

CO_2 and CH_4 emissions from agricultural soil, and dairy cattle

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Why are we interested in gas emissions?

Global Warming Potential and Atmospheric Lifetime for Major Greenhouse Gases

Greenhouse gas	Chemical formula	Global Warming Potential, 100-year time horizon	Atmospheric Lifetime (years)
Carbon Dioxide	CO_2	1	100*
Methane	CH_4	25	12
Nitrous Oxide	N_2O	265	121
Chlorofluorocarbon-12 (CFC-12)	CCl_2F_2	10,200	100
Hydrofluorocarbon-23 (HFC-23)	CHF_3	12,400	222
Sulfur Hexafluoride	SF_6	23,500	3,200
Nitrogen Trifluoride	NF_3	16,100	500

SOURCE

Fifth Assessment Report (Intergovernmental Panel on Climate Change, 2014).

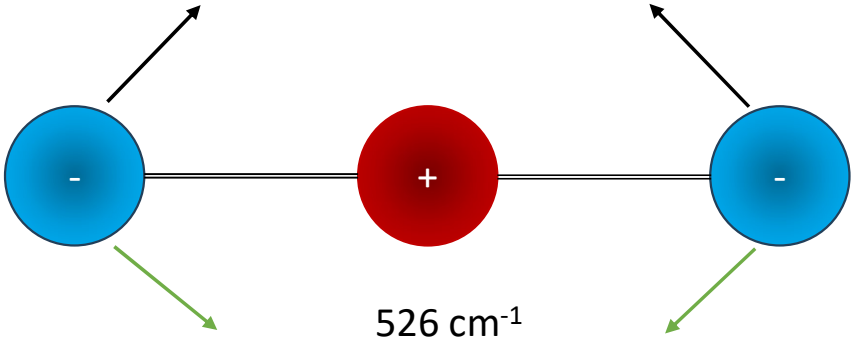
* No single lifetime can be given for carbon dioxide because it moves throughout the earth system at differing rates. Some carbon dioxide will be absorbed very quickly, while some will remain in the atmosphere for thousands of years.

Which molecule is missing in this table?

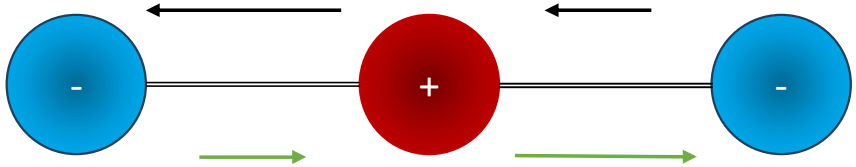
TROUT55/GETTY IMAGES

How do certain gases absorb/emit IR radiation?

- "Vibes" of molecules
- IR activity ↔ change of dipole moment!
- Example: CO_2 molecule



526 cm^{-1}



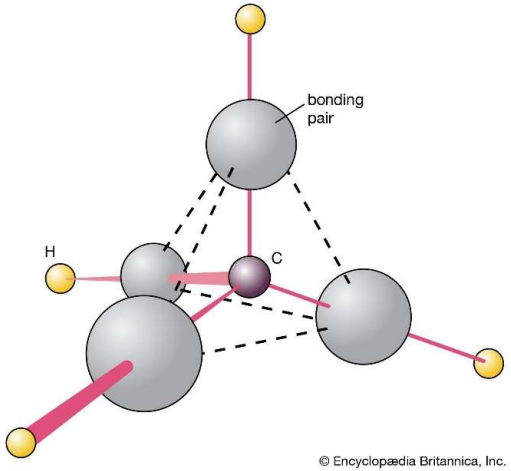
2565 cm^{-1}

- 526 cm^{-1} and 2565 cm^{-1} modes ↔ Absorbed wavelengths: 19.01 µm and 3.90 µm, respectively.

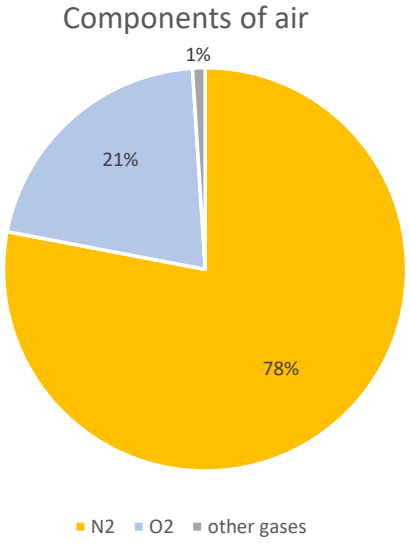
- CH_4: asymmetric stretching, and bending modes
- H_2O: additional IR active vibrational mode.

Chemical properties of CO_2 and CH_4

- CO_2: heavier than 99% of air molecules (44 u); colourless, odourless, tasteless, non-inflammable, soluble in water
- CH_4: lighter than 99% of air molecules (16 u); colourless, odourless, tasteless, burnable in mixture with air, slightly soluble in water



O_2 = 32 u



N_2 = 28 u

Where do gas emissions in agriculture originate? – E. g. the soil!

And emitted is mostly

- Carbon Dioxide (CO_2),
- Methane (CH_4),
- Nitrous Oxide (N_2O),
- Nitrogen (N_2),
- Ammonia (NH_3)

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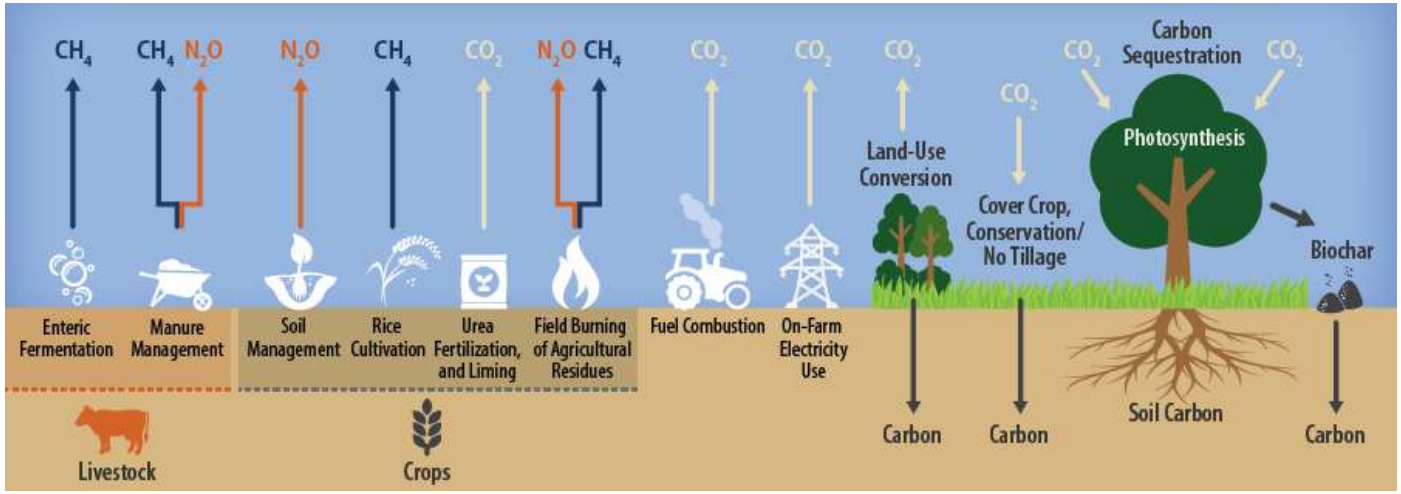
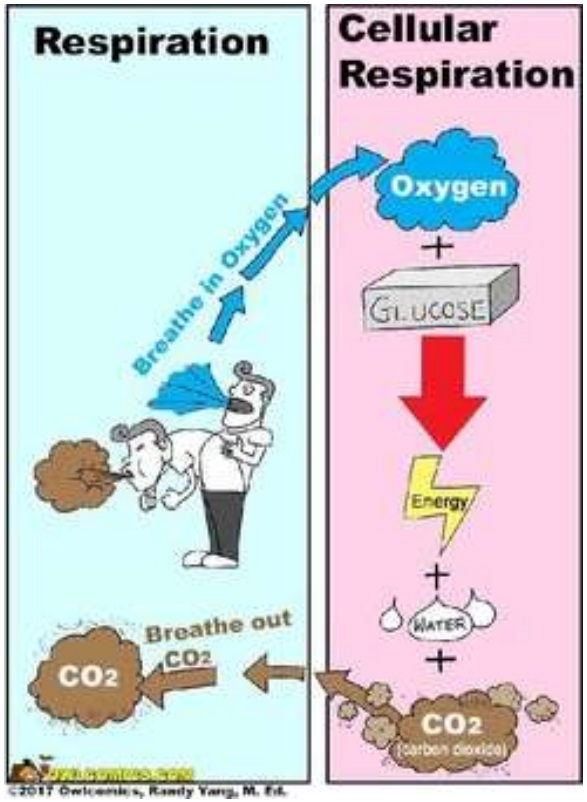


Source: CRS

1/4 - 1/3 of annual greenhouse emissions are attributed to food production (not all on land though!)

