

# A proof-of-concept framework for machine learning to link coccidiosis-related performance losses to changes in the carbon footprint

J. Gickel<sup>1</sup> and C. Visscher<sup>1,2</sup>

<sup>1</sup> Science and Innovation for Sustainable Poultry Production (WING),  
University of Veterinary Medicine Hannover, Germany

<sup>2</sup> Institute for Animal Nutrition,  
University of Veterinary Medicine Hannover, Germany



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# Why deal with the carbon footprint?

- 2015: Sustainability Development Goals (SDGs)
- 2019: **European Green Deal**  
reaching **climate neutrality** by **2050**
- Ecological impact of sustainability can be measured using life cycle assessment (**LCA**)
- Carbon footprint equals all **greenhouse gas emissions**, that arise **directly** or **indirectly** in a system

## SUSTAINABLE DEVELOPMENT GOALS



www.sdg-portal.de/en



# Effects of coccidiosis on broiler chickens



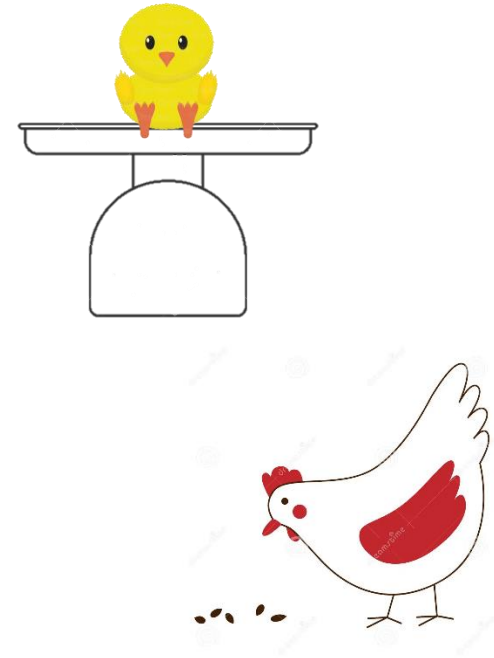
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- Carbon footprint of broiler chickens is **highly linked to the performance** of the animals
- An infection with *Eimeria* spp. is known to result in
  - Diarrhea
  - Reduction of feed intake
  - Reduction of weight gain
  - In severe cases: increase of mortality

→ Carbon footprint **increases** following an infection with *Eimeria* spp.,  
but **quantitative** links are **insufficiently explored**

