

Foodprint: Understanding the Connections Between Food and the Environment



Session 5
Land Use

Learning outcomes

By the end of this lecture you will be able to:

- Describe the status of the Land Use planetary boundary
- Understand some of the current literature (World Resource Institute, van Dooren et al.) on land use of various dietary scenarios
- Understand results of a study optimizing nutrition while minimizing environmental impact.

Climate Change

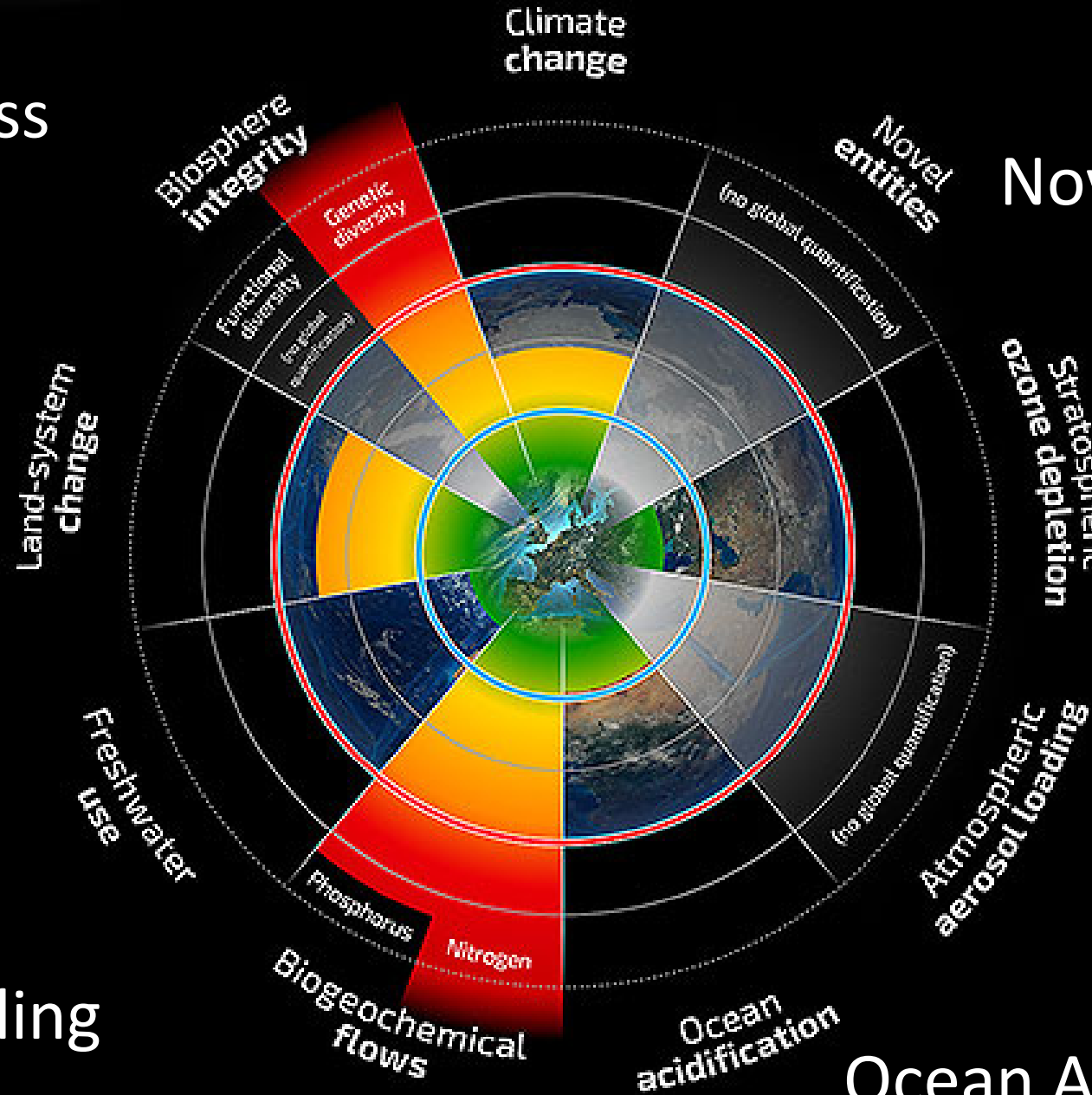
Planetary Boundaries
Steffen et al. 2015

Biodiversity Loss

Land Use
Change

Freshwater Use

Nutrient cycling



Novel entities

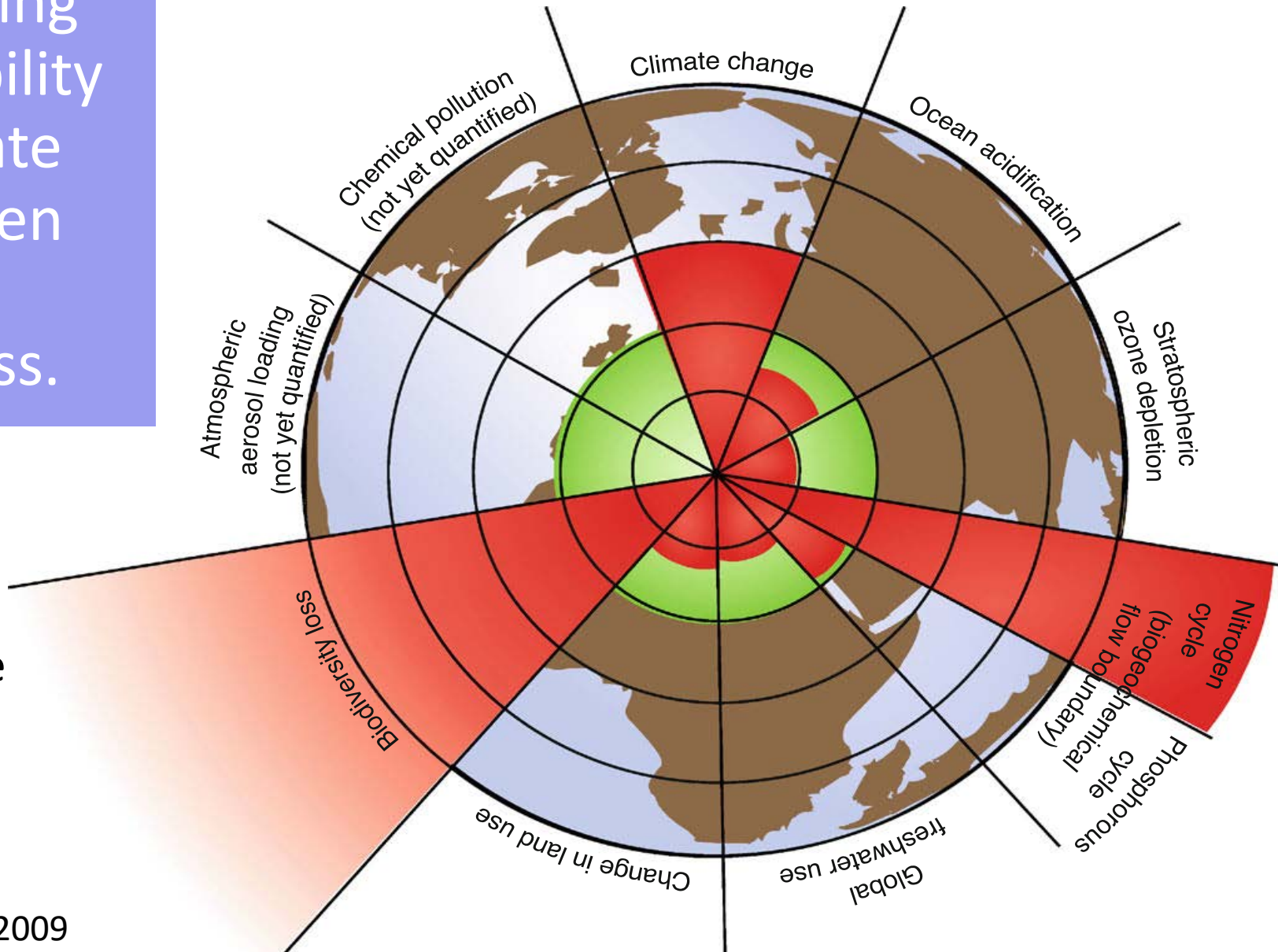
Ozone depletion

Atmospheric
Aerosol Loading

Ocean Acidification

In 2009, we were already exceeding global sustainability limits for climate change, nitrogen cycling, and biodiversity loss.

