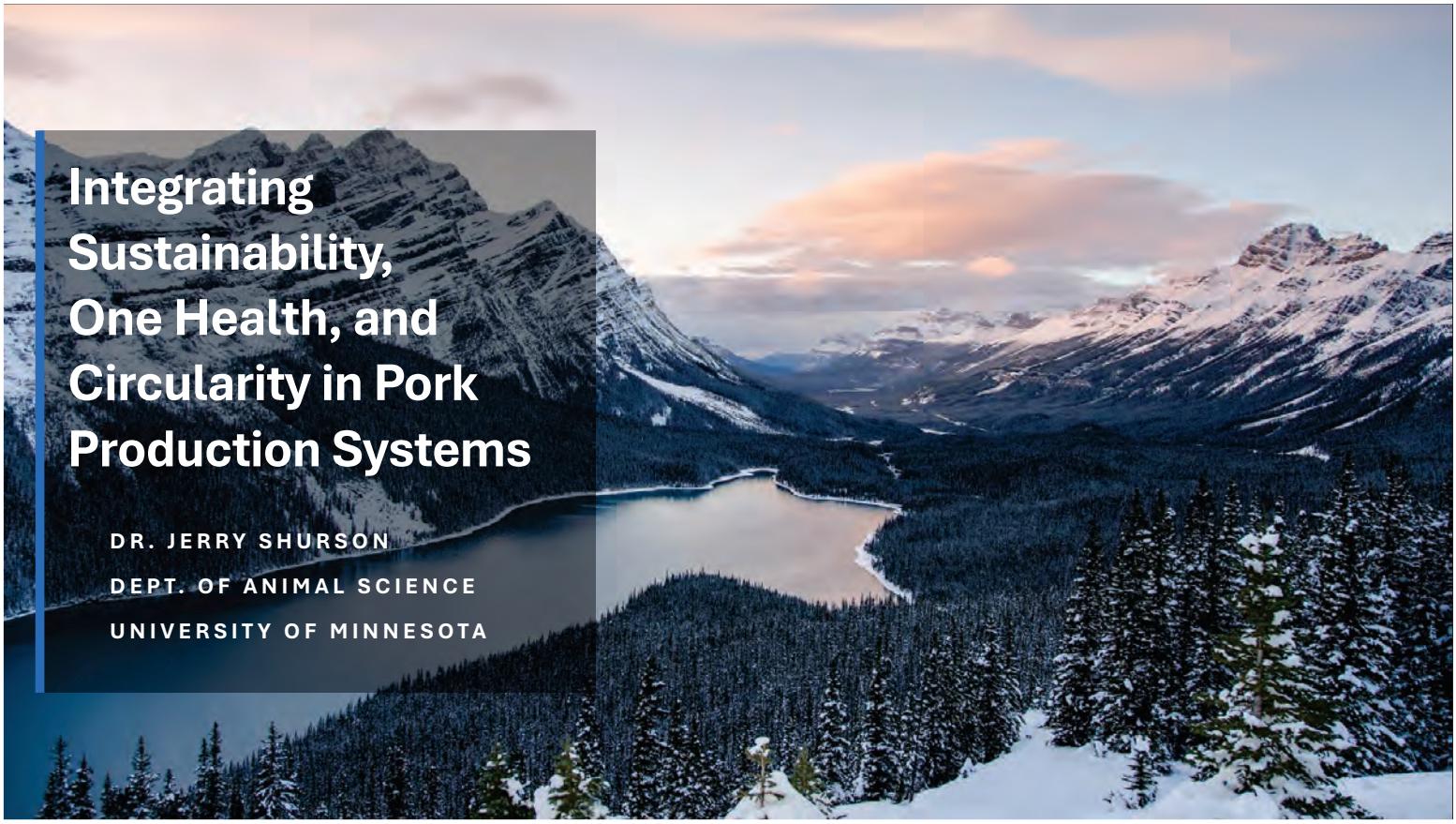


Integrating Sustainability, One Health, and Circularity in Pork Production Systems

DR. JERRY SHURSON
DEPT. OF ANIMAL SCIENCE
UNIVERSITY OF MINNESOTA

FeedStrategy®

The high cost of doing nothing: How climate inaction harms agribusiness

Governments must decide whether to invest now to mitigate climate risk, or pay later to bail out the agrifood industry

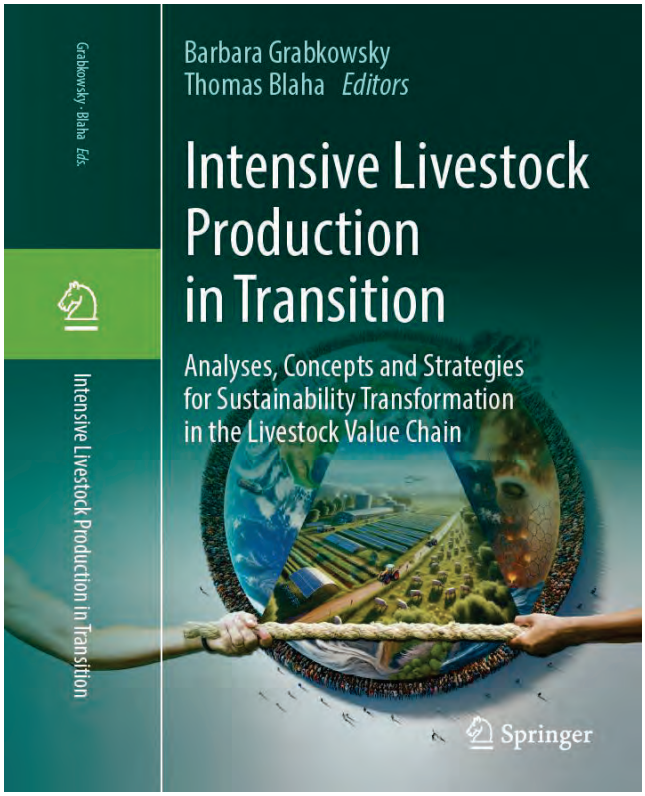
Emma Penrod

December 18, 2025

PROTEIN360

Chapter 2 –
Changing the Goal from Maximizing "Financial" to Optimizing "Sustainable" Return on Investment for the Future of Livestock and Food Production, People, Ecosystems, and the Planet

Chapter 31 –
Sustainable Transformation of Intensive Livestock Production Systems *Is Not* a Return to "Old McDonald's Farm"



https://link.springer.com/book/10.1007/978-3-031-97872-2?as=webp

Definitions

Sustainability – the simultaneous pursuit of human health and happiness, environmental quality, and economic well-being for current and future generations

One Health – integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems

Circularity – practices that minimize waste by recycling and reusing materials from production through consumption to optimize resource use and restore natural capital

WHY focus on sustainability, One Health, and circularity practices?

- **Environmental protection**
  - Reduce greenhouse gas emissions
  - Reduce land, water, and energy use
  - Replace fossil fuels with renewable energy
  - Reduce synthetic fertilizer use
  - Improve air, soil, and water quality

WHY focus on sustainability, One Health, and circularity practices?

- **Consumer, community, and general public trust and support**
  - Implement and document sustainability metrics
    - Demonstrate environmental stewardship
    - Data transparency strengthens public perception
    - Meet market demands and requirements in pork supply chains
    - Ensure future food security

WHY focus on sustainability, One Health, and circularity practices?

- **Long-term farm business viability**
  - Risk management and resilience to climate change
  - Adopt new technologies
    - increase efficiency and productivity
    - reduce environmental footprint and production cost
  - Create new revenue streams (e.g., carbon markets)
  - Support long-term business viability for future generations

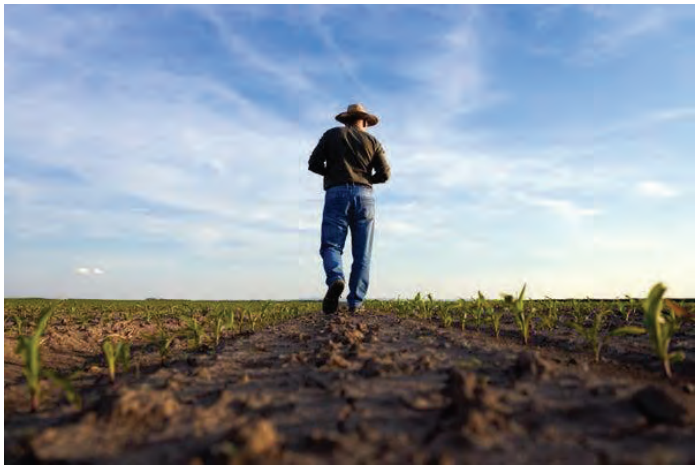
WHO will produce our food?

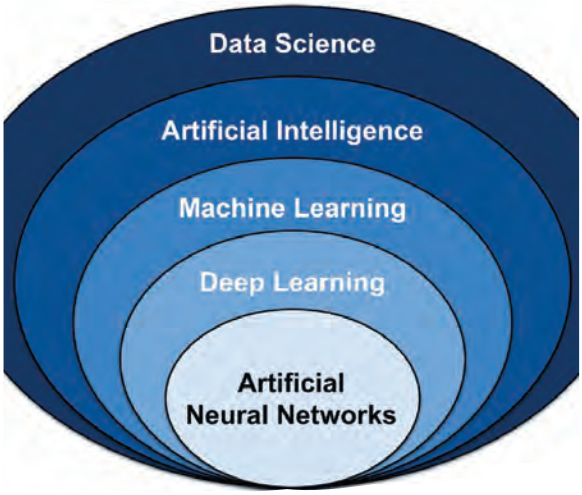
- Many aging farmers
- Not enough young farmers
- Contentious migrant worker policies
- Not enough large animal veterinarians

A Silent Truth Hidden in the Farm Economy: Farmer Suicides Are on the Rise

Farmers in Crisis, Long Overlooked, Are Finally Getting Mental Health Support

Amid a mounting mental health crisis among farmers, experts are working to make help more accessible





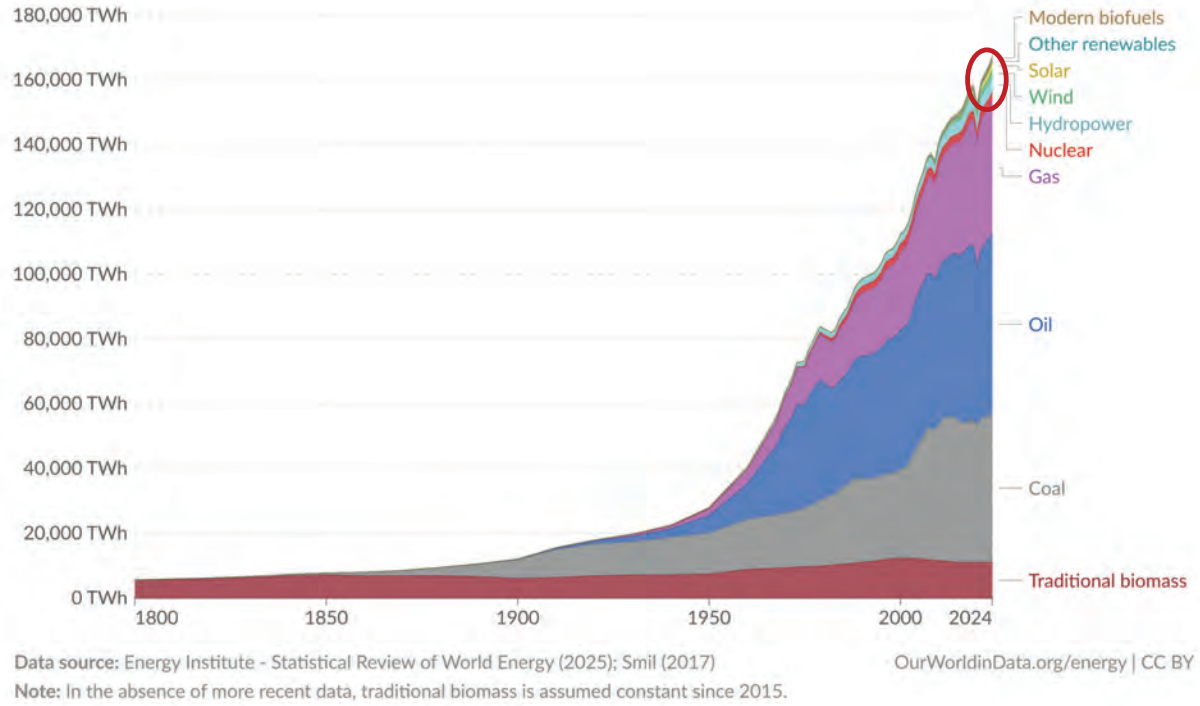
Farmers need to become proficient in digital and data technologies

WHY is there a serious threat to food security and sustainably?

