Environmental Footprinting to Support Sustainable Dairy Production

Georgia Dairy Conference, January 2023

Kristan Reed, PhD

Cornell University

Agriculture and the Environment

- All agriculture has an impact on the environment
  - Cultivating the land will alter immediate and surrounding ecosystem
- The goal is to understand and manage the impact and resources in sustainable ways

Climate
- Global Warming Potential

Water Quality
- Freshwater and Marine Eutrophication
- Groundwater Contamination

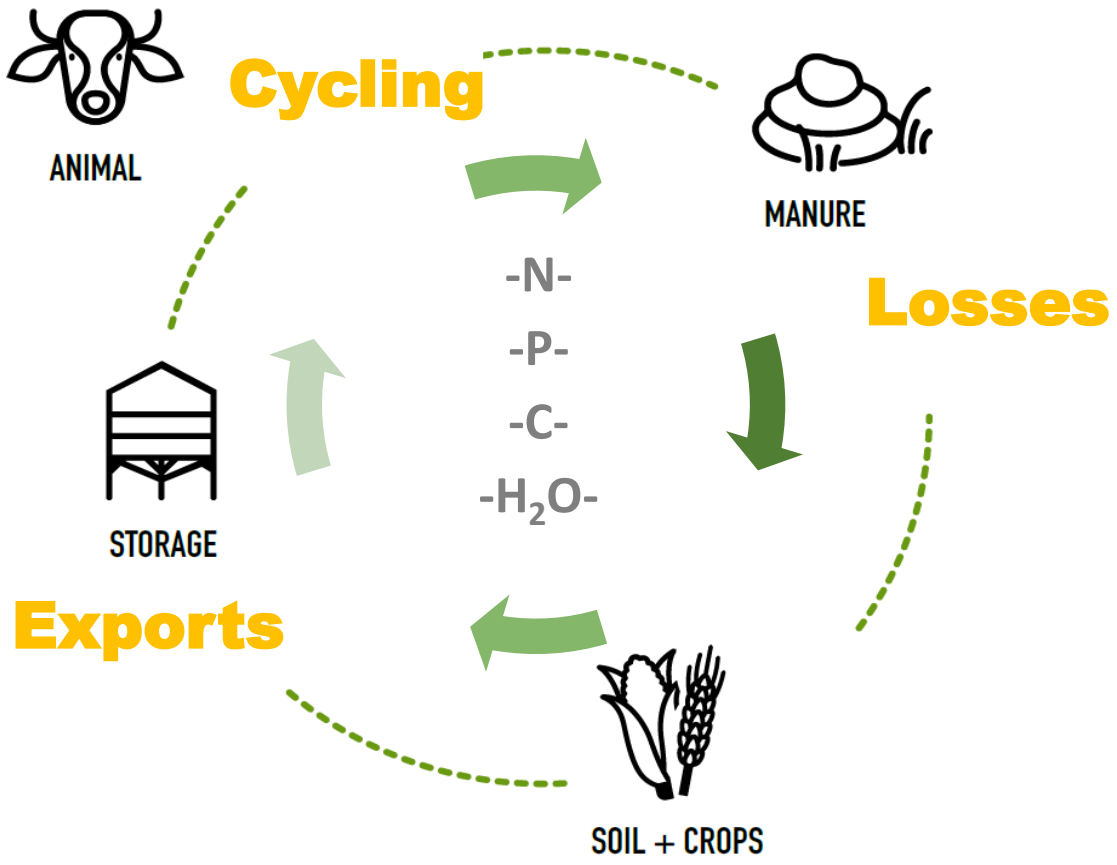
Air Quality
- Odors
- Particulate Matter
- Ammonia

Soil Health
- Soil Carbon
- Microbiome

Non-Renewable Resource Use
- Fossil Fuels
- Minerals
- Metals

Biodiversity
- Insects
- Birds
- Rodents

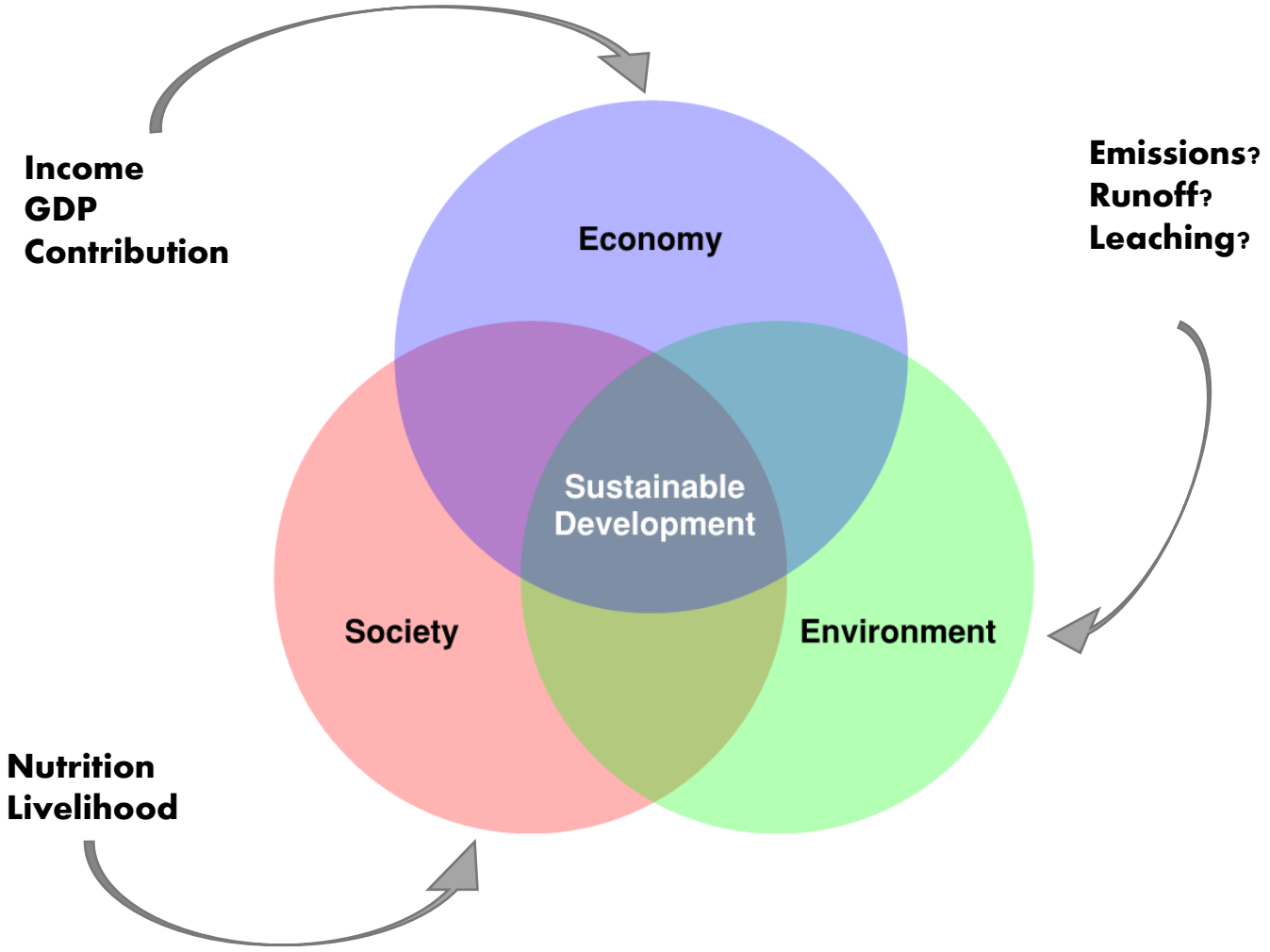
What are the ***potential*** environmental impacts of dairy production?

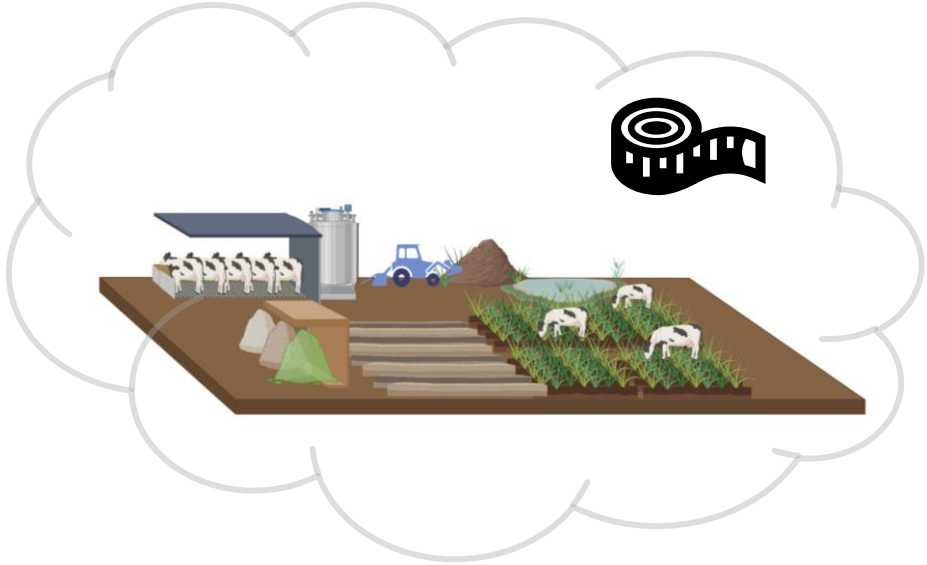


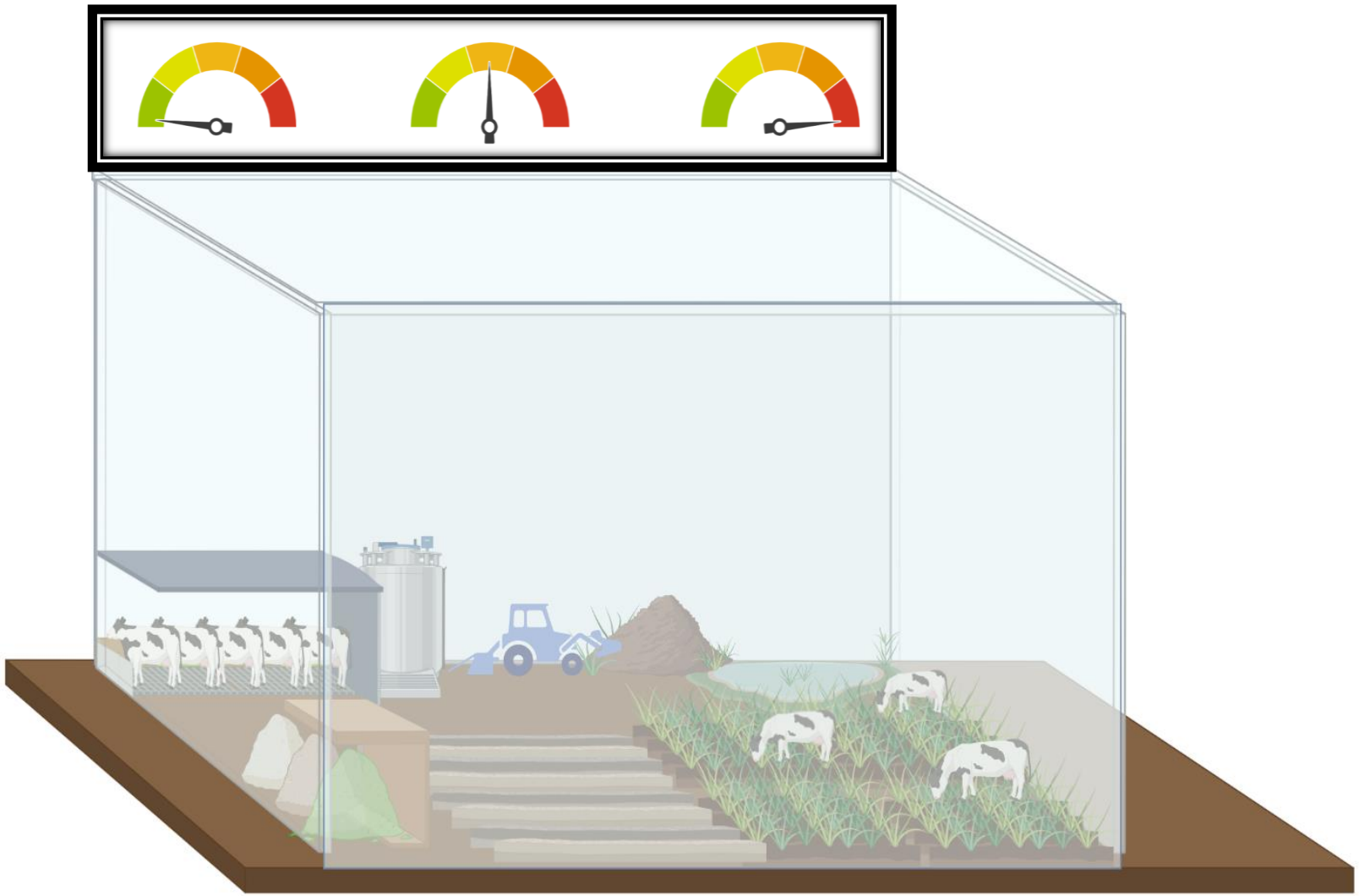
Sustainable Production is more than the environment…

Agriculture that…

- Continues to provide sufficient quantity and quality of food and fiber
- Preserves and enhances conservation of natural resources
- Efficiently uses non-renewable resources
- Maintains economic viability of farmers
- Enhances the quality of life in rural societies







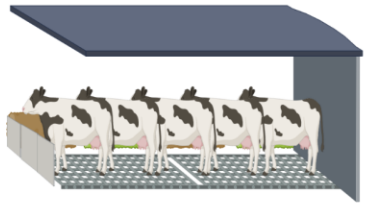
$$CH_4\ (MJ/d) = 2.94 + 0.0585 \times \text{ME intake (MJ/d)} + 1.44 \times \text{ADF (kg/d)} - 4.16 \times \text{lignin (kg/d)}.$$

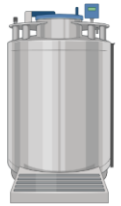
+

$$CO_2\left(\frac{kg}{d}\right) = 0.42\frac{kg}{kW} * 9.14^{-5}\frac{kW}{kg\ milk}$$

+

$$\text{Methane}_{\text{liquid}} = \left[\left(\frac{24*VS_d*b_1}{1000}\right) * e^{\ln(A)-\frac{E}{R*T_R}}\right] + \left[\left(\frac{24*VS_{nd}*b_2}{1000}\right) * e^{\ln(A)-\frac{E}{R*T_R}}\right]$$

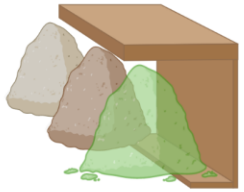




+

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2$$

+ HEAT (2870 kJ/mole) . . . . .



