Current and future opportunities to decrease enteric methane

Thomas R. Overton, Ph.D.
Professor and Chair
Department of Animal Science
Director, PRO-DAIRY program
Cornell University

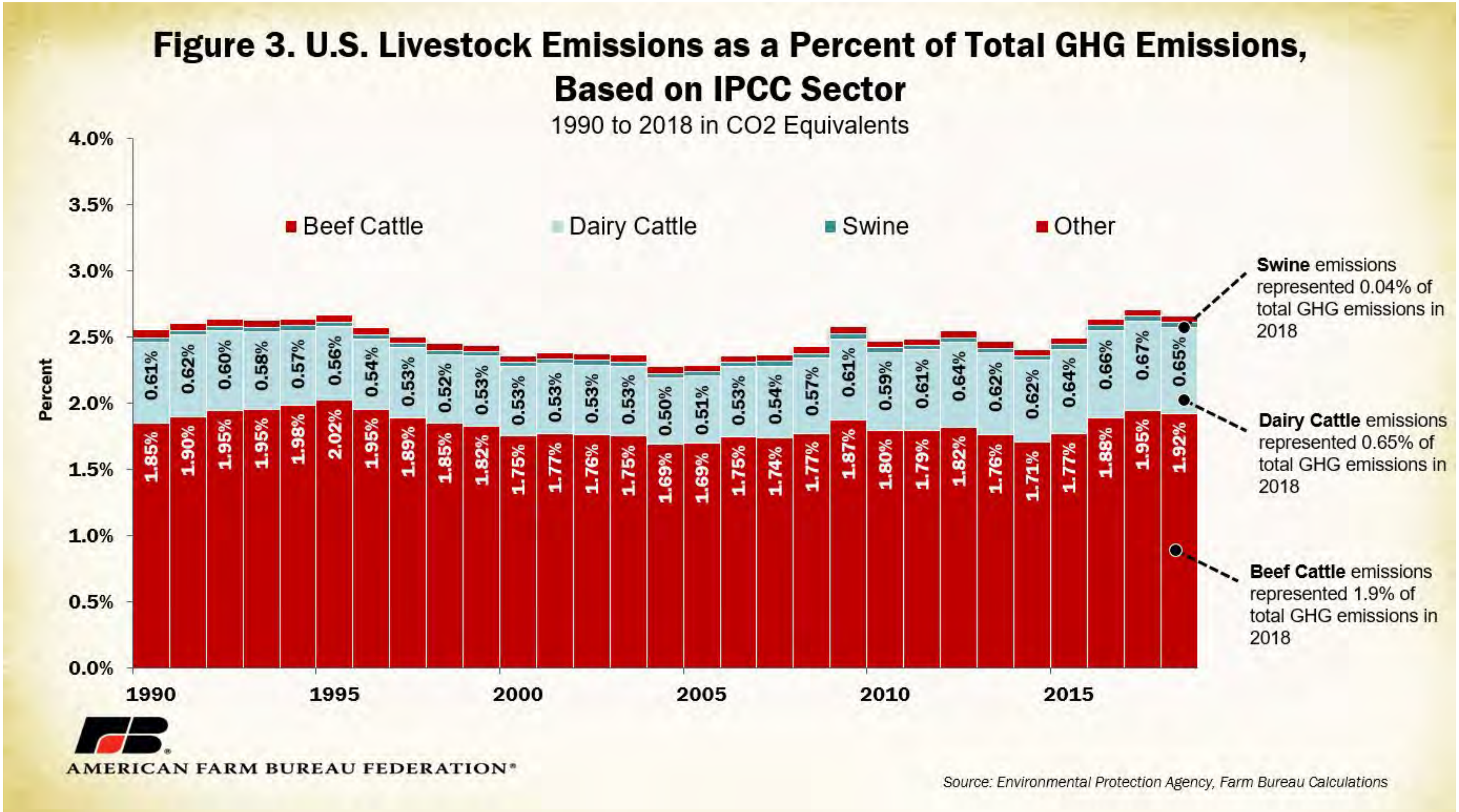


Figure 3. U.S. Livestock Emissions as a Percent of Total GHG Emissions, Based on IPCC Sector

