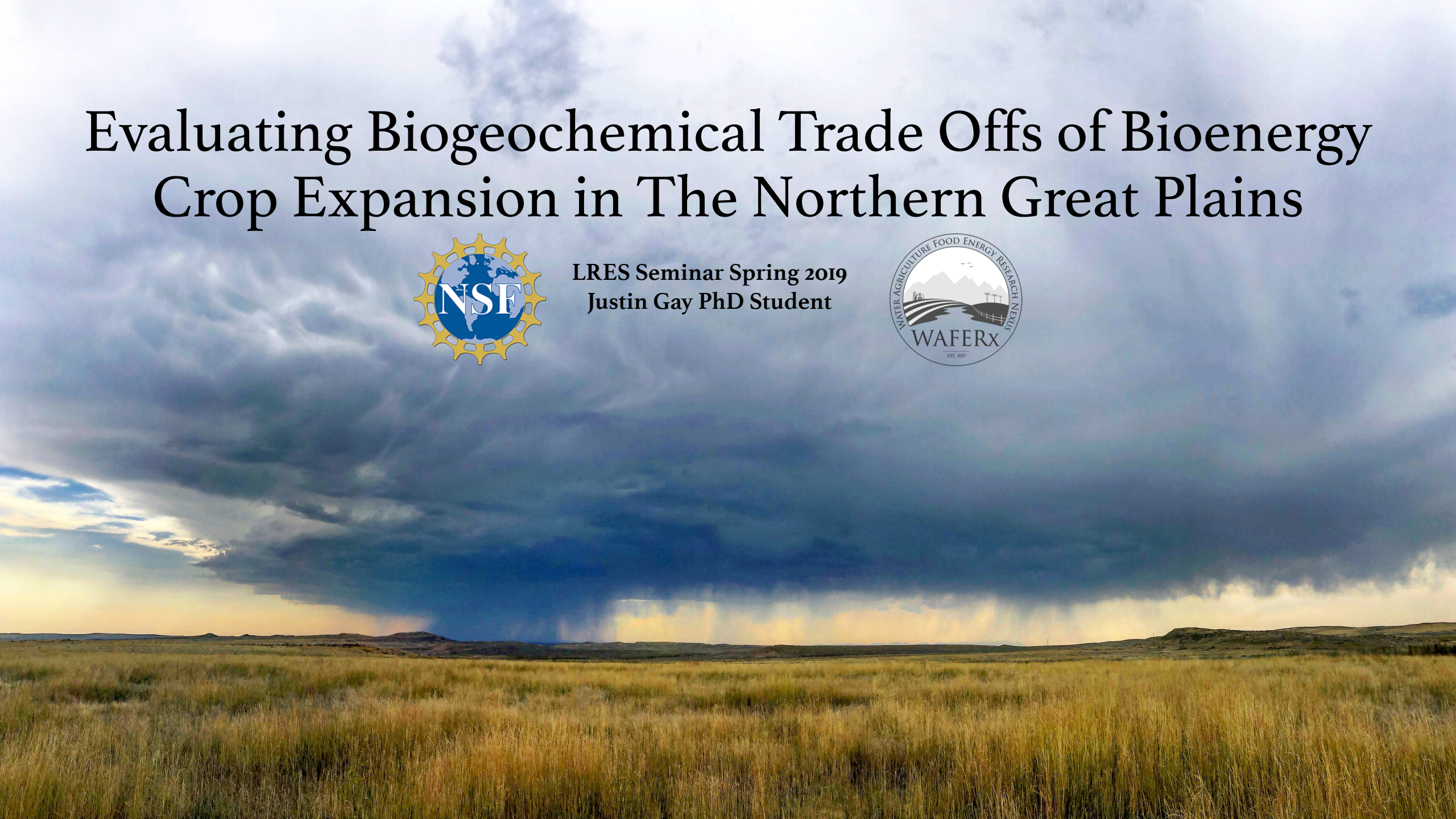
Evaluating Biogeochemical Trade Offs of Bioenergy Crop Expansion in The Northern Great Plains

LRES Seminar Spring 2019
Justin Gay PhD Student



Many Thanks

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How do terrestrial ecosystems function from a biogeochemical perspective?

Ecosystem response to global change and human activity.

Overview

1. **Intro & Background**
   - Climate Change & Mitigation
   - Fertilizer & Bioenergy Crops
   - WaferX Project
2. Objectives & Methods
3. Preliminary Analysis

1. Background

An Uncertain Future for the Planet

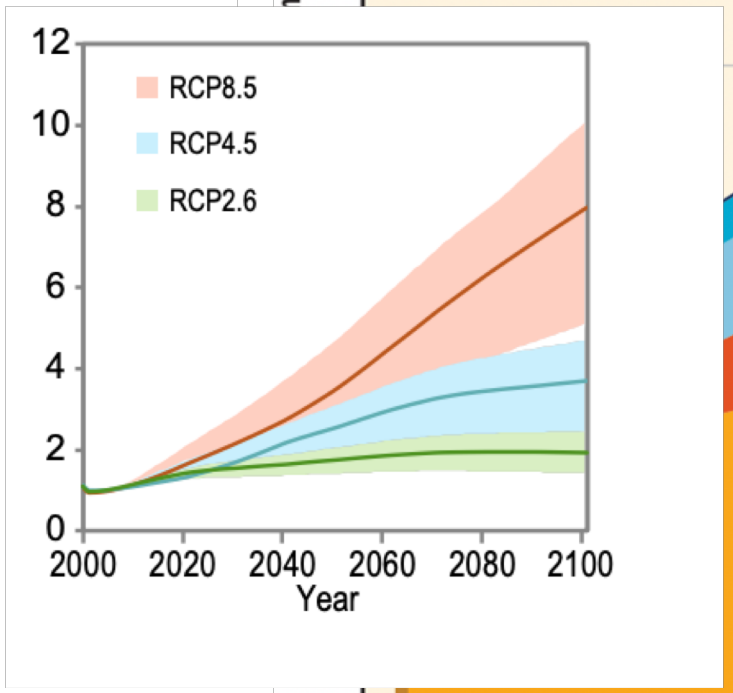
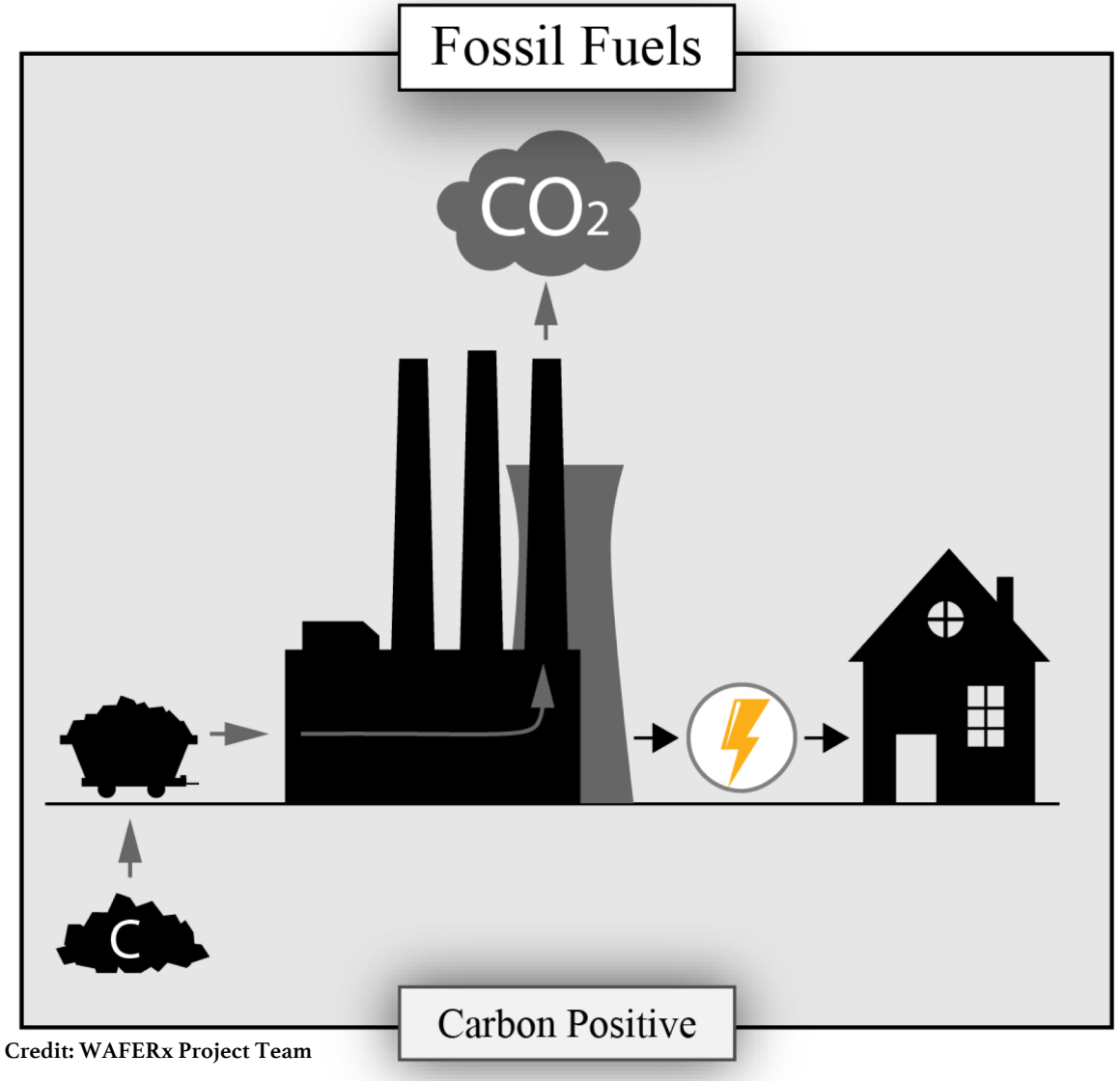
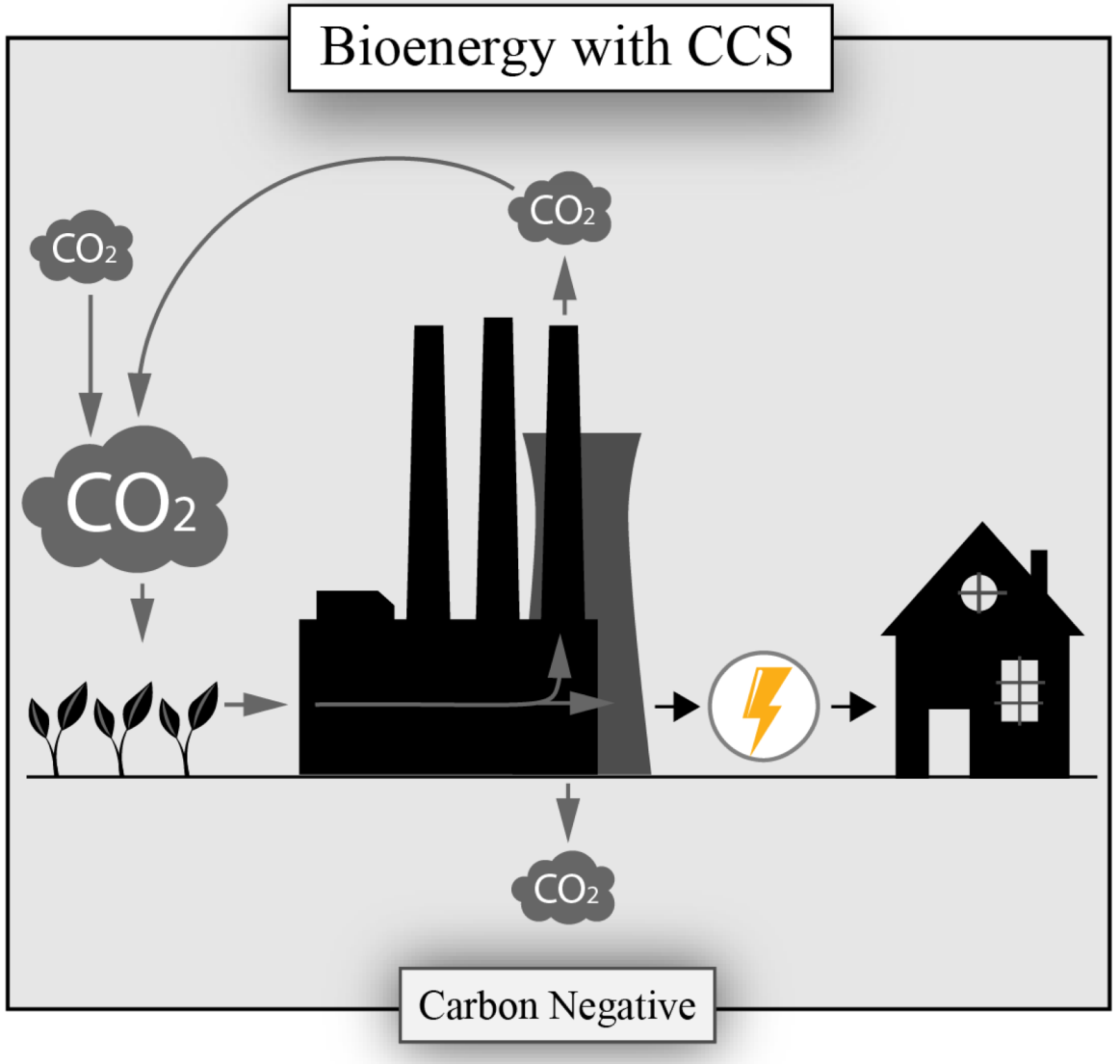


Figure : 5th Assessment Report IPCC

1. Background

BECCS: Regional Approach for Energy and Net Negative Emissions



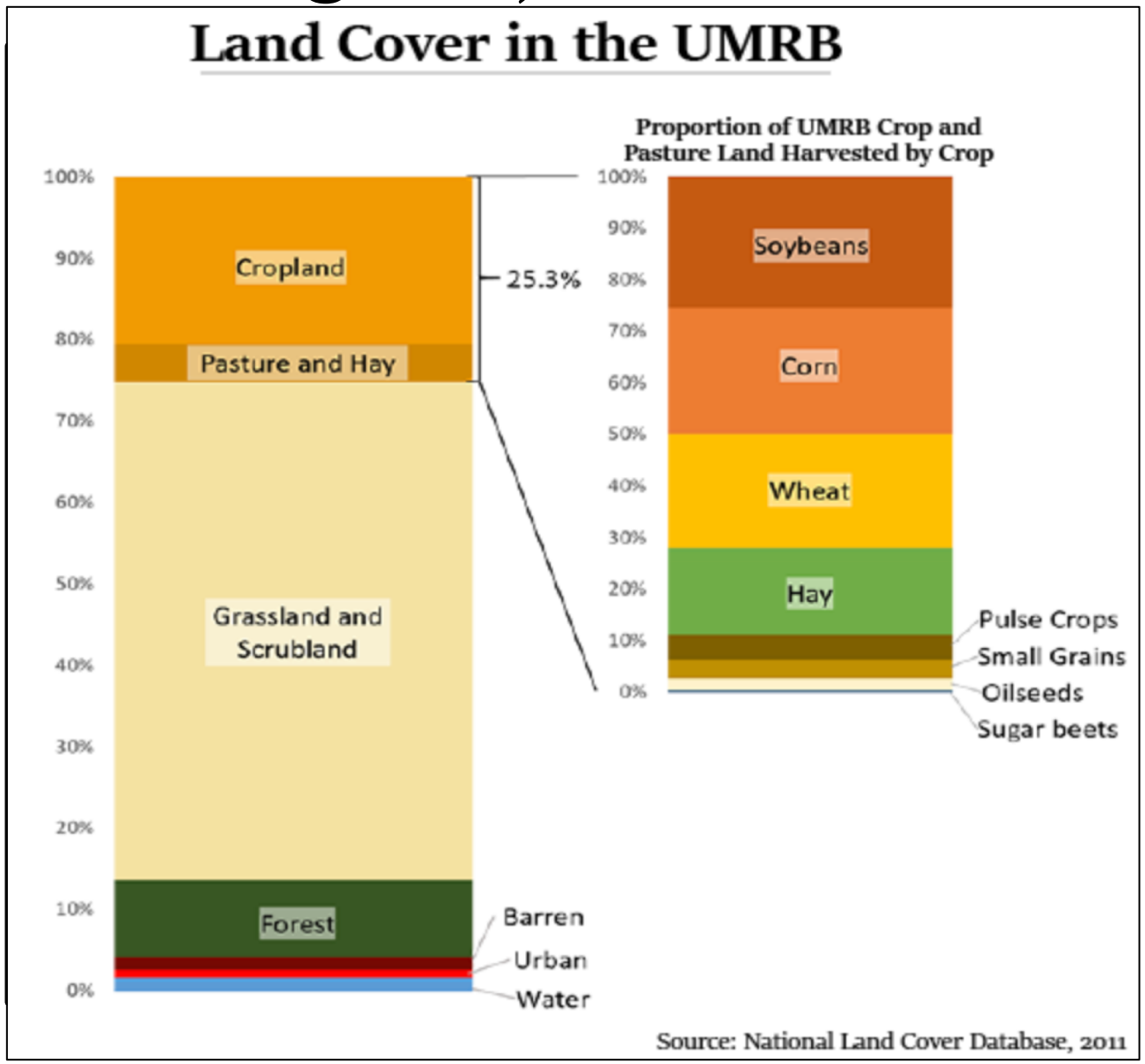


Credit: WAFERx Project Team

I. Background

WAFERx: Overarching Project Goals

- Is this energy system possible in the UMRB?
- Focus on marginal lands
- The assumptions of BECCS at regional scales are rarely tested. **How will they conflict with food, water, energy, biodiversity, *biogeochemical* and social/economic systems?**



