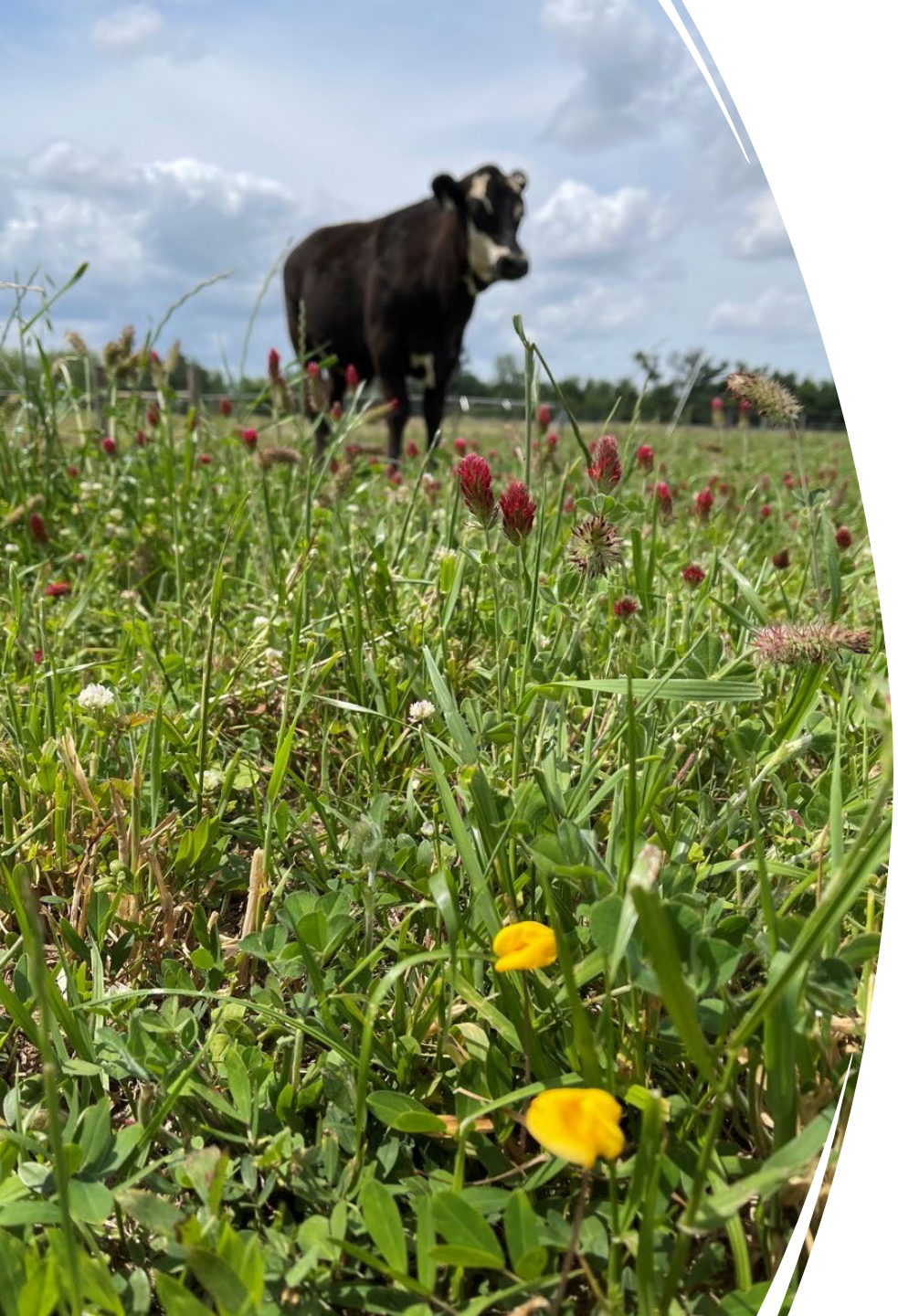

Nitrogen Cycle in Grass-Legume Mixtures

Jose Dubeux, K.R. Trumpp, L.D. Queiroz, I.L. Brêtas, J. Portuguez, K. Oduor, M. Ruiz-Moreno

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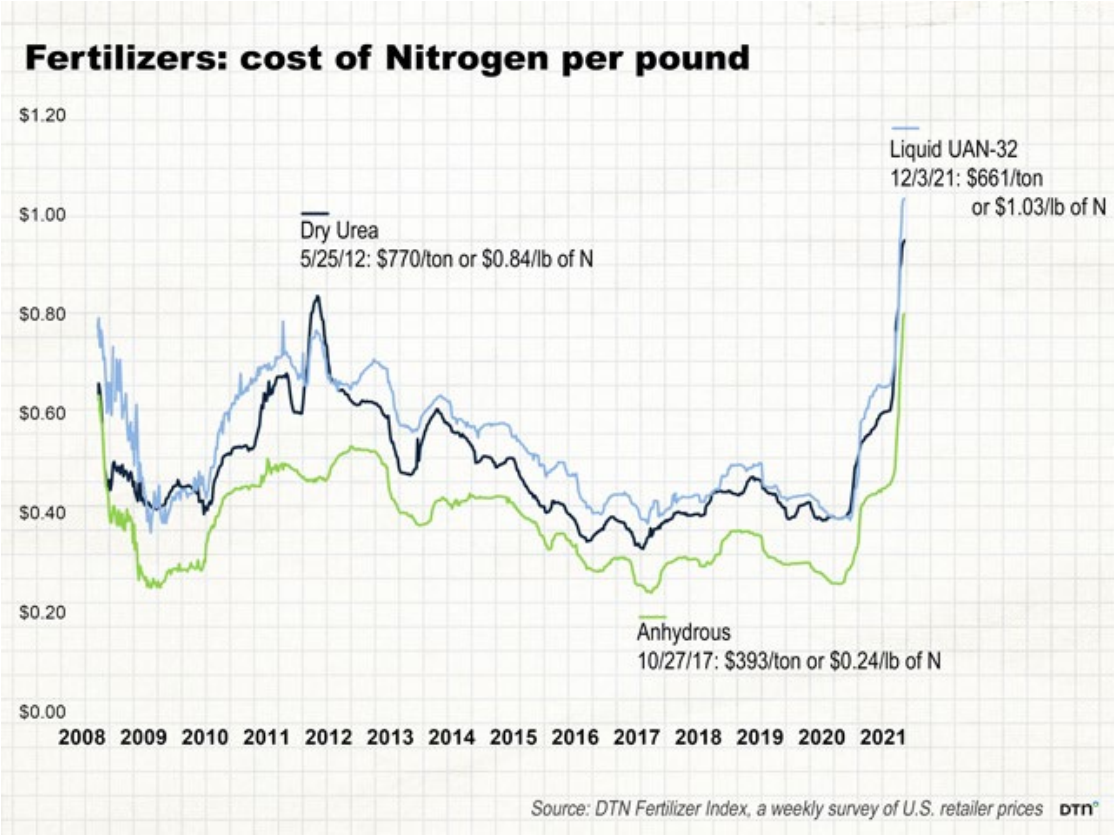
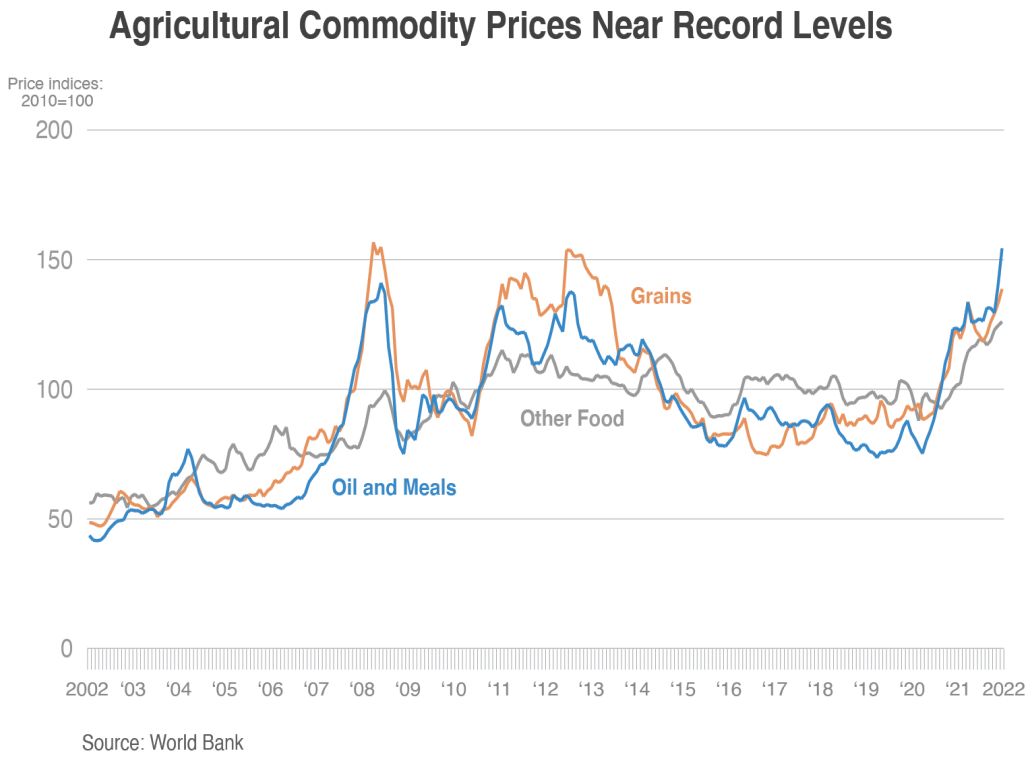
N fertilizer price



