The integration of manure, soil, diet and animal management to reduce on farm GHG

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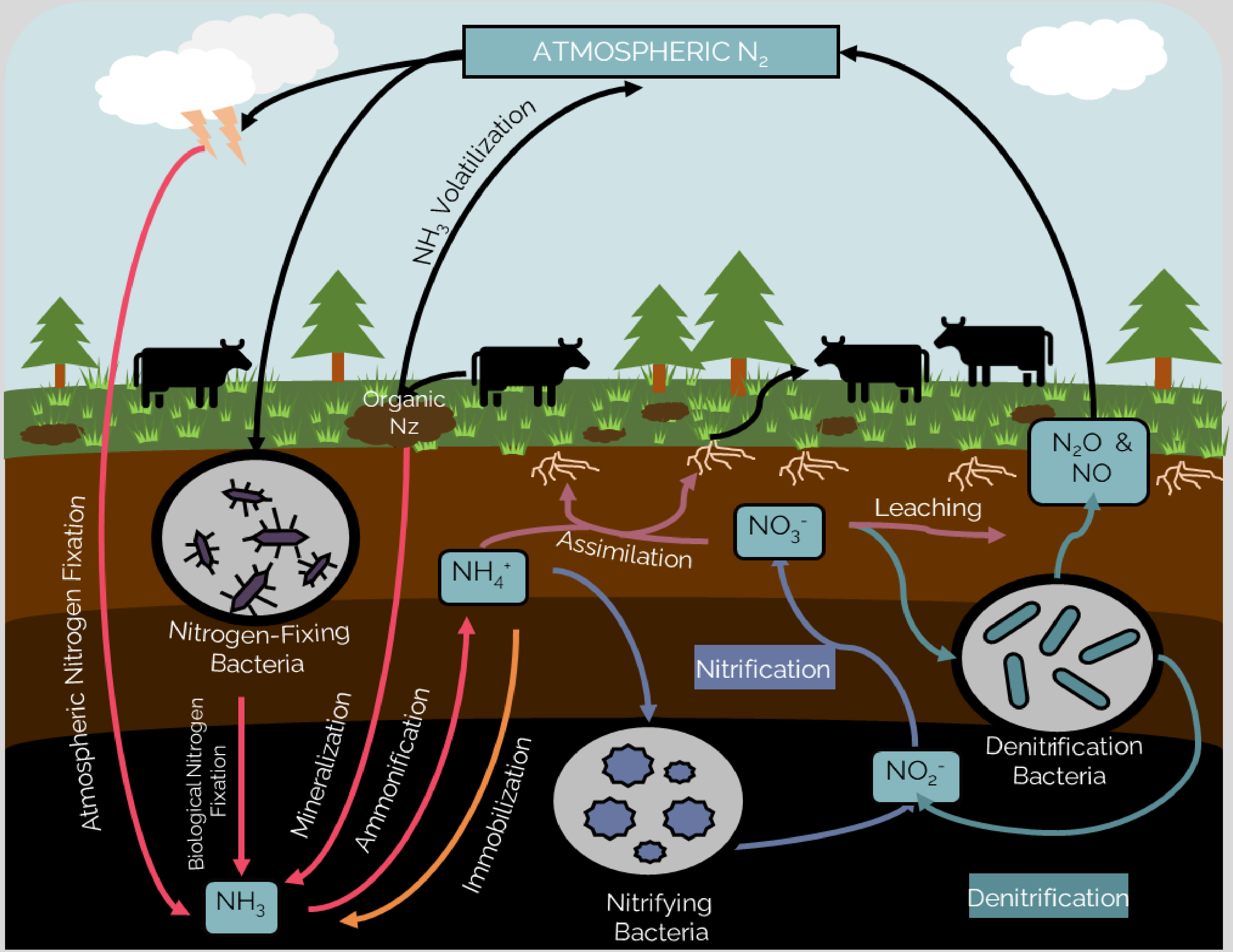
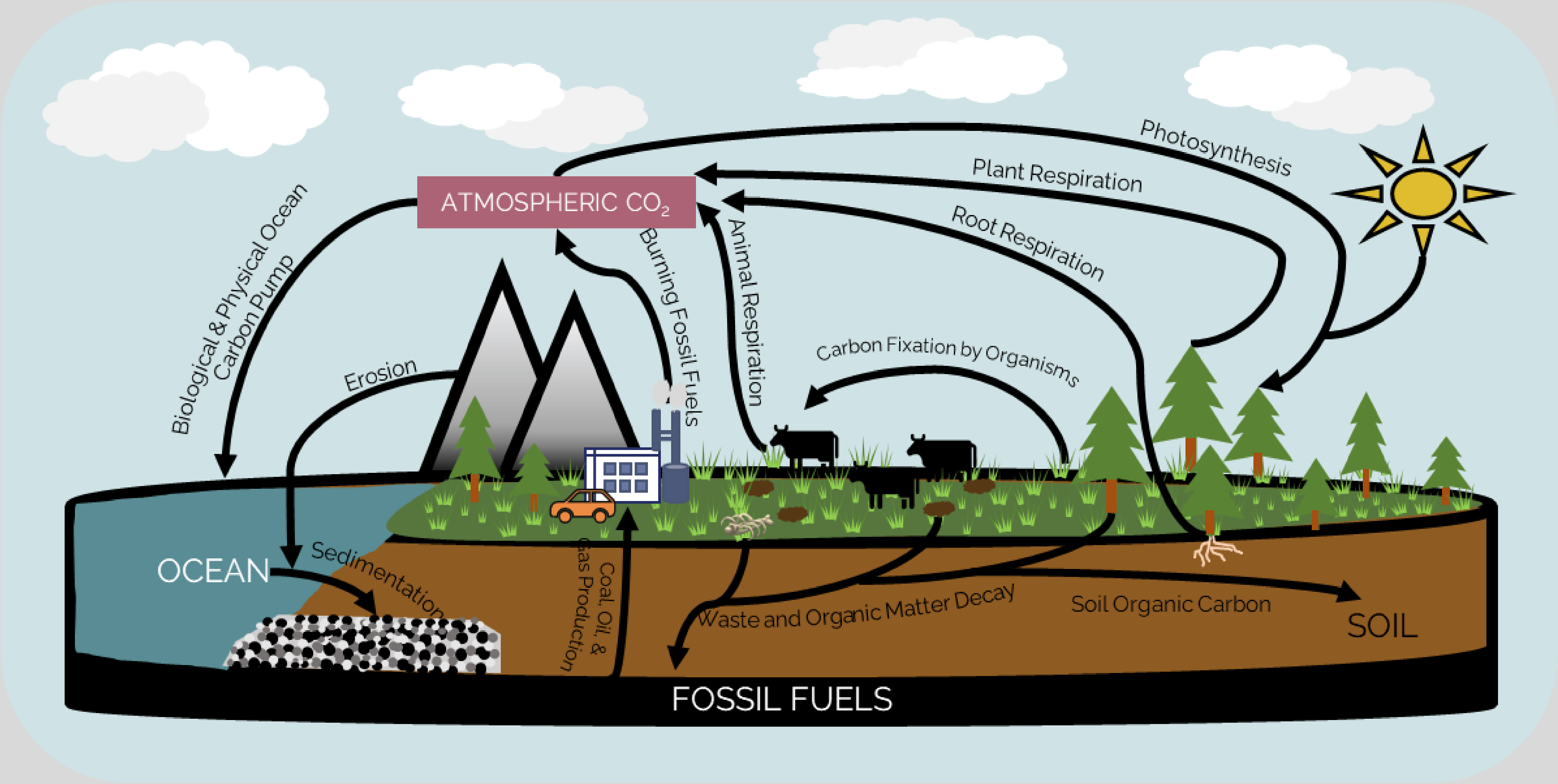
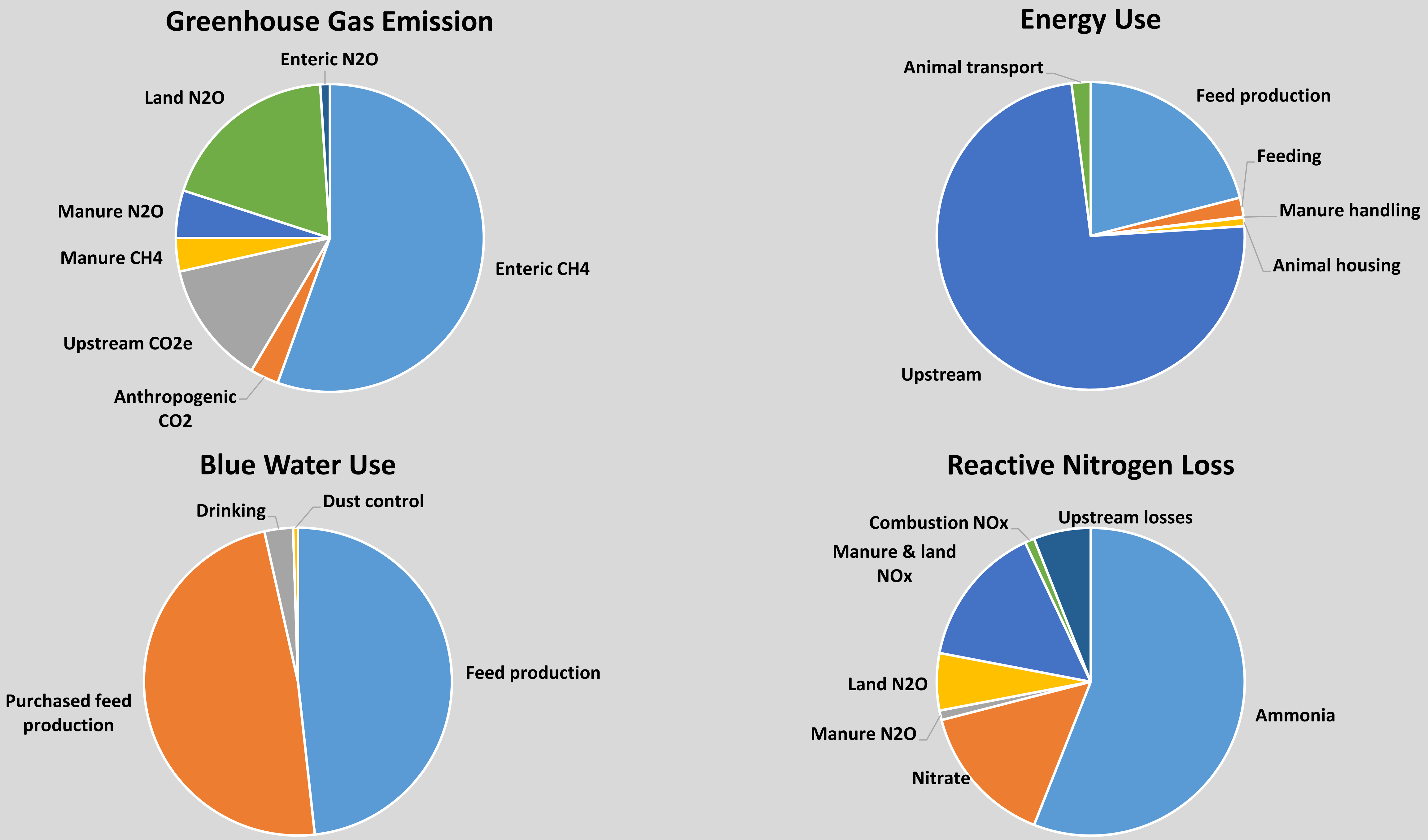
NITROGEN CYCLE



