Carbon Sequestration and Greenhouse Gas Emissions in Forested Wetlands of the Lower Mississippi River Valley

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USGS
science for a changing world

Carbon Management Strategies

- Increased Efficiency
- Alternative Energy Sources
- Sequestration
  - Terrestrial C Sequestration

The Approach . . .

- Annually sequester 25-50% of U.S. fossil fuel emissions
- Stabilize atmospheric CO_2 for the next 50-100 years to develop alternative technology
- Landscape-level processes

Mechanisms to Increase Terrestrial Carbon Sequestration

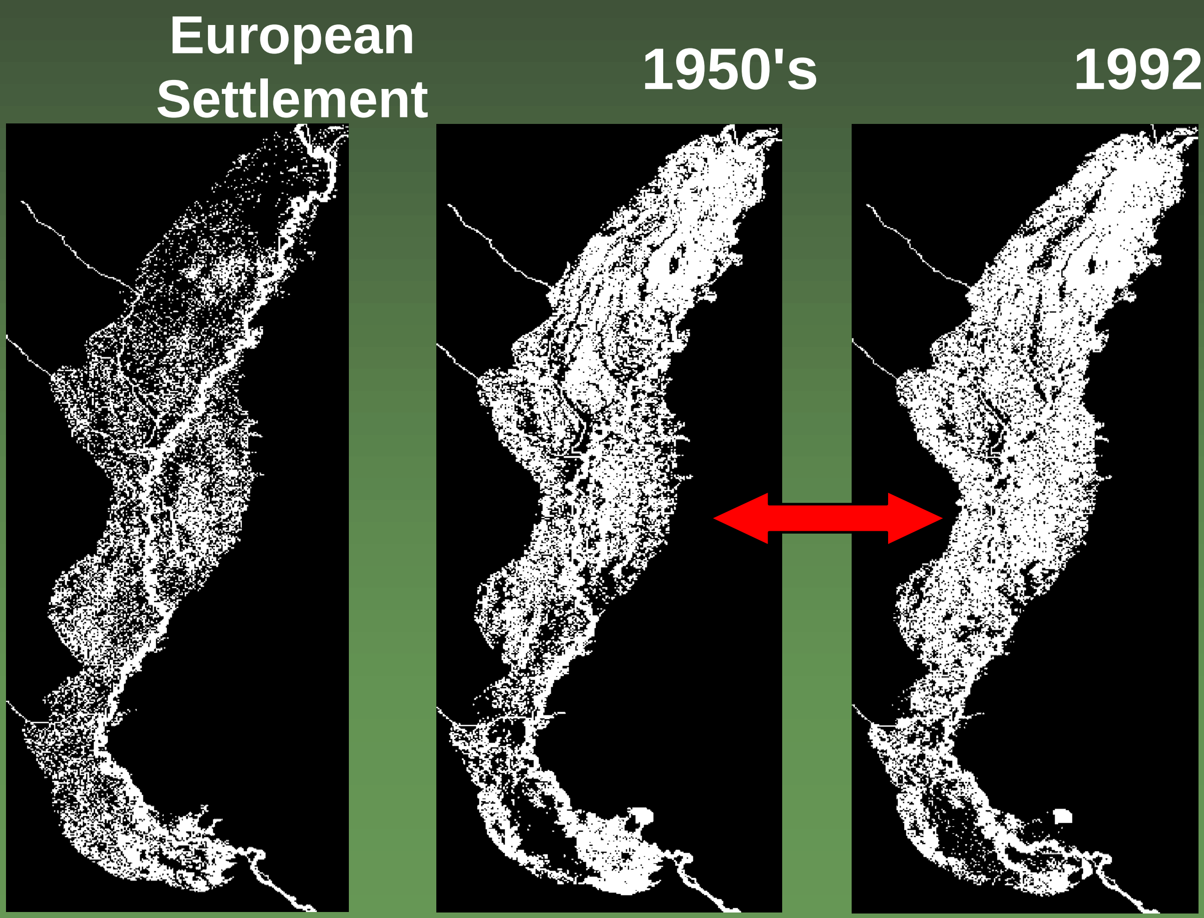
- Conservation of ecosystems with large existing C pools (forests, wetlands)
- Increased productivity through improved management
- Ecosystem restoration
- Reforestation/afforestation
- Biomass energy for fossil fuel

Annual Potential US Terrestrial Carbon Sequestration

Biomes	*Sequestration (Pg C/yr)*
Forests	0.17 - 0.37
Agriculture	0.0 - 0.04
Grass/Range Lands	0.12 - 0.13
Total	0.30 - 0.58
US GHG Emissions	1.66

Pacala et al., 2001

Forested Wetland Conversion in the Lower Mississippi Valley (LMV)