Feed price



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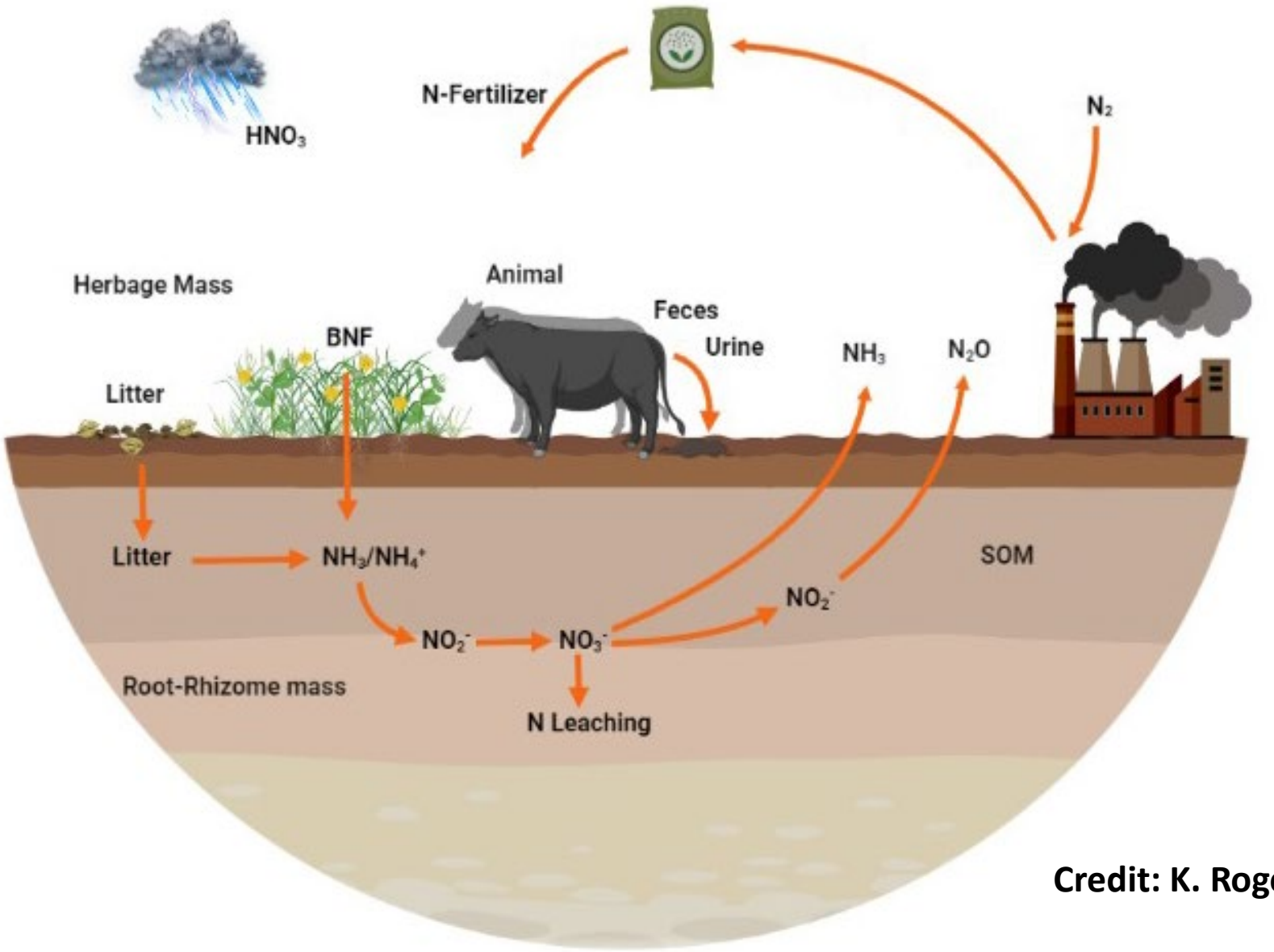
Nitrogen Use Efficiency

- Produce more livestock products per unit of N
- Enhance delivery of other ecosystem services per unit of N
- Reduce environmental problems

Nitrogen Cycle



Credit: K. Roger Trumpp

Biological Nitrogen Fixation (BNF)

