Perennial Forages for Sustainable Soil Nitrogen Cycling in East Africa

Research seminar (online)

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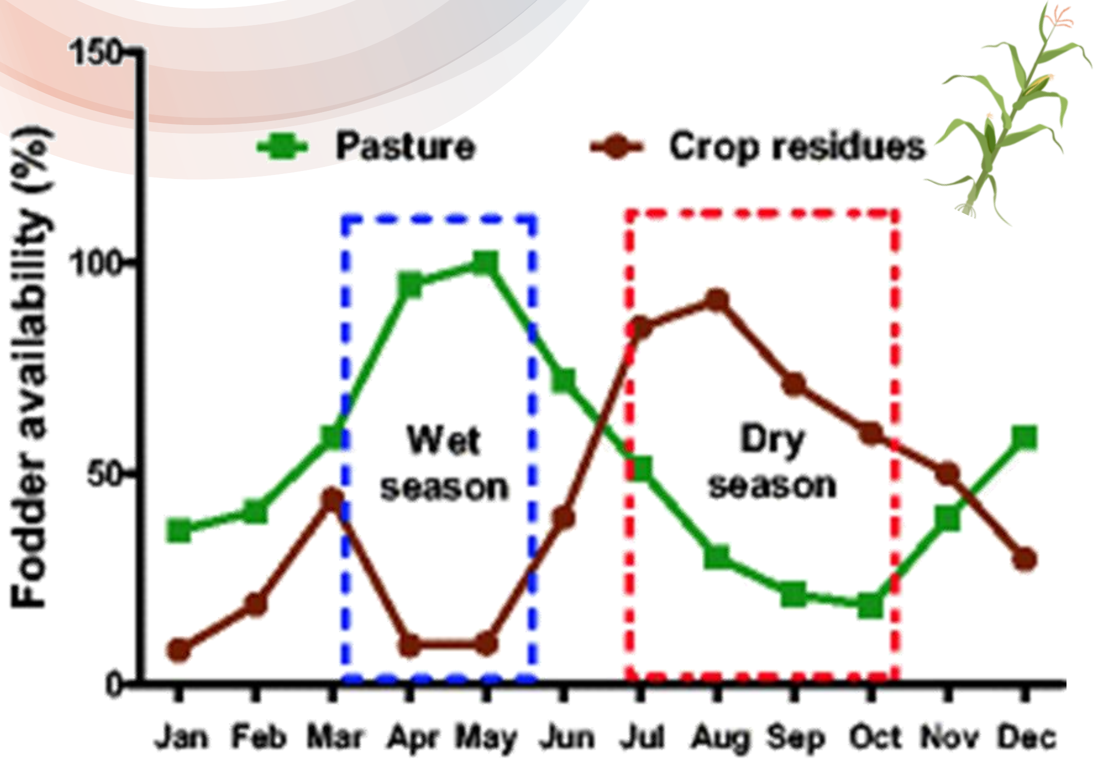
Schaedel, M.[1], Paul, B.[2], Mwendia, S.[2], Mutimura, M.[3], Venterea, R.[4], Grossman, J.[1]

1. Horticultural Science/University of Minnesota, 1970 Follwell Ave St. Paul MN, USA
2. Tropical Forages Program/International Center for Tropical Agriculture, PO Box 823-00621 c/o ICIPE Duduville Complex, Nairobi, Kenya
3. Department of Livestock Production/Rwanda Agricultural Board, PO Box 5016, Kigali, Rwanda
4. Agricultural Research Service/US Department of Agriculture, 1991 Upper Buford Circle St Paul, MN USA

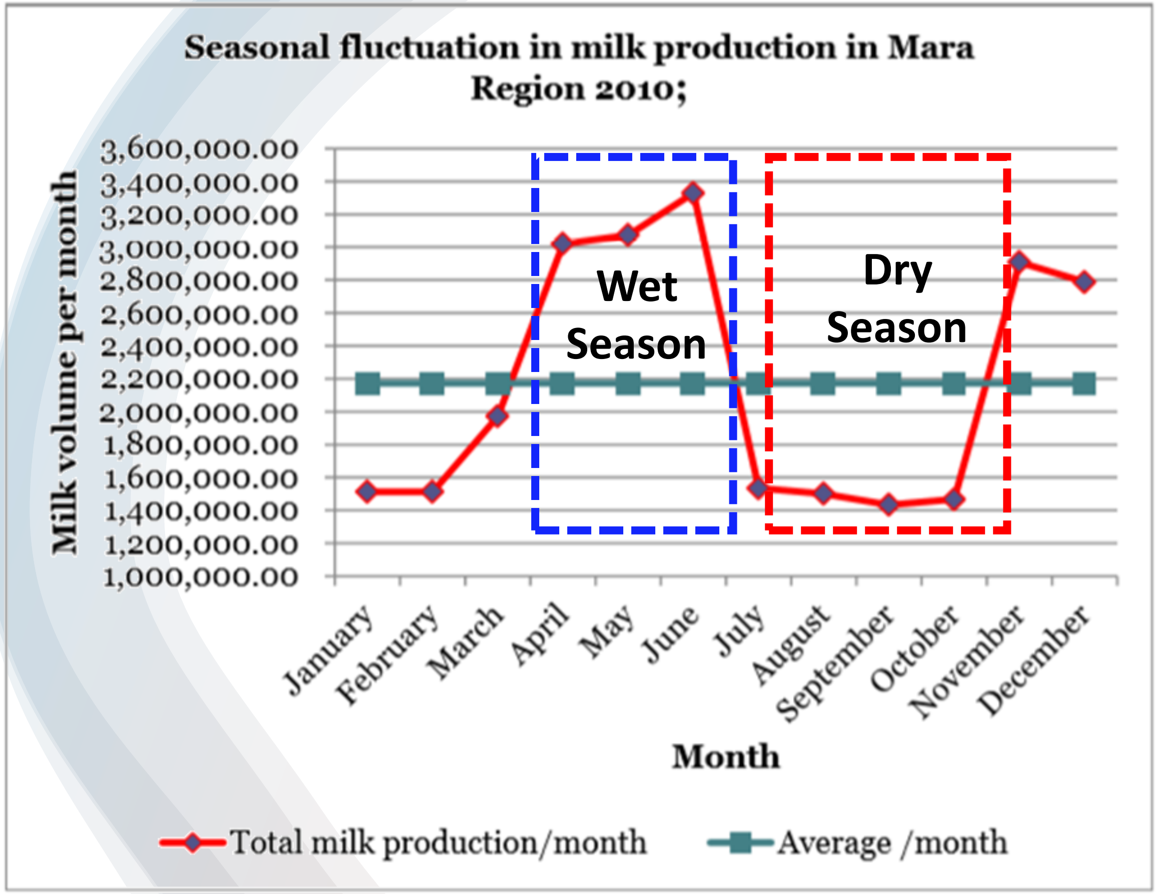
Dairy in Rwanda

- 15% GDP
- Annual production: 445 million liters
- Longstanding cultural significance
- Pathway out of poverty

