PLANETARY BOUNDARIES: FROM GLOBAL CHALLENGES TO LOCAL SOLUTIONS

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TRAVELING THE ROCKY ROAD FROM LOFTY GLOBAL GOALS TO LOCAL IMPLEMENTATION

Johan Bouma
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the Netherlands.

Contribution to symposium: Planetary Boundaries: from global challenges to local solutions.
March 22, Gent University Faculty of Bioscience Engineering.

Initiated by the Natural Capital Research Platform

Since the 1960’s awareness has been created as to the unsustainable and potentially catastrophic manner in which we treat our planet.

1963 Silent Spring, Rachel Carson
early 1970’s The Club of Rome
1988 The Brundtland Report:”Our Common Future”
1990 the Ecological Footprint : Wackernagel
2009 Planetary boundaries, Johan Rockström

Action oriented:
1988 IPCC , by now their fifth report and well established political action.
2002 The Millennium Goals of the UN
2015 The UN Sustainable Development Goals

The 17 UN Sustainable Development Goals (sept 2015)

1. End poverty in all its forms everywhere
2 .**End hunger, achieve food security and improve nutrition and promote sustainable agriculture**
3. Ensure healthy lives and promote well being for all ages.
4. Ensure inclusive and equitable quality education and promote life-long learning opportunities for all
5. Achieve gender equality and empower women and girls.
6. **Ensure availability and sustainable management of water and sanitation for all.**
7. Ensure access to affordable, reliable, sustainable and modern energy for all
8. Promote sustained, inclusive and sustainable economic growth,full and productive employment and decent work for all
9. Build resilient infrastructure and promote inclusive and sustainable industrialization and foster innovation.
10. Reduce inequality within and between countries
11. Make cities and human settlements inclusive, safe, resilient and sustainable.
12. Ensure sustainable consumption and production patterns
13. **Take urgent action to combat climate change and its impacts.**
14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development..
15. **Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably managed forests, combat desertification and halt and reverse land degradation and halt biodiversity loss**
16. Promote peaceful and inclusive societies for sustainable development, access to justice for all and build effective, accountable and inclusive institutions at all levels.
17. Strengthen the means of implementation and revitalize the global partnership for sustainable development

The Natural Capital Research Platform of Gent University (Faculty of Bioscience Engineering) has formulated four excellent considerations when focusing on local solutions:

1. raise awareness
2. perform high quality integrated research
3. act as an independant think tank
4. take up the role as facilitator.

But how does this work in the real world??

Three case studies will be briefly discussed , addressing the four considerations.

1. Comparing circular dairy-farming practices as compared with more conventional approaches (Frisian Northern Woods, the Netherlands) .

2. Precision fertilization on an arable farm (Zeeland, the Netherlands)

3. Coping with increasing drought in the Destre Sele area of Italy: to irrigate or buy drought resistant cultivars?

Noordelijke Friese Wouden: national landscape, reflecting centuries old cultural patterns.

Comparing the circular and conventional dairy systems:

non renewable energy use: 5.1MJ/kg milk vs.5.9 = -15%
input chem.fertilizer N: 128kg/ha vs 146 = -12%
nitrate leaching: 5.1 kgN/ha/yr vs 7.0 = -30%
ammonia emission: 30 kgN/ha/yr vs 35 = -15%

soil organic matter: 186 tonC/ha vs 156 = +20%
av.farm income: 8.3 €/100kg milk vs 5.9 = +40%
20% more labor for the circular system!

SO: WHAT IS GOOD FOR THE ENVIRONMENT IS GOOD FOR BUSINESS
(at least SDG's 2,6,13 and 15 apply here!)

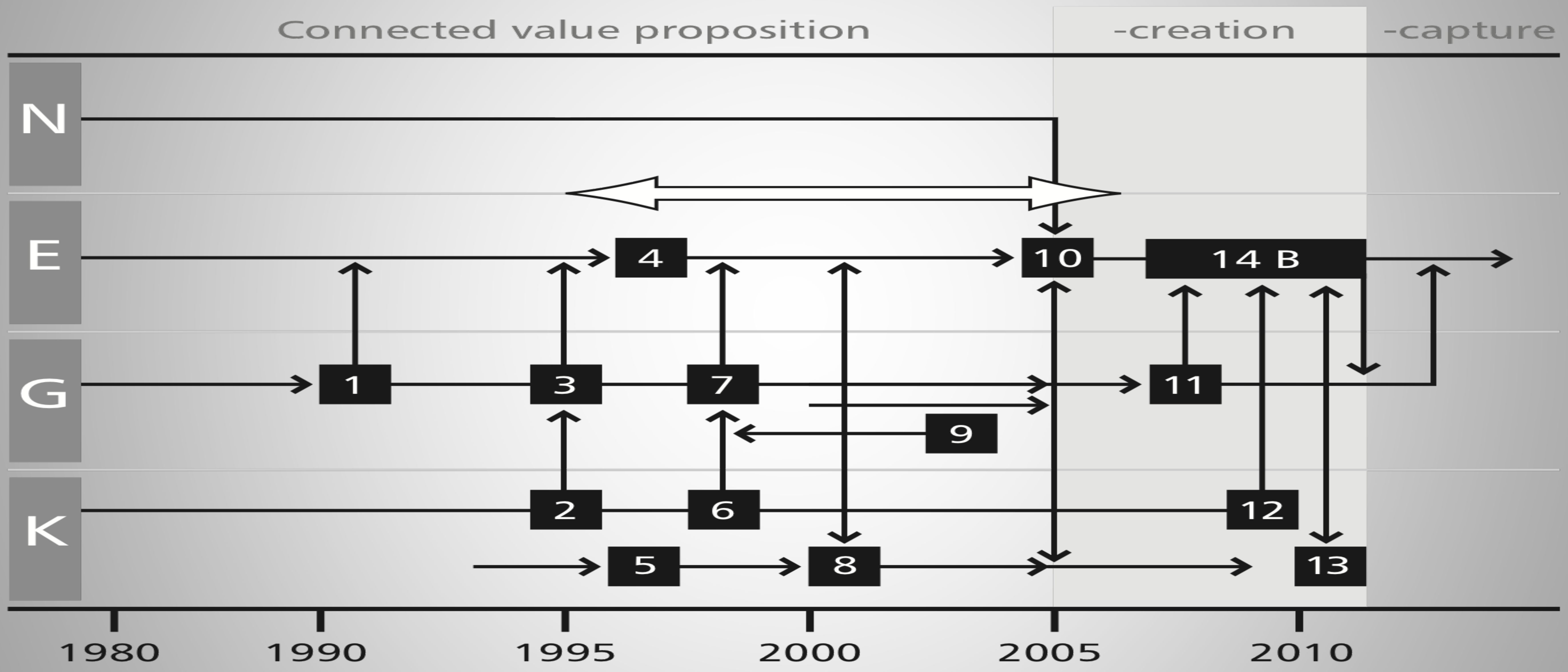
Dolman, M.A., M.P.W.Sonneveld, H.Mollenhorst and I.J.M.de Boer. 2014. Benchmarking the economic, environmental and social performance of Dutch dairy farms aiming at internal recycling of nutrients. J.of Cleaner Prod. (http//dx.doi.org/10.1016/j.jclepro.2014.02.043)

Ad 1: there was already much (too much?) awareness! How to reduce ammonia emissions?

Injection of liquid manure required by law. Farmers did not like it: contractors needed, loss of control. They produce manure with 20% lower N and like to spread that themselves. Not allowed.

Sonneveld, M.P.W., Schroder, J.J., De Vos, J.A., .Monteny, G.J., Musquera,J., Hol, J., Lantinga, M.J., Verhoeven, F., and Bouma, 2008. A Whole-Farm Strategy to Reduce Environmental Impacts of Nitrogen. Journal of Environmental Quality, 37 (3): 333-337.

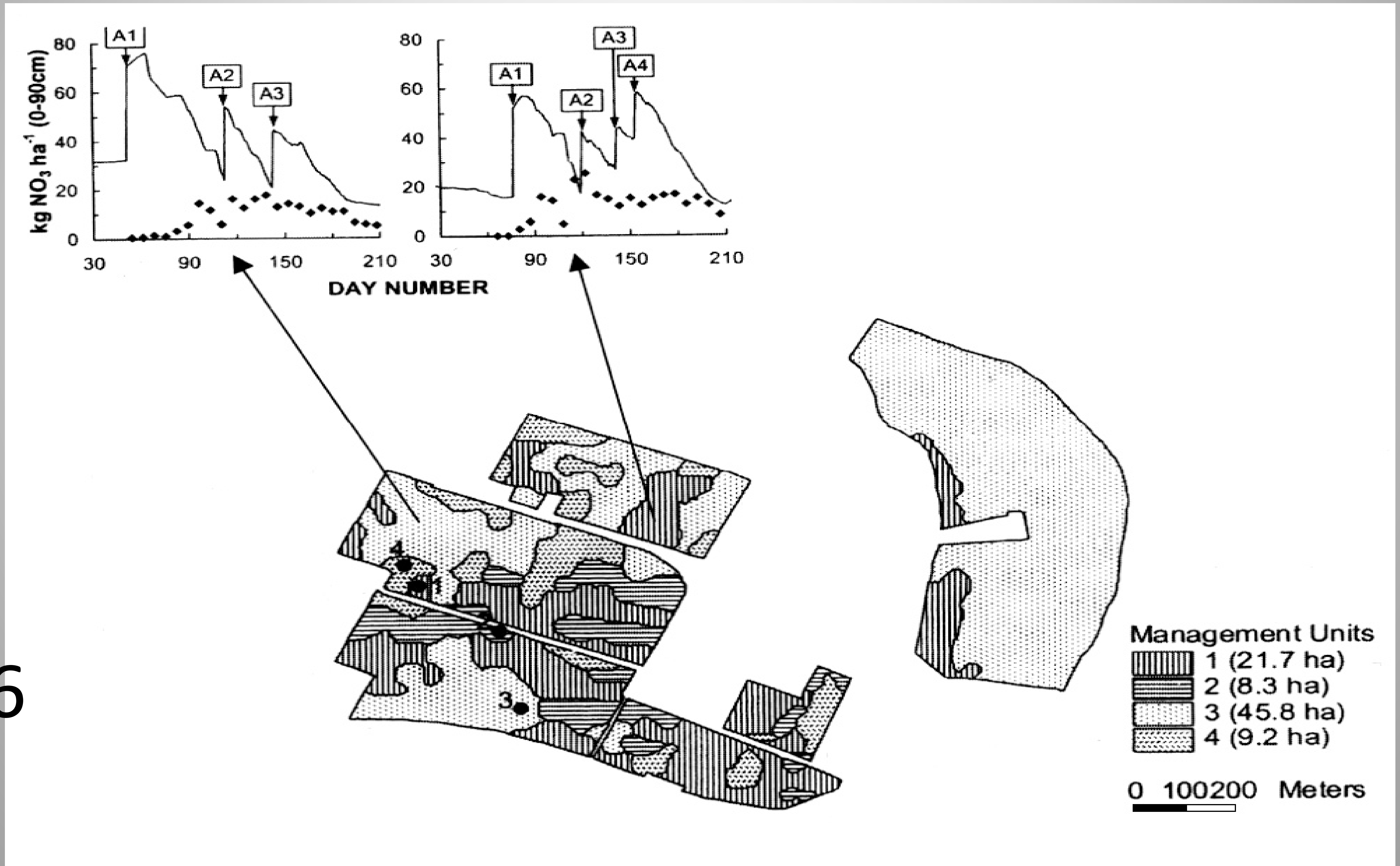
Ad 2: Life cycle analysis; ad 3: not independant and ad 4: role of knowledge brokers.



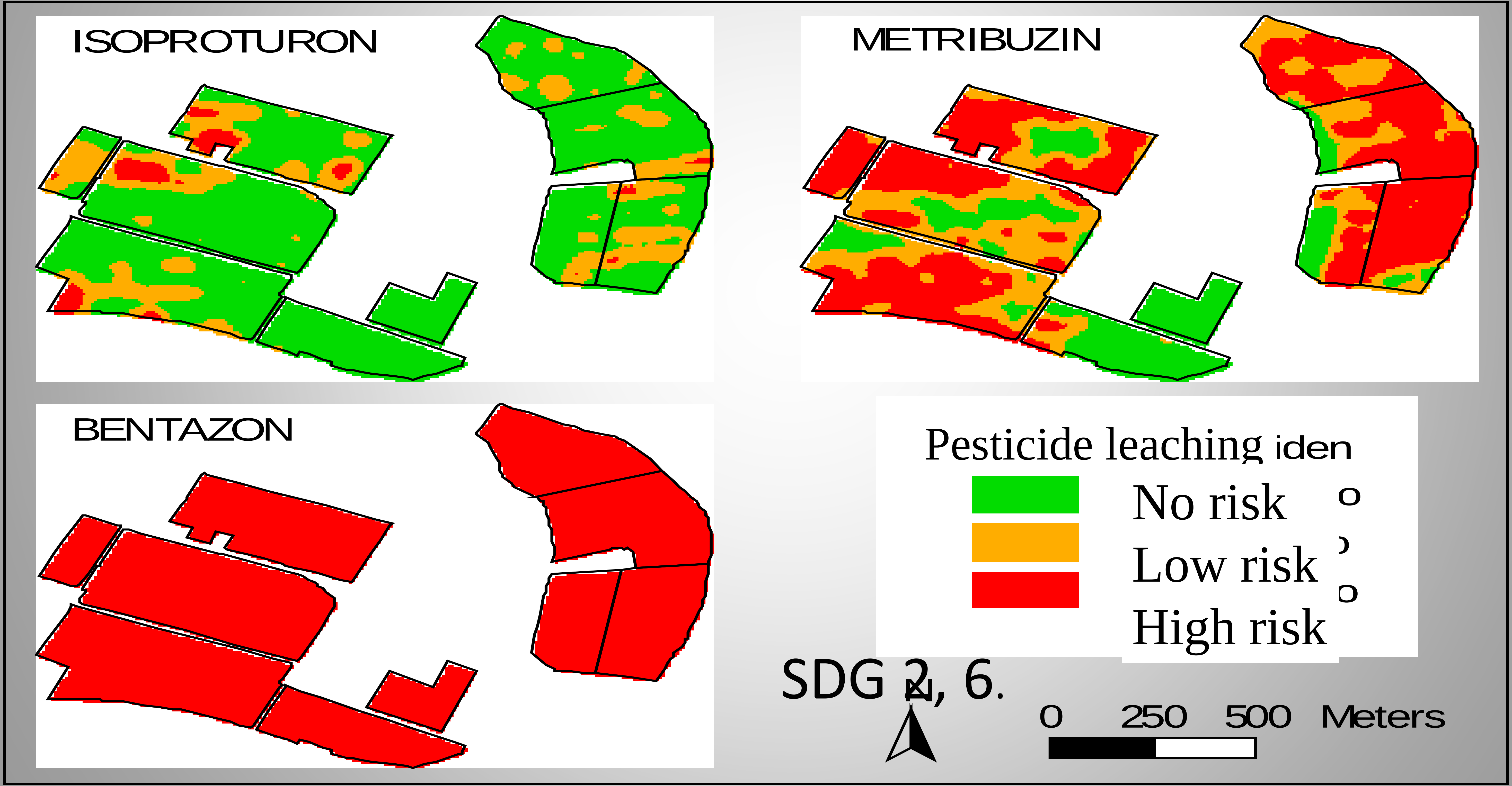
Bouma, J., A.C.van Altvorst, R.Eweg, P.J.A.M.Smeets and H.C.van Latesteijn. 2011. The role of knowledge when studying innovation and the associated wicked sustainability problems in agriculture. Advances in Agronomy 113:285-314.

Precision agriculture: applying plant nutrients at the right time and place. Also relevant for irrigation and pest control.

Bouma, J., B.J.van Alphen and J.J.Stoorvogel. 2002. Fine tuning water quality regulations in agriculture to soil differences. Environmental Science and Policy 5: 113-120.



SDG 2, 6


ISOPROTURON
METRIBUZIN
BENTAZON
Pesticide leaching iden
No risk
Low risk
High risk
N
0 250 500 Meters

SDG 2, 6.

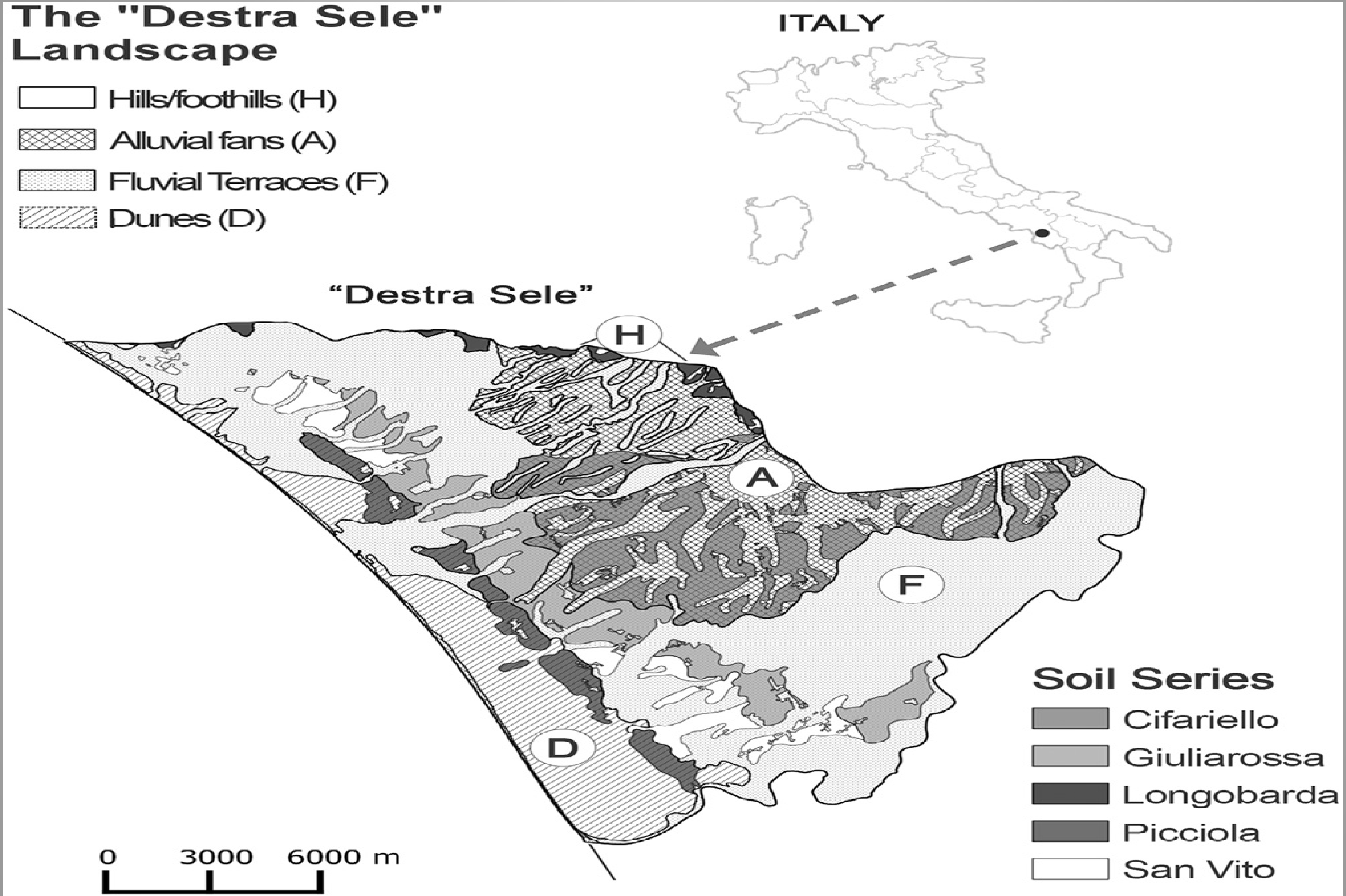

Borders with flowers along arable fields: increase biodiversity and biological crop protection.

Ad 1: the modern farmer was aware of PA but needed to be convinced to allow experiments.

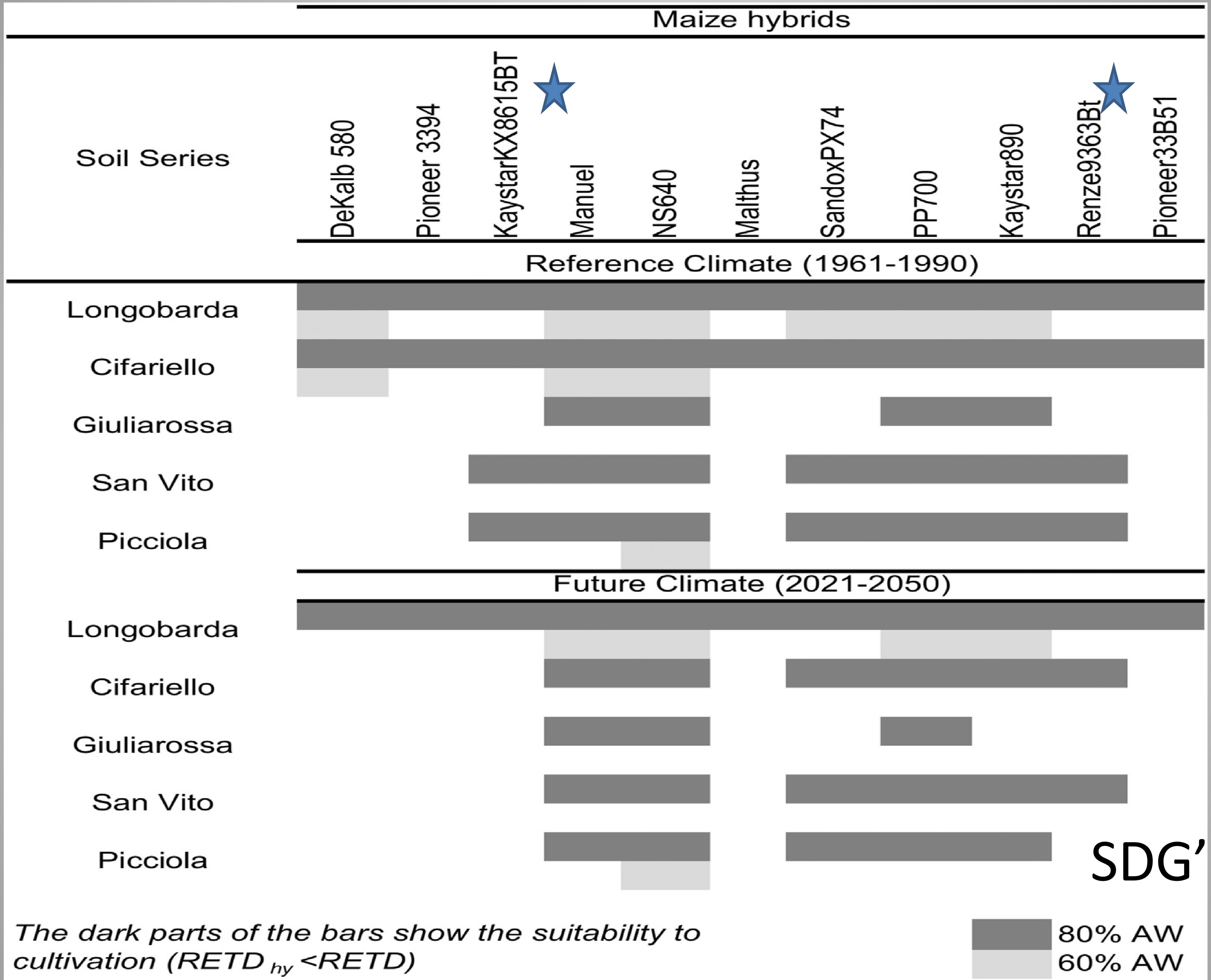
Ad 2: simulation modeling of the soil-water-plant-atmosphere system and of biocide adsorption.

Ad 3: scientists acted independantly, offering advise.

Ad 4: role of facilitator not needed: farmer increasingly liked the ideas of PA, particularly because of its financial aspects.



The "Destra Sele" Landscape
Hills/foothills (H)
Alluvial fans (A)
Fluvial Terraces (F)
Dunes (D)
ITALY
"Destra Sele"
H
A
F
D
Soil Series
Cifariello
Giuliarossa
Longobarda
Picciola
San Vito
0 3000 6000 m


Maize hybrids
Soil Series
DeKalb 580
Pioneer 3394
KaystarKX8615BT
Manuel
NS640
Malthus
SandoxPX74
PP700
Kaystar890
Renze9363Bt
Pioneer33B51
Reference Climate (1961-1990)
Longobarda
Cifariello
Giuliarossa
San Vito
Picciola
Future Climate (2021-2050)
Longobarda
Cifariello
Giuliarossa
San Vito
Picciola
The dark parts of the bars show the suitability to cultivation (RETD hy <RETD)
80% AW
60% AW

SDG'S 2, 6, 13

Ad 1: farmers were aware of the confusing advice as to how to deal with drought. They were not aware of the role scientists could play to offer independant advice. Scientists acted in a pro-active mode to engage farmers.
Ad 2: simulation models were used for the soil-water-plant-atmosphere system.
Ad 3: scientists played a key role offering independant advice that was much appreciated.
Ad 4: scientists provided suggestions but did not facilitate or engage in implementation.

Bonfante, A. and J.Bouma. 2015. The role of soil series in quantitative Land Evaluation when expressing effects of climate change and crop breeding on future land use. Geoderma 259-260, 187-195. (http://doi.org/10.1016/j.geoderma2015.06.010)

Every soil has an important and unique story to tell. We are as yet not very good to fully understand her story. Science has the task to “decifer”and “translate” her story into effective actions contributing to sustainable development.

What did we learn?

1. be pro-active: don't wait until stakeholders approach you; be alert as to what is "hot"and choose research topics strategically. Be aware of what really bothers people. And how do we deal with the post-truth era? "Joint learning".

Bouma, J., 2018. The challenge of soil science meeting society's demands in a "post-truth", "fact- free"world. Geoderma 310, 22-28.(http://dx.doi.org/10.1016/geoderma2017.09.017)

Farmers are bothered by the manure rules: 170 kg N from manure/ha. With derogation: 220 kg N/ha. But local groundwater and surface water quality are often OK now!

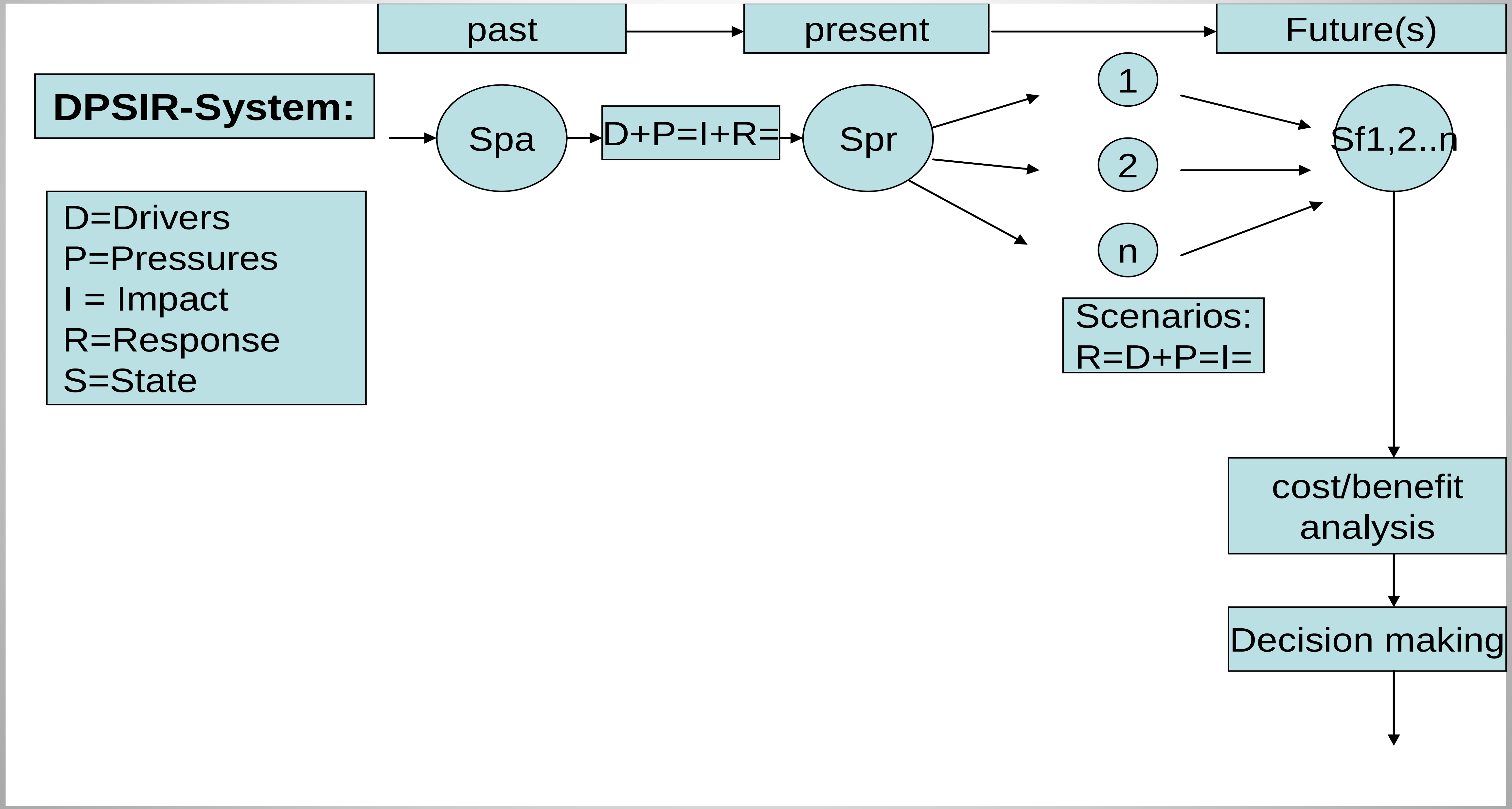
They have to pay arable farmers to receive their excess manure (according to the rules) while they have to buy chemical fertilizers to adequately fertilize their own fields.
A representative case: cost 4500 €'s !

They now document in detail all their in- and outflow of nutrients. Why not complete the system with on-farm soil and water quality data and provide licenses to farmers that comply with environmental rules? Time for bottom-up rather than top-down.

2. Soil-water-plant-atmosphere simulation models – cutting edge in terms of science- are ideal vehicles for interdisciplinary work. But take a step-by-step approach. After a hundred years of research we can do a lot with existing methods.

Bouma, J., C.Kwakernaak, A.Bonfante, J.J.Stoorvogel and L.W.Dekker. 2015. Soil science input in Transdisciplinary projects in the Netherlands and Italy. Geoderma Regional 5,96-105 . (http://dx.doi.org/10.1016/j.geodrs.2015.04.002)

3. Be independant. When focusing on SDG's formulate options. There are no straight solutions. Every idea, however weird, should be taken seriously. We show the economic, social and environmental consequences. Other choose!



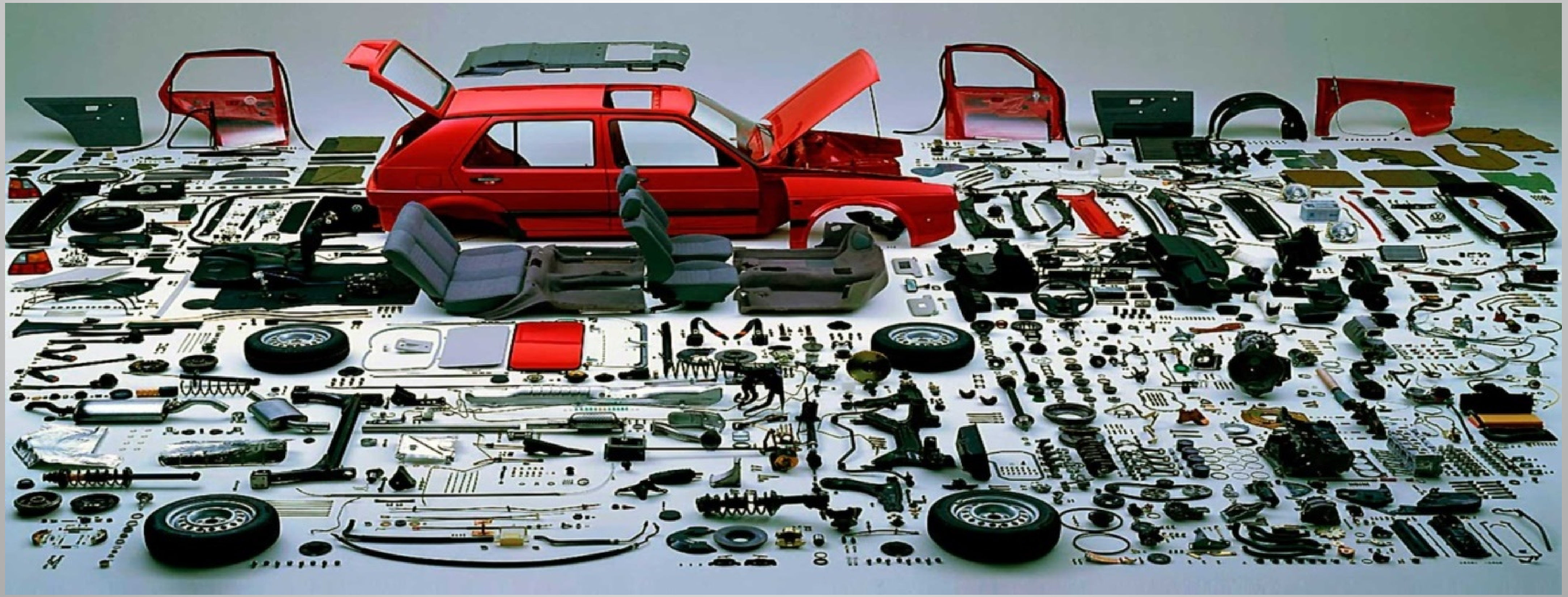
4. The role of facilitator

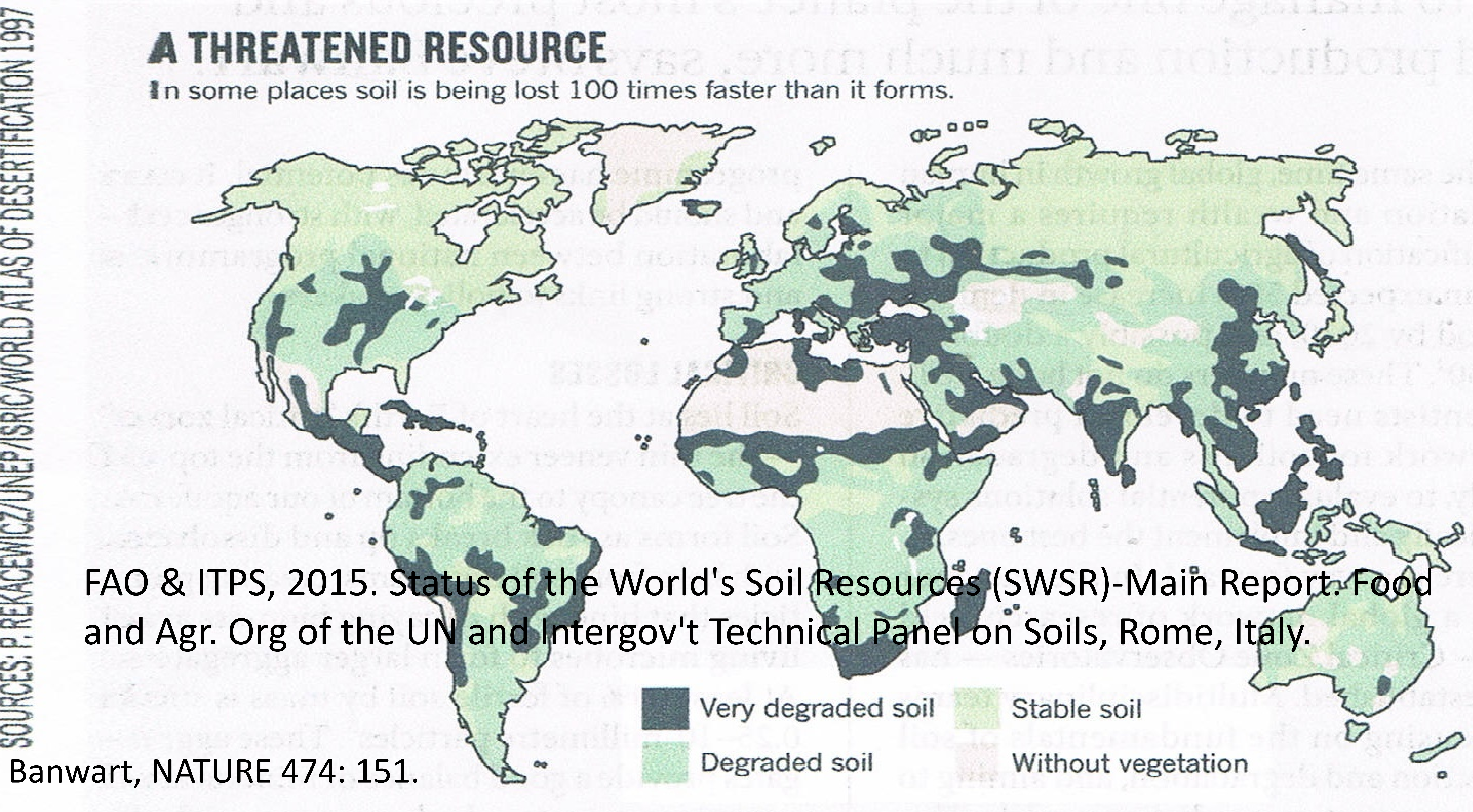
We need to communicate better with our stakeholders. Less top-down, more bottom-up. “joint learning”.