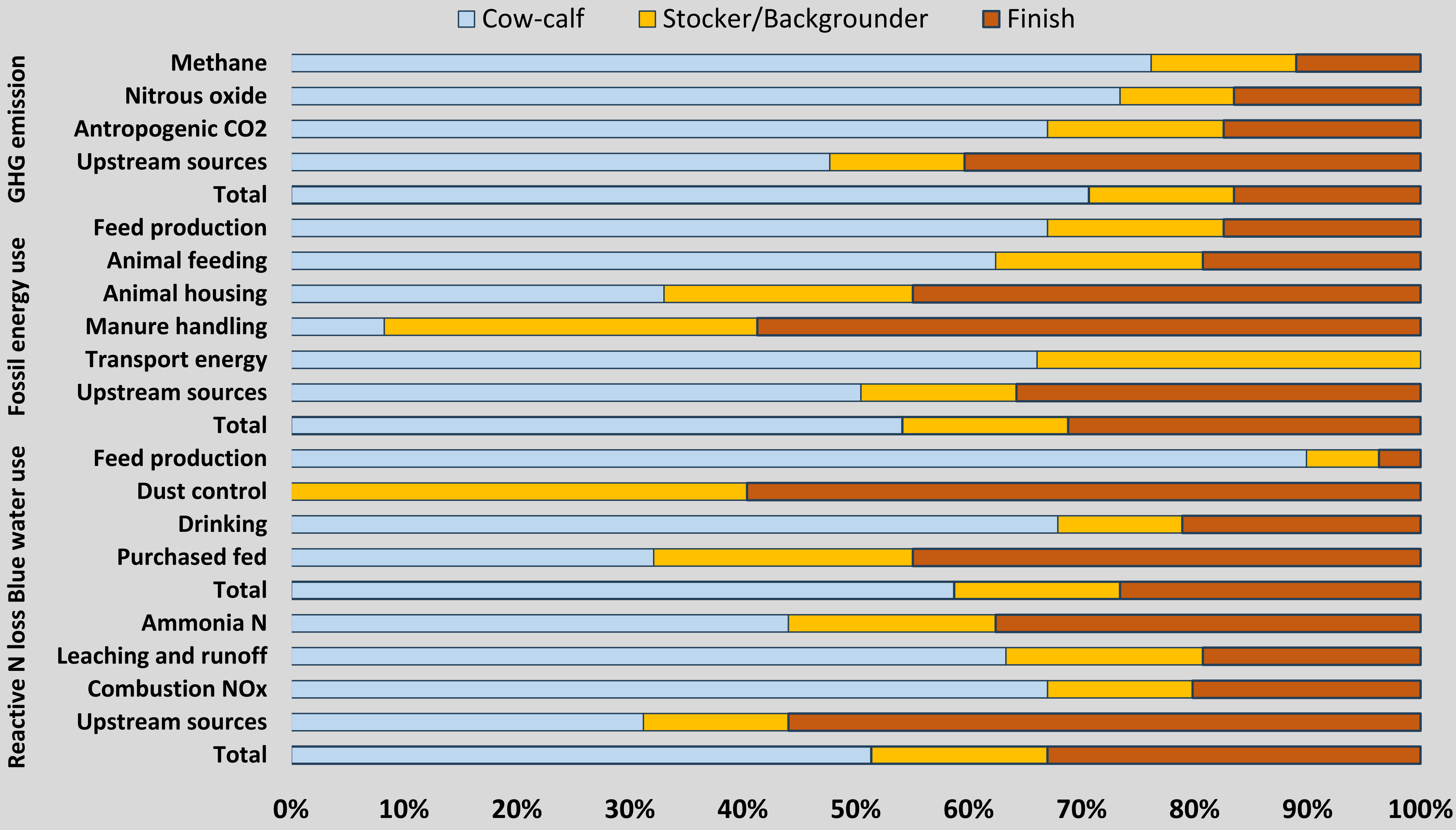
CARBON CYCLE





Rotz et al., 2019

Distribution of environmental impact sources across the three major phases of the beef cattle production life cycle



Rotz et al., 2019

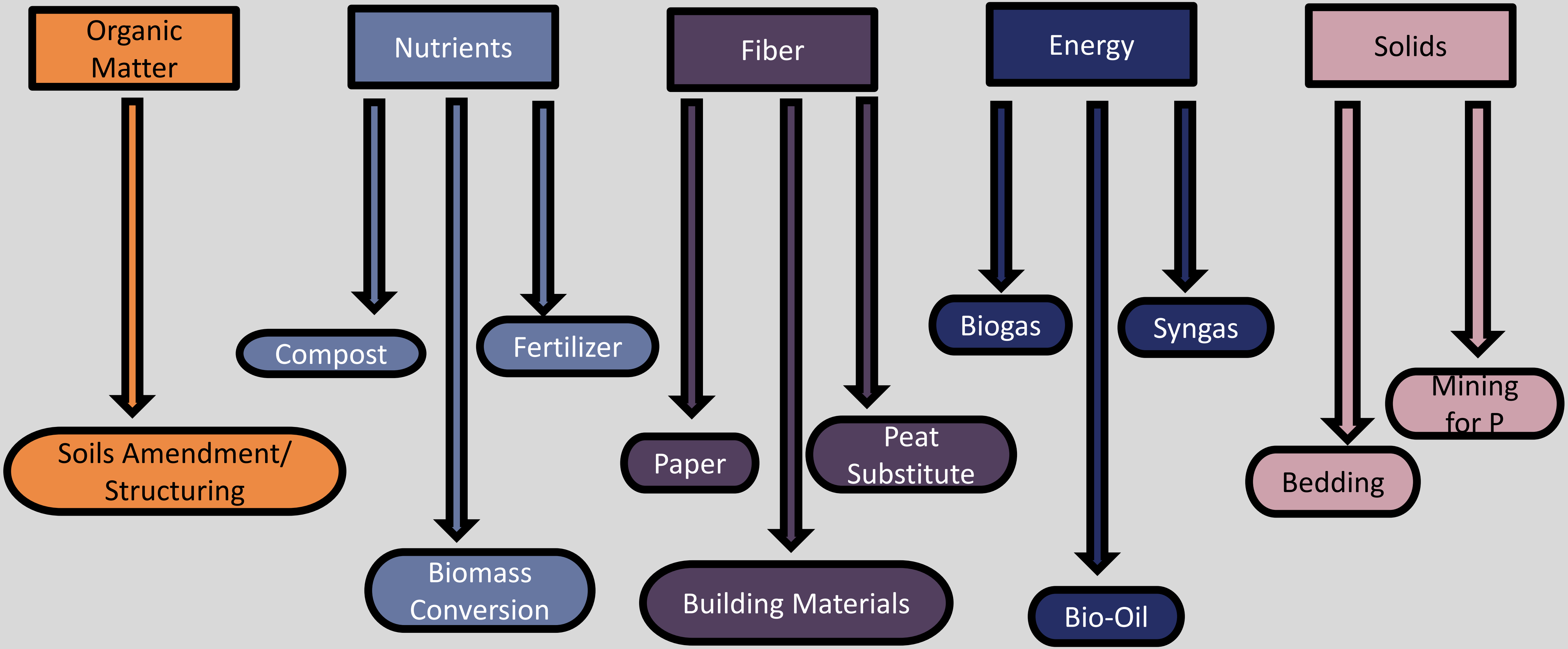
Reduction in enteric CH_4 emissions

- Improved digestibility of feed
- Feed additives
- Improvement in productivity/efficiency
- And others….many papers at this meeting

But there are trade offs……

- Manure emissions changed (e.g. digestors etc)
- Soil microbial population changes?
- Changes in types of fertilizer used (e.g. LCA)

MANURE BENEFITS



Adapted from EPA, 2015

ENVIRONMENTAL CONCERNS FROM MANURE

Anaerobic decomposition of manure increases odorous compounds) (Pfost et al., 2018)

Manure accounts for 14 % of GHG emission within the agriculture sector in the US (EPA, 2021)

20-45 % of the N in a lagoon lost as NH_3 (Rotz and Leytem, 2015)