Feed shortages limit milk production

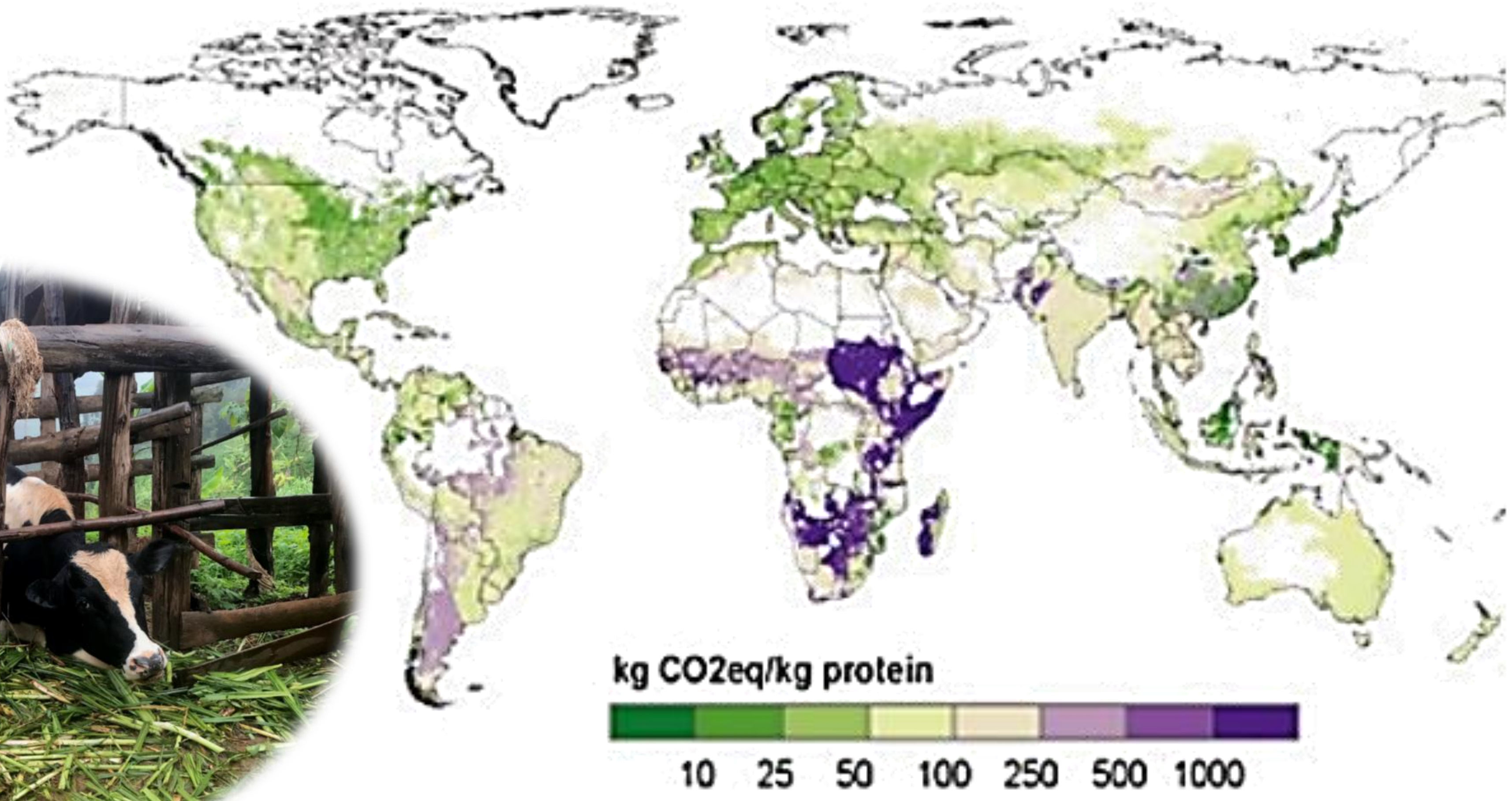


Adapted from Maleko et al, 2018



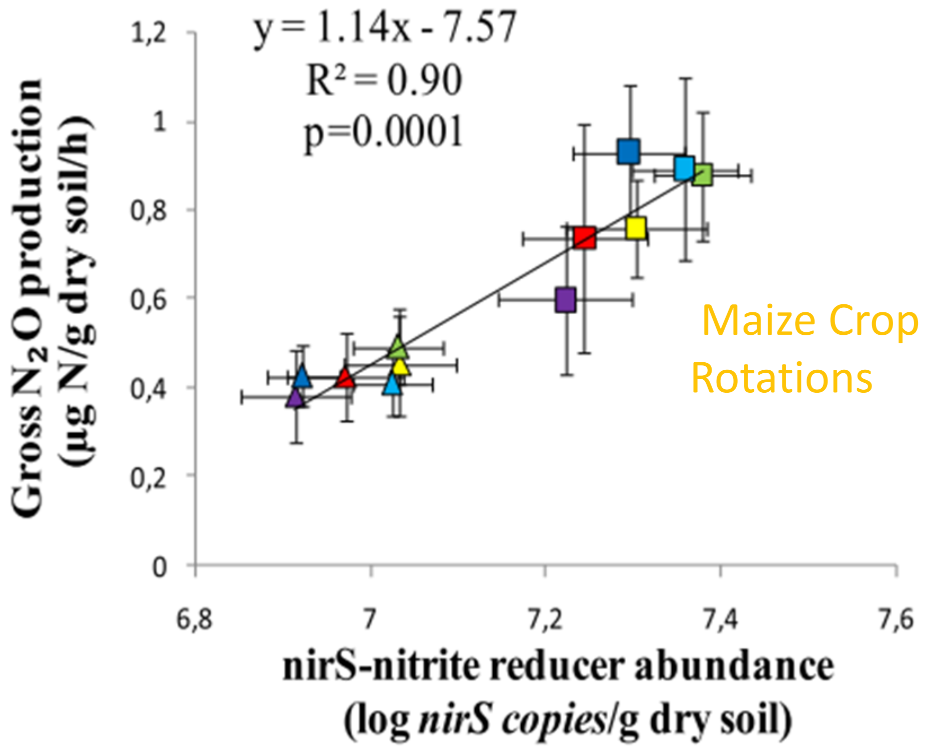
Adapted from Tanzania Dairy Industry Overview, 2012

