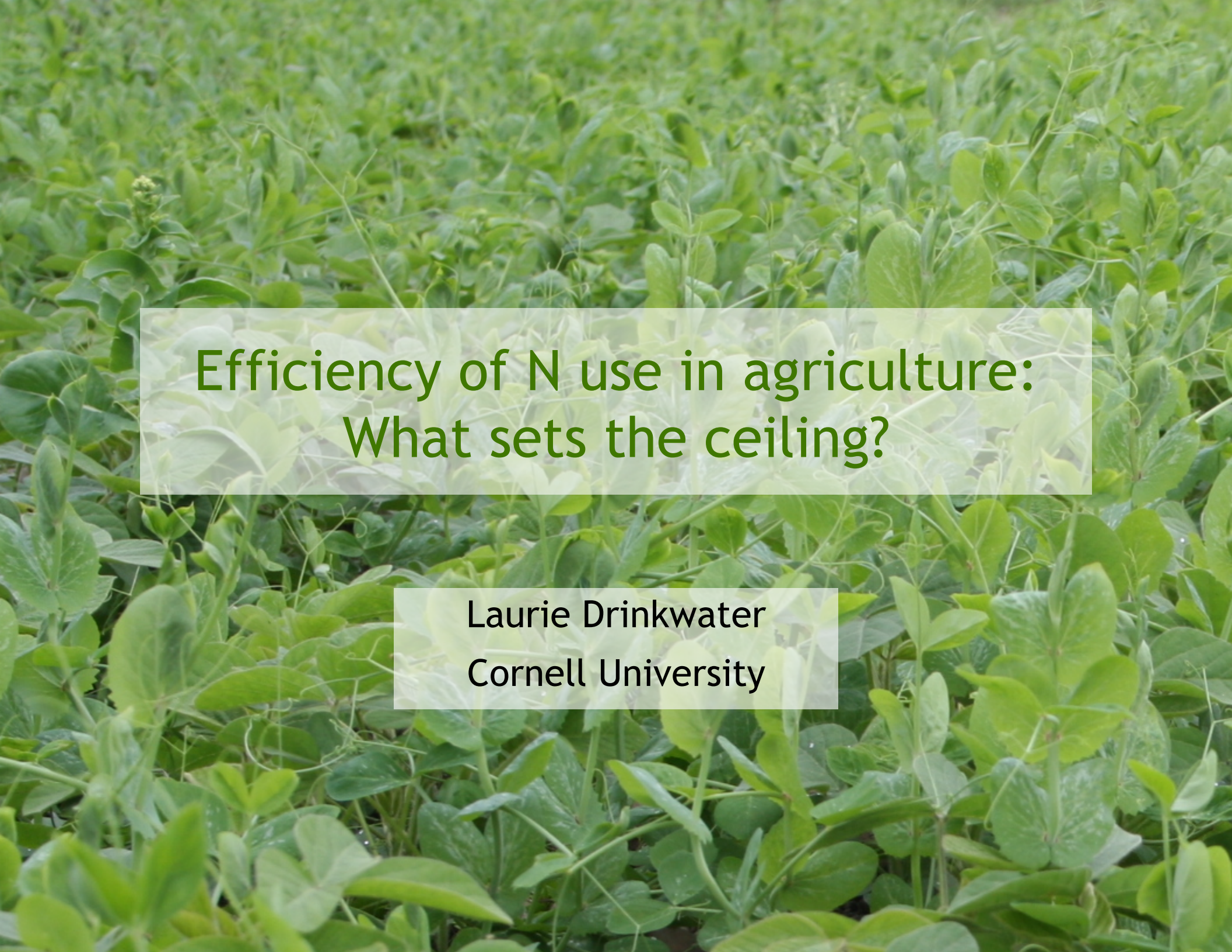


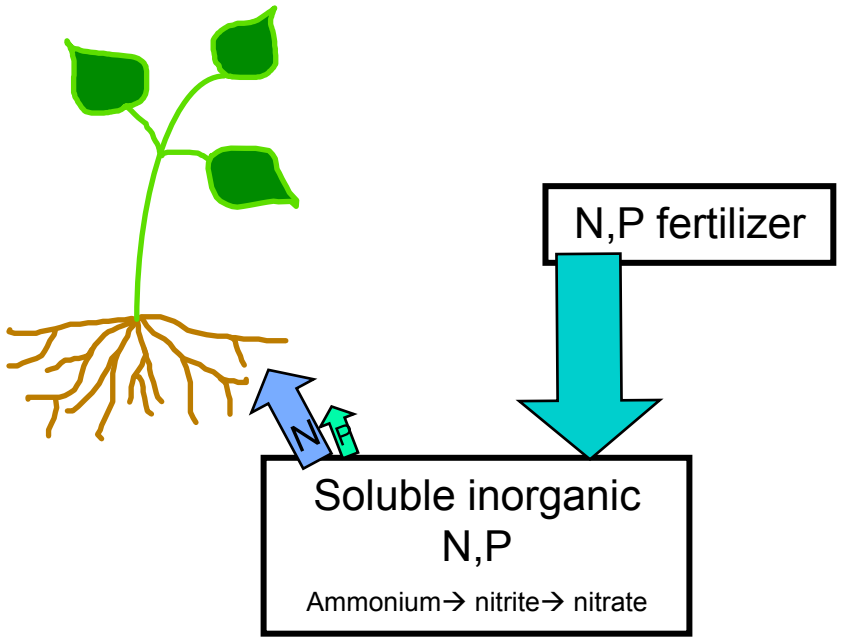
Efficiency of N use in agriculture: What sets the ceiling?

