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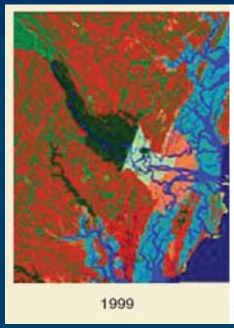
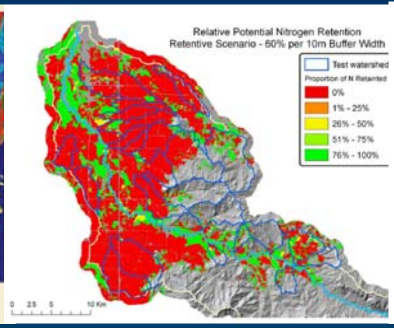
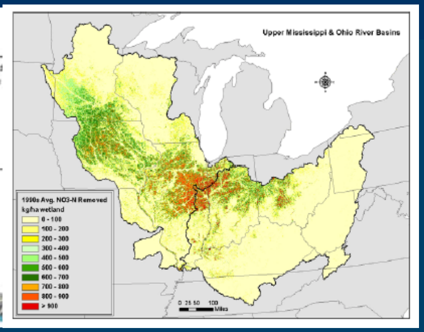
Approaches to Mapping Nitrogen Removal:

Examples at a Landscape Scale







Jay Christensen, Ric Lopez, Annie Neale

Landscape Ecology Branch

Office of Research and Development
National Exposure Research Lab, Environmental Science Division, Landscape Ecology Branch

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Landscape Scale – Overarching Issues

- Example using Wetlands and Nitrogen Removal:
  - Complex interactions of hydrology, soil type, nutrient loadings, and landscape position

- Challenge:
  - Adequately predict complex interactions and account for variability and uncertainty with limited data availability and resolution

  - Output meets the needs of the user

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Selected Landscape Approaches to Nitrogen Removal

- Accumulation/Denitrification Extrapolation
  - *Craft et al.* 2009

- GIS analysis of Riparian Wetlands
  - *Baker et al.* 2006, 2007

- Potential of Sited Wetlands
  - *Crumpton et al.* 2006, 2008

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Extrapolation of Potential Denitrification Rates

RESEARCH COMMUNICATIONS RESEARCH COMMUNICATIONS

Forecasting the effects of accelerated sea-level rise on tidal marsh ecosystem services

Christopher Craft[1], Jonathan Clough[2], Jeff Ehman[3], Samantha Joye[4], Richard Park[5], Steve Pennings[6], Hongyu Guo[6], and Megan Machmuller[4]

- Frontiers in Ecology and the Environment March 2009

Extrapolation of Potential Denitrification Rates
Craft et al. 2009

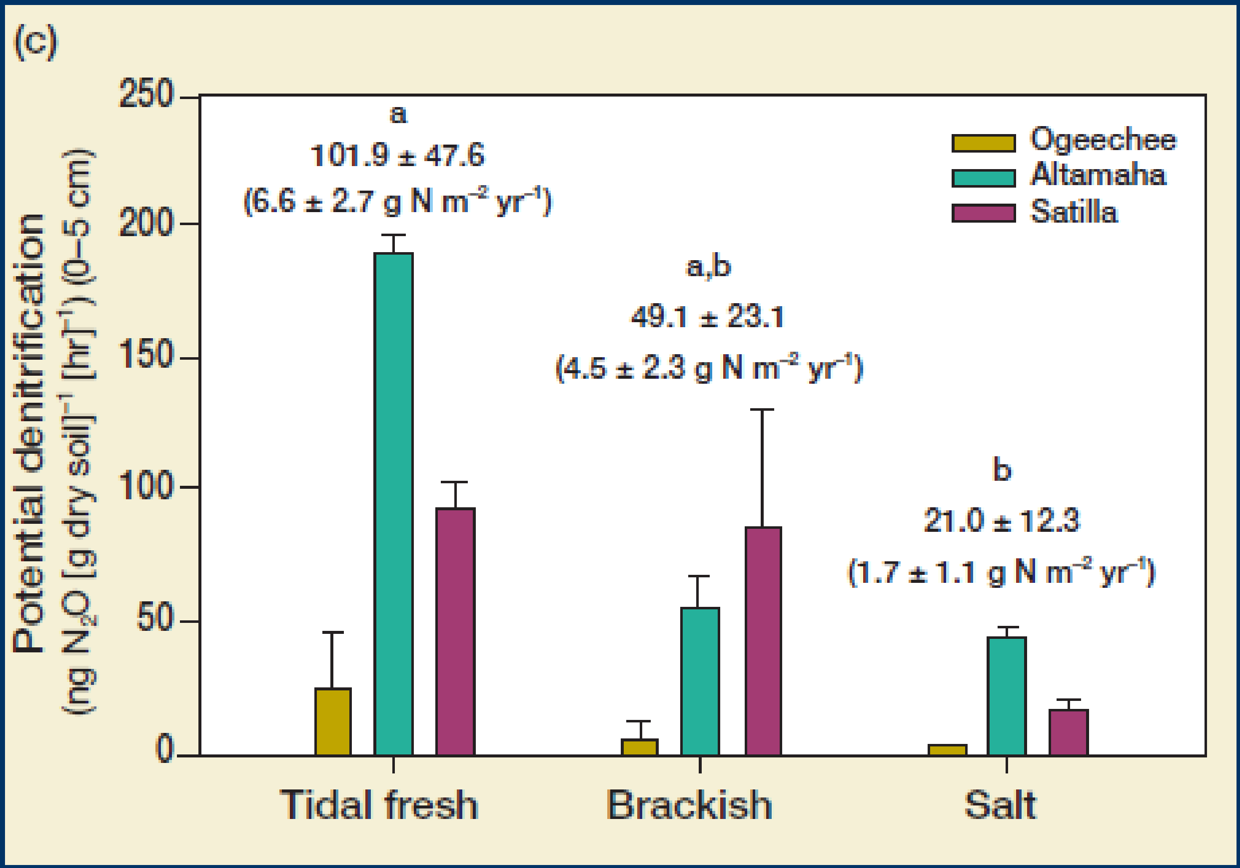
- Goal: “Predict how tidal marsh area (of Georgia) and delivery of ecosystem services would respond to different scenarios of sea-level rise (SLR)”

- Summary: SLR may dramatically affect nitrogen (and other) related coastal marsh ecosystem services, particularly at upper and lower ends of salinity ranges, depending on geomorphology and potential for wetland accretion/migration

Extrapolation of Potential Denitrification Rates

Craft et al. 2009

- Results: Denitrification

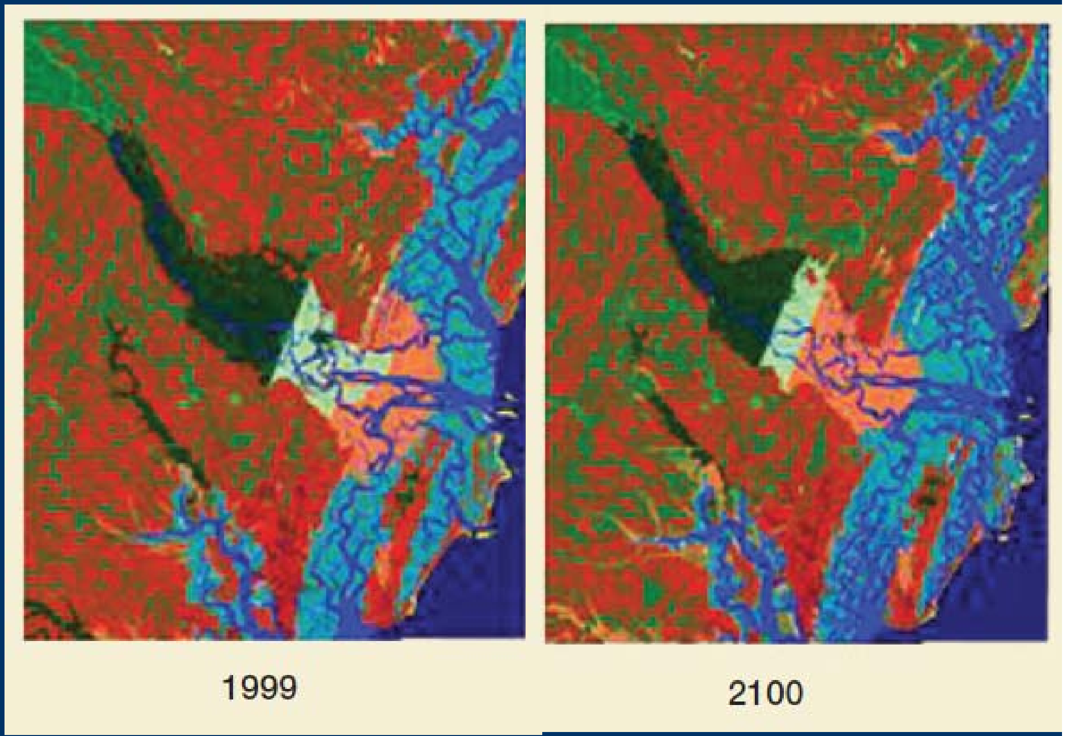


Extrapolation of Potential Denitrification Rates
***Craft et al.* 2009**

- Results: SLAMM

Habitat Change (km^2)

Marsh Type	52cm	82cm
Tidal Fresh (light green)	+1	-32
Brackish (pink)	+41	-4
Salt (turquoise)	-226	-496



52 cm increase for Altamaha River

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Extrapolation of Potential Denitrification Rates
Craft et al. 2009

- Limitations:
  - Uncertainties of scaling lab measurements to landscape level
  - SLAMM outputs
    - Data resolution – 30m DEM banding of wetland outputs
    - Uncertainty in wetland accretion
    - Extent of SLAMM using finer DEMs
  - Potential Nitrogen Removal
    - Modeling actual removal depends on N loading, hydrologic loading, and marsh characteristics
    - Difference as pronounced in palustrine systems?