P and K build up in lagoon sludge (Sharara and Kulesza, 2020)

Photo courtesy of Jael Batty at Probiotic Solutions

TYPES OF MANURE HANDLING ON DAIRIES

Aerobic Handling

Photo courtesy of WSU

Anaerobic Handling

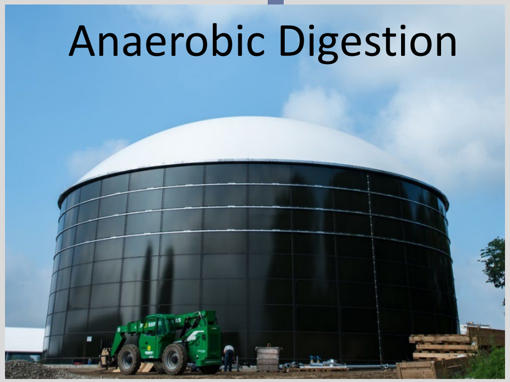
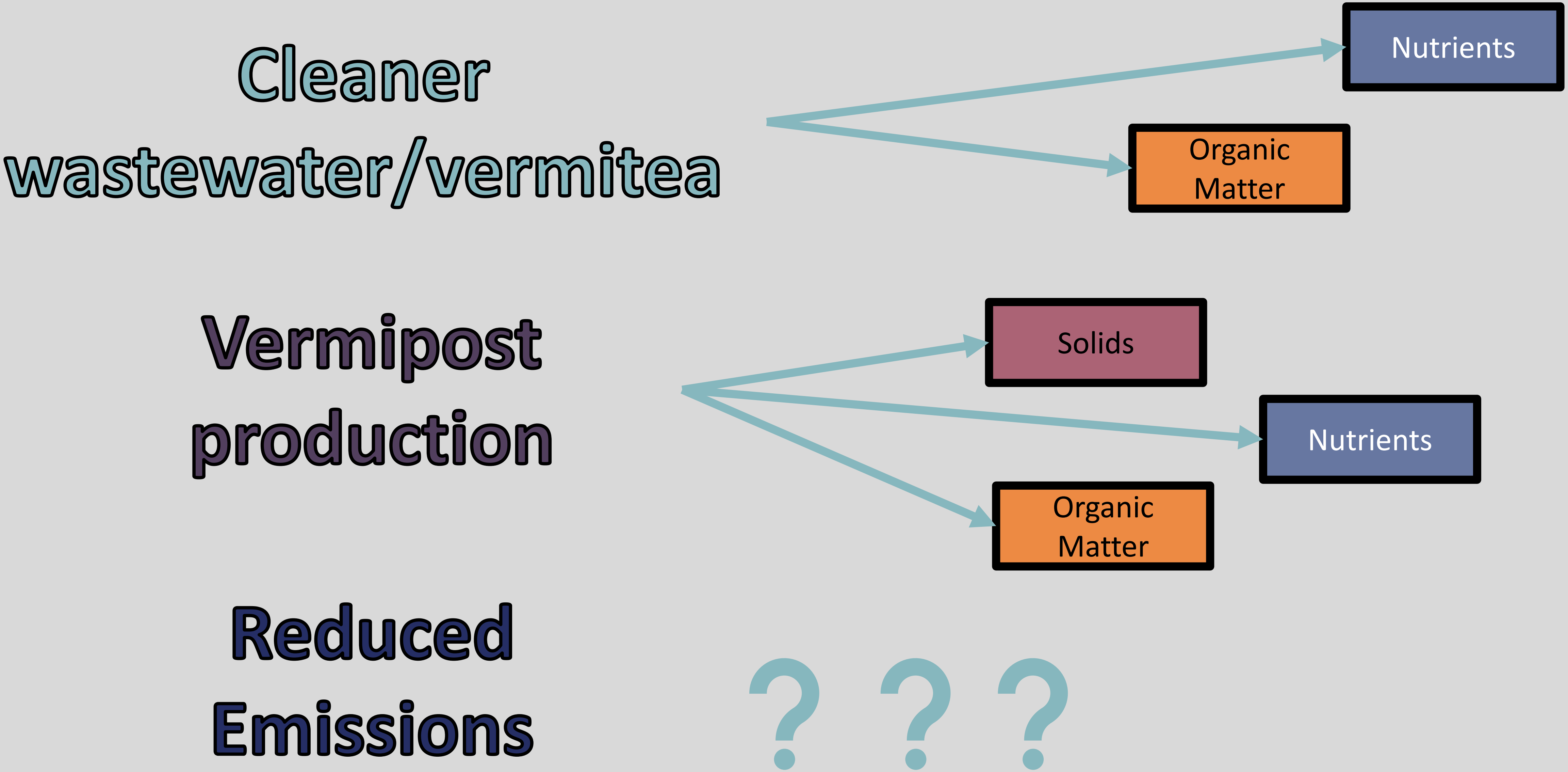


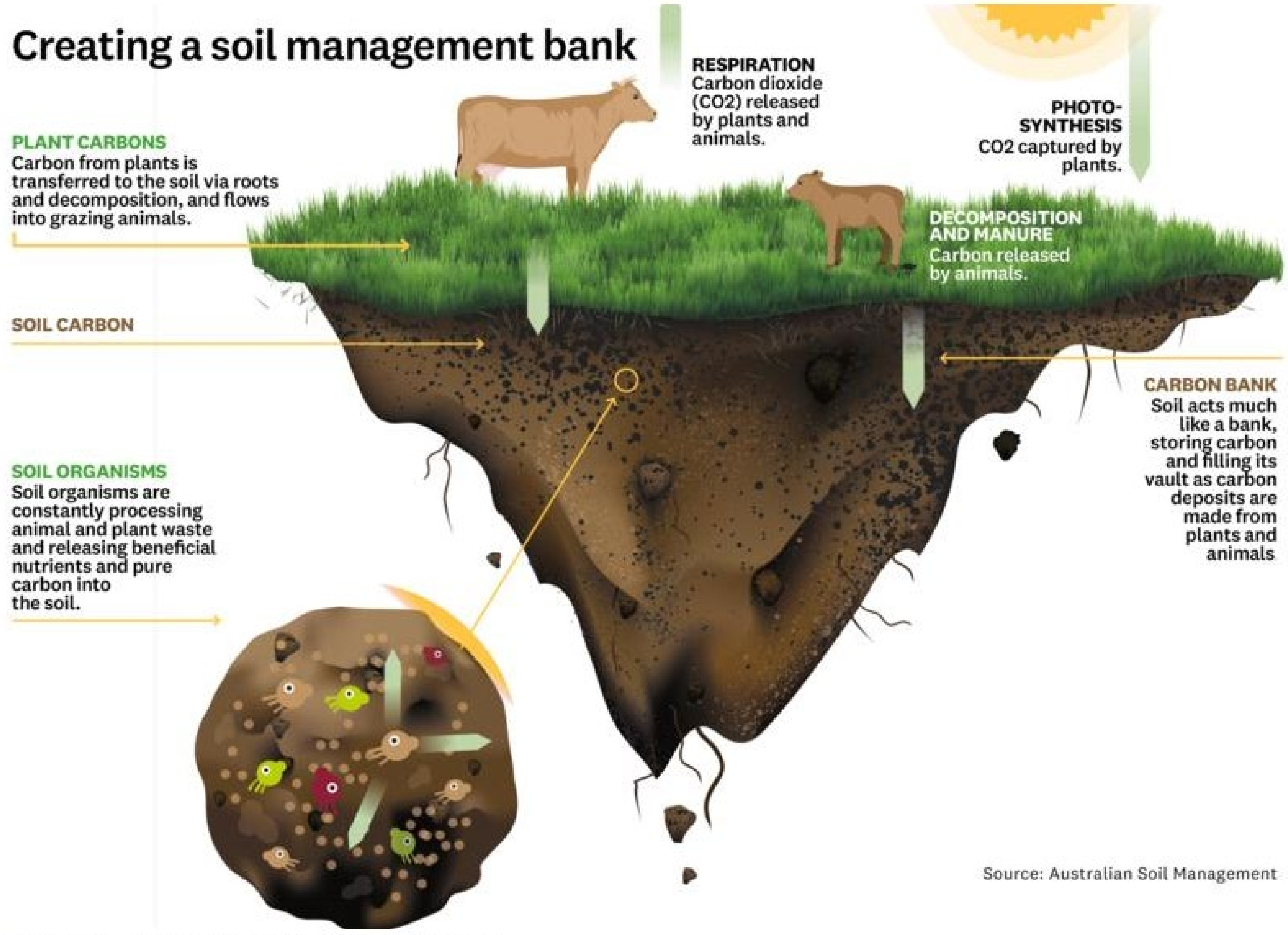
Photo courtesy of Michigan State University

