Sustainable transformation pathways for the food system: insights on models from outside prospective LCA

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Environmental impacts of the food system

The current food system is environmentally unsustainable:

- major driver of climate change (33% of GHG emissions, IPCC, 2019);
- major driver of land-use change and biodiversity loss (40% of the Earth's surface, Ramankutty et al, 2008; Houghton et al, 2012);
- major user of freshwater resources (70% of global freshwater withdrawals (WWAP, 2012);
- major polluter of terrestrial and aquatic systems through fertilizer runoff (Vitousek et al, 1997) ($\rightarrow$ dead zones in coastal oceans, Diaz and Rosenberg, 2008)

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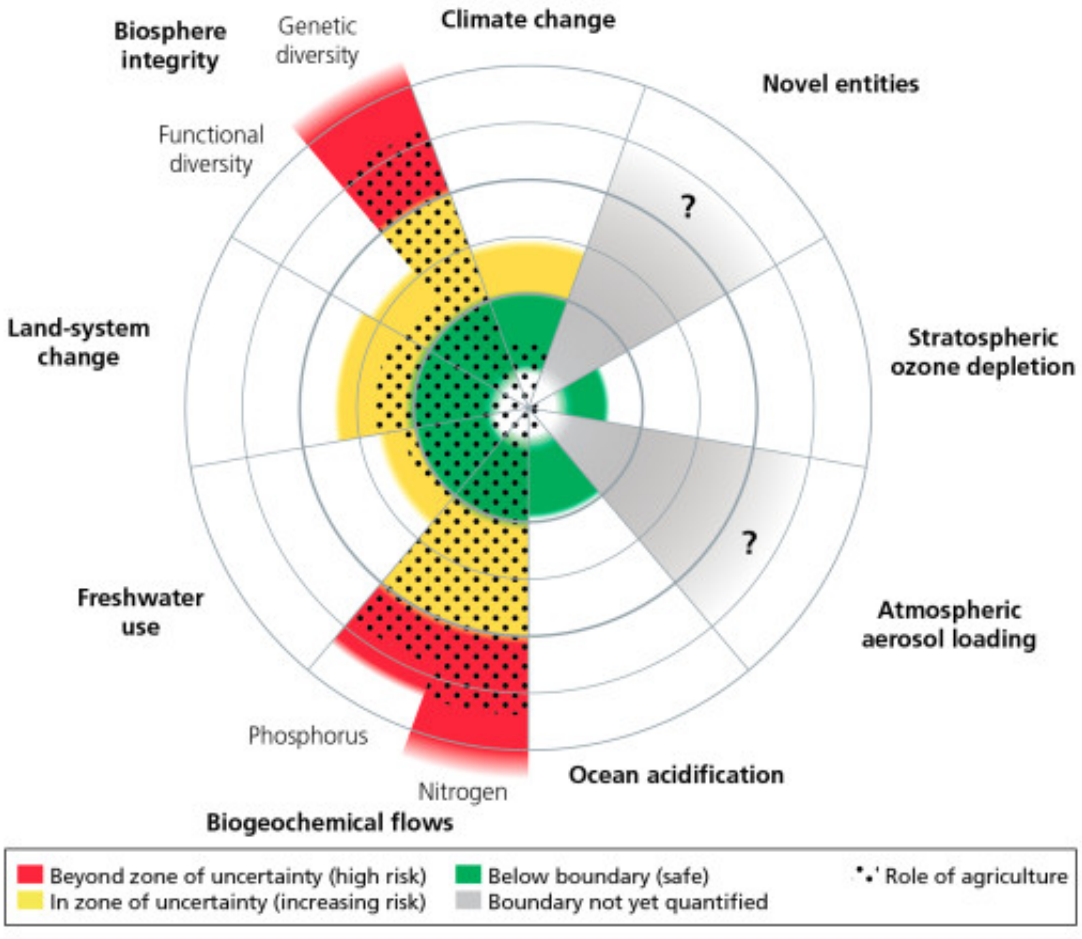
$\rightarrow$ major driver of planetary impacts

Planetary boundaries

- Transgressing put ecosystems at risk of being destabilised and losing regulating functions on which populations depend



Steffan et al (2015), Campbell et al (2017)

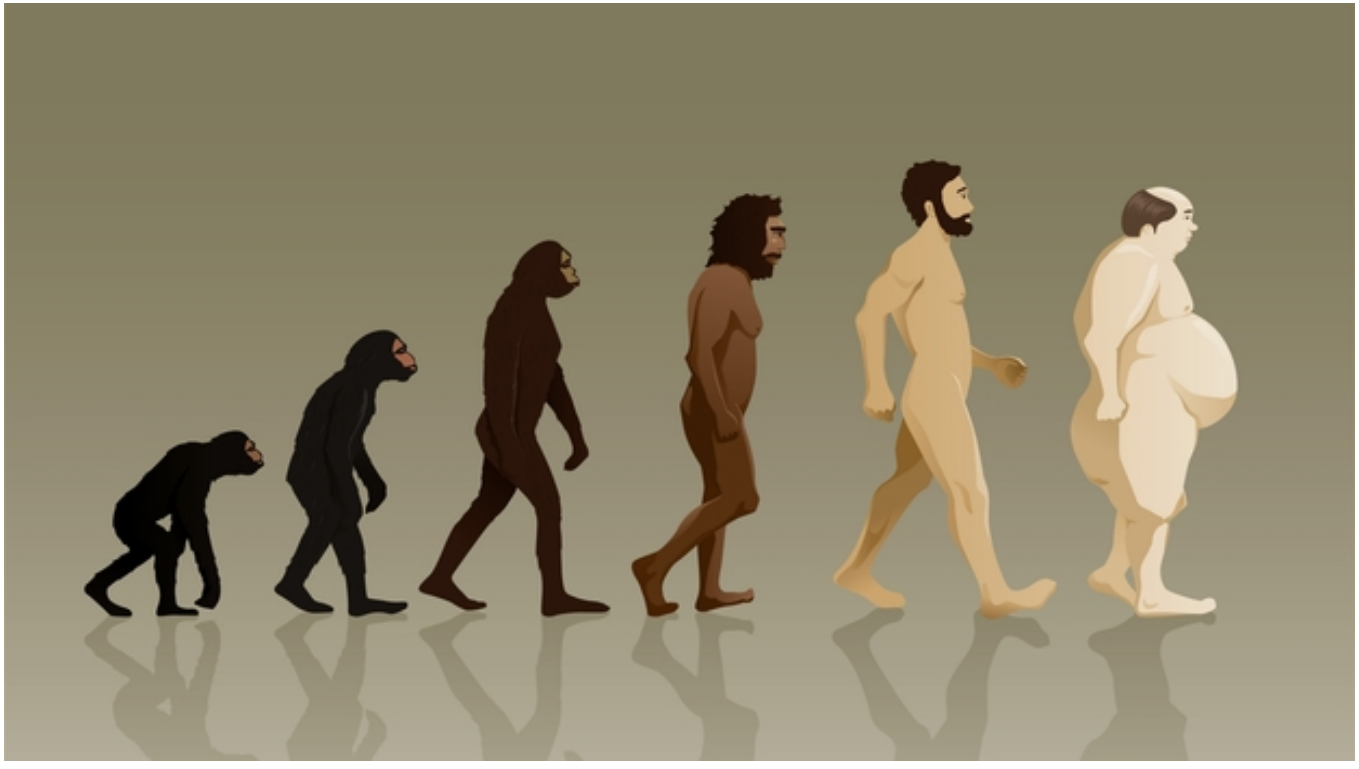
Health impacts of the food system

Current diets are not healthy:

- Less than half of all countries meet or are projected to meet dietary guidelines on red meat, fruits and vegetables, sugar, and total energy intake (Micha et al, 2015; Springmann et al, 2016).

Health impacts of the food system

- Global prevalence of overweight increased over a third, and obesity rates doubled over last 30 years (Stevens et al, 2012).



Health impacts of the food system

- Dietary risks are leading risk factors globally and in most regions (GBD, 2013):

	Global	High-income Asia Pacific	Western Europe	Australasia	High-income North America	Central Europe	Southern Latin America	Eastern Europe	East Asia	Tropical Latin America	Central Latin America	Southeast Asia	Central Asia	Andean Latin America	North Africa and Middle East	Caribbean	South Asia	Oceania	Southern Sub-Saharan Africa	Eastern Sub-Saharan Africa	Central Sub-Saharan Africa	Western Sub-Saharan Africa
Dietary risks	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	3	4	4
High blood pressure	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	5	1	1	3	3
Smoking	3	3	3	3	2	3	4	4	3	3	5	3	3	4	4	3	4	4	6	8	9	9
Household air pollution	4	23	24	24	24	10	14	13	5	11	9	4	9	8	13	7	3	6	8	2	2	2
High fasting plasma glucose	5	6	7	6	6	7	6	8	6	5	4	5	6	5	6	4	5	1	5	6	7	7
High body-mass index	6	7	4	4	4	4	3	5	9	4	3	9	4	3	3	5	12	3	3	10	15	10
Ambient PM pollution	7	5	8	11	8	8	11	9	4	12	10	7	7	13	7	11	6	16	15	12	12	8
Physical inactivity	8	4	5	5	5	5	5	6	7	7	7	6	5	7	5	6	7	7	7	9	8	11
Alcohol use	9	8	9	8	9	9	8	3	8	6	6	8	10	6	10	8	9	8	4	5	6	5
High total cholesterol	10	9	6	7	7	6	7	7	10	8	8	10	8	9	8	9	11	9	12	17	19	19
Childhood underweight	11	22	21	19	20	20	20	21	21	19	14	14	15	16	14	14	10	10	10	4	1	1
Occupational risks	12	11	11	10	12	12	10	12	11	10	12	11	12	11	11	15	8	11	13	13	17	15
Lead	13	10	10	9	11	11	9	10	12	9	11	12	11	10	9	10	14	13	11	16	18	18
Suboptimal breastfeeding	14	25	24	24	24	25	18	25	18	14	13	13	13	12	12	13	13	12	9	7	5	6
Sanitation	15	19	19	18	22	23	21	20	22	21	23	18	25	20	21	18	15	15	17	11	10	12
Low bone mineral density	16	12	12	12	13	13	13	17	13	15	17	15	22	19	18	16	18	22	22	21	23	20
Intimate partner violence	17	13	16	15	16	16	16	14	15	16	18	17	16	17	16	17	16	17	16	20	20	21
Drug use	18	14	14	13	10	15	12	11	17	13	16	16	14	14	15	19	24	19	14	22	21	22
Ozone	19	17	15	23	15	17	25	18	14	23	21	25	19	25	17	24	17	25	23	24	22	23
Vitamin A deficiency	20	24	23	22	23	24	24	24	25	25	25	22	23	22	24	22	19	21	18	14	13	13
Iron deficiency	21	18	18	16	18	19	15	19	20	17	15	21	21	15	22	12	20	14	19	19	16	14
Unimproved water	22	20	20	21	19	22	22	23	24	24	24	20	24	23	19	20	22	18	21	15	11	16
Zinc deficiency	23	21	22	20	21	21	23	22	23	22	20	19	17	18	23	21	23	20	20	18	14	17
Radon	24	16	13	17	14	14	17	15	16	18	19	23	18	24	20	25	25	24	25	25	25	25
Childhood sexual abuse	25	15	17	14	17	18	19	16	19	20	22	24	20	21	25	23	21	23	24	23	24	24

EAT-Lancet Commission

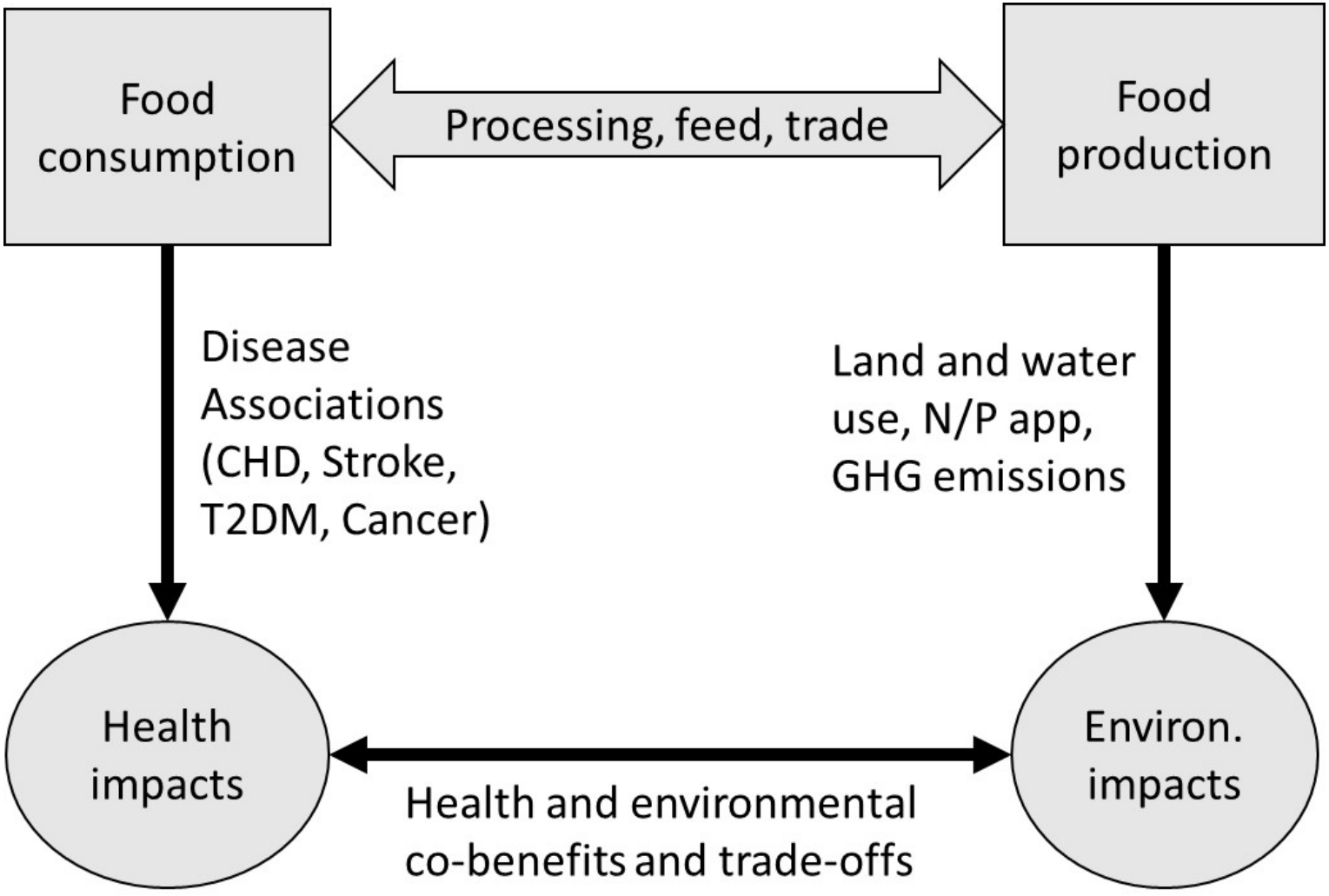
Goal of the **EAT-Lancet Commission on Healthy Diets from Sustainable Food Systems**:

- Achieve a sustainable food system that can deliver healthy diets for a growing population.