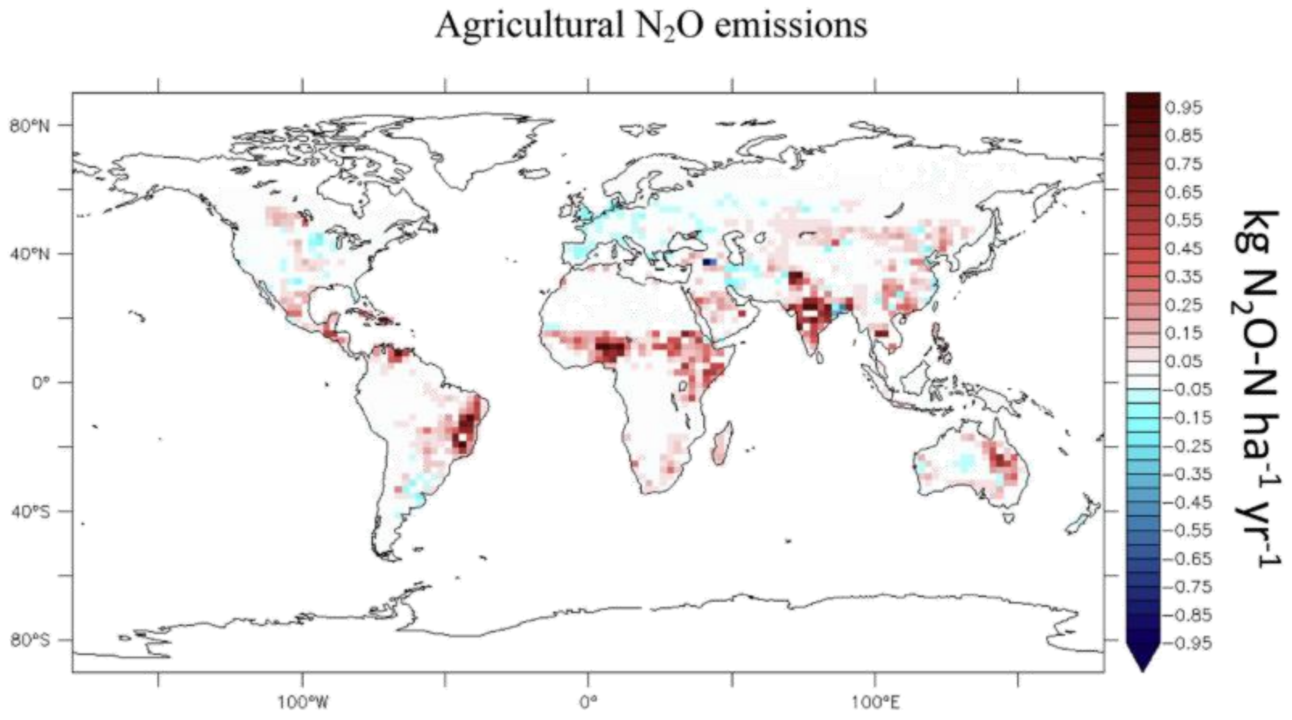
Livestock emission intensities



Herrero et al, 2013

Microbes control soil emissions

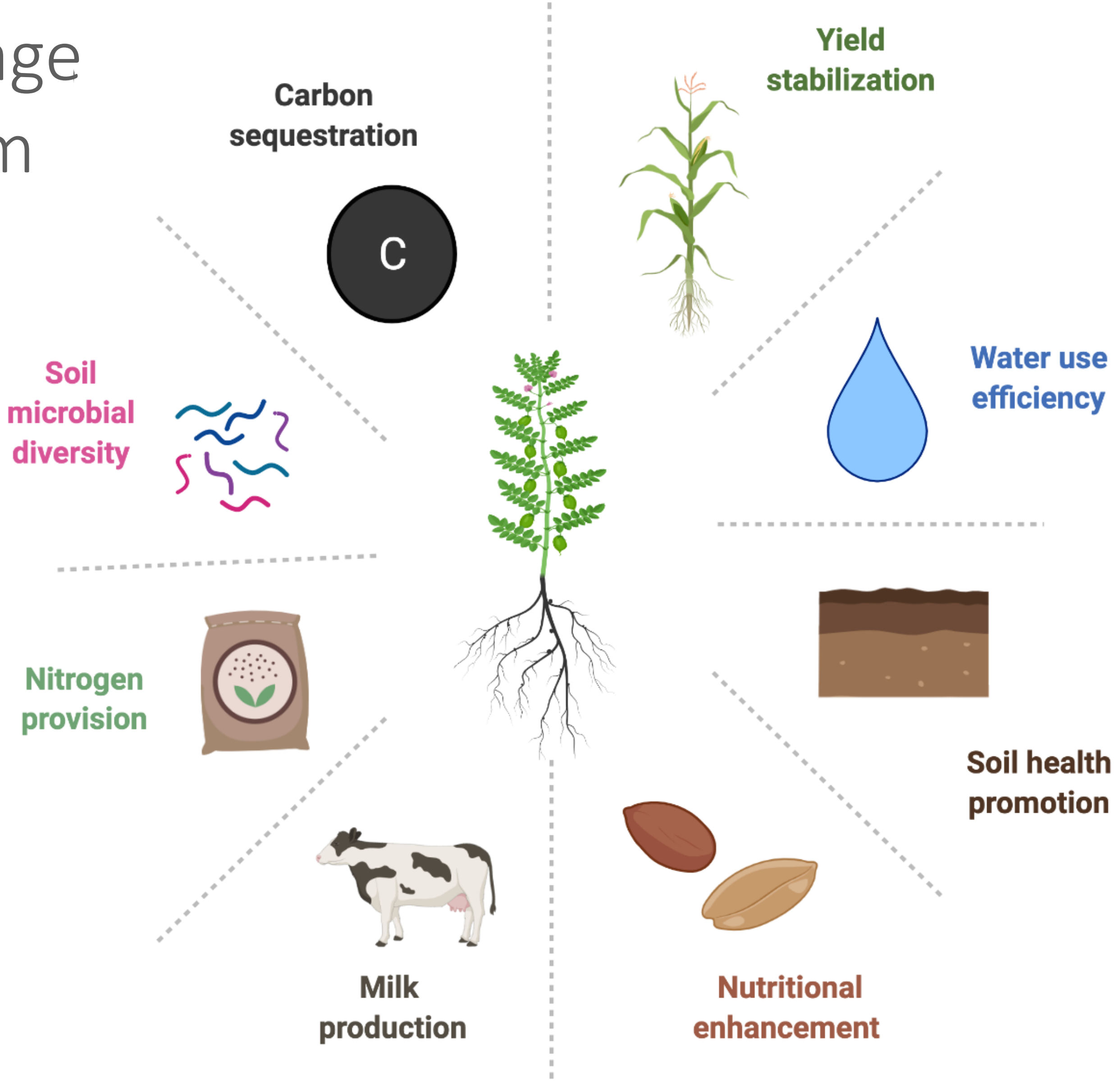


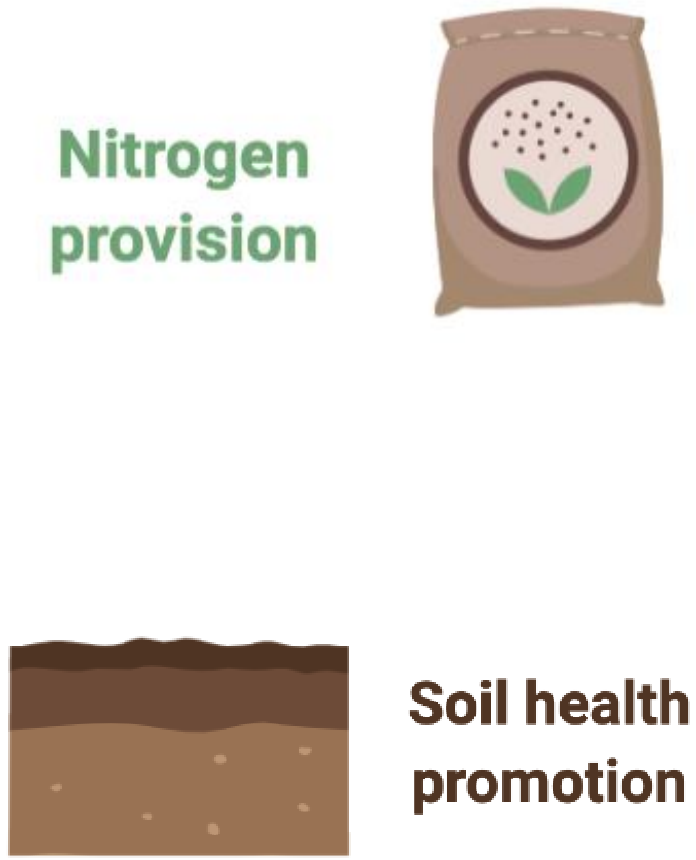


Adapted from Assemien et al, 2019

Kanter et al, 2016

Perennial Forage Agroecosystem Benefits





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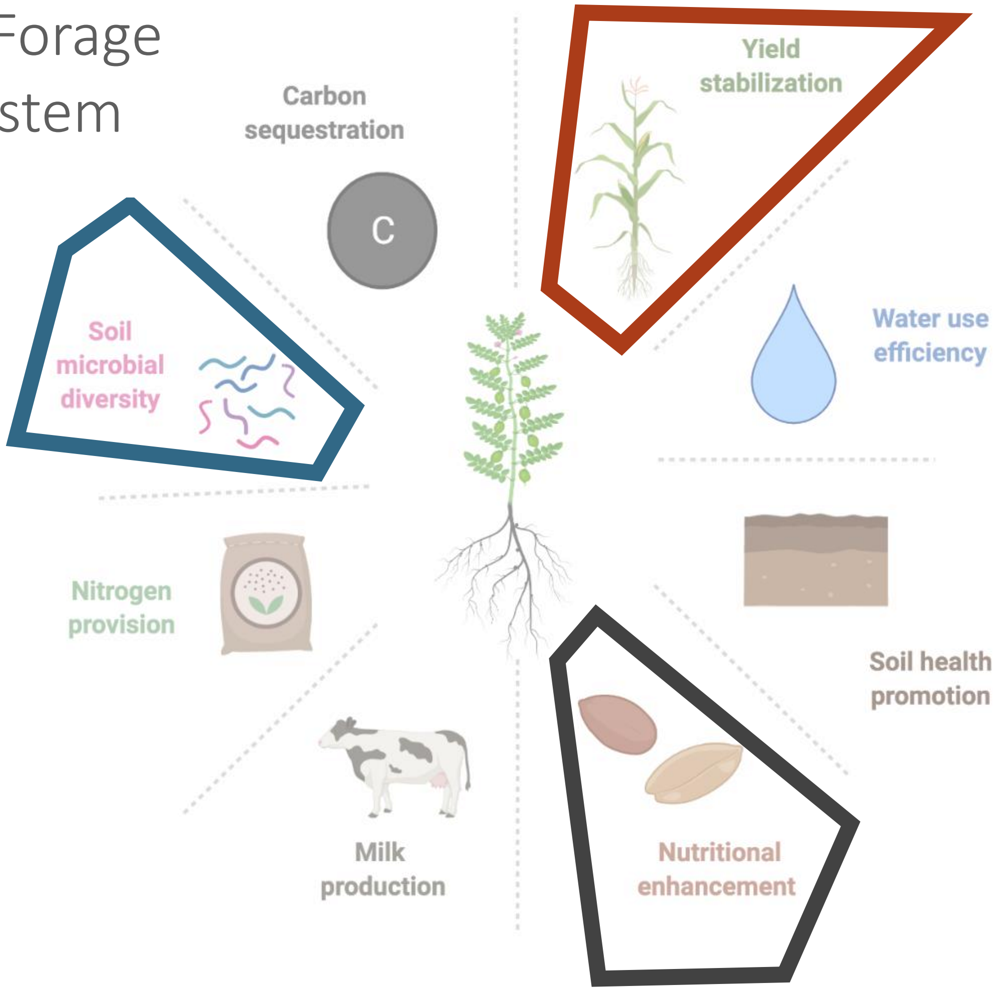
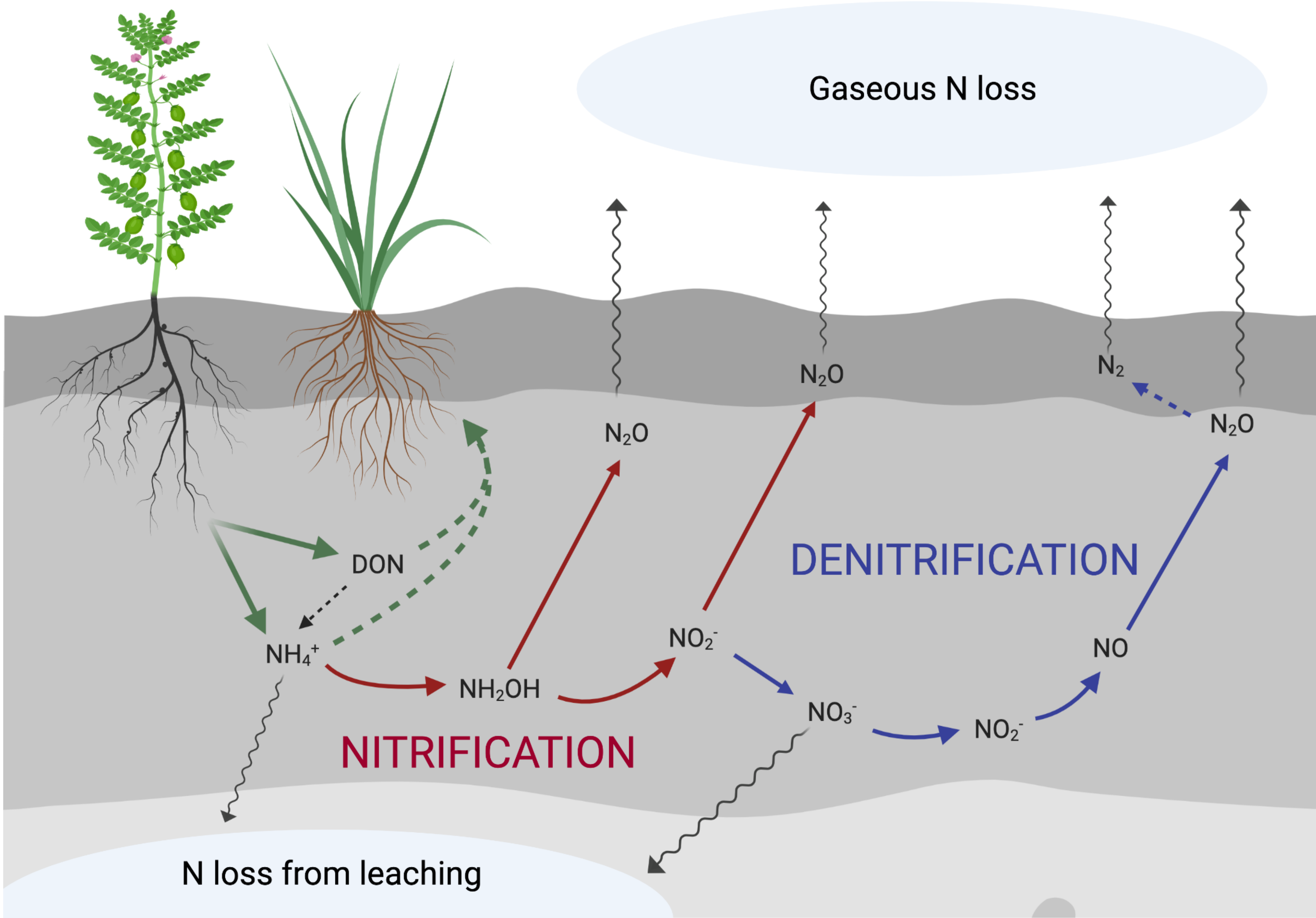


Two N acquisition strategies with implications for soil fertility

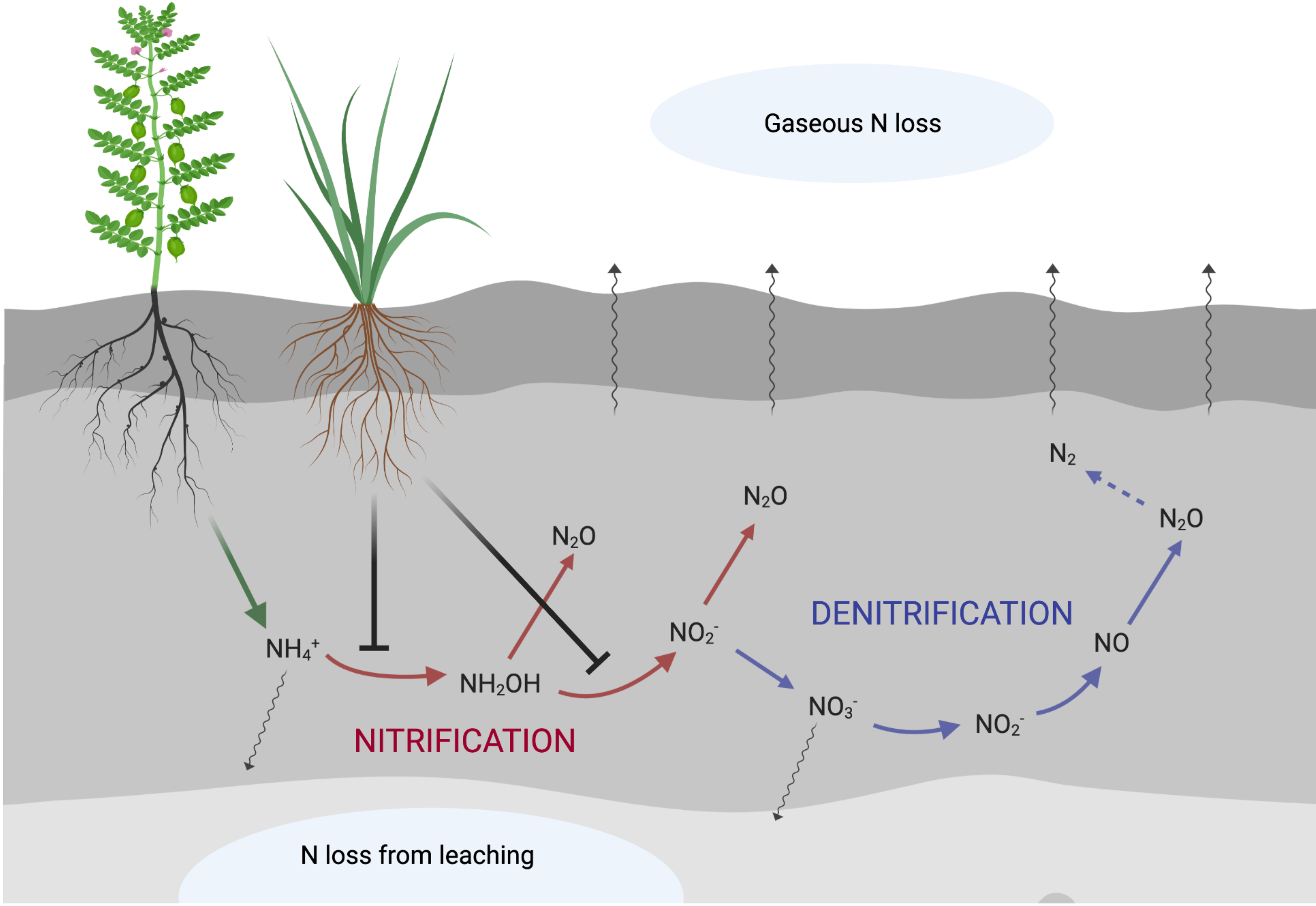
Legumes: **Biological nitrogen fixation (BNF)**

