Food, Feed & Fuel: Yields, Land Use and the Environment

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Overview

- Concerns of over ‘sustainability’ of agriculture in the long term
  - Trends over time of per-capita yields
  - Shift towards consumption of meat
  - Coupling of energy and agricultural sectors via biofuels
- Land Use Change
  - Conversion of forests and other ecologically important land classes
- Pervasive and ubiquitous environmental impacts
  - Water quality
  - Climate change

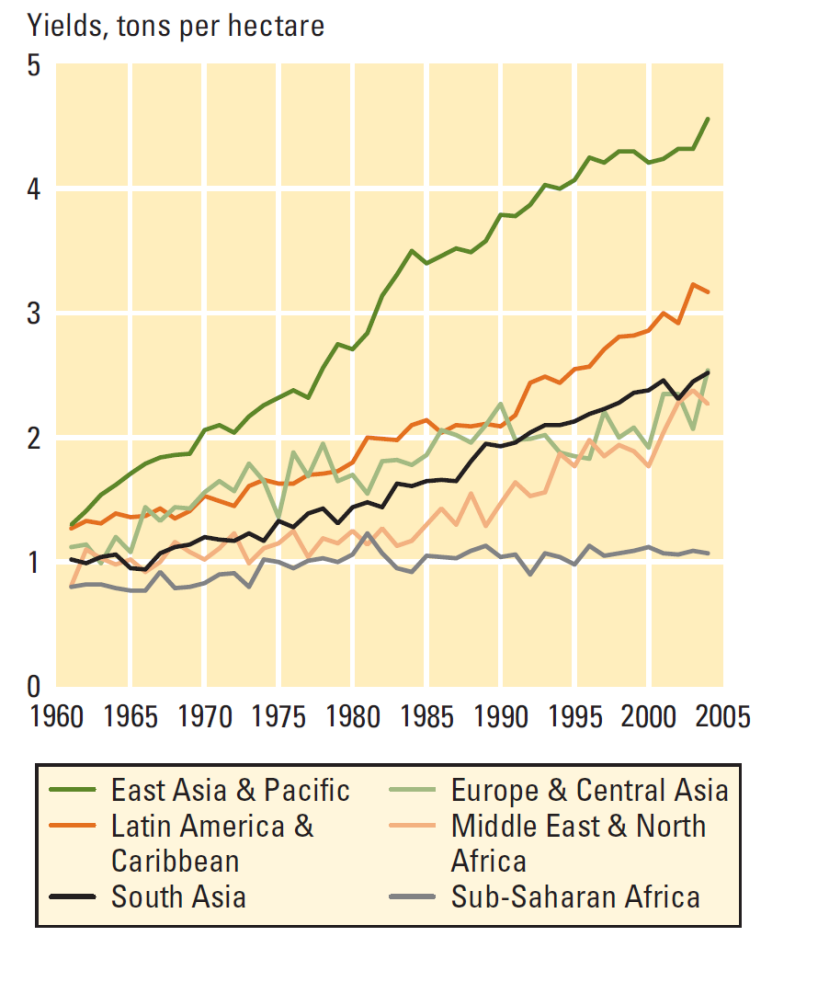
Impacts of Agriculture on the Global Environment

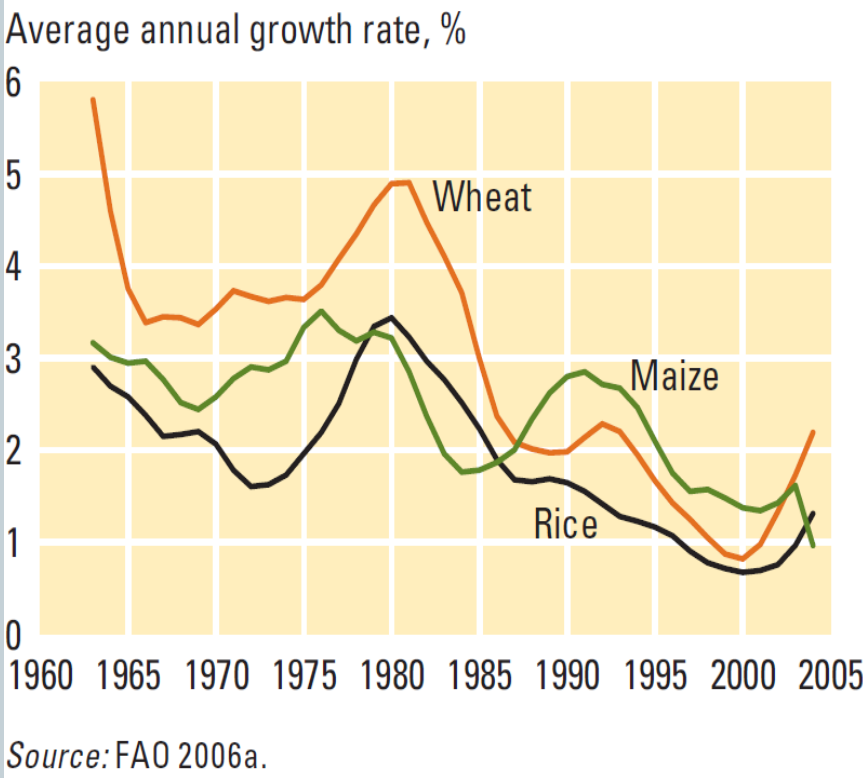
Climate change	**20-30% of GHG**
Ocean acidification	9-15% of CO_2
Nitrogen & Phosphorus cycle	Biggest driver
Global freshwater use	70% of withdrawals
Change in land use	**Biggest driver (34% of land)**
Biodiversity loss	Biggest driver (37% for birds)
Chemical pollution	? Pesticides
Atmospheric aerosol loading	?
Stratospheric ozone depletion	

Motivating Questions

- What is the relationship between yields/ productivity and land use change over the past few decades?
- How do changes in demand for crops, particularly for feed and fuel, influence land use and environmental outcomes?
- How might the tradeoffs between the need to feed people and global environmental concerns, particularly climate change, be reconciled?

