

Overestimation of global livestock methane emissions from omission of antimethanogenic forages

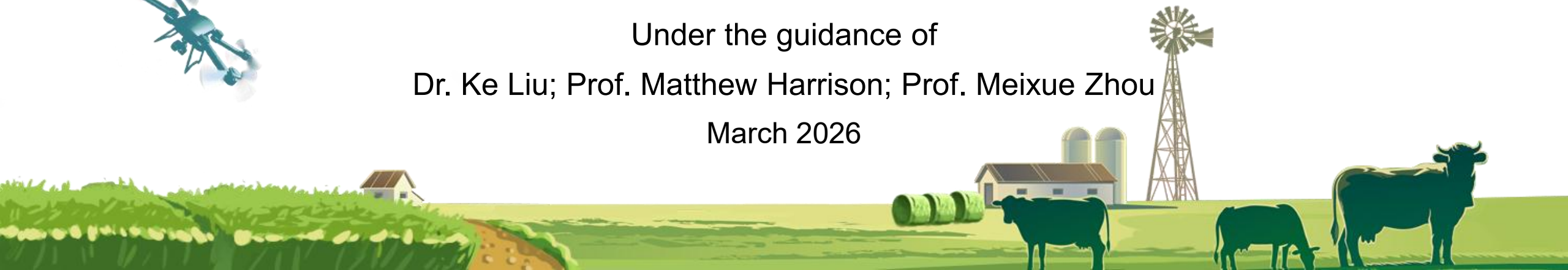
Unpublished work

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Under the guidance of

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Enteric methane

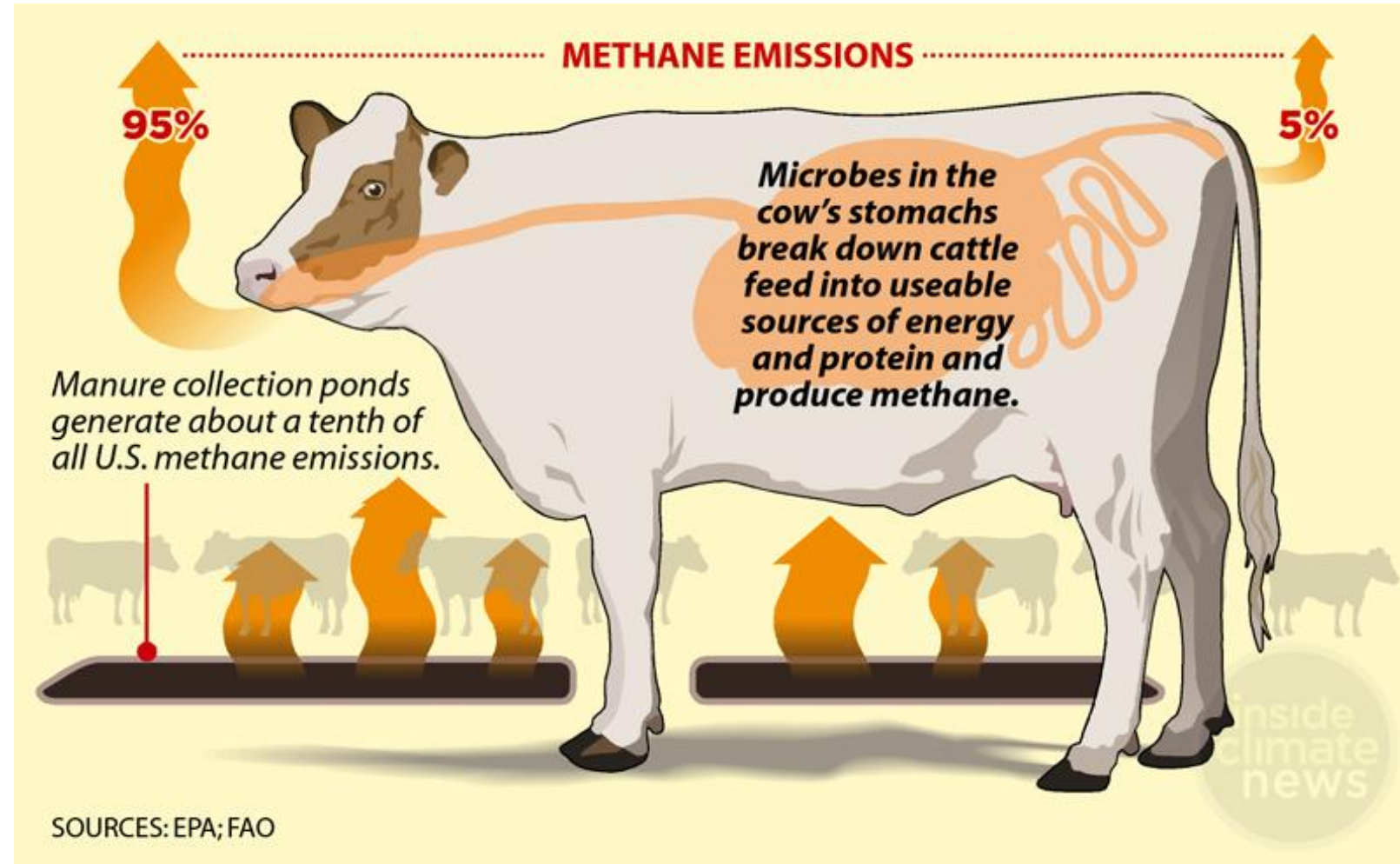
What is enteric methane emissions?

✓ Definition

Methane produced during microbial fermentation of feed in the rumen of livestock.

✓ Release pathway

Most methane is released by belching, with a small amount from manure.