Grasses: **Biological nitrification inhibition (BNI)**

Legume intercrops: N provision

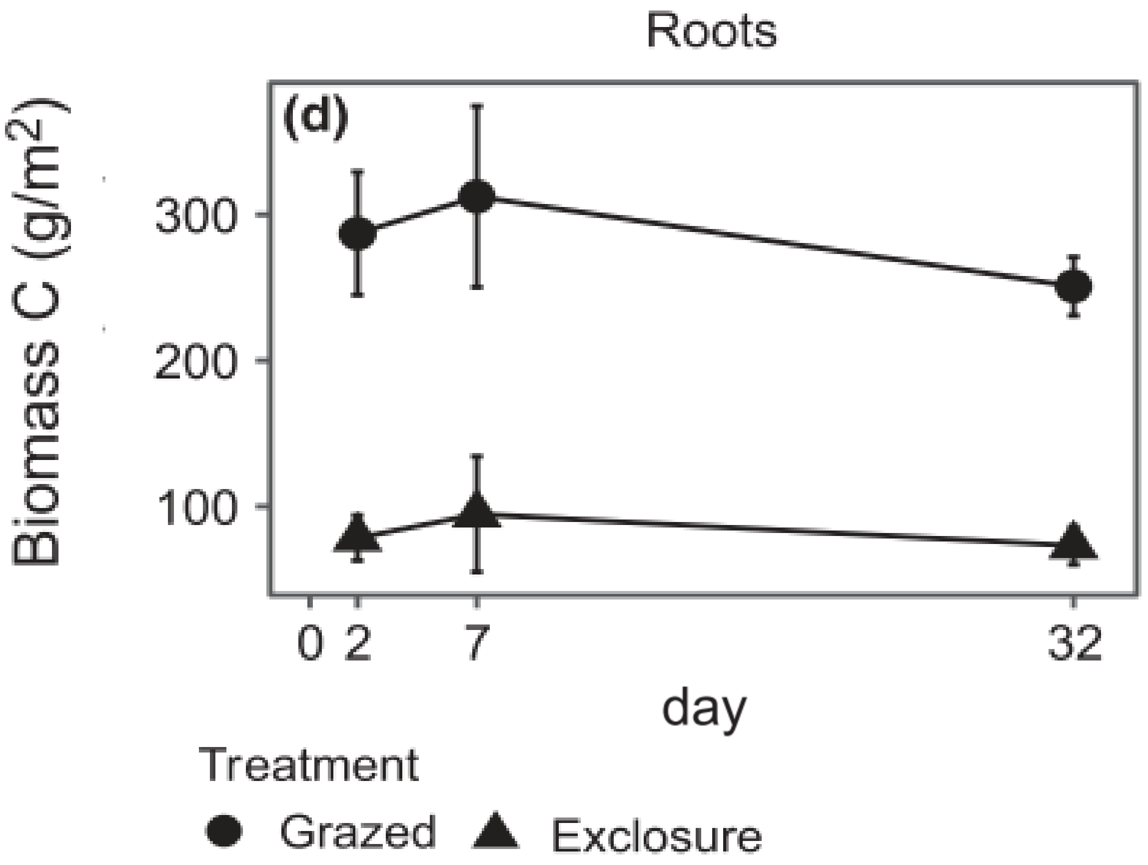


BNI grasses: N retention



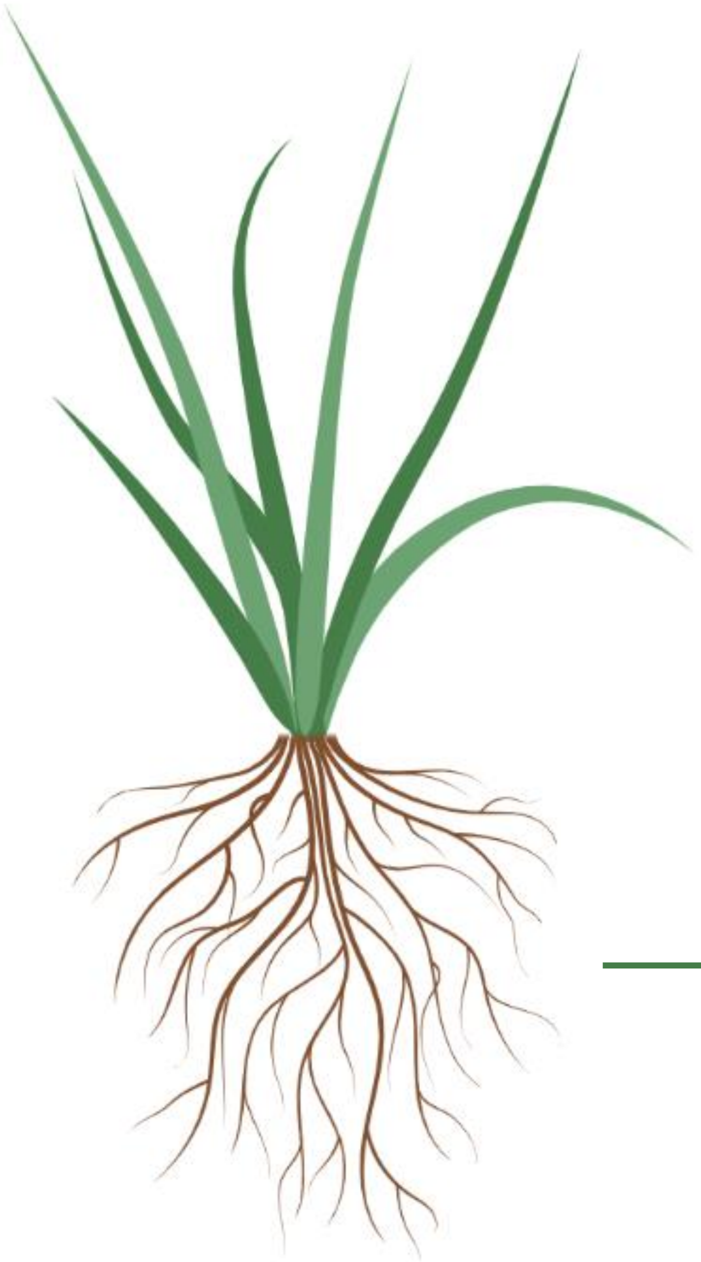
Defoliation impacts plant-microbe interactions

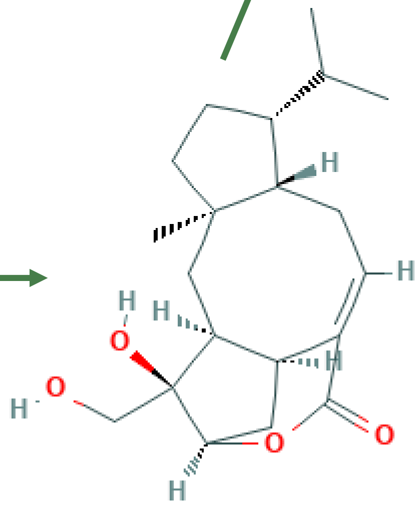
Defoliation increases root C allocation, which is strongly associated with root exudation and microbial biomass