The Global Picture



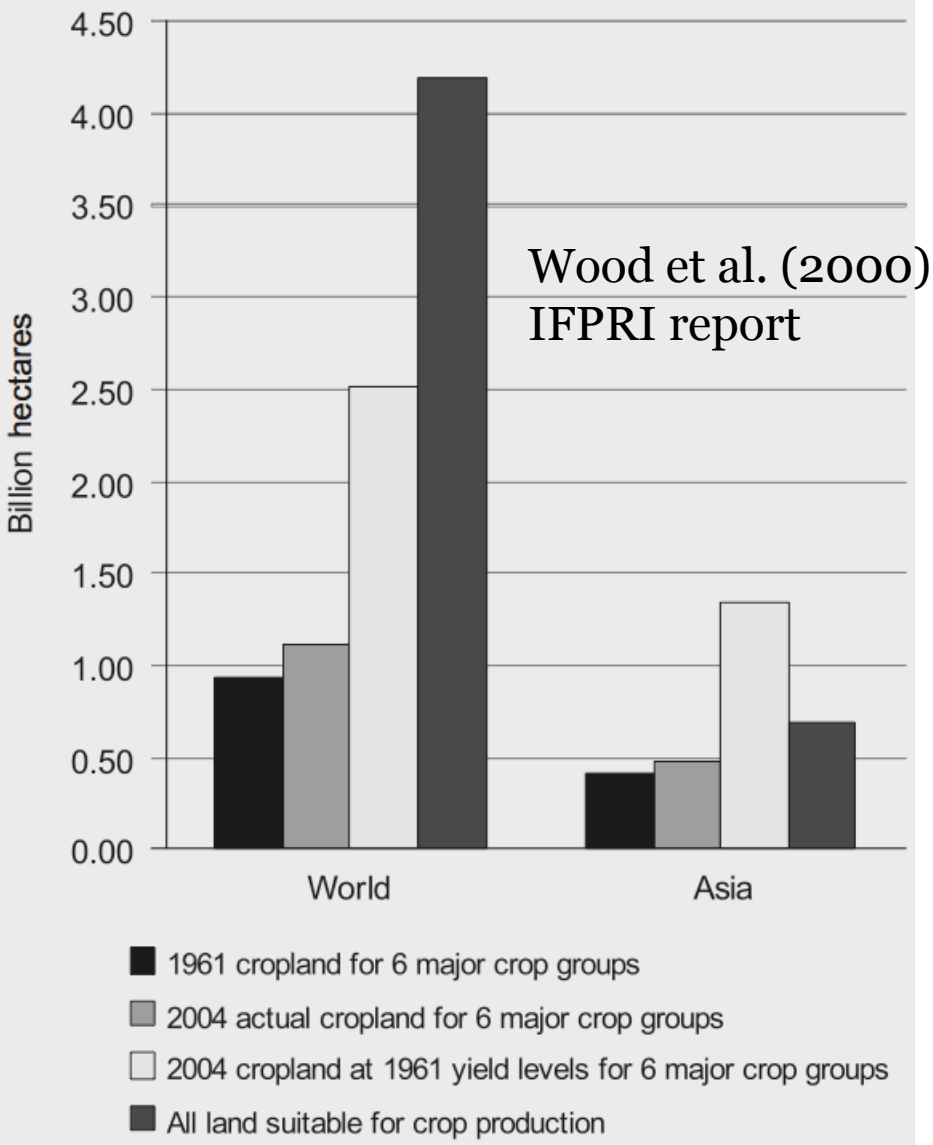


Land use and Yields

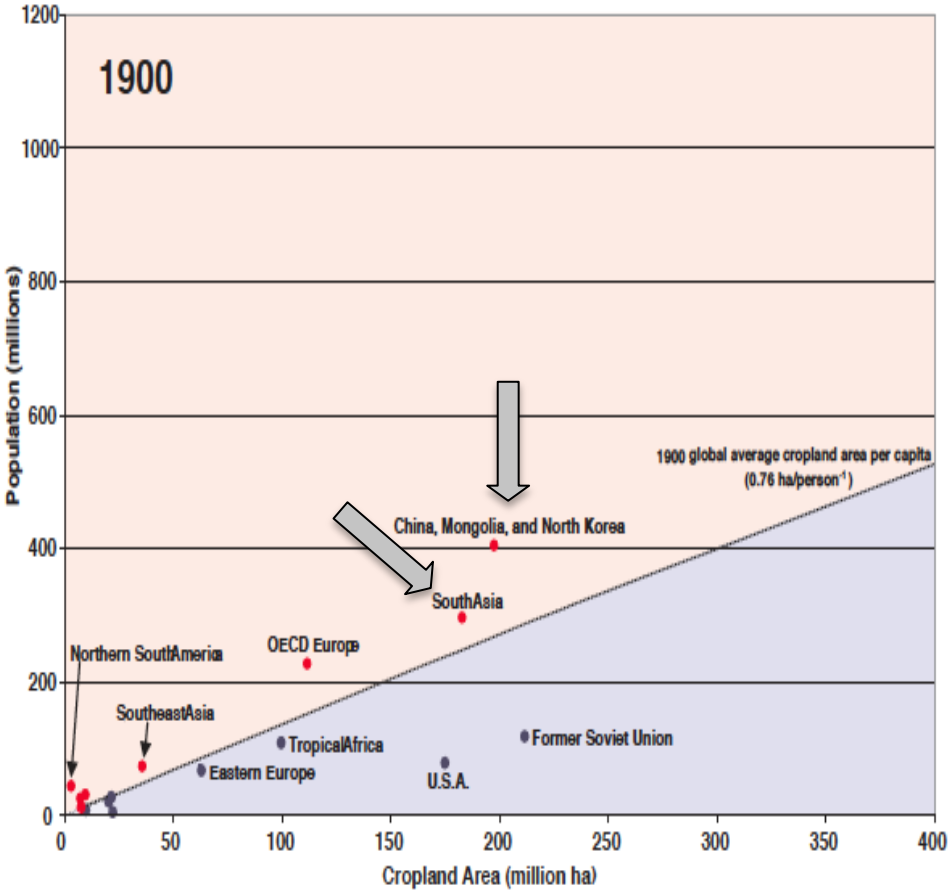
-Roughly ~35% of all land already farmed

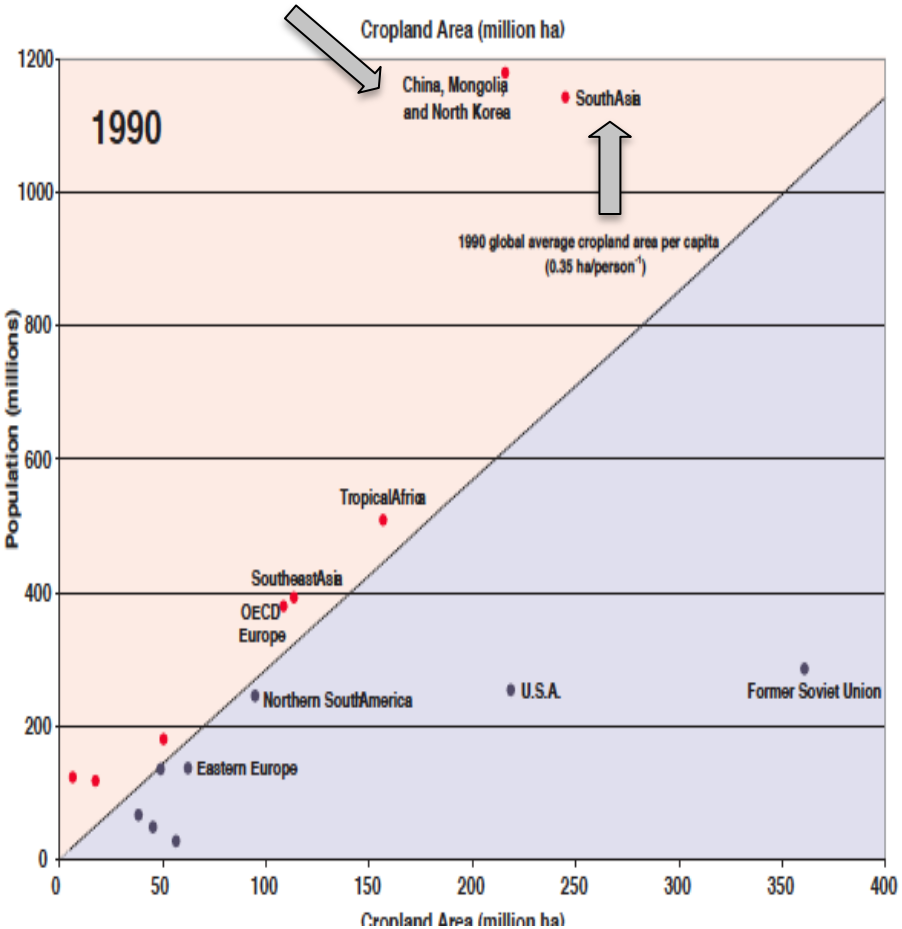
- In the absence of yield increases global land requirements go up by a factor of ~2.

- In Asia yield increases even more salient .

