Alfalfa to get back into planetary boundaries

2025 world alfalfa congress
FRANCE REIMS-CHÂLONS

High yield alfalfa for low carbon livestock in stressful climate

Session chair(s): Brummer C. & Odorizzi A.

Plenary session

FROM 03 › TO 06
nov. 2025

Alfalfa to get back into planetary boundaries

2025 world alfalfa congress
FRANCE REIMS - CHÂLONS

Alfalfa-based feeding strategies for reducing soil N_2O emissions in beef production systems

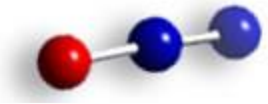
Alvarez C., Martínez Ferrer J., Figuerola E.L.M., Alves B.J.R., Costantini A.O.

FROM 03 › TO 06 nov. 2025

Mayors GHG; GWP

Carbon dioxide = CO_2

GWP = 1

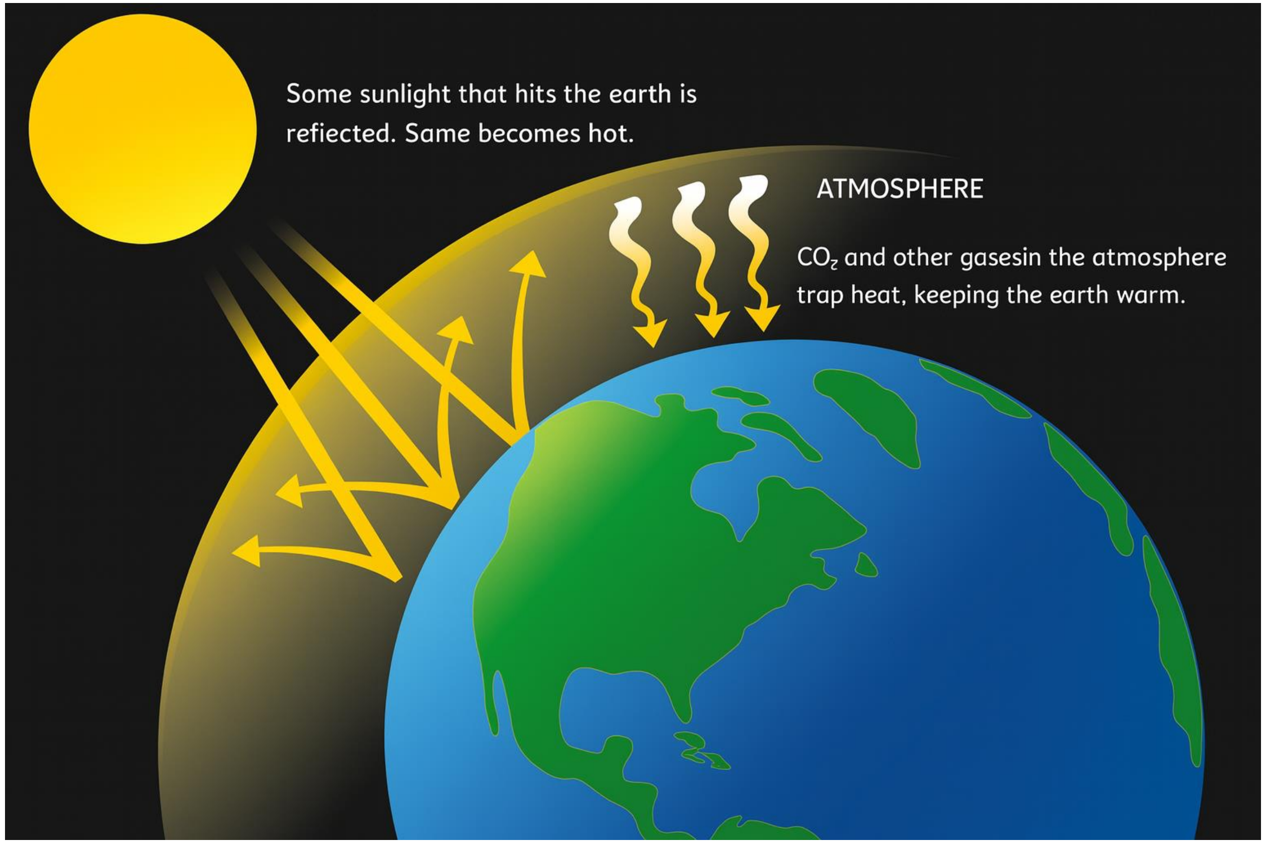


Nitrous oxide = N_2O

GWP = 273

Methane = CH_4

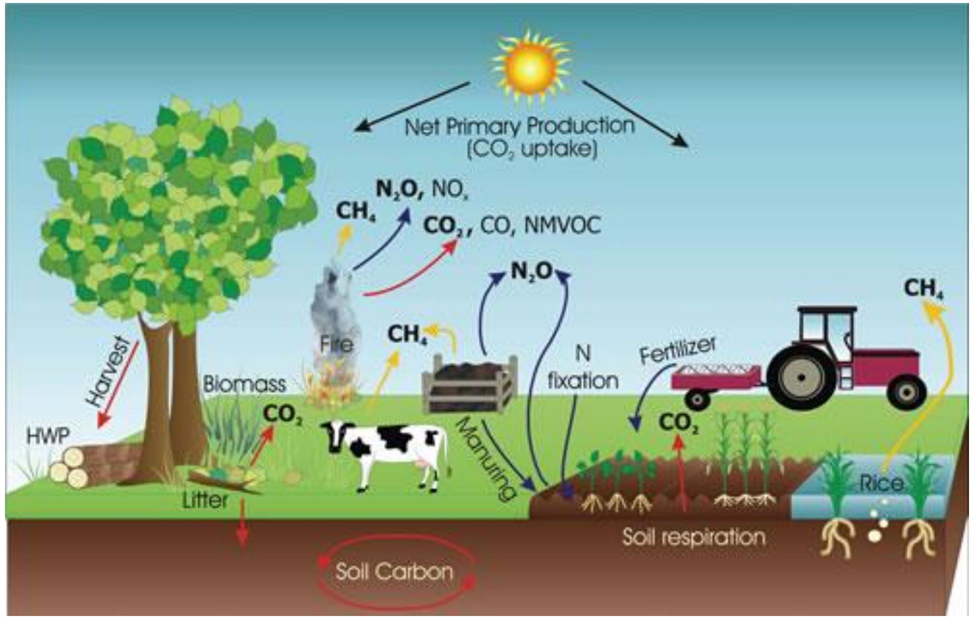
GWP = 28



- **Global Warming Potential ~ physical characteristics and residence time in the atmosphere**

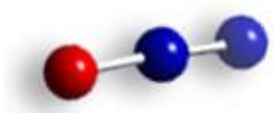
Alfalfa to get back into planetary boundaries

Mayors GHGs; sinks & sources in the (agro)ecosystem



CO_2

- ↓ Plant uptake during photosynthesis
- Plant respiration
- Burning of organic material
- Aerobic microbial respiration (soils)