Now we are also beyond the boundary for land use.



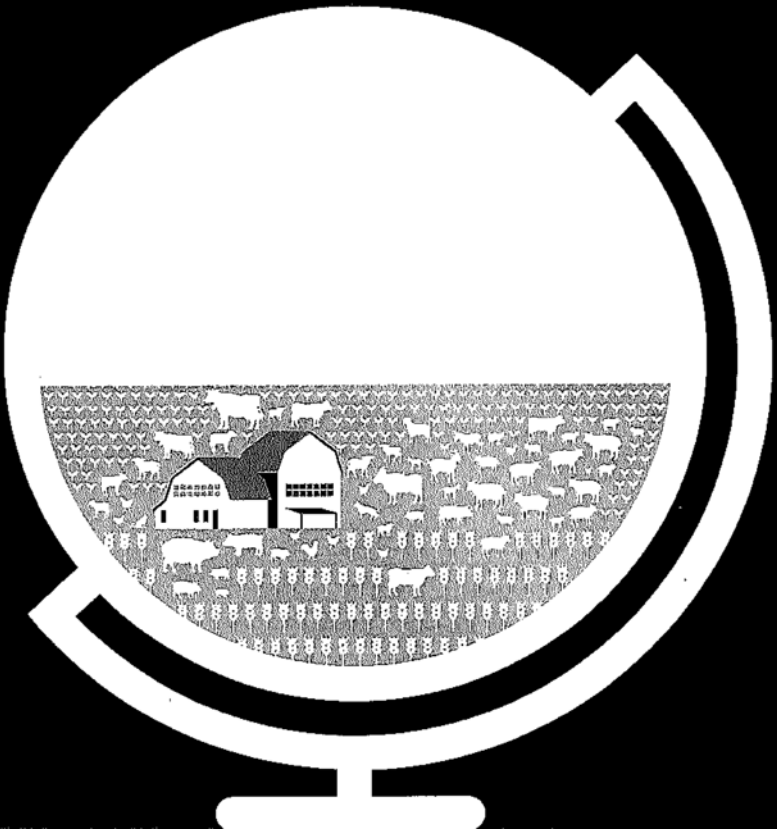
Source: Rockstrom et al, Nature, 2009

A bit over 70% of the Earth's surface is covered with water.

What percentage of the land surface is dominated by livestock alone?



45% of the planet's land surface is occupied by the global industrial livestock system.



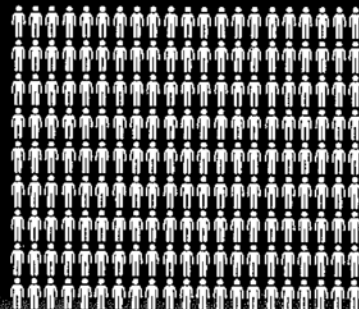
U.N. in 2006: Livestock production accounts for 70% of all agricultural land and 30% of the land surface of the planet.



Eat for the Planet. Zacharias and Stone, 2018

Human Population vs. Livestock Population

**7.5
billion**



**20
billion**



Livestock's role in habitat change

- Habitat destruction, fragmentation, and degradation are the major threat to biodiversity on a global scale.
- Livestock are a direct and dominant cause of habitat change, due to:



Livestock land (intensive)



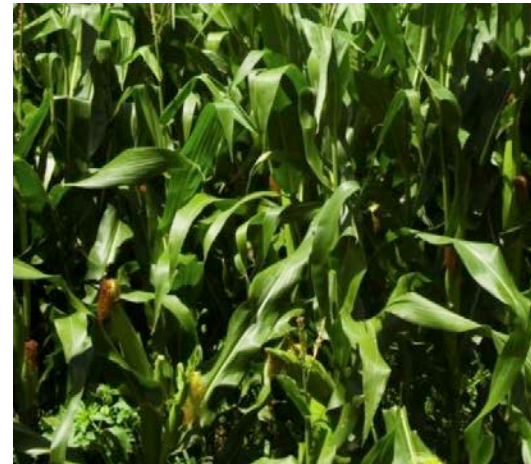
Feed crop production



Livestock land (extensive)
Often on former forests,
and overgrazing can
degrade land

There is much deforestation due to livestock production occurring in Latin America

- Cattle grazing on former forests
- Expansion occurring in diffuse matter, fragmenting landscape
- An increasing share of the region's cropland goes to animal feed (soybeans and corn)



Resource depletion

- Estimated pounds of grain needed to produce a pound of meat:
 - Beef - 7:1
 - Pork - 4:1
 - Chicken - 2:1



Image copyright.

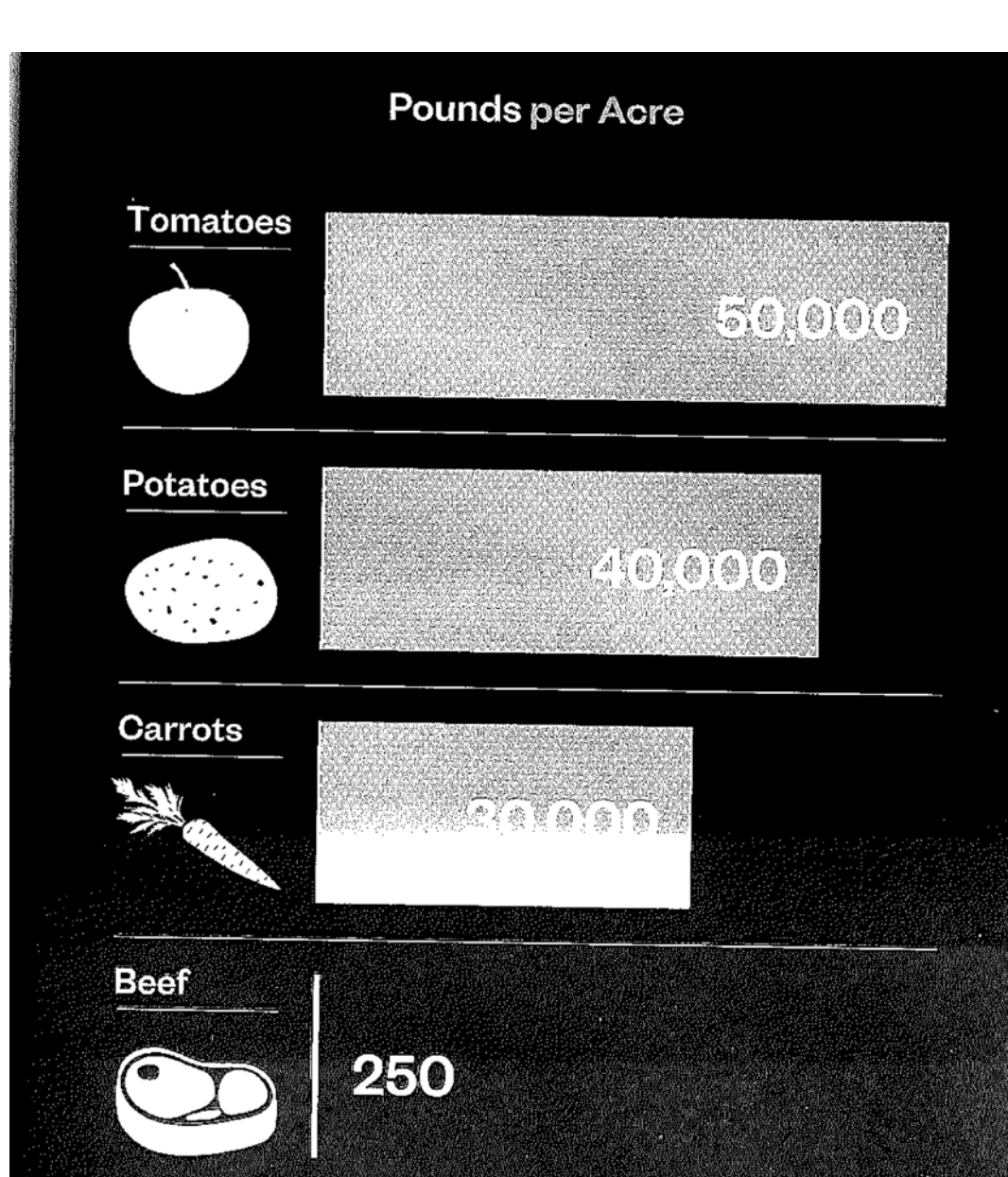
Per acre (about the size of a football field, how many pounds of the following foods can be raised per year:

Tomatoes??