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Application in ESRP

Summary of N-related coastal wetland work by Lopez, Christensen, Neale *et al. (National Atlas of Ecosystem Services & Wetlands-ESRP)*

Wetland "Mapping" components

NOAA Coastal Change Analysis Program data and modified remote-sensing approaches to map temporal/spatial change of coastal wetlands from 1970s-present

SLR and Urbanization "Modeling" components

New and existing SLAMM models for applicable portions of Carolinas, California, other applicable/feasible regions of the coastal US – with focal landscape-scale studies at selected locations

FORE-SCE and other urban change models

Nitrogen "Monitoring" component

Extrapolation, applying denitrification rates from existing literature and field collection of rates, as available/feasible

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GIS Riparian tool

Baker et al. 2006, 2007

Landscape Ecol (2006) 21:1327–1345
DOI 10.1007/s10980-006-0020-0

RESEARCH ARTICLE

Improved methods for quantifying potential nutrient interception by riparian buffers

Matthew E. Baker · Donald E. Weller ·
Thomas E. Jordan

Landscape Ecol (2007) 22:973–992
DOI 10.1007/s10980-007-9080-z

RESEARCH ARTICLE

Effects of stream map resolution on measures of riparian buffer distribution and nutrient retention potential

Matthew E. Baker · Donald E. Weller ·
Thomas E. Jordan

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GIS Riparian tool
Baker et al. 2006

- Fixed width analysis versus flow-path analysis
- Spatial location matters

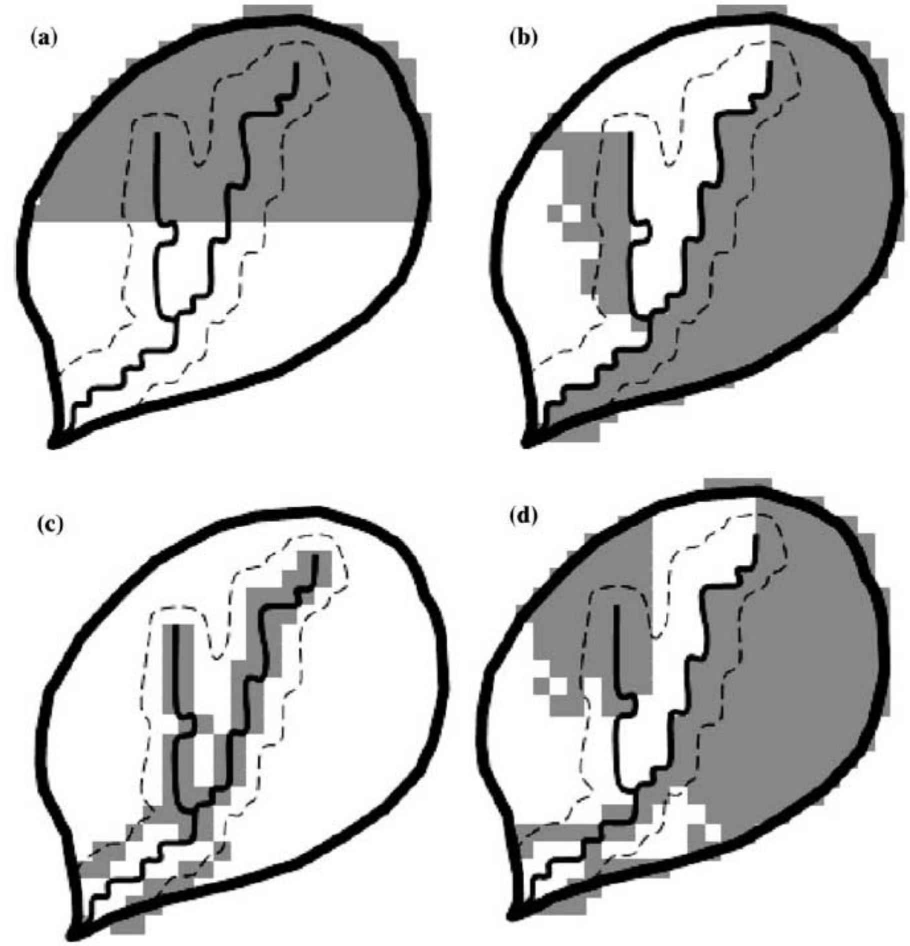

Fig. 2 Set of hypothetical watersheds with the same proportion of forests and wetlands (for-wet) within a fixed distance of the stream, but with different nutrient filtering potentials. The fixed-distance metric fails to account for a longitudinal patterns of land cover, **b** different buffer patterns on two stream banks, **c** contiguous versus disjunct near-stream for-wet, and **d** combinations of different patterns

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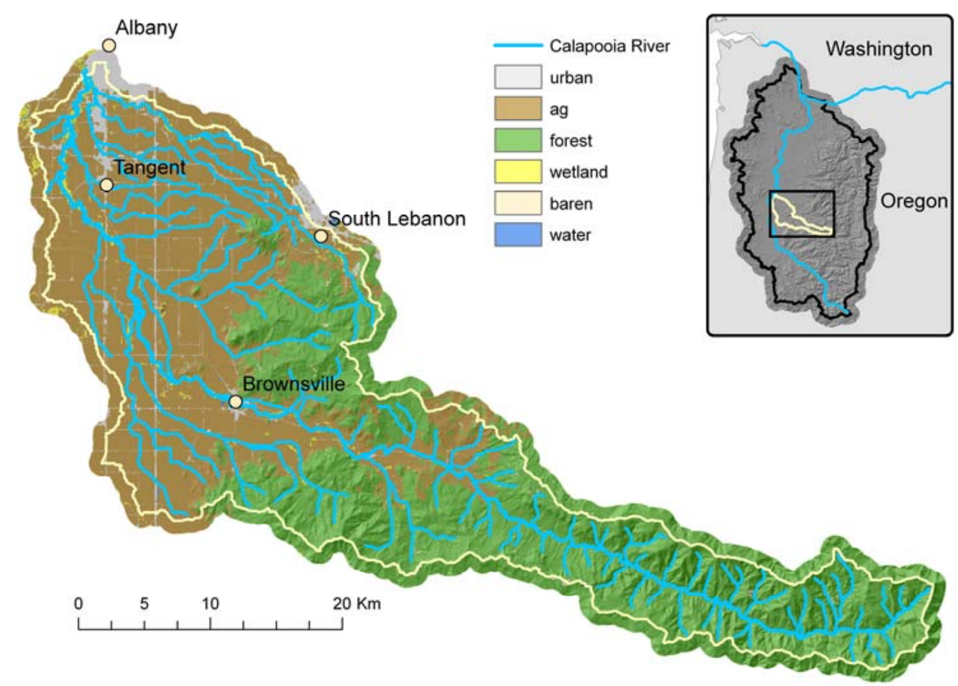
GIS Riparian tool
Baker et al. 2006

- Goal: "We focus on describing the connectivity of cropland to streams through riparian buffers"
- Our application of Baker et al. methods:

  Calapooia River Basin

  - Method requires 3 data inputs:
  - Elevation
  - Stream Network
  - Landcover



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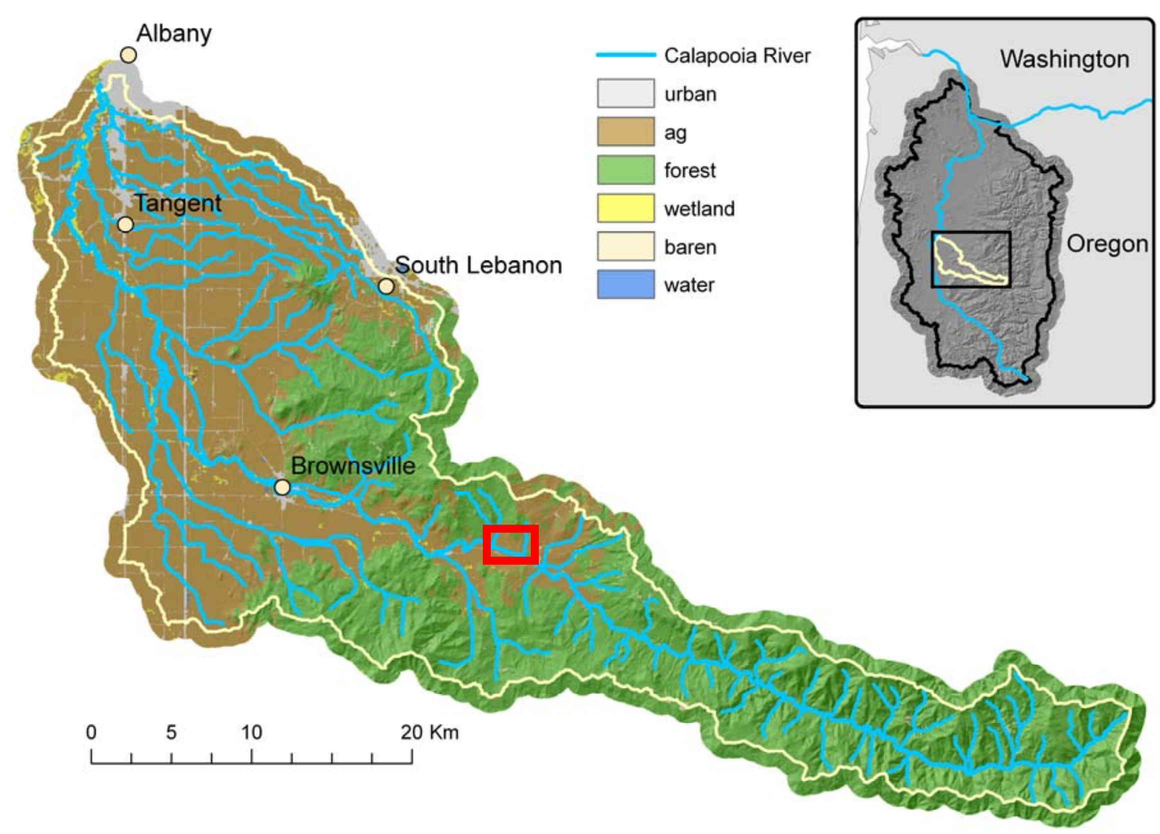
GIS Riparian tool

