Agricultural landscapes viewed from a biogeochemical perspective

KBS LTER
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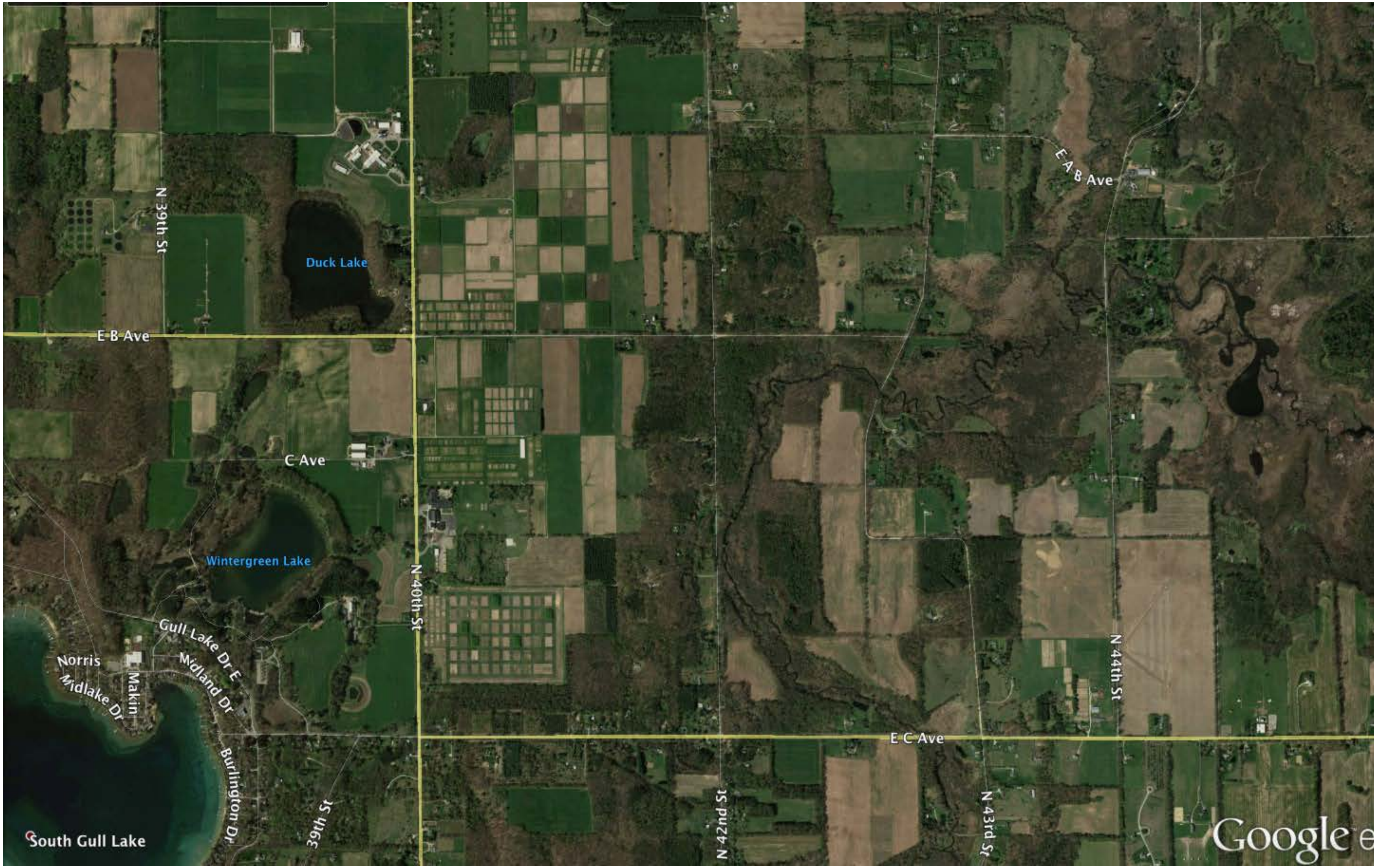
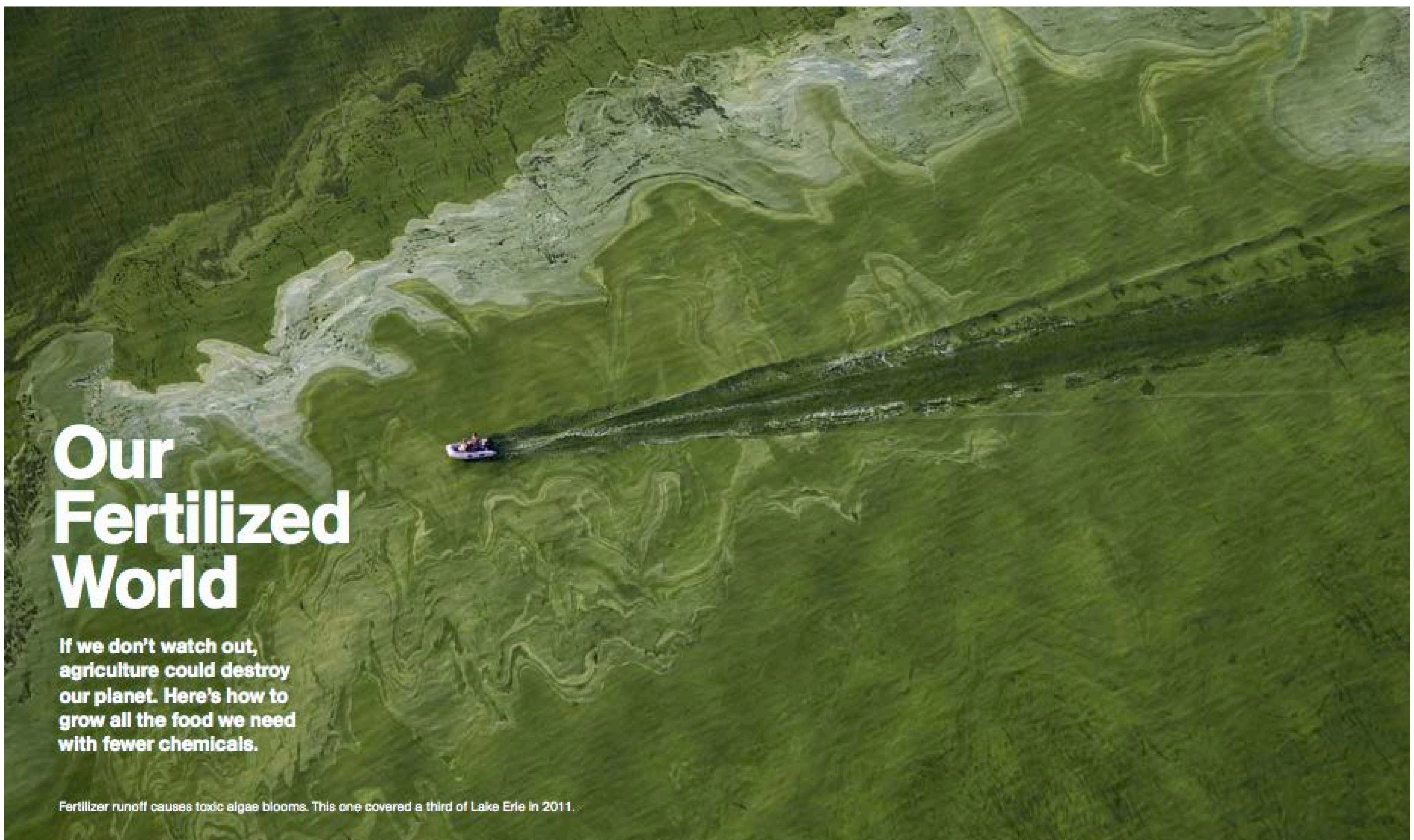
Long-term Ecological Research



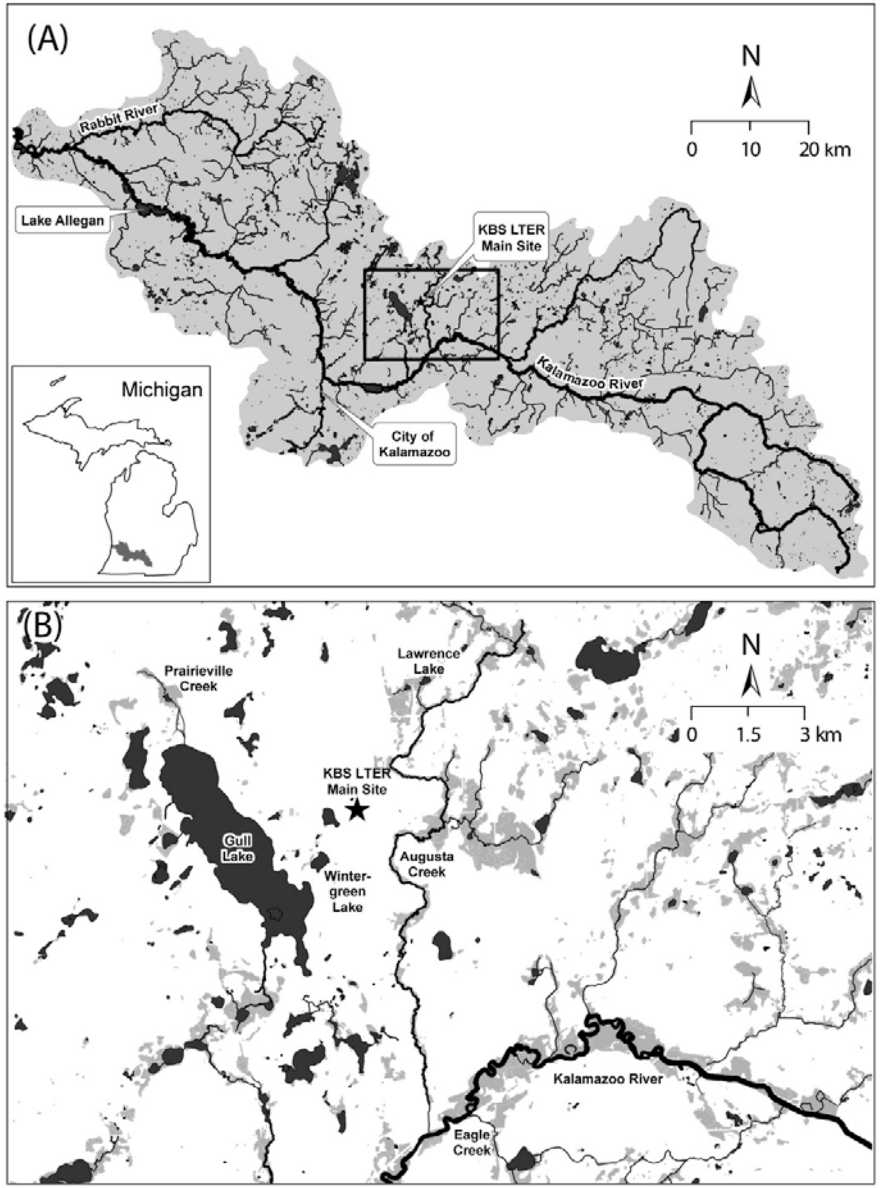
Stephen K. Hamilton, Kellogg Biological Station

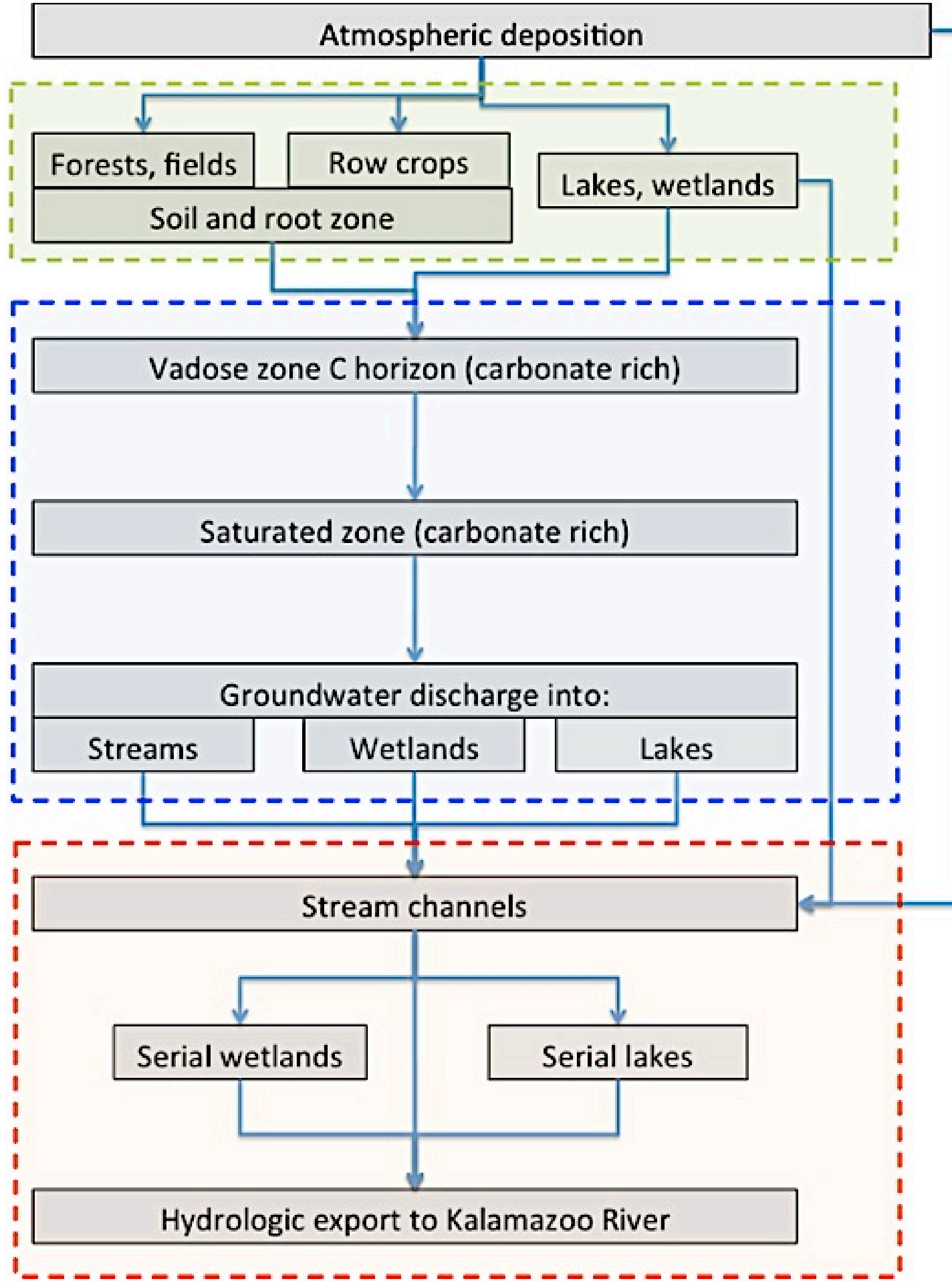
Biogeochemical ecosystem services (and disservices) extend from farms to landscapes