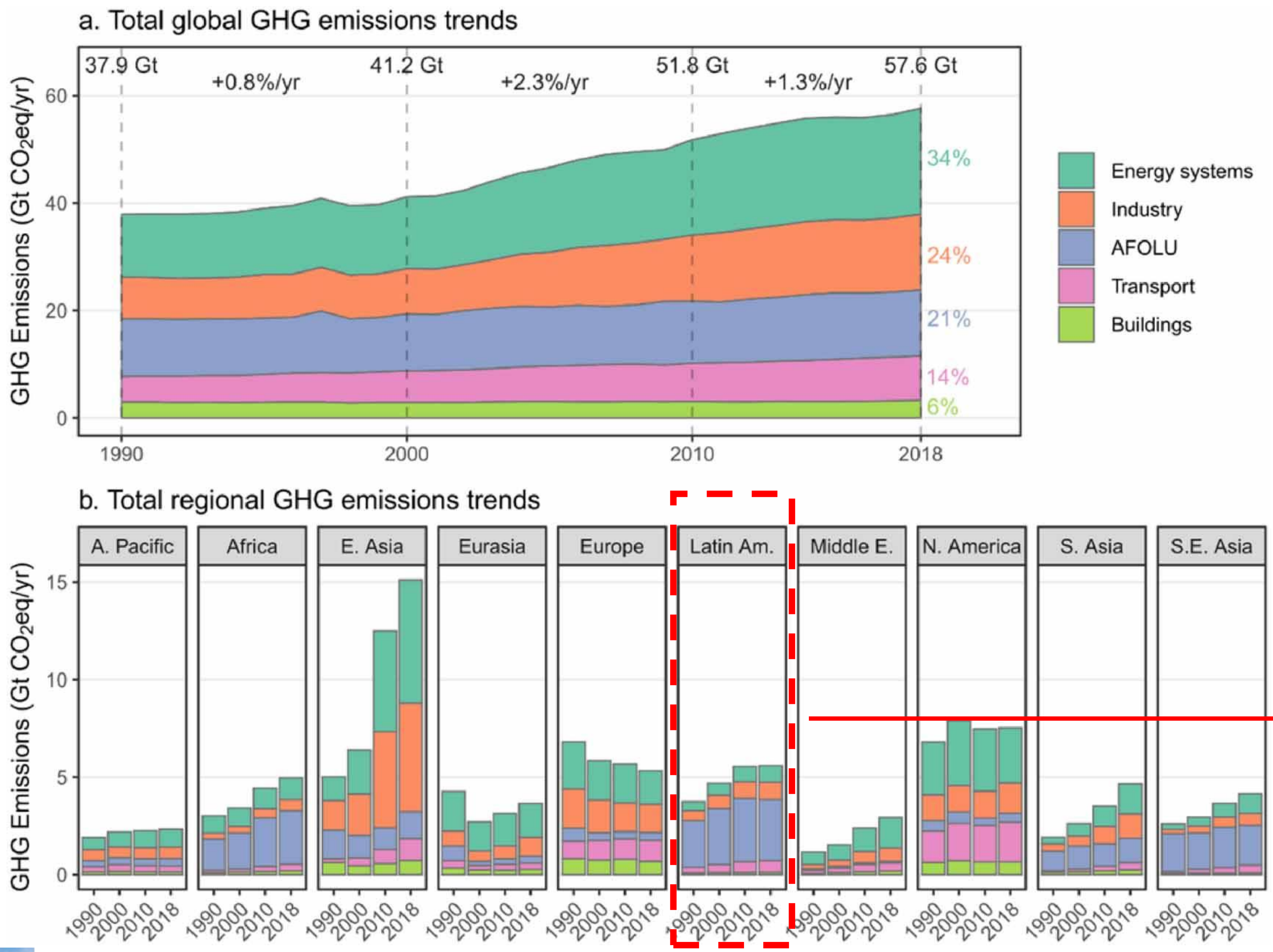


N_2O

- Microbial transformations in soil, manure, urine
- Mineralization of organic matter

CH_4

- Enteric fermentation and stored manure
- Anaerobic microbial decomposition (methanogenesis) in prolonged wet soils (rice paddies, peat bogs).



AFOLU Sector

21 % of global GHG emissions

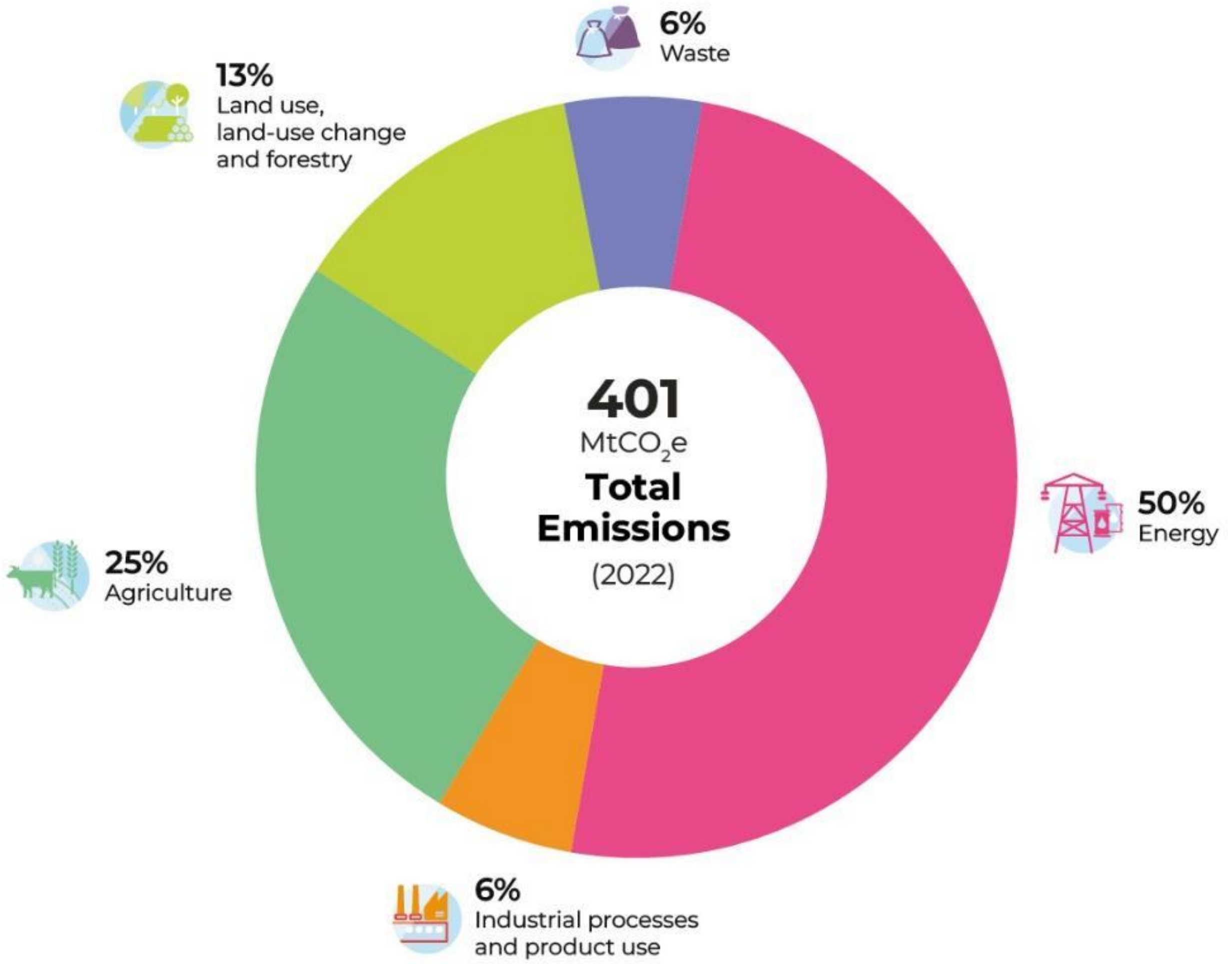
AFOLU Sector
Latin America

60% of GHG emissions
1-Land use change
2-Livestock

AFOLU: Agriculture, livestock, forestry, and other land uses" sector

Lamb *et al.*, 2021

Argentina



National GHG Inventory

AFOLU Sector

Livestock ⇨ **38 %**

- Enteric fermentation (CH_4) ⇨ 15,2 %

- N_2O emissions from beef excreta ⇨ 3 %

INI: Informe Nacional inventory, published in 2024
Sub-Secretary of Environment, 2024

Beef cattle in Argentina

- Beef cattle was **displaced** from the traditional productive structure due to the **advance** of the agricultural frontier in Argentina.

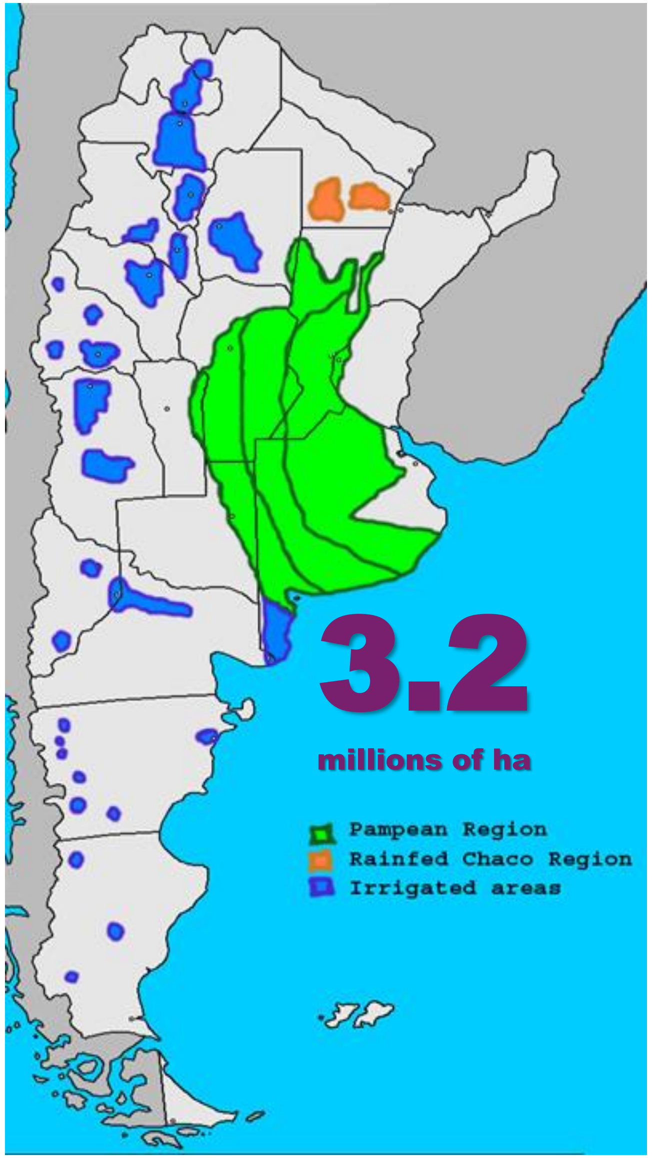
- The **rearing** and **fattening cycles** evolved into confined and **intensified systems**.

- The spatial distribution of animals changed and, consequently, so did the distribution of their **excreta on the soil.**

Alfalfa to get back into planetary boundaries

Tkachuk & Dossi, 2014

Alfalfa in Argentina



ALFALFA is the most important forage species in the country.

