IFST Spring Conference

18 April 2013

Sustainable production: the foundation of secure food supply

Ian Crute

AHDB Chief Scientist

AHDB Mission:
"To make our industries more competitive and sustainable"

Not Defra "family"

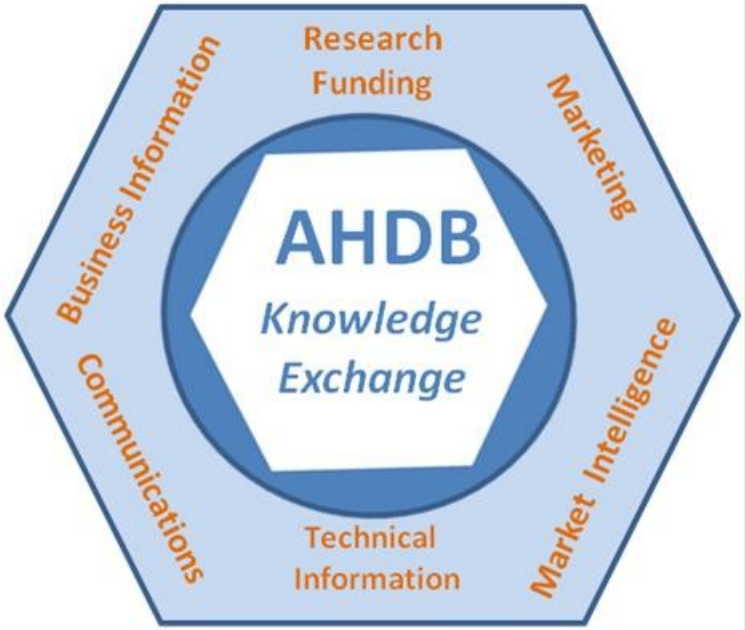
Not to deliver Defra/Government policies

Funded by and serving the needs of 300,000 UK farm holdings

- Partnerships
- Integration
- Co-ordination
- Added-value

AHDB Knowledge Exchange

AHDB is a "hub" to broker and orchestrate industry-led Knowledge Exchange



EBLEX – beef & lamb:	£15.6 m (England)
HGCA – cereals & oilseeds:	£10.5 m (UK)
BPEX – pigs:	£ 8.2 m (England)
DairyCo – milk:	£ 7.3 m (GB)
PCL – potatoes:	£ 6.4 m (GB)
HDC – horticulture:	£ 5.8 m (GB)

£53.8 m

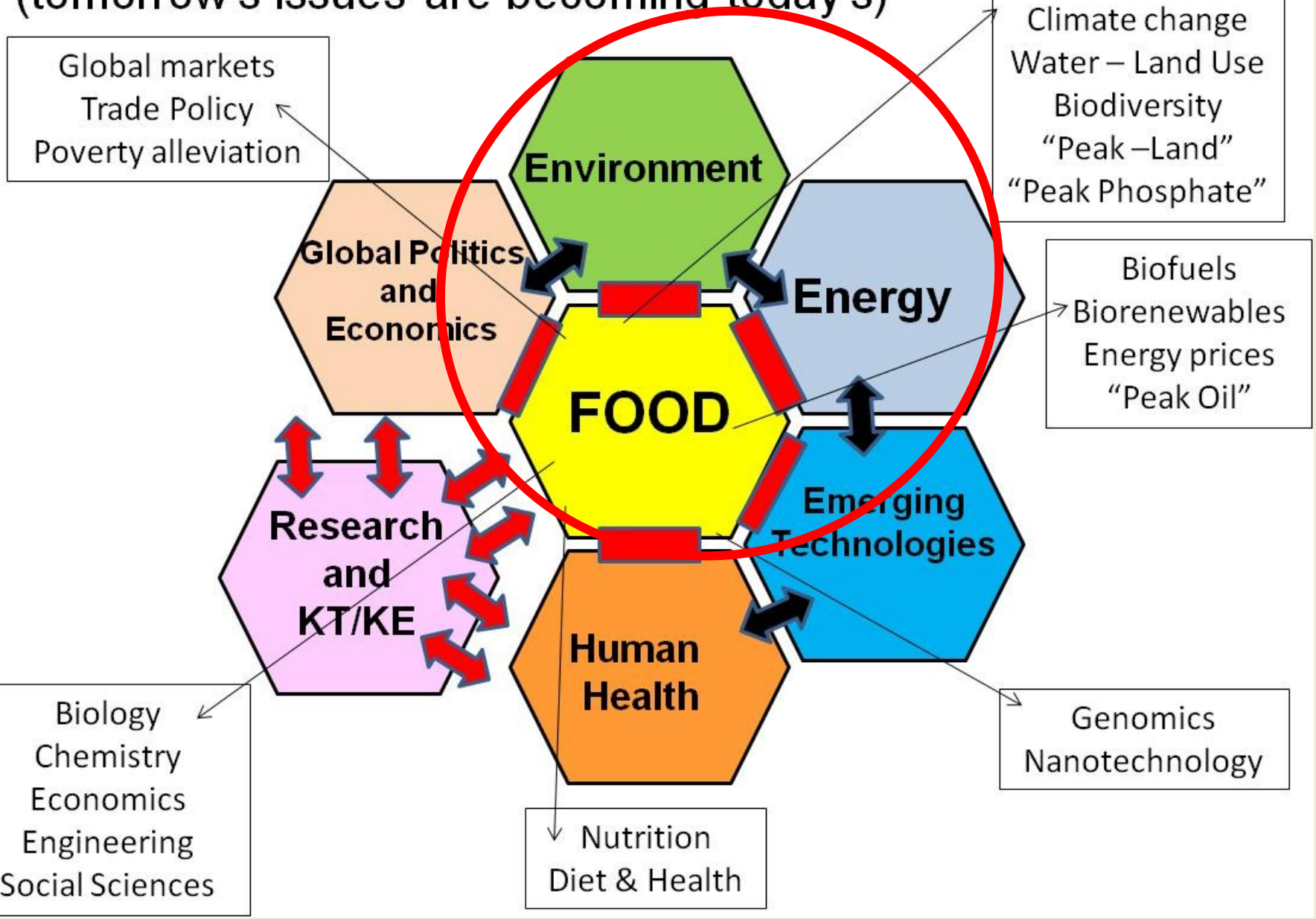
Take-home messages for further debate:

- More research and analysis is required to develop meaningful and refined metrics for determining comparative sustainability of production systems.

- The short-term costs, as well as the long-term benefits, of sustainable production need to shared fairly through the food chain.

- There is a shared responsibility to promote technology as a contributor to sustainability – "dumbing down" messages about sustainability is unhelpful.

Food (and agriculture) has rapidly become centre-stage (tomorrow's issues are becoming today's)

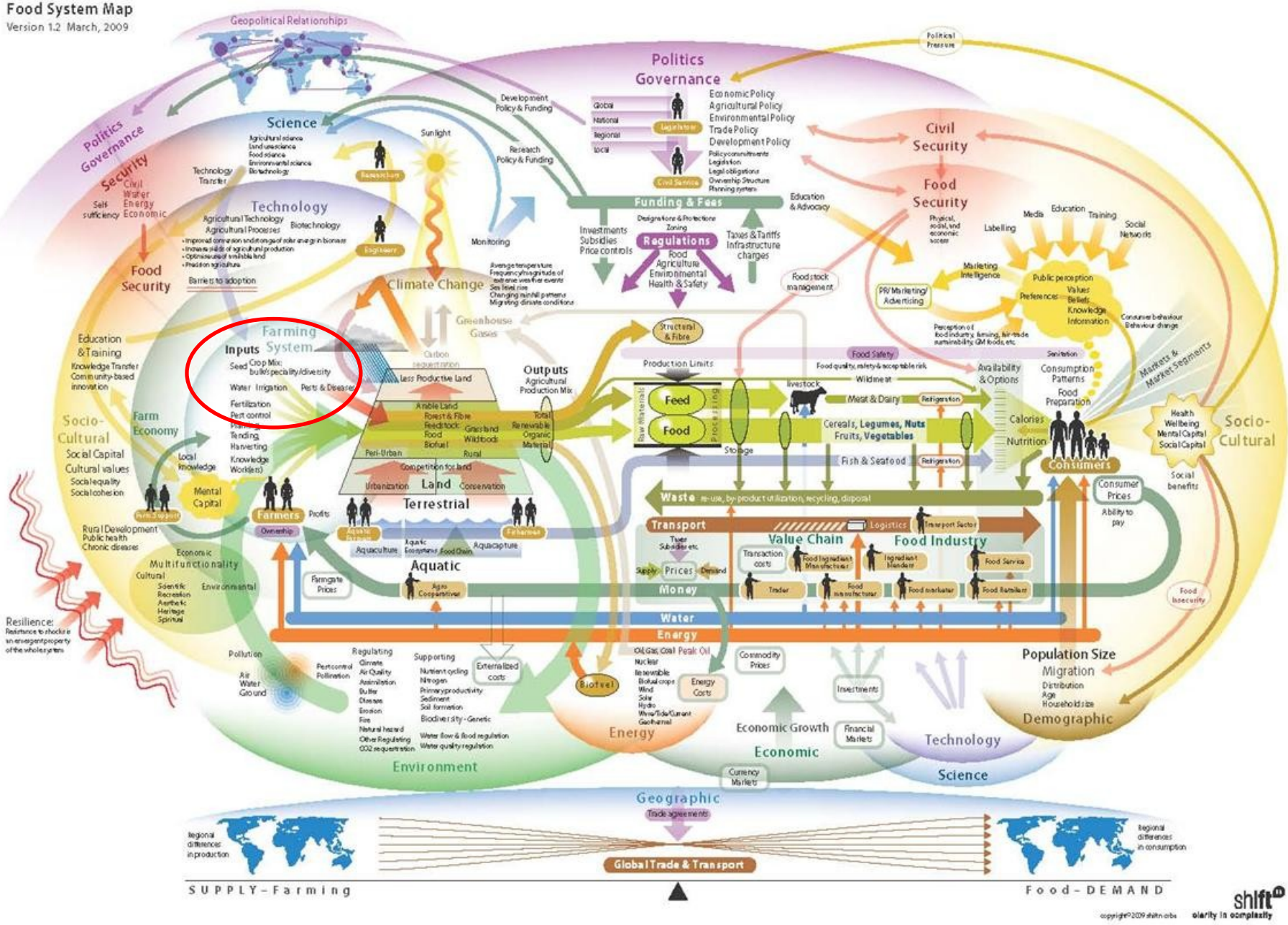


The Global Food System

Foresight project on Future of Food and Farming

Food System Map

Version 1.2 March, 2009



shift
clarity in complexity

Many things have changed over the last 160+ years

"The Fruit Seller" by Vincenzo Campi (ca. 1850)

There are some who want the present to be more like the past

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Many things have changed over the last 160+ years

"The Fruit Seller" by Vincenzo Campi (ca. 1850)

