Engineering resilient grazing systems to improve adaptation to climate change and helping to mitigate its adverse effects

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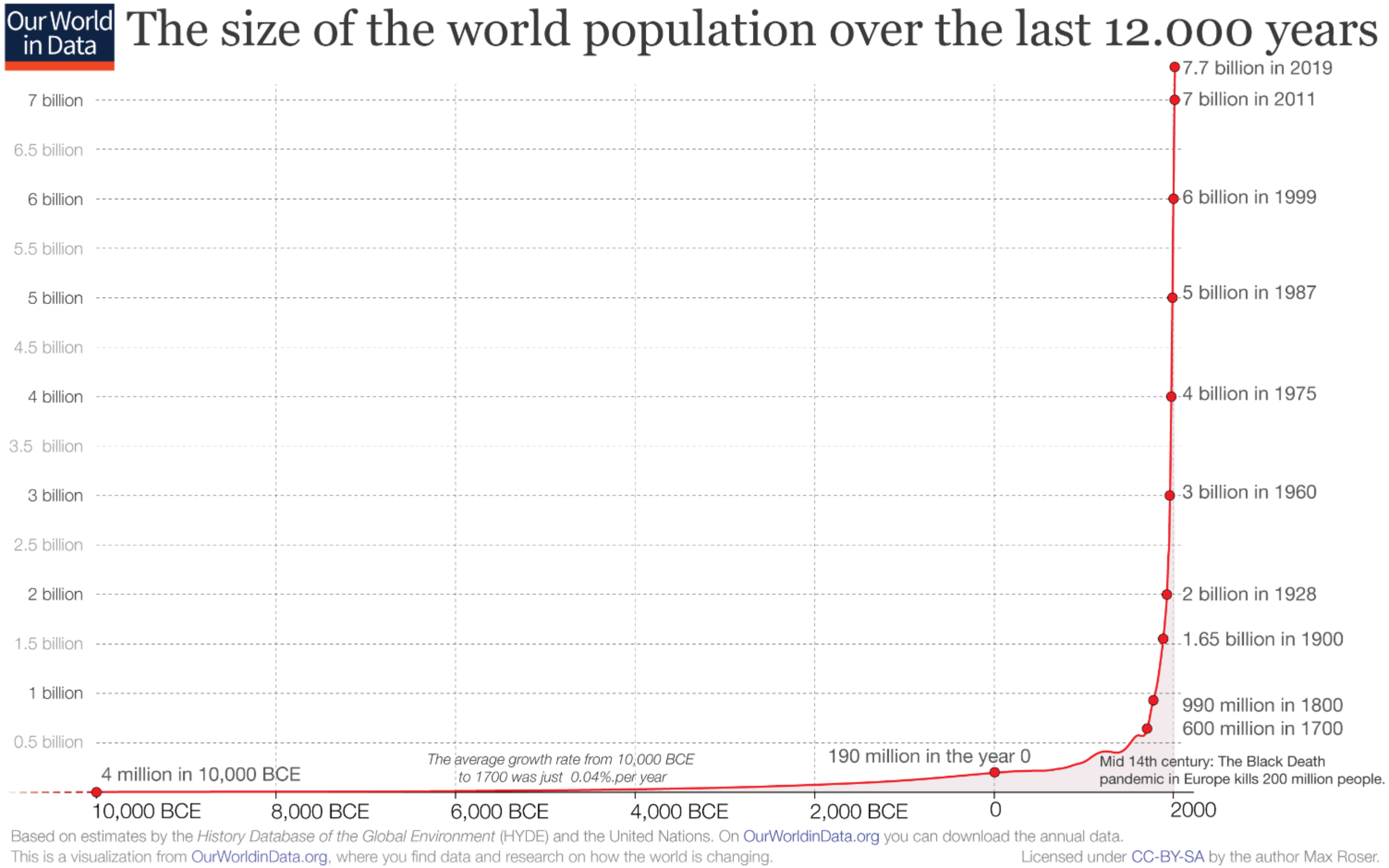

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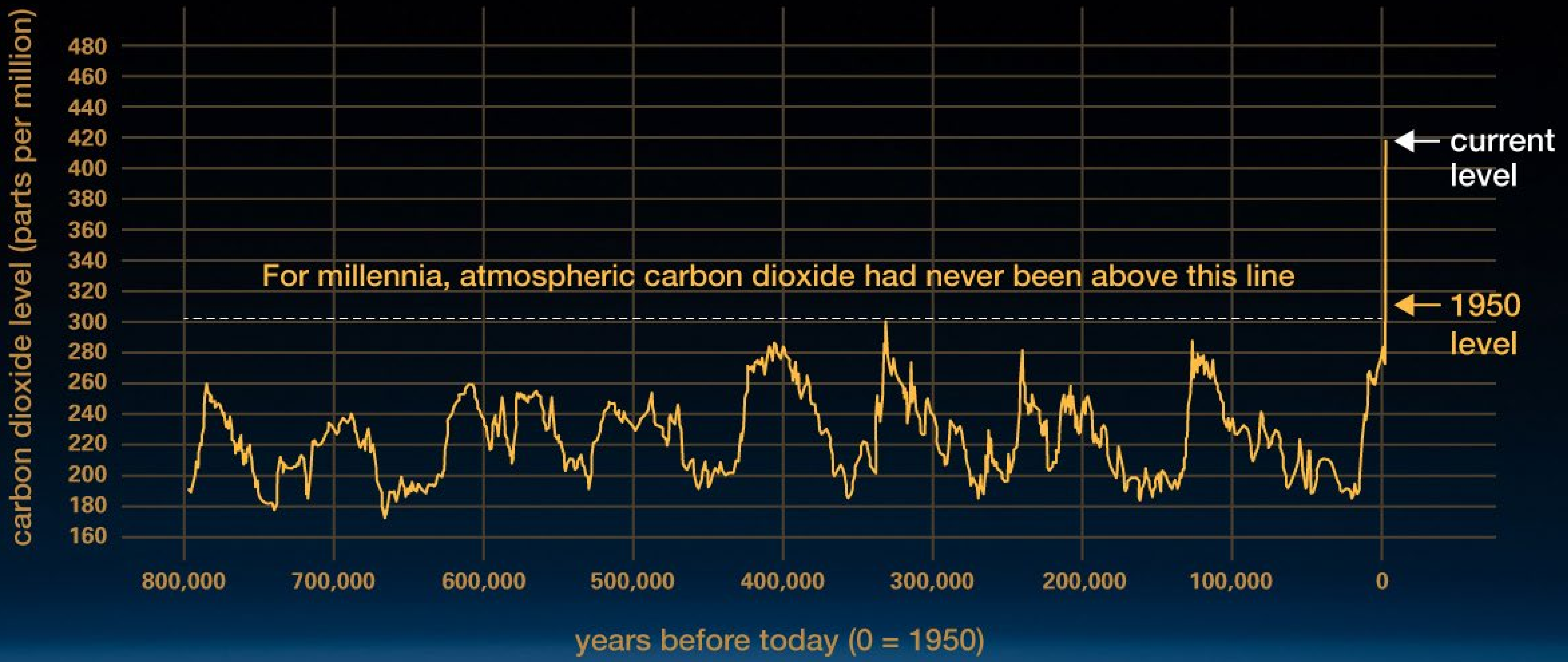
Challenges

9.7 billion people by 2050



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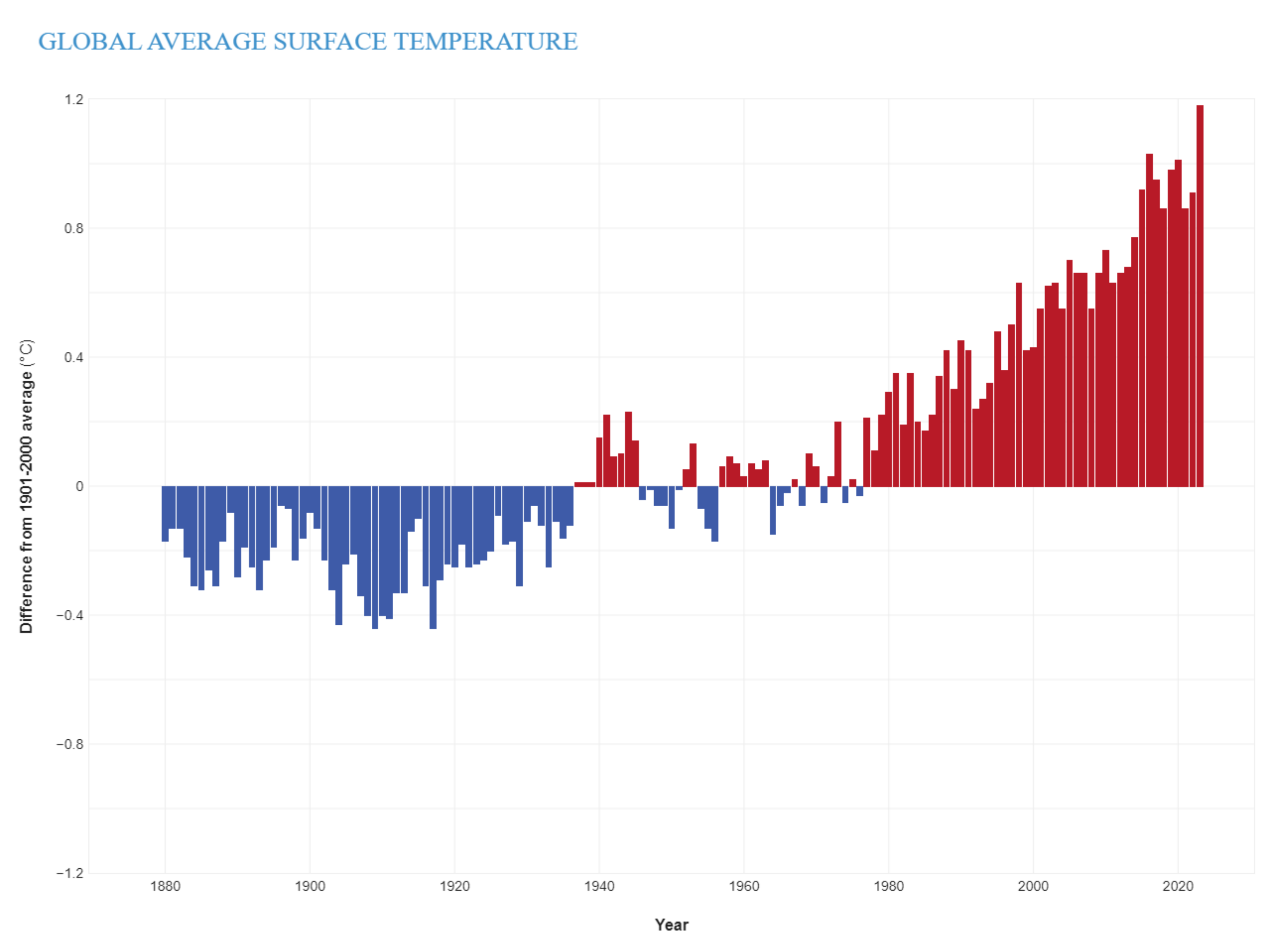
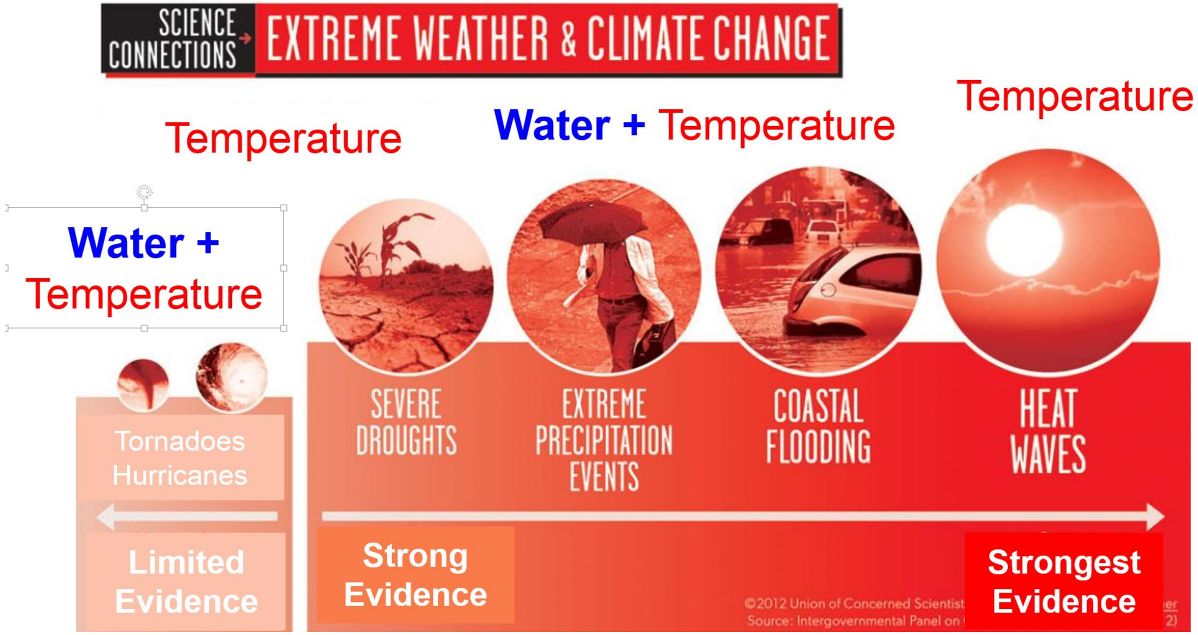
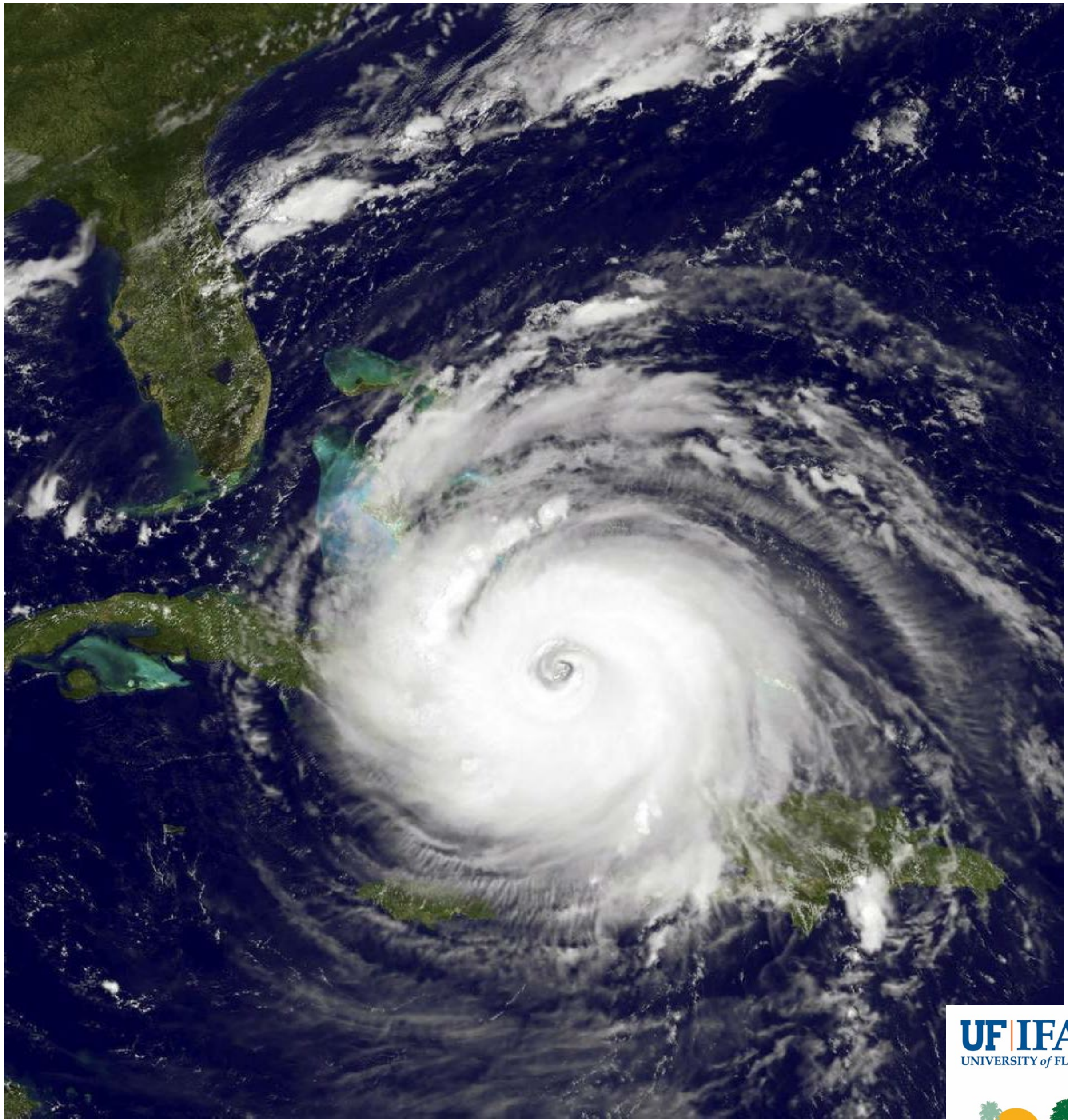
climate.nasa.gov