- 80% rainfed , milk/beef (Pampas Region)
- 20% irrigated, hay and seed (NOA, Cuyo and Patagonia)

- 60-65 % pure stand for hay/milk
- 40-35 % mixed stand for grazing (beef production)

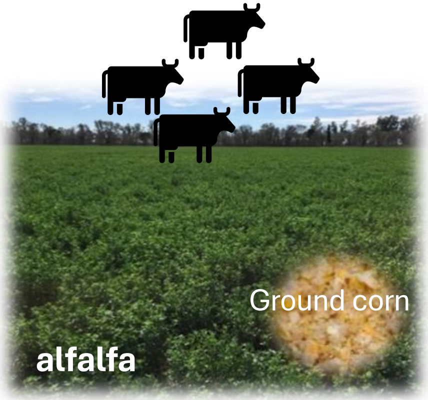
Alfalfa to get back into planetary boundaries

2025 world alfalfa congress FRANCE REIMS · CHÂLONS

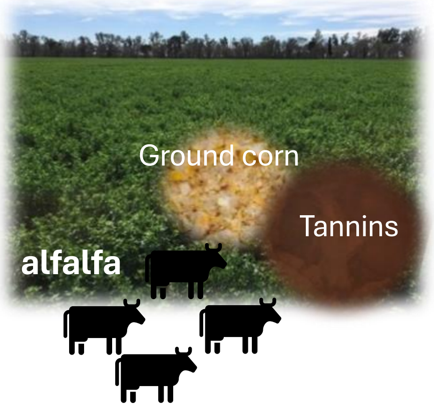
N_2O mitigations strategies

Grazing systems

Standard



Modified



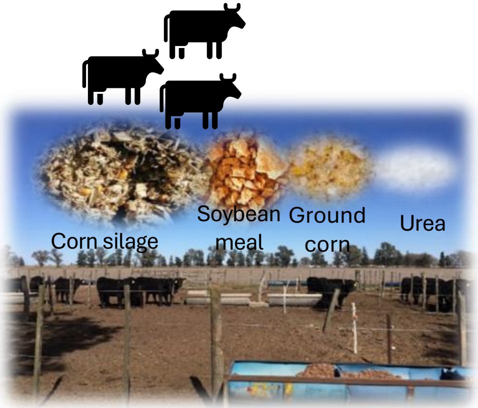
Tannins

Urine-N

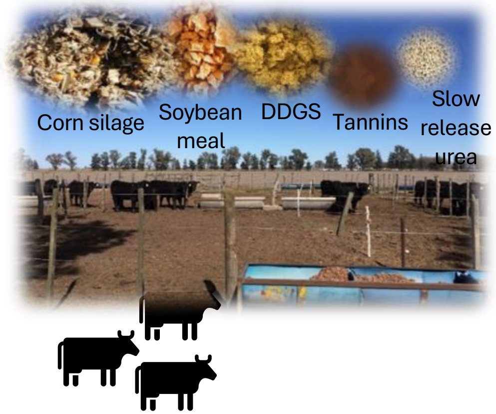
Dung-N

Feedlot systems

Standard

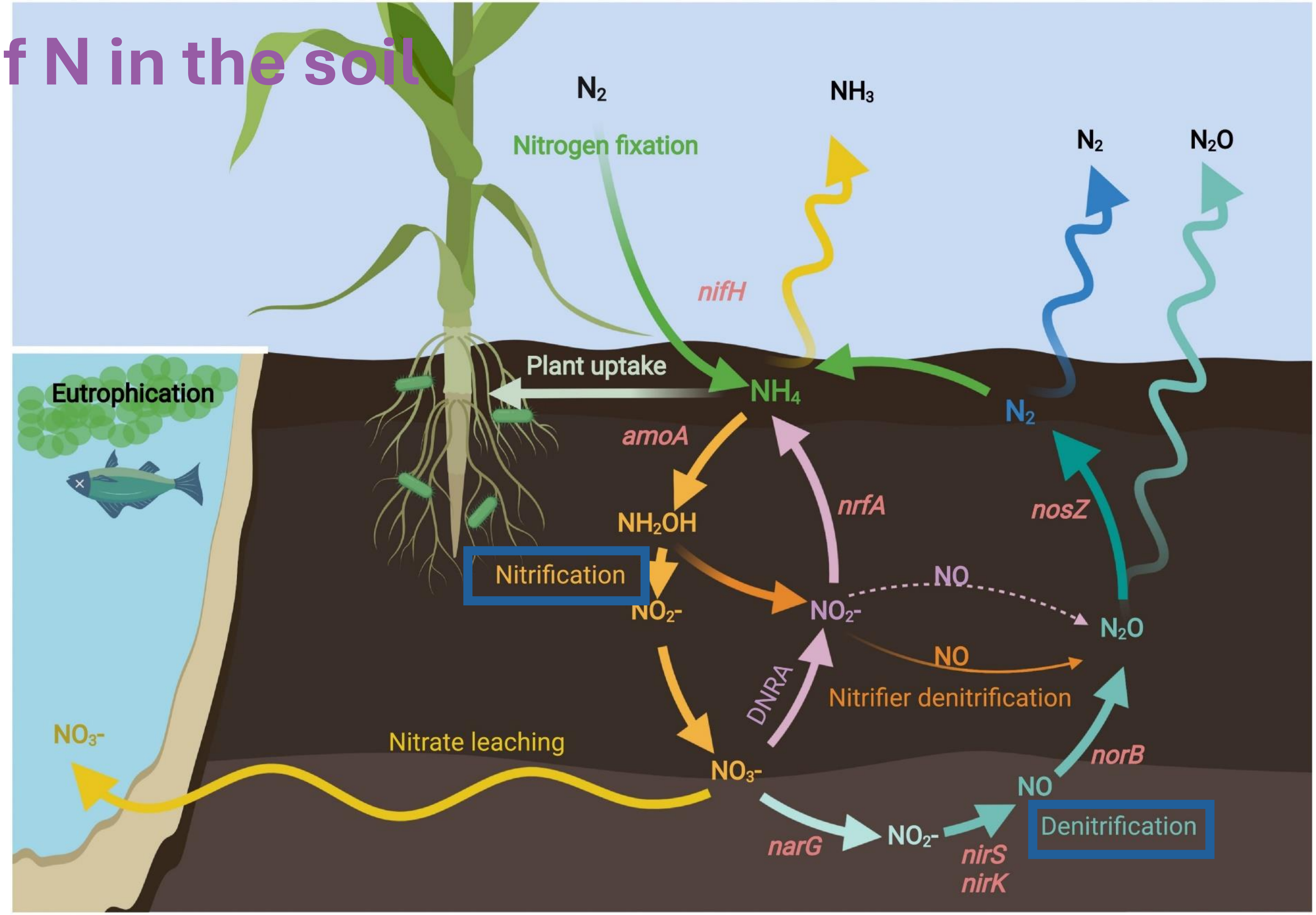


Modified



Transformations of N in the soil

N_2O



Trends in Microbiology

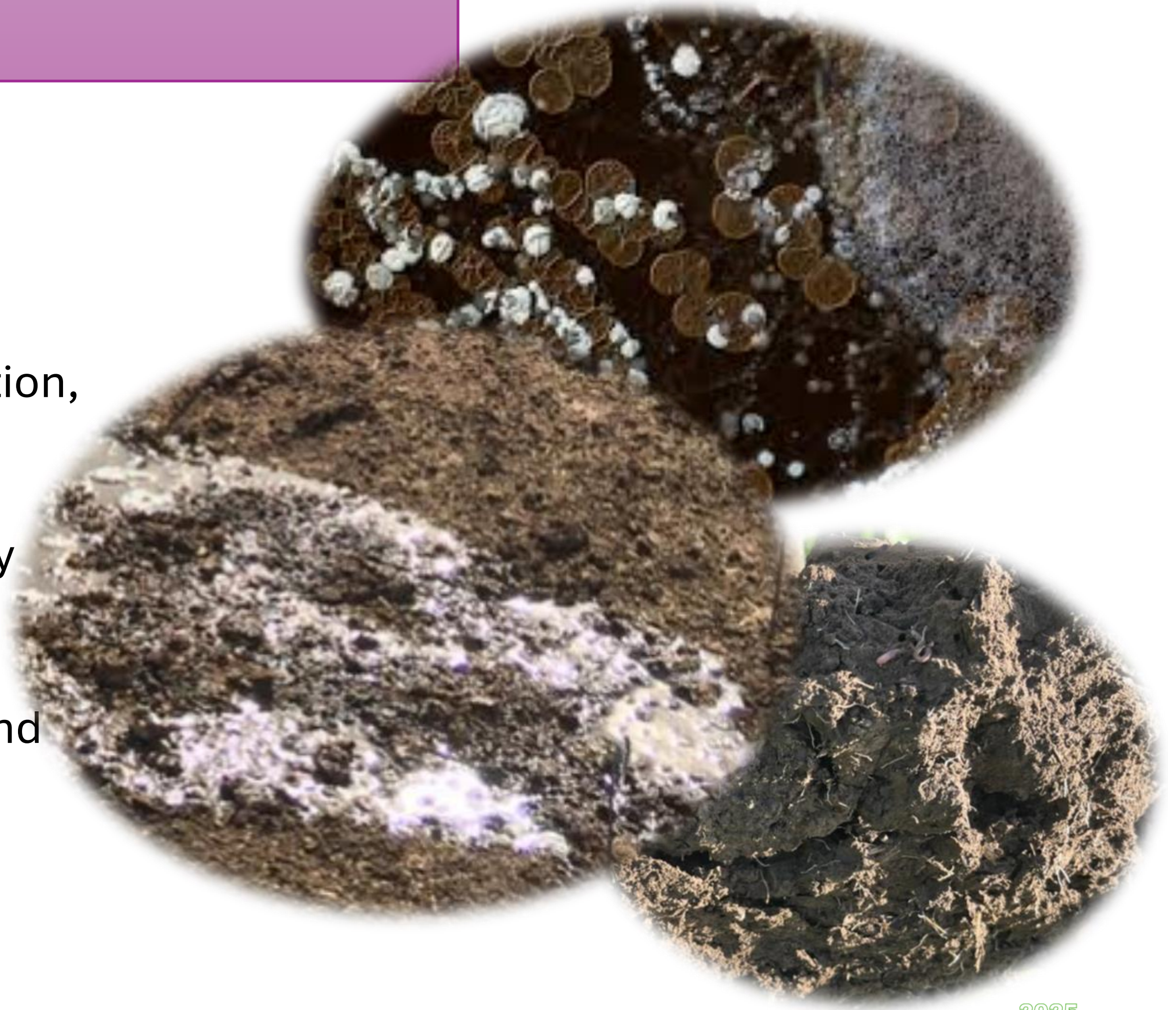
<u>Microbial transformations in soil</u>