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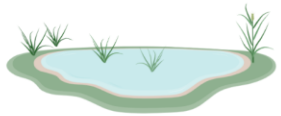
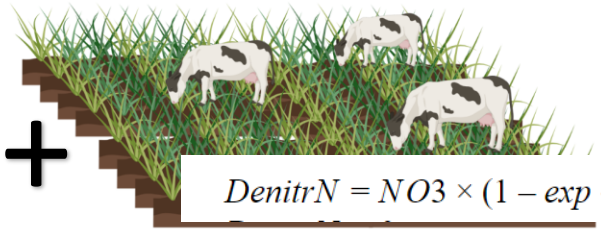


$$N2O_{strg-dir-daily} = N_{strg-pa} * \varepsilon_{MMS} * \epsilon_{N20-dir} * \sigma_{N-N2O}$$

[MS.5.B.II.a.1]

+

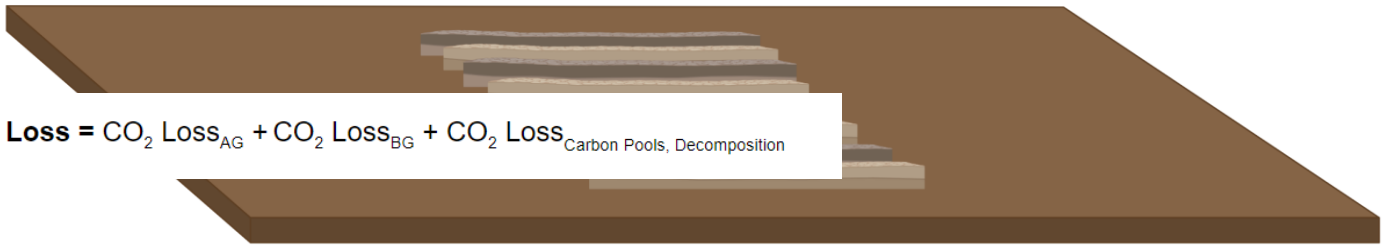


$$DenitrN = NO3 \times (1 - exp\{-deNrate \times TempFac \times OrgC\})$$

+

$$CO_2\left(\frac{kg}{d}\right) = 8.9\ \frac{kg}{gal} * 13.6\frac{gal}{hr} * 8\frac{hr}{d}$$

+



Total CO_2 Carbon Loss = CO_2 $Loss_{AG}$ + CO_2 $Loss_{BG}$ + CO_2 $Loss_{\text{Carbon Pools, Decomposition}}$

Two Approaches

Inventory

Objectives:

- Establish baseline
- Track Progress
- Set Goals

Features:

- Static, retrospective
- Longer Intervals
- Large Spatial Scales

Decision Support

Objectives:

- Predict Current & Future Outcomes
- Inform Decisions

Features:

- Static or dynamic
- Smaller scale (farm, field, animal)

Most impact estimates you hear about are from Inventories

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Eat less meat: UN climate-change report calls for change to human diet

The report on global land use and agriculture comes amid accelerating deforestation in the Amazon.

Quirin Schiermeier

The Counter

The misbegotten promise of anaerobic digesters

by Jessica McKenzie
12.03.2019, 9:30am

Environment

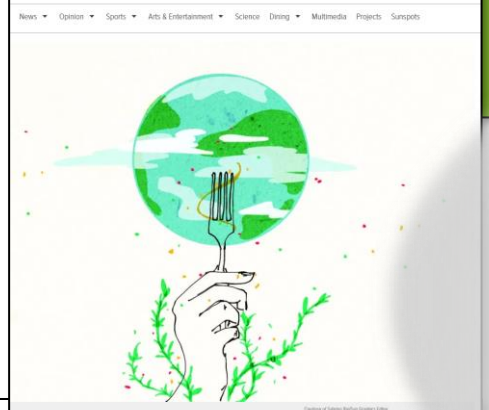
Meat And Agriculture Are Worse For The Climate Than Power Generation, Steven Chu Says

Jeff McMahon Contributor

Green Tech

From Chicago, I write about climate change, green technology, energy.

The Cornell Daily Sun



What if the World Went Vegan?

THE AGENDA

CLIMATE

Opinion | The Cow-Shaped Hole in Biden's Methane Plan

Agriculture emits more methane than any other sector of the economy. So why is it getting a pass?

Climate Change + Animal Ag News

The Salt WHAT'S ON YOUR PLATE

FOOD FOR THOUGHT

To Slow Global Warming, U.N. Warns Agriculture Must Change

August 8, 2019 · 4:00 AM ET
Heard on All Things Considered

REBECCA HERSHER ALLISON AUBREY

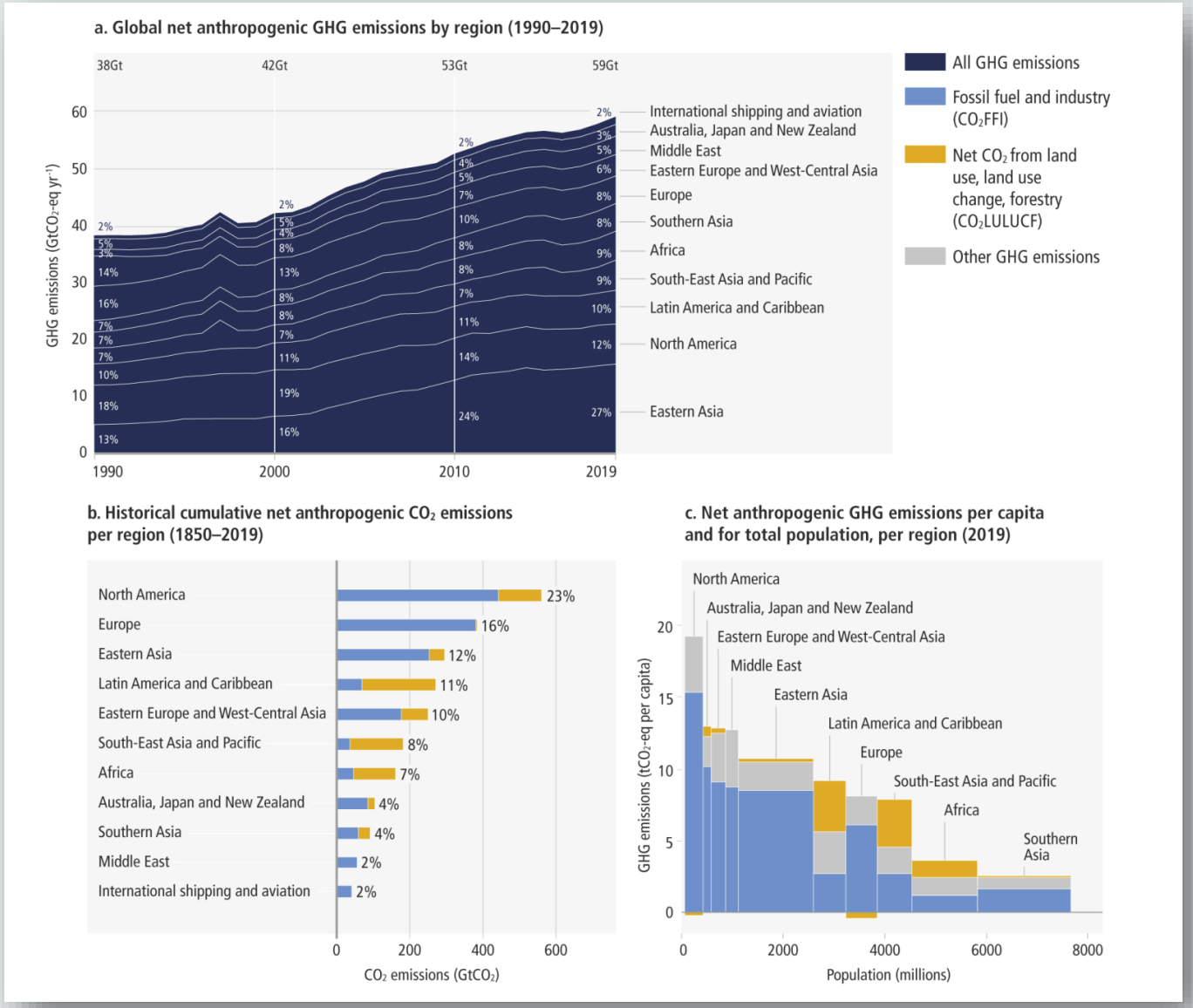
Keeping carbon in check: Carbon farming to address a changing climate

A two-pronged approach — one that reduces and reverses emissions — might be the answer.

Climate Adaptation

Starbucks Says Hold the Milk to Reduce Carbon Footprint

By Eric Pfanner
January 21, 2020, 9:00 AM EST *Updated on January 21, 2020, 10:15 AM EST*



Intergovernmental Panel on Climate Change

6th Assessment

April 2022

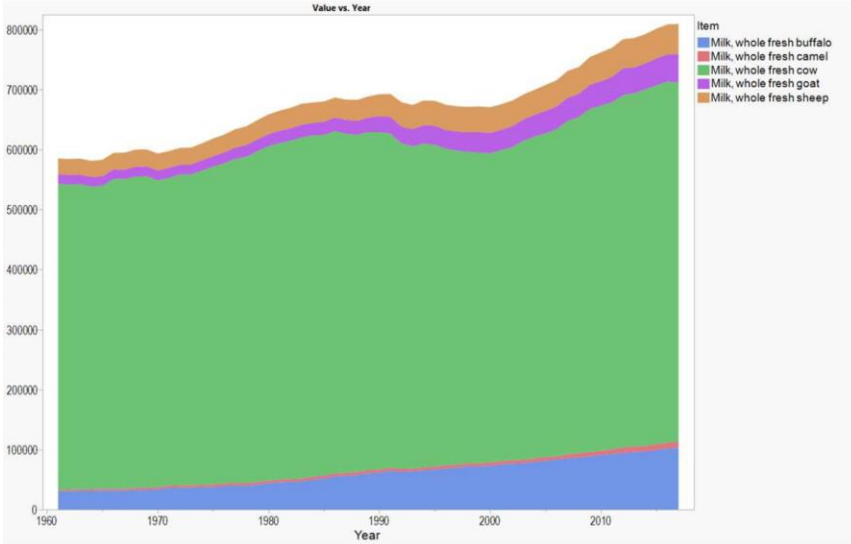
*Total **net anthropogenic GHG emissions have continued to rise** during the period 2010–2019, as have cumulative net CO2 emissions since 1850... but the **rate of growth** between 2010 and 2019 **was lower** than that between 2000 and 2009*

