Prairie Wetlands in a Changing Climate

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Outline

- Overview of climate change and projections for prairies
- Ramifications of climate change for prairie pothole wetlands
- Potential for prairie pothole wetlands to help adapt to, and mitigate against climate change
- Conclusions / Recommendations

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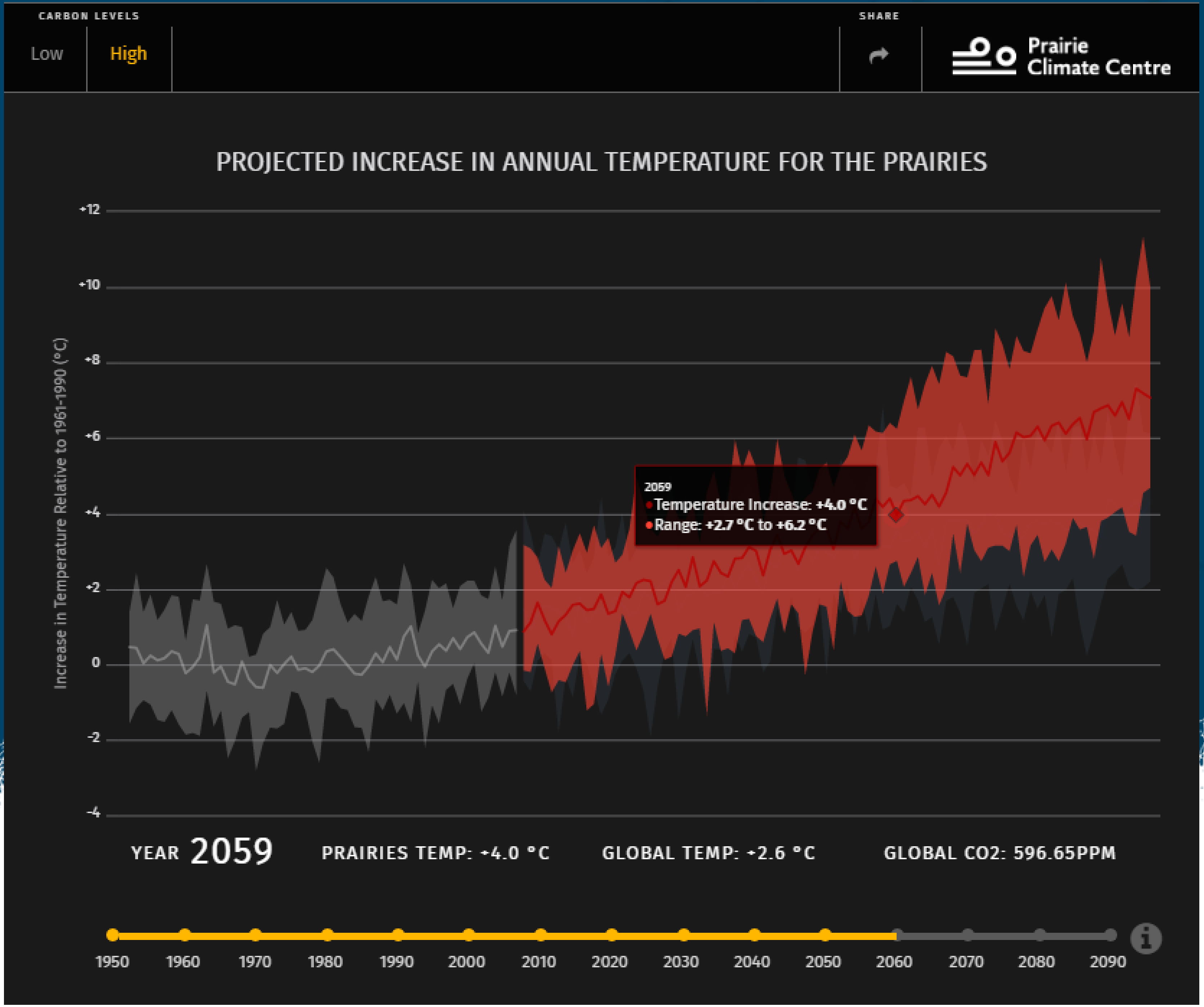
Under continued high carbon emissions, temperature in the Canadian Prairies is expected to increase by 4°C by the year 2059



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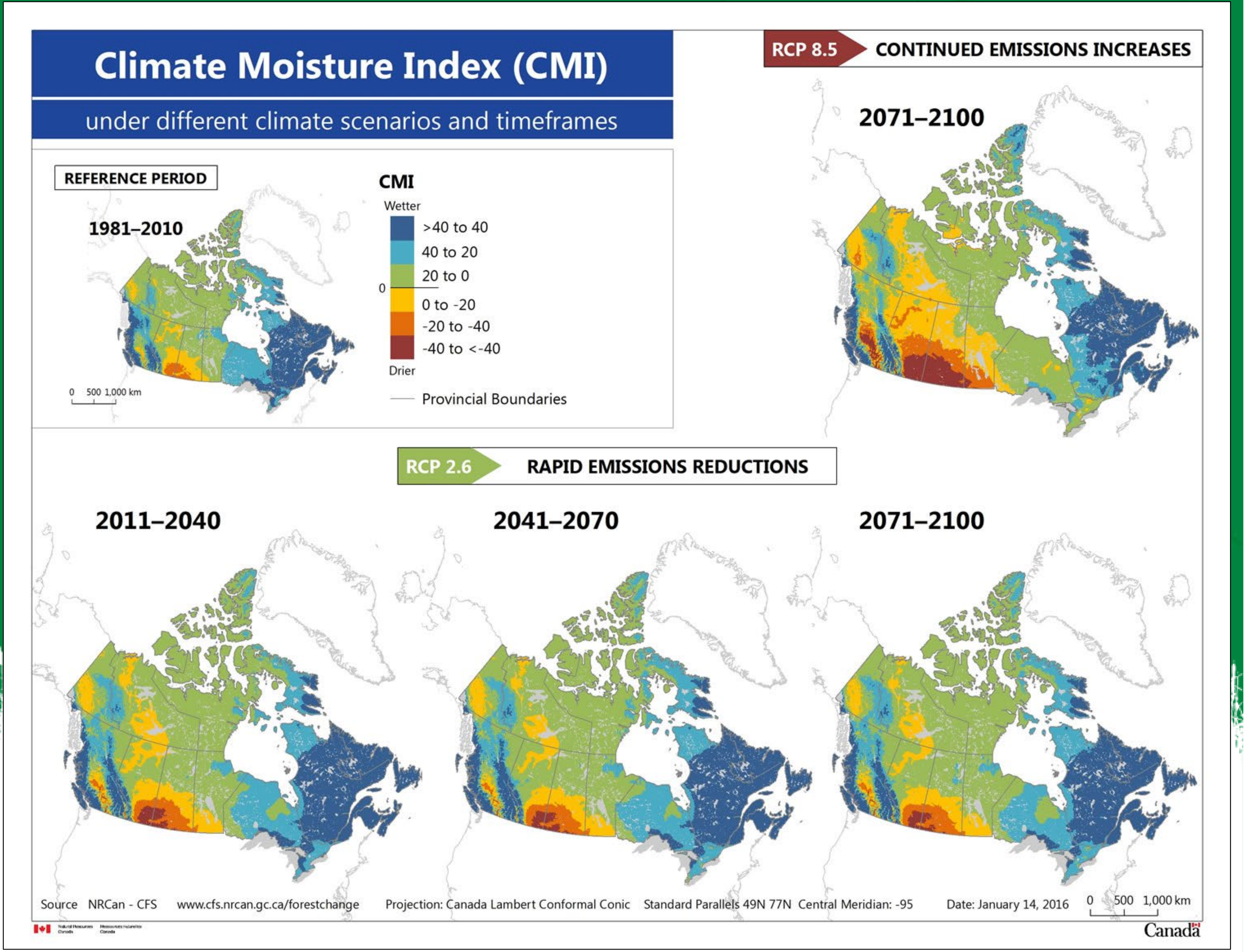
Even with rapid emissions reductions droughts will increase in the Canadian Prairies and will become potentially catastrophic if we do nothing



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How will climate change affect prairie wetlands?

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Prairie Pothole Region

- Encompasses approx. 777,000 km^2
- Contains between 5 – 8 millions wetlands (potholes)
- Spans a moisture gradient (300-900mm) and temperature gradient, with a very dynamic climate (drought-deluge, -40 °C – 40 °C)
- Region is vital to North America's waterfowl populations

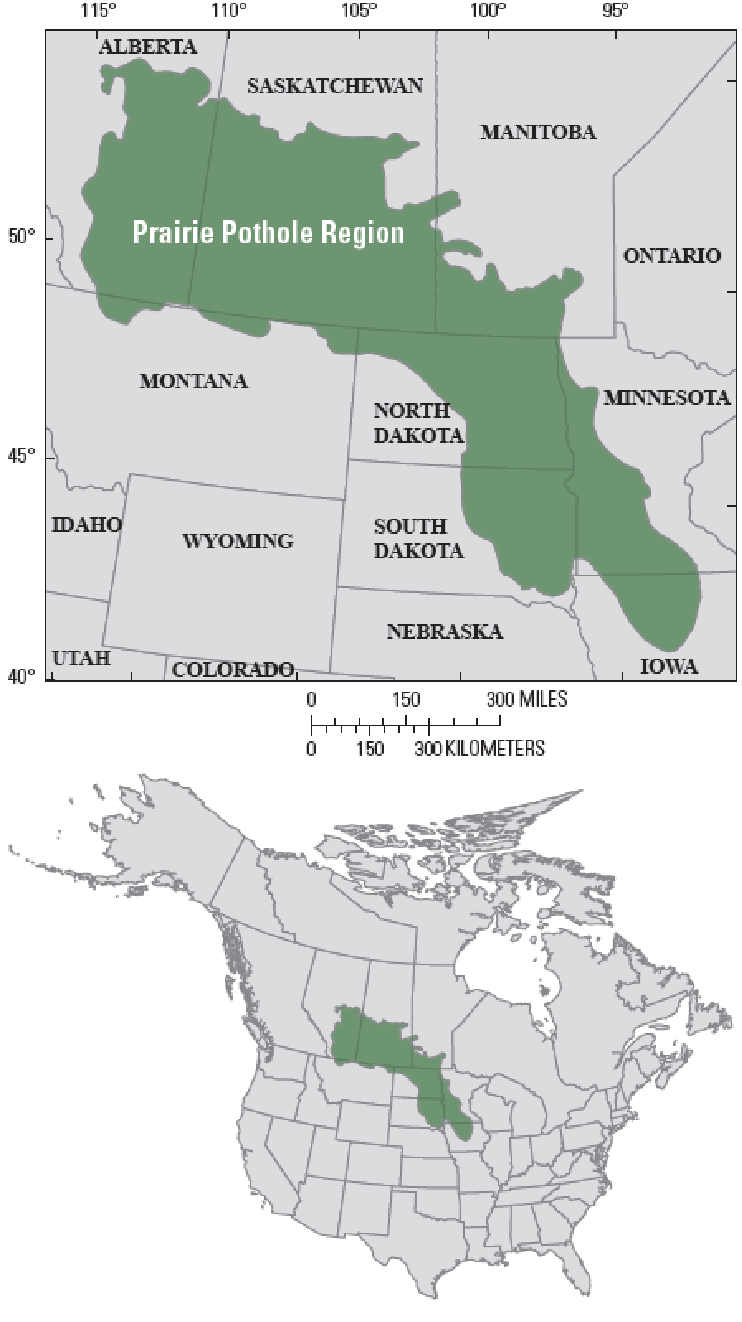
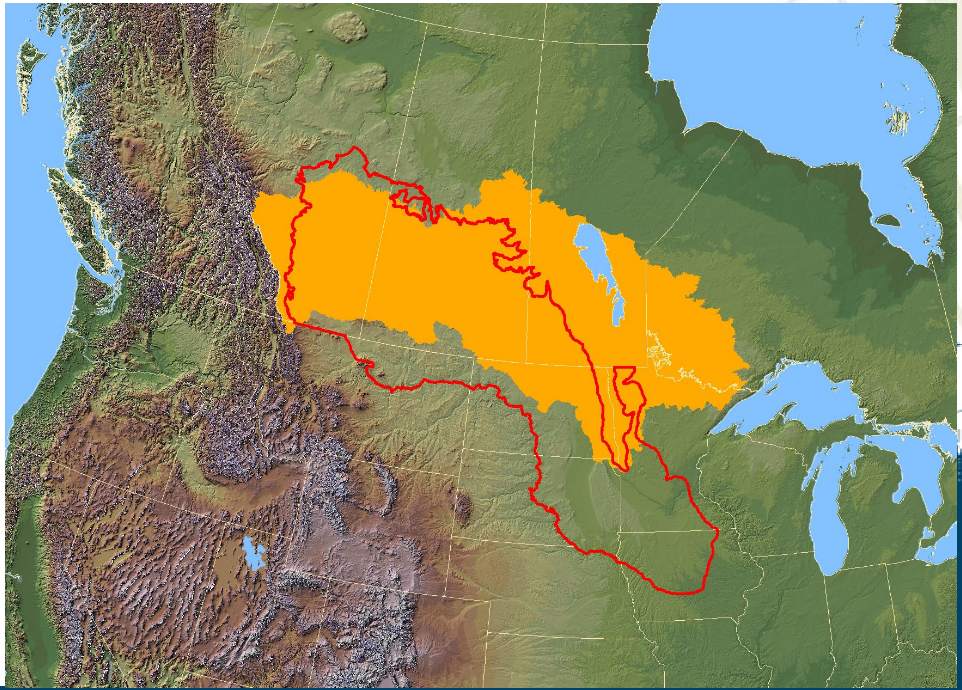