Approach:

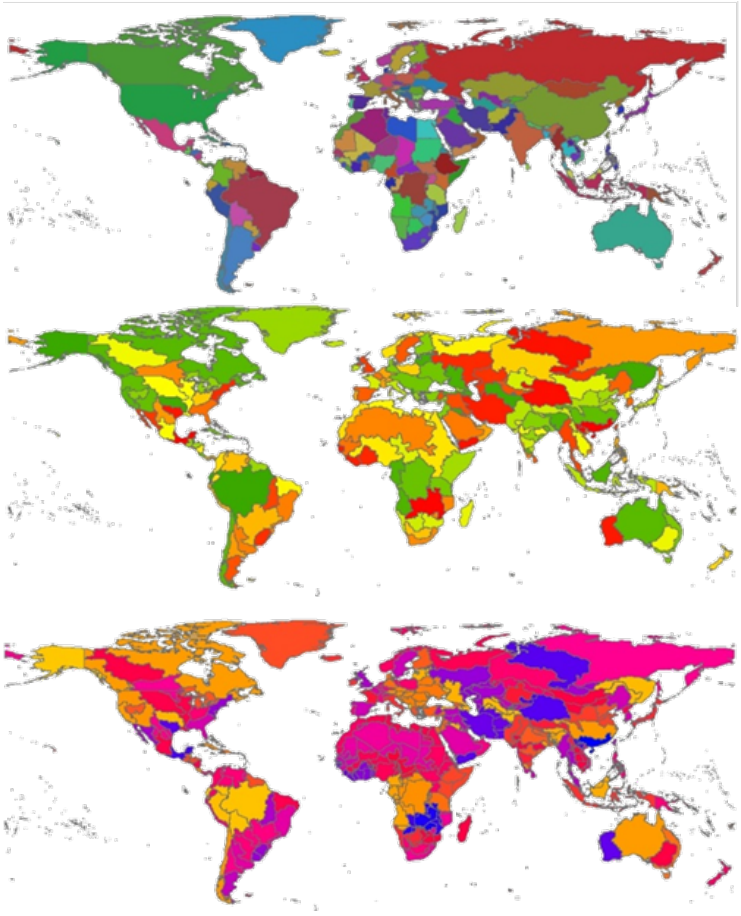
- Group of 19 commissioners and 18 co-authors from 16 countries and various fields, including human health, agriculture, political science and environmental sustainability.
- Define a healthy reference diet
- Define planetary boundaries of the food system
- Analyse diets and food system changes to stay within planetary boundaries
- Outline strategies to achieve healthy diets from sustainable food systems by 2050.

Environmental and food-systems analysis



Level of detail

Analysis based on future food projections for 159 regions and 62 agricultural commodities from IFPRI-IMPACT model:



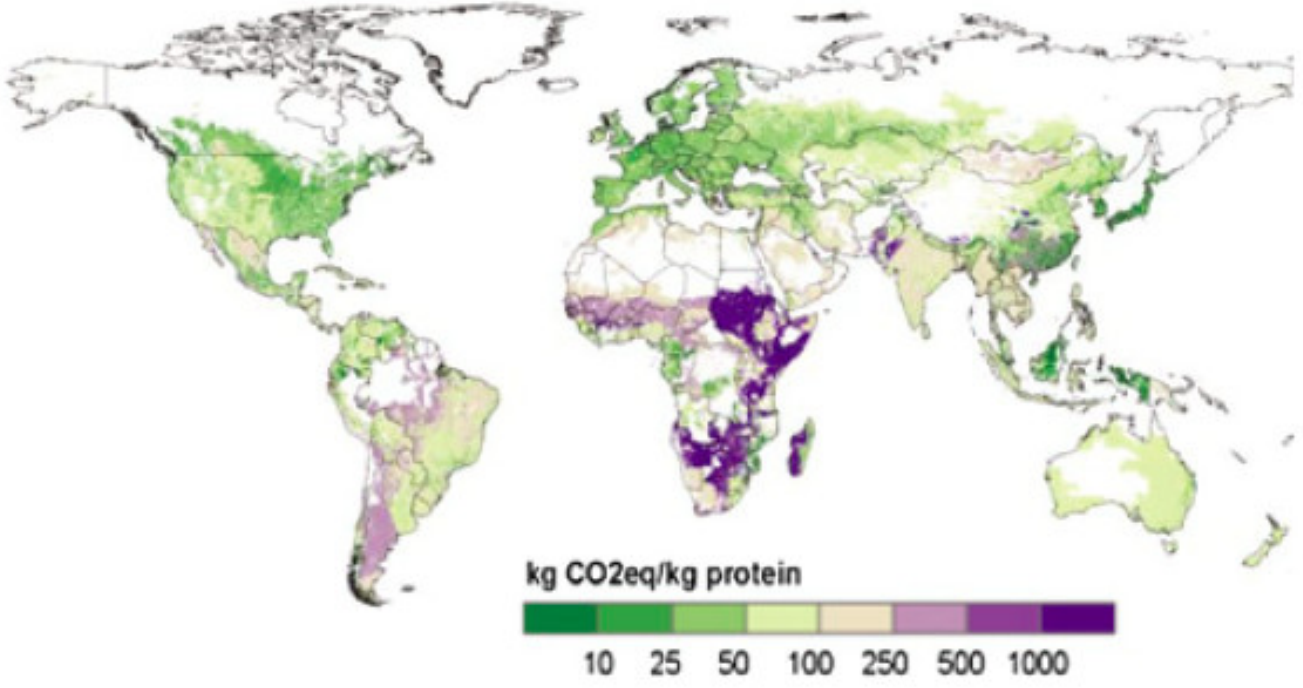
159
- Countries

154
- Water Basins

320
- Food Production Unit

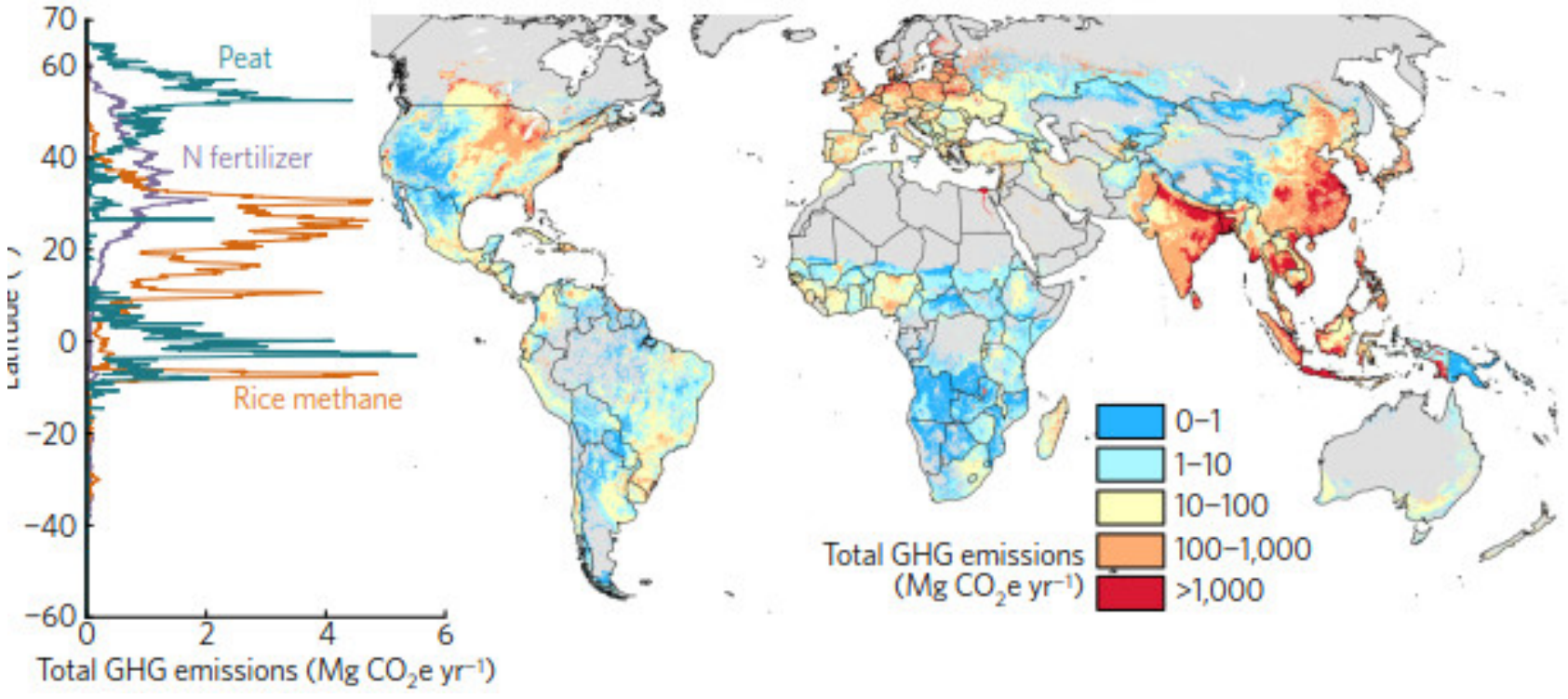
Add to that (1)

GHG emissions of livestock (Herrero et al 2013; FAOSTAT):



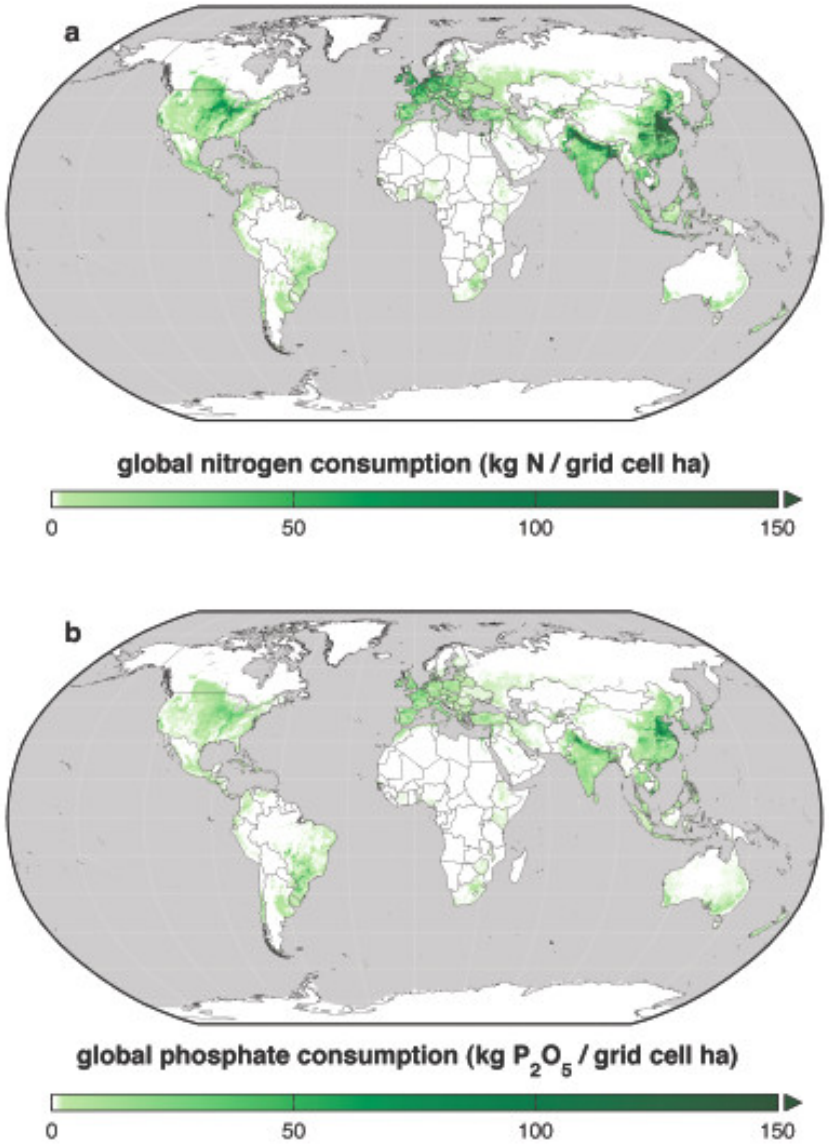
Add to that (2)