Climate Change: Global Temperature | NOAA Climate.gov





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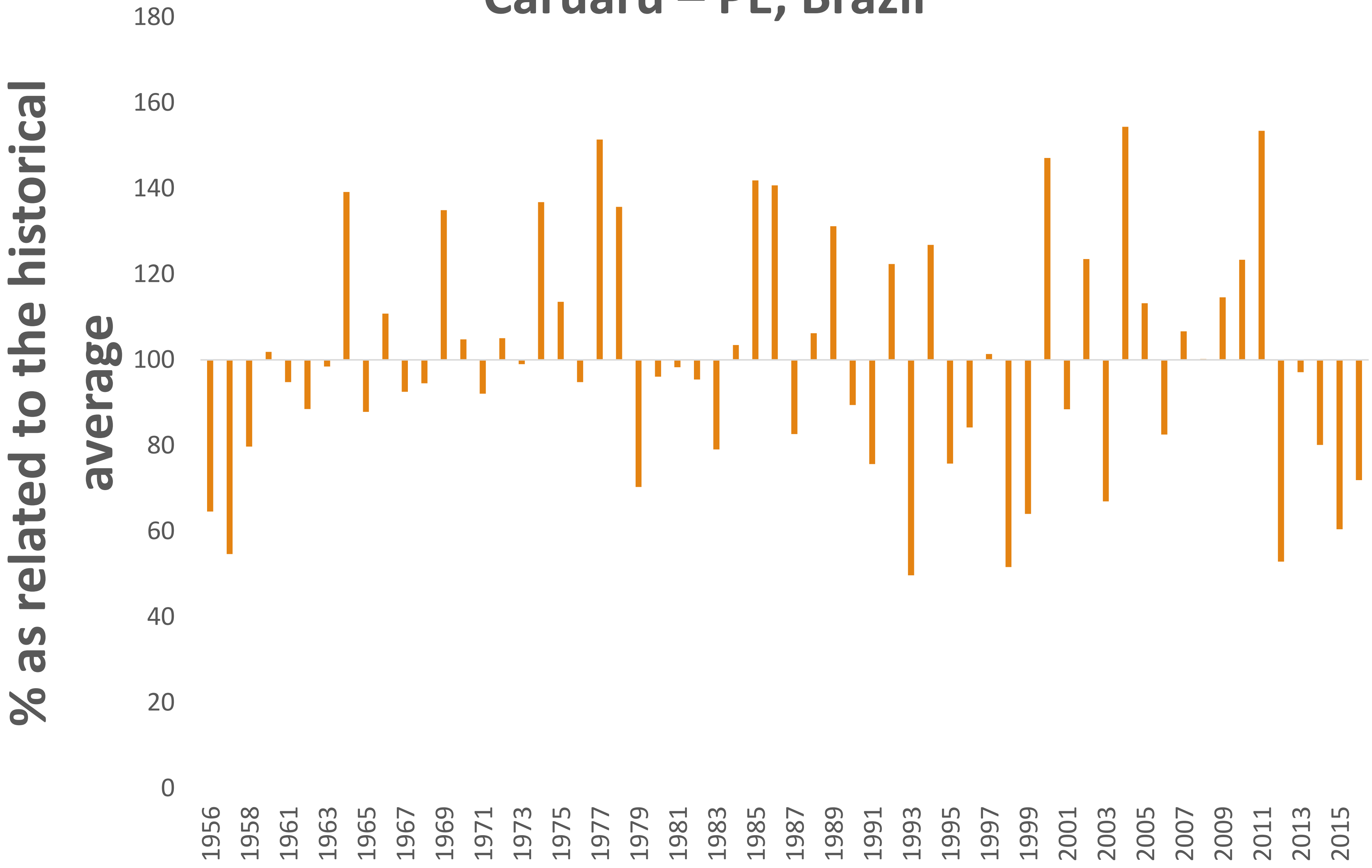
% of rainfall compared to historical average
Caruaru – PE, Brazil



Defining resilience…

“The capacity to prepare for disruptions, recover from shocks and stresses, and adapt and grow from a disruptive experience or condition”

Pine trees after hurricane Michael
Photo credit: Jose Dubeux

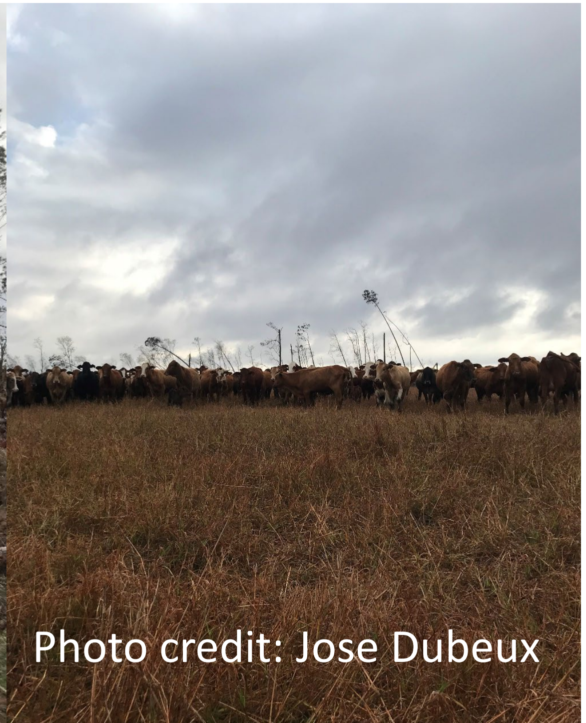
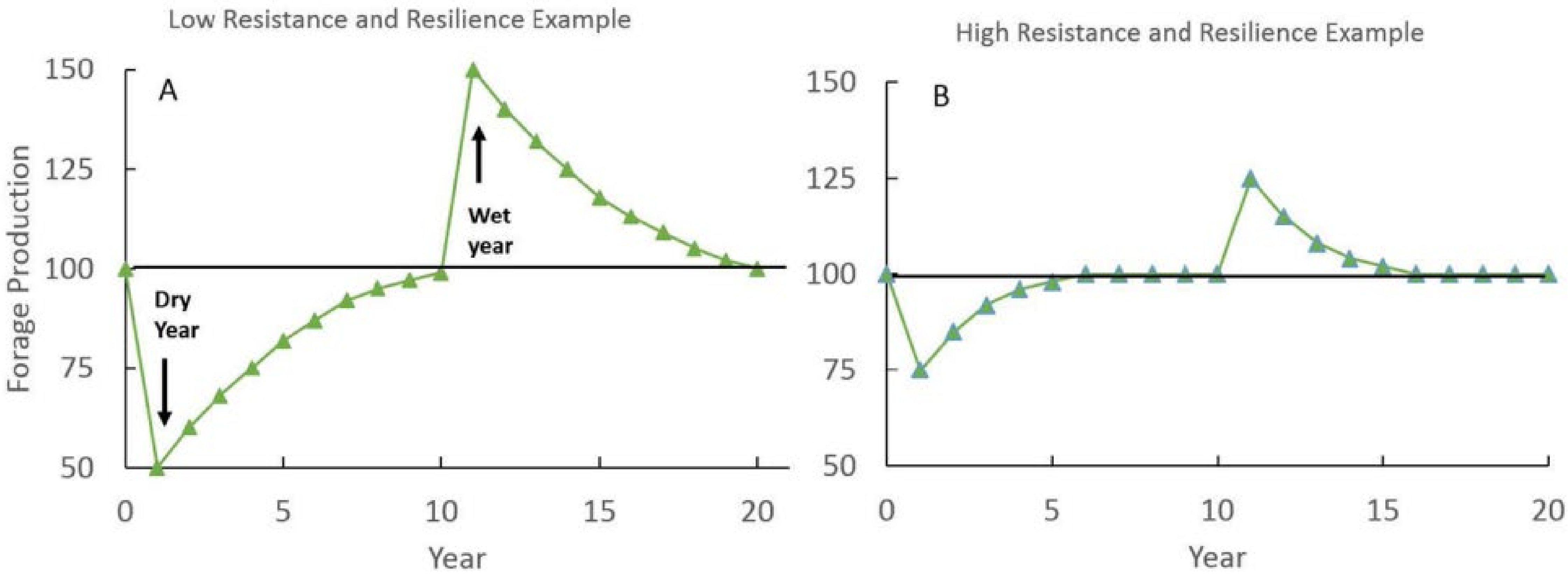


Photo credit: Jose Dubeux

Resilience:
Do you bend or break?



Tracy et al. 2018

Resistence vs. Resilience

Adaptation

Mitigation

- Adapted livestock
- Adapted plants
- Diversification in space and time
- ...

Diverse grazing systems

- SOC sequestration
- BNF
- Plant secondary compounds
- ...

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The Challenge

Be relevant for local farmers and at the same time help to solve global problems

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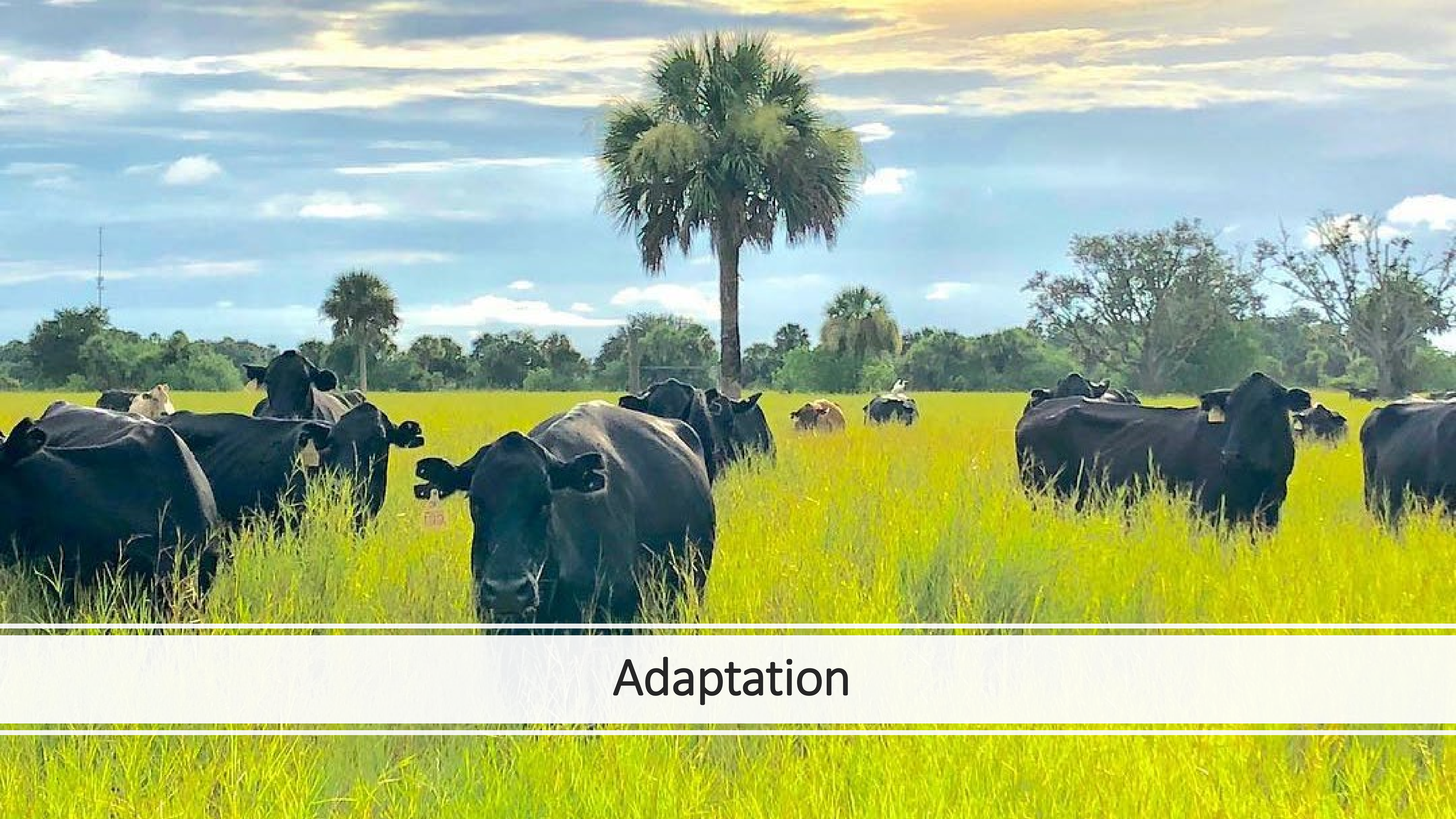
Adaptation

- Livestock must be adapted to extreme environments
- Fitting the right animal to the right environment

