



Sustainable Food Consumption and Production in a Resource- Constrained World

Erik Mathijs, K.U.Leuven

Integrated Pest Management - the way forward
to Sustainable Agricultural Production

19 June 2012

Foresight Expert Group 3

- **Annette Freibauer** (chair) (D) - Head of Emission Inventories Group, Institute of Agricultural Climate Research, von Thünen-Institute
- **Erik Mathijs** (rapporteur) (BE) – Katholieke Universiteit Leuven
- **Gianluca Brunori** (IT) - University of Pisa – Department of Agronomy and Management of Agro-Ecosystems
- **Zoya Damianova** (BU) - Programme Director Innovation Programme - Applied Research and Communications Fund
- **Elie Faroult** (F) - International Consultant, Brussels
- **Joan Girona i Gomis** (SP) - Director Irrigation Technology IRTA
- **Lance O'Brien** (IRL) - Head Foresight and Strategy Development, Teagasc
- **Sébastien Treyer** (F) - Directeur des programmes, Institut du développement durable et des relations internationales IDDRI

Background

- Standing Committee on Agricultural Research (SCAR), est. 1974, renewed in 2005
- Formed by MS representatives, presided by EC representative
- Advise EC and MS on the coordination of agricultural research in Europe
- Initiatives:
 - Common research agendas (collaborative working groups, JPI)
 - Mapping capacities
 - Foresight monitoring mechanism

Purpose

- **Purpose:** scanning and monitoring exercise of recent relevant national, regional or international foresight activities and science papers (2009 / 2010)
- **Emphasis:**
 - Resource scarcities and adverse environmental impacts
 - Role of the Knowledge-Based Bio-Economy
 - Balance between food, fibre, feed and fuel + new technologies towards sustainable, green bio-economy
- **Final aim:** building blocks for longer-term perspective to prepare a smooth **transition** towards a world with resource constraints and environmental limits

Main messages

1. Sense of urgency due to resource scarcities **accelerates** (due to interactions)
2. Way we look at problems and solutions **differs fundamentally** between productivity-oriented and sufficiency-oriented thinking
3. Productivity-oriented thinking still **dominates**, but technological solutions alone are inadequate
4. **Concerted** efforts are needed to enable the transition to a truly efficient and resilient agrofood system (policy at all levels, R&D, business)

Main messages

5. Main leverage points:
 - Radically increase resource use efficiency (eliminate waste at all levels)
 - New business models (organizational innovation)
 - Healthy consumer diet, worldwide
6. Not productivity **or** sufficiency, but productivity **and** sufficiency – **all approaches are necessary, no silver bullet**
7. Research: more coordination, more true transdisciplinarity, more room for (system) experimentation

