



Oluwakemi Izomo

# Mitigation and Adaptation Studies



## Class 4: Entering the Post-Holocene

### The Syndrome: Recent Global and Climate Change

#### Contents:

- Prolog
- The Data: Some examples
- Climate change, Post-Holocene, Rapid Changes, Heat Storage
- Global Change, Reengineering the Planet
- The Metrics**



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# The Earth System Metric

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We have information based on many system indicators, for example:

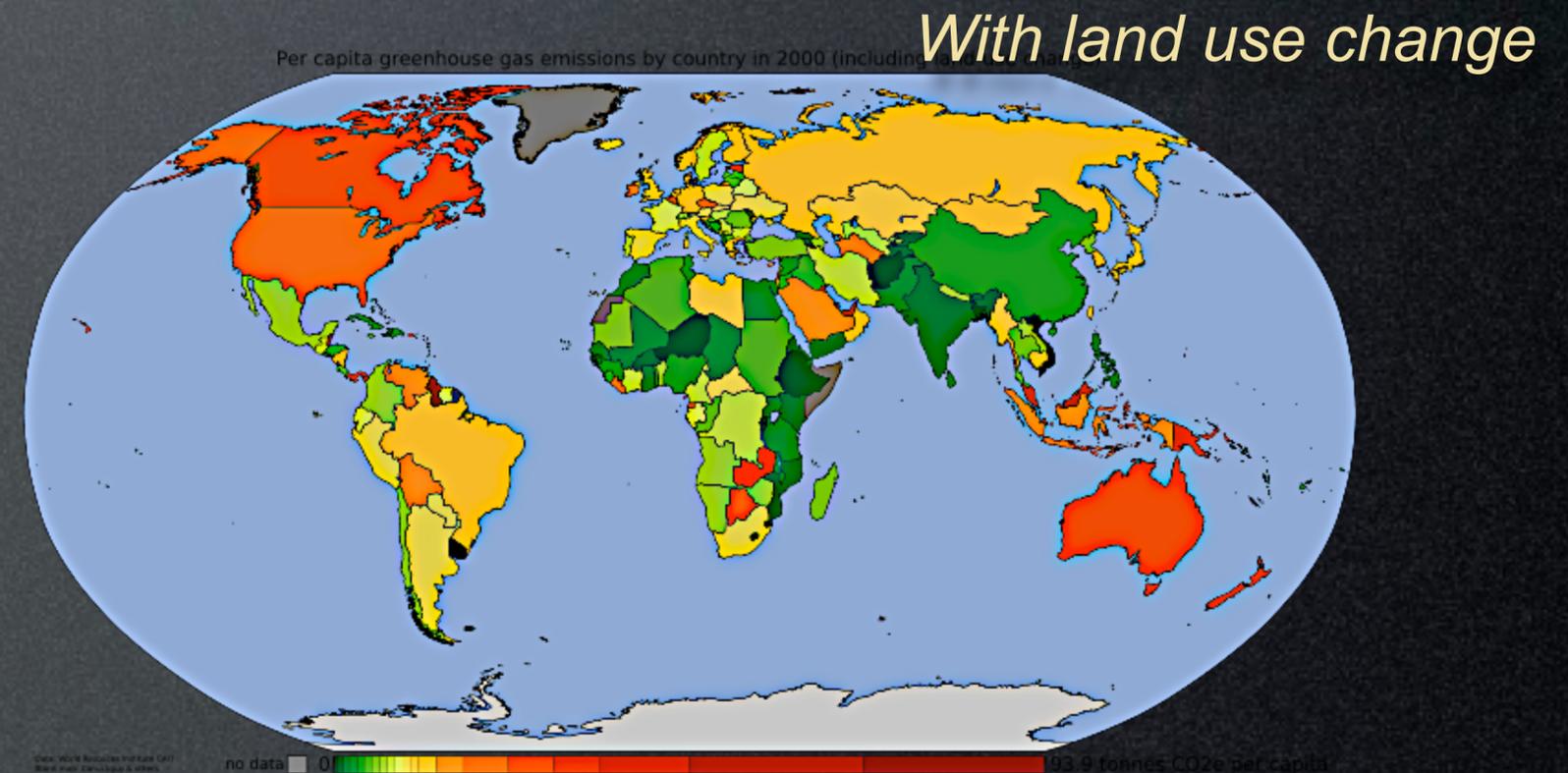
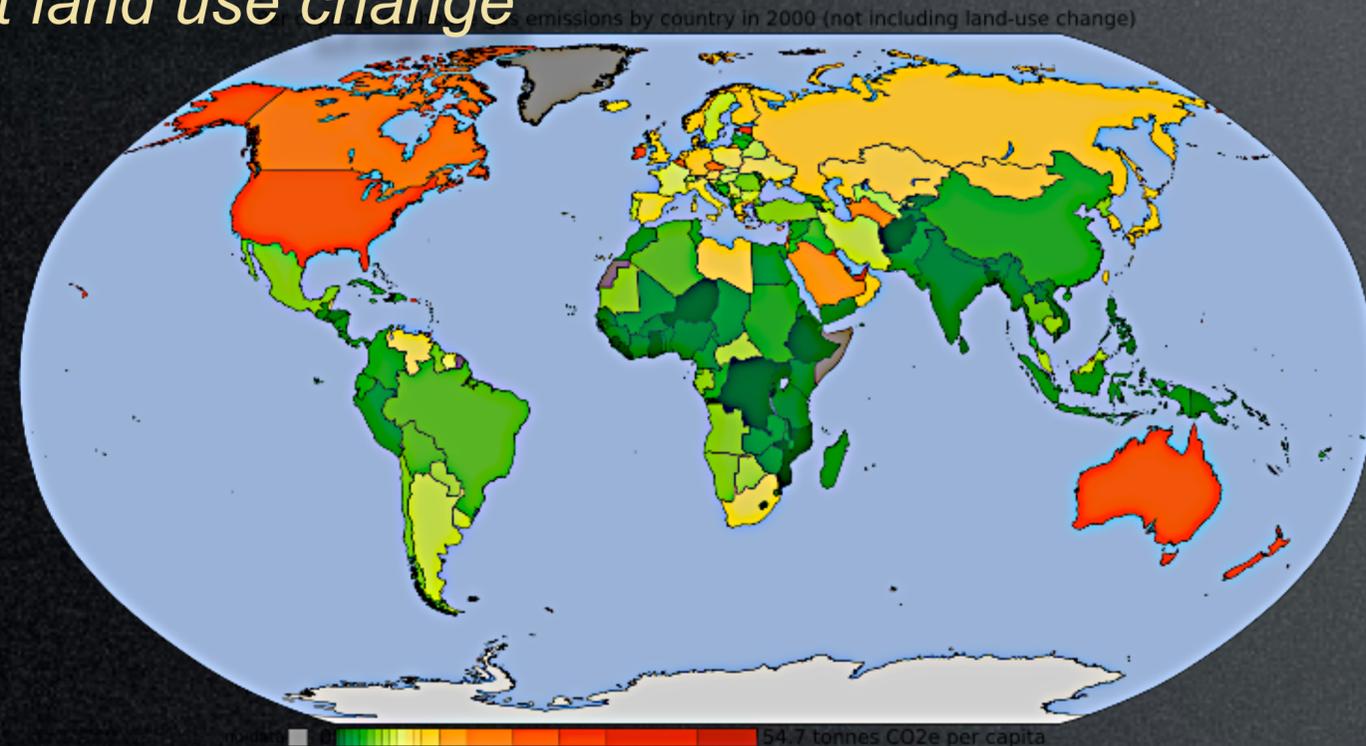
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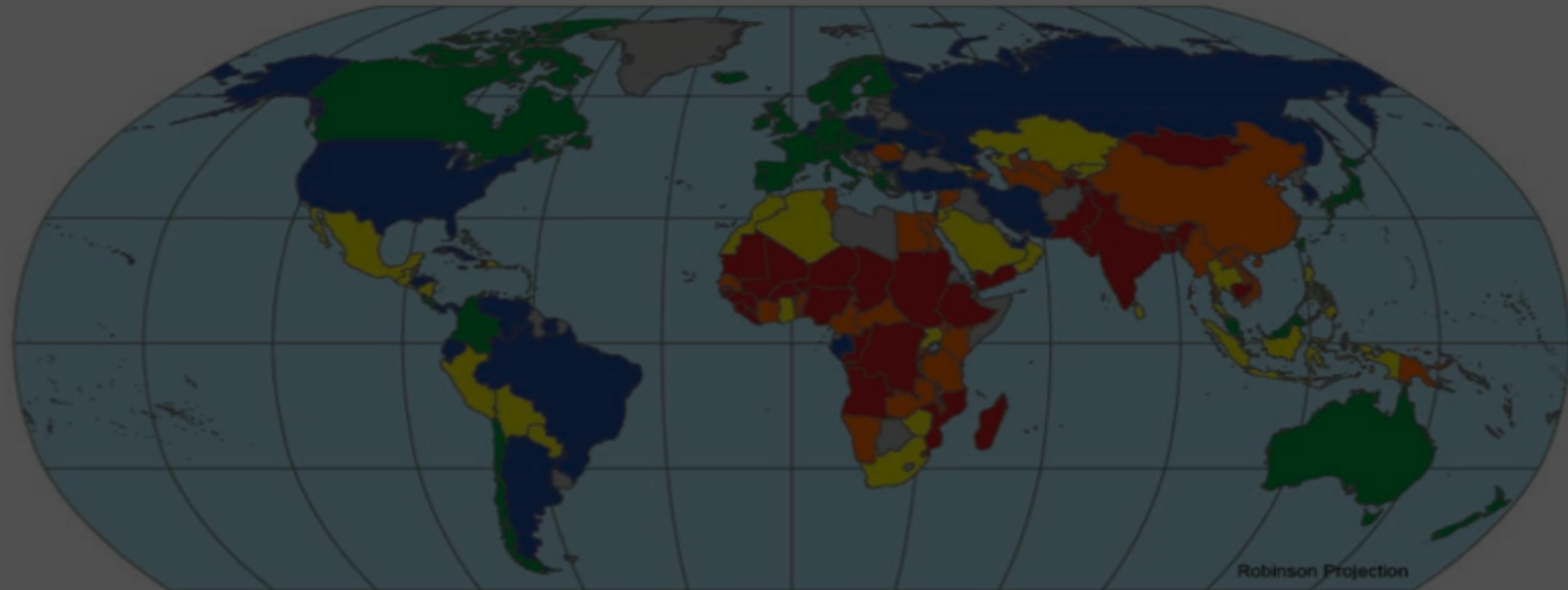
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*Per capita greenhouse gas emissions  
Without land use change*



# The Earth System Metric

Pilot 2006 Environmental Performance Index



Overall EPI Score by Country Quintile



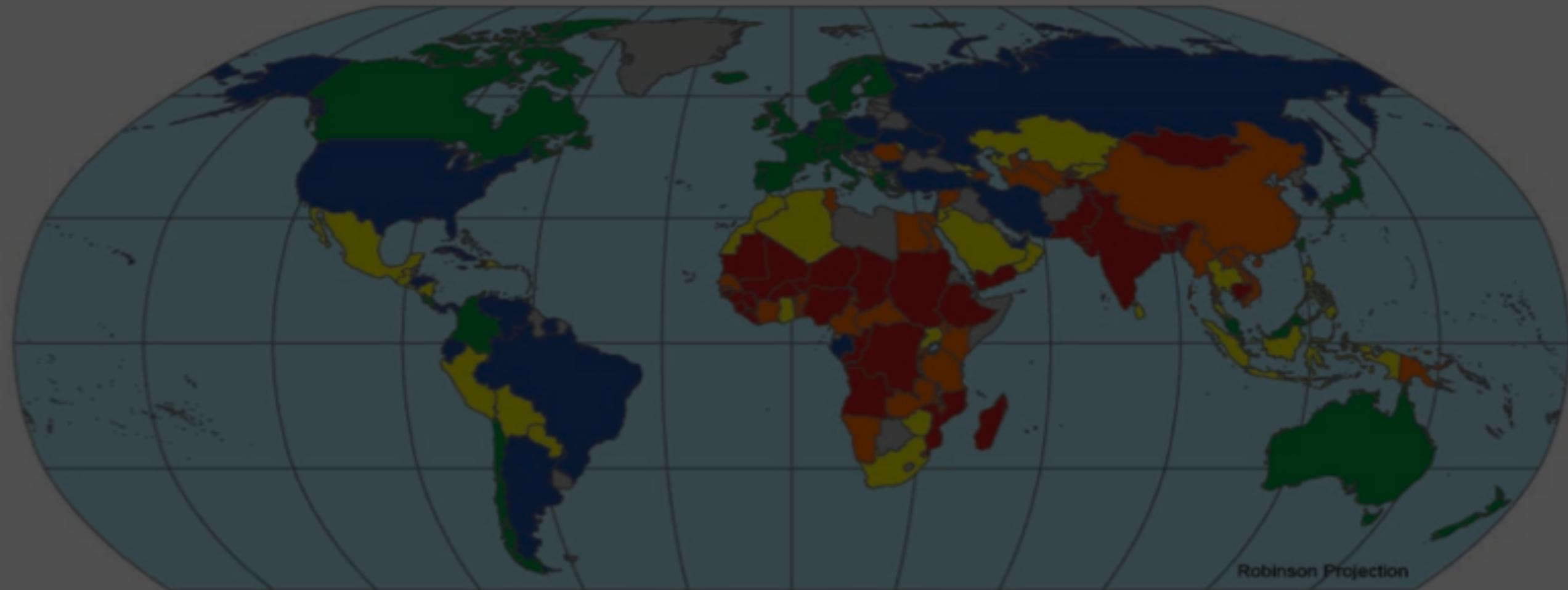
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Environmental Performance Index (EPI):

Two overarching environmental objectives:

- \* reducing environmental stresses to human health;
- \* promoting ecosystem vitality and sound natural resource management.

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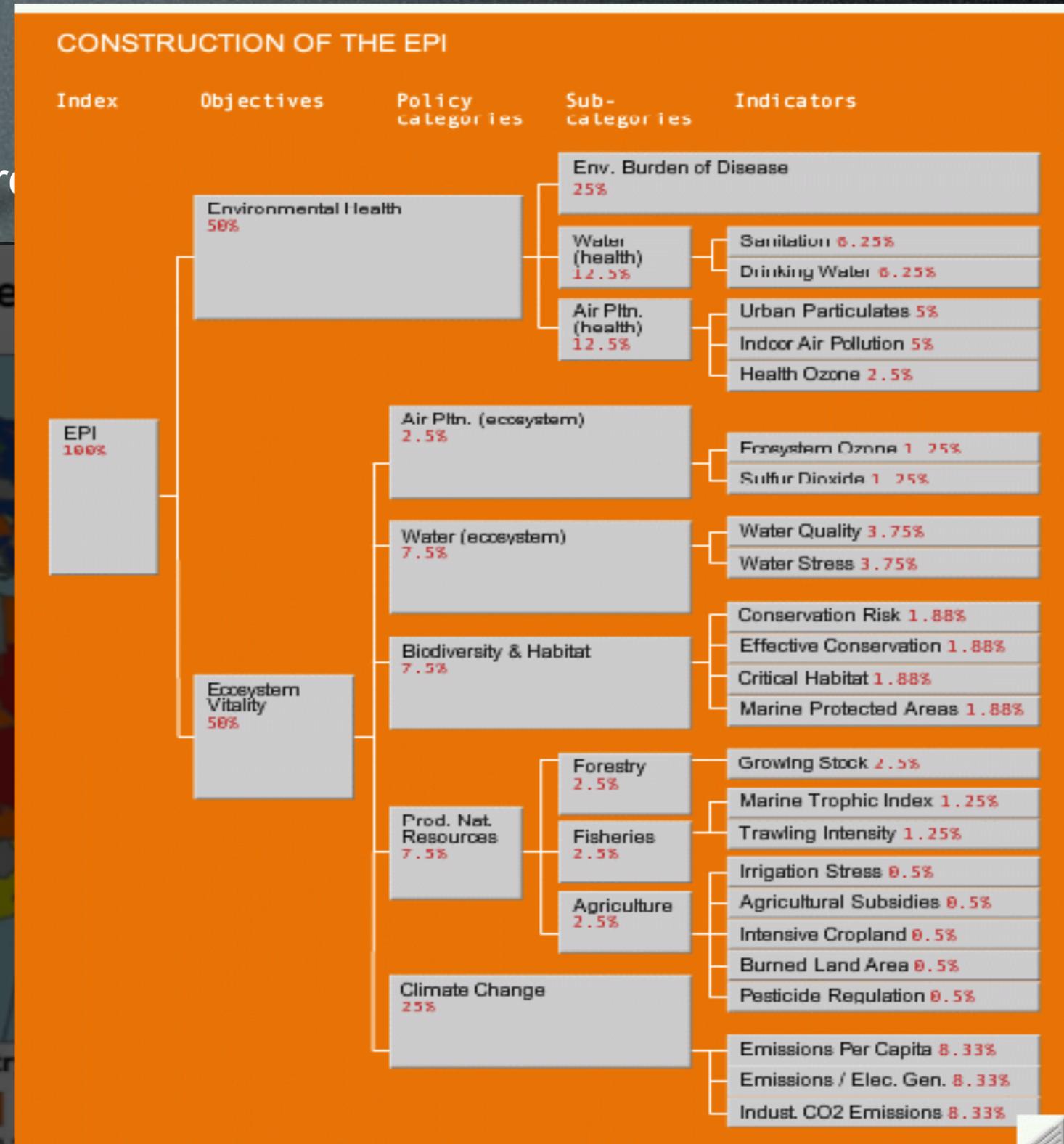
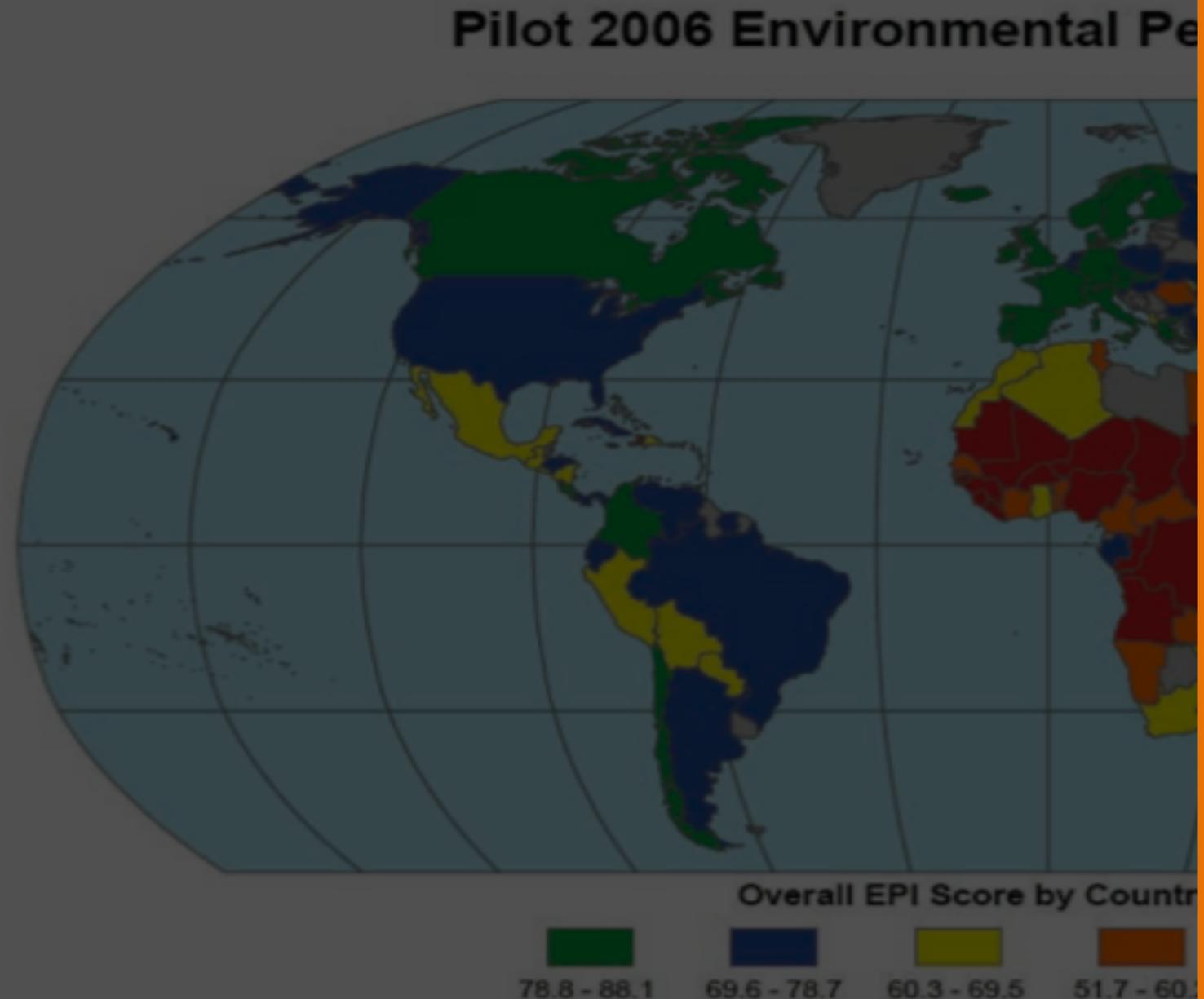