Figure 1. Extent of Prairie Pothole Region in North America.



- Increasingly recognized for the ecosystem services offered by its numerous wetlands

Prairie Pothole Landscape dominated by GIWs

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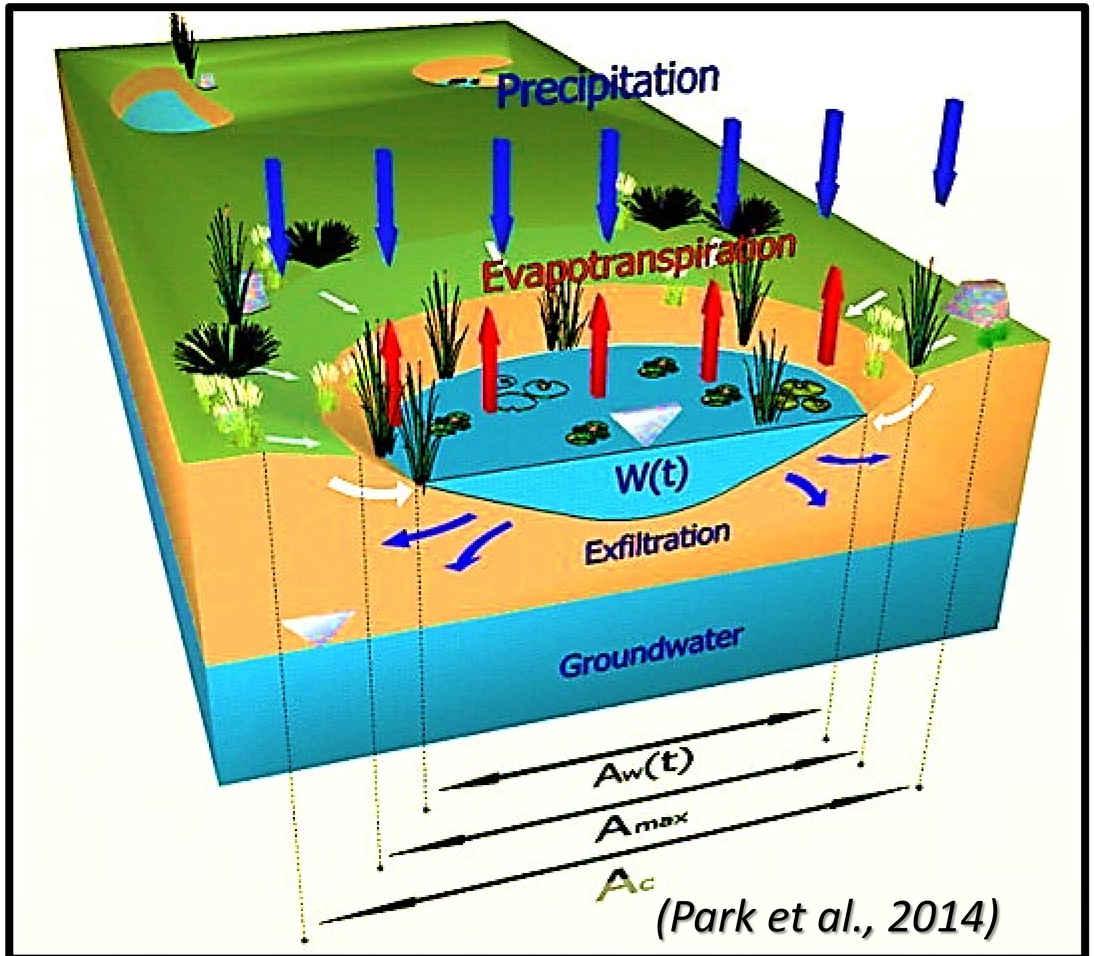
Why prairie wetlands are special

- Prairie wetlands are mostly non-floodplain wetlands / geographically isolated
    - Lack bidirectional hydrologic connections with adjacent streams and or rivers
        - Often embedded in uplands and without well defined surface inlets or outlets
- These wetland are often situated in working agricultural landscapes, where landuse change and drainage impact wetland function
- Are particularly vulnerable to climate change because unlike completely terrestrial ecosystems, prairie potholes cannot migrate with a changing climate

Prairie Wetland Hydroperiods



(Park et al., 2014)

- Length of time wetland is inundated
- Regulated by the balance between precipitation and evapotranspiration
- Controls wetland productivity and the types of biota that can be supported
- Determines suitability for species (100 days required for many waterfowl, amphibian, and aquatic invertebrates)

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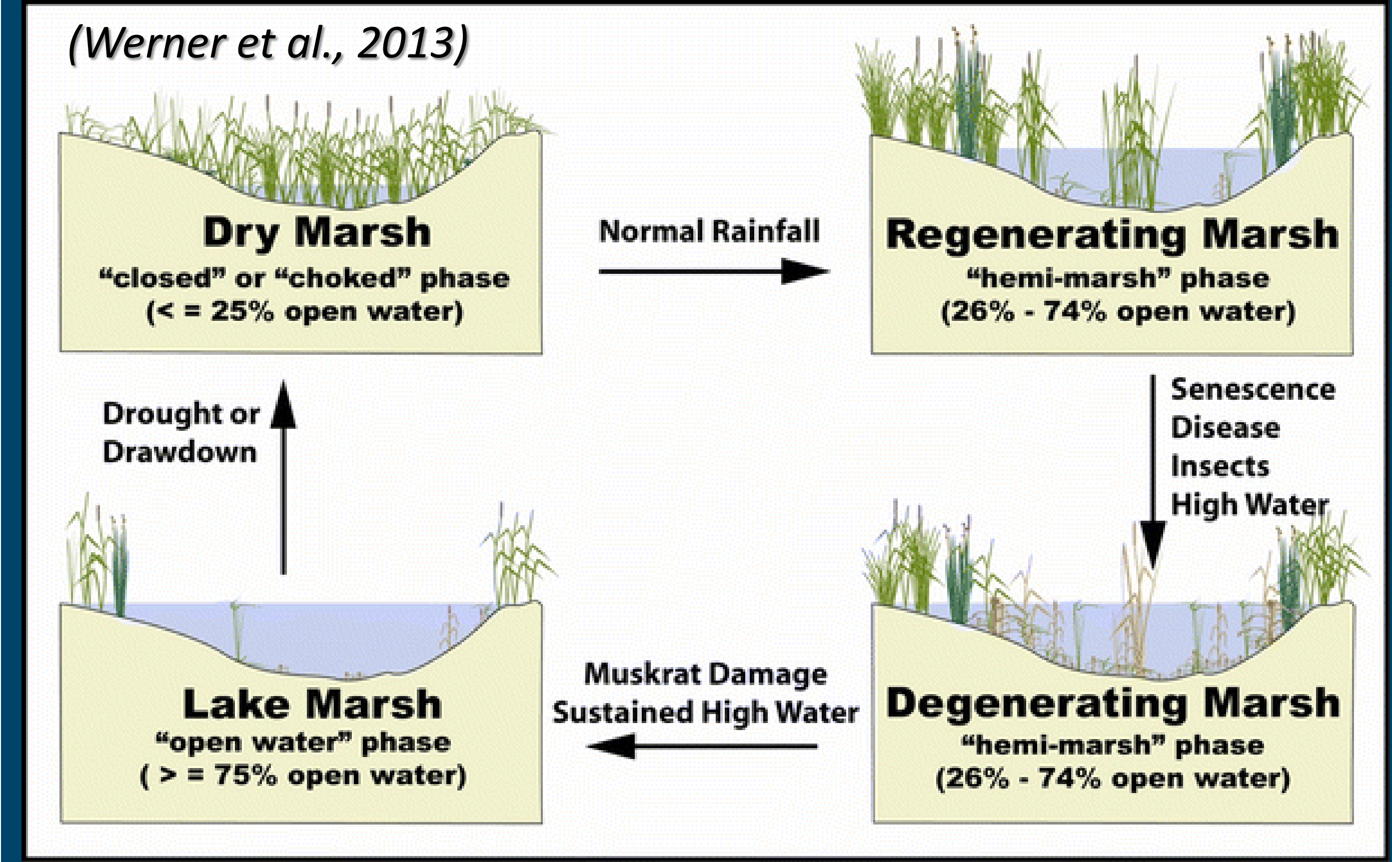
Wetland cover cycle



Wetland hydroperiod

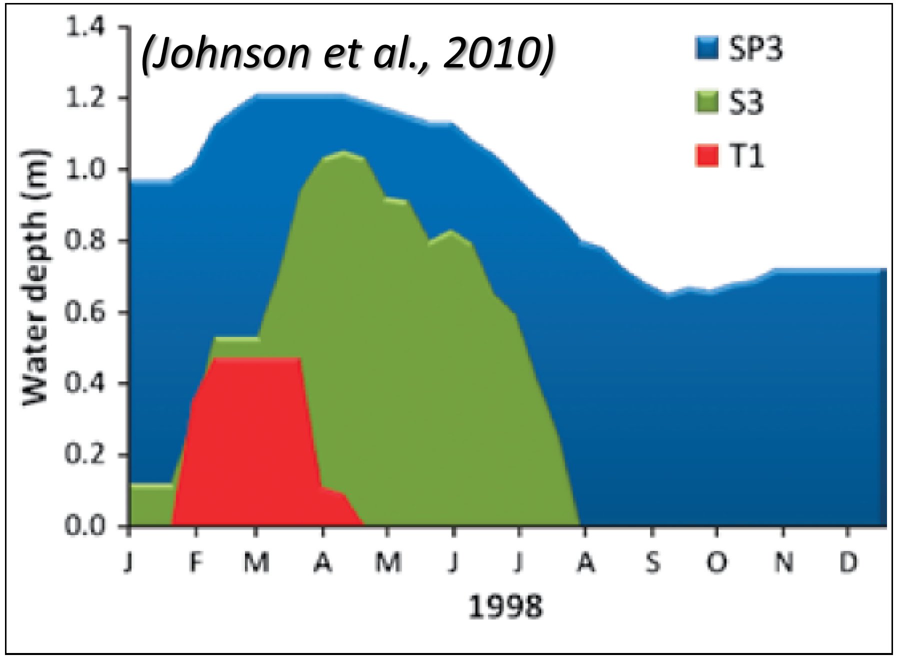


Figure 4. Modeled hydrograph comparisons among a temporary (T1), seasonal (S3), and semipermanent (SP3) wetland by the simulation model WETLANDSCAPE (WLS) from 1998 weather data for the Orchid Meadows field site.

