Wetlands in Cultivated Landscapes: Soil Carbon, Salinity, and GHGs

Chantel Chizen, PhD

Assistant Professor

UNIVERSITY OF SASKATCHEWAN
College of Agriculture and Bioresources
DEPARTMENT OF SOIL SCIENCE

DIGSS
Data-driven Innovations with Geospatial Soil Science

AGVISE Soil Fertility Seminars – March 2025

Background

University of Saskatchewan

FFAR Fellows
Future Leaders for Food & Agriculture

Ag-West Bio

UBC
The University of British Columbia

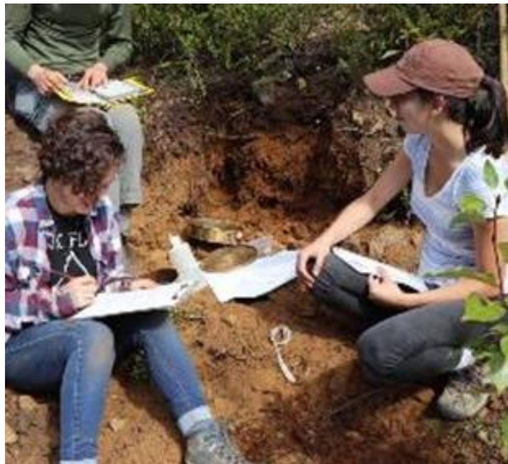
Carbon Sequestration

Alliance
Bioversity & CIAT

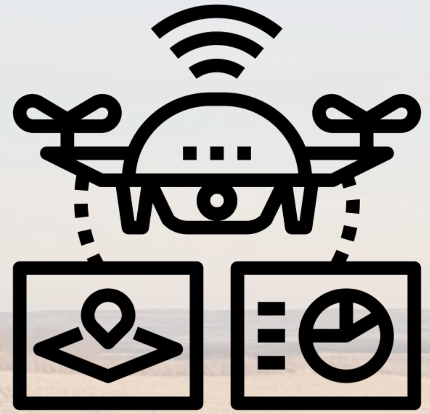
CGIAR





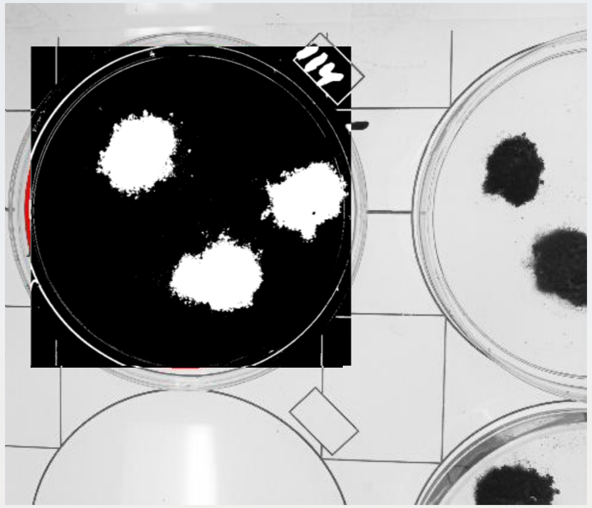


Digital Pedology & Pedometrics



Icon credit: dDara; Kukuh Wachyu Bias; iconvison656

Digital Pedology & Pedometrics Tool Cabinet



Aggregate Stability
Image Analysis

Analysis and Modelling Techniques

Geostatistics

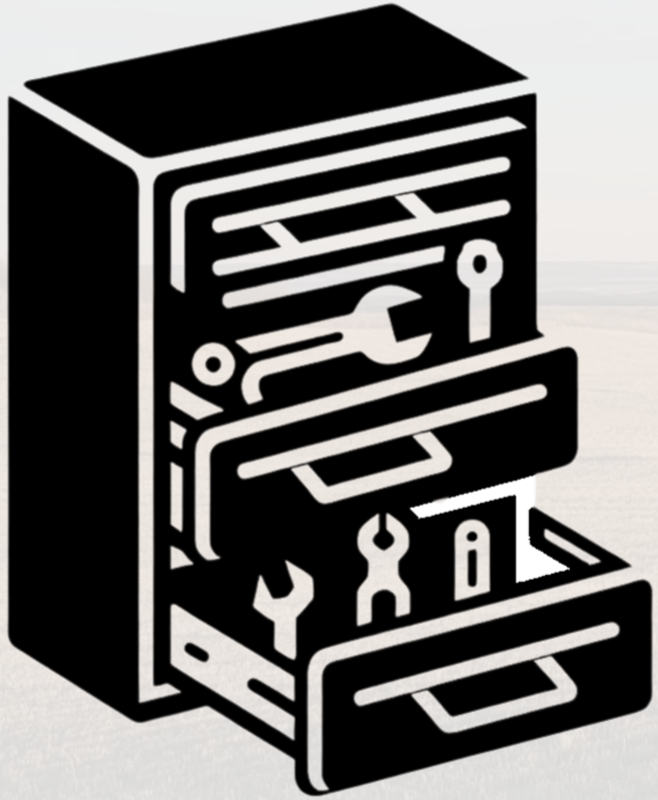
Machine Learning

Computer Vision

Image Processing

Artificial Intelligence

Digital Pedology & Pedometrics Tool Cabinet



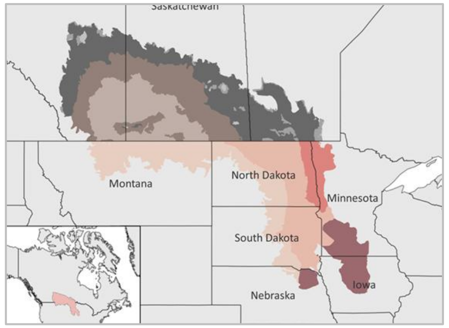
Data Acquisition

Analysis and Modelling Techniques

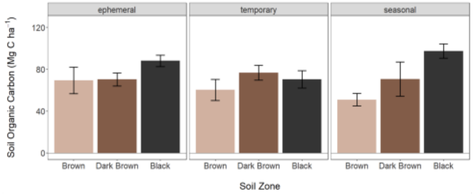
Digital Soil Mapping and Interpretation

Data Management

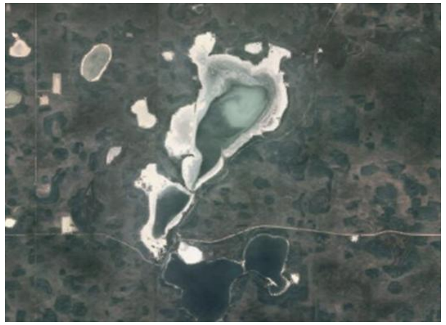
This presentation shares findings on how prairie pothole wetlands can contribute to agricultural landscapes



What are prairie pothole wetlands?



Soil carbon storage variability in prairie pothole wetlands



Salinity controls on wetland soil greenhouse gas emissions

The Prairie Pothole Region is an essential landscape for agricultural production and features millions of wetlands

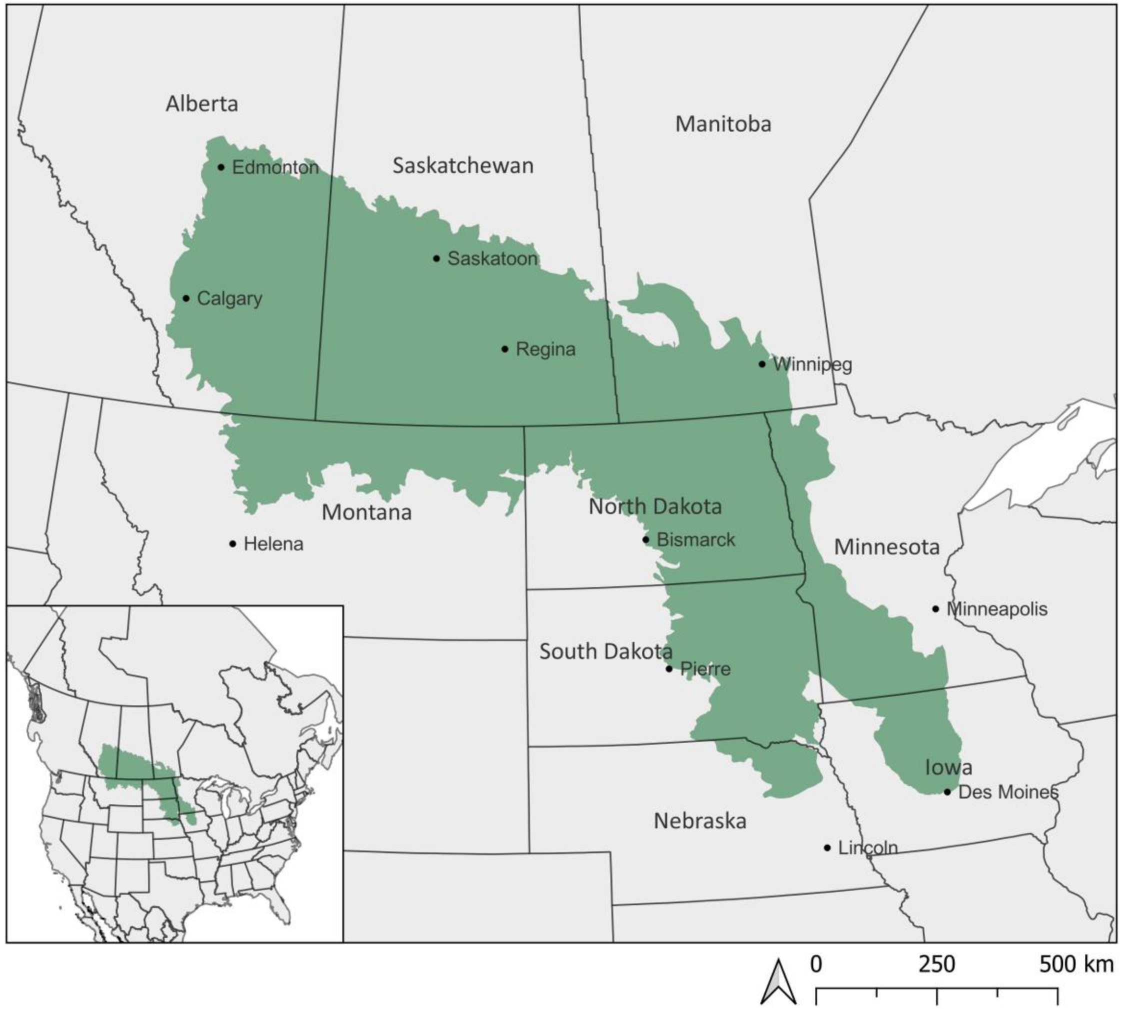


Photo: US Fish and Wildlife Service

The Stewart & Kantrud classification system groups prairie potholes based on pond permanence and vegetation

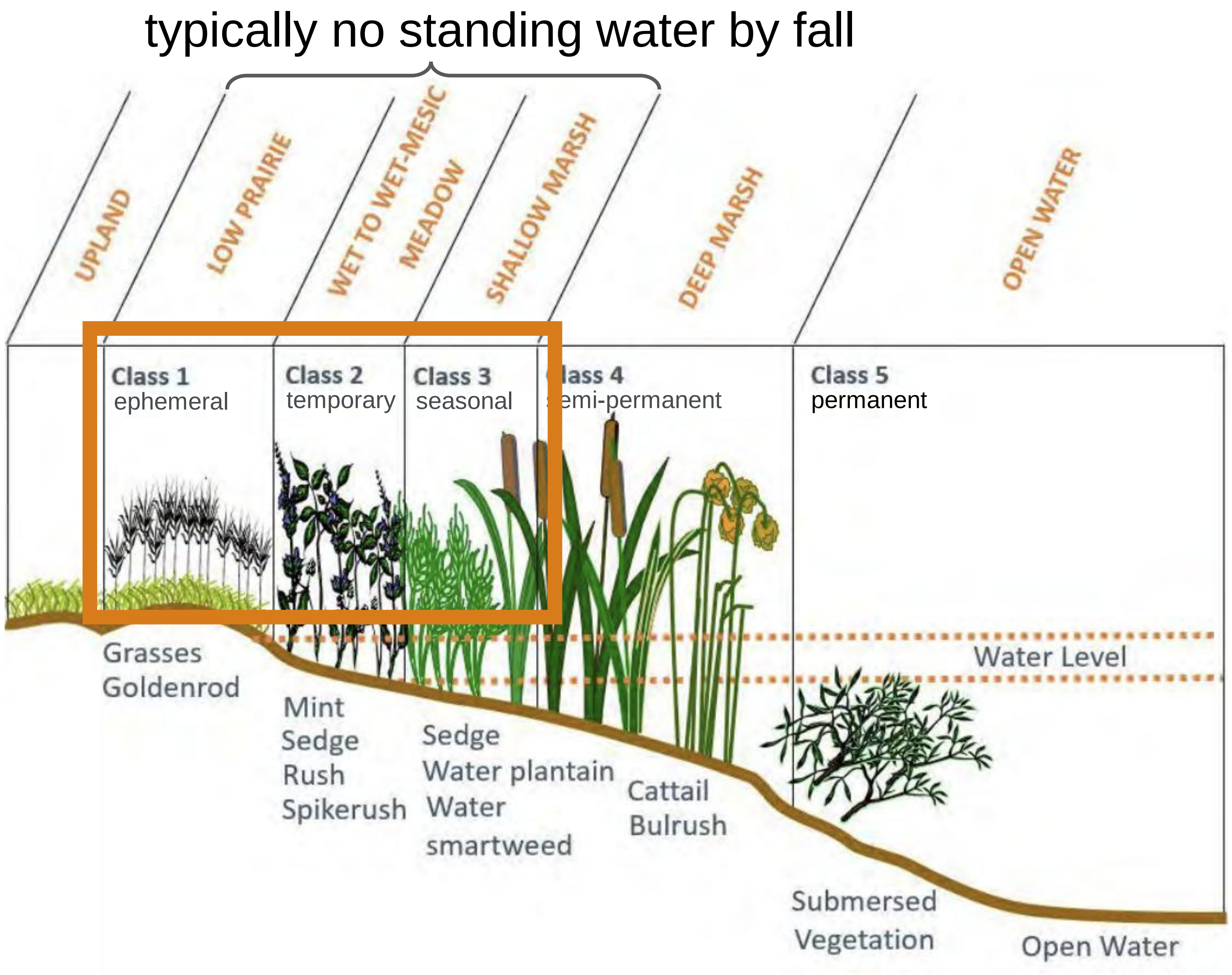


Photo credit: Michael Forsberg [Prairie potholes in cropland]; adapted from Ducks Unlimited [Classification]

