Environmental impacts of cropped depressional wetlands

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Outline

1. Environmental context of depressional wetlands in the southern Prairie Pothole Region (Des Moines Lobe)
2. Comparison of environmental impacts and benefits between cropped depressions and restored CREP wetlands
3. Next steps for science and management of these systems

Prairie Pothole Region

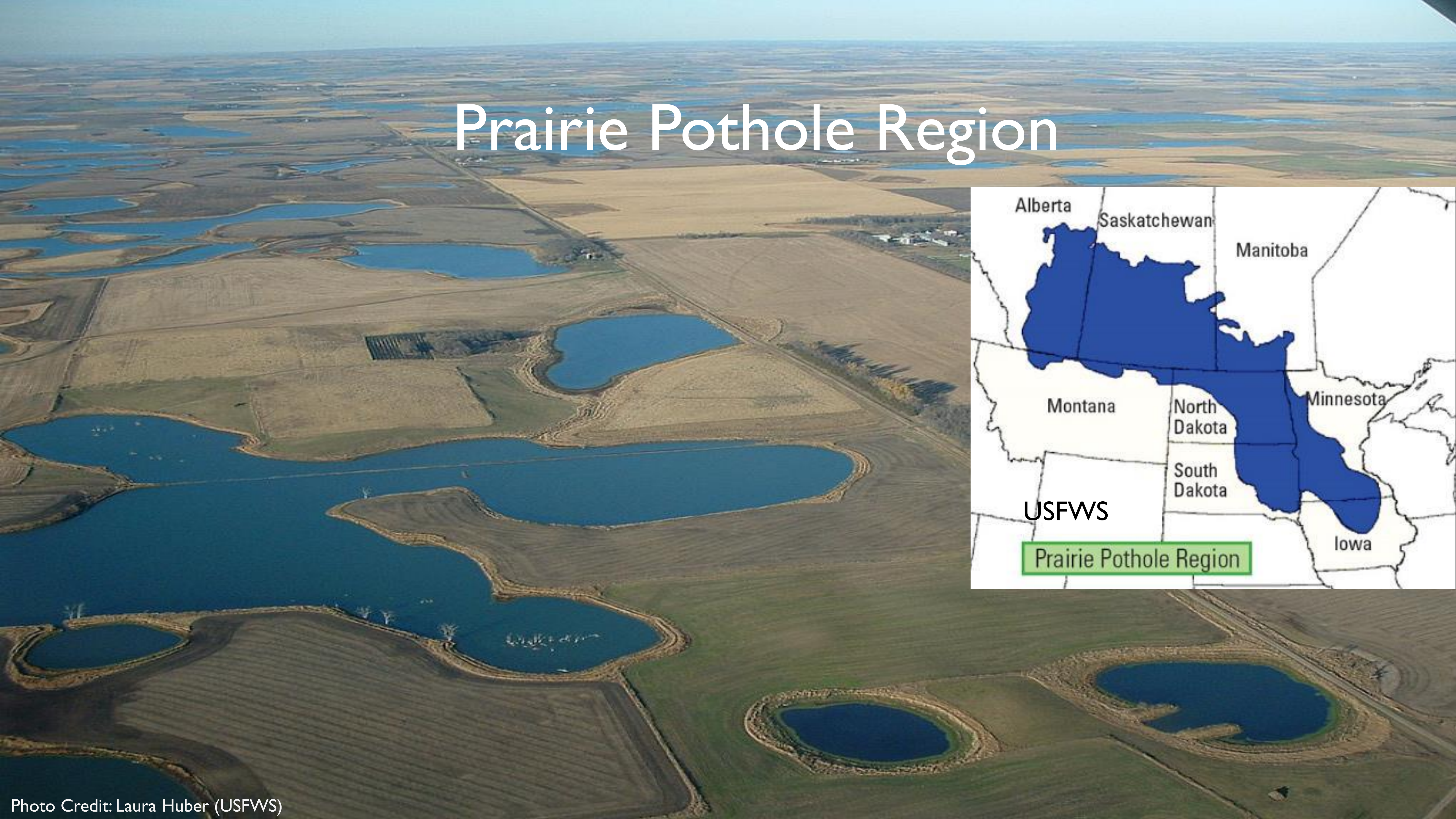

Photo Credit: Laura Huber (USFWS)

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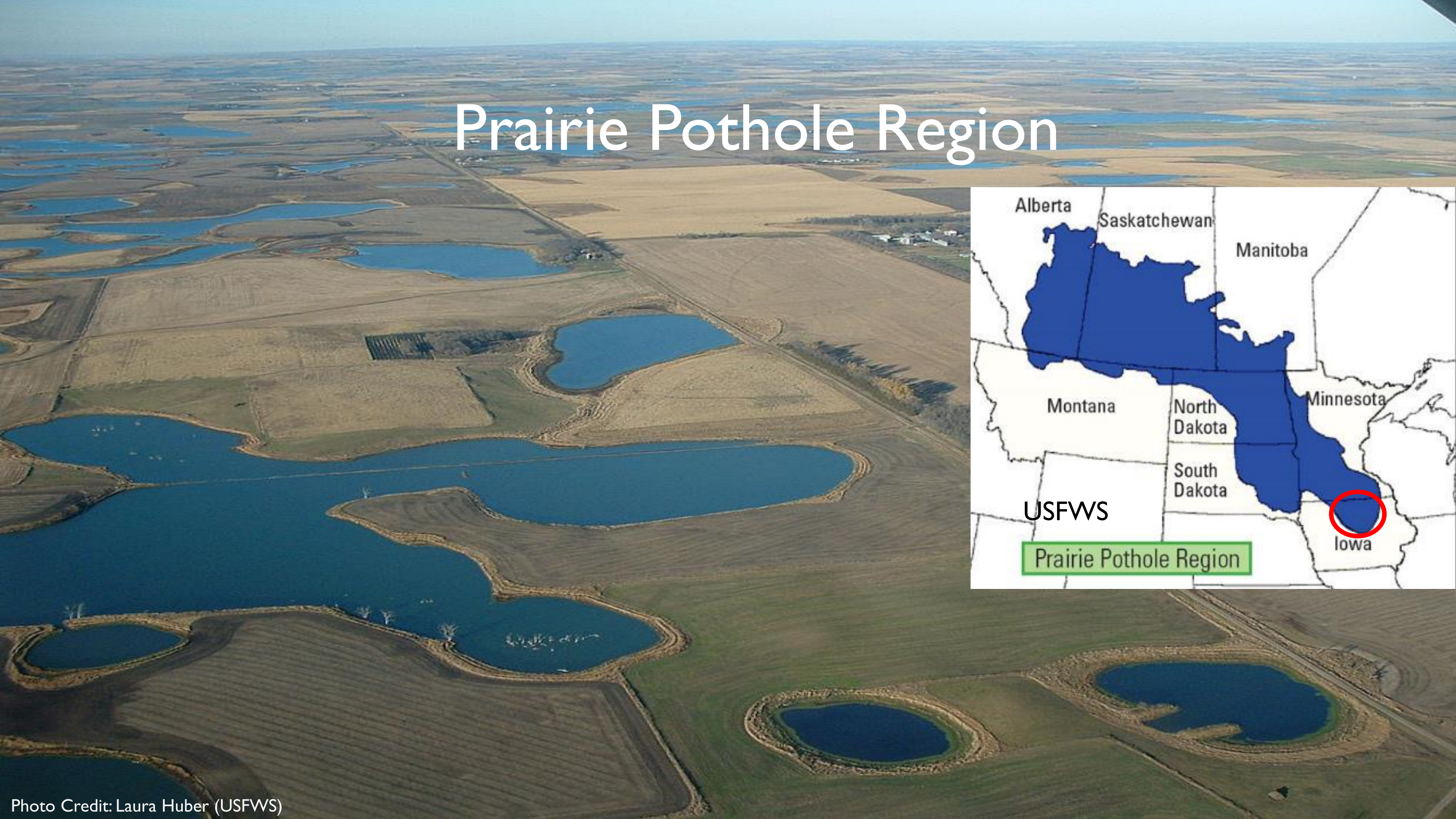
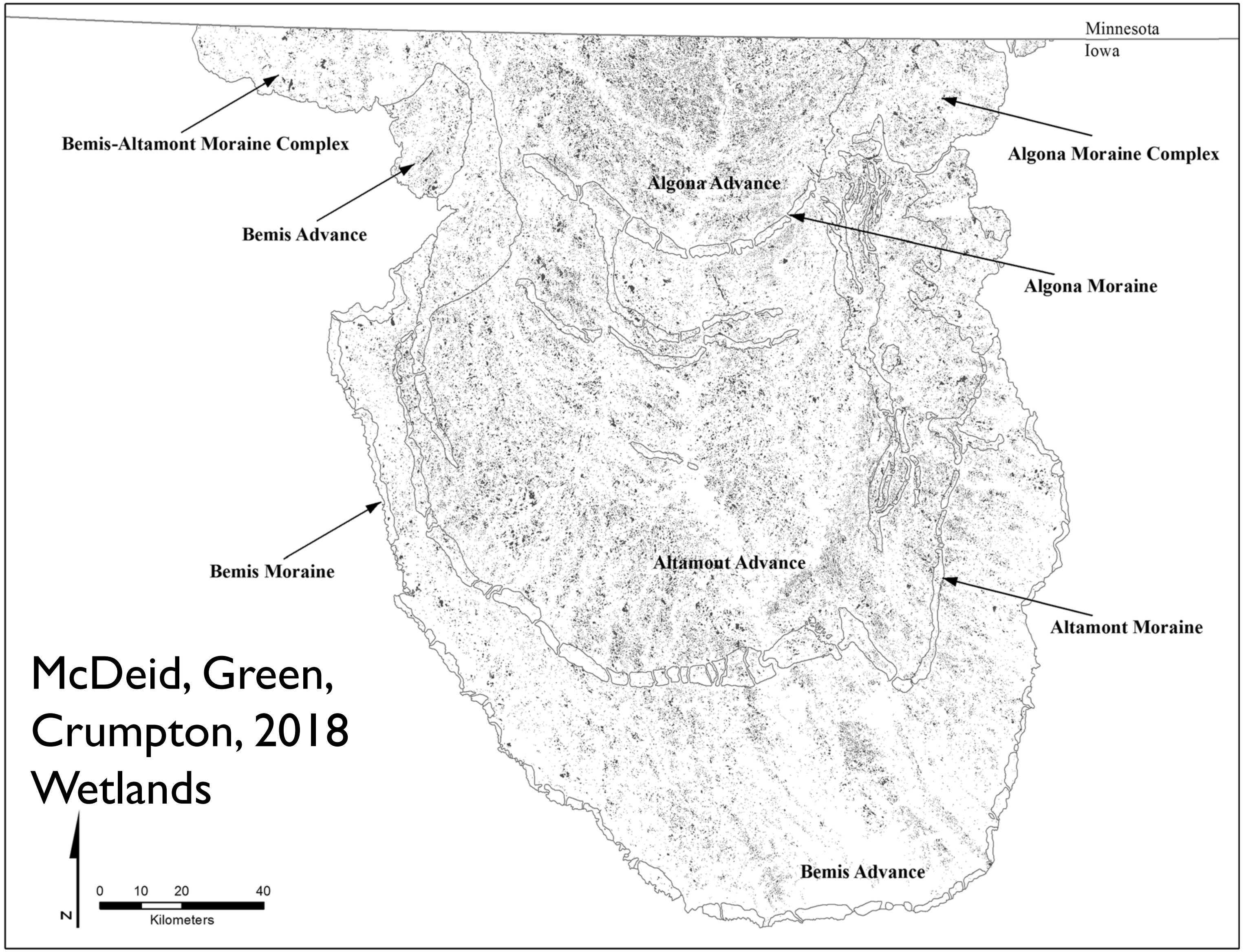


