UNIVERSITY OF LEEDS

CHATHAM HOUSE
The Royal Institute of International Affairs

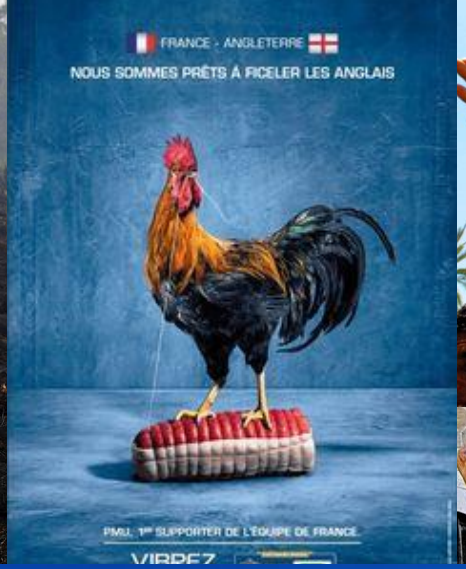
Food systems and their fragility in a globalized world

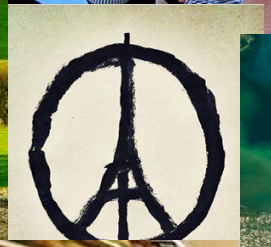
Tim Benton

University of Leeds and Royal Institute of International Affairs, Chatham House

t.g.benton@leeds.ac.uk

@timgbenton





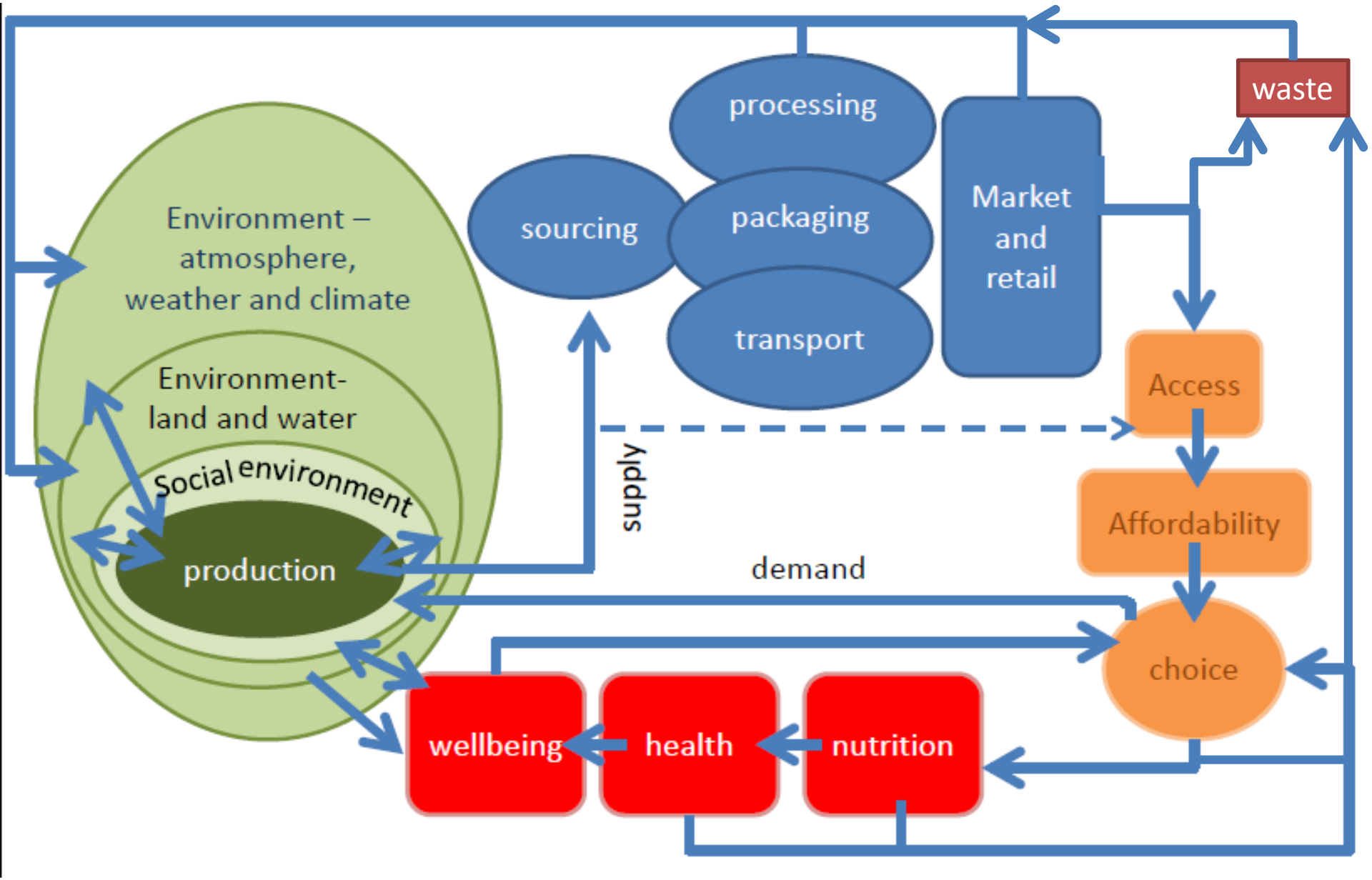
The State of Food Insecurity in the World

UNIVERSITY OF LEEDS

CHATHAM HOUSE
The Royal Institute of International Affairs

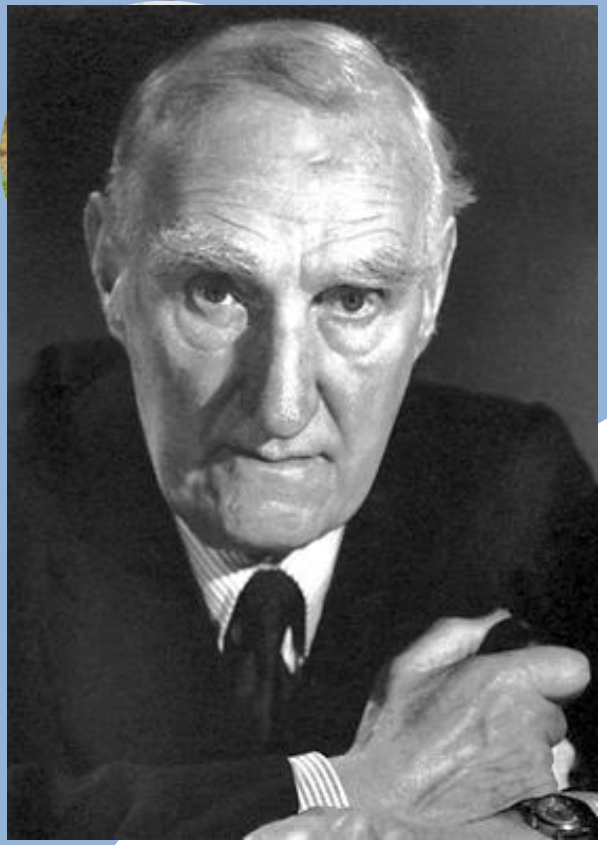
THE GROWTH AND EXTENT OF THE GLOBALISED FOOD SYSTEM

What is a food system?



Food systems are spatial: 90% of Singapore's food is produced by ~30 other countries

Consumerism and globalisation as a key post-WW2 strategy



Lord Boyd Orr resigned from the FAO in 1949 after running into opposition from governments for his program to insure that food would be available at prices fair to farmers and consumers. (Obit, NYT, 1971)

The economist Victor Lebow famously said, in 1955:

Our enormously productive economy demands that we make consumption our way of life, that we convert the buying and use of goods into rituals, that we seek our spiritual satisfactions, our ego satisfactions, in consumption. The measure of social status, of social acceptance, of prestige, is now to be found in our consumptive patterns. The very meaning and significance of our lives today expressed in consumptive terms….in terms of what he wears, drives, eats – his home, his car, his pattern of food serving, his hobbies….

We need things consumed, burned up, worn out, replaced, and discarded at an ever increasing pace. We need to have people eat, drink, dress, ride, live, with ever more complicated and, therefore, constantly more expensive consumption.

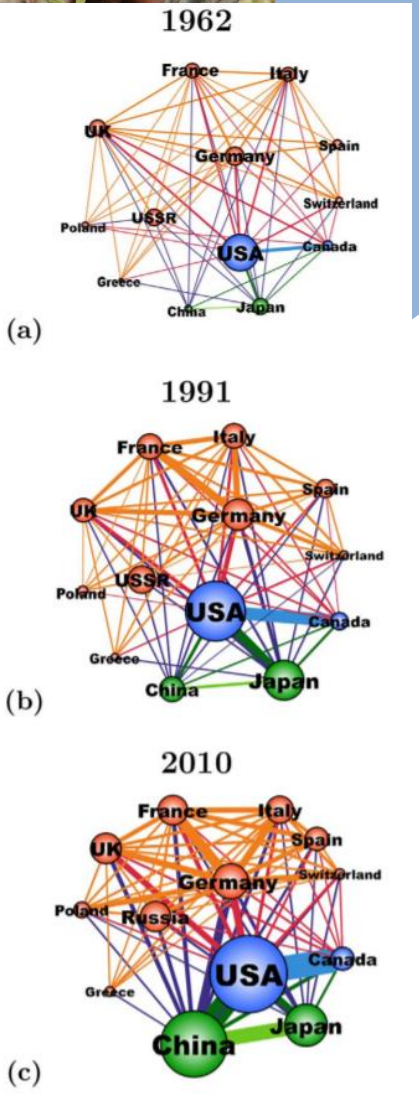
OPEN ACCESS Freely available online

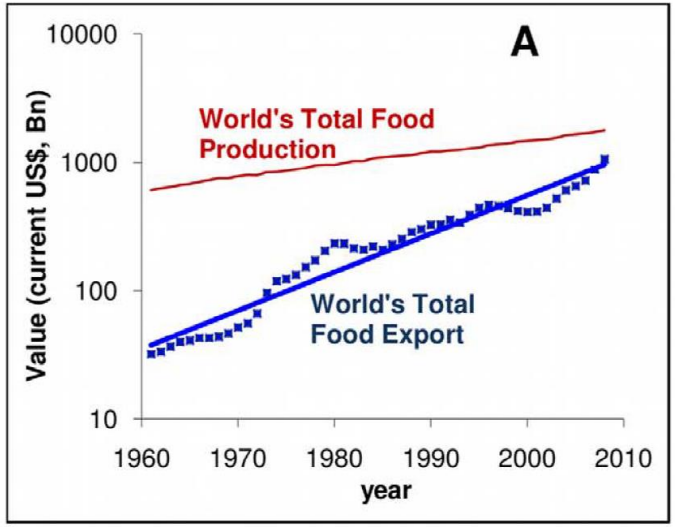
PLoS one

Complexity of the International Agro-Food Trade Network and Its Impact on Food Safety

Mária Ercsey-Ravasz[1,2], Zoltán Toroczkai[1], Zoltán Lakner[3], József Baranyi[4]*

May 2012 | Volume 7 | Issue 5 | e37810





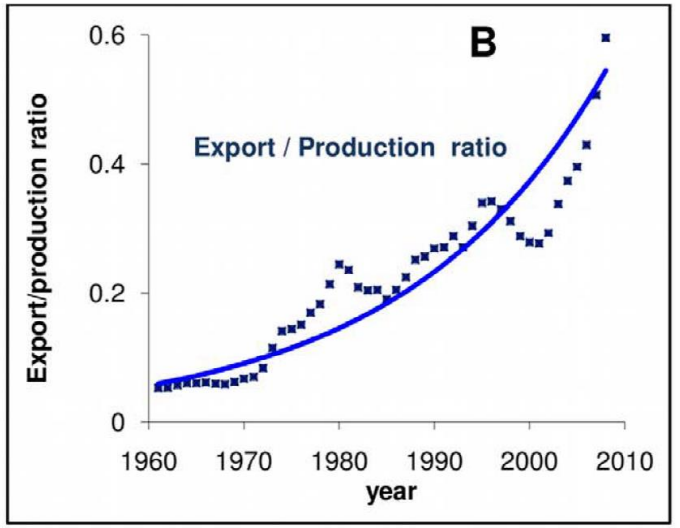


Figure 1. The world's food trade grows faster than the food production. (**A**) (Log-linear scale). The world's food production (thin red line), measured in current Billion US$, doubles in ca. 30 years, while the amount of food transported on the IFTN (linearly fitted small squares, blue) increases by ca. 10-fold in the same time. (**B**) (Linear scale). Food ingredients flow at an increasing rate from countries to countries, as shown by the exponentially increasing [world export]/[world production] ratio calculated from the above data (small squares fitted by an exponential curve). Note that this ratio is unaffected by the US$ inflation rate. Data obtained from UN databases [6,23].
doi:10.1371/journal.pone.0037810.g001

Revealing the Hidden Language of Complex Networks

Ömer Nebil Yaveroğlu[1], Noël Malod-Dognin[1], Darren Davis[2], Zoran Levnajic[1,6], Vuk Janjic[1], Rasa Karapandza[3], Aleksandar Stojmirovic[4,5] & Nataša Pržulj[1]