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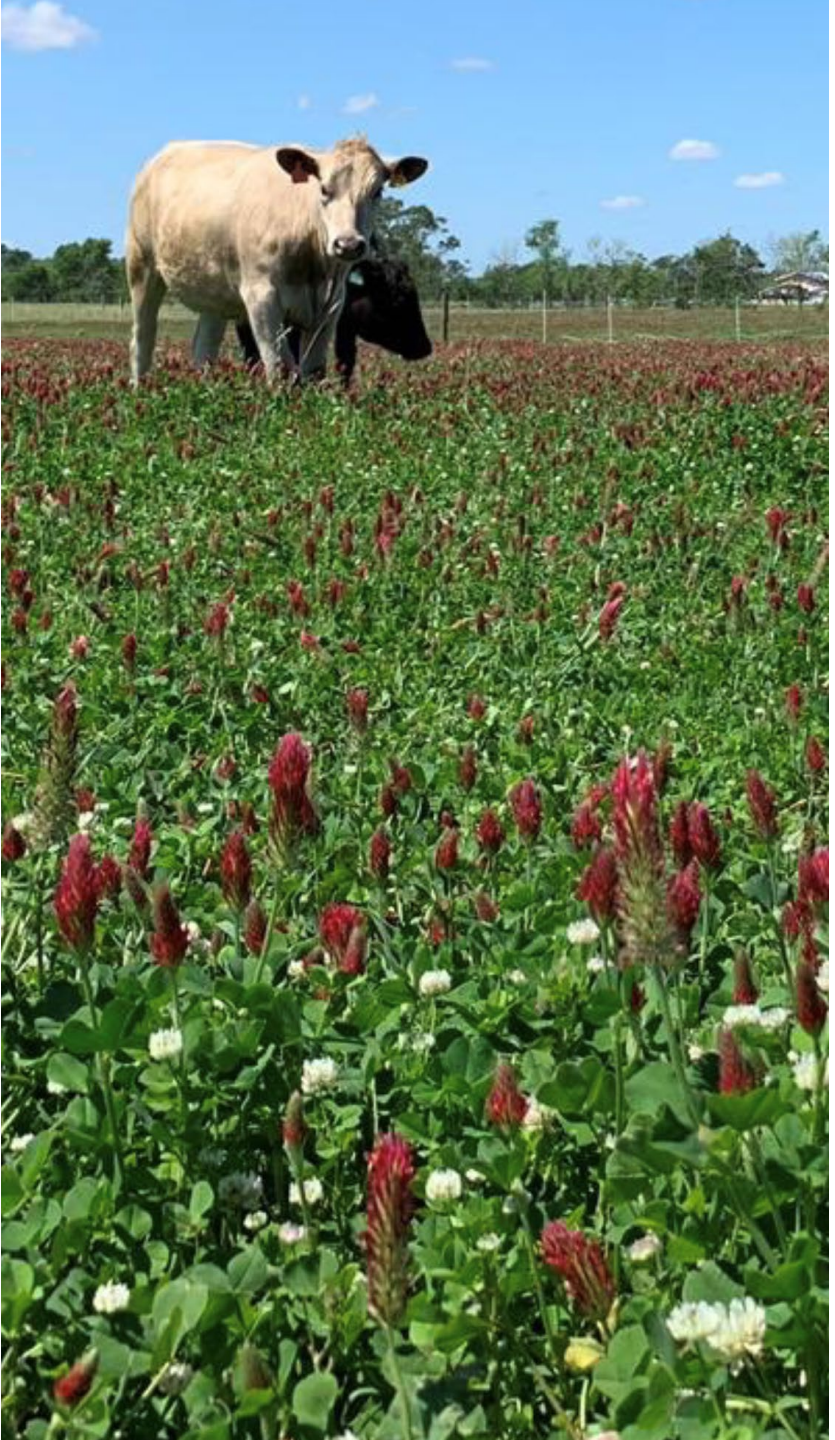
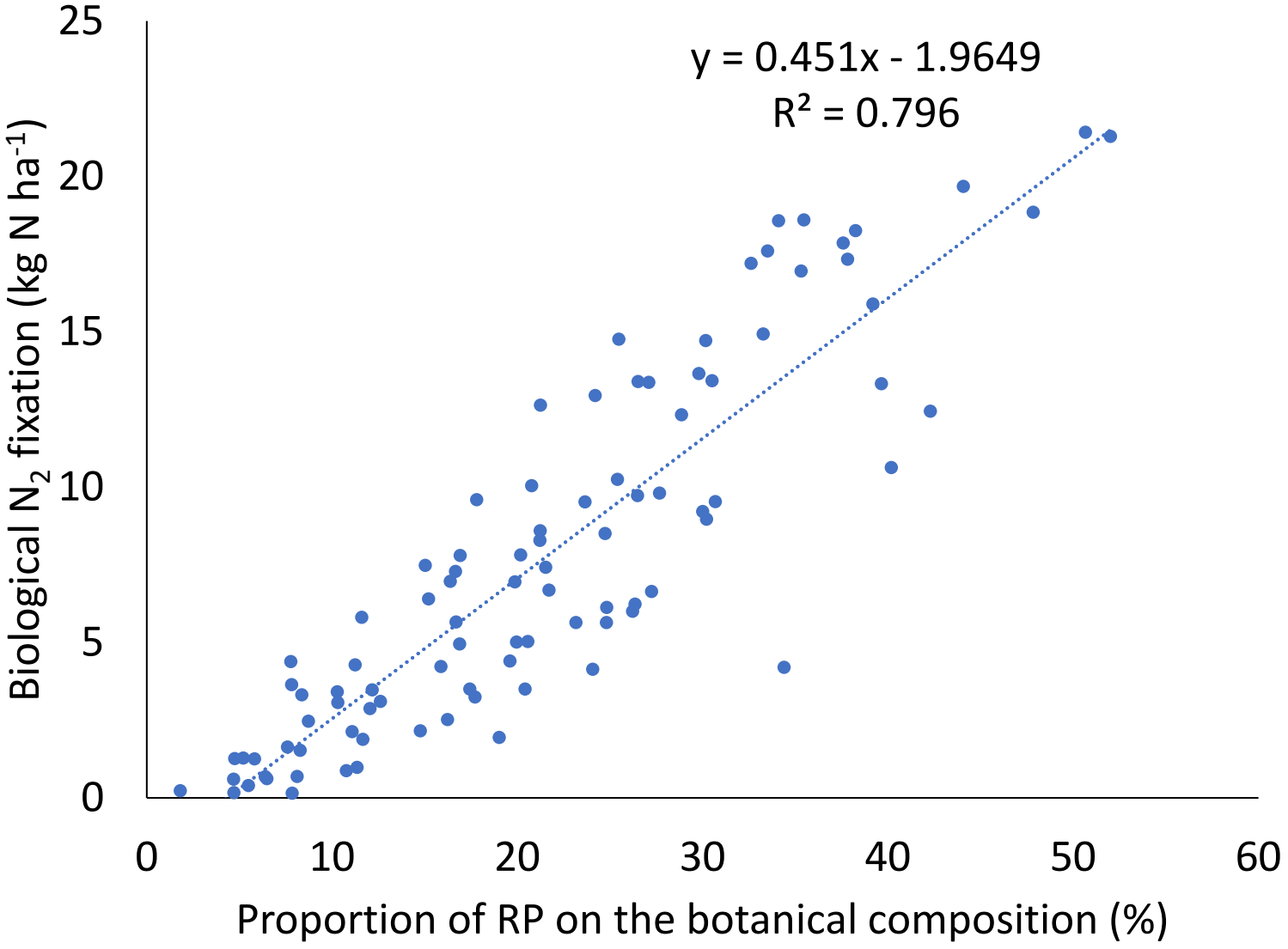


More legumes, more BNF…



L.D. Queiroz (2020)

UNIVERSITY OF FLORIDA IFAS
UNIVERSITY OF FLORIDA IFAS
Berseem Clover plus Ryegrass
UNIVERSITY OF FLORIDA IFAS
Crimson Clover plus Ryegrass
Annual ryegrass without N fertilizer
Berseem clover and annual ryegrass
Crimson clover and annual ryegrass

Clovers help ryegrass to grow…

Treatments	Total DMY	Clover DMY	Ryegrass DMY
	lb/ac	lb/ac	lb/ac
Ryegrass-Balansa Clover	1550 b	420 b	1040 b
Ryegrass-Ball Clover	2090 b	540 b	1490 b
Ryegrass-Berseem Clover	2030 b	1530 a	480 b
Ryegrass-Crimson Clover	**4090 a**	1990 a	**1960 a**
Unfertilized Annual Ryegrass	870 c	---	850 b
SE	247	201	173
P	< 0.0001	<0.0001	0.0006

Santos et al. (2017)

Best clovers fixed almost 50 lb N/acre just from aboveground growth, when mixed with ryegrass

Treatments	Total N Yield	Ndfa	N Fixation
	lb/ac	%	lb/ac
Ryegrass-Balansa Clover	26 b	98 a	12 c
Ryegrass-Ball Clover	36 b	67 c	10 c
Ryegrass-Berseem Clover	44 a	86 b	32 b
Ryegrass-Crimson Clover	78 ab	95 a	46 a
Unfertilized Annual Ryegrass	10 c	---	---
SE	6	2	4
P	< 0.0001	< 0.0001	< 0.0001

Santos et al. (2017)

How about summer legumes?

Sunn hemp Cultivar	Herbage accumulation (lb DM/acre)	IVDOM (%)	CP (%)	$\delta^{15}N$ (‰)	%Ndfa	BNF (lb N/acre)
Crescent Sun	2,864 a	53.1 b	17.6 b	0.88 a	48 a	**36 a**
Blue Leaf	1,570 b	56.4 a	18.8 a	0.58 a	56 a	22 b
P-value	<0.001	0.017	0.003	0.099	0.084	0.001
SE	383	2.4	1.3	0.15	7	6.2