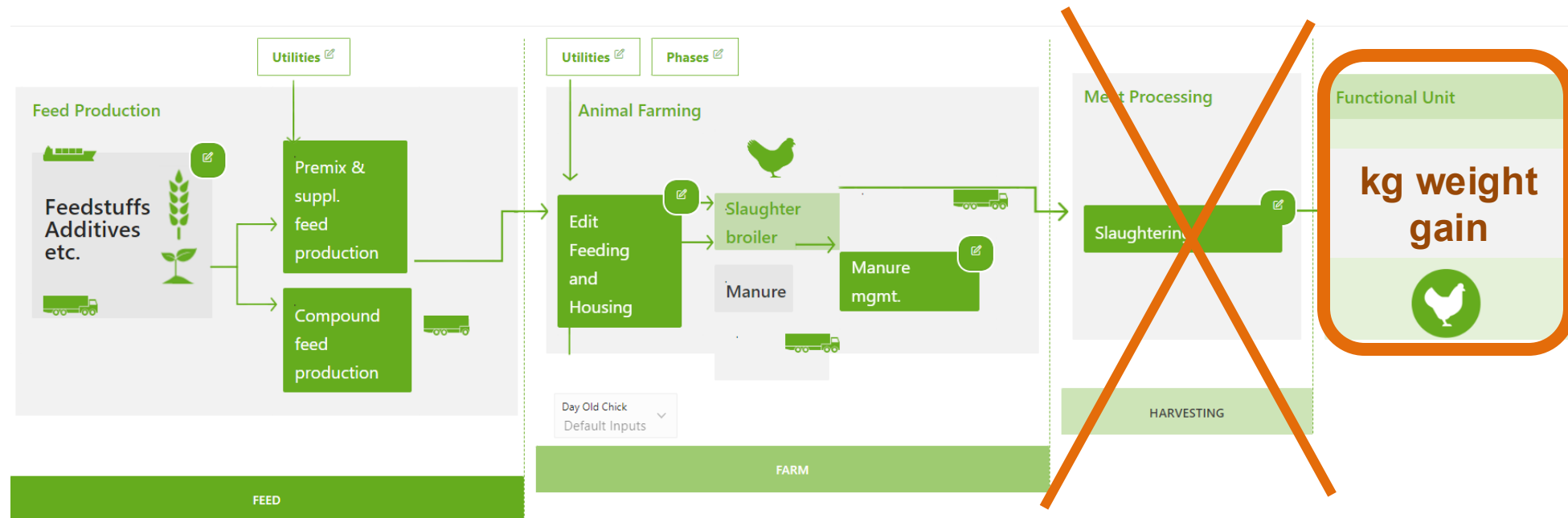
# Compilation of data from literature

- Literature research with PubMed to effects of an infection with *Eimeria* spp. (challenge trials)
- Included genetics: Cobb, Ross and Arbor Acres
- Comparison of **unchallenged and challenged** broiler chickens
- Extraction of:
  - day of challenge
  - amount of oocysts for challenge
  - duration of trial
  - average daily gain (ADG)
  - feed conversion ratio (FCR)
  - genetic of broiler chickens



# Determination of the carbon footprint

- Life cycle assessment (**LCA**) for each group of each comparison using the software application „Opteinics“ (now renamed to: Nuvio Planet) according to **ISO 14040 / 14044**
- Assuming identical feed for each group – feed data are from the database of the Global Feed LCA Institute (**GFLI**) according to **FAO and LEAP guidelines**



# About the dataset

| No. | country | genetic | DOC | amount | age_start | age_end | DOT | weight_start_1 | weight_start_2 | weight_end_1 | weight_end_2 | ADG_1 | ADG_2 | change_ADG | FCR_1 | FCR_2 | change_FCR | CF_1  | CF_2  | change_CF |
|-----|---------|---------|-----|--------|-----------|---------|-----|----------------|----------------|--------------|--------------|-------|-------|------------|-------|-------|------------|-------|-------|-----------|
| 01  | USA     | Cobb    | 15  | 175000 | 14        | 21      | 8   | 0.392          | 0.3926         | 0.7992       | 0.6646       | 50.9  | 34.0  | -33.20     | 1.28  | 1.66  | 29.69      | 1.16  | 1.49  | 28.45     |
| 02  | USA     | Cobb    | 14  | 6250   | 14        | 23      | 10  | 0.3594         | 0.3603         | 0.881        | 0.859        | 60.16 | 57.5  | -4.44      | 1.62  | 1.69  | 4.32       | 1.506 | 1.619 | 7.50      |
| 03  | USA     | Cobb    | 14  | 12500  | 14        | 23      | 10  | 0.3594         | 0.356          | 0.881        | 0.8769       | 60.16 | 58.83 | -2.21      | 1.62  | 1.71  | 5.56       | 1.506 | 1.592 | 5.71      |
| 04  | USA     | Cobb    | 14  | 25000  | 14        | 23      | 10  | 0.3594         | 0.3595         | 0.881        | 0.88573      | 60.16 | 58.97 | -1.98      | 1.62  | 1.67  | 3.09       | 1.506 | 1.554 | 3.19      |
| ... |         |         |     |        |           |         |     |                |                |              |              |       |       |            |       |       |            |       |       |           |

**In total: 41 comparisons from 33 challenge trials**

\_1 = group 1 (without challenge); \_2 group 2 (with challenge)

DOC = day of challenge; amount = amount of oocysts for challenge; DOT = days of trial; ADG = average daily gain; FCR = feed conversion ratio; CF = carbon footprint; change = relative (%) change in ADG/FCR/CF