SCIENTIFIC REPORTS | 4 : 4547 | DOI: 10.1038/srep04547

Puma et al 2015

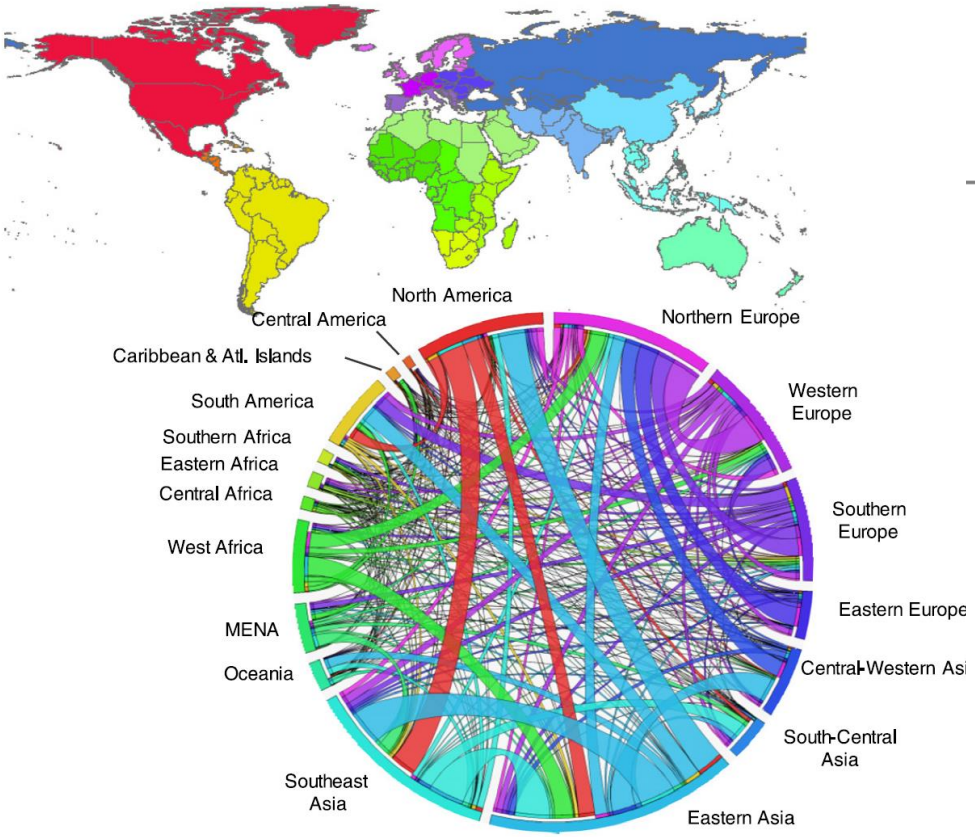


Figure 1. Global seafood trade among regions represented as color groups. The width of each band represents quantity traded (tonne per year), and the band color represents the importer. Note that MENA stands for Middle East and North Africa.

Environ. Res. Lett. **11** (2016) 035008 doi:10.1088/1748-9326/11/3/035008

Environmental Research Letters

LETTER

Vulnerability to shocks in the global seafood trade network

Jessica A Gephart[1], Elena Rovenskaya[2,3], Ulf Dieckmann[2], Michael L Pace[1] and Åke Brännström[2,4]

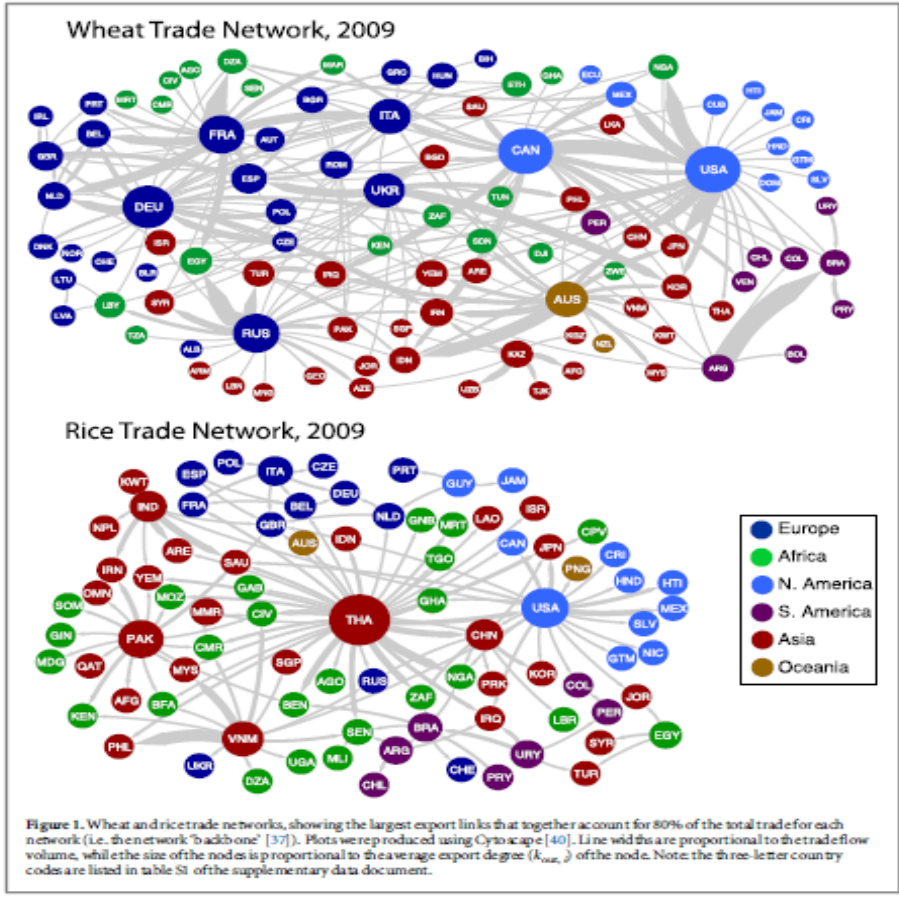
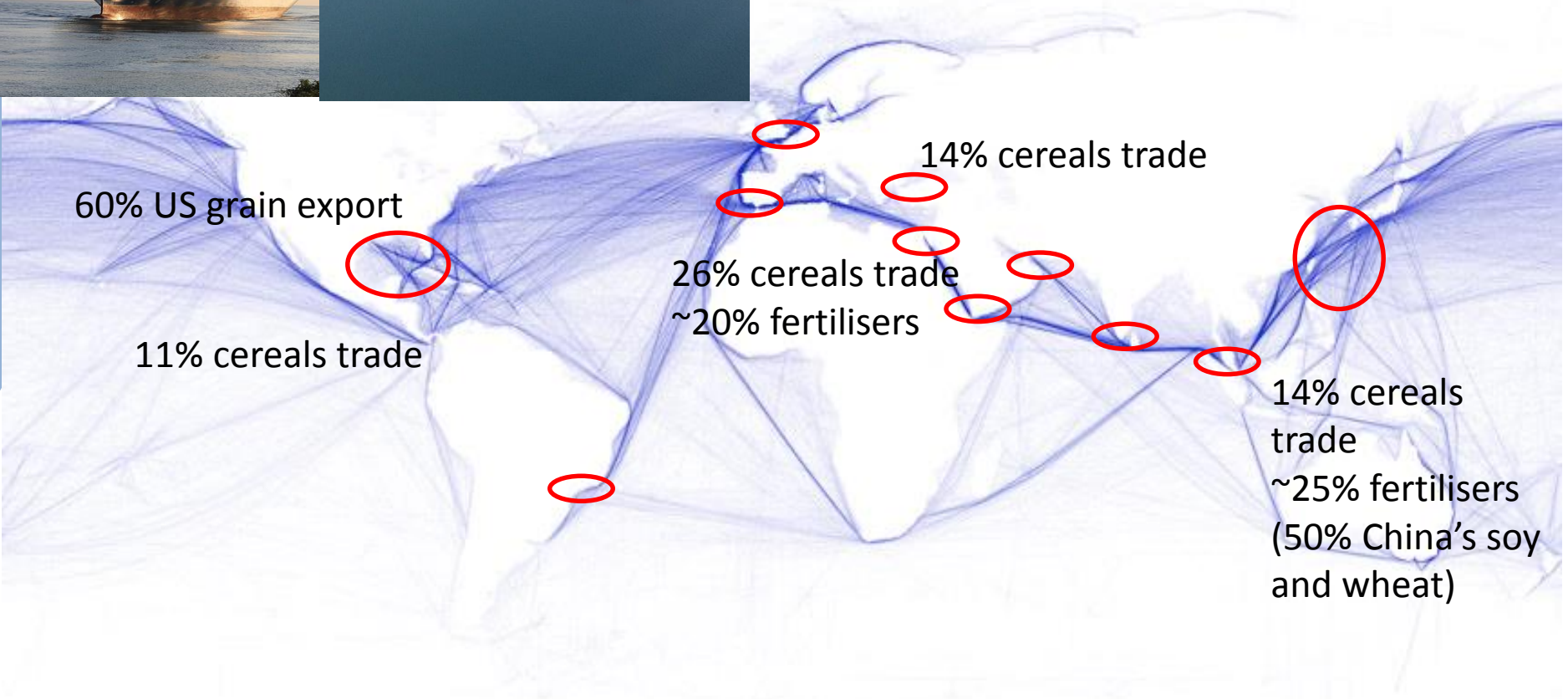


Figure 1. Wheat and rice trade networks, showing the largest export links that together account for 80% of the total trade for each network (i.e. the network 'backbone' [37]). Plots were reproduced using Cytoscape [40]. Line widths are proportional to the trade flow volume, while the size of the nodes is proportional to the average export degree ($k_{out,i}$) of the node. Note: the three-letter country codes are listed in table S1 of the supplementary data document.

Soy movements: direct and indirect

http://www.eea.europa.eu/data-and-maps/figures/net-trade-flows-in-soya (2012)

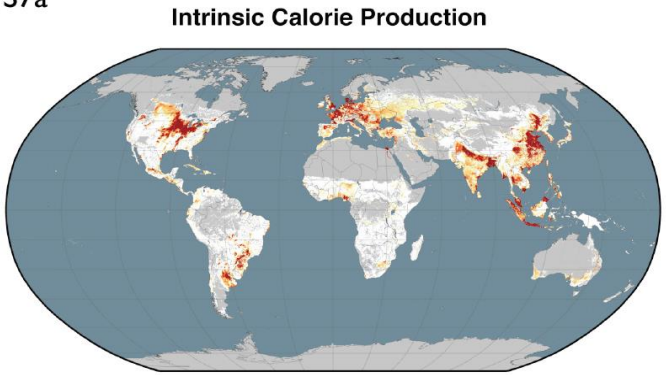
Supply chain logistics



courtesy of http://rsif.royalsocietypublishing.org/content/early/2010/01/19/rsif.2009.0495.full

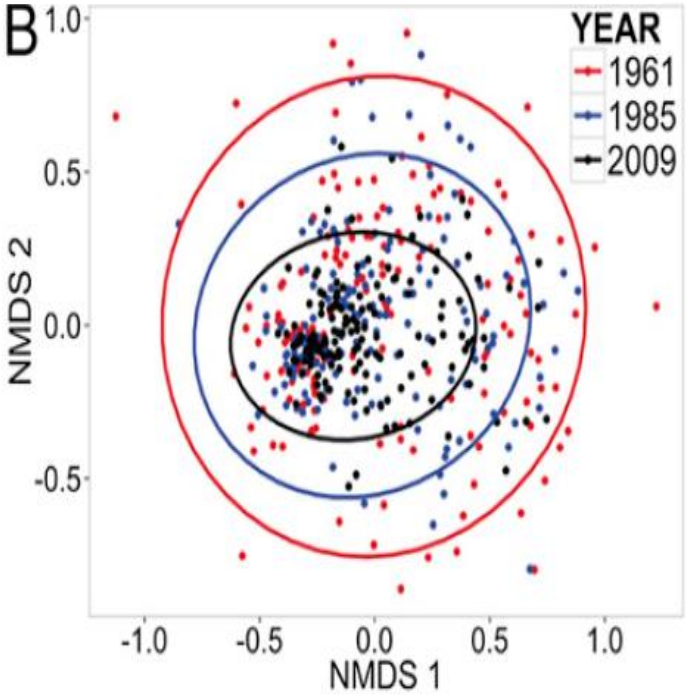
Comparative advantage leads to global concentration & homogenisation