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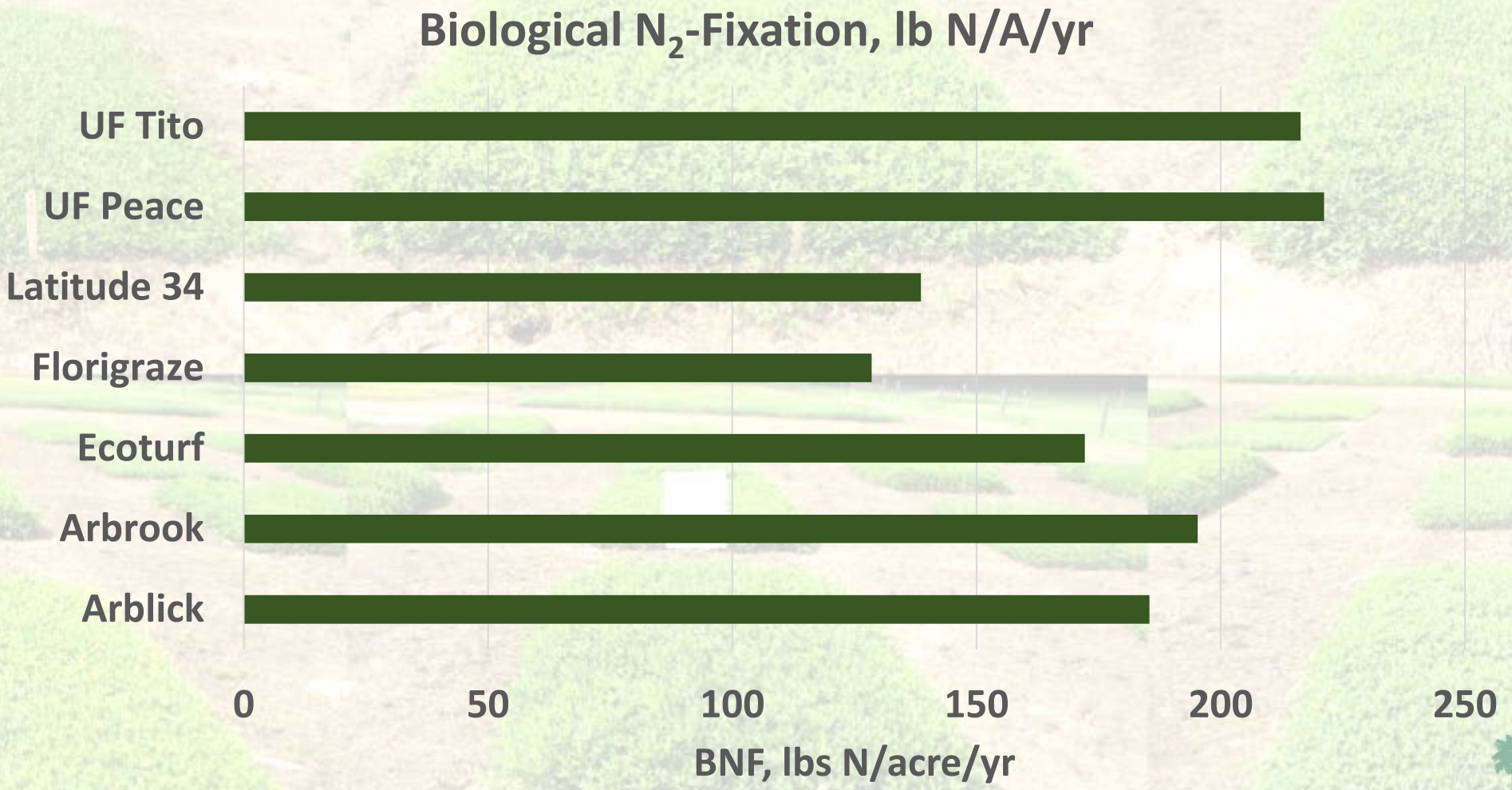
Adapted from Jaramillo et al. (2020)

How about perennial peanut?



Adapted from Dubeux et al. (2017)

Average across two seasons (2014 and 2015), with three harvests/season
UF/IFAS – NFREC, Marianna

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Internal N Recycling

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Internal N Recycling

- Root turn over
- Litter
- Excreta

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Root/Rhizome biomass and N pool in perennial peanut varieties

Cultivar	Root mass, ash-free basis, lb OM/A	Root N, %	Root N, lb N/A
Arblick	17450 ab	1.7 ab	325 abc
Arbrook	15420 ab	1.1 c	186 c
Ecoturf	23990 a	1.9 ab	511 a
Florigraze	9400 b	2.0 a	203 c
Latitude 34	24740 a	1.9 ab	506 ab
UF Peace	19090 ab	1.5 bc	302 bc
UF Tito	14970 ab	1.9 a	315 abc
SE	2475	0.1	50

Average of two seasons (2014 and 2015); Marianna, FL, USA

What is the belowground biomass decay during the year?

Root/rhizome decay from RP

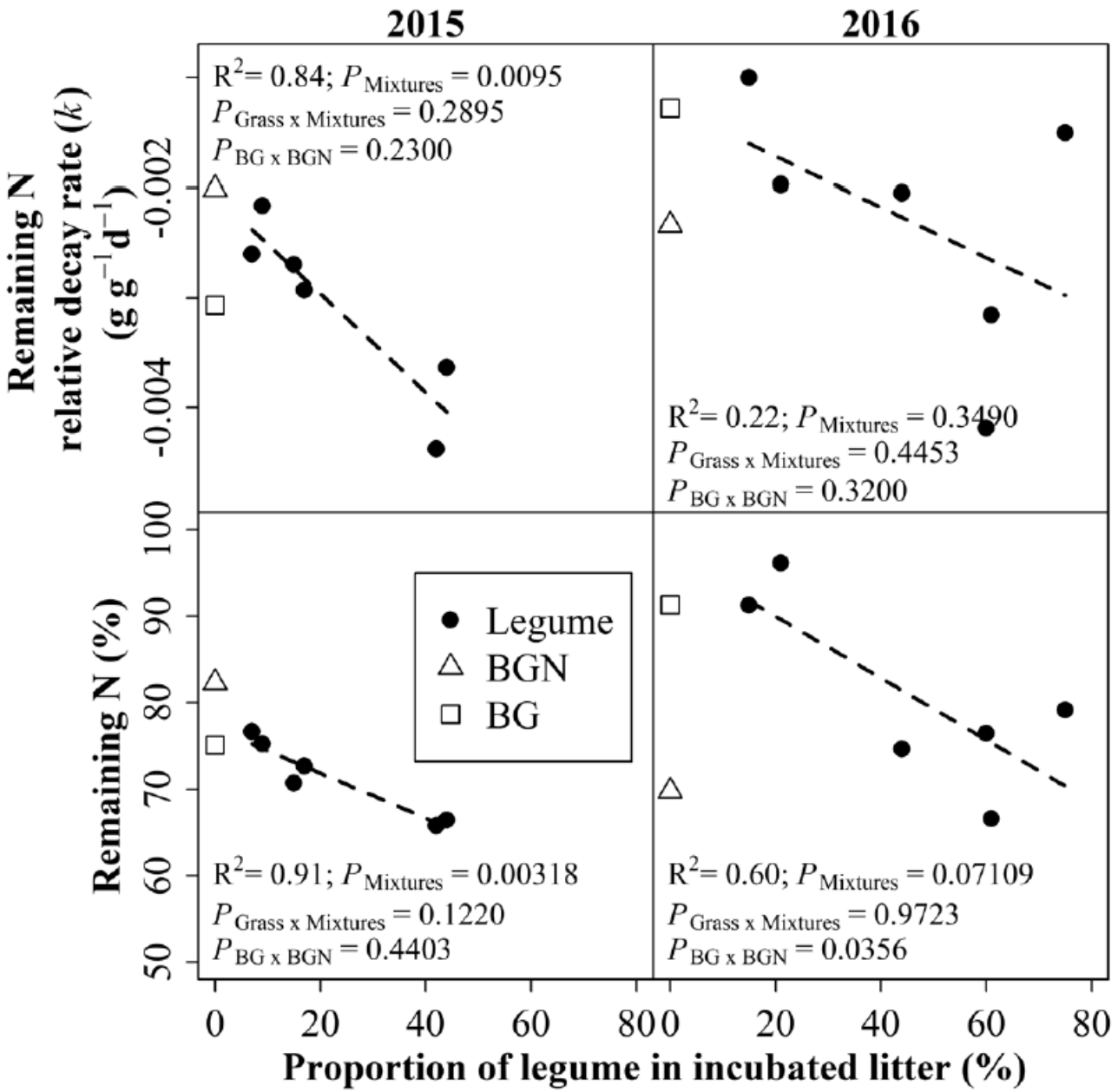
- Assuming 30% RP in the botanical composition, the average N input from root/rhizome tissues is 20 lb N/acre/yr

Santos et al. (2021; *in preparation*)

Litter

- Legumes help to improve litter quality
- Reduced C:N ratio leads to faster N release
- Faster N relase improves efficiency of N utilization

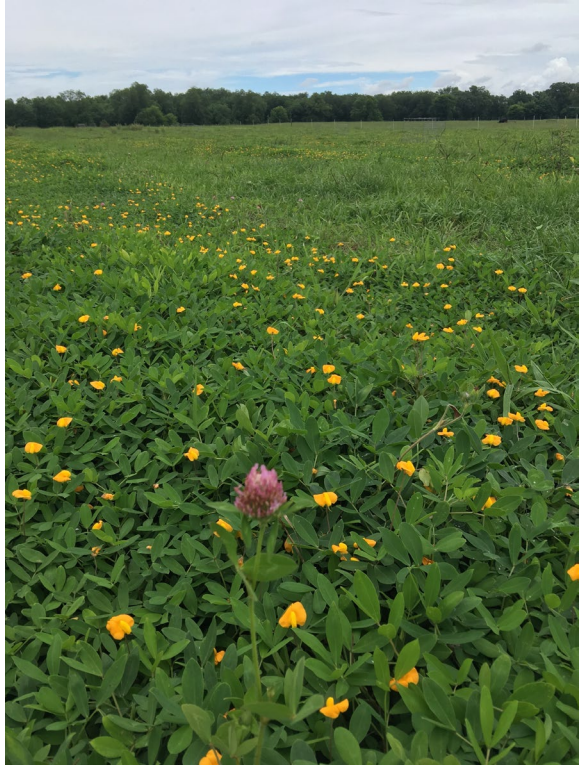
Greater legume proportion in the litter increases N mineralization

