World Development within Planetary Boundaries

GEF Governing Council

18th juni 2013

Prof. Johan Rockström
Stockholm Resilience Centre

Stockholm Resilience Centre
Research for Governance of Social-Ecological Systems

Stockholm University

A centre with:

SEI Stockholm Environment Institute

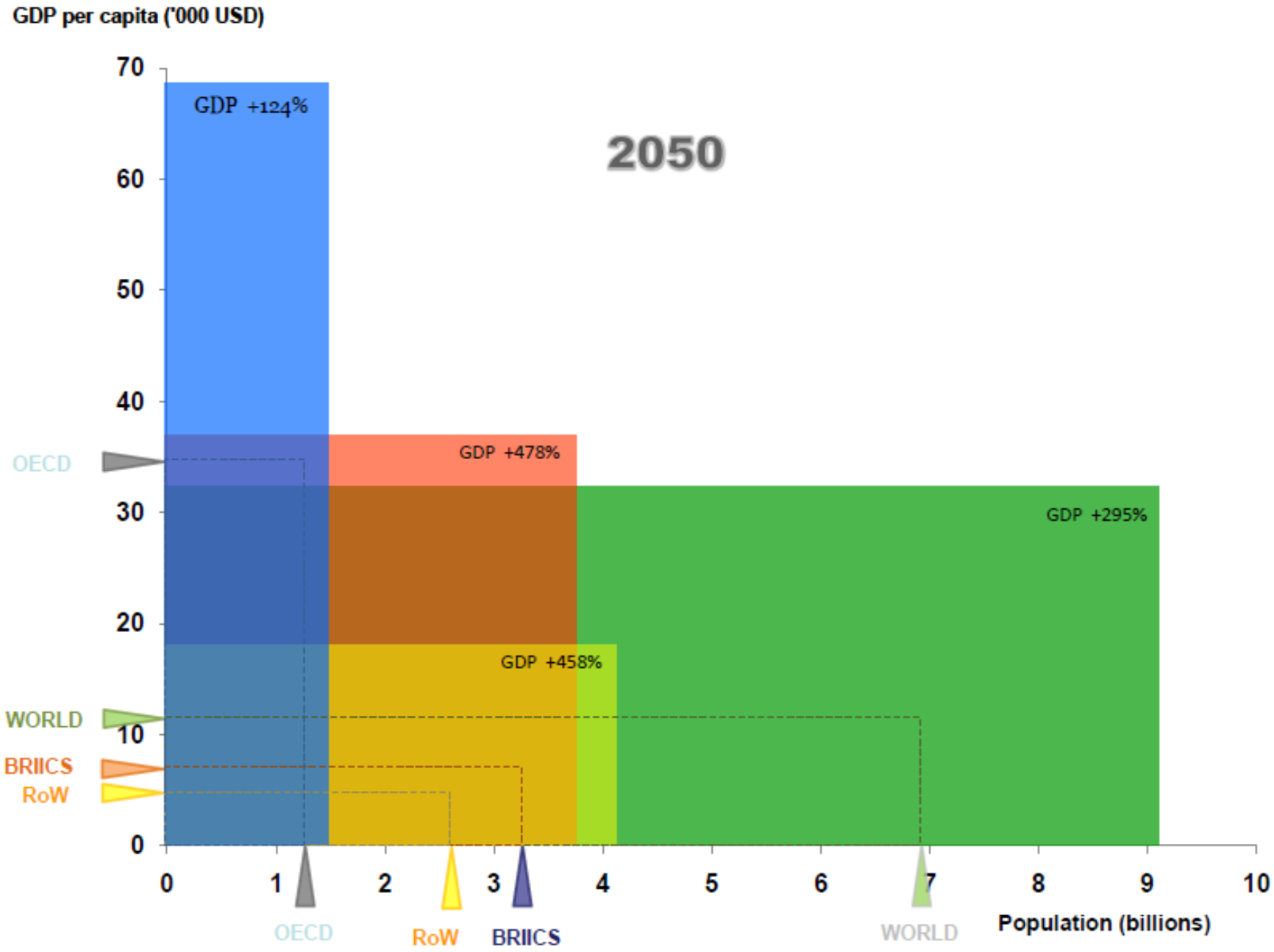
The Beijer Institute of Ecological Economics

FUNDED BY MISTRA

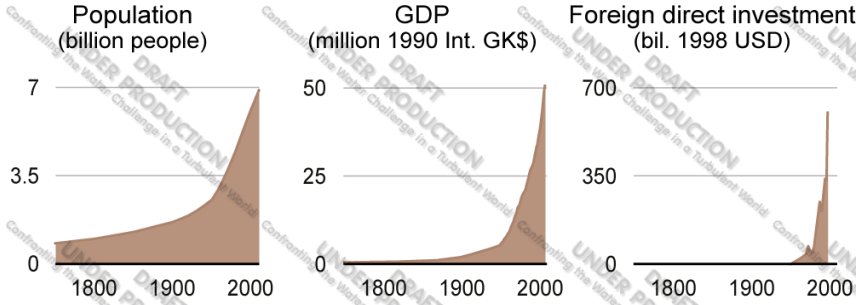
Article Will Steffen, Paul J. Crutzen and John R. McNeill

The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature?

Photos: Mattias Klum

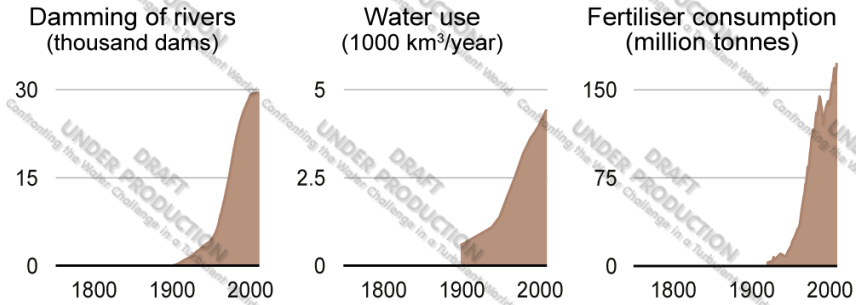


Source: OECD (2012), *OECD Environmental Outlook to 2050*, Baseline projection using ENV-Linkages model


Population
(billion people)
7
3.5
0
1800
1900
2000

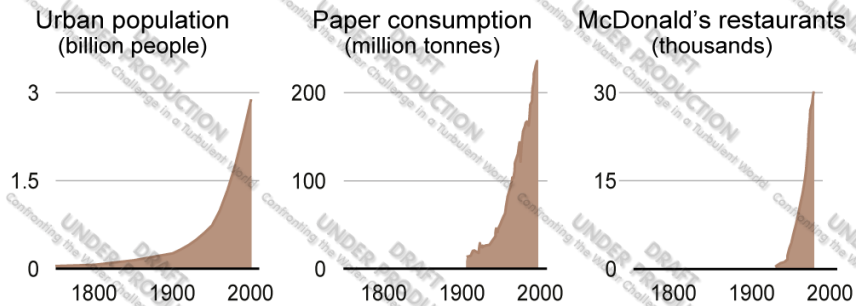
GDP
(million 1990 Int. GK$)
50
25
0
1800
1900
2000

Foreign direct investment
(bil. 1998 USD)
700
350
0
1800
1900
2000


Damming of rivers
(thousand dams)
30
15
0
1800
1900
2000

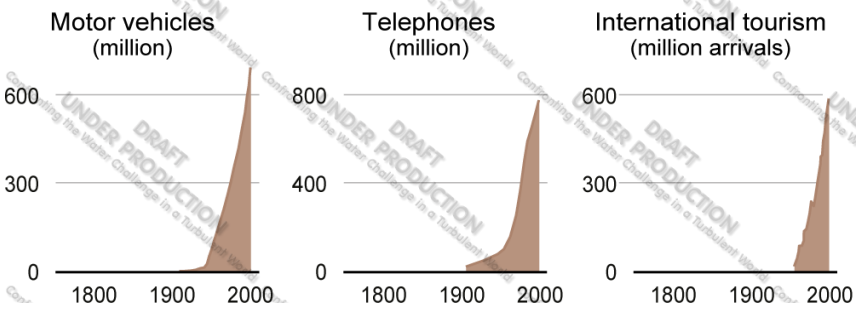
Water use
(1000 km³/year)
5
2.5
0
1800
1900
2000

Fertiliser consumption
(million tonnes)
150
75
0
1800
1900
2000


Urban population
(billion people)
3
1.5
0
1800
1900
2000

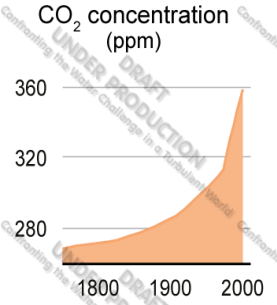
Paper consumption
(million tonnes)
200
100
0
1800
1900
2000

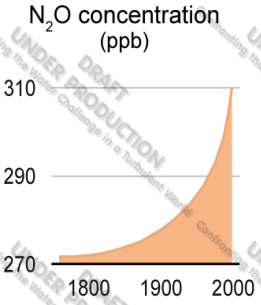
McDonald's restaurants
(thousands)
30
15
0
1800
1900
2000

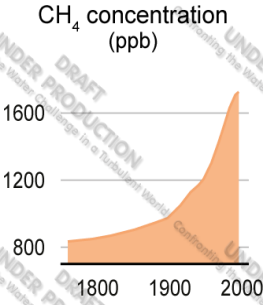

Motor vehicles
(million)
600
300
0
1800
1900
2000

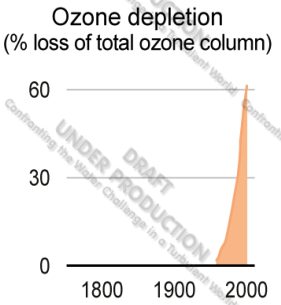
Telephones
(million)
800
400
0
1800
1900
2000

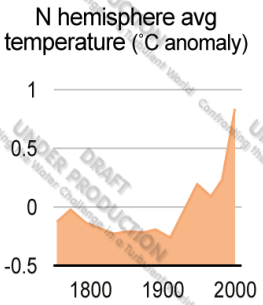
International tourism
(million arrivals)
600
300
0
1800
1900
2000