Laurie Drinkwater

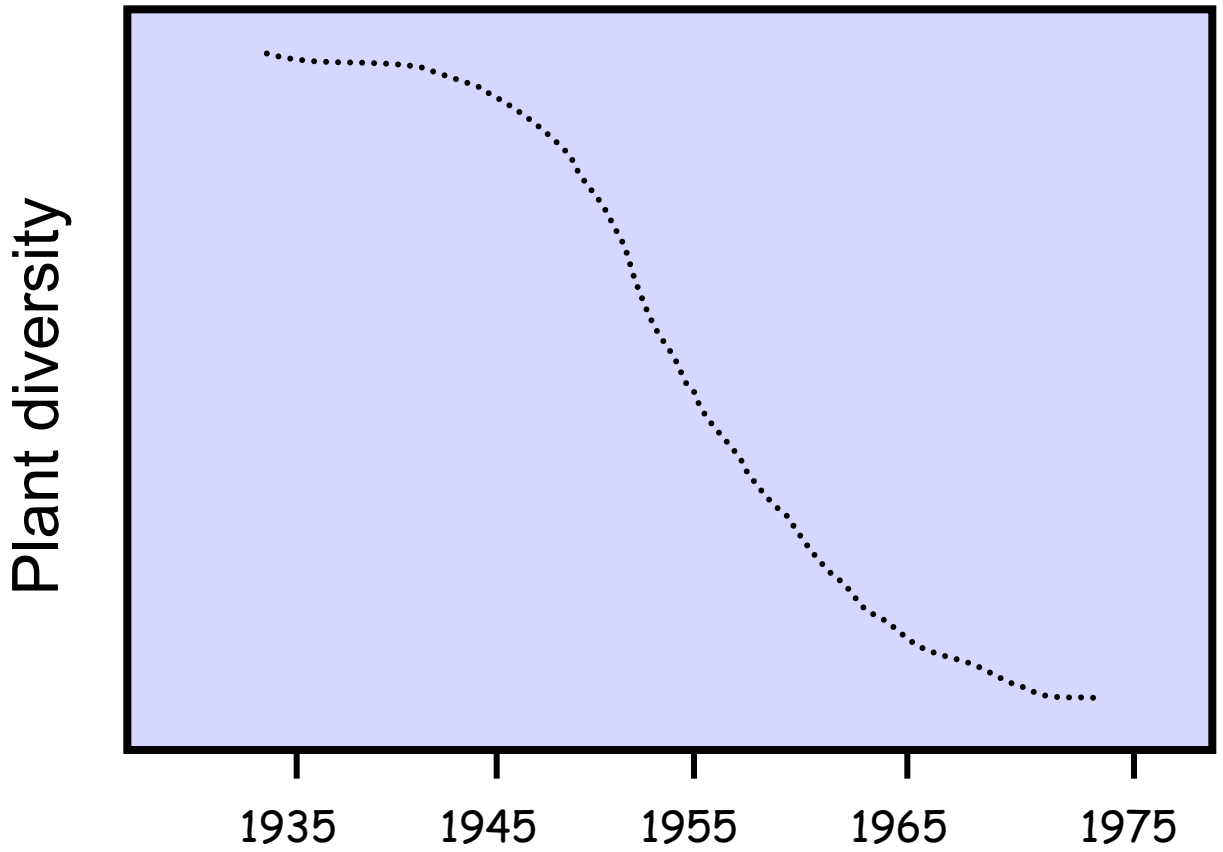
Cornell University

Nutrient management theory

- Predict plant-available N, P or assess nutrient status of crop
- Optimize delivery of soluble N fertilizer to the crop
- Eliminate all other limiting factors to maximize crop fertilizer uptake



Reductions in crop diversity parallel intensification

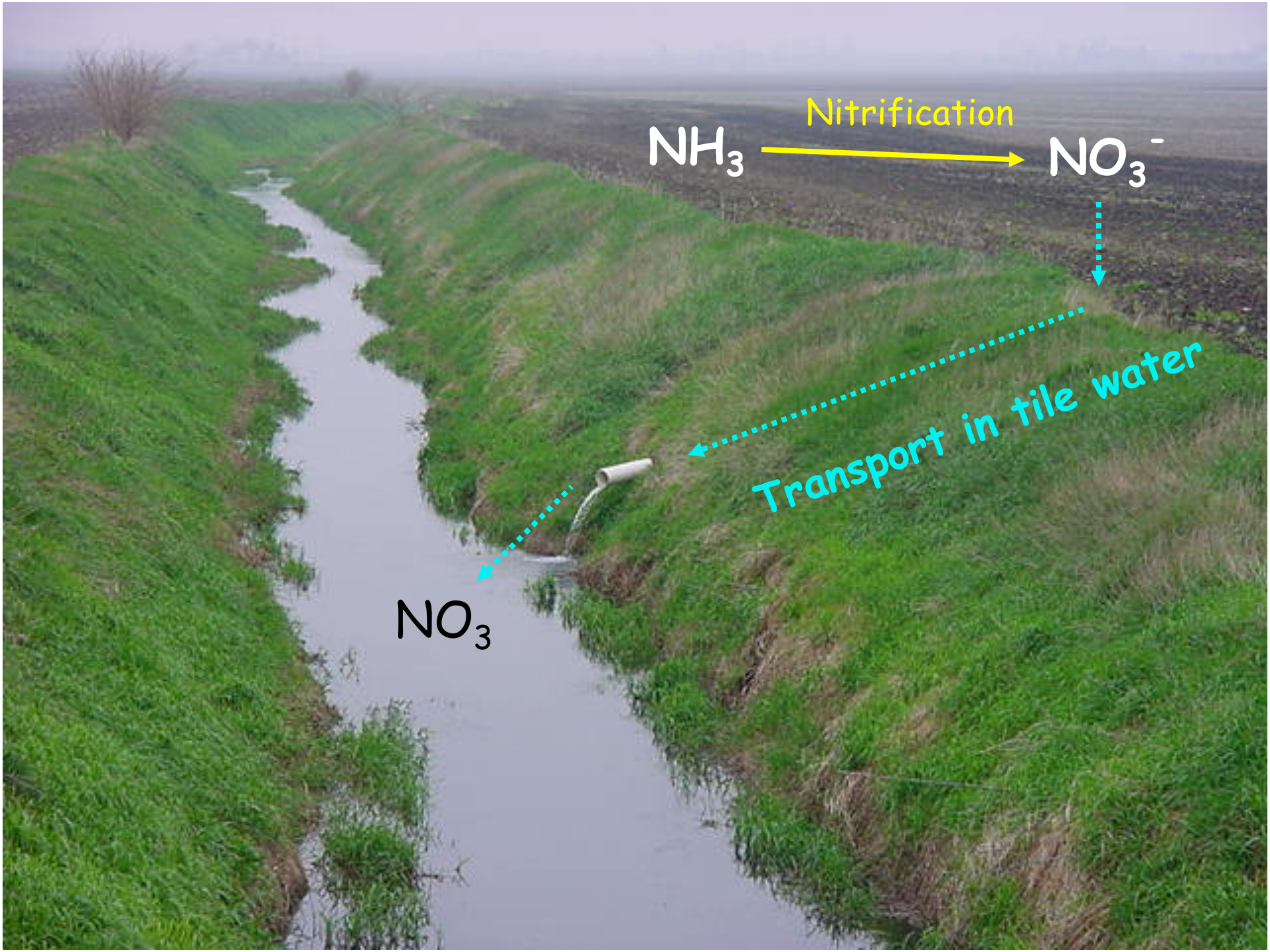


Modified after Auclair, 1976. Ecology.

