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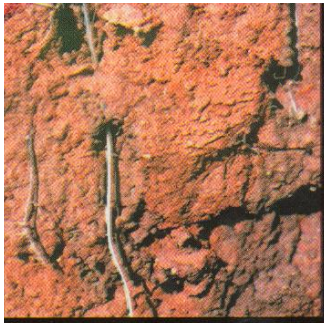
Climate Change and Sustainable Agriculture



Mitigating N_2O Fluxes in Croplands

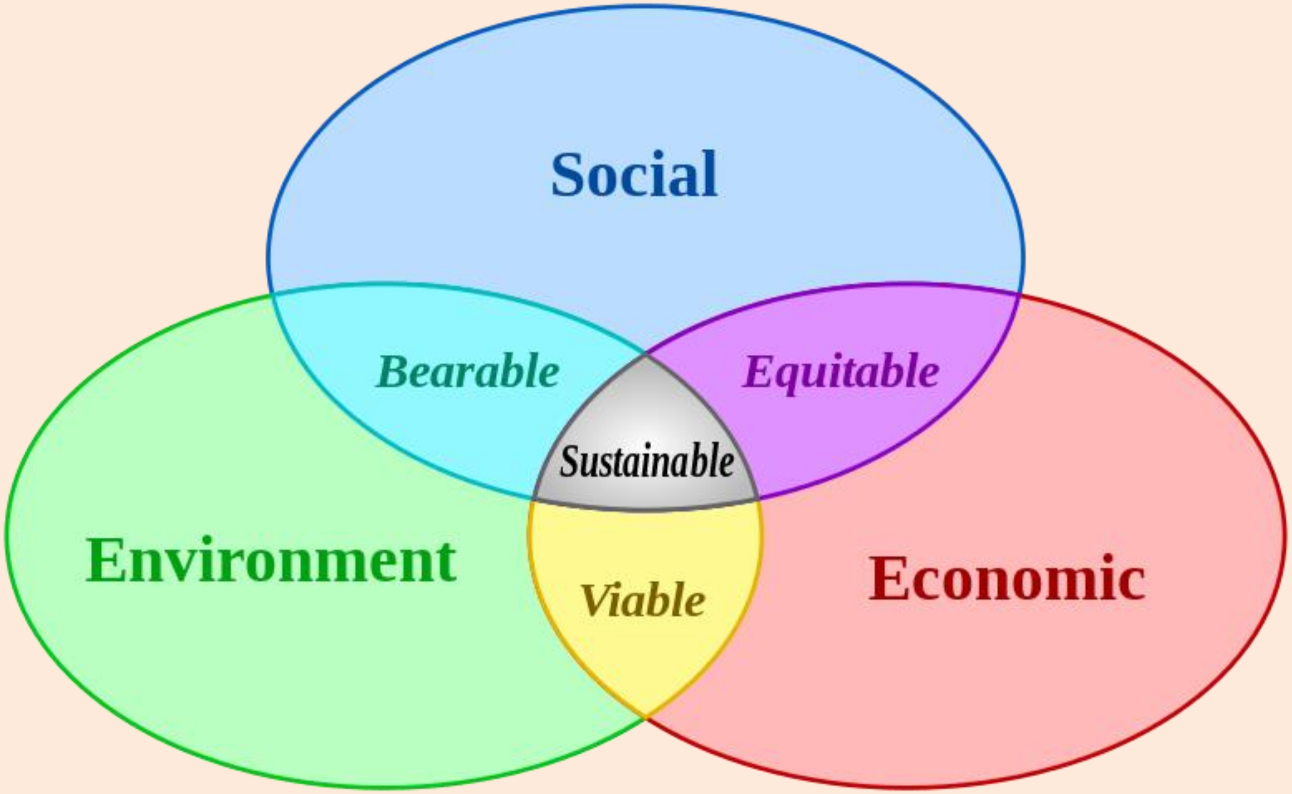
Adaptation for Enhanced H_2O Availability

Annual vs. Perennial Grain Cropping Systems

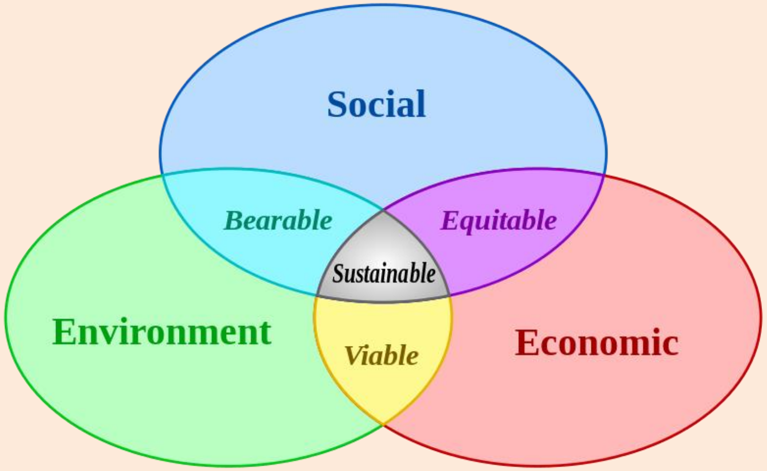
Guillermo
Hernandez Ramirez

UNIVERSITY OF ALBERTA
DEPARTMENT OF
RENEWABLE RESOURCES

Sustainability



Both Sustainability and CC share a **Long-Term** aspect



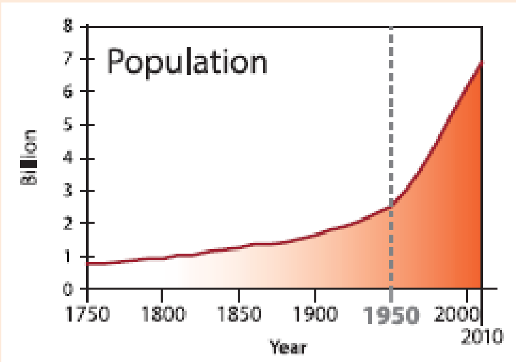
Ancestral Approaches to Sustainable Land Management and Climate Change

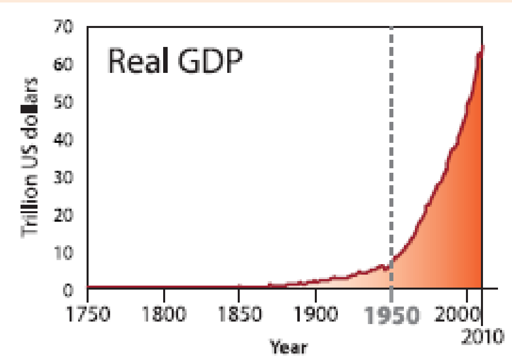
Moray site, Cusco

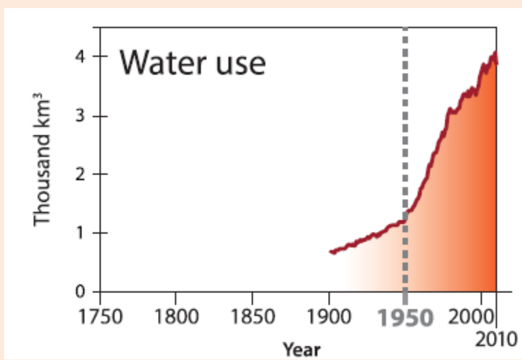
Terraces, irrigation

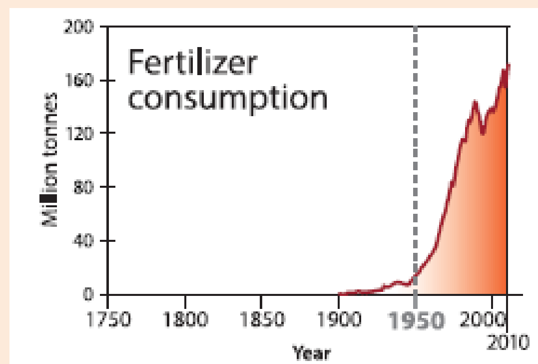
Water conservation: Qocha (yani, wachus)

The Great Acceleration Worldwide









The Anthropocene Review
2015, Vol. 2(1) 81–98

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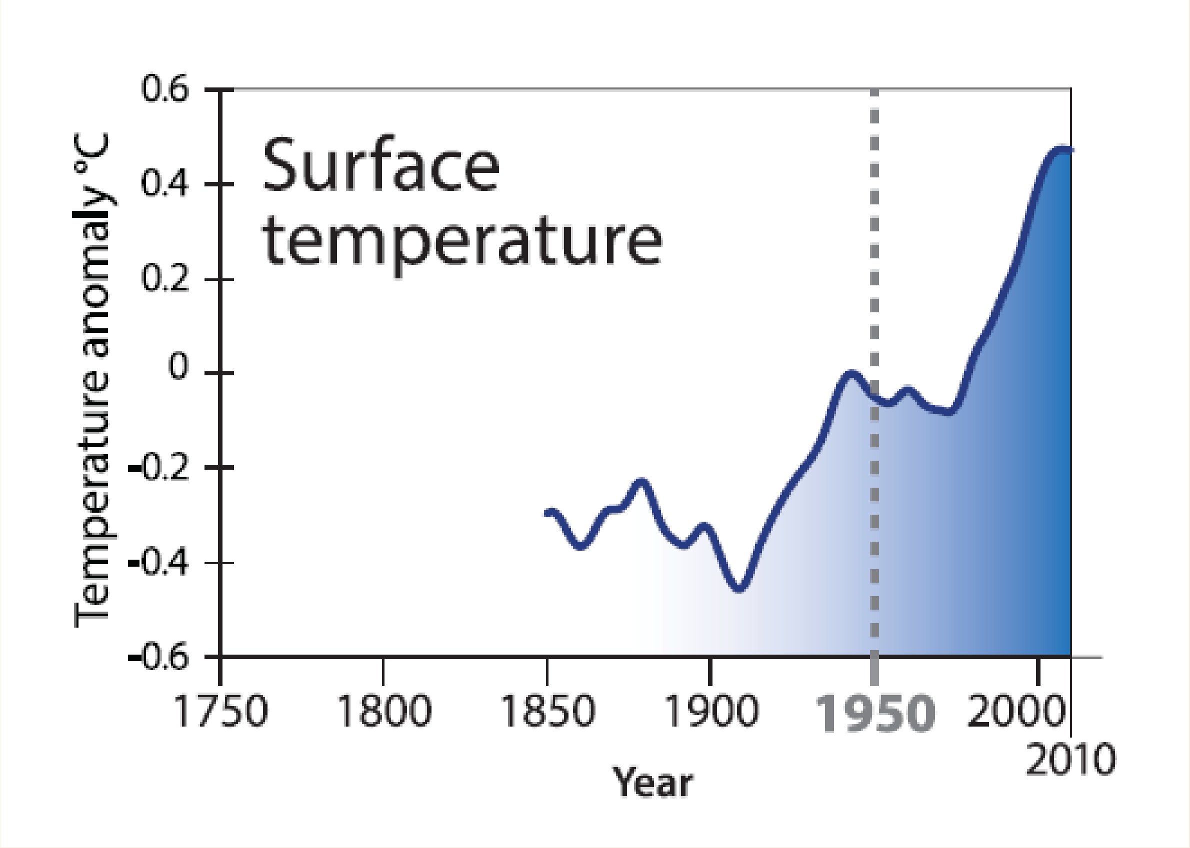
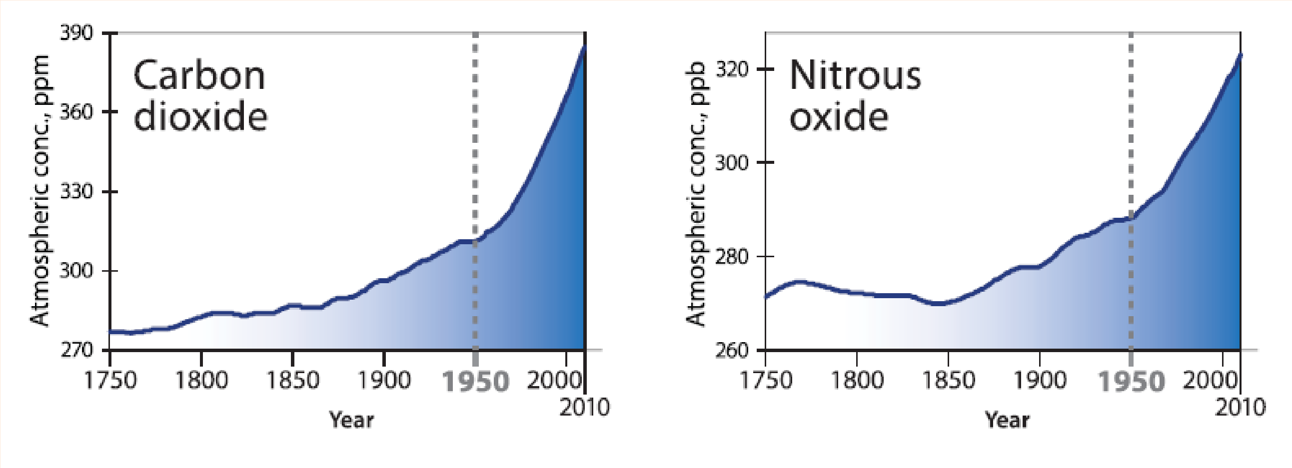
The trajectory of the Anthropocene: The Great Acceleration

Will Steffen,[1,2] Wendy Broadgate,[3] Lisa Deutsch,[1] Owen Gaffney[3] and Cornelia Ludwig[1]

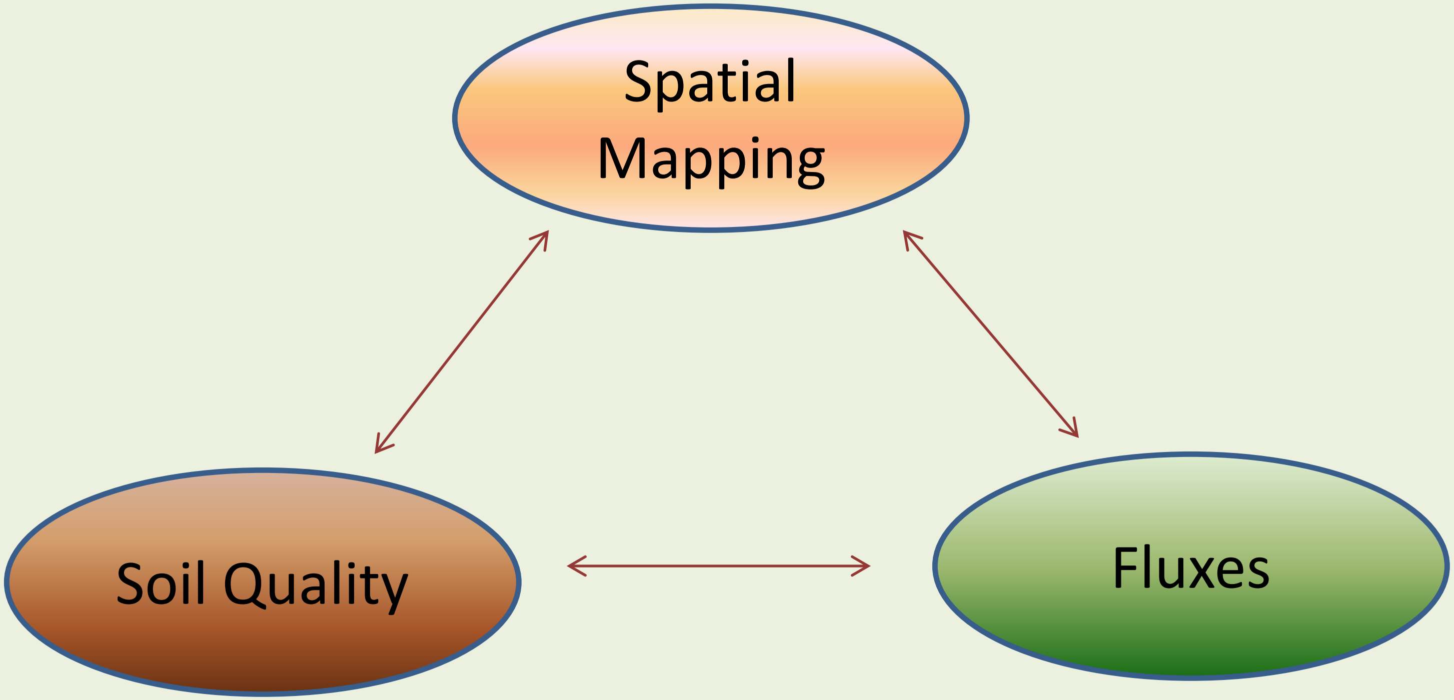
The Great Acceleration Worldwide



Atmospheric Trajectory



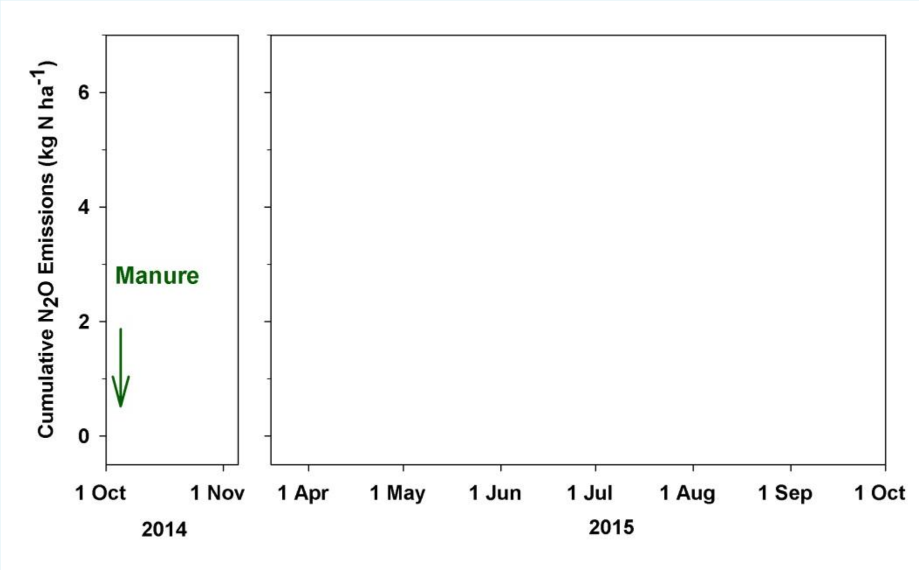
Research Scope(s)



Mitigating N_2O Fluxes in Croplands

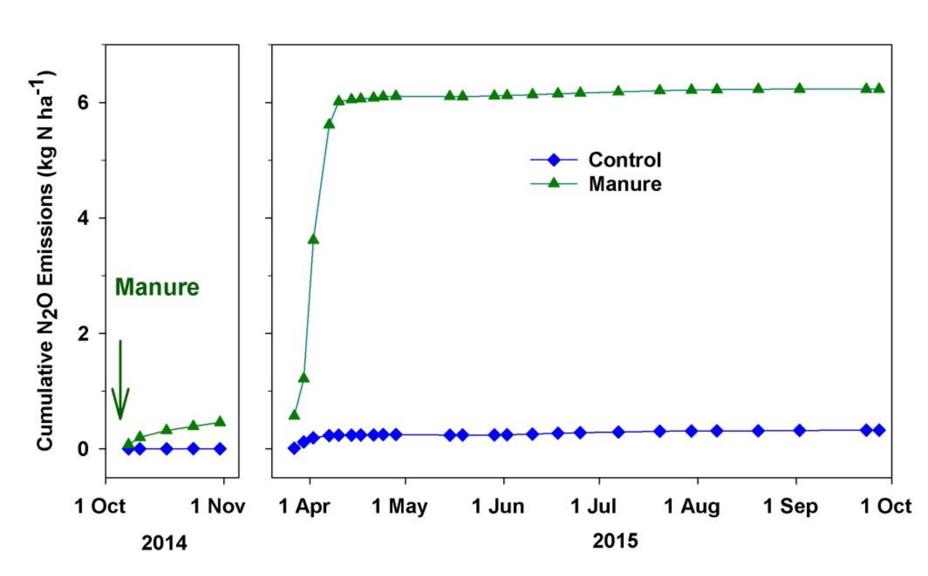
N_2O Fluxes in Croplands:

- N-saturated soils (due to high natural soil fertility and N additions)



N_2O Fluxes in Croplands:

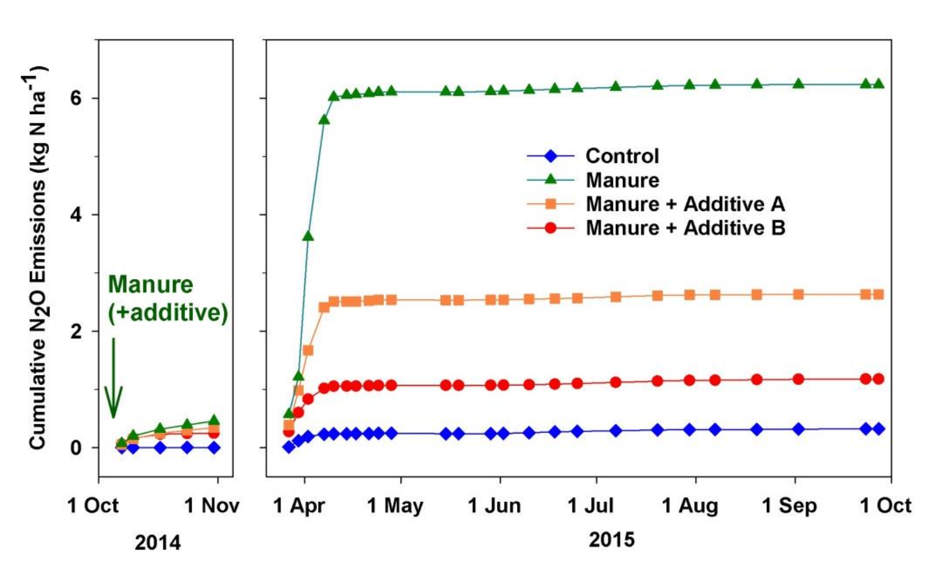
- N-saturated soils



- Manured fields 5.7 Kg N_2O-N ha^{-1} (1.8 Mg CO_2-C eq.)
- 2/3 of emissions occurred at the onset of the spring

N_2O Fluxes in Croplands:

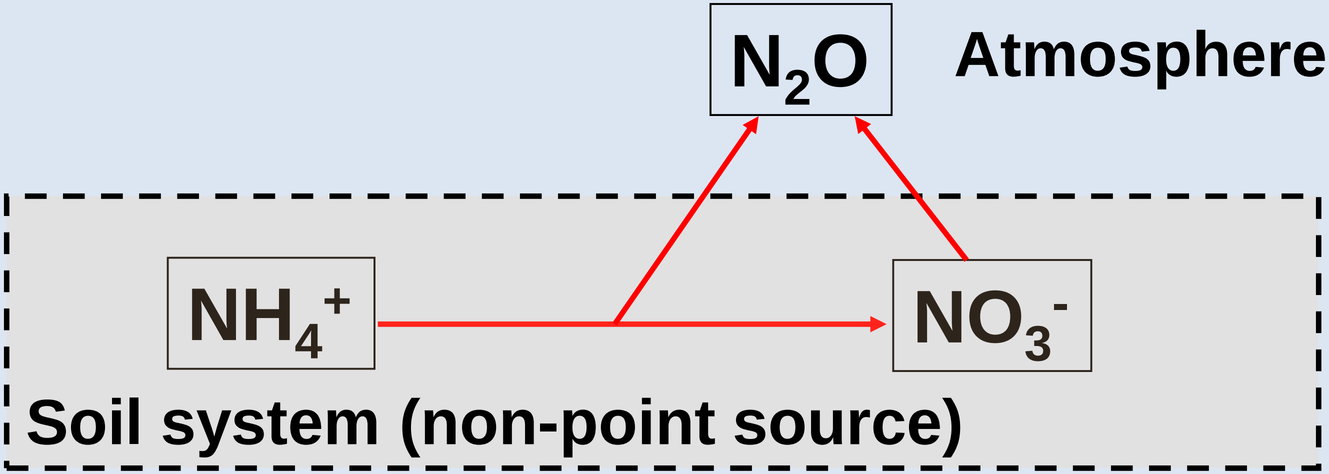
- N-saturated soils



- 58 or 81 % N_2O emission reduction using additives.