Photo Credit: Laura Huber (USFWS)

Intact depressions comprise 8.6% of the Des Moines Lobe land area

These depressions are typically smaller than one hectare, but may reach several hundred hectares in size



McDeid, Green, Crumpton, 2018 Wetlands

Q: What is the dominant present land use in pothole depressions on the Des Moines Lobe of Iowa?

a) Conservation Reserve Program (CRP) vegetation
b) Natural wetland vegetation / open water
c) Grain crop production
d) Grazing / forage production

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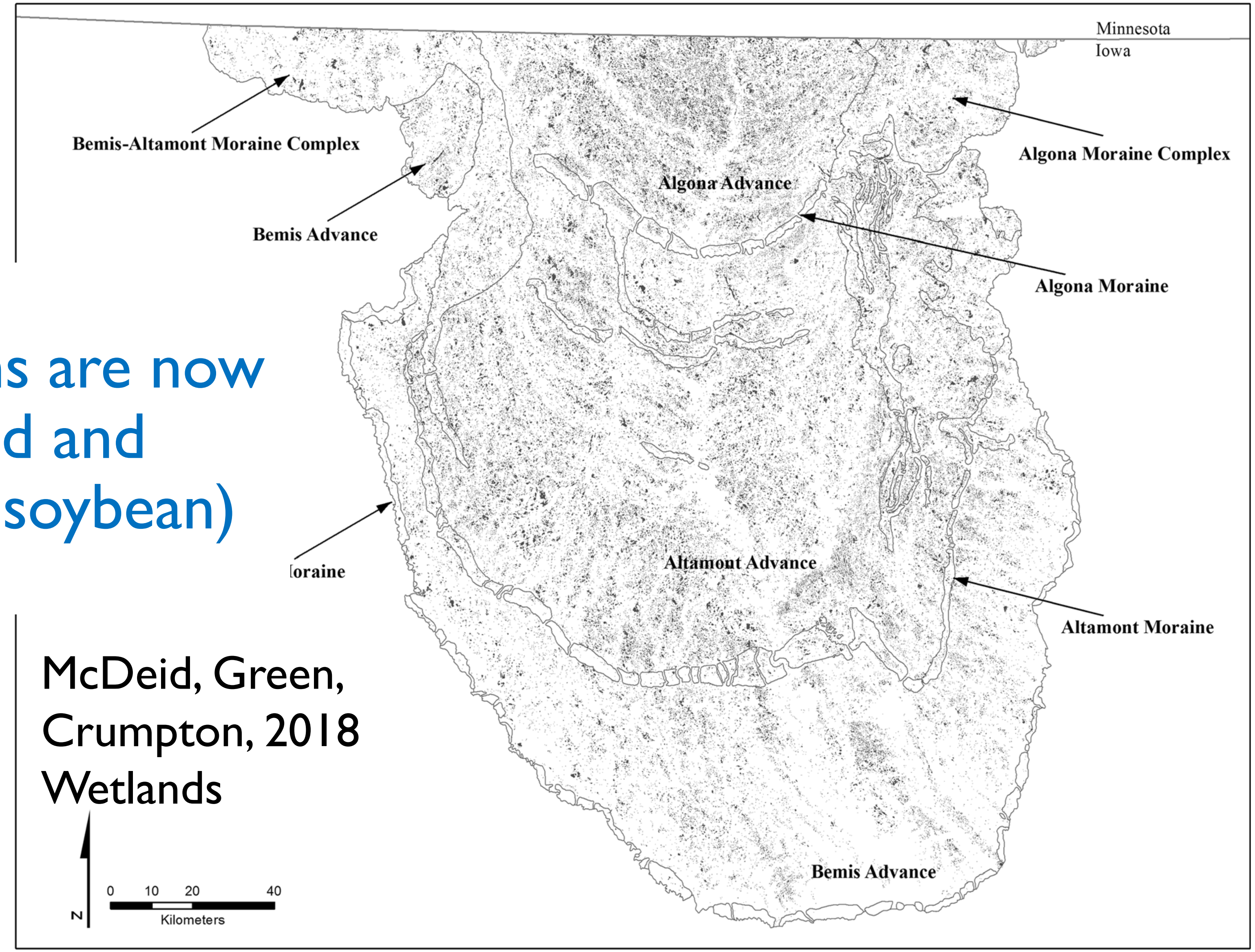


