Landscape Scale Response to Climate Change : A Biogeochemical Perspective

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USGS science for a changing world

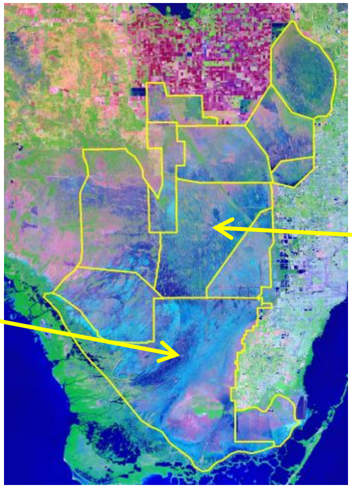
Presentation Objectives

-Present interpretations of modeling results relative to biogeochemical properties of Greater Everglades

-Focus on C, N, P, S, and Hg in ecosystem compartments

-Overview of key findings

-Discuss challenges / decisions facing future landscape scale interpretations



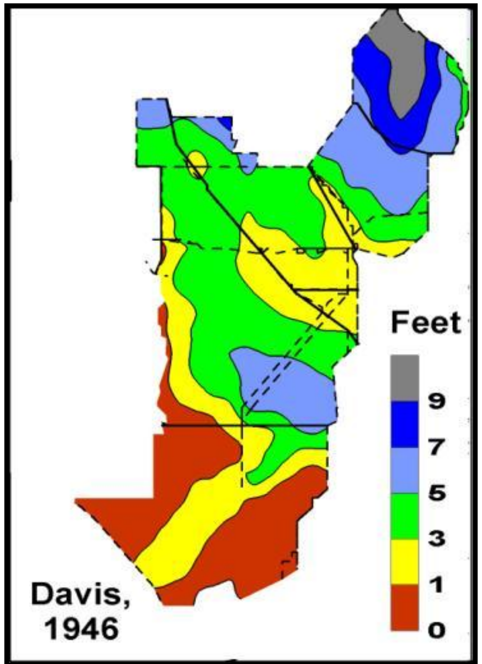
Rationale

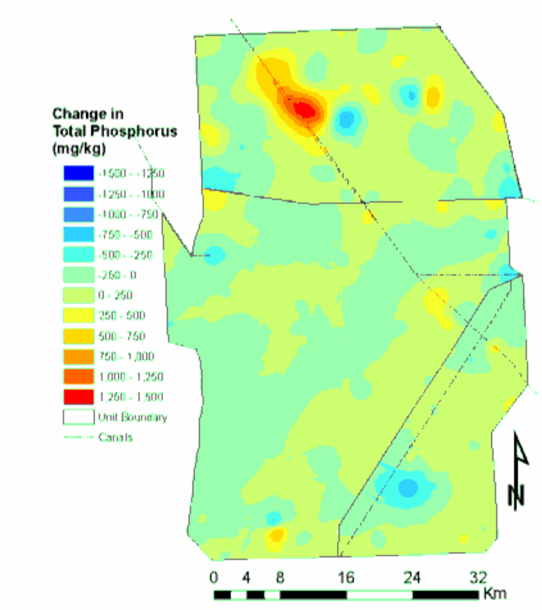
-Big picture perspective

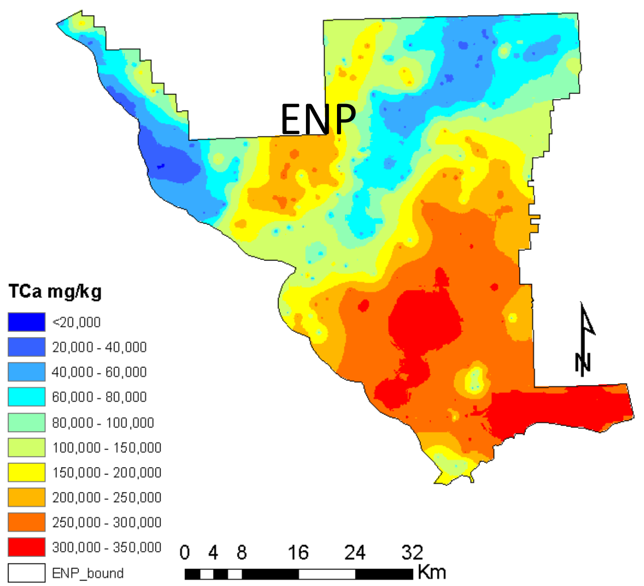
-Identify regional impacts “hot spots” = areas of concern