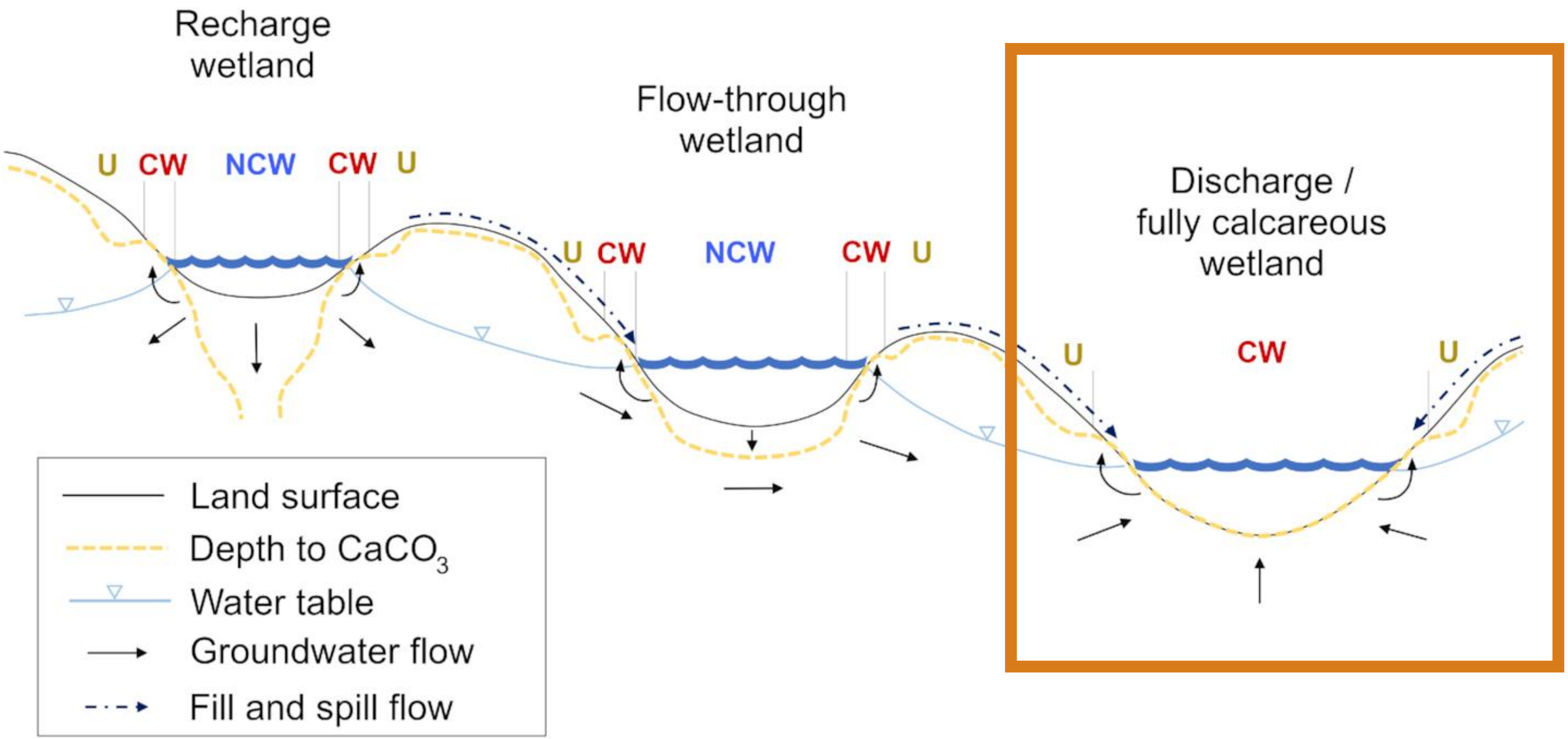
Using wetland pond permanence over a period of wet-dry climate cycles to assign wetland classification

	Class I ephemeral	**Class II** temporary	**Class III** seasonal	**Class IV** semi-permanent
pond permanence after snowmelt	< 1 month	1-2 months	3-4 months	5-6 months

Soil salinity is often associated with prairie pothole wetlands

Photo credit: Soils of Saskatchewan; Wetland Policy

The salts that accumulate in these wetlands, naturally originate from the groundwater



Kiss et al. (2022)

Saline prairie pothole wetlands are dynamic with the salinity levels fluctuating both within a year and across years

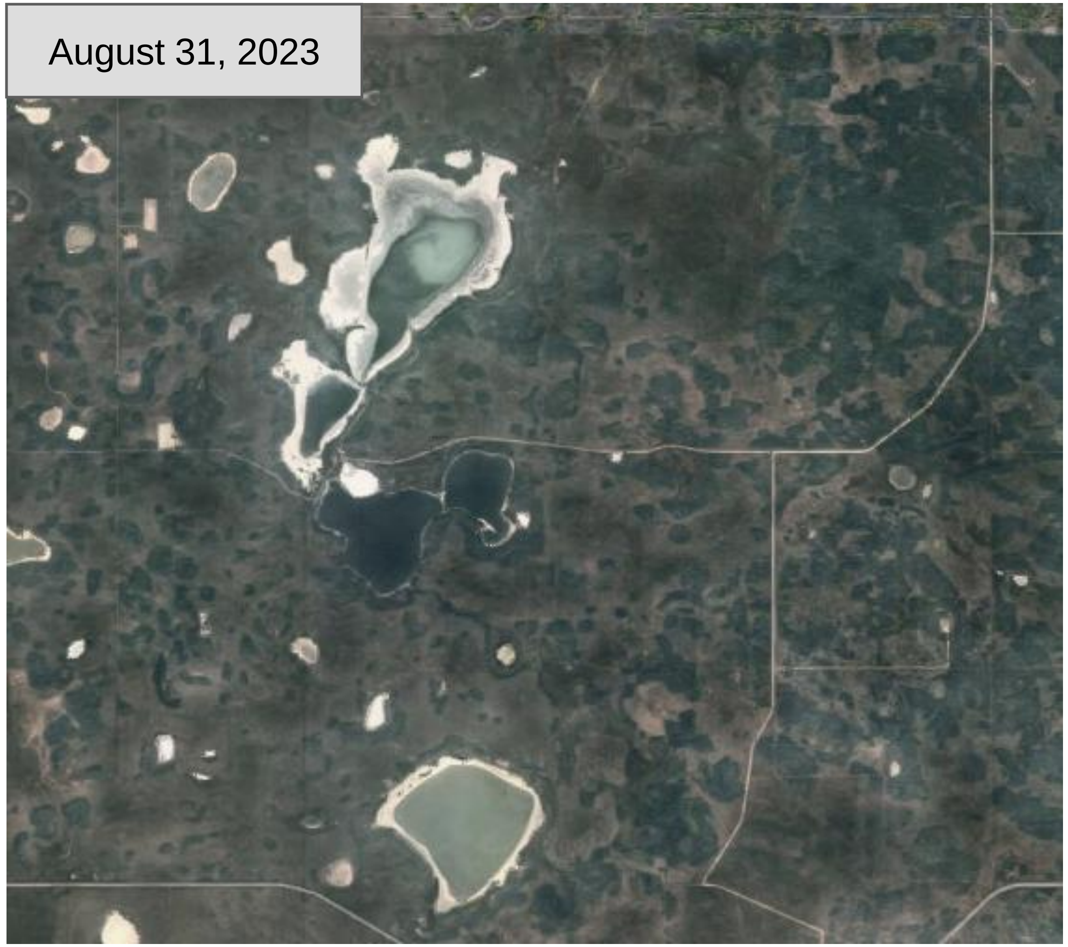


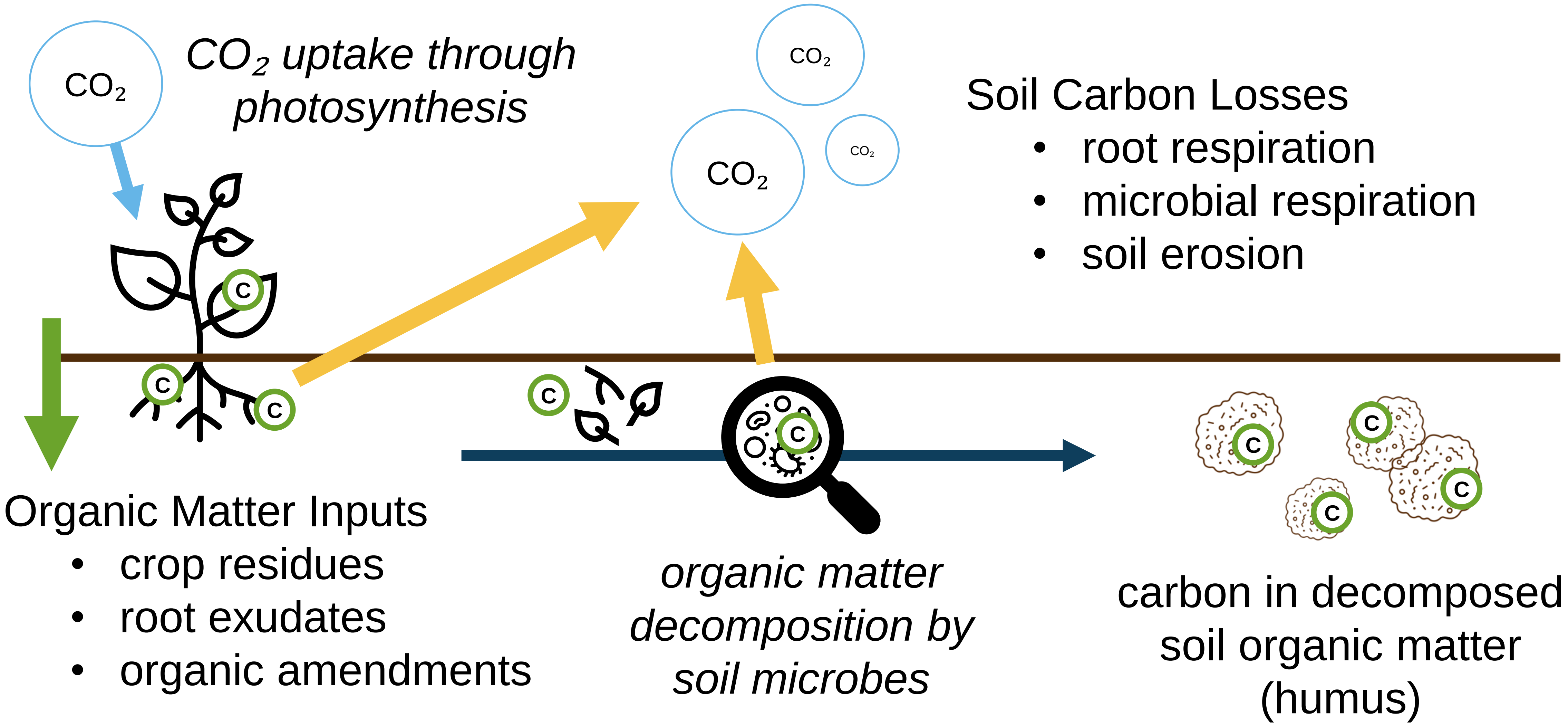
Photo credit: Google Earth, Maxar Technologies, Airbus

Prairie pothole wetlands provide several ecosystem services

- habitat and biodiversity
- water filtration
- drought and flood protection
- nutrient cycling and retention
- carbon storage

photo source: https://www.ducks.ca/assets/2015/08/pothole.jpg

The organic carbon in the soil is held within the soil organic matter and it can be lost during decomposition



Why does soil organic carbon matter?

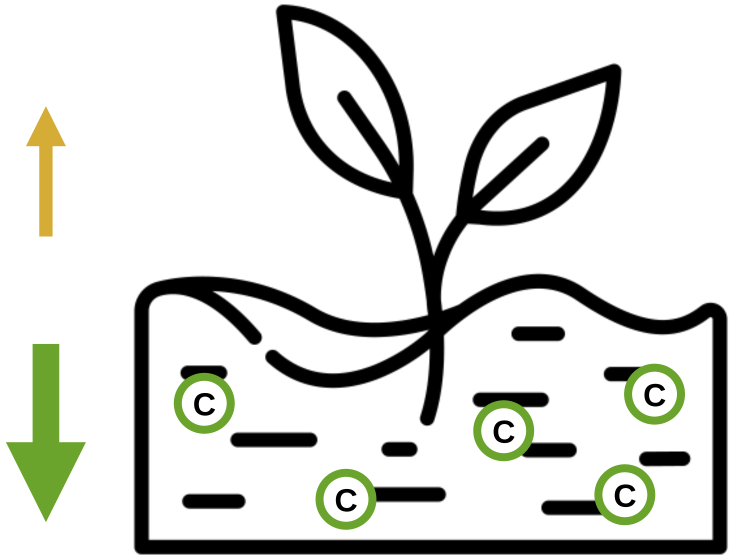
Soil organic carbon supports the soil's:

Nutrient Cycling → nutrient availability
nutrient holding capacity
soil microbial community