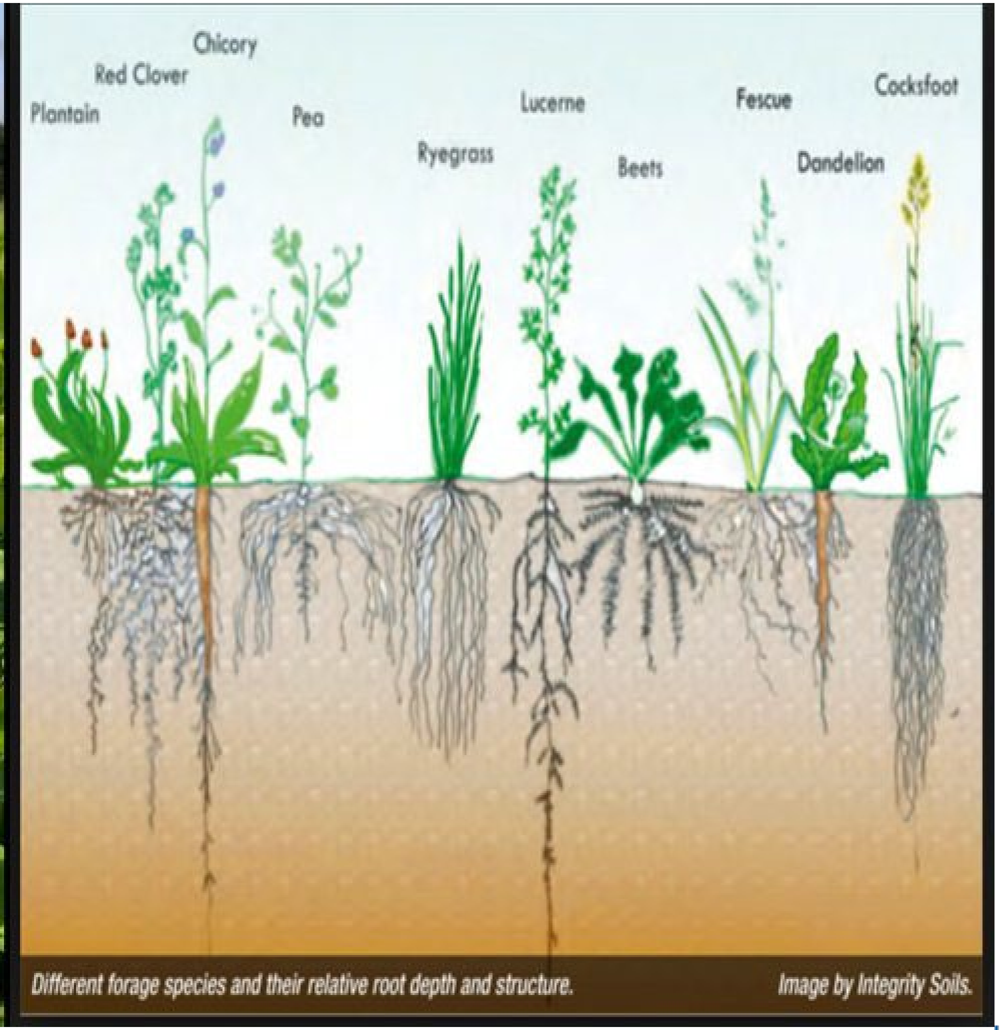


Adaptation

Adaptation

- Fitting the right plant to the right environment
- Diversifying forage species and functional groups is important

Spatial and temporal biodiversity is key to enhance efficiency of nutrient utilization



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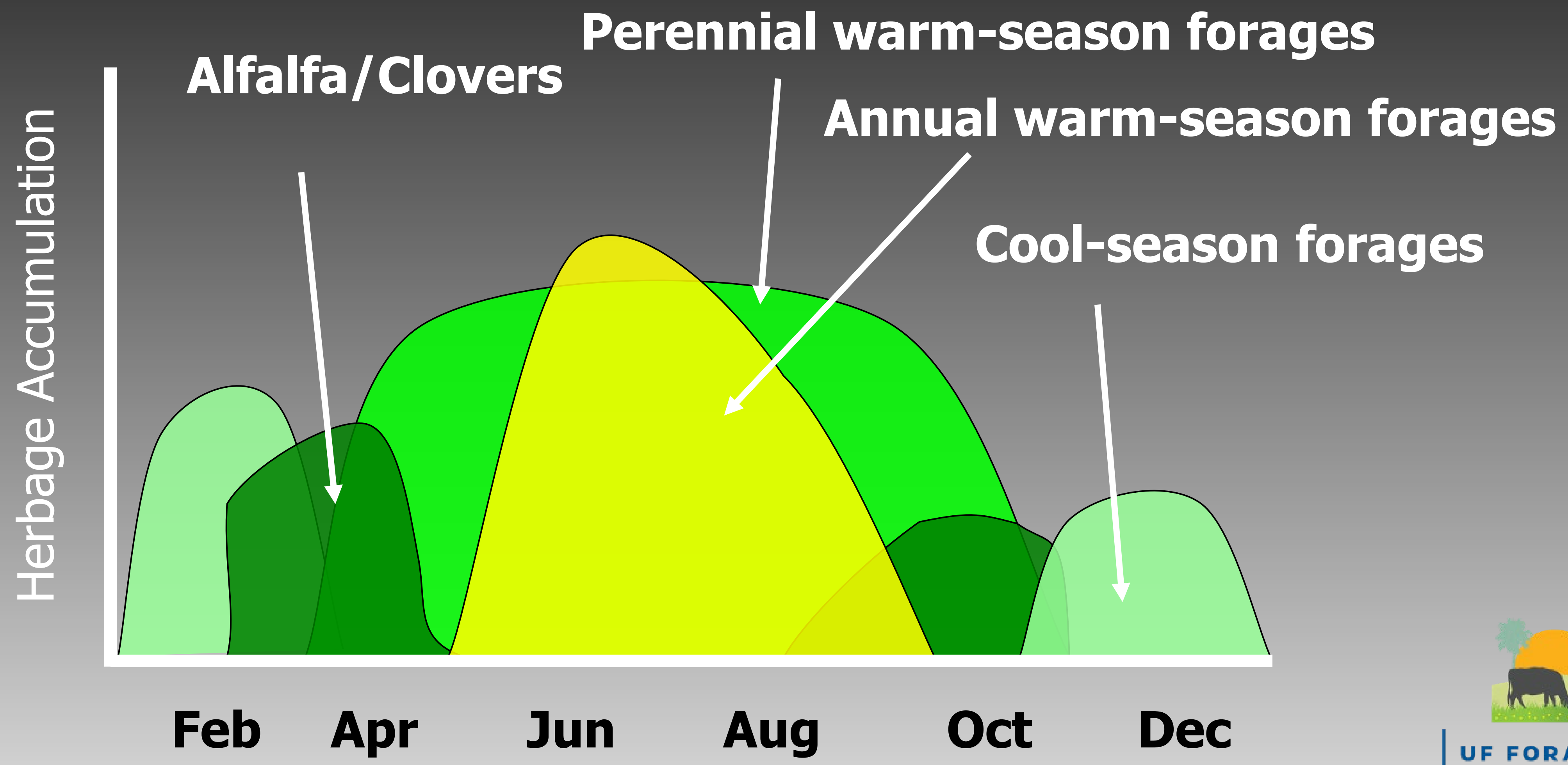
Temporal biodiversity



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Spatial and temporal biodiversity can improve productivity and resilience of productive systems as long as…

- Species must have spatial and temporal complementarity in resource utilization
- Species must present contrasting tolerances to pests, diseases, and extreme weather events
- Species must have different functionalities (e.g., BNF, soil P acquisition, deep root system) and explore different soil layers

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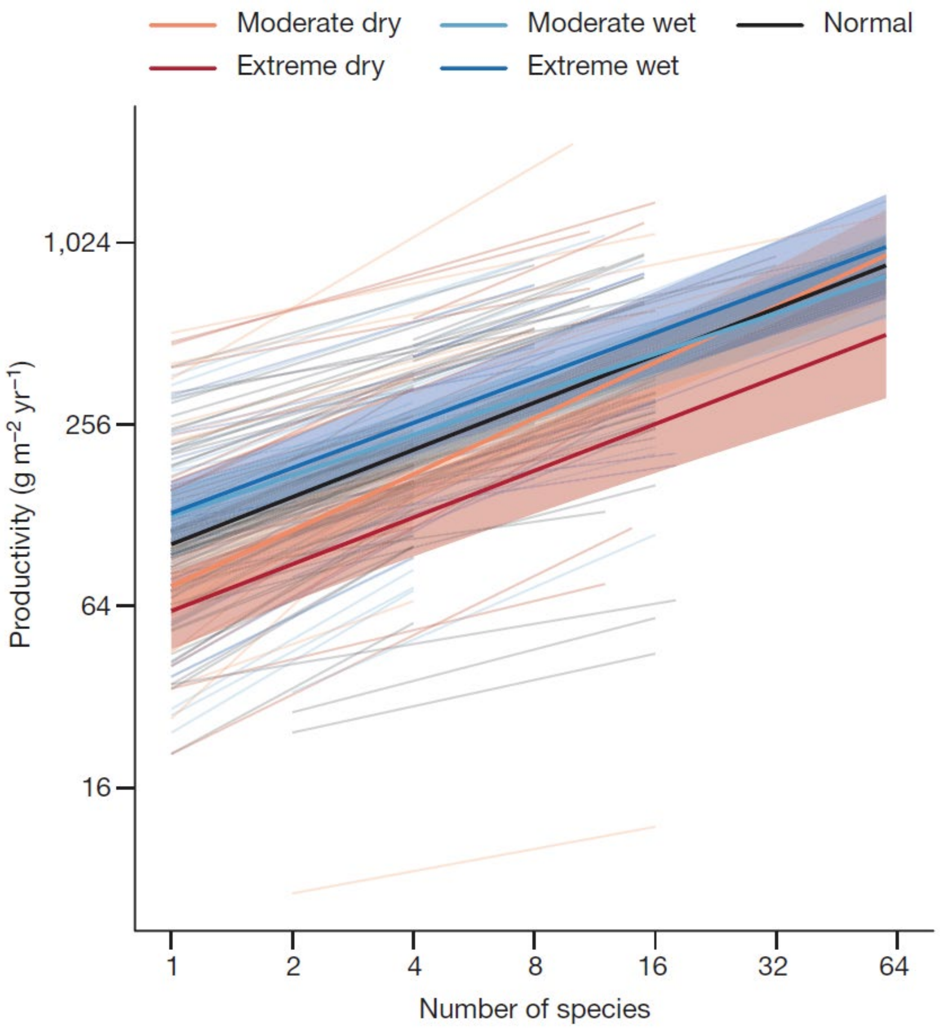
Species richness and productivity



Isbell et al. 2015 published in Nature

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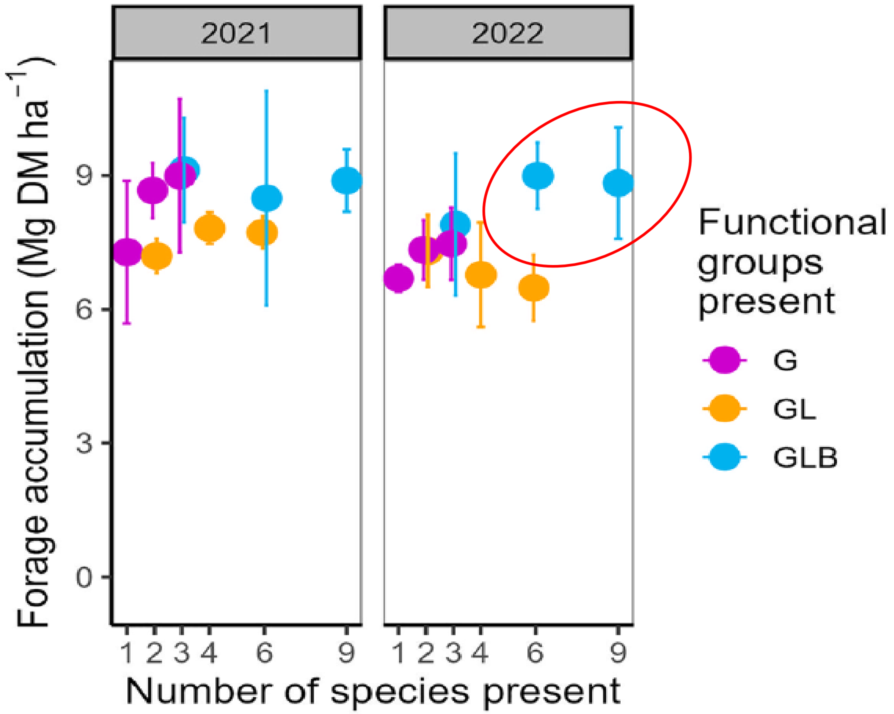
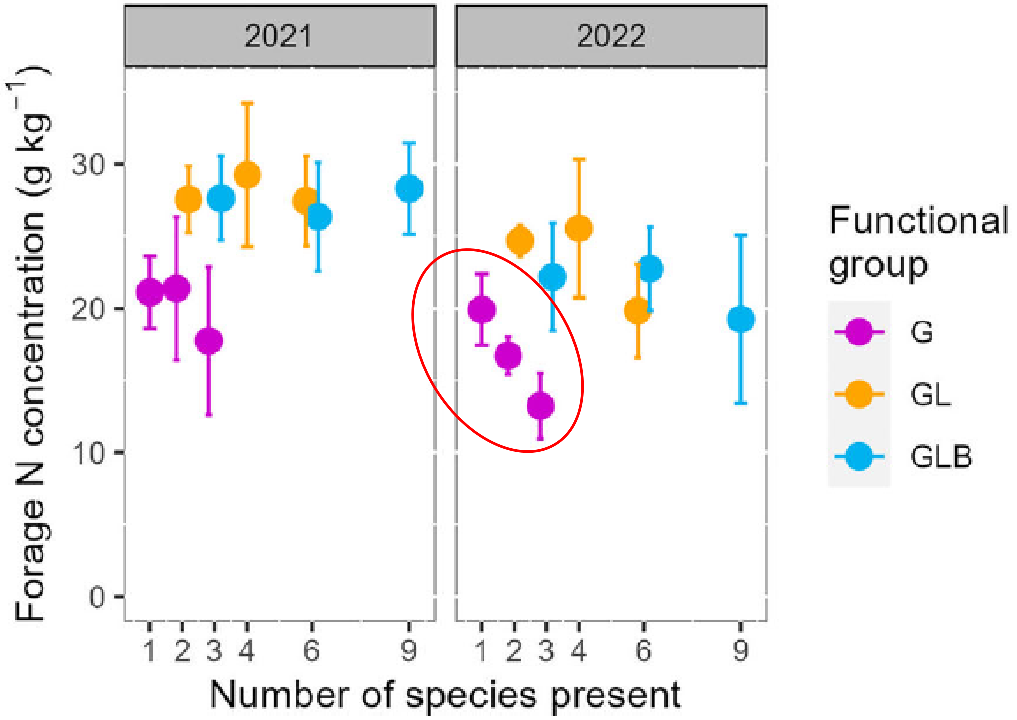
Species richness and functional groups





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Crop Science

ORIGINAL ARTICLE

Forage & Grazinglands

Species richness and functional diversity enhance winter annual forage productivity and nutritive value

Rusch et al. (2023)