Photo courtesy of UC-Davis

Photo courtesy of Lawn Care

POTENTIAL VERMIFILTRATION BENEFITS

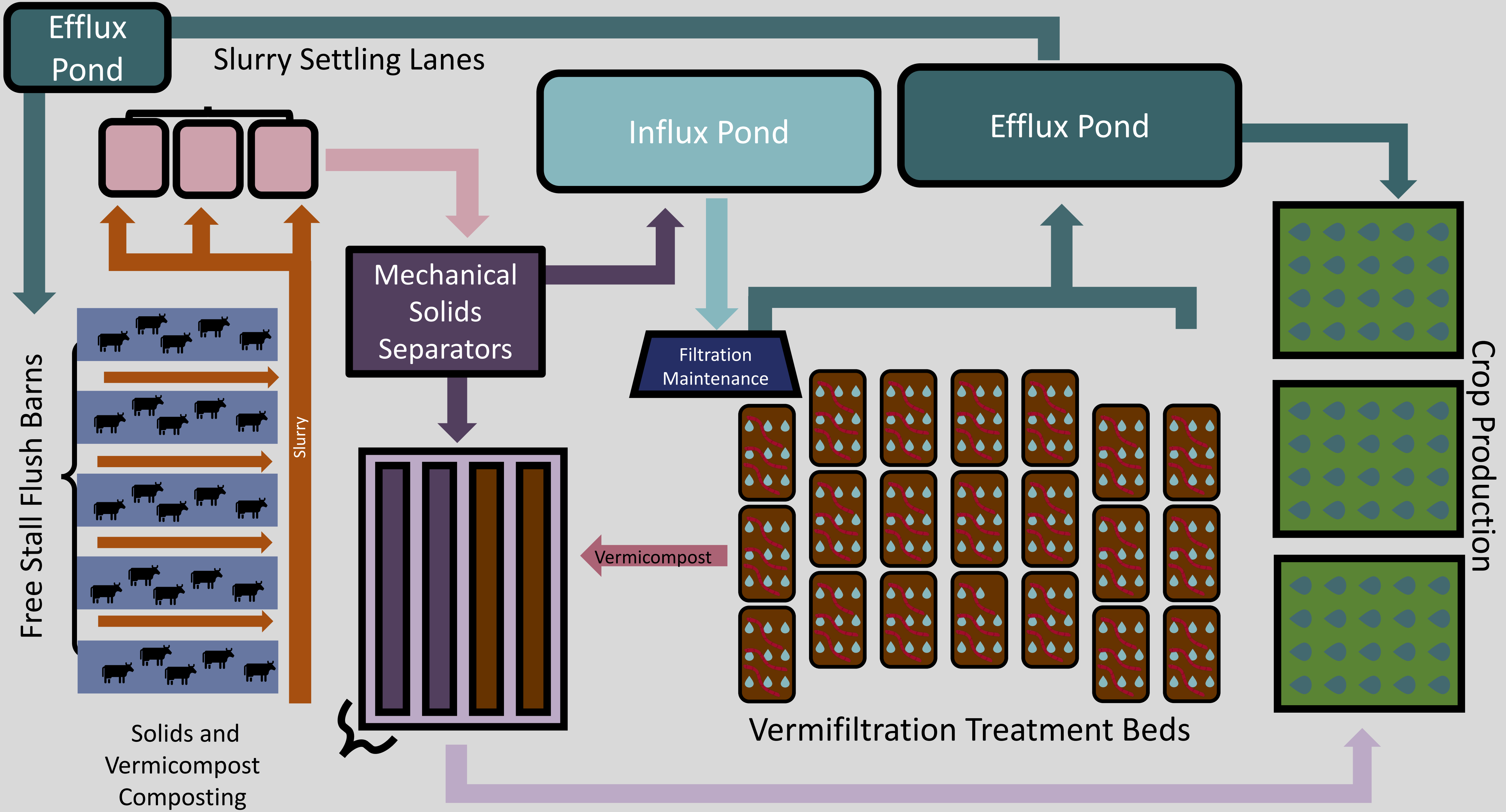




How to create a soil management bank to assist with carbon grazing.

https://nswfarmers.org.au/NSWFA/Posts/The_Farmer/Environment/Improving_pasture_growth_with_carbon_grazing.aspx

VERMIFILTRATION SYSTEM



VERMIFILTRATION EFFECTS ON LIQUID CATTLE MANURE

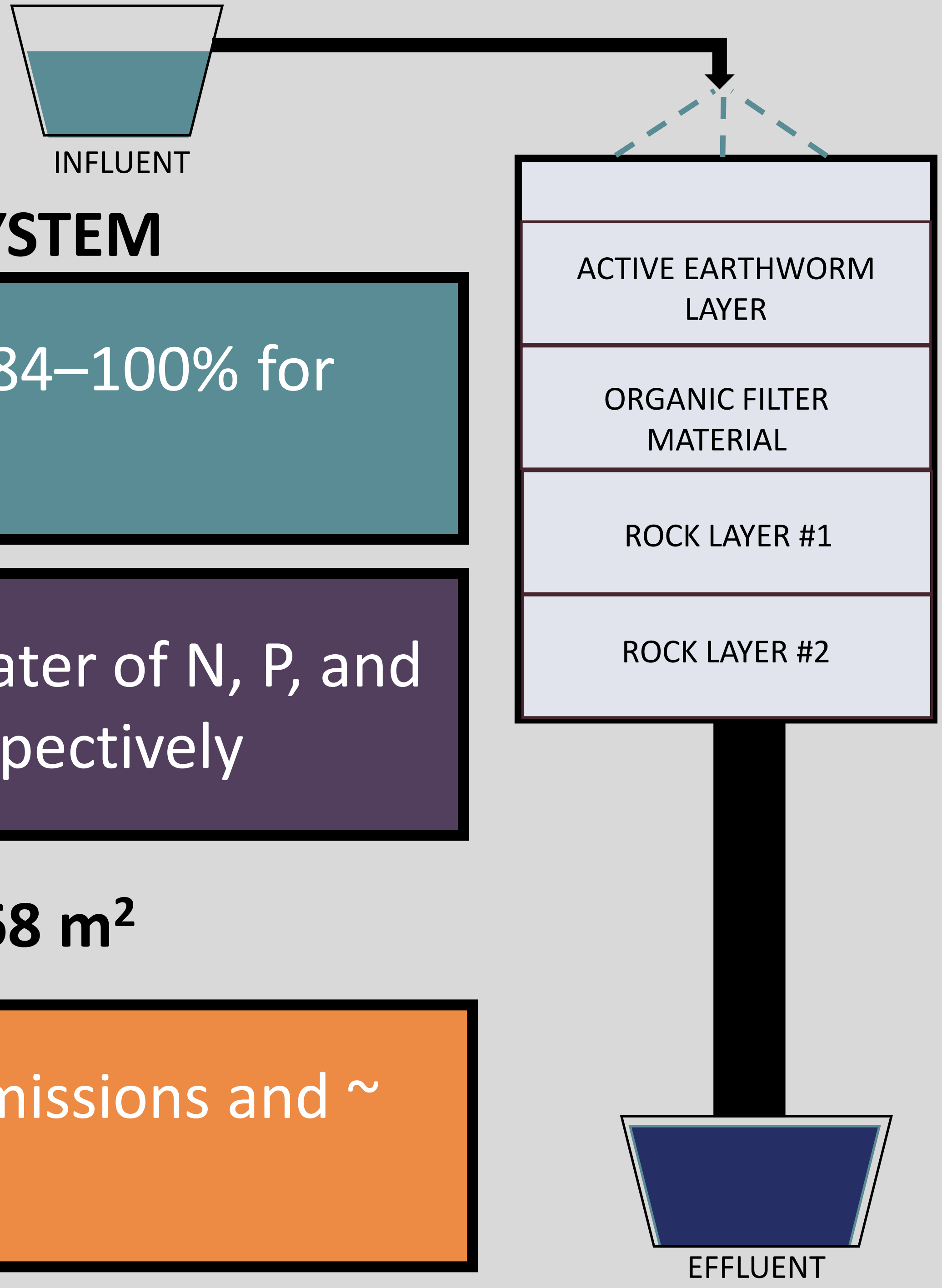
SHIPPING CONTAINER VERMIFILTRATION SYSTEM

Miito et al. (2022)--emission reductions of 84–100% for NH_3, 95–100% for CH_4

Miito et al. (2021)--reductions in effluent water of N, P, and suspended solids by 77%, 48% and 68%, respectively

SMALL SCALE VERMIFILTRATION SYSTEM ~68 m^2

Dore et al. (2022)-- 97% reduction in CH_4 emissions and ~ 83.5% reduction in N and P in effluent



QUESTIONS TO ADDRESS

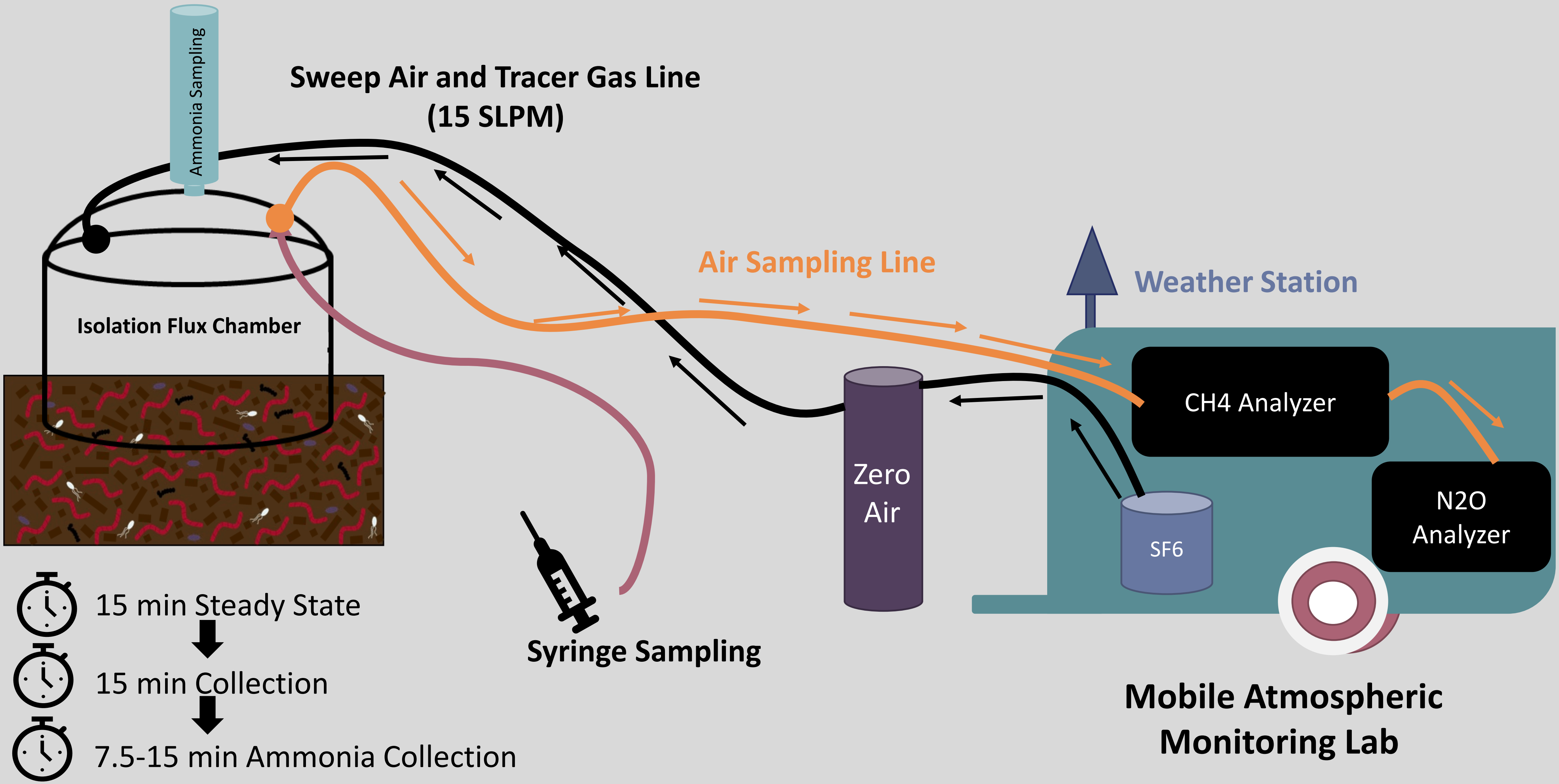
How does ambient temperature affect gas fluxes?