-Identify trends at ecosystem scale

-Assess of gaps in current understanding of the system



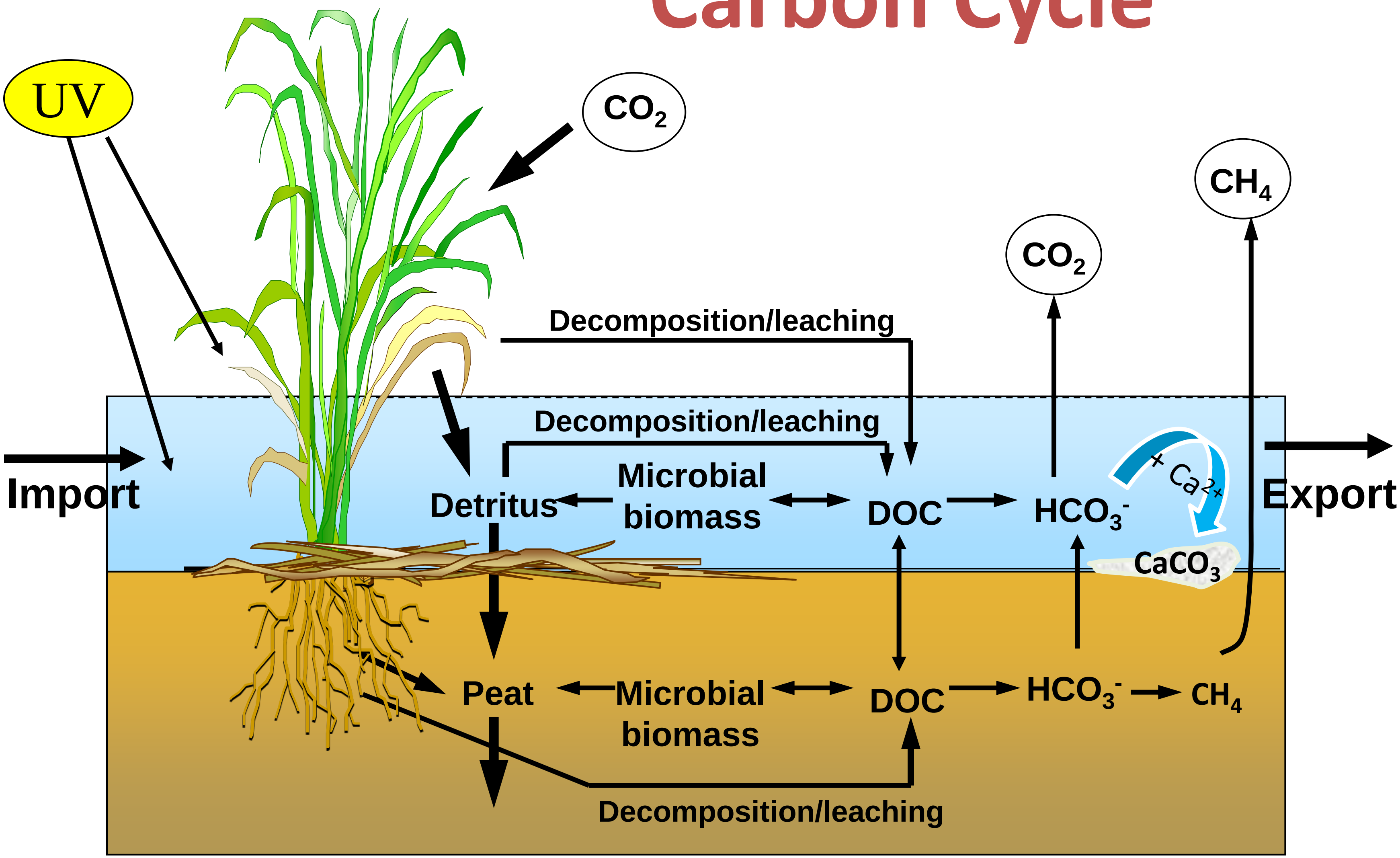




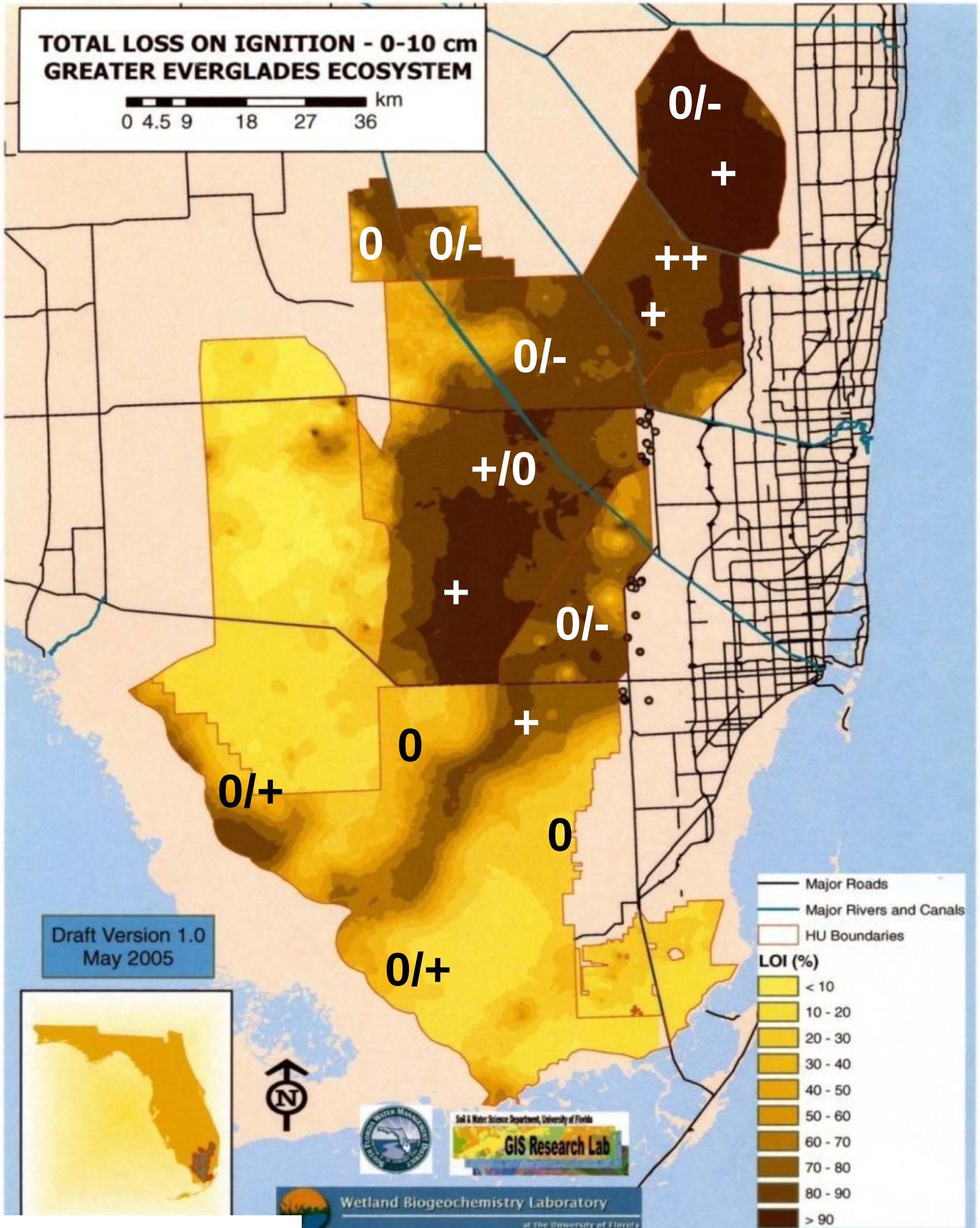
Approach and Assumptions

- Greater Everglades divided into hydrologic units, key zones within each unit highlighted (overdrained, “good”, ponded, enriched etc.)
- Climate change scenarios evaluated qualitatively- ± 30 days hydroperiod change considered within realm of modelling error, ± 60 days significant effect on soil chemistry. Evaluation presented as --, -, 0, +, ++.
- Used habitat hydroperiods from McVoy et al., 2011 to guide decisions re: accumulation and loss of different soils