Water Retention → water holding capacity

Soil Structure → root penetration
water infiltration
lower erosion risk

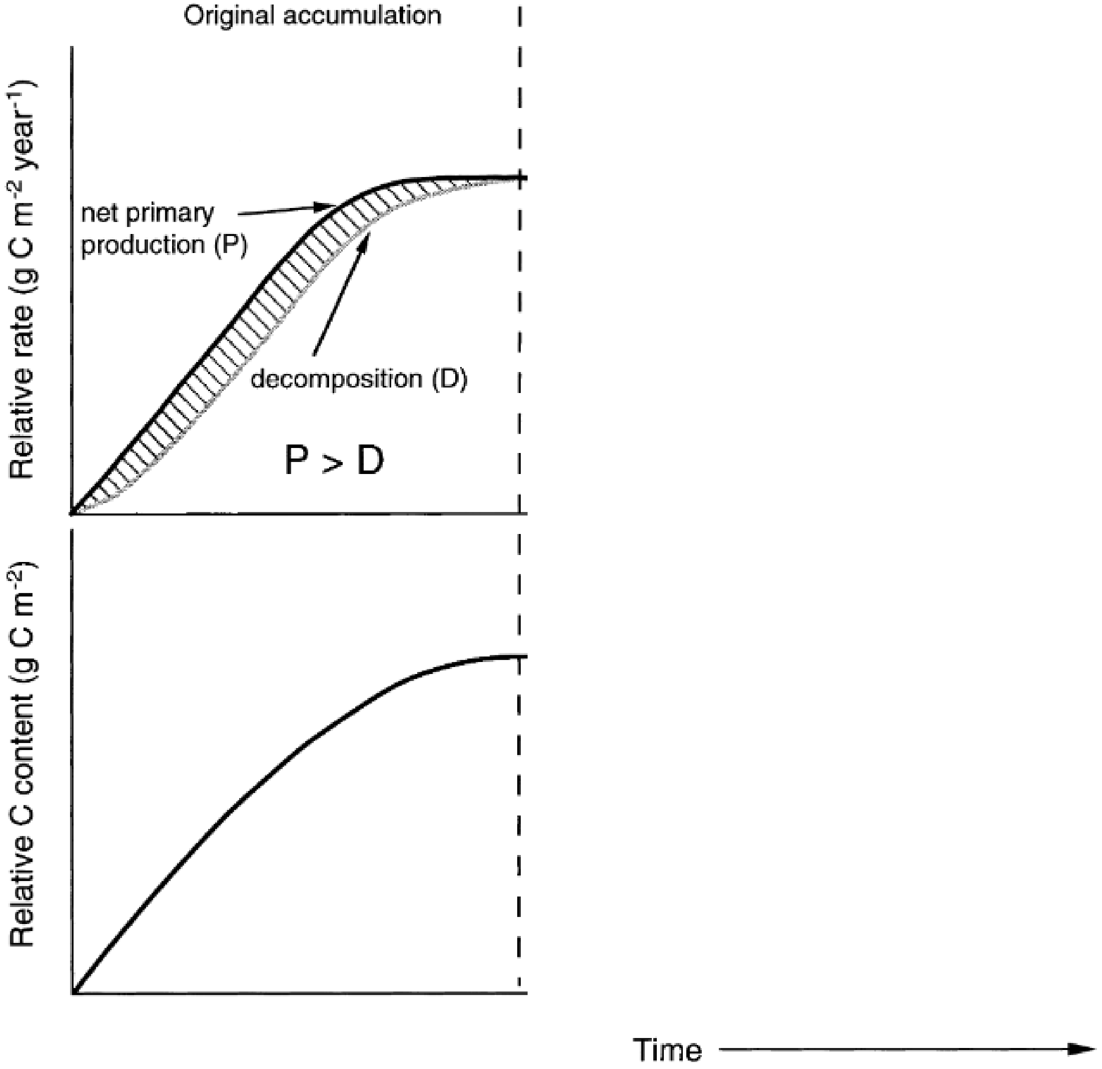
Soil carbon sequestration happens when there are more carbon inputs to the soil than losses



Examples of agricultural management that promote carbon sequestration:

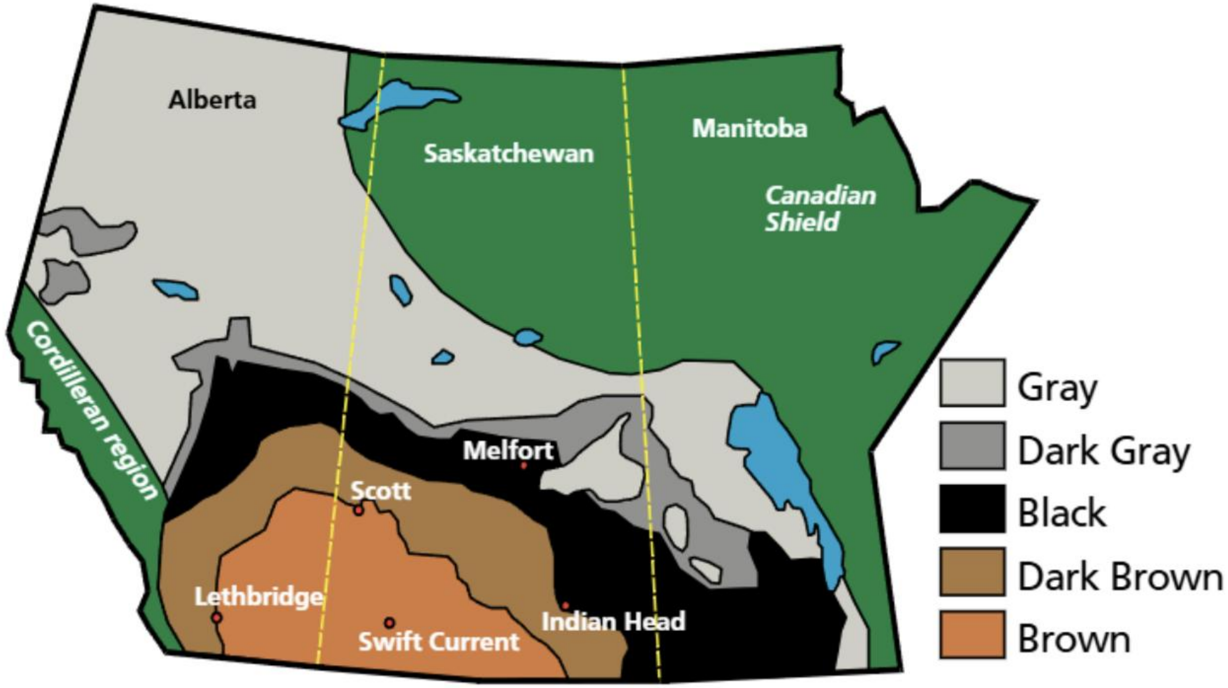
- Conservation tillage
- Avoid summer fallow

Soil carbon responds slowly to changes in management or land use



Janzen et al. (1998)

The amount of carbon that a soil can hold (carbon sequestration capacity) depends on the landscape and environment



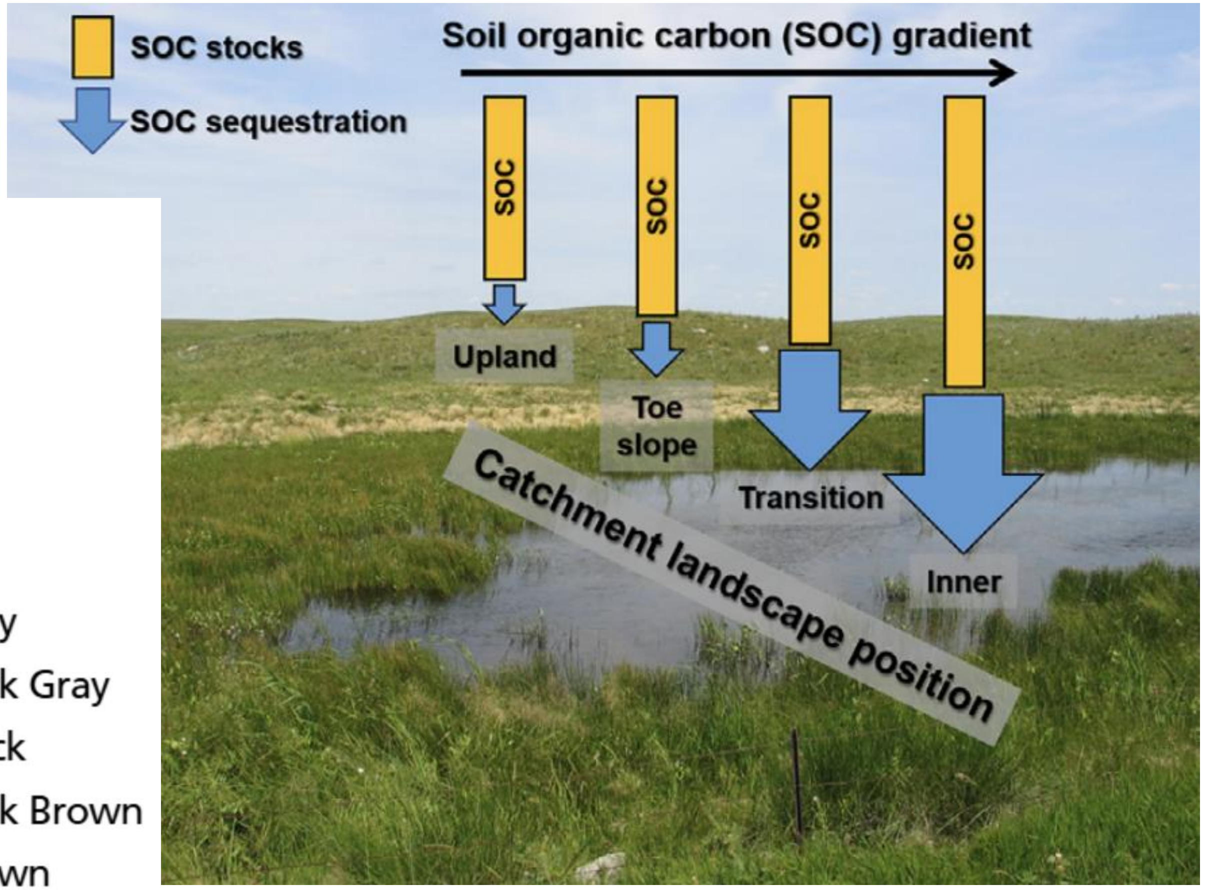


Photo credit: Willms et al. (2011) [soil zones]; Tangen & Bansal (2020) [landscape position]

Agricultural management practices have been overall restoring soil carbon stocks, that were once depleted

Figure 1: Soil organic carbon change (in kilograms per hectare, per year) in Canada in 2016

Legend:

Large decrease	Moderate decrease	No change	Moderate increase	Large increase

Photo credit: Government of Canada https://agriculture.canada.ca/en/agricultural-production/soil-and-land/soil-organic-matter-indicator

Soil carbon storage across land uses

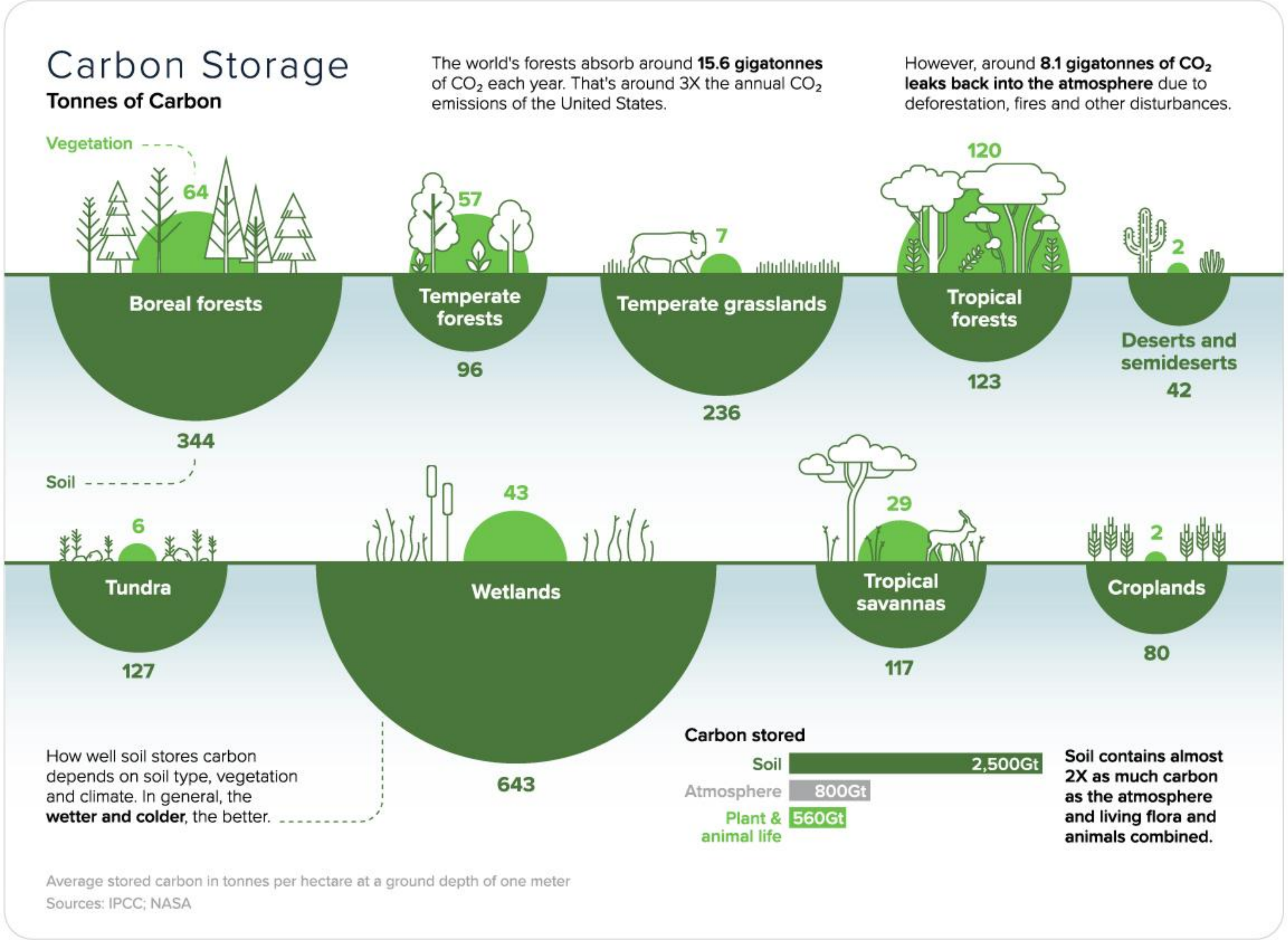
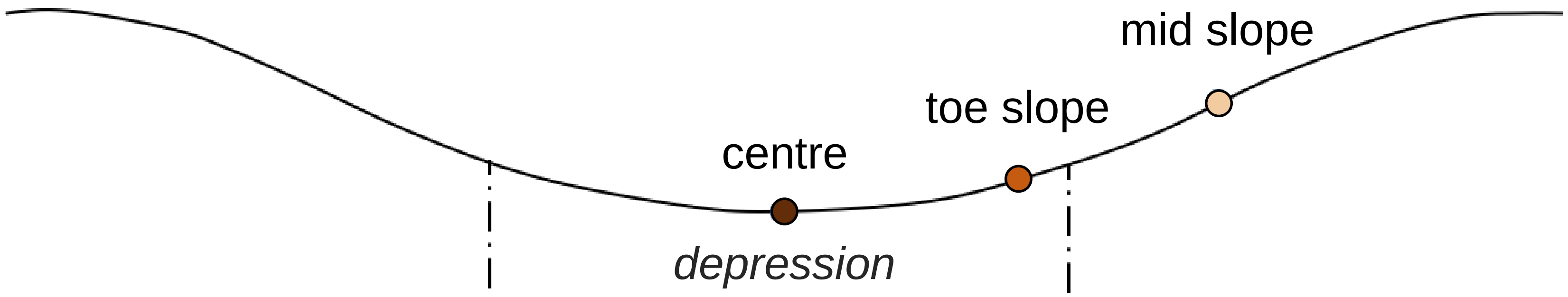