Fruit Logistica – Berlin 2013

There are some who want the present to be more like the past

In some ways the present is still like the past

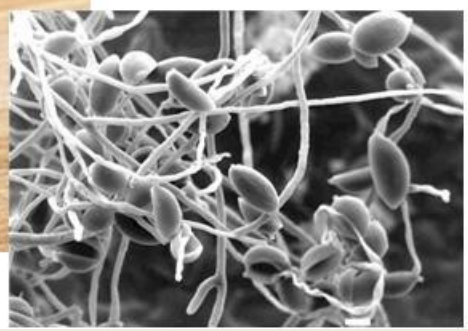
Potato Late Blight

Cause of the Irish Famine (***1846-52***) *and*
Birth of Plant Pathology

1 million died
1 million emigrated
70% loss of production

Phytophthora infestans

Still a problem today:
Controlled by up to 15 sprays per season



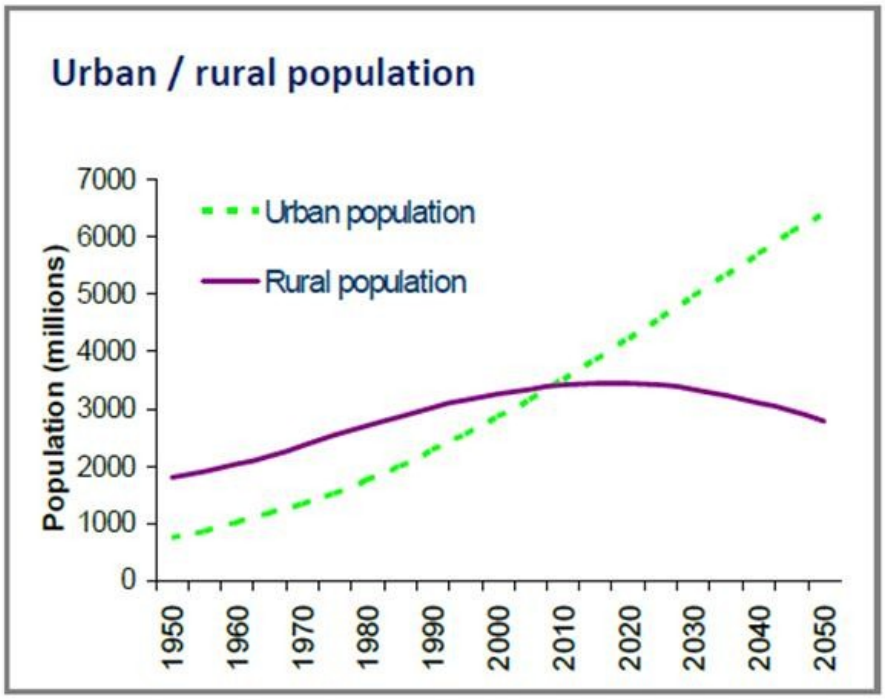
Here's the challenge:

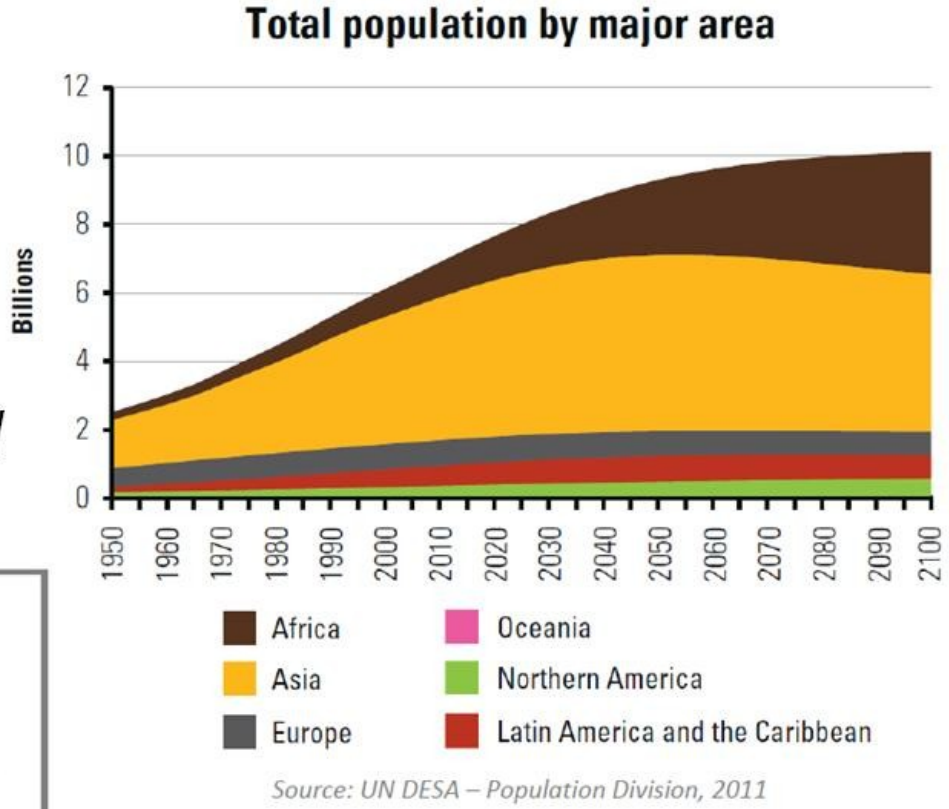
- **Increasing demand – quantity and quality (population and prosperity)**
- **Resource constraints – particularly land (biodiversity and CCS)**
- **Increasing extreme weather events (low global/local system resilience)**
- **Increasing pest and disease risk (climate – trade – loss of CPPs)**

Investment in science and innovation: necessary but not alone sufficient

Population growth :
Asia - Africa *and Urban*

Equivalent to a new city of 1 million every 5 years until 2050



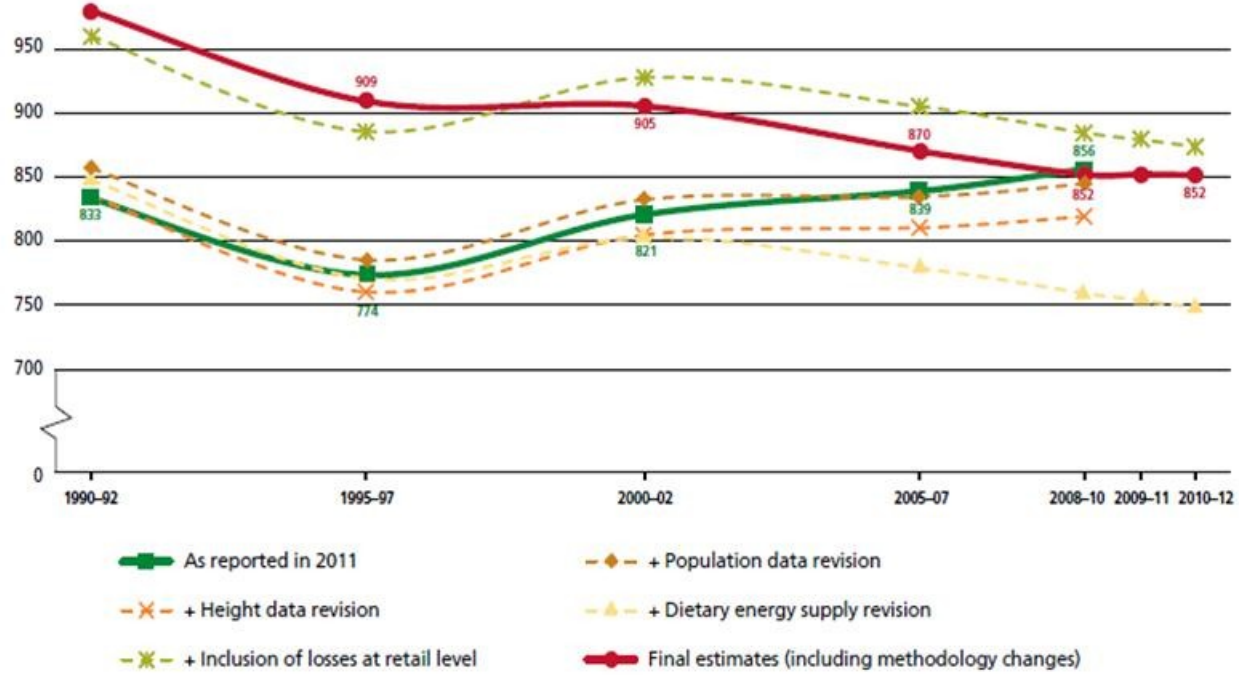


Source: UN DESA – Population Division, 2011

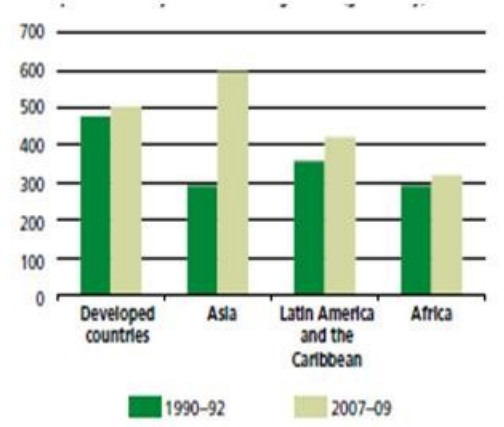
Urban populations:

- vulnerable to food price shocks
- can organise and communicate
- risks of civil unrest

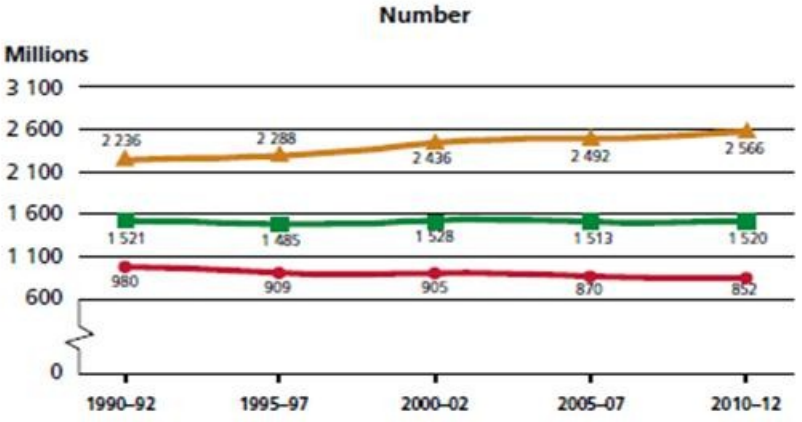
The state of food insecurity in the world – 2012 (FAO)

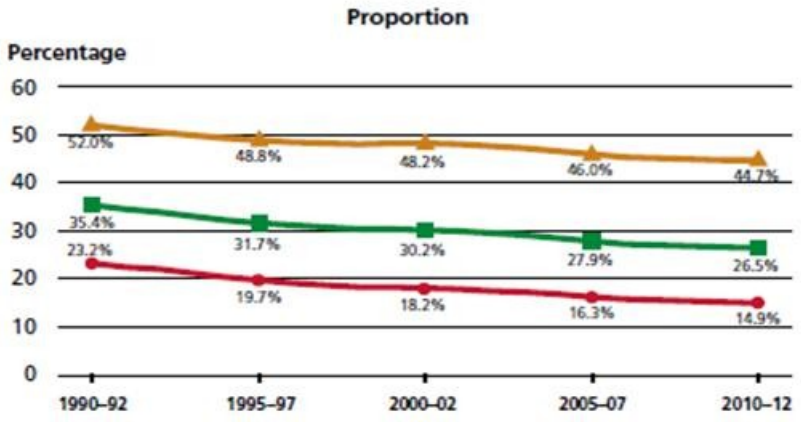


Per capita availability of fruit and vegetables: increasing but inadequate



Source of raw data: FAO.





Two wheat production systems
– 18 generations apart

Which system is sustainable?

Brazil – 2005

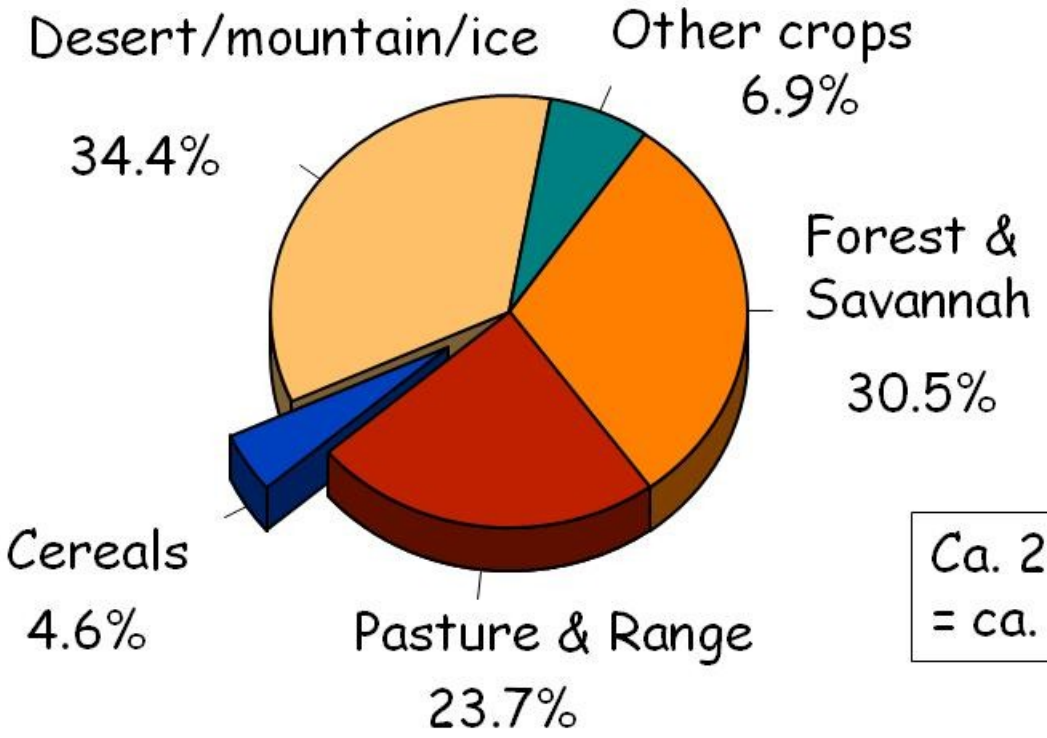
The Netherlands – 1565

Land use and management is a key to sustainability

If we didn't have this

We wouldn't have this

Current global land usage (Total = 13,400 M Ha)



Ca. 22% "wild"
= ca. 11% NPP

Ca 10 M Ha (= 0.25%) non-agricultural land (mostly forest) cultivated per annum

Ca 17 M Ha (= 1%) of agricultural land lost to erosion (5), salinisation (2) and urbanisation (10) per annum

Think (anthropogenic) ecosystem management !