The approach

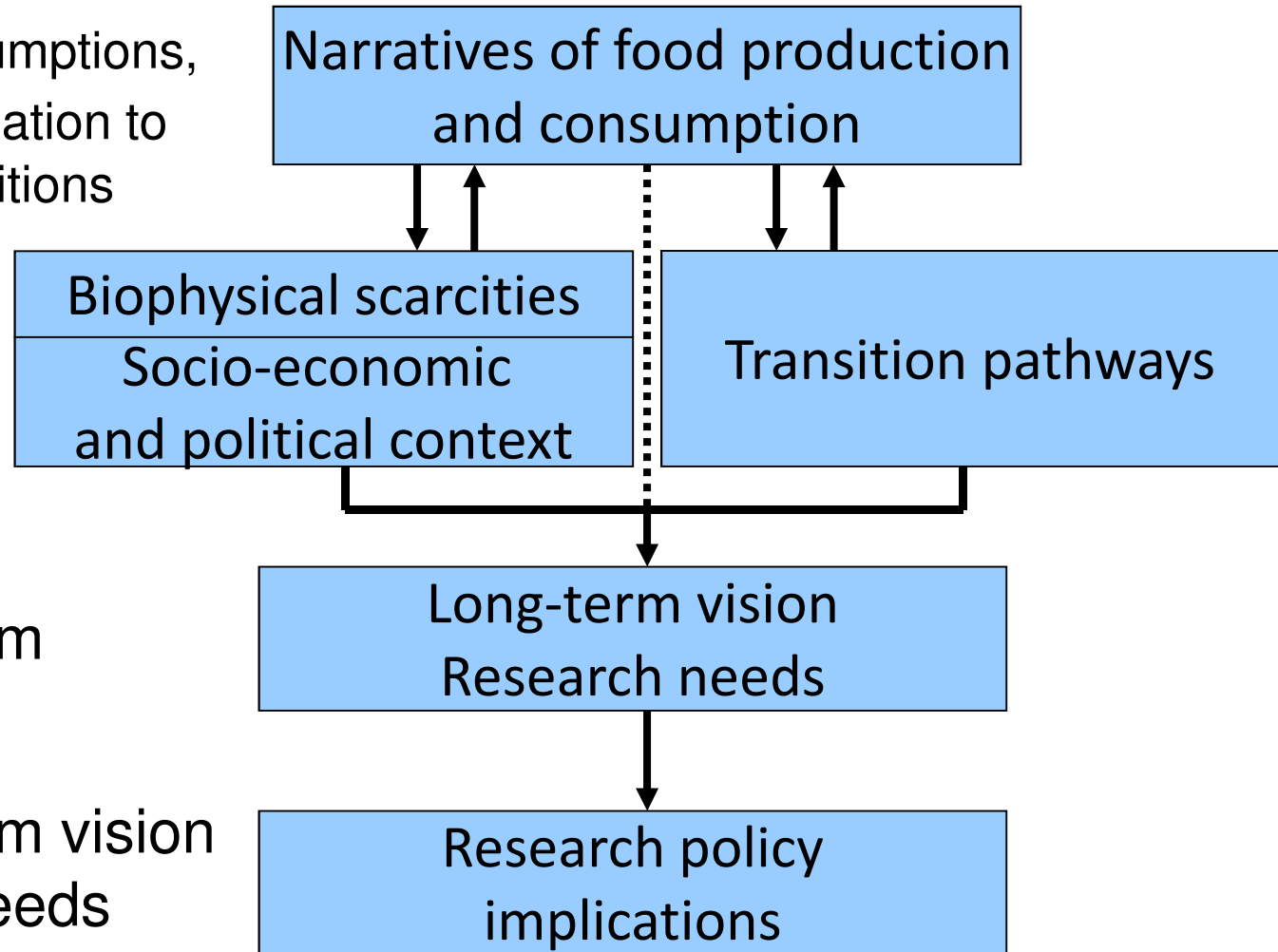
Starting point:

Extreme ends, assumptions, simplifications in relation to scarcities and transitions