Carbon Cycle



Modified from: K. R. Reddy, and R. Delaune 2008

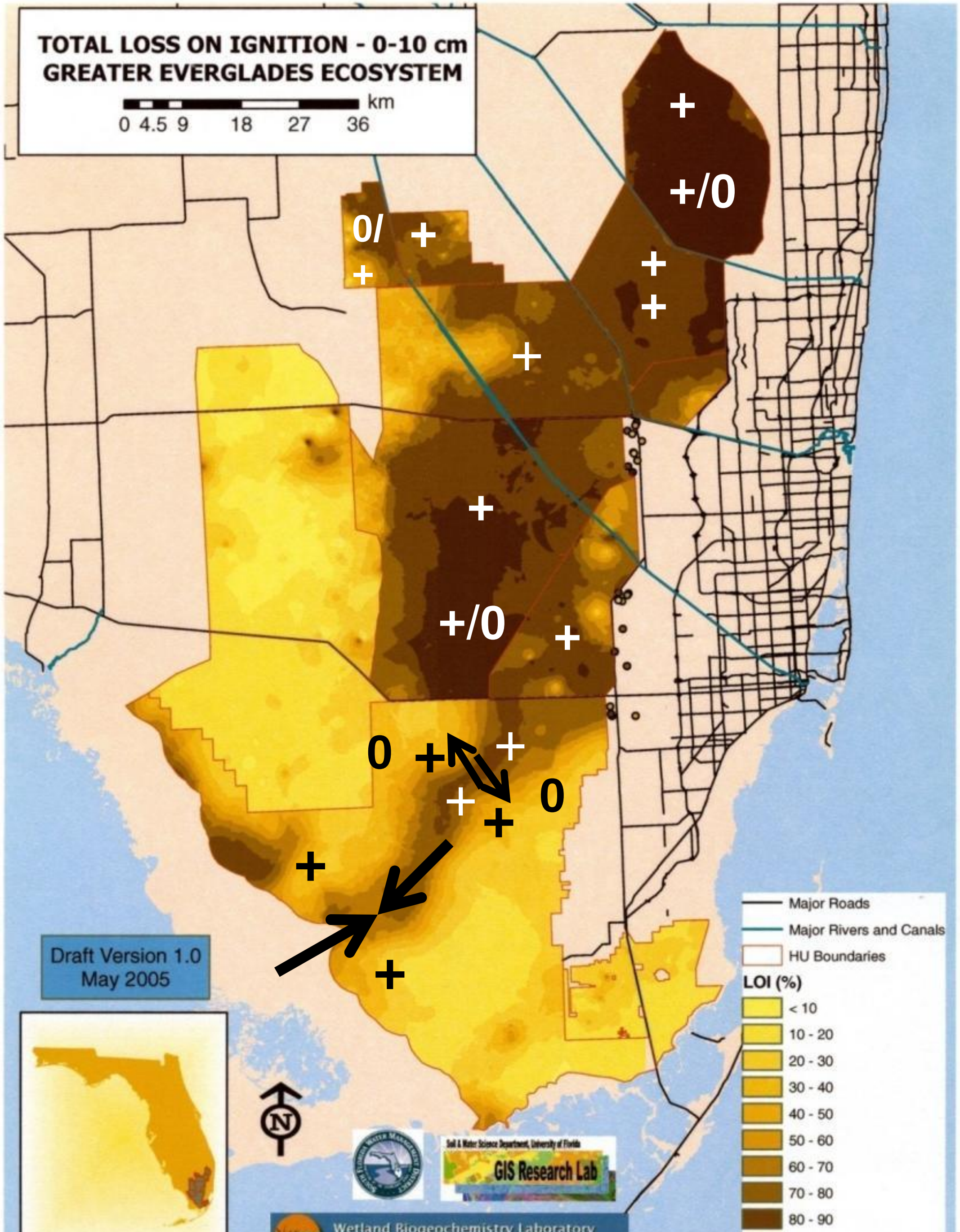


Source: Reddy et al., 2005

Baseline Condition

Key differences between wet and dry years

- northern WCA1 and most of WCA2A and HL are experiencing peat oxidation during dry years, with peat accumulation during normal/wet years. P enriched areas have increased soil accretion, but also greater decomposition so less organic C.
- northern portions of WCA3A and most of 3B are experiencing peat oxidation during dry years, peat accumulation during normal/wet years
- during normal/wet years ENP has peat accumulation only in major sloughs (Shark River and Taylor) little peat accumulation in Rocky glades areas during wet years. Oxidation throughout during dry years.
- coastal areas little impacted by wet and dry years; some mangrove areas accrete peat

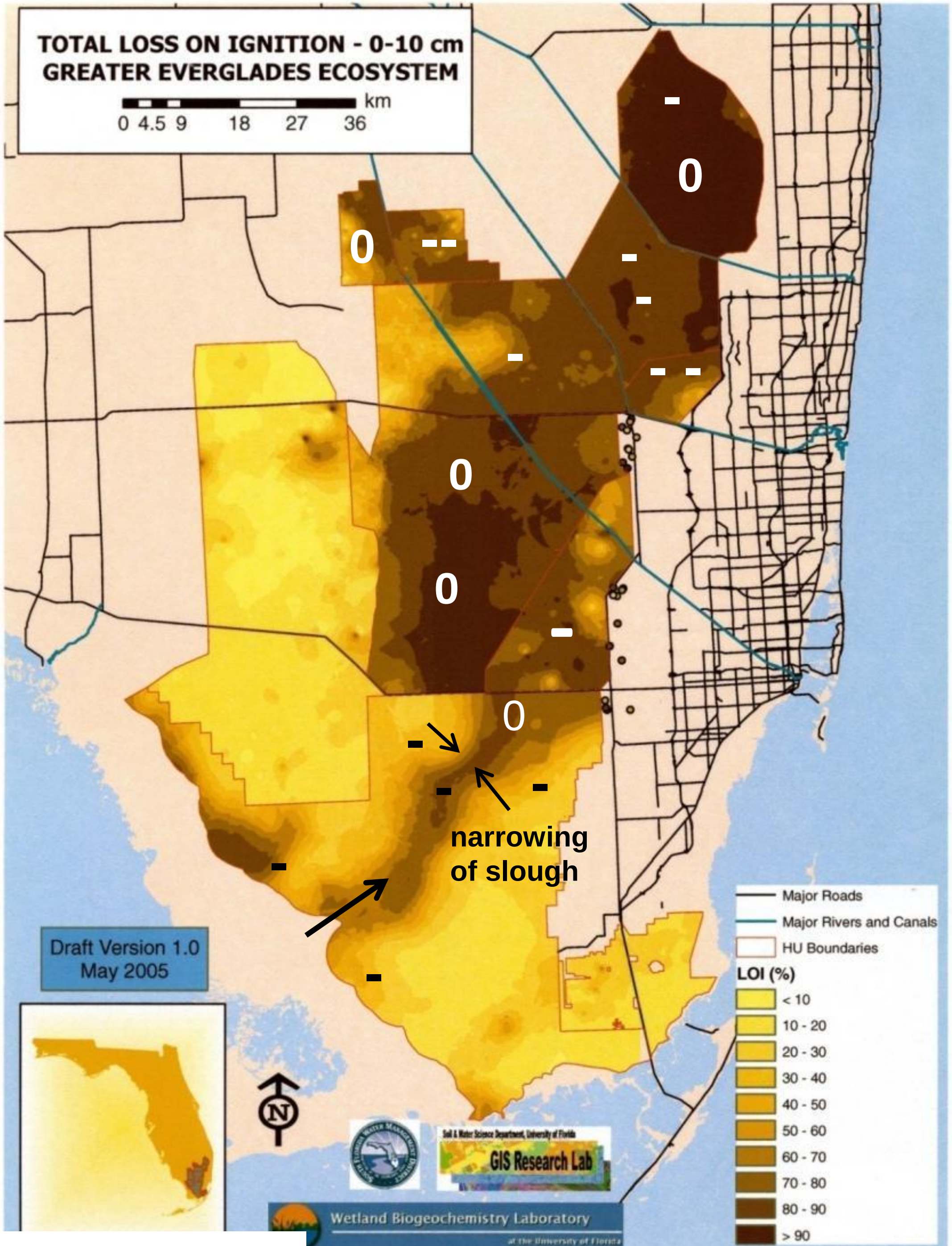


Source: Reddy et al., 2005

10 % increase rainfall

Key points

- overdrained areas of WCA1, WCA2A, WCA2B, HL, RTB, WCA3A and 3B get more water promoting peat accretion; other areas maintain peat accretion-dependent on ponding depth uncertainty.
- dry years still see shorter hydroperiods in overdrained areas and potential peat loss.
- increased freshwater flow down Shark/Taylor Sloughs widens sloughs and promotes peat accumulation; mutes seawater intrusion and peat erosion.