What causes soil emissions? – CO_2

- **Cellular respiration** by soil microorganisms from the decomposition of the active soil organic matter pool, through plant roots and soil fauna
- Product of **aerobic metabolic processes** – cellular respiration of heterotrophic organisms
- Diffusion through soil cavities

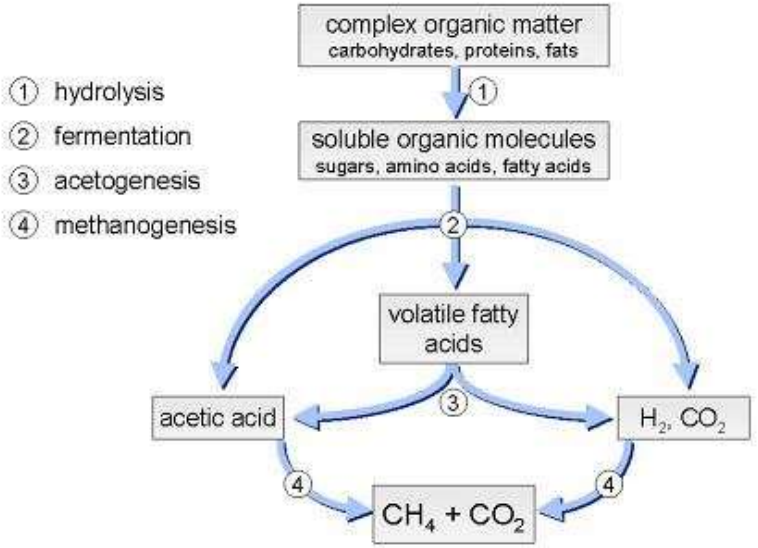


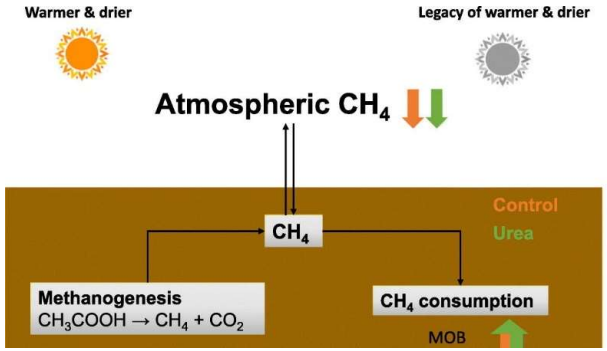
$C_6H_{12}O_2 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$ + energy (38 ATP)

What causes soil “emissions”? – CH_4

EMISSION

- anaerobic decomposition
- Acetogenic bacteria ↔ **methanogenic bacteria**
- Ebullition through (soil) water body
- Ca. 40% of annual global CH_4 emissions from human activities

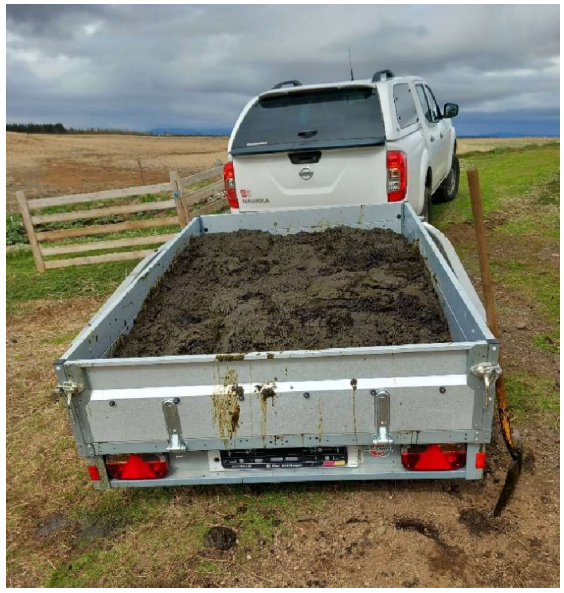




CONSUMPTION

- methane oxidizing bacteria/**methanotrophs** (MOB)
- Soil consumption of methane accounts for 5-15% of methane removed from the atmosphere on an annual basis

https://www.sciencedirect.com/science/article/pii/S0048969720357545
https://www.researchgate.net/publication/256076914_Environmental_impacts_on_the_diversity_of_methane-cycling_microbes_and_their_resultant_function



What influences soil emissions?

- Soil type
- Moisture
- Temperature
- Crop type
- Fertilization
- Irrigation
- Plowing ($\rightarrow$ ventilation)

The soil experiments

Long-term experiment 299-70

- 299-70: long-term experiment under cultivation since 1970
  - “Sveltitilraun”: the crops are systematically deprived of certain nutrients
  - Histosol/Histic andosol

Liður	Kg N/ha	Kg P/ha	Kg K/ha
a	0	30	100
b	50	0	100
c	50	30	0
d	100	0	100
e	100	30	0
f	100	30	100
g*	100	30	100

