Environmental Impact and Path Forward

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About Me

- Current: Assistant Professor of Sustainable Grazing, Kansas State University

Undergraduate: | Masters: | PhD: | PostDoc.

Overview

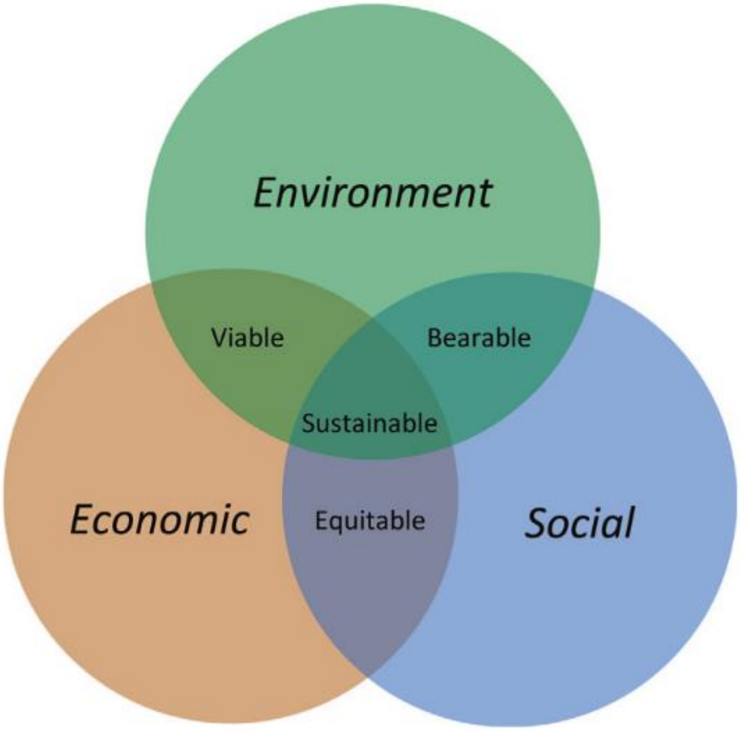
- Breakdown environmental impacts of agriculture, and specifically beef
- Identify key drivers
- Potential Solutions

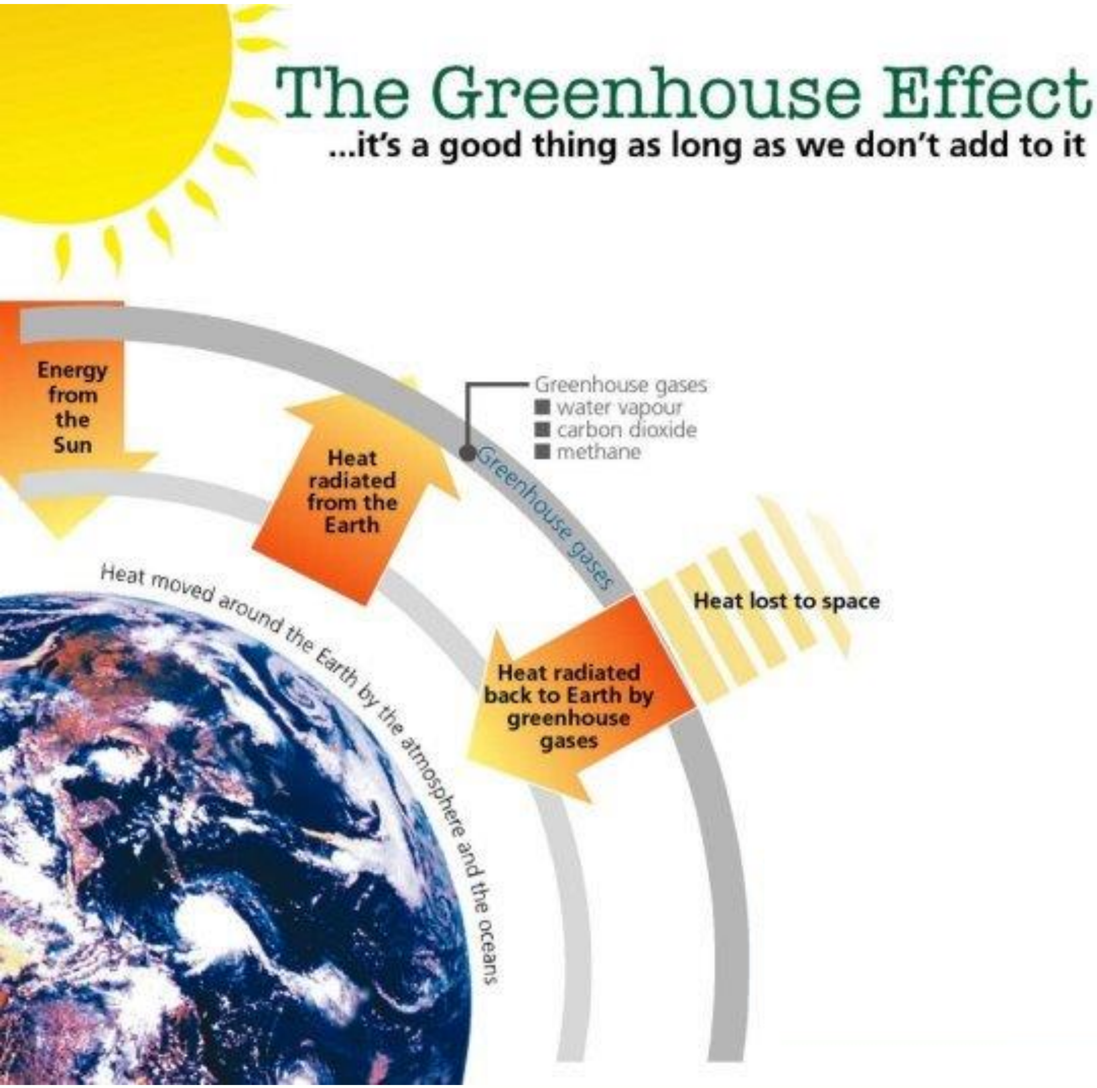
What is sustainability?

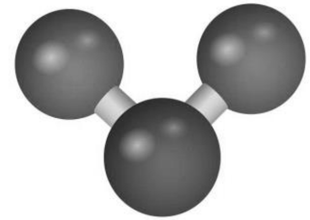
Sustainability is a wicked problem, one that has no solution but can only be managed (Rittel and Webber, 1973)

NRC (2010) identified four goals to define sustainable agriculture:

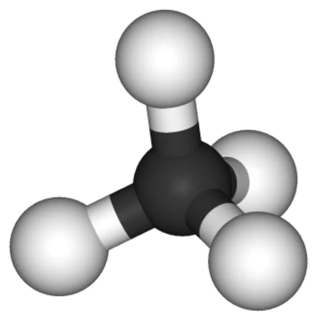
1. Satisfy human food, feed, and fiber needs, and contribute to biofuel needs
2. Enhance environmental quality and resource base
3. Sustain economic viability of agriculture
4. Enhance quality of life for farmers, farm workers, and society



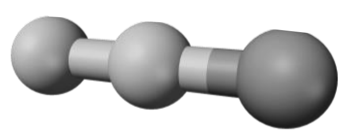




Carbon dioxide (CO_2)

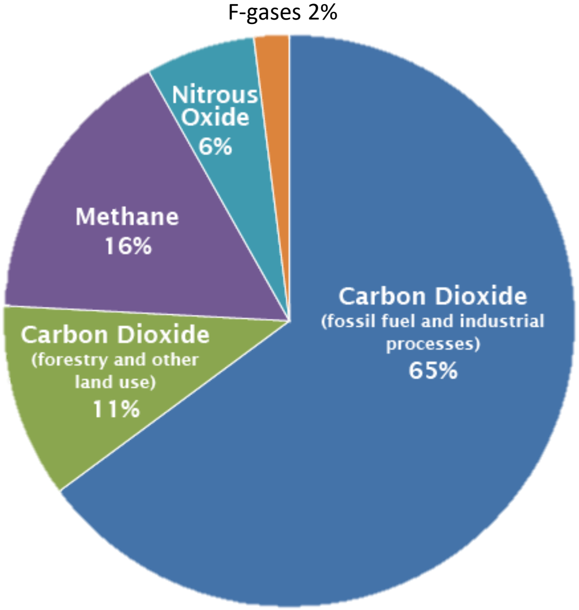


Methane (CH_4)

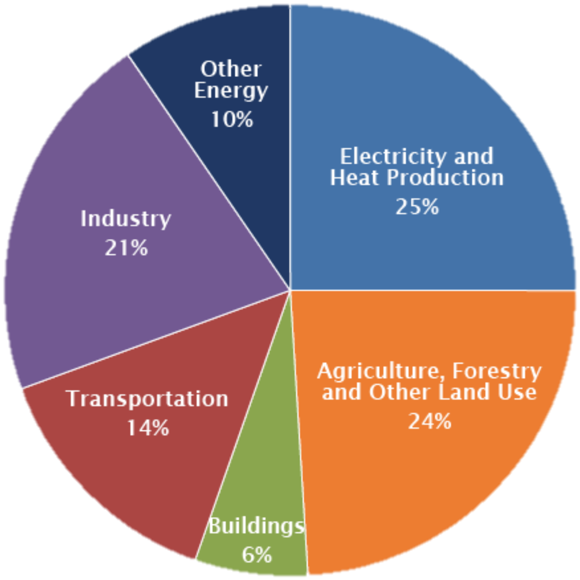


Nitrous Oxide (N_2O)