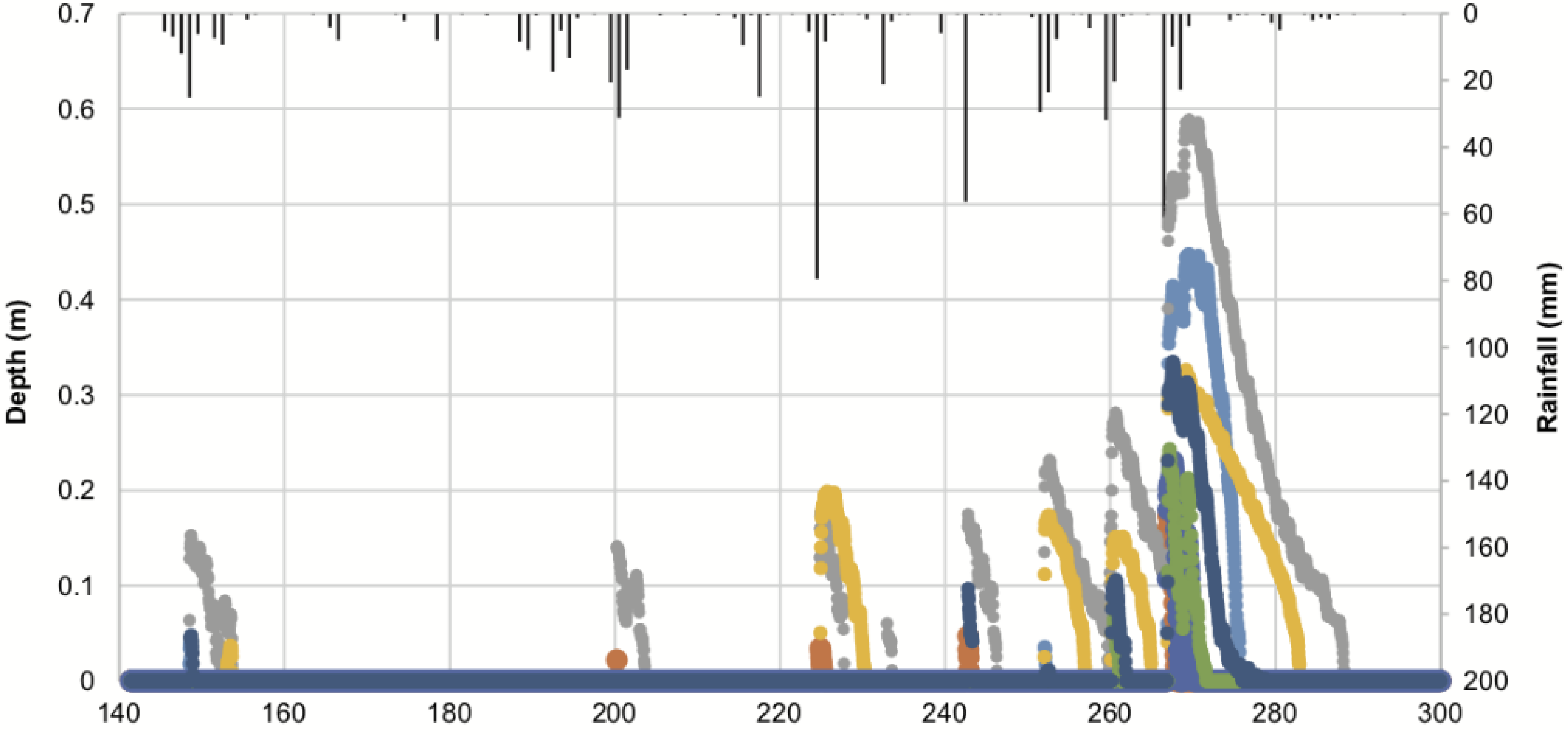
Most depressions are now (partially) drained and cropped (corn / soybean)

McDeid, Green, Crumpton, 2018 Wetlands

Periodic inundation drives widespread crop mortality in these farmed depressions

McDeid, Green, Crumpton 2018, Wetlands

Cropped depressions have flashy hydroperiods



Day of year 2016

Martin, Kaleita, Soupir, 2019
ASABE

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- Evaluate ***nitrate leaching*** and ***greenhouse gas emissions***
- How do these vary among cropped depressions, cropped uplands, and restored wetlands designed for nitrate removal?
- Combine new in-field measurements with long-term monitoring from CREP wetlands

Impacts of agricultural nitrogen losses on human health and the environment

- **Nitrate**:
  - A mobile form of nitrogen that readily leaches from agricultural soils to ground and surface water
  - Causes significant public health impacts when present in drinking water at elevated concentrations
  - Primary driver of the hypoxic "dead zone" in the Gulf of Mexico

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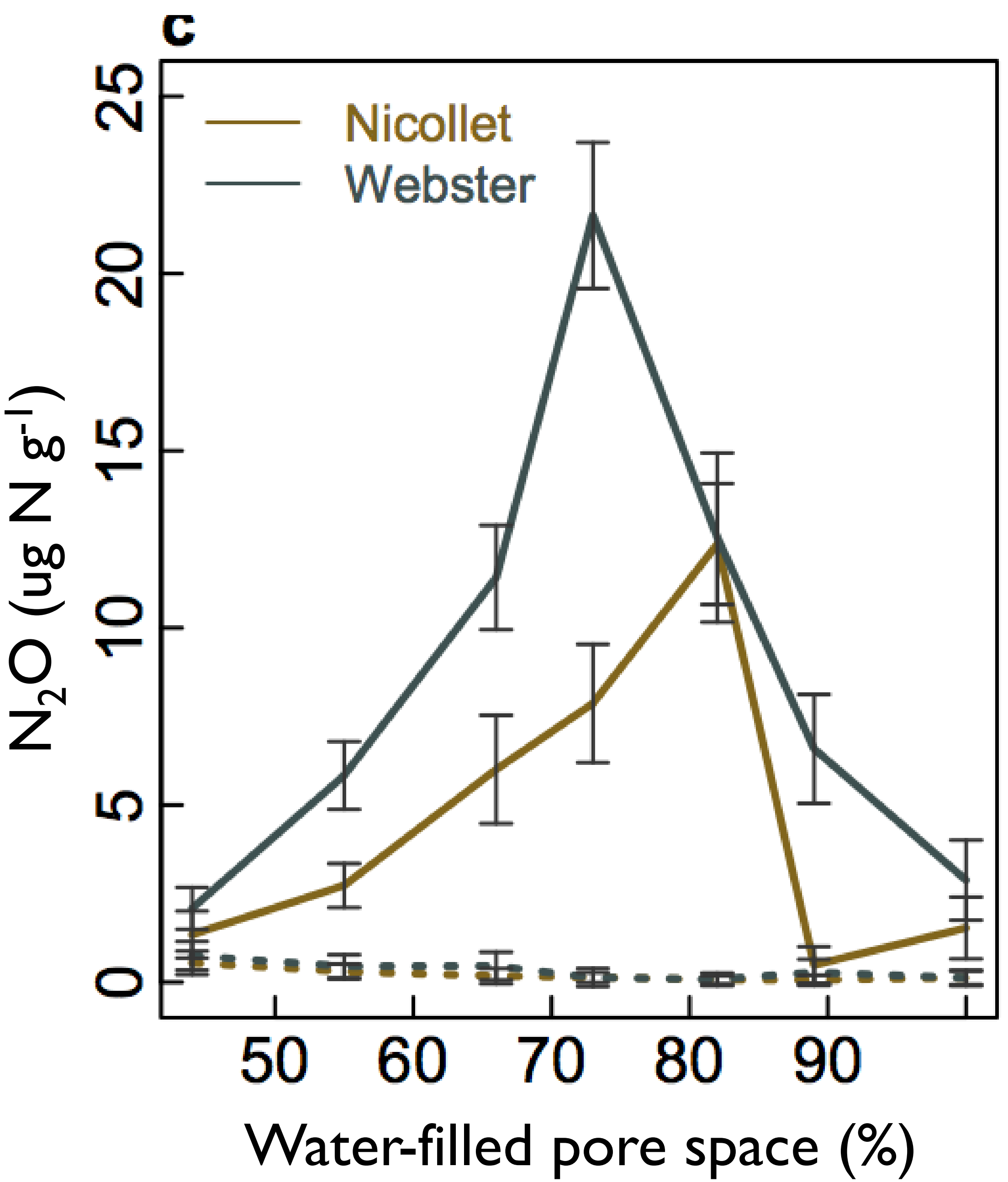
- **Nitrous oxide**:
  - A potent greenhouse gas produced by naturally occurring soil microbes, especially where nitrogen is abundant
  - Leading driver of stratospheric ozone loss

Q: What is the single largest current climate-change impact from Corn Belt agriculture?

a) Soil carbon loss
b) Fuel use for field operations
c) Energy use for nitrogen fertilizer production
d) Nitrous oxide emissions from soil and water

N_2O production is typically greatest when soil is wet, but not saturated

- Wet upland soils and intermittently flooded depressions may both produce significant N_2O
- Consistently flooded wetlands are smaller N_2O sources relative to their nitrogen inputs

