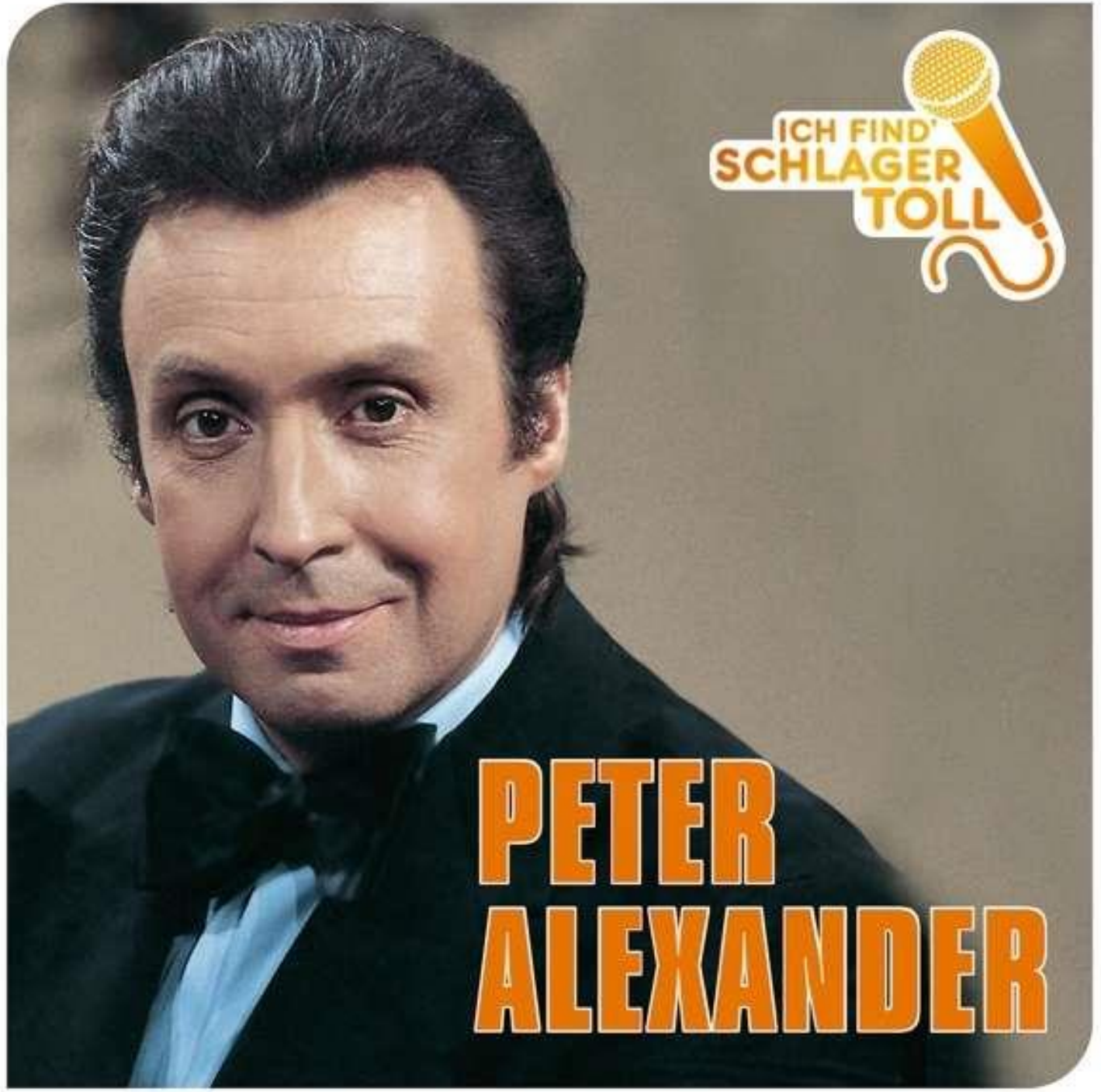
Could consumption of insect or cultured meat global agricultural land use?

peter.alexander@ed.ac.uk

13 November 2018

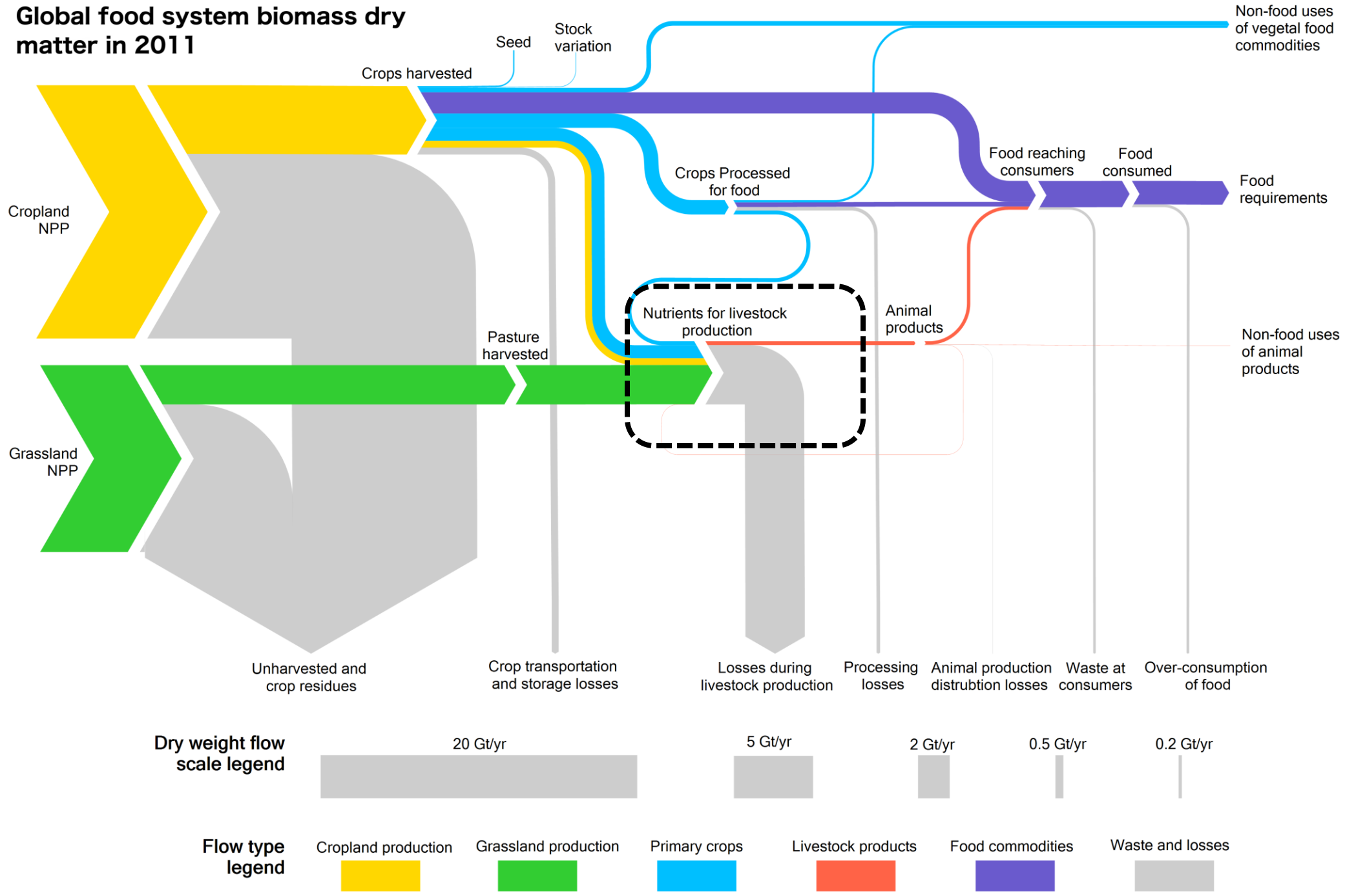
Sorry!