Global Greenhouse Gas Emissions by Gas

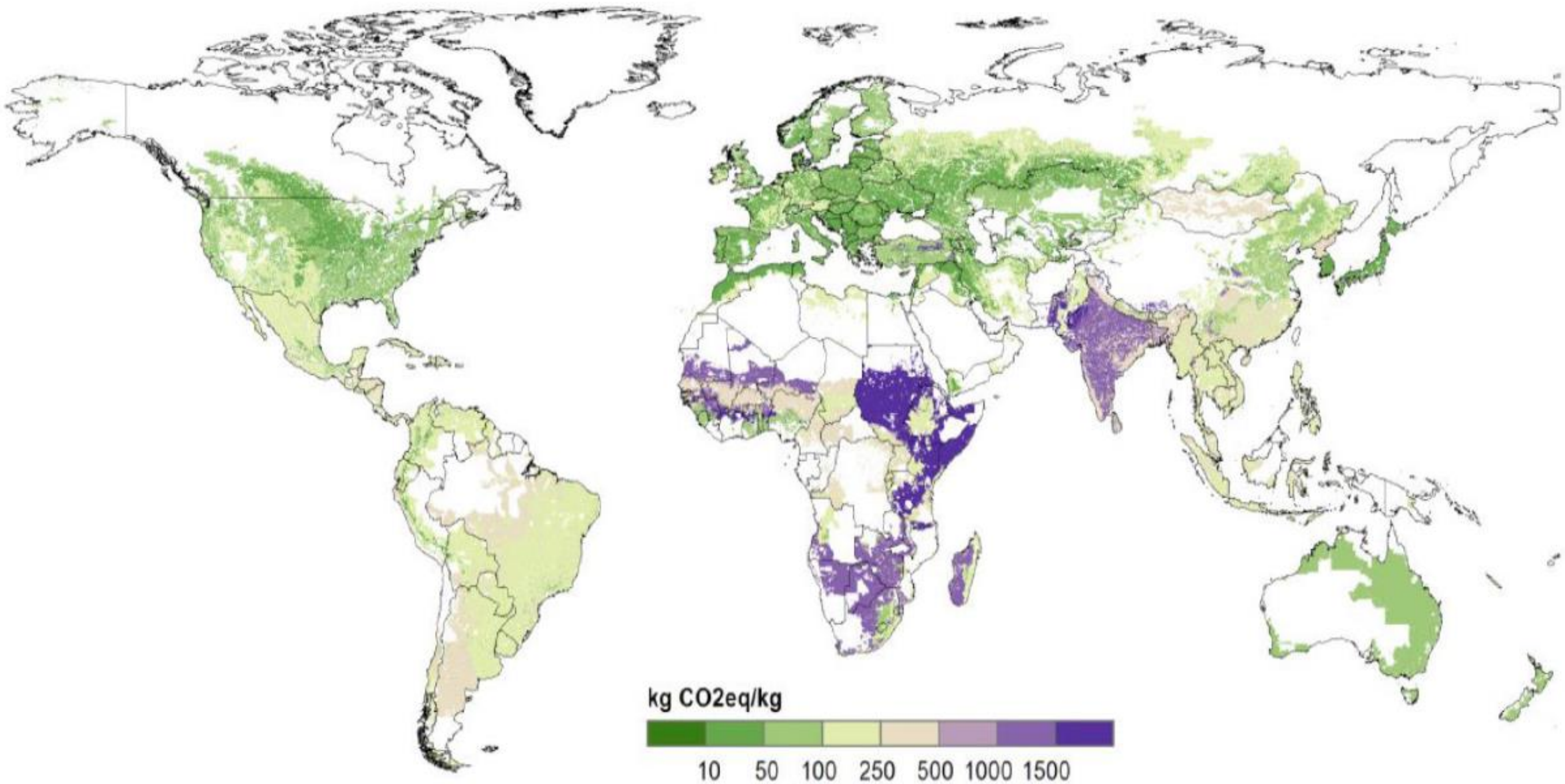


Global Greenhouse Gas Emissions by Economic Sector



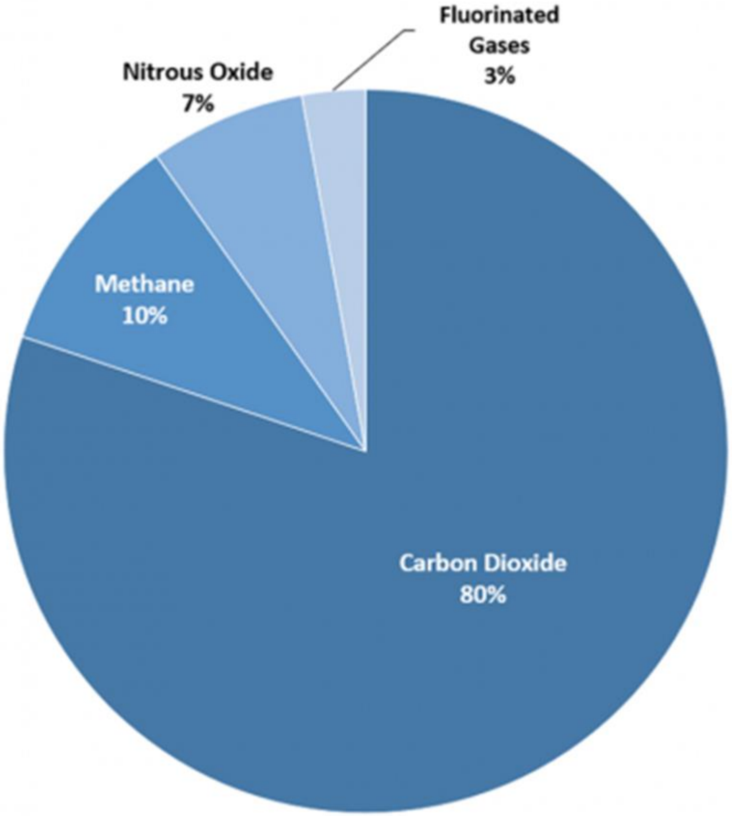
Source: IPCC (2014) based on global emissions from 2010. Details about the sources included in these estimates can be found in the *Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.

