Ruminant Farm Systems Model

2022 Annual Meeting

National Agricultural Library

Beltsville, MD

RuFaS Evolution

2017

Formalized vision and established principles for RuFaS development

2018

Computer simulation structure established, and first lines of code written

Submitted first federal proposal

Expanded collaborators to include Cornell

2019

First paper published

Initiated documentation and version control methods

Submitted first successful Federal proposal

2020

Formalized Industry Advisory Council

Connected nutrient cycle in biophysical model

2021

Published 2 manuscripts on Animal Module

Hired first Professional Software Engineer

2022

Initiated contract with FARM-ES

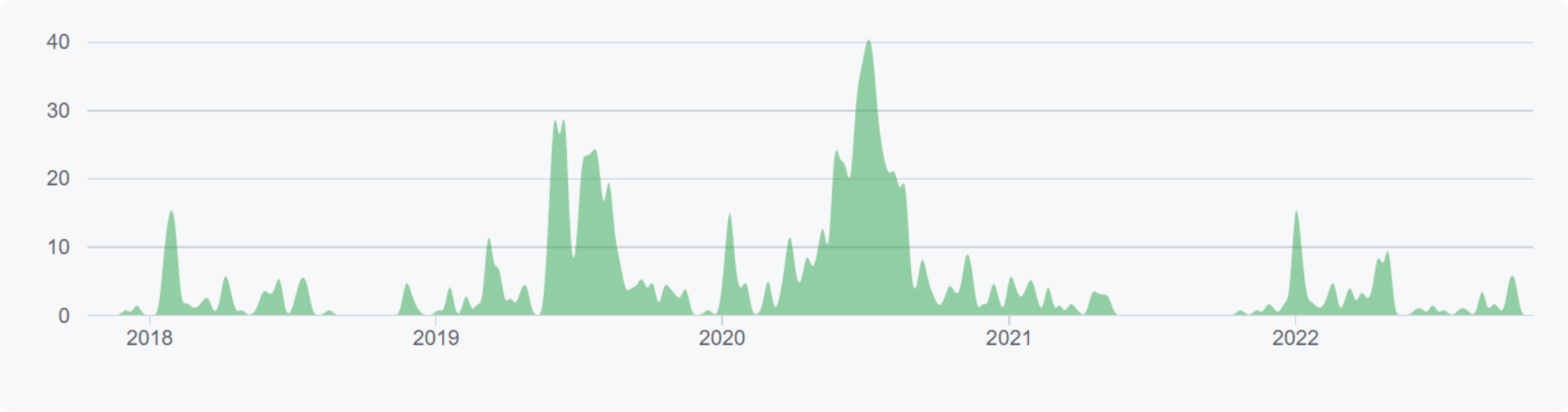
2 additional manuscripts on Animal Module

History of the Code

Oct 15, 2017 – Nov 1, 2022

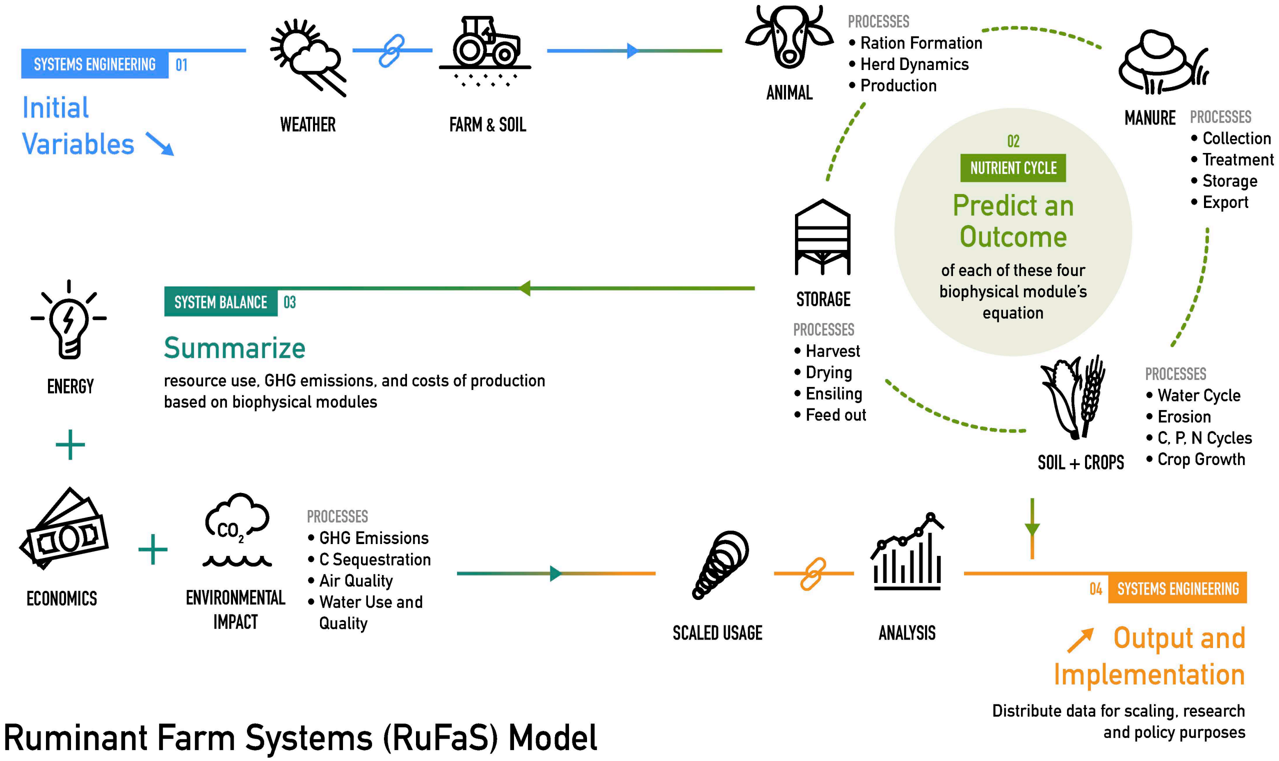
Contributions: **Commits**

Contributions to master, excluding merge commits and bot accounts



The RuFaS Vision

To ***support research and sustainable decision-making*** in ruminant animal production through ***a state-of-art, open-source modeling environment*** that is continuously adapting as technology and scientific knowledge advance.



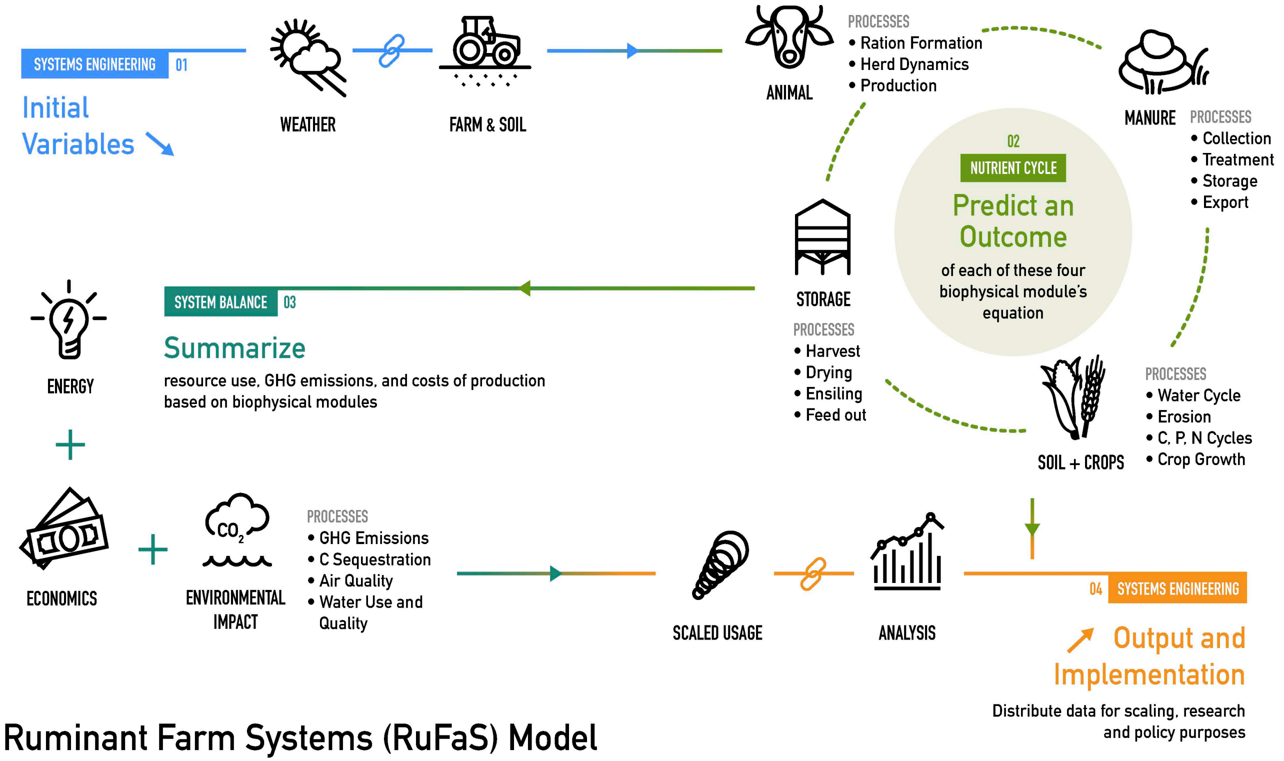
Ruminant Farm Systems (RuFaS) Model

The RuFaS Mission

To ***build an integrated, whole-farm model*** that simulates milk, meat, and crop production, greenhouse gas emissions, water quality impacts, soil health, and other ***sustainability outcomes*** of ruminant farms.

We strive to achieve the ***highest standards for prediction accuracy***, ***code structure*** and clarity, ***documentation***, and ***accessibility***.

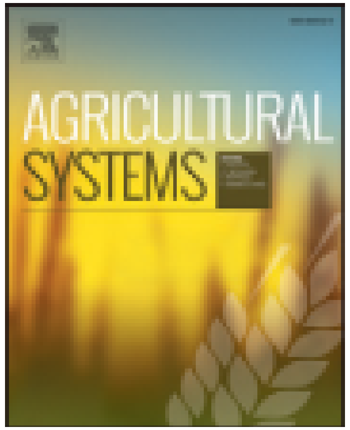
Through ***continuous learning*** and improvement of our methods and algorithms, we are ***creating an open and inclusive platform*** for scientific collaboration.



Ruminant Farm Systems (RuFaS) Model

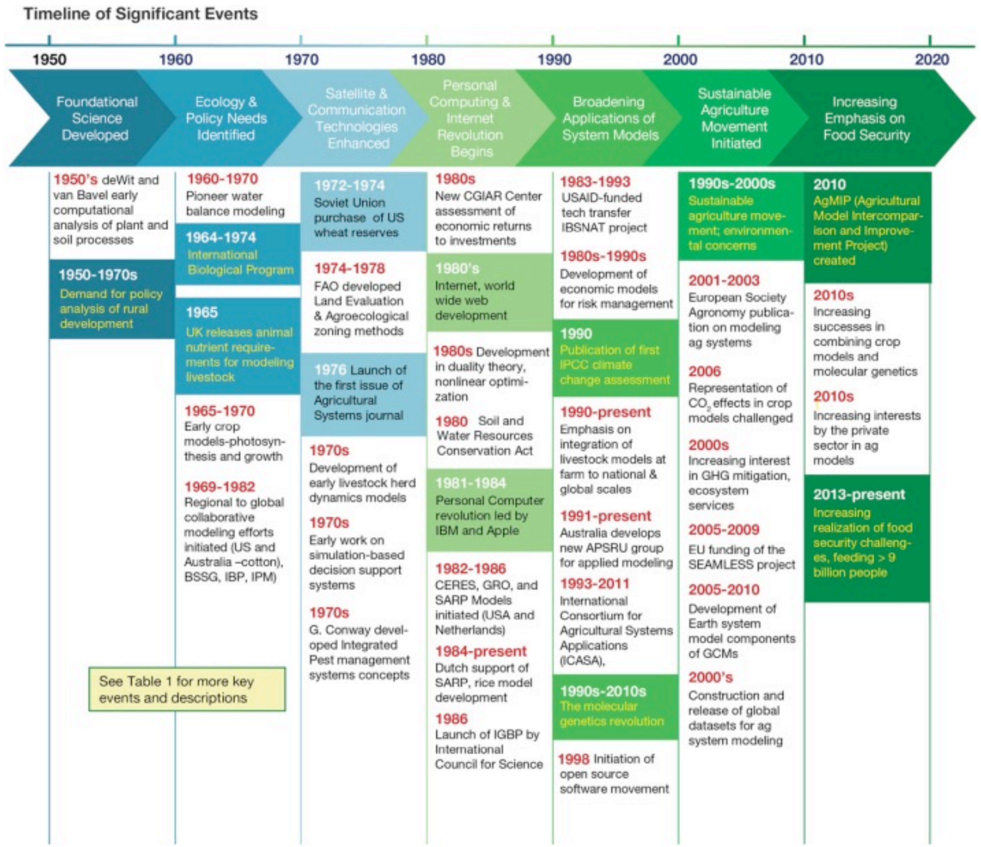
Need for a next-generation model

“Sometimes the hardest things in life, are the things most worth doing. It's because we haven't figured them out yet, doesn't mean we wont.”