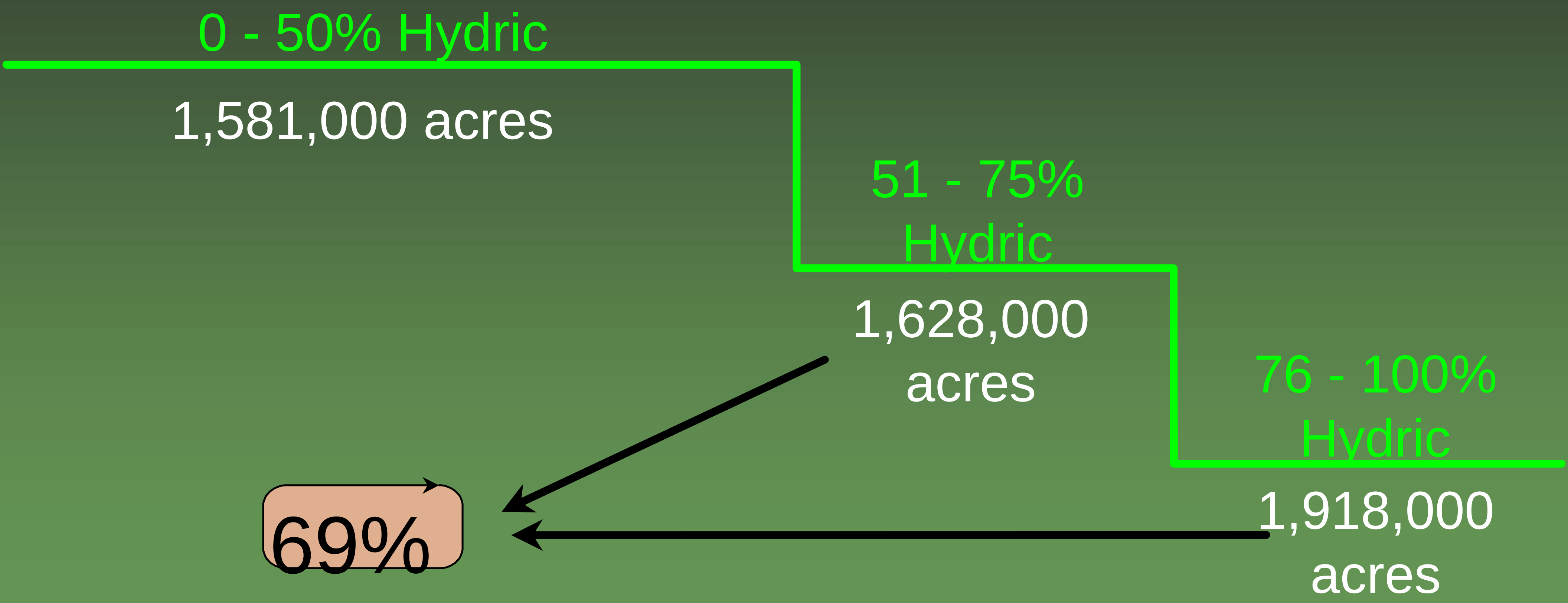


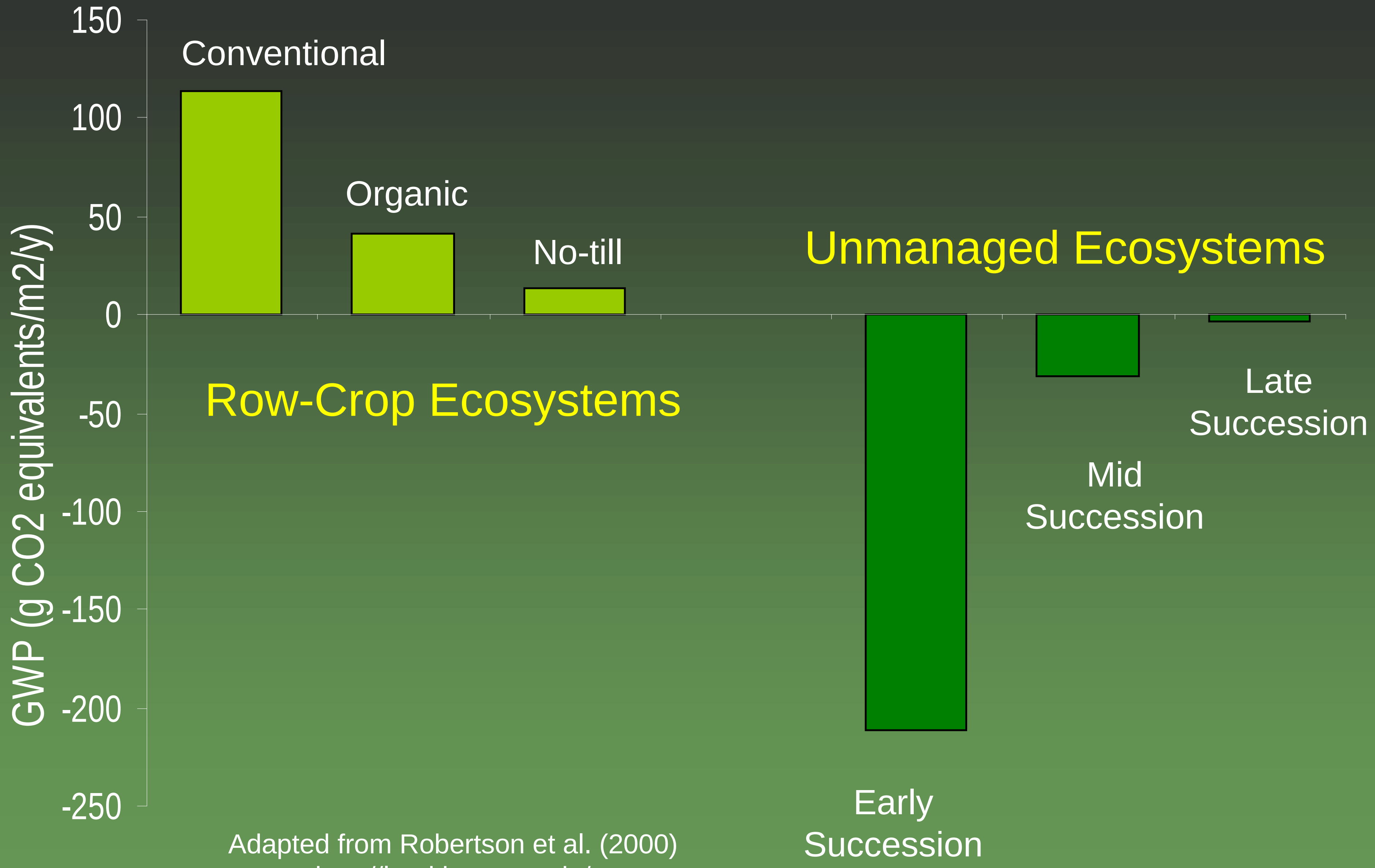
75% Reduction in Forested Area

Fragmentation of Remaining 25% into 35,000+ Blocks

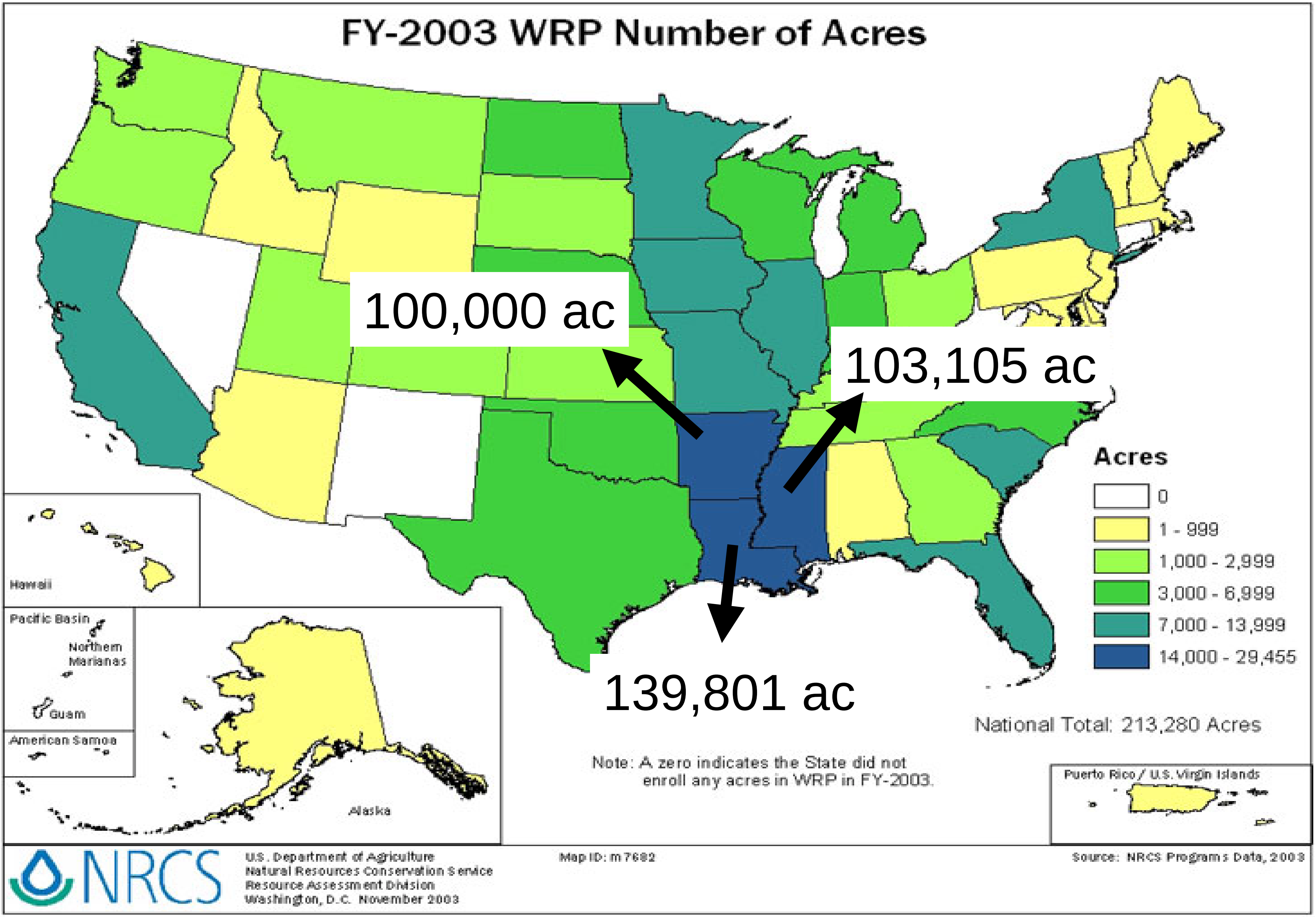
Nearly 100% Loss of “High-site" BLHW's

Forest Wetland Conversion 1950's -1992
Distribution by Hydric Soil Associations





Adapted from Robertson et al. (2000)
http://lter.kbs.msu.edu/

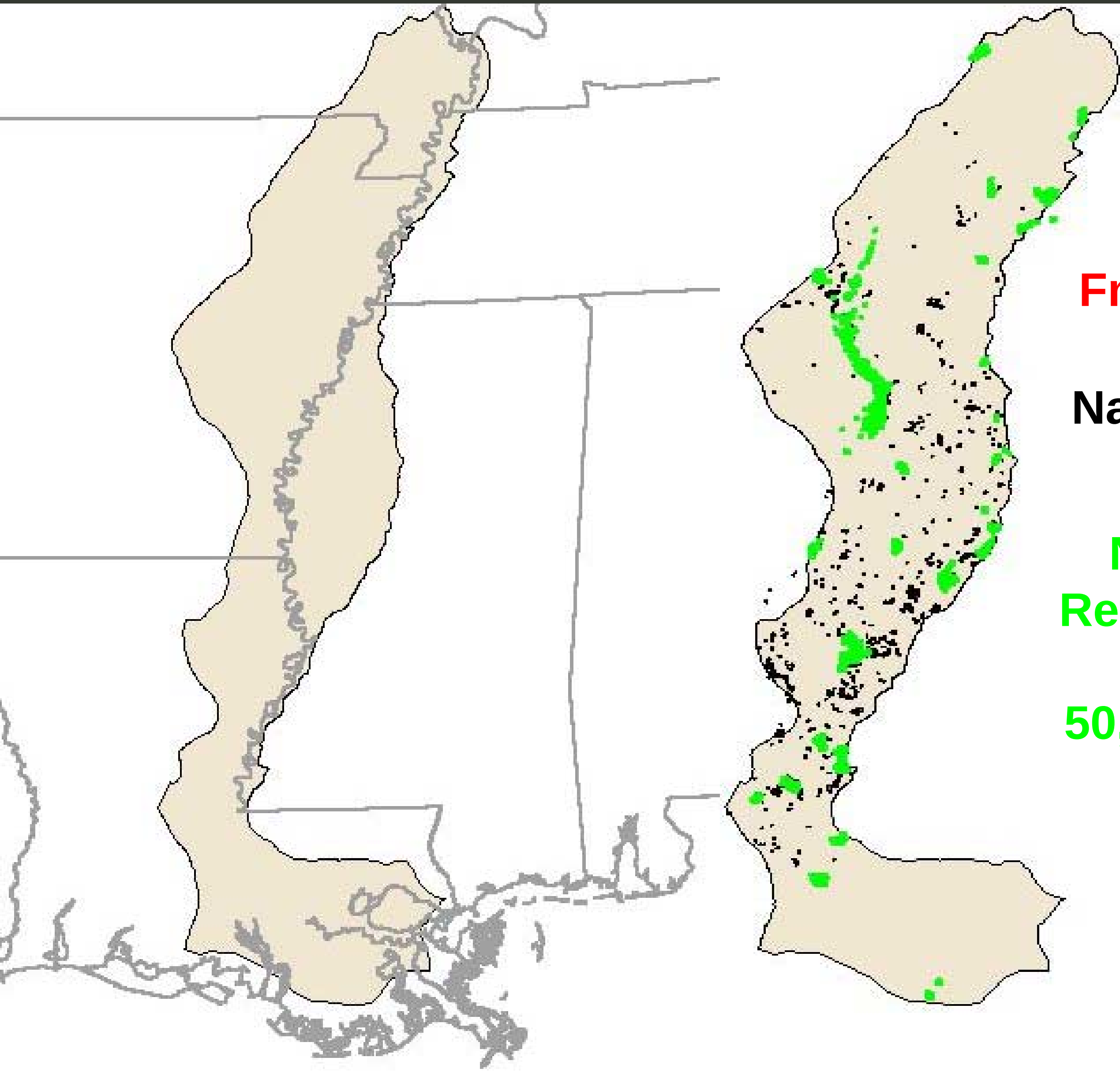


FY-2003 WRP Number of Acres
100,000 ac
103,105 ac
139,801 ac
Acres
0
1 - 999
1,000 - 2,999
3,000 - 6,999
7,000 - 13,999
14,000 - 29,455
National Total: 213,280 Acres
Note: A zero indicates the State did not enroll any acres in WRP in FY-2003.
Hawaii
Pacific Basin
Northern Marianas
Guam
American Samoa
Alaska
Puerto Rico / U.S. Virgin Islands
NRCS