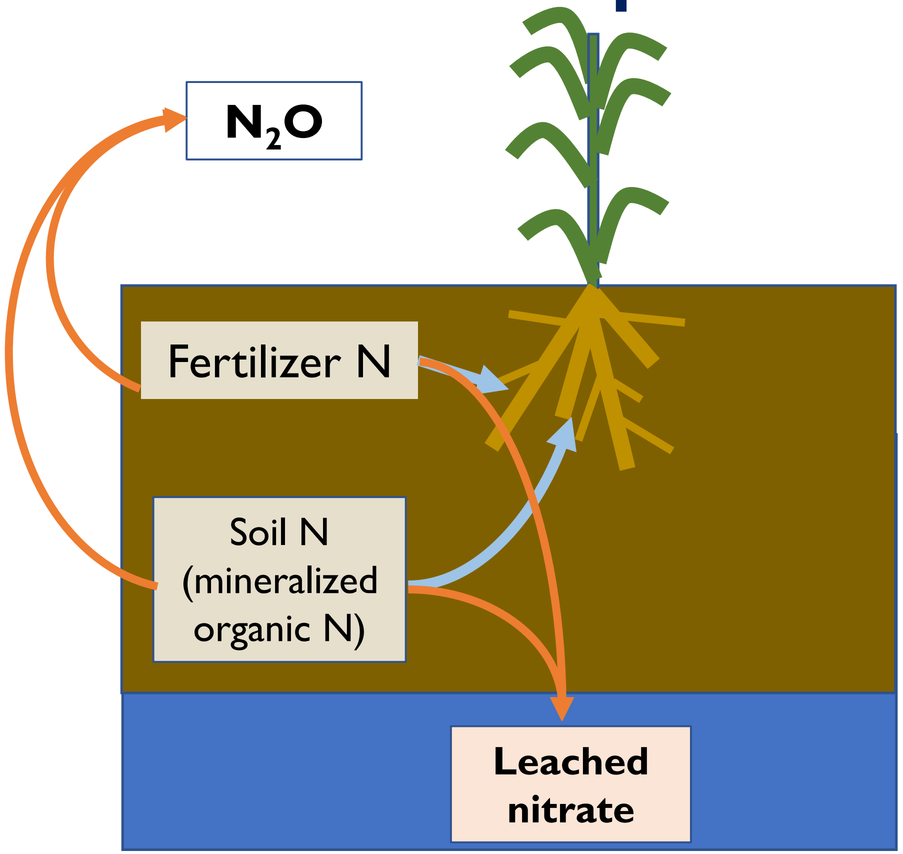


Hall et al. 2018, JGR-Biogeosciences

Compare N losses between cropped uplands and depressions

- Measurements spanned multiple depression/upland transects (100 – 150 m)
  - 9 transects for nitrate and 5 transects for N_2O
- Approximately weekly measurements of greenhouse gases from May 2018 – 2019
  - 10 plots per transect (1400 total measurements from 50 plots)
- Installation of buried resin lysimeters to measure cumulative nitrate leaching
  - 30 plots per transect (270 total measurements)

Nitrogen loss scenarios for cropped uplands and depressions



Uplands: adequate drainage promotes nitrate leaching and episodic N_2O production

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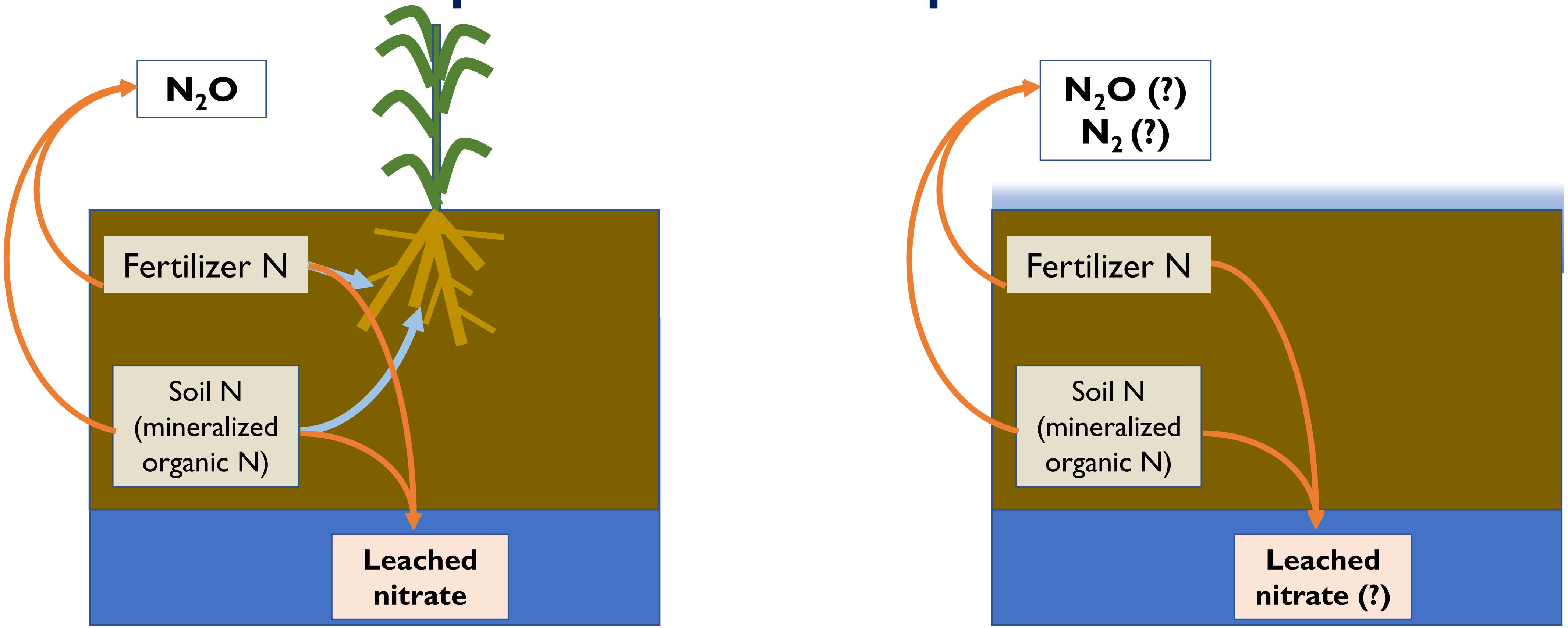
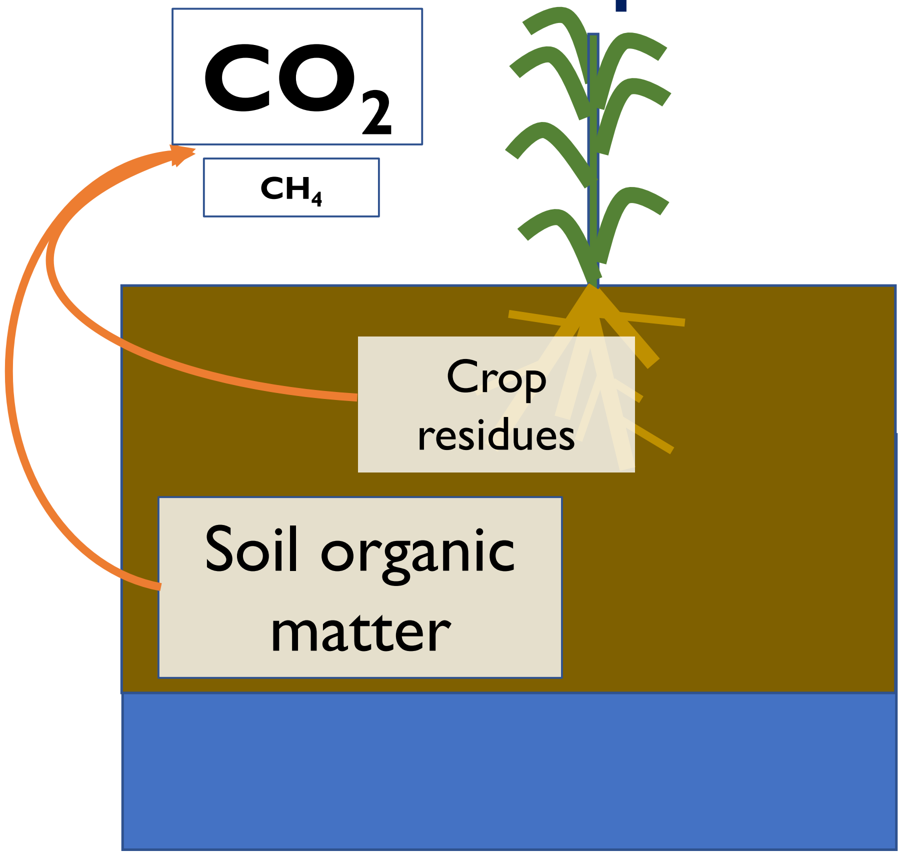


Uplands: adequate drainage promotes nitrate leaching and episodic N_2O production

Depressions: episodic ponding may promote denitrification to N_2, but significant N_2O and nitrate losses are possible

