THE SCIENCE BEHIND FOOD SYSTEM SUSTAINABILITY ISSUES AND FUTURE RESEARCH NEEDS

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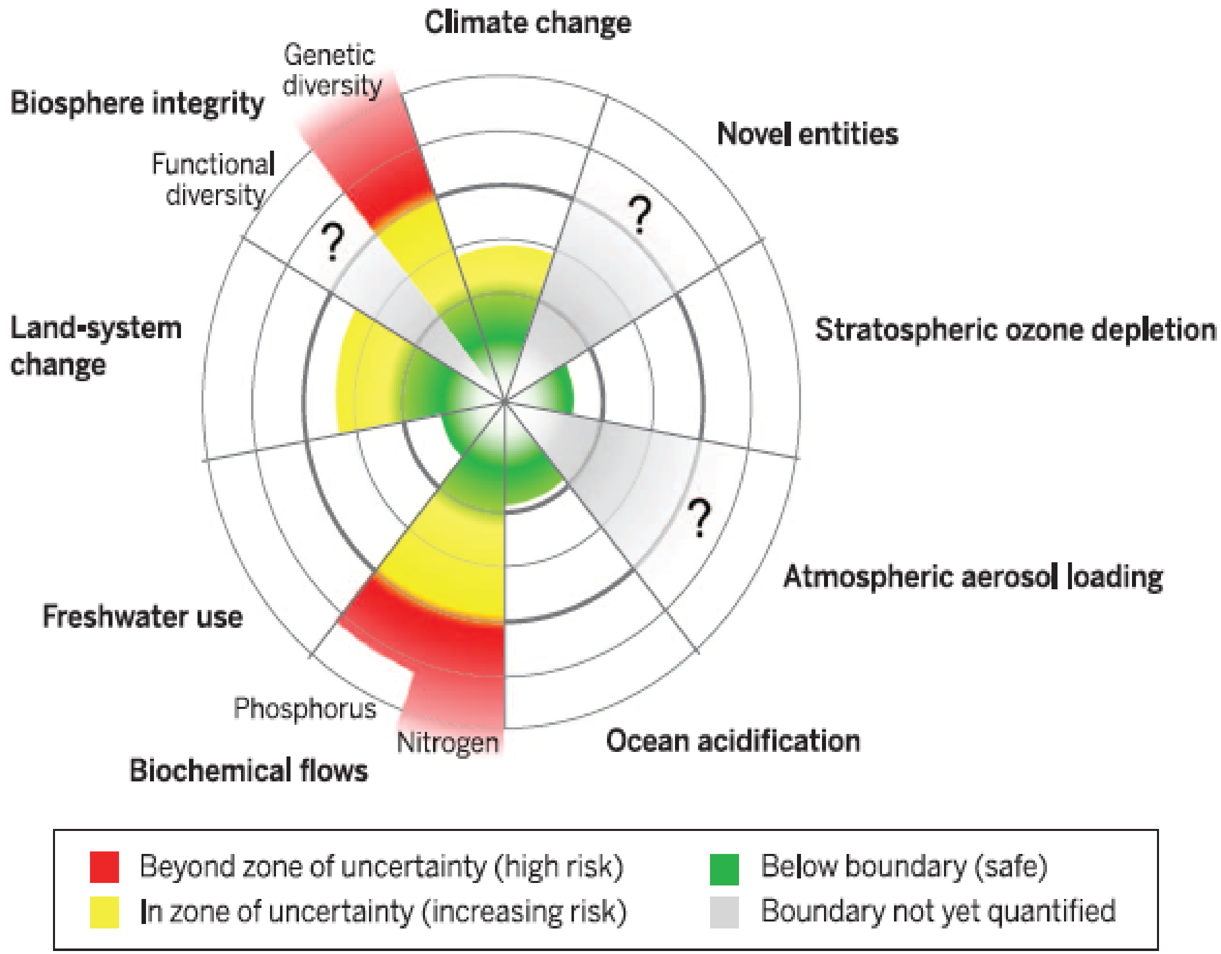
PLANETARY BOUNDARIES NOTION – IT'S NOT JUST ABOUT CARBON



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Rockstrom, J., Steffen, W., Noone, K., Persson, A., Chapin, F. S., 3rd, Lambin, E. F., . . . Foley, J. A. (2009a). A safe operating space for humanity. *Nature, 461*(7263), 472-475.

IMPORTANT IN A GLOBAL CONTEXT

MEETING GLOBAL FOOD NEEDS WILL DEPEND ON FOUR CONCURRENT APPROACHES:

- ✓ 1) Altering individual and population dietary patterns;
- ✓ 2) Adopting existing and developing new agricultural production practices that reduce impacts and conserve resources;
- ✓ 3) More equitable distribution of resources; and
- ✓ 4) Reduction of food waste

Adapted from: Garnett T. Food sustainability: problems, perspectives and solutions. Proc Nutr Soc. 2013 Feb;72:29–39

DIETARY PATTERN AND CARRYING CAPACITY

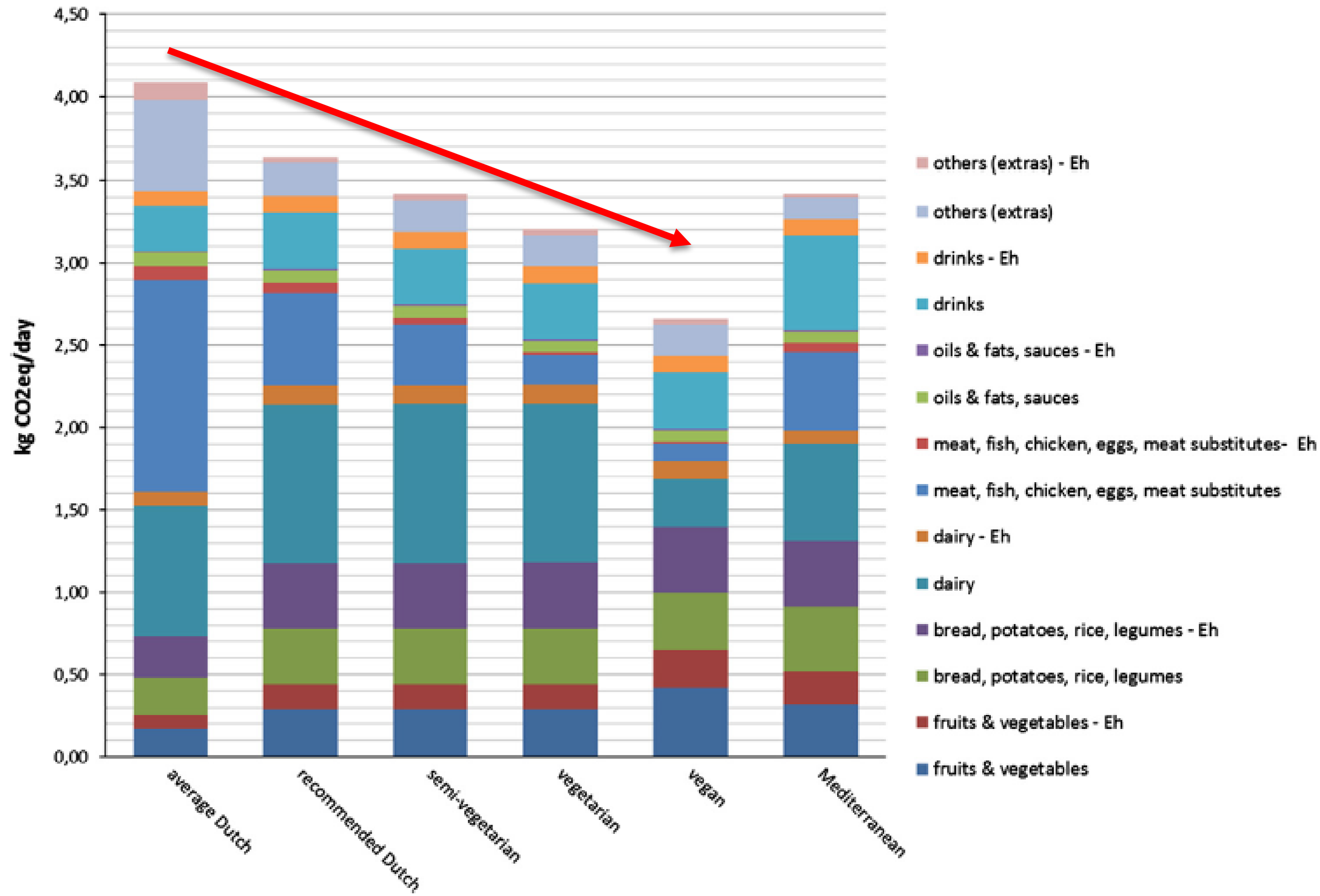
Table 4. Carrying capacity of the U.S. by diet scenario