- Water balance and movement
- Hydrologic transport of nutrients and sediments
- Air emissions (not covered here)

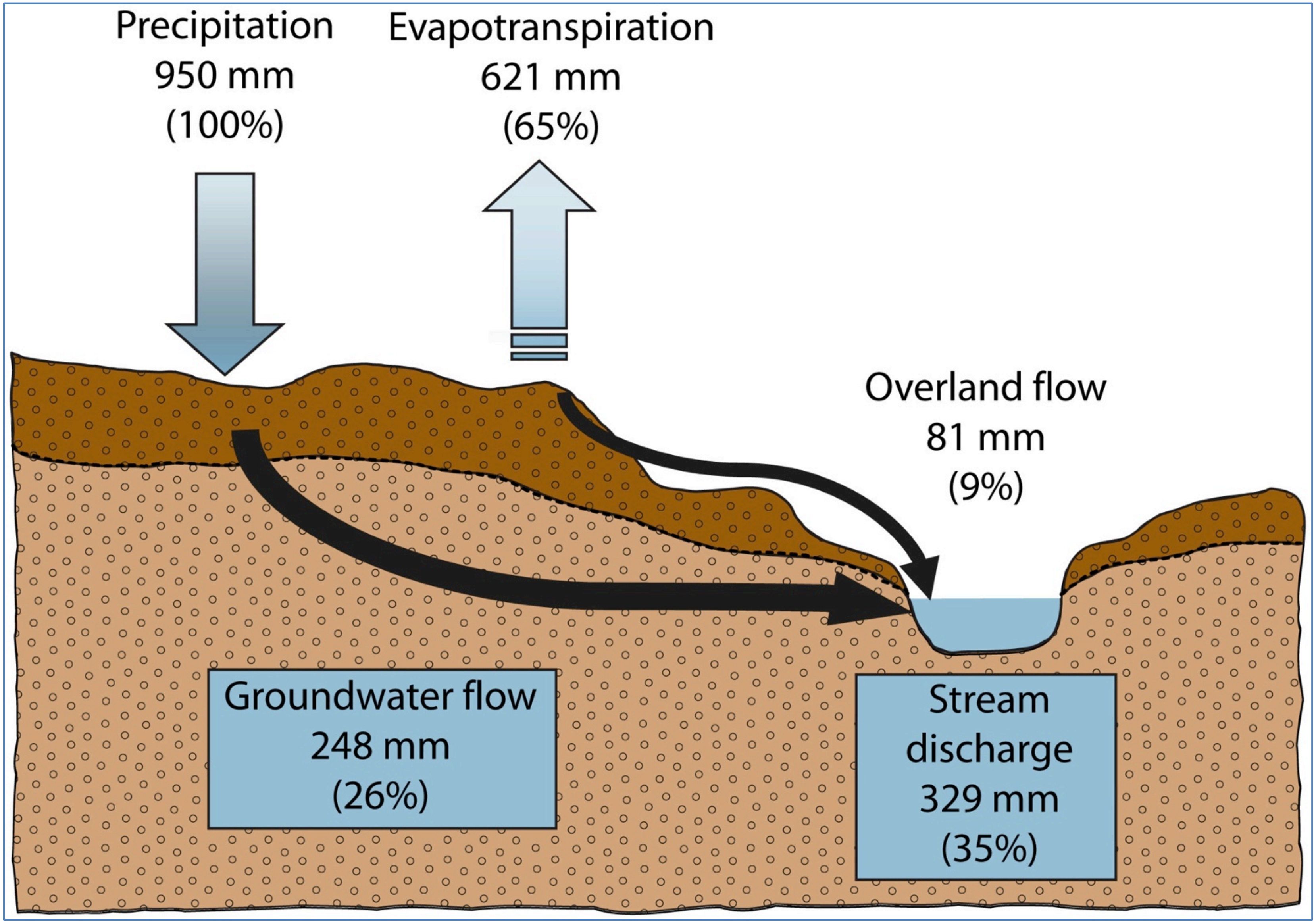


Landscape flow paths



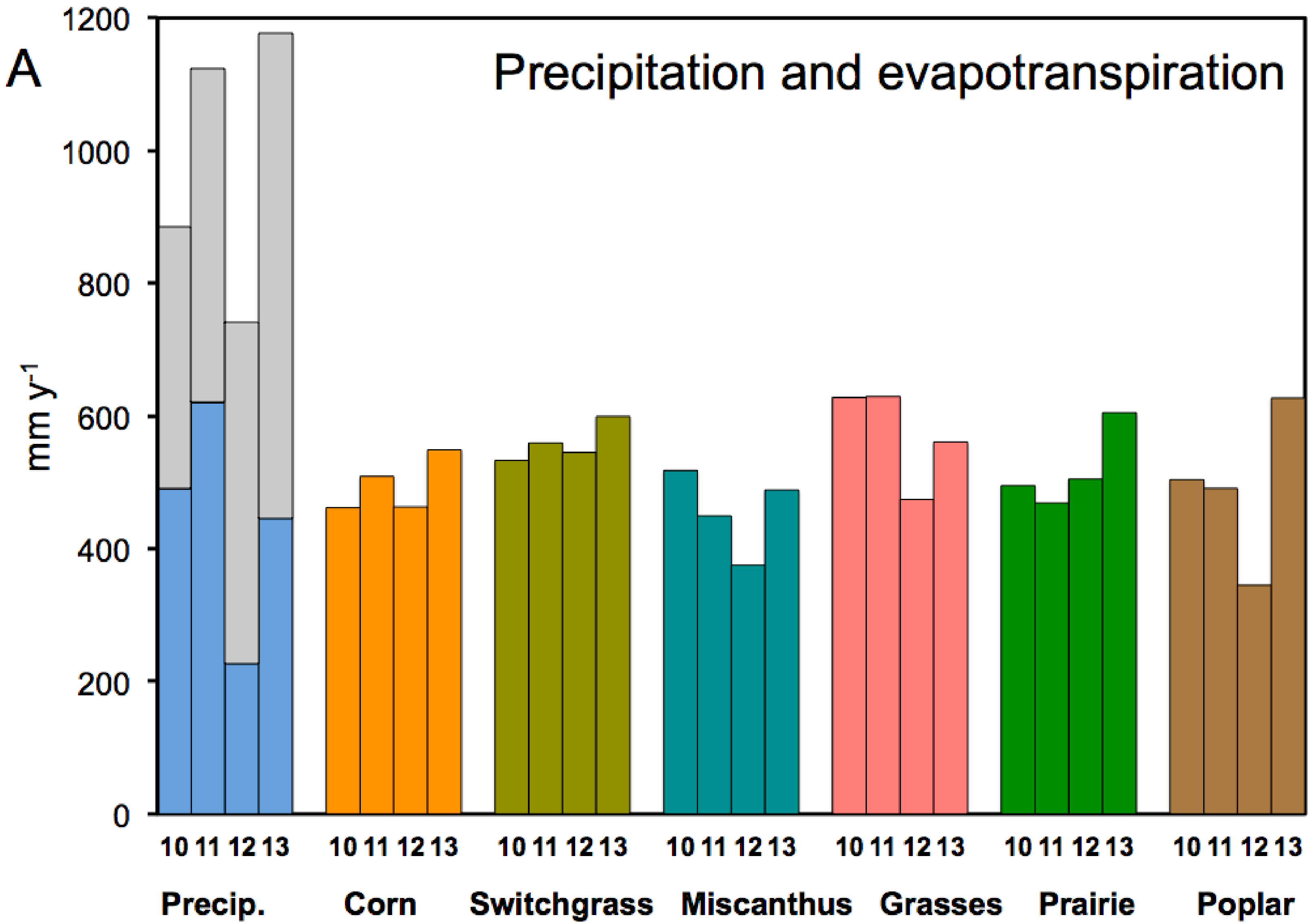


Terrestrial water balance for Augusta Creek



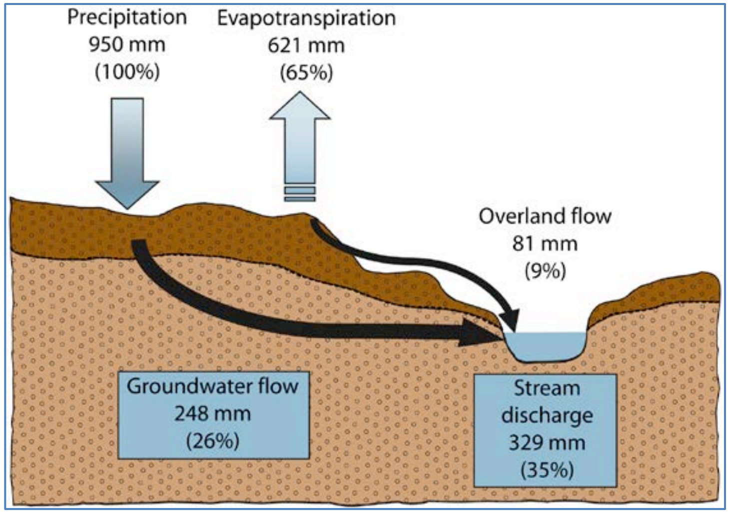
From data in Rheaume (1990) *USGS report*

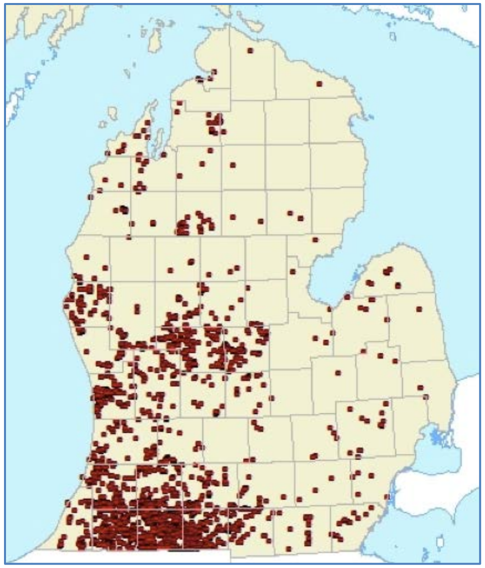
Evapotranspiration during the growing season