Some Key Lessons…

- Need for open, harmonized data including metadata and protocols for preservation
- Transdisciplinary work is needed for major advancements
- Strive for modularity and interoperability
- Focus on user-driven development
- Embrace new technology

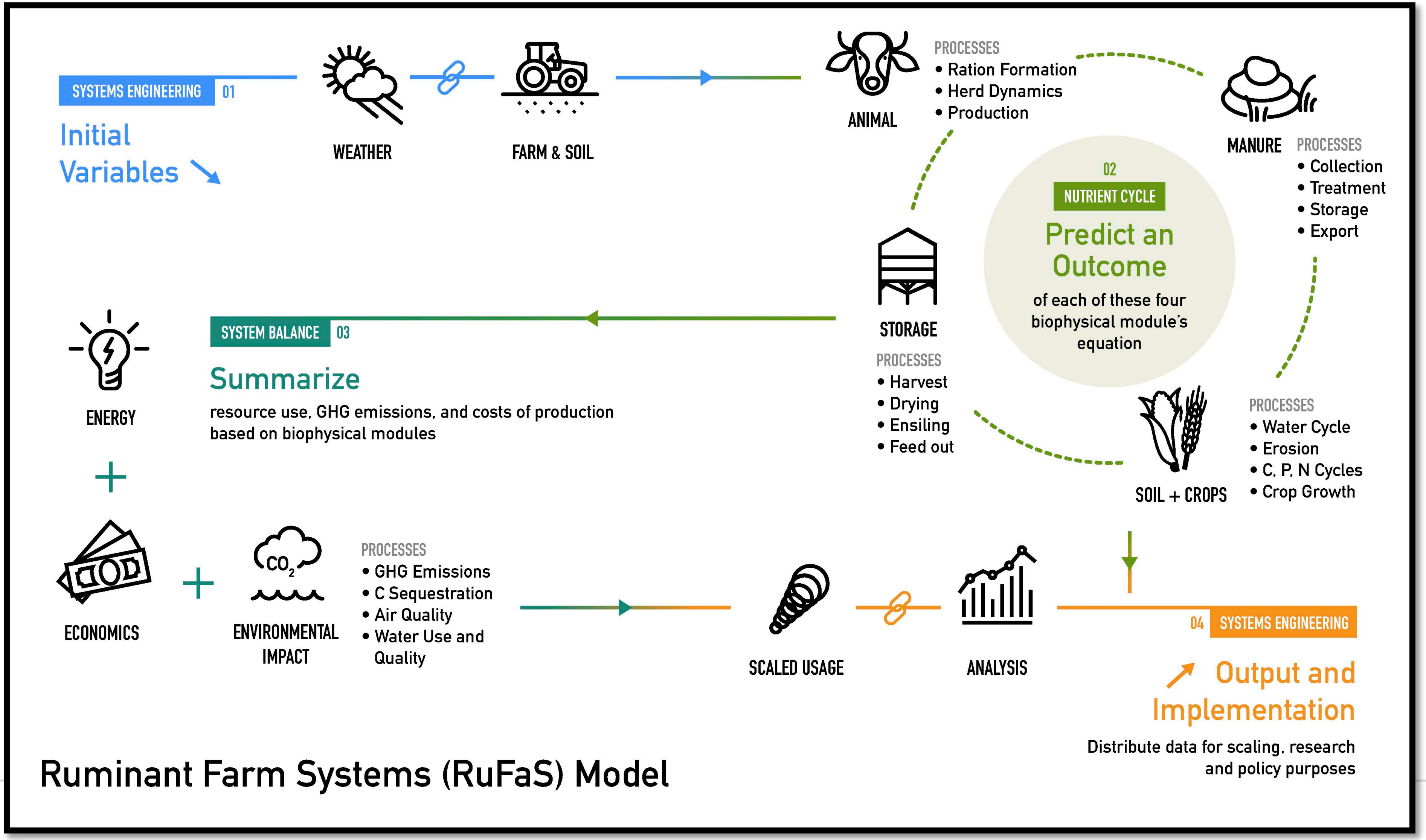


Special Issue: Next generation agricultural system data, models, and knowledge products

2017

"You have to act as if it were possible to radically transform the world. And you have to do it all the time"

RuFaS


SYSTEMS ENGINEERING 01
Initial Variables
WEATHER
FARM & SOIL
ANIMAL
PROCESSES
• Ration Formation
• Herd Dynamics
• Production
MANURE
PROCESSES
• Collection
• Treatment
• Storage
• Export
02
NUTRIENT CYCLE
Predict an Outcome
of each of these four biophysical module's equation
STORAGE
PROCESSES
• Harvest
• Drying
• Ensiling
• Feed out
SOIL + CROPS
PROCESSES
• Water Cycle
• Erosion
• C, P, N Cycles
• Crop Growth
SYSTEM BALANCE 03
Summarize
resource use, GHG emissions, and costs of production based on biophysical modules
ENERGY
ECONOMICS
CO_2
ENVIRONMENTAL IMPACT
PROCESSES
• GHG Emissions
• C Sequestration
• Air Quality
• Water Use and Quality
SCALED USAGE
ANALYSIS
04 SYSTEMS ENGINEERING
Output and Implementation
Distribute data for scaling, research and policy purposes
Ruminant Farm Systems (RuFaS) Model

Marlen Eve

USDA – Natural Resources and Sustainable Agricultural Systems

A few logical notes

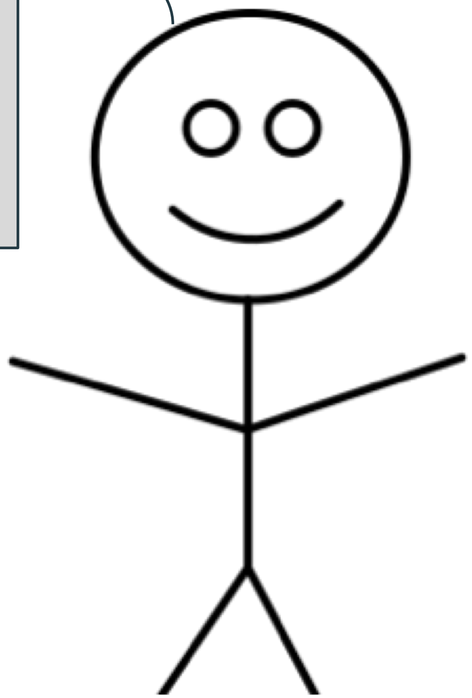
- Help yourself to coffee and snacks any time
- Note that most of the meetings will be recorded
- If you join the zoom meeting in-person, do not connect to computer audio
- Bathrooms and water fountains…

RuFaS Annual Meeting 2022

Introductions

Name: Position, Institution/Company

Add your picture here!



Make a copy of this slide and introduce yourself!

RuFaS Role: (Executive Committee, Stakeholder Advisory Committee, Manure Advisory Committee, Development team - Subject Matter Expert/Software Engineer, On-looker)

Bio: *a few sentences about you.*

Contact: what is the best way to reach you?

Kristan Reed: Assistant Prof., Cornell

RuFaS Role: Executive Committee

Bio: Kristan grew up on St. Croix in the US Virgin Islands before earning her B.S. in Animal Science from Cornell University. She spent three years as a Peace Corps Volunteer in the mountain nation of Lesotho before returning to school to complete a Ph.D. in Animal Biology at the University of California at Davis. RuFaS model development is a major component of her research program, through which, she aims to improve dairy production efficiency and sustainability.

Contact: kfr3@cornell.edu

Milestones

A year in review

Published 2 manuscripts (2 more in review!)

Presented 3 research abstracts at conferences

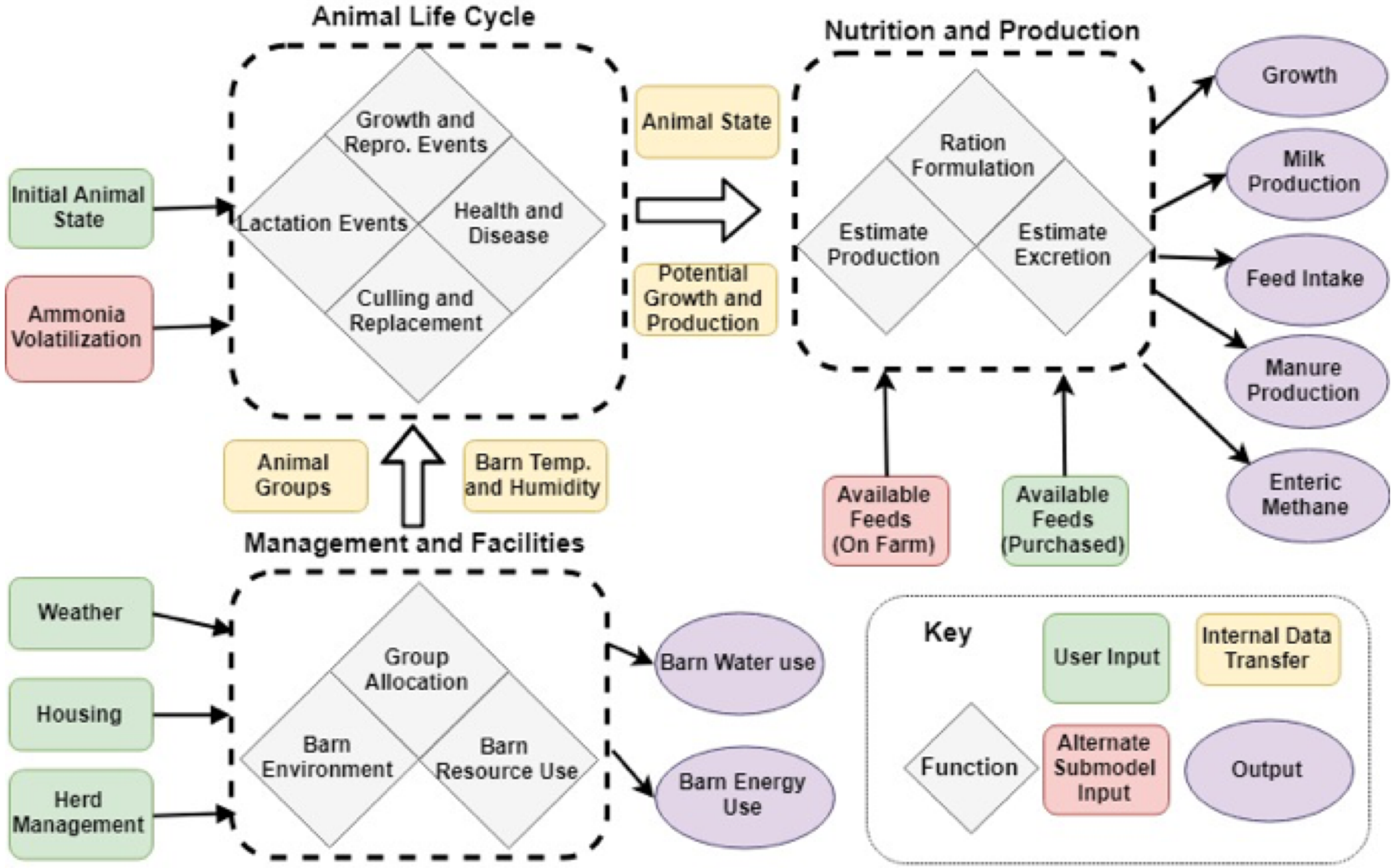
Shared RuFaS progress at 5 industry/extension meetings

Initiated contract with FARM-ES

Welcomed new personnel

Development milestones

- Completed ration formulation for all animal classes
- Significant progress towards completed manure module
- Initiated use of automated tests and standardized in-code documentation