- The primary objective of ***land use for agriculture is the efficient conversion of solar energy into varied and valued forms of chemical energy*** for utilisation by mankind (and in competition with other organisms in our ecosystem)

- ***Some land is best used to produce forage for animals*** as intermediates in the energy conversion process.

- ***The energy conversion process involves manipulation and management*** of the interaction between genotype (animal and/or plant) and the environment

- The requirement for ***consistency and predictability over generations demands continuity of agro-ecosystem functions*** – including geochemical cycles (C, N, H_20) - this captures the temporal and renewable concept of sustainability.

- ***Maximising efficiency of agriculture on the smallest necessary land area provides options*** to use non-agricultural land to achieve other objectives (these should not be confounded with the requirement to produce food and other agricultural products as efficiently as possible).

A clear acknowledgement of:
anthropogenic ecosystem management may be helpful

Humans control (anthropogenic) ecosystem functions and biodiversity as much as climate:

- Deforestation; ■ Habitat fragmentation; ■ Grazing;
- Arable agriculture; ■ Urbanisation; ■ Recreation/amenity

Ellis and Ramankutty –
"move beyond the urban + agriculture + wild model of ecosystems"

Ecosystem processes = f(C) where C = macroclimate
(precipitation and temperature affected by latitude, altitude and circulation)

Old thinking:

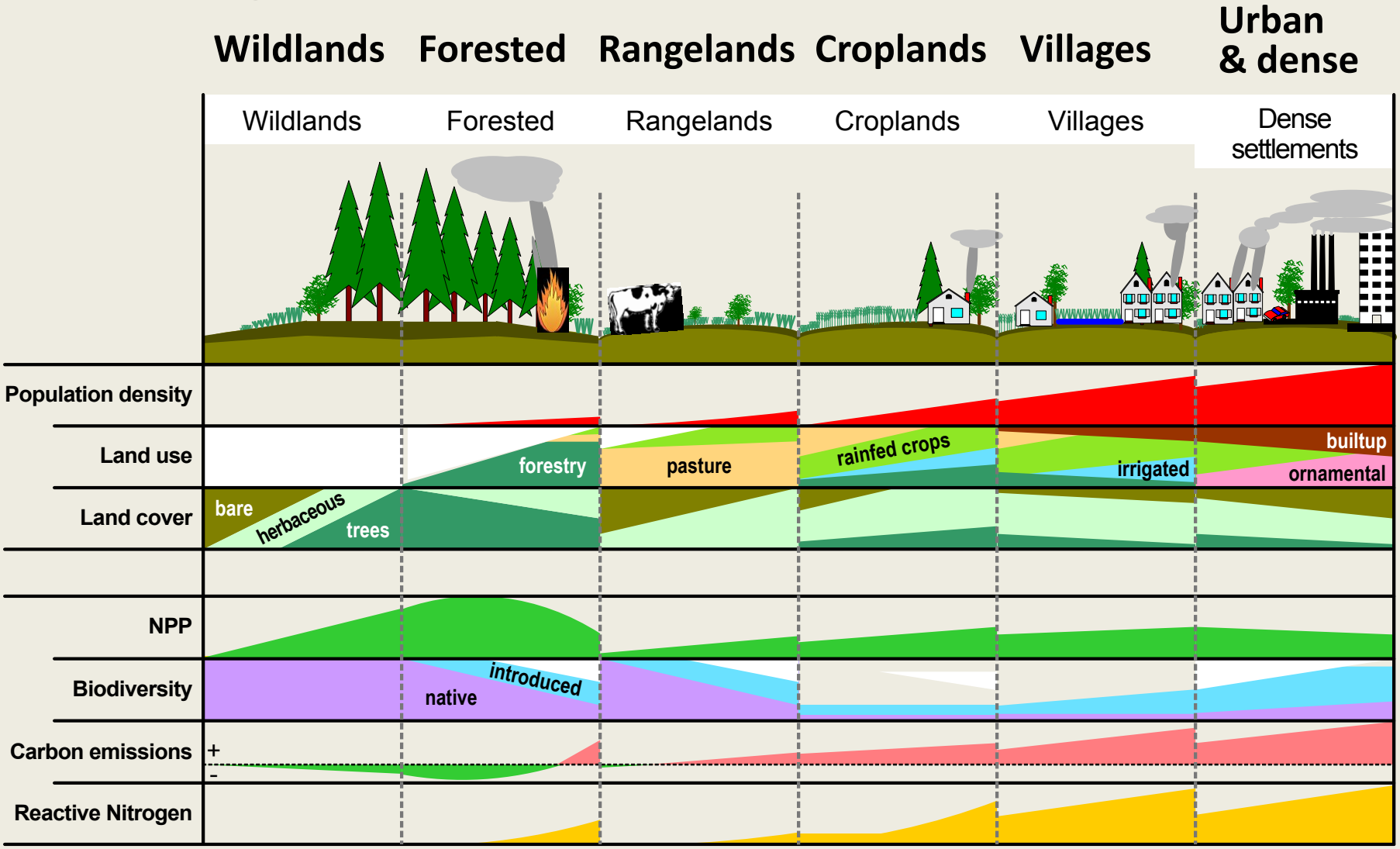
"Natural ecosystems with humans disturbing them"

Anthropogenic – ecosystem processes = f(P,T)
where P = population density and T = how land and resources are used

New thinking:

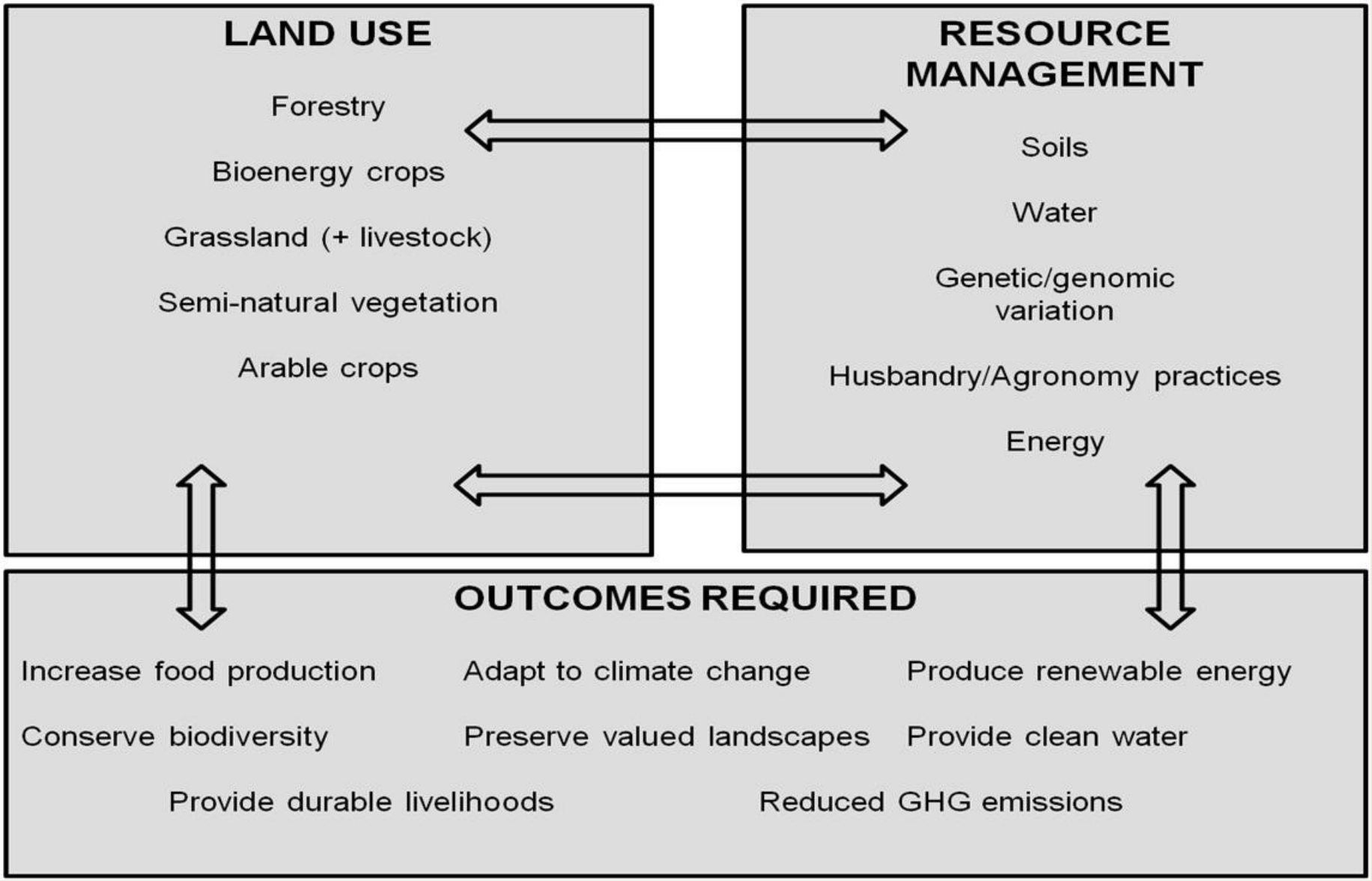
"Human systems with natural ecosystems embedded within"

Anthropogenic Biomes: Conceptual Model



Ellis & Ramankutty (19

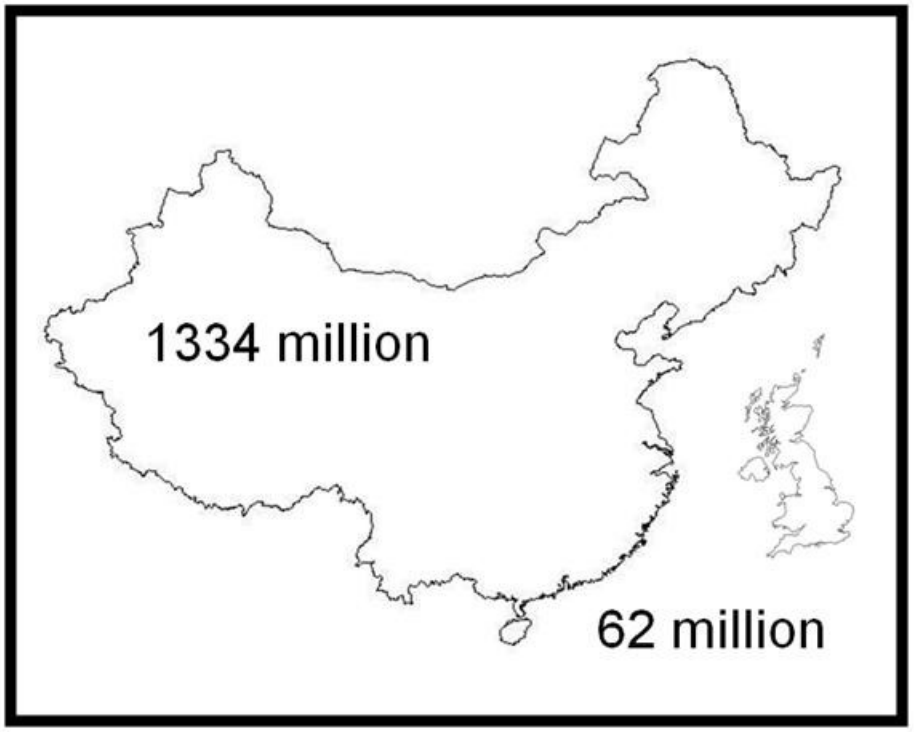
Managing an [eco]system



Britain's diverse geology, soils and climate causes land use constraints (and spatial diversity)

Land use and management is at the foundation of sustainable productivity

Are China and the UK so different?