Not this one…



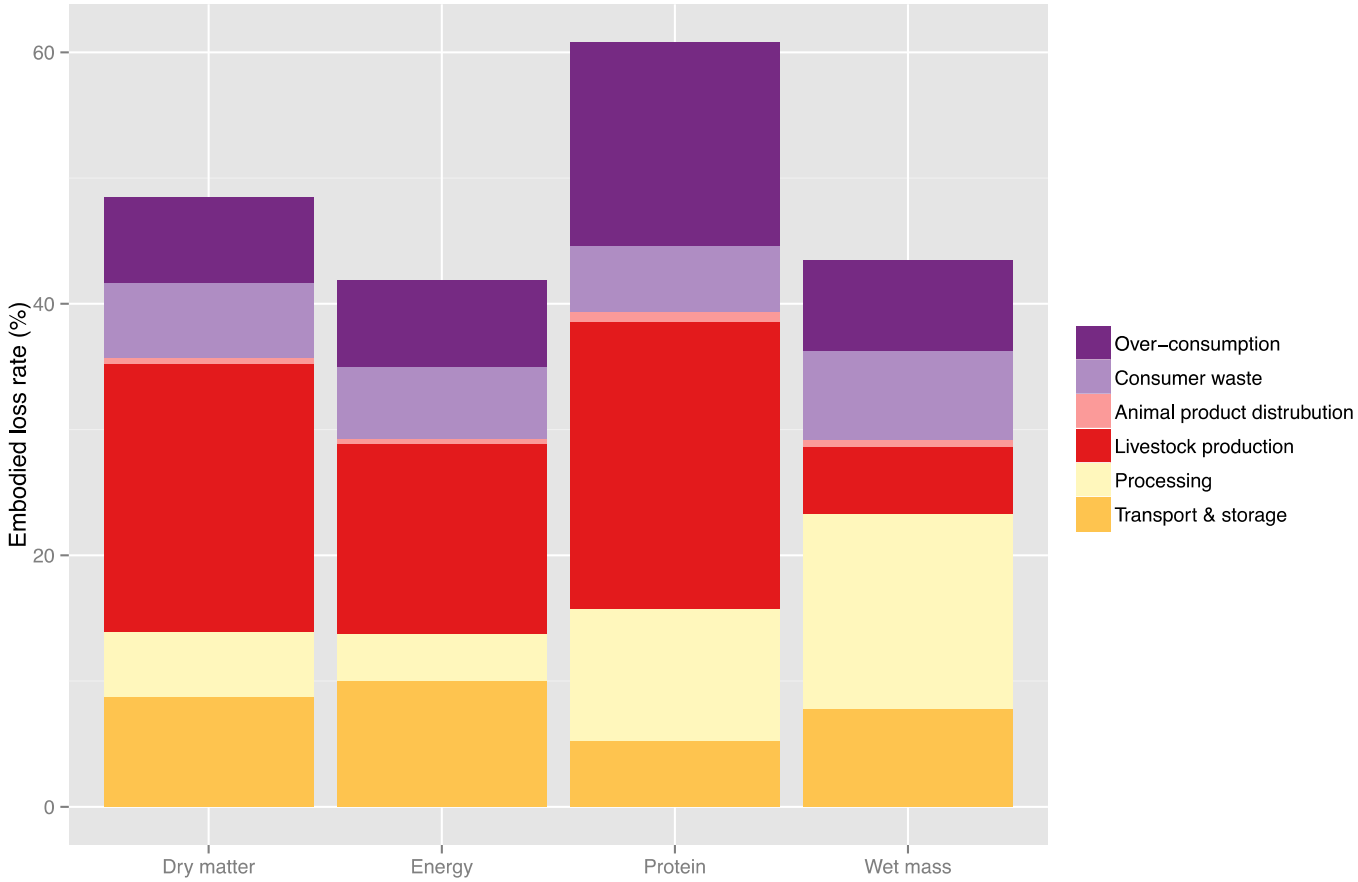
Why novel foods might play a role in environmental sustainability

- Food production overall
  - 26% of anthropogenic GHG emissions
  - 11% of anthropogenic CO_2 associated with land use change
  - Two-thirds of freshwater withdrawals for irrigation
  - Biodiversity loss, eutrophication, etc.
- Conventional livestock
  - 70% agricultural land globally is used for livestock production, including cropland for feed (50-65% of land use change)
  - Around half of agricultural greenhouse gas emission
  - But, proportion of food provide by animal products is lower
    - ~15% of energy and ~30% of protein


Global food system biomass dry matter in 2011
Seed
Stock variation
Crops harvested
Non-food uses of vegetal food commodities
Cropland NPP
Crops Processed for food
Food reaching consumers
Food consumed
Food requirements
Nutrients for livestock production
Animal products
Pasture harvested
Non-food uses of animal products
Grassland NPP
Unharvested and crop residues
Crop transportation and storage losses
Losses during livestock production
Processing losses
Animal production distrubtion losses
Waste at consumers
Over-consumption of food
Dry weight flow scale legend
20 Gt/yr
5 Gt/yr
2 Gt/yr
0.5 Gt/yr
0.2 Gt/yr
Flow type legend
Cropland production
Grassland production
Primary crops
Livestock products
Food commodities
Waste and losses

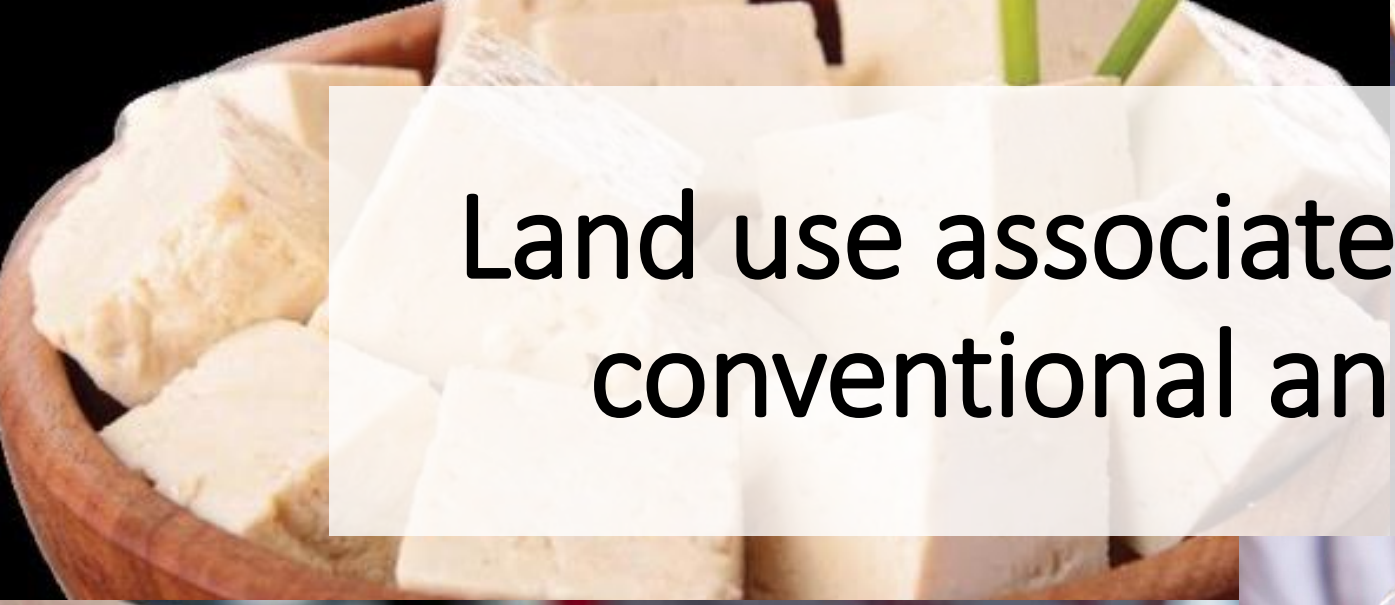
Global harvested crop losses

- Livestock single biggest loss to food system
  - Except in wet mass, which is highly misleading
- Overall, around half of harvested crops are lost
  - More than the 1/3 more commonly quoted
- Around ~10% of commodities reaching consumers or retailers is discarded
- At least as much lost due to over-consumption