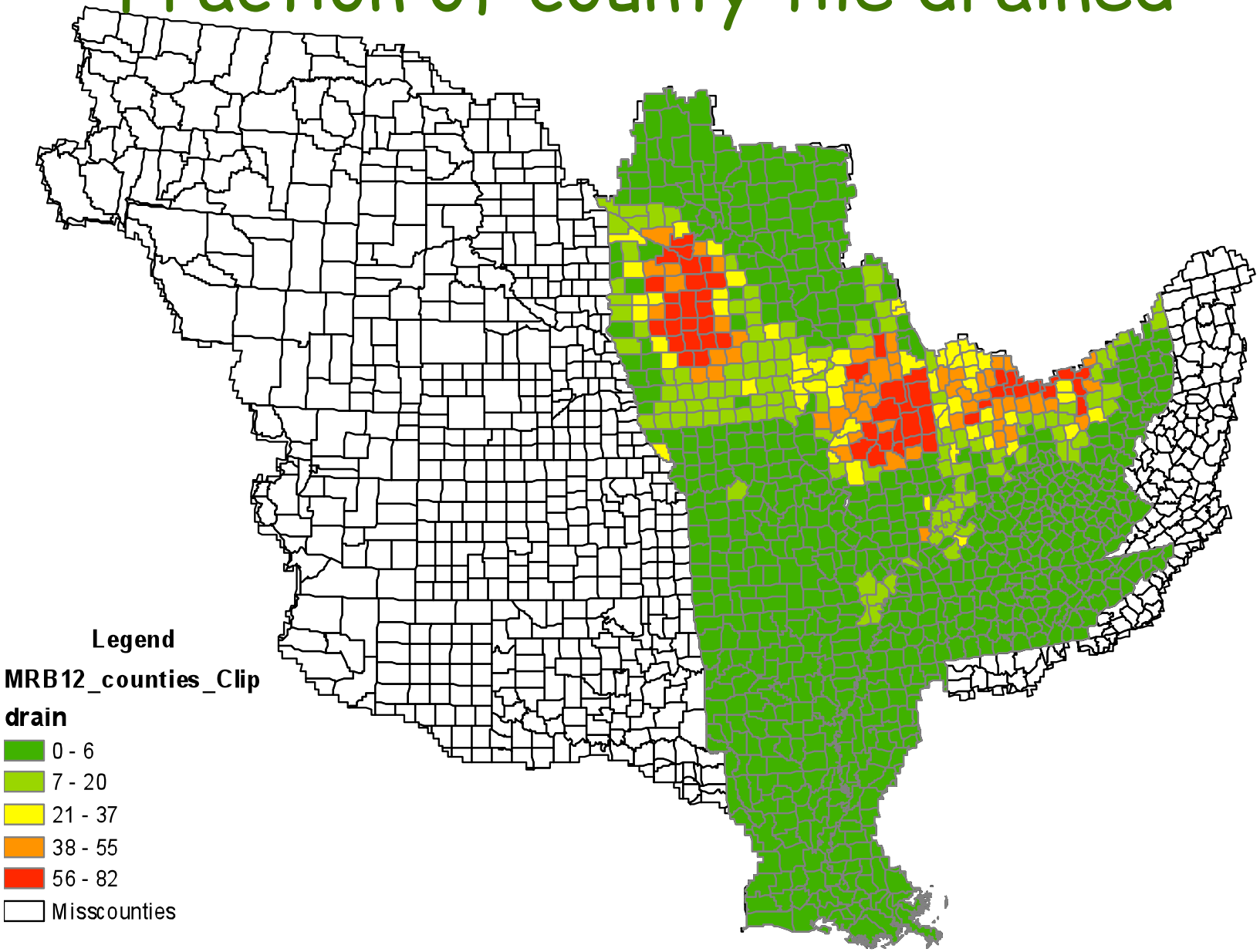
As a result, large tracts of land are left as bare fallows for 4-8 months