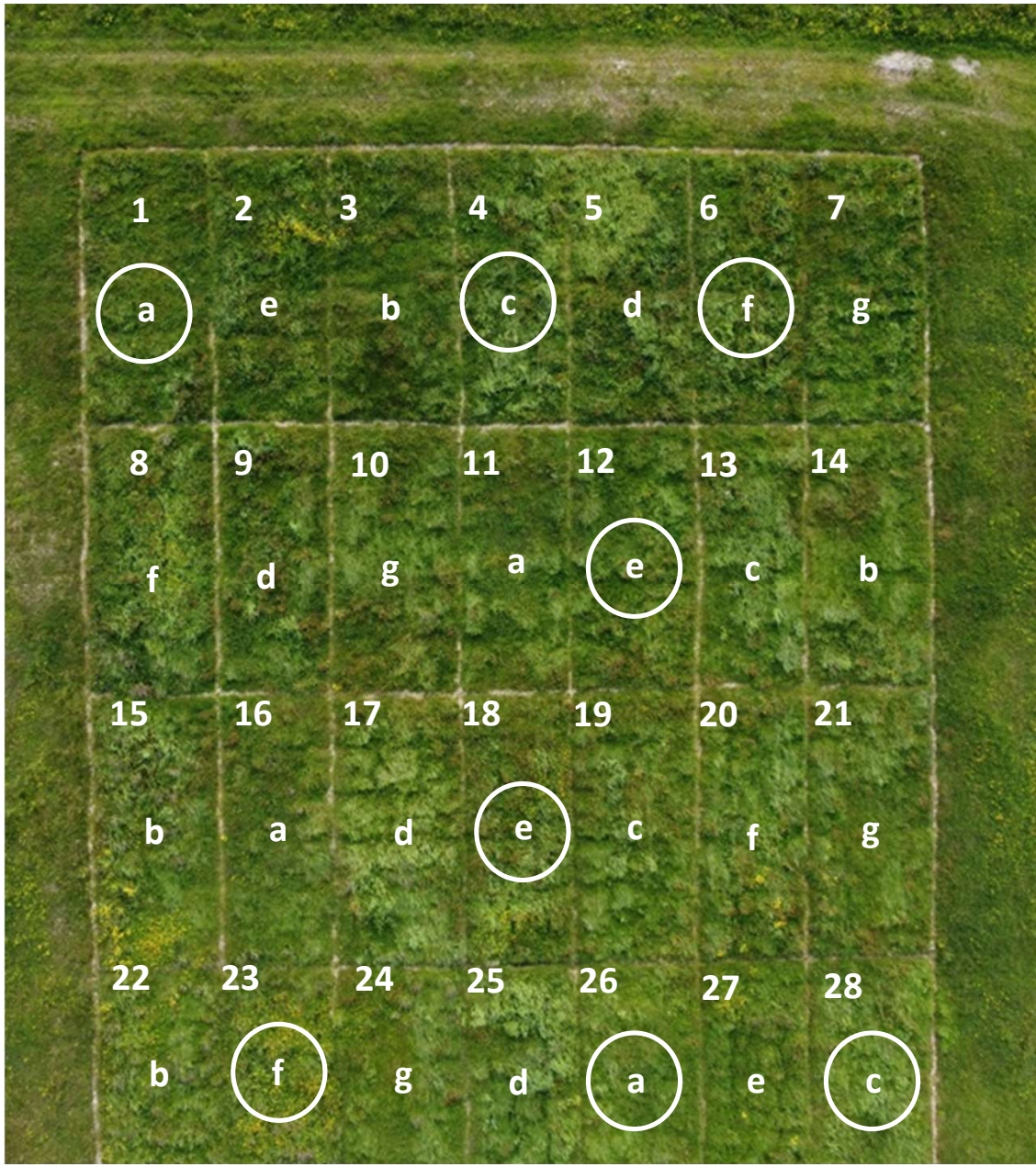
* liming in 1970 and 2023

Long-term experiment 437-77

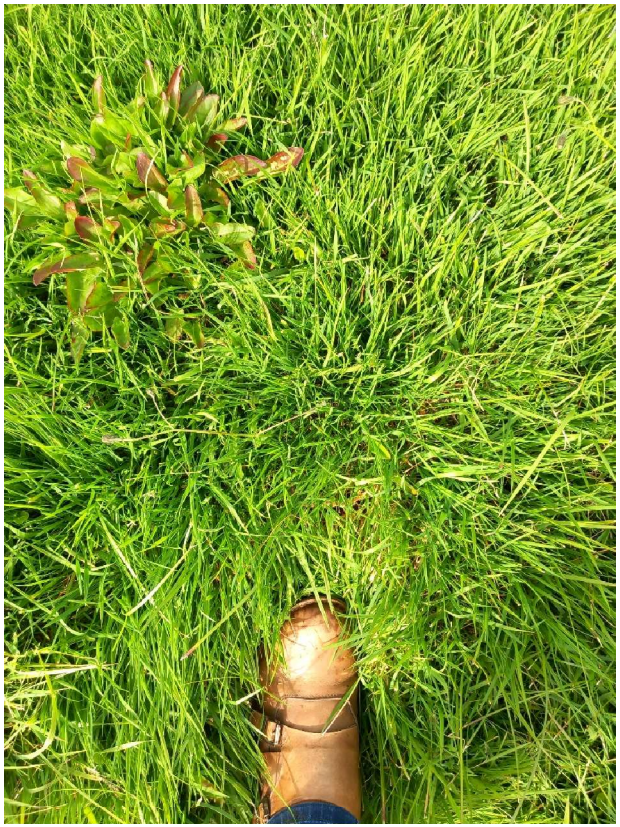
- 437-77: long-term experiment under cultivation since 1977
  - “Sauðatað”: additionally, to a variation in N and K, selected plots (e and f) receive 15 t/ha sheep manure each year
  - Histosol/Histic andosol

Liður	Kg N/ha	Kg P/ha	Kg K/ha
a	60	30	40
b	100	30	60
c	140	30	80
d	180	30	100
e	0	0	0
f	40	0	0
g*	100	30	60

* liming in 1977 and 2023

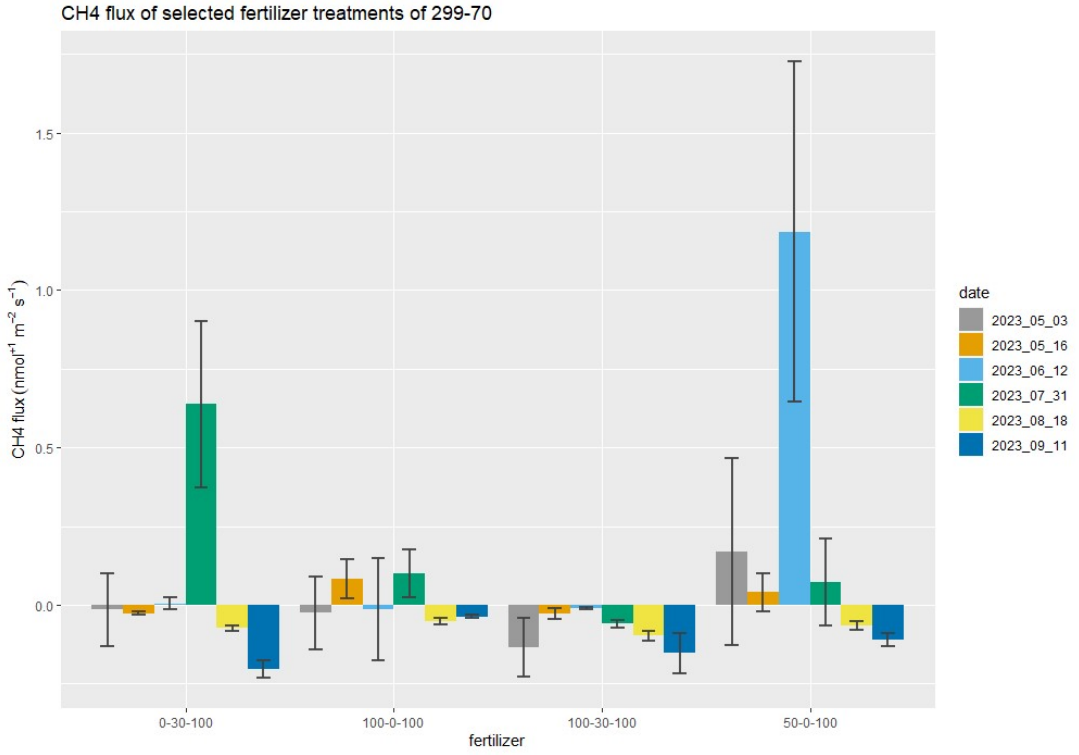


In the field

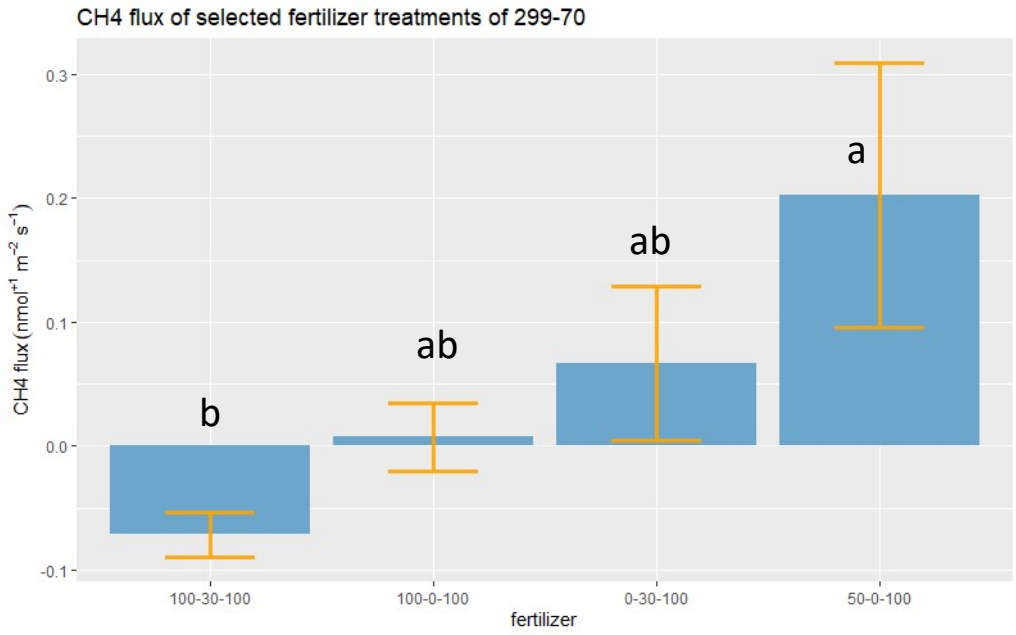


First results of the soil experiments

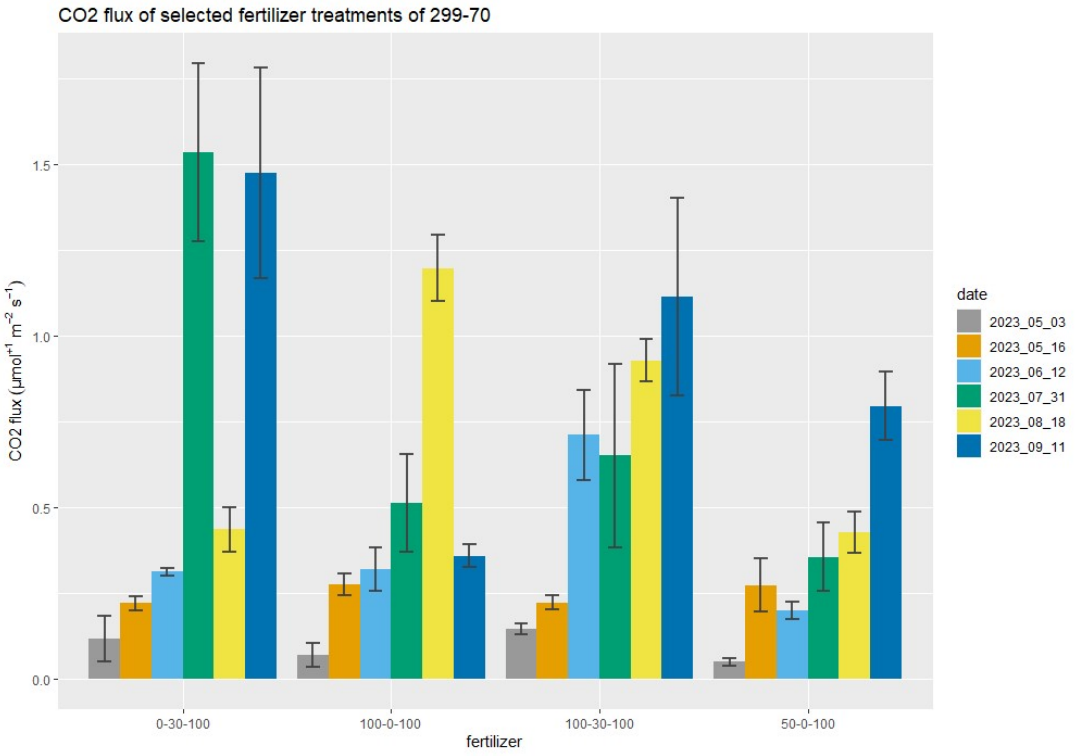
CH_4 fluxes in experiment 299-70 in 2023