1990 to 2018 in CO2 Equivalents

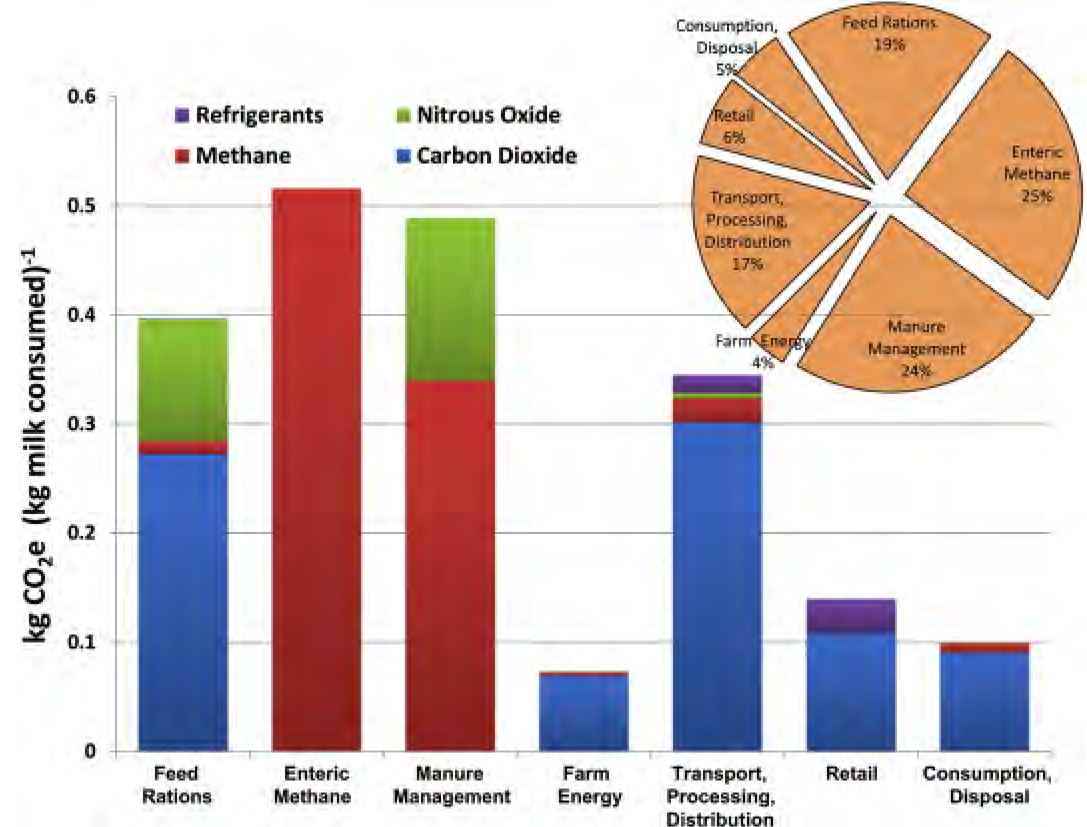
Swine emissions represented 0.04% of total GHG emissions in 2018

Dairy Cattle emissions represented 0.65% of total GHG emissions in 2018

Beef Cattle emissions represented 1.9% of total GHG emissions in 2018

Source: Environmental Protection Agency, Farm Bureau Calculations

https://www.fb.org/market-intel/ghg accessed 5/7/2020



~ 75% of GHG emissions occur on the farm

Thoma et al., 2013

Dairy Industry Has Significantly Decreased Resource Demand per Billion Pounds of Milk Produced Since 1944

Resource	1944	2007	2007 as % of 1944
Milking cows	188,250	42,500	**23.6%**
All cows, heifers, & bulls	423,000	91,500	**21.6%**
Feed (t)	8.39 mil	1.86 mil	**22.3%**
Land (ac)	1.87 mil	0.18 mil	**9.7%**
Manure (t)	9.32 mil	2.48 mil	**26.6%**
Water* (gal)	1.28 bil	0.45 bil	**35.2%**
Methane (t)	60,000	26,750	**44.5%**