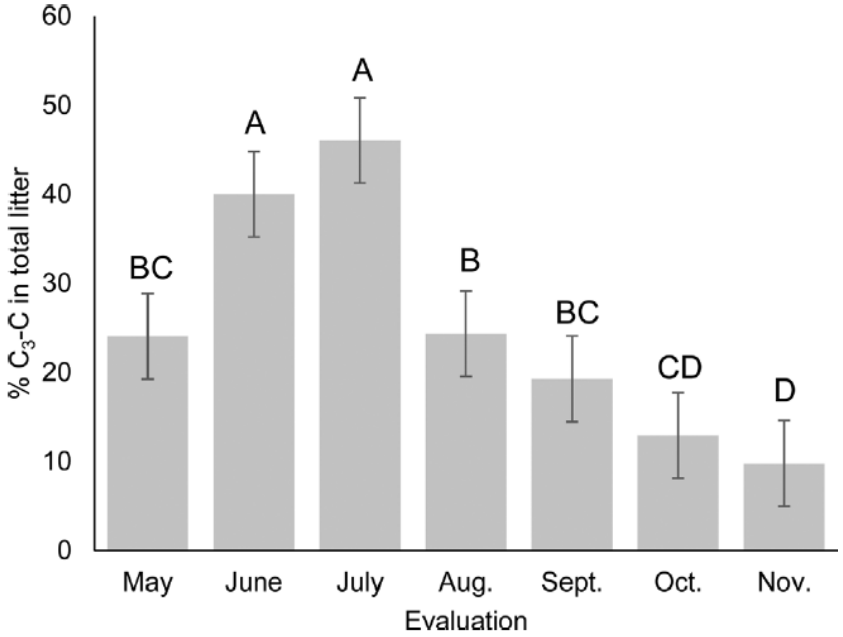


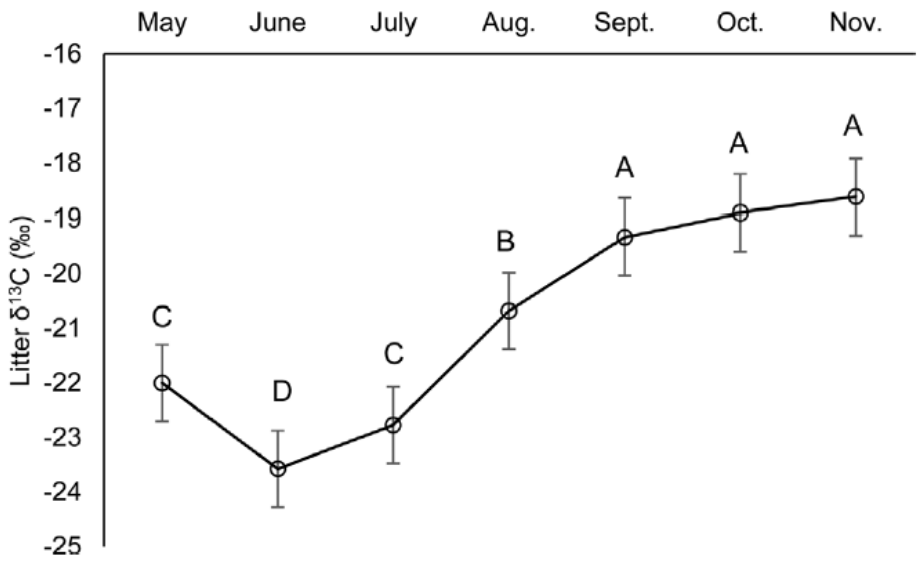
Kohmann et al. (2018)

Litter dynamics in a grass-legume pasture

- Jaramillo et al. (2021)







Litter N return

- Jaramillo et al. (2021)

Grazing system[a]	Deposition rate	N return per season
	kg OM[b] ha^{-1} d^{-1}	kg ha^{-1}
Grass+Clover	25A[c]	51
Grass+N	29A	63
Grass+CL+RP	13B	27
SE	3.2	16.9
P value	.002	.35

Average was 47 kg N/ha (≈42 lb N/acre)

Excreta

- Dung and urine are important pathways of N return
- N losses occur
- Improving spatial distribution with rotational stocking helps

Nitrogen return via excreta

Item	Grass + N	Grass + CL	Grass + CL + RP
Annual N input via fertilizer, lb N acre^{-1} yr^{-1}	200	30	30
Annual N input via BNF, lb N acre^{-1} yr^{-1}	---	39	48
Total N input, lb N acre^{-1} yr^{-1}	200	69	78
Fecal N, lb N acre^{-1} yr^{-1}	35 a	27 b	21 c
Urinary N, lb N acre^{-1} yr^{-1}	44	34	42
Total N excretion, lb N acre^{-1} yr^{-1}	79 a	61 b	63 b
%N returned, (returned/input)*100	39.5	88.4	80.8

Garcia et al. (2021)

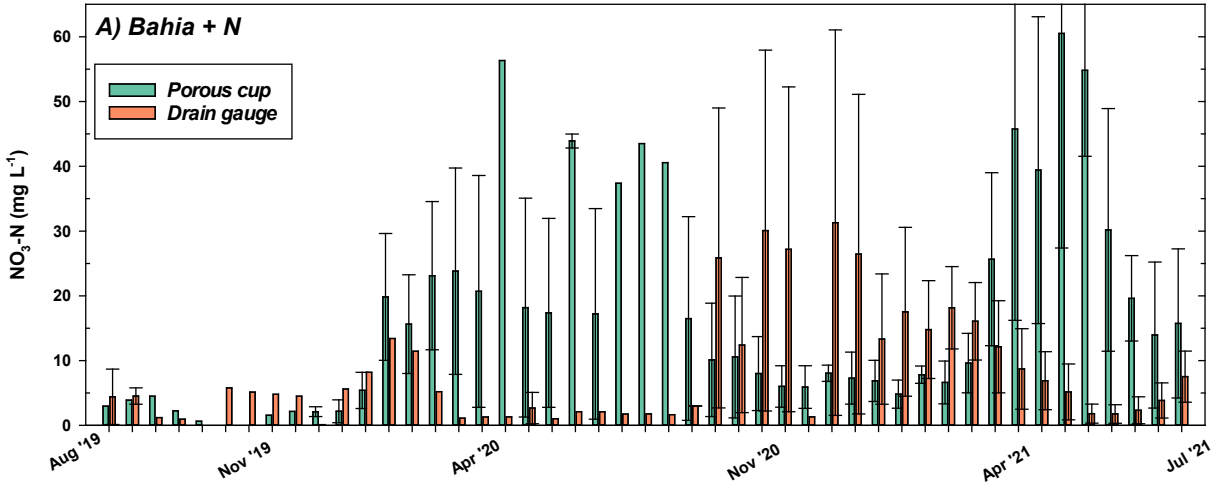
<u>In summary:</u>

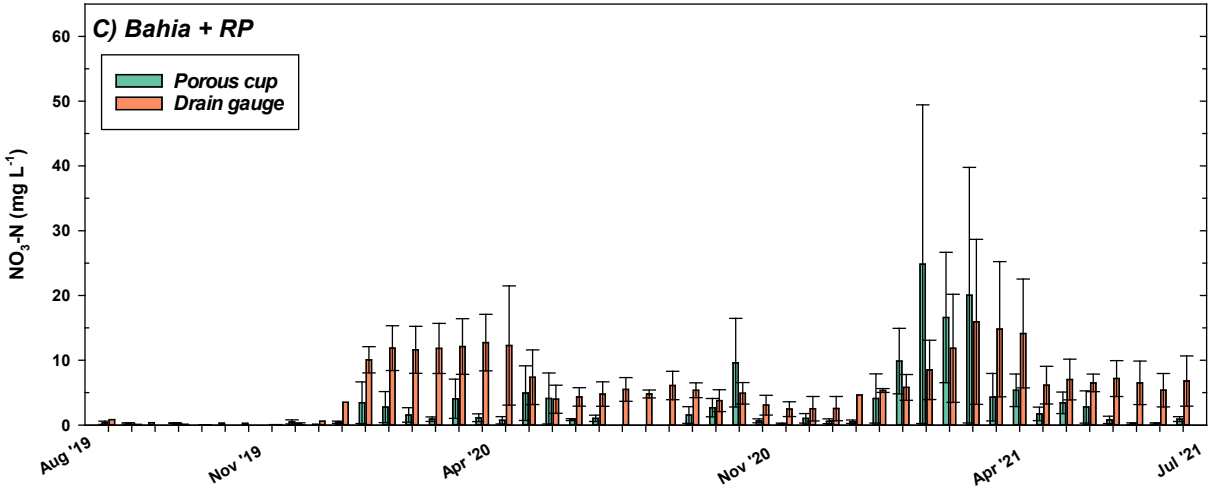
Nitrogen cycling in grass-legume pastures is more efficient compared with N cycling in N-fertilized systems