Losses of harvested crops (excluding grassland and forage crop inputs to livestock production) by stage in the food system.

Land use associated alternatives to conventional animal products

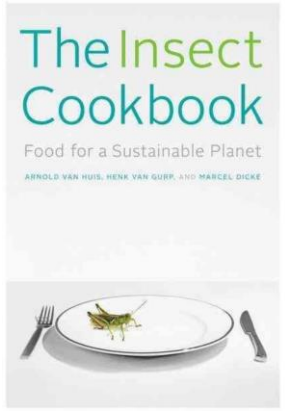


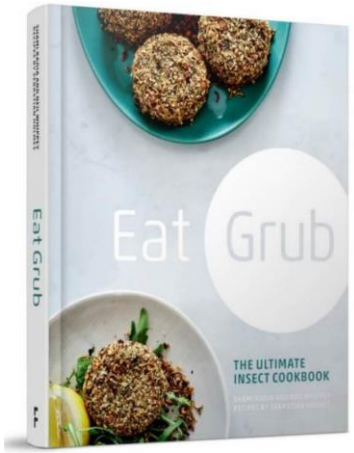
Entomophagy is worth considering

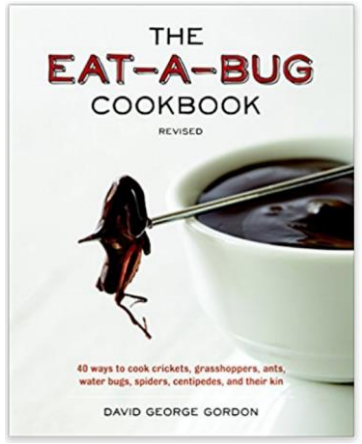
- Insects production for food (‘mini livestock’) is claimed to have lower GHG emissions and land use compared to conventional livestock
  - Higher fraction of insect consumed, up to 100%
    - e.g. only ~40% of live animal weight is consumed with cattle
  - Insects are poikilothermic
    - lower energy usage
  - Higher fecundity
    - potentially thousands of off-spring
    - rather than just one
  - Rapid growth rates
  - Reach maturity in days
    - rather than months or years
  - All contain essential amino acids

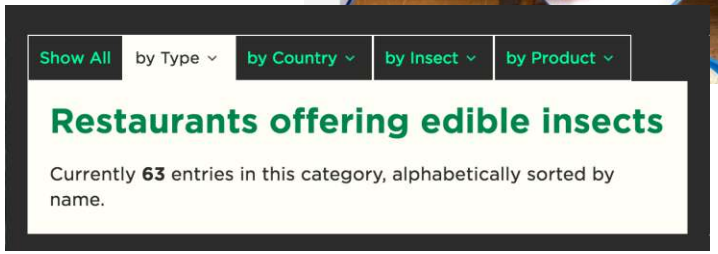
Current status of insect as food

- Isotope analysis of bones indicates that insectivorous diets are entrenched in human evolution
- > 2000 species currently consumed across 119 countries (Rumpold and Schlüter, 2013)
- Limited consumer acceptability, particularly in western countries
  - But some evidence this might be changing – slowly…









Ramos-Elorduy, J., 2009. Anthropo-entomophagy: cultures, evolution and sustainability. Èntomol. Res. 39, 271–288.
Rumpold, B. a., Schlüter, O.K., 2013. Potential and challenges of insects as an innovative source for food and feed production. Innov. Food Sci. Emerg. Technol. 17, 1–11.

Consumer acceptability of entomophagy

- Currently a major barrier in the western countries
- Historical precedents of slow changes being possible
  - tomatoes in Britain were widely viewed with suspicion and dismissed for over 200 years, until mid-1800s (Bir, 2014; K. A. Smith, 2013)
  - lobster in America was initially a poverty food eaten by slaves and prisoners, and used as fertiliser and fish bait (Dembosky, 2006).

- Arguably a slow change towards is occurrings, starting with awareness and interest.
  - Although still some element of ‘bush-tucker trial’.
- Less obvious inclusions of insects likely to be more easily accepted

Bir S (2014) *From Poison to Passion: The Secret History of the Tomato*. Hudson, NY, USA.
Dembosky A (2006) *How the Lobster Clawed its Way Up: A crustacean’s climb from pauper’s fare to modern-day delicacy*. San Francisco, CA, USA.
Smith KA (2013) Why the Tomato Was Feared in Europe for More Than 200 Years: How the fruit got a bad rap from the beginning. *Smithsonian*.

In-vitro or cultured meat

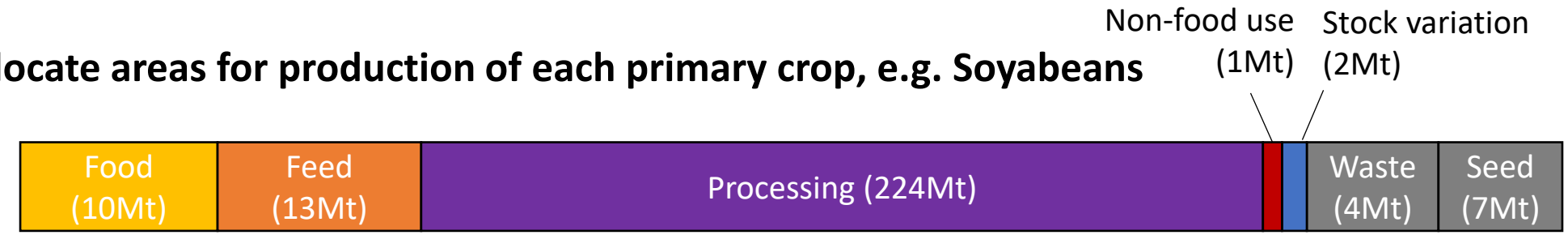
- Technology has been improving rapidly
  - Rapid drop in production costs, closer to conventional retail prices
- Avoids the issues of low edible percentages
- Still requires a feedstock (“broth”) in which to grow
  - Some research calculated using algae to provide feedstock
- Likely to also have high direct energy input requirements
  - Need a cheap energy source and low carbon

Allocating areas for existing (and then novel) food commodities

- Use global FAO data
  - Production areas
  - Uses of crops (‘commodity balance’)
  - Food supply, calorific and protein contents
- 90 commodities
  - 50 primary, 32 processed, 8 animal products
  - 99.4% of food calories consumed
- Links needed between
  - Production and consumption ‘items’
  - Primary and processed commodities
  - Feed and livestock products