MONTANA STATE UNIVERSITY

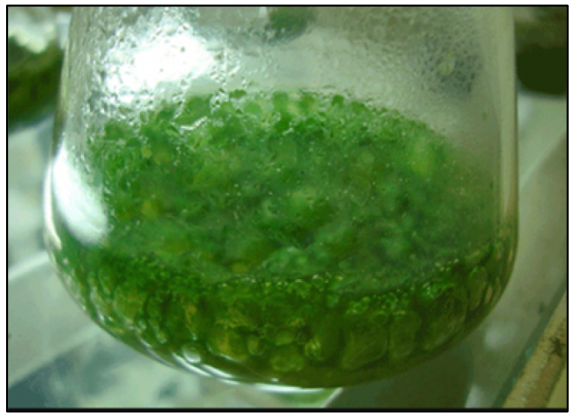
UNIVERSITY OF SOUTH DAKOTA

UNIVERSITY OF WYOMING

1. Background

Fertilizers & Bioenergy Crops

Granular Urea Fertilizer



Biofertilizer

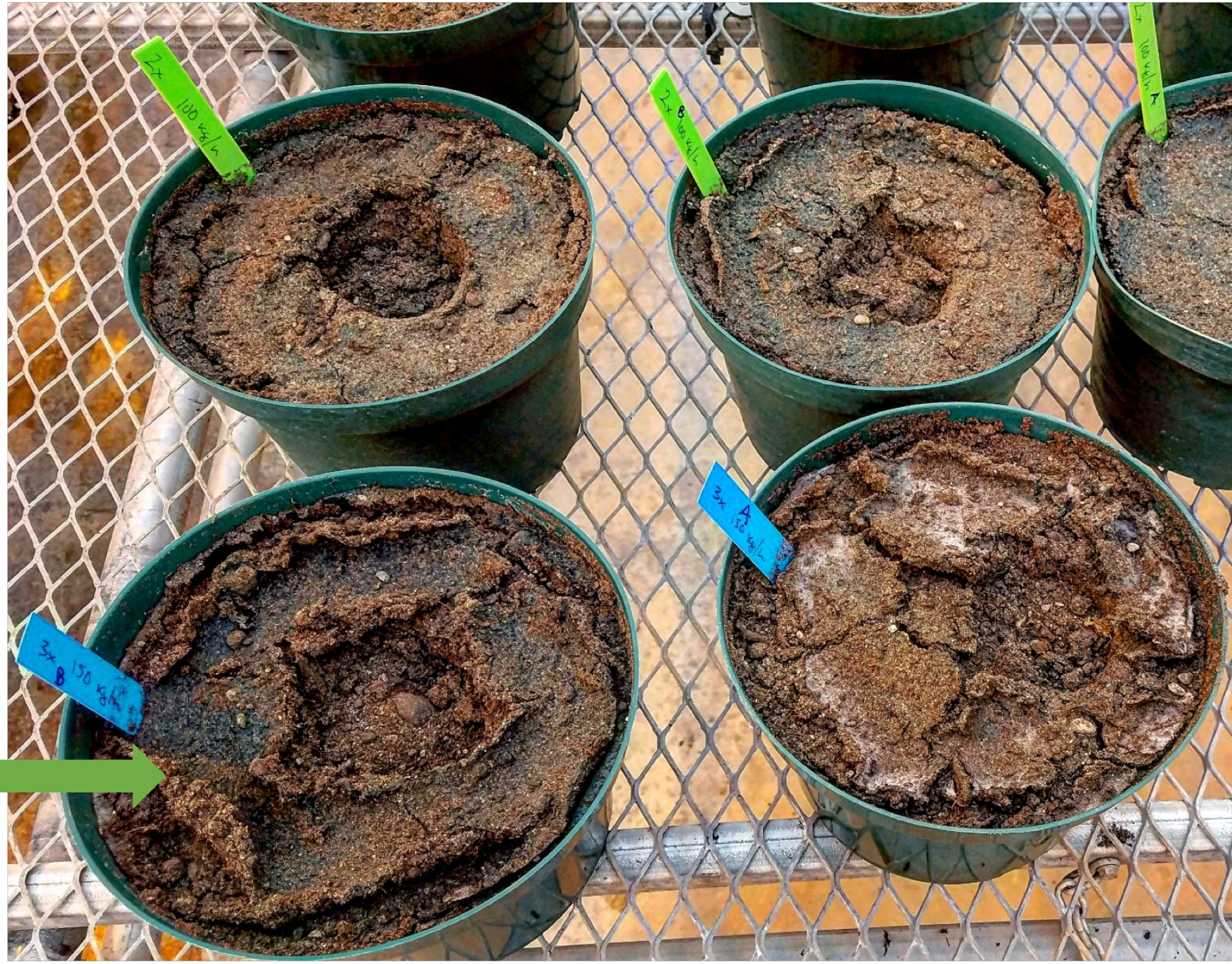
Maximize production &
Minimize inputs

Tall wheatgrass
(*Thinopyrum ponticum*)

Switchgrass
(*Panicum virgatum*)

2. Background

N fixing biocrust ??



Presentation Overview

1. Background

2. **Objectives & Methods**
   1. **Study Objectives**
   2. **Ecosystem N Modeling**
   3. **Experimental design/ Methods**

3. Preliminary Analysis

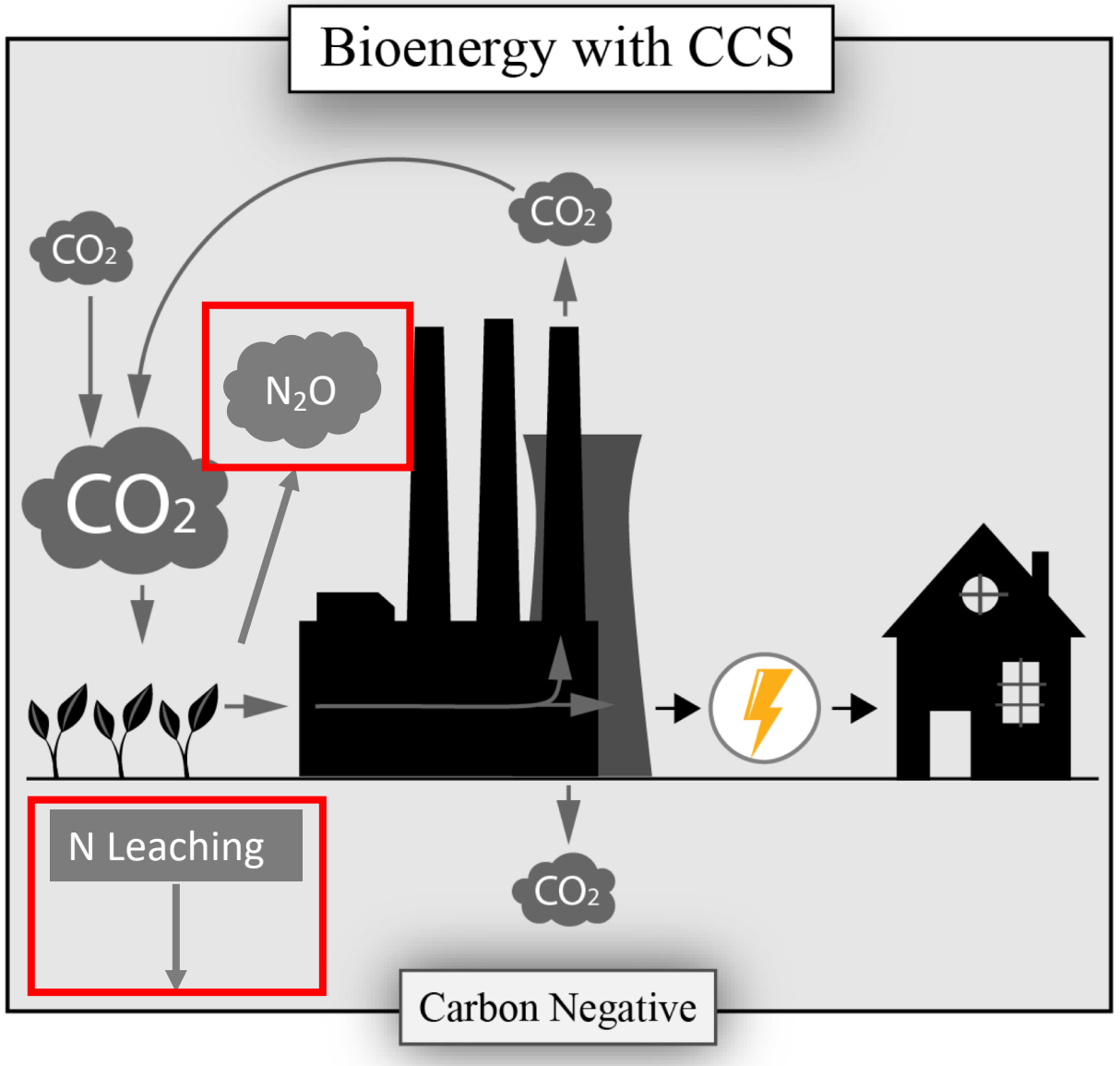
2. Objectives

Research Objectives

Evaluate N cycling to engineer the most efficient management system

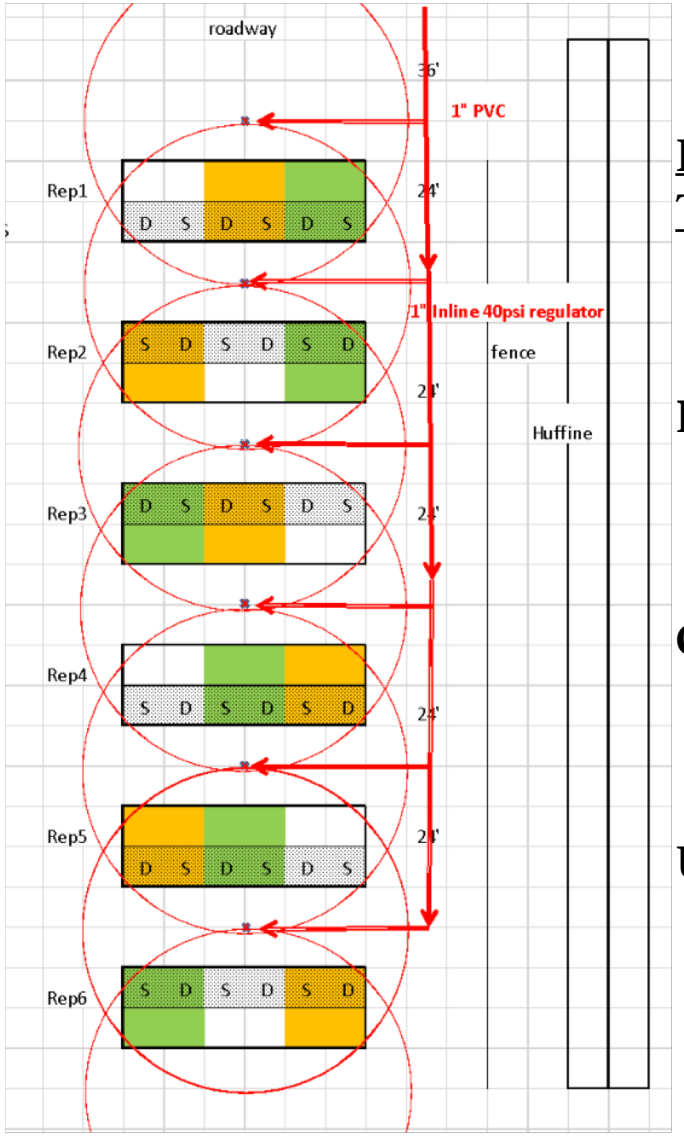
A. Which fertilizer treatment/ bioenergy crop combination offers the most efficient route to reduce direct greenhouse gas emissions, limit N leaching, while increasing soil carbon storage?