Global beef production footprints

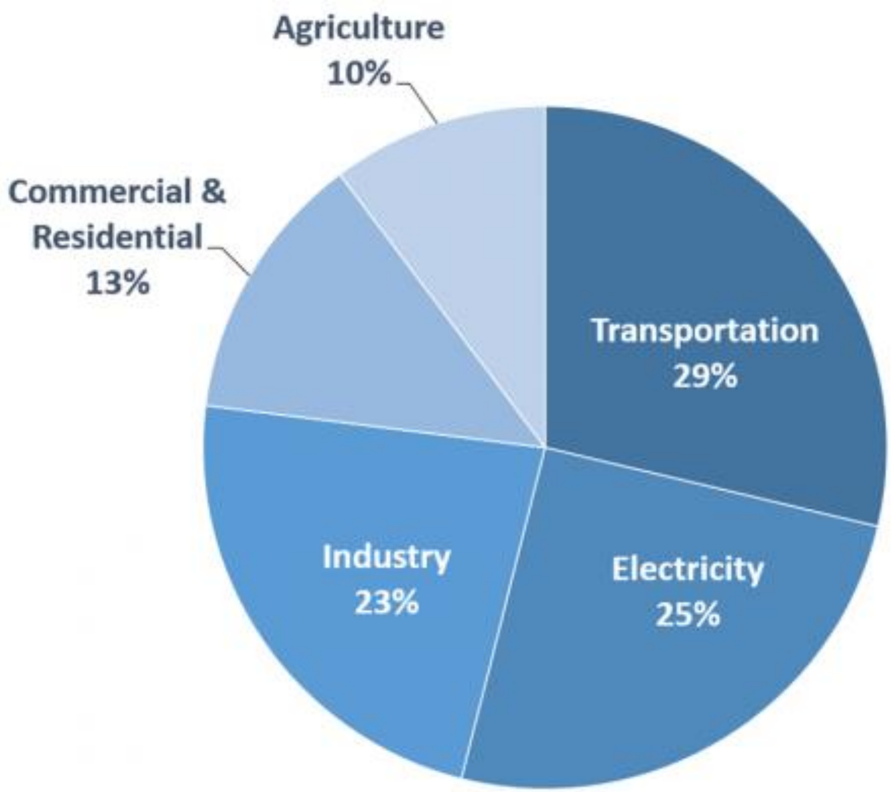


Source: UN FAO

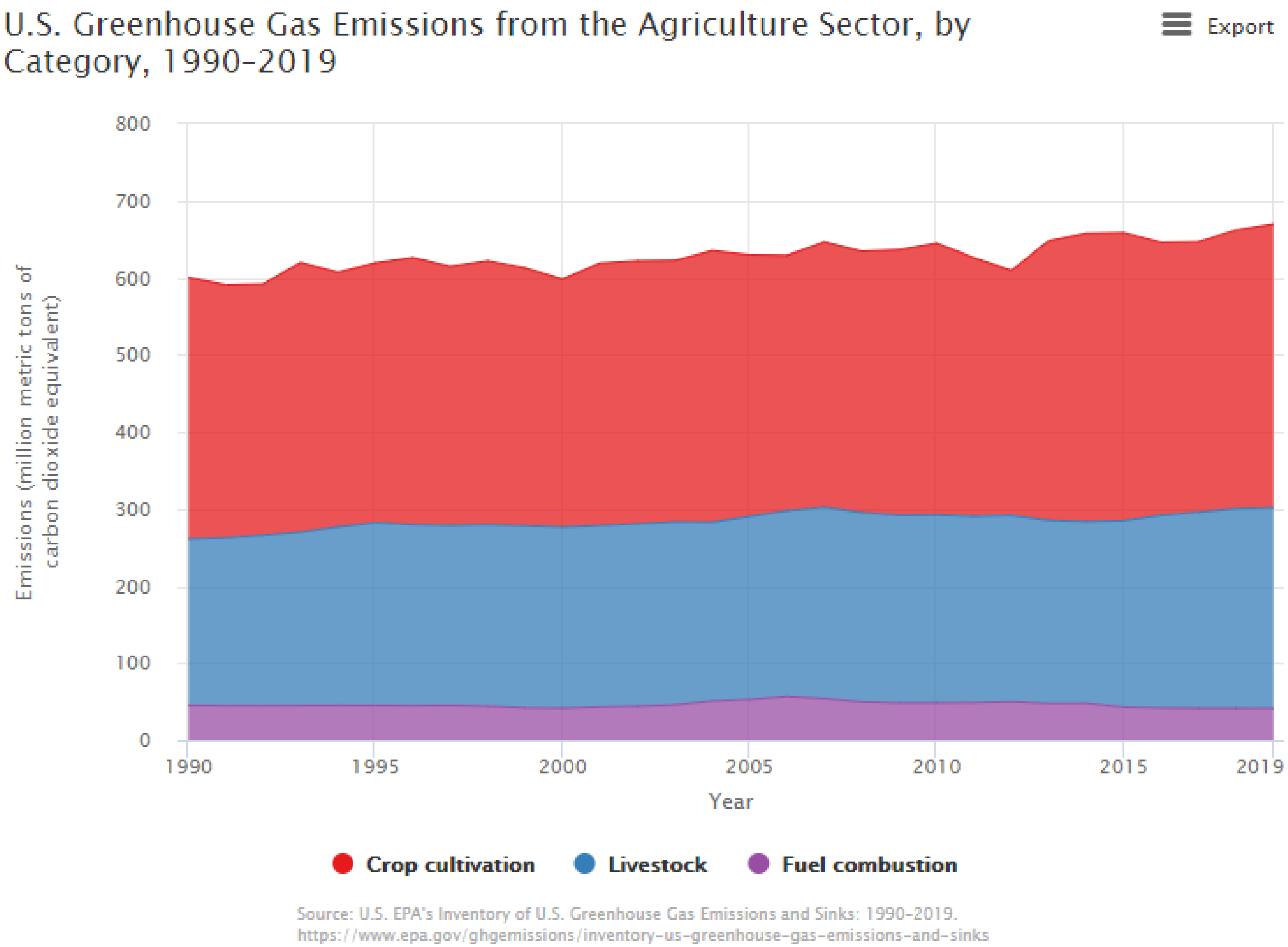
Overview of U.S. Greenhouse Gas Emissions in 2019



Sources of U.S. Greenhouse Gas Emissions in 2019



Source: US EPA (2021). Inventory of U.S. GHG emissions and sinks: 1990-2019



Percent change:

1990-2019

Crop cultivation:

▲ 8.4%

Livestock:

▲ 20.7%

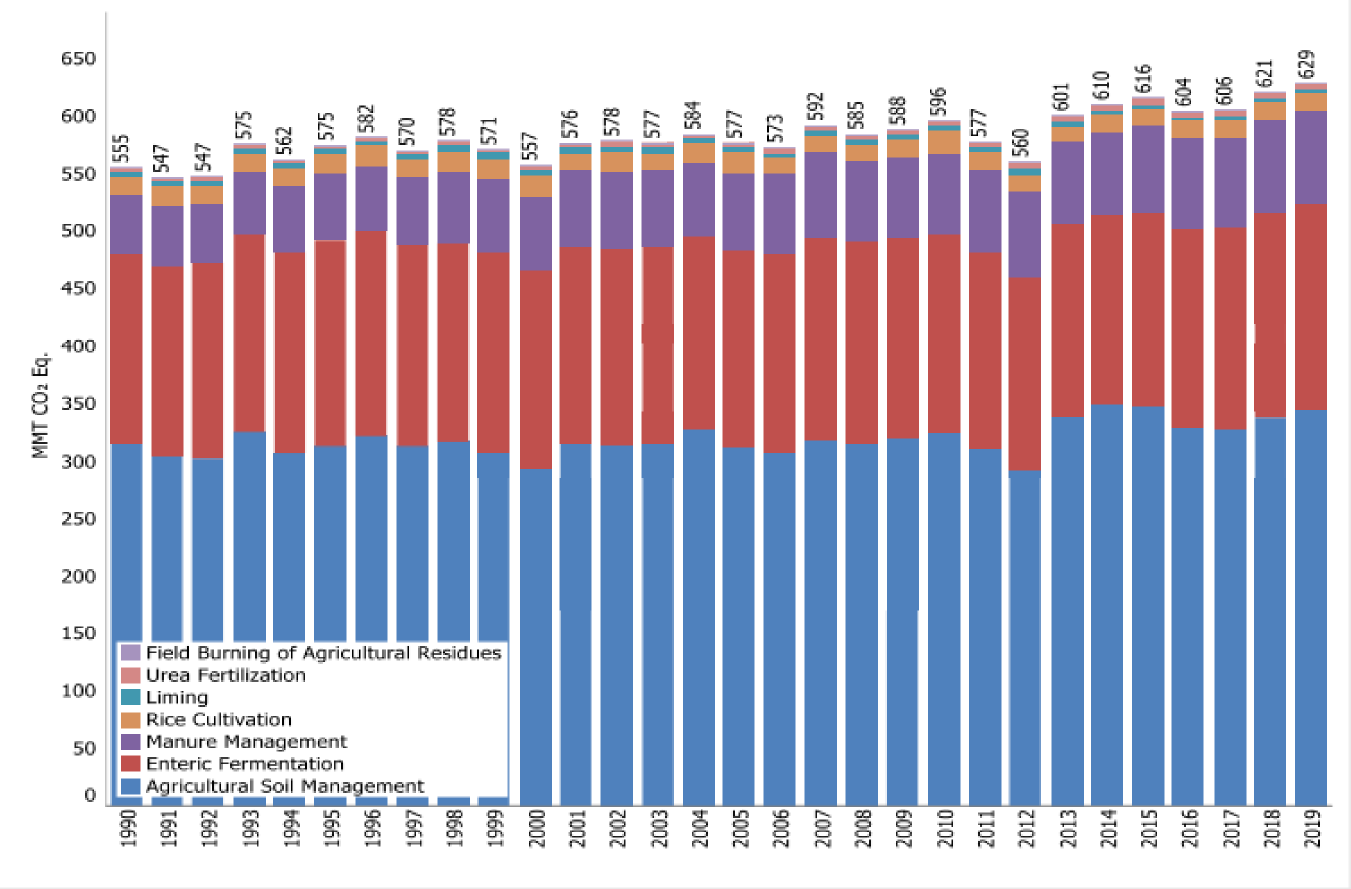
Fuel combustion:

▼ 8.9%

Total: ▲ 11.5%

Livestock is responsible for 3.8% of U.S. GHG emissions

Figure 5-2: Trends in Agriculture Chapter Greenhouse Gas Emission Sources



Between 1990 and 2019, CO_2 and CH_4 emissions from agricultural activities increased by 9.9 percent and 17.5 percent, respectively, while N_2O emissions from agricultural activities fluctuated from year to year, but increased by 10.4 percent overall.

Source: US EPA (2021). Inventory of U.S. GHG emissions and sinks: 1990-2019: Chapter 5 Agriculture

Environmental footprints of beef cattle production in the U.S.