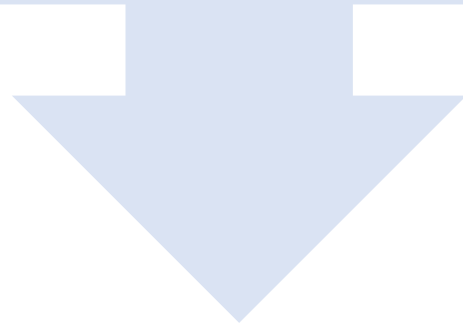
Calculation method

IPCC equation

$$EF-CH_4 = \frac{N \times GE \times \left(\frac{Y_m}{100}\right) \times 365}{55.65 \times Area}$$

where $EF-CH_4$ represents total methane emissions (kg CH₄ head⁻¹ year⁻¹); N is the number of animals (head); GE is the gross energy intake per animal (MJ); Y_m is the fraction of gross energy converted to CH₄ (%); 55.65 (MJ kg⁻¹ CH₄) is the energy content of CH₄, and $Area$ denotes the area of the grid cell (ha).

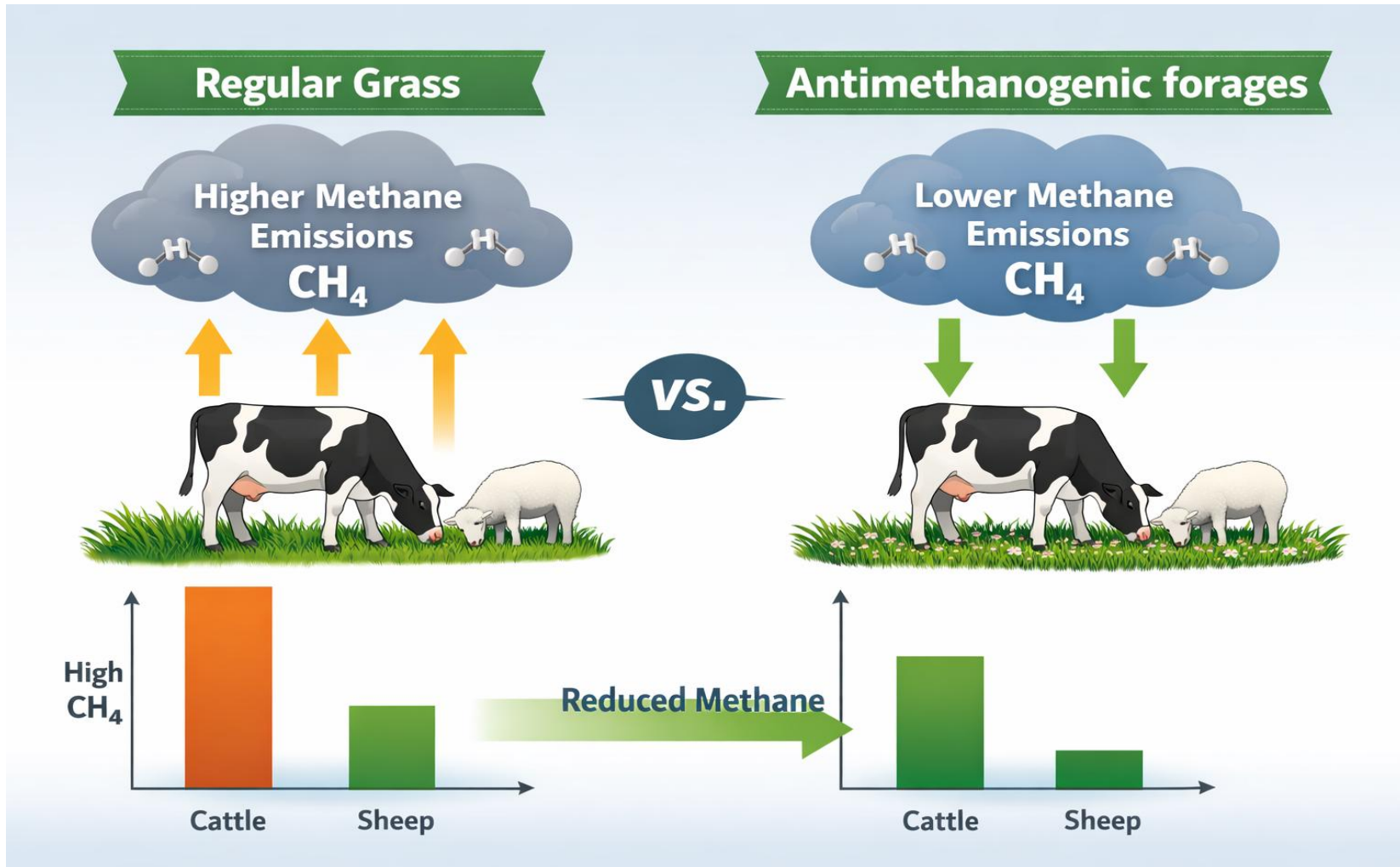
Animal parameters



Can plants influence methane emissions from animals?

Antimethanogenic forages

- ✓ Contain bioactive compounds that inhibit methanogenic archaea in the rumen



Difficulties



Farm-scale

National-scale

Global-scale

✓ **Limited spatial resolution of livestock emission data**

Livestock emissions are primarily based on annual national statistics, lacking large-scale high-resolution spatial datasets.

✓ **Lack of high-resolution maps of antimethanogenic forages**

The spatial distribution of antimethanogenic pasture species remains poorly quantified at high resolution.