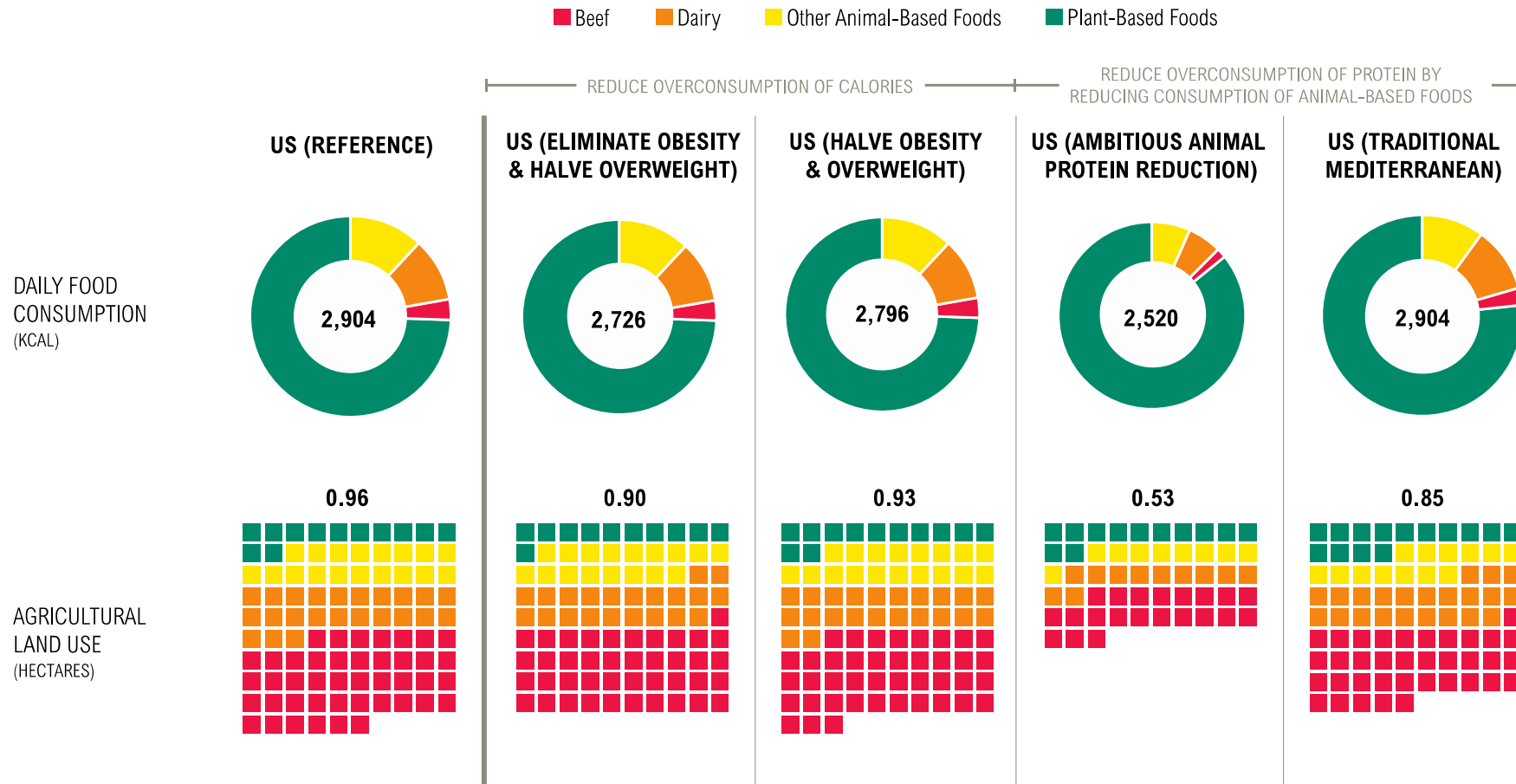
Potatoes??

Carrots??

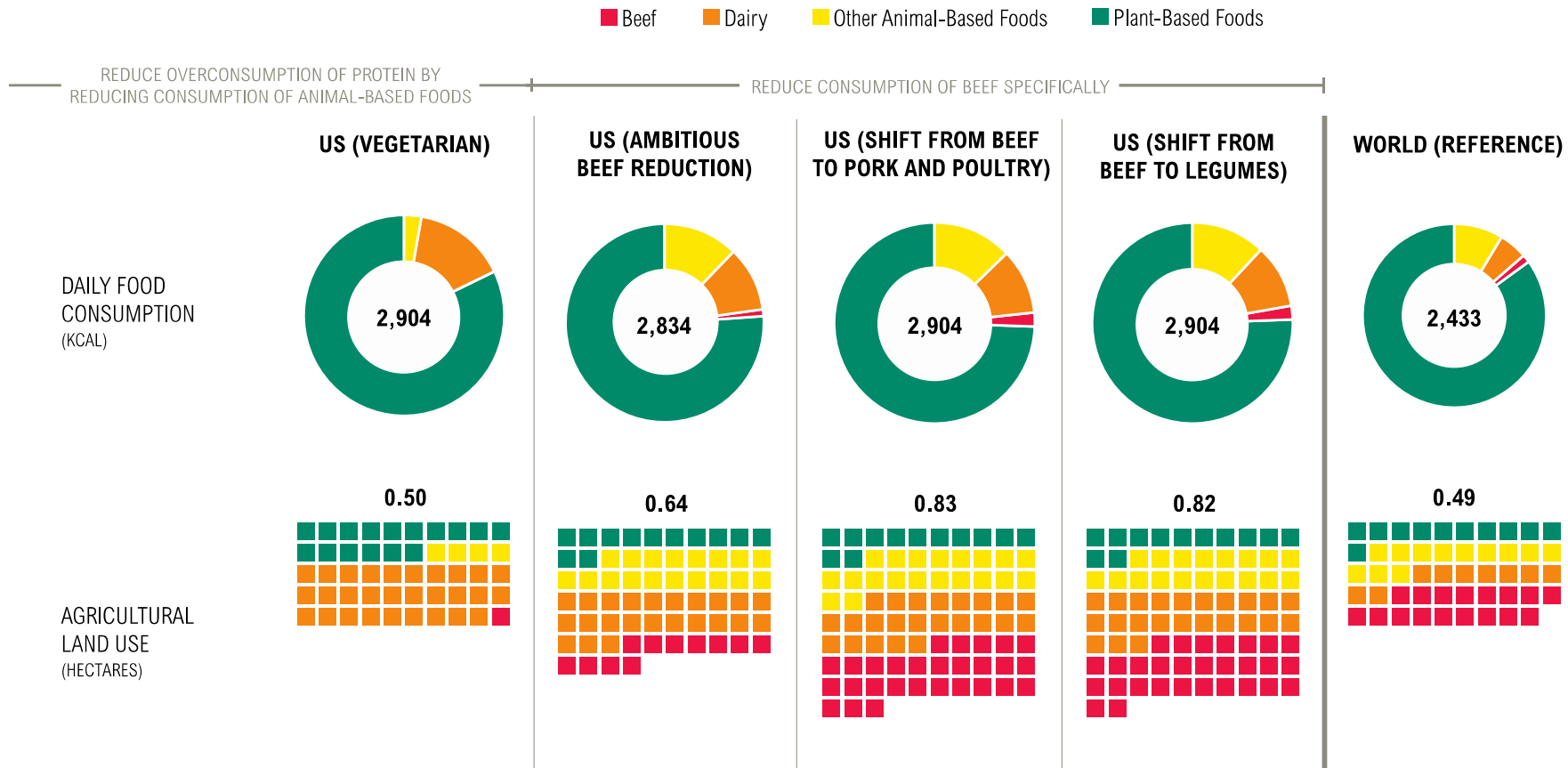
Beef??