Soil Sci. Soc. Am. J. 81:1595–1605
doi:10.2136/sssaj2017.03.0093

Soil N Cycling and N_2O Production



- Sources and flux modelling.

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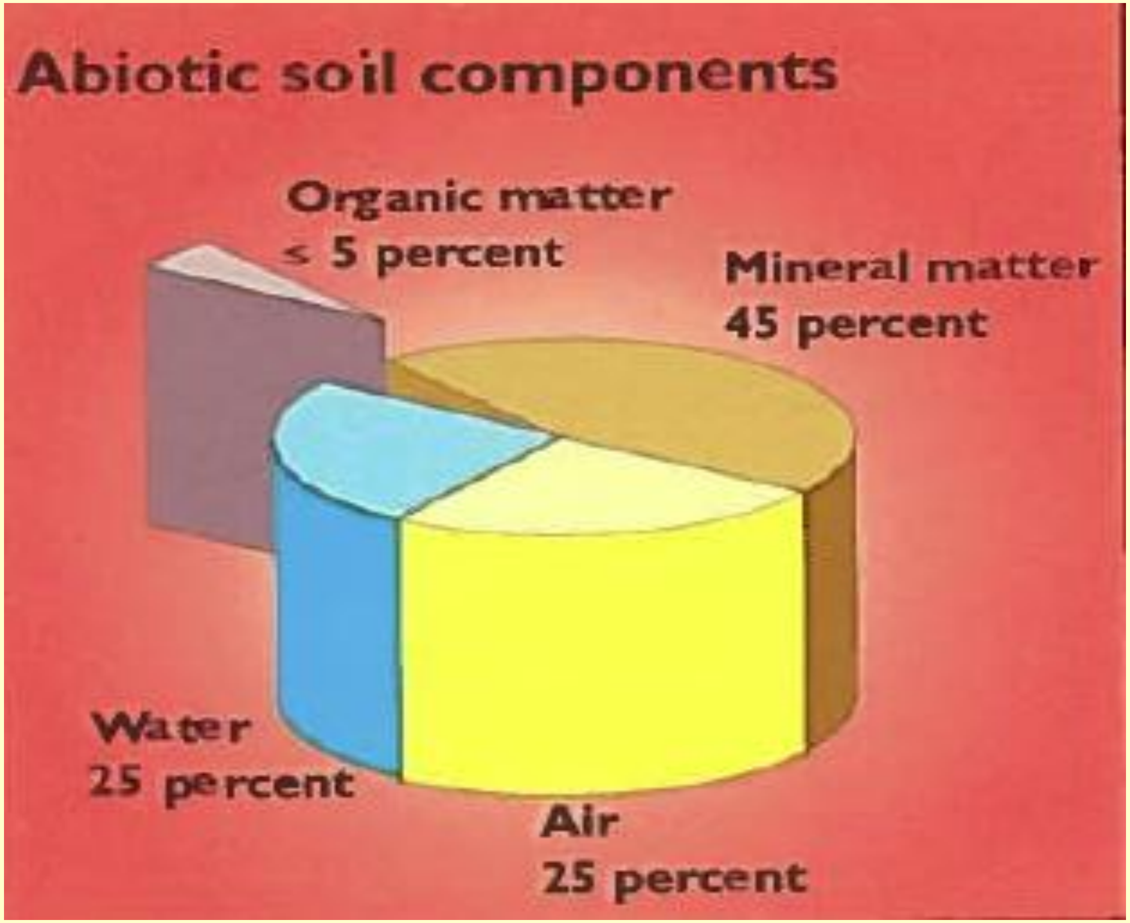
To Enhance Soil Water Availability can Buffer Weather Extremes

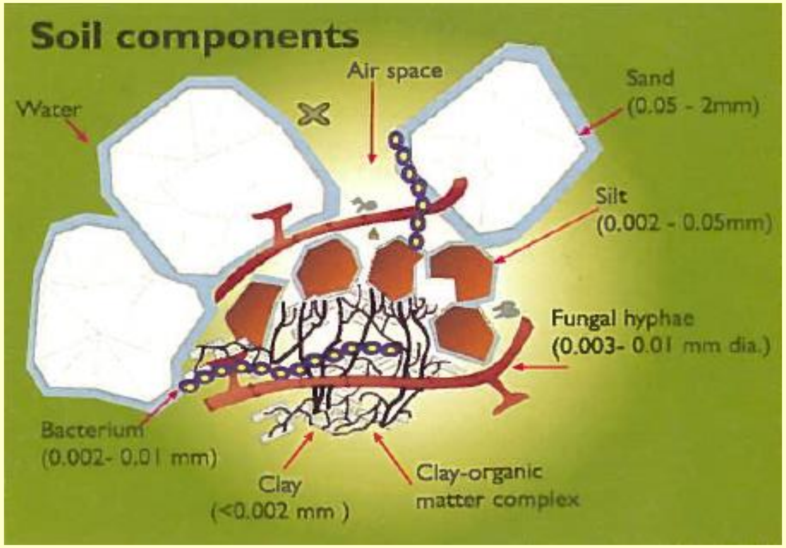
Research on Soil Water Availability

- Soil organic matter can increase moisture availability.
- Long-term experimental site at Breton, AB.

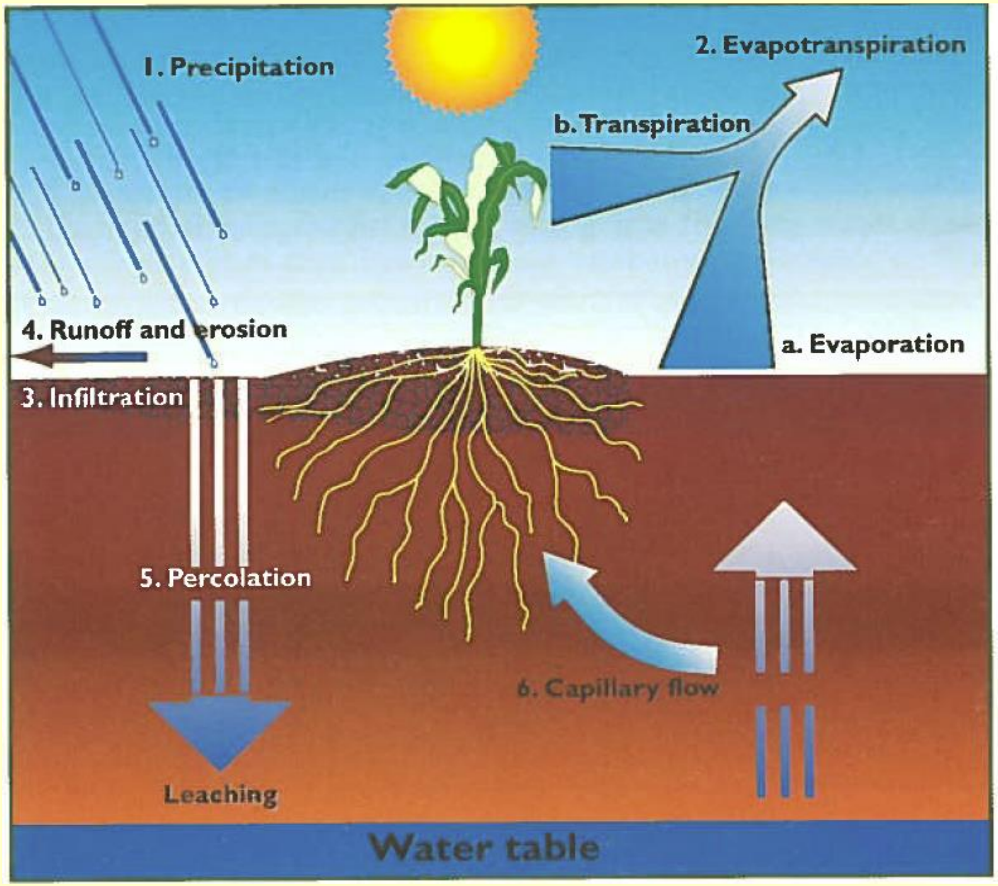
Soil Components



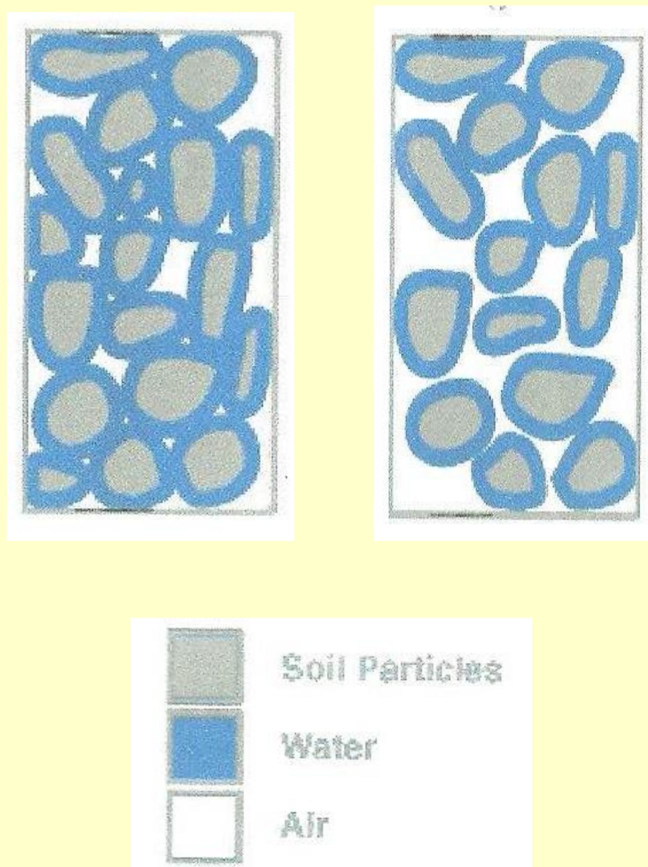
How soils are organized ?



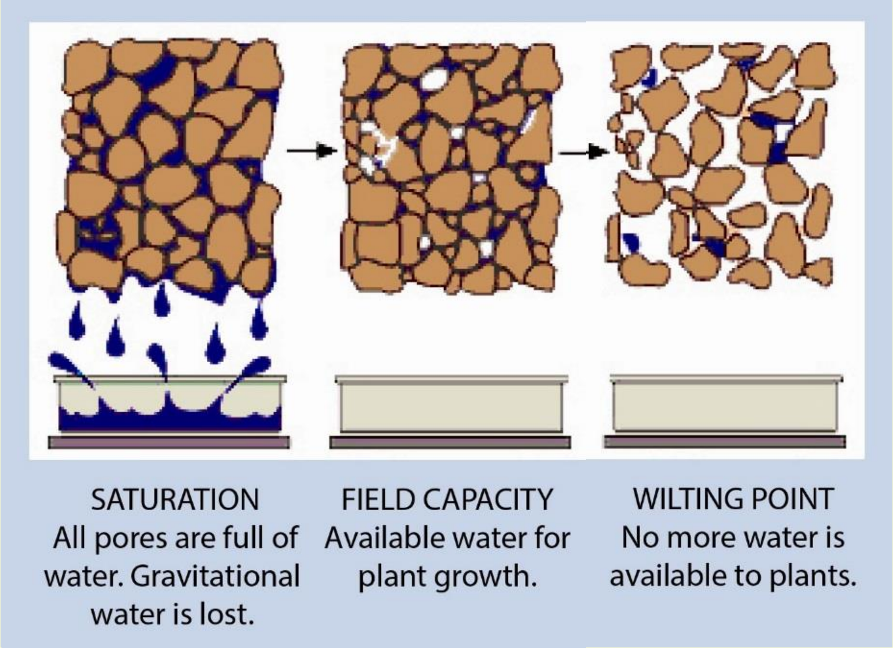
The Water Cycle

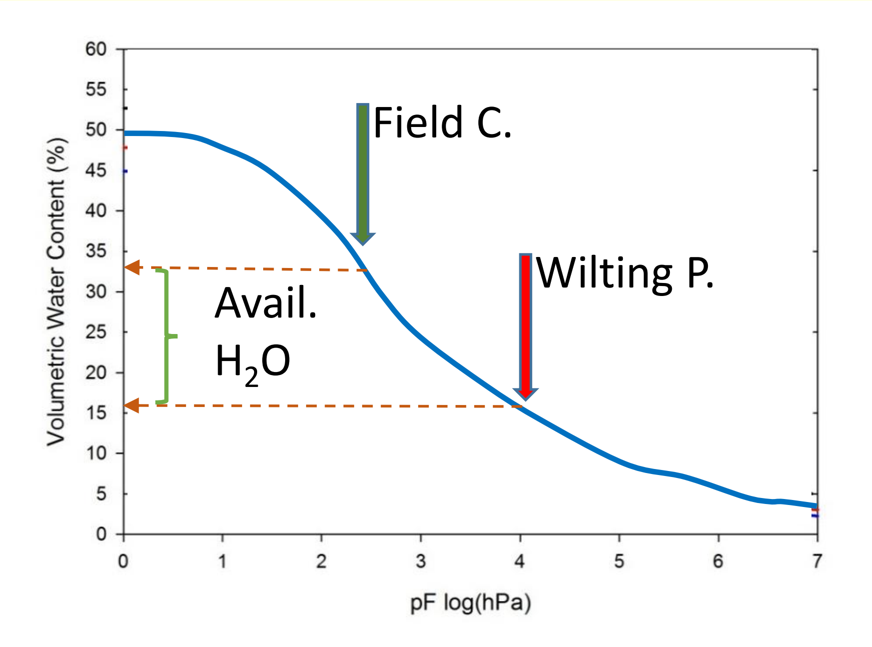


Where is water in soils?



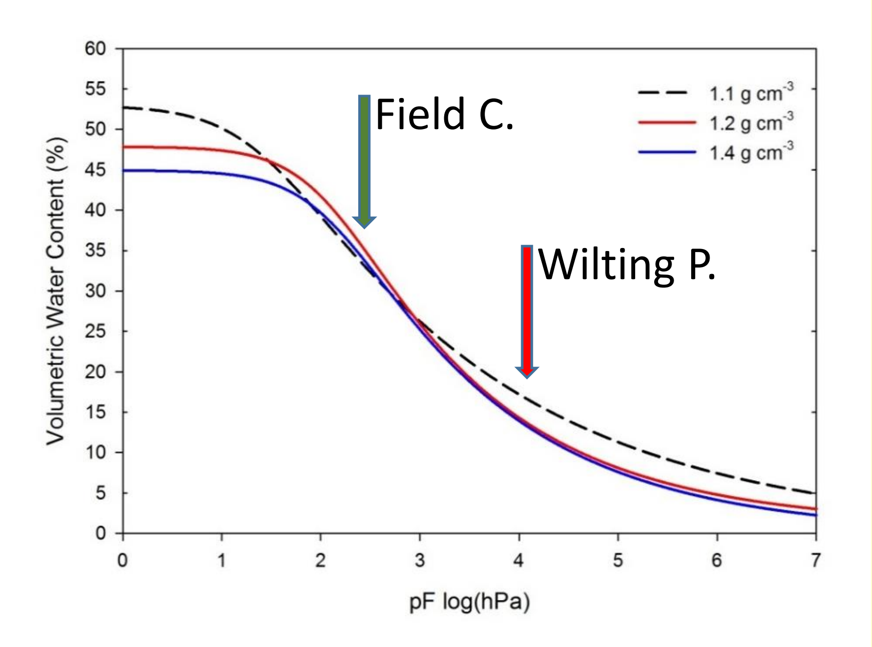
Water Retention in Soils





Measuring Water Retention

Water Availability and Soil Compaction (as bulk density)



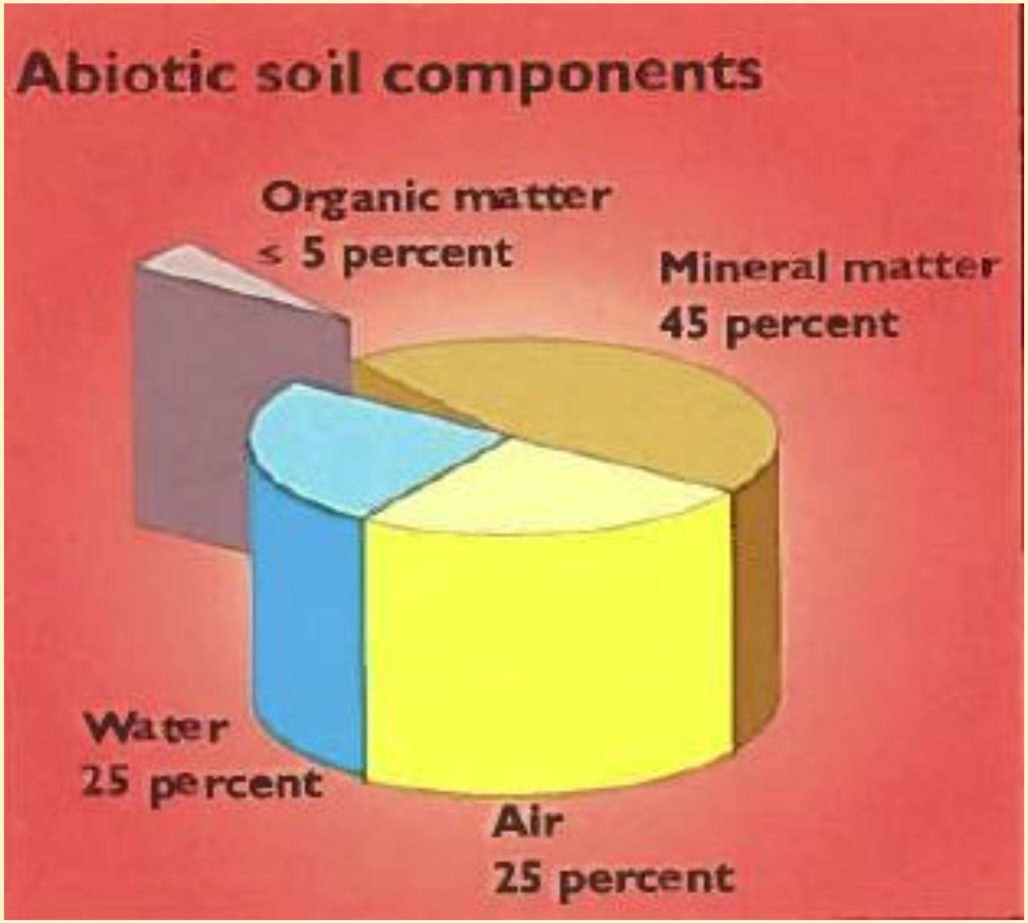
Guenette KG (2018) Agronomy

An Insight…

- Soils hold water available for plants.

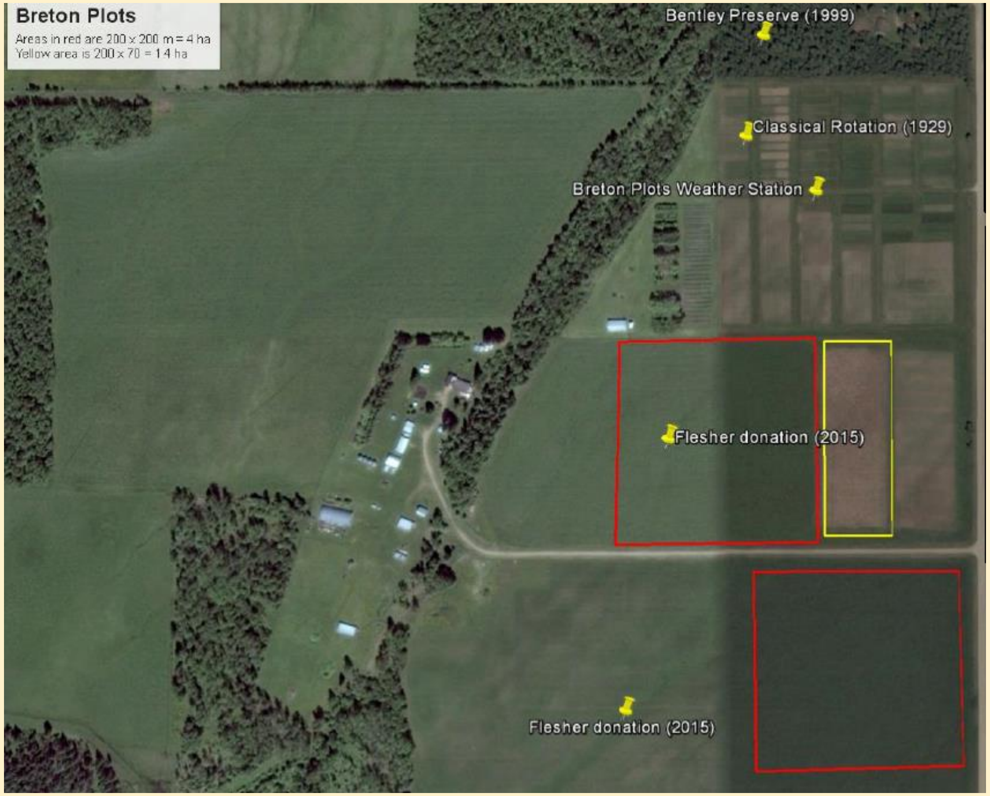
- How to improve this capacity ?