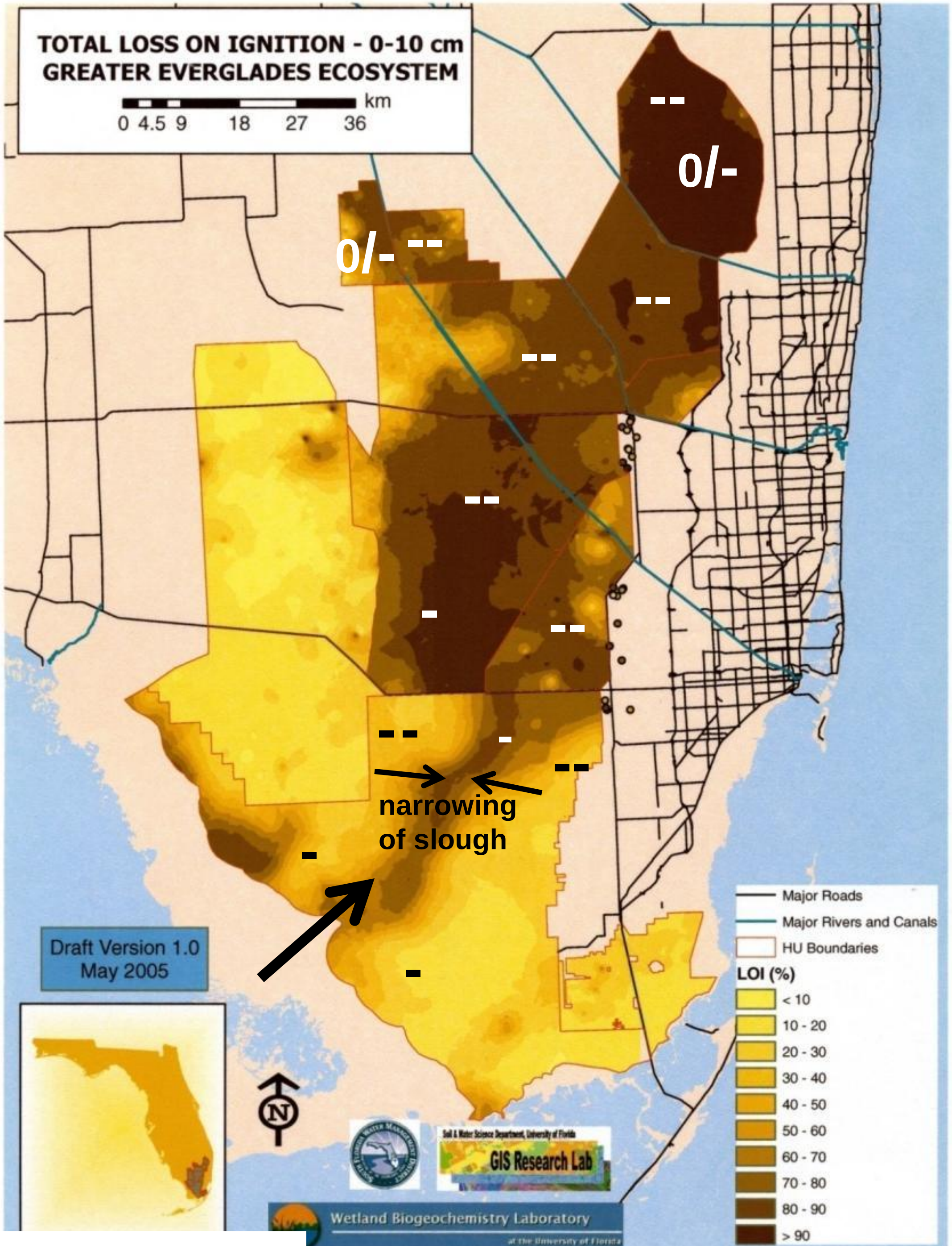


Source: Reddy et al., 2005

10 % decrease in rainfall or 10 % increase in ET

Key points between wet and dry years

- WCA1, WCA2A&B, HL, and WCA3A&B all are significantly drier under dry year condition- leading to peat oxidation.
- ENP at end of the water flow pipeline will experience significant drying, narrowing of Shark and Taylor sloughs, peat oxidation and absence of marl deposition in marl prairies; intrusion of saltwater up Shark Slough will result from SLR and decreased freshwater flow, erosion of coastal peat