- Fertilizers
- **Urine**
- **Feces**
- Organic matter mineralization

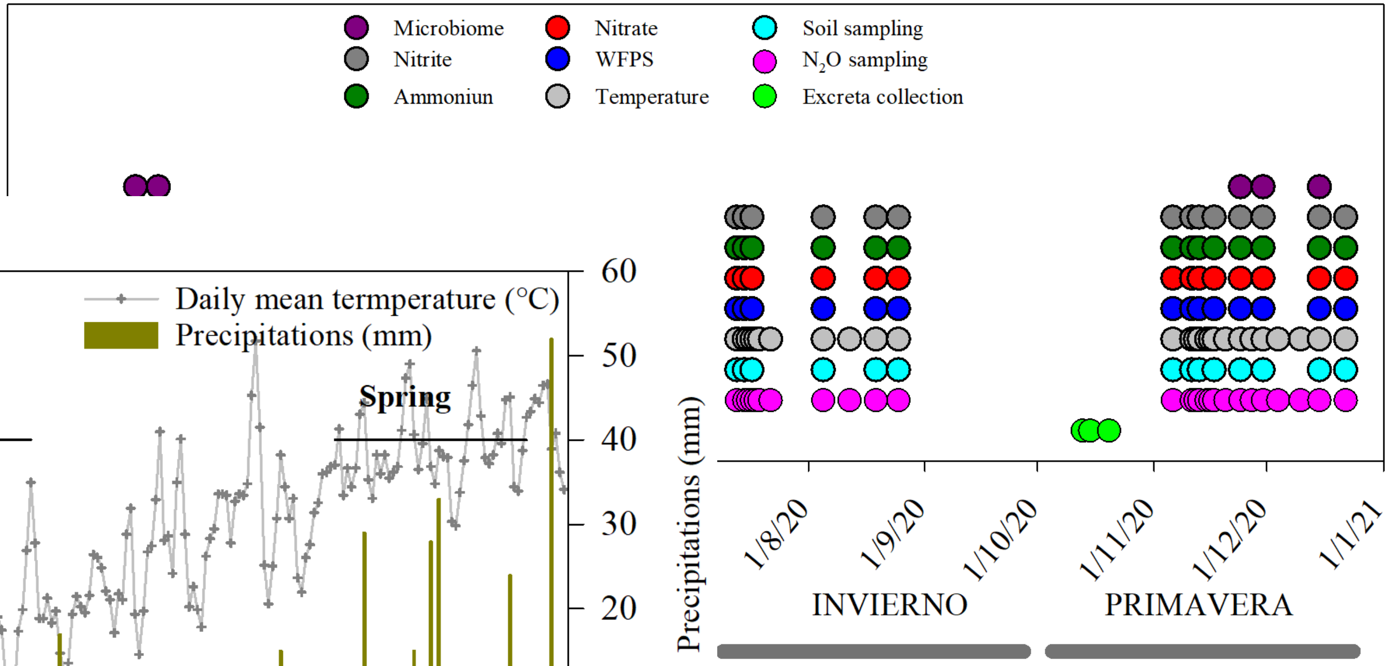
- Both nitrification and denitrification occur in the soil at the same time due to the heterogeneous nature of the soil habitat.
- Strongly affected by O_2, pH, temperature, and soil moisture.

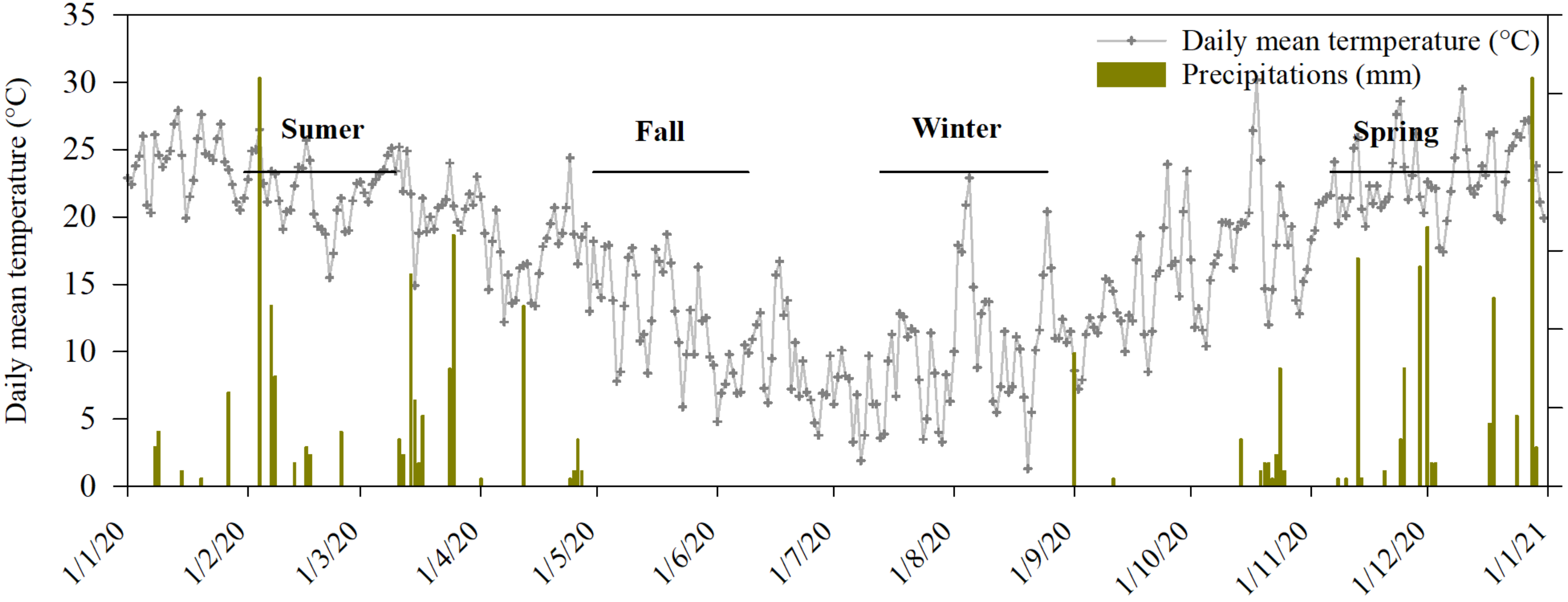
Soil microbiome and N_2O emissions

- ✓ Microorganisms are involved in >90% of soil functions (nutrients, decomposition, structure).
- ✓ Management practices modify the diversity, composition, and functionality of the microbiome.
- ✓ In livestock systems, excreta disturb the microbiota by adding N, C, and water.
- ✓ Urine patches generate quick microbial succession and N surpluses → N_2O, NH_3, and N_2.
- ✓ Fungi also contribute to N_2O, but their role is not well understood.