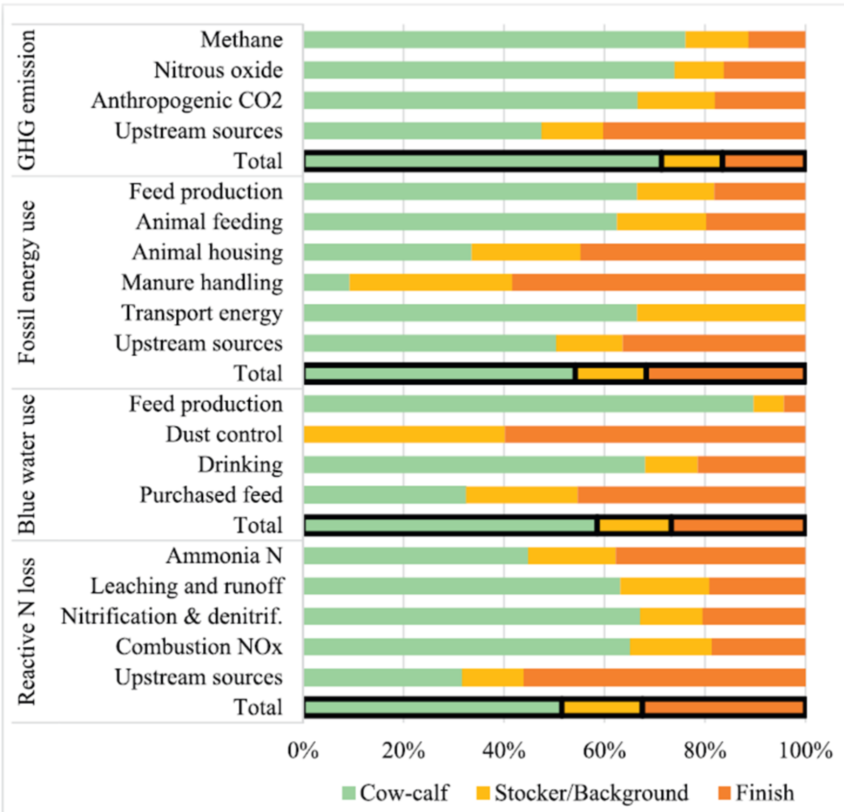


Fig. 2. Distribution of the sources of each environmental impact across the three major phases in the life cycle of beef cattle production.

Surveys and visits of farms, ranches and feedlots were conducted throughout ***seven regions*** *(Northeast, Southeast, Midwest, Northern Plains, Southern Plains, Northwest and Southwest) to determine common practices and characteristics of cattle production. These data along with other information sources were used to create about* ***150 representative production systems throughout the country****, which were simulated with the* ***Integrated Farm System Model using local soil and climate data.*** *The simulations* ***quantified the performance and environmental impacts of beef cattle*** *production systems for each region. A* ***farmgate life cycle assessment was used to quantify resource use and emissions for all production systems*** *including traditional beef breeds and cull animals from the dairy industry.*

Source: Rotz et.al, 2019. Agricultural Systems 1369:1-13.

Critical Points

- Accounting
  - Short-lived vs. Long-lived GHG's
- Enteric methane, primarily from cow-calf
- Feed production
  - Soil management
- Manure management
  - Nitrous oxide, Ammonia
- Maintaining rangeland

METHANE IN THE CARBON CYCLE

Carbon in cow

Enteric methane is a natural by-product of ruminal fermentation in reticulo-rumen and hindgut and is essential for normal rumen functioning. During the process of microbial fermentation, volatile fatty acids are produced and used to meet the metabolic needs of the animal. Carbon dioxide and H2 that are produced during this process are then converted into CH4 by rumen methanogens and eructated into the atmosphere.

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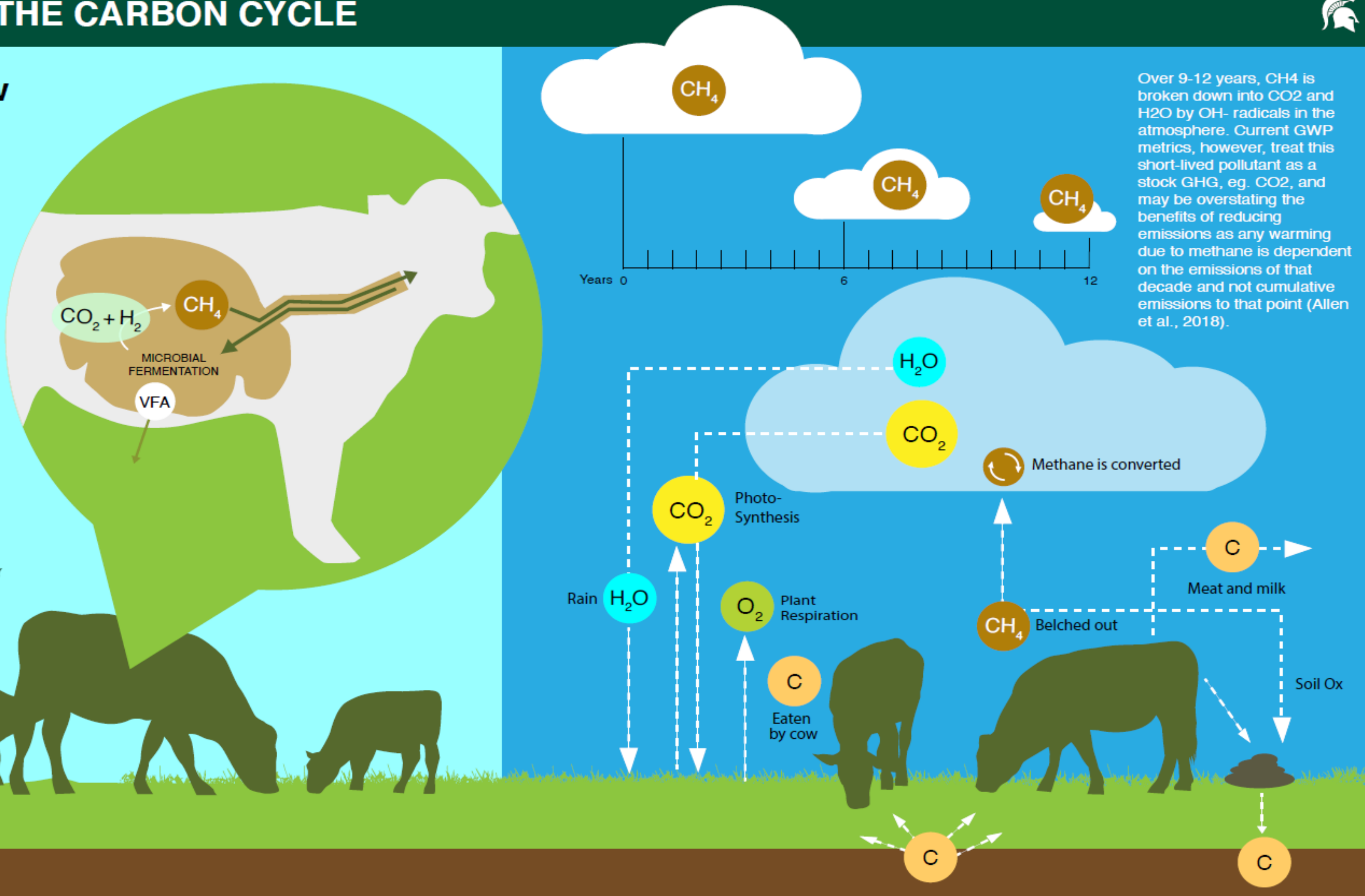
Over 9-12 years, CH4 is broken down into CO2 and H2O by OH- radicals in the atmosphere. Current GWP metrics, however, treat this short-lived pollutant as a stock GHG, eg. CO2, and may be overstating the benefits of reducing emissions as any warming due to methane is dependent on the emissions of that decade and not cumulative emissions to that point (Allen et al., 2018).



IPCC, 2021: Global Warming Potentials

Species	Lifetime (Years)	Radiative Efficiency (W m^{-2} ppb^{-1})	GWP-20	GWP-100	GWP-500	GTP-50	GTP-100	CGTP-50 (years)	CGTP (yea
CO_2	Multiple	$1.33 \pm 0.16 \times 10^{-5}$	1.	1.000	1.000	1.000	1.000		
CH_4-fossil	11.8 ± 1.8	$5.7 \pm 1.4 \times 10^{-4}$	82.5 ± 25.8	29.8 ± 11	10.0 ± 3.8	13.2 ± 6.1	7.5 ± 2.9	2823 ± 1060	3531 ±
CH_4-non fossil	11.8 ± 1.8	$5.7 \pm 1.4 \times 10^{-4}$	79.7 ± 25.8	27.0 ± 11	7.2 ± 3.8	10.4 ± 6.1	4.7 ± 2.9	2675 ± 1057	3228 ±
N_2O	109 ± 10	$2.8 \pm 1.1 \times 10^{-3}$	273 ± 118	273 ± 130	130 ± 64	290 ± 140	233 ± 110		
HFC-32	5.4 ± 1.1	$1.1 \pm 0.2 \times 10^{-1}$	2693 ± 842	771 ± 292	220 ± 87	181 ± 83	142 ± 51	78,175 ± 29,402	92,888 ±
HFC-134a	14.0 ± 2.8	$1.67 \pm 0.32 \times 10^{-1}$	4144 ± 1160	1526 ± 577	436 ± 173	733 ± 410	306 ± 119	146,670 ± 53,318	181,408 ±
CFC-11	52.0 ± 10.4	$2.91 \pm 0.65 \times 10^{-1}$	8321 ± 2419	6226 ± 2297	2093 ± 865	6351 ± 2342	3536 ± 1511		
PFC-14	50,000	$9.89 \pm 0.19 \times 10^{-2}$	5301 ± 1395	7380 ± 2430	10,587 ± 3692	7660 ± 2464	9055 ± 3128		

