Back-engineering nature: Disentangling plant strategies in support of the Corps' wetland ecosystem models

Gary Ervin

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Collaborators: Gray Turnage (MSU),
Brook Herman (USACE), Todd Swannack (USACCE)

My motivations for this research

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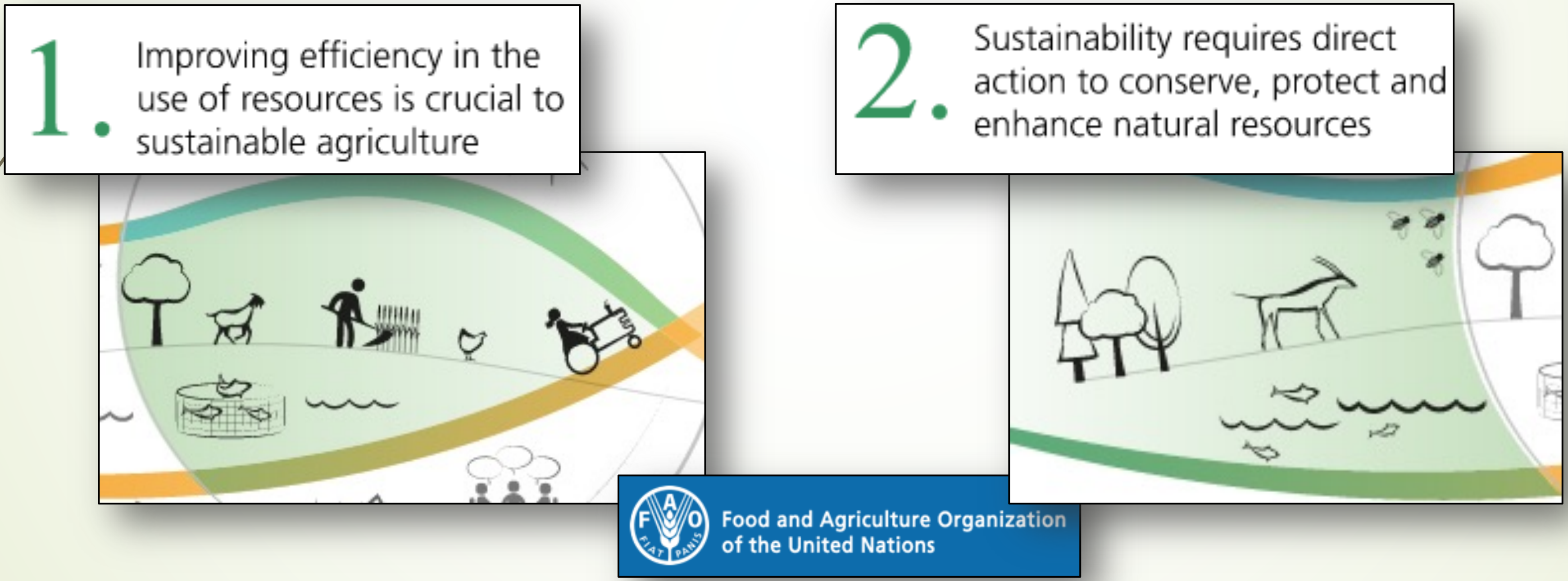
Six months ago

My motivations for this research

We need to find ways to mitigate the stresses we are add to our support system.

UN FAO on Sustainable Food and Agriculture

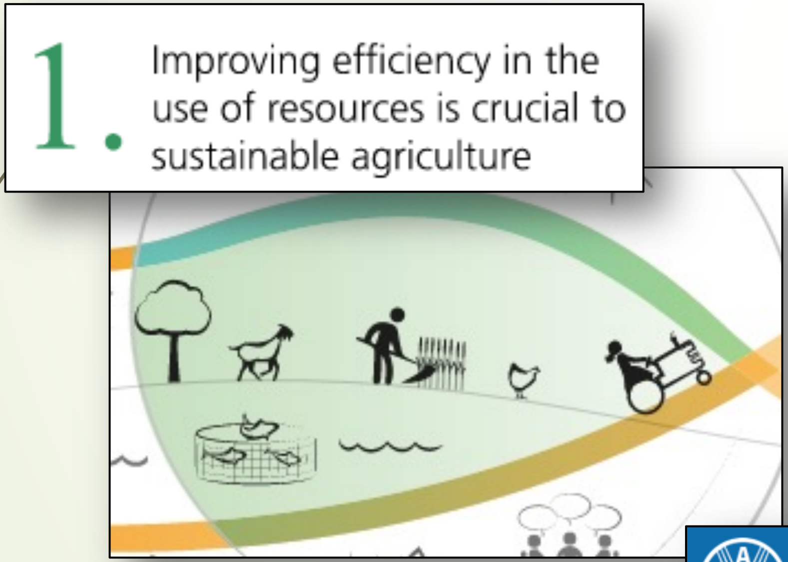
"The most widespread model of agriculture intensification involves intensive use of farm inputs…with subsequent pollution of water, destruction of freshwater habitats, and destruction of soil properties. Such trends in agricultural intensification are not compatible with sustainable agriculture and are a threat to future production."

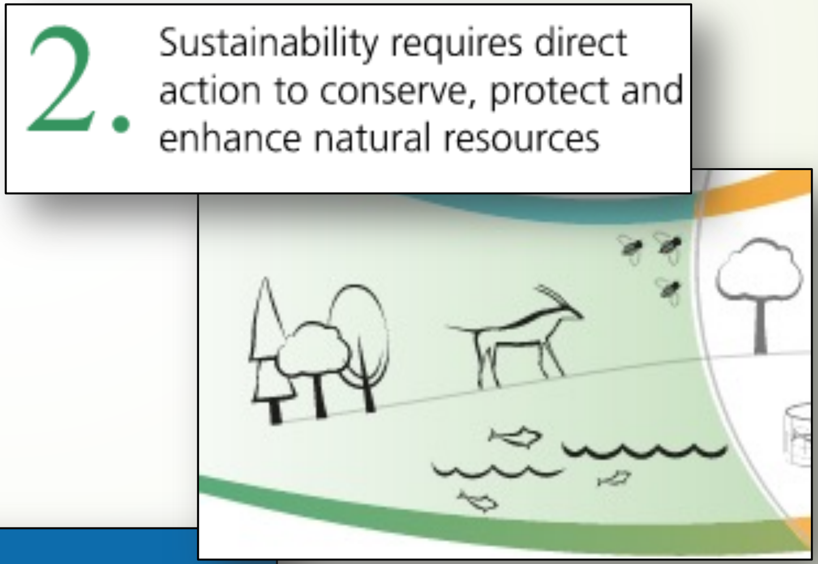


http://www.fao.org/sustainability/background/principle-1/en/

UN FAO on Sustainable Food and Agriculture

"The most widespread model of ***agriculture intensification*** involves intensive use of farm inputs…with subsequent ***pollution of water***, ***[alteration] of freshwater habitats***, and ***[alteration] of soil properties***. Such trends in agricultural intensification are not compatible with sustainable agriculture and are a ***threat to future production***."





Food and Agriculture Organization of the United Nations

http://www.fao.org/sustainability/background/principle-1/en/

Connections between wetlands and agriculture

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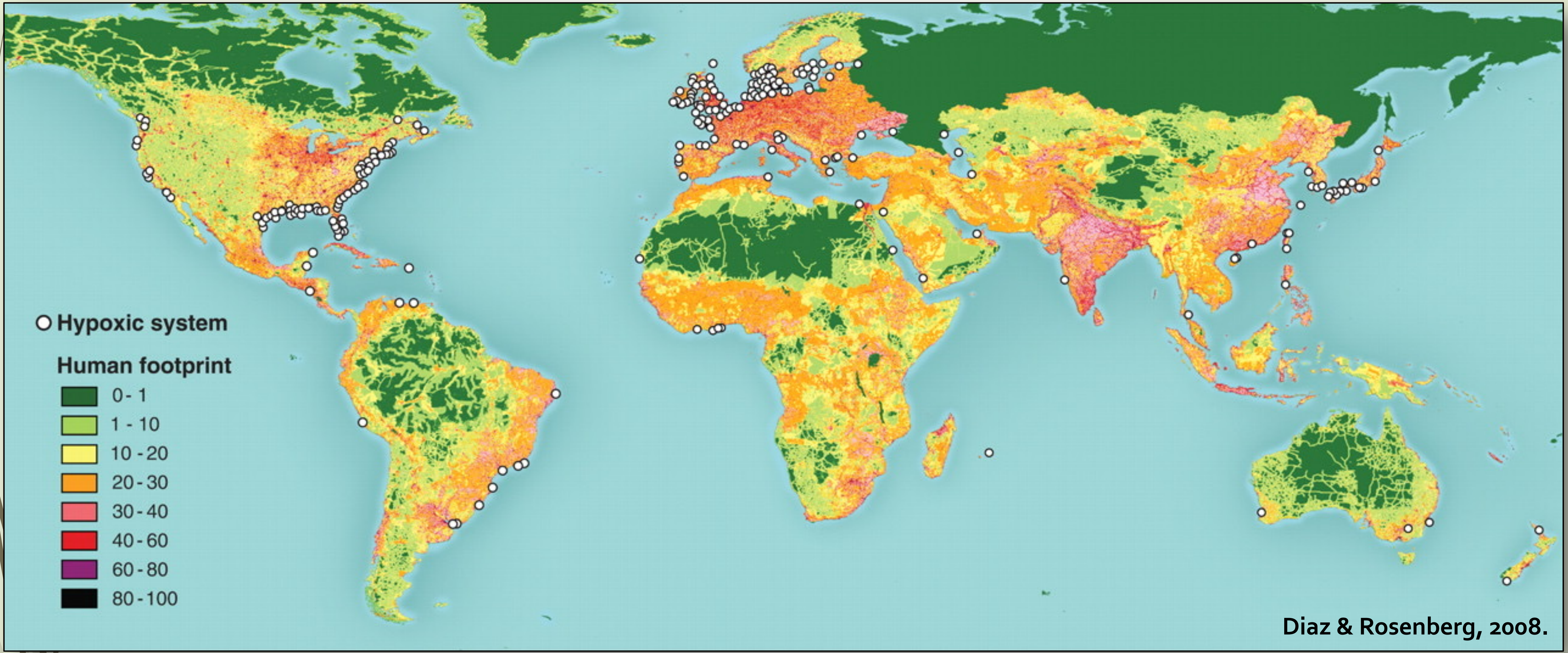

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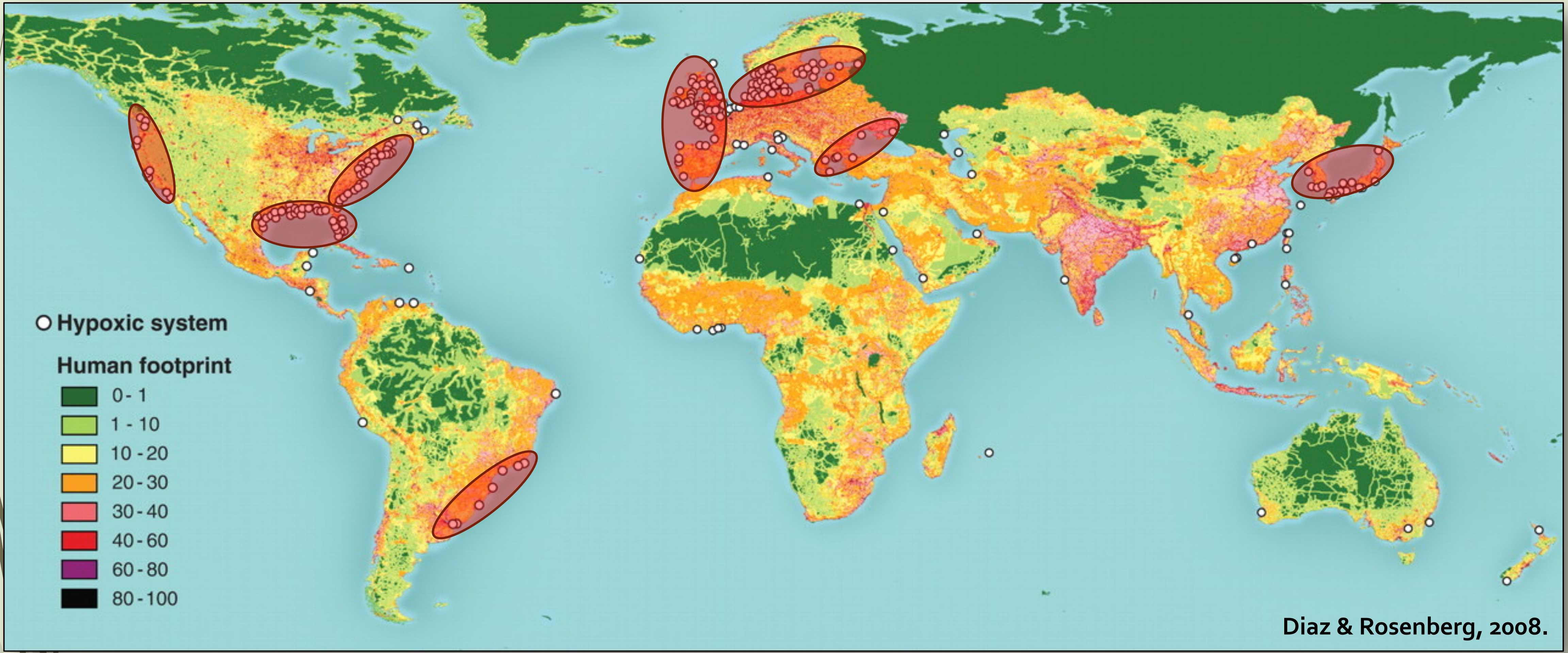
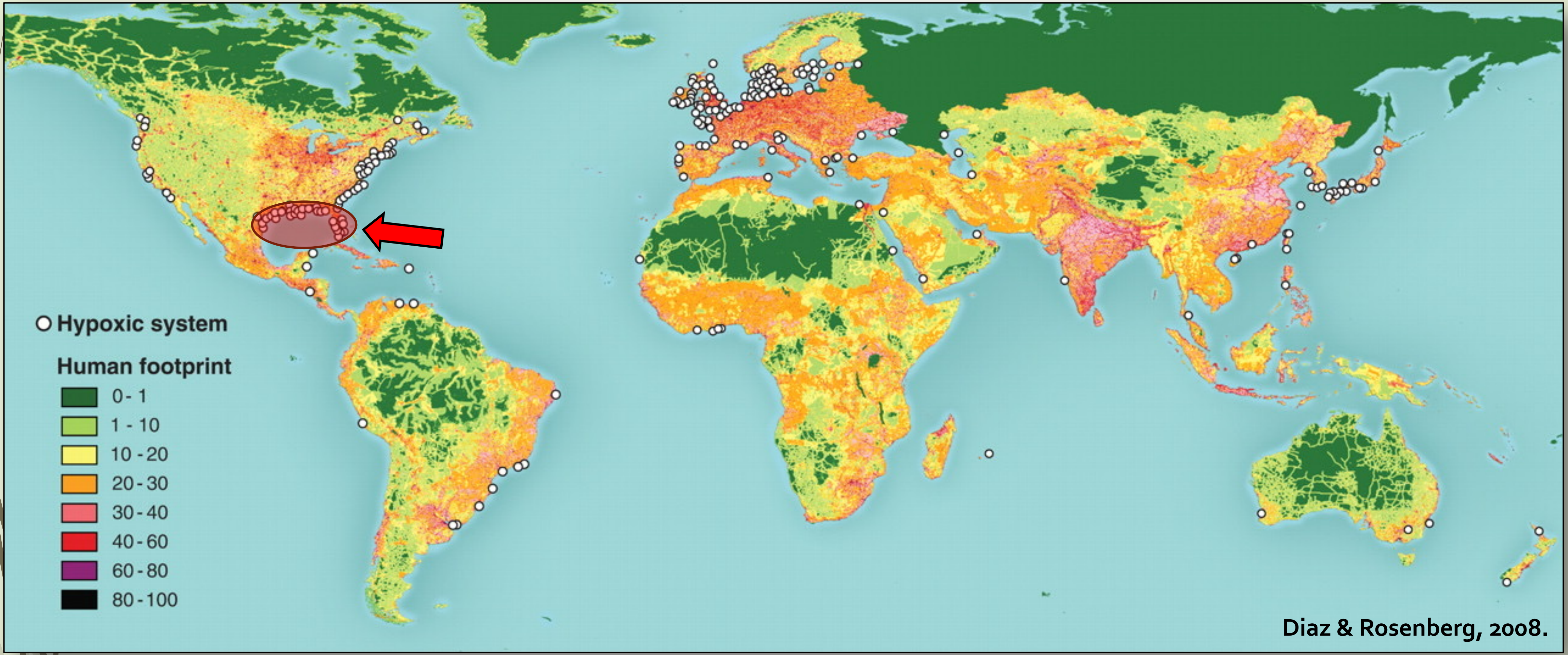


Diaz & Rosenberg, 2008.