Animal Module Updates

Diet Formulation

- Based on NRC (2001)
- Update to NASEM (2021) in progress

J. Dairy Sci. 105:2180–2189
https://doi.org/10.3168/jds.2021-20817

The application of nonlinear programming on ration formulation for dairy cattle

J. Li,[1] E. Kebreab,[1] Fengqi You,[2] J. G. Fadel,[1] T. L. Hansen,[3] C. VanKerkhove,[4] and K. F. Reed[3]*
[1]Department of Animal Science, University of California, Davis 95616
[2]Robert Frederick Smith School of Chemical and Biomolecular Engineering, Cornell University, Ithaca, NY 14853
[3]Department of Animal Science, Cornell University, Ithaca, NY 14853
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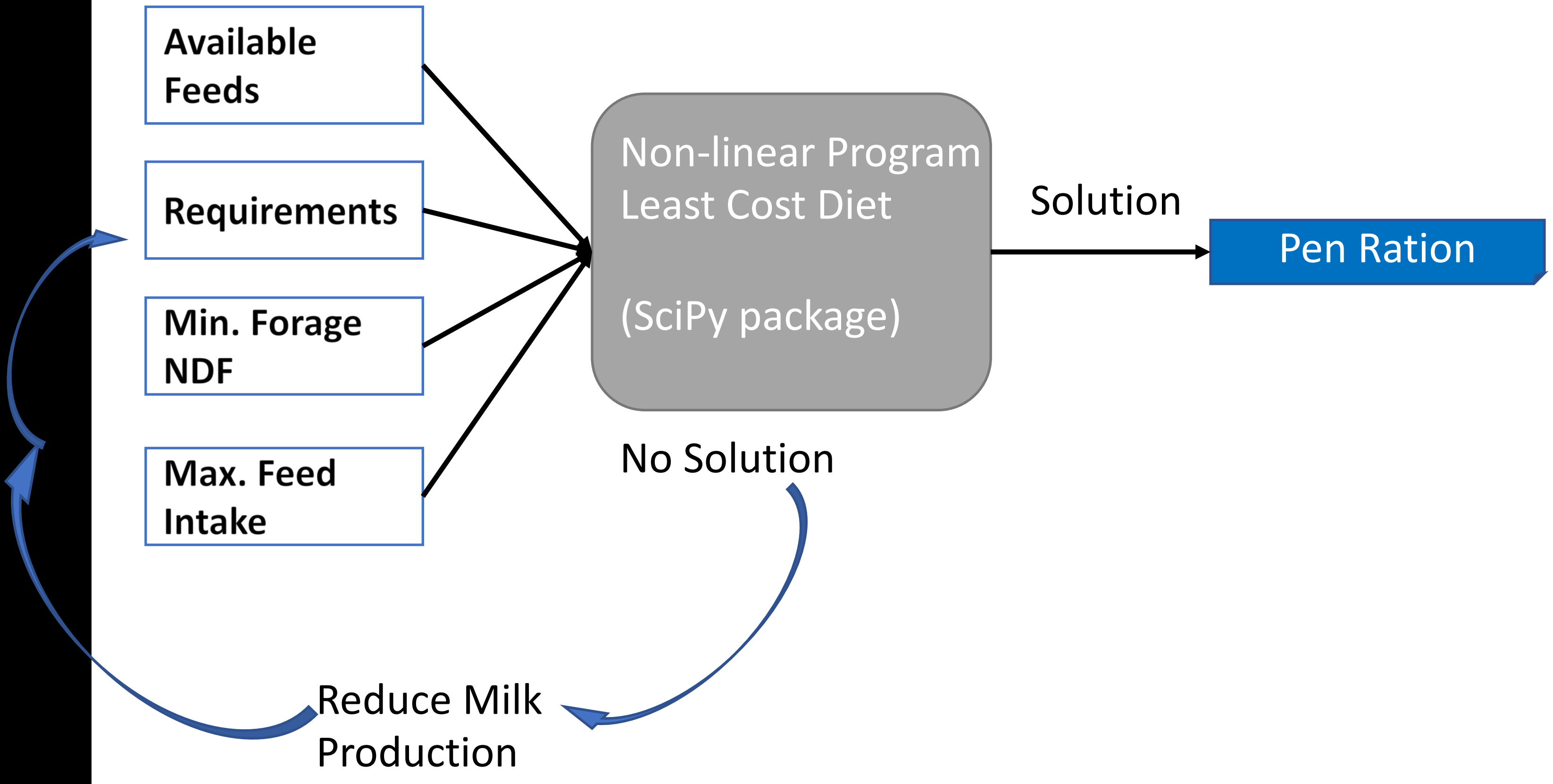
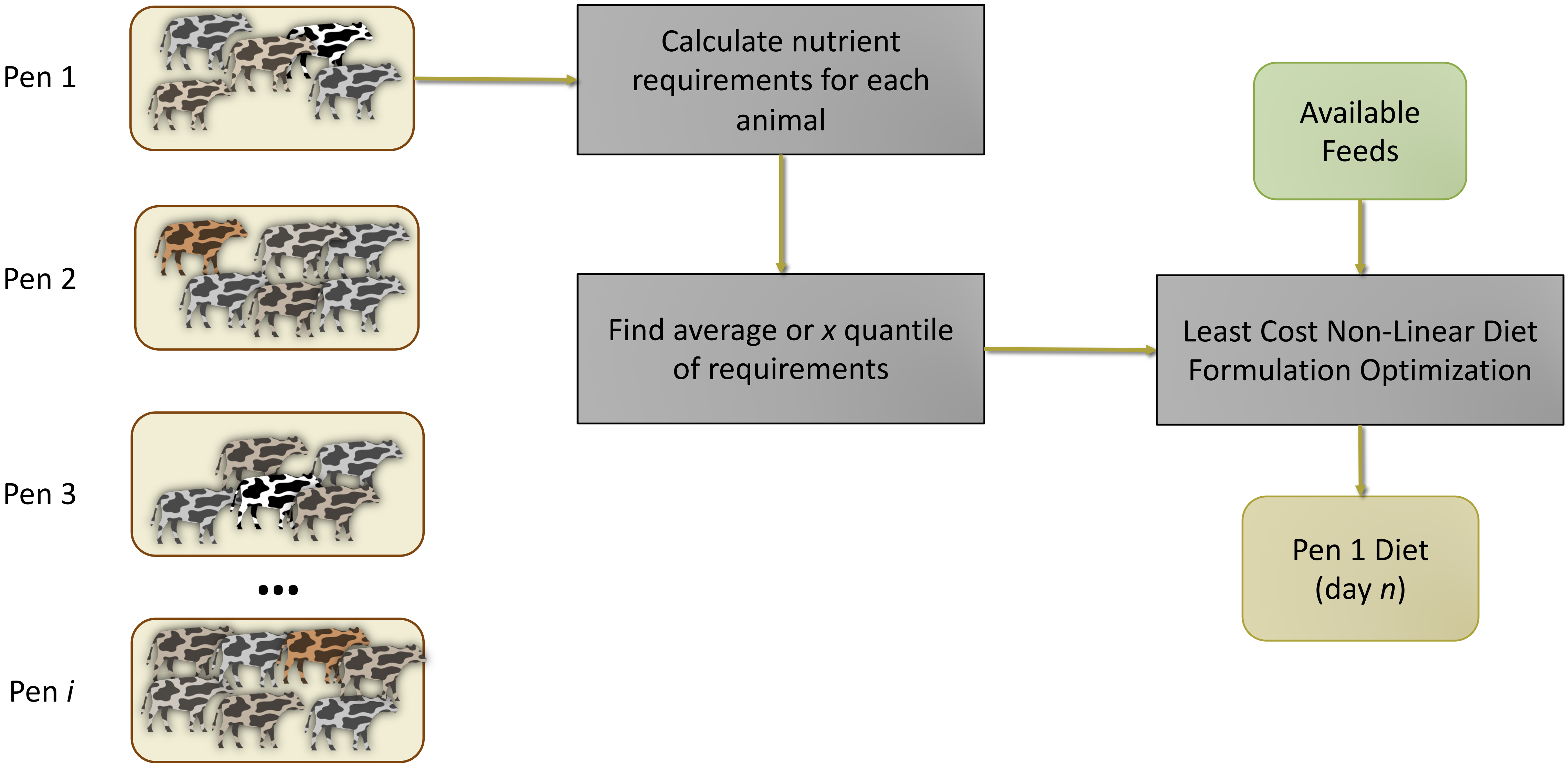
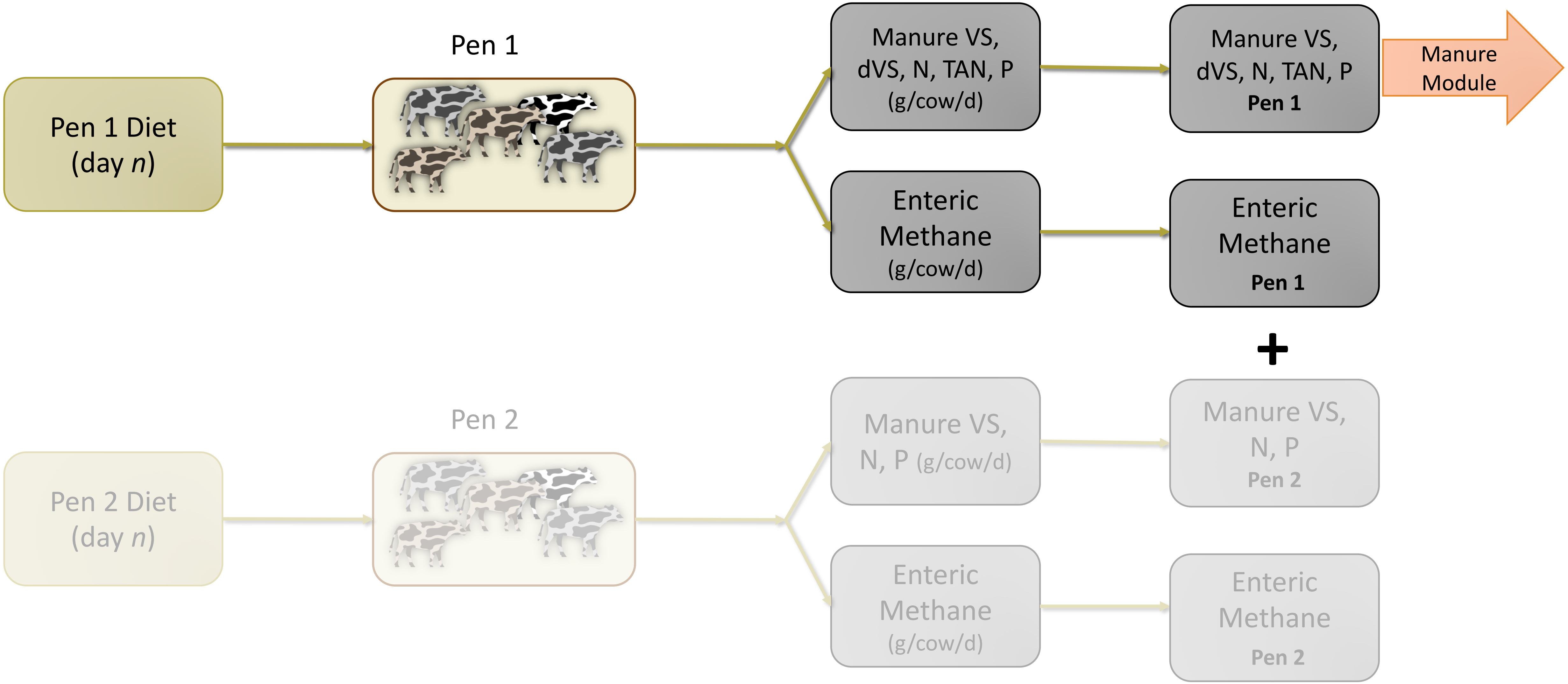


Animal Grouping and Diet Formulation

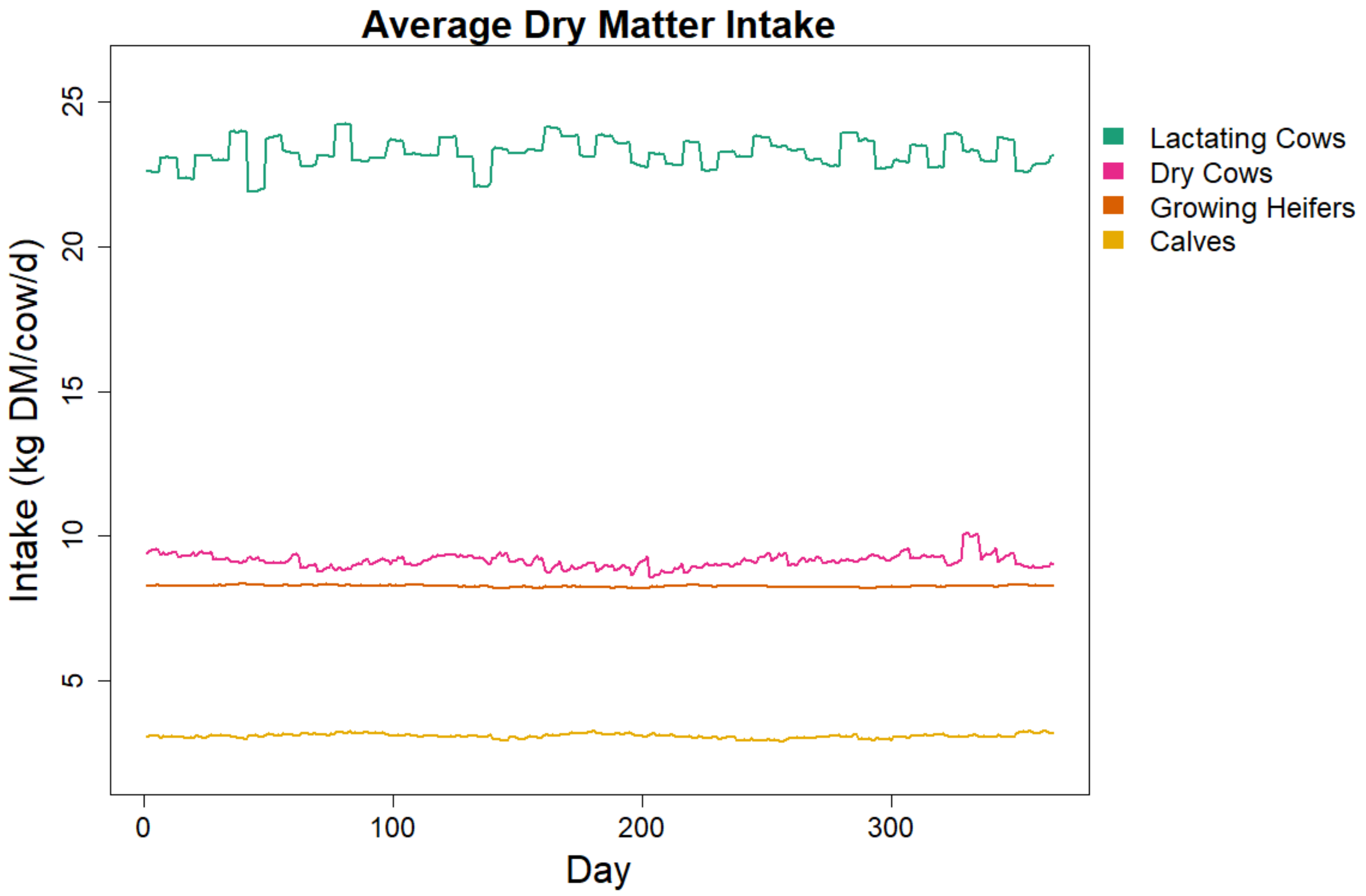


Happens on an interval set by the user (i.e. 1x/week; 1x/month)

Methane and Manure Production

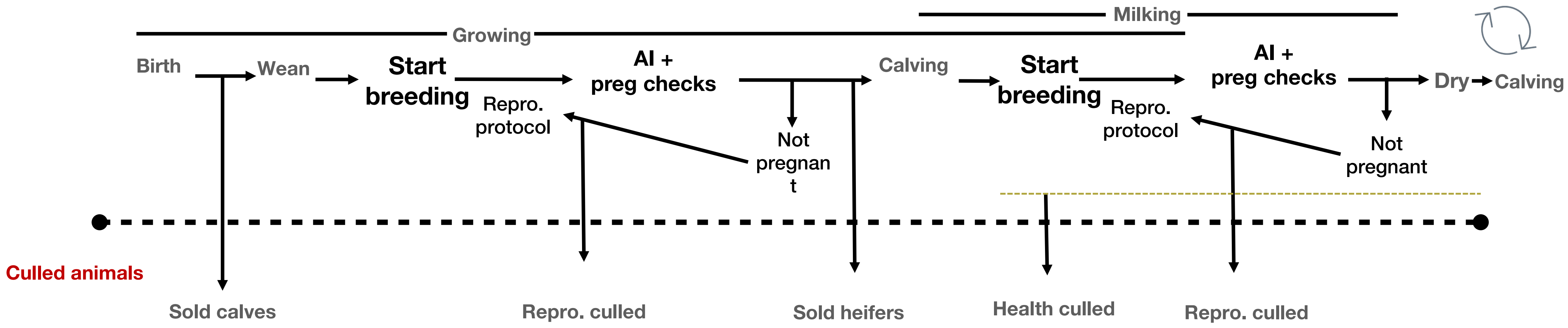


Implemented method for other animal classes



Life Cycle Model Progress

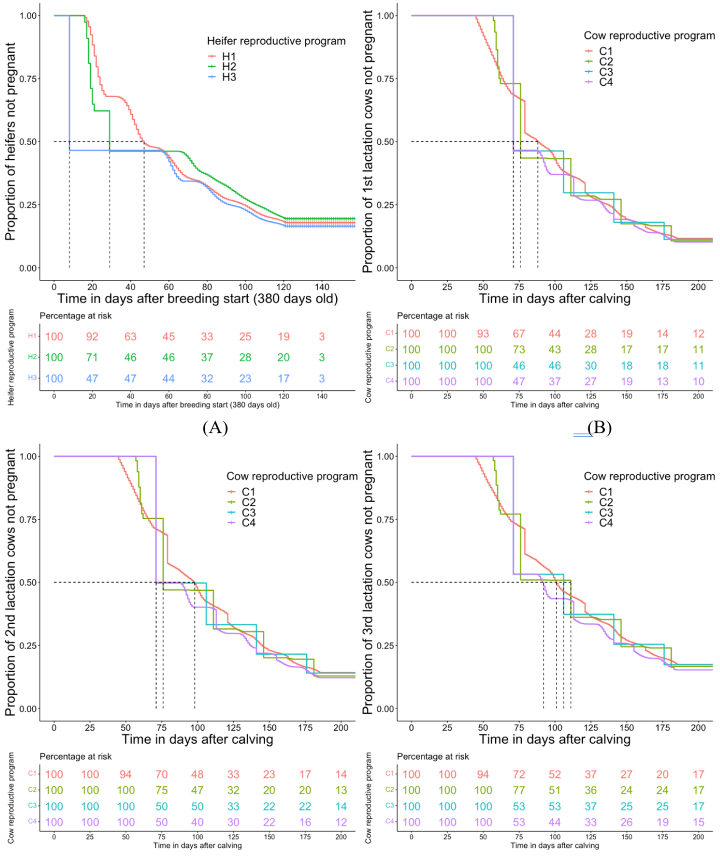
Calves	Heifers I	Heifers II	Heifers III	Cow
Birth - wean	Wean - breed	Breed – Close-Up	Close-Up to calving	Start lactating
0 - 60	60 - 400	400 - DIP > 250	- 1st calving	Calved - cull