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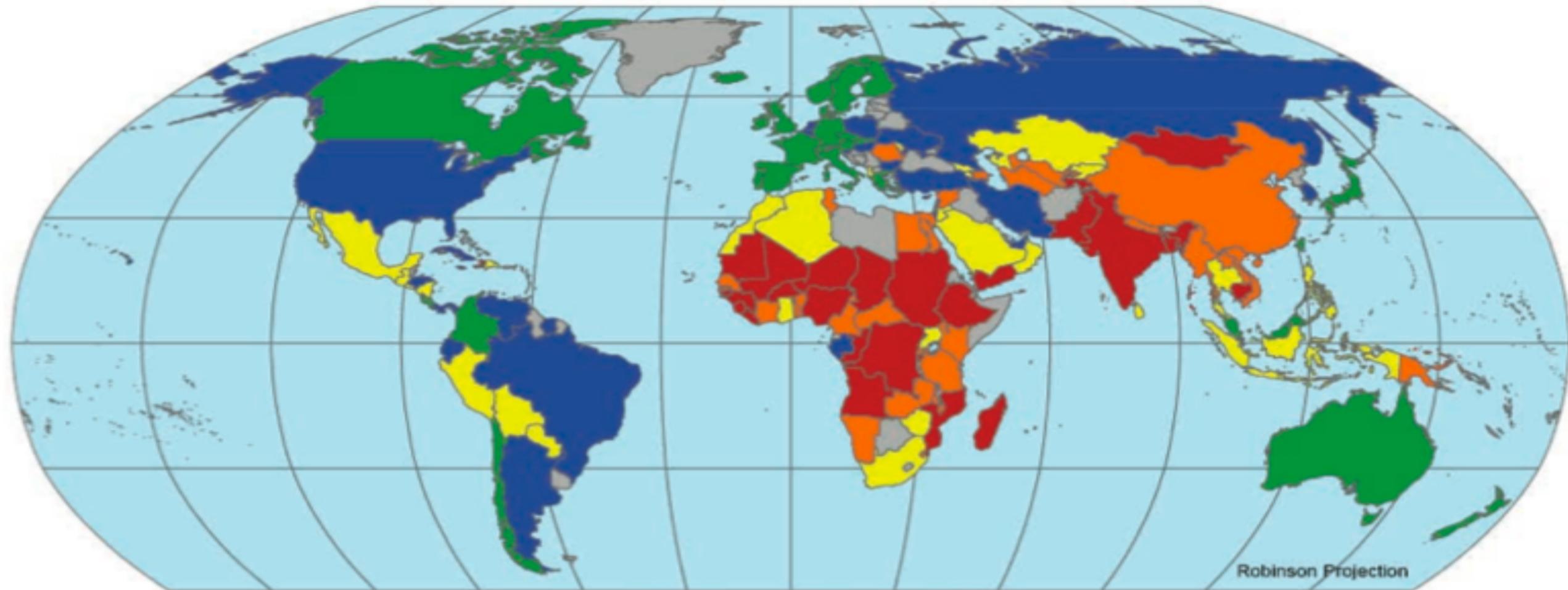
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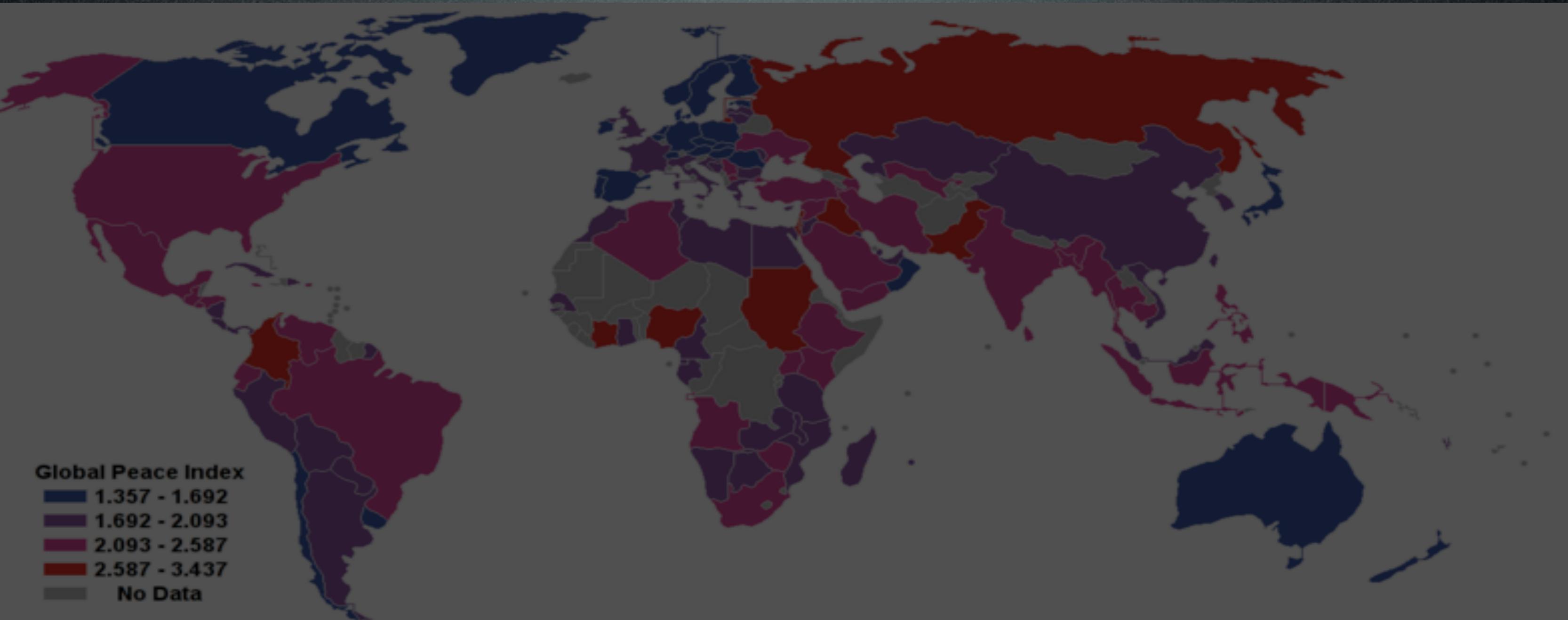
**Pilot 2006 Environmental Performance Index**



**Overall EPI Score by Country Quintile**

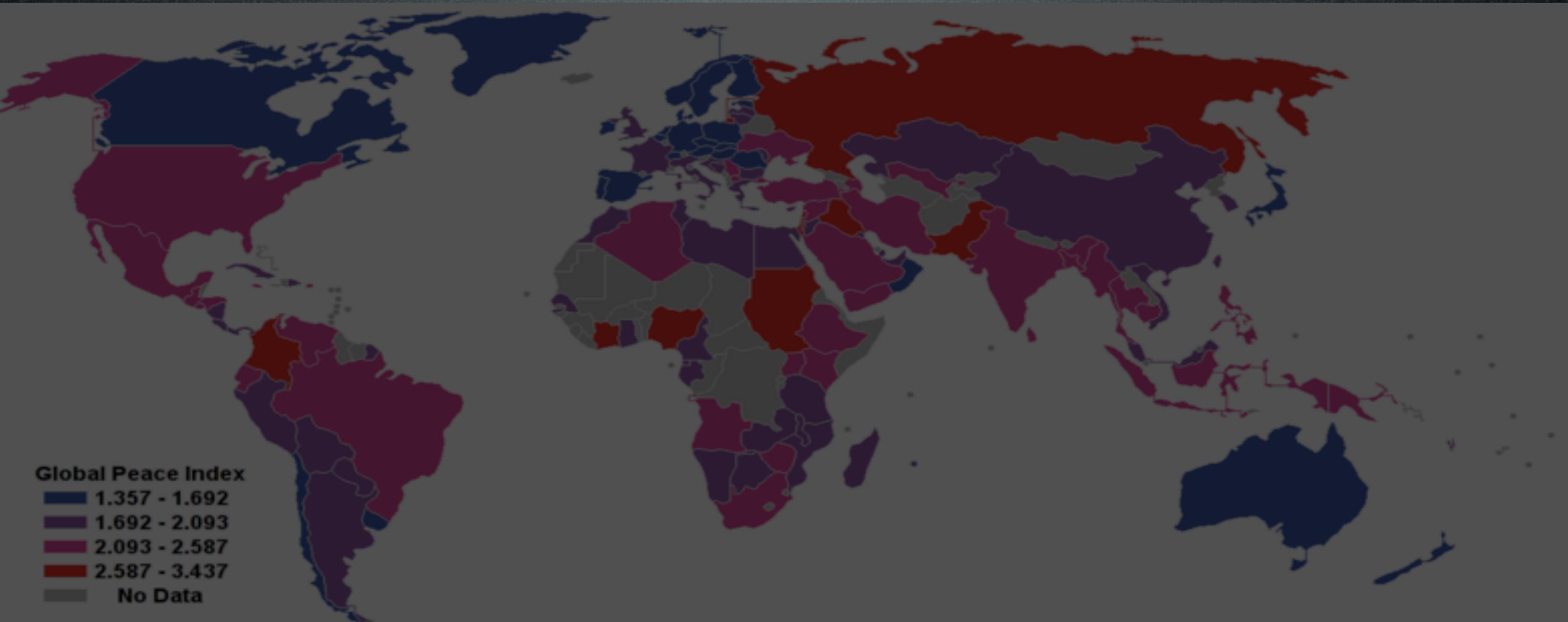


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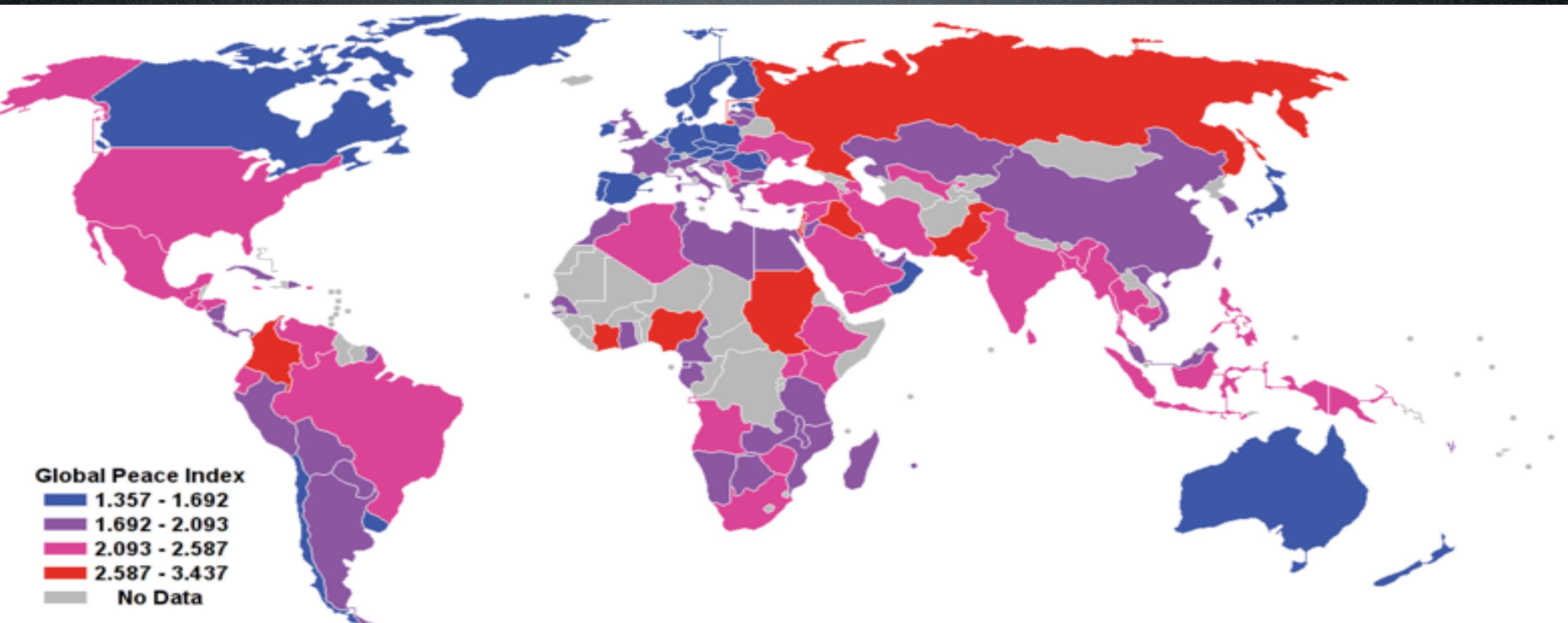
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Global Peace Index: *measures countries' peacefulness based on 24 external and internal indicators.*

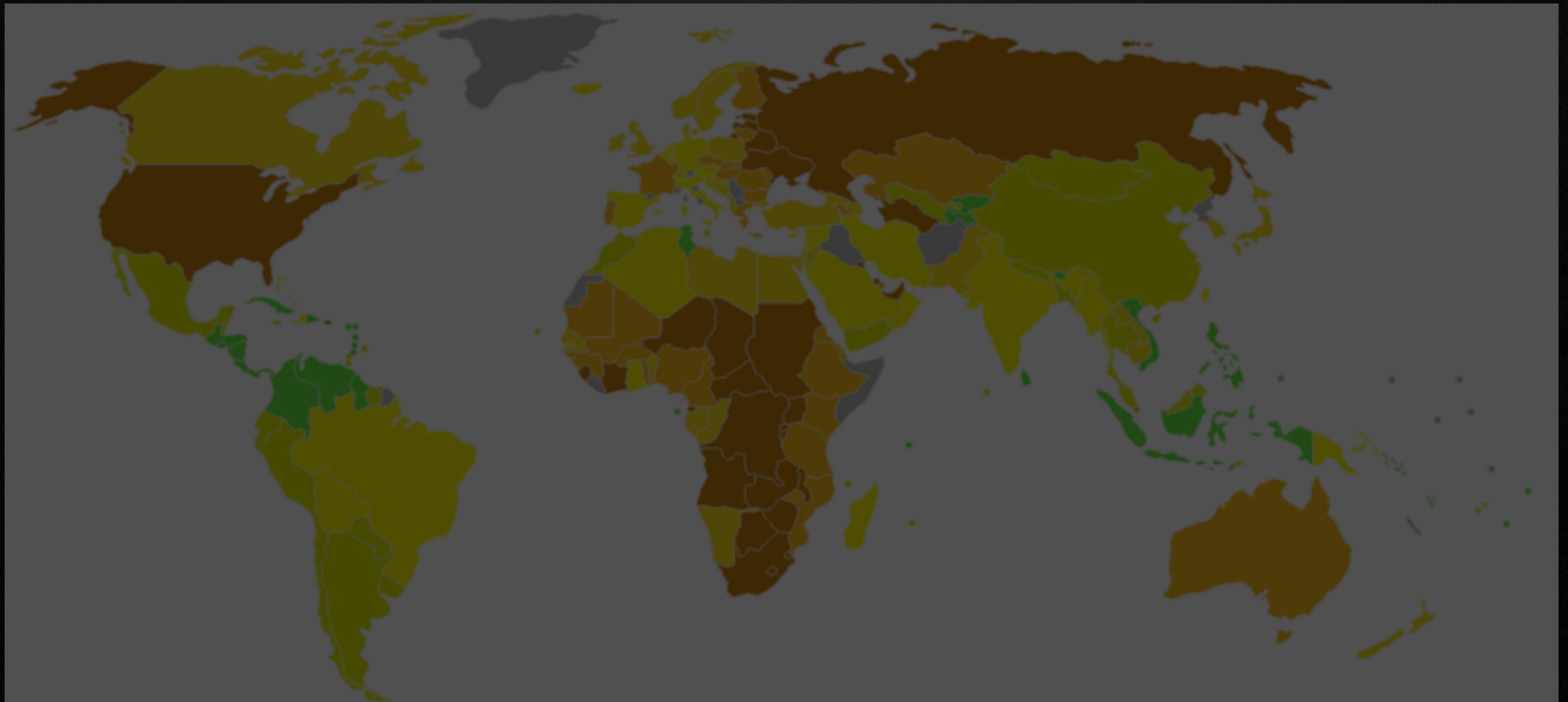


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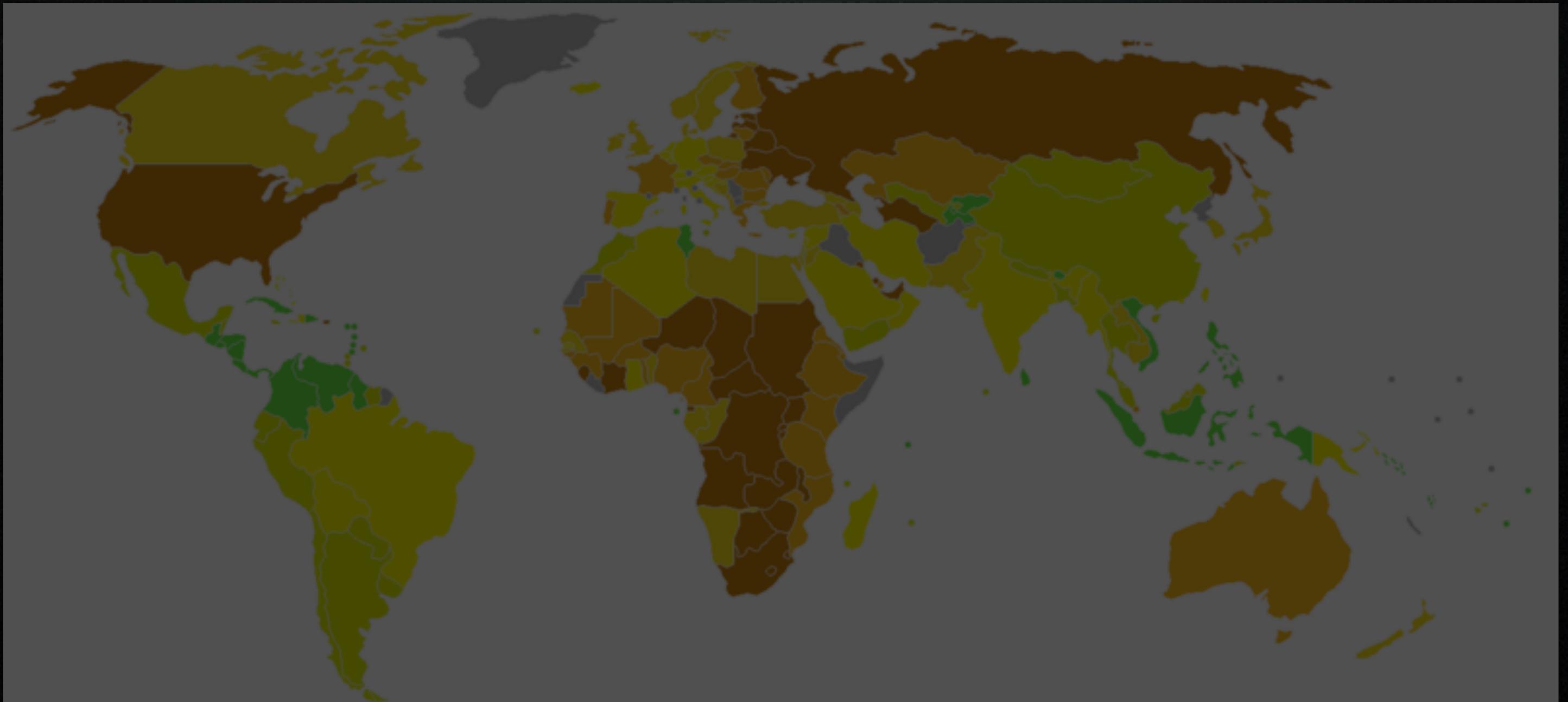