Photo credit: Visual Capitalist

Soils that are regularly water-logged have a higher carbon sequestration capacity because decomposition slows

centre

midslope



There are various land management practices that can affect prairie pothole wetland functions

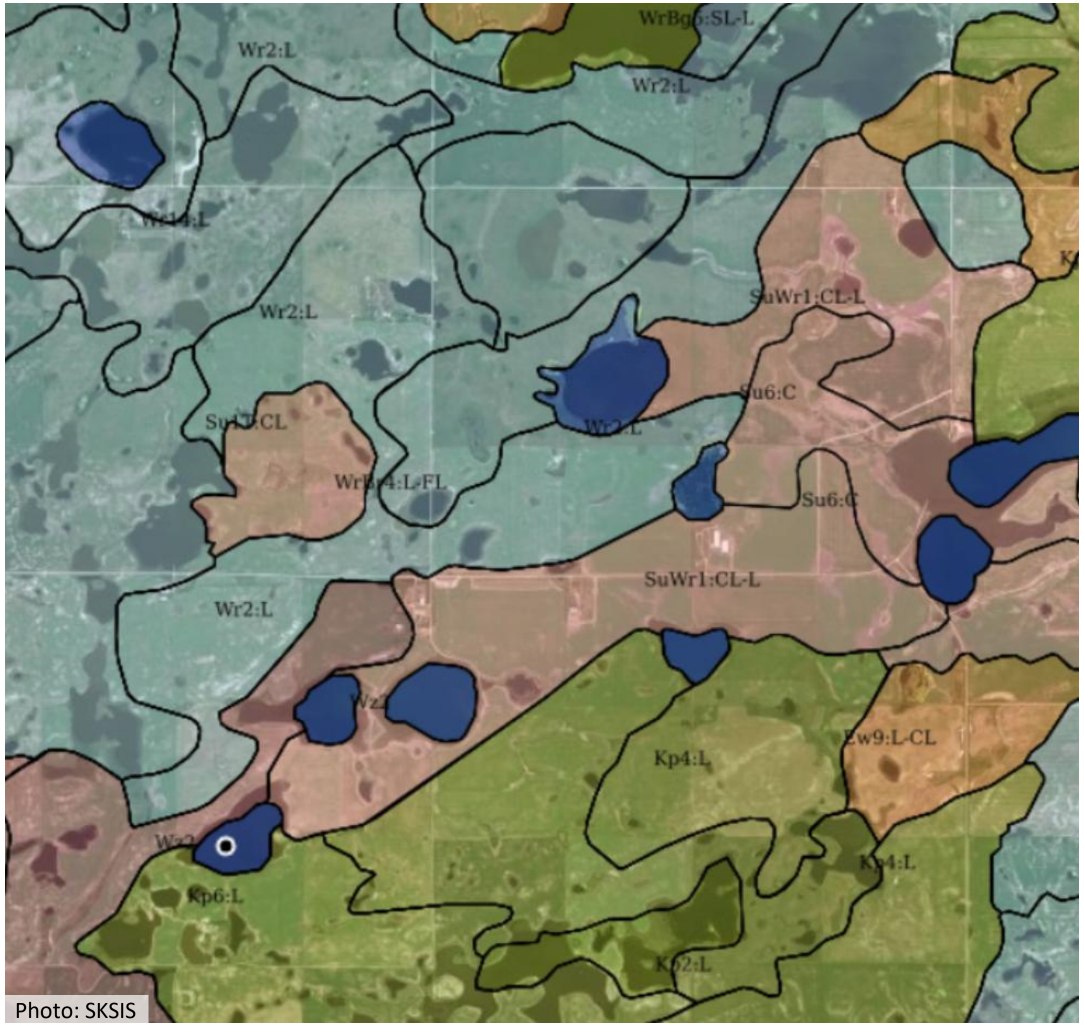

Photo: Michael Forsberg


Photo: Ducks Unlimited

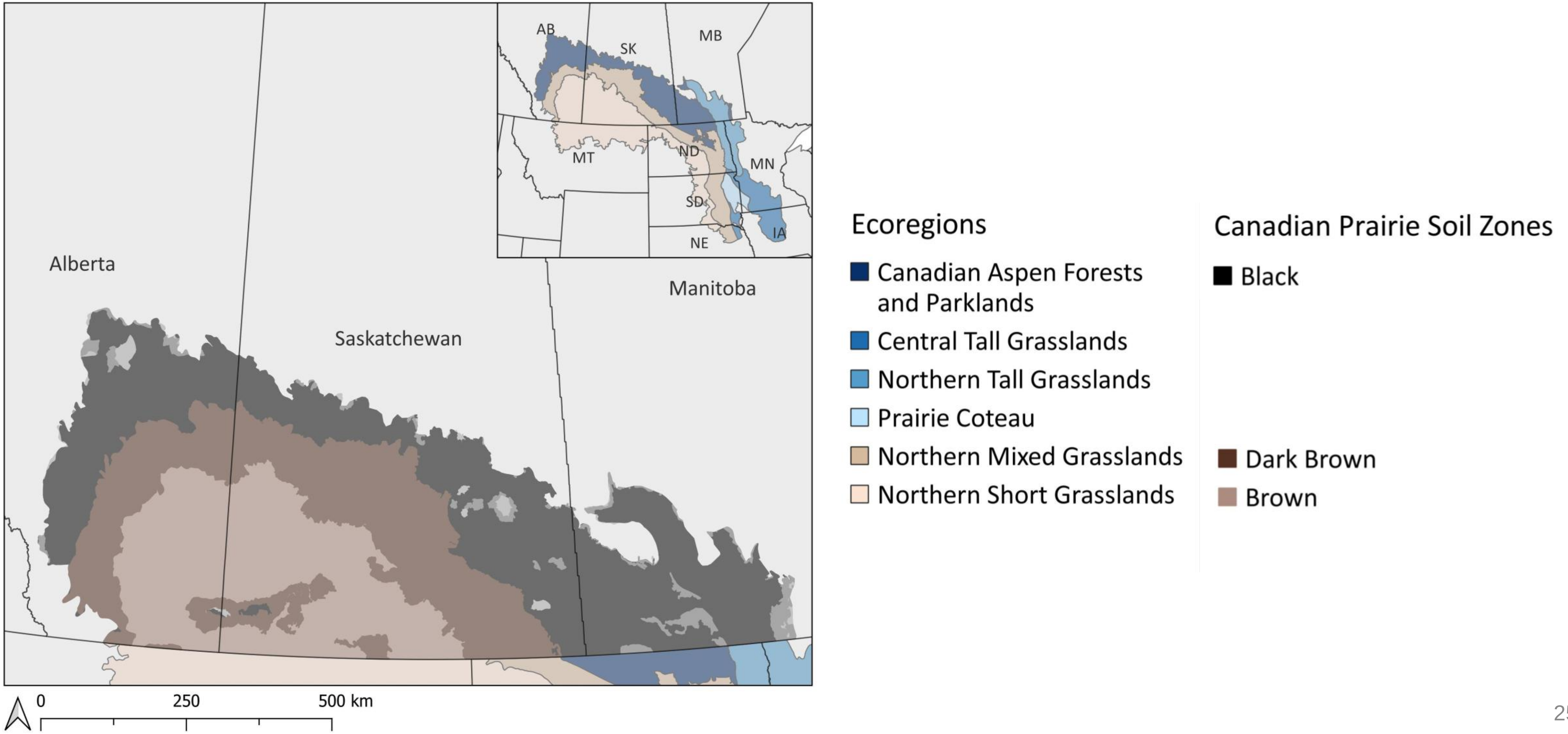

Photo: Penny Gustafson

Research Objective: Improve our understanding of how environmental factors and land management can influence soil carbon storage in cultivated prairie pothole wetlands

Can we assume that all prairie pothole wetlands store similar amounts of soil organic carbon?



Distinct ecoregions represent temperature and precipitation gradients across the region



Based on limited data, climate regime (soil zone) does not entirely explain wetland soil carbon variability

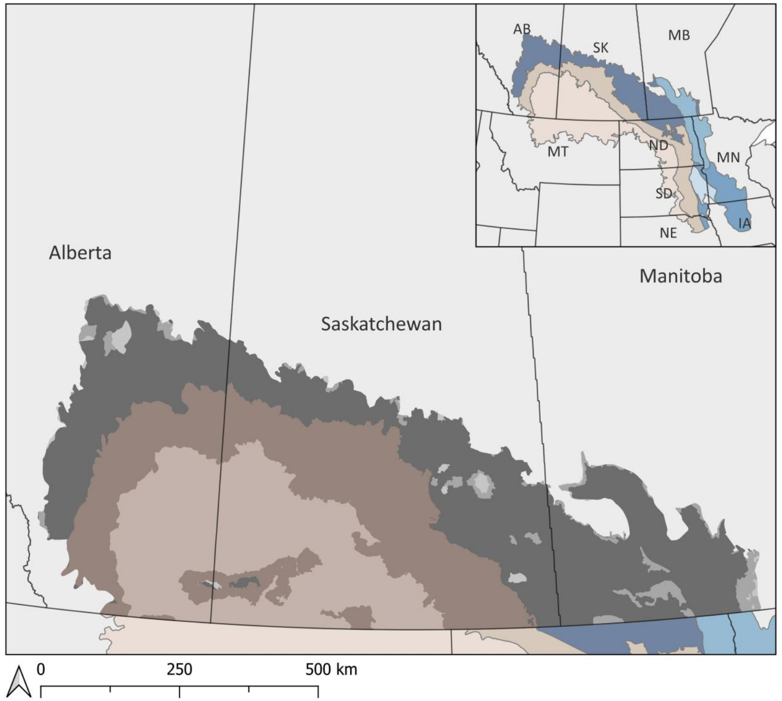
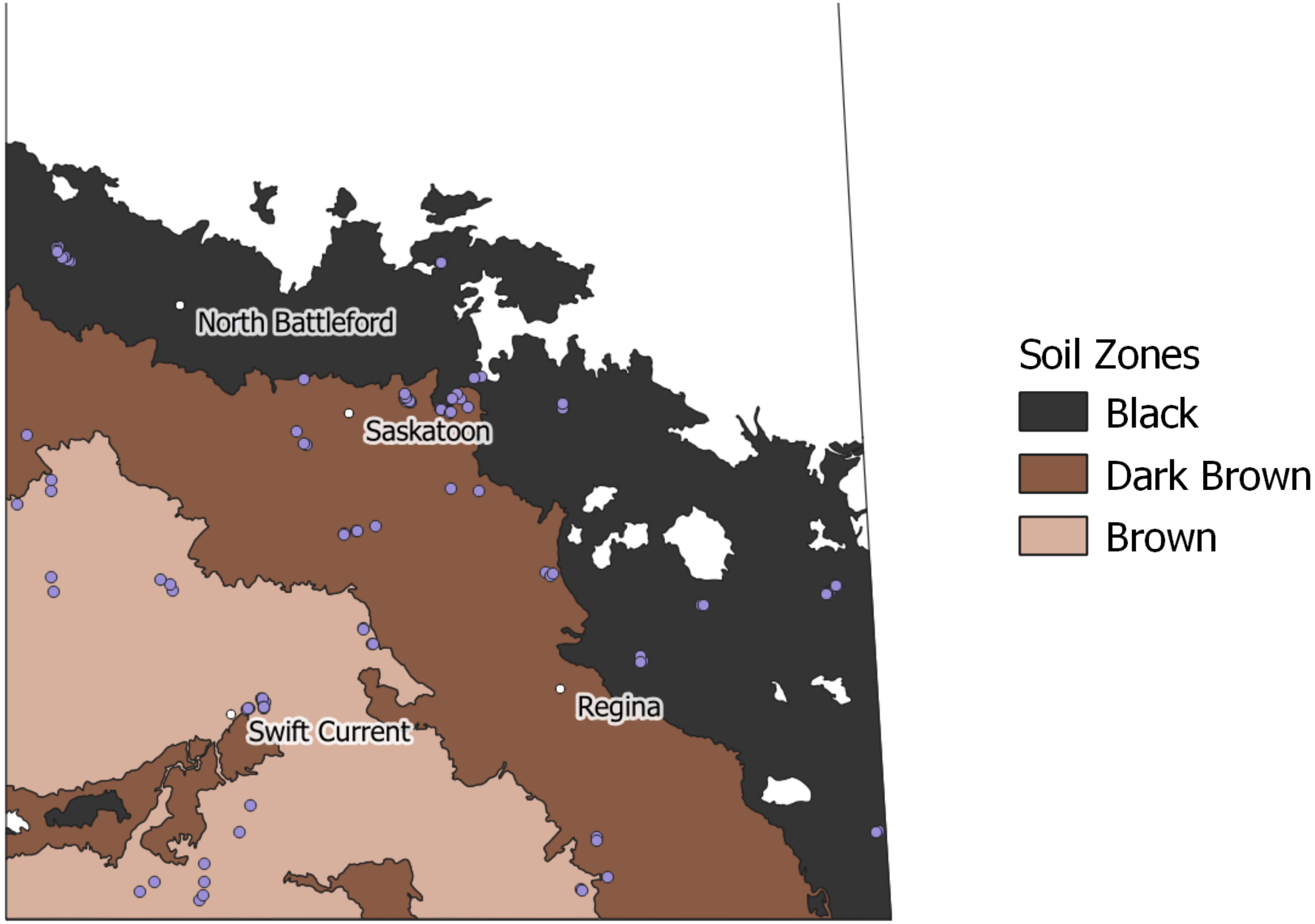