And remember:

(a) combine “IT”, “I” and “WE” .

(b) follow: data-information-knowledge-wisdom!



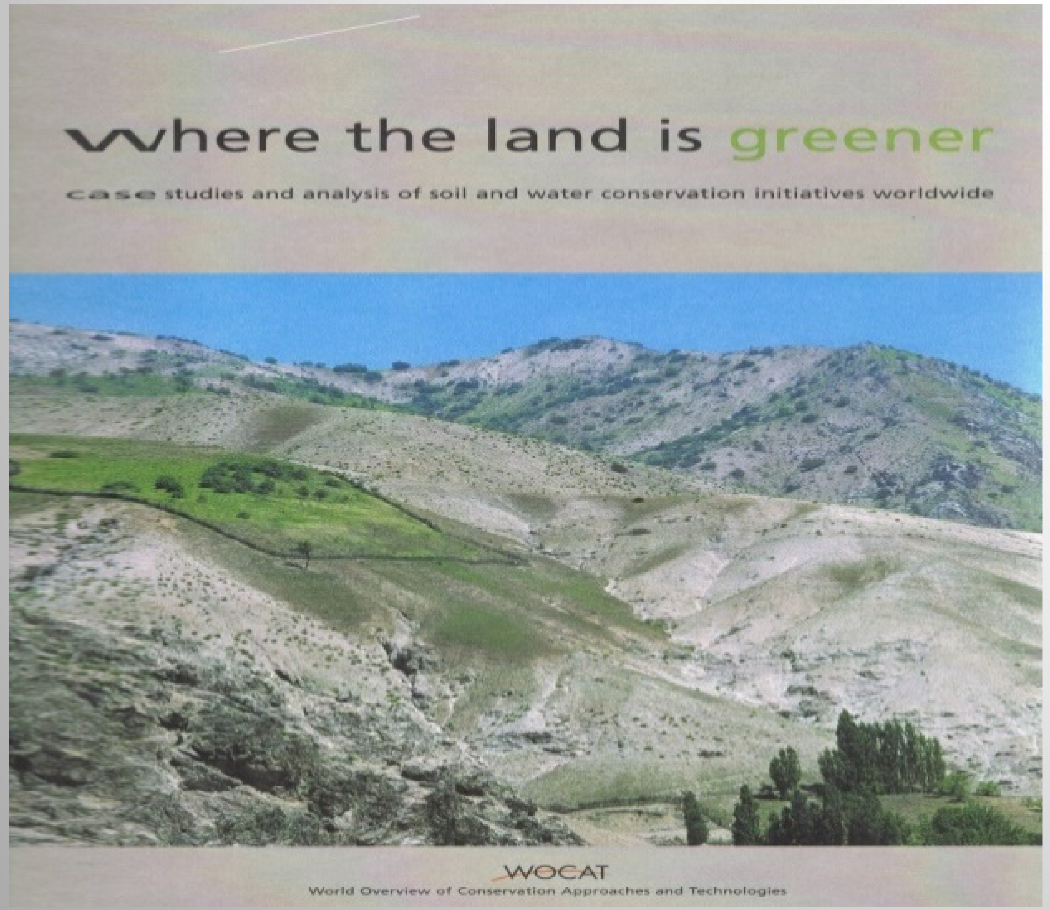


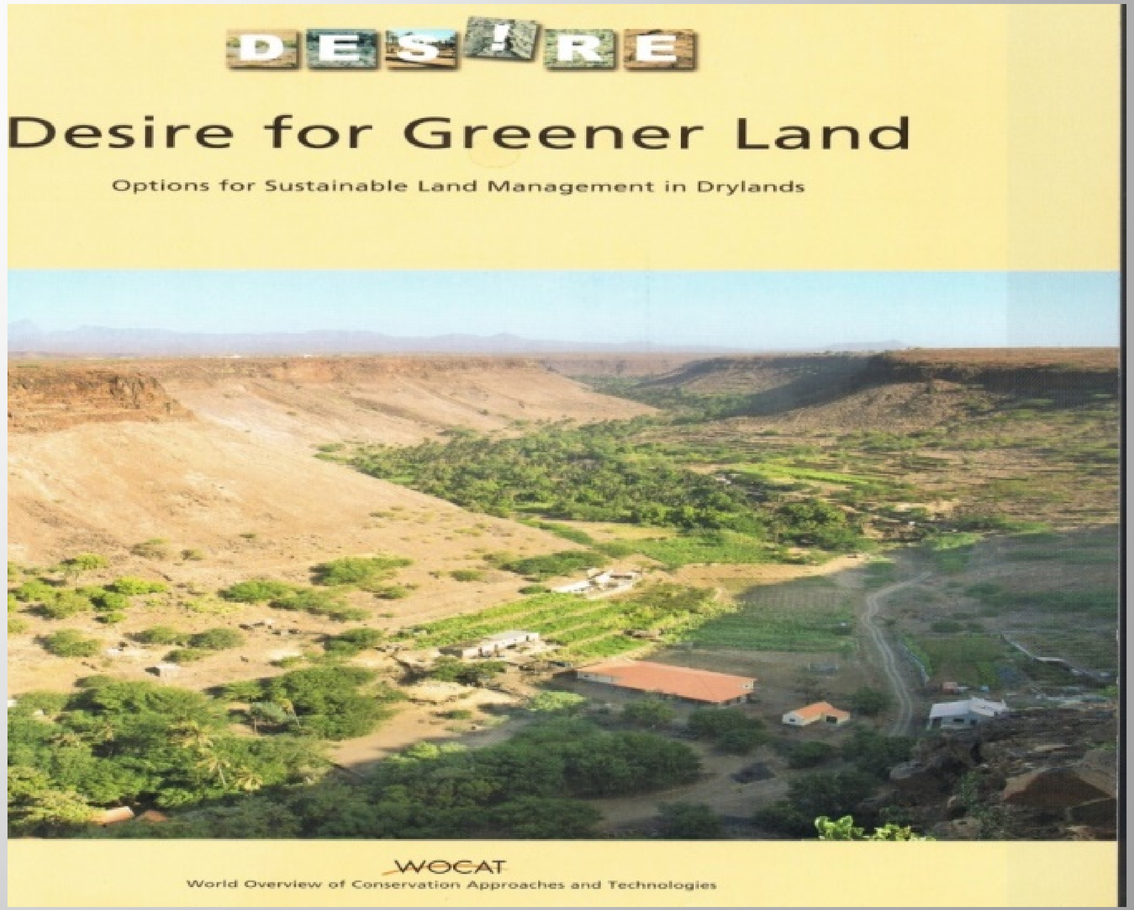
FAO & ITPS, 2015. Status of the World's Soil Resources (SWSR)-Main Report. Food and Agr. Org of the UN and Intergov't Technical Panel on Soils, Rome, Italy.

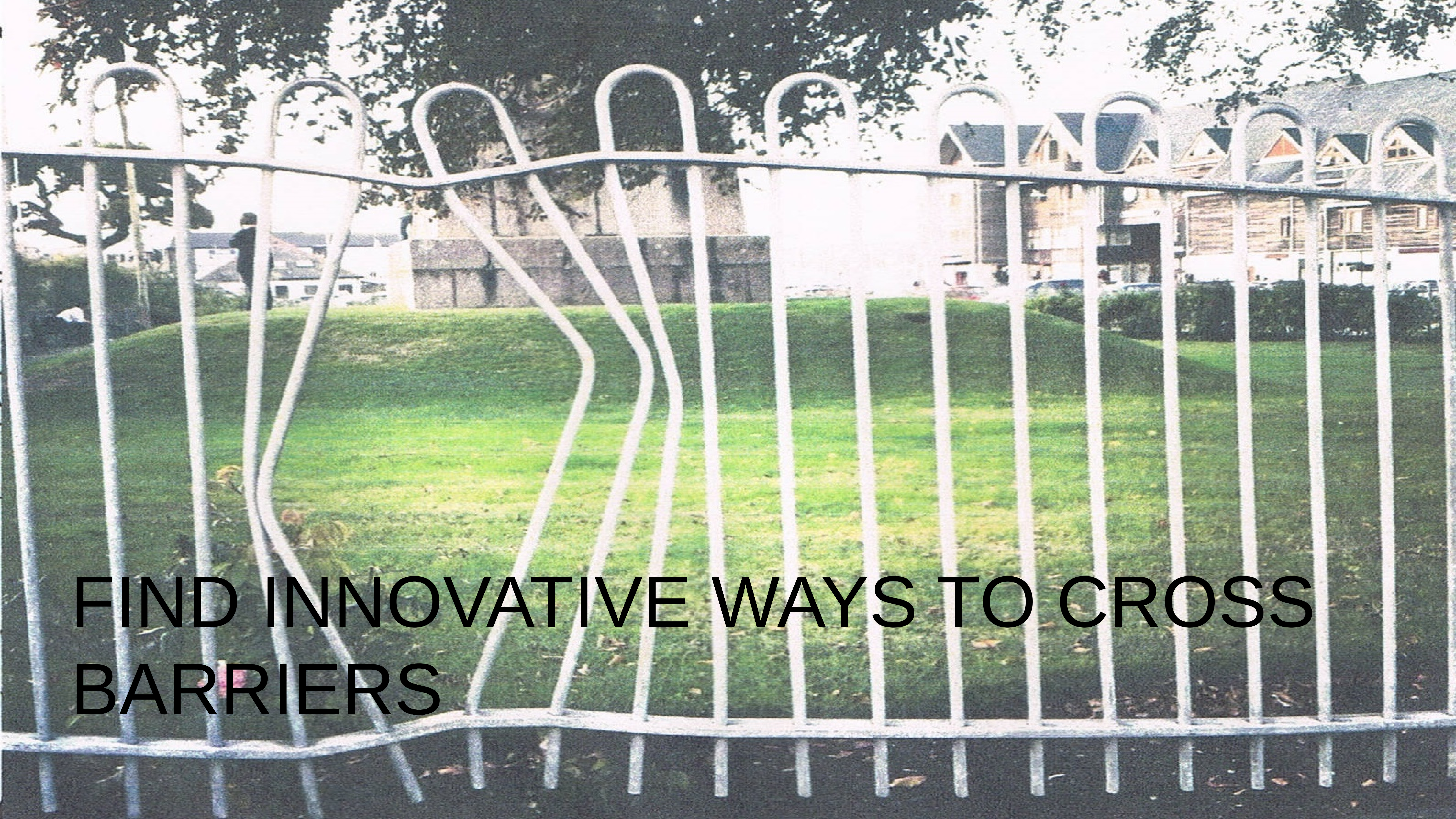
Banwart, NATURE 474: 151.

I believe there is room for a number 5 consideration:

5. Improve interaction processes and communicate research results with modern methods; focus on well-documented “lighthouses” to spread the word of what modern science can do!   Scientific papers should not be the end of the story!






FIND INNOVATIVE WAYS TO CROSS BARRIERS

PROF. ERIC DAVIDSON

University of Maryland

GHENT UNIVERSITY

Manure Happens: The Consequences of Feeding Seven Billion Human Omnivores

Eric A. Davidson

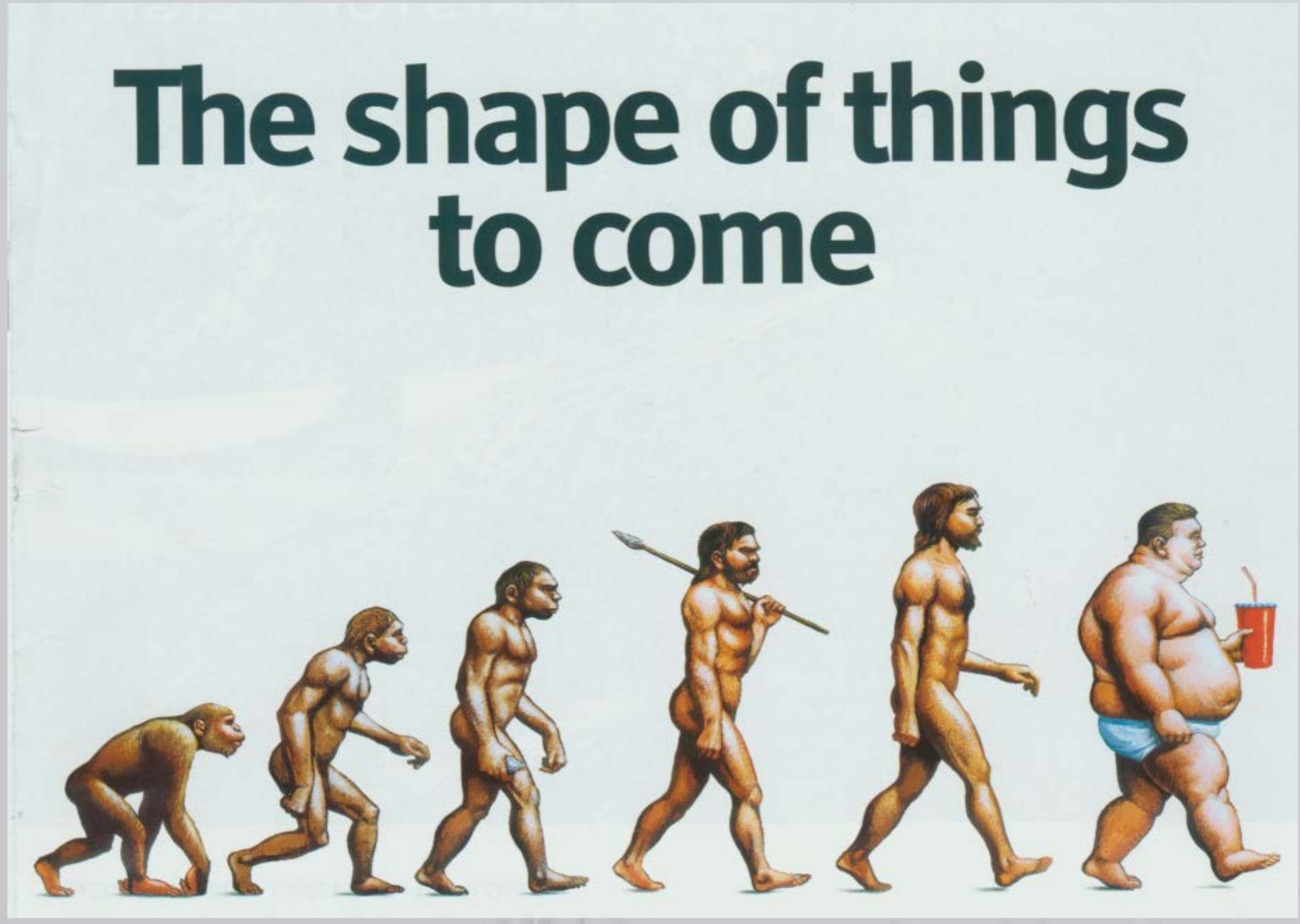
March 22, 2018

Ghent University

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE
APPALACHIAN LABORATORY

The Haber-Bosch process is one of the greatest public health boons in human history

- Eutrophication of estuaries; dead zones; harmful algal blooms
- Nitrate in drinking water
- NOx, O_3, and PM2.5 air pollution
- N_2O as greenhouse gas & stratospheric ozone reactant
- Acid rain & biodiversity loss



Mo Fo; Lo Po

About 80% of N harvested from global crop and pasture production is used for feeding livestock

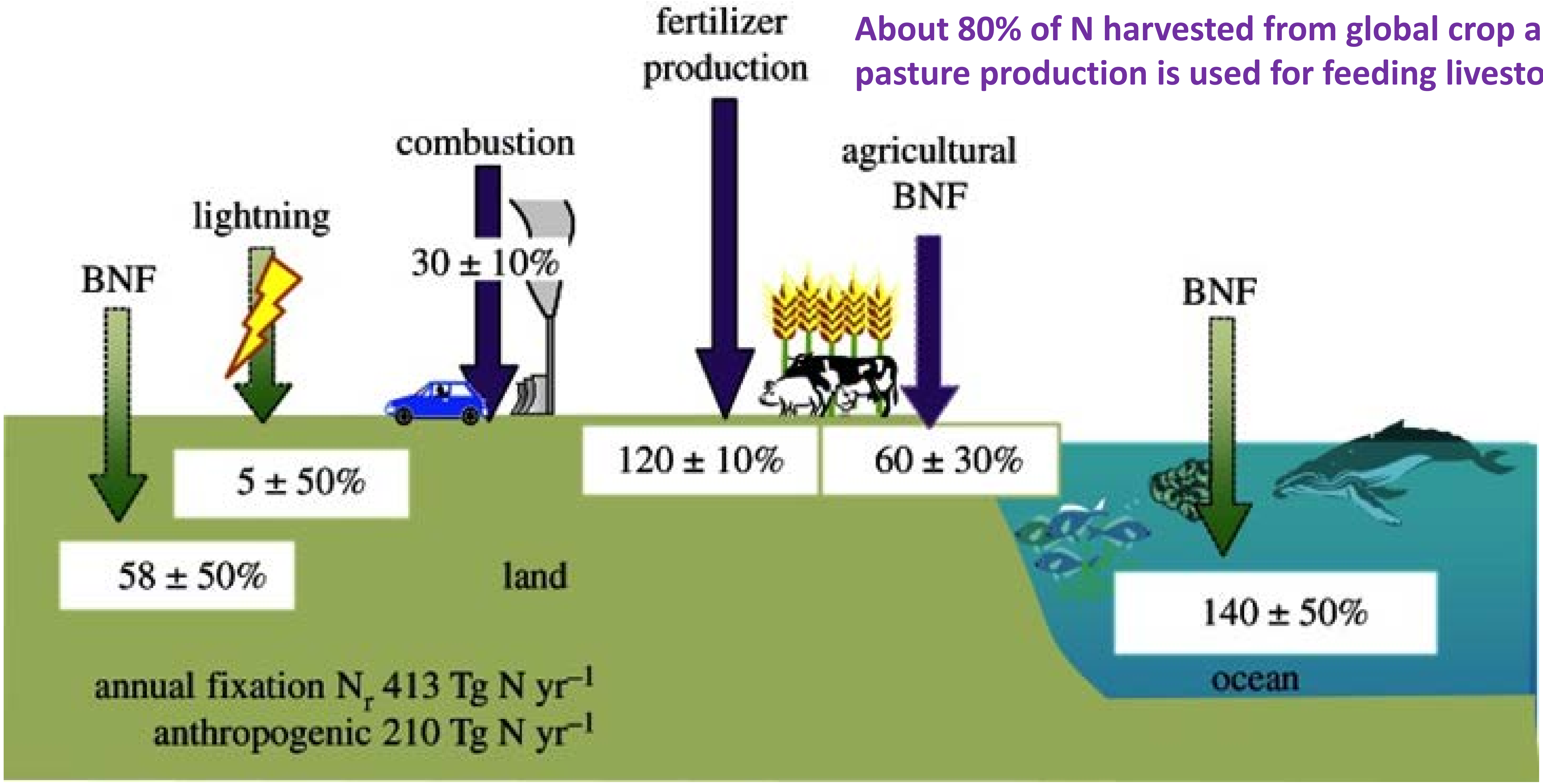
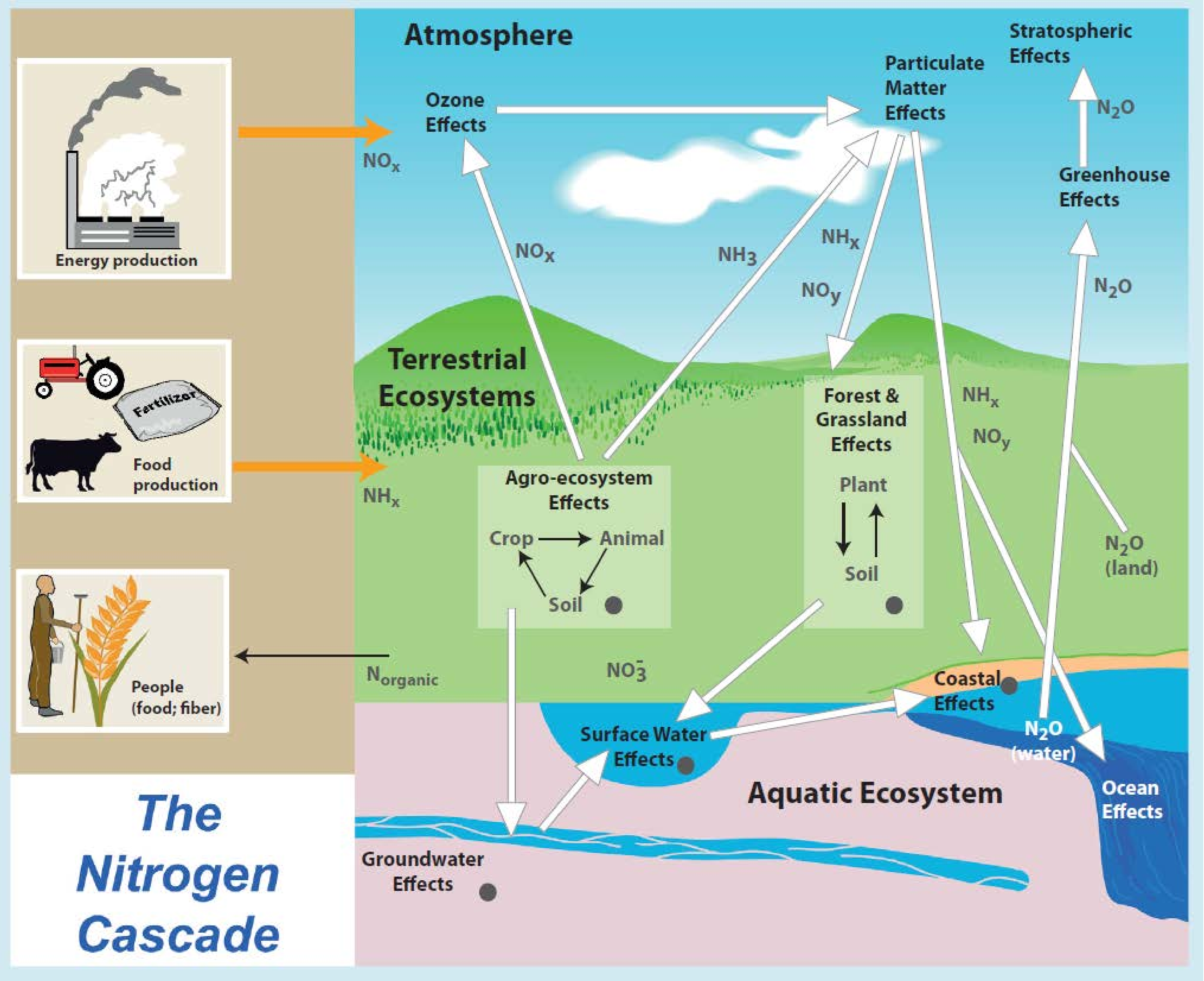


Figure 1. Global nitrogen fixation, natural and anthropogenic in both oxidized and reduced forms through combustion, biological fixation, lightning and fertilizer and industrial production through the Haber–Bosch process for 2010. The arrows indicate a transfer from the atmospheric N_2 reservoir to terrestrial and marine ecosystems, regardless of the subsequent fate of the N_r. Green arrows represent natural sources, purple arrows represent anthropogenic sources.

Fowler et al. 2013 The global nitrogen cycle in the twenty-first century. Phil Trans R Soc B 368: 20130164



Galloway et al. 2003. BioScience

IPCC AR5

nature Vol 461|24 September 2009

FEATURE

A safe operating space for humanity

Identifying and quantifying planetary boundaries that must not be transgressed could help prevent human activities from causing unacceptable environmental change, argue **Johan Rockström** and colleagues.

NATURE|Vol 461|24 September 2009
"Editor's note Please note that this Feature and the Commentaries are not peer-reviewed research. This Feature, the full paper and the expert Commentaries can all be accessed from http://tinyurl.com/planetboundaries."

Updated by Steffen et al. 2015. Science

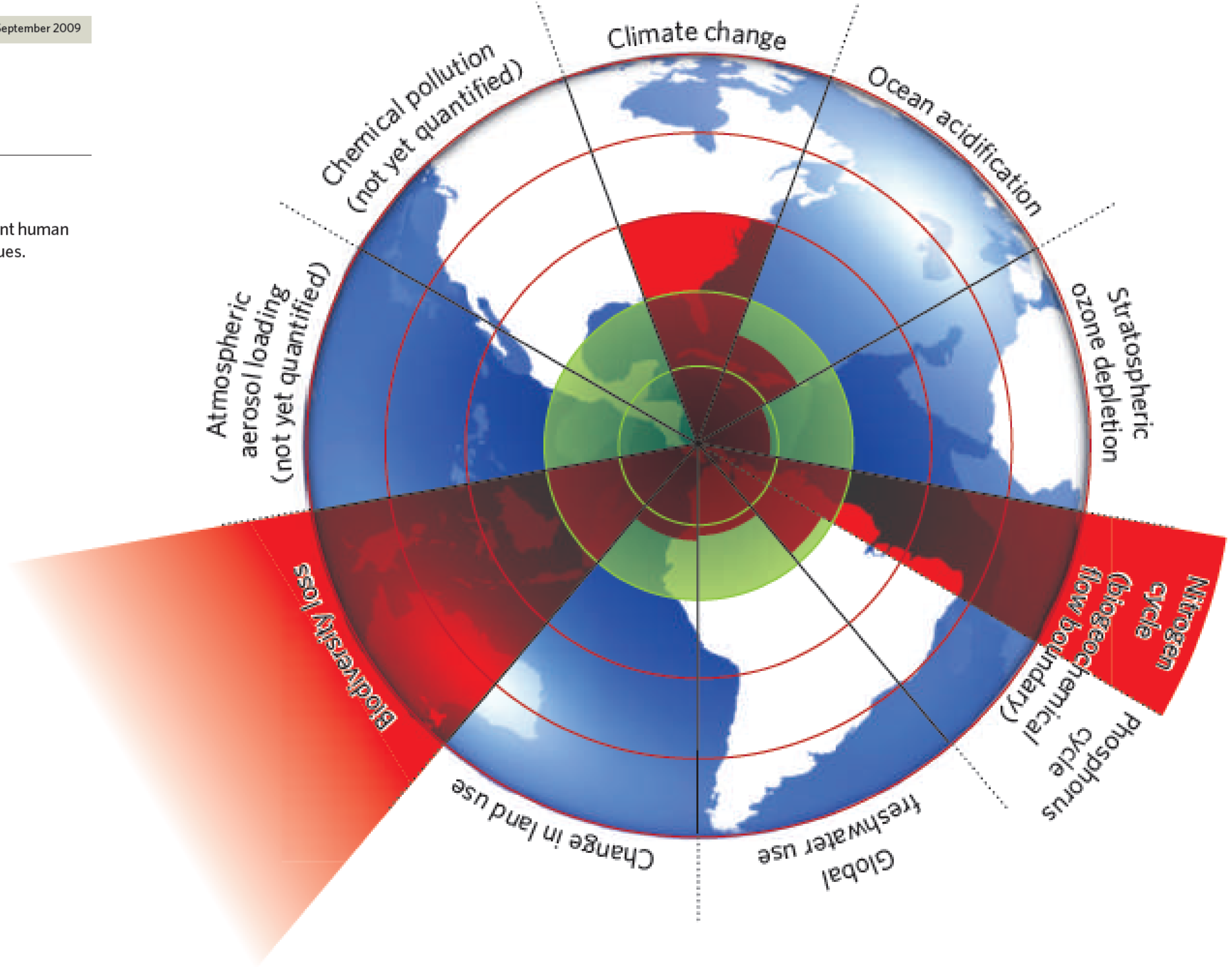
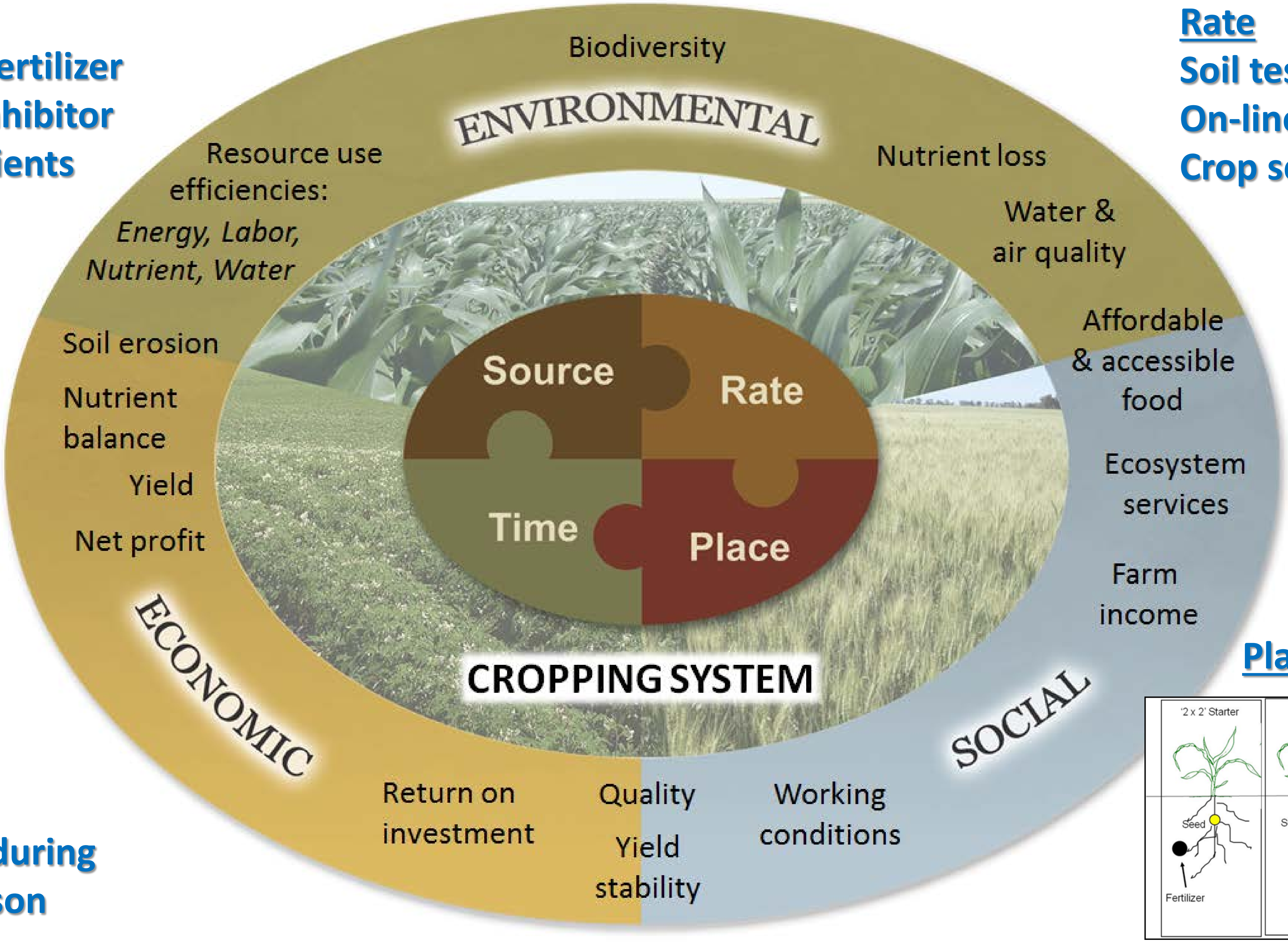


Figure 1 | Beyond the boundary. The inner green shading represents the proposed safe operating space for nine planetary systems. The red wedges represent an estimate of the current position for each variable. The boundaries in three systems (rate of biodiversity loss, climate change and human interference with the nitrogen cycle), have already been exceeded.