Scenario	Population fed	
Symbol	(10^8 persons)	(% of 2010 population)[a]
BAS	4.02	130%
POS	4.21	136%
OMNI 100	4.67	151%
OMNI 80	5.48	178%
OMNI 60	6.69	217%
OMNI 40	7.52	244%
OMNI 20	7.69	249%
OVO	7.87	255%
LAC	8.07	261%
VEG	7.35	238%

Peters, C. J., Picardy, J., Darrouzet-Nardi, A. F., Wilkins, J. L., Griffin, T. S., & Fick, G. W. (2016). Carrying capacity of U.S. agricultural land: Ten diet scenarios. *Elementa: Science of the Anthropocene, 4*, 000116. doi:10.12952/journal.elementa.000116

CARRYING CAPACITY IS A FIRST STEP

FIG. 2. GHG EMISSIONS PER DAY ACCORDING TO THE 6 DIETS AND BROKEN DOWN INTO 7 FOOD GROUPS (FEMALE ADULTS). EH = ENERGY USE IN THE HOUSEHOLD PHASE.



C. van Dooren et al. (2014) Exploring dietary guidelines based on ecological and Nutritional values: A comparison of six dietary patterns.Food Policy 44; 36–46.

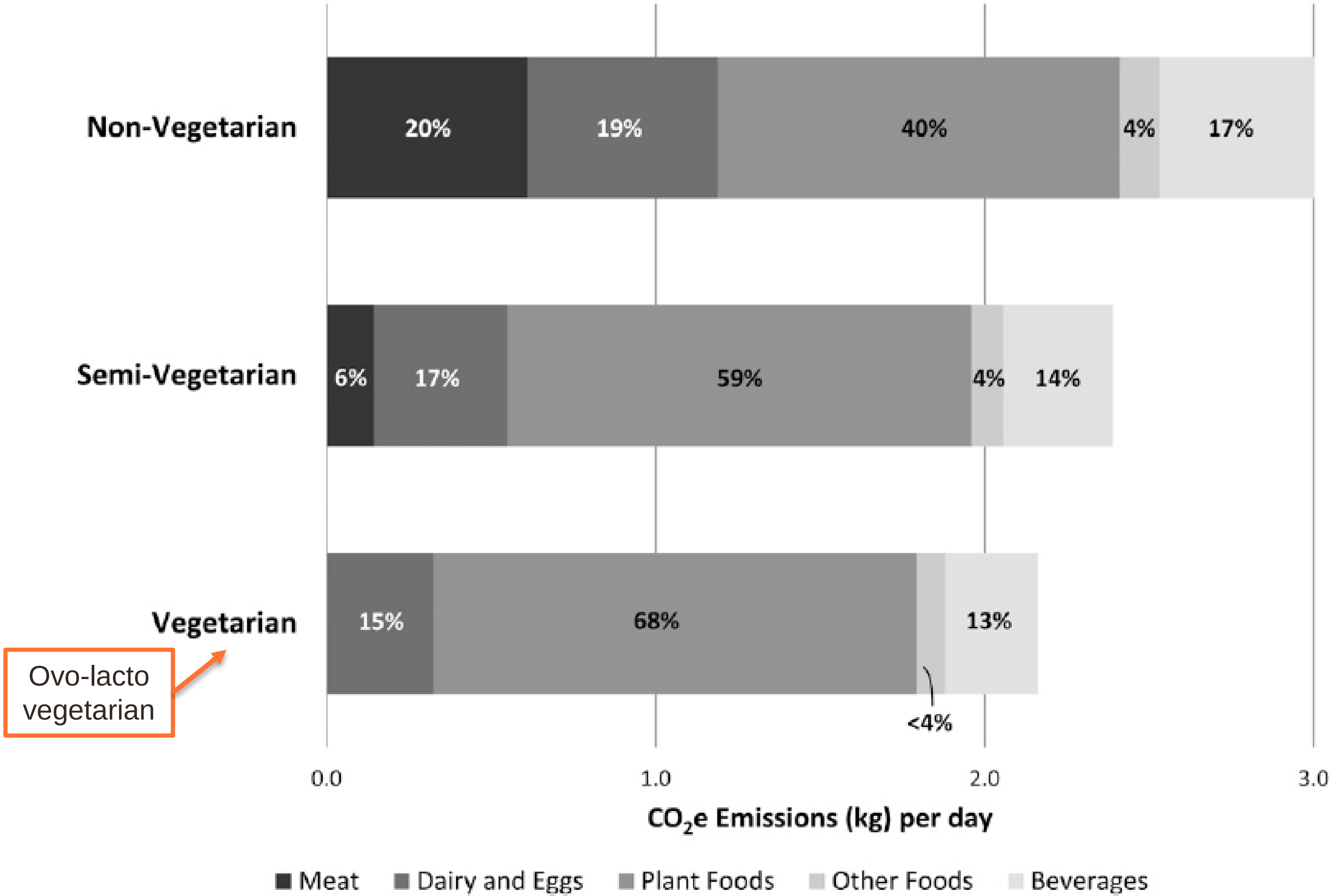


FIGURE 1. Comparison of greenhouse gas emissions (kg CO_2e/d) by major food groups and dietary pattern, adjusted to 2000 kcal. CO_2e, carbon dioxide equivalent emissions.