U.S. Department of Agriculture
Natural Resources Conservation Service
Resource Assessment Division
Washington, D.C. November 2003
Map ID: m7682
Source: NRCS Programs Data, 2003

2003 Wetland Reserve Program Enrollment

State	Funded	Unfunded	Total
	- - - - - - - - - - - - - -	acres	- - - - - - - - - - - - - - - -
AR	26,347	110,380	136,727
IL	8,778	22,559	31,337
IA	7,408	43,588	50,996
LA	29,455	169,447	198,902
MN	13,700	40,129	53,829
MS	14,693	68,862	83,555
MO	10,194	33,489	43,683
Total	110,575	488,454	**599,029**

Federal Land Ownership in the LMV



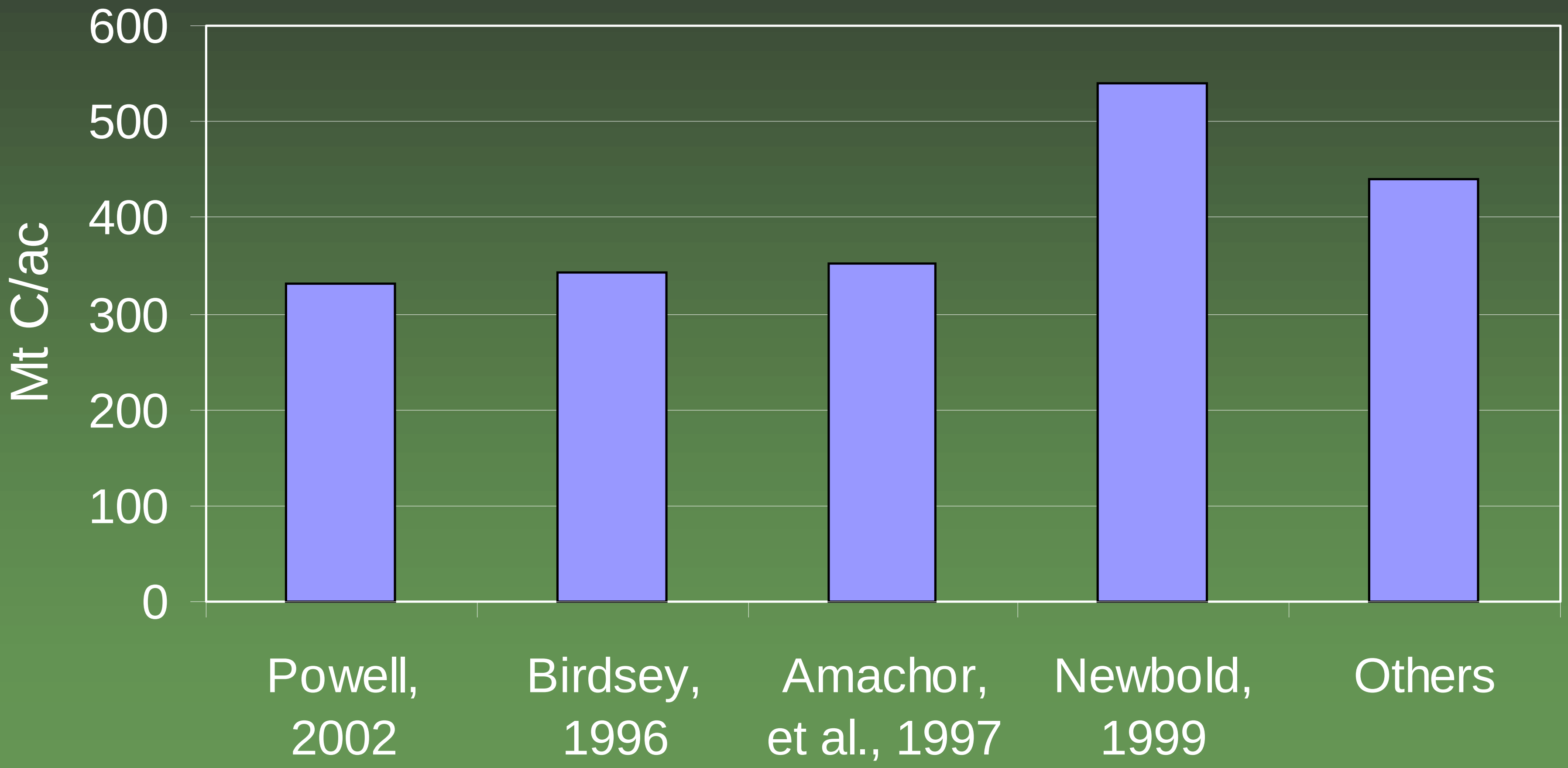
FmHA - 21,625 ha

National Forests - 32,993 ha

National Wildlife Refuges - 249,003 ha

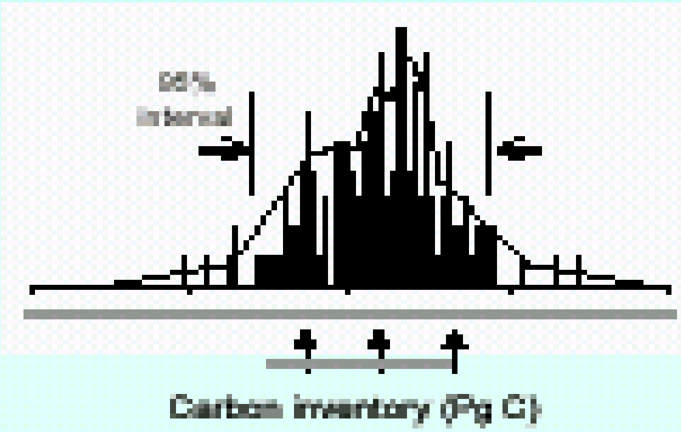
50,000 ha reforested

Estimated Biomass in Southeastern Forests (70 yr)