Source: Eat for the Planet, Zacharias, N.

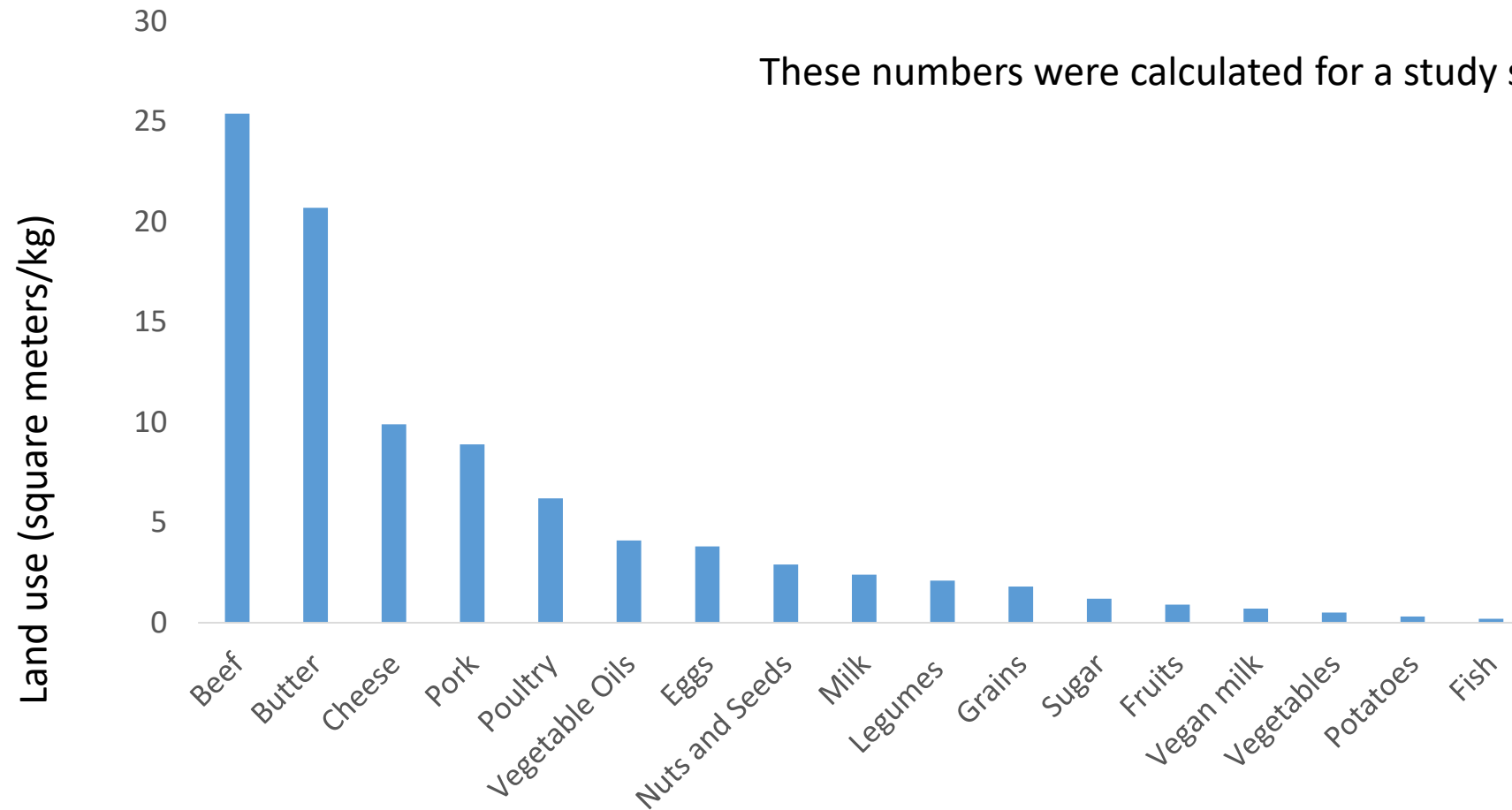


Source: World Resource Inst. "Shifting Diets for a Sustainable Food Future." 2016



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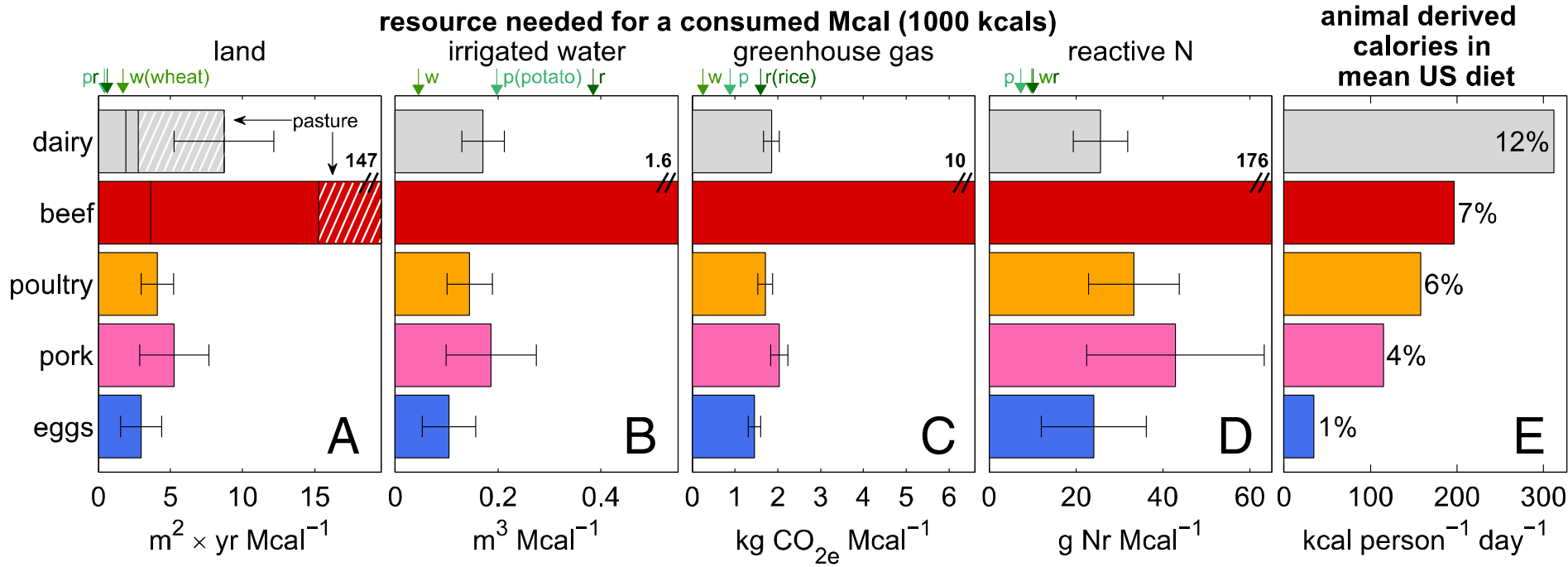
Foods require different amounts of land for their production.