S. Soret et al (2014) Climate change mitigation and health effects of varied dietary patterns in real-life settings throughout North America. Am J Clin Nutr doi: 10.3945/ajcn.113.071589

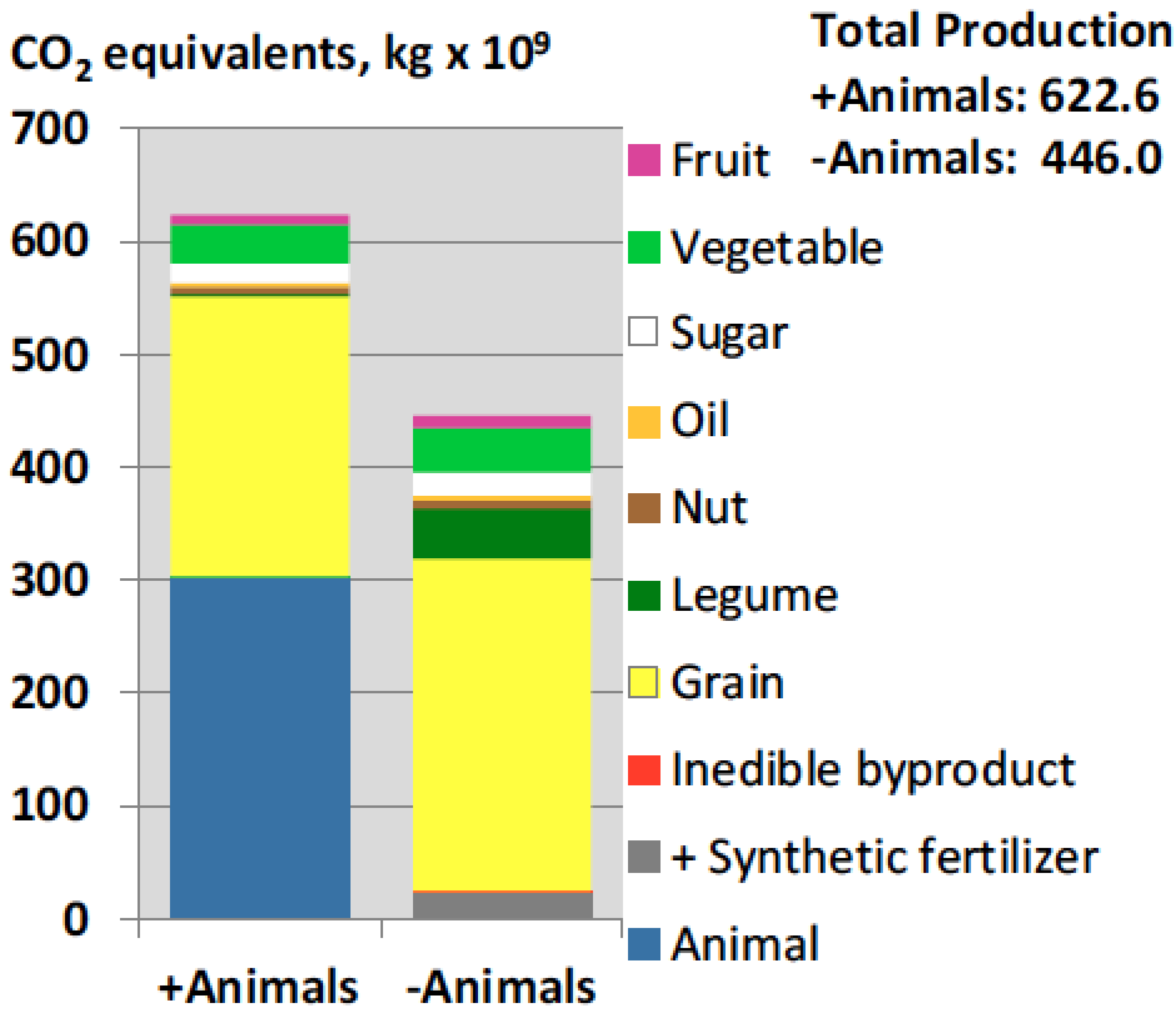


Fig. 5. GHG emissions associated with food production in a system representative of the current United States and a modeled system in which animal-derived food inputs are eliminated.

R.R.White and M.B.Hall (2017) Nutritional and greenhouse gas impacts of removing animals from US agriculture. www.pnas.org/cgi/doi/10.1073/pnas.1707322114