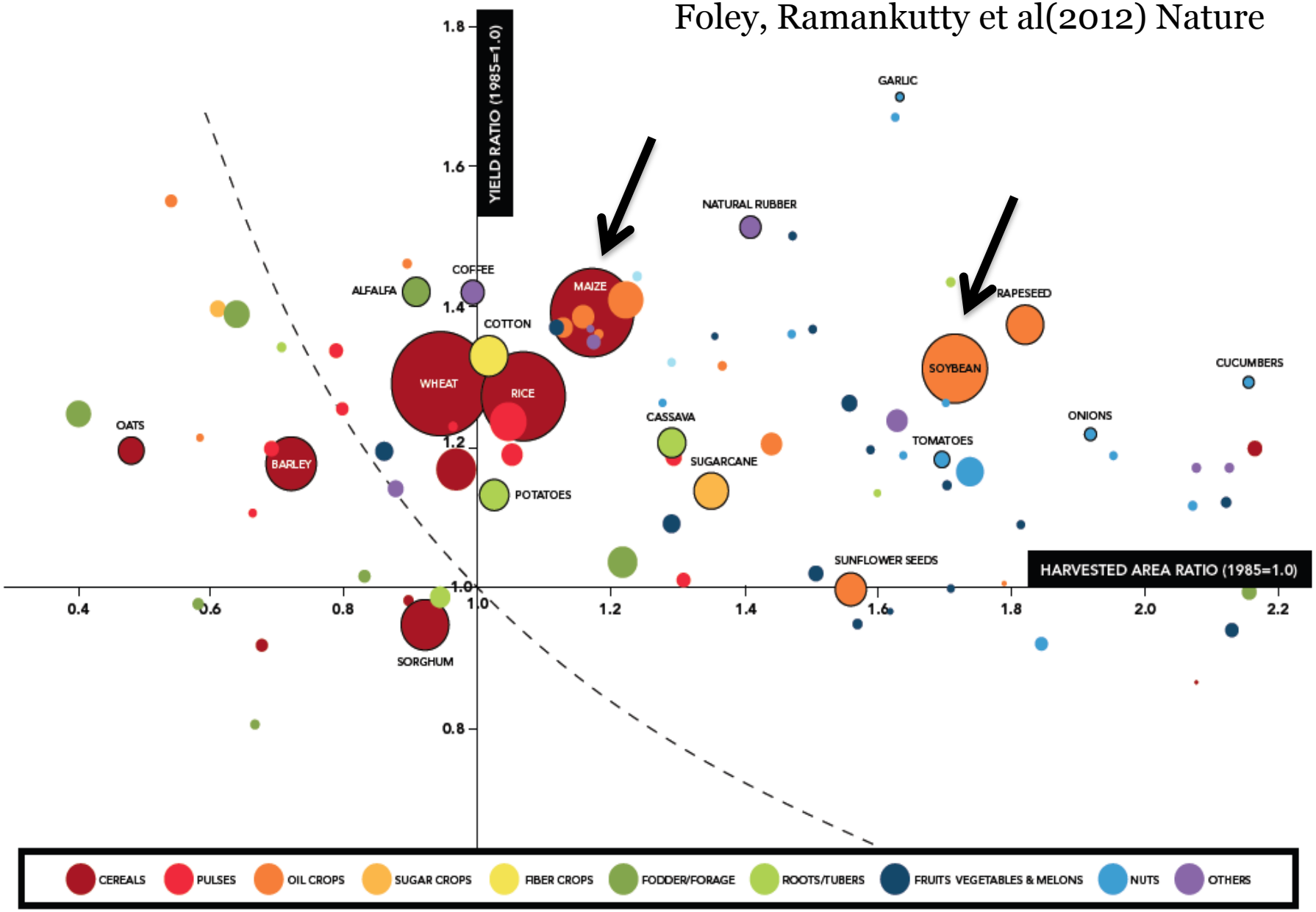


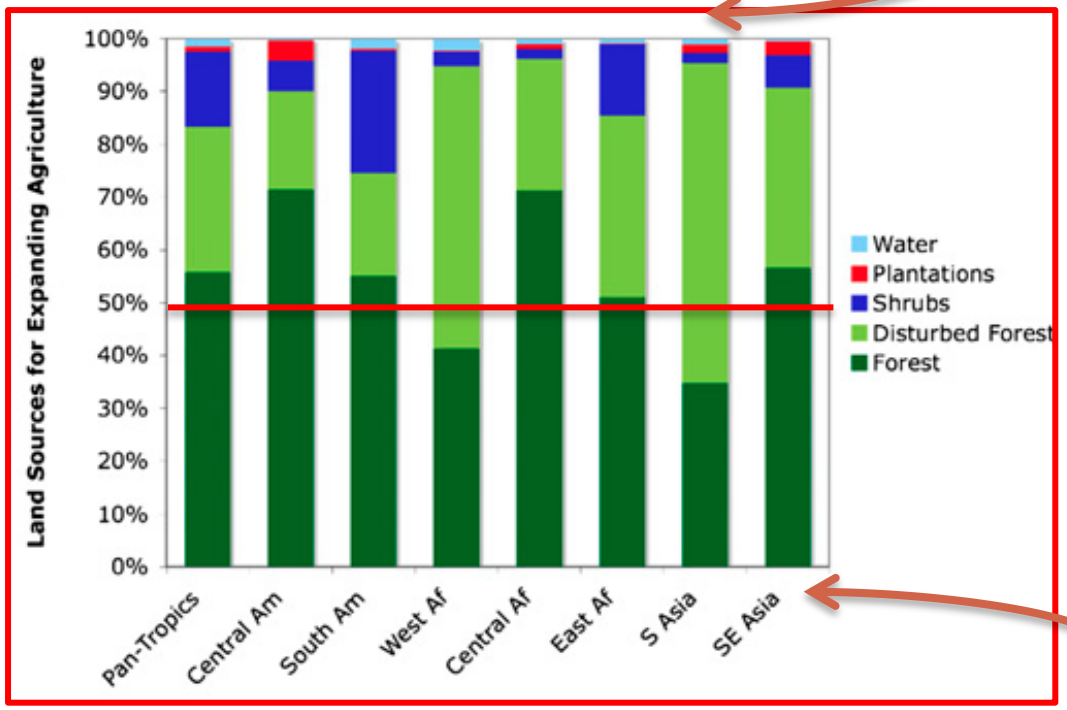
Seufert, Ramankutty et al. (2002)