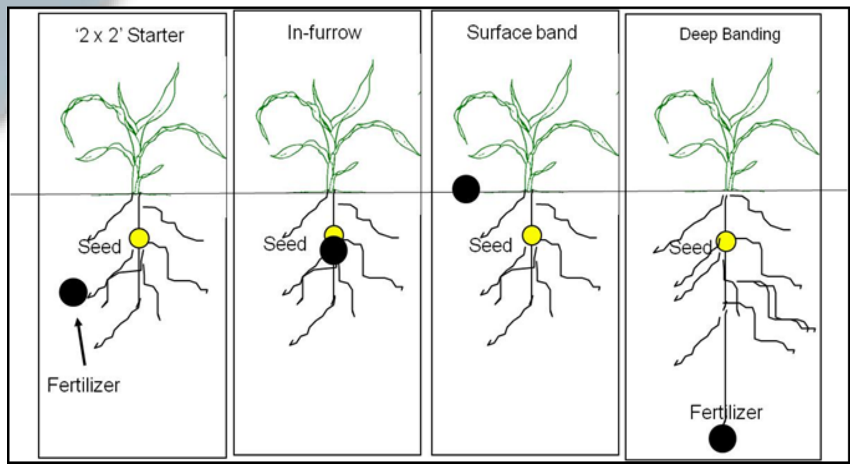
Source
Slow-release fertilizer
Nitrification inhibitor
Balanced nutrients

Rate
Soil testing
On-line tools
Crop sensors



Time
Spring vs. fall
Side dressing during growing season

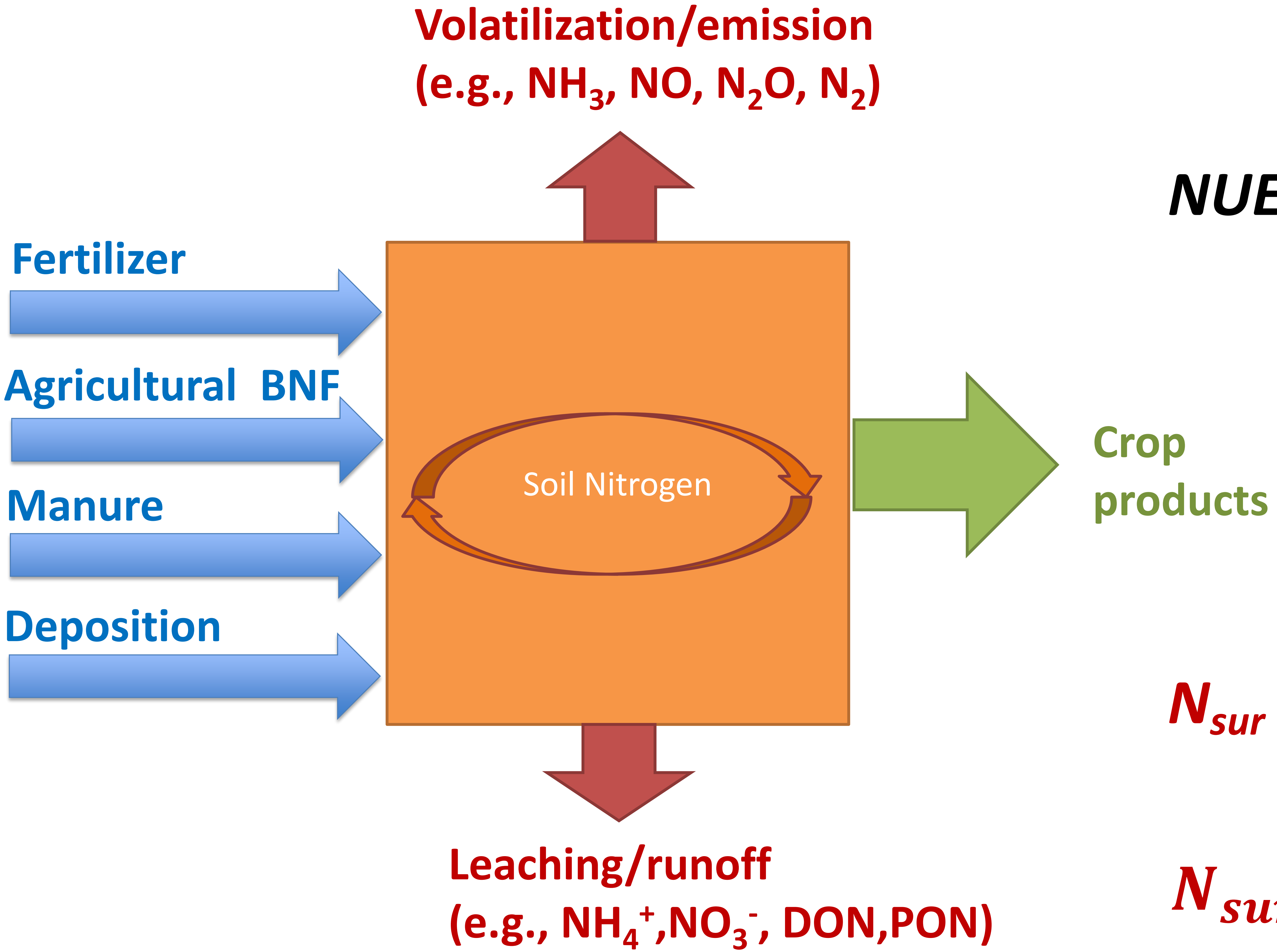
Place



Applying the *Right Source* at the *Right Rate* at the *Right Time* and in the *Right Place, where Right* is defined by practice impact on system performance

Paul Fixen

IPNI
INTERNATIONAL PLANT NUTRITION INSTITUTE



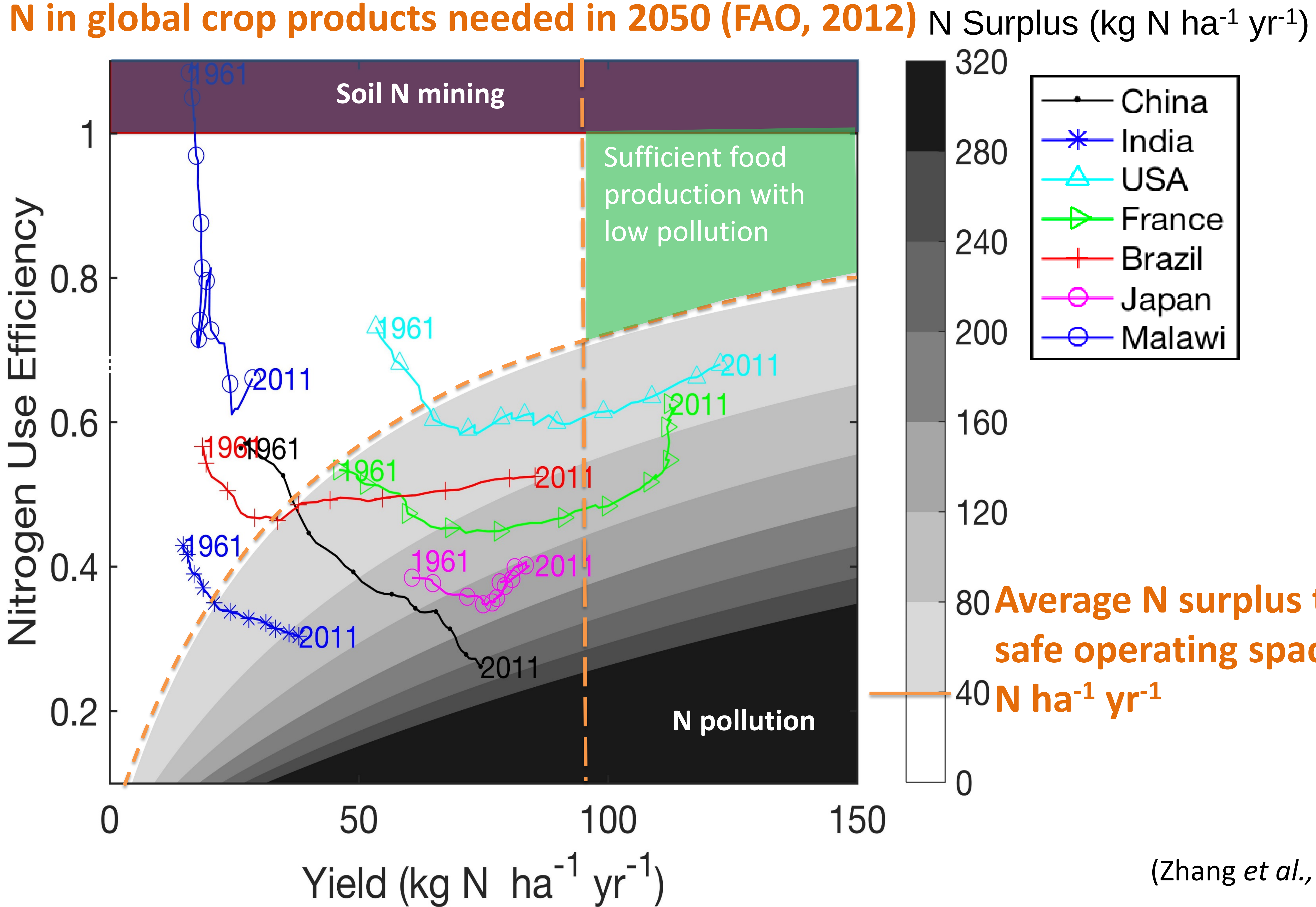
$$NUE = N_{yield}/Inputs$$

$$N_{sur} = Inputs - N_{yield}$$

$$N_{sur} = N_{yield}\left(\frac{1}{NUE} - 1\right)$$

(Zhang *et al.*, 2015, *Nature*)

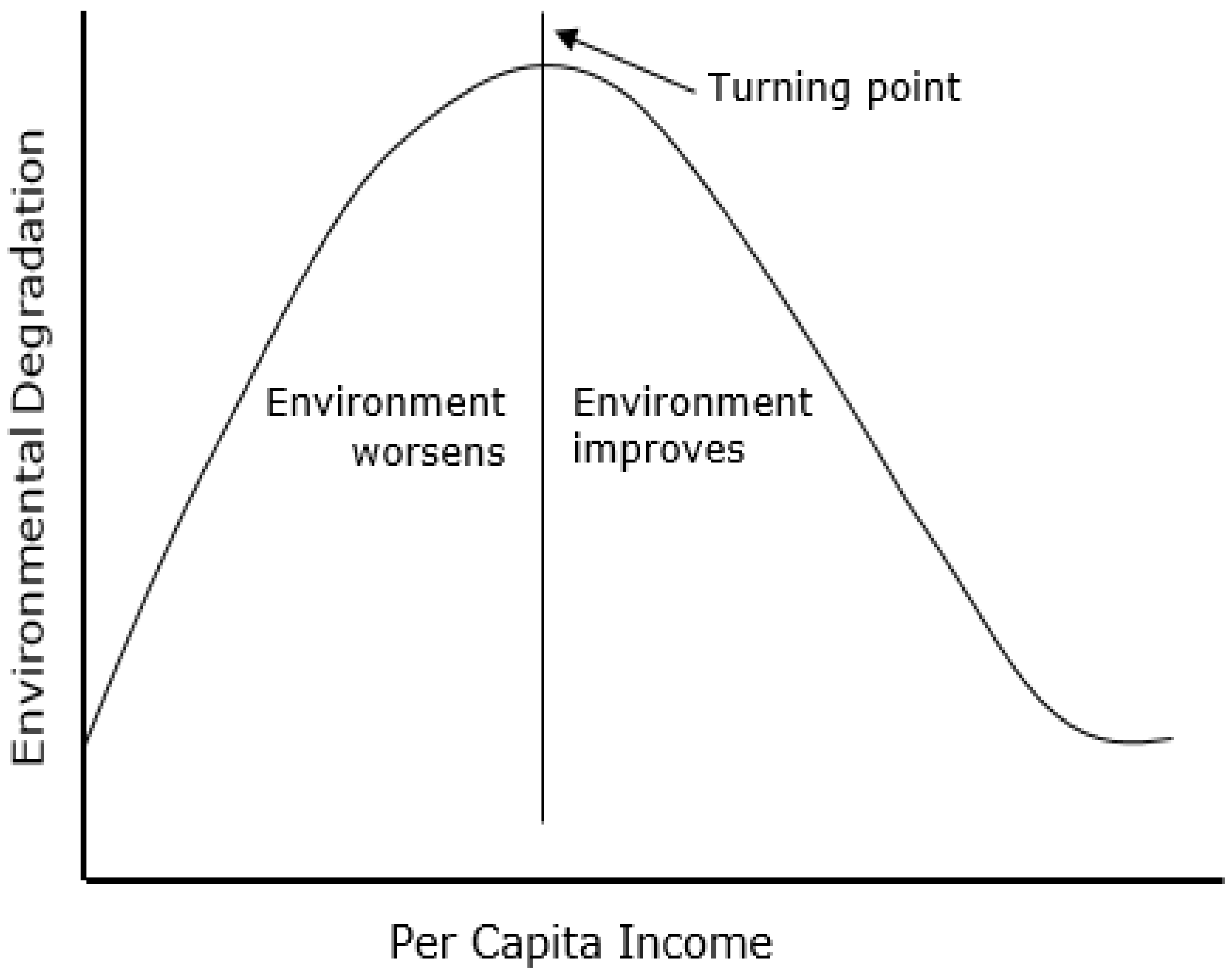
107 Tg N in global crop products needed in 2050 (FAO, 2012)



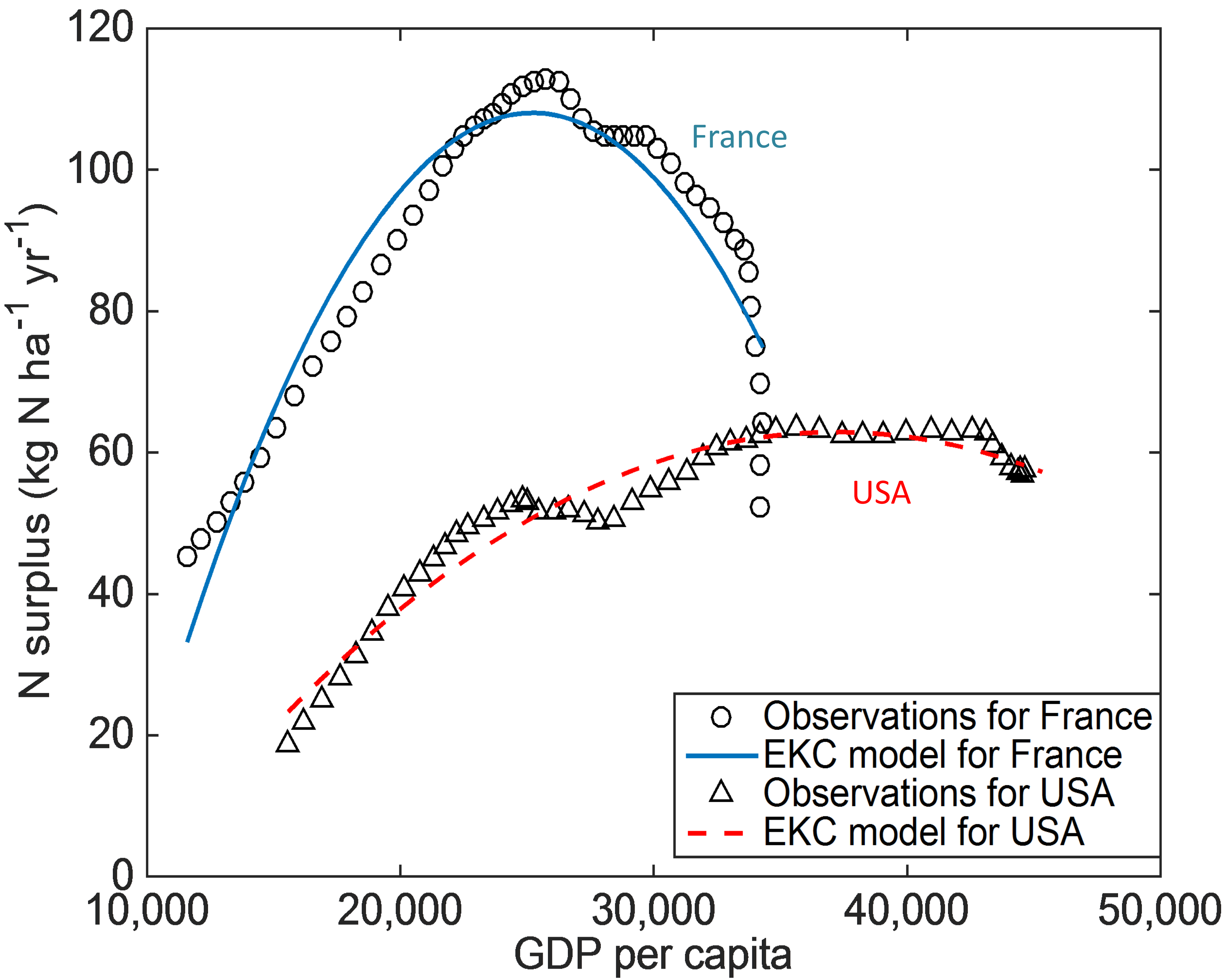
Average N surplus tolerable for safe operating space: ~40 kg N ha^{-1} yr^{-1}

(Zhang *et al.*, 2015, *Nature*)

Environmental Kuznets Curve

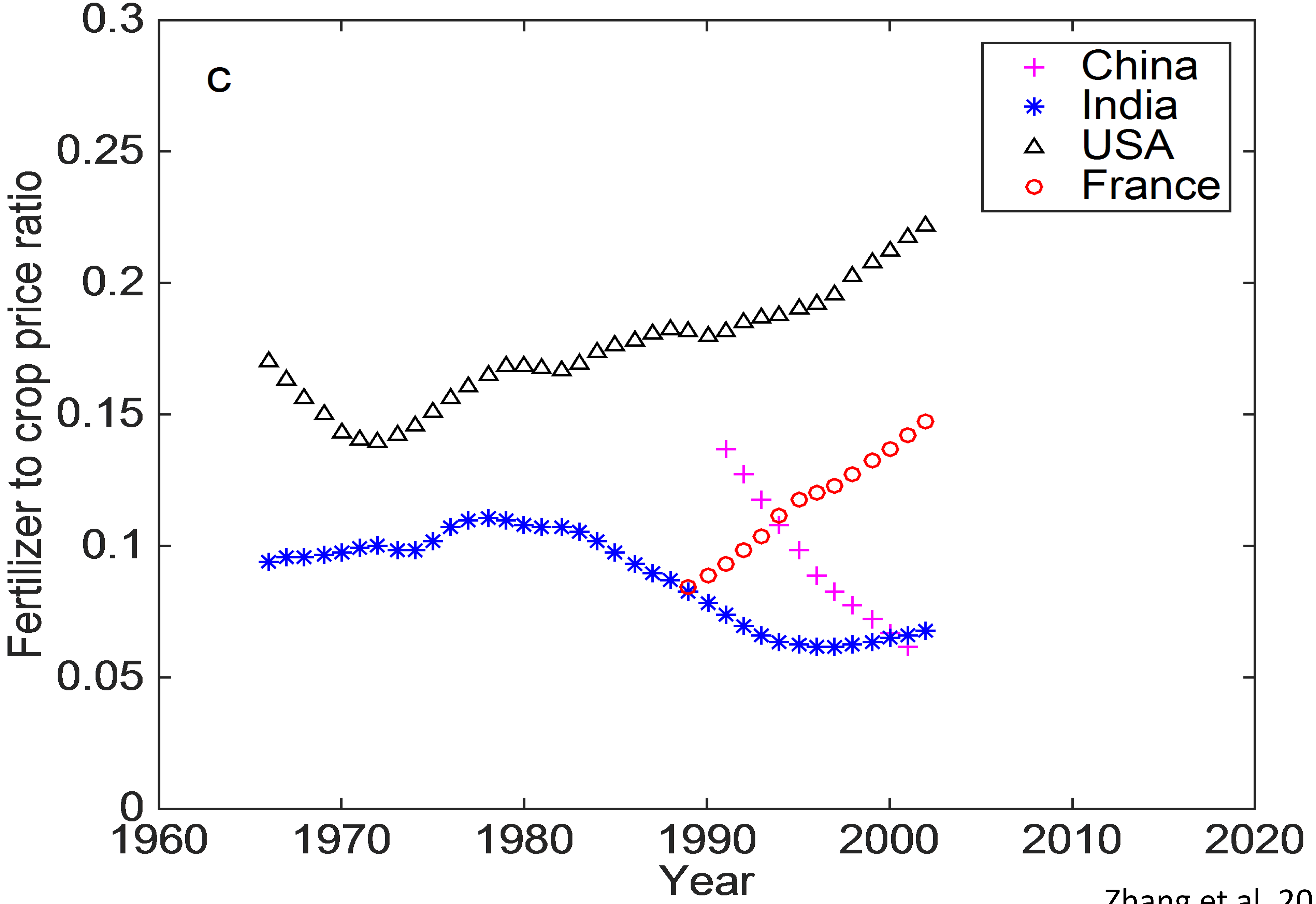


N surplus follows the EKC model for western Europe and North America



Zhang et al. 2015. Nature 528:51-59

Strong fertilizer subsidies have kept the fertilizer/crop price ratios low in China and India, which discourages NUE

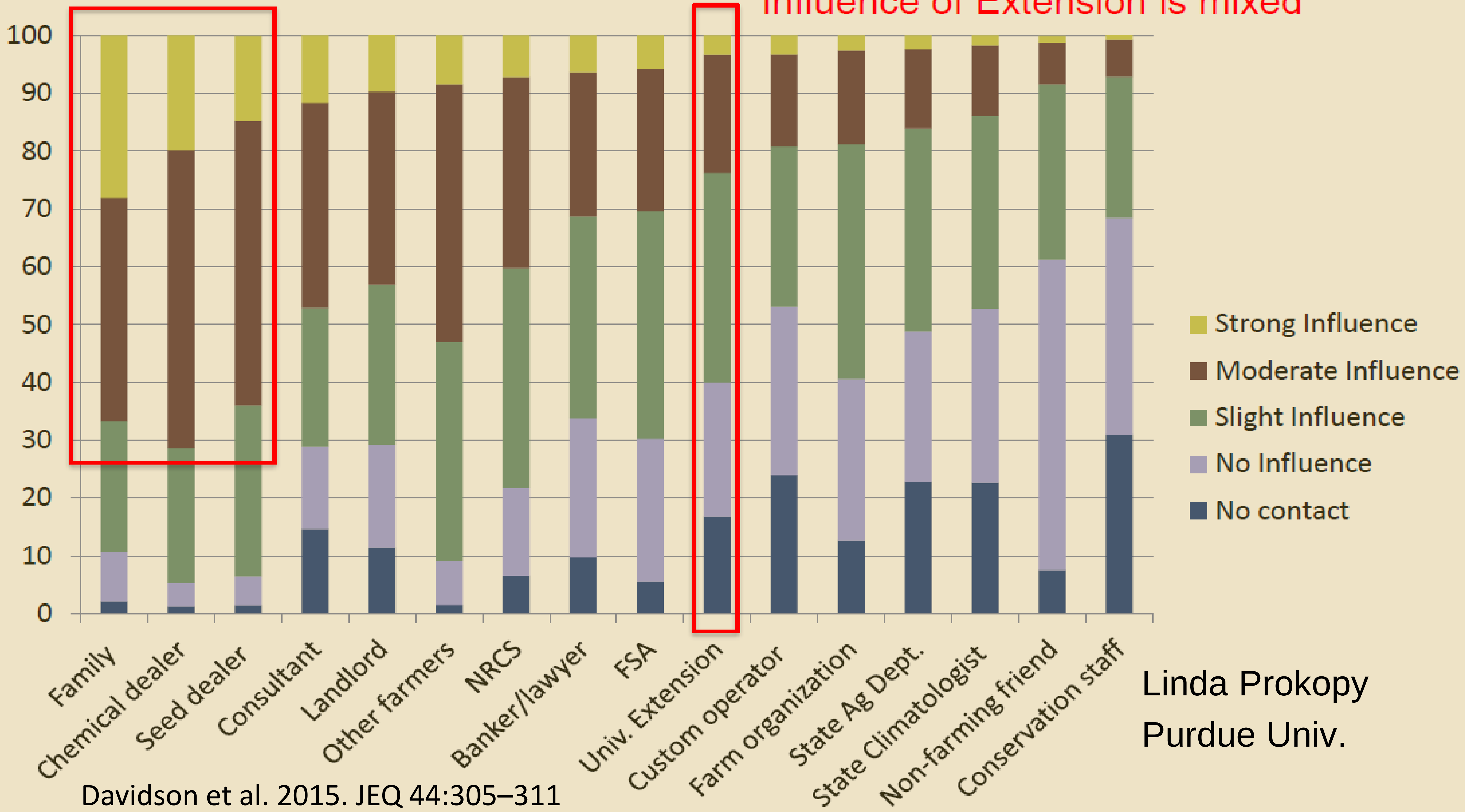


Zhang et al. 2015. Nature 528:51-59

Please indicate how influential the following groups and individuals are when you make decisions about agricultural practices and strategies. (16 options)

Family, chemical dealers, and seed dealers are most influential

Influence of Extension is mixed



Linda Prokopy
Purdue Univ.

Davidson et al. 2015. JEQ 44:305–311

Sustainable Development Goals

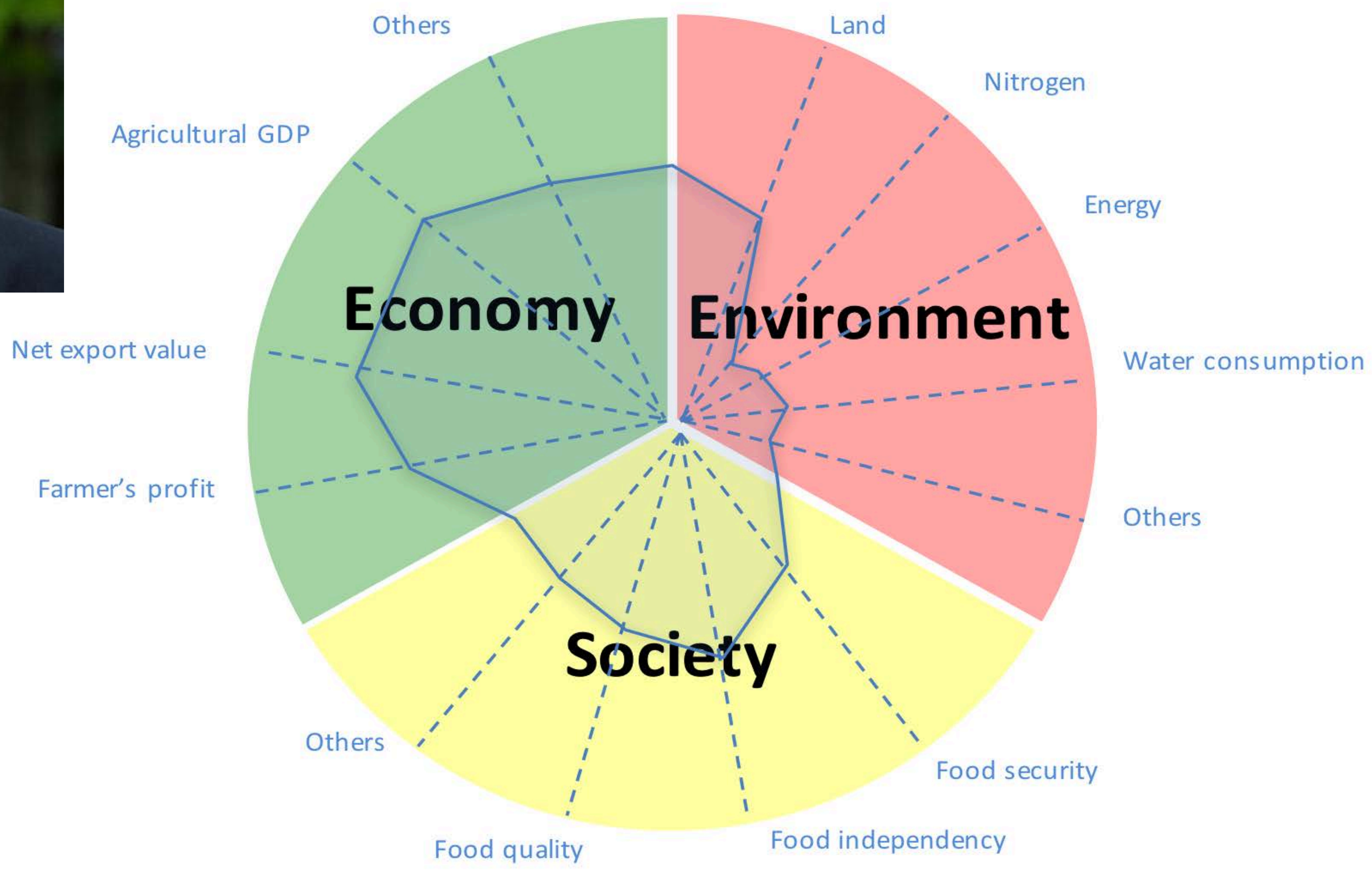
Goal 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture

Indicator 2.4.1: Percentage of agricultural area under sustainable agricultural practices

But how can sustainable agriculture be measured?

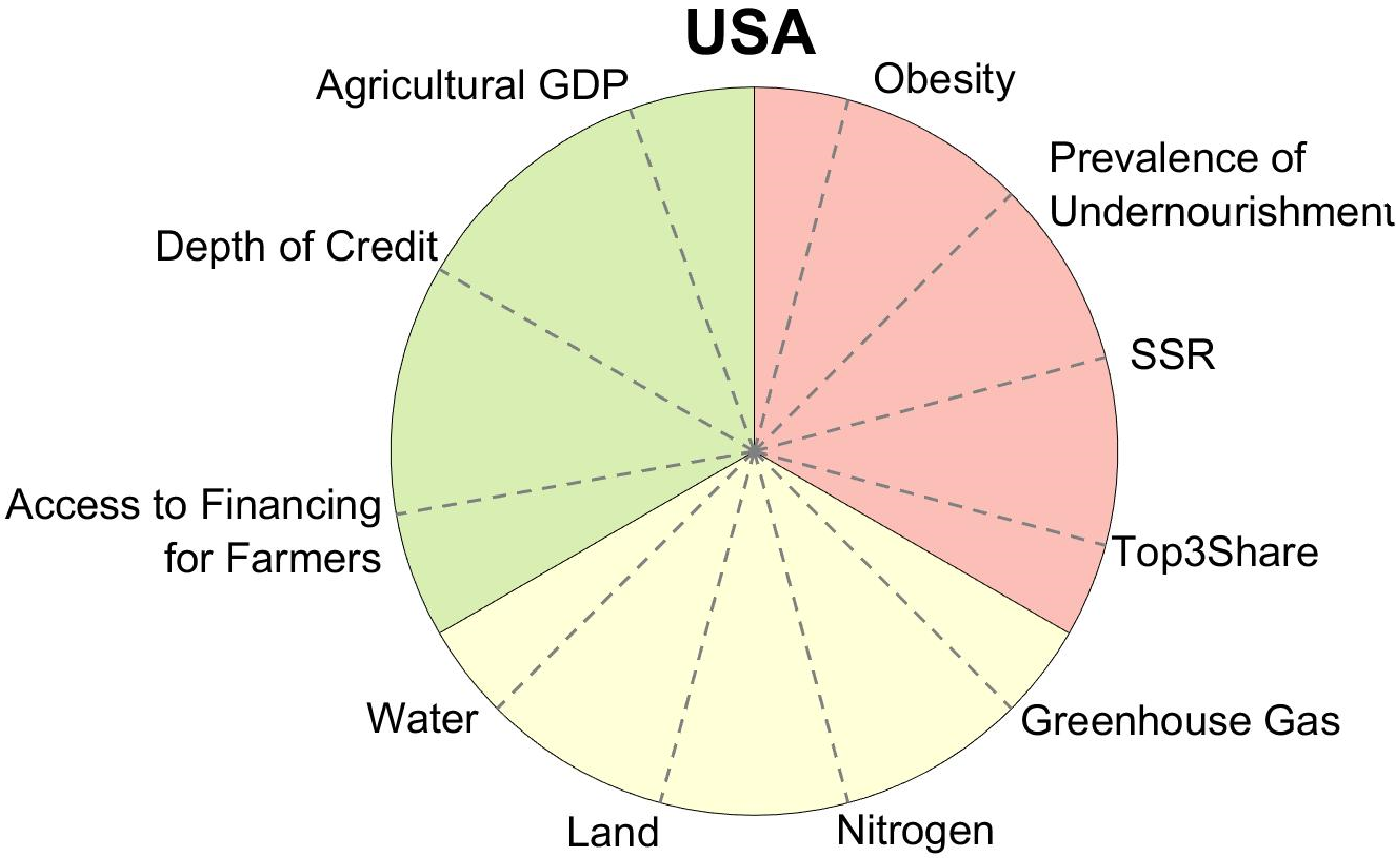
Sustainable Agriculture Matrix

Xin Zhang
Univ. of Maryland Center for Environmental Science, Appalachian Lab



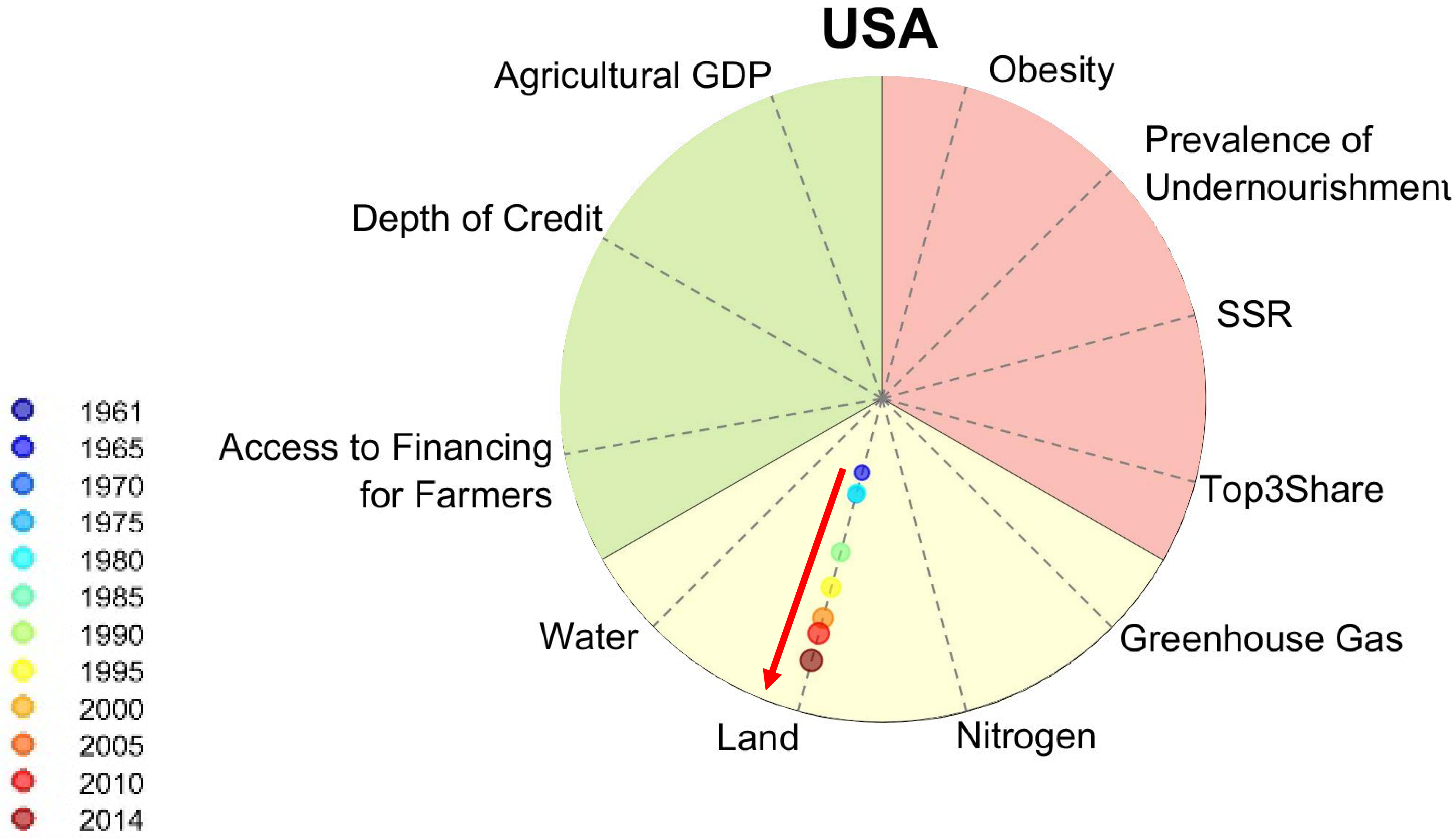
A radar chart for visualizing a country's performance in sustainable agricultural production.