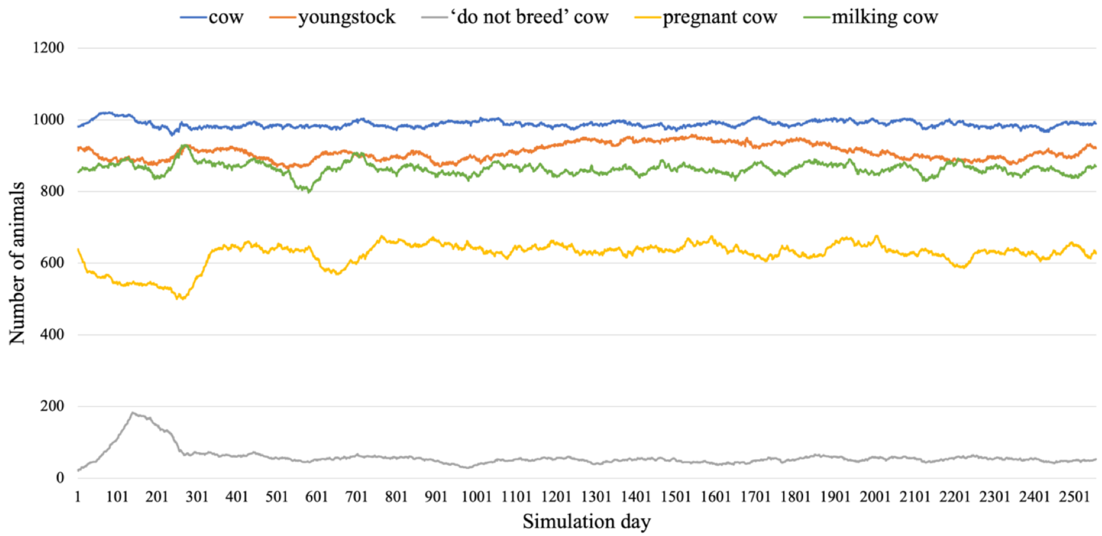
Demonstrated capability of life-cycle model with reproduction case study

A stochastic animal life cycle simulation model for a whole dairy farm system model: Assessing the value of combined heifer and lactating dairy cow reproductive management programs

M. Li*, K. F. Reed†, M. R. Lauber*, P. M. Fricke*, and V. E. Cabrera*[1]



(A) (B) (C) (D)



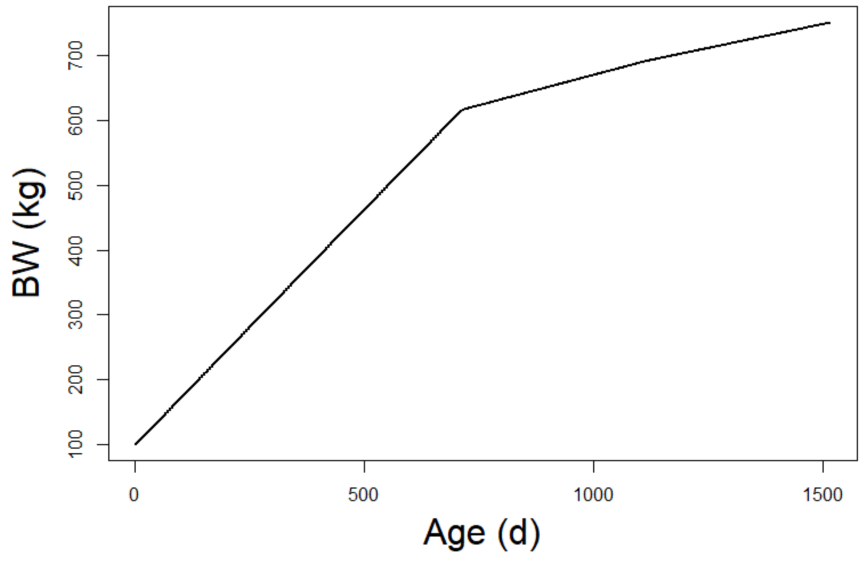
Body Weight Change

Growth + Conceptus + Tissue Change

Growth based on NRC (2001)

$$\text{heifer ADG (kg/d)} = \begin{cases} \dfrac{(0.55 * \text{MatBW} - \text{BW})}{\text{days at first pregnancy} - \text{age in days}}, \text{nonpregnant heifer} \\ \dfrac{(0.82 * \text{MatBW} - \text{BW})}{\text{gestation length} - \text{DIP}}, \text{pregnant heifer} \end{cases}$$

$$\text{cow ADG}\left(\frac{\text{kg}}{\text{d}}\right) = \begin{cases} \dfrac{(0.92 - 0.82) * \text{MatBW}}{\text{average calving interval}}, \text{if parity} = 1 \text{ and nonpregnant} \\ \dfrac{0.92 \times \text{MatBW} - \text{BW}}{\text{gestation length} - \text{DIP}}, \text{if parity} = 1 \text{ and pregnant} \\ \dfrac{(1 - 0.92) * \text{MatBW}}{\text{average calving interval}}, \text{if parity} = 2 \text{ and nonpregnant} \\ \dfrac{\text{MatBW} - \text{BW}}{\text{gestation length} - \text{DIP}}, \text{if parity} = 2 \text{ and pregnant} \\ 0, \text{ else} \end{cases}$$



Body Weight Change

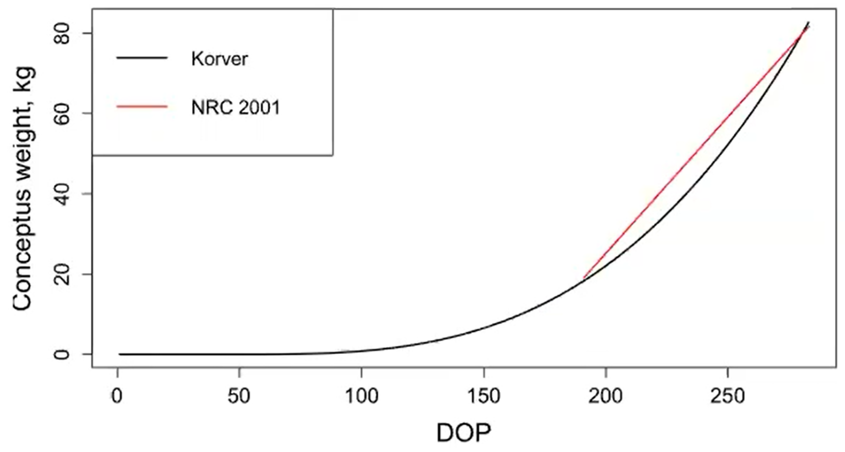
Growth + Conceptus + Tissue Change

Conceptus weight change based on Korver et al. 1984

$$\text{conceptus growth}\left(\frac{\text{kg}}{\text{d}}\right)=\begin{cases}0, & \text{if DIP} < 50\\ 3\times\text{conceptus parameter}^3\times(\text{DIP}-50)^2, & \text{if DIP} > 50\\ -\text{total conceptus weight}, & \text{if DIP} = \text{gestation length}\end{cases}$$

$$\text{total conceptus weight (kg)} = (0.0148\times\text{gestation length} - 2.408)\times\text{calf birth weight}$$

$$\text{conceptus parameter} = (\text{total conceptus weight}^{\frac{1}{3}}/\text{gestation length} - 50)$$



Body Weight Change

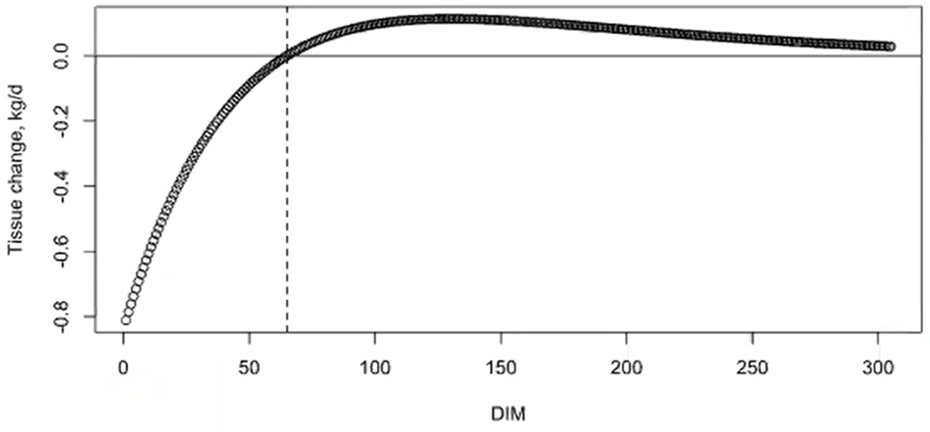
Growth + Conceptus + Tissue Change

Tissue Change derived from Korver et al. (1984), DeVries et al., (2006)

$$\text{Tissue change}\left(\frac{\text{kg}}{\text{d}}\right) = \begin{cases} -\frac{P_1}{P_2} * \exp\left(1 - \frac{\text{DIM}}{P_2}\right) + \frac{P_1}{{P_2}^2} * \text{DIM} * \exp\left(1 - \frac{\text{DIM}}{P_2}\right), \text{Lactating cow} \\ \frac{P_1 * \frac{\text{DIM}}{P_2} * \exp\left(1 - \frac{\text{DIM when dry}}{P_2}\right)}{\text{gestation length} - \text{DIP when dry}}, \text{Dry cow} \end{cases}$$