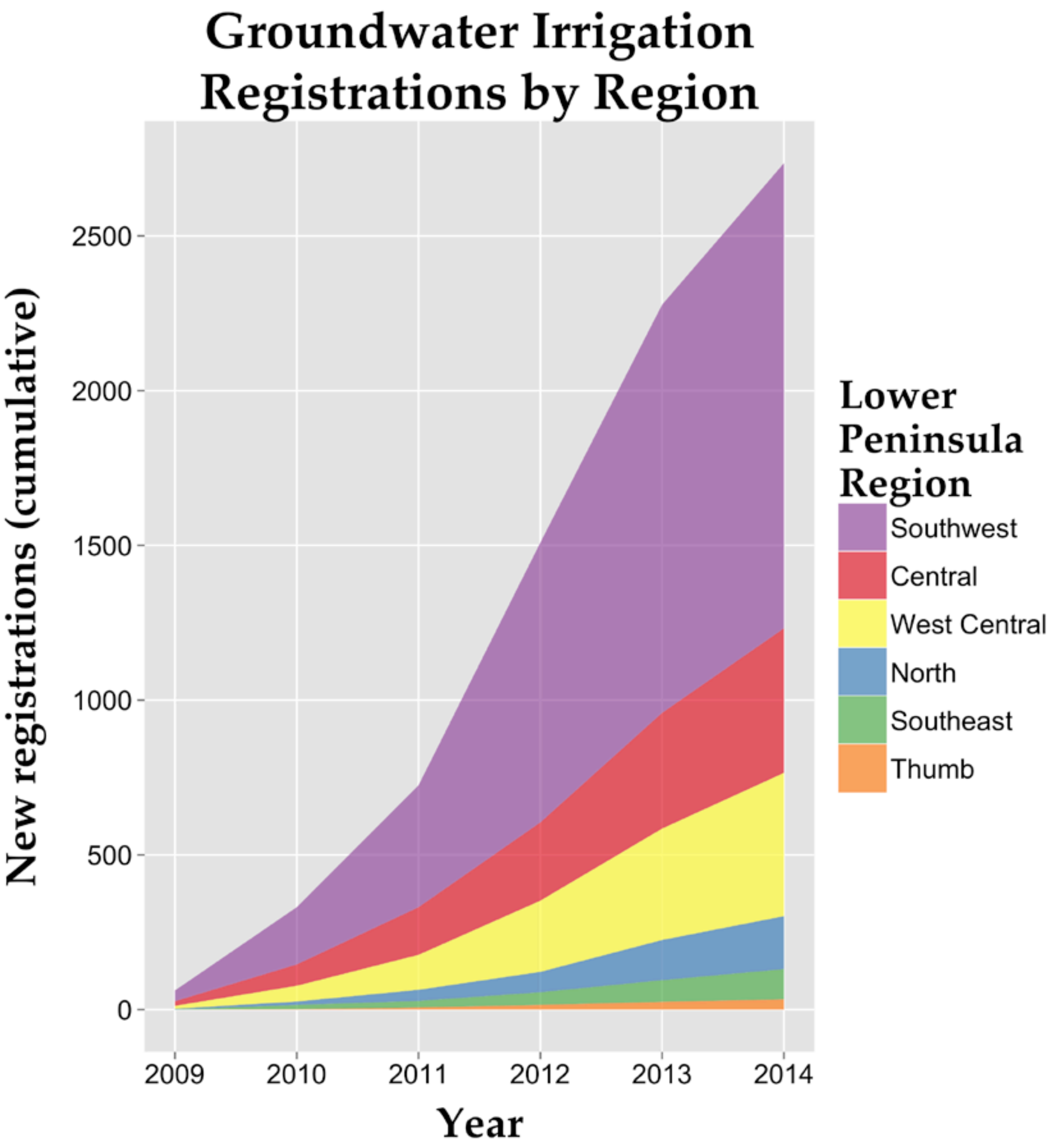


Hamilton et al., in revision, *ERL*

Irrigation is on the increase



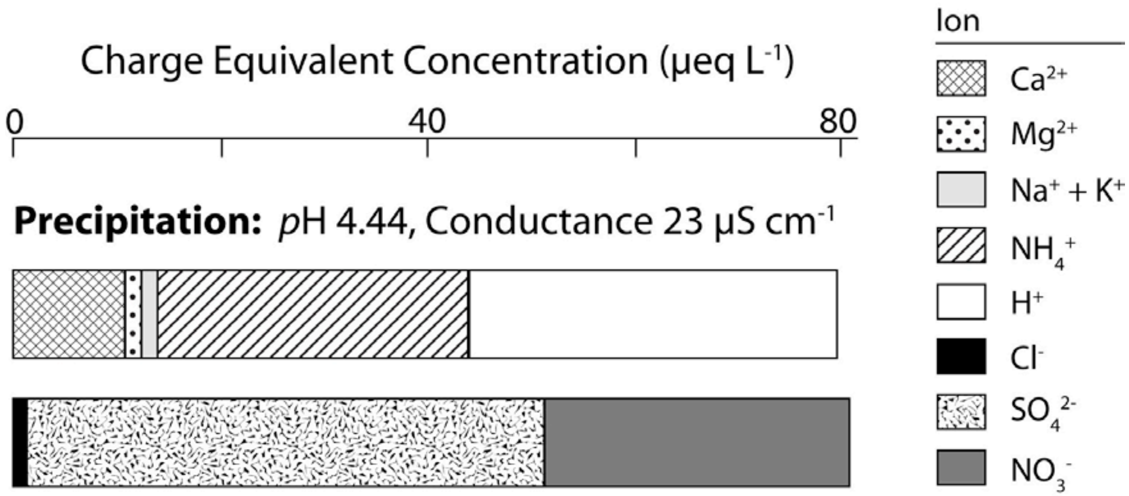


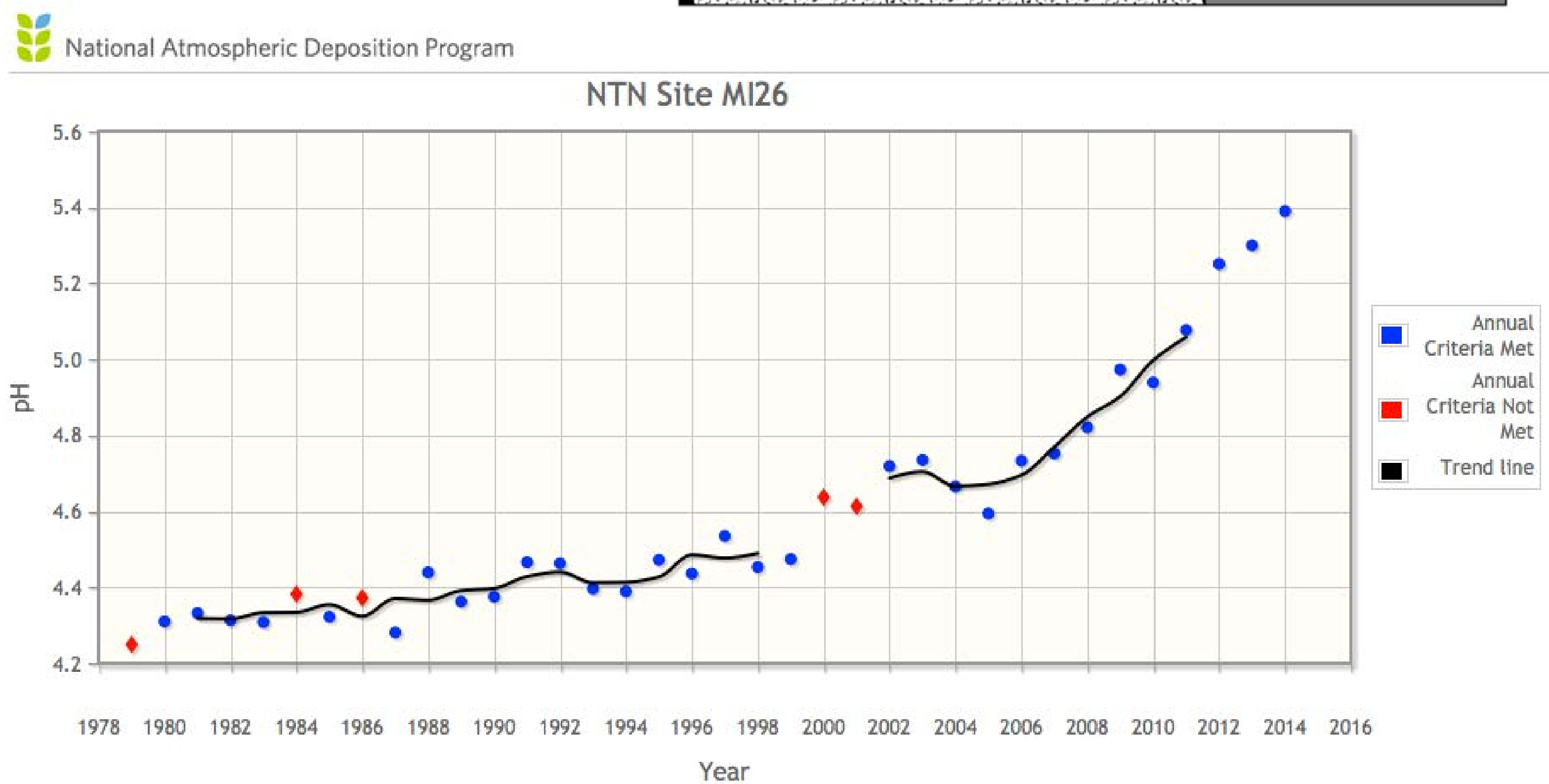


Data from MDEQ; chart by Bonnie McGill

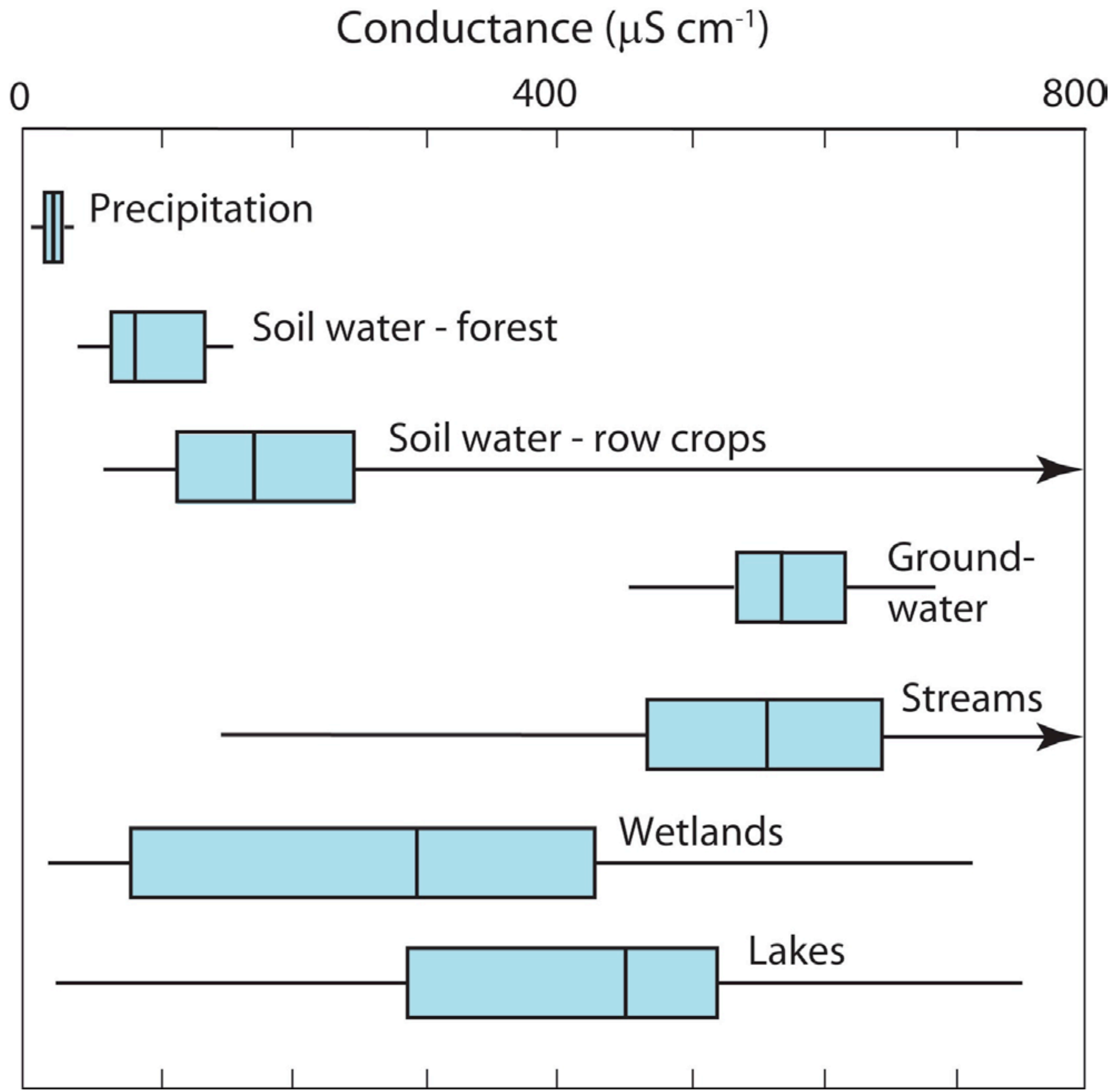
Precipitation chemistry

- It's getting better all the time!