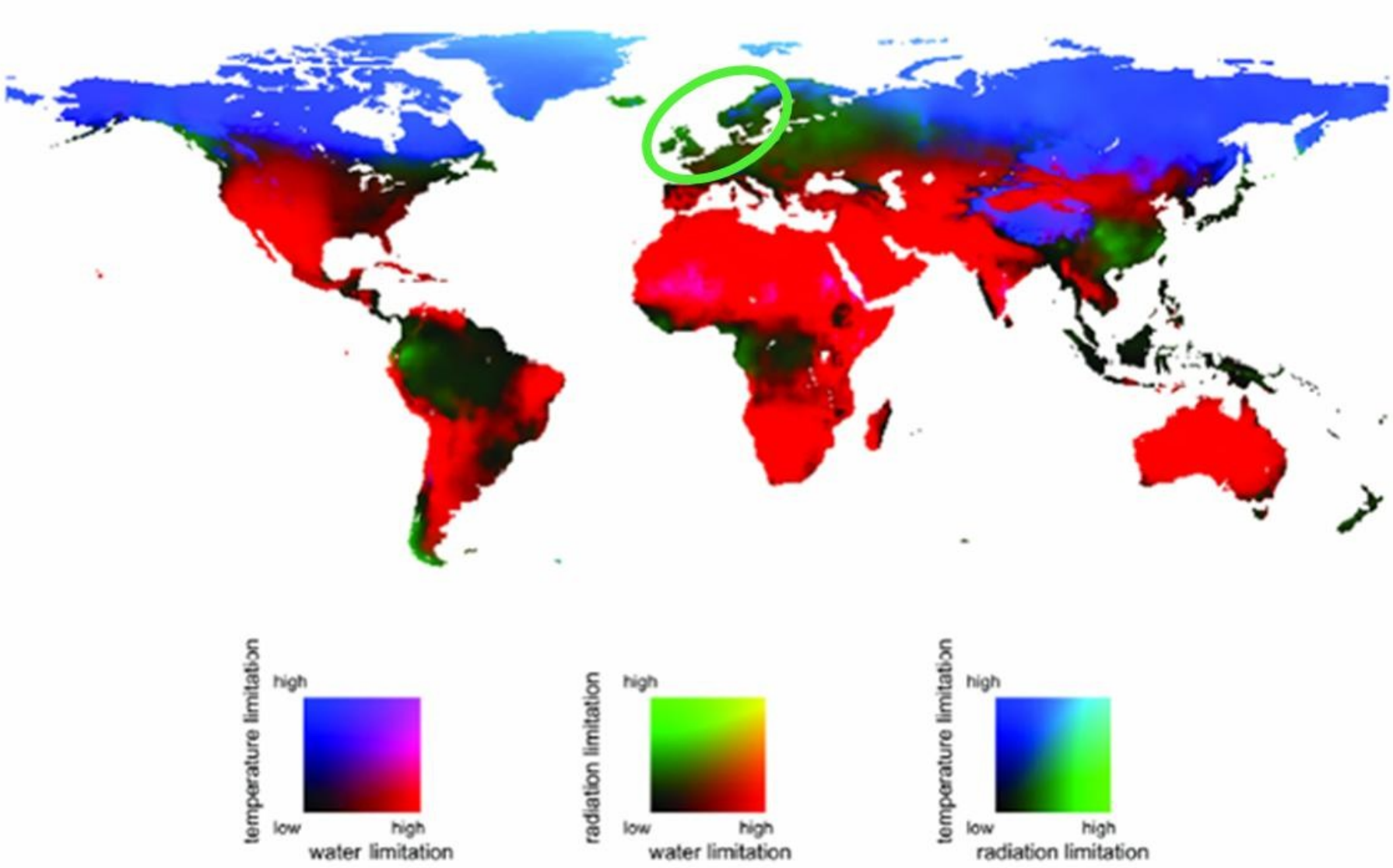
- UK has < 5% of China's population and < 3% of China's land area

but

- ca. 25% less agricultural land per person and about the same area of crop land per person (ca. 0.1ha)

	China	UK
Land	933 mHa	24 mHa
Ag. Land	524 mHa (56%) 0.4 Ha/person	17 mHa (71%) 0.3 Ha/person
Crop Land	124 mHa (13%) 0.1 Ha/person	6 mHa (25%) 0.1 Ha/person
Pasture Land	400 mHa (43%) 0.3 Ha/person	11 mHa (46%) 0.2 Ha/person

Limiting factors for global plant productivity

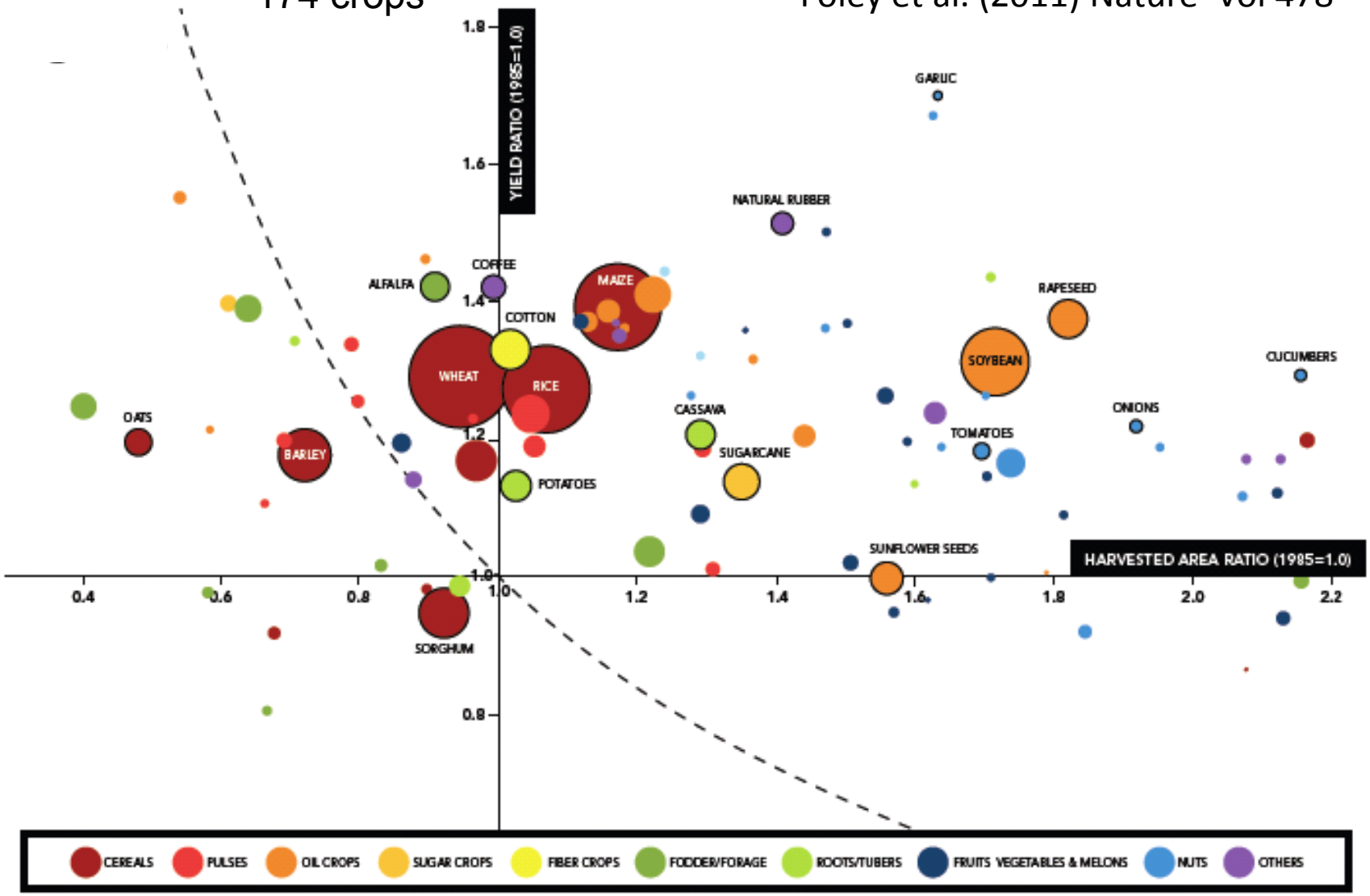


Baldocchi et al. 2004 SCOPE 62

Trends in Global Crop Production 1985-2005

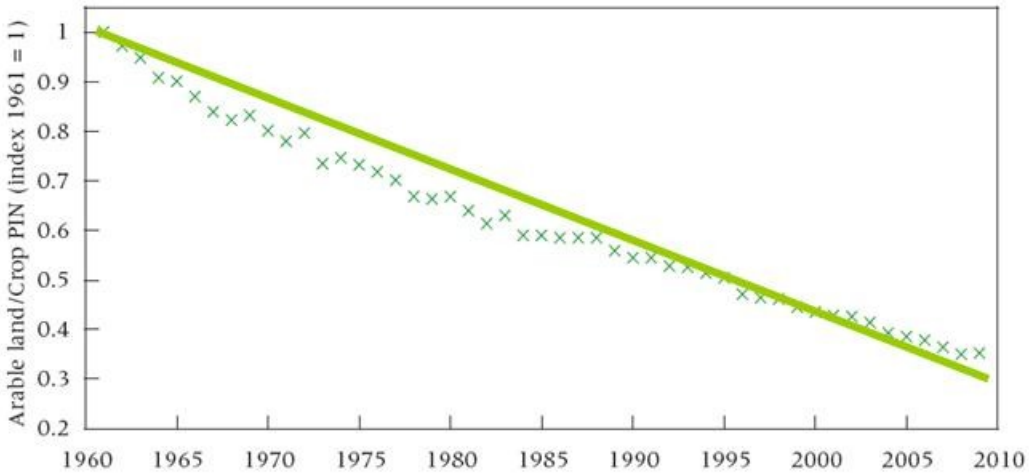
174 crops

Foley et al. (2011) Nature Vol 478

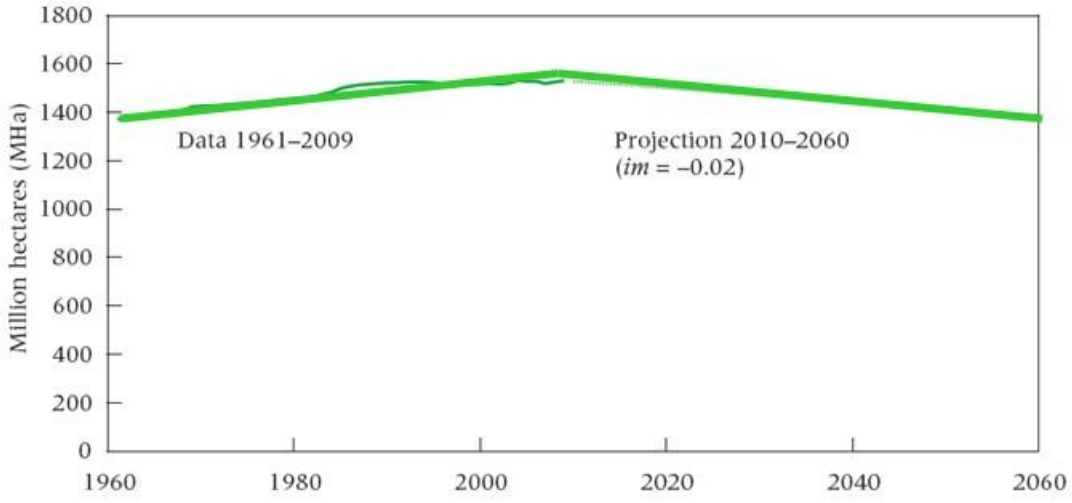


Use and management of land needs to embrace the notion that "peak land" has been reached.