We have violated the guiding principles of sustainability

- Never extract more than ecosystems can generate
- Never waste or pollute more than ecosystems can safely absorb

Fossil fuels continue to dominate global energy consumption

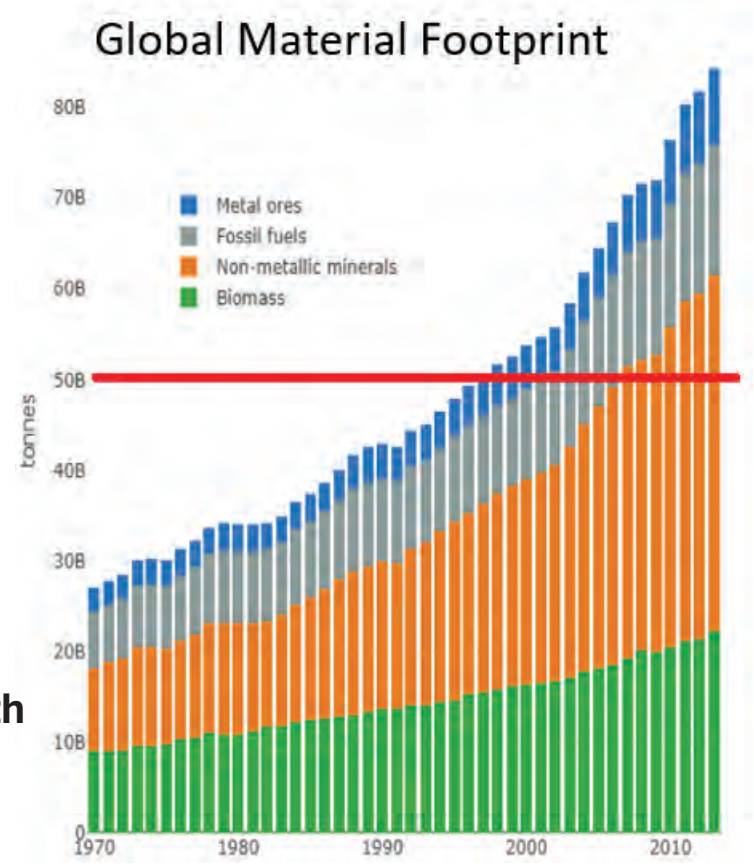


Data source: Energy Institute - Statistical Review of World Energy (2025); Smil (2017)
OurWorldinData.org/energy | CC BY
Note: In the absence of more recent data, traditional biomass is assumed constant since 2015.

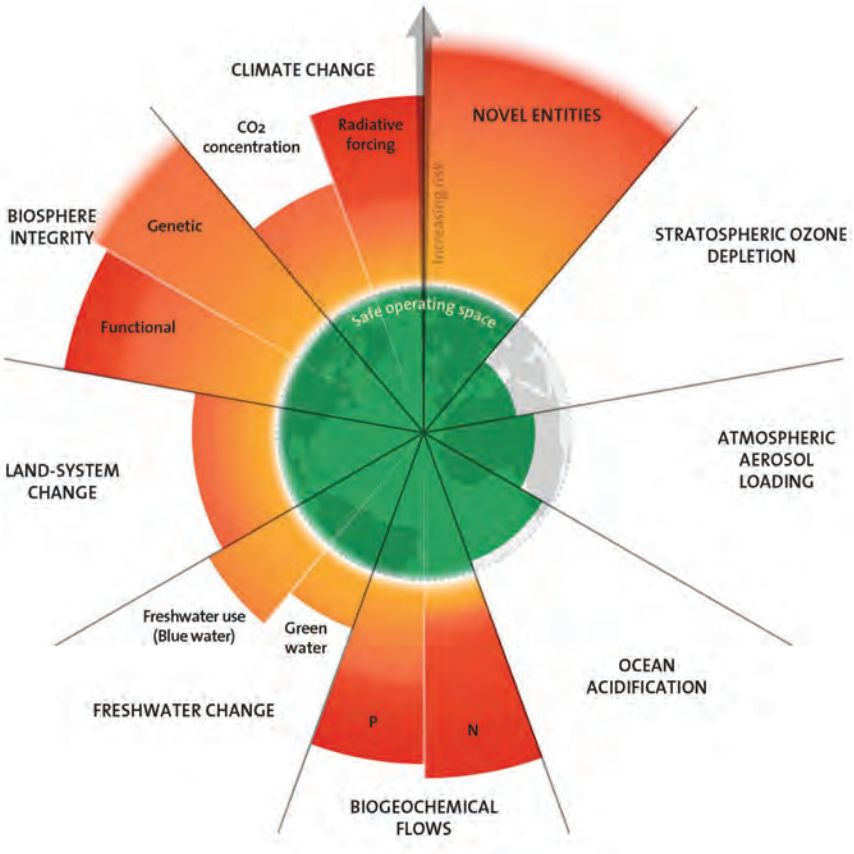
We are taking more than ecosystems can generate

"We are persuaded to spend money we don't have, on things we don't need, to create impressions that won't last, on people we don't care about"

– Tim Jackson, Prosperity Without Growth



Human exploitation of Earth's natural resources has been like a "bull in a china shop"

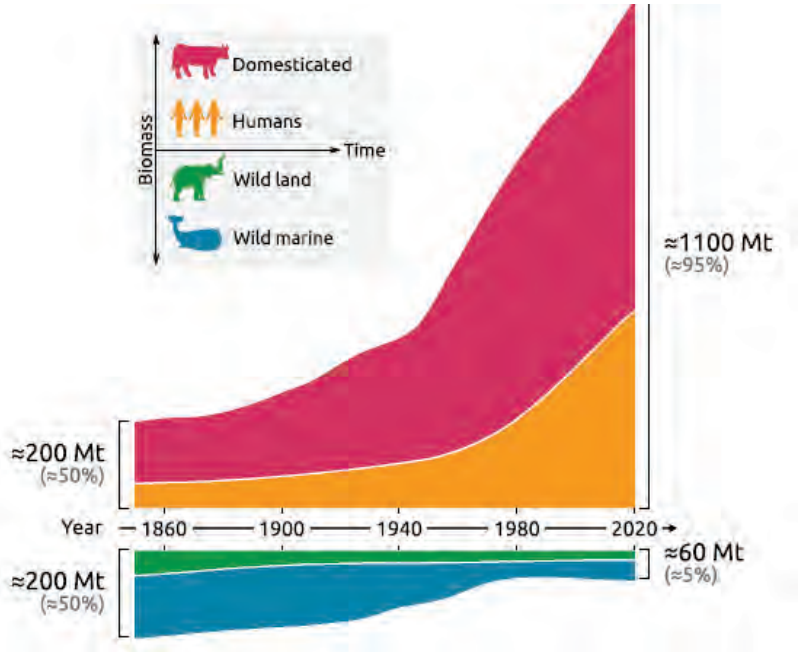


Six of 9 planetary boundaries have been exceeded

Richardson et al. (2023)

Global biomass of domesticated animals and humans has dramatically increased since 1850

Greenspoon et al. (2025)



Environment and One Health costs of animal agriculture

- Greenhouse gas emissions
- Fossil fuel use
- Disrupted N and P flows
- Biodiversity loss
- Freshwater scarcity and eutrophication
- Land use and management
- Air quality effects on human health
- Antibiotic resistance
- Endocrine disruptors and ecotoxicity
- Zoonotic disease transmission

Climate change induced natural disasters

- Global ag losses = $99 billion/year
- Agriculture losses (1991-2023)
  - 4.6 billion tonnes cereals
  - 2.8 billion tonnes fruits/vegetables
  - 900 million tonnes of meat and dairy
- Americas = 22% of global ag losses
  - Droughts, hurricanes, floods, extreme weather events

FAO (2025)

Glyphosate: Cancer, liver disease, endocrine disruption and other health concerns

Stacy Malkan | September 30, 2025

Conflict Over A Blockbuster Farm Chemical

Use and safety of Roundup questioned in Michigan and Midwest.

by Keith Schneider May 19, 2025

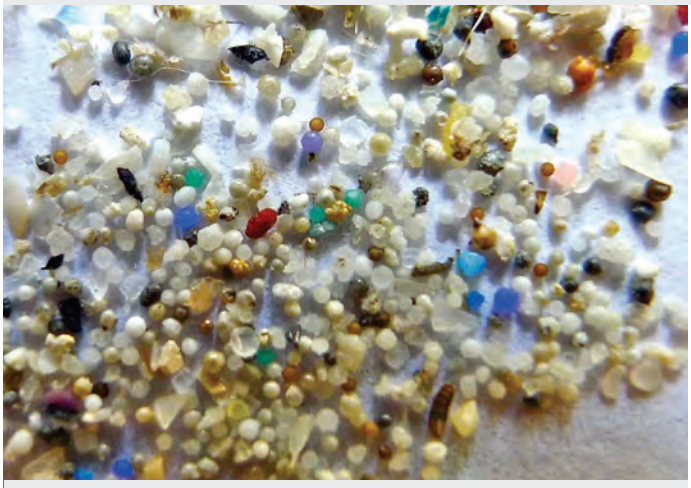
Study: Because of Pesticides, Living in Farm Towns Is as Risky as Smoking

New research shows that the pesticides used heavily by industrial agriculture contribute to inflated cancer risk in farm country, “with few areas spared.”