Methodology of Tool: GIS analysis



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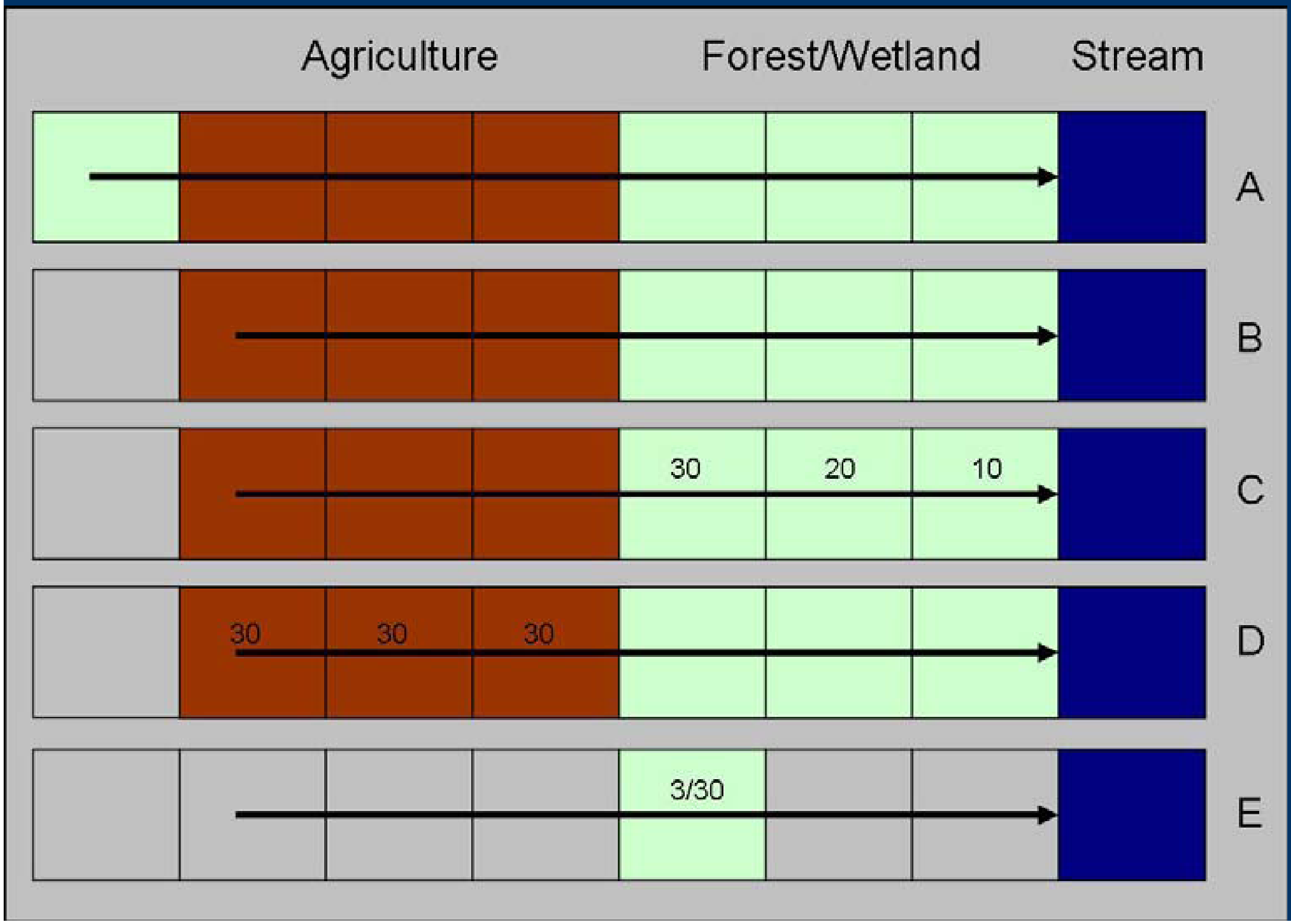
GIS Riparian tool



Methodology of Tool: GIS analysis

- A) Flow path determined
- B) Isolate source cell flow paths
- C) Length of sink cells calculated
- D) Buffer width assigned
- E) Ag/Buffer Ratio determined

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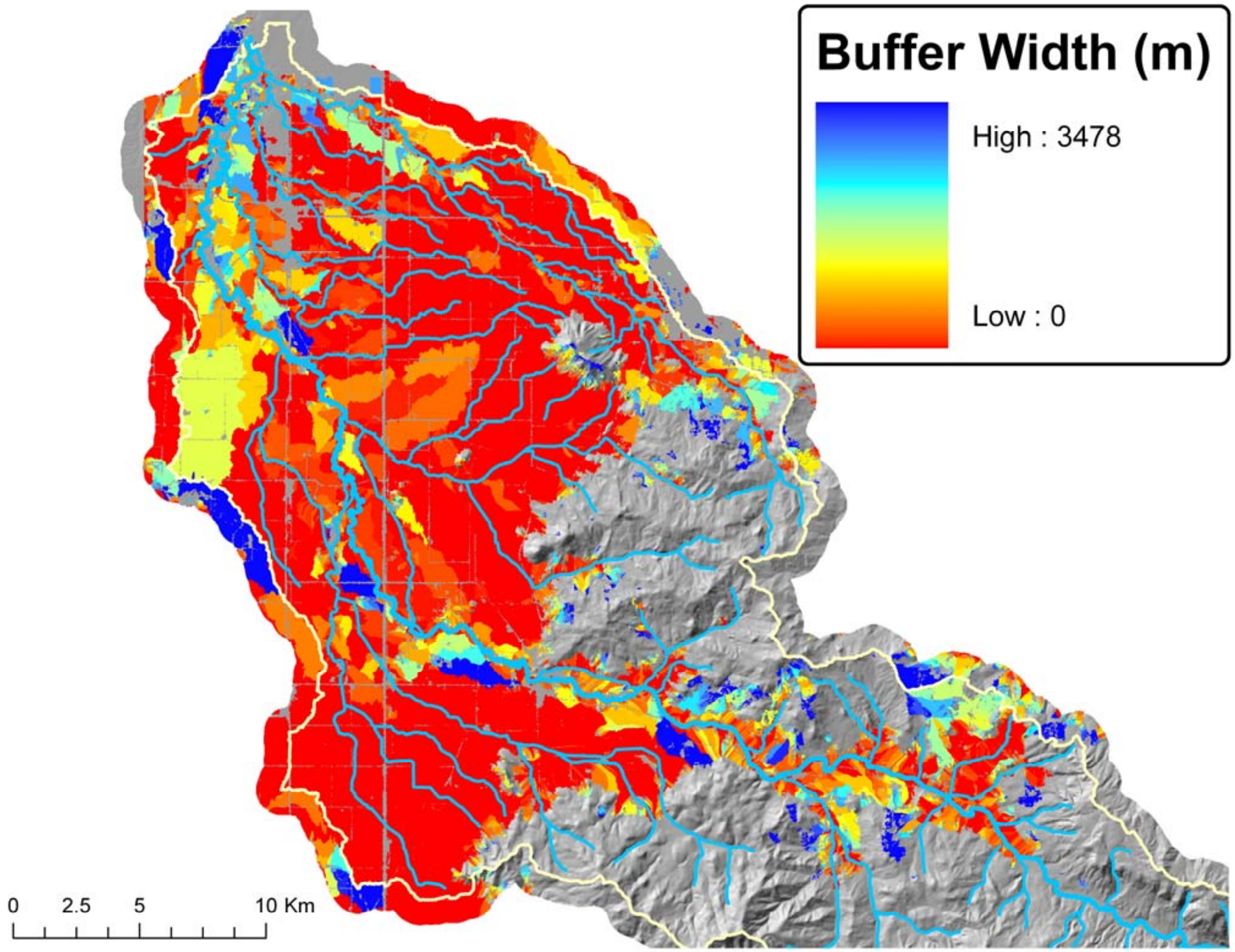
GIS Riparian tool

- Resulting in GIS outputs for:
- Buffer Width on Agricultural Lands



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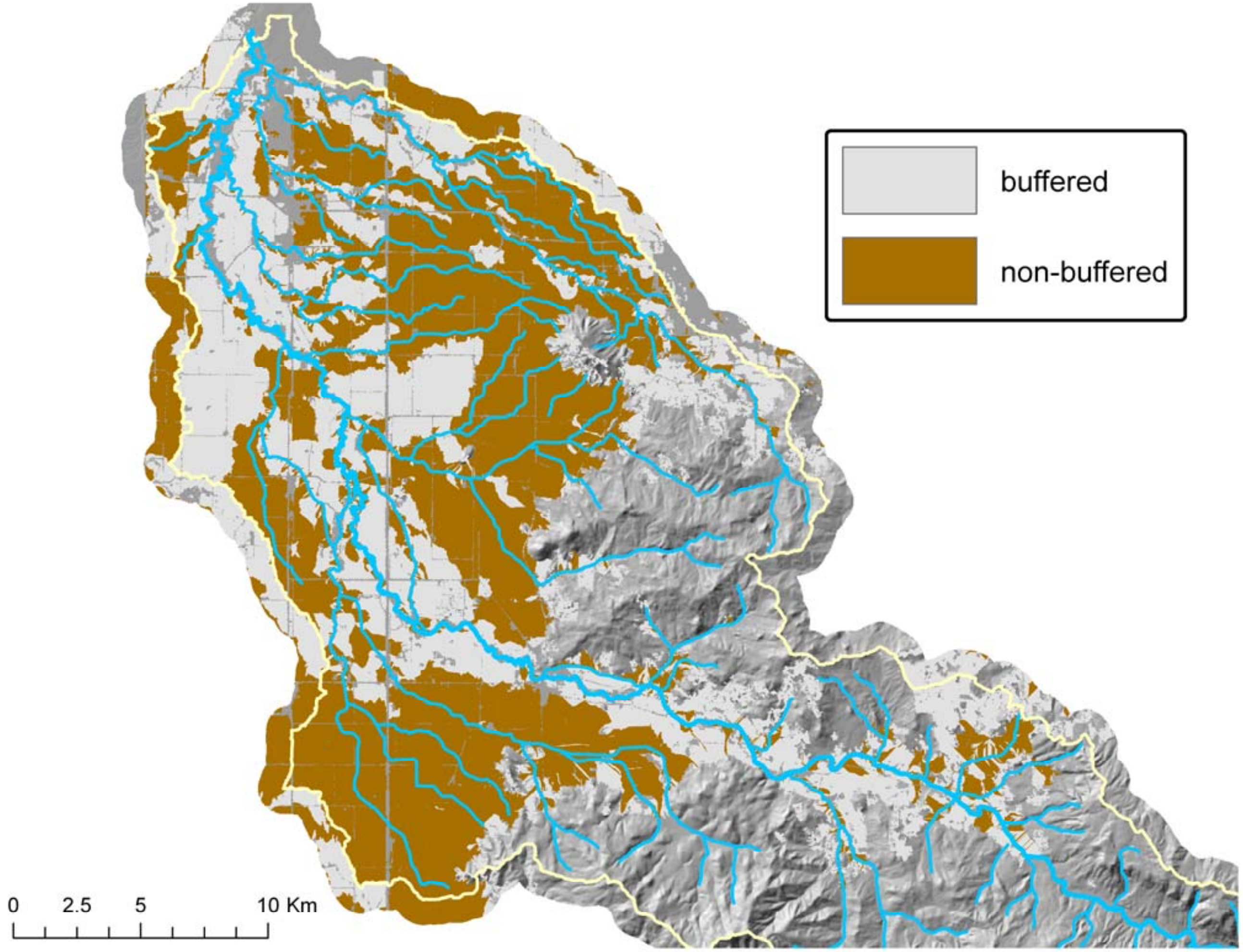
GIS Riparian tool