https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/

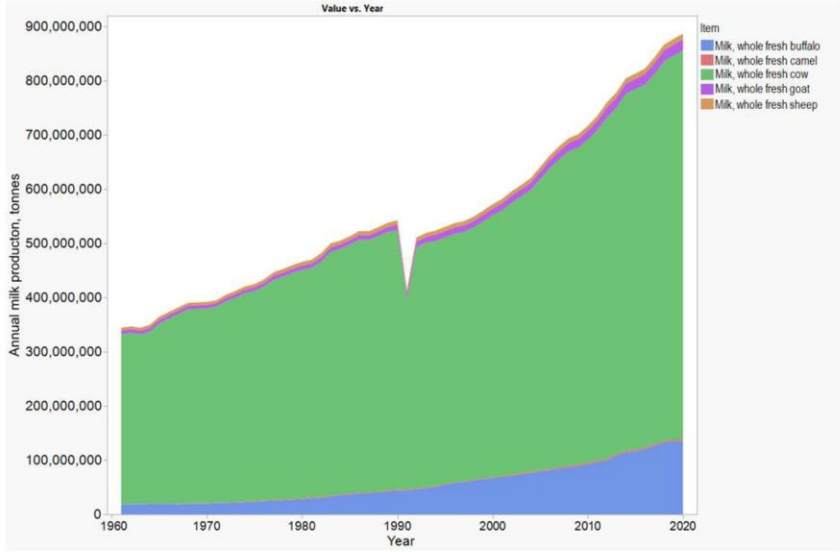
Inventories Establish Long Term Trends

Total direct emissions vs total milk production globally

1961 – 2017 increase in emissions: **+38.3%**



1961 – 2017 increase in production: **+144%**



Source: https://www.fao.org/faostat/en/#data/EI

Shared by Dr. Place Elanco

Inventories can highlight important relationships that hold true at large scales

Production = Emissions Intensity

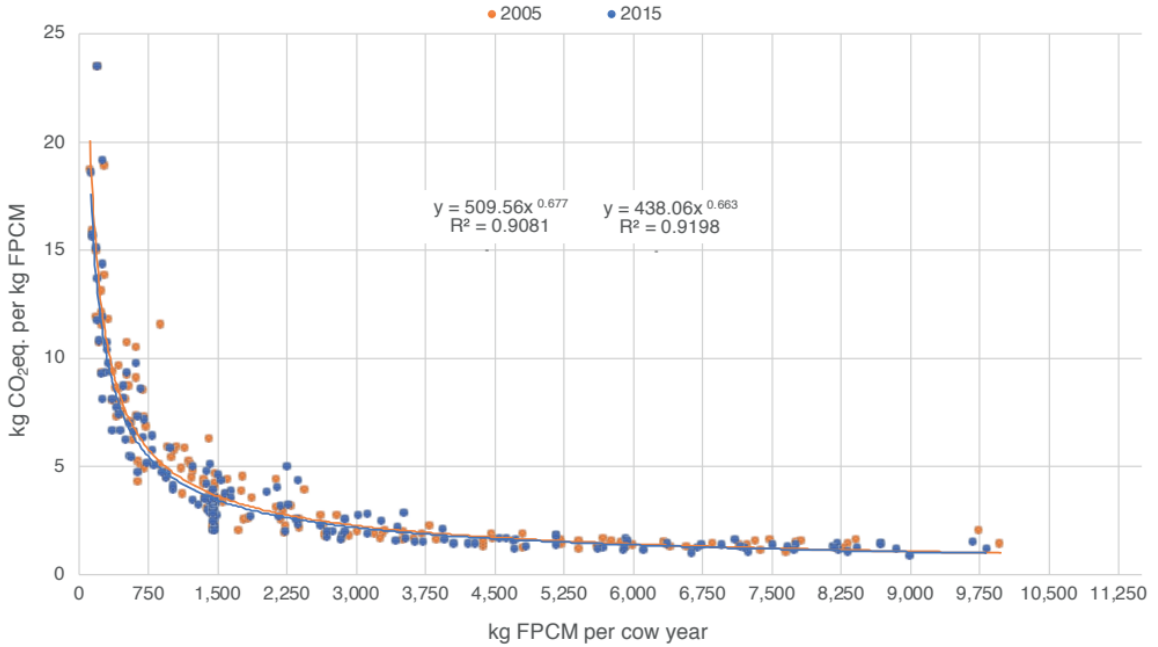
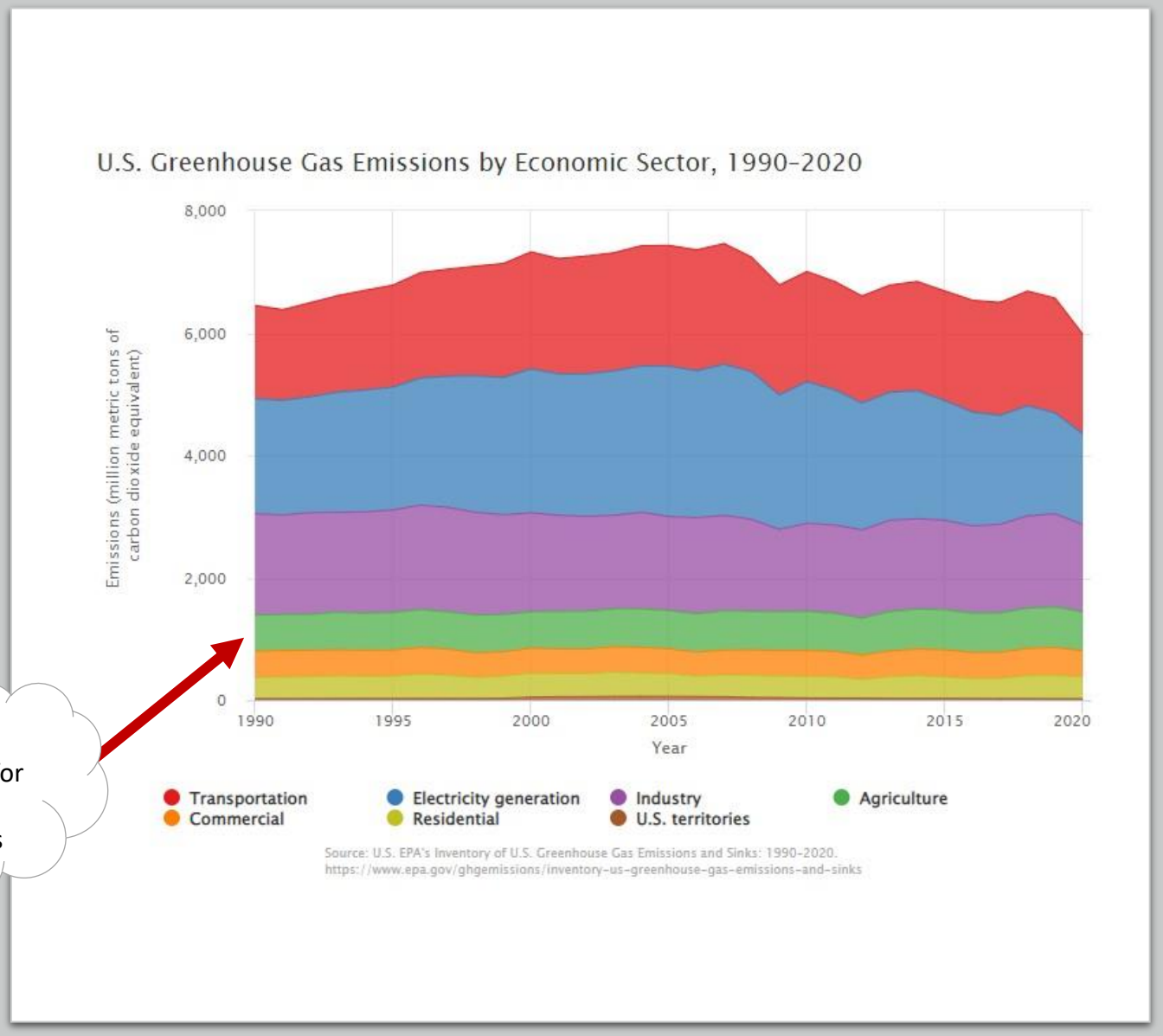


Figure 12: Emission intensity and milk yield

Note: Each dot represents a country. The fitted line clearly indicates an inverse relationship between milk yield per cow and emission intensity, i.e. as milk yield increases there is more milk to spread the emissions over.

FAO Stats: fao.org/faostat/

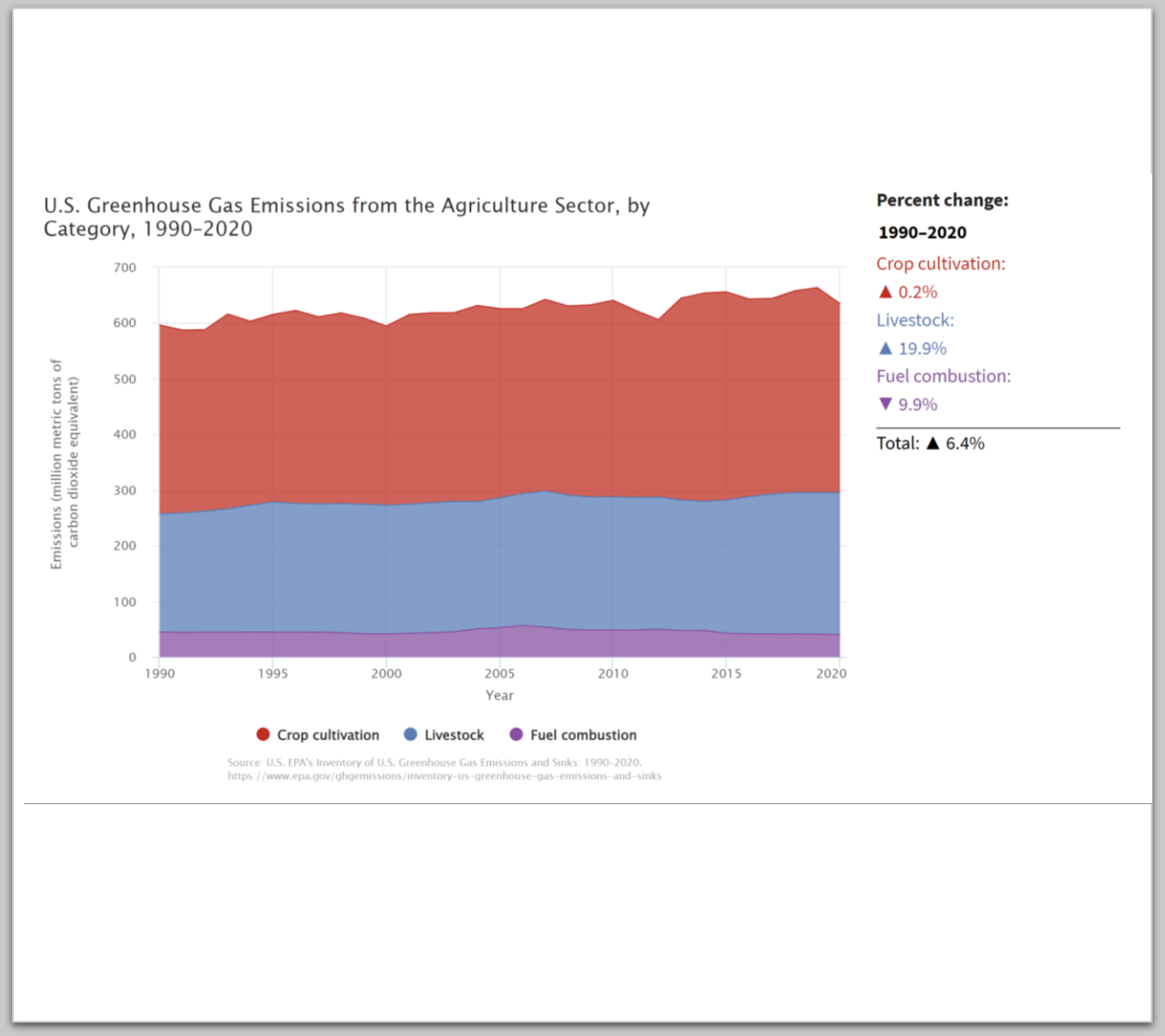
Knowledge gained from inventories will depend on the scale…



Agriculture responsible for ~11% of US emissions

EPA, 2021 https://www.epa.gov/ghgemissions/overview-greenhouse-gases

… and how total emissions are partitioned/ reported



EPA, 2021 https://www.epa.gov/ghgemissions/overview-greenhouse-gases

Methodology Matters

- Must be reproducible to enable comparisons over time
- As data availability improves so can the inventories

Capper and Cady: doi:10.1093/jas/skz291

SUSTAINABLE ANIMAL SCIENCE AND PRACTICES

The effects of improved performance in the U.S. dairy cattle industry on environmental impacts between 2007 and 2017

Judith L. Capper,[†,1] and Roger A. Cady[‡]