Methane emission scenarios for cropped uplands and depressions



Uplands: Net CH_4 release should be negligible

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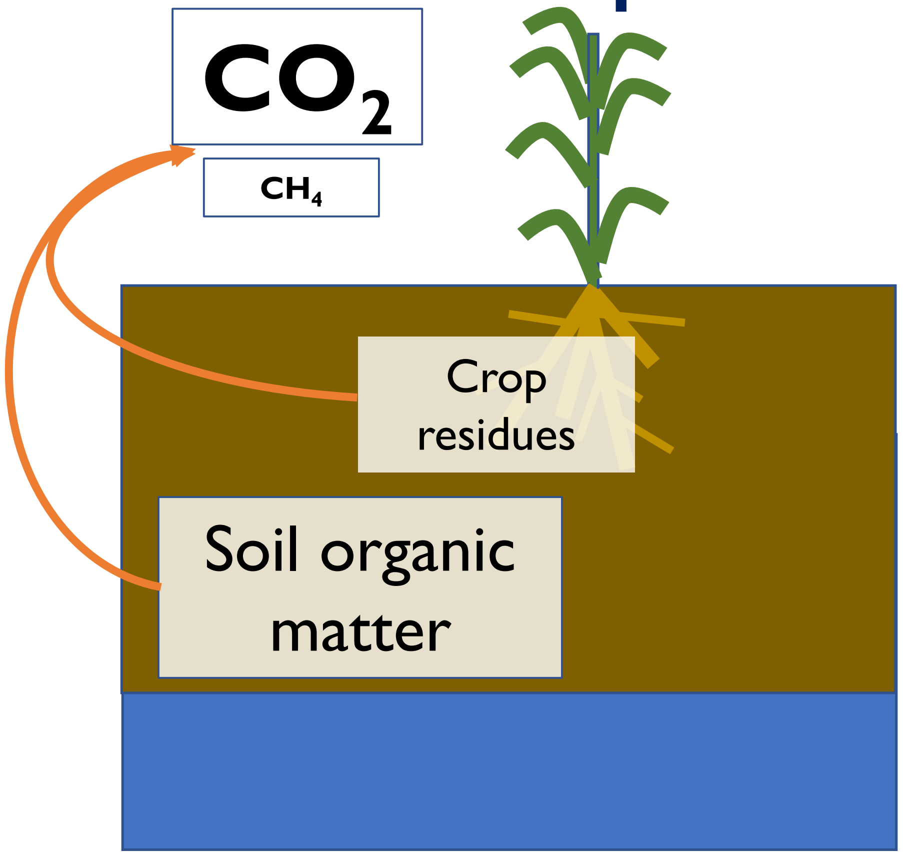
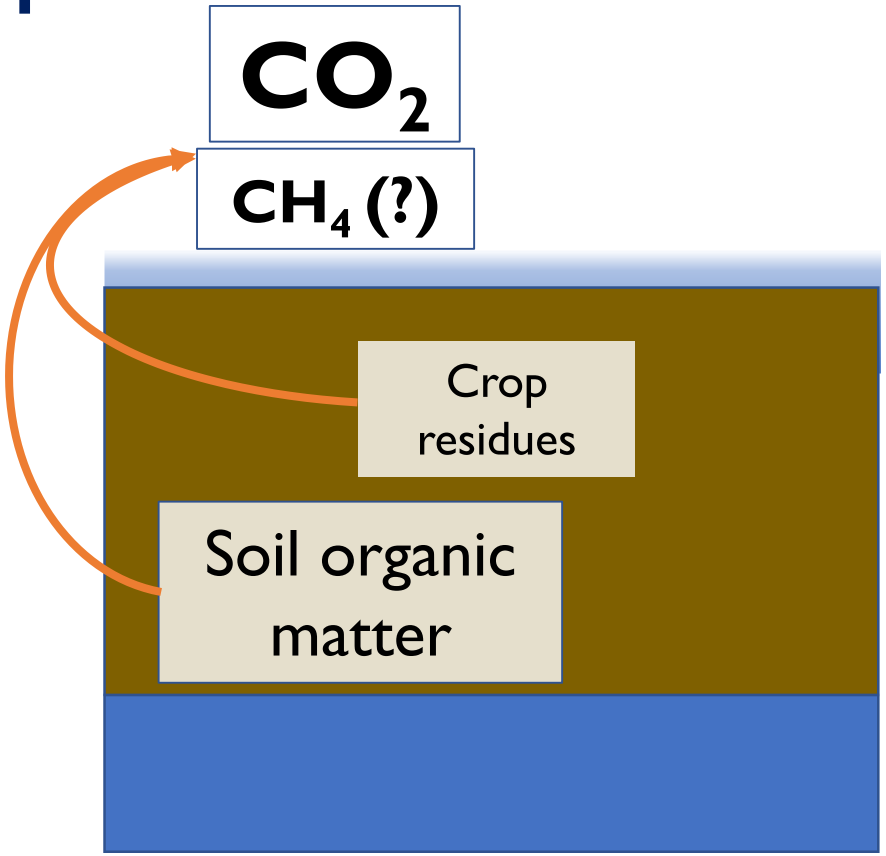
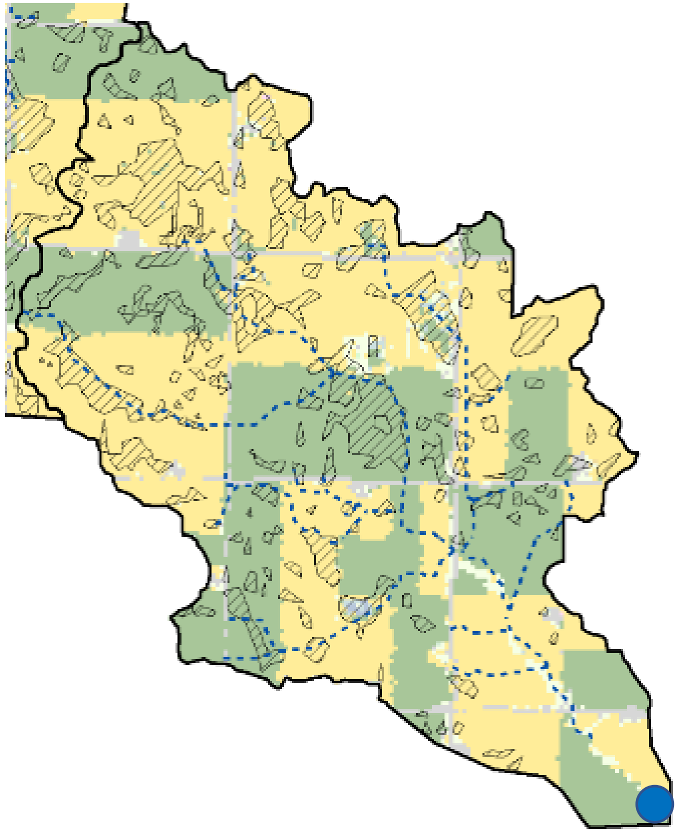




Uplands: Net CH_4 release should be negligible

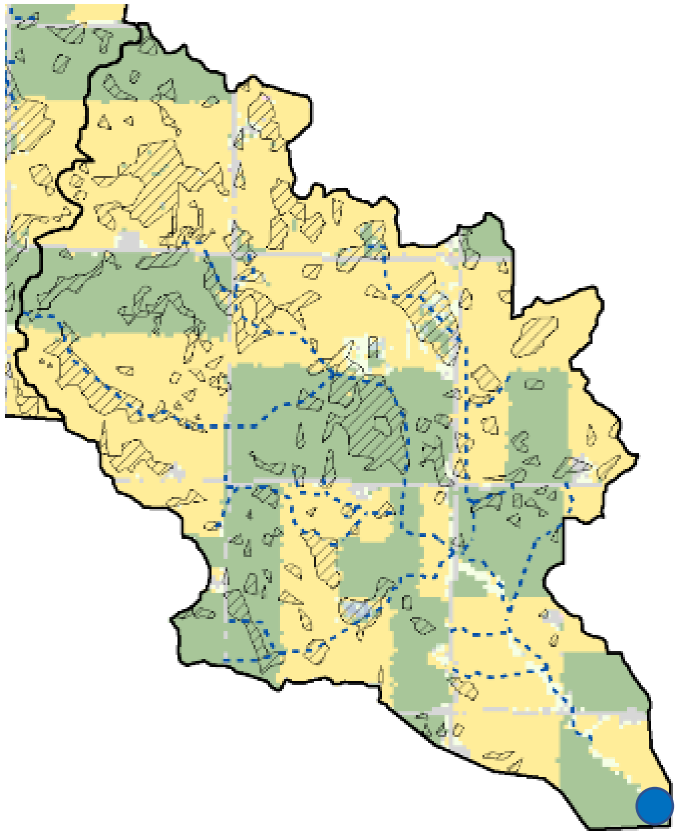
Depressions: Net CH_4 emissions could be substantial

Conservation Reserve Enhancement Program (CREP) wetlands



Conservation Reserve Enhancement Program (CREP) wetlands

- Located at the outlet of agricultural catchments where tile mains discharge to surface water
- Designed to maintain shallow ponding under typical conditions
- Effective for nitrate removal via denitrification to N_2