- Resulting in GIS outputs for:
- Non-Buffered agricultural lands



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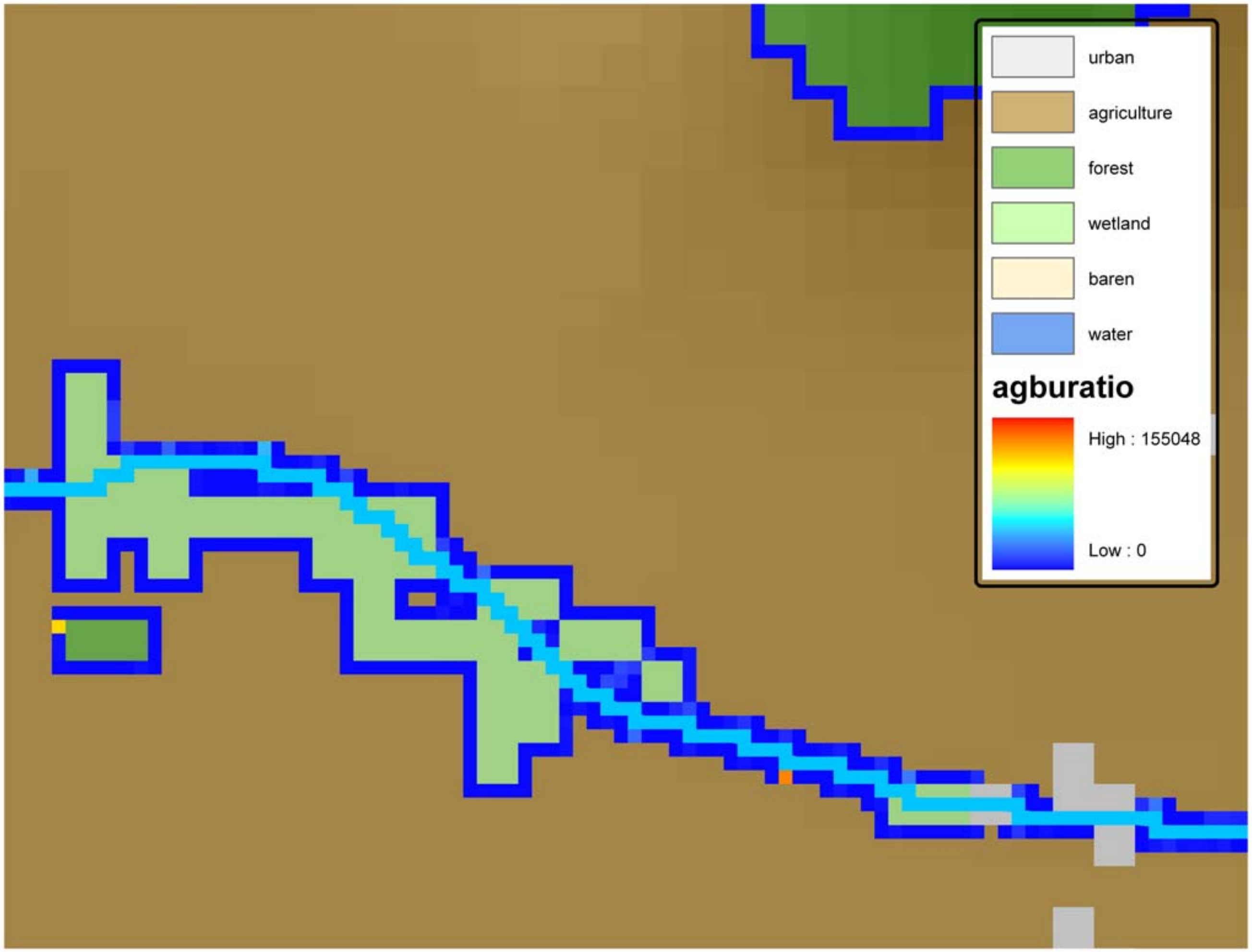
GIS Riparian tool

- Resulting in GIS outputs for:
- Agricultural accumulation / Buffer Width Ratio



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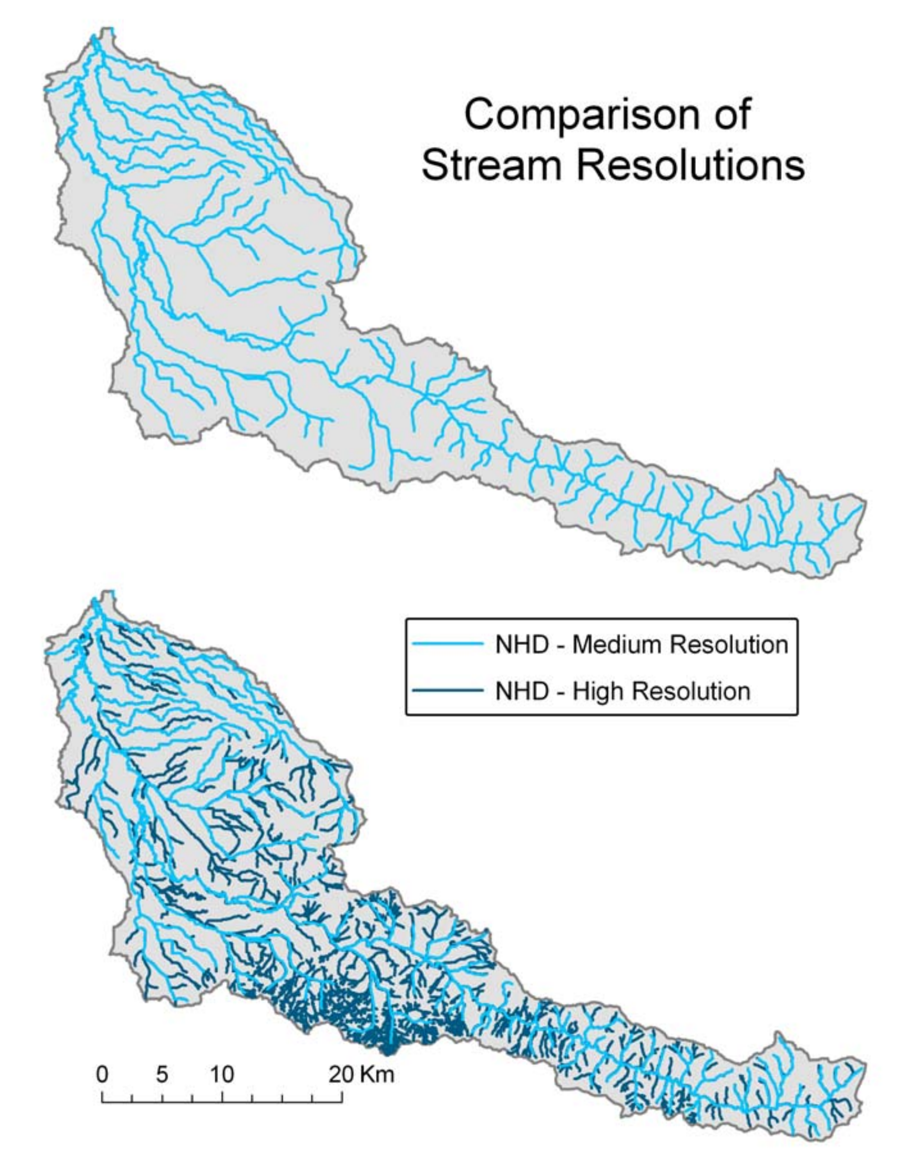
GIS Riparian tool

- Resulting metrics and subsequent interpretation are influenced by the resolution of the inputs

Data availability & Computational capacity

versus

Representation of reality



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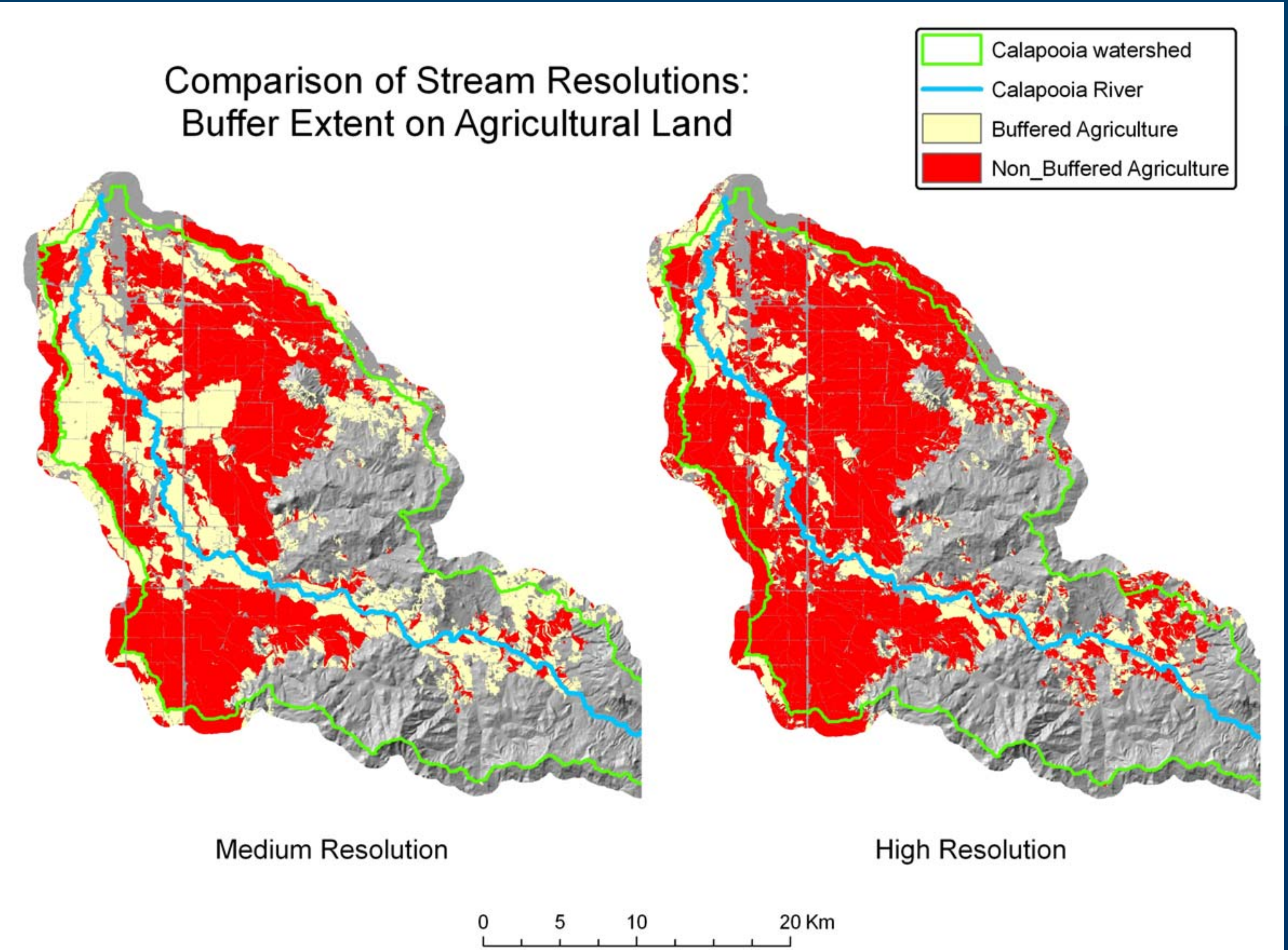
GIS Riparian tool



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GIS Riparian tool

- Riparian tool creates buffer width for each agricultural cell

- Ability of Riparian Buffers to retain nutrients
  - Baker et al. 2007 reviewed empirical studies and generalized buffers as:

  - Leaky - 5% nutrient retention / 10m buffer
  - Retentive – 60% nutrient retention / 10m buffer