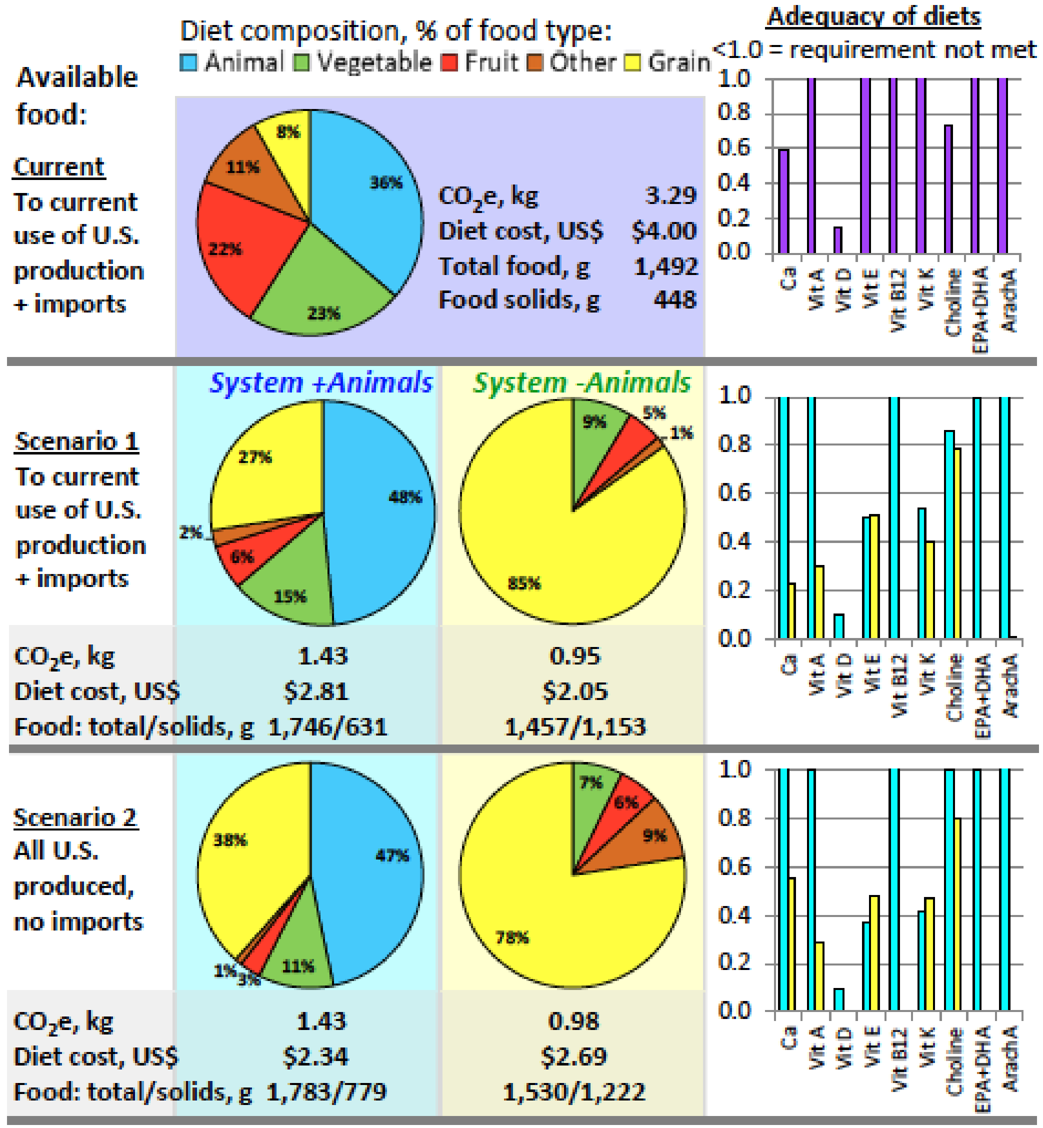


Fig. 4. Comparison of the daily diet composition, CO_2e emissions, intake, cost, and nutrient adequacy of the current US diet compared with a series of optimized diets with and without (modeled) animal-derived foods. Bar

R.R.White and M.B.Hall (2017) Nutritional and greenhouse gas impacts of removing animals from US agriculture. www.pnas.org/cgi/doi/10.1073/pnas.1707322114

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AND FROM THE UK…

Table 3 Mean greenhouse gas emissions per 2,000 kcal by diet type and sex

	Men (observed values)			Women (observed values)			Adjusted for age and sex	
	N	Mean dietary GHG emissions (kgCO2e)	SD	N	Mean dietary GHG emissions (kgCO2e)	SD	Mean dietary GHG emissions (kgCO2e)	95 % CIs
All meat-eaters	6,380	5.93	2.01	22,759	5.71	1.75		
High meat-eaters (≥100 g/day)	2,310	7.26	2.11	5,976	7.17	1.94	7.19	(7.16, 7.22)
Medium meat-eaters (50–99 g/day)	2,654	5.66	1.60	9,317	5.62	1.38	5.63	(5.61, 5.65)
Low meat-eaters (<50 g/day)	1,866	4.67	1.35	7,466	4.67	1.05	4.67	(4.65, 4.70)
Fish-eaters	1,448	3.94	1.12	6,675	3.90	0.88	3.91	(3.88, 3.94)
Vegetarians	3,641	3.85	1.29	12,110	3.80	0.93	3.81	(3.79, 3.83)
Vegans	747	2.94	1.25	1,294	2.87	0.90	2.89	(2.83, 2.94)

SD, Standard deviation; *CIs*, Confidence intervals; *N*, Number of Participants
kgCO2e, kilograms of carbon dioxide equivalents

P. Scarborough et al (2014) Dietary greenhouse gas emissions of meat-eaters, fish-eaters, vegetarians and vegans in the UK. Climatic Change. 125:179–192
DOI 10.1007/s10584-014-1169-1

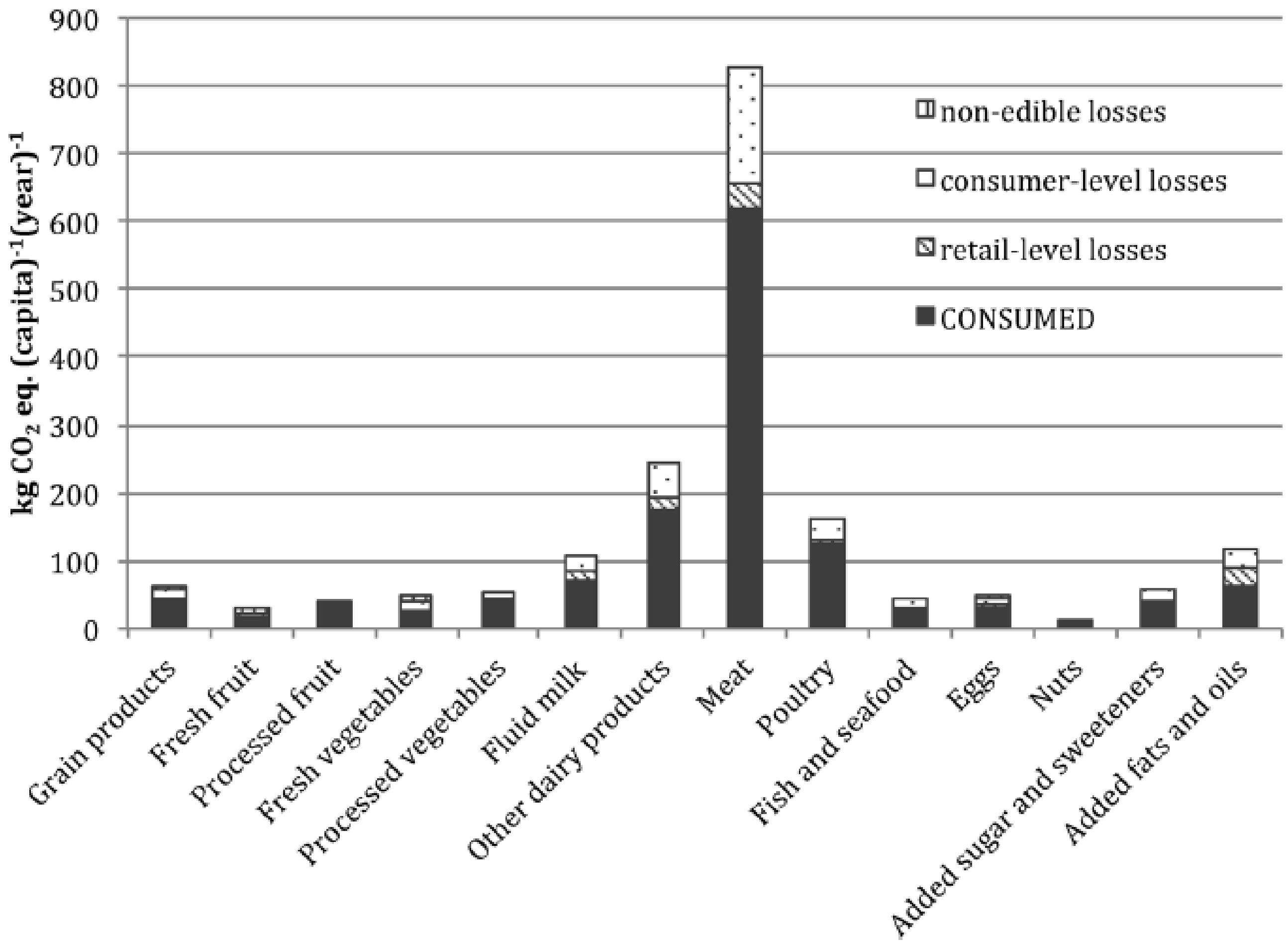
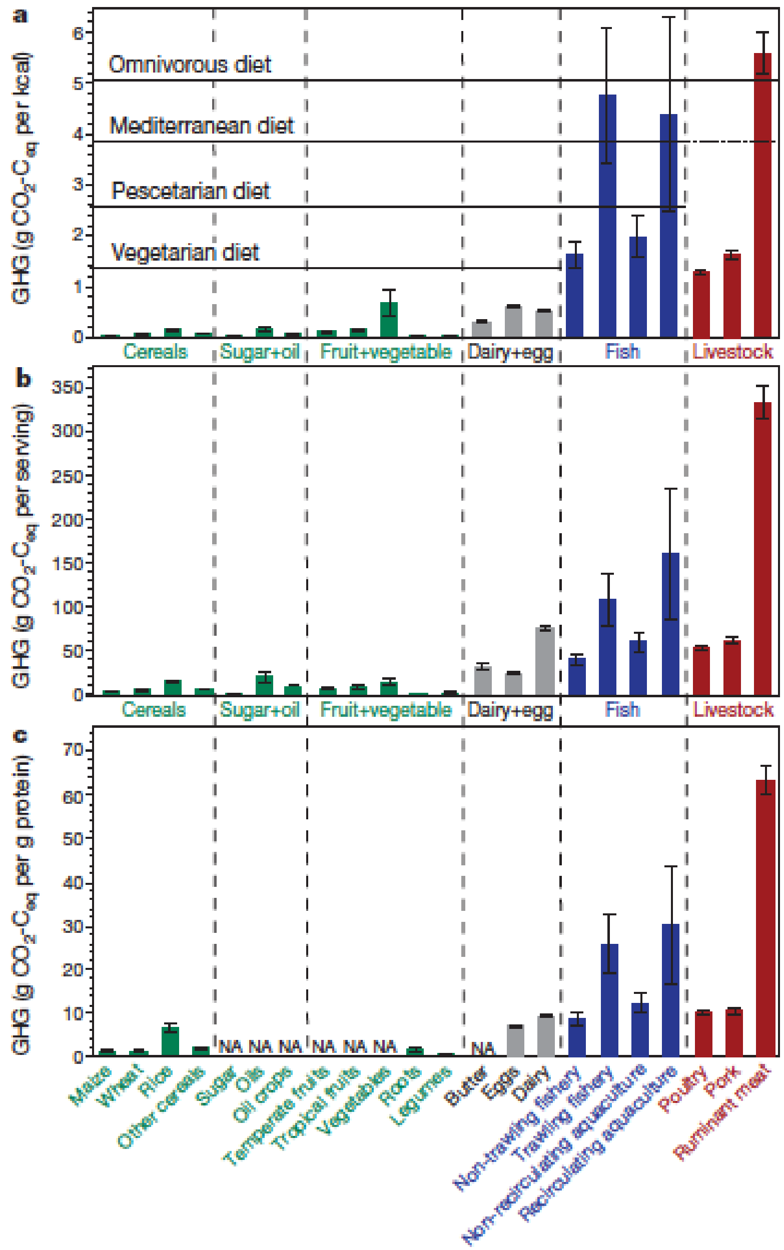