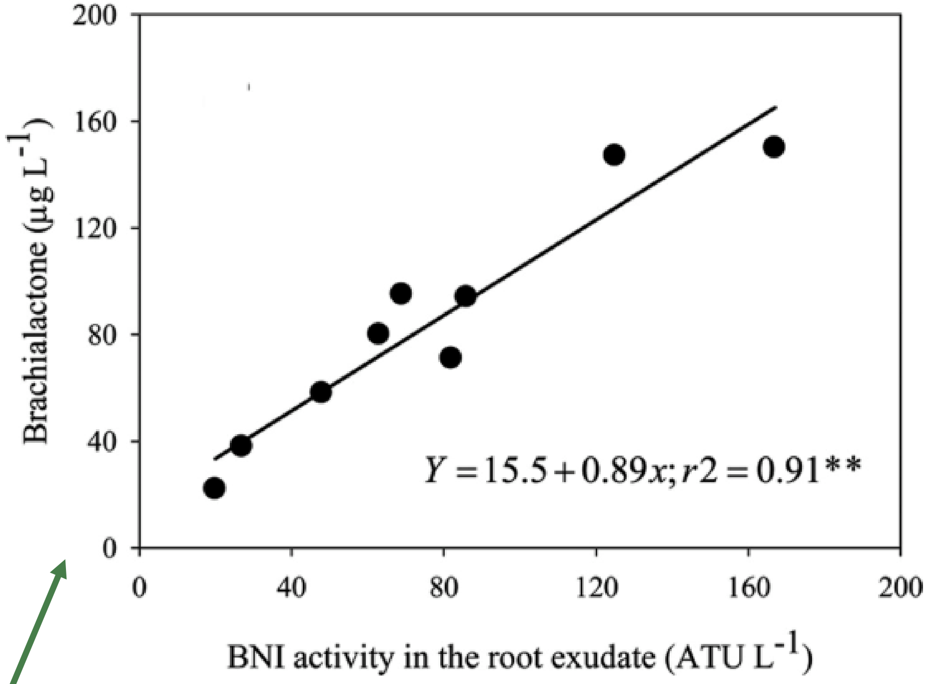
Wilson et al, 2018

Defoliation and BNI





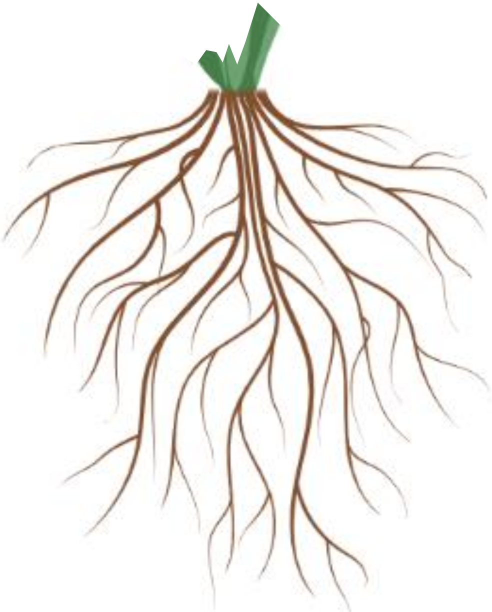
Brachialactone

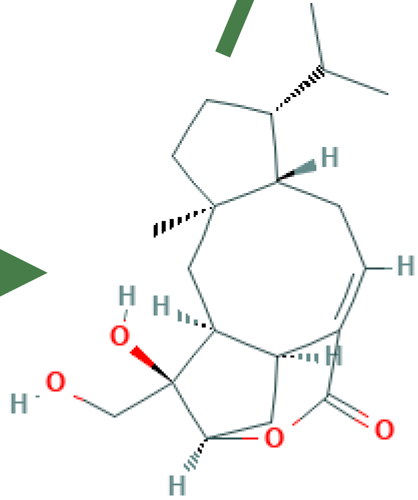


Subbarao et al, 2009

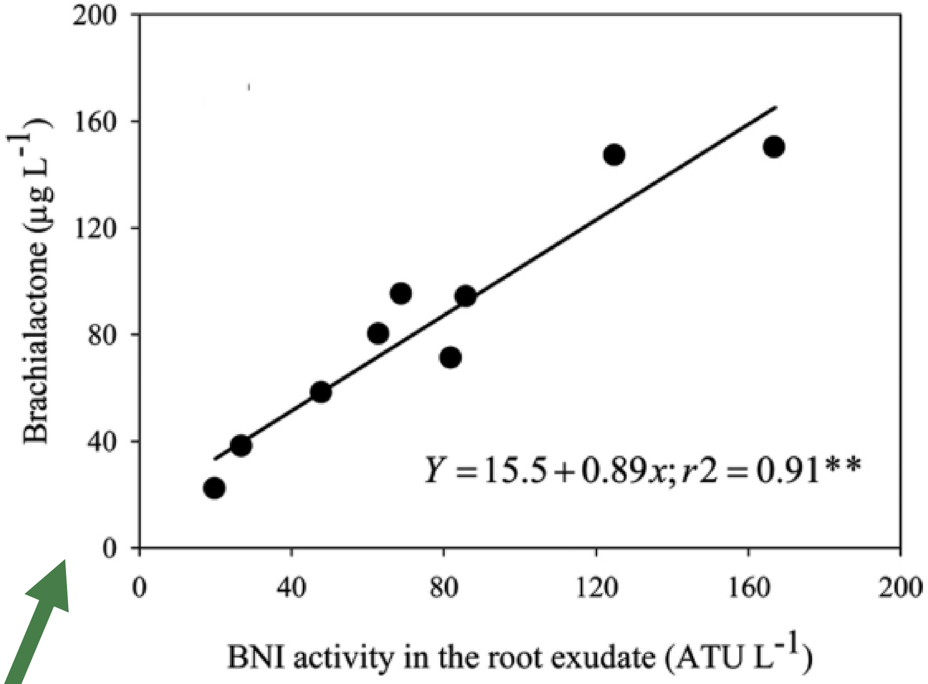
Defoliation and BNI

Carbon allocation





Brachialactone



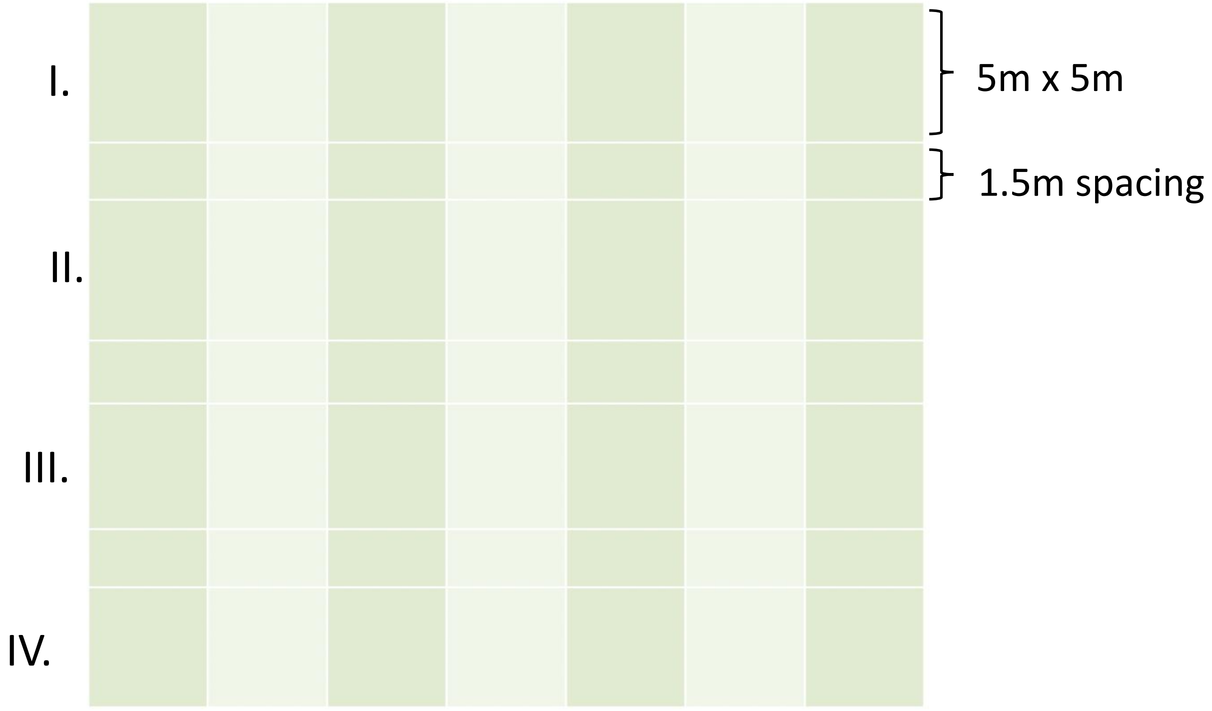
Subbarao et al, 2009

Research Questions

1. Do legume forage cropping systems contribute to soil N fertility? Can microbial N-loss pathways be mitigated by intercropping with *Brachiaria*?

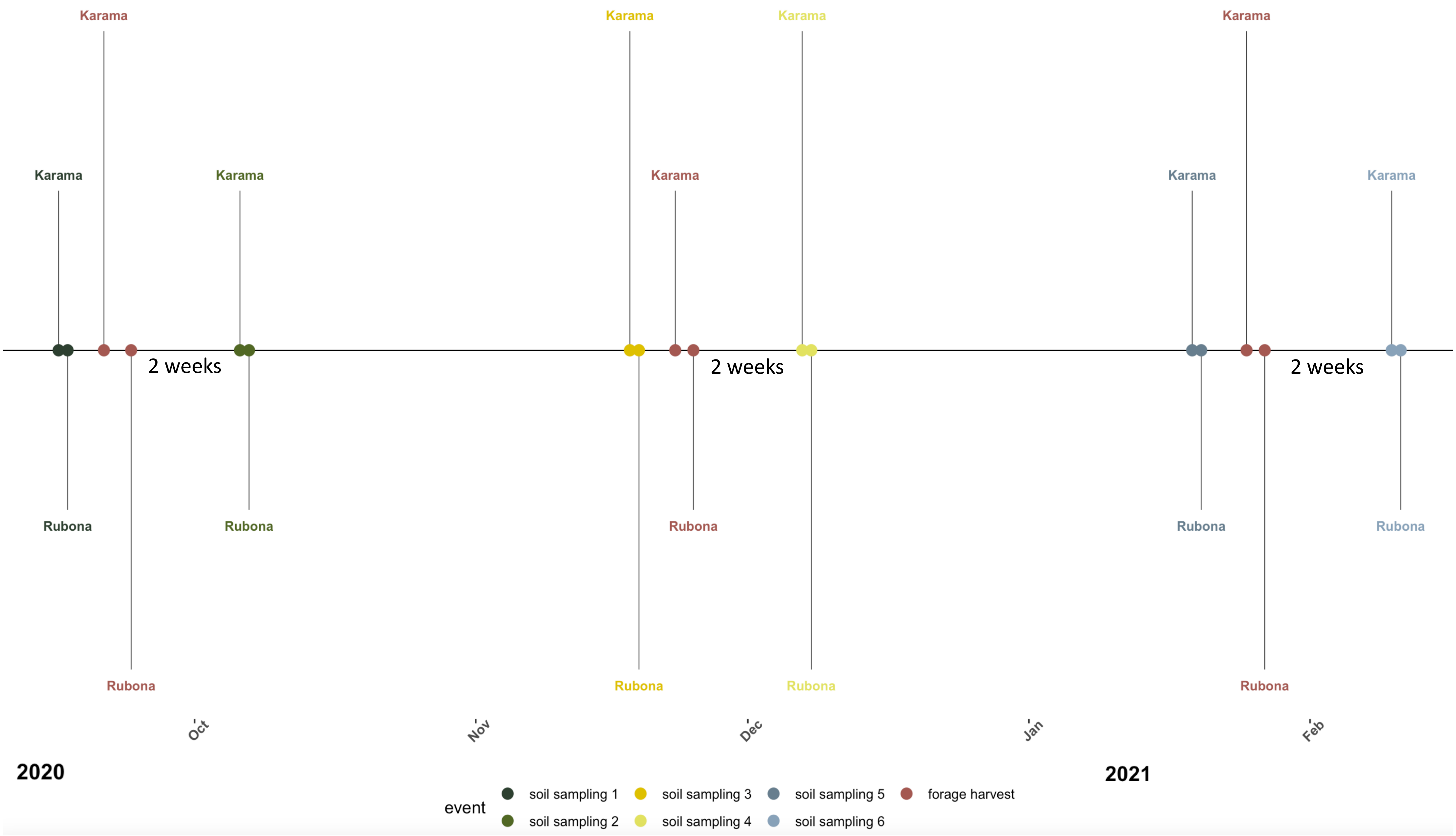
2. How are belowground N cycling processes impacted by defoliation?