(Meier and Christen, ES&T 2012)

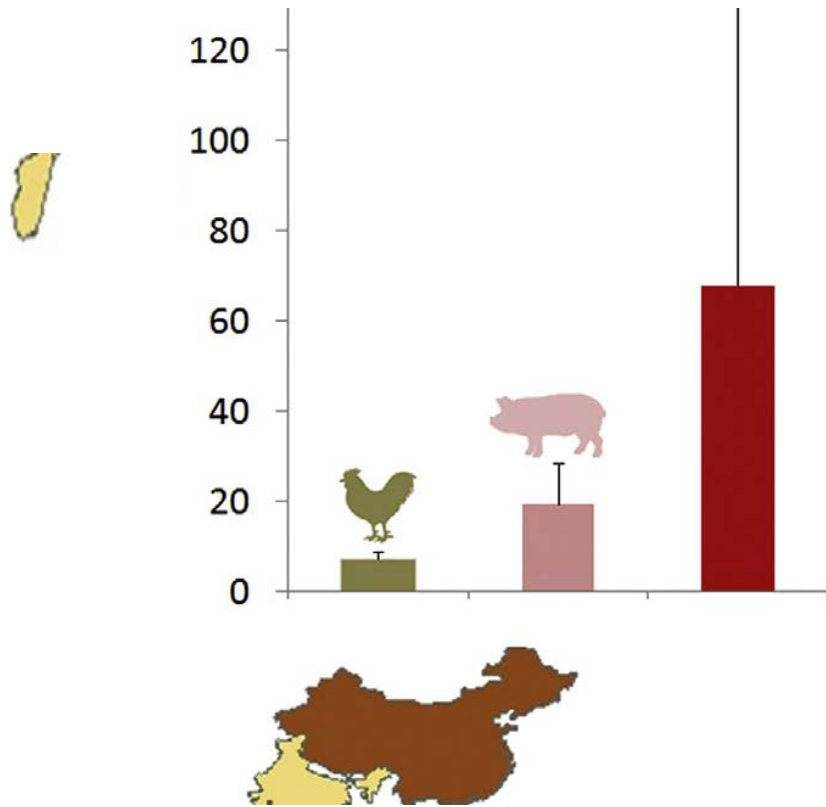
Land, irrigation water, greenhouse gas, and reactive nitrogen burdens of meat, eggs, and dairy production in the United States

Gidon Eshel^{a,1,2}, Alon Shepon^{b,1}, Tamar Makov^c, and Ron Milo^{b,2}



These numbers were calculated specifically for the U.S. While the numbers agree for most food types, the beef land use number is approximately 440 m²/kg food.

Foods require different amounts of land for their production.



Recognizing that producing beef requires a lot of land, Eshel et al. (next slide) created a mathematical model that takes into account both nutrition and environmental footprint information to find out what foods people could use to get the nutrition they are getting from beef with minimal environmental impact.

Environmentally Optimal, Nutritionally Aware Beef Replacement Plant-Based Diets

Gidon Eshel,^{*,†} Alon Shepon,[‡] Elad Noor,[§] and Ron Milo[‡]

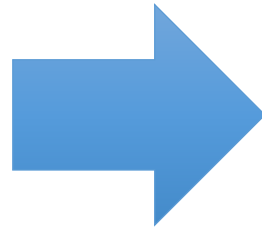


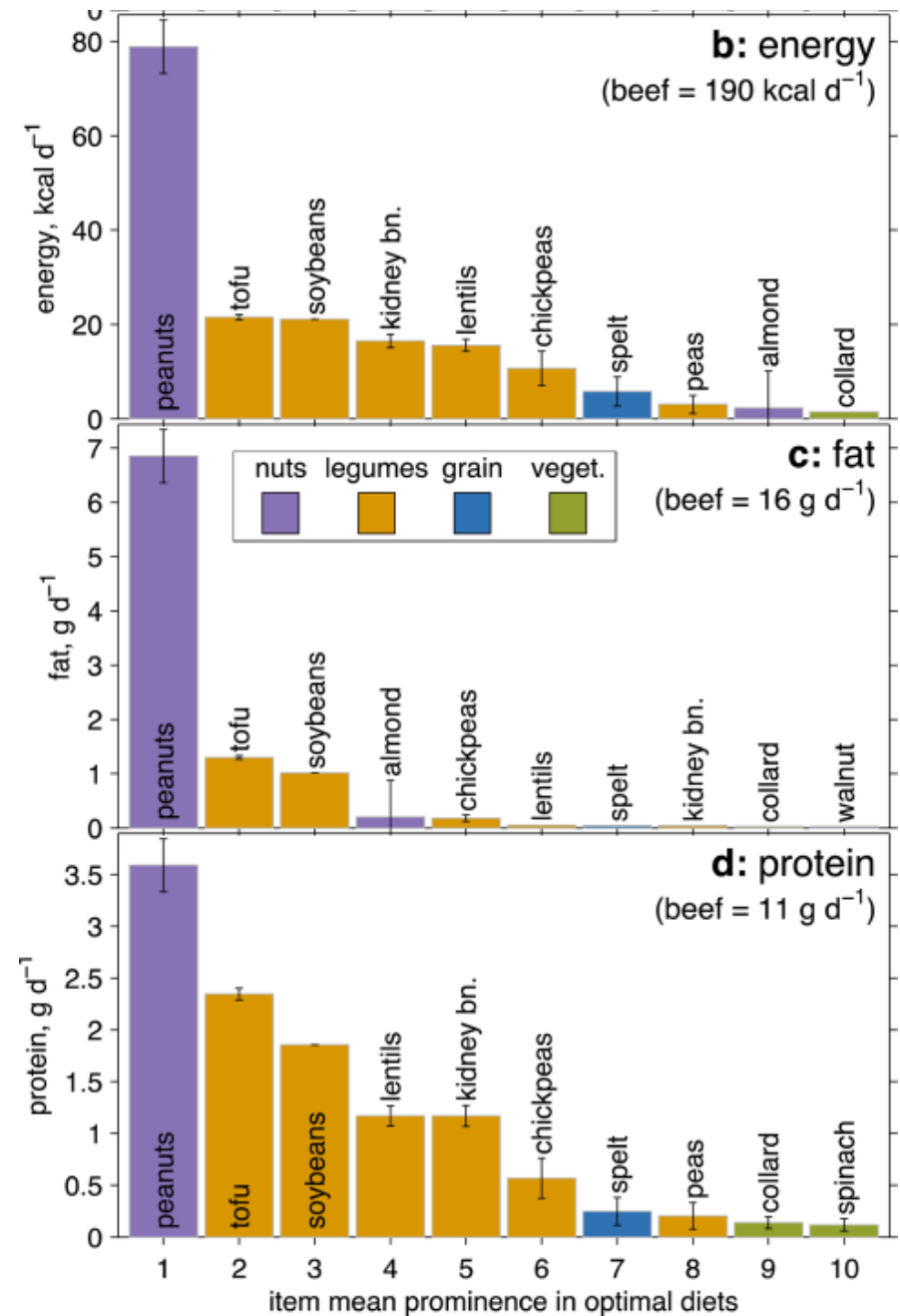
Table S1: The 65 considered plant items, in alphabetical order along the rows.

almonds	apples	apricots	asparagus	avocado	bananas
barley	blueberries	broccoli	buckwheat	cabbage	canola oil
cantaloupe	carrots	cauliflower	celery	cherry	chickpeas
collard	corn flour	corn starch	corn grits	cucumbers	garlic
grapefruit	grapes	green pepper	hazelnuts	honeydew	kidney beans
kiwi	lemon	lentils	lettuce	macadamia	oats
olive oil	onions	orange	peaches	peanuts	pears
peas	pineapple	pistachio	potato	pumpkin	raspberry
rice	rye	safflower oil	snap beans	soybeans	soy oil
spelt	spinach	squash	strawberry	sweet corn	sweet potato
tofu	tomato	walnut	watermelon	wheat	