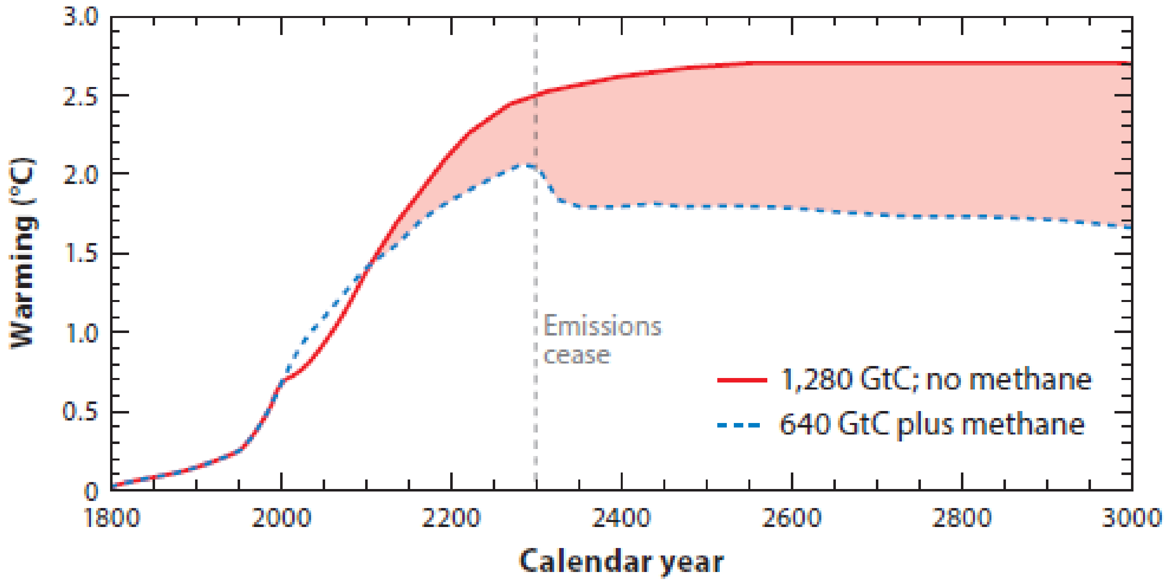


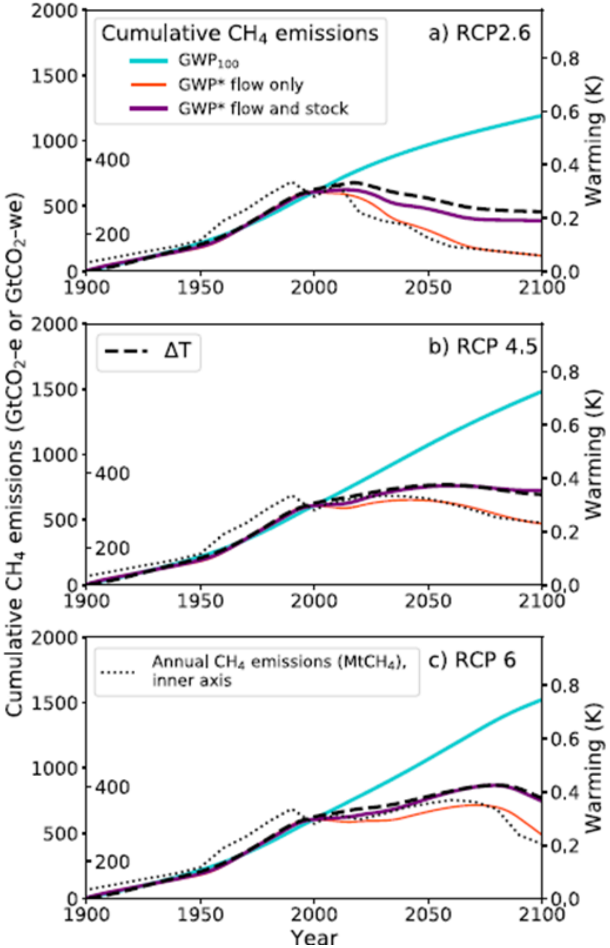
Figure 9

Warming resulting from the 1,280-GtC extended A2 CO_2 emission scenario of Eby et al. (2009), and from the 640-GtC extended A2 scenario augmented by methane emissions at a constant rate between the years 2000 and 2300 followed by zero methane emissions. The methane emission rate is chosen such that the GWP_{100}-weighted emissions in the two cases are identical.

Pierrehumbert, 2014

Treating methane as a short-lived gas species

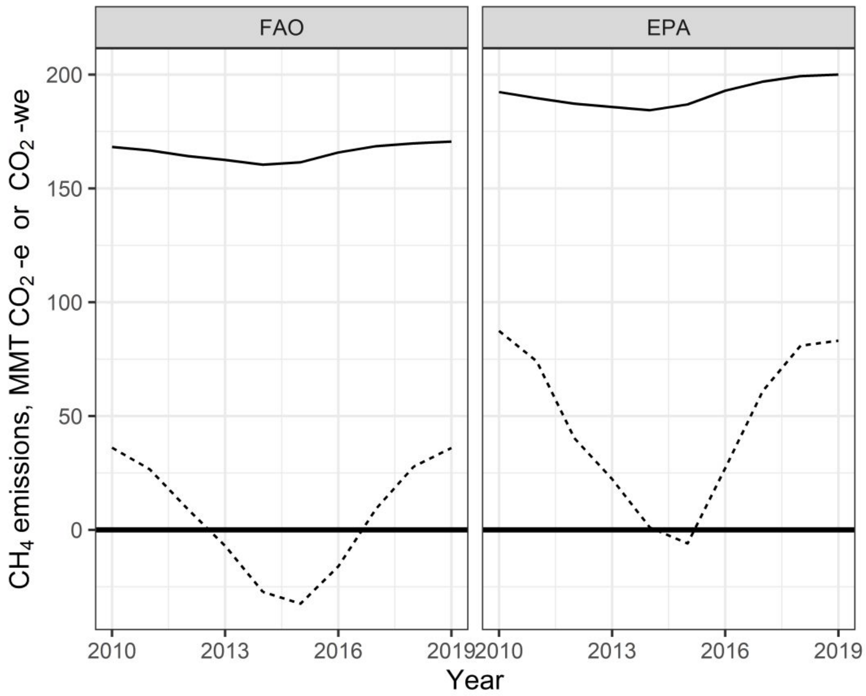
- New metric, GWP*, has been proposed for use in calculating GWP-warming equivalents for short-lived gas species
- A “fit-for-purpose” equation that has caused considerable debate in the climate community



Cain et al., 2019

How we account matters!

- We compare FAO (Tier 1) accounting method vs. EPA (Tier 2) accounting method for methane production from beef and dairy in the U.S.
  - Tier 1 = Default emission factor x number of animals
  - Tier 2 = Emission factor based on diet



Beck et al., in press

Enteric Solutions

	Seaweed	3-NOP	Nitrate	Essential Oils	Lipids	Genetic Selection	Vaccine	Management Strategies
Animal production	↓	Little change	Little change	↓	Little change	??	??	↑
Methane, g/day	↓	↓	↓	↓	↓	Unlikely, not directly	Unknown	↓
Methane, g/kg HCW	↓	↓	↓	↓	↓	??	??	↓
Long term monitoring	147 days	115 days	90 days	70 days	250 days	Early stages	??	Life cycle analyses ongoing
Status	Lack of largescale cultivation of seaweed	Not FDA approved in U.S.	Experimental, acclimation is critical	Lack of largescale cultivation	DMI declines at high levels	Research ongoing	Research ongoing	Research ongoing
Scalability	Unlikely to be successful, decreases in HCW (20 lb)	Unknown	Unlikely to be successful, may increase N_2O	Unlikely to be successful due to palatability and cost	Unlikely to be successful due to cost and intake	Unknown	Unknown	Ongoing for 30+ years

Source: Dr. Hales and Dr. Stackhouse-Lawson

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Feed Production

- Total feed consumed to produce 1 kg CW of beef is 22 kg DM, 74% consumed in the cow-calf phase (Rotz et al., 2019)
- Total consumption consists of 82% forage, 11% grain and 7% byproduct and waste product feeds
  - *This indicates that 10–15% of the feed consumed in beef production comes from sources that might be available for human consumption.*

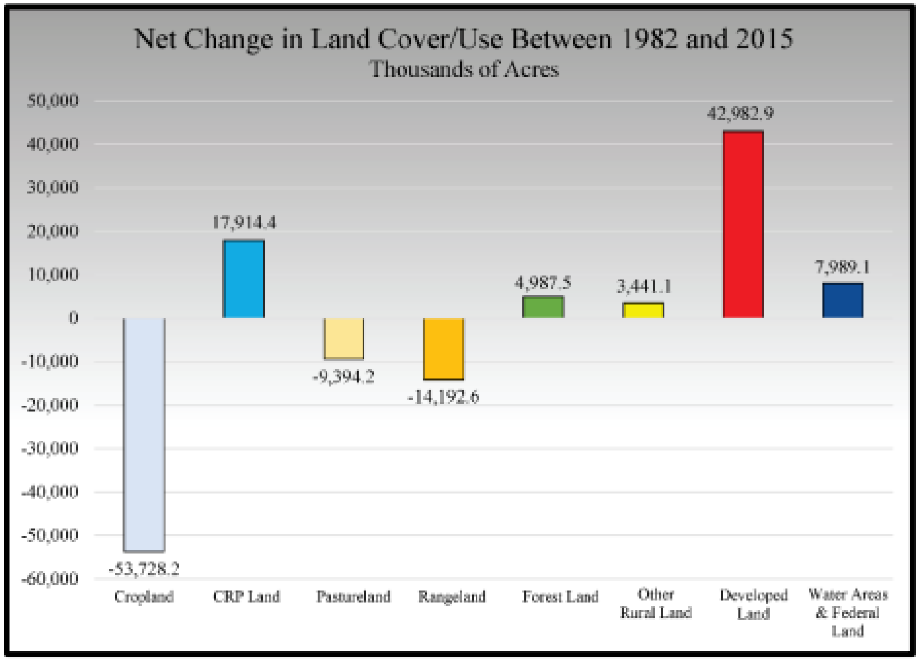
- Sources:
  - Nitrous oxide
    - Produced primarily during fert. Application
  - Anthropogenic CO2
    - Electricity and Fossil fuels
  - Upstream
    - Fertilizer, electricity generation
  - Soil C gain/loss

