METHANE PRODUCTION RATES OF DAIRY COWS:

AN ALTERNATIVE APPROACH

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1. PROBLEM DEFINITION

Reduction of greenhouse gases emissions from agriculture is needed

Main emitted =

Enteric methane from ruminants

Cows = number 1

Possible to reduce methane production

(e.g., genetics, feed)

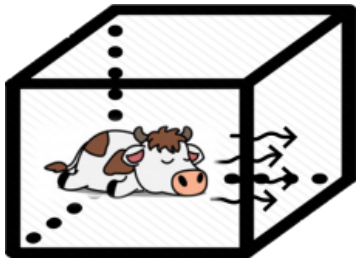
Monitoring needed (in practice)

2. THE CUBICLE HOOD SAMPLER (CHS):

AN ALTERNATIVE PRACTICAL SYSTEM

2. CUBICLE HOOD SAMPLER

WORKING PRINCIPLES



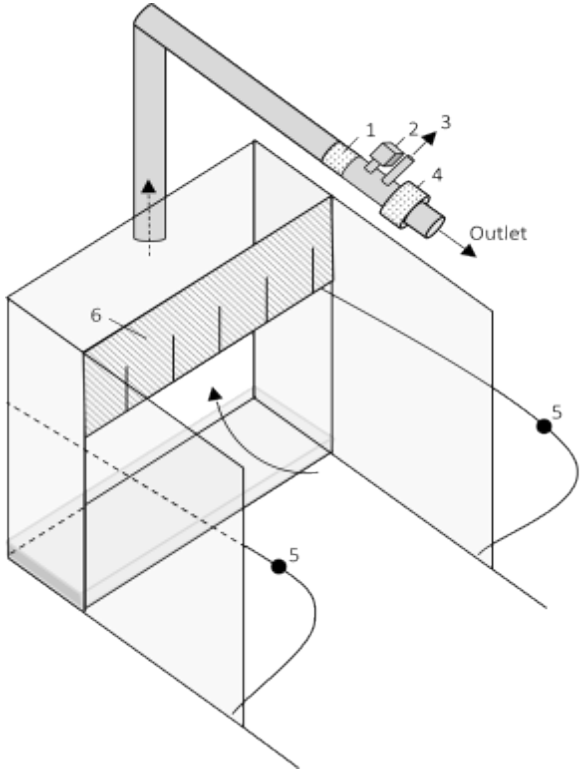
Working principles:

- Capture cow breath & eructation

- Differentiate breath from background emissions

→ Done though physical isolation

+ suction (fan + under-pressure effect)



1: Flowmeter, **2:** T-RV sensor, **3:** Sampling point, **4:** Fan, **5:** Background sampling points, **6:** Rear flap.

2. ALTERNATIVE PRACTICAL SYSTEM

GAS ANALYSIS

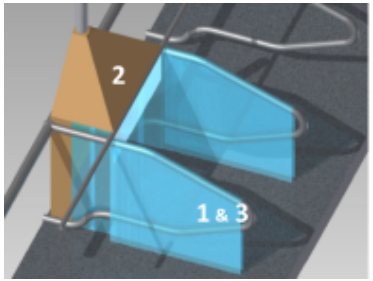
Measurement cycle:

1. Background - 2. Hood – 3.Background

6 min - 16 min – 6 min

- Started upon arrival of a cow

- Coupled to Fourier Transform Infrared (FTIR) spectroscopy gas analyser



2. CUBICLE HOOD SAMPLER

COW IDENTIFICATION

Radio Frequency Identification (RFID):

- Set of tags worn by cows
- Detected by antennas in cubicles

→ Starts measurements

→ Attributes data to the right cow

2. ALTERNATIVE PRACTICAL SYSTEM

HEAD POSITION MONITORING

Problem:

- Head position affects recovery

Camera vision algorithm:

- Repurposed SLEAP [1]
- Detect key points on cow
- Calculate head angle

→ Allows to filter out measurements

[1] Pereira et al., 2022. SLEAP: A deep learning system for multi-animal pose tracking. DOI: 10.1038/s41592-022-01426-1

3. EXPERIMENTAL STUDY

EXPERIMENTAL SETUP

28 lactating dairy cows

Holstein Friesian

2.3 ± 0.9 lactations

93 DIM ± 27 DIM

22 ± 1.5 kg/d DM intake

29.3 ± 4.4 kg/d MY

Free stall barn: 7-d

Adaptation to group (7 groups of 4 cows)