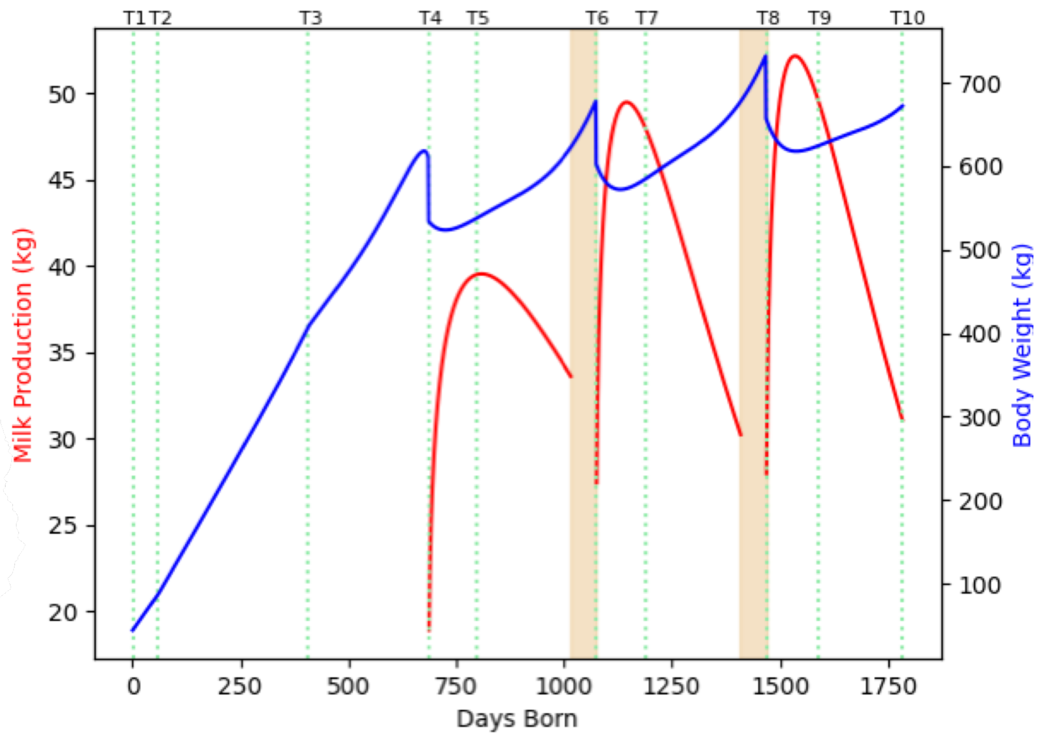
P_1 = max decrease in BW

P_2 = DIM with lowest BW



Body Weight Change

Growth + Conceptus + Tissue Change

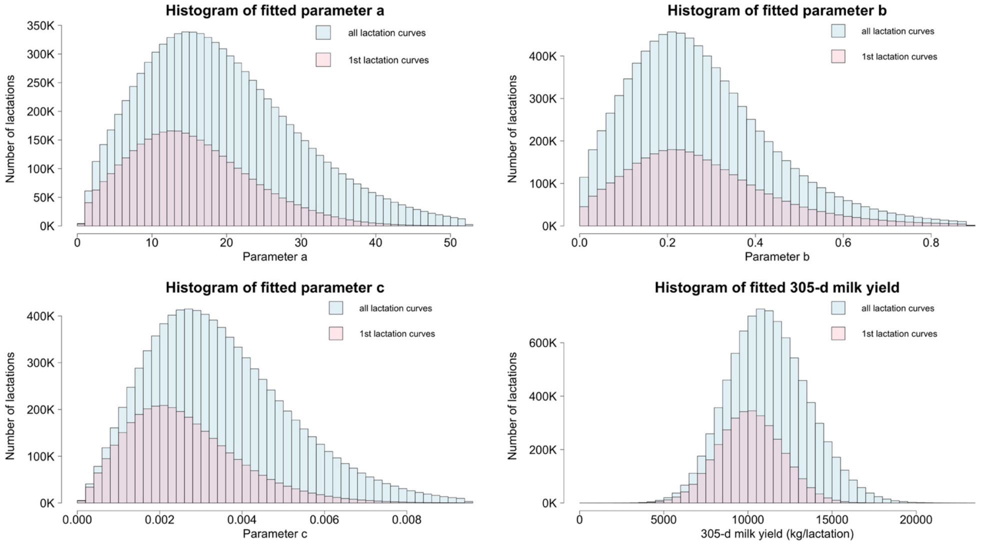


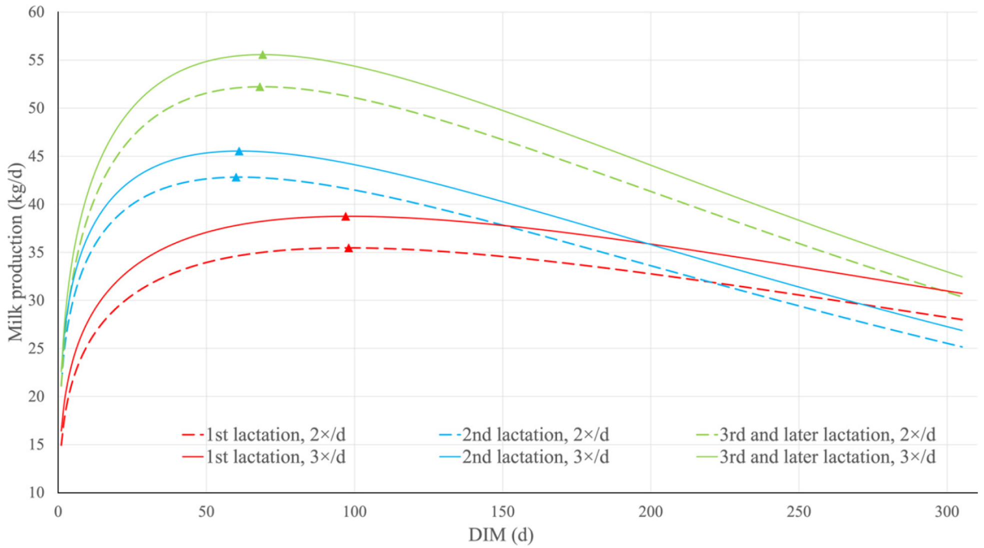
Published new parameters to predict milk production

J. Dairy Sci. 105:7525–7538
https://doi.org/10.3168/jds.2022-21882

Investigating the effect of temporal, geographic, and management factors on US Holstein lactation curve parameters

M. Li,[1] G. J. M. Rosa,[1] K. F. Reed,[2] and V. E. Cabrera[1]*
[1]Department of Animal and Dairy Sciences, University of Wisconsin–Madison, Madison 53705
[2]Department of Animal Science, Cornell University, 272 Morrison Hall, Ithaca, NY 14850

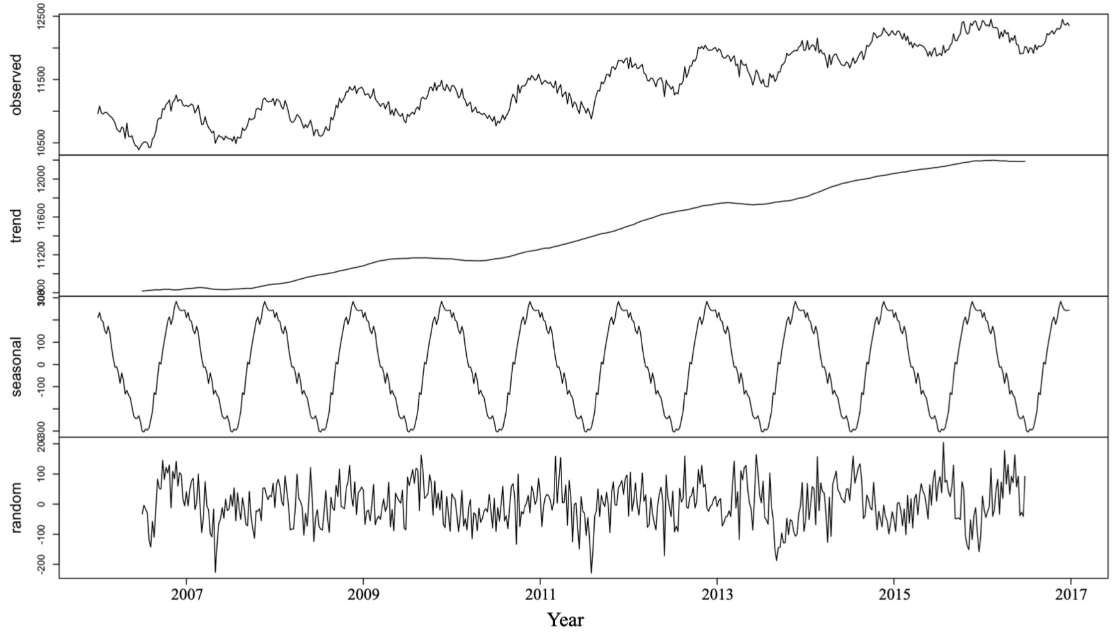


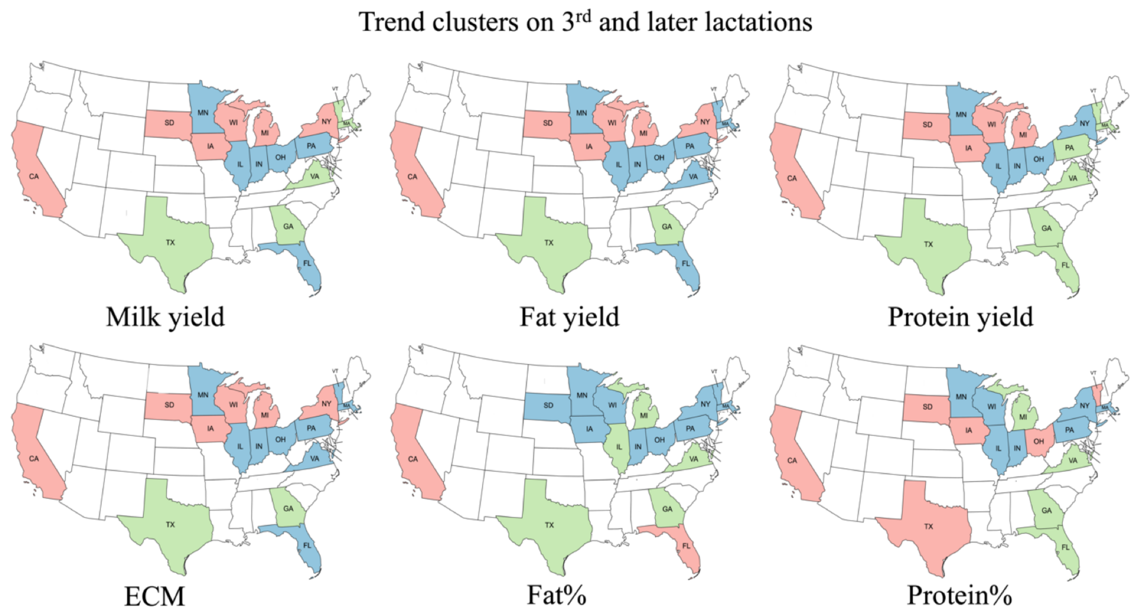


Developed methods to predict trends in milk production over time

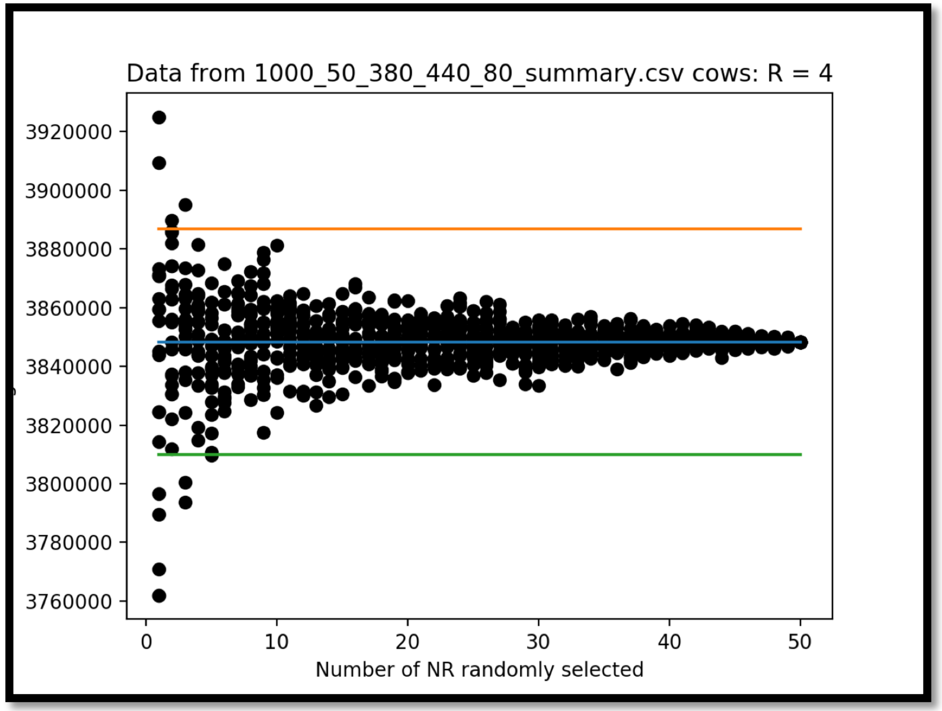
A time series analysis of milk productivity in US dairy states

M. Li, * K. F. Reed, † V. E. Cabrera, *

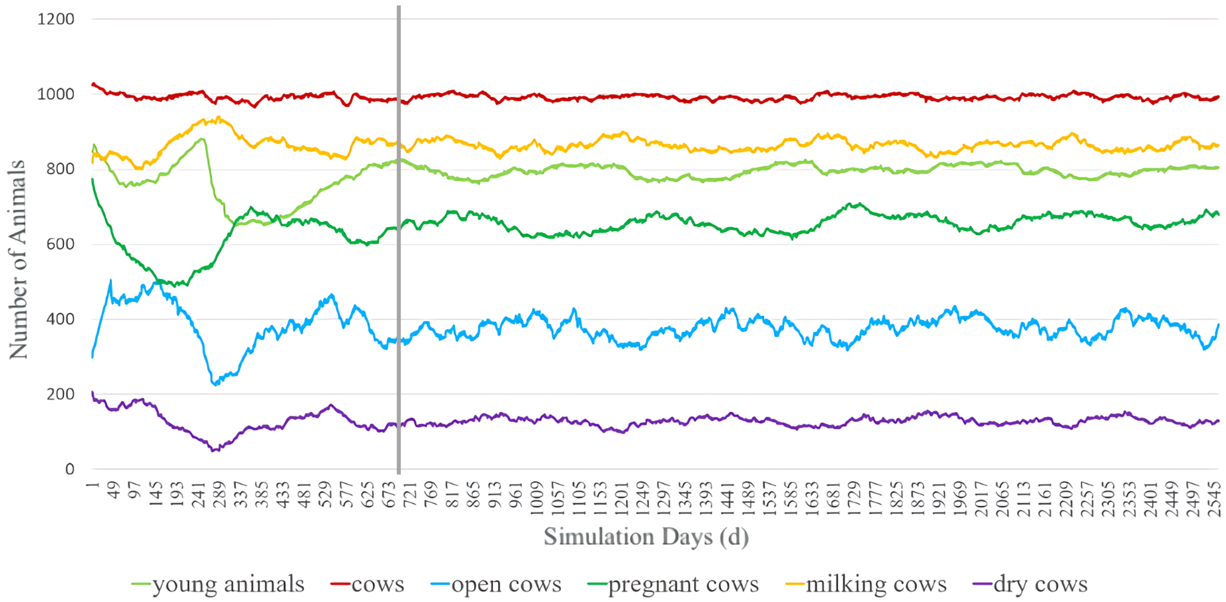




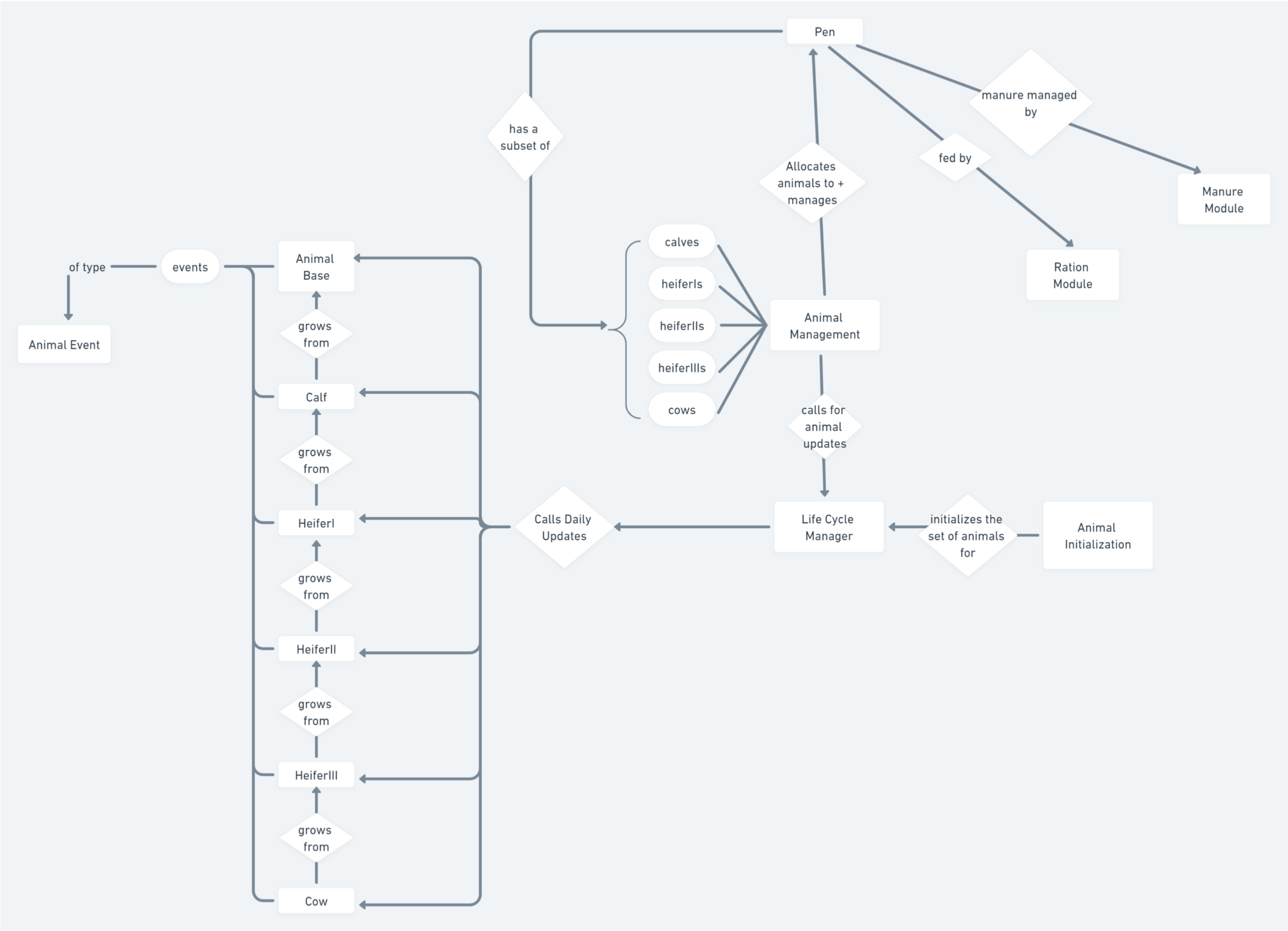
Determined methods to accommodate Monte Carlo model in application