How pesticides help fuel Iowa’s cancer crisis

Plastics on Track to Account for 20% of Oil and Gas Consumption by 2050

Health & Environment 11/11/2022 · Stefan Anderson & Elaine Ruth Fletcher



Plastic pollution treaty fails as countries remain divided

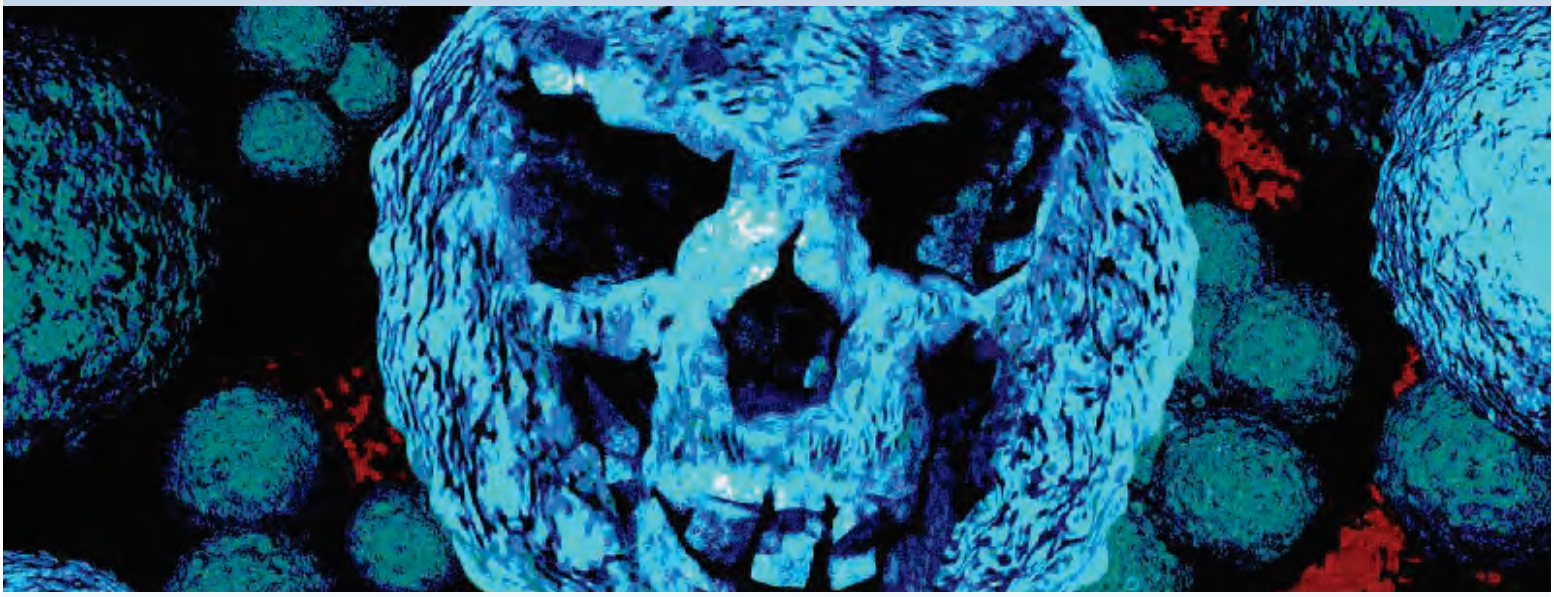
By Mia Hunt on 19/08/2025

New Analysis Finds PFAS in 98% of Tested U.S. Waterways Across 19 States

September 12, 2025

EPA Seeks to Eliminate Critical PFAS Drinking Water Protections

Antimicrobial resistance is getting worse
WHO reported a 40% increase in resistance from 2018-2023

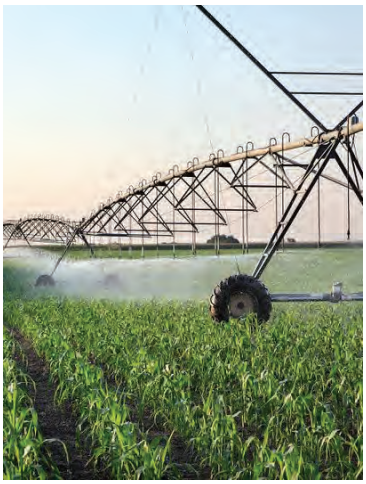


Directly responsible for 1.2 million deaths/year
Contributes to 5 million deaths/year

Total food loss and waste is > 2.5 billion tonnes globally
40% of all food produced is not consumed

Environmental costs of food loss and waste

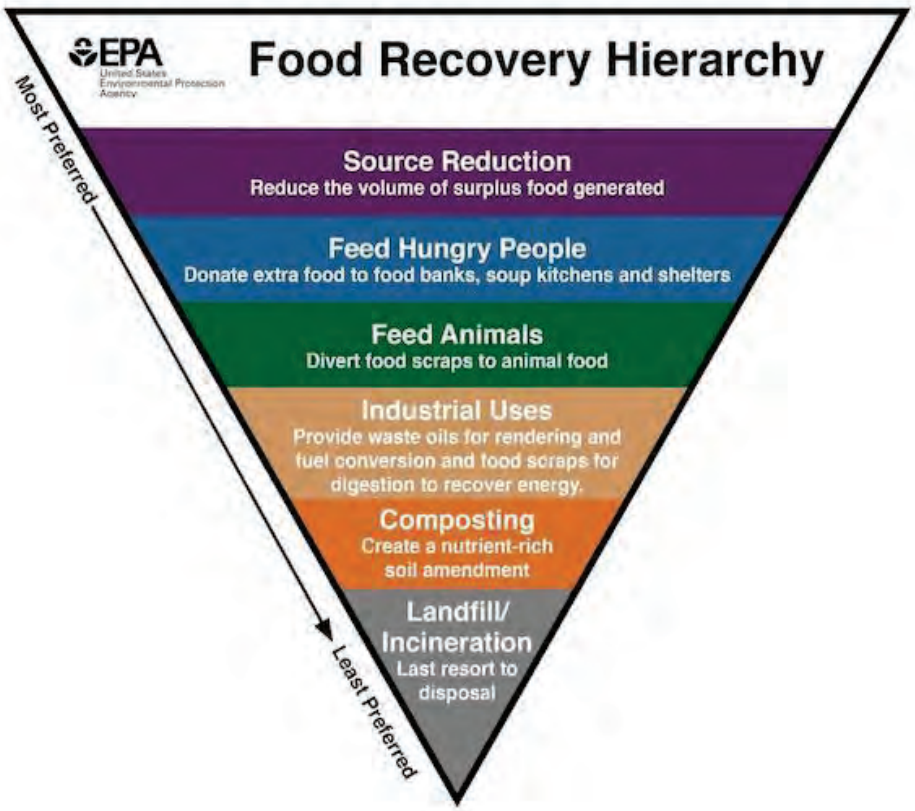
30% of total agricultural land is wasted



25% of total freshwater is wasted

38% of total energy consumption for food production is wasted

8% to total global GHG emissions is caused by food waste disposal in landfills


EPA
United States Environmental Protection Agency
Food Recovery Hierarchy
Most Preferred
Least Preferred
Source Reduction
Reduce the volume of surplus food generated
Feed Hungry People
Donate extra food to food banks, soup kitchens and shelters
Feed Animals
Divert food scraps to animal food
Industrial Uses
Provide waste oils for rendering and fuel conversion and food scraps for digestion to recover energy.
Composting
Create a nutrient-rich soil amendment
Landfill/ Incineration
Last resort to disposal


Report Card
HOW are we doing?

2022 Global Food Security Index (113 countries)

Overall Rank	Affordability	Availability	Quality and Safety	Sustainability and Adaptation
1 Finland	1 Australia	1 Japan	1 Canada	1 Norway
2 Ireland	2 Singapore	2 China	2 Denmark	2 Finland
3 Norway	3 Netherlands	3 Singapore	3 U.S.A.	3 New Zealand
4 France	4 Ireland	4 Portugal	4 Belgium	4 Ireland
5 Netherlands	5 Belgium	5 Switzerland	5 Finland	5 Costa Rica
6 Japan	25 Canada	6 Canada	7 France	12 U.S.A.
7 Canada	28 U.S.A.	31 U.S.A.	109 Sierra Leone	29 Canada
8 Sweden	109 Haiti	109 Venezuela	110 Mozambique	109 Sudan
13 U.S.A.	110 Burundi	110 Sierra Leone	111 Guinea	110 Haiti
109 Madagascar	111 Syria	111 Cameroon	112 Haiti	111 Cambodia
110 Sierra Leone	112 Zambia	112 Yemen	113 Madagascar	112 Botswana
111 Yemen	113 Nigeria	113 Syria		113 Paraquay
112 Haiti				
113 Syria				

Source: The Economist (https://impact.economist.com/sustainability/project/food-security-index)

2021 Global Food Sustainability Index (78 countries)

Overall Rank	Minimizing Impacts of Food Loss and Waste	Enhancing Sustainable Agriculture	Reducing Nutritional Challenges
1 Sweden	1 Canada	1 Finland	1 Japan
2 Japan	2 Italy	2 Estonia	2 Sweden
3 Canada	3 Germany	3 Austria	3 Denmark
4 Finland	4 Japan	4 Tanzania	4 France
5 Austria	5 Netherlands	5 Sweden	5 China
6 Denmark	6 Sweden	6 Ireland	16 Canada
7 Australia	8 U.S.A.	36 Canada	46 U.S.A.
30 U.S.A.	75 Cameroon	75 U.S.A.	75 Madagascar
75 Mali	76 Dem. Rep. Congo	76 Algeria	76 Mali
76 Dem. Rep. Congo	77 Niger	77 Lebanon	77 Niger
77 Niger	78 Algeria	78 United Arab Emirates	78 Mozambique
78 Madagascar			
	Food loss End-user waste	Water management Land use and biodiversity Pesticide use Synthetic fertilizers Climate change	Life quality Life expectancy Dietary patterns

Source: The Economist (https://impact.economist.com/projects/foodsustainability/fsi/about-the-food-sustainability-index/)

We are not transitioning to sustainability fast enough

- > 50% of SDG targets will not be met by 2030
- No action toward meeting 30% of SDG targets
- Exceeded the +1.5°C limit for average global temperature increase in 2024
  - Trigger for multiple catastrophic tipping points
- Biodiversity action plans are inadequate and lack financial and institutional support

WWF (2024)

Status of Global Circularity in 2025

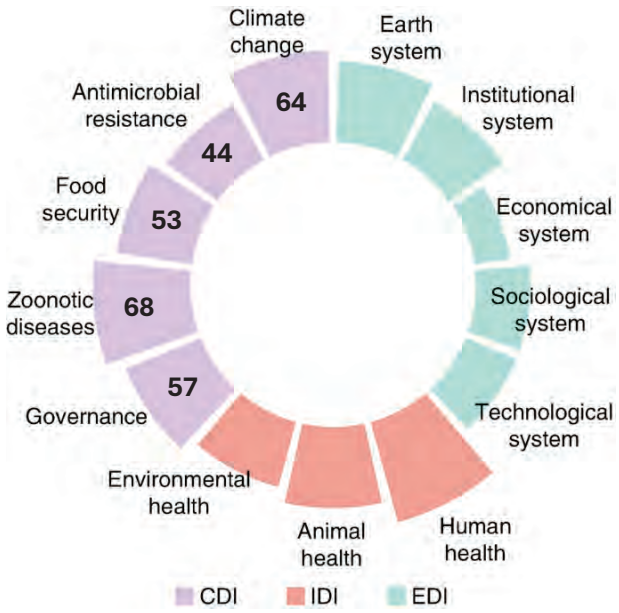
- **Only 7.2% of the global economy is circular**
- **Circularity is declining due to increasing material extraction and use**
- **All human needs can be met with 70% of materials we currently use while staying within safe limits of the planet**

Global Circularity Gap Report, Circle Economy (2025)

Global One Health Index (160 countries)

Global rank	
1 USA	**70.6**
2 UK	69.9
3 Australia	69.3
4 Norway	68.9
5 Germany	68.8
8 Canada	**67.6**
12 Japan	66.7
21 S. Korea	64.4
22 China	63.2
31 Argentina	61.3
32 Brazil	61.3
38 Mexico	60.4

