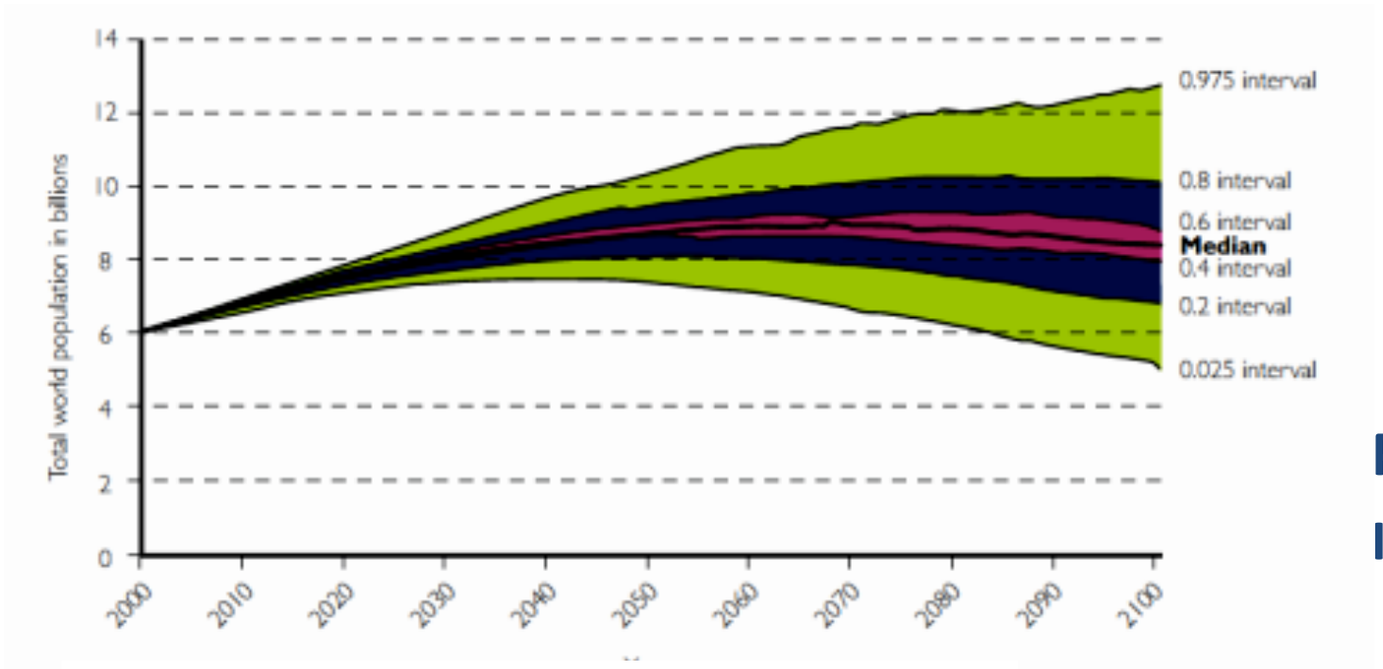
UNIVERSITY OF LIVERPOOL



Total world population in billions, probabilistic projections.

Global Food Security and Climate Change

Prof Martin Mortimer

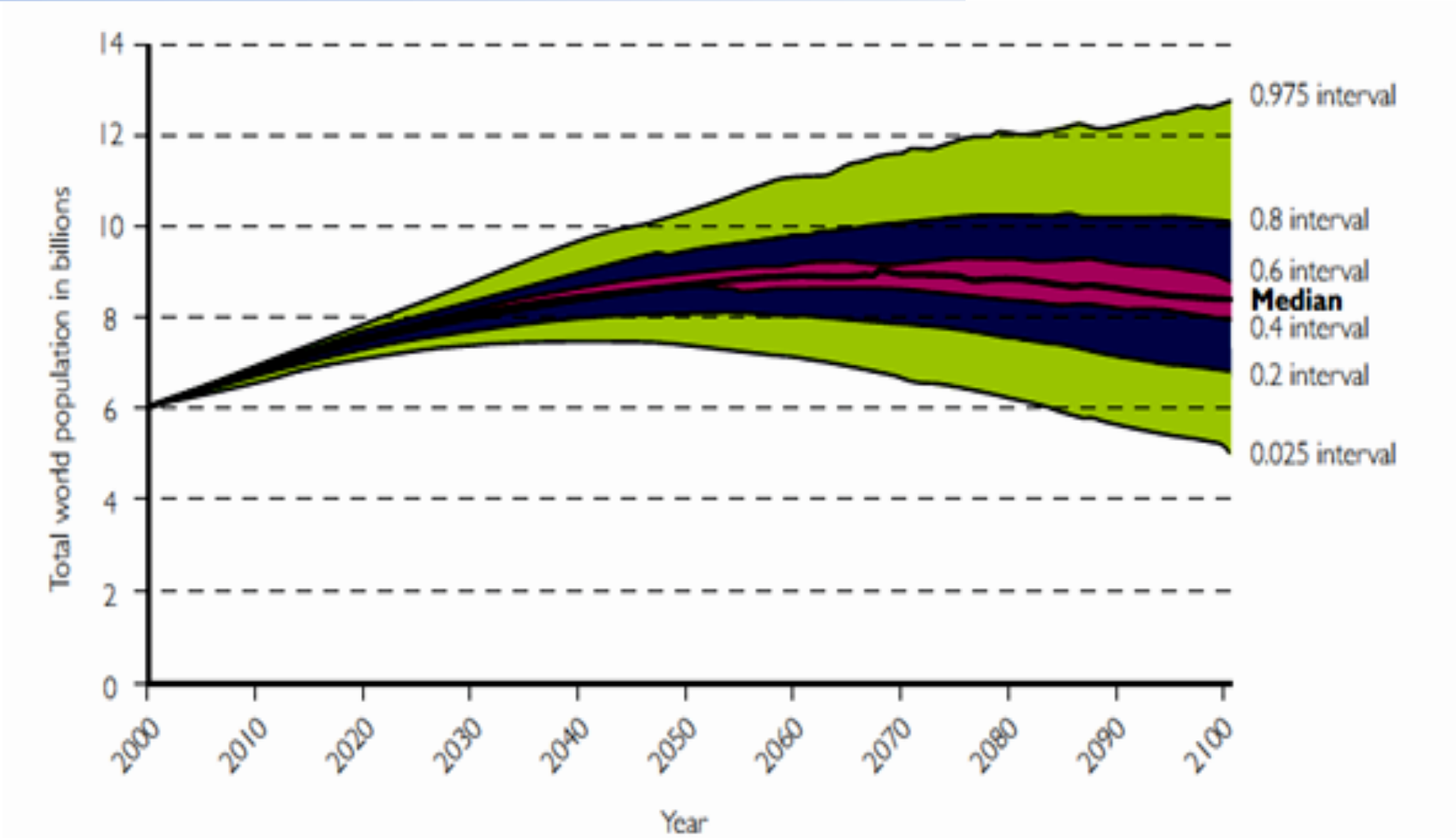
Institute of Integrative Biology

Selected metrics on the state of the world

People in the world (2011)[58]	**7 billion**
Undernourished people (2010)[59]	**0.9 billion**
Overweight people over age 20 (2008)[60]	**1.5 billion**
People living on less than USD 1.25 per day (2005)[61]	**1.4 billion**
People living in dryland areas (2007)[62]	**2 billion**
People dependent on degrading land[63]	**1.5 billion**
Losses due to climatological events (extreme temperature, drought, forest fire) (2011)[64]	**USD 11.4 billion**
Area of agricultural land (2009)[65]	**4.9 billion hectares**
Area of croplands, pasture and grazing lands devoted to raising animals[66]	**3.7 billion hectares**
Annual growth in world agricultural production (1997–2007)[67]	**2.2%**
Food produced for human consumption lost or wasted annually[68]	**1.3 billion tonnes**

Source : CCAFS

A future of rising human population – more mouths to feed

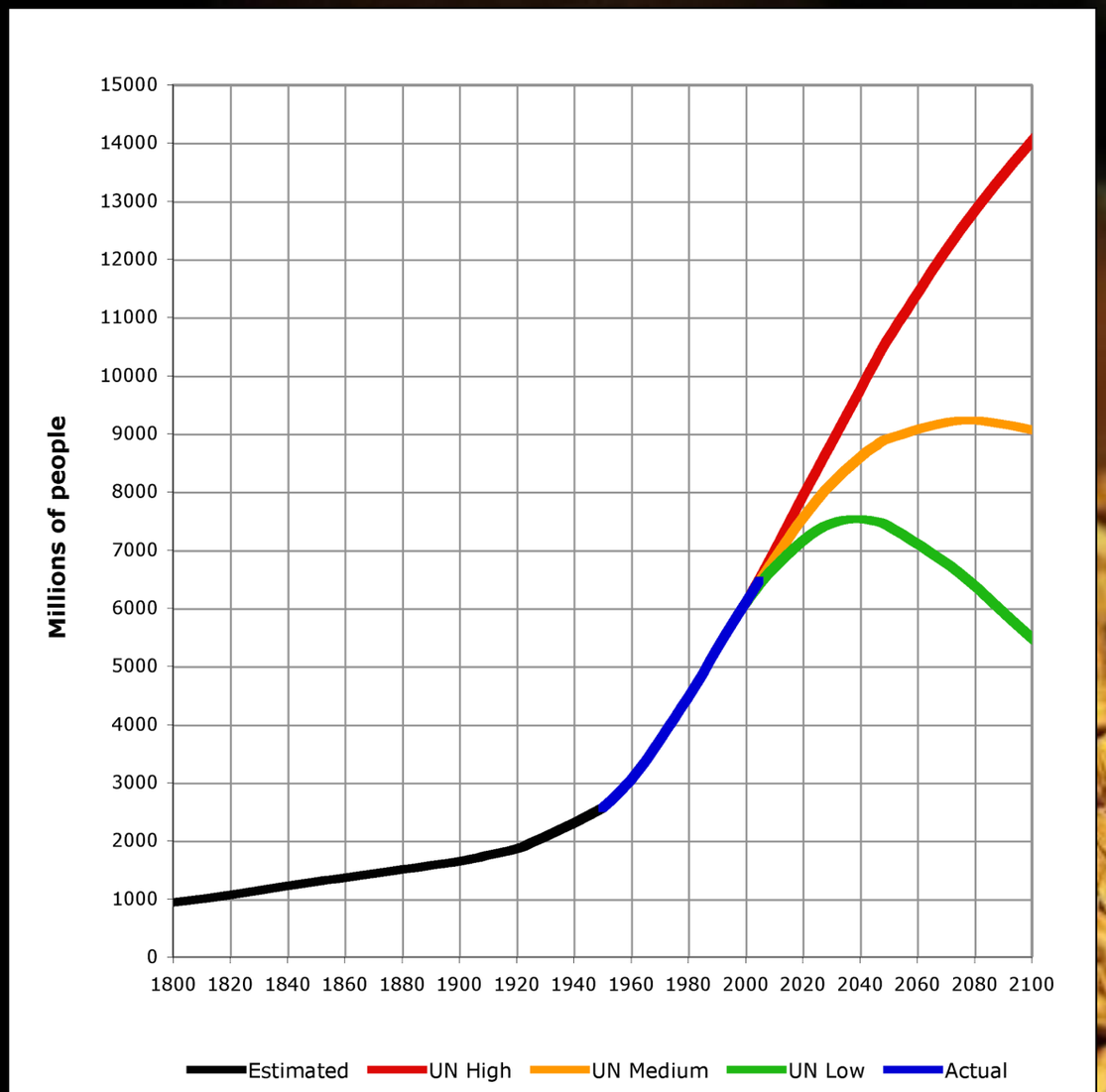


What's behind these figures and why is the median projection around 9 billion to the end of the century ? What will it mean ? Listen to the first 30 minutes of Professor Hans Rosling's talk. He is Professor of International Health at the Karolinska Institute in Sweden and co-founder and chairman of the Gapminder Foundation.

http://www.dailymotion.com/video/x175qup_bbc-this-world-don-t-panic-the-truth-about-population-h264-1280x720-aac-rmac_news

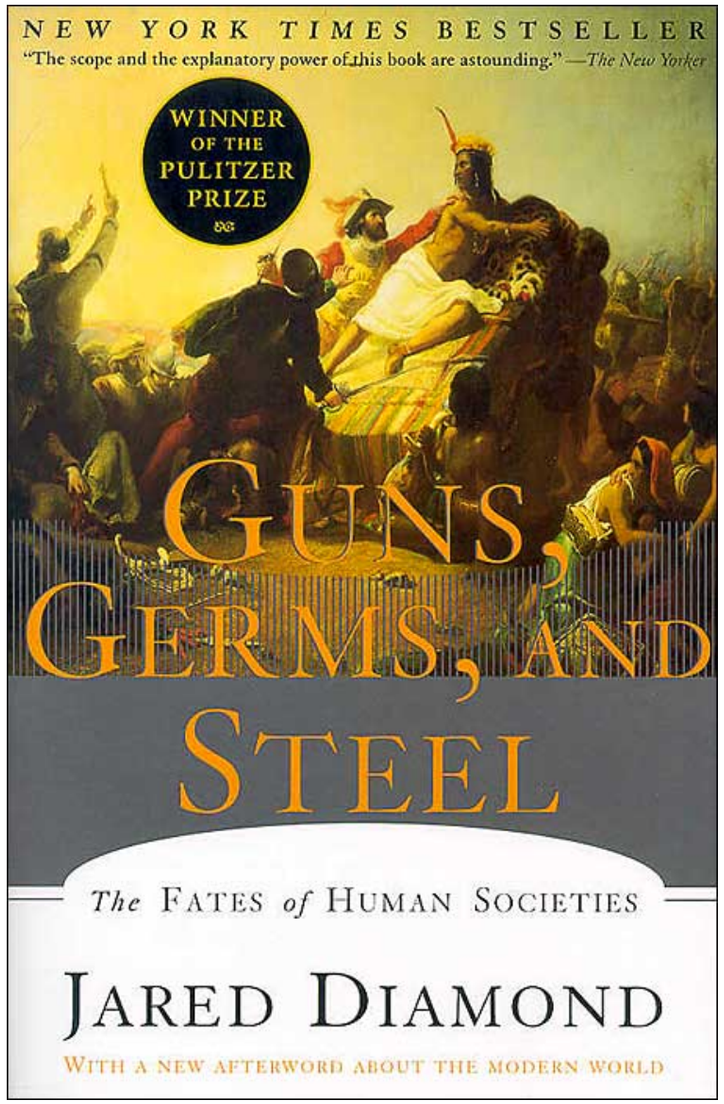
The case of rice

Currently 700 million tons of rice grain/year feeds 3 billion people



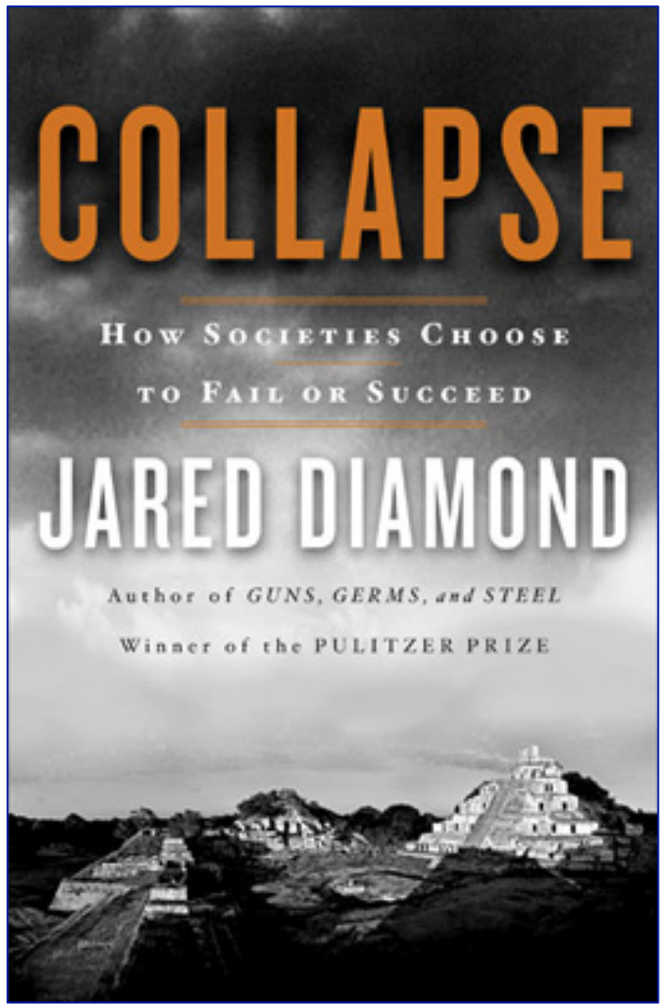
More will be needed

Source : IRRI



'Agriculture - the worst mistake in the history of the human race' (Jared Diamond, 1989).

The 'worst mistake' refers to the lack of appreciation of the interconnected-ness of factors underpinning agriculture and
'How societies choose to fail or succeed' depends on that understanding.



The politics of food

"Food is the world's secret stabiliser—or destabiliser. It is the very basis of all reconstruction; hunger and insecurity are the worst enemies of peace …….. but there will be winners and losers……

and the strain is likely to set off conflicts along the way: over water and land; over policies; between farmers who want higher prices and consumers who don't; and between countries or groups of countries". George Marshall, 1947.

Death by starvation in the Ukraine, 1929, due to Stalin's policy of farm collectivisation

Wheat so dense children can stand on it. China Pictorial 1952.