Nitrogen losses

- Nitrate leaching
- Ammonia volatilization
- Nitrous oxide emissions

Grass-legume mixtures have less nitrate leaching than N-fertilized grasses



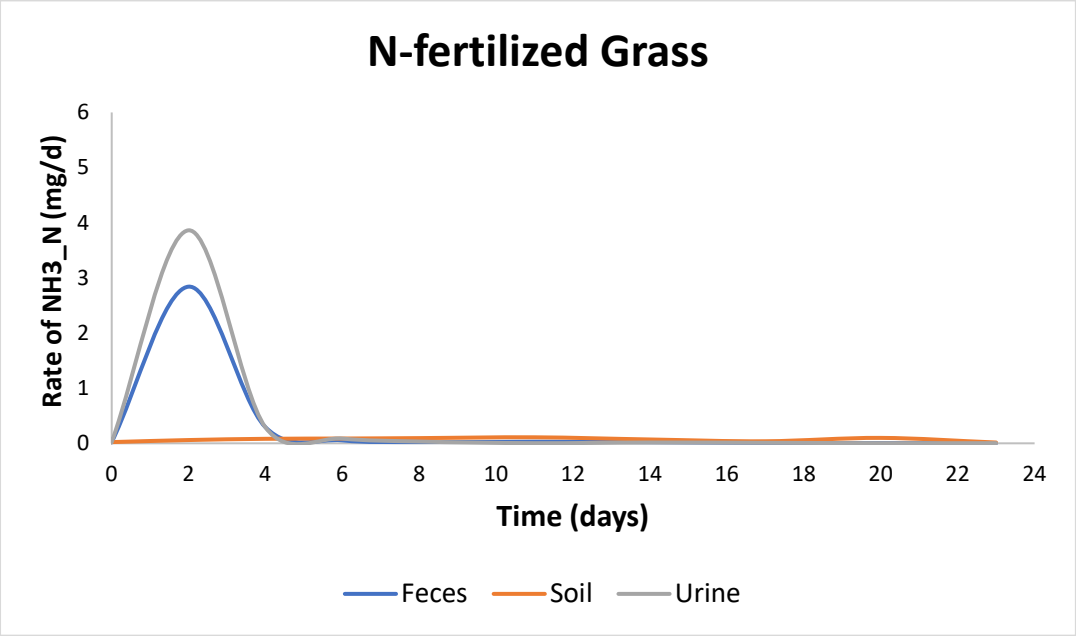


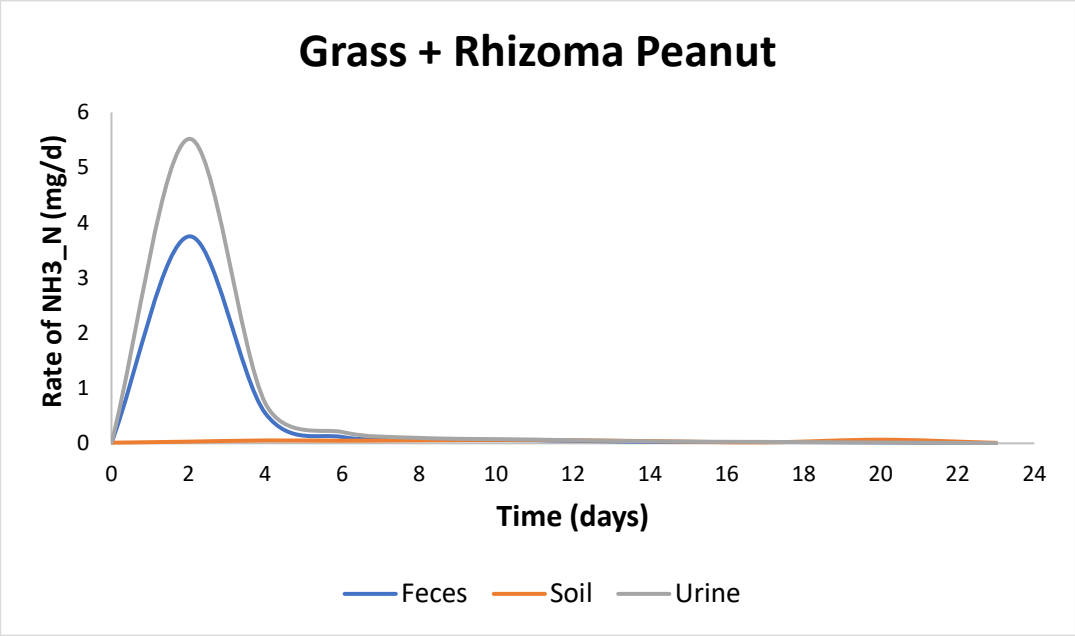
Avg. 118 lb NO_3-N $Acre^{-1}$ Yr^{-1}

Avg. 58 lb NO_3-N $Acre^{-1}$ Yr^{-1}

Dubeux and Mackowiack (2021)
FDACS Final Report

Legume inclusion increased ammonia volatilization from excreta compared with N-fertilized grasses

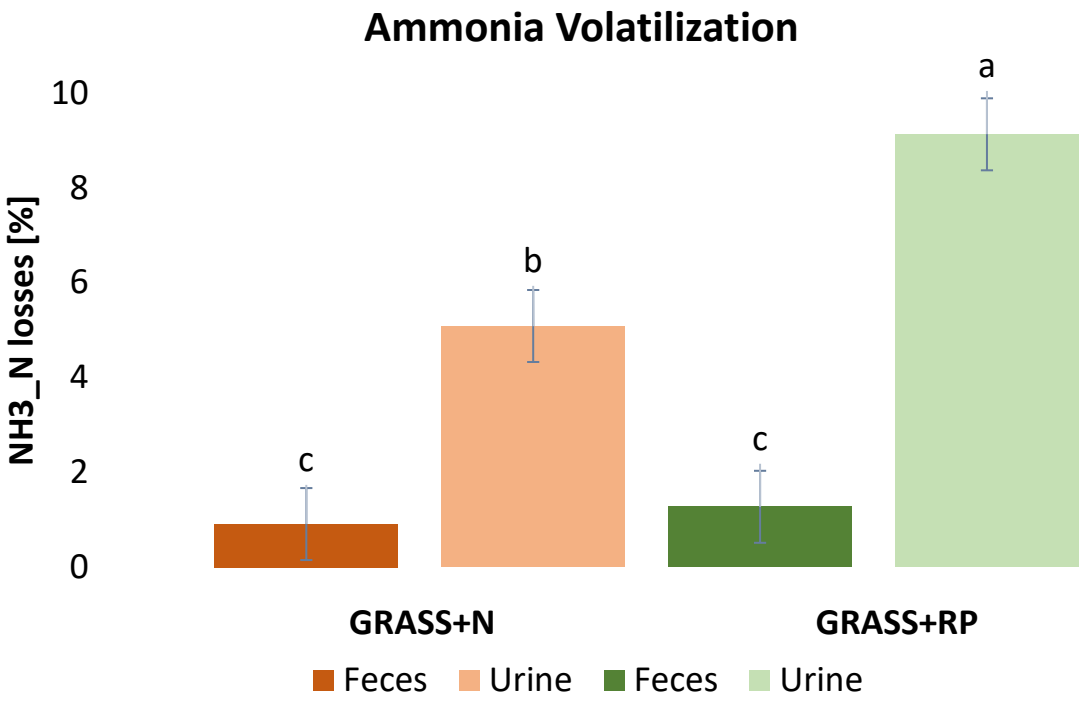




K.R. Trumpp (2023; *Personal communication*)