New insights since FEG2

Conclusions from insights

Conclusions from vision and research needs



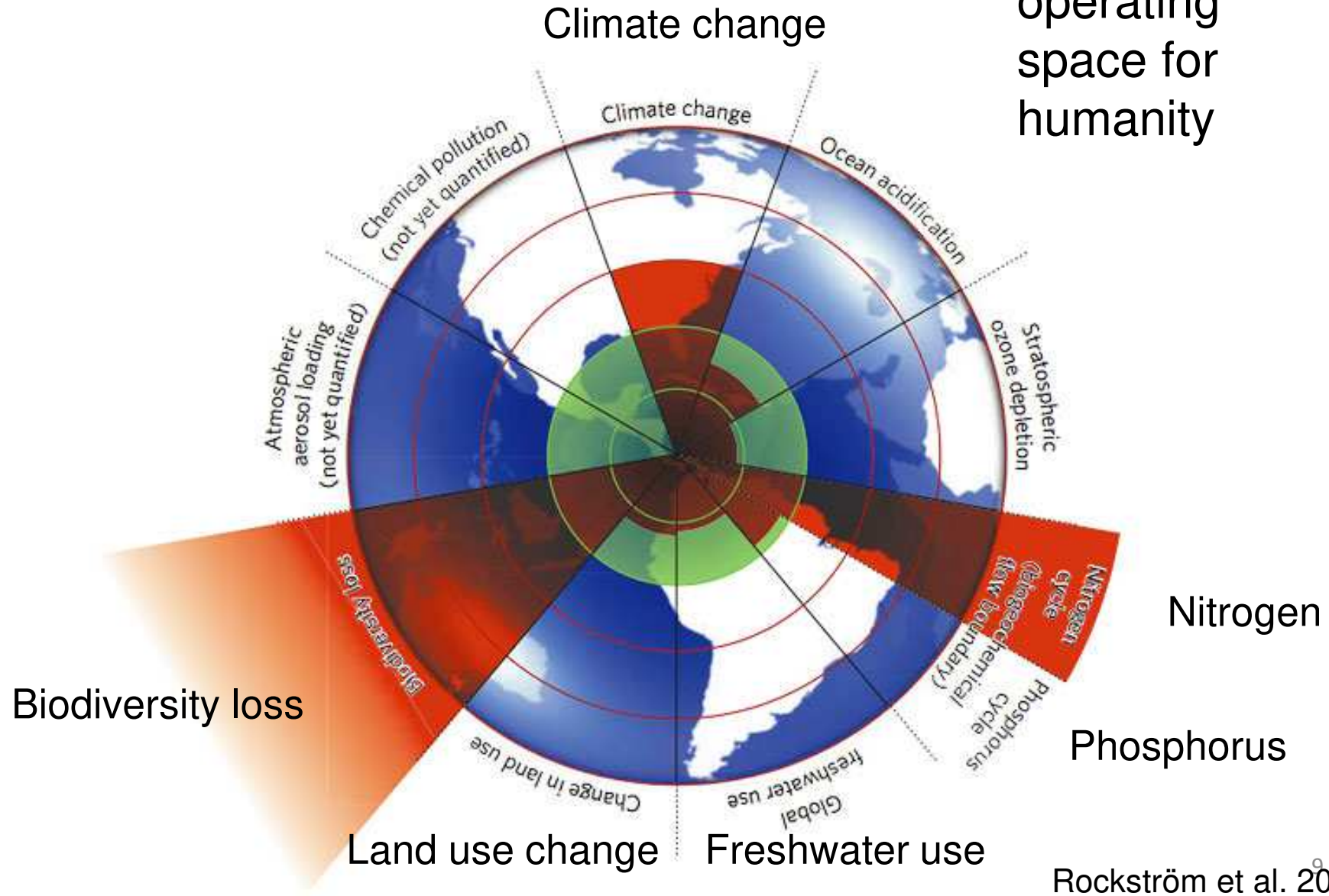
We show directions for solutions but even more, how research can direct us towards them

Scarcities

- ***Definition: a social concept of imbalances, inefficiencies, constraints***
- Observed shortage of natural resources,
- Perceived dependency on natural resources and fear of global depletion
- Political, social, organisational, institutional and economic obstacles also contribute to scarcities.
- “Old scarcities”: fertile land, freshwater, energy, P
- “New scarcities” increase “old” ones: climate change, biodiversity loss
- Socio-economic context: agricultural knowledge systems, governance, economic development, urbanization as drivers, barriers and solutions

'New' scarcities

A safe operating space for humanity



Rockström et al. 2009

Scarcities

Insights:

- Economic development = strongest driver, further worsened by urbanisation
- Amount, method and type of food production = strong impact on water, energy and nutrients, pollution and consequences, e.g. climate change and biodiversity loss
- Water, N and energy: no shortage, but efficiency issue
- P least connected to other scarcities
- Climate change and biodiversity loss aggravate each other in manifold ways, but badly understood; combined effect makes food production system vulnerable

Scarcities

- Reinforcing feedbacks that speed up change are the most prominent mechanism of interactions between scarcities.
- Tipping points = unquantifiable risk for food security; mainly related to climate change - biodiversity relations.
 - Die-back of coral reefs, destruction of coastal ecosystems and over-exploitation of marine resources = most urgent, maybe even catastrophic risks for global food security
 - Systemic instability = large-scale, multi-source pressures
- Time lagged scarcities (P, soil degradation, genetic diversity) underresearched
- Governance = key root of any scarcity + heart of the solution

Godfray et al., Science, 2010

- Closing the yield gap
- Increasing production limits
- Reducing waste
- Changing diets
- Expanding aquaculture



REVIEW

Food Security: The Challenge of Feeding 9 Billion People

H. Charles J. Godfray,^{1,2} John R. Beddington,² Ian R. Crane,³ Lawrence Hatfield,⁴ David Lawrence,⁵ James F. Meade,⁶ Jules Pretty,⁷ Sherrin Robinson,⁸ Sandy M. Trnka,⁹ Camilla Toulson¹⁰

Continuing population and consumption growth will mean that the global demand for food will increase for at least another 40 years. Growing competition for land, water, and energy in addition to the overexploitation of fisheries, will affect our ability to produce food, as will the urgent requirement to reduce the impact of the food system on the environment. The effects of climate change are a further threat. But the world can produce more food and can ensure that it is used more efficiently and equitably. A multifaceted and linked global strategy is needed to ensure sustainable and equitable food security, different components of which are explained here.