Food Security

'The physical and economic access to food for all people at all times to meet dietary needs and food preferences' (FAO, 1996)

Availability - (sustainable) production

Utilisation - dietary patterns and nutritional food quality

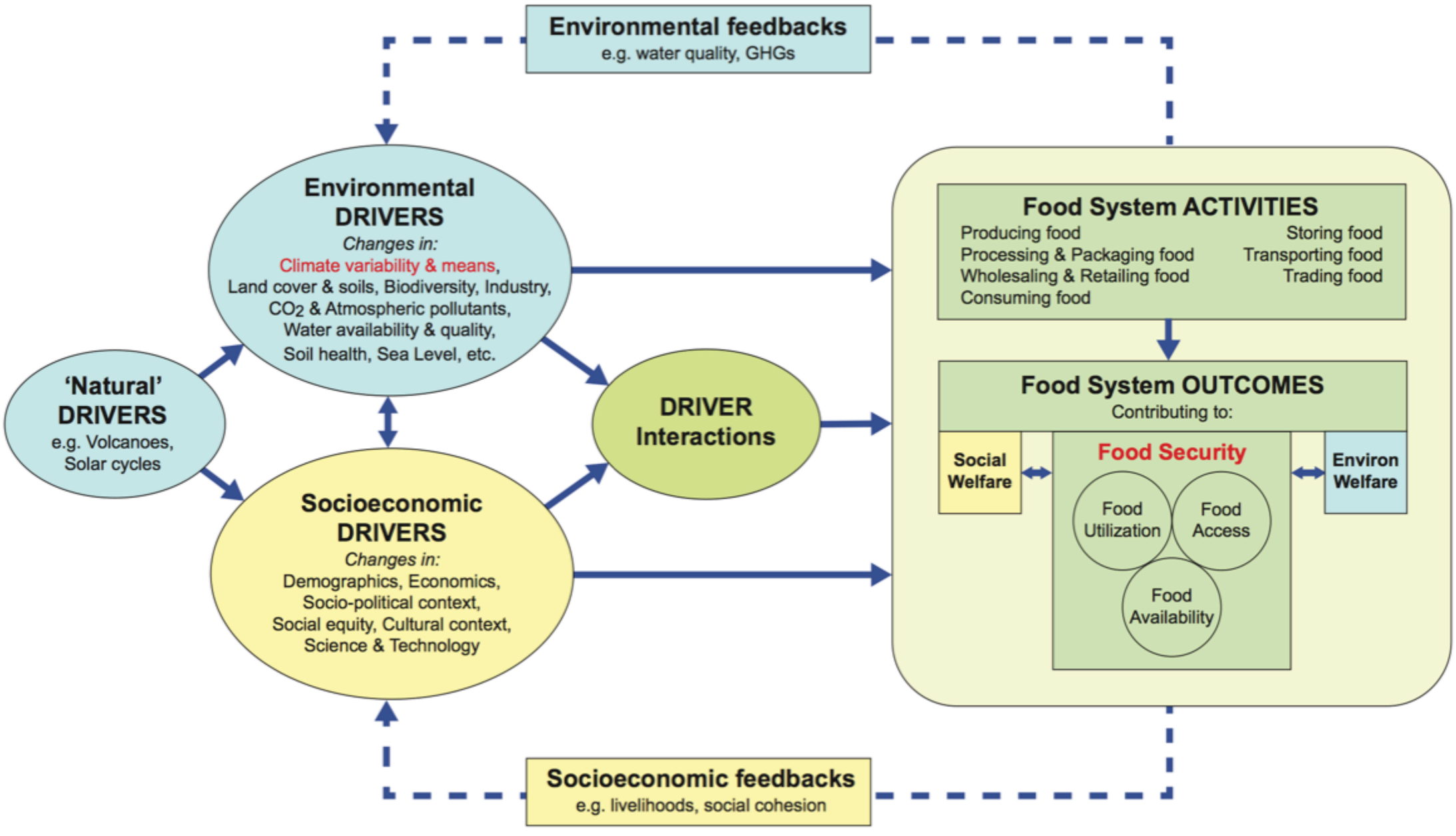
Accessibility - markets, supply chains, affordability

Stability - resilience in availability and accessibility

Why should we be concerned about it ?

Erickson, 2011

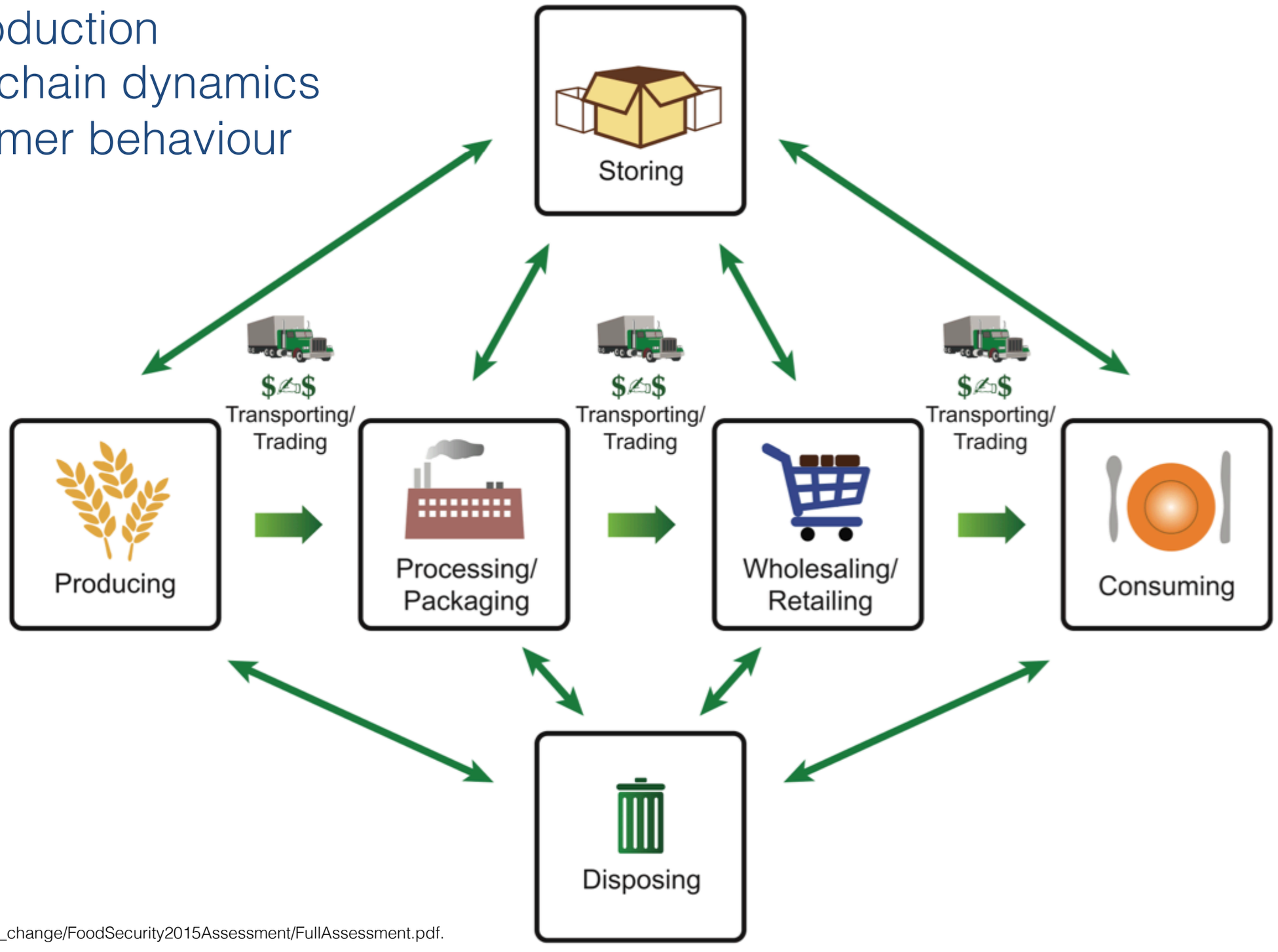
Food security depends on the interaction of bio-physical and socio-economic drivers



Source : http://www.usda.gov/oce/climate_change/FoodSecurity2015Assessment/FullAssessment.pdf.

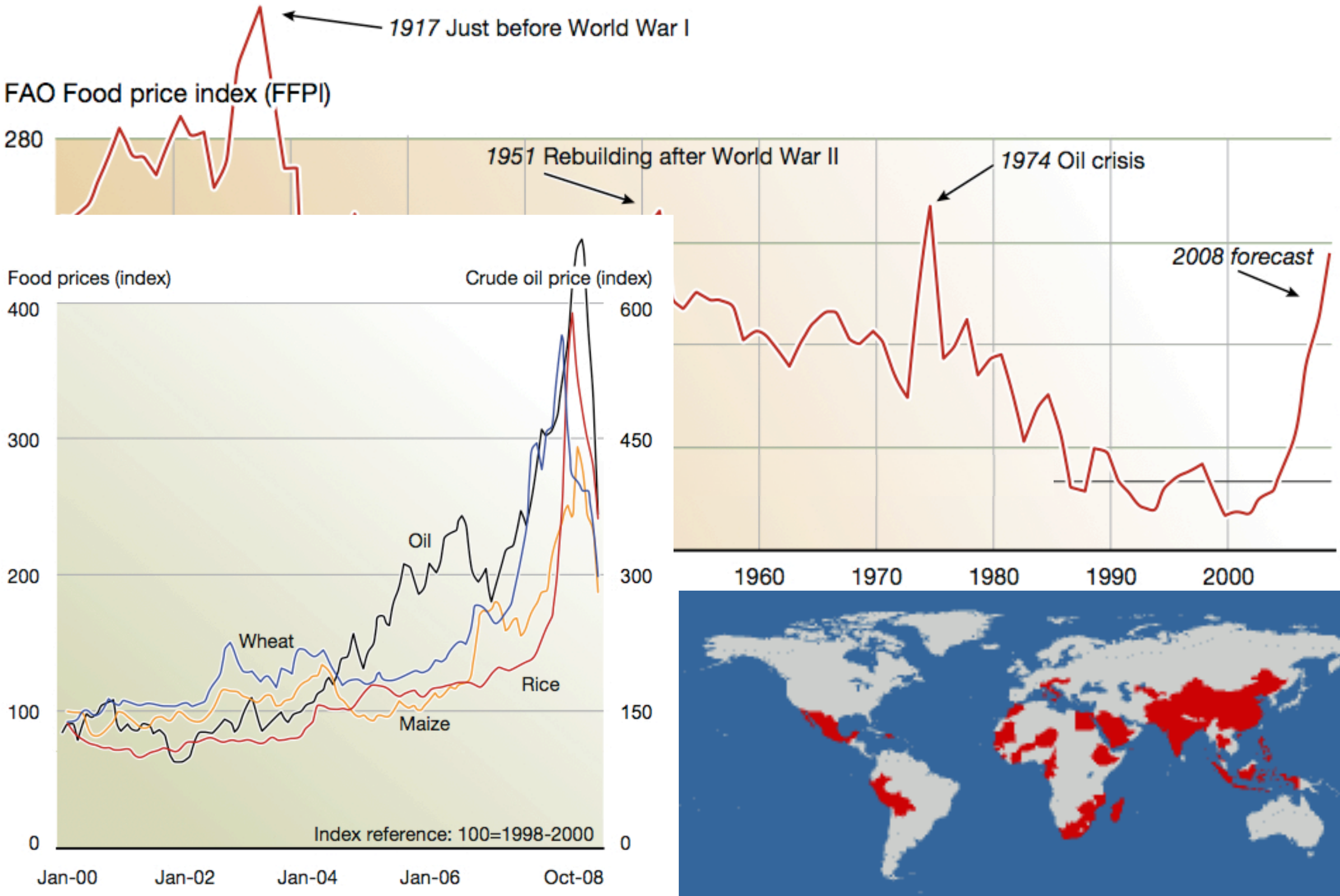
Food security involves all issues ‘from farm to fork’

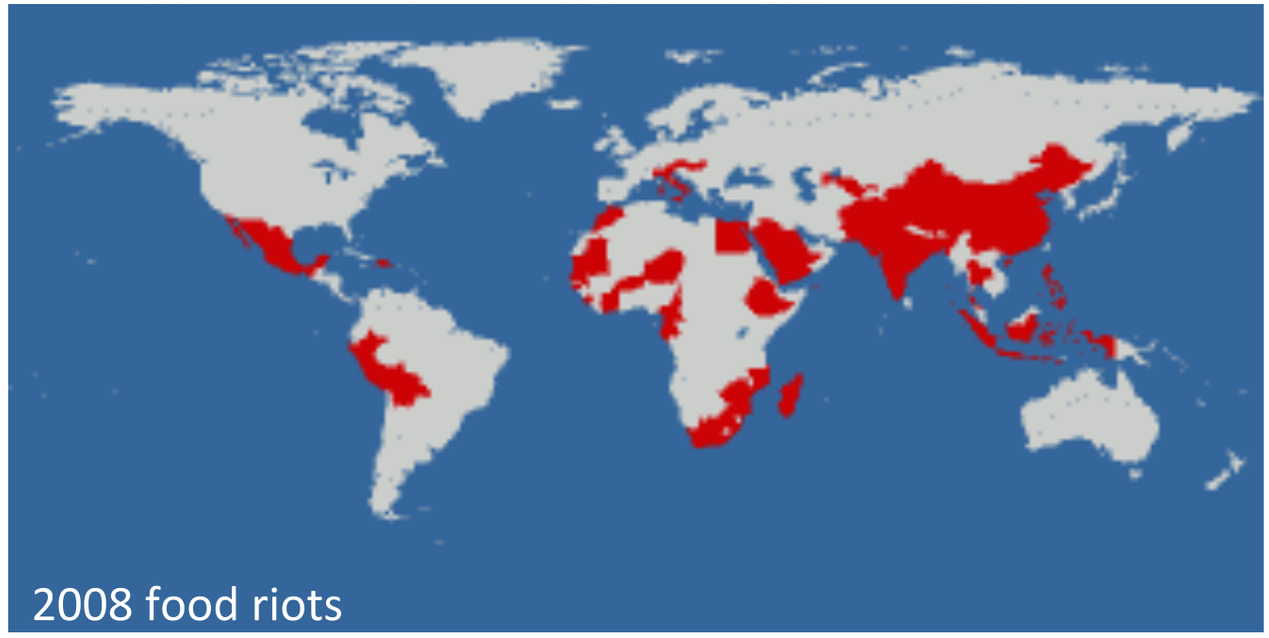
- Farm production
  - supply chain dynamics
    - consumer behaviour



Source : http://www.usda.gov/oce/climate_change/FoodSecurity2015Assessment/FullAssessment.pdf.

The price (FPI, relative to 1985-9) of food 1900 - 2000





Source : World Bank 2008

Food price spikes globally correlated with increases in food riots

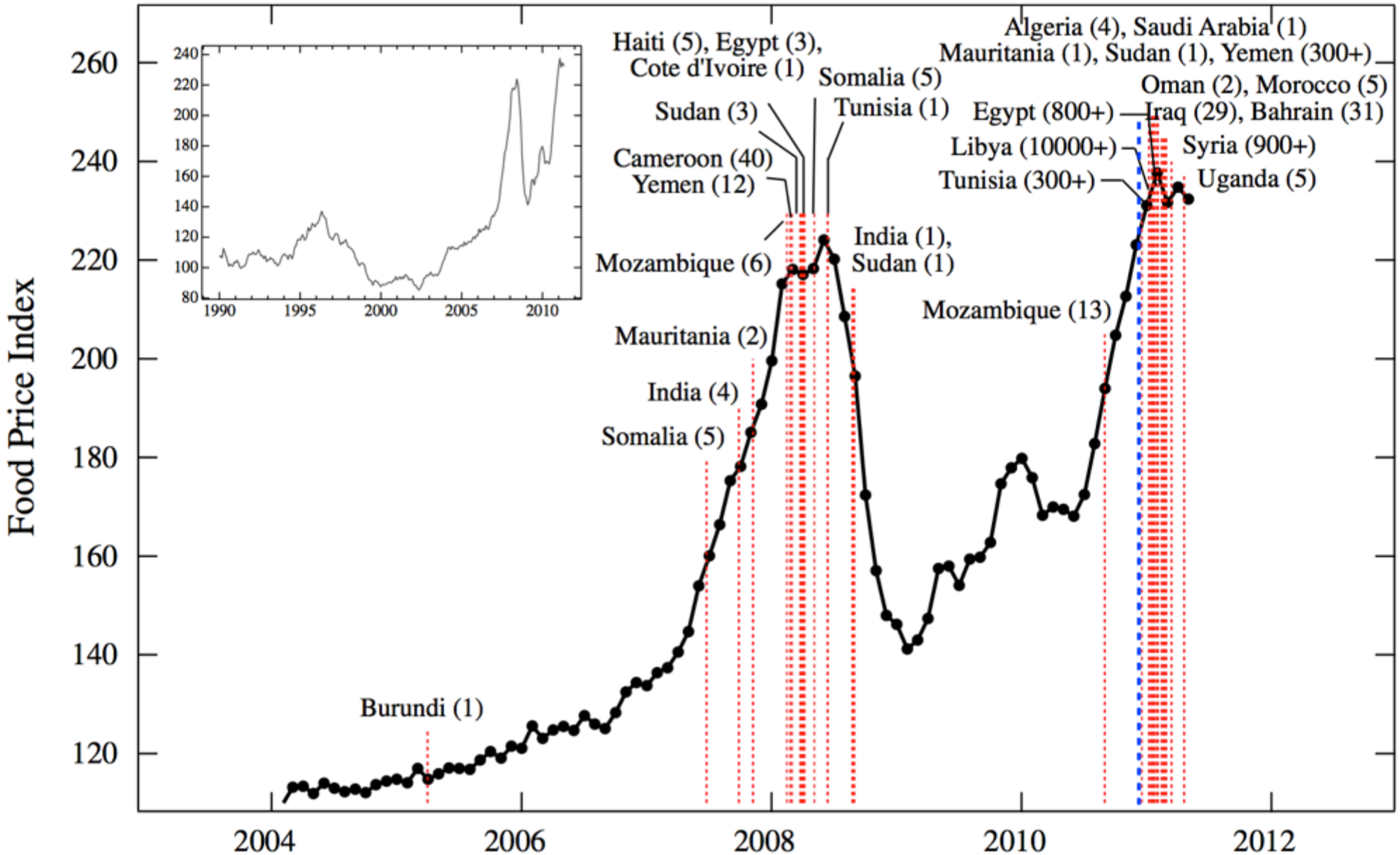
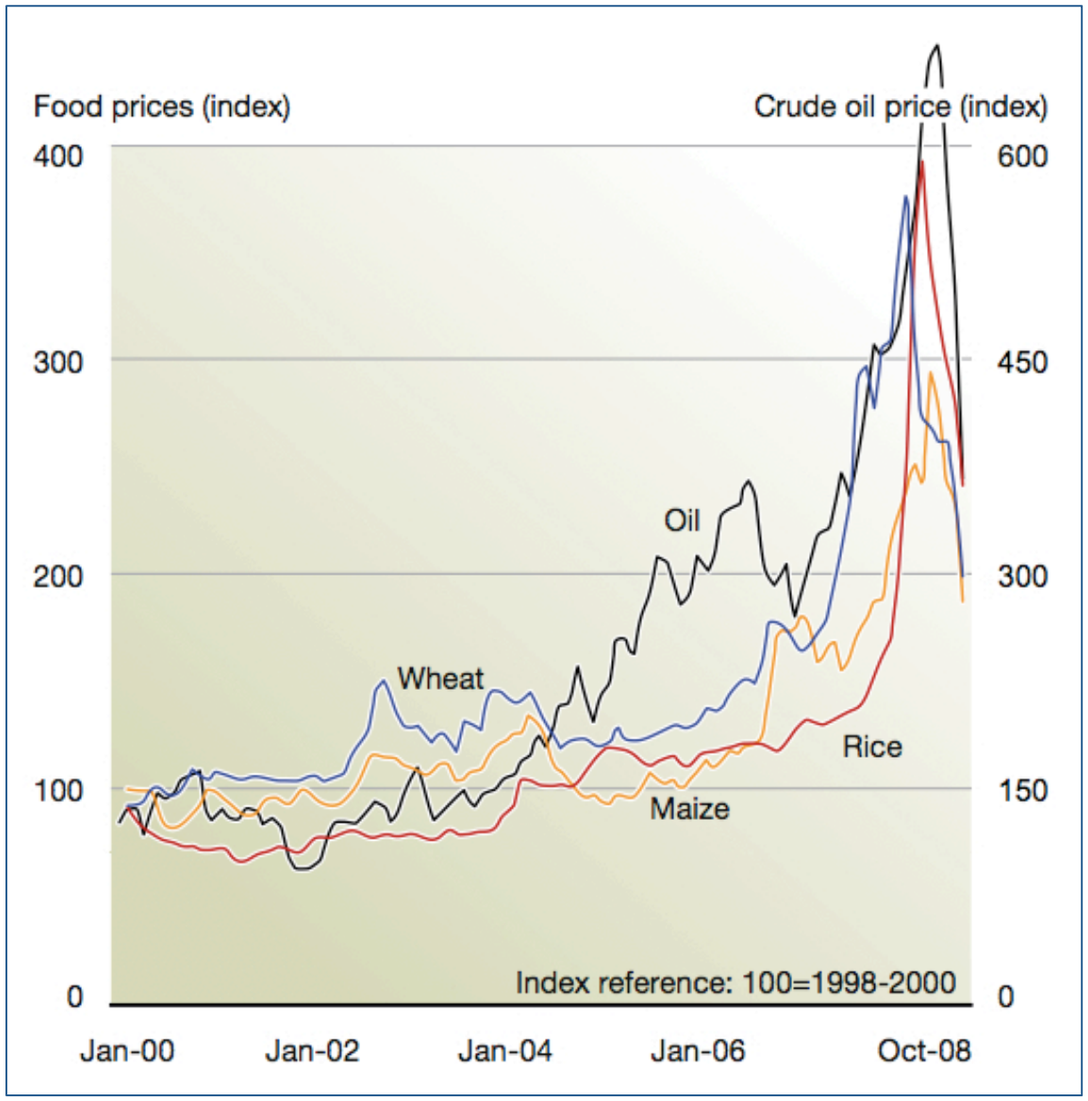


Fig. 1 Food price spikes are correlated with increases in food riots. *Red dashed vertical lines* correspond to beginning dates of "food riots" and protests associated with the major recent unrest in North Africa and the Middle East. The overall death toll is reported in *parentheses*. The *blue vertical line* indicates the date on which the authors of the cited report [1] submitted a report to the U.S. government warning of the link between food prices, social unrest, and political instability. The *inset* shows the FAO Food Price Index from 1990 to 2011. (The figure is reproduced with permission from [1]).