Figure 3 Annual greenhouse gas emissions per capita associated with producing the 2010 U.S. food availability. kg CO_2-eq = kilograms of carbon dioxide equivalents.

M.C. Heller & G.A. Keoleian (2014) Greenhouse Gas Emission Estimates of U.S. Dietary Choices and Food Loss. J.Ind.Ecol., 19:3, p. 391-401

LOOKED AT GLOBALLY



Tilman, D., & Clark, M. (2014). Global diets link environmental sustainability and human health. *Nature, 515*(7528), 518-522. doi:10.1038/nature13959

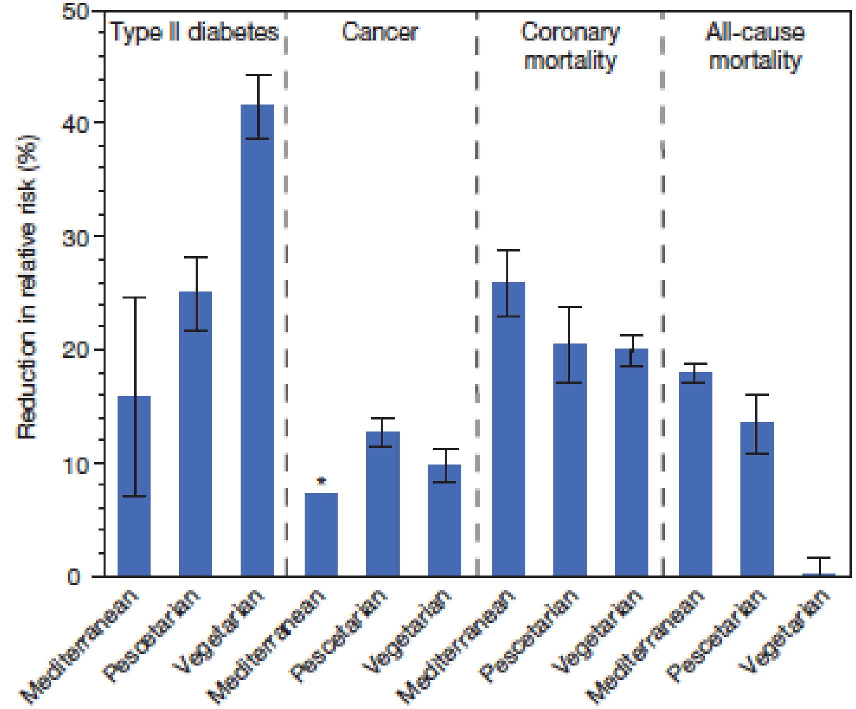


Figure 3 | Diet and health. Diet-dependent percentage reductions in relative risk of type II diabetes, cancer, coronary heart disease mortality and of all-cause mortality when comparing each alternative diet (Mediterranean, pescetarian and vegetarian) to its region's conventional omnivorous diet (Methods). Results are based on cohort studies[32–39]. The mean and s.e.m. values shown are weighted by person-years of data for each study. Number of studies for each bar are, from left to right, 3, 2, 2, 1, 2, 2, 4, 2, 5, 13, 2 and 4. *Cancer in Mediterranean diets is from a single study so no s.e.m. is shown.

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Tilman, D., & Clark, M. (2014). Global diets link environmental sustainability and human health. *Nature, 515*(7528), 518-522. doi:10.1038/nature13959

CONSIDERATIONS

- ✓ **This doesn't take into account variation in production strategies**
  - ✓E.g. of beef and pasture v. grain
  - ✓E.g. of high-efficiency water use (trickle irrigation for e.g)
- ✓ **Intra- vs inter- food item and sustainability**
- ✓ **The U.S. has a high calcium (hence dairy) recommended intake compared to most other countries – this complicates things in our case since 50% of total calcium consumption is from dairy in U.S.**

HOW SOME OF OTHER VARIABLES BECOME IMPORTANT!