The past half-century has seen marked growth in food production, allowing for a dramatic decrease in the proportion of the world's people that are hungry, despite a doubling of the total population (Fig. 1) (1, 2). Nevertheless, more than one in seven people today still do not have access to sufficient protein and energy from their diet, and even more suffer from some form of micronutrient malnutrition (3). The world is now facing a new set of intersecting challenges (4). The global population will continue to grow, yet it is likely to plateau at some 9 billion people by roughly the middle of this century. A major driver of this deceleration is population growth in nonindustrial wealth, and with higher purchasing power comes higher consumption and a greater demand for processed food, meat, dairy, and fish, all of which add pressure to the food supply system. At the same time, food producers are experiencing greater competition for land, water, and energy, and the need to curb the many negative effects of food production on the environment is becoming increasingly clear (5, 6). Overarching all of these issues is the threat of the effects of substantial climate change: increased sea level rise, more frequent and intense extreme weather events, and adaptation measures may affect the food system (7, 8).

A threefold challenge now faces the world (9). Match the rapidly changing demand for food

from a larger and more affluent population to its supply, do so in ways that are environmentally and socially sustainable, and ensure that the world's poorest people are no longer hungry. This challenge requires changes in the way food is produced, stored, processed, distributed, and consumed that are as radical as those that occurred

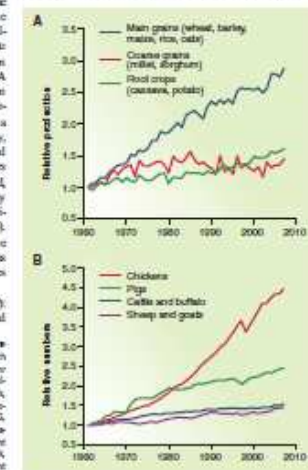


Fig. 1. Changes in the relative global production of crops and animals since 1961 (when relative production scaled to 1 in 1961). (A) Major crop plants and (B) major types of livestock. [Source: (2)]

during the 18th- and 19th-century Industrial and Agricultural Revolutions and the 20th-century Green Revolution. Increases in production will have an important part to play, but they will be essential to ensure that the finite resources provided by Earth's lands, oceans, and atmosphere (10).

Patterns in global food prices are indicators of trends in the availability of food, at least for those who can afford it and have access to world markets. Over the past century, grain food prices have generally fallen, leveling off in the past three decades but punctuated by price spikes such as that caused by the 1970s oil crisis. In mid-2008, there was an unexpected rapid rise in food prices, the cause of which is still being debated, but abated when the world economy went into recession (11). However, many (but not all) commentators have predicted that this spike heralds a period of rising and more volatile food prices driven primarily by increased demand from rapidly developing countries, as well as by competition for resources from bio-energy and bio-fuels production (12). Increased food prices will stimulate greater investment in food production, but the critical importance of food to human well-being and also to social and political stability makes it likely that governments and other organizations will want to encourage food production beyond that driven by simple market mechanisms (13). The long-term nature of options on investment for many aspects of food production and the importance of policies that promote sustainability and equity also argue against purely relying on market solutions.

So how can more food be produced sustainably? In the past, the primary solution to food shortages has been to bring more land into agriculture and to exploit new fish stocks. Yet over the past 5 decades, while grain production has more than doubled, the amount of land devoted to arable agriculture globally has increased by only ~9% (14). Some new land could be brought into cultivation, but the competition for land from other human activities makes this an increasingly unlikely and costly solution, particularly if protecting biodiversity and the public goods provided by natural ecosystems (for example, carbon storage in soil) are given higher priority (15). In recent decades, agricultural land that was formerly productive has been lost to urbanization and other human uses, as well as to desertification, salinization, soil erosion, and other consequences of unsustainable land