Allocating production areas to commodities

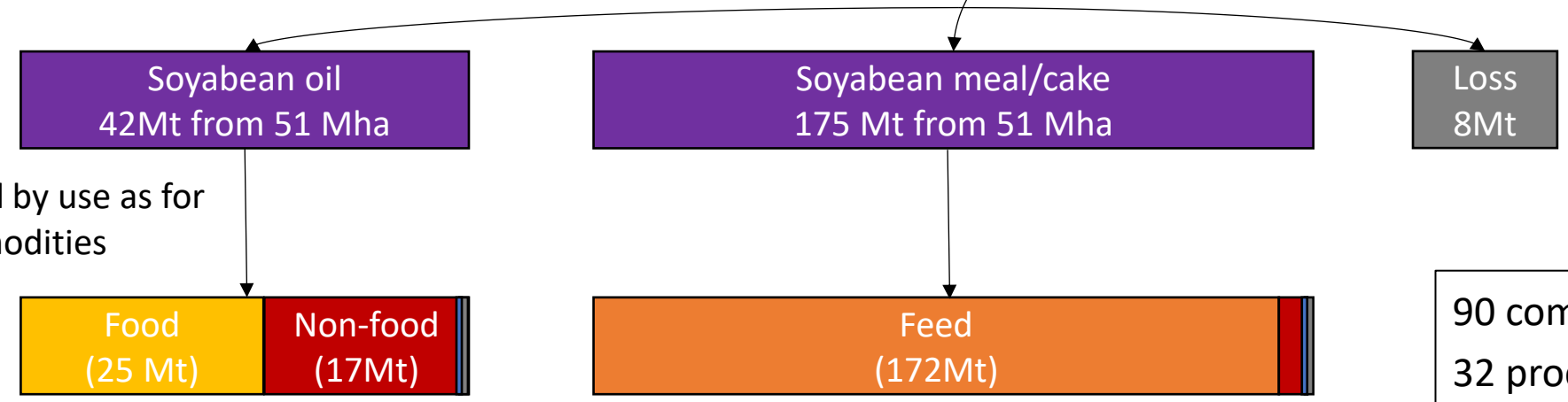
1. Allocate areas for production of each primary crop, e.g. Soyabeans



Areas not allocated to losses, waste or seed

NOT to scale.

2. Allocate areas for processed commodities by economic value



Then allocated by use as for primary commodities

3. Allocate areas for animal products

- Feed requirements from feed conversion ratios
- Monogastrics just from feed, ruminants each remainder of feed (~20-30%) plus all pasture

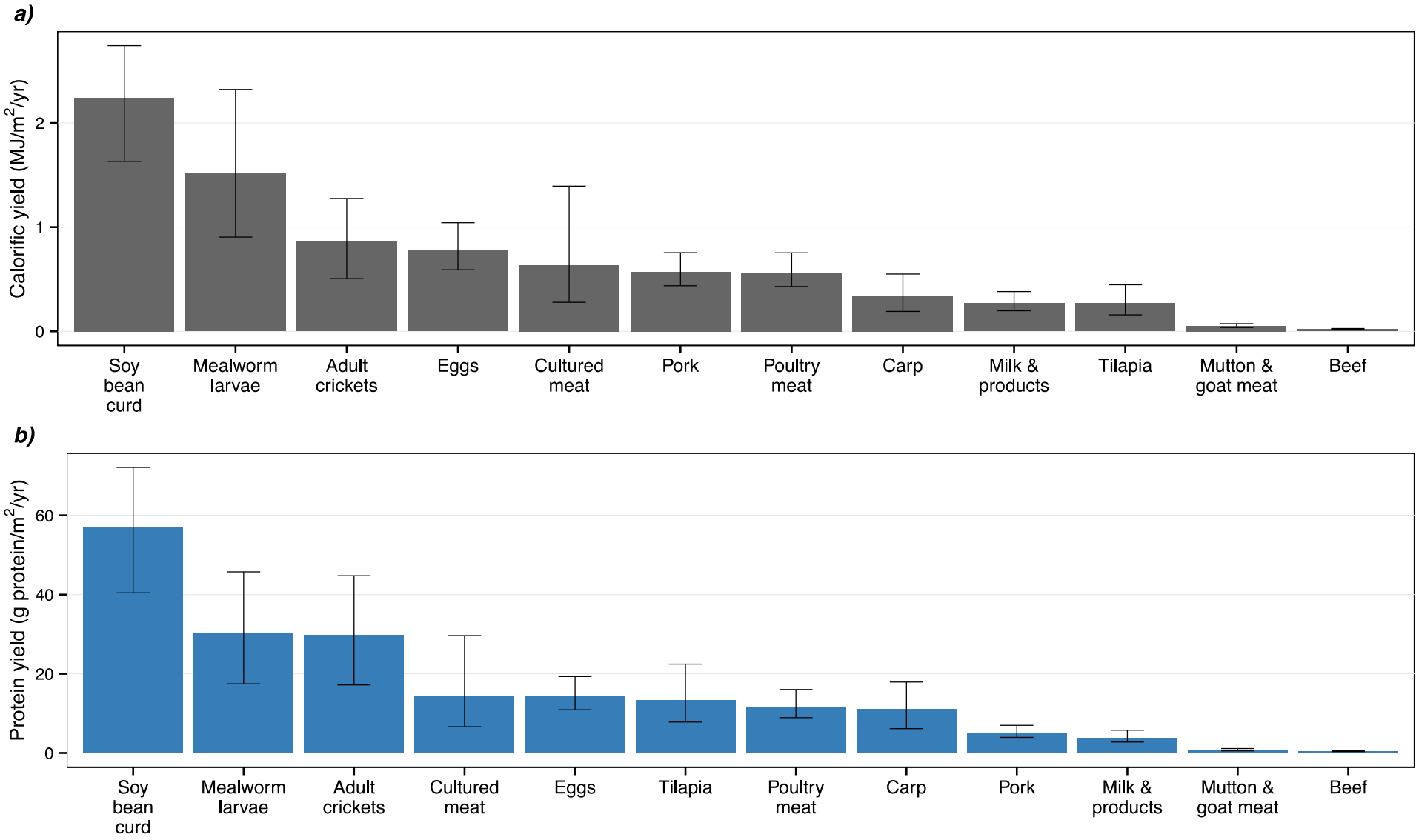
90 commodities (50 primary, 32 processed, 8 animal products), 99.4% of food calories consumed, for each year and country in FAO panel data

Alternatives to conventional animal products

- Insects
  - Mealworm larvae (*Tenebrio molitor*) & Crickets (*Acheta domesticus*)
  - Selected on availability of data
- Cultured (a.k.a. *in vitro*) meat
- Imitation meat (based on tofu)
- Aquaculture of herbivorous species (Carp & Tilapia)

Commodity	Percentage edible (% EW of LW)	Feed conversion by mass (kg DM feed/kg EW)	Energy content (MJ/kg EW)	Protein content (g / kg EW)
Mealworm: larvae (Tenebrio molitor)	100	1.8	8.9	179
Crickets: adults (Acheta domesticus)	80	2.1	5.9	205
Cultured meat	100	4	8.3	190
Imitation meat (based on soy bean curd)	-	0.29	3.2	81
Tilapia	37	4.6	4.0	201
Chinese Carp	37	4.9	5.3	178

