Nutritional and Greenhouse Gas Impacts of Removing Animals from U.S. Agriculture

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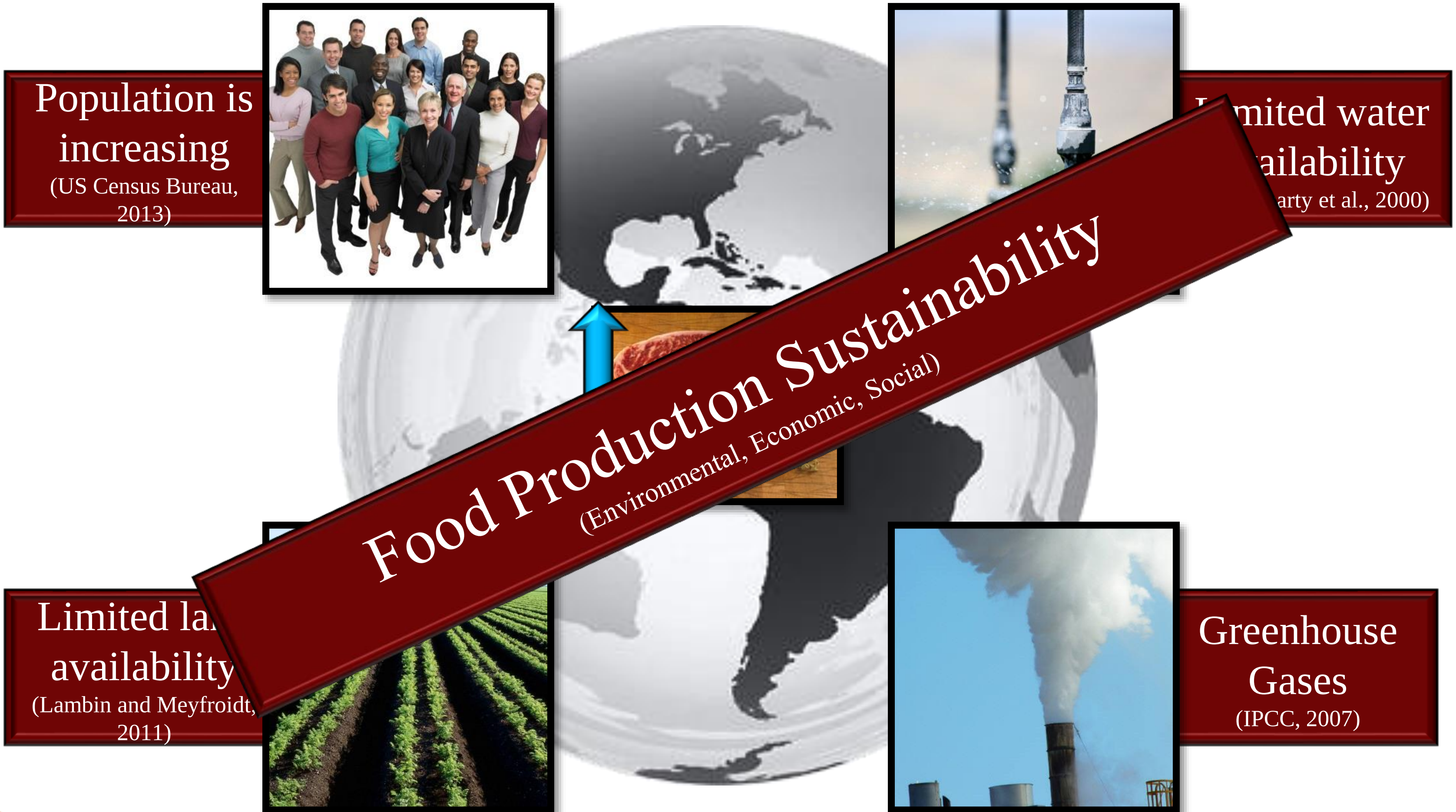
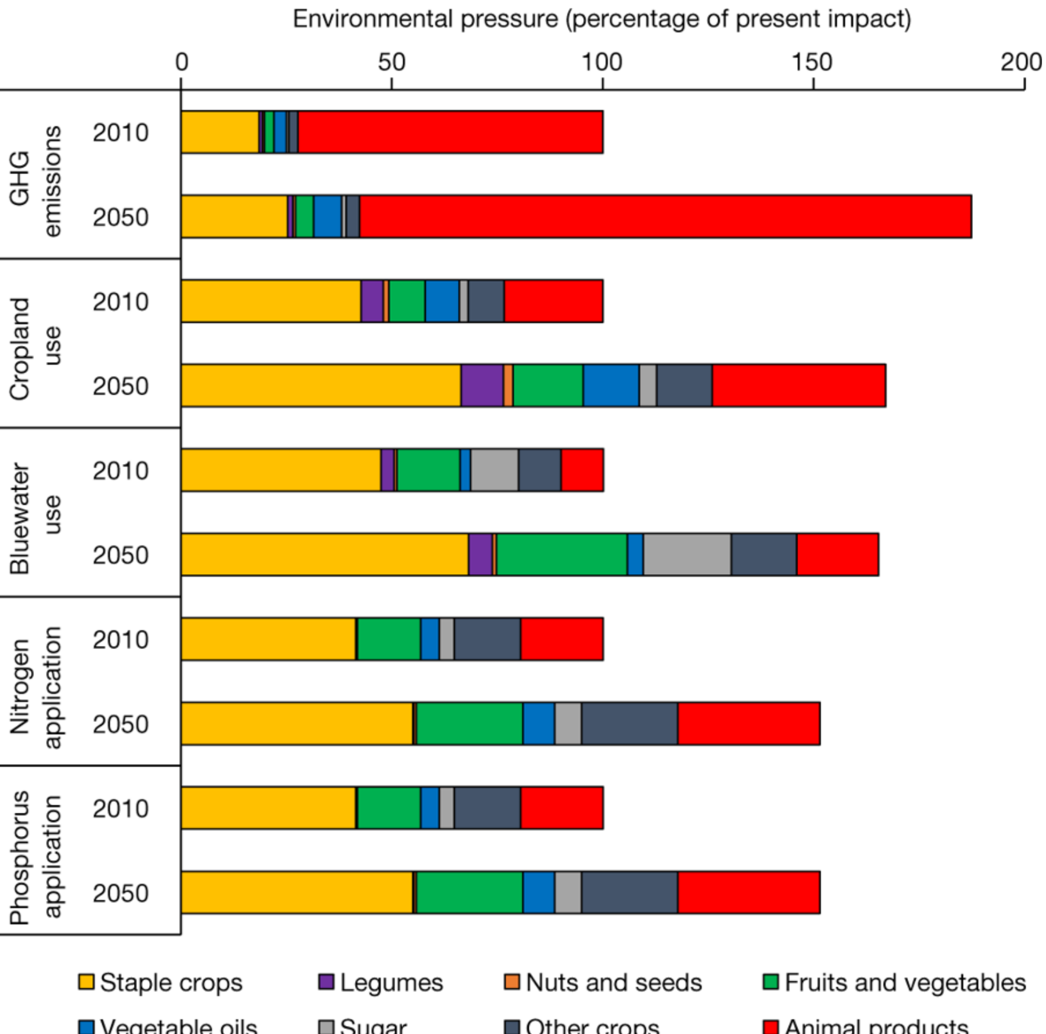
A Roadmap

- Global Trends
- Food Webs & Sustainability
- Our Research
- Next Steps

Why Focus on Sustainability?



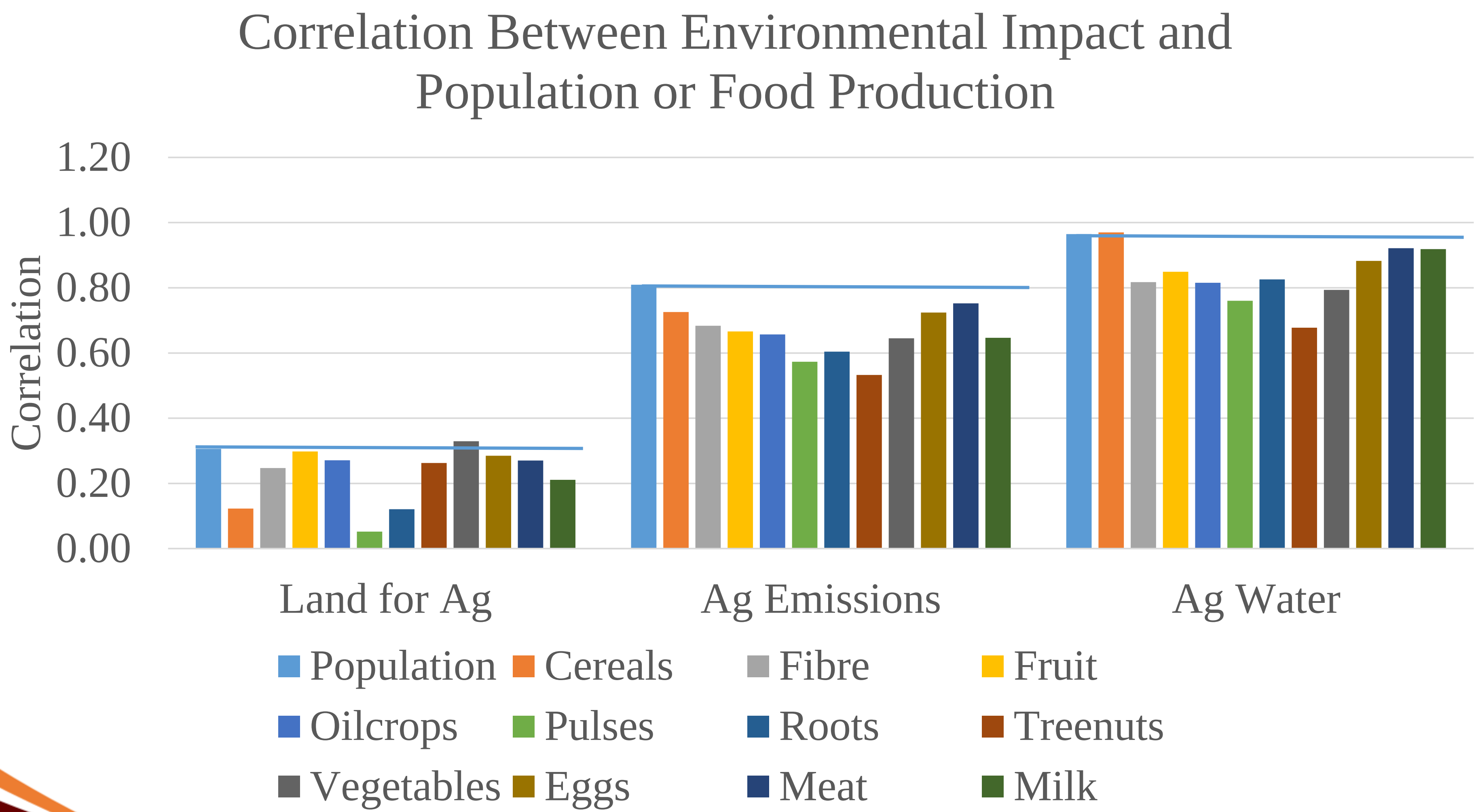
Animal Source Food Impacts the Environment



Specific food groups vary in their environmental impacts but animal production generates the majority of GHG emissions