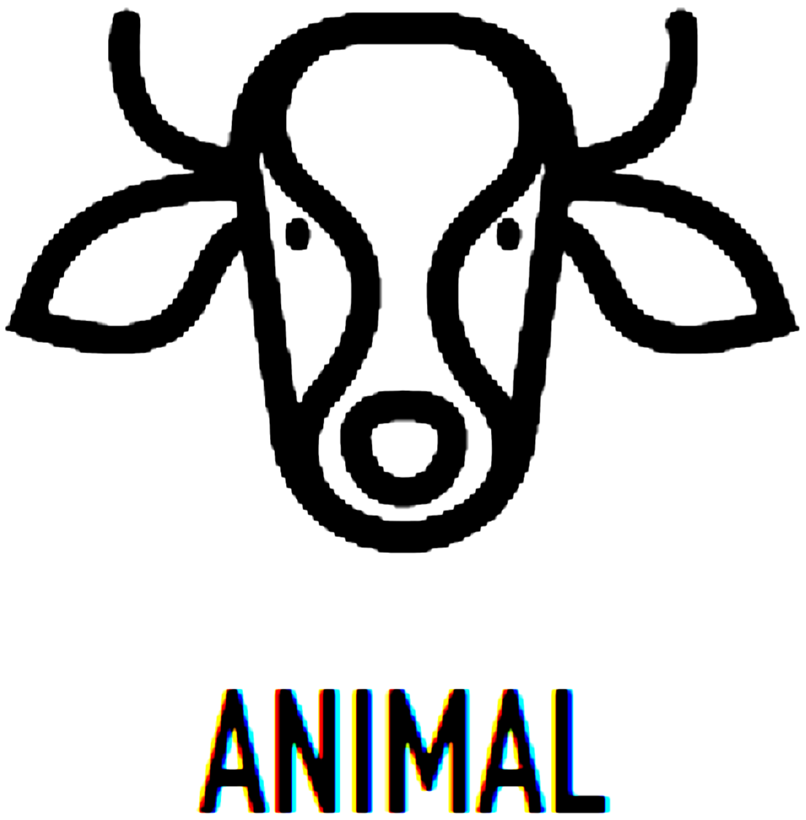


Steady state reached around d 700



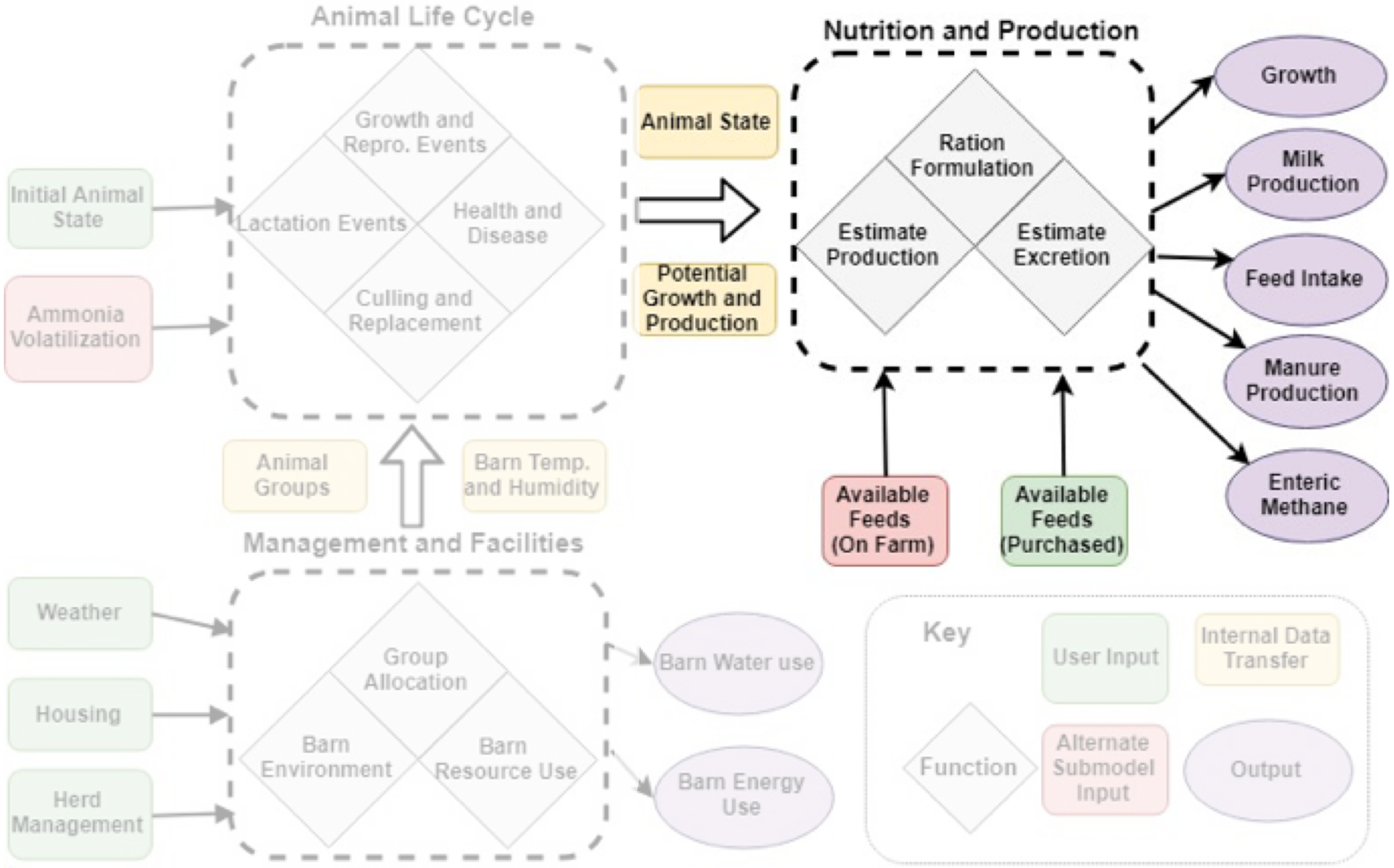
On-going improvements and refactoring of the codebase





You'll also hear more about:

- Plans to account for methane mitigation supplements
- Progress towards a grazing module
- Sensitivity analysis methods and application



Animal Module

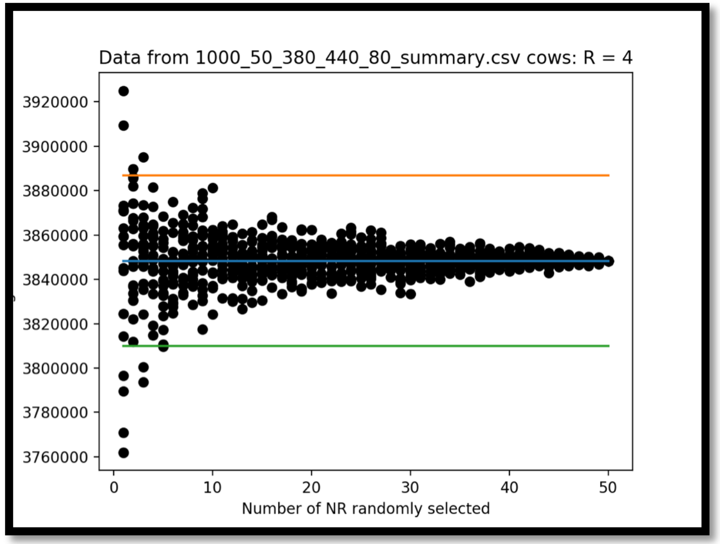
Nutrition impacts on environmental outcomes

How does forage quality impact manure and emissions outcomes?

GENERAL HERD CHARACTERISTICS	
Breed	Holstein
Herd Size	1000
TMR Diet	Corn Silage, Alfalfa Haylage, SBM, Corn Grain
Mature Body Weight (lbs/kg)	1,630 / 740

Simulation Characteristics:

- Animals grouped by class
- Last 365 days of a 4-year simulation
- Average of 10 simulations

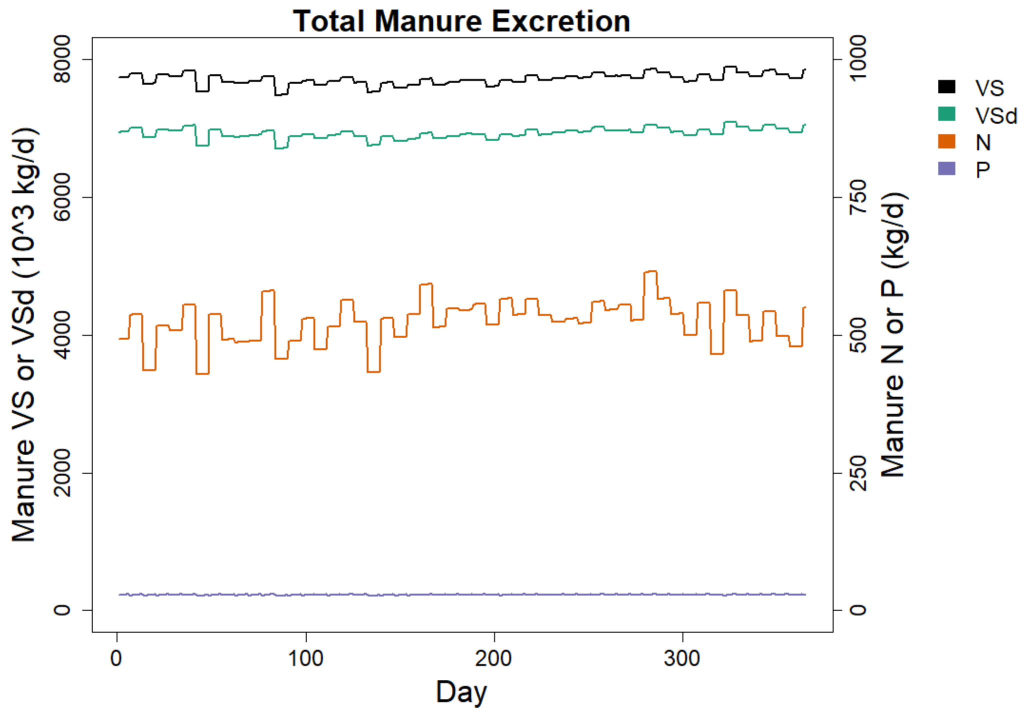


Forage Quality Comparison

	Corn Silage				Alfalfa Haylage		
Scenario	DM	NDF	DE	Starch	DM	NDF	CP
Baseline	35.1	45	2.84	32.87	43.3	47	18.3