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Impacts to Wetland Hydroperiod

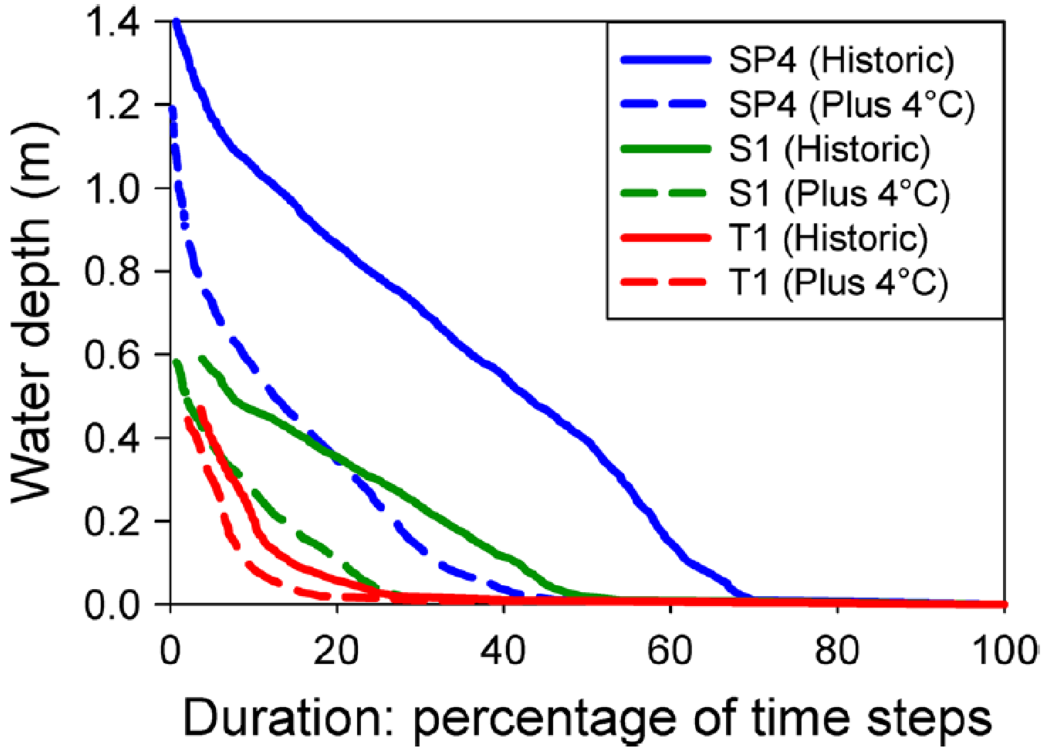

Fig. 6 Comparison of wetland stage-duration curves from WLS for historic climate and a 4 °C climate change scenario for the Academy, South Dakota, weather station. [source: Fig. 10 in Johnson et al. (2010). Prairie wetland complexes as landscape functional units in a changing climate. BioScience 60:128–140]

In the Canadian Prairies climate change is expected to increase temperature and evapotranspiration while only minimally increasing annual precipitation.

The balance between P and ET is expected to result in larger water deficits for prairie wetlands

Water depth (stage) and duration of a given water depth is predicted to decline significantly across all wetland classes but specifically in semi-permanent and seasonal wetlands

Impacts to Wetland Hydroperiod

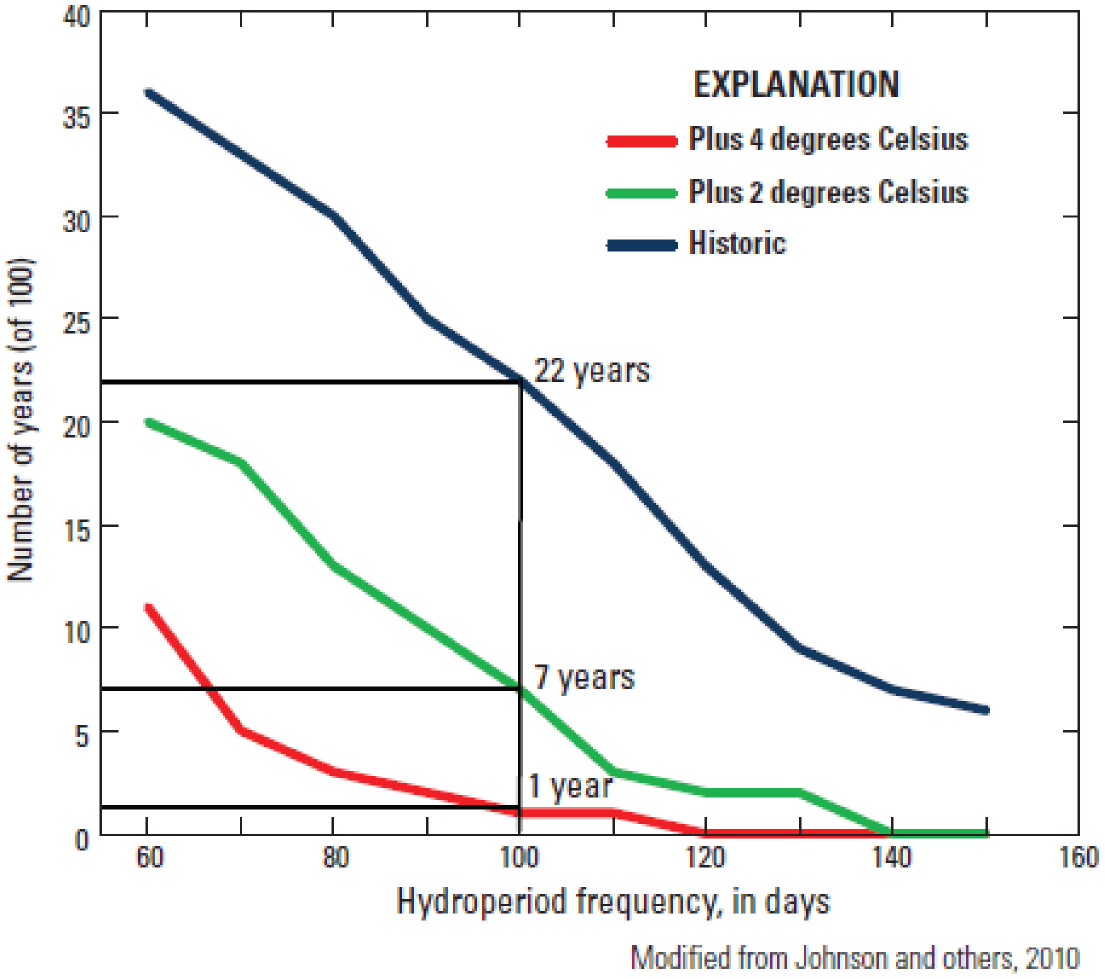

Figure 4. Frequency of hydroperiod calculated for a seasonal prairie pothole wetland. Vertical line shows frequency of a 100-day hydroperiod.

- In seasonal wetlands a hydroperiod of 100 days occurred in 22 out of 100 years. This is reduced by 68% for a climate that is 2°C warmer and by 95% for a climate that is 4°C warmer

- This has serious implications for species that require longer hydroperiods and may result in ecological trap effects

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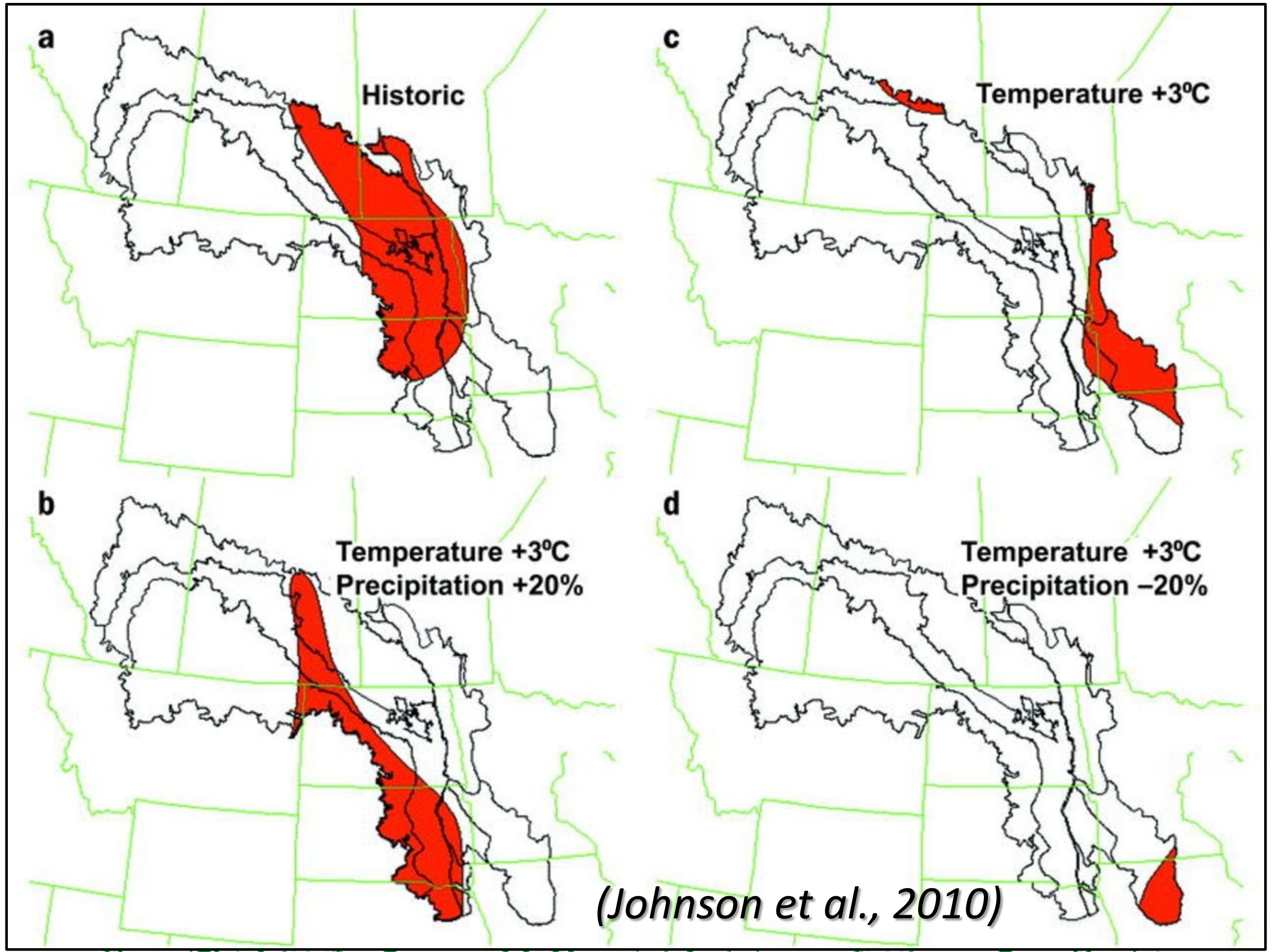