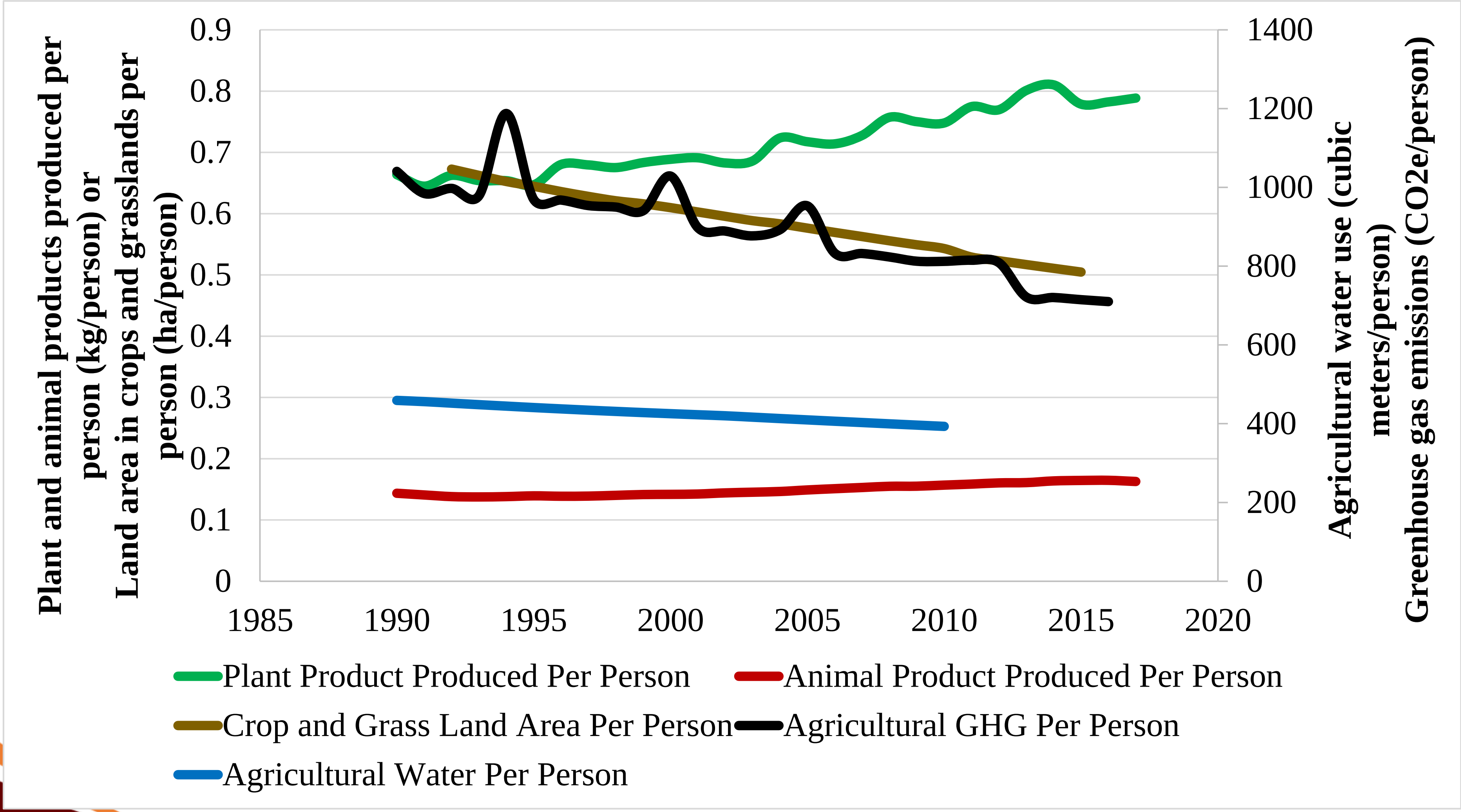
Springmann et al., 2018

Global System Drivers



Data from UN-FAO, downloaded Feb 2019

Global System Efficiency



Data from UN-FAO, downloaded Feb 2019

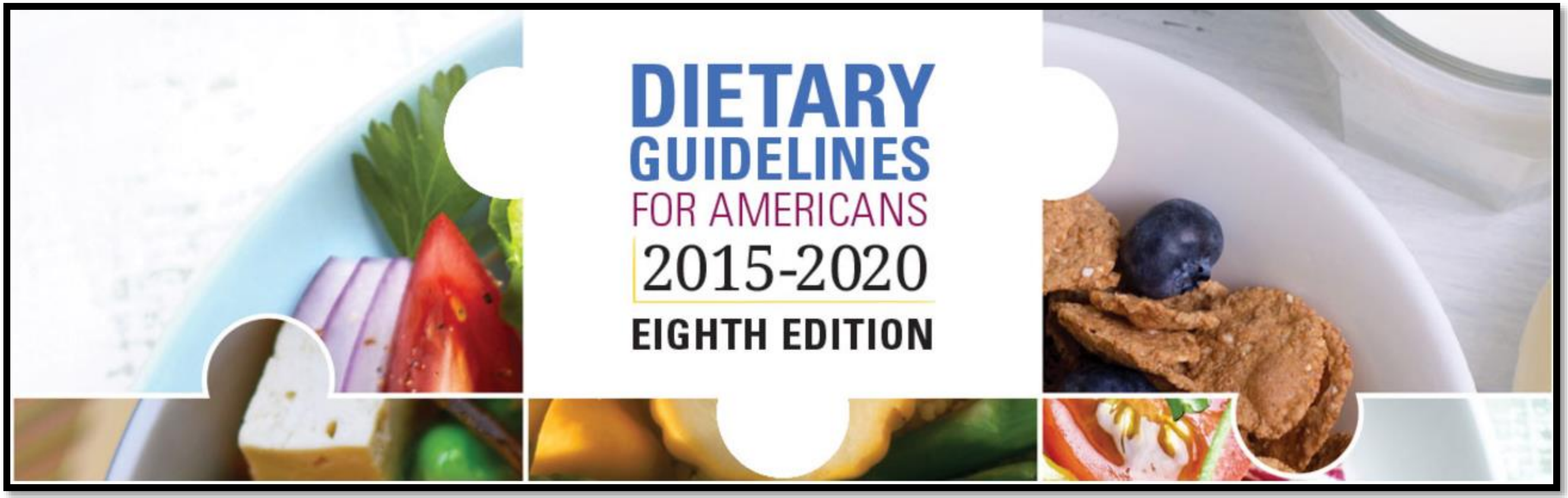
Where do we stand currently?

PLANETARY BOUNDARIES

Earth-system process	Parameters	Proposed boundary	Current status	Pre-industrial value
Climate change	(i) Atmospheric carbon dioxide concentration (parts per million by volume)	350	387	280
	(ii) Change in radiative forcing (watts per metre squared)	1	1.5	0
Rate of biodiversity loss	Extinction rate (number of species per million species per year)	10	>100	0.1-1
Nitrogen cycle (part of a boundary with the phosphorus cycle)	Amount of N_2 removed from the atmosphere for human use (millions of tonnes per year)	35	121	0

Cropped Table from Rockstrom et al., 2009

Policy Responses



Based on review of the available literature, the 2015 Dietary Guidelines Advisory Committee claimed that plant-based diets would promote health and improve long-term sustainability of the U.S. food supply

Livestock In The News

Planetary diet: Save the planet and lives by eating less meat, more vegetables

Meat is unhealthy both for the people who eat too much of it and for the planet, the report says.

Food in the Anthropocene: the EAT–*Lancet* Commission on healthy diets from sustainable food systems

Published: January 16, 2019

The Lancet: Diet and food production must radically change to improve health and avoid potentially catastrophic damage to the planet

Feeding a growing population of 10 billion people by 2050 with a healthy and sustainable diet will be impossible without transforming eating habits, improving food production, and reducing food waste.

THE LANCET

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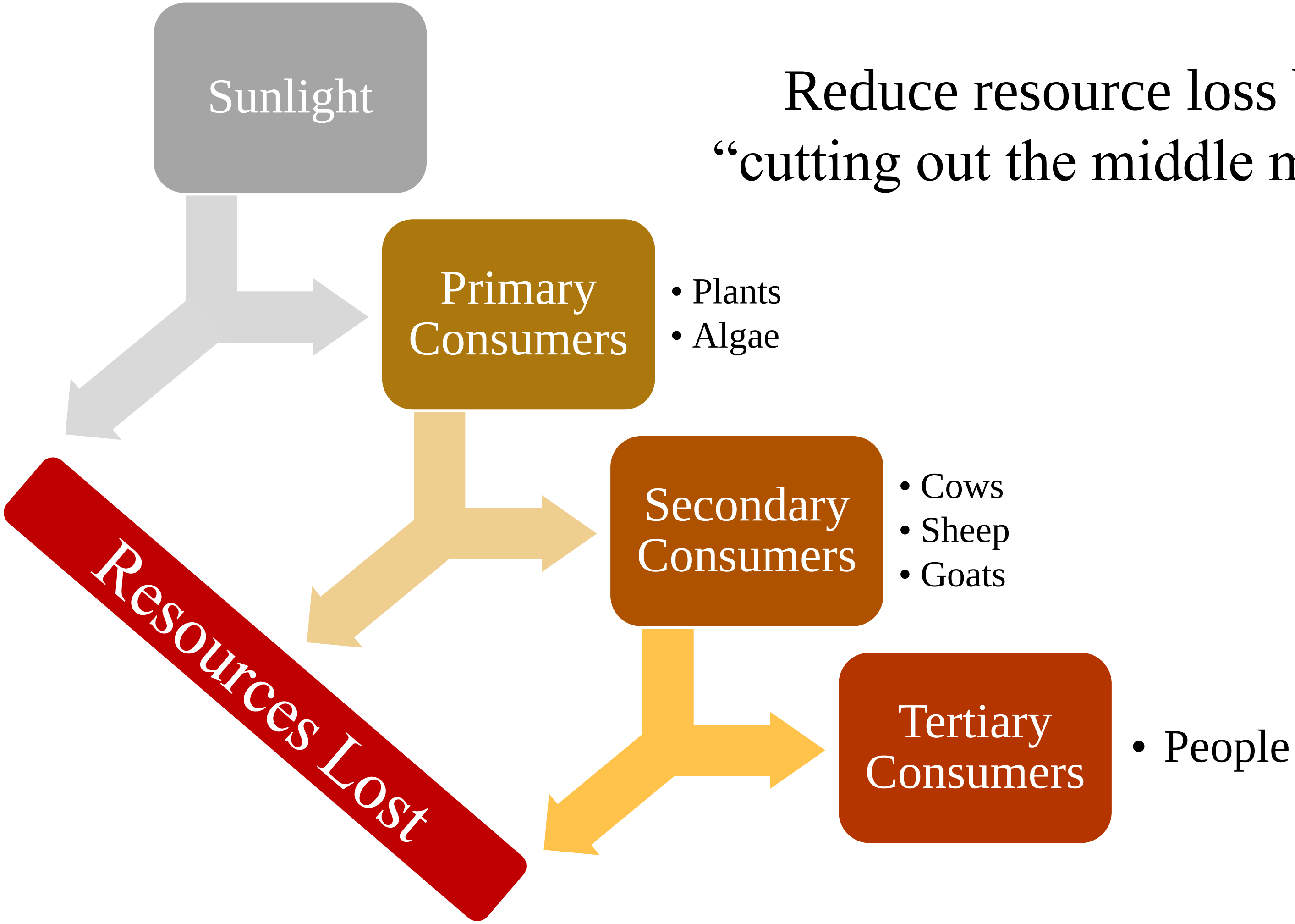
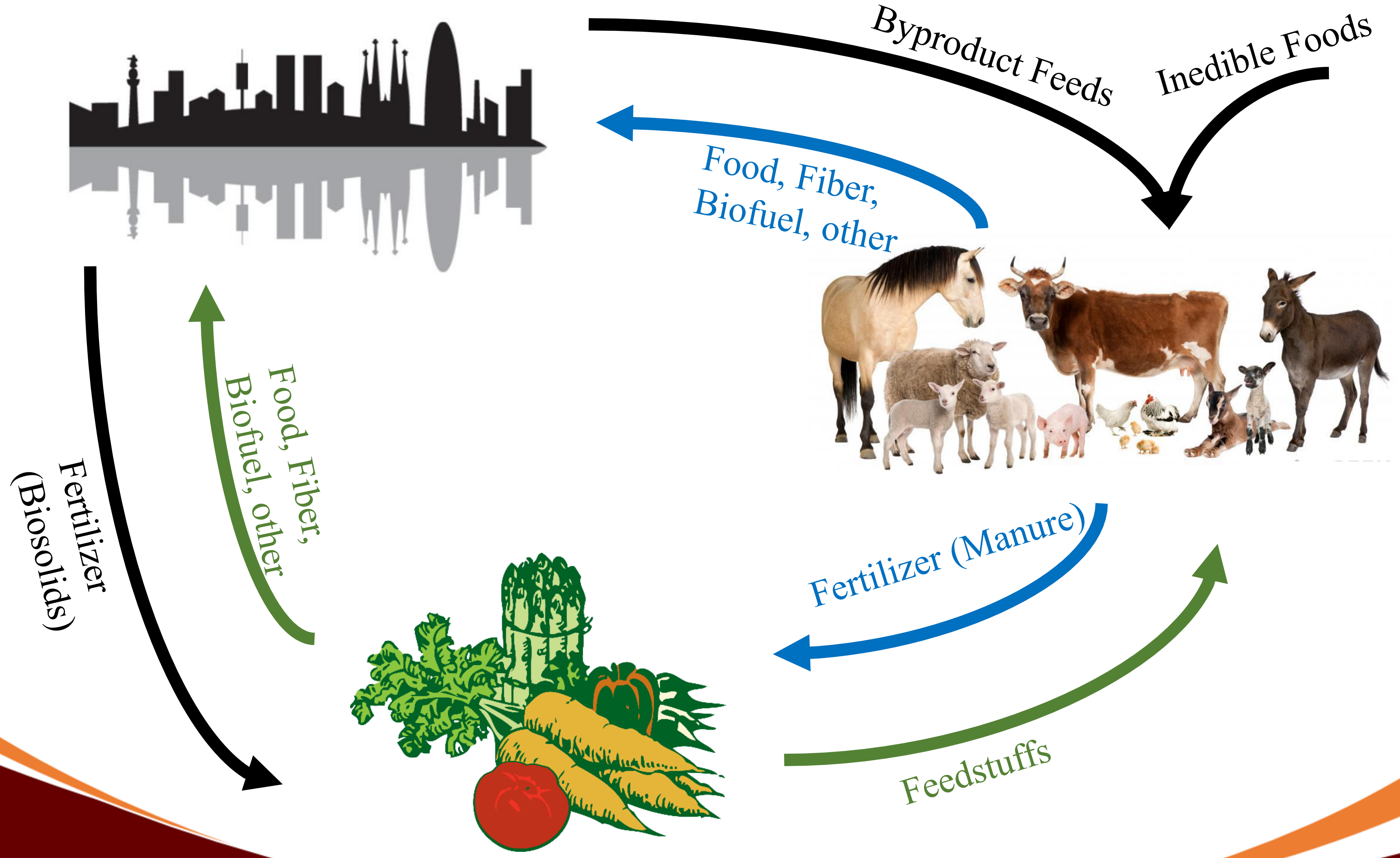
Food Webs: Balance is Essential for Sustainability