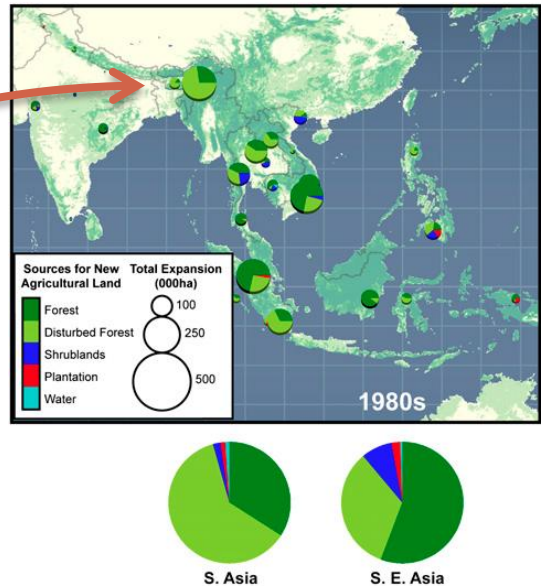


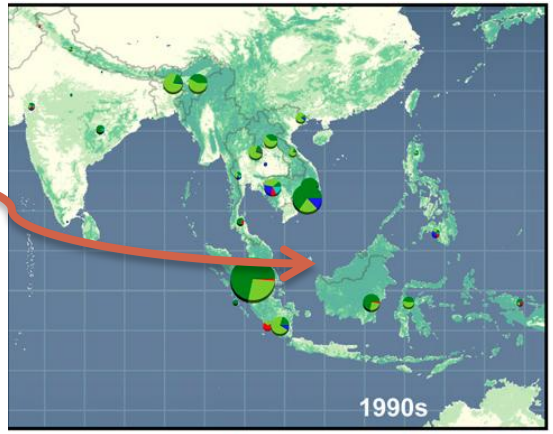


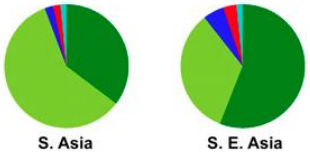
Foley, Ramankutty et al(2012) Nature





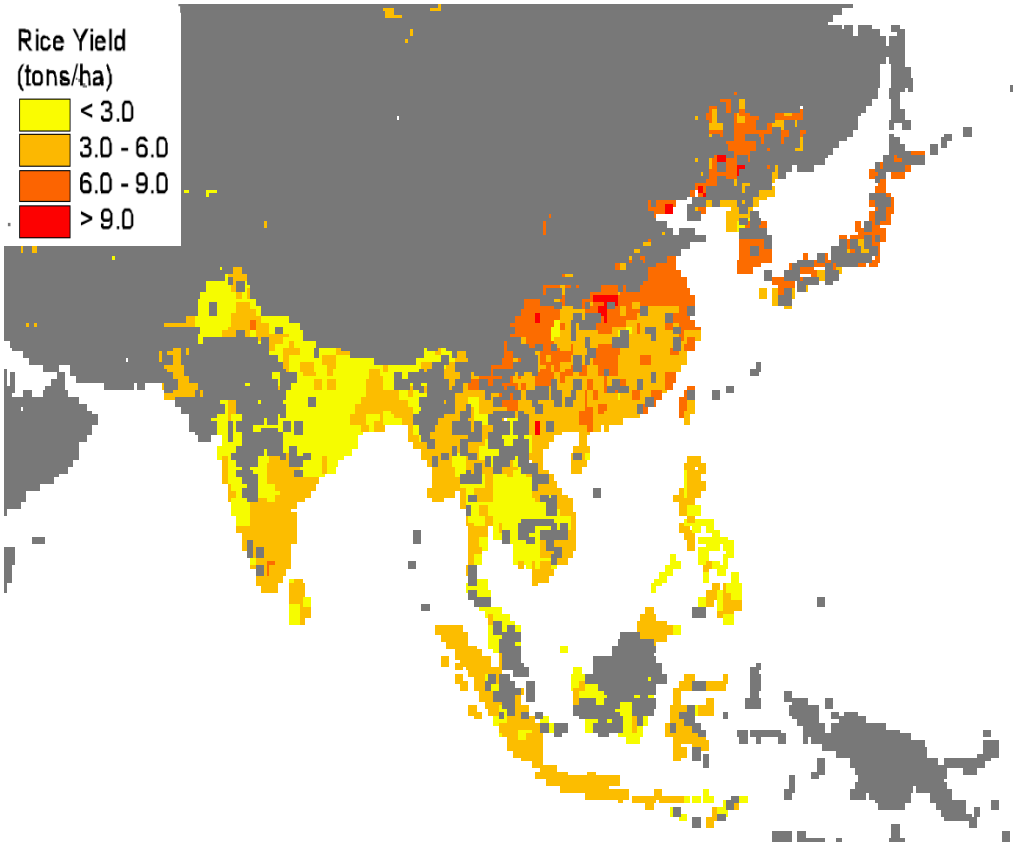






From Gibbs et al 2010, PNAS

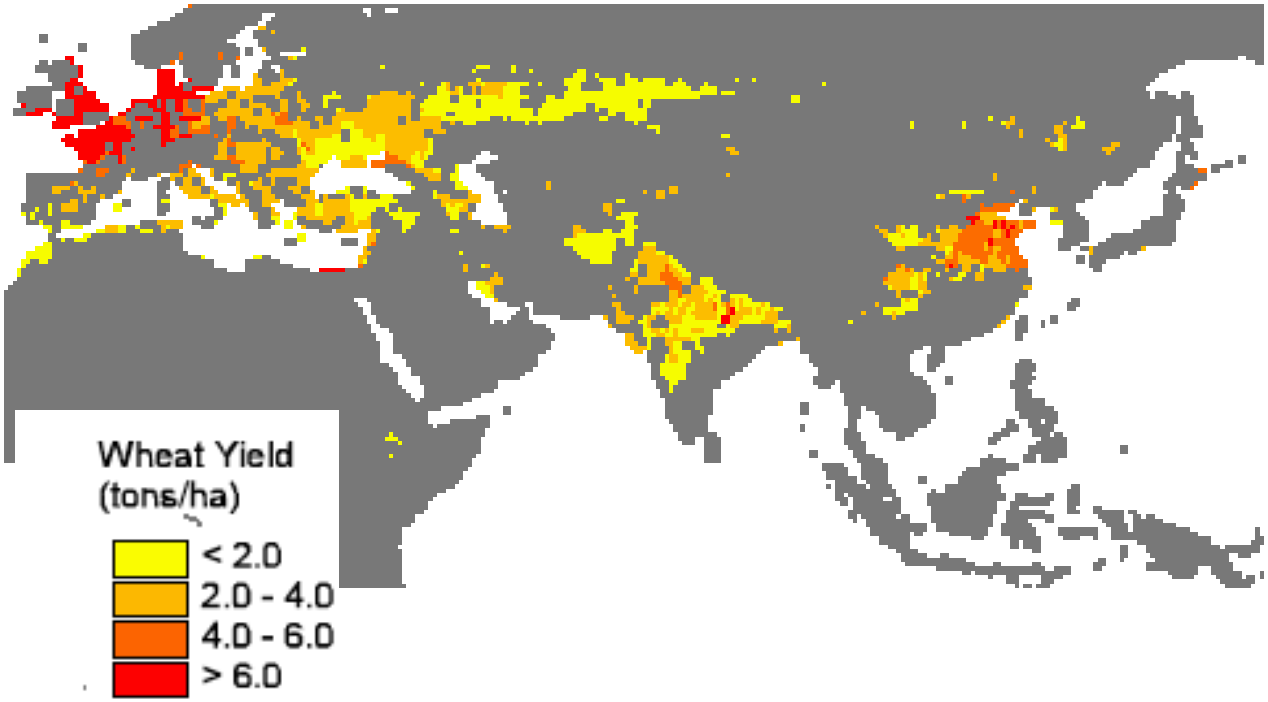
Variability in Rice yields across Asia.



From Monfreda et al. (2008)

Disaggregation of subnational yield statistics using remote-sensing based global cropland map.

Variability in Wheat yields across Asia.



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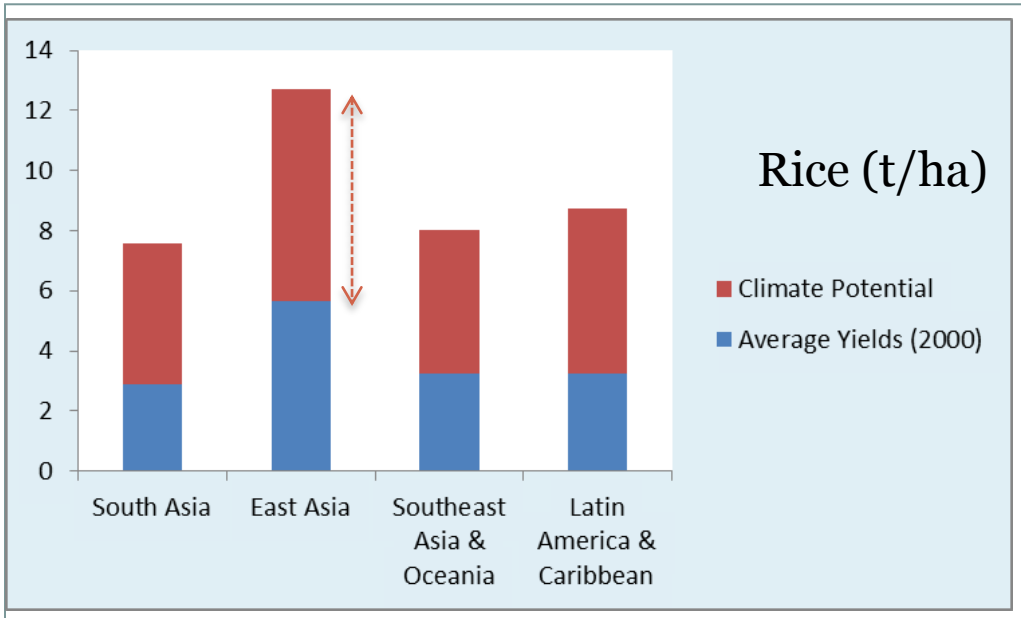
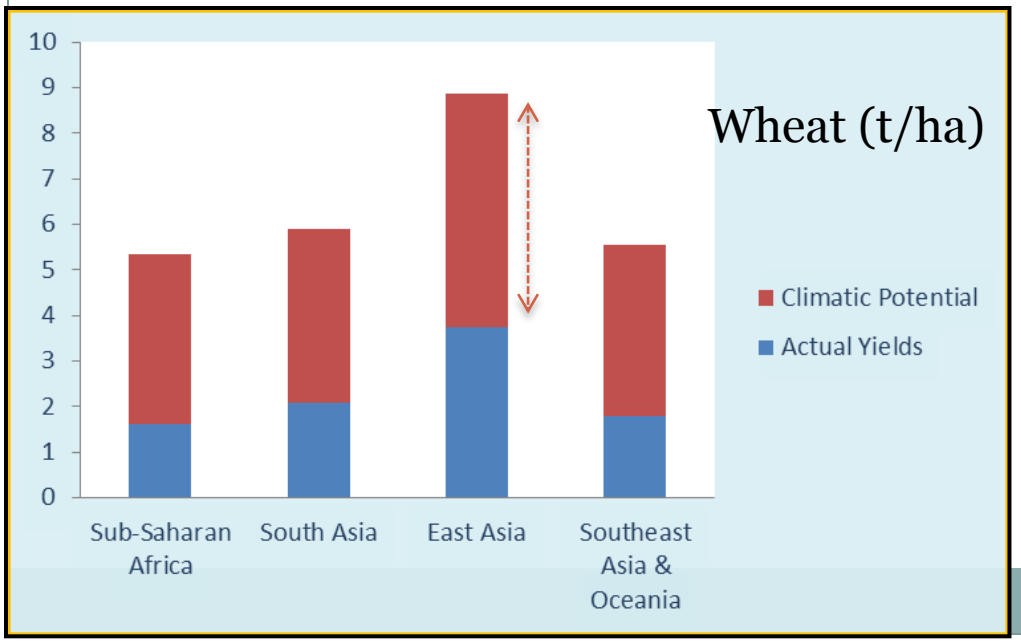
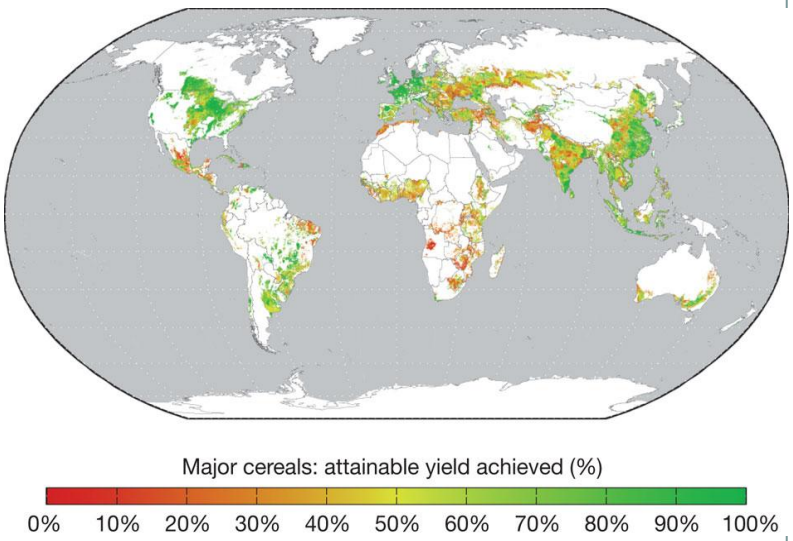