(Johnson et al., 2010)

- **Simulated occurrence of highly favorable water and cover conditions for waterfowl breeding across the prairie pothole region under historic (a) and alternative (b, c, and d) future climatic conditions.**
- **Changes in availability/suitability of habitat may potentially reduce waterfowl populations to 30-70% below historical averages.**
- **These changes do not incorporate potential land use changes (grass to crop) that will accompany climate change and resulting impacts to wetlands (increased drainage, reduced quality of remaining wetlands.**

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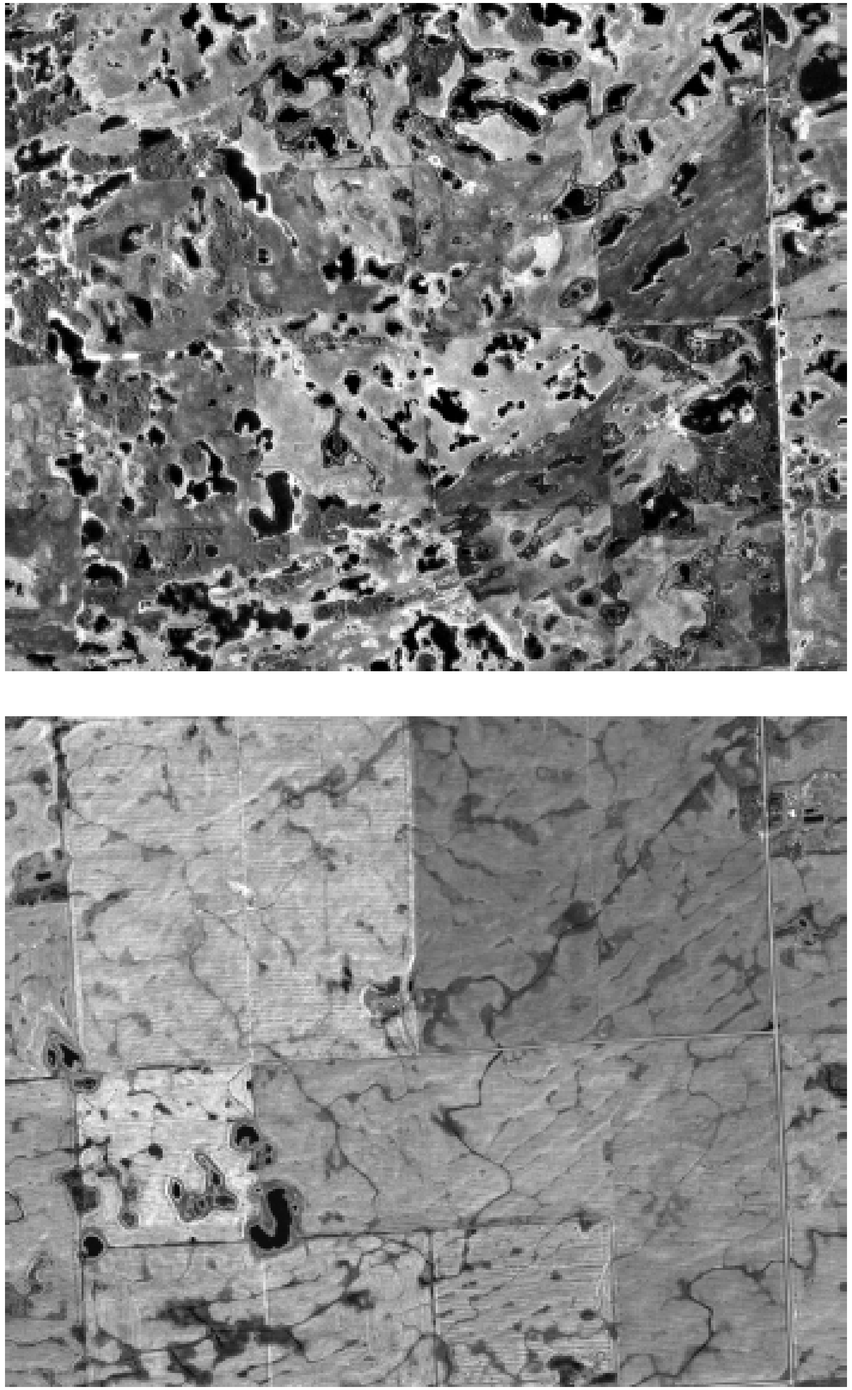
Status and Trends: Prairie Wetlands

- A significant amount of the wetlands in developed areas of Canada have been lost (>90% in some regions)
- We have lost approximately 665,000 ha of wetlands in prairie Canada and southern ON over the last 60 years:
  - *southern AB (133,000)*
  - *southern SK (250,000)*
  - *south western MB (105,000)*
  - *southern ON (177,000)*

Summary of climate change impacts on prairie wetlands



Smith Creek, SK (1958-2008)

- **Climate change will increase temperature, reduce water availability, reduce hydroperiods and alter the cover cycle.**
- **Result of past pressures applied to wetland landscapes such as the PPR will likely amplify the effects of climate change in these regions**
- **There is concern that in combination these could result in an ecological threshold/tipping point. These are often rapid/irreversible state shift**

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The role of prairie wetlands in climate change mitigation and adaptation

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The role of prairie wetlands in climate change mitigation and adaptation

- From a global perspective, wetlands store approx. 30% of terrestrial carbon but only occupy 5-8% of the landscape (mostly peatlands)
- Wetlands are among the most productive ecosystems in the world
- Of the many types of wetlands, inland freshwater marshes have the highest rates of net primary productivity (250-3,000 g C/m2/yr)

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The role of prairie wetlands in climate change mitigation and adaptation

- Wetlands are important global carbon stores but also important sources of GHGs
- Neubauer (2014): no natural wetlands older than ~250 years can be considered net sources of radiative forcing (pre-industrial baseline conditions.

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- Largest source of wetland methane is from tropical regions

- Temperate wetland methane emissions are driven by the vast extent of boreal peatlands contained within this zone, but freshwater mineral soil wetlands like marshes can have large fluxes on a per unit basis

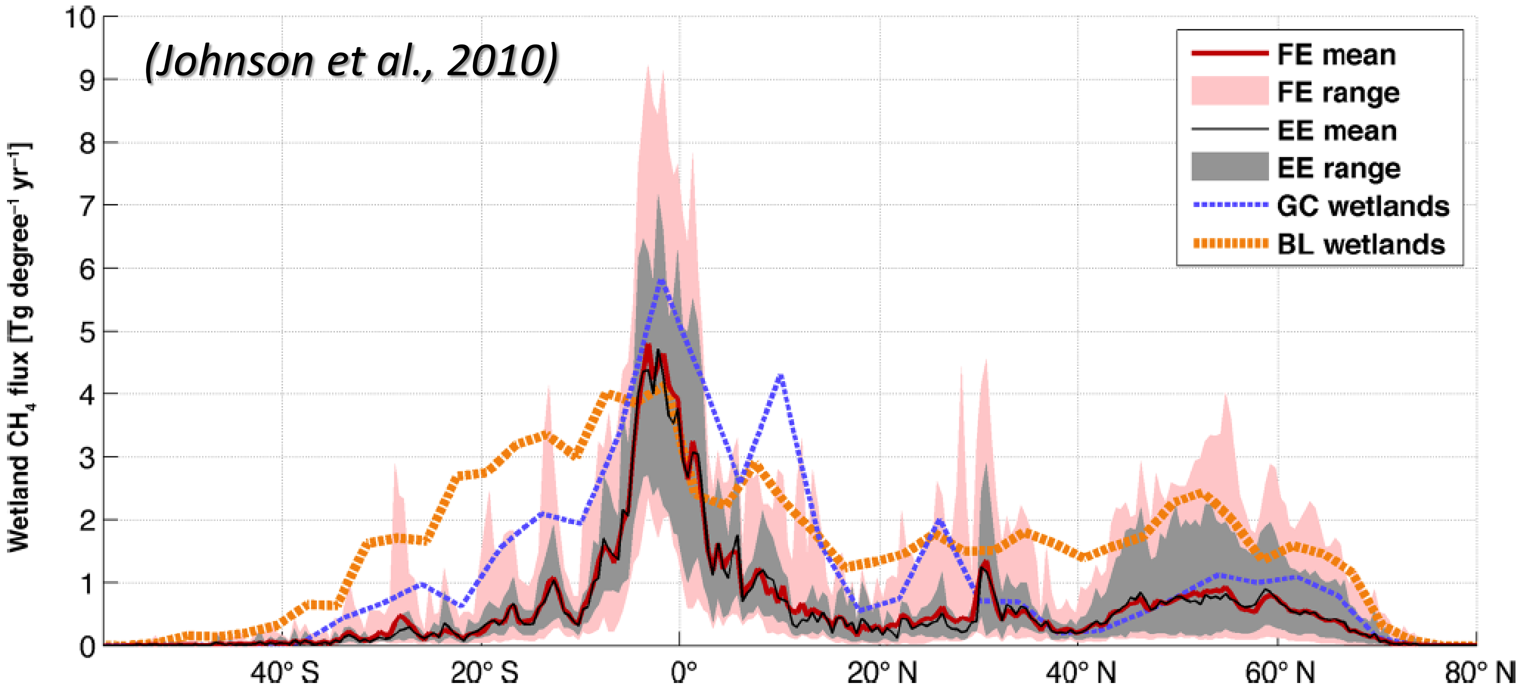
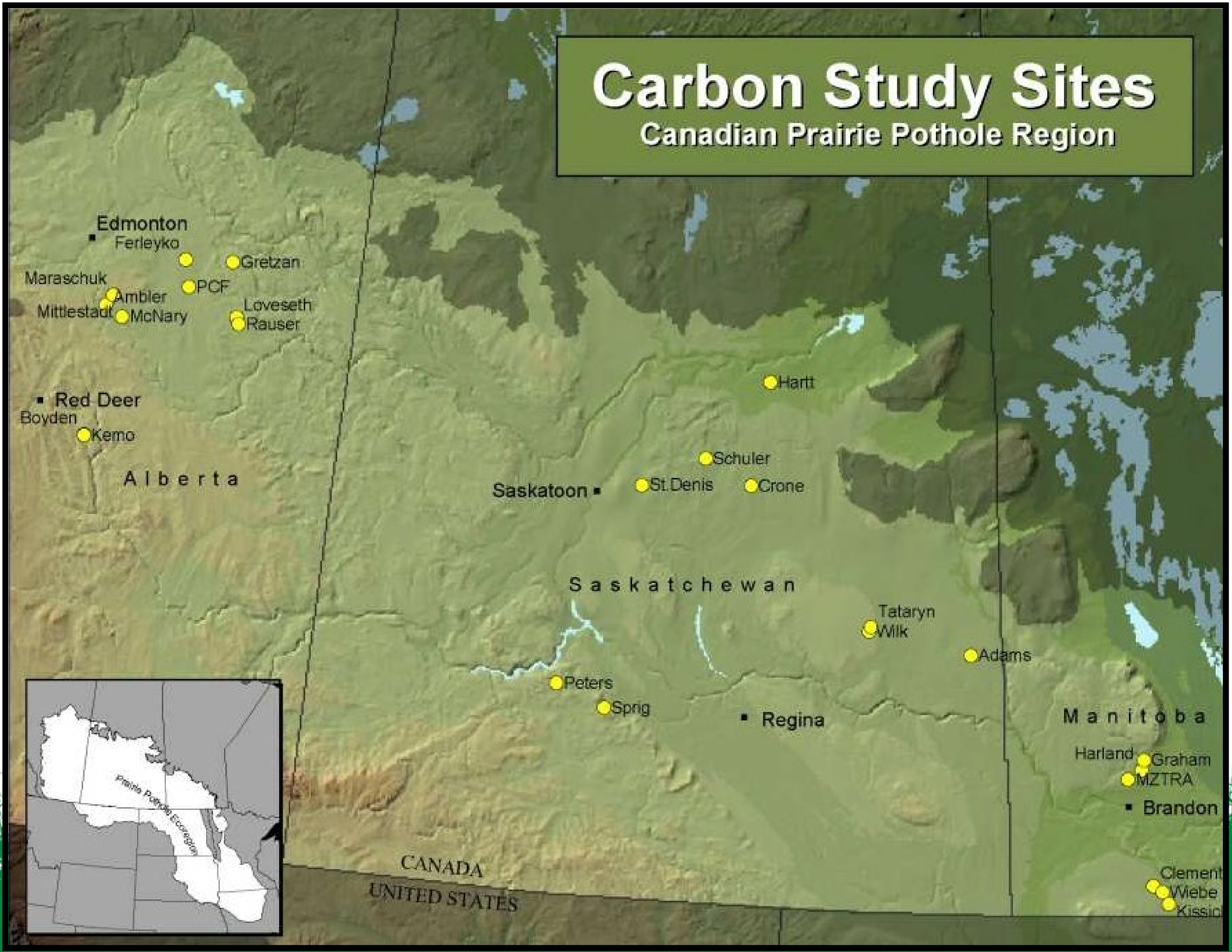