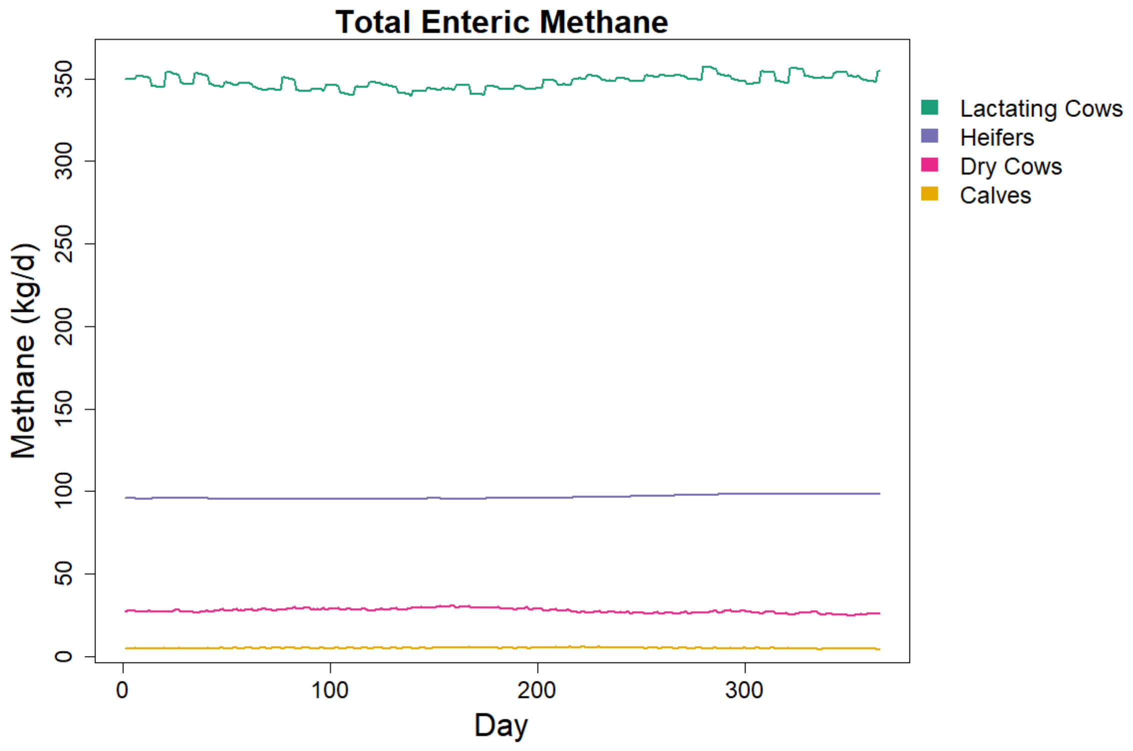
Some neat results…

Herd Manure



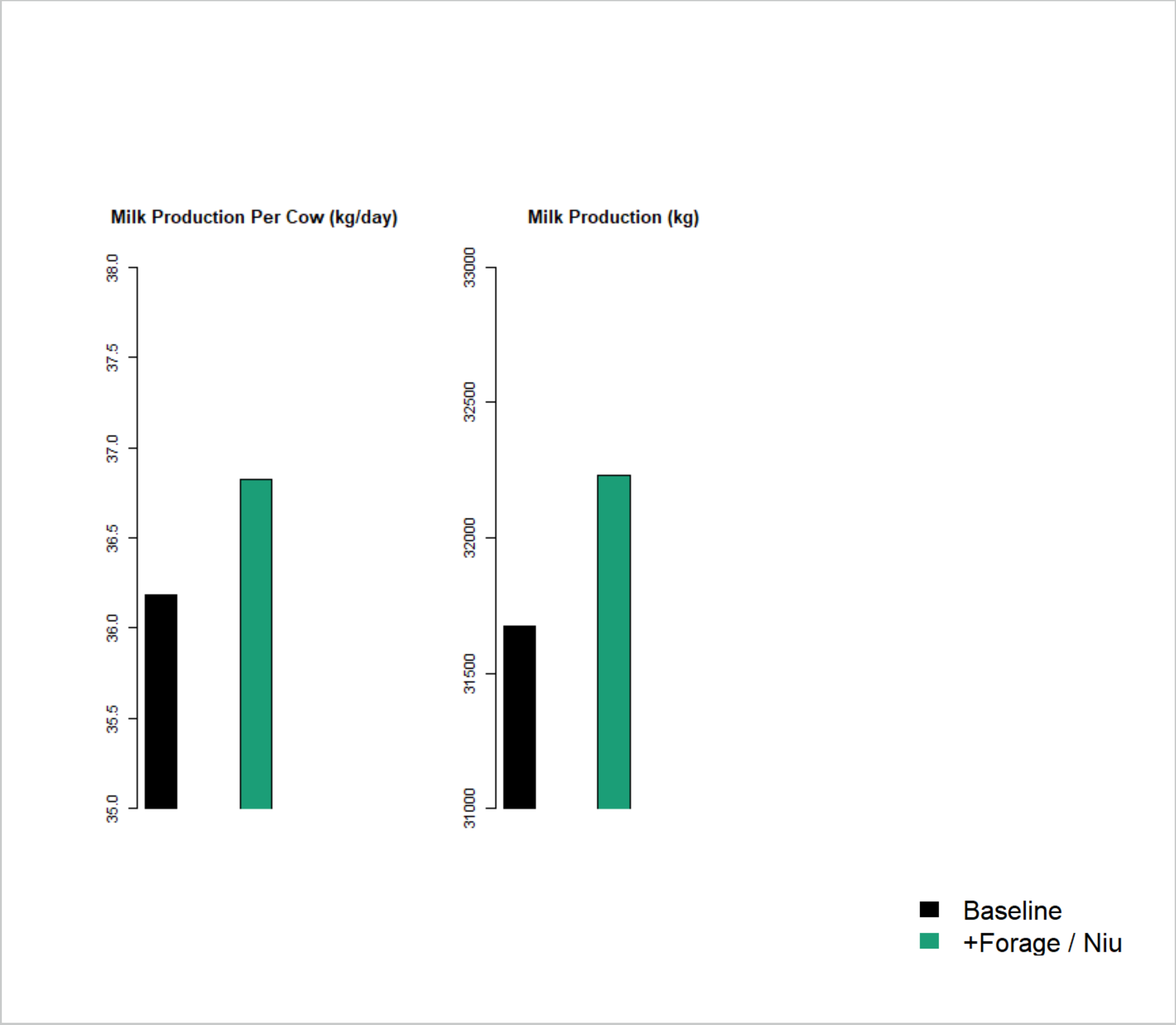
Some neat results…

Animal Enteric Methane

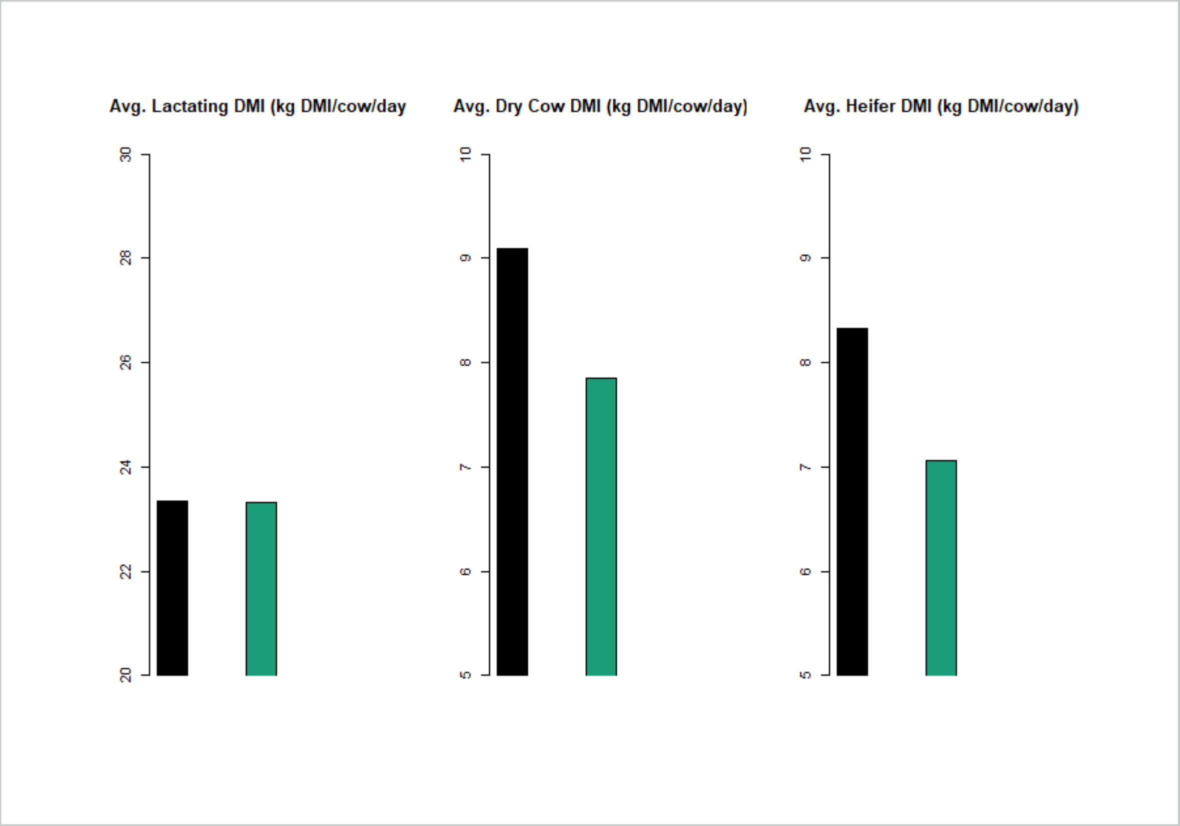


Milk Production & Intake

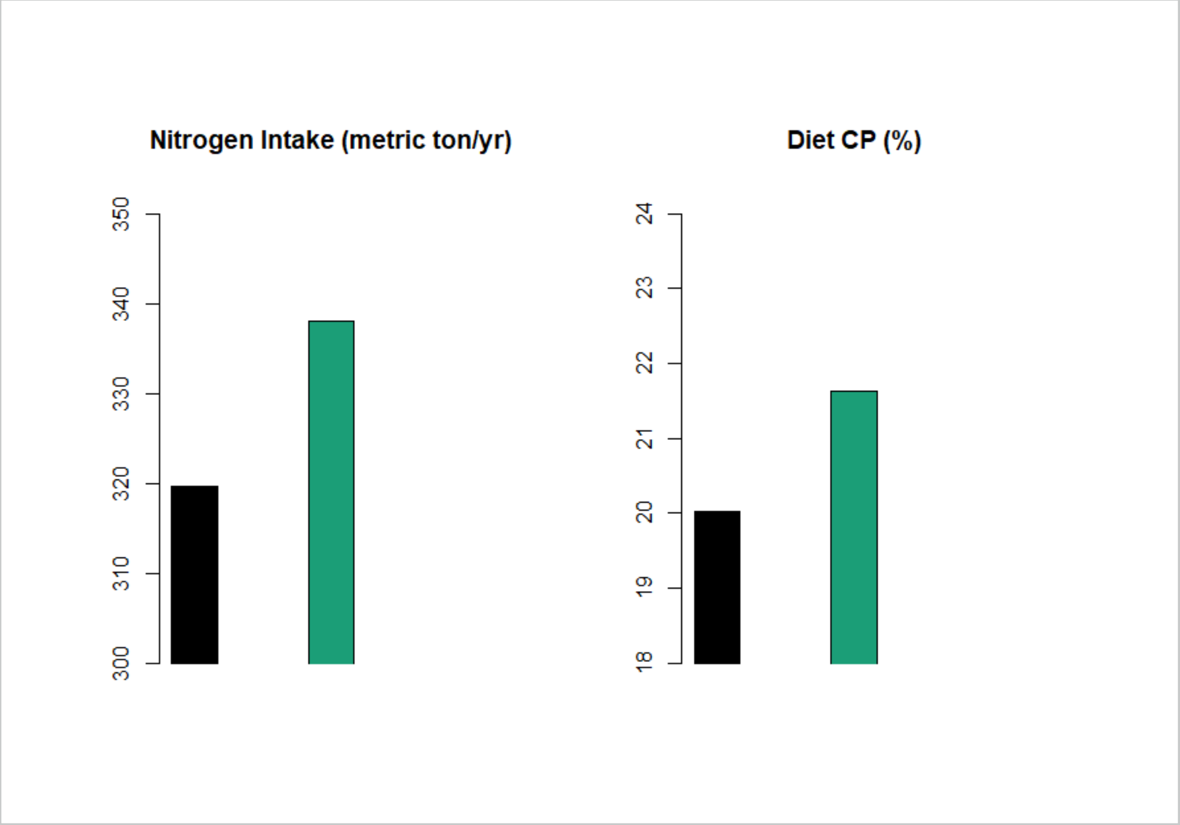
- Achieved increased milk production response to forage quality
- Reduced total intake