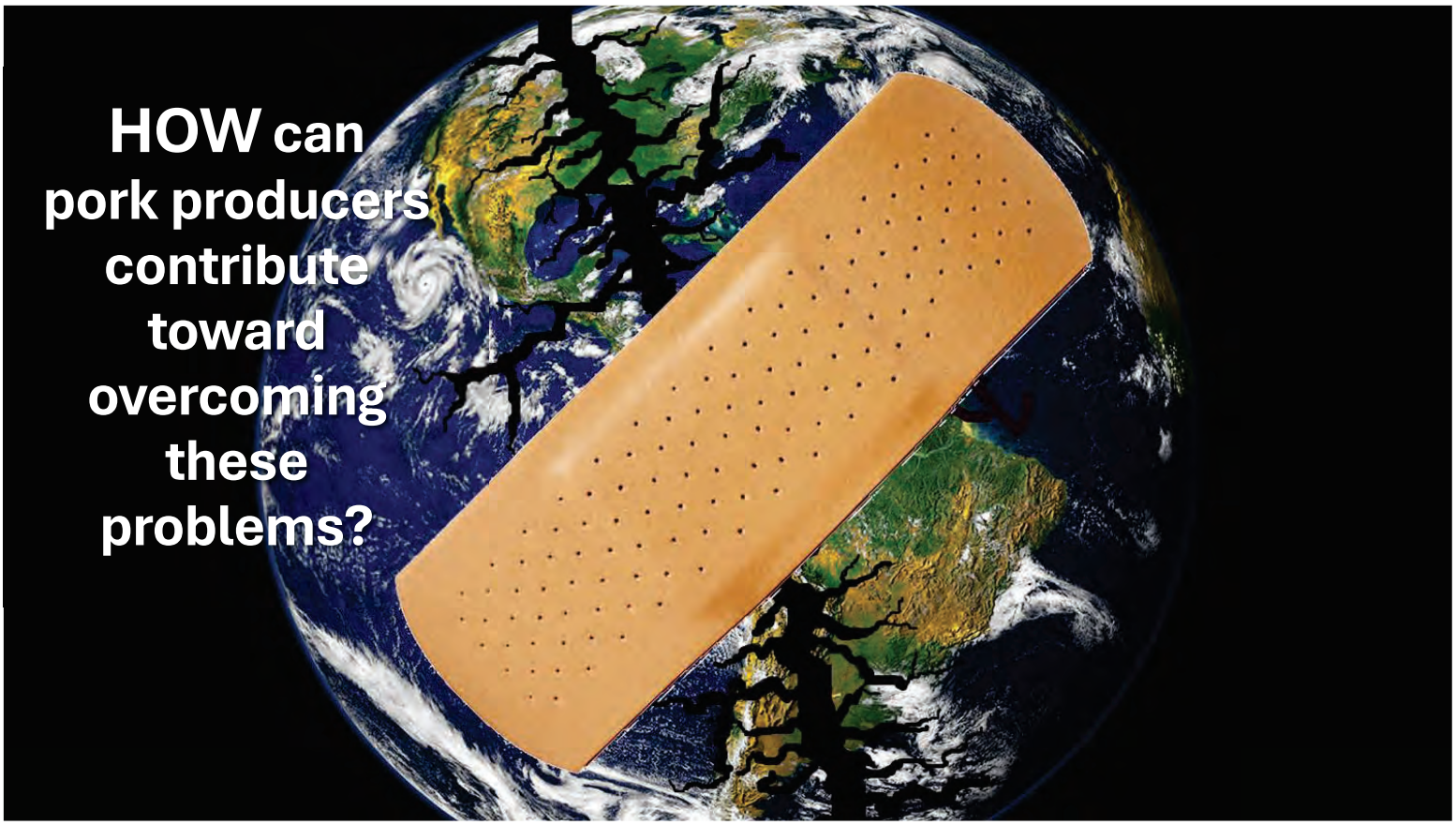
Zhang et al. (2024)



CDI = Core Drivers Index

IDI = Intrinsic Drivers Index

EDI = External Drivers Index



Focus on the "Big 5" environmental measures

- Land use
- Water use
- Carbon emissions (carbon dioxide and methane)
- Nitrogen waste
- Phosphorus waste

Adopt circularity practices

- **Reduce resource inputs**
  - Synthetic fertilizers, pesticides, water
- **Reduce food loss and waste**
- **Recover and recycle wasted nutrients**
  - Animal feed
  - Anaerobic digesters to produce biogas
  - Composting
- **Conserve and improve energy efficiency**
- **Transition to renewable energy sources**

Feeding program and manure management are the main drivers of environmental sustainability of pork production systems

We must use a holistic approach to swine nutrition

Public Health
antibiotic resistance

Climate Change
heat stress
mycotoxins

Environmental Impact
GHG emissions
C, N, P, Zn, Cu

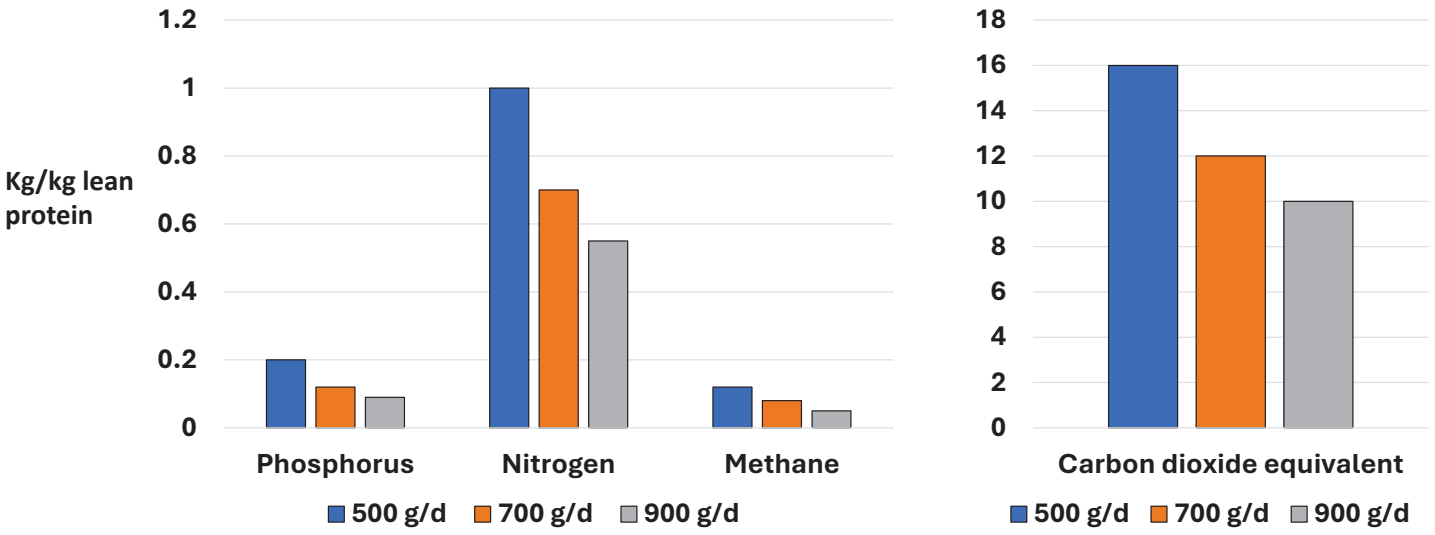
Pathogen Transmission
biosecurity of feed ingredient sourcing

Enhancing Caloric and Nutritional Efficiency
high fiber diets
precision feed formulation

Functional Nutrients/Ingredients
specific and non-specific disease challenges

Pig Well-Being
oxidative stress
optimal gut health

Nitrogen and phosphorus losses and GHG emissions decline as ADG increases in growing-finishing pigs



Flachowsky and Kamphues (2011)

Sustainable pork production systems MUST include environmental impacts from the production pathway AND the consumption pathway

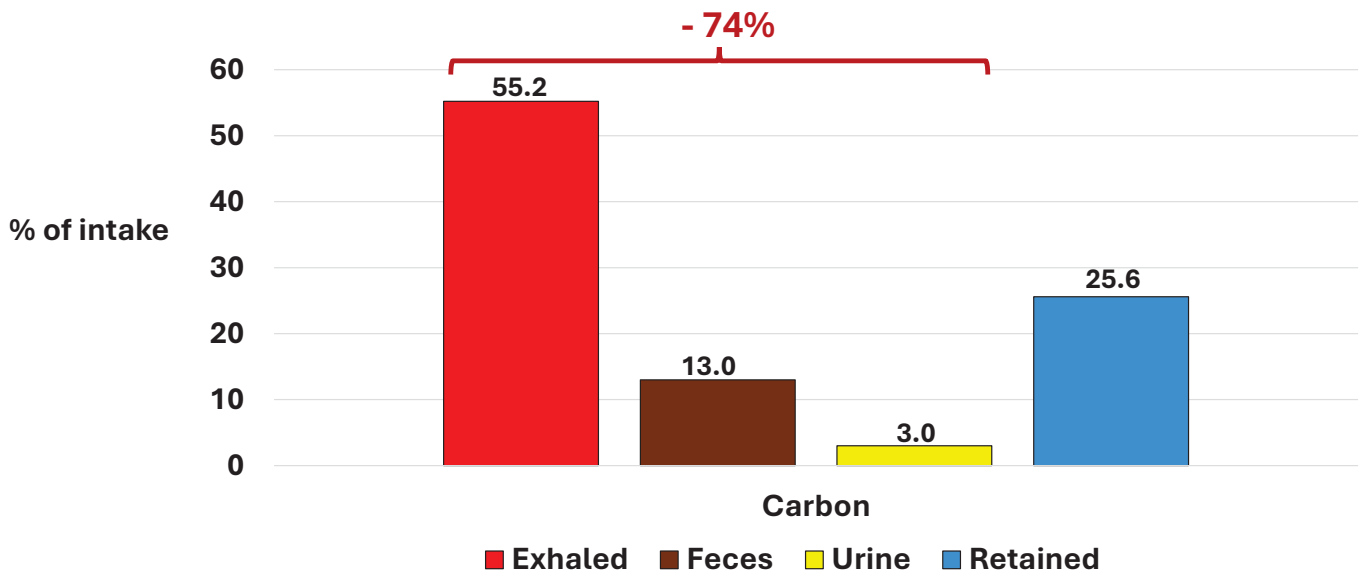
Production pathway

Productivity-based
Produce more with fewer resources

Consumption pathway

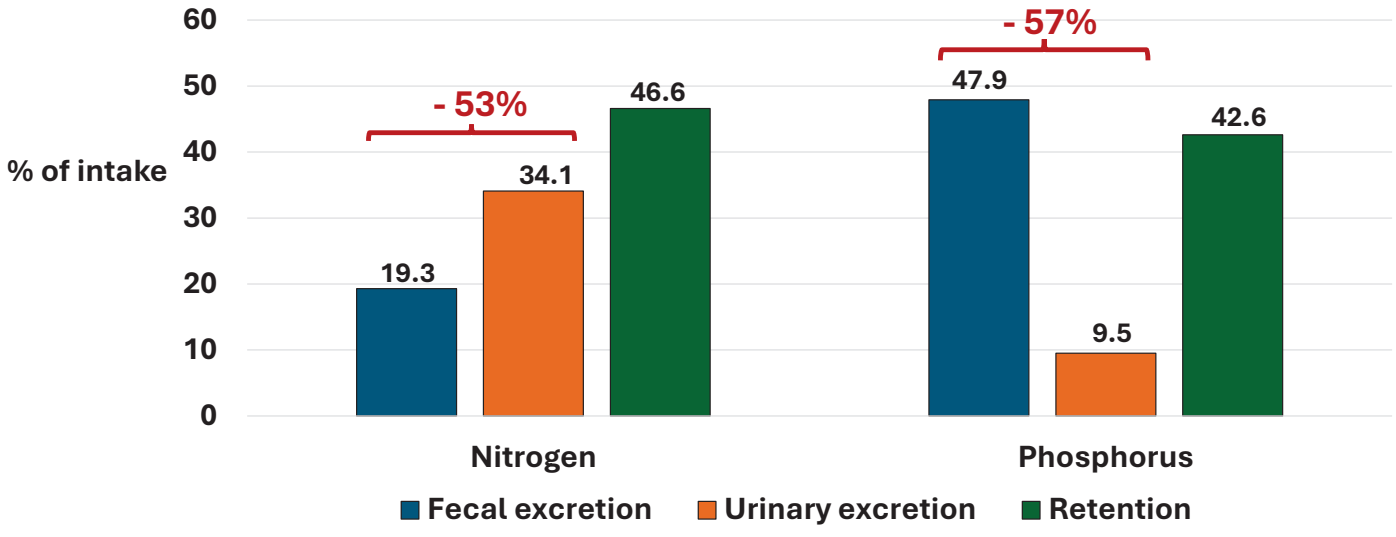
Circular and regenerative practices
Waste, emissions, non-renewable resource reduction
Resource recovery and recycling