Figure 2. Mean wetland CH_4 emission zonal profiles: full ensemble mean (FE: red line) and corresponding range (pink area); extended ensemble mean (EE; black line) and corresponding range (grey area); GEOS-Chem emissions inventory (GC; dashed blue line); Bloom et al. (2012) emissions (BL; dashed orange line).

- DUC and partners monitored over 60 wetlands across the Canadian PPR (references sites and restored wetlands of various ages)
- Measured SOC, and GHG emissions (CO2, CH4, and N2O) across landscape transects from upland contributing areas to wetland centers



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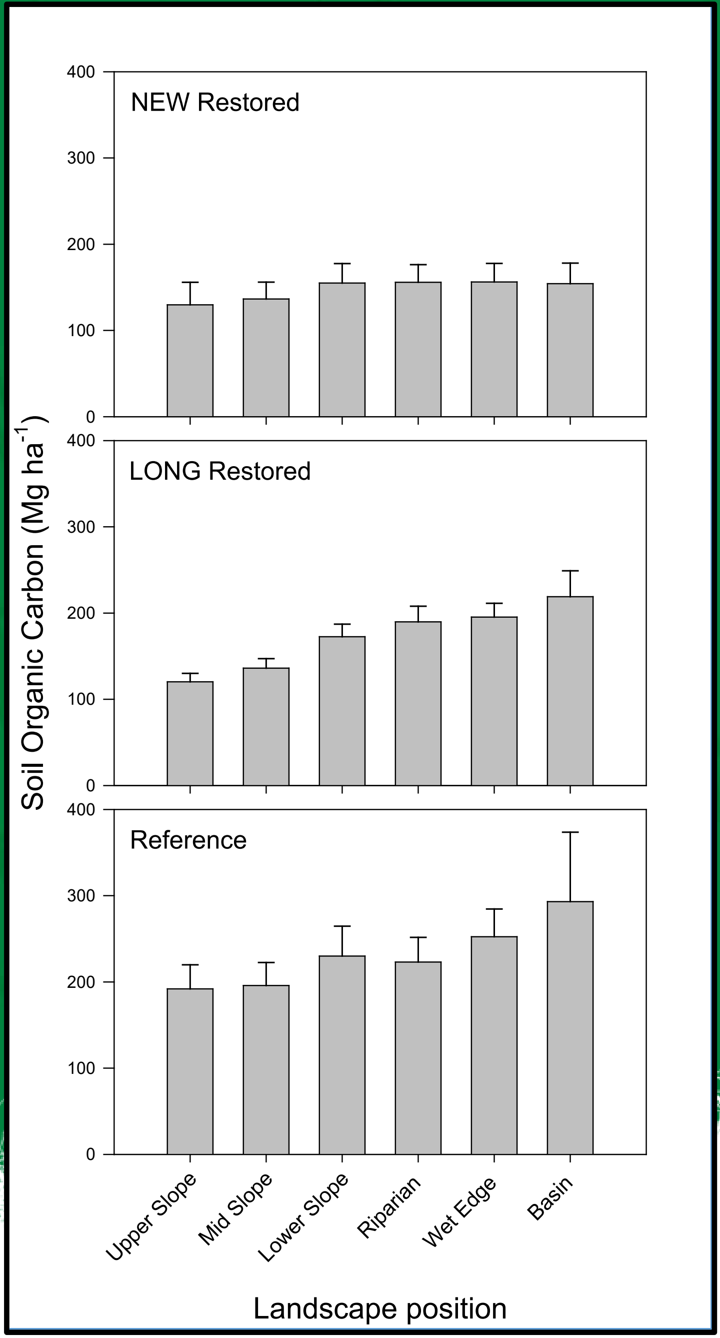
RESULTS

- Carbon stores were highest in intact wetlands and increased with restoration age and were significantly higher in wetlands relative to uplands
- Even after accounting for methane emissions, restoration predicted to sequester 3.25 tonnes of CO_2/ha/yr
- Wetland drainage results in a loss of 89 tonnes of SOC/ha
- Research is referenced in the *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*



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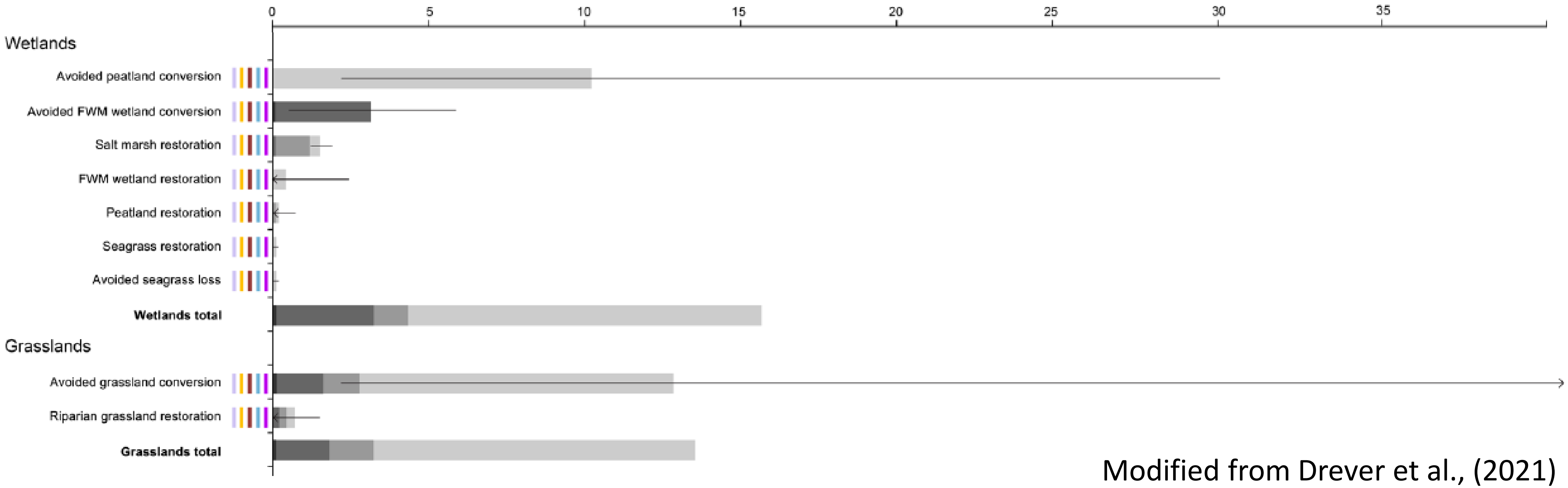
SCIENCE ADVANCES | RESEARCH ARTICLE

APPLIED ECOLOGY

Natural climate solutions for Canada



Modified from Drever et al., (2021)

Can we manage agricultural wetlands to help mitigate climate change?