* **Note:** Water estimate does not include sanitation use

Source: Adapted from Capper *et al.* (2008) ADSA-ASAS Annual Meeting

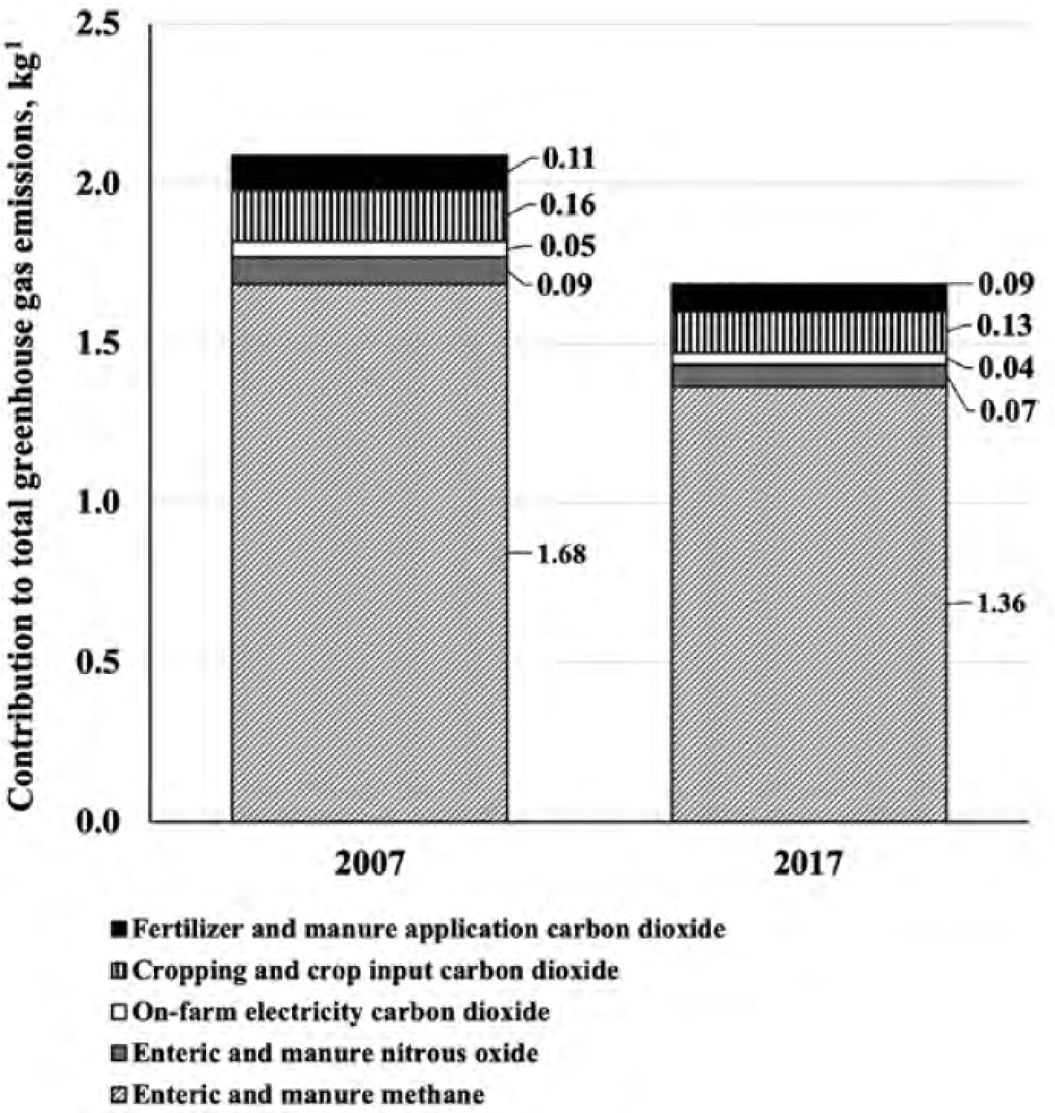
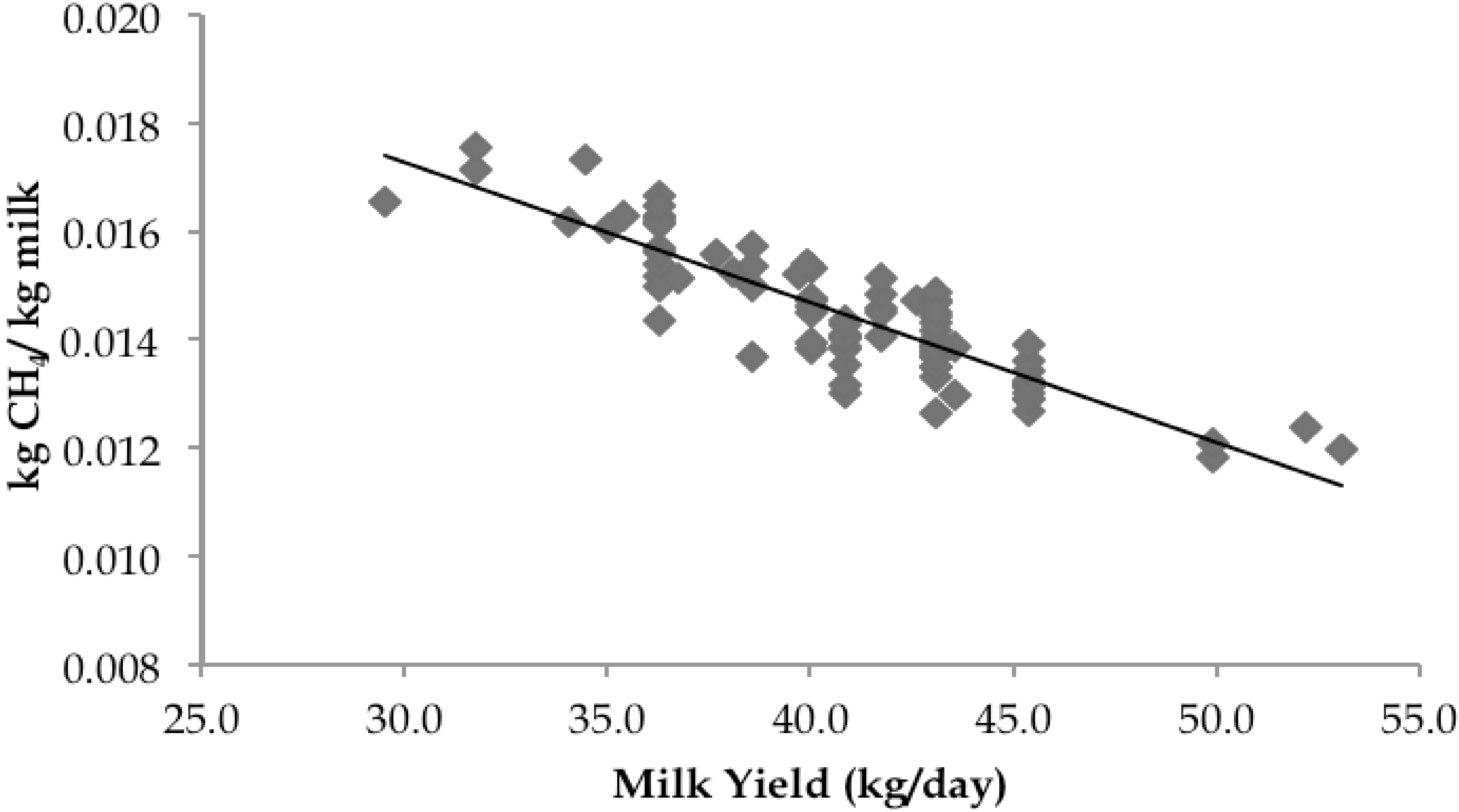


Figure 3. Greenhouse gas sources as contributors to total emissions (CO_2-eq) per kilogram of energy-corrected milk. A value of 0.01 for feed and crop input transport carbon dioxide is not shown.