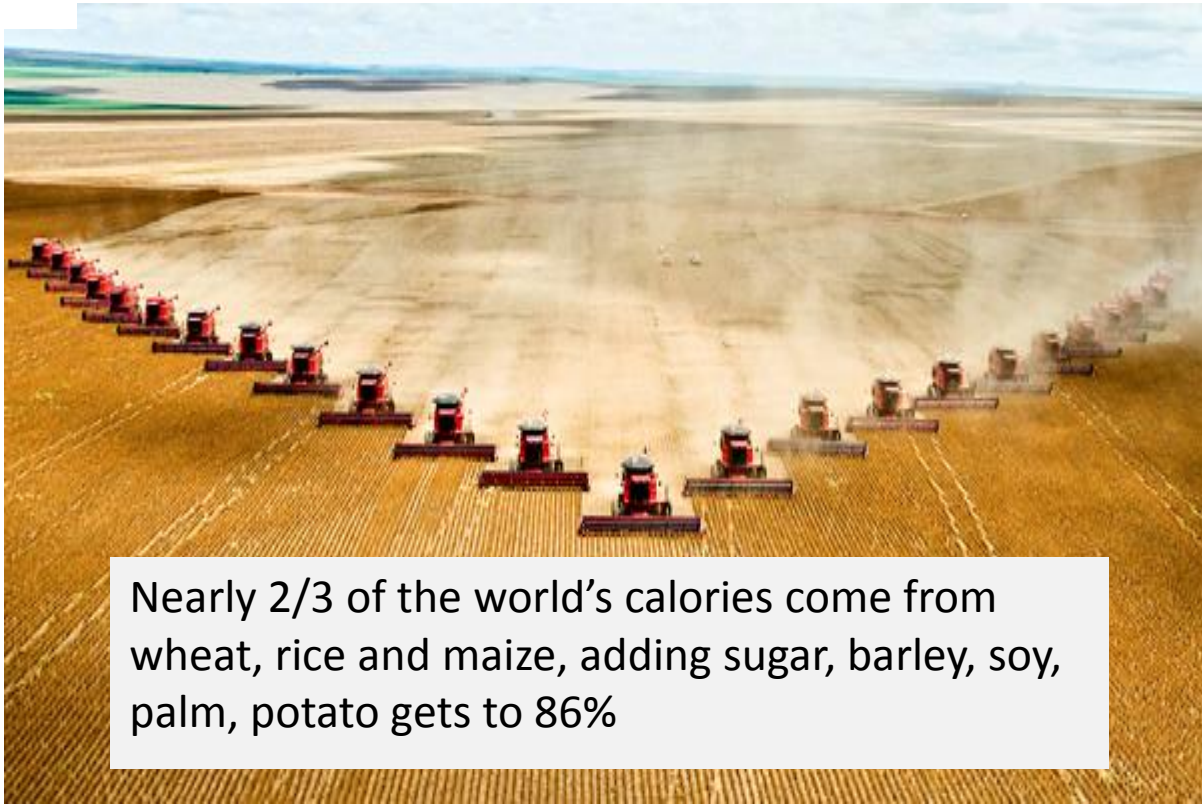
Fig 37a



Foley et al 2011

Statistical “map” of global diets





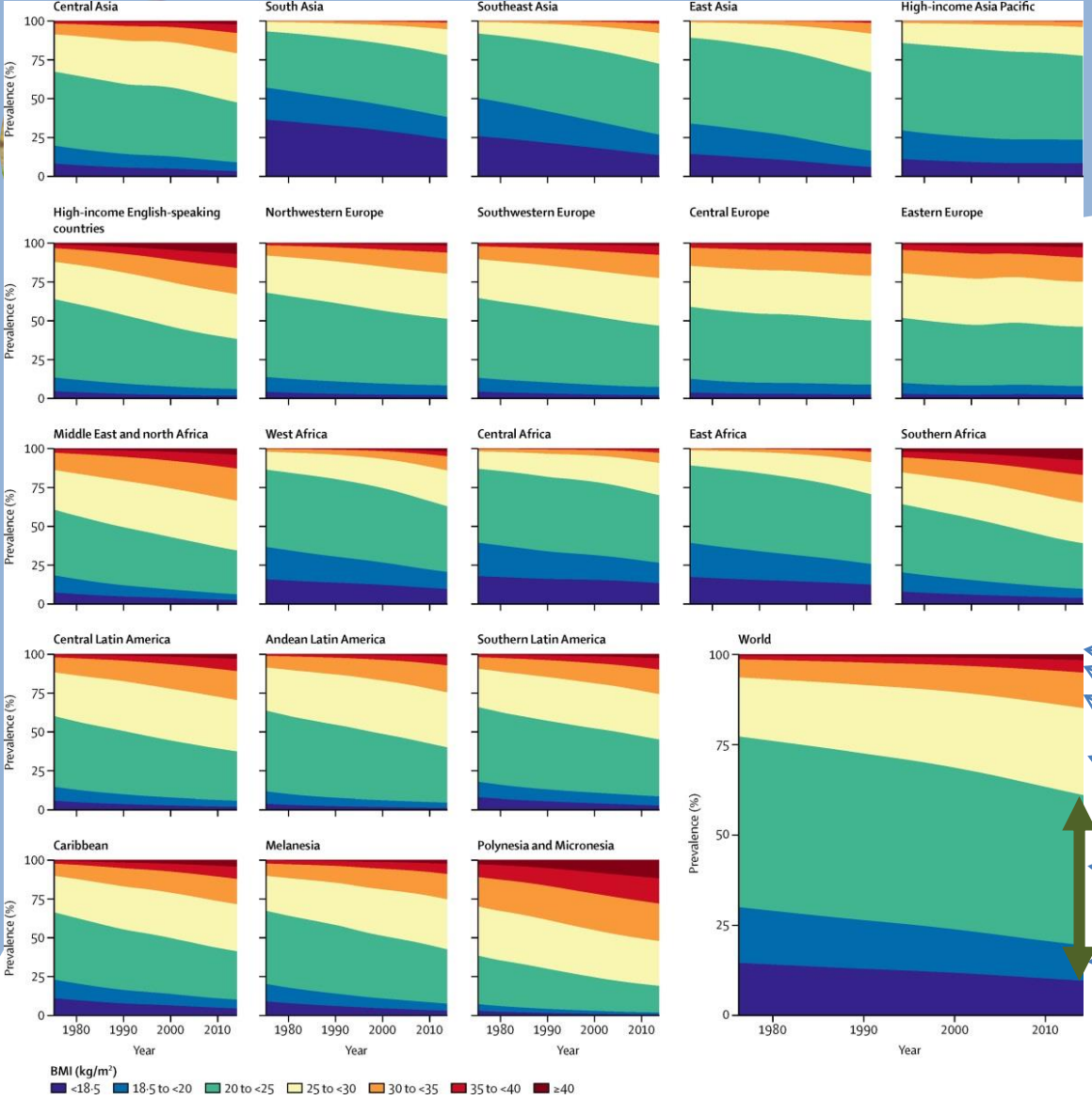
Nearly 2/3 of the world’s calories come from wheat, rice and maize, adding sugar, barley, soy, palm, potato gets to 86%

Increasing homogeneity in global food supplies and the implications for food security

Colin K. Khoury[a,b,1], Anne D. Bjorkman[c,d], Hannes Dempewolf[d,e,f], Julian Ramirez-Villegas[a,g,h], Luigi Guarino[f], Andy Jarvis[a,g], Loren H. Rieseberg[d,e,i], and Paul C. Struik[b]

Trends in adult body-mass index in 200 countries from 1975 to 2014: a pooled analysis of 1698 population-based measurement studies with 19·2 million participants *The Lancet* Volume 387, Issue 10026, Pages 1377-1396 (April 2016) DOI: 10.1016/S0140-6736(16)30054-X

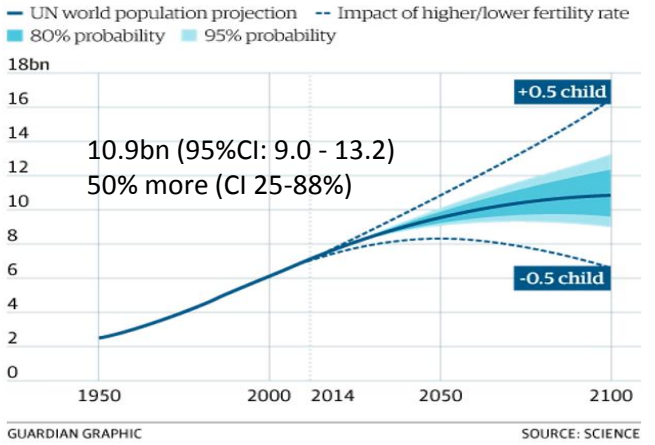
Trends in age-standardised prevalence of BMI categories in women by region



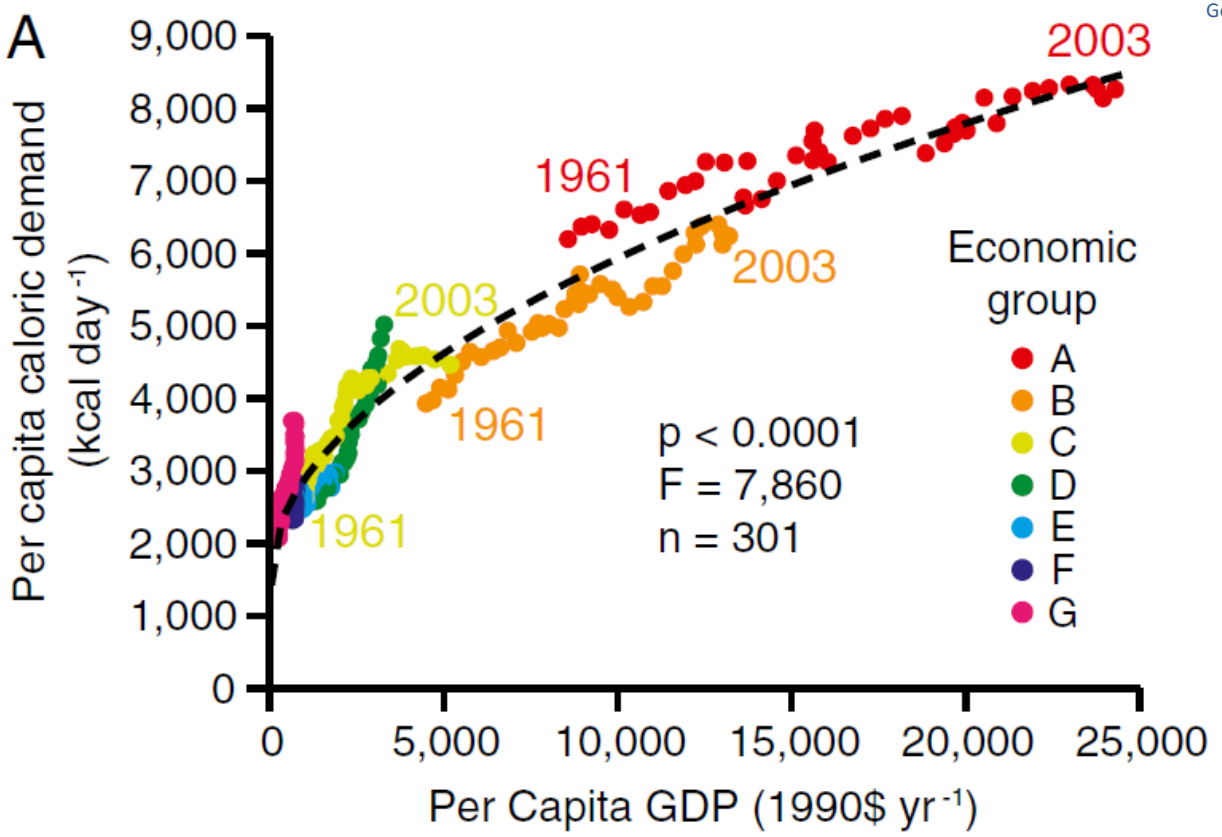
Very very obese
Very obese
Obese
Overweight
Normal
Low normal
Underweight

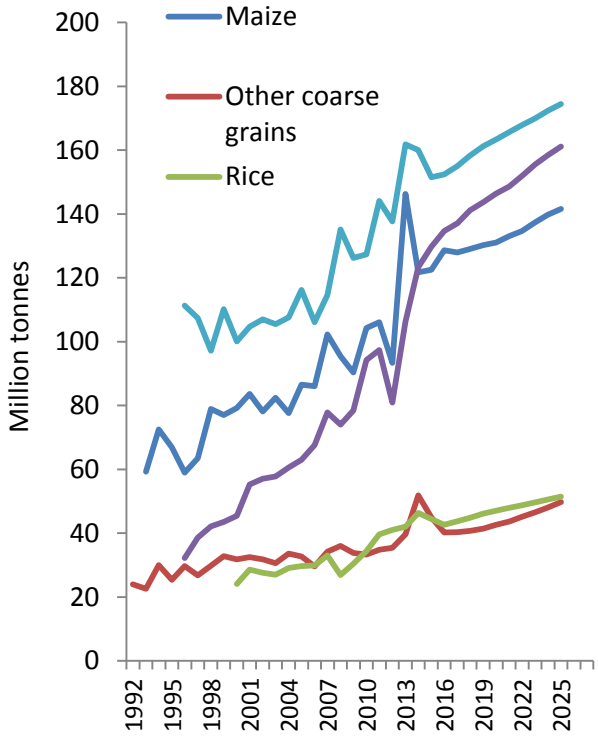
UNIVERSITY OF LEEDS

Growing global income creates demand



Gerland et al 2014 Science **World population stabilization unlikely this century**

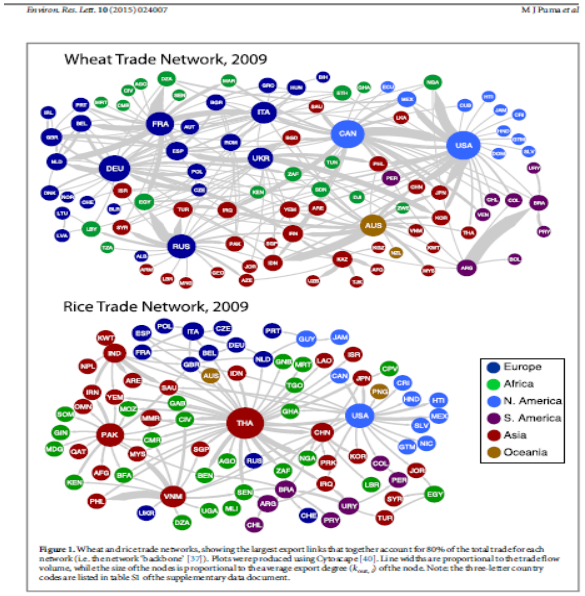




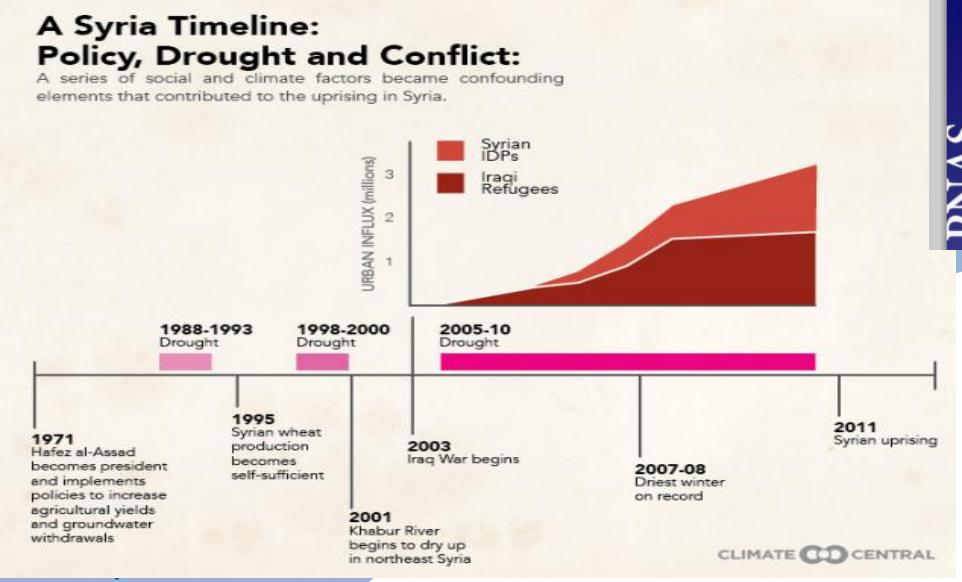
Tilman et al., 2011 (PNAS)

UNIVERSITY OF LEEDS

CHATHAM HOUSE
The Royal Institute of International Affairs



GROWING THREATS



International Affairs

PNAS

Climate change in the Fertile Crescent and implications of the recent Syrian drought

Colin P. Kelley[a,1], Shahrzad Mohtadi[b], Mark A. Cane[c], Richard Seager[c], and Yochanan Kushnir[c]

[a]University of California, Santa Barbara, CA 93106; [b]School of International and Public Affairs, Columbia University, New York, NY 10027; and [c]Lamont–Doherty Earth Observatory, Columbia University, Palisades, NY 10964

Edited by Brian John Hoskins, Imperial College London, London, United Kingdom, and approved January 30, 2015 (received for review November 16, 2014)

Before the Syrian uprising that began in 2011, the greater Fertile Crescent experienced the most severe drought in the instrumental

Syria's water security by exploiting limited land and water resources without regard for sustainability (10).