Tie stall: 12-d

Adapt. restricted movement + diet

Climate respiration chamber (CRC): 4-d

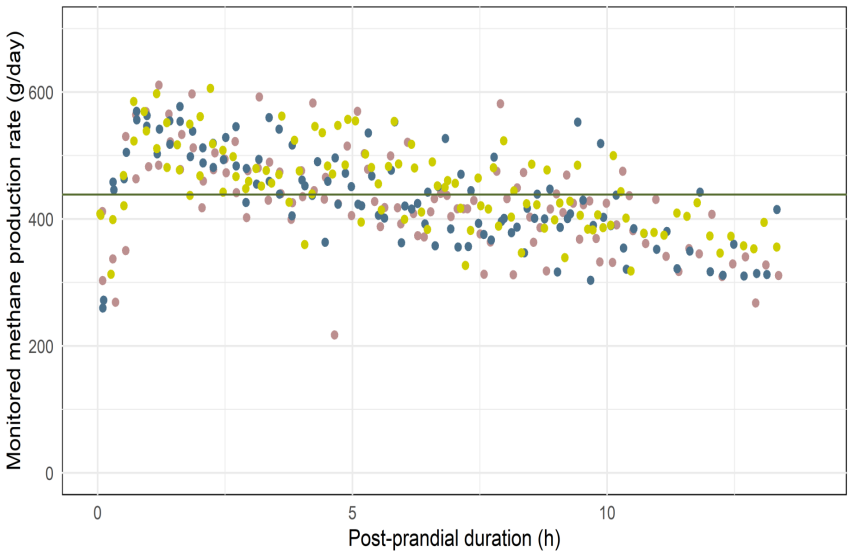
Reference measurements

CHS: 7-d

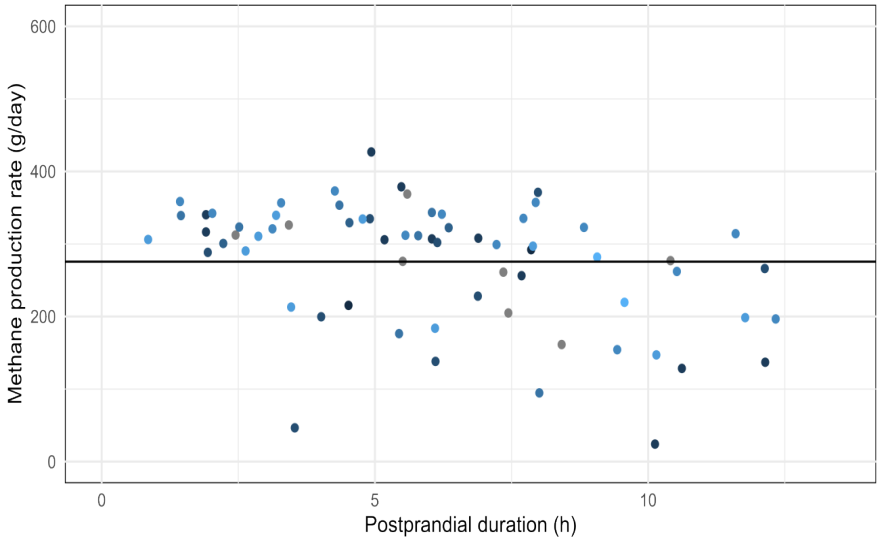
4. DATA ANALYSIS

DAILY METHANE PRODUCTION RATES (MPR) ORIGINAL SET

CRC (Example of one cow)



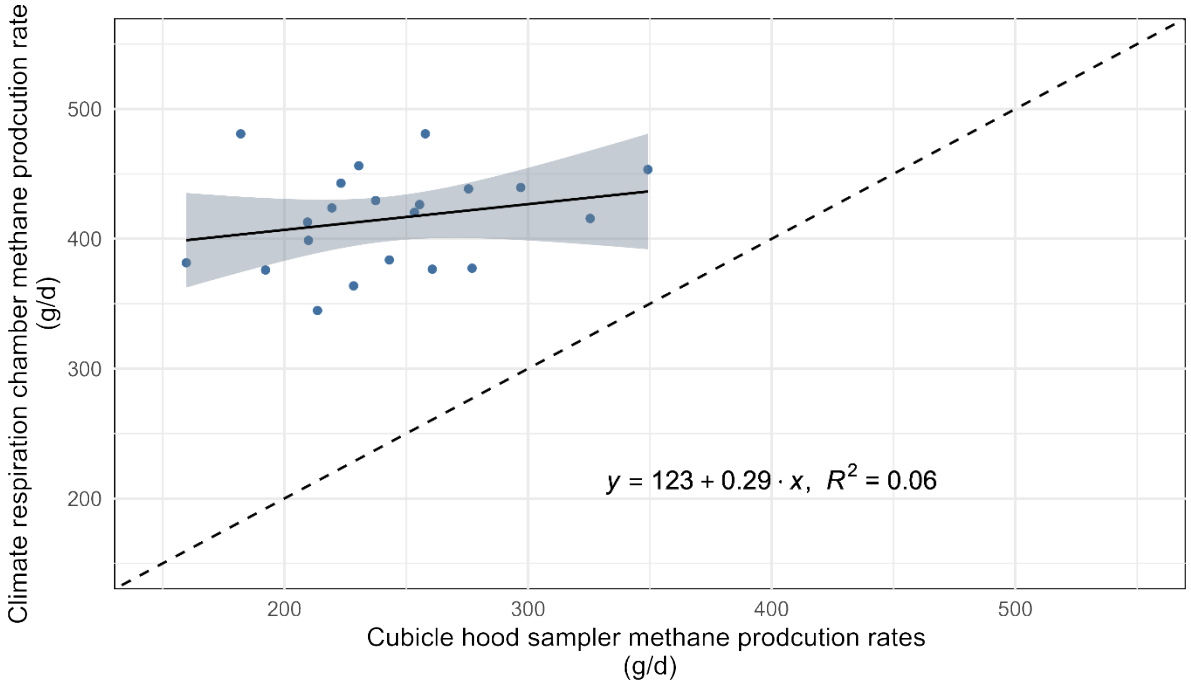
CHS (Same cow)