Capper and Cady, 2020

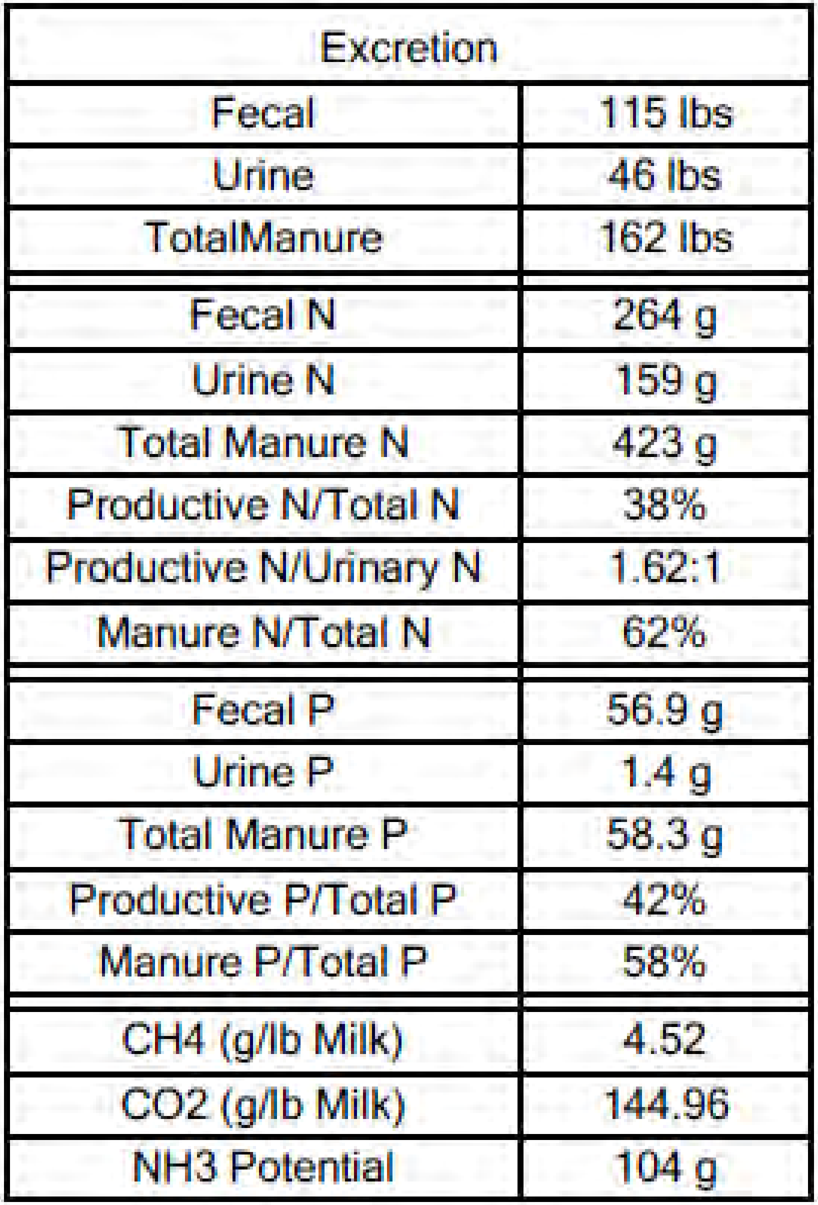
Predicted CH_4 emissions per kg of milk versus milk yield



kg CH_4/Kg milk = -0.0003 × milk yield (kg/d) + 0.03
($R^2 = 0.89$; RMSE = 0.0005 kg CH_4/ kg milk.

Strategies that improve milk/cow, decrease cow numbers, or increase feed efficiency will reduce impact

- Forage quality
- More precise diet formulation
- Ionophores (monensin)
- Milking frequency
- Reproductive efficiency
- rbST
- Transition cow (peripartum) management
- Reduced age at first calving
- Genetic selection



Excretion	
Fecal	115 lbs
Urine	46 lbs
TotalManure	162 lbs
Fecal N	264 g
Urine N	159 g
Total Manure N	423 g
Productive N/Total N	38%
Productive N/Urinary N	1.62:1
Manure N/Total N	62%
Fecal P	56.9 g
Urine P	1.4 g
Total Manure P	58.3 g
Productive P/Total P	42%
Manure P/Total P	58%
CH4 (g/lb Milk)	4.52
CO2 (g/lb Milk)	144.96
NH3 Potential	104 g

CNCPS 6.55 output

1585 lb Holstein cow
110 DIM
~ 105 lb milk, 3.6% fat, 3.1% protein
62 lbs DMI
15.1% CP
0.36% P

Van Amburgh et al., CU Animal Science

Feed Additives for Enteric Methane Reduction

- Ionophores (Monensin)
  - Variable reductions (up to 25%)
- Essential oils/botanicals
  - Mixed results – 10% maybe
  - Agolin (tradename)
  - Mootral (tradename)
- Lipids
  - ~3.8% reduction per 1% increase in lipid addition
- 3NOP (3 nitrooxypropanol)
  - 30% reduction with 40-80 mg/kg DMI
- Microalgae (*Asparagopsis taxiformis*)
  - 95% methane reduction with 5% inclusion rate
  - *In vitro* work

(Roque et al., 2019, Animal Microbiome)

Monensin (Rumensin)

- Increased feed efficiency by 3 to 5%
  - Increased milk output with slightly less DMI
- Can reduce methane output by up to 20%
  - Van Nevel and Demeyer, 1996
  - Effects on methanogens and on capture of carbon as propionate vs. acetate
- Variability of response?
- Currently available and widely fed in the US

3-nitrooxypropanol (3NOP)

- Feed additive
- Direct inhibitor of methane production
  - Inhibits last enzyme in methanogenesis
  - Potent – inclusion rate < 2 grams/day
- Received production scale evaluation