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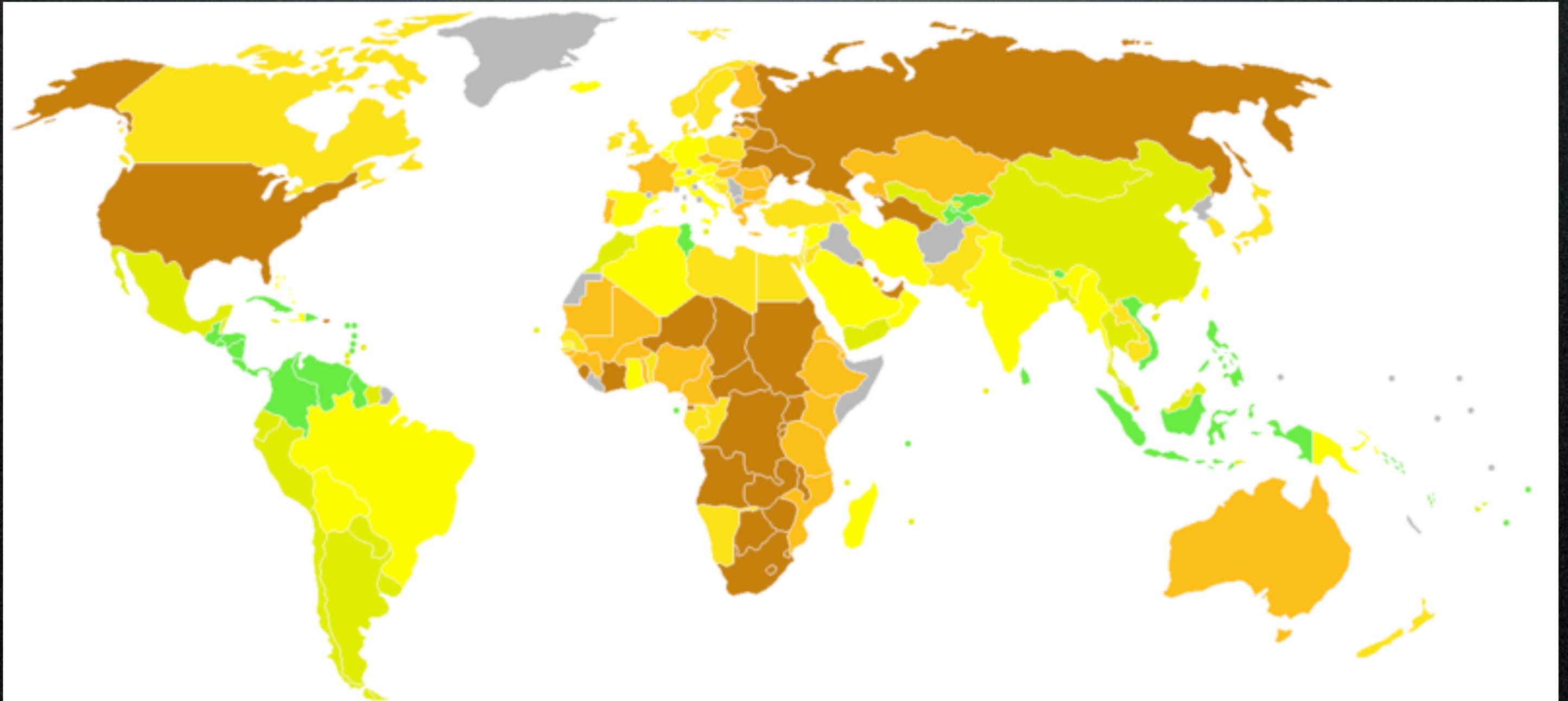
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Happy Planet Index: *measures the ratio of well-being to resource useage.*

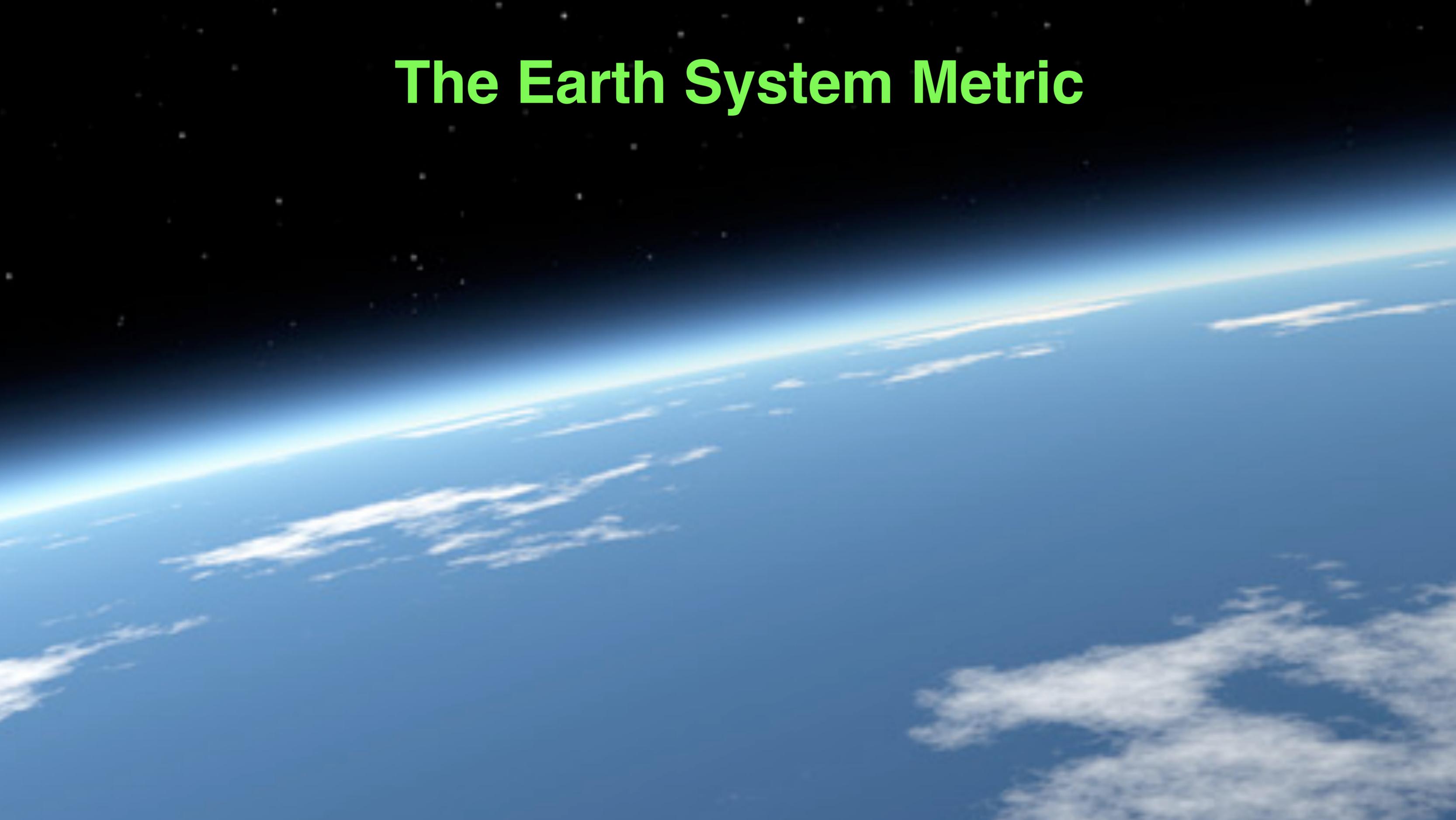


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# The Earth System Metric



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... shows that we are rapidly modifying Earth



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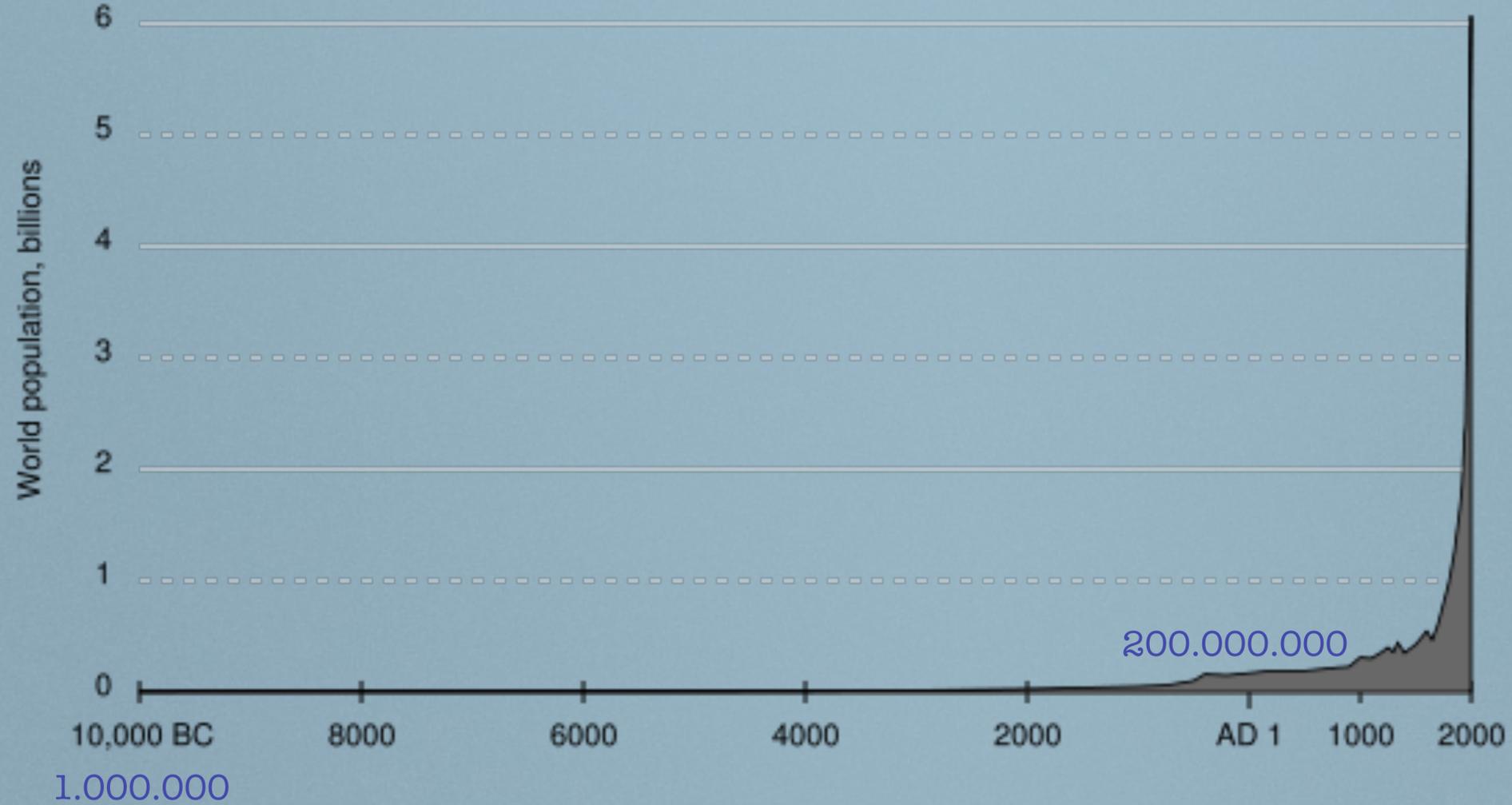
A few examples ...

# Humanity has grown

- *in number ...*

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- in number ...



# Humanity has grown

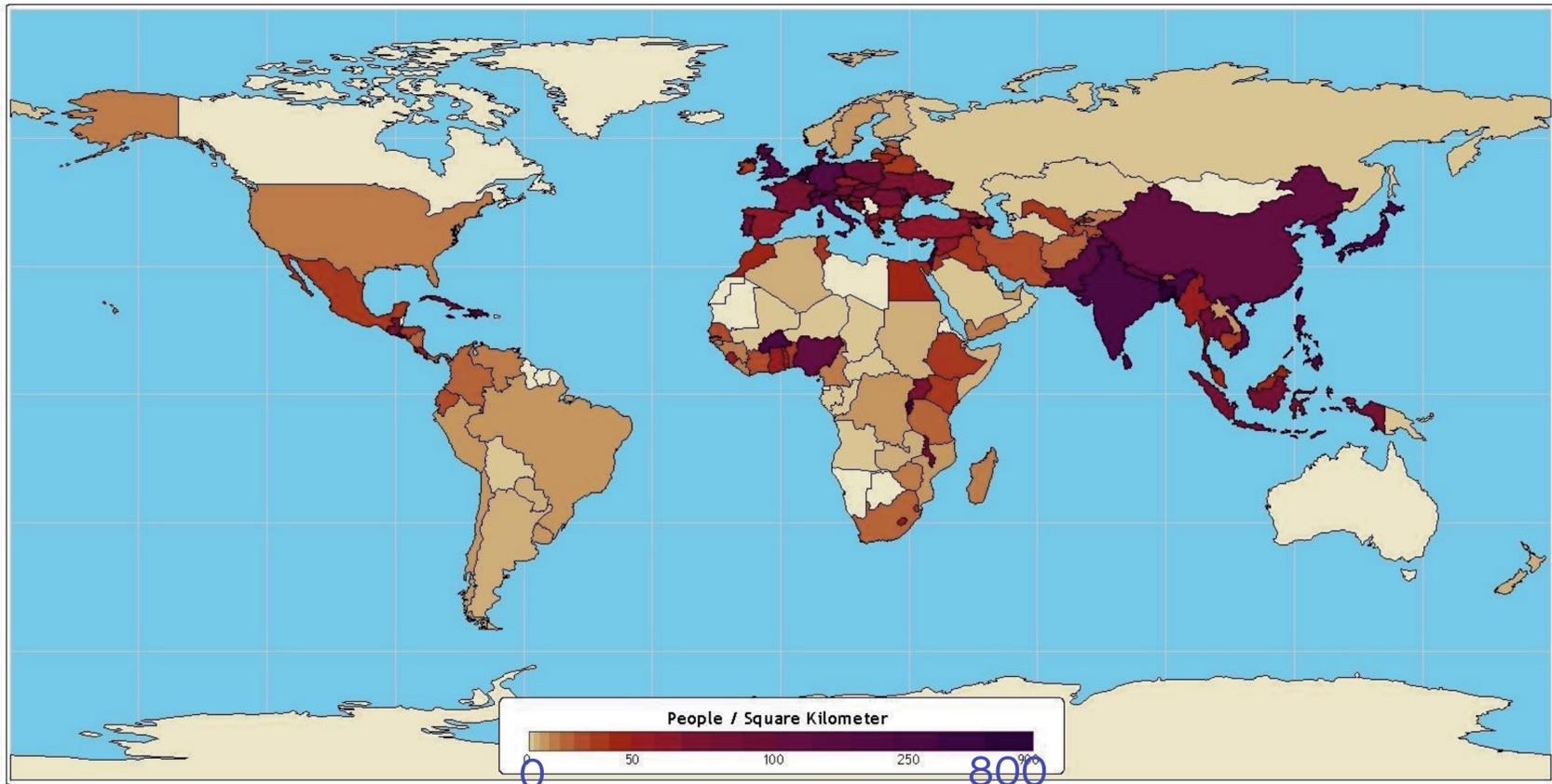
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## Population Density by Country



Data taken from: ESRI (2000)

### Atlas of the Biosphere

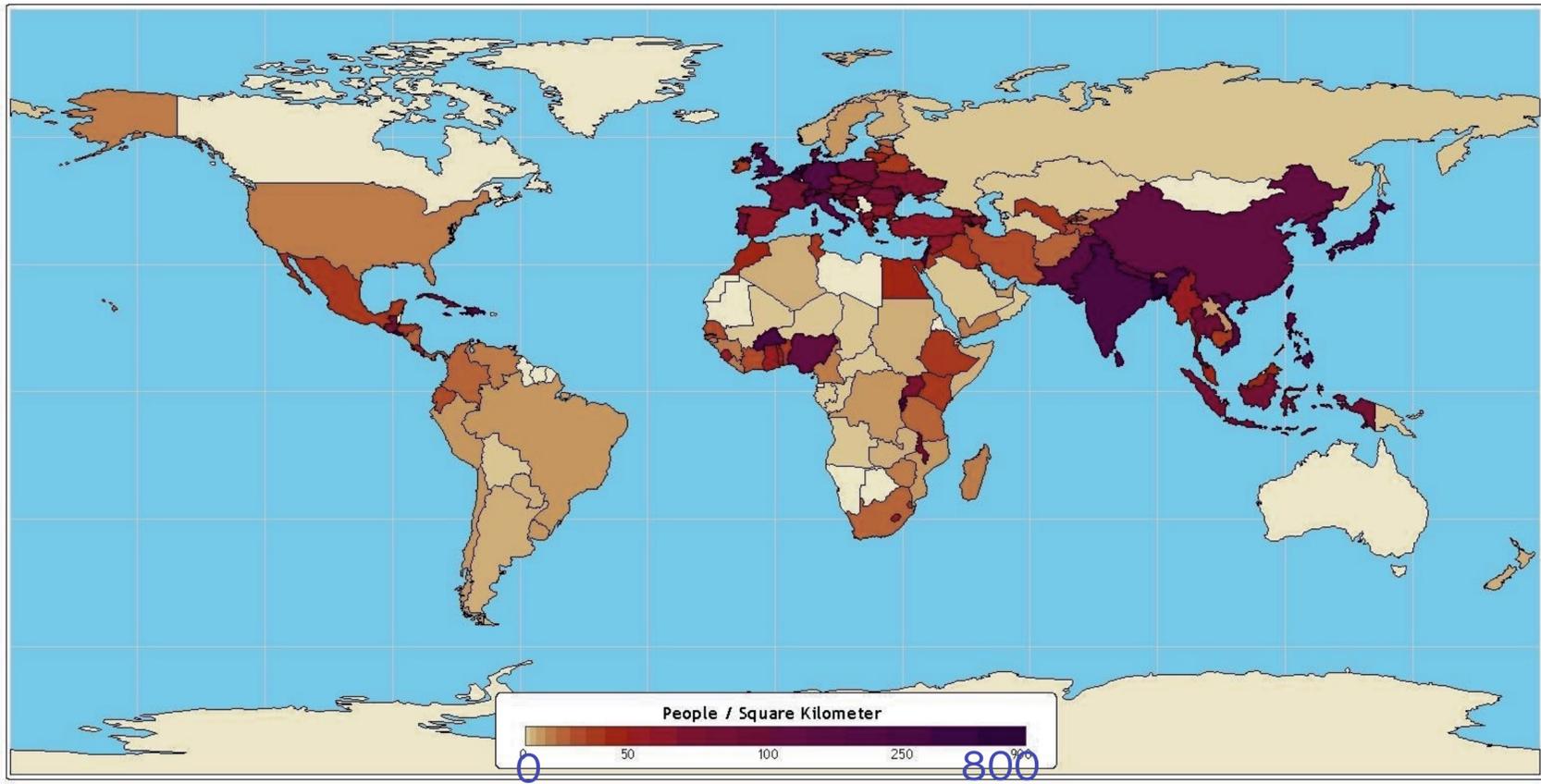
Center for Sustainability and the Global Environment  
University of Wisconsin - Madison



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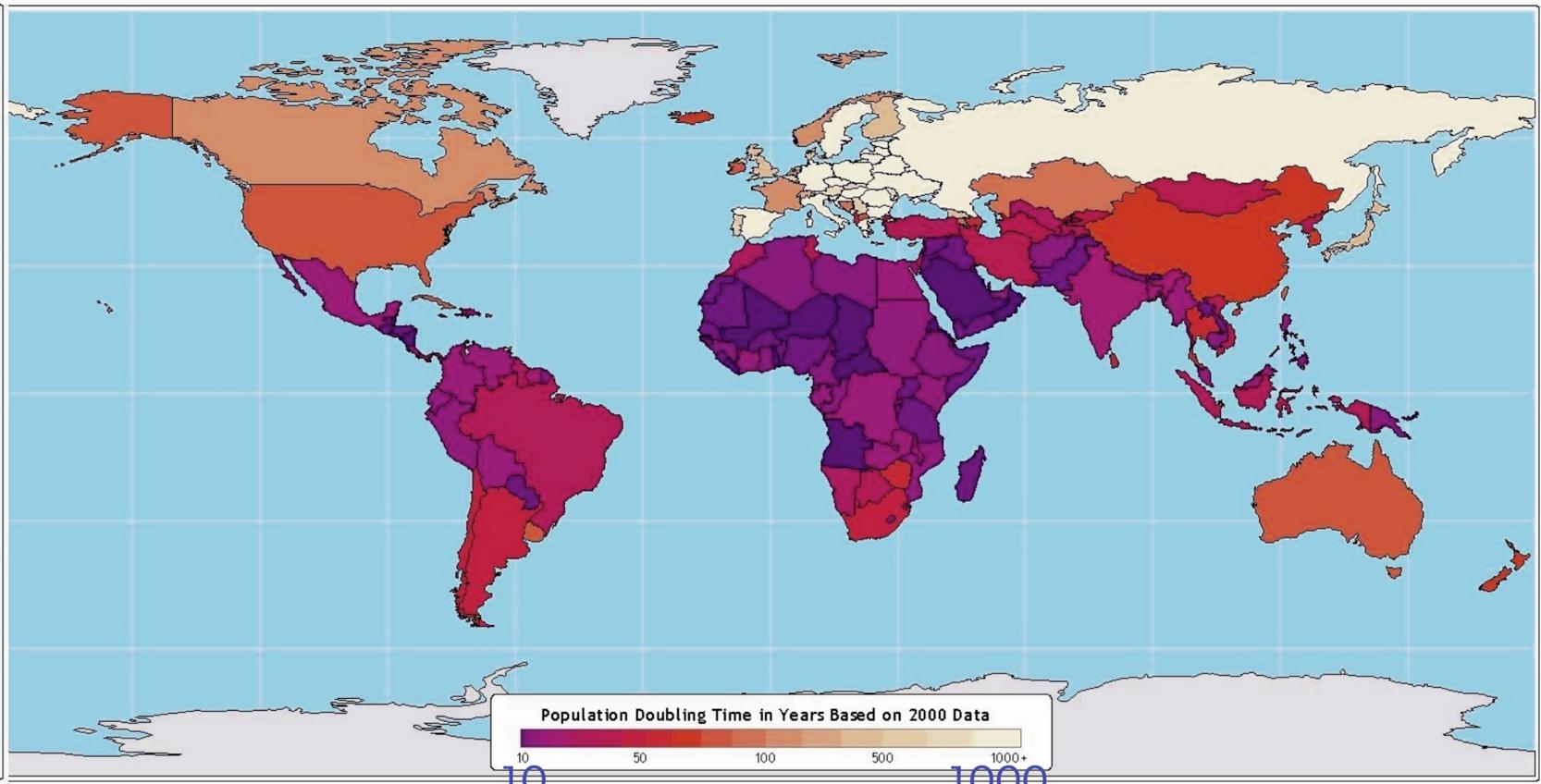
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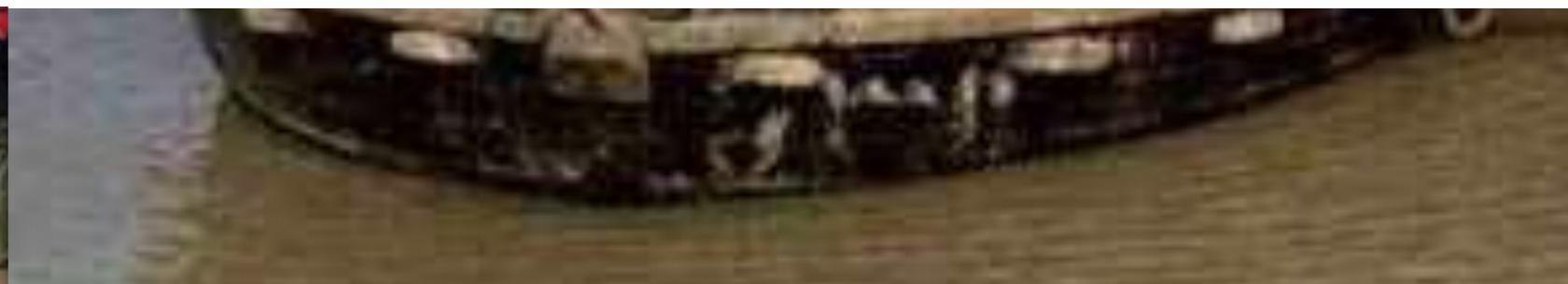
**Atlas of the Biosphere**  
Center for Sustainability and the Global Environment  
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## Population Doubling Time