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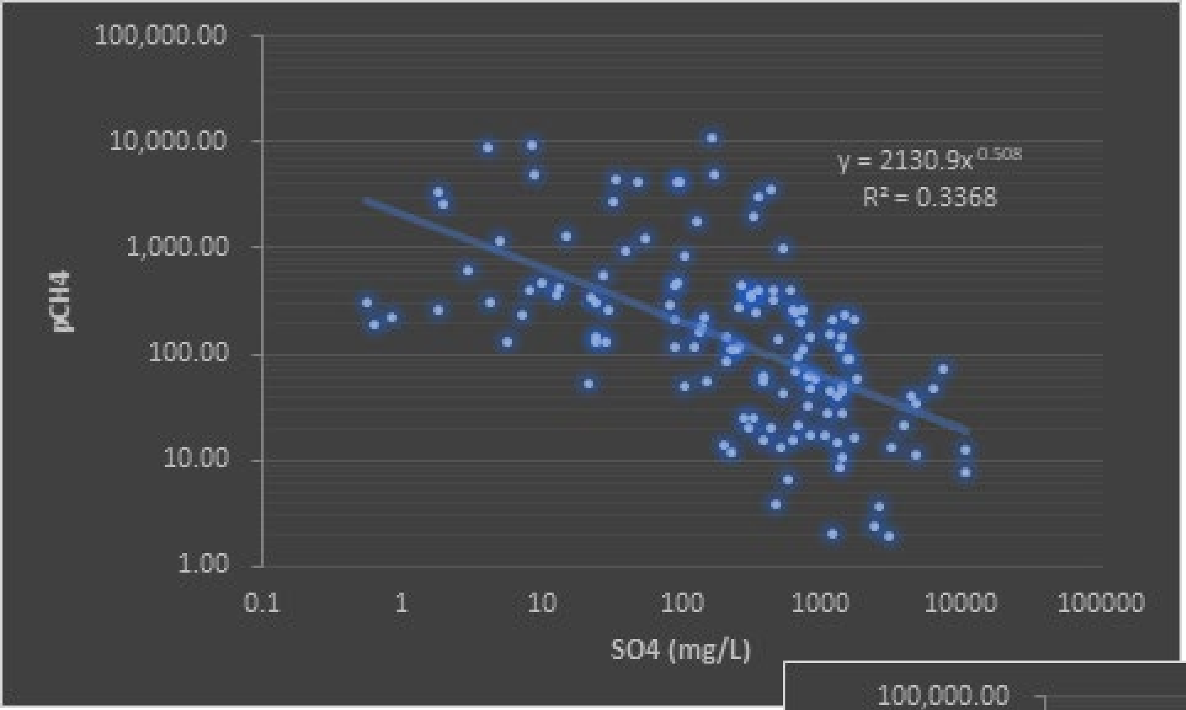
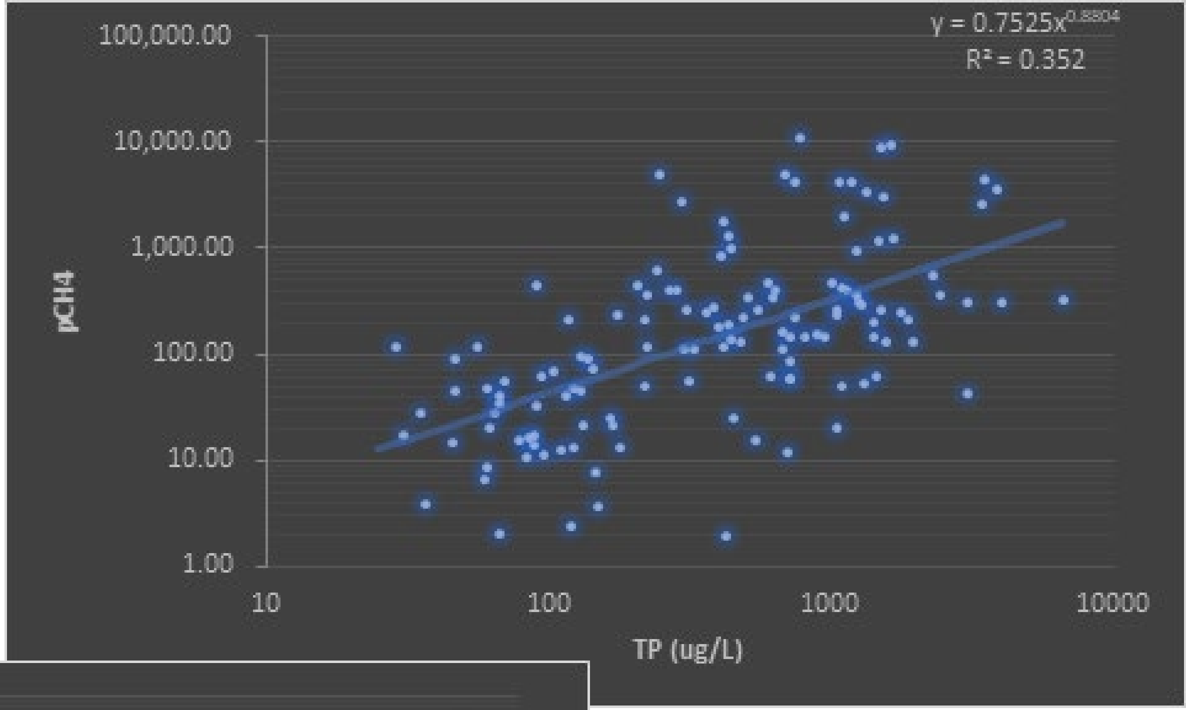
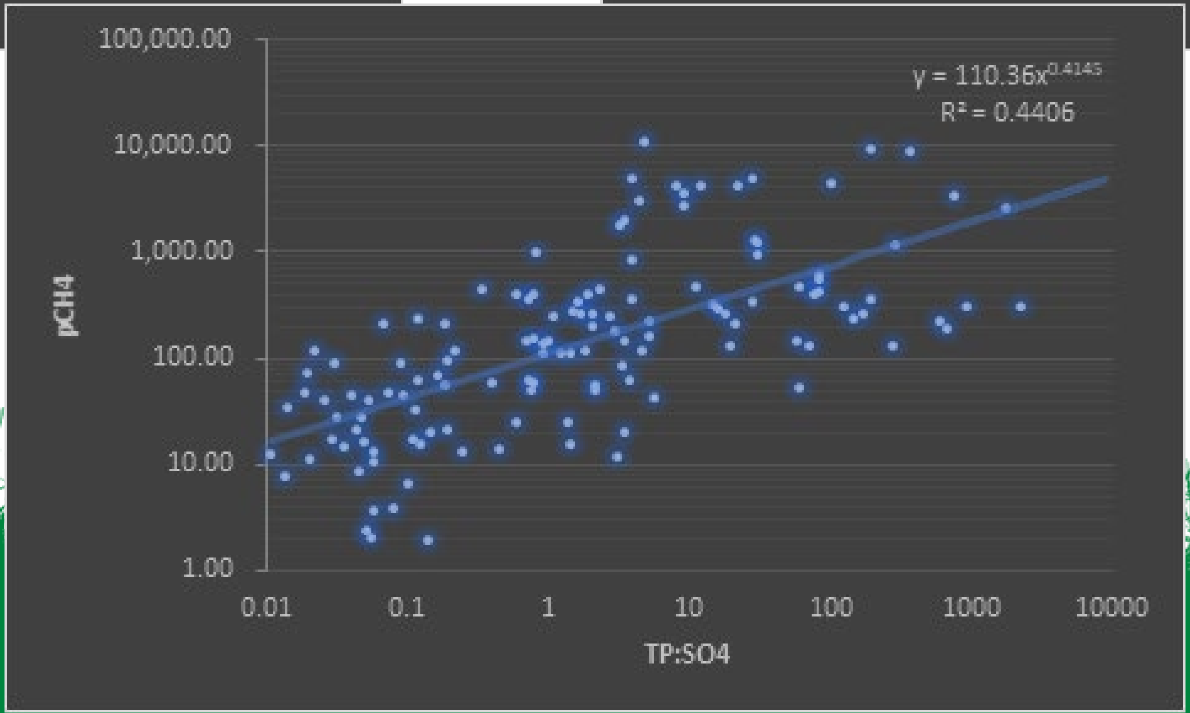




Relationships between water quality and pCH4 (across all sites n = 48)



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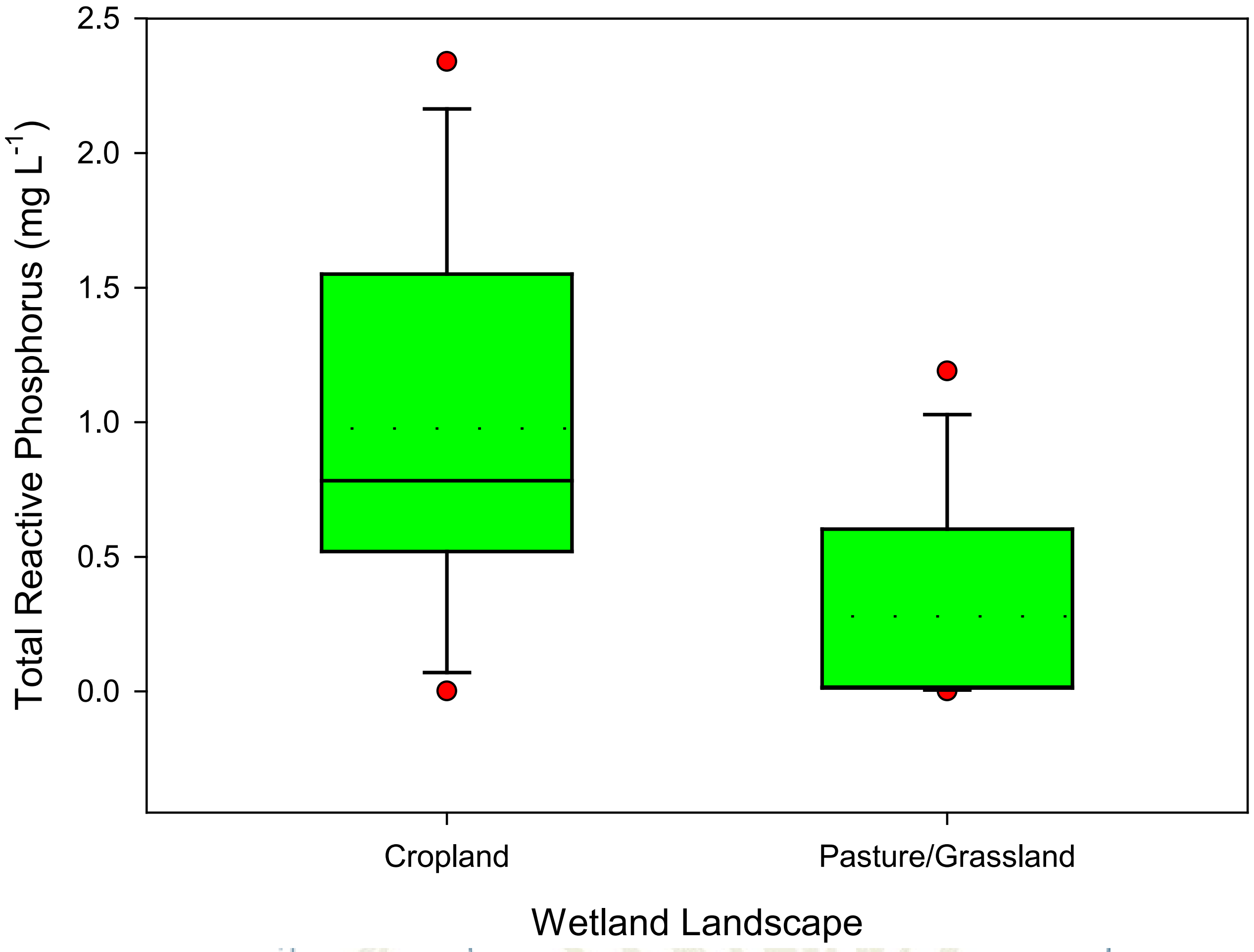
Survey (summer 2013) of wetlands embedded in cropland vs pasture/grassland

- 31 wetlands were sampled, cropland (n=17), pasture/grassland (n=14)
- Mean [P] in cropland wetlands (0.98 mg L^{-1}) were more than 3x those in grass/pasture wetlands (0.28 mg L^{-1})
- Median [P] in cropland wetlands (0.78 mg L^{-1}) were more than 40x higher than those in grass/pasture wetlands (0.02 mg L^{-1})



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Allied attack: climate change and eutrophication (Moss et al., 2011)