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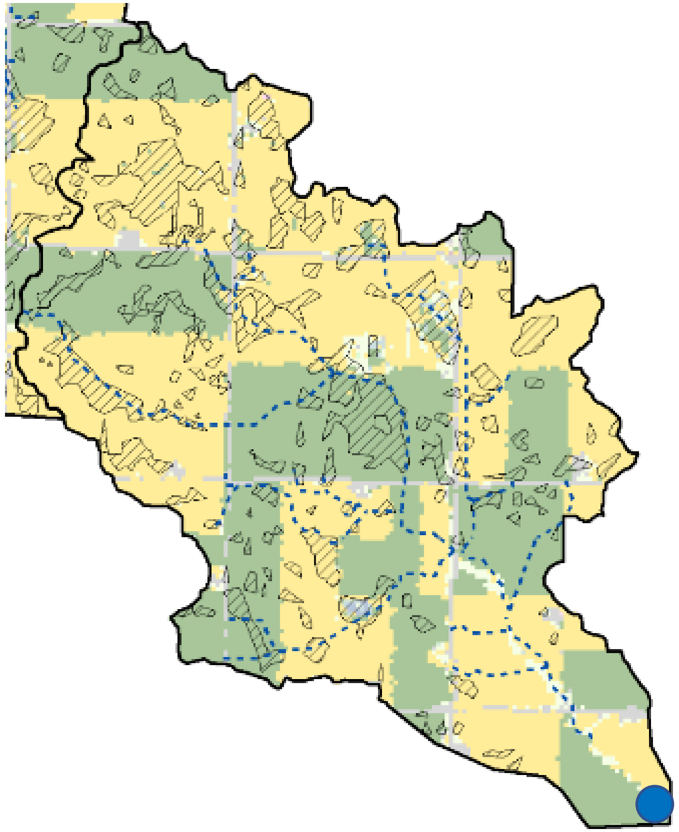
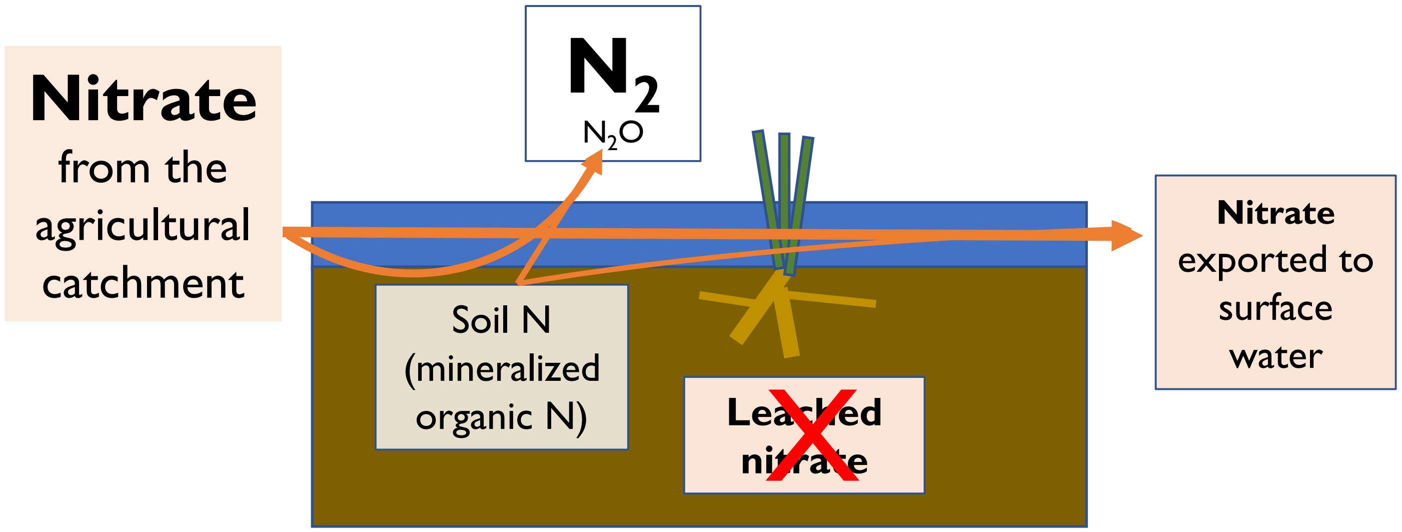
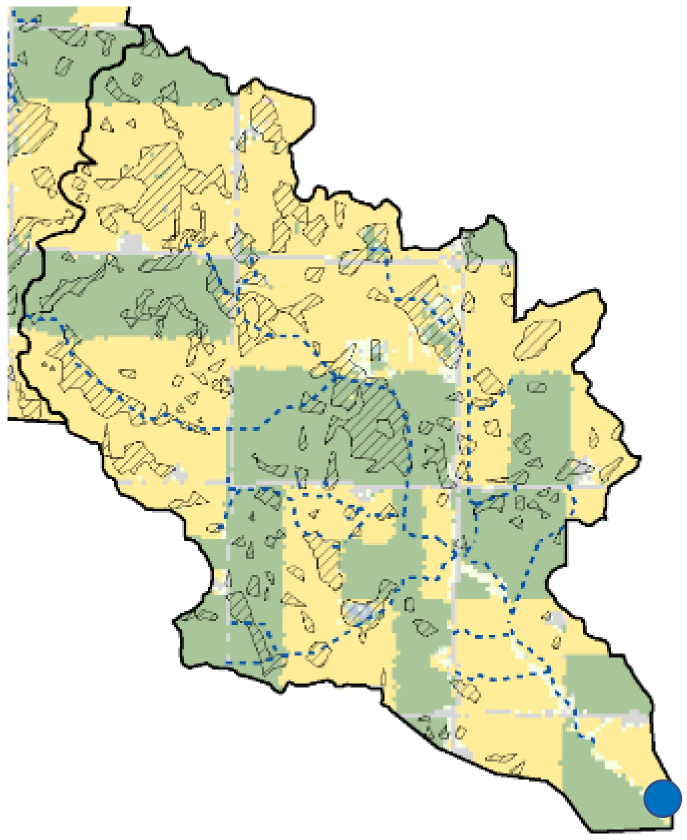
- Designed to maintain shallow ponding under typical conditions
- Effective for nitrate removal via denitrification to N_2
  - CREP wetlands removed **30%** of nitrate inputs, on average
  - Only **0.5%** of nitrate removed was emitted as N_2O



Crumpton et al. 2020, JEQ

Nitrogen loss scenario for CREP wetlands



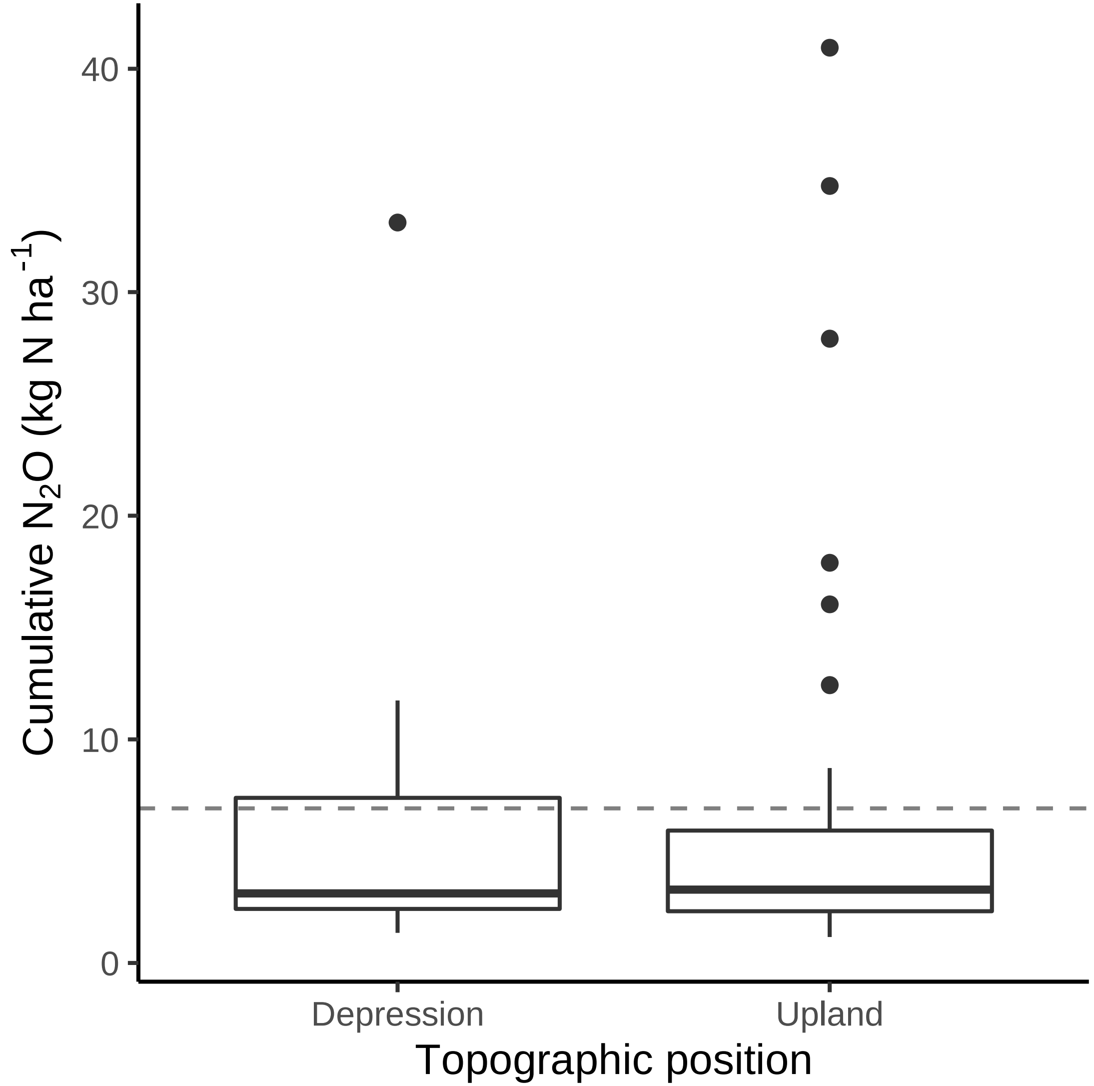


CREP wetlands:
- Net removal of reactive nitrogen as N_2
- Low N_2O emissions
- Moderate CH_4 emissions