Data taken from: Population Reference Bureau (2000)

**Atlas of the Biosphere**  
Center for Sustainability and the Global Environment  
University of Wisconsin - Madison

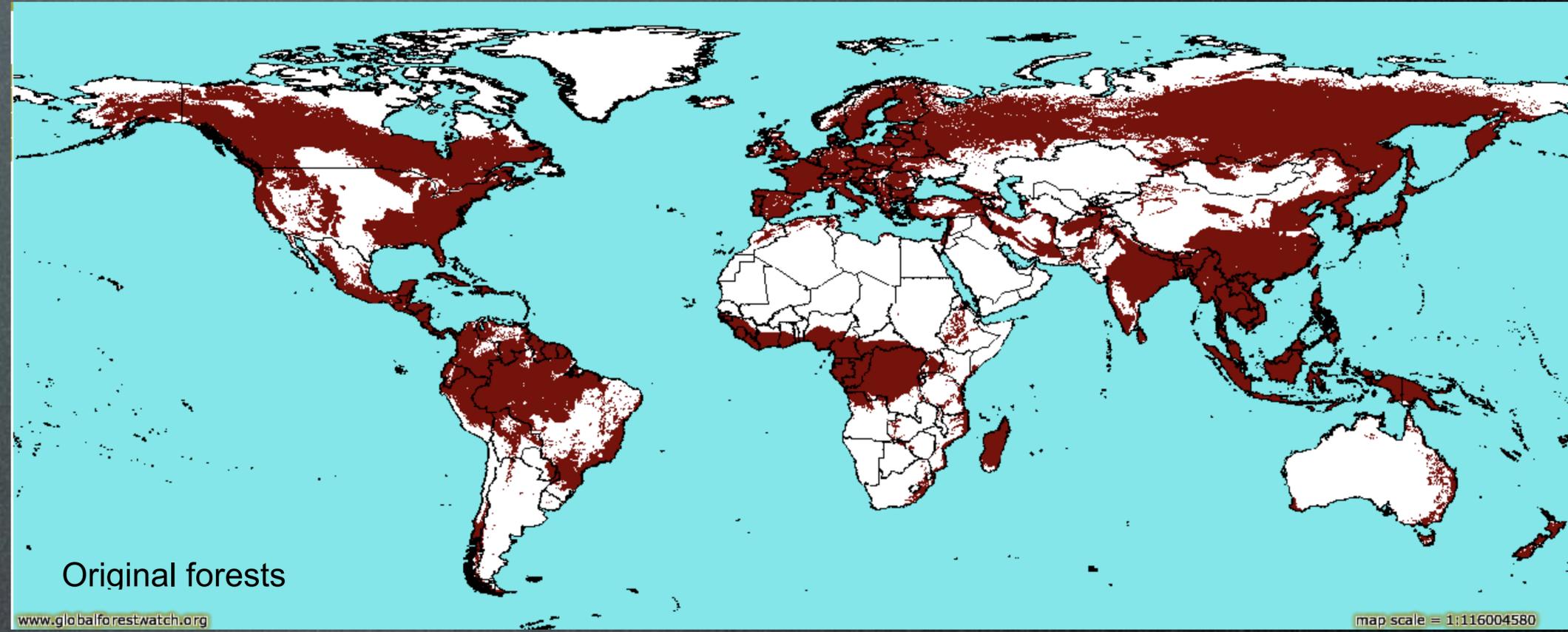


# Humanity has grown

- *in number ...*
- *in activity: deforestation...*

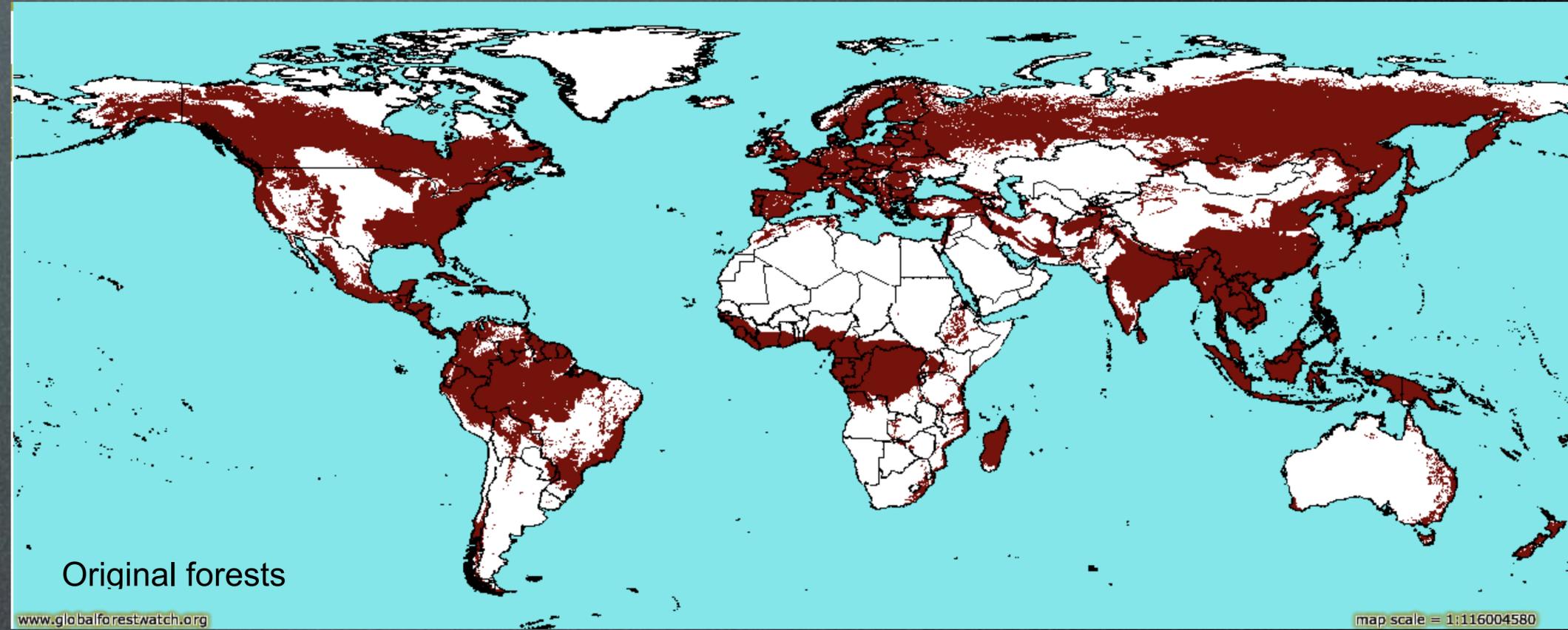
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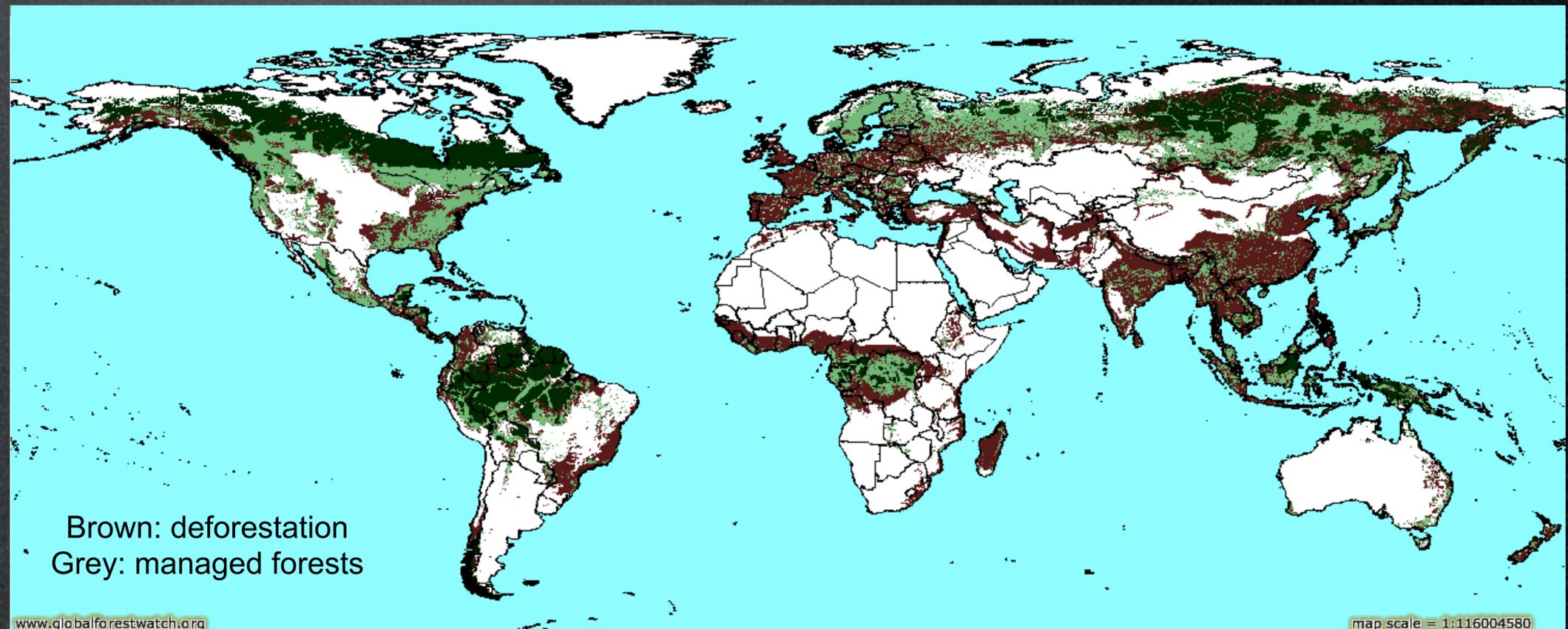


# Humanity has grown

- *in number ...*
- *in activity: deforestation...*



- About 50% of the original forests are gone;
- Only 20% of frontier forests remain



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- *in number ...*
- *in activity: example land use...*

- More than 50% of the ice-free surface of the solid Earth is modified and managed by human activities

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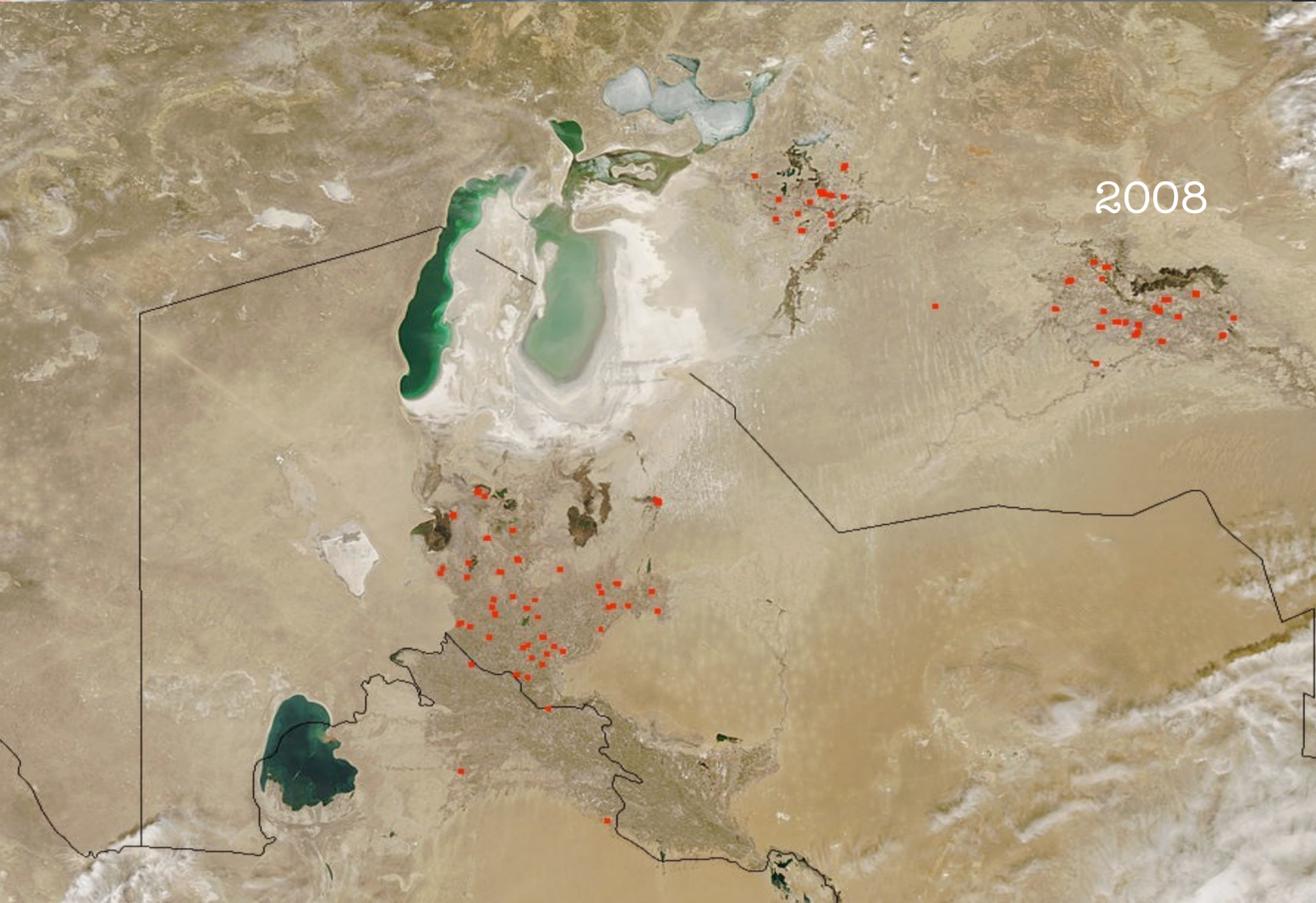
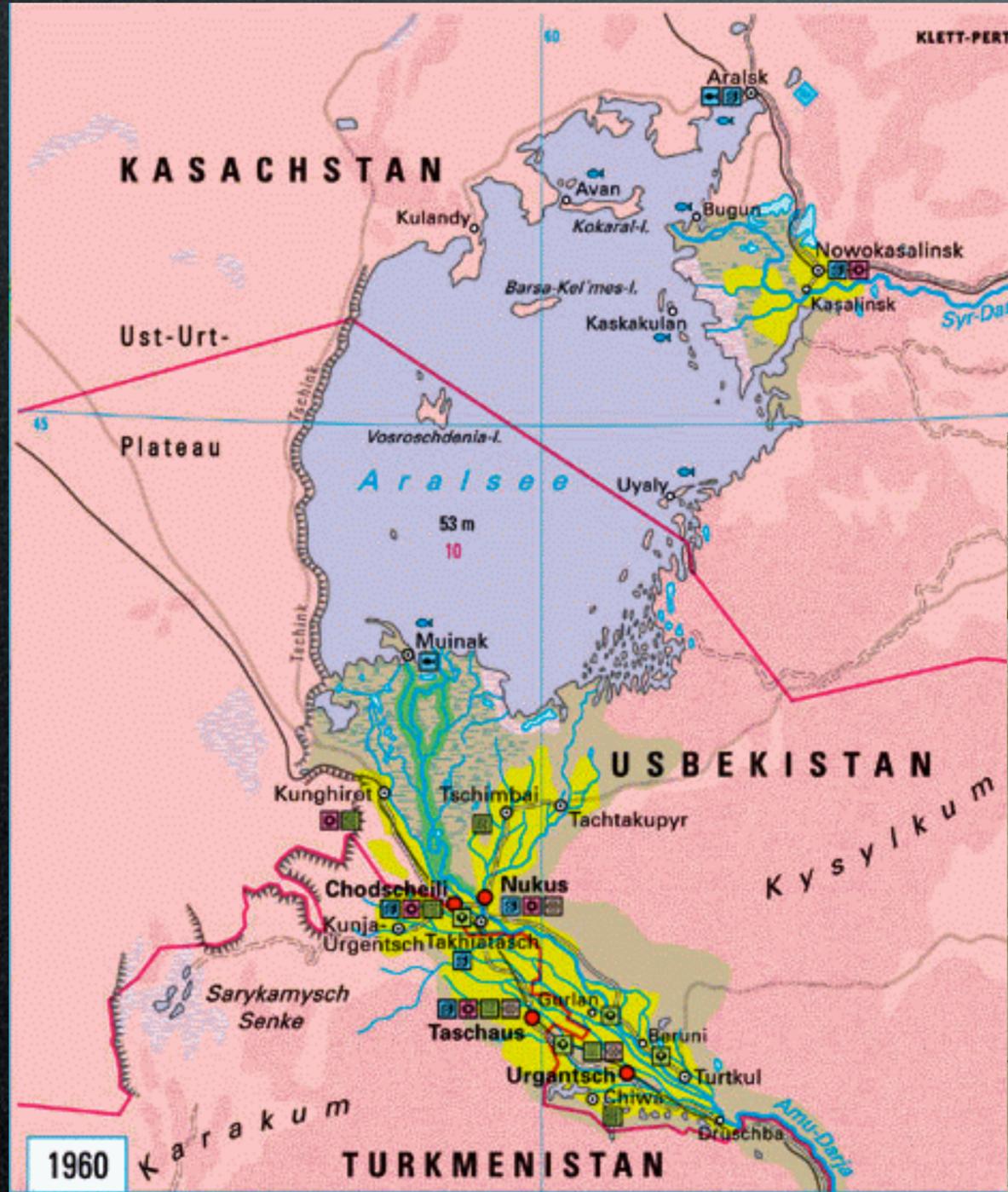
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- *in impact: Aral Sea*

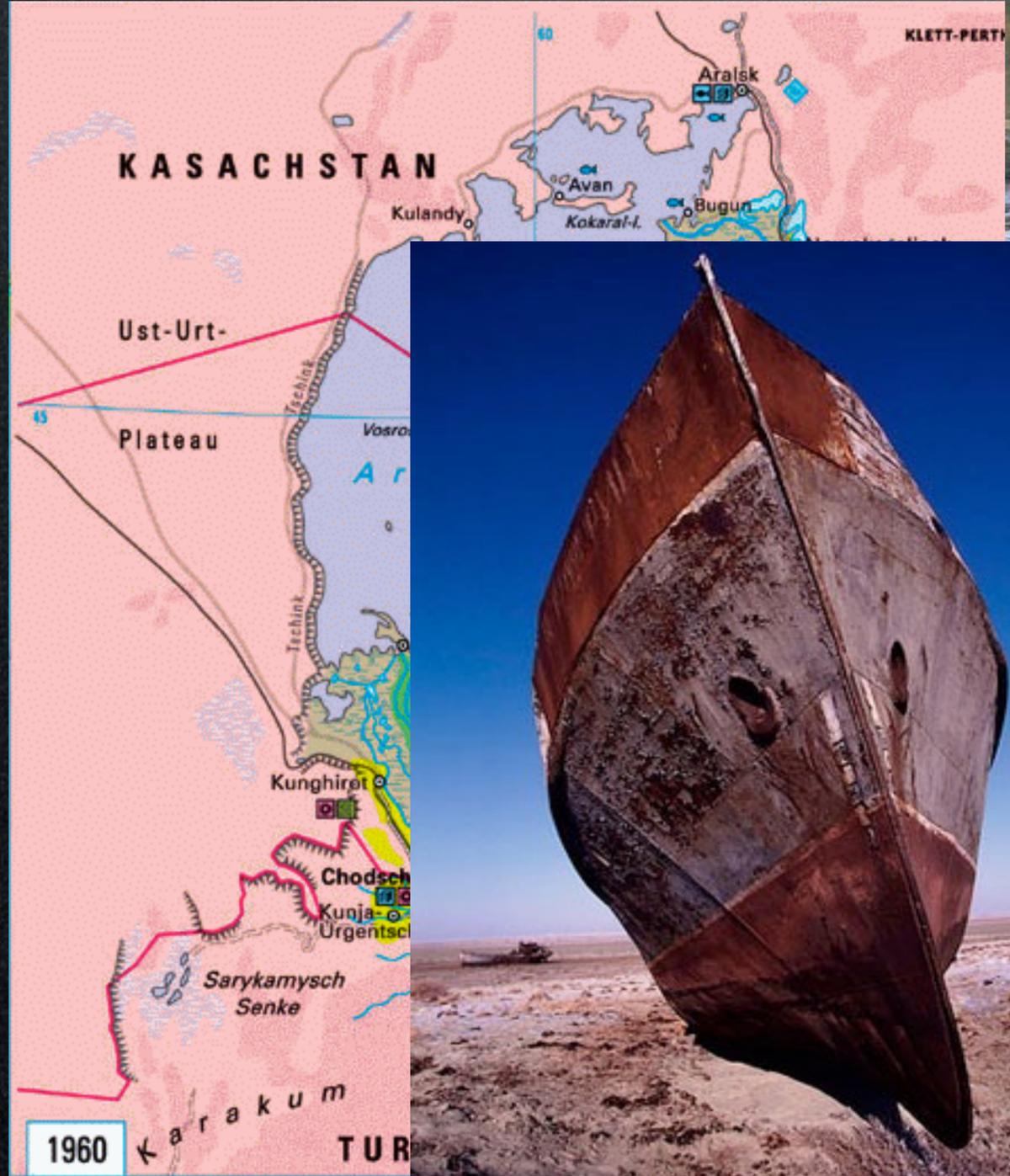
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## Degradation of the Earth's Life-Support System:

- ~50% of the ice-free Earth surface are transformed, managed, utilized ecosystems
- Human-mobilized material and energy flows are exceeding natural flows
- We have changed major mass cycles, including C, N, P, H<sub>2</sub>O, ...
- We have introduced pollutants that did not exist in free form or were not abundant (mercury, aluminum, PCBs, ...)
- We have fragmented or eliminated ecosystems, and innumerable species are in decline or already extinct.
- We changed the biosphere significantly over the last 300 years, and we are creating the greatest extinction crisis since the natural disaster that wiped out the dinosaurs 65 million years ago.
- These extinctions are irreversible and threaten our own well-being.
- The magnitude of human-induced environmental changes at global scale is enormous.