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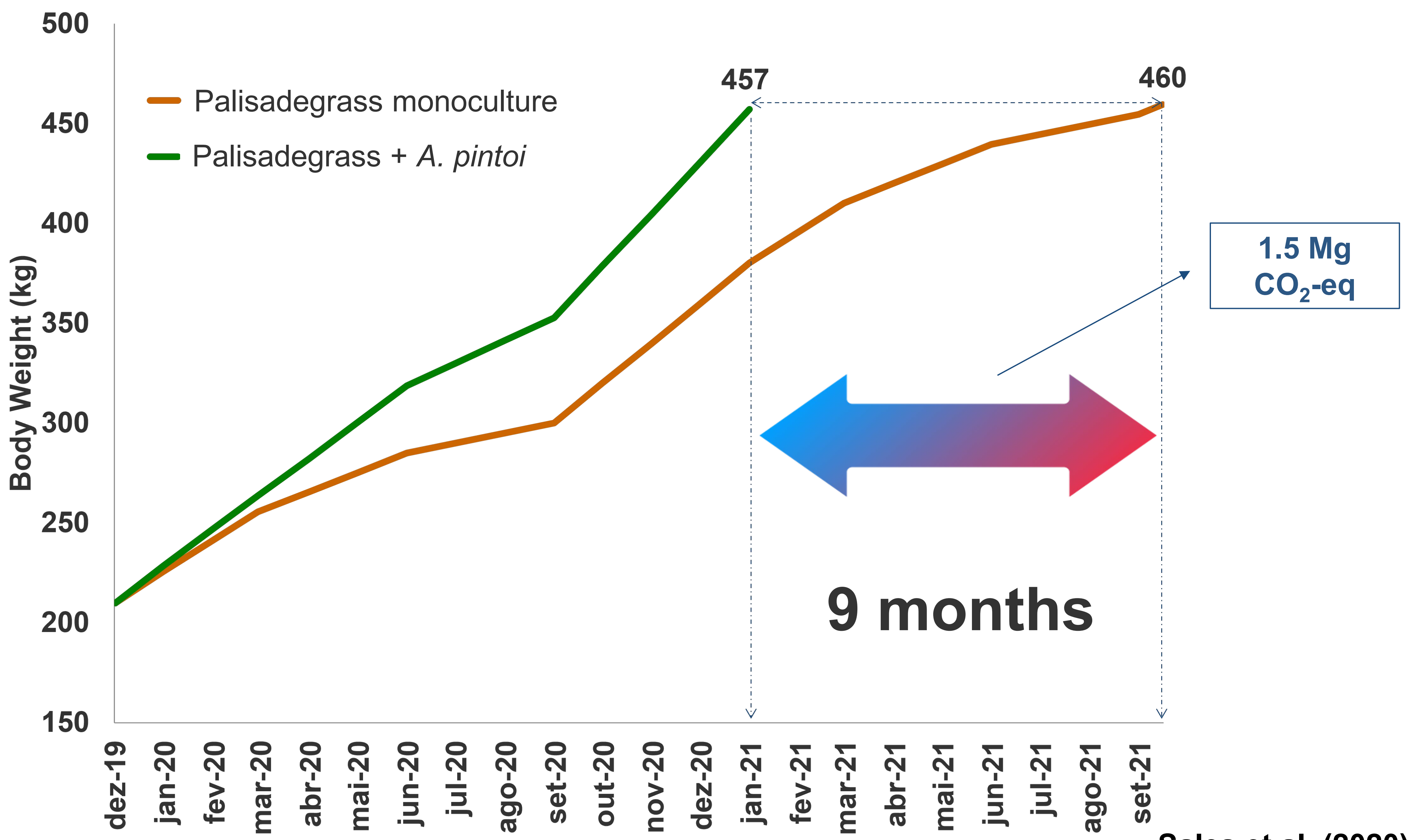
Mitigation

- **Reduce GHG emissions** (e.g., feed additives, secondary compounds, improved forage quality reducing emission intensity)

- **Offseting GHG emissions** (e.g., SOC sequestration, BNF, reduced C footprint)



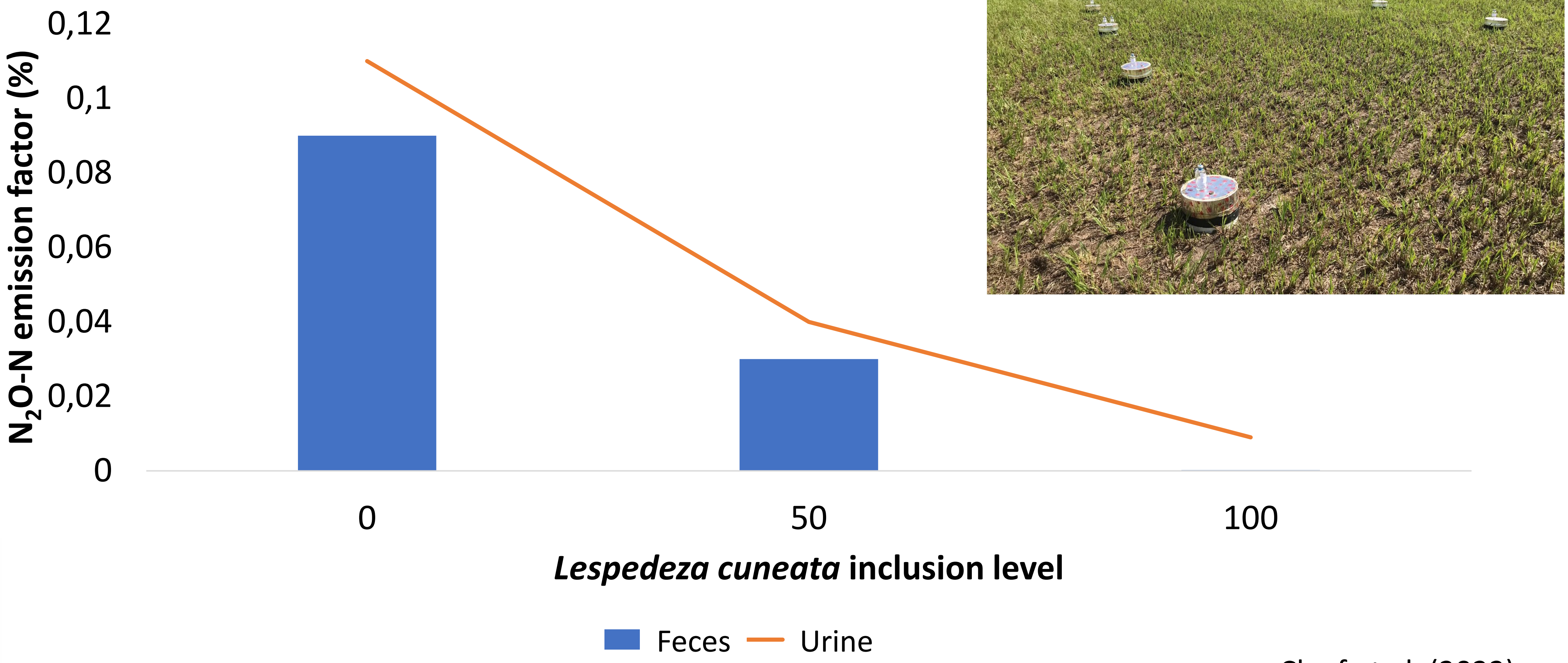
Sales et al. (2020)

Cow reproductive efficiency is key

	Calves weaned per cow per year		
	1	0.75	0.5
kg CO_2e/weaned calf	9,970	12,355	16,473
C sequestration needed to offset emissions (kg C/ha/yr)	2,720	3,370	4,493
Typical C sequestration (kg C/ha/yr)	**750**	**750**	**750**
Déficit (kg C/ha/yr)	**- 1,970**	**-2,620**	**-3,743**

1. Assuming 1 cow with 450 kg BW weaning a 240-kg calf and a carbon footprint of 28.9 kg CO2e/kg carcass (Rotz et al., 2019) and 50% carcass yield we would have 9,970.5 kg CO2e per cow-calf per year
2. If the cow spend the year without weaning a calf, we would have 6,502.5 kg CO2e for the cow without calf and 9,970.5 for the cow-calf pair.

Tannin-rich legumes might reduce N_2O emission from excreta – the case of *Lespedeza cuneata*



van Cleef et al. (2022)

Successful Stories of Resilient Grazing Systems Around the Globe

Grass-Legume Mixtures in North Florida

Grazing System in North Florida – A Case Study

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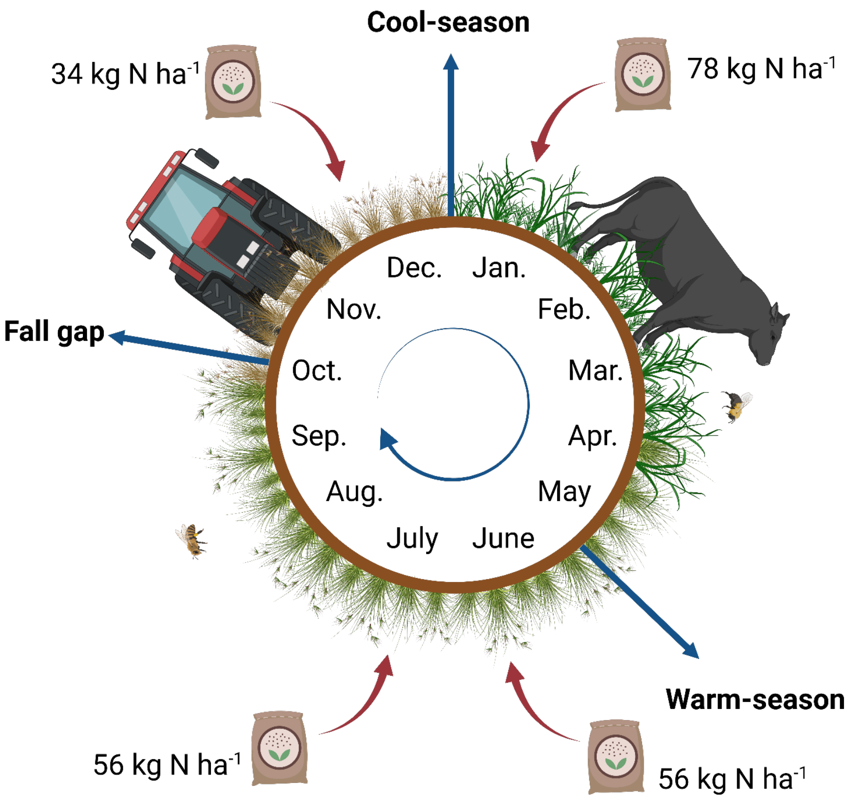
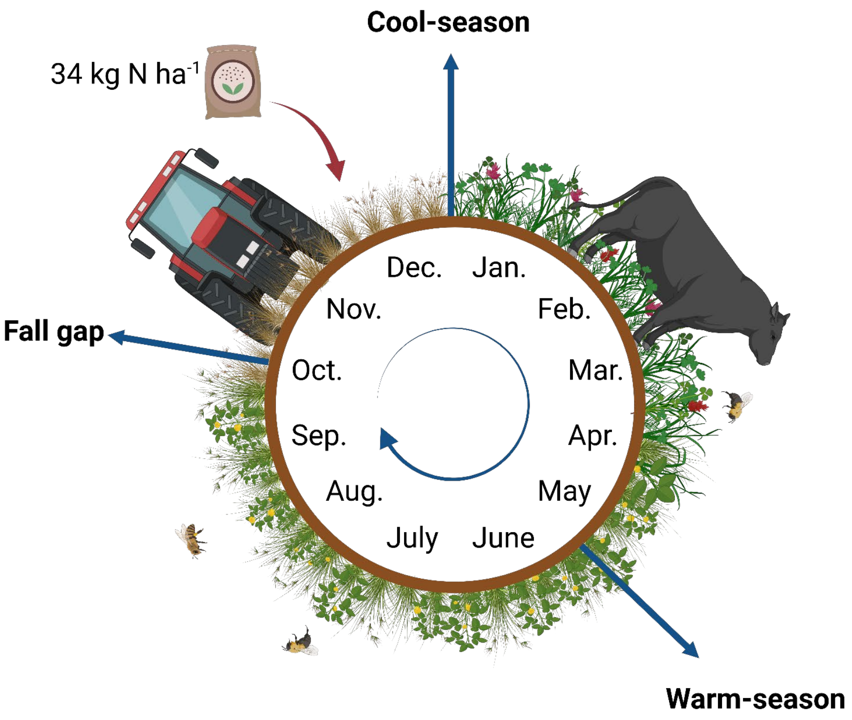
Systems

Grass+N

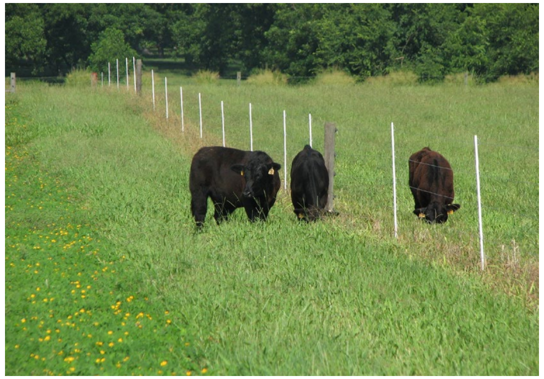


Grass+RP



K.R. Trumpp (2024)

Animal performance

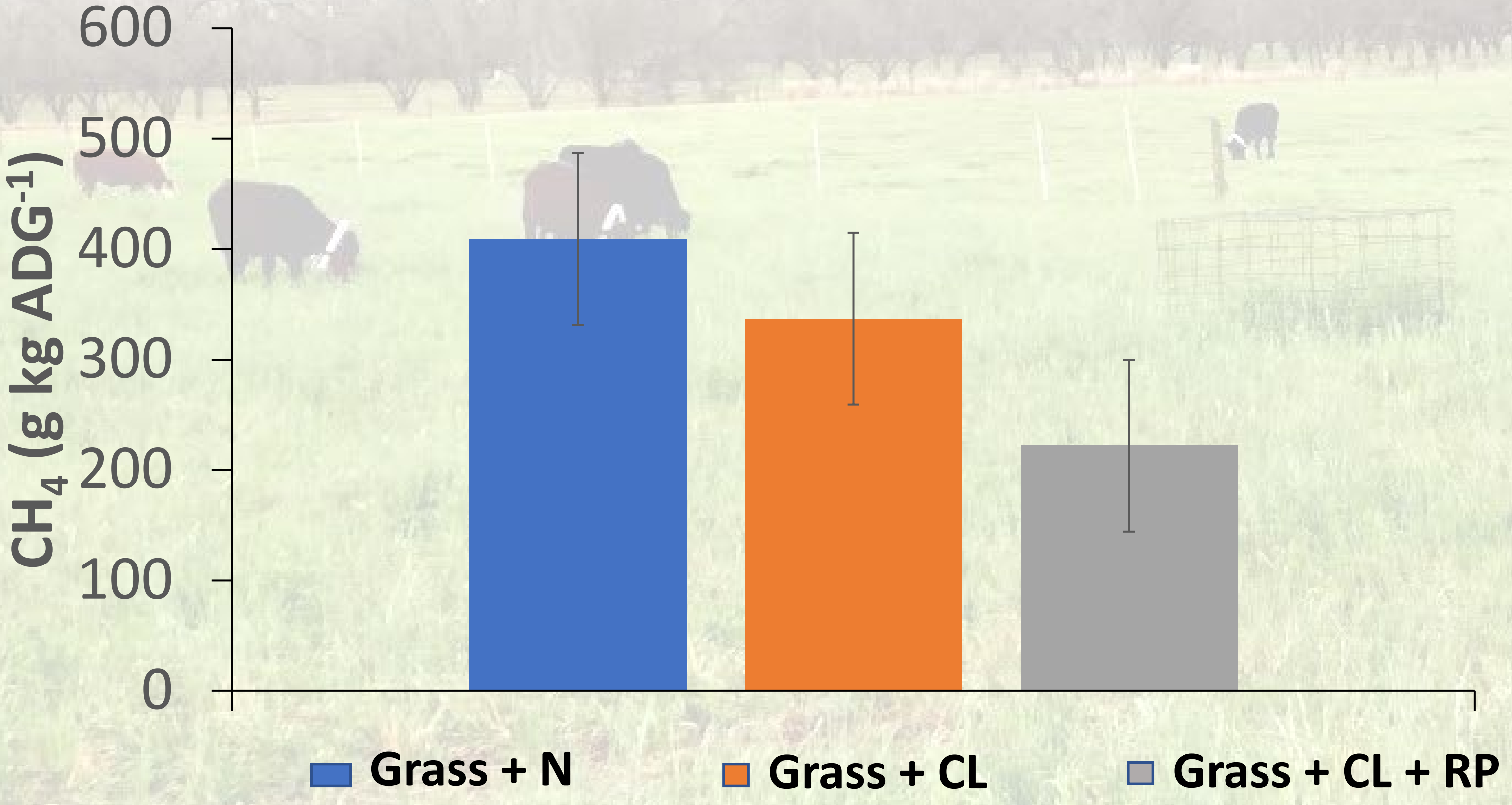


Cool + Warm Season	Grazing System				
	Grass+Clover	Grass+N	Grass+Clover+RP	SEM	P
ADG, kg hd^{-1} d^{-1}	0.56	0.58	0.69	0. 07	.18
GPA, kg ha^{-1}	563	618	667	103	.46
Stocking rate, steer ha^{-1}	4.4 A	4.9 A	3.7 B	0.35	.01