→ **Less data, more variability, peak MPR not monitored**

4. DATA ANALYSIS

LINEAR REGRESSION MPR ORIGINAL SET



Concordance metrics

$R^2 = 0.06$

Pearson' $r = 0.24$

RMSE = 180

Mean MPR:

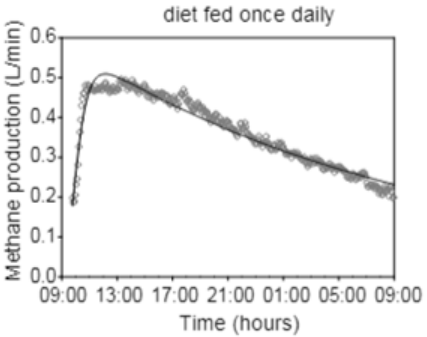
CRC = 415 ± 36 g/d

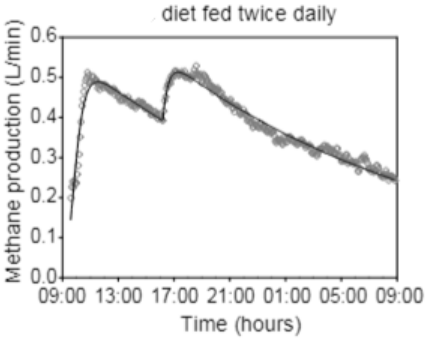
CHS = 243 ± 45 g/d

CV of 9 versus 18%

STEP BACK: WHAT ARE WE DEALING WITH NOW?

- Problem: only **spot sampling** is possible
- Methane production rate (MPR) is **not linear**
- Depending on **feeding** (what, how much) and **time** after feeding
- Postprandial status when sampling **impacts estimate**





4. DATA ANALYSIS

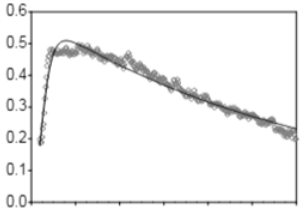
MODELING MPR

- **Goal:** Convert discrete measurements into continuous MPR curves

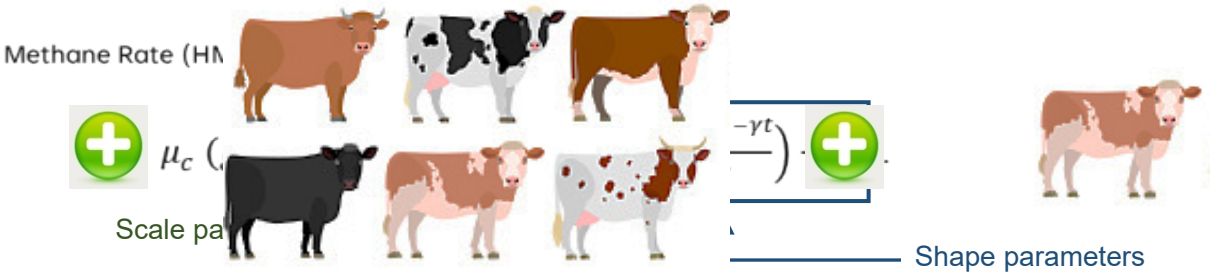
→ Get a better representation of the physiological process