Environmental conditions and measurement frequency





2020 => 28% lower than historical mean PP

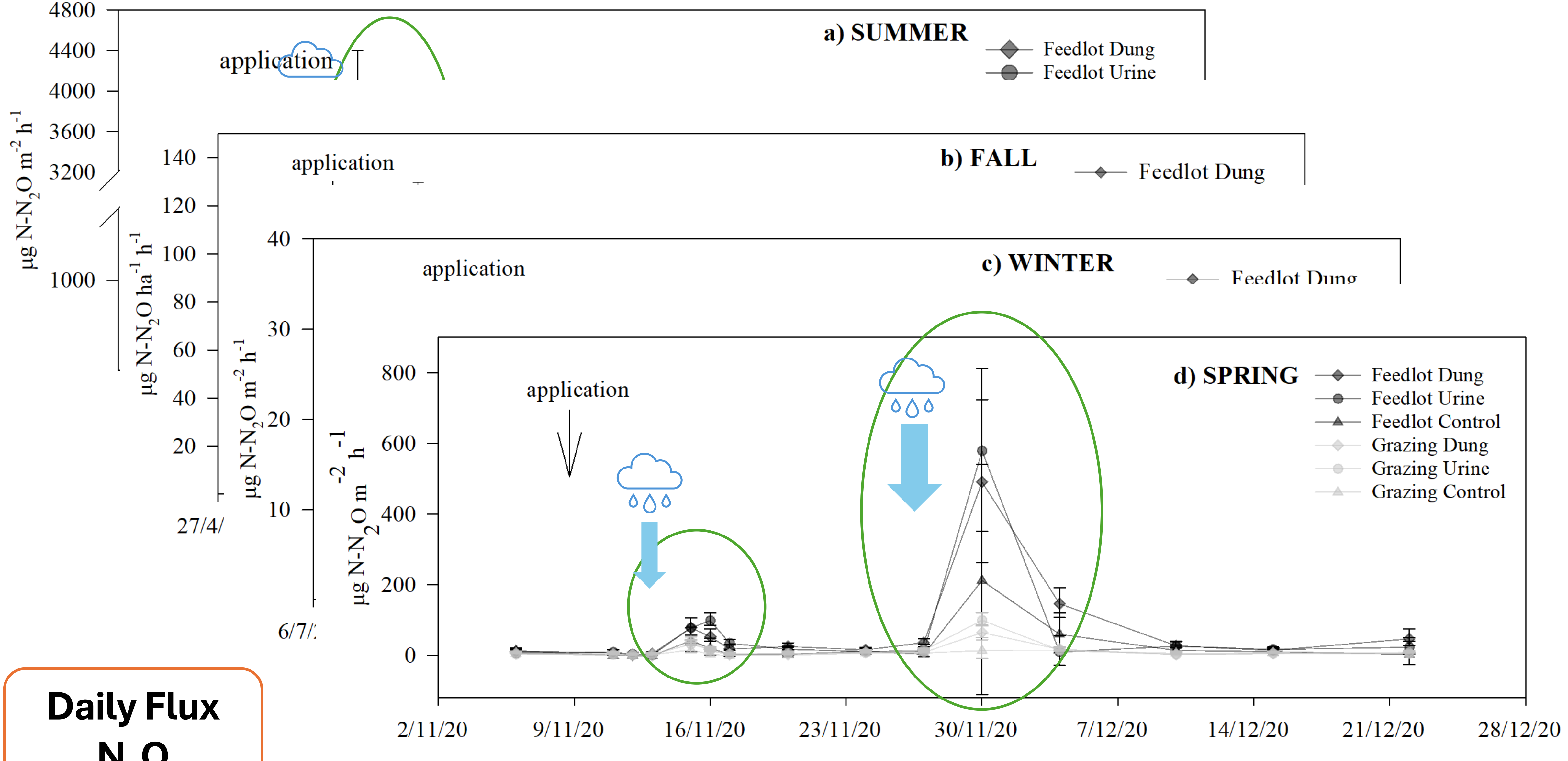
	Temperature (°C)	Precipitations		
Season	Mean	Mean (1931-2019) (mm)	Total (mm)	Number of events
Summer (01/31 a 03/10)	21,9	136	108	7
Fall (04/30 a 06/09)	12,2	29	0	0
Winter (07/13 a 08/28)	9,8	15	0	0
Spring (11/06 a 12/22)	22,7	172	154	13

Composition of excreta

Seasons	Systems	Diet	Excreta type: Urine-N (g N l^{-1})	Excreta type: Dung-N (% DM)
Summer	Feedlot	Standard	3,70±0,42 A	3,45±0,16 A
		Modified	3,30±0,37 A	2,75±0,16 B
	Grazing	Standard	4,85±0,45 A	2,92±0,12 A
		Modified	2,58±0,45 B	3,03±0,10 A
Fall	Feedlot	Standard	4,77±0,55 A	3,01±0,10 A
		Modified	4,13±0,55 A	2,68±0,05 B
	Grazing	Standard	4,82±0,25 A	3,01±0,08 A
		Modified	4,20±0,25 A	2,82±0,07 A
Winter	Feedlot	Standard	7,02±0,69 A	2,73±0,13 A
		Modified	3,29±0,69 B	2,80±0,16 A
	Grazing	Standard	5,30±0,66 A	3,42±0,13 A
		Modified	4,03±0,66 A	3,15±0,19 A
Spring	Feedlot	Standard	12,71±1,37 A	2,82±0,11 A
		Modified	6,90±1,37 B	2,87±0,10 A
	Grazing	Standard	5,05±1,30 A	2,58±0,08 A
		Modified	5,34±1,30 A	2,53±0,09 A

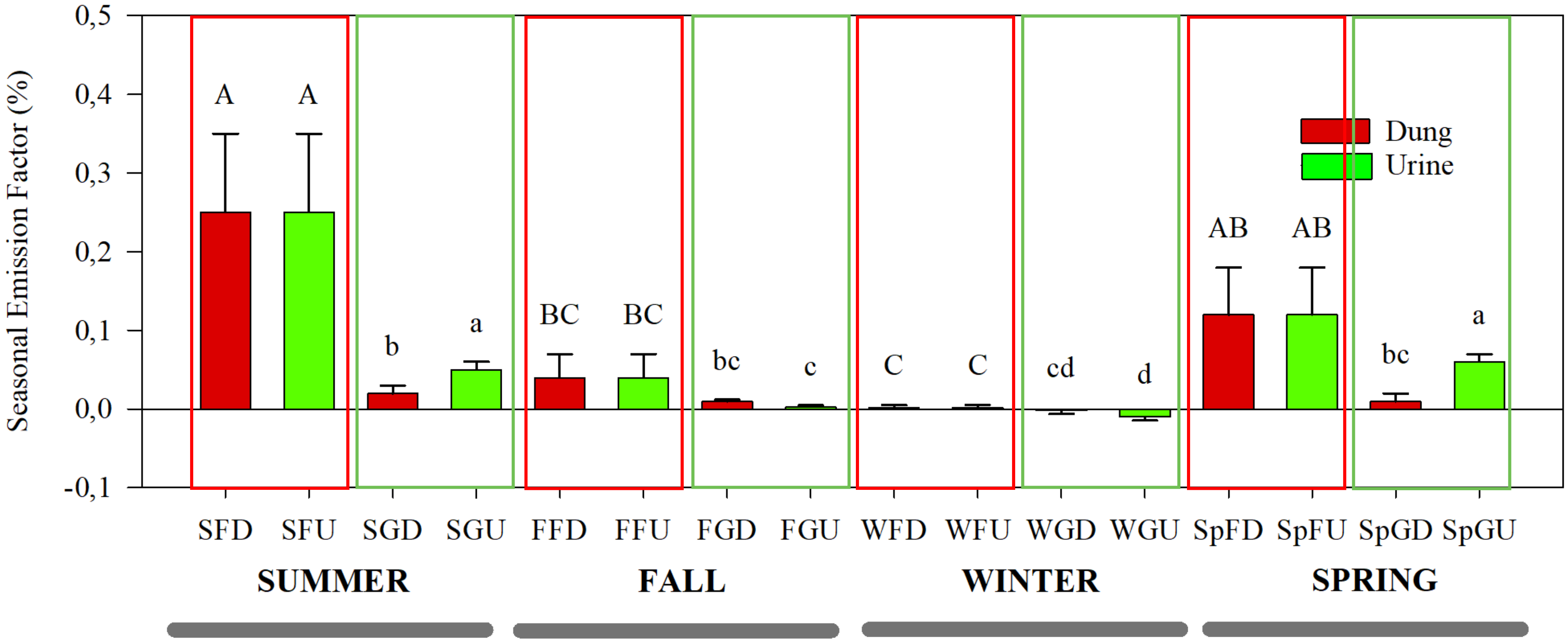
Composition of excreta applied to soil

Seasons	Systems	Diet	N rate applied (kg N/ha): Urine-N	N rate applied (kg N/ha): Dung-N
Summer	Feedlot	Standard	138	198
		Modified	119	476
		Soil	0	
	Grazing	Standard	198	511
		Modified	119	523
		Soil	0	
Fall	Feedlot	Standard	177	531
		Modified	175	547
		Soil	0	
	Grazing	Standard	202	440
		Modified	161	488
		Soil	0	
Winter	Feedlot	Standard	295	480
		Modified	159	507
		Soil	0	
	Grazing	Standard	178	646
		Modified	129	641
		Soil	0	
Spring	Feedlot	Standard	266	444
		Modified	215	471
		Soil	0	
	Grazing	Standard	157	498
		Modified	135	450
		Soil	0	



Daily Flux N_2O

Alvarez et al, unpublished



Grazing Systems

Feedlot Systems

<u>Feedlot</u>

Season: p=0,0138, Excreta: *p=NS*

<u>Grazing</u>

Season x Excreta: *p=0,0001*

Diet: *p=NS* (excluded from the analysis)

Seasonal Emission Factor N_2O

S: summer, F: fall, W: winter, Sp: spring.

F: Feedlot, G: grazing; D: dung, U: urine.