74% of dietary C is lost in emissions and manure of growing pigs



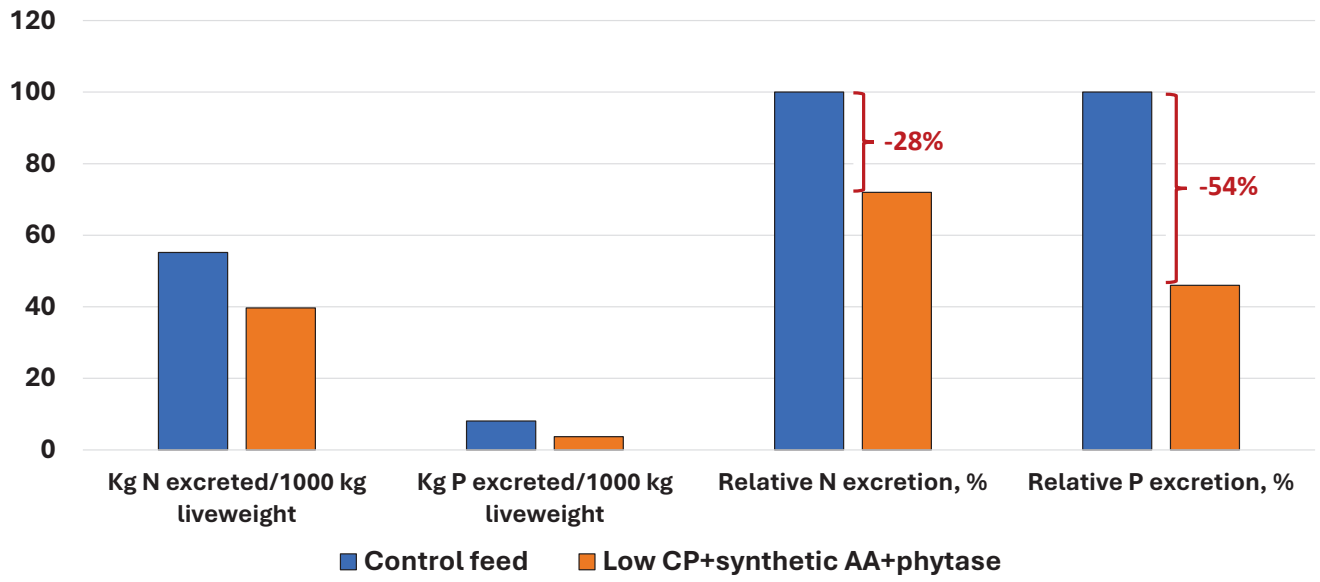
Kerr et al. (2026)

53% of dietary N and 57% of dietary P is excreted in manure of growing pigs

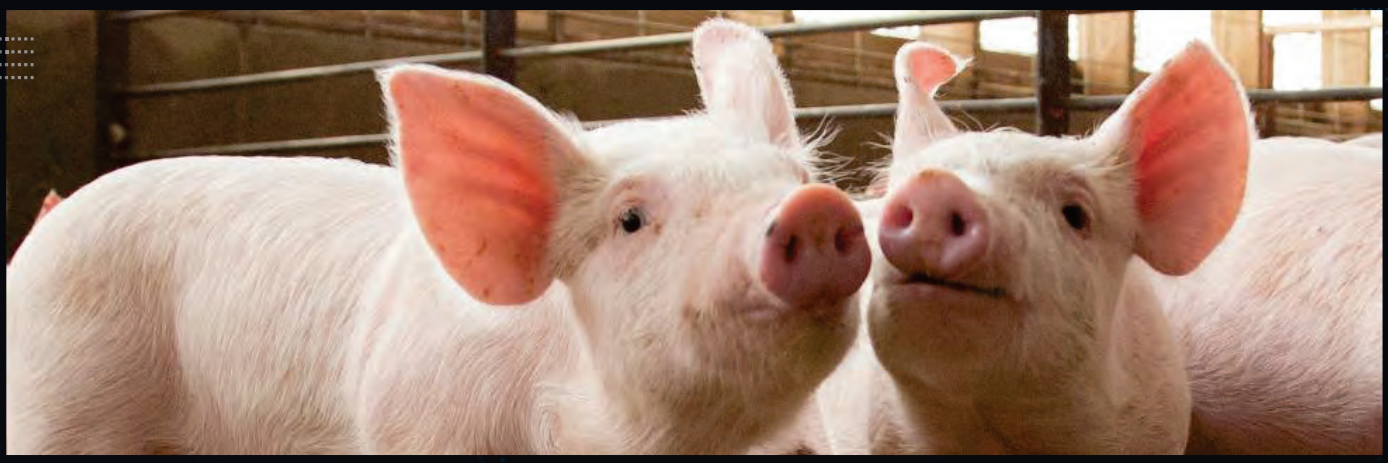


Jorgensen et al. (2013)

Combined use of synthetic amino acids and phytase in low crude protein swine diets reduces N excretion by 28% and P excretion by 54%



IFIF and FEFANA (2015)



Improving C, N, and P utilization efficiency in pork production systems requires getting...

- The right **amount of digestible nutrients** in
- The right **feed** fed to
- The right **pigs** at
- The right **time**

Use multi-objective feed formulation

- Accurate nutritional values
- Best cost

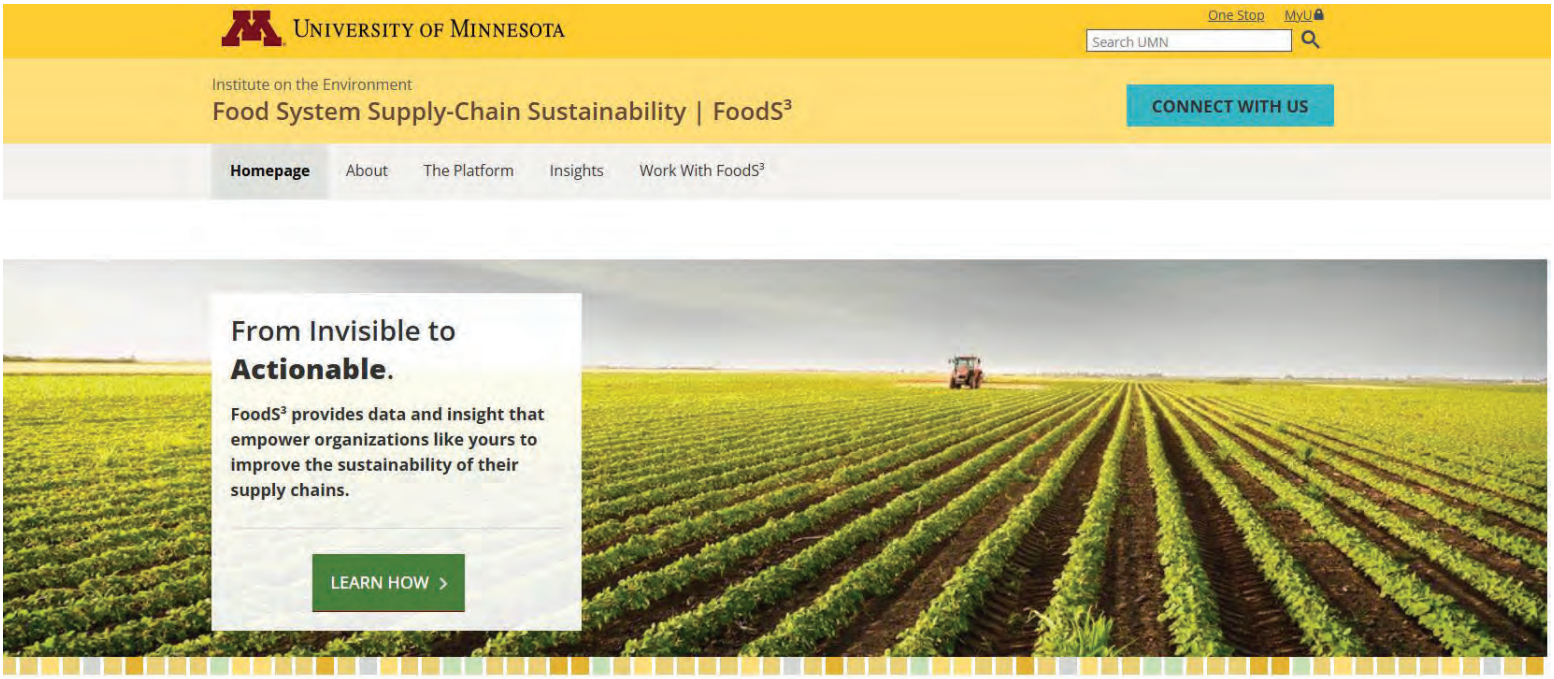
- Biosecure feed supply chains
- “Functional” health benefits

- C, N, and P utilization efficiency
- LCA environmental impacts

Life Cycle Assessment environmental impact measures for feed ingredients

Measure	Measure
Global warming with land use change	Human non-carcinogenic toxicity
Global warming without land use change	Ionizing radiation
Terrestrial acidification	Ozone formation, human health
Freshwater eutrophication	Ozone formation, terrestrial ecosystems
Marine eutrophication	Stratospheric ozone depletion
Terrestrial eutrophication	Fine particulate matter formation
Terrestrial ecotoxicity	Mineral resource scarcity
Freshwater ecotoxicity	Fossil resource scarcity
Marine ecotoxicity	Land use
Human carcinogenic toxicity	Water use

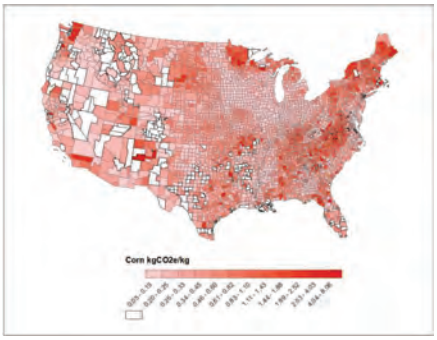
gfli
Global Metrics for Sustainable Feed

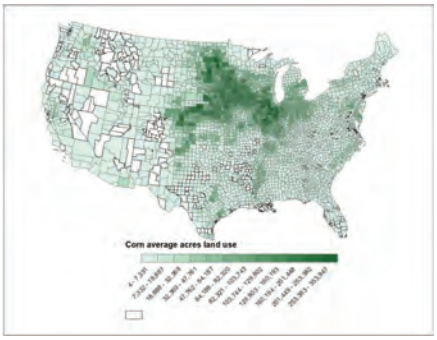


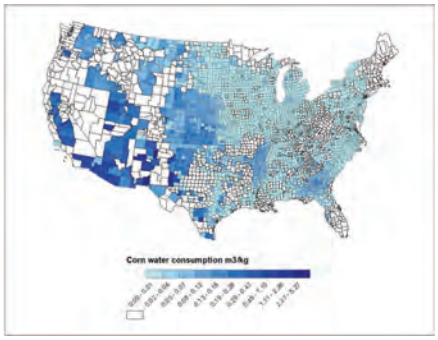
What is FoodS^3?