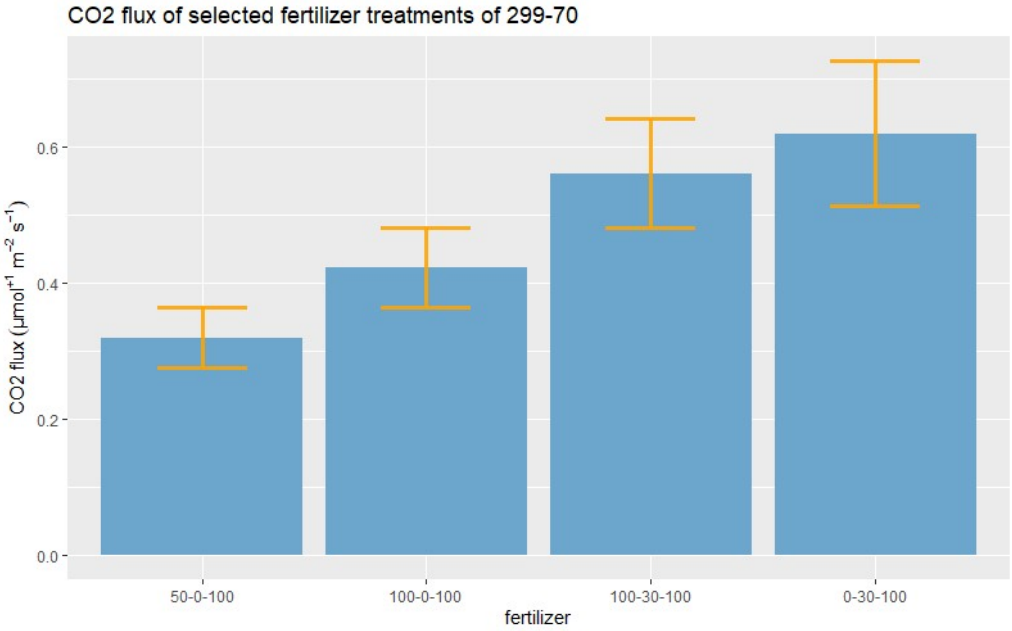
Flux means



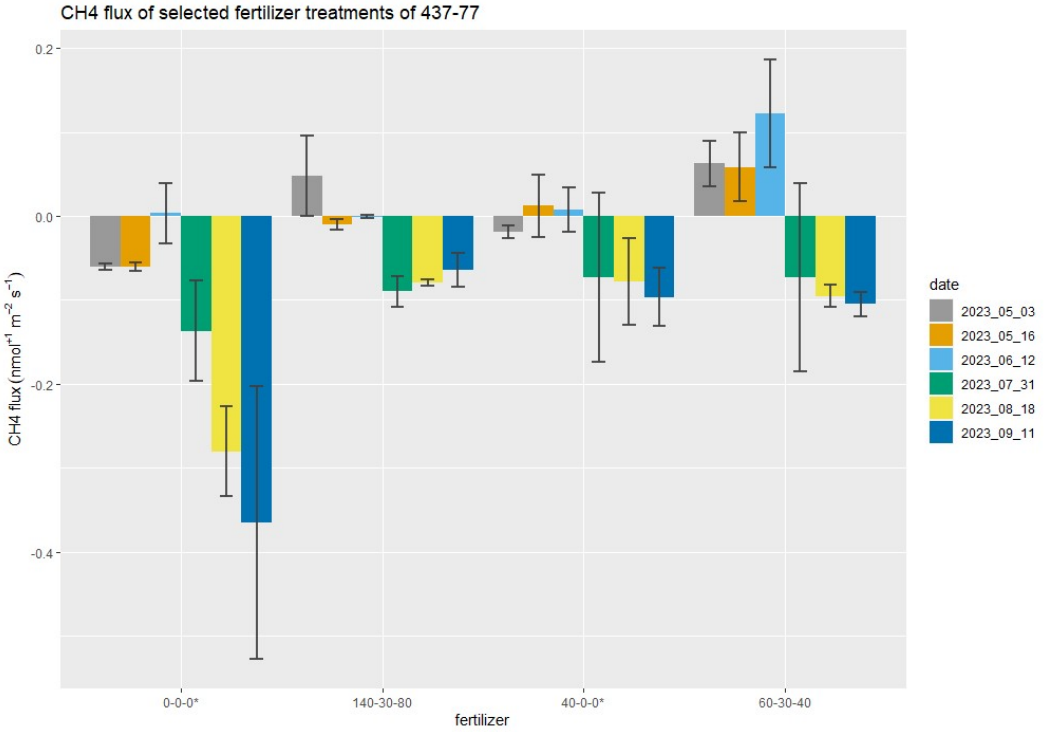
CO_2 fluxes in experiment 299-70 in 2023