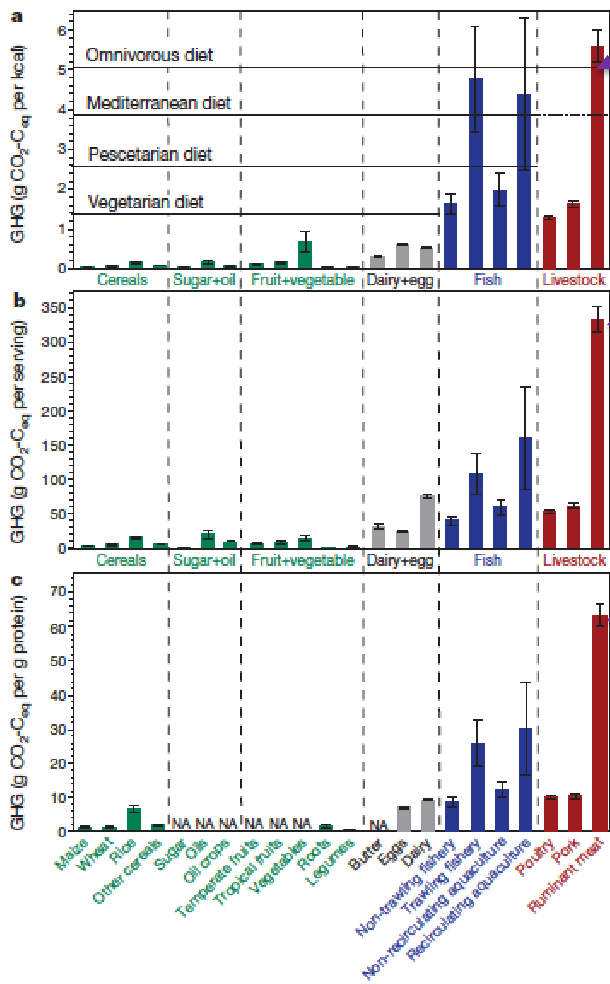
Photo Credit: Dr. Jason Rowntree, Dept. Animal Sciences

BEEF AND U.S. POPULATION GROWTH

Table 2	U.S. Beef Consumption	
	2020	2050
Constant Per Capita Consumption	+.5 billion kgs	+2.2 billion kgs
Constant National Production	26.4 kg/person	22.3 kg/person

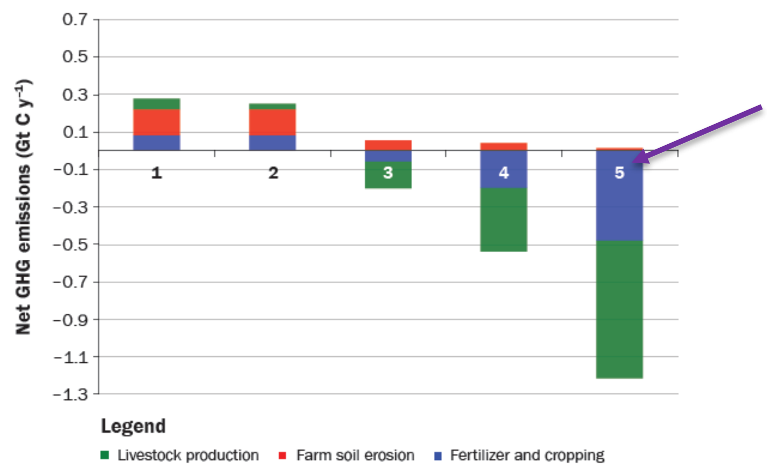
Currently about 28 kg/person/yr

RUMINANTS, SYSTEMS, AND ?S - CAN RUMINANT GRAZING SYSTEMS HELP MITIGATE CLIMATE CHANGE?



VS

Figure 2
Hypothetical North American net greenhouse gas (GHG) emission scenarios for: (1) current agriculture; (2) current agriculture with 50% current ruminants; (3) 25% conservation cropping and adaptive multipaddock (AMP) grazing with current numbers of ruminants; (4) 50% conservation cropping and AMP grazing with current numbers of ruminants; and (5) 100% conservation cropping and AMP grazing with current numbers of ruminants.



Tilman, D., & Clark, M. (2014). Global diets link environmental sustainability and human health. *Nature, 515*(7528), 518-522. doi:10.1038/nature13959

W.R. Teague, S. Apfelbaum, R. Lal, U.P. Kreuter, J. Rowntree, C.A. Davies, R. Conser, M. Rasmussen, J. Hatfield, T. Wang, F. Wang, and P. Byck (2016) *The role of ruminants in reducing agriculture's carbon footprint in North America*. J.of Soil and Water Conservation. 71:2, p. 156-164.