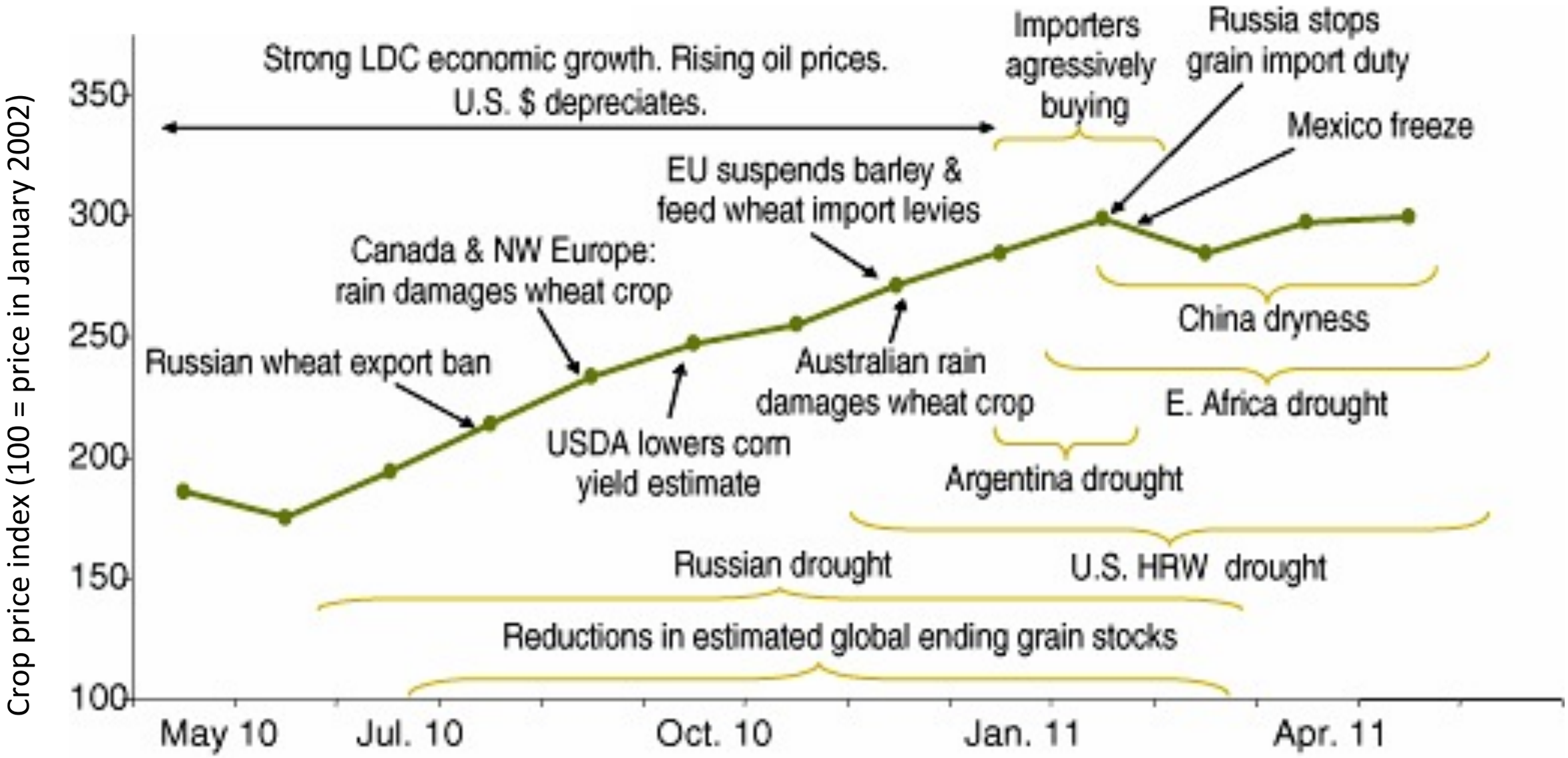
Fedoroff *Agric & Food Secur (2015) 4:11*



Food price spike in 2008, was due to

- oil prices rising
- switching land use towards biofuel crops (maize and oilseed rape) in the US and EU
- market speculation

The impact of global adverse weather events on global crop price increases, 2010-11



Notes: LDC=Least developed country. HRW=Hard red winter wheat. * = Four-crop price index: Monthly wheat, rice, corn, and soybean prices, weighted by global trade shares.

Source: USDA, Economic Research Service using International Monetary Fund, International Financial Statistics.

Future Food Security – the Perfect Storm,
an interlinked global concern by 2030
(Sir John Beddington, 2008 UK Government Chief Scientist)

Population increase

Climate change

Food security

Loss of ecosystem services

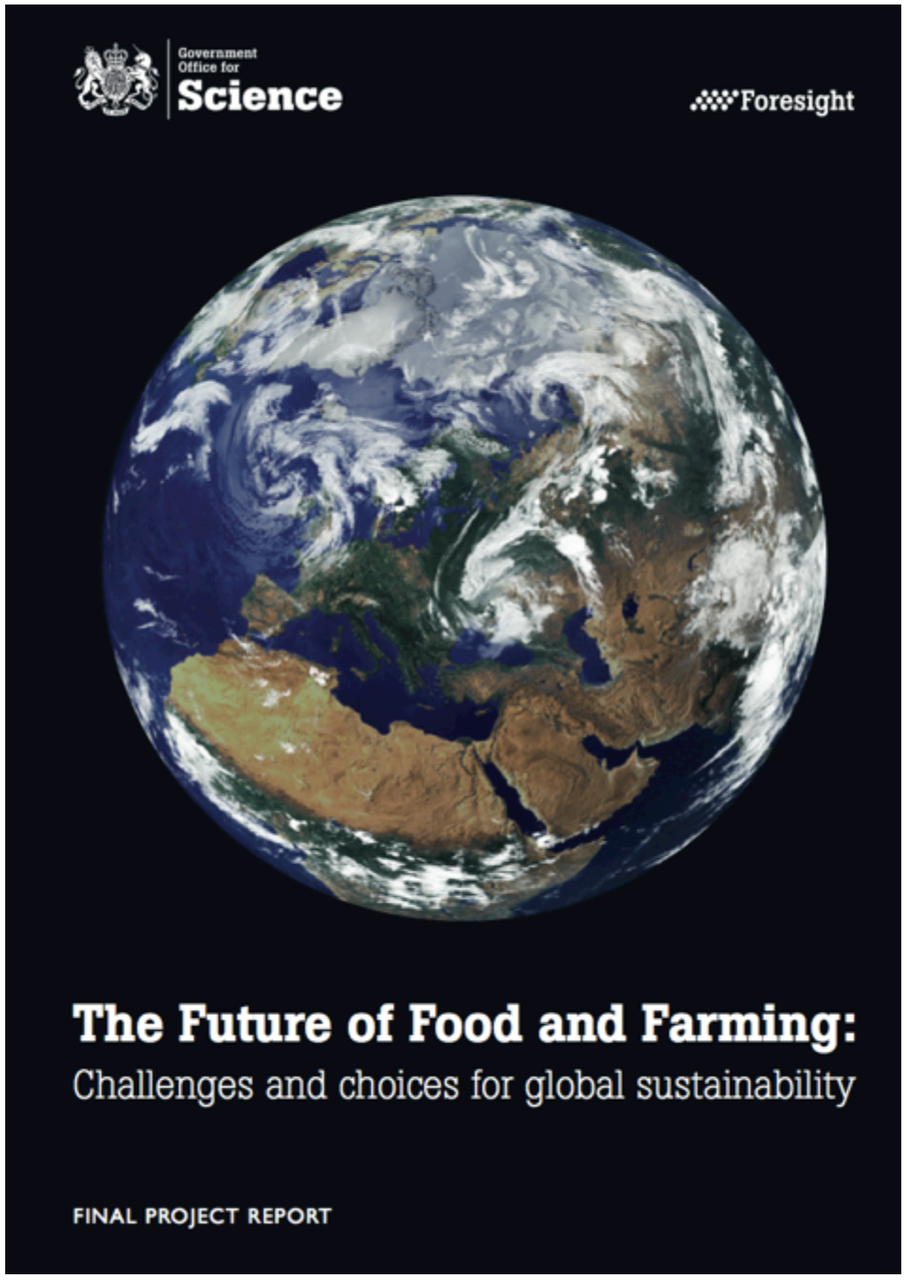
Renewable energy

Globalisation and trade

Poverty alleviation

Technological change

The future of food and farming



Conclusions :

The current global food system is failing on sustainability grounds, because :

Agriculture currently consumes 70% of total global water withdrawals from rivers and aquifers, many of which are over-exploited.

Of 11.5 billion hectares of vegetated land on earth, around 24% has undergone human induced soil degradation, with loss of associated biodiversity and ecosystem services.

Agriculture **directly** contributes 10 – 12% of anthropogenic greenhouse gas emissions that contribute to climate change.

So how do we ensure global food security ?

‘Limited land, requires a transition to agriculture which is high production, intensified, resilient and at the same time sustainable with low emissions – *sustainable intensification*’.

‘National self sufficiency is not a viable option for nations to contribute to global food security, rather the importance lies in crafting the food governance system to maximise the benefits of globalisation and ensure they are fairly distributed - *food justice’.*

The Future of Food and Farming:
Challenges and choices for global sustainability
UK Foresight Report 2011

Farming

UK will need to import over half of its food within a generation, farmers warn

Fiona Harvey, environment correspondent

Tuesday 24 February 2015 06.01 GMT

theguardian

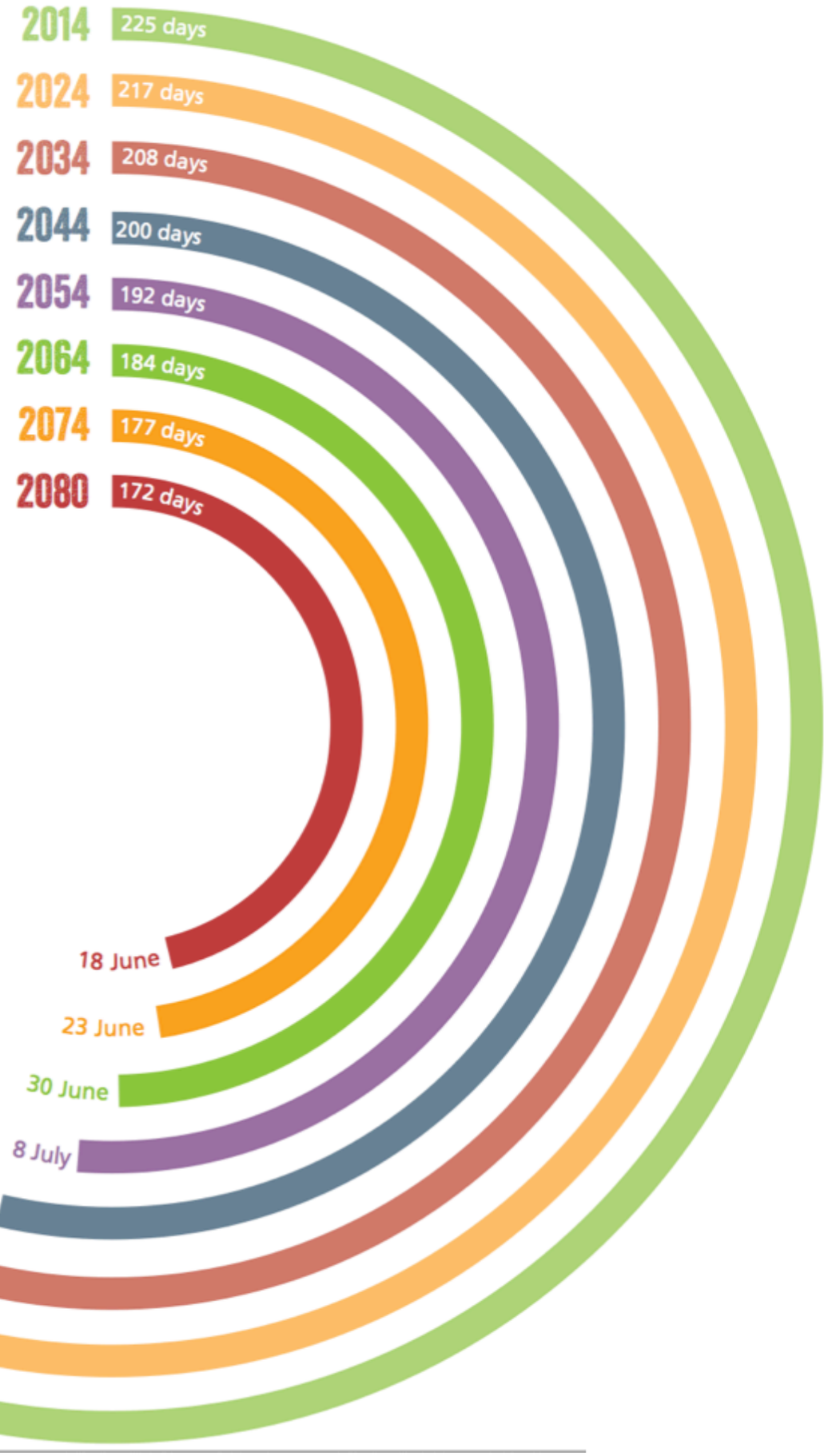
Wheat field in the English countryside after the harvest. Photograph: Tim Gainey/Alamy

More than half of the UK's food will come from overseas within a generation, as a rising population and stalling farm productivity combine to erode what remains of the UK's self-sufficiency, according to farming leaders.

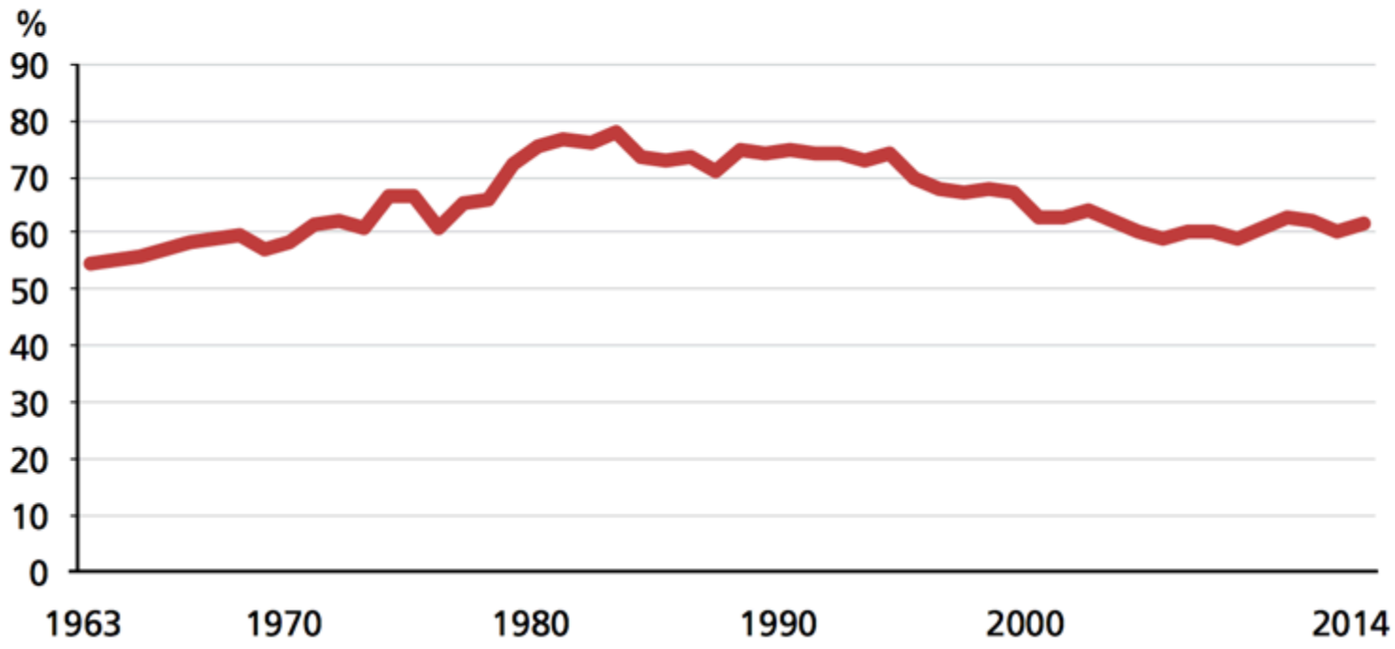
The UK's failure to produce more food will leave households more vulnerable to volatile prices and potential shortages, the National Farmers' Union will say at its annual conference on Tuesday. The farming body will call on politicians to encourage new investment in farming, and develop a national plan for a higher degree of food self-sufficiency.

THE DAY OUR FOOD RUNS OUT

This graphic shows the number of days domestically produced food will last at ten year intervals.