Dominant rotation

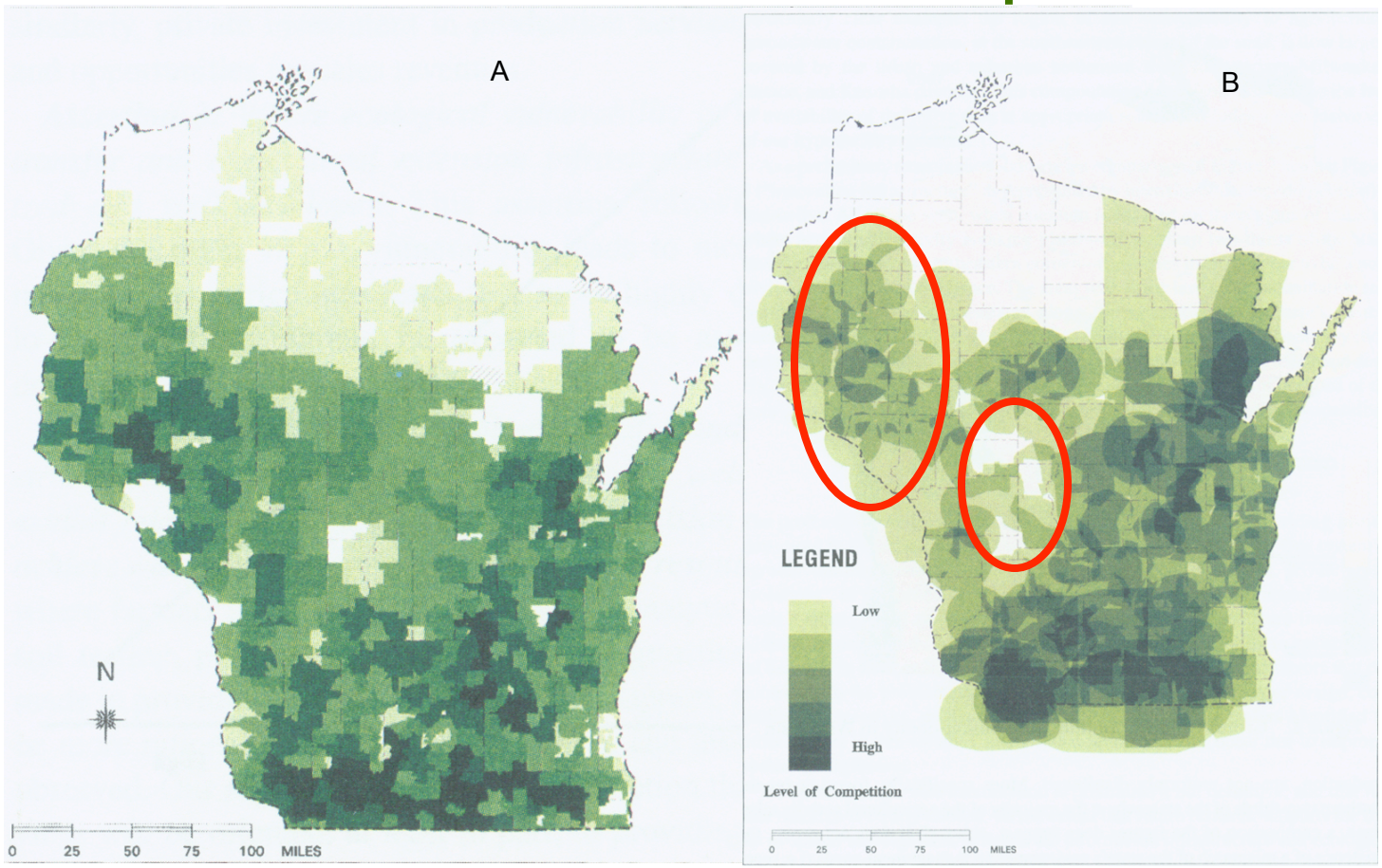
Rotation with a cover crop


Nitrification
NH_3
NO_3^-
Transport in tile water
NO_3

Fraction of county tile drained

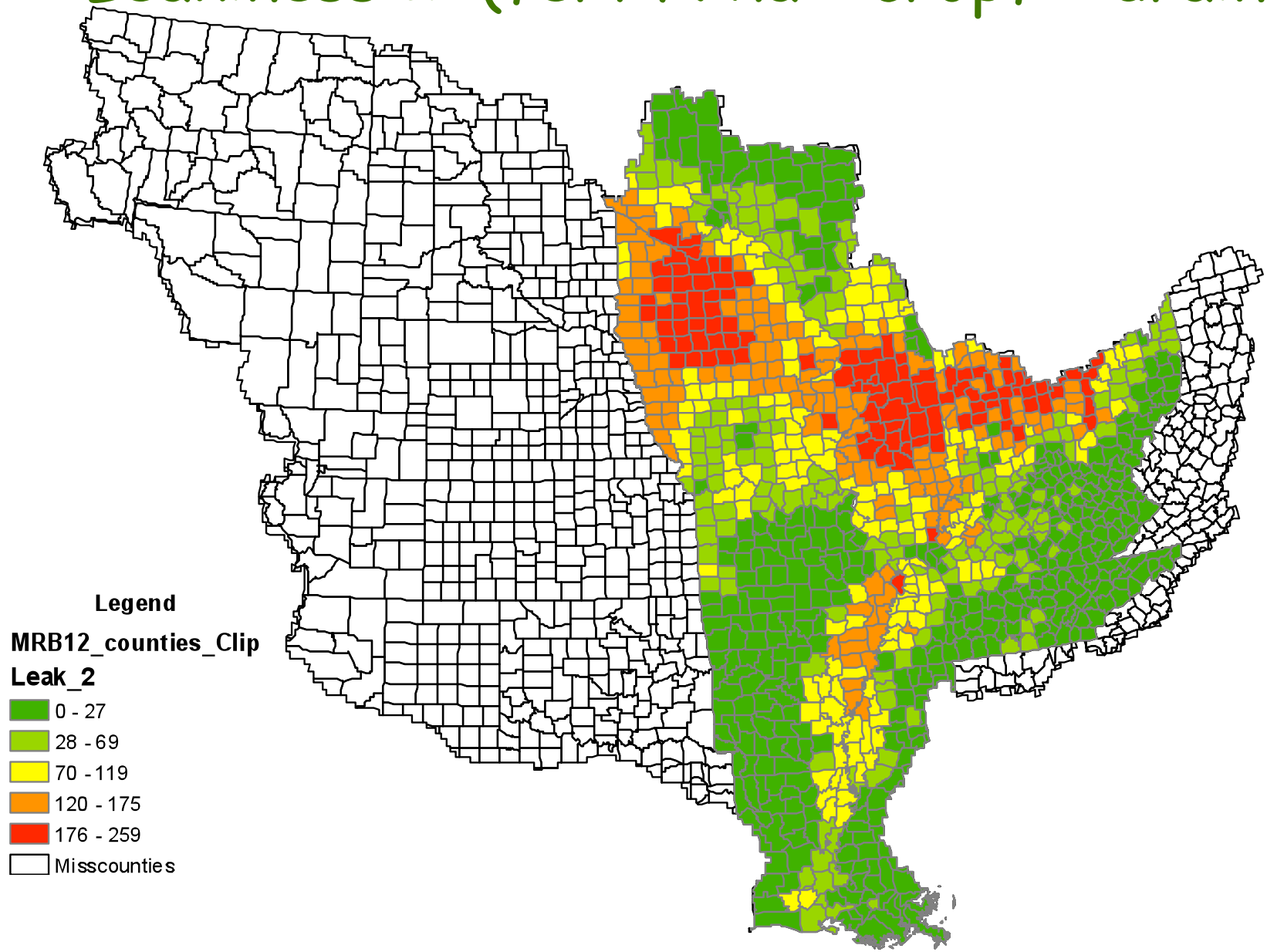


Technical support tracks corn production, misses areas critical for pollution

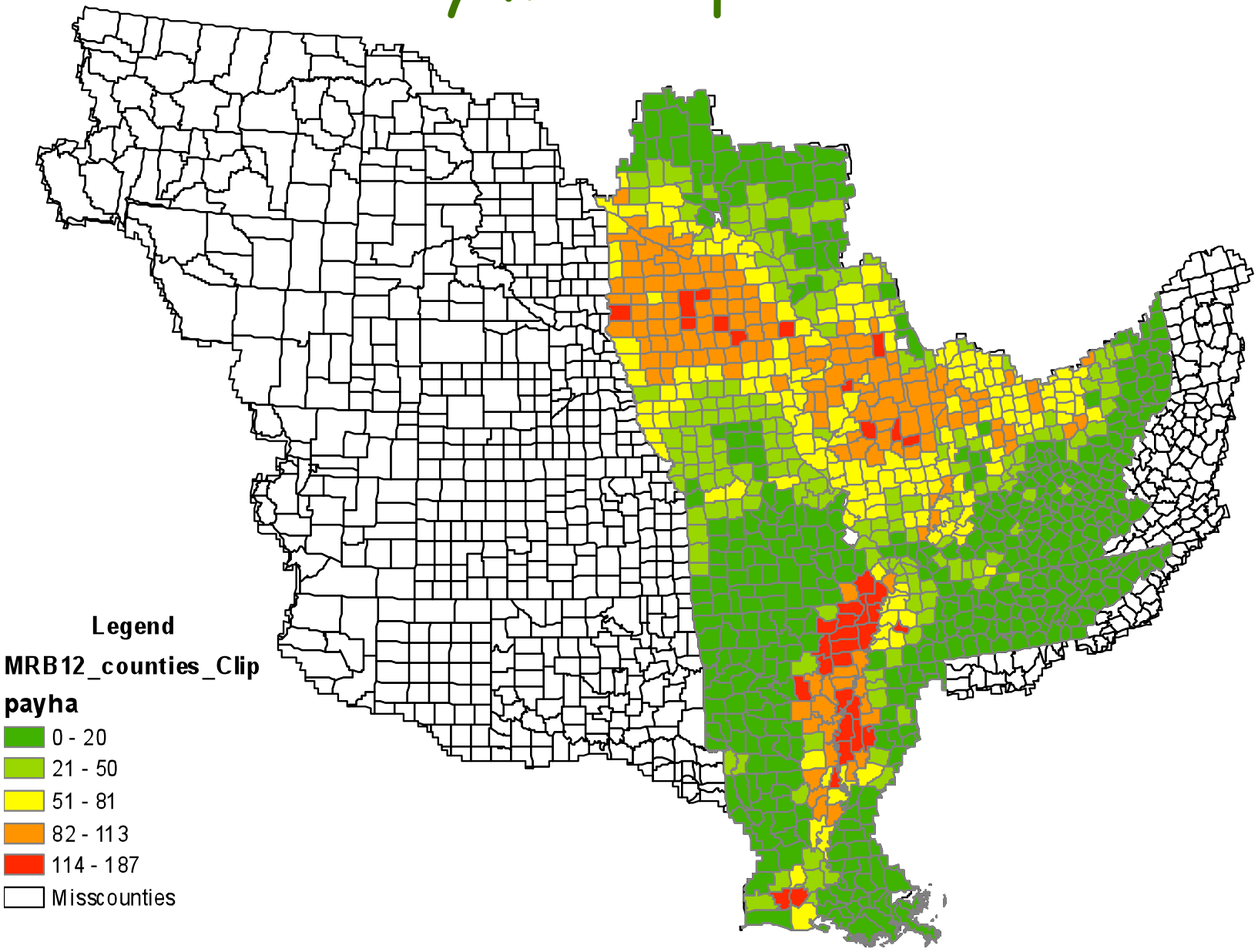