**(To what extent) can the carbon footprint be explained by animal health parameters?**

# Materials and methods

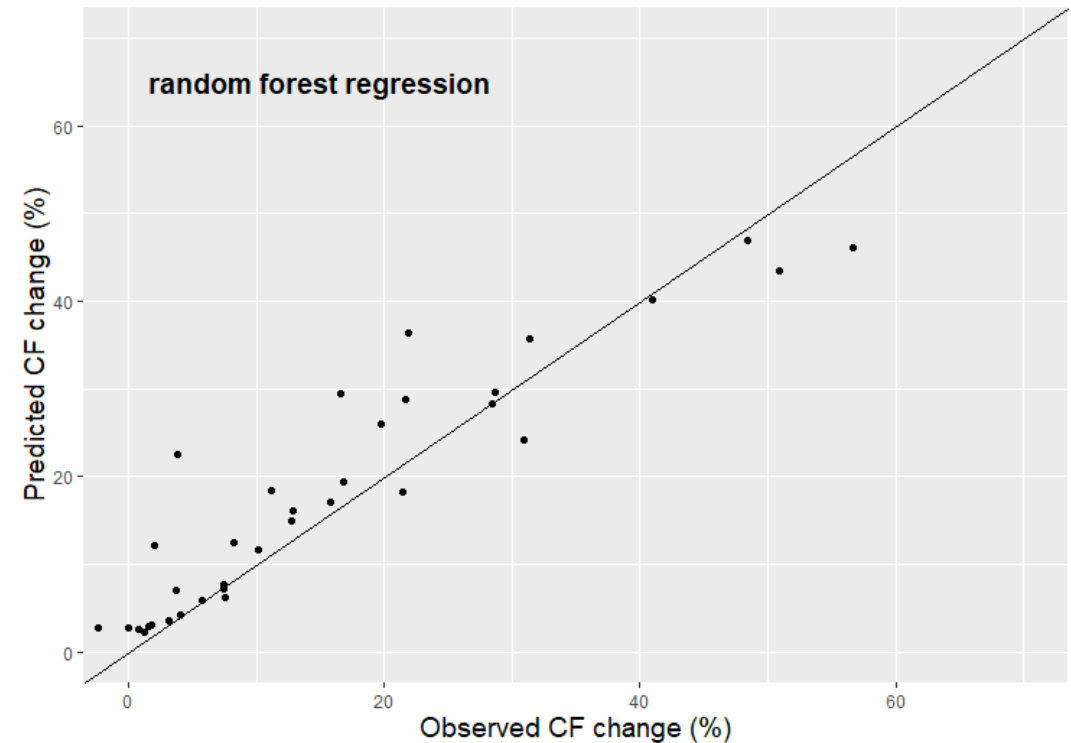
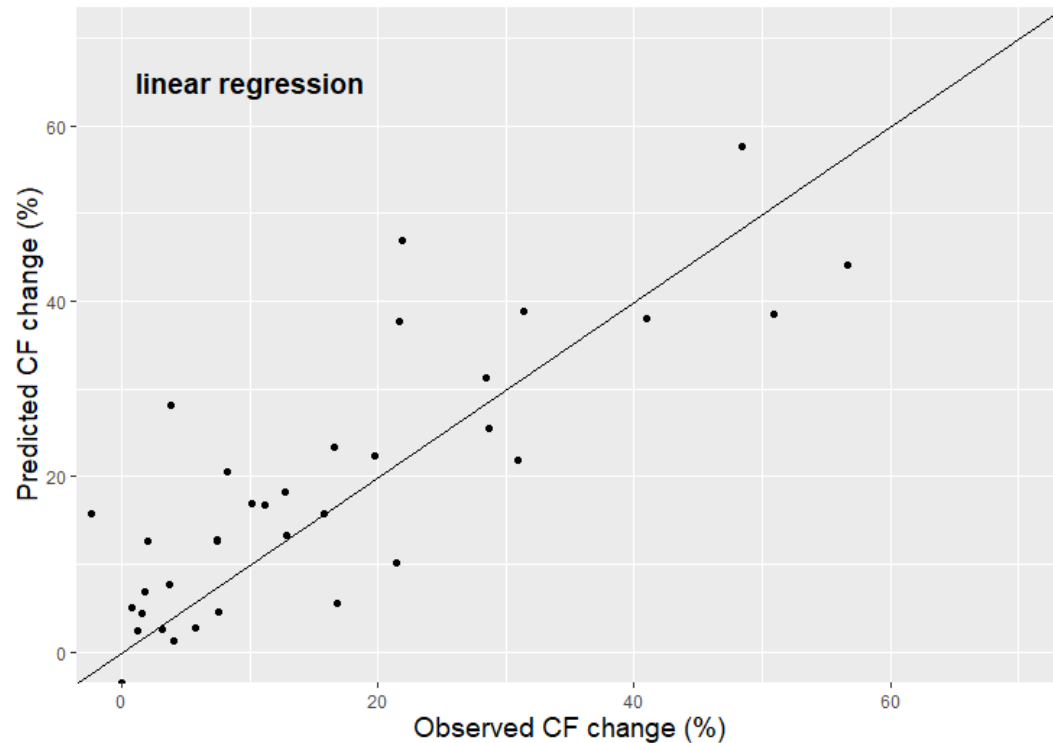
- Linear regression and random forest regression using 80:20 training-test split
- predictor variables (light blue) and outcome variable (orange):