A Key Soil Component: Organic Mater



Breton Experiment Since 1930

- Grey wooded soil
  - Dark Gray Luvisol
  - Alfisols



Breton Rotations:

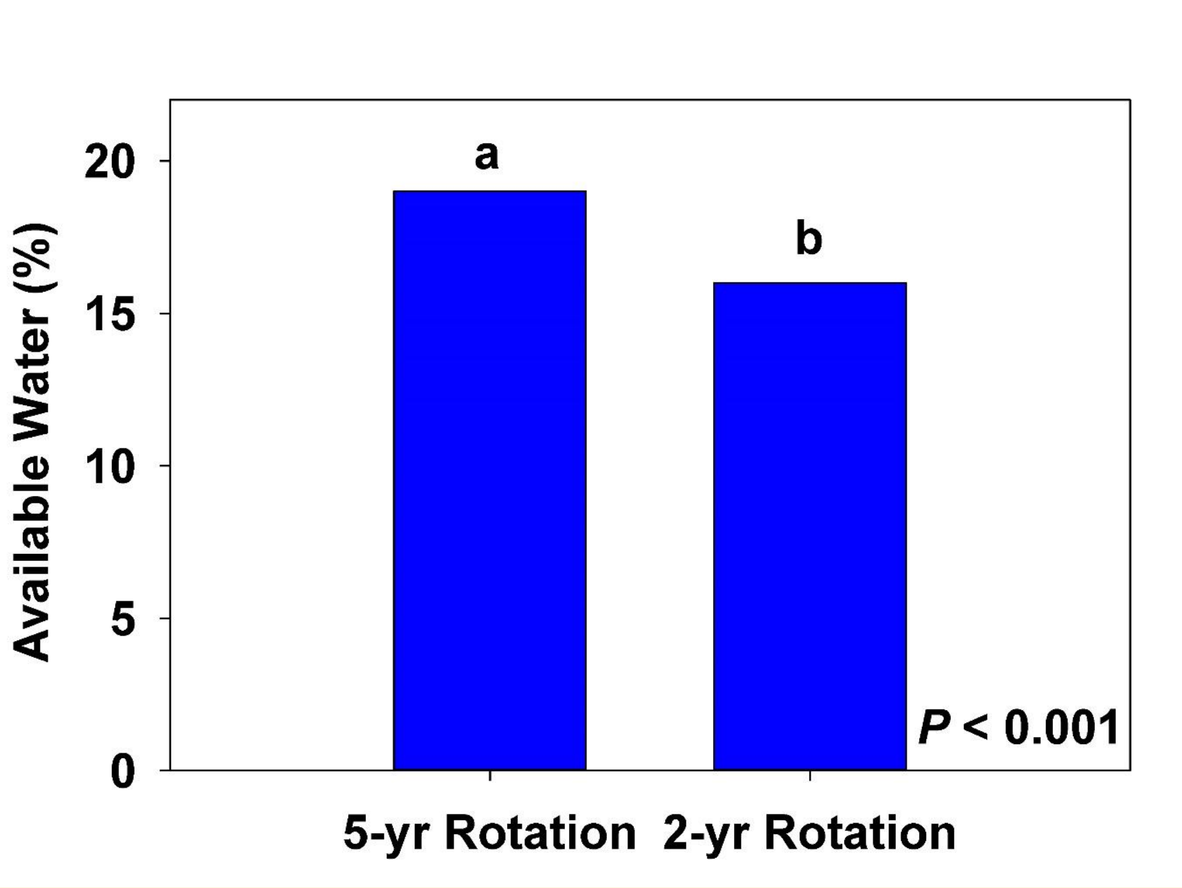
Two-year Wheat-Fallow Rotation

Wheat$_{2yrR}$ → Fallow

Complex Five-year Crop Rotation

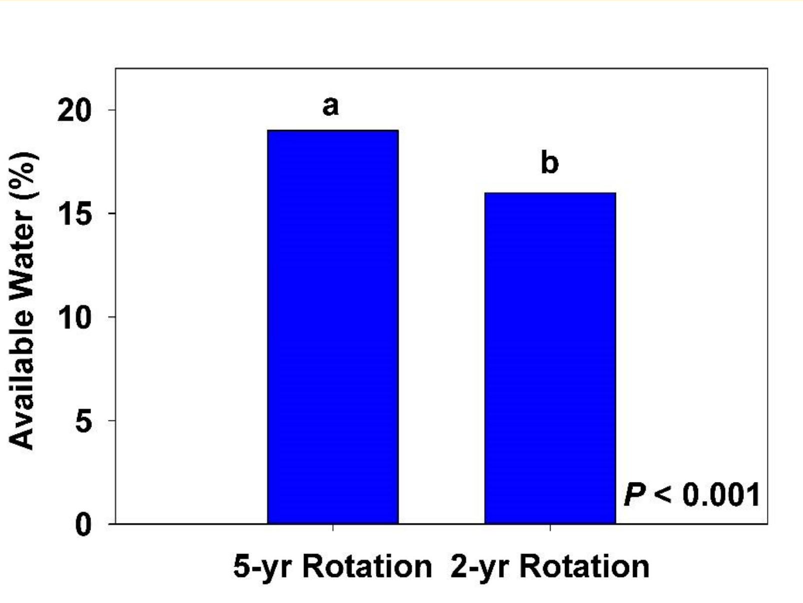
Wheat$_{5yrR}$ → Oats → Barley/Hay → **Hay$_1$** → Hay$_2$

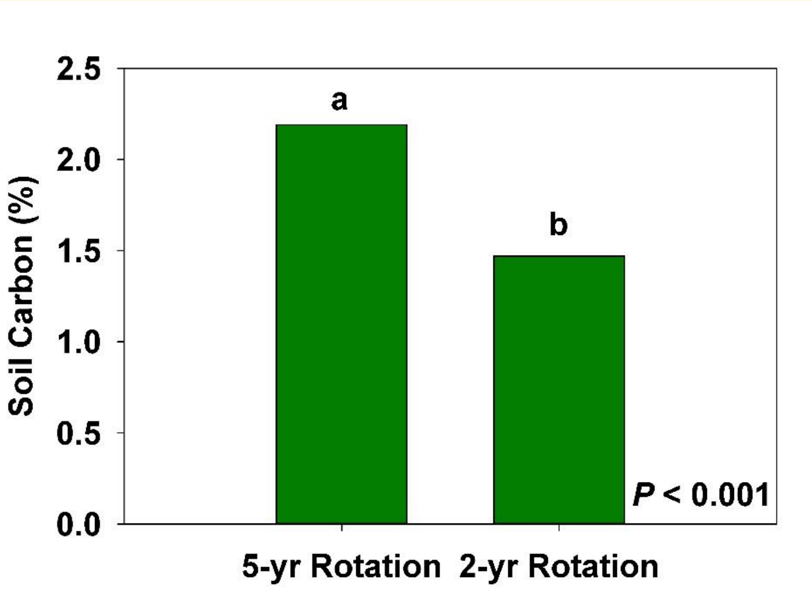
Water Availability with Rotation



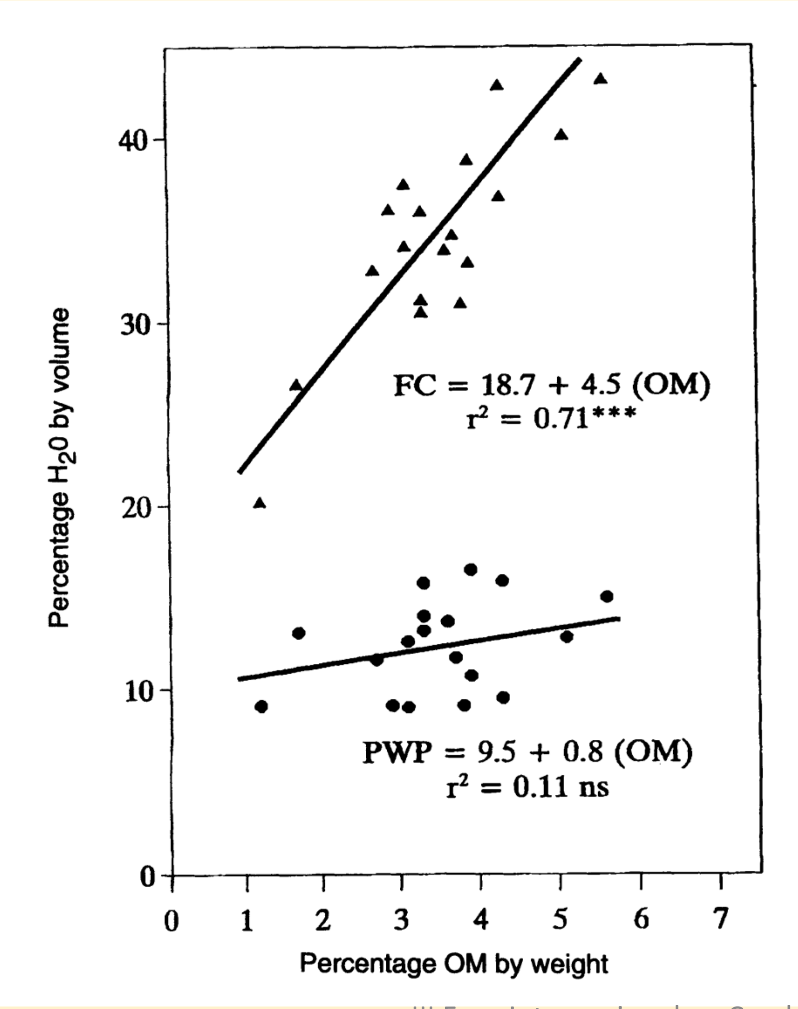
Kiani M (2017) Agriculture, Ecosystems and Environment

More Water Availability with more Soil Carbon (Organic Matter)



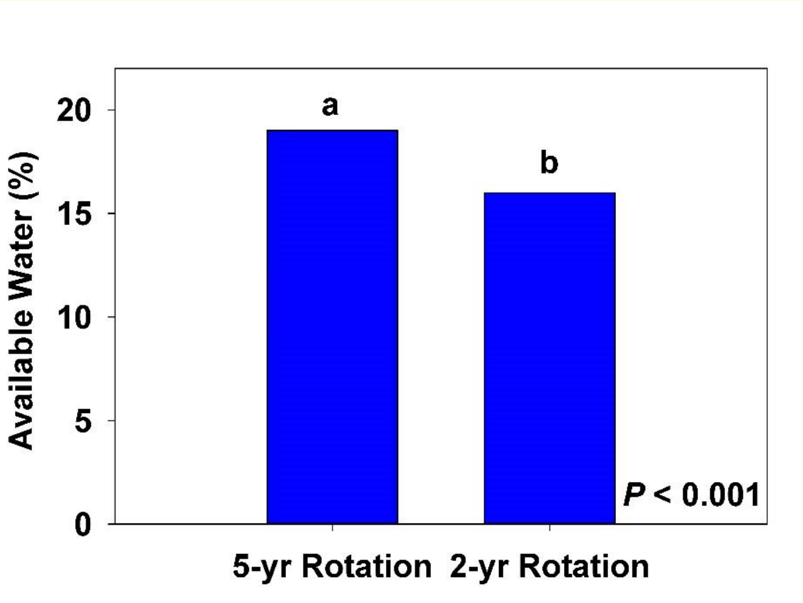


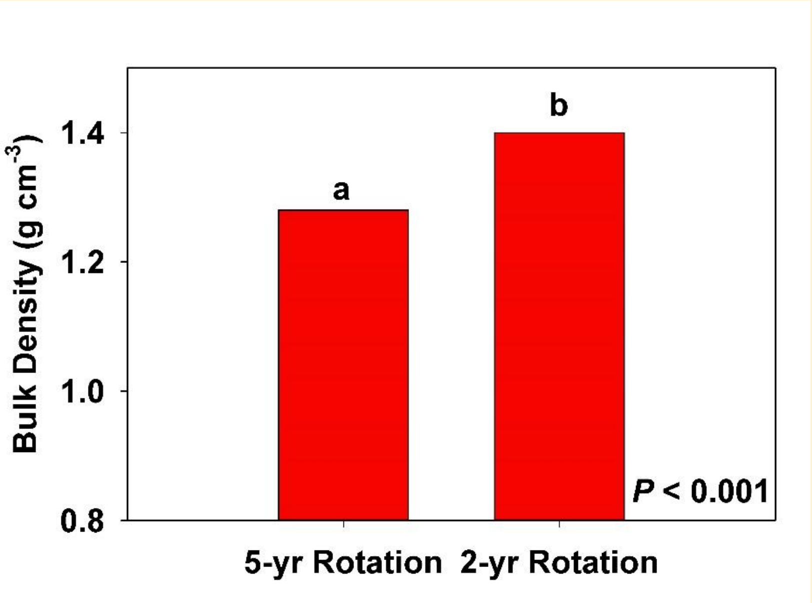
Soils hold water…
even more when enriched with organic matter



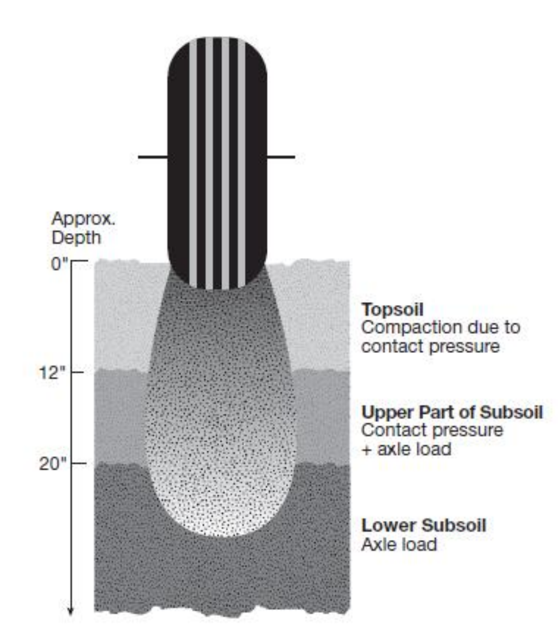
Hudson, 1994
Journal of Soil and Water Conservation

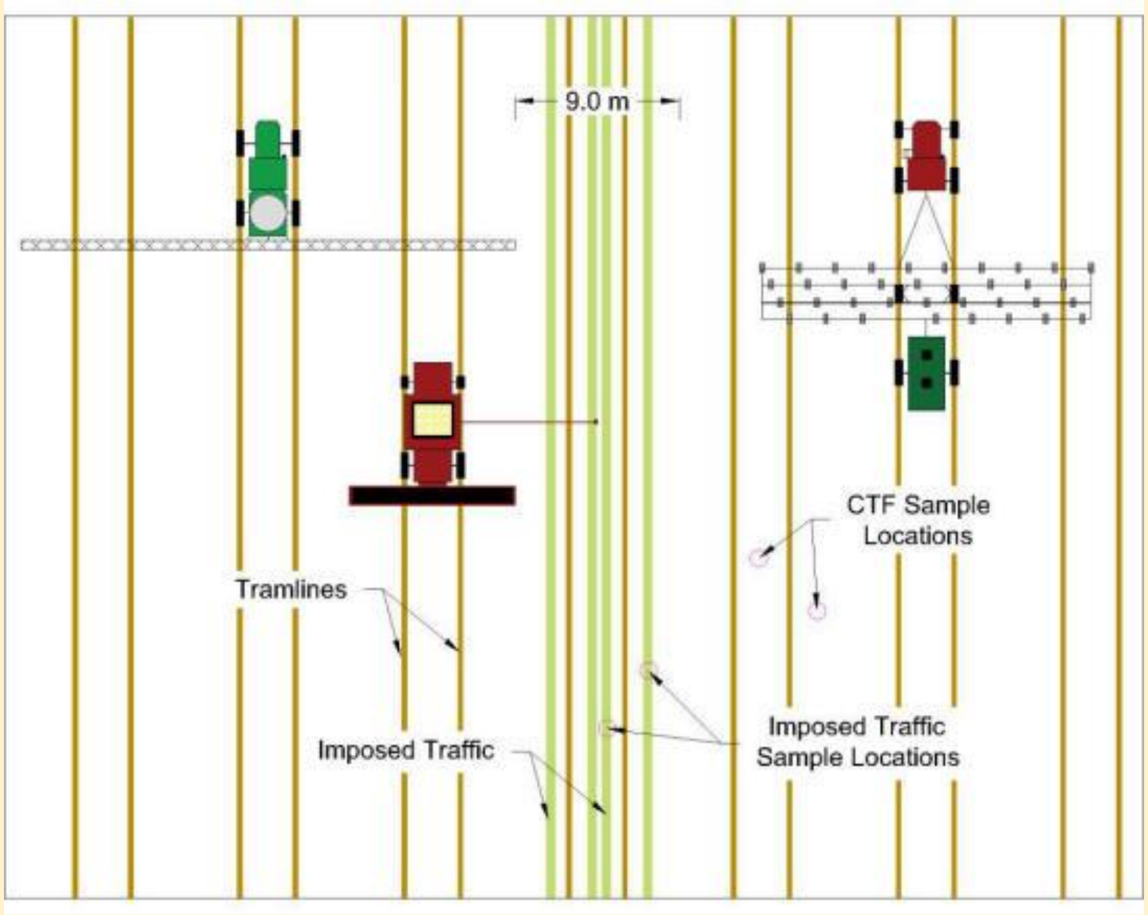
More Water Availability with less Soil Density



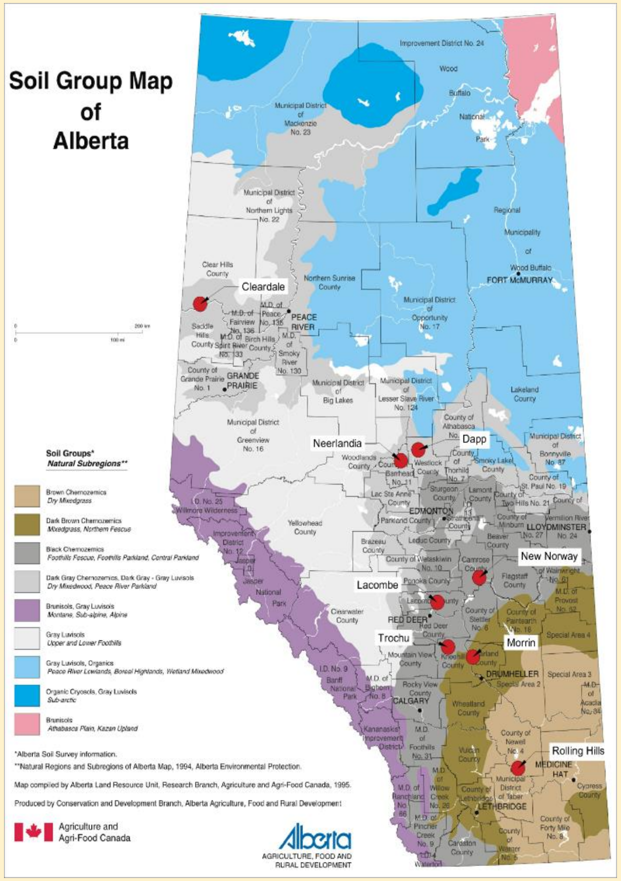


Traffic in Croplands



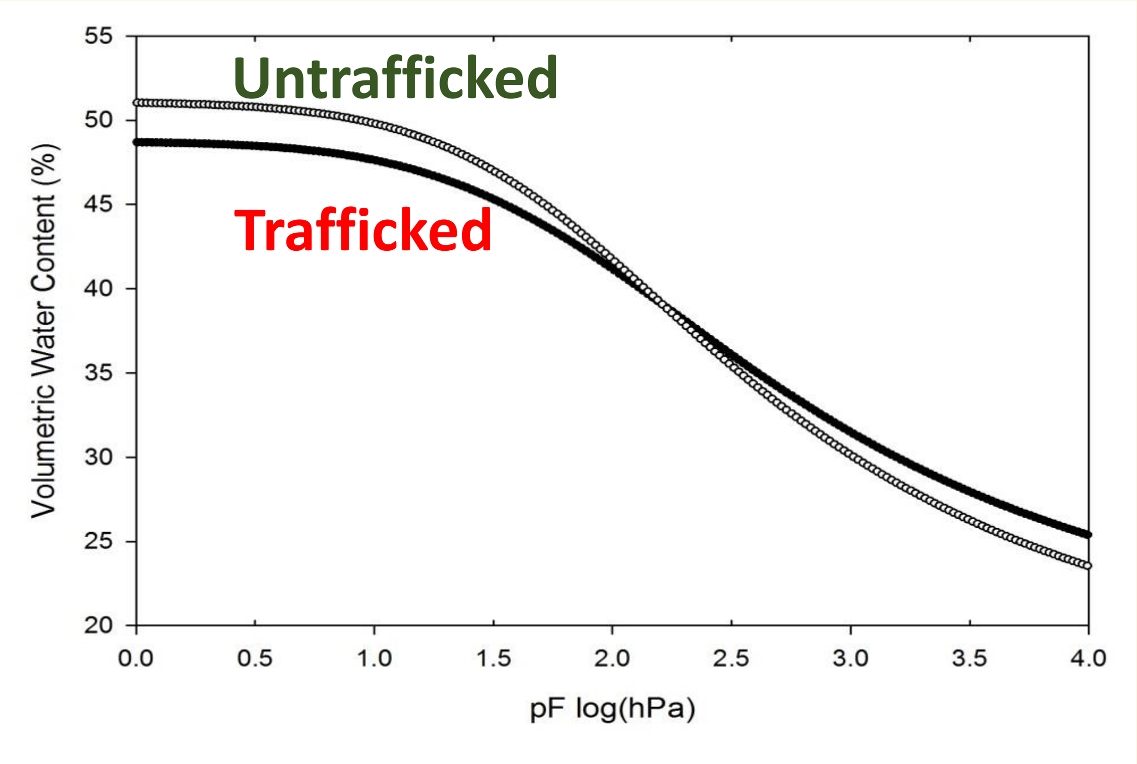


Studying traffic effects in no-tillage farms in Alberta



by Alberta Agriculture & Forestry:
http://www1.agric.gov.ab.ca/soils/

Effects of Farm Equipment Traffic



Guenette KG (2019) Can. J. Soil. Sci

Managing Plant Residues

With escalating climate change, one strategy is to transform cropping systems… *from annual to perennial cereals*