Connections between wetlands and agriculture



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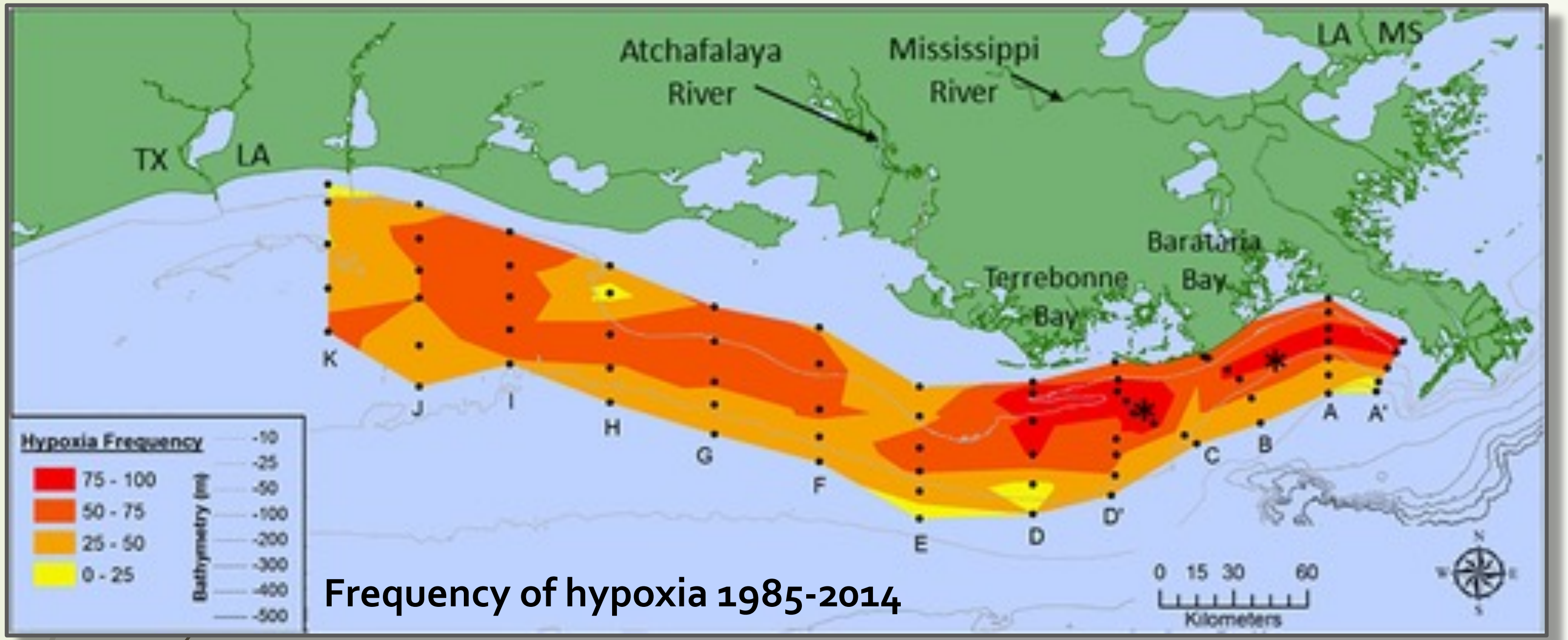
Gulf of Mexico hypoxic zone



Rabalais & Turner, 2019.
https://aslopubs.onlinelibrary.wiley.com/doi/full/10.1002/lob.10351

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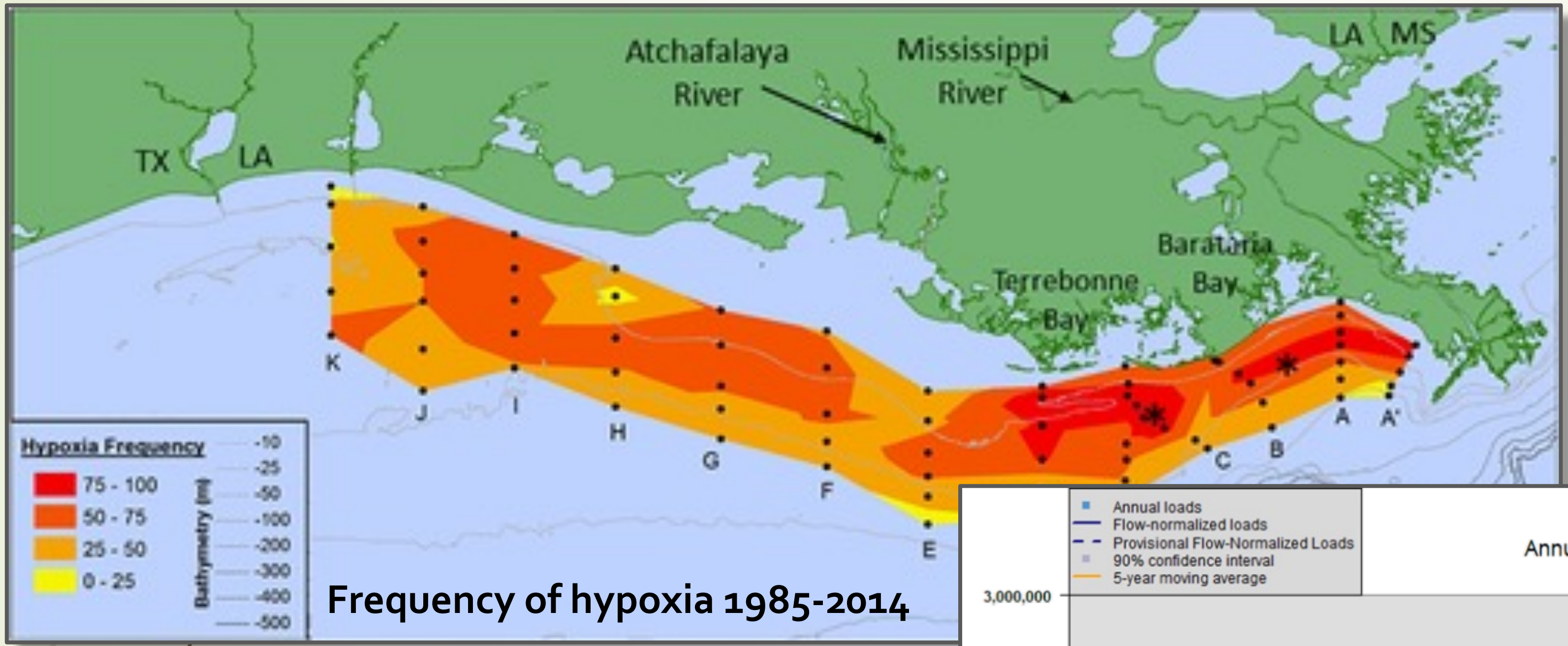

Rabalais & Turner, 2019.
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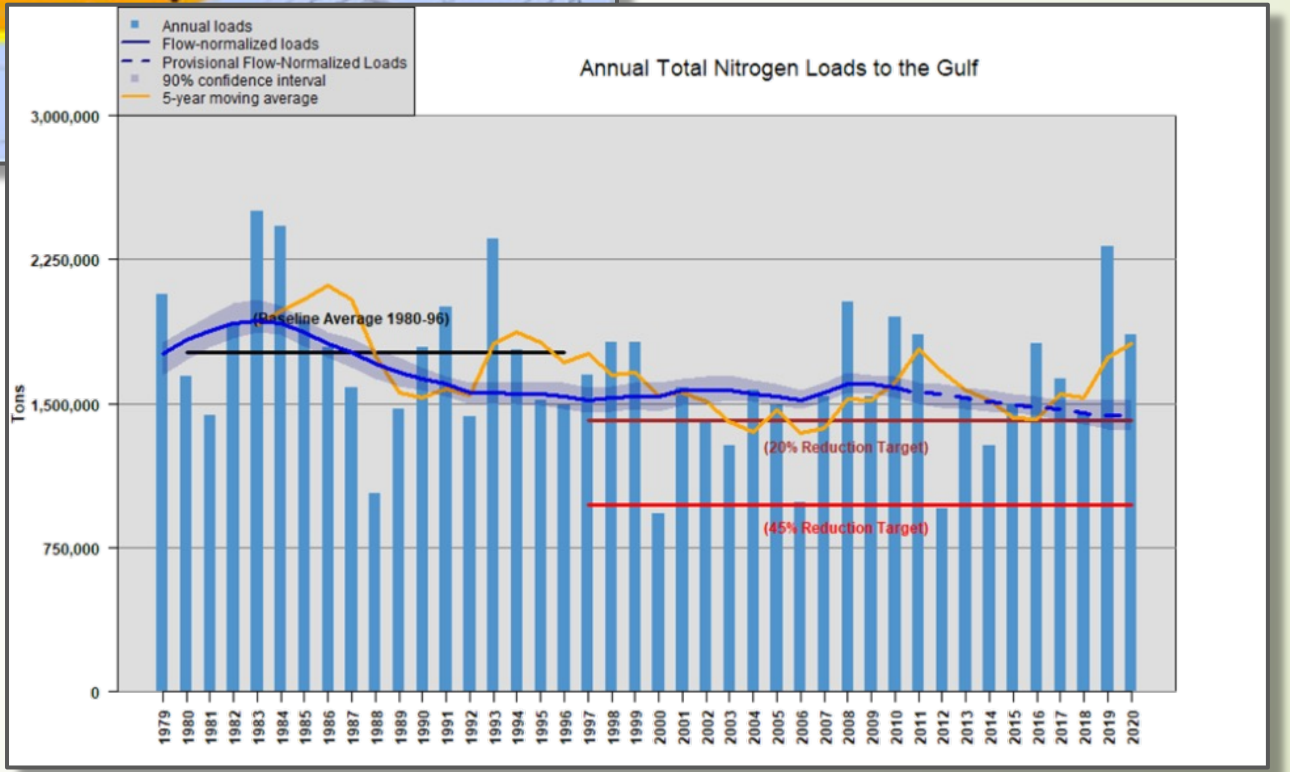
https://nrtwq.usgs.gov/nwqn/#/GULF



Land use and nutrient transport within the basin

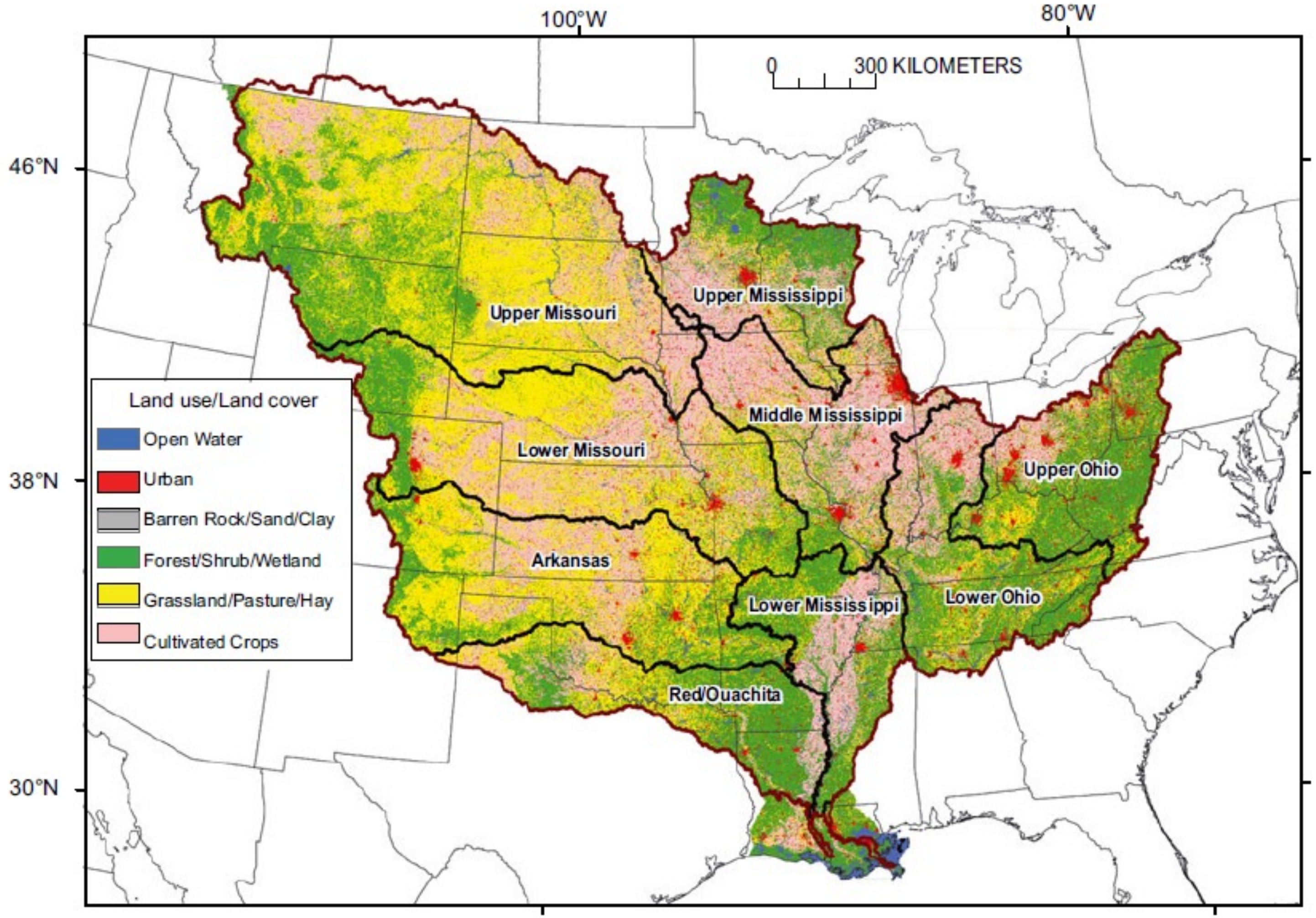
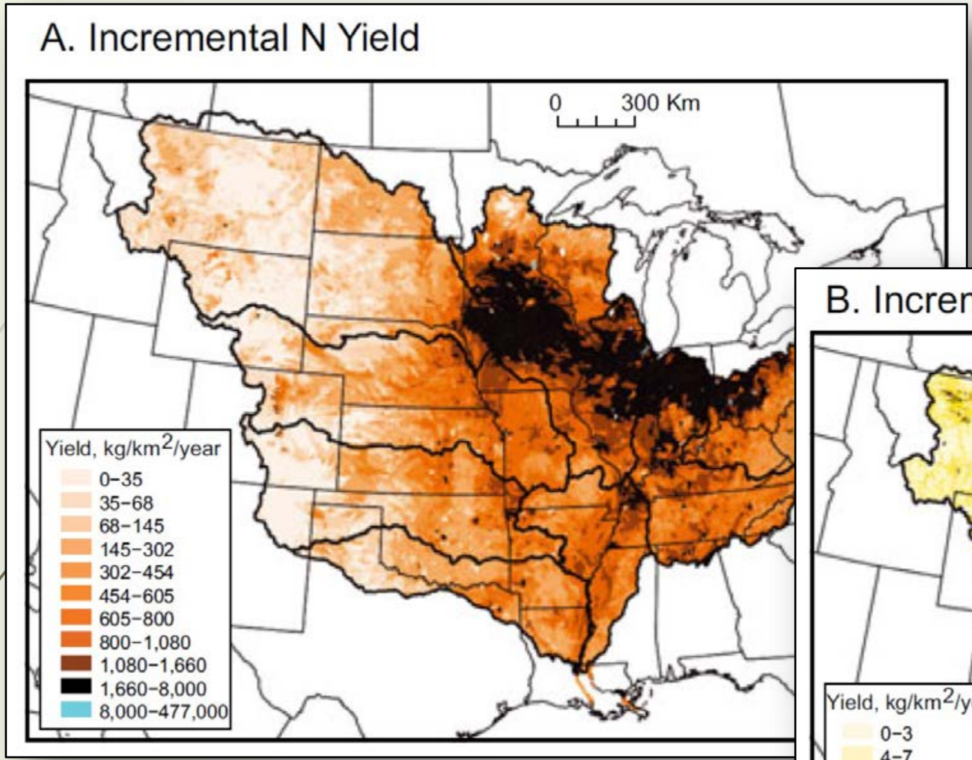
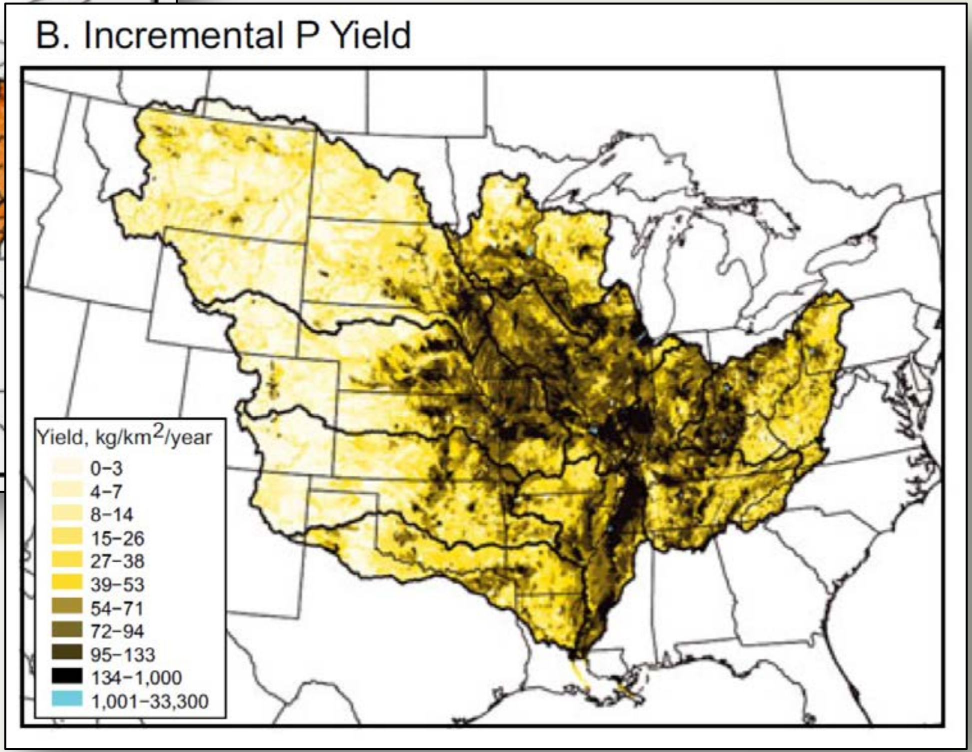