Equivalent crop production in 2009 required only 35% of land required in 1961



"Peak farmland": arable land use 1961 – 2009 and projections to 2060



SOURCE: For 1961–2009: FAO (2012).

"Land sparing" – a key component of sustainability

Graphs from Ausubel *et al.* 2012

Sustainable Intensification

"Simultaneously raising productivity, increasing resource use efficiency and reducing negative environmental impacts of agriculture"

An integrating concept to meet all primary challenges

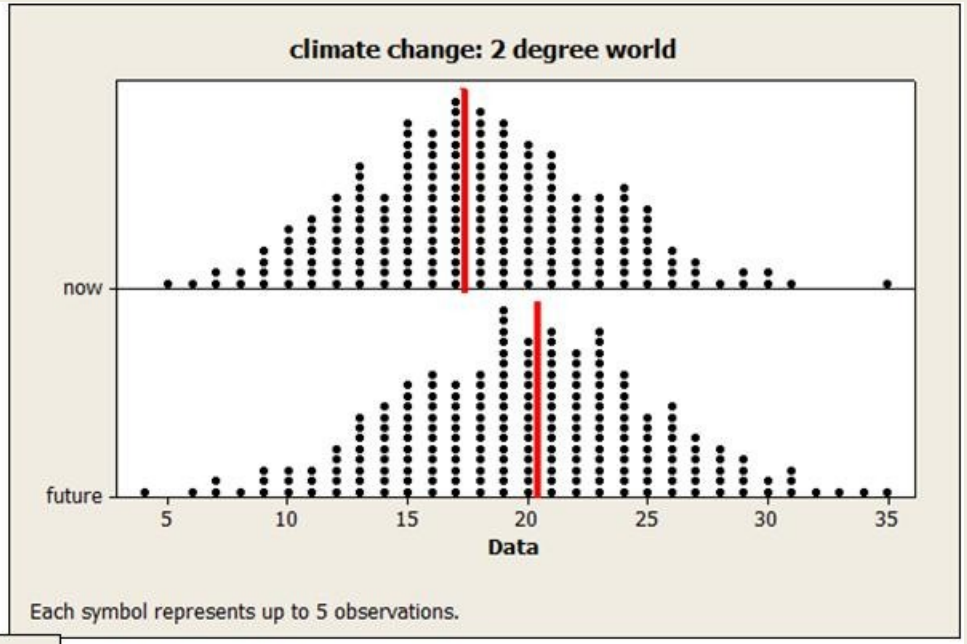
Producing as efficiently as possible on the smallest footprint of land capable of delivering (market) requirements is the "greenest" and usually the most profitable way to farm

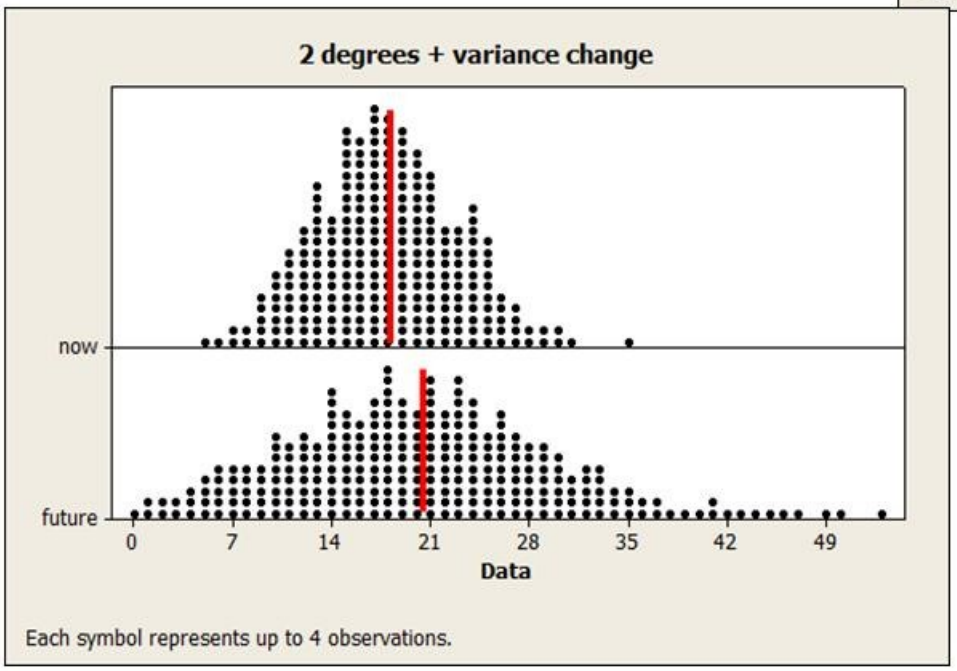
Bad weather may be under-estimated by climate models but there is increasing evidence for greater frequency of extreme weather events

Adapting to a changing climate is essential
- and starting now

E.g. Climate models are predicting increasing droughts in China over next 15 years

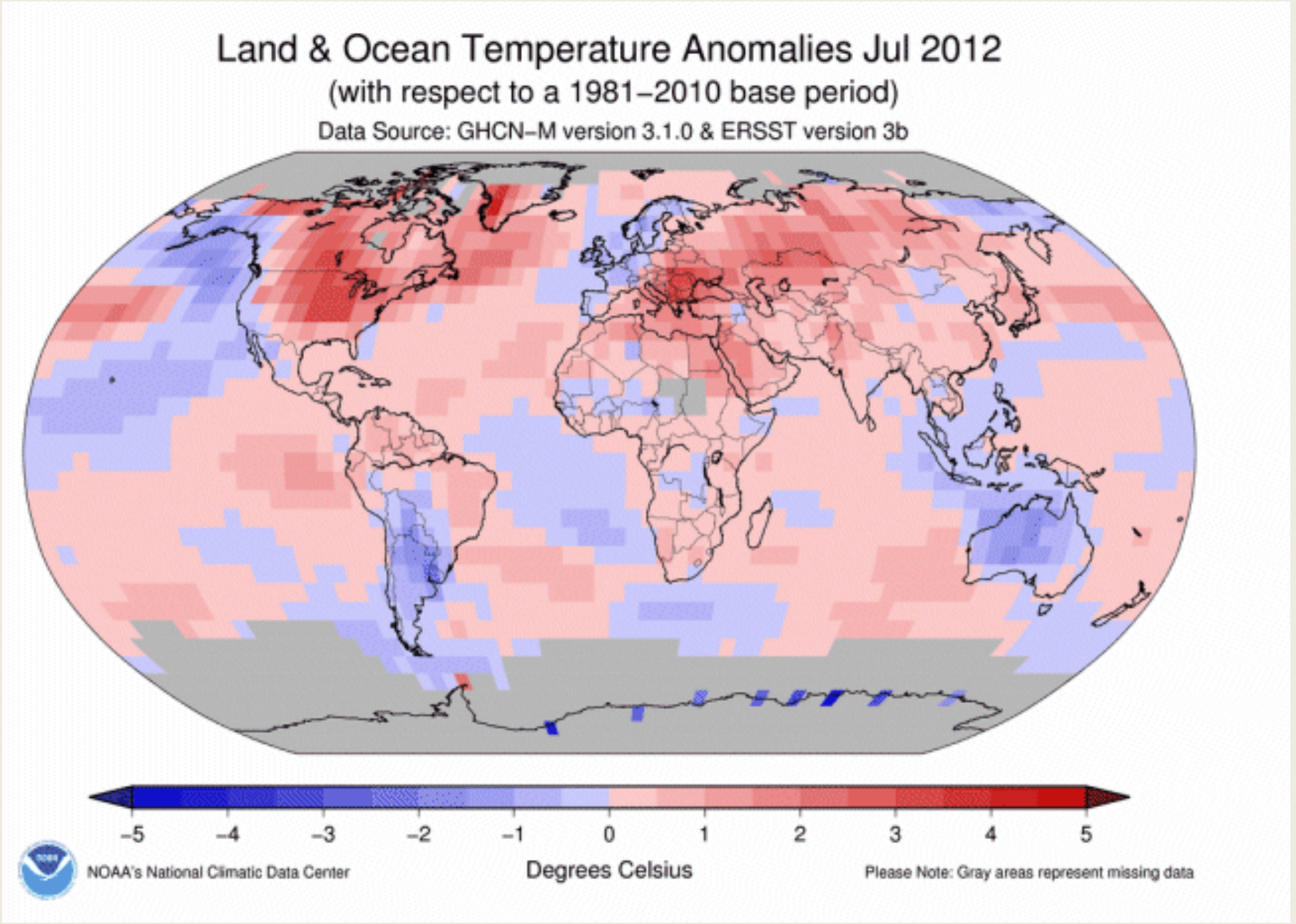
Increasing mean temperature and variance results in more frequent and more extreme events that can be global and difficult to predict





2012

- US heat-wave last summer 60x more likely than it would have been without climate change
- IPCC (2012) indicates 1-in-20 year heat events will become 1-in-2 by end of century
- Patterns of global supply threatened

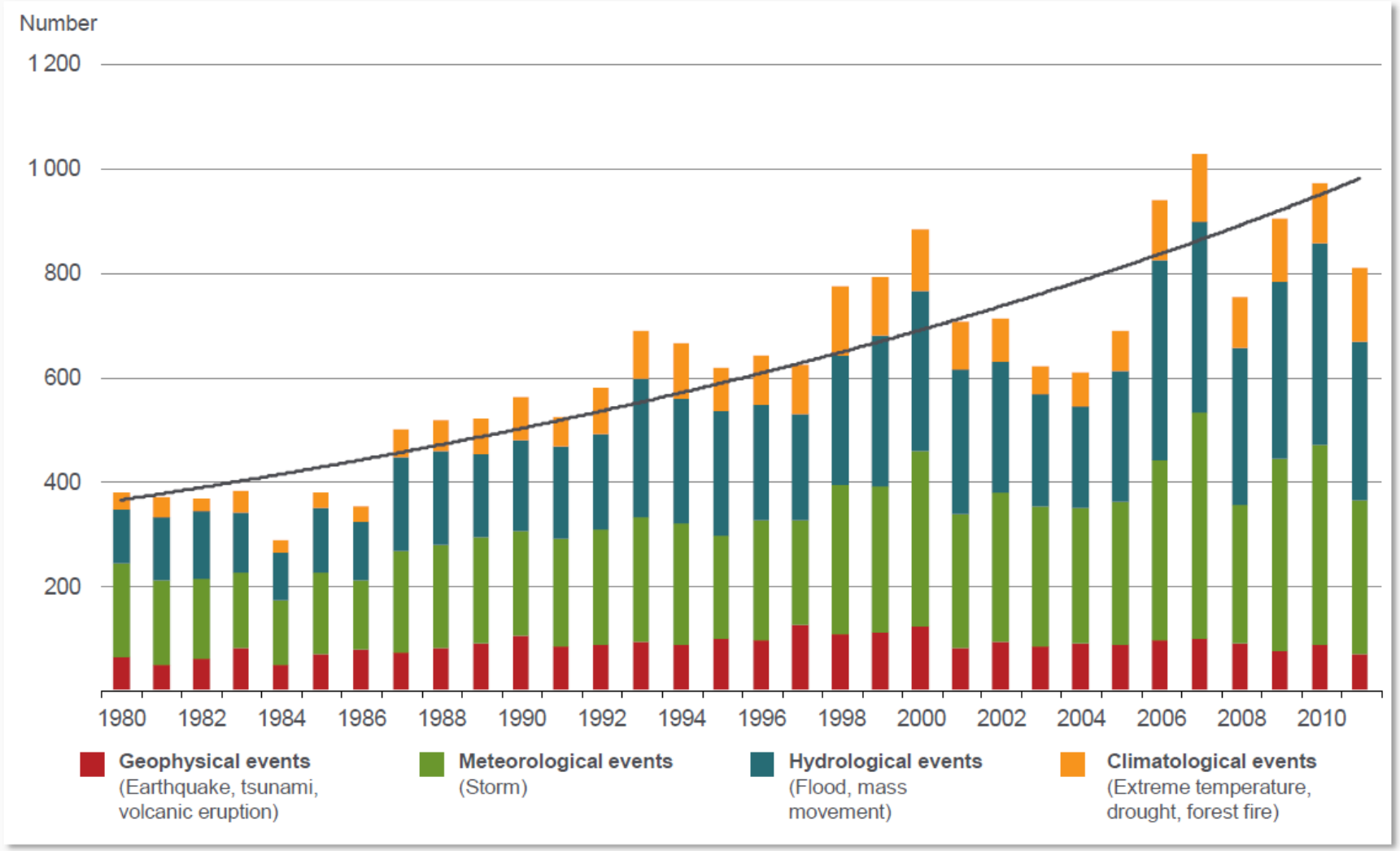

Land & Ocean Temperature Anomalies Jul 2012
(with respect to a 1981–2010 base period)
Data Source: GHCN–M version 3.1.0 & ERSST version 3b
–5
–4
–3
–2
–1
0
1
2
3
4
5
NOAA's National Climatic Data Center
Degrees Celsius
Please Note: Gray areas represent missing data