Confidence in Carbon Estimates at Regional Scale

Live biomass	Good
Woody debris and litter	Fair
Soil organic matter	Poor
Wood and Ag Products	Fair



(Heath and Smith 2000)

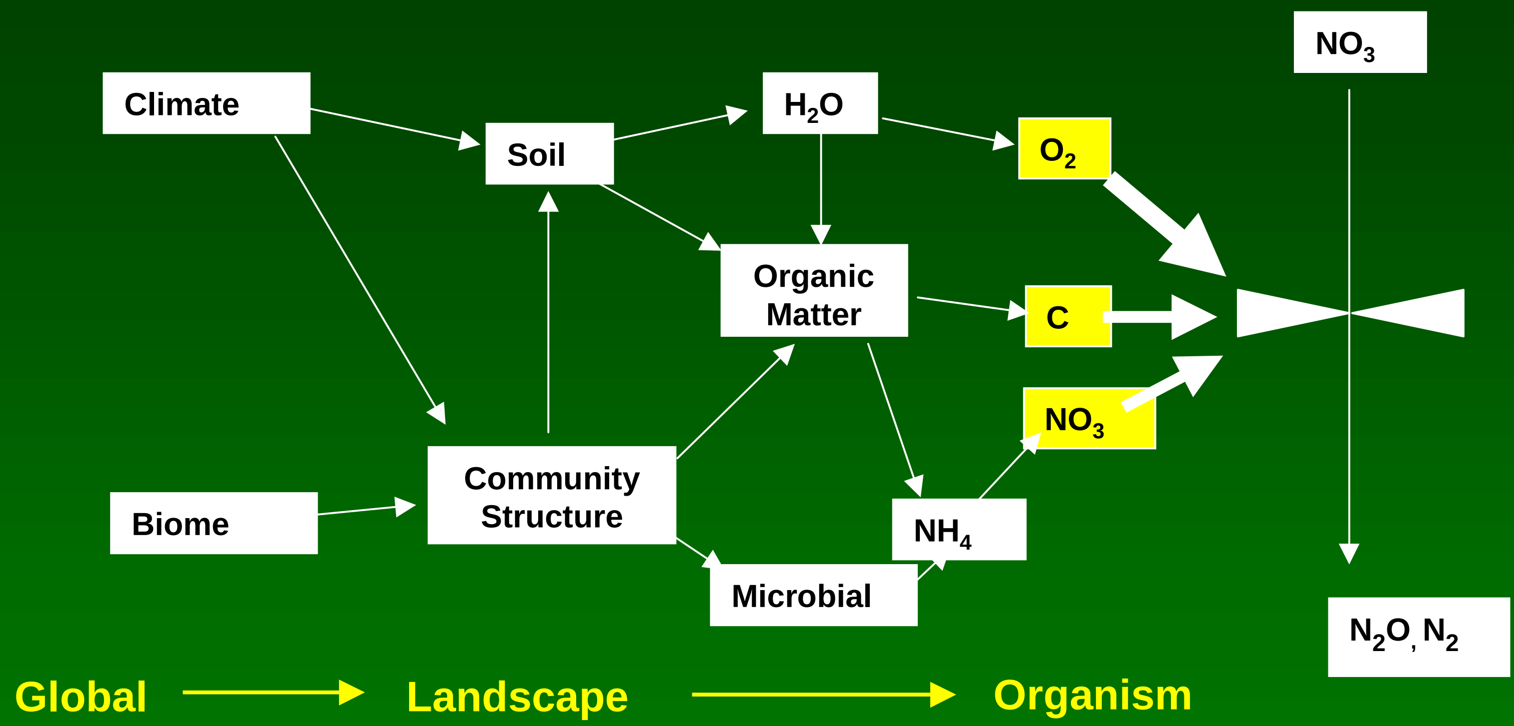
➢ ***Research needs***: efficient protocols for extensive monitoring; enhanced network of long-term intensive study sites; improved models and analysis

From Heath, 2001

➢ ***Implementation need***: not all lands are monitored effectively for changes in ecosystem C

Research Questions

- How do land-use changes and management practices affect carbon storage and greenhouse gas emissions?
- What environmental factors control carbon sequestration and greenhouse gas emissions?

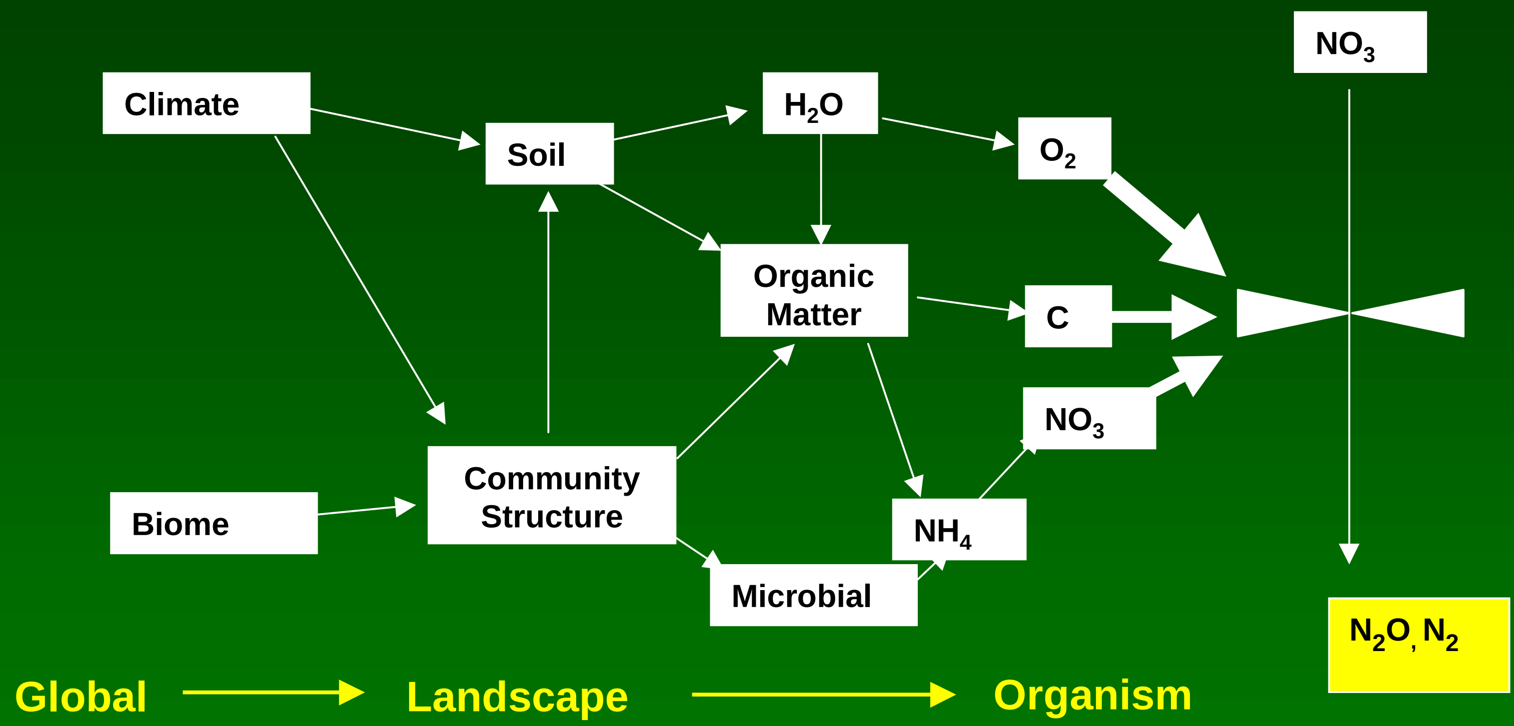


Factors controlling denitrification at various spatial scales

(Adapted from Myrold, 1998)