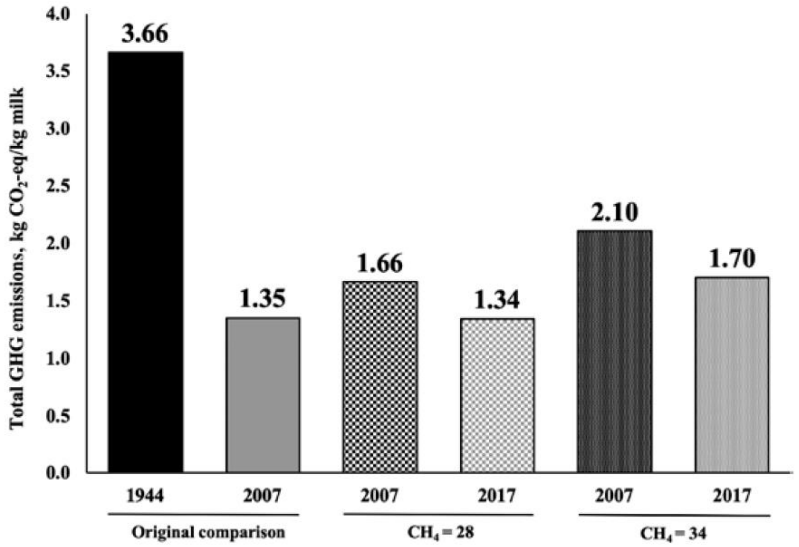
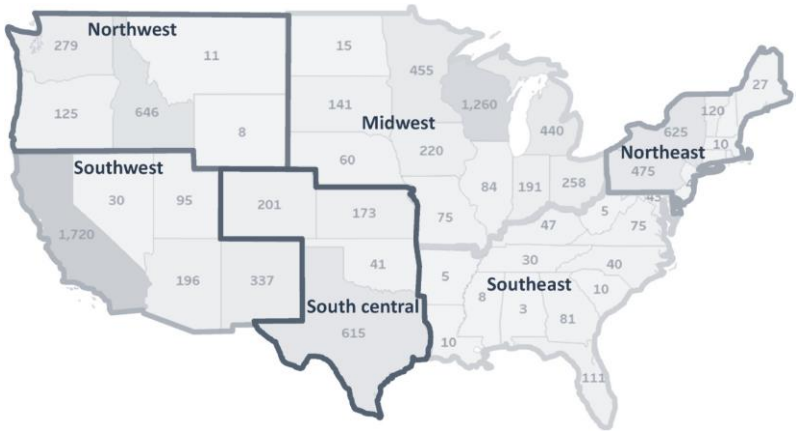
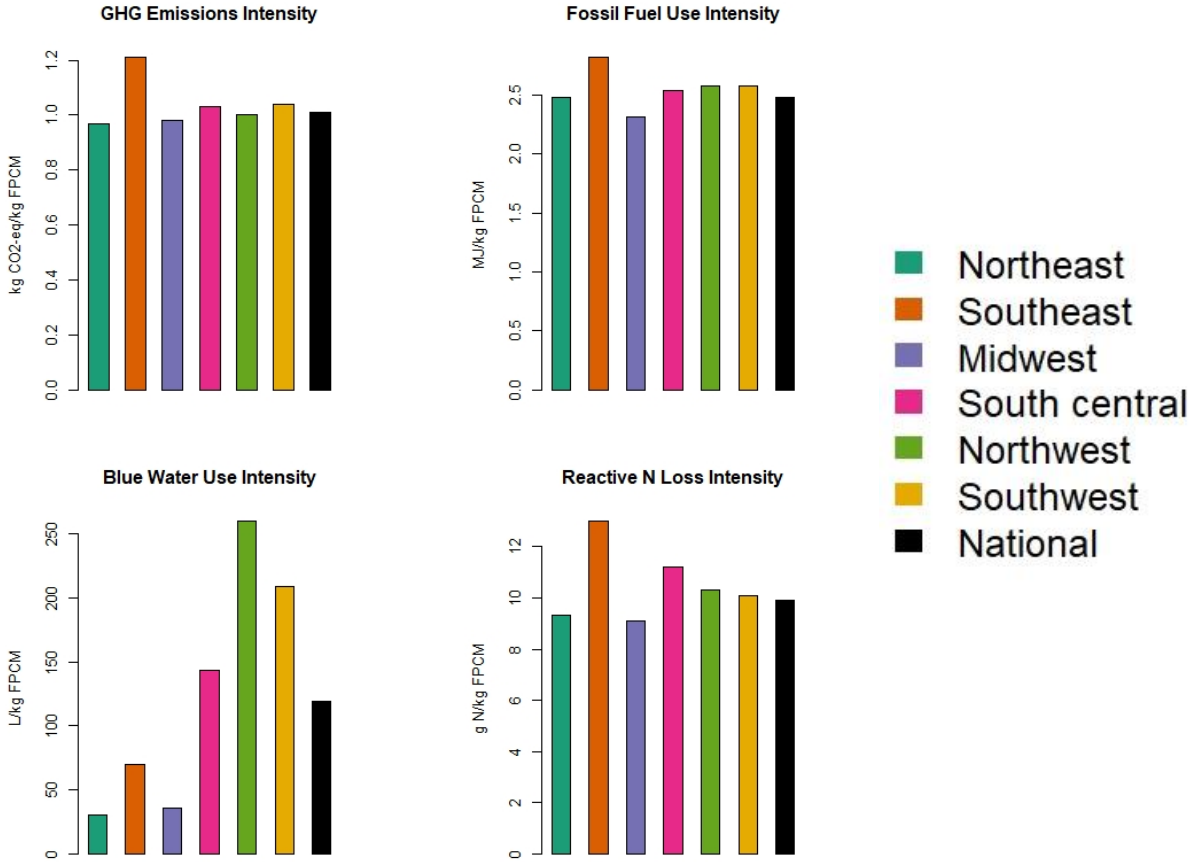


Figure 2. Greenhouse gases (CO_2-eq) per kilogram of milk in original 1944 vs. 2007 comparison (Capper et al., 2009) compared to the current 2007 vs. 2017 comparison with global warming potential values for methane set at 28 (IPCC, 2006) and 34 (IPCC, 2013).

Methodology Depends on Objectives

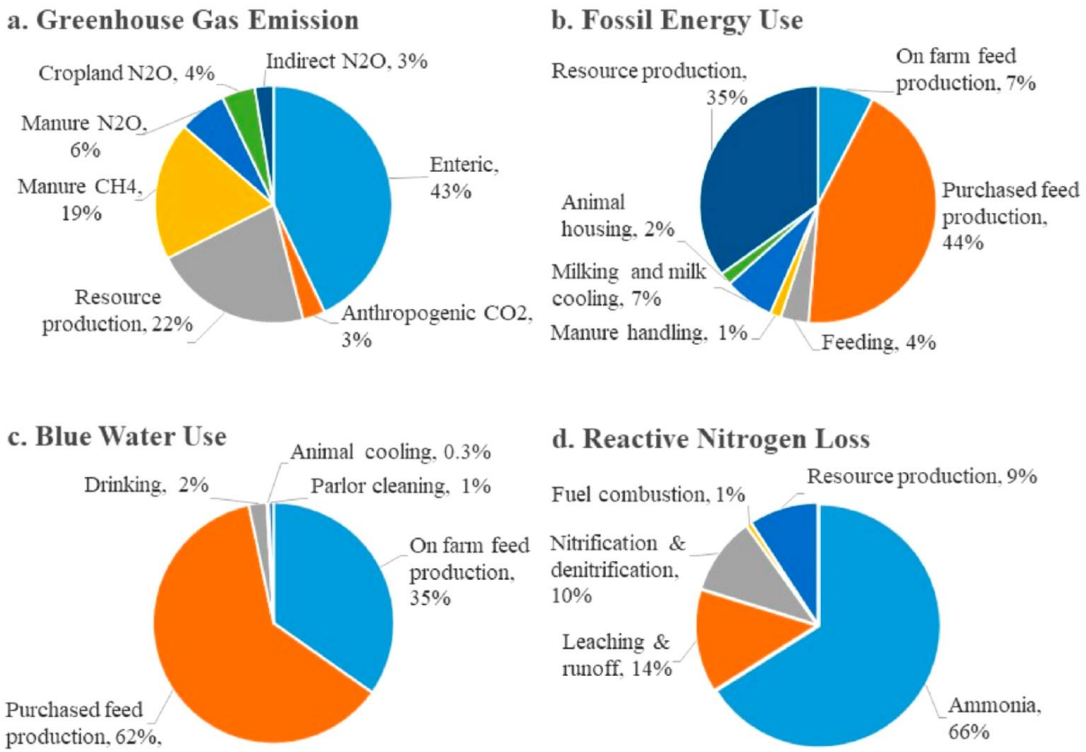




Rotz et al. (2021): https://doi.org/10.1016/j.jclepro.2021.128153

Farm level insights are possible

43% of 1.0 kg Total GHG Intensity
=
430 g Enteric Methane Intensity



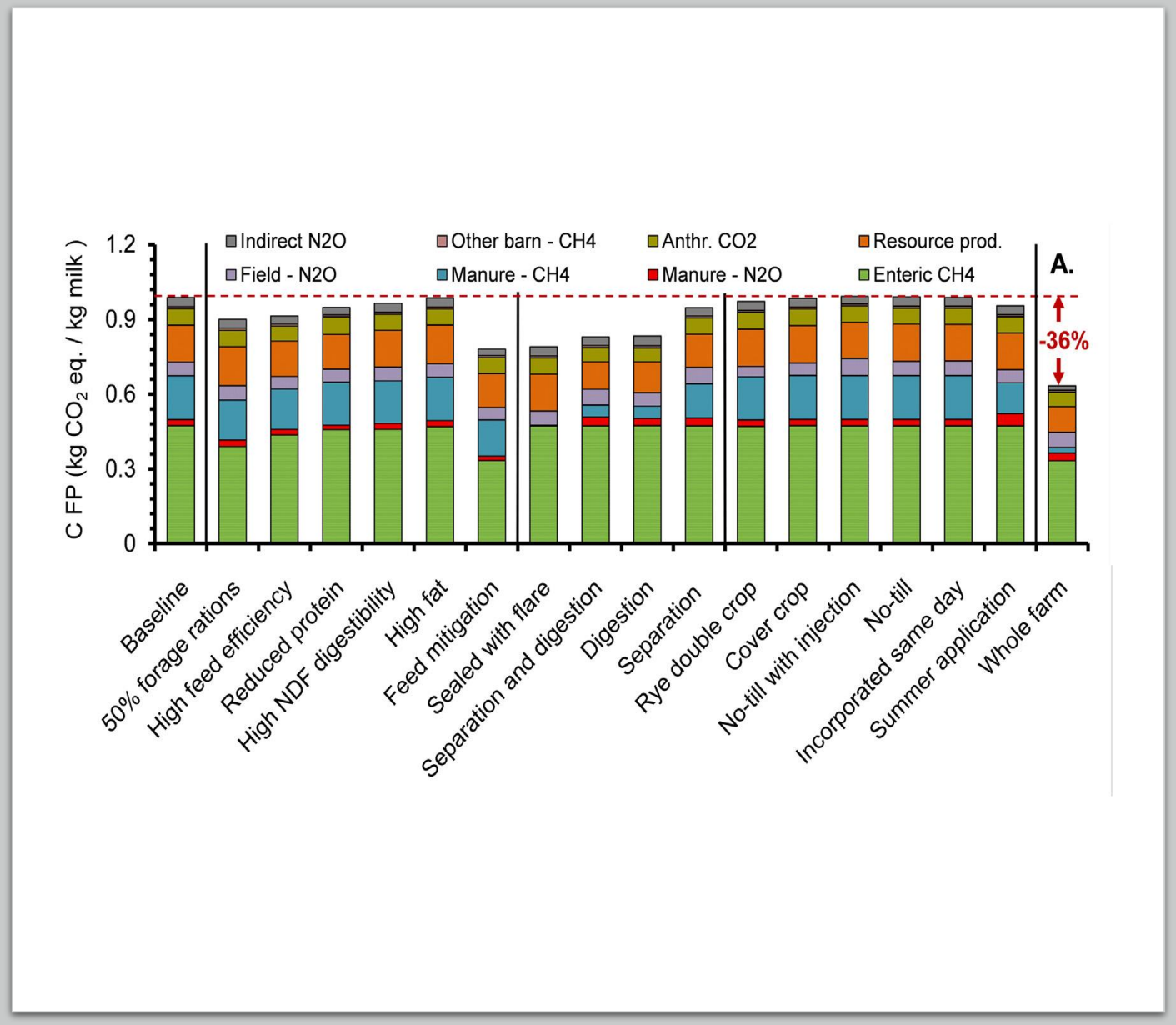
Rotz et al. (2021): https://doi.org/10.1016/j.jclepro.2021.128153

IFSM can also provide more detailed estimates to compare management strategies

This is an example from a representative farm in NY (they haven't released a similar study for the SE yet)