UK SELF-SUFFICIENCY TREND



Backing British farming in a volatile world. http://www.nfuonline.com/635-15tl-the-report-digital-low-res/

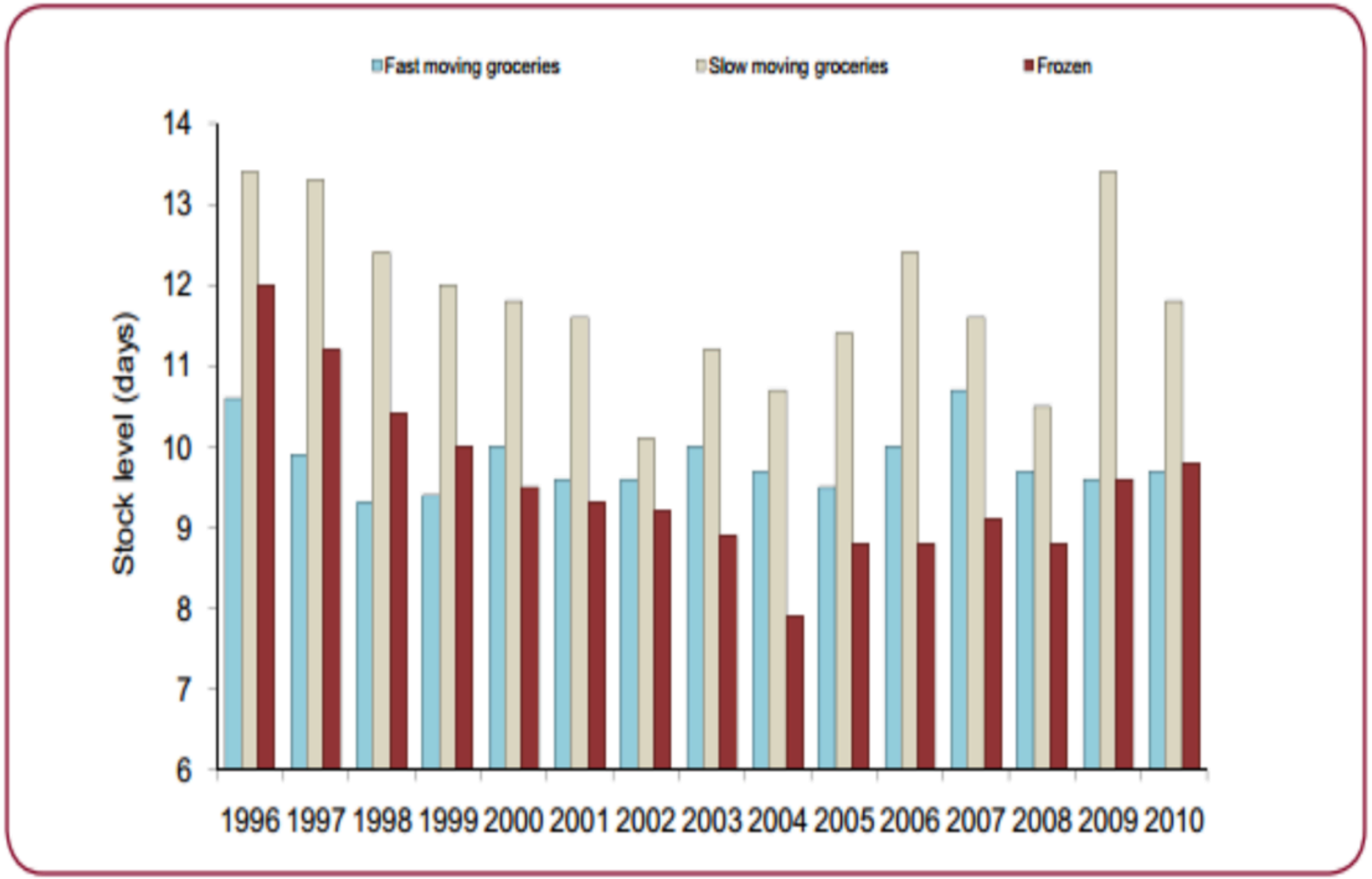
- The NFU estimates that if UK farm production stays at current levels and population grows as predicted, by the mid-2040s UK self-sufficiency would have slumped to 54.5 per cent of the nation's needs.

- This level was last seen in the early 1960s. Unaddressed this slump would continue through to 2080 by which time only 47.2 per cent of the nation's needs would be met by UK farming.

- Such a level of dependency would be akin to the levels last seen in the post-war period.

Average retailer warehouse stock levels (days) by grocer category

The just-in-time supply model of large retailers



Source: IGD Research, 2012.

	World Population *(billion)*	Arable Land & permanent Crops *(billion hectares)*	Farmland per Person *(hectares)*
1950	2.5	1.3	0.5
1975	4.0	1.4	0.4
2000	6.0	1.5	0.3
2020	7.5	1.5	0.2

Source: United Nations

‘Limited land, requires a transition to agriculture which is high production, intensified, resilient and at the same time sustainable with low emissions – sustainable intensification’.

‘National self sufficiency is not a viable option for nations to contribute to global food security, rather the importance lies in crafting the food governance system to maximise the benefits of globalisation and ensure they are fairly distributed’.

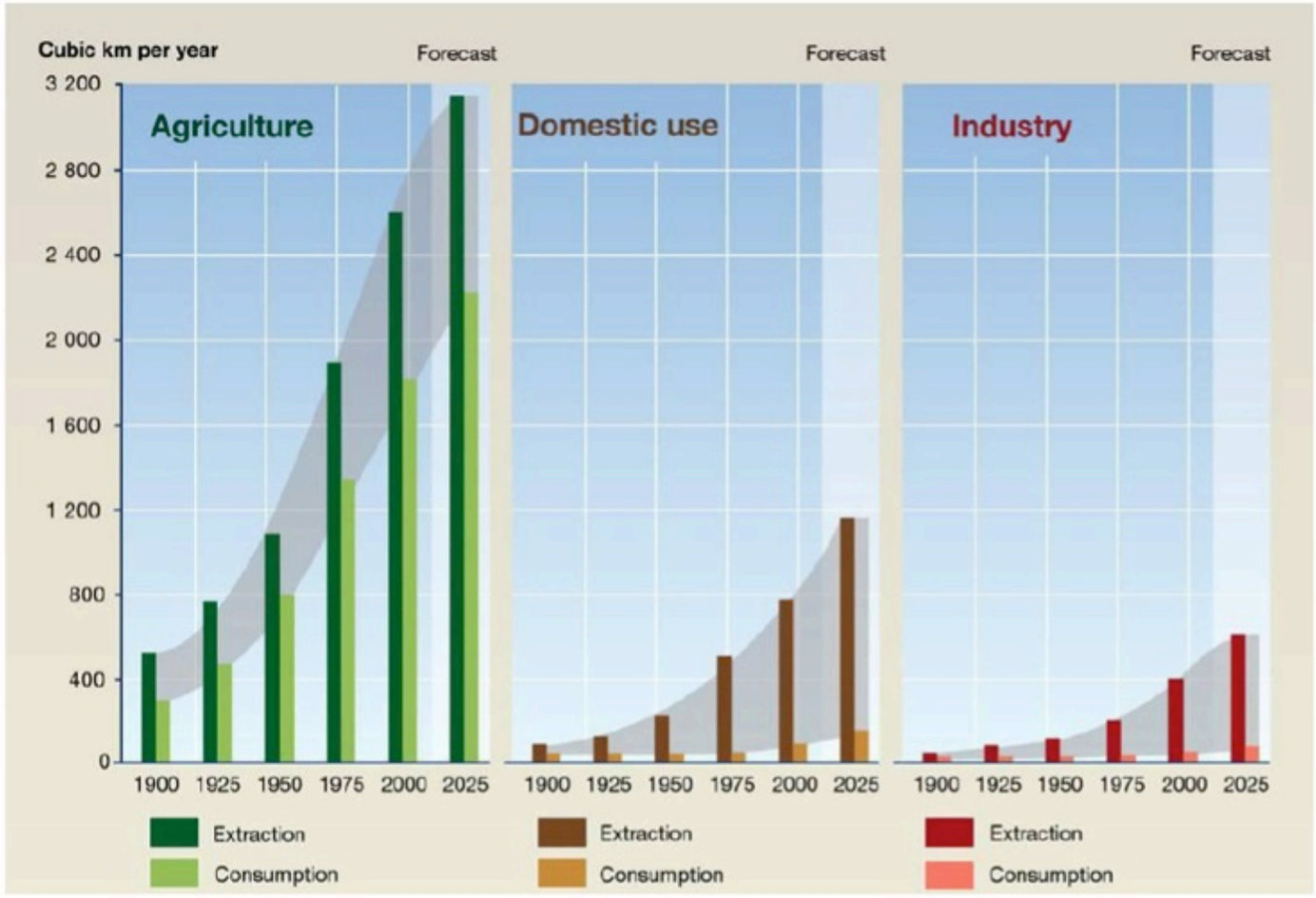
Food production and water use are intimately linked and globally agriculture uses more water than industry and domestic uses

3,500 litres of water is required to produce enough food for a daily minimum of 3,000 calories.

Growing a kilo of rice takes 2,000 – 5,000 litres of water.

Producing a single hamburger takes about 11,000 litres.

To produce a single cup of coffee we need 140 litres of water.

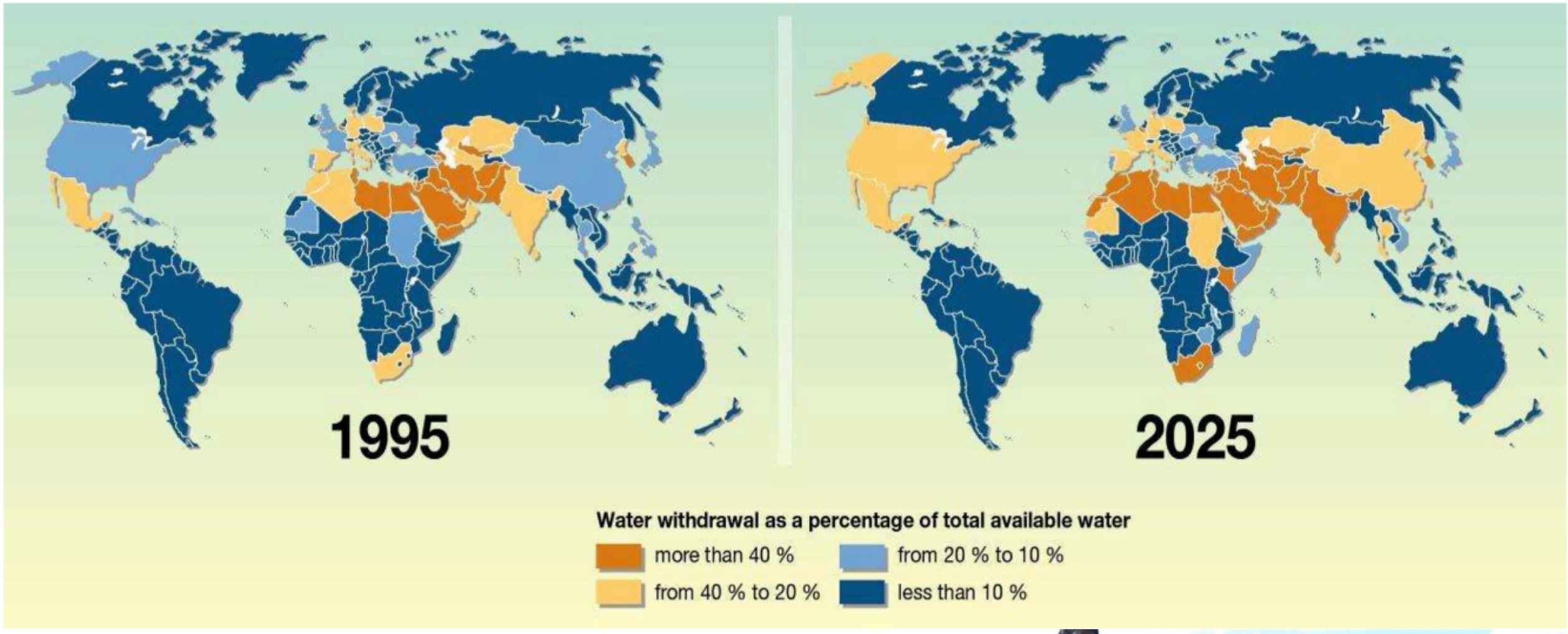


1.7 billion people lack access to clean water.
2.3 billion people suffer from water-borne diseases each year.
12 percent of the world's population uses 85 percent of its water, and none of the 12 percent lives in developing countries.

After Beddington (2008)

Water stress, 1995-2025

(UNEP GRID-Arendal, 2009) http://www.grida.no/publications/vg/water2/page/3289.aspx



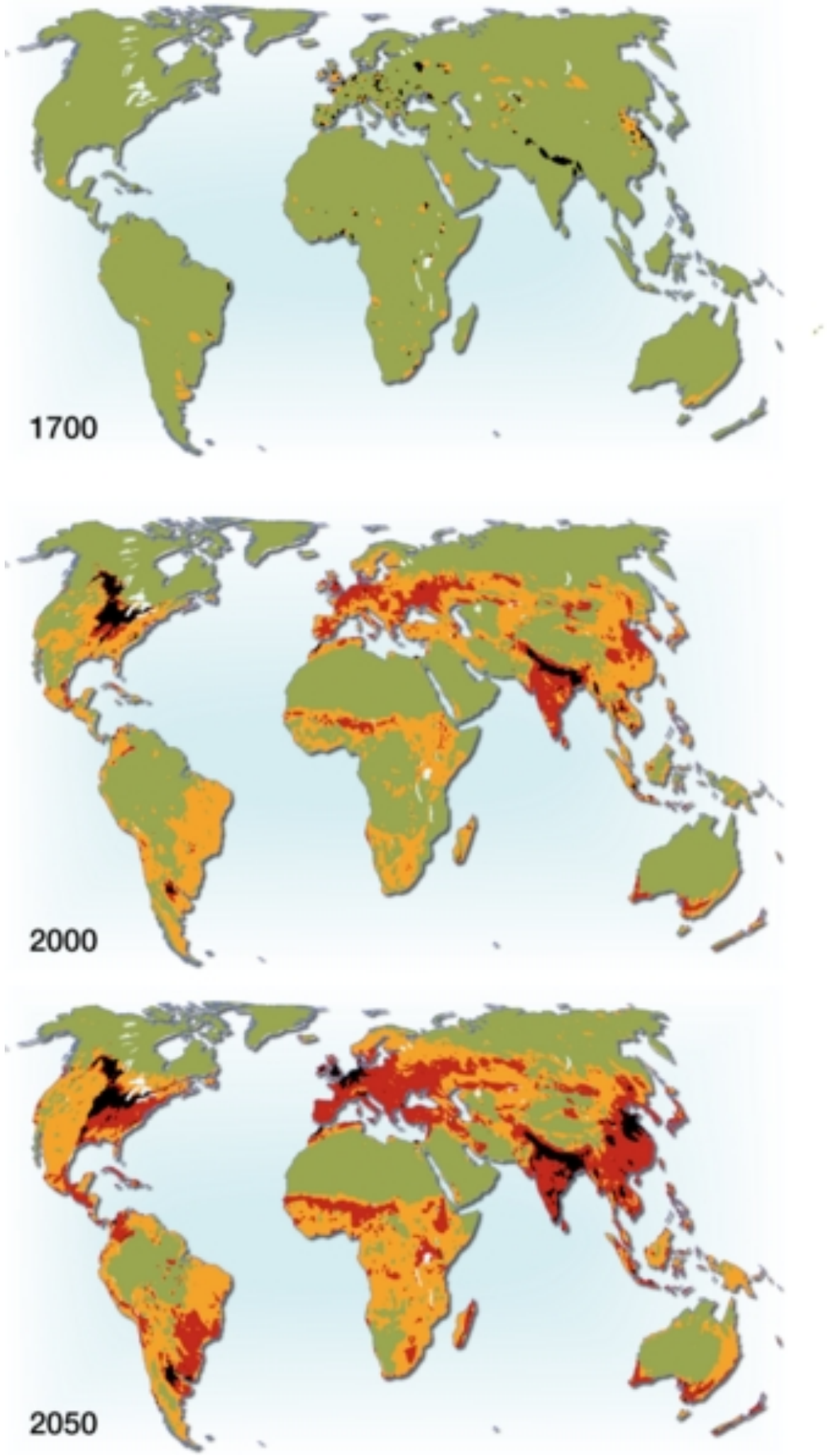
In agricultural landscapes, farming and biodiversity are inevitably interlinked since …

…… crops and livestock are a restrictive and dominant part of biodiversity, but less so with crop rotation

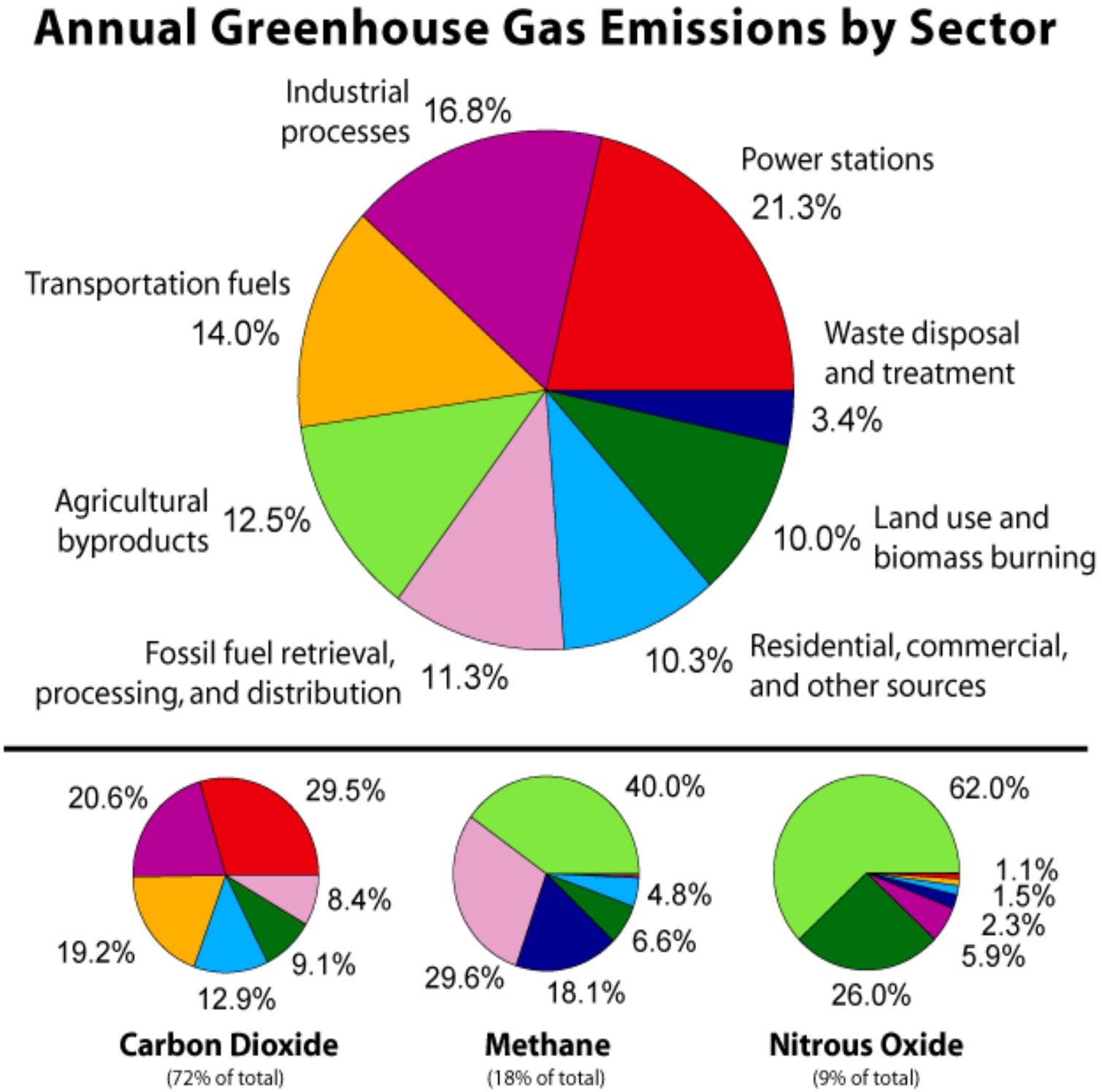
…… farming needs biodiversity providing ecosystem services in maintaining soil health, pollination services and pest control