NatCatSERVICE

Natural catastrophes worldwide 1980 – 2011

Number of events with trend

Munich RE

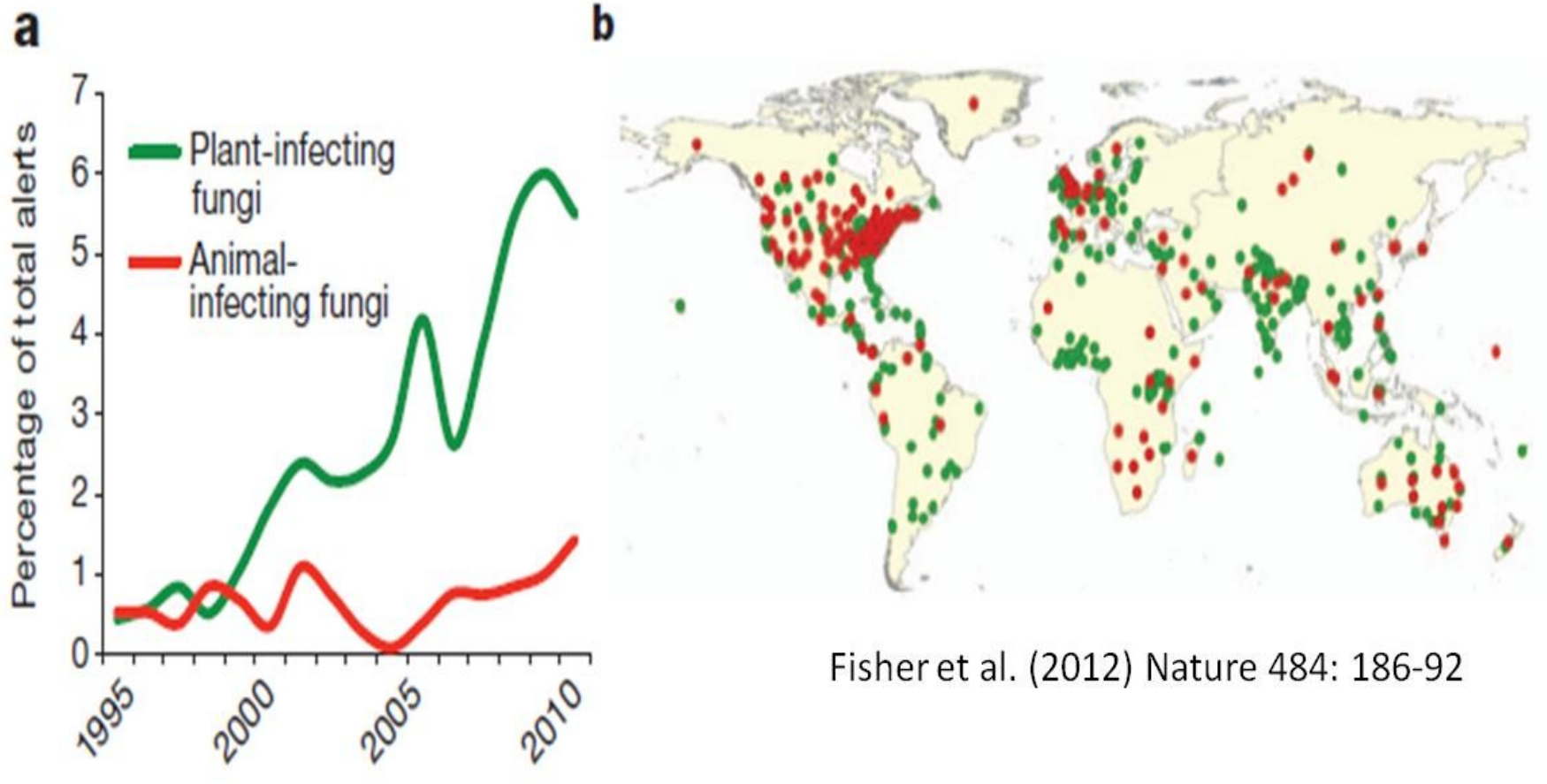


The global significance of crop loss due to diseases, pests and weeds.

Pests and diseases are on the move: new problems & new places

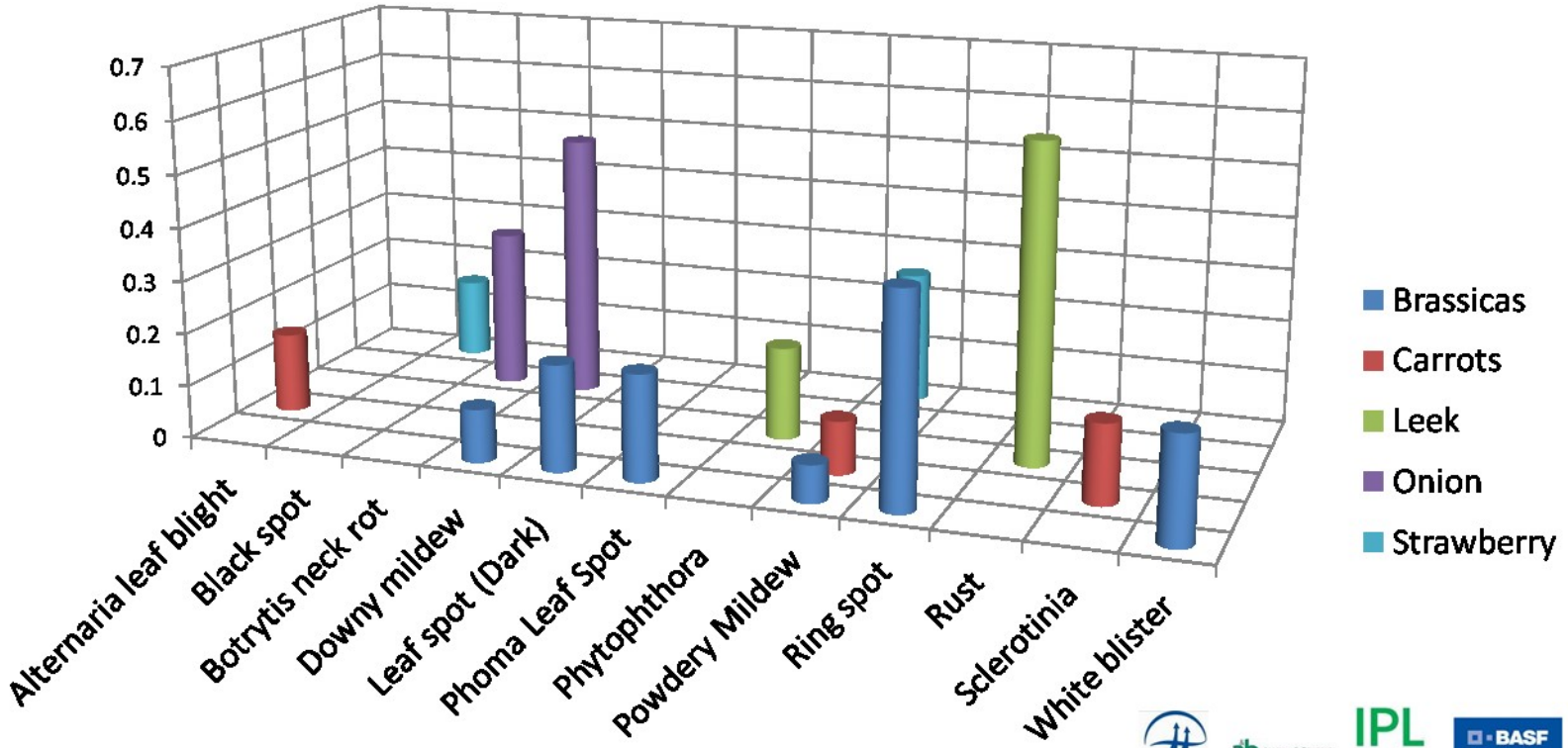
Climate change……Global trade……Loss of CPPs……?

Emerging infectious diseases(EIDs) - pathogens that are increasing in: ***incidence***, ***geographic or host range***, and ***virulence***



Fisher et al. (2012) Nature 484: 186-92

Estimated yield losses threatened by EU 91.414 impact on fungicides



AHDB Agriculture & Horticulture DEVELOPMENT BOARD

SCEPTRE

(Sustainable Crop & Environment Protection Targeted Research for Edibles)