Source: Reddy et al., 2005

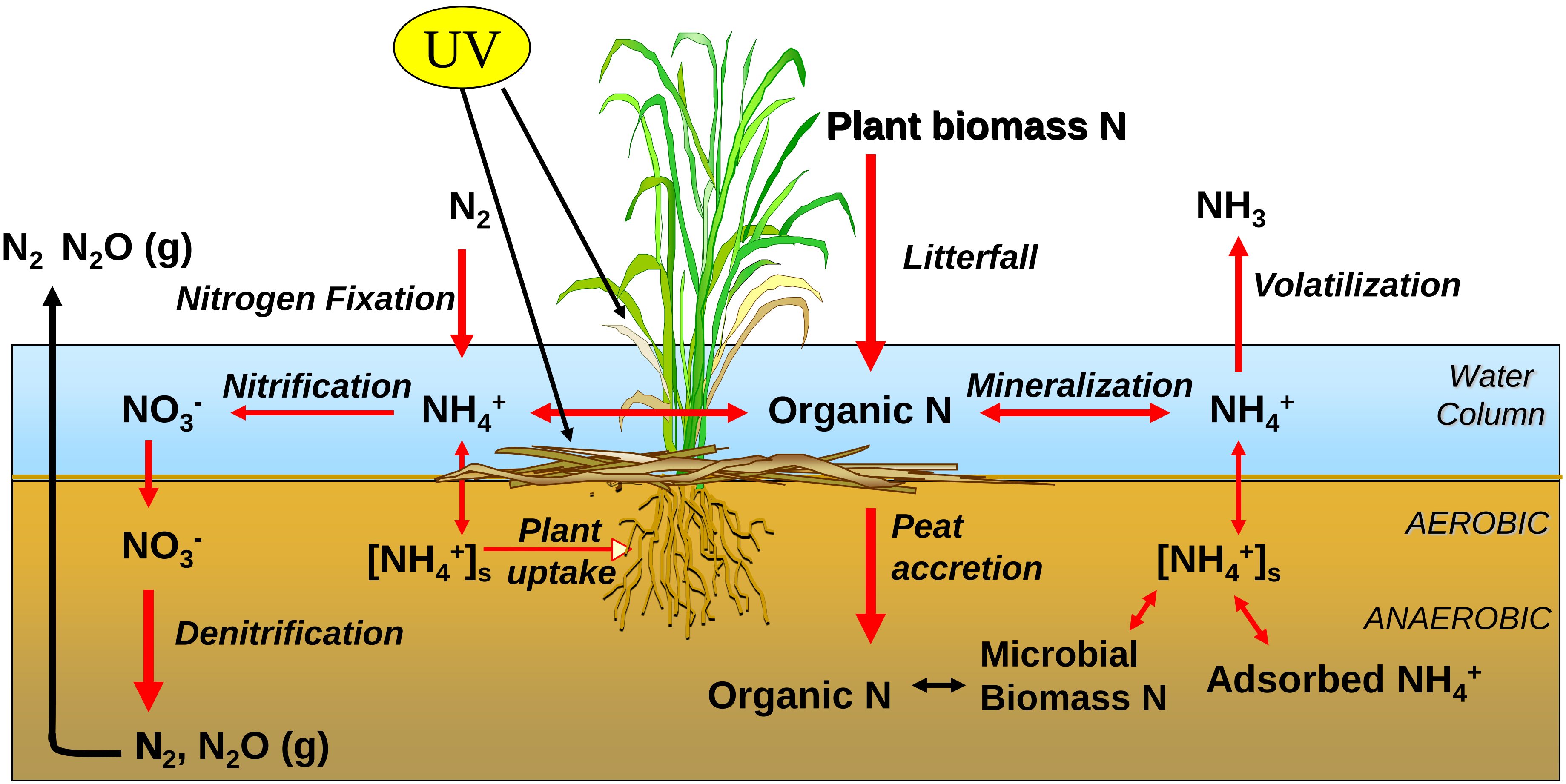
10 % decrease rainfall + increase ET

Key points

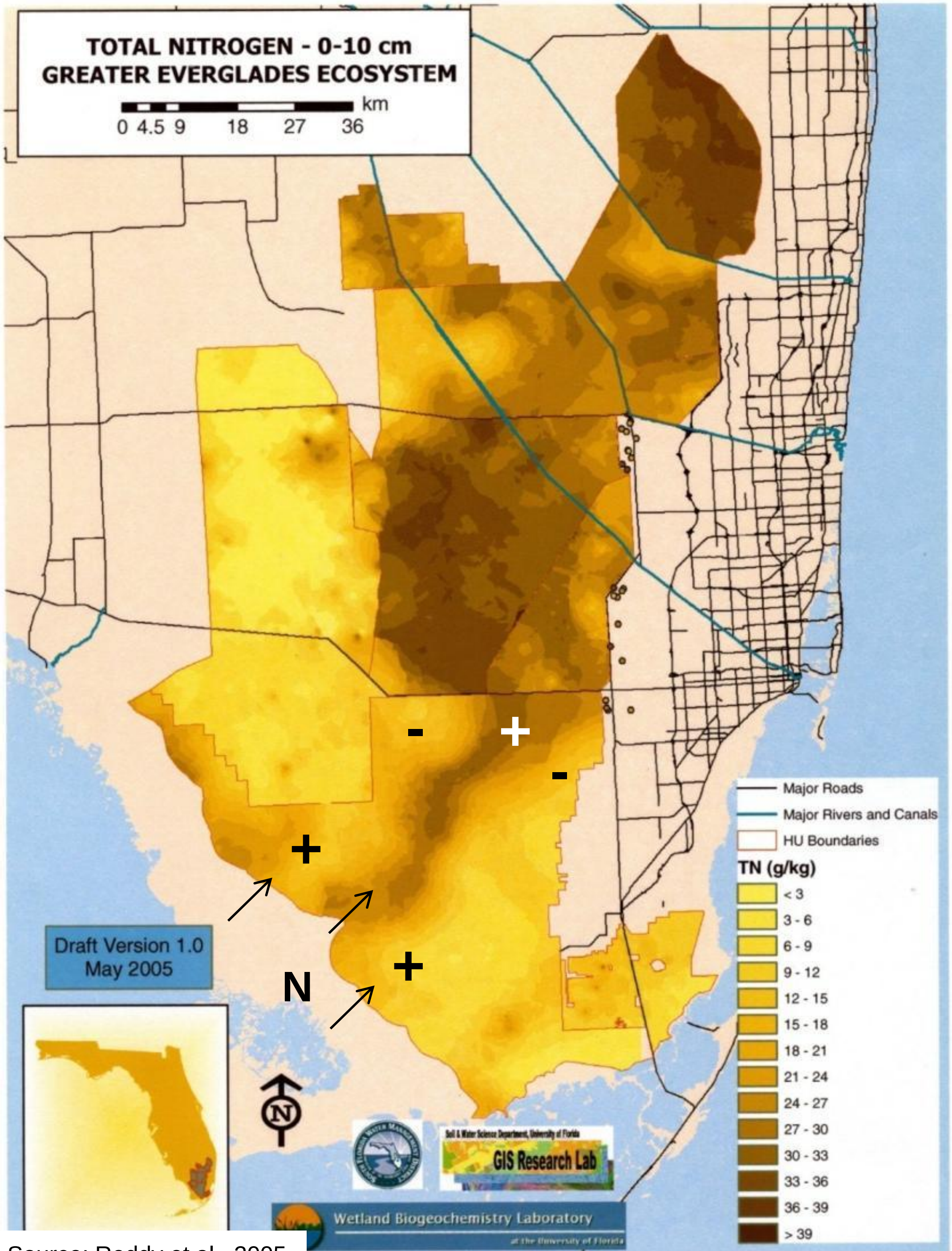
- northern & central peatlands are overly dry even in wet years
- ENP narrowing of Shark/Taylor Sloughs; peat loss outside of center slough
- dry years are catastrophic with limited water throughout and systemwide peat loss; likely greater fire frequency

- saltwater intrusion; initial peat tidal erosion before mangrove peat established.

Nitrogen Cycle



Source: K. R. Reddy, and R. Delaune 2008



Source: Reddy et al., 2005

Baseline

Effects of climate change scenarios

Overall, strongly tied to C cycling, so systemwide responses are similar under the different scenarios.

Key differences with C cycle

• most peat C originates from vascular plants while N is from N-fixation in cyanobacteria

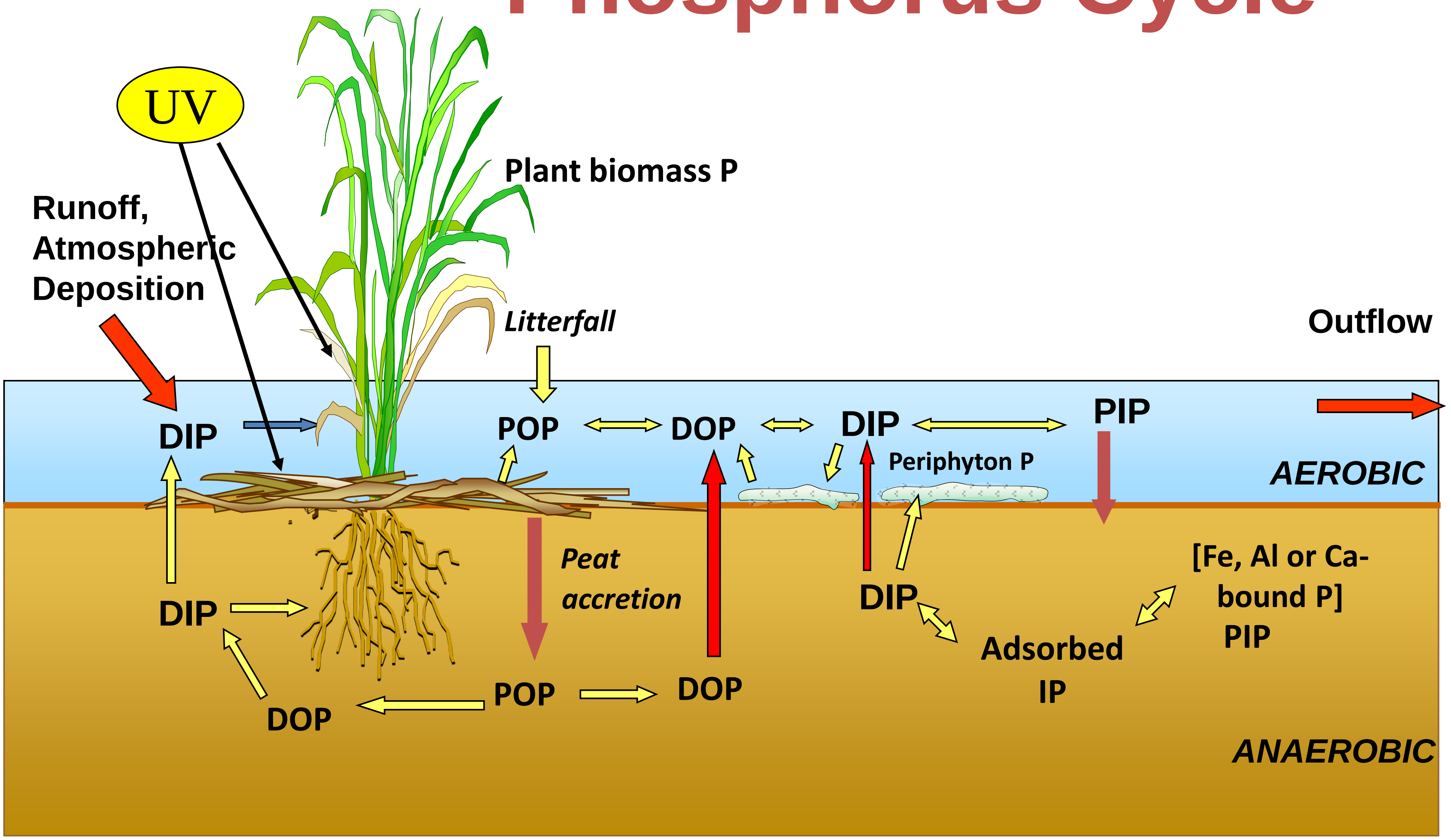
•coastal zone N sourced from offshore

Increased rainfall: Increased freshwater flow down Shark/Taylor Sloughs widens sloughs and enhances N fixation; freshwater mutes seawater intrusion and offshore N flux