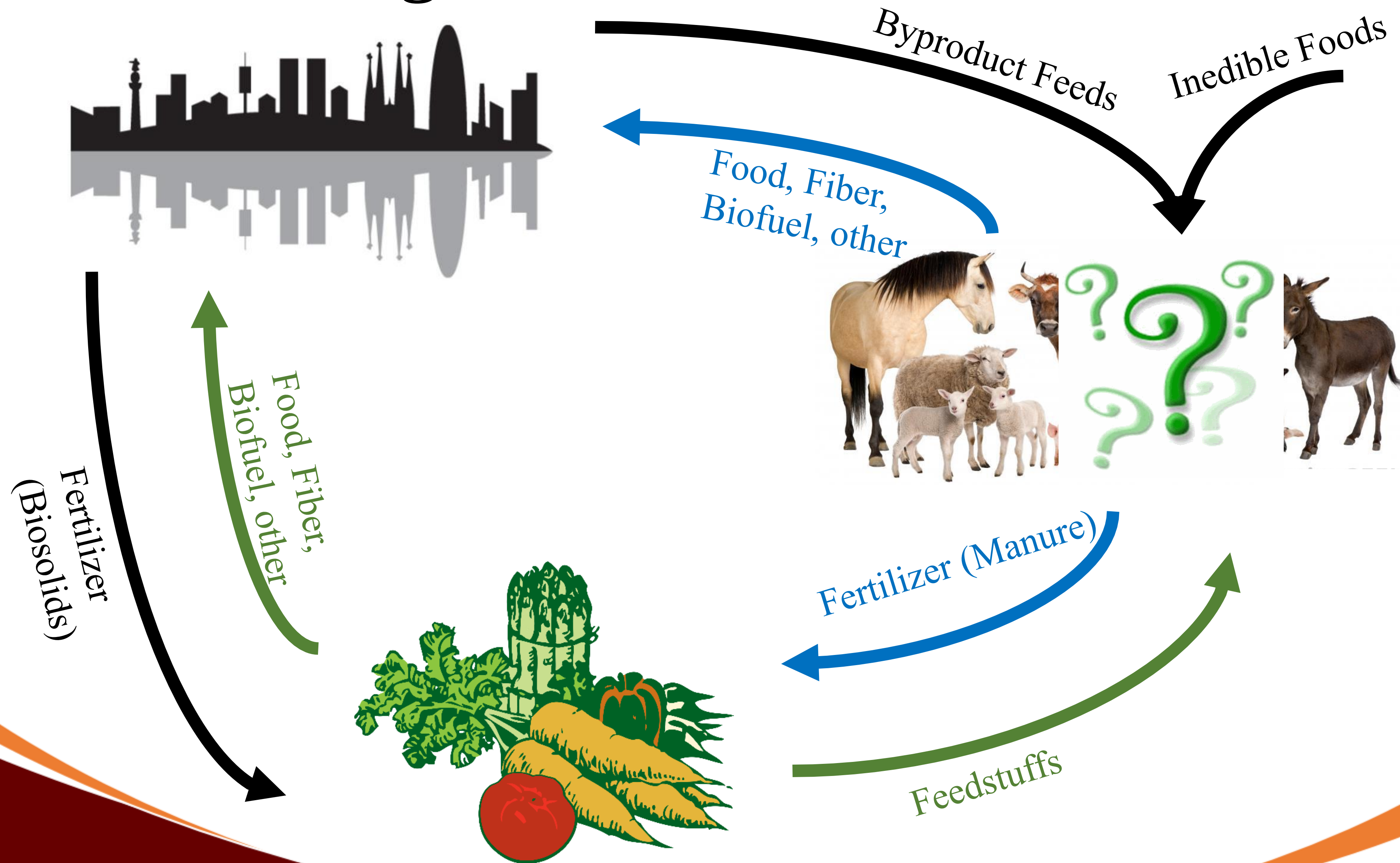
Reduce resource loss by “cutting out the middle man”?

A Slightly More Complex Picture



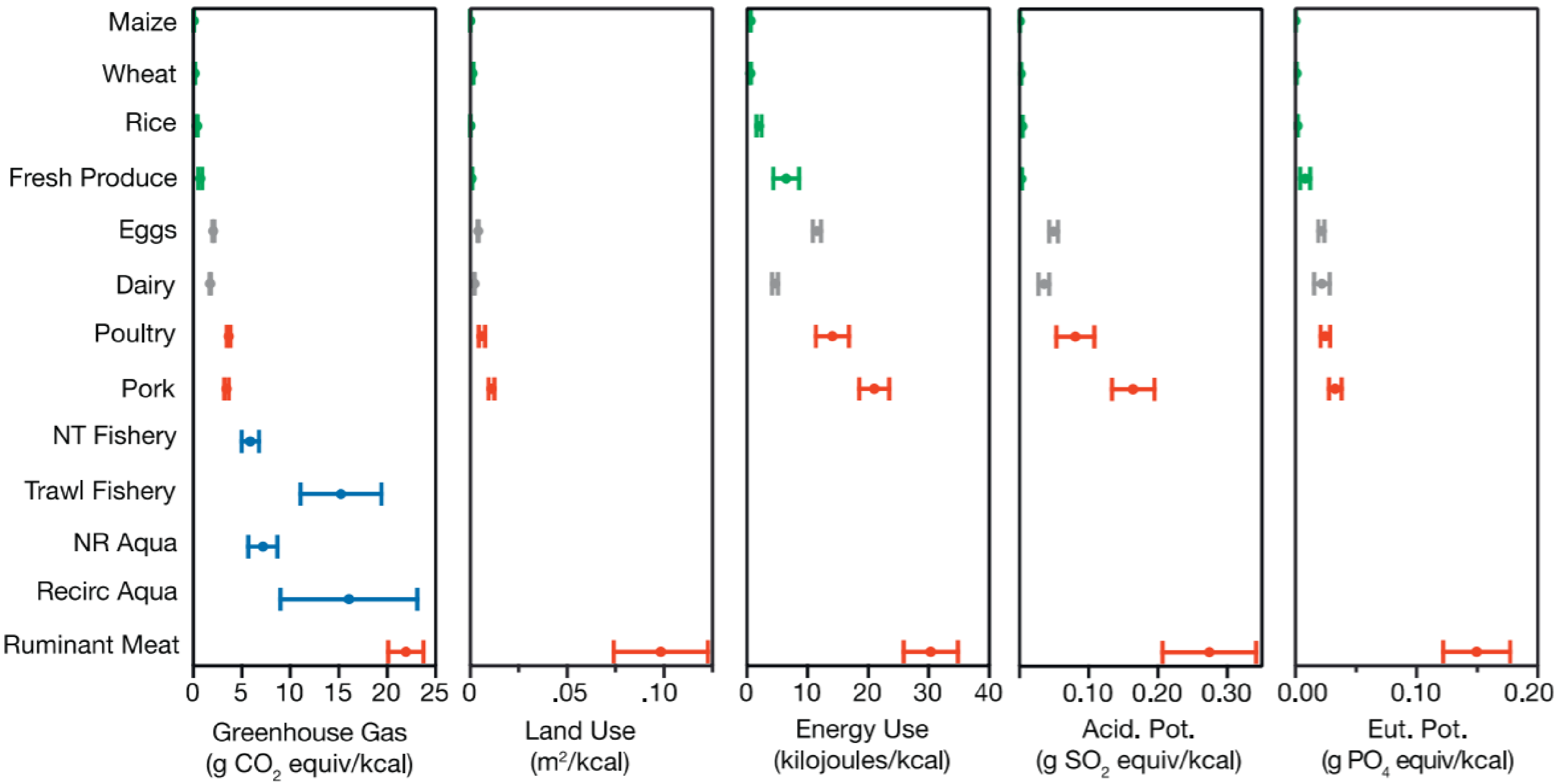
Van Horn and Hall, 1997

What happens when one part of the web changes?



A substitution example

Do humans obtain the same utility from a kg of maize and a kg of beef?