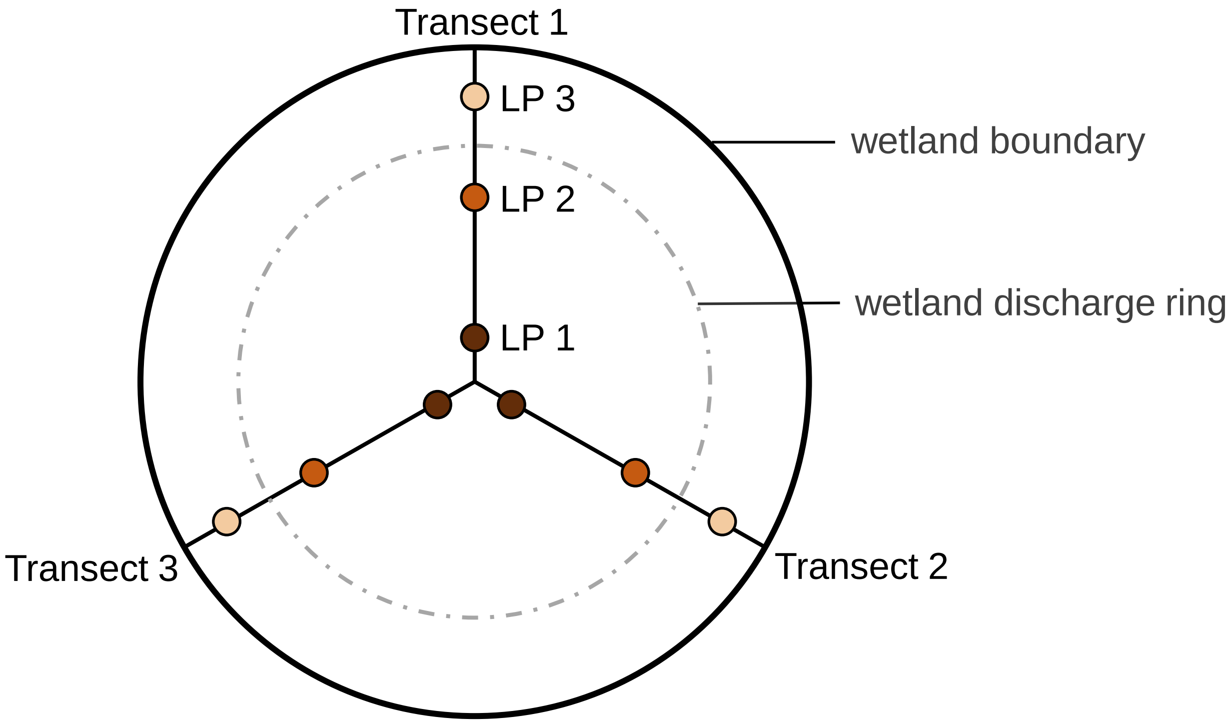
Table 2. SOC estimates for 0-30 cm

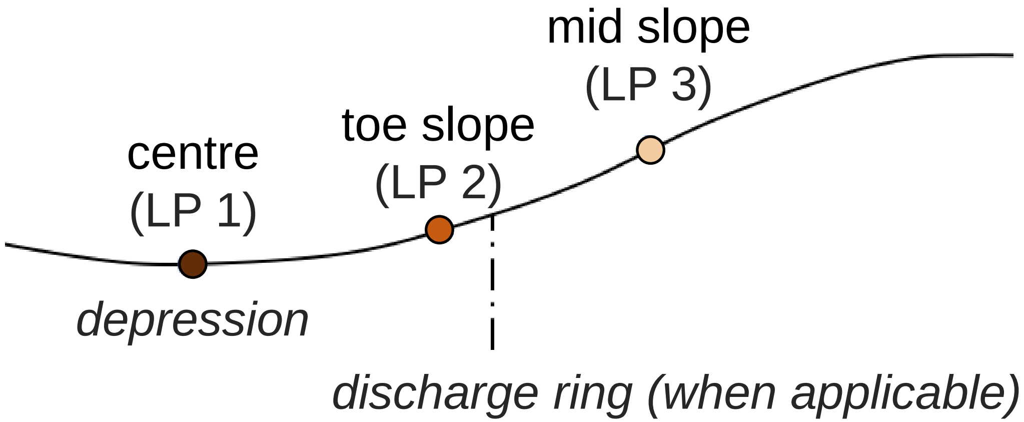
Soil Organic Carbon (Mg C ha^{-1})	Location	No. of Sites	Source
205	AB, SK, MB	22	Badiou et al. (2011)
175	SK	12	Bedard-Haughn et al. (2006)
168	SK	7	Bedard-Haughn et al. (2006)
128	global - humid	42	IPCC (2014) - temperate
106	ND, SD, MN	40	Euliss et al. (2006)
87	global - arid	NA	IPCC (2014) - temperate
87	SK	7	Bedard-Haughn et al. (2006)
78	SK	10	Brown et al. (2017)

92 prairie pothole wetlands in cultivated fields were sampled to refine regional soil organic carbon estimates

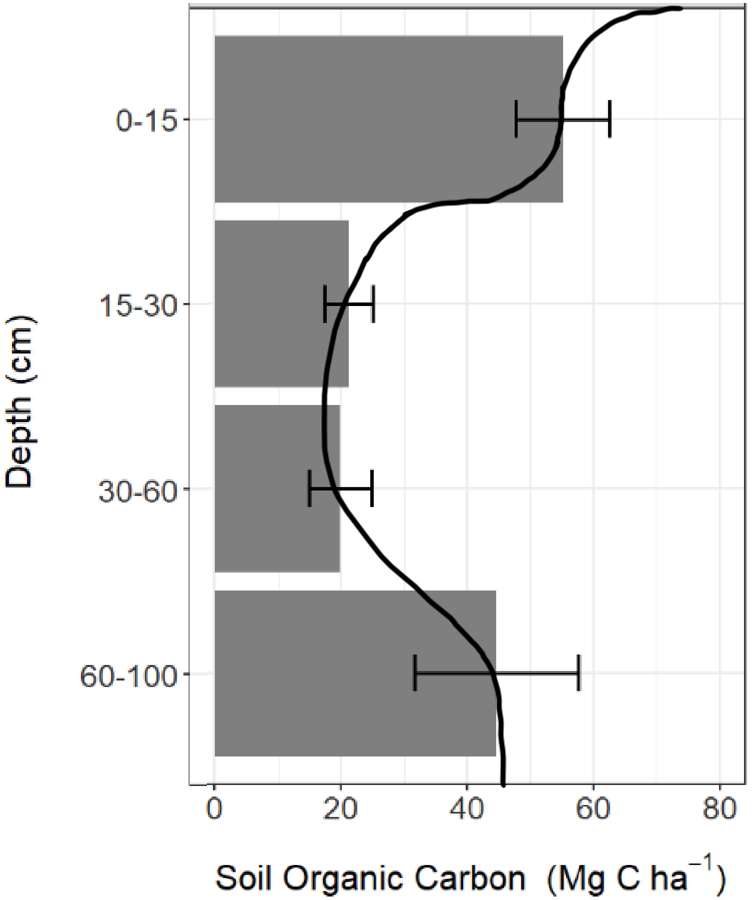


Soil samples were collected after harvest at three landscape positions within the wetland





Soil organic carbon for each sampling point was calculated using an equal-area spline and equivalent soil mass



0 – 30 cm

0 – 60 cm

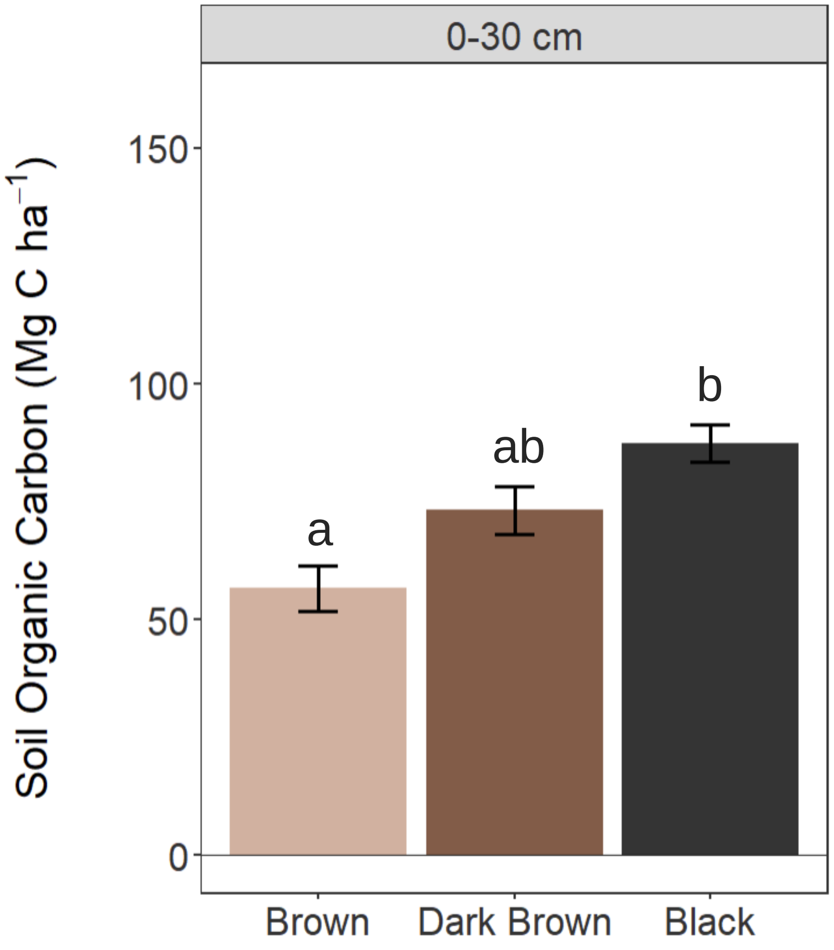
0 – 100 cm

Soil carbon that has accumulated in cultivated prairie pothole wetlands does differs across soil zones

Table 3. Soil organic carbon storage in wetlands with till parent material across ecoregions. Standard error is shown in brackets.

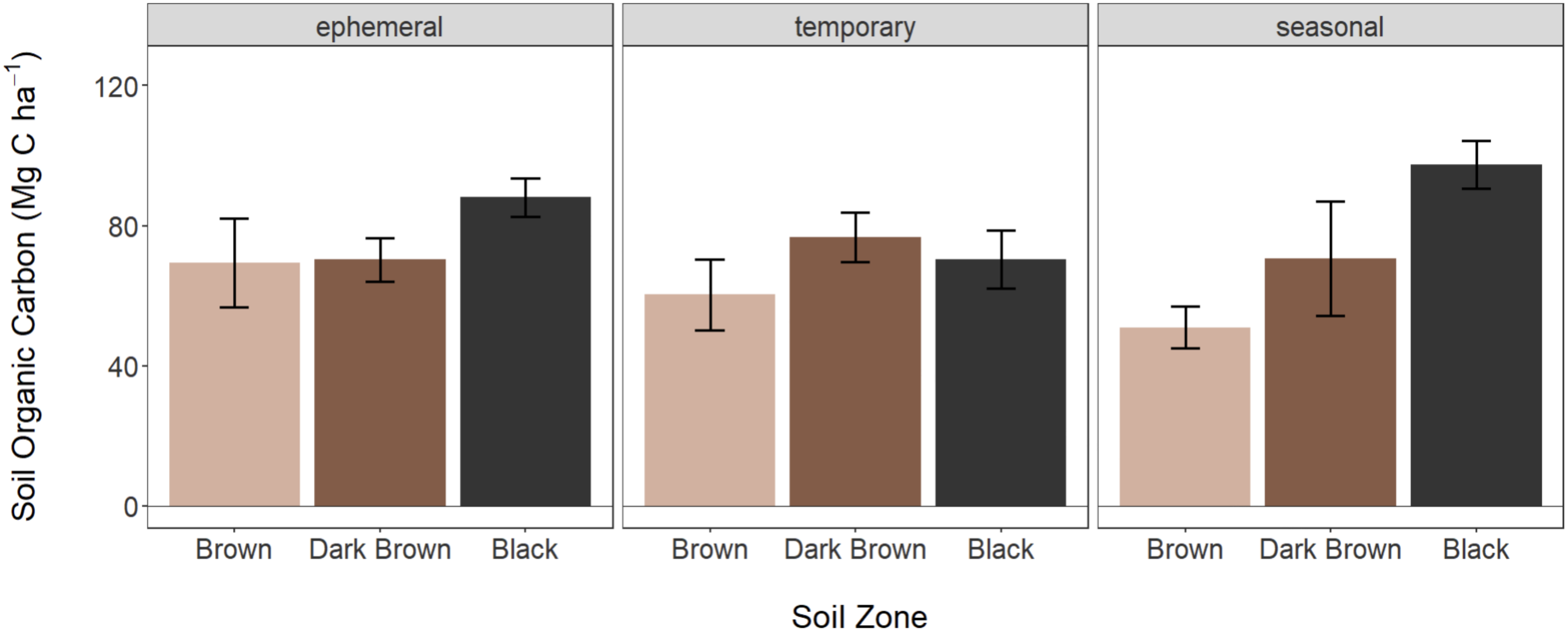
Soil Zone	Soil Organic Carbon ($Mg\ C\ ha^{-1}$)	
	0-30 cm	**0-100 cm**
Black	96.9 (7.77) a	144.3 (13.92)
Dark Brown	60.5 (6.01) b	120.8 (10.36)
Brown	64.0 (5.20) b	118.4 (8.46)

Soil carbon storage to 1 metre is similar across soil zones, highlighting the buried soil carbon in the depressions