We have change global population, distribution of wealth, access to resources

We entered the “Anthropocene” a long time ago ...

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*Having gained the power to change Earth,  
we need to take a new look at humanity and  
ask the question who we are*

We are Facing a Great Challenge, if not Extinction

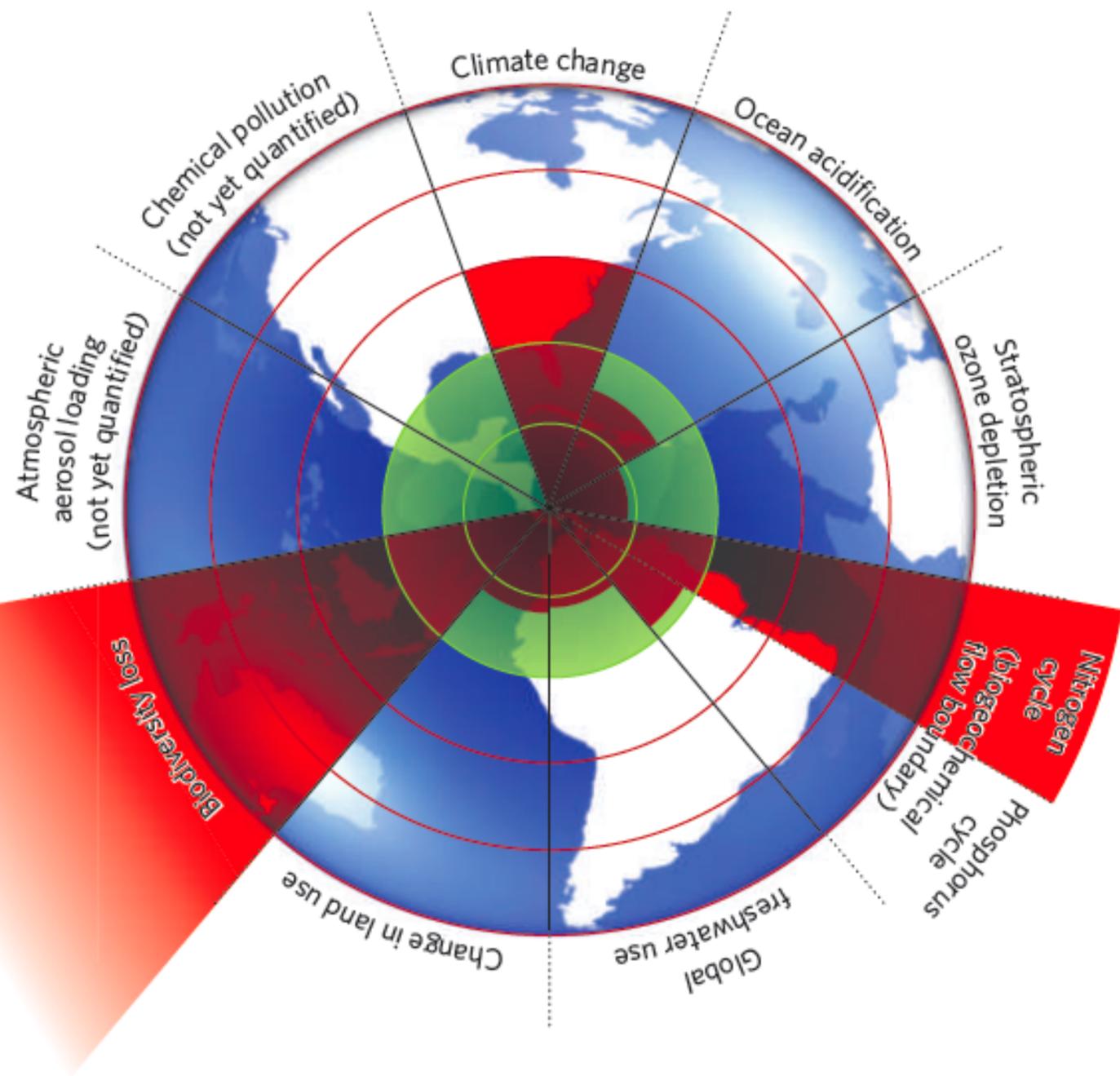
## We are Facing a Great Challenge, if not Extinction

*Guide for “United Nation's Convention on Biological Diversity” :*

*“It is reckless if not downright dangerous to keep chipping away at our life support system. It is unethical to drive other forms of life to extinction, and thereby deprive present and future generations of options for their survival and development.*

*Can we save the world's ecosystems, and with them the species we value and the other millions of species, some of which may produce the foods and medicines of tomorrow? The answer will lie in our ability to bring our demands into line with nature's ability to produce what we need and to safely absorb what we throw away.”*





We are moving out of the Holocene and the “safe operating space for humanity” (Rockstroem et al., 2009):

Climate Change (\*\*\*)

Ocean acidification (\*\*)

Stratospheric ozone depletion (\*)

Nitrogen (\*\*\*\*\*) and Phosphorous cycles (\*\*)

Global freshwater (\*)

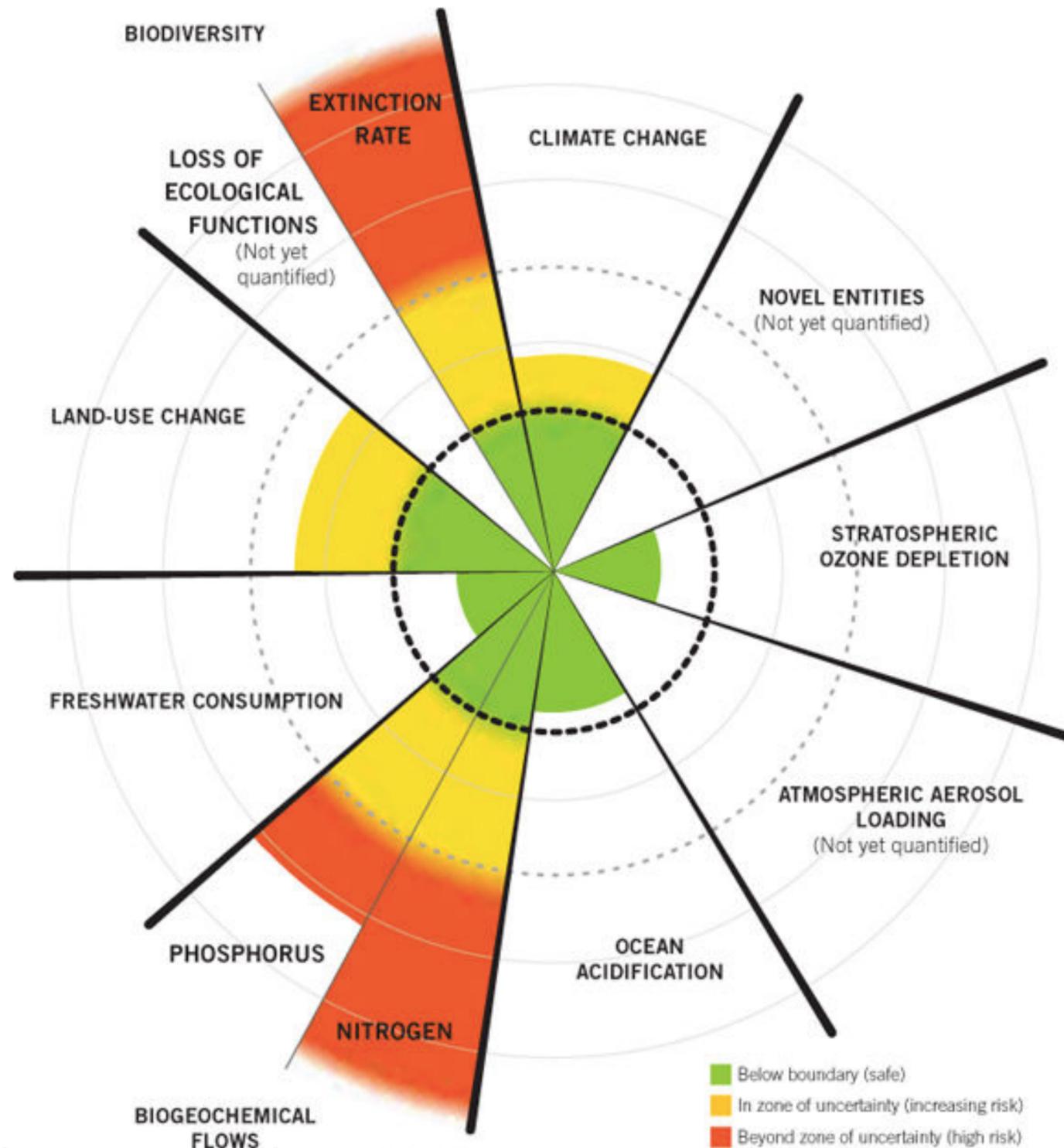
Change in land use (\*)

Biodiversity loss (\*\*\*\*\*)

Atmospheric aerosols (?)

Chemical pollution (?)

**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.



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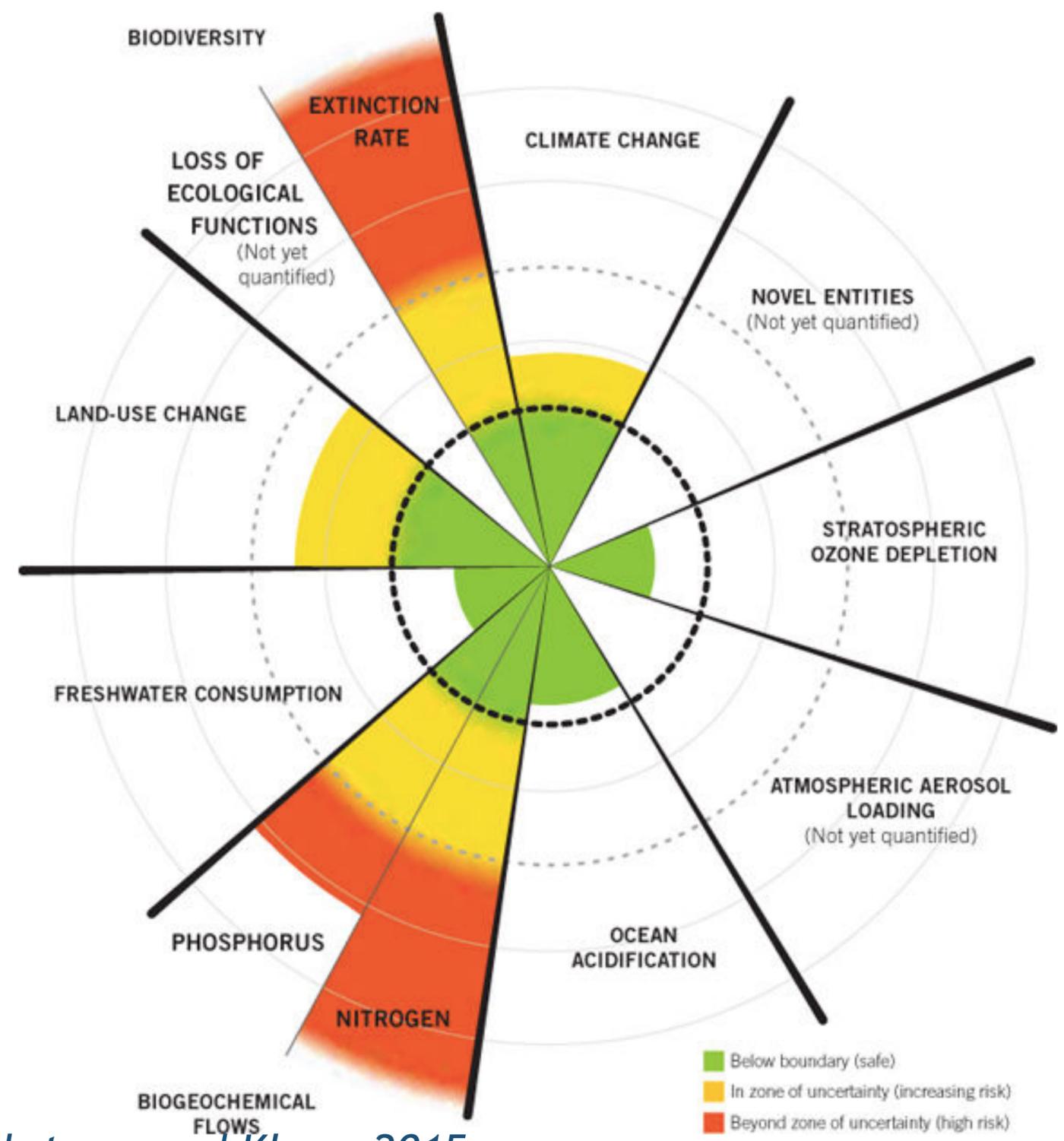
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# The Syndrome: Entering the Post-Holocene



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Climate change and sea level rise are symptoms, not the cause, not the “sickness.”

# The Syndrome: Entering the Post-Holocene

During the Holocene, climate and sea level were exceptionally stable

During the Holocene, global disasters caused by geohazards, asteroids, solar storms, etc. were very limited and not at the upper end of the scale

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The Holocene was a “safe operating space for humanity”

Civilization could develop despite many anthropogenic conflicts and disasters

During the last hundred years, we have introduced rapid and large changes in all major flows

We have initiated the transition into the Post-Holocene

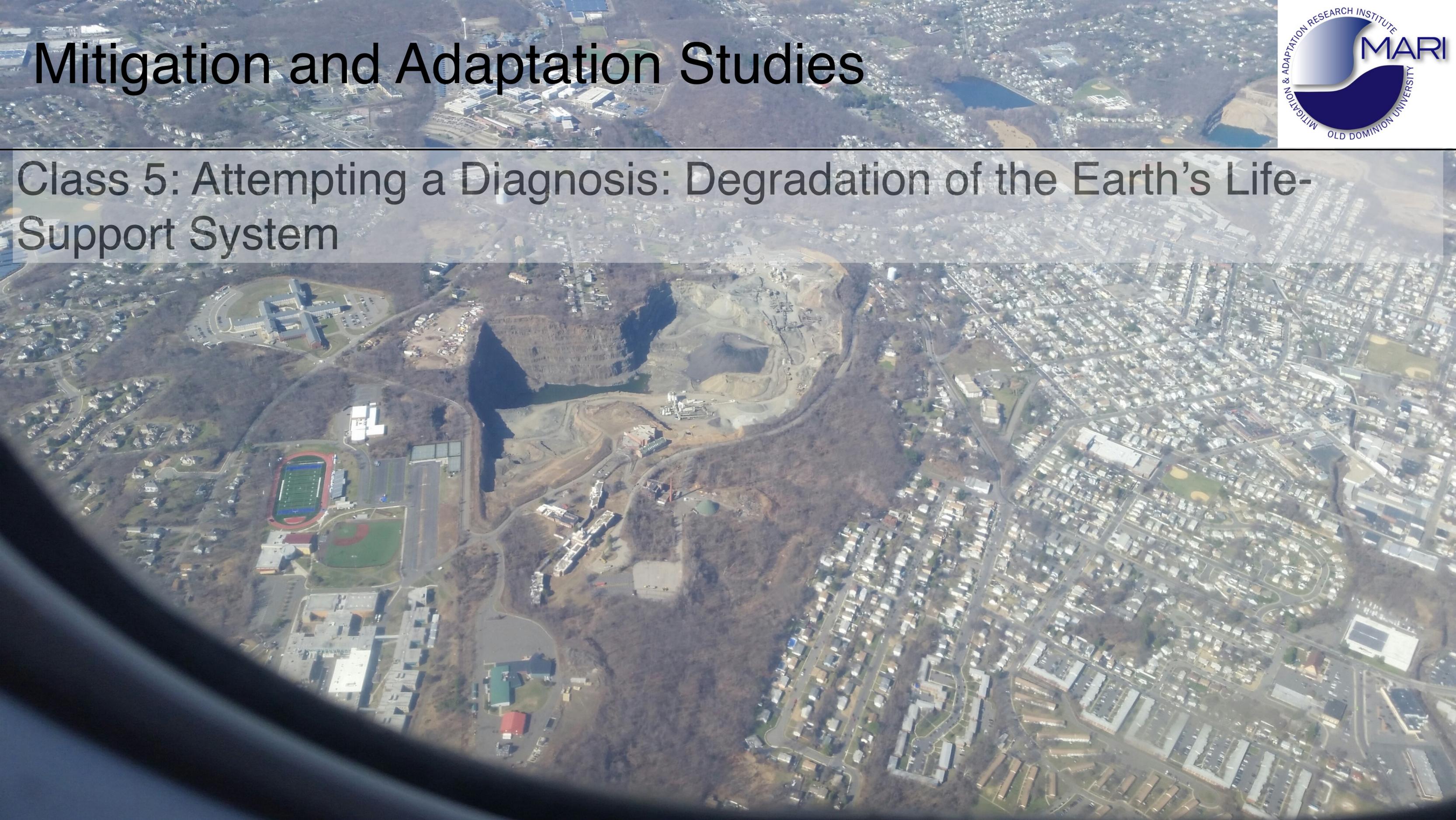
# Mitigation and Adaptation Studies



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Class 5: Attempting a Diagnosis: Degradation of the Earth's Life-Support System



# Mitigation and Adaptation Studies



## Class 5: Attempting a Diagnosis: Degradation of the Earth's Life-Support System

### Contents:

- Changing the Life-Support System
- Crossing Boundaries
- The Role of Economy in the Degrading the Life-Support System

# Changing the Life-Support System

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*Griggs et al., 2013*



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Core question:

What is our relationship to the planet?

- Owner?
- Steward?
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Native American proverb:

“We have not inherited the earth from our fathers, we are borrowing it from our children.”