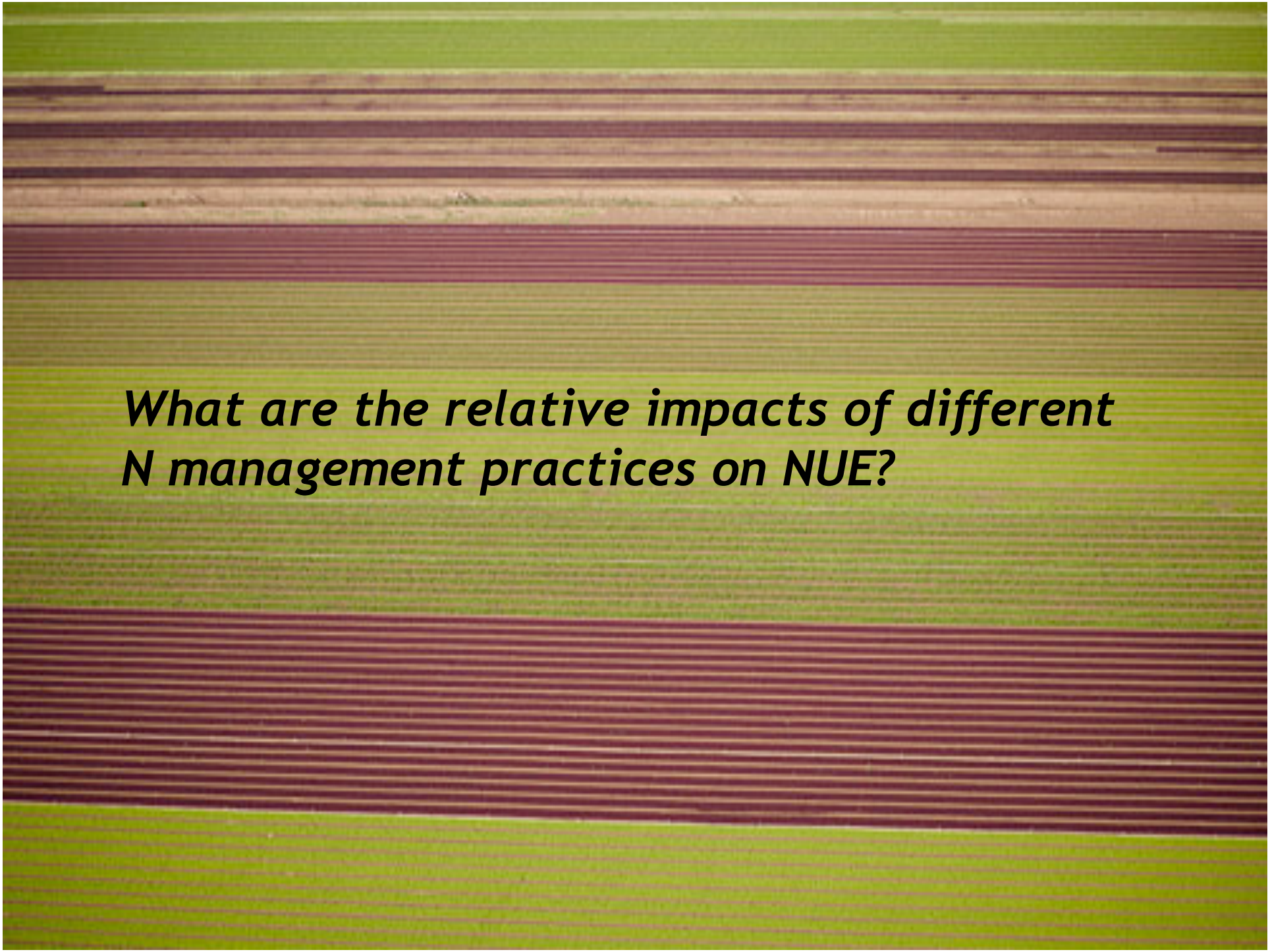
Spatial relationship between (A) intensive corn production and (B) technical support services for optimizing fertilizer efficiency. (Wolf and Novak, 1999)

Leakiness 2 (fert N ha + cropf + drain)



Payments per ha




What are the relative impacts of different N management practices on NUE?