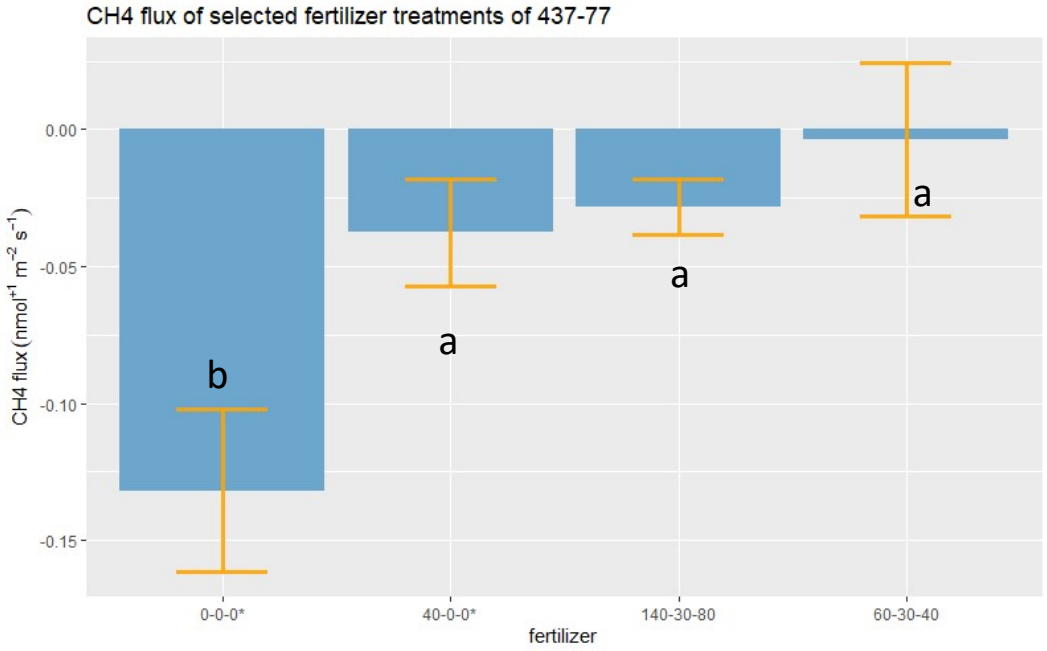
Flux means



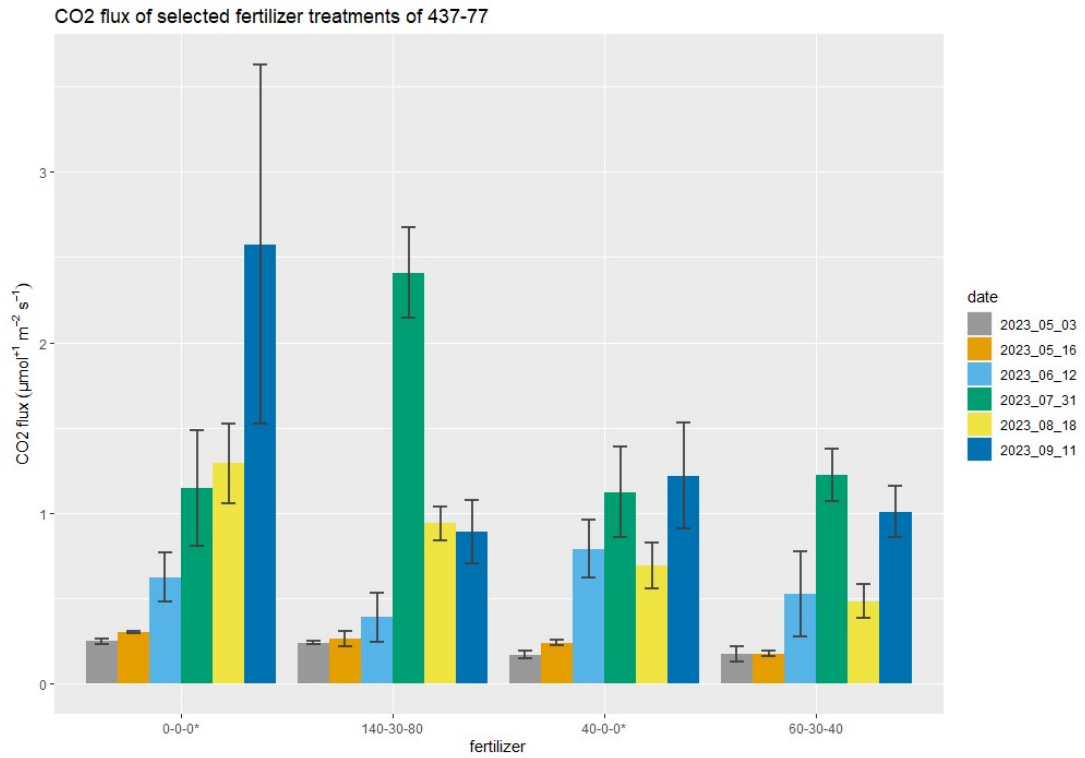
CH_4 fluxes in experiment 437-77 in 2023



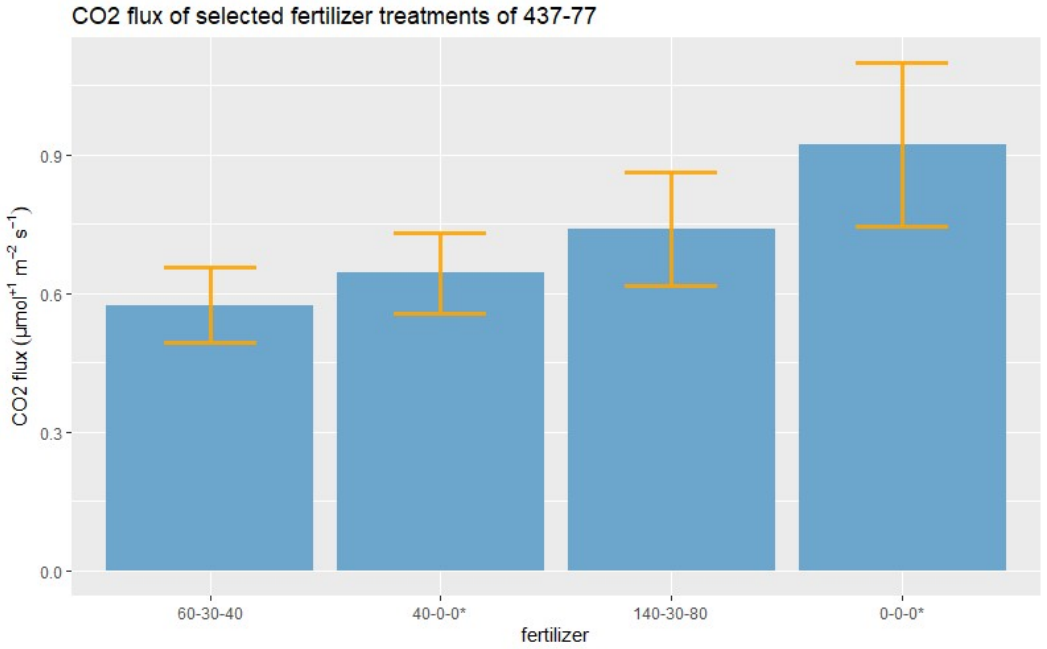
Flux means



CO_2 fluxes in experiment 437-77 in 2023



Flux means



From the field to the barn!

Where do gas emissions in agriculture originate? – E. g. Dairy cattle!

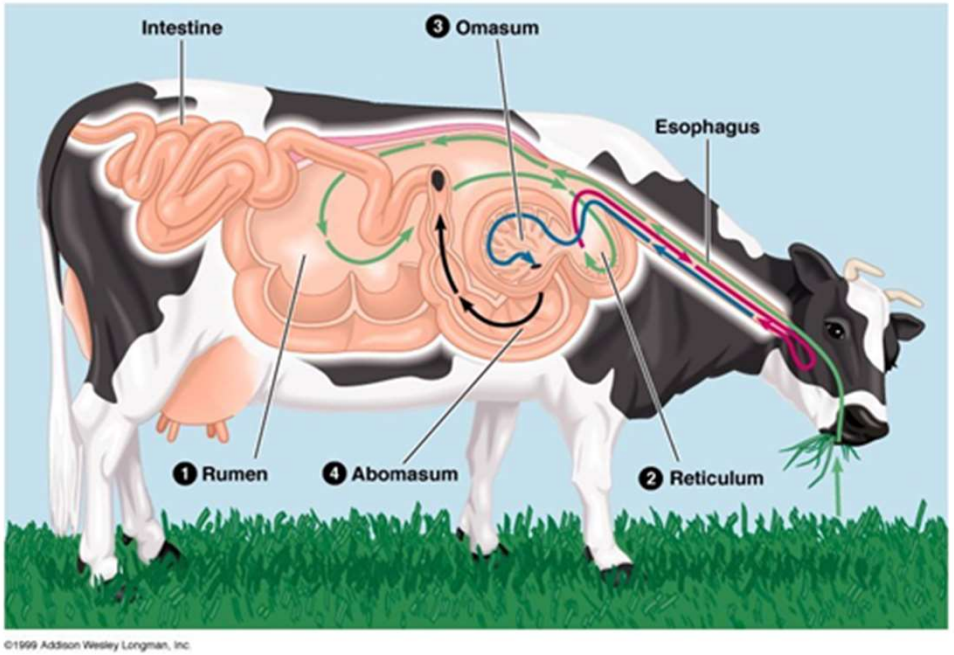
And emitted is...

- Methane (CH_4),
- Carbon Dioxide (CO_2)

during rumination.

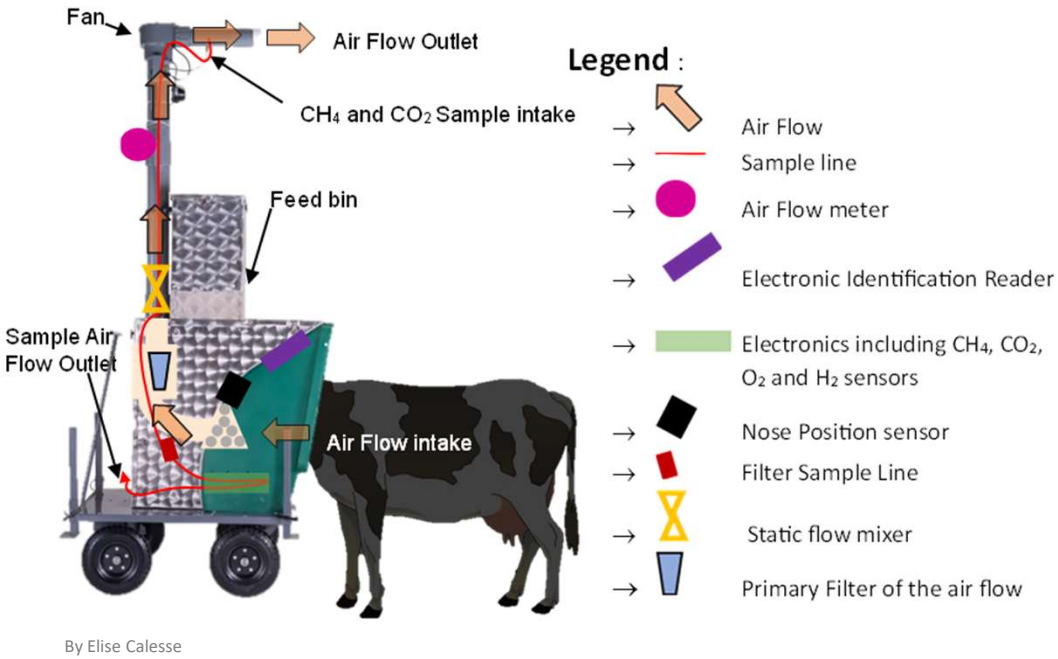
Methane

- is mostly produced by enteric fermentation (anaerobic)
- 33 to 55 L per hour produced in the rumen
- 5% leave as flatulence, 95% as burps.