B. What is the capacity of biofertilizers to provide a sustainable source of plant available N in agroecosystems.



2. Methods

Field Site and Plot Layout: Post Farm



Fertilizer Treatments

Biofertilizer

Control

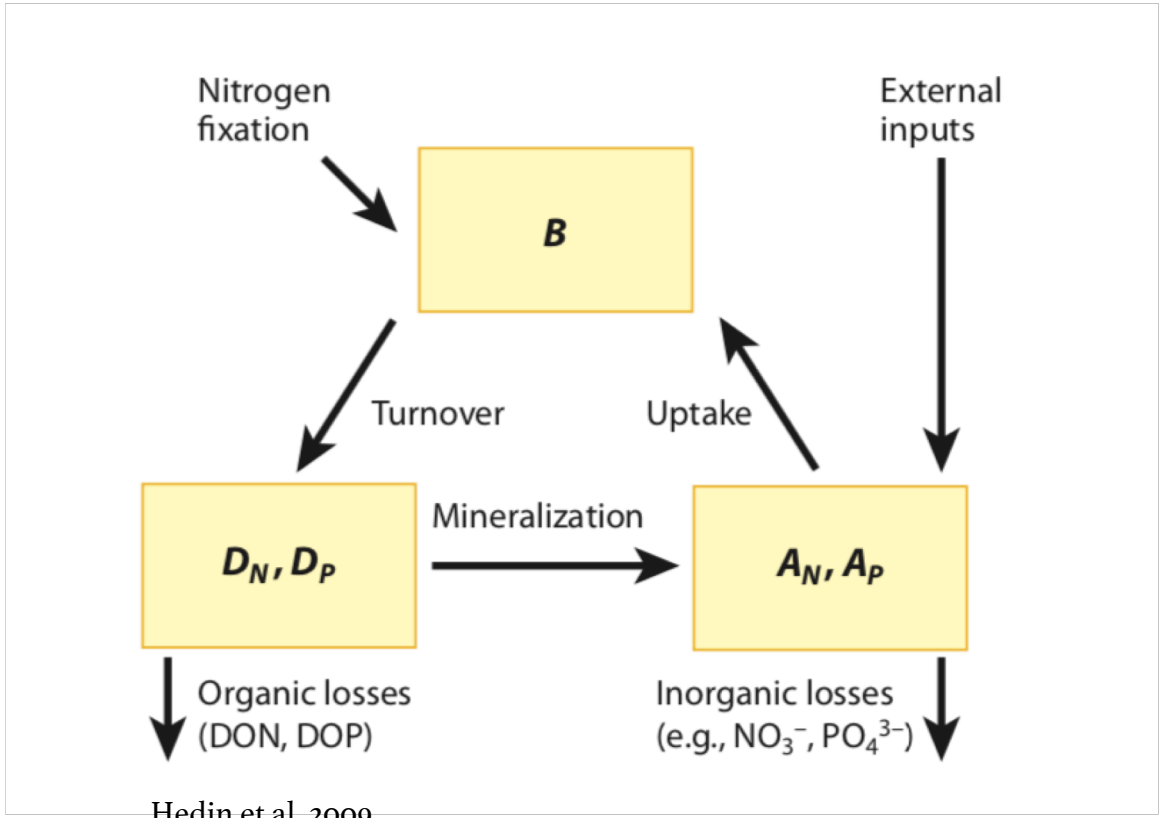
Urea

N

Credit: Jeff Holmes

2. Methods

Ecosystem Nutrient Cycling Model: Nitrogen

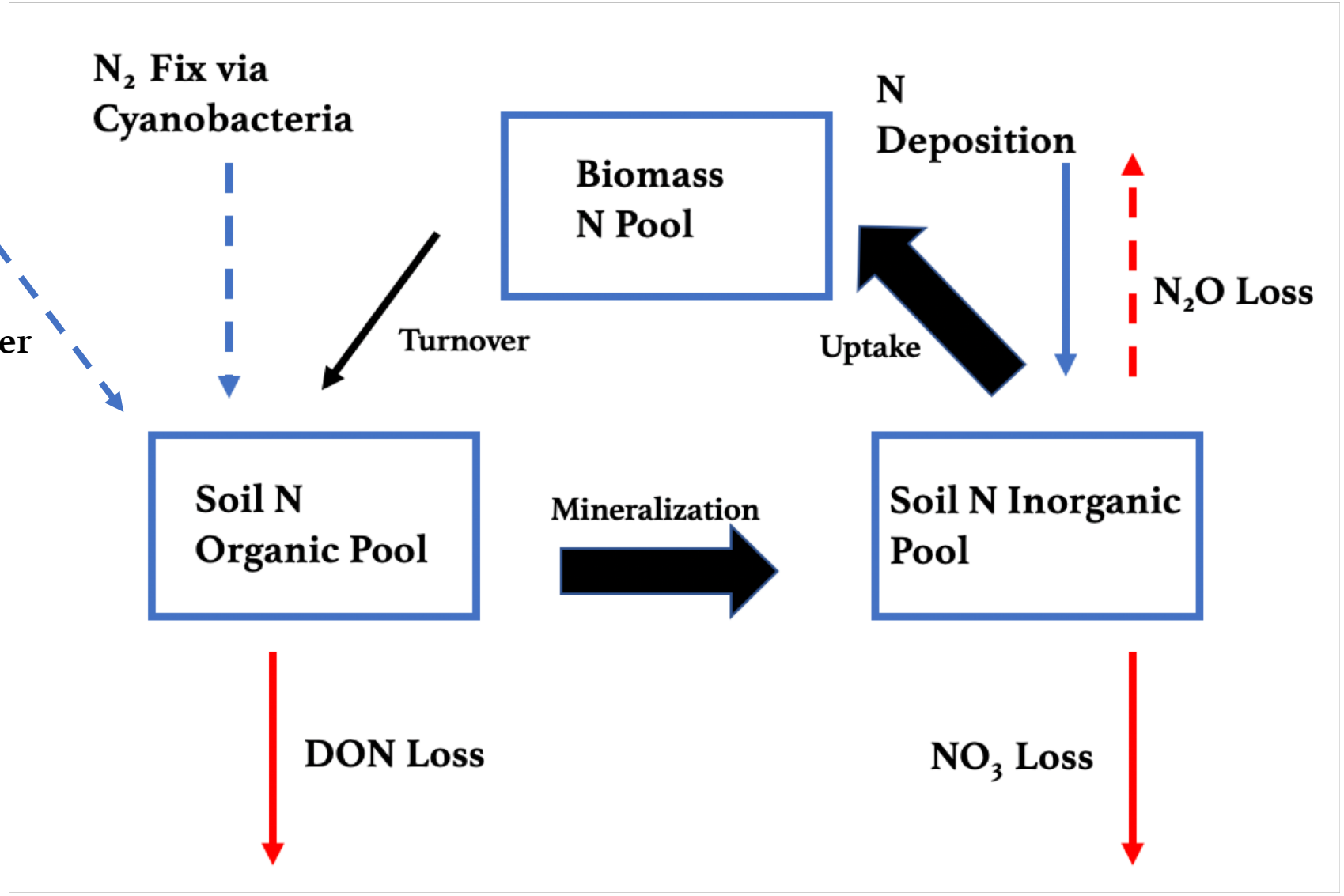


Hedin et al. 2009

Assuming Steady State
Inputs = Outputs

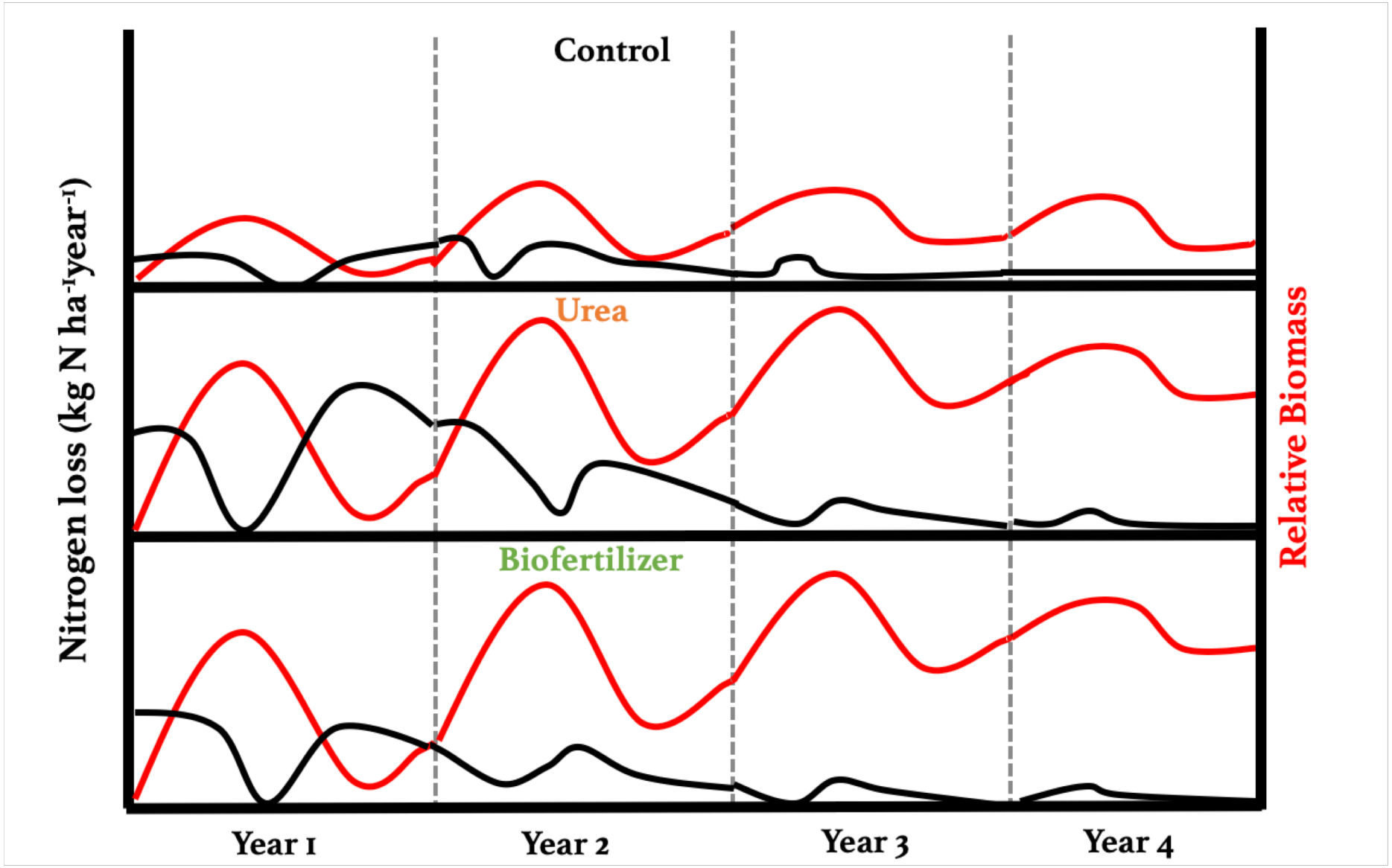
2. Methods

Conceptual N Cycling Model: Agroecosystem



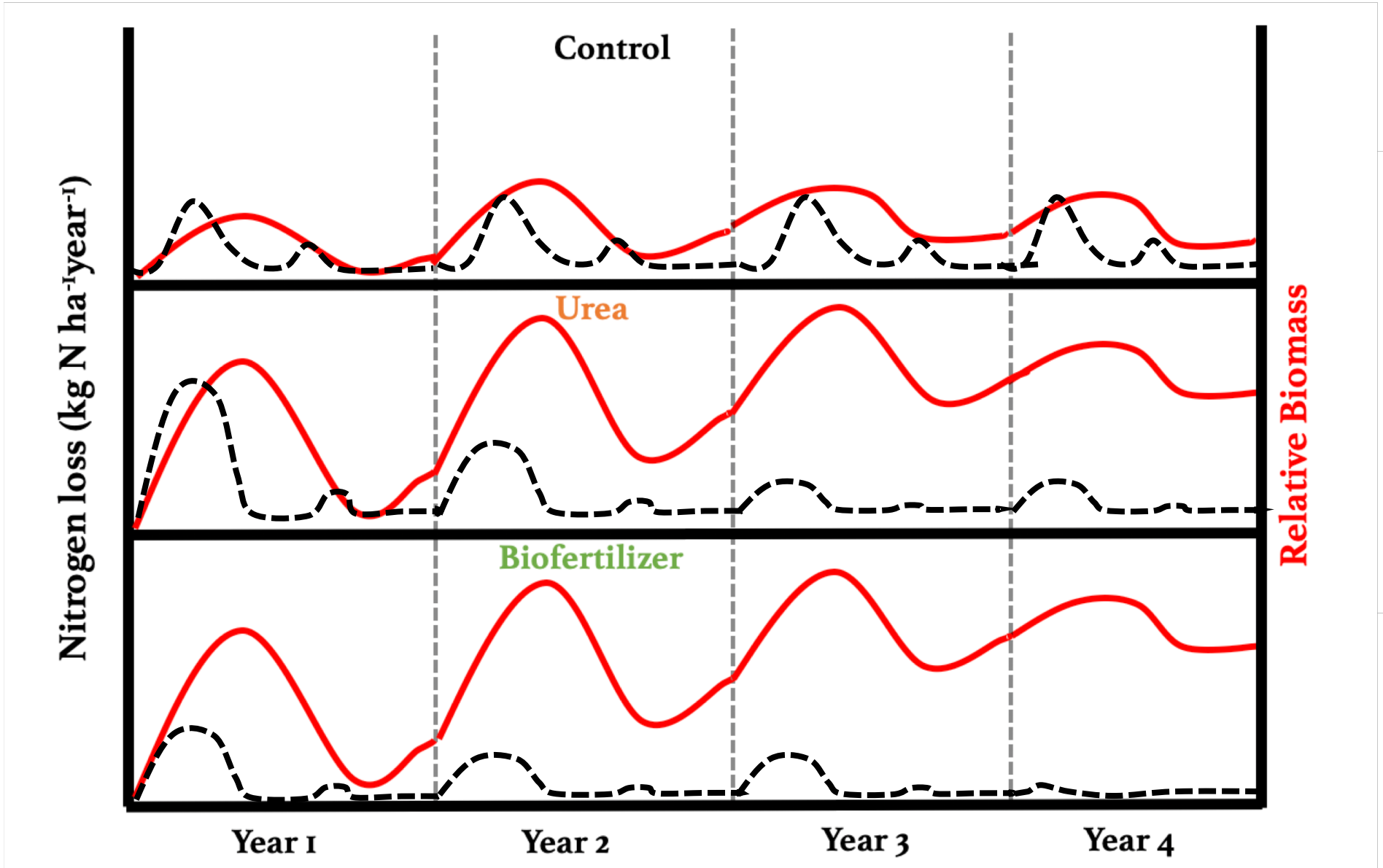
2. Methods

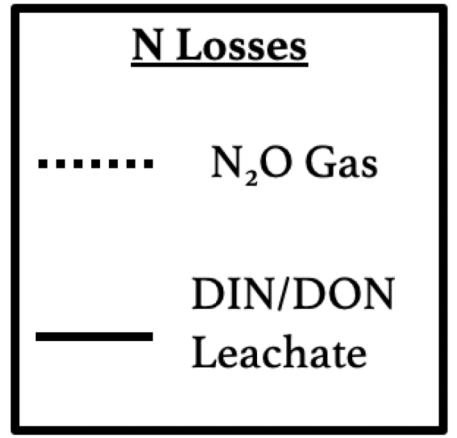
Evolution of Agroecosystem N Losses



2. Methods

Evolution of Agroecosystem N Losses

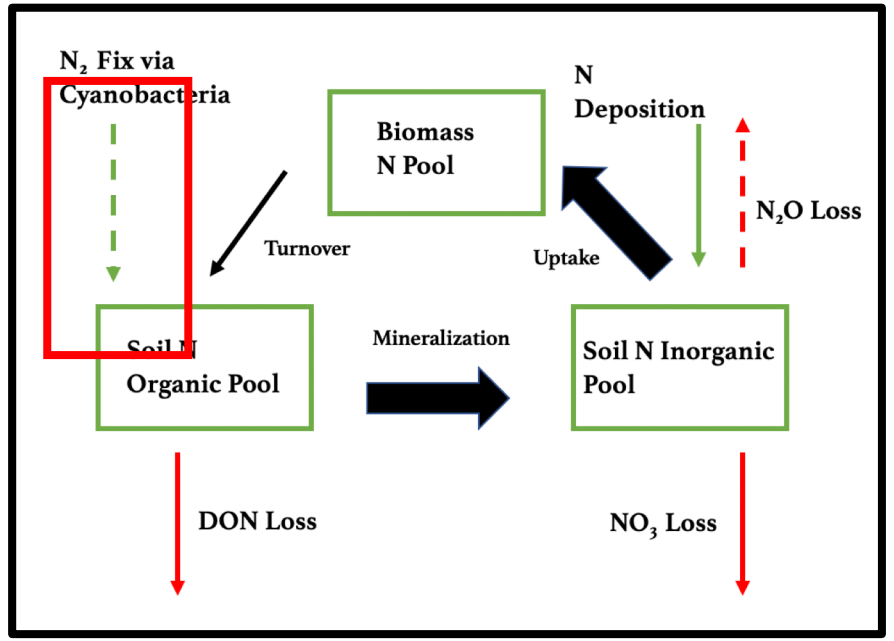




2. Methods

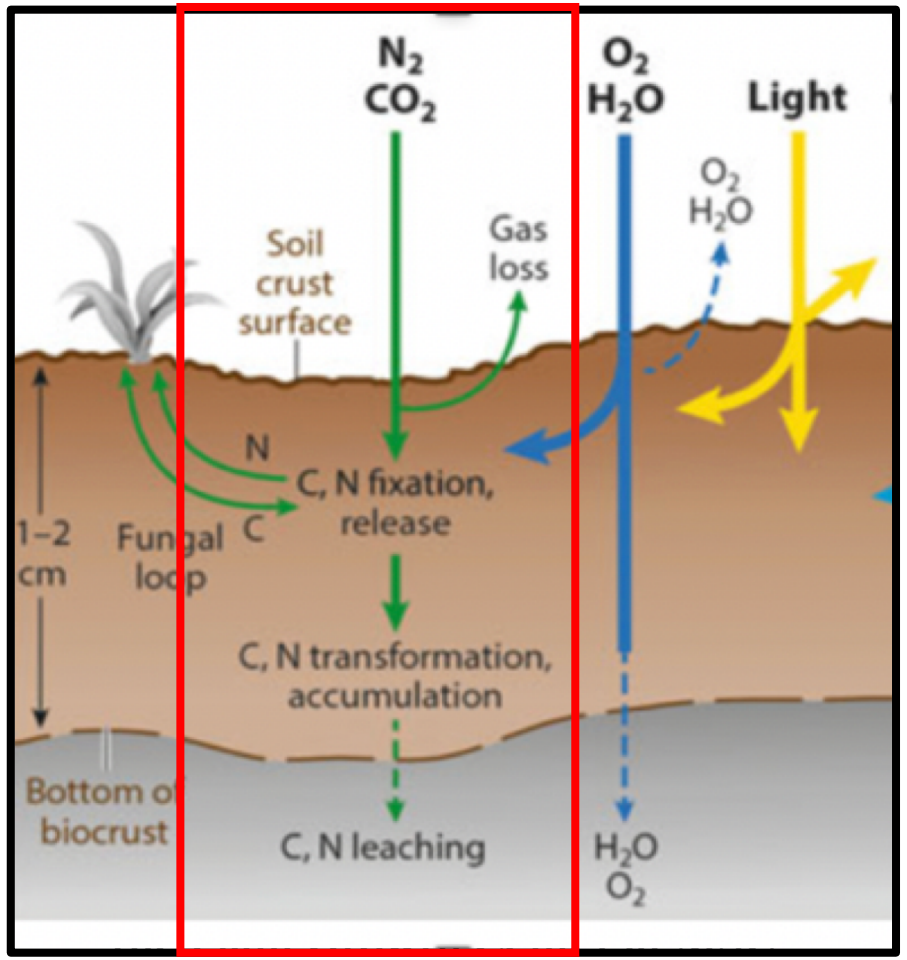
Biocrust Development as a Sustainable Biofertilizer