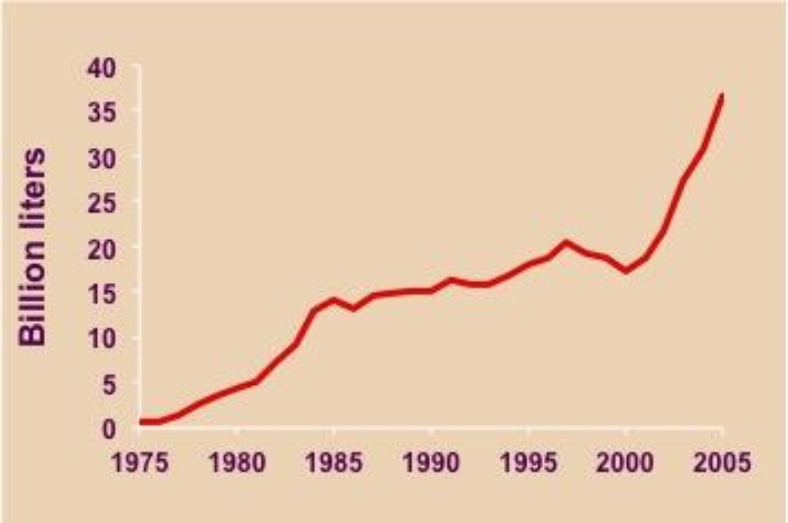
From Mueller et al Nature 2012.

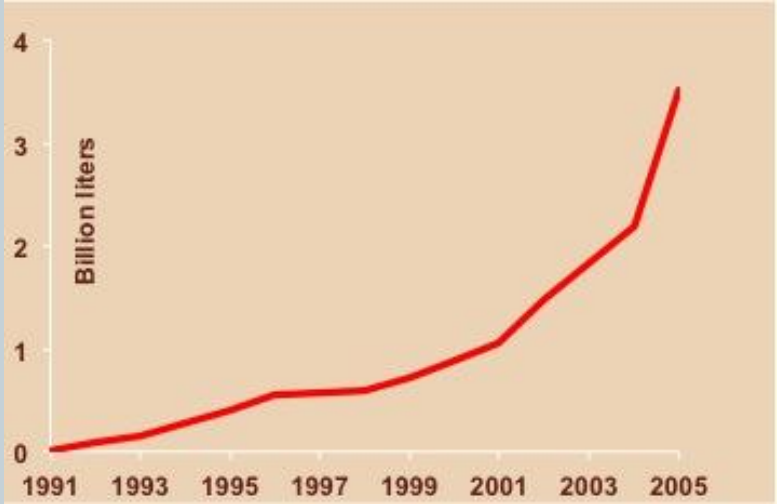
Within each of 100 climate zones of the world, the distribution of yields was examined to determine potential yields (95th %ile) and yield gaps.