Greenhouse gas emissions, land use, and water use of U.S. corn and soybean production

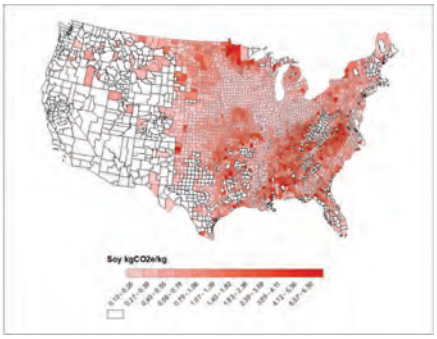
Corn

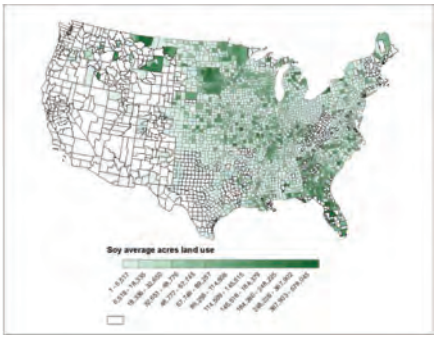


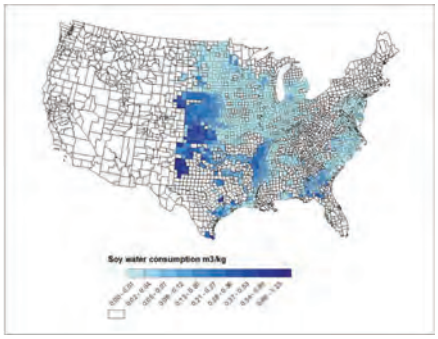




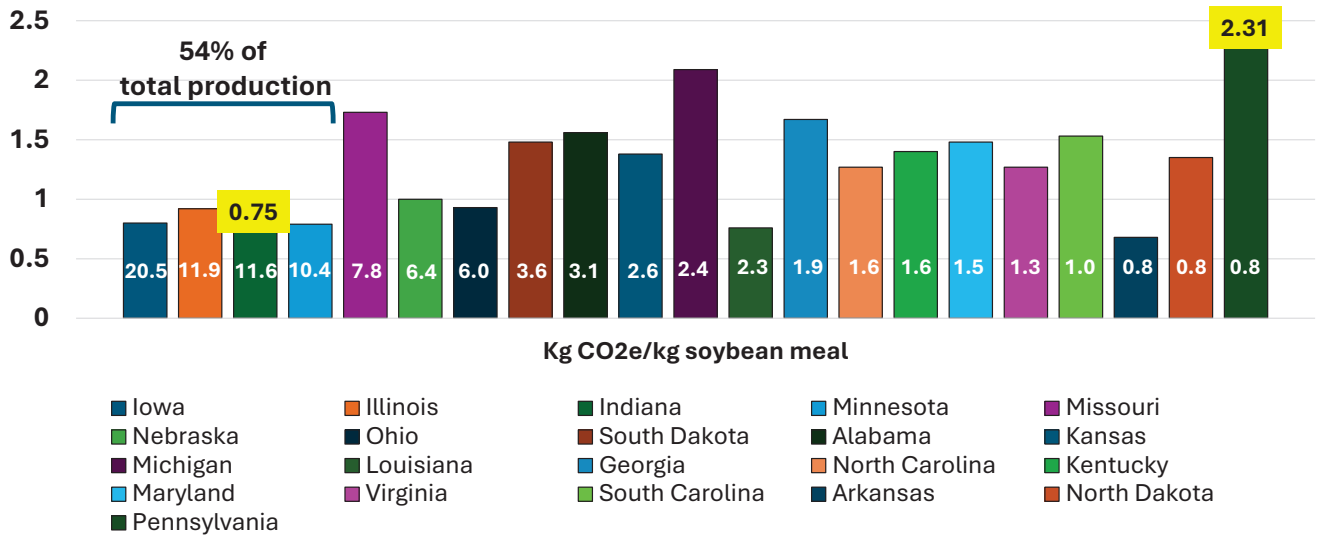
Soybeans





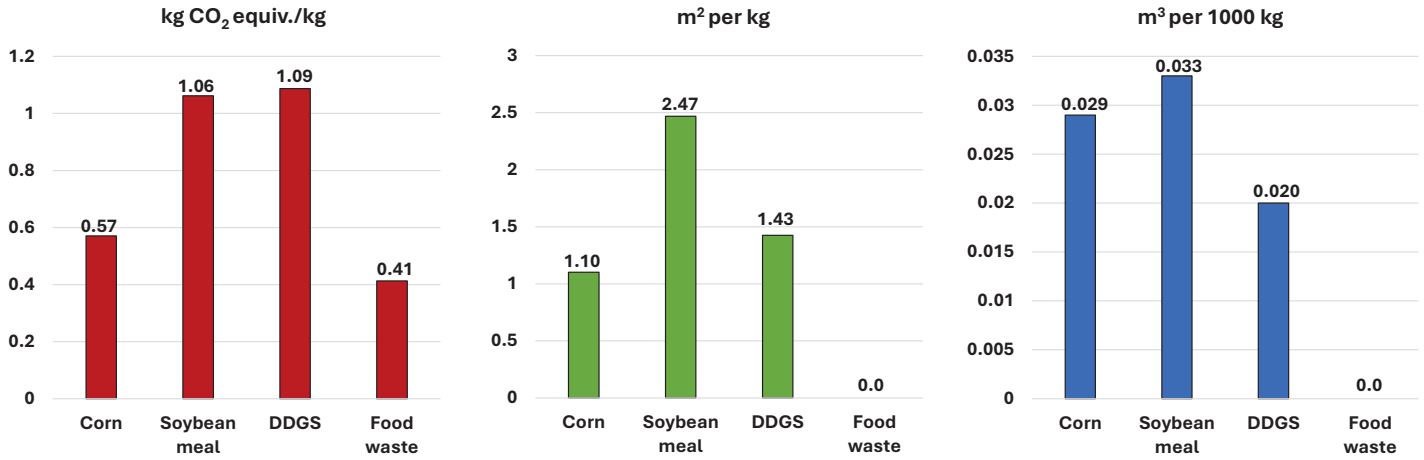


Weighted average GHG emissions of soybean meal by state and share of total U.S. production



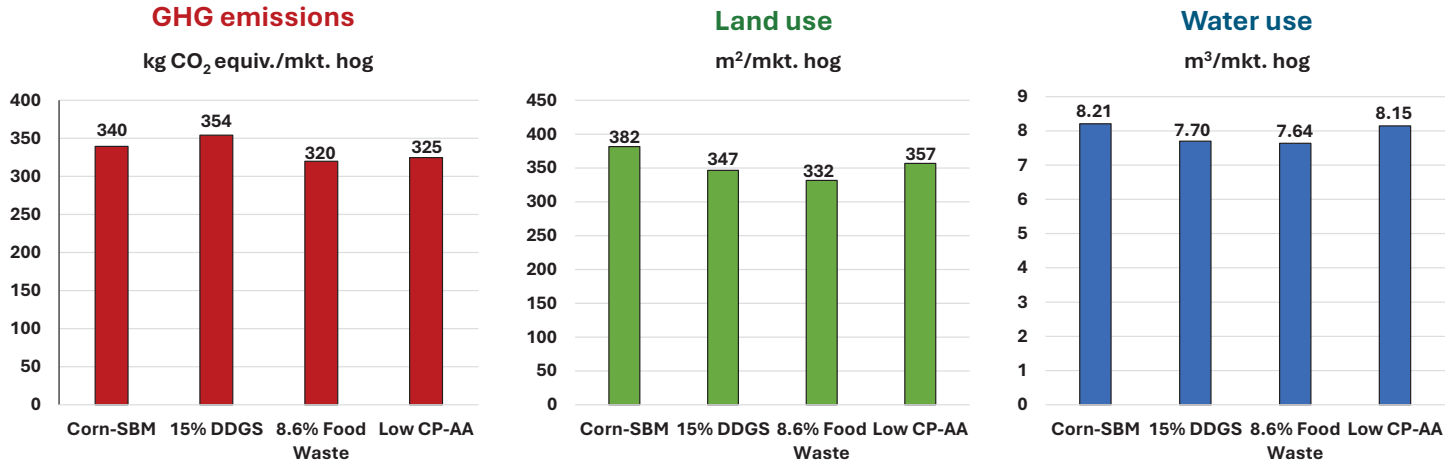
Pelton et al. (2026)
under review for publication

Average GHG emissions, land use, and embedded water use of ingredients used in grower-finisher feeding programs in major U.S. pork production regions



Shurson et al. (2022)

Average impact of feeding program on GHG emissions (feed+manure), land use, and embedded water use among major U.S. pork production regions



Shurson et al. (2022)

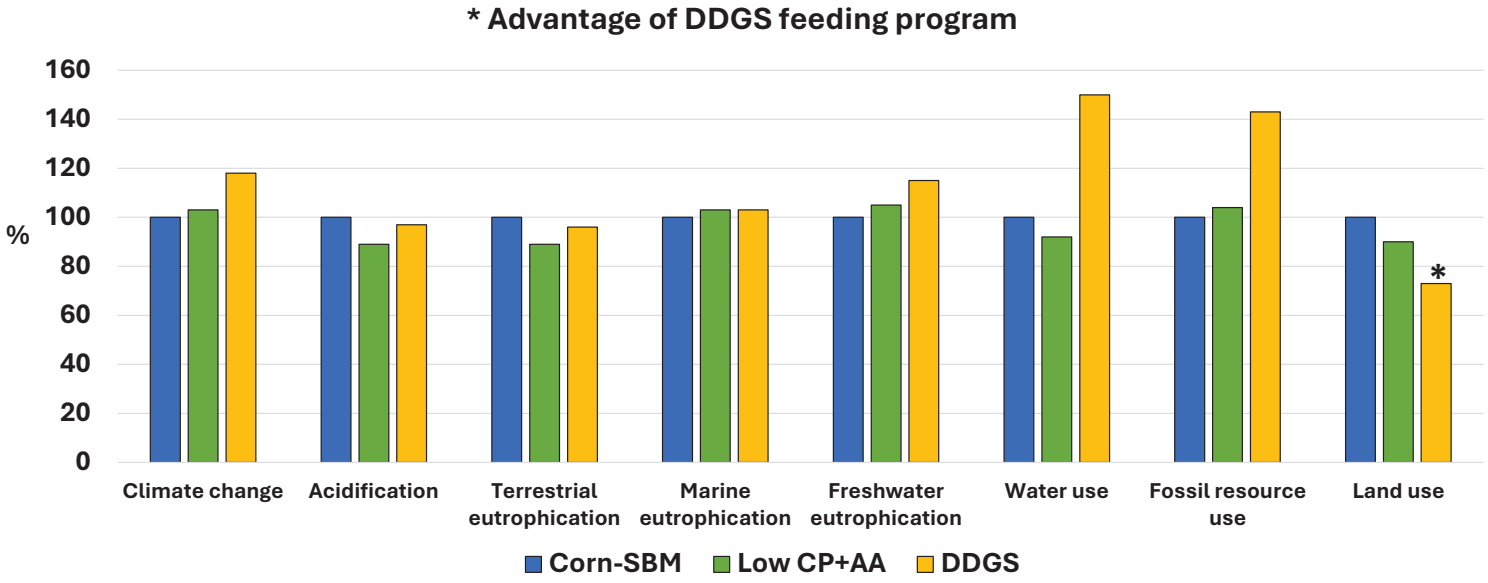
Feeding food waste to swine increases N use efficiency and reduces N losses

Uwizeye et al. (2019)

Recycling 39% of total global FLW in swine feed would save:

- 31 million tonnes soybeans
- 20 million tonnes grains
- 16 million hectares of land use

Trade-offs of relative environmental impacts among grower-finisher swine feeding programs



Environmental impacts (1000 kg carcass) using Opteinics model (Nuvio Planet) and LCA data from GFLI database

Yang et al. (2023)

What is precision livestock farming?