¹Department of Zoology and Institute of Biodiversity at Brunel University, Brunel Road, Uxbridge, Middlesex, UK; ²U.K. Government Office for Science, 1 Victoria Street, London SW1H 0ET, UK; ³Agriculture and Horticulture Development Board, Warwick Park, Kenilworth, Warwickshire CV3 2JF, UK; ⁴Technical of Development Studies, London SW1H 0ET, UK; ⁵Virginia Tech, Pamplin College, Blacksburg, VA, USA; ⁶Department of Agricultural Science, University of Reading, Whiteknights, Reading, RG2 2AT, UK; ⁷International Centre for Tropical Agriculture, IITA, Ibadan, Nigeria; ⁸International Centre for Agricultural Sciences, ICRISAT, Patancheru, Andhra Pradesh, India; ⁹International Centre for Agricultural Sciences, ICRISAT, Patancheru, Andhra Pradesh, India; ¹⁰International Centre for Agricultural Sciences, ICRISAT, Patancheru, Andhra Pradesh, India; ¹¹International Centre for Agricultural Sciences, ICRISAT, Patancheru, Andhra Pradesh, India; ¹²International Centre for Agricultural Sciences, ICRISAT, Patancheru, Andhra Pradesh, India; ¹³International Centre for Agricultural Sciences, ICRISAT, Patancheru, Andhra Pradesh, India; ¹⁴International Centre for Agricultural Sciences, ICRISAT, Patancheru, Andhra Pradesh, India; ¹⁵International Centre for Agricultural Sciences, ICRISAT, Patancheru, Andhra Pradesh, India.

Foley et al., Nature, 2011

- Stop expanding agriculture
- Close yield gaps
- Increase agricultural resource efficiency
- Increase food delivery by shifting diets and reducing waste

ANALYSIS

doi:10.1038/nature10452

Solutions for a cultivated planet

Jonathan A. Foley¹, Navin Ramankutty², Kate A. Brauman³, Emily S. Cassidy⁴, James S. Gerber⁵, Matt Johnston¹, Nathaniel D. Mueller⁶, Christine O'Connell⁷, Deepak K. Ray⁸, Paul C. West⁹, Christian Balzer¹⁰, Elena M. Bennett¹¹, Stephen R. Carpenter¹², Jason Hill¹³, Chad Monfreda¹⁴, Stephen Polasky¹⁵, Johan Rockström¹⁶, John Sheehan¹⁷, Stefan Siebert¹⁸, David Tilman^{19,20} & David P. M. Zakarias²¹

Increasing population and consumption are placing unprecedented demands on agriculture and natural resources. Today, approximately a billion people are chronically malnourished while our agricultural systems are concurrently degrading land, water, biodiversity and climate on a global scale. To meet the world's future food security and sustainability needs, food production must grow substantially while, at the same time, agriculture's environmental footprint must shrink dramatically. Here we analyse solutions to this dilemma, showing that tremendous progress could be made by halting agricultural expansion, closing 'yield gaps' on underperforming lands, increasing cropping efficiency, shifting diets and reducing waste. Together, these strategies could double food production while greatly reducing the environmental impacts of agriculture.

Contemporary agriculture faces enormous challenges^{1–3}. Even with recent productivity gains, roughly one in seven people lack access to food or are chronically malnourished, stemming from continued poverty and mounting food prices^{4,5}. Unfortunately, the situation may worsen as food prices experience shocks from market speculation, bioenergy crop expansion and climatic disturbances^{6,7}. Even if we solve these food access challenges, much more crop production will probably be needed to guarantee future food security. Recent studies suggest that production would need to roughly double to keep pace with projected demands from population growth, dietary changes (especially meat consumption), and increasing bioenergy use^{8–10}, unless there are dramatic changes in agricultural consumption patterns.

Compounding this challenge, agriculture must also address tremendous environmental concerns. Agriculture is now a dominant force behind many environmental threats, including climate change, biodiversity loss and degradation of land and freshwater^{11–13}. In fact, agriculture is a major force driving the environment beyond the 'planetary boundaries'¹⁴ of ref. 13.

Looking forward, we face one of the greatest challenges of the twenty-first century: meeting society's growing food needs while simultaneously reducing agriculture's environmental harm. Here we consider several promising solutions to this grand challenge. Using new geospatial data and models, we evaluate how new approaches to agriculture could benefit both food production and environmental sustainability. Our analysis focuses on the agronomic and environmental aspects of these challenges, and leaves a richer discussion of associated social, economic and cultural issues to future work.

The state of global agriculture

Until recently, the scientific community could not measure, monitor and analyse the agriculture–food–environment system's complex linkages at the global scale. Today, however, we have new data that characterize worldwide patterns and trends in agriculture and the environment^{15–17}.