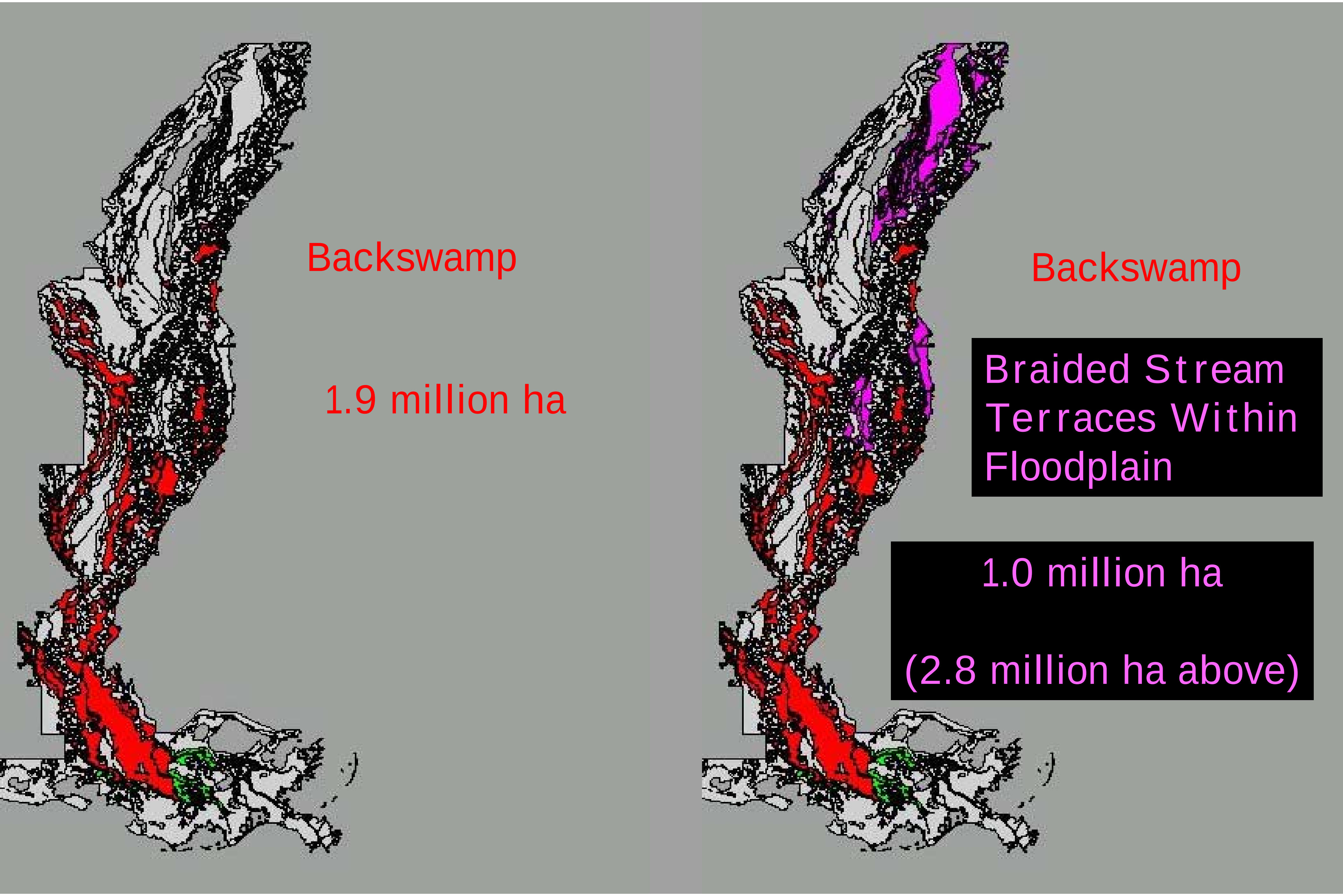
Nitrogen loss rates for selected wetland and riparian zone studies (adapted from Mitsch et al., 2001)

Reference	Rates g N m^{-2} yr^{-1}	Ecosystem Characteristics
Dieberg and Brezonik (1985)	28	Nutrient-enriched swamp (FL)
Phipps and Crumpton (1994)	171	River-fed constructed wetlands (IL)
Peterjohn and Correll (1984)	4.5-6.0	Riparian forest, Chesapeake Bay (MD)
Groffman et al. (1991)	80.3	NO3 + glucose, buffer zones
	576	NO3 + glucose, grass strips
Hanson et al. (1994)	0.5-1.6	Riparian maple swamp (unenriched)
	2.0-3.6	Riparian maple swamp (enriched)
Lowrance et al. (1985)	6.9	Restored riparian wetland
	4.3	Young hardwood riparian forest
Groffman and Hanson (1997)	1.5-15.52	Alluvial soil
	1.0-2.02	Light till



Factors controlling denitrification at various spatial scales

(Adapted from Myrold, 1998)

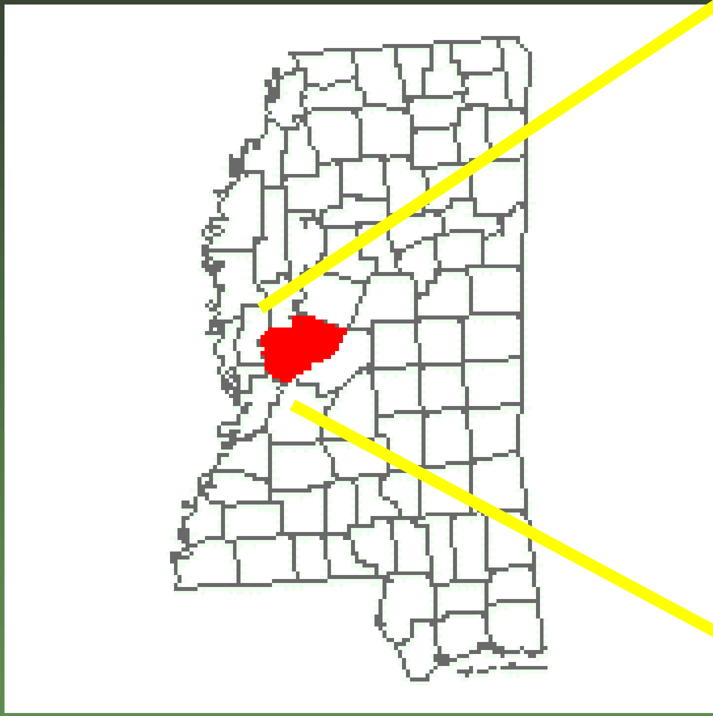

Backswamp
1.9 million ha
Backswamp
Braided Stream Terraces Within Floodplain
1.0 million ha
(2.8 million ha above)