Clark and Tilman, 2017

A diet example

	Macronutrient intake (possible range), g/day
Whole grains*	
Rice, wheat, corn, and other†	232 (total gains 0–60% of energy)
Tubers or starchy vegetables	
Potatoes and cassava	50 (0–100)
Vegetables	
All vegetables	300 (200–600)
Dark green vegetables	100
Red and orange vegetables	100
Other vegetables	100
Fruits	
All fruit	200 (100–300)
Dairy foods	
Whole milk or derivative equivalents (eg, cheese)	250 (0–500)
Protein sources‡	
Beef and lamb	7 (0–14)
Pork	7 (0–14)
Chicken and other poultry	29 (0–58)
Eggs	13 (0–25)
Fish§	28 (0–100)
Legumes	
Dry beans, lentils, and peas*	50 (0–100)
Soy foods	25 (0–50)
Peanuts	25 (0–75)
Tree nuts	25
Added fats	
Palm oil	6·8 (0–6·8)
Unsaturated oils¶	40 (20–80)
Dairy fats (included in milk)	0
Lard or tallow‖	5 (0–5)
Added sugars	
All sweeteners	31 (0–31)

Willett et al., 2019

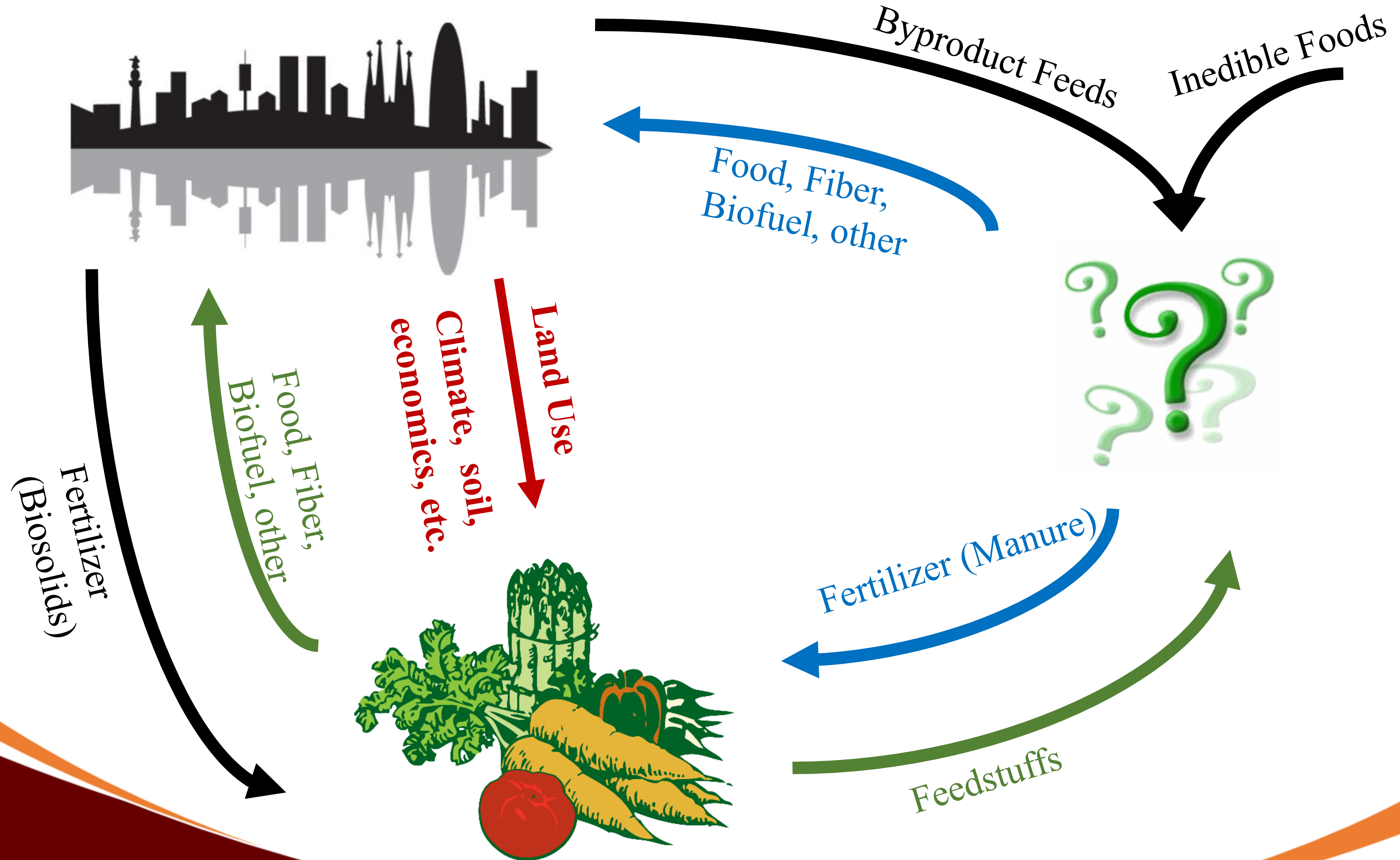
A diet example

Food Type	EAT-Lancet	
	g/d	% Used[1]
Grains	232	28
Tubers	50	21
Vegetables	300	100
Fruit	200	84
Dairy	250	113
Meat (Red + Poultry)	43	47
Eggs	13	55
Fish	28	
Legumes	50	380
Nuts	25	586
Oils	52	
Sweeteners	31	

[1]% Used refers to the percentage of current production (FAOStat, 2019) that would need to go for human consumption if 10 billion people consumed this average diet.

Can the agricultural system sustain this increase in legume and nut production globally?

What are other practical challenges here?



What CAN the food web support?

Nature's Recycler – *Producing High Quality Human-Edible Protein from Human-Inedible Fiber*

Wasteful Extravagance – *Degrading Natural Resources and Producing Unhealthy Foods*

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Publication Information…

PNAS PLUS

Nutritional and greenhouse gas impacts of removing animals from US agriculture

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http://www.pnas.org/content/114/48/E10301.abstract

Only one way of looking at the problem
Only looking at the U.S. system
Asking – How should we ask these questions?

Objective 1

Quantify the impact of animal agriculture to U.S. society by evaluating nutrient and GHG changes when animals are removed from U.S. agriculture

Modeling Total Removal of Livestock

- Fewest assumptions.
- Sets a bound for all other interventions.
- Modelled with freely available data.
- No outside funding.

Data Sources

- USDA-Economic Research Service
- USDA-National Agricultural Statistics Service
- USDA Food Composition Database
- Published life cycle analyses
- U. S. Census of Agriculture
- UN Food and Agriculture Organization (FAO)
- US Food and Drug Administration (FDA)
- US Environmental Protection Agency
- Other published data

Methods: Nutrient Balance

Population Weighted-Average Nutrient Requirements

Domestic Supply of 39 Nutrients from 121 Foods

A Simulated System Without Animals

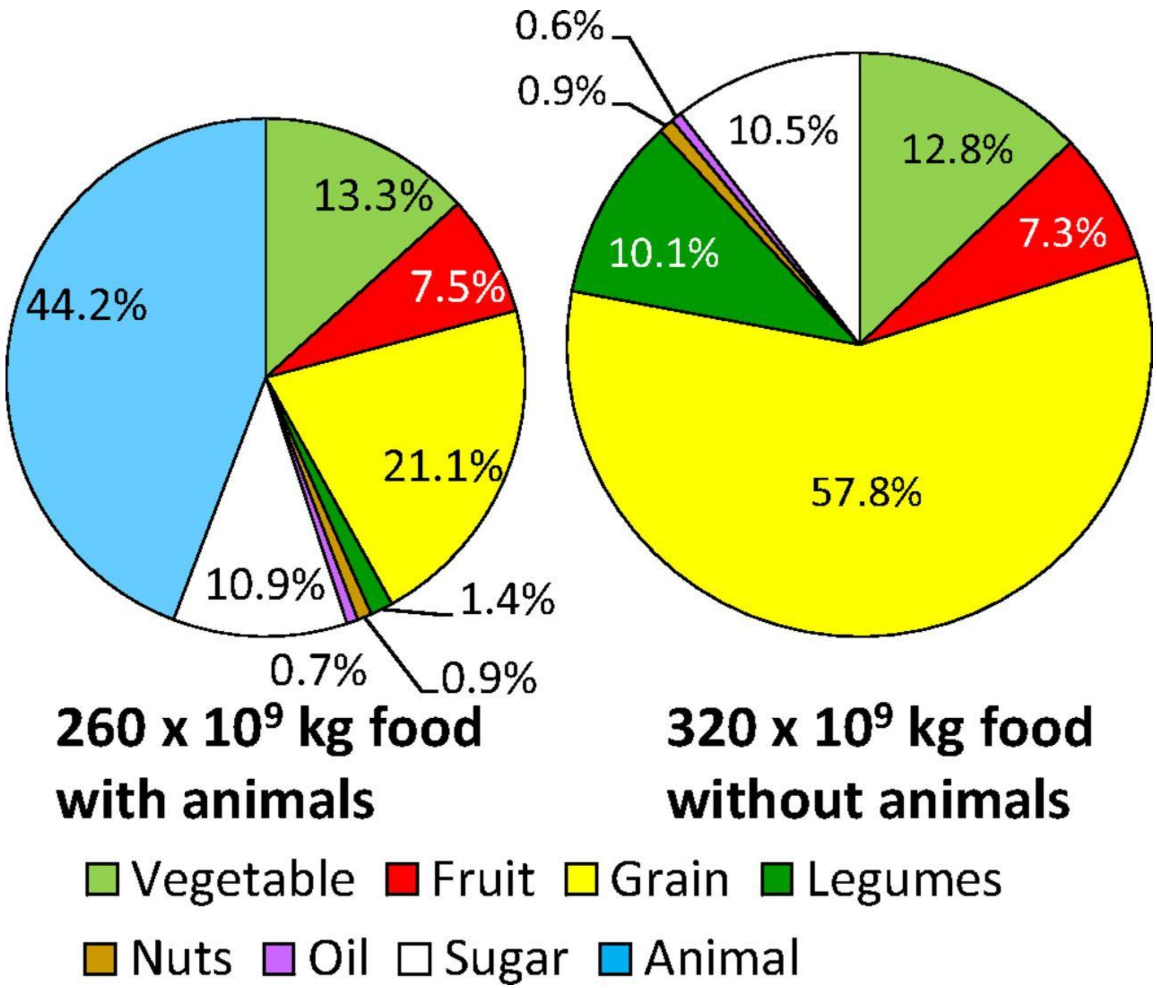
Changes

- Cropable pasture land, hay, and silage land were converted to human food production assuming the current ratio of land use for human edible crops was maintained.
- Grains and human-edible byproducts currently consumed by animals were repurposed for human consumption.
- Fertilizer previously produced by livestock was not available and would need to be commercially synthesized.
- Excess food processing byproducts would be combusted.