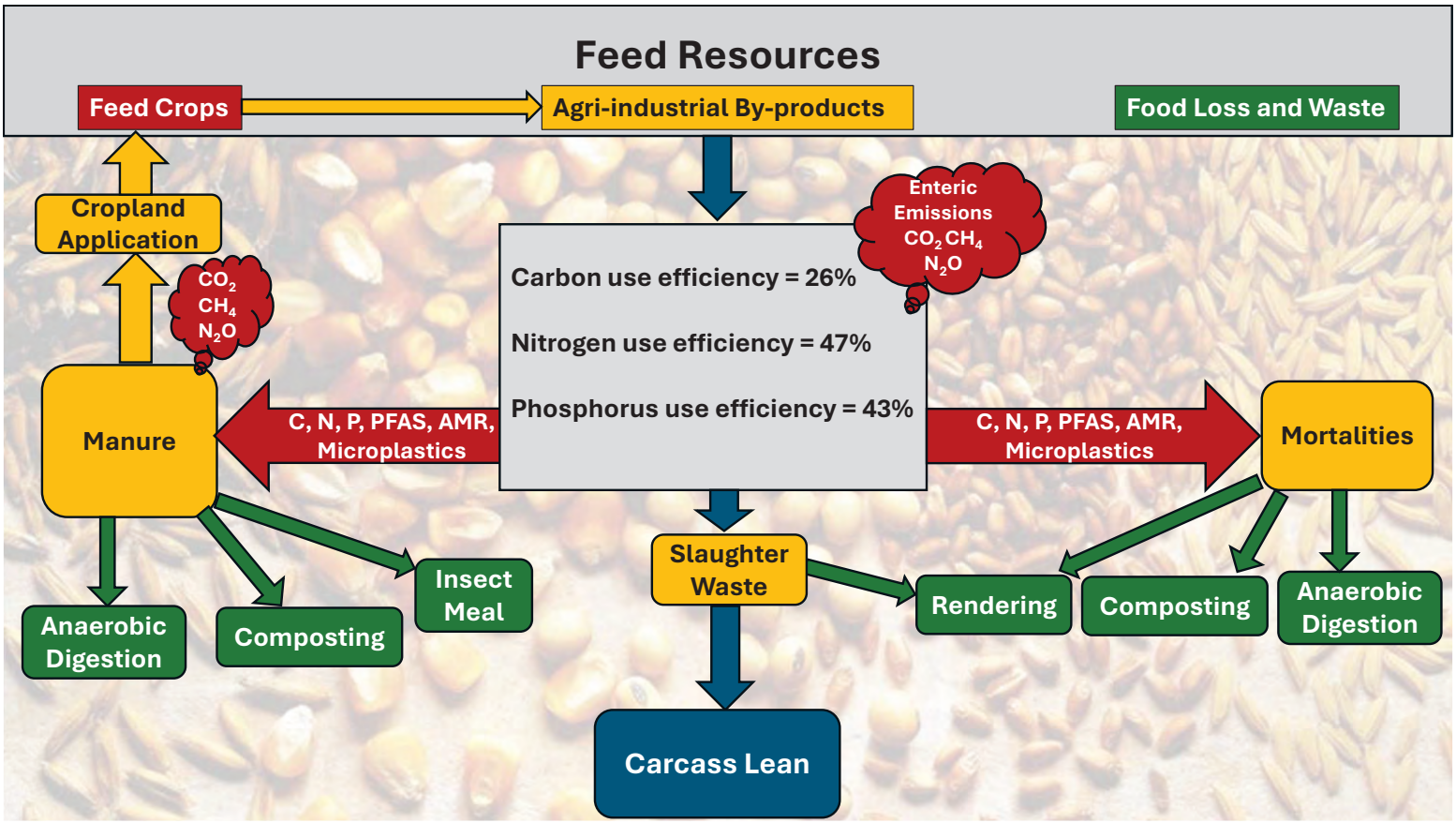
- Sensors, control systems, software, data collection and analysis and other advanced technologies
- Used to monitor and manage individual animals and their environment in real-time
- Helps farmers make more informed and timely decisions
- Improves animal health, welfare, and productivity
- Reduces labor and environmental impact

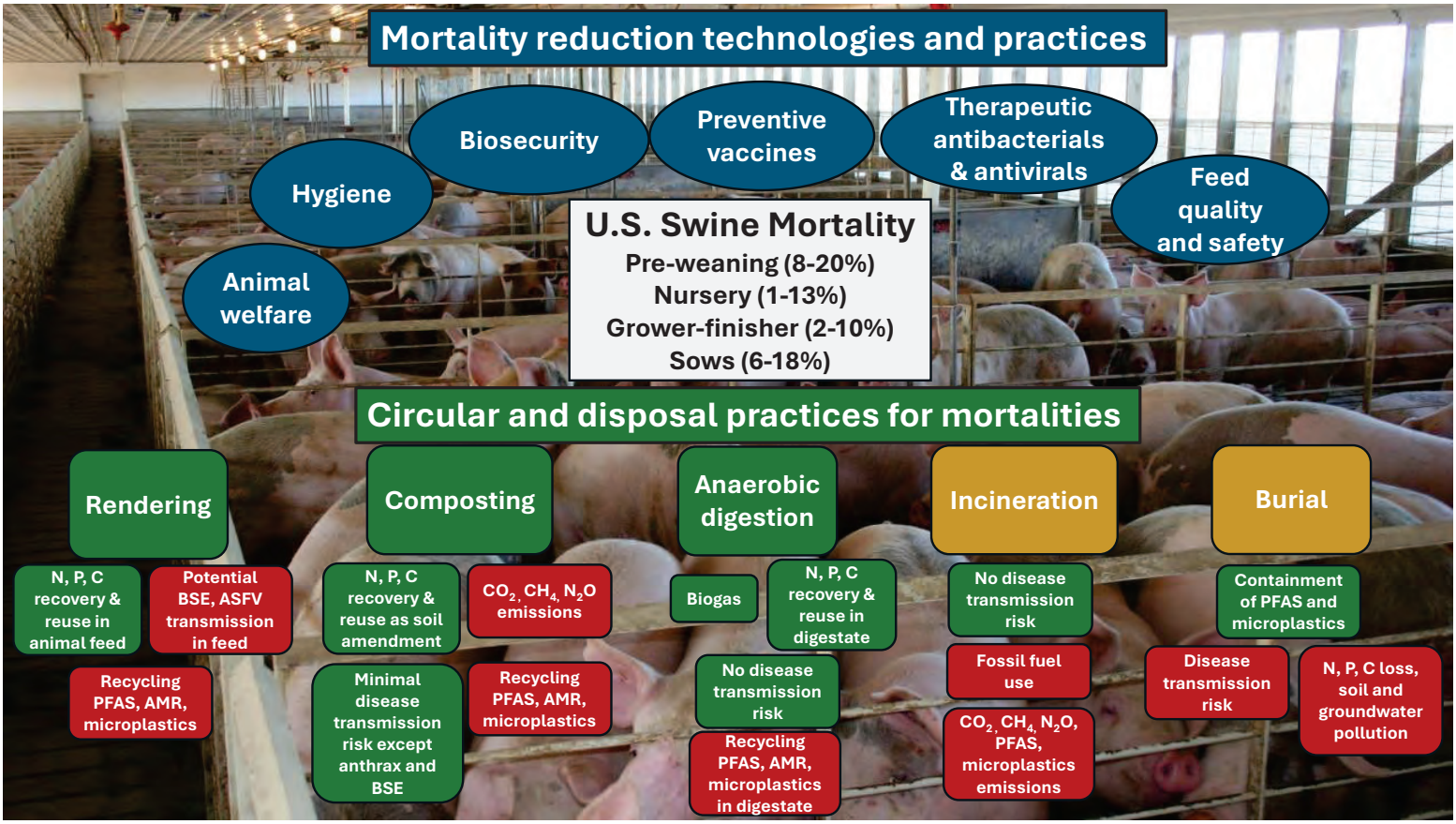
Precision pig feeding

Individual precision feeding
vs.
traditional 3-phase G-F group feeding

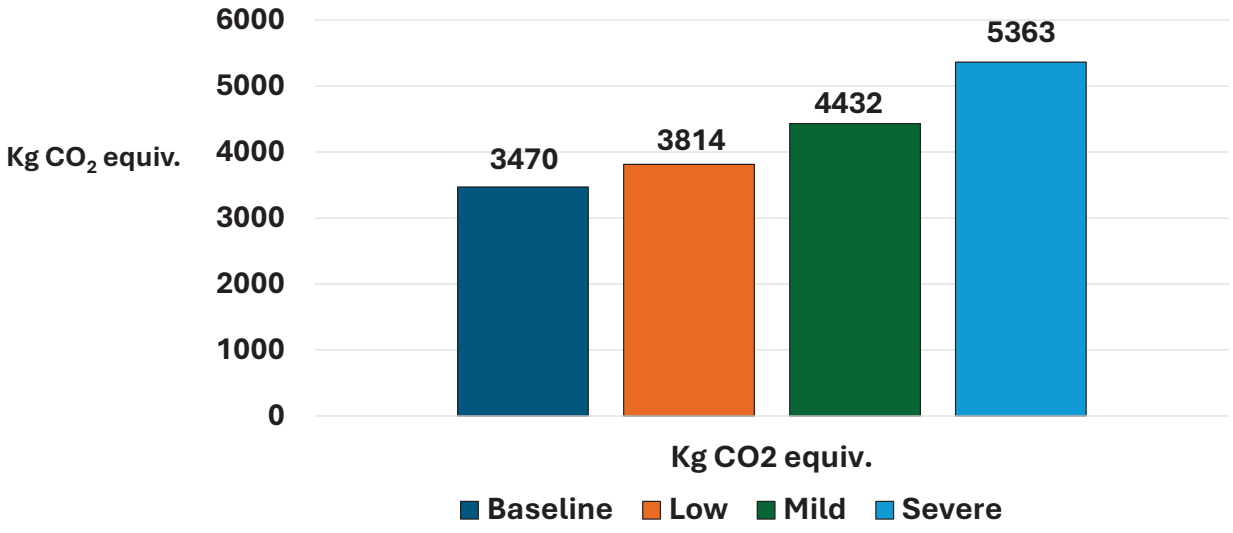
- 8% in CO_2 equiv. emissions
- 30% in N excretion
- 40% in P excretion
- 16% in SO_2 equiv. emissions (acidification)
- 13% in PO_4 equiv. emissions (eutrophication)
- 10% in feed cost

Llorens et al. (2024)





Impact of Mycoplasma hyopneumoniae infection on global warming potential in growing-finishing pigs