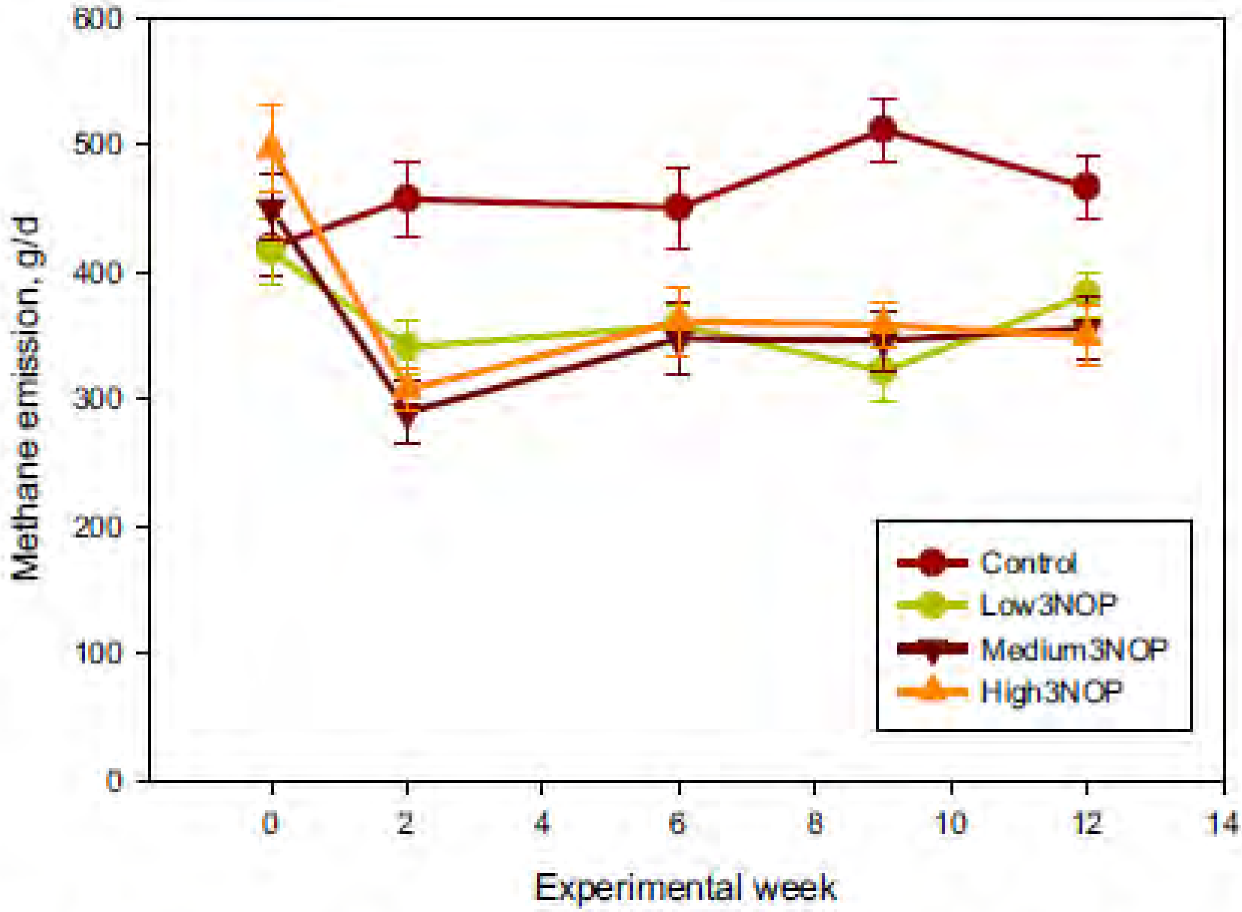


Fig. 1. Methane emission of dairy cows treated with 3-nitrooxypropanol (3NOP). Control = 0 mg/kg of 3NOP, Low3NOP = 40 mg/kg of 3NOP, Medium3NOP = 60 mg/kg 3NOP, and High3NOP = 80 mg/kg 3NOP (dietary dry matter basis). Methane emission was measured using the GreenFeed system (C-Lock, Inc.). Data are treatment means and bars represent SE; *n* = 12 (number of independent data points for each mean value).

Hristov et al., 2015. Proceedings National Academy of Sciences. 112:10663-10668.

Effects of 3NOP on performance of Holstein cows

Item	Control	Low 3NOP	Med 3NOP	High 3NOP	SEM	C vs TRT	L	Q
DMI, kg/d	28.0	28.0	27.7	27.5	0.45	0.58	0.38	0.69
Milk, kg/d	46.1	46.4	45.9	43.6	1.21	0.59	0.21	0.19
Fat, %	4.08	3.98	4.02	4.25	0.12	0.98	0.43	0.15
TP, %	3.06	3.14	3.12	3.13	0.03	0.07	0.14	0.31
BW, kg	664	672	672	664	5	0.38	0.83	0.13
BW change, kg/d	0.21	0.35	0.45	0.33	0.07	0.05	0.09	0.16

Hristov et al., 2015. Proceedings National Academy of Sciences. 112:10663-10668.