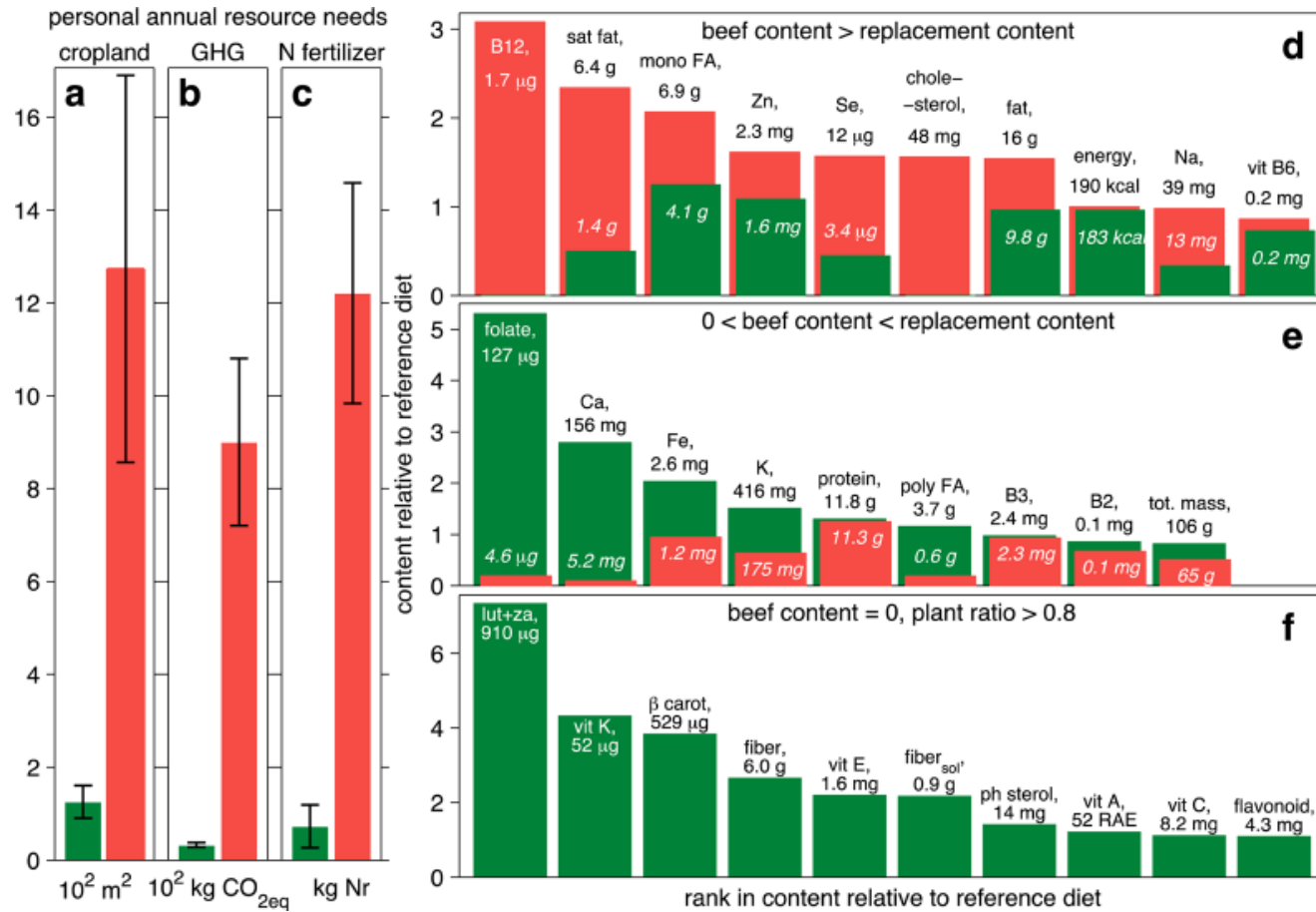
Peanuts and beans dominate the most nutritious and environmentally friendly food combinations.



These are affordable, available items



Eshel et al. 2016 continued



equivalents.

ity

Eshel et al. 2016 continued:
Much cropland would be freed, and GHG decreased significantly

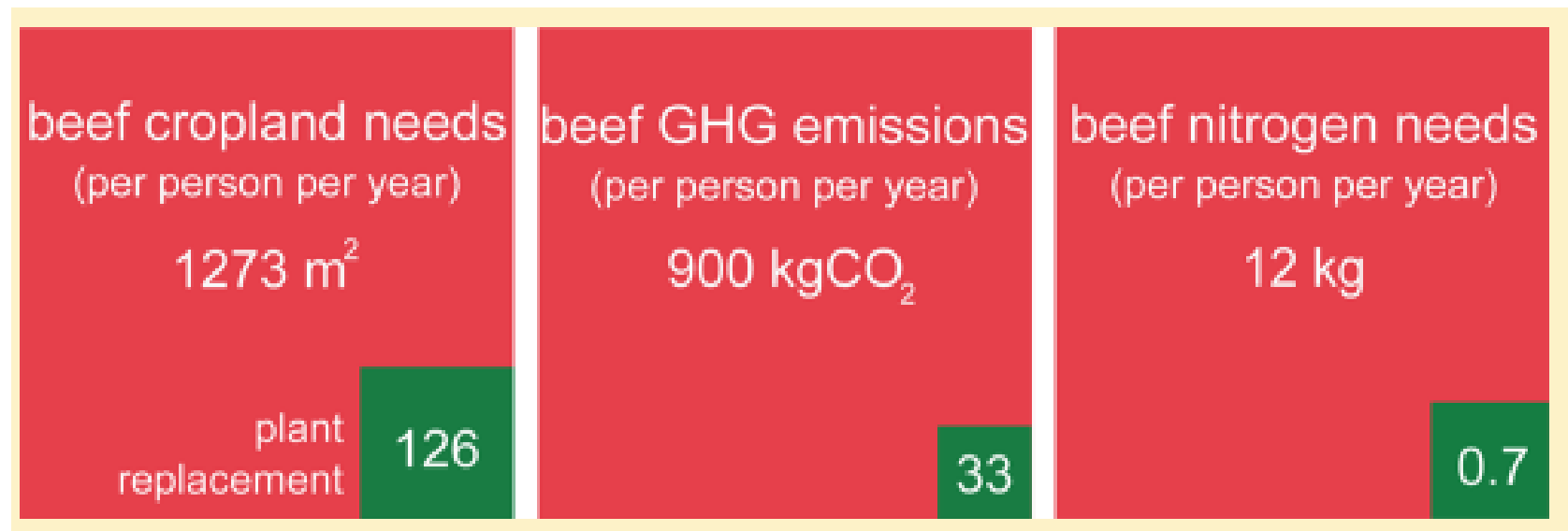
Table 1. Resource Savings Expected from a Nationwide Beef-to-Plants Dietary Shift

resource	mean (\pm std. dev.)	units
high quality cropland	91 (58, 124)	million acres
rangeland	771 (490, 1052)	million acres
GHG emissions	278 (220, 335)	million metric ton CO ₂
reactive nitrogen	3.7 (2.9, 4.4)	million metric ton Nr

- 0.8 billion acres (800 Mill. acres) is 40% of the contiguous US land surface area!
- 3.7 million tons of Nr savings is twice the delivery of N to the Mississippi
- More than half the 447 million metric ton reduction required by Paris Accord

Eshel et al—Environmentally optimal, nutritionally aware beef replacement plant-based diets

- If the freed land were reallocated to wheat and apples, could support a 600% increase in caloric availability
- Or, could rewild much of the Midwestern land, providing land for biodiversity maintenance. Also carbon sequestration.



Activity: What the World Eats

- Go to the What the World Eats site by National Geographic.
- Choose a country and a time
- Enter the total grams of food per person per day in D8.
- Working down column D in the Land Use Excel, please fill in the % of grams that come from each food group. You may have to hover over a category in order to get the breakdown. For example, if you hover over Meat, you will see how much of the meat is beef, pork, etc.
- Use google to find the population of the country you chose, and the area. Put those items in the spreadsheet.
- You will be able to compare the actual land area of the country to the amount required to grow its food, as estimated by these data.

END of presentation

- Note: The Eshel numbers (specific for the US) were used when available. In other cases, Meier and Christen numbers were used.

Next: More slides on Eshel et al. Beef replacement paper



Environmentally Optimal, Nutritionally Aware Beef Replacement Plant-Based Diets

Gidon Eshel,^{*,†} Alon Shepon,[‡] Elad Noor,[§] and Ron Milo[‡]

Modeled the environmental benefits in terms of GHG production, land use, and nitrogen use in replacing beef with nutritionally appropriate foods.

Step 1) Created replacement diets for the 190 kcal of beef in average diet:

A) Randomly selected 60 plant foods, many times over (Monte Carlo analysis)

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peas	pineapple	pistachio	potato	pumpkin	raspberry
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spelt	spinach	squash	strawberry	sweet corn	sweet potato
tofu	tomato	walnut	watermelon	wheat	

Chose 500 combinations (over 8 million options).

Sought the masses for those 60 items that replace beef while satisfying four in equality constraints.