What is the variability across a vermifiltration system?

How does the process affect the chemical and physical components of liquid manure?

VERMIFILTRATION BED SAMPLING

GHG AND AMMONIA MEASUREMENTS



GHG AND AMMONIA EMISSION CALCULATIONS

$$E_{gas} = Q_s\left(\frac{C_T}{C_{Chamber\ T}}\right) C_{Chamber\ gas} - Q_s C_{s(gas)} - \left[\left\{Q_s\left(\frac{C_T}{C_{Chamber\ T}}\right) - Q_{s}\right\} C_{A(gas)}\right]$$

E_{gas}= emission rate or gas
Q_s = Zero air flow rate
C_T = Expected concentration of SF_6 3200 ppt
$C_{Chamber\ T}$ = measured SF_6 from syringe sample
$C_{Chamber\ gas}$ = measured gas (N_2O, CH_4, NH_3) from syringe
C_s ($_{gas}$) = measured gas (N_2O,CH_4, NH_3) in zero air
$C_{A\ (gas)}$ measured gas (N_2O, CH_4, NH_3) in ambient air

STATISTICAL ANALYSIS

SAS: Proc Mixed
Split Plot Design
Evaluated effect of temperature, bed, and bed by ambient temperature

ENVIRONMENTAL CONDITIONS

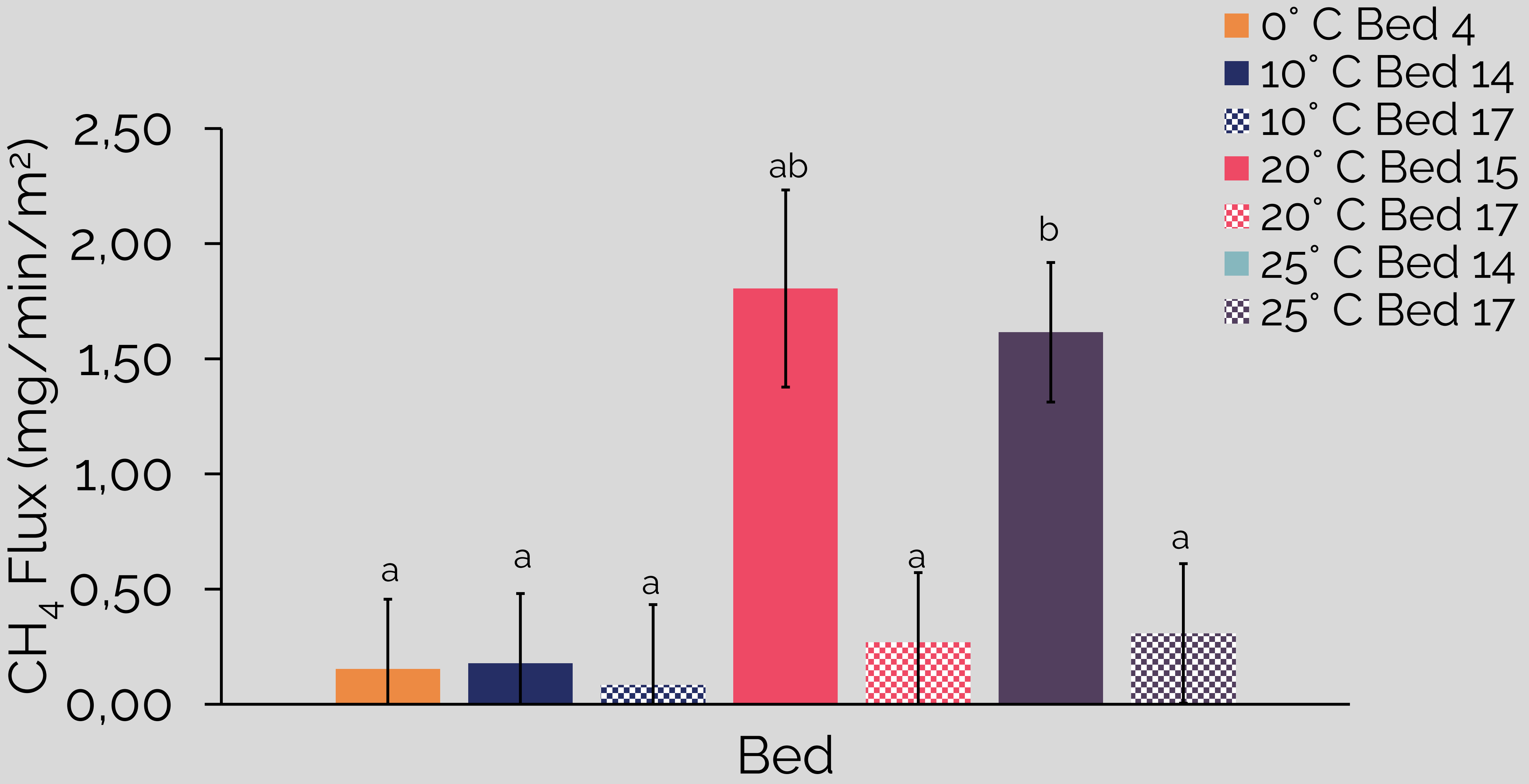
0 °C	Min	Max	Average
Windspeed, m/s	0.3	3.8	1.8
Temperature, °C	0.8	2.7	2.0
Relative Humidity, %	53.0	65.3	58.1
Pressure, hPa	983.9	984.6	984.1

20 °C	Min	Max	Average
Windspeed, m/s	0.1	5.8	2.3
Temperature, °C	20.2	25.2	22.5
Relative Humidity, %	38.4	60.0	48.5
Pressure, hPa	957.8	959.5	958.9

10 °C	Min	Max	Average
Windspeed, m/s	0.1	4.8	1.6
Temperature, °C	4.6	13.6	9.9
Relative Humidity, %	32.3	58.0	42.1
Pressure, hPa	978.0	981.2	979.8

25 °C	Min	Max	Average
Windspeed, m/s	0.3	8.2	2.6
Temperature, °C	19.6	25.6	23.5
Relative Humidity, %	34.2	63.1	43.6
Pressure, hPa	968.1	969.1	968.8