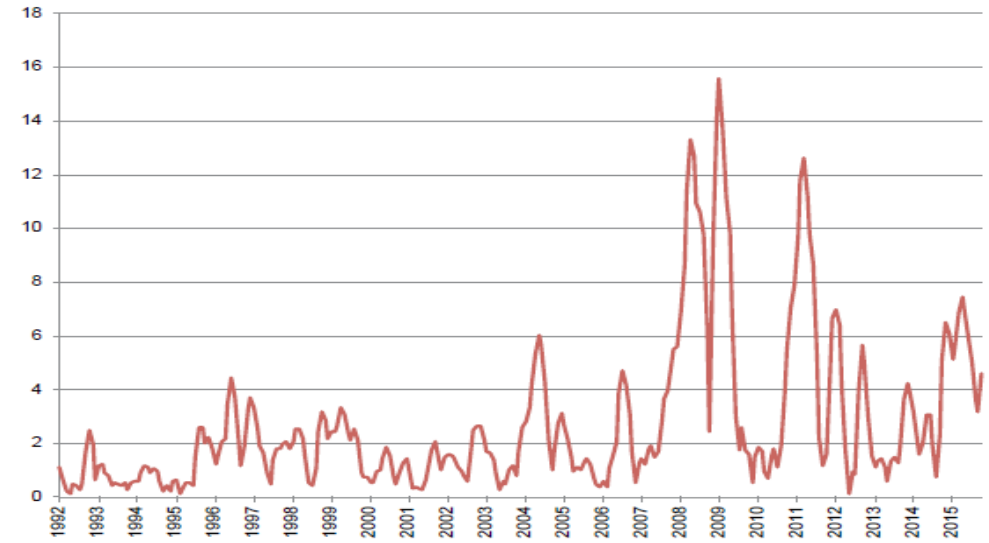


Figure 4: Relative standard deviations of monthly food price index from moving annual average, January 1991 to September 2015.

This figure is an update of the analysis done by Chatham House[10], realised with IMF Food price index data.[25]

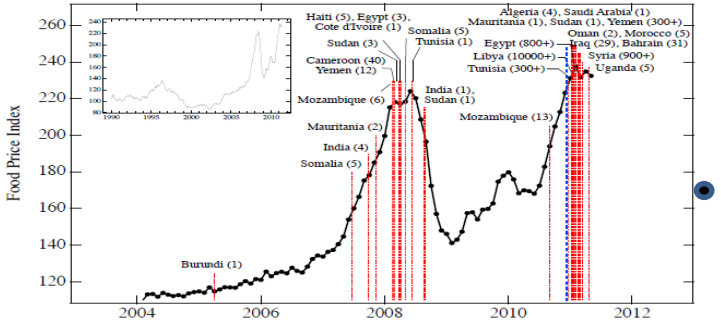
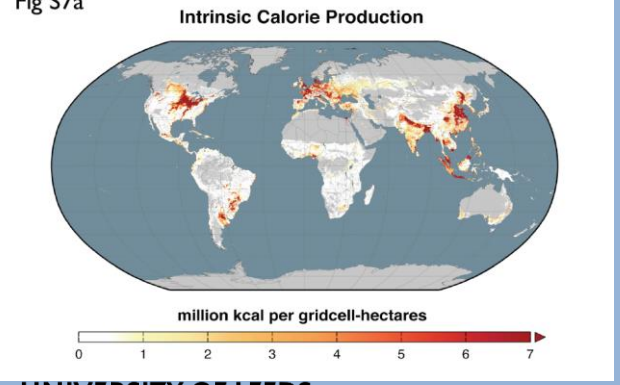


FIG. 1: Time dependence of FAO Food Price Index from January 2004 to May 2011. Red dashed vertical lines correspond to beginning dates of "food riots" and protests associated with the major recent unrest in North Africa and the Middle East. The overall death toll is reported in parentheses [26–55]. Blue vertical line indicates the date, December 13, 2010, on which we submitted a report to the U.S. government, warning of the link between food prices, social unrest and political instability [56]. Inset shows FAO Food Price Index from 1990 to 2011.

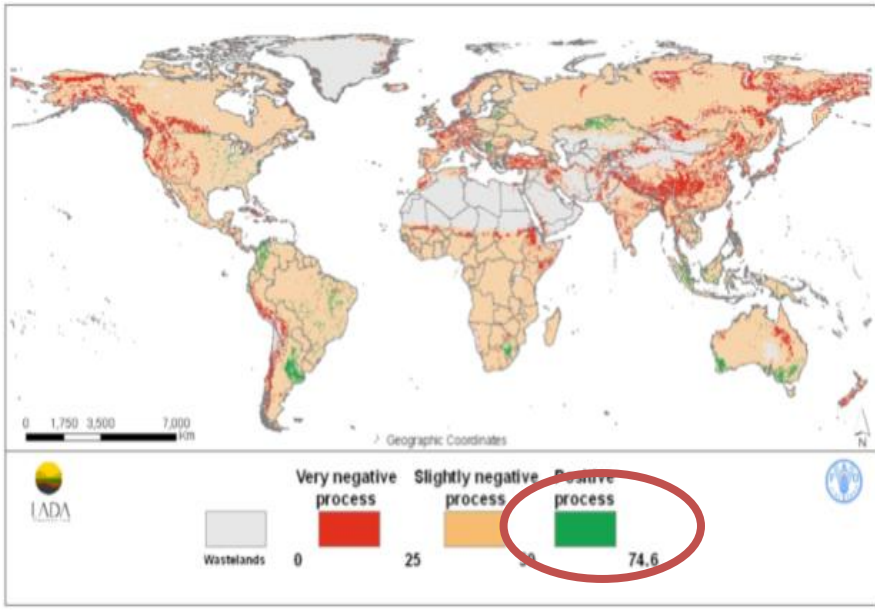
Fig 37a



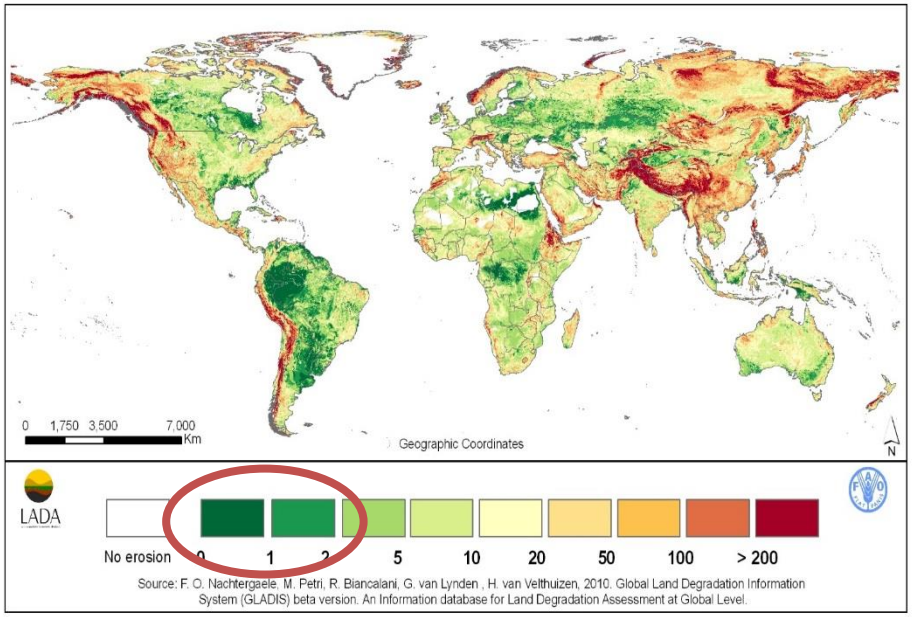
UNIVERSITY OF LEEDS

Soils underpin agriculture

Soil carbon proxy



Predicted soil loss t/ha/yr

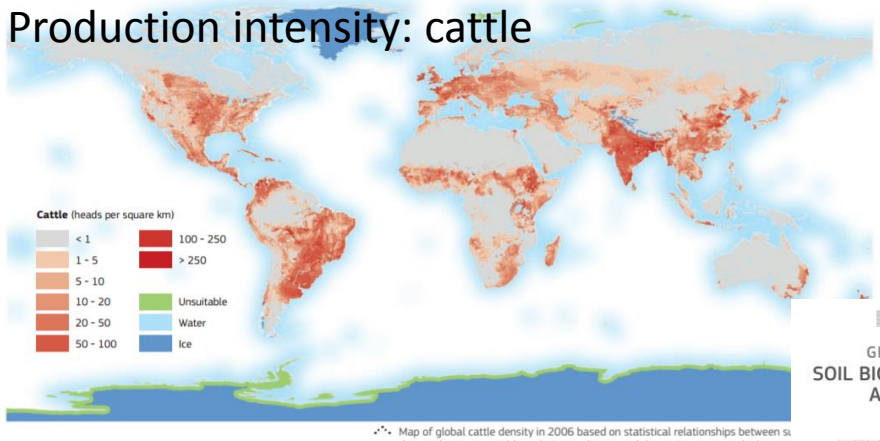


http://www.enea.it/it/pubblicazioni/EAI/anno-2012/n.-4-5-luglio-ottobre-parte-I/the-use-of-soil-organic-carbon-as-an-indicator-of-soil-degradation

UNIVERSITY OF LEEDS

Production intensity on a global basis

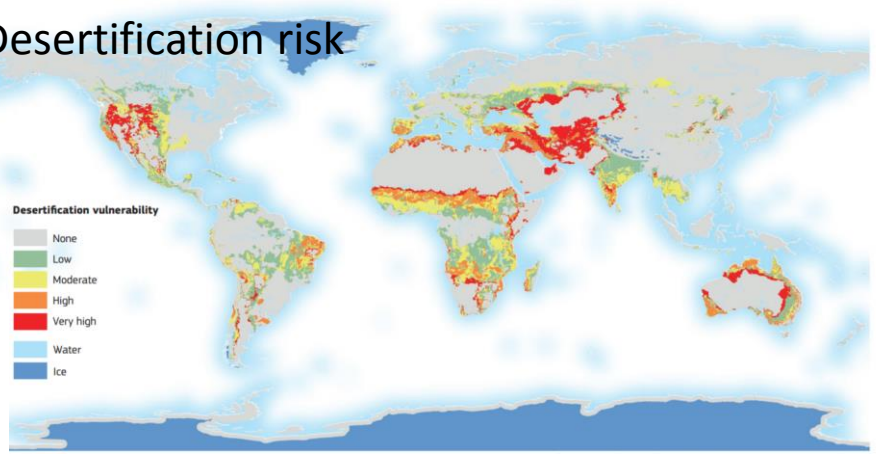
Production intensity: cattle



Map of global cattle density in 2006 based on statistical relationships between su
data and various variables relating to climate and the environment, and other spa
and land-cover data (derived from Robinson *et al.*, PLOS ONE,2014). (LJ, JRC) [15

GLOBAL SOIL BIODIVERSITY ATLAS

Desertification risk

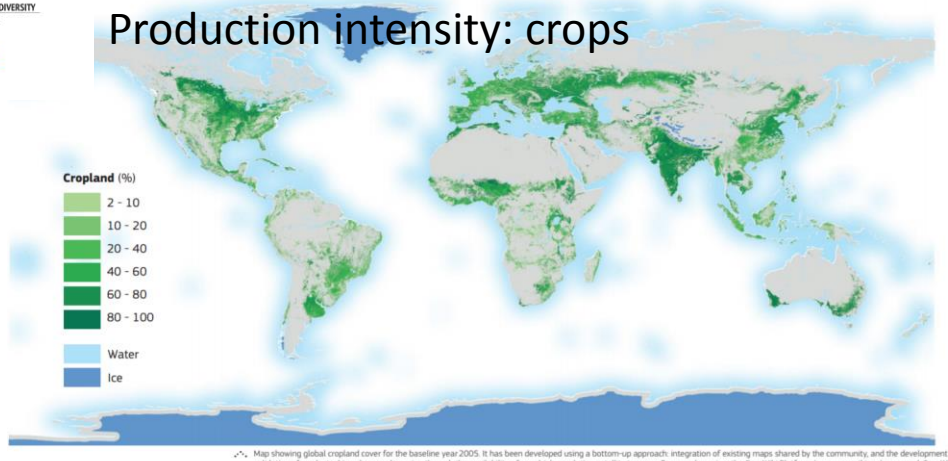


Desertification vulnerability map. The vulnerability was assessed through biophysical properties (i.e. soil

Production intensity: sheep

Map of global sheep density in 2006 based on statistical relationships between survey and census
data and various variables relating to climate and the environment, and other spatial data relating
to demography and land cover (derived from Robinson *et al.*, PLOS ONE, 2014). (LJ, JRC) [152]