Sustainable Agriculture Matrix



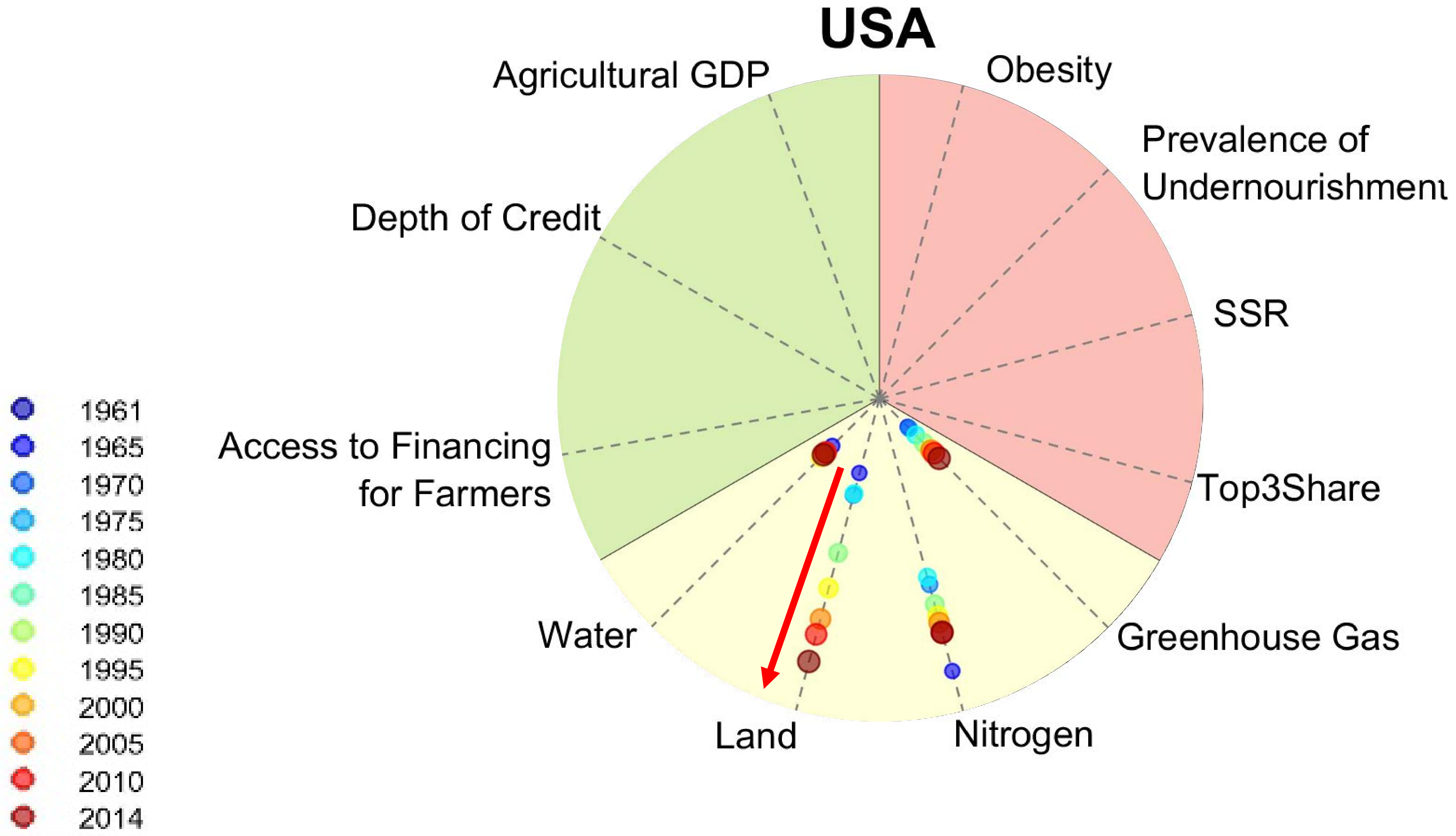
A radar chart for visualizing America's performance in sustainable agricultural production.

Sustainable Agriculture Matrix



A radar chart for visualizing America's performance in sustainable agricultural production.

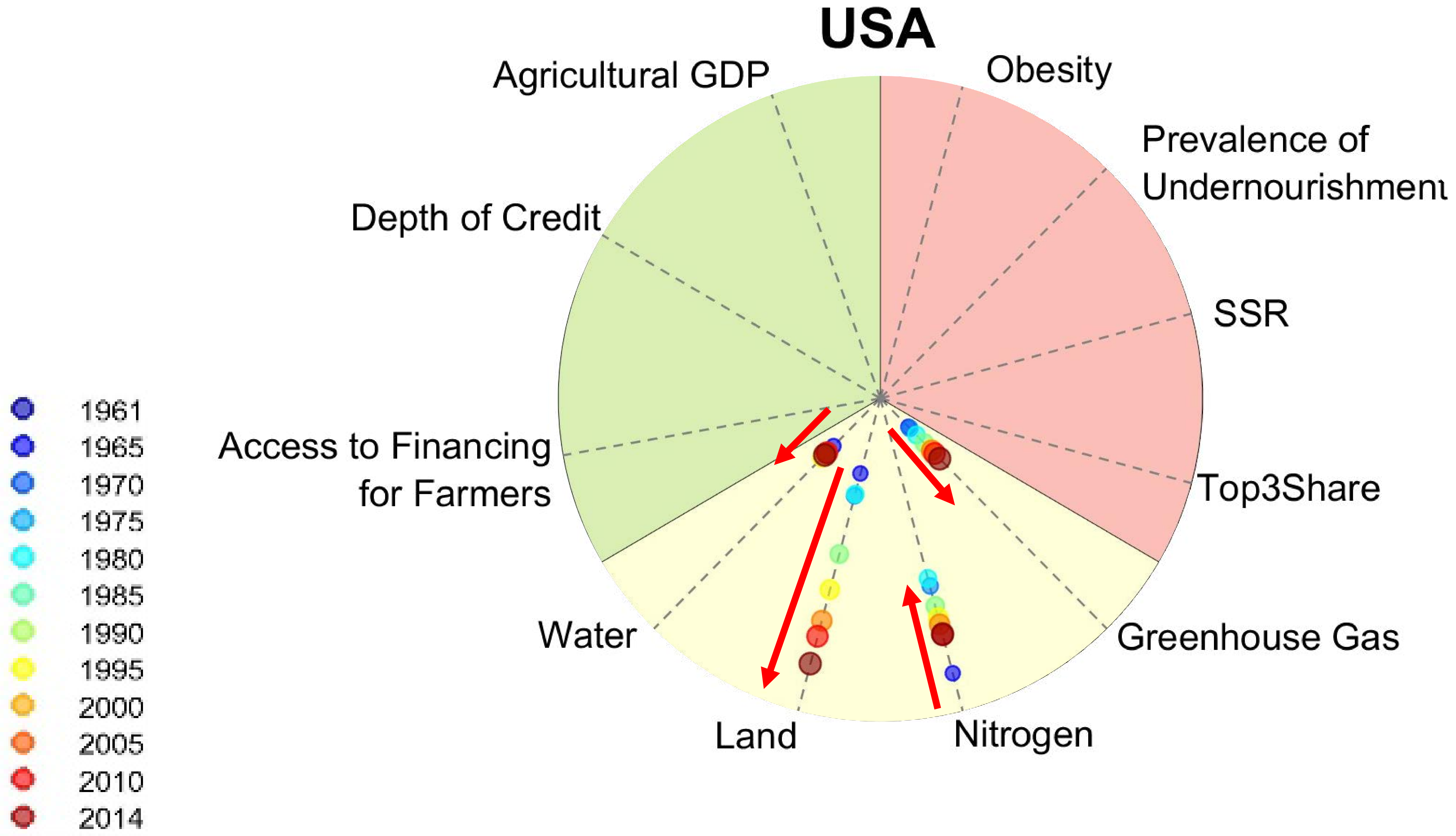
Sustainable Agriculture Matrix



A radar chart for visualizing America's performance in sustainable agricultural production.

SESYNC

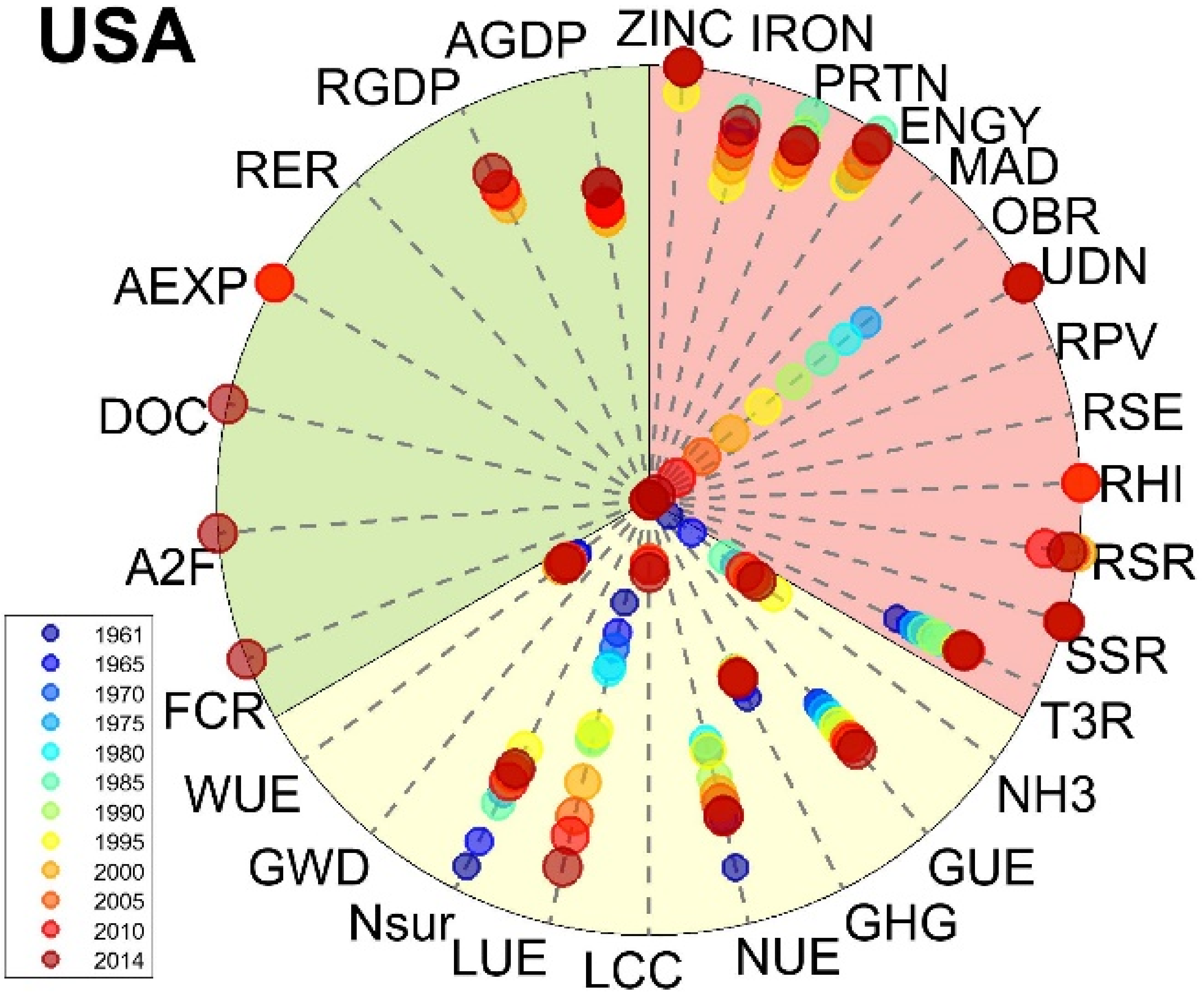
Sustainable Agriculture Matrix



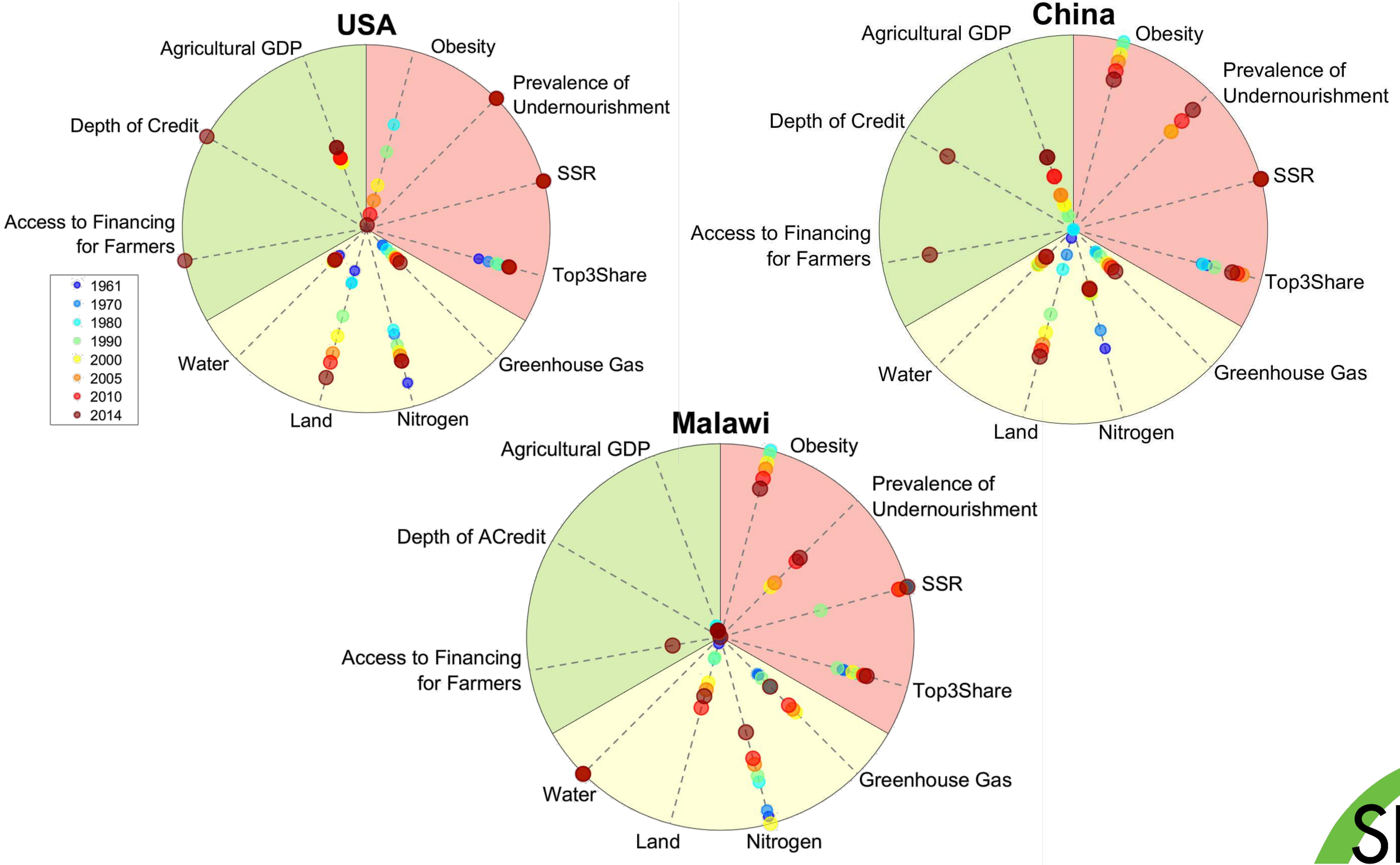
A radar chart for visualizing America's performance in sustainable agricultural production.

SESYNC

Sustainable Agriculture Matrix

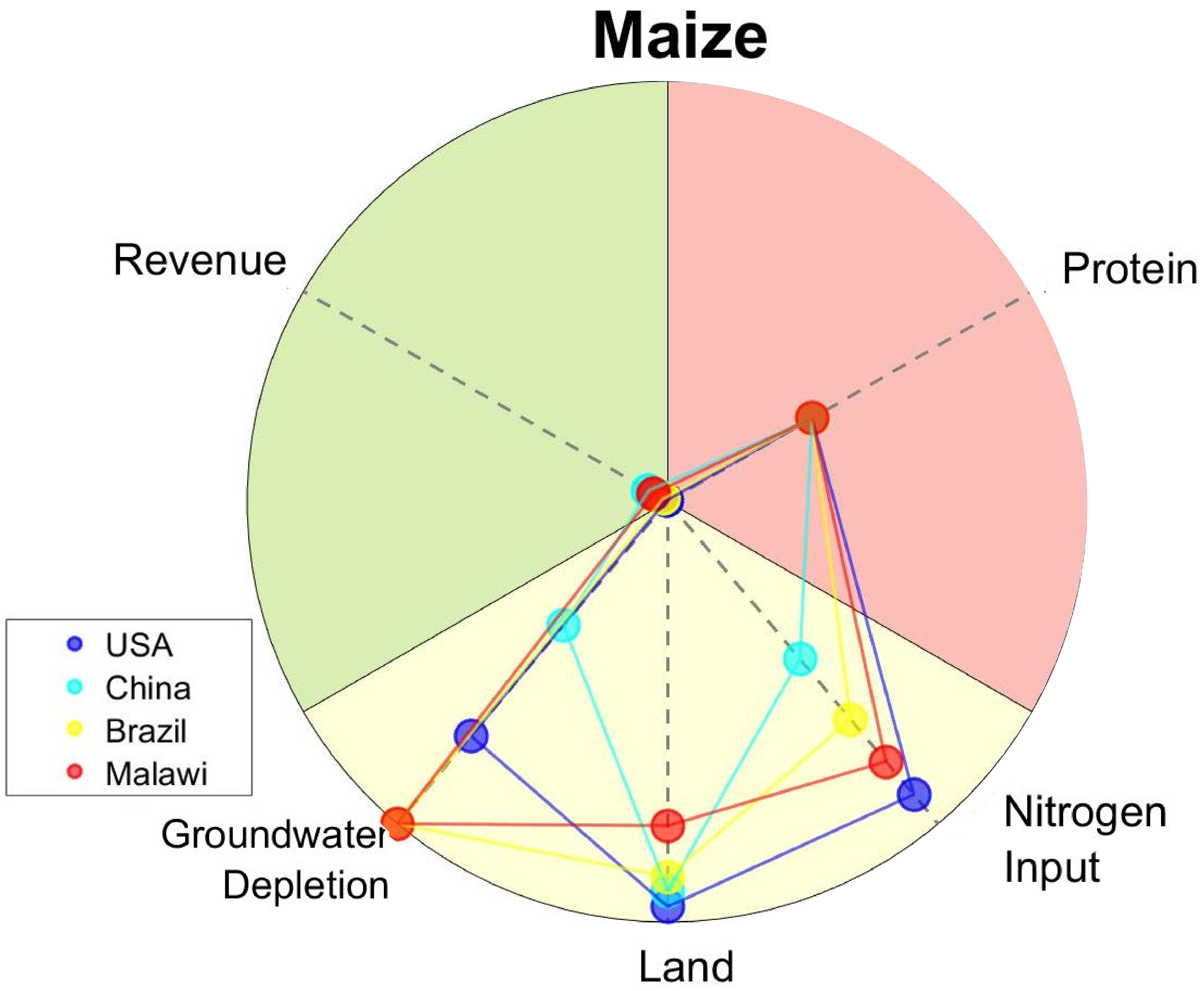


Sustainable Agriculture Matrix

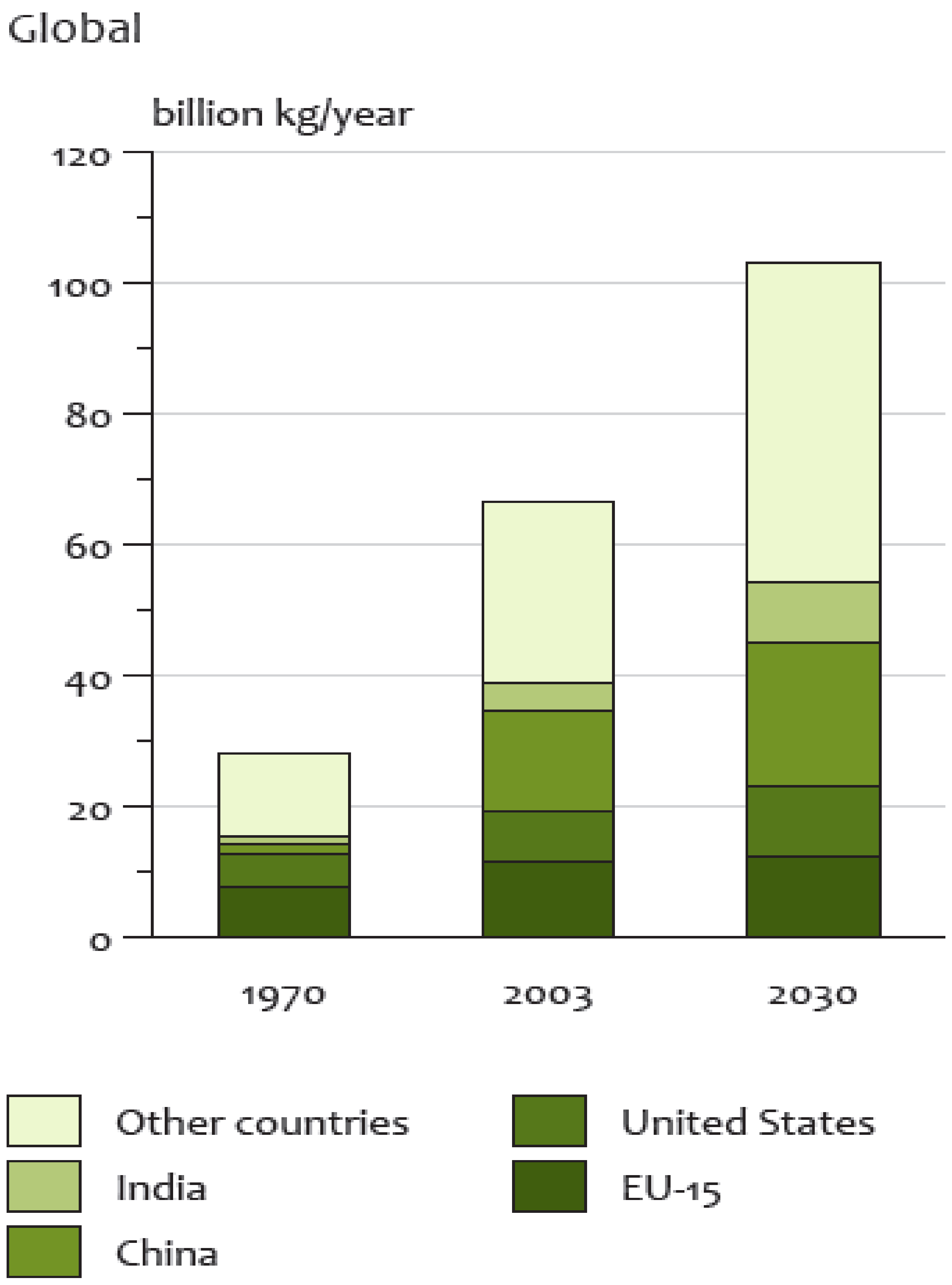


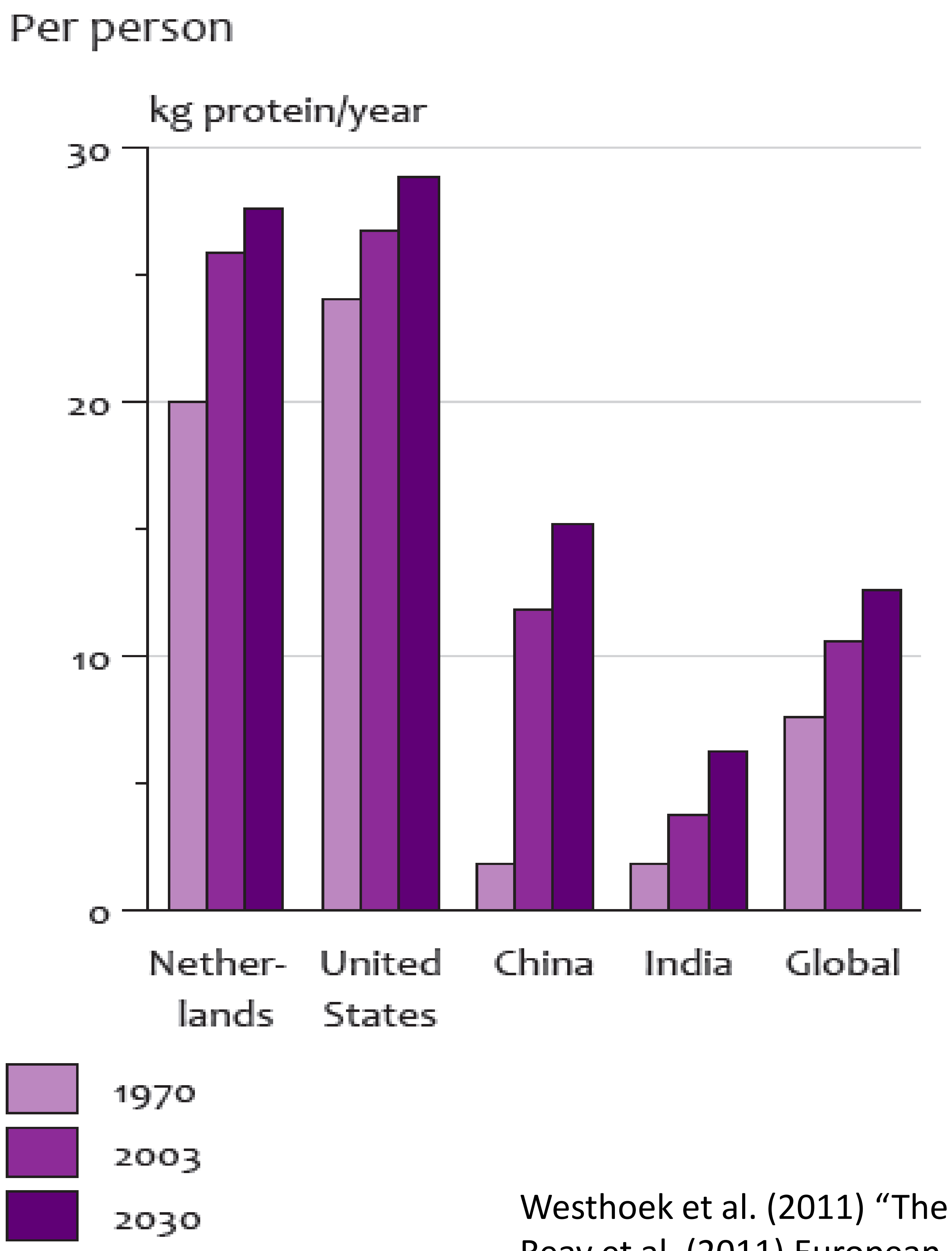
SESYNC

The role of crop mixes and trade



Increasing consumption of animal protein

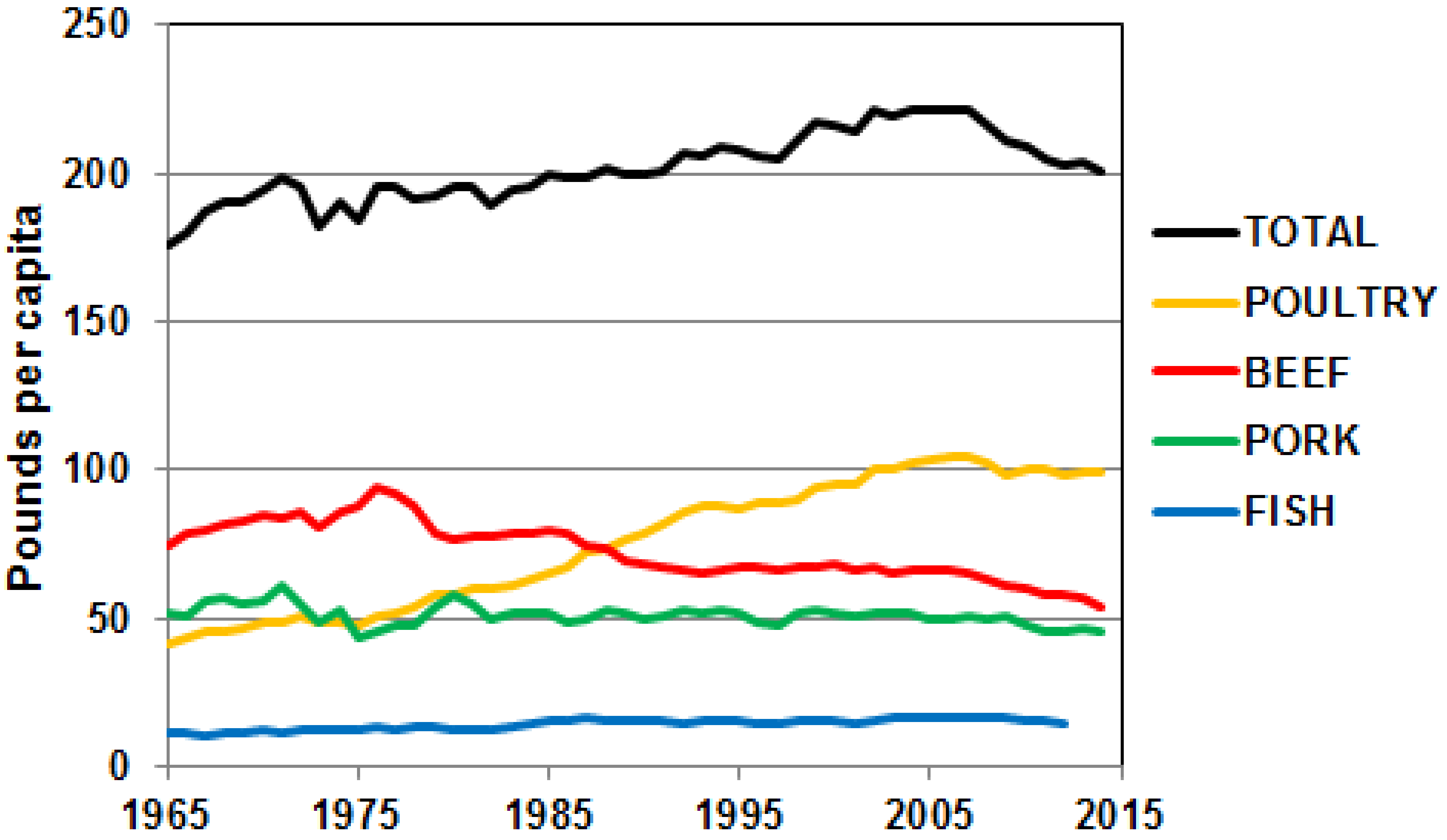




Westhoek et al. (2011) “The Protein Puzzle”
Reay et al. (2011) European Nitrogen Assessment

Per capita meat consumption has started to decline in the USA, especially beef consumption.

http://www.nationalchickencouncil.org/



Calculate your nitrogen footprint at: www.N-Print.org

Introduction

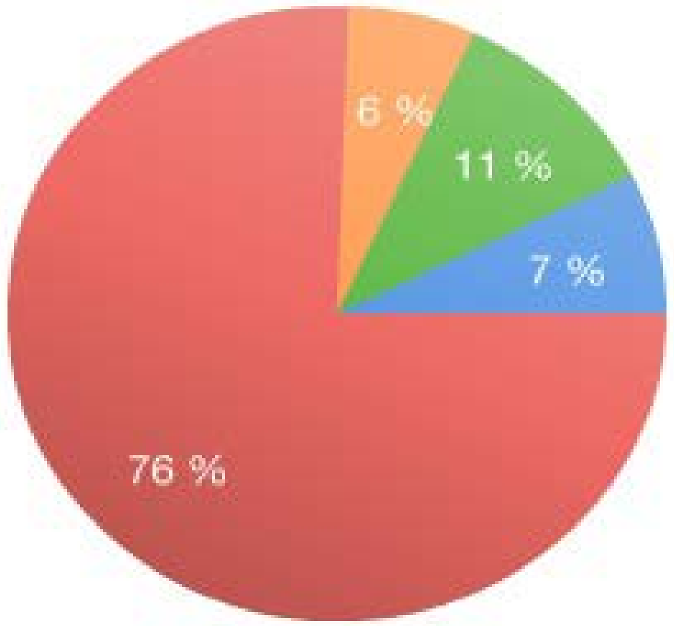
Welcome to the Nitrogen Footprint Calculator! A nitrogen footprint is a measure of the amount of nitrogen released to the environment as a result of human activities.

The human use of nitrogen through agriculture, energy use, and resource consumption has profound beneficial and detrimental impacts on all people. The beneficial impacts include food produced by nitrogen fertilizer. However, in areas that already have a lot of nitrogen, excess nitrogen lost to the environment negatively impacts both people and ecosystems. Once lost to the environment, nitrogen moves through the Earth's atmosphere, forests, grasslands, and waters. This excess nitrogen can lead to smog, acid rain, forest dieback, coastal "dead zones", biodiversity loss, stratospheric ozone depletion, and an enhanced greenhouse effect. This expansive impact makes it important to understand one's nitrogen footprint.

The pie chart to the right initially shows the average footprint of a person from the country you selected. As you answer the N Calculator questions, the pie chart will change to reflect your answers.

Your footprint

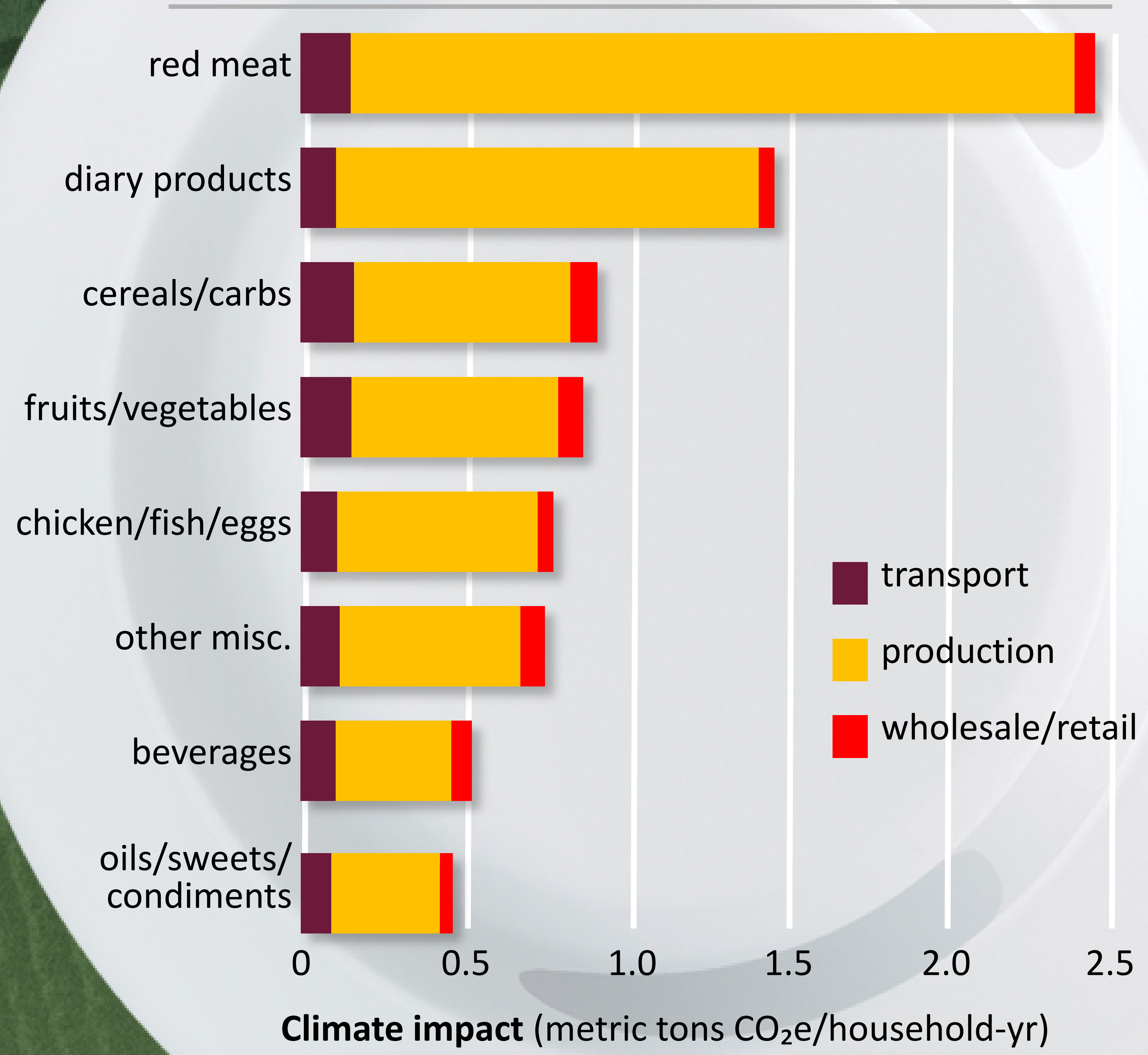
This is your personal footprint.



- Food consumption: 76.3 kg
- Housing: 6.3 kg
- Transportation: 10.9 kg
- Goods and Services: 7.5 kg

Leach et al. 2016. Food Policy 61:213–223

Total greenhouse gas emissions by supply chain tier associated with household food consumption in the U.S.