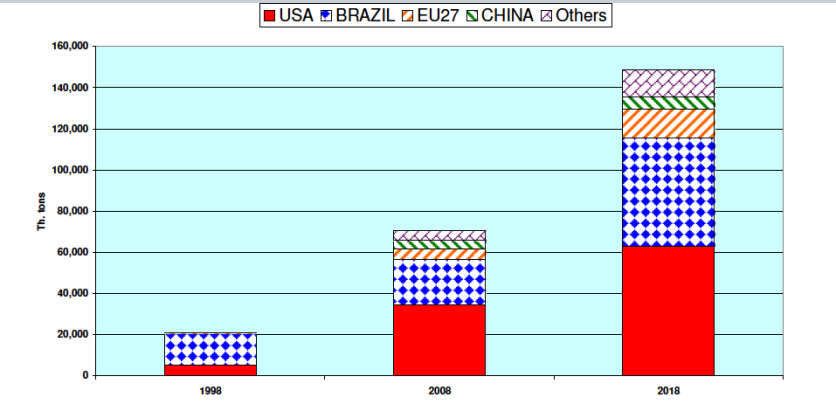


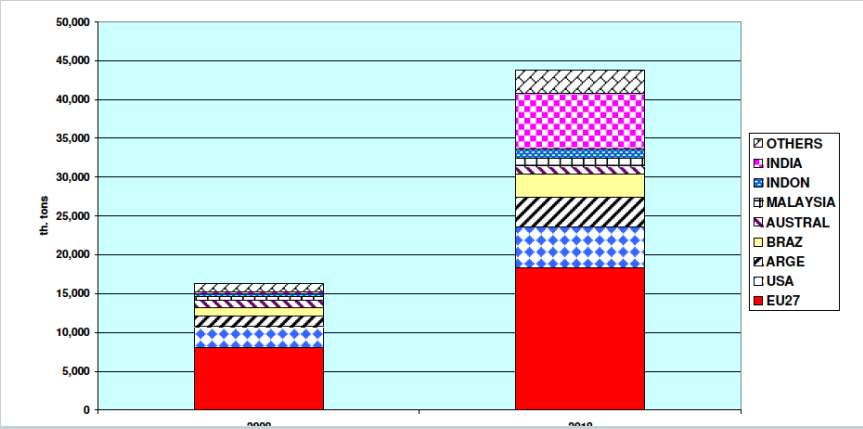


Biofuel Production



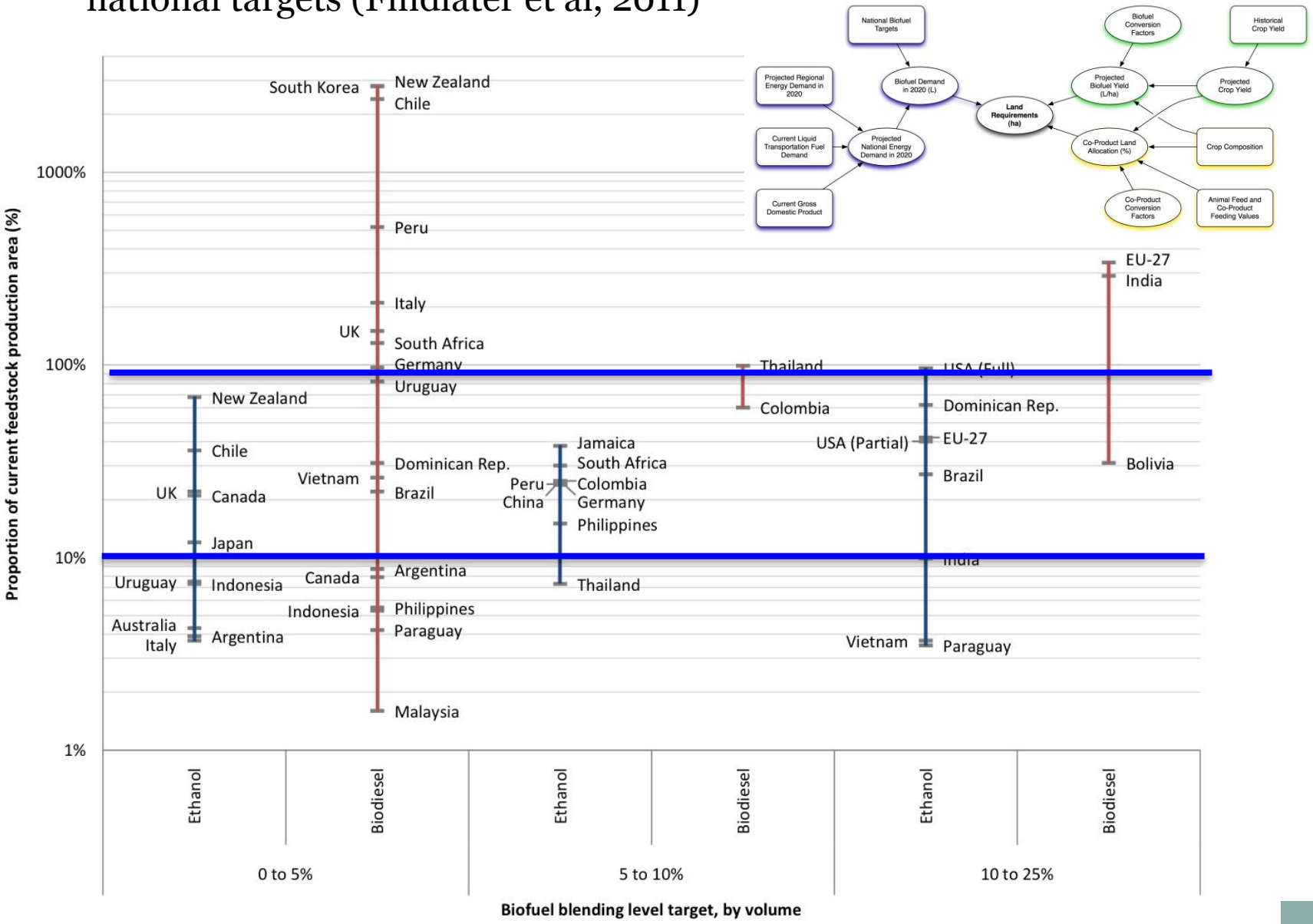




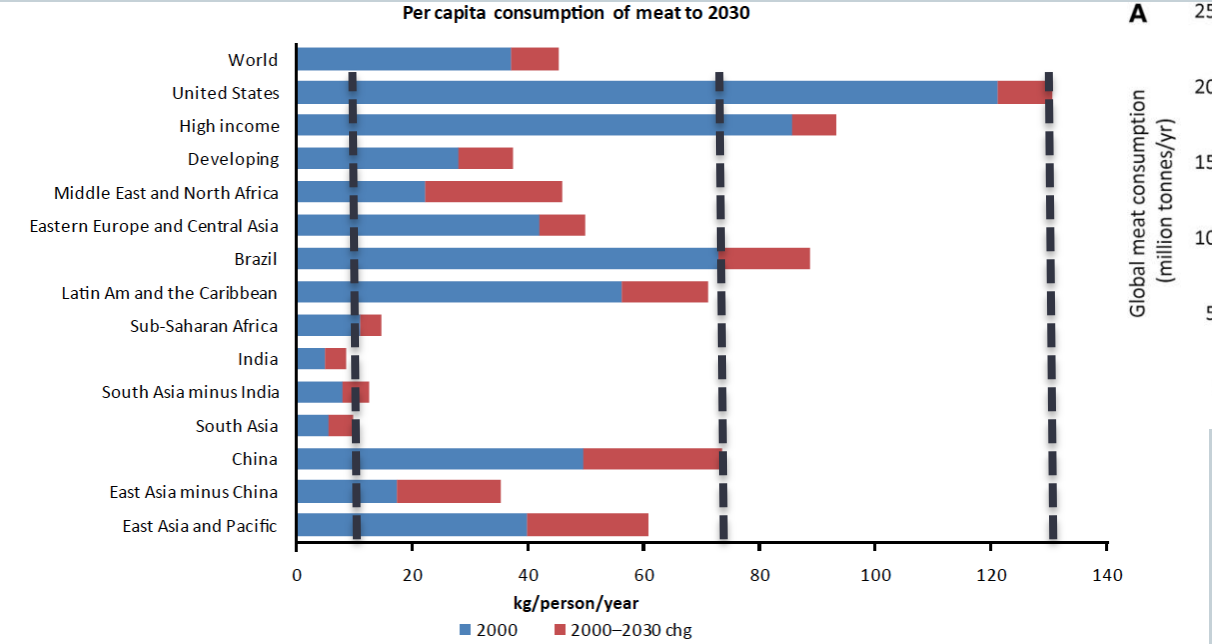


Data and models projections from :OECD/FAOSTAT & FAO:WORLD FOOD AND AGRICULTURE TO 2030/50

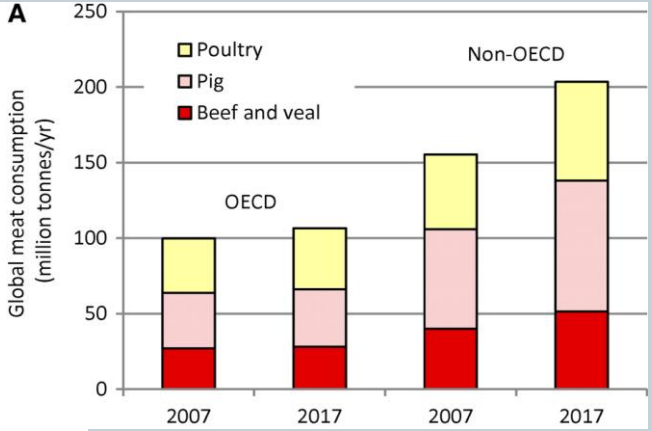
Land required to meet national targets (Findlater et al, 2011)



Shifting Diets



Source: IMPACT model projections

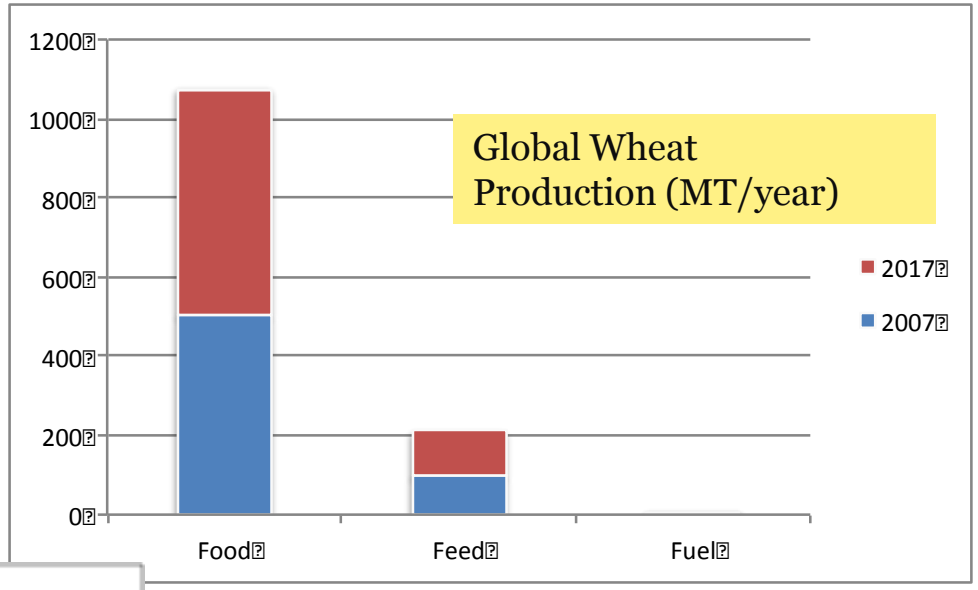


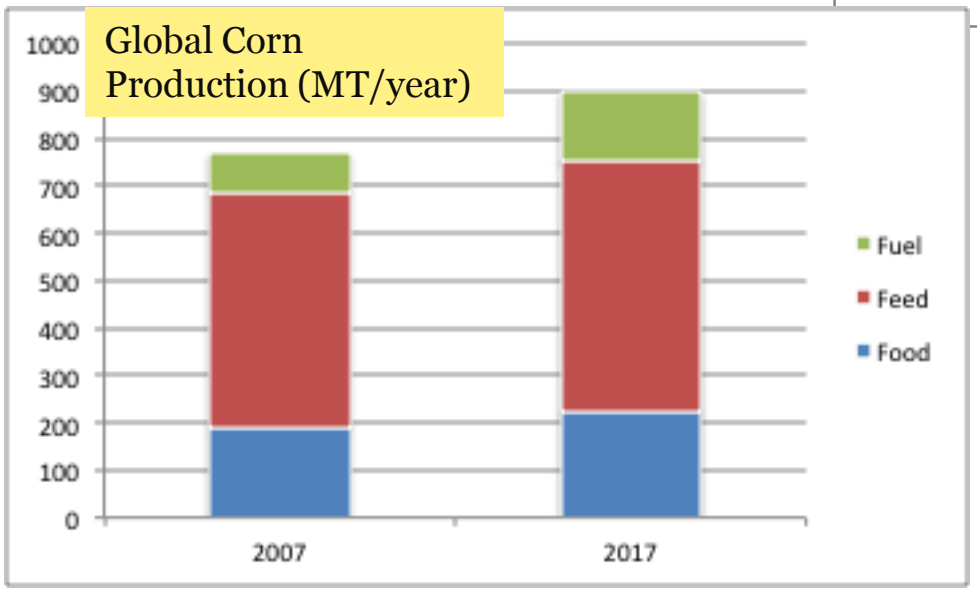
In the next decade:

~22% increase in global meat consumption

~ Higher in developing Asia

Wheat over the next decade:
~12-13% increase in production for feed and food.