Agricultural extent

According to the Food and Agriculture Organization (FAO) of the United Nations, croplands cover 1.53 billion hectares (about 12% of Earth's ice-free land), while pastures cover another 3.38 billion hectares (about 26% of Earth's ice-free land) (Supplementary Fig. 1). Altogether, agriculture occupies about 38% of Earth's terrestrial surface—the largest use of land on the planet¹⁸. These areas comprise the land best suited for farming¹⁹; much of the rest is covered by deserts, mountains, tundra, cities, ecological reserves and other lands unsuitable for agriculture²⁰.

Between 1985 and 2005 the world's croplands and pastures expanded by 154 million hectares (about 3%). But this slow net increase includes significant expansion in some areas (the tropics), as well as little change or a decrease in others (the temperate zone²¹, Supplementary Table 1). The result is a net redistribution of agricultural land towards the tropics, with implications for food production, food security and the environment.

Crop yields

Global crop production has increased substantially in recent decades. Studies of common crop groups (including cereals, oilseeds, fruits and vegetables) suggest that crop production increased by 47% between 1985 and 2005 (ref. 18). However, considering all 174 crops tracked by the UN FAO and ref. 15, we find global crop production increased by only 28% during that time²².

This 28% gain in production occurred as cropland area increased by only 2.4%, suggesting a 25% increase in yield. However, cropland area that was harvested increased by about 7% between 1985 and 2005—nearly three times the change in cropland area, owing to increased multiple cropping, fewer crop failures, and less land left fallow. Accounting for the increase in harvested land, average global crop yields increased by only 20% between 1985 and 2005, substantially less than the often-cited 47% production increase for selected crop groups. (Using the same methods as for the 20% result, we note that yields increased by 56% between 1985 and 1989, indicating that yields are now rising less quickly than before.)

¹ Institute of the Environment (IEnE), University of Minnesota, 1505 Buford Avenue, Saint Paul, Minnesota 55108, USA. ² Department of Geography and Global Environmental and Climate Change Centre, McGill University, 805 Desmarées Street, West Montreal, Quebec H3A 2K6, Canada. ³ Department of Ecology, Evolution and Marine Biology, University of California, Santa Barbara, California 93104, USA. ⁴ School of Environment and Department of Natural Resource Science, McGill University, 1111 Lakeshore Road, Ste Anne des Alpes, Quebec, H9B 2K6, Canada. ⁵ Center for Limnology, University of Wisconsin, 620 North Park Street, Madison, Wisconsin 53706, USA. ⁶ Department of Agricultural and Biological Engineering, University of Illinois, 2004 Food Building, Urbana, Illinois 61824, USA. ⁷ Center for the Science, Policy and Economics (CSPE), Arizona State University, 1120 S. Cayle Mall, Tempe, Arizona 85287, USA. ⁸ Department of Applied Economics, University of Warwick, 1994 Coventry Avenue, Coventry CV4 7AL, UK. ⁹ School of Earth and Atmospheric Sciences, Georgia Institute of Technology, 770 Chastain Road, Atlanta, Georgia 30332, USA. ¹⁰ Institute of Energy Studies and Resources Governance, University of Bonn, 53115, Bonn, Germany. ¹¹ Department of Ecology, Evolution and Systematics, University of Minnesota, 1907 Upper Buford Circle, Minneapolis 55455, USA. ¹² Center for Sustainability and the Global Environment (CSGE), University of Wisconsin, 1710 University Avenue, Madison, Wisconsin 53706, USA.

Two Narratives

- **Narrative:** discourse based on a coherent set of assumptions and principles underpinning and communicating a certain worldview
- Levidow (2008):
 - descriptive accounts: claims about objective reality as threats, opportunities and imperatives
 - normative accounts: claims about necessary or desirable responses to that objective reality
 - policy instruments for carrying out those responses

“Regardless of its stated aims, a dominant narrative succeeds in the normative sense of gaining resources and power, while pre-empting alternative futures”

The Productivity Narrative

- *The problem* - World population 9.2 billion in 2050 - agricultural productivity slowing down - rising income levels shift diets to more protein rich food and will increase energy demand - serious threat that food demand will not be met - hunger and political instability - resource constraints and climate change limit the world's capacity to expand food production.
- *The solution* - Scientific advances have the potential to bring forward varieties, breeds and technologies that boost productivity and take into account resource scarcities and environmental problems - massive investments into R&D -removal of barriers to adoption by farmers, such as infrastructure, trade barriers and access to markets.