Production intensity: crops



Map showing global cropland cover for the baseline year 2005. It has been developed using a bottom-up approach: integration of existing maps shared by the community, and the development and validation of products driven by crowdsourcing through the availability of very high-resolution satellite imagery. For crowdsourcing, the Geo-Wiki Platform (www.geo-wiki.org) was used. Geo-Wiki is a platform that provides citizens with the means to engage in environmental monitoring. In this case, land cover information was gathered for the validation of the map. The map has a resolution of 1 km² (derived from Fritz *et al.*, Global Change Biology, 2015). (LJ, JRC) [149]

Environ. Res. Lett. **11** (2016) 055008 doi:10.1088/1748-9326/11/5/055008

Environmental Research Letters

PAPER

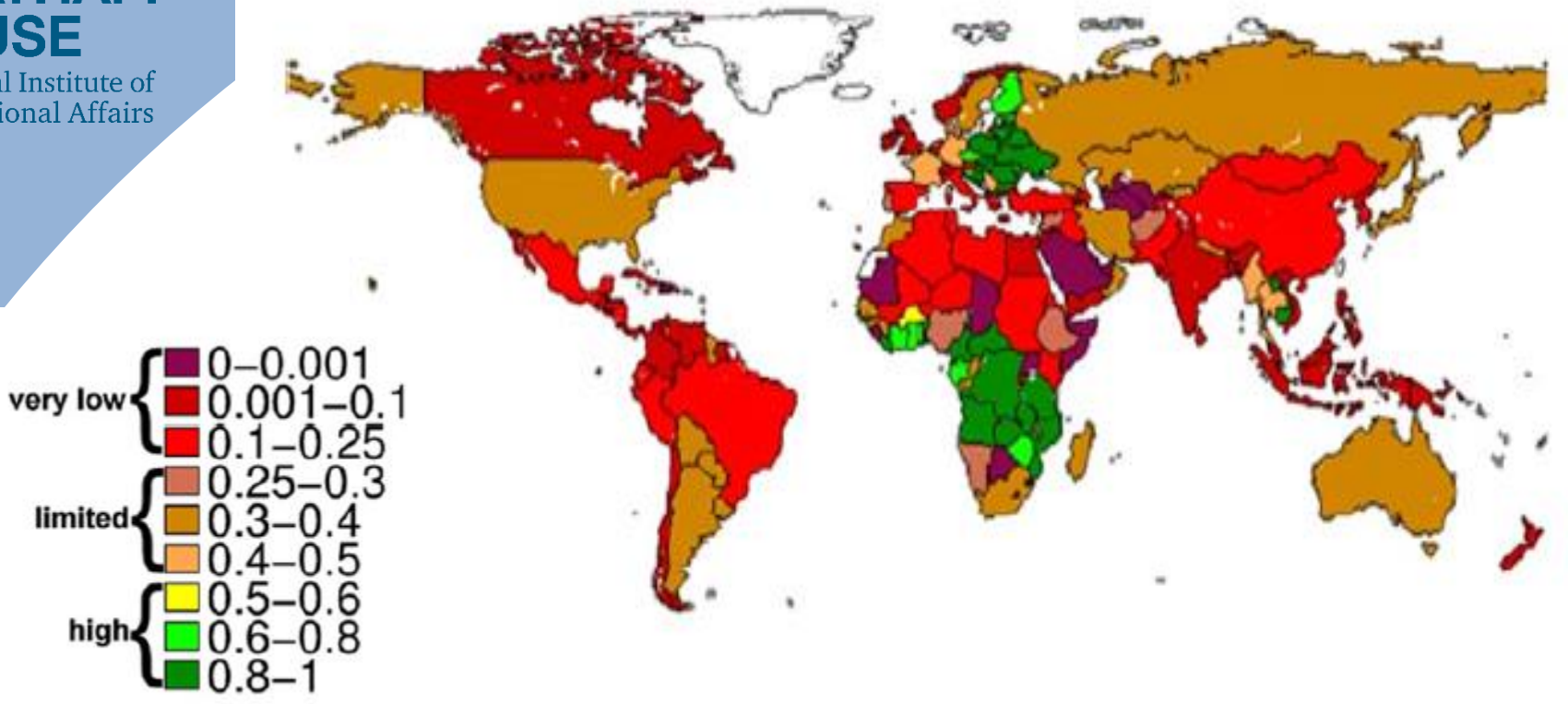
Past and present biophysical redundancy of countries as a buffer to changes in food supply

Marianela Fader[1], Maria Cristina Rulli[2], Joel Carr[3], Jampel Dell'Angelo[4], Paolo D'Odorico[3], Jessica A Gephart[3], Matti Kummu[5], Nicholas Magliocca[4], Miina Porkka[5], Christina Prell[6], Michael J Puma[7], Zak Ratajczak[3], David A Seekell[8], Samir Suweis[9] and Alessandro Tavoni[10]

UNIVERSITY OF LEEDS

CHATHAM HOUSE
The Royal Institute of International Affairs

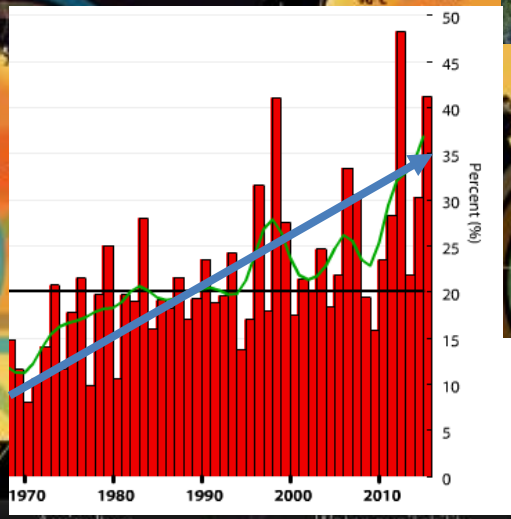
Buffering capacity reducing: no spare land



Met Office

The impact of a global temperature rise of 4°C (7 °F)

HM Government



Climate Extremes Index

Contiguous U.S. CEI (All Steps Combined)
Annual (January-December) 1910-2015

9-Point Binomial Filter
Mean
Actual Percent

The Amazon Forest | Agriculture | Water availability | Sea-level rise | Carbon cycle | Temperature rises

Crops | Water Availability | Sea Level Rise | Marine | Drought | Permafrost | Tropical Cyclones | Extreme Temp | Health

+ °Celsius

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
2	4	5	7	9	11	13	14	16	18	20	22	23	25	27	29

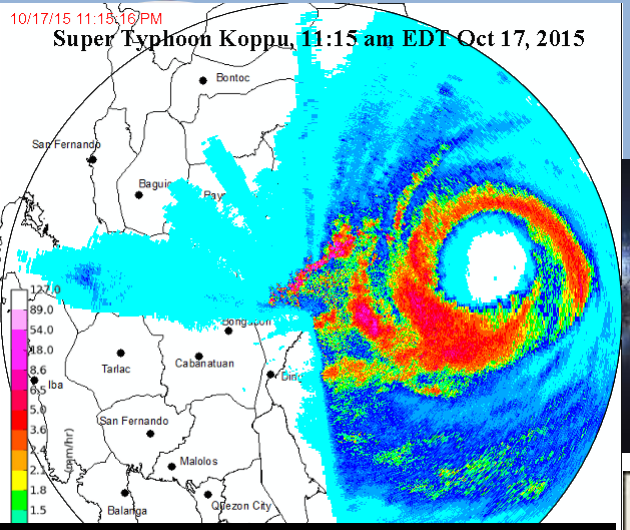
+ °Fahrenheit

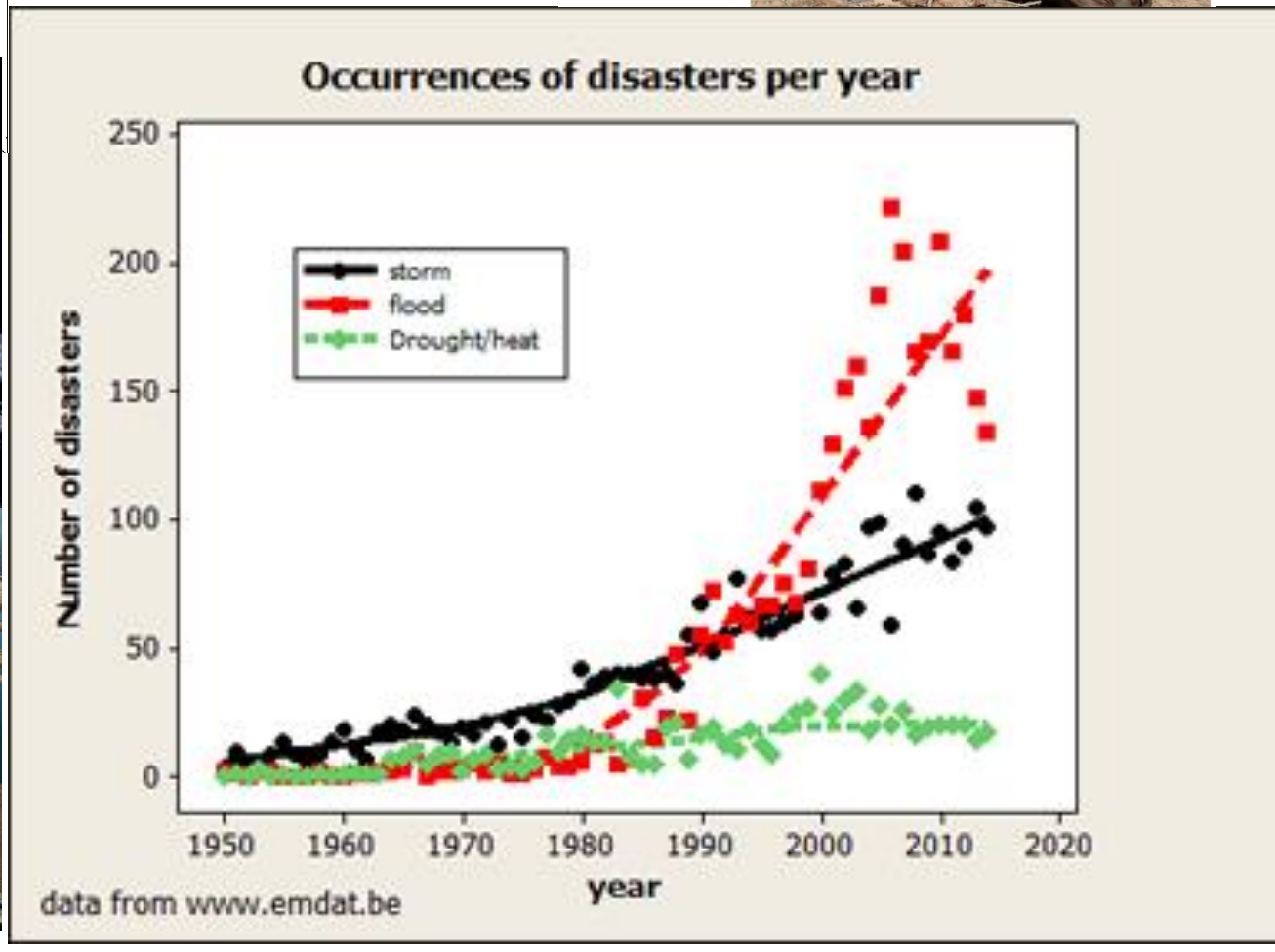
City populations
5-10 Million
10-20 Million

Source: UN Statistics Division Demographic Yearbook 2007

Credits

Extreme weather is getting more extreme

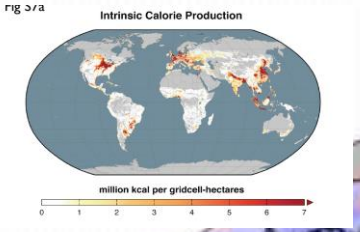


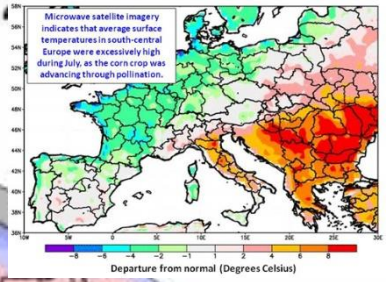


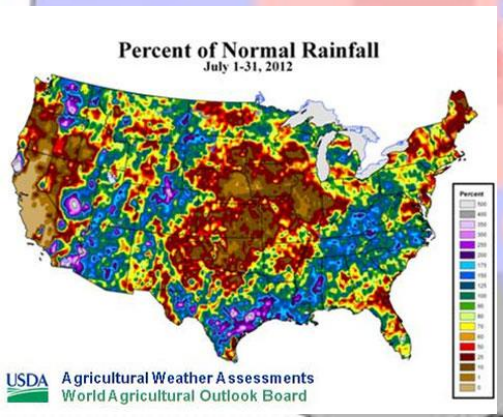
Land & Ocean Temperature Anomalies Jul 2012

(with respect to a 1981–2010 base period)