Need to measure ammonia losses right after N fertilizer application (10 to 50% of applied N can be lost; Morais et al, 2013)

Legume inclusion increased ammonia volatilization from excreta compared with N-fertilized grasses



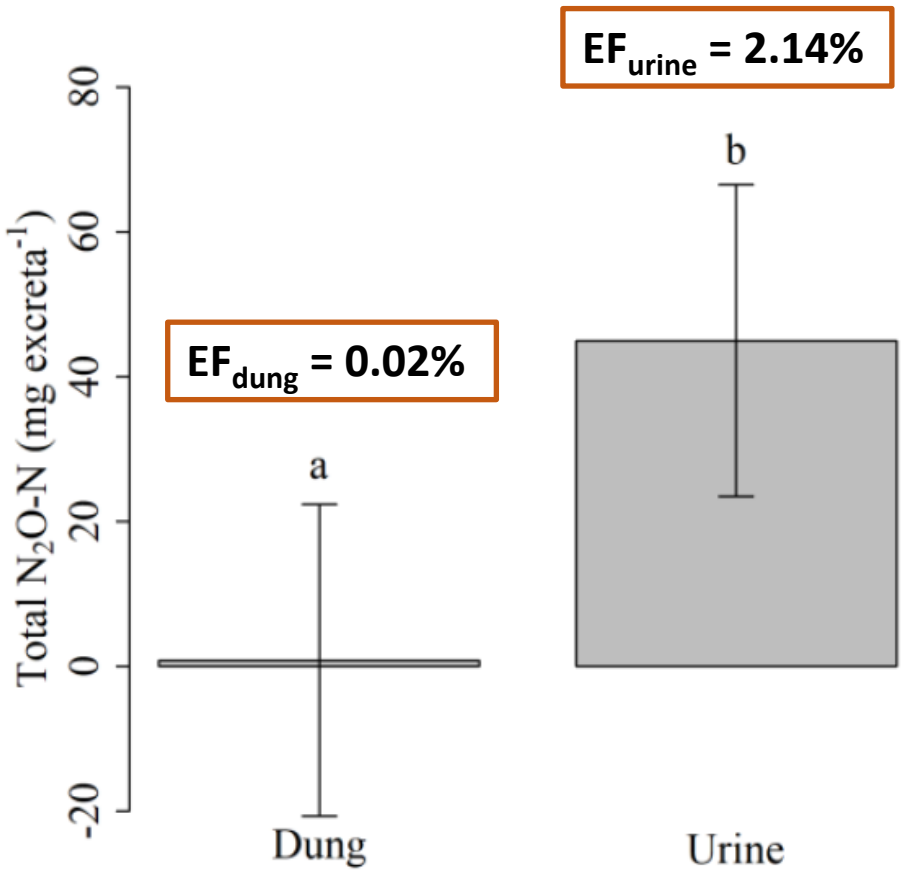
K.R. Trumpp (2023; *Personal communication*)

Summer

System	Total Fecal N output (lb/acre)*	Total Urinary N output (lb/acre)*	Total N-NH3 losses (lb/acre)
Grass + N	21.4	30.8	1.8
Grass + RP	9.5	27.5	2.6

*Data from Garcia et al. (2021)

Nitrous oxide emission



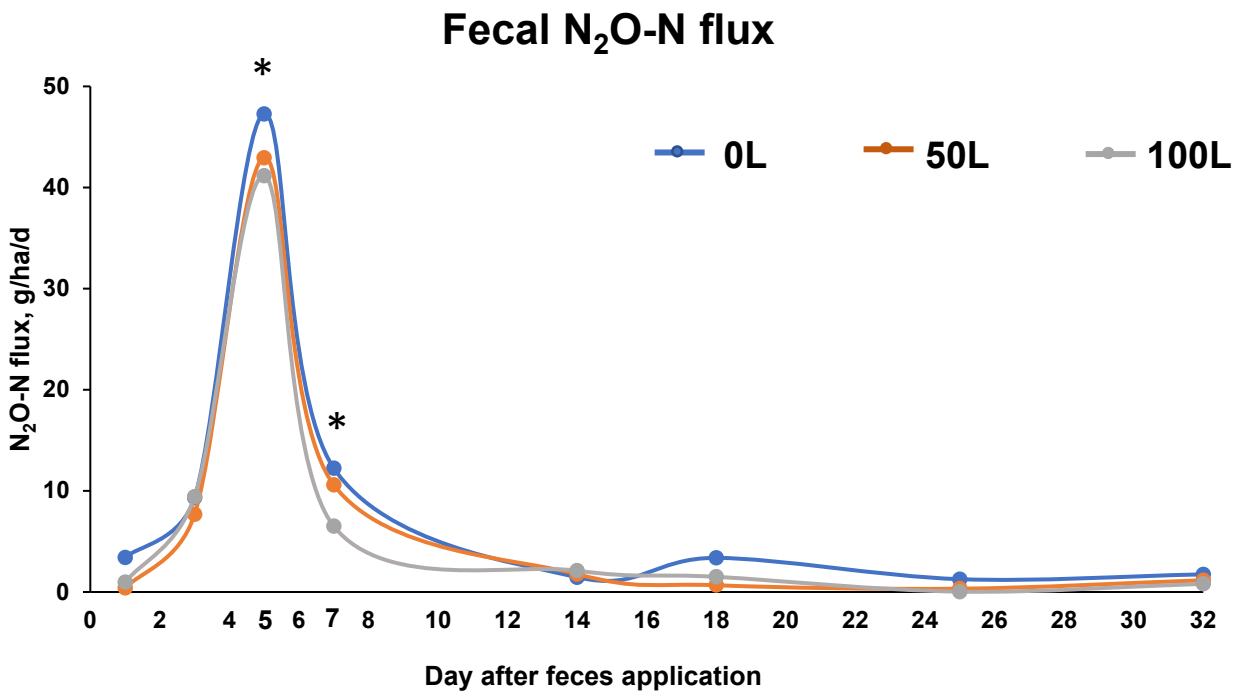
Cummulative 30-d N2O emission from cattle excreta grazing BGN or BG-RP; data average across 2 yr. (M. Khomann, 2017)

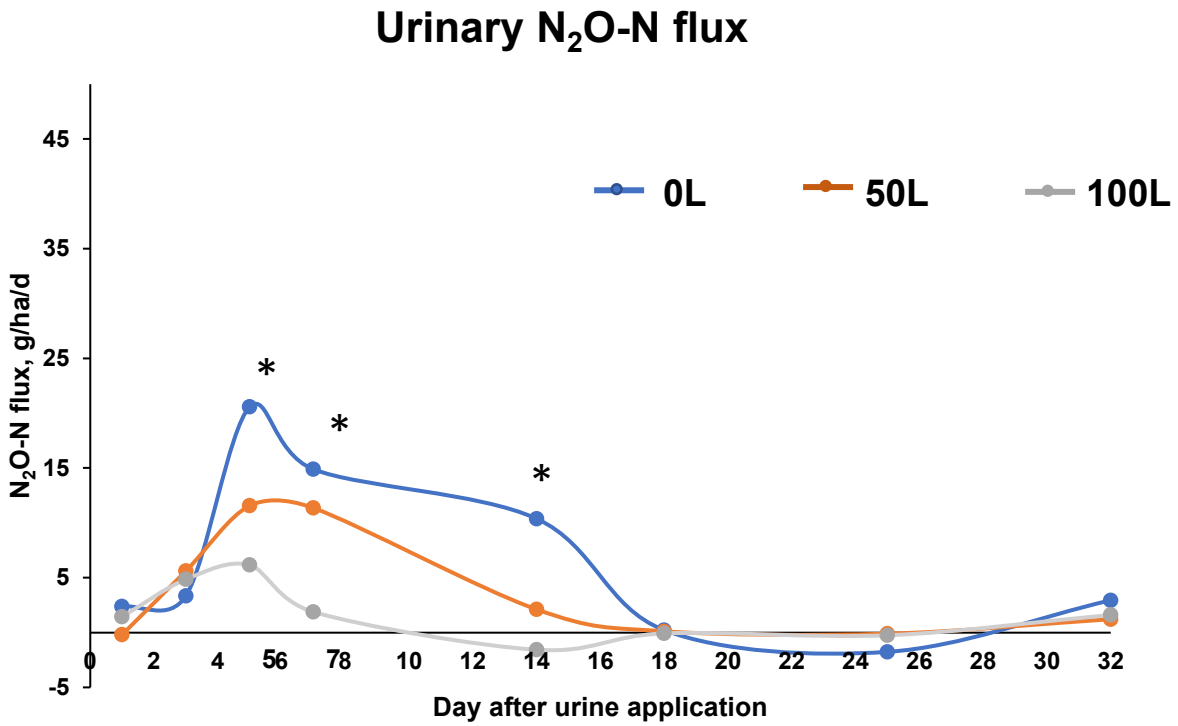
Summer

System	Total Fecal N output (lb/acre)*	Total Urinary N output (lb/acre)*	Total N-N_2O losses (lb/acre)
Grass + N	21.4	30.8	0.7
Grass + RP	9.5	27.5	0.6