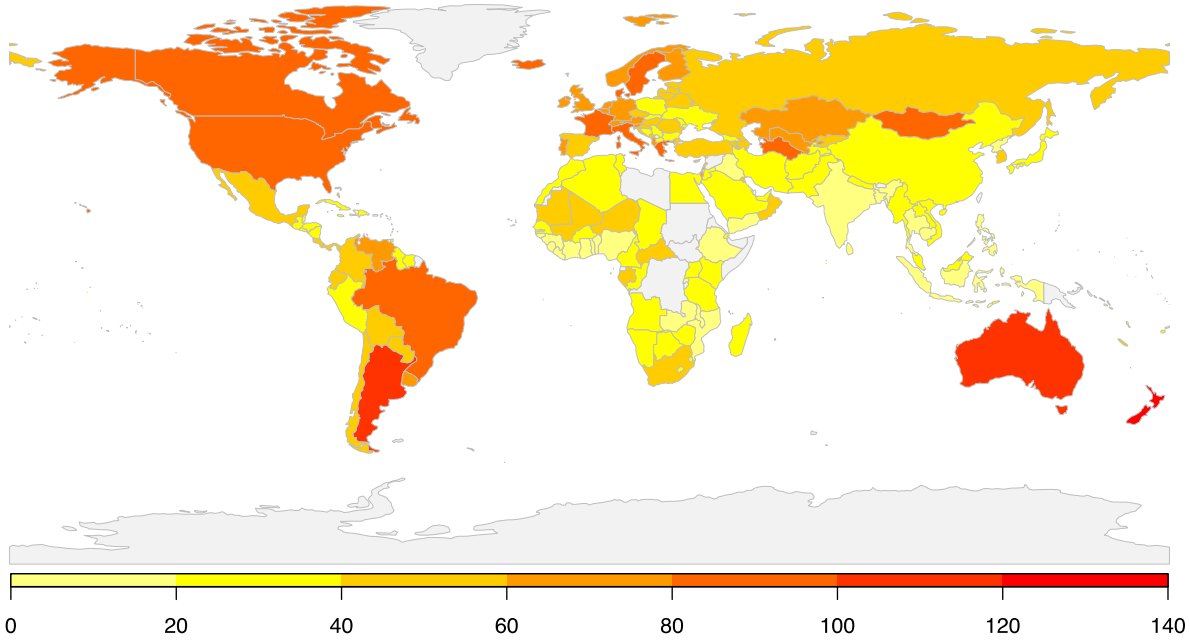
Land use efficiency of conventional animal products and alternatives



Energy and protein per unit area of agricultural land for conventional and alternatives to animal production. Error bars show the yield range from uncertainty in feed conversion ratios and nutrient contents

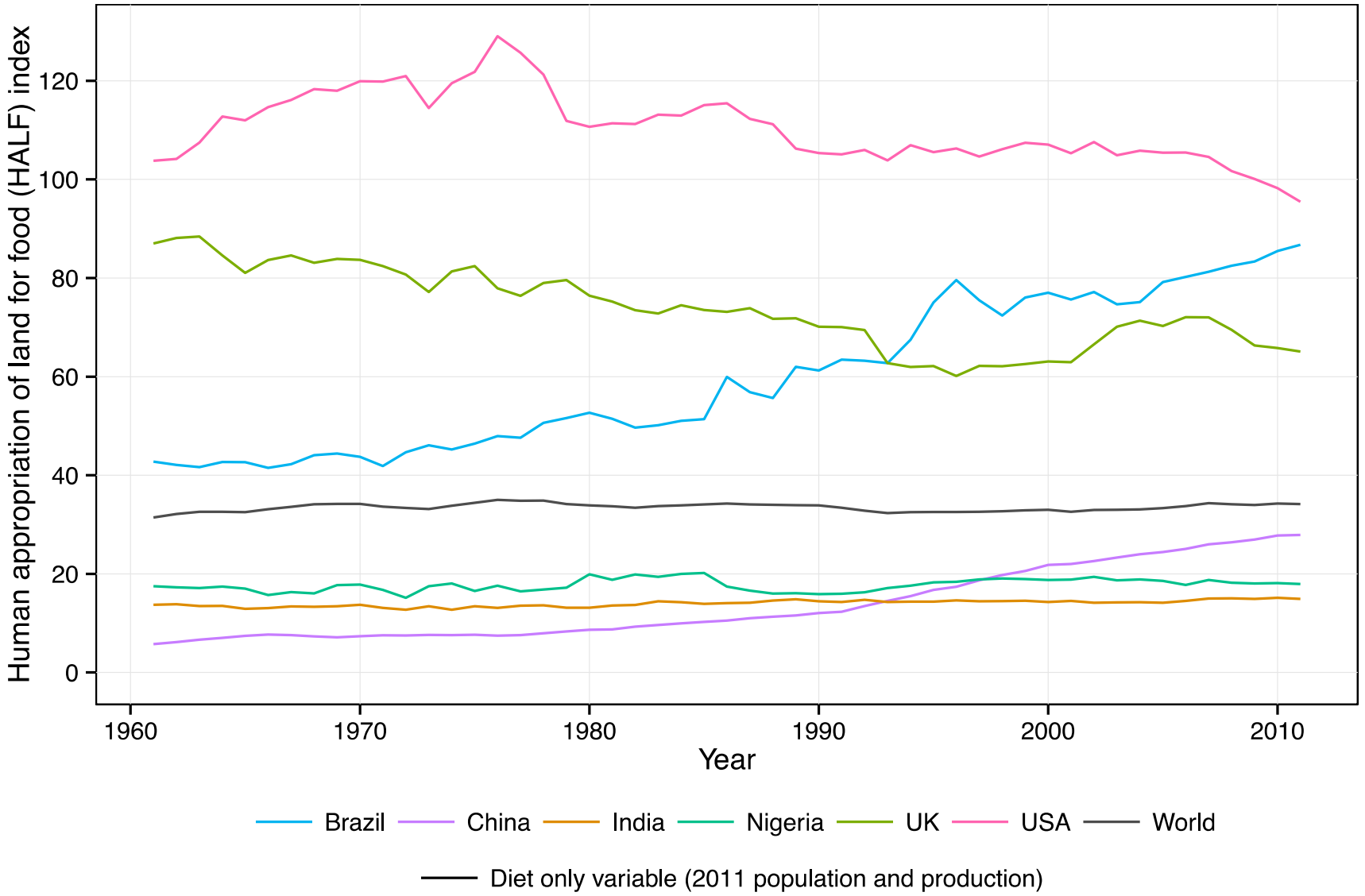
Putting dietary changes in a global context

- Land allocation values to quantify land require for any diet
- Calculated for average diets consumed in each country
  - **NOT** a land use footprint – which combines aspects of consumption and production
  - Rather, a comparative metric for diet only
- Expressed as percentage of the world land surface required for the global population to consume that diet - or HALF index.