GHG emissions of crops (Carlson et al 2016):



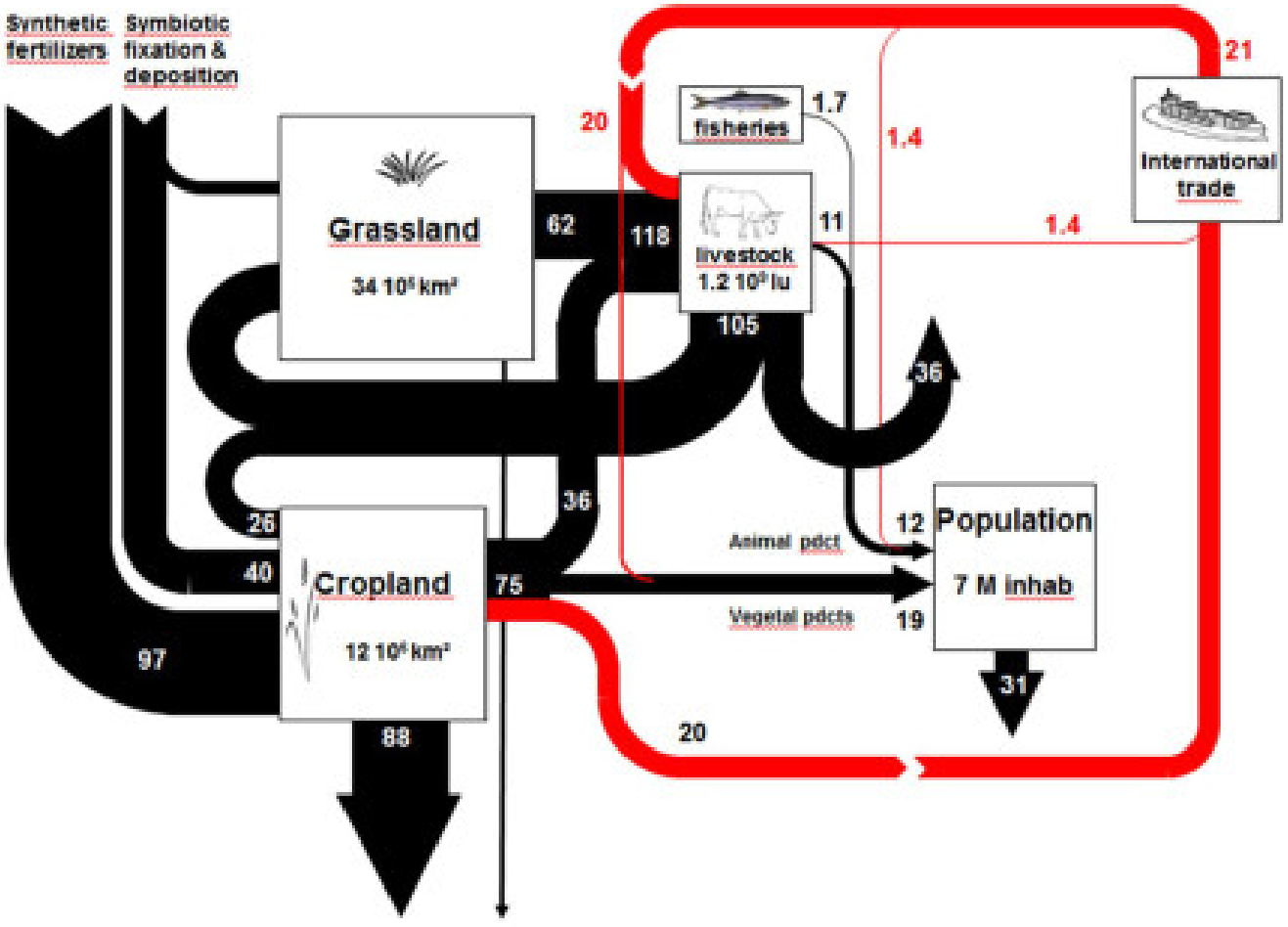
Add to that (3)

Fertilizer application (Mueller et al, 2012):



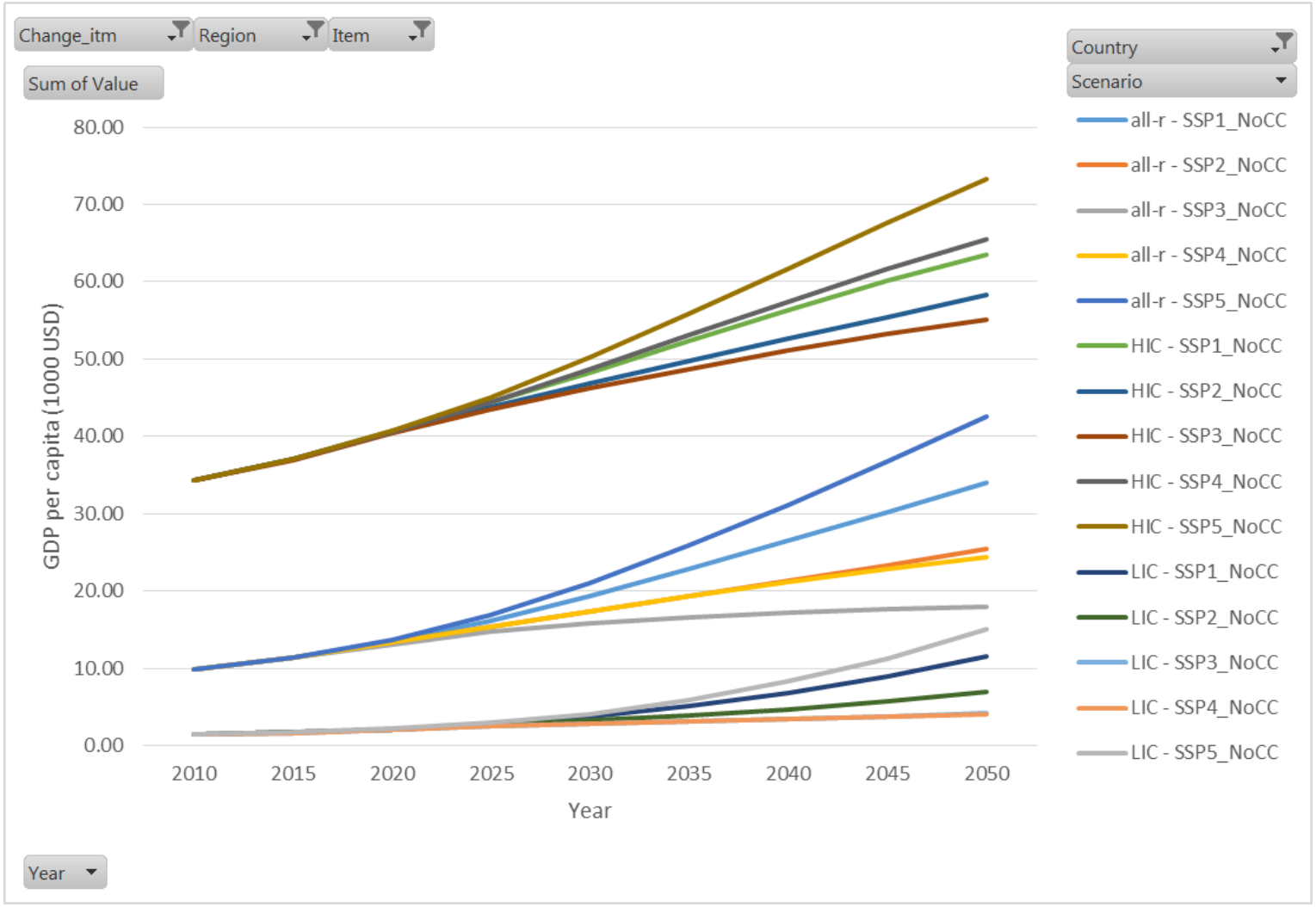
Add to that (4)

Nitrogen balance model (Lassaletta et al, 2016):



Add to that (5)

Drivers of future food demand (population and income, SSPs):



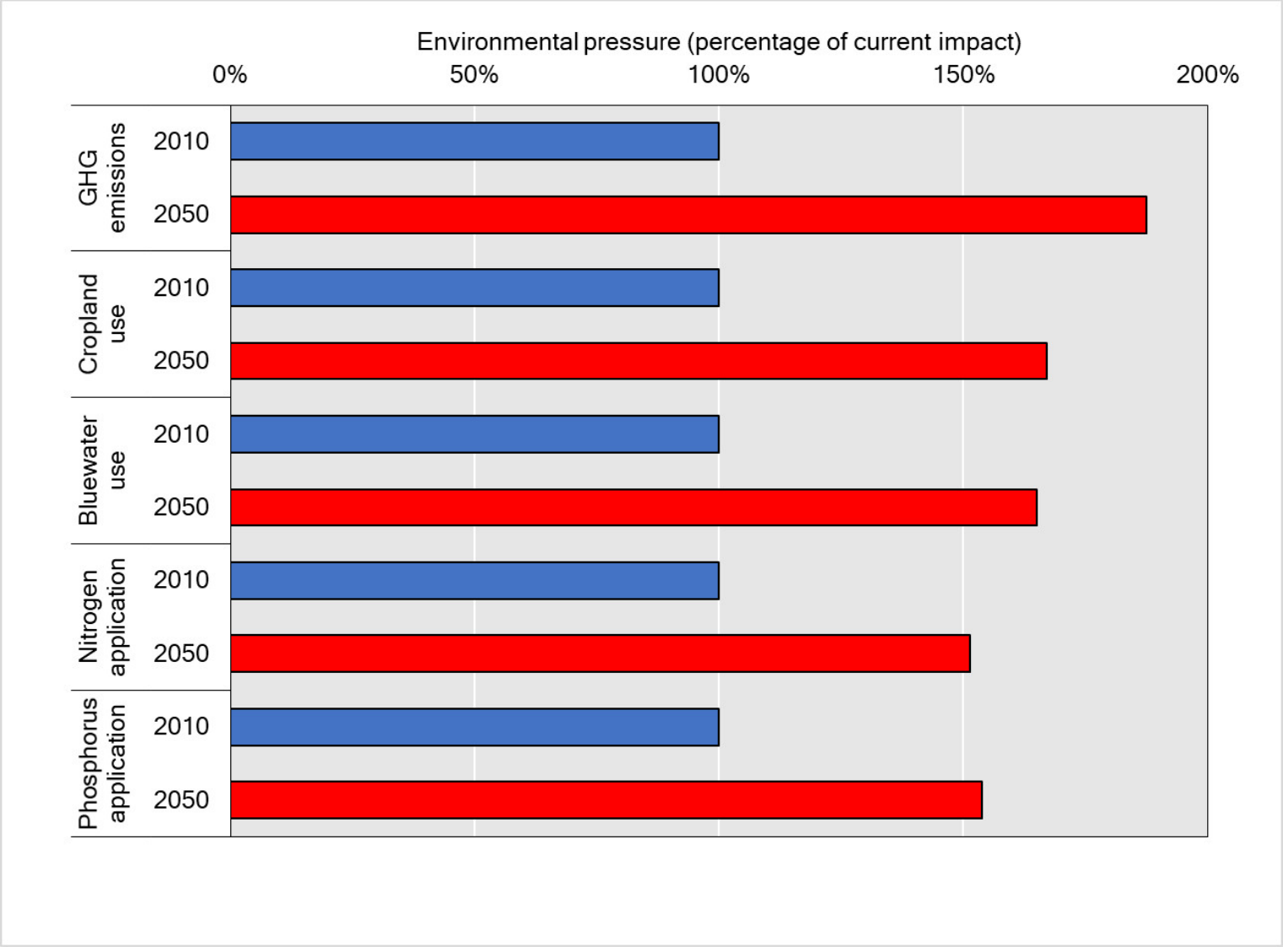
Add to that (6)

Scenario assumptions:

Waste/2	Food losses and waste are reduced by half, in line with pledges made as part of the Sustainable Development Goals.
Waste/4	Food losses and waste are reduced by three quarters, %, a value likely close to the maximum value that can be theoretical avoided (Parfitt et al., 2010).
TECH	Closing of yield gaps between attained and attainable yields to about 75% (Mueller et al., 2012; Robinson et al., 2015); Rebalancing nitrogen and phosphorus fertilizer application between over and under-applying regions (Mueller et al, 2012); improving water management, including increasing basin efficiency, storage capacity, and better utilization of rainwater (Robinson et al., 2015); and implementation of agricultural mitigation options that are economic at the projected social cost of carbon in 2050, including changes in irrigation, cropping and fertilization that reduce methane and nitrous oxide emissions for rice and other crops, as well as changes in manure management, feed conversion and feed additives that reduce enteric fermentation in livestock (Beach et al., 2015).
TECH+	Additional measures on top of TECH scenario, including additional increases in agricultural yields that close yield gaps to 90% (Mueller et al, 2012); a 30% increase in nitrogen use efficiency in line with suggested targets (Sutton et al., 2013), and 50% recycling rates of phosphorus; implementation of all available bottom-up options for mitigating food-related GHG emissions (Beach et al, 2015).
HGD	Dietary shifts towards global dietary guidelines (WHO, 2004, 2003), including maximum intakes for red meat (three 100g servings per week) and sugar (5% of energy intake), minimum intakes of fruits and vegetables (five servings a day), and energy intakes in line with recommendations on healthy body weight and physical activity (2100-2200 kcal per day on average)
FLX	Dietary shifts towards flexitarian dietary patterns based on recent evidence on healthy eating (Willett and Stampfer, 2013) that include, in addition to HGD requirements, more stringent limits for red meat (one serving a week), limits for white meat (half a portion a day) and dairy (one portion a day), and greater minimum amounts of legumes, nuts, and vegetables.
VEG VGN	Dietary shifts towards nutritionally-balanced vegetarian and vegan diets that are based on FLX diets, but substitute meat (vegetarian) or all animal products (vegan) to two thirds with legumes and to one third with vegetables, in line with observed dietary changes in those groups.