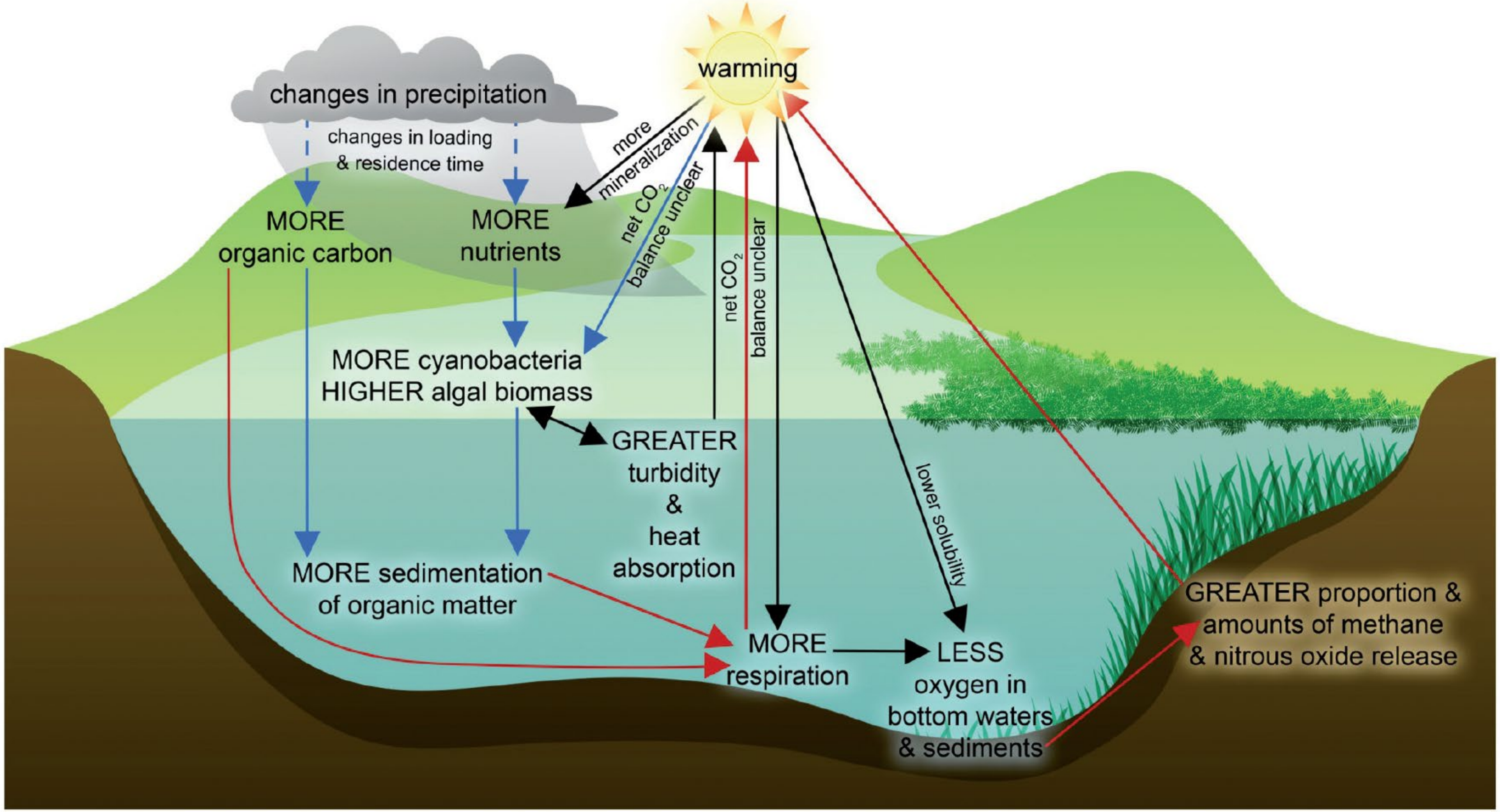

Fig. 2. Current indications of feedback effects of eutrophication on climate change. Blue arrows indicate carbon sequestration routes; red arrows indicate carbon emission routes; black arrows indicate other climate effects. Because CO_2 uptake and release may both increase with eutrophication, net CO_2 balance is unclear. The increase in methane and nitrous oxide is more probable. Dashed arrow indicates that changes in precipitation regimes may either lead to more or less organic carbon loading, depending on local and regional circumstances.

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Effects of cyanobacterial blooms on GHG fluxes

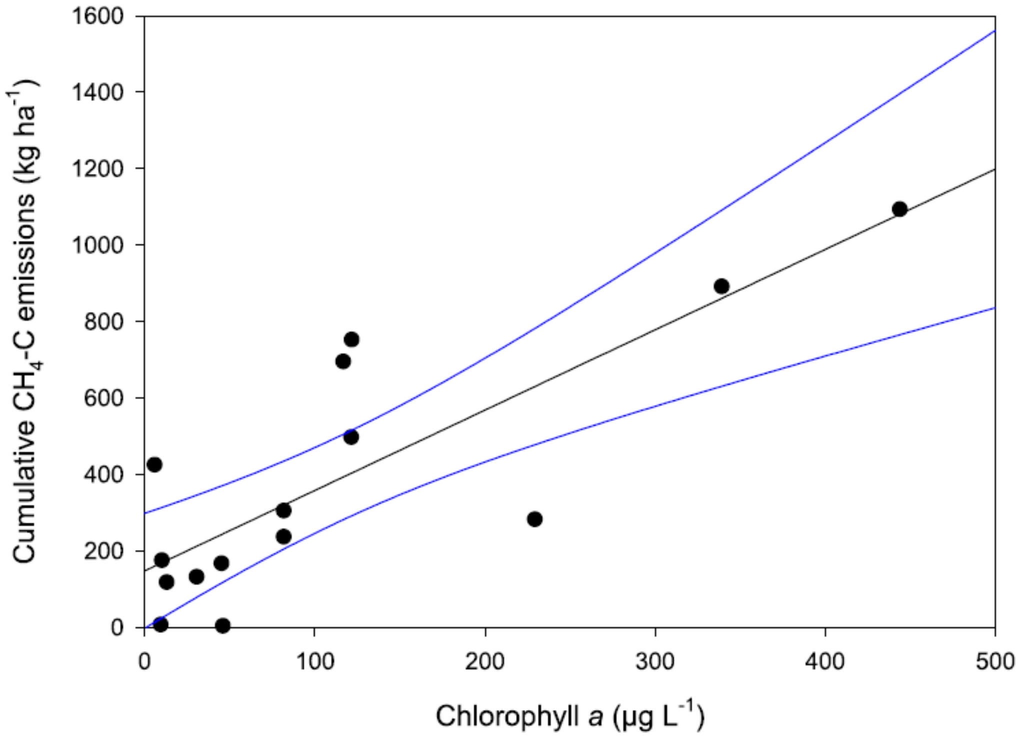

Fig. 5. Relationship between mean Chl-*a* concentrations and total basin cumulative CH_4 flux across all basin types with upper and lower 95% confidence limits.

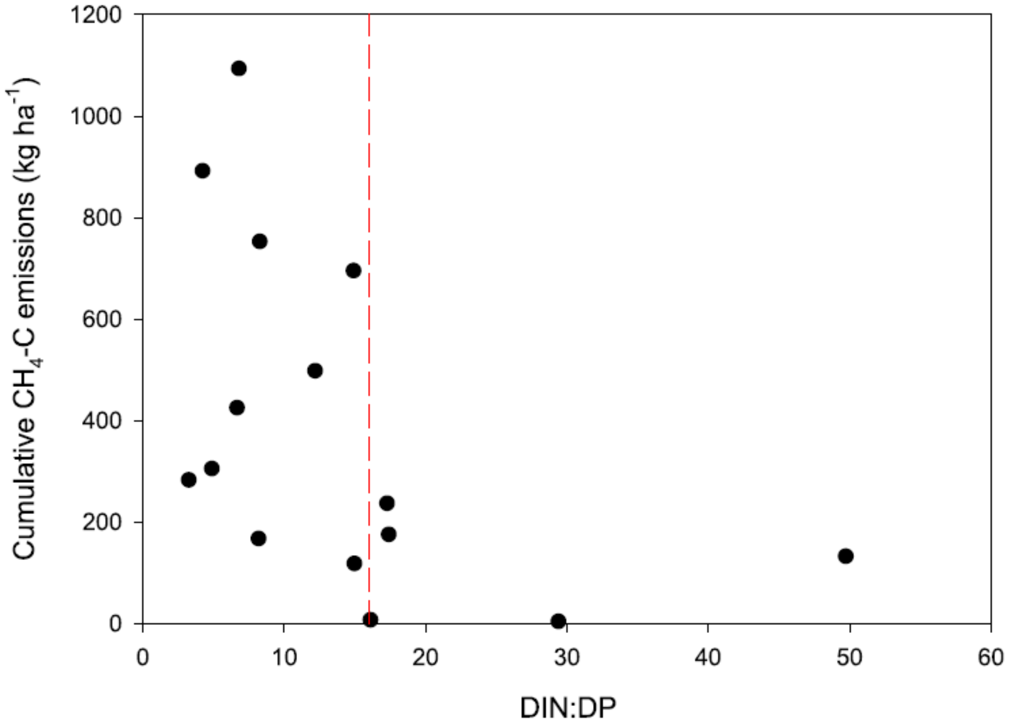

Fig. 6. DIN:DP ratios and total basin cumulative CH_4 flux across all basin types in relation to the Redfield Ratio of 16:1 which is show here as the red dashed line.

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How wetlands help buffer against the impacts of climate change

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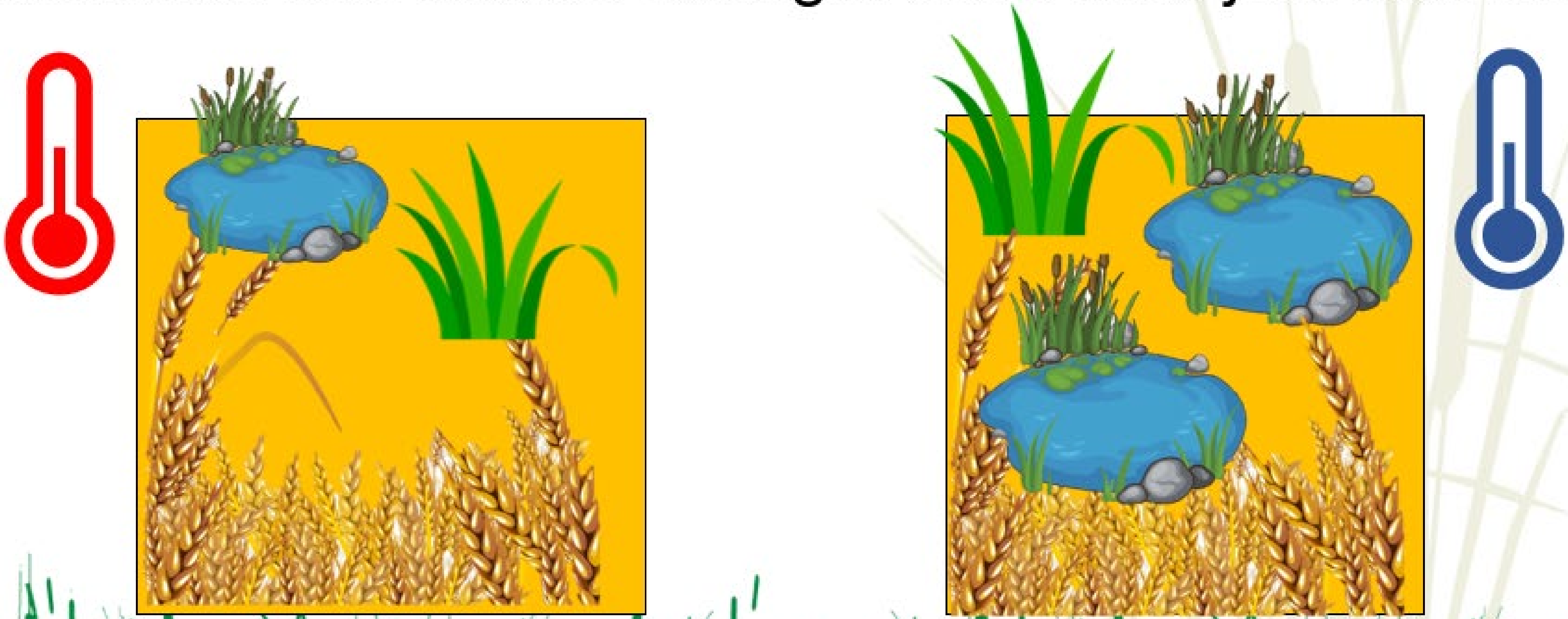
Wetlands and climate change: More than just carbon!