Detecting N Fixation: Running Acetylene Reduction Assay in the Plant Growth Center at MSU



2. Background

Biocrust Development as a Sustainable Biofertilizer

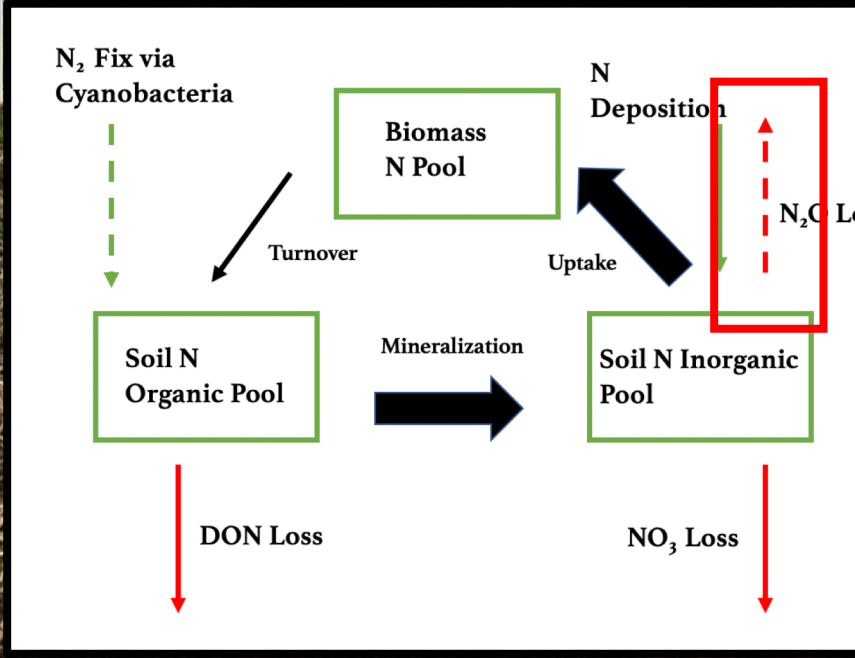


Hannah Goemann & Jeff Holmes Applying Cyanobacteria Biofertilizer at the Post Farm

Belnap et al 2016

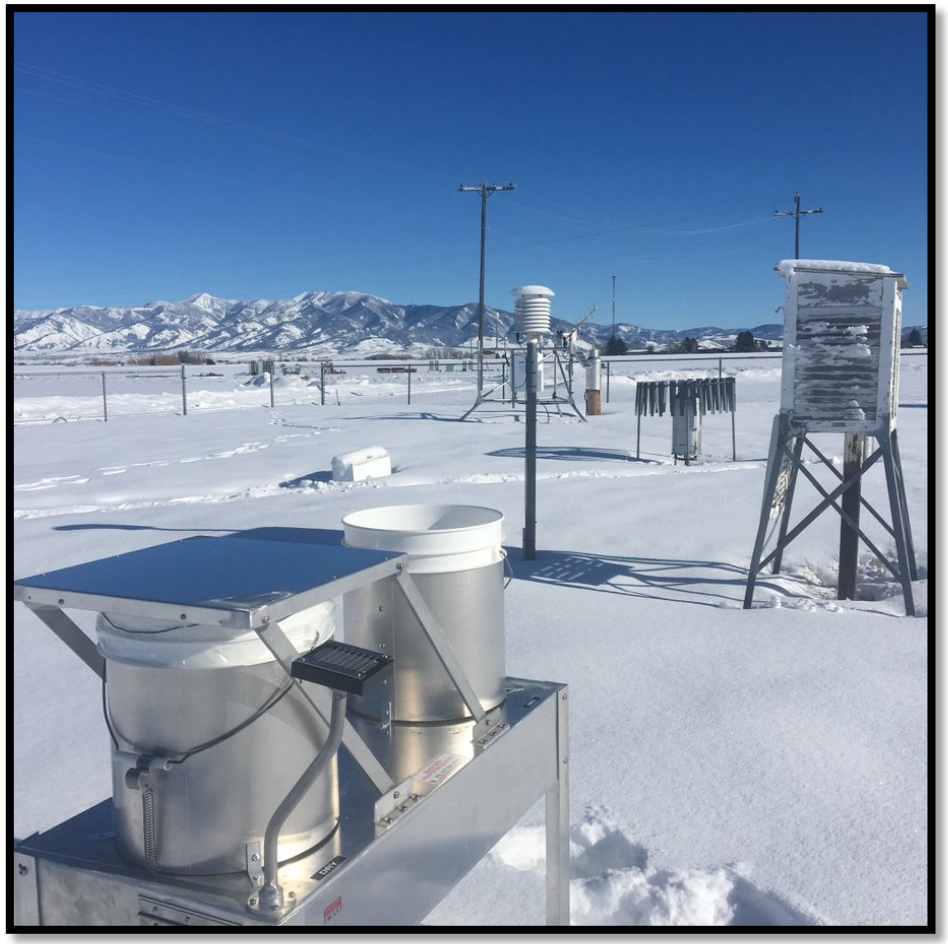
2. Methods

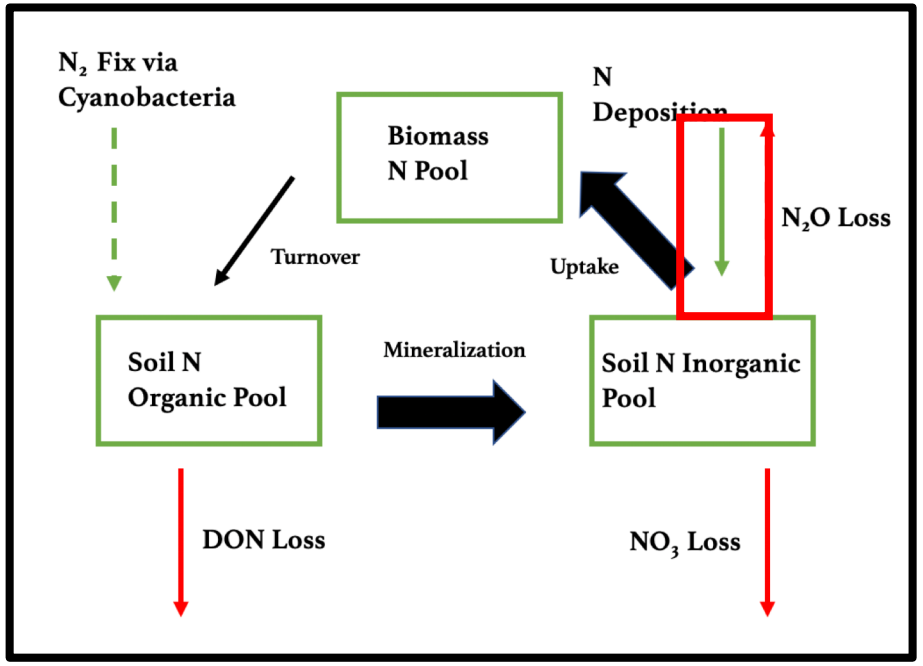
N_2O Emissions in Perennial Grass Systems