Water acquires dissolved material as it flows through soils

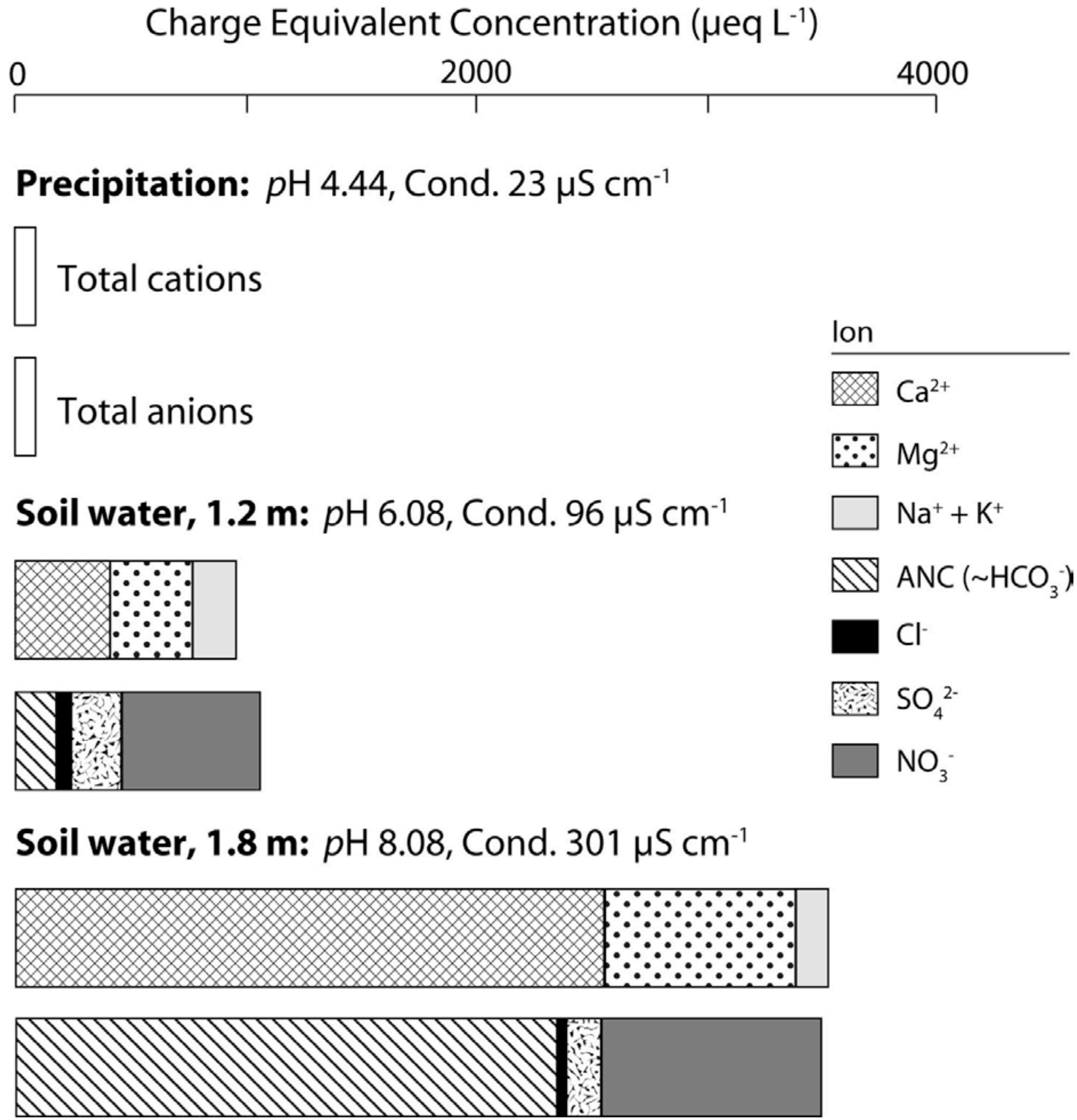


Hamilton (2015) *LTER synthesis book*

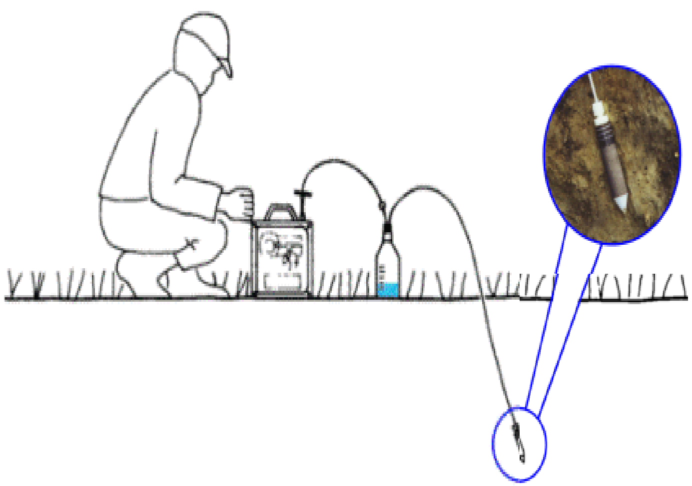
Chemical changes as water percolates through soils

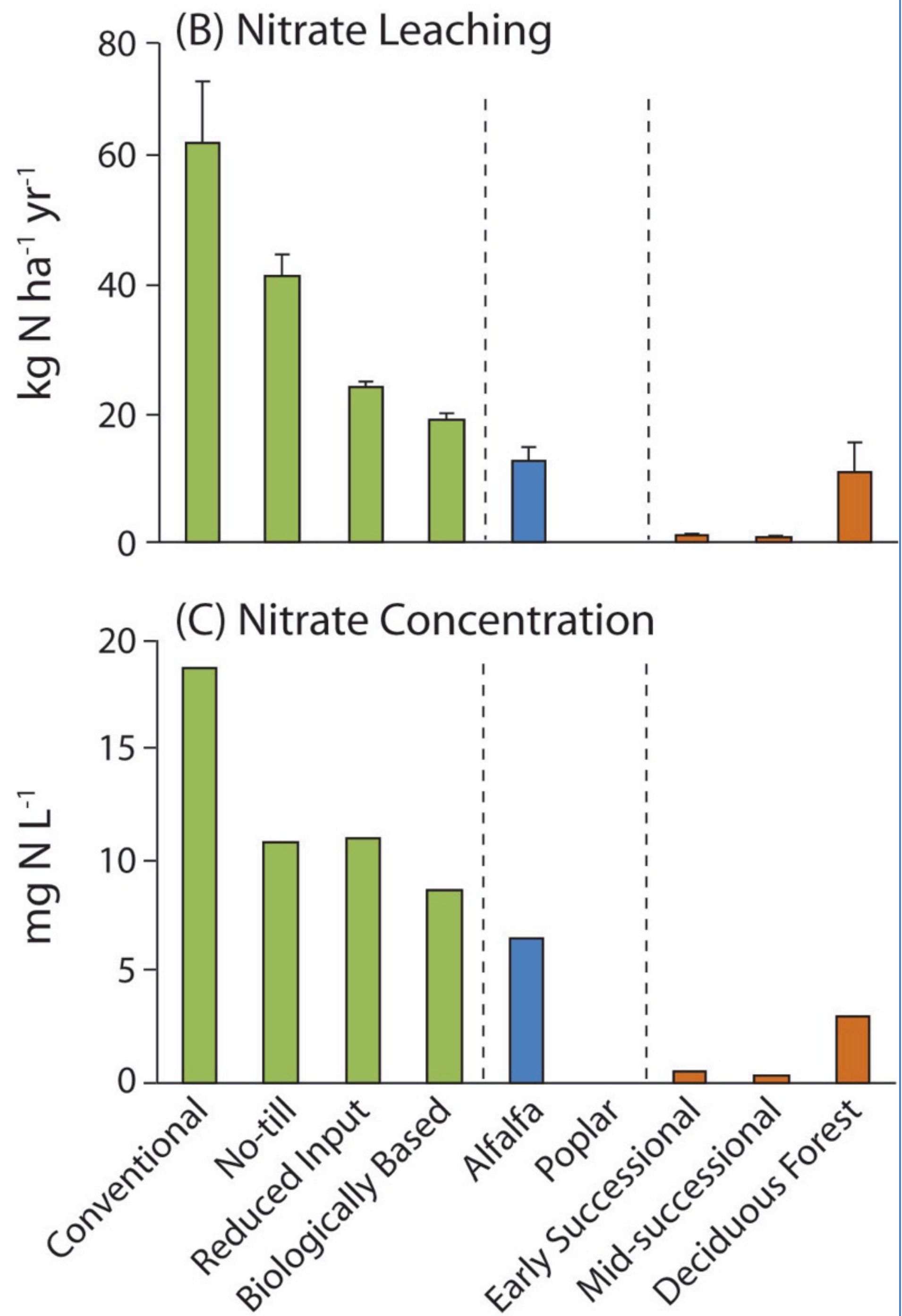
- Leaching from soils
- Carbonate minerals below ~1.4 m

Hamilton (2015) *LTER synthesis book*



Nitrate leaching from the root zone

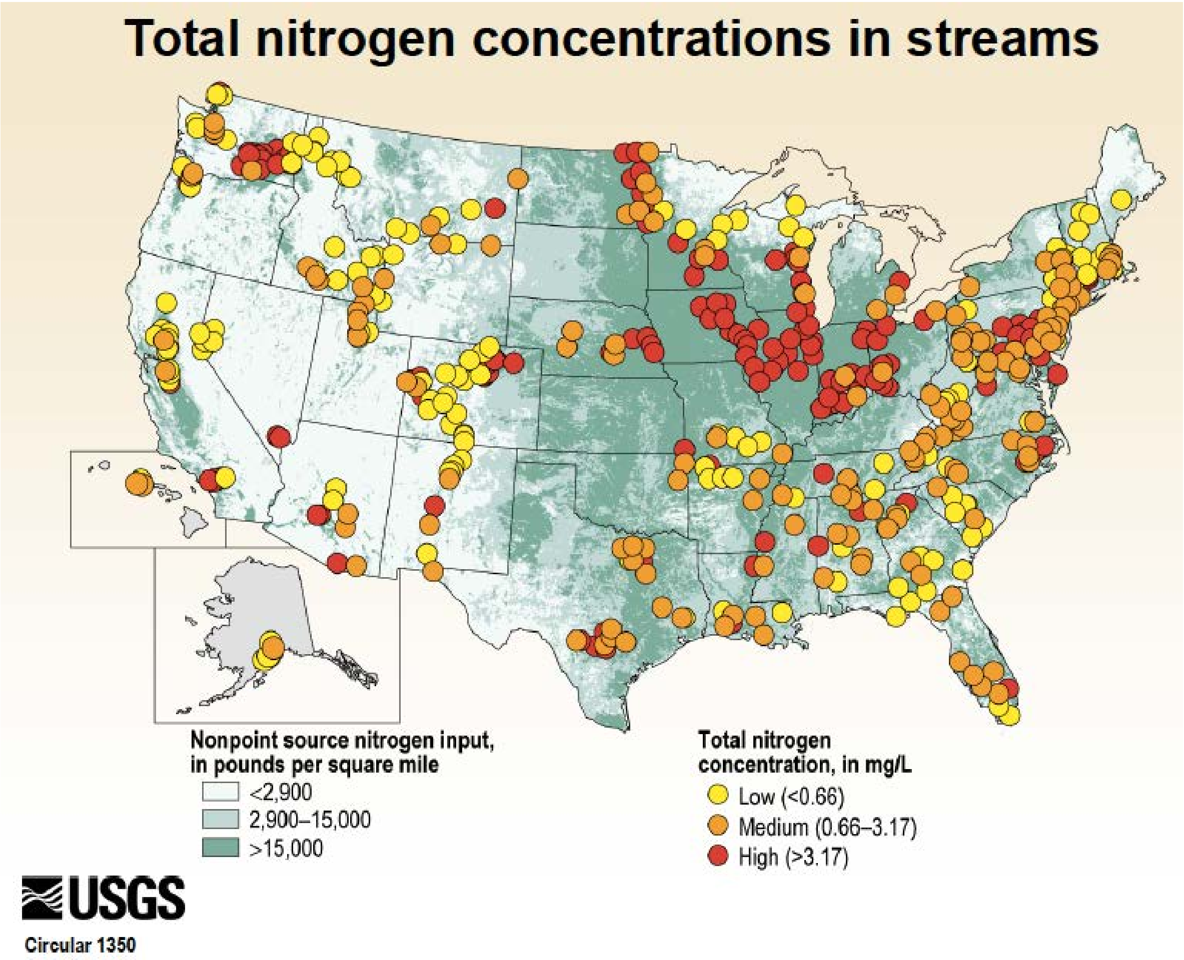




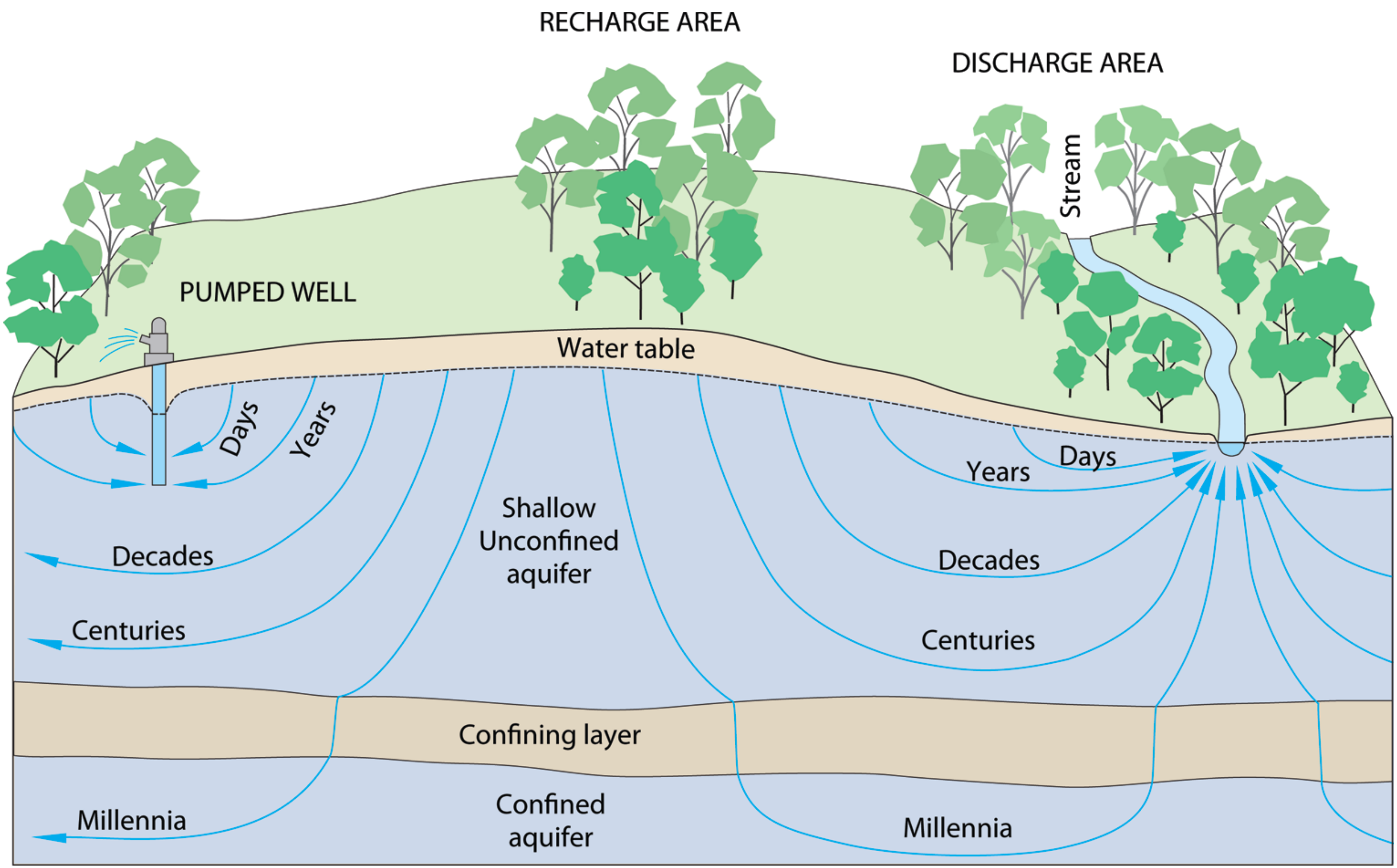
Syswerda et al. (2012), *AEE*

N enrichment of landscapes extends to groundwater and downstream water bodies

- Much of the total N in streams is NO_3^- from groundwater inputs
- Rivers in North America and Europe are enriched in N by 2-20 fold