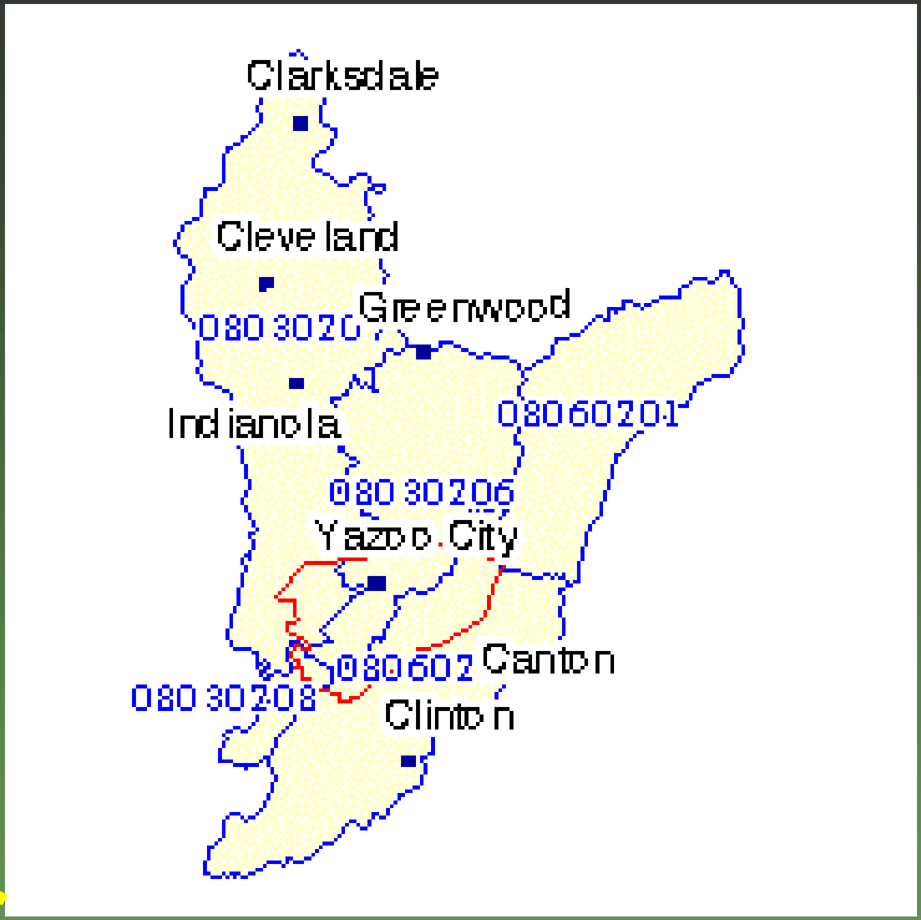
Research Questions

- Where are the best locations in the watershed?
- What tools and techniques are needed to achieve restoration and carbon sequestration goals?
- How do we evaluate the ecological tradeoffs?

Research Area and Design

- Multiple sampling locations throughout Yazoo delta region in the LMV
- Selected agricultural, reforested, and natural forests comprising a range of elevations and soil types (Beasley Watershed):
  - Potential denitrification assay (PDA) determination
  - Total soil C and N
- Collected intact soil cores from adjacent ag and natural forest (Sharkey soil series, Beasley Watershed) to determine:
  - Denitrification and N_2O:N_2 emission ratio at different percentages of water-filled pore space, w/wo NO3



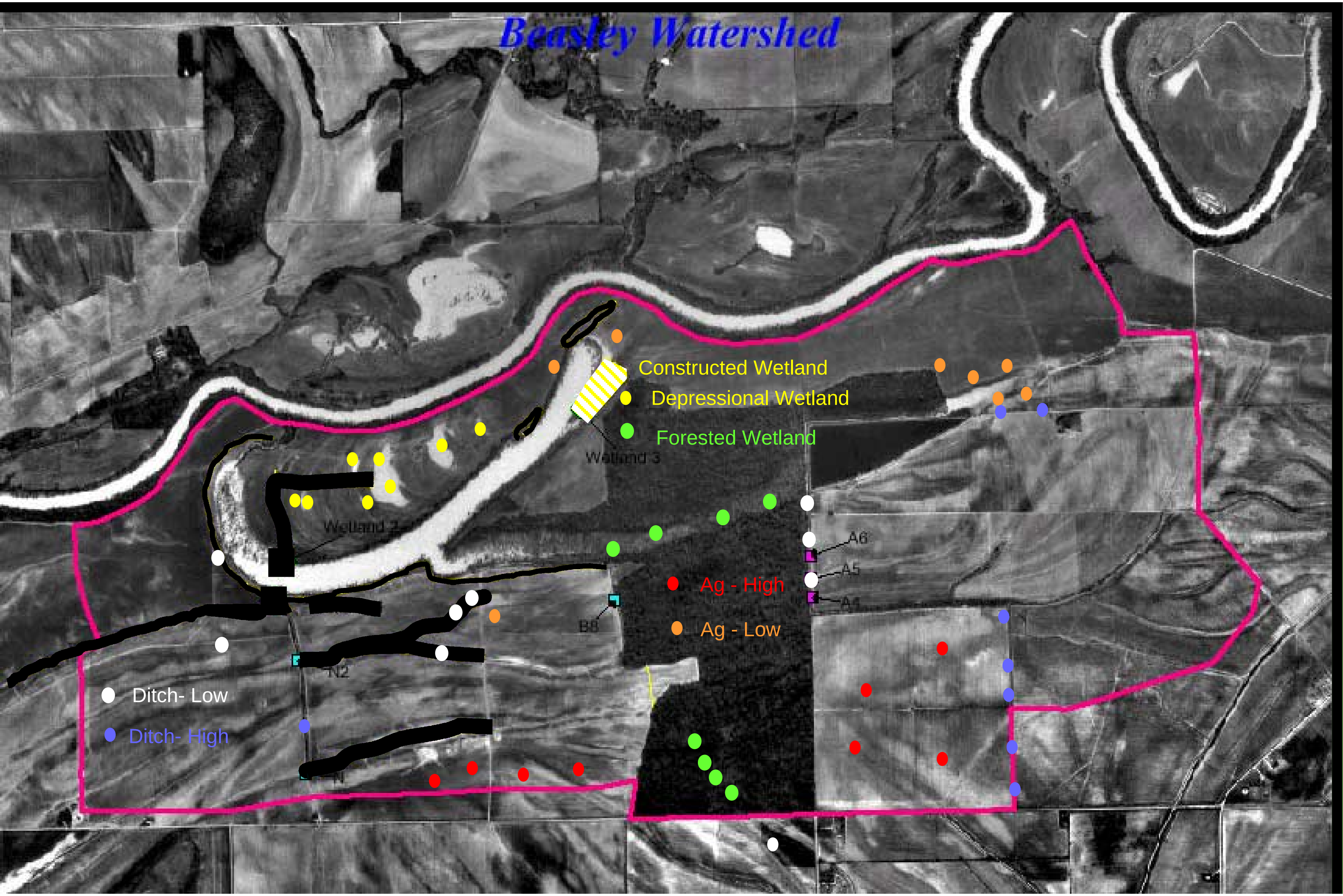


Clarksdale
Cleveland
Greenwood
08030207
Indianola
08060201
08030206
Yazoo City
Canton
080602
08030208
Clinton