| No. | country | genetic | DOC | amount | age_start | age_end | DOT | weight_start_1 | weight_start_2 | weight_end_1 | weight_end_2 | ADG_1 | ADG_2 | change_ADG | FCR_1 | FCR_2 | change_FCR | CF_1  | CF_2  | change_CF |
|-----|---------|---------|-----|--------|-----------|---------|-----|----------------|----------------|--------------|--------------|-------|-------|------------|-------|-------|------------|-------|-------|-----------|
| 01  | USA     | Cobb    | 15  | 175000 | 14        | 21      | 8   | 0.392          | 0.3926         | 0.7992       | 0.6646       | 50.9  | 34.0  | -33.20     | 1.28  | 1.66  | 29.69      | 1.16  | 1.49  | 28.45     |
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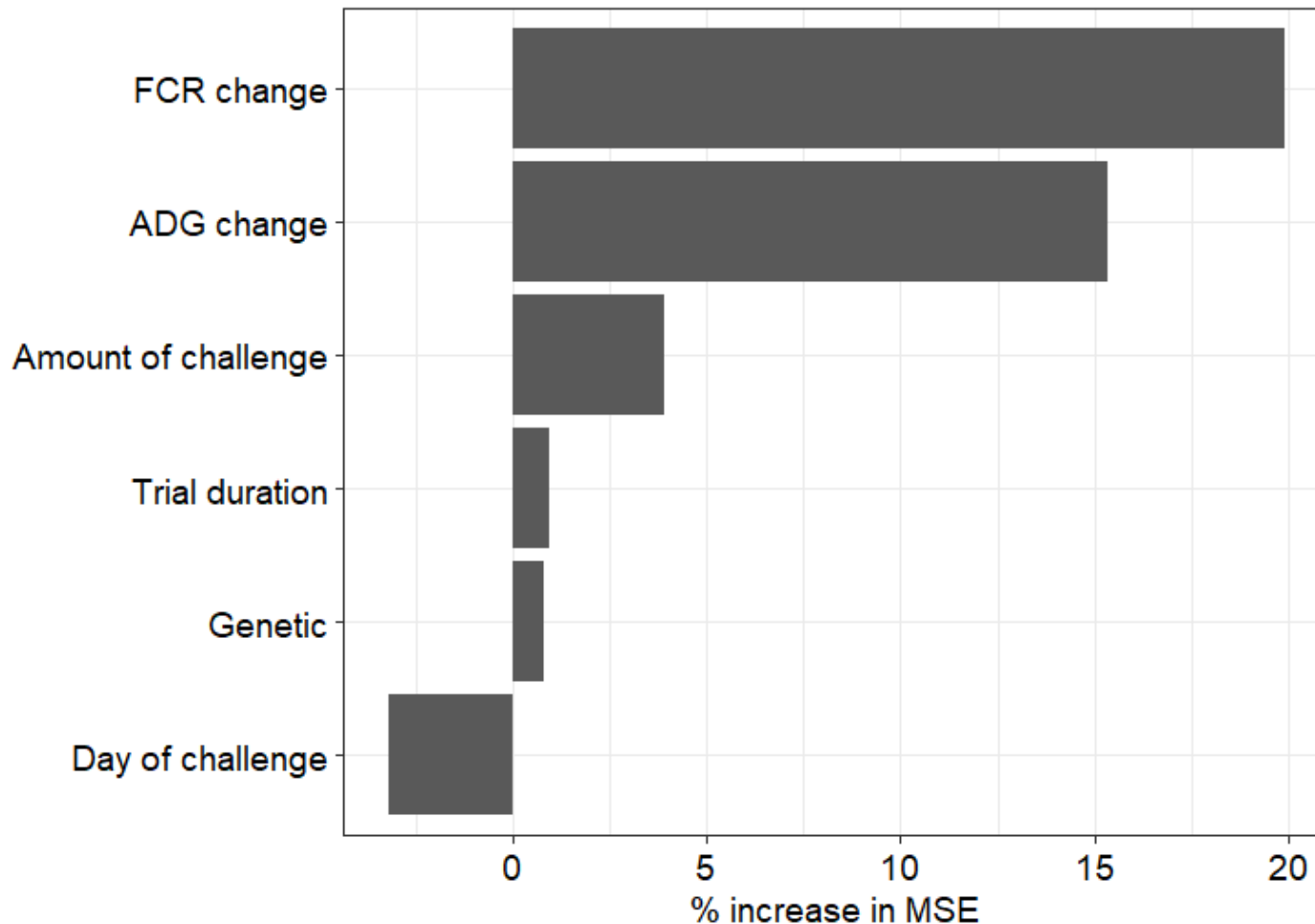
- Additional parameters for random forest model:
  - 1000 trees
  - mtry (predictor variables randomly considered at each split) = square root of all variables  
→ 2