- Wheat, rye, rice…
- A perennial root system is key

Annual and Perennial Rye for Grain

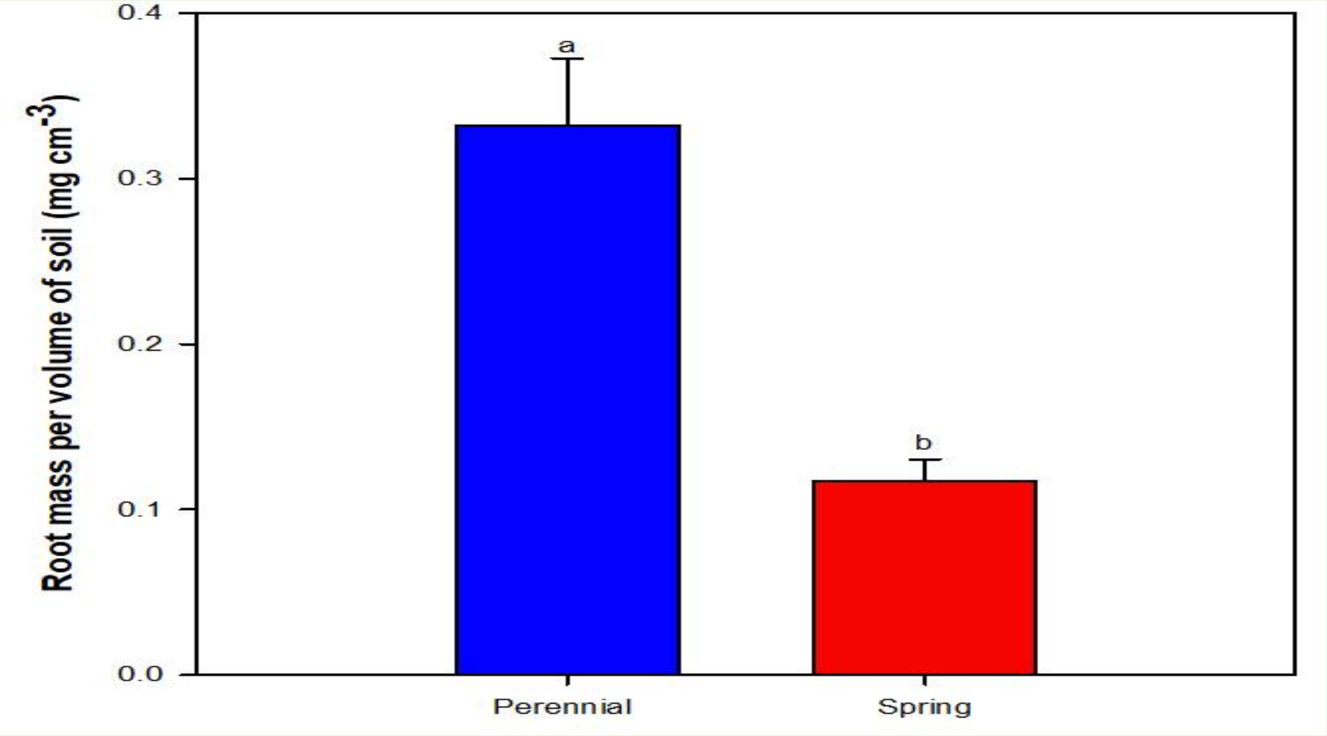
Perennial Grain Fields at Breton

Roots

Root Sampling at various Soil Depths

- 0-15 cm depth
- 15-30 cm depth
- 30-60 cm depth

Roots at Breton *at 30-60 cm depth*

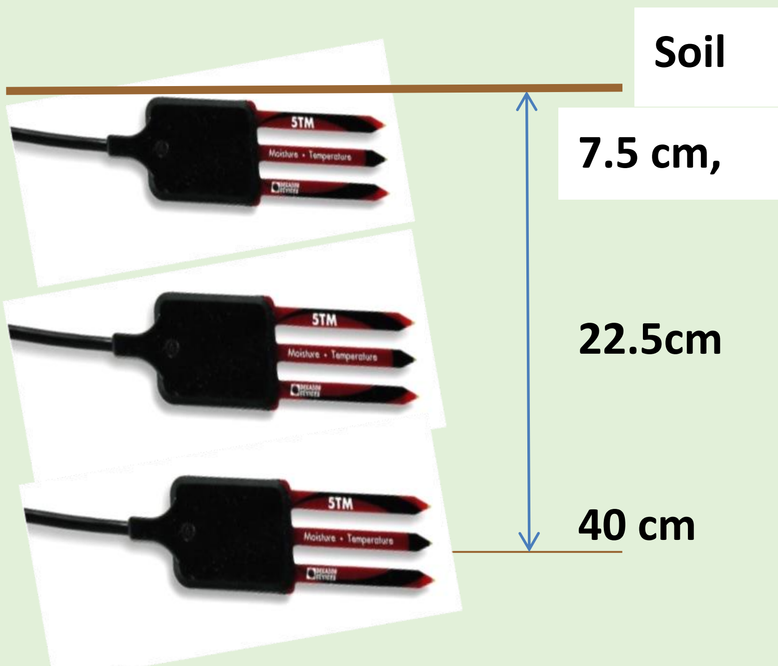


Visuals

Early July: Perennial and Annual

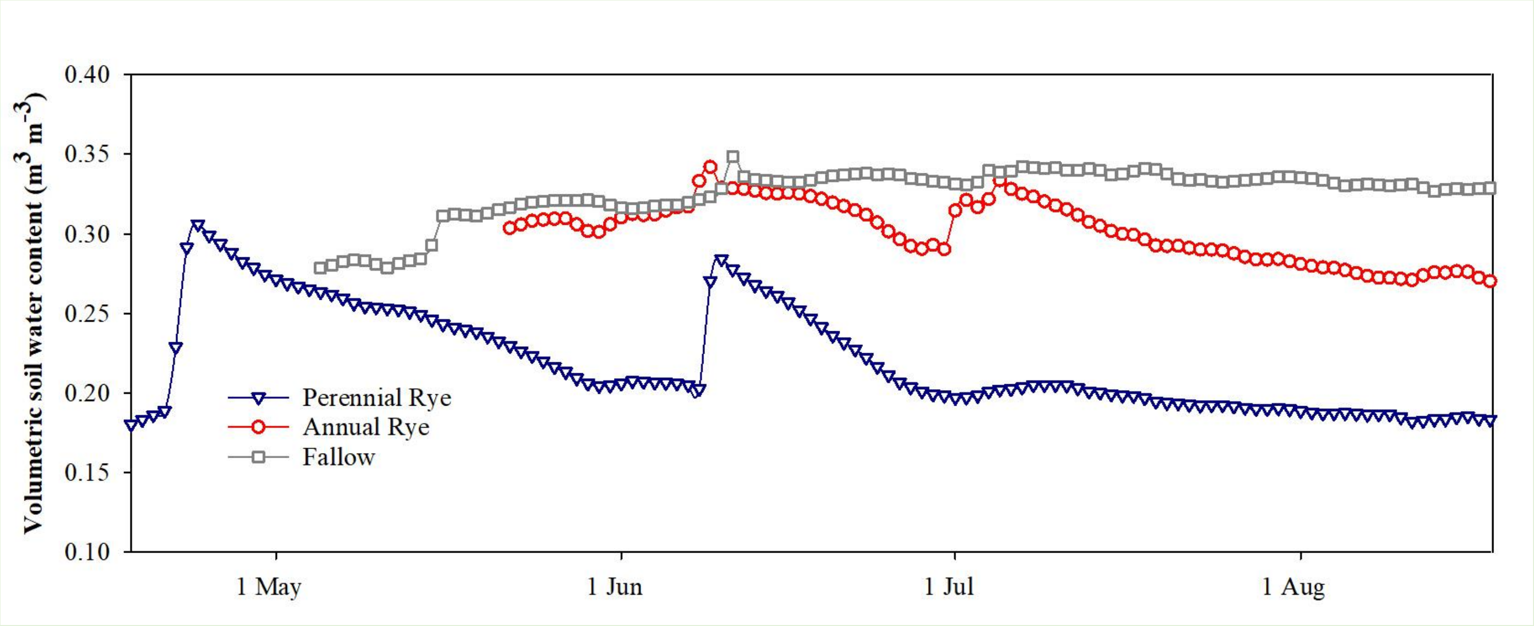
Annual in the early Fall

Soil Sensors for Moisture Content

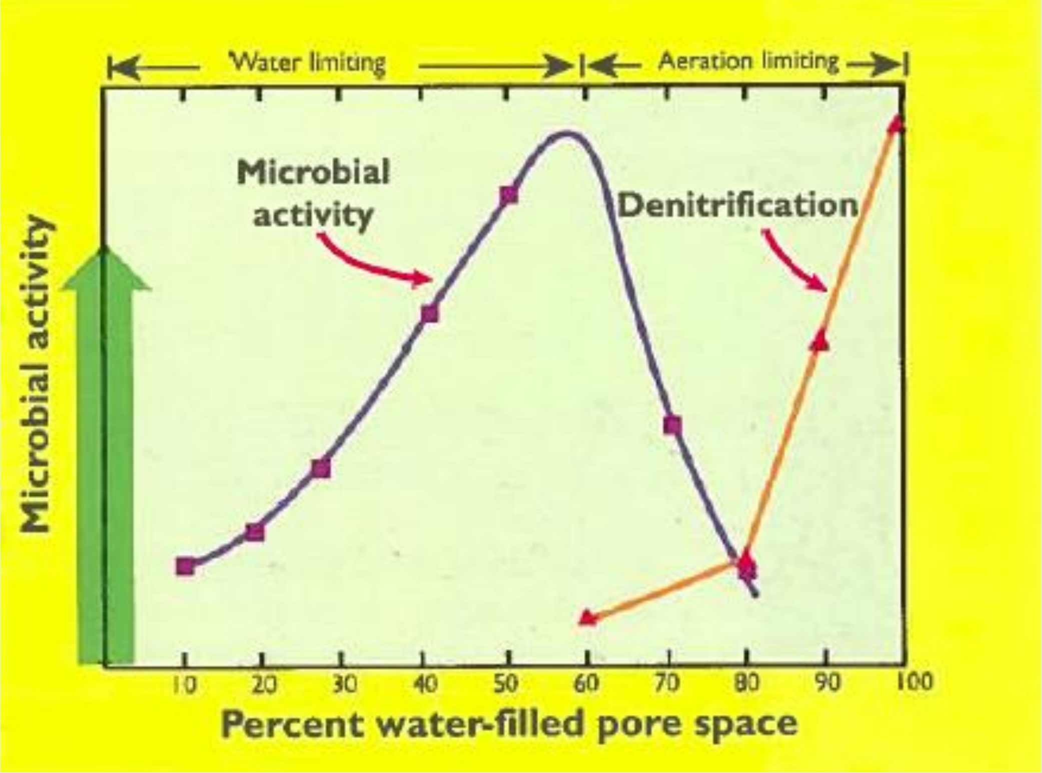


5TM sensor installation in the soil profile

Water Uptake at 40 cm Soil Depth



More than water uptake…

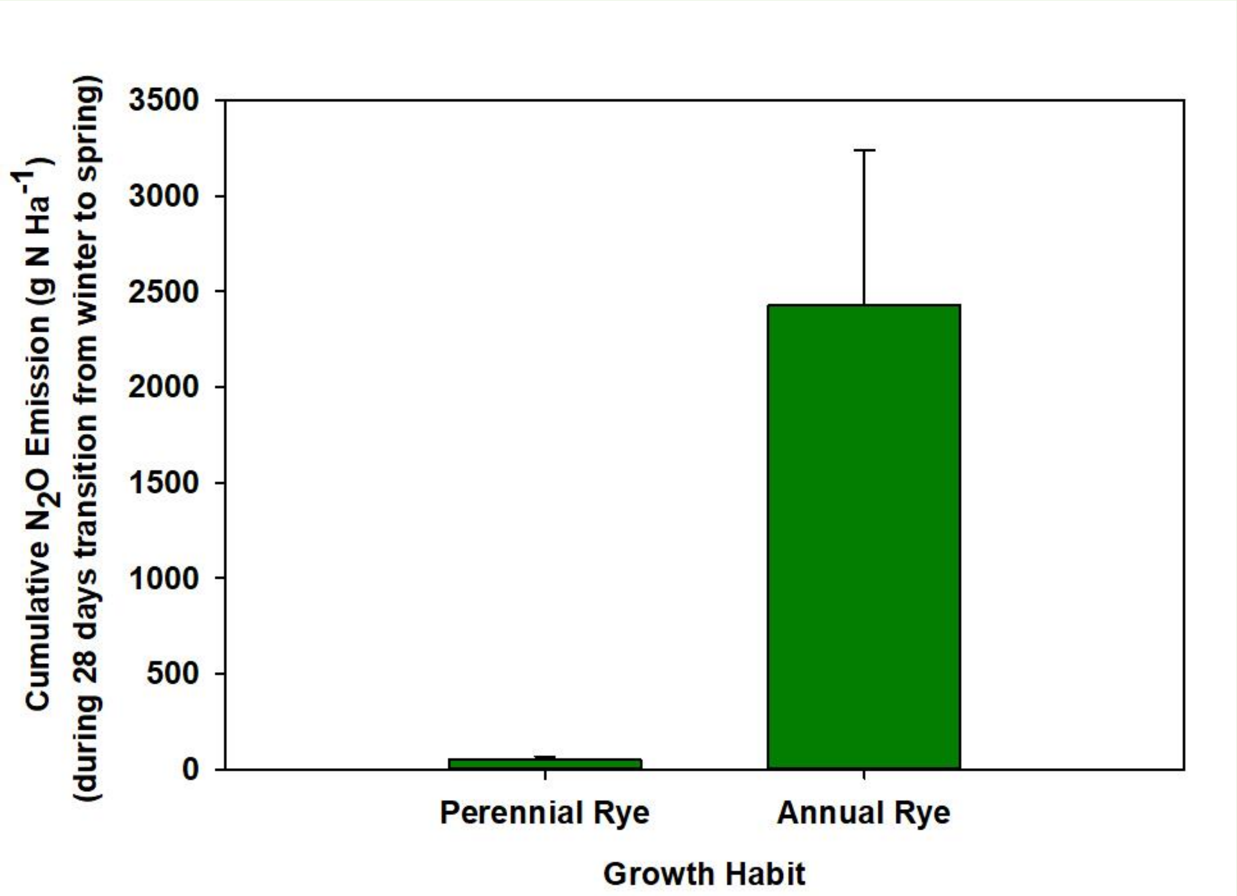


N_2O Emissions in 4 Ha Fields

A Laser Beam, Mirrors, and Anemometers

Real Time, High Frequency Flux Measurements

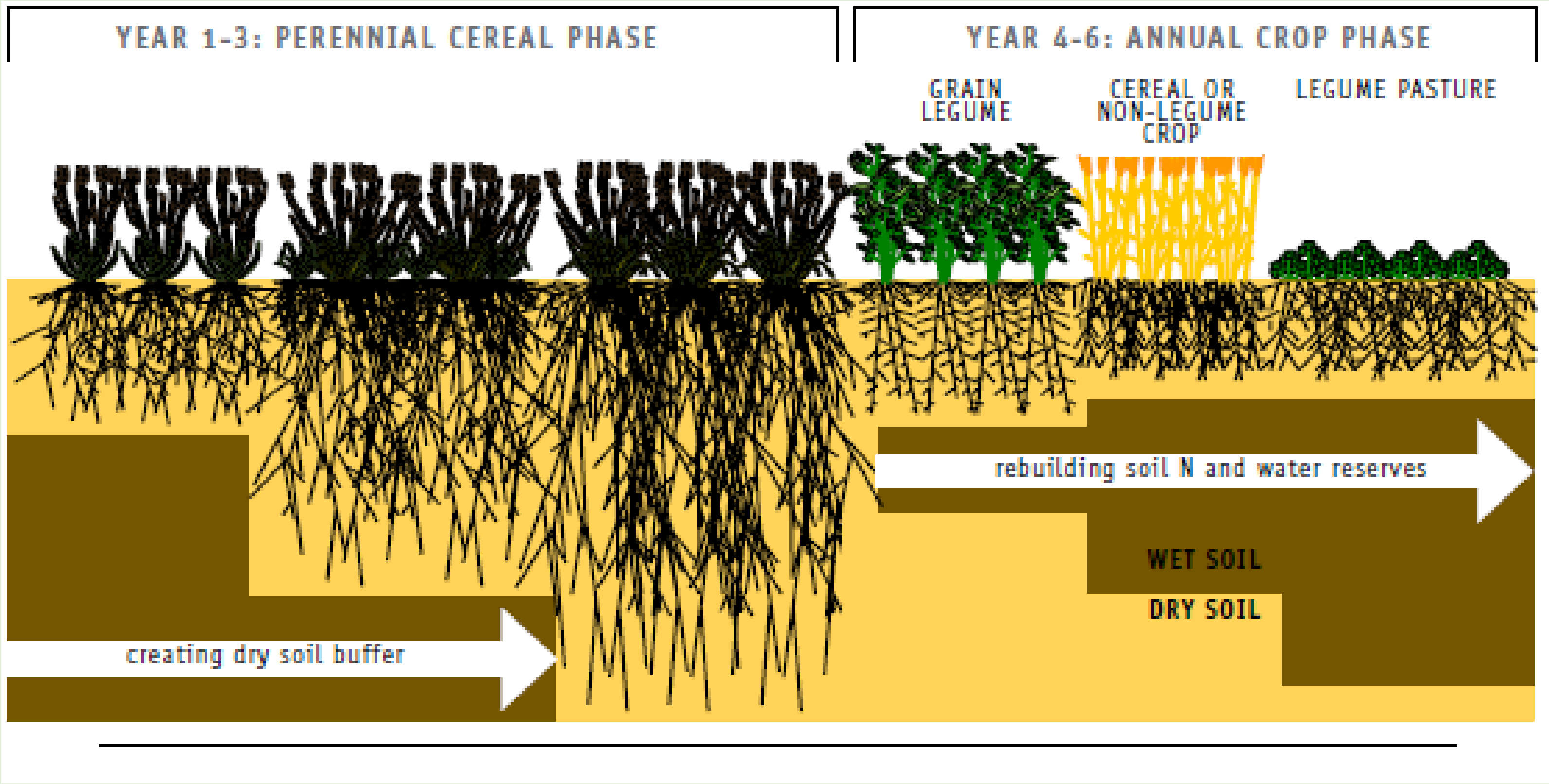
N_2O Emissions in 4 Large Fields



Agronomy of Perennial Grains Research and Prospects?

- **Soil Health**
- **Mycorrhizae**
- **N rate for perennial ?**
  - **Response curve**
- **Population dynamics**
- **Productivity**
- **Diseases, weeds mgt ?**
- **Aerial imaging and sampling strategies for precision agriculture.**
- **Crop rotations including perennials**

Crop rotations with perennial grains



Water & N Effects

- Irrigated croplands
- N use-efficiency
- For *Modelling!*

Recycling Organics

- **Use of manure, plant residues, and biosolids (*nutrients from urban to rural landscapes*)**

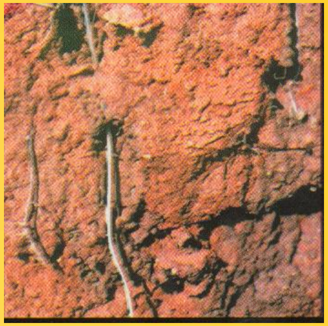
Dissemination & Collaboration

Approaches to Land Sustainability and Climate Change

- Continual soil cover
- Organic matter dynamics
- Balanced fertilization
- Trees in agricultural landscapes

Celebrating 100 years of Soil Science at University of Alberta (1919 to 2019).

A recognition to the research group!!! And the support from collaborators, stakeholders, and funders.



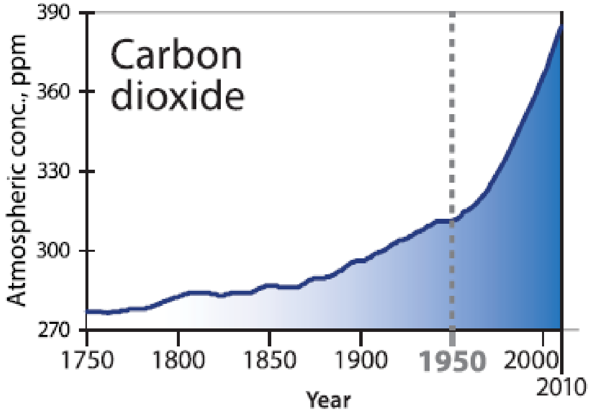
"uplifting the whole people"

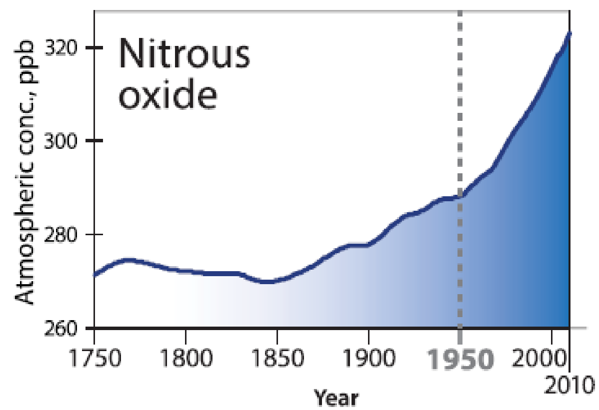
— HENRY MARSHALL TORY, FOUNDING PRESIDENT, 1908

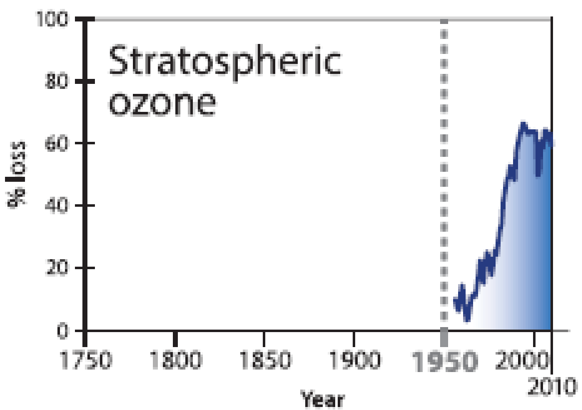
Thanks

Soils sustain life!

Atmospheric Trajectory







- Success of Montreal Protocol
- CC: a global problem… *that needs local solutions!*

Agriculture under escalating CChange: shifting ecological valences

- Phenotype =

Genotype

- Ag. Management:

Water, Fertilization, Tillage, Rotation, Plant population & Pests

- Attributes de Agroecosystems:

Multifunctional, EcoServices, Externalities

Plant Productivity ?