Data Source: GHCN-M version 3.1.0 & ERSST version 3b





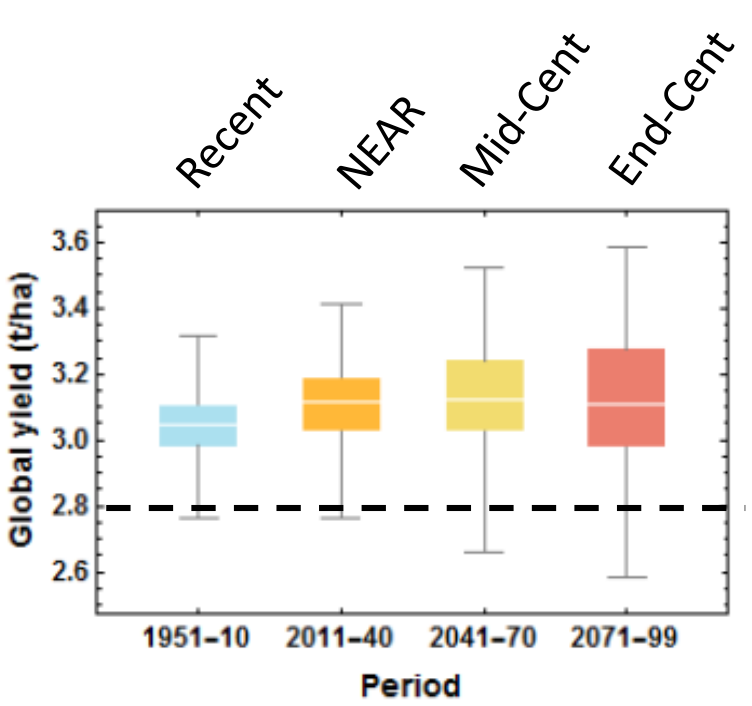


−5 −4 −3 −2 −1 0 1 2 3 4 5

NOAA's National Climatic Data Center

Please Note: Gray areas represent missing data

Production shocks from weather



CO2 fertilisation

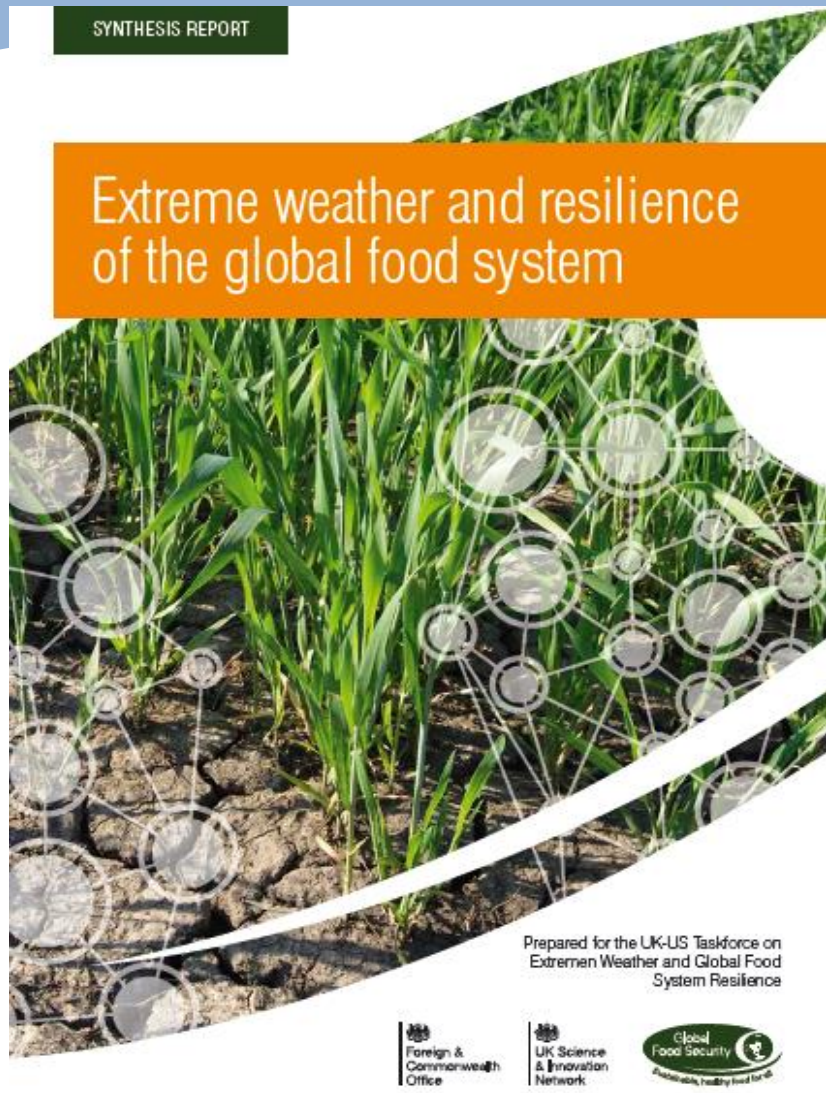
Yields maintained; nutritional quality may decline

Model-based distributions of global calorie-weighted yield of maize, soy, wheat, and rice for the historical (1951-2010) and future with (top row) and without (bottom row) the effects of fertilization from increasing atmospheric CO_2 included. The estimated magnitude of a current 1-in-200 year event is indicated by the horizontal line

UNIVERSITY OF LEEDS

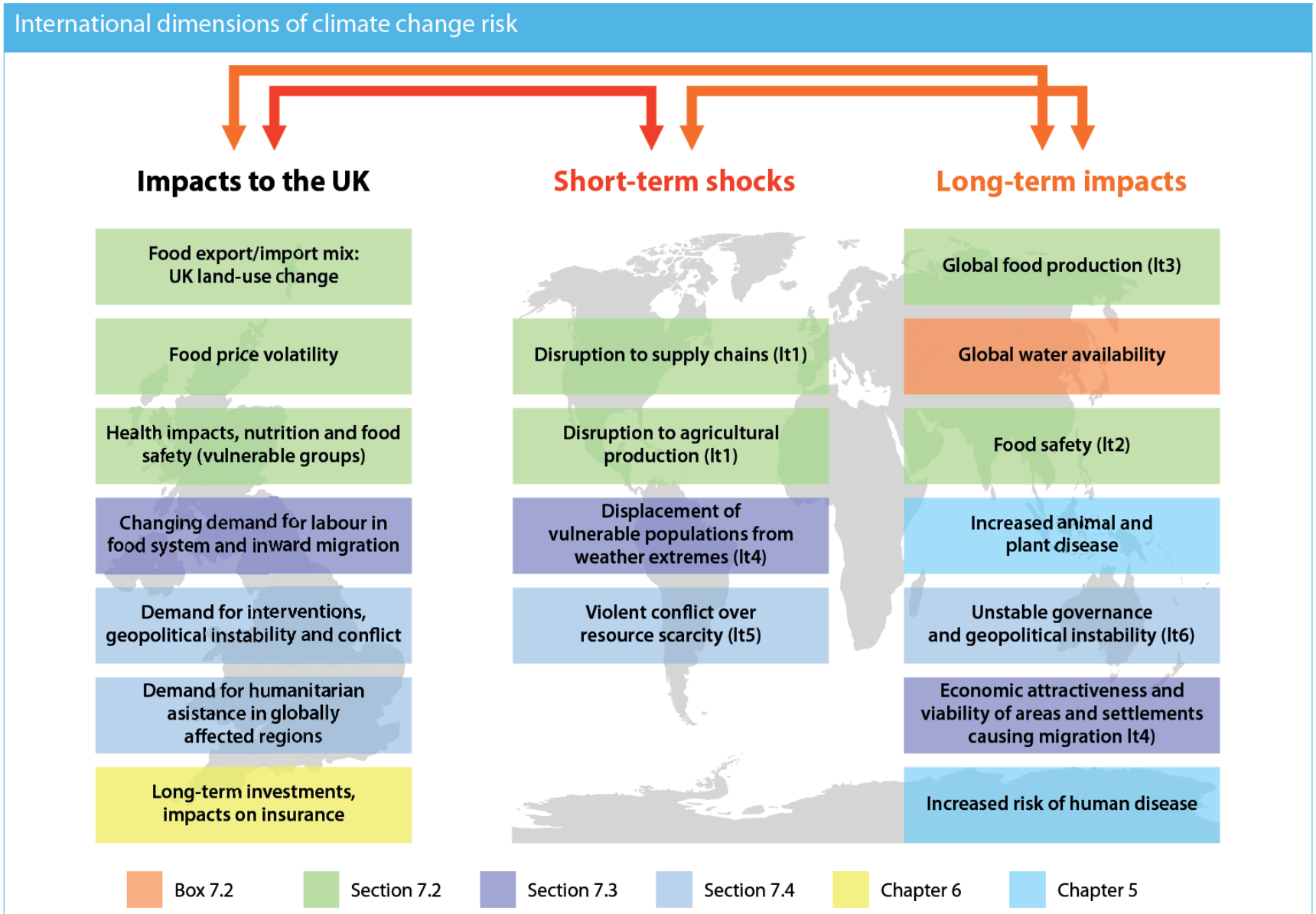
CHATHAM HOUSE
The Royal Institute of International Affairs

UK's Global Food Security Programme is a multi-agency (government departments and research councils) partnership based around the "grand challenge" of ensuring global food security – involving identifying issues, knowledge gaps and setting research agenda



http://www.foodsecurity.ac.uk/assets/pdfs/extreme-weather-resilience-of-global-food-system.pdf

Direct and indirect effects of climate risks



UNIVERSITY OF LEEDS

CHATHAM HOUSE
The Royal Institute of International Affairs

THE FOOD SYSTEM AND SYSTEMIC RISK

Homer-Dixon, T., B. Walker, R. Biggs, A.-S. Crépin, C. Folke, E. F. Lambin, G. D. Peterson, J. Rockström, M. Scheffer, W. Steffen, and M. Troell. 2015. Synchronous failure: the emerging causal architecture of global crisis. *Ecology and Society* **20**(3): 6. http://dx.doi.org/10.5751/ES-07681-200306

Synthesis

Synchronous failure: the emerging causal architecture of global crisis

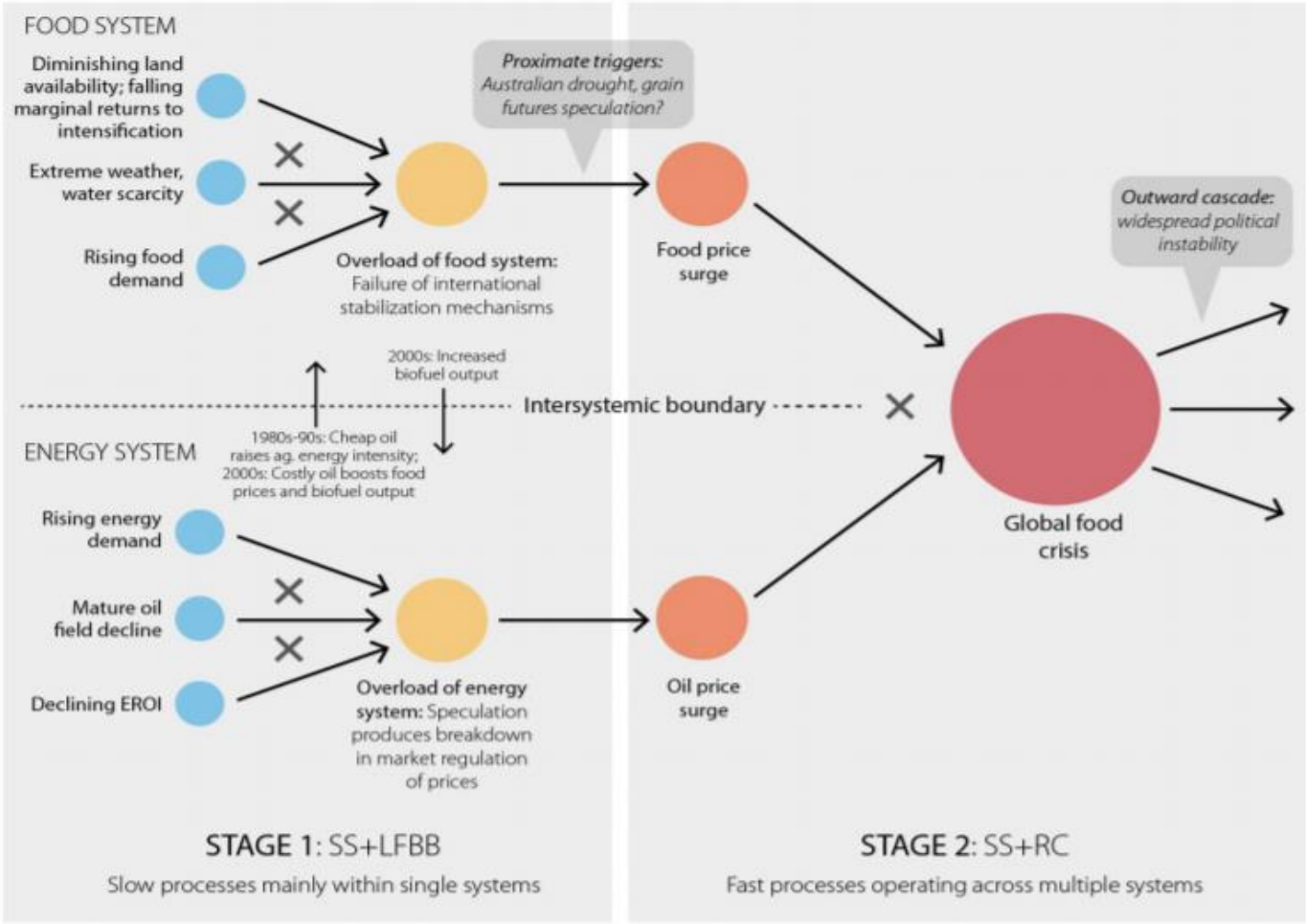
Thomas Homer-Dixon[1], Brian Walker[2], Reinette Biggs[3,4], Anne-Sophie Crépin[3,5], Carl Folke[3,5], Eric F. Lambin[6,7], Garry D. Peterson[3], Johan Rockström[3], Marten Scheffer[8], Will Steffen[3,9] and Max Troell[3,5]

UNIVERSITY OF LEEDS

CHATHAM HOUSE
The Royal Institute of International Affairs

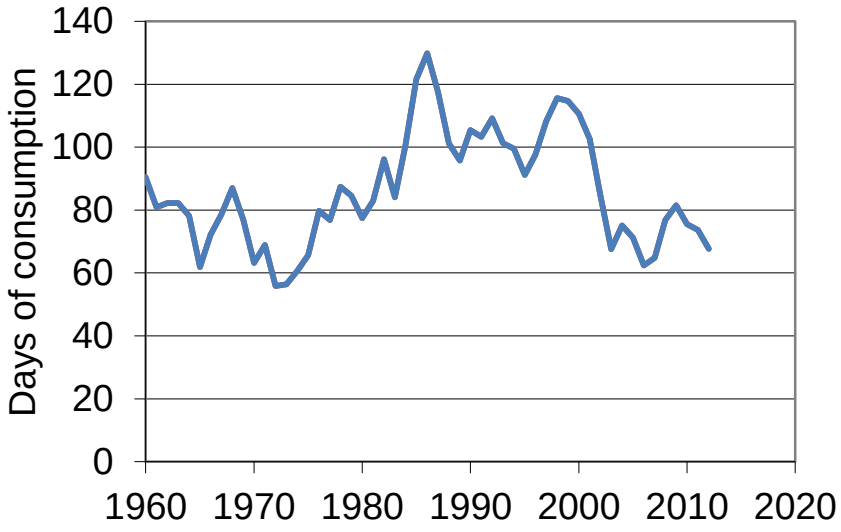
Systemic risks

Fig. 3. The 2008 food-energy crisis. SS = simultaneous stresses; LFBB = long fuse big bang; RC = ramifying cascade.