Results: Proportions of Food Produced

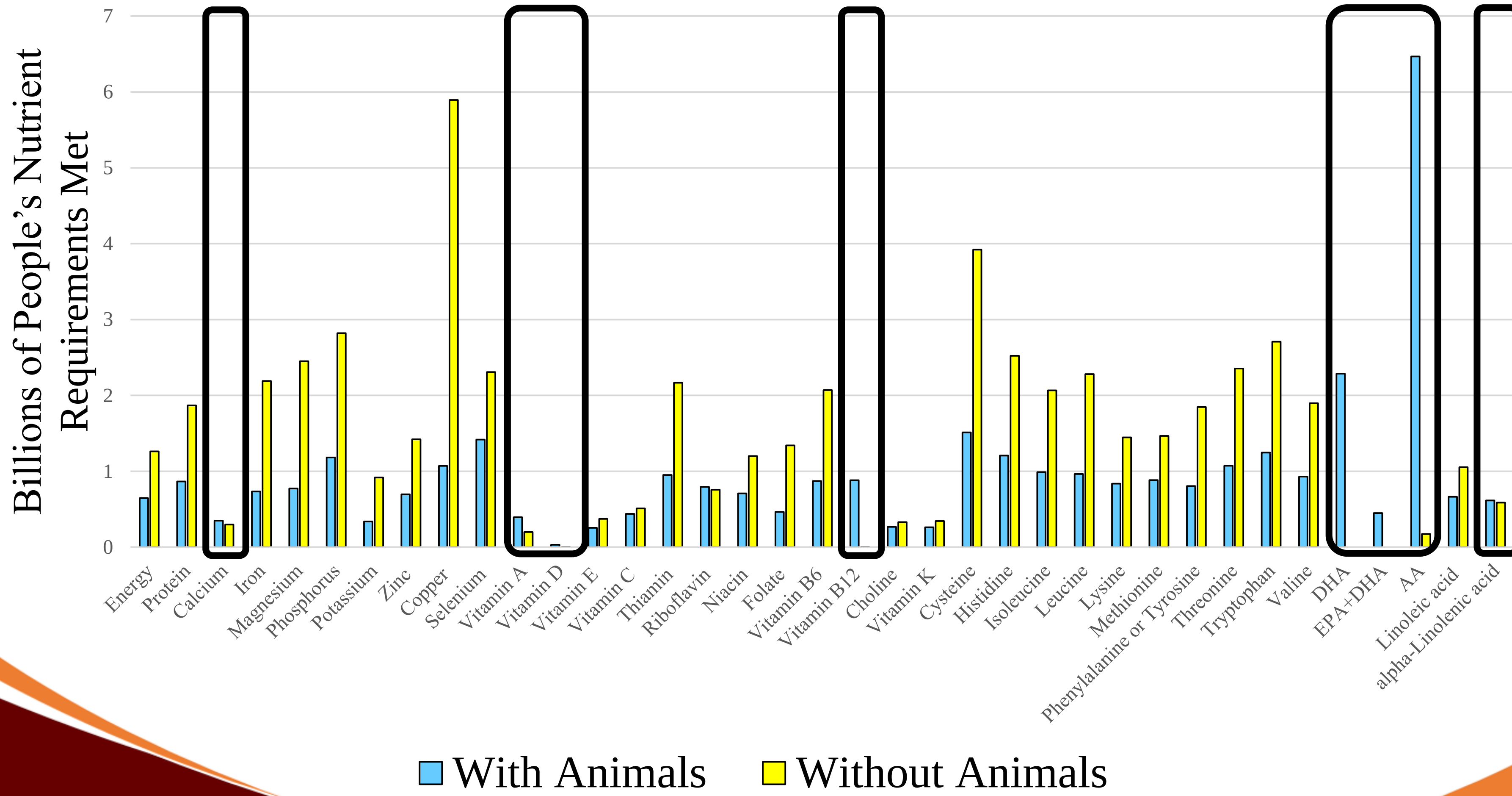
Plants-only system:

- Food production increased 23%, primarily as grain.
- Grain: 77% corn.
- Legumes: 92% soy and soy flour.

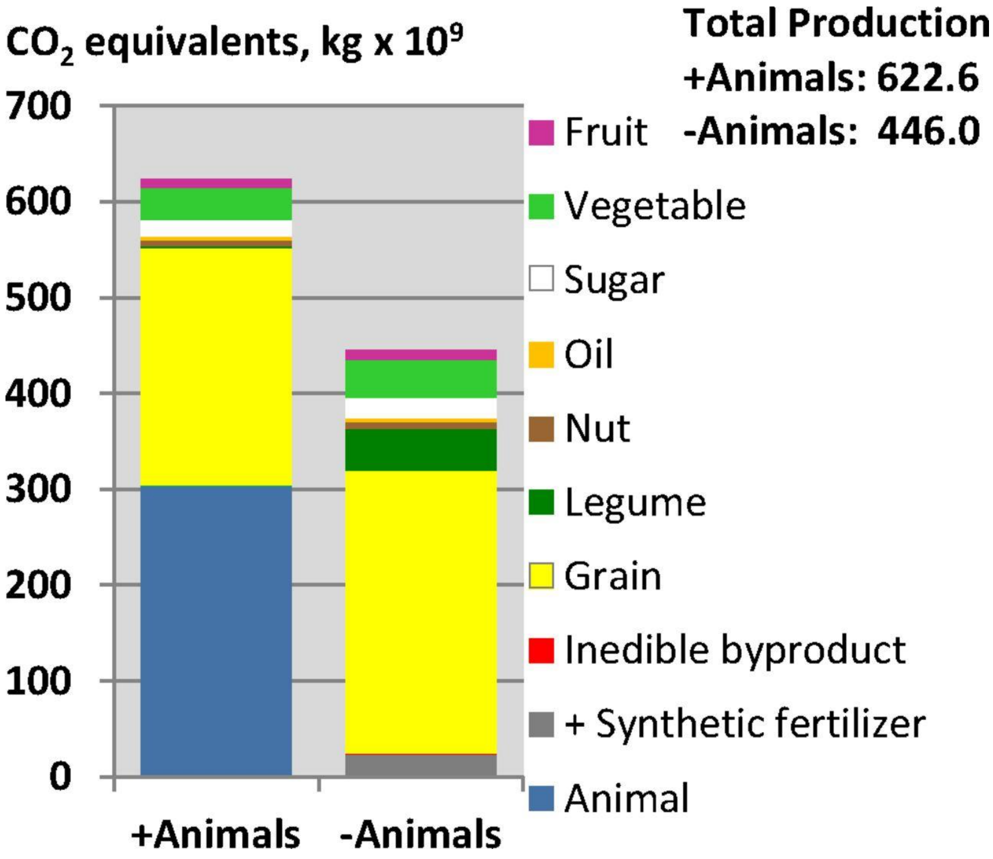


Results: Individual Nutrient Supplies

Reduced domestic production of Calcium, Vitamin A, Vitamin D, Vitamin B12, DHA, EPA, AA, alpha-linolenic acid



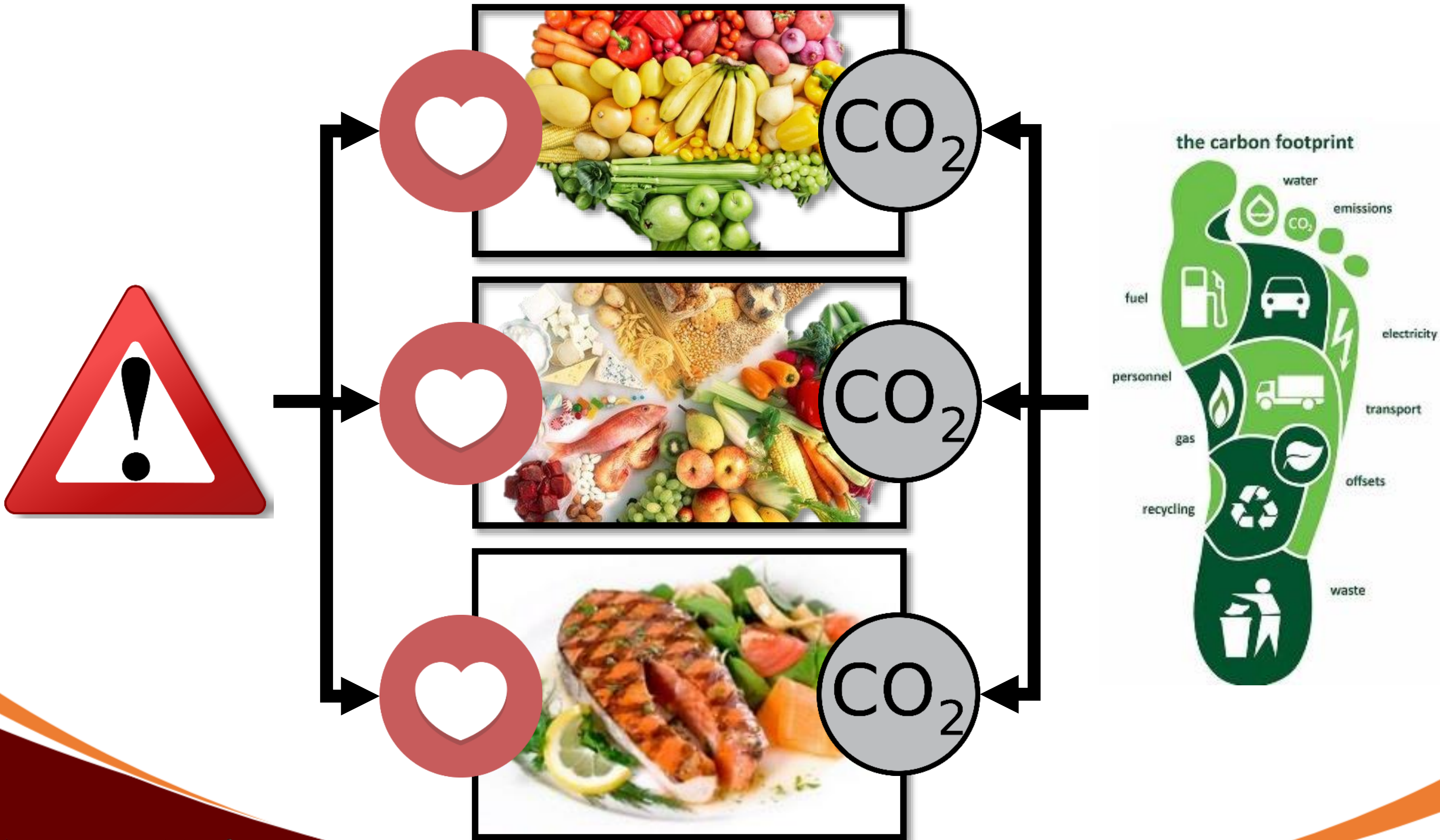
Results: Greenhouse Gas



Plants-only system:

- Agricultural GHG ↓ 28%, but not the ~50% associated with animals.
- Counterbalanced by fertilizer synthesis & all land now allocated to food production.
- US National GHG ↓2.6%.

How does this pertain to human diets?



Objective 2:

How do least-cost diets balanced for humans differ when animal products are not available, following the assumption we must feed the entire population, not just a subset of it.

Methods: Nutrient Planning

Population Weighted-Average Nutrient Requirements

Domestic Supply of 39 Nutrients from 121 Foods

Optimization

M
I
N
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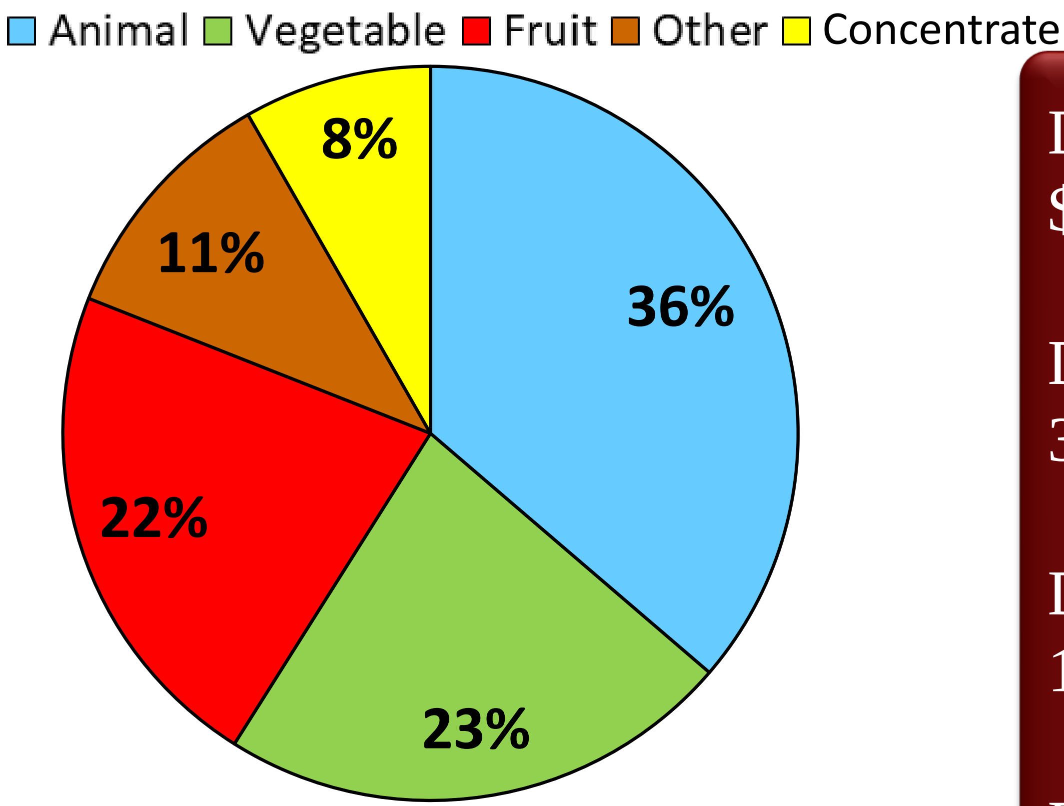
M
I
Z
E

Adjust daily intake of different feed ingredients to minimize daily ration cost, $/person/d

s.t. Constraints:

- Nutrient requirements must be satisfied
- Total U.S. population intake must not exceed domestic production + imports

What do U.S. Citizens Currently Eat?