***Data from Garcia et al. (2021)**

Inclusion of Sericea lespedeza reduced N_2O emissions



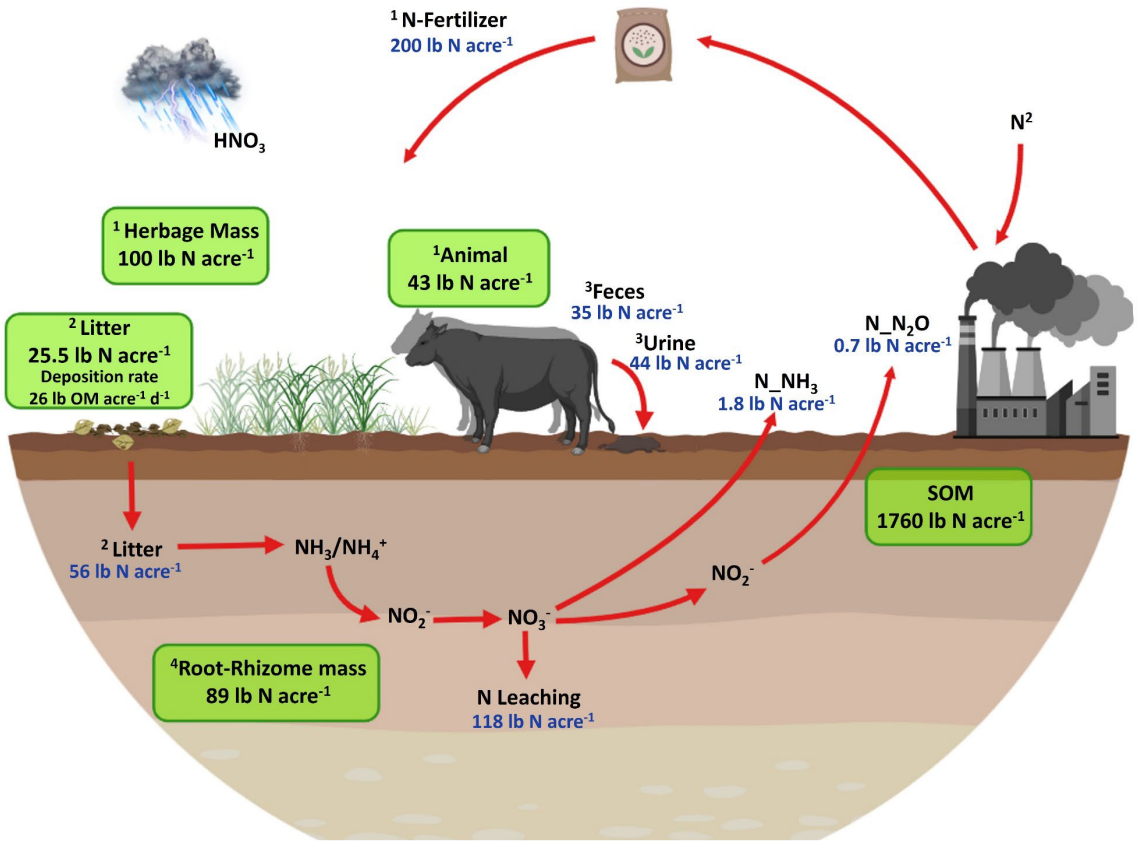


Possible presence of aromatic compounds from CT in urine (e.g., hippuric acid) reducing N_2O emission

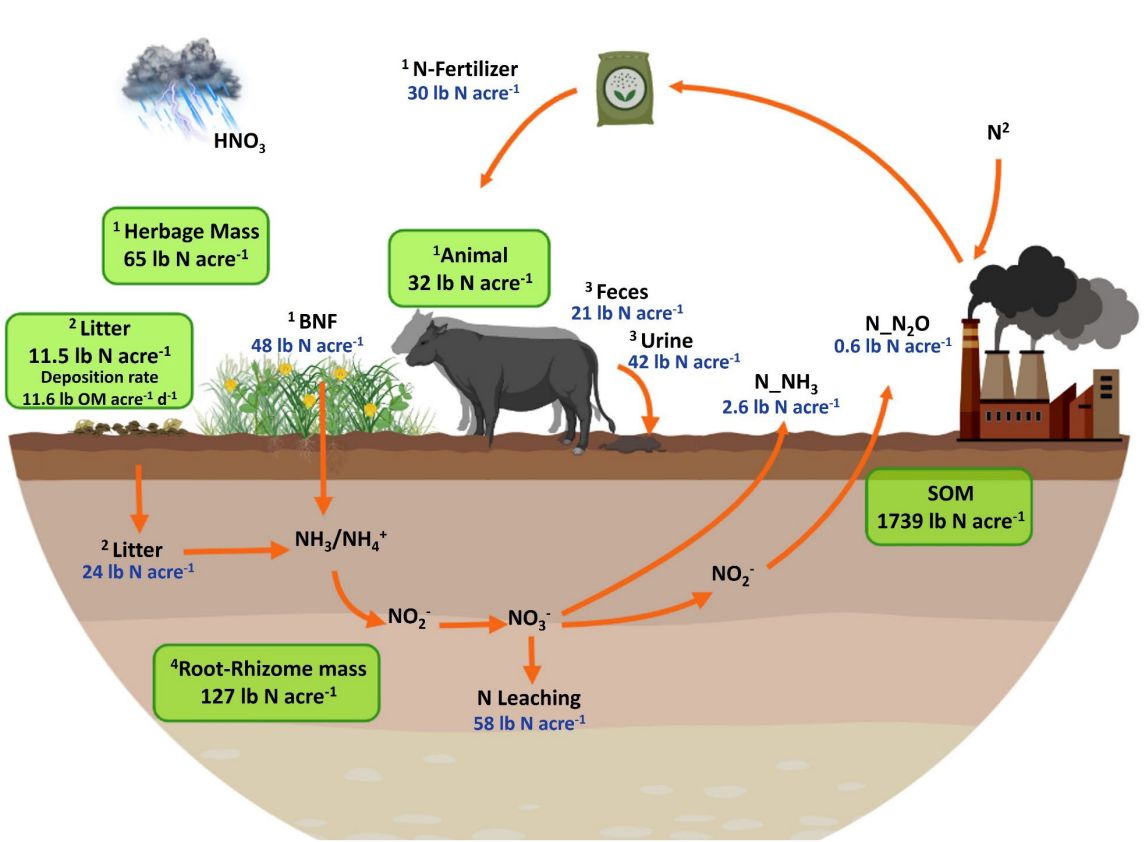
van Cleef et al. (2022)

Putting it all together

N-Fertilized Grass



Grass-Legume mixture



N-Fertilized grass (Cool and Warm Seasons)	
Average Daily Gain, lb hd^{-1} d^{-1}	1.3
Gain per Area, lb $Acre^{-1}$	552
Stocking Rate, AU $Acre^{-1}$	2.0
Gain per lb of N input	2.8

GrassLegume Mixtures (Cool and Warm Seasons)	
Average Daily Gain, lb hd^{-1} d^{-1}	1.5
Gain per Area, lb $Acre^{-1}$	595
Stocking Rate, AU $Acre^{-1}$	1.5
Gain per lb of N input	7.6

Take Home Messages

- Forage legumes are key to enhance sustainability of forage livestock systems in SE USA
- Forage legumes adds N, enhance diet, and provide other ecosystem services
- Nitrogen cycling is more efficient when using BNF than N from fertilizer

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Thank you!