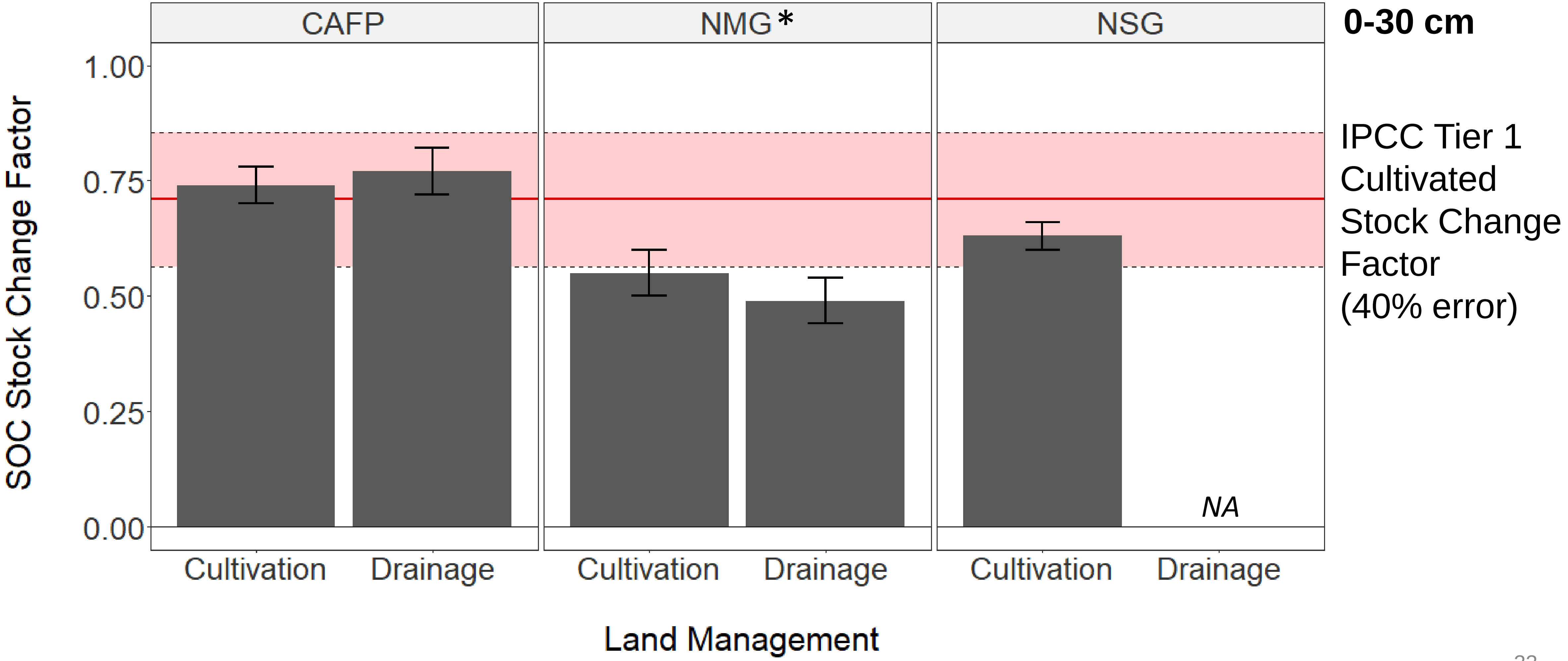
Soil Zone

Ephemeral and temporary wetlands are equally important as seasonal wetlands for soil carbon storage



No statistical significant between wetland classes, α = 0.05

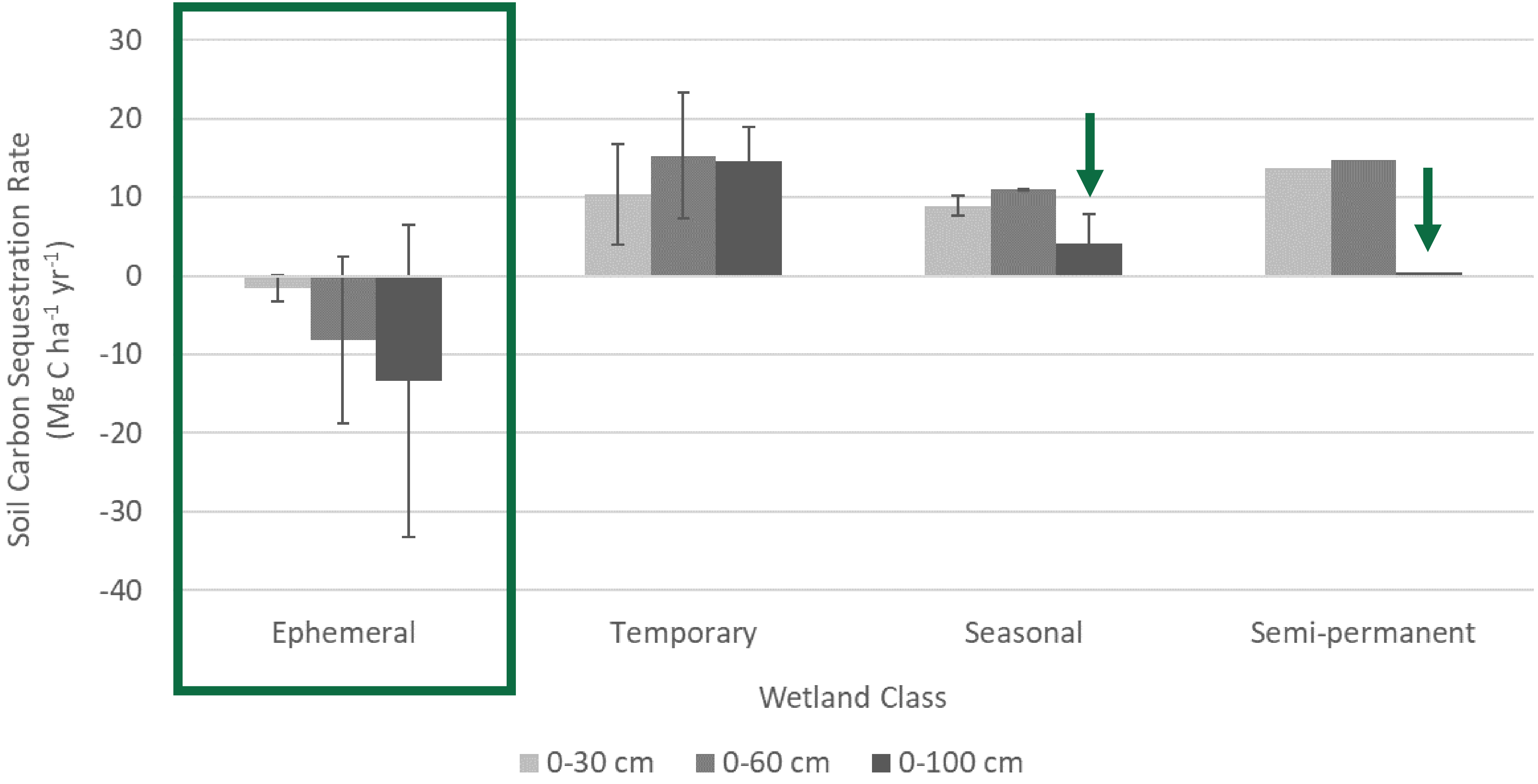
Regional soil organic carbon data for prairie pothole wetlands has reduced uncertainty in management stock change factors



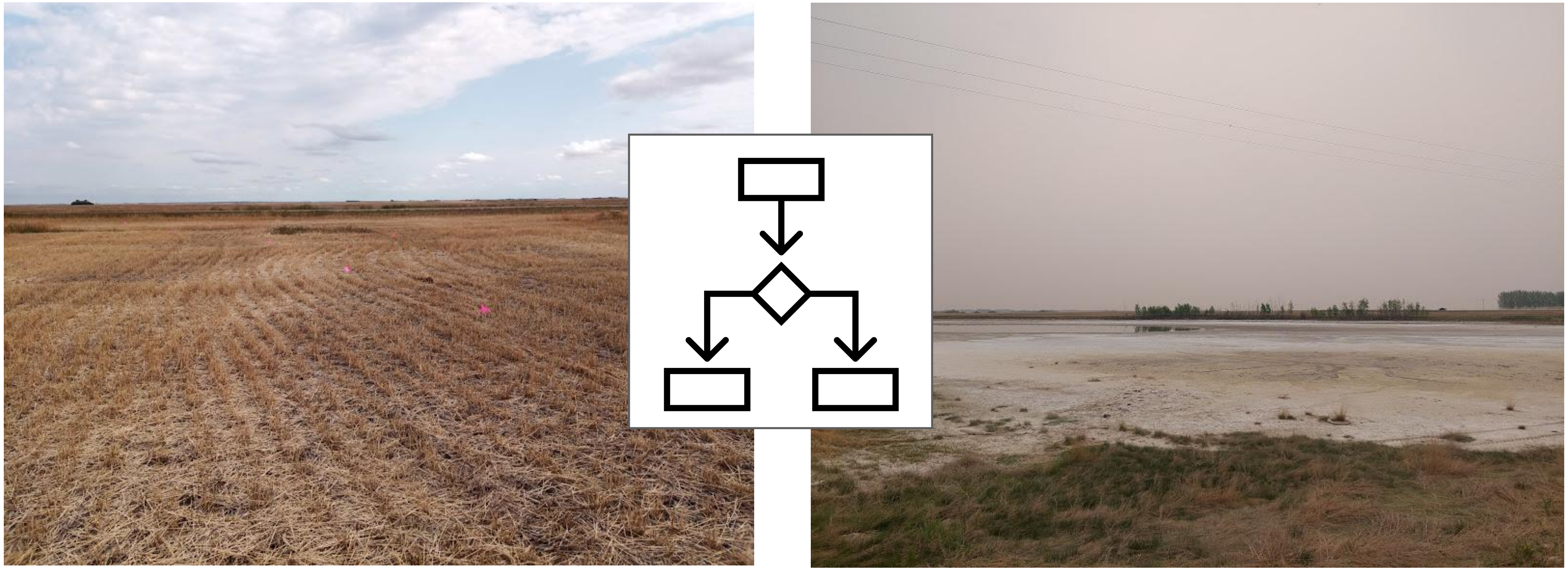
Drainage was implemented across 8 wetland basins at Discovery Farm, near Langham SK

May 2014 October 2020

Ephemeral wetlands were most susceptible to soil carbon losses in the 2 years following drainage implementation



Drainage, crop types, salinity, soil texture, and soil carbon analysis methods are other contributing factors to wetland soil carbon variability that are being explored



Research Objective: Evaluate the response of wetland soil greenhouse gas emissions to changes in salinity

There is limited experimental research on greenhouse gas emissions from saline prairie pothole wetlands

Published: 14 June 2021

Elevated salinity and water table drawdown significantly affect greenhouse gas emissions in soils from contrasting land-use practices in the prairie pothole region

Shayeb Shahariar, Richard Farrell, Raju Soolanayakanahally & Angela Bedard-Haughn

Biogeochemistry **155**, 127–146 (2021) | Cite this article

Geoderma

Volume 155, Issues 3–4, 15 March 2010, Pages 308-319

Landscape controls on N_2O and CH_4 emissions from freshwater mineral soil wetlands of the Canadian Prairie Pothole region

Dan Pennock [a], Thomas Yates [a], Angela Bedard-Haughn [a], Kim Phipps [a], Richard Farrell [a], Rhonda McDougal [b]

In spring, intact soil cores from 0-10 cm were taken from the center of a saline wetland and a non-saline wetland