Livestock headcounts

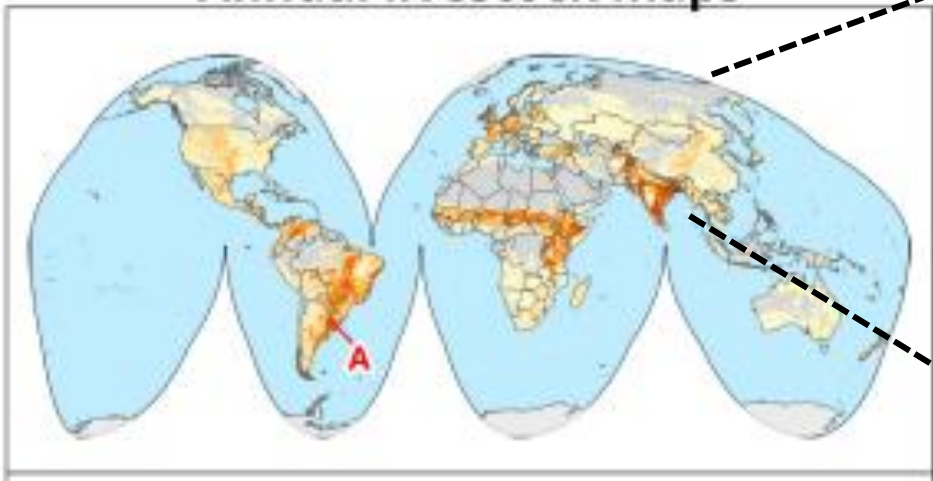
Annual livestock statistics



2001 to 2022

Annual livestock maps

Cattle distribution

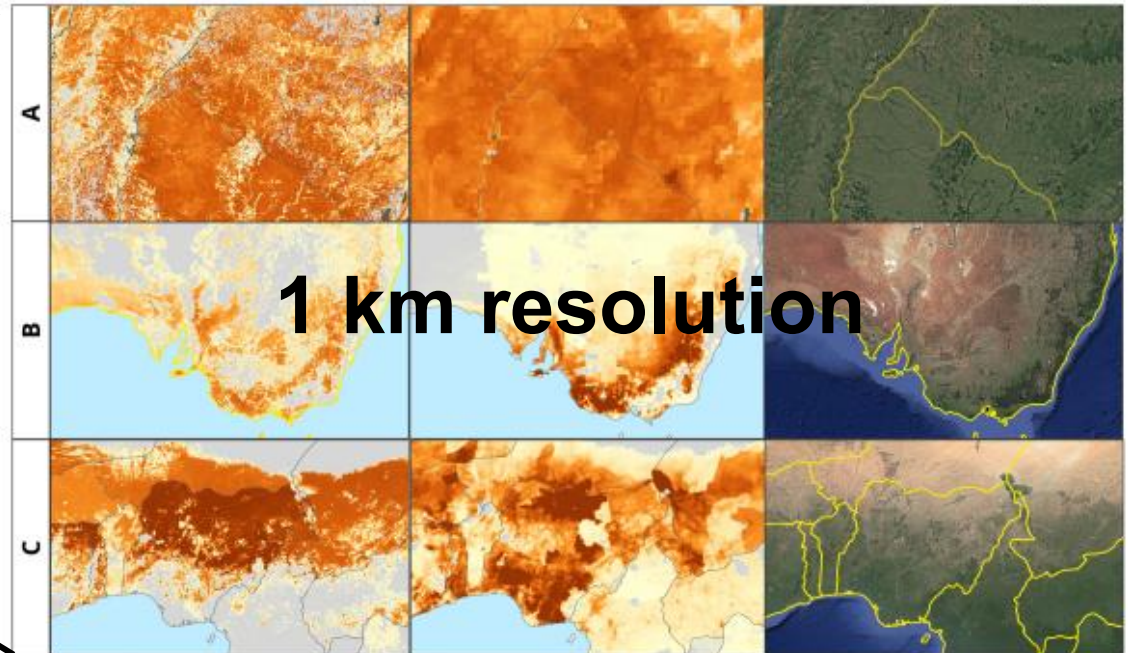


Parente, L et al. 2025

Annual livestock maps

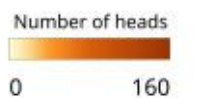
GLW4

Google Maps images



1 km resolution

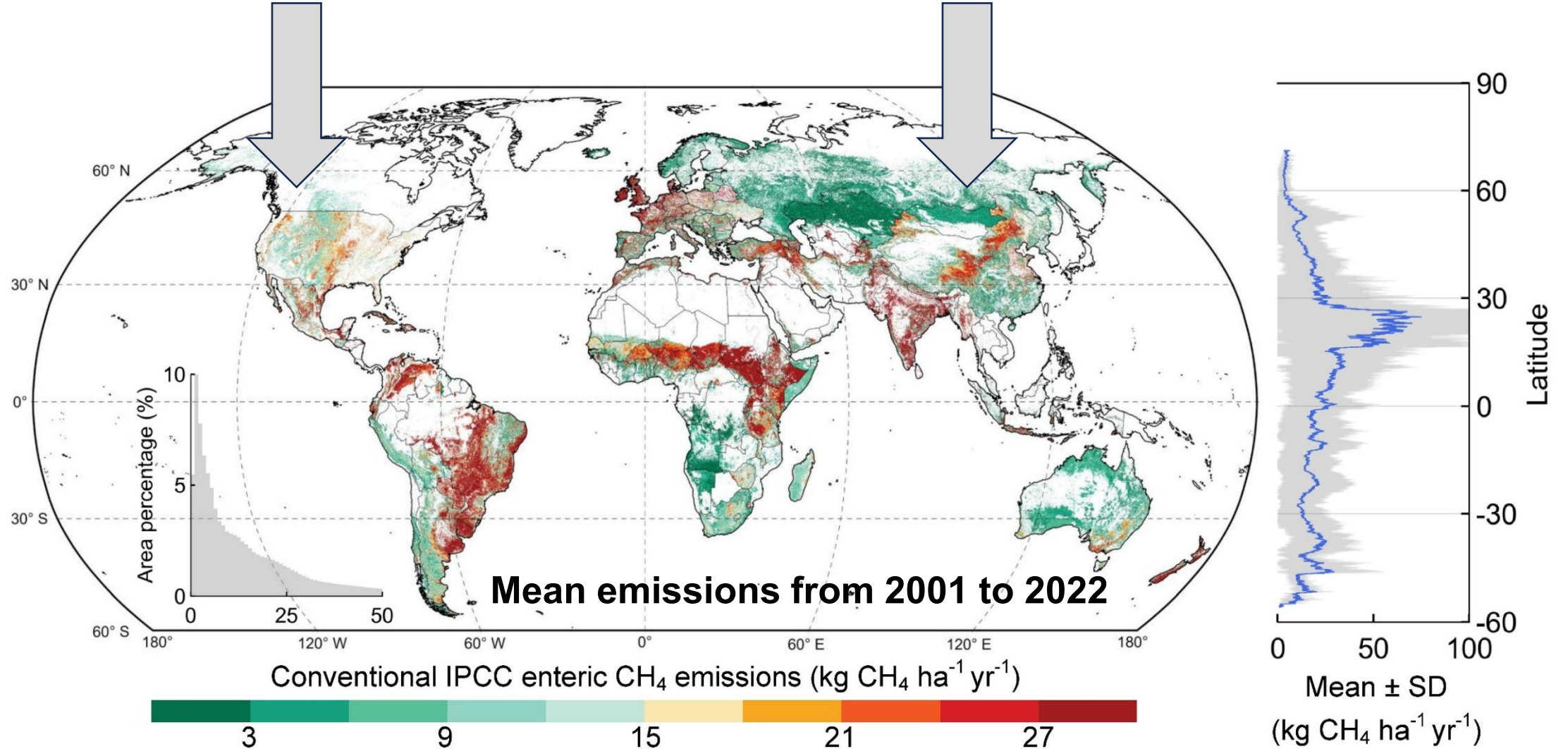
Projection system: Goode Homolosine - Land (ESRI:54052)