“The Problem of What to Eat” *Conservation.* Natasha Loder, Elizabeth Finkel, Craig Meisner, and Pamela Ronald. July-September 2008 9(3):31

Jason Clay
SVP Markets, WWF-US

Take-home messages

- Sustainable intensification can improve NUE, increase crop yields, and reduce N pollution, and
- Technological advances will be helpful and a lot can be done with existing technology, but
- Social and economic impediments remain, therefore
- MoFoLoPo will require integration among agronomy, social sciences, and other disciplines and cooperation across sectors and stakeholder groups,
- SAM will help nations gauge their progress towards sustainability and modify their policies accordingly, and
- Personal dietary choices matter

PROF. JOHAN ROCKSTRÖM

Stockholm Resilience Center

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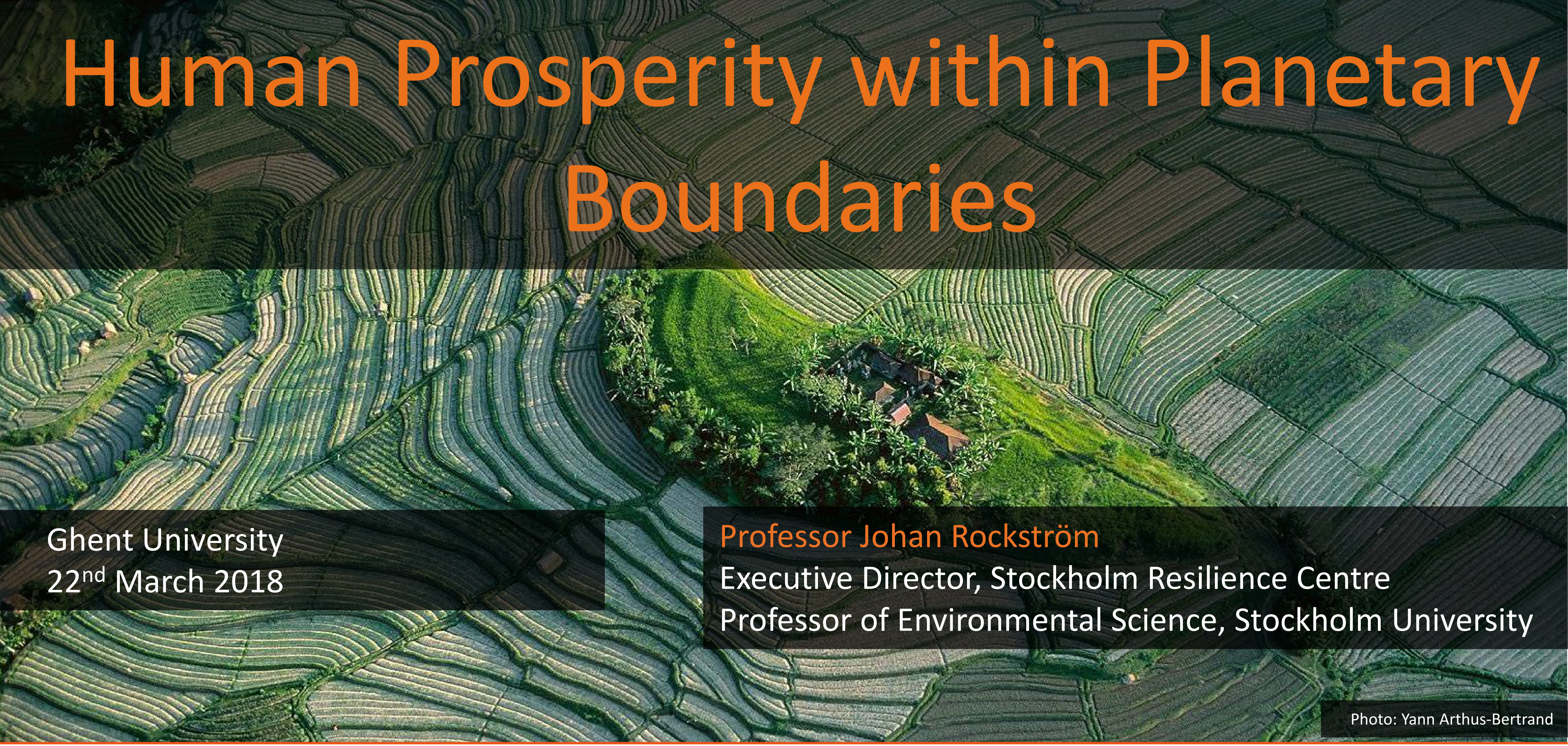
Human Prosperity within Planetary Boundaries



Ghent University
22nd March 2018

Professor Johan Rockström
Executive Director, Stockholm Resilience Centre
Professor of Environmental Science, Stockholm University

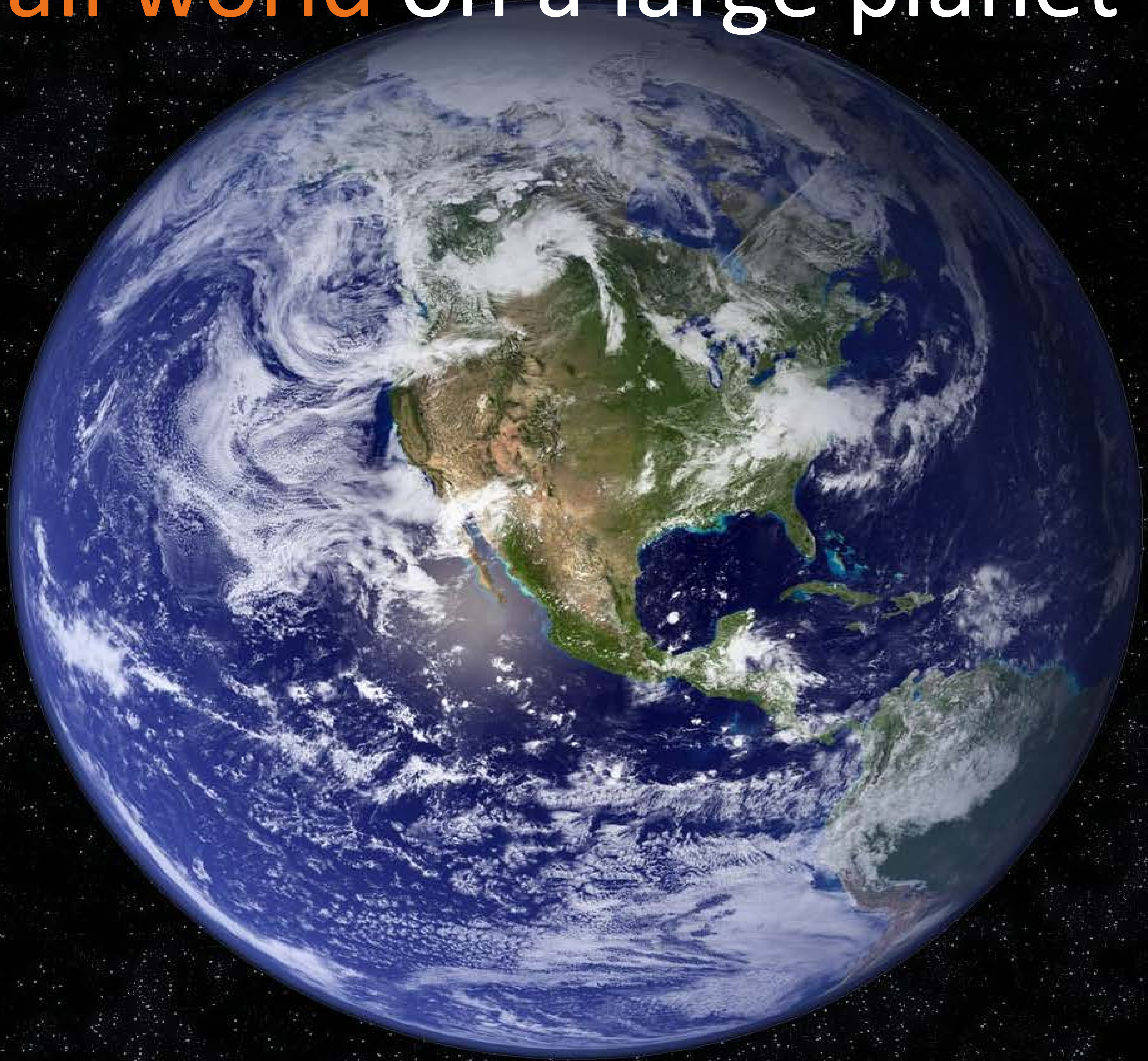
Photo: Yann Arthus-Bertrand

Stockholm Resilience Centre
Sustainability Science for Biosphere Stewardship
Stockholm University
The Beijer Institute of Ecological Economics
Kungl. Vetenskaps-Akademien
The Royal Swedish Academy of Sciences
FUNDED BY
MISTRA
The Swedish Foundation for Strategic Environmental Research

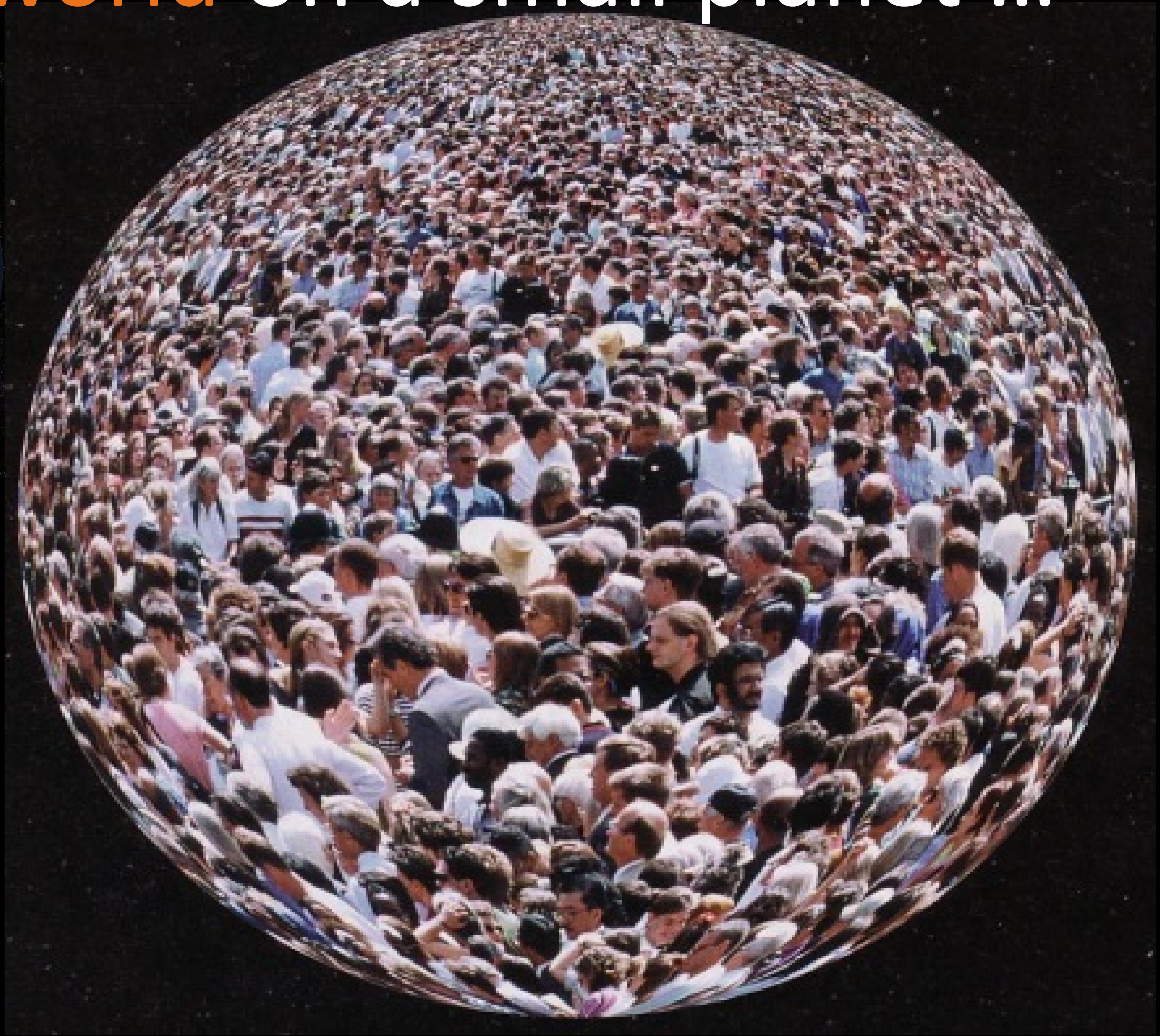
People are embedded parts of the biosphere and shape it, from local to global scales, from the past to the future

At the same time - people are fundamentally dependent on the capacity of the biosphere to sustain human development

From a small world on a large planet …



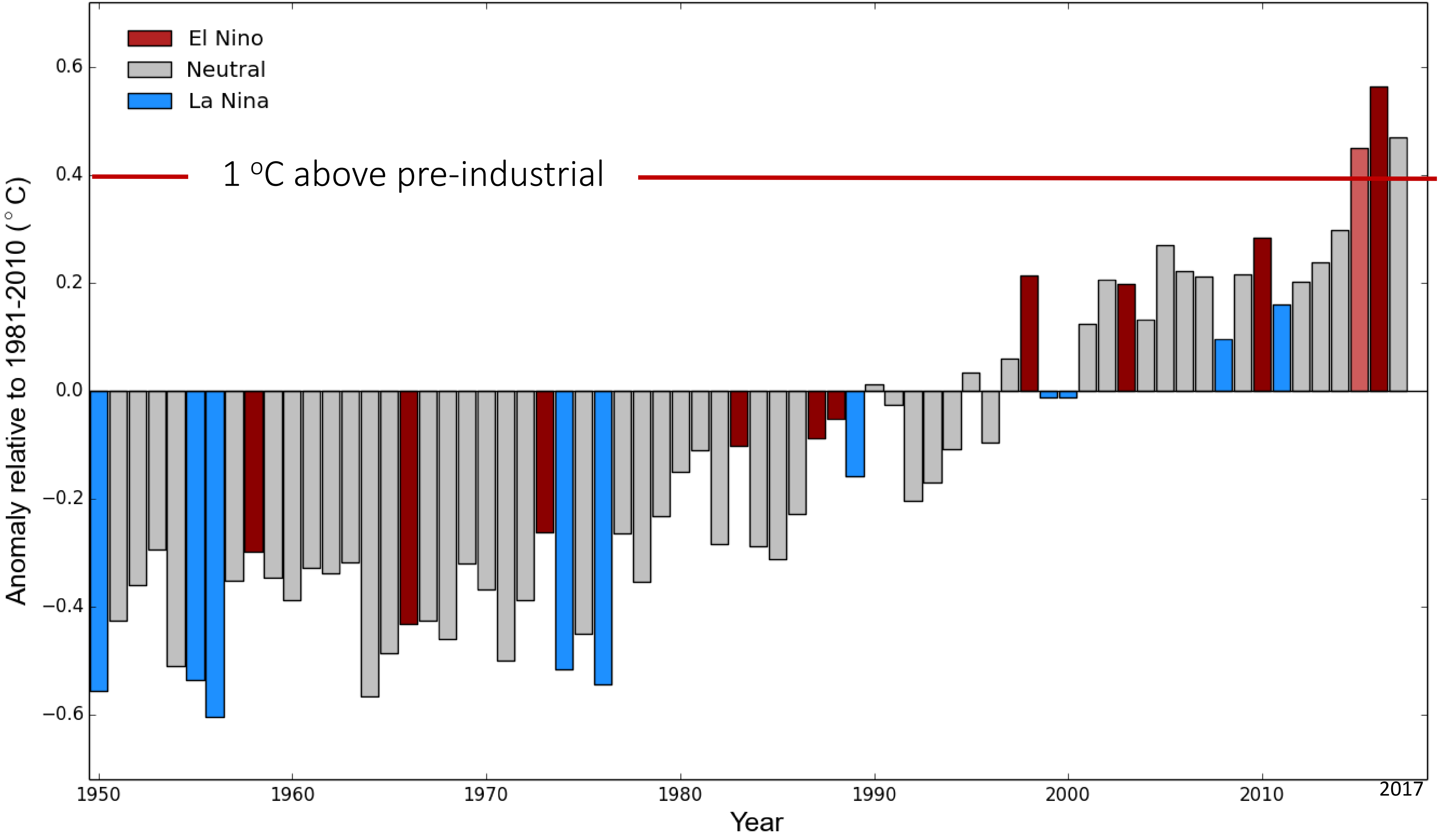
To a large world on a small planet …



Home

WORLD METEOROLOGICAL ORGANIZATION

Weather · Climate · Water



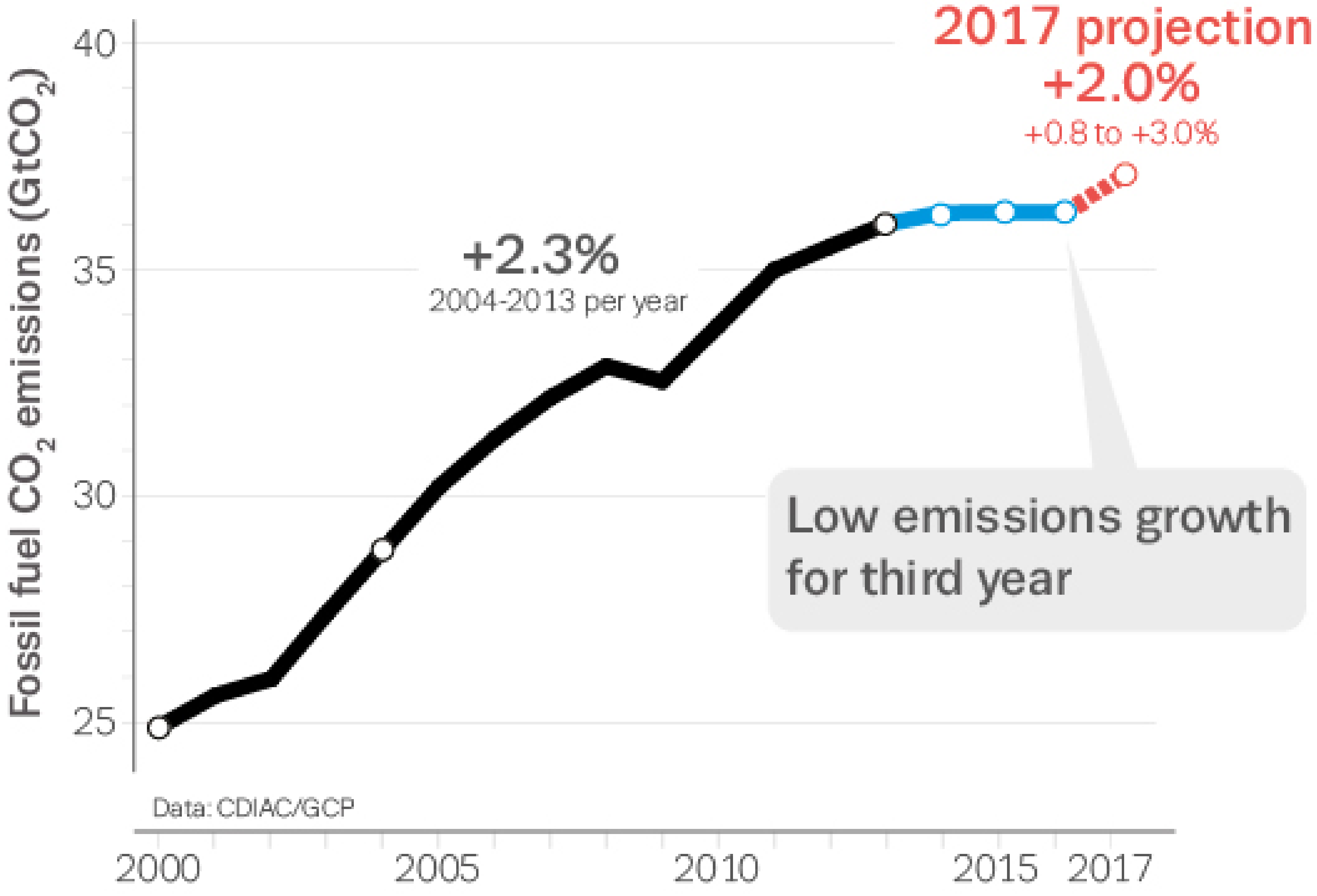
8

The plateau of last year was not peak emissions after all…2% growth

37 billion tonnes

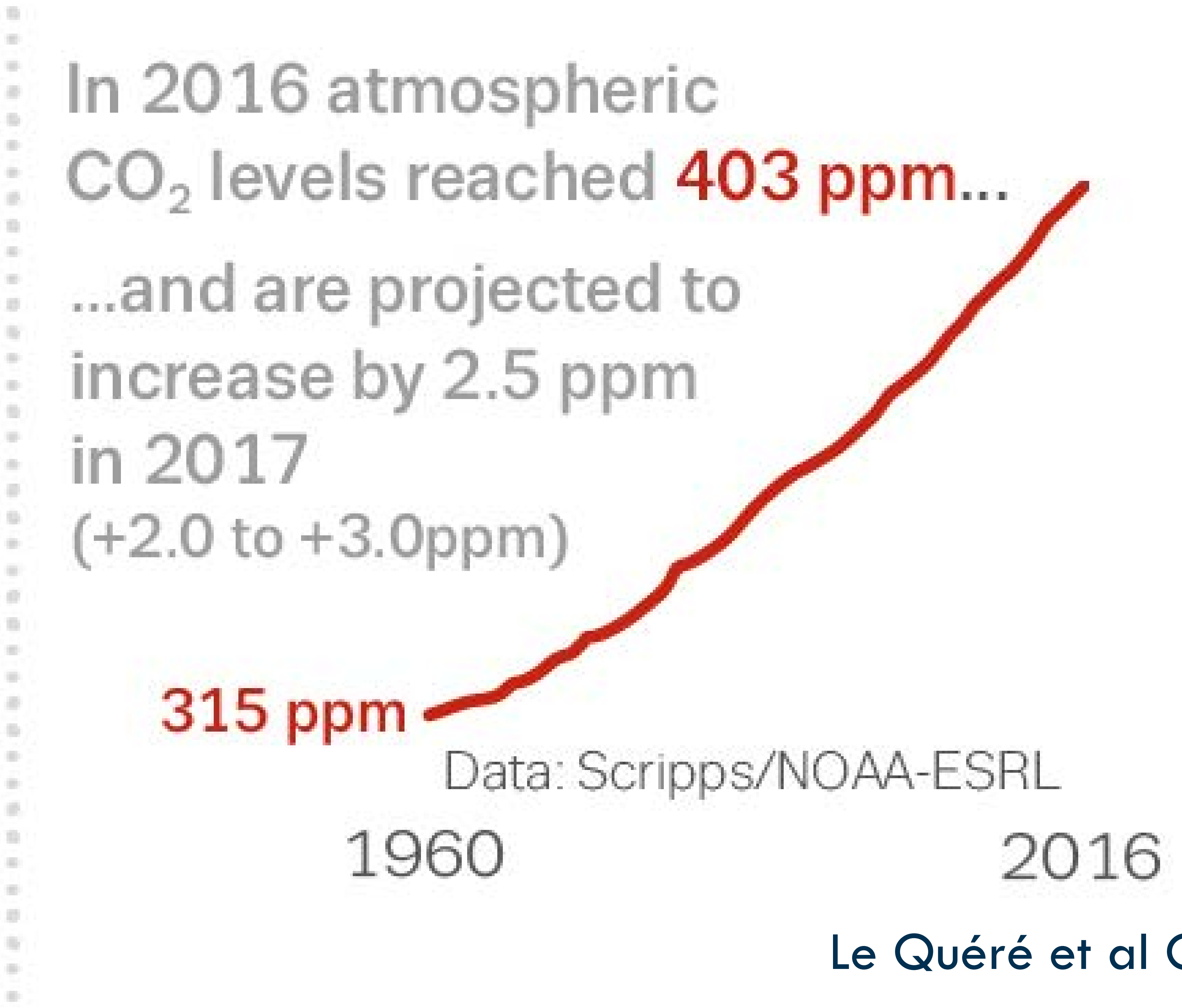
In 2017, global carbon dioxide emissions from fossil fuels and industry will reach around 37bn tonnes of carbon dioxide.

Total emissions from all sources: approx 41GtCO2



Le Quéré et al ESSDD Global Carbon Budget 2017

… but atmospheric concentrations continue to rise

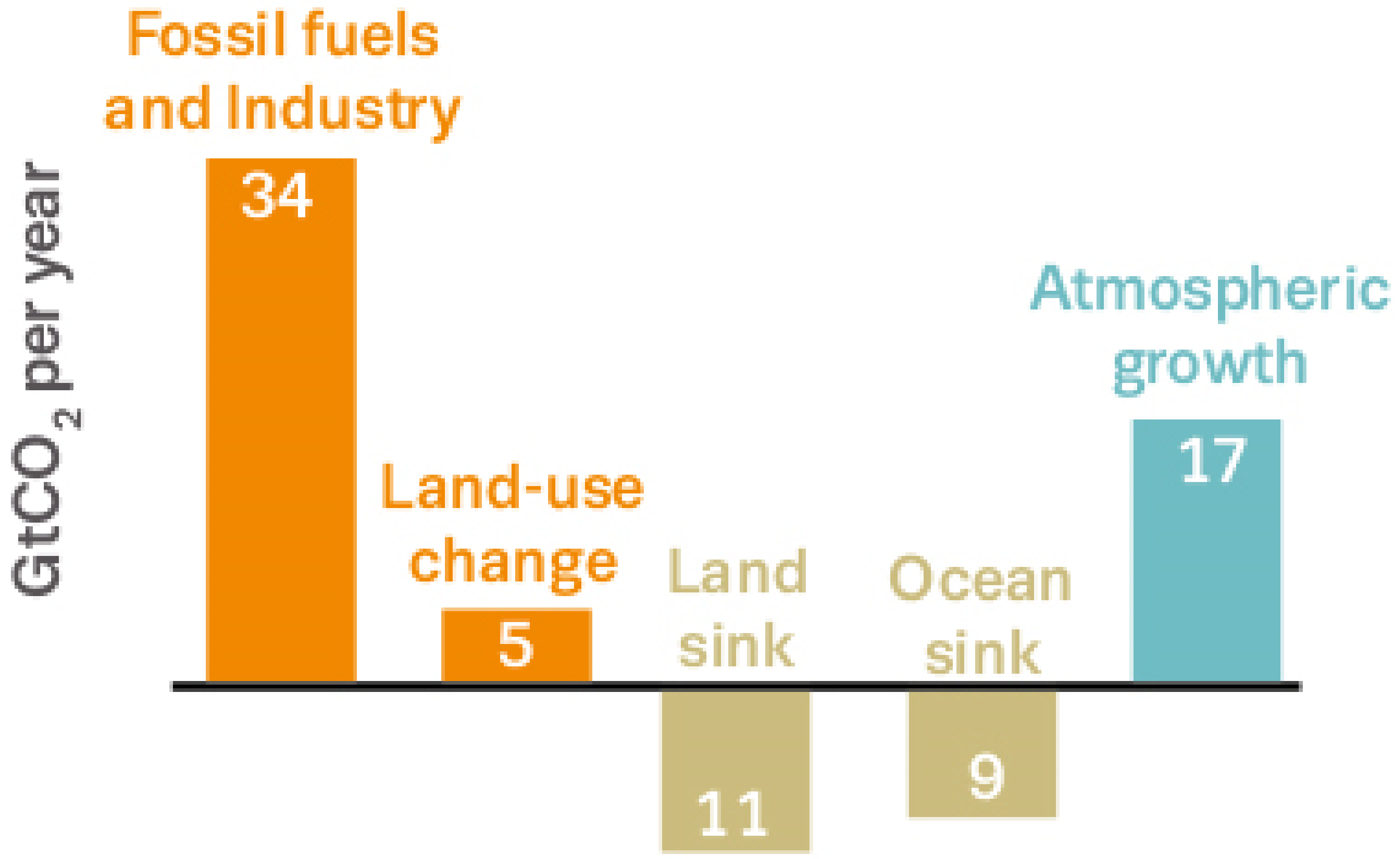


Le Quéré et al Global Carbon Budget 2017

8

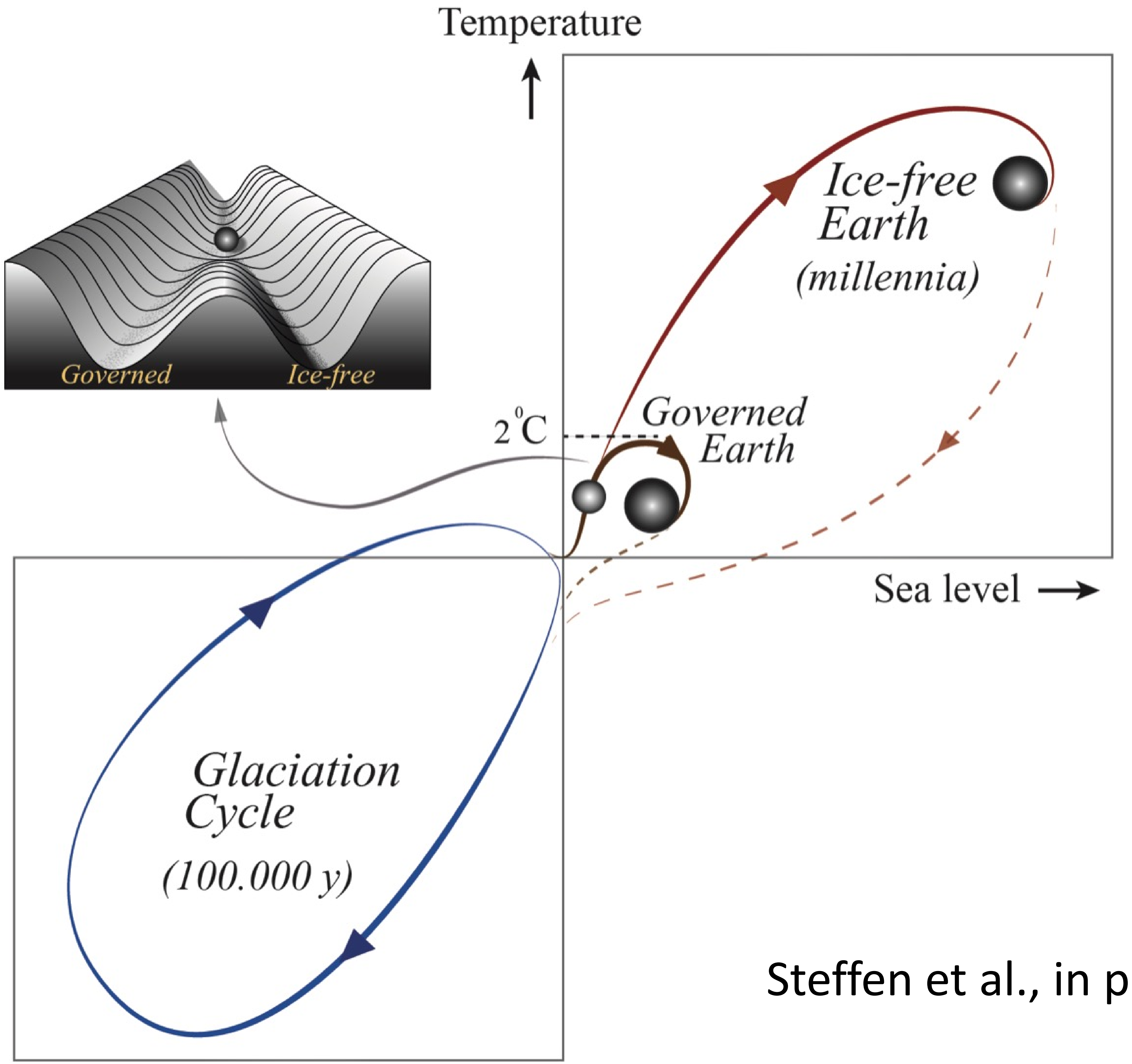
The land and ocean absorb around half the emissions

The carbon cycle has both emissions sources and carbon sinks, and their difference is the atmospheric growth (2007-2016)



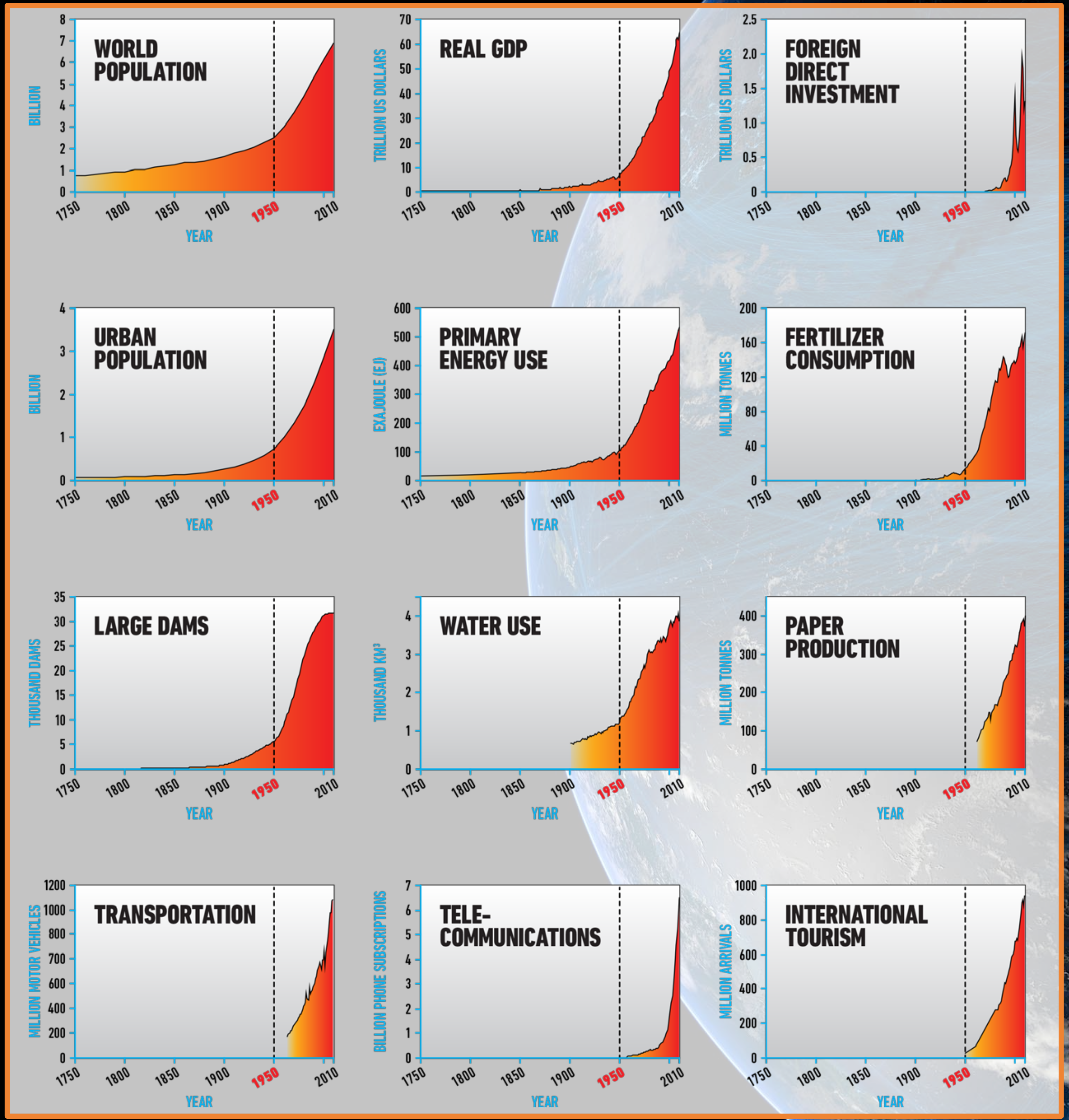
Le Quéré et al ESSDD Global Carbon Budget 2017

Risk of Tipping the Earth System away from Manageable Inter-glacial?