→ Partially compensate for missing information

→ Hopefully: more accurate estimations of MPR



Bayesian



Partially pooled

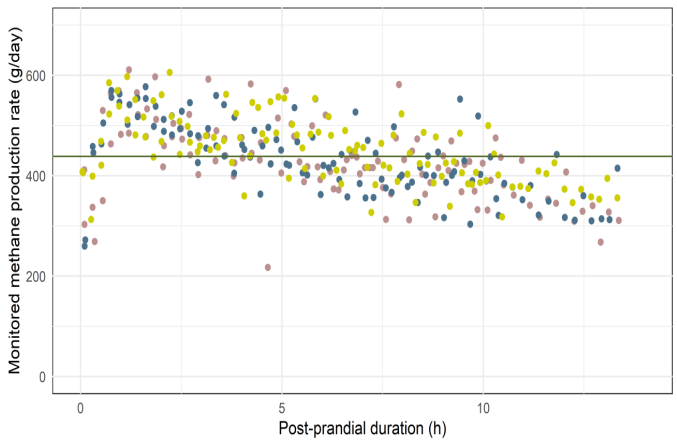
Hierarchical

4. DATA ANALYSIS

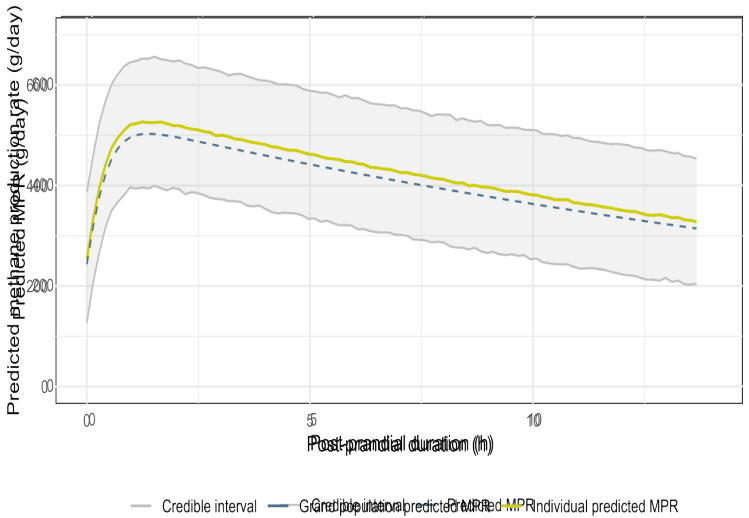
VALIDATING HMR MODEL WITH CRC DATA

Gold standard's dataset

(Example of one cow)



Fitted population curve
Deduced individual curve
(n=28 cows)