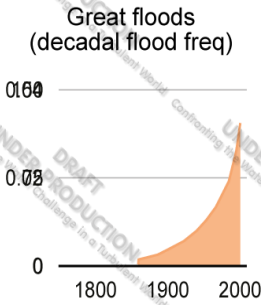

CO_2 concentration
(ppm)
360
320
280
1800
1900
2000

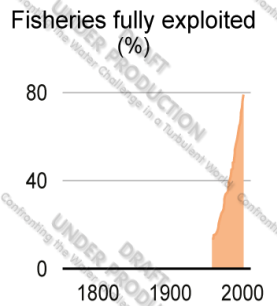

N_2O concentration
(ppb)
310
290
270
1800
1900
2000

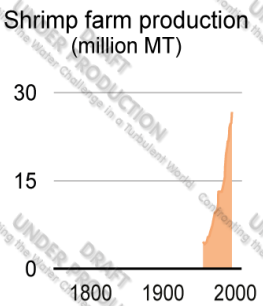

CH_4 concentration
(ppb)
1600
1200
800
1800
1900
2000

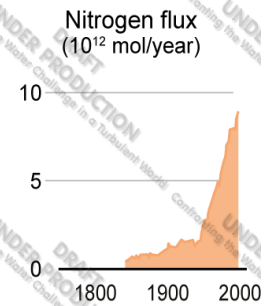

Ozone depletion
(% loss of total ozone column)
60
30
0
1800
1900
2000

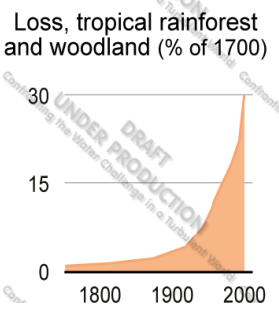

N hemisphere avg
temperature (°C anomaly)
1
0.5
0
-0.5
1800
1900
2000

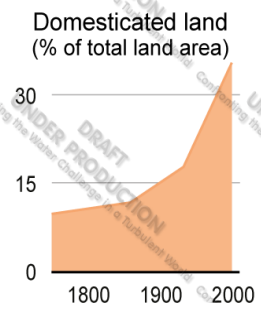

Great floods
(decadal flood freq)
0
1800
1900
2000

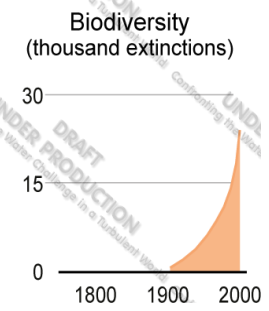

Fisheries fully exploited
(%)
80
40
0
1800
1900
2000


Shrimp farm production
(million MT)
30
15
0
1800
1900
2000

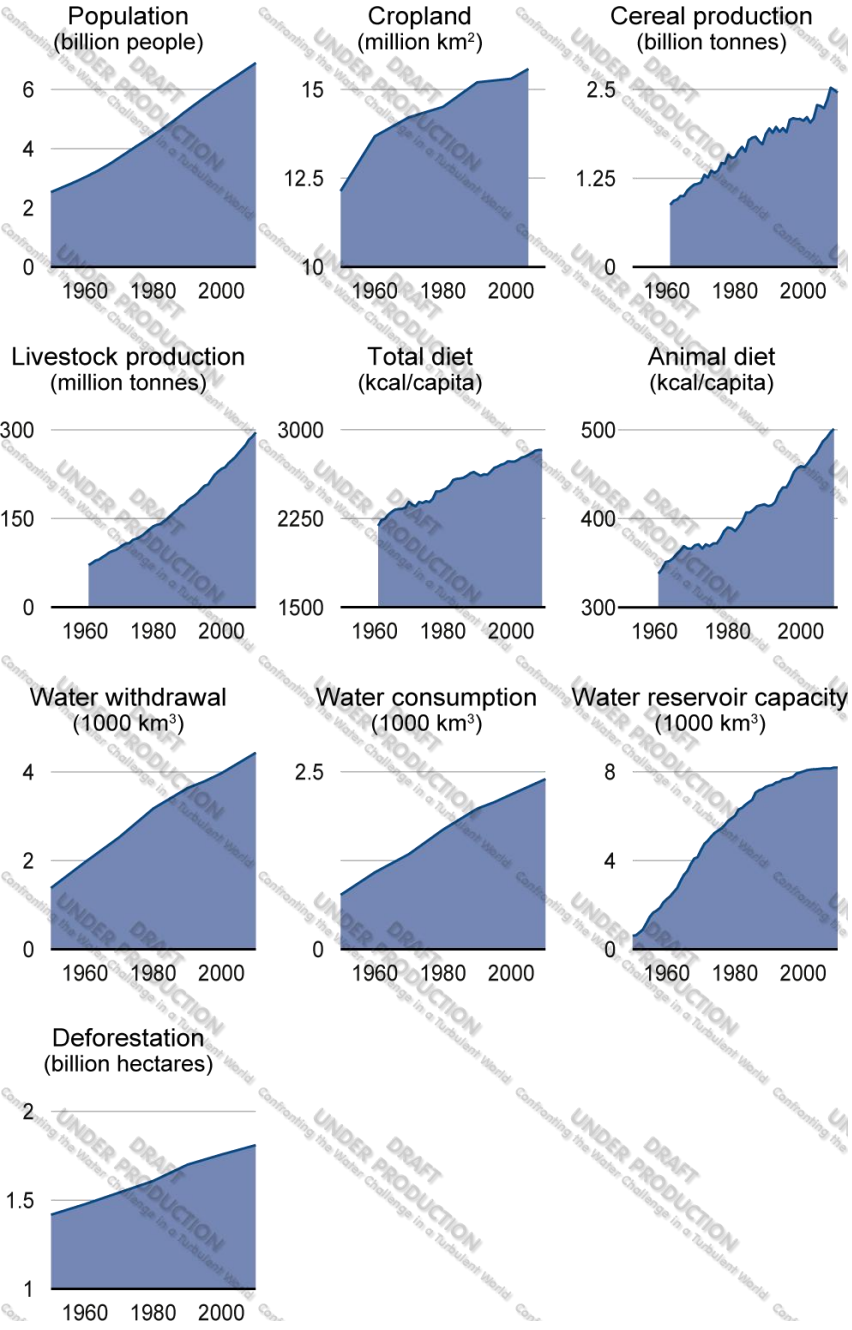

Nitrogen flux
(10^{12} mol/year)
10
5
0
1800
1900
2000

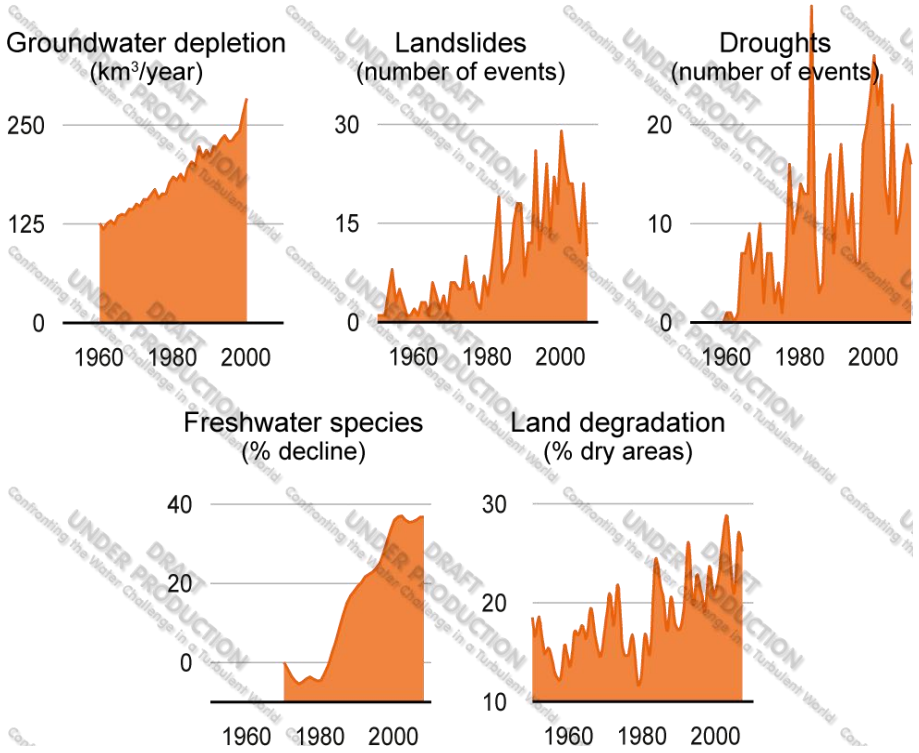

Loss, tropical rainforest
and woodland (% of 1700)
30
15
0
1800
1900
2000

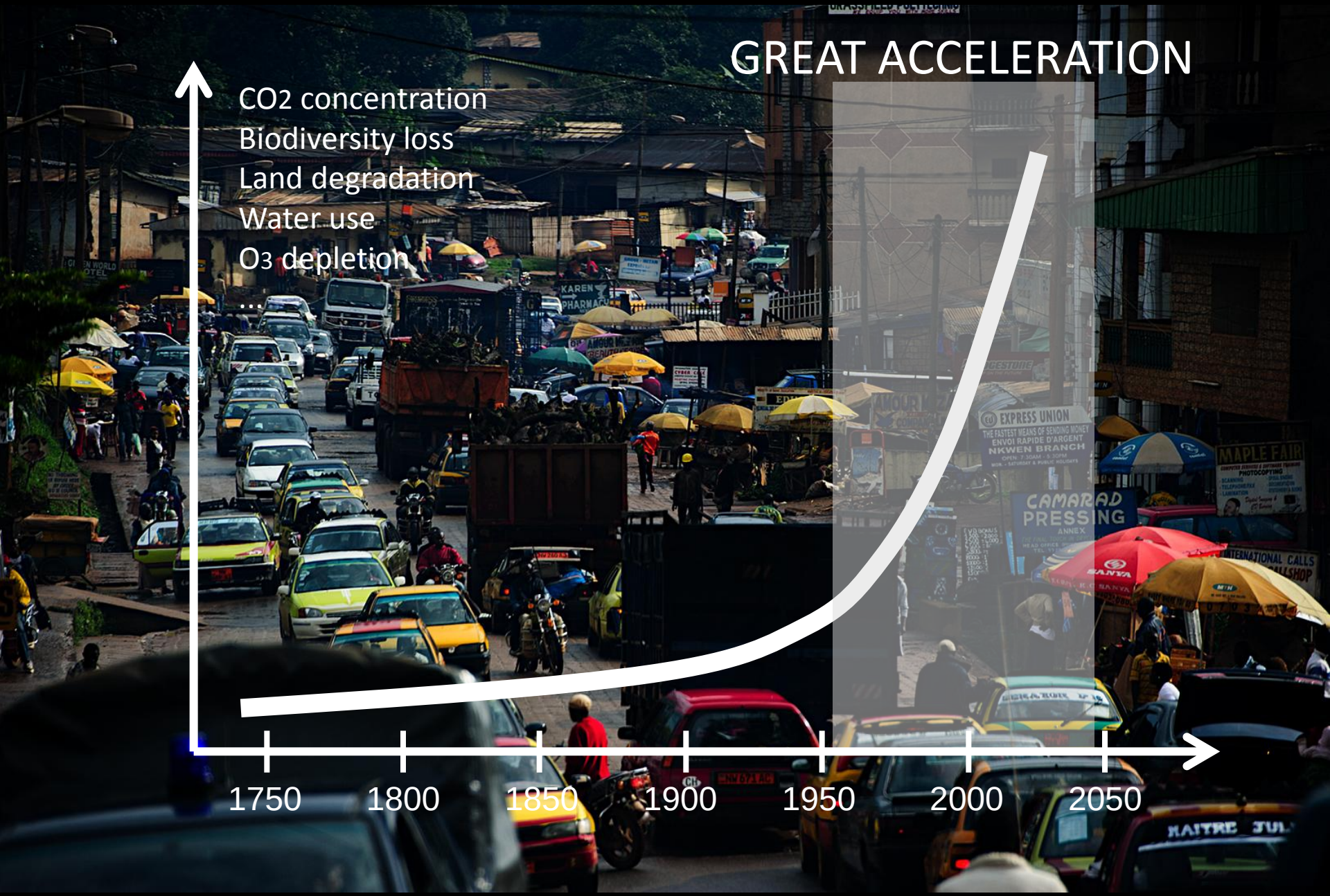

Domesticated land
(% of total land area)
30
15
0
1800
1900
2000


Biodiversity
(thousand extinctions)
30
15
0
1800
1900
2000

The Great Acceleration of the Human Enterprise






GREAT ACCELERATION
CO2 concentration
Biodiversity loss
Land degradation
Water use
O3 depletion
...
1750
1800
1850
1900
1950
2000
2050