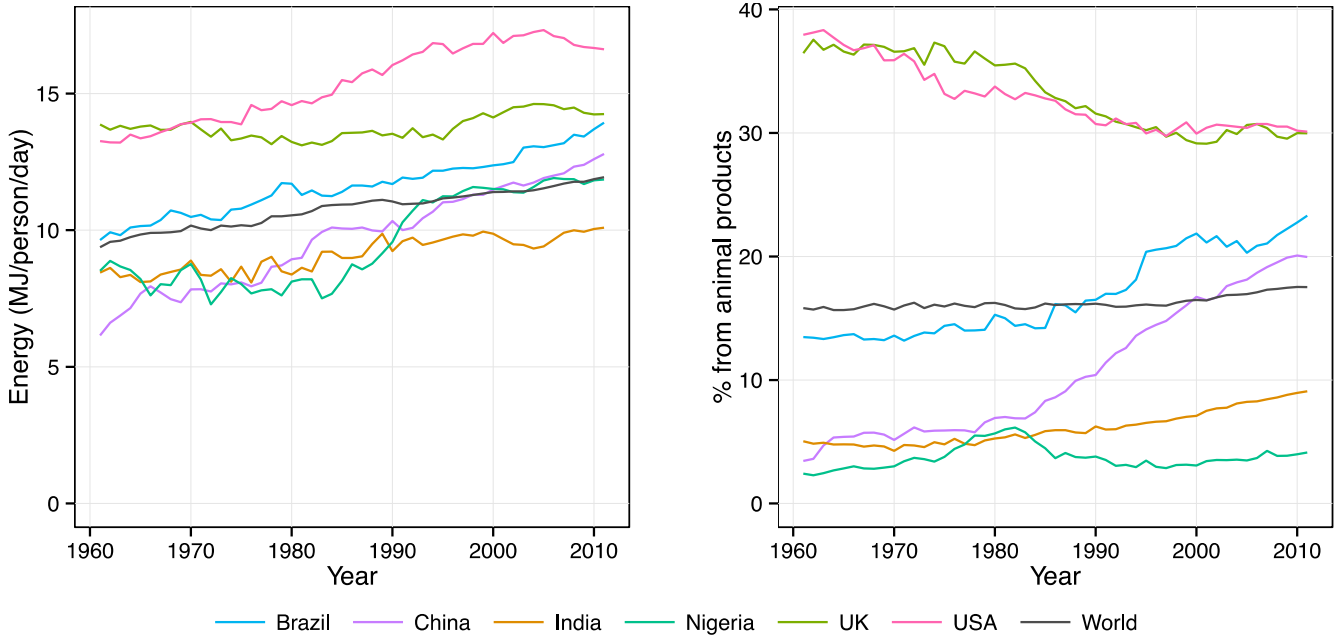
Map of HALF index by country in 2011.

Human Appropriation of Land for Food (HALF) over time

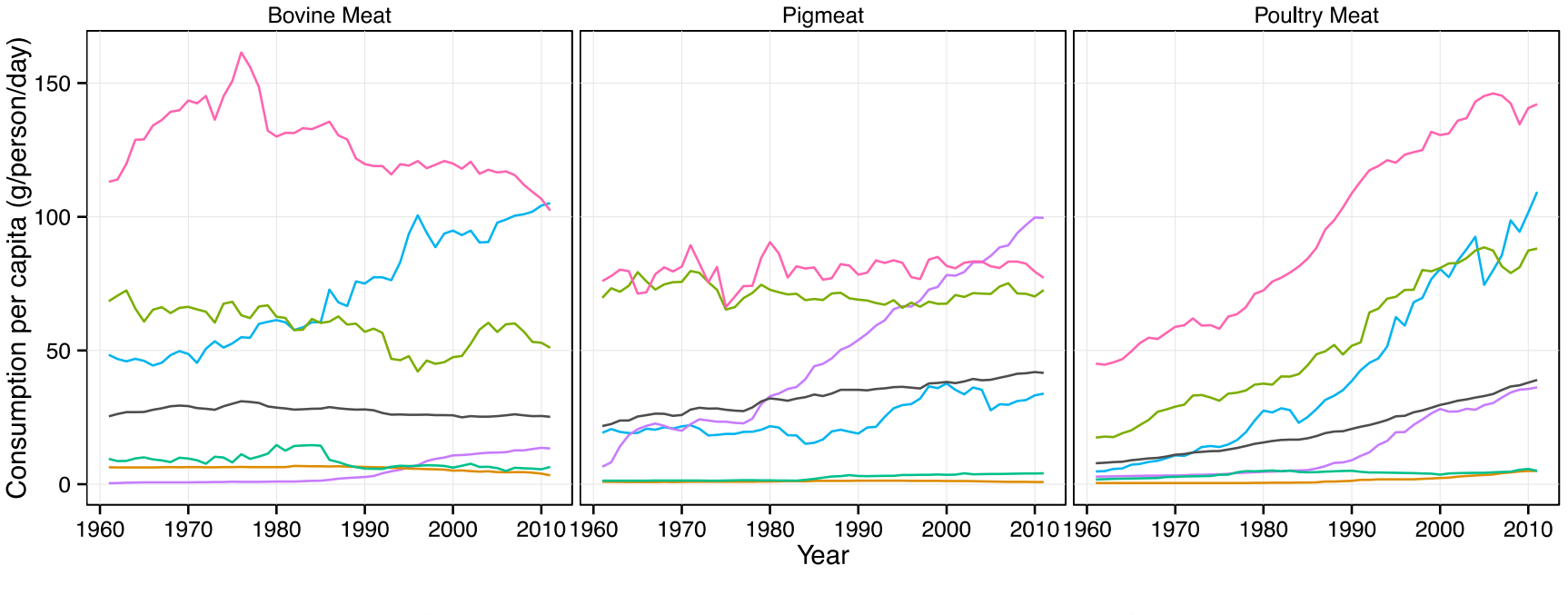


HALF index from 1961 to 2011, globally and for selected counties. Solid lines show variable diets, but constant population and agricultural production systems (at 2011 values).