Livestock emissions

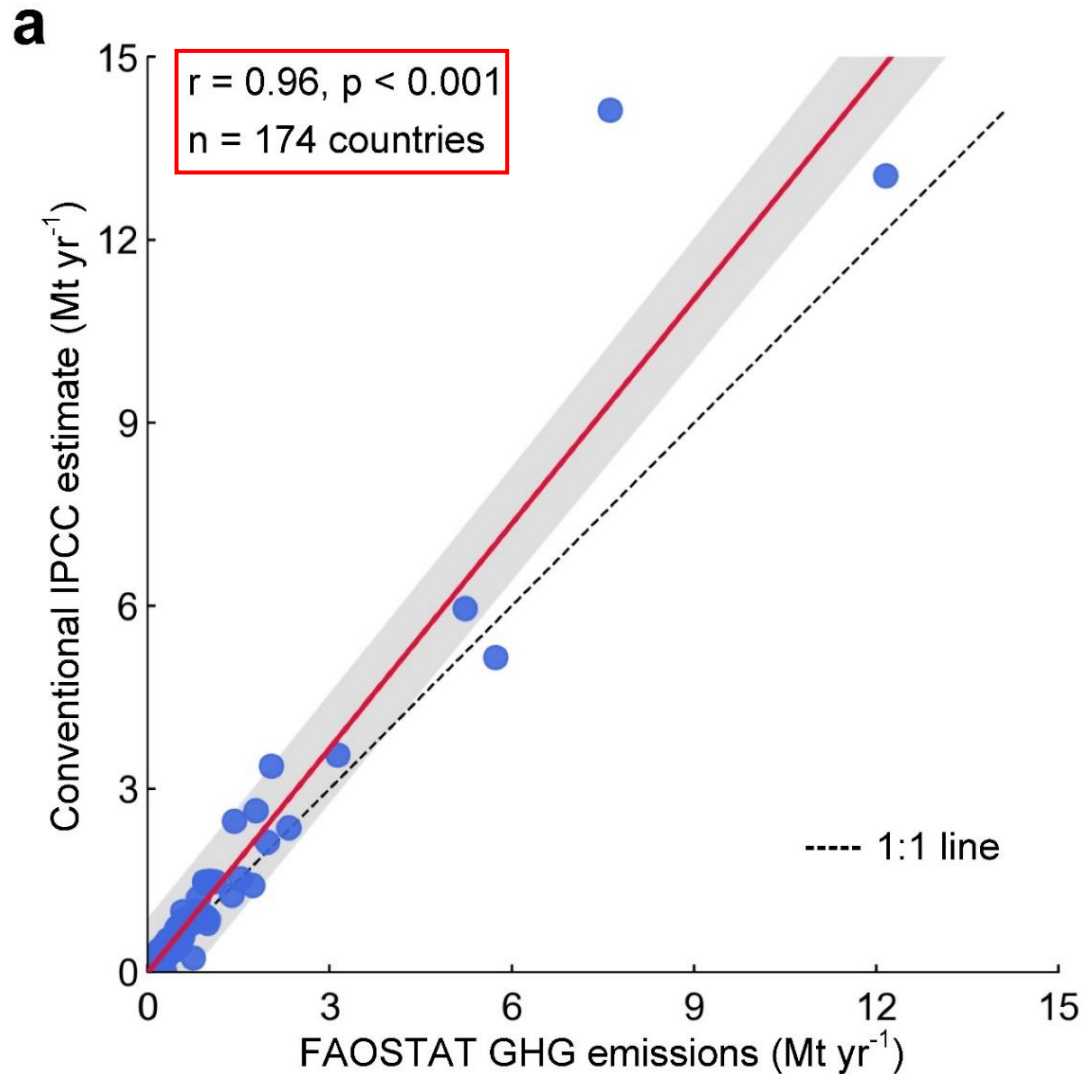
Headcount maps

IPCC equation

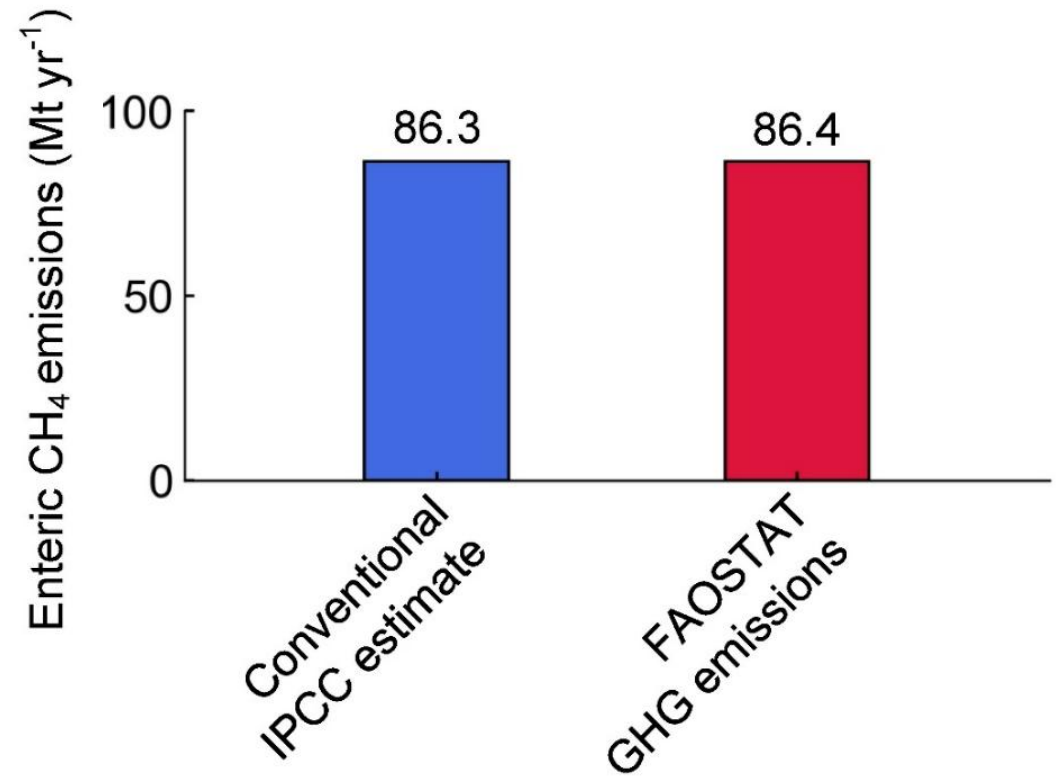


Validation with official statistics

National scale



Global scale



Global multi-year mean total emissions differed by only **0.1%**

Livestock emissions



✓ Maps1: livestock emissions



Maps2: Methane mitigation by antimethanogenic forages



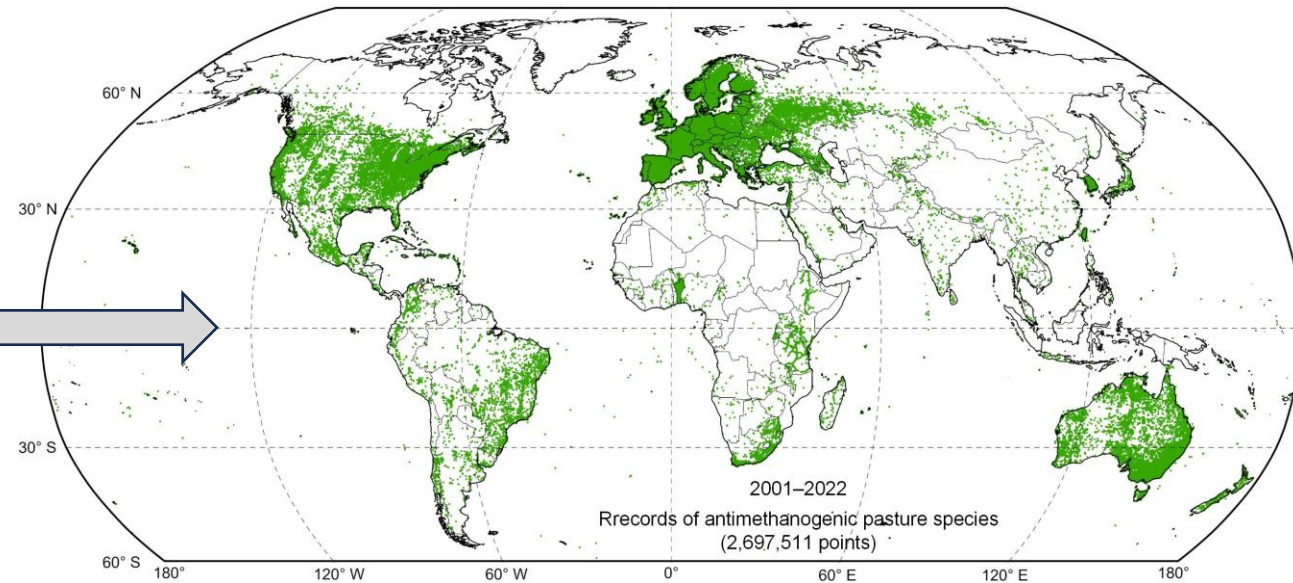
Maps3: Adjusted emissions

Field observation sites

- ✓ Location records of 40 antimethanogenic forage species



Sources: GBIF
(<https://www.gbif.org/>)



Training samples in our study
2.7 million

Theoretical mitigation

- ✓ Mapping the probability distribution of antimethanogenic forages using a Random Forest model with climate factors, satellite metrics, and soil properties.
- ✓ Calculated a theoretical methane mitigation map using mitigation rates of 40 antimethanogenic forages collected from previous studies.