Compares a Baseline farm with other BMPs

- Feed efficiency
- Double Cropping
- No till
- Anaerobic Digestion

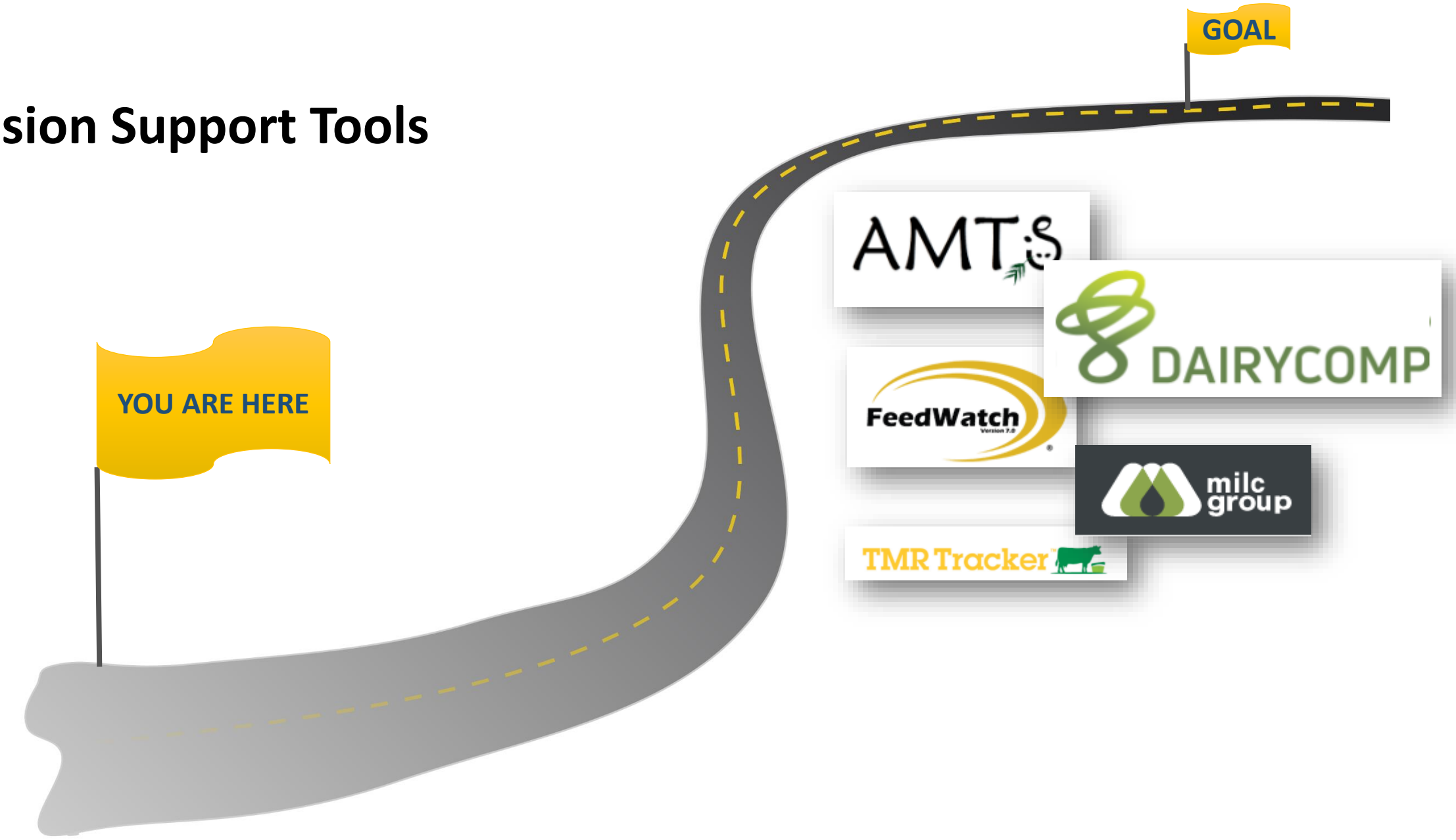


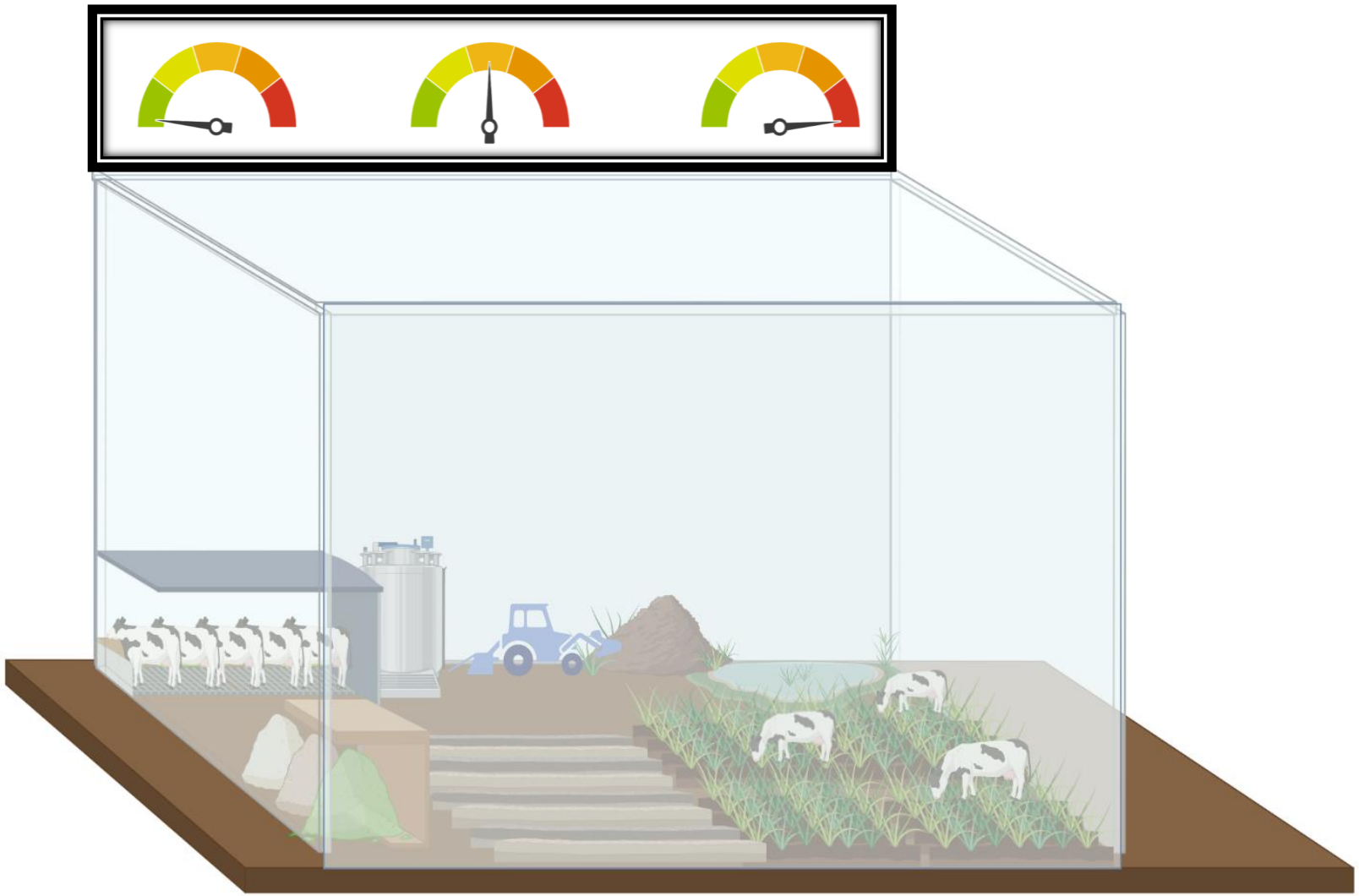
Veltman et al Ag. Syst. 2018:
https://doi.org/10.1016/j.agsy.2018.07.005

Why do we need Decision Support Models?

Inventories

Decision Support Tools





Decision Support Tools

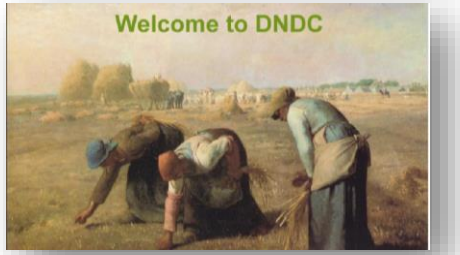
GOAL

YOU ARE HERE

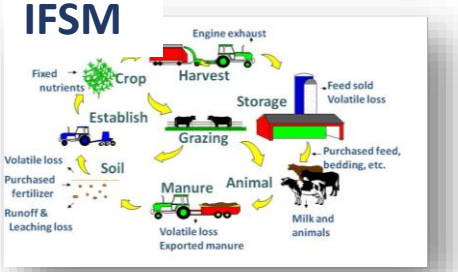
COMET Farm
USDA United States Department of Agriculture Natural Resources Conservation Service
Colorado State University
Whole Farm and Ranch Carbon and Greenhouse Gas Accounting System.

CFA COOL FARM ALLIANCE

FARMERS ASSURING FARM RESPONSIBLE MANAGEMENT
FARM Environmental Stewardship



IFSM



HISTORY

In 2009, National Dairy Farmers Assuring Responsible Management (FARM)™ Program was **created by the dairy industry**, through National Milk Producers Federation with support from Dairy Management, Inc.

DAIRY MANAGEMENT INC.™

NMPF

Through the Innovation Center, the dairy community has aligned behind FARM as the **industry-wide on-farm social responsibility program**.

INNOVATION CENTER FOR U.S. DAIRY®

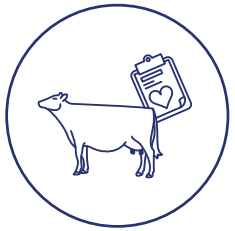
HEALTHY PEOPLE • HEALTHY PRODUCTS • HEALTHY PLANET

PROGRAM AREAS

1990

ANTIBIOTIC STEWARDSHIP

2009



ANIMAL CARE

2017

ENVIRONMENTAL STEWARDSHIP

2018

WORKFORCE DEVELOPMENT

2021

BIOSECURITY

1990 2000 2010 2020

FARM Environmental Stewardship

Status

- **2,600+** FARM ES assessments completed since 2017
- **41** participating co-ops and proprietary processors representing **80%** of milk supply
- Trained, 2nd party evaluators
- Resources for implementation and continuous improvement

FARM ES Evaluation

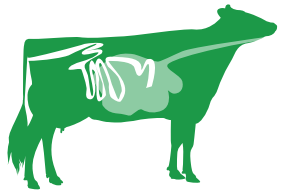
Data Inputs

The data needed to estimate GHG emissions and energy use intensity include:

- Milk Production
- Herd Data
- Rations
- Manure Management
- Energy Use

Results

Footprint (lb CO2e / lb FPCM) broken down by category



On-Site Enteric

On-Site Energy Use

On-Site Manure

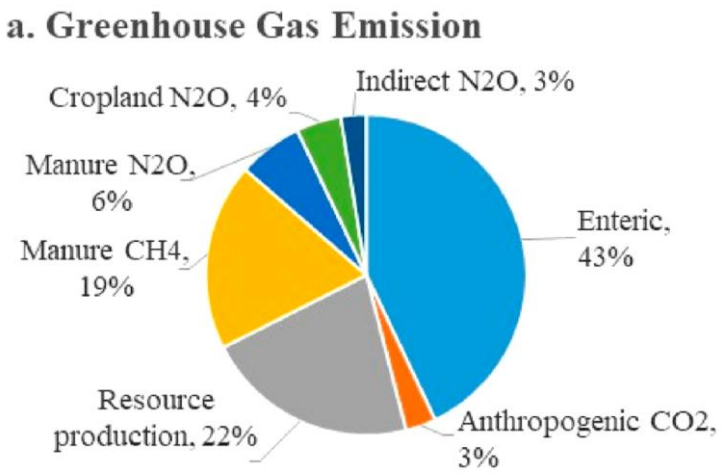
Feed Production

GOAL!

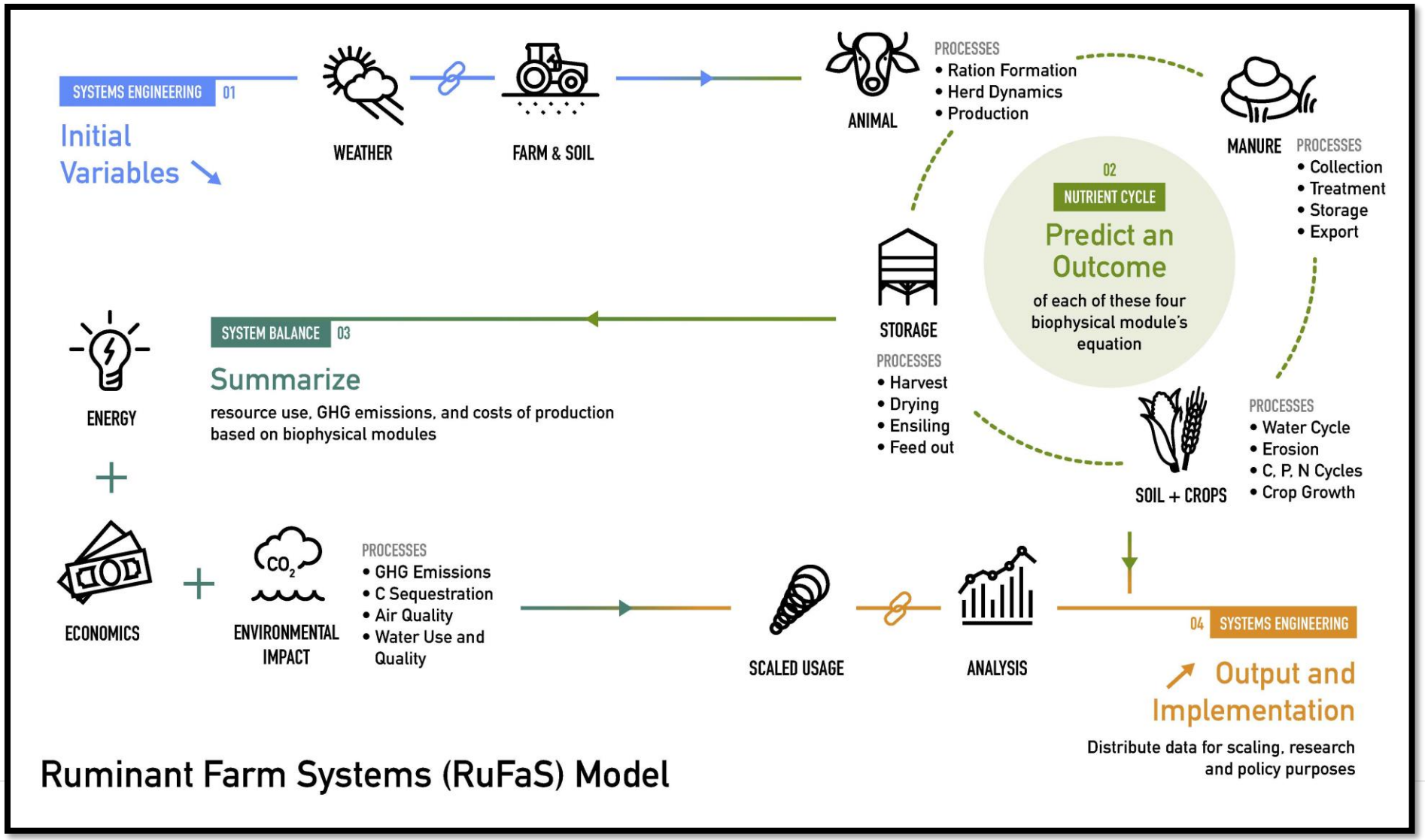
The FARM-ES program currently provides an inventory

*It provides a static, **snapshot** of the previous year's footprint from an individual farm and the dairy sector*

YOU ARE HERE



This leads us to RuFaS…



Founders

Key Stakeholders

USDA

Cornell University

University of Arkansas

UC Davis University of California

University of South Dakota

Innovation Center for U.S. Dairy
Healthy People • Healthy Products • Healthy Planet

Wisconsin University of Wisconsin-Madison

The Nature Conservancy

WWF

NEAFA Northeast Agribusiness & Feed Alliance
Advocate · Educate · Collaborate

General Mills Making Food People Love

DMI Dairy Management Inc.™

How can we use this model for decision support?