Food consumption trends

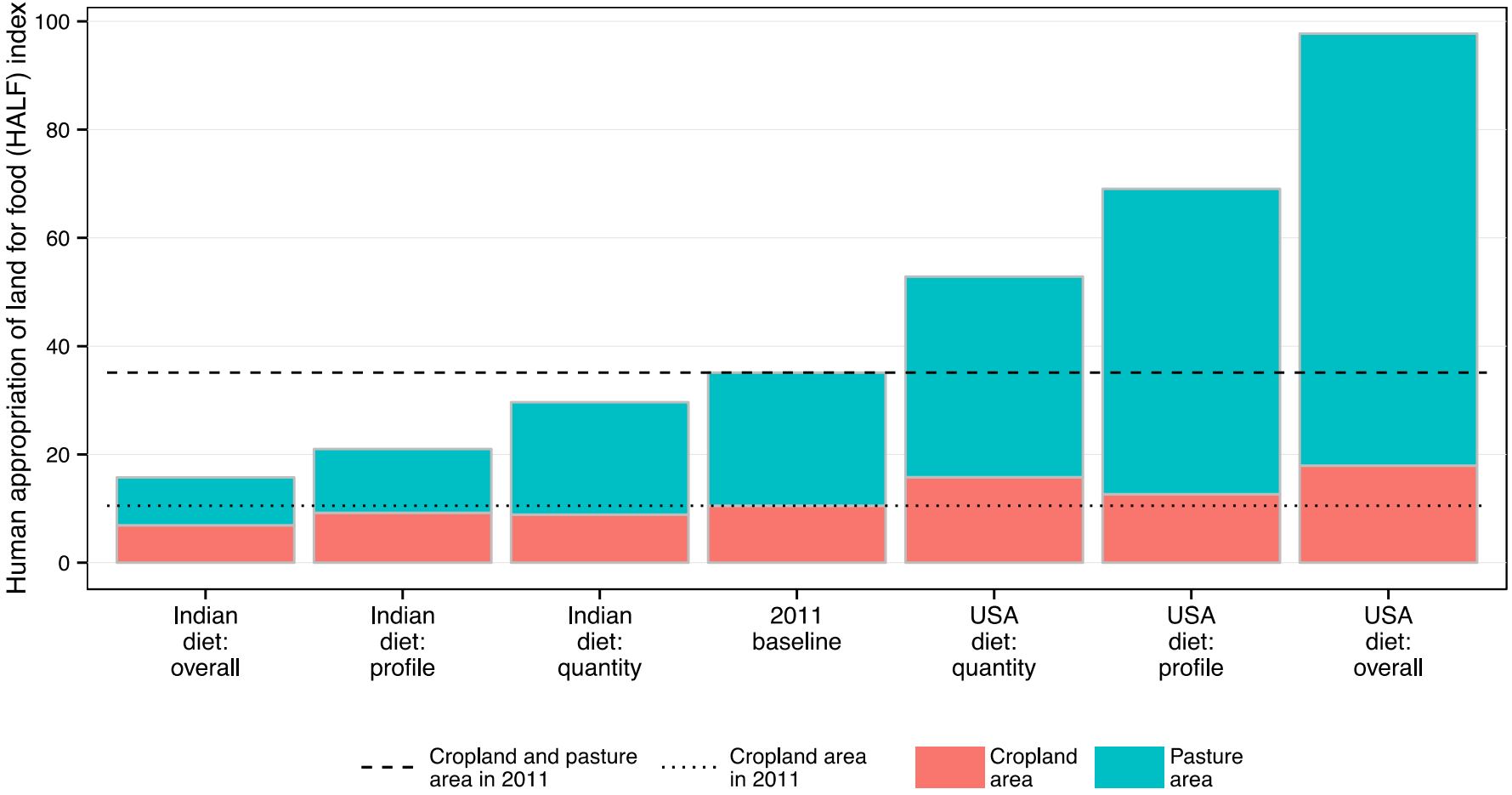


Total energy per capita and percentage from animal products



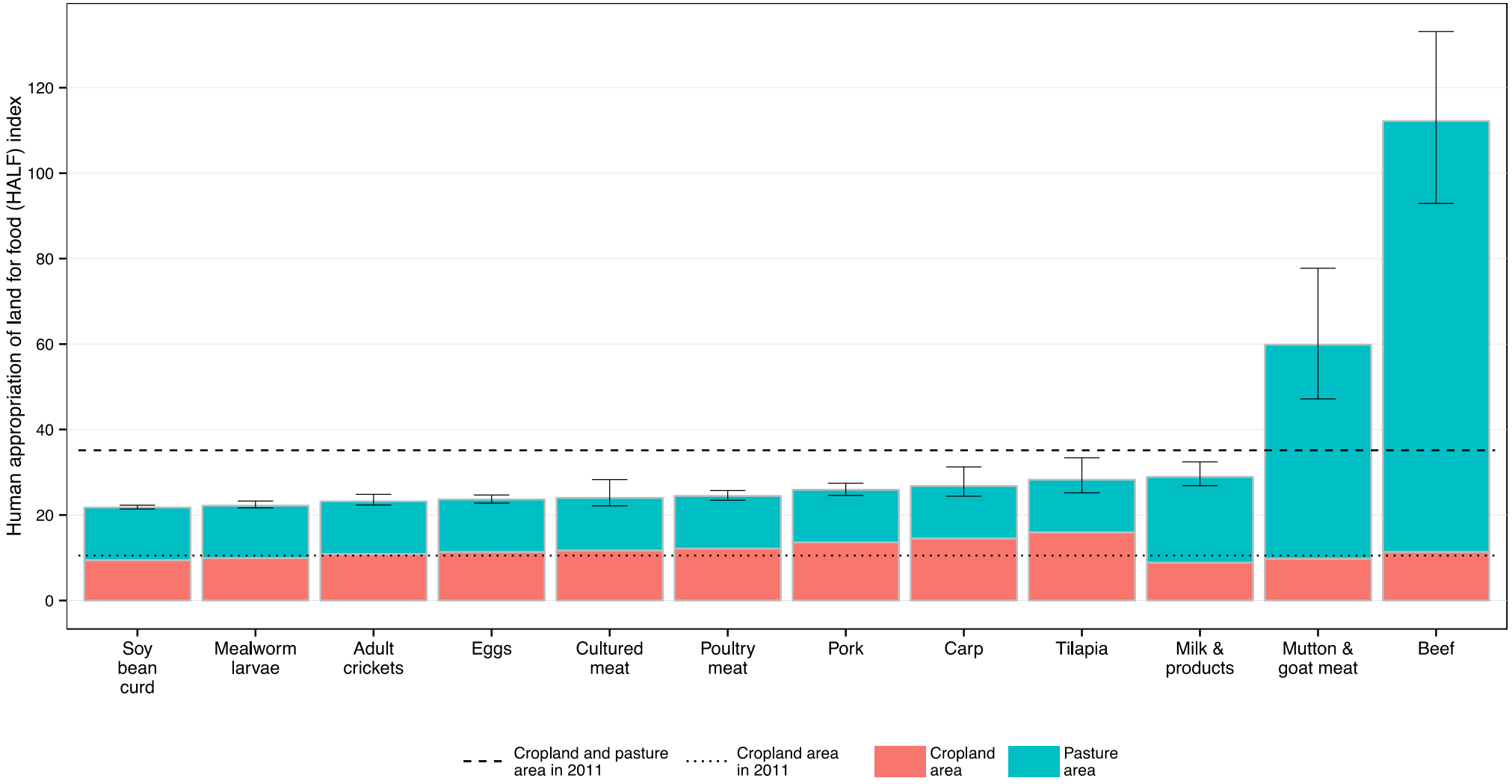
Main types of animal products consumed over time

Comparison between some current diets



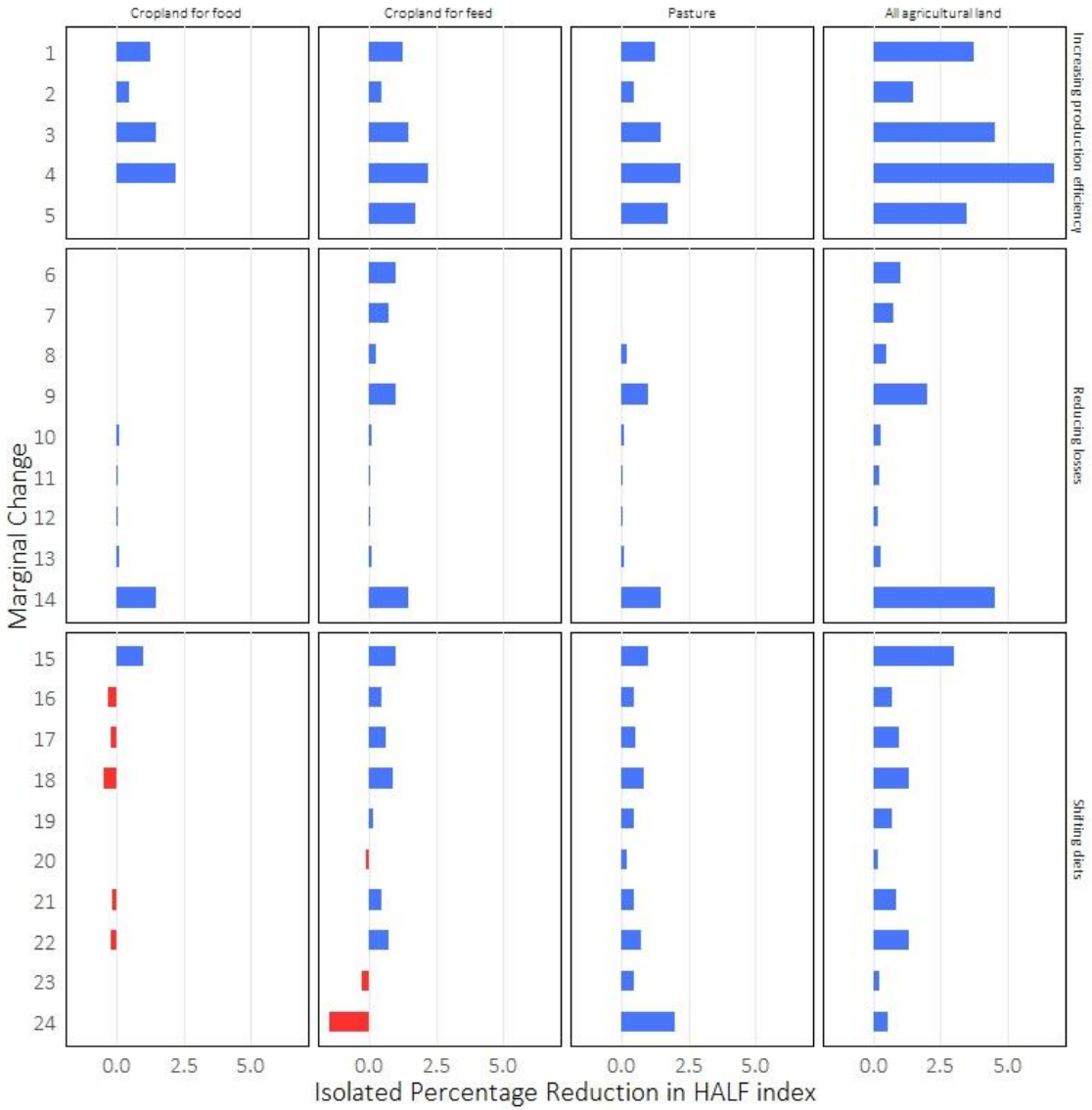
Cropland and pasture required to produce food under alternative dietary scenarios, expressed as required percentage of world land area to produce food required for global population given current global average production.