Lotus pedunculatus Cav.



Hedysarum coronarium L.



Plantago lanceolata L.



Cichorium intybus L.



Trifolium repens L.



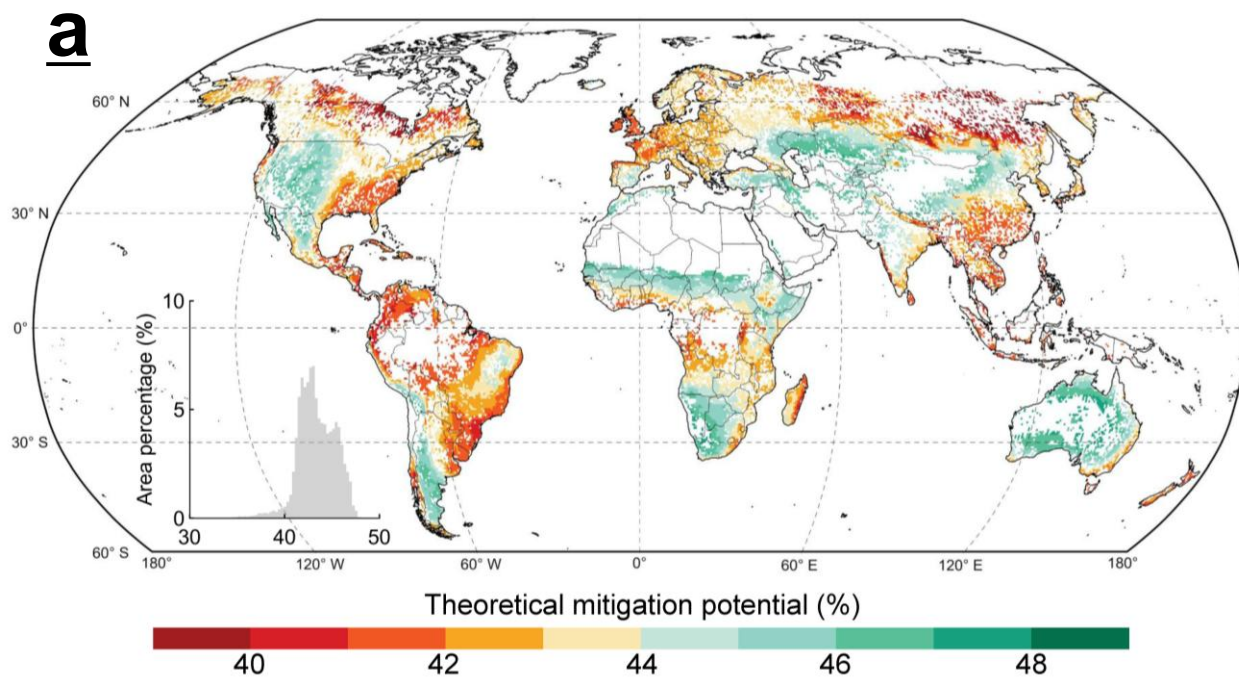
Trifolium pratense L.



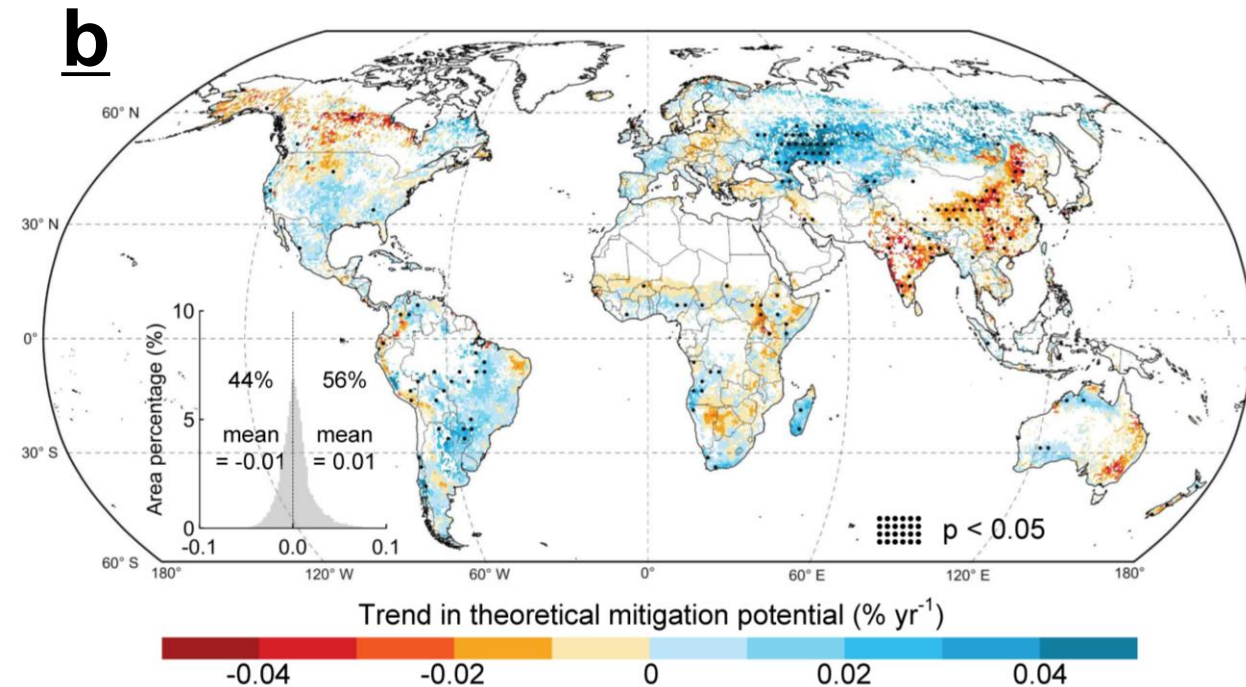
Typical antimethanogenic forages 

Theoretical mitigation

- a. Antimethanogenic forages are widespread and offer strong methane mitigation potential
- b. Low-baseline regions increased slightly, while high mitigation potential regions declined over time