Baseline Soil Characteristics

Saline

Texture: Loam

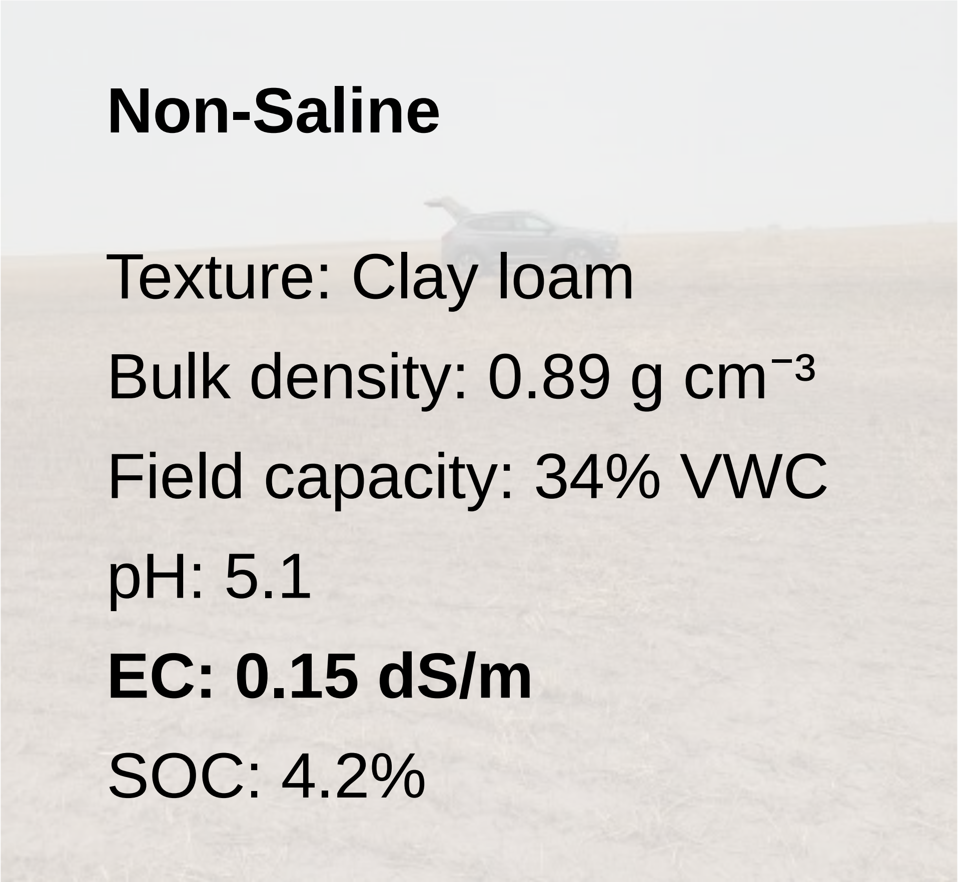
Bulk density: 0.96 g cm^{-3}

Field capacity: 45% VWC

pH: 8.3

EC: 11.3 dS/m

SOC: 2.2%



Non-Saline

Texture: Clay loam

Bulk density: 0.89 g cm^{-3}

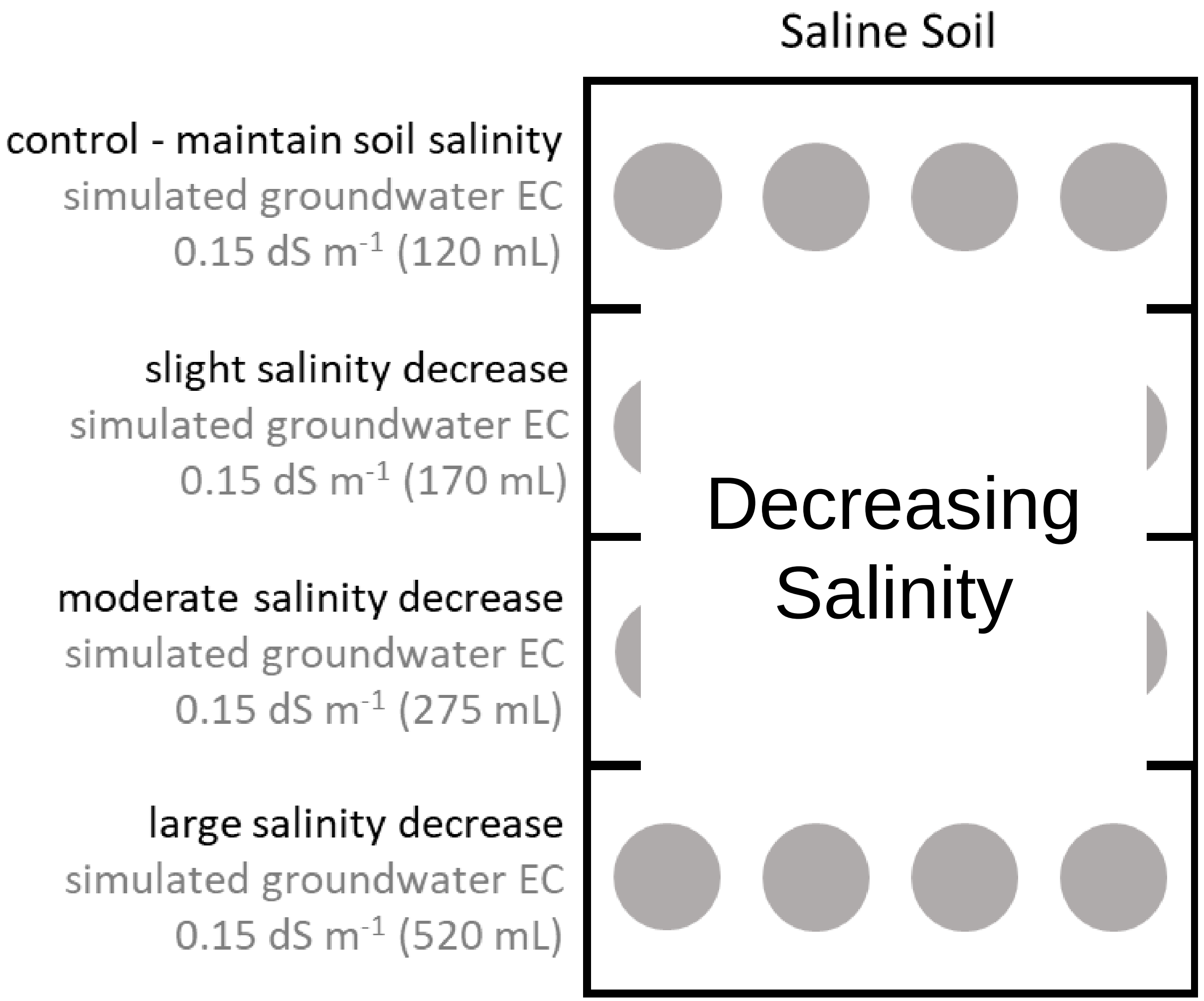
Field capacity: 34% VWC

pH: 5.1

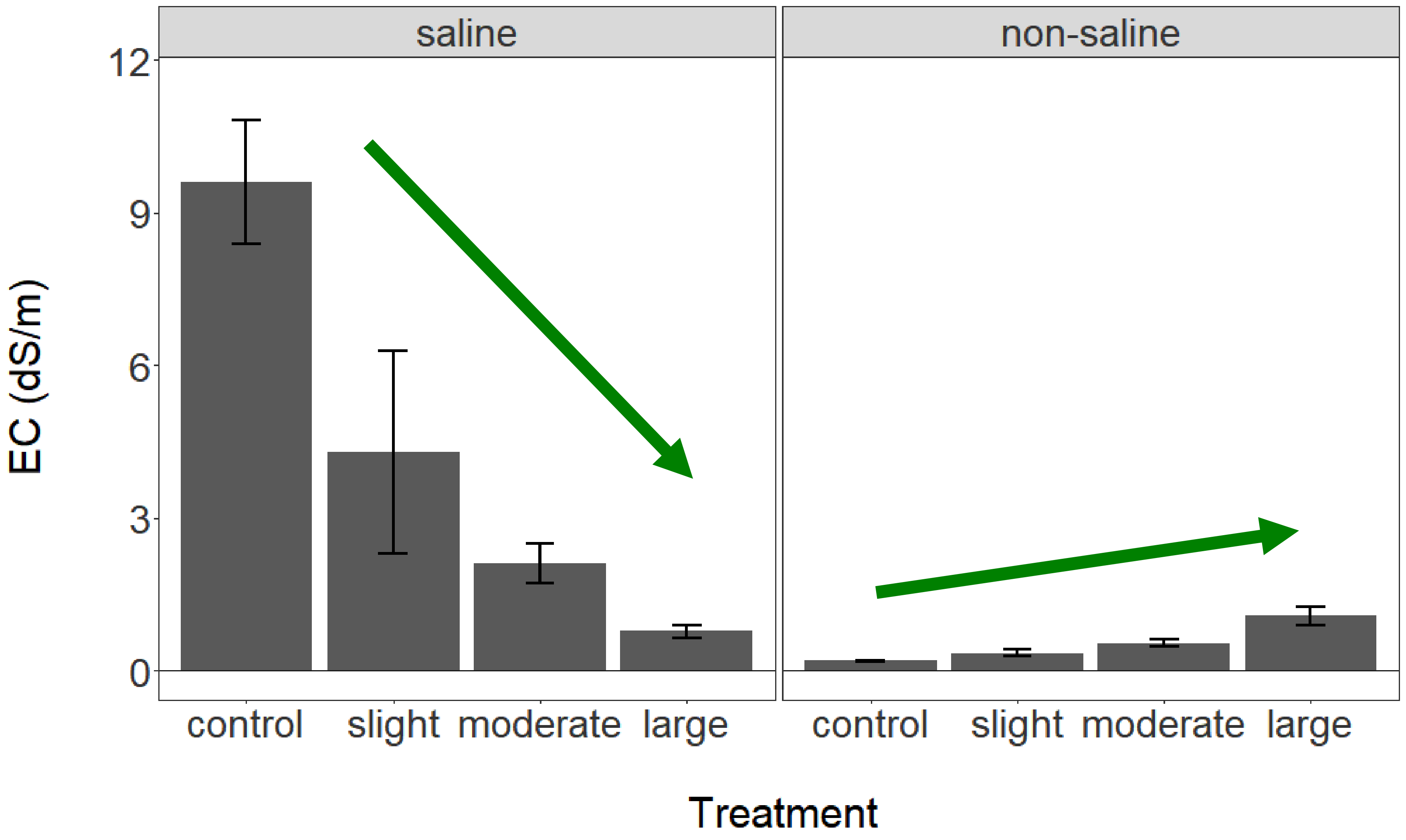
EC: 0.15 dS/m

SOC: 4.2%

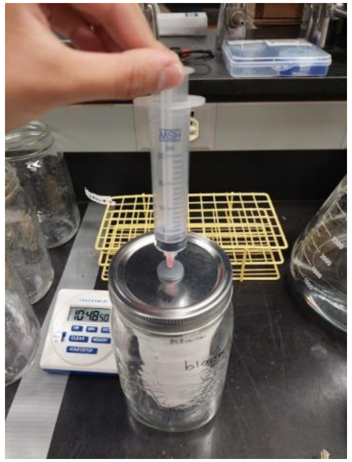
Simulating dynamic wetland salinity conditions with intact soil cores



Changes in soil EC reflected the salinity treatments applied



Greenhouse gas emissions (CO_2, N_2O, and CH_4) were measured using the static chamber method where jars were sealed for 16 hours then the headspace was sampled

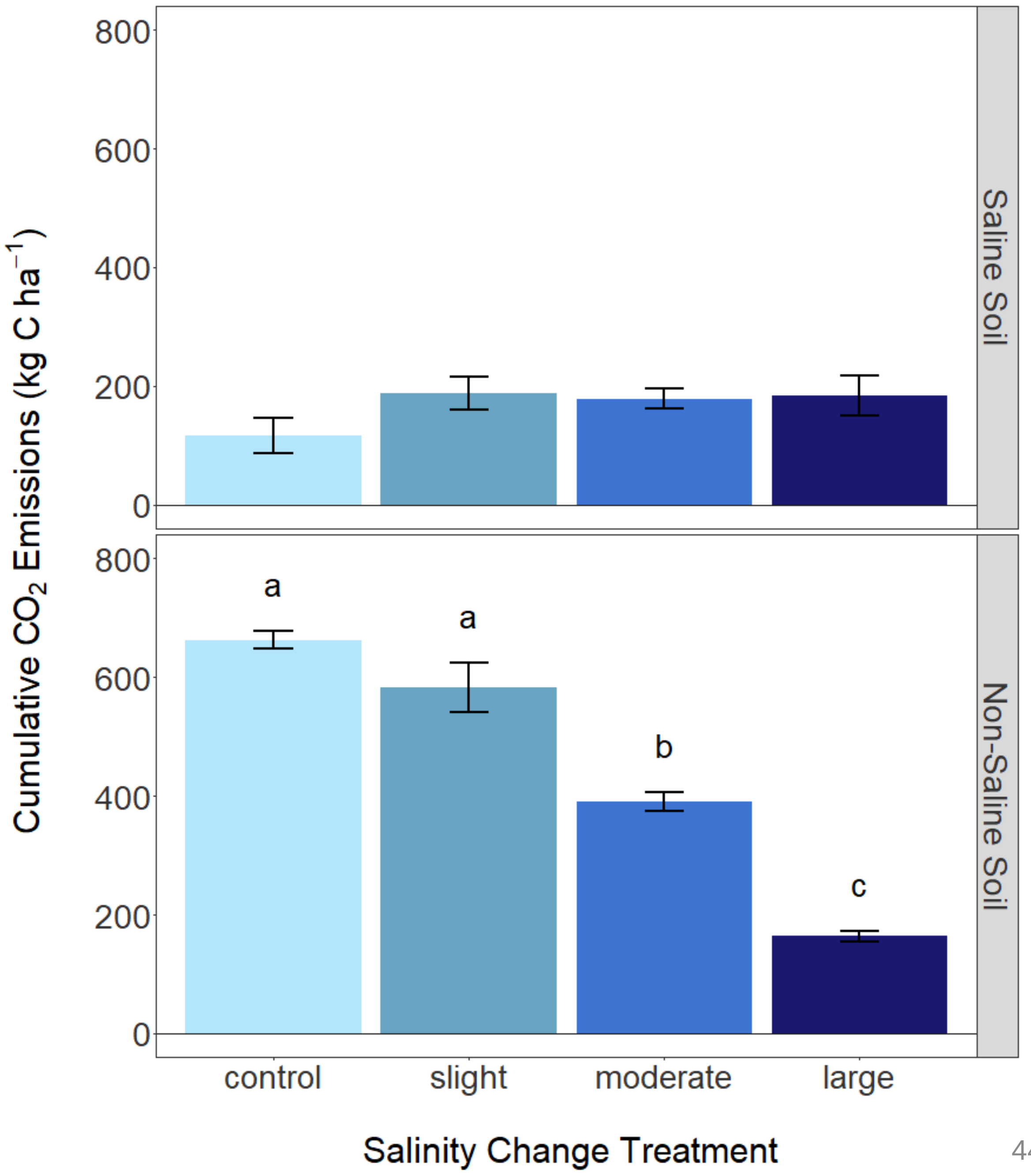


25 sampling dates over 8 weeks
- daily for the first week
- then every 3 days

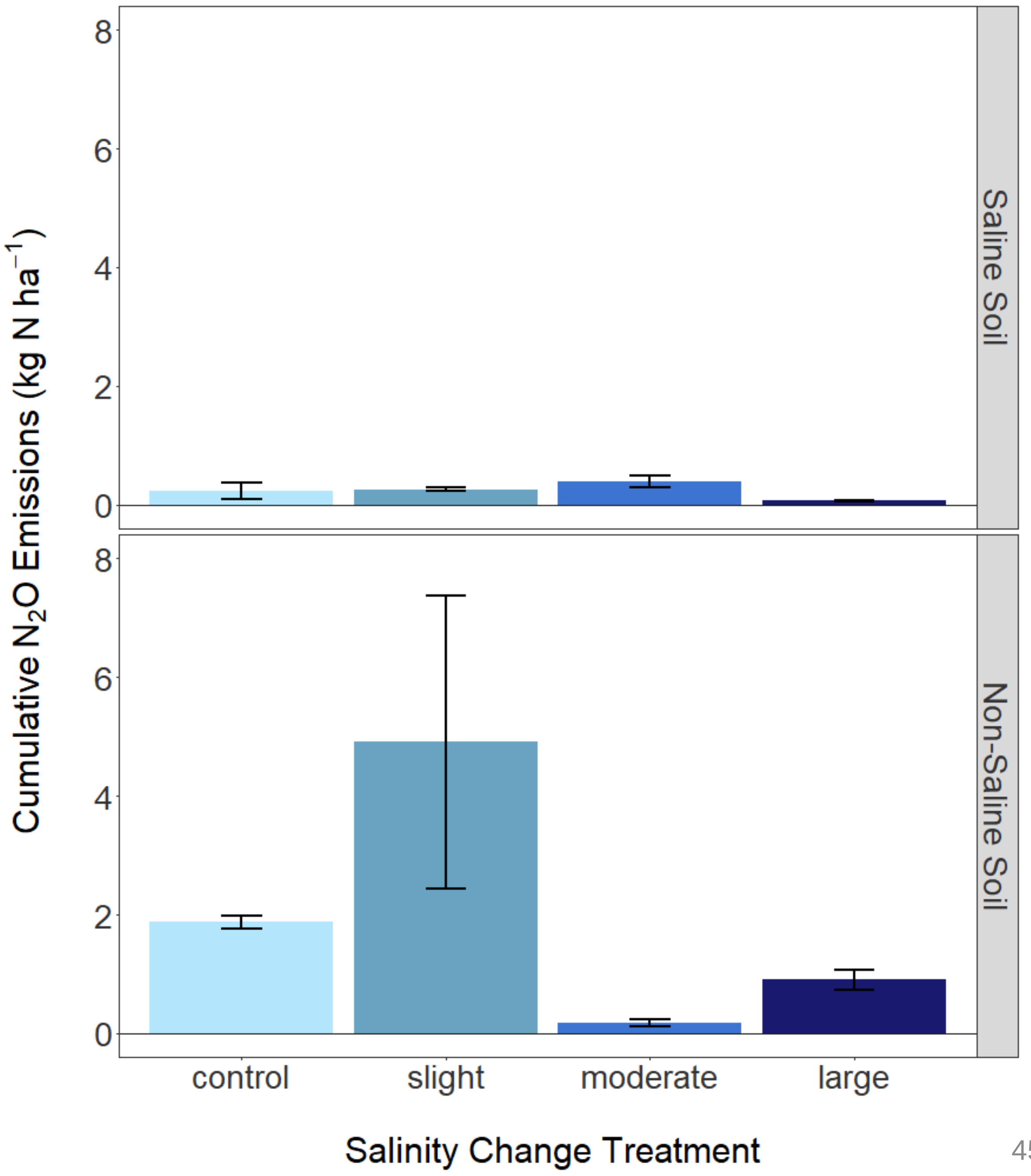
Carbon dioxide emissions had the greatest response to changing soil salinity