Grass+N = 224 kg N ha^{-1} yr^{-1}
Grass+CL, Grass+CL+RP = 34 kg N ha^{-1} yr^{-1}

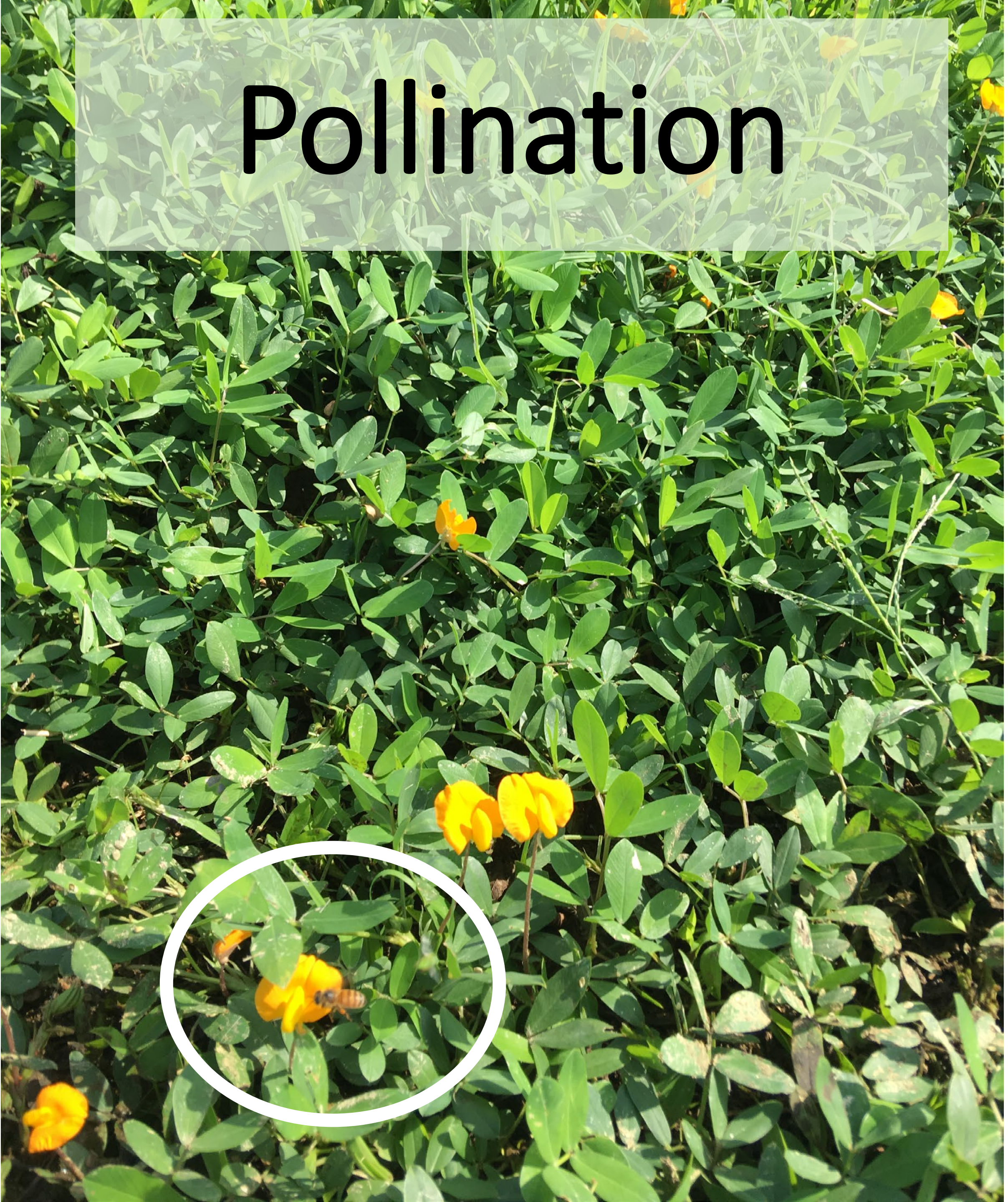
Jaramillo et al. (2021)

Reduction of GHG emissions

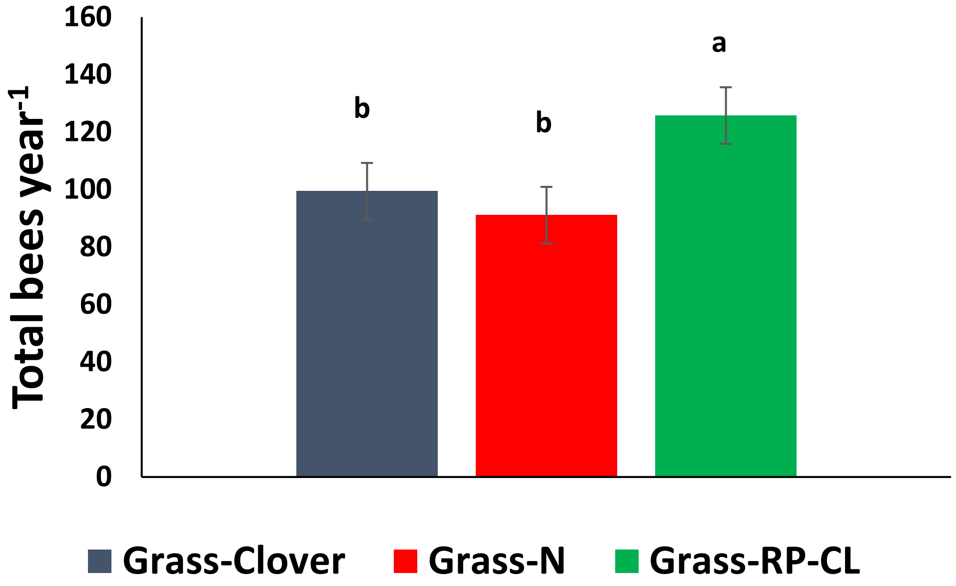


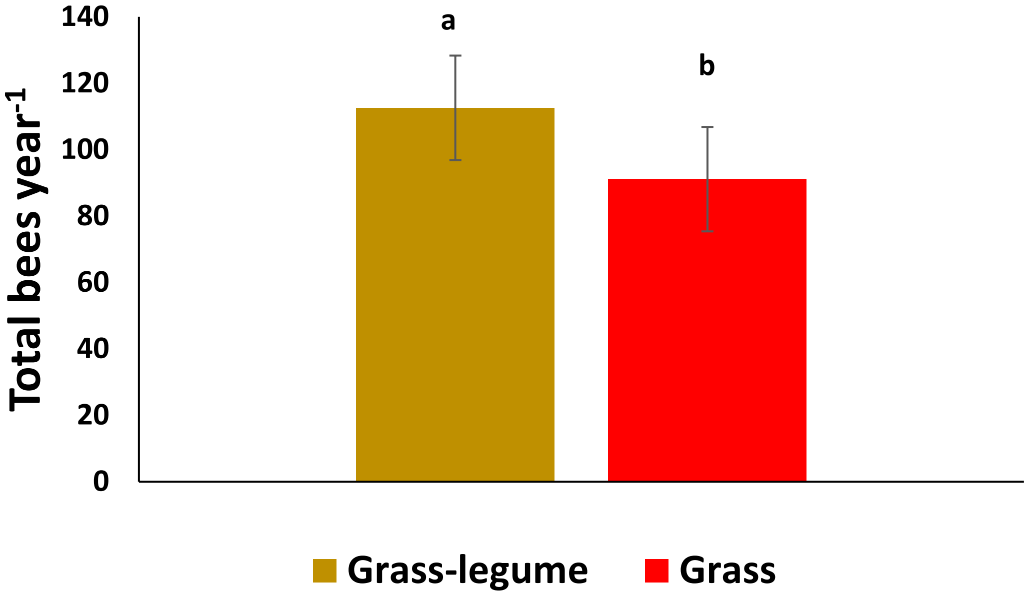
Garcia-Jimenez (2019)

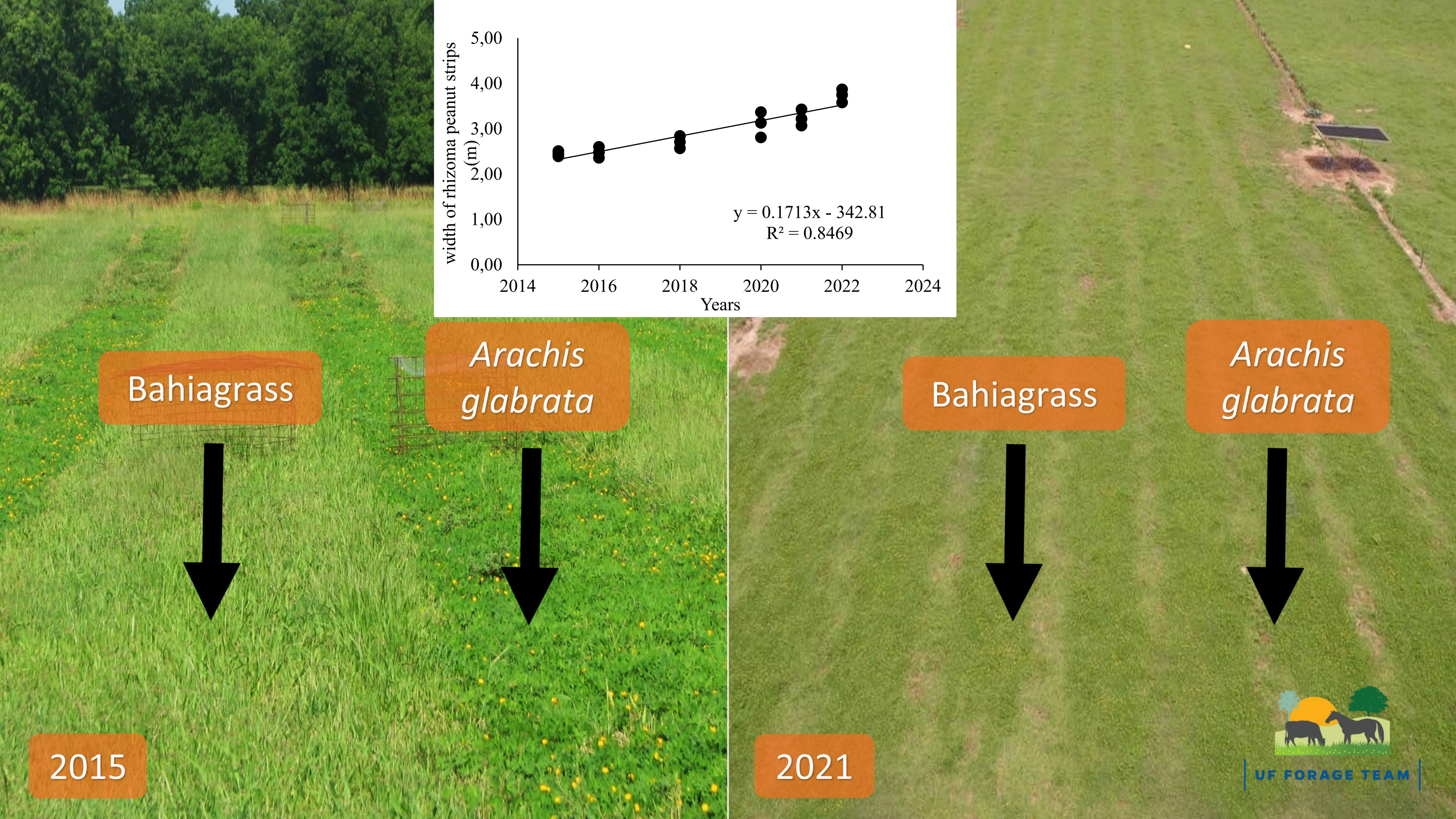
Pollination



Garcia-Jimenez (2019)







5,00
4,00
3,00
2,00
1,00
0,00
width of rhizoma peanut strips (m)
2014
2016
2018
2020
2022
2024
Years
y = 0.1713x - 342.81
R² = 0.8469
Bahiagrass
Arachis glabrata
2015
Bahiagrass
Arachis glabrata
2021
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Carbon footprint of grass monoculture + N vs. grass-legume mixtures

	Treatment			
Item	**Grass+N**	**Grass+RP**	**SE**	**P**
CO_{2e} Enteric-CH_4	4233.8	3148.6	433.2	0.11
Dung CH_4-CO_{2e}	0.173	0.085	0.022	0.12
Dung N_2O-CO_{2e}	0.52	0.14	0.087	0.12
Urine CH_4-CO_{2e}	0.037	-0.030	0.016	0.09
Urine N_2O-CO_{2e}	1.44[a]	0.59[b]	0.245	0.04
Soil CH_4-CO_{2e}	-1.14	-13.75	4.956	0.16
Soil N_2O-CO_{2e}	239.3	173.1	17.28	0.13
N fert., CO_{2e}	869	132	-	-
Total, CO_{2e}	5343[a]	3441[b]	425.8	0.04