FIGURE 1. Land Use and Land Cover in the Mississippi/Atchafalaya River Basin (MARB) (USGS, 2000). The nine main river basins (subbasins) in the MARB defined by Goolsby *et al.* (1999) are delineated.

Robertson, Dale M., David A. Saad, and Gregory E. Schwarz, 2014. Spatial Variability in Nutrient Transport by HUC8, State, and Subbasin Based on Mississippi/Atchafalaya River Basin SPARROW Models. *Journal of the American Water Resources Association* (JAWRA) 1-22. DOI: 10.1111/jawr.12153

Land use and nutrient transport within the basin





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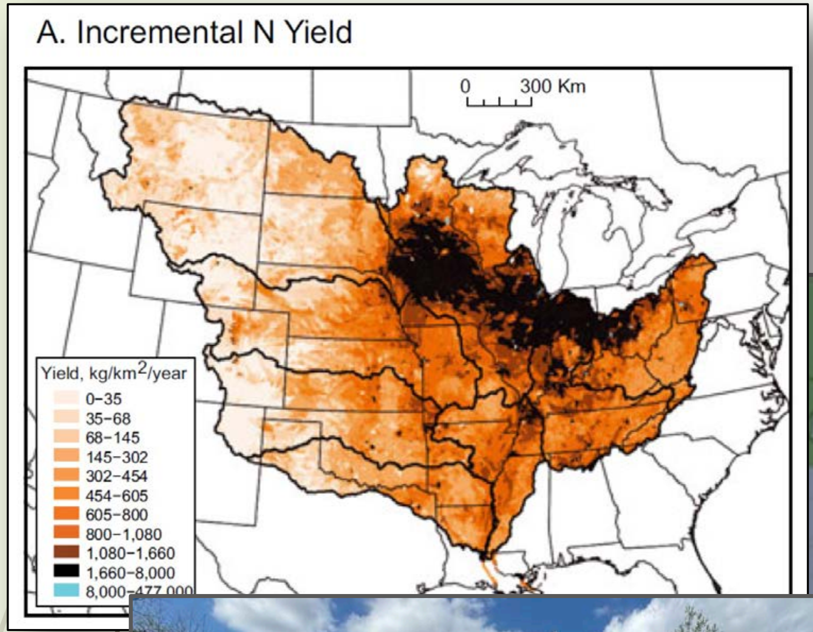
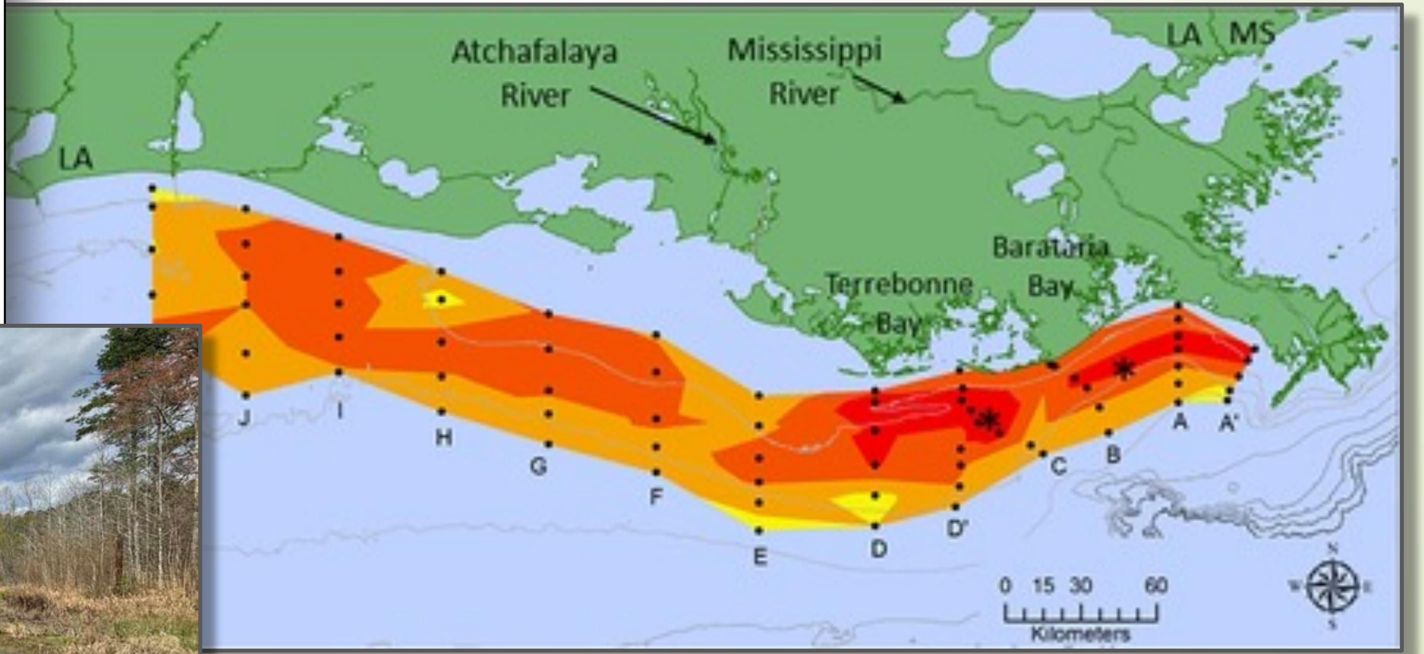
Connections between wetlands and agriculture





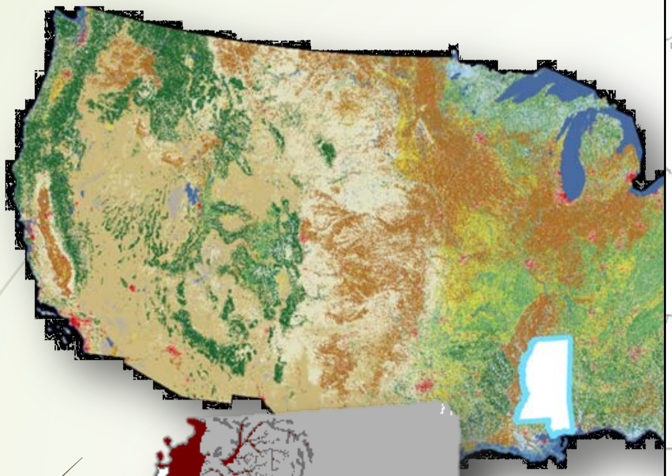
Two areas that we have studied

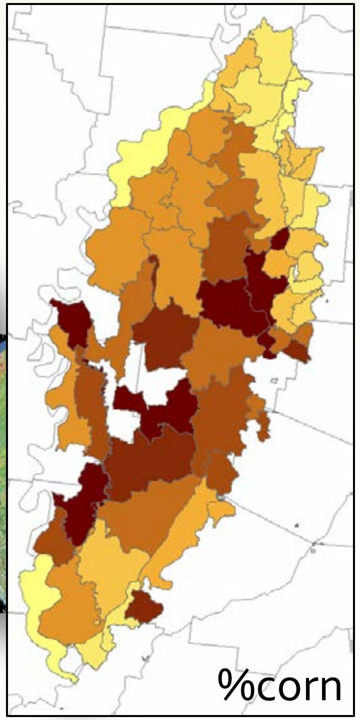
1. Stressors associated with agricultural runoff could negatively affect adjacent wetlands and wetland plant assemblages.

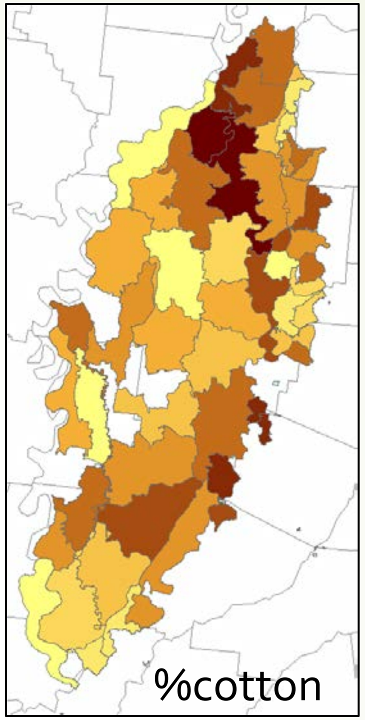
2. Wetland plants that could serve as biological buffers to reduce downstream transport of nutrients and sediment

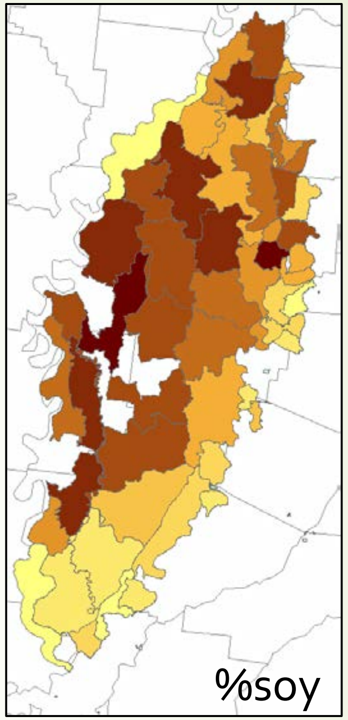
Some of our early work investigating these possibilities

Ag in "The Delta"