"Supply shocks" interact with a range of other factors to affect prices

UNIVERSITY OF LE
CHATHA
HOUSE
The Royal Institute
International Affa

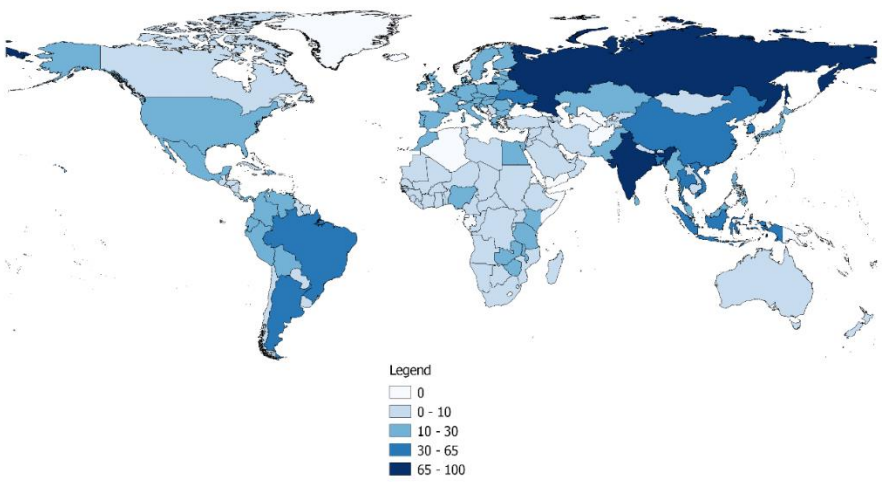


- A production shock can become a market shock if:
  - there are multiple grains affected in different places
  - export restrictions are put in place,
  - stocks are low
  - food is prioritised for other uses (e.g. biofuel)
  - the US $ is devalued increasing demand
  - There is panic buying (or speculation) accelerating price rises
  - "other things are going on" e.g. logistics (shale sand, Sao Paulo, Suez disruption)

UNIVERSITY OF LEEDS

CHATHAM HOUSE
The Royal Institute of International Affairs

How does policy respond?



Consequences of the 2008 food price shock showing total number of policy responses including export and import restrictions between 2008 and 2014 by country. Source: World Bank Food Price Crisis Observatory [accessed 28 April 2015]

Export restrictions are political responses. If an exporting government perceives food shortages or price rises (or volatility), they may impose export restrictions (and even complete bans) or enforce technical barriers (*such as customs procedures including quality monitoring or other restrictions that reduce export potential – for example, loading of rail in Russia).*

UNIVERSITY OF LEEDS

CHATHAM HOUSE
The Royal Institute of International Affairs

PERTURBATIONS FROM CHANGING WEATHER ARE LIKELY TO INCREASE

Plausible worst case scenario 2017-18

*A disappointing **Indian monsoon** in 2017 opens with a poor outlook for wheat in India. Followed by early spring 2018, when large areas of the **Black Sea winter wheat** crop are killed by a temporary snow thaw and refreeze, that alarm mounts.*

Russia and Ukraine both impose export bans followed by Kazakhstan, India, China and Pakistan; Argentina tightens existing export restrictions. Several countries including China, Saudi Arabia, Morocco and Iran implement measures to reduce import prices, such as tariff reductions or consumption subsidies.

In response to poor harvests of wheat in India and poor outlook for China, both increase export controls on rice in a bid to shore-up domestic availability of cereals. Pakistan and Bangladesh follow suit. As mounting export controls constrain supply, the number of importing countries slashing cereal tariffs or hiking consumption subsidies continues to grow, driving up effective demand.

*In late spring, **drought sets in in North America** and persists throughout the summer. Soybean and maize forecasts drop steadily over the period whilst prices, already dragged high by wheat, climb rapidly.*

Argentina raises export taxes on both commodities; China imposes an export tax on maize.

*The situation is compounded by a **heatwave and drought that hits the European wheat crop**, leading to further rises across all cereals.*

The US indicates it will not waive the ethanol mandate despite calls for it to do so, from other governments and from interests in the livestock and food and beverage sectors.

*In **early summer a second failure of the Indian monsoon is confirmed**, raising concerns about the rice harvest later in the year.*

Panic sets in in the rice market. Myanmar, Sri Lanka, Egypt and Nepal impose export restrictions. Major importers such as Nigeria, Malaysia and the Philippines place orders far in excess of normal levels in a bid to calm domestic markets, bidding-up a tight market. The commitment from governments in the Association of SE Asian Nations (ASEAN) to coordinate trade responses buckles under pressure and Vietnam, Cambodia and Indonesia impose export bans.

Summary of report's conclusions

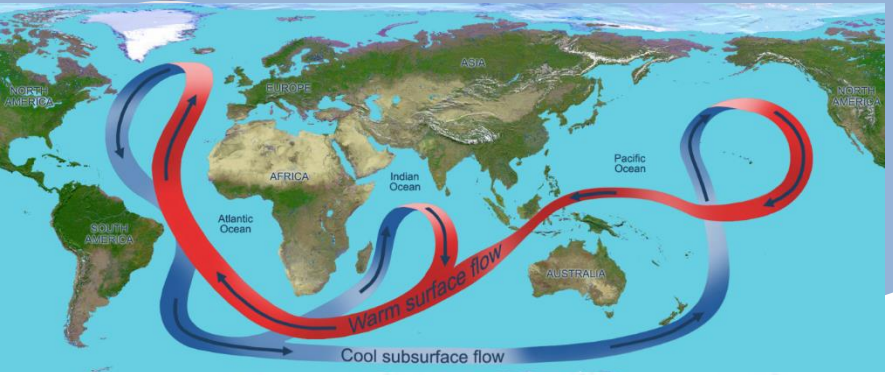
Low Income Countries (average 2000-2005 GDP cap <975 constant 2000 USD)	
Net Food Exporters	Net Food Importers
a	*b*
Chad	Angola
Cote d'Ivoire	Benin
Ghana	Burkina Faso
Guinea-Bissau	Burundi
Madagascar	Cameroon
	Cen. African Rep
	Comoros
	Congo, Dem Rep
	Djibouti
	Eritrea
	Ethiopia
	The Gambia
	Guinea
	Kenya
	Lesotho
	Liberia
	Malawi
	Mali
	Mauritania
	Mozambique
	Niger
	Nigeria
	Rwanda
	Senegal
	Sierra Leone
	Sudan
	Tanzania
	Togo
	Uganda
	Zambia
	Zimbabwe

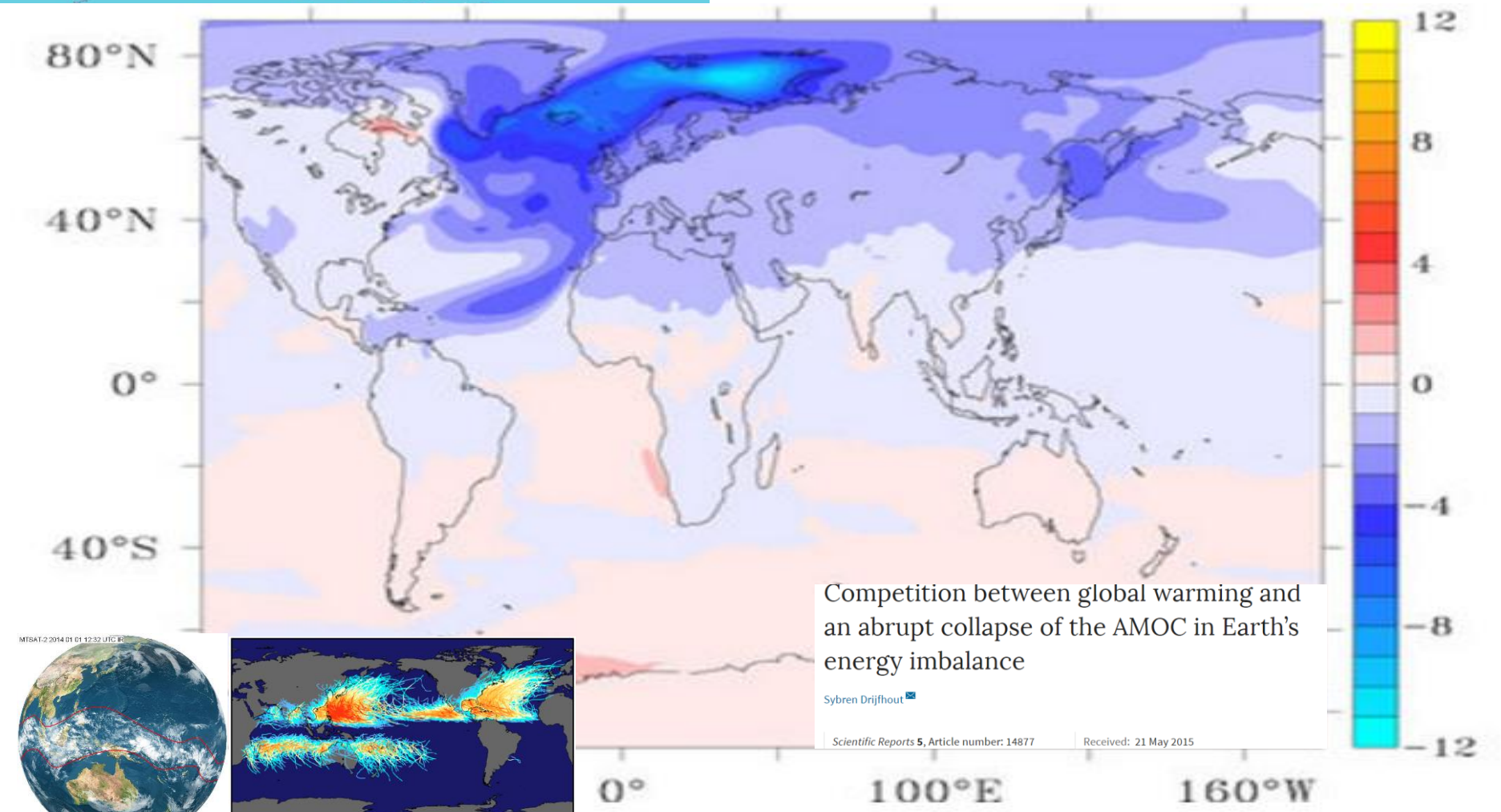
625 m

- **A 10% loss of calories would potentially lead to:**
  - **FAO food prices rising to unprecedented levels (>250) and prices of affected crops increasing threefold**
  - **The hardest impacts would be felt by import dependent developing countries, particularly in Sub-Saharan Africa. Other import dependent countries could experience social unrest.** The highly import dependent countries of the Middle East and North Africa region could be particularly vulnerable.
  - **Impacts on major economies would be muted on average.** "Food poverty" and malnutrition would increase as food prices increase. The crop sectors of these economies, and other major agricultural producers, would likely benefit from higher prices, though other sectors could suffer.
  - **The supply response may have negative consequences in the longer term.** In response to the price spike, agricultural output would likely increase through a combination of extensification and intensification.

http://www.fao.org/docrep/015/i2497e/i2497e00.pdf

But what would a major tipping point do?