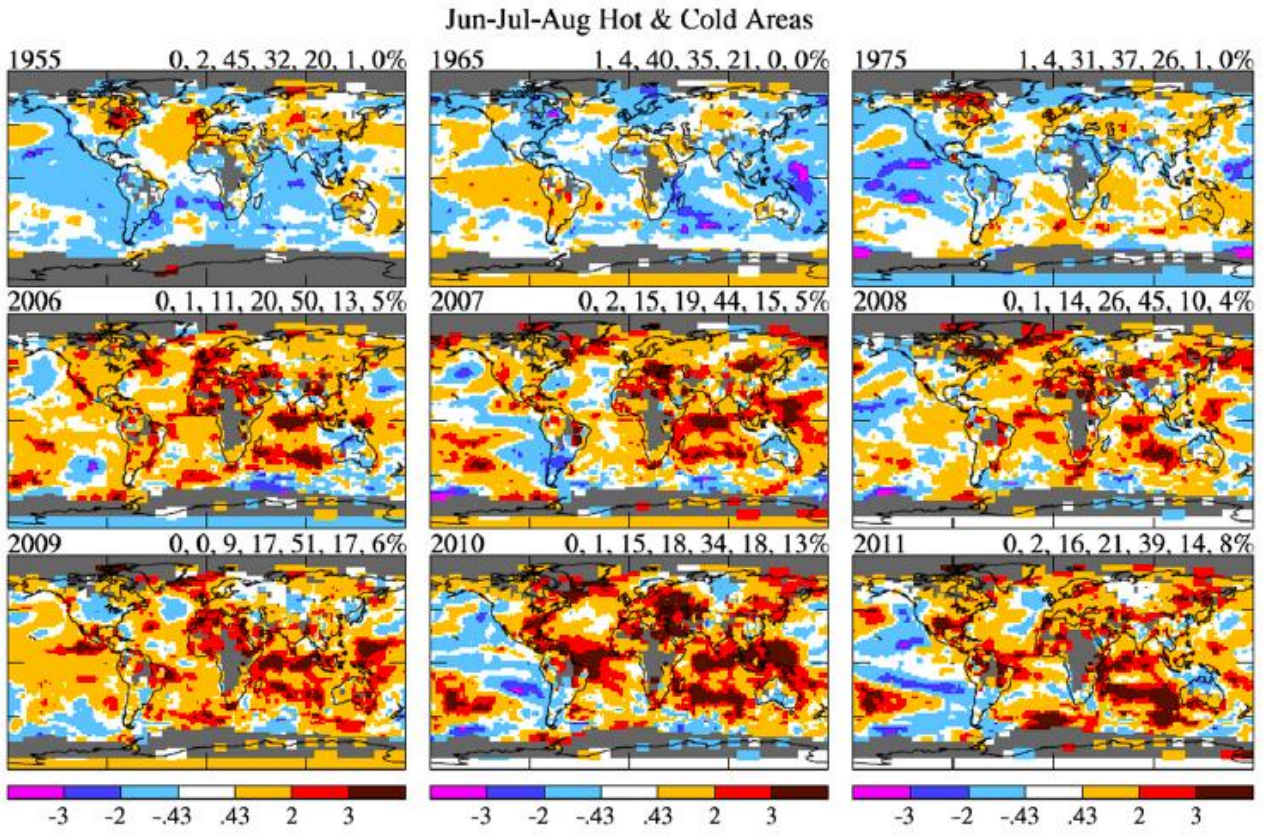
The Extreme Exception has become Today's Normality

% of Earth's surface hit by + 3 SD Events:

1955: 1 %

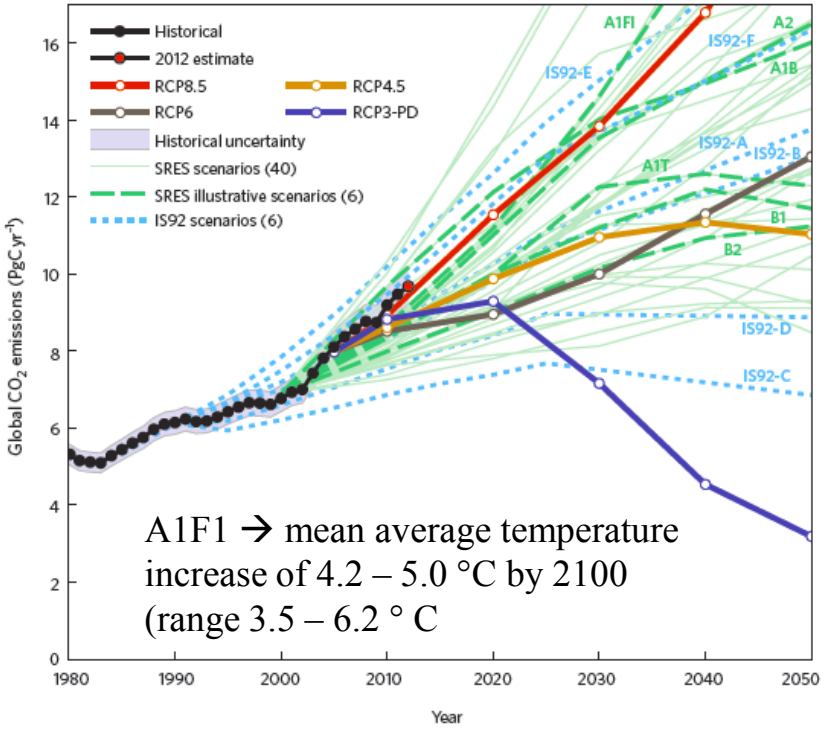
2011: 15 %

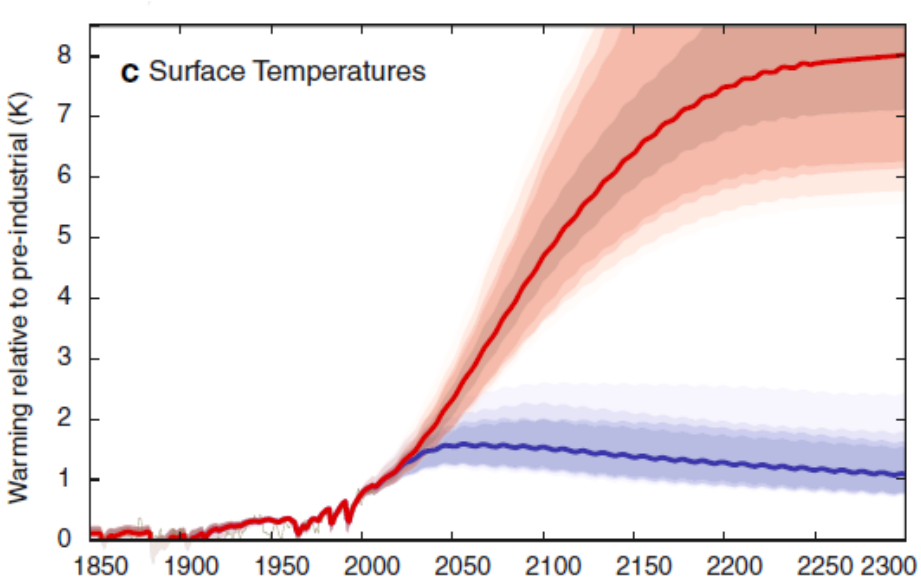
Sandy
US 2012 Drought
Russian forest fires
Europe 2003 Heatwave
East African Drought



Hansen et al 2012

Tipping the Scales towards a stable future basis for humanity





The RCP greenhouse gas concentrations and their extensions from 1765 to 2300

Malte Meinshausen • S. J. Smith • K. Calvin • J. S. Daniel • M. L. T. Kainuma • J-F. Lamarque • K. Matsumoto • S. A. Montzka • S. C. B. Raper • K. Riahi • A. Thomson • G. J. M. Velders • D.P. P. van Vuuren

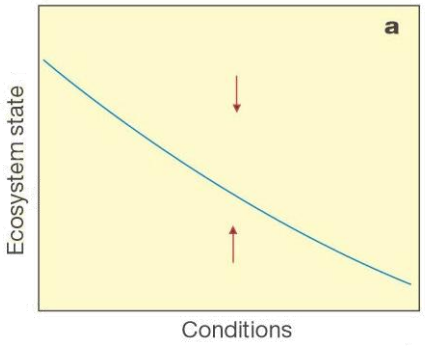
The challenge to keep global warming below 2 °C

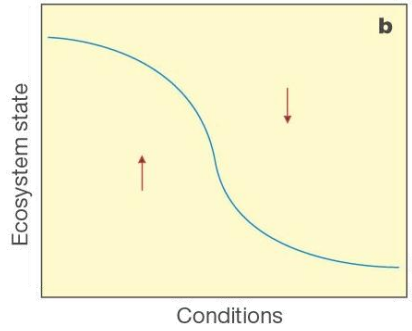
Glen P. Peters, Robbie M. Andrew, Tom Boden, Josep G. Canadell,
Philippe Ciais, Corinne Le Quéré, Gregg Marland, Michael R. Raupach and Charlie Wilson

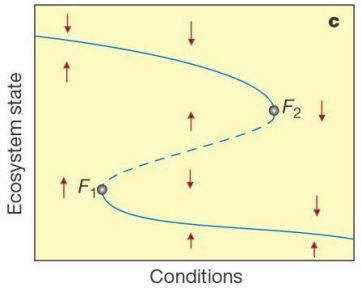
NATURE CLIMATE CHANGE | VOL 3 | JANUARY 2013 | www.nature.com/natureclimatechange

Critical transitions or regime shifts

Regime shifts are substantial, persistent, reorganizations in ecosystem structure and processes