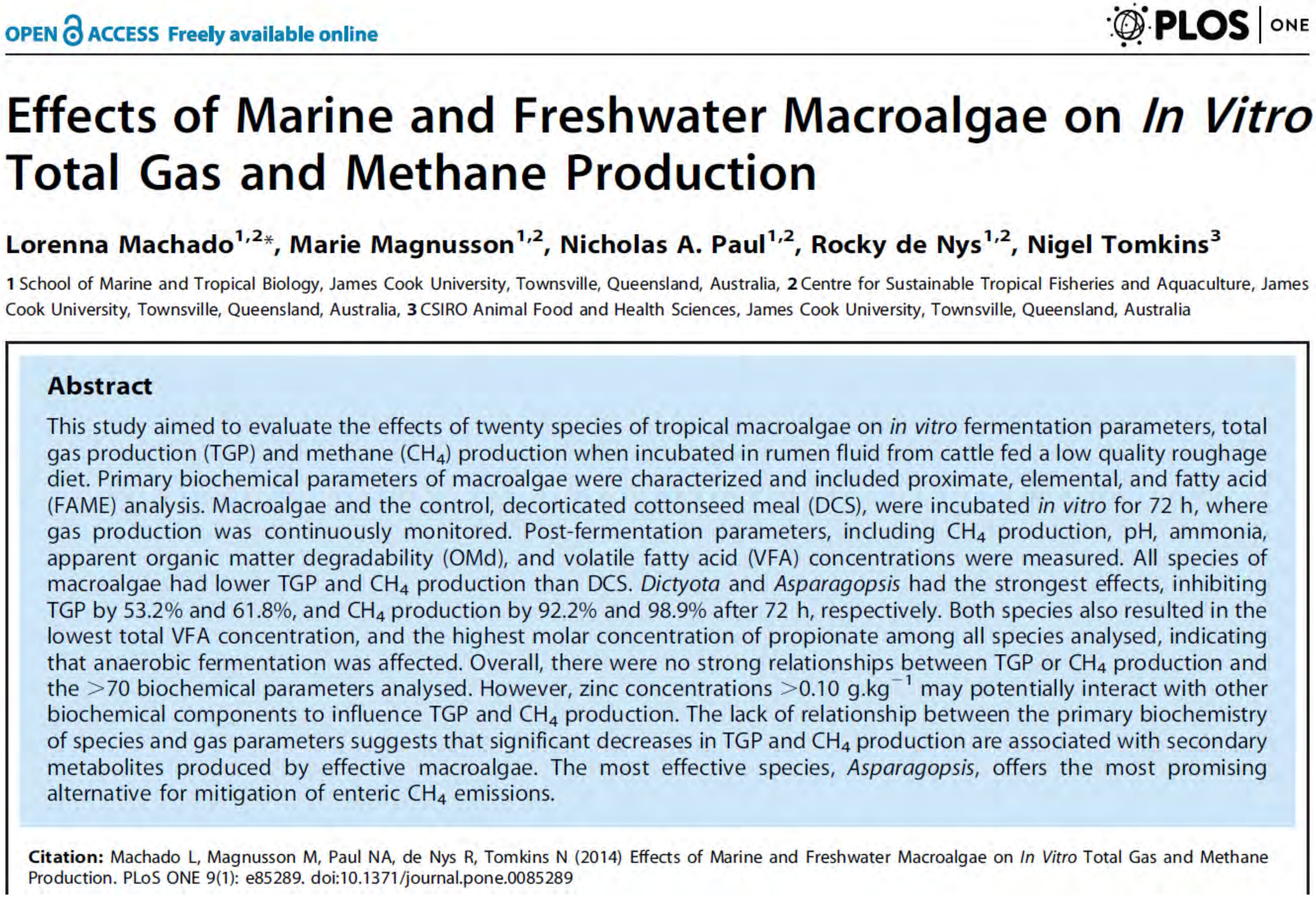
What about seaweed et al???

RESEARCH NEWS

Adding Red Seaweed To Cow Feed Could Cut Bovine Flatulence

December 2, 2020 · 5:05 AM ET
Heard on Morning Edition

Seaweed can potentially help fight climate change. Research shows that a specific type of seaweed can cut cows' methane production by up to 98%.



OPEN ACCESS Freely available online

PLOS | ONE

Effects of Marine and Freshwater Macroalgae on *In Vitro* Total Gas and Methane Production

Lorenna Machado[1,2]*, Marie Magnusson[1,2], Nicholas A. Paul[1,2], Rocky de Nys[1,2], Nigel Tomkins[3]

1 School of Marine and Tropical Biology, James Cook University, Townsville, Queensland, Australia, **2** Centre for Sustainable Tropical Fisheries and Aquaculture, James Cook University, Townsville, Queensland, Australia, **3** CSIRO Animal Food and Health Sciences, James Cook University, Townsville, Queensland, Australia

Abstract

This study aimed to evaluate the effects of twenty species of tropical macroalgae on *in vitro* fermentation parameters, total gas production (TGP) and methane (CH_4) production when incubated in rumen fluid from cattle fed a low quality roughage diet. Primary biochemical parameters of macroalgae were characterized and included proximate, elemental, and fatty acid (FAME) analysis. Macroalgae and the control, decorticated cottonseed meal (DCS), were incubated *in vitro* for 72 h, where gas production was continuously monitored. Post-fermentation parameters, including CH_4 production, pH, ammonia, apparent organic matter degradability (OMd), and volatile fatty acid (VFA) concentrations were measured. All species of macroalgae had lower TGP and CH_4 production than DCS. *Dictyota* and *Asparagopsis* had the strongest effects, inhibiting TGP by 53.2% and 61.8%, and CH_4 production by 92.2% and 98.9% after 72 h, respectively. Both species also resulted in the lowest total VFA concentration, and the highest molar concentration of propionate among all species analysed, indicating that anaerobic fermentation was affected. Overall, there were no strong relationships between TGP or CH_4 production and the >70 biochemical parameters analysed. However, zinc concentrations >0.10 g.kg^{-1} may potentially interact with other biochemical components to influence TGP and CH_4 production. The lack of relationship between the primary biochemistry of species and gas parameters suggests that significant decreases in TGP and CH_4 production are associated with secondary metabolites produced by effective macroalgae. The most effective species, *Asparagopsis*, offers the most promising alternative for mitigation of enteric CH_4 emissions.