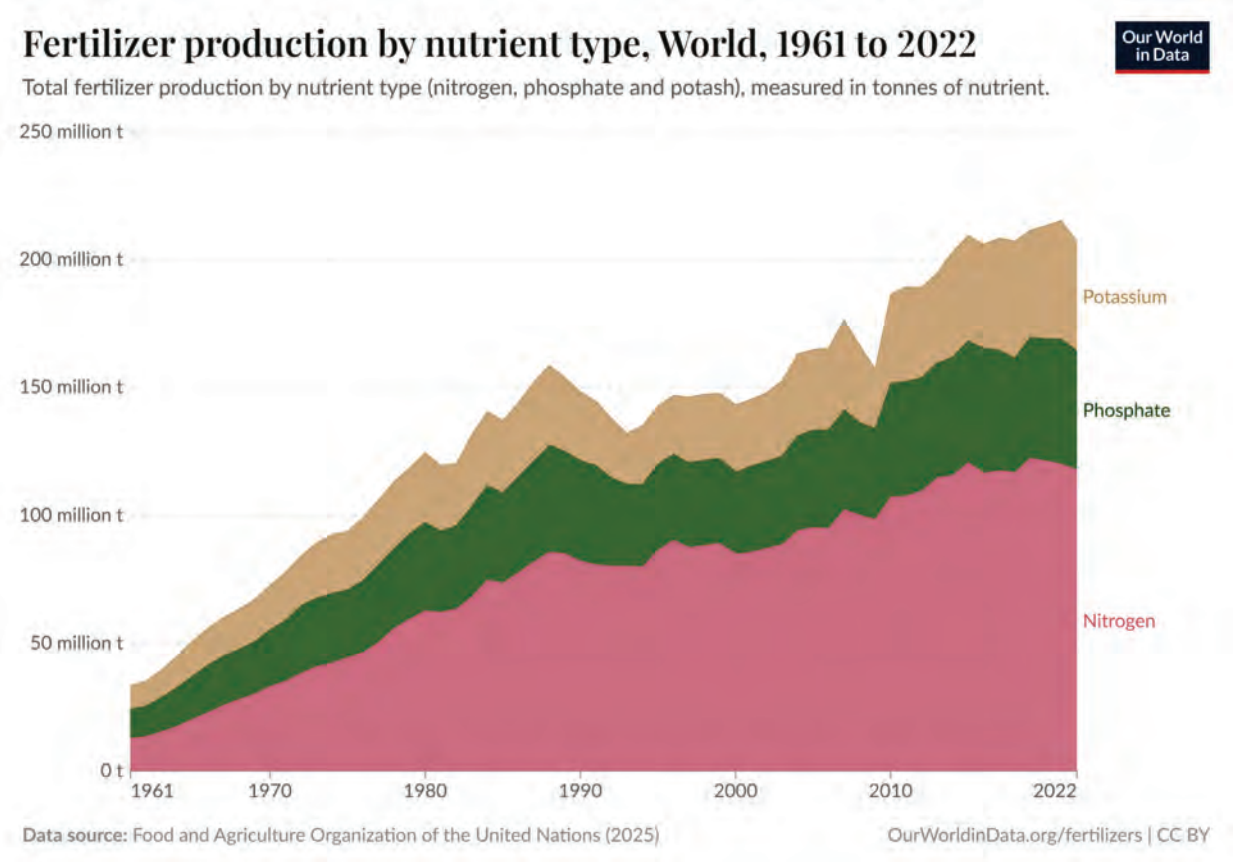


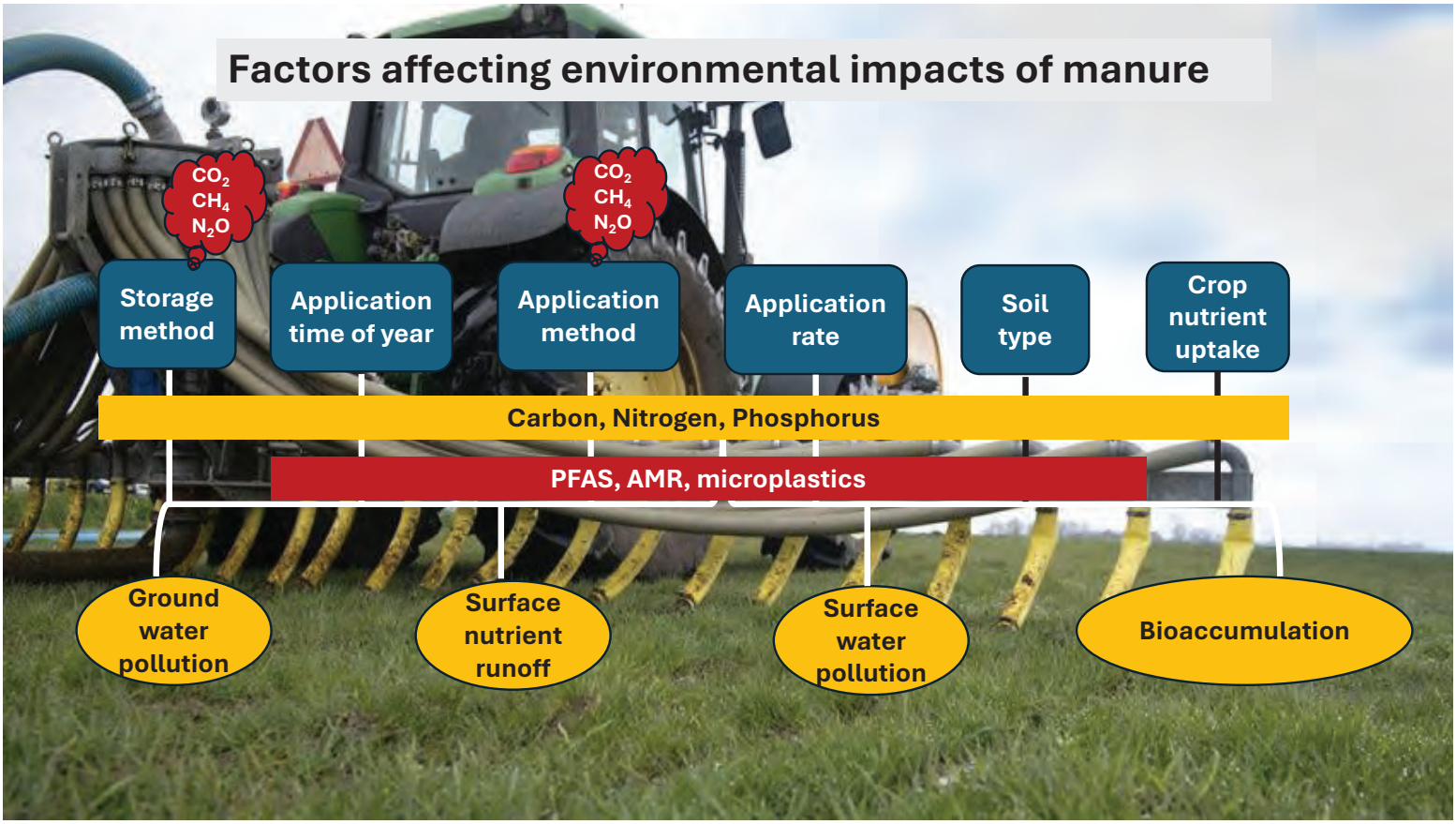
Krebs et al. (2025)

Strategic Use of Zinc Oxide

Manure volume and composition can be used to assess...

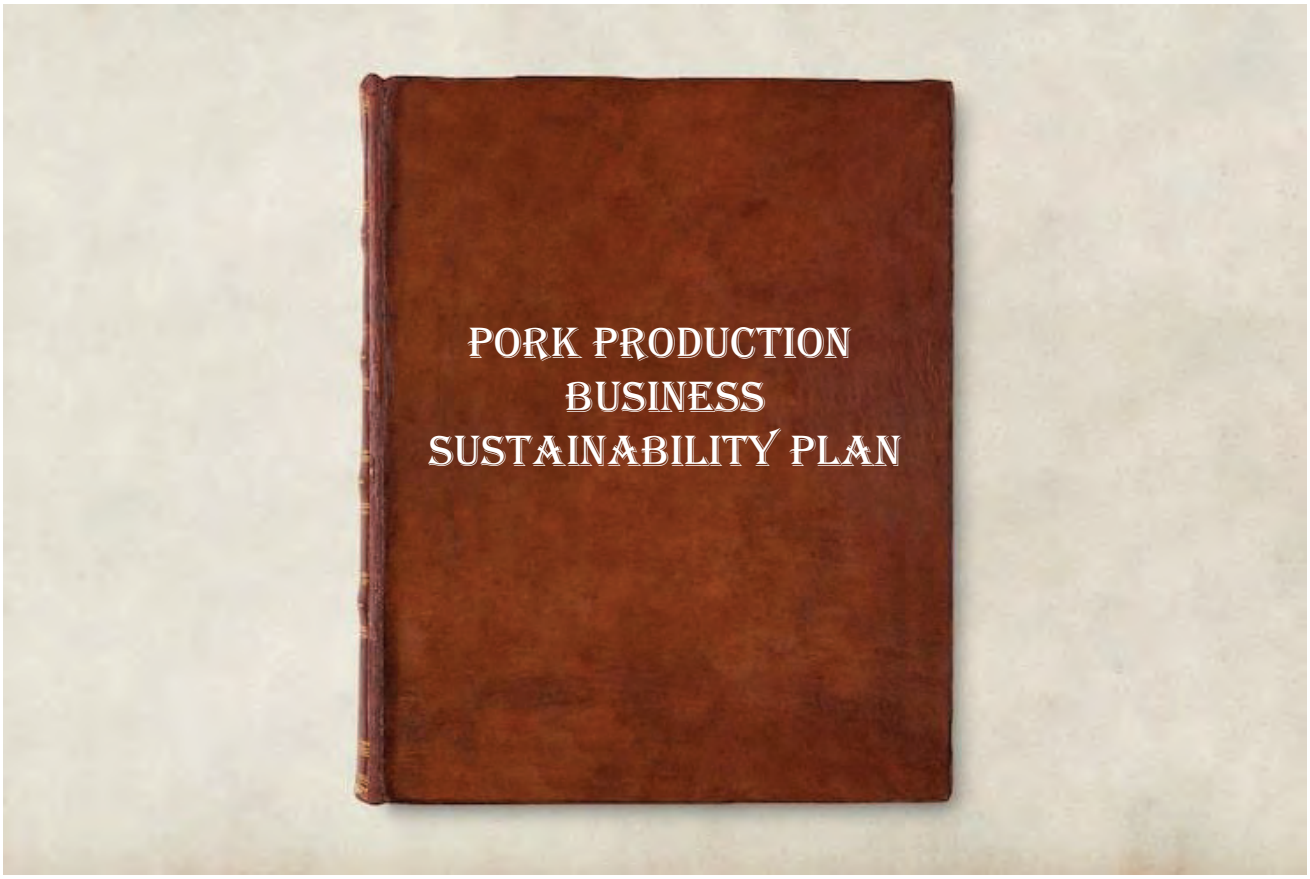
- N, P, C efficiency of diets and feeding programs
- Feed wastage
- Water use and wastage
- Antibiotic and zinc use
- Novel entities (microplastics and PFAS (forever chemicals)





RESPONSIBLE manure management is key for achieving sustainability and One Health goals

- Reduce GHG and odor emissions
  - Diet composition and digestibility
  - Manure storage type, application rate and method
- Circularity
  - Nitrogen, phosphorus, and carbon recycling
- Improve water quality and reduce scarcity
- Regenerate soils
  - Nutrients and organic matter
- Reduce fossil fuel reliance
  - Anaerobic digesters and biogas
  - Less dependence on synthetic fertilizer
- Minimize animal and human health concerns
  - Ammonia and hydrogen sulfide
  - Pathogen transmission
- Social responsibility in the community



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Each one of us has a responsibility to contribute toward making the world that we share healthier and more sustainable
How will you contribute?