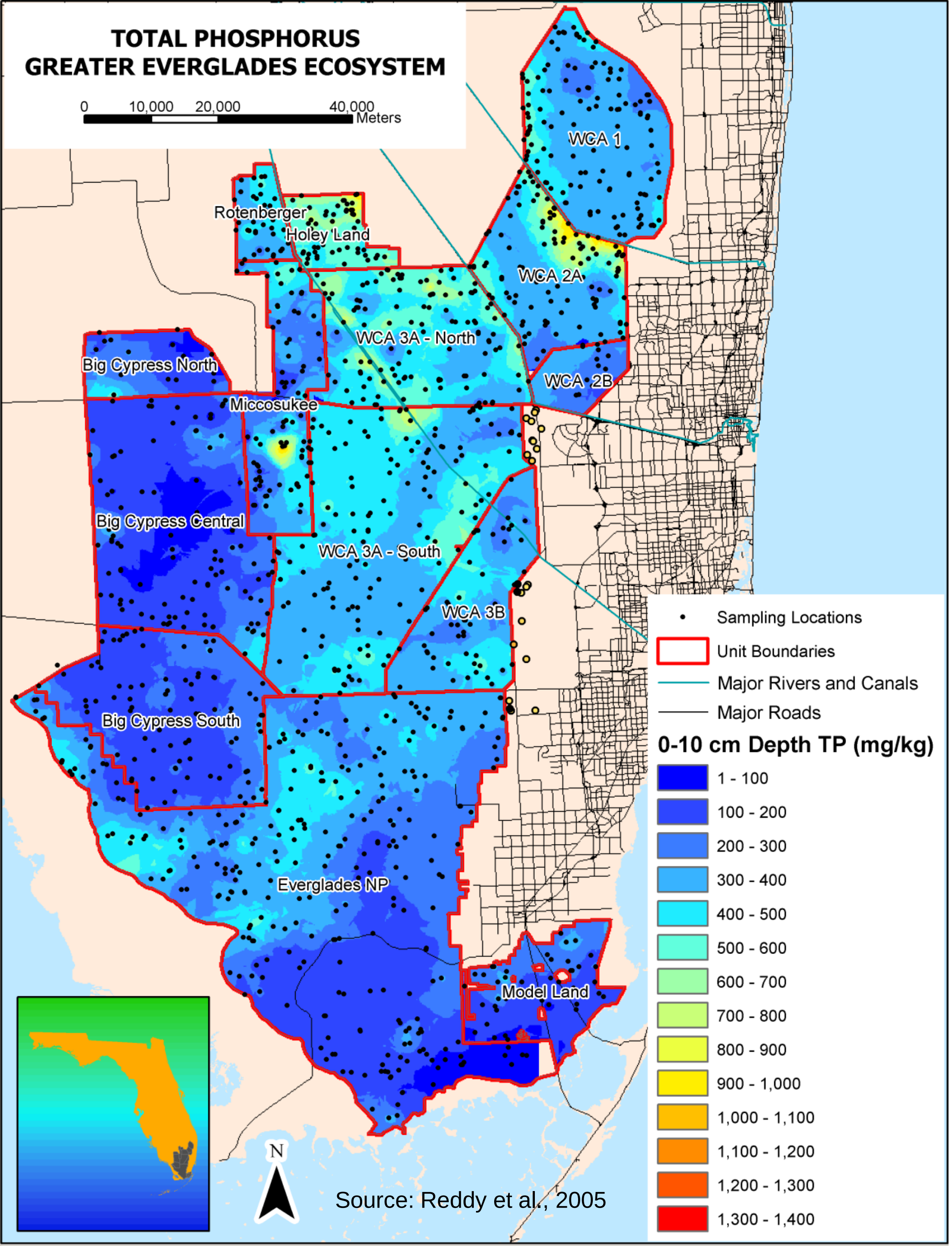
Decreased water present: ENP narrowing of Shark/Taylor Sloughs; less wetland for N-fixing cyanobacteria

Saltwater intrusion; increased N flux from offshore

Phosphorus Cycle



Source: K. R. Reddy, and R. Delaune 2008



Baseline Condition

Key differences with climate change

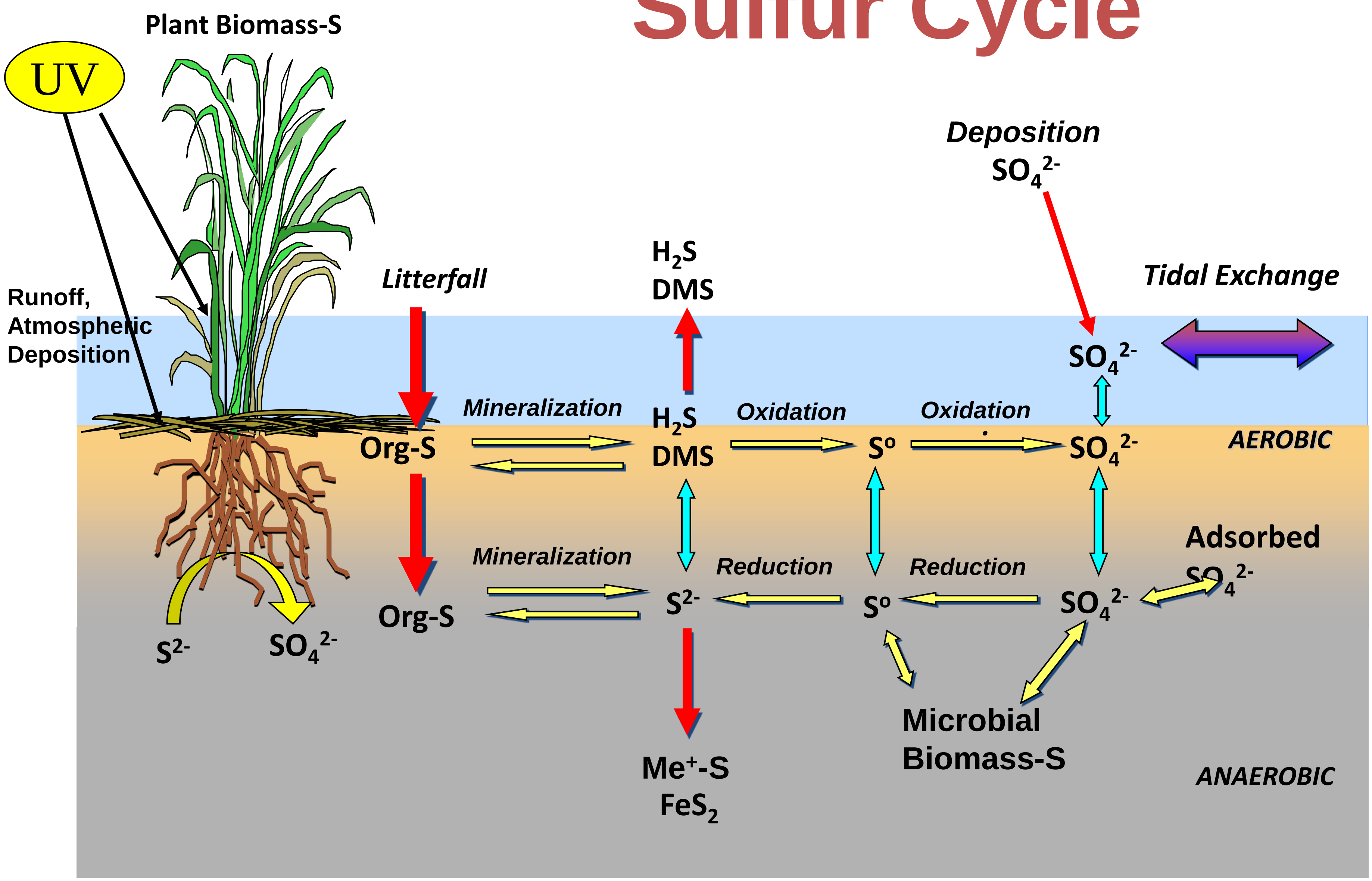
Increased rainfall

- may see increased P loads through structures, potentially greater fertilizer and particulate runoff
- increased flows- increased P supply- potential for local nutrient loading
- excessive inundation leading to P release from more stable pools due to more acidic pH