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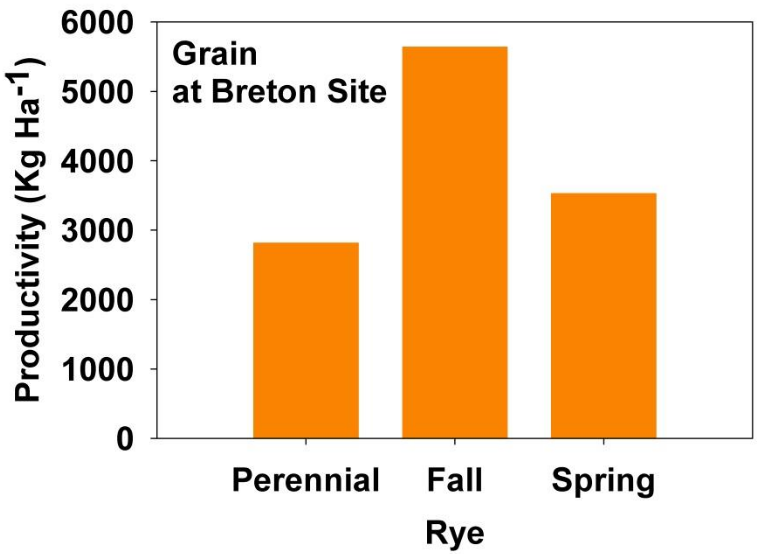
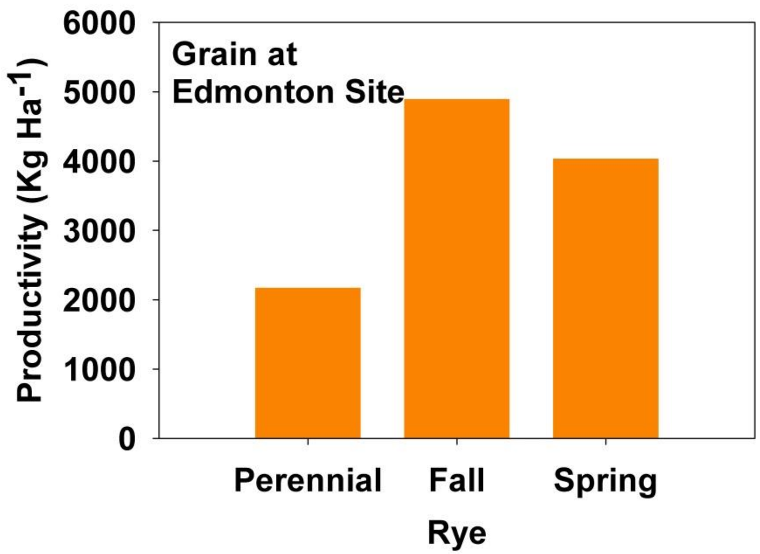
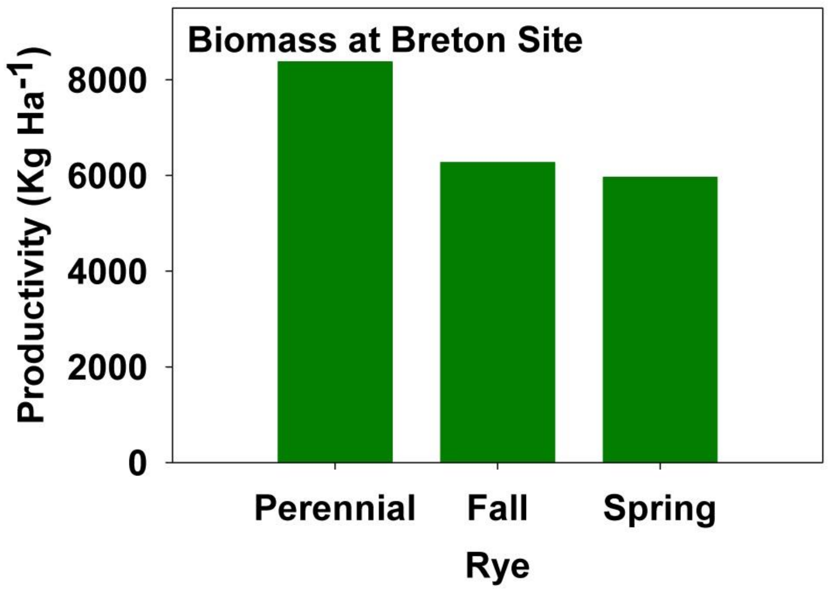
MINAGRI

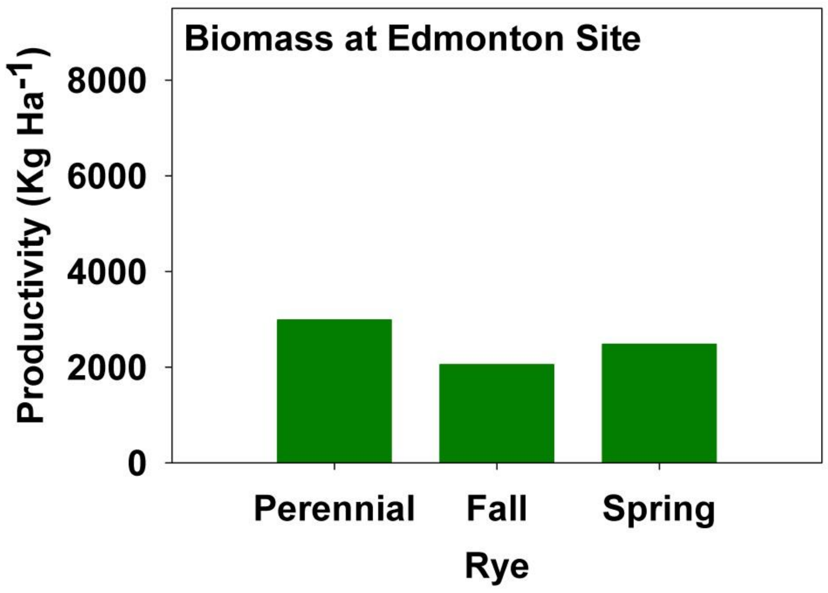
Plant Productivity – Grain





Plant Productivity – Biomass

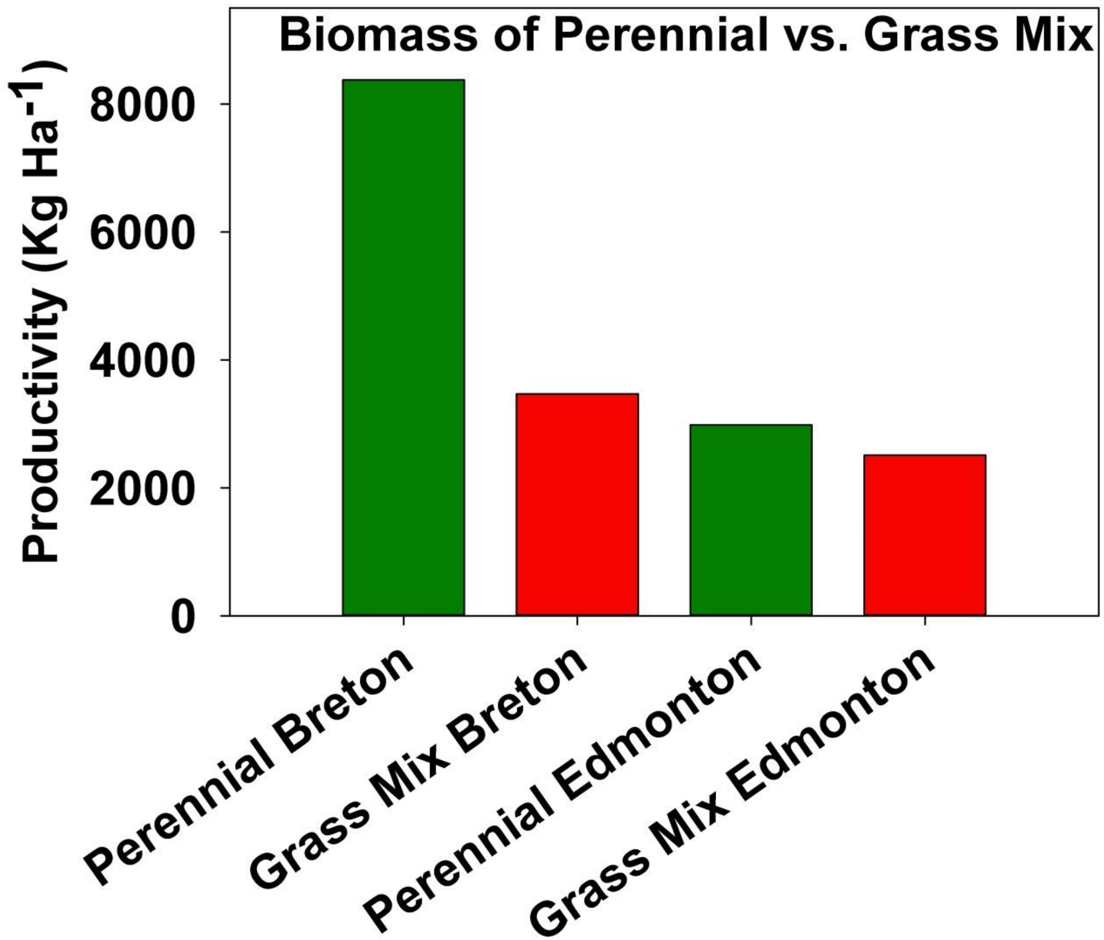




Forage from Grass Mix

- Grass mix early summer and after first harvest

Plant Productivity – Forage 2018



At harvest time in Breton

Perennial on 16 Aug.

Fall rye on 16 Aug.

Spring in Oct.

At time of Perennial harvest on 16 Aug. in Breton

Perennial rye

Spring rye

What are the Social Benefits of Perennial Cereals?

- Reduction in farm labour and stress
  - Seeding is spread out…over years!
  - Think of perennial grains like fall seeded grains=earlier harvest
  - Reduced handling and application of pesticides
  - More access to soil water and increase soil organic carbon means production stability for farms
  - Gains in efficiency
- Benefits to civilization
  - Many linked to environmental improvements
  - Stable cost effective food production
  - Potential for productive buffer crop to limit nutrient loading around riparian areas

What Would a Perennial Grain System Look Like?

- Monoculture vs. polyculture
- Livestock focused vs. grain production system
- Natural vs. intensive management

The truth is we don’t know!

- Major factors include
  - Life span of perennial plant
  - Complimentary species in polyculture
  - Type and productivity of the soils
  - Environmental conditions (moisture, length of season)

Summary

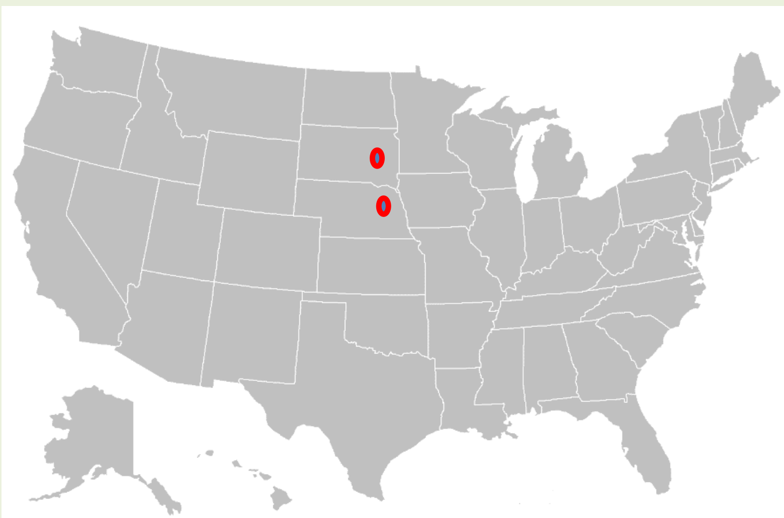
- Perennial cereal are all perennial cereal crops being improved through plant breeding
- Large root systems and constant ground cover drive important differences between perennial and annual species
- Deep roots enable access to soil moisture, nitrogen and lead to the storing of significantly more soil organic carbon
- Unique environmental attributes of the crop could drive economics of the crop
- Research on potential cropping systems for perennial grains is currently in its infancy

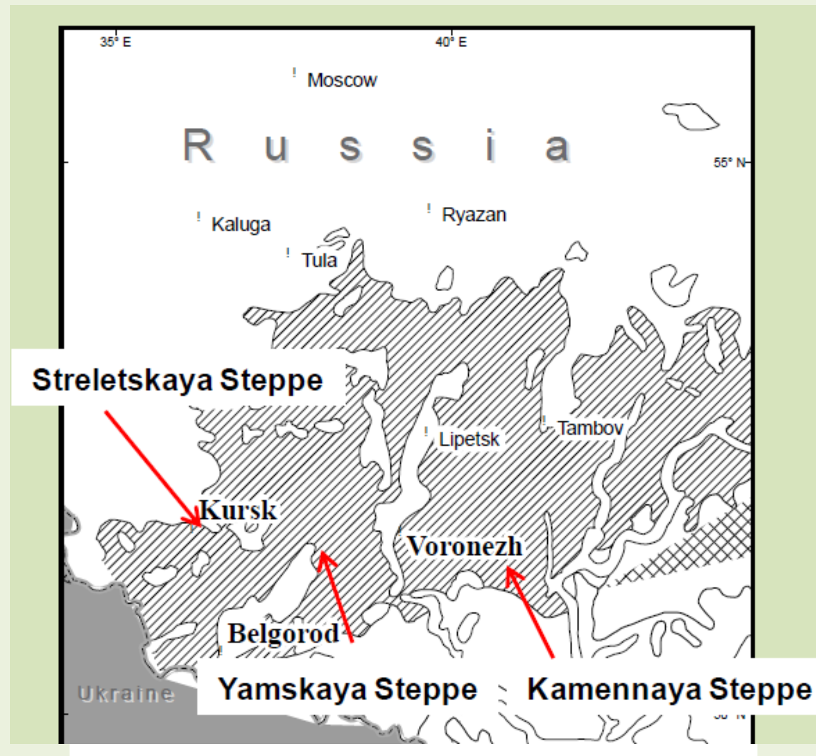
Soil C Accrual & Turnover

- **Soil C changes due to afforestation.**
- **Central Russian Steppe & US Great Plains.**

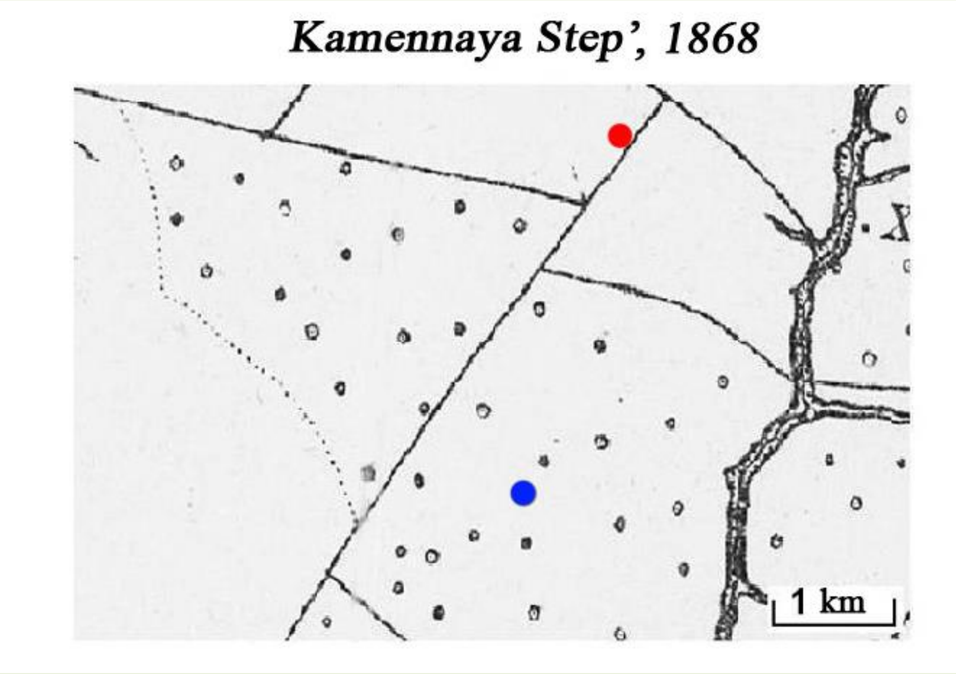
Shelterbelts
in US & Russia

Sites in
US & Russia

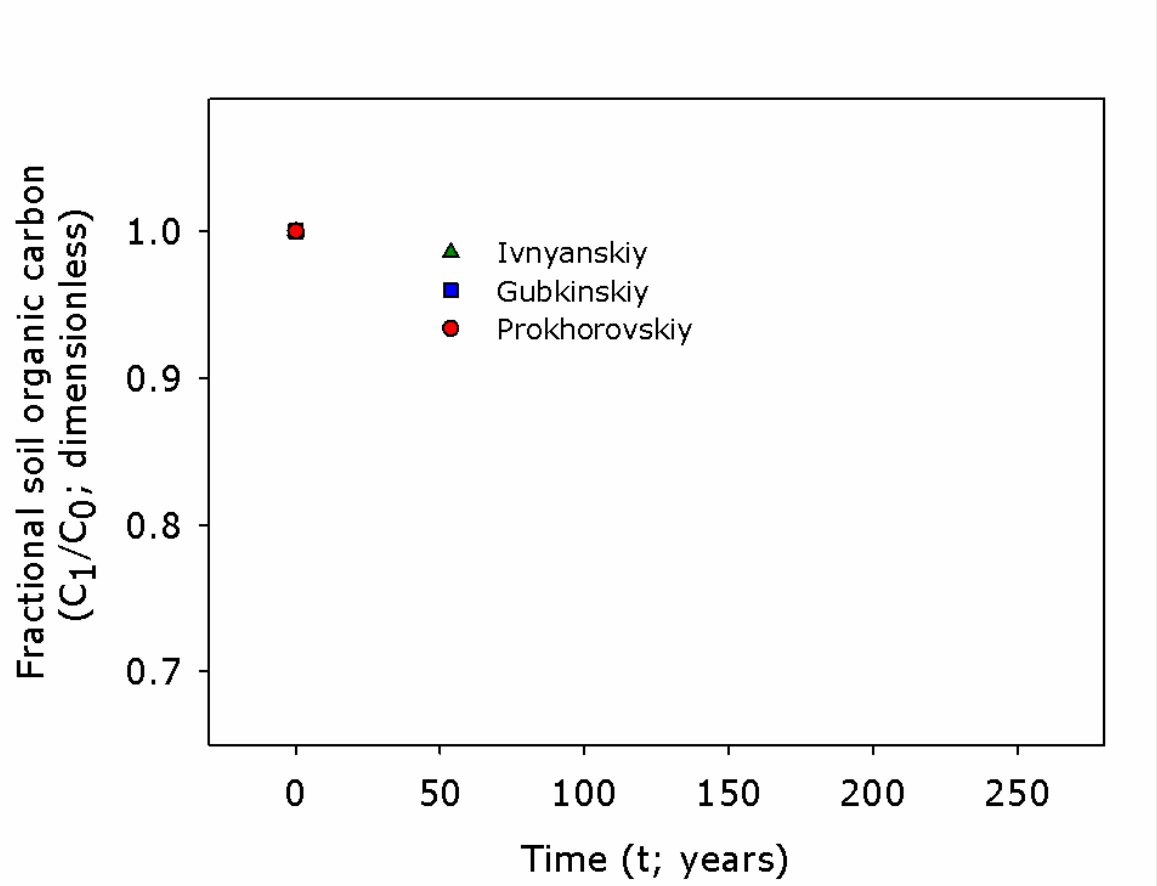




Russian Chronosequences
based on historical records



Russian Chronosequences:
Conversion from Grassland to Cropland



Russian Chronosequences:
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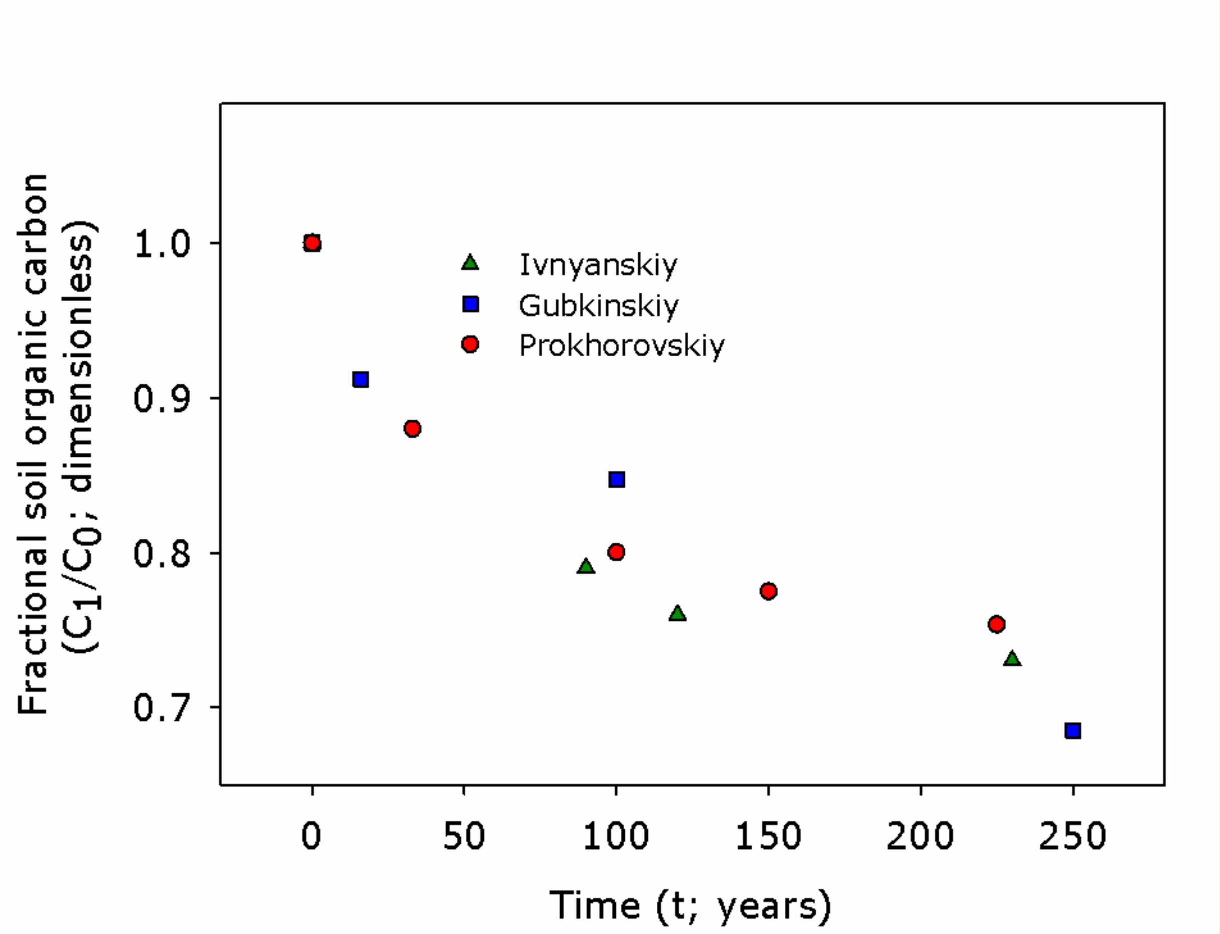
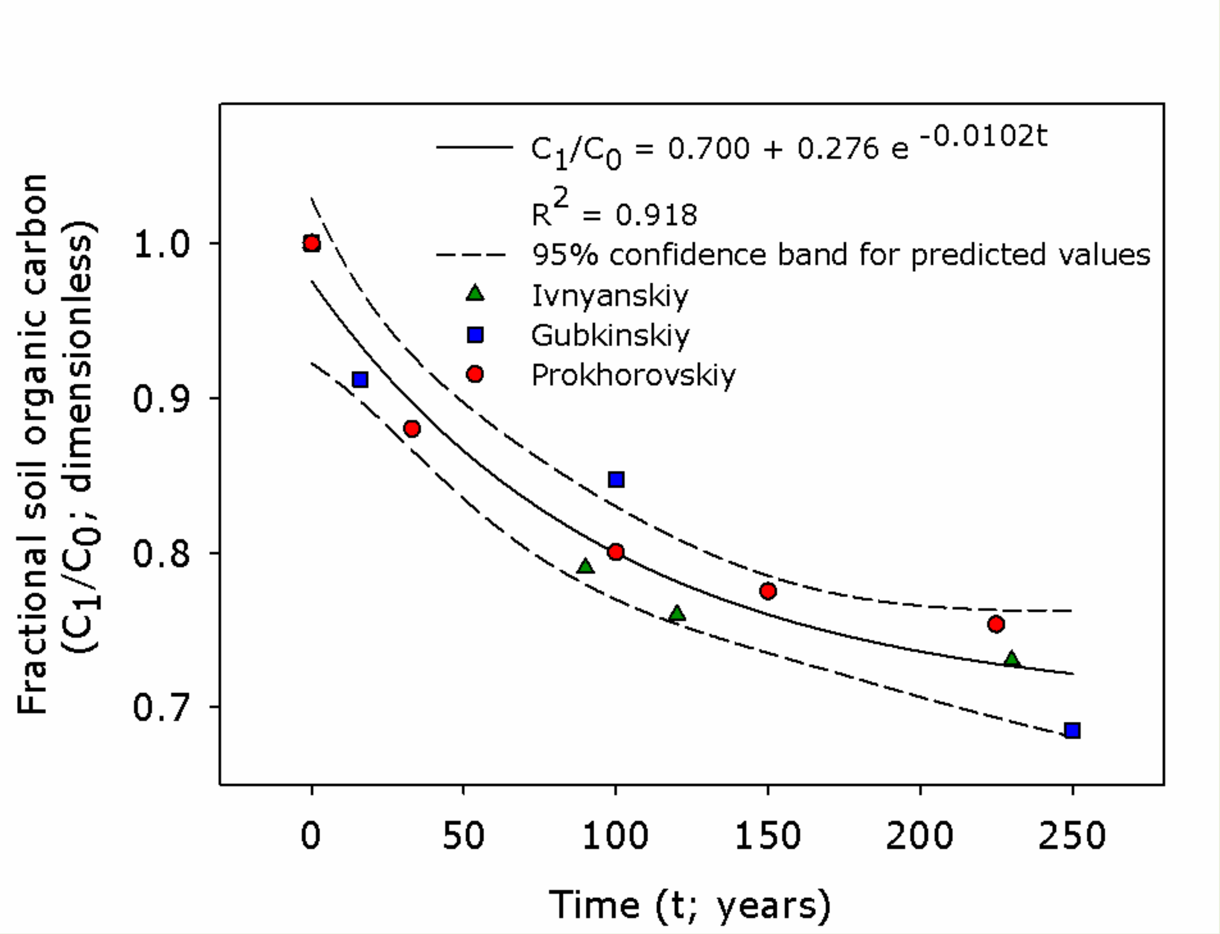