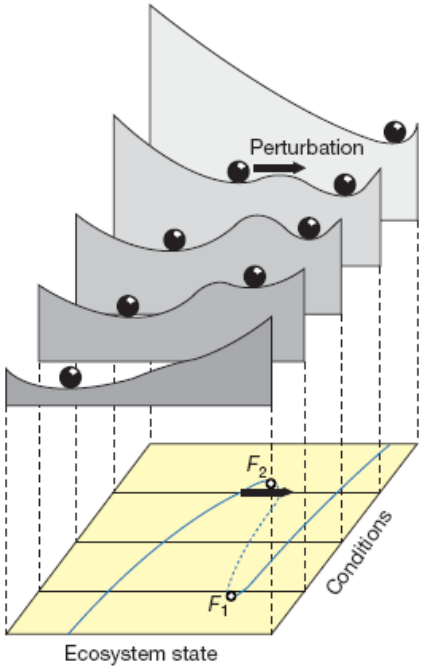






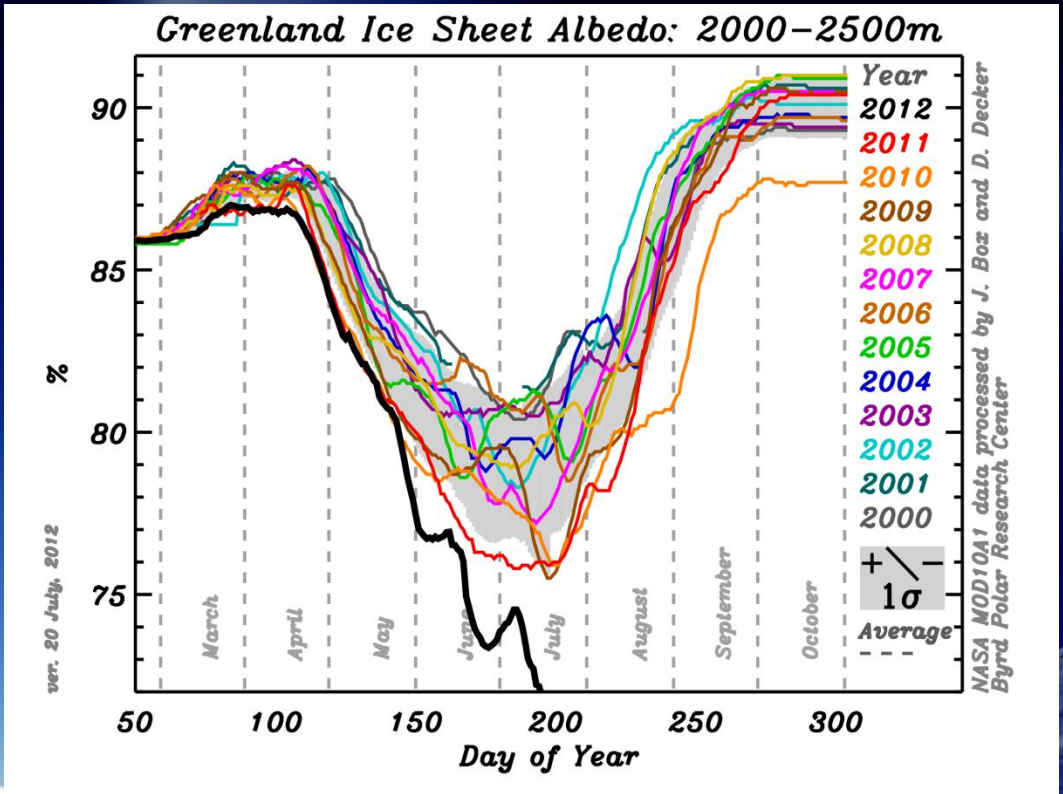
Parkland Savanna

Bush steppe



Diverse Coral dominated

Algae Dominated Reef



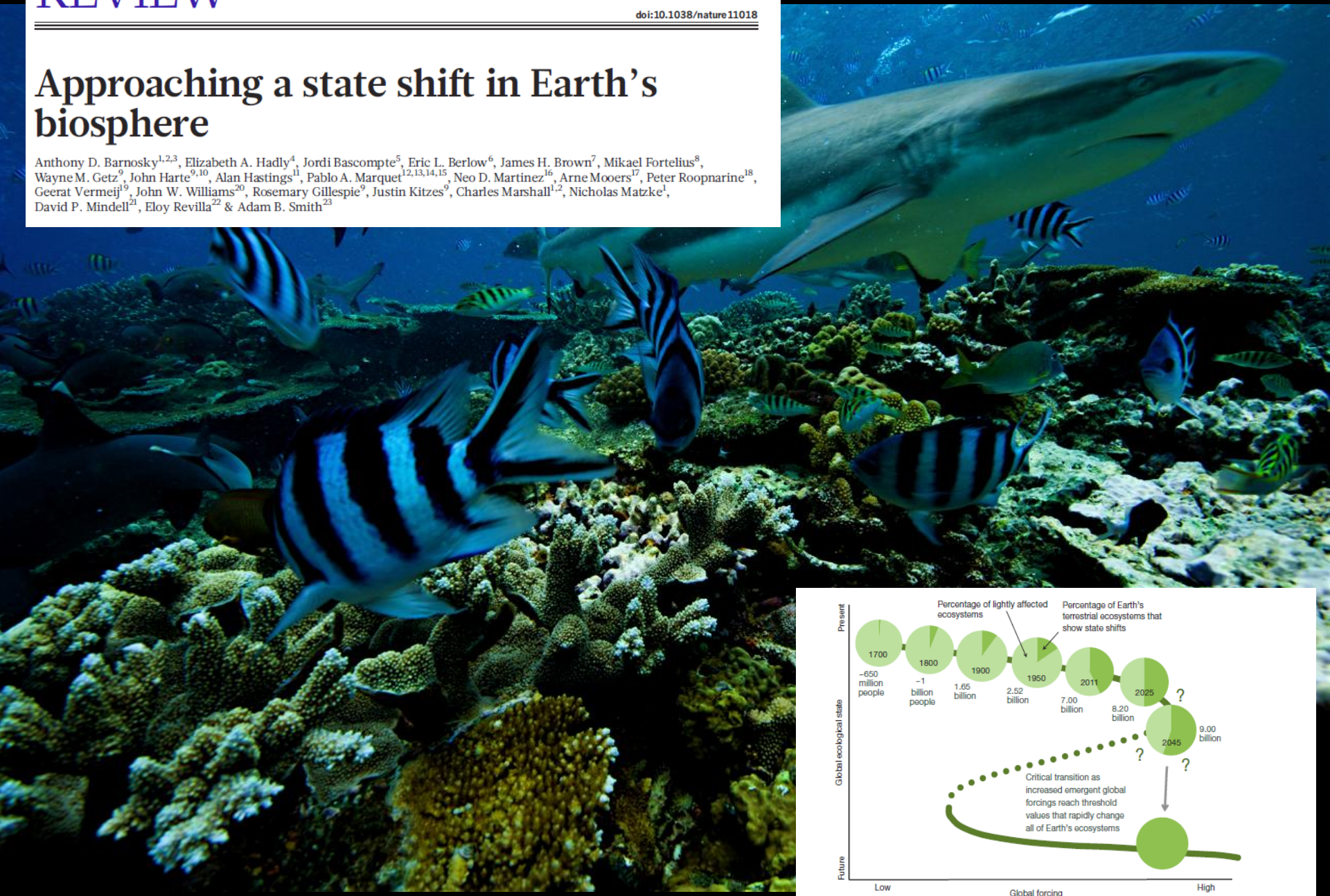
Jason Box et al., 2013. Byrd Institute

REVIEW

doi:10.1038/nature11018

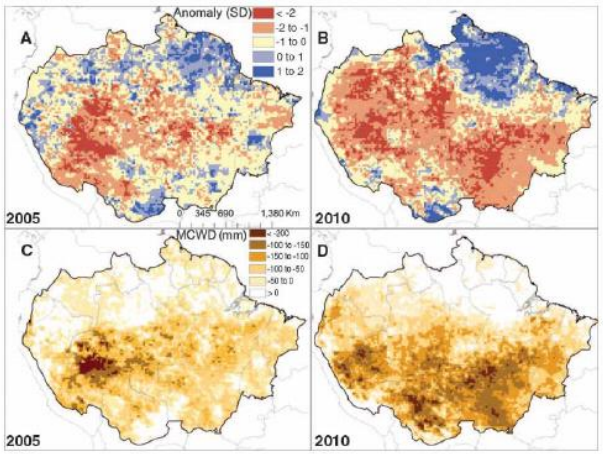
Approaching a state shift in Earth's biosphere

Anthony D. Barnosky[1,2,3], Elizabeth A. Hadly[4], Jordi Bascompte[5], Eric L. Berlow[6], James H. Brown[7], Mikael Fortelius[8], Wayne M. Getz[9], John Harte[9,10], Alan Hastings[11], Pablo A. Marquet[12,13,14,15], Neo D. Martinez[16], Arne Mooers[17], Peter Roopnarine[18], Geerat Vermeij[19], John W. Williams[20], Rosemary Gillespie[9], Justin Kitzes[9], Charles Marshall[1,2], Nicholas Matzke[1], David P. Mindell[21], Eloy Revilla[22] & Adam B. Smith[23]



Risk of Tipping Point in the Amazon Rainforest

Interactions between climate and land use change



Lewis et al. 2011 Science

Fig. 1. (**A** and **B**) Satellite-derived standardized anomalies for dry-season rainfall for the two most extensive droughts of the 21st century in Amazonia. (**C** and **D**) The difference in the 12-month (October to September) MCWD from the decadal mean (excluding 2005 and 2010), a measure of drought intensity that correlates with tree mortality. (A) and (C) show the 2005 drought; (B) and (D) show the 2010 drought.