Manure Management

- Varies greatly based on how it is handled (Waldrip et al., 201)
  - The magnitude of N_2O fluxes from open-lot cattle systems is highly variable
  - Methods to mitigate feedyard N_2O emissions are available but have yet to be thoroughly evaluated
  - N_2O fluxes vary with measurement methods, management, and environmental conditions
  - Mitigation strategies:
    - Improved animal performance and reducing N intake are best options to reduce feedyard N_2O losses
    - Reducing manure retention time
    - Proper timing of application is key
    - No direct inhibitors are close to market ready

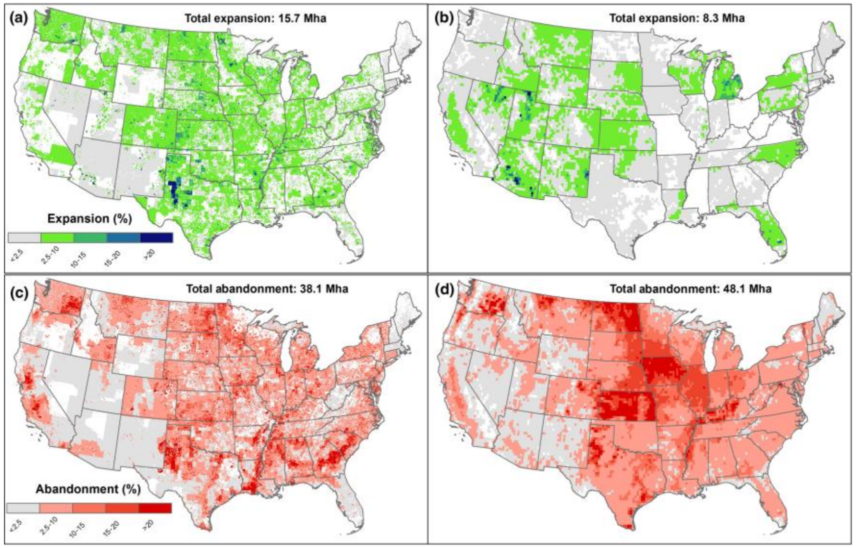
Land use changes

- Loss of land is a key concern for ruminant production
  - Shifting crop production
  - Drought
  - Urban expansion

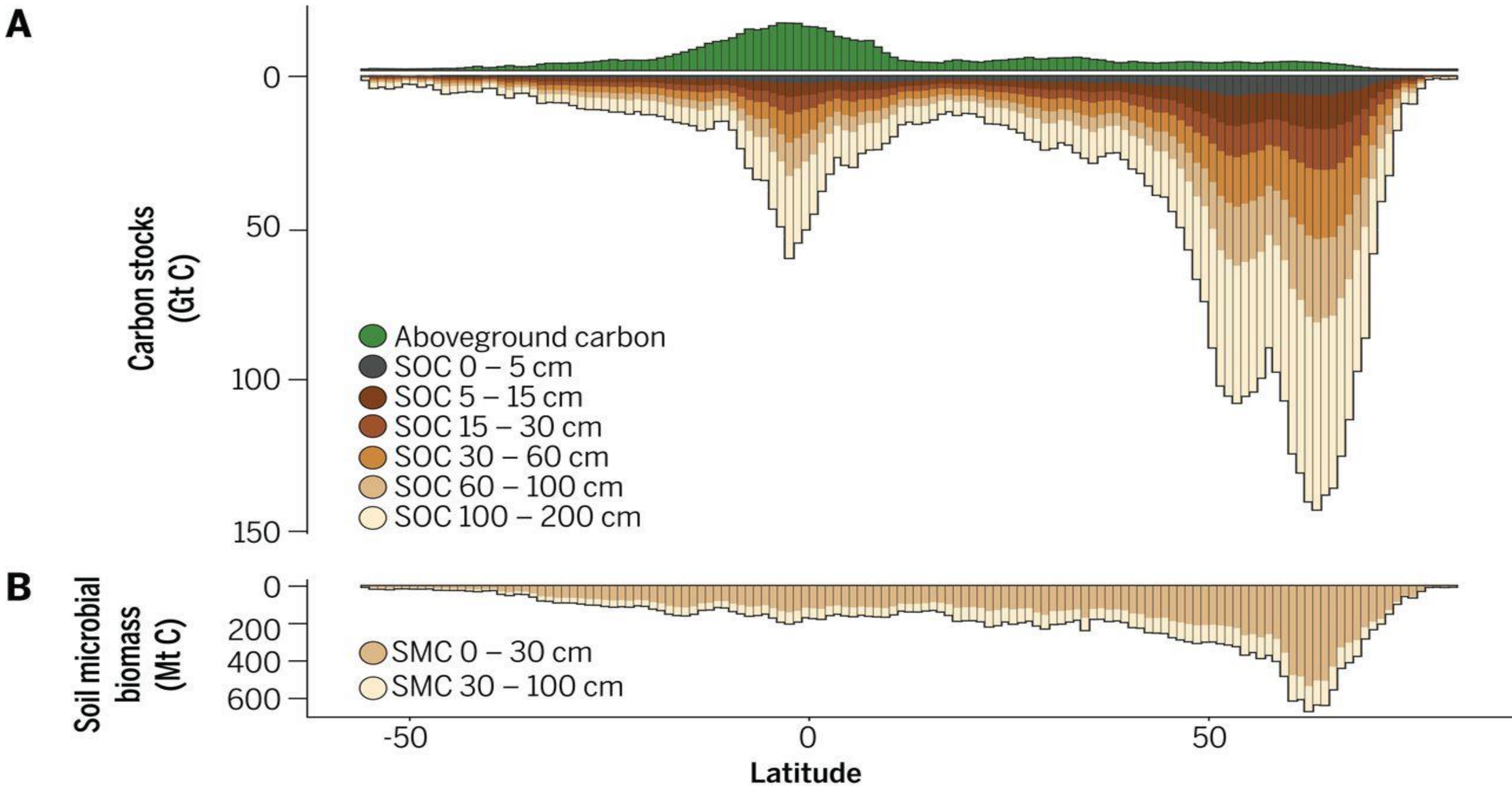


Land use changes

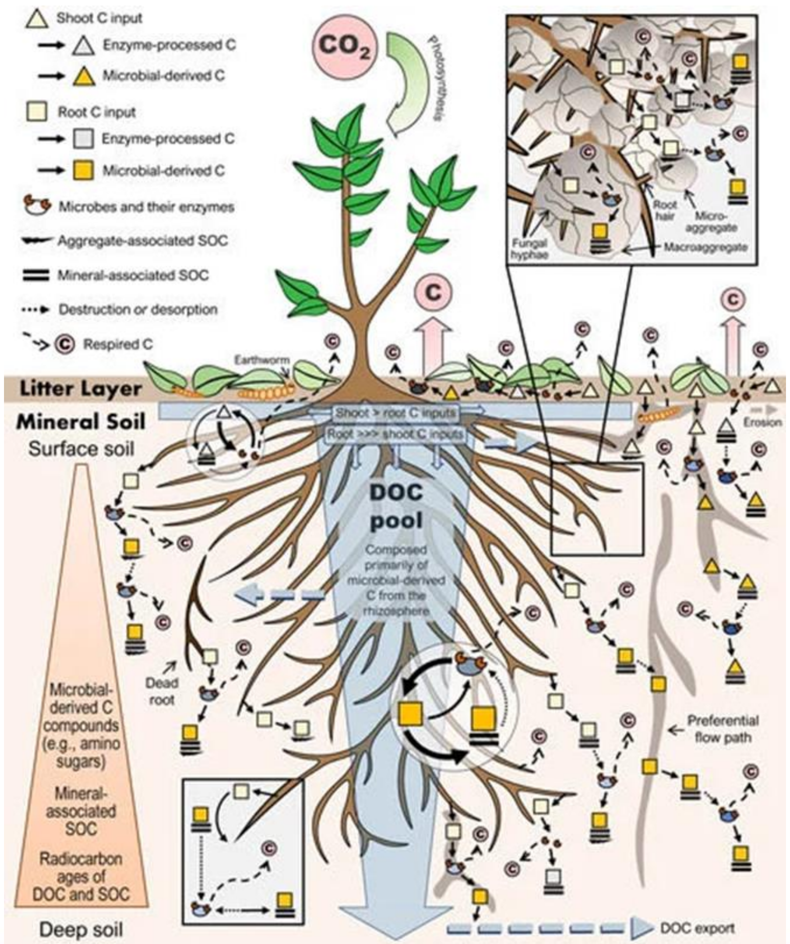
- Yu et al. 2019, examined land use and land use changes 1980-2016
  - Crop land expanding into new regions (Generally less productive ground)
  - Increase in abandoned crop land