Created replacement diets:

Optimized each of the 500 sets of 60 foods for minimal land use, GHG production, and nitrogen use. (Linear programming)

All diets had to have:

Energy: ≤ 190 kcal/day

Fat: ≤ 16 g/day

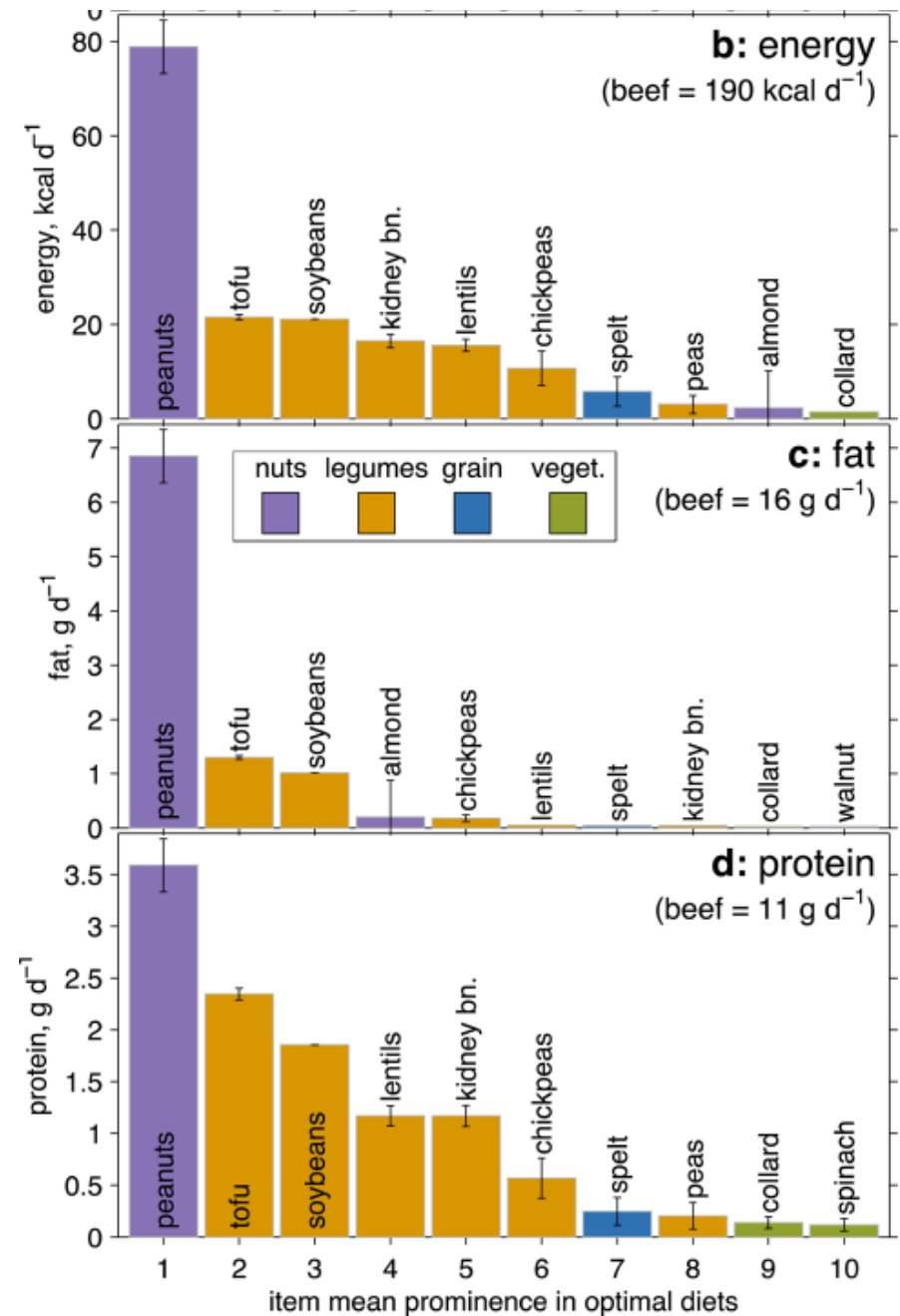
Protein ≥ 11 g/day

Not more than twice the mass of the beef diet

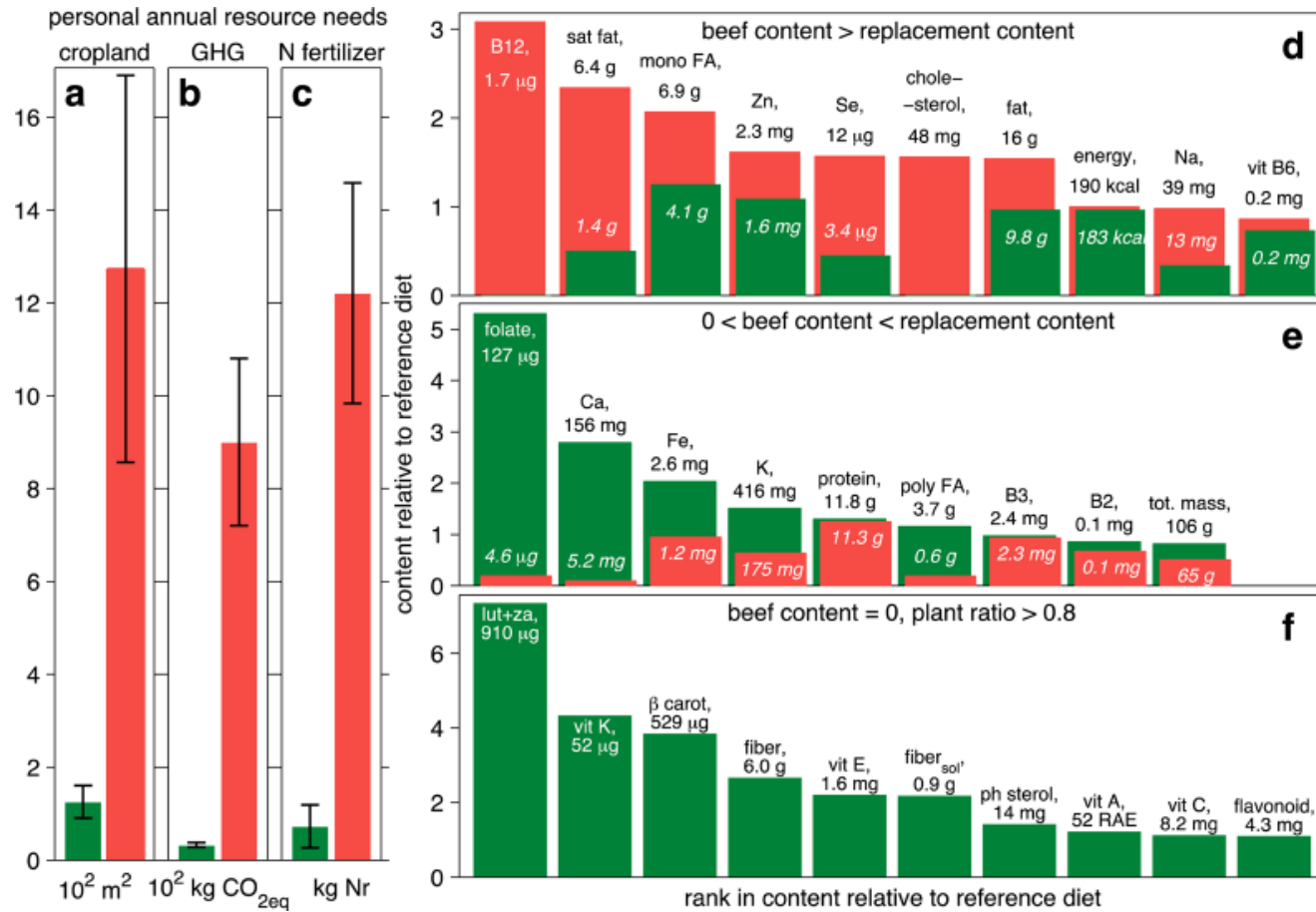
500 sets * 3 optimizations/set = 1500 different diet scenarios

Composition of diets, average over 1500 replacement diets, listed in decreasing contribution to each metric.