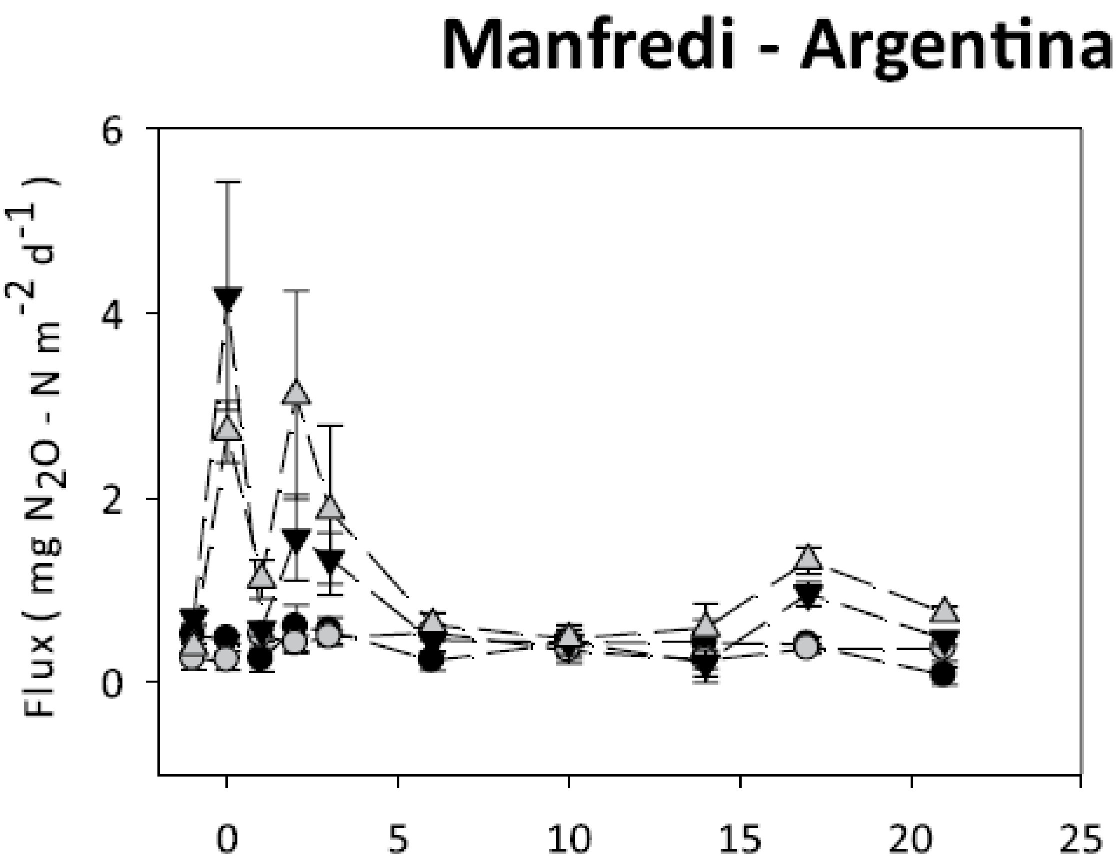
Alfalfa to get back into planetary boundaries