Citation: Machado L, Magnusson M, Paul NA, de Nys R, Tomkins N (2014) Effects of Marine and Freshwater Macroalgae on *In Vitro* Total Gas and Methane Production. PLoS ONE 9(1): e85289. doi:10.1371/journal.pone.0085289

Machado et al., 2014. PLoS ONE

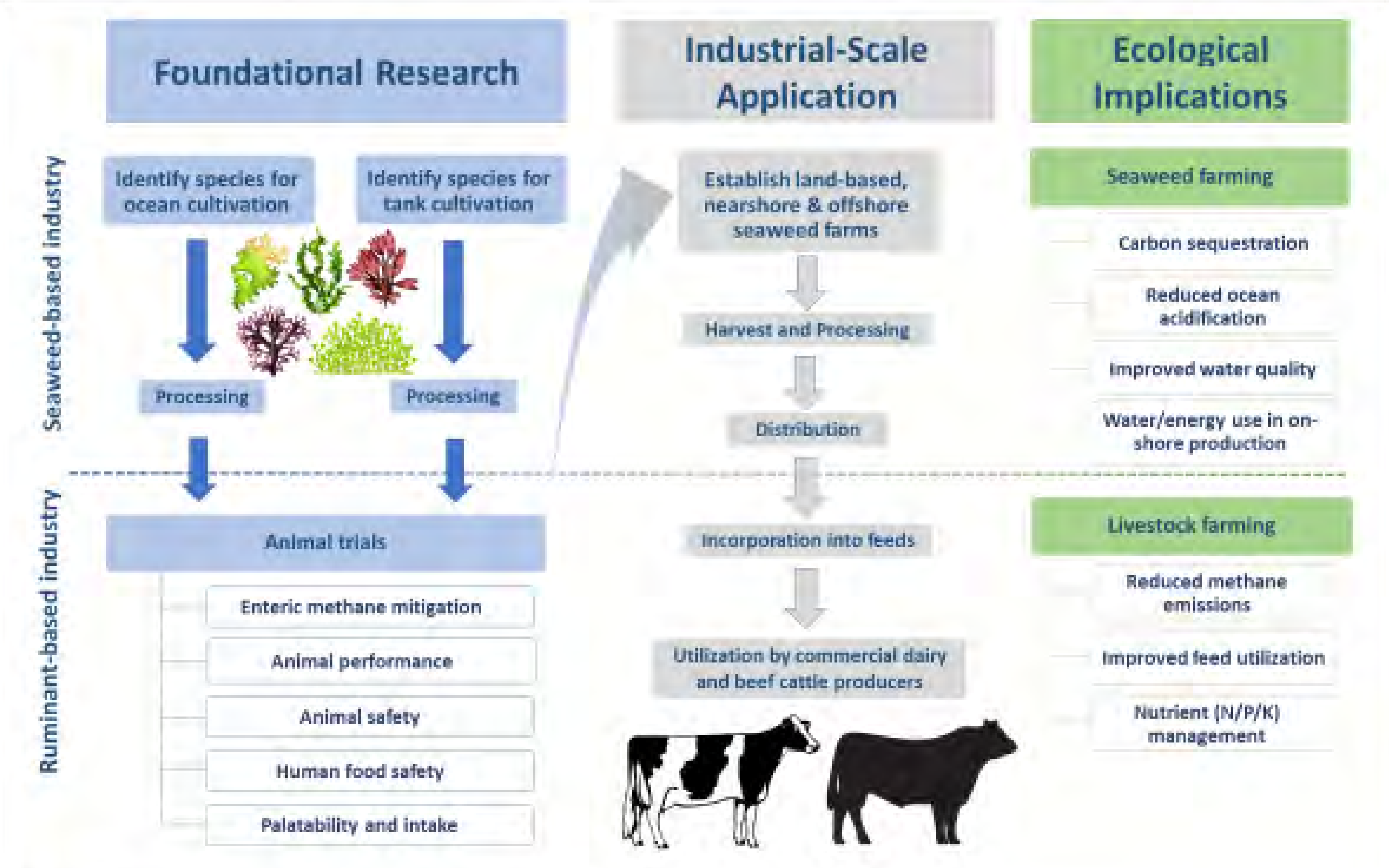


FIGURE 1 | Proposed pathways to development of seaweed products for enteric methane mitigation.

Vijn et al., 2020. Frontiers Vet Sci doi: 10.3389/fvets.2020.597430

“Use of seaweeds for enteric methane mitigation in a commercial setting is still largely untested. Several in vivo studies have evaluated the effects of a specific seaweed, Asparagopsis sp., on methane emissions and productivity of sheep, beef and dairy cows. However, it is unclear whether the observed effects are repeatable in the long-term and across different production systems.”