Peanuts and soybeans dominate the scenarios, and these are affordable, available items



Eshel et al. 2016 continued



equivalents.

ity

Eshel et al. 2016 continued:
Much cropland would be freed, and GHG decreased significantly

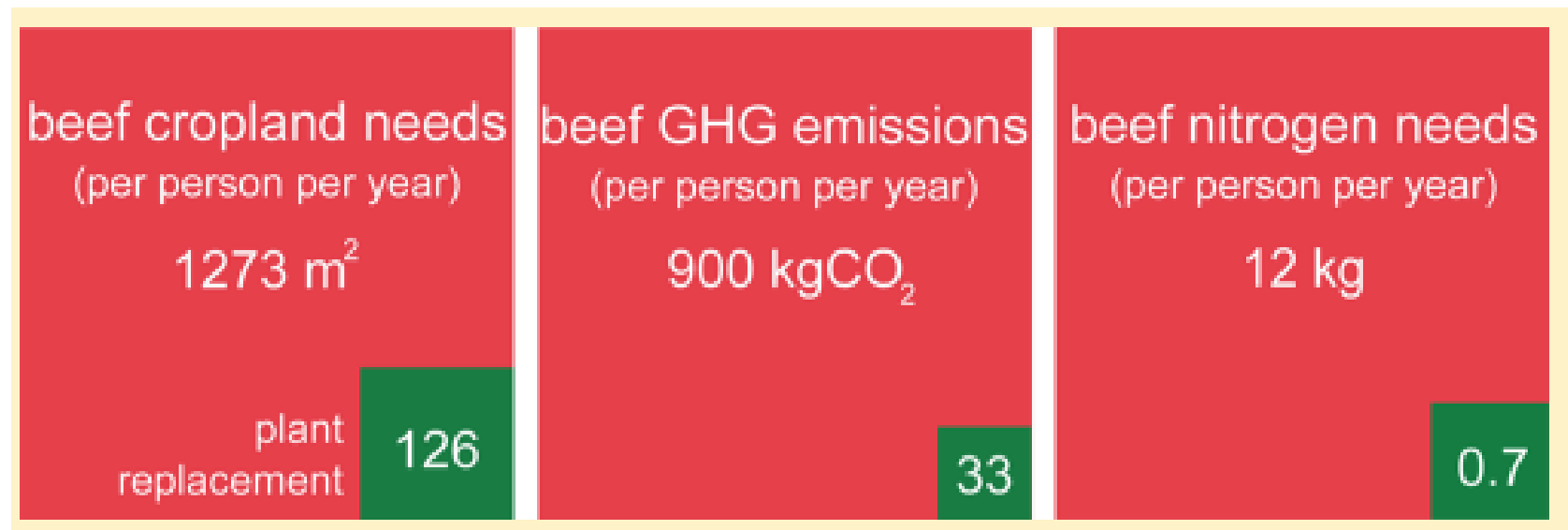
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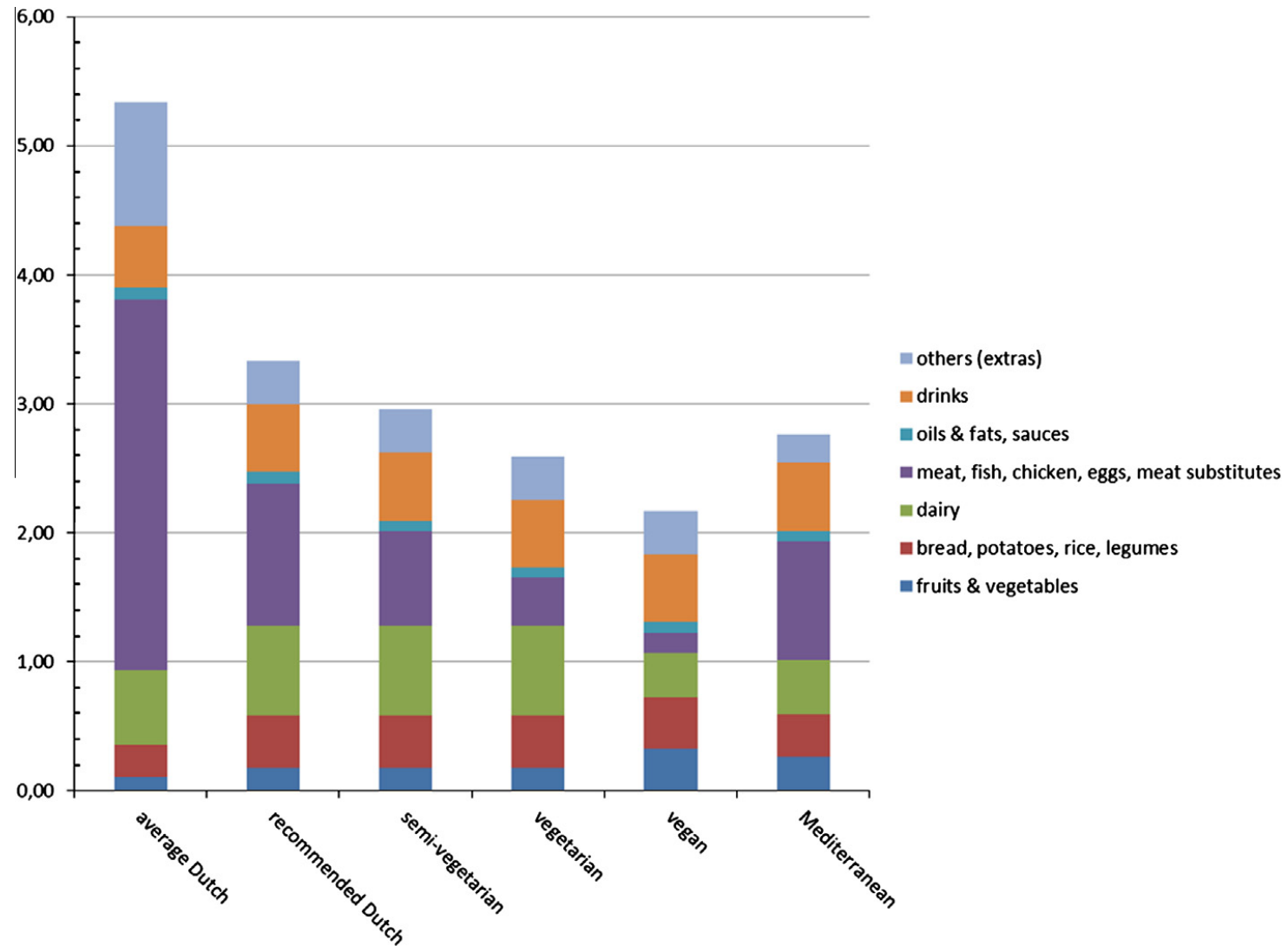


Extra slides

Van Dooren et al. (2014) Exploring dietary guidelines based on ecological and nutritional values: A comparison of six dietary patterns

- Van Dooren et al. (2014) investigated both healthfulness and environmental sustainability of six diets: current Dutch diet, official Dutch “recommended”, semi-vegetarian, vegetarian, vegan, and Mediterranean.
- The authors created scoring systems for both environmental sustainability (including GHG emissions and land use) and health (ten nutritional indicators).
- In general, the two metrics go hand in hand—diets high in meat and dairy received lower scores for both health and sustainability.

Van Dooren et al. (2014)



From Meier and Christen

Table 3. Conversion Factors, Environmental Impact Factors, and Degree of Self-Sufficiency of the Food Groups Analyzed

		butter	high-fat dairy products (cheese, cream)	Low-fat dairy products (milk, yoghurt)	vegan milk products (in whole milk equivalents)	meat products				egg products	fish products	grains	vegetables	legumes	fruits	nuts & seeds	potato products	vegetable oils, margarine	sugar
						beef, veal	pork	poultry	other meat										
land use	$\text{m}^2 \text{ kg}^{-1}$	20.7	9.9	2.4	0.7	25.4	8.9	6.2	19.9	3.8	0.2	1.8	0.5	2.1	0.9	2.9	0.3	4.1	1.2

Rangeland degradation occurs if livestock density exceeds capacity of pasture.