Global Soil C



Carbon Sequestration



- Carbon Sequestration
  - Gross and Harrison, 2019

Carbon sequestration in grazing systems

- Cycles nutrients back to the soil
- Proper grazing management can protect and restore C on degraded land
- Inclusion on highly productive forages (legumes often included) may help improve soil C
- Inclusion of deep-rooted plants within forage mixtures may help store C deeper into the soil profile

Livestock allow us to produce food on land unsuitable for cultivation, while enhancing ecosystems

Rangeland's store 20% of the globes soil organic carbon

The most important thing we can do for soil organic C in rangelands is to:

1. Preserve rangelands (avoid conversion)
2. Restore cultivated and degraded lands
3. Practice adaptive livestock management

Source: Sanderson et. al, 2020. Cattle, conservation and carbon in the western Great Plains. Journal of Soil and Water Conservation

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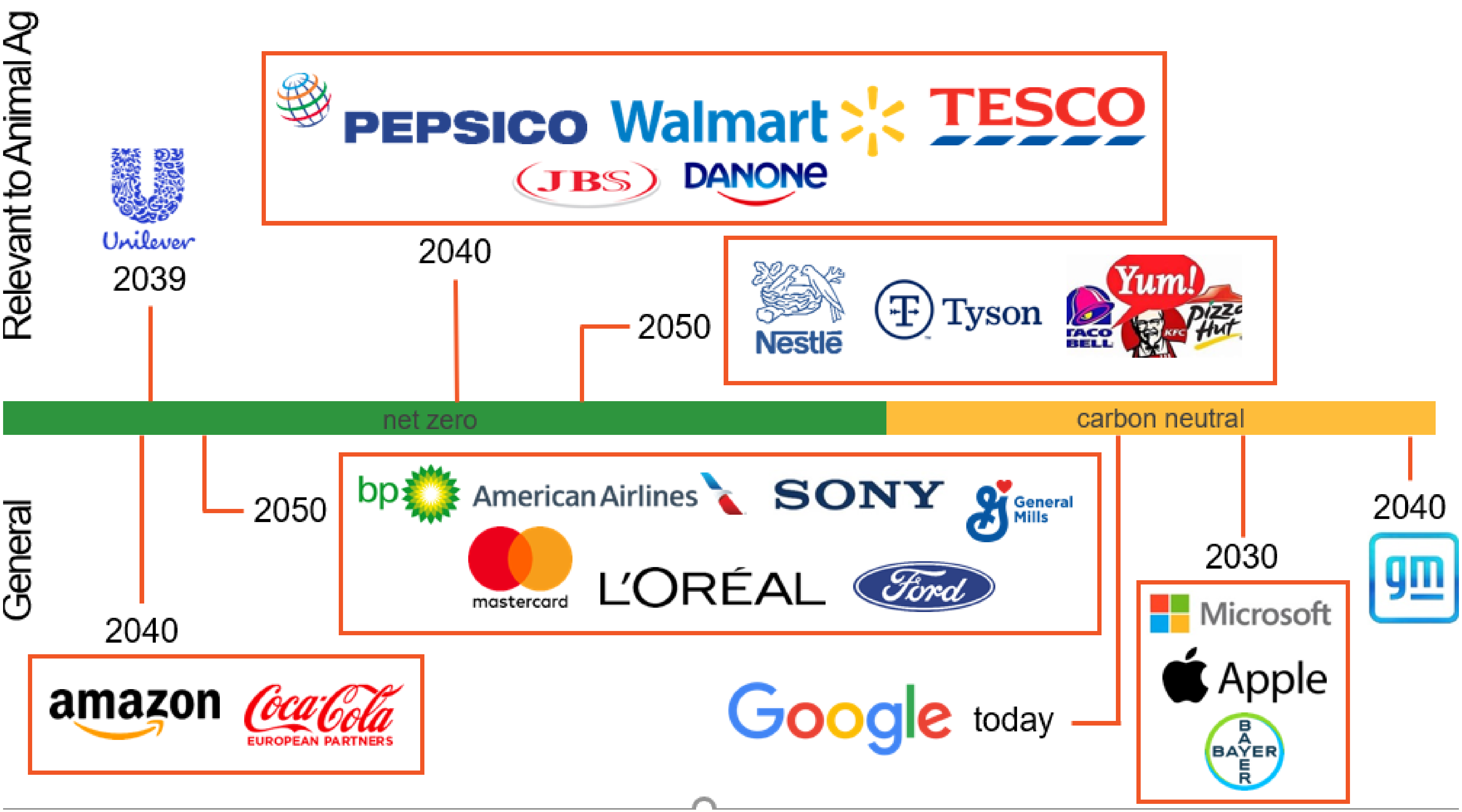
Where are we headed?

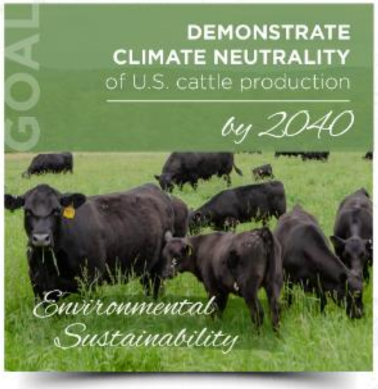

Relevant to Animal Ag
Unilever
2039
PEPSICO
Walmart
TESCO
JBS
DANONE
2040
2050
Nestlé
Tyson
Yum!
TACO BELL
KFC
Pizza Hut
net zero
carbon neutral
General
2050
bp
American Airlines
SONY
General Mills
mastercard
L'ORÉAL
Ford
2040
amazon
Coca-Cola EUROPEAN PARTNERS
Google
today
2030
Microsoft
Apple
BAYER
2040
gm

Environmental Sustainability

Goal: Demonstrate the climate neutrality of U.S. cattle production by 2040.

According to the United Nation's Food and Agriculture Organization, the U.S. beef supply chain has the lowest greenhouse gas emissions footprint of all beef-producing countries in the world and has been the global leader since 1996. This is not the product of resting on our laurels. Beef production in the United States is a shining example of how ingenuity, creativity, and thinking outside the box can facilitate global progress.

U.S. cattle producers have a personal stake in protecting our environment. For generations, ranchers have raised cattle on native grasslands, steep mountainsides, and coastal plains, working in harmony with nature to produce one of the most nutrient-dense food products on our grocery store shelves.



Specifically, the goals are:

- Achieve GHG neutrality
- Optimize water use while maximizing recycling
- Improve water quality by optimizing utilization of manure and nutrients.

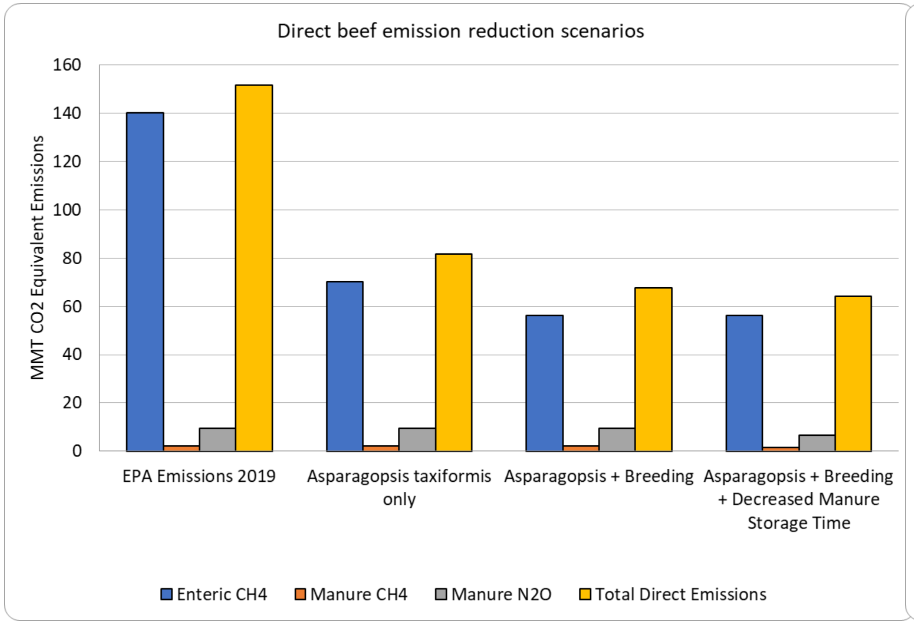
U.S. dairy is working collectively to balance GHG emissions with reductions and removals to reach net zero, as guided by the work of the Intergovernmental Panel on Climate Change.