Examples of disease resistance in action

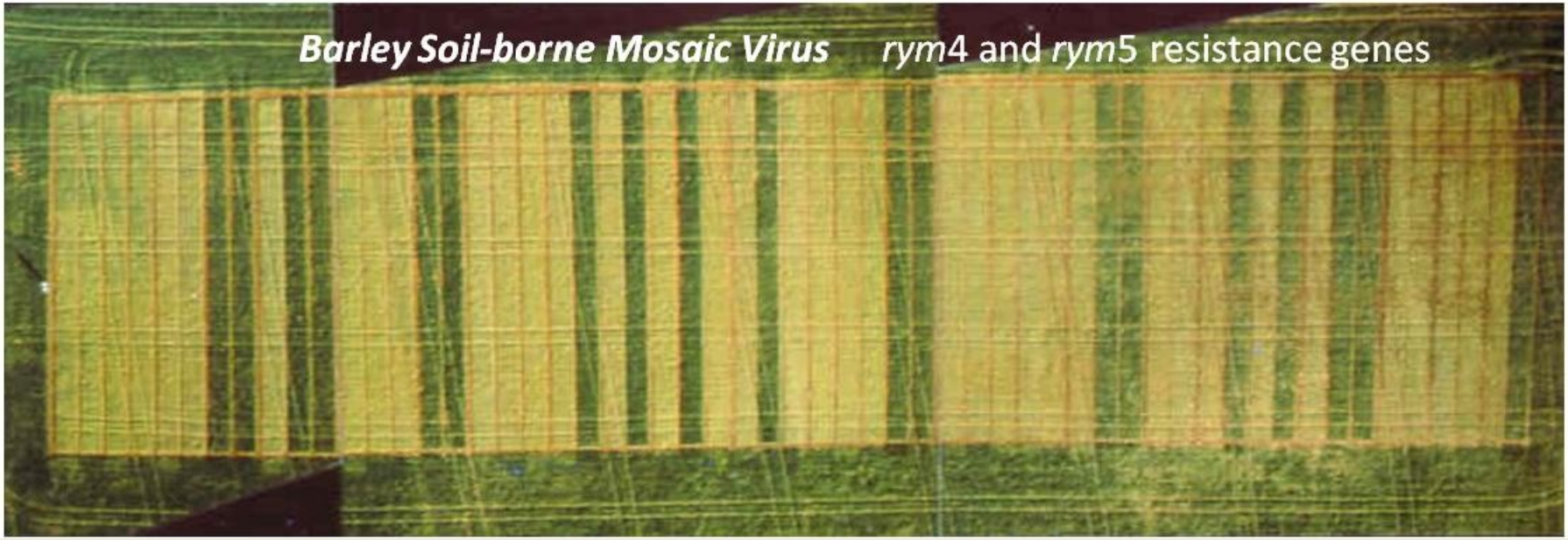
- often due to single genes

Parsnip canker

Lettuce root aphid

Strawberry Wilt

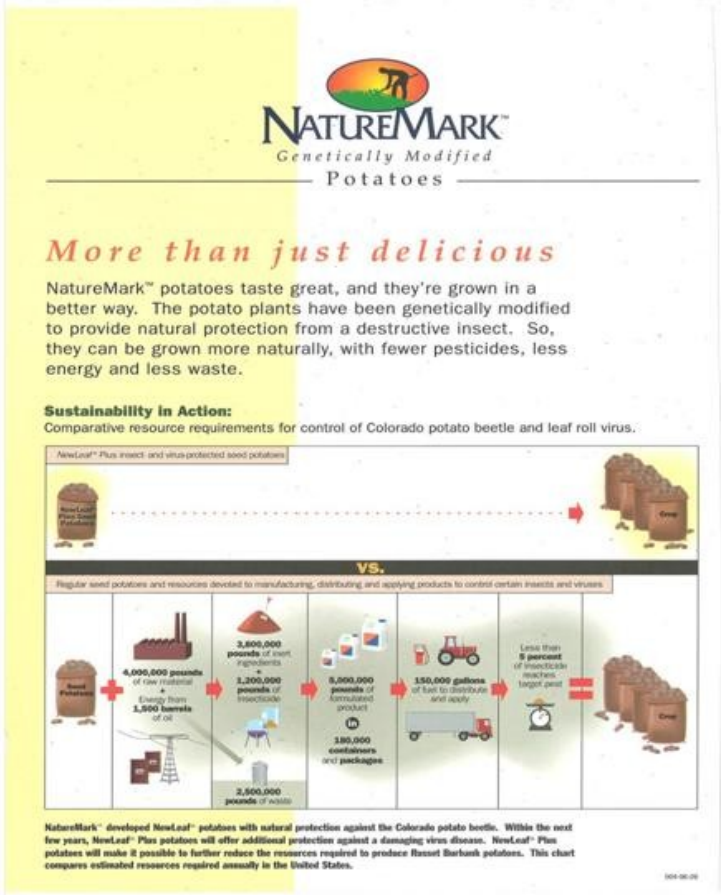
Clubroot of brassicas



Barley Soil-borne Mosaic Virus *rym*4 and *rym*5 resistance genes

1996 Product Promotion

- How long before we will see this again for fresh produce?
- Is this 17 wasted years *and* 17 years of waste?



NATUREMARK™
Genetically Modified
Potatoes

More than just delicious

NatureMark™ potatoes taste great, and they're grown in a better way. The potato plants have been genetically modified to provide natural protection from a destructive insect. So, they can be grown more naturally, with fewer pesticides, less energy and less waste.

Sustainability in Action:
Comparative resource requirements for control of Colorado potato beetle and leaf roll virus.

NewLeaf™ Plus insect- and virus-protected seed potatoes

Crop

VS.

Regular seed potatoes and resources devoted to manufacturing, distributing and applying products to control certain insects and viruses

Seed Potatoes

4,000,000 pounds of raw material + Energy from 1,500 barrels of oil

3,800,000 pounds of inert ingredients + 1,200,000 pounds of insecticide

2,500,000 pounds of waste

5,000,000 pounds of formulated product in 180,000 containers and packages

150,000 gallons of fuel to distribute and apply

Less than 5 percent of insecticide reaches target pest

Crop

NatureMark™ developed NewLeaf™ potatoes with natural protection against the Colorado potato beetle. Within the next few years, NewLeaf™ Plus potatoes will offer additional protection against a damaging virus disease. NewLeaf™ Plus potatoes will make it possible to further reduce the resources required to produce Russet Burbank potatoes. This chart compares estimated resources required annually in the United States.

More than just delicious

NatureMark™ potatoes taste great, and they're grown in a better way. The potato plants have been genetically modified to provide natural protection from a destructive insect. So, they can be grown more naturally, with fewer pesticides, less energy and less waste.

1996 Product Promotion

"Sustainability in Action"

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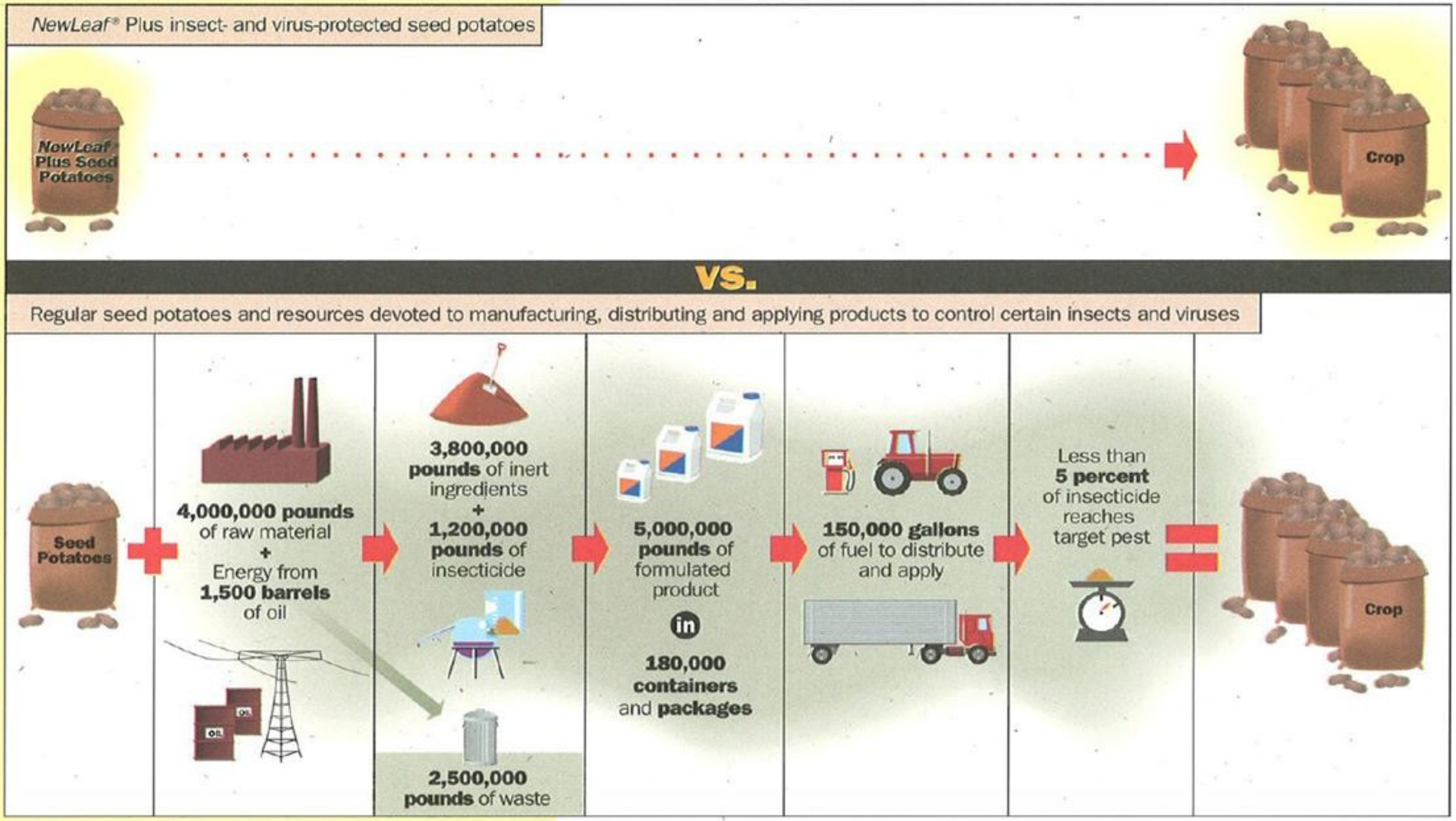


It can't be pesticides ***or*** genetics

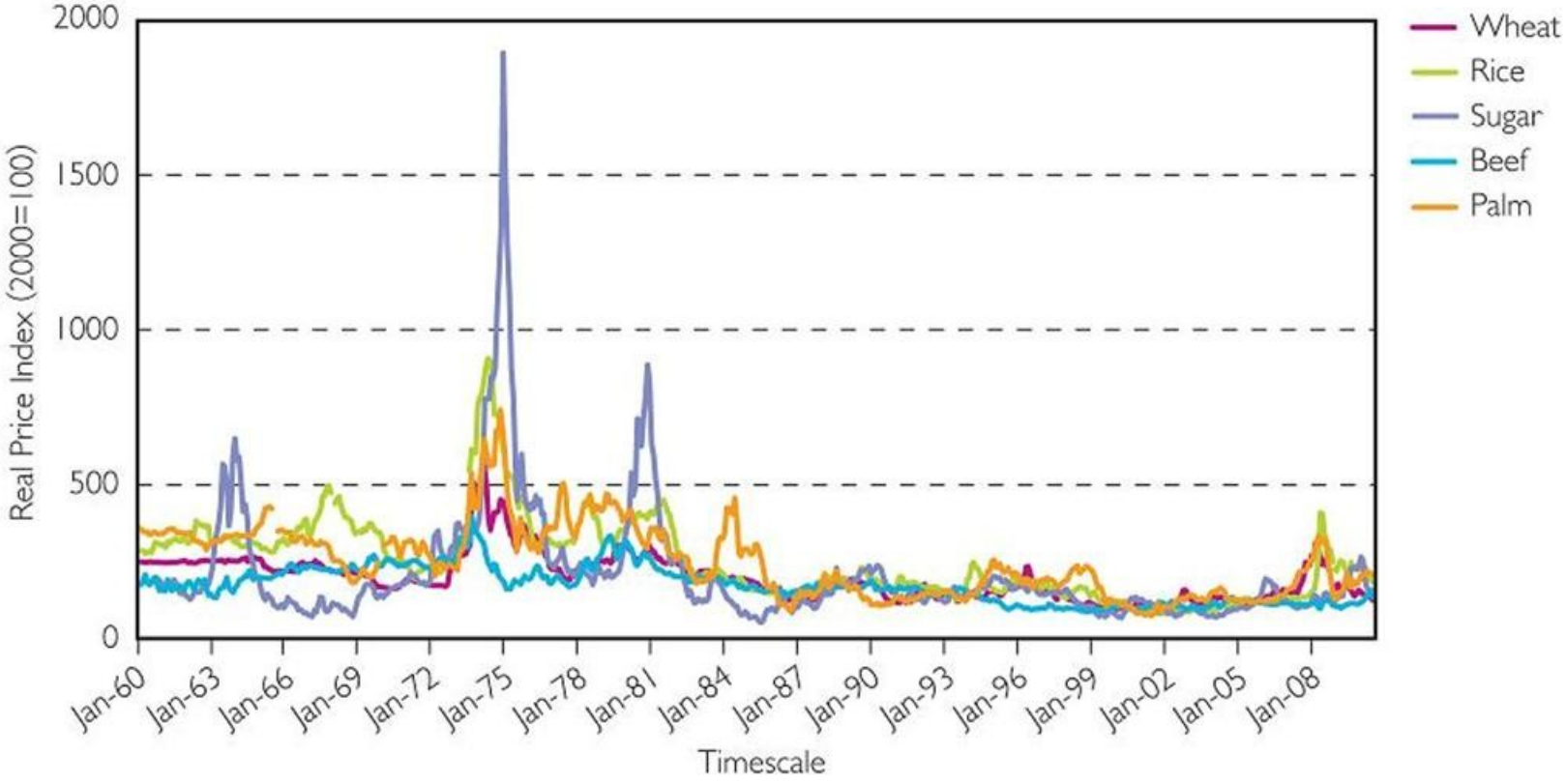
It must be pesticides ***and*** genetics

We need all the tools in the box!