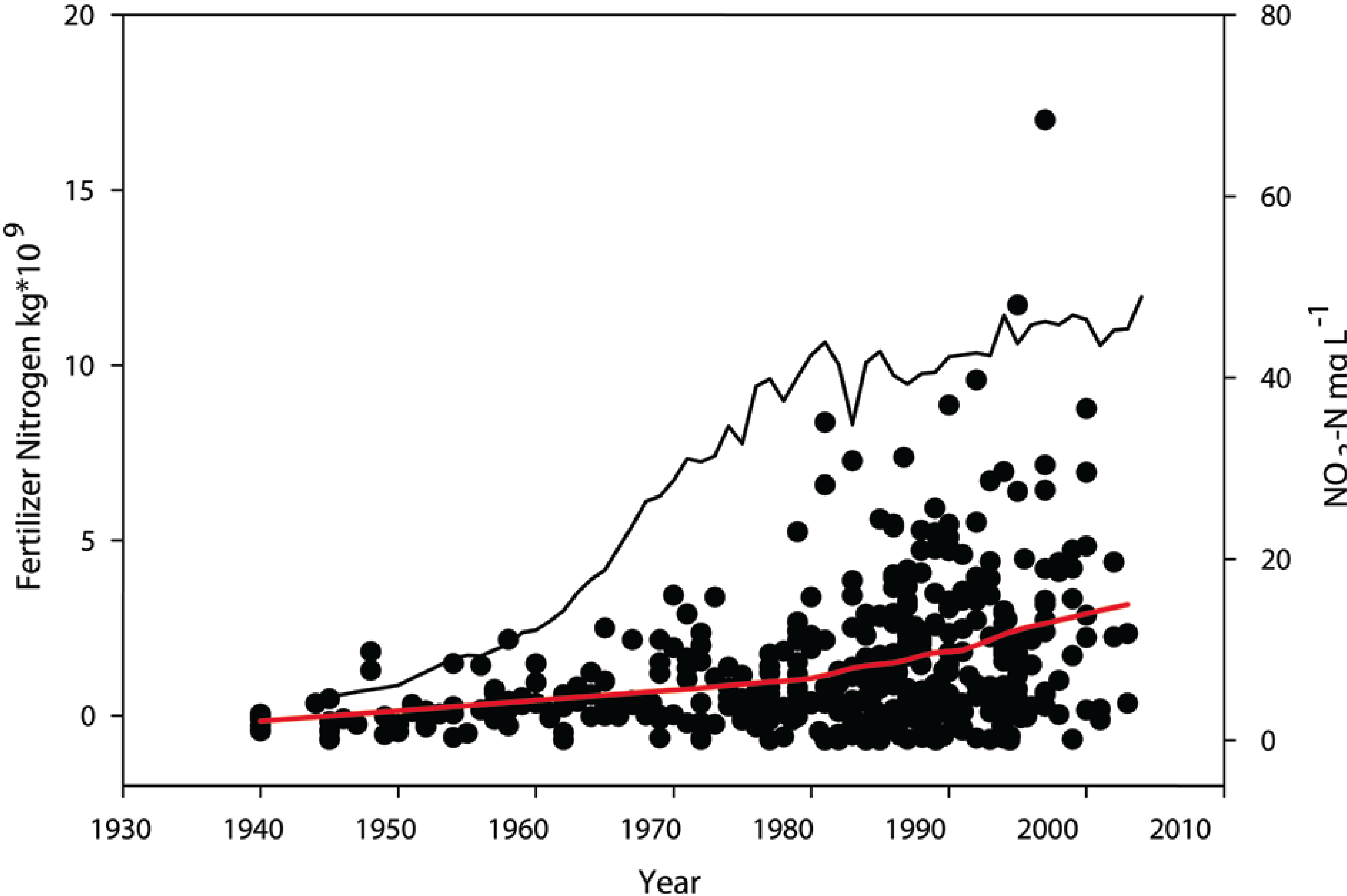


Groundwater flows slowly



Heath (1983) *USGS report*

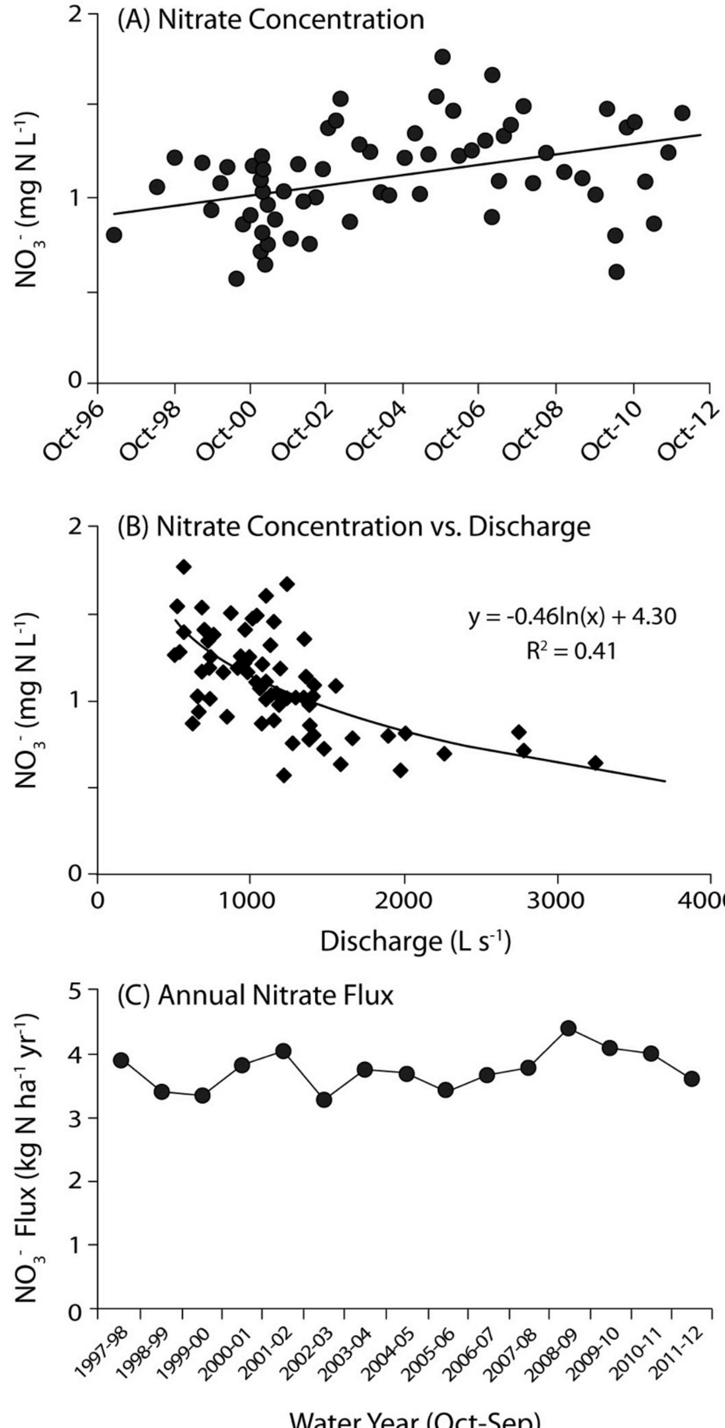
Groundwater contaminants display a long time lag



Puckett et al. (2011) *ES&T*; see also Hamilton (2012) *Freshw. Biol.*

Nitrate export by Augusta Creek

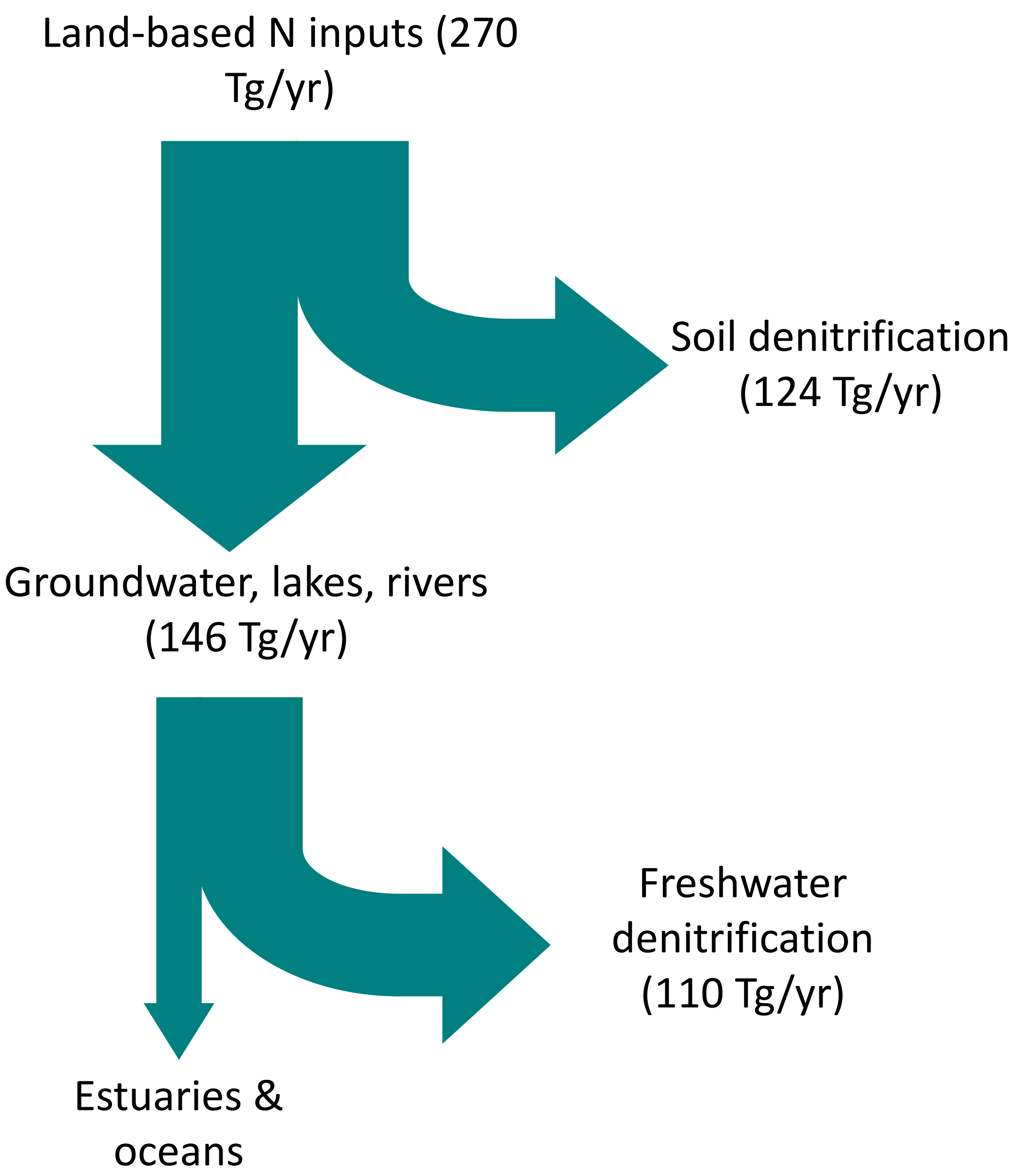
- 46% in agriculture, mainly row crops
- Formerly more agricultural