4. DATA ANALYSIS

VALIDATING HMR MODEL WITH CRC DATA

• **Comparison of MPR monitored by CRC vs predicted by HMR:**

r = 0.997

RMSE = 10.03

RMSE % of observed MPR mean = 2.4%

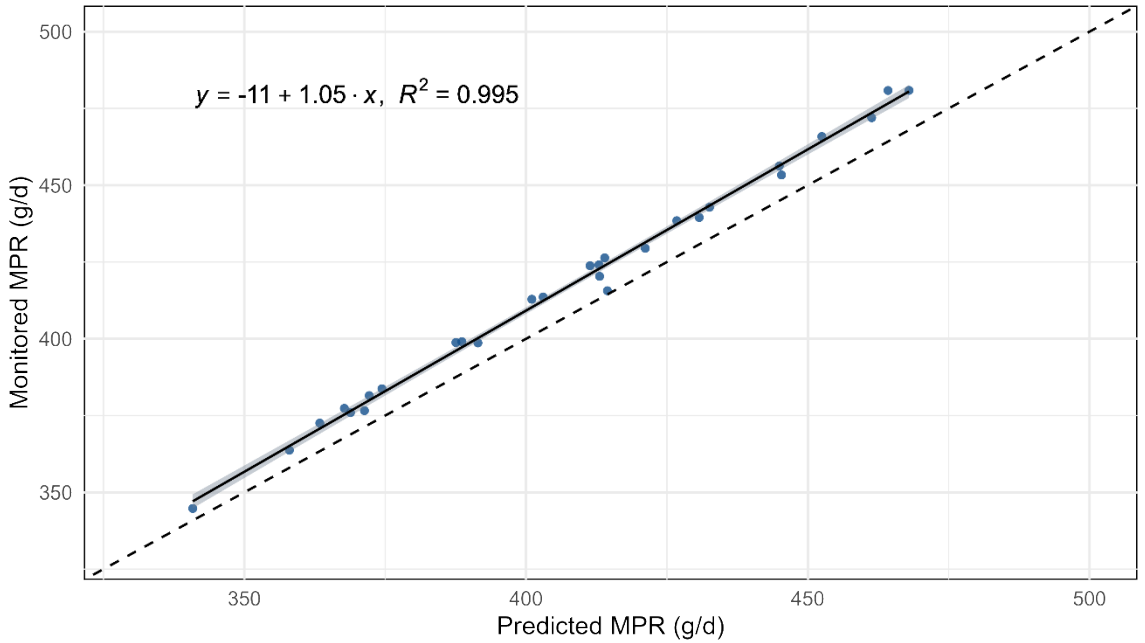
CCC = 0.961

• **Validation model:**

- Posterior predictive checks

- Leave one out cross validation

→ **Model validated**



4. DATA ANALYSIS

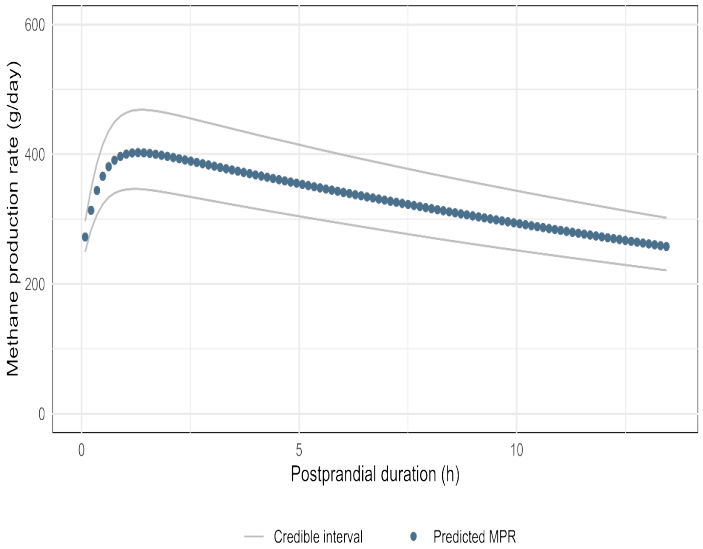
FITTING HMR WITH CHS DATA

Kept 11 cows

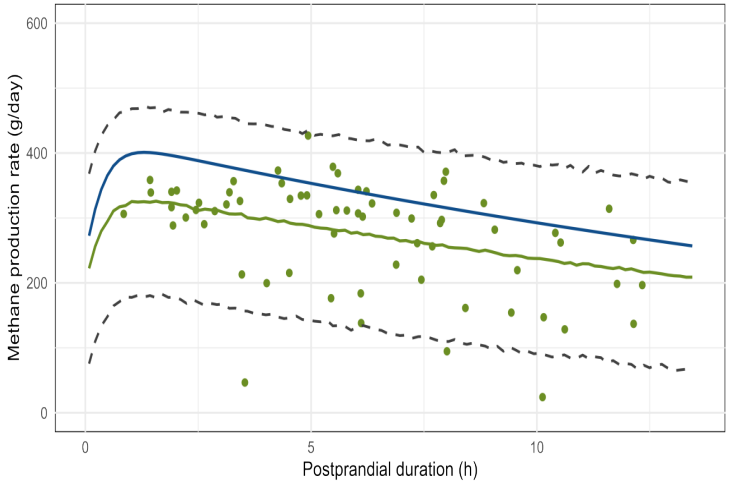
(out of the 28)

with the most obs. (>30)

Fitted population curve

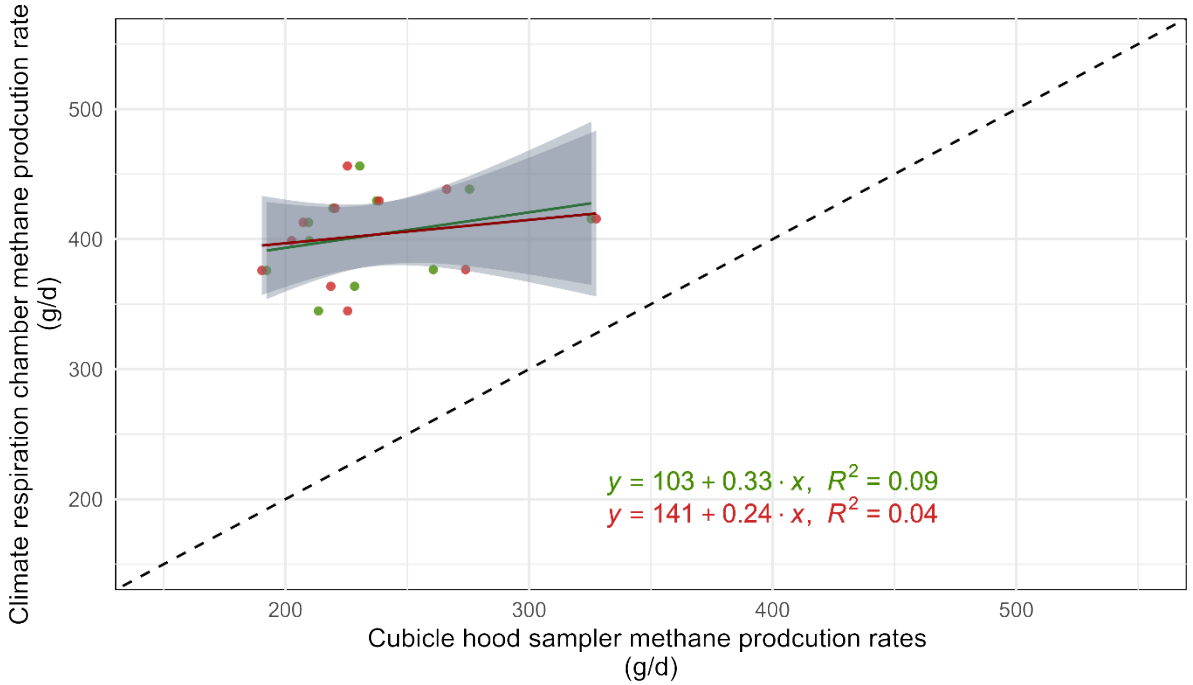


Fitted individual curve



4. DATA ANALYSIS

COMPARING MPR ESTIMATED BY CRC & CHS/HMR



Concordance metrics

Green: CHS alone	Red: CHS with HMR
R^2 = 0.09	R^2 = 0.04
Pearson' *r* = 0.30	Pearson' *r* = 0.20
RMSE = 172	RMSE = 173
Mean MPR:	Mean MPR:
CRC = 403 ± 33 g/d	CRC = 403 ± 33 g/d
CHS = 237 ± 36 g/d	CHS = 236 ± 37 g/d
CV of 8 versus 15%	**CV of 8 versus 17%**