Vijn et al., 2020. Frontiers Vet Sci doi: 10.3389/fvets.2020.597430

The **Ru**minant **Fa**rm **S**ystems Model

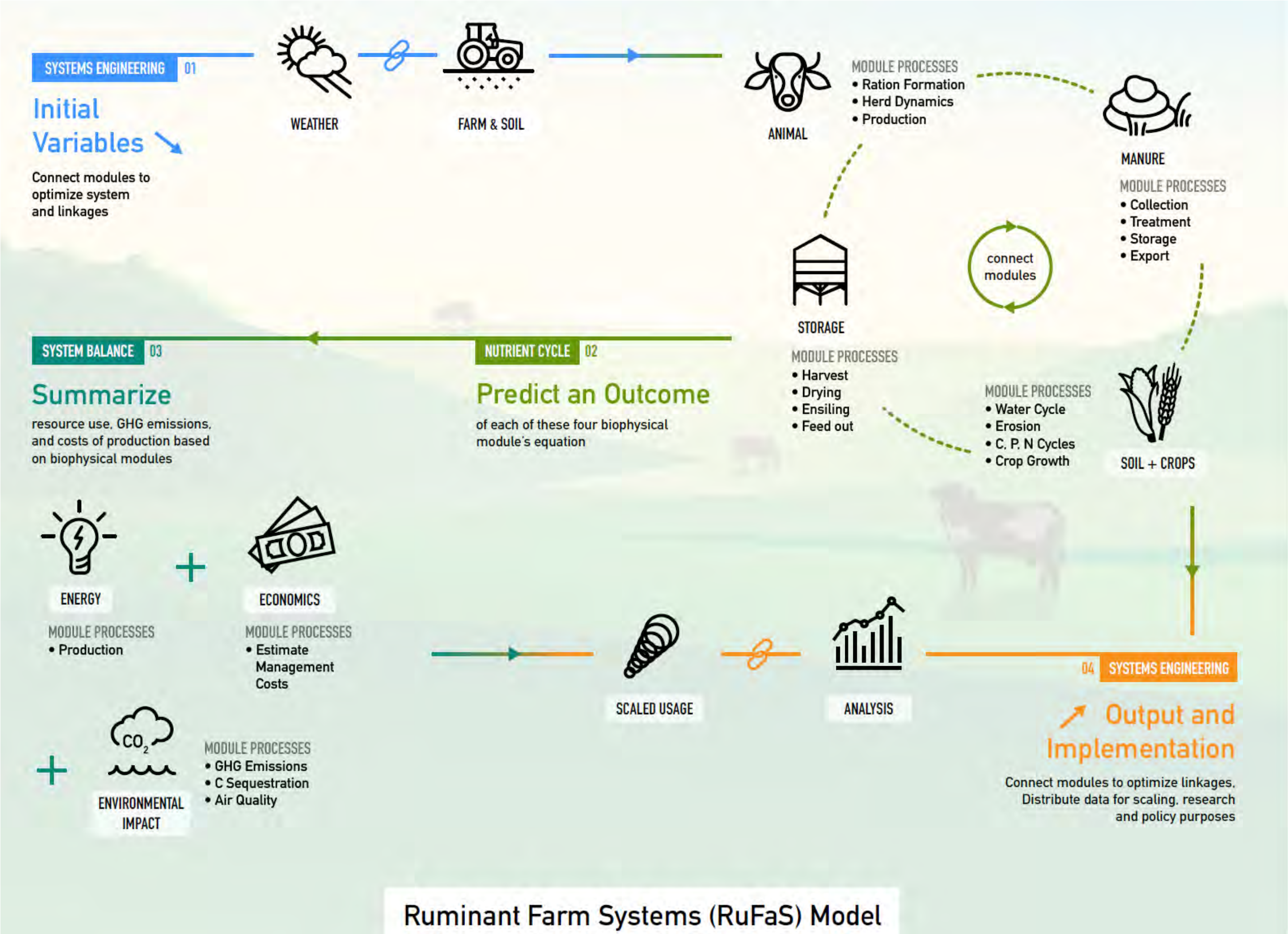
What is RuFaS?

- A next-generation, adaptable, whole-farm dairy systems simulation model that:
  - flexibly represents the diversity of management practices on US dairy farm
  - implements modern modular coding standards to enhance interoperability with other programs and increase model use

Examples of Questions RuFaS will address:

- How does herd nutrition affect nutrient fate in crop uptake, crop nutritional quality, and soil health?
- How does genetic selection and/or breed choice impact whole farm nutrient efficiency? Productivity? GHG emissions?
- Does reduction in enteric methane shift emissions to manure or soil?
- How does sequential linking of manure processing technologies influence GHG emissions, energy and nutrient recovery, and value of processed manure outputs for soil amendments?
- How do crop system choices affect whole farm nutrient efficiency? Soil health? Long term productivity?

Reed et al., CU Animal Science



SYSTEMS ENGINEERING 01

Initial Variables ↘

Connect modules to optimize system and linkages

WEATHER

FARM & SOIL

ANIMAL

MODULE PROCESSES
- Ration Formation
- Herd Dynamics
- Production

MANURE

MODULE PROCESSES
- Collection
- Treatment
- Storage
- Export

connect modules

STORAGE

MODULE PROCESSES
- Harvest
- Drying
- Ensiling
- Feed out

SOIL + CROPS

MODULE PROCESSES
- Water Cycle
- Erosion
- C, P, N Cycles
- Crop Growth

NUTRIENT CYCLE 02

Predict an Outcome

of each of these four biophysical module's equation

SYSTEM BALANCE 03

Summarize

resource use, GHG emissions, and costs of production based on biophysical modules

ENERGY

MODULE PROCESSES
- Production

\+

ECONOMICS

MODULE PROCESSES
- Estimate Management Costs

\+

ENVIRONMENTAL IMPACT

MODULE PROCESSES
- GHG Emissions
- C Sequestration
- Air Quality

SCALED USAGE

ANALYSIS

04 **SYSTEMS ENGINEERING**

↗ Output and Implementation

Connect modules to optimize linkages. Distribute data for scaling, research and policy purposes

Ruminant Farm Systems (RuFaS) Model

Reed et al., CU Animal Science

Thanks!!

tro2@cornell.edu

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