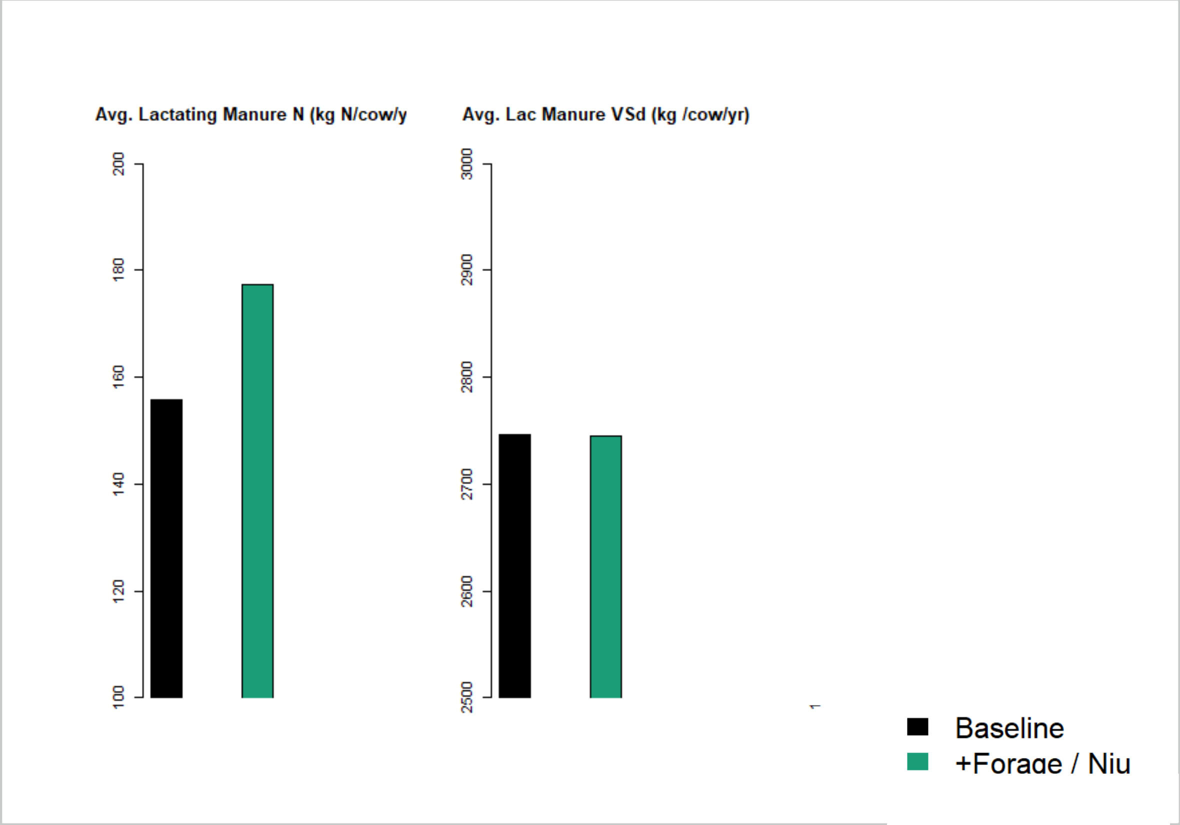


Feed Efficiency

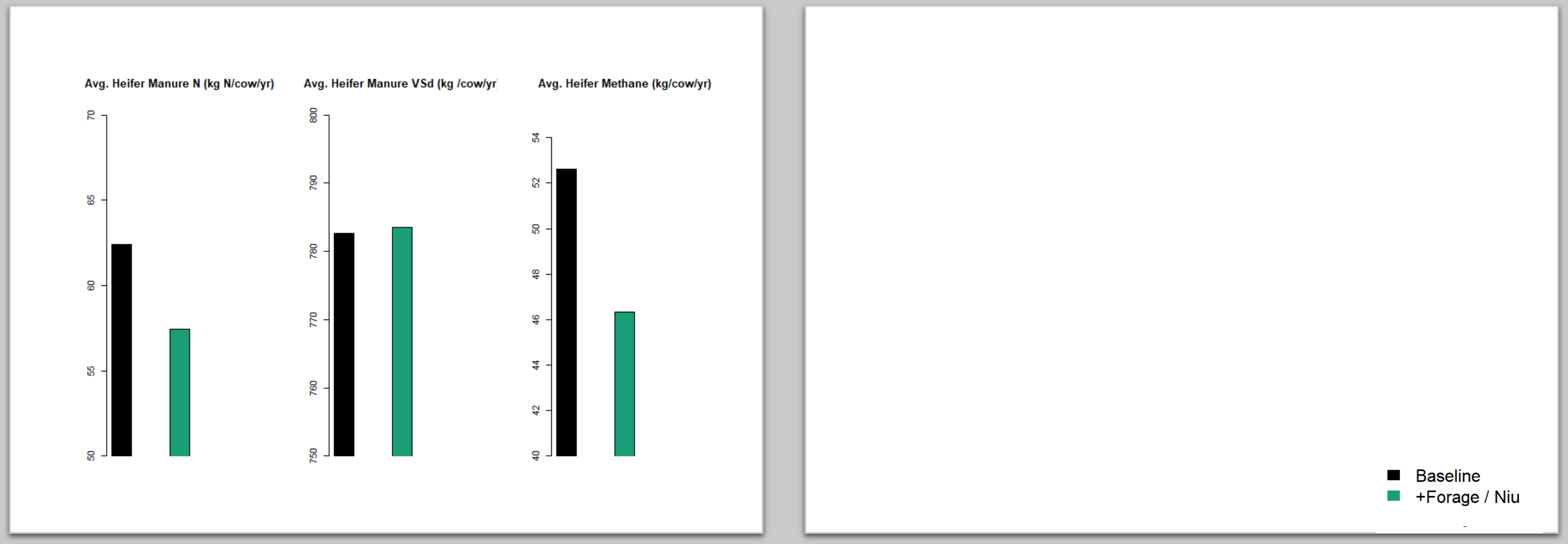


Intake and Excretion



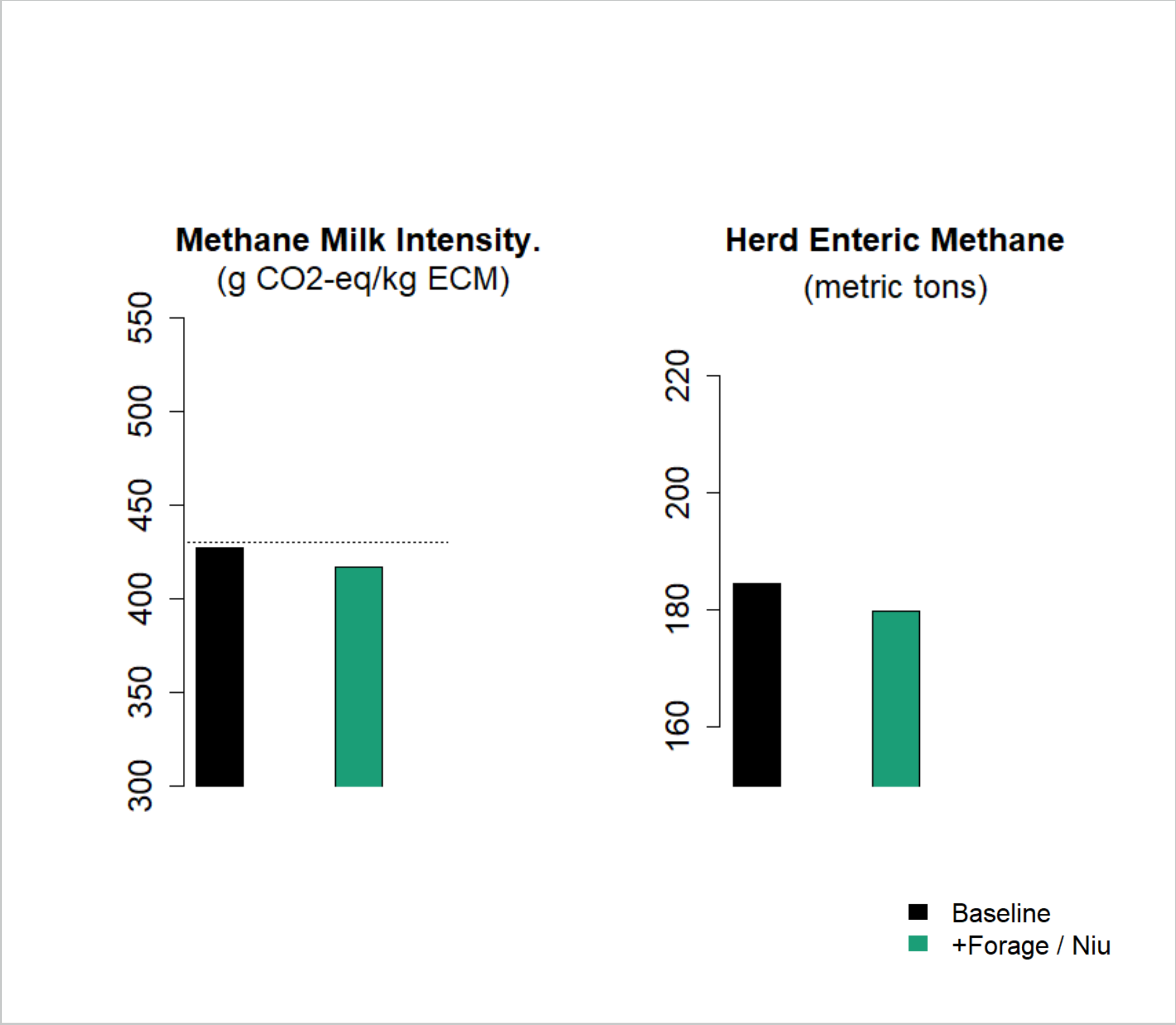


Dry Cow and Heifer Excretion



Methane Intensity and Total Methane

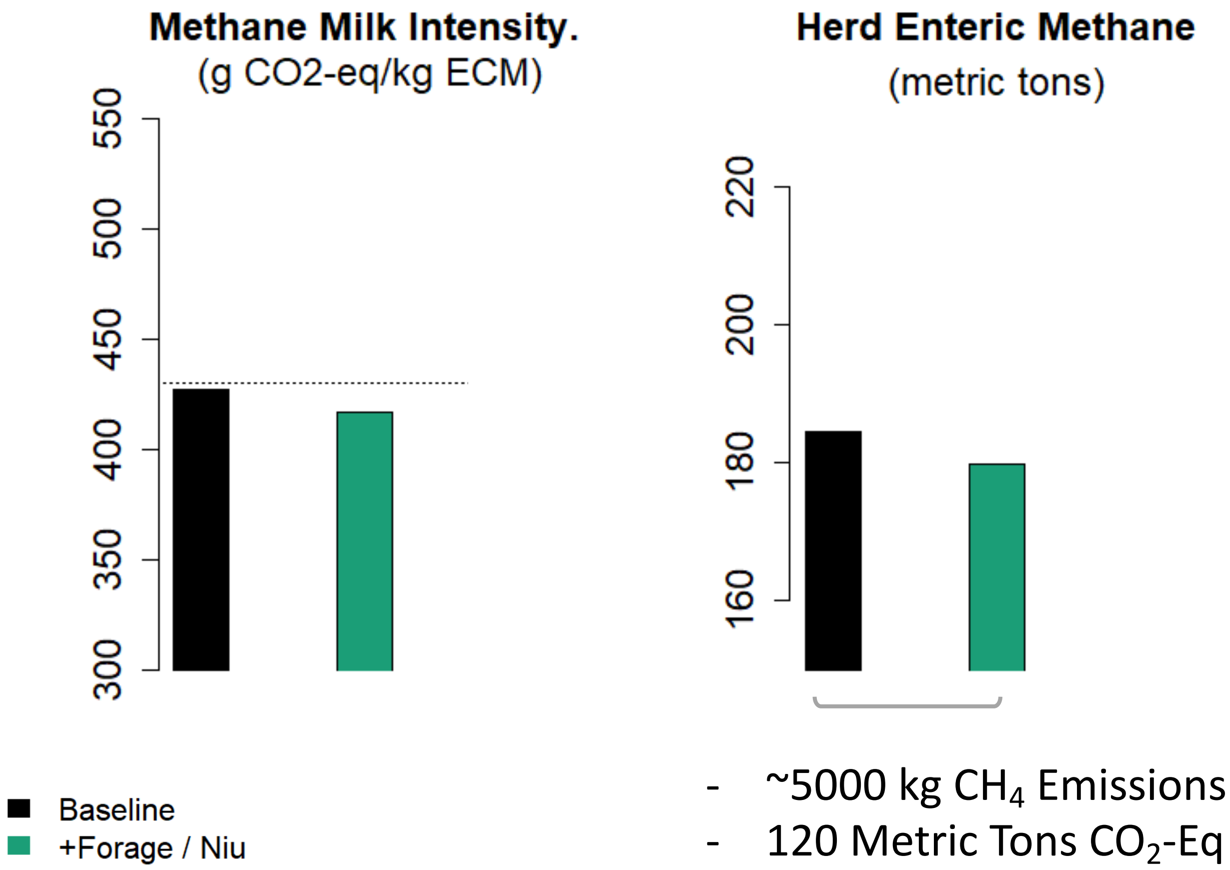
- Baseline scenario is close to US National average enteric methane intensity around 430 g CO_2-eq/kg ECM
- Improved forage quality reduces intensity and total emissions
- Essential to have enteric emissions equations that are sensitive to diet composition



Methane Intensity and Total Methane

- Baseline scenario is close to US National average enteric methane intensity around 430 g CO_2-eq/kg ECM
- Improved forage quality reduces intensity and total emissions
- Essential to have enteric emissions equations that are sensitive to diet composition

Same as taking **25** gas-powered cars off the road!



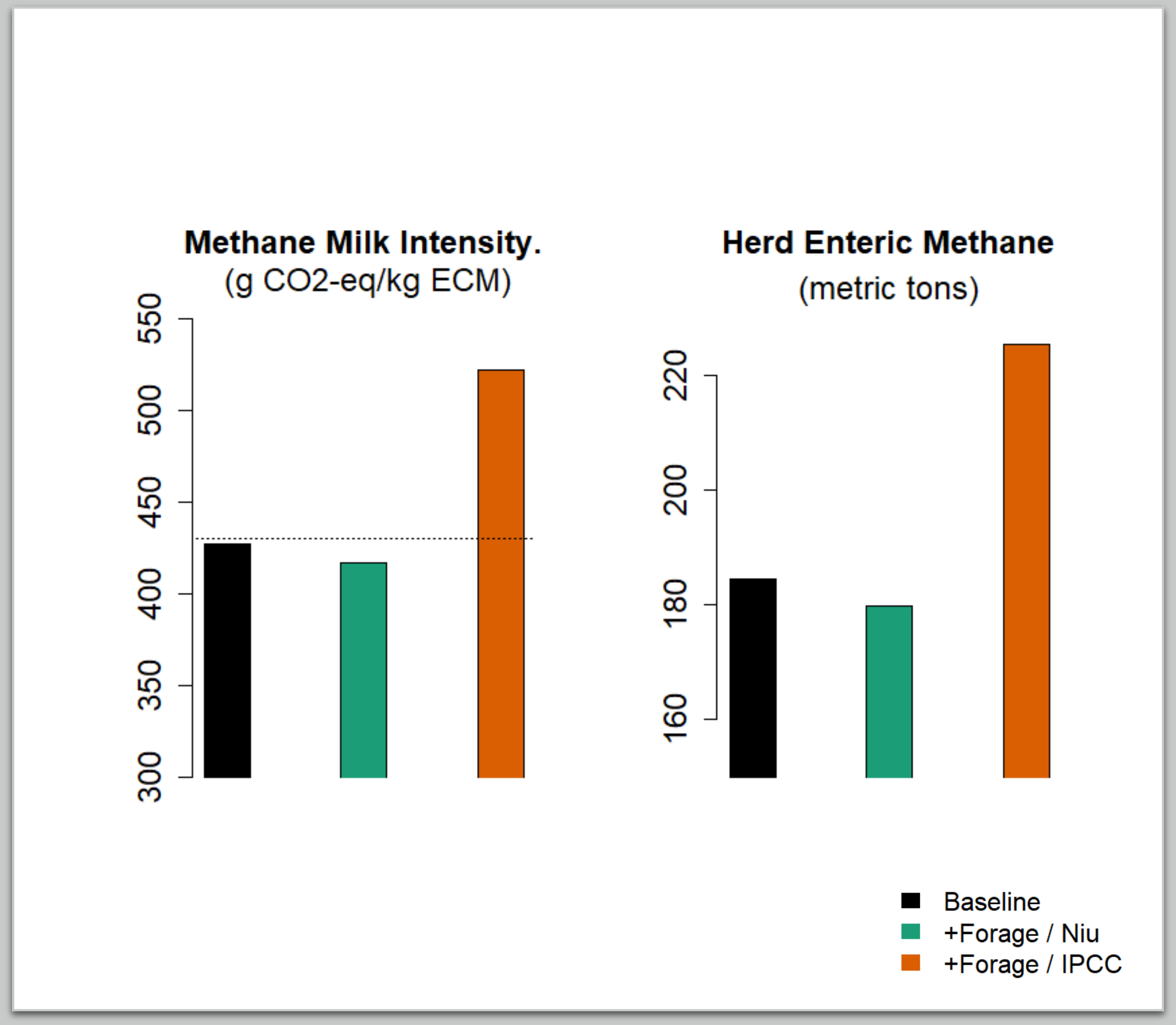
- ~5000 kg CH_4 Emissions
- 120 Metric Tons CO_2-Eq

Forage Quality Comparison

	Corn Silage				Alfalfa Haylage			
Scenario	DM	NDF	DE	Starch	DM	NDF	CP	Lac. Methane Model
Baseline	35.1	45	2.84	32.87	43.3	47	18.3	Niu et al
+Forage / Niu	34.6	38	2.99	38.18	37.5	45.6	19.0	Niu et al
+Forage / IPCC	34.6	38	2.99	38.18	37.5	45.6	19.0	IPCC

Methane Intensity and Total Methane

- IPCC Tier 2 methane predictions based on GE Intake cannot account for feed efficiency gains due to improved forage quality
- Essential to have enteric emissions equations that are sensitive to diet composition



Completing the processes in the other modules will enable a more holistic understanding of environmental outcomes