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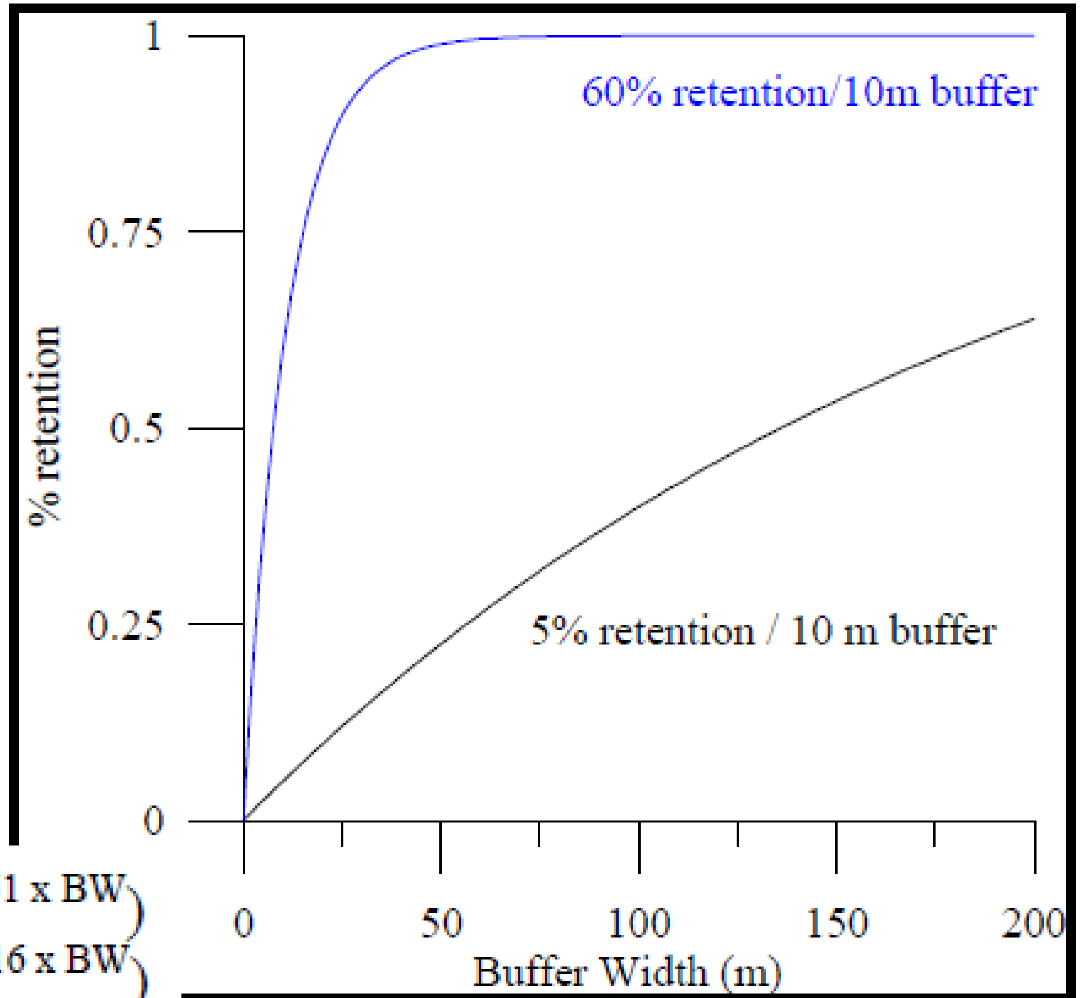
GIS Riparian tool

- Exponential equation developed
- Applied to the buffer width of each ag cell



$$\text{Buffer Retention}_{5\%} = 1 - (e^{-.0051 \times BW})$$
$$\text{Buffer Retention}_{60\%} = 1 - (e^{-.0916 \times BW})$$

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GIS Riparian tool

- Simple Model of Potential Nitrogen Retention
- Why it's simple and potential:
- Assumptions
  - All source cells equal in nutrient load = 1
  - All source cells equal in loss and transport
  - All Buffer cells equal in nutrient retention
    - 5% or 60% retention scenarios
  - Hydrologic load not considered
  - Surface Hydrology

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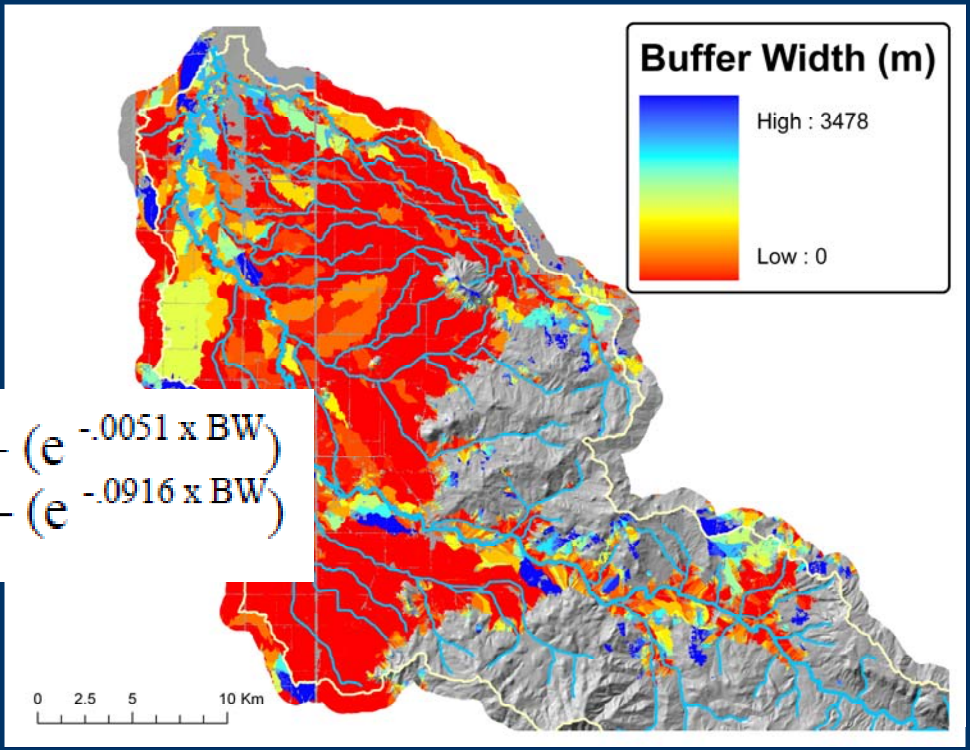
GIS Riparian tool

- Simple Model of Potential Nitrogen Retention



$$\text{Buffer Retention}_{5\%} = 1 - (e^{-.0051 \times BW})$$
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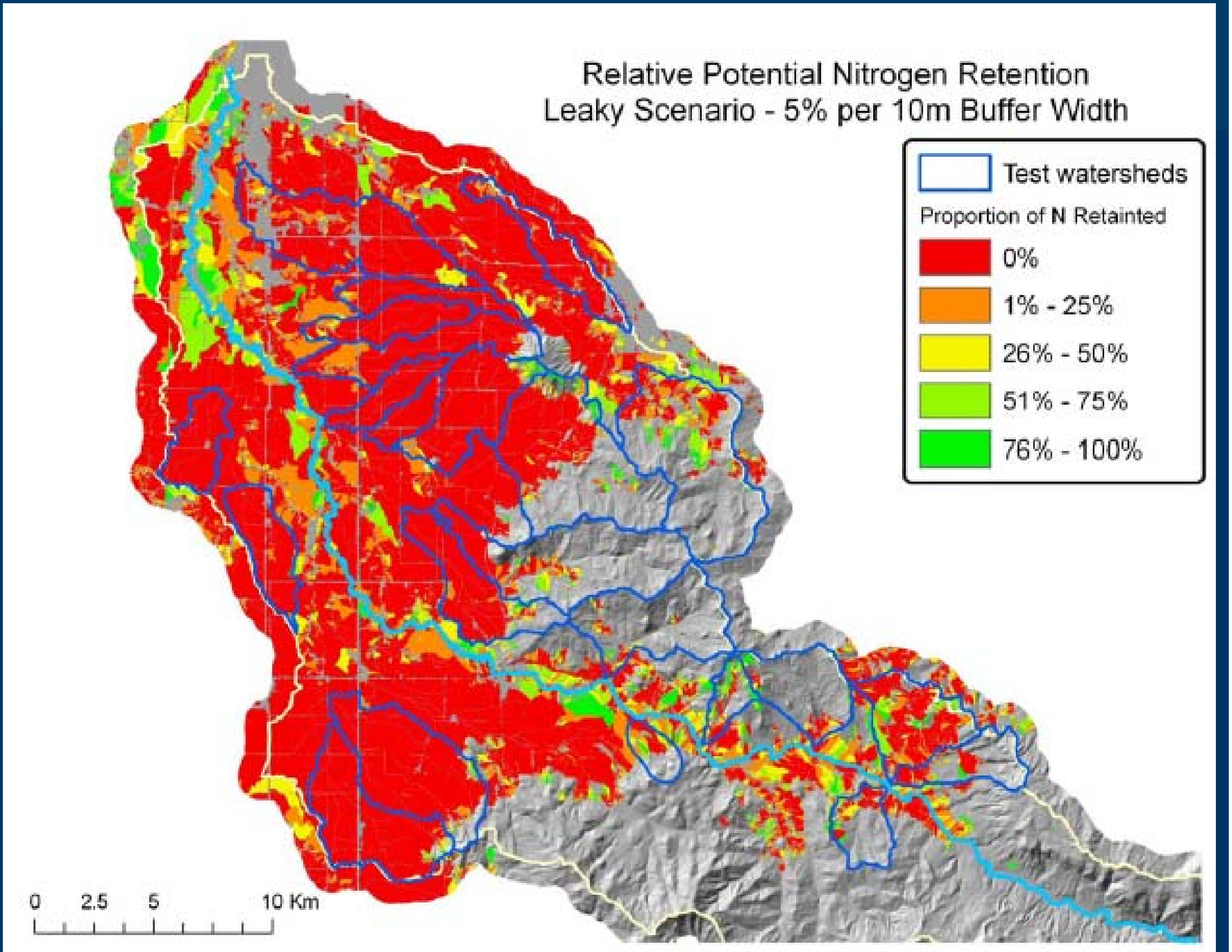
GIS Riparian tool