Hamilton (2015) *LTER synthesis book*

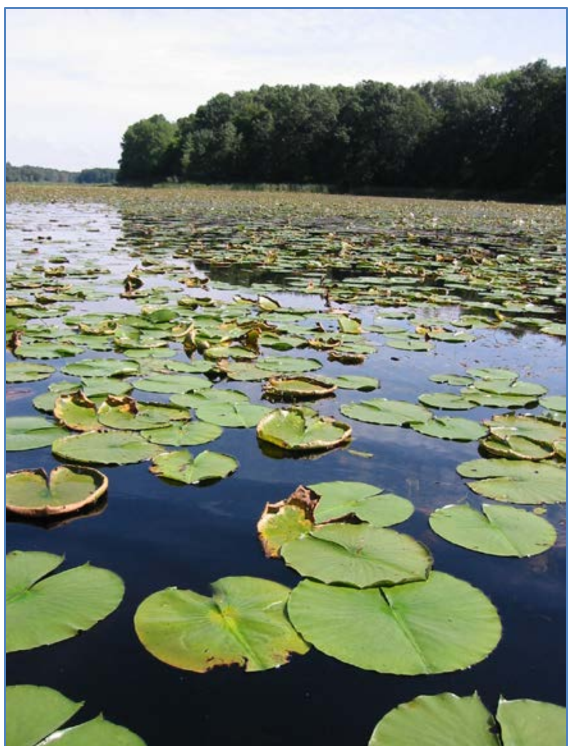
Most N disappears somewhere in transit

- Spatially distributed global models
- At least 75% must either be stored or, more likely, denitrified to N_2



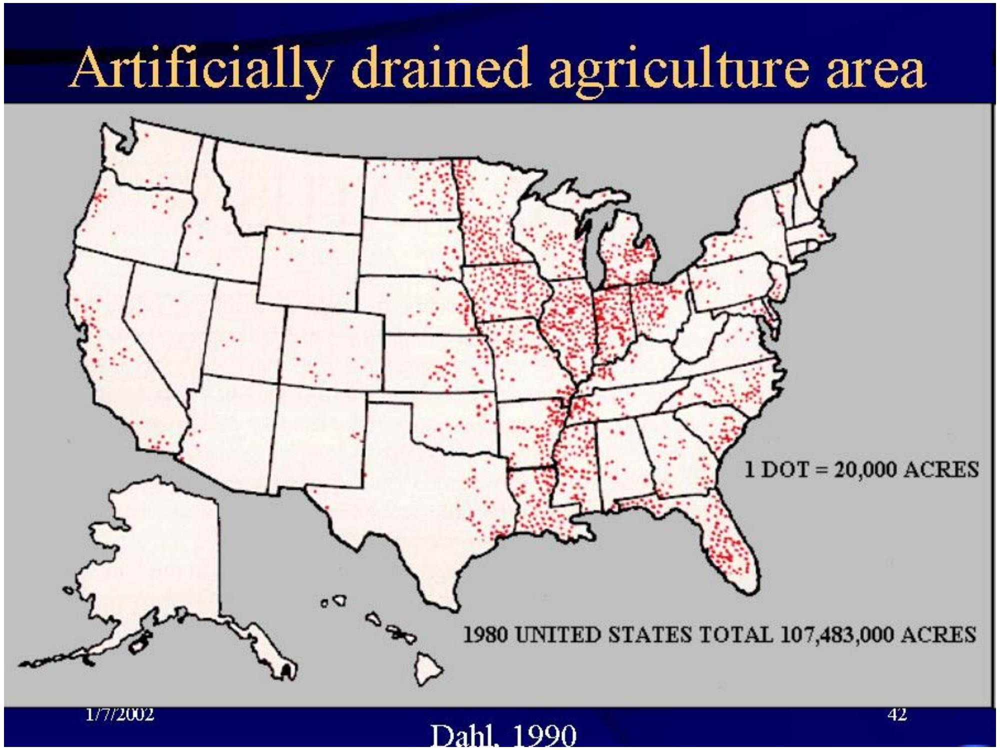
Data from Seitzinger et al. (2007) *Ecol. Applic.*

Shallow streams, lakes and wetlands retain/remove agricultural N (and P)



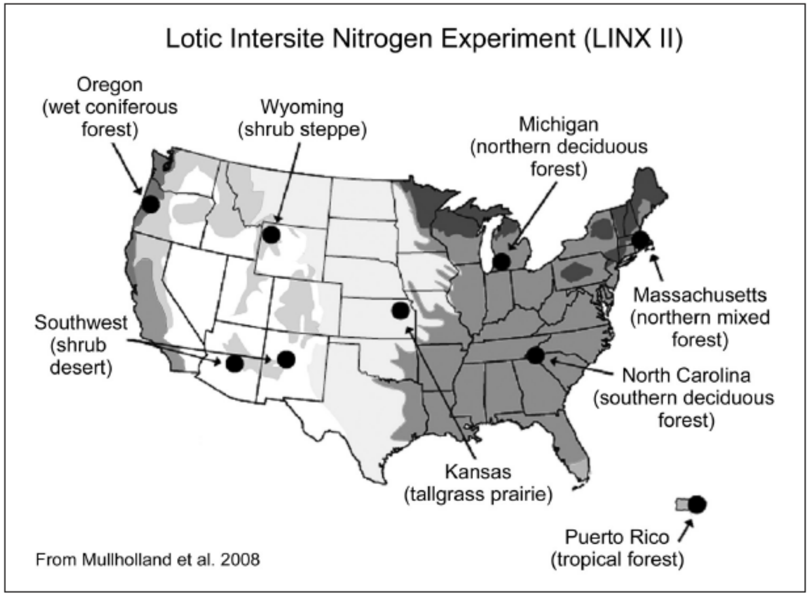
Alteration of streams and loss of wetlands may be part of the problem

- Extensive drainage of wetlands; stream channel alterations
  - Reduced efficiency of nutrient removal?
- Interest in restoration has been growing



LINX experimental design

- Coordinated ^{15}N tracer additions in 72 streams:
  - 3 in each of 3 land-use types (reference, agricultural, urban) in each of 8 biomes



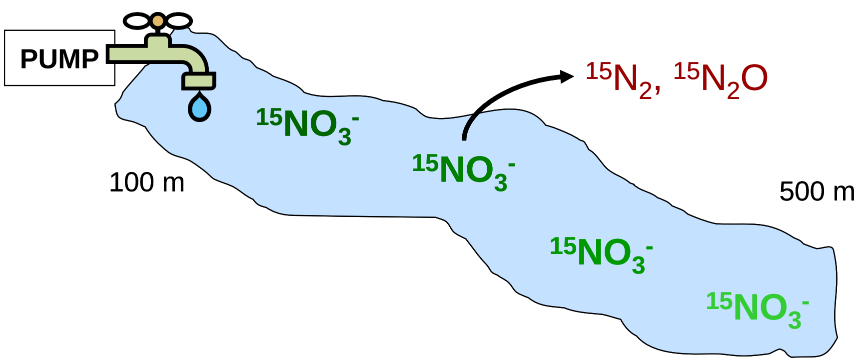


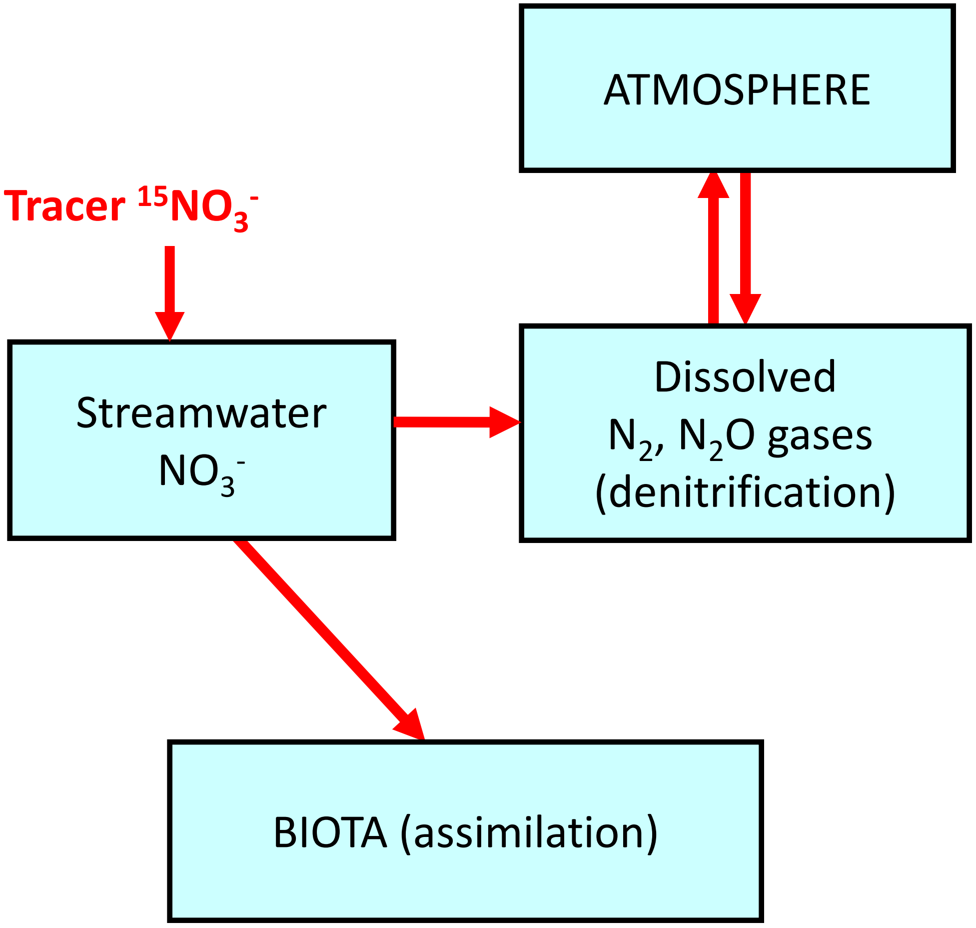




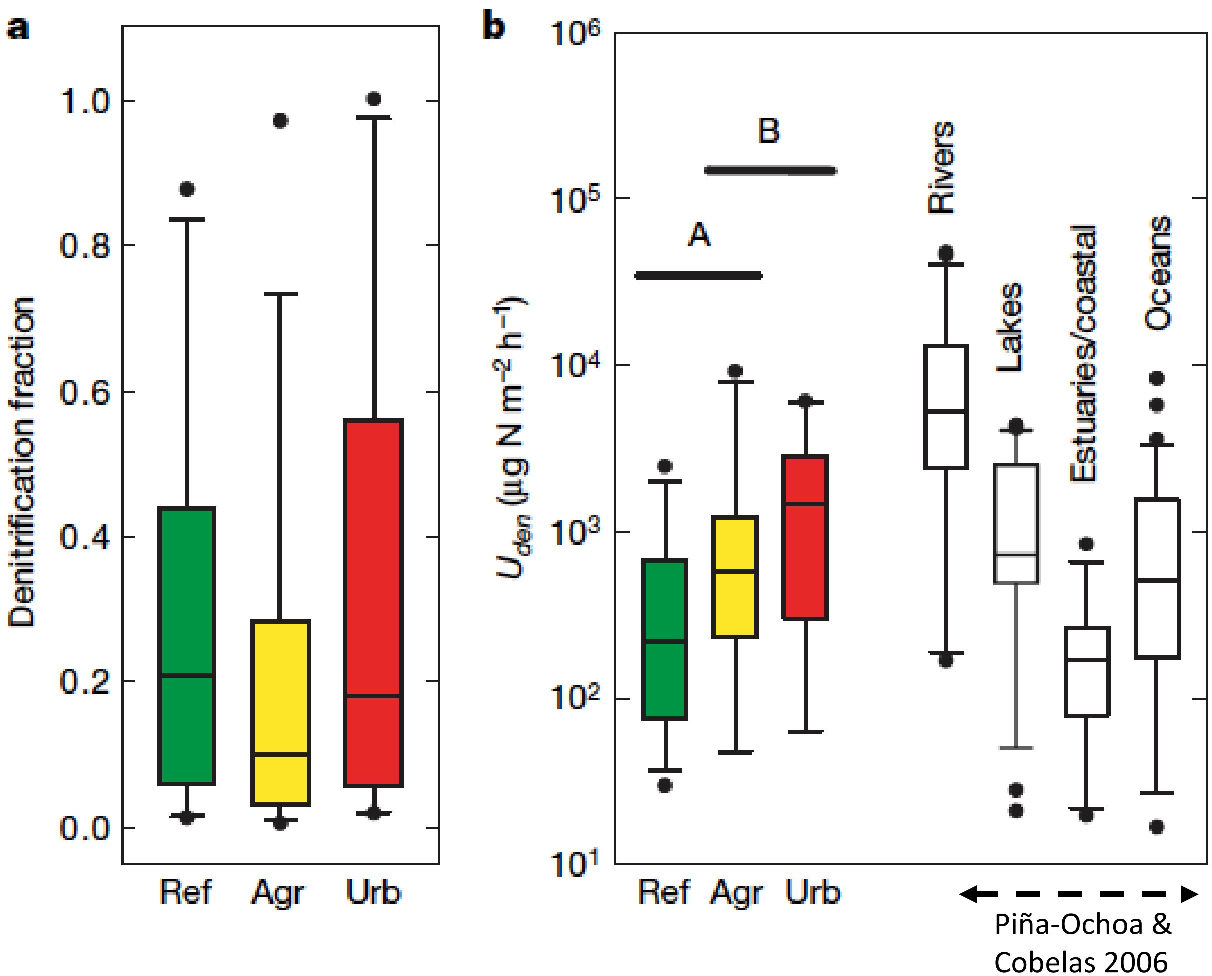

Nitrate uptake and denitrification in the LINX II experiments

- Whole-stream tracer additions
- 24-hour addition of tracer levels of $^{15}NO_3^-$