Steffen et al., in prep

GREAT ACCELERATION 1950 TO PRESENT

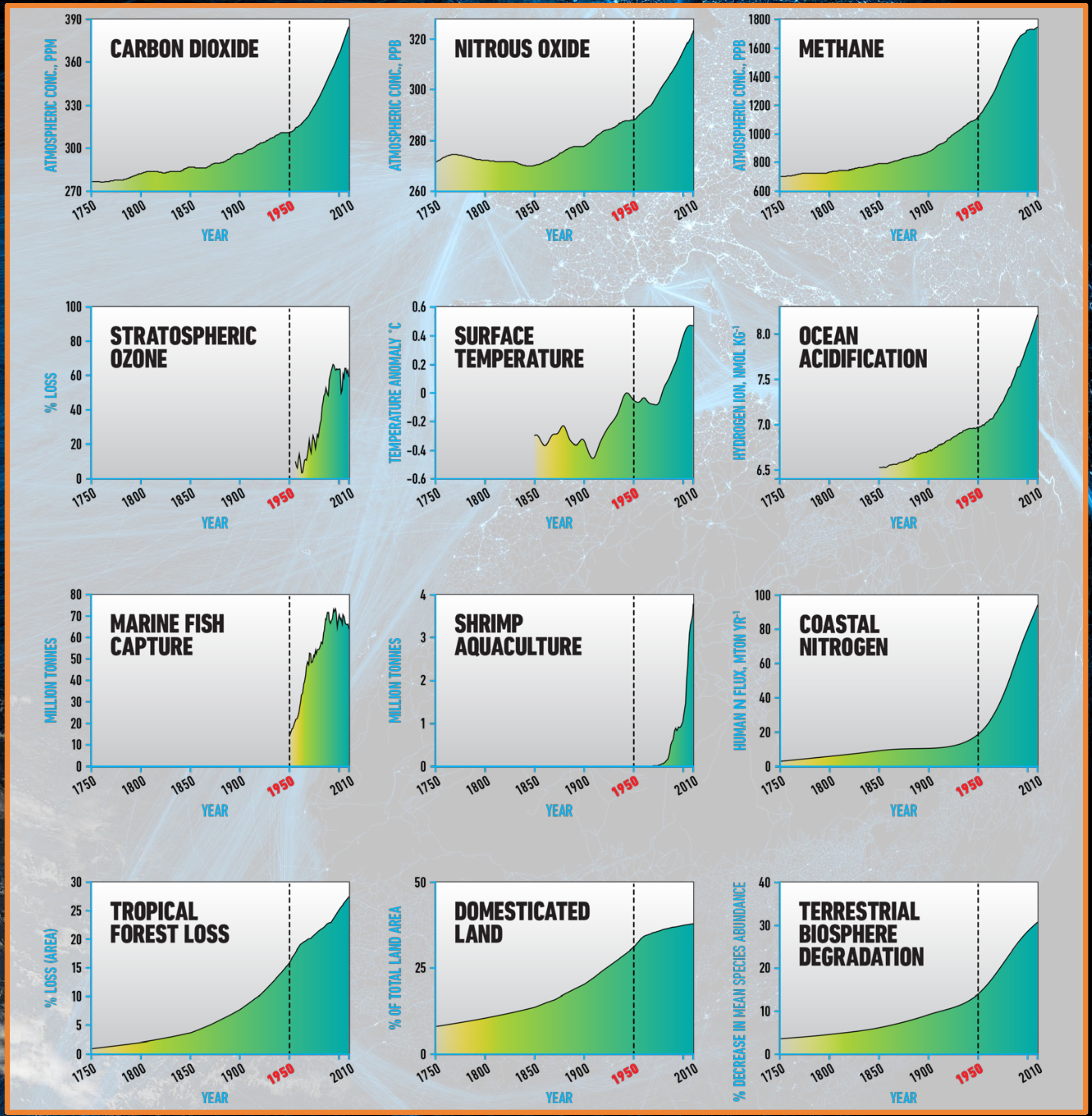


GREAT ACCELERATION 1950 TO PRESENT

Global development occurred due to our STABLE, RESILIENT PLANET

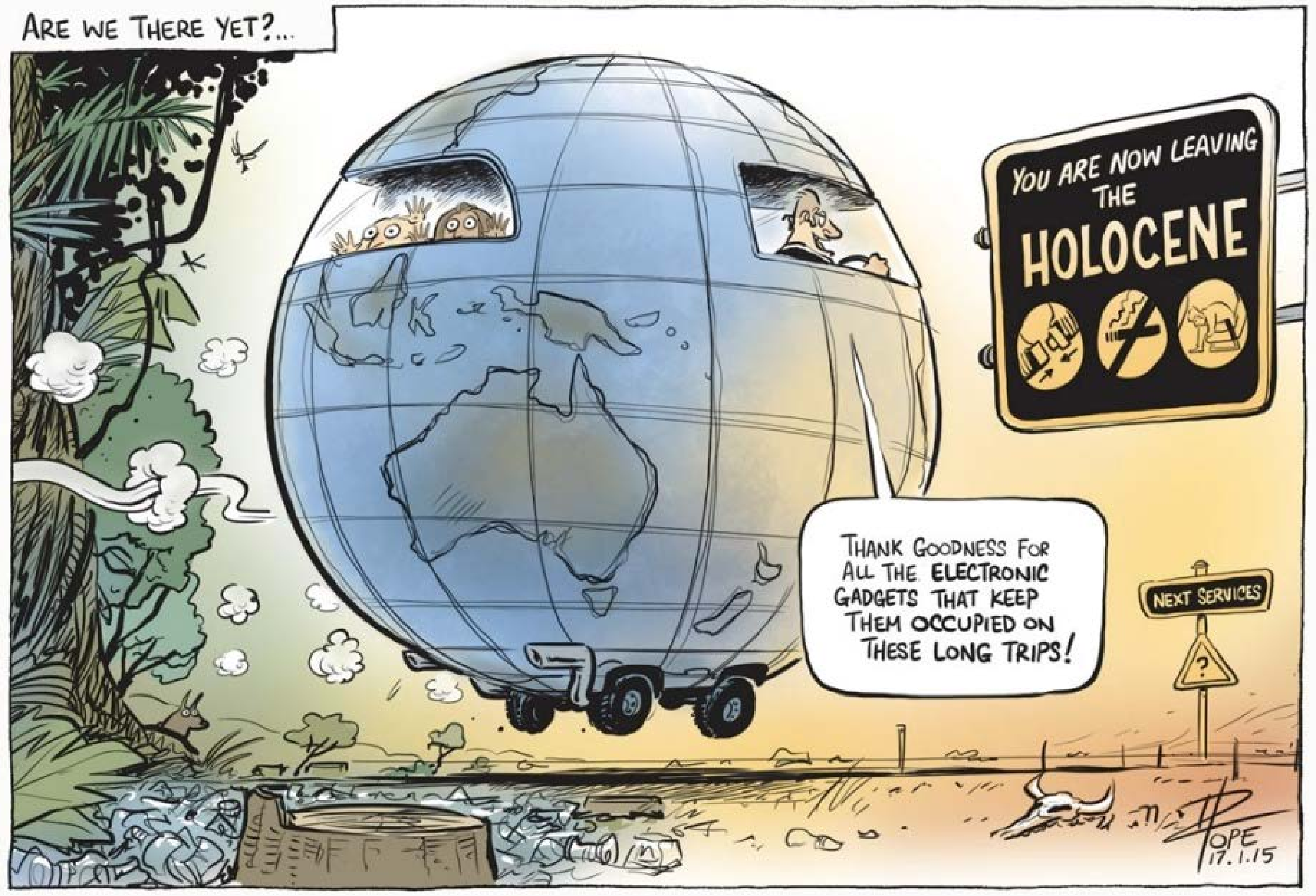
This is now at

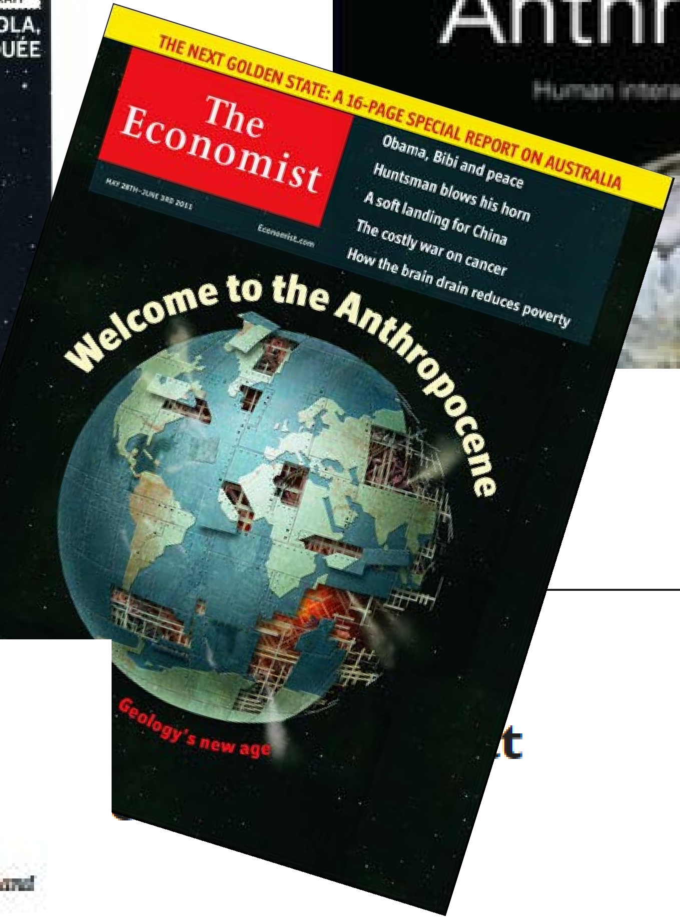
RISK



Welcome to the Anthropocene

Image: GLOBAIA





THE ANTHROPOCENE REVIEW

The Anthropocene Review
1–18
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DOI: 10.1177/2053019614564785
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The New World of the Anthropocene[1]

JAN ZALASIEWICZ*
Department of Geology, University of Leicester, U.K.
MARK WILLIAMS
Department of Geology, University of Leicester, U.K. and British Geological Survey, Nottingham, U.K.
WILL STEFFEN
Australian National University, Canberra
PAUL CRUTZEN
Max-Planck-Institute for Chemistry, Mainz, Germany

ELEMENTA
Science of the Anthropocene

Dating the Anthropocene: T… an empirical global history of… transformation of the terrest…

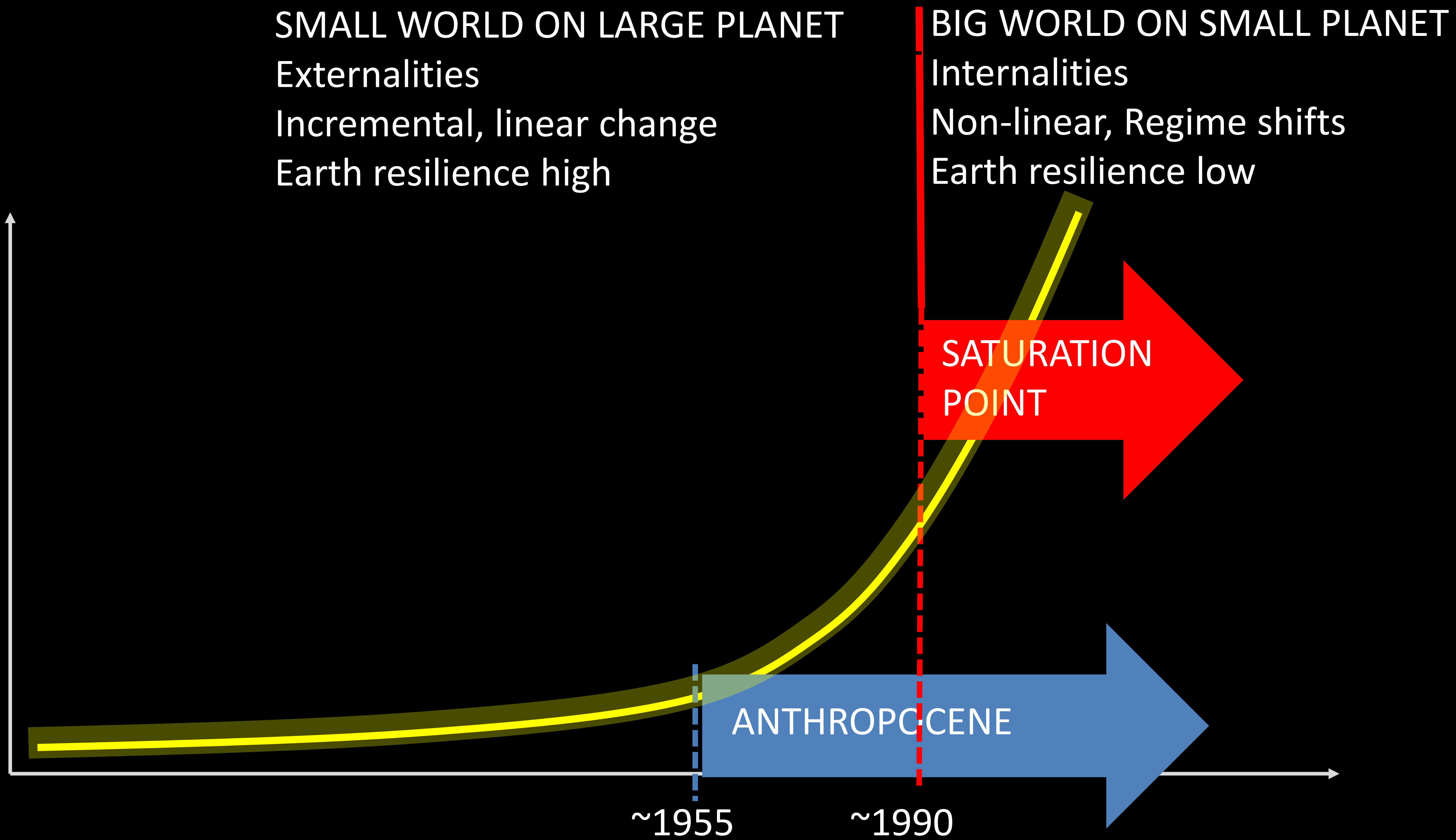
Erle C. Ellis[1*] • Dorian Q. Fuller[2] • Jed O. Kaplan[3] • Wayne G. Lutters[4]

…t

…[2] Wendy Broadgate,[3] Lisa Deutsch,[1]
…[3] and Cornelia Ludwig[1]

…e Anthropocene biosphere

…k Williams,[1] Jan Zalasiewicz,[1] PK Haff,[2]
…istian Schwägerl,[3] Anthony D Barnosky[4,5,6]
and Erle C Ellis[7]


SMALL WORLD ON LARGE PLANET
Externalities
Incremental, linear change
Earth resilience high
BIG WORLD ON SMALL PLANET
Internalities
Non-linear, Regime shifts
Earth resilience low
SATURATION POINT
ANTHROPOCENE
~1955
~1990


In 50 years we tipped from 10,000 years Holocene
to the Anthropocene
What we do next 50 years will determine next 10,000 years
Image: Mattias Klum

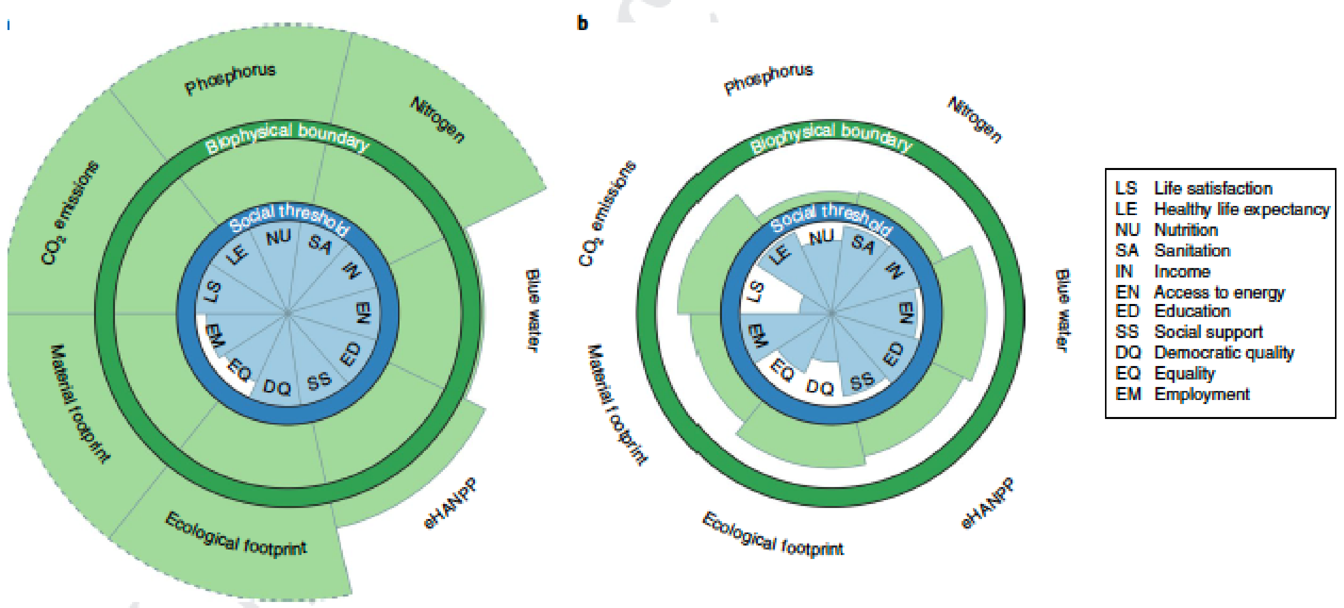
nature sustainability

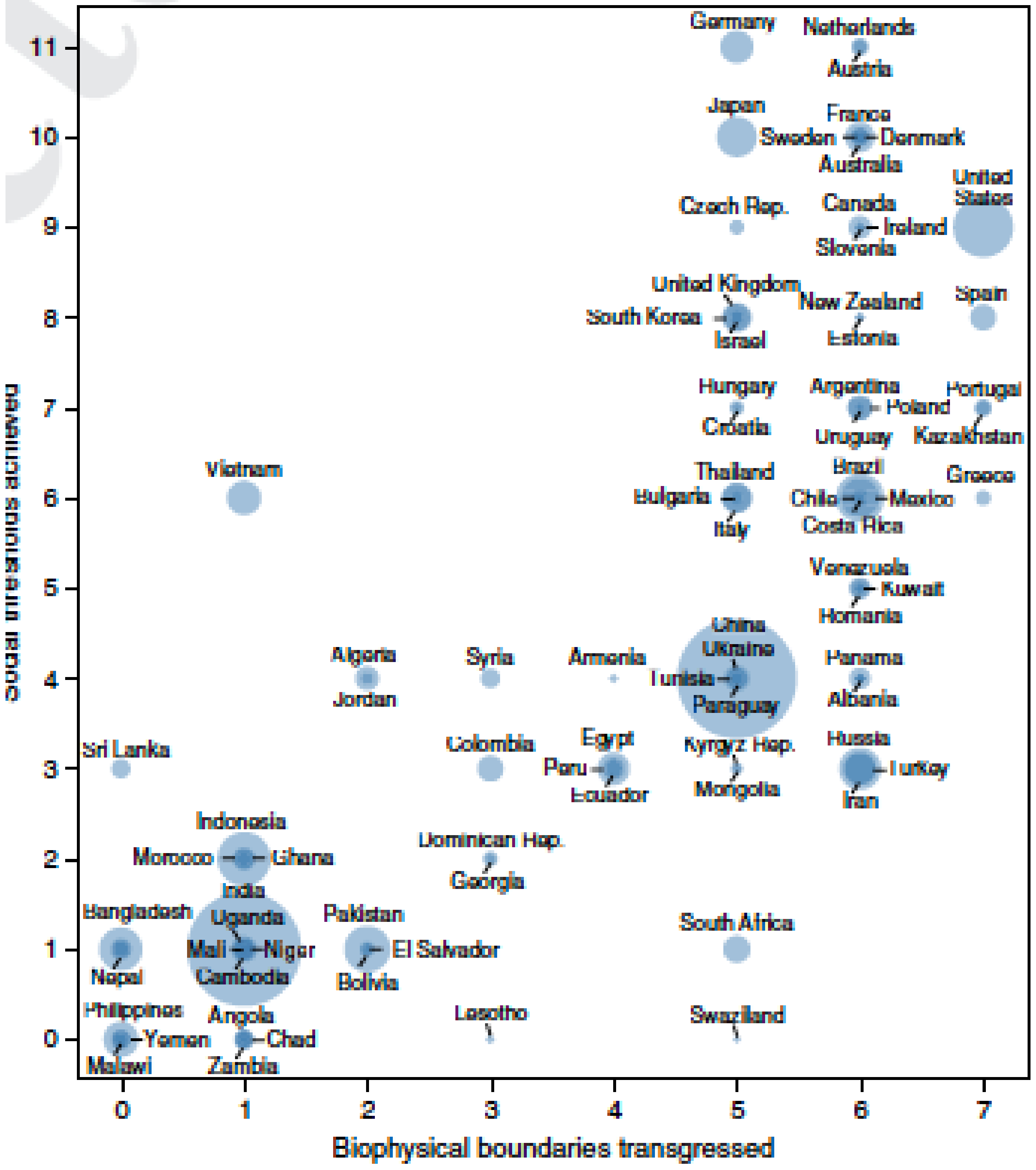
ARTICLES

https://doi.org/10.1038/s41893-018-0021-4

A good life for all within planetary boundaries

Daniel W. O'Neill[1]*, Andrew L. Fanning[1], William F. Lamb[2] and Julia K. Steinberger[1]





Holocene Our Garden of Eden

Image: GLOBAIA

The Holocene - Humankinds 10 000 years of grace

Stockholm Resilience Centre and Rockström and others, Ecology and Society 2009:14

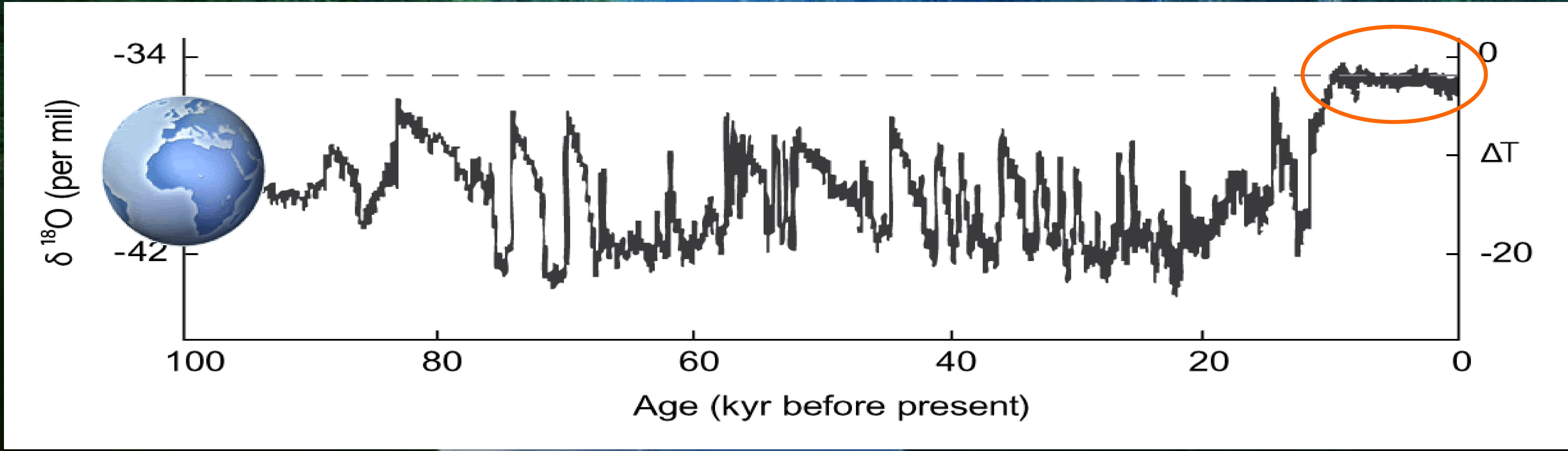


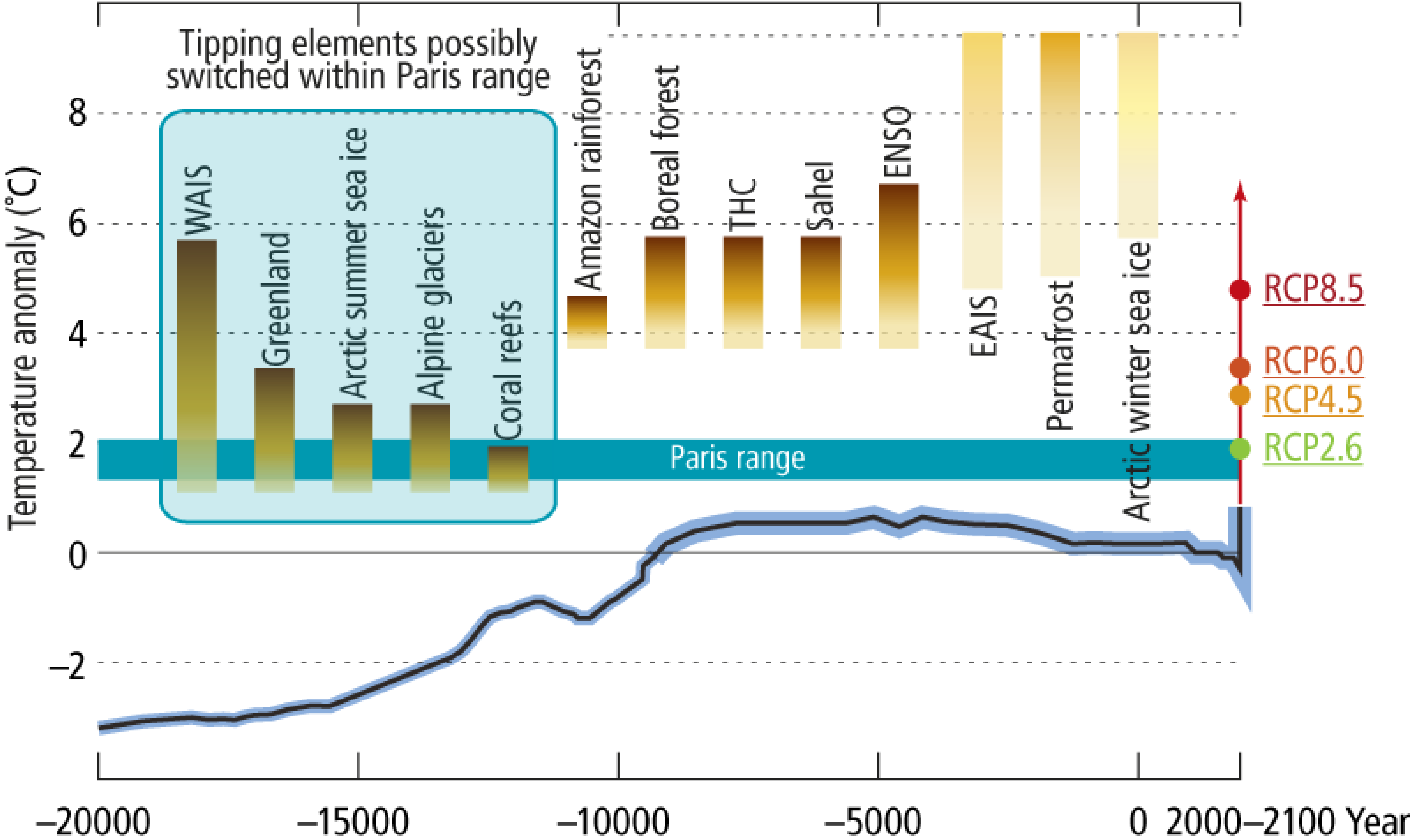
Photo: Michael A. Stecker

Earth System Tipping Points

Image: GLOBAIA

Tipping Points & the Paris Agreement

Sources: Adapted from Schellnhuber et al. (2016). Nature Climate Change



Anthropocene

+

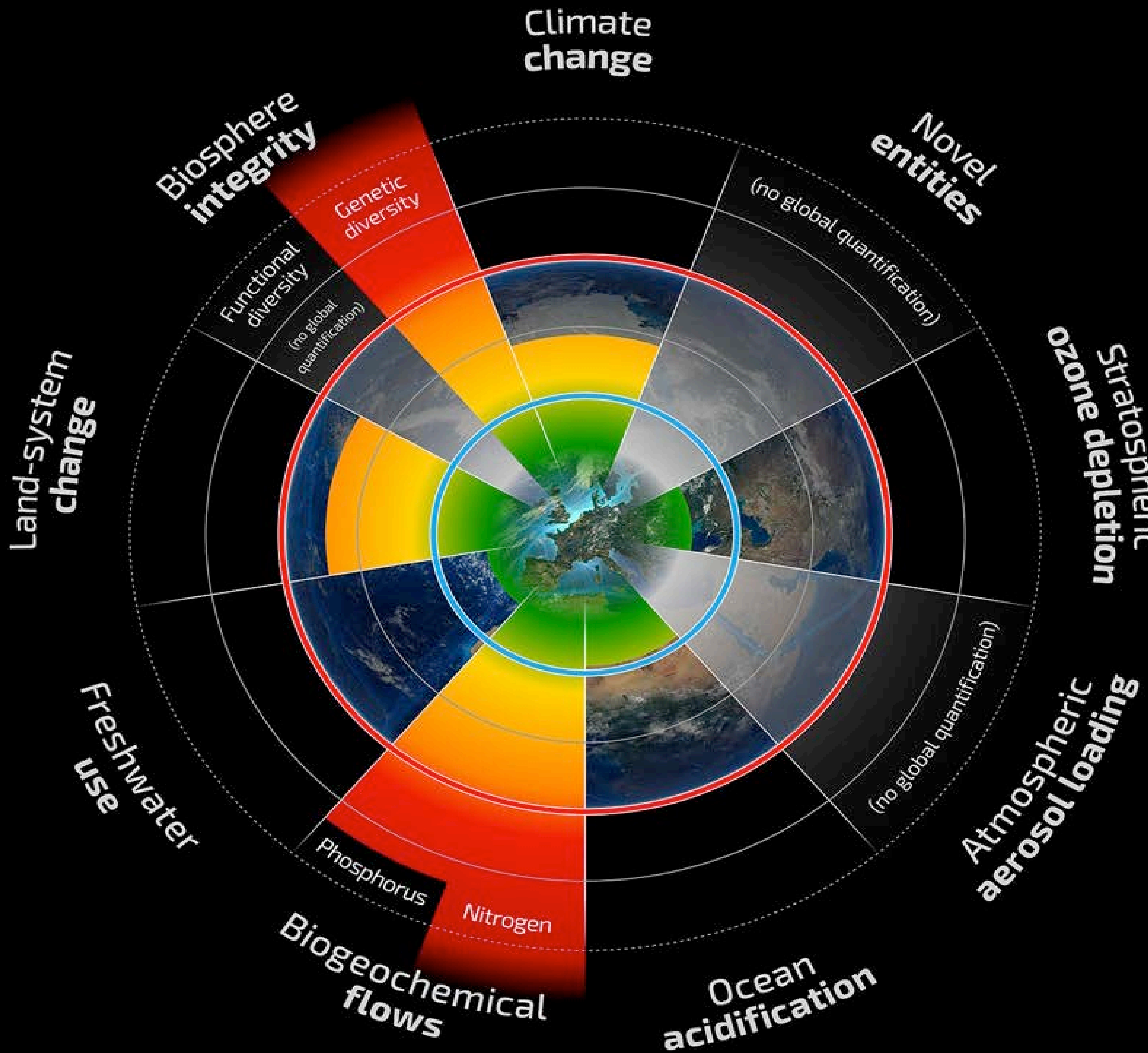
Holocene

+

Tipping Points

=

Planetary Boundaries



Climate
change
Novel
entities
(no global quantification)
Stratospheric
ozone depletion
Atmospheric
aerosol loading
(no global quantification)
Ocean
acidification
Biogeochemical
flows
Nitrogen
Phosphorus
Freshwater
use
Land-system
change
Biosphere
integrity
Genetic
diversity
Functional
diversity
(no global
quantification)

Planetary Boundaries: Experiments in the business world

H&M

Unilever

ABB

THE BODY SHOP

VOLVO

SKF

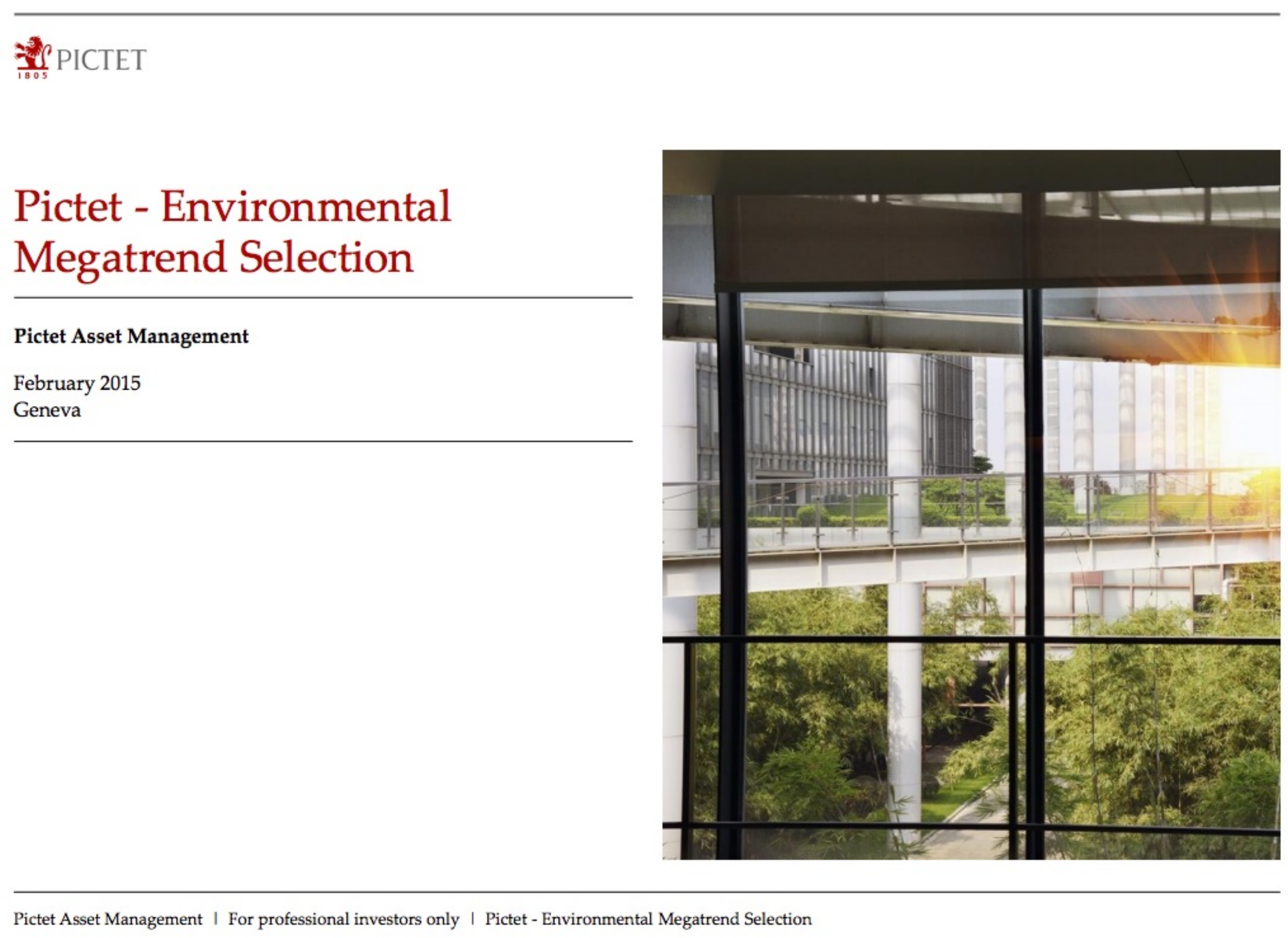
Virgin unite

World Business Council for Sustainable Development

KERING

PICTET 1805

pwc


PICTET

Pictet - Environmental Megatrend Selection

Pictet Asset Management

February 2015
Geneva

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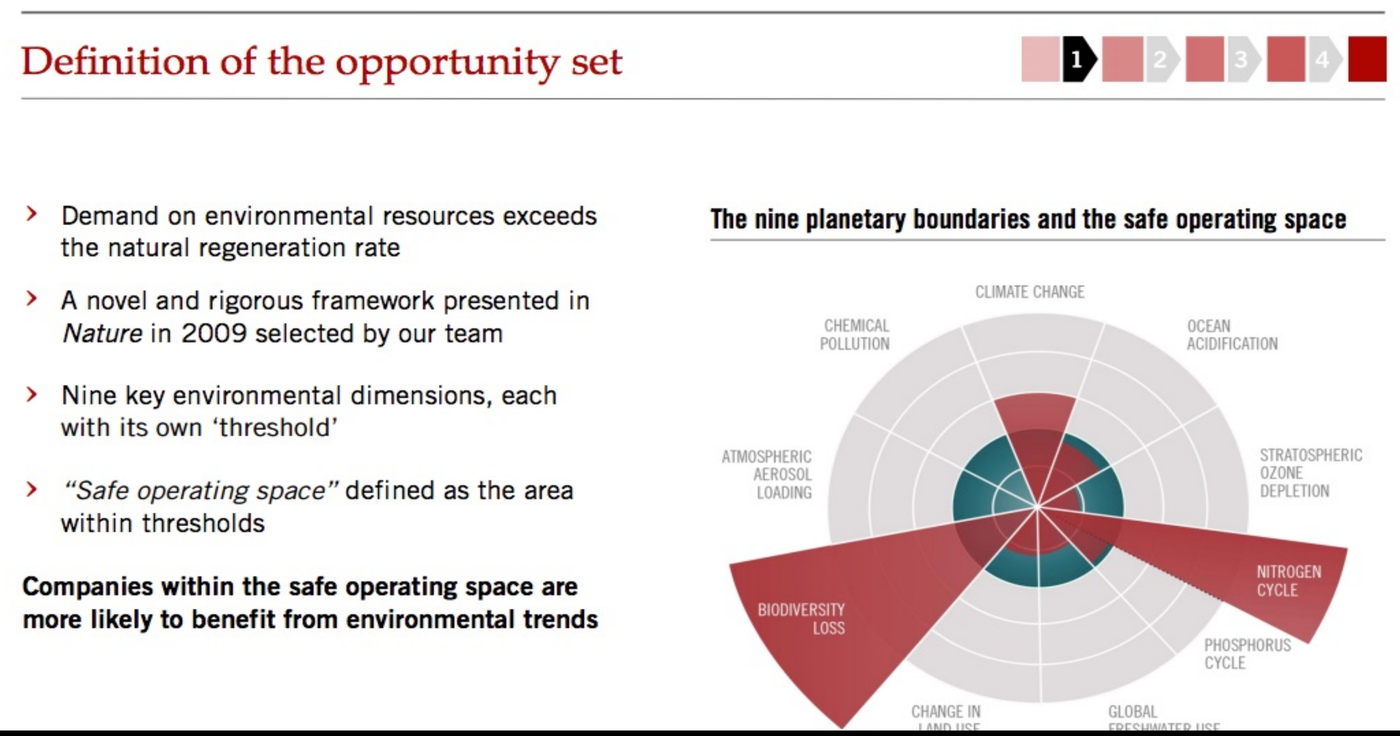
Definition of the opportunity set