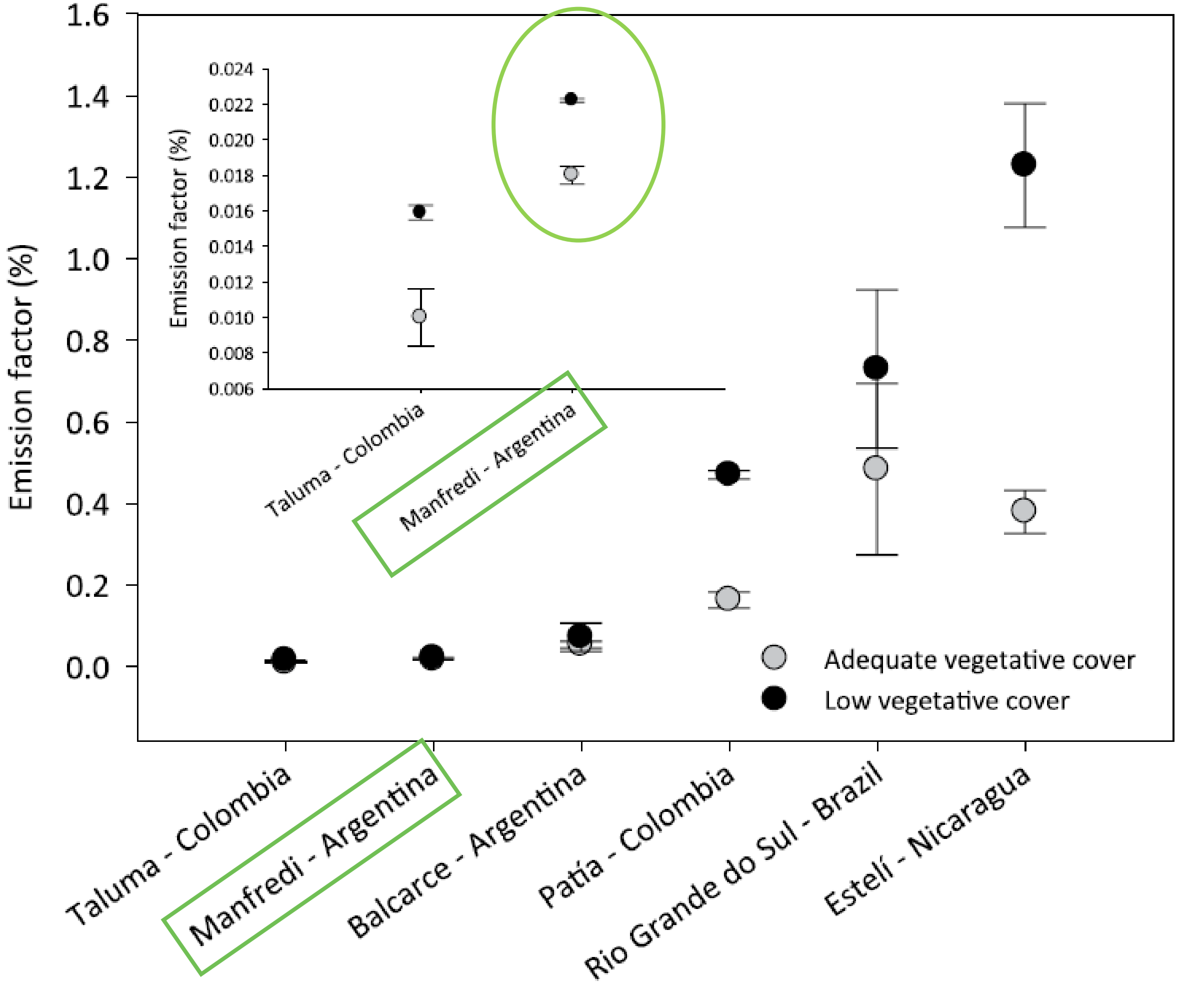
Alvarez et al, unpublished

N_2O from URINE Paches

Urine from Dairy Systems

ALFALFA ==> EF: 0,02 %



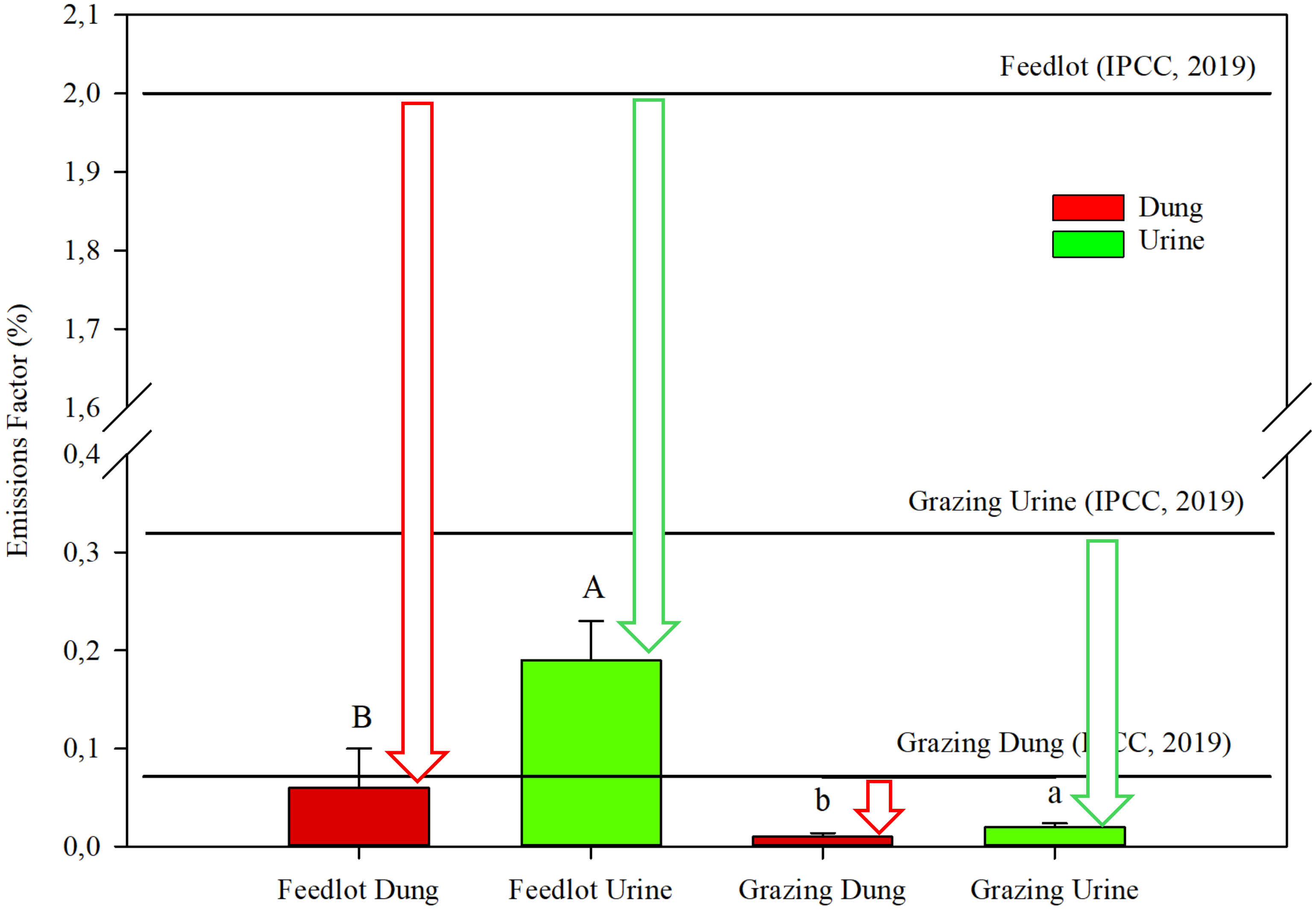


Seasonal Emission Factors in LATAM

Alfalfa to get back into planetary boundaries

Chirinda et al, 2019; Scientific Report

alfalfa congress



Emission Factors

Systems, Excreta type
IPCC 2019

Alfalfa to get back into planetary boundaries

Alvarez et al, unpublished

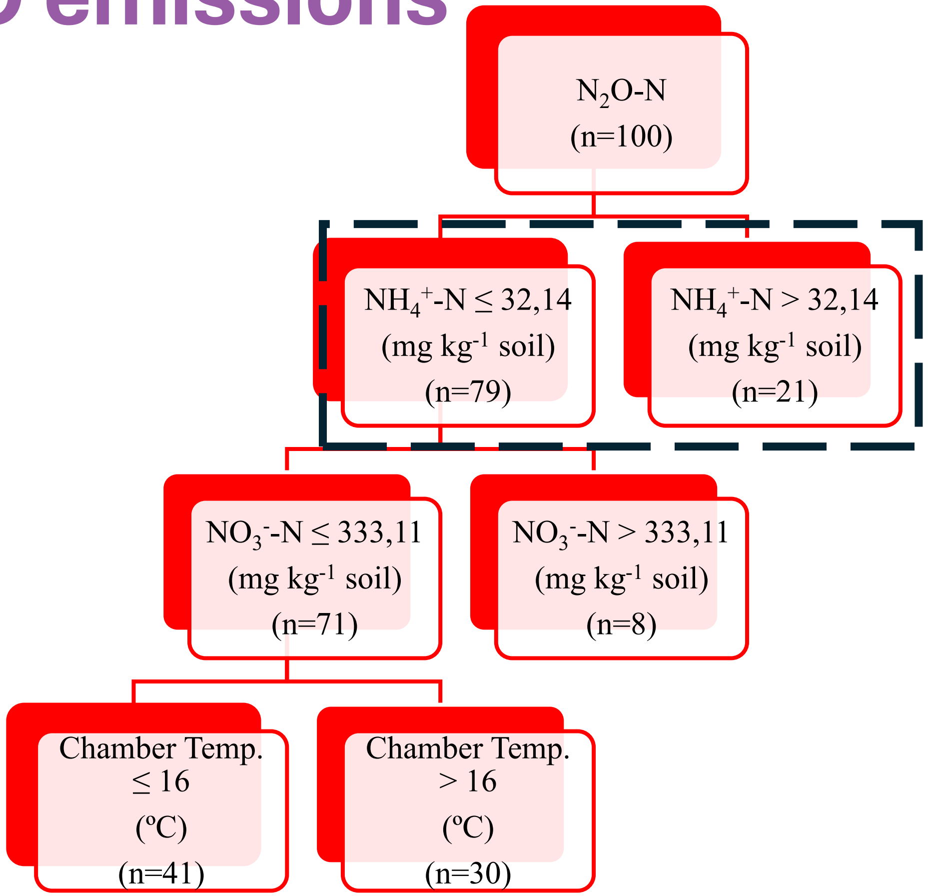
2025 world alfalfa congress

Edaphic and environmental factors correlations

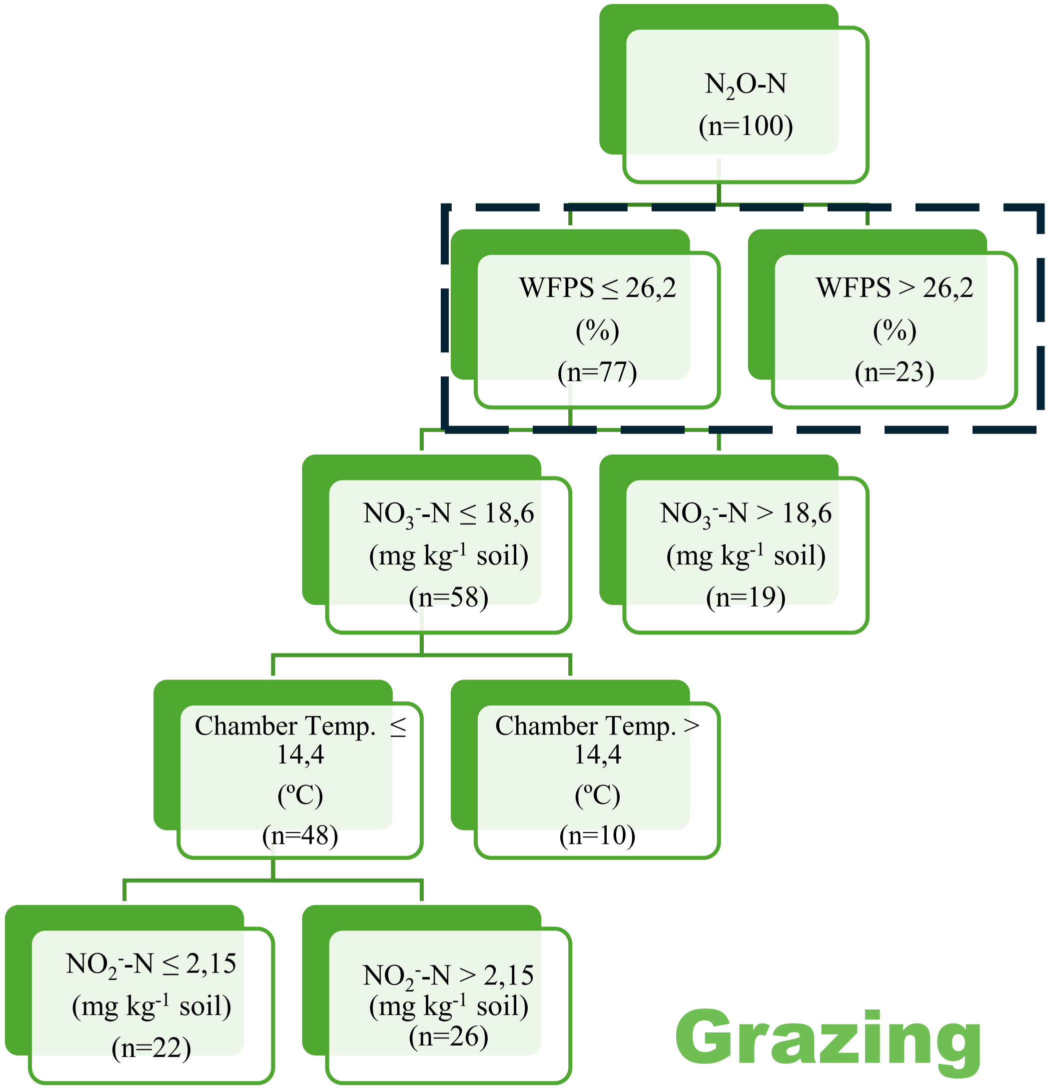
	Daily N_2O-N flux ($mg\ m^{-2}\ h^{-1}$)		WFPS (%)		Chamber temp. (°C)		NH_4^+-N ($mg\ kg^{-1}$)		NO_3^--N ($mg\ kg^{-1}$)		NO_2^--N ($mg\ kg^{-1}$)
Daily N_2O-N flux ($mg\ m^{-2}\ h^{-1}$)	1										
WFPS (%)	0,4402	*	1								
Chamber temp. (°C)	0,3296	*	0,1226		1						
NH_4^+-N ($mg\ kg^{-1}$)	0,1645	*	-0,0703		0,4160	*	1				
NO_3^--N ($mg\ kg^{-1}$)	0,3237	*	0,6017	*	0,2653	*	-0,0853		1		
NO_2^--N ($mg\ kg^{-1}$)	-0,1525	*	0,0761		-0,4203	*	-0,3726	*	0,2865	*	1