Stream denitrification rates

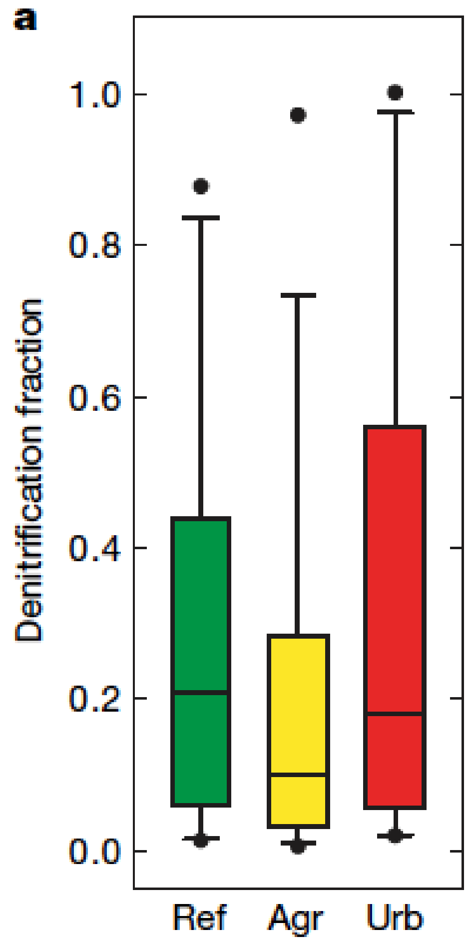


- Denitrification averaged 16% of total NO_3^- uptake (median)
- Large overlap among land-use types
- Within range of estimates for other aquatic systems

Mulholland et al. (2008) *Nature*

LINX II results: Most N uptake was assimilated, not denitrified

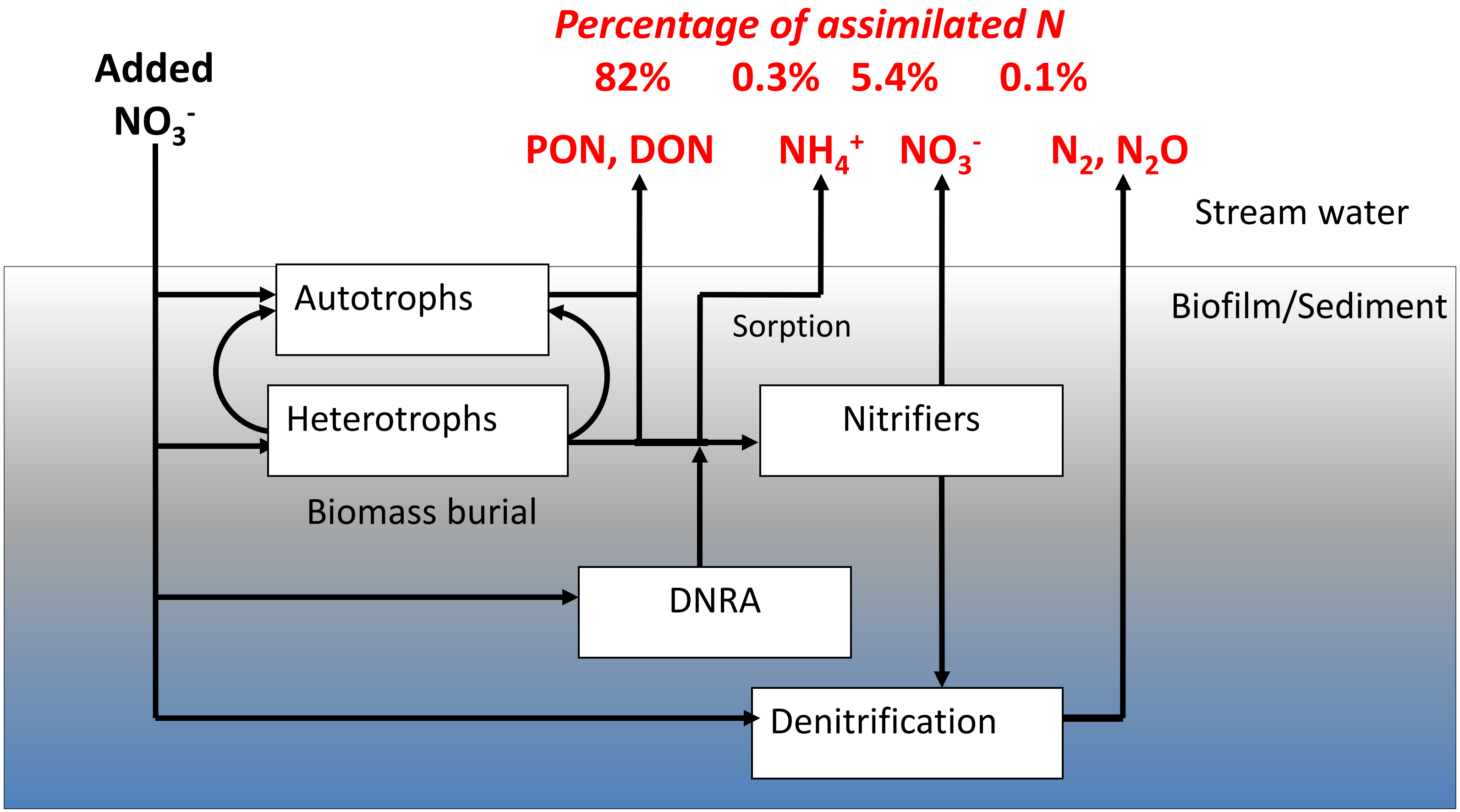
- Median of 16% was direct denitrification
- Balance was assimilated into algal, plant and microbial biomass
- What is the fate of assimilated N?
  - Could there be "indirect denitrification"?



Mulholland et al. (2008) *Nature*

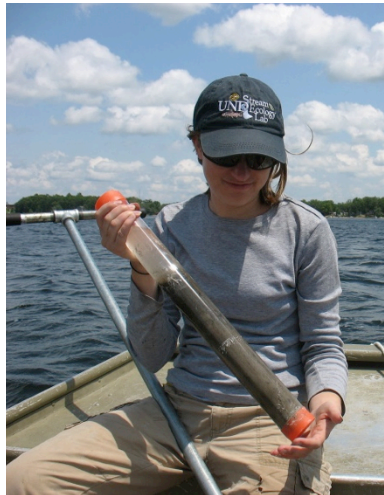
What is the eventual fate of assimilated nitrate?

- Little evidence for eventual (indirect) denitrification of assimilated N



O'Brien et al. (2012) *Freshw. Biol.*

Understanding sediment-water nitrogen exchanges



Ecosystems
DOI: 10.1007/s10021-008-9169-5
ECOSYSTEMS

NO_3^--Driven SO_4^{2-} Production in Freshwater Ecosystems: Implications for N and S Cycling

Amy J. Burgin[1]* and Stephen K. Hamilton[2]

Rapid Removal of Nitrate and Sulfate in Freshwater Wetland Sediments

JEQ JOURNAL OF ENVIRONMENTAL QUALITY
Stefanie L. Whitmire and Stephen K. Hamilton*

Limnol. Oceanogr., 57(1), 2012, 221–234

doi:10.4319/lo.2012.57.1.0221

Nitrogen transformations in a through-flow wetland revealed using whole-ecosystem pulsed ^{15}N additions

Jonathan M. O'Brien,[a,1,*] Stephen K. Hamilton,[a,b] Lauren E. Kinsman-Costello,[a] Jay T. Lennon,[a,c] and Nathaniel E. Ostrom[b]

Vol. 54: 233–241, 2009
doi: 10.3354/ame01272
AQUATIC MICROBIAL ECOLOGY
Aquat Microb Ecol
Printed March 2009
Published online February 24, 2009

Sediment nitrate manipulation using porewater equilibrators reveals potential for N and S coupling in freshwaters

E. K. Payne[1,2], A. J. Burgin[2,3,*], S. K. Hamilton[2]

COUPLED BIOGEOCHEMICAL CYCLES

Beyond carbon and nitrogen: how the microbial energy economy couples elemental cycles in diverse ecosystems

Amy J Burgin[1*], Wendy H Yang[2], Stephen K Hamilton[3], and Whendee L Silver[2]

What about phosphorus?

- P tends to sorb to soils and sediments
- Large P reservoirs:
  - Upland soils
  - Floodplains
  - Aquatic sediments, including behind existing and former dams

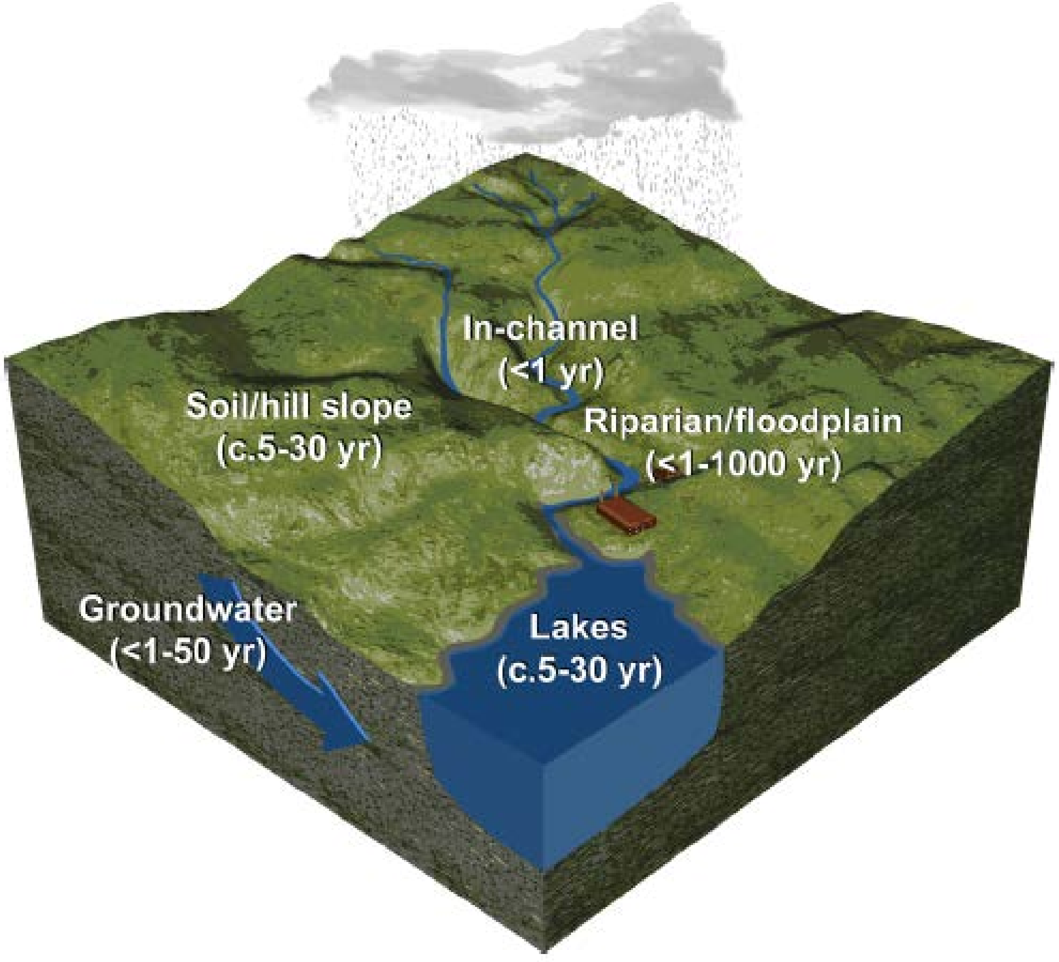


Figure 1. Typical time scales for phosphorus (P) retention and recycling in watershed and waterbody legacy P stores. These result in a continued chronic release of "legacy P", impairing downstream water quality over time scales of years to decades, or even centuries (from data provided by Sharpley et al, 2013).

Jarvie et al. (2013) *ES&T*

Phosphorus often moves with particulate material…

Photo: Steve Davis

But not always exclusively so.