2. Methods

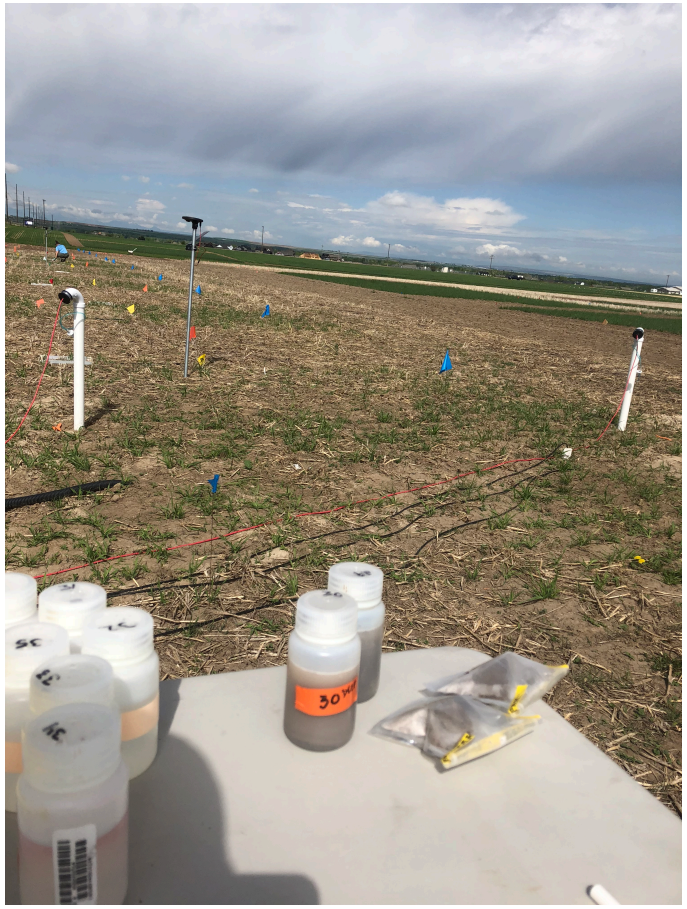
Atmospheric Deposition Collection

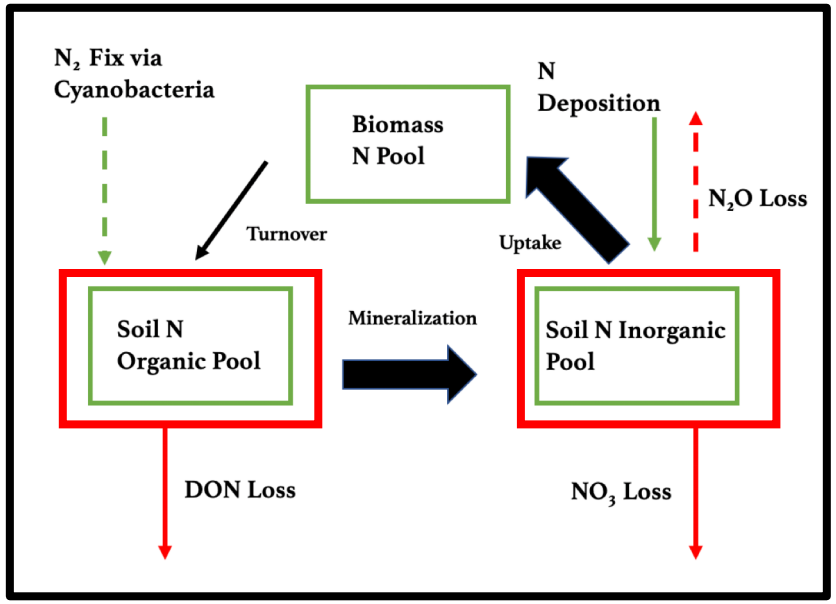




2. Methods

Soil chemistry

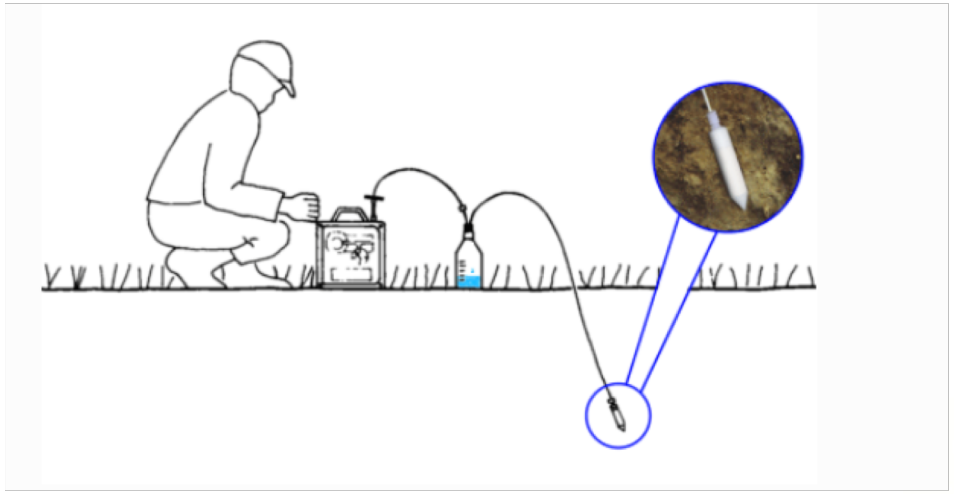


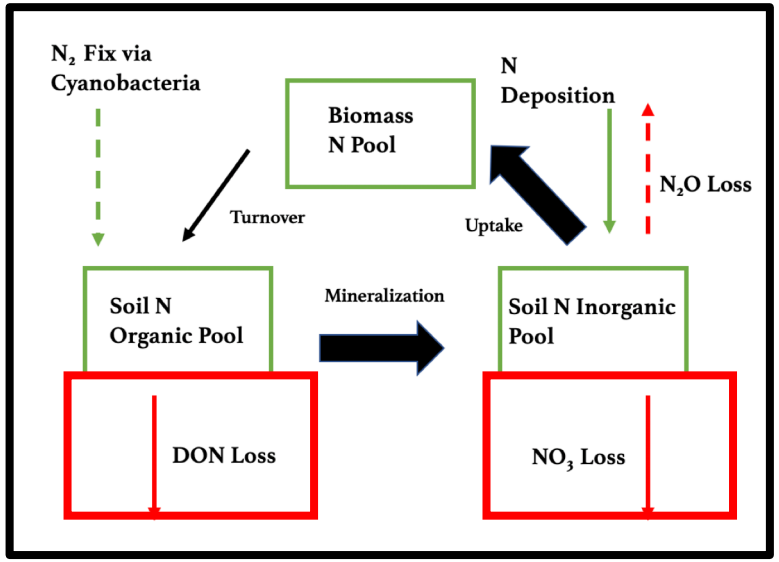


Soil cores (0-15cm, 15-30cm) to extract soil available N and process for total N

2. Methods

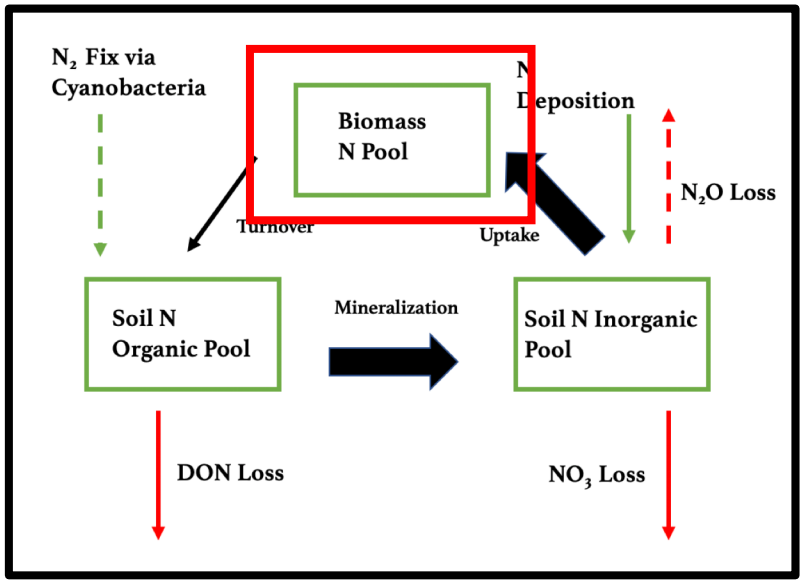
Nitrogen Leaching





2. Methods

Aboveground Biomass



Overview

1. Intro & Background

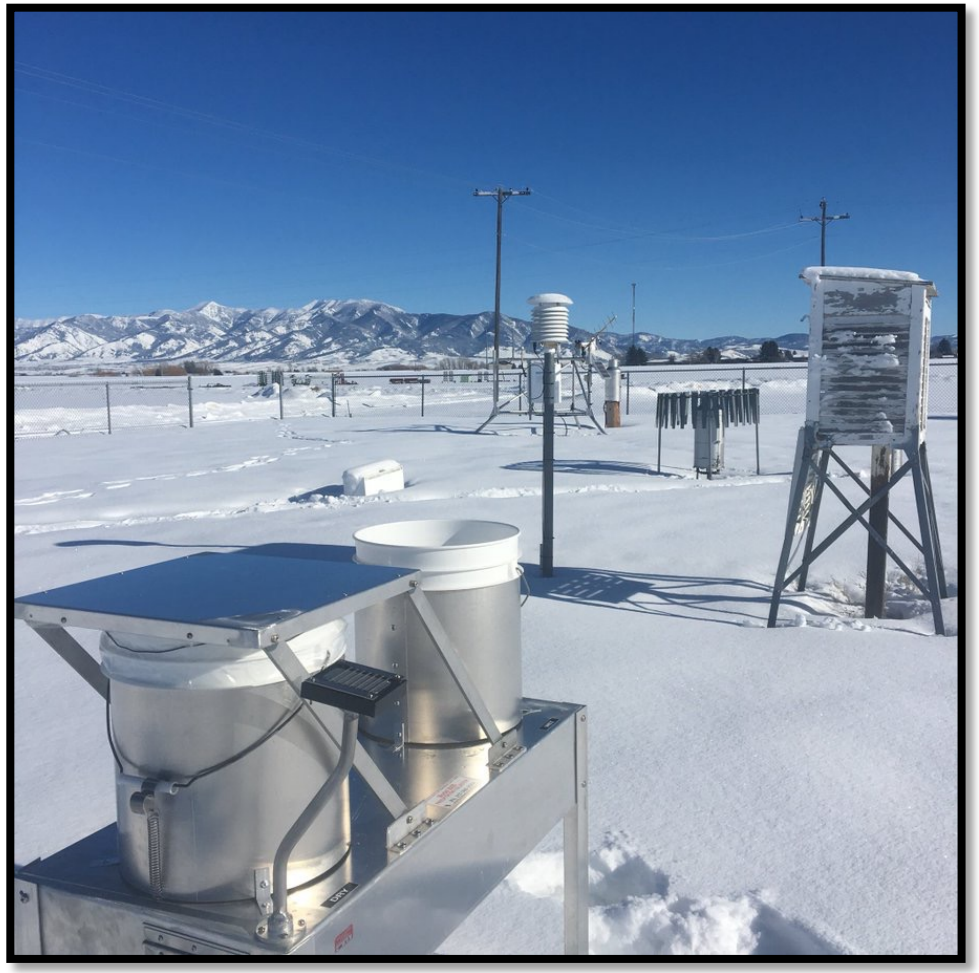
2. Objectives & Methods

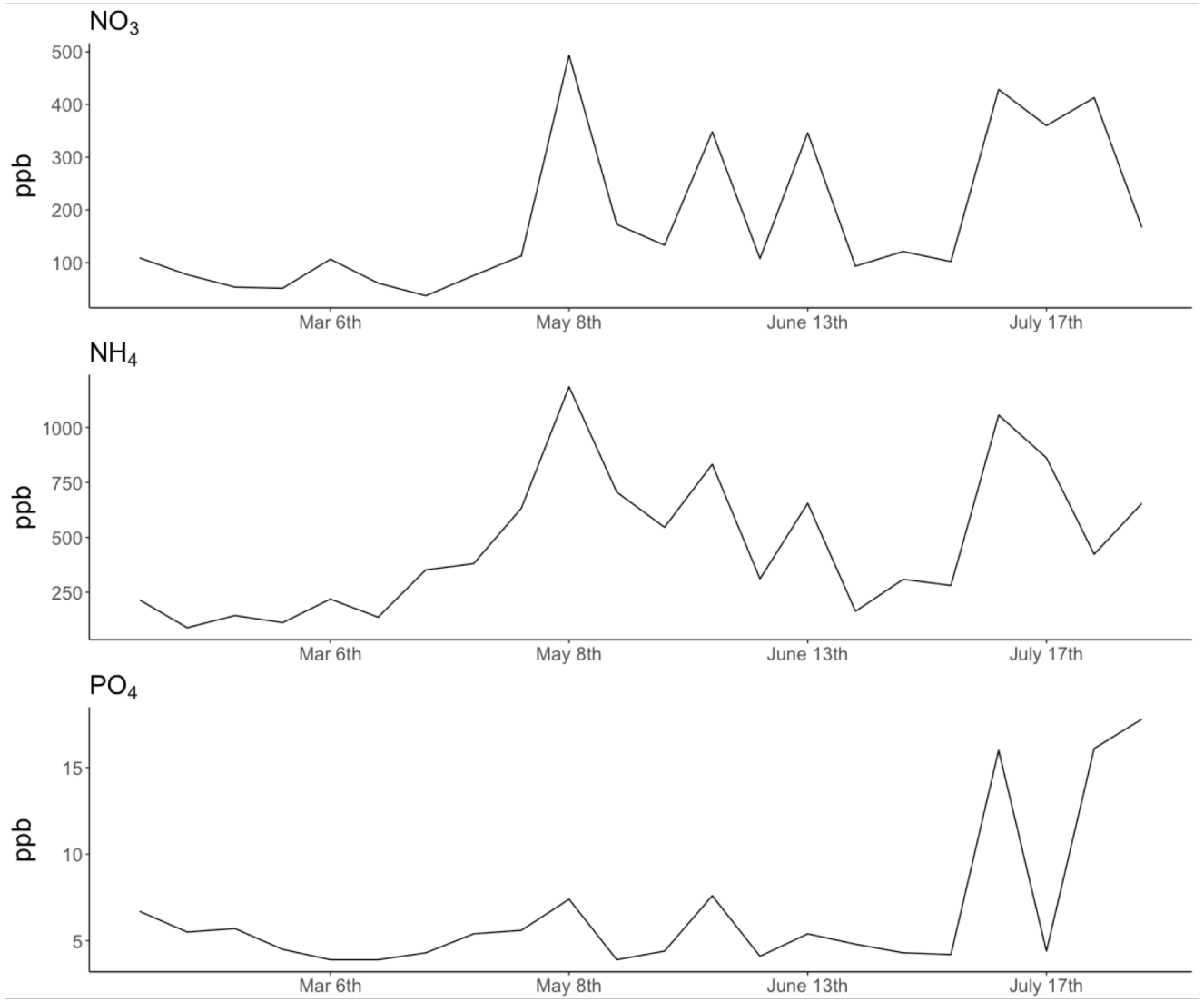
3. **Preliminary Analysis**

1.Summer 2018: Barley Yield