2001-2022 mean



2001-2022 trend

Actual mitigation

Situation 1



Situation 2



Higher forage availability increases the probability of intake

Situation 3



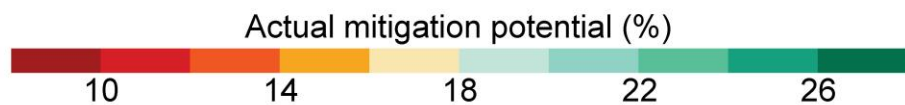
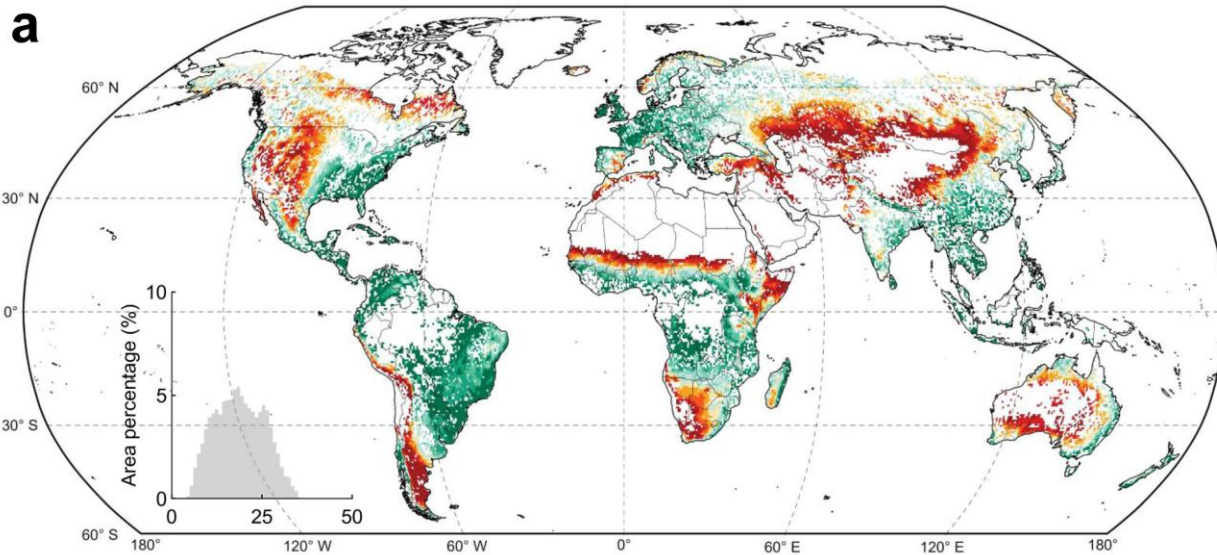
Situation 4



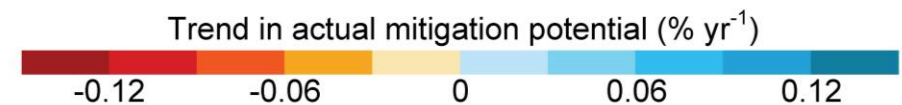
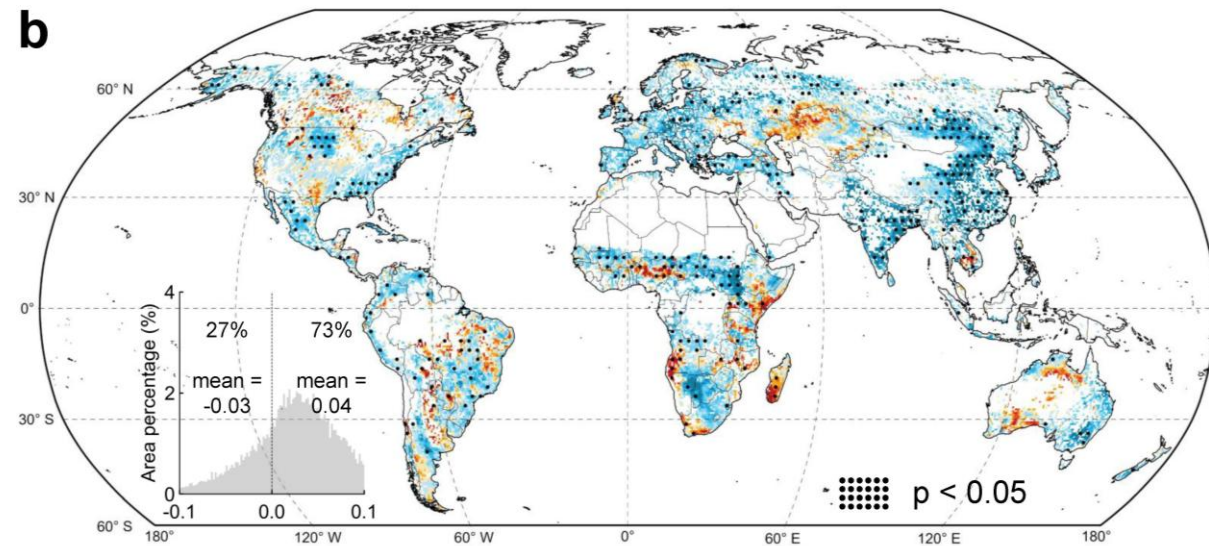
Higher livestock density increases the intake of antimethanogenic forages within a region