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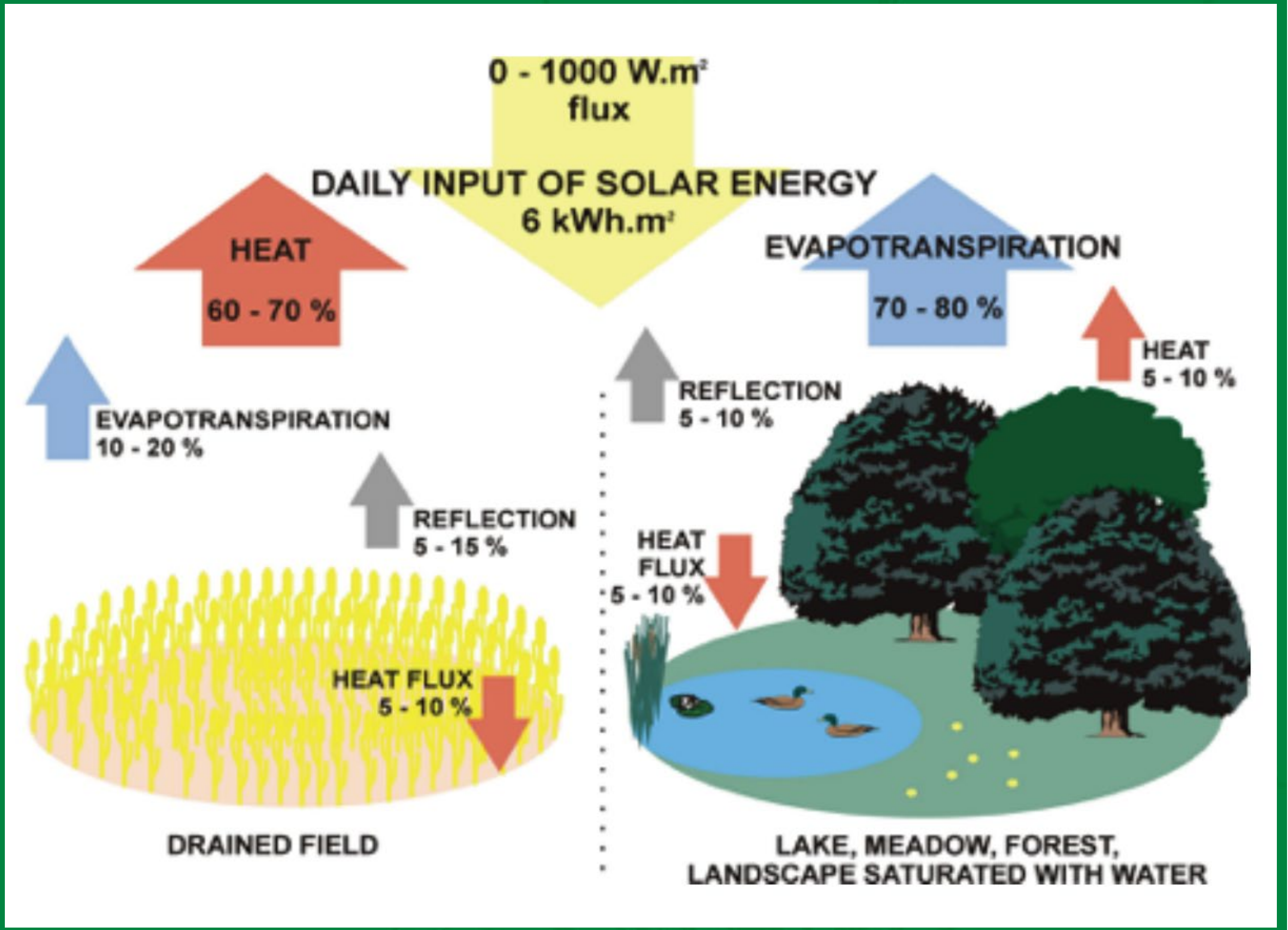
The dissipation of solar energy. A comparison of heat flows over a drained wheat field and a wetland.

Note the differences in solar energy transformation into sensible heat, reaching up to 60% to70% over a drained crop field compared to only 5% to10% over an intact wetland. In wetland landscapes, 70% to 80% of heat is dissipated via evapotranspiration (Pokorny et al., 2010).



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DECEMBER 1995 BONAN 2691

Sensitivity of a GCM Simulation to Inclusion of Inland Water Surfaces

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National Center for Atmospheric Research, Boulder, Colorado*

(Manuscript received 19 August 1994, in final form 10 April 1995)

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 108, NO. D16, 4520, doi:10.1029/2002JD002597, 2003

Impact of lakes and wetlands on boreal climate

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Received 31 May 2002; revised 22 October 2002; accepted 21 March 2003; published 28 August 2003.

VOLUME 11 JOURNAL OF HYDROMETEOROLOGY OCTOBER 2010

Parameterization of Lakes and Wetlands for Energy and Water Balance Studies in the Great Lakes Region*

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(Manuscript received 25 August 2009, in final form 28 April 2010)

The importance of accounting for cooling/humidifying effect of wetlands is well documented in the literature

Models generally find that wetlands:

- Increase regional evapotranspiration
- Increase regional latent heat flux
- Decrease sensible heat flux
- Produce summer cooling (July) of 2-3°C
- Potential to alter regional precipitation patterns

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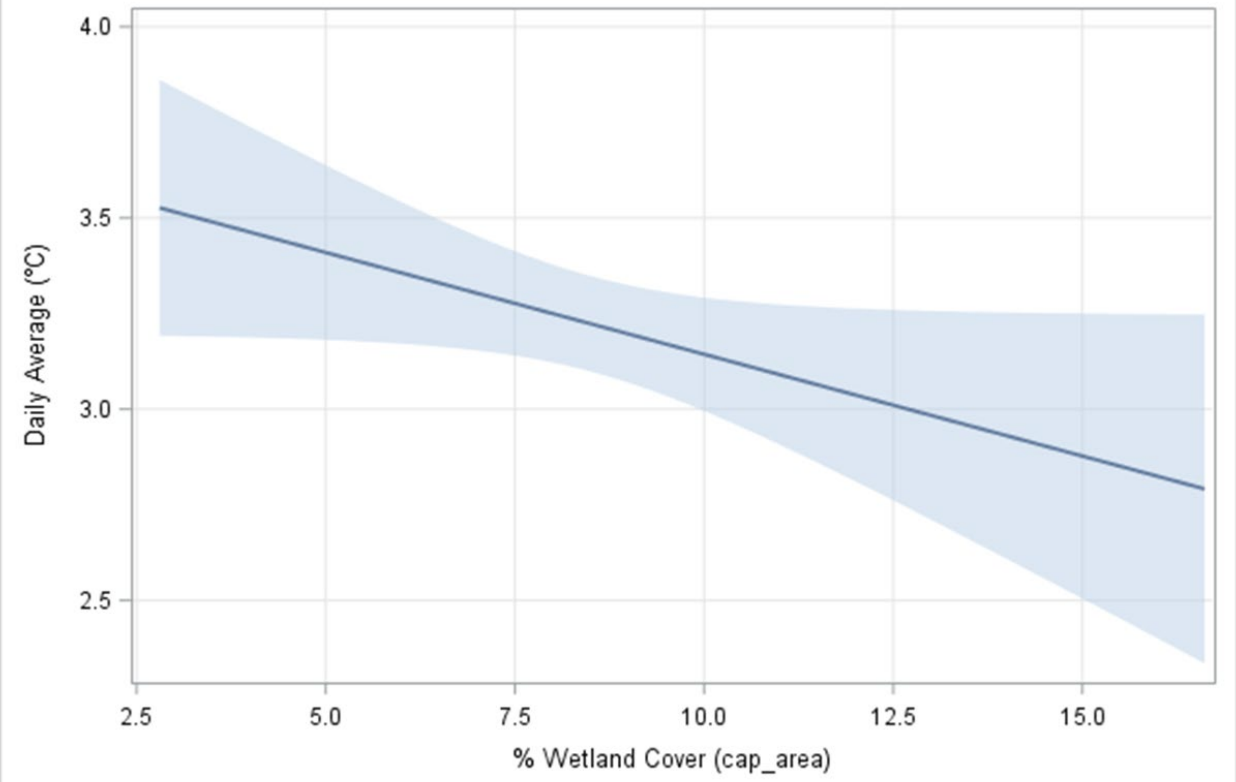

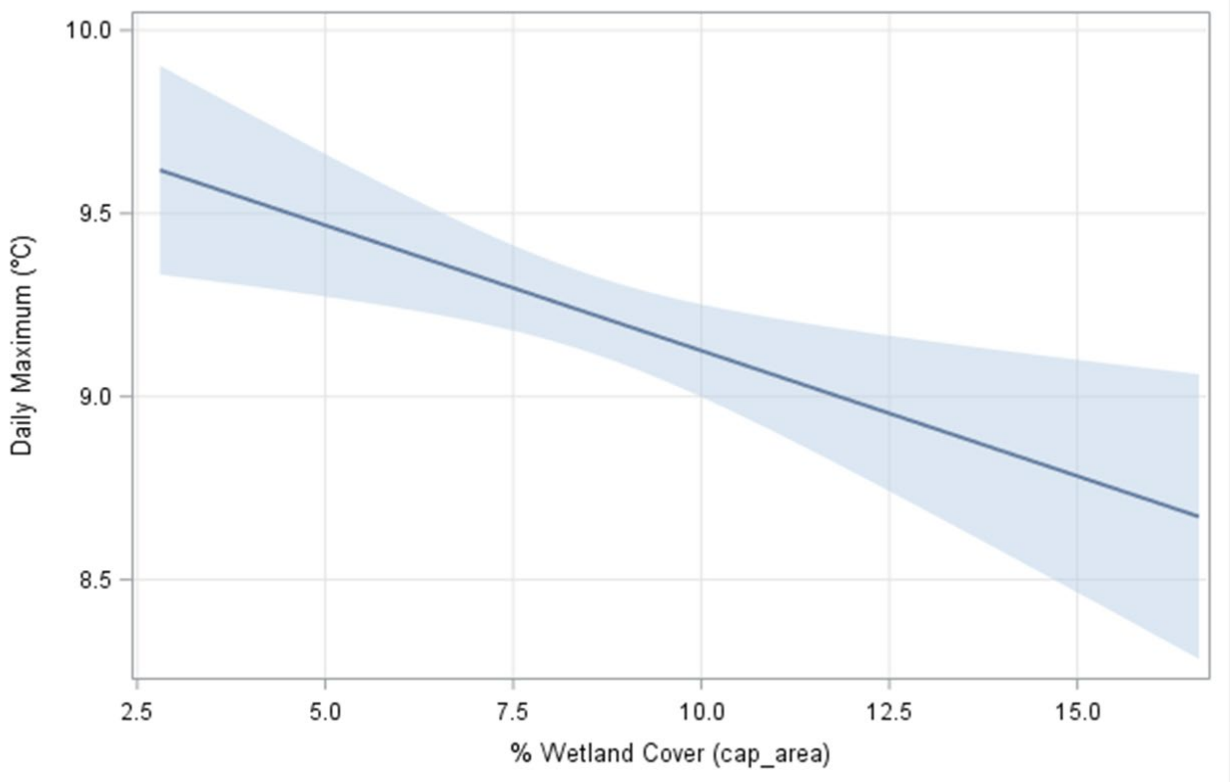

Relationship between Daily Average Temp and Daily Maximum Temp and wetland cover for 64 climate stations spanning the PPR

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Key take aways:

- **Wetlands are very productive systems and globally significant carbon stores – including freshwater mineral soil wetlands**
- **Conversion of wetlands releases significant amounts of carbon to the atmosphere**
- **Restored wetlands can sequester significant amounts of carbon from the atmosphere**
- **Wetlands can help mitigate climate change via other mechanisms such as influencing surface energy budgets and other ecosystem co-benefits**

Questions?

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