An informative graph from Foresight

Price volatility

Global real price indices for major agricultural products since 1960



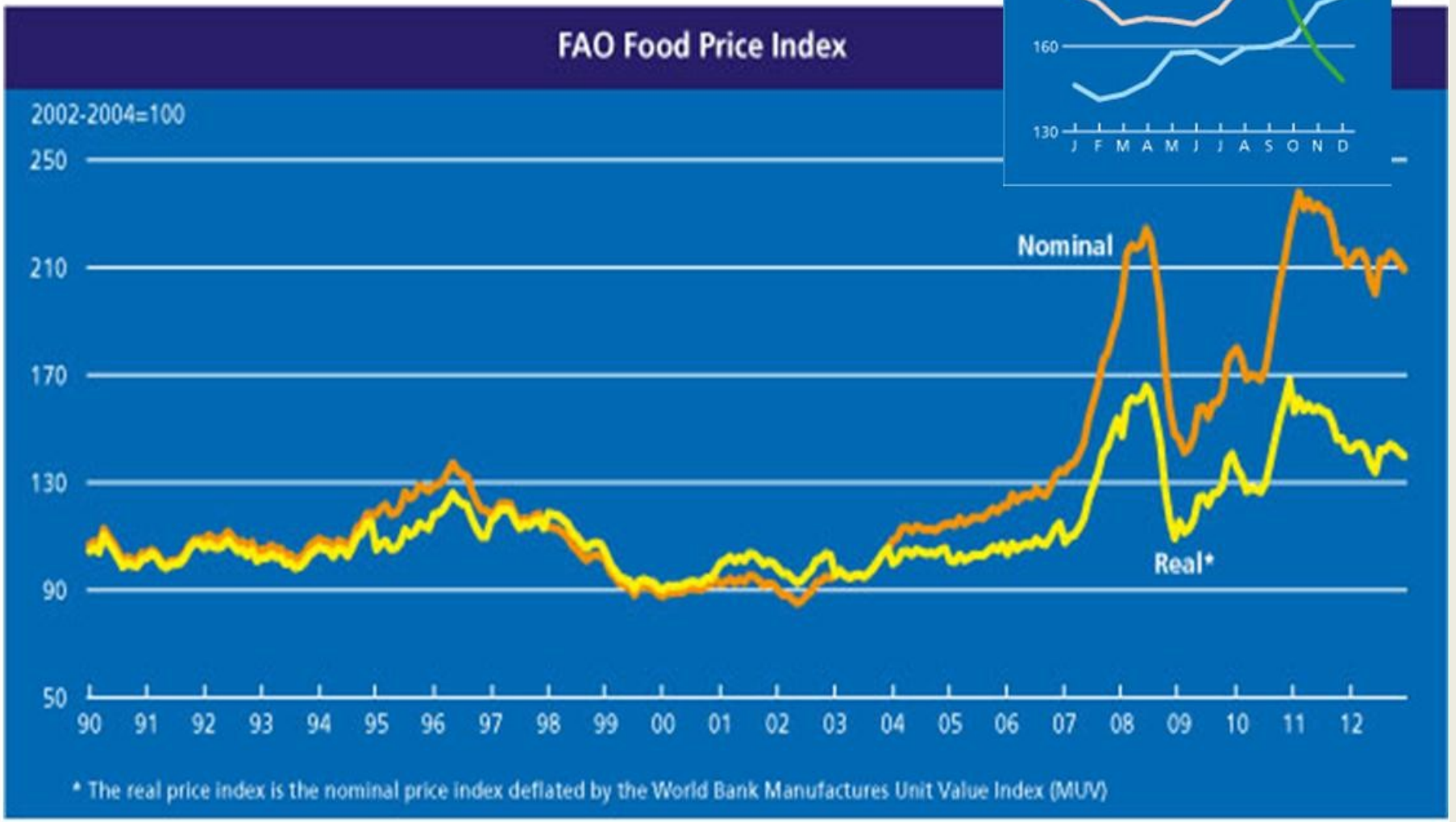
Source: HMG (2010) Data sourced from UNCTAD, BEA

More than twenty years (’86 – ’07) of plentiful, cheap food led globally (with exceptions) to:

- Government complacency (but commercial innovation)
- Disinvestment in technical skills, research capacity and extension;
- A change of primary focus (for public investment):
  - environmental impact;
  - socio-economic issues;
  - basic science.

But we have now entered a different world……

The days of cheap food may be over - perhaps for ever



Components of the sustainable elevation of solar energy conversion

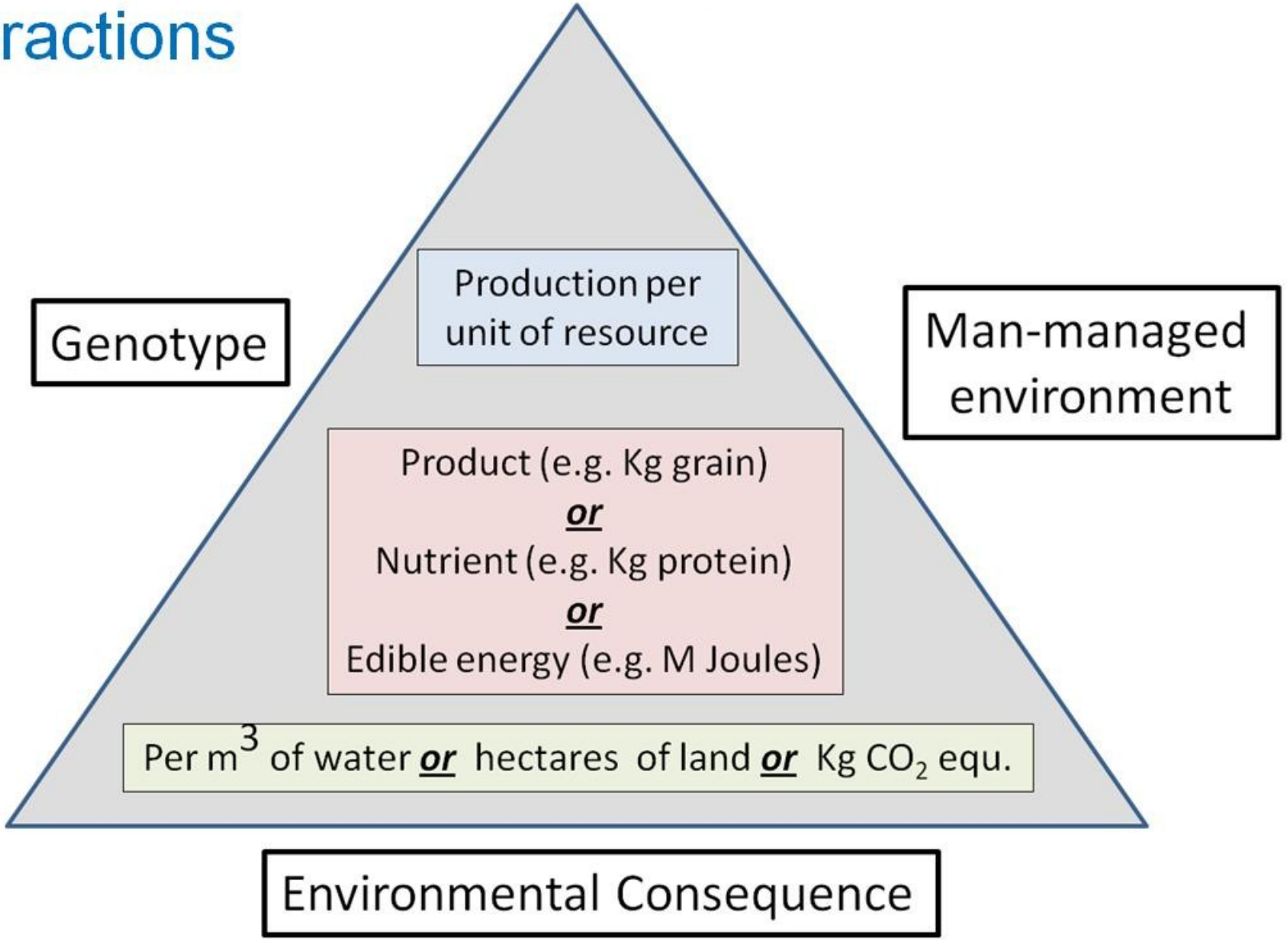
Increase genetic potential

Realise genetic potential

Reduce waste

Reduce environmental impact

Metrics for understanding, managing and manipulating outcomes, impacts and interactions



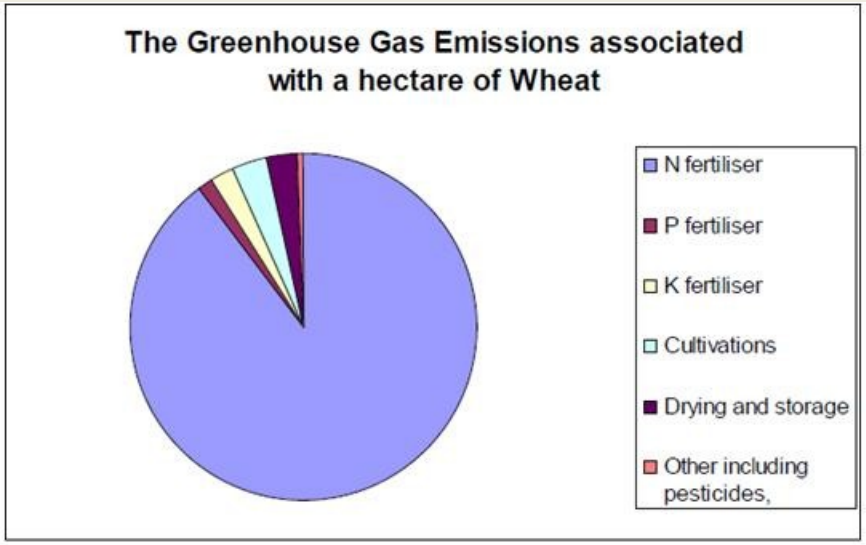
Crop (and livestock) health is fundamental to GHG emissions reduction

GHG emissions to grow a crop of wheat
– ca. 4000 - 5000 $KgCO_2eq./ha$

(N, other ag-chem, machinery, cultivations, spraying, harvesting)

Waste = lost yield + wasted inputs (economic) and > emissions/tonne

Nitrogen inputs, cultivated areas, yield and N use efficiency are key determinants of GHG emissions from cropped land



Mortimer (2003)

Nine UK & Danish wheat crops			
	Fungicide	No fungicide	SEM
Opt. N (kg/ha)	158	106	11.5 **
Yield (t/ha)	8.9	6.7	0.55 **
GHG emissions – Kg CO_2 eq. per tonne			
Fungicide/treated optimum	417		
No fungicide/untreated optimum	430		12 (NS)
No fungicide/treated optimum	546		31**
No fungicide/untreated opt. + LUC	740		70**

Berry et al (2010)

Comparative "sustainability" – UK Crops

	Potatoes	Wheat
Yield (tonne/Ha)	45	8
% starch	15	70
Starch (tonne/Ha)	6.8	5.6
Energy (GJ/Ha) [A]	116 (15%>)	95
Man-days of carb. /Ha[B]	*ca.*17,000	*ca.*14,000
N-use Kg/Ha	150	200
KgStarch/KgN	45	28
$KgCO_2$ equ./GJ [C]	3.9	6.3
Area (KHa)	130	1900
Irrigation m^3/Ha	615	3
MJ/m^3 irrigation (UK crop)	190	32,000

A – starch delivers 17kJ/g; B – 6.8MJ/day from carb.; C – I Kg N yields ca. 3 Kg CO_2 equ.
(? Relative proportion of GJ "consumed" – i.e. relative waste?)

Efficiency/Sustainability Metrics: - some (preliminary) considerations

- Must enable meaningful comparisons ["benchmarking"?]
  - over time, between systems or products or enterprises or businesses….
- Must be transparent to identify opportunities for "improvement"
- Must be spatially specific & explicit (e.g. allow for +ve/-ve edaphic and climatic factors

The Efficiency Ratio (O:I): "Output" Numerator and "Impact" Denominator

Output Numerator(s) (O) – Mass (Kg) and/or Energy (KJoules)
E.g. total biomass; macronutrients (carbs.; protein; oil/fat); food/feed energy

Impact Denominator(s) (I) – *weighted by site/time specific importance*
- land area (surrogate for biodiversity?) – Ha
- extracted water (m^3)
- fossil fuel use (KJoules) – incl. embedded in manufactured inputs
- net GHG emissions ($KgCO_2eq.$) – CH_4, N_20, CO_2
- NH_4 emissions
- eutrophication potential (NO_3 , PO_4)

Crute, I.R. (2012)

"Balancing the environmental consequences of agriculture with the need for food security".

Issues in Environmental Science and Technology **34:** 129-49.

Environmental Impacts of Modern Agriculture
(Edited by R.E. Hester and R.M. Harrison)

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Take-home messages for further debate:

- More research and analysis is required to develop meaningful and refined metrics for determining comparative sustainability of production systems.

- The short-term costs, as well as the long-term benefits, of sustainable production need to shared fairly through the food chain.

- There is a shared responsibility to promote technology as a contributor to sustainability – "dumbing down" messages about sustainability is unhelpful.