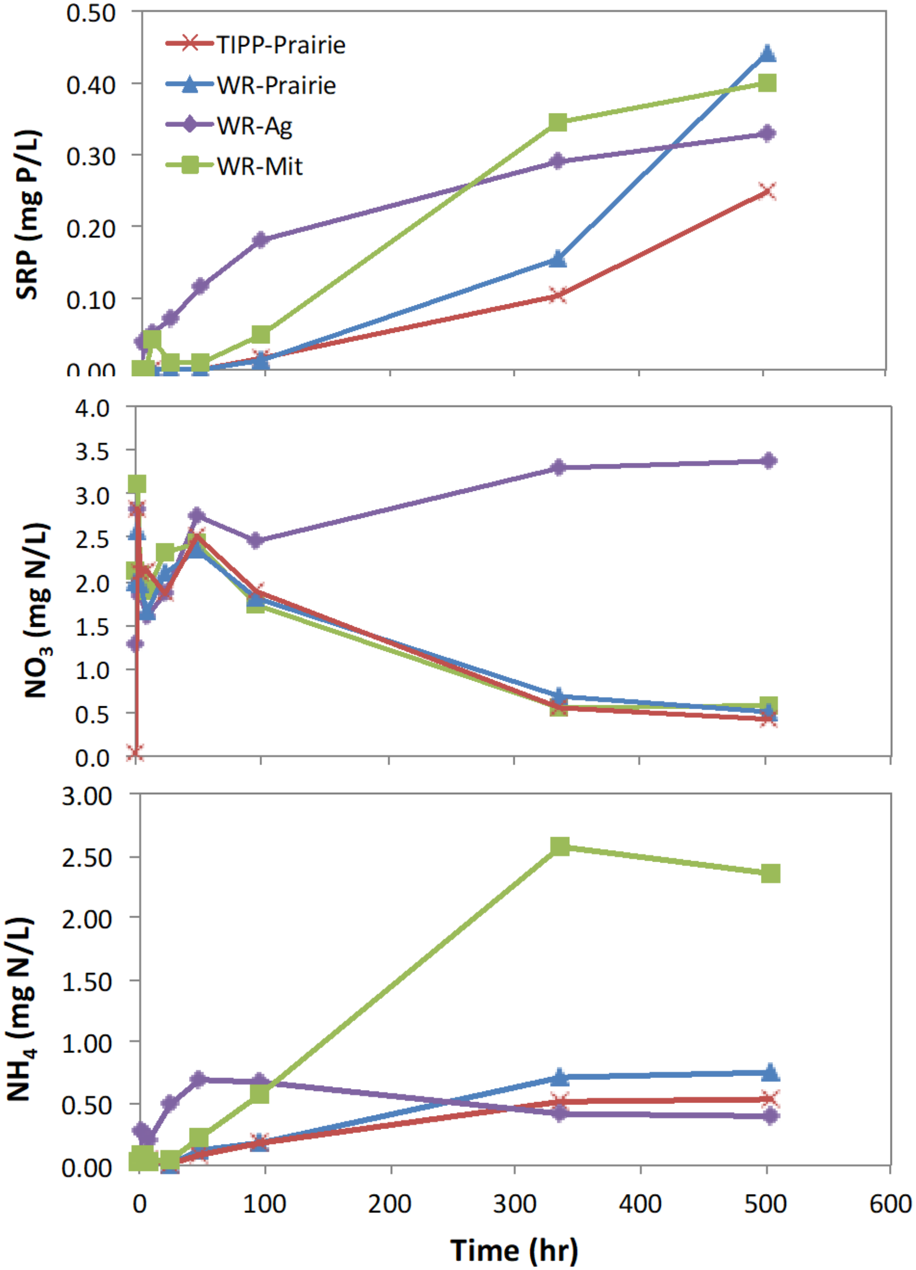


P2: Sediment biogeochemistry – carbon pools



- Greater soil carbon at restored WR sites
- WR-Prairie driven by high C in hillslope seepage wetland
- WR-Ag lower than all restored sites; similar to other croplands in the region

P2: Sediment biogeochemistry – 21 day core incubations



<u>SRP</u>

- Restored sites: Delayed release
- WR-Ag: immediate release

<u>NO_3</u>

- High variability
- Restored sites: Initial increase, followed by decrease
- WR-Ag: sustained high concentrations

<u>NH_4</u>

- Slow increase early in incubation at restored sites
- WR-Mit: many cores with high concentrations likely because of C-rich soils
- WR-Ag: immediate increase and sustained high concentrations

Take home message from our early data

- Spatial variability in floodplain topography creates distribution of flooding frequencies and these are different for each site.
- Hydrodynamic connectivity influences soil carbon cascading effects on denitrification
- Nutrient flux function of current land use and level of intervention