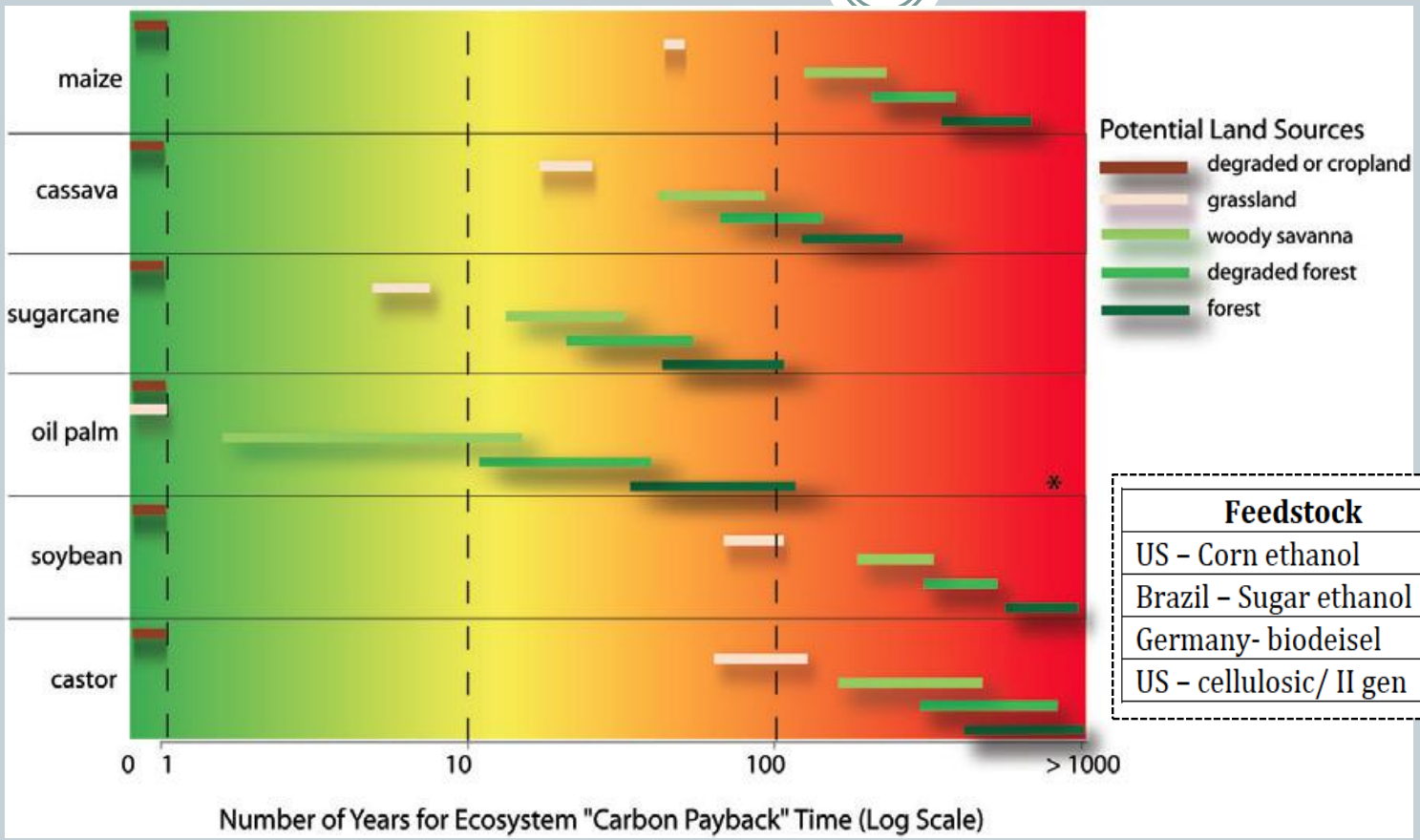




Corn over the next decade:
70% increase in production for fuel
7% for feed & 15% for food.

Data and model projections from: OECD/FAOSTAT & FAO:WORLD FOOD AND AGRICULTURE TO 2030/50

Biofuel Carbon 'Debt'



Feedstock	Energy Balance
US – Corn ethanol	1.15 - 1.3
Brazil – Sugar ethanol	6-8
Germany- biodeisel	~2
US – cellulosic/ II gen	2-35

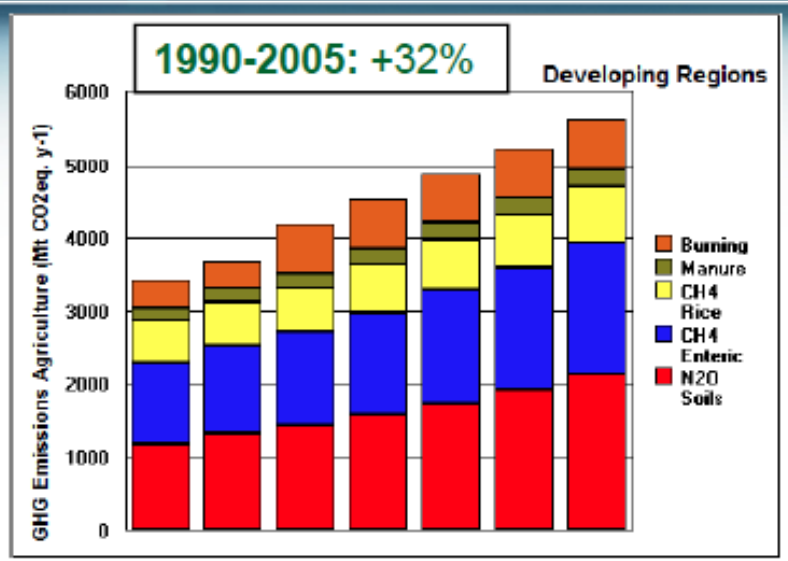
2nd Generation/Non-food crop based Biofuels

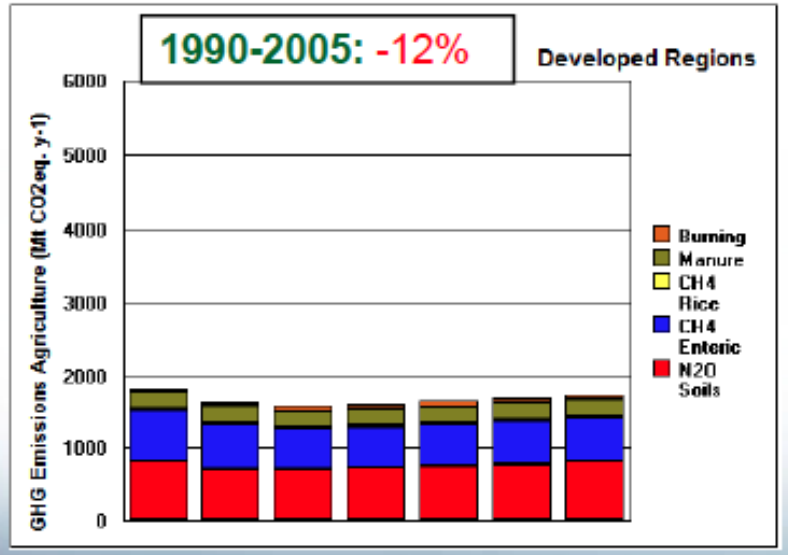
- Cellulosic Ethanol (Switch grass, corn Stover)
  - Prelim. LCA Studies show dramatic benefits of second generation fuels
  - Expensive - Biotech innovations needed to take advantage of feedstock
- Biodiesel from non-edible oilseeds
  - Jatropha has failed to take-off
    - benefits overstated and costs understated
  - Need improved understanding of Jatropha agronomy