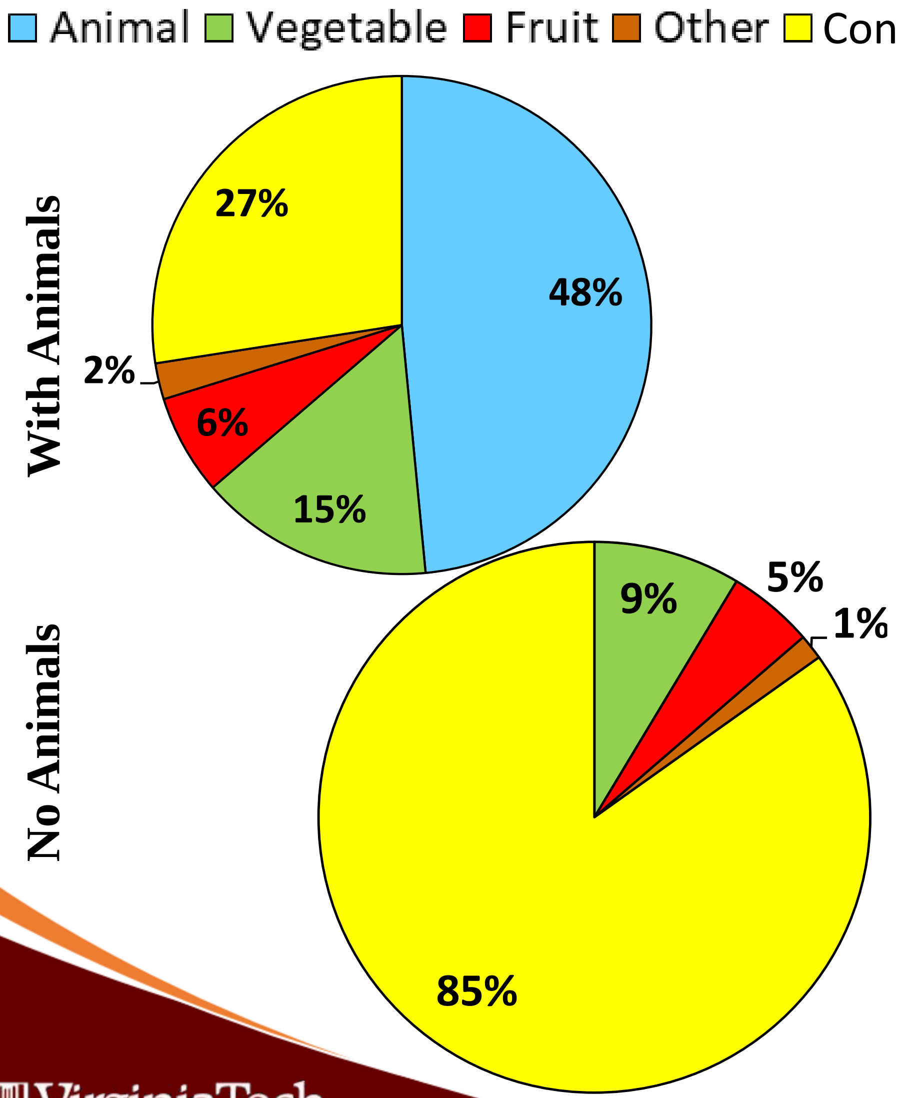
Daily Diet Cost:
$4.00/person/d

Daily C-Footprint:
3.29 kg CO_2e/person/d

Daily As-Fed Intake:
1.49 kg/person/d

Daily DM Intake:
0.45 kg/person/d

Results: Least Cost Rations for Humans



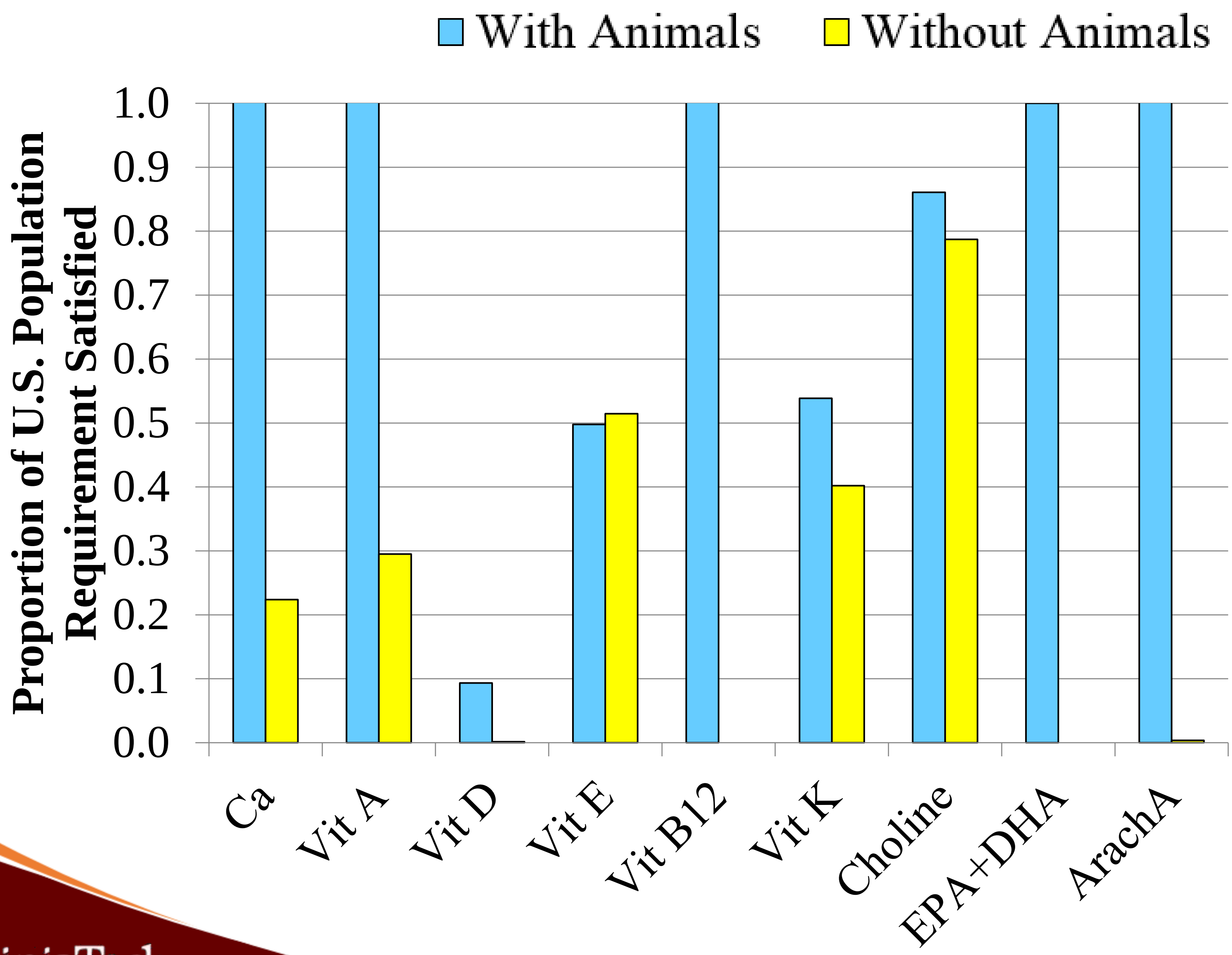
Daily Diet Cost:
$2.81 vs $2.05/person/d

Daily C-Footprint:
1.43 vs 0.95 kg CO_2e/person/d

Daily AF Intake:
1.75 vs 2.05 kg/person/d

Daily DM Intake:
0.63 vs 1.2 kg/person/d

Results: Nutrient Sufficiency of Rations



Plants-Only: Nutrient Deficiency

<u>Does this mean all vegetarian diets are deficient?</u>

- No, entirely possible to formulate balanced vegetarian diets.
- BUT: plants do not have, or have low concentrations of some nutrients.

Long Chain Fatty Acids

<u>Omega-3: EPA & DHA</u>
Infants: Cognitive & visual development
Adults: Cardiovascular health

<u>Omega-6: Arachidonic</u>
Infants: Visual acuity

<u>Calcium</u>
Bone, electrolyte, milk
Many physiological functions

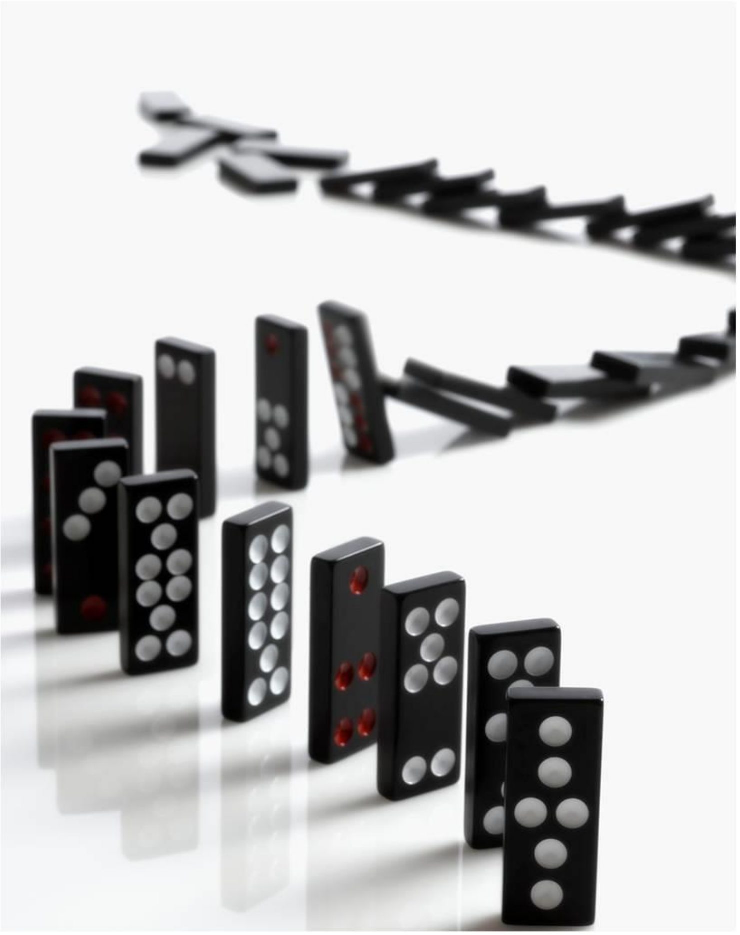
<u>Vitamin B12</u>
Brain & nervous system
Red blood cell formation

Ca --Weaver et al., 1999

Take Home Messages…

A change in the system for one purpose has collateral impacts:

- More total food.
- More nutrient deficiencies & excess calories.
- No resemblance to studied vegan diets.
- Small national GHG decline.



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"Essentially, all models are wrong, but some are useful."