ADAPTIVE MULTI-PADDOCK GRAZING VS. FEEDLOT FINISHING

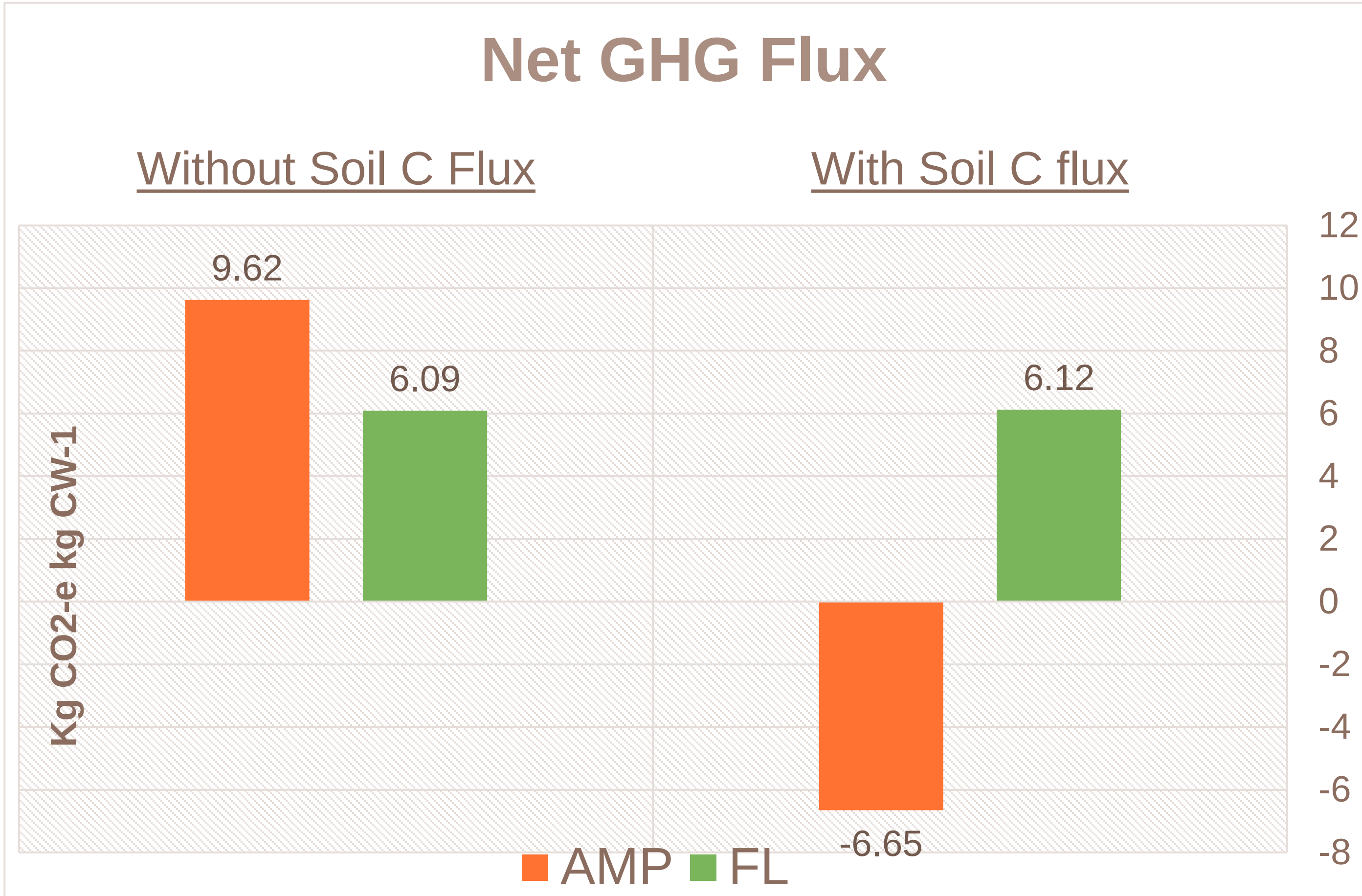


Fig. 2. Estimated emissions (kg CO_2-e kg CW^{-1}) for each finishing strategy – feedlot (FL) and adaptive multi-paddock (AMP) grazing – before (left) and after (right) net C flux from soils (sequestration and erosion) is incorporated.

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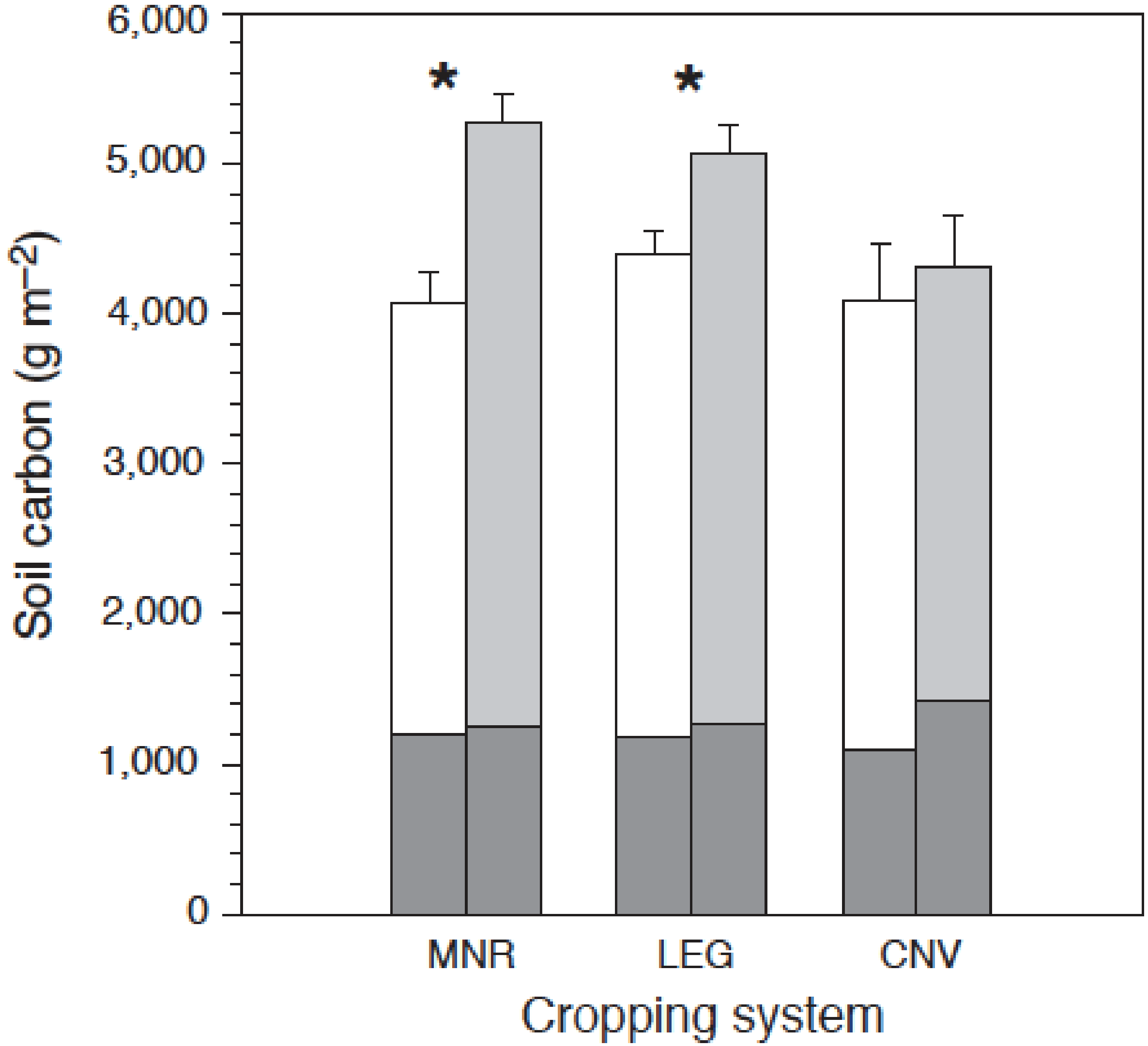
P.L.Stanley, J.E.Rowntree, D.K.Beede, M.S.DeLonge, & M.W.Hamm (2018) Impacts of soil carbon sequestration on life cycle greenhouse gas emissions in Midwestern USA beef finishing systems. Agricultural Systems 162 (2018) 249–258

SOIL CARBON LEVELS IN 1981 AND 1995: RODALE FST



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Drinkwater, L.E., Wagoner, P., & Sarrantonio, M. (1998) Legume-based cropping systems have reduced carbon and nitrogen losses. Nature, 396, p 262-265

E.G. RELATIVE LOCATION OF PRODUCTION

Photos from: MSU Student Organic Farm


HORTICULTURAL EXPERIENCE CENTRE
LEARN HOW TO GROW!
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Education
Section 5
168m²
1 A unique cooperation with educational institutes
2 Teaching students via learning by doing
3 Your personal growth by training exercise
4 Training for international growers in practice