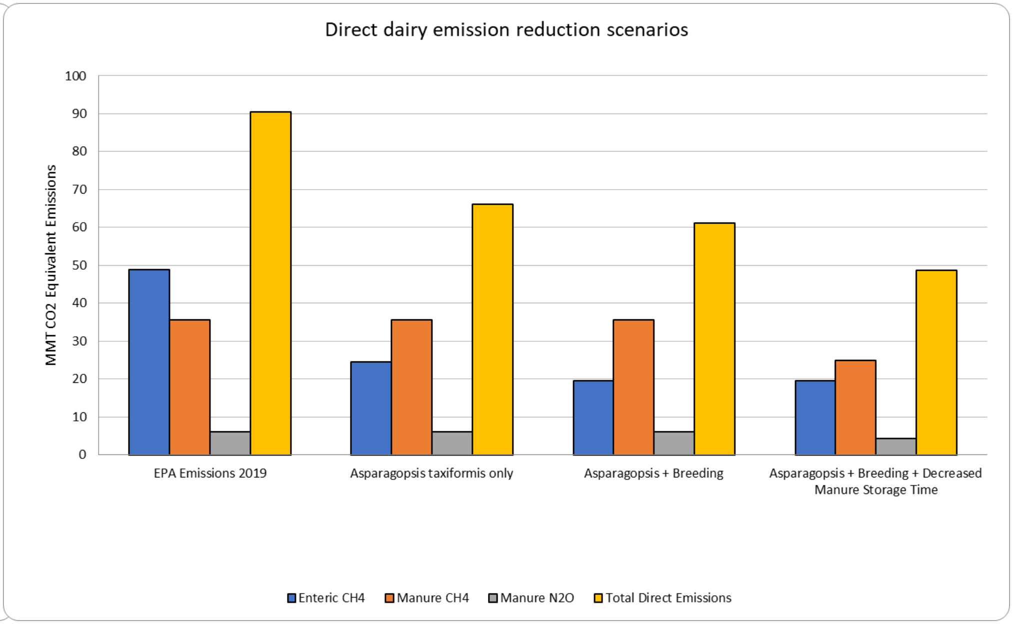
The U.S. Dairy Net Zero Initiative (NZI) is an industry-wide, on-farm effort that will play a key role in helping U.S. dairy continue to make progress toward these goals. Through foundational research, on-farm pilots and development of new product markets, NZI is breaking down barriers to make technology and best practices more accessible and affordable to farms of all sizes and geographies – recognizing there is no one-size-fits-all solution. NZI has four key areas of focus, including feed production, manure handling and nutrient management, enteric emission reduction and efficiency, and on-farm energy efficiency and renewable energy use.

Can we achieve this?

- Thompson et al. (in prep.) examined pathways using standard accounting
  - 50% reduction in enteric CH4 (*Asparagopsis taxiformis*)
  - Above + 10% reduction in enteric CH4 (breeding)
  - Above + 30% reduction in manure CH4 and N2O (decreased manure retention time)

Results for beef and dairy

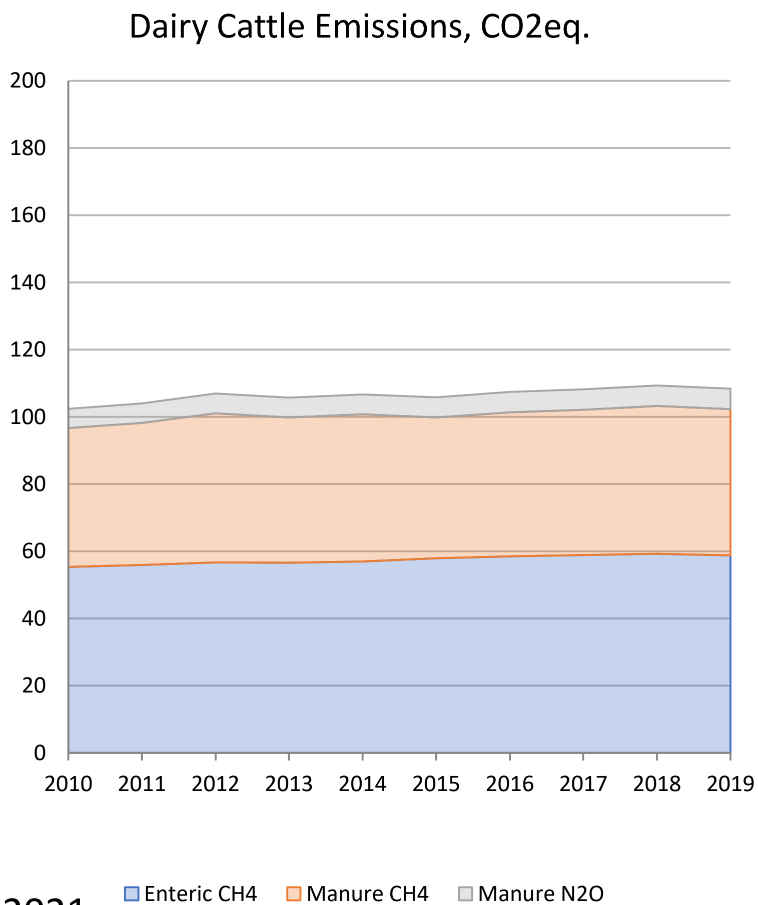




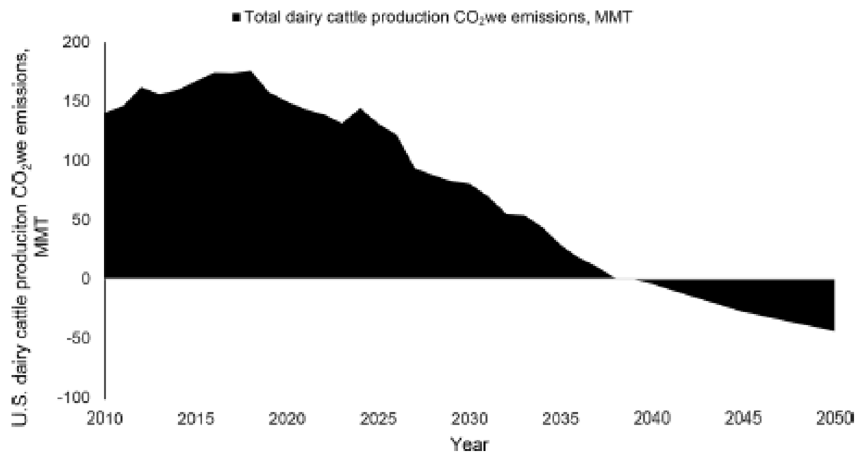
Can we achieve this?

- Place et al., 2022 examined the U.S. dairy industry as a case study with GWP*
  - Examined scenario:
    - Dairy herd remains stable from 2019 – 2050
    - 31% reduction in manure CH_4 – (implementing digesters)
    - 23% reduction in enteric CH_4 – (3-Nitroxypropnal)

Place et al., 2022



EPA, 2021



4. Annual US dairy cattle production cradle-to-farm gate carbon dioxide warming equivalent (CO2we) emissions expressed as millior

Policy

- Nature based solutions to climate change are growing in popularity:
  - “Agroecological practices such as agroforestry, intercropping, rotational grazing, organic manuring, and integrating livestock production with cropping can also contribute to both climate mitigation and adaptation” – IPCC AR6, February 27th (environmental pillar)
- However, technological innovation is a must
- Remember, there **no one size fits all** approach rather the strategy must **fit the manager and climate first** (social, economic and environmental pillars)

Policy

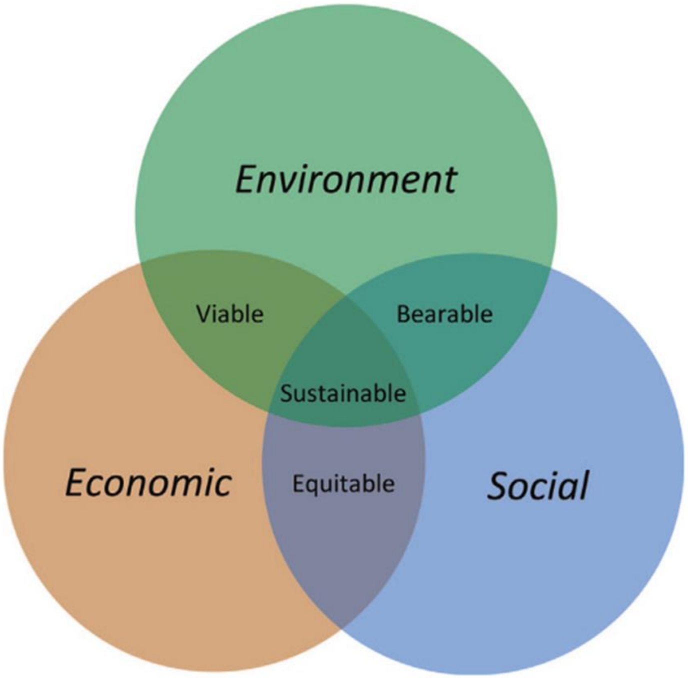
- Biden's Executive Action: Biden-Harris Administration Commits on Climate Change – Creating Jobs, Building Infrastructure, and Delivering Environmental Justice
- NetZero economy by 2050
  - Carbon pollution-free power sector by 2035
  - 30 by 30 program, conserving 30% of lands and oceans by 2030
  - Reduce methane emissions by 30% by 2030 relative to 2020 emission rates
- "Part of our efforts will focus on enhancing climate-smart agricultural practices, the development of biofuels, carbon capture and sequestration, better forest management, and reforestation." – Tom Vilsack

Current needs

- Research that addresses:
  - Enteric CH_4 mitigation solutions
  - Improved nitrogen emission estimates
  - Soil C sequestration rates across regions
  - Ecosystem service markets to develop
- Policy can't outpace the science
- Who pays the bill?

Lastly…

- Solutions need to help farmers/ranchers, not hurt them



Questions?