Framework conditions of the experiment

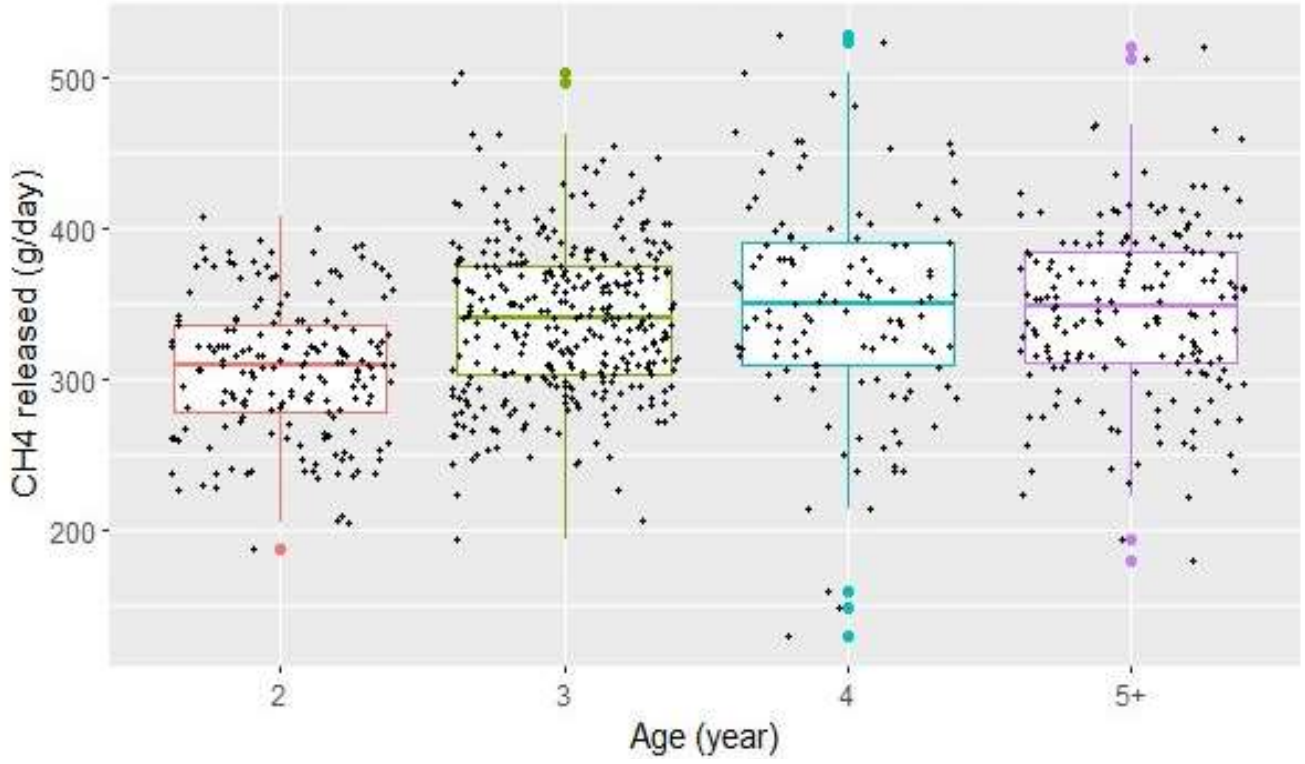
- Location: Hvanneyrarbúið
- Data recording: 25.9.2022 – 18.10.2022 (3 weeks)
- Evaluation of data of 40 cows that participated throughout the experiment (61.5% of the herd)
- Concentrate feed ad libitum up to 2 kg/day (also at the milking robot)
- Roughage ad libitum
- Average time spent daily in the feeding device: 4 min 42 s
- Average feed eaten at the feeder: 841 g/day (lowest 38 g/day, highest 1520 g/day)