CH_4 FLUXES BY AMBIENT TEMPERATURE & BED



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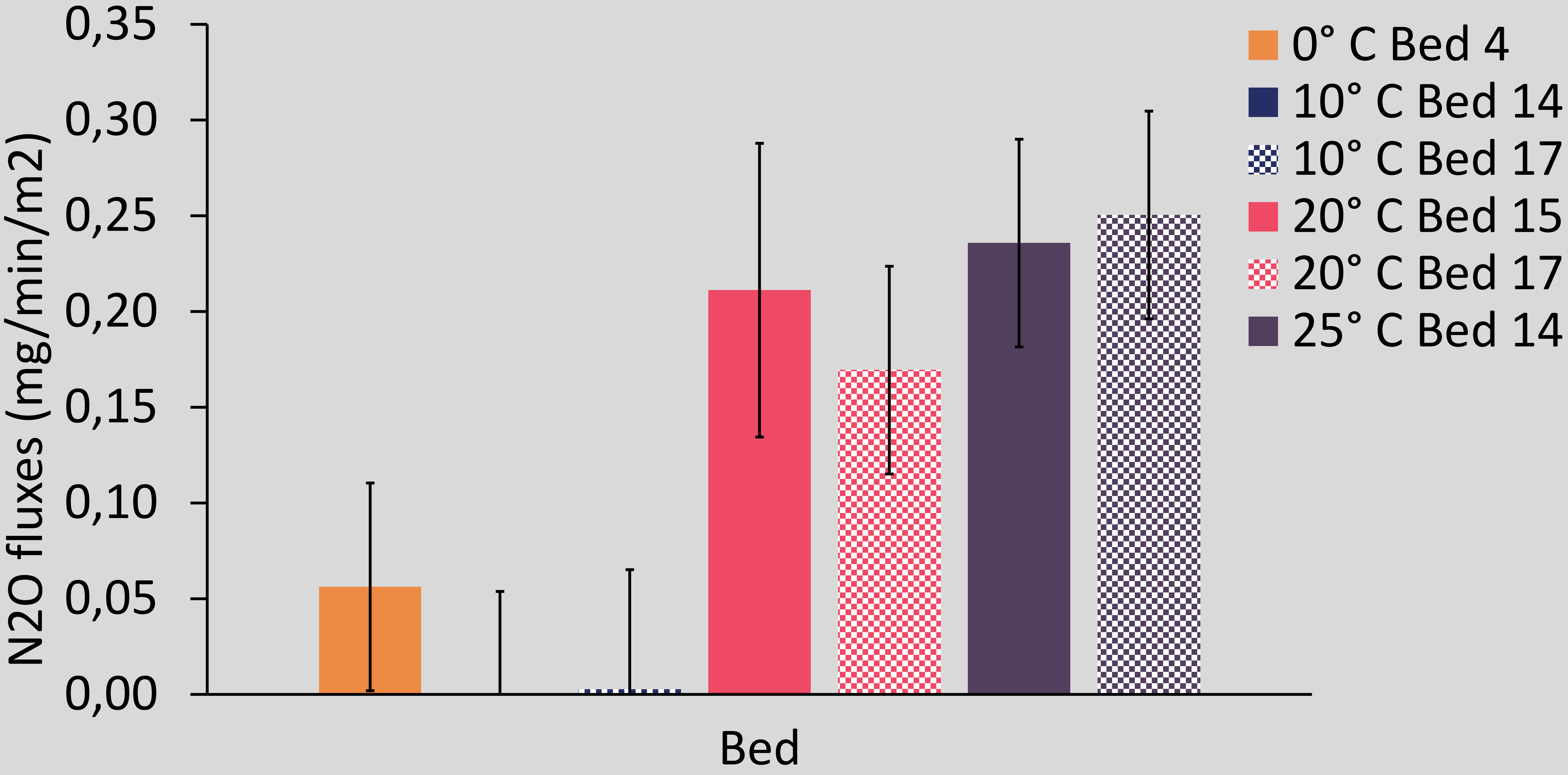
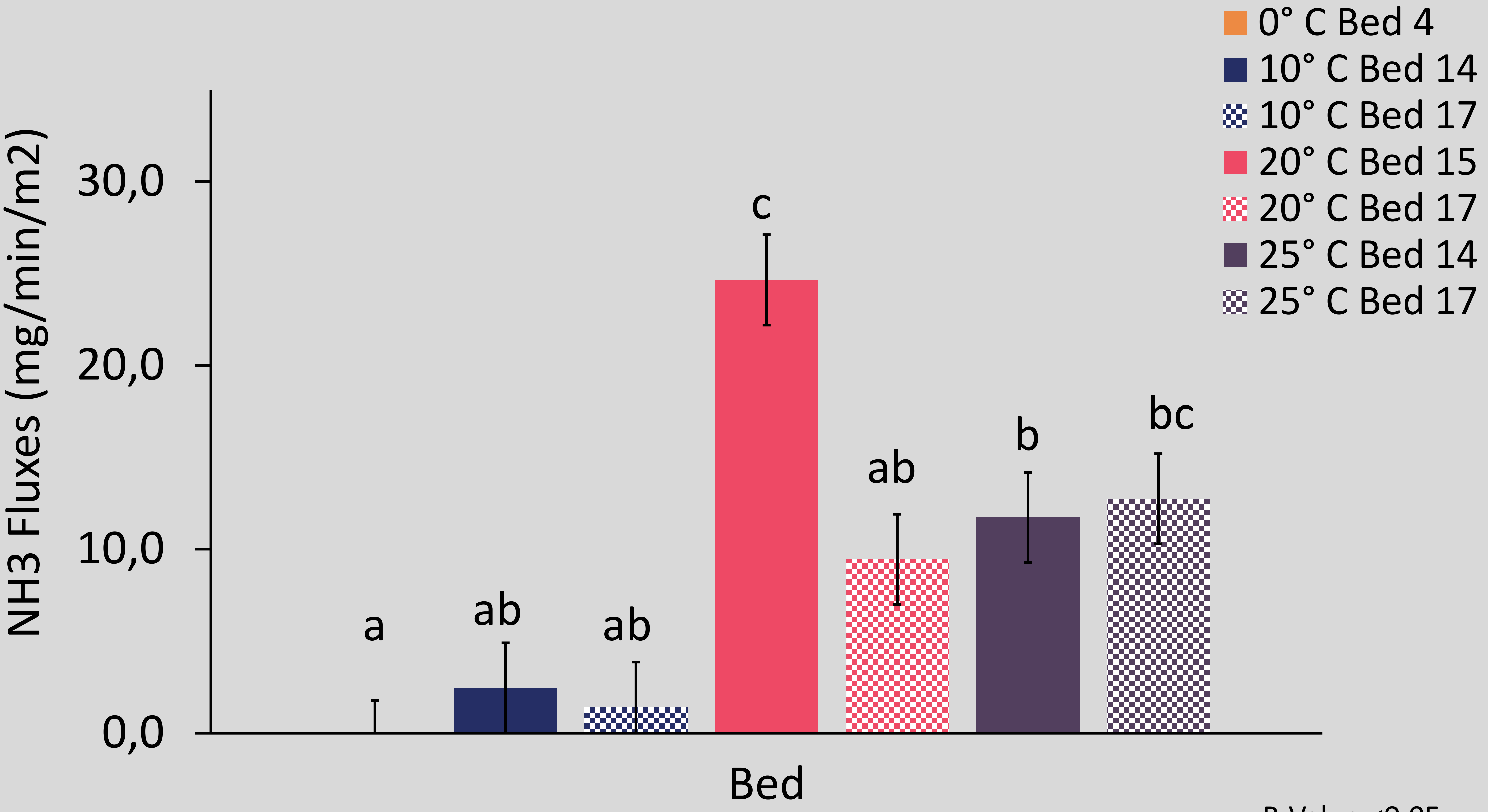
N_2O FLUXES BY AMBIENT TEMPERATURE & BED



P-Value <0.05

NH_3 FLUXES BY AMBIENT TEMPERATURE & BED



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SUMMARY OF GHG and NH_3 EMISSIONS

ESTIMATED YEARLY EMISSIONS FROM 3 HA WORM BEDS

Ambient Temperature	Days in Temperature Period	NH_3 metric tons	CH_4 metric tons CO_2-eq	N_2O metric tons CO_2-eq
0° C	57	0.06	10.23	36.60
10° C	113	9.14	18.16	1.05
20° C	107	76.37	97.96	224.21
25° C	88	44.46	99.19	244.53
TOTAL	**365**	**130.03**	**225.55**	**506.39**

ESTIMATED YEARLY EMISSIONS FROM LAGOON SYSTEM SCALED TO 3 HA

Ambient Temperature	Days in Temperature Period	NH_3 metric tons	CH_4 metric tons CO_2-eq	N_2O metric tons CO_2-eq
0° C	57	3.50	902.18	384.61
10° C	113	7.18	15,030.96	444.03
20° C	107	5.10	5,685.30	101.93
25° C	88	4.20	4,675.76	83.83
TOTAL	**365**	**19.98**	**26,294.20**	**1,014.39**
		85%	**100%**	**55%**

(LEYTEM ET AL., 2011)

NITROGEN AND PHOSPHOROUS COMPOSITION IN INFLUENT/EFFLUENT

NITROGEN

Sample ID	TEMPERATURE (°C)	Organic N ppm	%	Ammonium (NH_4^+) ppm	%	Nitrate (NO_3^-) ppm	%	Total N ppm	%
INFLUENT	0	141.7[a]	54%	498.0[a]	75%	0.6[a]	83%	640.3[a]	71%
EFFLUENT	0	65.0[a]		122.4[b]		1.1[a]		188.5[b]	
INFLUENT	10	552.8[a]	79%	931.6[a]	90%	0.2[a]	50%	1,484.5[a]	86%
EFFLUENT	10	114.4[a]		97.5[b]		0.1[a]		212.1[b]	
INFLUENT	20	532.3[a]	64%	657.1[a]	61%	1.2[a]	83%	1,190.6[a]	62%
EFFLUENT	20	193.9[a]		258.8[b]		0.2[a]		452.9[b]	
INFLUENT	25	722.5[a]	41%	644.2[a]	72%	0.3[a]	0%	1,367.0[a]	56%
EFFLUENT	25	422.8[a]		180.9[b]		0.3[a]		604.0[b]	

PHOSPHOROUS

Sample ID	TEMPERATURE (°C)	Phosphate (P_2O_5) ppm	%	Orthophosphate (PO_4-P) (ppm)	%
INFLUENT	0	242.6[a]	72%	44.1[a]	68%
EFFLUENT	0	69.0[b]		14.1[b]	
INFLUENT	10	569.6[a]	87%	84.8[a]	83%
EFFLUENT	10	72.2[b]		14.3[b]	
INFLUENT	20	522.5[a]	77%	73.0[a]	67%
EFFLUENT	20	120.0[b]		24.3[b]	
INFLUENT	25	505.1[a]	51%	21.3[a]	21%
EFFLUENT	25	247.9[b]		25.8[b]	

CHEMICAL AND PHYSICAL CHANGES IN INFLUENT AND EFFLUENT

Potassium (K_2O), Sulfur (S), Calcium (Ca), Magnesium (Mg,), Sodium (Na), Zinc (Zn), Iron (Fe), Manganese (Mn), Copper (Cu), Boron (B), Soluble Salts, pH, Dry Matter, Organic Matter, Ash, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Volatile Suspended Solids (VSS), Total Solids, Total Carbon Organic Carbon, C: N

Ca, Mg, Zn, Fe, Mn, TSS, and Total C at O °C, 10 °C, 20 °C, and 25 °C

P value <0.05

MASS BALANCE

	INFLUX LAGOON		WORM BED EMISSIONS		WORM BED MATERIAL		EFFLUX LAGOON	ERROR
P	100%	=	0%	+	63%	+	29%	8%
K	100%	=	0%	+	9%	+	105%	-5%
C	100%	=	1%	+	53%	+	39%	7%
N	100%	=	26%	+	19%	+	30%	25%