Box and Draper, 1987

Not Considered

- Nutrient bioavailability
- Waste
- Nonfood products: alternatives
- Supplement: production & supply
- Life cycle analysis applicability
- Nonlinearity
- Economic impact
- Non-GHG impact
- Cropping viability

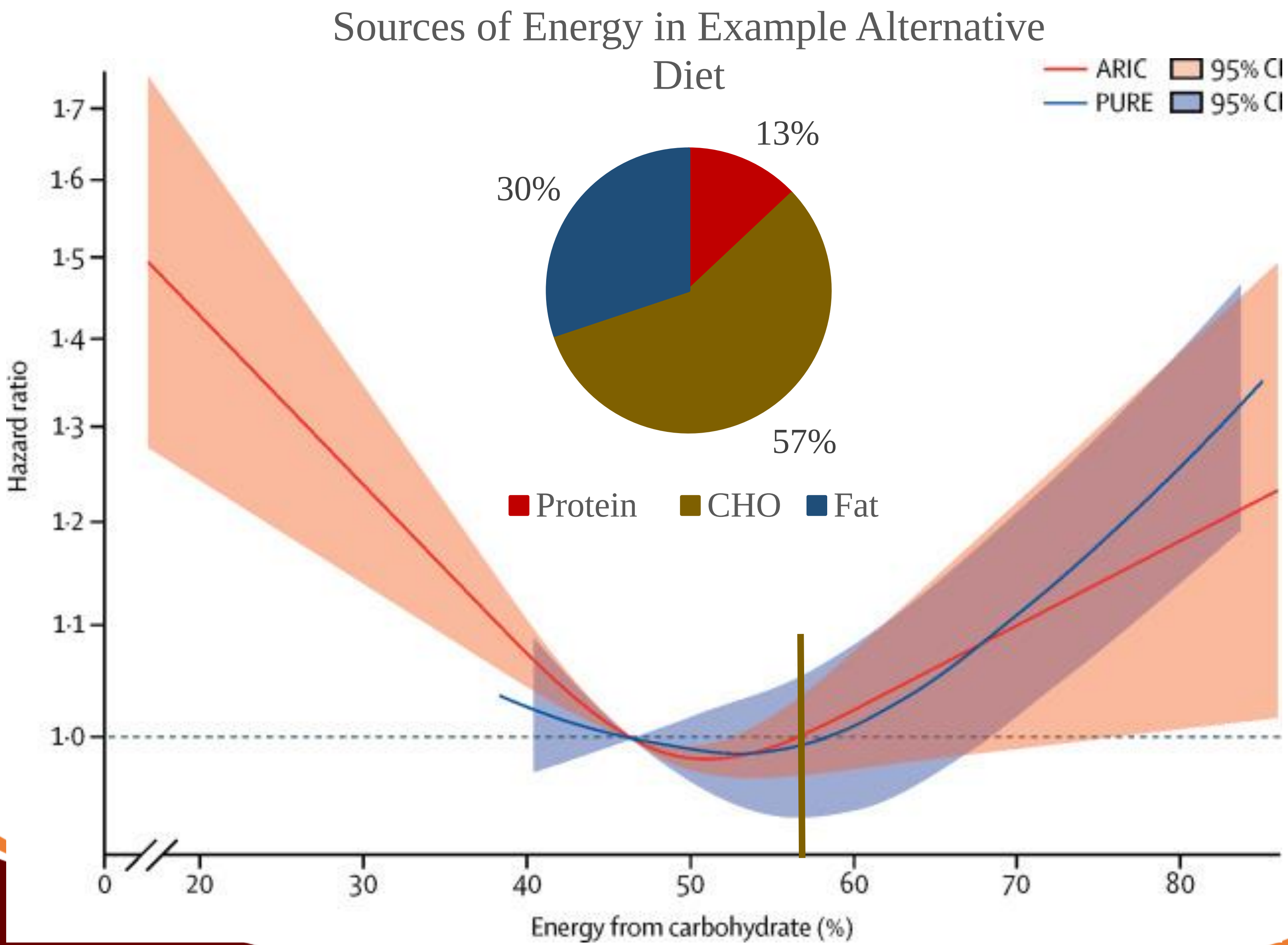
The Importance of Considering Waste…

Food Type	EAT-Lancet		Example Alternative	
	g/d	% Used[1]	g/d	% Used
Grains	232	28	232	28
Tubers	50	21	100	41
Vegetables	300	100	300	100
Fruit	200	84	200	84
Dairy	250	113	220	100
Meat (Red + Poultry)	43	47	90	98
Eggs	13	55	23	96
Fish	28		28	
Legumes	50	380	25	95
Nuts	25	586	4	94
Oils	52		52	
Sweeteners	31		31	

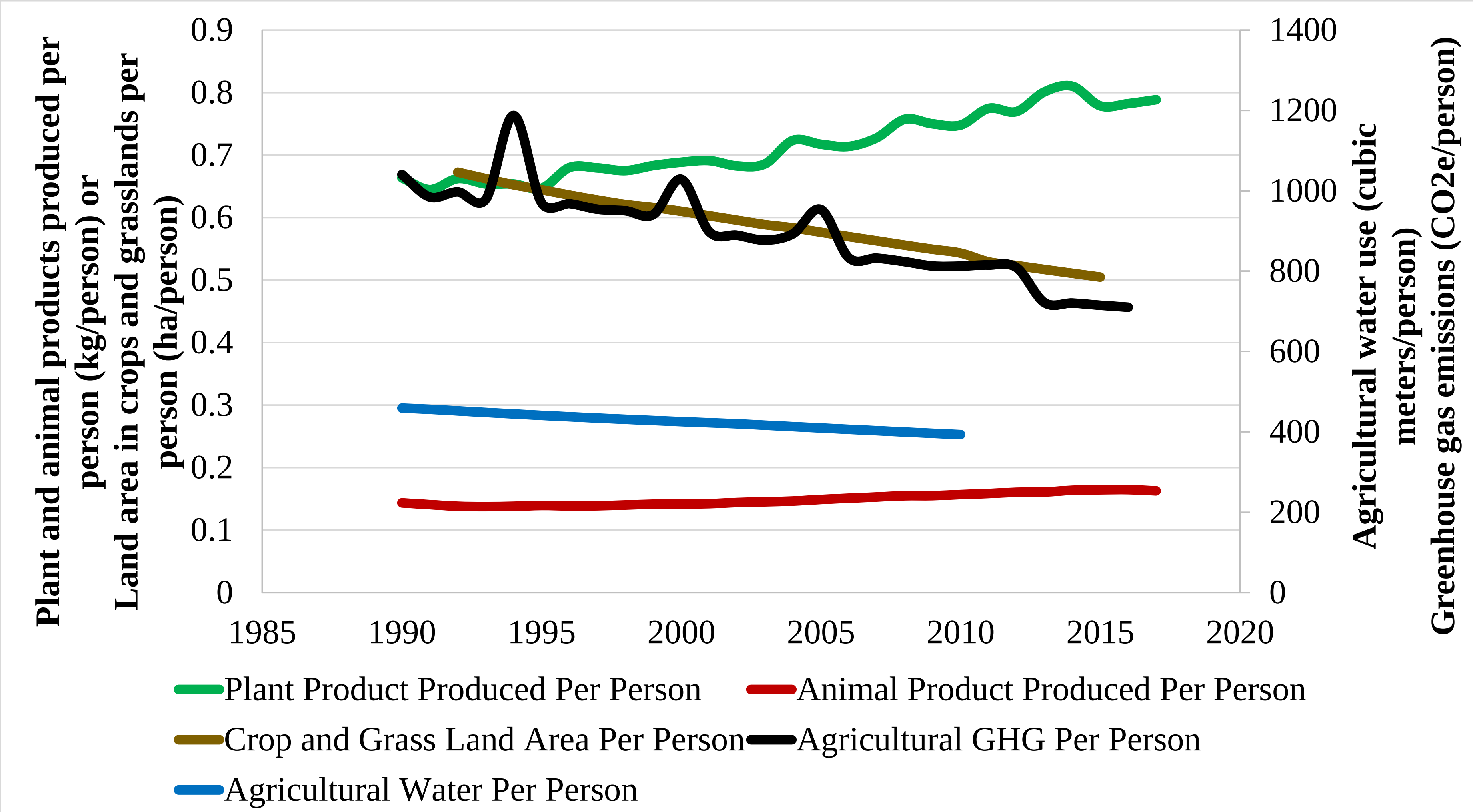
[1]% Used refers to the percentage of current production (FAOStat, 2019) that would need to go for human consumption assuming a population of 10 billion people.

We currently produce enough food to feed 10 billion people with select nutrient deficiencies (Ca, K, Choline)

Is that a healthy diet?



A different question:
How do we continue these trends?



Data from UN-FAO, downloaded Feb 2019

Questions?

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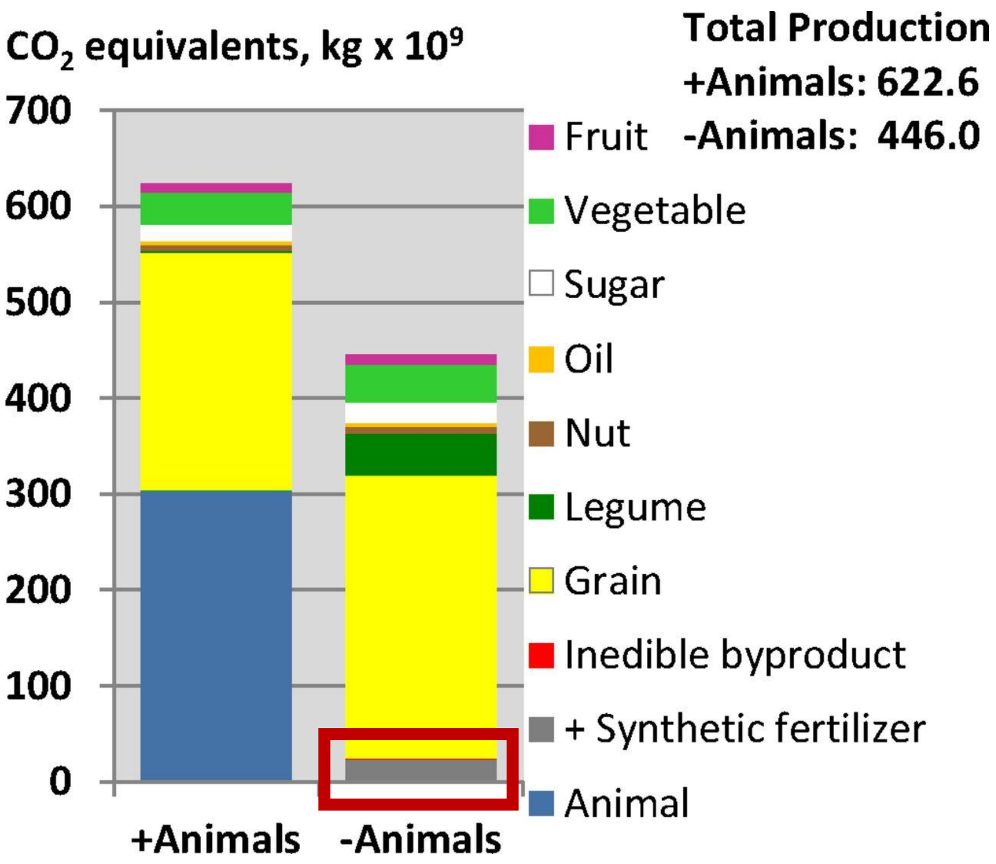
Limitations of This Study

- Composition of diet does not match previously studied vegetarian and vegan diet
- Other ways to synthesize fertilizer and dispose of byproducts
- Land could possibly support more fruits and vegetables