Land use of alternatives to animal products

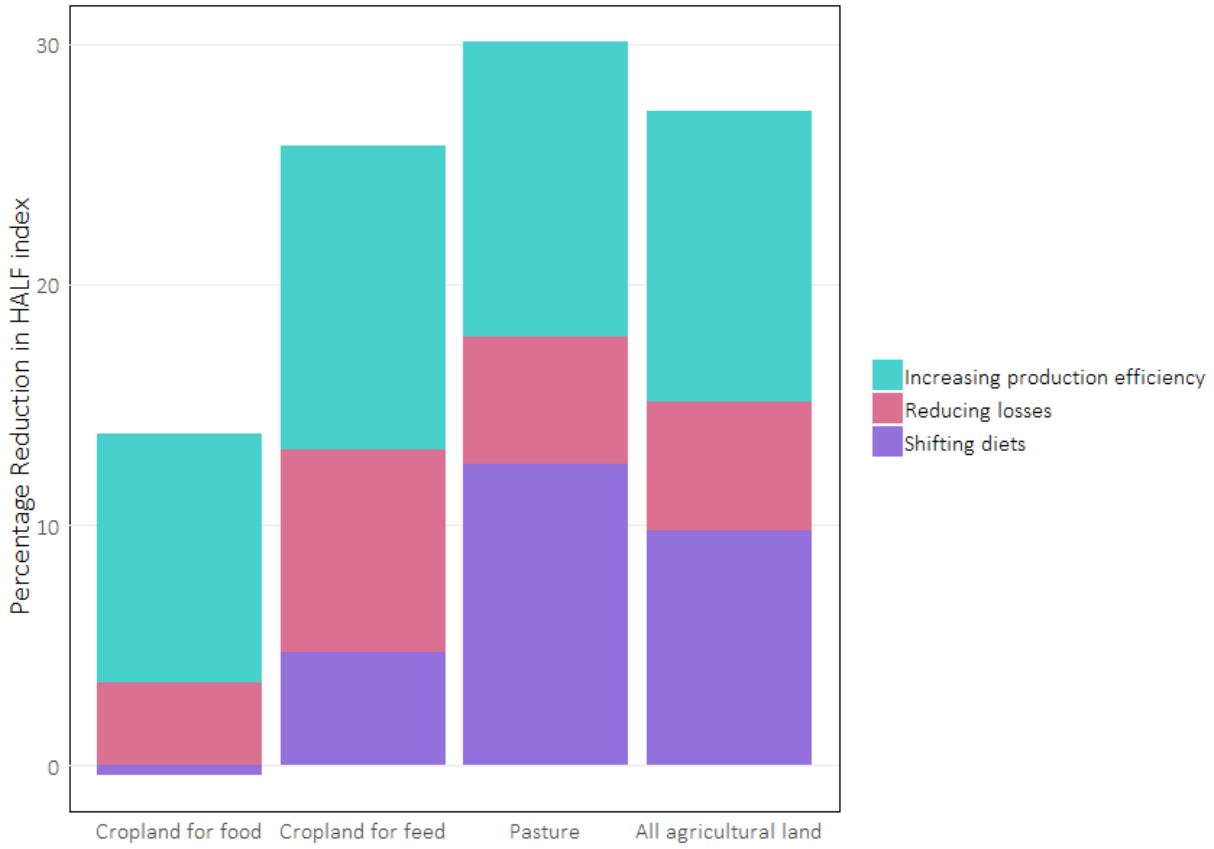


Cropland and pasture areas for food production under scenarios assuming 50% of current nutrients from animal productions are substituted with the indicated food, to provide at least equal energy and protein. Results expressed as percentage of global land required, or HALF index, based on 2011 population and food production systems.

Transformation through marginal gains



Estimated percentage reduction in the HALF index that would be observed if each of the 24 marginal changes acted in isolation. Red bars indicate a percentage increase in HALF. The numbers 1-24 refer to the following changes: (1) Trade and infrastructure, (2) Vertical and urban farms, (3) Multi-cropping and reduced fallows, (4) Crop technologies, (5) Livestock technologies, (6) Food waste as feed, (7) Alternative feeds, (8) Household pets, (9) Offal, (10) Harvest losses, (11) Transport and storage losses, (12) Processing losses, (13) Retailer losses, (14) Consumer losses, (15) Over-consumption, (16) Vegan diets, (17) Vegetarian diets, (18) Low-meat diets, (19) Insects, (20) Cultured meat, (21) Tofu, (22) Imitation meat, (23) Aquaculture, (24) Monogastrics



Conclusions

- Importance of diet for environmental sustainability
- Multiple small changes cumulatively have substantial impact, e.g.
  - Less meat over-all
  - Switch from beef to chicken
  - Less over-consumption and other forms of waste
- Novel foods such as insects and cultured meat part of a solution
- No single “silver bullet” or technology solution and consumer behaviours/diets in developed countries do need to alter.

Thank you.

Alexander P, Brown C, Arneth A, Finnigan J, Moran D, Rounsevell MDA. Losses, inefficiencies and waste in the global food system. *Agricultural Systems* 2017; **153**: 190–200.

Alexander P, Brown C, Rounsevell M, Finnigan J, Arneth A. Human appropriation of land for food: The role of diet. *Global Environmental Change* 2016; **41**: 88–98.

Alexander P, Brown C, Arneth A, *et al.* Could consumption of insects, cultured meat or imitation meat reduce global agricultural land use? *Global Food Security* 2017.

Alexander P, Rabin S, Anthoni P, Henry R, Pugh TAM, Rounsevell MDA, Arneth A (2018) Adaptation of global land use and management intensity to changes in climate and atmospheric carbon dioxide. *Global Change Biology*, **24**, 2791–2809.

peter.alexander@ed.ac.uk