….. farming practices strongly influence biodiversity, both negatively and positively

The reduction in biodiversity due to to agricultural land expansion



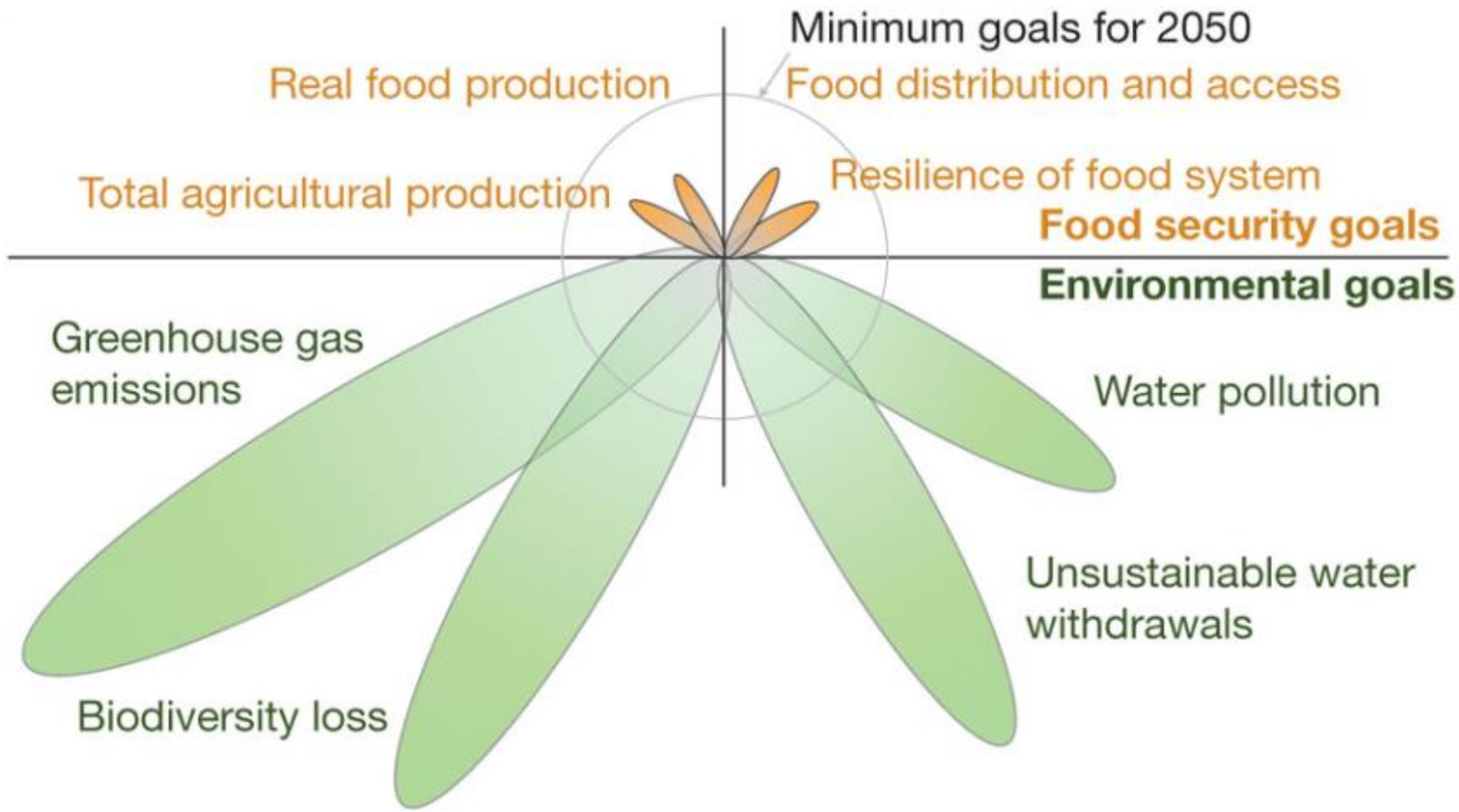
Green House Gas emissions



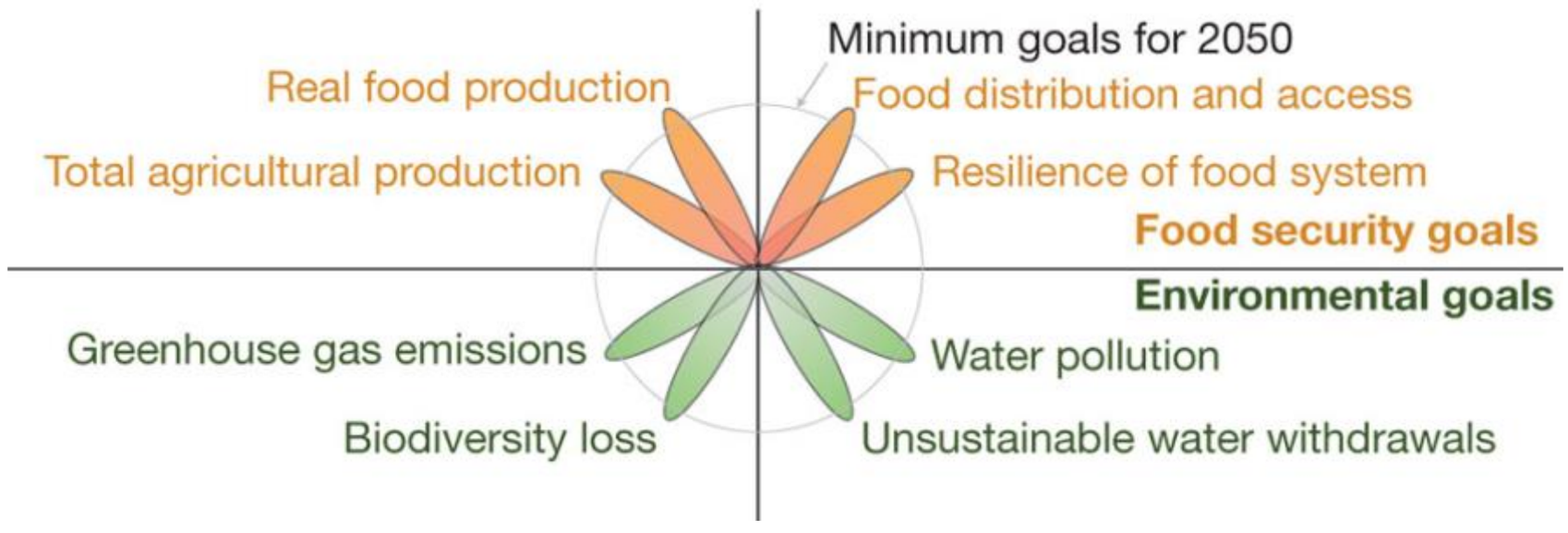
IPCC (2007)

Meeting goals for food security and environmental sustainability by 2050

Now



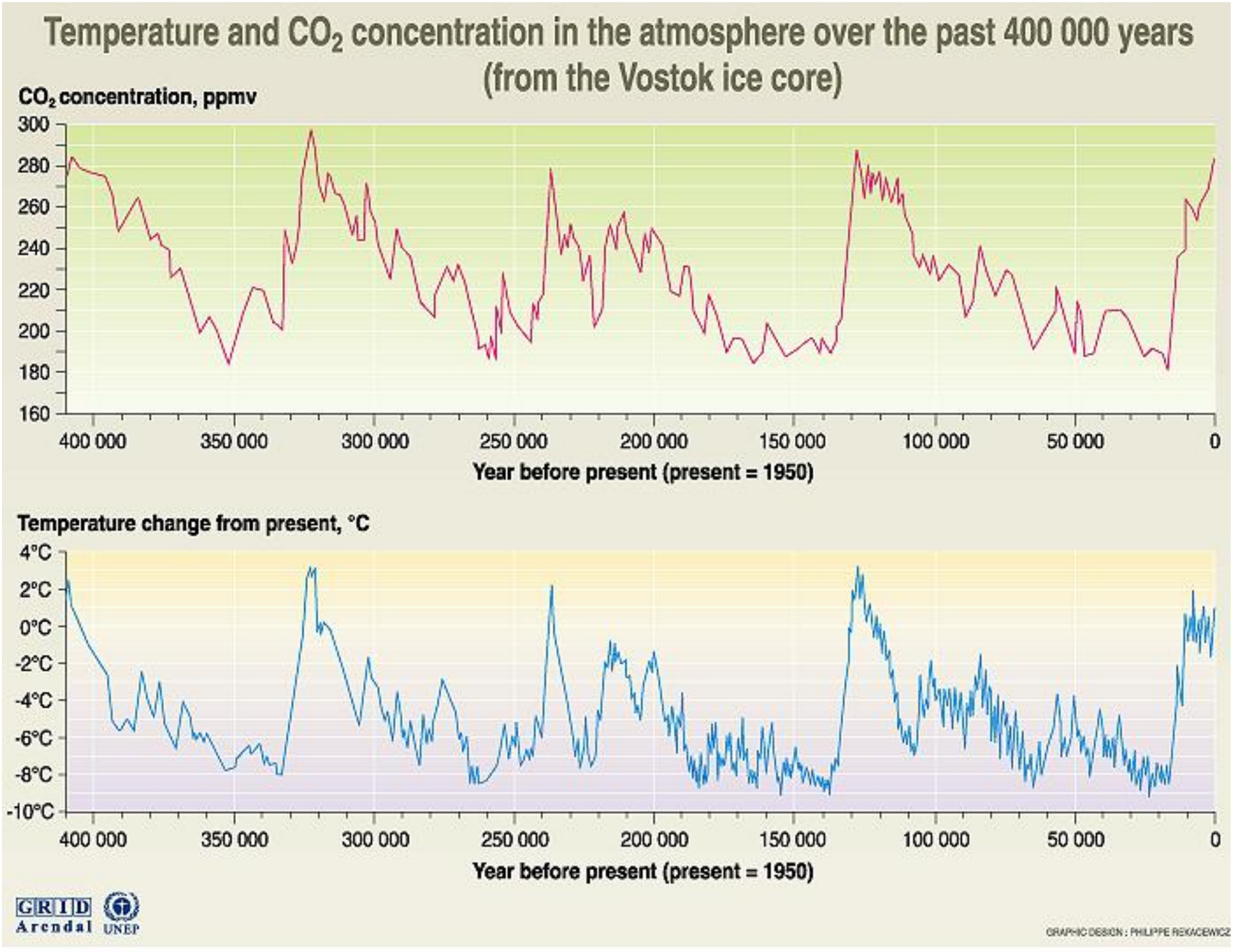
2050 ?



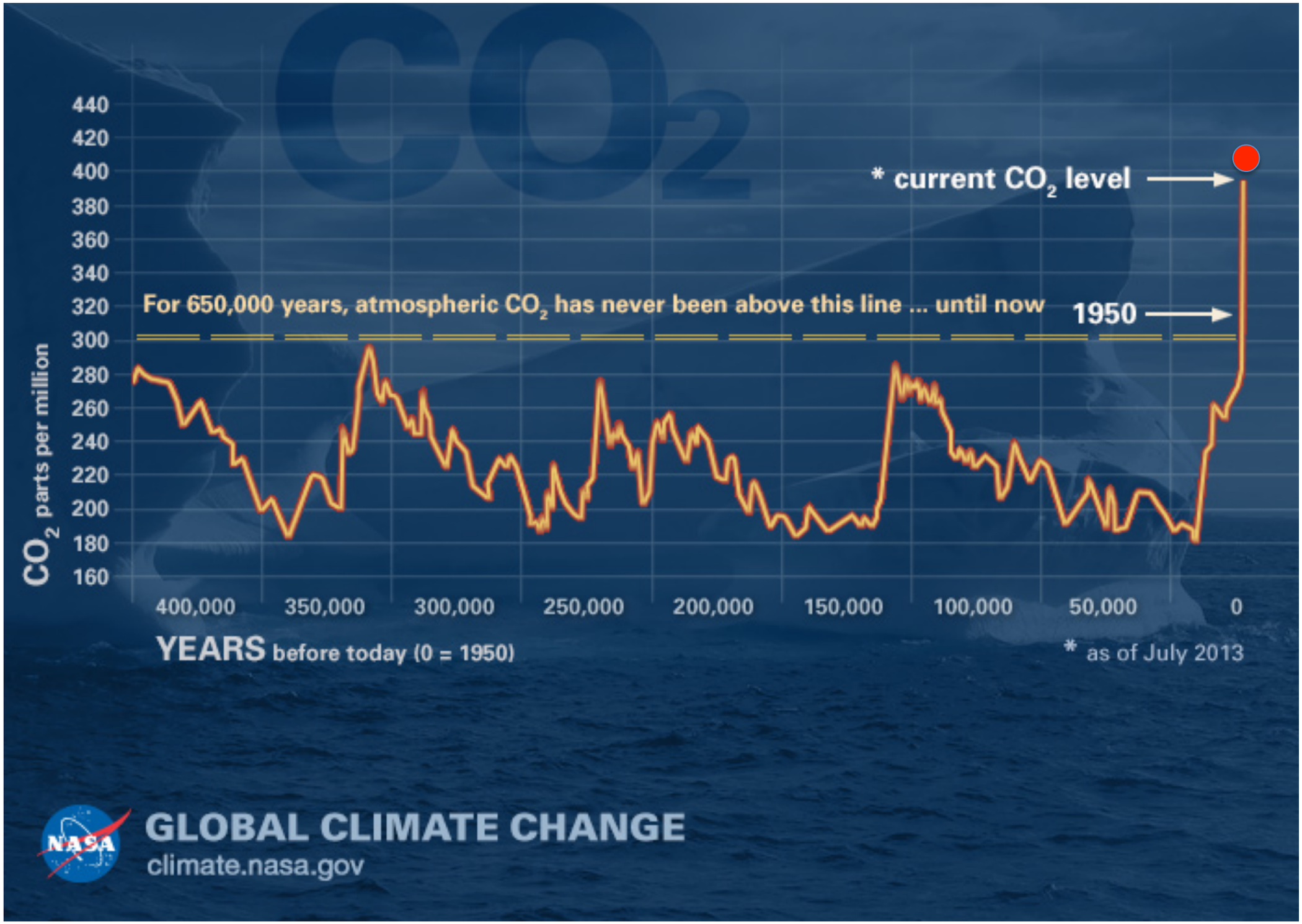
JA Foley *et al*. *Nature* 478, 337 (2011) doi:10.1038/nature10452

Let’s talk a bit about climate change

The Vostok ice core analysis– compelling evidence for the link between atmospheric temperature and CO_2 concentration



Source: J.R. Petit, J. Jouzel, et al. Climate and atmospheric history of the past 420 000 years from the Vostok ice core in Antarctica, Nature 399 (3JUne), pp 429-436, 1999.


CO_2
440
420
400
380
360
340
320
300
280
260
240
220
200
180
160
CO_2 parts per million
* current CO_2 level
For 650,000 years, atmospheric CO_2 has never been above this line ... until now
1950
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
YEARS before today (0 = 1950)
* as of July 2013
NASA
GLOBAL CLIMATE CHANGE
climate.nasa.gov

Monthly Global Average Temperature in March

Trend=0.85 (℃/Century)

Base Line : 1981-2010 Average

2016

Temperature Anomaly (℃)

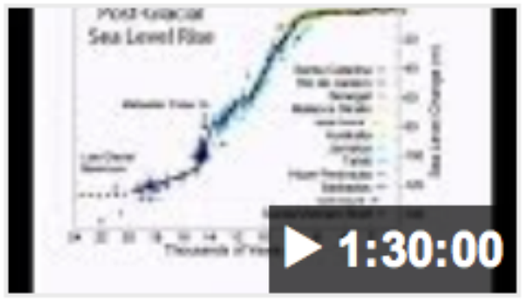
1.0
0.5
0.0
-0.5
-1.0
-1.5

1890 1900 1910 1920 1930 1940 1950 1960 1970 1980 1990 2000 2010 2020

Japan Meteorological Agency

Climate change, climate science, models, hysteria ?

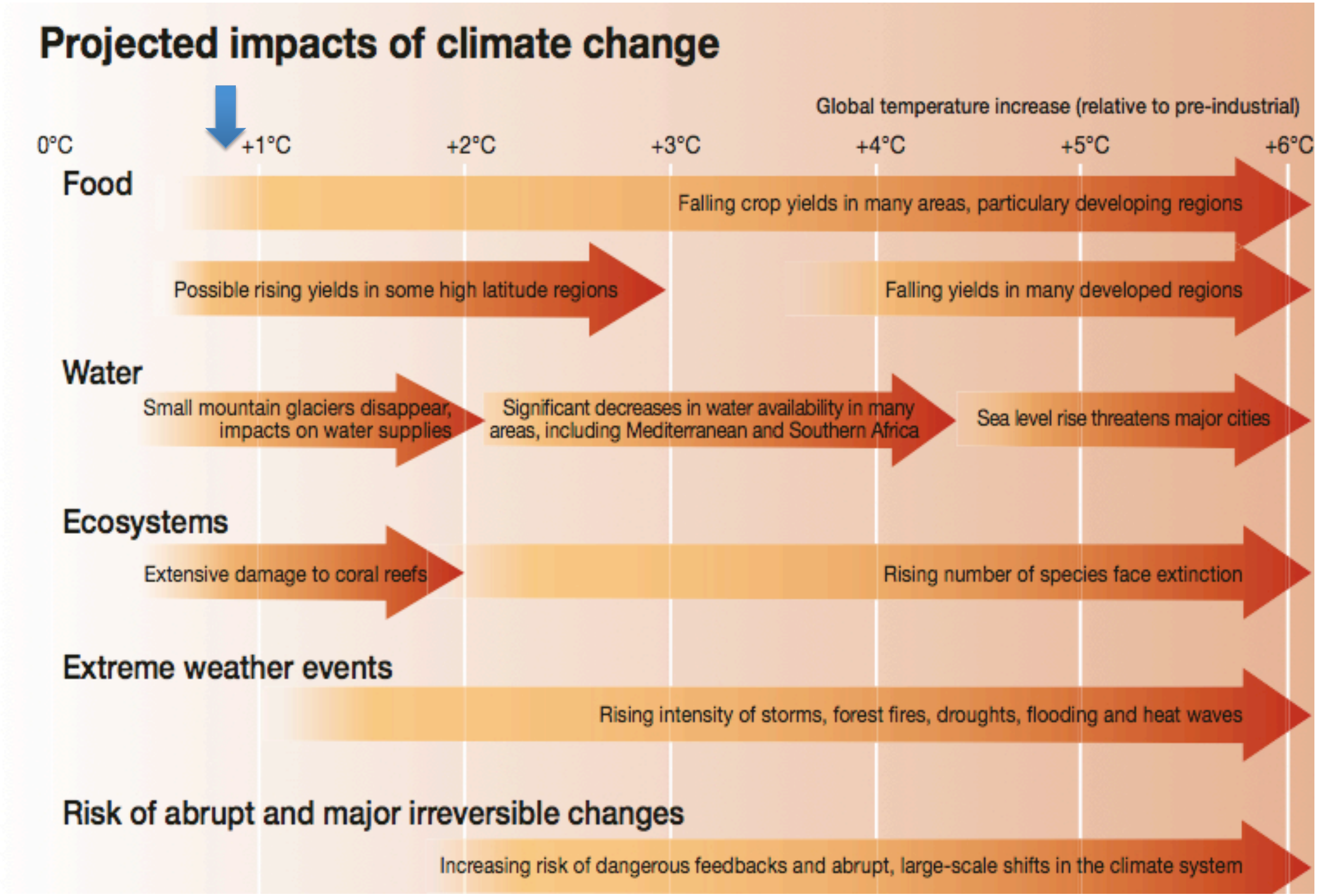
What We KNOW About Climate Change - Kerry Emanuel ...



https://www.youtube.com/watch?v=7so8GRCWA1k

11 Apr 2014 - Uploaded by MIT Club of Northern California

Professor **Kerry Emanuel** has been known for his "Show me the data!" approach to climate science. In this ...