3. Do the strength of these effects depend on seasonal changes in soil moisture?



Treatments:

1. *Desmodium intortum*
2. *Brachiaria* cv. Mulato II
3. *Pennisetum purpureum* (Napier)
4. Maize
5. *D. intortum* + Mulato II
6. *D. intortum* + Maize
7. *D. intortum* + Napier


Karama
Karama
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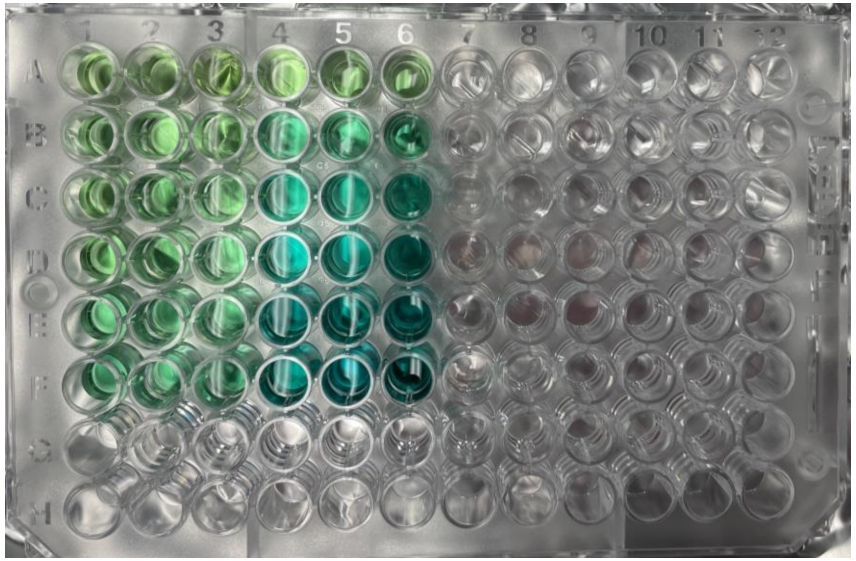
Karama
Karama
2 weeks
2 weeks
2 weeks
Rubona
Rubona
Rubona
Rubona
Rubona
Rubona
Rubona
Rubona
Rubona
Oct
Nov
Dec
Jan
Feb
2020
2021
event
soil sampling 1
soil sampling 2
soil sampling 3
soil sampling 4
soil sampling 5
soil sampling 6
forage harvest

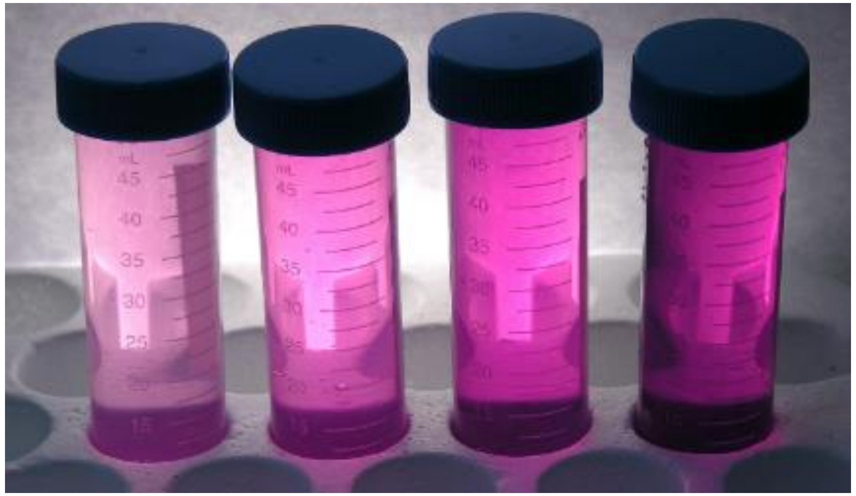
Soil Nitrogen

- Mineral N
  - NH_4^+
  - NO_3^-
- Organic N
  - Potentially mineralizable N (PMN)

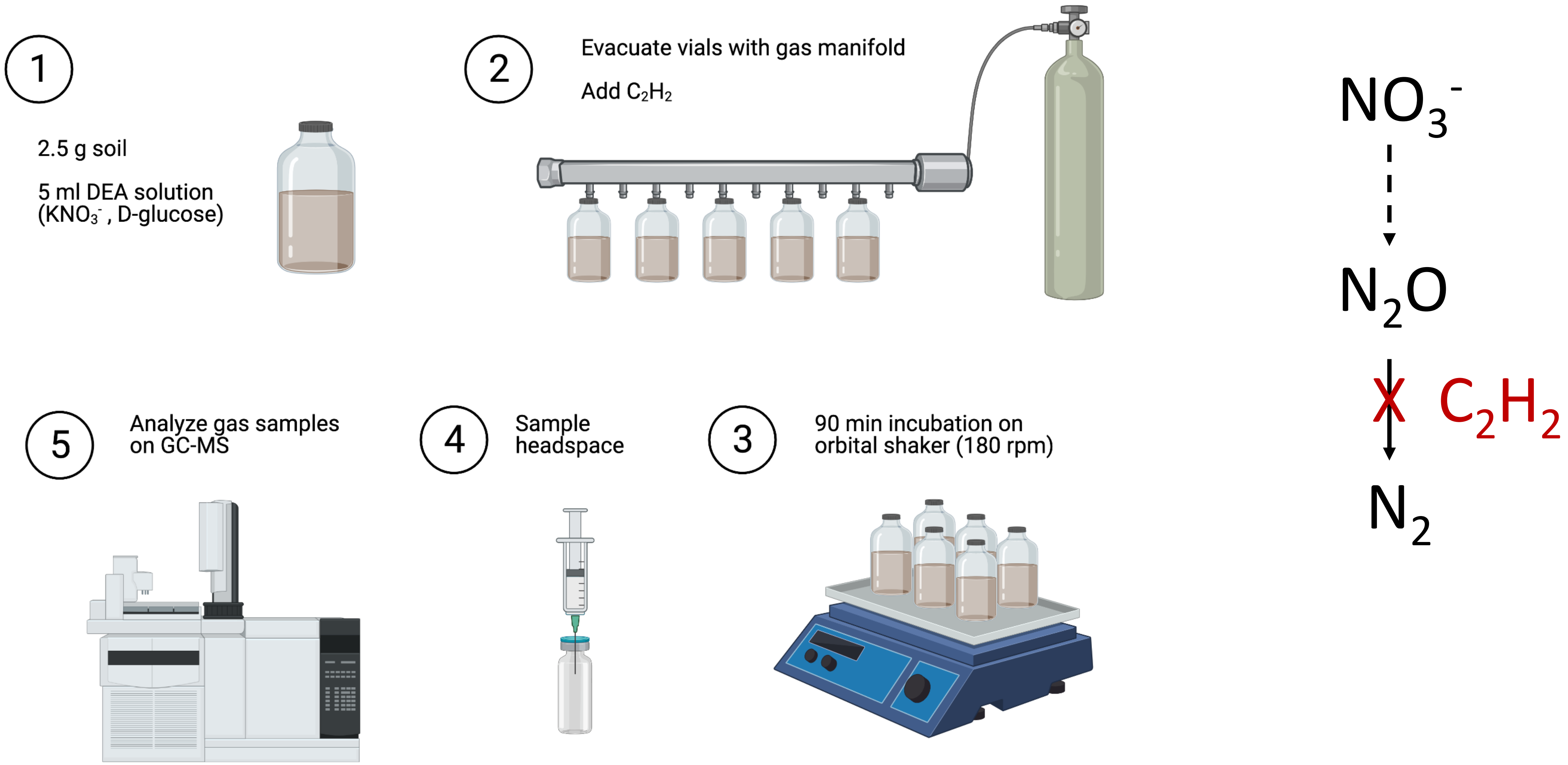


Active Carbon

- Permanganate oxidizable carbon (POX-C)



Denitrification enzyme activity (DEA)

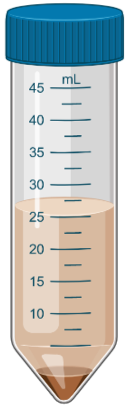


Nitrification Potential (NP)

1

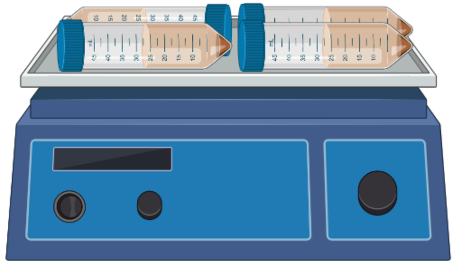
2.5 g soil

25 ml NP solution
(K_2HPO_4, $(NH_4)_2SO_4$)



2

36 hr incubation on orbital shaker
(180 rpm)