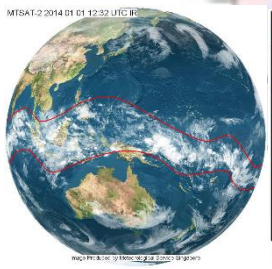


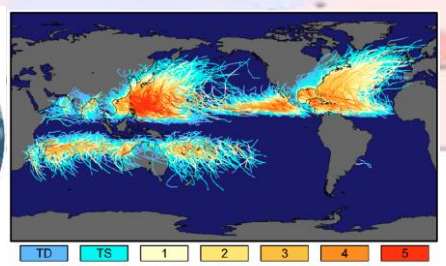


Competition between global warming and an abrupt collapse of the AMOC in Earth's energy imbalance

Sybren Drijfhout

Scientific Reports **5**, Article number: 14877 Received: 21 May 2015

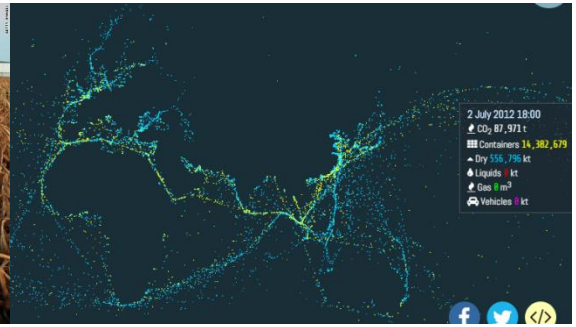




Saffir-Simpson Hurricane Intensity Scale

UNIVERSITY OF LEEDS

CHATHAM HOUSE
The Royal Institute of International Affairs

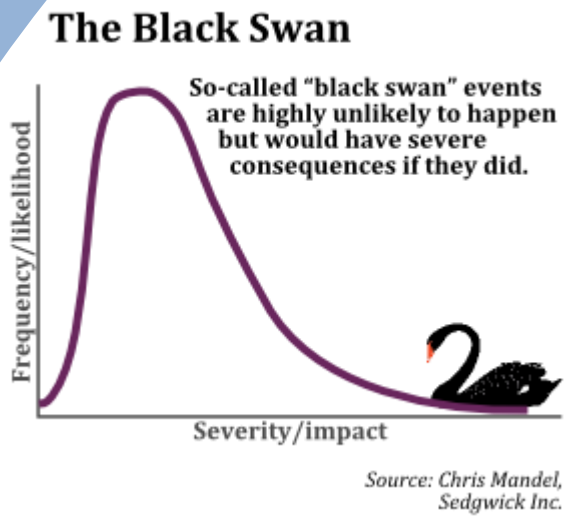


BUILDING RESILIENCE

UNIVERSITY OF LEEDS

CHATHAM HOUSE
The Royal Institute of International Affairs

- *"global free trade is a public good"* is not a risk-free ideology



- Unprecedented things do happen

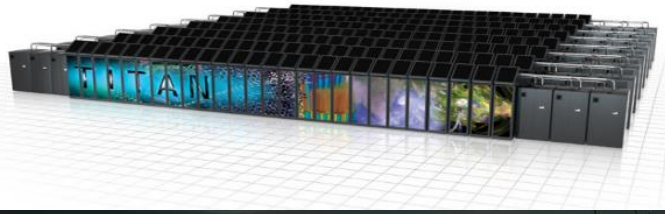
UNIVERSITY OF LEEDS

CHATHAM HOUSE
The Royal Institute of International Affairs

Recommendations

1 **Better understand the risks**
Our knowledge is limited by available model simulations. Modelling limitations also constrain our ability to understand how production shocks translate into short run price impacts.

2 **Adapt agriculture for a changing climate**
Increases in productivity, sustainability *and* resilience to climate change are required. "Sustainable and resilient intensification"



UNIVERSITY OF LEEDS

CHATHAM HOUSE

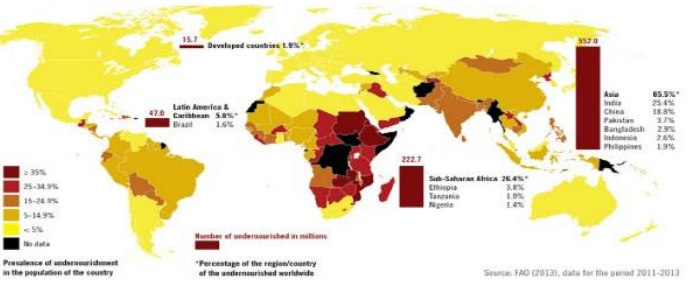
courtesy of http://rsif.royalsocietypublishing.org/content/early/2010/01/19/rsif.2009.0495.full

3 Improve the functioning of international markets; e.g.:

- **Improving the quality and accessibility of key market data**, not least estimates of public and private stockholdings. Building on the recent success of the Agricultural Market Information System will be important in this regard.
- Agreeing **international rules to limit the scope for unilateral export controls** in the agriculture sector.
- Developing mechanisms to **increase the flexibility of biofuel mandates**.
- Research to **identify critical geographical pinch points in international trade** and approaches to address their vulnerability, such as investment in infrastructure or plurilateral agreements to maintain sea lanes for example.

UNIVERSITY OF LEEDS

CHATHAM HOUSE
The Royal Institute of International Affairs



4 Bolster national resilience to market shocks

The precise mix of appropriate policy measures will vary according to national context (particularly important for import dependent SSA).

- E.g. greater self-sufficiency, diversity or stocks

5 Explore opportunities for coordinated risk management

As knowledge on risks emerges, develop contingency plans and establish early warning systems with agreed response protocols, and explore opportunities include coordinated management of emergency and/or strategic reserves.

UNIVERSITY OF LEEDS

CHATHAM HOUSE
The Royal Institute of International Affairs

“BUSINESS AS USUAL” CANNOT BE AN OPTION

Brundtland Report (1987): *"Sustainable development is development that meets the **needs** of the present without compromising the ability of future generations to meet their own needs."*

Food loss and waste

Global food losses/waste is estimated to be 1.3 billion tonnes per annum (pa), equating to approximately one third of edible food intended for human consumption

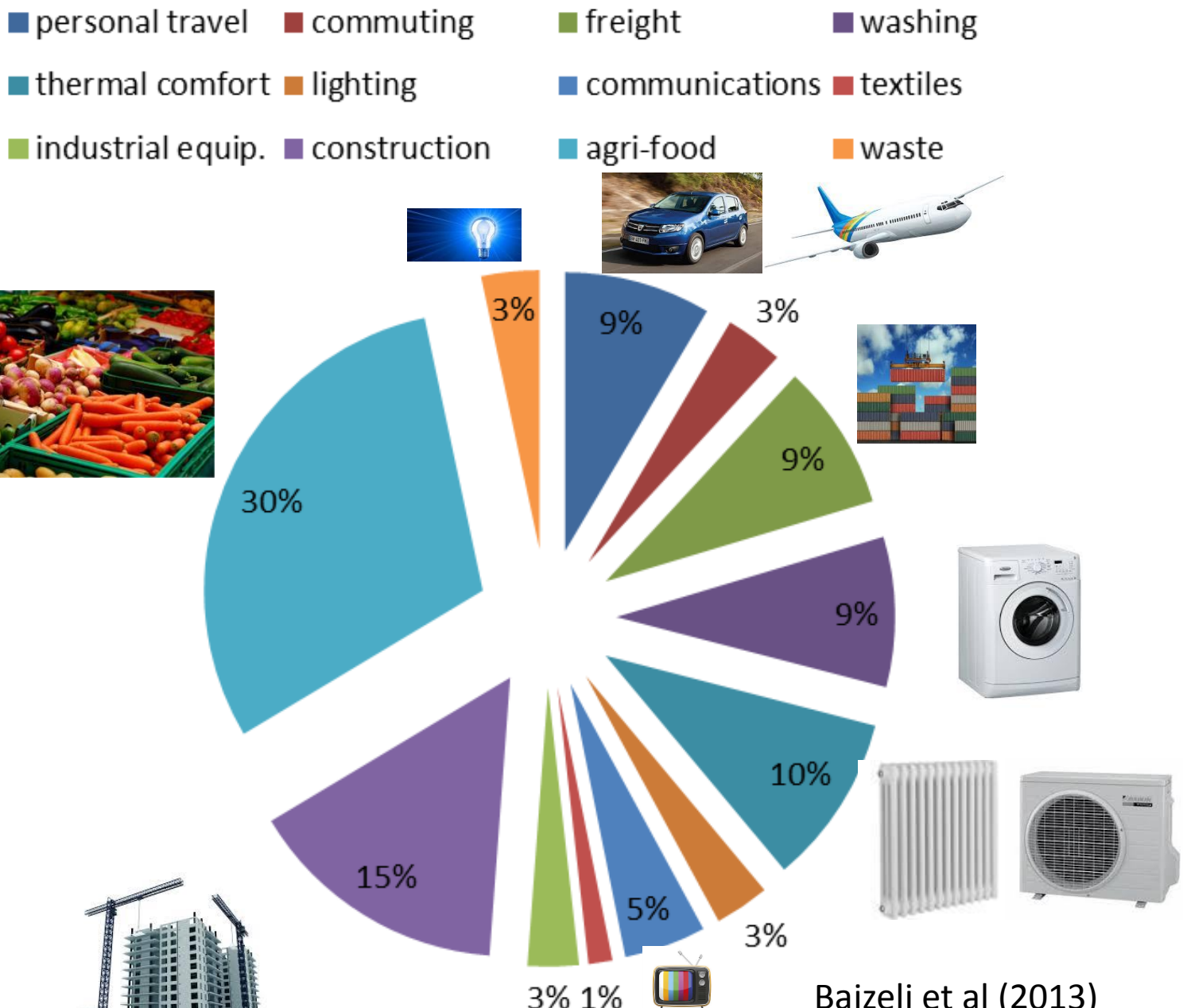
The total food production of sub-Saharan Africa = EU+N Am food waste (230mt).

Total food waste has enough embedded calories to feed 2-3bn people

Many reasons for loss and waste: pack size, safety, food is cheap, culture

Need to recycle “from farm to flush”

GHG emissions by service (50.6 Gt CO2e total)



Baizeli et al (2013)

Globally, “business as usual” is unsustainable…

- Demand projections are increasing faster than yield projections. If demand is to be met:
- It will require 120% more water; 42% more cropland and loss of 14% more forest
- It will emit enough carbon dioxide to create 2 degrees of global warming (alone)
- We’ll lose much of the world’s biodiversity
- Malnourishment will continue to grow

Importance of food-demand management for climate mitigation

Bojana Bajželj[1]*, Keith S. Richards[2], Julian M. Allwood[1], Pete Smith[3], John S. Dennis[4], Elizabeth Curmi[1] and Christopher A. Gilligan[5]

NCC 2014

Dietary change could keep food systems within what is sustainable

vs

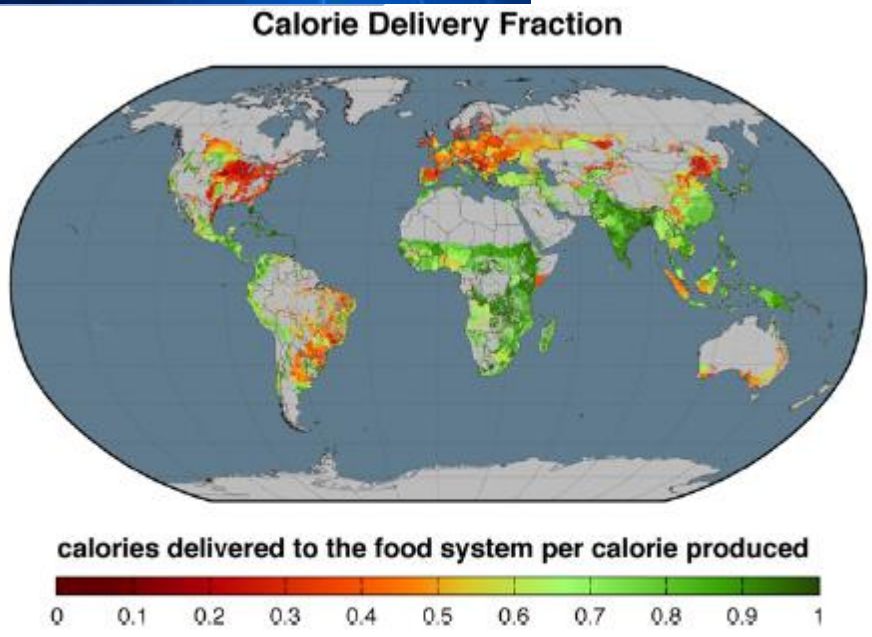


Figure 1. Calorie delivery fraction per hectare. The proportions of produced calories that are delivered as food are shown.

E S Cassidy *et al* Environ. Res. Lett. **8** (2013) 034015

The population of all Asia is 4.2bn

UNIVERSITY OF LEEDS

CHATHAM HOUSE
The Royal Institute of International Affairs

Business as usual is a Jevon's paradox: more is not enough

Less waste
Healthy consumption
Low environmental impact
Less demand

"full cost of food"

Production
(sustainable)

Sustainable nutrition

Production
(unsustainable)

Cheap food

Waste
Over consumption
Environmental impact
Increasing demand

The M25 model

2/3*2/3*(1-(1/3*1/5))=56/135=41% used
Food not lost/wasted/fed to animals or overeaten

UNIVERSITY OF LEEDS

CHATHAM HOUSE
The Royal Institute of International Affairs

Game changers: 2015

People

We are determined to end poverty and hunger, in all their forms and dimensions, and to ensure that all human beings can fulfil their potential in dignity and equality and in a healthy environment.

Planet

We are determined to protect the planet from degradation, including through sustainable consumption and production, sustainably managing its natural resources and taking urgent action on climate change, so that it can support the needs of the present and future generations.

UNIVERSITY OF LEEDS

CHATHAM HOUSE
The Royal Institute of International Affairs

Game changers: 2016

Future food

UNIVERSITY OF LEEDS

CHATHAM HOUSE
The Royal Institute of International Affairs

Free trade, global markets

Unchecked consumption
- *Growing ill-health*
- *More climate change*
- *Big biz controls*

Sustainable, high-tech world
- *Global innovations and tech platforms*
- *High efficiency*
- *App-driven personalised nutritious diets*
- *Consumers buy attributes*

Unsustainable and unhealthy diets

sustainable and healthy diets

Money talks most
- *Disconnected world with weak economic growth*
- *"post war economy"*
- *Unsustainable production to meet demands locally*

Local is lovely
- *Sustainable nutrition drives local industry*
- *"local food" SMES and artisanal food valued*
- *Holistic economies – low waste, high health and well being*

Local or regional markets

WORLD ECONOMIC FORUM
COMMITTED TO IMPROVING THE STATE OF THE WORLD

UNIVERSITY OF LEEDS

CHATHAM HOUSE

The Royal Institute of

Conclusions

- Systemic risks to the global food system are increasing from extreme weather and climate change, as well as a host of other “simultaneous stressors”
- Building resilience requires concerted strategic action to prevent price amplification in a “crisis” and efforts to ensure smooth market functioning to avoid crisis
- Need “whole government” approaches to deal with complexity; plus better international governance.
- Globalised trade networks carry benefits AND risks
- There is no “magic bullet” but scope for many innovations in many areas (including “climate smart agriculture”)
- Existing emissions trajectories are problematic (e.g. AMOC) and reducing demand (or population size) probably required for long term resilience

UNIVERSITY OF LEEDS

CHATHAM HOUSE
The Royal Institute of International Affairs

Thank you!

t.g.benton@leeds.ac.uk

@timgbenton

www.foodsecurity.ac.uk