- Demand on environmental resources exceeds the natural regeneration rate
- A novel and rigorous framework presented in *Nature* in 2009 selected by our team
- Nine key environmental dimensions, each with its own 'threshold'
- *"Safe operating space"* defined as the area within thresholds

Companies within the safe operating space are more likely to benefit from environmental trends

The nine planetary boundaries and the safe operating space

THE B TEAM

Agile organizations… sustainability shifts

The Global Commons in the Anthropocene – Biomes, Biogeochemical cycles and Biodiversity

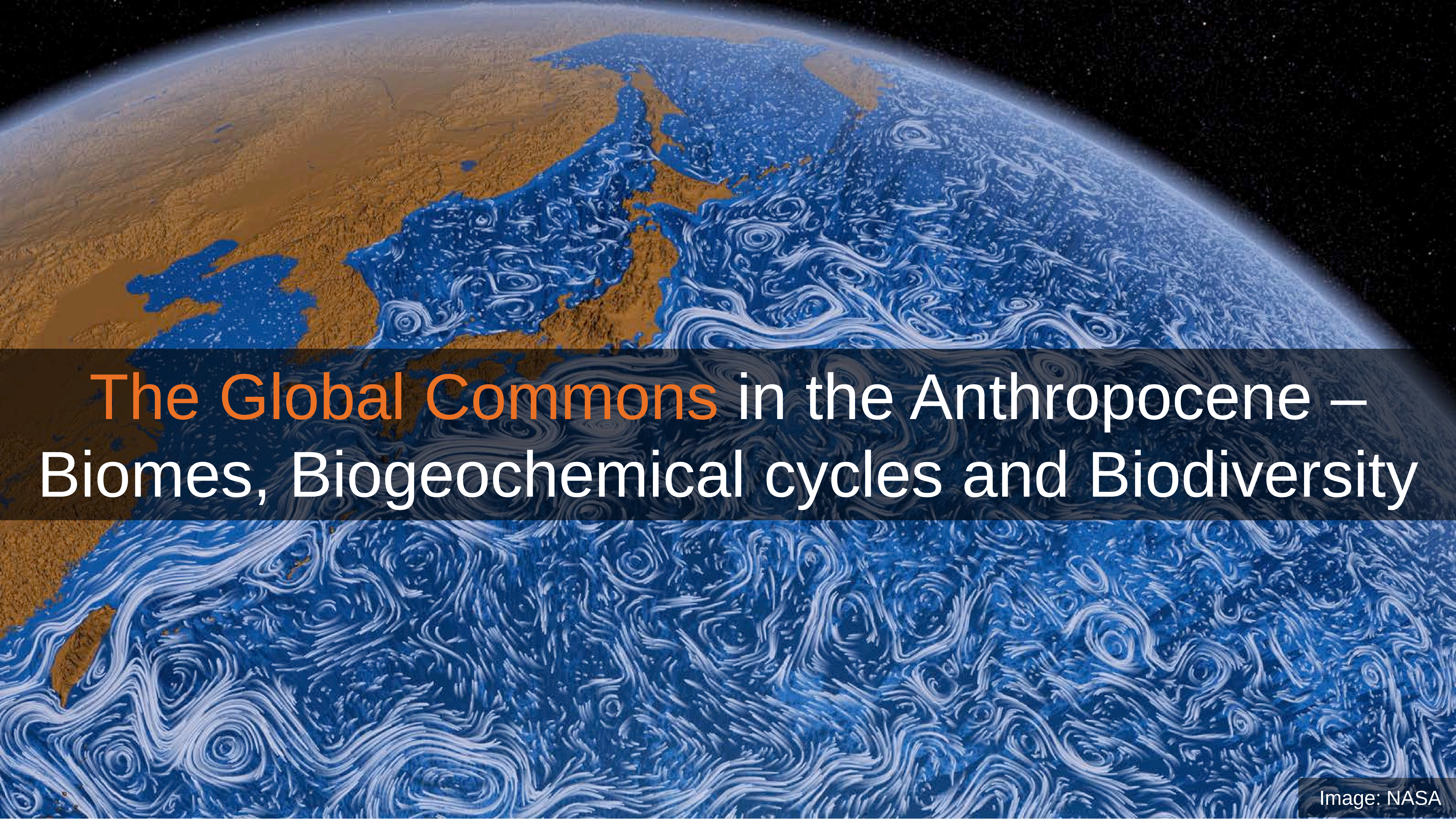

Image: NASA

3 PRINCIPLES FOR GLOBAL COMMONS IN THE ANTHROPOCENE

NASA 2014

Principle 1: The inclusivity principle

The Global Commons are not external to human activity; they are internal to development at all scales and need to be treated inclusively

Principle 2: The universality principle

Managing the Global Commons requires a paradigm shift in human worldviews toward planetary stewardship.

Photo: Wikimedia commons

Principle 3: The resilience principle

Planetary stewardship of the Global Commons is fundamentally about safeguarding social-ecological resilience, from local communities to Earth stability.

Photo: timsteeves.com


Major Biomes on earth that regulate 'Earth Resilience'
Photos: World Wildlife Fund, breakingenergy.com, saguidedtours.com,
Sierra Club Pennsylvania, Projectaware.com, Duncan Greene/Wired UK.

Photo: NASA

The Carbon Law – A Moore’s law for climate stability

Photo: Google

THE CARBON LAW

EMBARGOED UNTIL 2:00 PM US ET THURSDAY, 23 MARCH 2017

POLICY FORUM

CLIMATE POLICY

A roadmap for rapid decarbonization

Emissions inevitably approach zero with a "carbon law"

By **Johan Rockström,[1] Owen Gaffney,[1,2] Joeri Rogelj,[3,4] Malte Meinshausen,[5,6] Nebojsa Nakicenovic,[4] Hans Joachim Schellnhuber[1,5]**

Although the Paris Agreement's goals (*1*) are aligned with science (*2*) and can, in principle, be technically and economically achieved (*3*), alarming inconsistencies remain between science-based targets and national commitments. Despite progress during the 2016 Marrakech climate negotiations, long-term goals can be trumped by political short-termism. Following the Agreement, which became international law earlier than expected, several countries published mid-century decarbonization strategies, with more due soon. Model-based decarbonization assessments (*4*) and scenarios often struggle to capture transformative change and the dynamics associated with it: disruption, innovation, and nonlinear change in human behavior. For example, in just 2 years, China's coal use swung from 3.7% growth in 2013 to a decline of 3.7% in 2015 (*5*). To harness these dynamics and to calibrate for short-term realpolitik, we propose framing the decarbonization challenge in terms of a global decadal roadmap based on a simple heuristic—a "carbon law"—of halving gross anthropogenic carbon-dioxide (CO_2) emissions every decade. Complemented by immediately instigated, scalable carbon removal and efforts to ramp down land-use CO_2 emissions, this can lead to net-zero emissions around mid-century, a path necessary to limit warming to well below 2°C.

The Paris goal translates into a finite planetary carbon budget: a 50% chance of limiting warming to 1.5°C by 2100 and a >66% probability of meeting the 2°C target imply that global CO_2 emissions peak no later than 2020, and gross emissions decline from ~40 gigatons (metric) of carbon dioxide ($GtCO_2$)/year in 2020, to ~24 by 2030, ~14 by 2040, and ~5 by 2050 (*3*) (see the figure, top). Risks could be further reduced by moderately increasing ambition to halve emissions every decade (see the figure, bottom right). Following such a global carbon law means at least limiting cumulative total CO_2 emissions from 2017 until the end of the century to ~700 $GtCO_2$, which allows for a small but essential contingency (~125 $GtCO_2$ less compared with total CO_2 emissions in the pathway in the figure, top) for risks of biosphere carbon feedbacks (*6*) or delay in ramping up CO_2-removal technologies.

A carbon law applies to all sectors and countries at all scales and encourages bold action in the short term. It means, for example, doubling of zero-carbon shares in the energy system every 5 to 7 years, a rate consistent with the trajectory of the past decade (see the figure, bottom left). All sectors (e.g., agriculture, construction, finance, manufacturing, transport) need comparable transformation pathways. In addition, in the absence of viable alternatives, the world must aim at rapidly scaling up CO_2 removal by technical means from zero to at least 0.5 $GtCO_2$/year by 2030, 2.5 by 2040, and 5 by 2050. CO_2 emissions from land-use must decrease along a nonlinear trajectory from 4 $GtCO_2$/year in 2010, to 2 by 2030, 1 by 2040, and 0 by 2050 (see the figure, bottom right). The endgame is for cumulative CO_2 emissions since 2017 to be brought back from around 700 $GtCO_2$ to below 200 $GtCO_2$ by the end of the century (see the figure, top) and atmospheric CO_2 concentrations to return to 380 ppm by 2100 (currently at 400 ppm).

Roadmaps are planning instruments, linking shorter-term targets to longer-term goals. They help align actors and organizations to instigate technological and institutional breakthroughs to meet a collective challenge. An explicit carbon roadmap for halving anthropogenic emissions every decade, codesigned by and for all industry sectors, could help promote disruptive, nonlinear technological advances toward a zero-emissions world. The key to such a carbon law will be a dual strategy that pushes renewables and other zero-emissions technologies up the creation and dissemination trajectory, while simultaneously pulling fossil-based value propositions from the market. Thus, the transformation unfolds at a pace governed by novel schemes rather than by inertia imposed by incumbent technologies (see the figure, bottom left).

We sketch out a broad decadal decarbonization narrative in four dimensions—innovation, institutions, infrastructures, and investment—to provide evidence of feasibility and depth of transformation for economies to stay on a carbon-law trajectory. The narrative provides no guarantees but identifies crucial steps, grounded in published scenarios combined with expert judgment. Each step has two parts: actions for rapid near-term emissions reductions, and actions for systemic and long-term impact, creating the basis for the next steps. Such a narrative, specifically designed with decadal targets and incentives, could provide key elements for national and international climate strategies.

2017–2020: NO-BRAINERS

Annual emissions from fossil fuels must start falling by 2020. Well-proven (and ideally income-neutral) policy instruments such as carbon tax schemes, cap-and-trade

The road to global decarbonization must involve renewable energy, as from these wind turbines in Germany, and improved transportation technologies.

PHOTO: GFC COLLECTION / ALAMY STOCK PHOTO

[1]Stockholm Resilience Centre, Stockholm University, 114 18 Stockholm, Sweden. [2]Future Earth, The Royal Swedish Academy of Sciences, 104 05 Stockholm, Sweden. [3]International Institute for Applied Systems Analysis, 2361 Laxenburg, Austria. [4]ETH Zurich, 8092 Zurich, Switzerland. [5]Potsdam Institute for Climate Impact Research, 14473 Potsdam, Germany. [6]Australian-German Climate and Energy College, School of Earth Sciences, University of Melbourne, Victoria 3010, Australia. Email: johan.rockstrom@su.se

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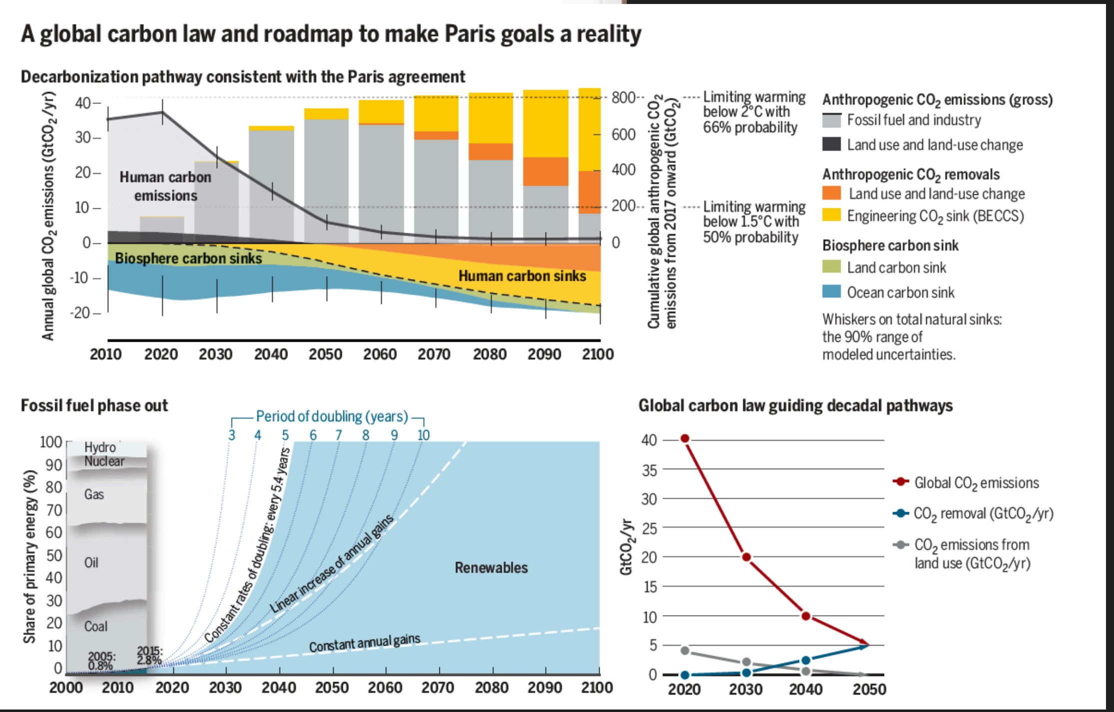
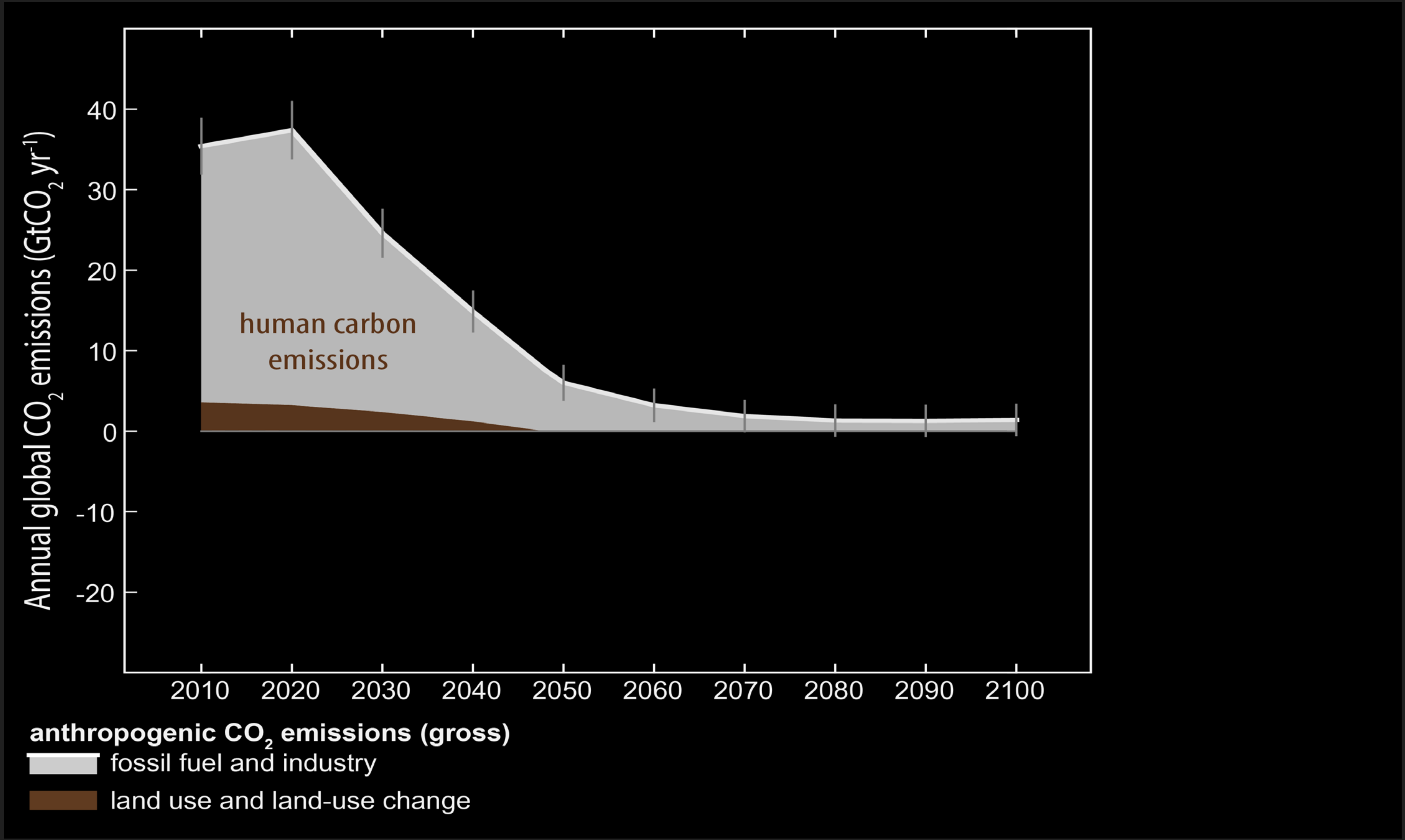
2. To Understand 'Brexit,' Look to Britain's Tabloids
3. BEST OF LATE NIGHT Jimmy Kimmel's Emotional...
4. Police Officer Who Fatally Shot 15-Year-Old...
5. Ivanka Trum[p] Has the President's Ea[r]

The Opinion Pages | OP-ED CONTRIBUTOR

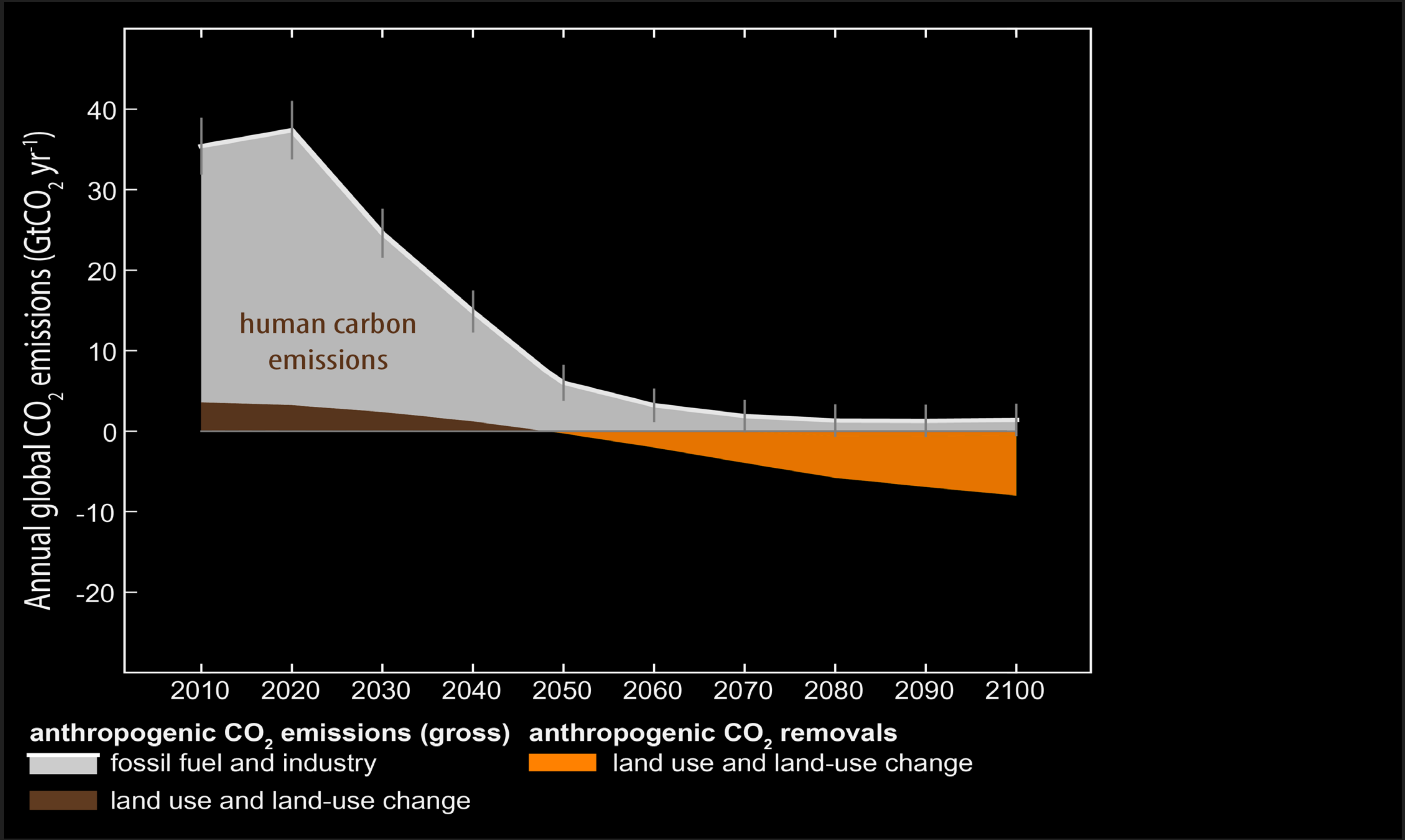
Why the World Economy Has to Be Carbon Free by 2050

By JOHAN ROCKSTROM MARCH 23, 2017





Rockström, Gaffney, Joeri, Meinshausen, Nakicenovic, Schellnhuber. *Science* 24 March 2017



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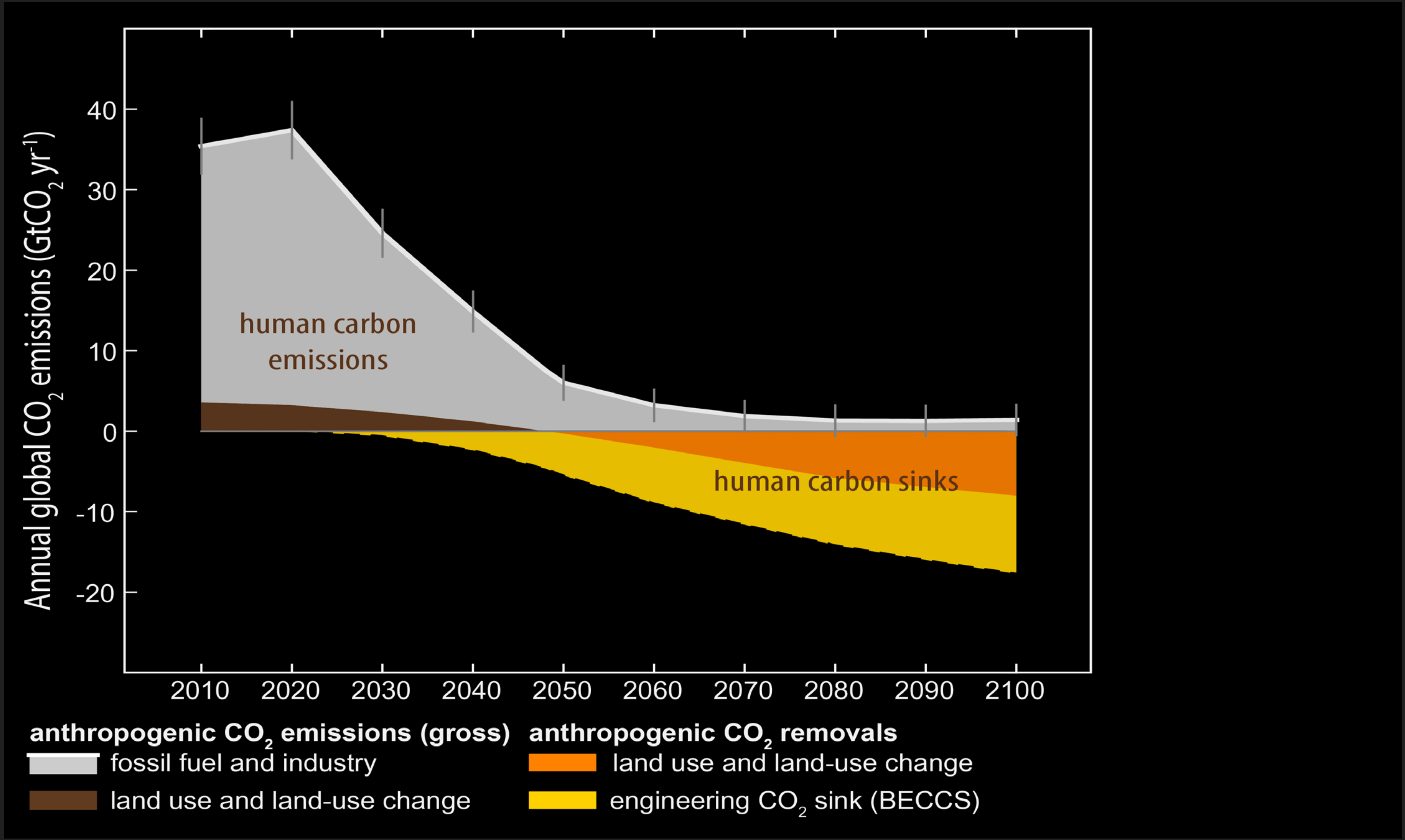

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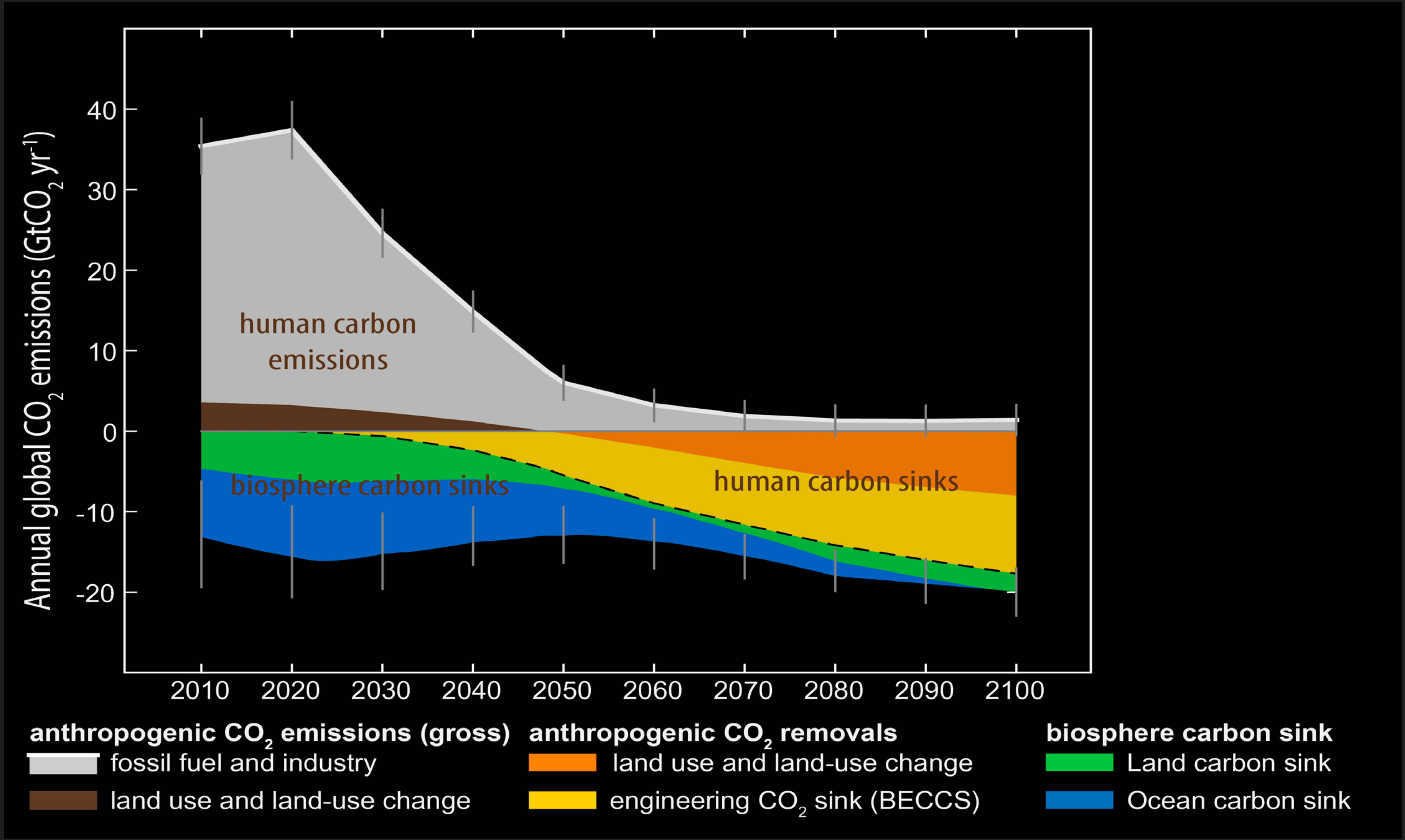
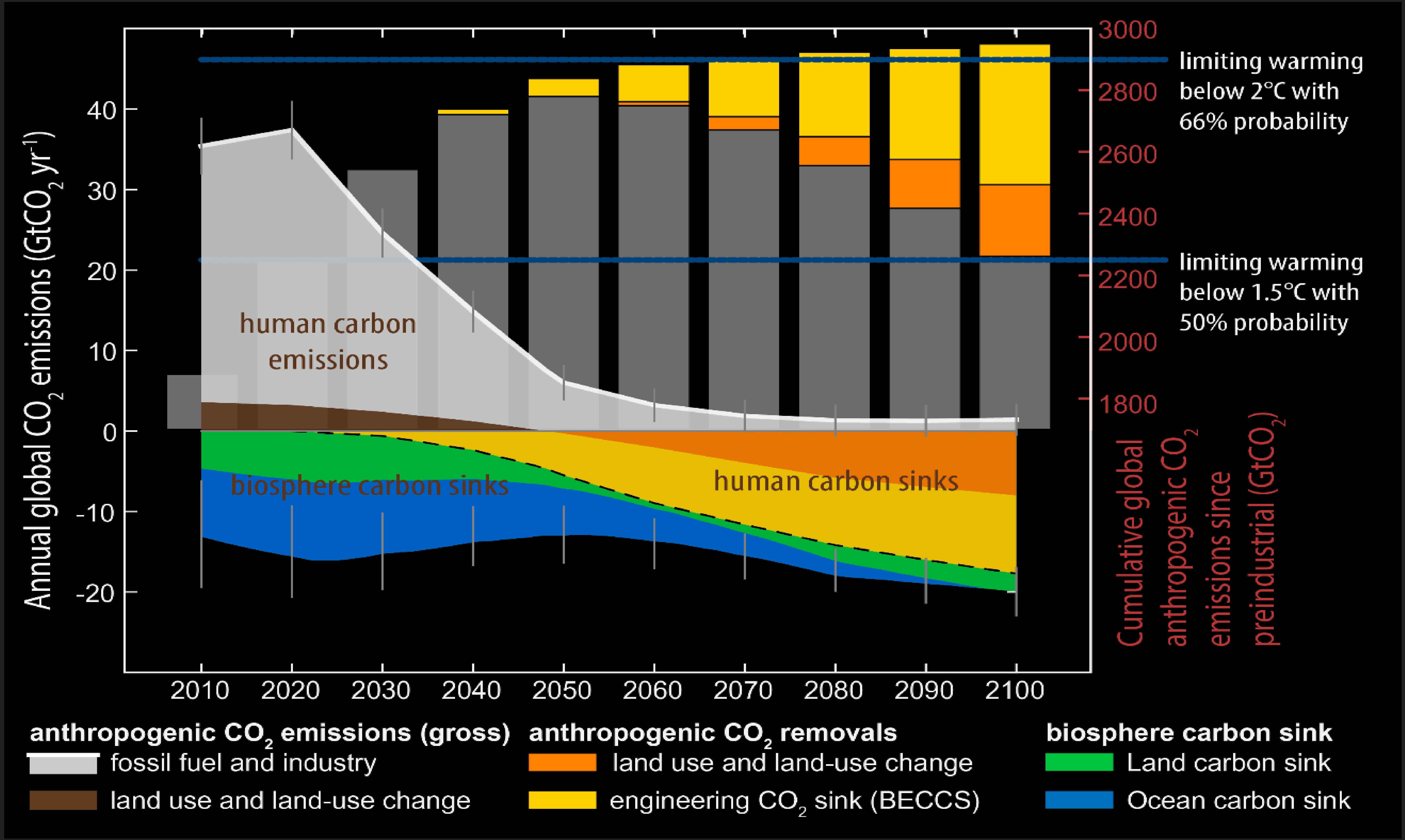
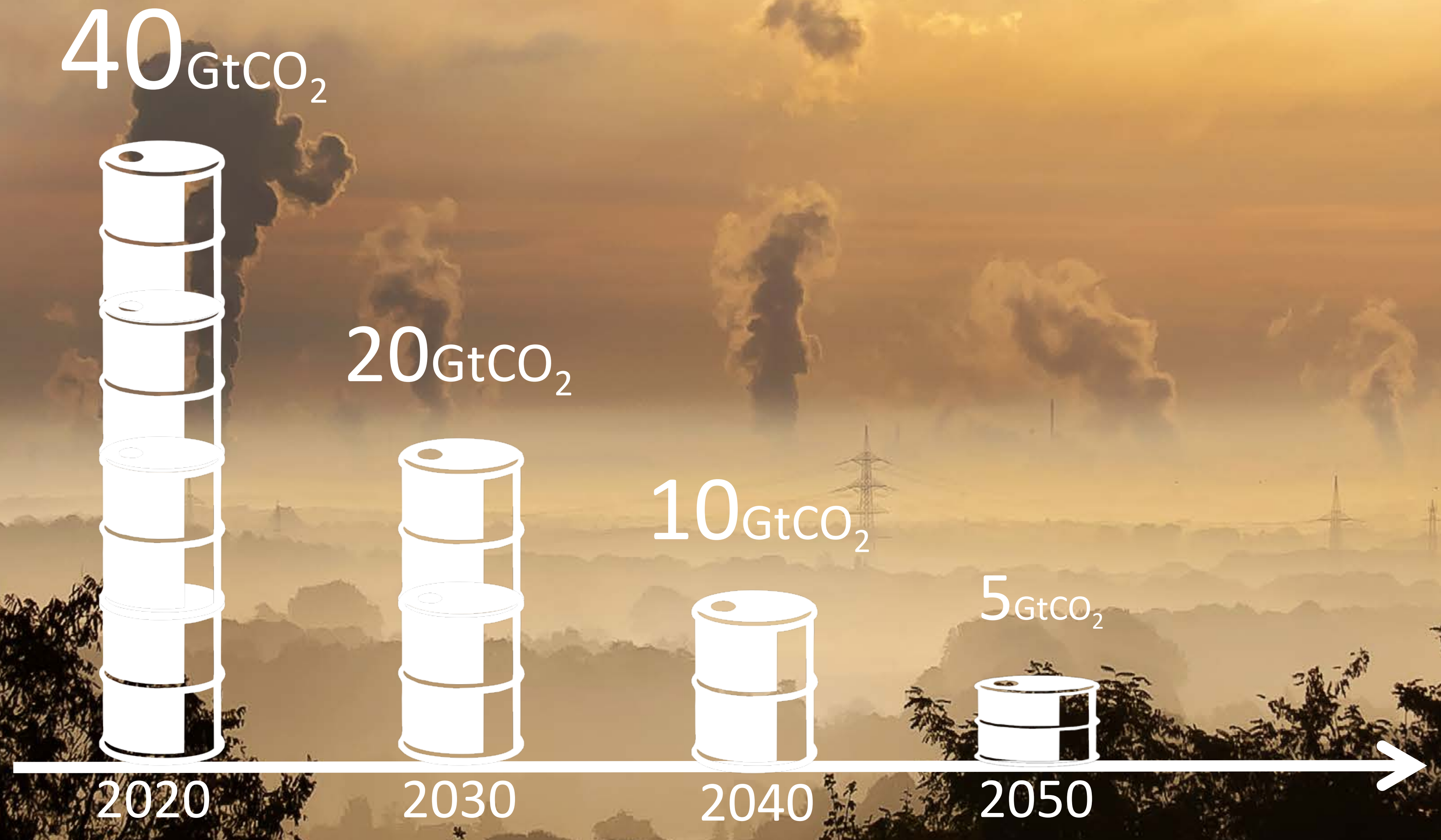