Decreased rainfall and/or increased ET

- increased overdrainage, conversion of organic to inorganic P- internal eutrophication, greater P input due to soil loss upstream

Sulfur Cycle



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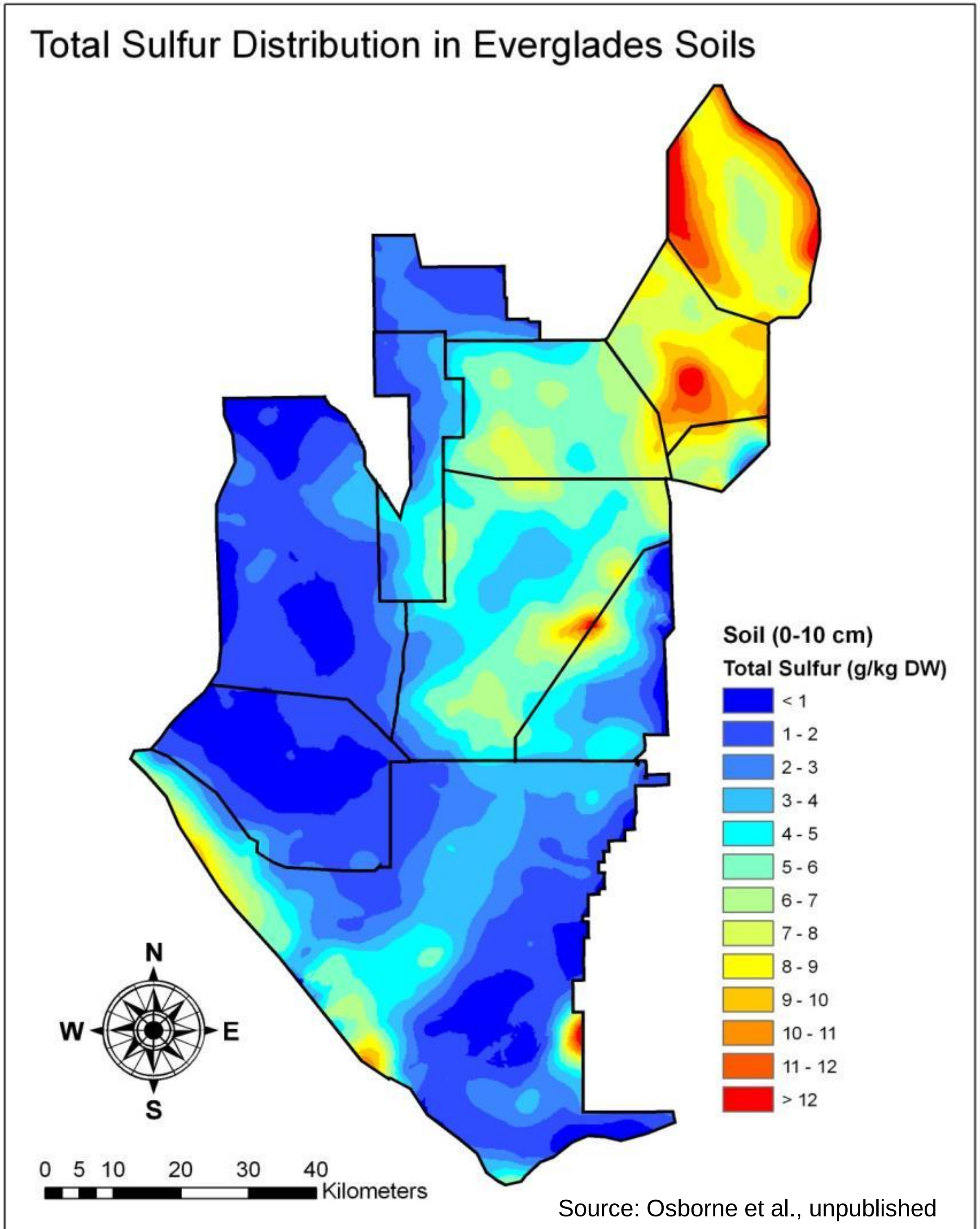


Baseline

Effects of climate change scenarios

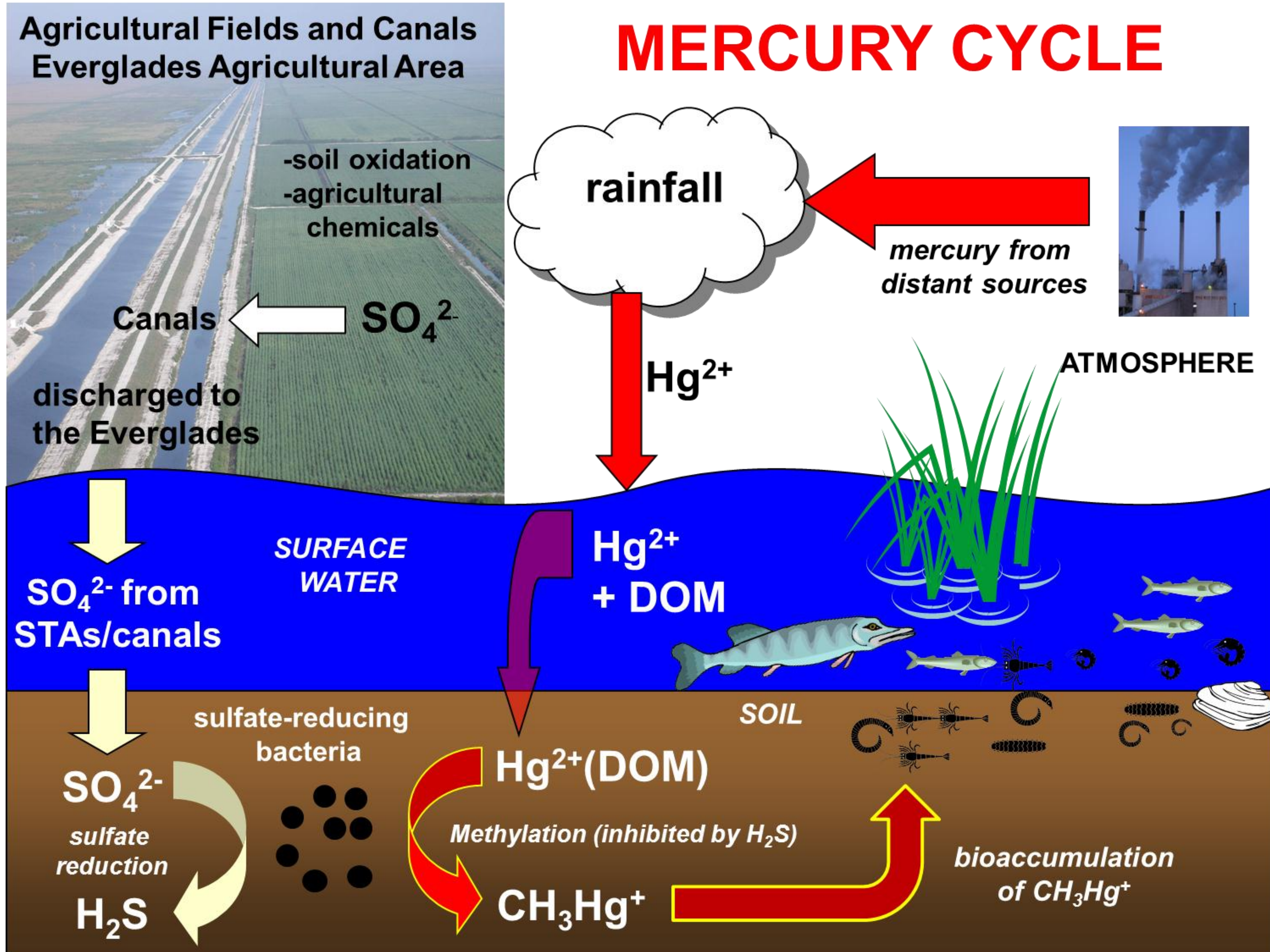
Overall, strongly tied to C cycling, so systemwide responses are similar under the different scenarios. Key differences are:

Increased rainfall

- increased loading due to increased runoff from surrounding EAA and soil oxidation
- less oxidation of soils will result in H_2S accumulation
- likely will result in small increases in atmospheric S loading.