Moisture feedback critical for rainfall

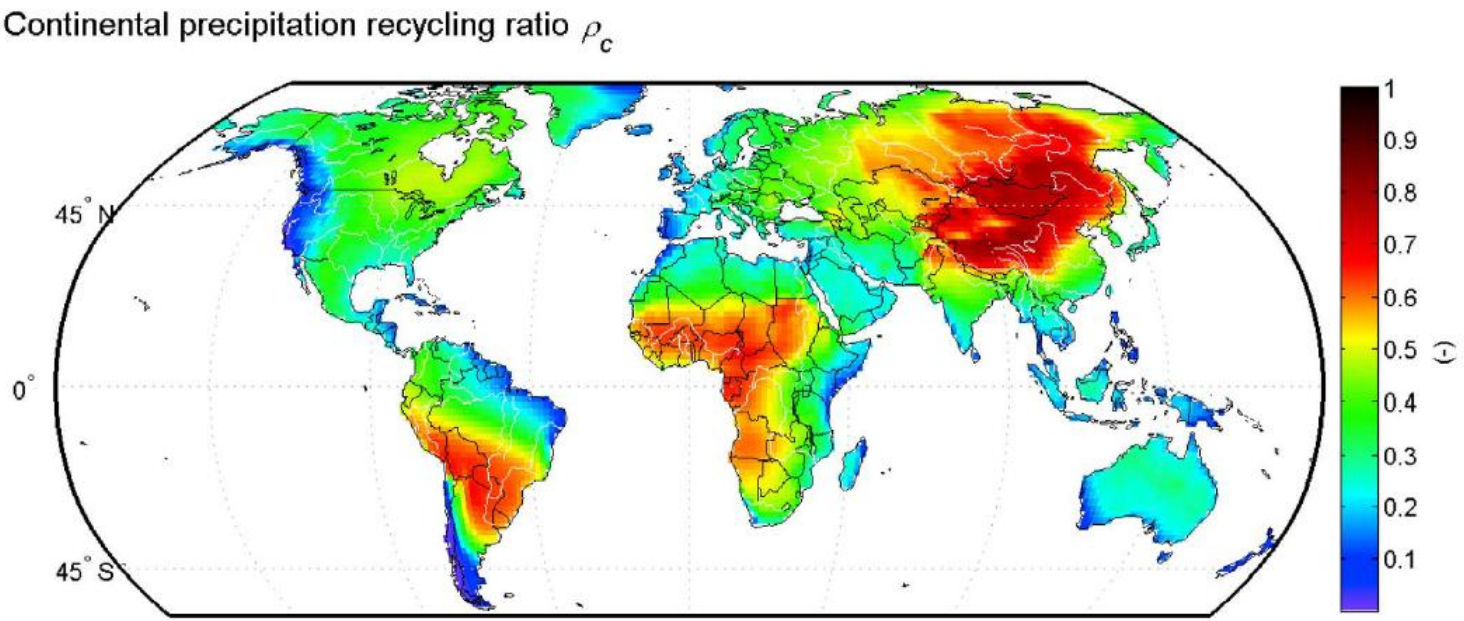


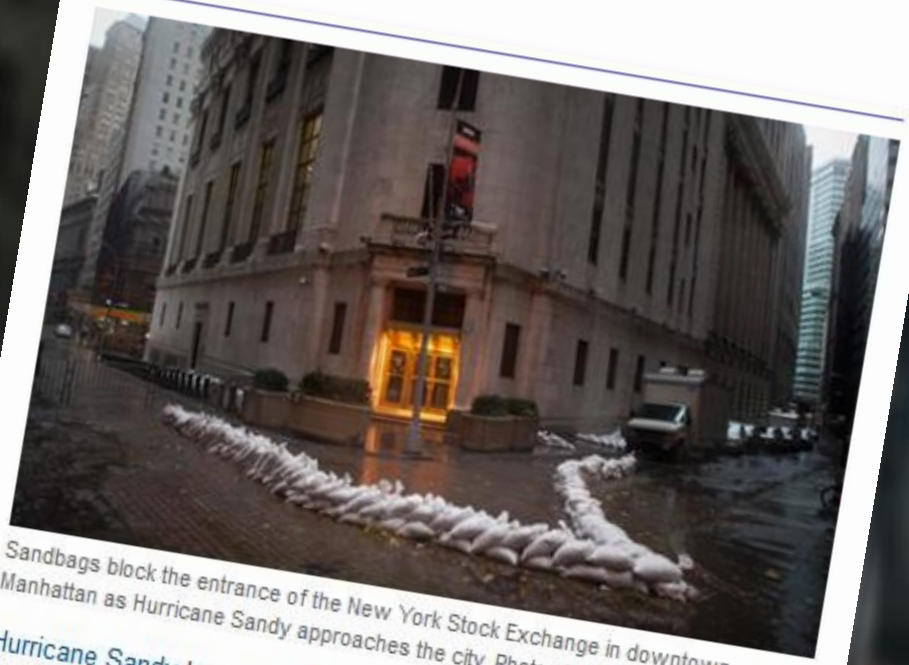
Figure 3. Average continental precipitation recycling ratio ρ_c (1999–2008).

guardian

New York stock markets close as insurers calculate hurricane damage

Financial analysts prepare for significant disruption to business and infrastructure and billions of insured loss

Dominic Rushe and Heidi Moore in New York
guardian.co.uk, Monday 29 October 2012 18.30 GMT
Jump to comments (11)



Sandbags block the entrance of the New York Stock Exchange in downtown Manhattan as Hurricane Sandy approaches the city. Photo: Andrew Kelly/Reuters

Hurricane Sandy has closed New York's stock markets as the city prepares for the worst – but although finance chiefs may be sitting it

Photo: Jordan Balderas

SCIENTIFIC AMERICAN™

Climate Change and Rising Food Prices Heightened Arab Spring

The effects of climate change on the food supply exacerbated the underlying tensions that have led to ongoing Middle East instability

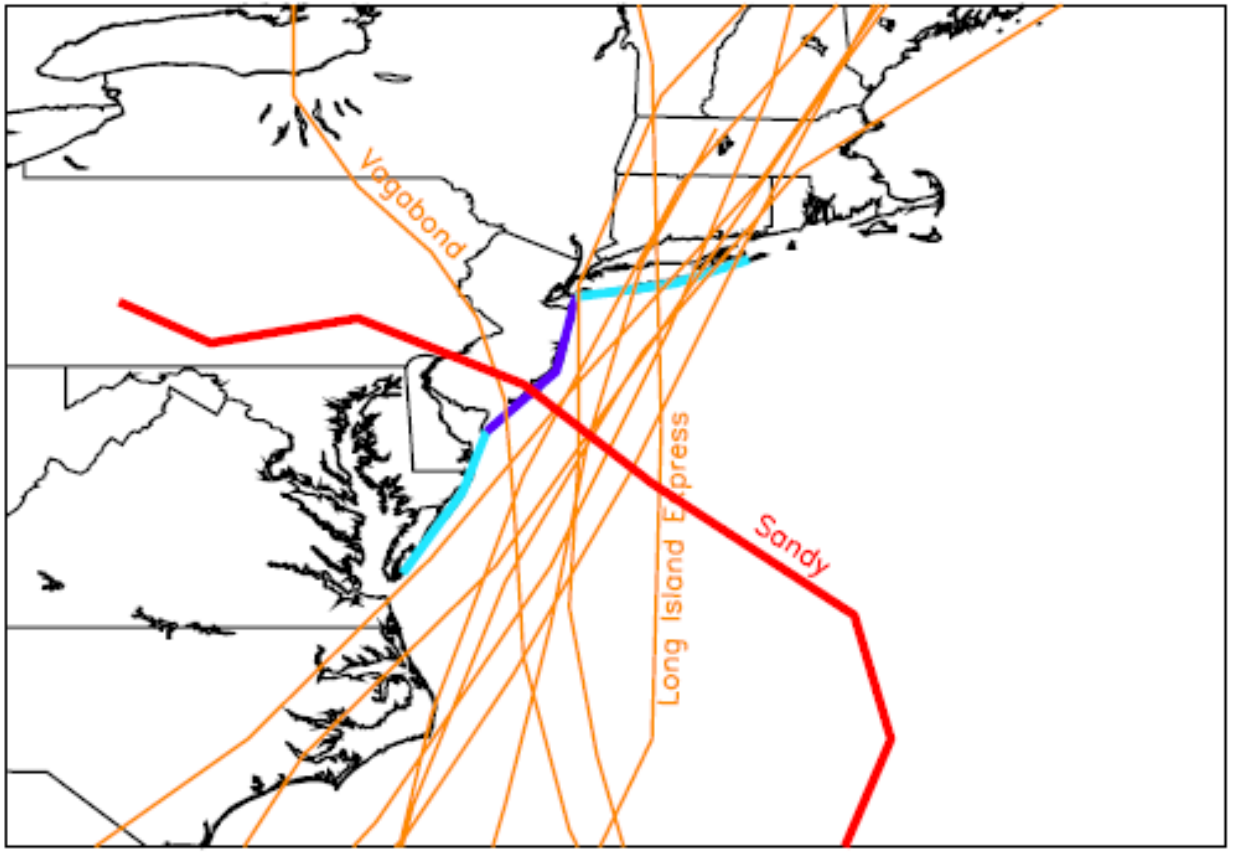
By Ines Perez and ClimateWire

ClimateWire

If the Arab Spring taught us something, it is that the effects of climate change can serve as stressors, contributing to regional instability and conflict, experts said.

In a report published last week, researchers from the Center for American Progress, the Center for Climate and Security and the Stimson Center examined the role of climate change in the Middle East's upheaval during 2010 and 2011. Looking at long-term trends in rain, crops, food prices and migration, they were able to determine how these factors contributed to social instability in the

The Middle East and North Africa region is extremely vulnerable to fluctuations in food



GEOPHYSICAL RESEARCH LETTERS, VOL. 40, 1–4, doi:10.1002/grl.50395, 2013

On the impact angle of Hurricane Sandy's New Jersey landfall

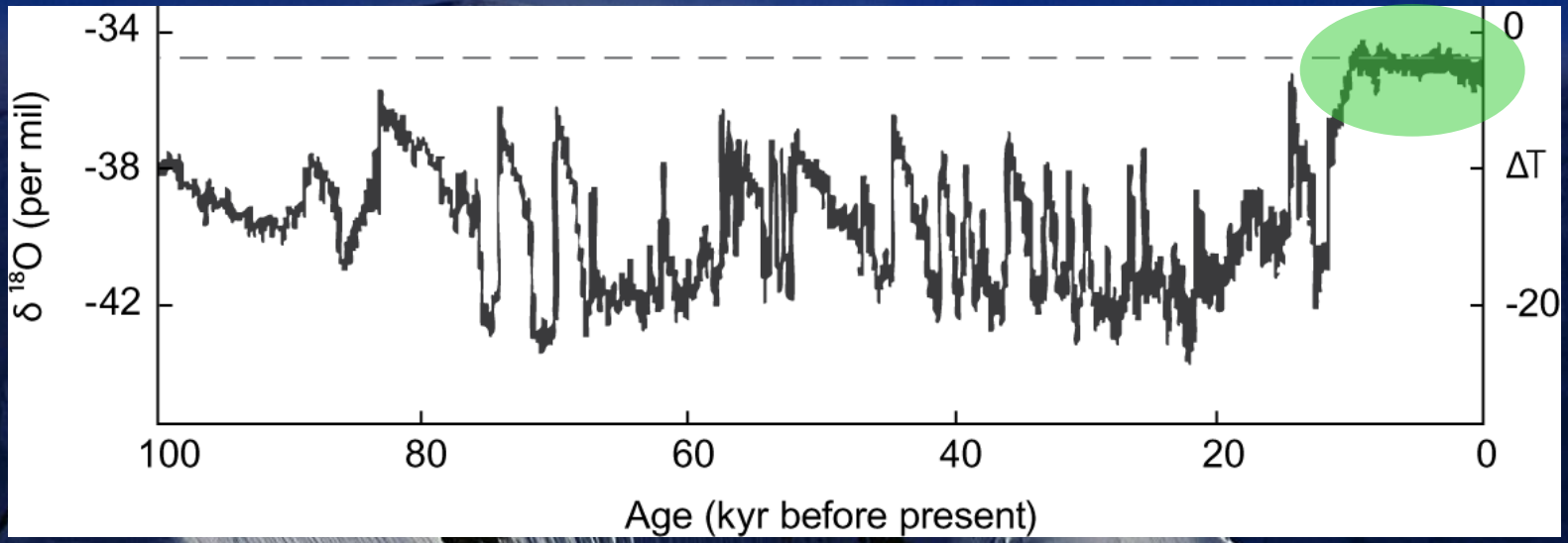
Timothy M. Hall[1] and Adam H. Sobel[2]