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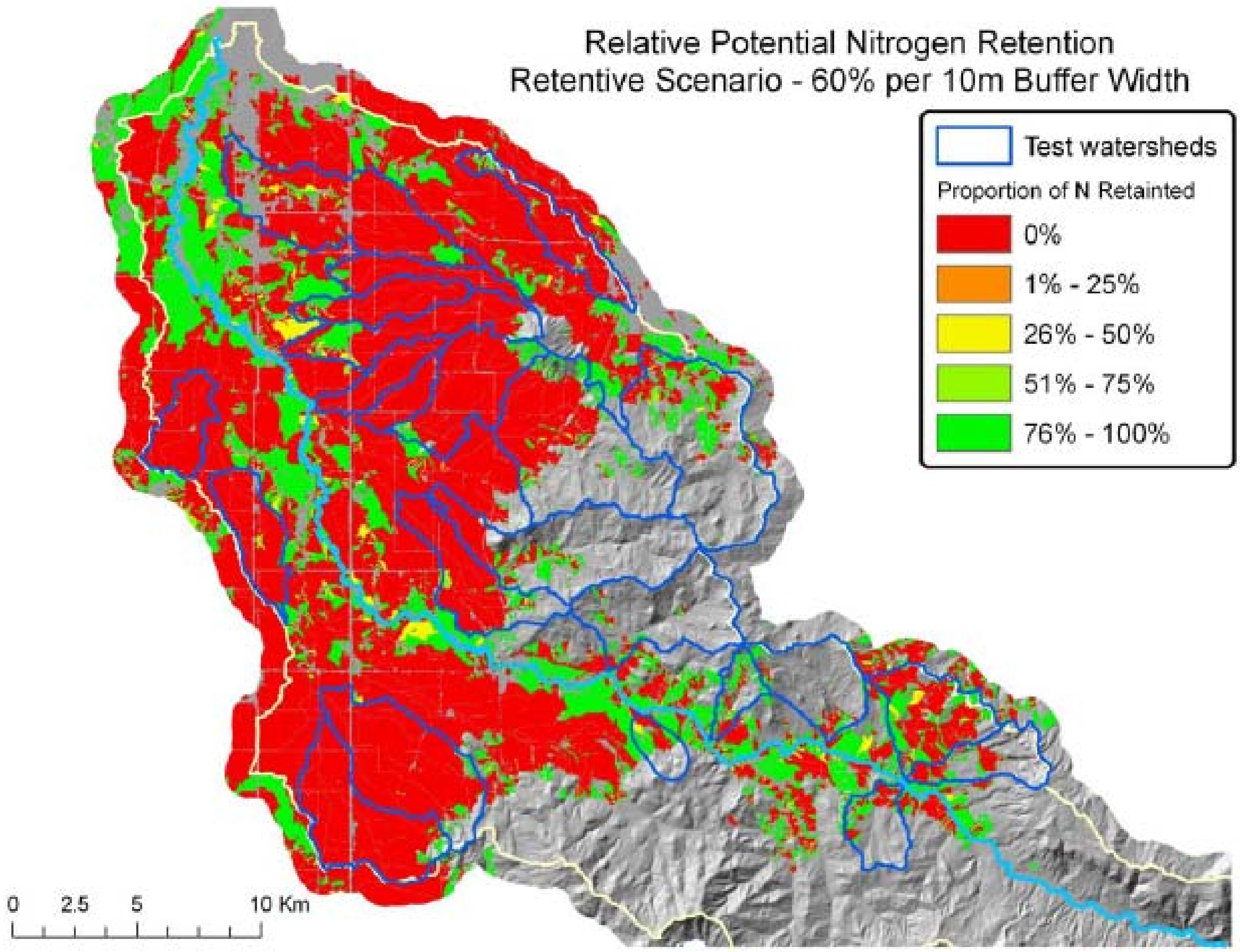
GIS Riparian tool



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GIS Riparian tool

Next Steps: Simple Riparian Model

- Assumptions
  - All source cells equal in nutrient load
    - Use of cropland data, atmospheric deposition, proximity to CAFOs
  - All source cells equal in loss and transport
    - Incorporate soils, slope, CN
  - All Buffer cells equal in nutrient retention
    - Differentiate wetlands, hydric soils, Mayer et al 2007
  - Hydrologic load not considered
    - CN GIS tool to determine relative load
    - Seasonal effectiveness

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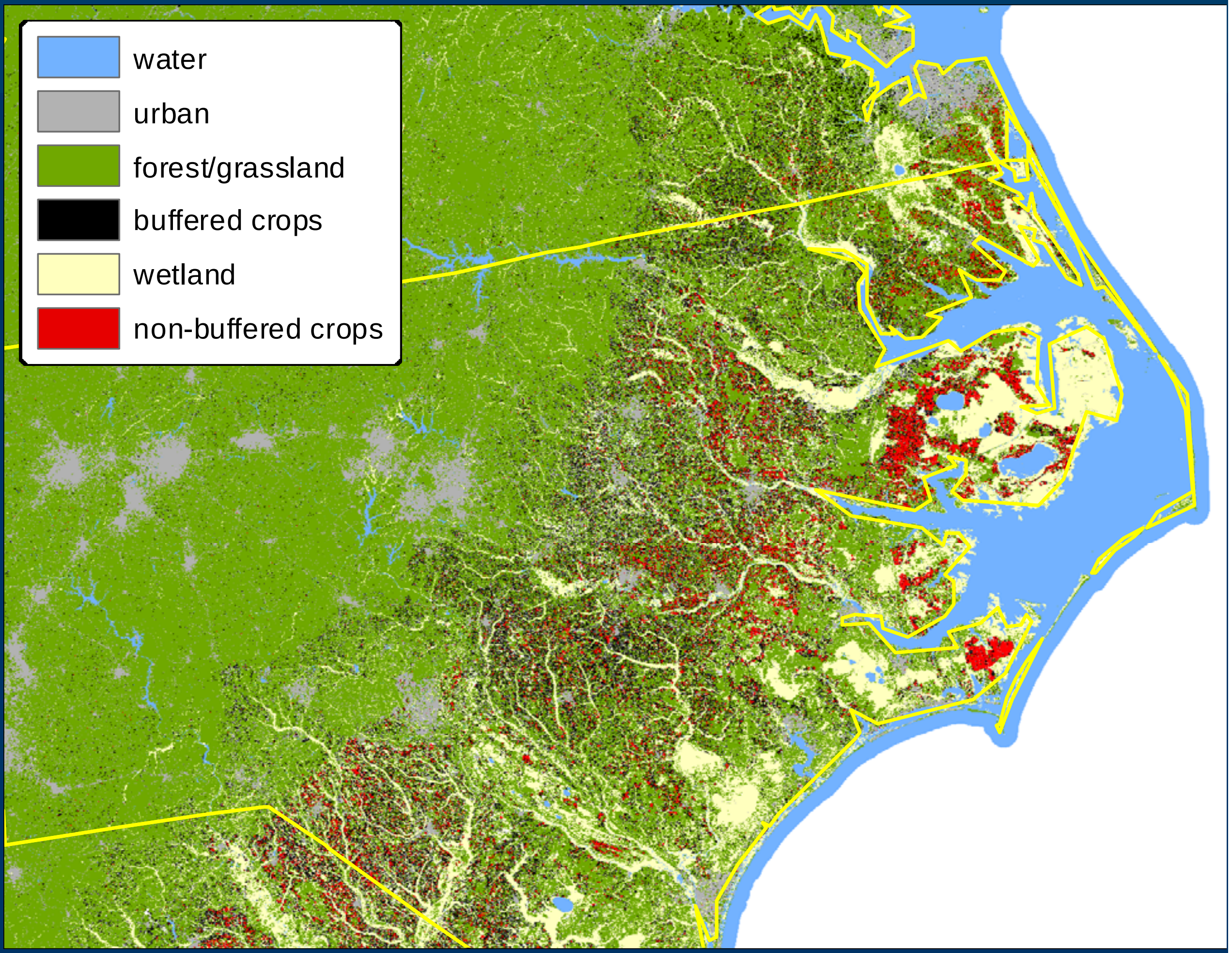
GIS Riparian tool

Next Steps:

- Riparian Tool
  - Relationship between stream nutrients and metrics – Willamette and NC/SC



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GIS Riparian tool

Next Steps: Simple Riparian Model

- Limitations:
  - Continued assumption that hydrology of system is surface/shallow sub-surface driven
  - Interaction of upland and riparian considered, riparian and stream interaction ignored
  - Dependent on 30m resolution land cover
  - Lack of validation
    - Relate model to WQ measurements
    - Selection of smaller watersheds to validate

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GIS Riparian tool

Next Steps: Simple Model

- Challenges:
  - Inclusion of uncertainty/error
    - in Riparian tool – inputs: landcover, streams
    - in model and improvements, such as nitrogen loads
  - Data for Validation
  - Variability
    - Effectiveness of retention
    - Temporal

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Potential Removal by Sited Wetlands

Pp. 29-42 in UMRSHNC (Upper Mississippi River Sub-basin Hypoxia Nutrient Committee). 2008. *Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop*. St. Joseph, Michigan: ASABE.

Potential of Restored and Constructed Wetlands to Reduce Nutrient Export from Agricultural Watersheds in the Corn Belt

3

William G. Crumpton, Department of Ecology, Evolution, and Organismal Biology, Iowa State University
David A. Kovacic, Department of Landscape Architecture, University of Illinois
Donald L. Hey, The Wetlands Initiative
Jill A. Kostel, The Wetlands Initiative

Potential Benefits of Wetland Filters for Tile Drainage Systems: Impact on Nitrate Loads to Mississippi River Subbasins

Final project report to U.S. Department of Agriculture
Project number: IOW06682

*Crumpton, W. G., G. A. Stenback, B. A. Miller, and M. J. Helmers

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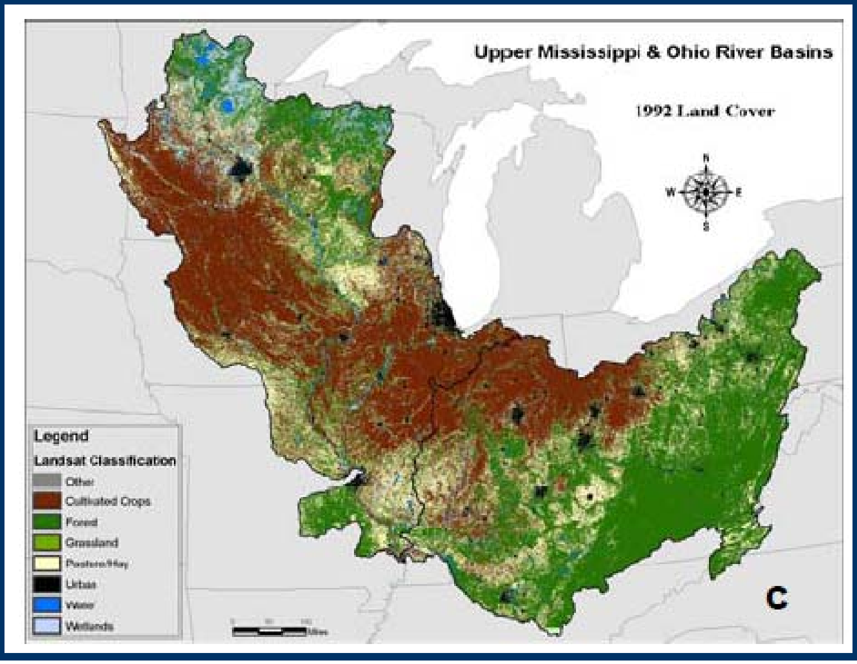
Potential Removal by Sited Wetlands

Crumpton et al. 2006, 2008

- Goal: “to provide an assessment of nitrate concentrations and loads across the UMR and Ohio River basins and the mass reduction of nitrate loading that could be achieved using wetlands to intercept nonpoint source nitrate loads.”