# Results

|                                | Linear regression | Random forest regression |
|--------------------------------|-------------------|--------------------------|
| $R^2$                          | 0.57              | 0.70                     |
| Root Mean Squared Error (RMSE) | 13.3              | 11.7                     |

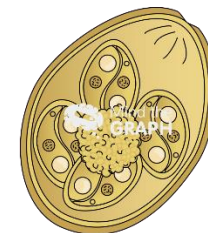
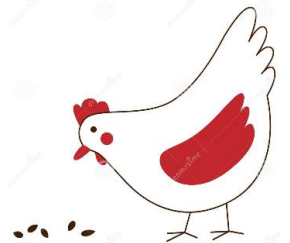


# Variable importance of random forest



- FCR change = strongest predictor
- ADG change = second strongest predictor
- Challenge characteristics and genetics had minor influence

- Random forest model outperformed linear regression
  - Relationship between infection severity, performance and carbon footprint (CF) not purely linear
- FCR change and ADG change strongest predictors of CF variation
  - carbon footprint primarily mediated through reduced production efficiency
- Oocyst dose and challenge timing contributed comparatively little
  - Challenge characteristics were less important (than expected)



# Limitations/Outlook

- Small sample size (41 comparisons from 33 trials)
- Literature-derived dataset induced heterogeneity → uncertainty
- Assumptions for carbon footprint → uncertainty
- Limited predictor set → important factors such as nutrition or housing missing
- No external validation (train/test split from within dataset)



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- Validation of machine learning models with larger datasets
  - Real-time estimation of sustainability impacts of animal health challenges
  - AI-supported decision-making for sustainable livestock production



- **Animal health and carbon footprint** closely interconnected
- **Feed conversion ratio** and **average daily gain** key indicators linking coccidiosis to carbon footprint changes
- **Machine learning** shows **potential to quantify** sustainability impacts of animal health challenges

**Dr. Julia Gickel**

Science and Innovation for Sustainable Poultry Production (WING),

University of Veterinary Medicine Hannover, Foundation,

Hannover, Germany

[julia.gickel@tiho-hannover.de](mailto:julia.gickel@tiho-hannover.de)



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