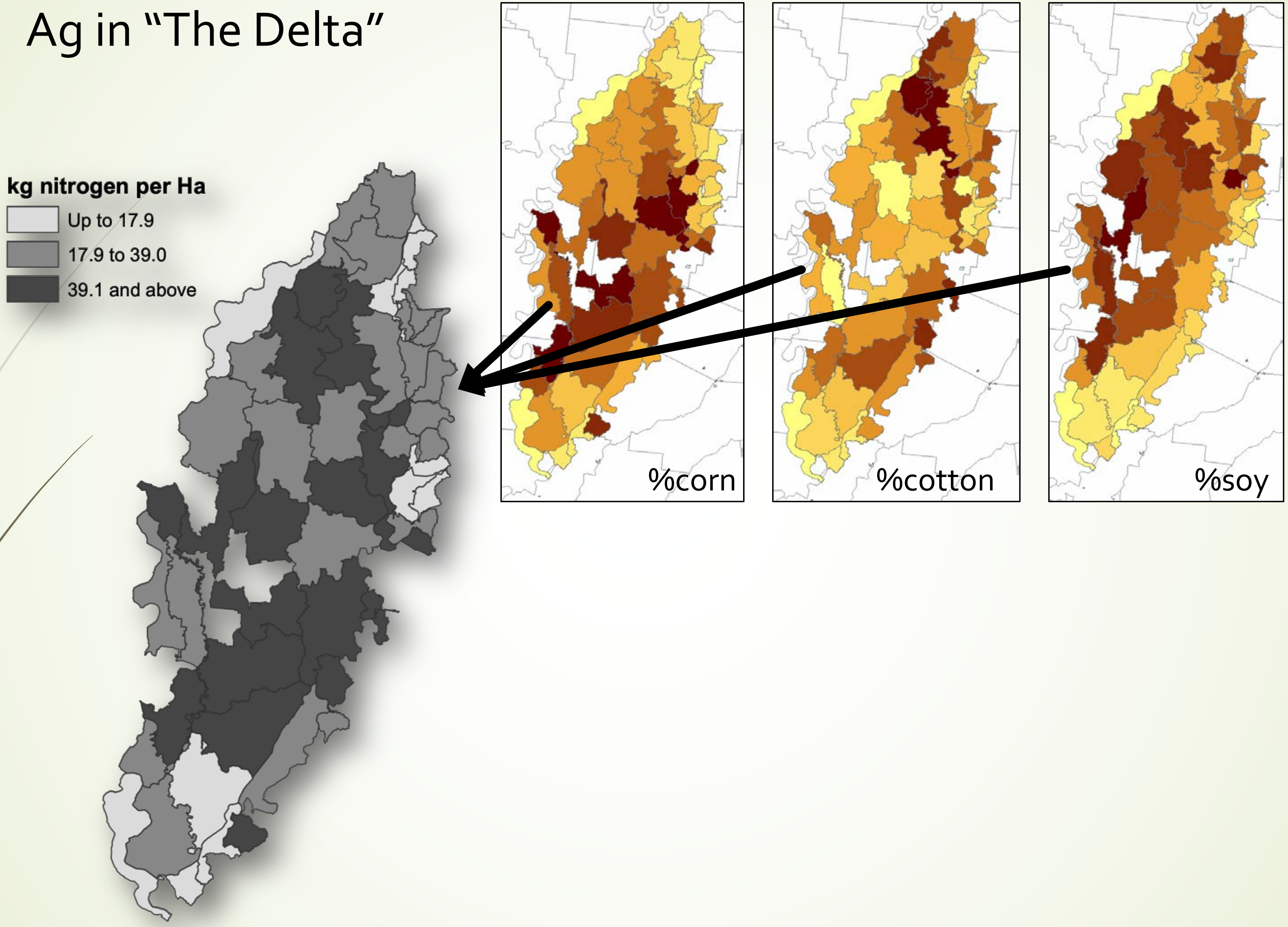




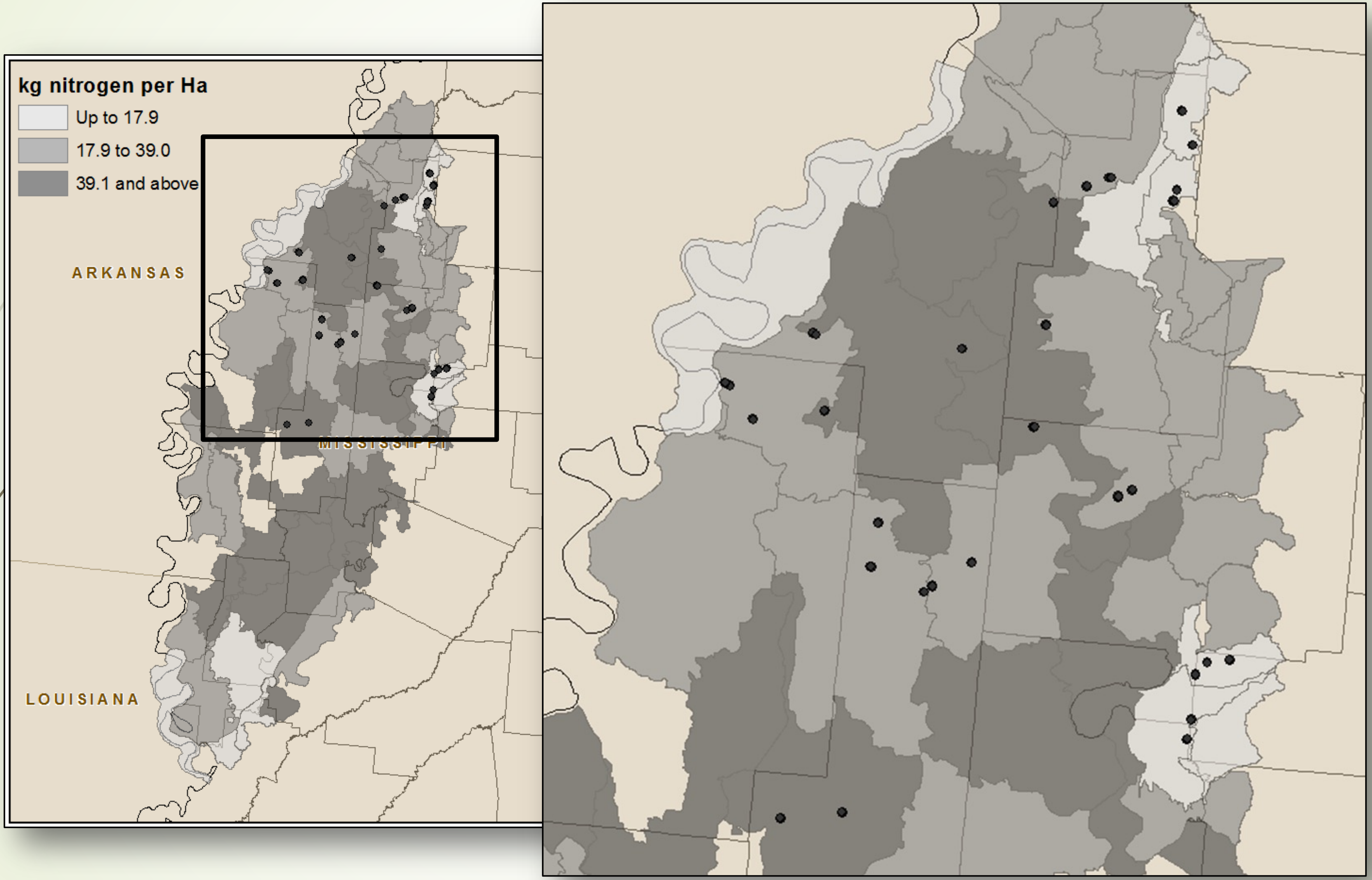


	corn	cotton	soy
mean	11	8	28
min	0	0	0
max	25	32	48

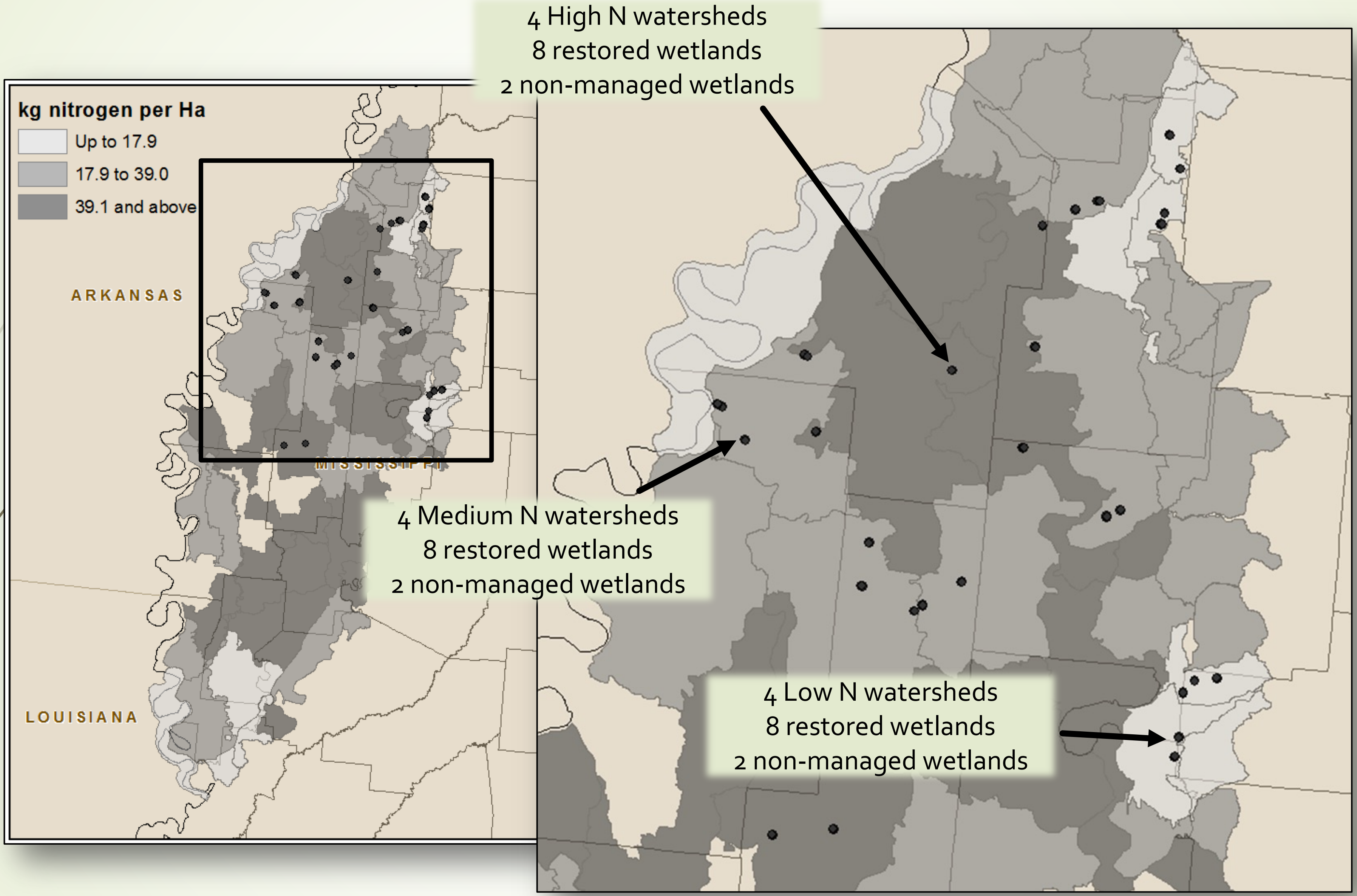
Ag in "The Delta"



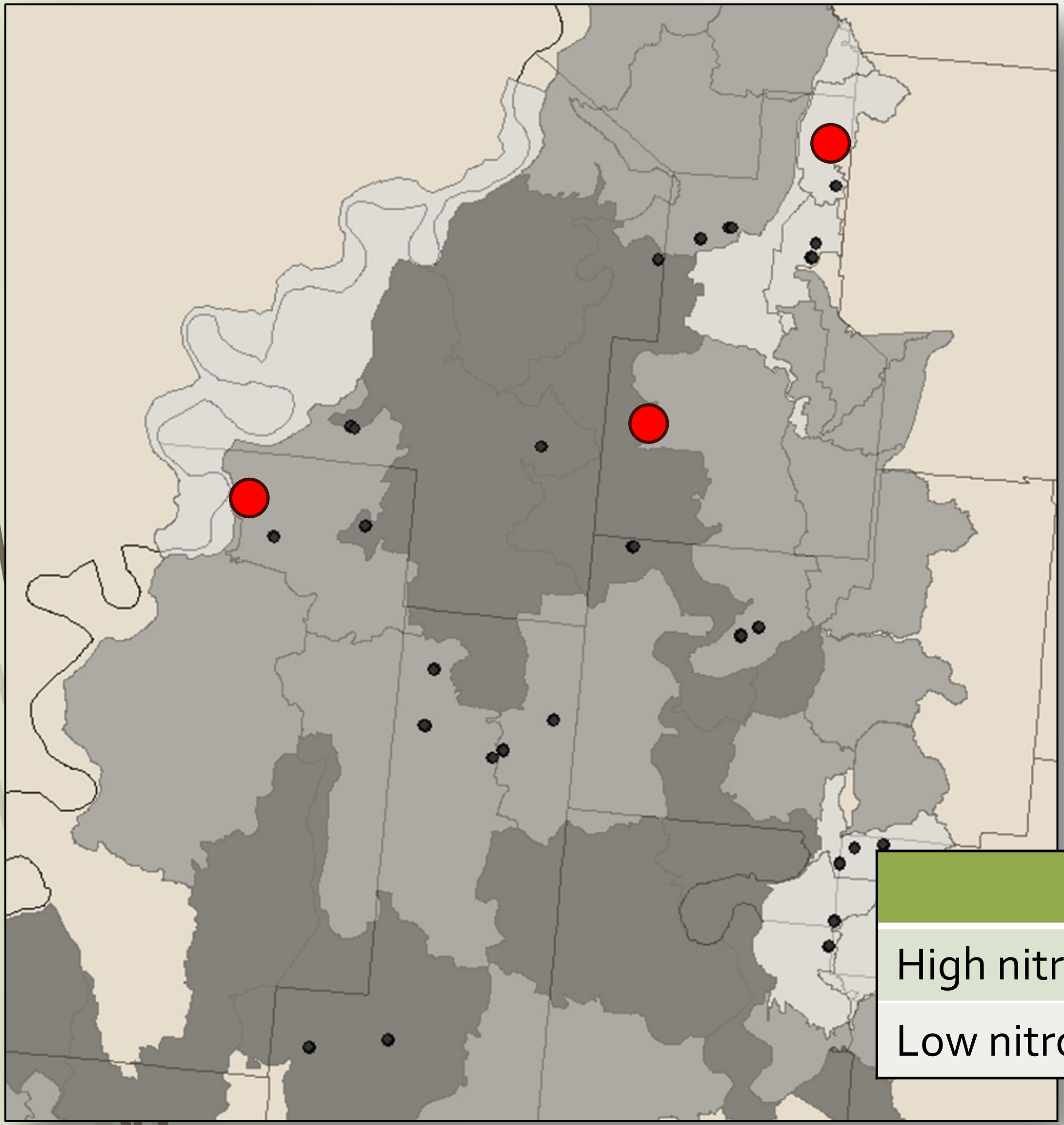
Study sites

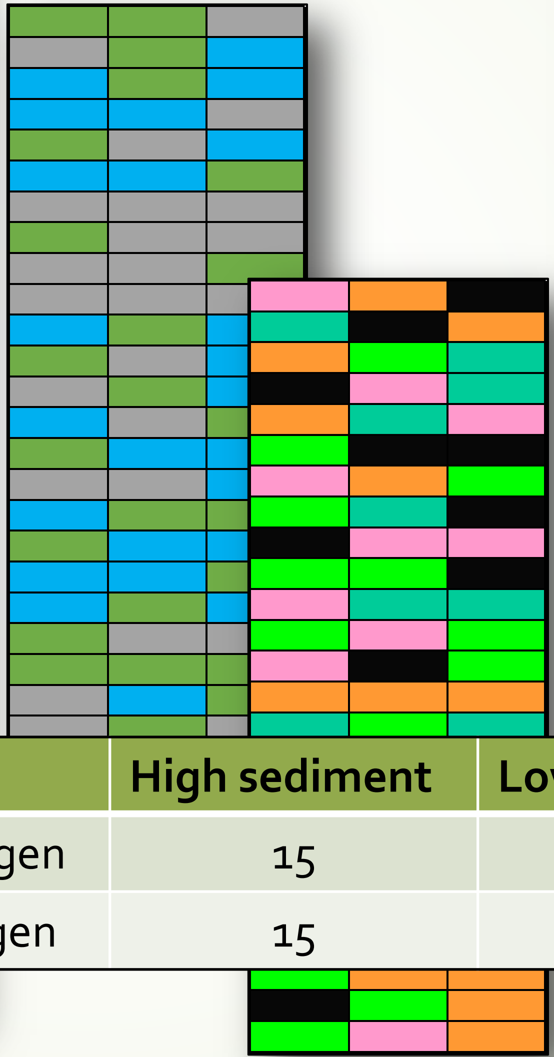

kg nitrogen per Ha
Up to 17.9
17.9 to 39.0
39.1 and above
ARKANSAS
LOUISIANA
MISSISSIPPI

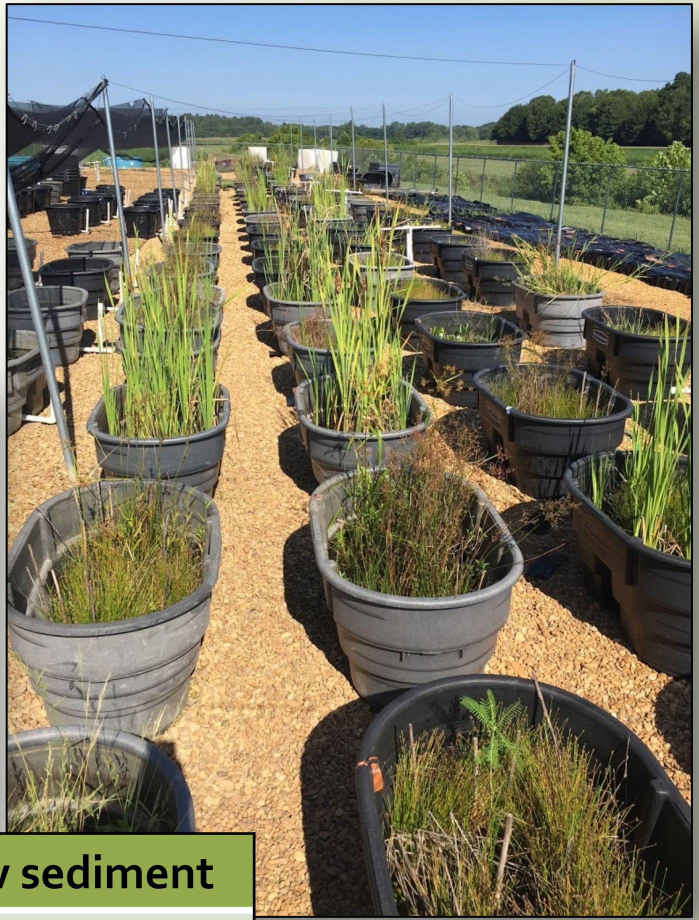
Study sites


kg nitrogen per Ha
Up to 17.9
17.9 to 39.0
39.1 and above
ARKANSAS
LOUISIANA
4 High N watersheds
8 restored wetlands
2 non-managed wetlands
4 Medium N watersheds
8 restored wetlands
2 non-managed wetlands
4 Low N watersheds
8 restored wetlands
2 non-managed wetlands

Experimental test of common "stressors"