Russian Chronosequences:

Conversion from Grassland to Cropland



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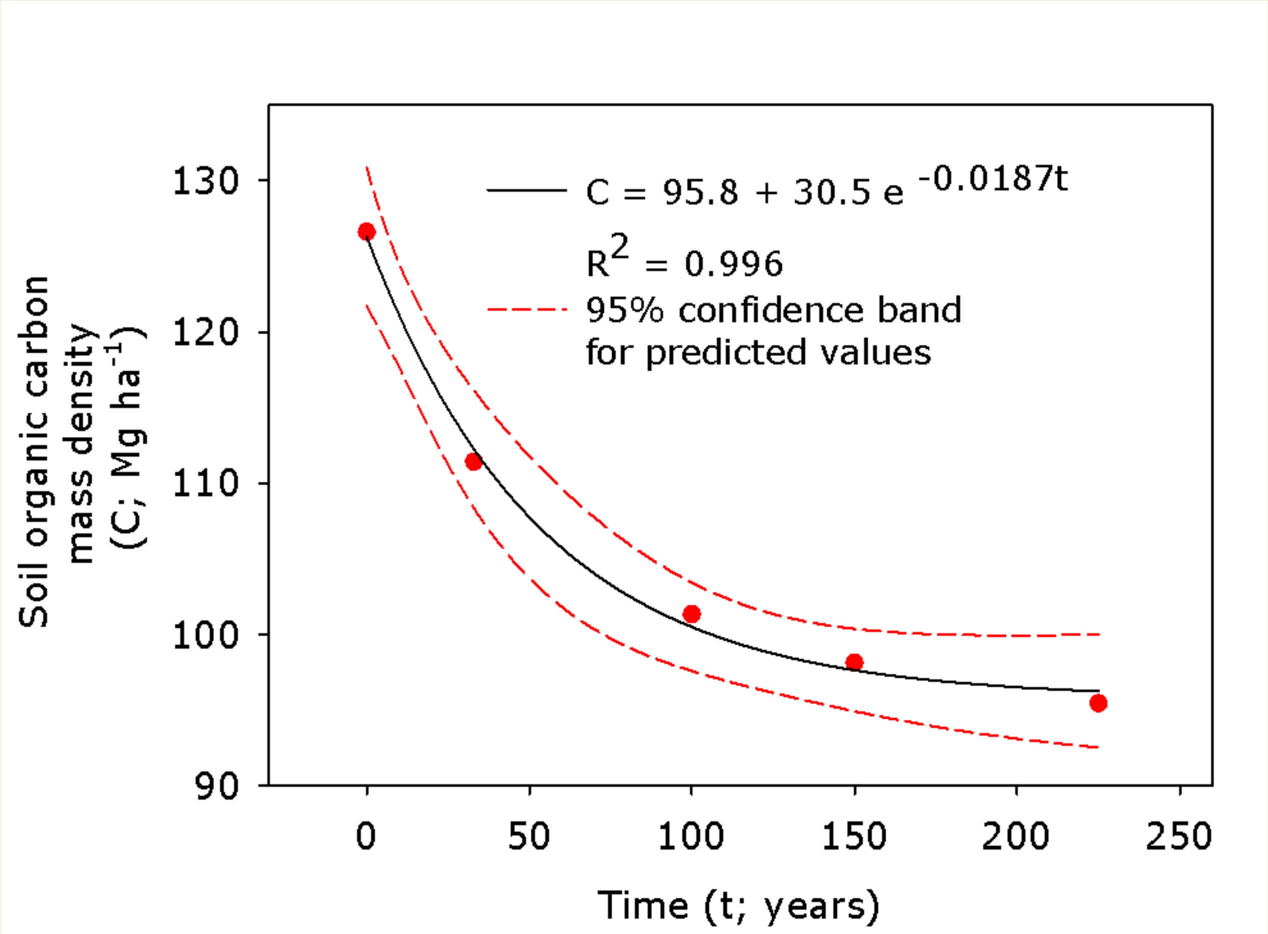
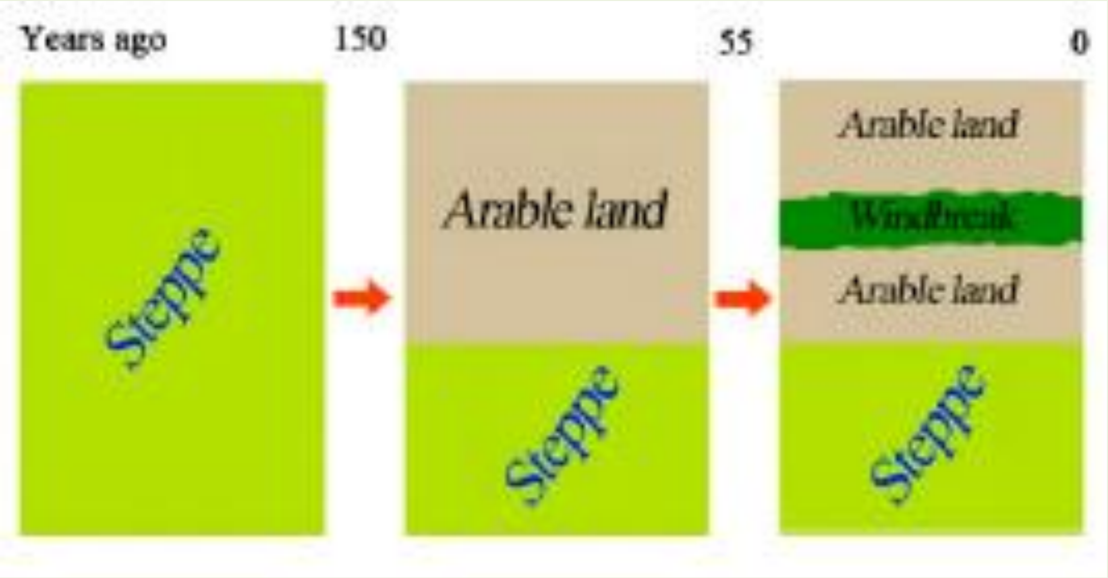
Russian Chronosequences:
Conversion from Grassland to Cropland

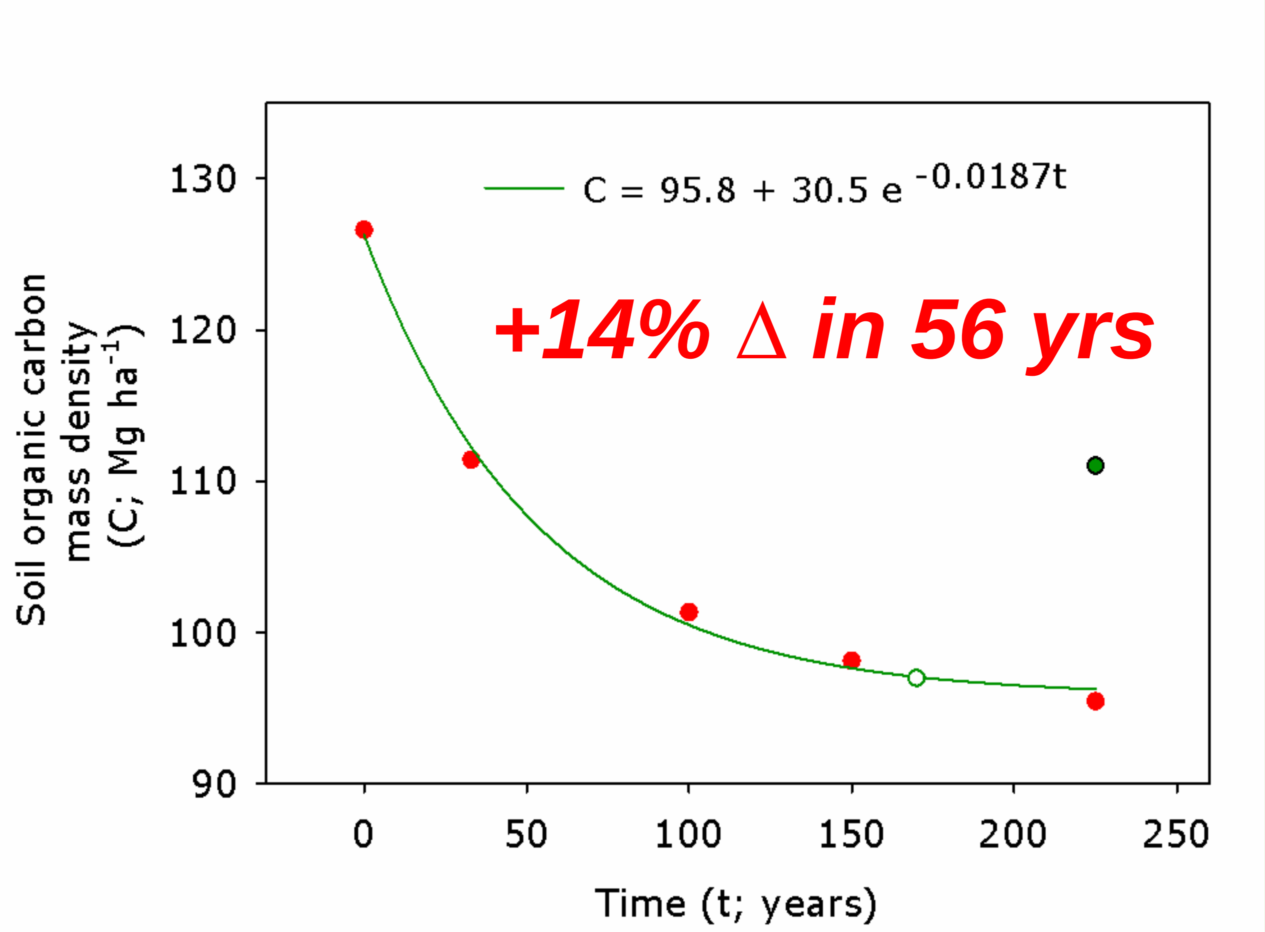


Russian Chronosequences:

Conversion from Grassland to Cropland and then Afforestation



Russian Chronosequences:
Conversion from Cropland to Afforestation



Russian Chronosequences:

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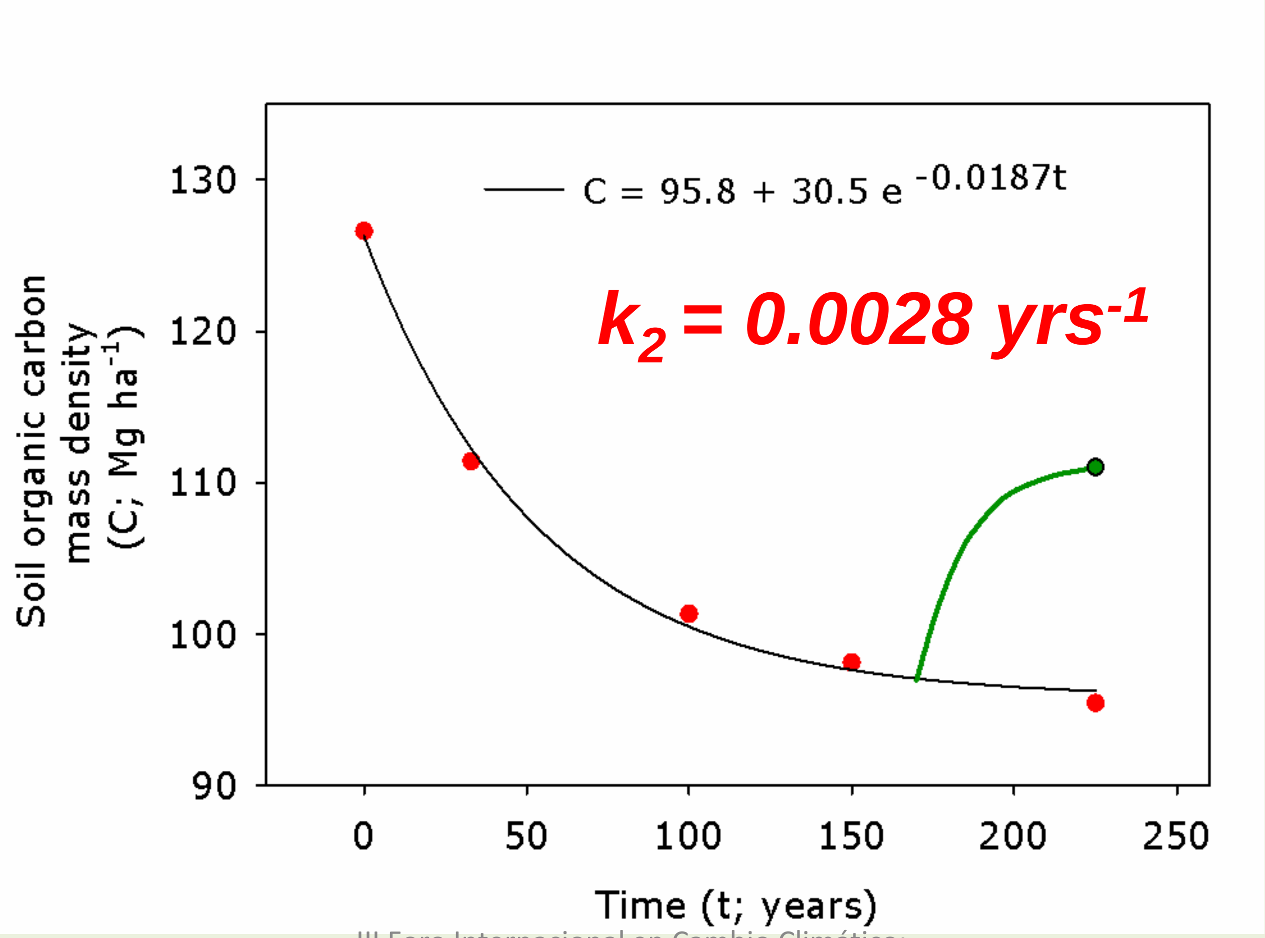


Afforestation in US Great Plains

A Different Approach…

- ^{13}C isotope in soil.
- Soils under native vegetation and tree samples used as references.
- Approach based on shifts in isotope signatures between different vegetation types: $C_3 \Leftrightarrow C_4$ photosynthetic pathways.

Prairie => Cropland => Afforestation

Field Locations

Nebraska

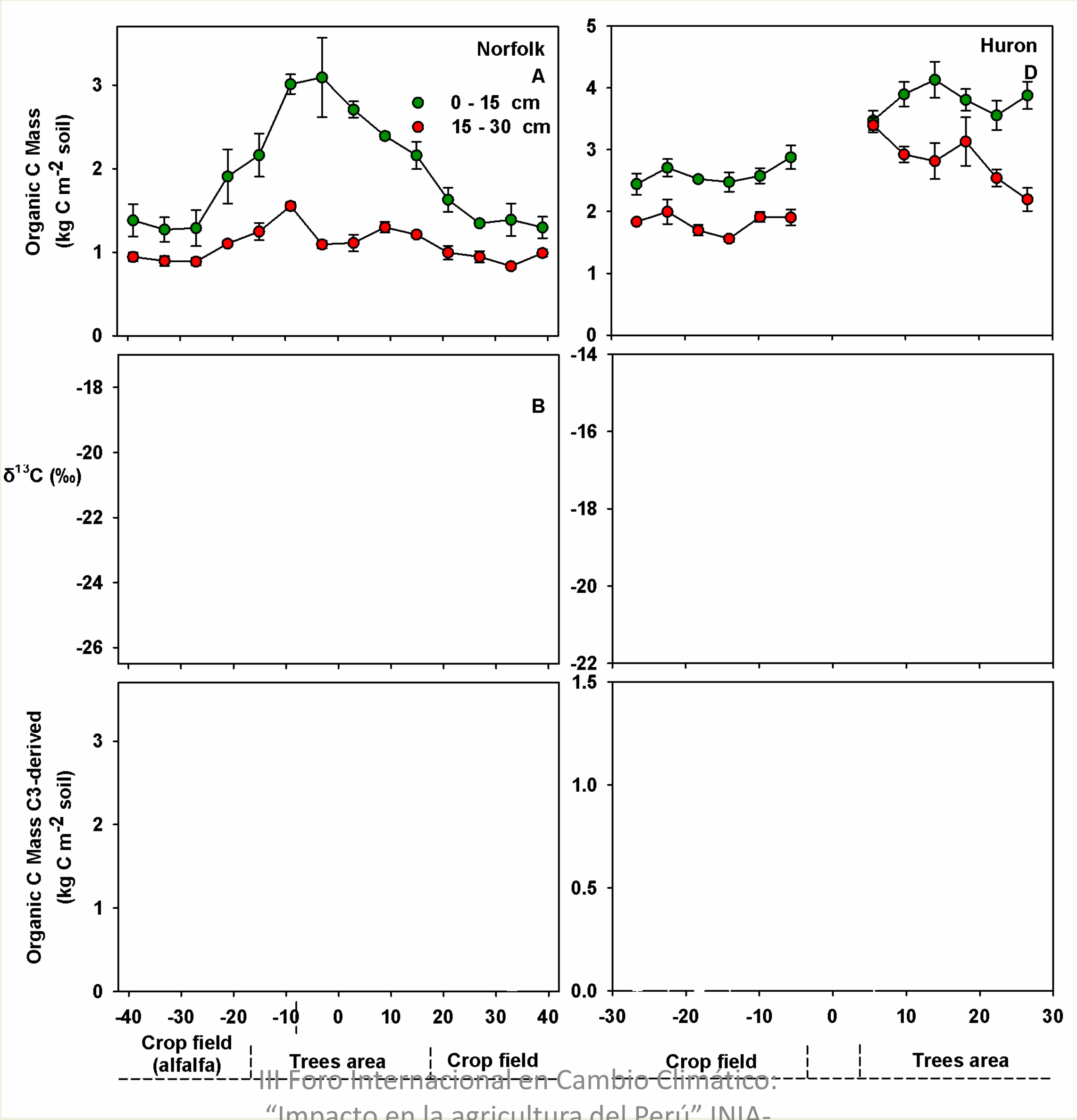
S. Dakota

Conversions:

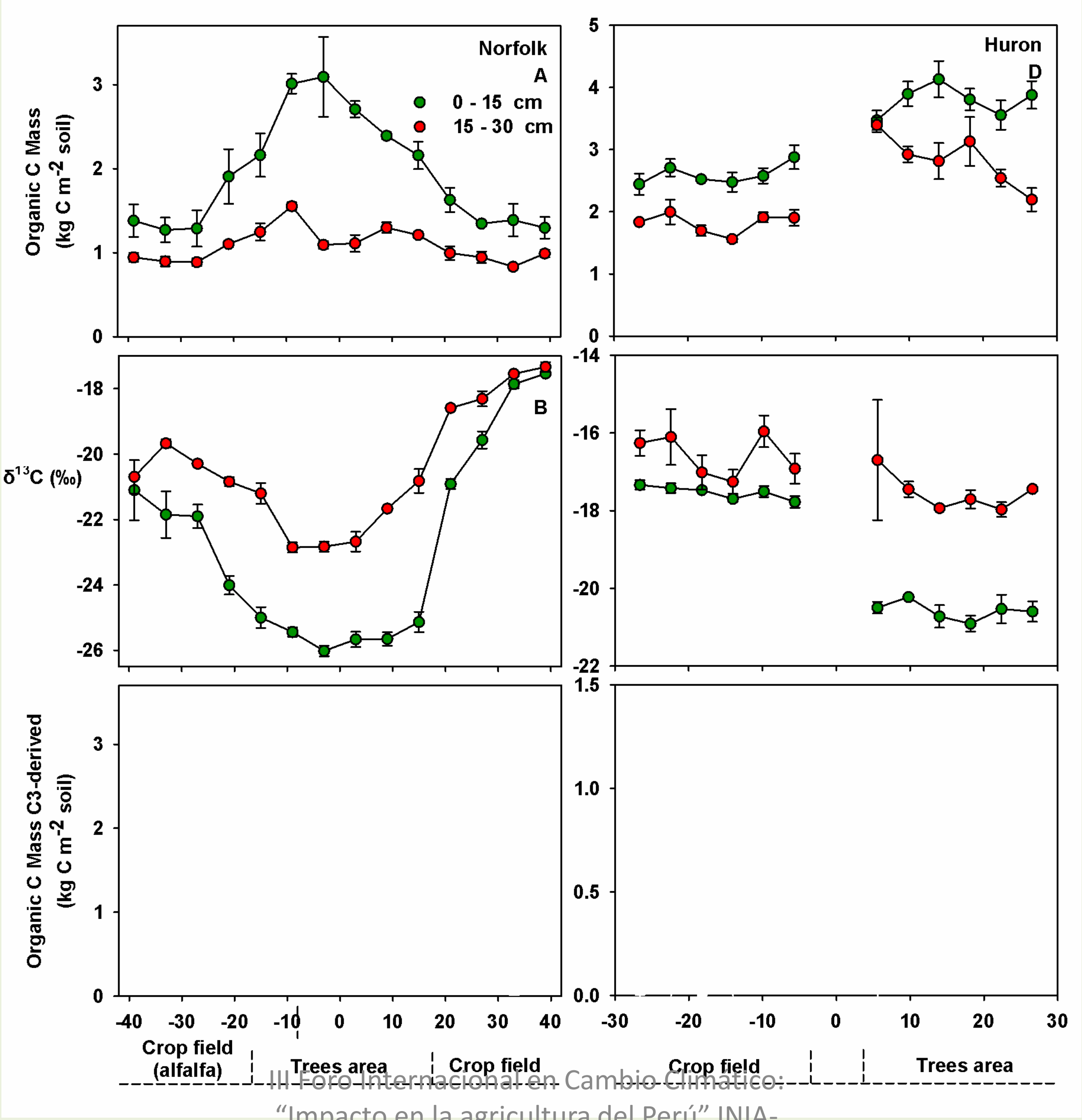
120 yrs to cropland, 70 yrs to afforestation