By Elise Calesse

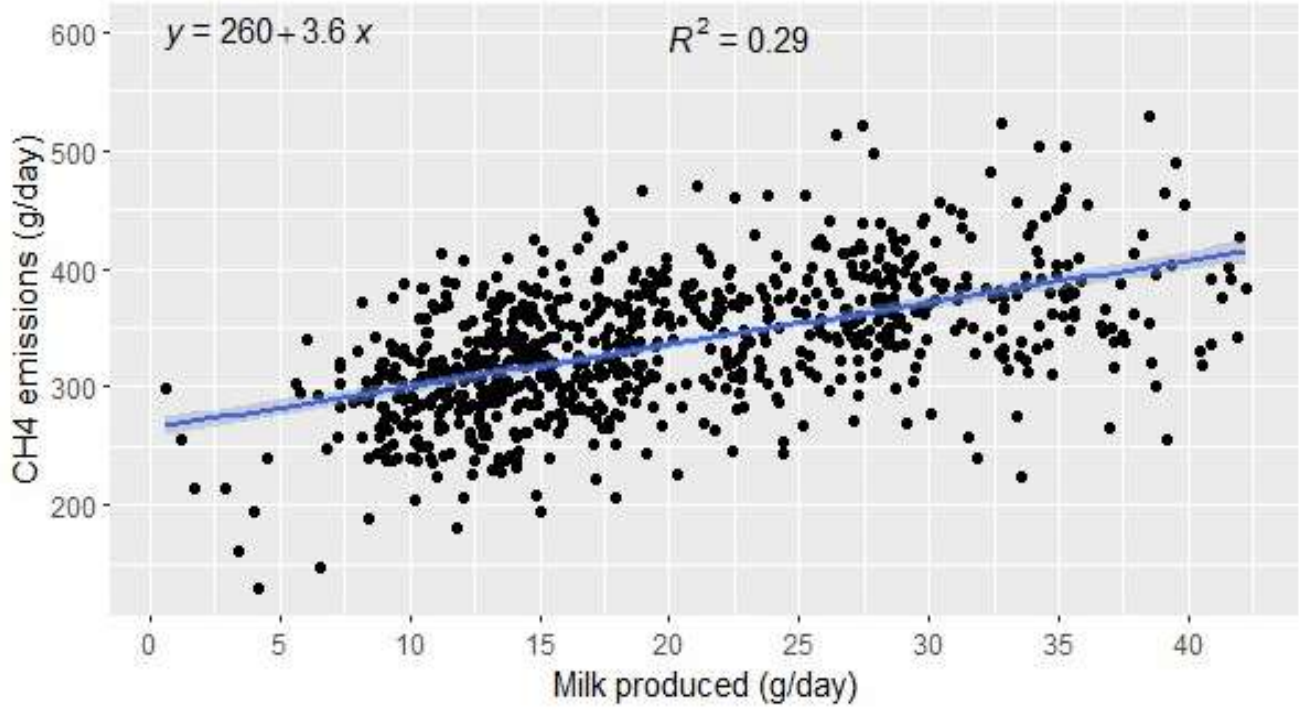
Results from the barn

CH_4 emissions vs. cow age

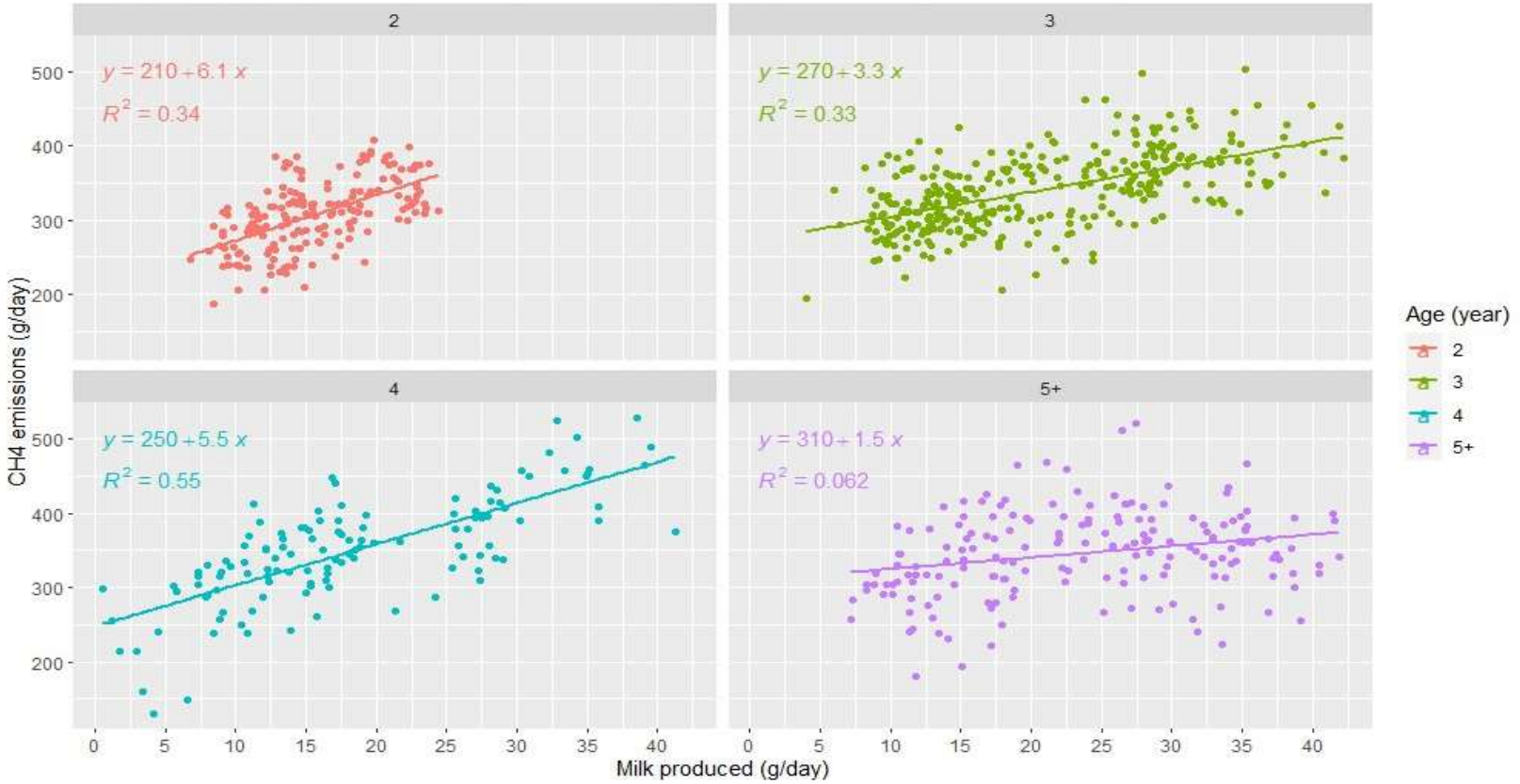


E. CALESSE

CH_4 emissions vs. milk production



CH_4 emissions vs. milk production vs. cow age



E. CALESSE

Summary

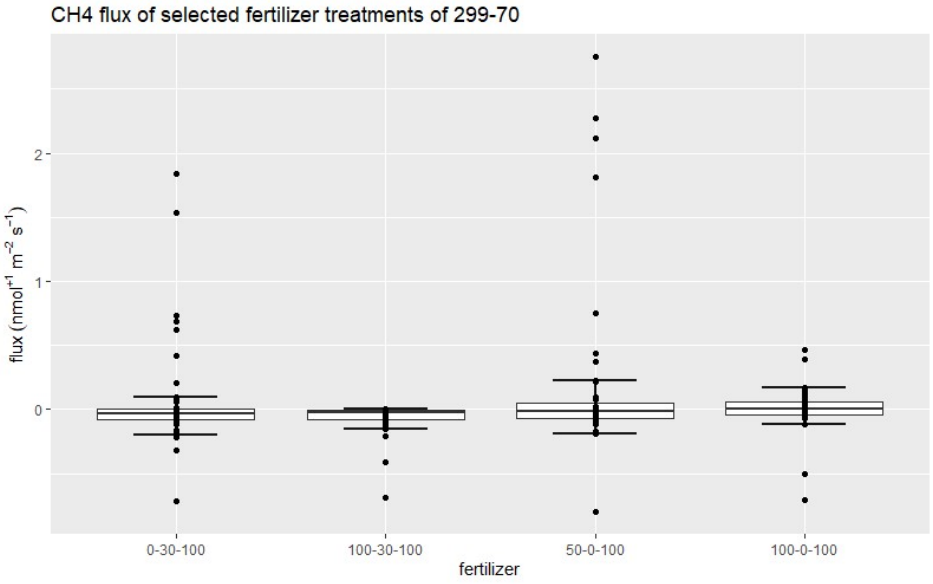
Age group	Average of milk produced (L/day)	CH_4/kg milk produced	CO_2/kg milk produced
2	16	20	559
3	21	16	485
4	18	19	567
5+	24	15	445

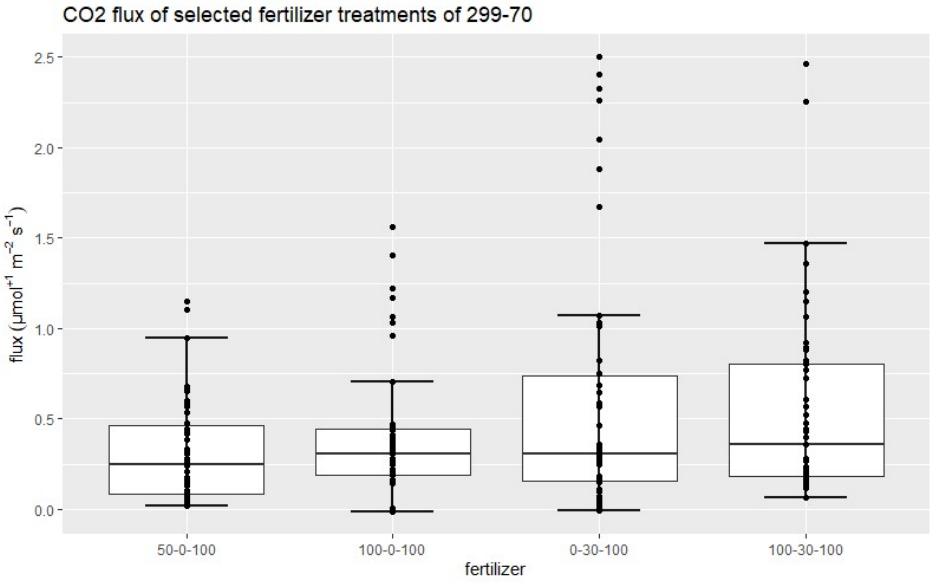
A big “thank you” to this year’s interns, Elise, Julie, and Nathan!

…and to everyone who contributed to the realization of these experiments!

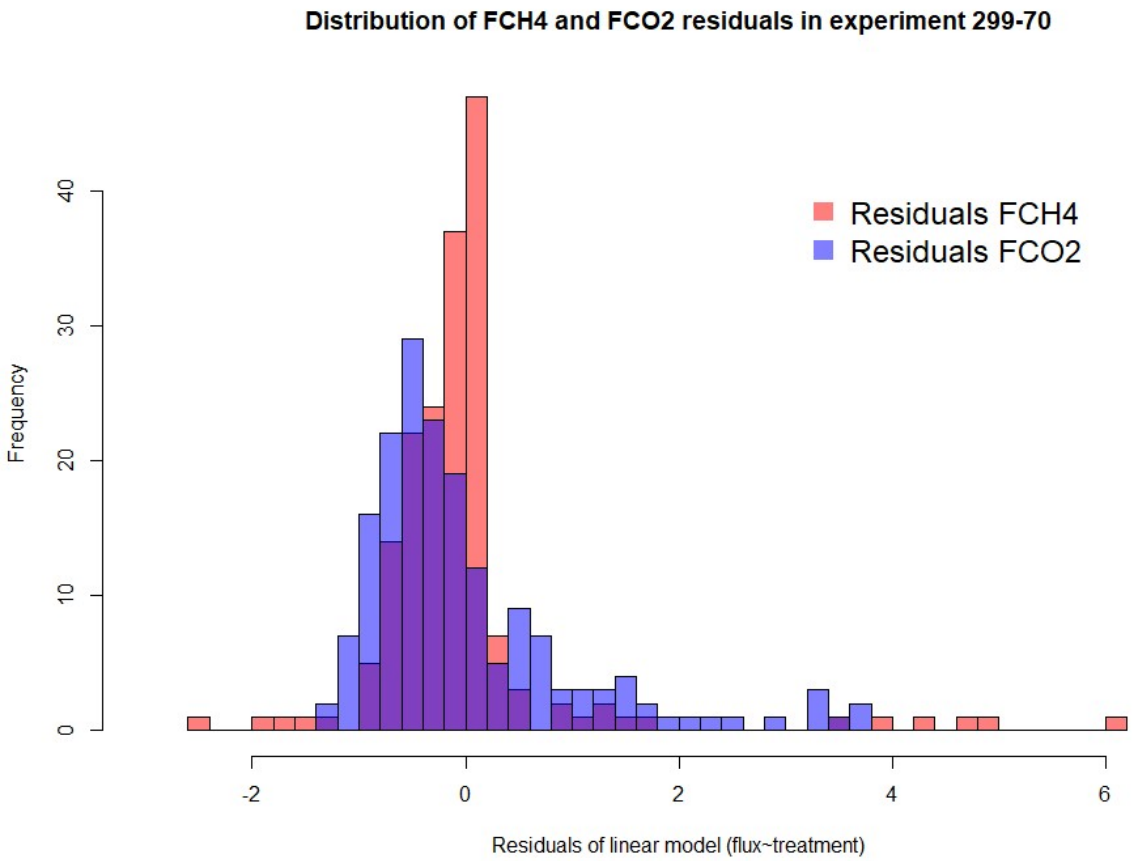
Gracias!
Merci beaucoup!
Takk kærlega!
Danke!