Stern review (2010)

The predicted decline in agricultural production due to climate change by 2080 (predicted population ~ 9 billion)

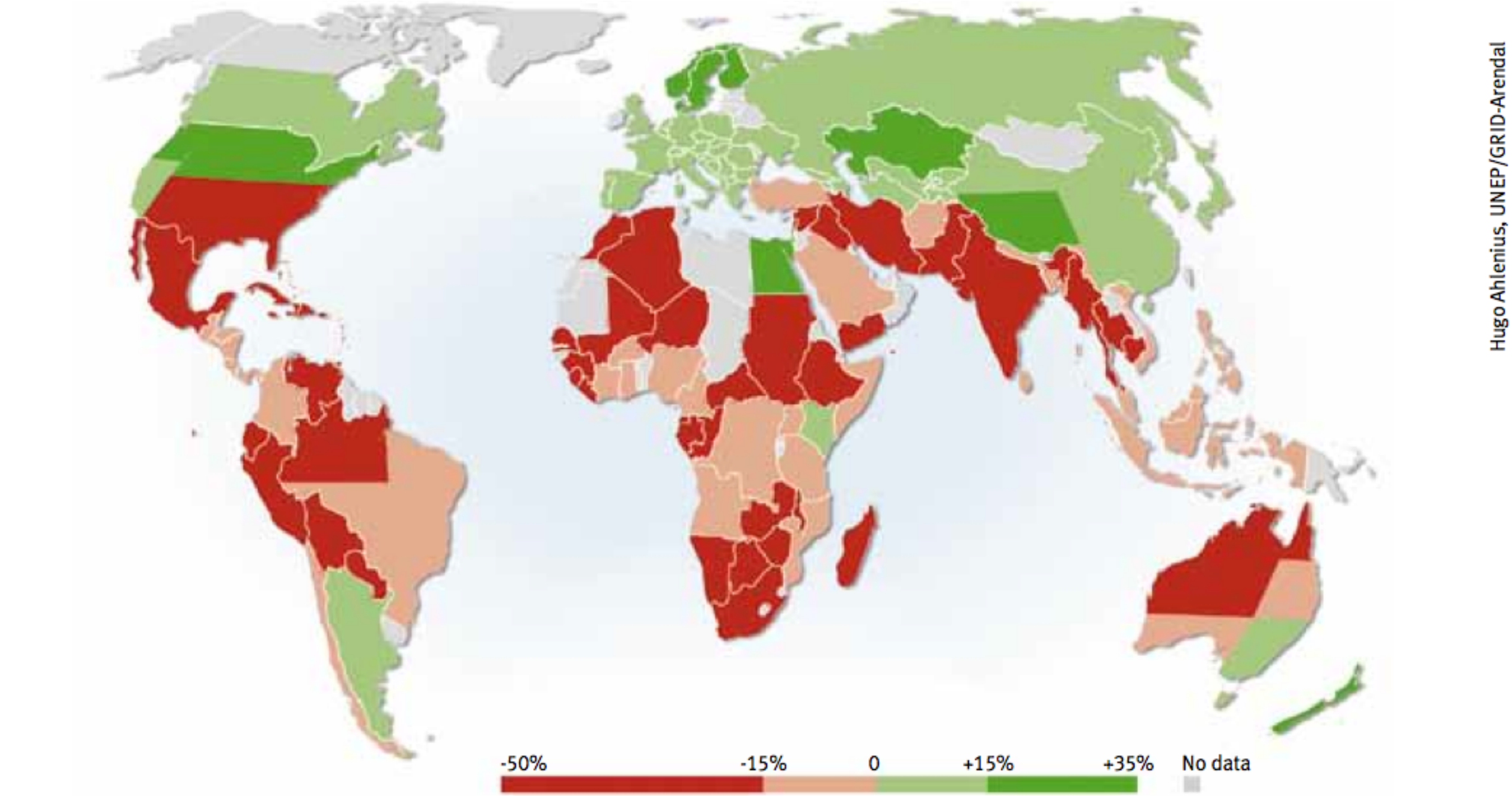


Figure 6. Projected changes in agricultural production in 2080 due to climate change. Source: Cline. 2007. Projections assume a uniform 15% increase in yields due to the fertilization effect of rising carbon dioxide in the atmosphere on some plant species. (Note that this coarse-grain analysis does not project local-scale impacts which require geographically-specific analysis.)

Source : CCAFS

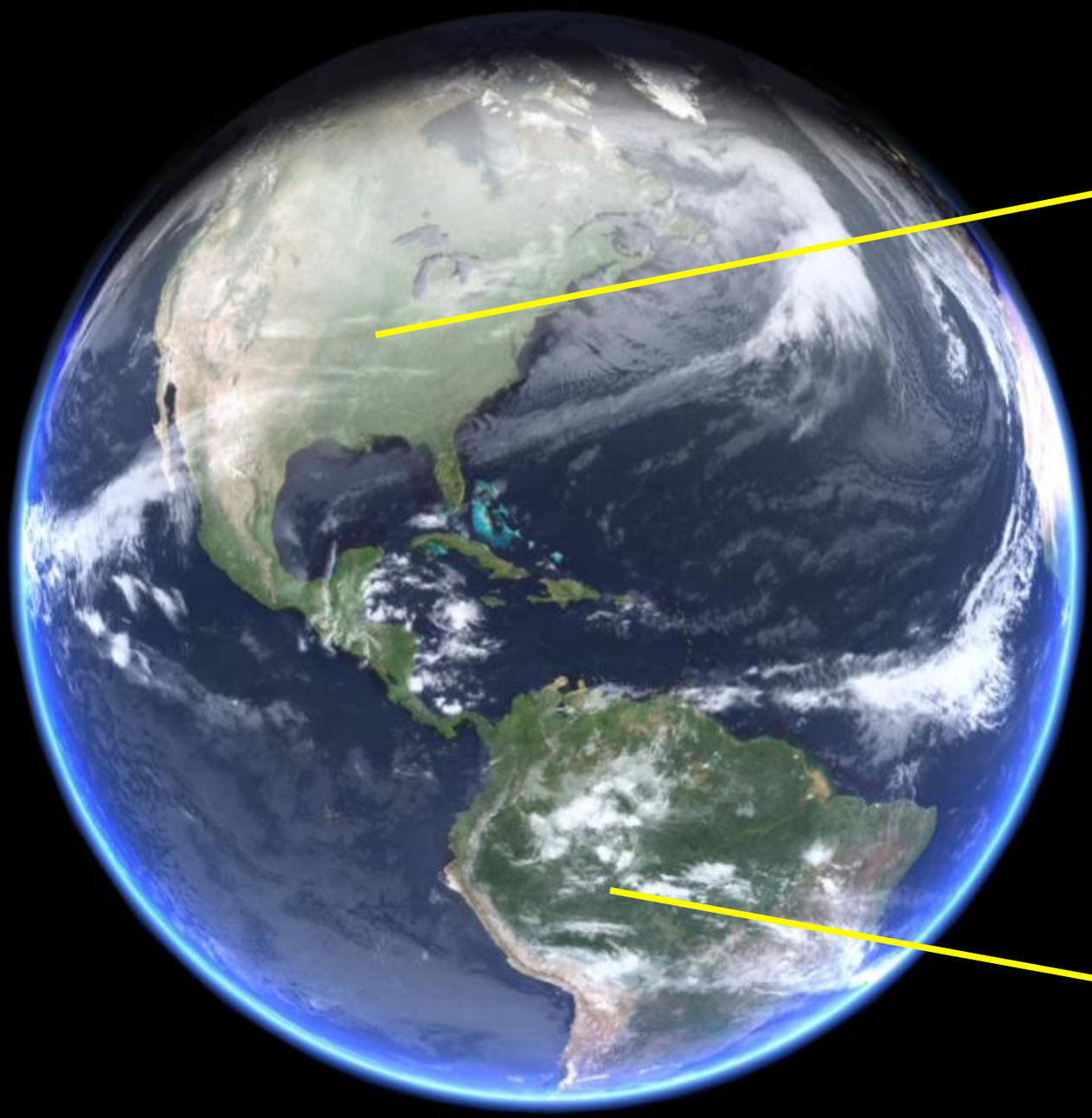
So how do we ensure food security ?

- Practice **sustainable intensification** – produce more using existing knowledge and innovate to increase production.

- **Reduce waste, influence consumer demand** and **change awareness**. Move to a more vegetarian / low animal protein diet.

- **Mitigate greenhouse gas emissions** from agriculture.

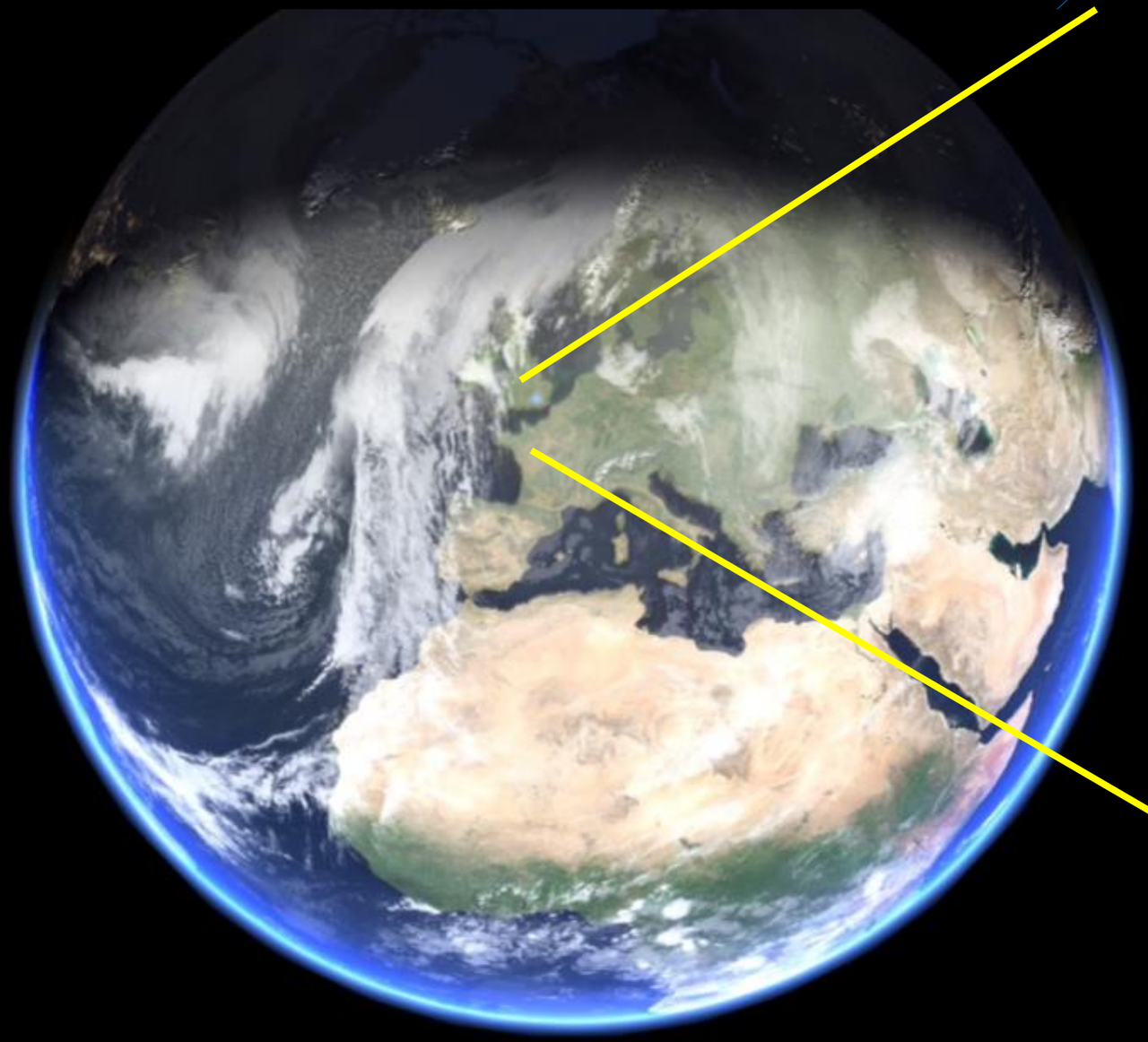
All adds up to policy change and altered governance structures



Government subsidies of nearly USD 20 Billion went to US corn and soybean producers in 2003-2005.

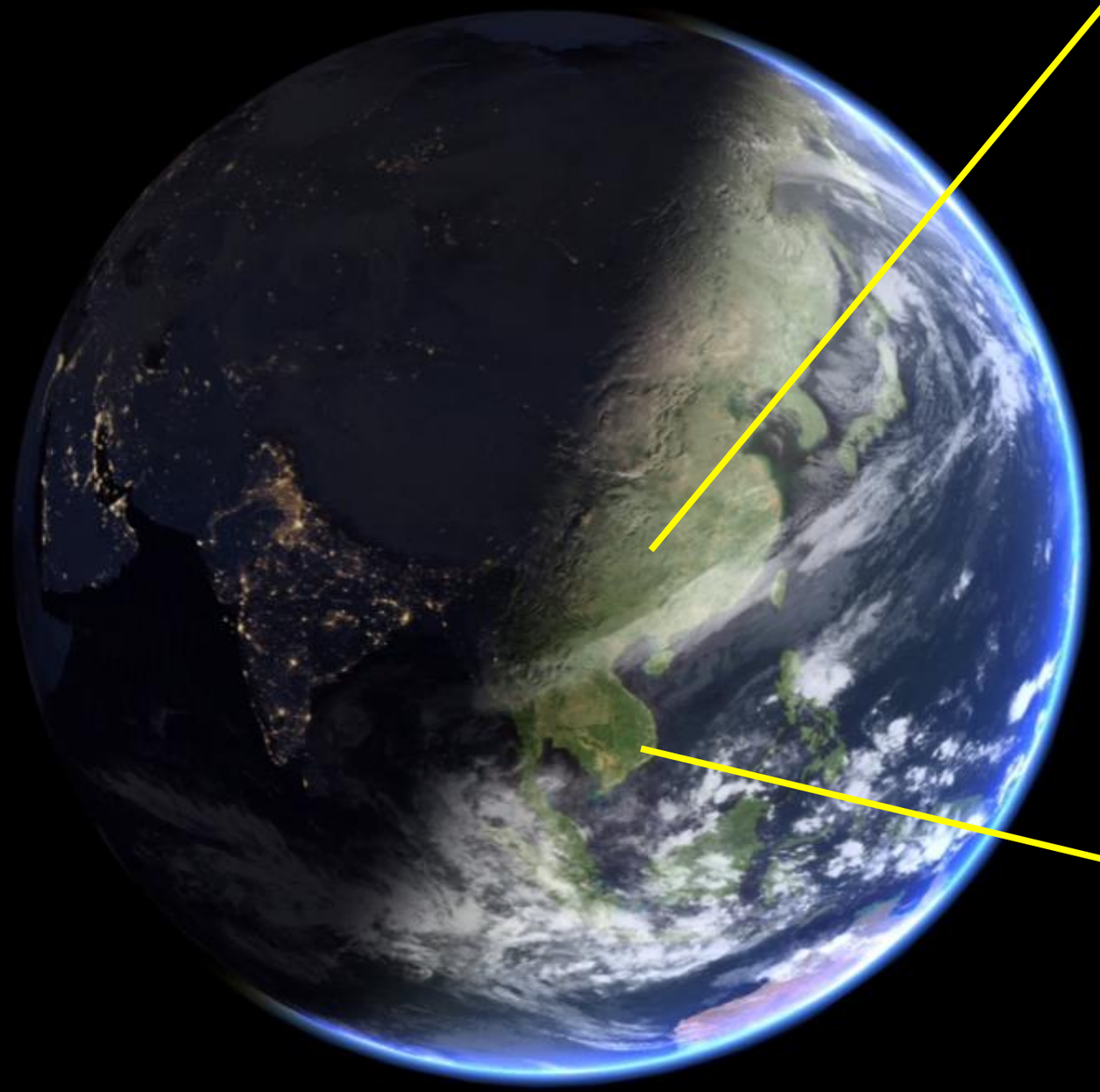
Climate change is predicted to substantially reduce corn exports in coming decades.

Deforestation and land use changes associated with agriculture account for over 70% of greenhouse gas emissions in Brazil, a major global food producer.



18% of total UK greenhouse gas emissions are linked to food supply chains. Approximately 22% of household food and drink is wasted.

In France, 70% of food is purchased in supermarkets and more than 40% of calories in the average diet come from lipids. 40% of adults are overweight or obese.

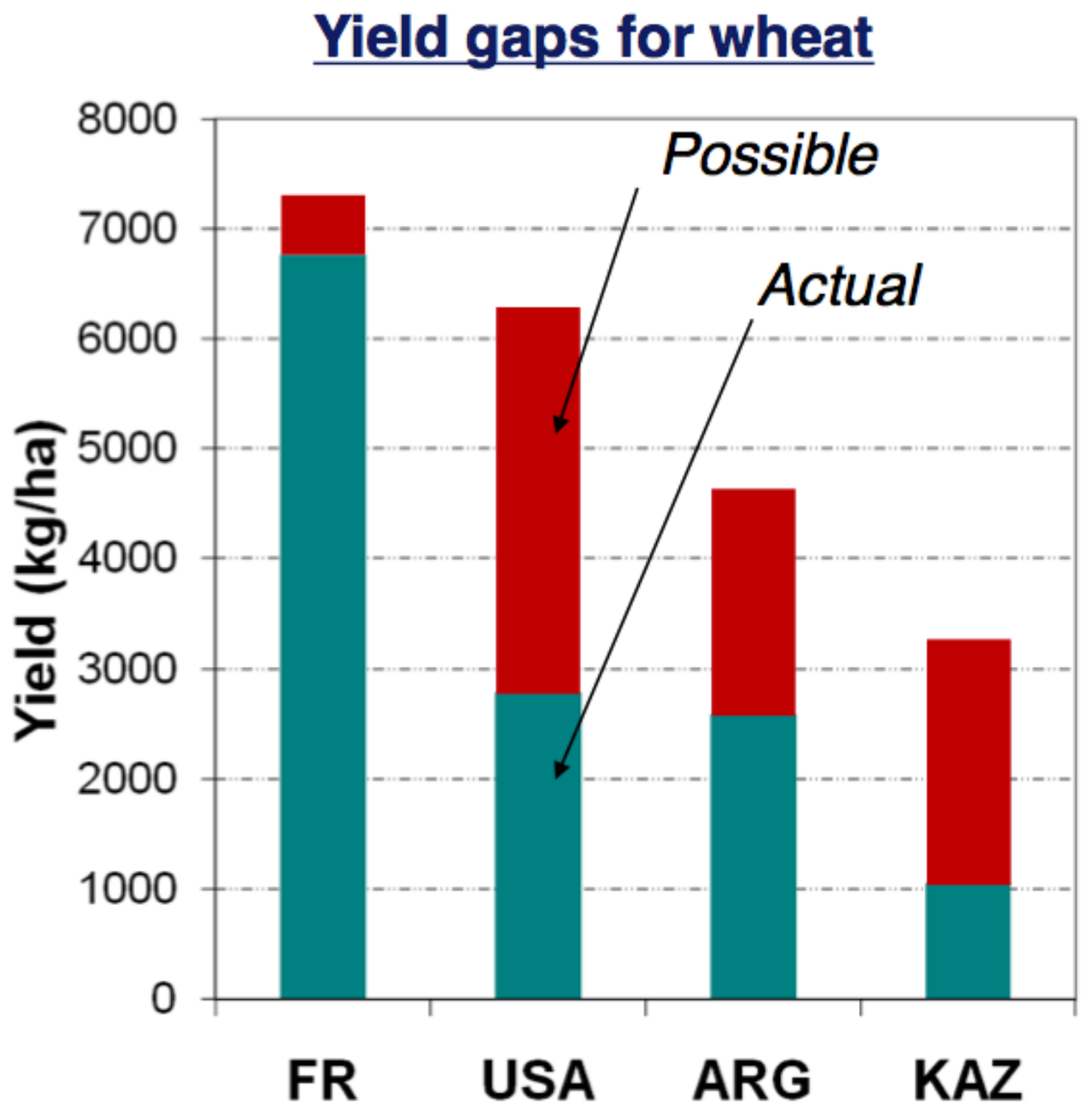


With 6% average annual agricultural GDP growth, chemical fertiliser use in China (> 350 kg / ha) is contributing to non-point source pollution and greenhouse gas emissions.