Alvarez et al, unpublished

Relative importance of the abiotic variables measured in N_2O emissions



Feedlot systems



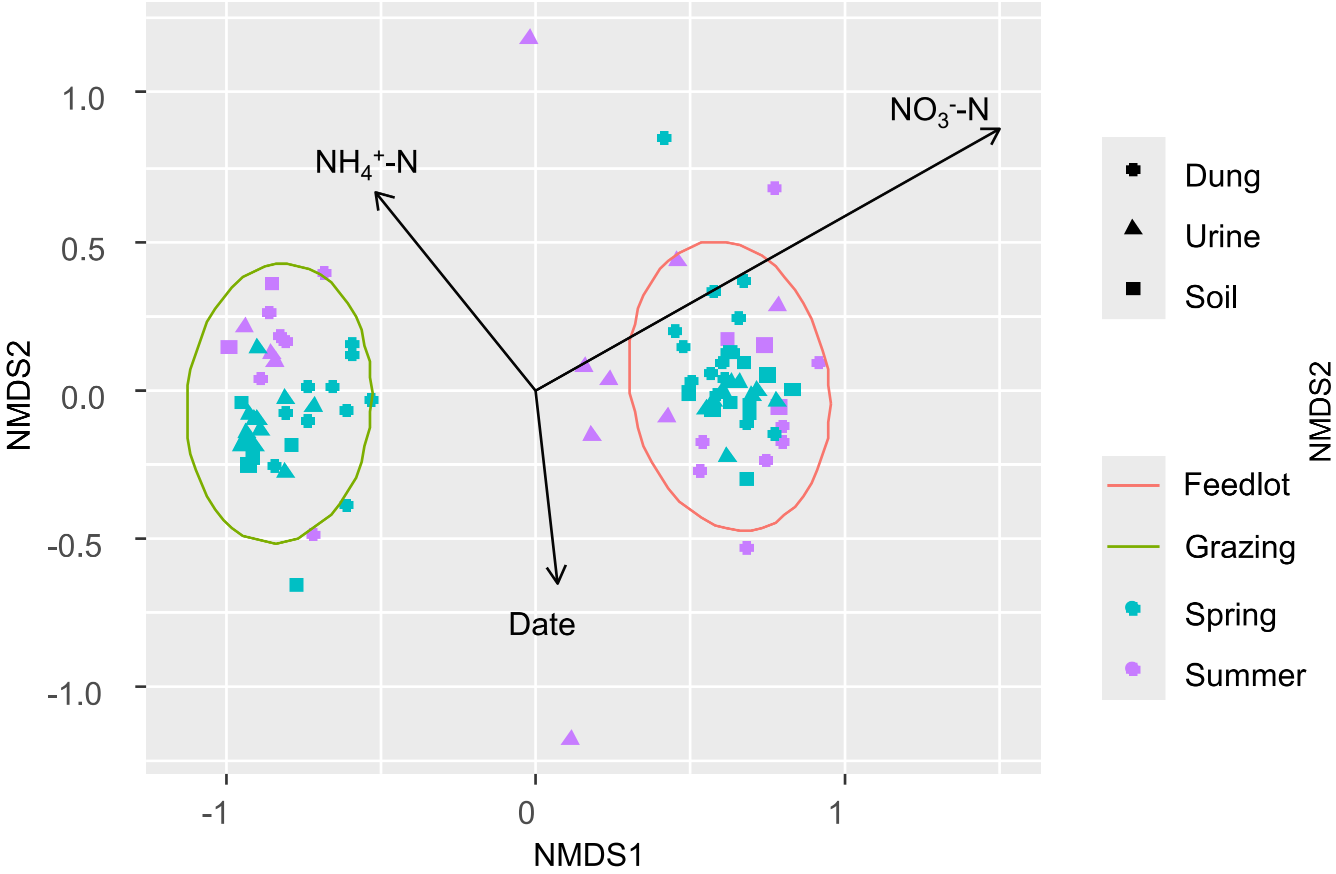
Grazing systems

Alvarez et al, unpublished

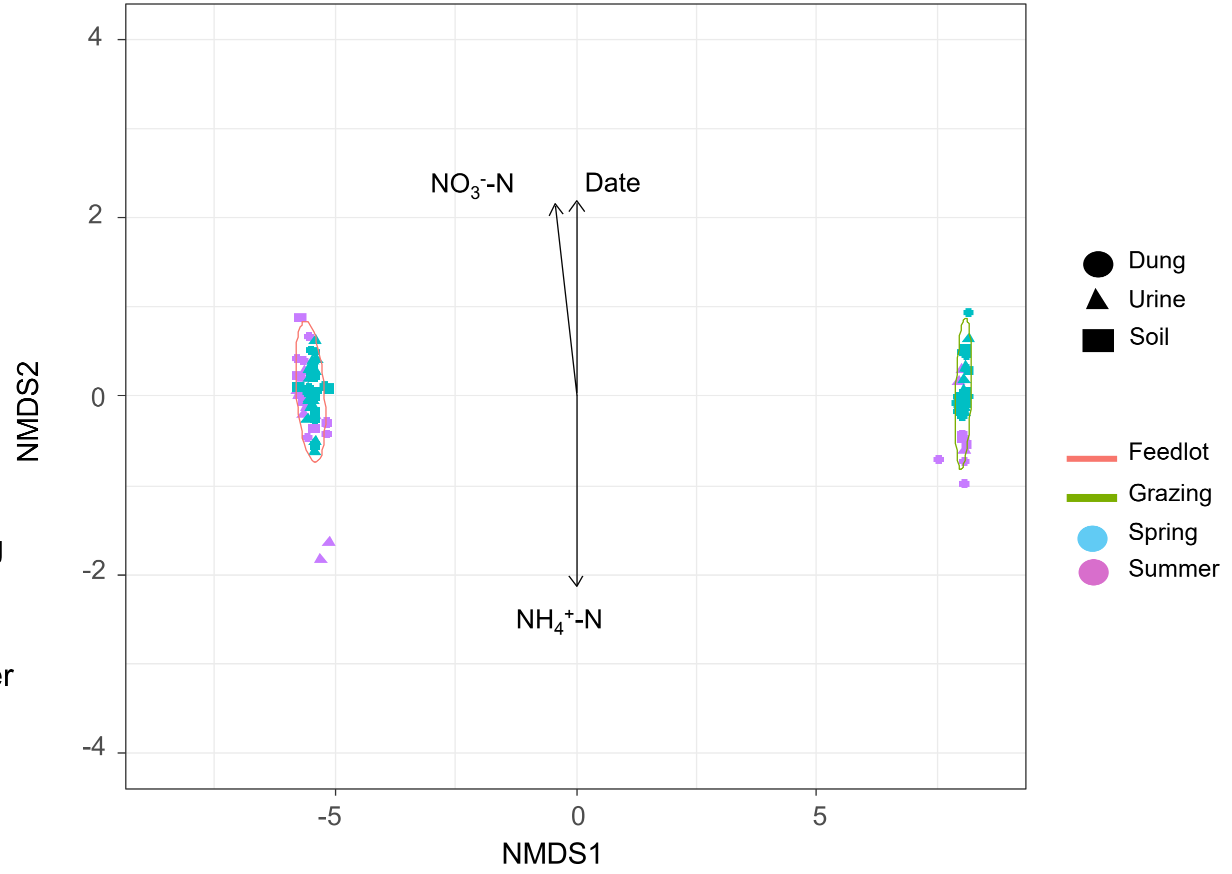
Alfalfa to get back into planetary boundaries

Soil microbiome

Fungi



Bacteria



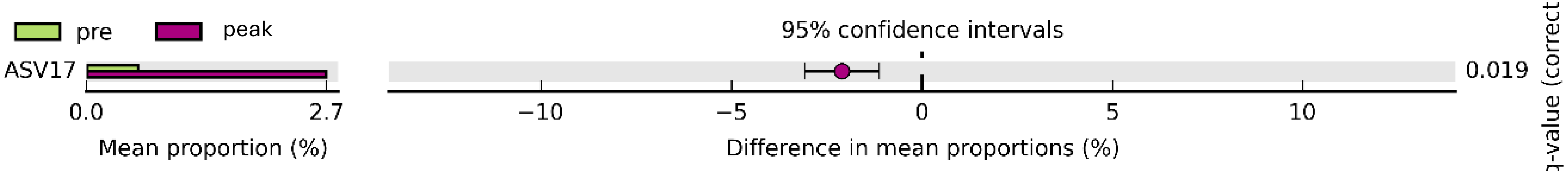
Non-metric multidimensional scaling representing the structure of the fungal and bacterial community (ITS and 16S) as a function of system (feedlot, grazing), season (spring, summer), excretion (urine, dung), and soil without applications, with adjustment for environmental variables.

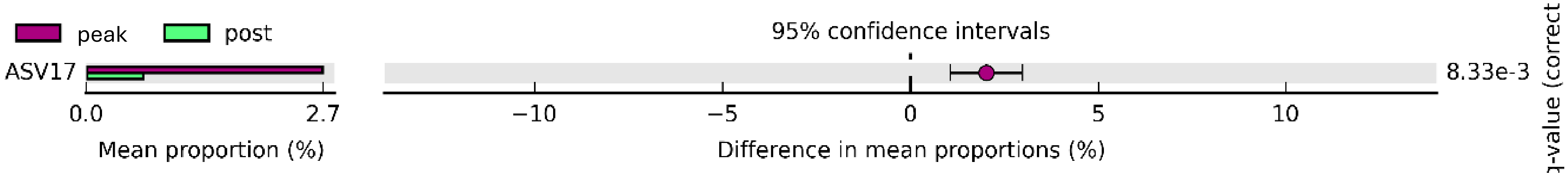
The distances between points reflect the dissimilarity in species composition; nearby samples have similar communities, while more distant points represent more different communities. The arrows show only those with $p<0.05$.

Alvarez et al, unpublished

N_2O Flux

Difference in the relative abundance of dominant amplicon sequence variants (relative abundance >0.05%)





Bacterial community

B_ASV17 ***Sphingomonas sp.***

DENITRIFIER

reduces NO_2^- to N_2O

ASV: amplicon sequence variants

Alvarez et al, unpublished

Final conclusions

- **Alfalfa-based grazing systems** emitted **less N_2O** than Feedlots systems.
- Local **emission factors** were much **lower** than **IPCC defaults**, highlighting the need for region-specific inventories.
- **Condensed Tannins** (1 %) reduced N in urine but did not significantly decrease N_2O emissions.
- N_2O fluxes were driven by soil conditions, N availability, and the soil microbiome.
- Soil microbial communities responded to management and explained N_2O emission peaks.
- These findings provide local evidence to support a more sustainable and climate-smart livestock production.

Alfalfa to get back into planetary boundaries

Thanks...

alvarez.carolina@inta.gob.ar