Boxplots 299-70





Statistics 299-70



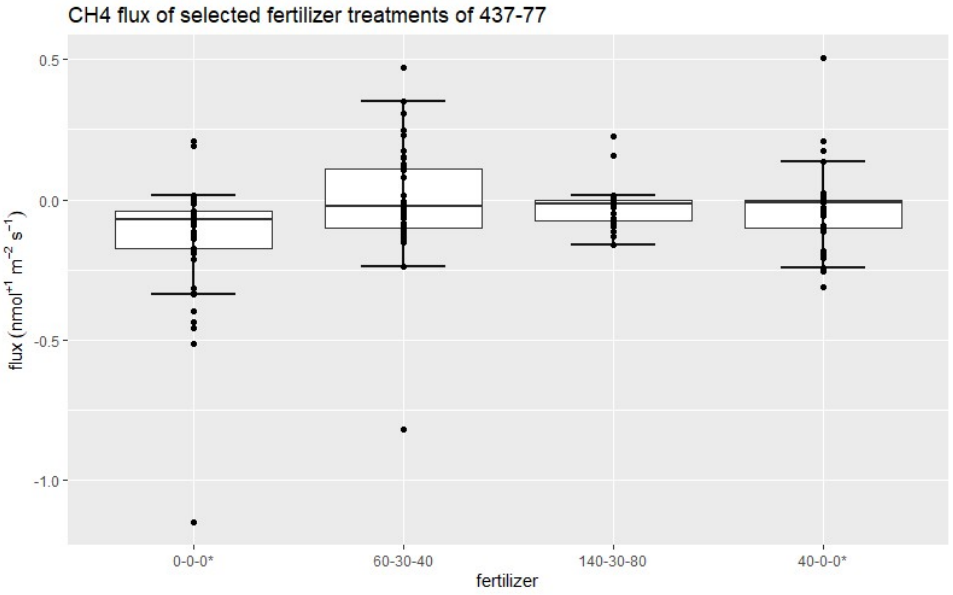
- Residuals of both datasets not normal (Shapiro-Wilk)
- Kruskal-Wallis:

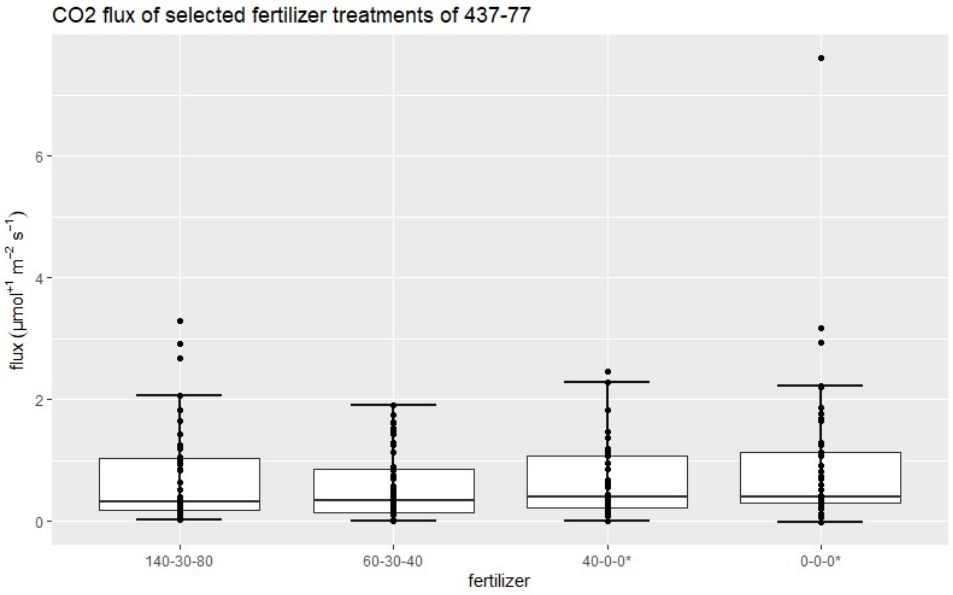
p(CH4) = 0.003958,
p(CO2) = 0.115

- Post-hoc: Dunn-Bonferroni

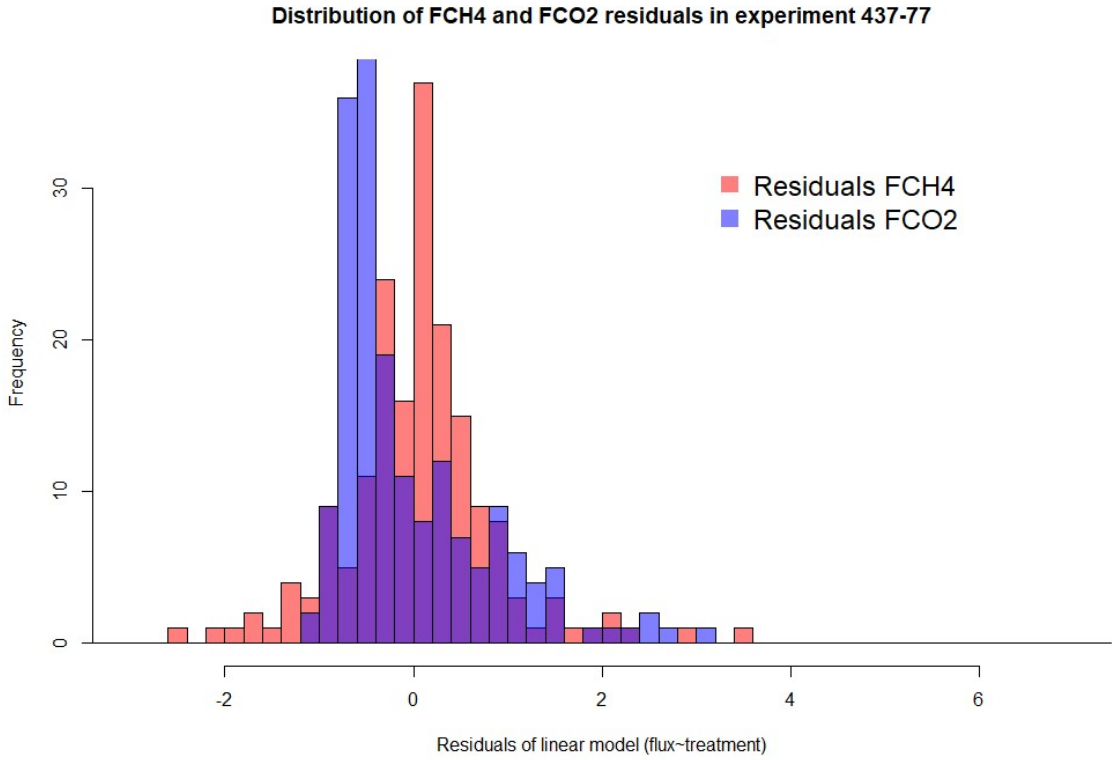
CH4: 100-0-100 ↔ 100-30-100; padj. = 0.00532452
CO2: -

Boxplots 437-77





Statistics 437-77



- Residuals of both datasets not normal (Shapiro-Wilk)
- Kruskal-Wallis:

p(CH4) = 0.001539,
p(CO2) = 0.2814

- Post-hoc: Dunn-Bonferroni

CH4: 0-0-0* ↔ 40-0-0*; padj. 0.031755191
0-0-0* ↔ 140-30-80; padj. 0.006330598
0-0-0* ↔ 60-30-40; padj. 0.005299772
CO2: -