3

Collect 1.25 ml samples

2 hrs

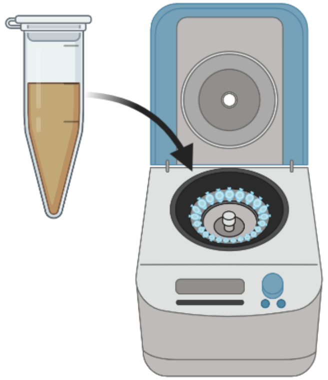
12 hrs

24 hrs

36 hrs

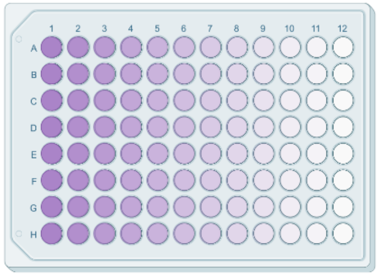
4

Centrifuge



5

Quantify NO_3^-

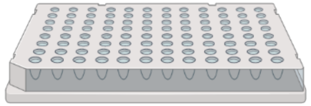


NH_4^+ → NO_3^-

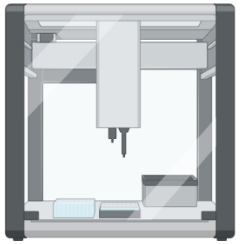
Upcoming: NiCE Chip qPCR

NiCE = Nitrogen Cycling Evaluation

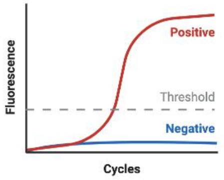
1 Soil DNA extractions

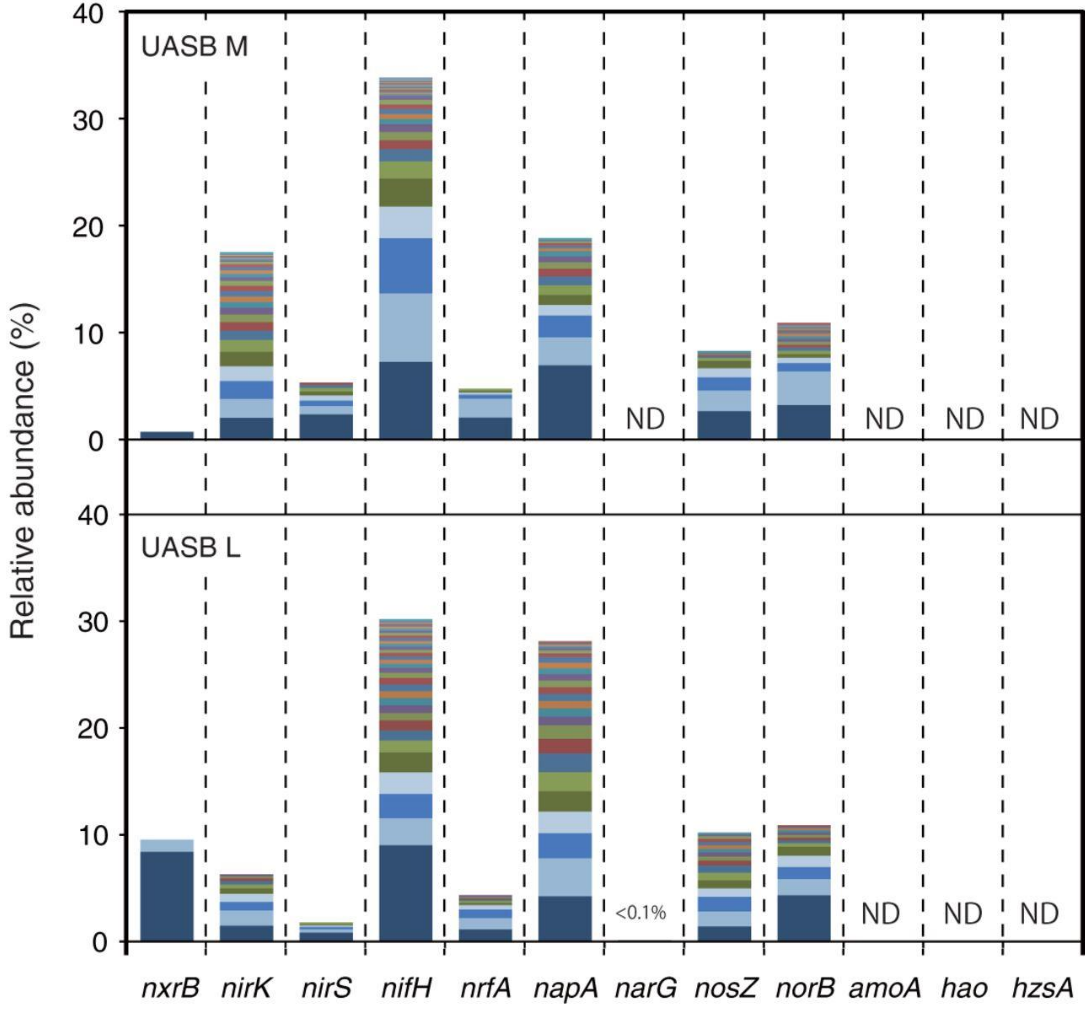


2 Sample loading



3 qPCR





Oshiki et al, 2018

Hypotheses

1. Legume intercropping

Legume plots will have higher mineral and organic N compared to non-legume treatments, stimulating nitrification and denitrification activity.

2. Defoliation

Following defoliation, Brachiaria plots will have lower levels of mineral N due to BNI and NH_4^+ uptake; nitrification and denitrification activity will be suppressed in these plots relative to other treatments.

3. Seasonal effects

Anaerobic soil conditions during rainy season months will result in increased denitrifier activity across all treatments, with the largest increases in legume treatments. Brachiaria plots will experience lower levels of nitrification and denitrification.

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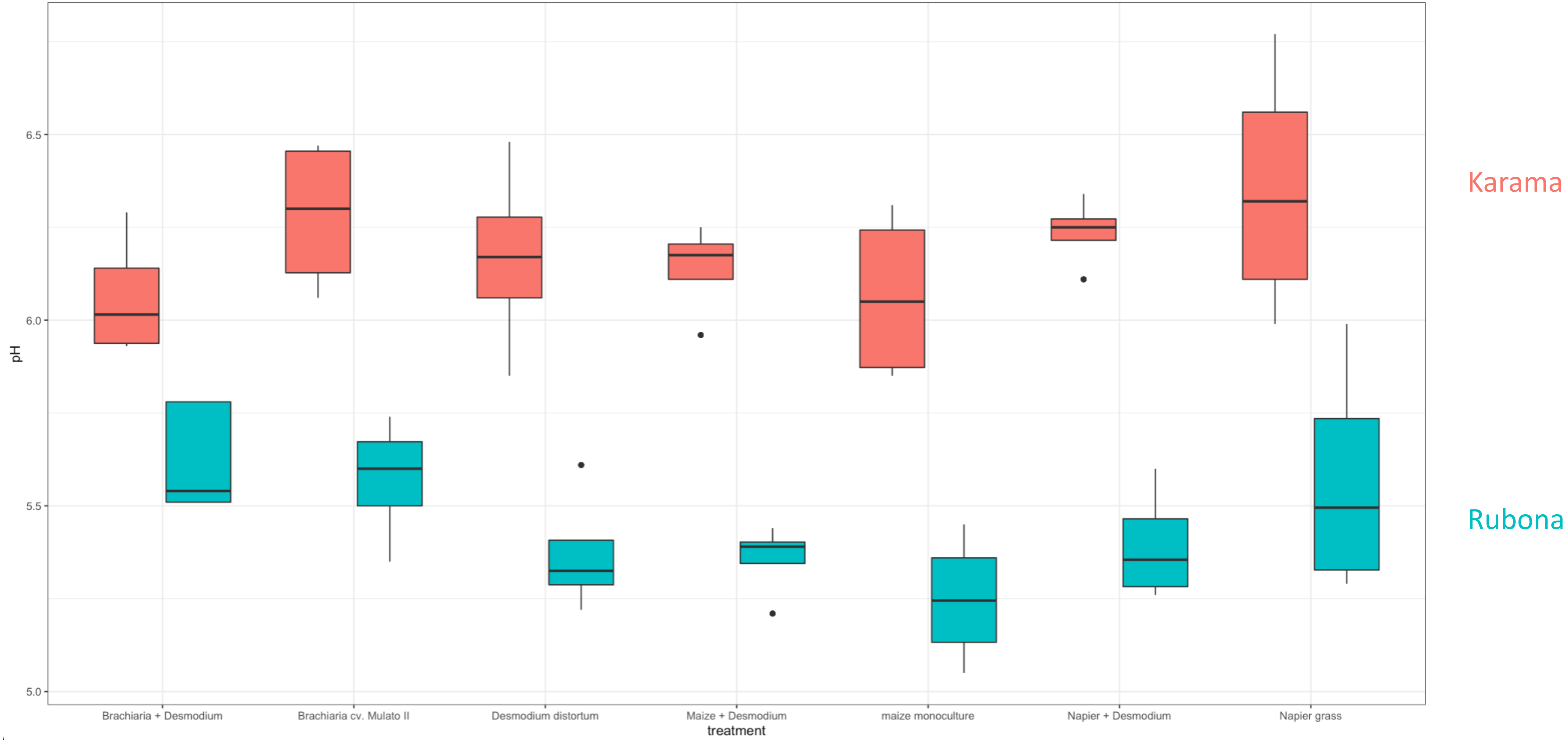
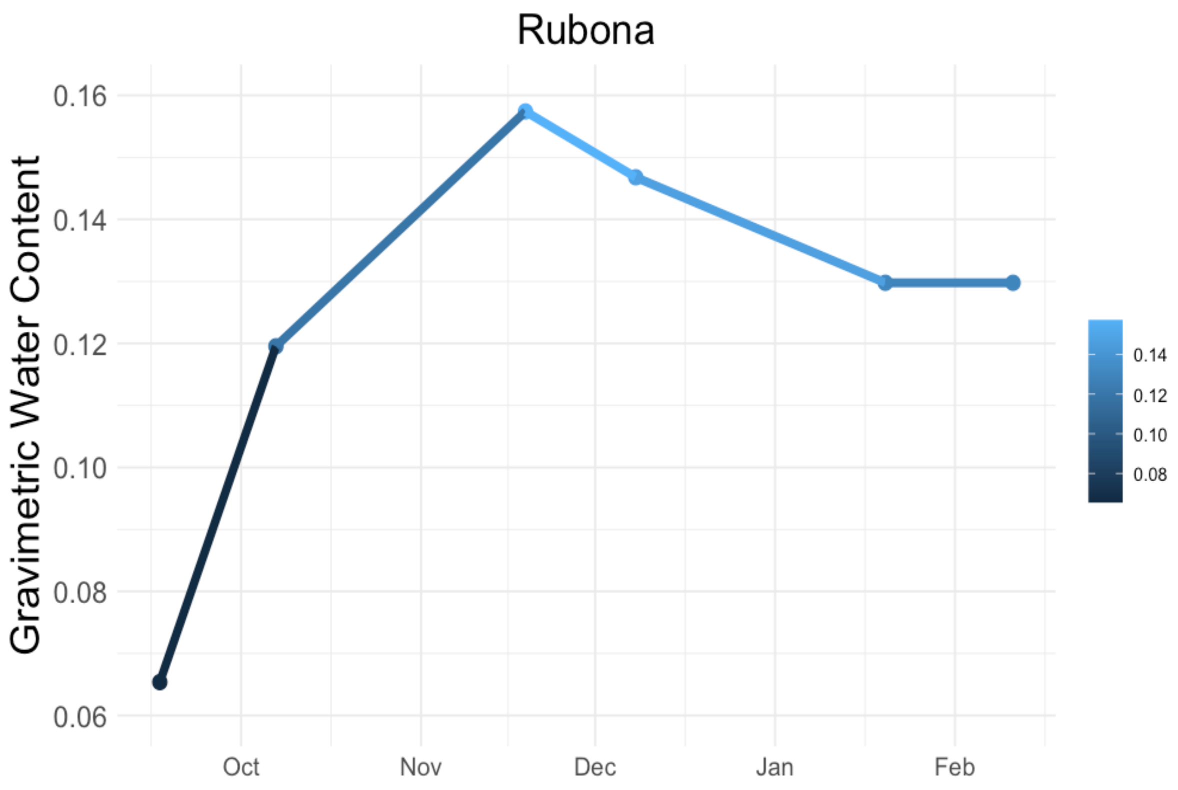
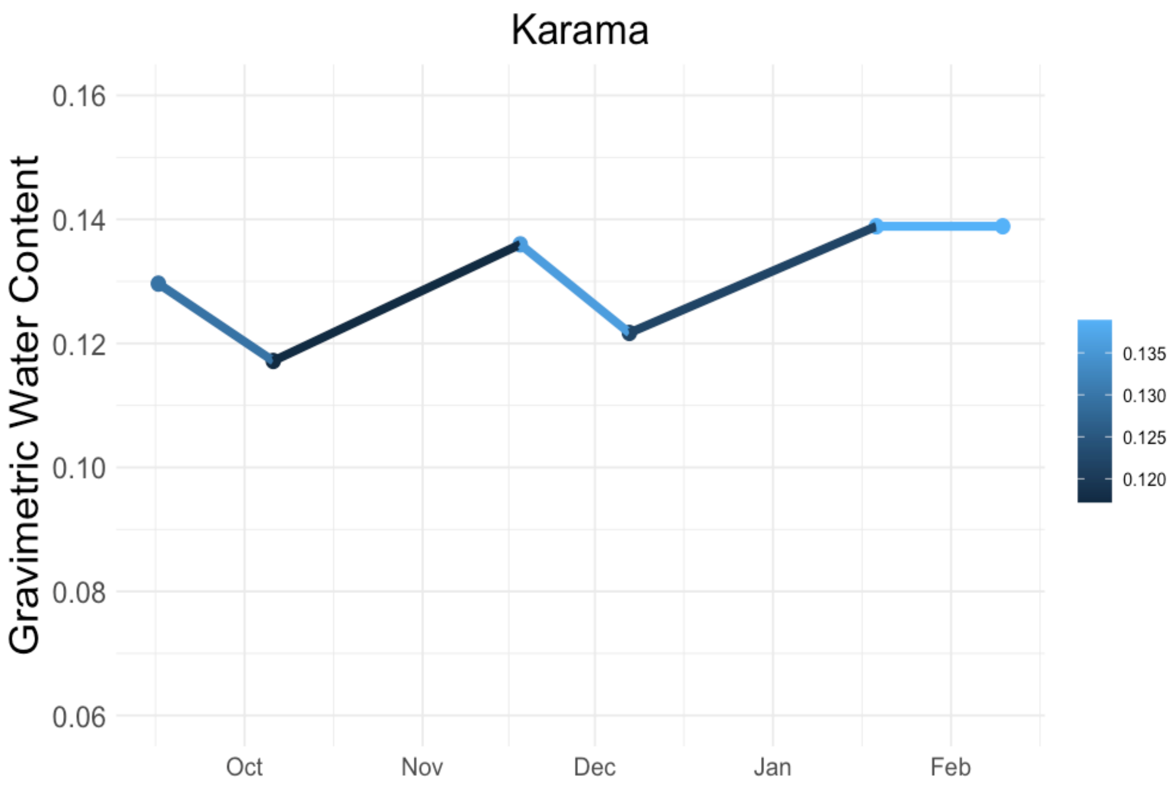
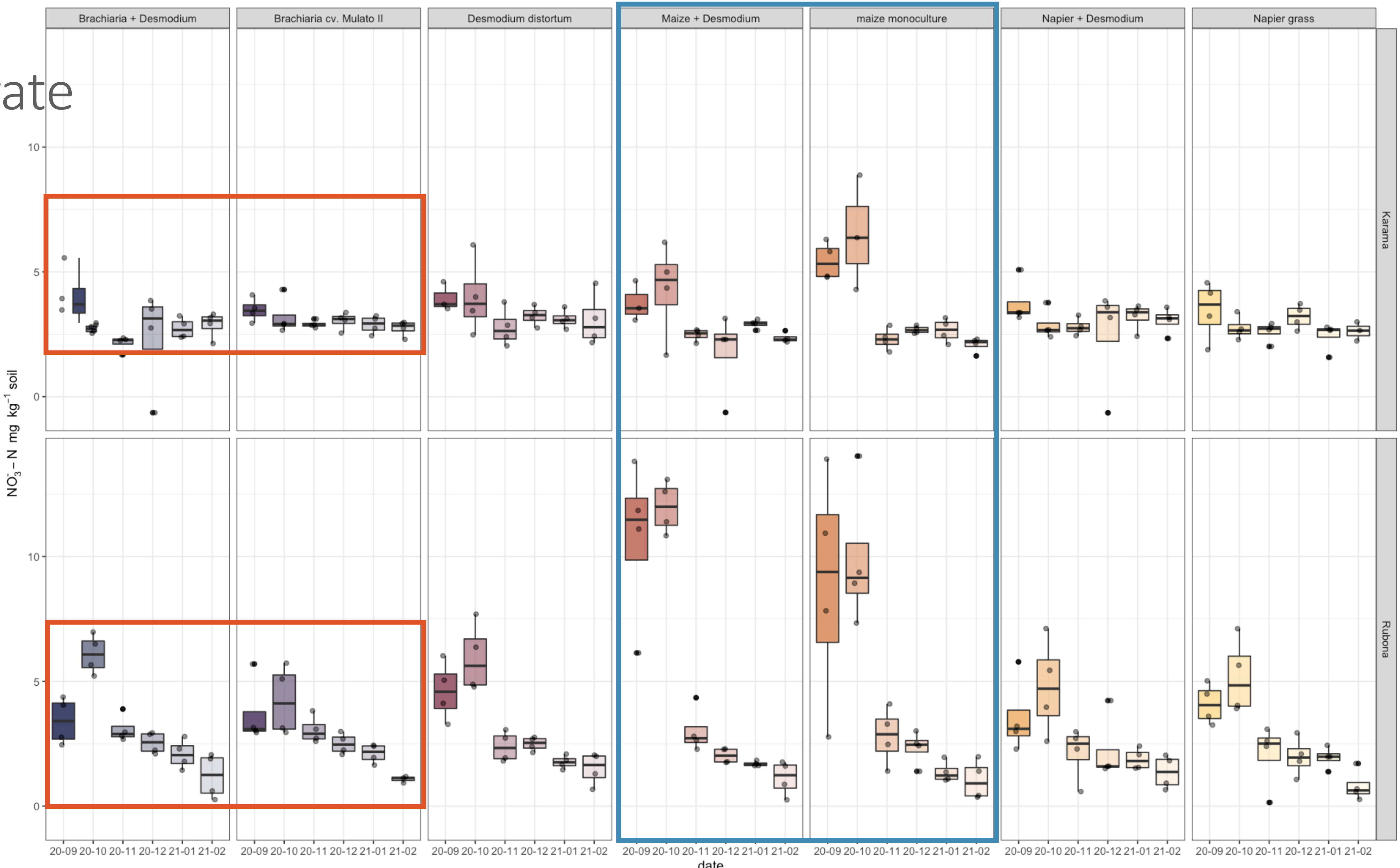