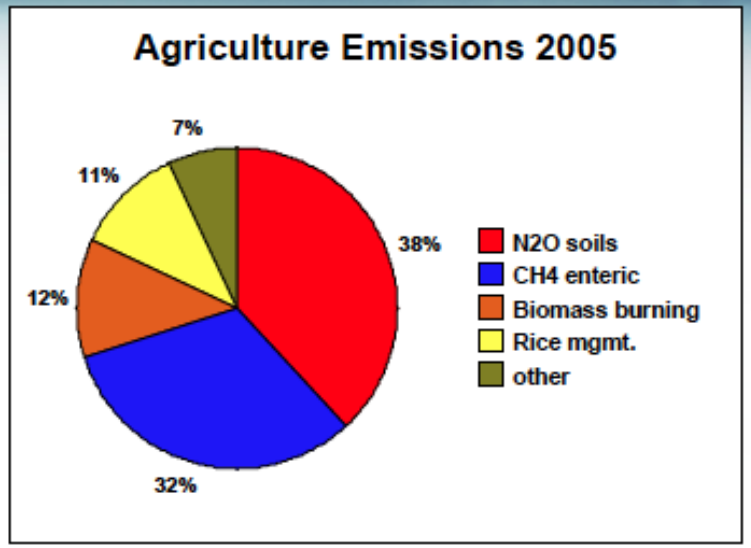
From: IPCC AR4 2007

Baseline emissions: Agriculture

IPCC Intergovernmental Panel on Climate Change







Main drivers for trends

- Increase in GHGs: population pressure, income increase, diet changes, technological changes
- Decrease in GHGs: increased land productivity, conservation tillage, non-climate policies

Commonly consumed foods	Emissions[1]			
	Carbon dioxide	Nitrous oxide	Methane	Total
	kg CO_2 equivalents/kg product			
Carrots: domestic, fresh	0.38	0.04	0.0	0.42
Potatoes: cooked, domestic	0.40	0.06	0.0	0.45
Honey	0.46	0.0	0.0	0.46
Whole wheat: domestic, cooked	0.54	0.08	0.0	0.63
Apples: fresh, overseas by boat	0.80	0.02	0.0	0.82
Soybeans: cooked, overseas by boat	0.92	0.0	0.0	0.92
Milk: domestic, 4% fat	0.45	0.14	0.45	1.0
Sugar: domestic	1.04	0.03	0.0	1.1
Italian pasta: cooked	0.96	0.12	0.0	1.1
Oranges: fresh, overseas by boat	1.1	0.10	0.0	1.2
Rice: cooked	0.59	0.21	0.52	1.3
Green beans: South Europe, boiled	1.2	0.12	0.0	1.3
Herring: domestic, cooked	1.5	0.0	0.0	1.5
Vegetables: frozen, overseas by boat, boiled	2.2	0.05	0.0	2.3
Eggs: Swedish, cooked	1.7	0.74	0.04	2.5
Rapeseed oil: from Europe	1.5	1.5	0.0	3.0
Chicken: fresh, domestic, cooked	3.1	1.2	0.01	4.3
Cod: domestic, cooked	8.5	0.0	0.0	8.5
Pork: domestic, fresh, cooked	3.9	1.6	3.8	9.3
Cheese: domestic	5.0	1.3	4.5	11
Tropical fruit: fresh, overseas by plane	11	0.23	0.0	11
Beef: domestic, fresh, cooked	6.9	6.6	17	30

[1] Values represent kg CO_2 equivalents over a 100-y time period.

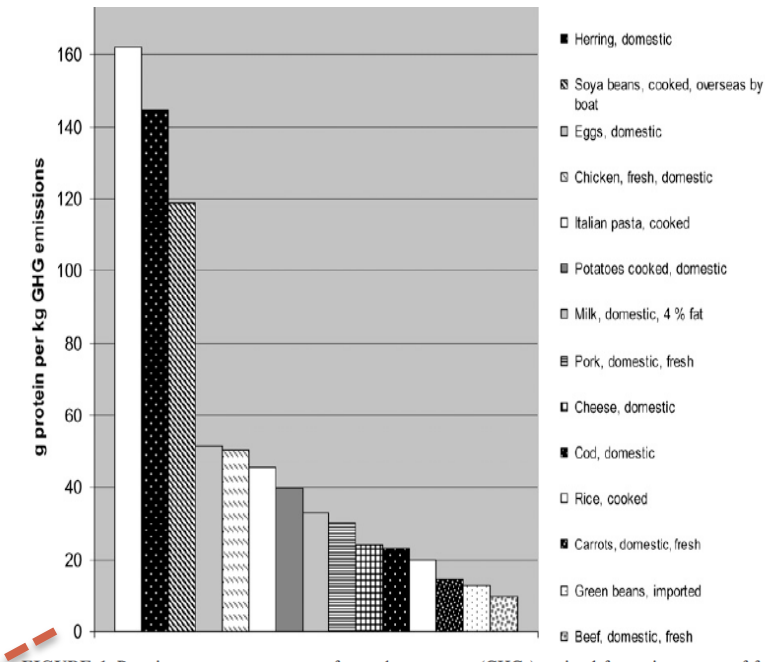
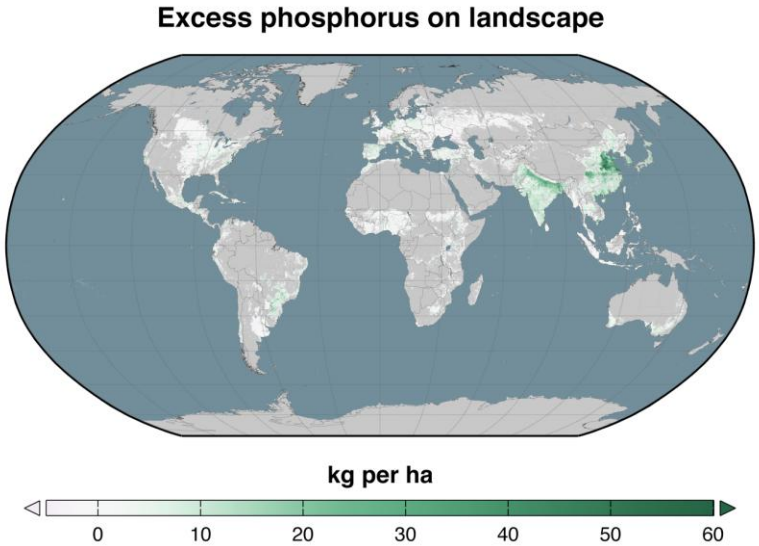
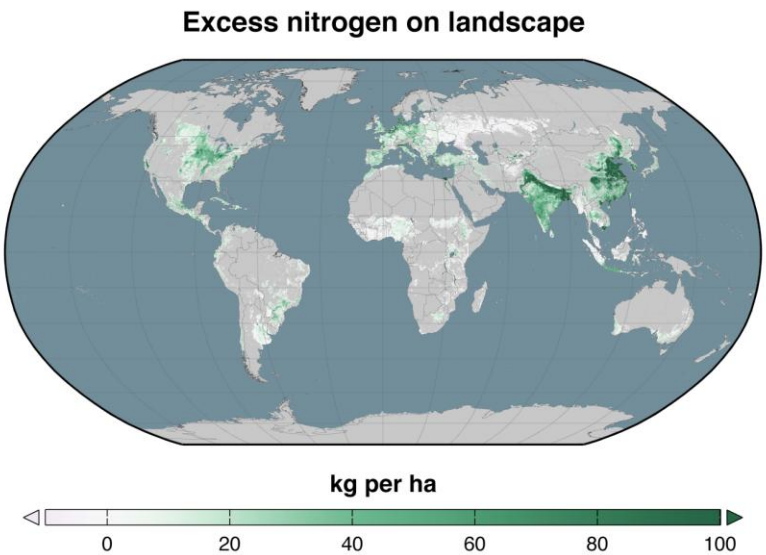


FIGURE 1. Protein content per amount of greenhouse gases (GHGs) emitted for various types of food.

Carlson-Kanyama and Gonzalez (2010)

Excess Fertilizer Use Example





From Foley et al (2012) Nature

Conclusions

- Average yield growth slow, barely keeping up with population growth
- Not much land left to grow, especially in Asia – need to further intensify
- Lots of geographical variability in yields by climatic zones
  - Potential for large (45 to 70%) increases through management practices (fertilizer applications and irrigation)
- Competing land use pressures from feed and fuel production
  - Fuel mandates (if met) could divert substantial amounts of ag. land to biofuel production
- Tradeoffs in the management of agricultural yields vis-à-vis climate change need to be understood.
  - Fertilizer overuse and its consequences
  - More plant based food, meat from animals with low enteric fermentation.