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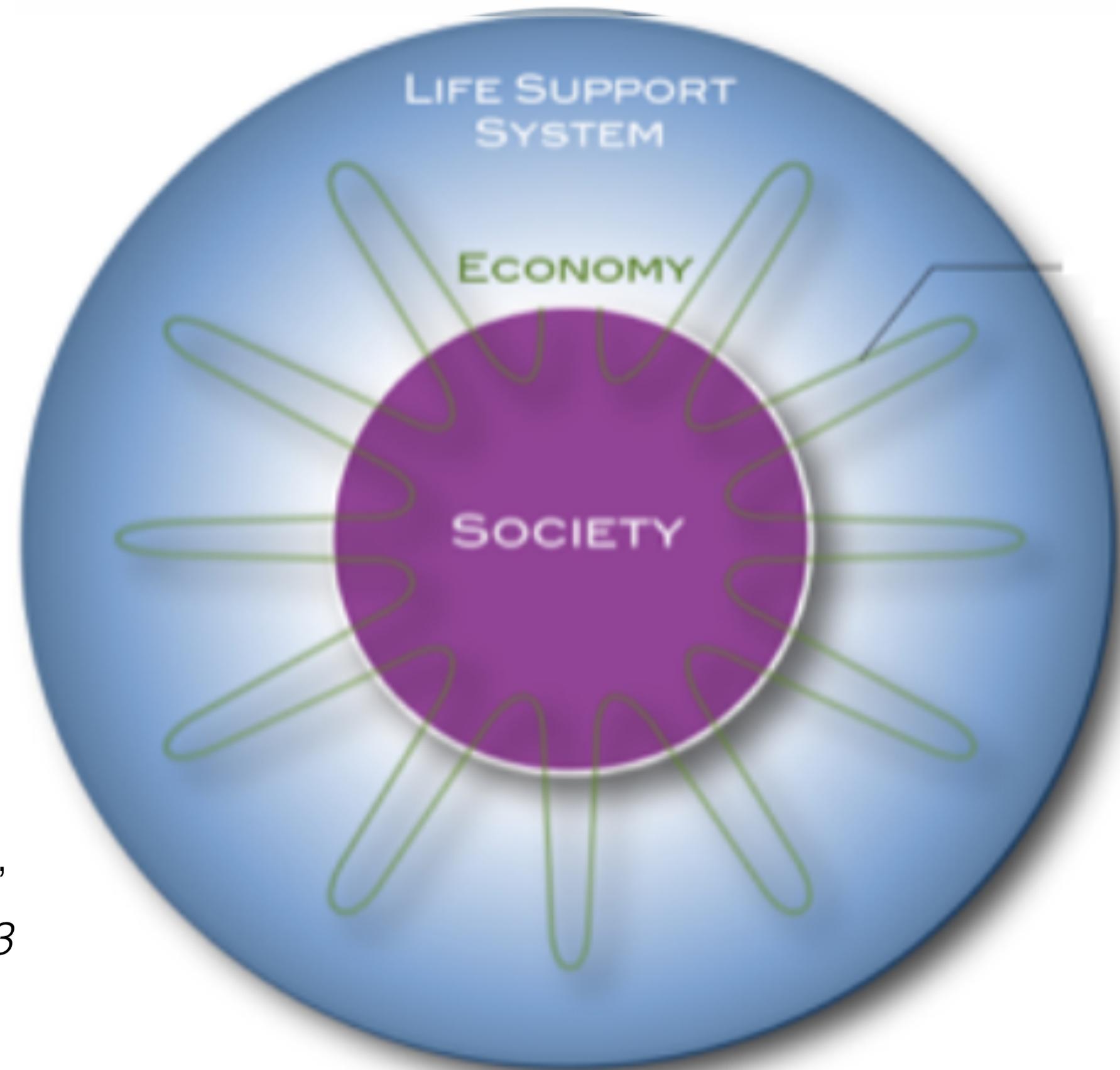
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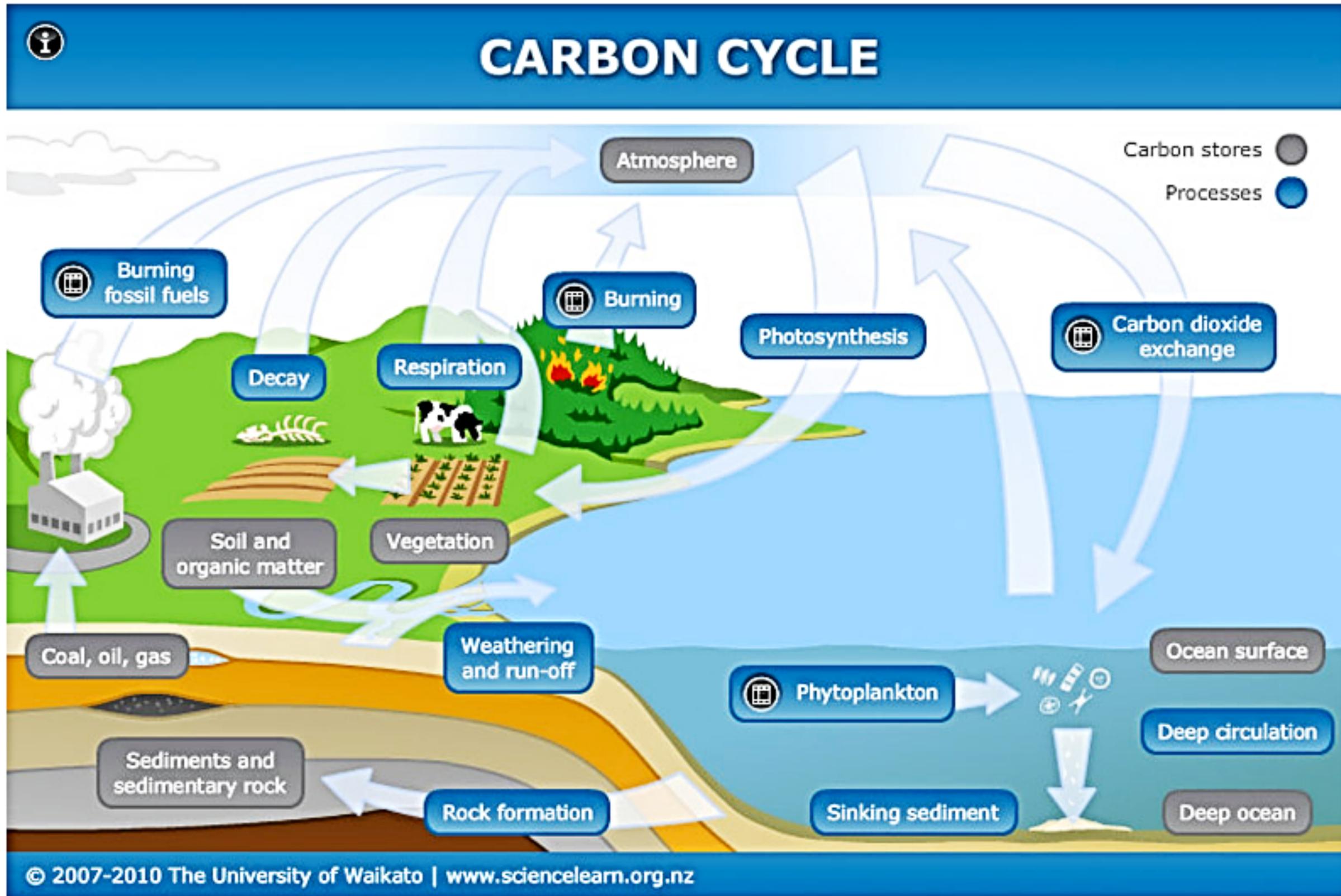
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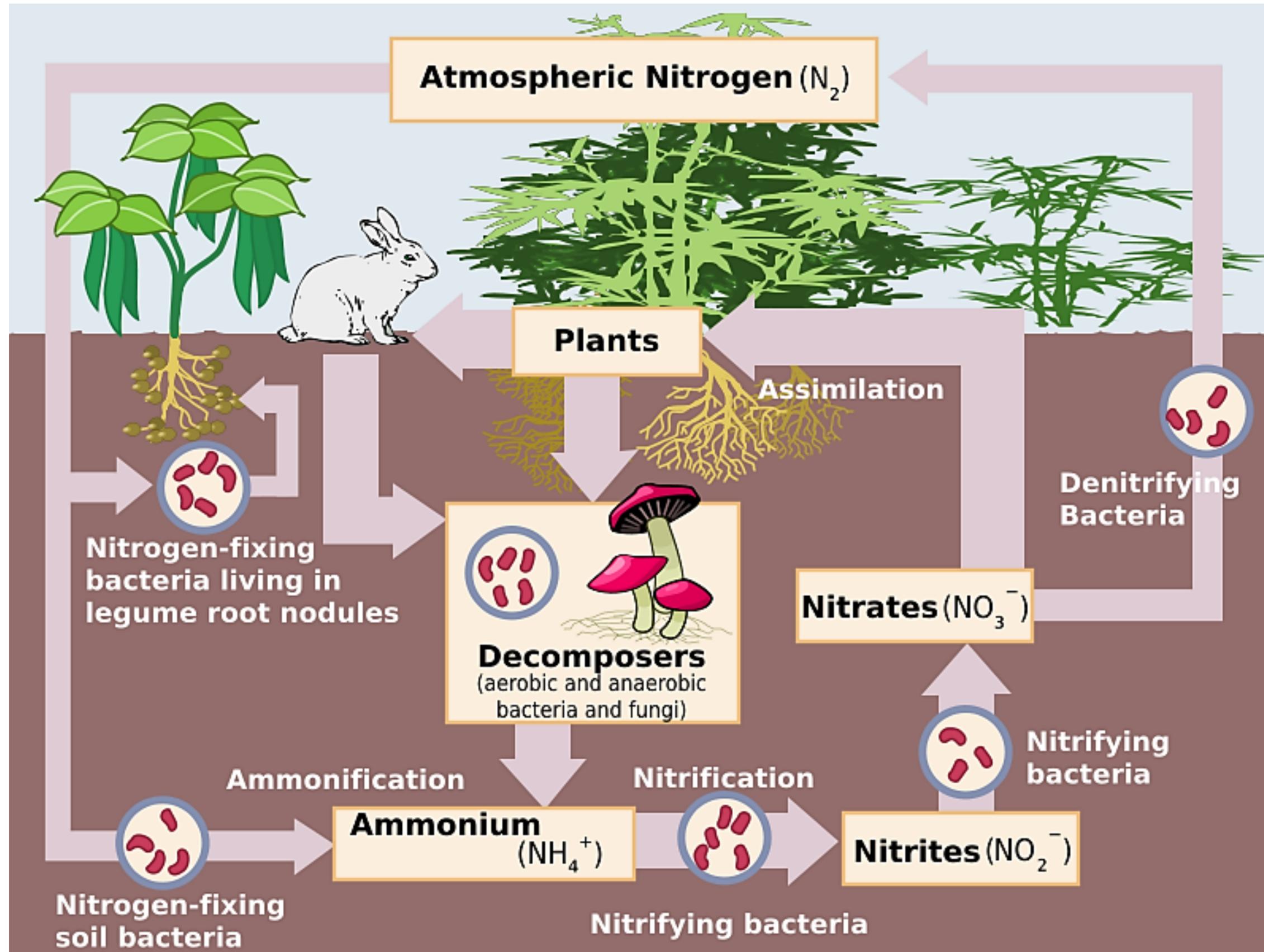
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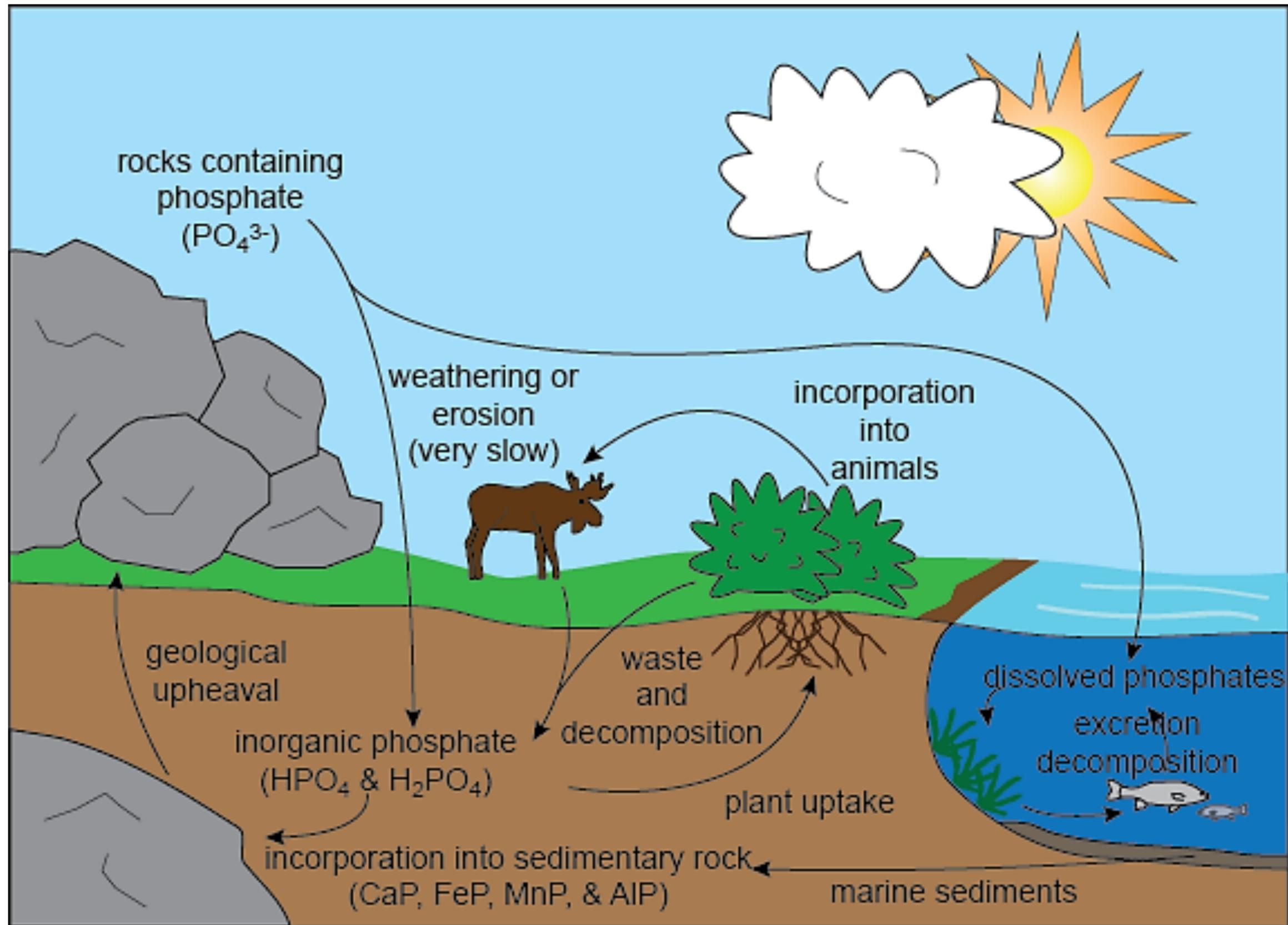


# Changing the Life-Support System

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# Changing the Life-Support System



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*State of the World 2013*

IS

**SUSTAINABILITY**

*Still Possible?*



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If Ecological Footprint calculations are even roughly accurate, humanity is currently consuming the ecological capacity of 1.5 Earths. That suggests that no more than 4.7 billion people could live within the planet's ecological boundaries without substantially reducing average individual consumption.

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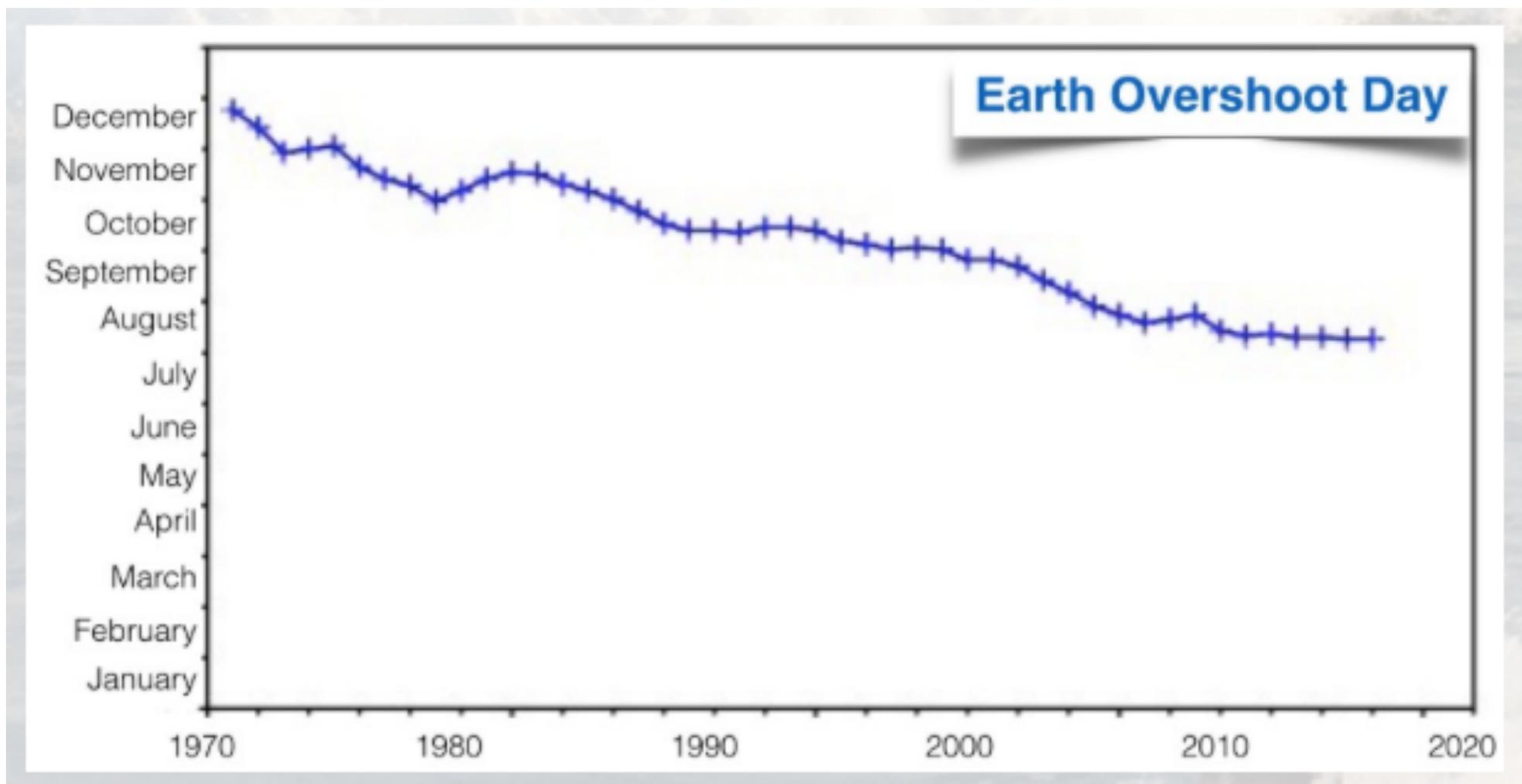