Results from our in-field measurements

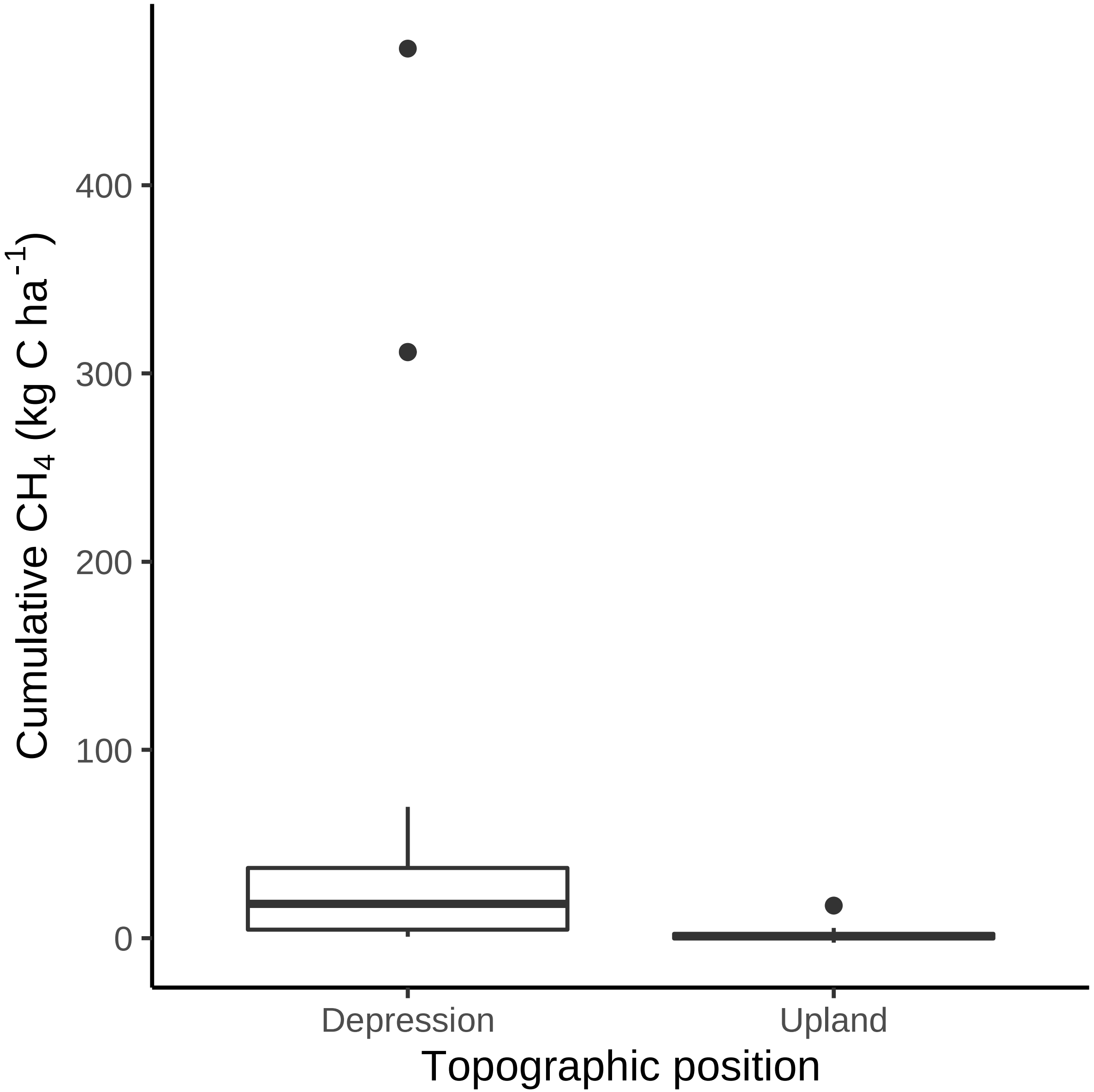
N_2O emissions from cropped depressions

- No difference in N_2O emissions between depressions and uplands
- Overall mean of **6.9** kg N ha^{-1} y^{-1}
  - 12.9 kg for corn
  - 2.9 kg for soybean
- Upshot: cropped depressions are significant direct N_2O sources
- They also export significant dissolved N_2O in drainage water (!)



CH_4 emissions from cropped depressions

- Greater CH_4 emissions from depressions than uplands
  - **72** kg C ha^{-1} y^{-1} vs. **2** kg C ha^{-1} y^{-1}
  - $P < 0.0001$



Nitrate leaching from cropped depressions

- Nitrate leaching at 35 cm depth was greater in depressions than uplands
  - 142 kg N ha^{-1} vs 96 kg N ha^{-1}
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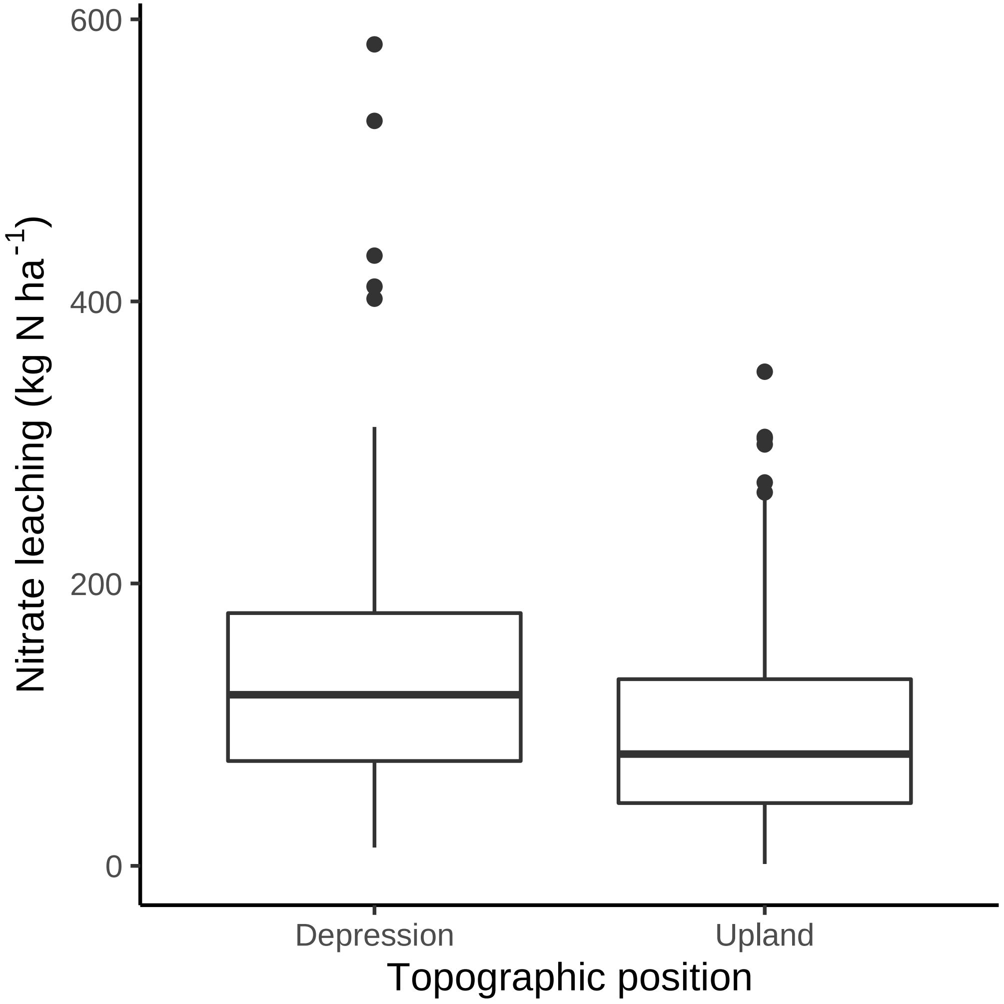