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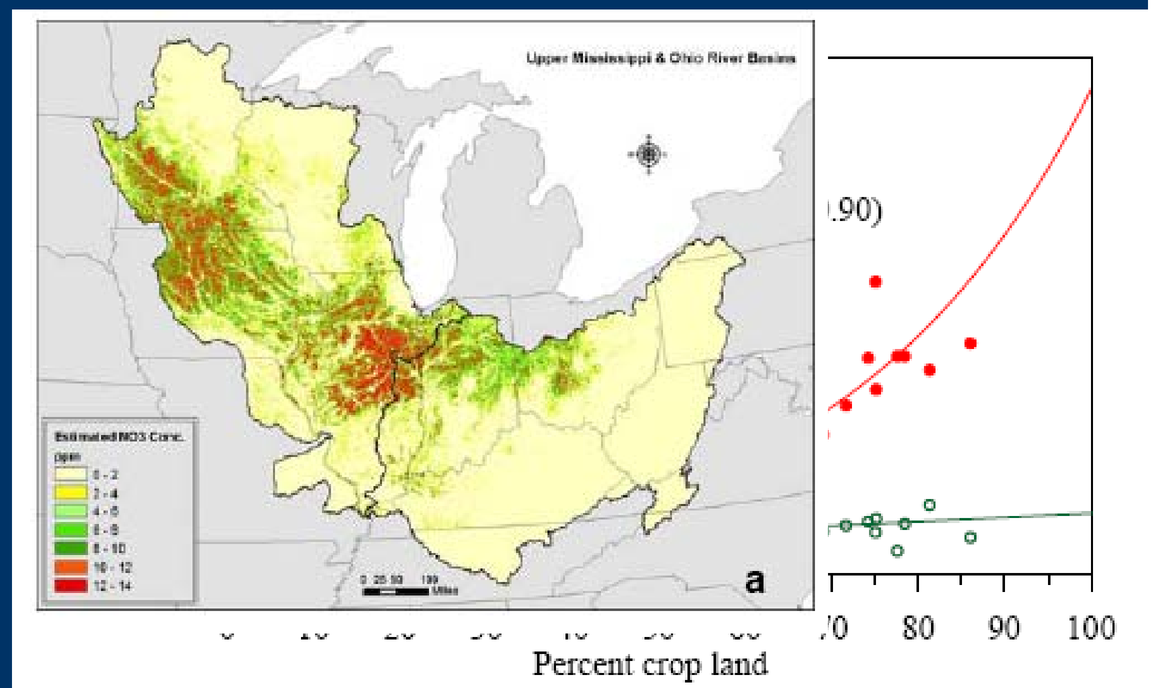
Potential Removal by Sited Wetlands

Crumpton et al. 2006, 2008

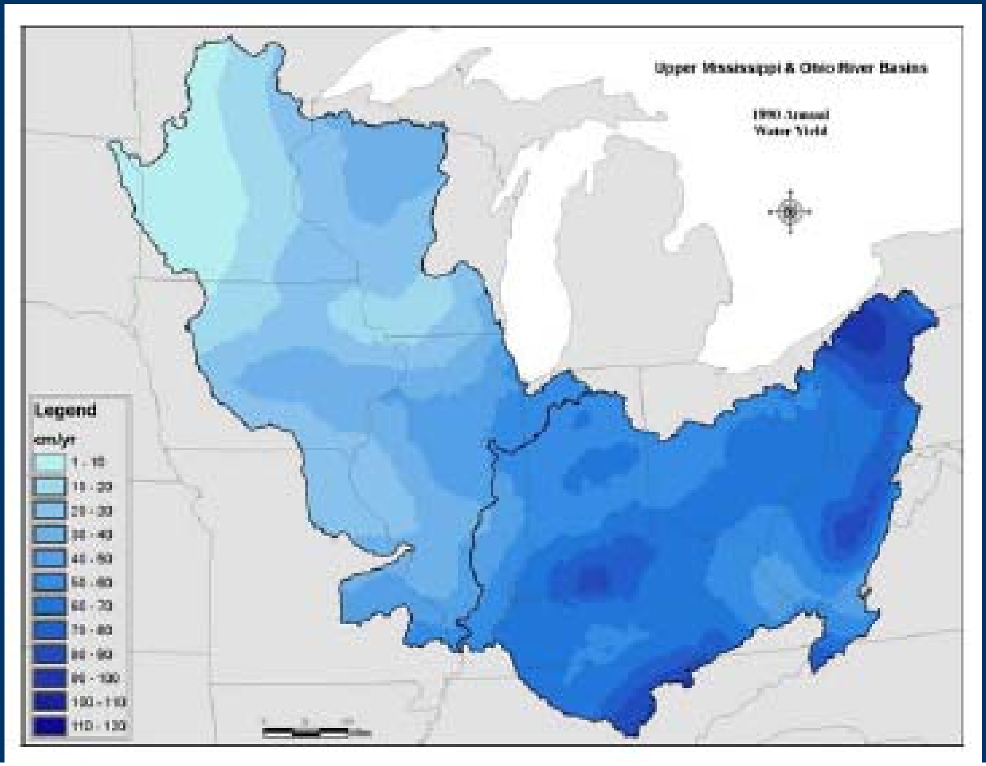
- Methods:
- Nitrate concentration and stream discharge data used to calculate annual flow-weighted average (FWA) nitrate concentrations
- Applied FWA model to 1 km^2 grid cells across the UMR and Ohio River basins.
- Model FWA nitrate concentration based on land use



Potential Removal by Sited Wetlands

Crumpton et al. 2006, 2008

- Methods:
- Annual water yield estimated by interpolating over selected USGS monitoring stations



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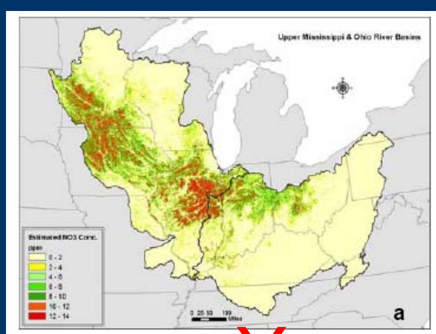
Potential Removal by Sited Wetlands

Crumpton et al. 2006, 2008

- Methods:
- FWA nitrate concentrations and water yield provide estimate of annual mass nitrate export of each grid cell in UMR and Ohio River Basin



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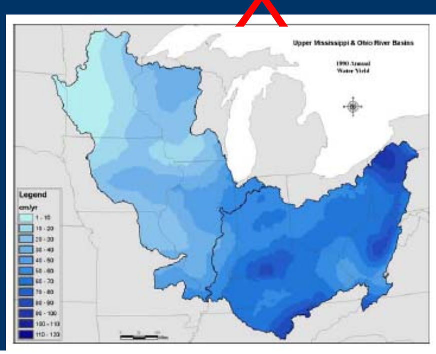

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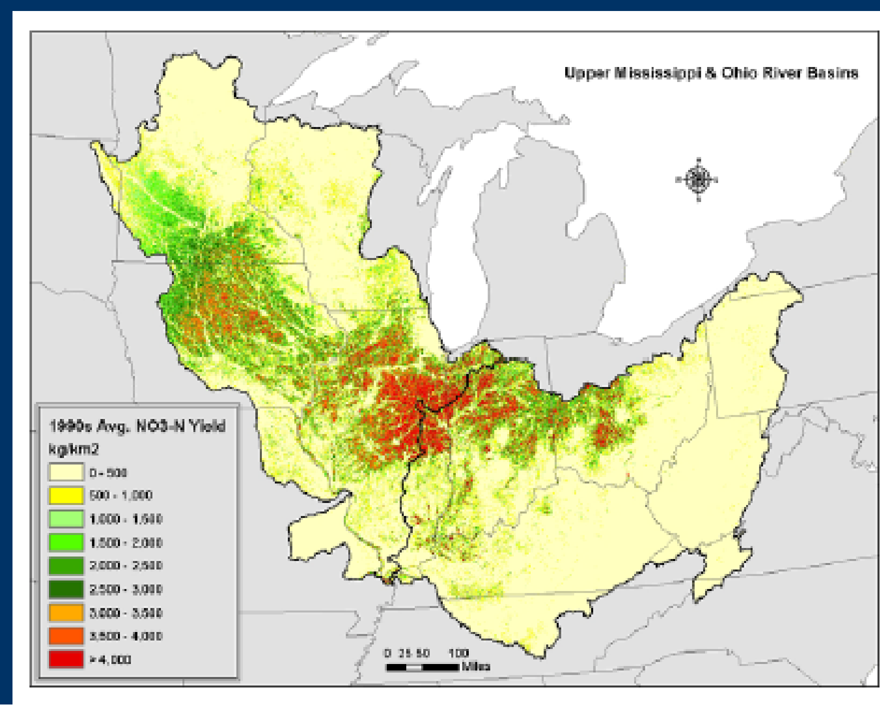

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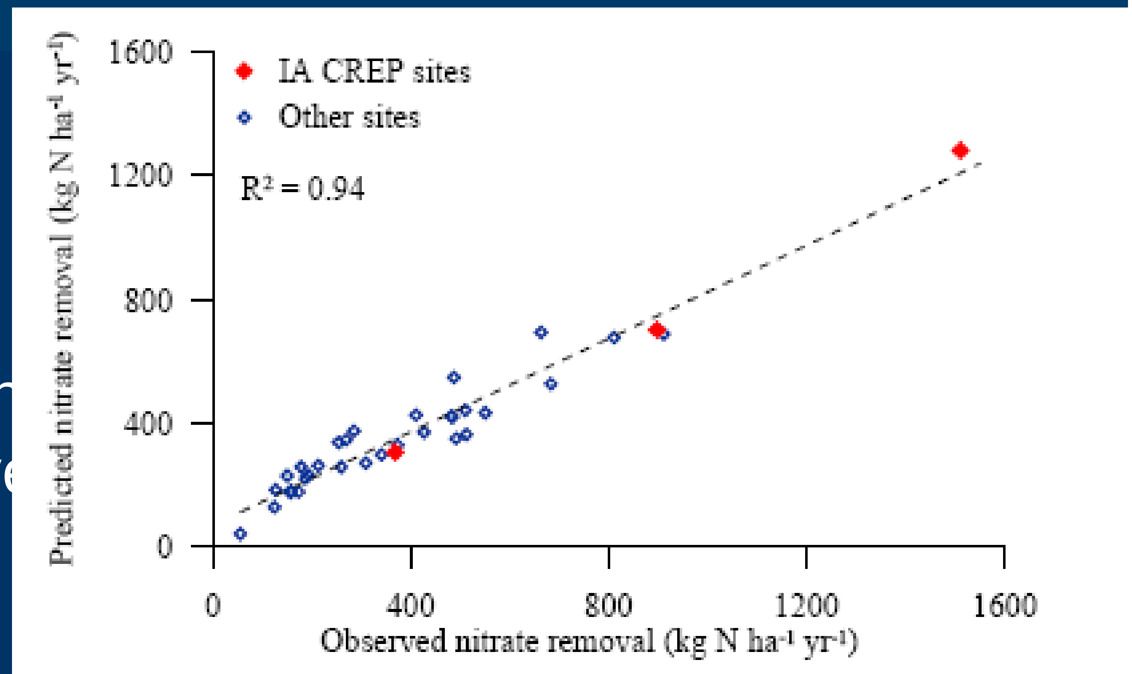
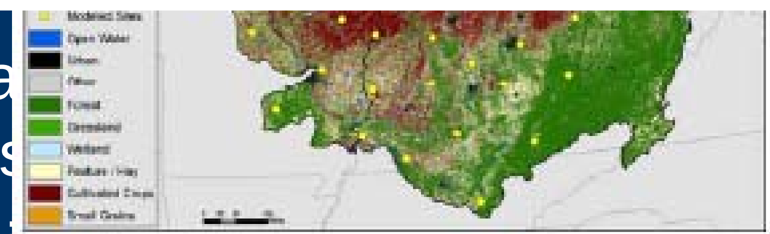
Potential Removal by Sited Wetlands