A major rice-exporting country, Vietnam's average wet season rice production achieves over 63% of economic yield and 50% of climatic yield potential.

Sustainable intensification - producing more with existing knowledge and inputs

- The yield gap
- Best production & sustainability practice
- Invest in the skills base
  - Revitalise extension
- Invest in economic and physical infrastructure
- Strengthen land rights



After Beddington (2008)

The opportunity for closing the yield gaps for major crops – 58% increase over 2011 production

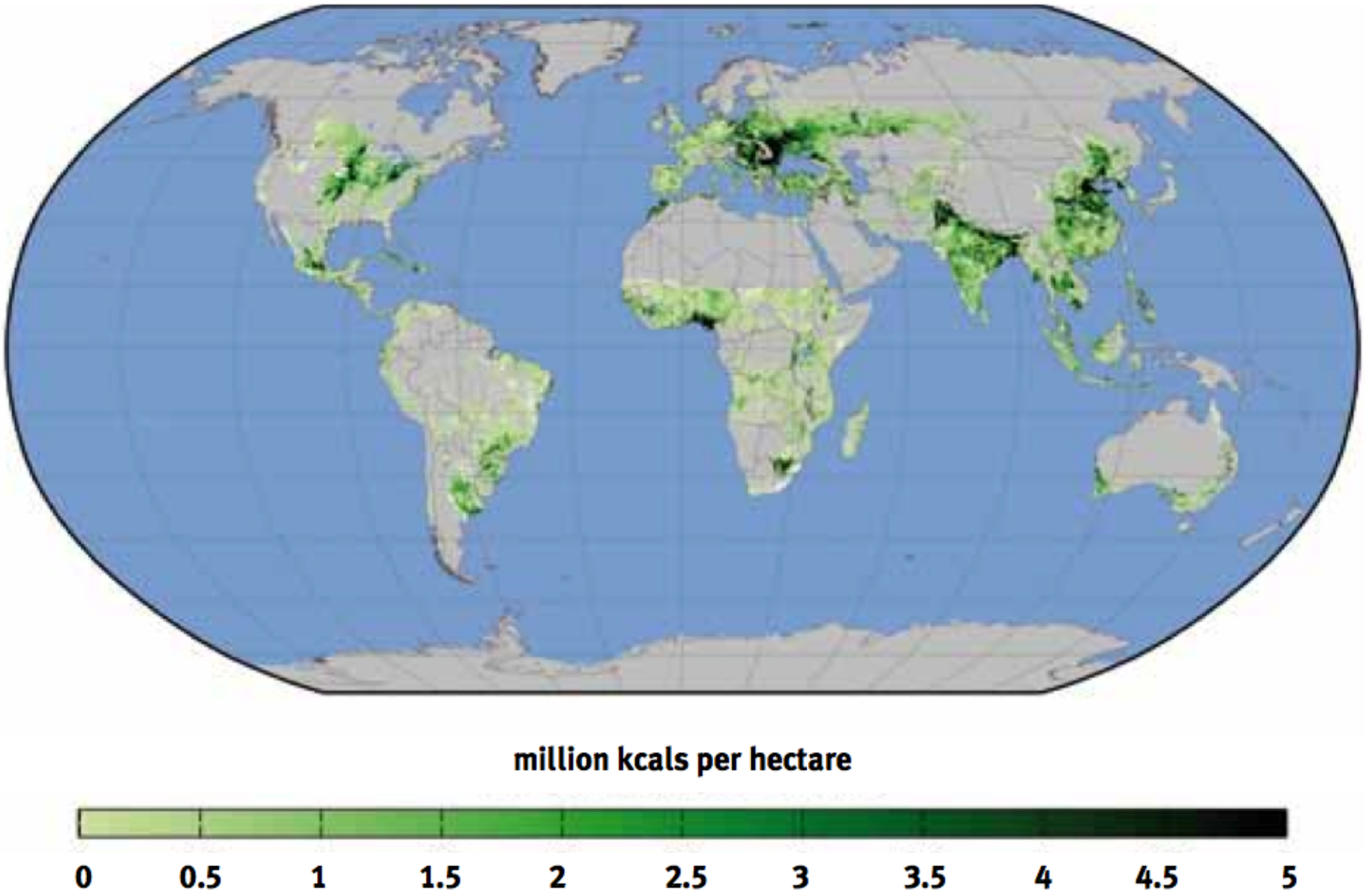


Figure 7. Closing yield gaps for major crops. Crop production in many parts of the world does not meet its full yield potential. Improved nutrient and water supplies and other production strategies can lead to significant improvements in crop yield. A recent analysis of 16 major staple food and feed crops[87] estimated that increasing yields to within 95% of their potential would add 2.3 billion tonnes of crop production (5 x 10^15 kilocalories), which is a 58% increase over current production. *Source*: Foley et al, 2011. Data provided by University of Minnesota's Institute on the Environment.

Source : CCAFS

Sustainable intensification - innovate to increase production with less inputs

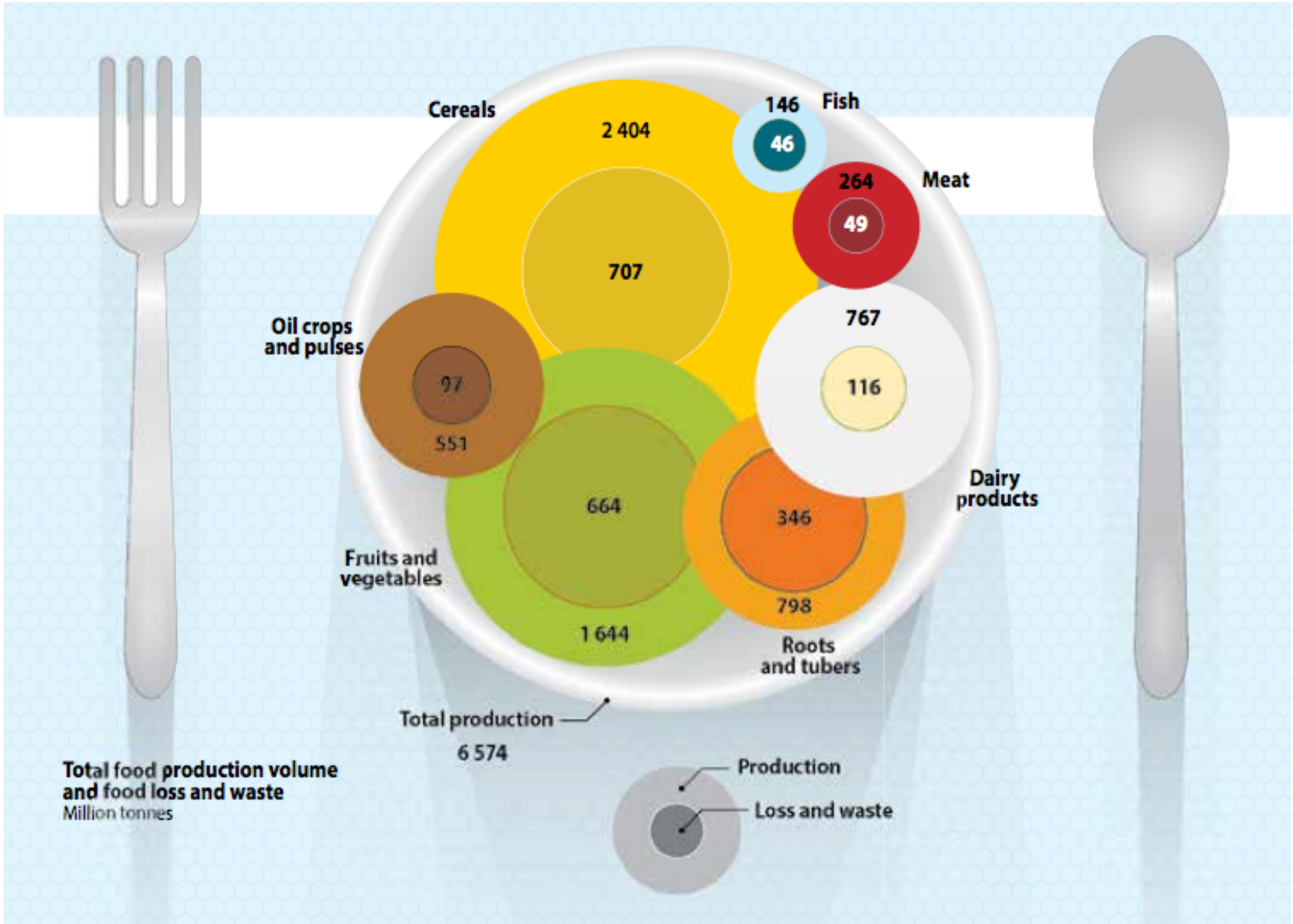
We need new scientific knowledge to maintain and increase crop yields

This involves:

- Examining the **yield potential of cropping systems**.
- Looking at the implications for sustainability in terms of **efficiency of fertiliser use**, especially nitrogen based fertilisers.
- **Optimising the use of pesticides**, looking for alternatives.
- Harnessing the use of biotechnology including GM to **breed crop varieties adapted to stressed environments** and for improved human nutrition e.g. Golden Rice – enhanced Vitamin A.
- **Research investment in neglected subjects** including agronomy, agricultural ecology and soil science.
- **Understanding the social and economic context** of scientific innovations.

After Beddington (2008)

Reduce waste – up to a 1/3rd of food produced is wasted or lost in the supply and consumption chain



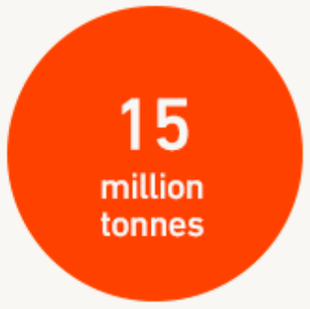
Food waste reduction

Our extensive knowledge makes us the go-to organisation for food waste prevention in the UK. This expertise is now being recognised internationally. We're working with the EU to prevent waste in the food supply chain, are part of the United Nations Think.Eat.Save campaign and are bringing together like-minded organisations to create a global network focussed on making grocery products more sustainable.

Start exploring

Exploring what's possible

Food and drink accounts for 20% of UK's CO_2eq emissions.



The sector produces 15 million tonnes of food waste.

WRAP's work is underpinned by groundbreaking, evidence-based research. Our studies give us unique market and behavioural insight and help prioritise action to tackle the significant carbon, water and waste impacts of the UK's food and drink supply chain.

We turn this research into practical support for businesses, local authorities and consumers – creating transferable learnings and replicable approaches for implementing resource efficiency.

Learn more

Resilient Supply Chains
Farmers & Food Industry Tackle the Share Challenge of Climate Change
A STRATEGIC DIALOGUE | 19 OCTOBER 2015 | LONDON
#ResilientSupplyChains
WORLD BANK GROUP
THE WORLD BANK
IFC
Department for International Development
wbcsd
Ministry of Foreign Affairs of the Netherlands

Opening Remarks
Short Term - Income and Bottom Line Implications of More Volatility
9:00 – 9:20 | A STRATEGIC DIALOGUE | LONDON | 19 OCTOBER 2015
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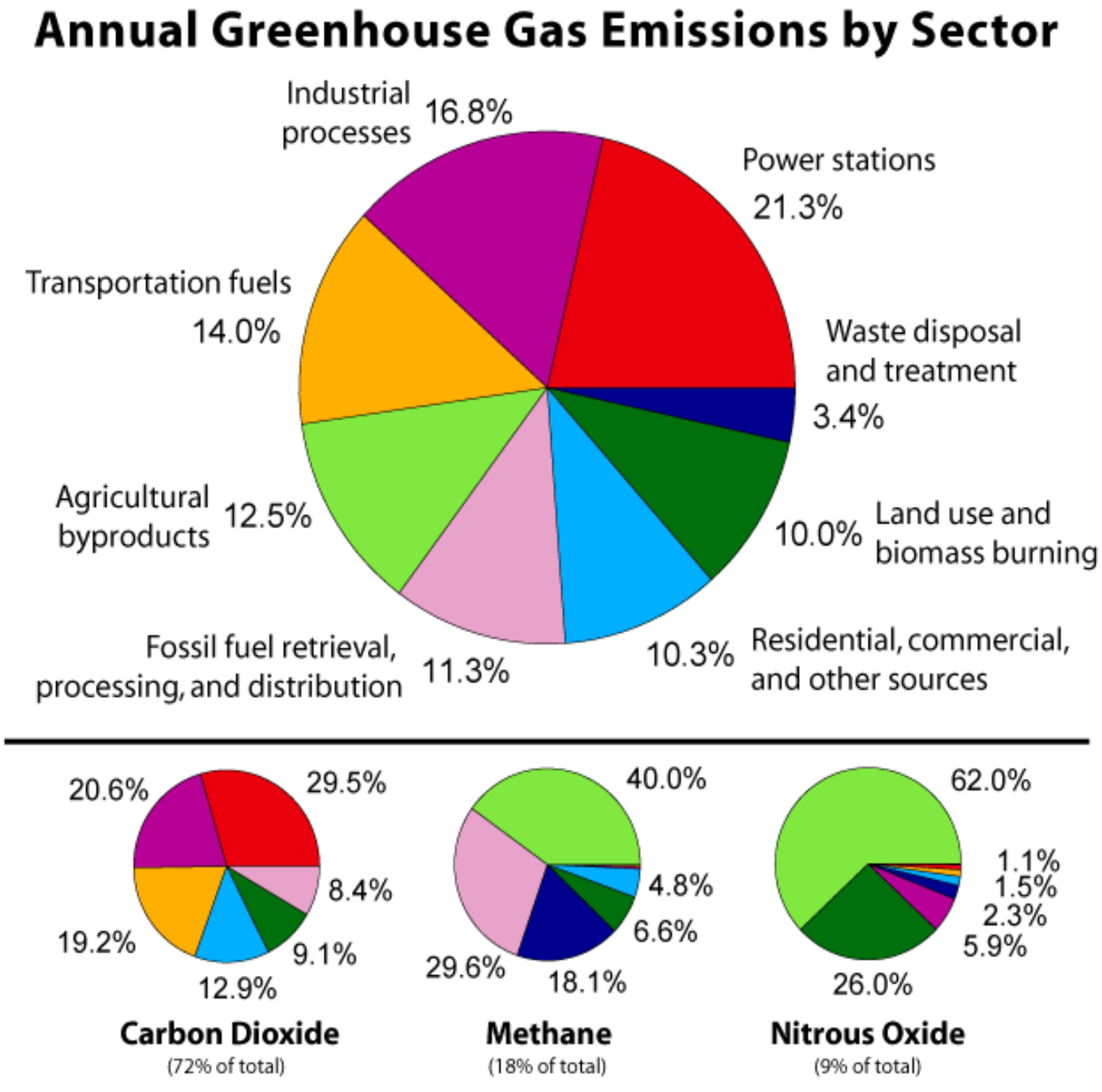
Green house gases (GHG) and global warming potential (GWP)

- CO_2, CH_4, and N_2O are different
  - How much heat they trap
  - Their lifetime in the atmosphere
- Global warming potential (GWP):
  - is a measure of how much heat a gas traps in the atmosphere relative to *CO_2*
  - *CO_2:CH_4:N_2O = 1:25:300*
  - expressed in CO_2 equivalents

GHG emissions



IPCC (2007)

1. Carbon footprint of a sector is driven by three greenhouse gases: CO_2, CH_4, and N_2O
2. Agriculture is the largest contributor to N_2O emissions (>60%)
3. Rice is the largest contributor to global agricultural CH_4 emissions
4. BUT agriculture can be SMART

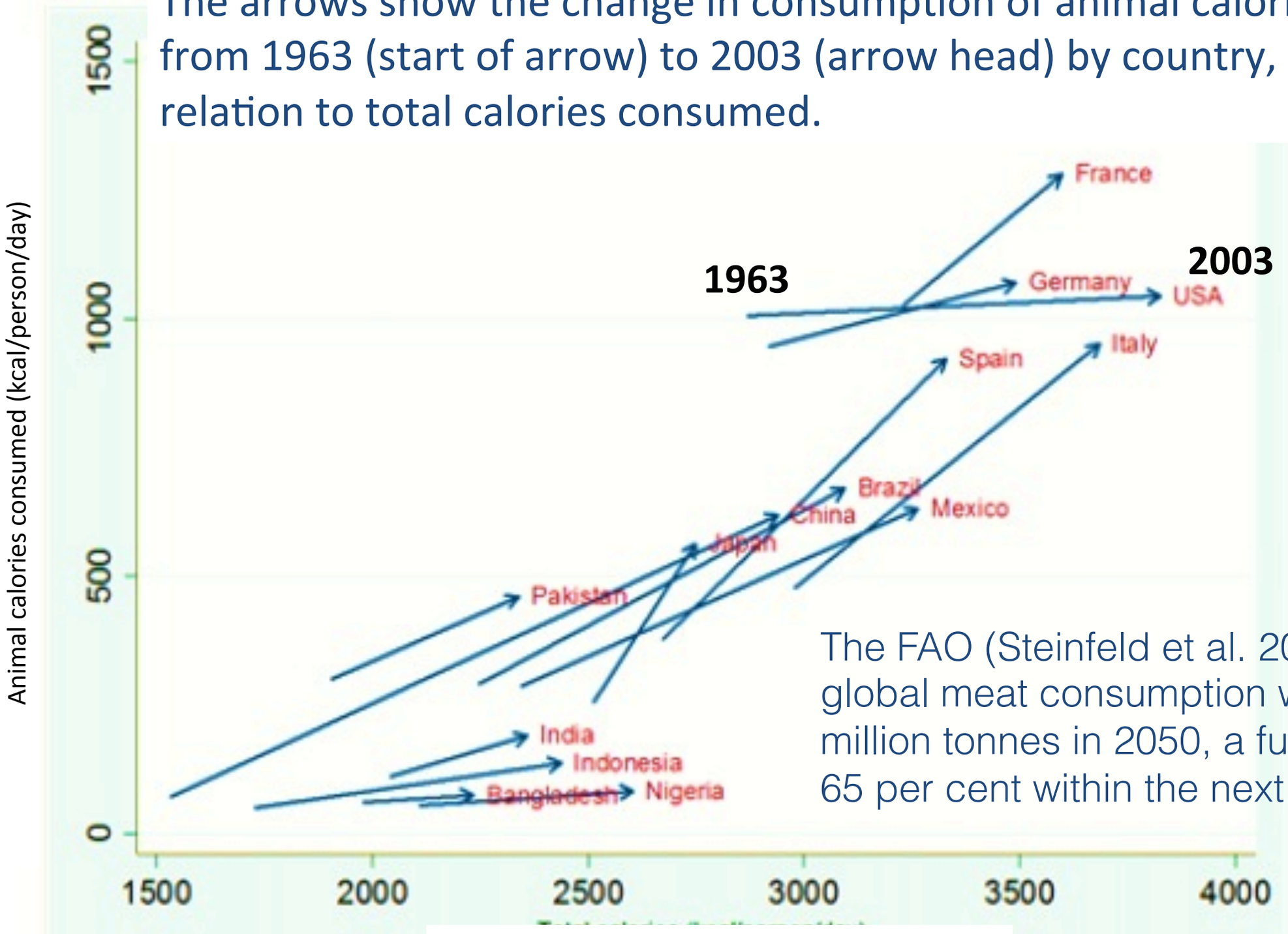
Are we causing a problem ?