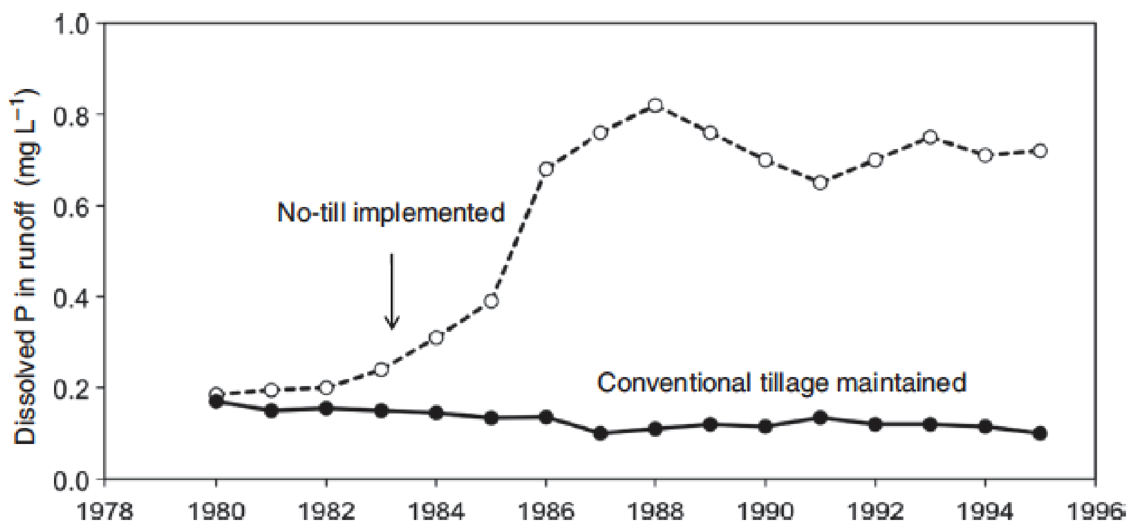
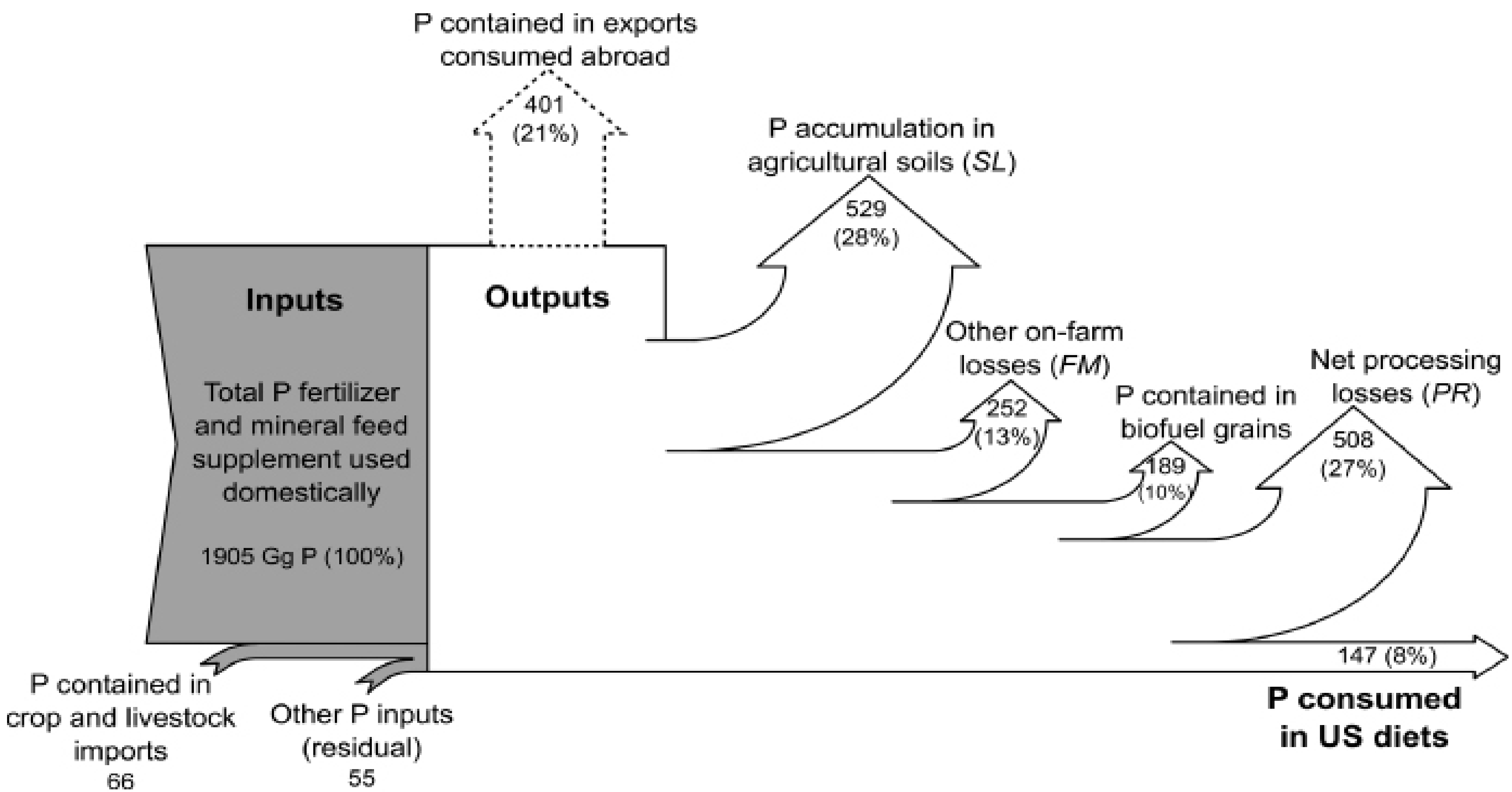


Fig. 4. Average annual dissolved P concentrations in runoff from two wheat fields in Oklahoma, US. Both were tilled until 1984, when one was converted to no-till. Adapted from Sharpley and Smith (1994).

Kleinman et al. (2011)
Can J Soil Sci

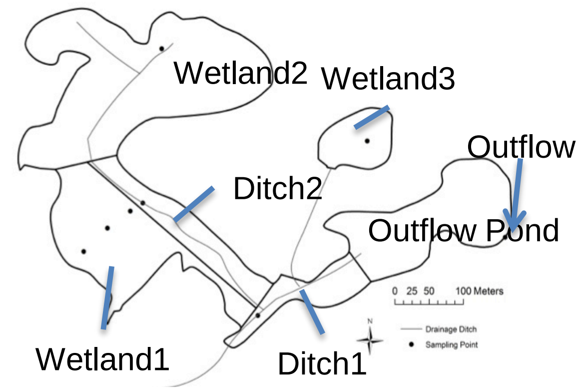
P application rates have long exceeded removal by harvest

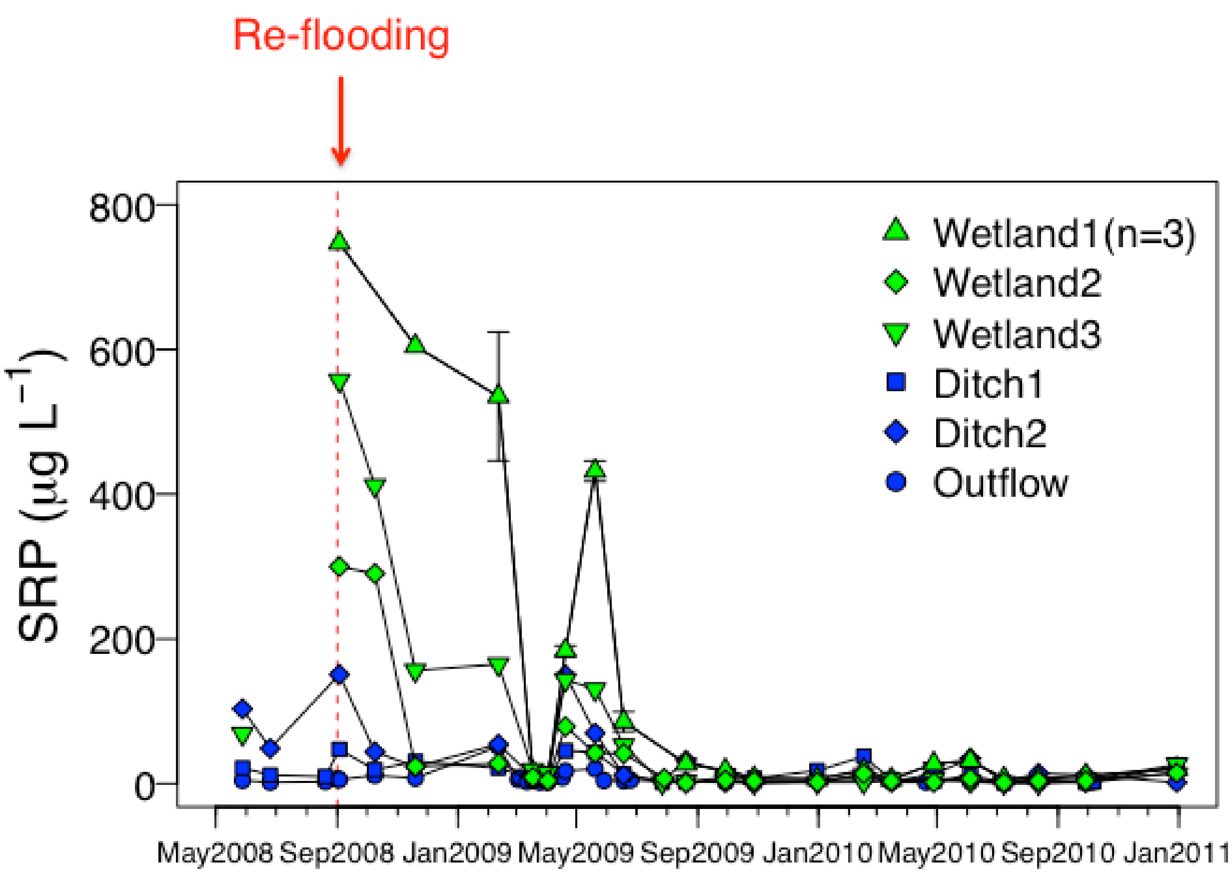


- Most fertilizer P applied so far remains in soils and sediments (MacDonald et al. 2012, Sattari et al. 2012, Jarvie et al. 2013)
- Some is potentially released…

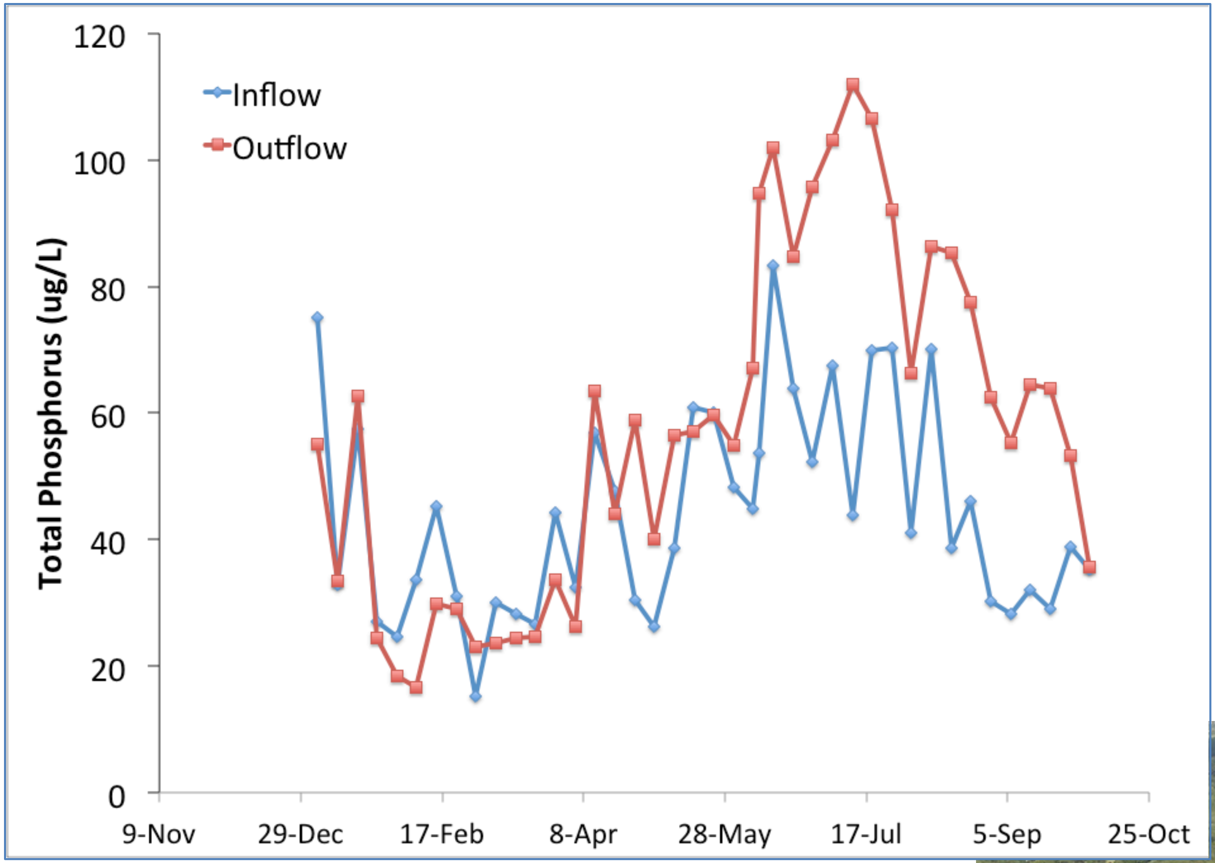
Phosphorus remobilization in reflooded soil

- Restored wetland
- Kinsman-Costello et al. (2014) *Ecosystems*





Phosphorus remobilization in reservoir sediments



- Morrow Lake (Baas 2009 dissertation)

Near-future directions

- Terrestrial water balances in non-crop landscape elements
- More work on fate of carbon in lime
- Irrigation:
  - Effects on water balances, groundwater-dependent wetlands
  - Global warming impact
  - Source of nitrogen and alkalinity to crops
- Flocculent sediments in shallow waters

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