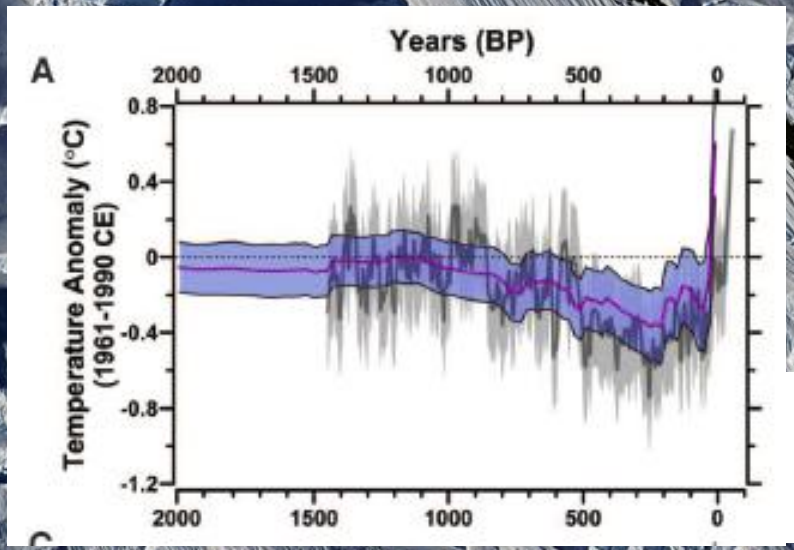
The Great Acceleration:
facing the risk that we have only reached
Humanity's Double Apperitif

Putting in the Social High Gear

Earth system starting its Engine of positive feedbacks

A new unified framework for human development within Earth's safe operating space

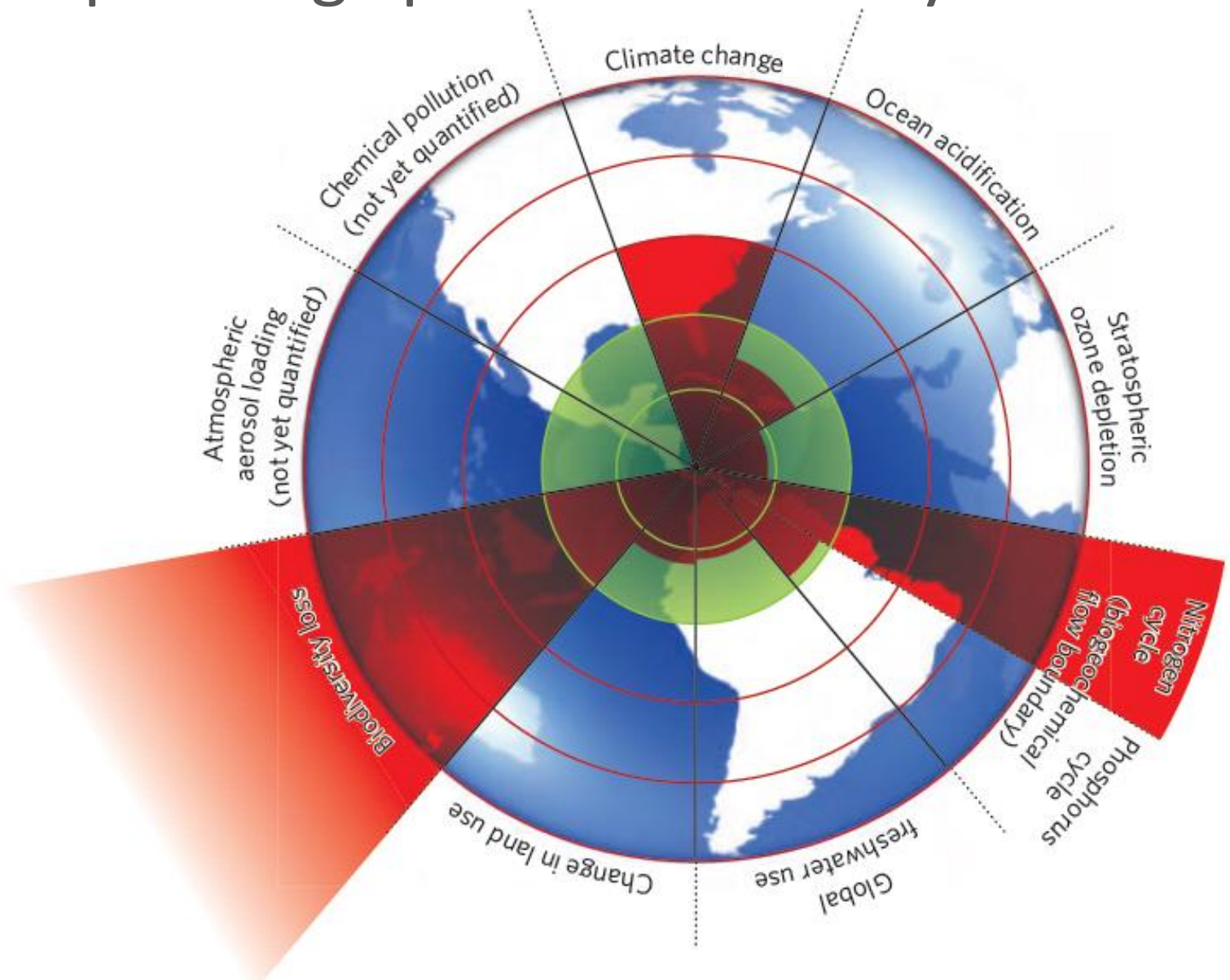




A Reconstruction of Regional and Global Temperature for the Past 11,300 Years

Shaun A. Marcott,[1] Jeremy D. Shakun,[2] Peter U. Clark,[1] Alan C. Mix[1]

Human Development within the Safe Operating Space of Planetary Boundaries

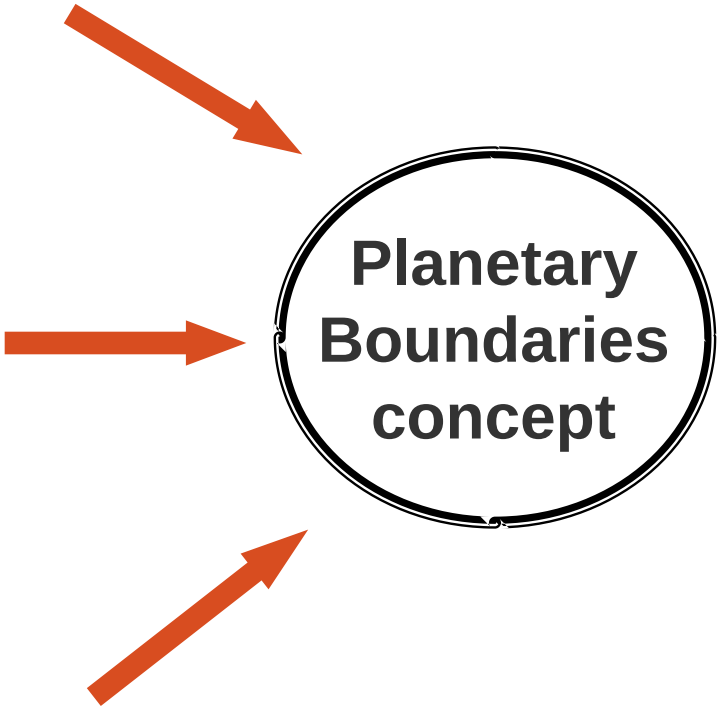


PB concept rests on three branches of Scientific inquiry

1. **Earth System and sustainability science**
   (Understanding Earth System processes; ICSU, IGBP, ESSP, IPCC, MEA, evolution of sustainability science…)

2. **Scale of human action in relation to the capacity of the planet to sustain it**
   (Kenneth Boulding Spaceship Earth, Herman Daly, Club of Rome, Ecological Economics reserach agenda, Ecological Footprint...)

3. **Shocks and Abrupt change in Social-Ecological systems from local to global scales**
   (Resilience, tipping elements, guardrails...)

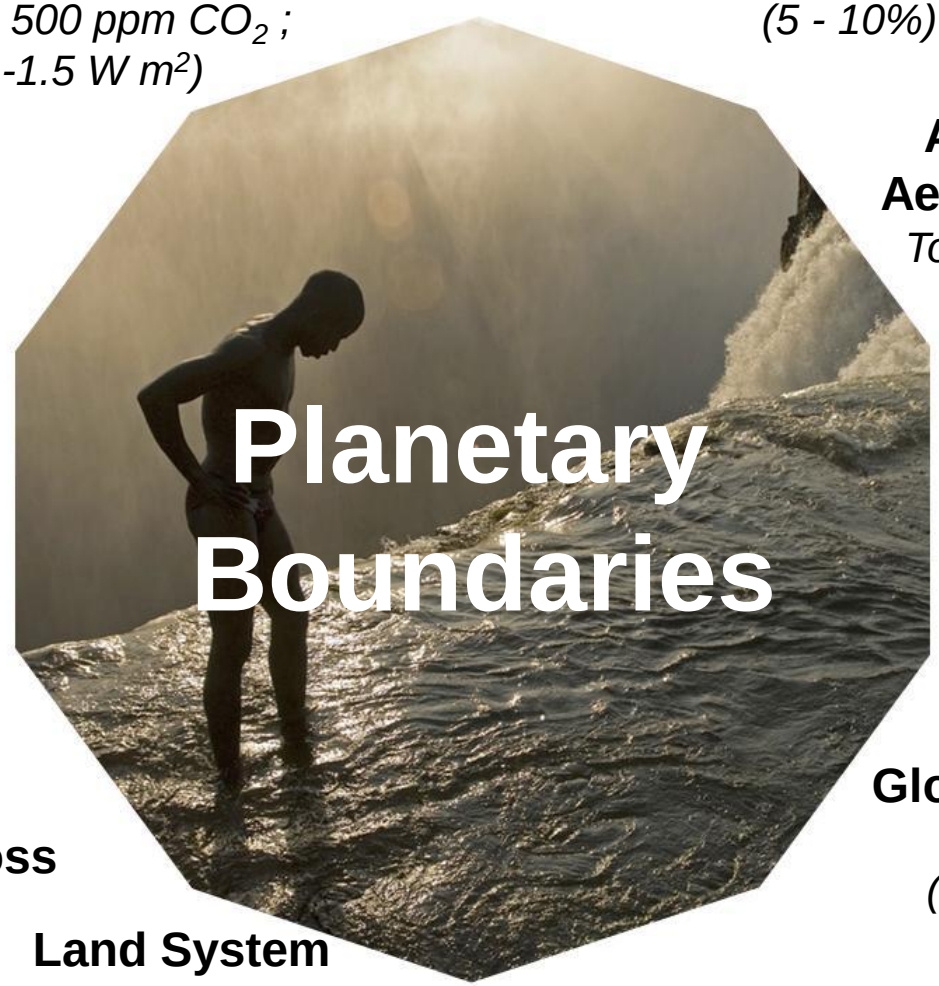



futureearth
research for global sustainability

Climate Change
< 350 ppm CO_2 < 1W m^2
(350 – 500 ppm CO_2 ;
1-1.5 W m^2)

Ozone depletion
< 5 % of Pre-Industrial 290 DU
(5 - 10%)

Biogeochemical loading: Global N & P Cycles
Limit industrial fixation of N_2 to 35 Tg N yr^{-1}(25 % of natural fixation)
(25%-35%)
P < 10× natural weathering inflow to Oceans
(10× – 100×)



Atmospheric Aerosol Loading
To be determined

Ocean acidification
Aragonite saturation ratio > 80 % above pre-industrial levels
(> 80% - > 70 %)