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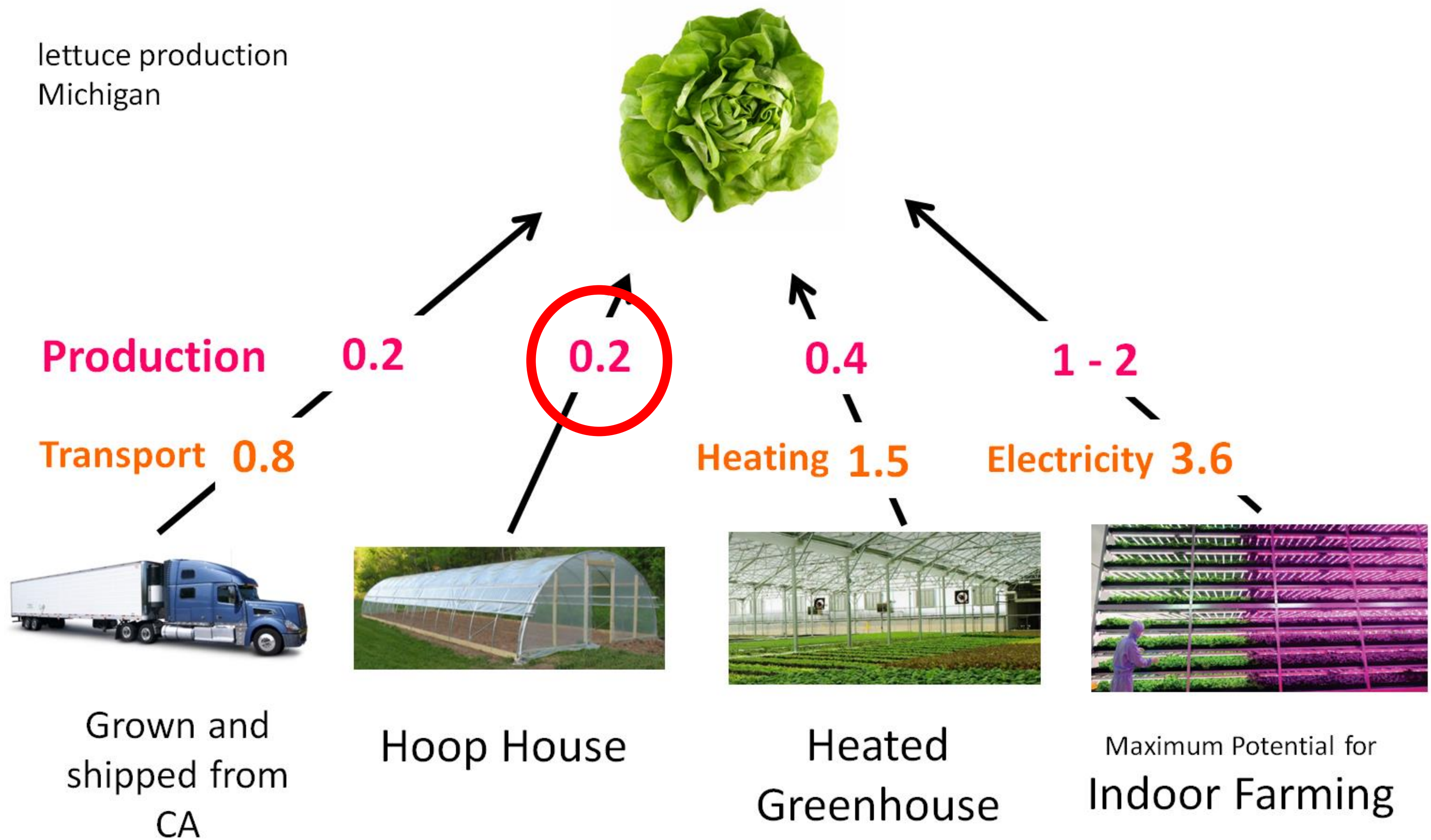
CO_2 equivalents per kg

lettuce production
Michigan



Slide from Dr. Bruce Bugby, Utah State University

Imported and hoophouse data derived from: R. Plawecki, R. Pirog, A. Montri, and **Michael Hamm** 2013. Comparative carbon footprint assessment of winter lettuce production in two climatic zones for Midwestern market. *Renewable Ag. and Food Systems: 29 (4) 310-318*

E.G. OF WATER - NEW YORK METRO – WATER FROM LOW TO HIGH WATER AREAS

Food Category	U.S. Consumption kg (per capita)	Approx. Water Content/100 gm	Total Water Content/Person/Yr (liters)	Total Water Content NY Metro (2014 pop.; liters)	Total Water Content NY Metro (2042 est. pop.; liters)	Total Water Content NY Metro (2042 est. pop. plus F/V increase 50%; meat decrease 25%; liters)
Meat	88.7	71.7	63.6	1,310,519,564	1,420,603,207	1,065,452,405
Dairy (all)	269.5					
Fluid Milk	88.4	87.7	170.5	3,512,069,280	3,807,083,100	1,730,492,318
Total Fruits and Vegetables	321.7		**420.6**	**8,664,227,973**	**9,392,023,122**	**14,088,034,684**
Total Fruits	279.4	86.5	241.7	4,978,628,600	5,396,833,402	8,095,250,104
Total Vegetables	194.7	91.9	178.9	3,685,599,373	3,995,189,720	5,992,784,580
Total Grain Products	90.9	10.4	**9.4**	**194,666,255**	**211,018,220**	**211,018,220**

Modeling research showed 70% of NYC food needs could be met with respect to dairy, eggs, fruits, vegetables from NY State*

*Peters, C. J., et al. (2007). "Testing a complete-diet model for estimating the land resource requirements of food consumption and agricultural carrying capacity: The New York State example." Renewable Agriculture and Food Systems **22**(02): 145.

DIETARY PATTERNS AND NUTRIENTS

✓ Challenge of 'tonnage' of food needed

Metro Areas	Population (2014 estimate)	Vegetables (lbs)	Fruits (lbs)	Total Food (lbs)
		428.3	279.4	707.7
Lansing	470,458	201,497,161	131,445,965	332,943,127
NYC	20,092,883	8,605,781,789	5,613,951,510	14,219,733,299
Phoenix	4,489,109	1,922,685,385	1,254,257,055	3,176,942,439
St. Louis	2,806,207	1,201,898,458	784,054,236	1,985,952,694

Lansing		302,245,742	197,168,948	499,414,690
NYC		12,908,672,683	8,420,927,265	21,329,599,949
Phoenix		2,884,028,077	1,881,385,582	4,765,413,659
St. Louis		1,802,847,687	1,176,081,354	2,978,929,041

Consuming 50% more – approximately dietary recommendations

CHALLENGE OF SCALE

Table 1	U.S. Farms (Current and Needed)		
	Current Farms (total, all sizes)	Needed (2020)	Needed (2050)
0.8 hectare fruit/ vegetable farms	194,000	5,600,000	7,000,000
8 hectare fruit/ vegetable farms	194,000	560,000	700,000
8 hectare fruit/ vegetable farms*	194,000	840,000	1,350,000
*this assumes U.S. consumer increases consumption of produce 50% to approach dietary guidelines			

DIETARY PATTERNS AND PROTEIN

- ✓ **Insect protein and palatable foods**
  - ✓ Species, diet, micronutrient potential
  - ✓ Use of indoor space
  - ✓ Challenges from production to processing to consumer acceptance

CONCLUSION - FOUR RECOMMENDATIONS IN DGAC REPORT

- ✓ Conduct research to determine whether sustainable diets are affordable and accessible to all sectors of the population ...
- ✓ Develop, conduct, and evaluate in-depth analyses of U.S. domestic dietary patterns and determine the degree to which sustainability practices, domestically and internationally, are important to food choice …
- ✓ Develop a robust understanding of how production practices, supply chain decisions, consumer behaviors, and waste disposal affect the environmental sustainability of various practices ...
- ✓ Determine the potential economic benefits and challenges to supply chain stakeholders …

The End