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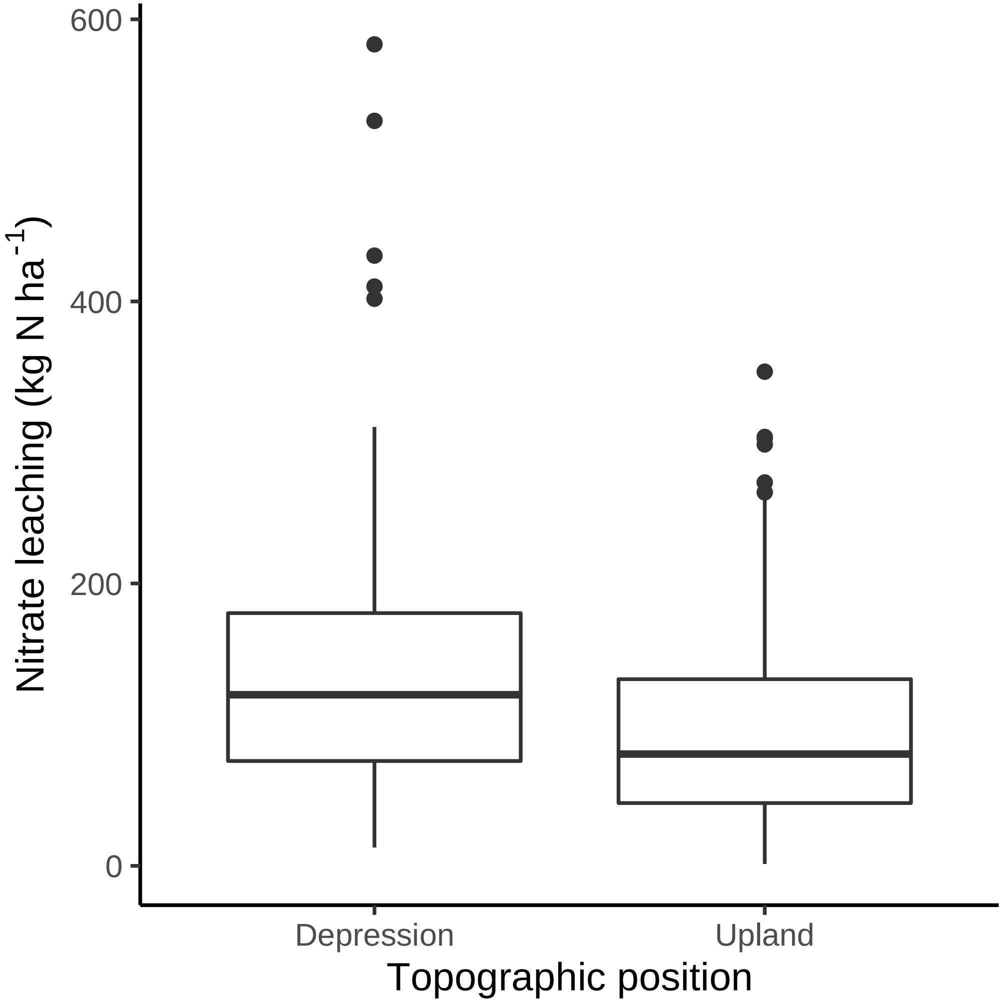
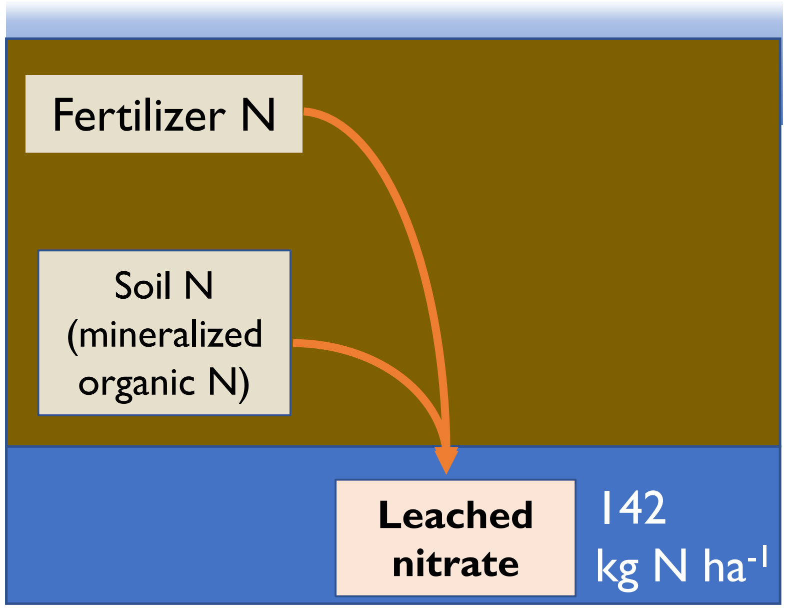
- Nitrate leaching at 35 cm depth was greater in depressions than uplands
  - 142 kg N ha^{-1} vs 96 kg N ha^{-1}
  - $P < 0.0001$
- No relationship between depression drainage characteristics and nitrate leaching



Nitrate dynamics in cropped depressions and CREP wetlands



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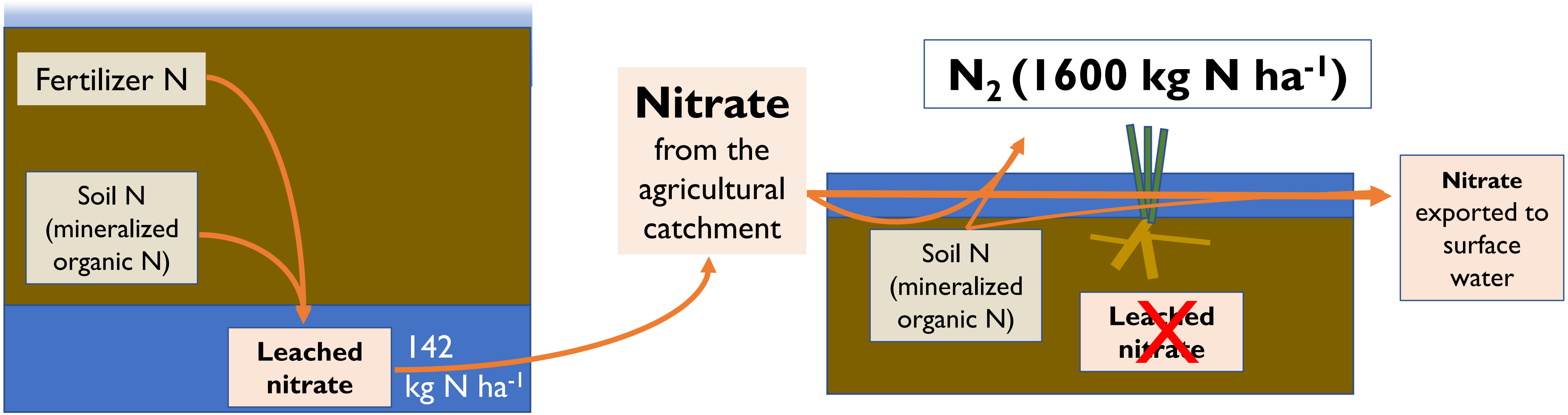

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CREP wetlands:

Removed **1600 kg** nitrate N ha^{-1}, almost entirely as N_2

Comparison of biogeochemical cycling between cropped depressions and CREP wetlands

- Cropped depressions:
  - Produced N_2O emissions equivalent to upland soils
  - Produced variable but potentially significant CH_4
  - **Had higher nitrate leaching than upland soils**
  - Low crop production

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- Cropped depressions:
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- CREP wetlands:
  - Did not increase net N_2O production relative to other land cover types
  - Had moderate CH_4 emissions (similar to natural wetlands in our region)
  - **Removed significant nitrate as N_2**
  - Provisioned wildlife / plant habitat

Some alternative management scenarios to consider for cropped depressions:

- Cease cultivation, restore facultative wetland vegetation
  - Problems: logistical challenges for sub-field-scale management; lack of incentives

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- Adopt conservation tillage and cover crops and reduce nutrient inputs
  - Problems: soil properties change slowly; inconsistent performance
- Improve subsurface drainage, offset with CREP wetlands at catchment outlets
  - May provide optimal balance of agronomic and environmental performance
  - Problems: logistical constraints for CREP siting and financing.

Take-home points:

- Cropped depressions are often poor croplands *and* poor wetlands
- Cropped depressions may exacerbate nitrate losses and greenhouse gas emissions as compared with cropped uplands
- CREP wetlands provide significant net nitrate removal with relatively low greenhouse gas production

Acknowledgements:

- This work was supported in part by EPA Wetland Development Program Grant 97763001
- CREP monitoring was supported in part by the Iowa Department of Agriculture and Land Stewardship
- We thank Greg Stenback for compiling CREP wetland data

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