MORE WITH LESS

The Sufficiency Narrative

- *The problem* - World population 9.2 billion people in 2050 - dramatic environmental problems - no Earth capacity to support consumption - current food systems produce waste and overconsumption - mass health problems - destruction of important ecosystems will have dramatic feedback effects that undermine the foundations of our food systems - more poverty and conflict.
- *The solution* - Scientific advances have the potential to bring forward agro-ecosystems that are both productive, respectful for ecosystems and resource saving - demand increases need to be mitigated through behavioural change - environmental externalities need to be internalized in markets - appropriate governance structures that address disruptive effect of trade.

LESS IS MORE

Productivity Narrative

“We should produce more efficiently”

Business model contested

Sufficiency Narrative

“We should consume less”

No business model or
small niche market

SYNTHESIS

Sustainability = efficiency +
sufficiency

Transitions

- Processes instigated to achieve **long-term** changes in **systems** so that “wicked” problems (such as potential scarcities) can be tackled
- Entail a wide **complexity** of interrelated developments in economics, culture, technology, institutions and the environment
- Imply great **uncertainty** because the course they take is unpredictable and is influenced by exogenous factors

Transitions

A transition is a *social transformation process* with the following characteristics:

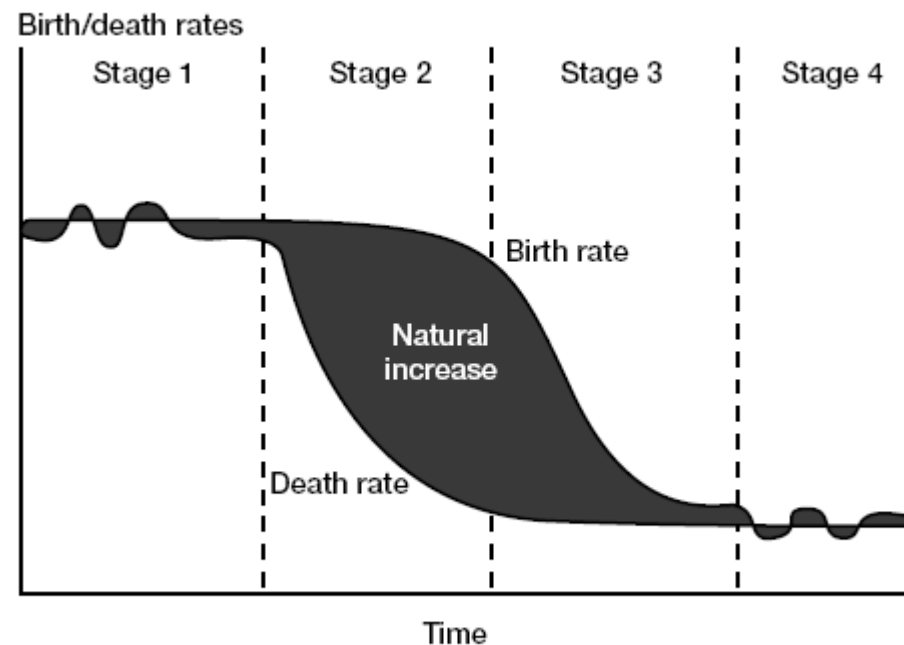
- structural change in society (or complex subsystem of society)
- a long-term process that covers at least one generation
- large-scale technological, economic, ecological, socio-cultural and institutional developments that influence and strengthen each other
- interactions between developments at different scale levels

(Jan Rotmans)