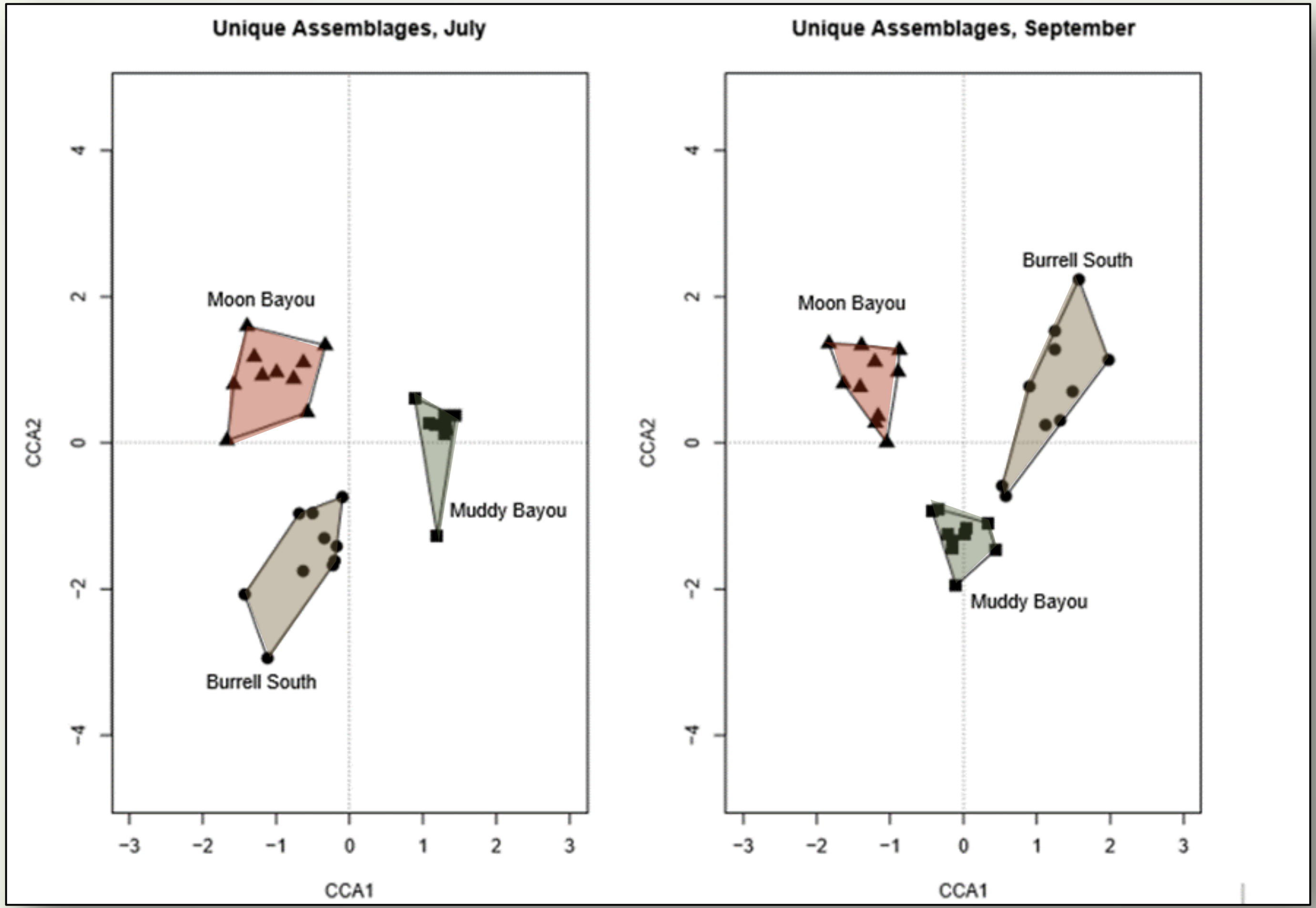






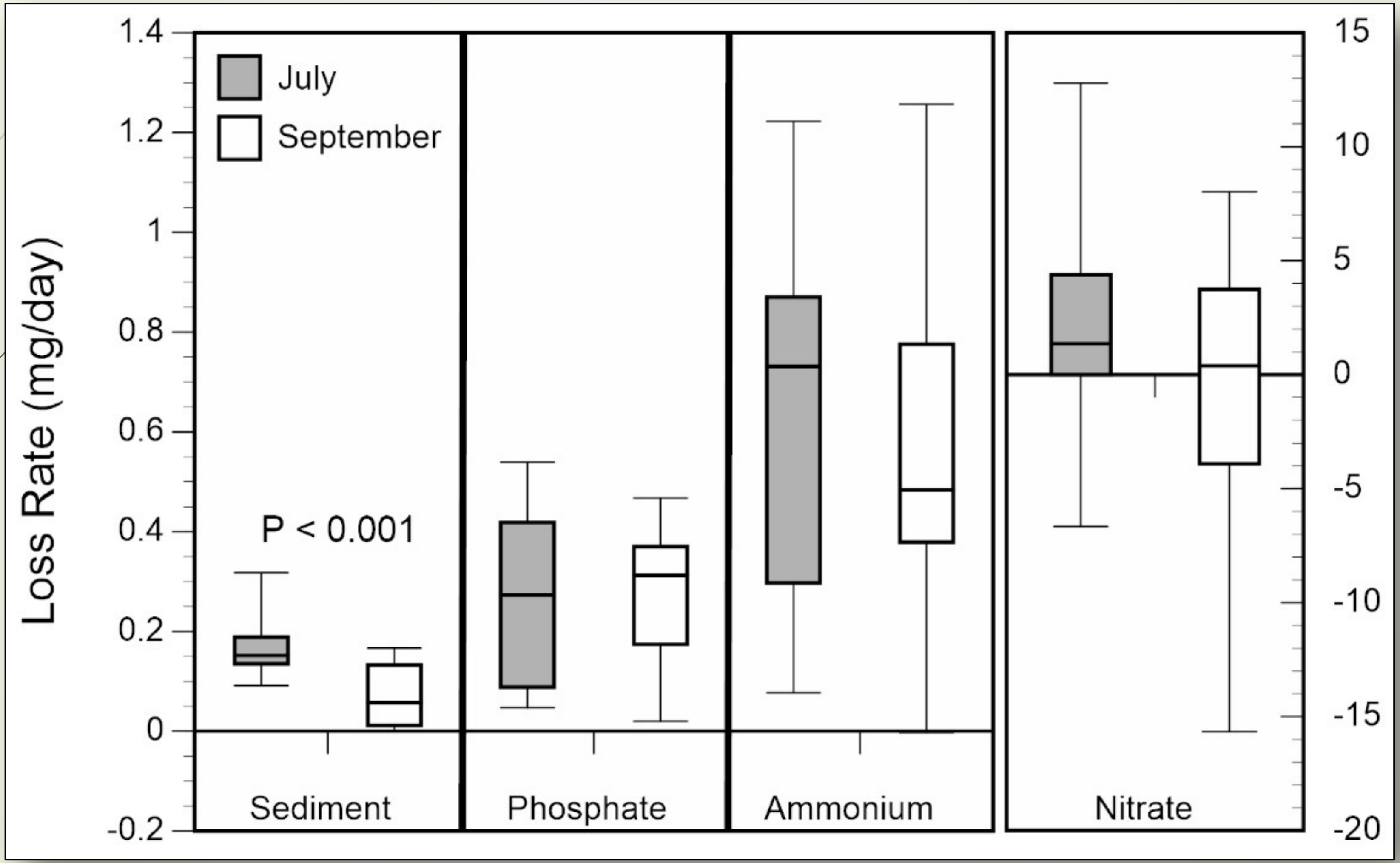
	High sediment	Low sediment
High nitrogen	15	15
Low nitrogen	15	15

Plant species differed depending on the wetland soil source



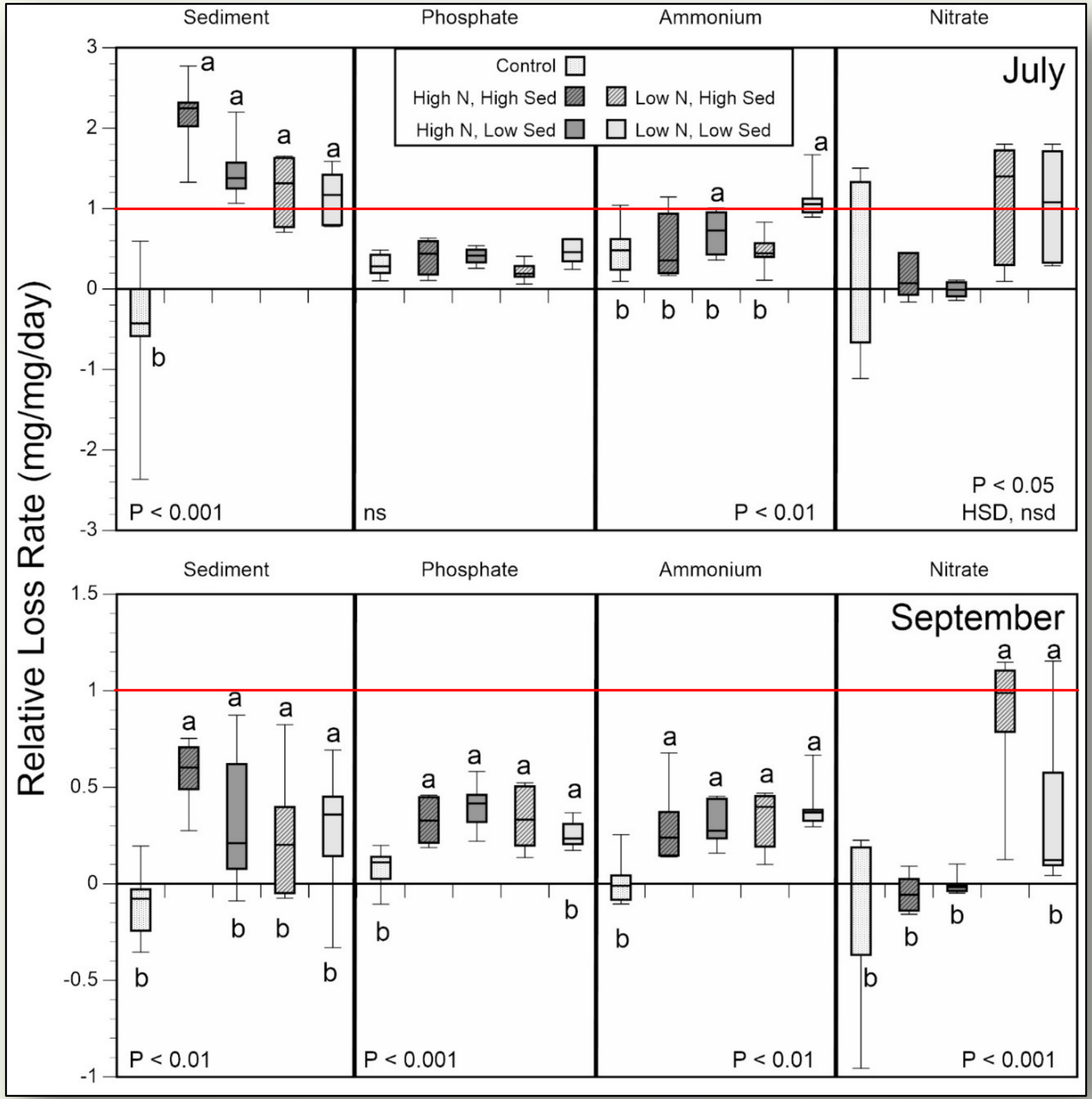
Shoemaker et al. 2017

Few significant differences were found between July & September



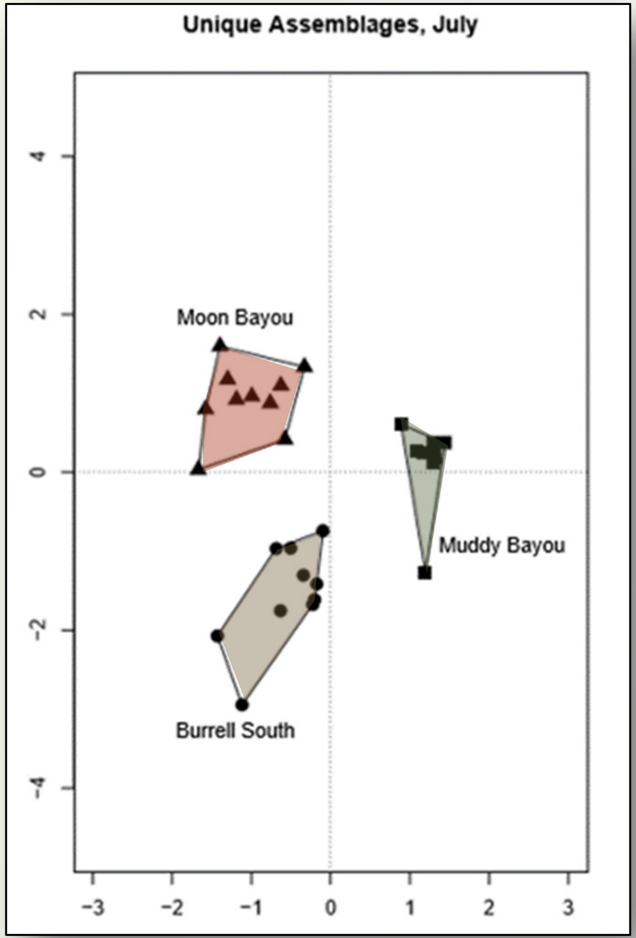
Shoemaker et al. 2017

Relatively high capacity for removal of contaminants



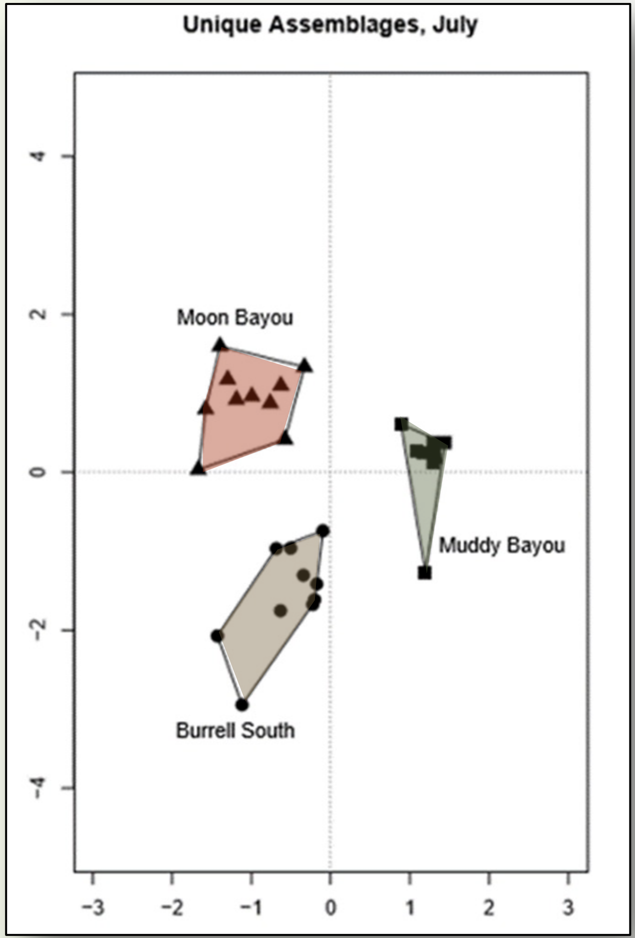
Shoemaker et al. 2017

Finally, the difference between plant species among wetlands…

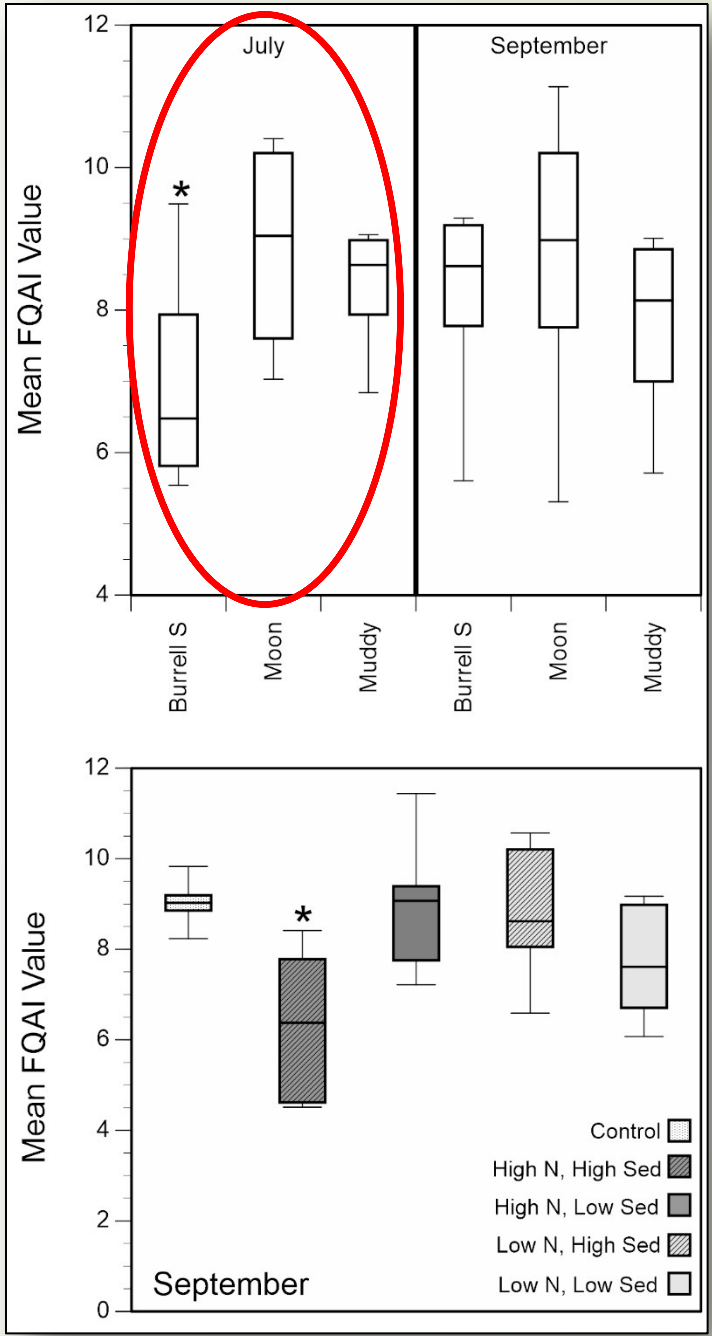


Shoemaker et al. 2017

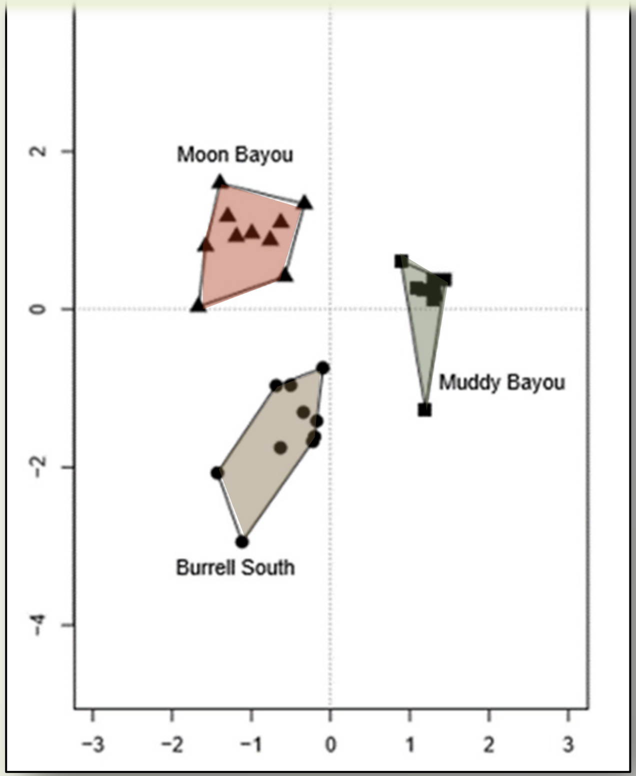
...was accompanied by differences in the floristic quality of species (in July)