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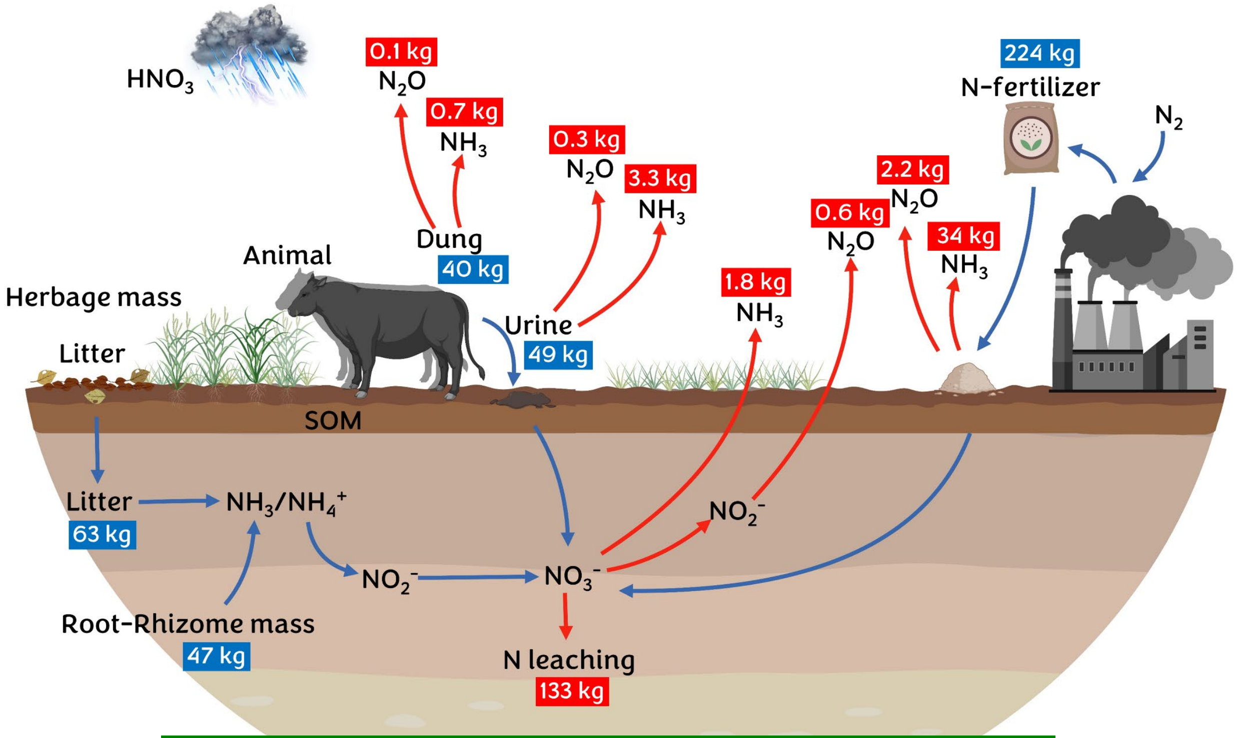
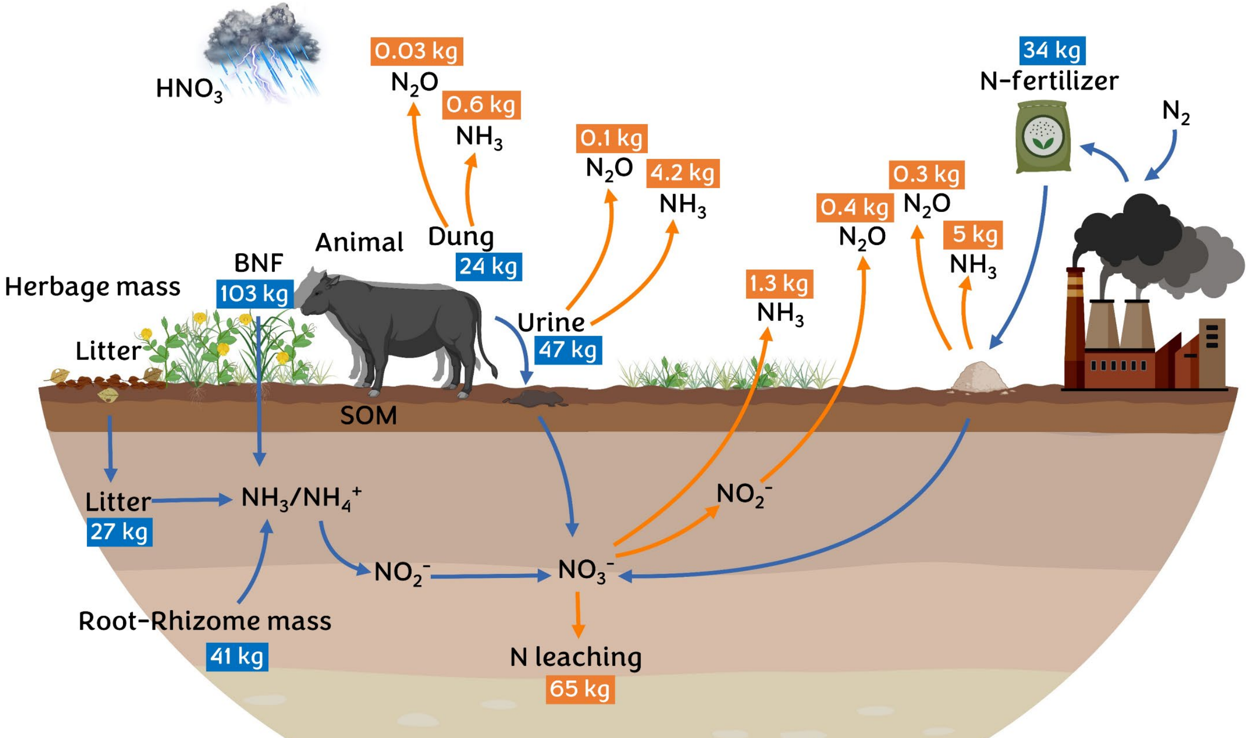
K.R. Trumpp (2024)

N Cycling

Grass + N



Grass + Legumes



Inputs – Losses = 80 kg N ha^{-1}

Inputs – Losses = 51 kg N ha^{-1}

Inputs – Losses = -144 kg N ha^{-1} **= Without N fertilizer =** **Inputs – Losses = 17 kg N ha^{-1}**

References:

- Jaramillo DM, Dubeux JCB, Sollenberger L, et al. Litter mass, deposition rate, and decomposition in nitrogen-fertilized or grass-legume grazing systems. Crop Science. 2021;61:2176–2189. https://doi.org/10.1002/csc220475
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- Jaramillo D M, Dubeux J C B, Sollenberger L E, Vendramini J, Mackowiak C, DiLorenzo N, Garcia L, Dantas Queiroz L M, Santos E R S, Homem B G C, van Cleef F, & Ruiz-Moreno, M. Water footprint, herbage, and livestock responses for nitrogen-fertilized grass and grass–legume grazing systems. Crop Science. (2021);61:3844–3858. https://doi.org/10.1002/csc2.20568
- Aniela C. Honig , Vivienne Inhuber, Hubert Spiekers, Wilhelm Windisch, Kay-Uwe Gotz, Manfred Schuster, Thomas Ettle. Body composition and composition of gain of growing beef bulls fed rations with varying energy concentrations. Meat Science. (2022);184:-9 https://doi.org/10.1016/j.meatsci.2021.108685

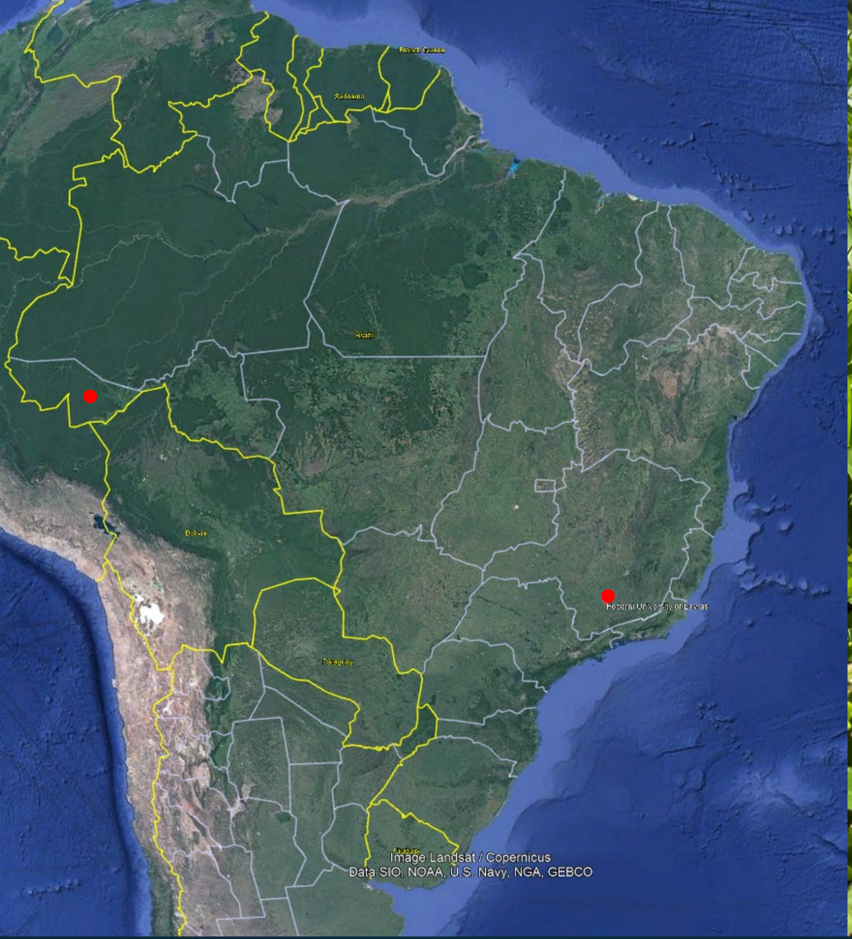
Grass + N

Cool and warm season	
Average daily gain, kg hd^{-1} d^{-1}	0.58
Gain per area, kg ha^{-1}	620
Stocking rate, AU ha^{-1}	4.9a
Grass in BC warm season, %	92
RP in BC, %	-
Gain per kg of N input	2.8

Grass + Legumes

Cool and warm season	
Average daily gain, kg hd^{-1} d^{-1}	0.69
Gain per area, kg ha^{-1}	669
Stocking rate, AU ha^{-1}	3.7b
Grass in BC warm season, %	47
RP in BC, %	32
Gain per kg of N input	7.6

In summary, grass-legume mixtures yielded 171% more beef per unit of recycled N




Brachiariagrass-*Arachis pintoi* mixtures in Lavras (and Acre), Brazil

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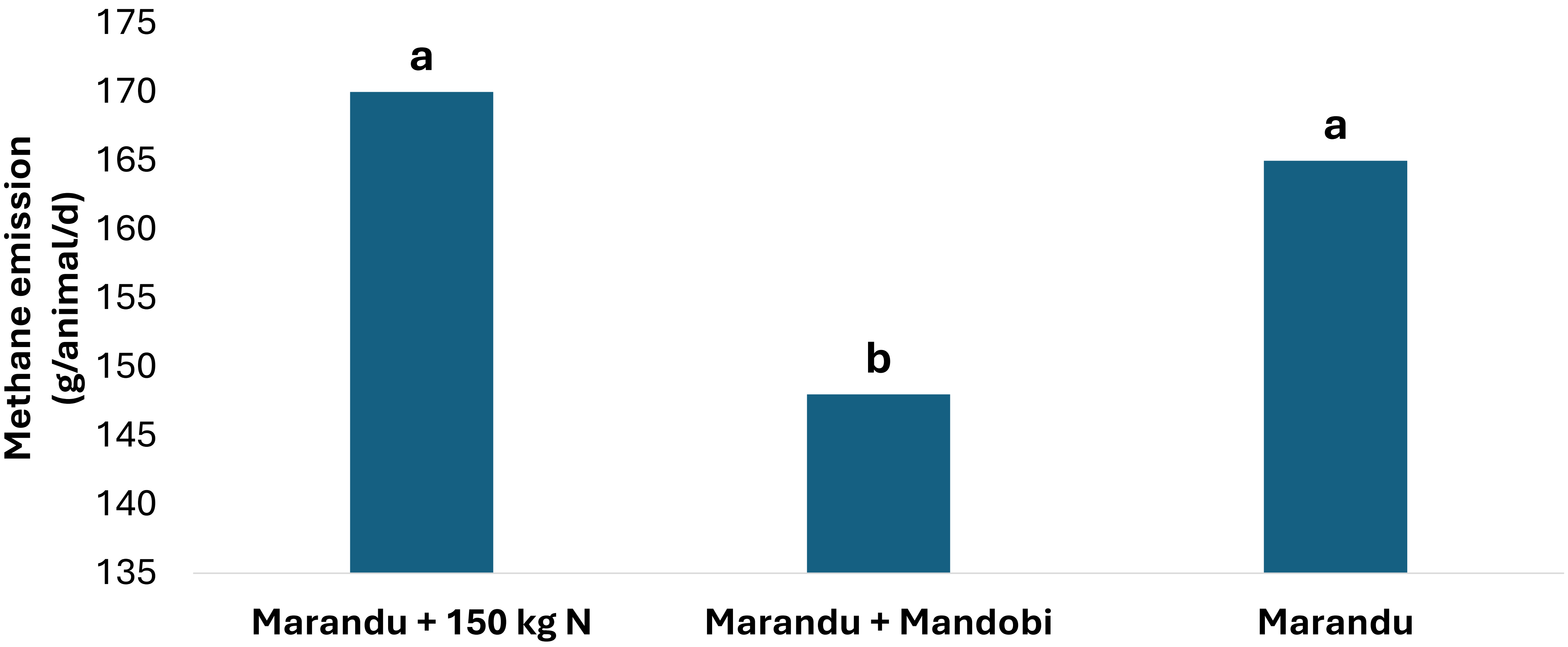
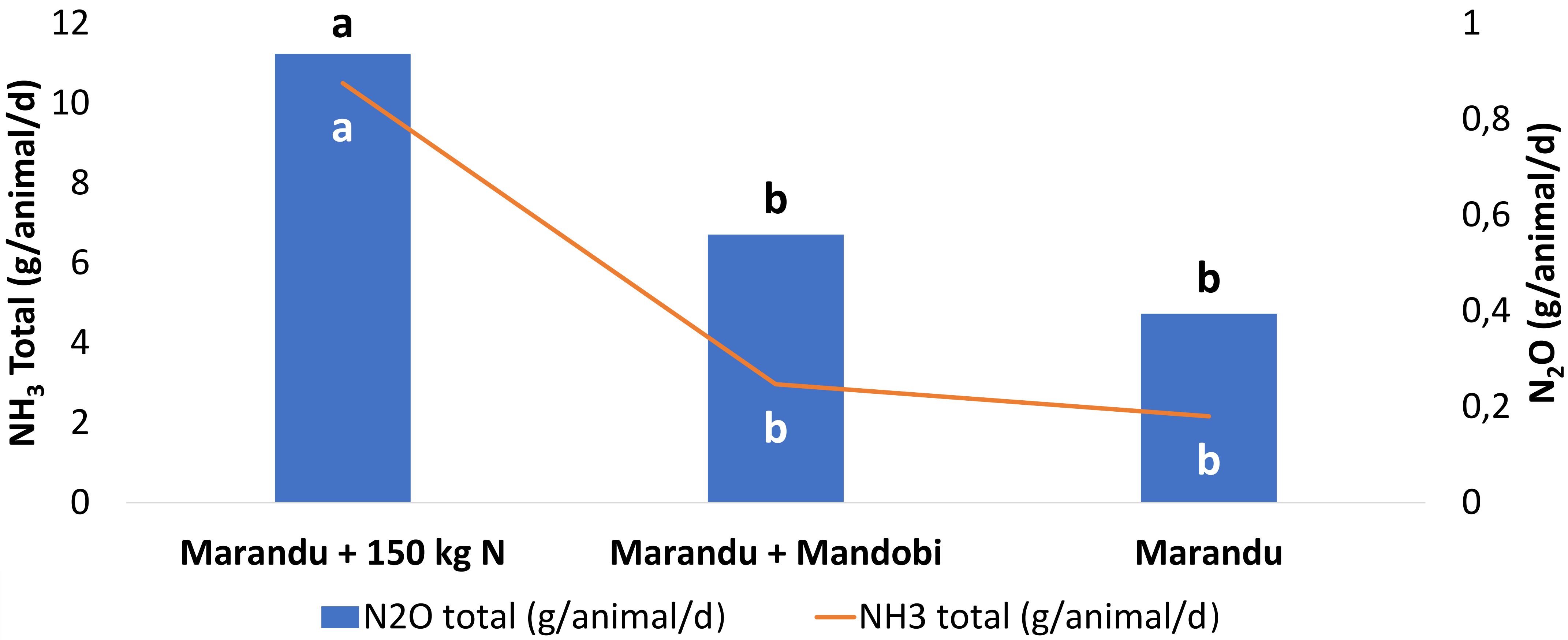
Marandu palisadegrass and *A. pintoi* cv. Mandobi reduced methane emission