3. Analysis

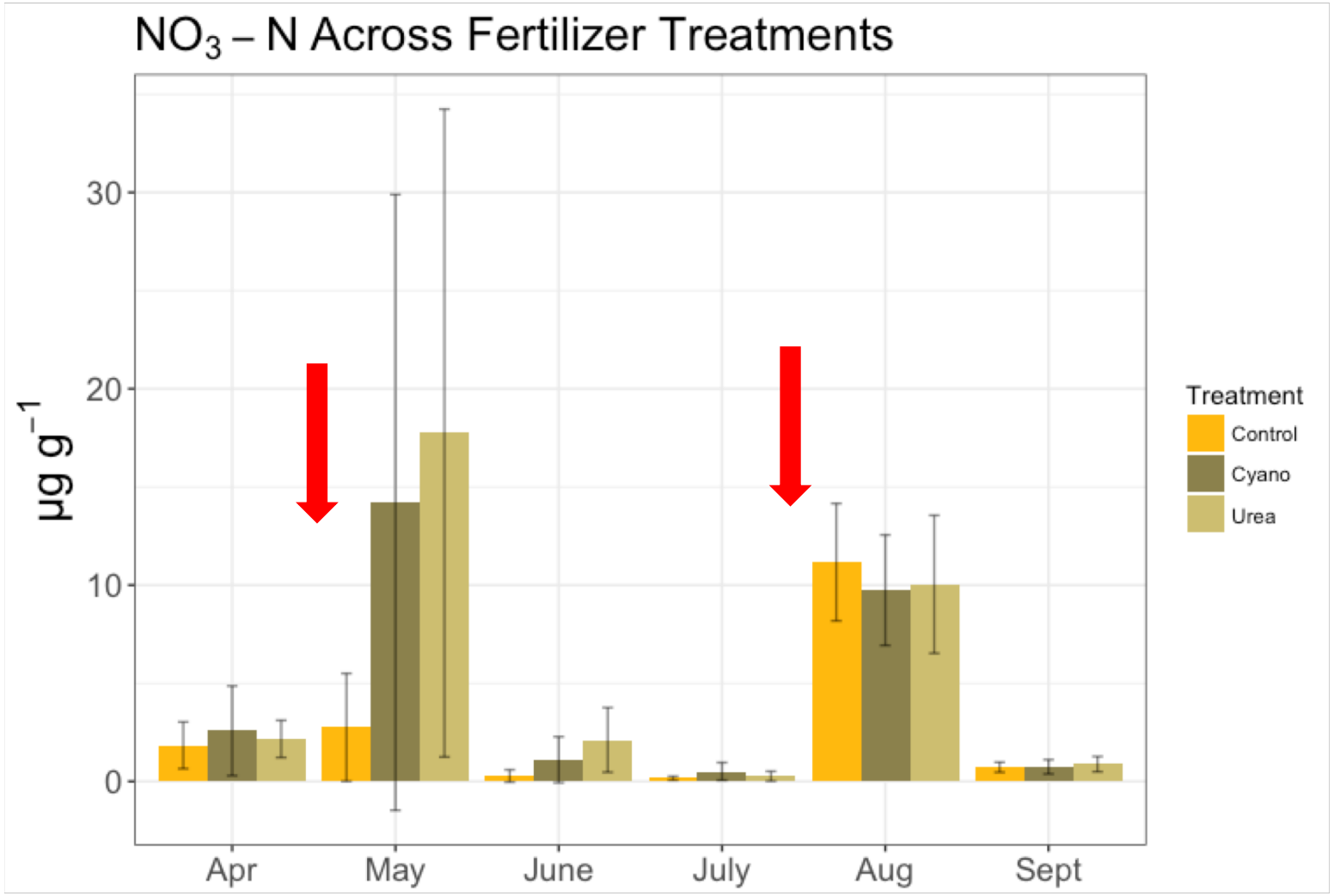
Atmospheric Deposition Collection

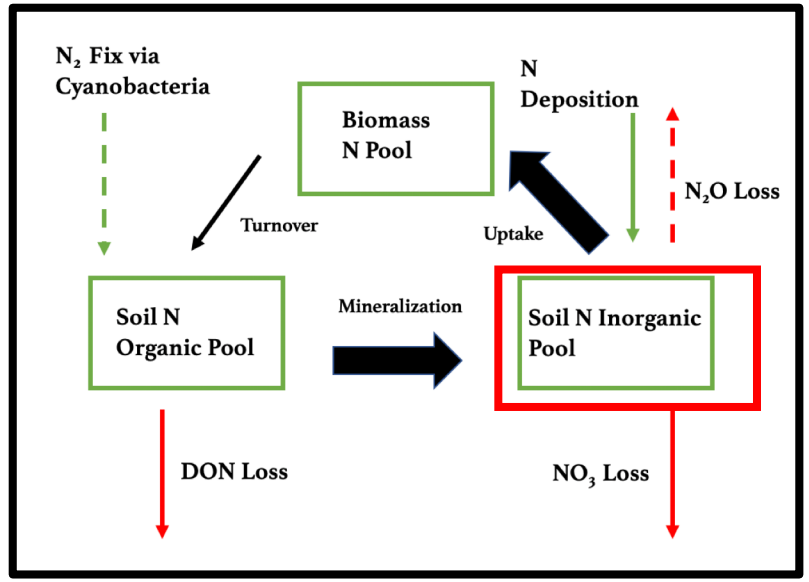




3. Analysis

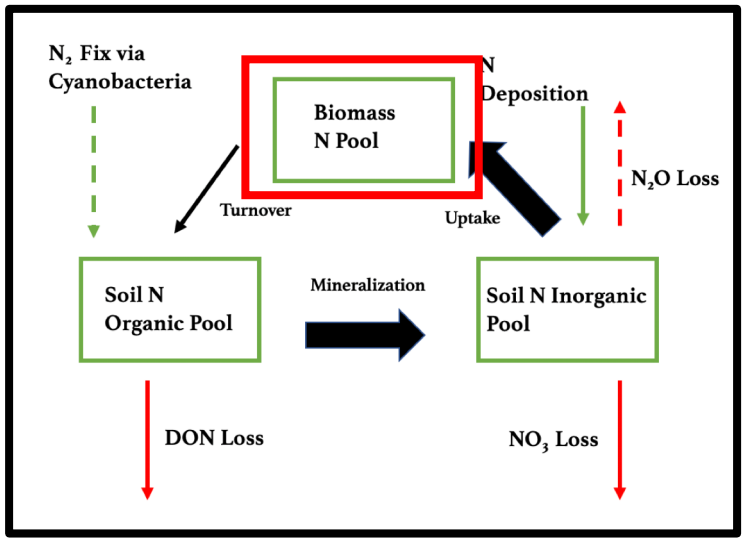
Plant Available Inorganic N Pool

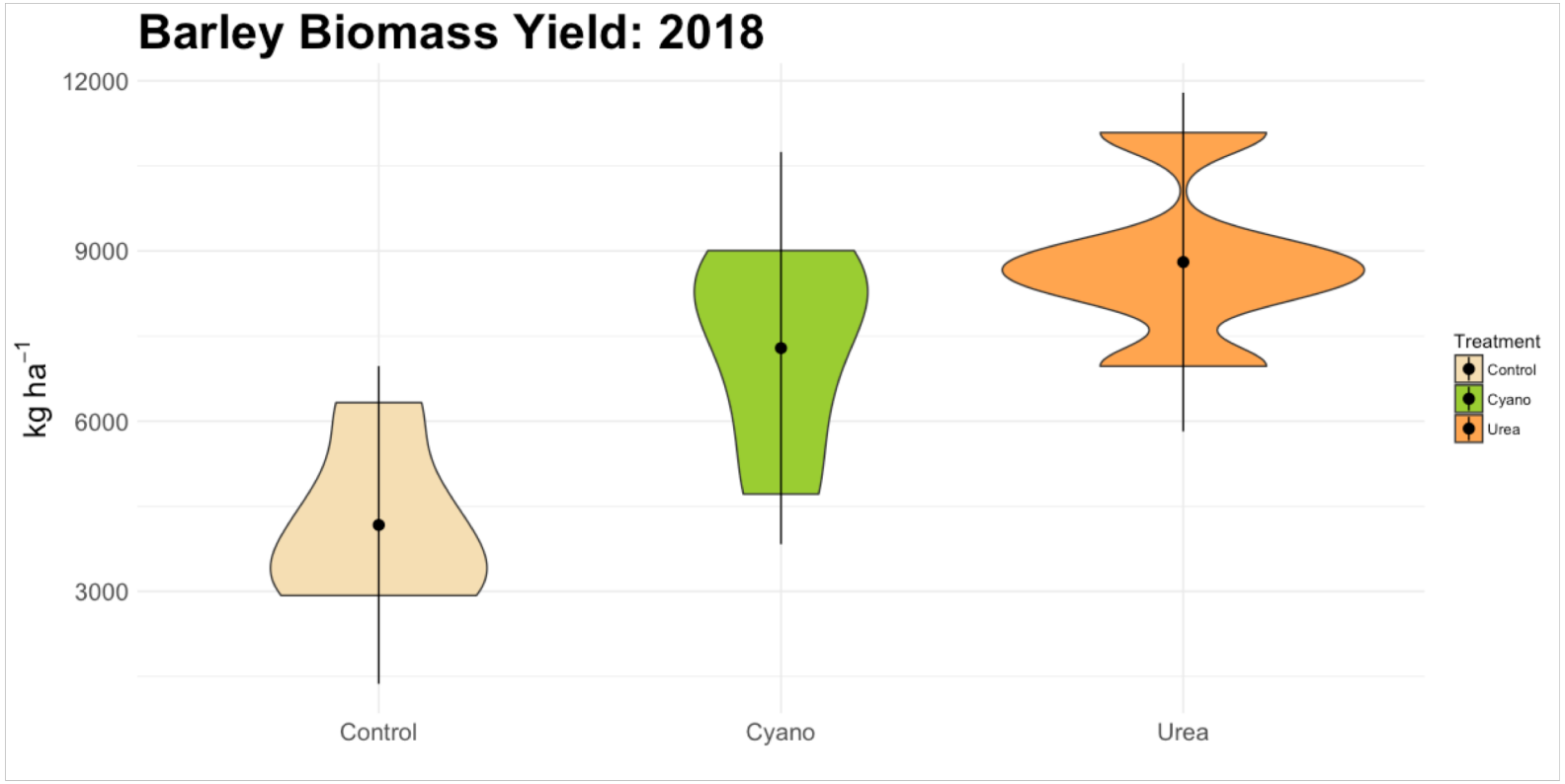




3. Analysis

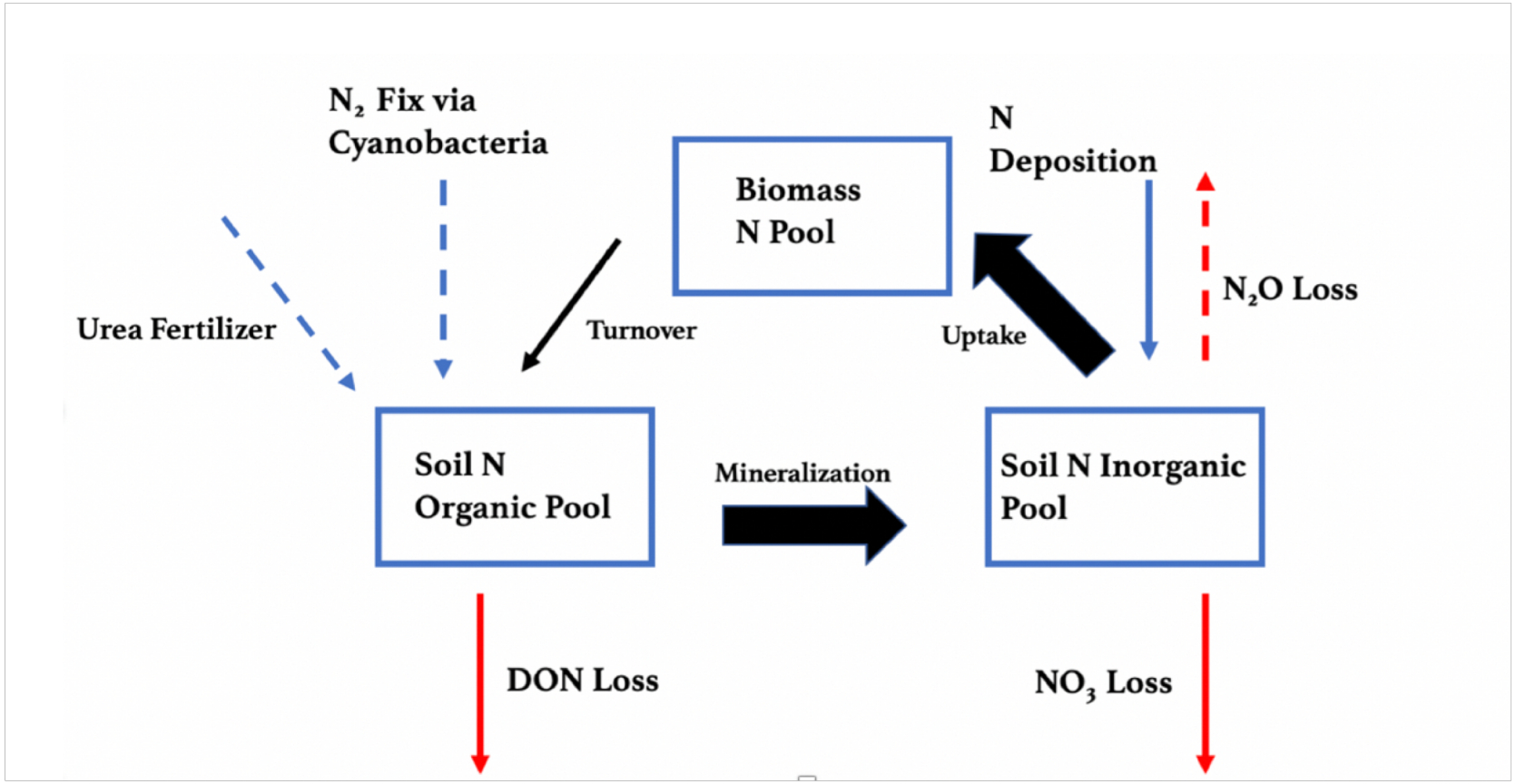
Aboveground Biomass





3. Analysis

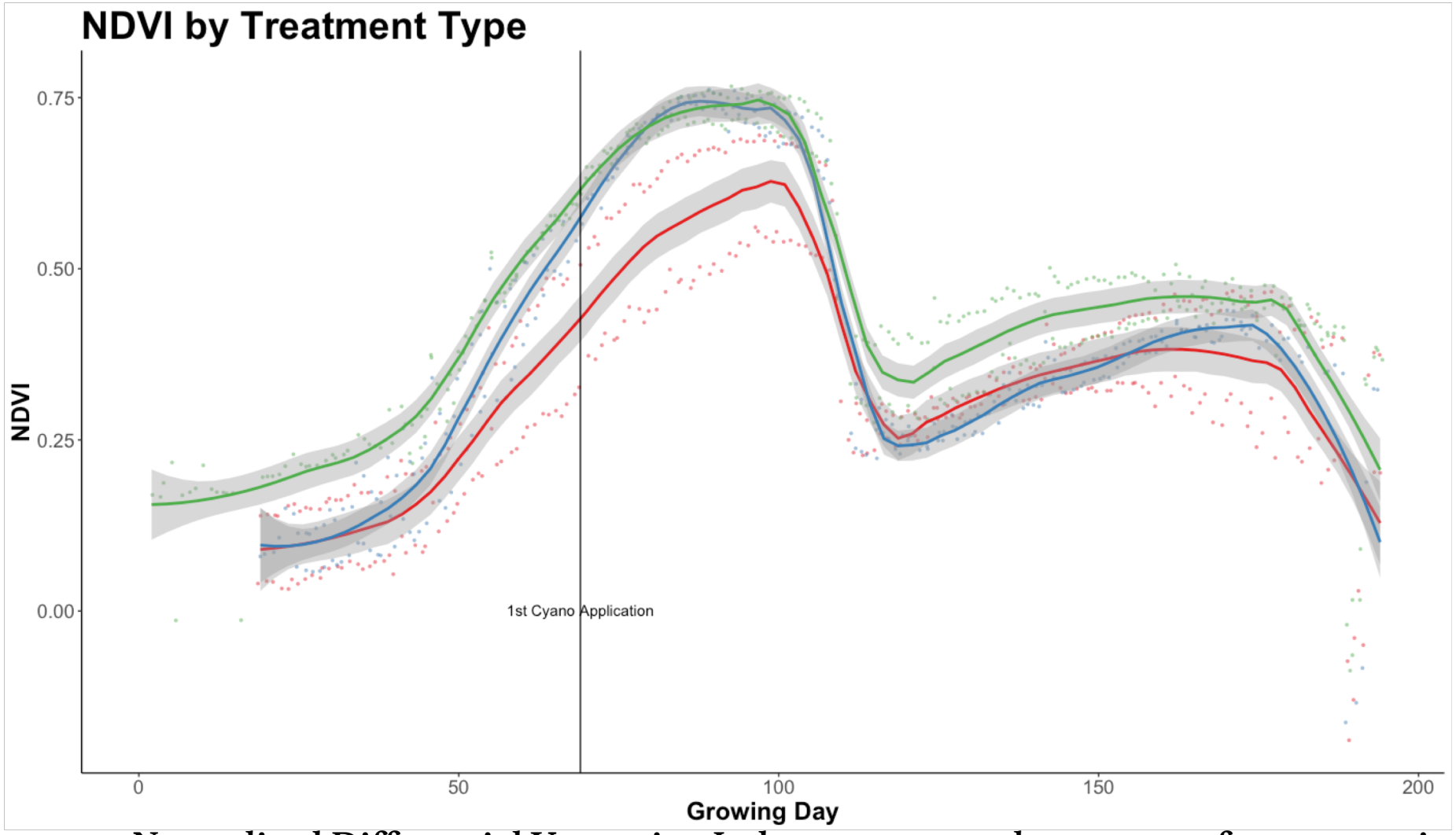
More to come….. Questions?



Extra Slides

3. Analysis

Arable Marks



Biofertilizer

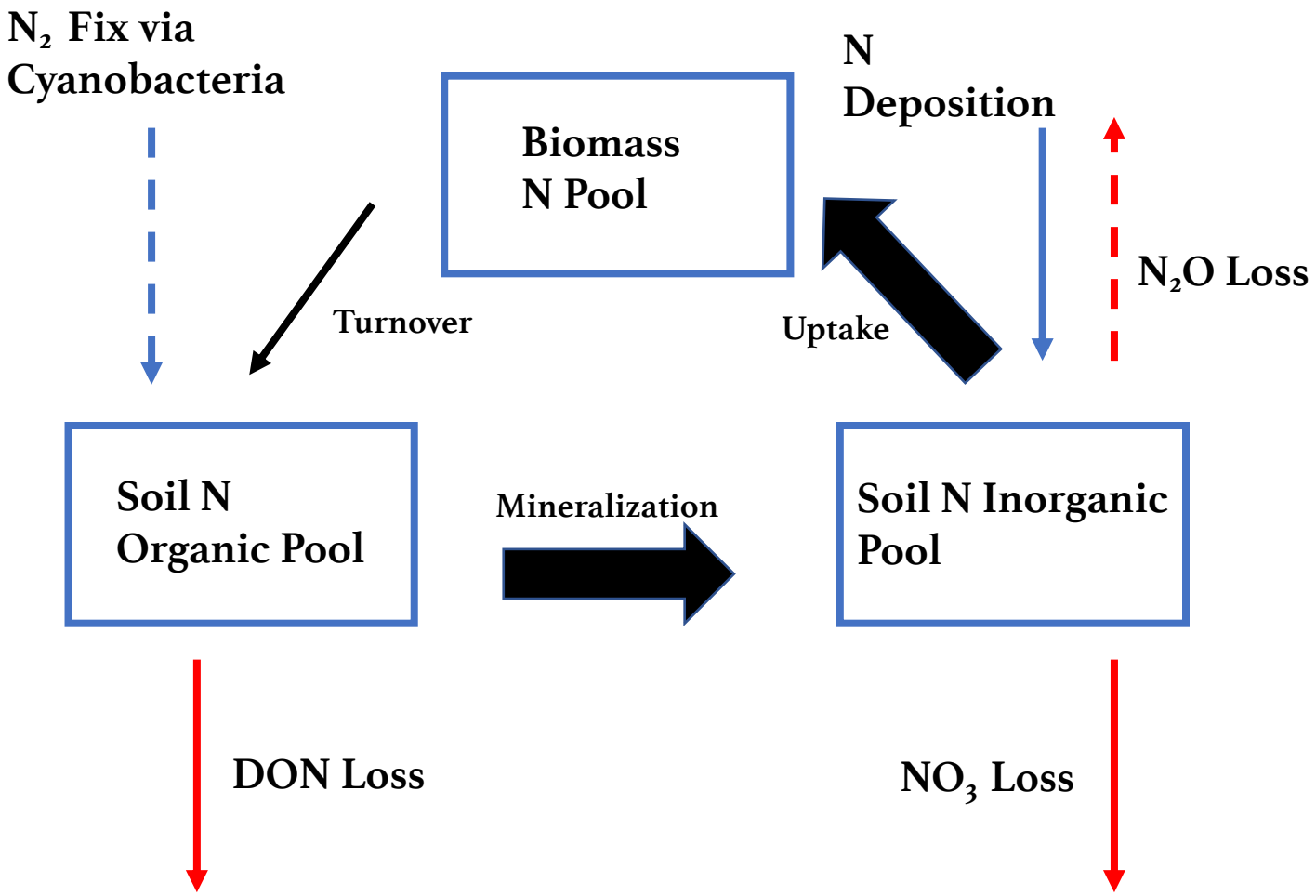
Control

Urea

Normalized Differential Vegetation Index, represents the amount of green growing material present.