	Enteric fermentation (CH_4)	Manure (N_2O)	Manure (CH_4)	Soils (N_2O)
Latin America	460	11	17	394
Africa	280	6	14	361
China	259	69	22	536
India	218	0	23	58
Asia (except China	175	35	24	192
Western Europe	160	26	69	257
North America	136	22	43	300
Non Eu former Sov	97	28	12	76
Australia/New Zeal	88	1	3	32
Eastern Europe	28	12	7	43
Middle East	27.3	0.7	1.6	50.7
World	**1929**	**211**	**235**	**2299**

In terms of GHG emissions “the consumption of 1 kg domestic beef in a household represents automobile use of a distance of ~160 km (99 miles)” (Carlsson-Kanyama and González 2009).

Changes in consumer demand for meat

The arrows show the change in consumption of animal calories from 1963 (start of arrow) to 2003 (arrow head) by country, in relation to total calories consumed.



The FAO (Steinfeld et al. 2006) expects that global meat consumption will rise to 460 million tonnes in 2050, a further increase of 65 per cent within the next 40 years.

Source : Combris (2006)

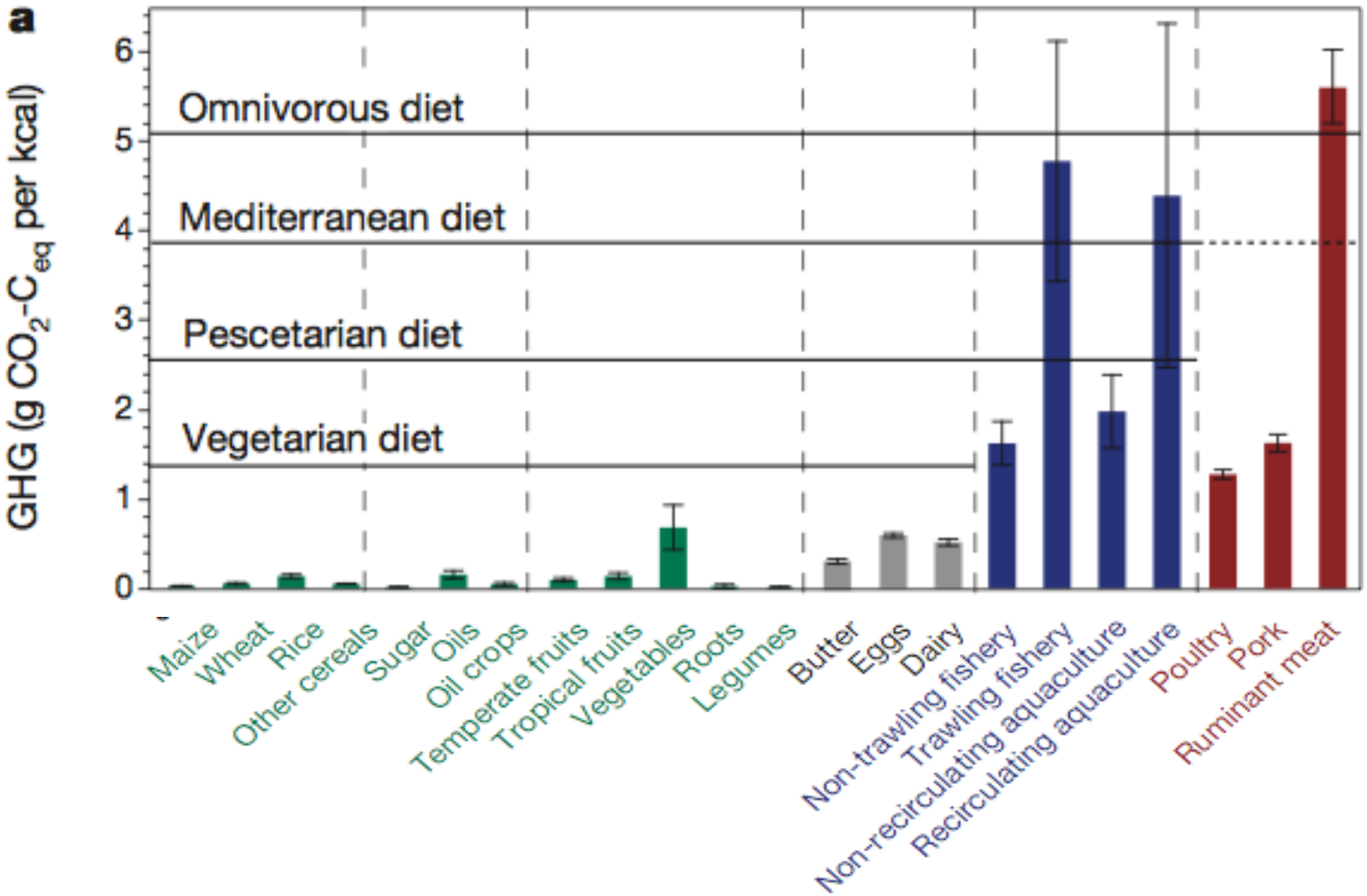
The role of aquaculture

In 2010 aquaculture supplied half of the total fish and shell-fish for human consumption.

Fish can convert food to muscle at a higher efficiency than cattle, pigs and poultry.
Illustrative Food Conversion rates -

Salmon : 1.5 kg feed to produce 1 kg body mass.
Poultry : 3.2 kg feed to produce 1kg body mass
Cattle : 8.2 kg feed to produce 1 kg body mass.

Consumers increasingly favor products high in short chain omega-3 fish oil content for health reasons.



- Emissions per gram of protein for beef and lamb are about 250 times those of legumes; pork, chicken, dairy, and fish have much lower emissions;
- Twenty servings of vegetables have fewer greenhouse gas emissions than one serving of beef.
- Fish caught by trawling, which involves dragging fishnets along the ocean floor, can have three times the emissions of fish caught by traditional methods.
- And among cereal grains, rice has five times the emissions per gram of protein as wheat.

http://www.nature.com/nature/journal/v515/n7528/full/nature13959.html

ARTICLE

doi:10.1038/nature13959

Global diets link environmental sustainability and human health

David Tilman[1,2] & Michael Clark[1]

http://www.nature.com/nature/journal/v515/n7528/full/nature13959.html

% reduction in risk of illness relative to a region's conventional omnivorous diet

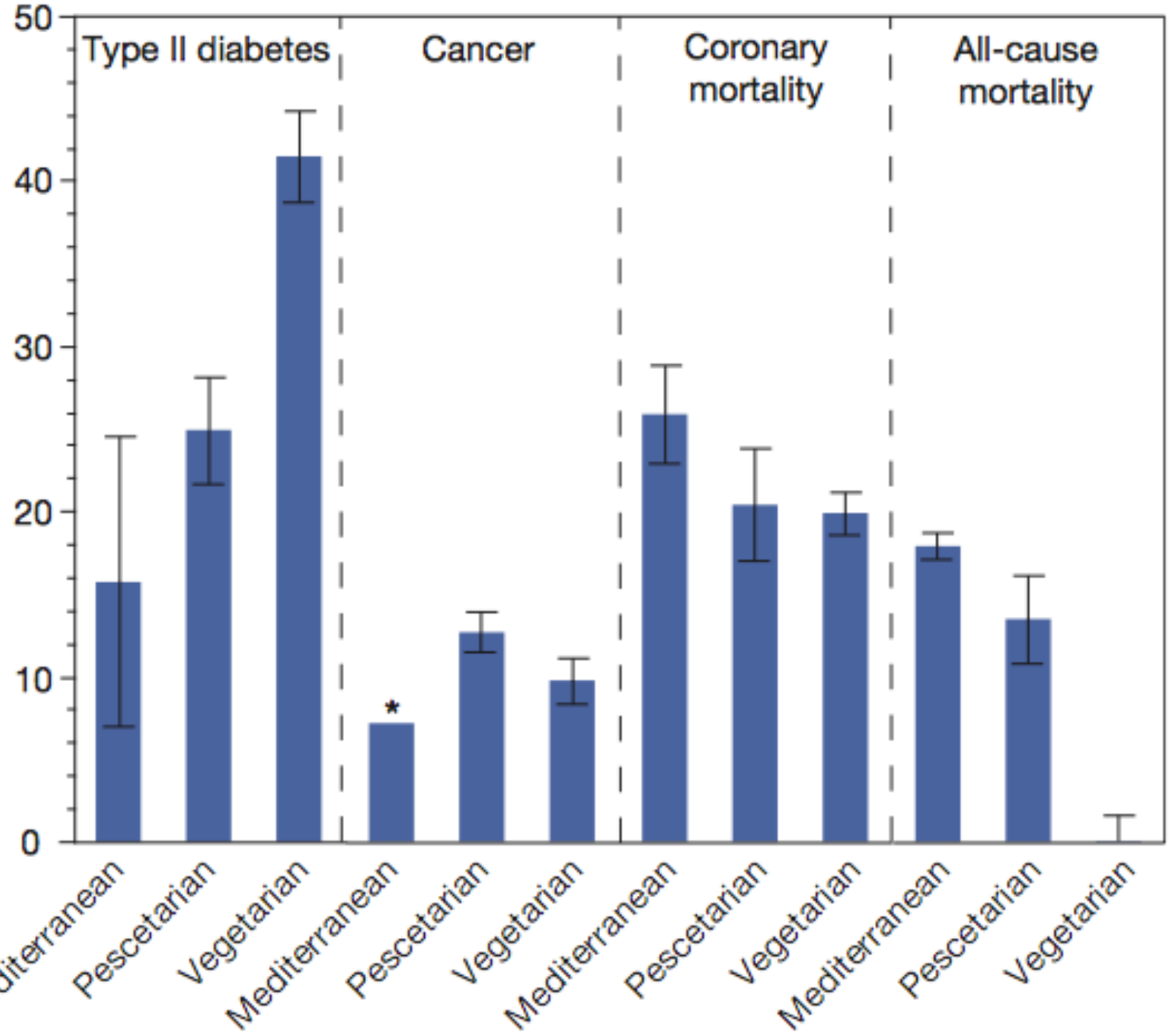


Figure 3 | Diet and health. Diet-dependent percentage reductions in relative risk of type II diabetes, cancer, coronary heart disease mortality and of all-cause mortality when comparing each alternative diet (Mediterranean, pescetarian and vegetarian) to its region's conventional omnivorous diet (Methods).

Food supply and demand

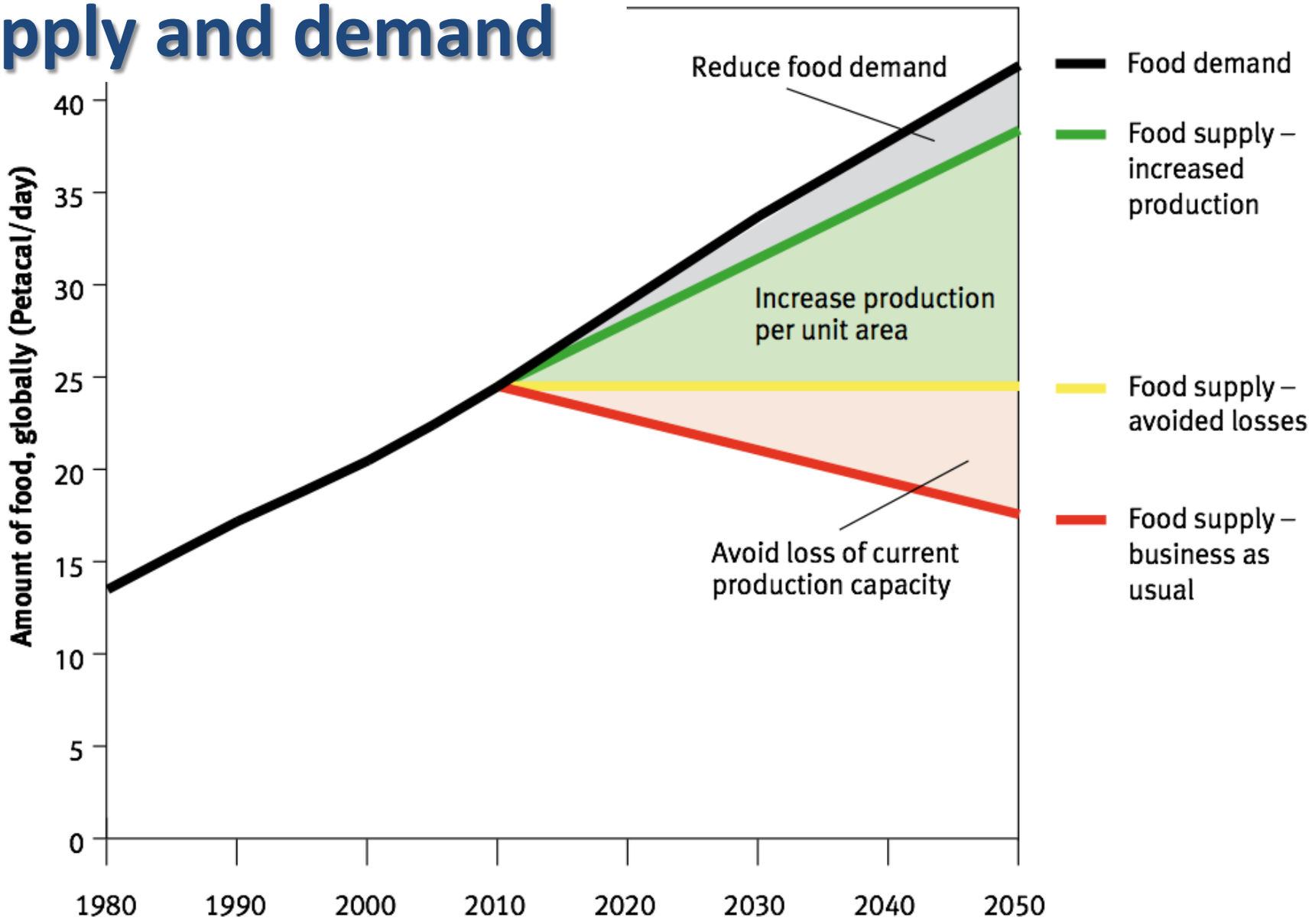


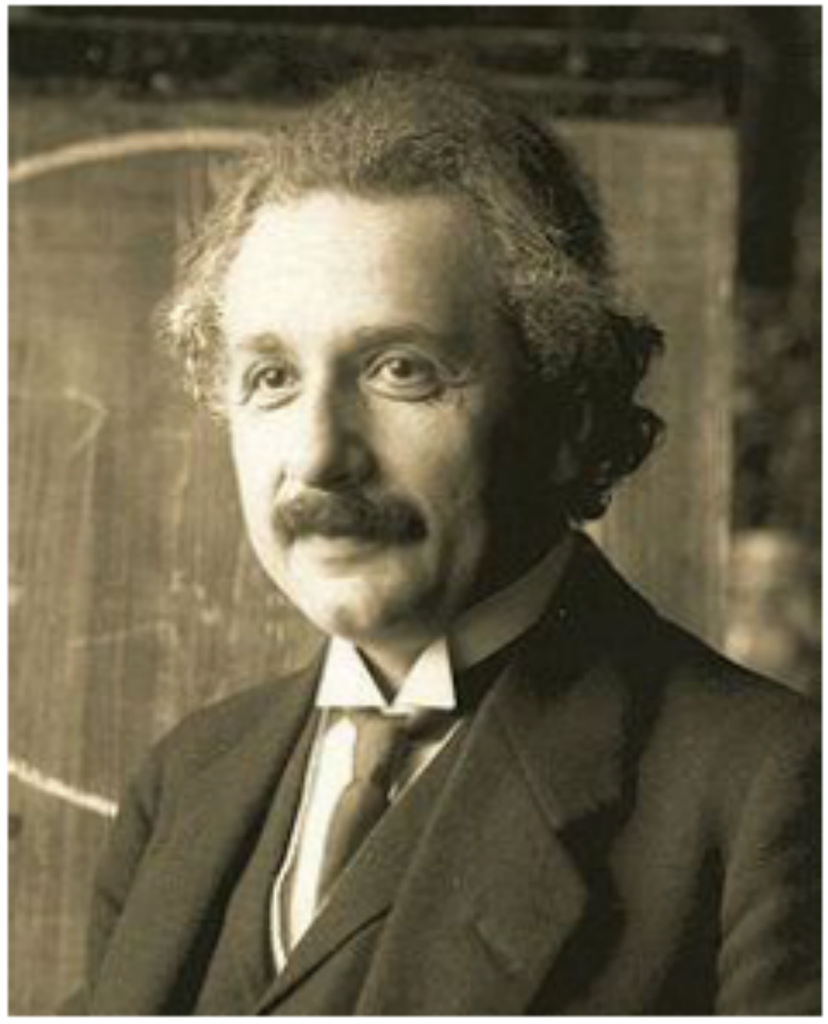
Figure 10. Balancing food supply and demand. Globally, food demand will grow in the future due to population growth and changing diets (*upper line*) and food supply must somewhat exceed food demand if everyone's needs are to be met and food prices are to remain affordable. Under a 'business as usual' approach, food production will decrease over time due to land degradation, climate change and the emergence of new pests (*lower line post 2010*). The large resulting gap between food supply and demand can be bridged by simultaneously applying three general approaches. (1) Avoiding losses in current productive capacity can include actions to adapt to or mitigate climate change, to reduce land and water degradation and to protect against emerging pests and disease. (2) Increasing agricultural production per unit land area can be achieved through use of improved technologies, practices and policies, more efficient use of existing agricultural land and targeted expansion of agricultural land and water use (where negative environmental impacts are minimal). (3) Reducing food demand can be accomplished through efforts to promote healthier and more sustainable food choices and to reduce food waste across supply chains. None of these three approaches alone are sufficient and all three require substantial innovation in the food system. *Source*: B Keating, CSIRO Sustainable Agriculture, based on Keating and Carberry (2010).

Source : CCAFS

Conclusion – staying connected at new scales

"The significant challenges we face cannot be resolved at the same level of thinking we were at when we created them."

Albert Einstein



Thank you