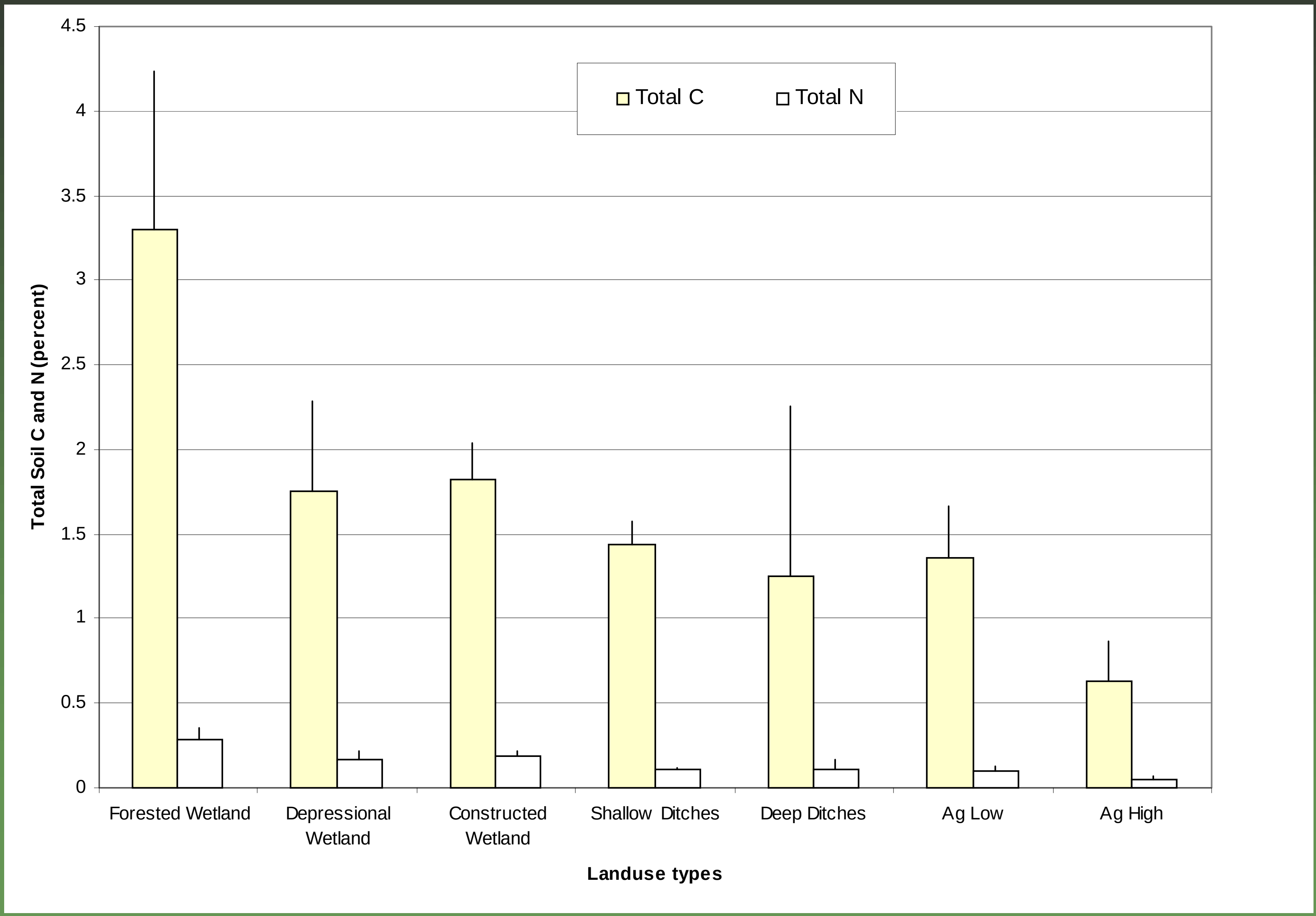
Research Area and Design

- Collected intact soil cores from Yazoo and Panther Swamp NWR, Delta NF (Sharkey soil series) to determine
  - Total soil C and N
- Measured CH_4 emissions from adjacent reforested (15 yo) and natural forest (Sharkey soil series, Panther Swamp NWR)
- Calculated global warming potential (GWP)