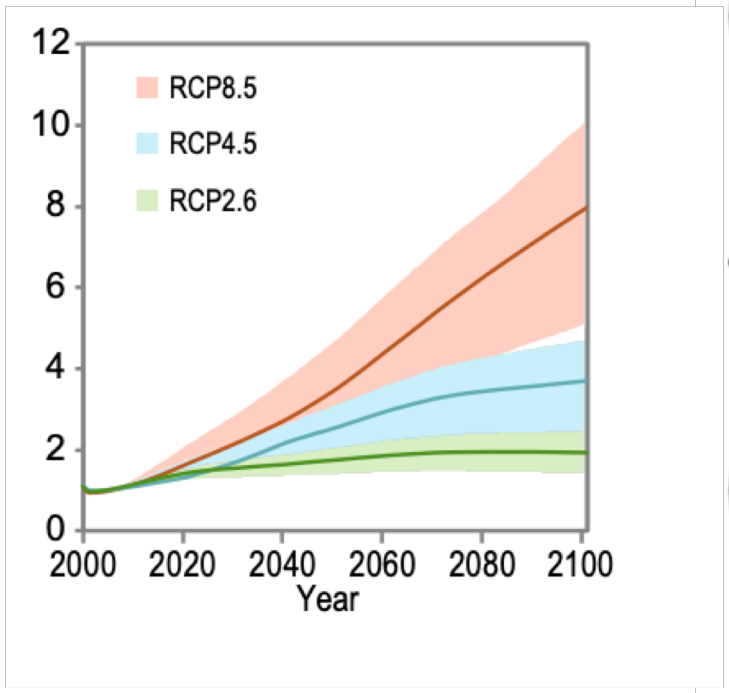
2. Methods

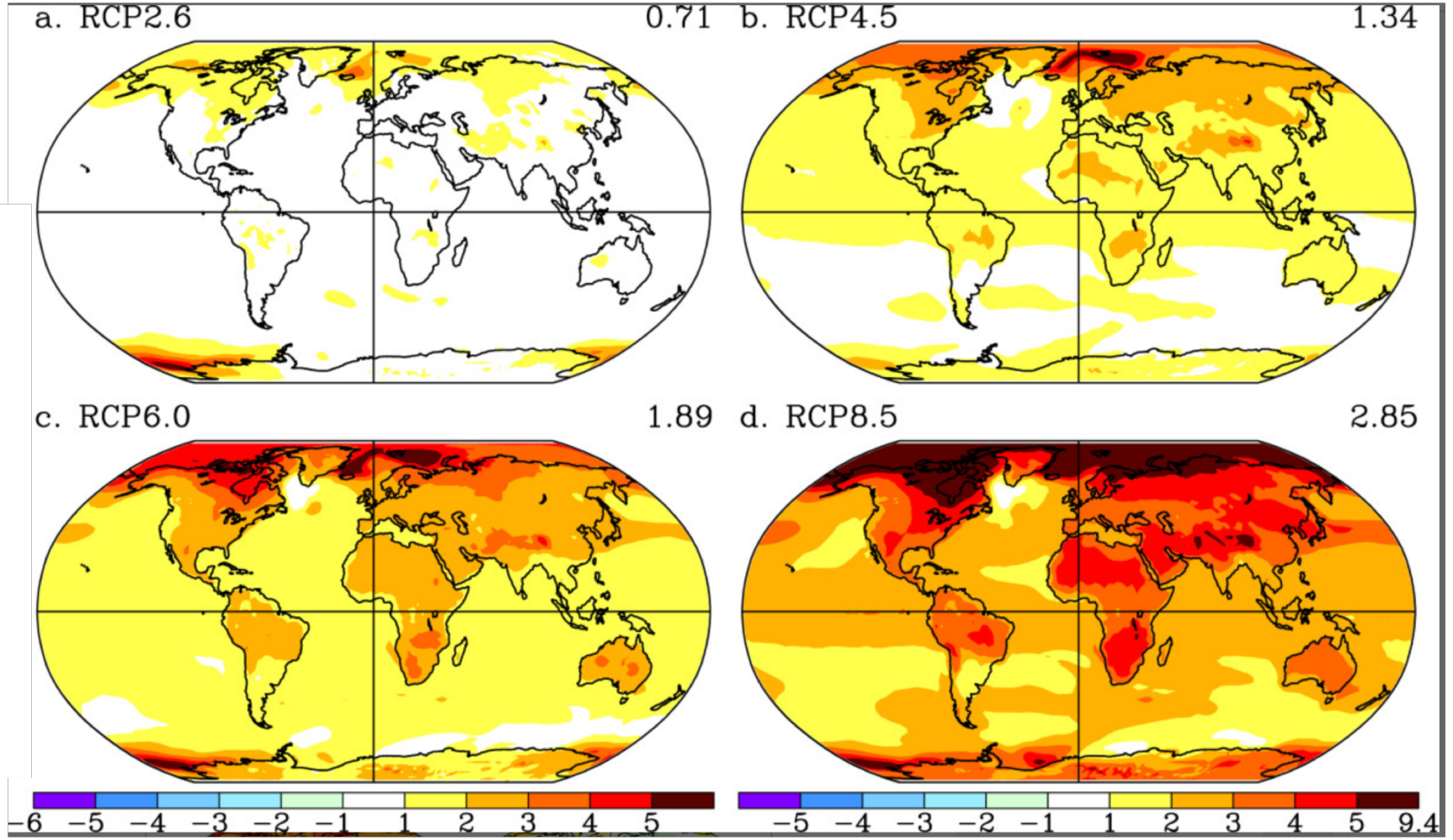
Conceptual N Cycling Model: Agroecosystem



1. Background

RCPs and Future Warming of the Planet



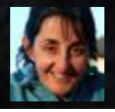


Nazarenko et al. 2015

The Royal Society of Chemistry: 2019

NEWS

Biomass carbon capture pilot points to a new sector whose time has come



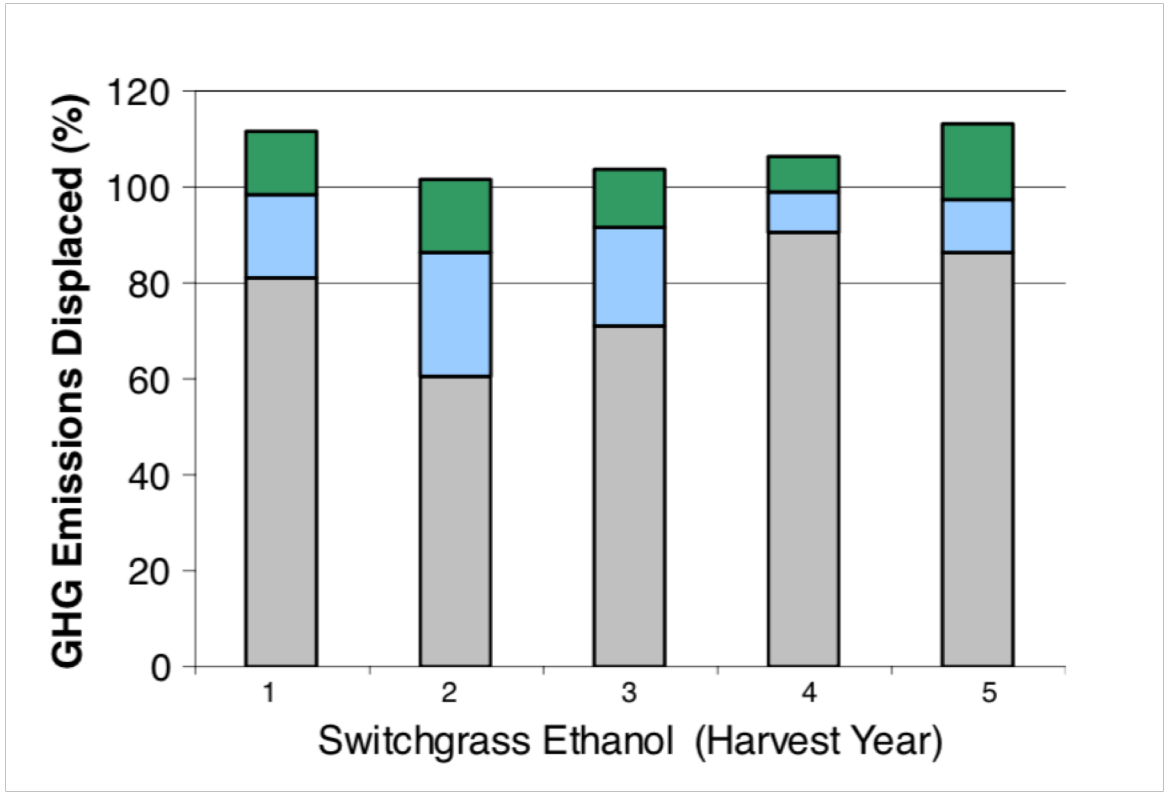
BY ANGELI MEHTA | 30 JANUARY 2019

SOURCE: © DRAX

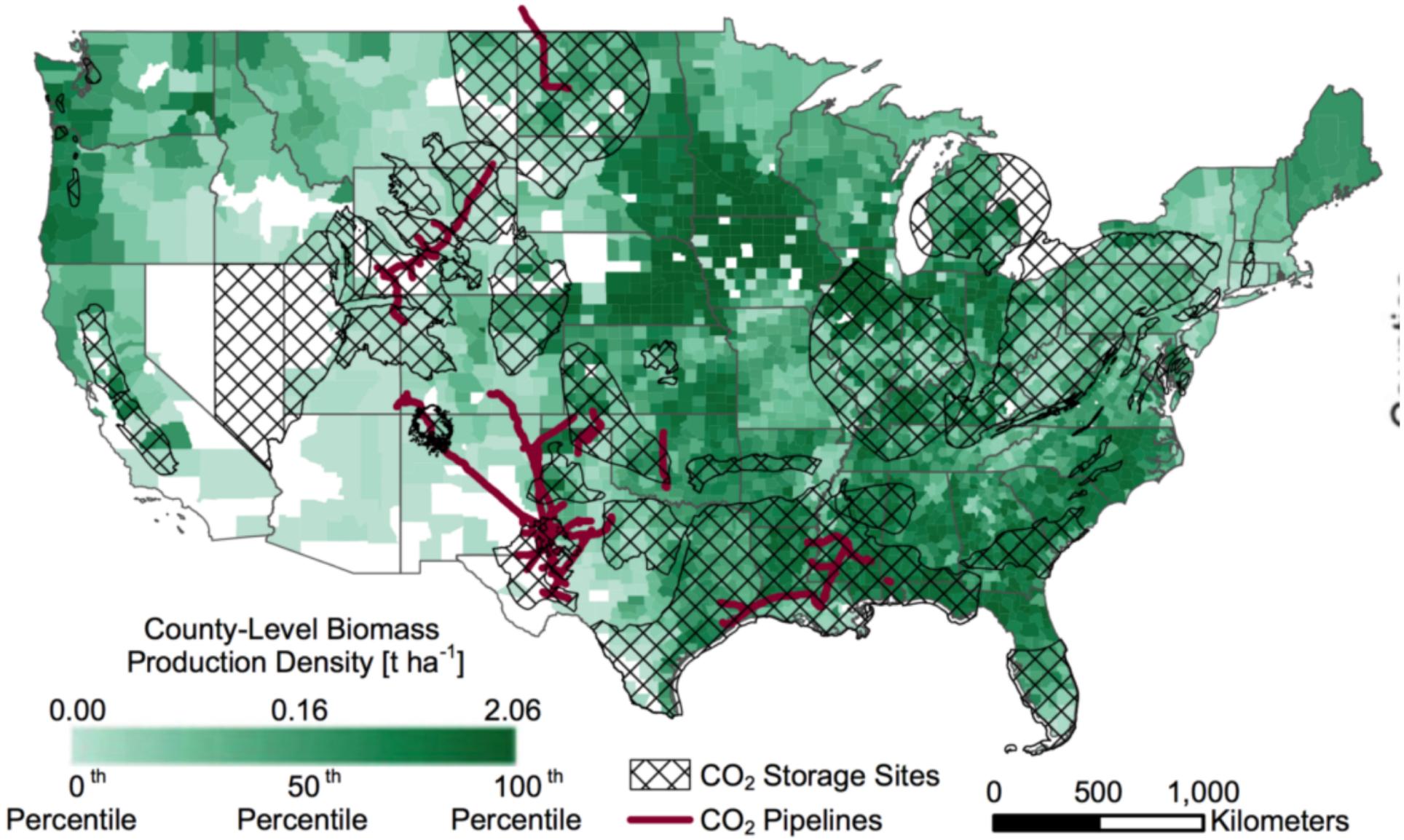
1. Background

Bioenergy Crops and GHG Emissions

Bioenergy crops are plants that are used for fuel or energy rather than to feed animals or humans. They are seen as fast growing and renewable sources of energy, and a clean alternative to fossil fuels.

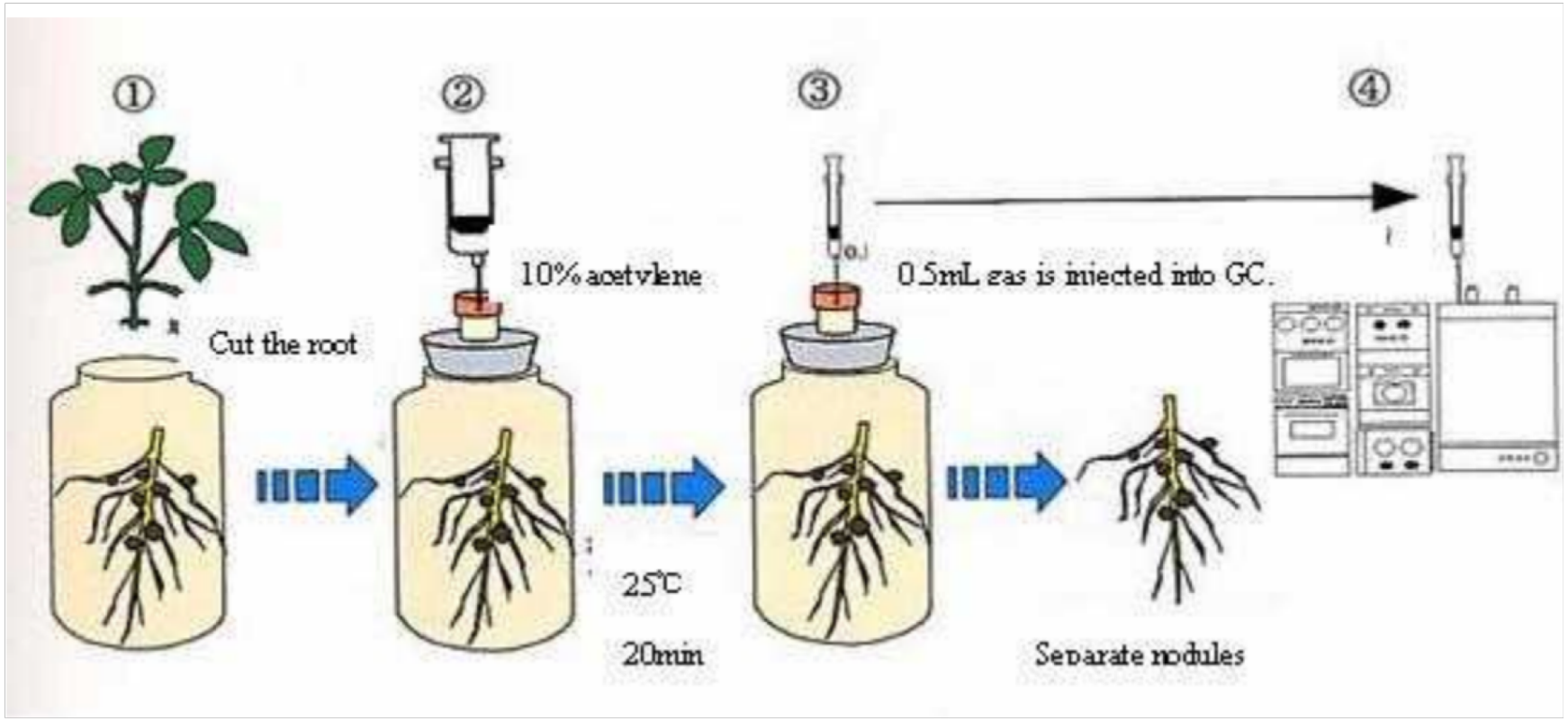


Schmer et al. 2007, PNAS



Projected 2020 biomass production (green) from the US DOE and potential CO2 storage sites (black crosshatches) from the USGS. Existing CO2 pipelines are included in red. Adapted from Figure 1 in Baik et al. (2018)

Acetylene Reduction Assay



Ecosystem Ecology

Inputs

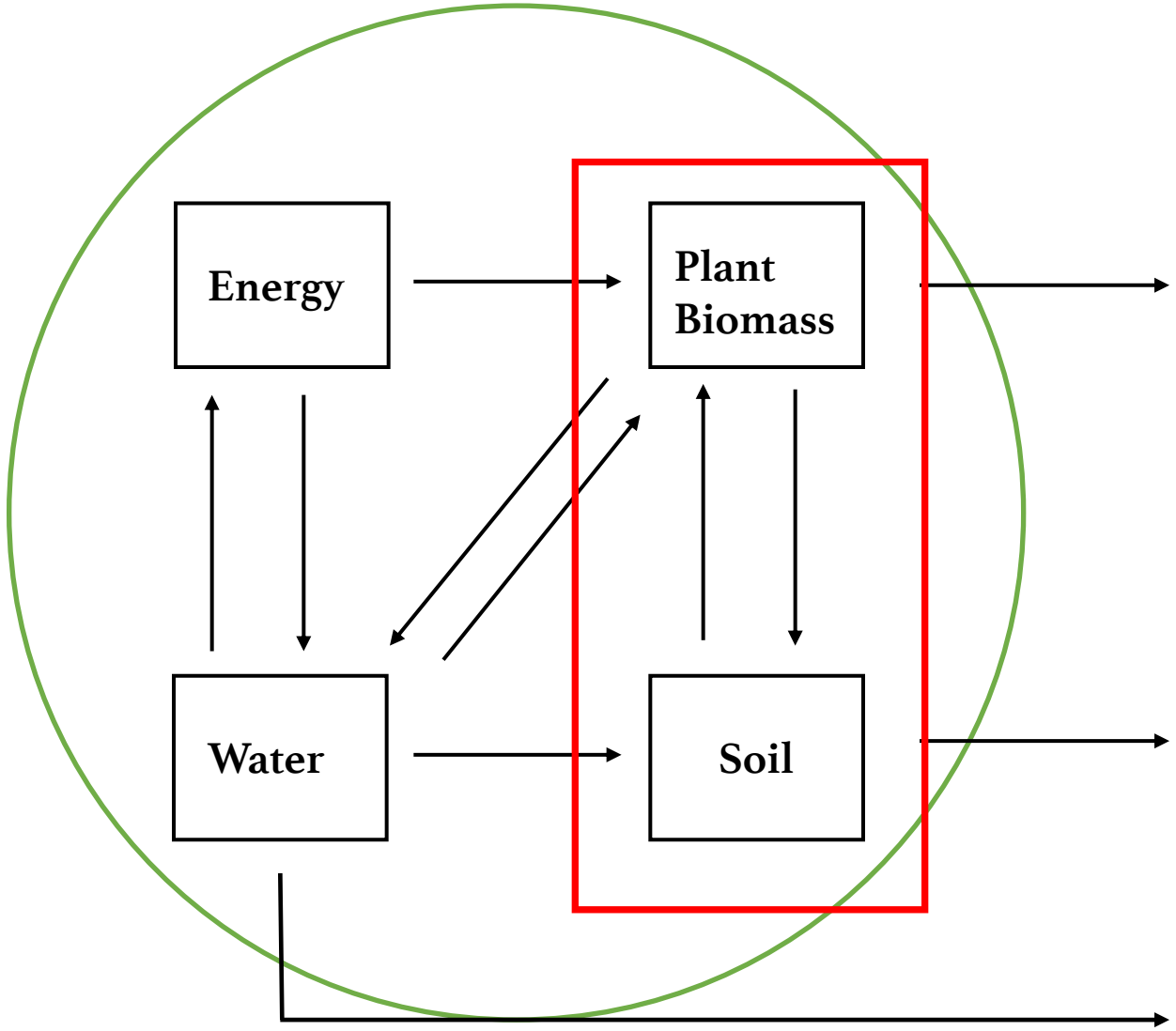
Physical climate

Chemical climate

Mechanical action

Species migration

Human impact



Outputs

Cyano by the numbers

Application Date:	6/15/2018	6/28/2018	7/12/2018	7/26/2018	8/9/2018	
% live cyano biomass	15	25	15	15	2	TOTAL
Total N application (kg N/ha)	10	10	10	10	10	50