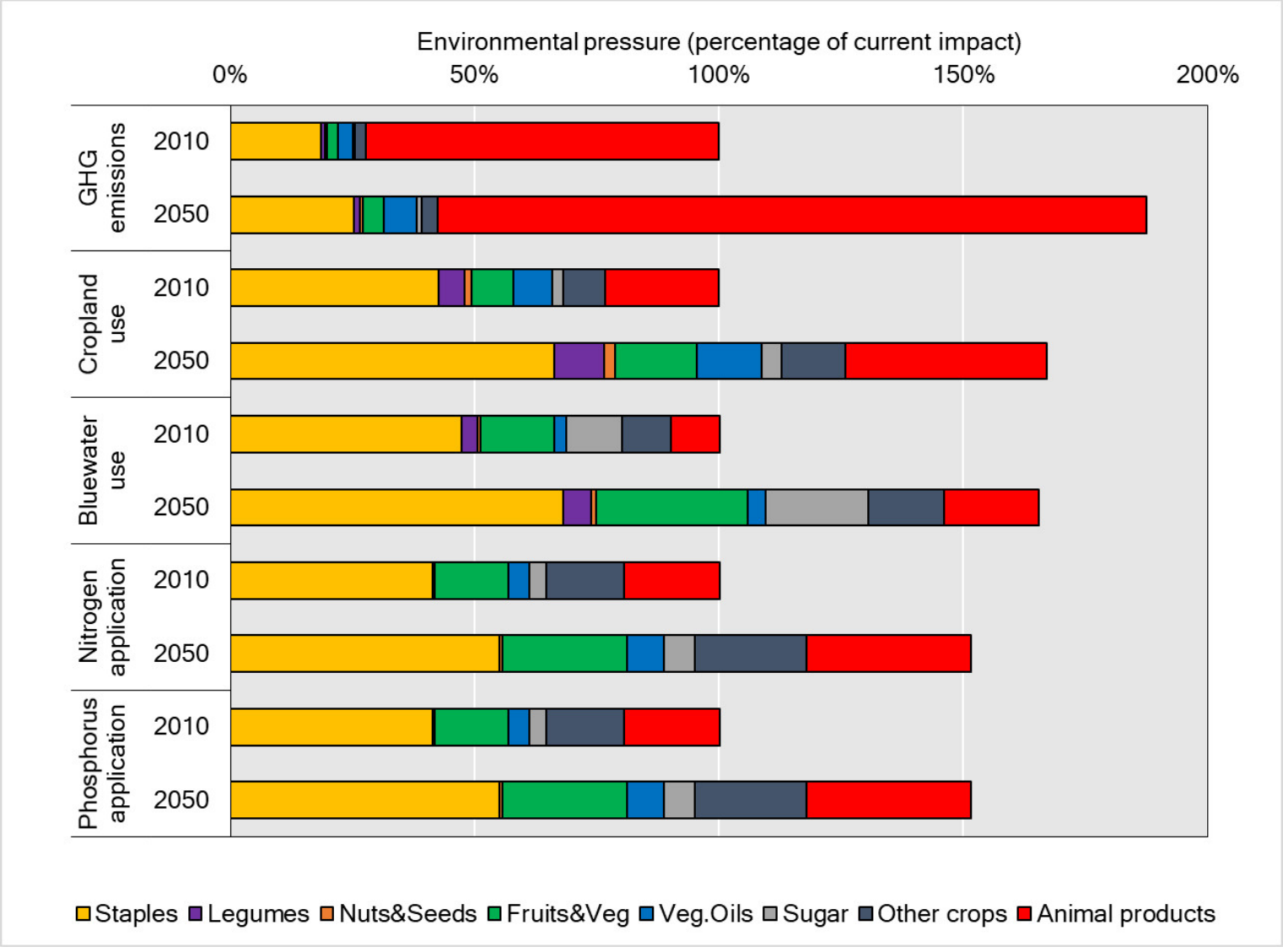
Results

Increase in resource demand by 2050: 50-90%



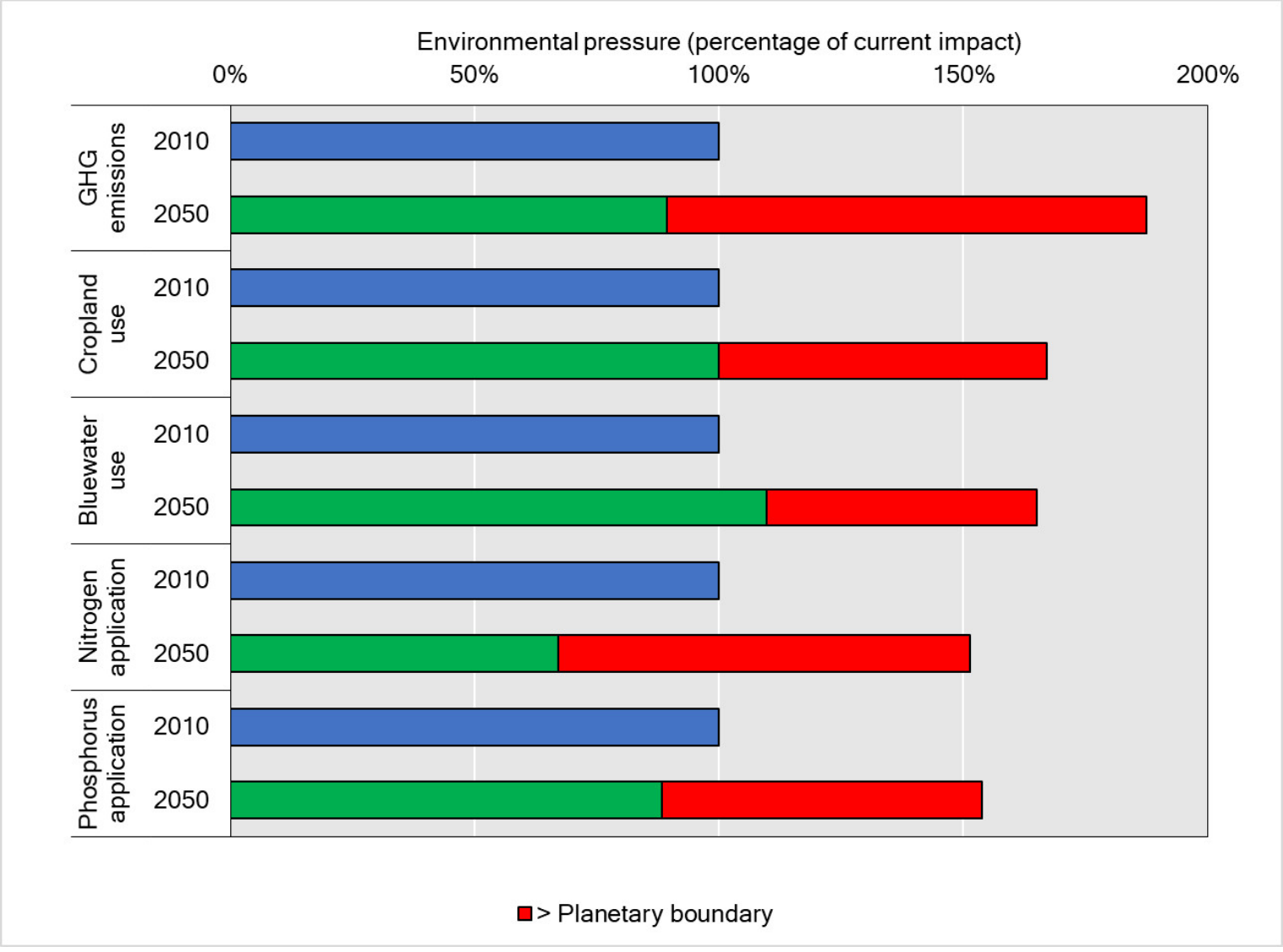
Results

Domains: livestock-dominated or staple-crop-dominated



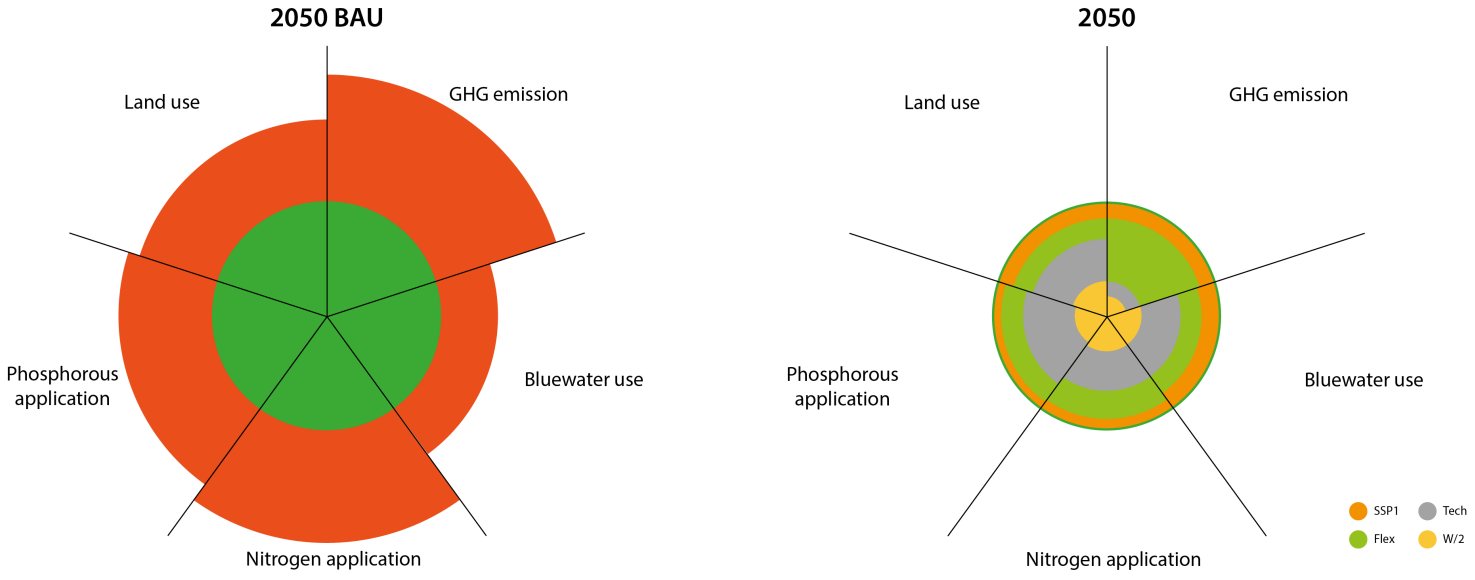
Results

All planetary boundaries could be exceeded by 2050:



Food-systems analysis

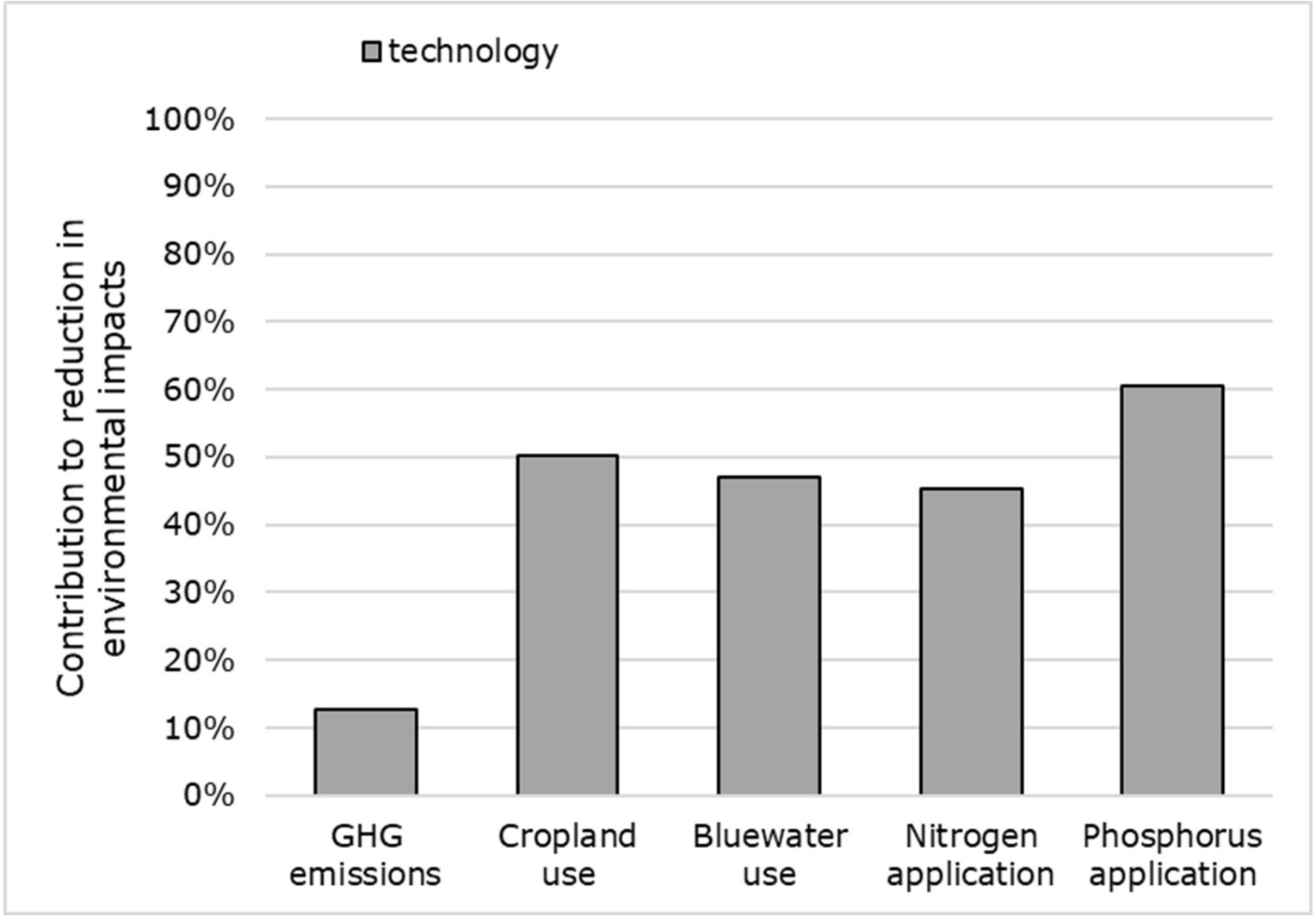
Combination of measures needed to stay within **planetary boundaries** of the food system:



Springmann et al, *Nature* 2018

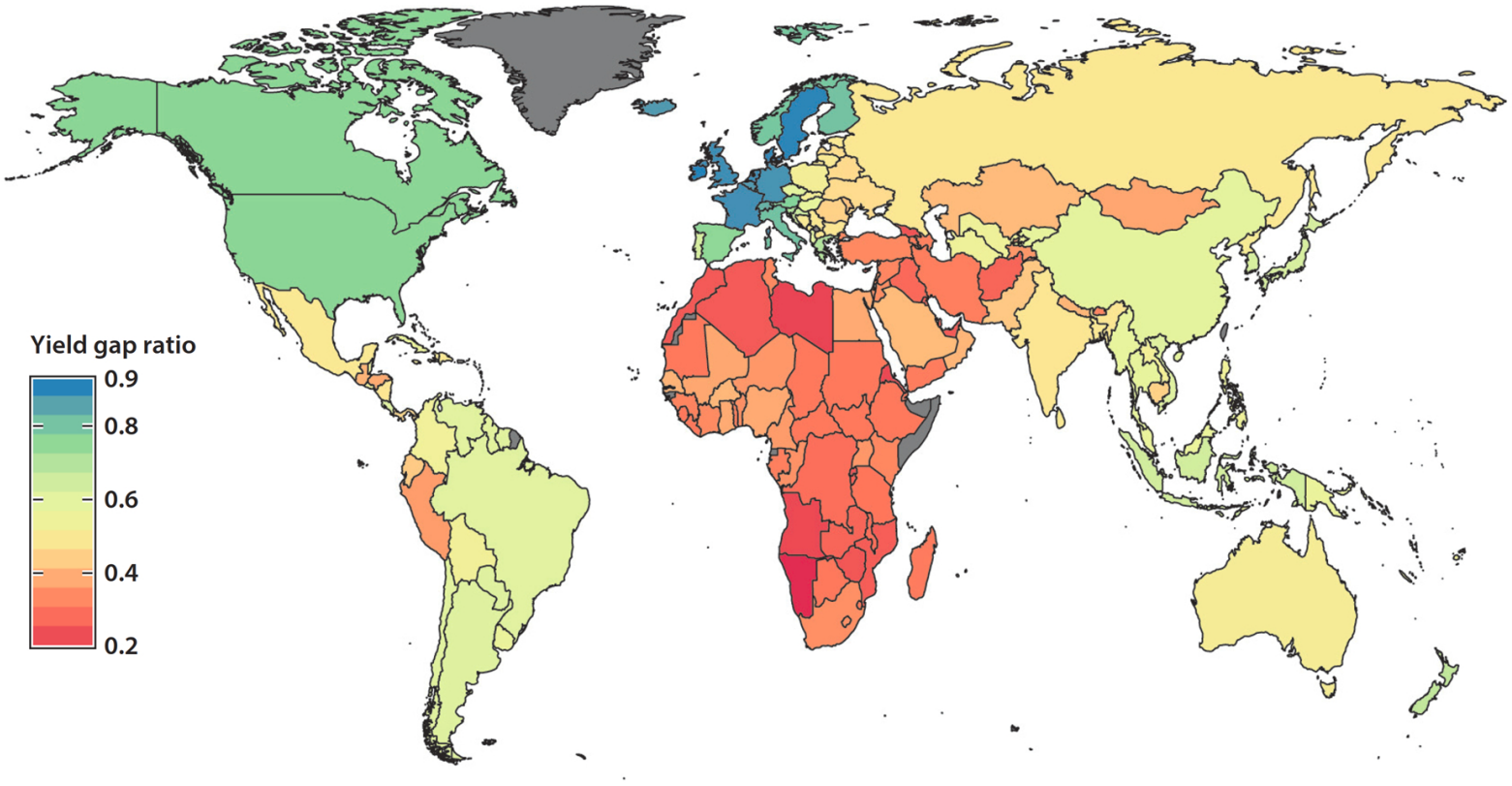
Food-systems analysis

Contribution of improvements in **technology and management**:



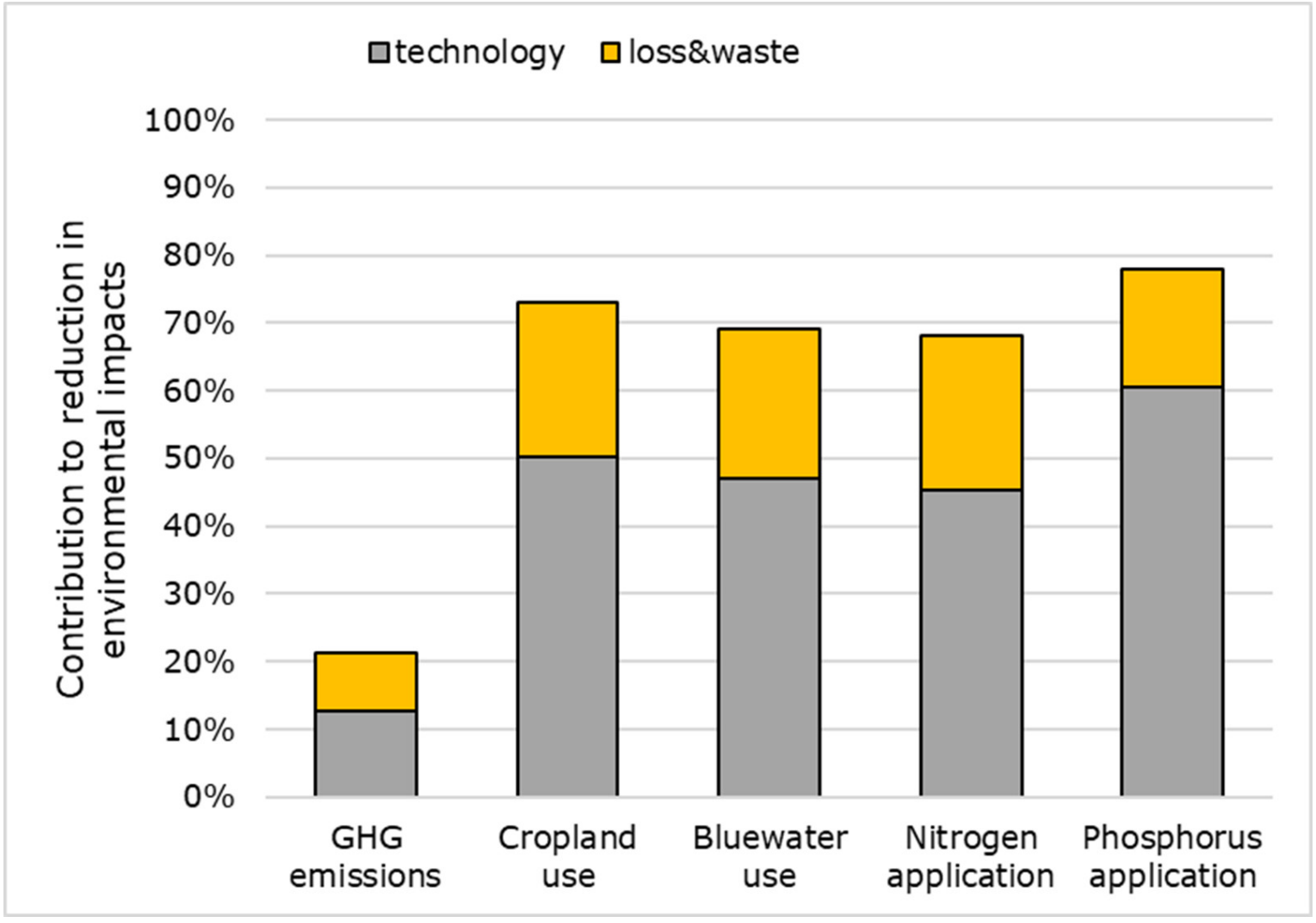
Food-systems analysis

Unequal **distribution** of technology and capital (Mueller et al, 2012):



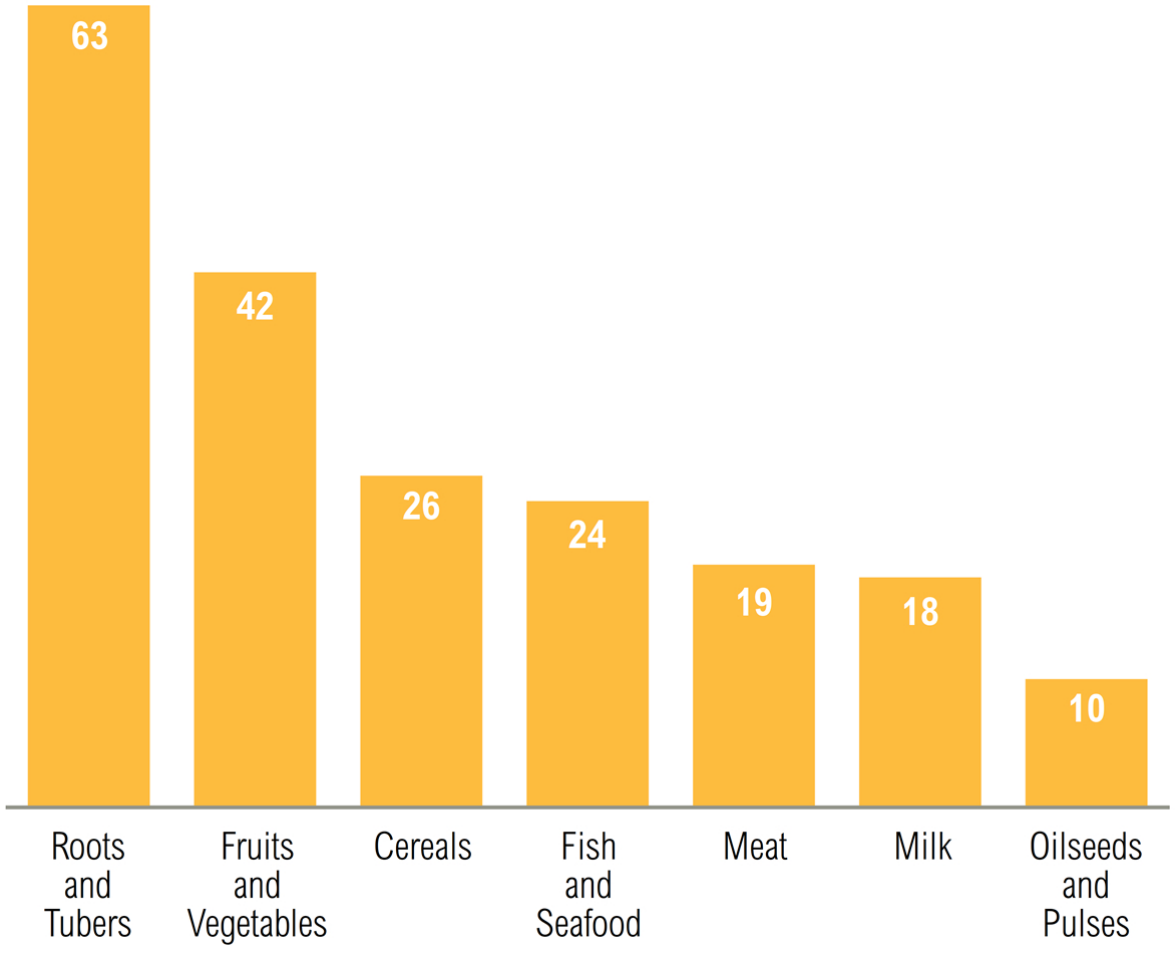
Food-systems analysis

Contribution of reductions in **food loss and waste**:



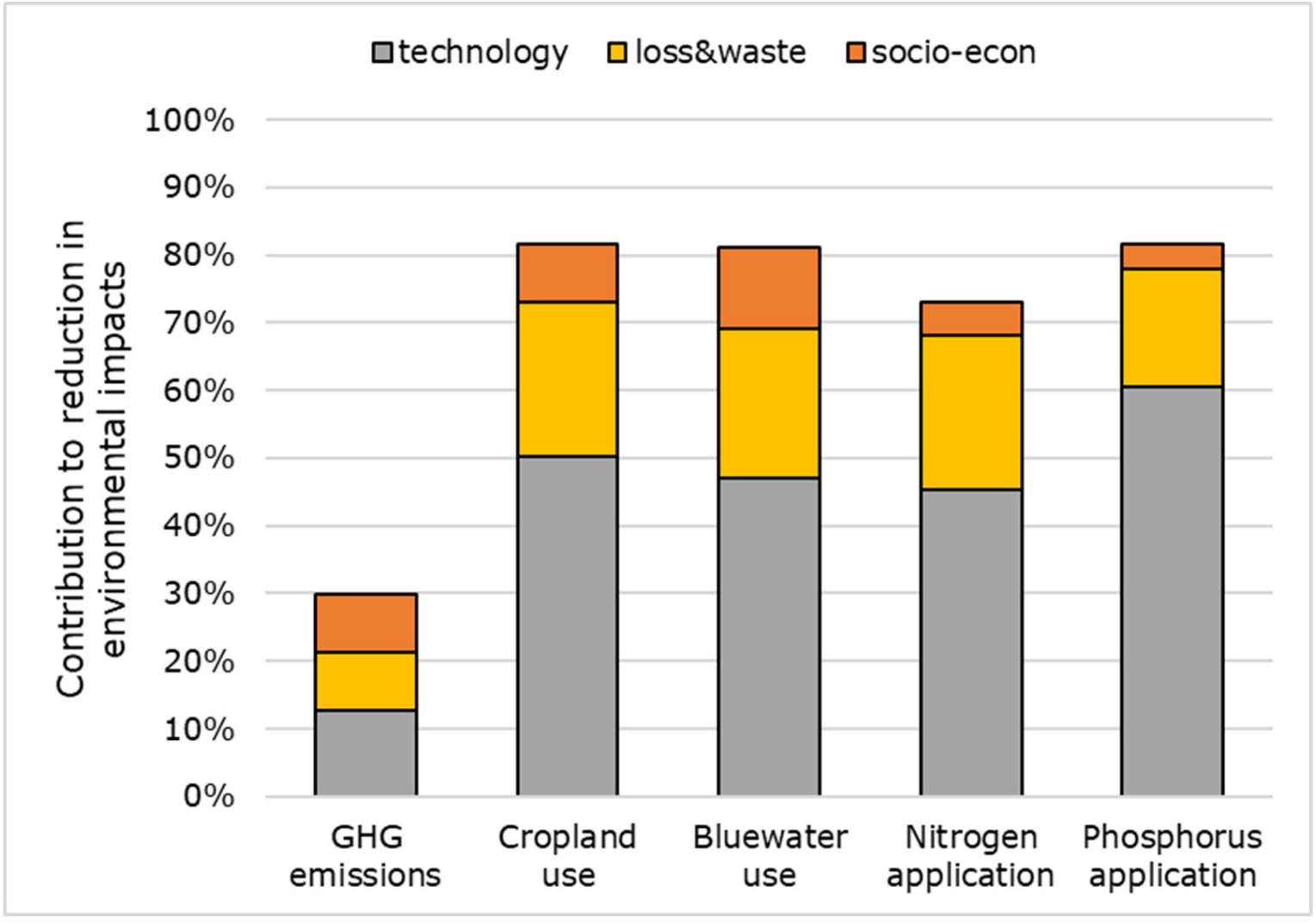
Food-systems analysis

Food **waste** by food group (FAO, 2012; WRI, 2013):



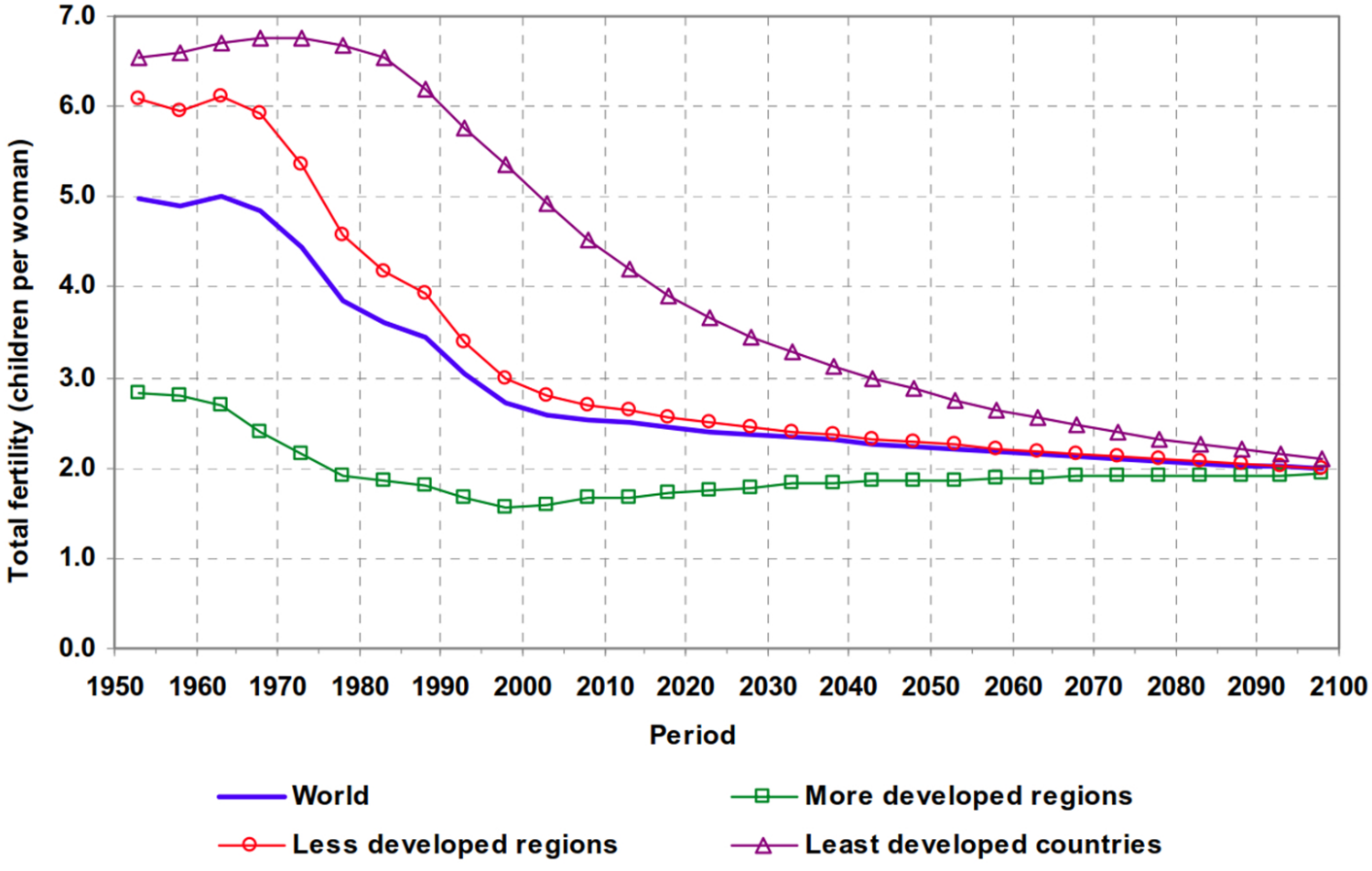
Food-systems analysis

Contribution of improvements in **socio-economic conditions**:



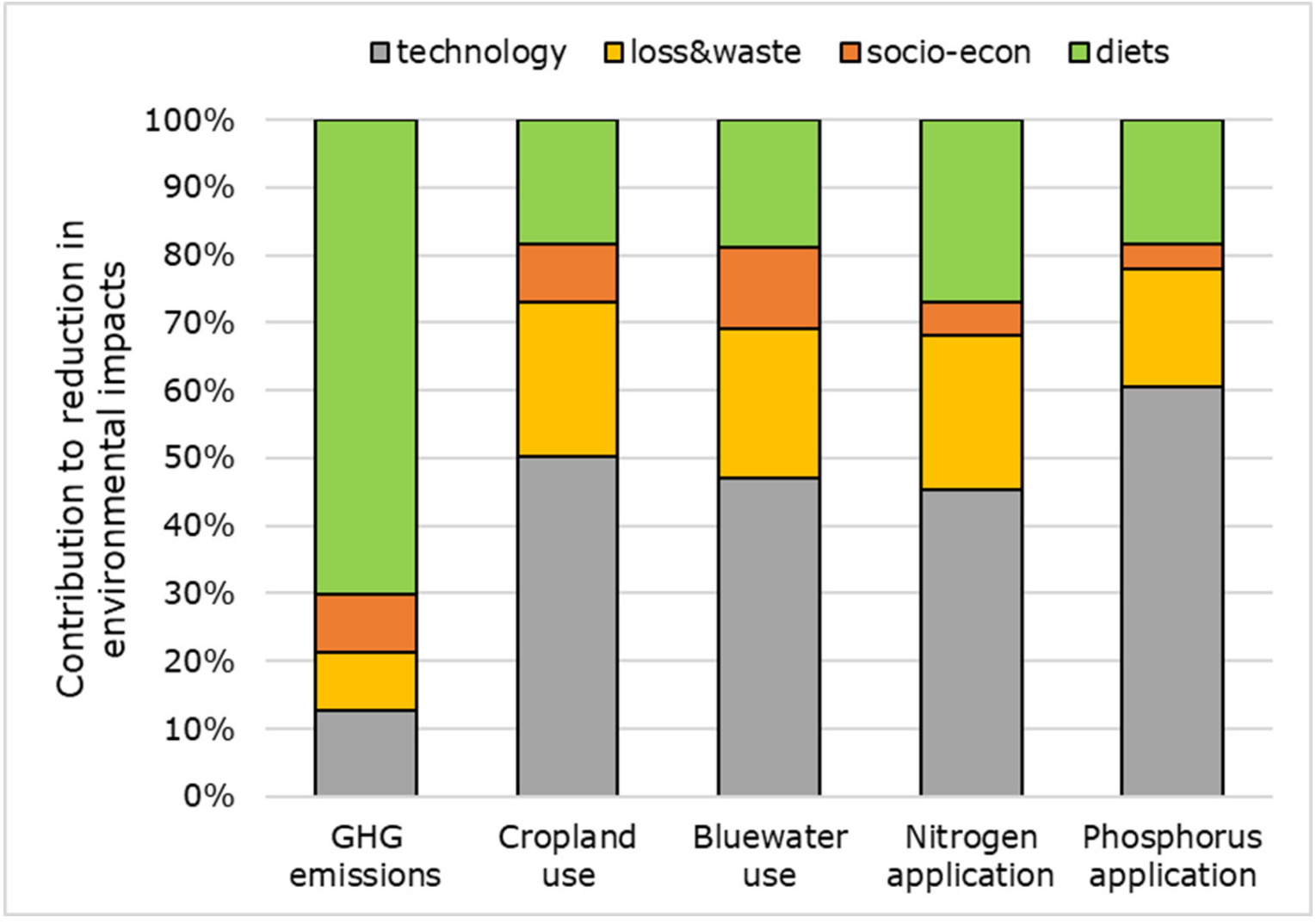
Food-systems analysis

Fertility by region (UN Population Division, 2013):



Food-systems analysis

Contribution of improvements in **diets**:

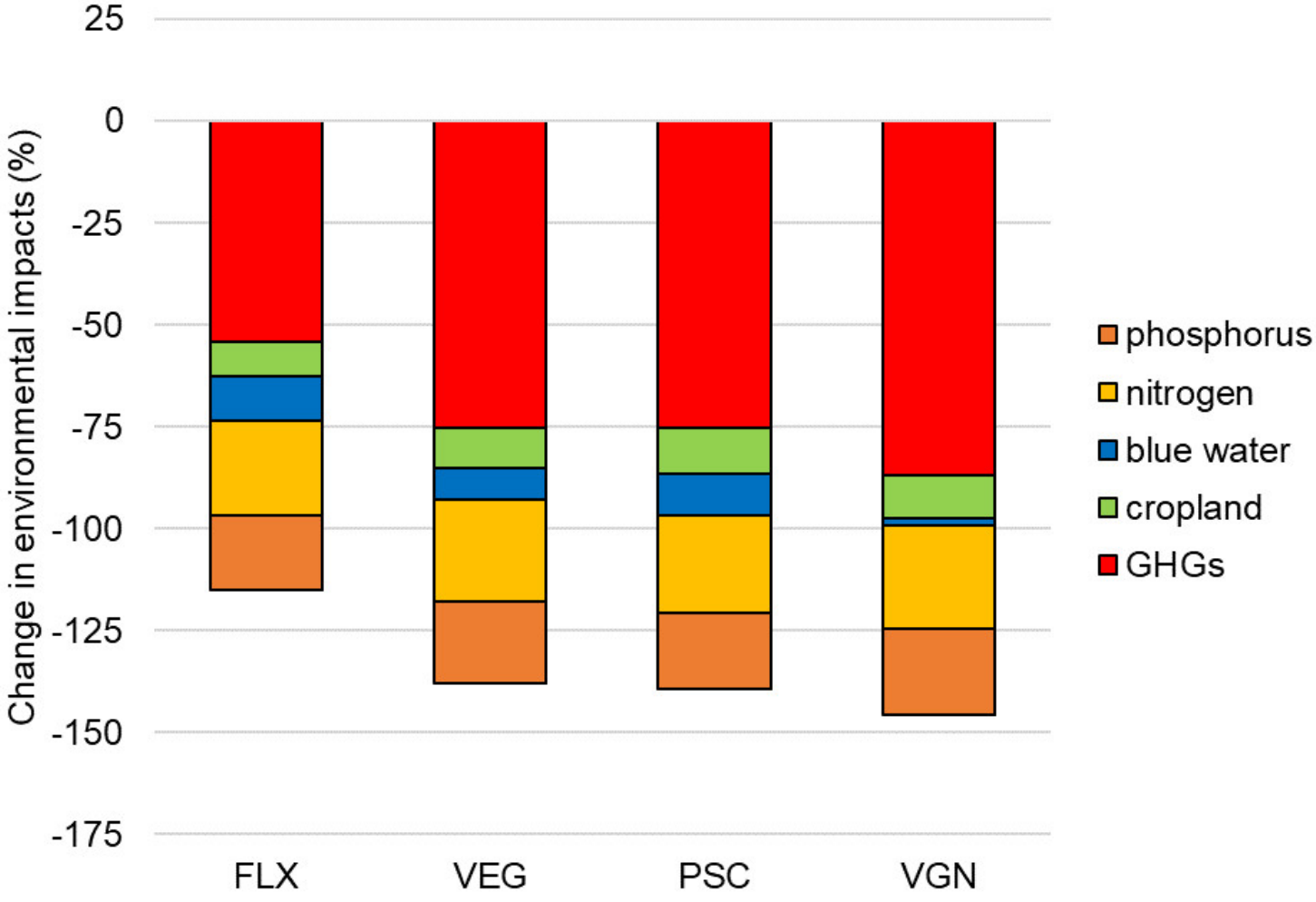


Food-systems analysis

Environmental **footprints** per serving of food:

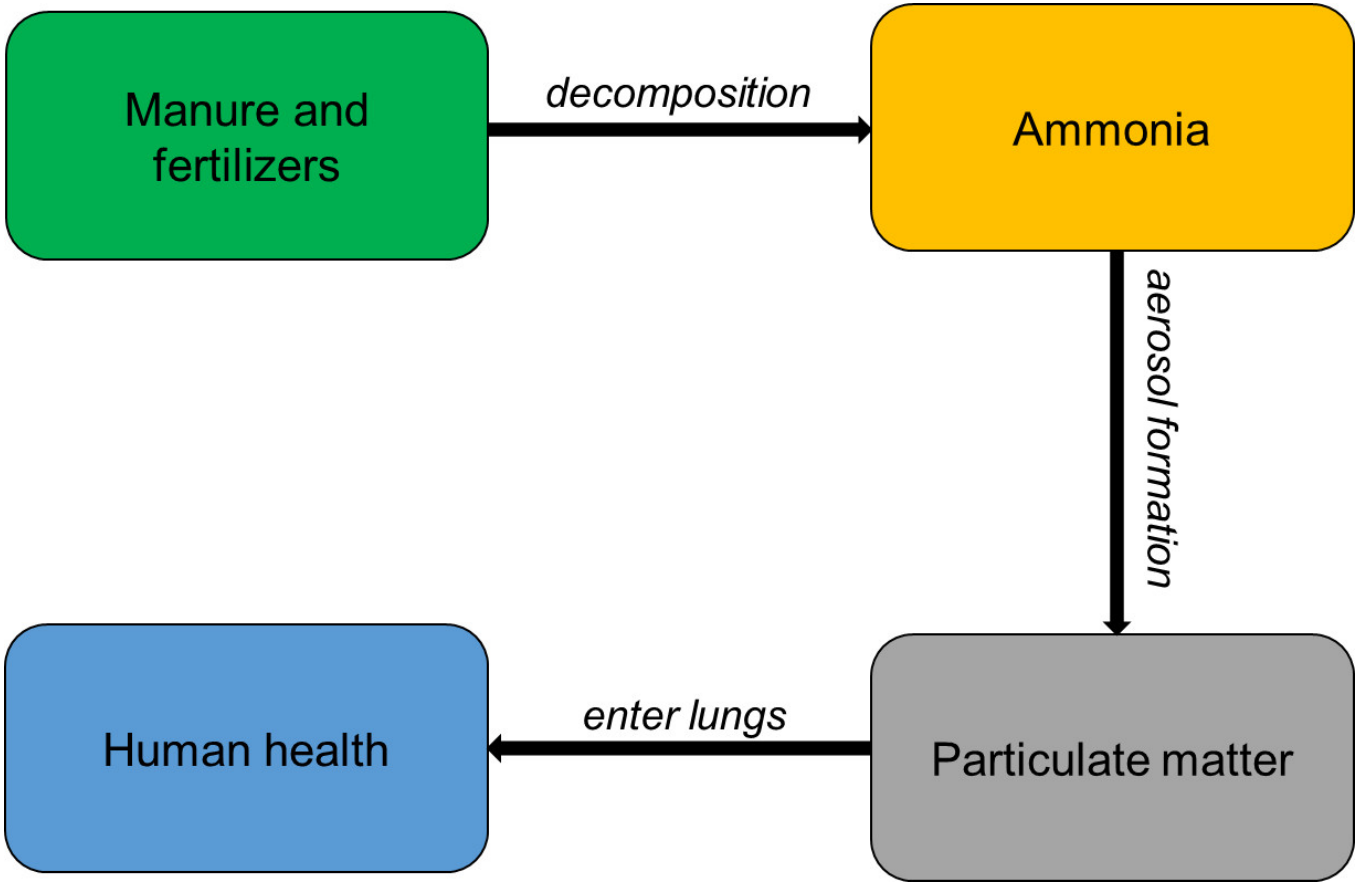
Food item	GHG emissions ($10kgCO_2$/serving)	Cropland use ($10m^2$/serving)	Freshwater use ($10m^3$/serving)	Nitrogen use (10gN/serving)	Phosphorus use (10gP/serving)
wheat	0.10	1.51	0.22	12.93	1.98
rice	0.53	1.58	0.48	16.49	2.34
maize	0.08	0.89	0.07	10.25	1.60
other grains	0.13	2.76	0.07	7.36	1.22
roots	0.08	0.76	0.05	3.99	0.78
legumes	0.08	3.86	0.33	0.00	0.00
soybeans	0.04	1.38	0.05	0.96	2.06
nuts & seeds	0.21	1.92	0.13	4.28	0.63
vegetables	0.05	0.41	0.07	8.12	1.42
fruits (temperate)	0.11	1.65	0.47	17.82	2.67
fruits (tropical)	0.13	1.32	0.45	14.38	2.21
fruits (starchy)	0.15	1.18	0.16	8.76	1.50
sugar	0.01	0.07	0.05	0.89	0.15
palm oil	0.26	0.43	0.00	3.13	0.50
vegetable oil	0.09	1.44	0.07	5.98	1.61
beef	35.74	4.64	0.24	30.01	5.89
lamb	36.33	6.86	0.54	30.27	5.43
pork	3.21	6.69	0.38	56.68	9.75
poultry	1.55	7.25	0.44	55.22	9.92
eggs	0.79	3.43	0.22	25.61	4.40
milk	2.93	3.21	0.19	15.18	3.79
shellfish	0.08	0.40	0.04	3.69	0.89
fish (freshwater)	0.33	1.66	0.11	18.46	3.98
fish (demersal)	0.02	0.14	0.01	1.32	0.32
fish (pelagic)	0.00	0.00	0.00	0.00	0.00

Environmental benefits by diet



Springmann et al, *Lancet Planetary Health* 2018

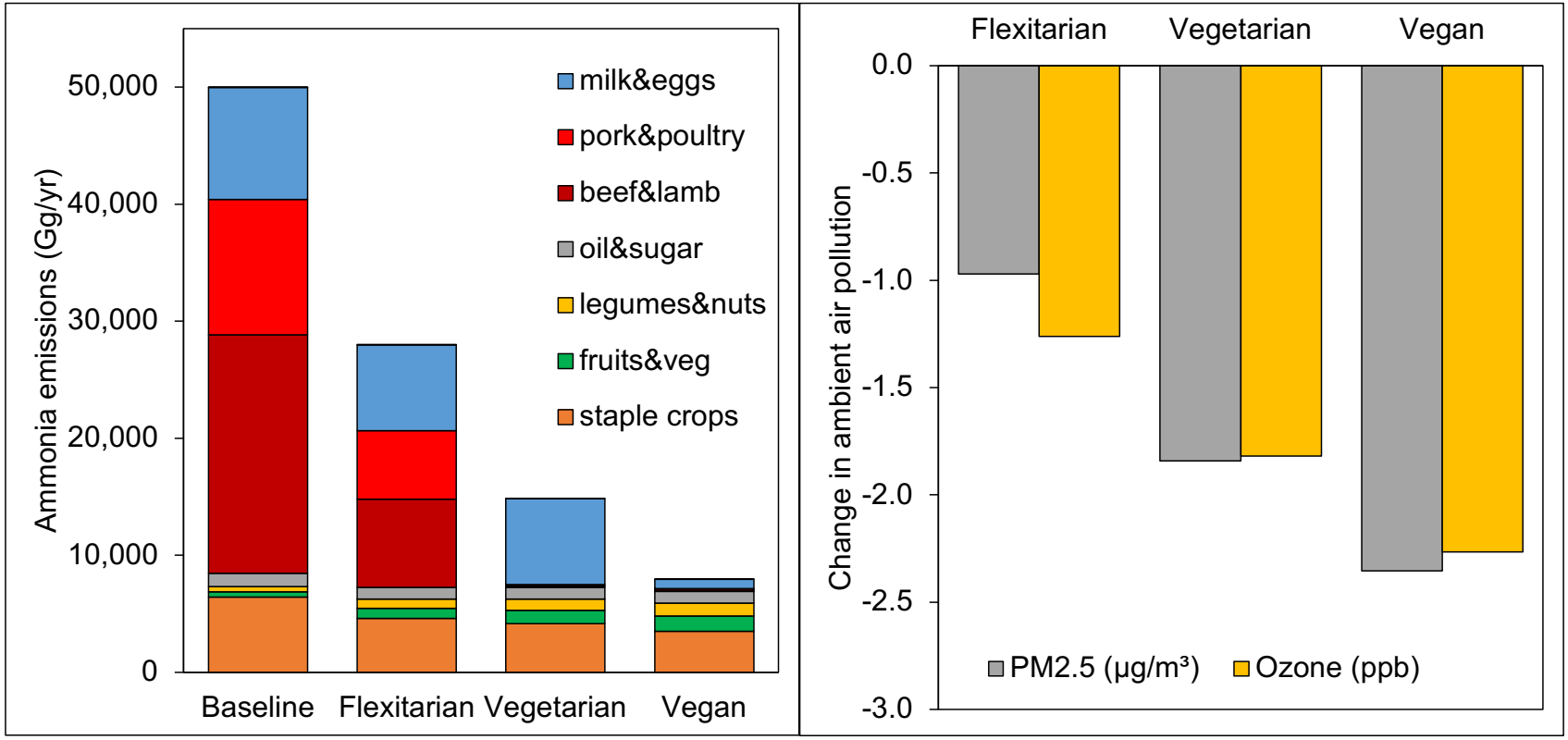
Air-pollution impacts of dietary change



Springmann et al (Nature Communications, 2023)

Air-pollution impacts of dietary change

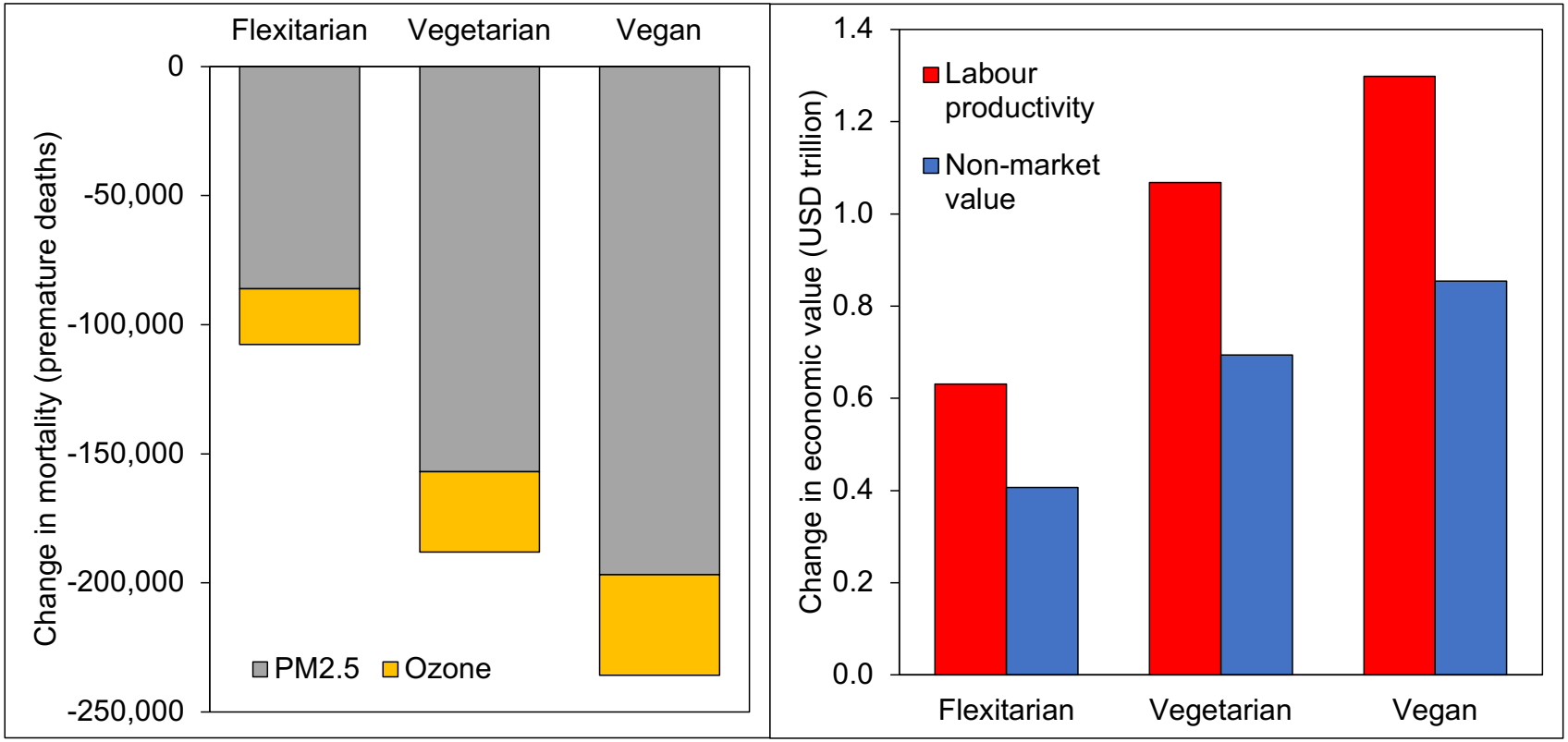
Changes in air pollution:



Springmann et al (Nature Communications, 2023)

Air-pollution impacts of dietary change

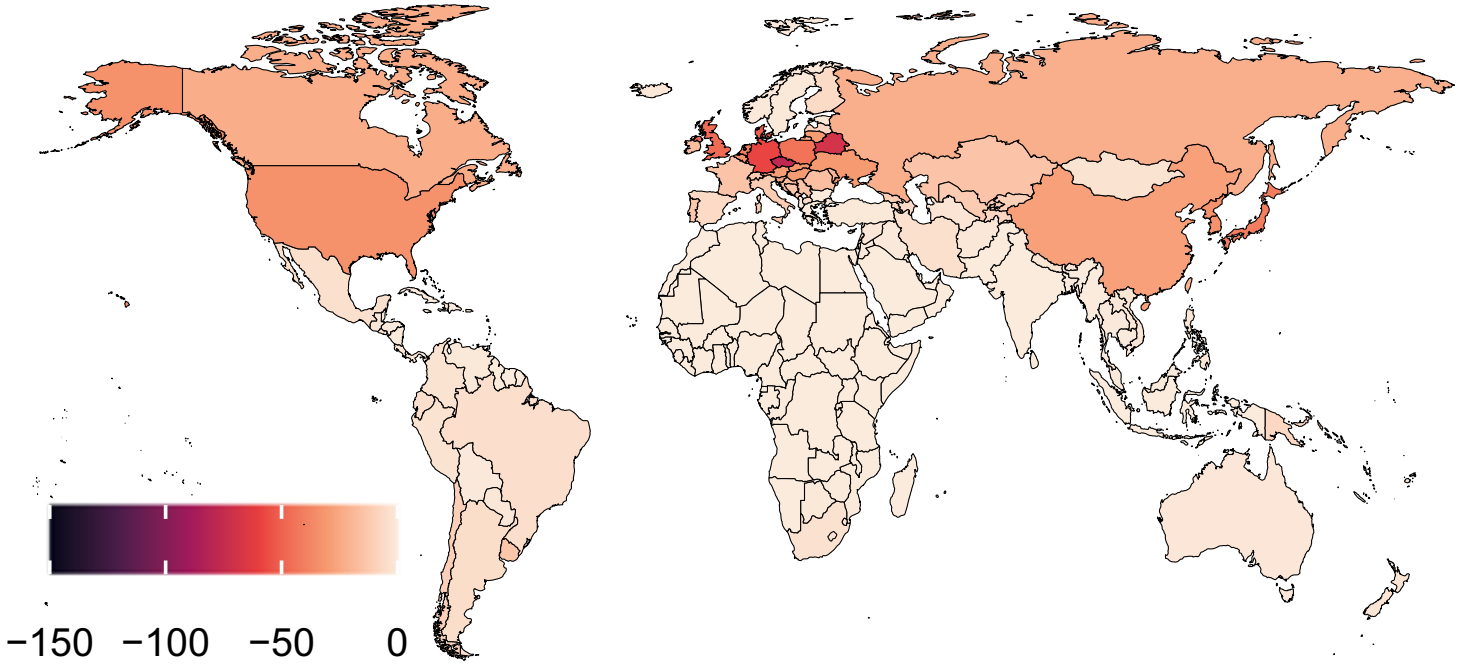
Can have **health and economic benefits**:



Springmann et al (Nature Communications, 2023)

Air-pollution impacts of dietary change

Change in mortality from $PM_{2.5}$ air pollution (per million people)



Springmann et al (Nature Communications, 2023)

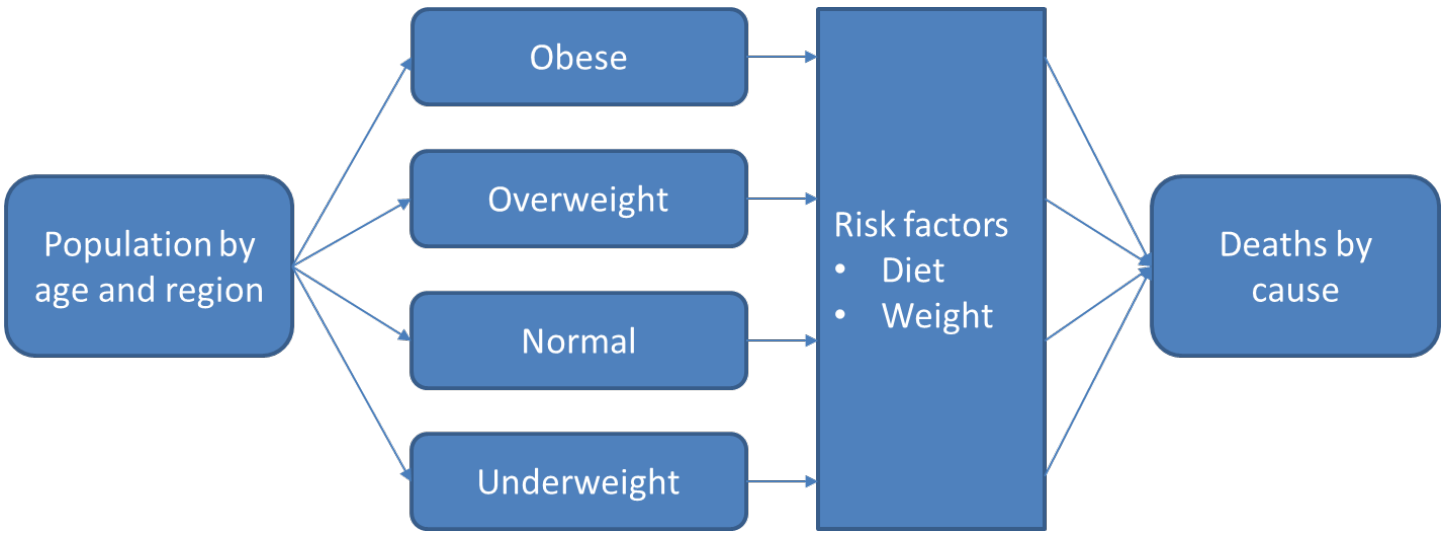
Healthy diets

Predominantly **plant-based** dietary patterns (flexitarian, pescatarian, vegetarian, vegan):

	Macronutrient intake grams per day (possible range)	Caloric intake kcal per day
Whole grains		
Rice, wheat, corn and other	232	811
Tubers or starchy vegetables		
Potatoes and cassava	50 (0–100)	39
Vegetables		
All vegetables	300 (200–600)	78
Fruits		
All fruits	200 (100–300)	126
Dairy foods		
Whole milk or equivalents	250 (0–500)	153
Protein sources		
Beef, lamb and pork	14 (0–28)	30
Chicken and other poultry	29 (0–58)	62
Eggs	13 (0–25)	19
Fish	28 (0–100)	40
Legumes	75 (0–100)	284
Nuts	50 (0–75)	291
Added fats		
Unsaturated oils	40 (20–80)	354
Saturated oils	11.8 (0-11.8)	96
Added sugars		
All sugars	31 (0–31)	120

Health analysis

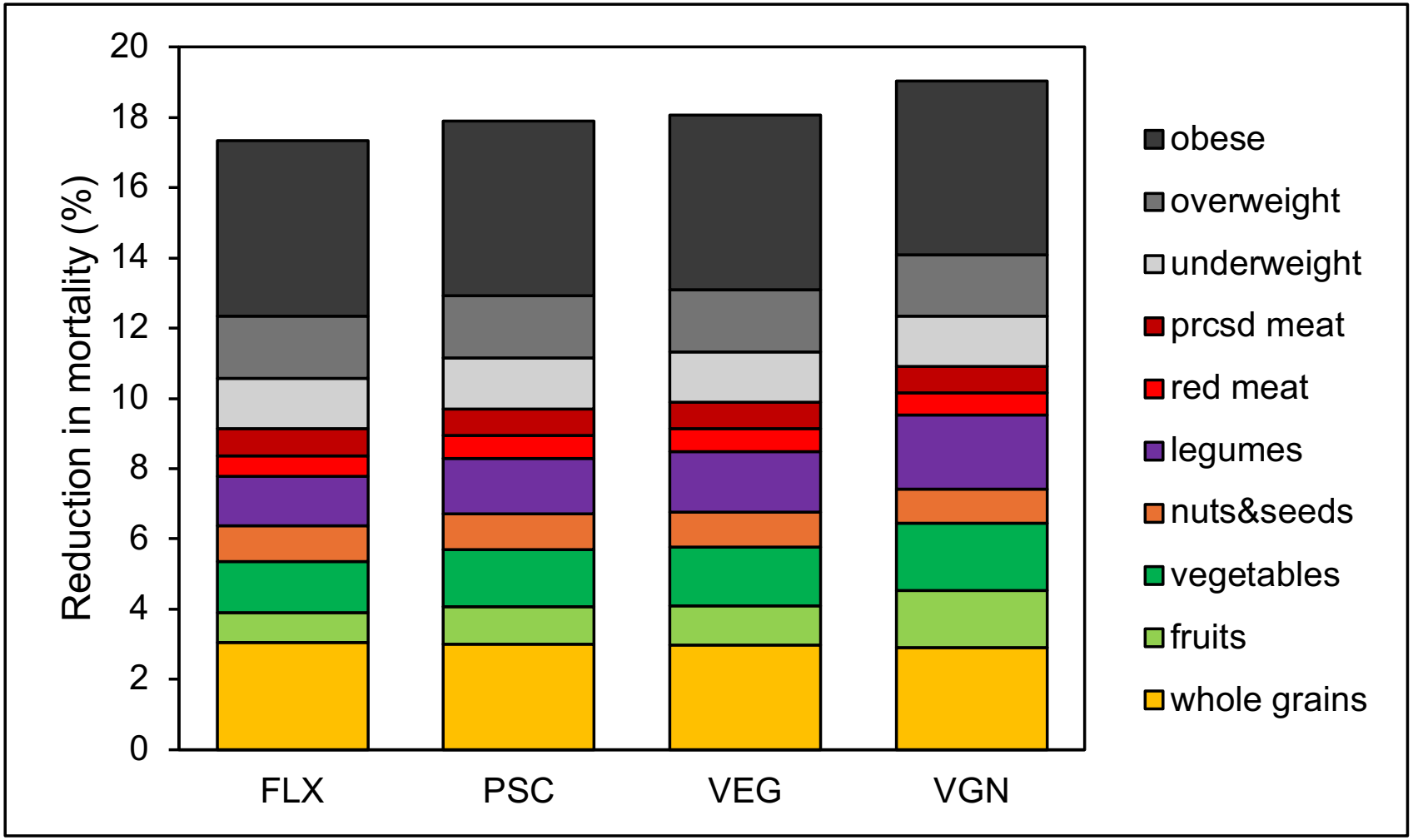
Comparative risk framework:
burden of disease mortality due to risk exposure



- 10 risk factors: high red meat and processed meat; low fruits, veg, nuts, legumes, whole grains; underweight, overweight, obese
- 5 causes of death: CHD, stroke, T2DM, and cancer, respiratory disease

Health analysis

Risk assessment of dietary patterns:



Dietary change

How to incentivise healthy and sustainable diets?

- Providing information without additional economic or environmental changes has limited influence on behaviour;
- Integrated, multicomponent approaches that include clear policy measures are best suited for changing diets (Mozaffarian et al, 2012, 2016):

1. Media and education campaigns; labelling and consumer information; update national dietary guidelines
2. Fiscal measures, such as taxation, subsidies, and other economic incentives, including for producers
3. School and workplace approaches; local environmental changes;
4. Direct restriction and mandates

Policy options

Available assessments:

- Adjust VAT rates to address sustainability objectives
  (Springmann et al, Nature Food 2025)
- Adjust food prices for climate damages
  (Springmann et al, Nature Climate Change 2017)
- Adjust meat prices for cost of illness
  (Springmann et al, Plos One 2018)
- Reform agricultural subsidies
  (Springmann and Freund, Nature Communications, 2022)
- Reform national dietary guidelines
  (Springmann et al, BMJ 2020)

Conclusion

Healthy diets and sustainable food systems are achievable, but it will require:

- Strong regulation and right incentives are required;
- Combining measures with attention to local contexts important for defining region-specific sustainable-development pathways;
- The country-specific data and suite of scenarios produced for the report and associated studies can be a starting point.

Inaction is not an option:

- Food-system demand for environmental resources could increase by 50-90% without targeted mitigation measures;
- Key planetary boundaries could be exceeded by 2050, risking destabilization of ecosystems;

Thank you

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Bibliography

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