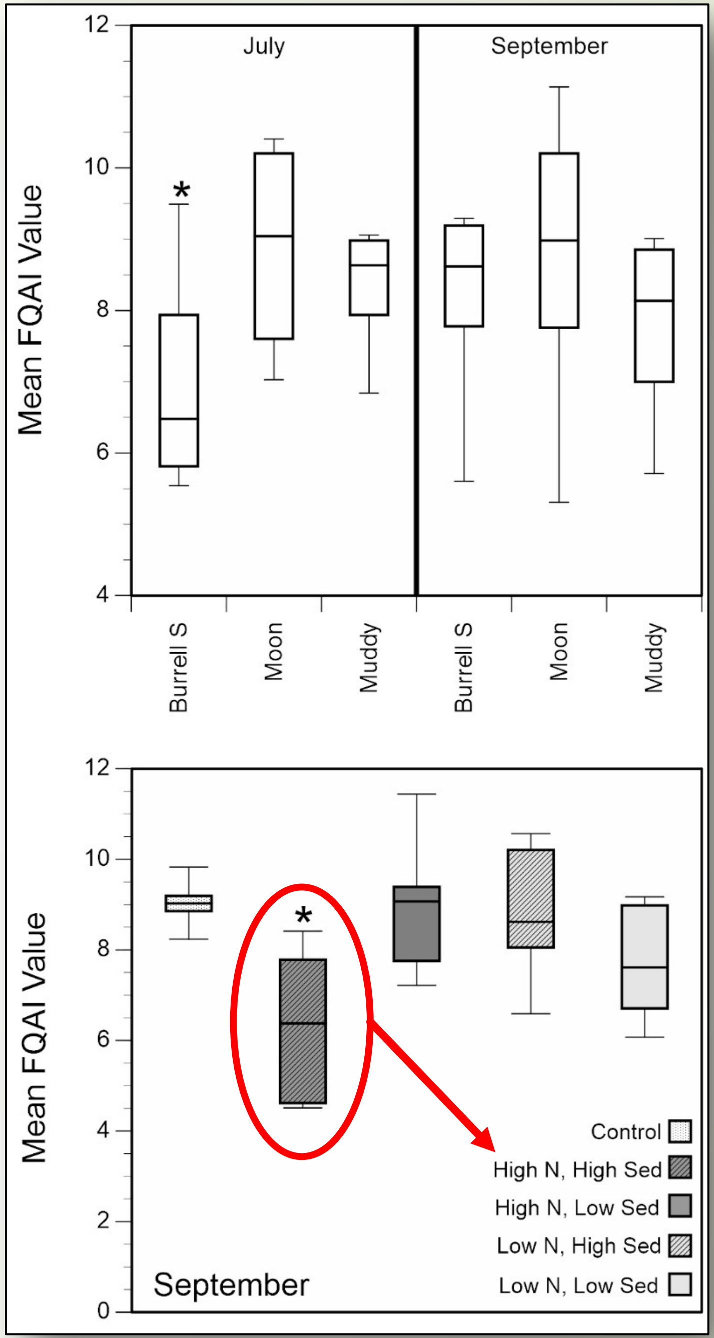
Shoemaker et al. 2017



And… the combination of high sediment and high N resulted in the lowest FQAI among the five treatments



Shoemaker et al. 2017



Summary of these findings

- Plant species are strongly influenced by individual wetland identity, but all plant assemblages showed ability to remove nutrients and sediment
- Soil source strongly determines assemblage identity, but the addition of stressors can alter richness and diversity in these systems
- Plant assemblage dynamics may be driven by environmental filtering mechanisms

Summary of these findings

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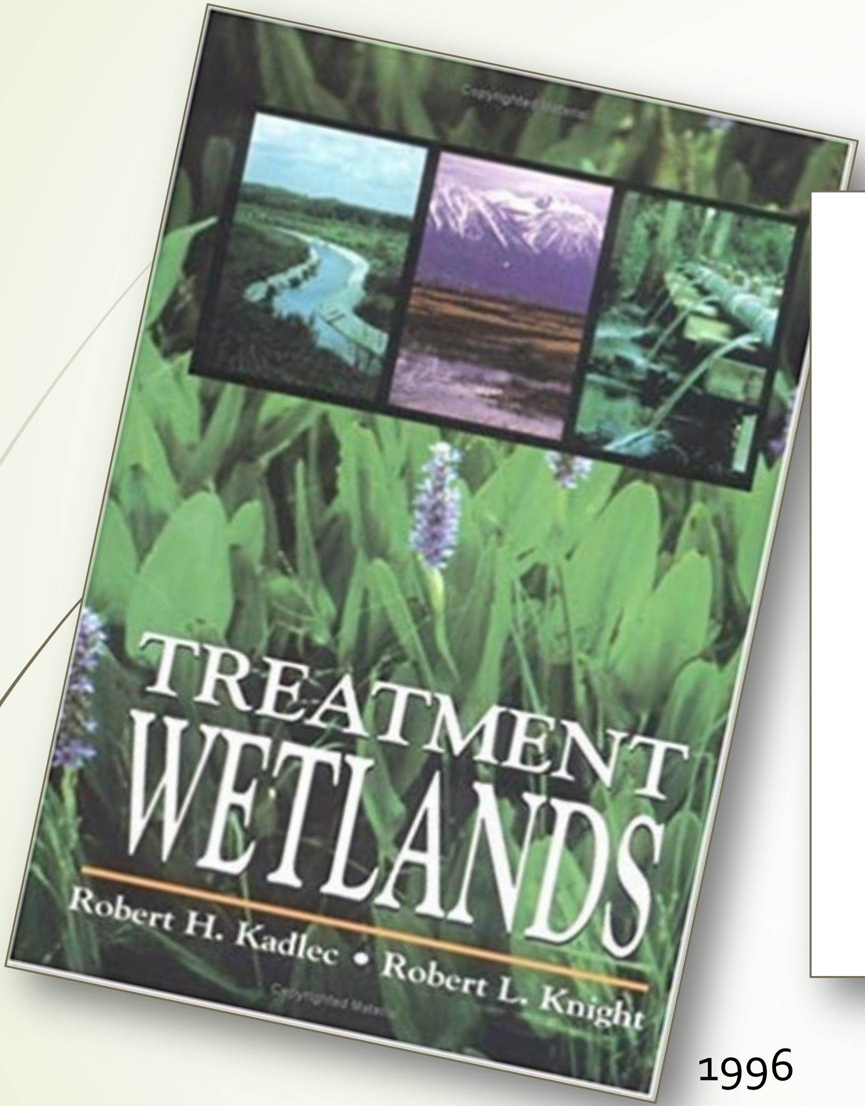
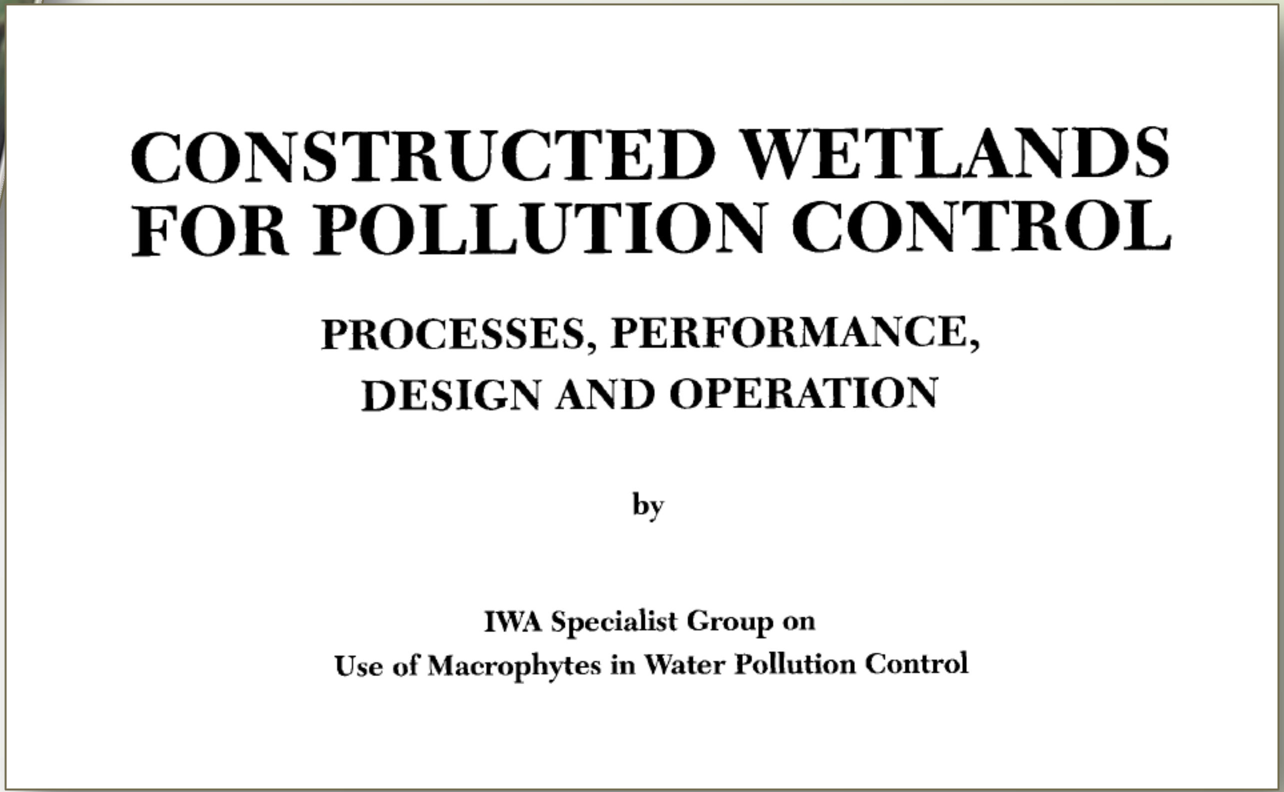


1996



CONSTRUCTED WETLANDS
FOR POLLUTION CONTROL

PROCESSES, PERFORMANCE,
DESIGN AND OPERATION

by

IWA Specialist Group on
Use of Macrophytes in Water Pollution Control

Kadlec et al. 2006

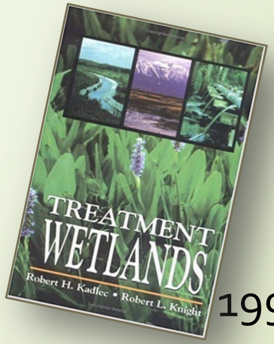
…no evidence that [water quality performance] differs among common emergent species

The best selection criteria are growth potential, survivability, and cost…

…species that provide structure year-round perform better

…fast-growing emergent species that have high lignin contents…are most ideal

Wetland plant genera that most successfully meet these criteria include *Typha*, *Scirpus*, and *Phragmites*.



1996

Is it really that simple?

From the primary literature

ROLE OF AQUATIC PLANTS IN WASTEWATER TREATMENT BY ARTIFICIAL WETLANDS

R. M. GERSBERG[1,*], B. V. ELKINS[1], S. R. LYON[1] and C. R. GOLDMAN[2]

[1]San Diego Region Water Reclamation Agency, 10887 Woodside Avenue, P.O. Box 70, Santee, CA 92071 and [2]Division of Environmental Studies, University of California, Davis, CA 95616, U.S.A.

(*Received August 1985*)

Wat. Res. Vol. 20, No. 3, pp. 363–368, 1986
Printed in Great Britain.

Abstract—This report describes investigations using artificial wetlands which quantitatively assess the role of each of three higher aquatic plant types, *Scirpus validus* (bulrush), *Phragmites communis* (common reed) and *Typha latifola* (cattail), in the removal of nitrogen (via sequential nitrification–denitrification), BOD and TSS from primary municipal wastewaters. During the period August 1983–December 1984, the mean

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Typha, *Scirpus*, and *Phragmites*…

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ROLE OF AQUATIC PLANTS IN WASTEWATER TREATMENT BY ARTIFICIAL WETLANDS

R. M. Gersberg[1,*], B. V. Elkins[1], S. R. Lyon[1] and C. R. Goldman[2]
[1]San Diego Region Water Reclamation Agency, 10887 Woodside Avenue, P.O. Box 70, Santee, CA 92071 and [2]Division of Environmental Studies, University of California, Davis, CA 95616, U.S.A.

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Typha, *Scirpus*, and *Phragmites*…

These two were a bit better.

From the primary literature

Plants for constructed wetland treatment systems – A comparison of the growth and nutrient uptake of eight emergent species

Chris C. Tanner

National Institute of Water and Atmospheric Research, P.O. Box 11-115, Hamilton, New Zealand

Received 3 August 1995; accepted 12 December 1995

Ecological Engineering 7 (199

Bioresource Technology 179 (2015) 1–7

Contents lists available at ScienceDirect

Bioresource Technology

journal homepage: www.elsevier.com/locate/biortech

ELSEVIER

omparison of four aquatic plant treatment systems for nutrient emoval from eutrophied water

CrossMark

hua Li, Xiaoying Yang, Zhengfang Wang, Ying Shan, Zheng Zheng*

artment of Environmental Science and Engineering, Fudan University, Shanghai 200433, PR China

Ecological Engineering 91 (2016) 302–309

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

ELSEVIER

Does the combination of two plant species improve removal efficiency in treatment wetlands?

Mariana Rodriguez, Jacques Brisson*

Institut de Recherche en Biologie Végétale, Département de sciences biologiques, Université de Montréal, 4101 East, Sherbrooke St., Montreal, Quebec, H1× 2B2, Canada

Ecological Engineering 37 (2011) 560–568

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

ELSEVIER

Nutrient removal in constructed microcosm wetlands for treating polluted river water in northern China

Haiming Wu[a], Jian Zhang[a,*], Peizhi Li[b], Jinyong Zhang[a], Huijun Xie[c], Bo Zhang[a]

[a] *Shandong Key Laboratory of Water Pollution Control and Resource Reuse, School of Environmental Science & Engineering, Shandong University, Jinan 250100, PR China*
[b] *Shandong Nansi Lake Water Quality Monitoring Center, Jining 272045, PR China*
[c] *Environment Research Institute, Shandong University, Jinan 250100, PR China*

From the primary literature

Maximizing pollutant removal in constructed wetlands: Should we pay more attention to macrophyte species selection?