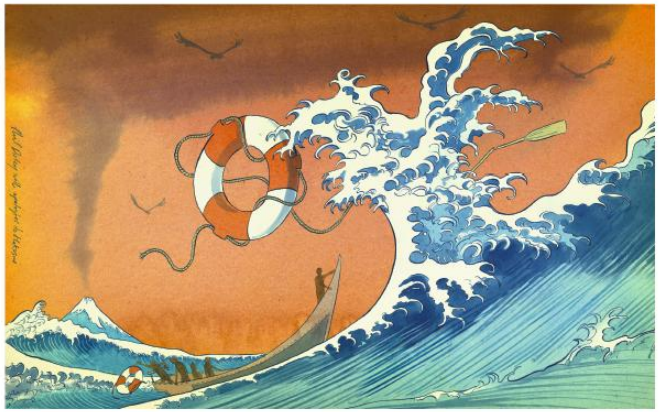
Rate of Biodiversity Loss
< 10 E/MSY
(< 10 - < 1000 E/MSY)

Global Freshwater Use
<4000 km^3/yr
(4000 – 6000 km^3/yr)

Land System Change
≤15 % of land under crops
(15-20%)

Chemical Pollution
Plastics, Endocrine Desruptors, Nuclear Waste Emitted globally
To be determined

Earth System Process	Control Variable(s)	Thresholds	Planetary Boundary (zone of uncertainty)	Current Value of Control Variable(s)	State of Knowledge
Land system change	Global: area of forested land Biome: area of forested land	Tropical: Amount of land clearing beyond which self-reinforcing feedbacks lead to land-cover change across a much larger area, with atmospheric circulation teleconnections: Temperate: No known thresholds. Boreal: Possible threshold related to albedo changes associated with land clearing	Global: 75% of early Holocene (pre-agric) forest cover Biome: Tropical: 85% of original forest cover Temperate: 50% Boreal: 85%		Threshold for tropical forests best understood for Amazon, but complex with significant uncertainties. Albedo effect for boreal forest well understood but position of any possible threshold is not known
Biodiversity loss	Genetic diversity (library of life): Extinction rate Functional diversity: Mean species abundance (MSA)	"Soft threshold" proposed somewhere around 50% drop in MSA, beyond which rapid and much larger loss of biodiversity. Threshold known at ecosystem level and proposed for global level	Genetic: no more than 10x background extinction rate but aspirational goal of no loss of genetic diversity. Functional: Maintain MSA at 70% or above (uncertainty range of 70-30%)	Genetic: Current extinction rate is 100-1000x background Functional: Global MSA is currently estimated to be ca. 67%	Aspirational genetic boundary based on first principles. Growing body of evidence for threshold of functional biodiversity loss at multiple levels (ecosystem to global)



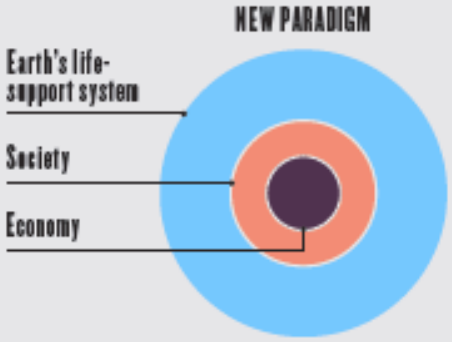
Reaching Twin-objectives of global sustainability and Eradicating Poverty

21 MARCH 2013 | VOL 495 | NATURE | 305

Sustainable development goals for people and planet

A UNIFIED FRAMEWORK

A set of six sustainable development goals (SDGs) follow from combining the Millennium Development Goals (MDGs) with conditions necessary to assure the stability of Earth's systems.



NEW DEFINITION
Sustainable development in the Anthropocene: "Development that meets the needs of the present while safeguarding Earth's life-support system, on which the welfare of current and future generations depends."

People

UPDATED MILLENNIUM DEVELOPMENT GOALS
End poverty and hunger
Universal education
Gender equality
Health
Environmental sustainability
Global partnership

Planet

PLANETARY MUST-HAVES
Materials use
Clean air
Nutrient (N and P) cycles
Hydrological cycles
Ecosystem services
Biodiversity
Climate stability

SUSTAINABLE DEVELOPMENT GOALS
Thriving lives and livelihoods
Sustainable food security
Sustainable water security
Universal clean energy
Healthy and productive ecosystems
Governance for sustainable societies

The Choices appear to be:

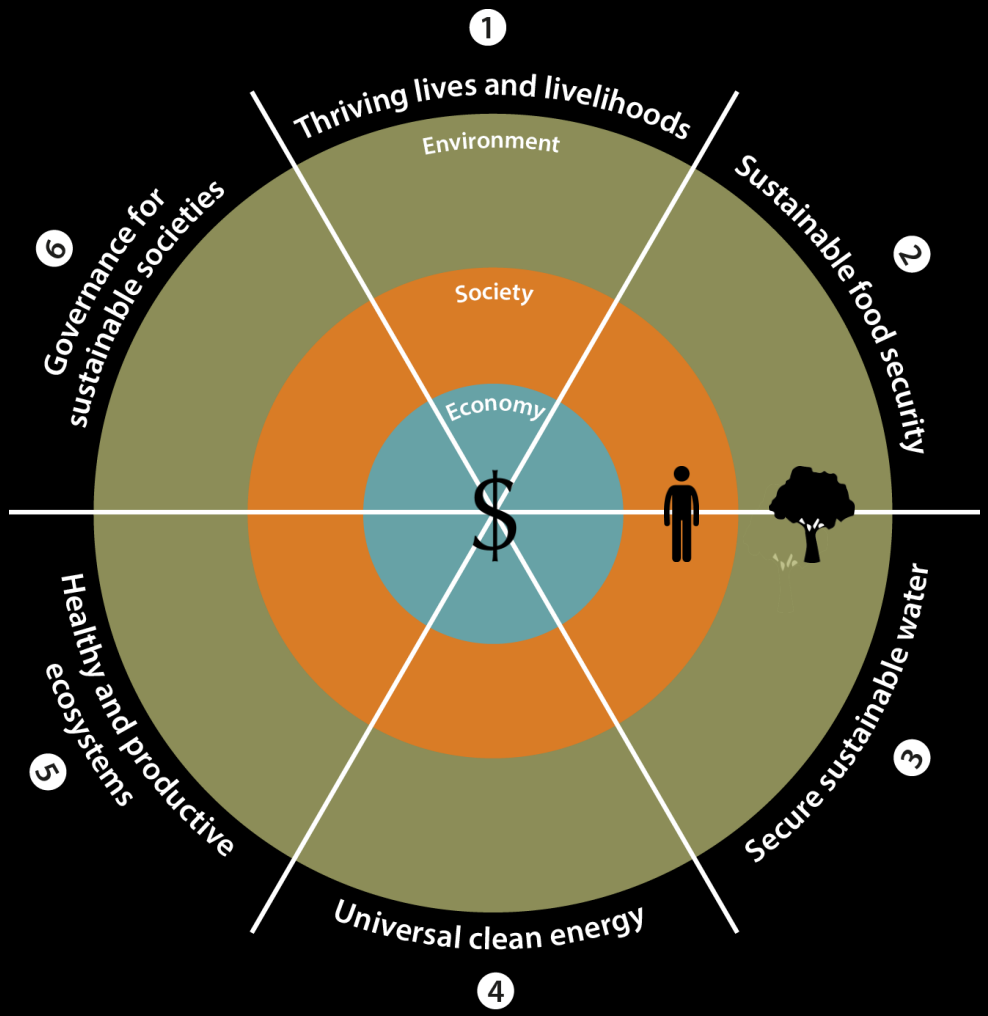
1.Kick away the Ladder
"the party is over"

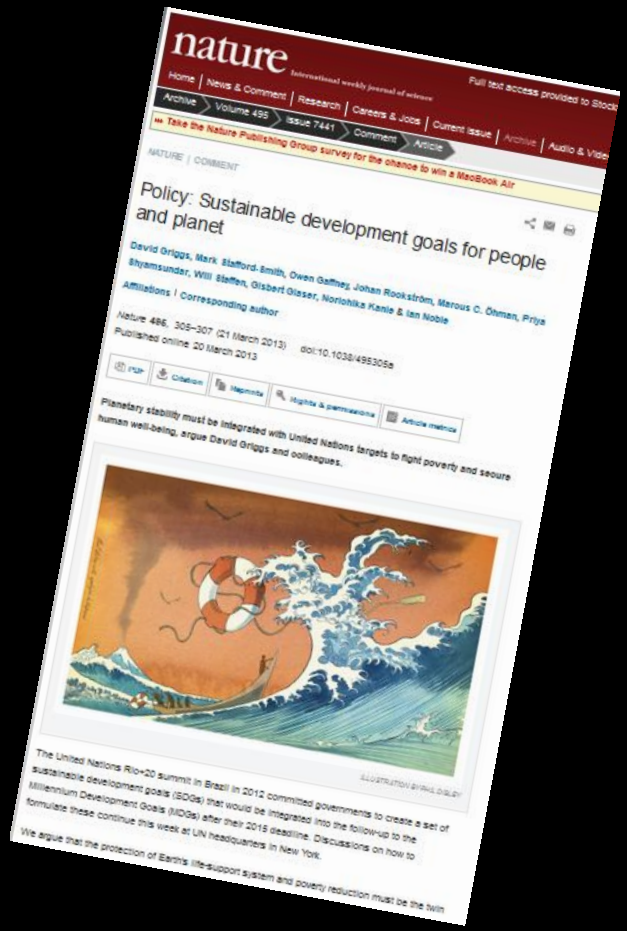
2. Contract and Converge
"burden pathway"

3. Business as Usual
"head in the sand pathway"

4. Sustainable Development Trajectory of Growth within Earth's playing field

- New Rules of the Game (Cooperation)
- Sustainable technologies/Innovations
- Stabilise World Pop
- Protect remaining ecosystems





nature

Policy: Sustainable development goals for people and planet

Planetary stability must be integrated with United Nations targets to fight poverty and secure human well-being, argue David Griggs and colleagues.

The United Nations Rio+20 summit in Brazil in 2012 committed governments to create a set of sustainable development goals (SDGs) that would be integrated into the follow-up to the Millennium Development Goals (MDGs) after their 2015 deadline. Discussions on how to formulate these continue this week at UN headquarters in New York.