CONCLUSION

Vermifiltration is a “low-cost” technology to treat liquid dairy waste that reduced CH_4 and N_2O emissions, but increases NH_3 emission compared to literature values

Vermifiltration alters wastewater components

Dairies may participate in carbon markets and vermicompost sales

FUTURE WORK

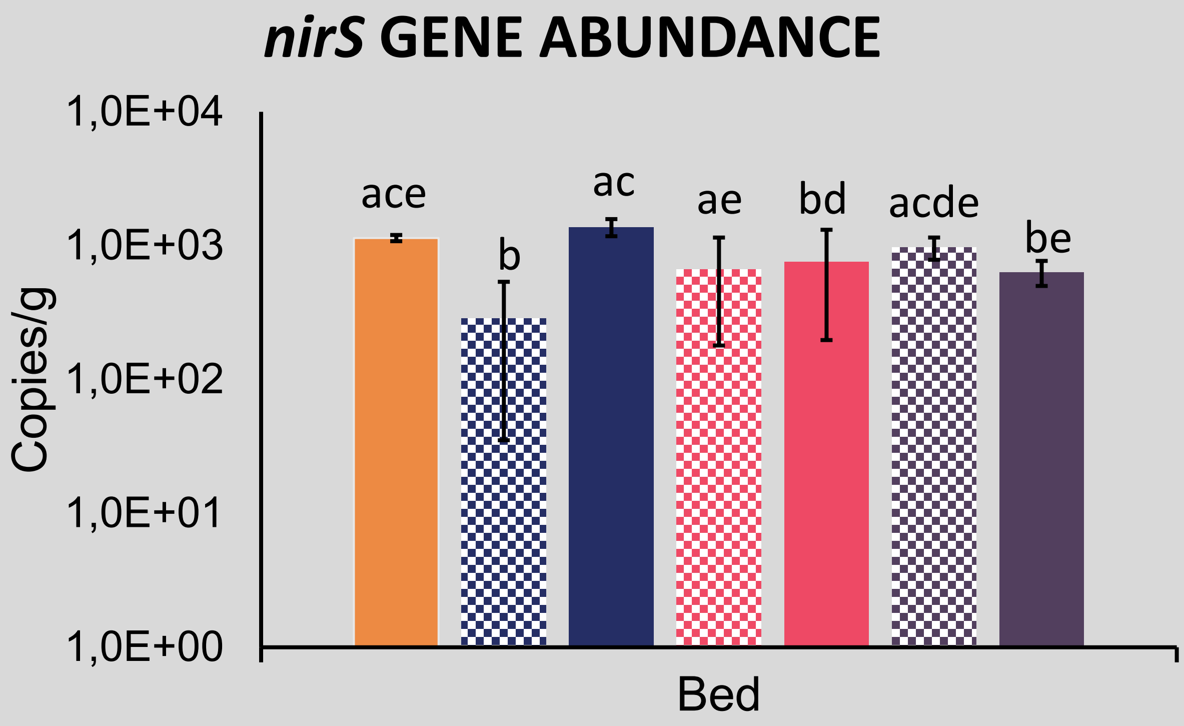
Implement technologies to mitigate NH_3 e.g. lower pH of influent or addition of biochar

Create a whole farm emission profile with diet/management changes

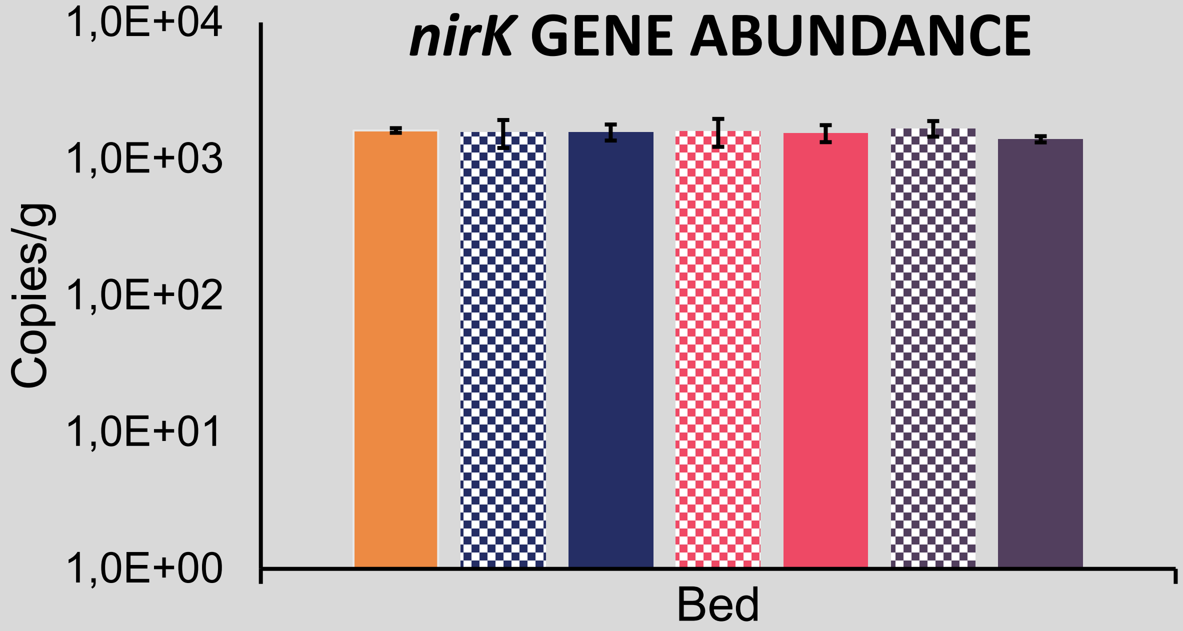
The whole farming enterprise must be examined when considering mitigation strategies so reduction in one species does not inadvertently result in higher emissions of another pollutant.

CHEMICAL AND PHYSICAL PROPERTIES IN VERMIFILTRATION BED MATERIAL AND VERMICOMPOST

Item	BED MATERIAL		VERMIPOST	
	Average	SE	Average	SE
Organic N %	1.86[a]	0.09	3.14[b]	0.33
Ammonium (NH_4^+) %	0.02[a]	0.01	0.01[a]	0.02
Nitrate (NO_3^-) %	0.01[a]	0.00	0.17[b]	0.00
Total N %	1.88[a]	0.09	3.32[b]	0.33
Phosphate (P_2O_5) %	2.67[a]	0.15	4.52[b]	0.55
Orthophosphate (PO_4-P) %	0.11[a]	0.01	0.17[a]	0.05
Potassium (K_2O) %	1.76[a]	0.20	2.36[a]	0.73
Sulfur (S) %	0.49[a]	0.03	1.00[b]	0.10
Calcium (Ca) %	6.04[a]	0.54	7.08[a]	1.96
Magnesium (Mg) %	1.69[a]	0.10	1.39[a]	0.35
Molybdenum (Mo) %	2.75[a]	0.54	3.52[a]	1.94
Sodium (Na) %	0.69[a]	0.10	0.45[a]	0.35
Zinc (Zn) ppm	276.72[a]	14.93	496.80[b]	53.87
Iron (Fe) ppm	5880.80[a]	513.24	5556.70[a]	1850.53
Manganese (Mn) ppm	334.84[a]	14.81	668.70[b]	53.39
Copper (Cu) ppm	48.78[a]	1.95	76.10[b]	7.03
Boron (B) ppm	53.62[a]	2.31	72.10[a]	8.33
Soluble Salts mnho/cm	23.81[a]	3.80	49.66[a]	13.69
pH	9.24[a]	0.17	8.10[a]	0.63
Ash %	35.22[a]	1.93	39.40[a]	6.97
Organic Matter %	64.78[a]	1.93	60.60[a]	6.97
Moisture %	73.37[a]	0.83	58.28[b]	2.98
Dry Matter %	26.63[a]	0.83	41.72[b]	2.98
Organic Carbon %	37.57[a]	1.12	35.15[a]	4.04
C: N Ratio	22.12[a]	1.12	11.20[b]	4.04
Total Carbon %	31.46[a]	1.09	32.51[a]	3.94