Differential Equations for Change in N Over Time

I = N Dep
M =Mineralization
F = Fertilizer
BF = N Fixation
B = Net Biomass

Control

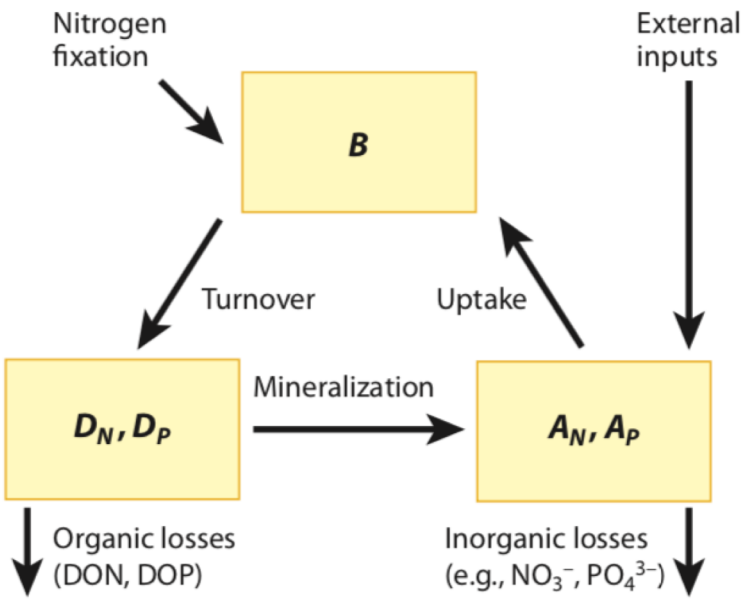
$$\frac{dN}{dT} = I + M - k(N)_L - (N)_G - B(N)$$

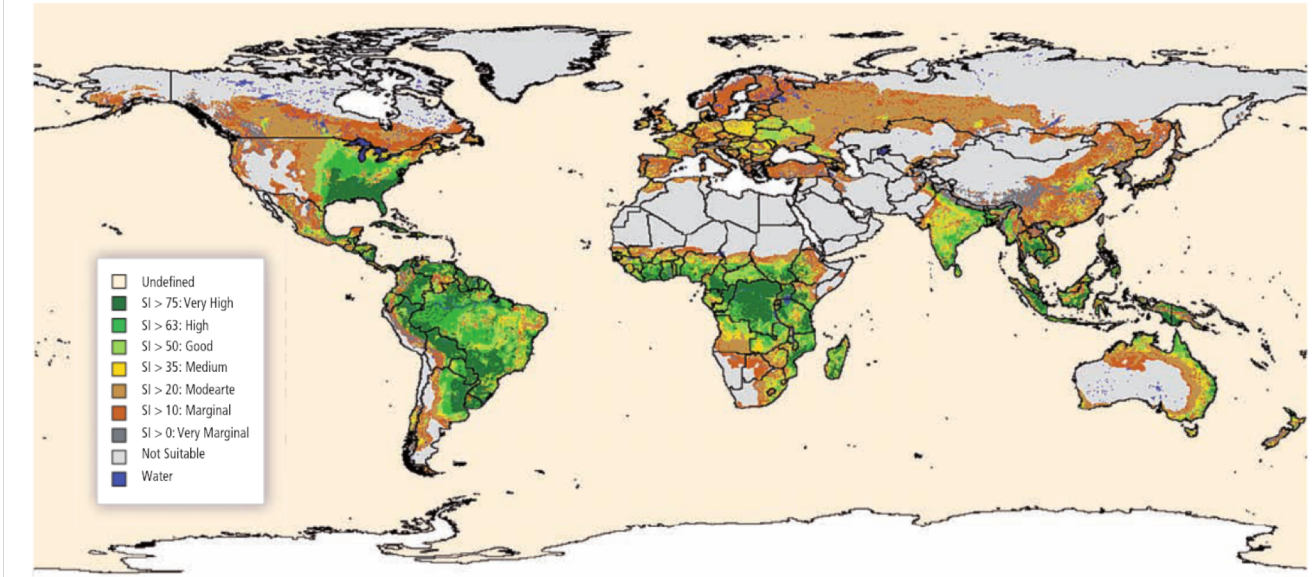
Urea

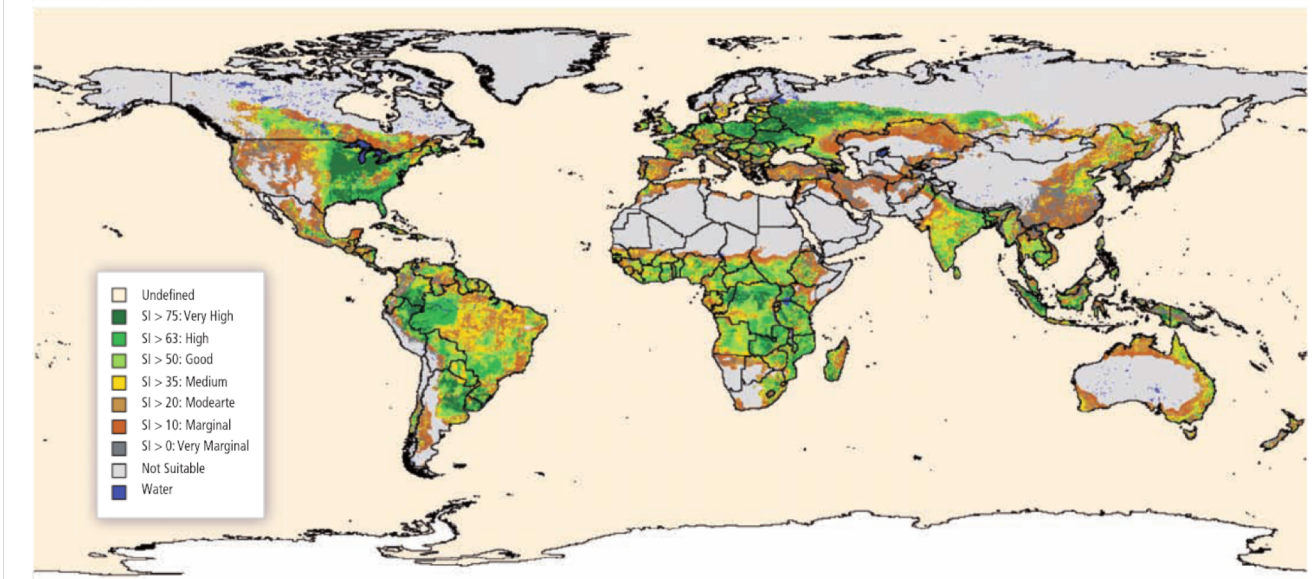
$$\frac{dN}{dT} = I + F + M - k(N)_L - (N)_G - B(N)$$

Biofertilizer

$$\frac{dN}{dT} = I + F + M + BF - k(N)_L - (N)_G - B(N)$$


Nitrogen fixation
External inputs
B
Turnover
Uptake
D_N, D_P
Mineralization
A_N, A_P
Organic losses (DON, DOP)
Inorganic losses (e.g., NO_3^-, PO_4^{3-})


Undefined
SI > 75: Very High
SI > 63: High
SI > 50: Good
SI > 35: Medium
SI > 20: Modearte
SI > 10: Marginal
SI > 0: Very Marginal
Not Suitable
Water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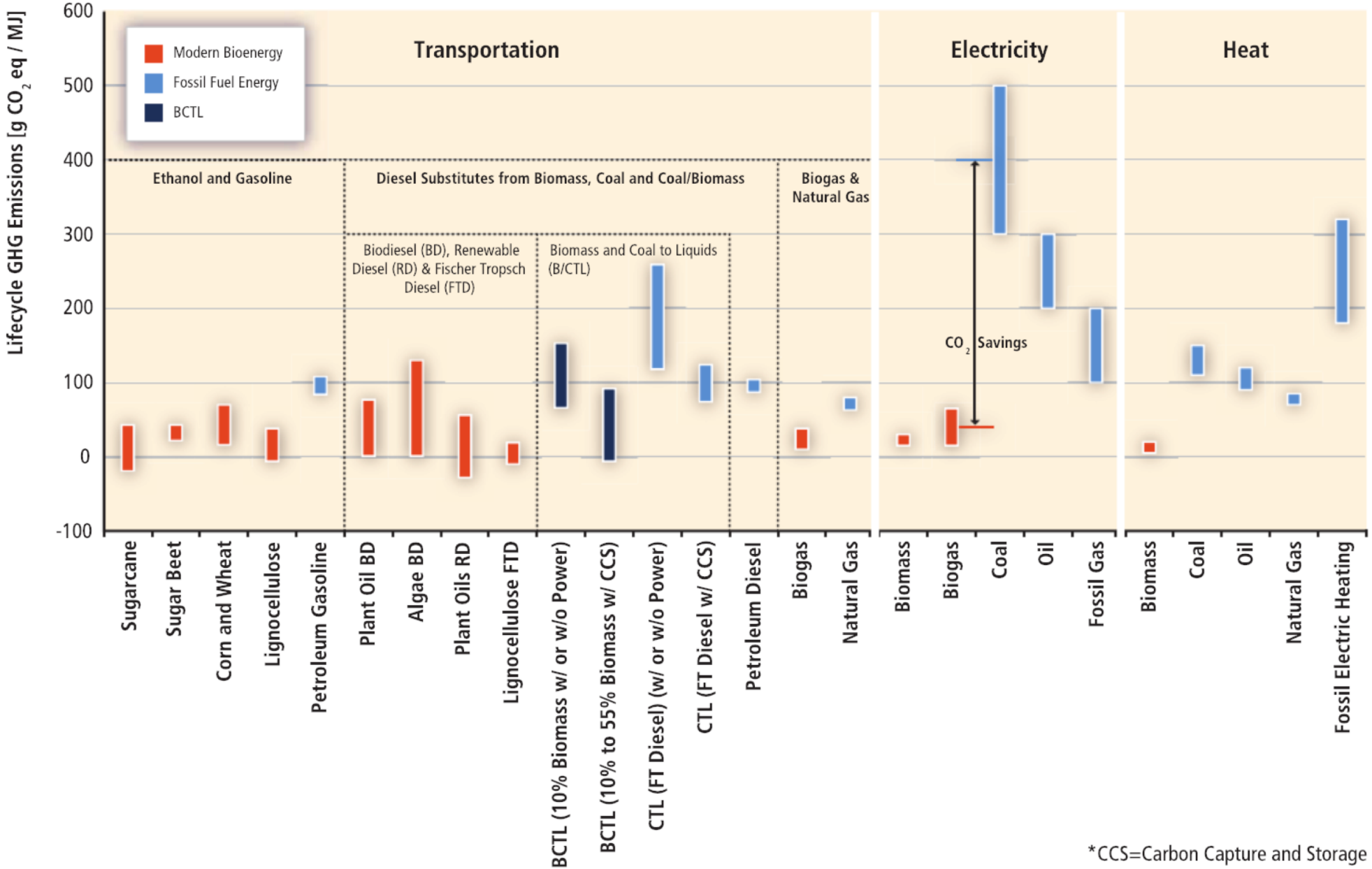
Lifecycle GHG Emissions [g CO_2 eq / MJ]
600
500
400
300
200
100
0
-100
Modern Bioenergy
Fossil Fuel Energy
BCTL
Transportation
Electricity
Heat
Ethanol and Gasoline
Diesel Substitutes from Biomass, Coal and Coal/Biomass
Biogas & Natural Gas
Biodiesel (BD), Renewable Diesel (RD) & Fischer Tropsch Diesel (FTD)
Biomass and Coal to Liquids (B/CTL)
CO_2 Savings
Sugarcane
Sugar Beet
Corn and Wheat
Lignocellulose
Petroleum Gasoline
Plant Oil BD
Algae BD
Plant Oils RD
Lignocellulose FTD
BCTL (10% Biomass w/ or w/o Power)
BCTL (10% to 55% Biomass w/ CCS)
CTL (FT Diesel) (w/ or w/o Power)
CTL (FT Diesel w/ CCS)
Petroleum Diesel
Biogas
Natural Gas
Biomass
Biogas
Coal
Oil
Fossil Gas
Biomass
Coal
Oil
Natural Gas
Fossil Electric Heating
*CCS=Carbon Capture and Storage

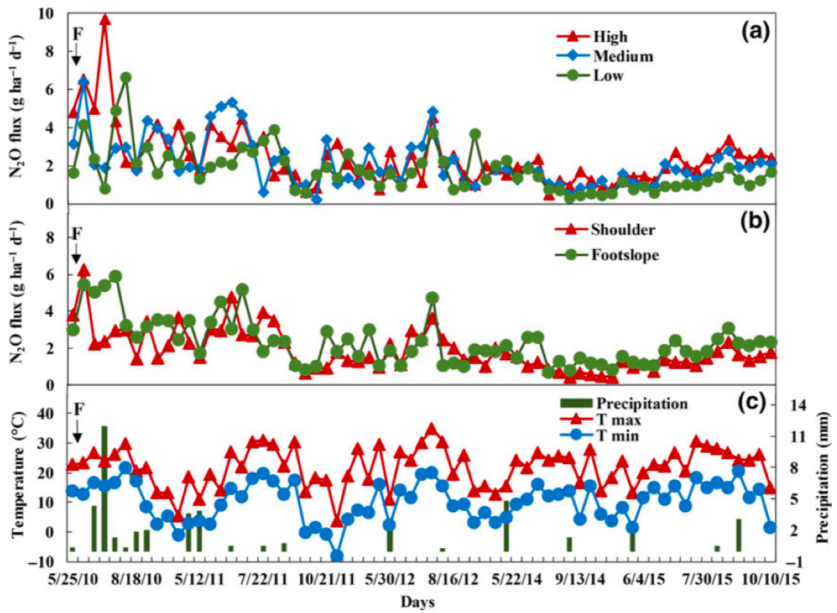

Fig. 2 Trends of daily mean soil N_2O fluxes (g ha^{-1} day^{-1}) from switchgrass fields under (a) the three N rates at (b) the two landscape positions and (c) daily maximum (T_{Max}) and minimum (T_{Min}) air temperature and precipitation over the observed days in 2010–2015. The *arrows* indicate the fertilization dates. The N fertilizer was applied in late May or early June for each year.