Crumpton et al. 2006, 2008

- Methods:
- To estimate potential
  across the same grid
  were used
  - Hypothetical wetlan
    UMR and Ohio Rive





  - Nitrate removal was estima
    dependent, area-based, firs
  - Empirically tested across sites in Iowa and validated
    in sites across UMR and Ohio River Basins

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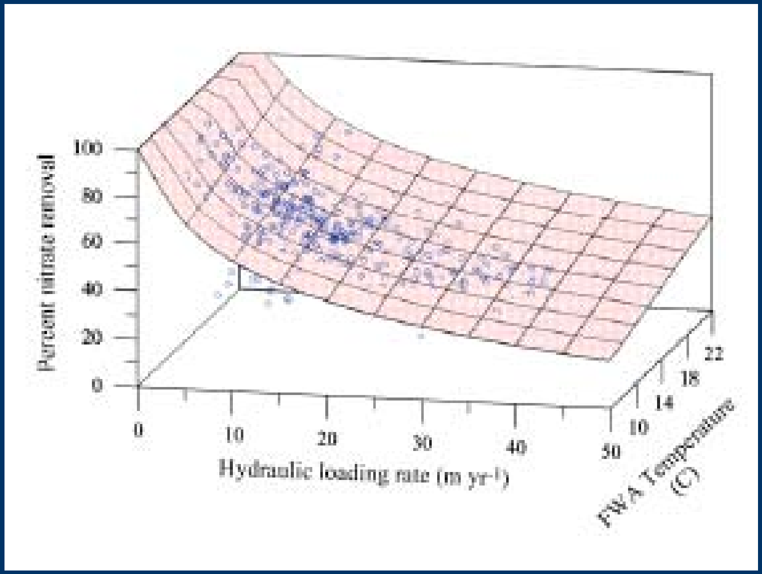
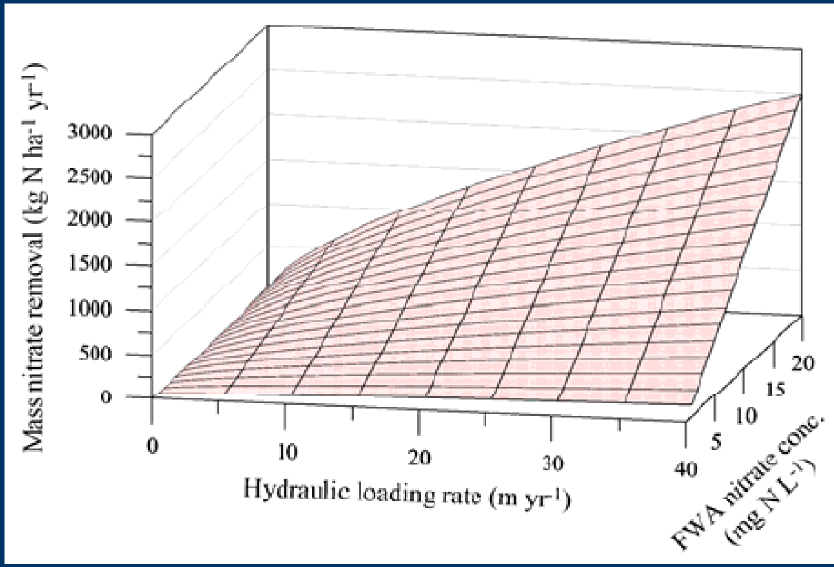
Potential Removal by Sited Wetlands

Crumpton et al. 2006, 2008

- Methods:
- Developed a nonlinear model for percent nitrate removal as a function of hydraulic loading rate (HLR) and temperature





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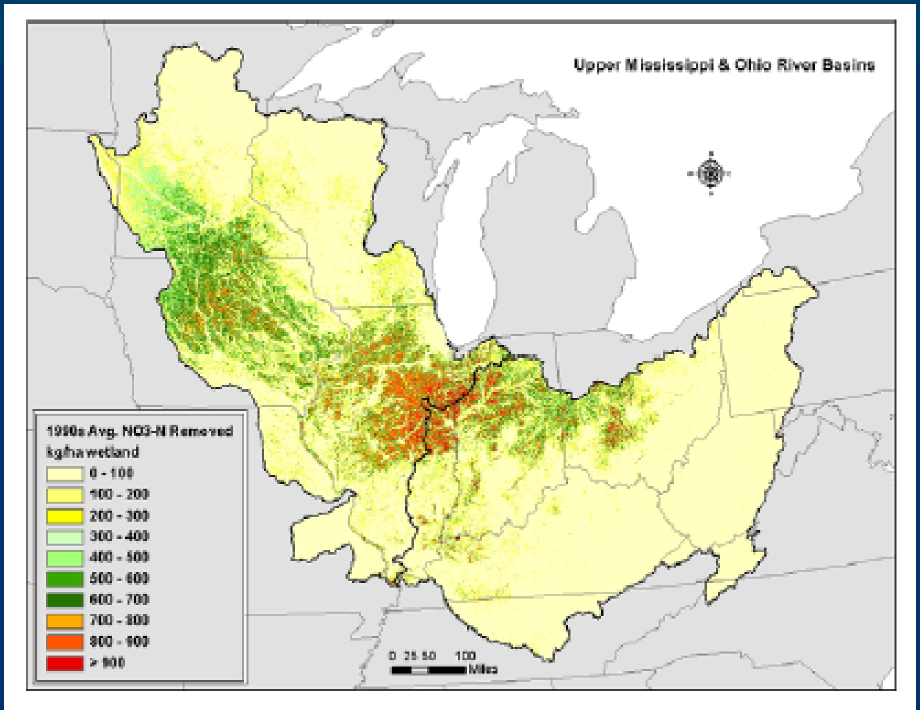
Potential Removal by Sited Wetlands

Crumpton et al. 2006, 2008

- Results:



- Mass nitrate removal for potential wetland restorations estimated using expected mass load and the predicted percent removal (function of HLR).

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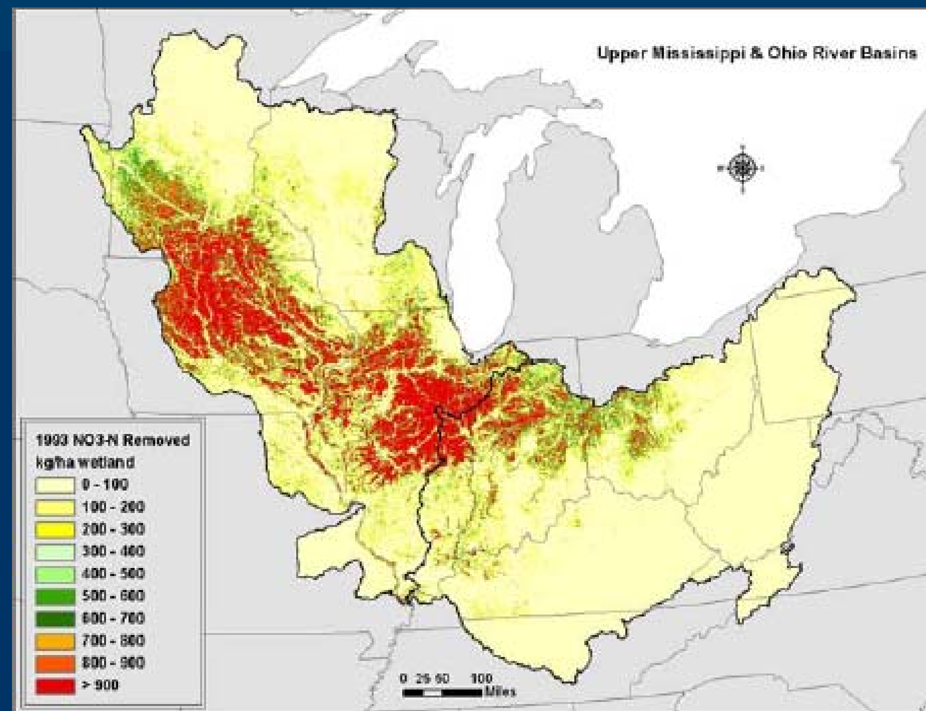
Potential Removal by Sited Wetlands

Crumpton et al. 2006, 2008

- Results:



1993

- Annual variability in when and where wetness occurs dramatically shifts the nitrogen removal

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Potential Removal by Sited Wetlands

- Application
  - Acquisition of nutrient data in the Coastal Plain of North and South Carolina is underway
  - Relationship of FWA to landcover first step
    - Influence of CAFOs
    - Atmospheric deposition
  - Collaborating with Crumpton lab to incorporate wetland modeling
    - Affect of higher temperatures on removal
    - Variability of soils, groundwater
    - Fate of ammonium
- Sites for validation needed (Hunt et al. 1999)

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Potential Removal by Sited Wetlands

- Limitations:
  - Related to surface water inputs
  - Assume FWA nitrate concentration LC relationship is reasonable estimate of nitrate concentrations
  - FWA/LC relationship and removal model only tested in corn belt
  - Potential removal related to 2% wetland/watershed ratio
    - Does not address removal from existing wetlands
    - Actual ratios difficult to determine

Summary

- 3 landscape approaches out of many
- Landscape insights:
  - Wetland type (salt versus fresh) can differ
  - Distribution of wetland type influences cumulative effect
  - Spatial location information essential
  - Resolution of data inputs influences metric outputs
  - Variability in wetland performance needs to be included
  - Strong relationship of removal and hydrologic loading
  - Percent reduction vs mass removed
  - Temporal variability influences the ecosystem service

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Challenges

- Data availability
  - Wetland land cover, data for nitrogen loading
- Resolution versus feasibility
- Validation of removal models
- Output resolution versus desired use of product
- Quantifying variability
  - Spatial and temporal