pH
6.5
6.0
5.5
5.0
Brachiaria + Desmodium
Brachiaria cv. Mulato II
Desmodium distortum
Maize + Desmodium
maize monoculture
Napier + Desmodium
Napier grass
treatment
Karama
Rubona

GWC


Rubona
Gravimetric Water Content
0.16
0.14
0.12
0.10
0.08
0.06
Oct
Nov
Dec
Jan
Feb
0.14
0.12
0.10
0.08

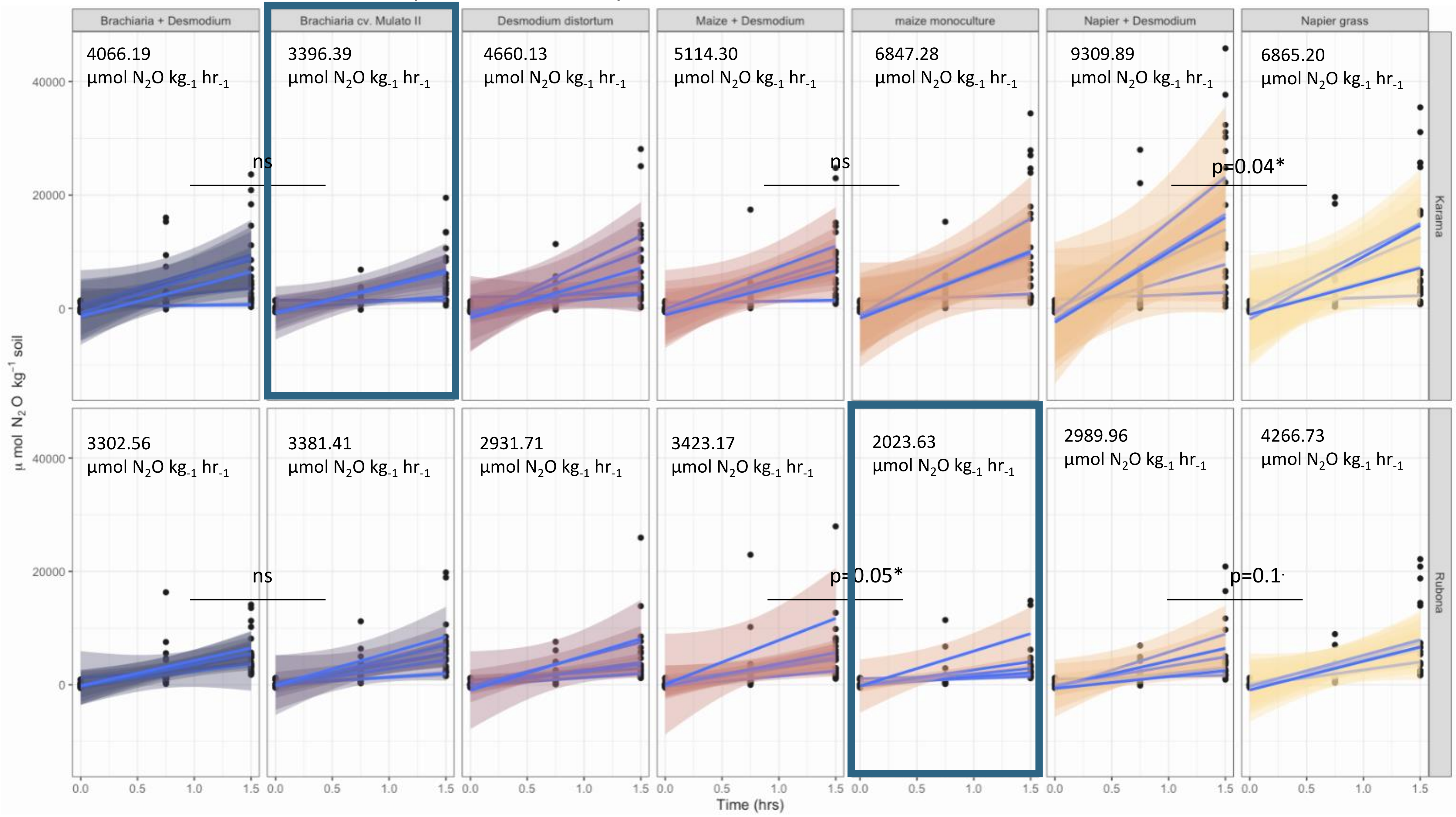

Karama
Gravimetric Water Content
0.16
0.14
0.12
0.10
0.08
0.06
Oct
Nov
Dec
Jan
Feb
0.135
0.130
0.125
0.120

Nitrate



Brachiaria + Desmodium
Brachiaria cv. Mulato II
Desmodium distortum
Maize + Desmodium
maize monoculture
Napier + Desmodium
Napier grass
Karama
Rubona
$NO_3^- - N$ mg kg^{-1} soil
0
5
10
20-09 20-10 20-11 20-12 21-01 21-02
date

Denitrification Enzyme Activity



- Further analysis needed to identify site-specific drivers
- Nitrogen leaching from topsoil during the rainy season is likely a significant challenge (Hagedorn et al, 1997)
- Ongoing work will elucidate the strength of the connection between nitrification and denitrification in bulk soil, in addition to the relevance of functional microbial communities
- Intercropping BNI-competent grasses with legumes offers a novel strategy to approach the dual goals of supplying nitrogen and limiting its loss to the environment

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Committee Members
Dr. Kristen Nelson
Dr. Jacob Jungers
Dr. Satoshi Ishii
Dr. Jessica Gutknecht

CIAT
Dr. An Notenbaert
Dr. Rolf Sommer
Technician: Paulin Mutanguha
Driver: Wellars
Staff

RAB
Jules Mutabazi
Interns: Olivia, Theophile, Danilla

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