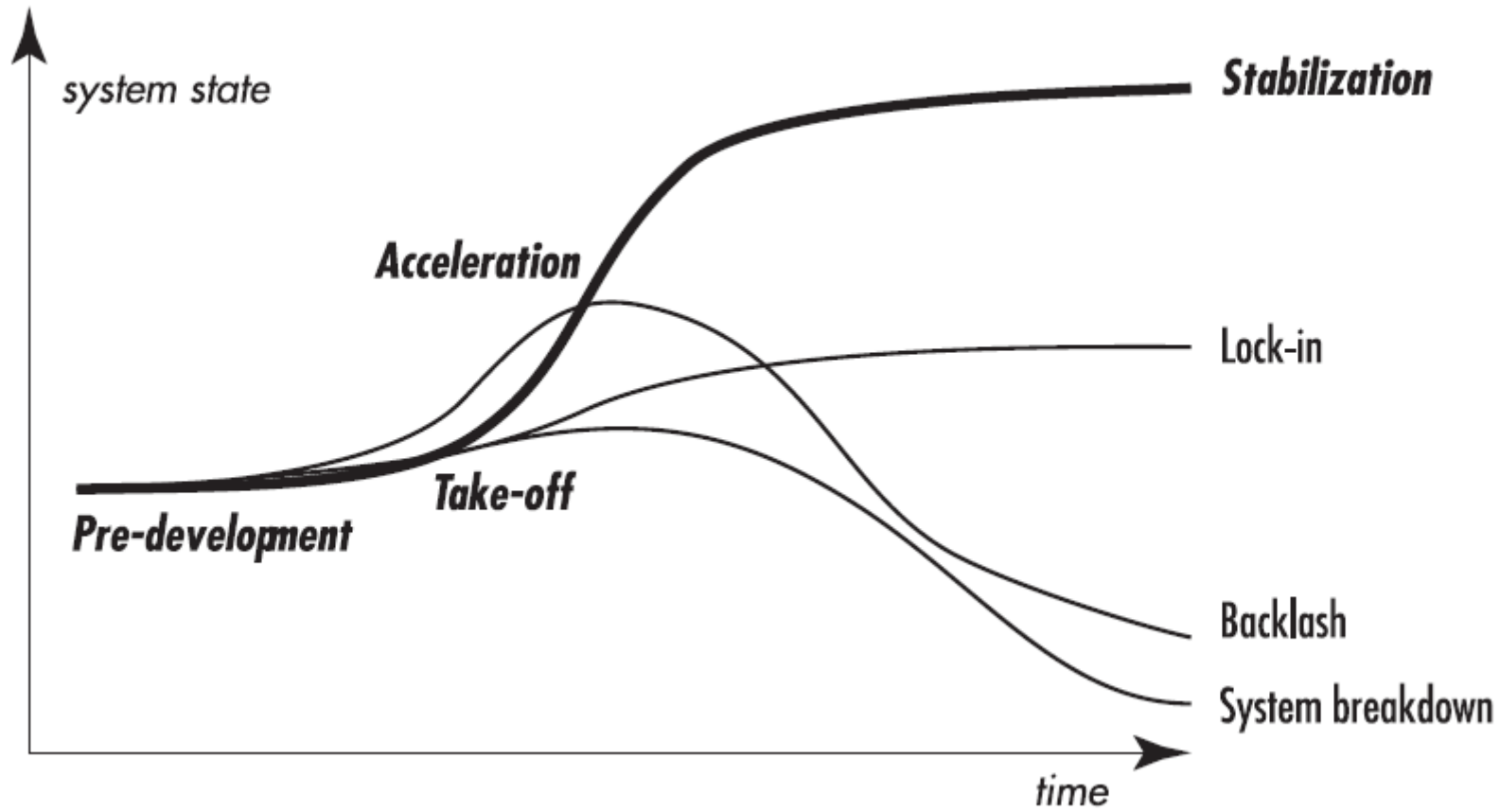
Transitions

- Fundamental system changes towards sustainability
- Long run
- Integrated approach
- Multiple actors from multiple domains
- Multi-level

The Classic Stages of Demographic Transition



Note: Natural increase or decrease is produced from the difference between the number of births and deaths.



The different phases of a transition and different transition pathways (Rotmans, 2005)

Implications

- Traditional approach fails: worked well in the past, insufficient progress towards sustainability, innovation gap, narrow focus not aiming at tackling multiple challenges simultaneously
- New approach of two parallel and overlapping approaches:
 - Build on existing technologies and knowledge systems
 - Develop radically new farming systems

Implications

- Build on existing food systems (component type research):
 - Builds on existing research on productivity and sustainability
 - ‘Incremental approach’ (NRC), ‘Sustainable Intensification’ (The Royal Society)
 - Identify and develop methods that enhance certain aspects of sustainability
 - socio-economic and cultural research needed to accelerate adoption

Implications

- Develop new food systems (holistic):
 - Builds on science & technology in which agriculture is a vital component in the management of natural resources and emphasizes a systems-based approach to knowledge production and sharing
 - Current knowledge infrastructure excluded ecological, local and traditional knowledge, but also the socio-cultural sciences → embrace broader set of understandings + focus on multiple scales
 - Builds on the strengths of natural systems and favors diversity that is fundamental to design resilient systems