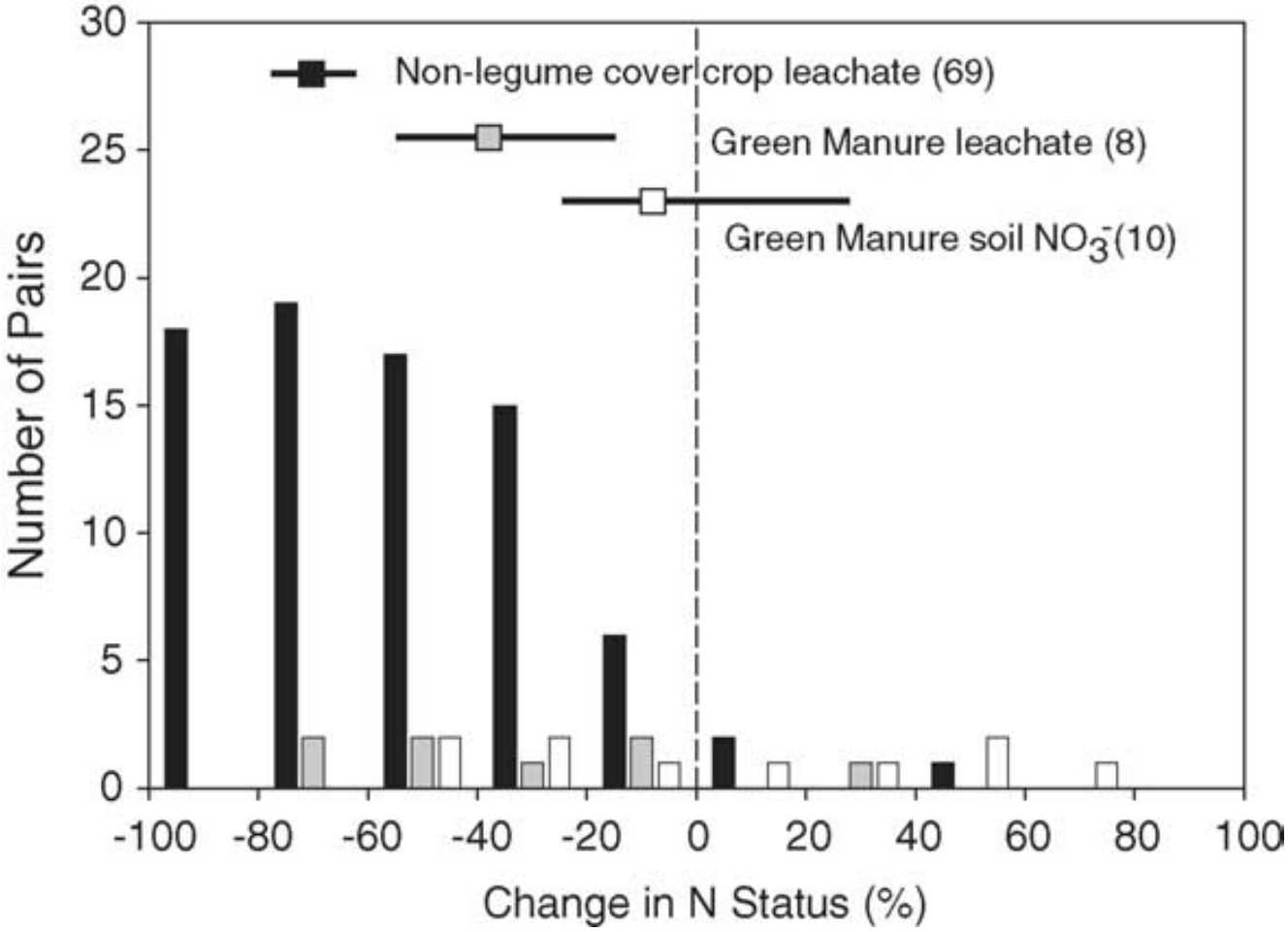
Strategies for reducing N losses

- Improved placement and timing of fertilizer
- Variable rate application technologies
- Block microbially-mediated transformations
- Improved crop nutrient use efficiency
- Primary focus of N research (~57% of studies)
- Reduction in N losses by 5-20%

- Cover cropping, intercropping
- Use of organic N sources
- Management of plant-microbial interactions
- Perennial grain crops
- Limited research (~20% of studies)
- Reduction in N losses by 30-70%