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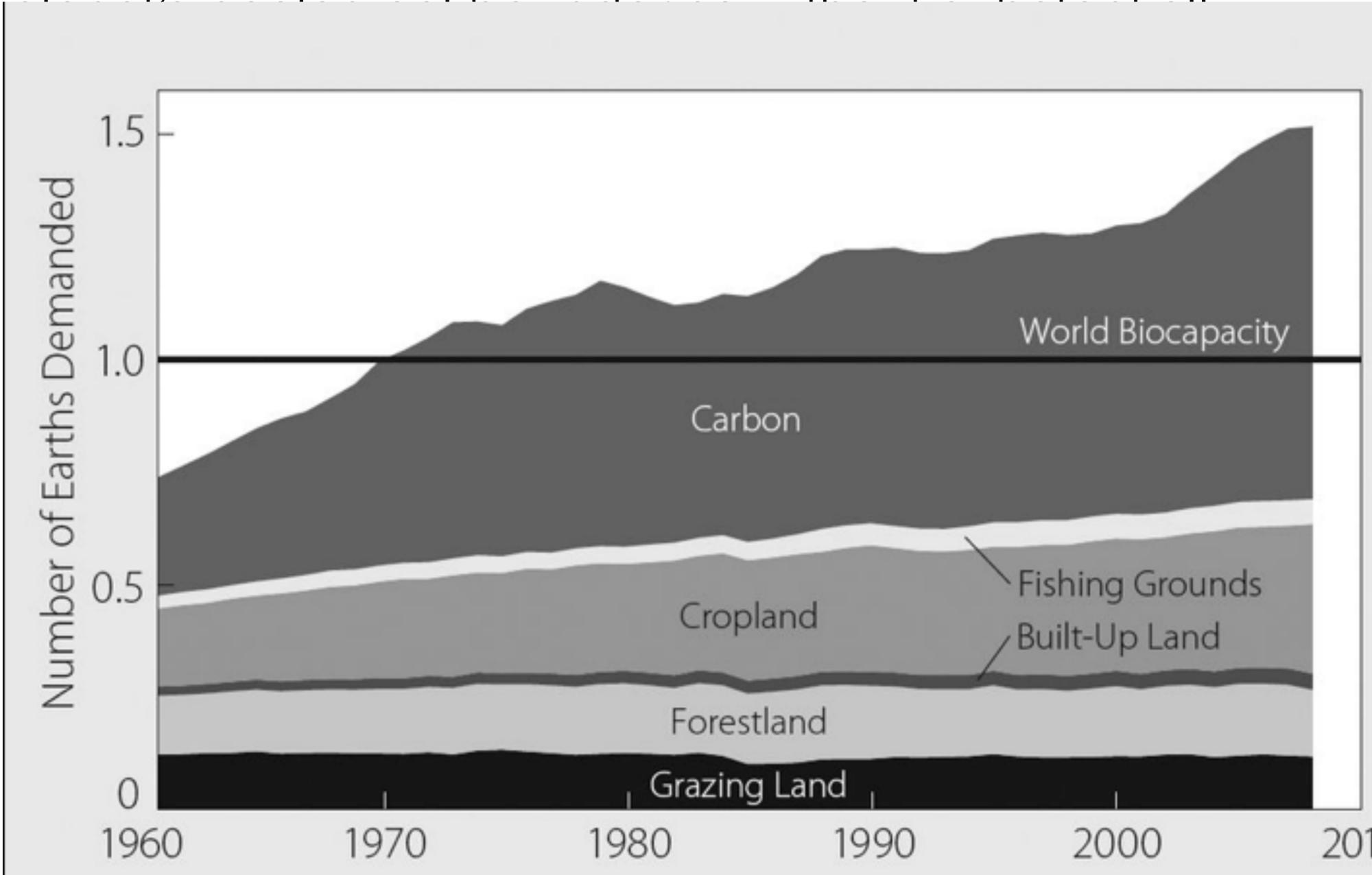
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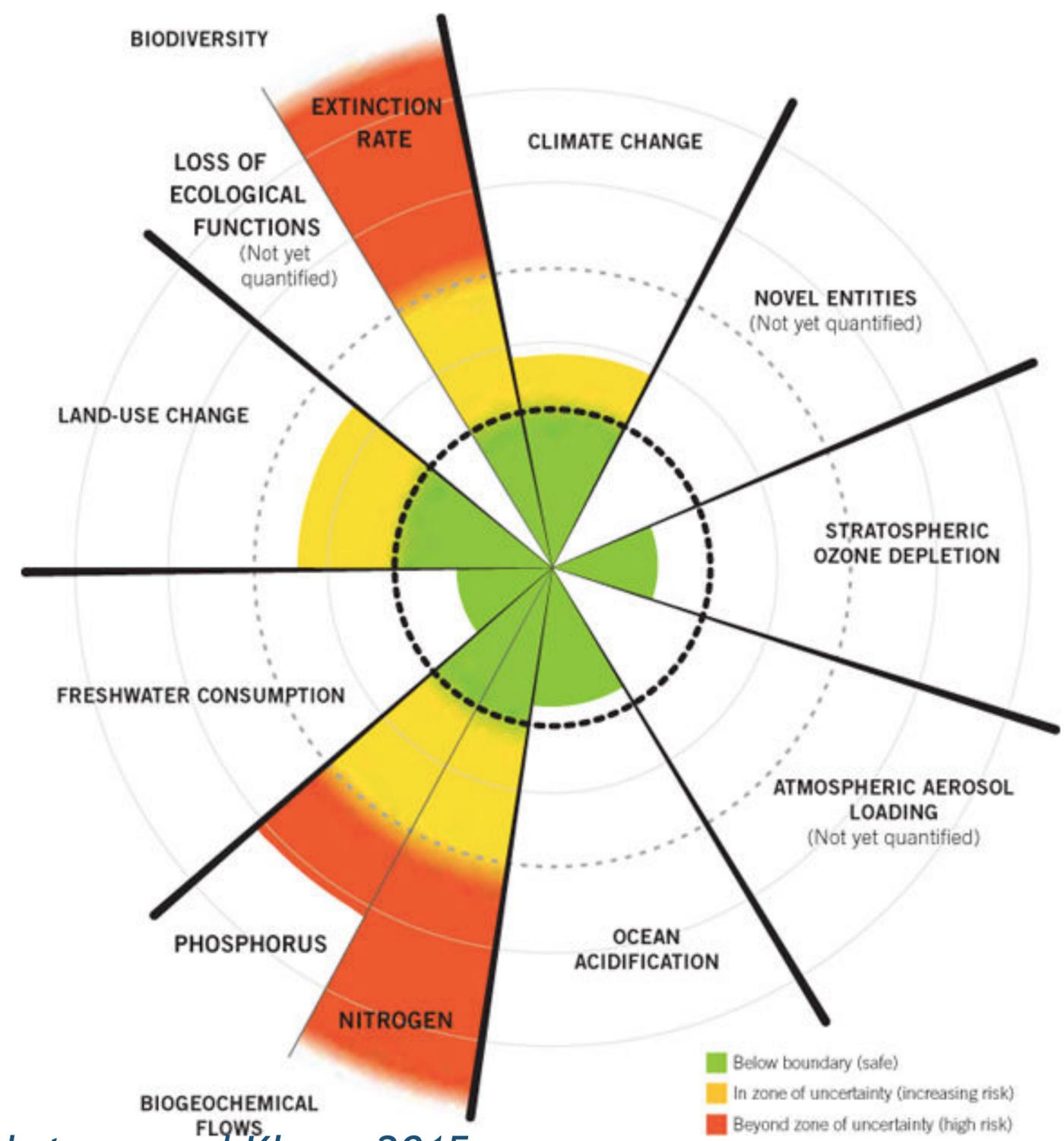
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# Crossing Boundaries



**Table 2-1. The Nine Planetary Boundaries\***

Earth System Process	Parameters	Proposed Boundary	Current Status	Pre-industrial Value
Climate change	(i) Atmospheric carbon dioxide concentration (parts per million by volume)	350	387	280
	(ii) Change in radiative forcing (watts per meter squared)	1	1.5	0
Rate of biodiversity loss	Extinction rate (number of species per million species per year)	10	>100	0.1-1
Nitrogen cycle (part of a boundary with the phosphorus cycle)	Amount of N <sub>2</sub> removed from the atmosphere for human use (millions of tons per year)	35	121	0
Phosphorus cycle (part of a boundary with the nitrogen cycle)	Quantity of P flowing into the oceans (millions of tons per year)	11	8.5-9.5	-1
Stratospheric ozone depletion	Concentration of ozone (Dobson unit)	276	283	290
Ocean acidification	Global mean saturation state of aragonite in surface seawater	2.75	2.90	3.44
Global freshwater use	Consumption of freshwater by humans (km <sup>3</sup> per year)	4,000	2,600	415
Change in land use	Percentage of global land cover converted to cropland	15	11.7	low
Atmospheric aerosol loading	Overall particulate concentration in the atmosphere, on a regional basis		To be determined	
Chemical pollution	For example, amount emitted to, or concentration in, the global environment of persistent organic pollutants, plastics, endocrine disruptors, heavy metals, and nuclear waste, or their effects on the functioning of ecosystems and the Earth System		To be determined	

\*Boundaries of processes in gray have been crossed.  
Source: See endnote 10.

Rockstrom and Klum, 2015

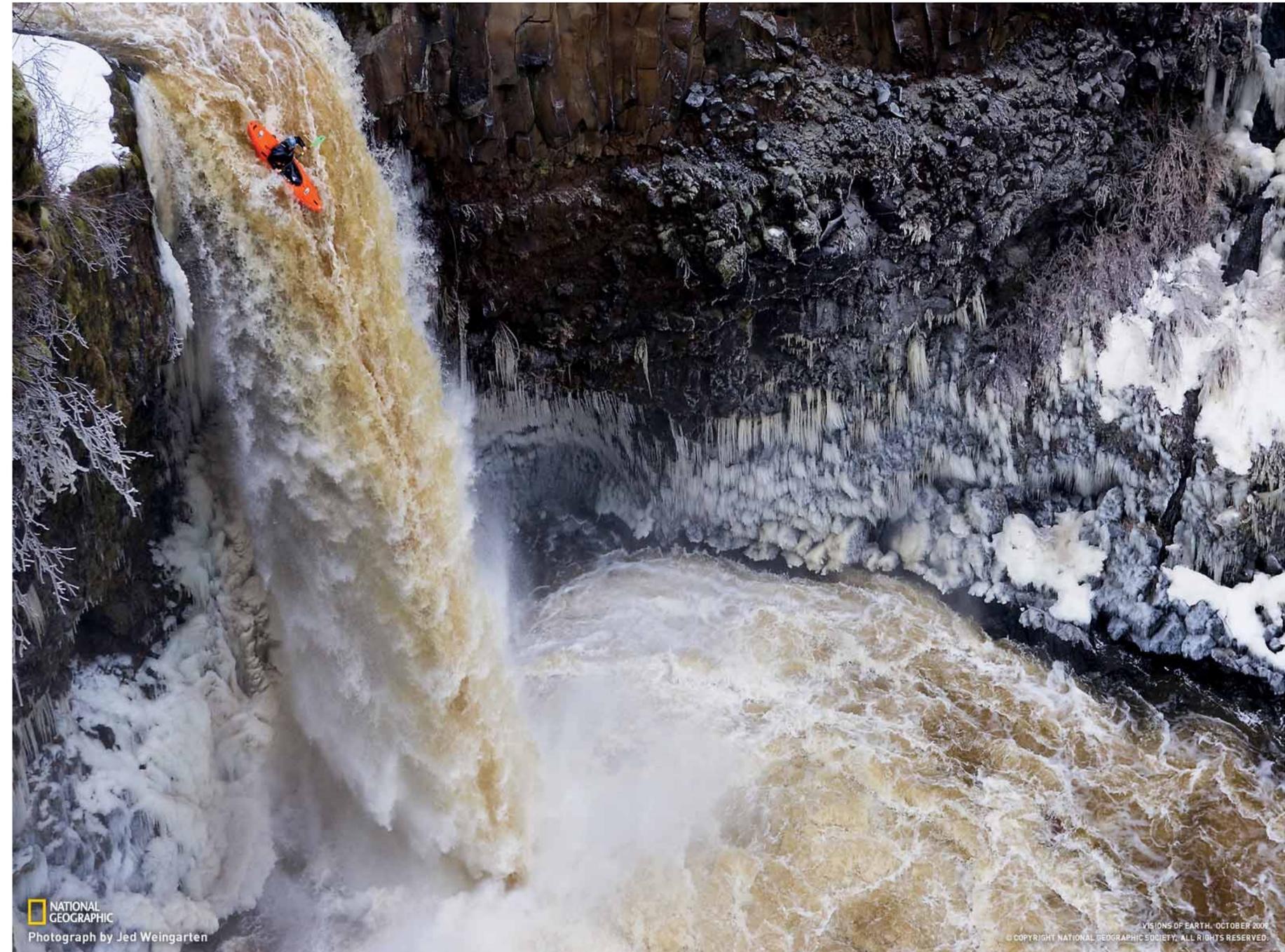
Folke, 2013



## Understanding thresholds

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The threshold is not where the boat goes over the edge, it is far up the river, when the people in the boat lose the option to get to the shore

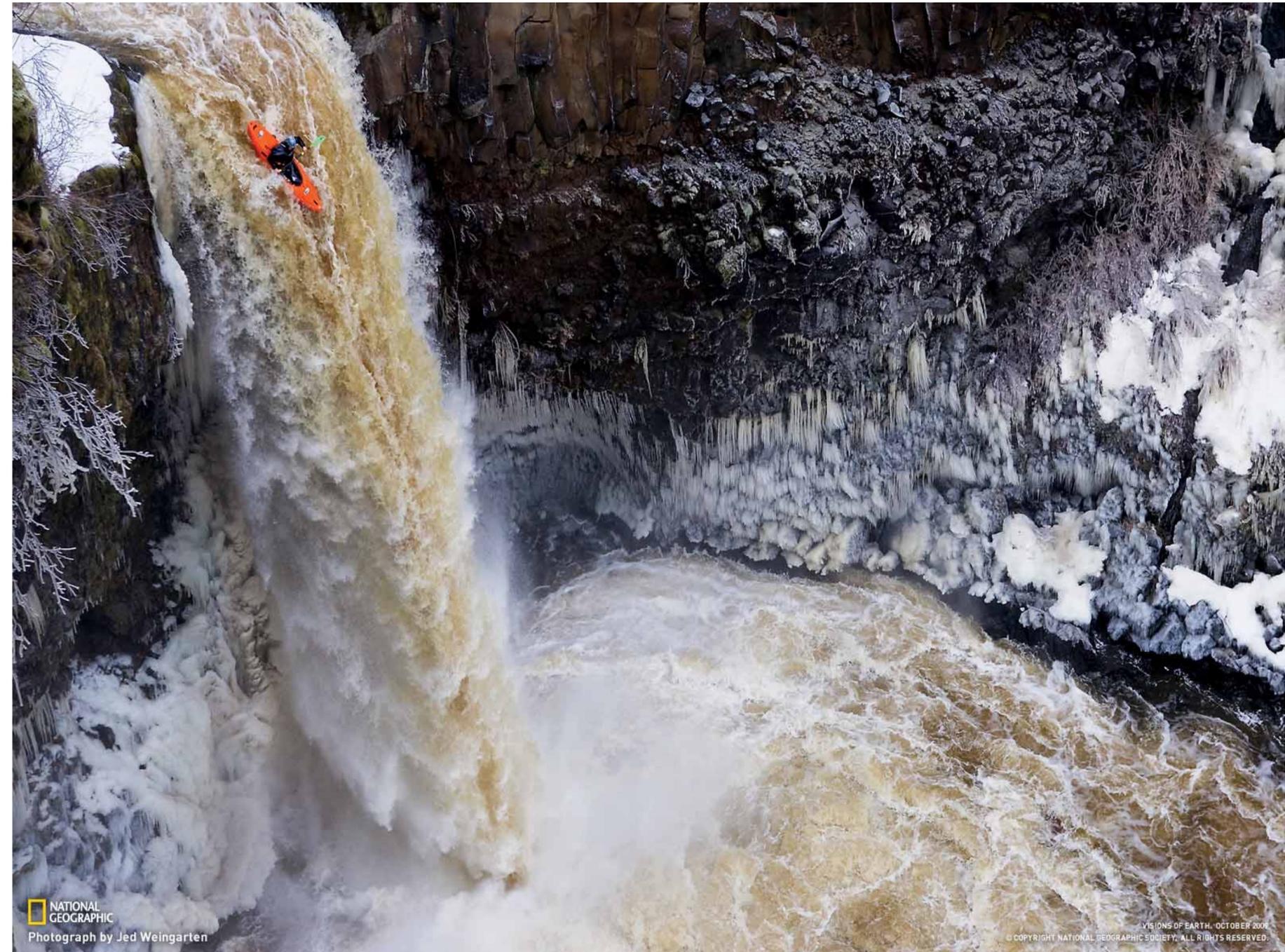


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On a big, unknown river, don't go into the middle, stay close to the shore

*Jim White*



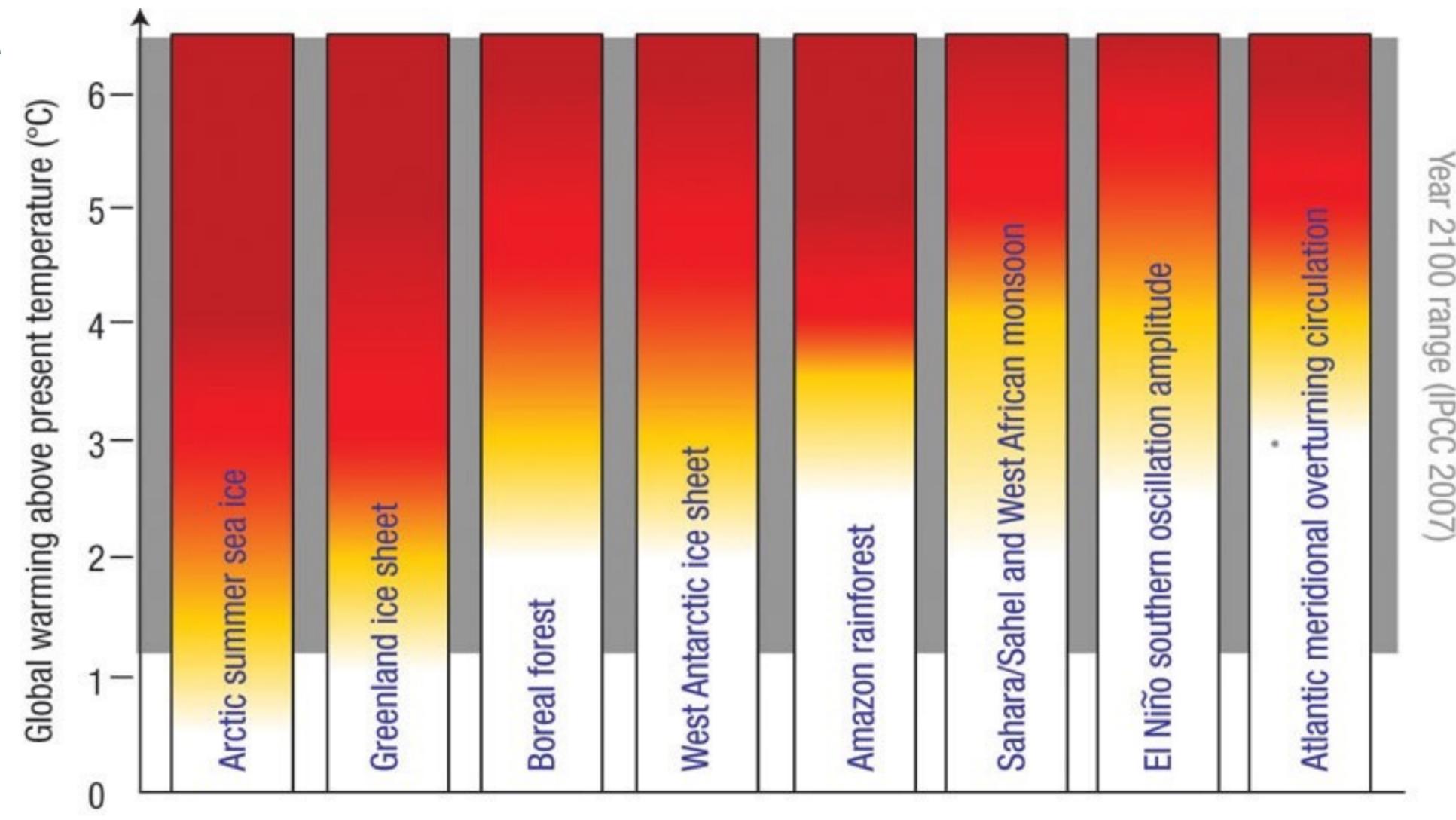
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Many thresholds, including climate change related ones ...



Lenton & Schellnhuber (2007) *Nature Reports Climate Change*

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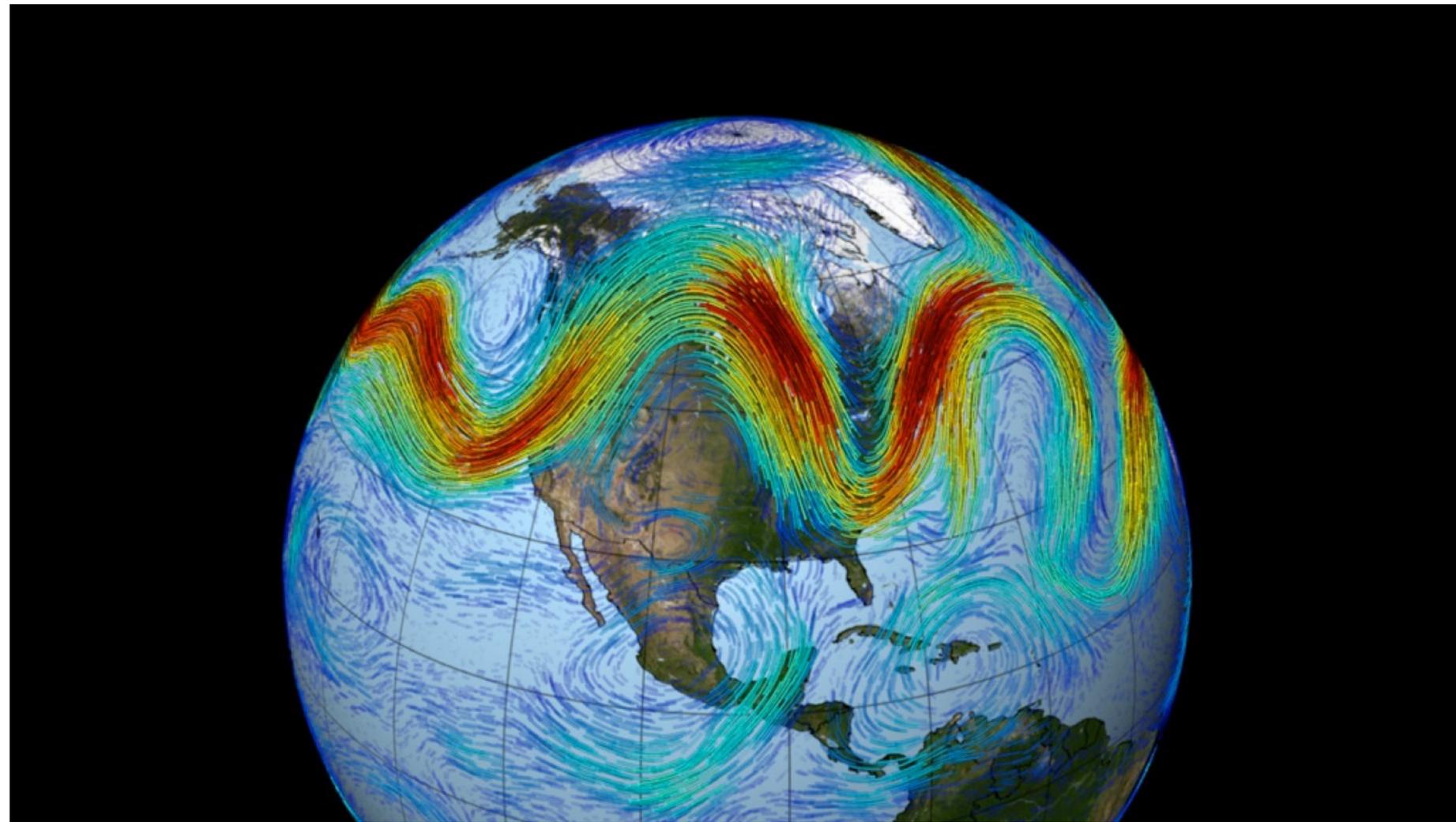
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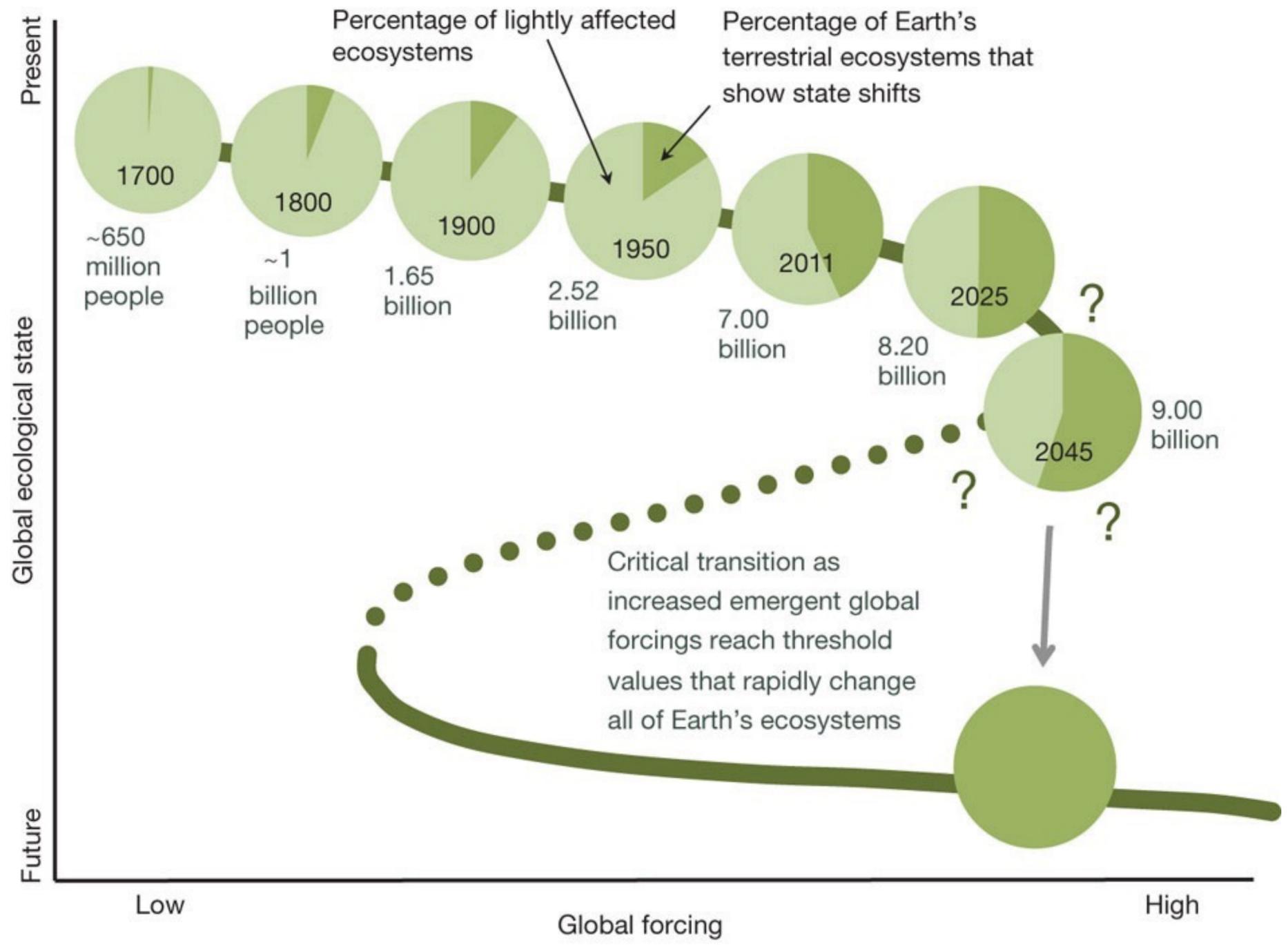
The warming of the Arctic could be a threshold we have crossed ...