We argue that the protection of Earth's life-support system and poverty reduction must be the twin

Goal 1: Ending Extreme Poverty

Goal 2: Achieving Development within Planetary Boundaries

Goal 3: Achieve Gender Equality, Human Rights and the Rule of Law

Goal 4: Achieving Food Security and Rural Prosperity

Goal 5: Empowering Inclusive, Productive and Resilient Cities

Goal 6: Achieving Health and Wellbeing at all Ages

Goal 7: Ensure Effective Learning for Every Child for Life and Livelihood

Goal 8: Curbing Human-Induced Climate Change

Goal 9: Securing Ecosystem Services and Biodiversity

Goal 10: Transforming Governance for Sustainable Development

Planetary "Must Haves" by 2020
In partnership with WBCSD

Planetary Boundary	2020 "Must Have"	Key Links	Key Business Tools
Climate Boundary	Bend Global Emission curve of CO2 by 2020 5-6 %/yr decline thereafter 80-100 % global reduction by 2050	Land, Water, Nutrients, Ocean Acidification	Footprint analysis LCA Target setting
Land Boundary	Sustaining remaining Rainforests on Earth Keep > 70 % forest stand	Water, Climate, Nutrients, Biodiversity	Sustainable Agric and Forest strategy
Water Boundary	Ensure > 30 % river flow	Climate, Land, Biodiversity, N&P	Water productivity indicator Sustainable intensification of production systems Product labelling
Nitrogen & Phosphorus Boundary	>50 % reduction of P leakages in soils > 50 % reduction in N leakage in soils	Land, Water, Climate, Biodiversity	Monitor N and P flows in entire value chain Sustainable Agriculture
Biodiversity Boundary	Absolute global halt of habitat loss Safeguard Critical Biomes (Forests, Marine systems, Polar ecosystems)	Land, Water; Climate	Restoring "hot-spots" Protect critical biomes Economic value of ecosystem services (TEEB)

Sustainable Development Trajectory

6 Transformations:

1. Global Energy Transformation (>80 % reduction in CO2 emissions 2050)
2. Food Security Transformation (+70% by 2050; Sustainable Intensification)
3. Urban Sustainability Transformation
4. The Population Transition (Aim for a 9 billion world or below)
5. The Biodiversity Management Transformation (Protect, Restore, Manage; Sustain Critical Biomes)
6. Private and Public Governance Transformation (Strengthen Global Governance)

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Solutions for a cultivated planet

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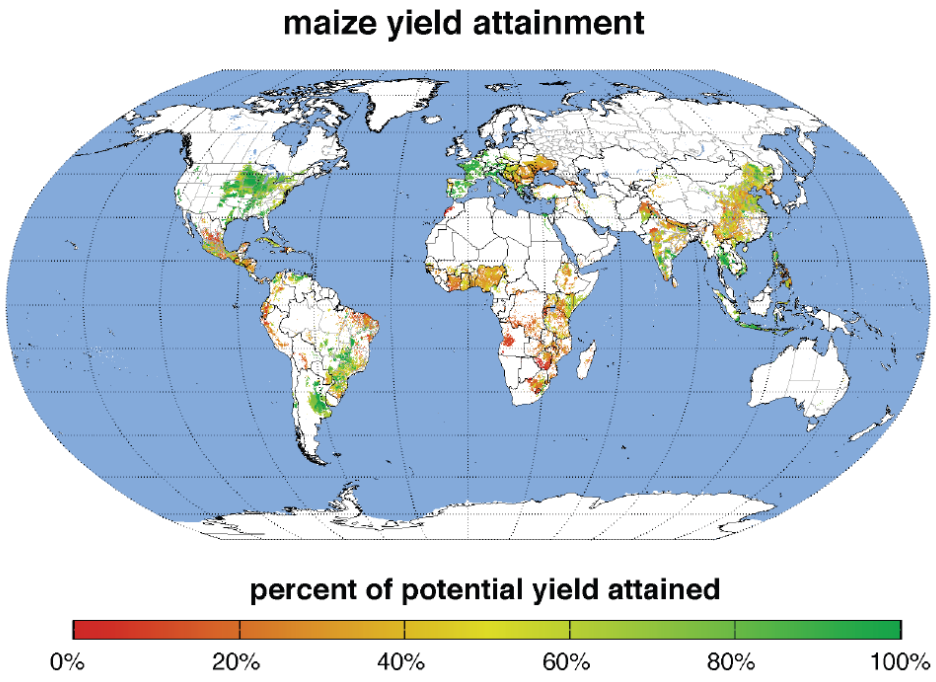
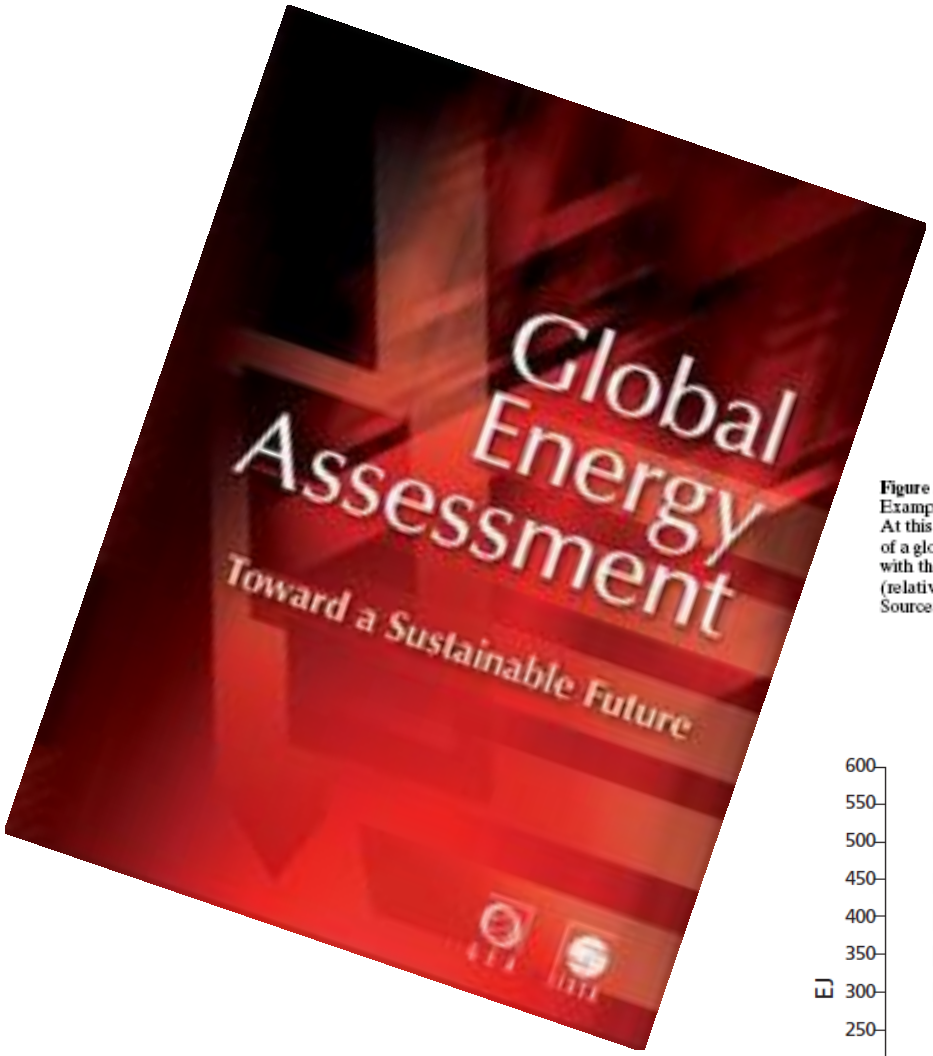




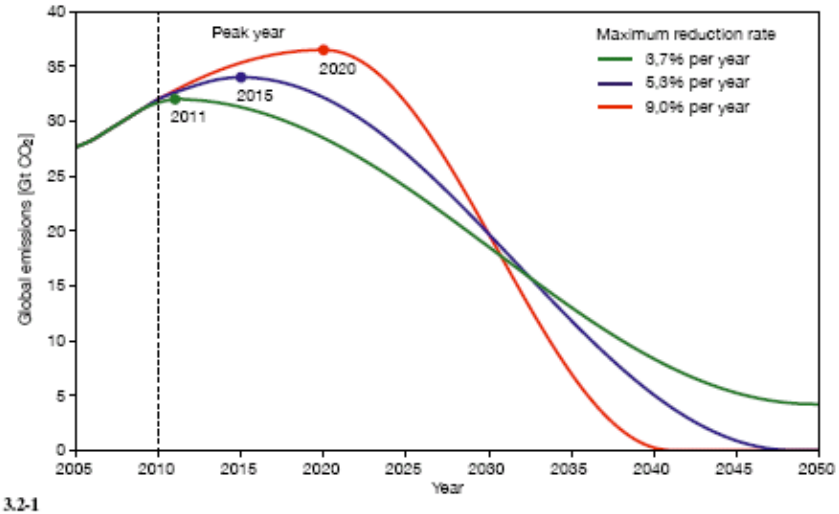
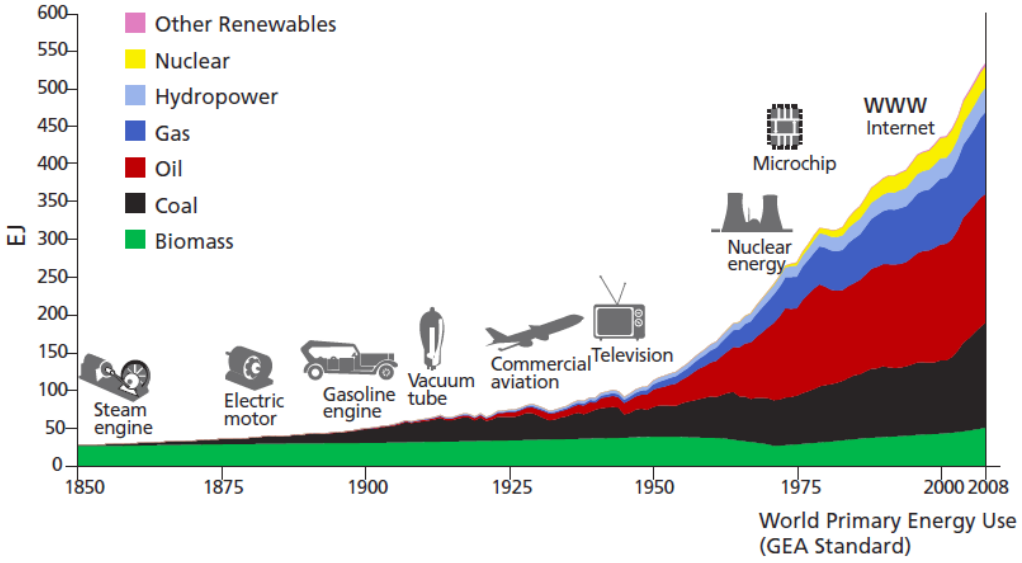


Figure 3.2-1
Examples of global emission pathways for the period 2010–2050 with global CO_2 emissions capped at 750 Gt during this period. At this level, there is a 67 % probability of achieving compliance with the 2°C guard rail (Chapter 5). The figure shows variants of a global emissions trend with different peak years: 2011 (green), 2015 (blue) and 2020 (red). In order to achieve compliance with these curves, annual reduction rates of 3.7 % (green), 5.3 % (blue) or 9.0 % (red) would be required in the early 2030s (relative to 2008).
Source: WBGU



- Humanity at a new Juncture – Prosperity in the Anthropocene
- The Holocene – Our desired state!
- Global Sustainability and Poverty eradication twin-objectives for human development
- Planetary boundaries define of a safe-operating-space for Growth and Prosperity
- A unified framework possible in the transition from MDGs to SDGs

- A world transition to a resilient and sustainable future not only necessary, but possible (and desirable)

From

Growth Without Limits

To

Growth Within Limits