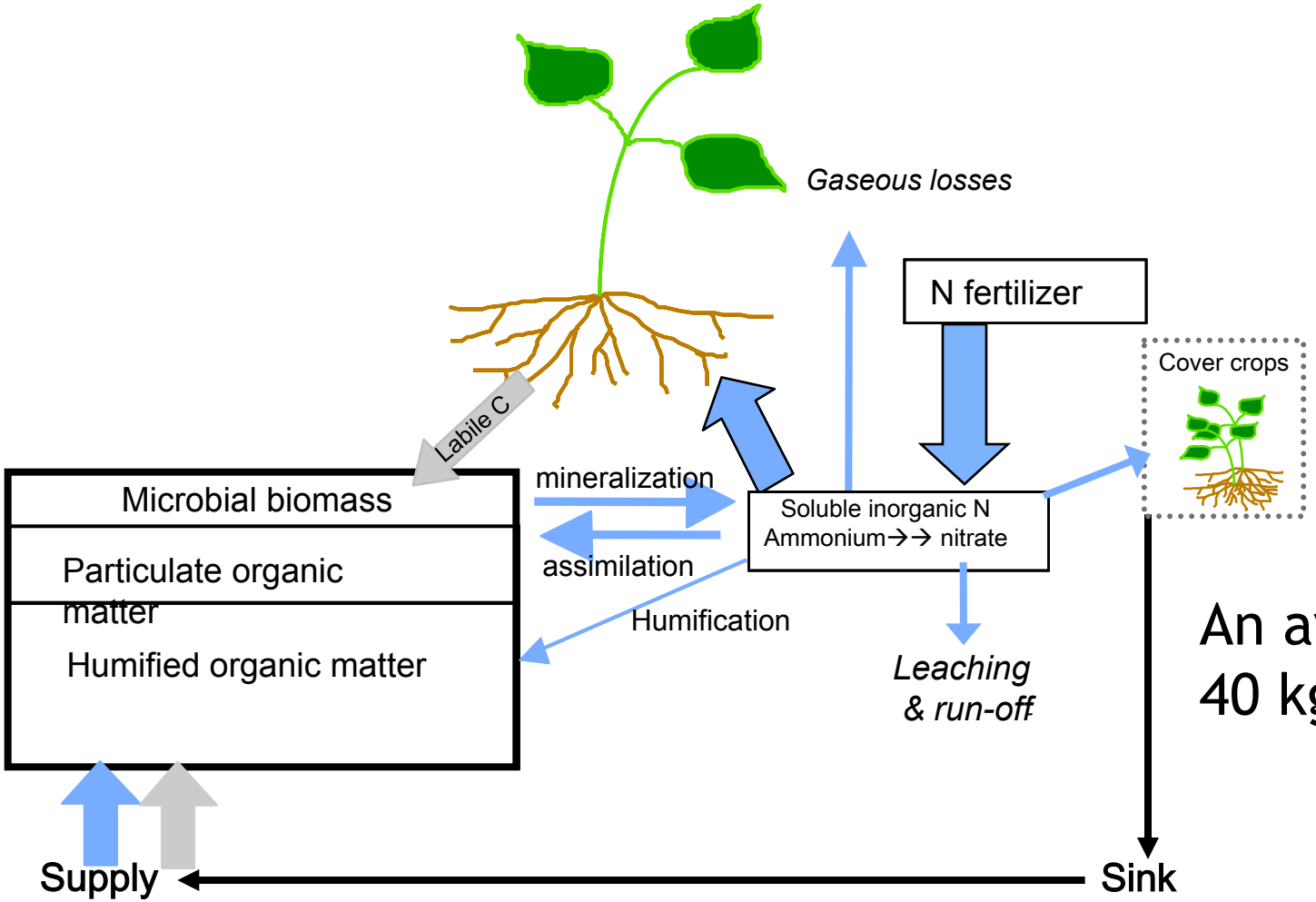
Gardner and Drinkwater, in review
Tonitto et al., 2006

Both cover cropping and leguminous green manures reduce NO_3^- leaching



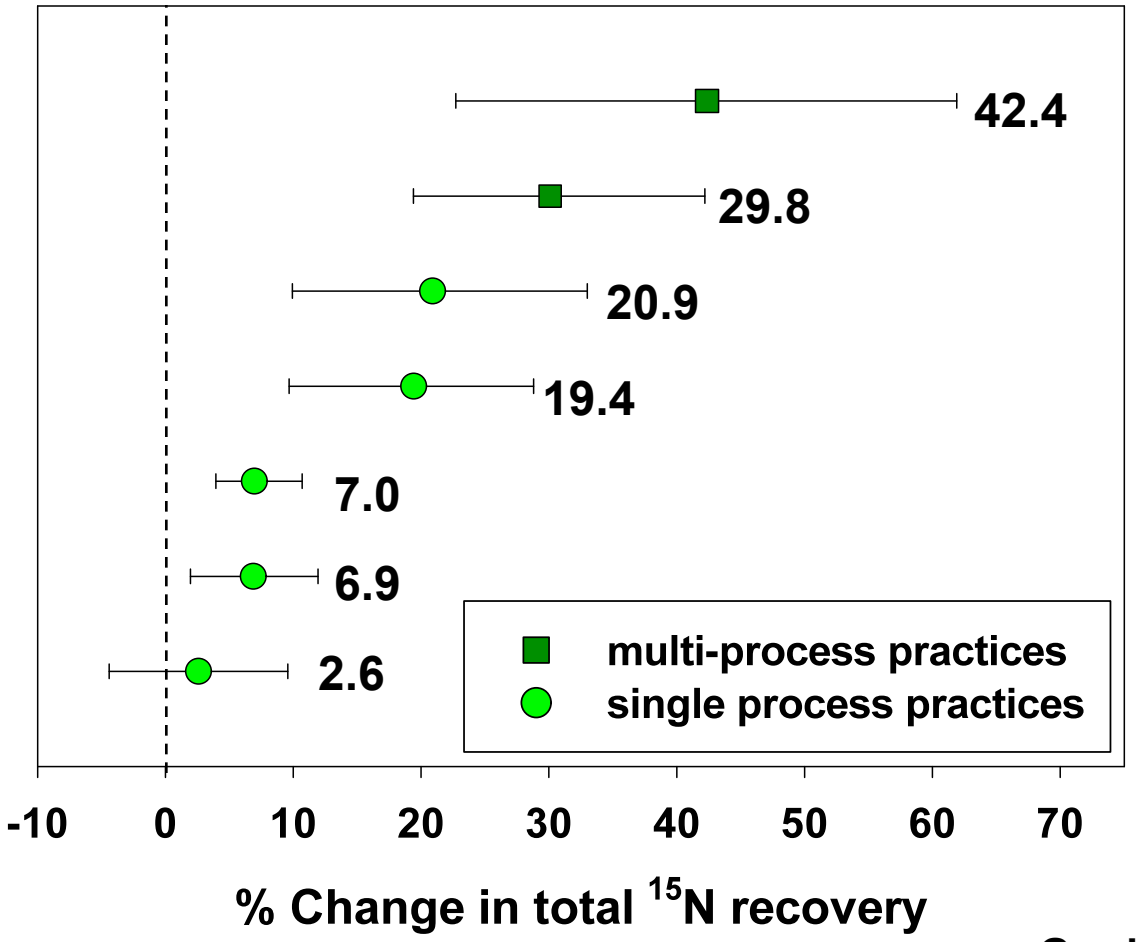
Tonitto et al. 2006

The cover crop N “pump”



An average of 40 kg N/ha

Meta-analysis of ^{15}N literature



organic N source

more diverse rotation

spring fertilizer application

proximity to roots

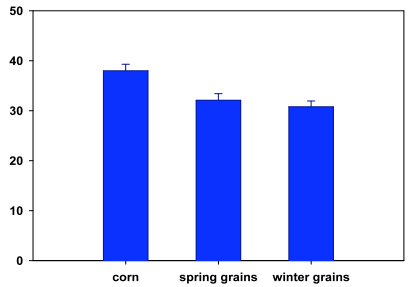
reduced N fertilizer rate

nitrification inhibitor

different inorganic N form

Gardner and Drinkwater, in review

In these studies, the proportion of ^{15}N fertilizer in crop biomass averages ≤40%



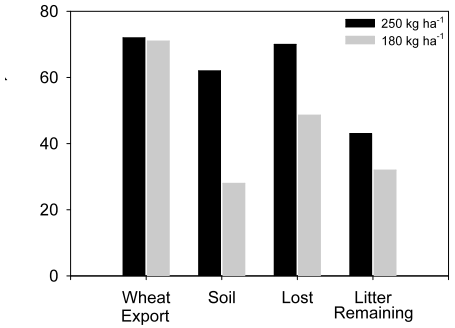
Gardner and Drinkwater, submitted Ecol. Applications

Effect of improved fertilizer N efficiency on fate of N

	Broad-cast	Side dress
Fertilizer N rate	**250**	**180**
Yield (MT/ha)	6.08	6.16
Total N grain (%)	2.55	2.54
Total biomass	12.67	12.83

Matson et al. 1998 and Ortiz-Monasterio, pers. comm.