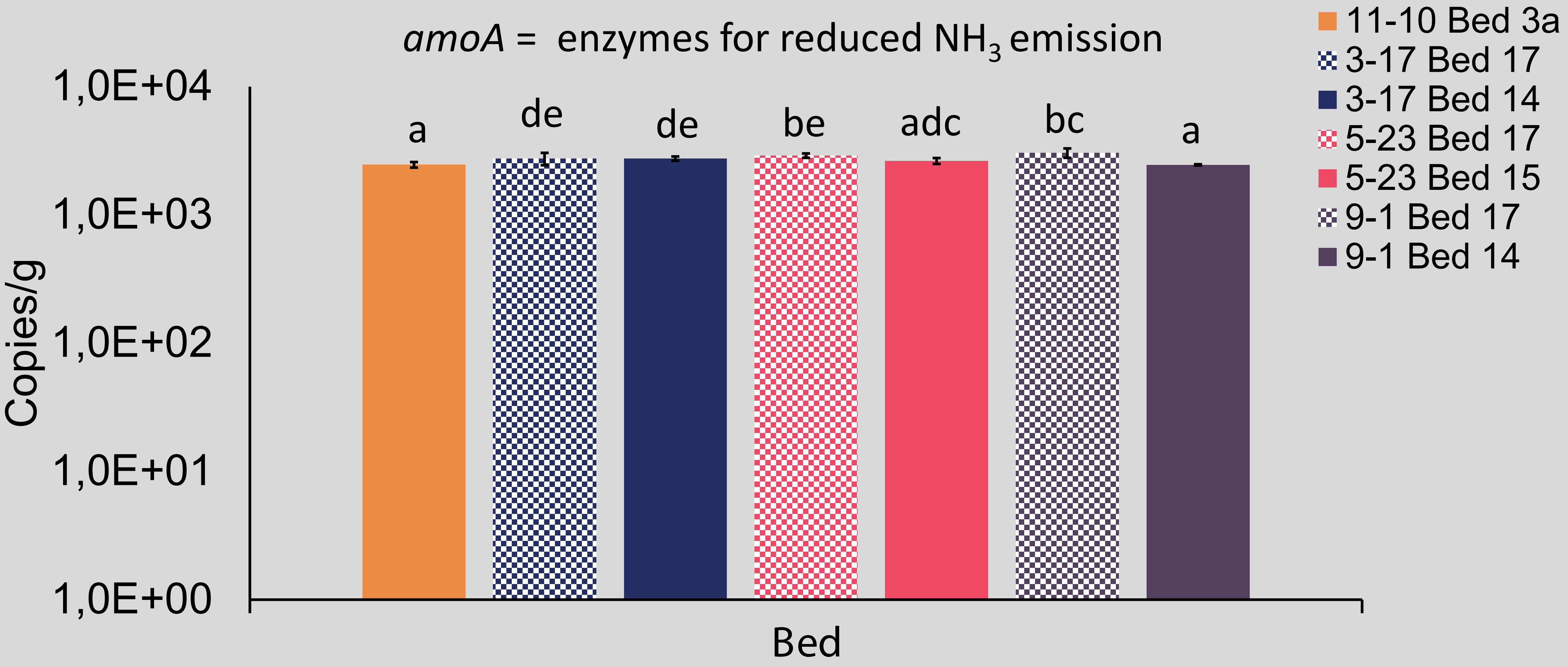
Nir genes = enzymes for nitrite to NO gas



(Falcon et al., unpublished)

P-Value <0.05

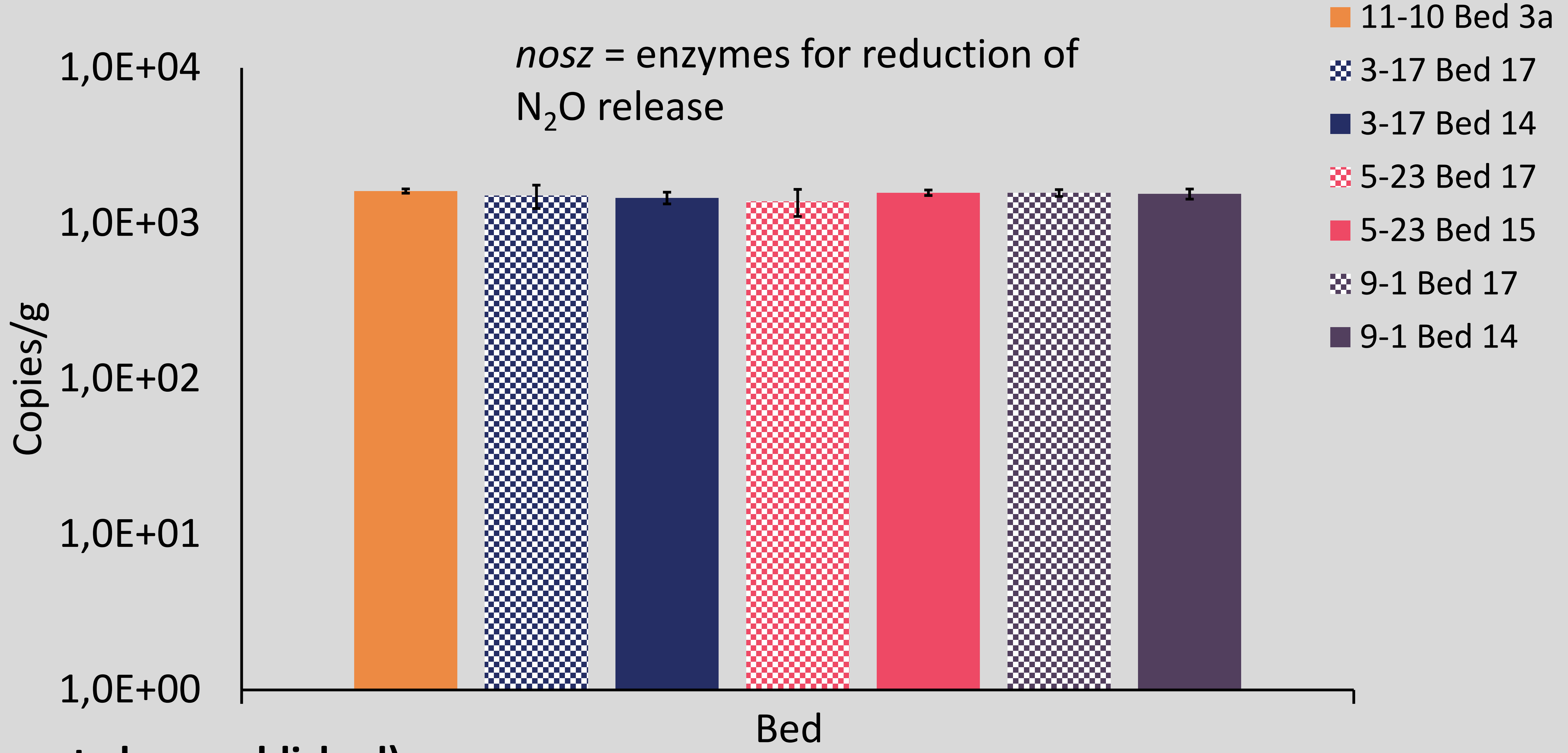
amoA GENE ABUNDANCE IN WORM BEDS



P-Value <0.05

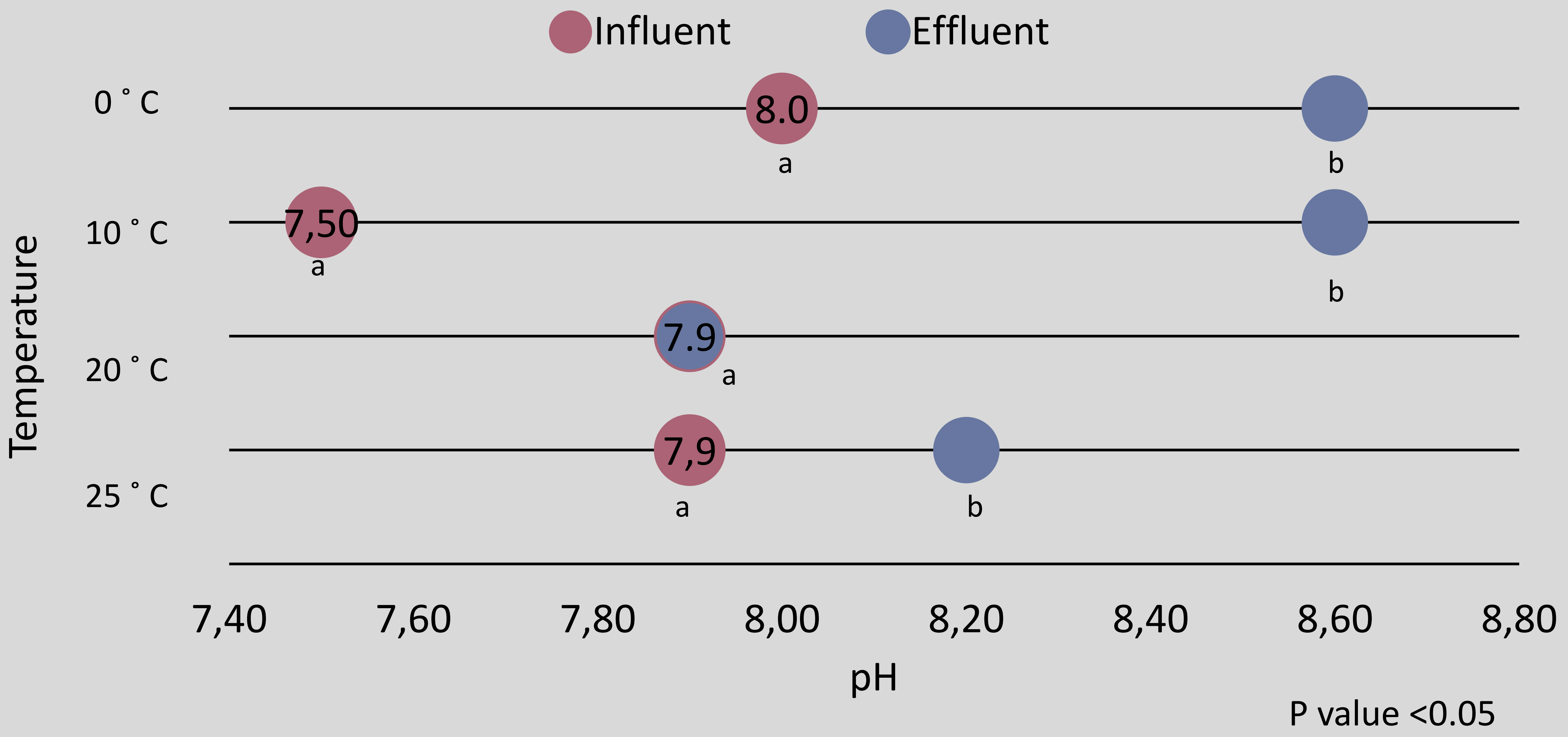
(Falcon et al., unpublished)

nosZ GENE ABUNDANCE IN WORM BEDS



(Falcon et al., unpublished)

VARIATION IN pH IN INFLUENT AND EFFLUENT WATER



SOLID AND LIQUID CHEMICAL COMPOSITION & ANALYSIS

Statistical Analysis
SAS Proc Mixed
ANOVA procedure