21 yrs to cropland, 19 yrs to afforestation

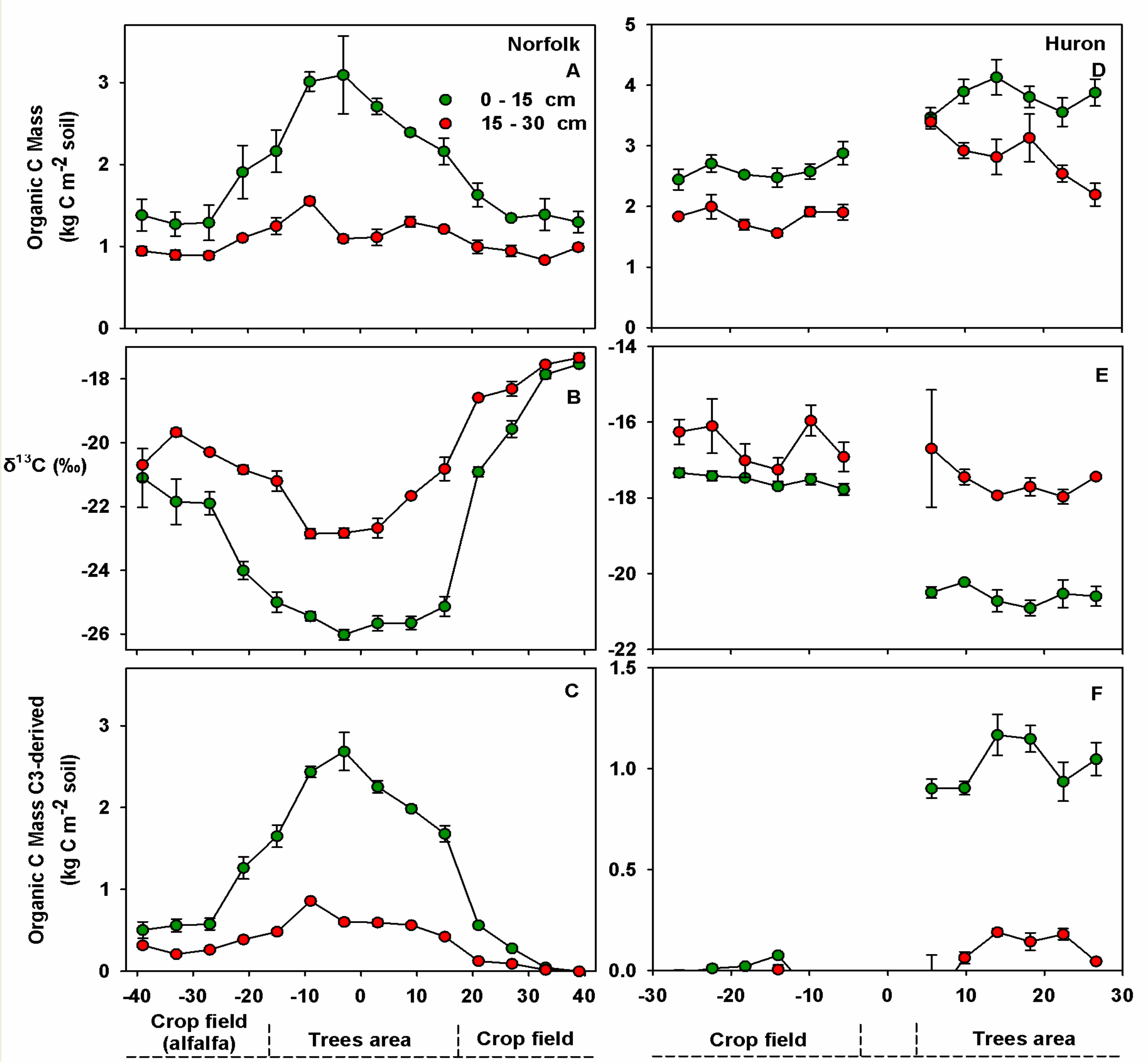
C stored beneath the Trees…



Soil ^{13}C Signature



Soil C Sources



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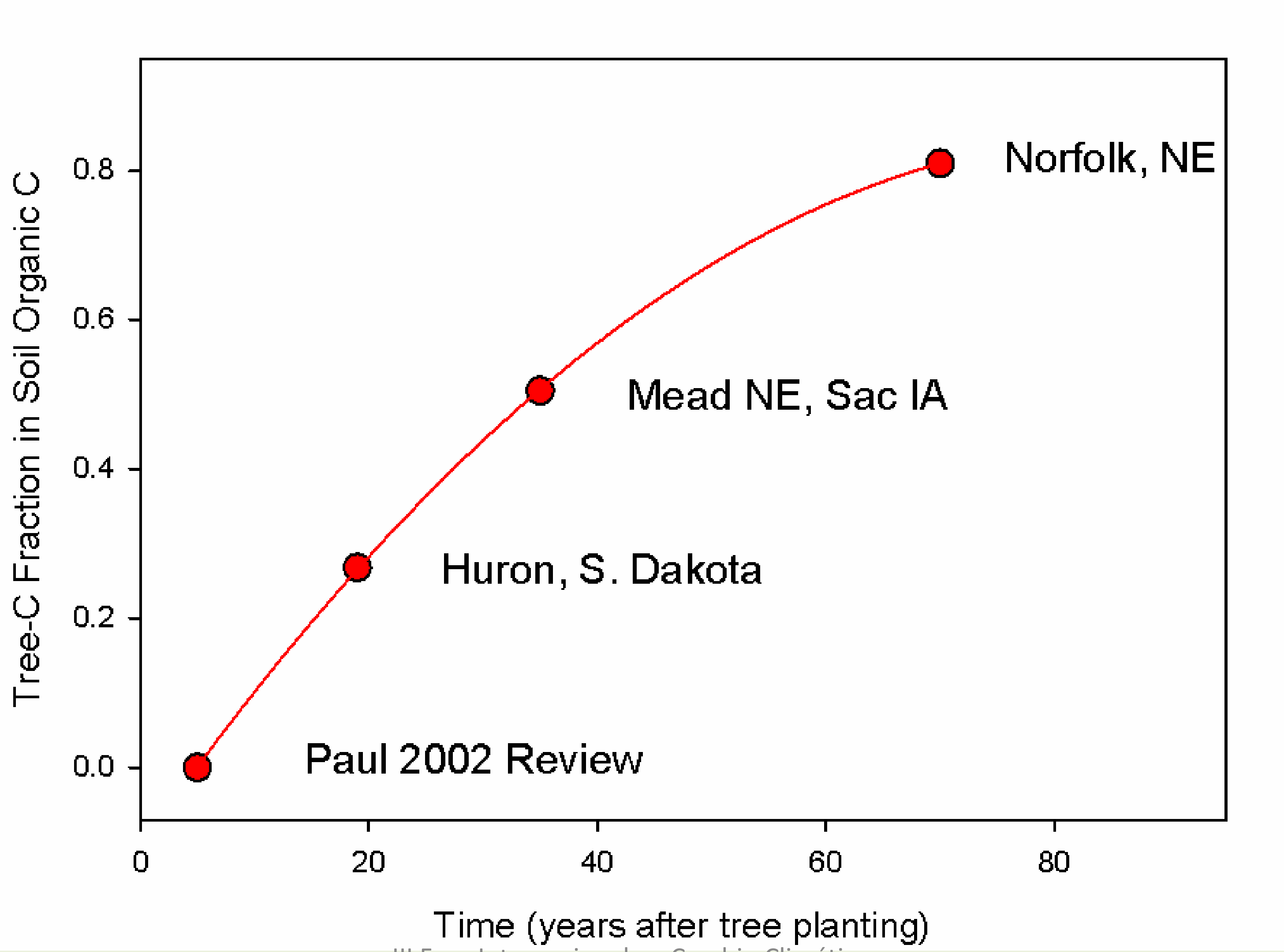
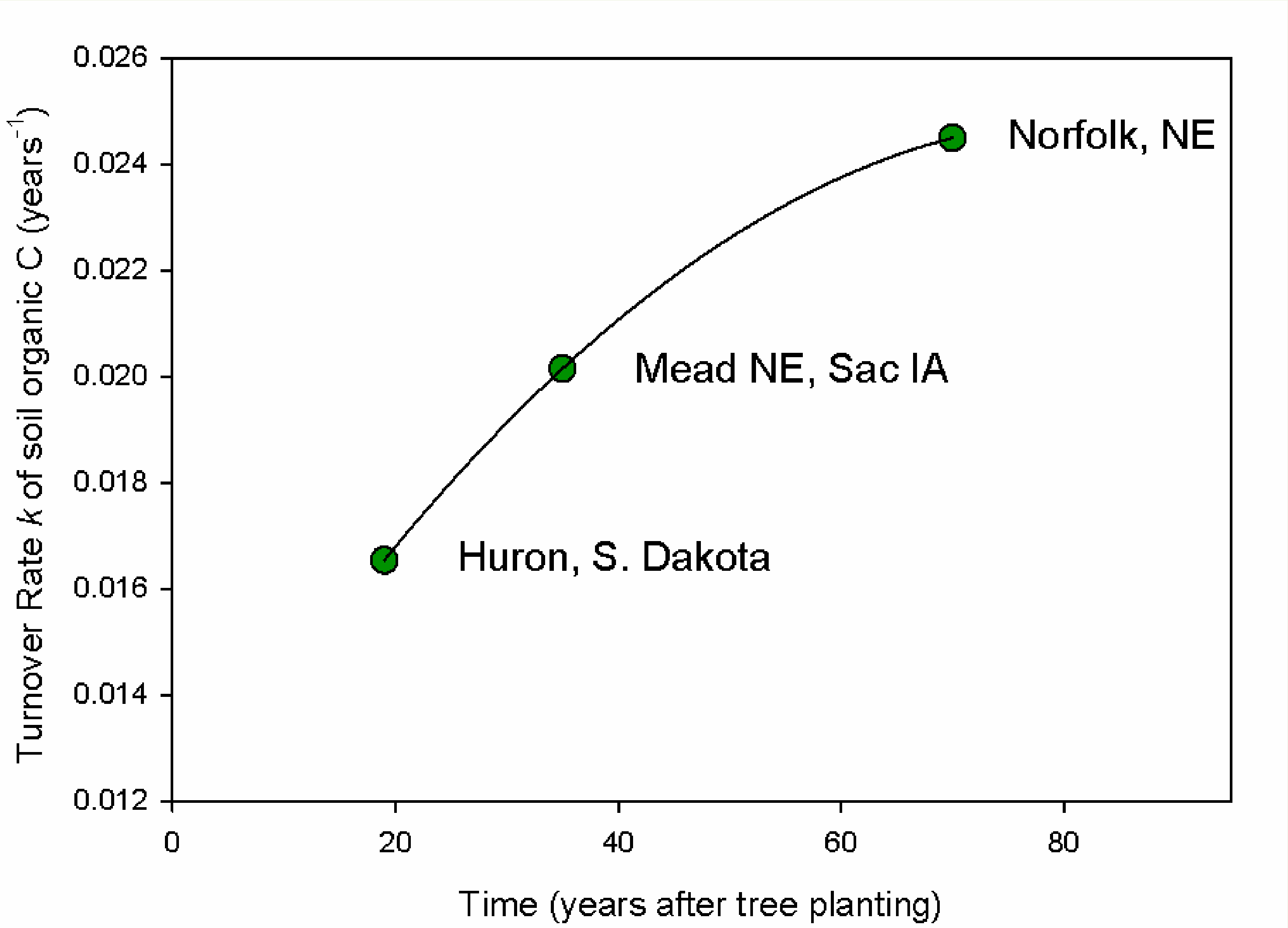
Tree Contribution to Soil C



Soil C Turnover Rate



What we learned…

What we learned…

- Carbon *mean residence time* for grassland to cropland

  100 years

- *MRT* in afforested soils:

  40 to 60 years

- Tree biomass removal can reverse org. C accrual by changing source–sink balance.

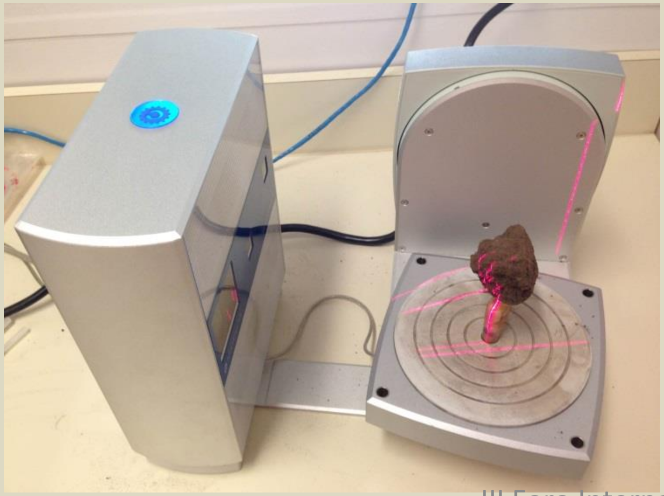
- *On going work on organic matter dynamics as function of land use, rotation and nutrient additions.*

A Robust Soil Quality Indicator

- Soil aggregation reflects multiple soil functions
- Looking at the scaling of aggregates
  - Mass versus volume ~ *aggregate density*
  - Fractal model of soil hierarchical aggregation

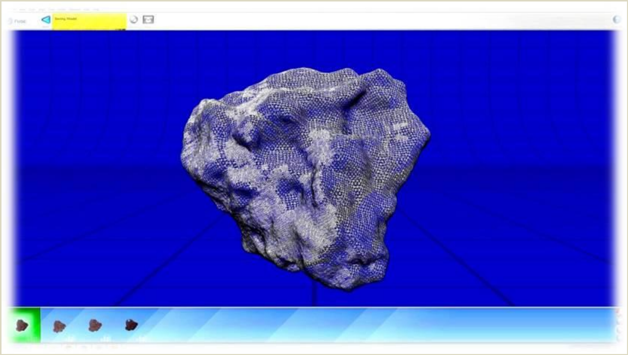
How to?

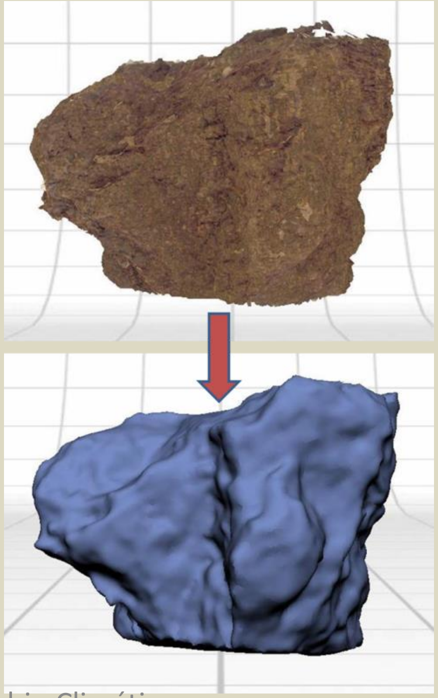
- Undisturbed field-moist clod samples
- Hand broken into aggregates or peds
- Size classes from 0.25 to 16 cm diameter
- Mass: scale
- Volume: 3D laser scanning



How to?

- Computation of:
  - 3D model,
  - volume,
  - surface…

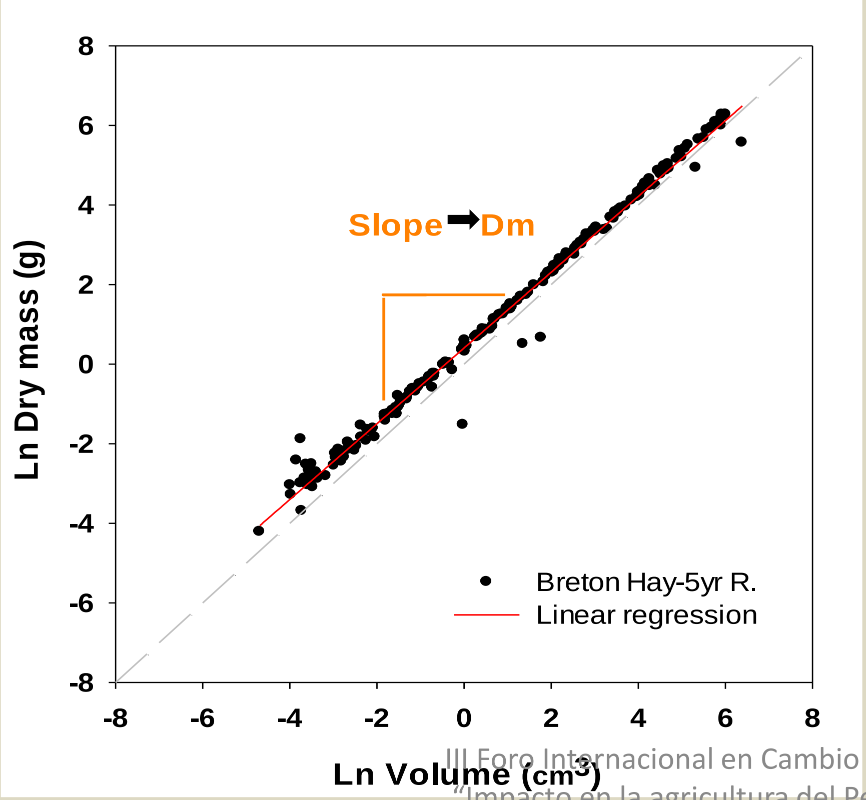


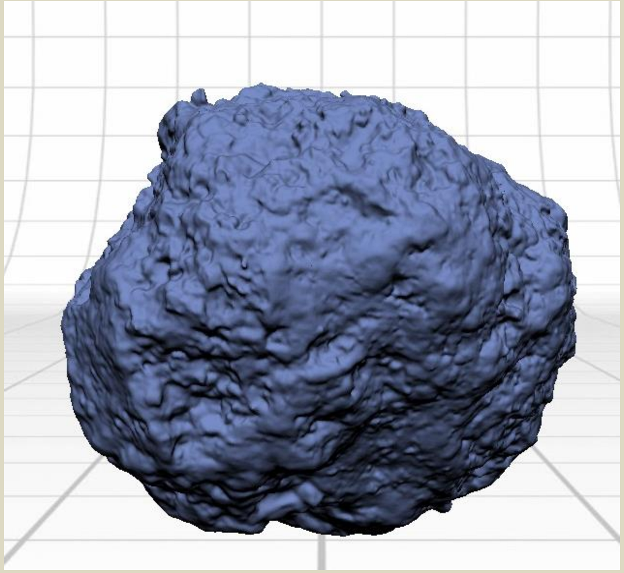


How to?

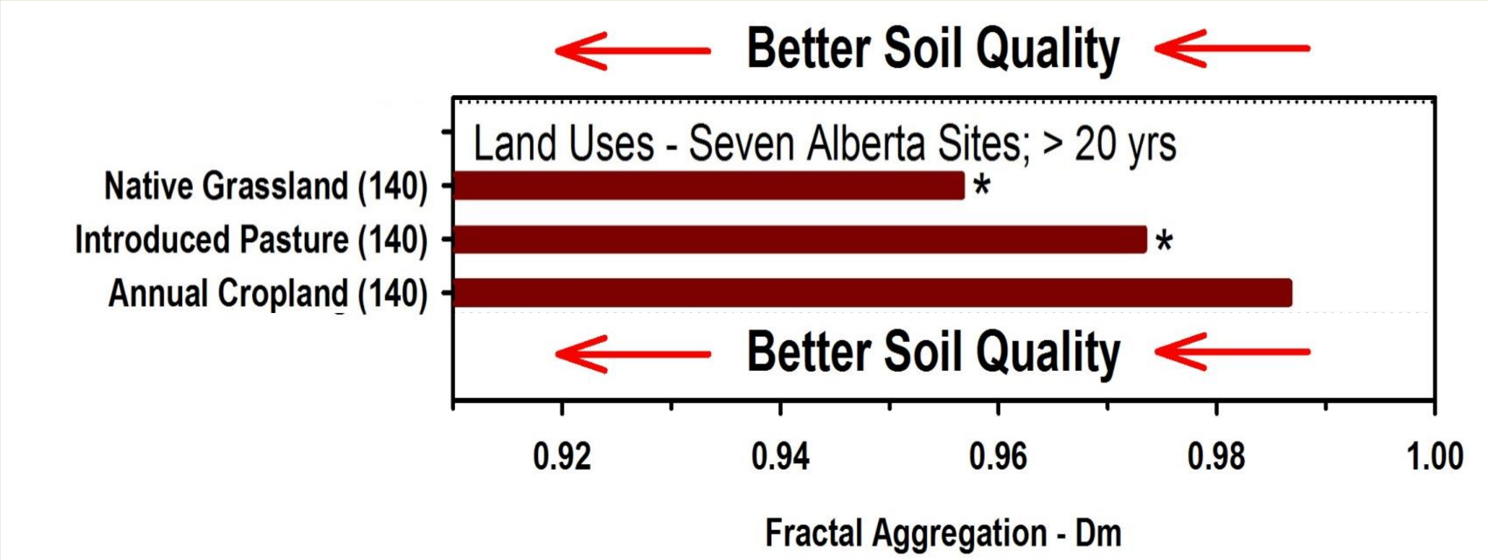
- Fractal calculations

$$Mass = K_m volume^{D_m}$$





Clear Differentiation across Land Uses



Fractal aggregation (Dm) consistently detected improved soil quality and land use.

A Soil Quality Indicator

- Native grasslands had greater soil quality than pastures and annual croplands.
- Perennial plants and low disturbance enhanced soil quality.
- Fractal aggregation emerged as a robust metric.