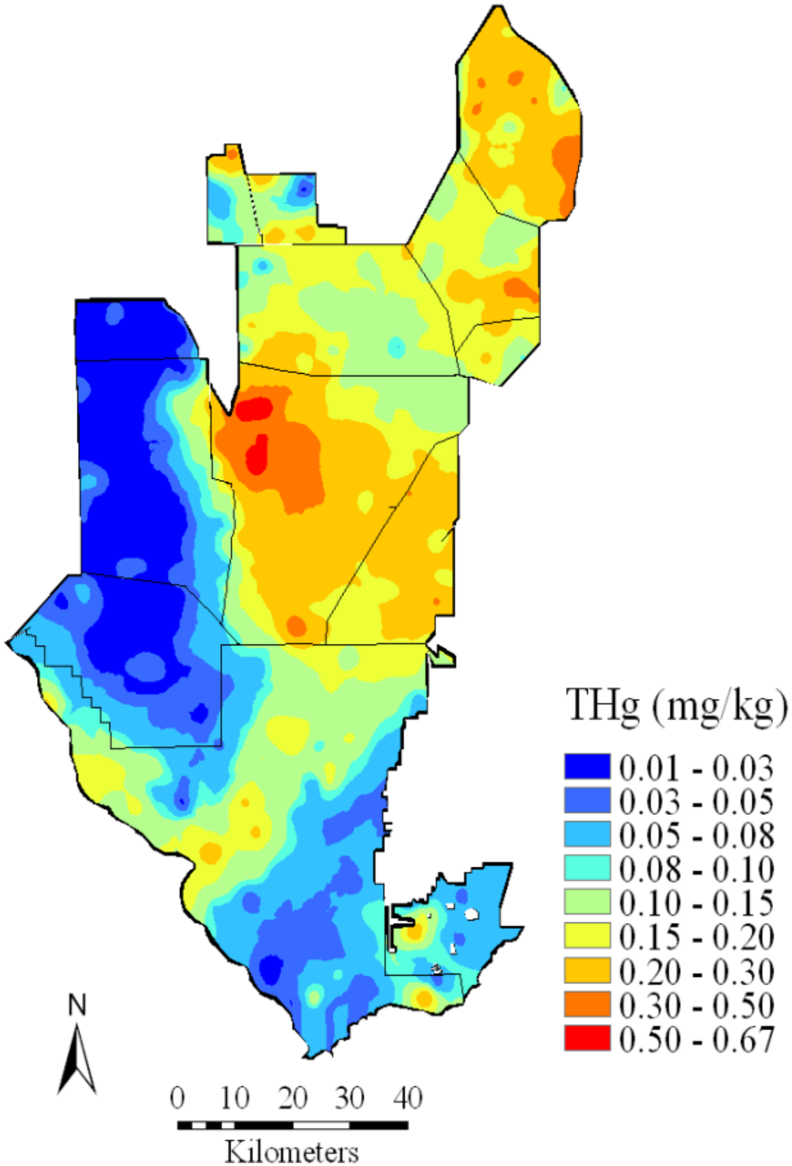
Decreased rainfall/increased ET

- oxidation induced S release is a significant risk in the water conservation area soils
- SLR and saltwater intrusion at coast- extent of intrusion will be a function of balance between rate of C accumulation and rate of SLR



Agricultural Fields and Canals
Everglades Agricultural Area
MERCURY CYCLE
-soil oxidation
-agricultural chemicals
rainfall
mercury from distant sources
Canals
SO_4^{2-}
discharged to the Everglades
Hg^{2+}
ATMOSPHERE
SURFACE WATER
SO_4^{2-} from STAs/canals
Hg^{2+} + DOM
SOIL
sulfate-reducing bacteria
Hg^{2+}(DOM)
SO_4^{2-}
sulfate reduction
H_2S
Methylation (inhibited by H_2S)
CH_3Hg^+
bioaccumulation of CH_3Hg^+

Baseline



Increased rainfall

-larger area submerged and anoxic - increase CH_3Hg^+ production

-greater Hg^{2+} deposition on Everglades - increase CH_3Hg^+ production

-greater runoff of SO_4^{2-} from EAA - increase CH_3Hg^+ production overall; but H_2S buildup will cause inhibition of methylation in some regions especially in the north and near STA and canal discharges

OVERALL IMPACT ++

Decreased rainfall/increased ET

-more frequent drying events and organic soil oxidation and release of Hg^{2+} and SO_4^{2-} from soil - increase CH_3Hg^+ production

-lower Hg^{2+} deposition on Everglades - decrease in CH_3Hg^+ production

-lower runoff of SO_4^{2-} from EAA - decrease in CH_3Hg^+ production overall

-smaller area submerged and anoxic - decrease in CH_3Hg^+ production

OVERALL IMPACT -

Source: Cohen et al., 2009

Effect of increased temperature

Increased microbial activity

- increased decomposition
- increased growth rates and nutrient uptake
- increased CO_2 and CH_4 production
- increased rate of nitrification, denitrification and biological N_2 fixation
- increased rate of organic P and S mineralization
- increase CH_3Hg^+ production- typically see higher rates of methylation in the summer than winter

Effect of increased CO_2 to 490 ppm

Increased primary productivity

- ↑ C, N and P sequestration

Increased microbial activity

- ↑ nitrification rate, denitrification, and biological N_2 fixation
- ↑ increased rate of nutrient release from soils

Constraints

In P limited areas, P limitation may constrain increased productivity, unless microbial activity sufficiently increased, and org P pools made available to remove P limitation

Uncertainties

- Water depth/duration that results in anaerobic processes outcompeting productivity
- At southern end of system, with +RF scenario, difficult to assess what is ponding versus saltwater intrusion
- Seasonality of rainfall versus total rainfall; impacts of longer dry seasons under + and - RF scenarios
- To what extent fire frequency changes under the different scenarios
- Effects of increased CO_2 in P limited areas of the system
- Increased saltwater on the stability of organic matter
- Will increase SLR cause erosion of accumulated C due to tidal flux (increased DOC/DON load to Fl Bay), or increase C due to mangroves expanding northward

Research Suggestions

- Studies to test water depth/duration that results in anaerobic processes outcompeting productivity.
- Studies of optimum conditions for stimulating peat accumulation – can peat growth be manipulated to keep up with SLR
- What are salinity limits for freshwater Everglades – could salt/fresh mix augment water in Glades under dry scenario
- Relationships between the peat capillarity, water table and subsidence-number of dry days to negate accretion

Research Suggestions

- Modeling Hg deposition under different rainfall scenarios
- Assessment of increased CO_2 on balance between productivity, microbial activity and P availability

Conclusions

Thank You Questions?