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

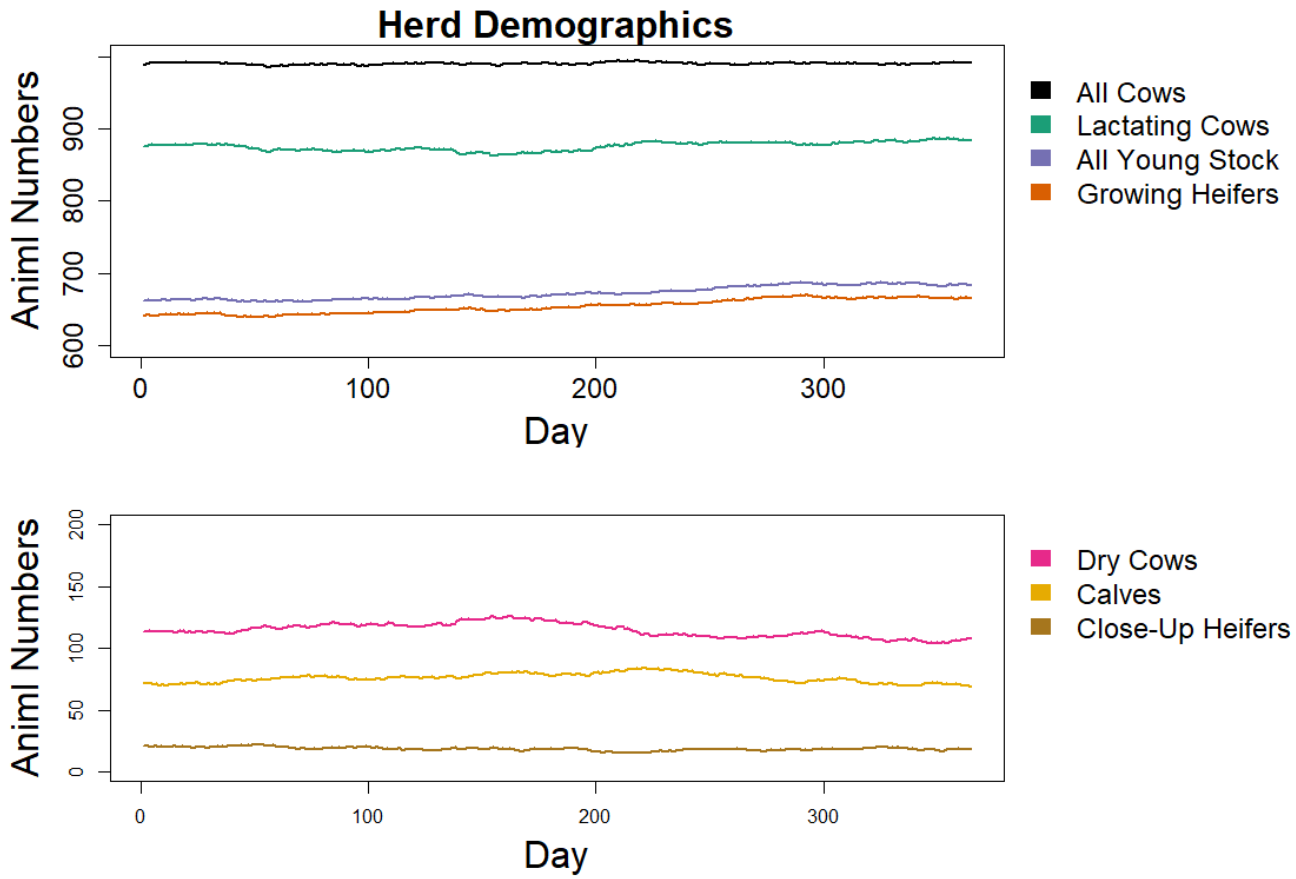
Parity	Average 305 MY
First	20,935 lbs (9,516 kg)
Second	24,476 lbs (11,125 kg)
Third+	25,481 lbs (11,582 kg)

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
+Forage	34.6	38	2.99	38.18	37.5	45.6	19.0