Distribution of N fertilizer

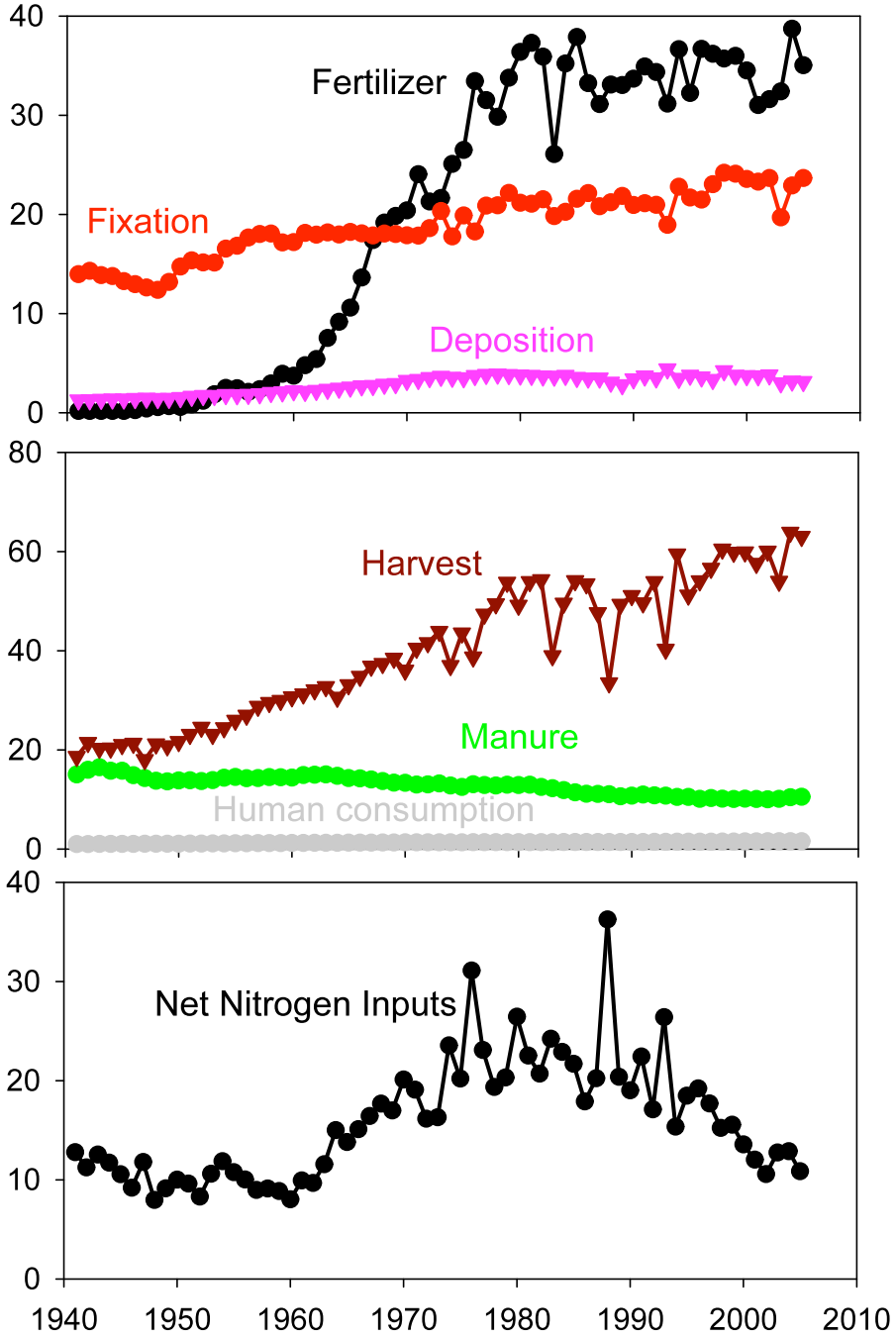


Drinkwater and Snapp, 2007 based on data from Matson et al. 1998 and Ortiz-Monasterio, pers. comm.

To summarize key challenges:

- Nutrient management focuses on inorganic, soluble pools which are subject to loss and are ephemeral
- Despite surplus fertilizer additions, the majority of crop N uptake is still dependent on internal cycling
- Nutrient management research: Predominance of short-term, studies mainly focus on crop FUE
- Emphasis on crop FUE misses opportunities to proactively manage other processes governing nutrient cycling and NUE
- With the exception of rare instances, the current system ***requires*** surplus N additions
- Agricultural infrastructure and farmer behavior: tile drainage, mismatch of fertilization supply structure and technical support with farming needs, farm policy

Upper Mississippi River Basin – nitrogen balance



David, M.B., source David and Gentry, 2000

Dominant framework	Ecosystem-based
Nutrient supply	
• Optimize delivery of soluble, inorganic fertilizers to cash crop • Single growing season	• Use of a variety of nutrient sources • Target soil reservoirs that supply plant nutrients • Promote exchanges of C, N & P between plants and decomposers
Soil pools actively managed	
•Inorganic N, extractable P	• All N and P pools, organic and inorganic • Emphasize pools with longer MRT's
Plant-mediated processes	
• Manage crop to create a strong sink for fertilizers; remove all growth limiting factors	• Maximize C-fixation, N & P uptake in time & space via increased plant diversity
Microbial transformations	
• Inhibit nitrification	• Reduce soluble, inorganic N & P pools • Promote microbial transformations to conserve nutrients
Measures of NUE	
• Metrics focus on a single field season, limited to crop uptake (yield, $)	• Metrics reflect greater spatial and temporal scales

Nitrogen balance after 15 years by cropping system