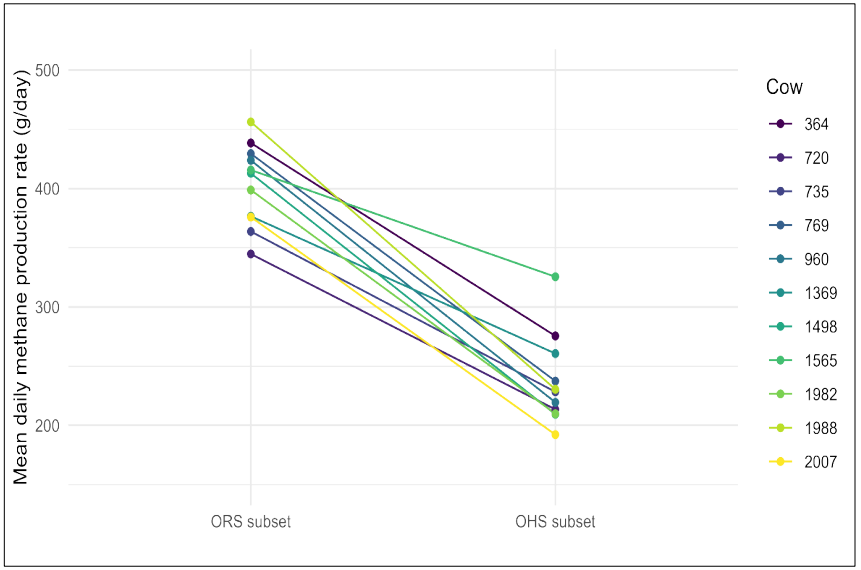
→ CHS cannot yet be used to measure absolute MPR levels

4. DATA ANALYSIS

RANKING COWS BASED ON THEIR MPR LEVELS

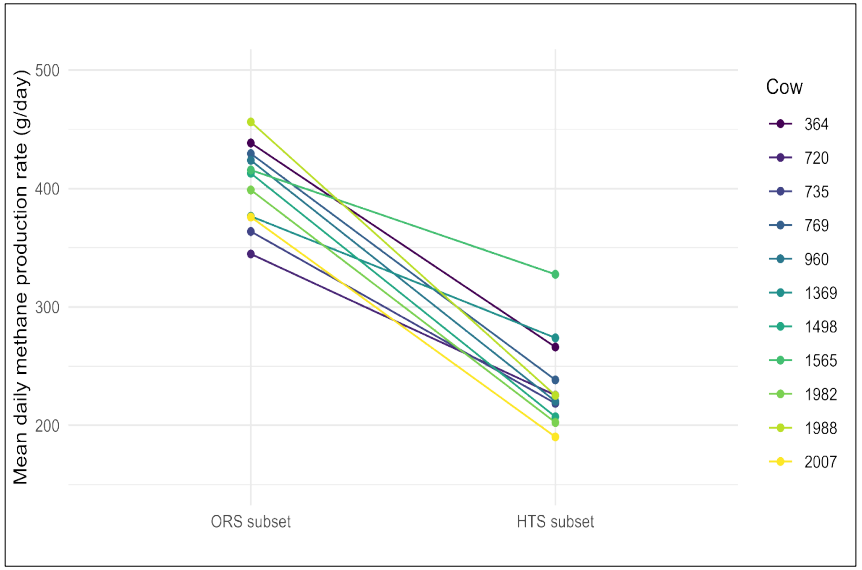
Ranking with Kendall W:

CHS alone



W = 0.74

CHS with HMR



W = 0.66

→ CHS can be used to rank animals

With care, and depending on desired agreement levels

4. DATA ANALYSIS

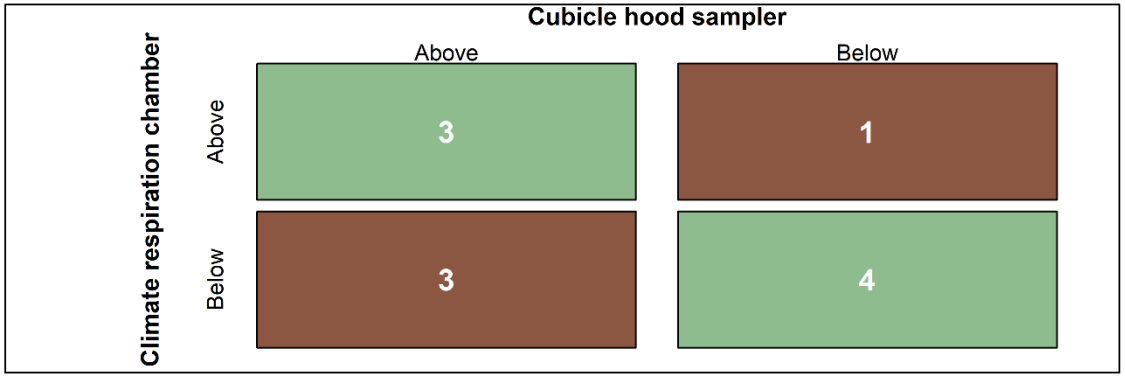
CLASSIFYING COWS AS “ABOVE OR BELOW” POPULATION LEVEL

- **Interesting for genetic selection:**

- Is a cow above or below mean population level?

- CHS (with and without HMR) yielded the same results

→ **Too many errors still being made**



DETAILS

Sensitivity	Specificity	Precision	Recall	F1
0.5	0.8	0.75	0.5	0.6

Accuracy	Kappa
0.636	0.29

CONCLUSIONS, RECOMMENDATIONS

& FOOD FOR THOUGHTS

1

- **Identify source of bias!**

- Persistent bias in CHS measurement

- **Can't be used for accurate MPR measurements** until addressed

3

- **Fix issue:**

- Increase suction?

- Reposition background sampling point?

2

- **Prime suspects:**

- Low recovery breath sample

- Simultaneous amplifying effect on background sampling

- Overall errors in monitoring background concentrations

- **Keep using HMR:**

- Better representation of the MP process

- Allows borrowing of info across cows

→ Deal with less observations

- BUT cannot compensate for biased data

4

CONCLUSIONS, RECOMMENDATIONS

& FOOD FOR THOUGHTS

- **Different feeding regimes:**

  Effect on model's prediction?

- **Missing the production peak:**

  Is MPR estimation still accurate?

- **Work on portability**

  CHS currently not easily transportable

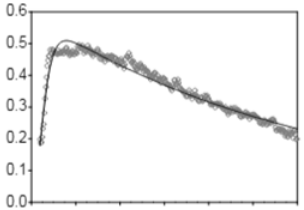
THANK YOU

2. MODEL DEFINITION

HIERARCHICAL METHANE RATE (HMR) MODEL

Model likelihood defined as

$$M_c \sim N(\mu_c, \sigma_\epsilon),$$



With

$$\mu_c\ (g/d) = (\bar{\alpha} + \alpha_c) \cdot \exp\left[\beta \cdot \left(\frac{1 - e^{-\gamma t}}{\gamma}\right) - \delta t\right]$$

Scale parameter

Shape parameters

Formulated prior distributions:

$\bar{\alpha} \sim N(500, 200)$

$\alpha_c \sim N(0, \sigma_\alpha)$

$\beta \sim N_+(0, 2)$

$\gamma \sim N_+(0, 2)$

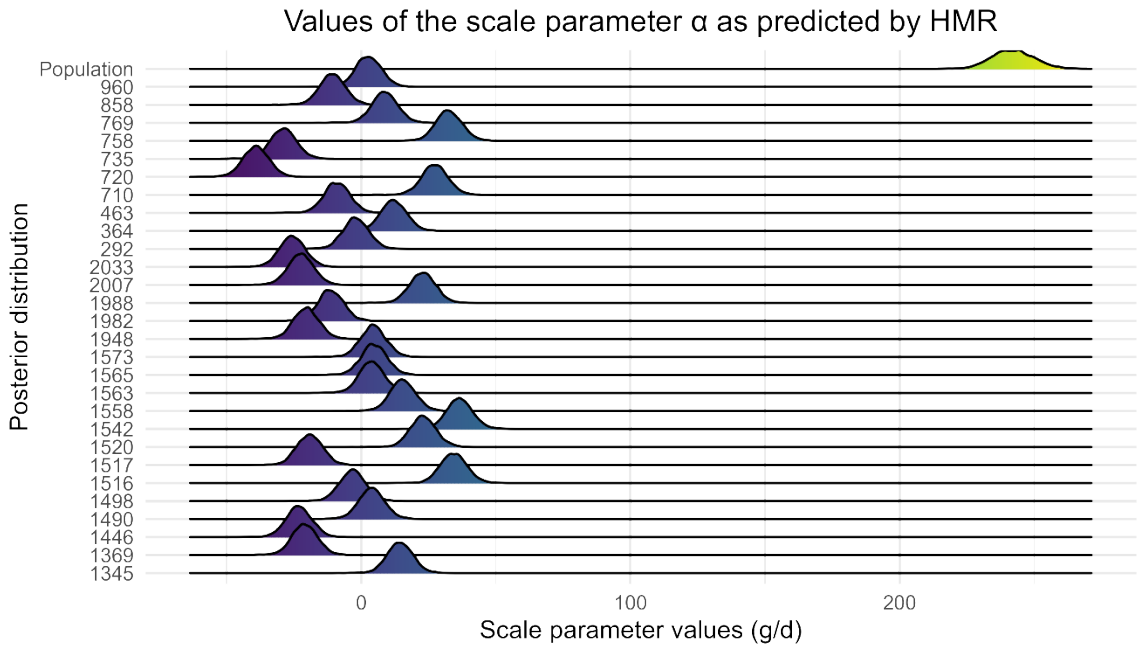
$\delta \sim N_+(0, 2)$

$\sigma_\alpha \sim T_3^+(0, s)$

$\sigma_\varepsilon \sim T_3^+(0, s)$

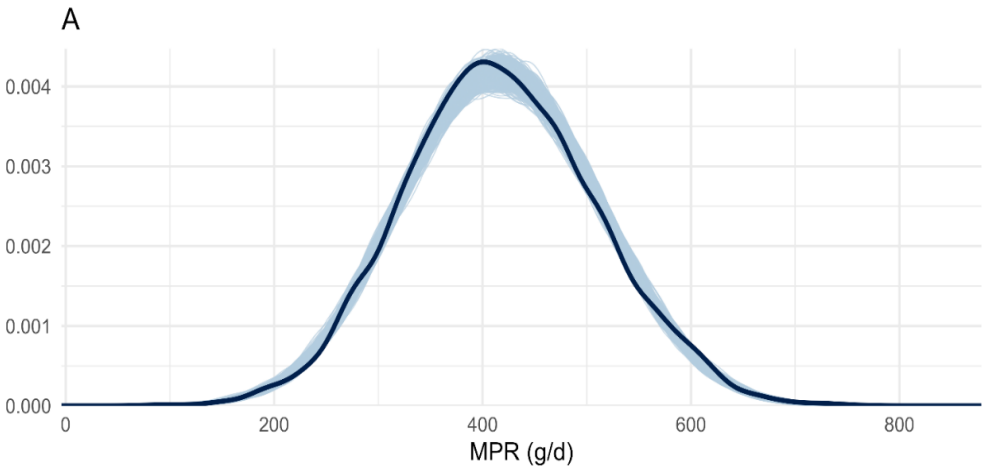
3. MODEL VALIDATION

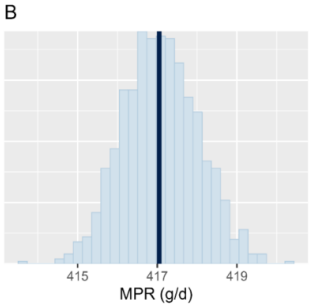
B. EXTRACTING INDIVIDUAL SCALE PARAM



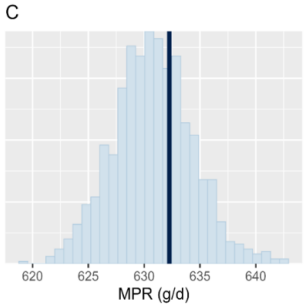
3. MODEL VALIDATION

C. DATA REPLICATION: POSTERIOR PREDICTIVE CHECKS





PPD mean



PPD 99th quantile

PPC 1000 draws.

Dark line: observed values, light lines: replicated values.

3. MODEL VALIDATION

D. LEAVE ONE OUT CROSS VALIDATION

- Loo-cv done against fully pooled equivalent of the model

(= All parameters are population parameters)

Model	ELPD difference	SE difference
Partially pooled (HMR)	0.0	0.0
Fully pooled	-1652.9	69.3

> |4|

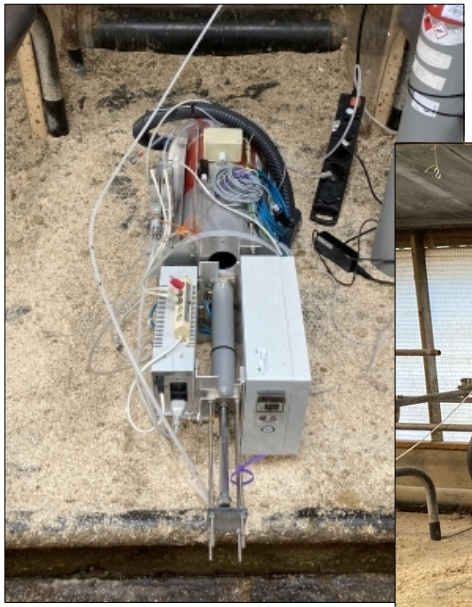
→ HMR predicts data significantly better

= 4.2% of difference in ELPD

→ Shows low uncertainty that difference in prediction accuracy = due to chance

3. EXPERIMENTAL STUDY

RECOVERY TESTS



System calibration

- Injection of known masses of methane

- 2 levels: **200 g/d & 400 g/d**

- 3 replicates

(Before, halfway, after the experiment)

→ Mean recovery of **110.5% ±8.7**

across CHS, treatments, and repetitions

→ No significant differences between CHS, treat, nor rep