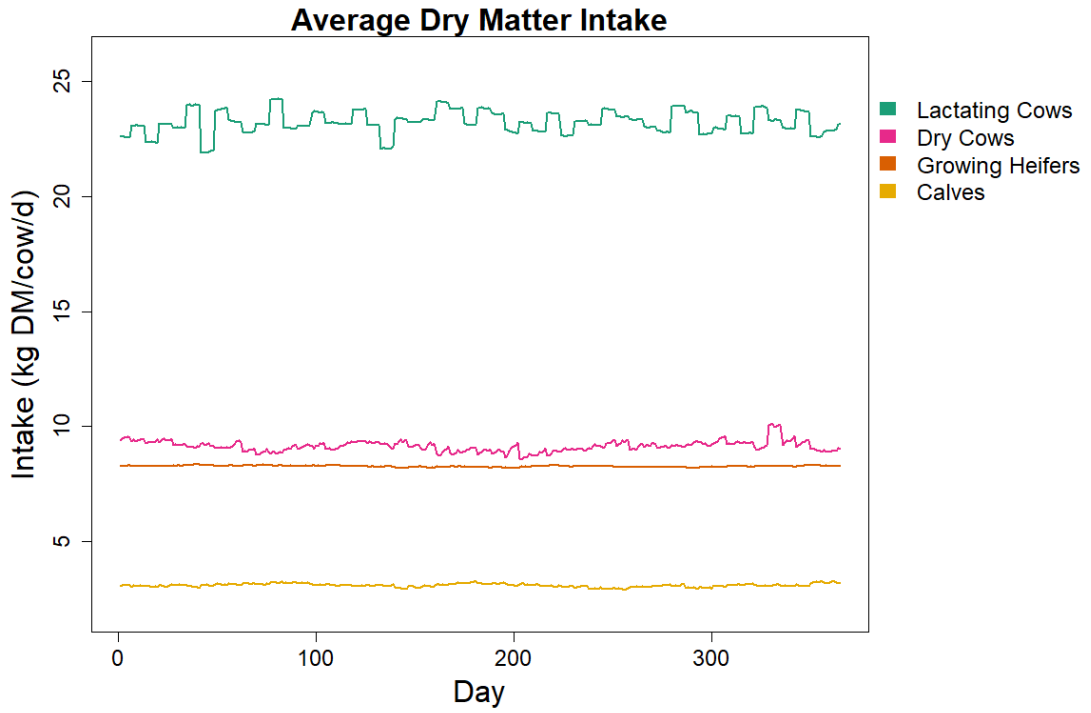
Some neat results…

Daily outputs of animal numbers



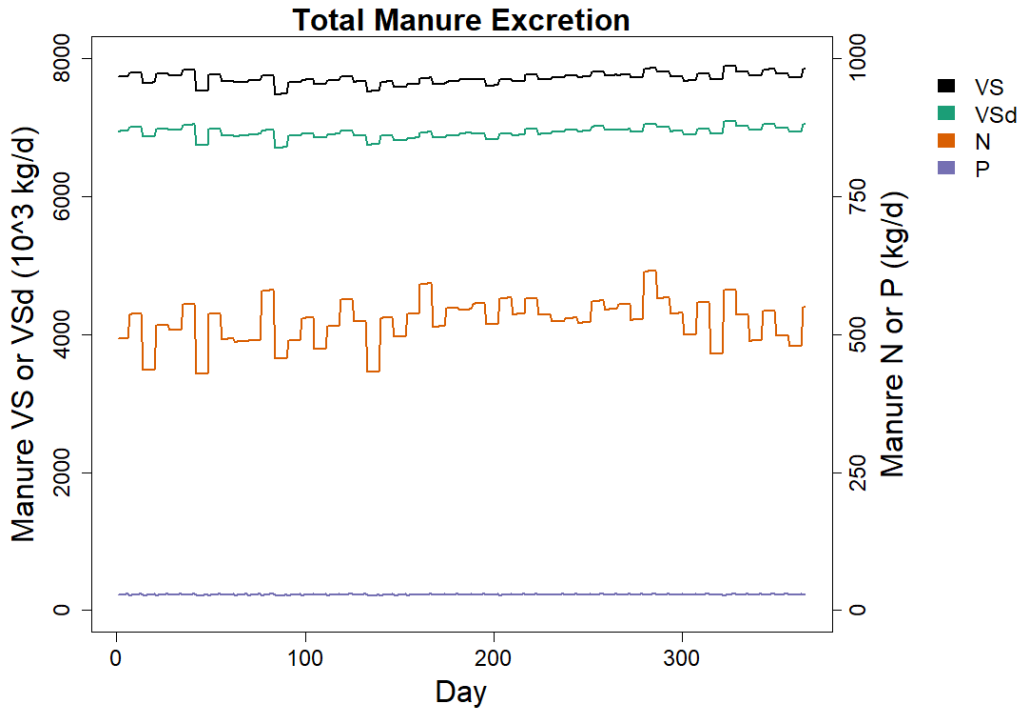
Some neat results…

Animal Intake



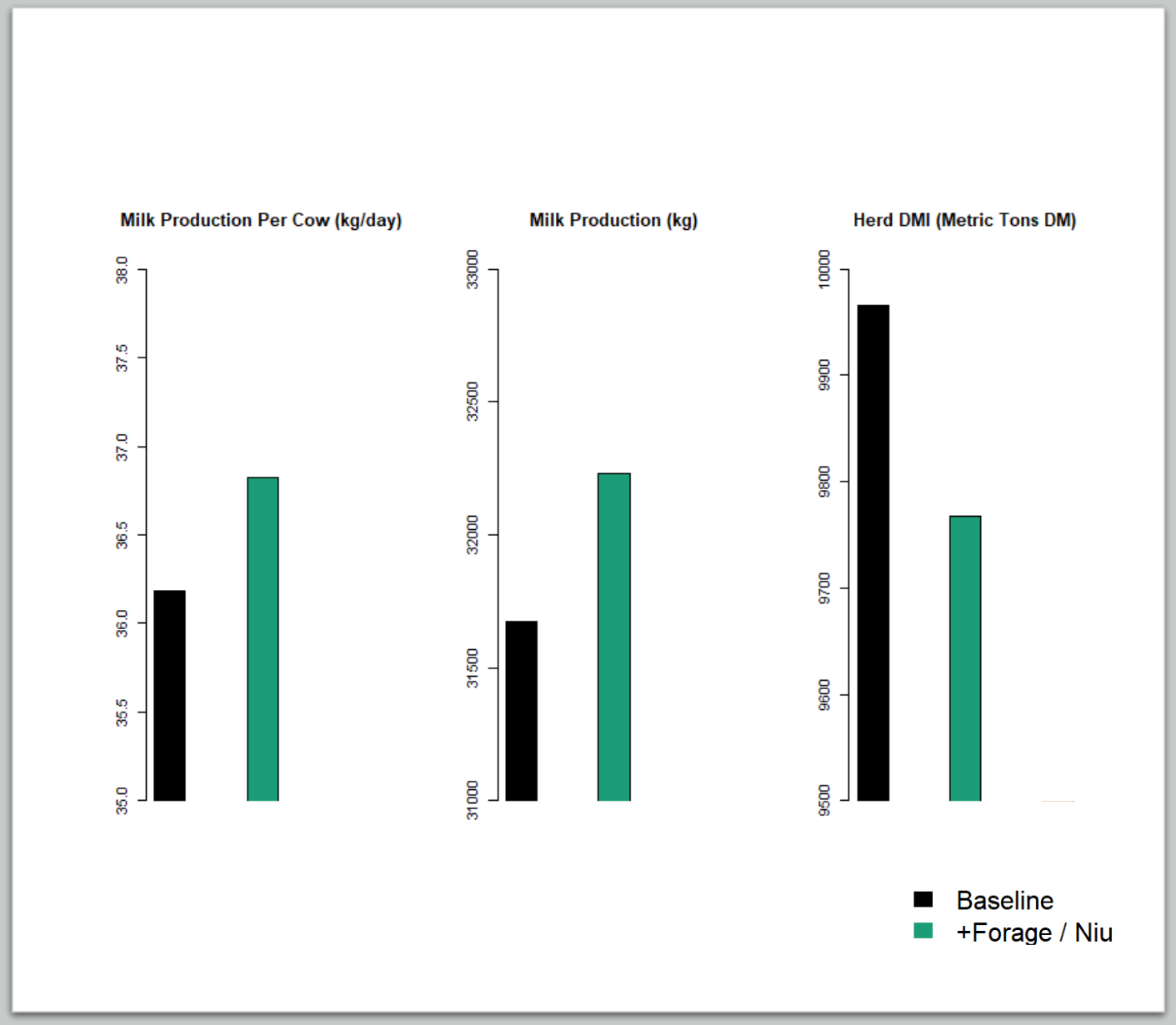
Some neat results…

Herd Manure

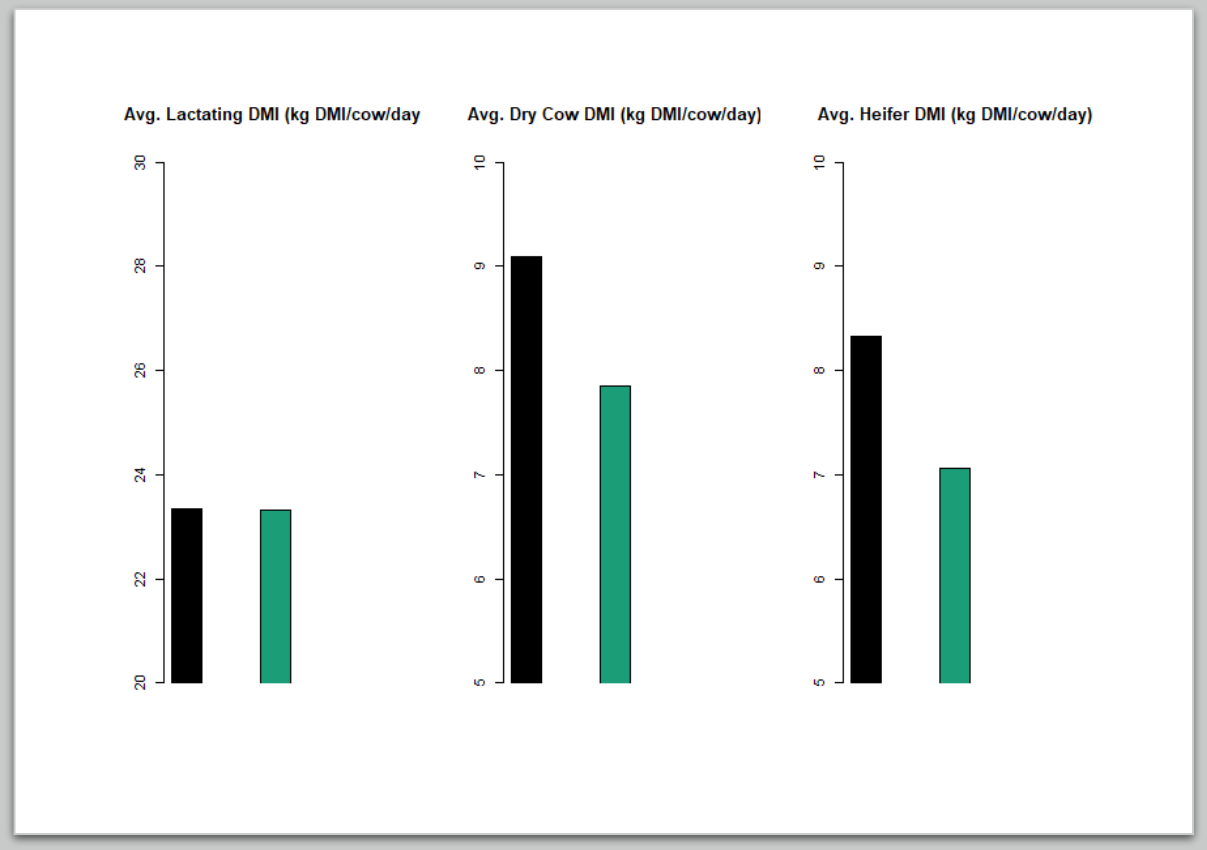


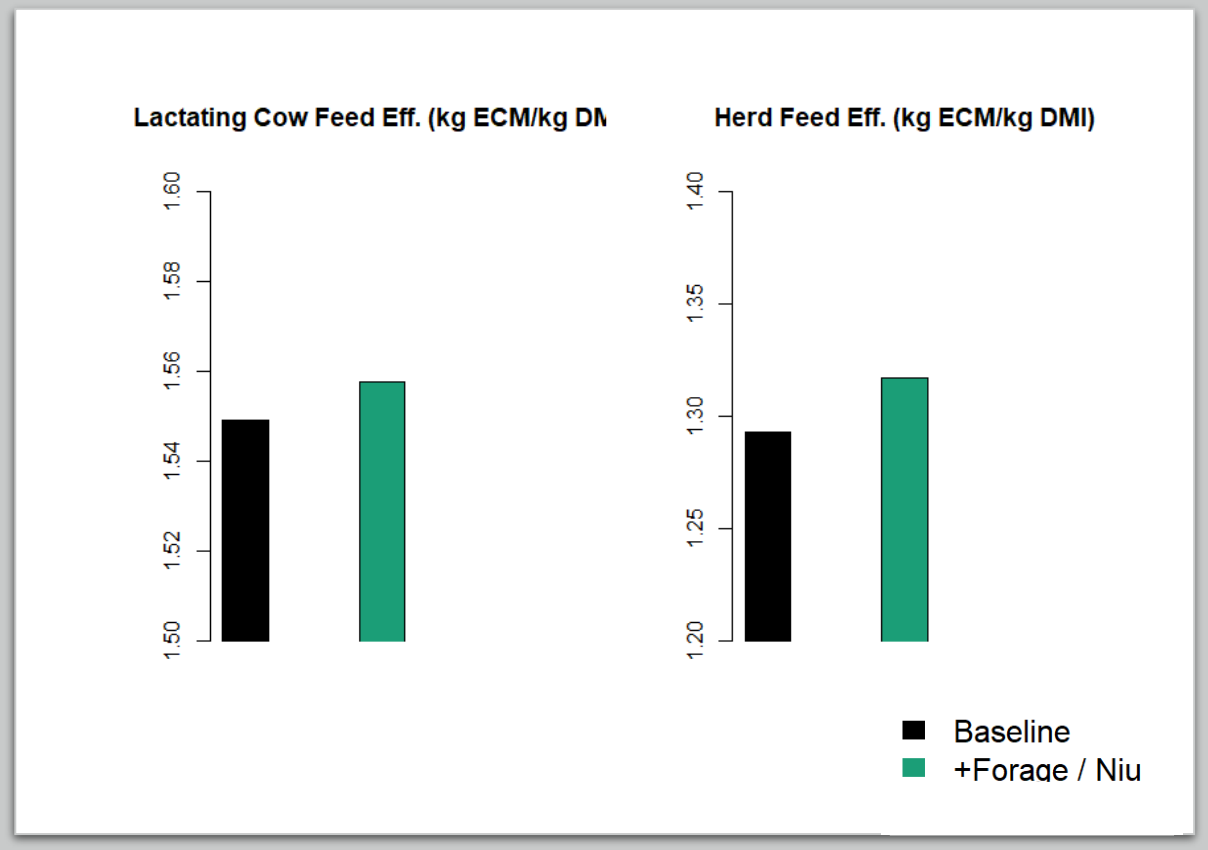
Milk Production & Intake

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

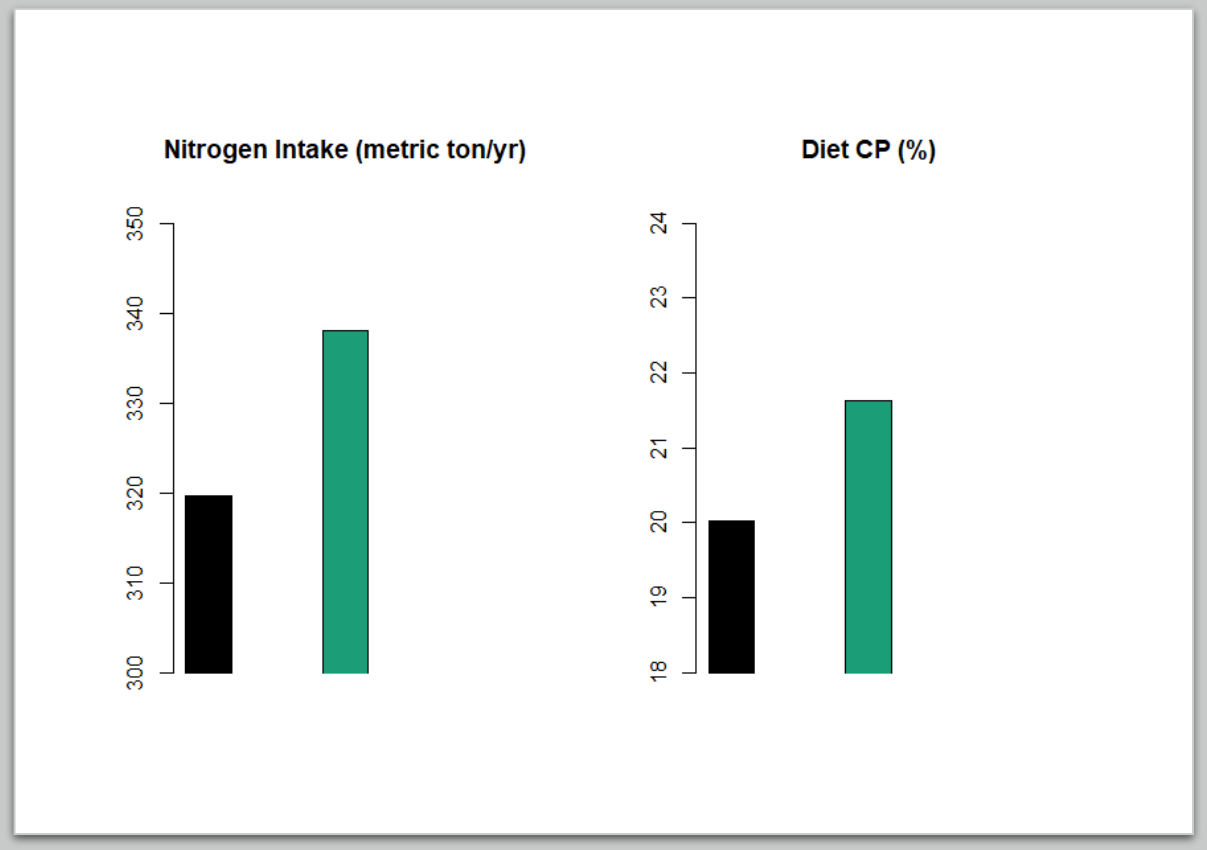


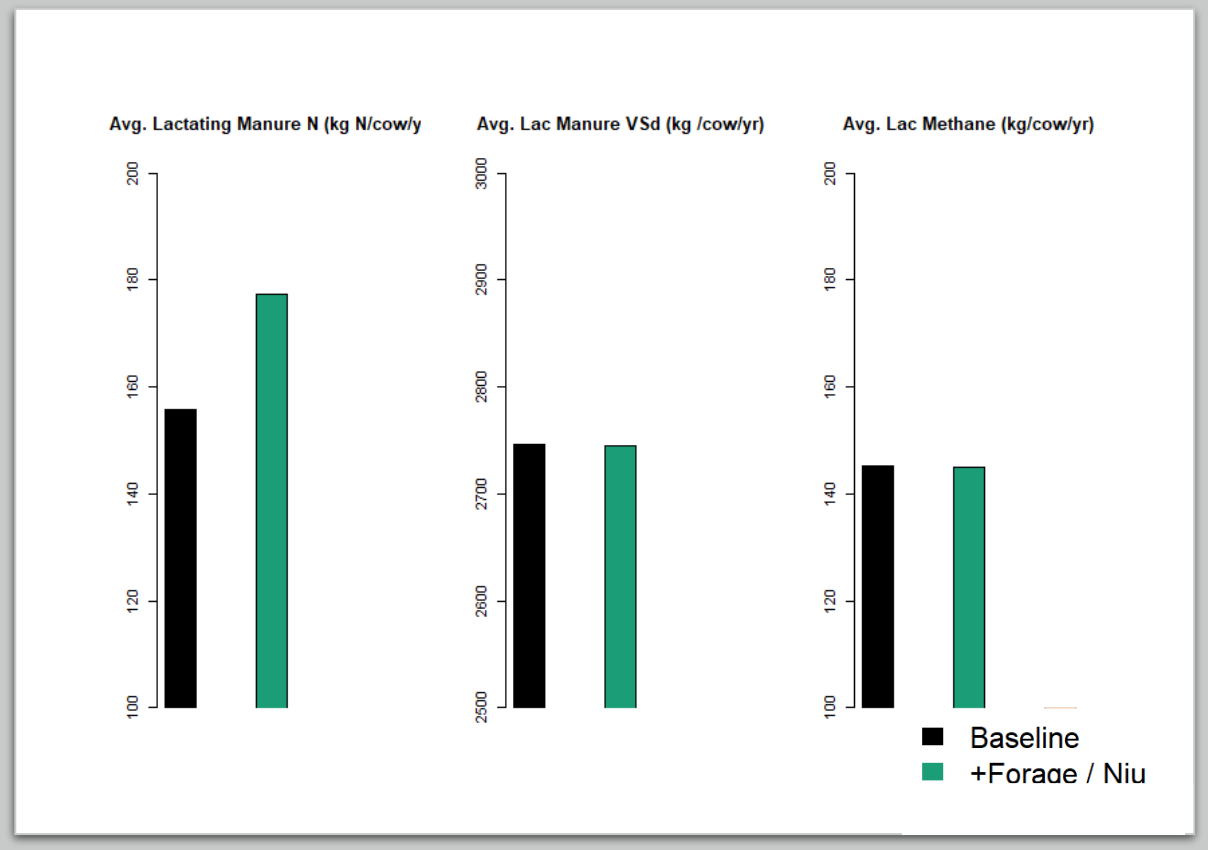
Feed Efficiency





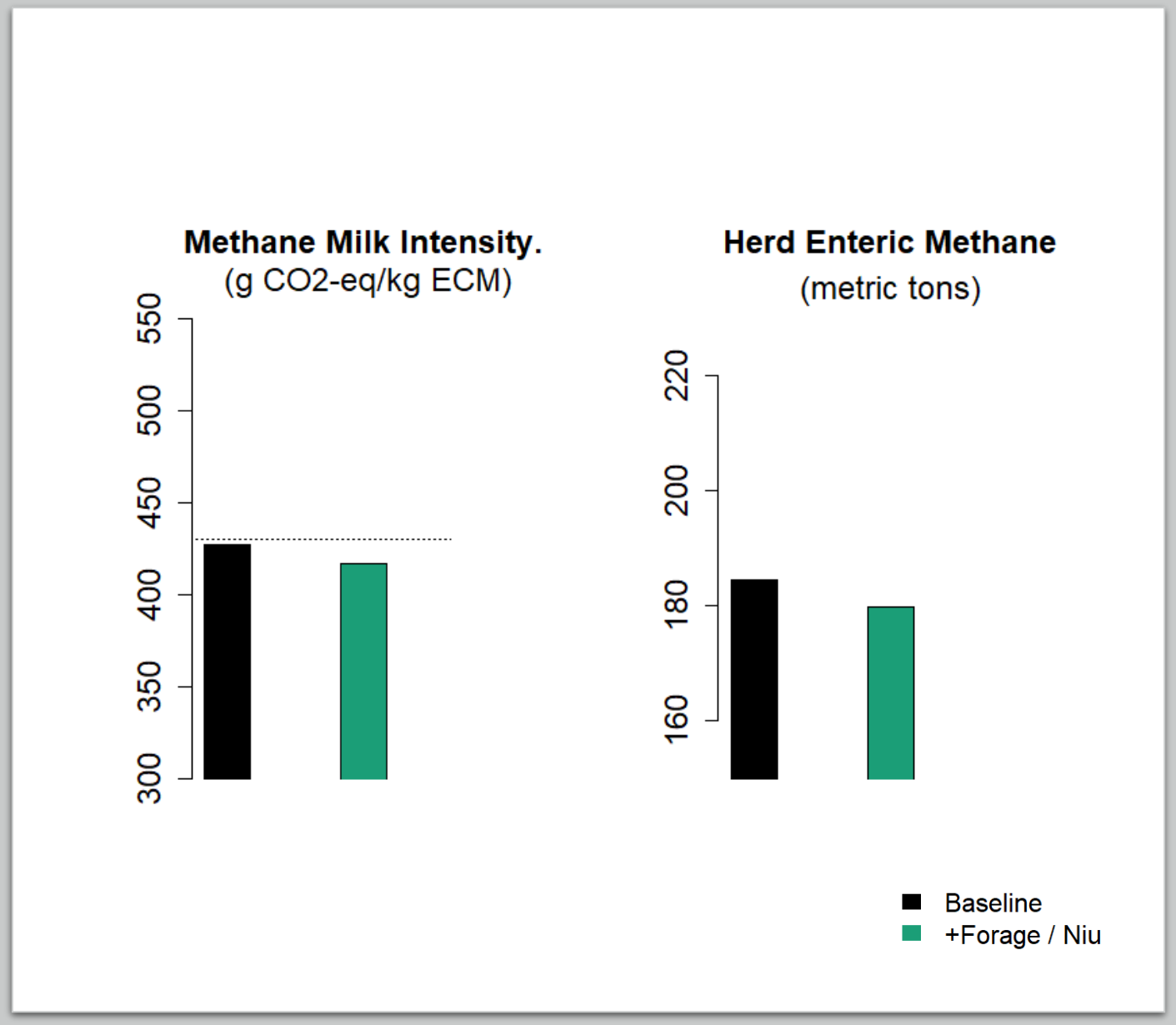
Intake and Excretion





Methane Intensity and Total Methane

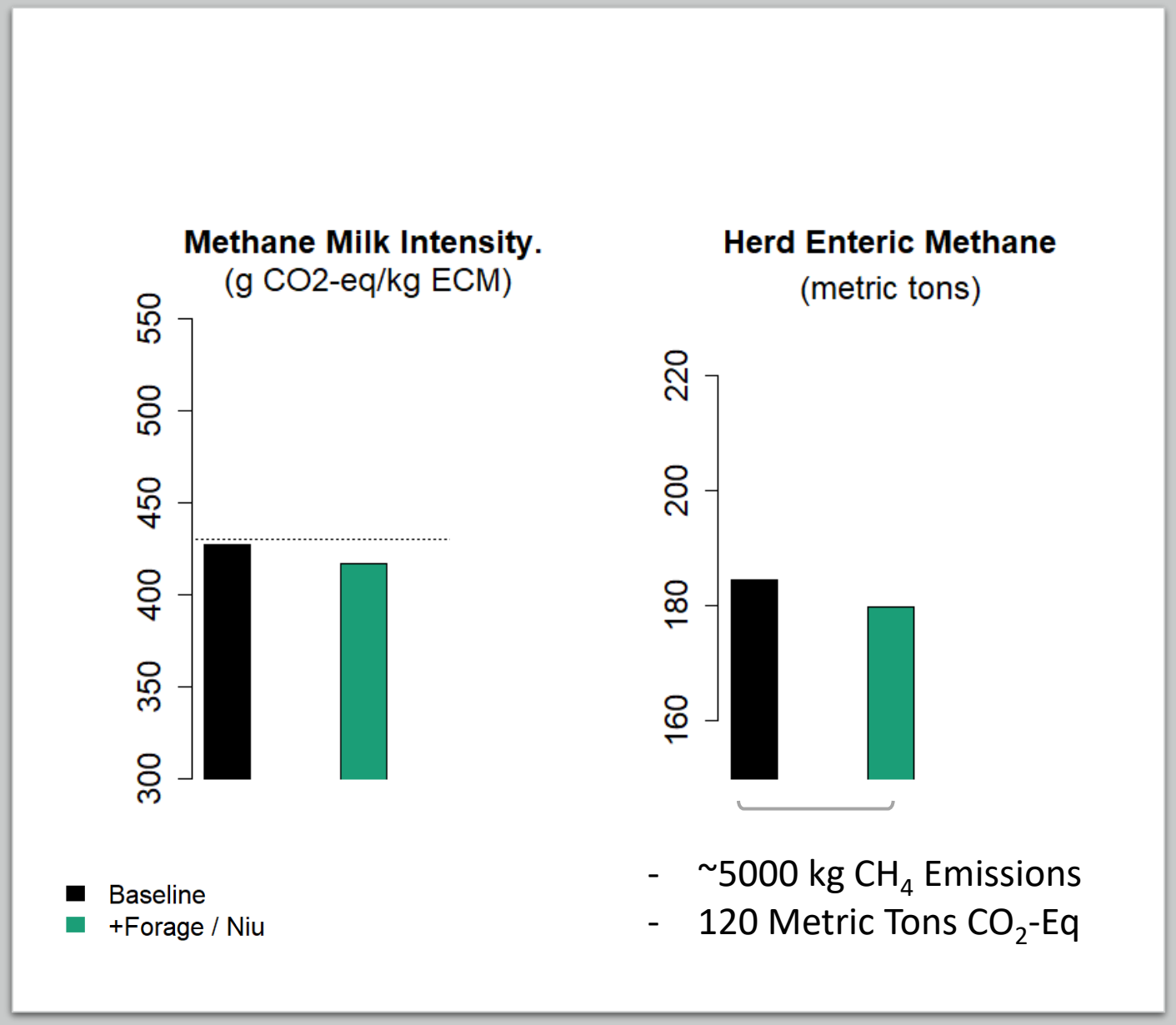
- Baseline scenario is close to US National average enteric methane intensity around 430 g CO_2-eq/kg ECM
- Improved forage quality reduces intensity and total emissions
- Essential to have enteric emissions equations that are sensitive to diet composition



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!



Methane Intensity and Total Methane

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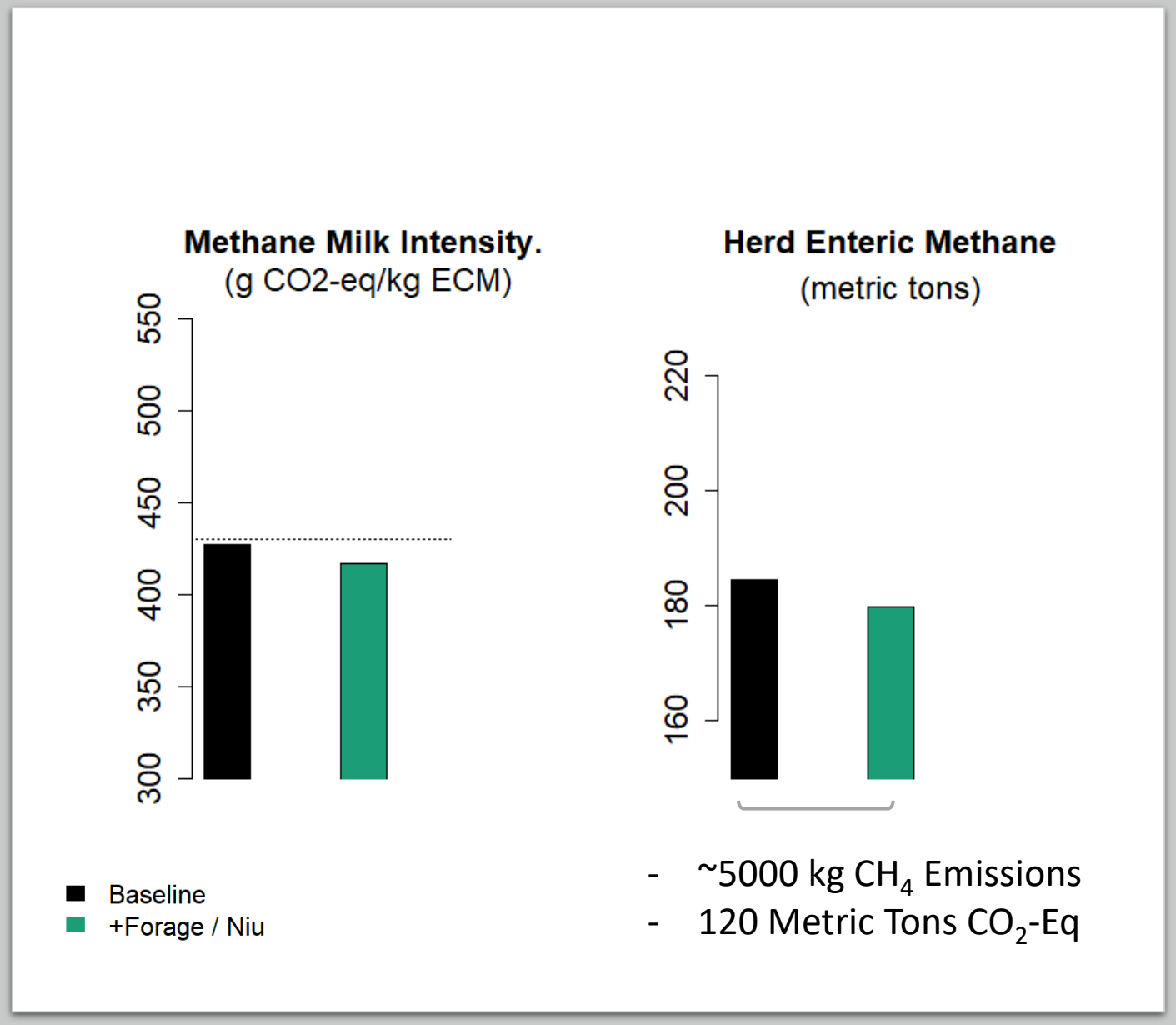
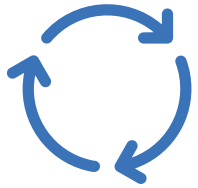