J. Brisson, F. Chazarenc*[1]

SCIENCE OF THE TOTAL ENVIRONMENT 407 (2009) 3923–3930

Institut de Recherche en Biologie Végétale, Université de Montréal, 4101, rue Sherbrooke Est, Montréal (Québec) Canada H1X 2B2

From the primary literature

Maximizing pollutant removal in constructed wetlands: Should we pay more attention to macrophyte species selection?

J. Brisson, F. Chaz*

Institut de Recherche en Biolog

The species:

51 species included in the 35 studies

20 Cyperaceae (9 "*Scirpus*")
17 Poaceae (4 *Phragmites*)
7 *Typha*

1 Juncus

45 perennial species with similar structural morphology

6 Other (Genera: *Canna*, *Commelina*, *Eriocaulon*, *Iris*, *Ludwigia*, *Sagittaria*)

From the primary literature

Maximizing pollutant removal in constructed wetlands: Should we pay more attention to macrophyte species selection?

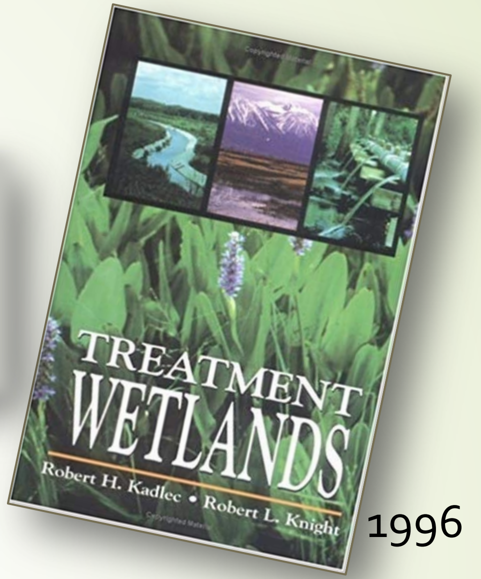
*J. Brisson**, *F. Chaz*

Institut de Recherche en Biolog

Results varied from study to study, for example:

"The pair *T. latifolia* and *S. validus* was examined in four studies… one of them finding *Typha* to be more efficient than *Schoenoplectus*... two of them finding the opposite… and the last one failing to find a difference."

Maybe we should just use fast-growing emergent perennials.



1996

But what happens when fast-growing graminoids with different growth strategies grow together?

The aims of this work:

- Investigate effects of invasive plant species on growth and nutrient removal by subordinate species

- Determine whether those effects will differ between typical vs eutrophic conditions

Representative Invaders

T. latifolia

P. australis

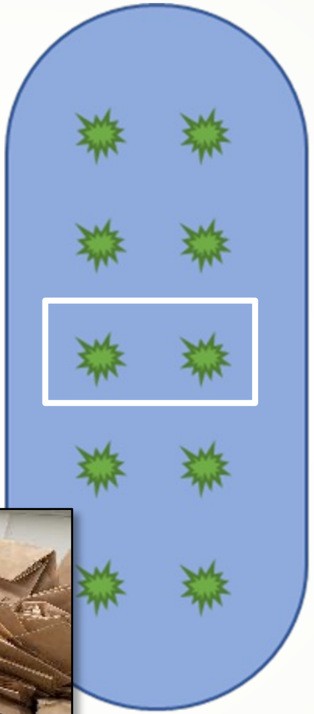
Subordinate Species

J. effusus

S. tabernaemontani


Behlen
COUNTRY

Biomass Harvests



3 per year – pre and post flood

- Separate root/shoot tissues
- Dry, weigh, grind

- Tissue nutrient analysis: %C, %N, %P

Water Sampling

During flood simulations

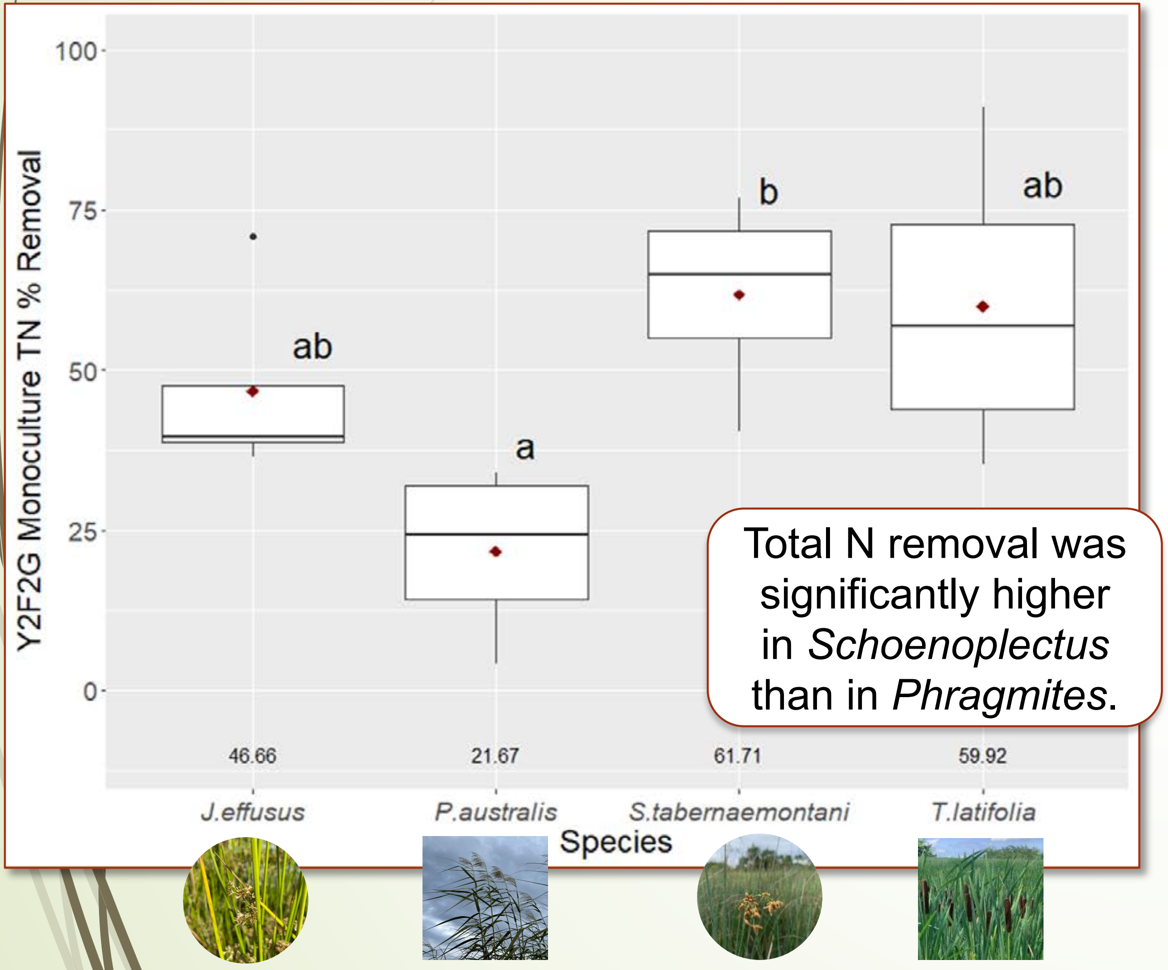
- In situ: pH, DO, ℃, Conductivity

- Grab samples - start and end of flood (Days 1 & 8)
    - (2) surface and (1) groundwater per mesocosm
    - TN, NH_3, NO_x
    - PO_4^{3-}

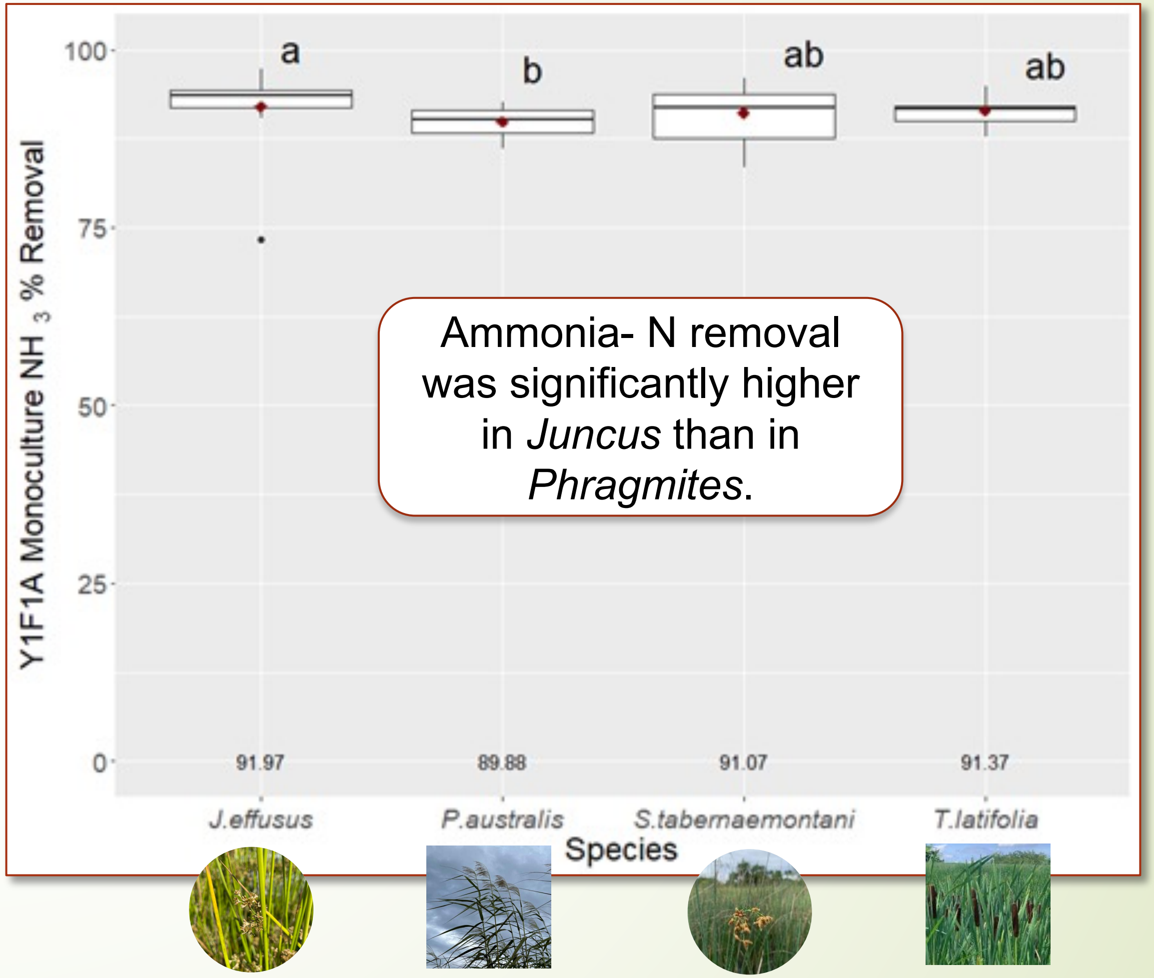
Some findings from Year Two (Summer 2022)

Nitrogen removal efficiency among species (monoculture)

Total N

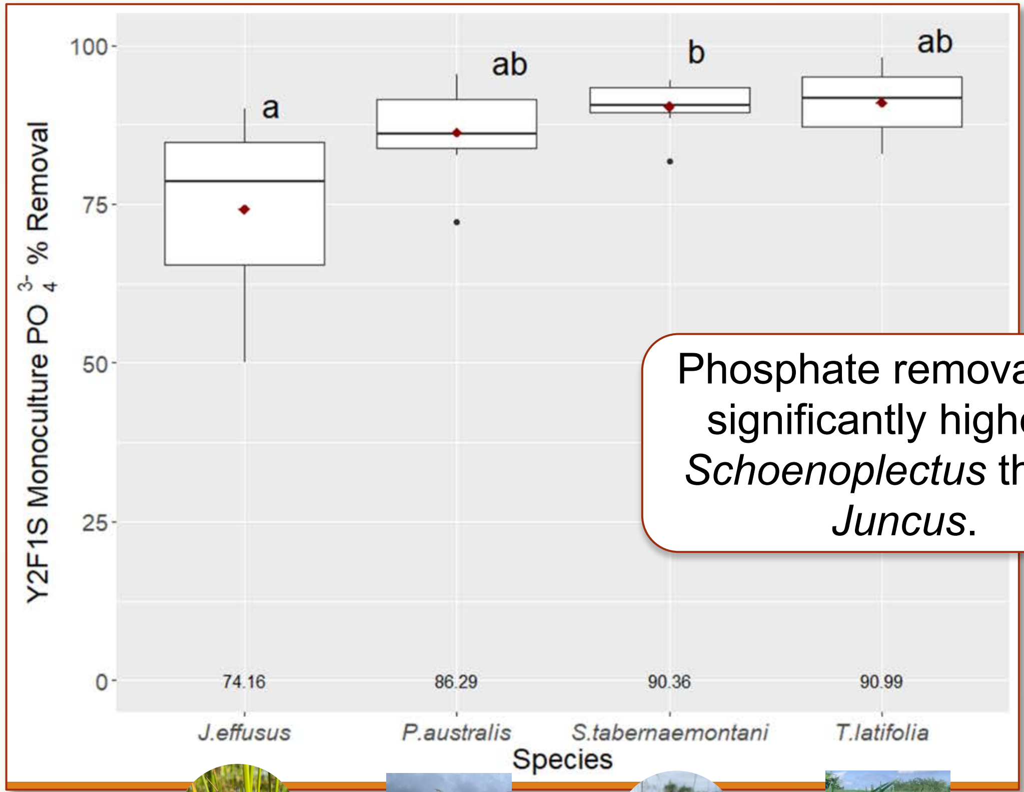


NH_3-N



Phosphate removal efficiency among species (monoculture)

PO_4^{3-}

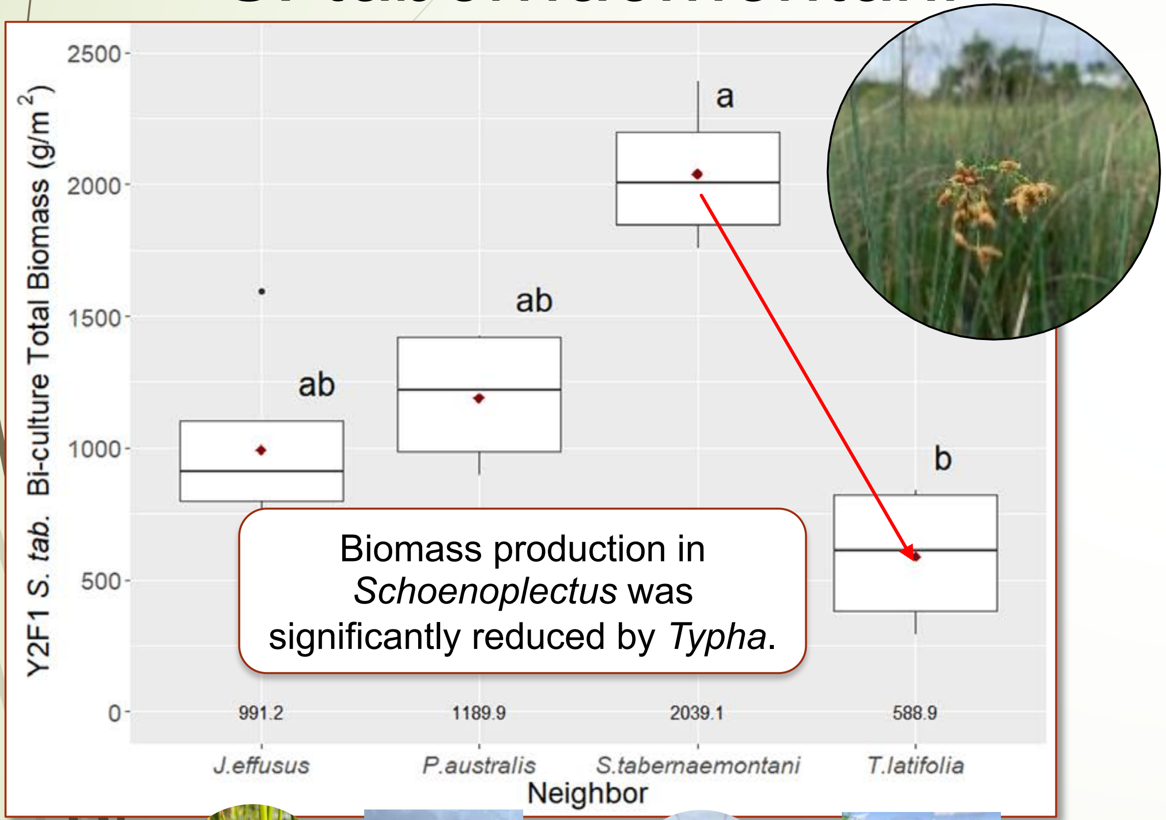


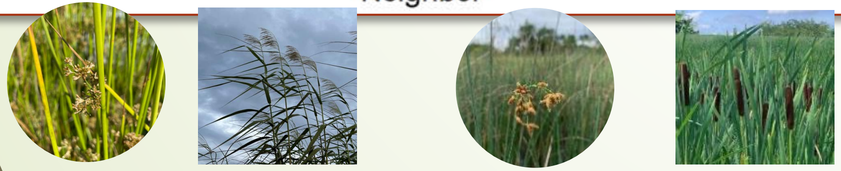
Phosphate removal was significantly higher in *Schoenoplectus* than in *Juncus*.