CO_2 emissions increased when soil salinity was lowered

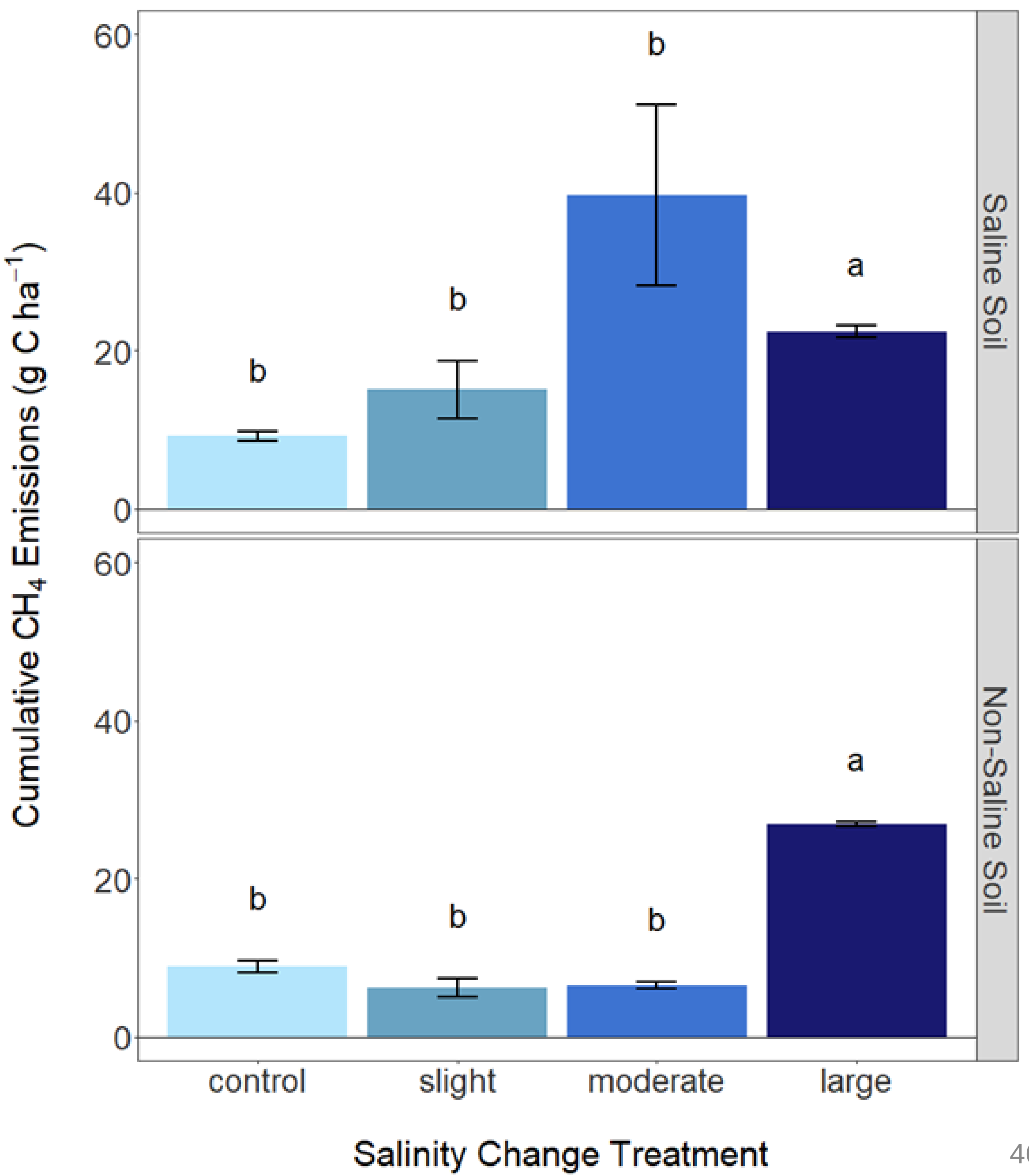
CO_2 emissions decreased when soil salinity was increased



Nitrous oxide emissions were highly variable with no clear trends over the 8-week period

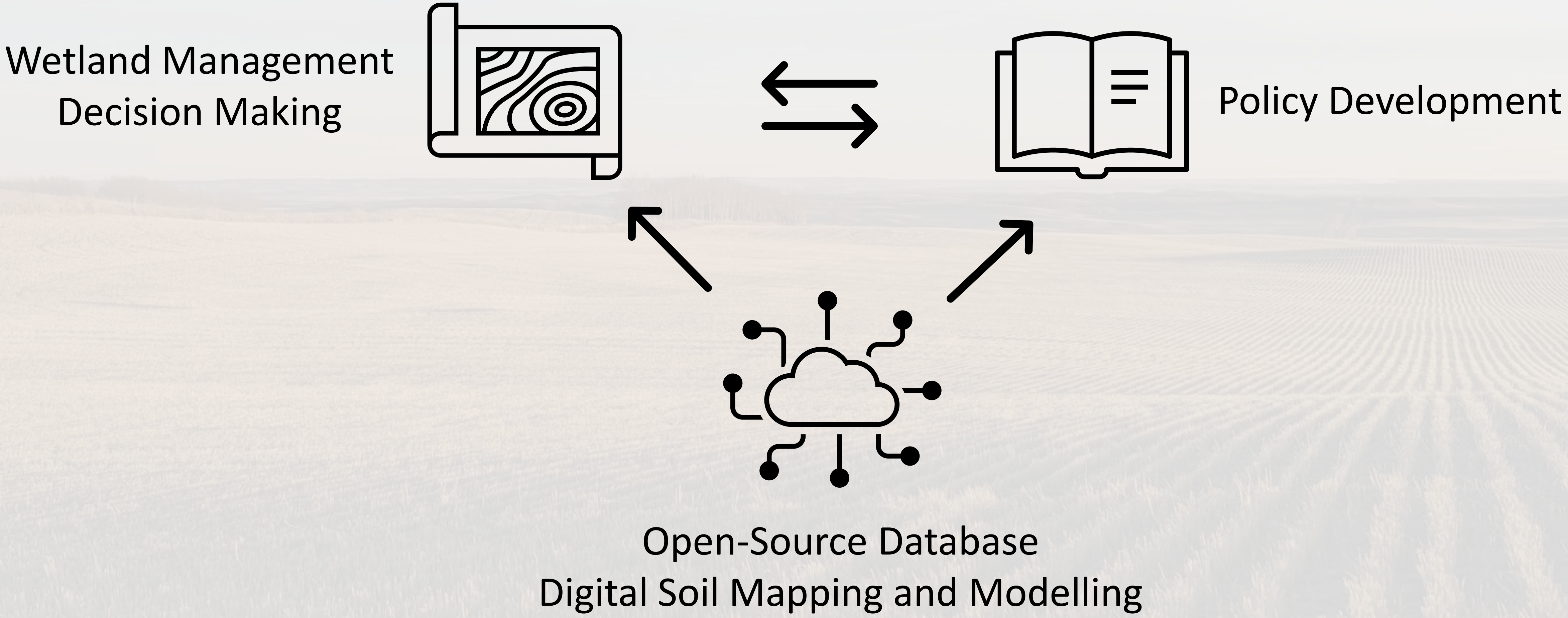


Methane emissions increased with both decreasing and increasing soil salinity



The salinity experiment results demonstrate the link between salinity and GHG emissions, which is relevant to both natural and management-induced salinity changes

The revised soil carbon estimates for the Prairie Pothole Region can be used for environmental carbon budgeting, wetland decision making, and future research



Future Research Directions

PRAIRIE PRECISION SUSTAINABILITY NETWORK

Agricultural practices and soil carbon sequestration in marginal soils

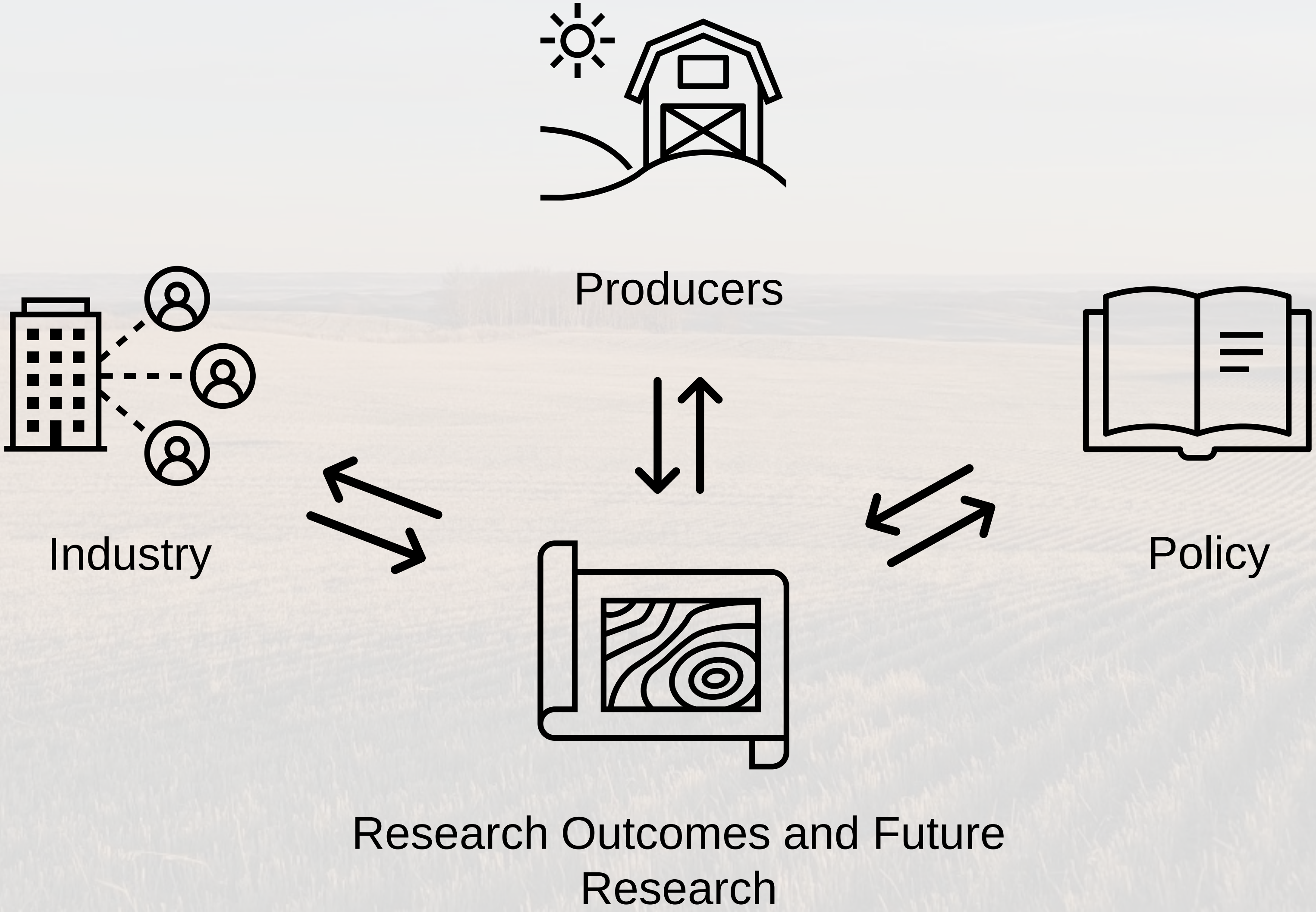
Soil carbon and GHG measurement and monitoring for saline soils

DIGSS

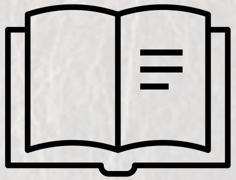
Reference soil organic carbon stocks for prairie pothole wetlands

Soil data management and ownership for land-owners

Research innovation and adoption achieved through collaboration and extension

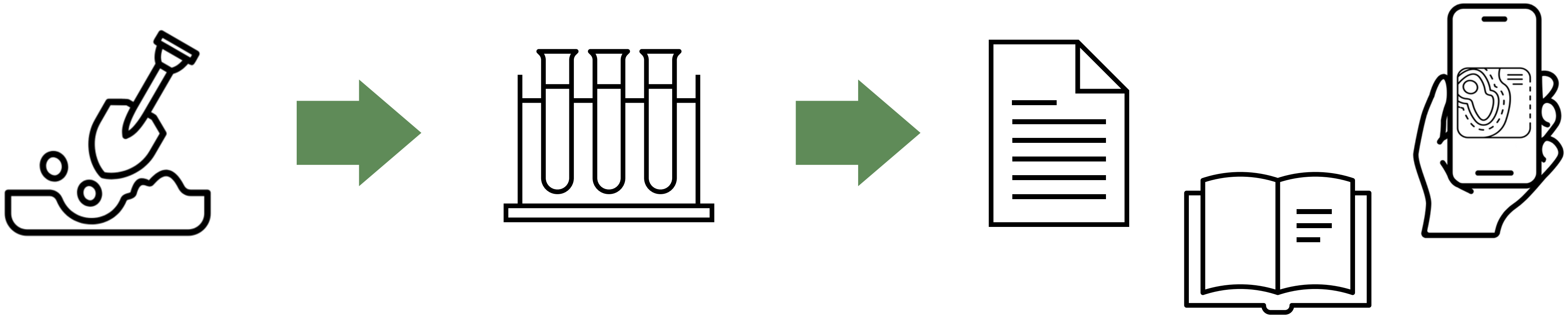


Extension – Making Soil Data Interpretation Accessible



Beneath the Surface: Understanding Your Soil

a free, customizable reference guide for interpreting soil analyses



Icon credit: Melisa Lutfiani

UNIVERSITY OF SASKATCHEWAN

Saskatchewan

Water Security Agency

NSERC CRSNG

PRAIRIE WATER
GLOBAL WATER FUTURES

NSERC RESNET

FFAR Fellows
Future Leaders for Food and Agriculture

Thank You!

Collaborators: Angela Bedard-Haughn, Helen Baulch,

Jeff Schoenau, Derek Peak, and Bobbi Helgason

Chantel Chizen
chantel.chizen@usask.ca

DIGSS
Research Group
dig-soilscience.research.st