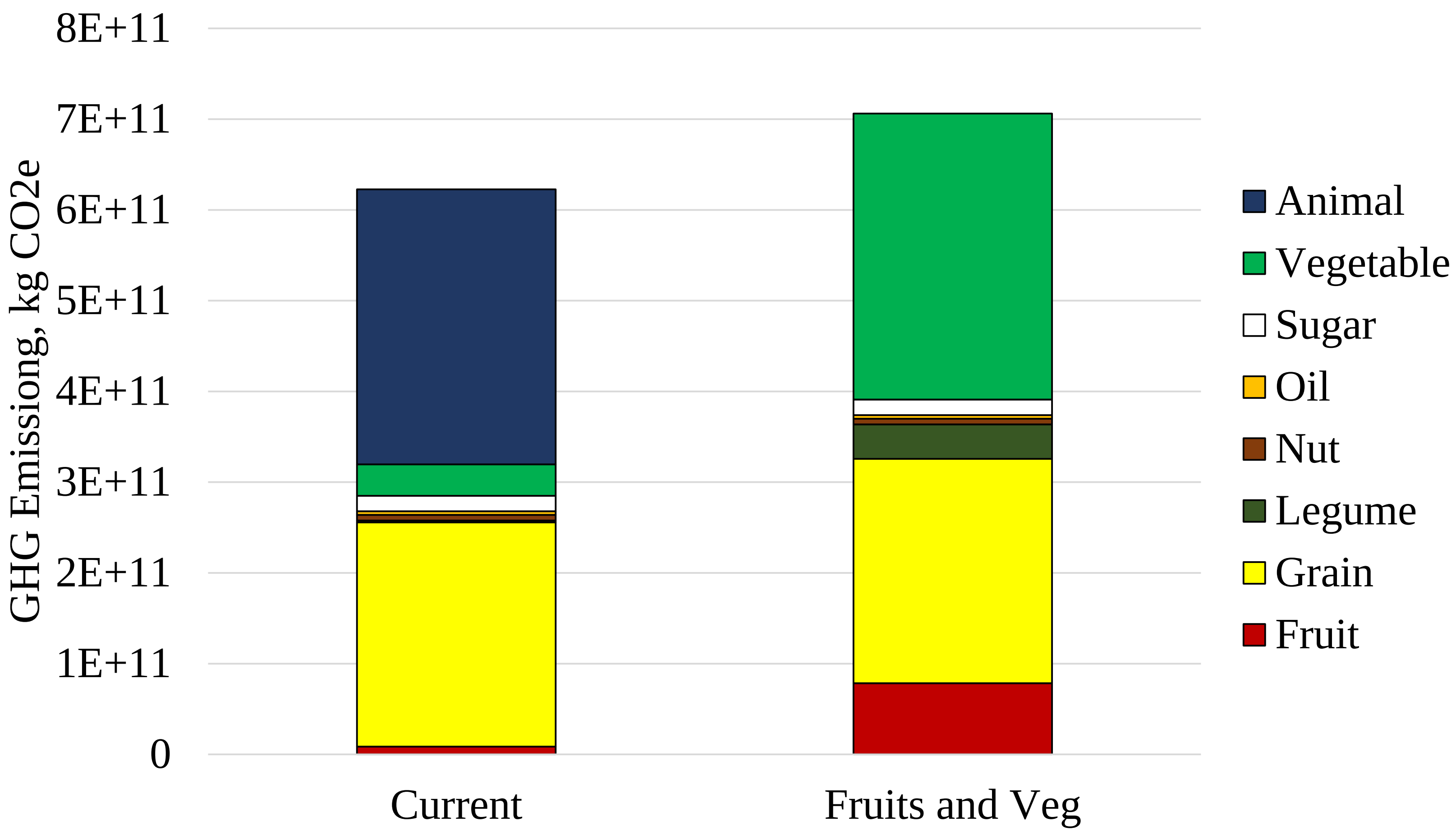
Alternatives to Fertilizer and Byproducts



Plants-only system:

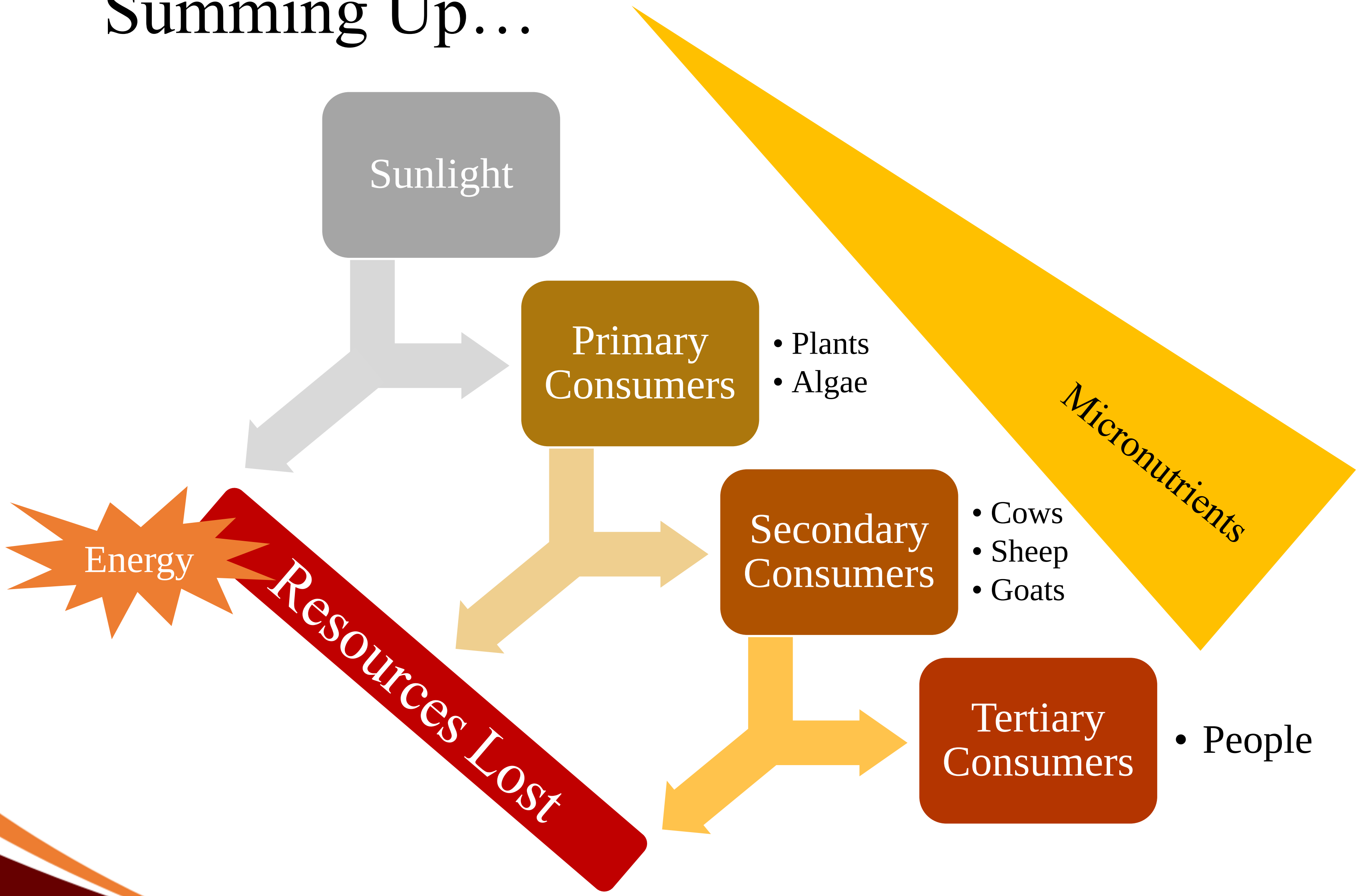
- US National GHG ↓2.9%.
- Agricultural GHG ↓ 32%, but not the ~50% associated with animals.

Alternative Land Use Assumptions:



Still a challenge with insufficient domestic production of essential fatty acids and vitamins

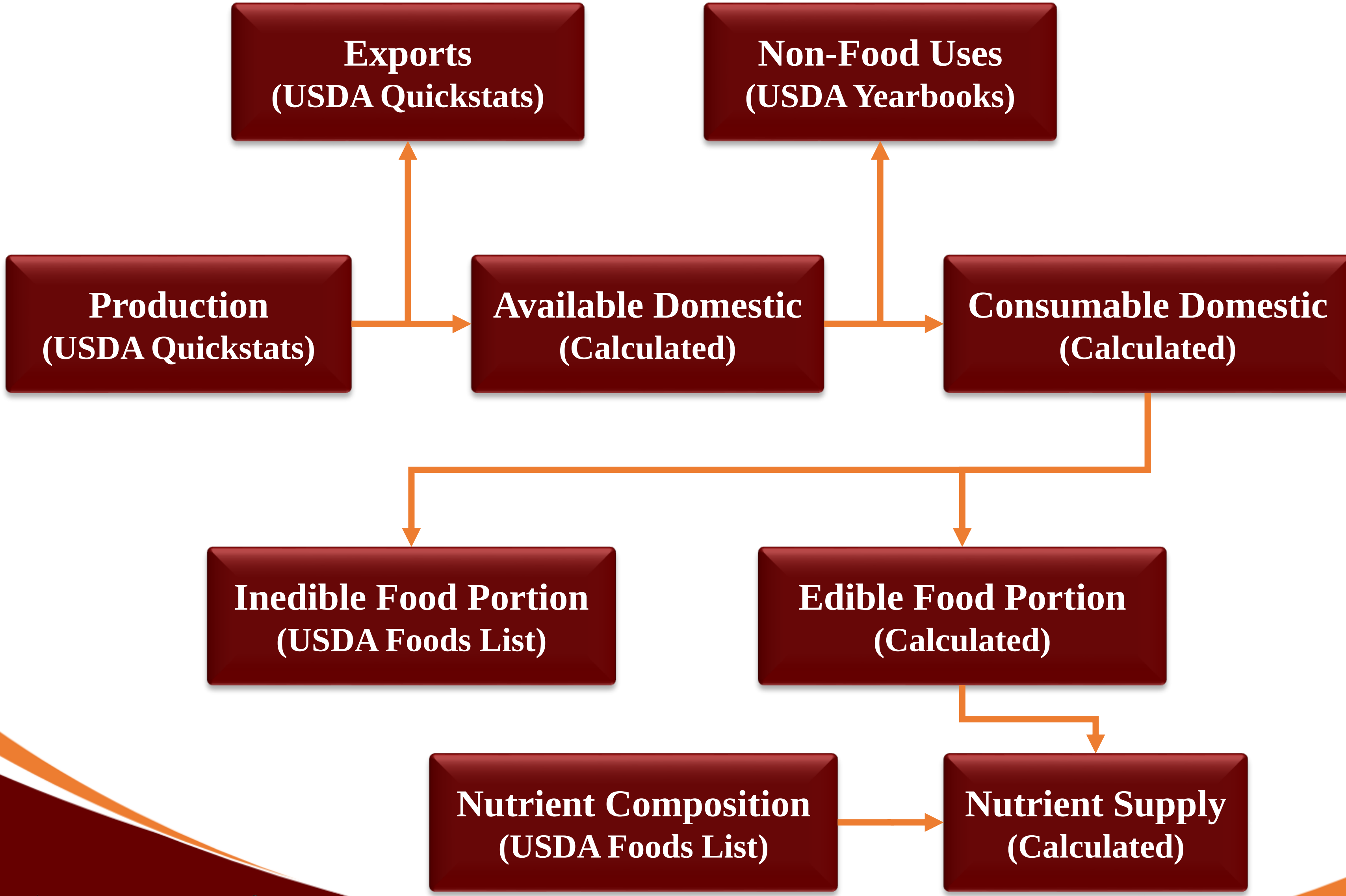
Summing Up…


Sunlight
Primary Consumers
• Plants
• Algae
Secondary Consumers
• Cows
• Sheep
• Goats
Tertiary Consumers
• People
Micronutrients
Energy
Resources Lost

Future Directions: Quantitative & Integrative

- Meet nutritional needs of the population. Supplements? Fortification?
- Profitability
- Land/resource use sustainability
- Environmental impact
- Use all acceptable tools
- Evaluate actual feasibility
- Ideology

Methods: Estimated Food Supply



Methods: Nutrient Requirements

Age/Gender-Based Requirement
(USDA Dietary Recommendations for Americans; WHO Recommendations on Fatty Acids)

Age/Gender-Based Population
(US Census Bureau)

Population Weighted-Average Nutrient Requirements

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