Or the amount of carbon sequestered by planting over **2,000** tree seedlings and growing them for 10 years!

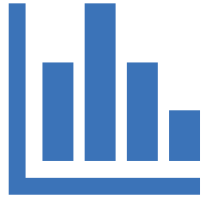


RuFaS, a process-based model, as new “engine” in Version 3 (2024)



Account for physical, chemical, and biologic cycles

Provide ability to extrapolate beyond known conditions (“what-if” scenario analysis)

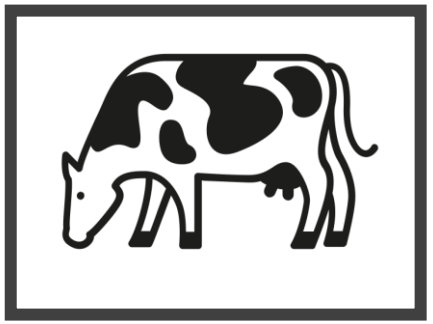


Generate environmental and economic analysis of multiple management scenarios

FARM ES, as it’s built today, cannot complete these more complicated calculations

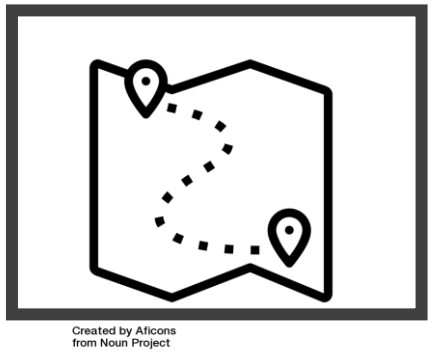
Slide courtesy of Kaitlyn Briggs (DMI) and Nicole Ayache, NMPF

Vision of Success



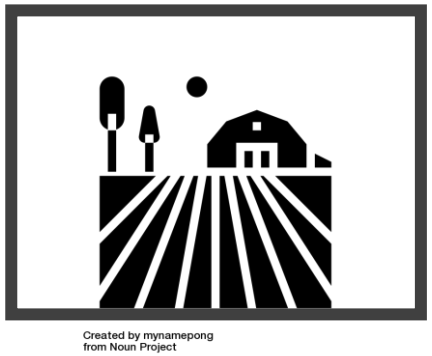
Footprinting

Calculate baseline estimates of current farm outputs and environmental outcomes



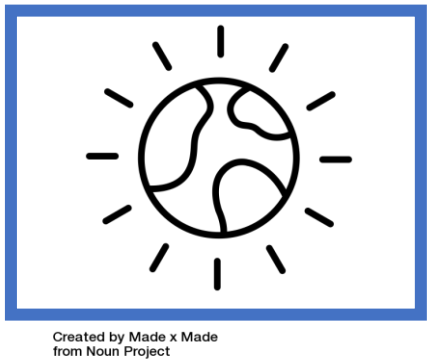
Planning

Identify management practices that will generate progress towards your sustainability goals



Implementation

Implement management plan, track progress, strive for continuous improvement



Impacts

Achieve industry-wide progress towards sustainable dairy production

NIFA AWARD # 2020-68014-31466

Thanks for listening!

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