Rockström, Gaffney, Joeri, Meinshausen, Nakicenovic, Schellnhuber. *Science* 24 March 2017



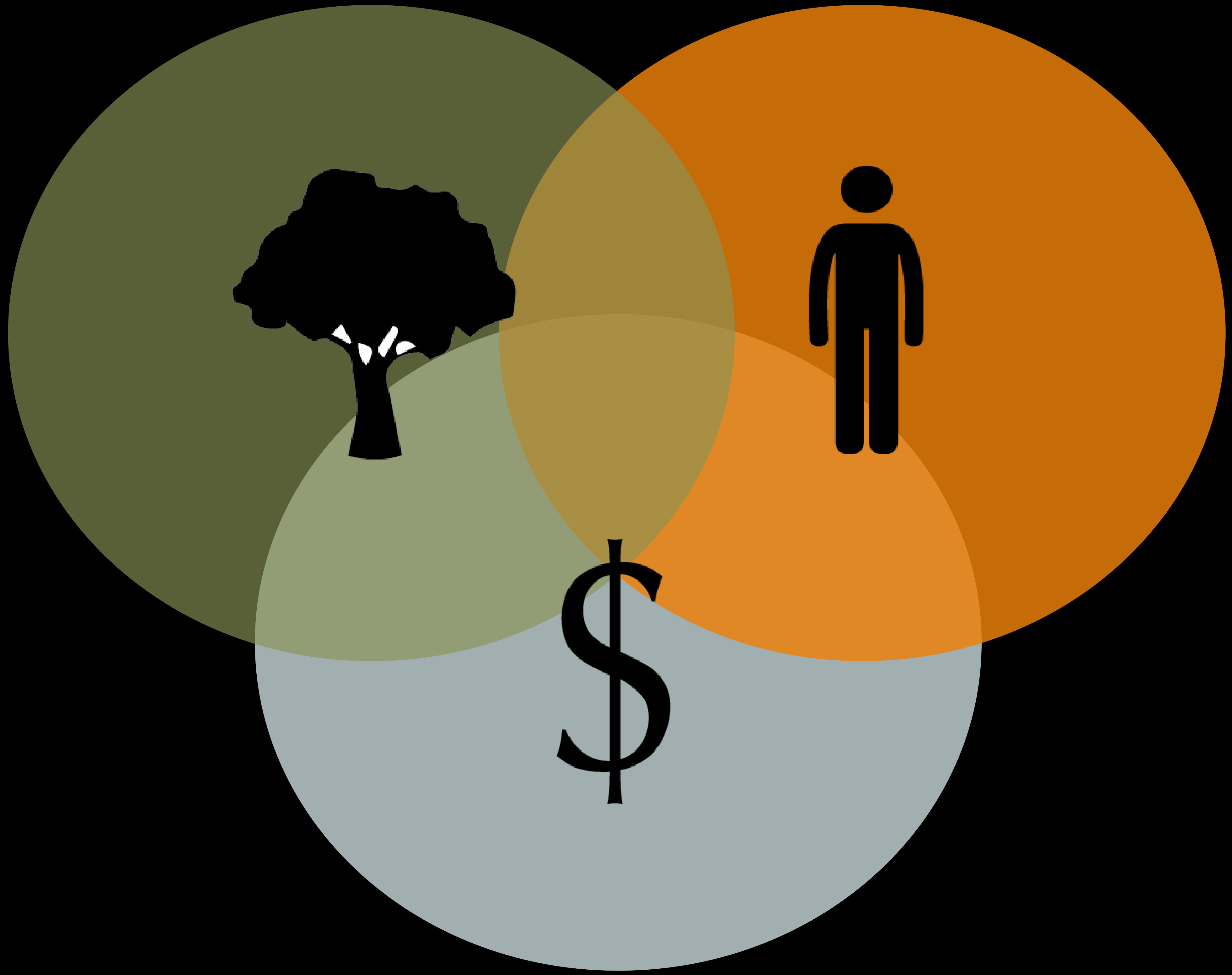
Rockström, Gaffney, Joeri, Meinshausen, Nakicenovic, Schellnhuber. *Science* 24 March 2017

A Global Carbon Law
Halving Emissions Every Decade

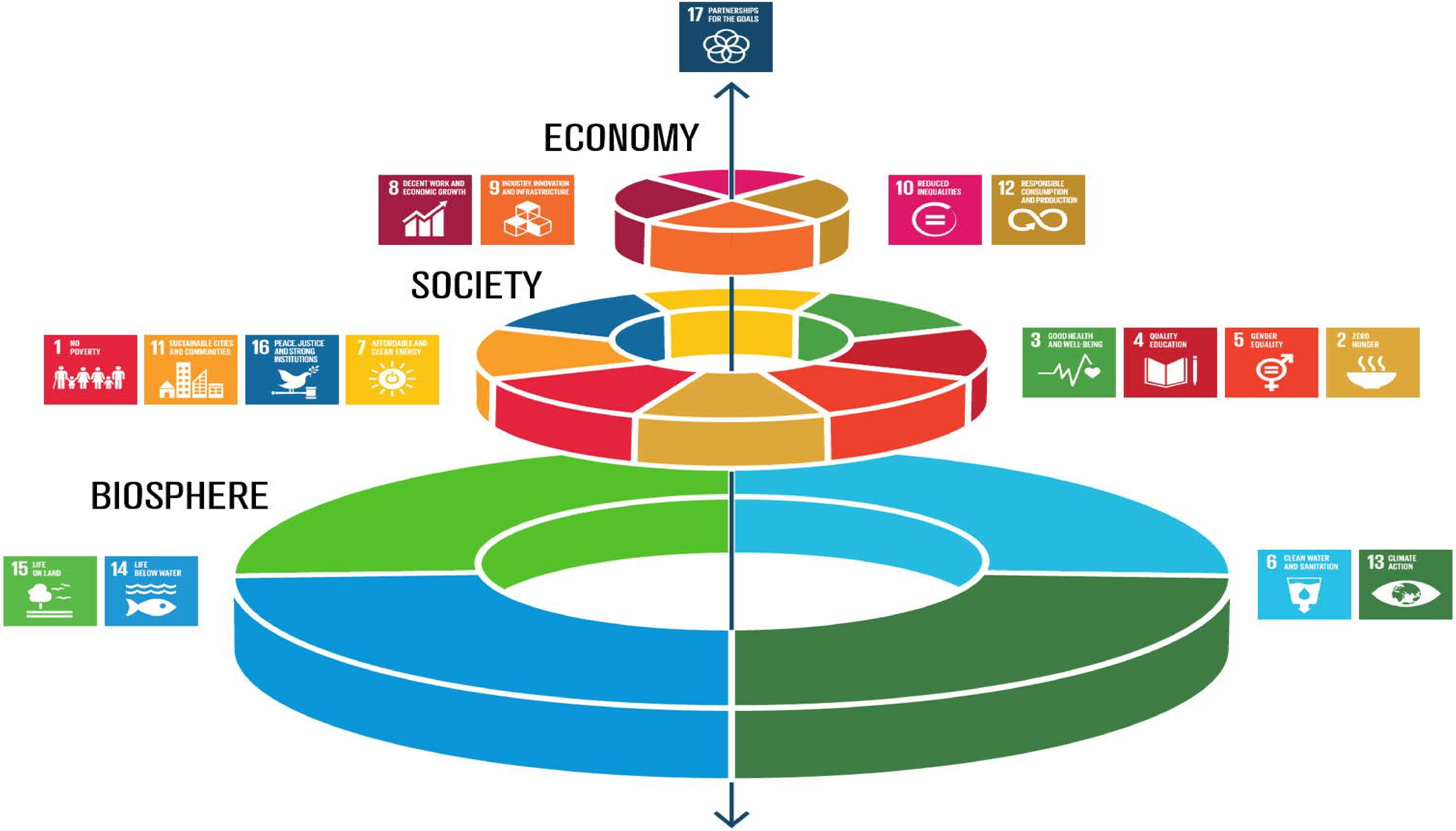


Planetary Stewardship

Photo: Trollbäck and Company




SUSTAINABLE DEVELOPMENT GOALS
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS
SUSTAINABLE DEVELOPMENT GOALS



17 PARTNERSHIPS FOR THE GOALS
ECONOMY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
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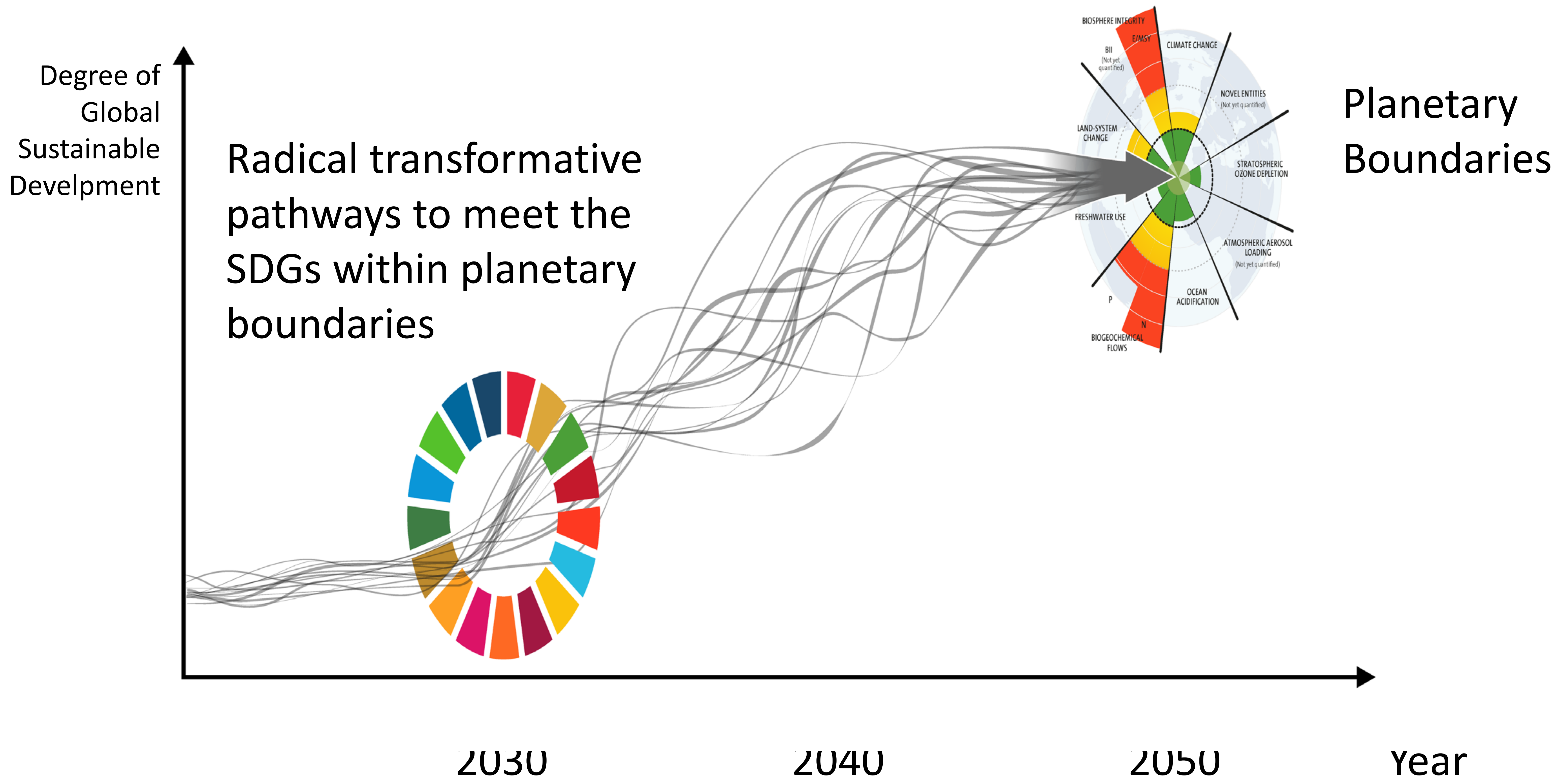
4 QUALITY EDUCATION
5 GENDER EQUALITY
2 ZERO HUNGER
BIOSPHERE
15 LIFE ON LAND
14 LIFE BELOW WATER
6 CLEAN WATER AND SANITATION
13 CLIMATE ACTION

The World In 2050



Interdisciplinary Global Sustainability science emerging as critical research field on Humanity in Anthropocene

Sustainable and Healthy food key transformation for human prosperity on Earth

Thank you

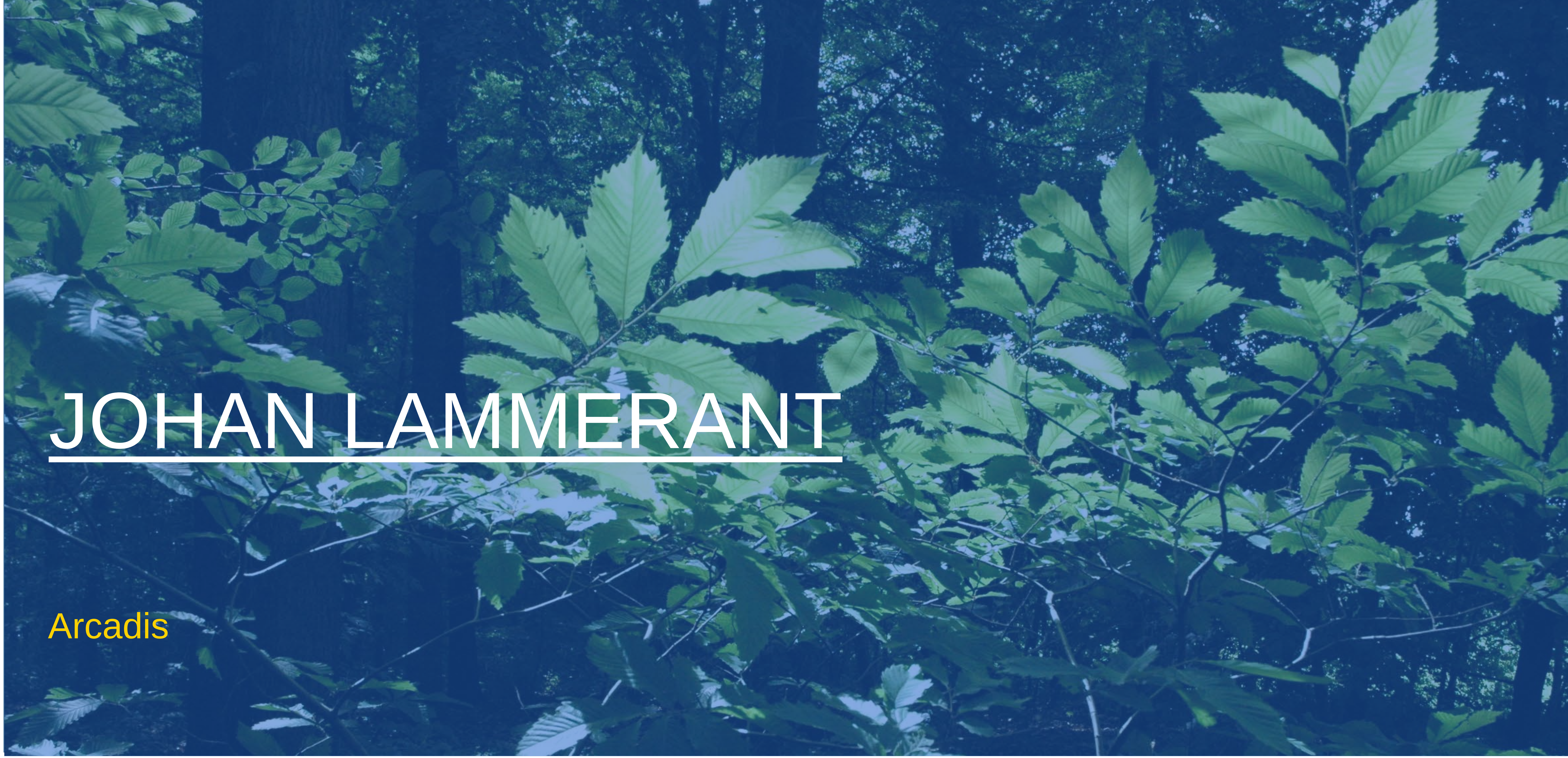
www.stockholmresilience.su.se

Photo: O.Henriksson/Azote

TINE HEYSE

City of Ghent

GHENT
UNIVERSITY



JOHAN LAMMERANT

Arcadis

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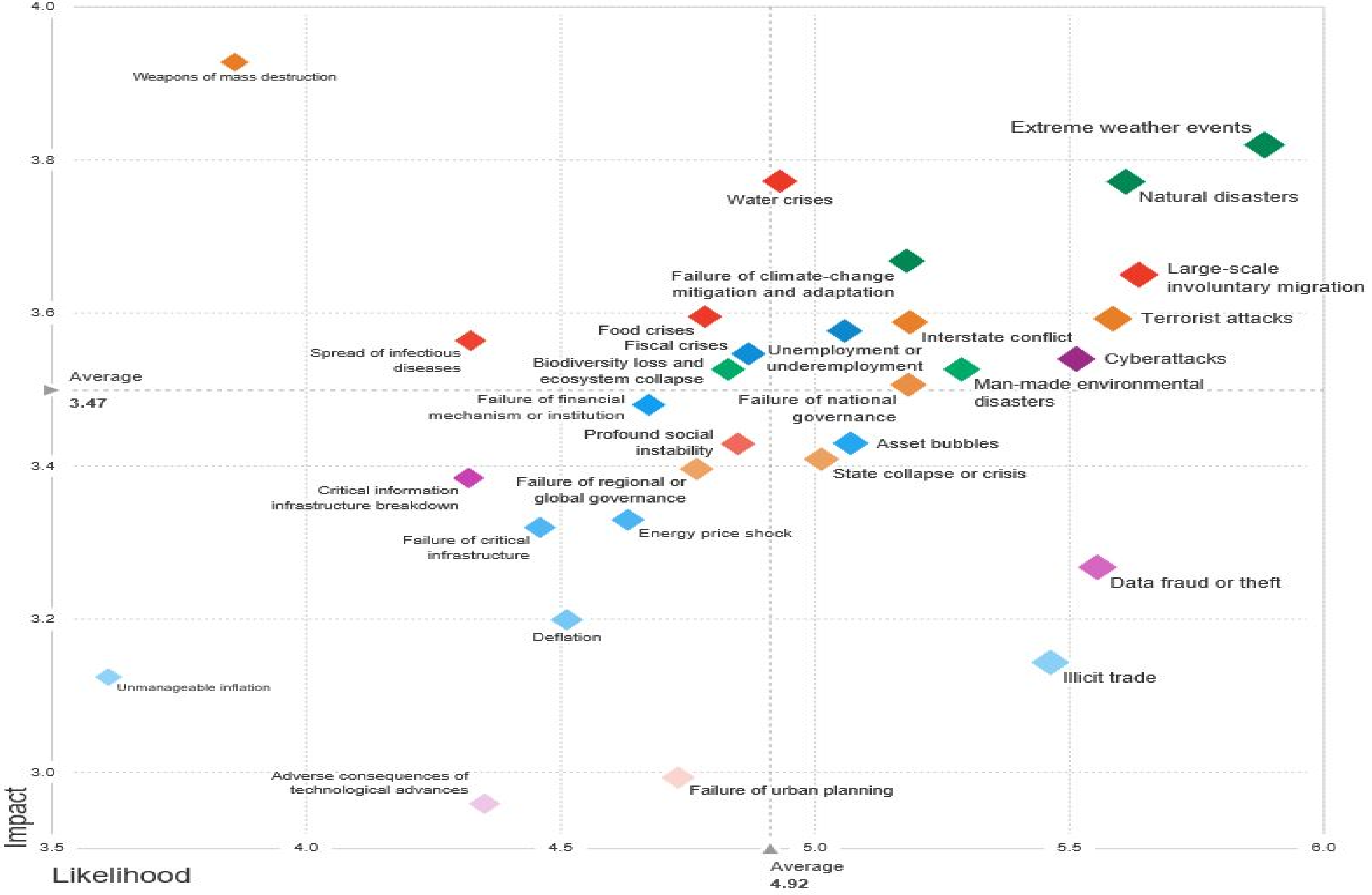
ARCADIS Design & Consultancy for natural and built assets

UGENT SYMPOSIUM "FROM GLOBAL CHALLENGES TO LOCAL SOLUTIONS"

Reflections by Arcadis

Is the private sector aware?

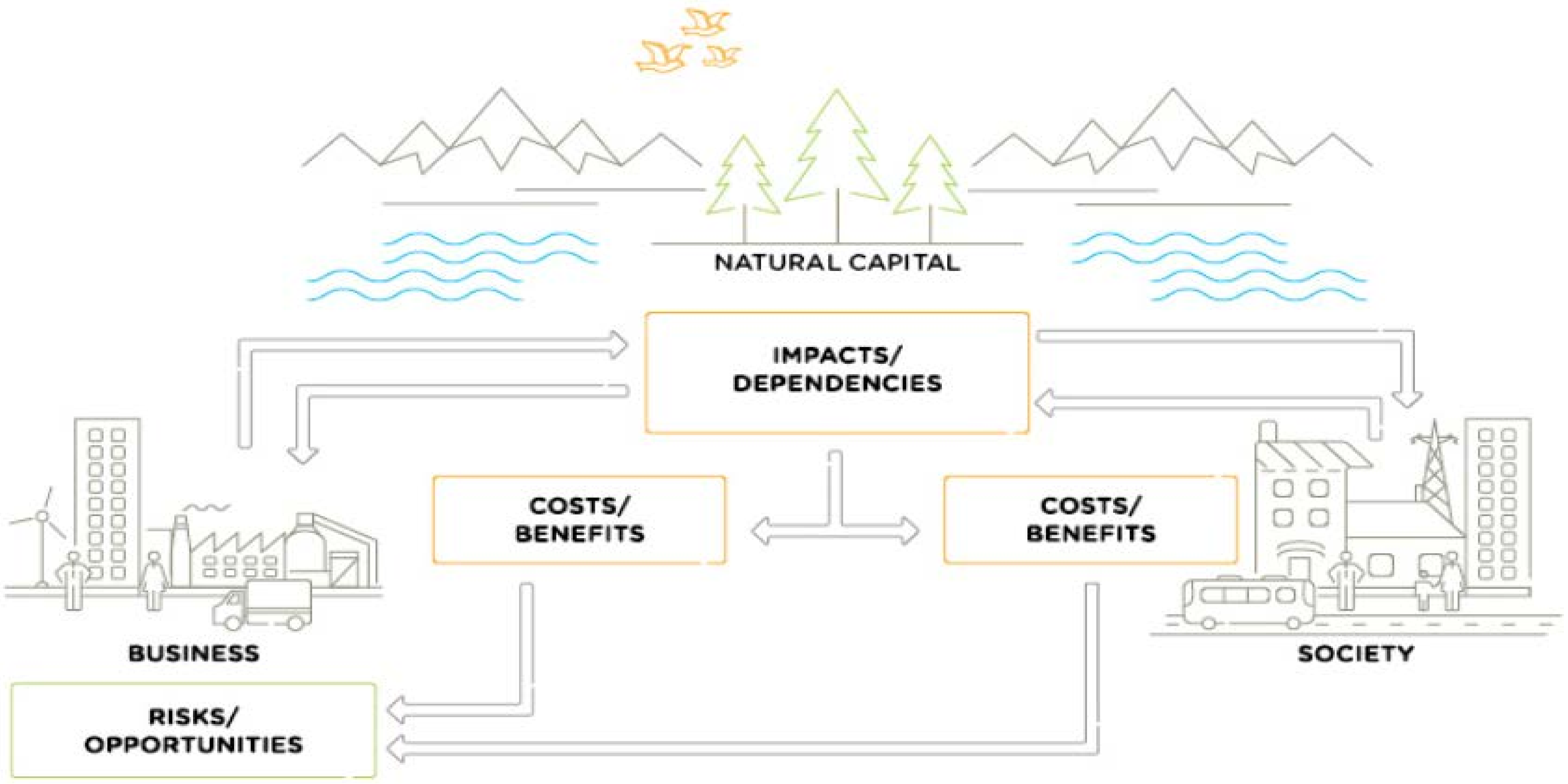
ARCADIS Design & Consultancy for natural and built assets



World Economic Forum

2017 Global Risk Report

Link between business activities and natural capital



The business case for natural capital

It's all about risk management, cost reduction, revenue maximisation

Financial optimization: creating business value by investing in ecosystem restoration e.g. opportunities related to nature based solutions, surplus assets, …

Strategic Decision Making: scarcity of resources mean businesses are increasingly incorporating natural capital risks & impacts into their investment decision processes

Regulatory Pressure: Non-financial reporting requirements (e.g. EU Directive) will require certain businesses to report on natural capital assets & liabilities

Access to Finance: captured in the Banking "Natural Capital Declaration" – international finance increasingly requires demonstration of "no net loss" of natural capital.

Stakeholder Expectations: pressure for businesses to demonstrate sustainable consumption and production e.g. reduced carbon emissions, freshwater use and pollution

Development of a Protocol for Applying the Planetary Boundaries Concept to Nitrogen Emissions, as an example of Business Pressures on Biodiversity

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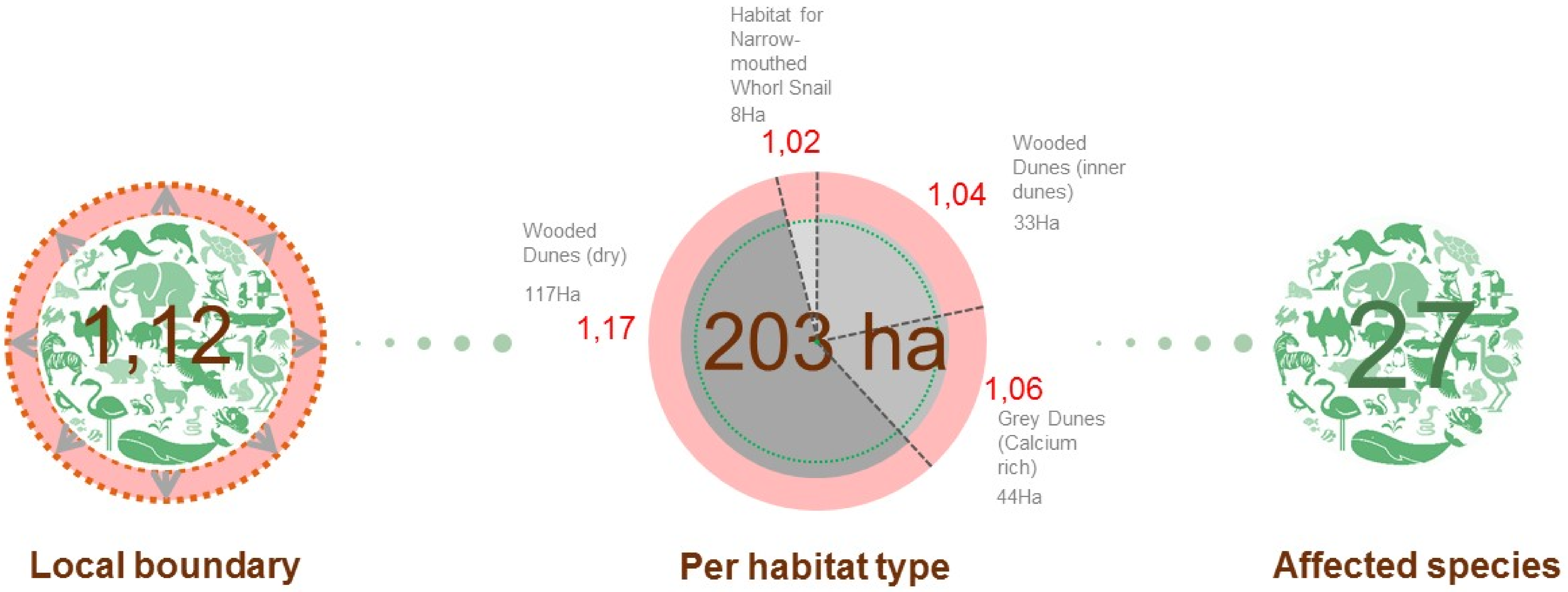
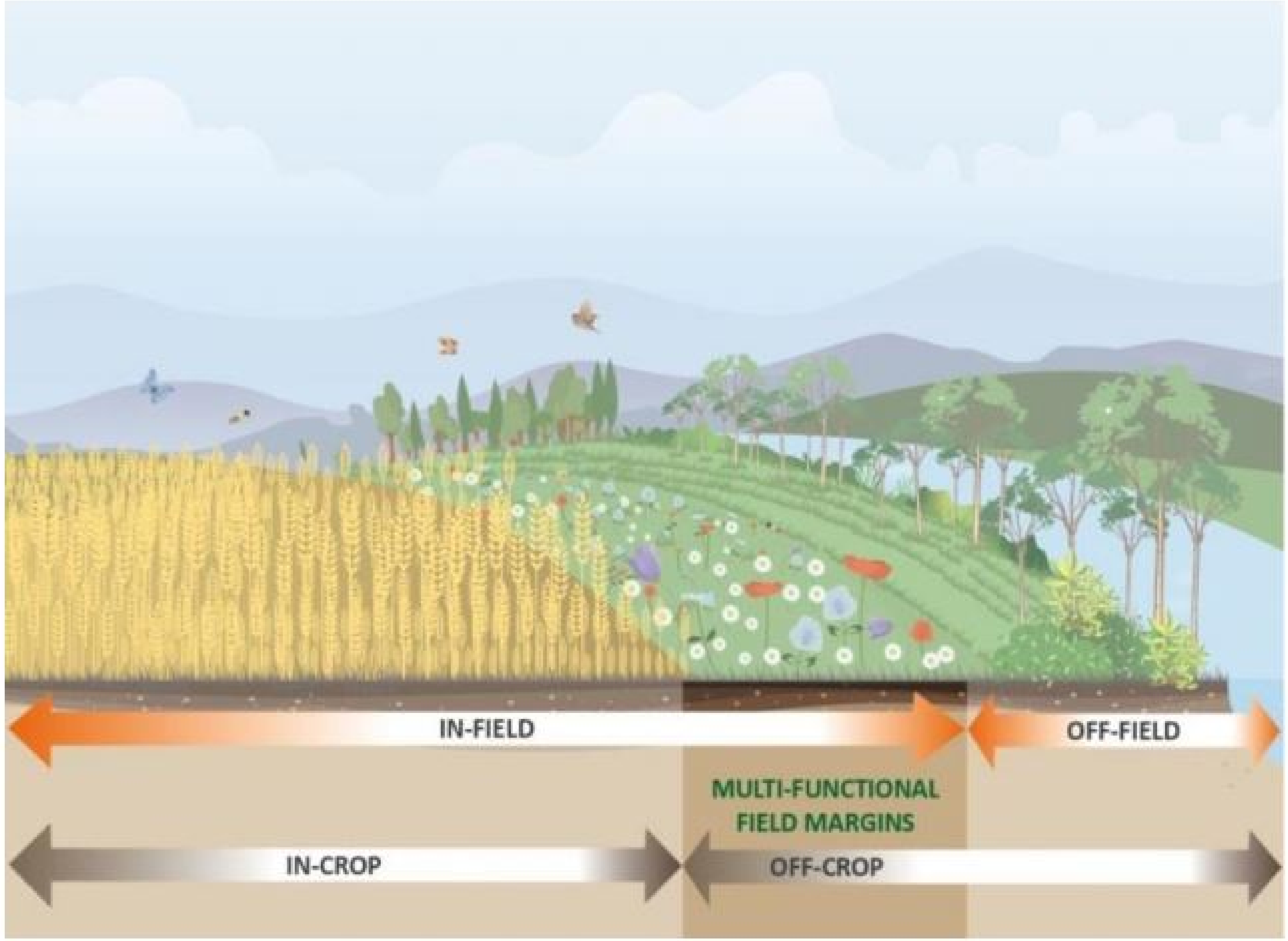
Eneco



Biodiversity is a challenging issue for businesses...



1. Demonstrating real impact on biodiversity of Good Growth Plan measures
2. Supporting the concept of ecological corridors in agricultural landscapes
3. Validating the natural and social capital benefits of implemented measures, and their business value

Challenges

- Translating global concepts and goals to company level strategies and actions
- Providing business solutions based on a balance between scientifically robust and pragmatic
- Identifying the business value! Apply the risks and opportunities approach

Without the uptake by the private sector we will never achieve our quest for a society that doesn't exceed the planetary boundaries

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Improving quality of life

PLANETARY BOUNDARIES: FROM GLOBAL CHALLENGES TO LOCAL SOLUTIONS

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