Homem et al. (2024)

Marandu palisadegrass and *A. pintoi* cv. Mandobi reduced nitrous oxide and ammonia emissions



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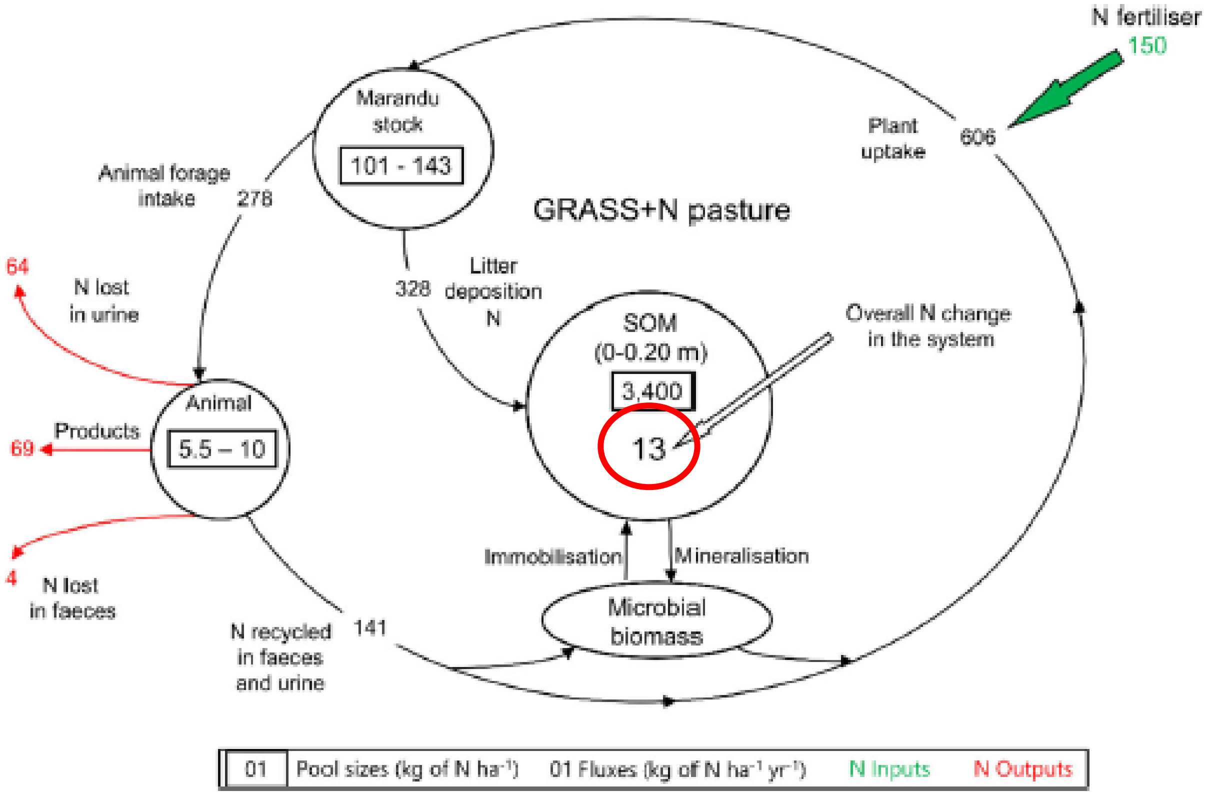
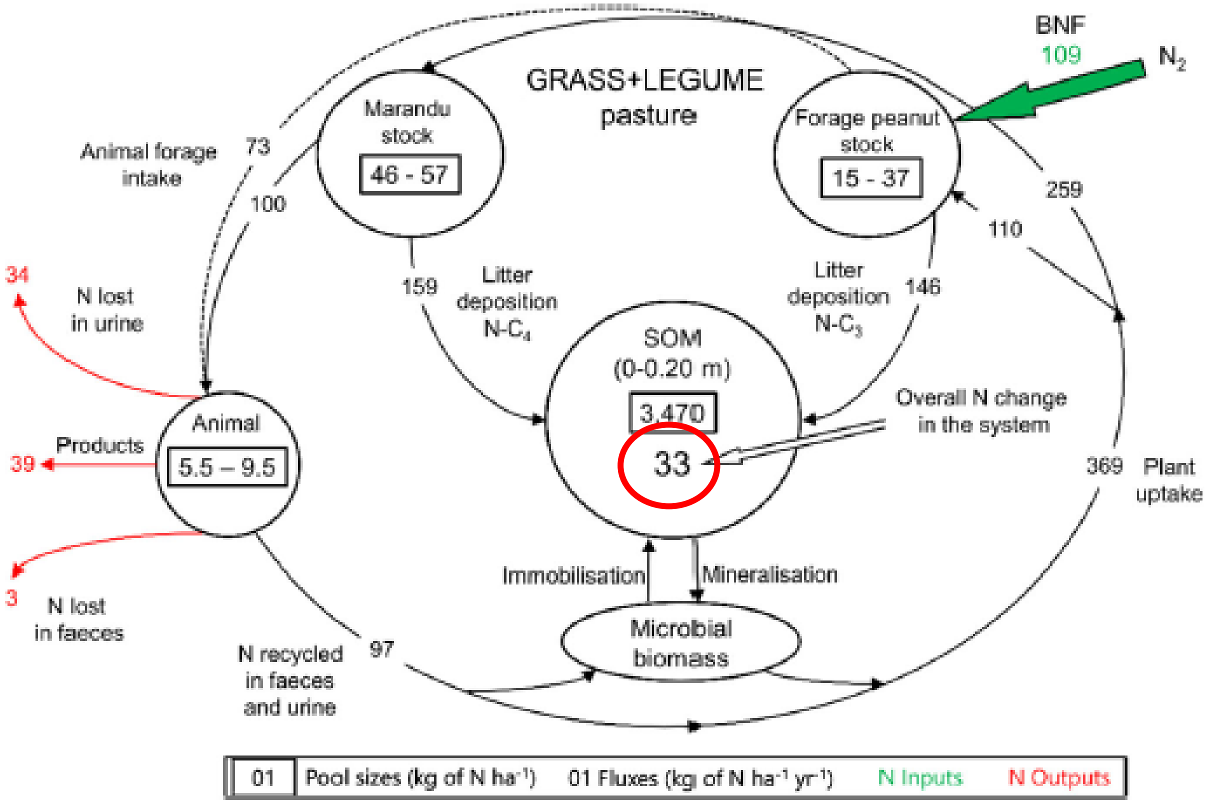
Homem et al. (2024)

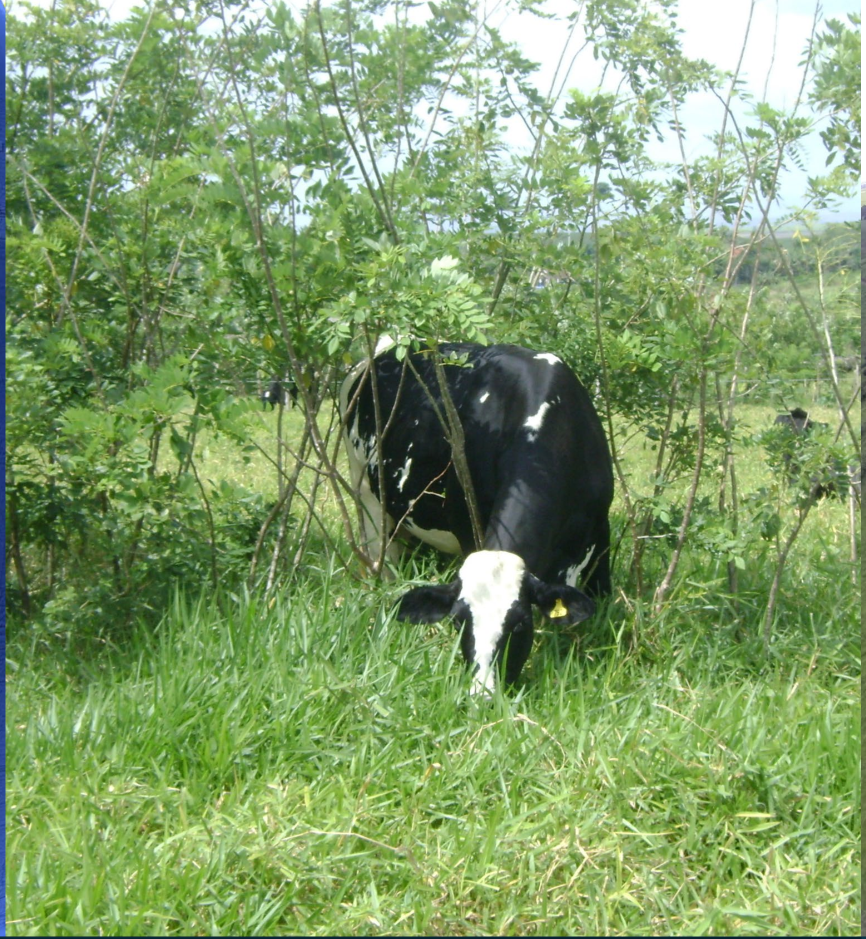
Palisadegrass + 150 kg N fertilizer per ha



Palisadegrass + *Arachis pintoi*



Homem et al. (2021)




Silvopasture System from Northeast Brazil

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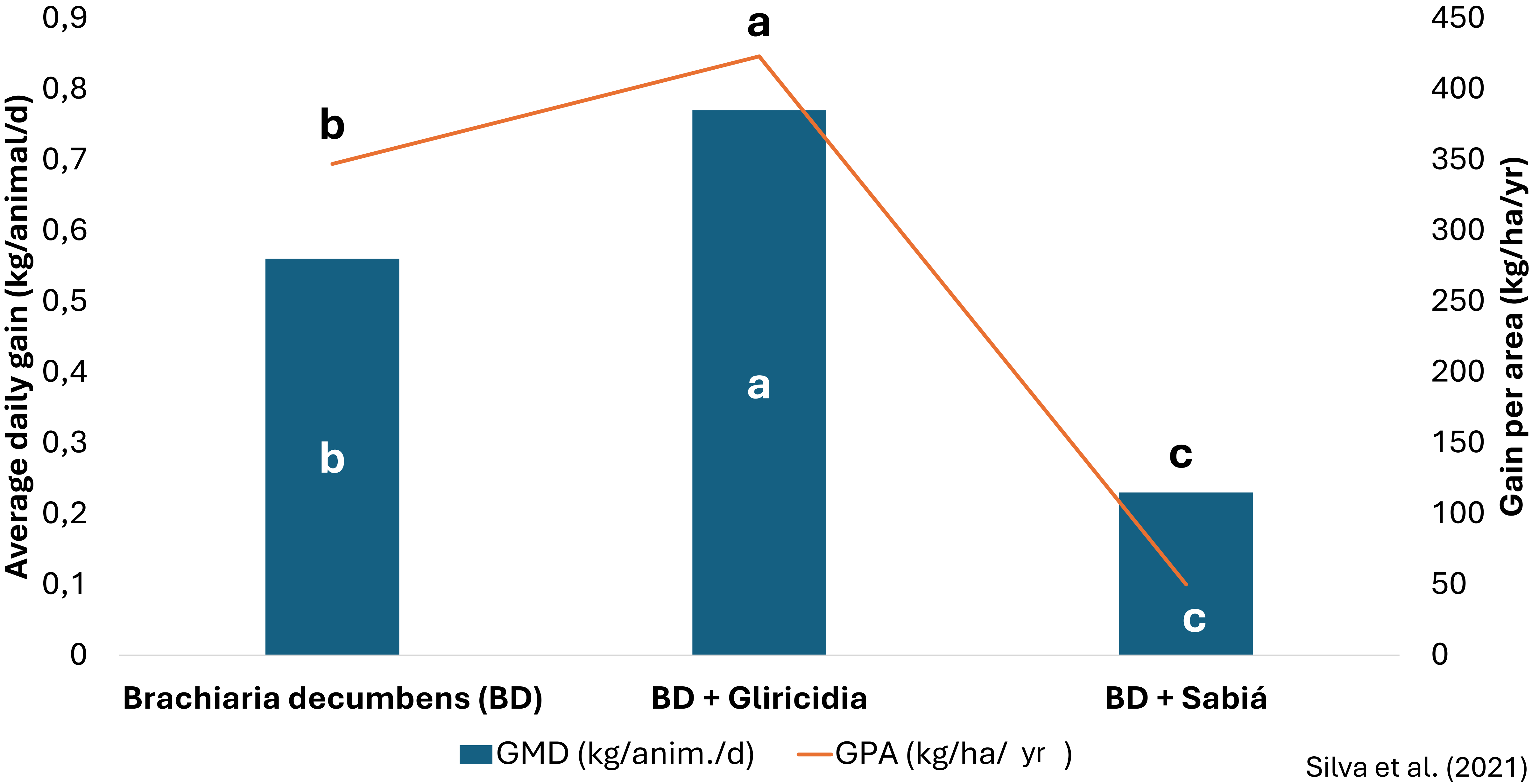
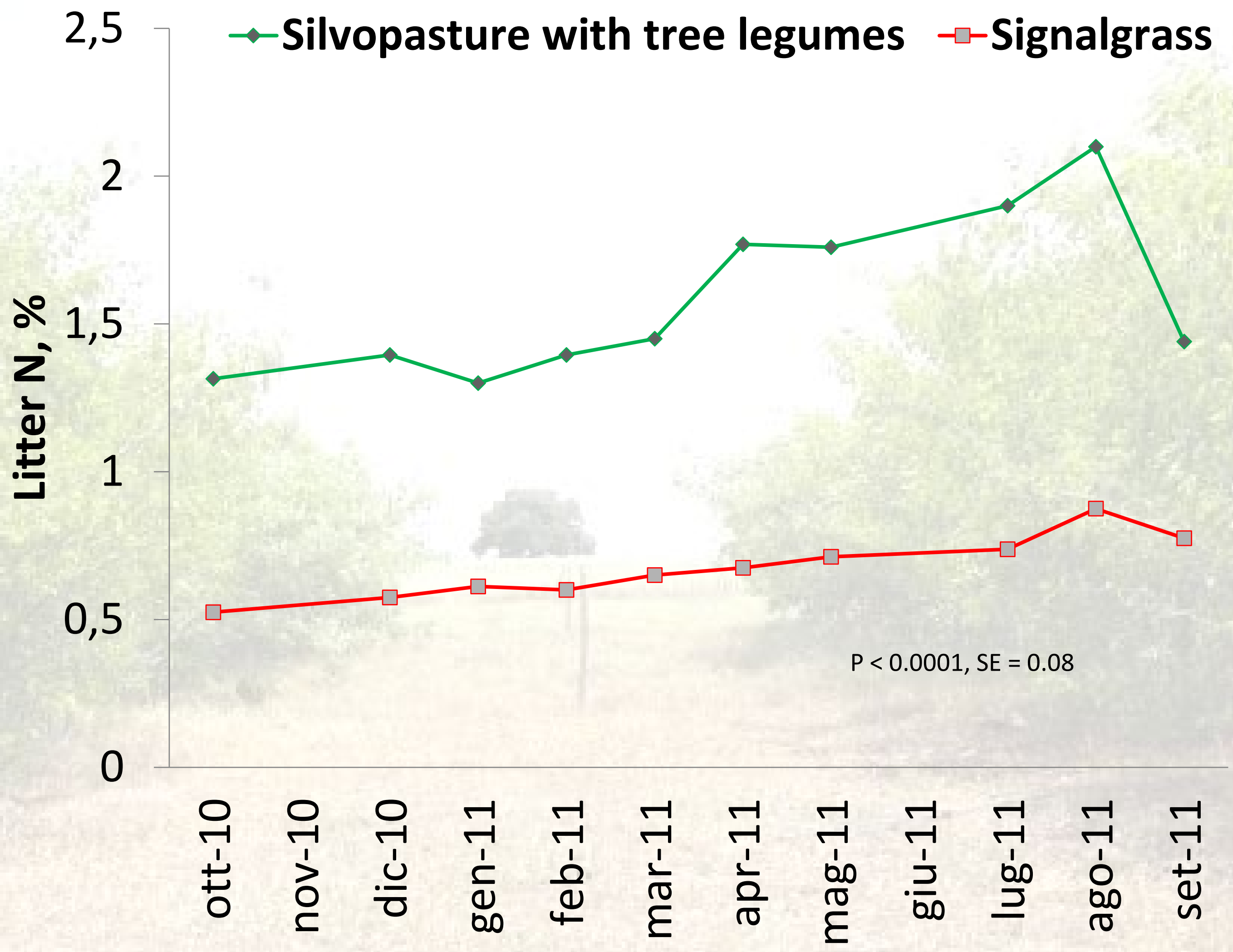
Silvopasture systems might be an option