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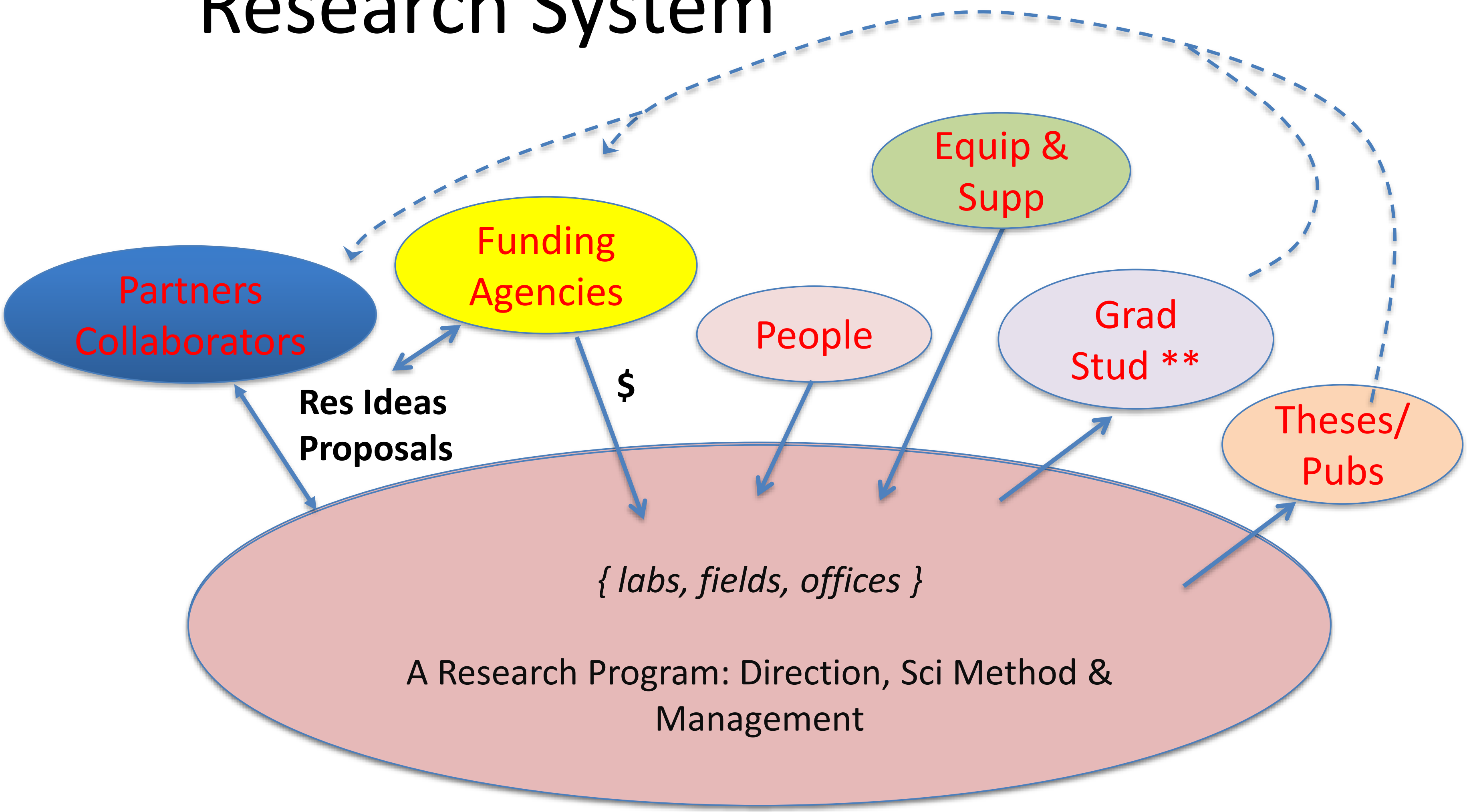
Soil physical quality varies among contrasting land uses in Northern Prairie regions

CrossMark

Christina Hebb[a], Donald Schoderbek[c], Guillermo Hernandez-Ramirez[b,*], Daniel Hewins[d], Cameron N. Carlyle[c], Edward Bork[c]

Research System



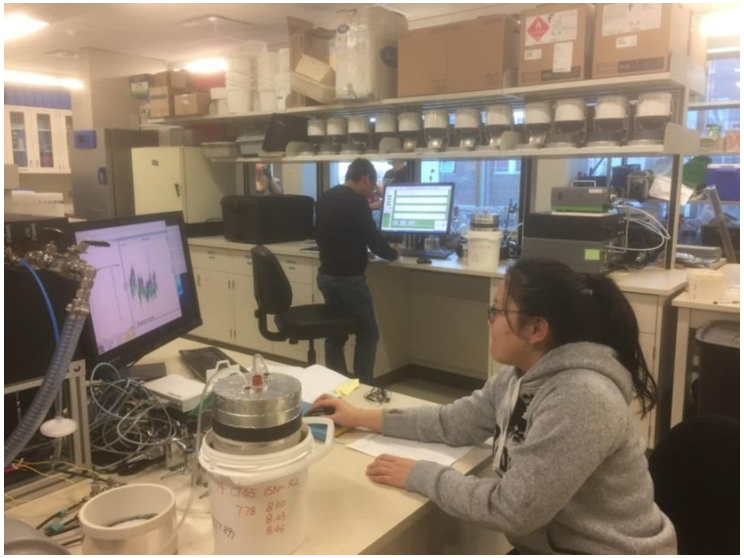

CE
SPECTROMETER

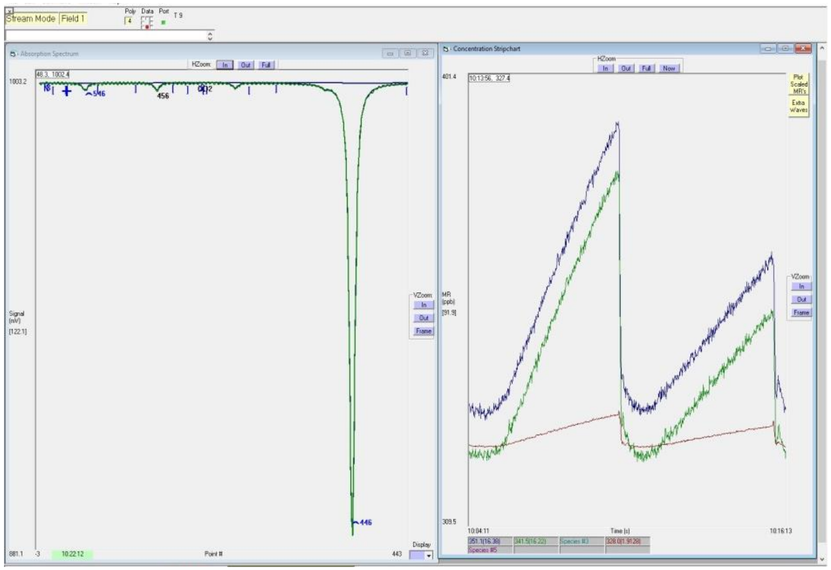
N_2O Sources – How ?

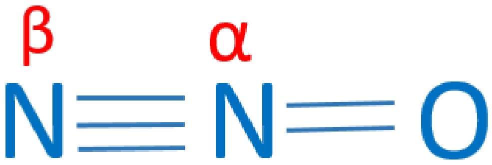
- Isotope ^{15}N position in N_2O.
- Keeling plots
- Priming

N_2O Sources – How ?

- Isotope ^{15}N position in N_2O (alpha & beta).

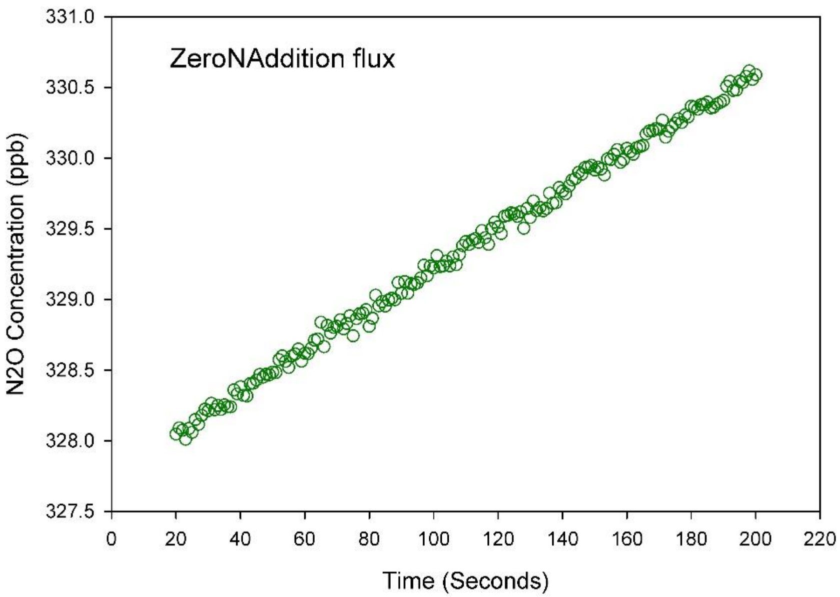


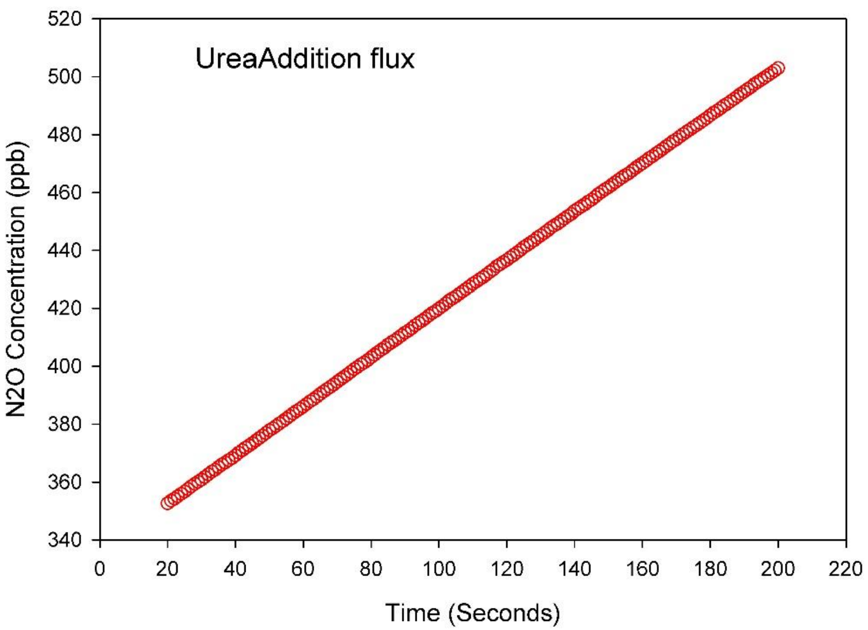




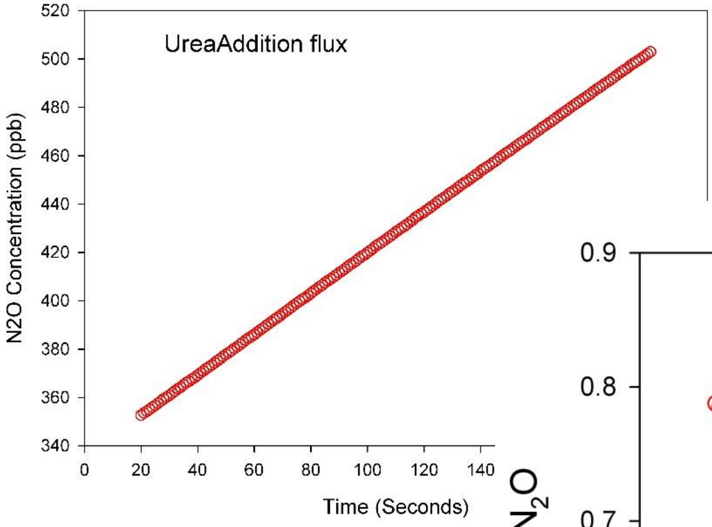
$\alpha - \beta = {}^{15}N$ site preference(SP)

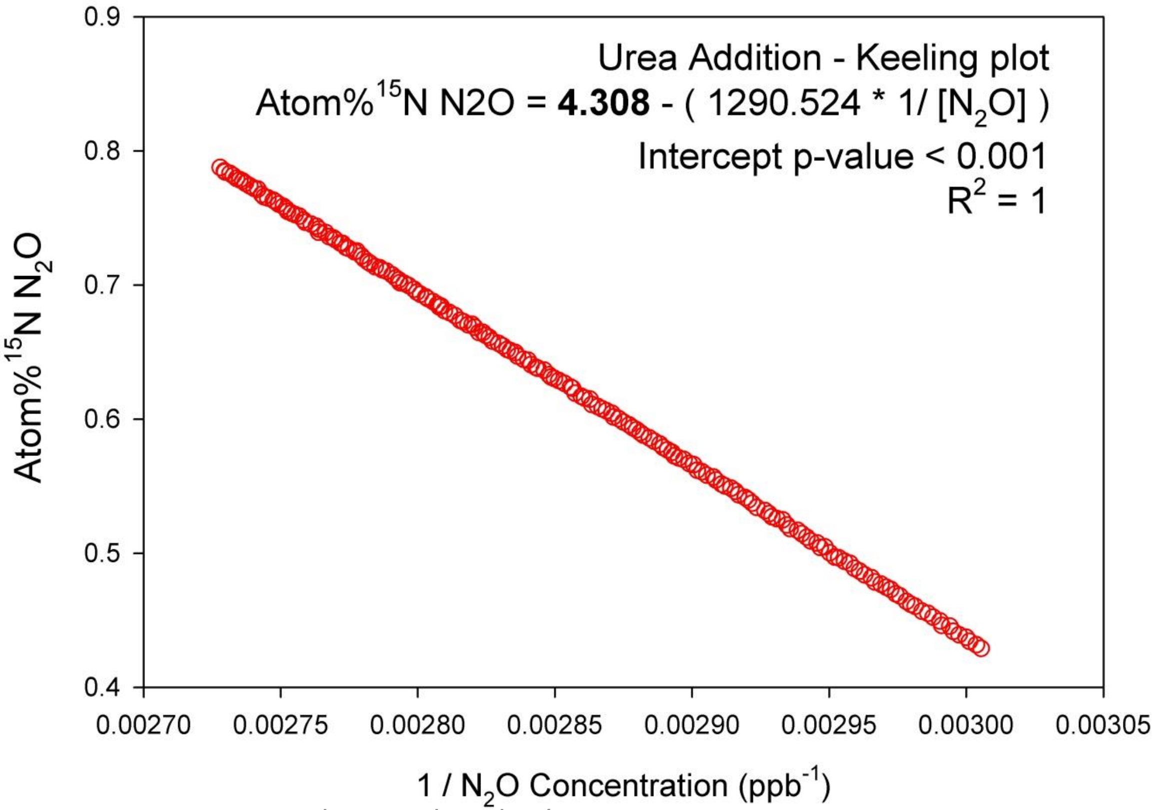
Response to N addition





Keeling Plot

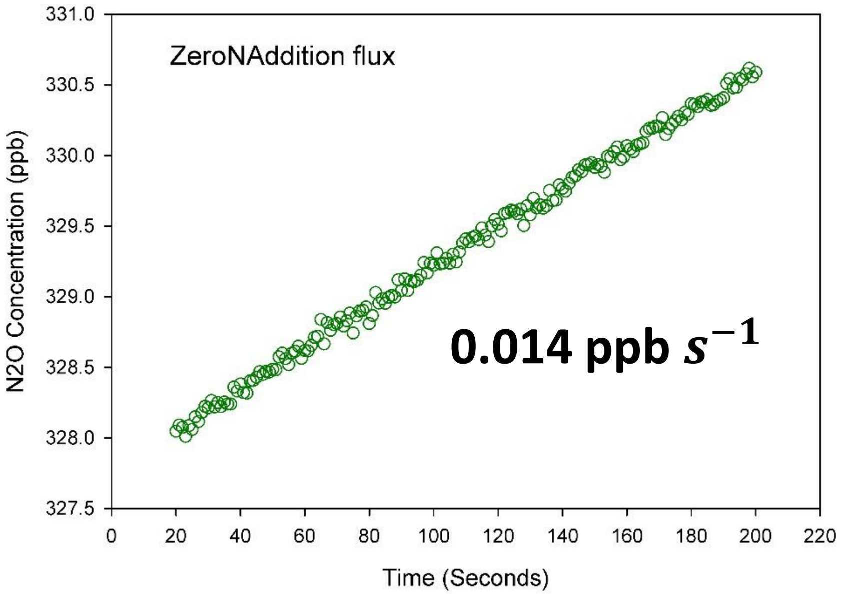


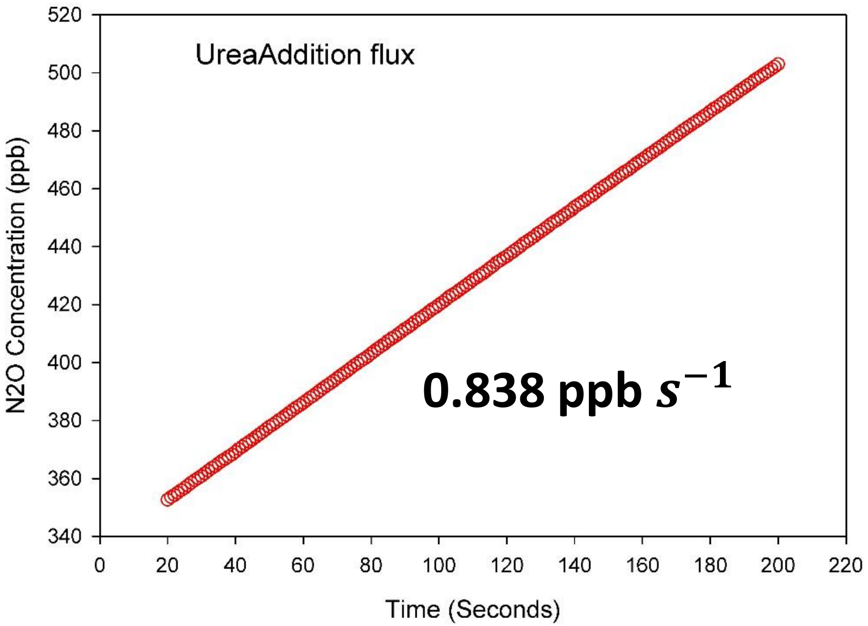


15N Mass Balance

- End members:
  - 5 Atom% labelled urea
  - 0.364 Atom% (in N_2O from control soil or in soilN)
- If 4.308 Atom%, N_2O pool-sources are
  - 85% from added urea
  - 15% from soilN

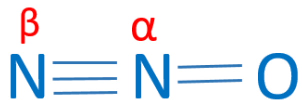
Priming on Soil Flux



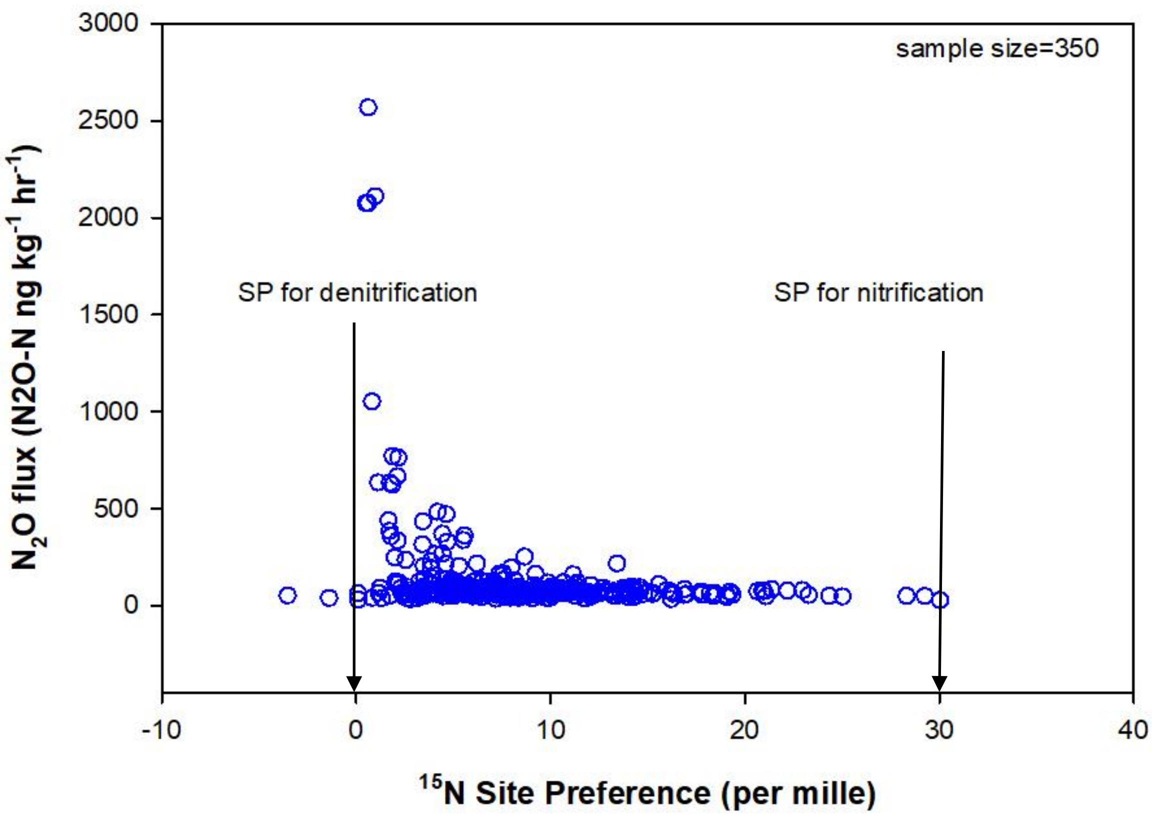


- 15% * 0.838 = 0.125 ppb s^{-1}
- Priming = 0.125 – 0.014 = **+0.111 ppb s^{-1}**

Source-Process

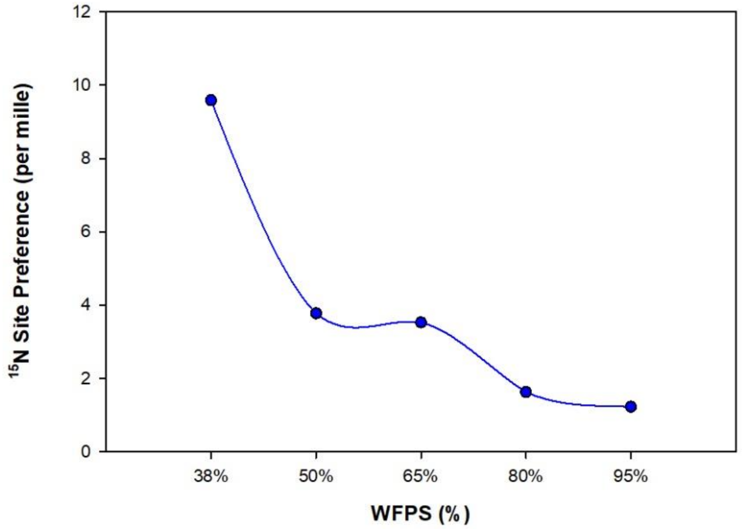


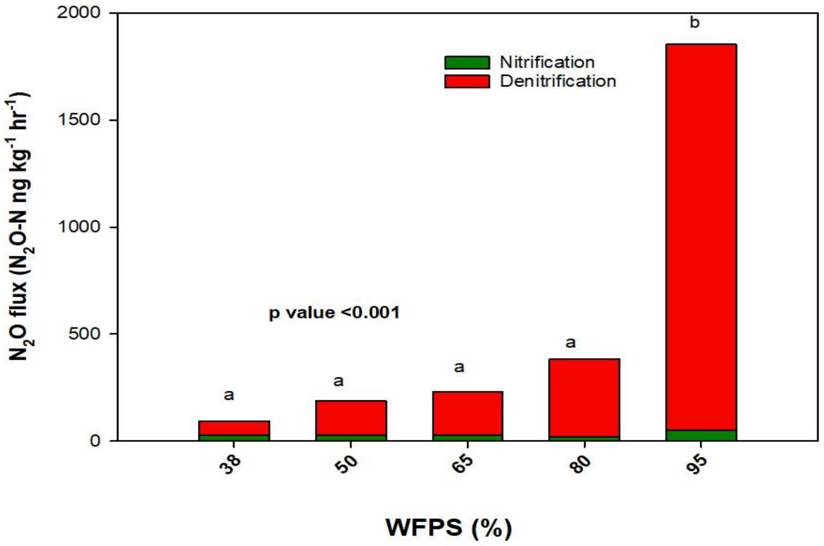
$\alpha - \beta = {}^{15}N$ site preference(SP)



Source-Process

delta 15 N Site Preference vs WFPS





Our Vital Soils:

- Carbon Turnover beneath Trees
- Carbon Mapping in Grasslands
- Peak N_2O Fluxes in Croplands
- Shifting Alpine Ecotones
- OnGoing & Prospects

Guillermo
Hernandez Ramirez

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