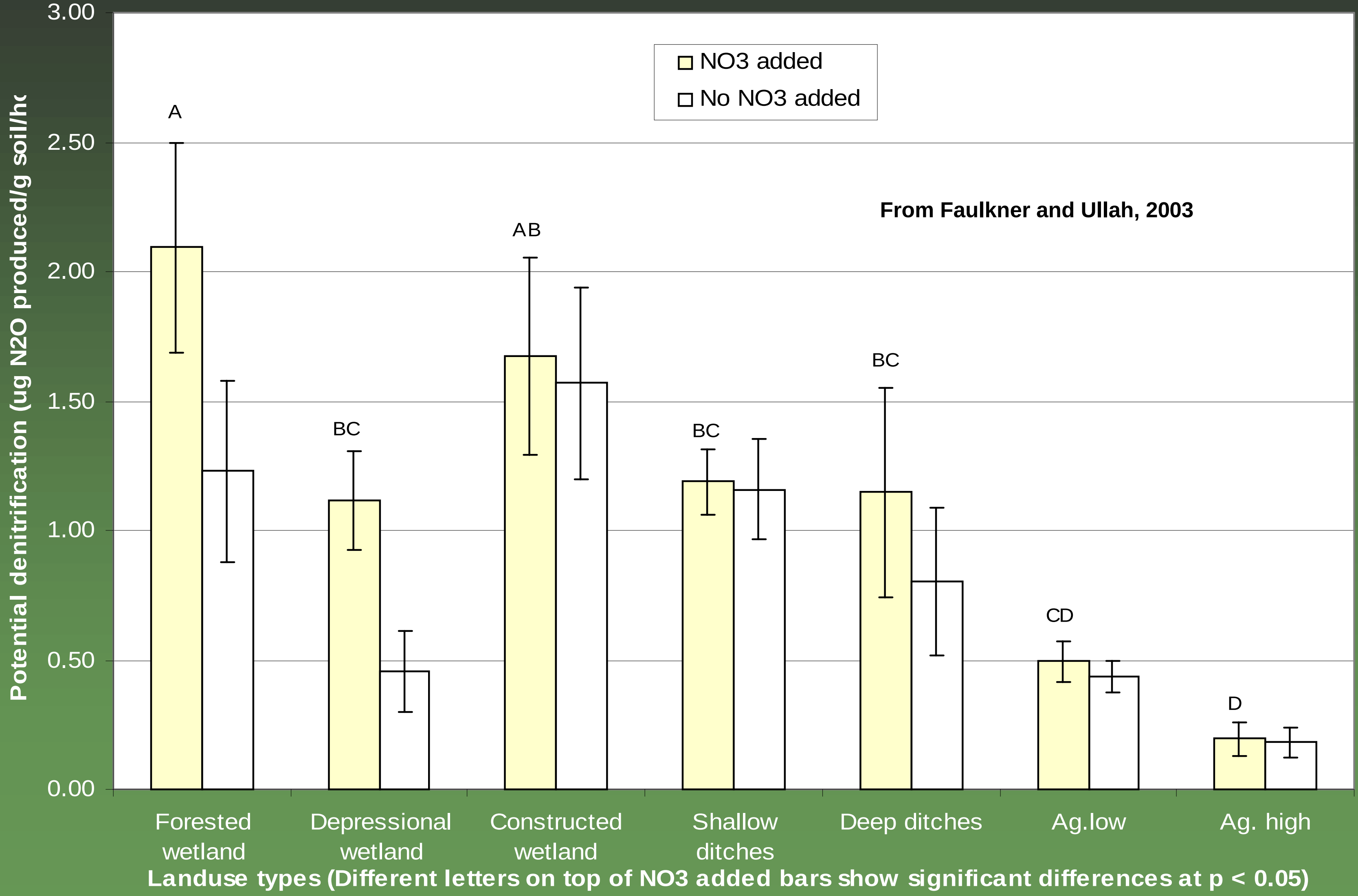
Beasley Lake Watershed

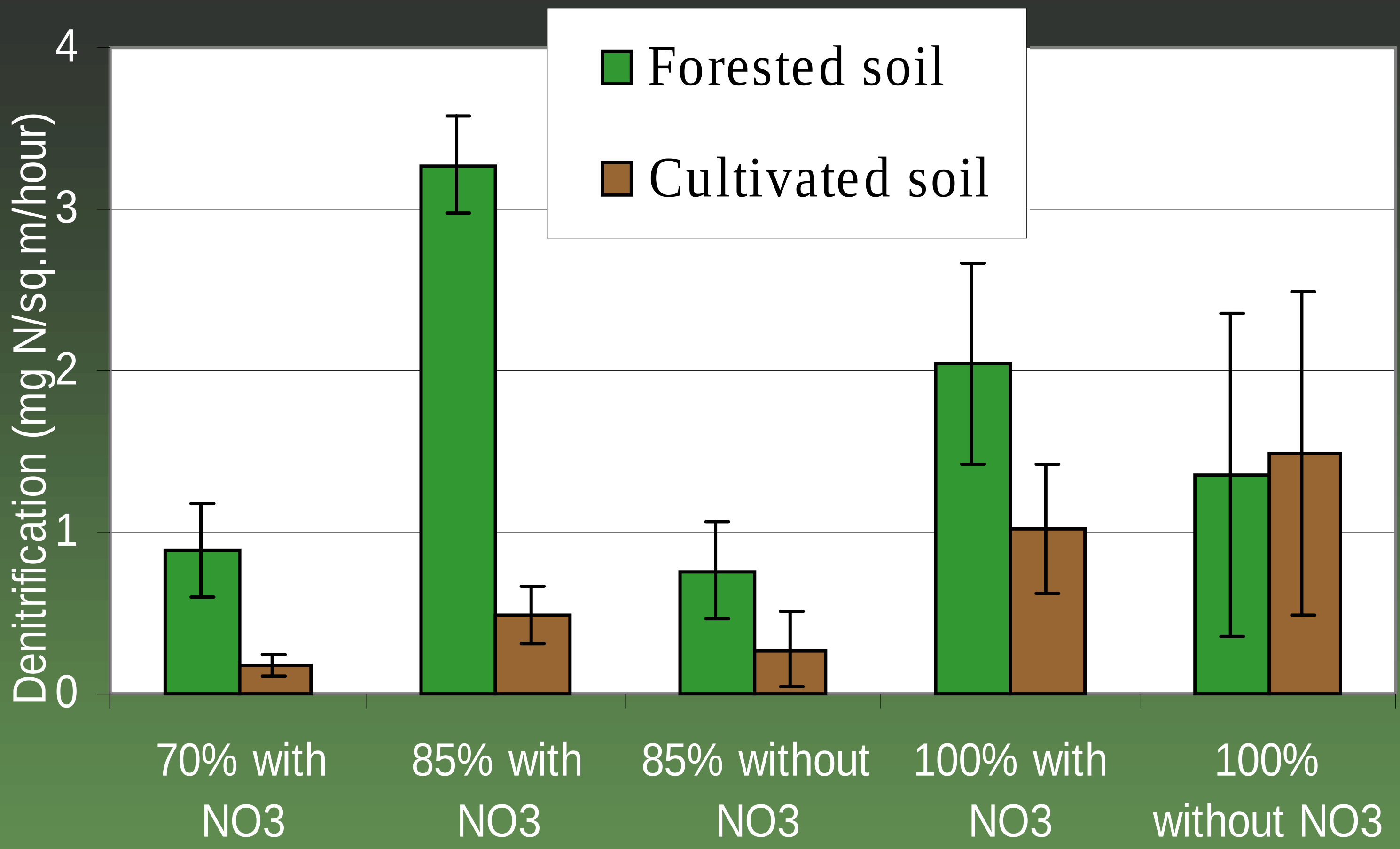

Beasley Watershed
Constructed Wetland
Depressional Wetland
Forested Wetland
Wetland 3
Wetland 2
A6
A5
A4
B8
N2
N
Ag - High
Ag - Low
Ditch- Low
Ditch- High

Total Soil C and N in Cultivated and Wetland Soils, Beasley Watershed

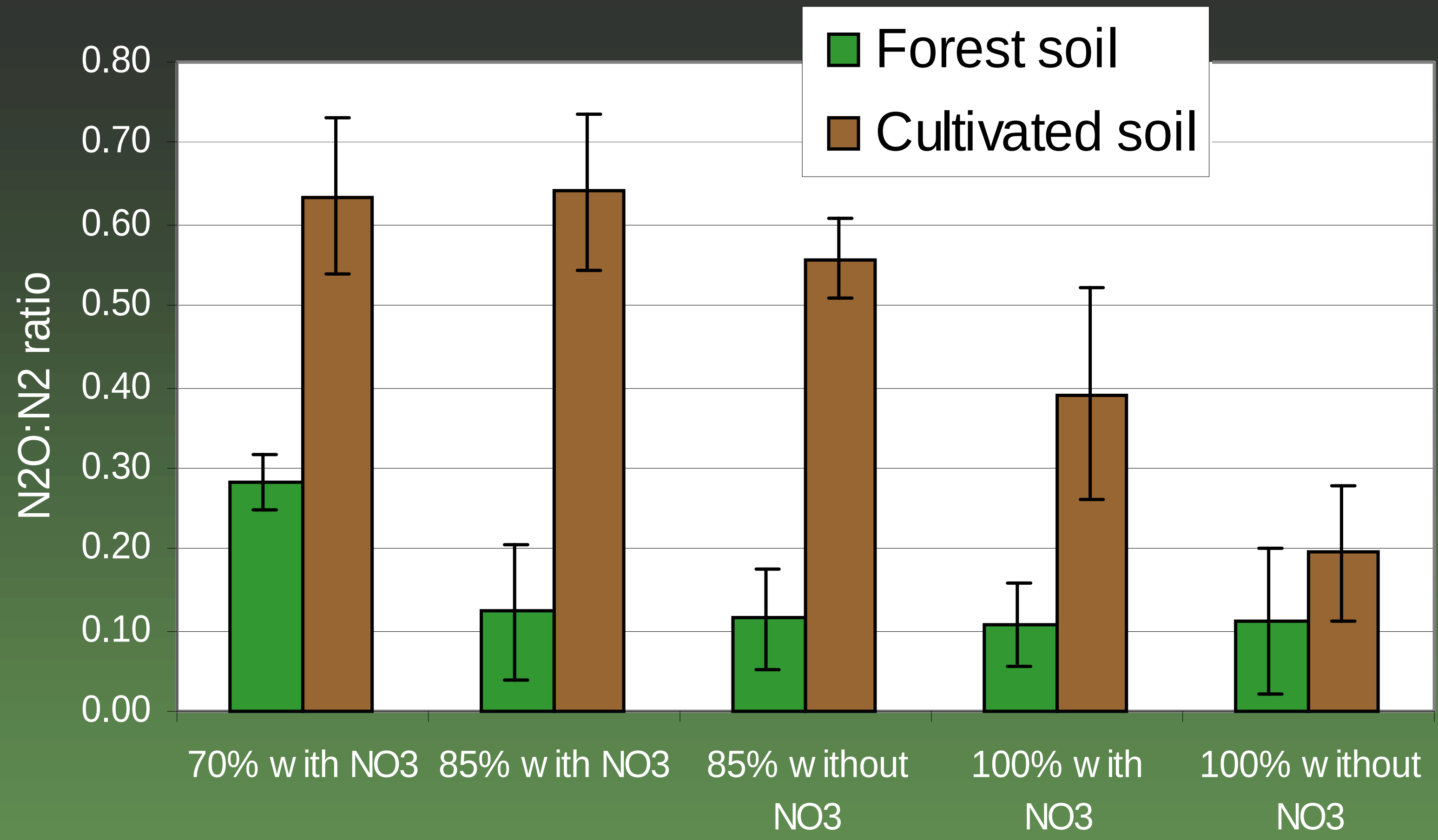


Denitrification Potential of Cultivated and Wetland Soils, Beasley Watershed, MS





- Increase in WFPS from 70-100% led to increase in denitrification
- Denitrification in forest soil was 3.5 times greater than cultivated soil when amended with NO_3



Significantly lower $N_2O:N_2$ emission ratios from forest soil compared to cultivated soil

Natural and Reforested Sites

Soil C (kg/m2)
4.0
3.0
2.0
1.0
0.0
Yazoo NWR, 13
Panther NWR, 14
Panther NWR, 25
Delta NF, 26
Yazoo NWR, 34
Panther NWR, NAT
Beasley, NAT
Stand Locations and Age

Relative Global Warming Potential

	g CO_2 equivalents m^{-2} y^{-1}				
Ecosystem	Soil	Tree Biomass	N2O	CH4	Net GWP
Ag - NO3	0	0	field cores, 100 y equiv		
Ag + NO3	0	0			
FOR - NO3	increase from Ag to natural forest over 100 y				
FOR + NO3	growth in oak-gum-cypress forest, South Central states, 1987-1997 (Birdsey and Lewis, 2003)				
FOR - NO3					
FOR + NO3	increase from 14 yo to 25 yo plantation, Sharkey soil, Panther Swamp NWR				

Relative Global Warming Potential

	g CO_2 equivalents m^{-2} y^{-1}				
Ecosystem	Soil	Tree Biomass	N2O	CH4	Net GWP
Ag - NO3	0	0	896	10	906
Ag + NO3	0	0	1,467	10	1,477
FOR - NO3	-35	-972	489	12	-506
FOR + NO3	-35	-972	1,263	12	269
FOR - NO3	-412	-972	489	12	-882
FOR + NO3	-412	-972	1,263	12	-108

Conclusions

- Natural forested wetlands had the highest soil carbon content and denitrification rates
- Landscape position has a significant impact on soil carbon storage in reforested sites
- Landscape position also has a significant impact on greenhouse gas emissions with higher N_2O emissions from lower elevation locations.

Conclusions

- These differences are likely related to hydrology, available carbon, and soil denitrifier populations
- Nitrate additions to restored forested wetlands may offset CO2 mitigation from carbon storage
- Accurate estimates of global warming potential from reforestation requires a complete budget of all carbon sources and sinks