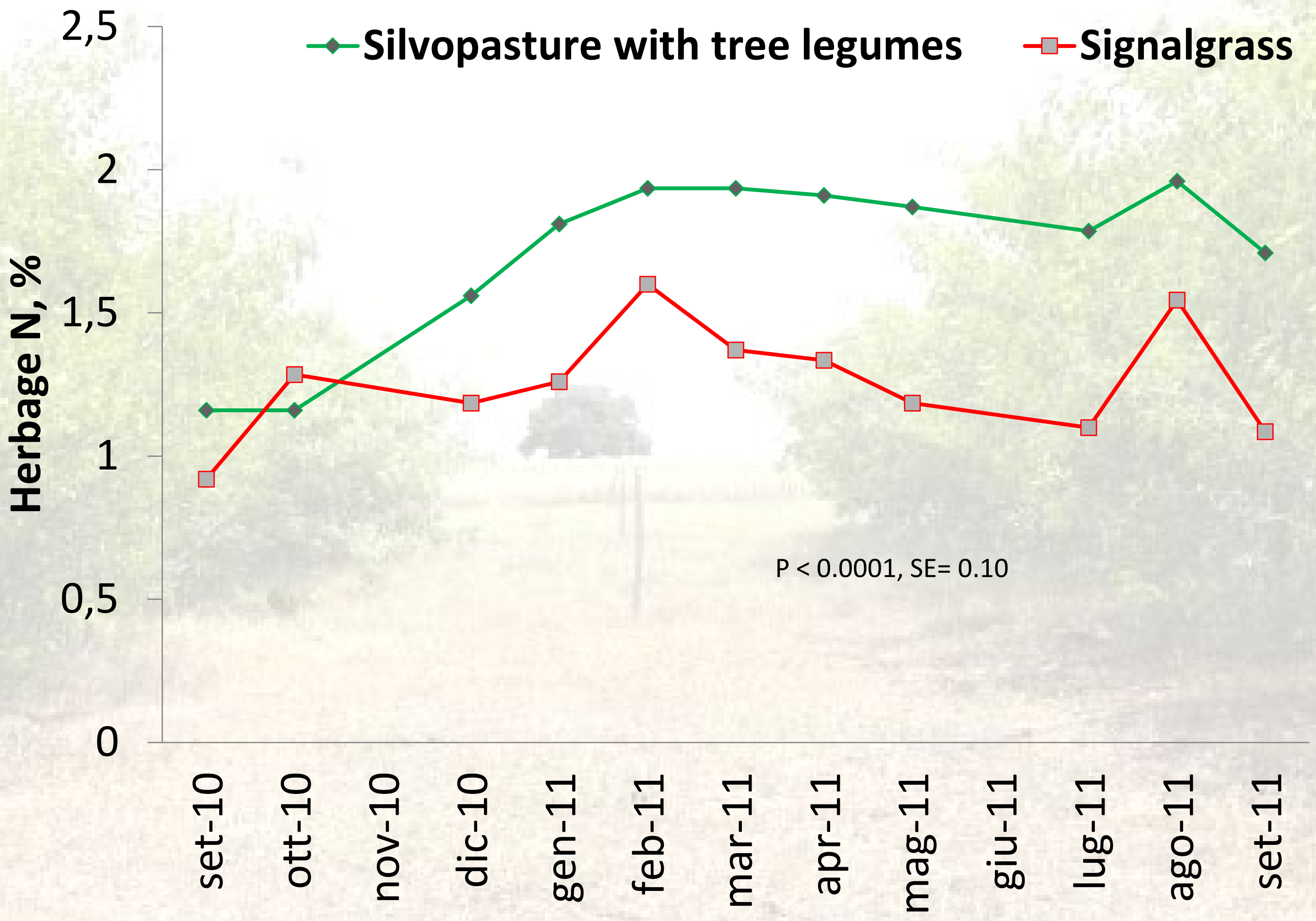
Silva et al. (2021)

Litter deposition by tree legumes is another pathway to add N to the system



Cabral et al. (2013)

Herbaceous vegetation increases its N concentration when mixed with tree legumes



Cabral et al. (2013)

C sequestration and GHG mitigation

4 Mg C ha^{-1} yr^{-1} sequestered above ground with 90% in branches and timber (Apolinario et al., 2015)

3.6 Mg C ha^{-1} yr^{-1} is equivalent to 13.2 Mg CO_2 eq. ha^{-1} yr^{-1}

Assuming 2 steers/ha, releasing on average 250 g methane $head^{-1}$ d^{-1}, we would have 4.5 to 5.0 Mg CO_{2eq} ha^{-1} yr^{-1} emitted as methane

Assuming that 20% of aboveground carbon is sequestered belowground, we would have 0.8 Mg C ha^{-1} yr^{-1} sequestered belowground, equivalent to 2.9 Mg CO_2 eq. ha^{-1} yr^{-1}

Multispecies Swards from Ireland

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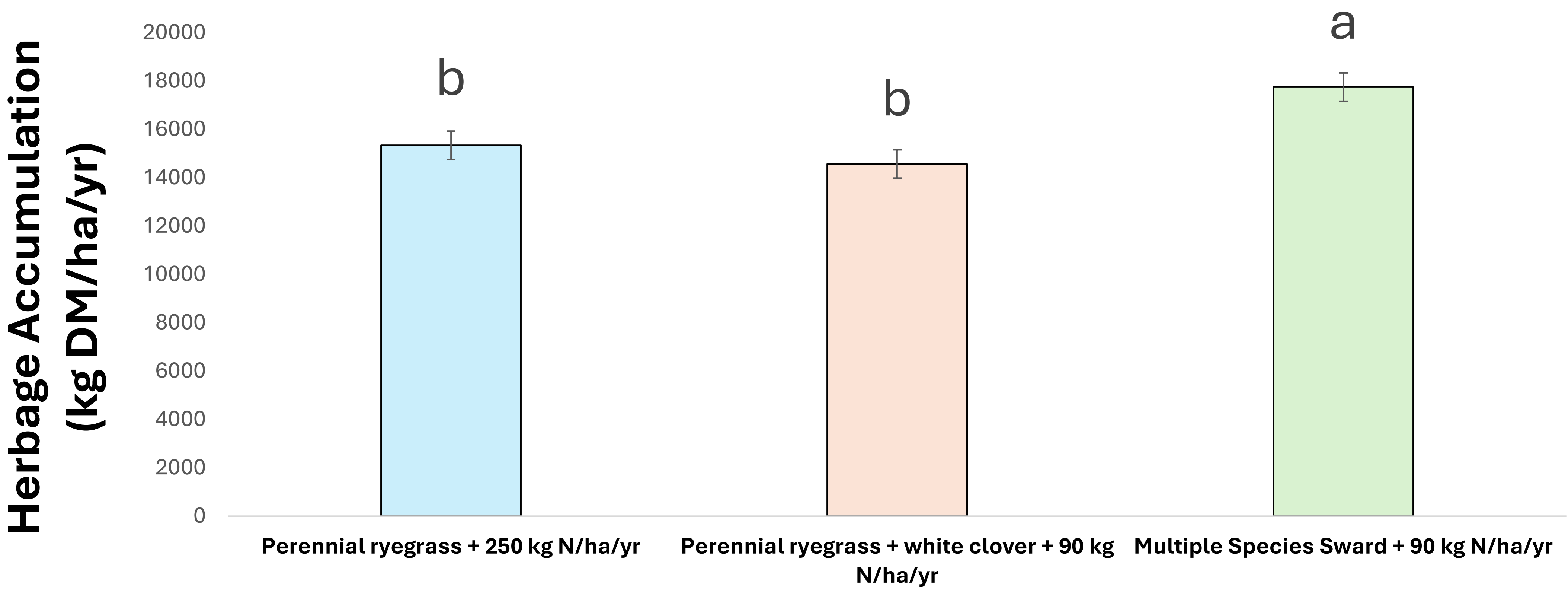
The Irish Story

- Perennial ryegrass + N fertilizer (250 kg N/ha/yr) is the standard in Ireland
- Multiple Species Sward (MSS) receiving only 90 kg N/ha/yr has shown greater delivery of ecosystem services

Multiple Species Swards produced more biomass with less nitrogen fertilizer (28-d rotation)



Multiple Species Sward = *L. perenne, Phleum pratense, Trifolium repens, Trifolium pratense, Plantago lanceolata and Cichorium intybus*

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Adapted from Baker et al. (2023)

Item	Treatment* PRG	PRGWC	MULTI	SEM
Dry matter intake (kg/d)				
Total	17.06[a]	18.30[b]	20.14[c]	0.149
Forage	15.55[a]	16.82[b]	18.88[c]	0.160
BCS	2.96	2.99	3.06	0.053
Milk production (kg/d)				
Milk yield	20.28[a]	20.19[a]	21.20[b]	0.437
Energy corrected milk (ECM)	23.95[a]	22.94[b]	24.80[a]	0.441
4% Fat corrected milk	21.63[a]	20.78[b]	22.48[c]	0.438
Milk efficiency (ECM/DMI)	1.40[a]	1.19[b]	1.11[b]	0.054

McCarthy et al. (2023)

Multiple Species Sward increased DMI and Milk Yield compared with Perennial ryegrass and Perennial ryegrass-white clover mixture in a zero-grazing study

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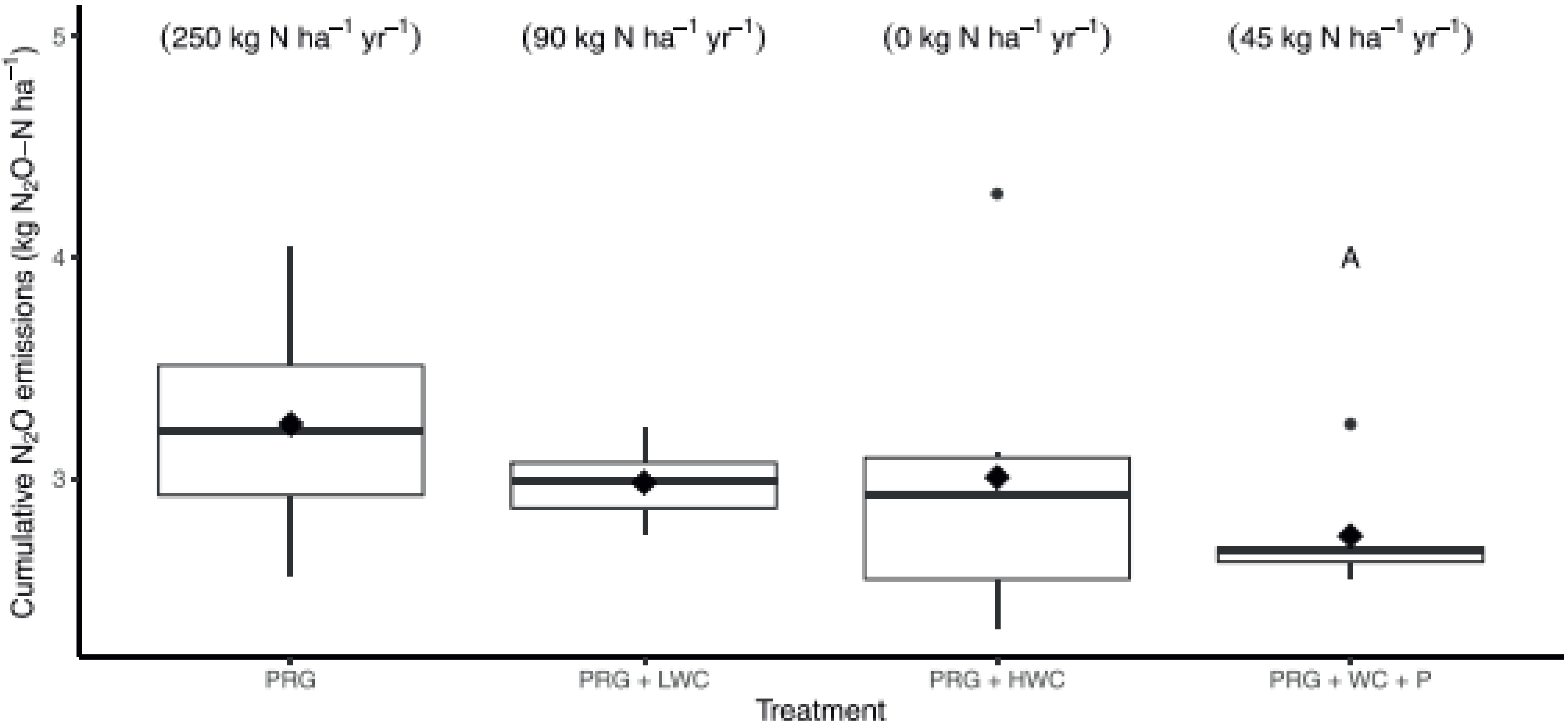
Multiple Species Sward reduced N_2O emissions



Bracken et al. (2022)

Take Home Messages

- Diverse swards enhance resilience, improves adaptation, and help to mitigate the negative effects of climate change

- Reducing off-farm inputs and maintaining or increasing grassland productivity is a key sustainable intensification for the Anthropocene

- Multiple species swards provide more ecosystem services to the entire society, and those must be valorized and recognized

Thank you!
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