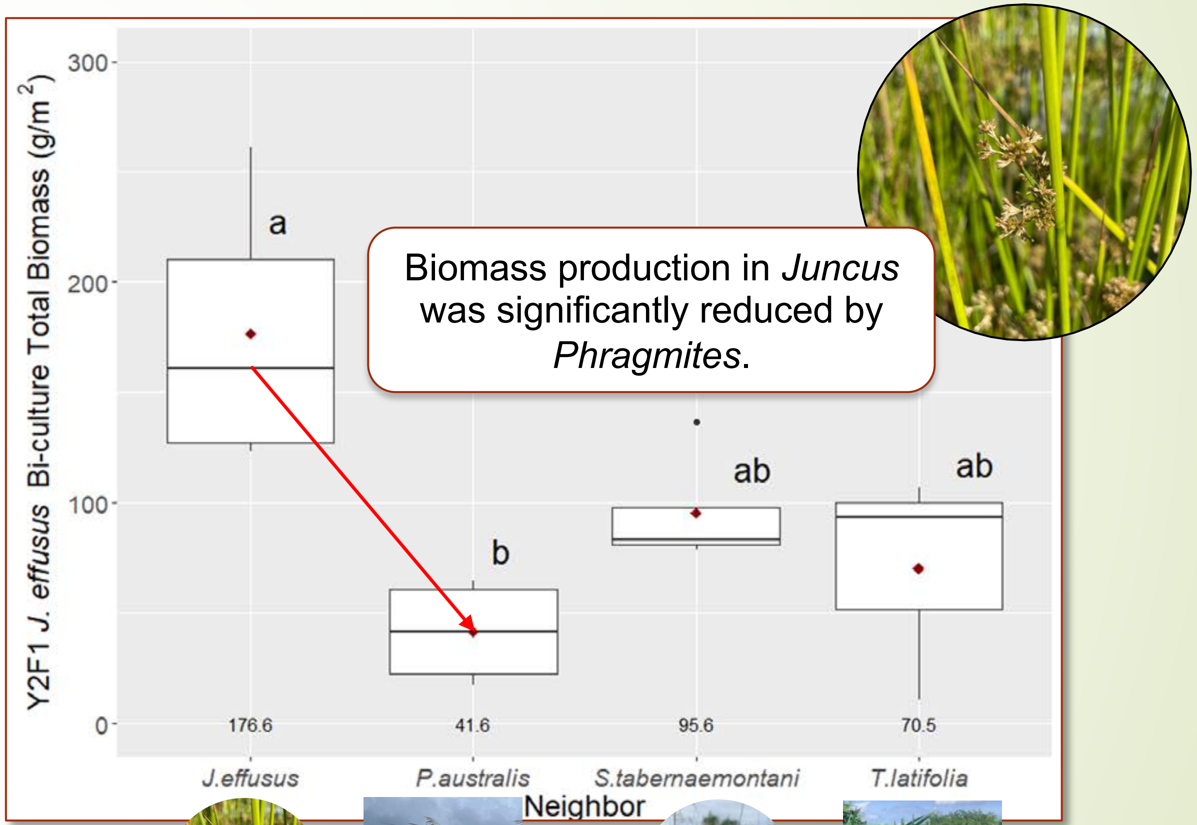

Total Biomass – bi-culture

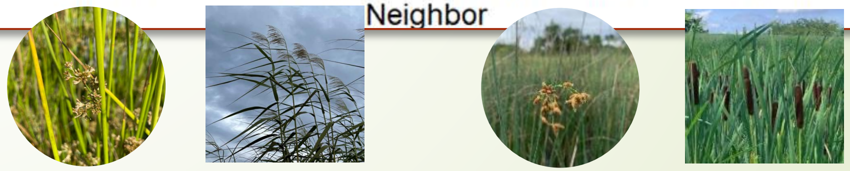
S. tabernaemontani





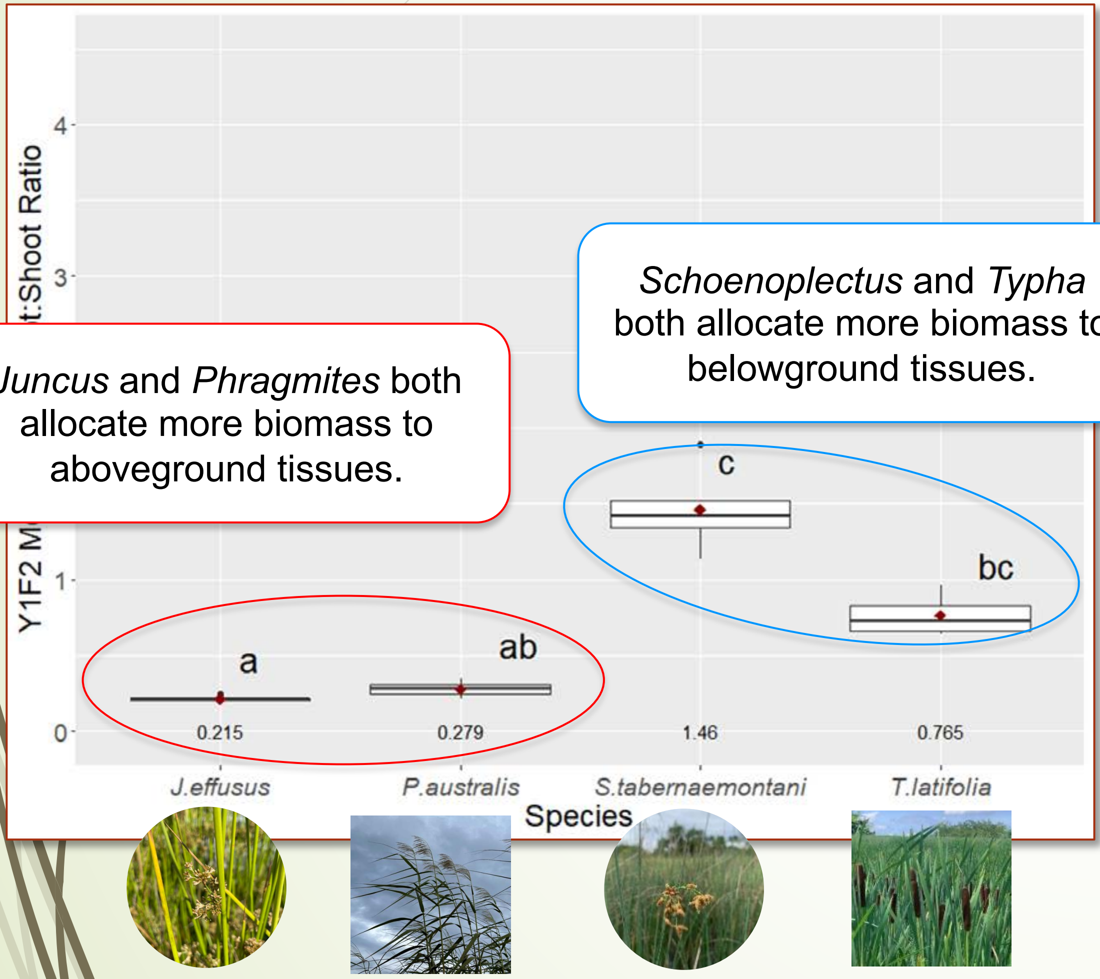
J. effusus





Root:Shoot ratios - monoculture

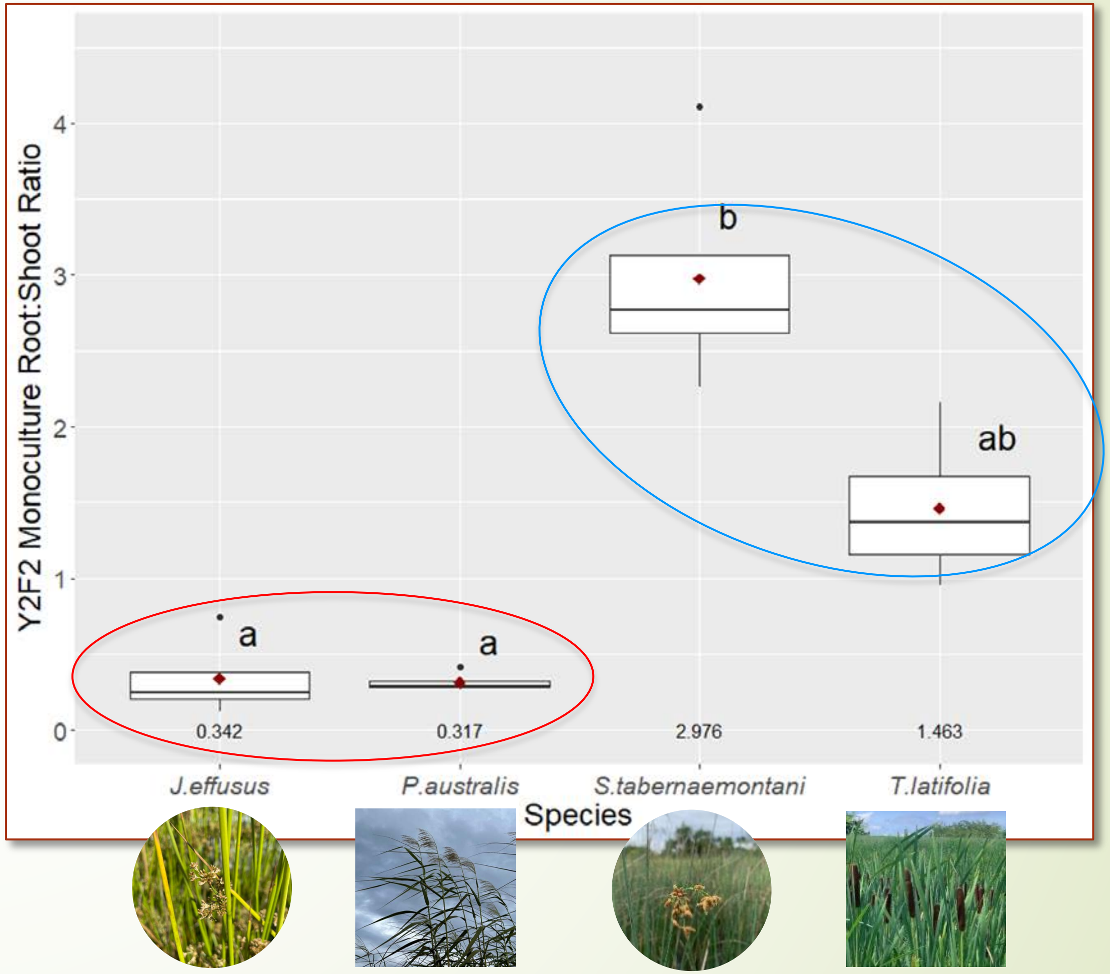
Y1



Juncus and *Phragmites* both allocate more biomass to aboveground tissues.

Schoenoplectus and *Typha* both allocate more biomass to belowground tissues.

Y2



What does this mean?

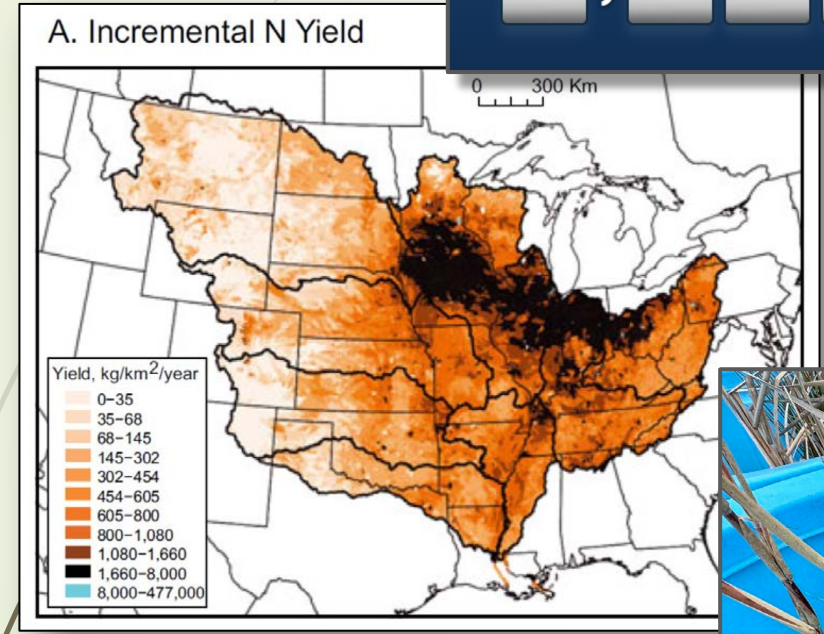
Although it seems that Kadlec and colleagues may be correct about similarities in nutrient removal among species…

What does this mean?

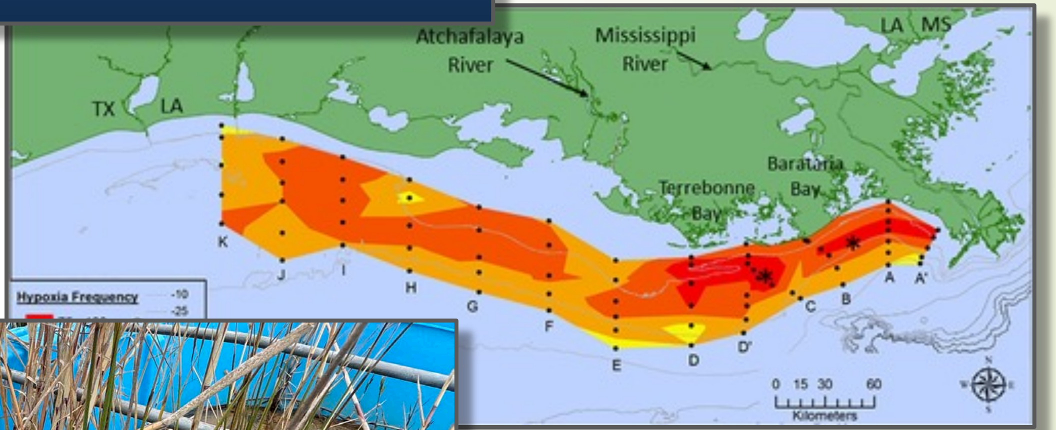
Although it seems that Kadlec and colleagues may be correct about similarities in nutrient removal among species…

…there are ecological differences in species that may be important in more complex, multi-species treatment wetland systems…

…and broad categories like “invasive species” may tell us little about how the system overall will behave.


A. Incremental N Yield
0 300 Km
Yield, kg/km^2/year
0–35
35–68
68–145
145–302
302–454
454–605
605–800
800–1,080
1,080–1,660
1,660–8,000
8,000–477,000


World Population
8,035,404,450


Atchafalaya River
Mississippi River
LA MS
TX LA
Terrebonne Bay
Barataria Bay
Hypoxia Frequency
K J I H G F E D D' C B A A'
0 15 30 60
Kilometers

Thank you!

Gratitude to:

Cory Shoemaker, Evelyn DiOrio, Jacob Hockensmith, & Andy Sample

Beth Baker, Charles Bryson, Ryan Folk, Brook Herman, Todd Swannack, Gray Turnage

John MacDonald, Kevin Nelms, and MS Delta landowners

Sam Schmid, Ben Blassingame, Dallis Barker, Coby Bell, Chandler Bryant, Watson Burch, Garrett Ervin, Bram Finkel, Jill Jackson, Joey Kauppi, MacKenzie Lee, Graham Lightsey, Josh Long, Christa Lott, Walt Maddox, Anna McLeod, Oliva Robinson, Esther St. Pierre, Logan Tomlinson, Phillip Whitman

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