Actual mitigation

- a. Incorporating livestock intake reduced the mitigation potential slightly, yielding an average of 19%
- b. This potential increased during 2001–2022, with 75% of grazing lands showing positive trends



2001-2022 mean

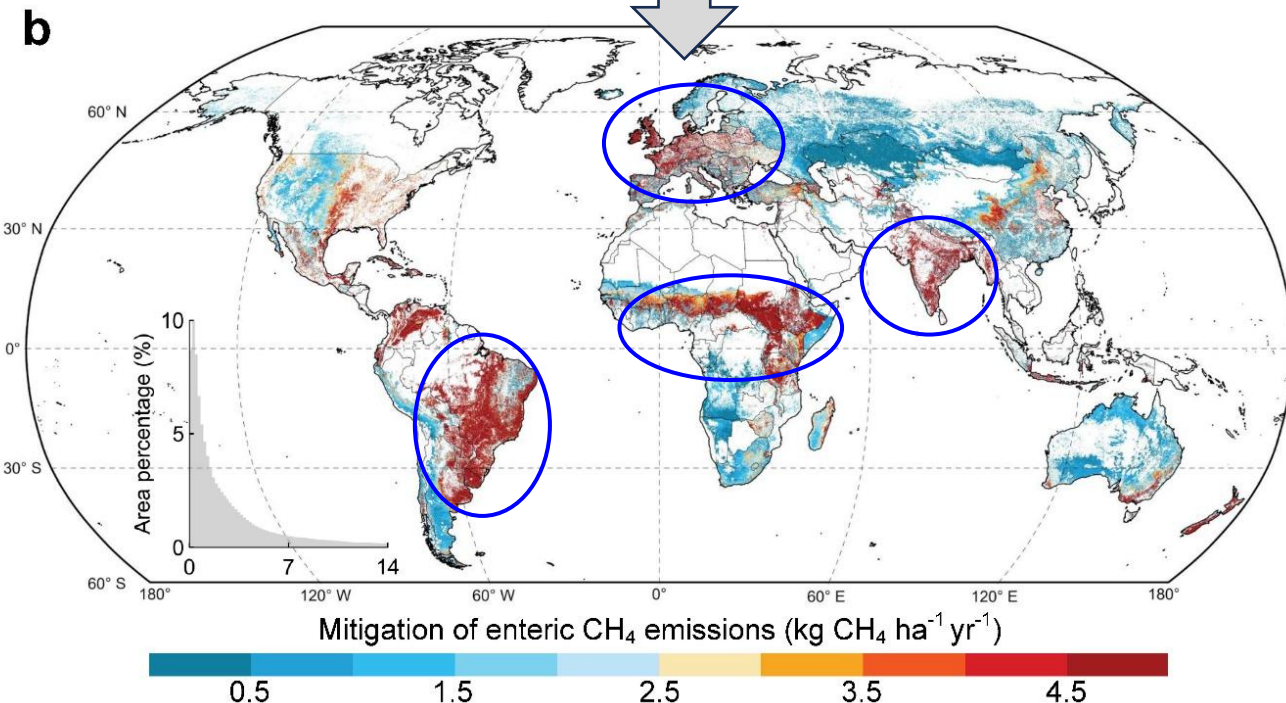
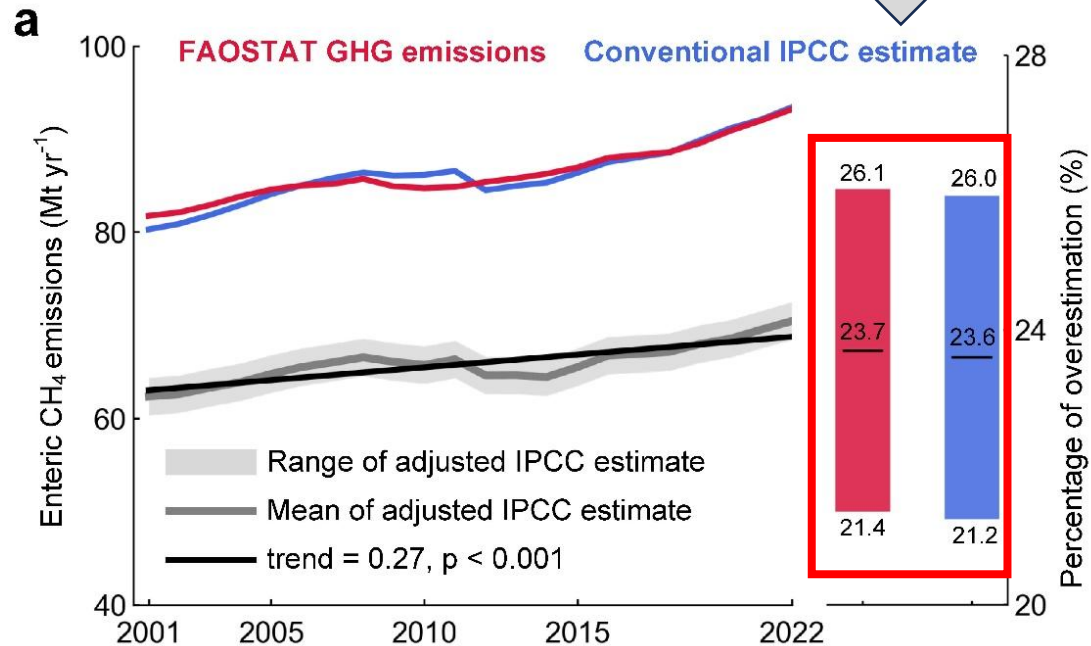


2001-2022 trend

Final results

a. After accounting for the antimethanogenic-forage effect, enteric methane estimates were reduced by 24%

b. The strongest effects were concentrated in India, Brazil, Central Africa, and Western Europe



Thank you

Any questions?



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