*Francis and Vavrus, 2015*

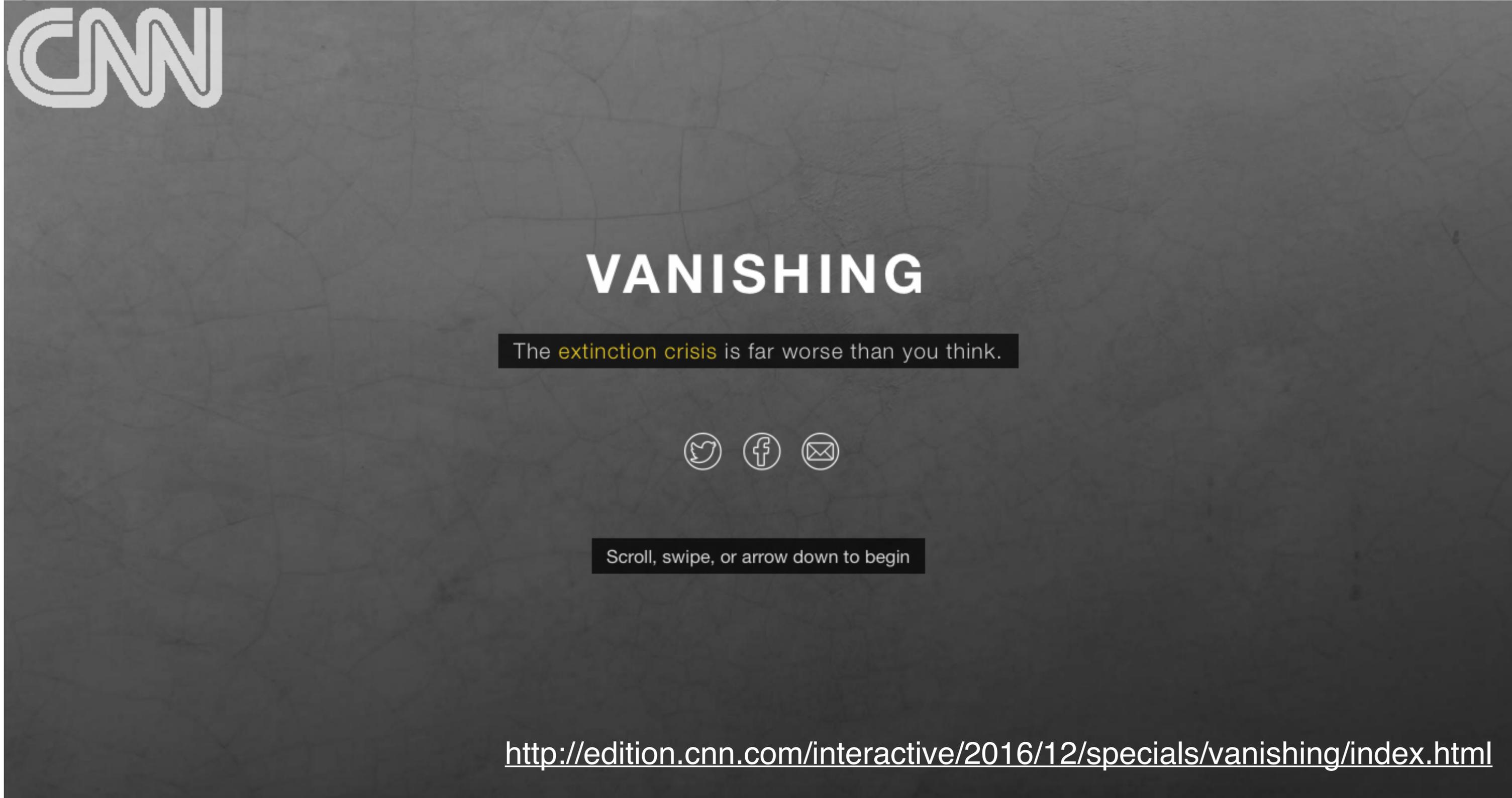


## Crossing thresholds could lead to systemic changes ...



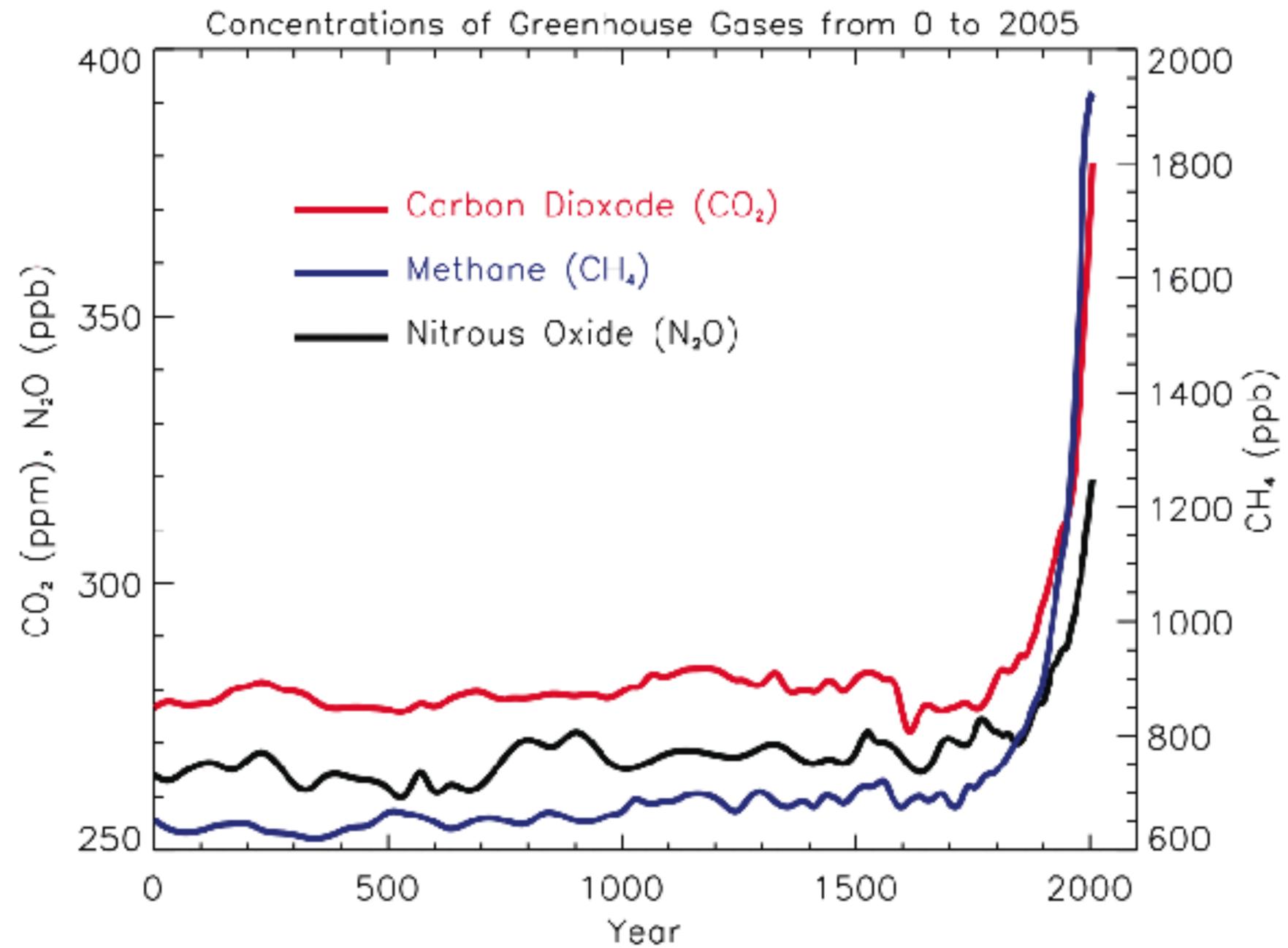
(Generally increases with human population size)

## Crossing thresholds could lead to systemic changes ...



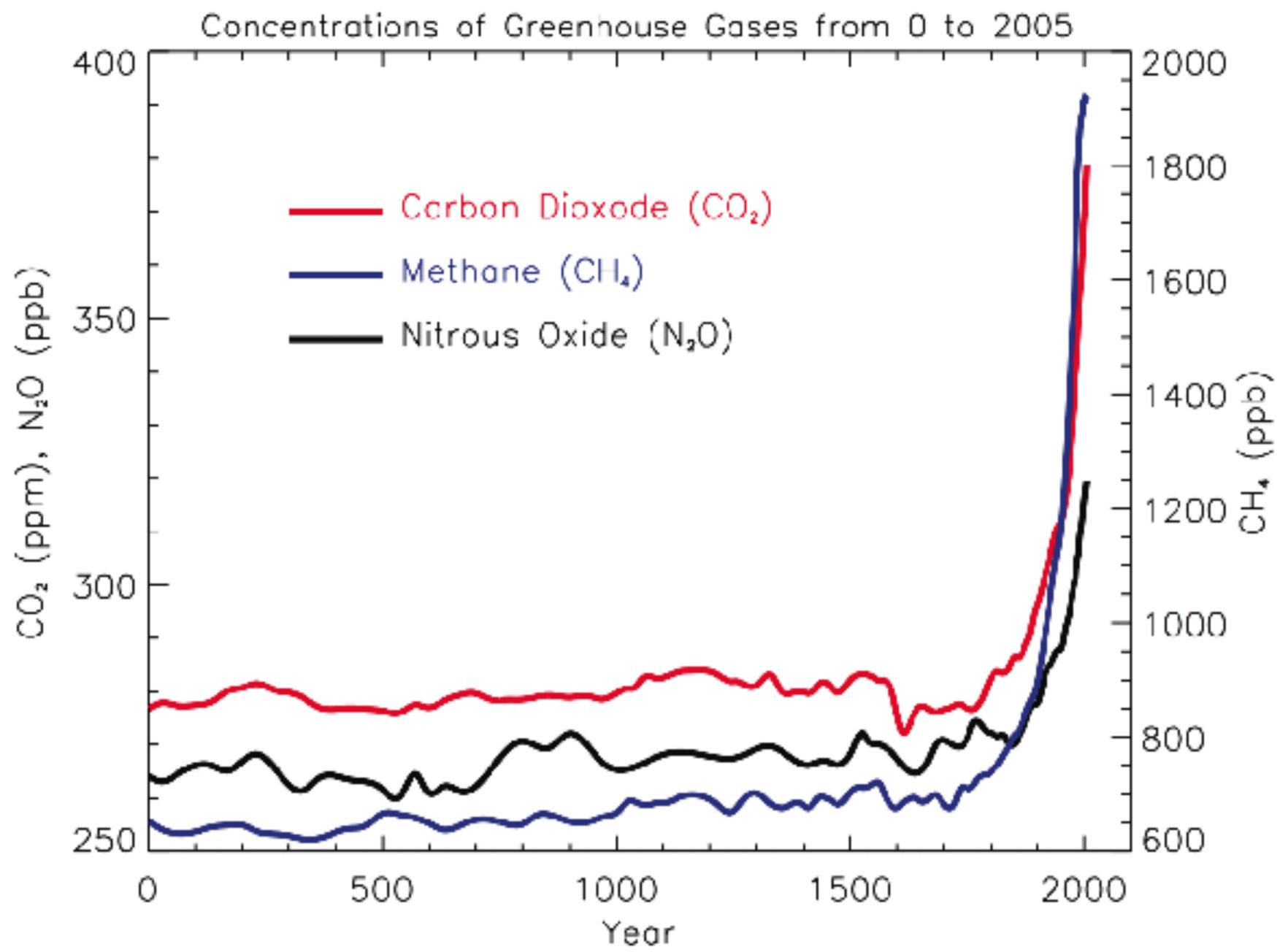


## Changing the chemistry and physics



# Crossing Boundaries

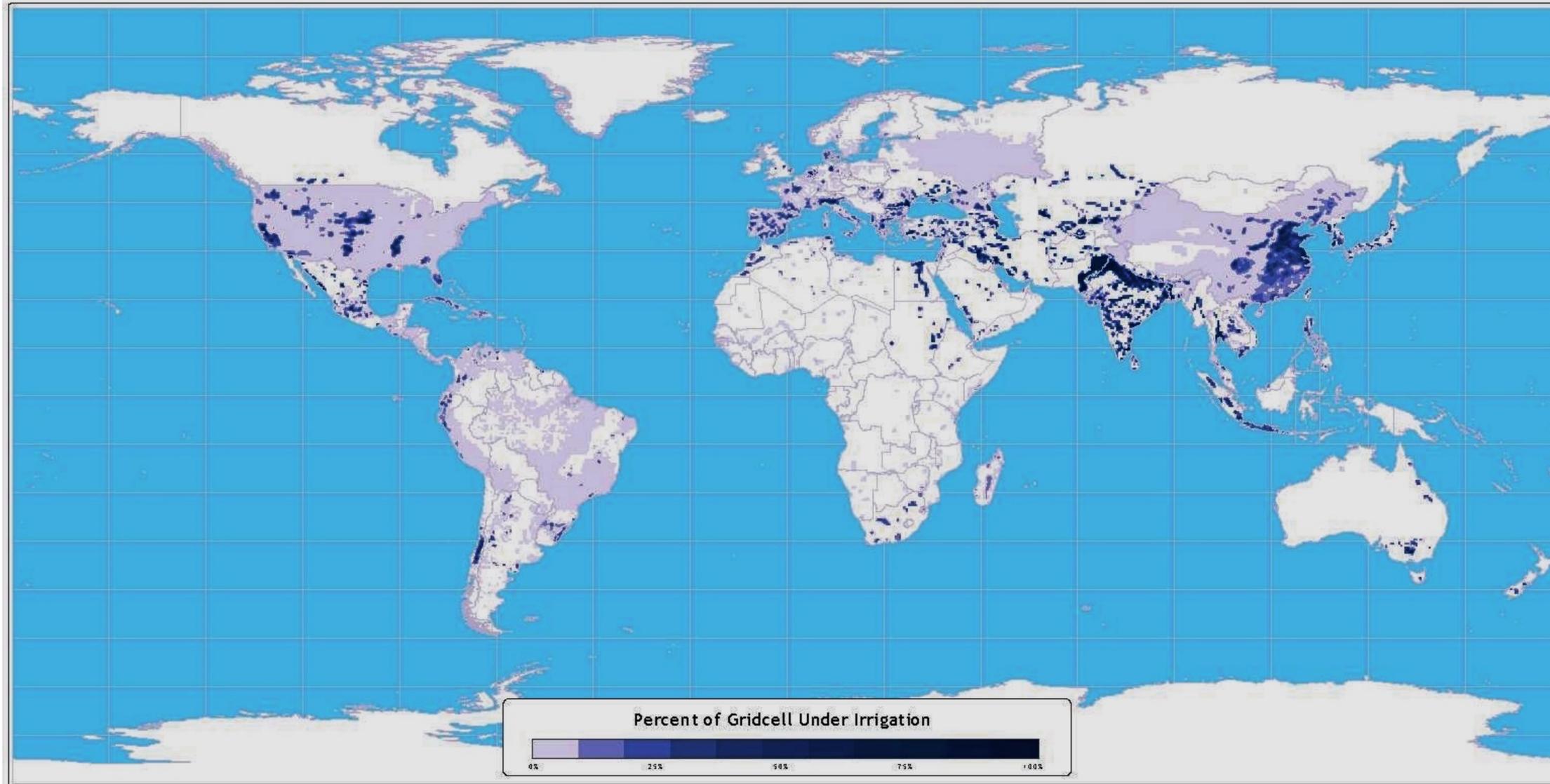
## Changing the chemistry and physics



Pollution: introduction of contaminants into the environment:

- Mercury
- Aluminum
- Lead
- Plastics
- ...

## Irrigated Agricultural Land



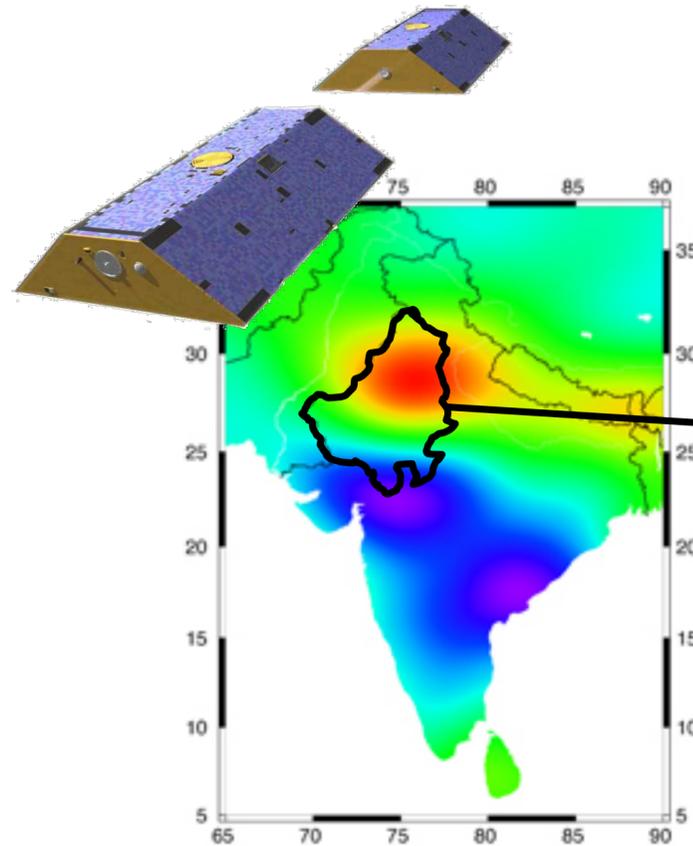
Data taken from: Döll and Siebert (2000) , Siebert and Döll (2001)

**Atlas of the Biosphere**  
Center for Sustainability and the Global Environment  
University of Wisconsin - Madison

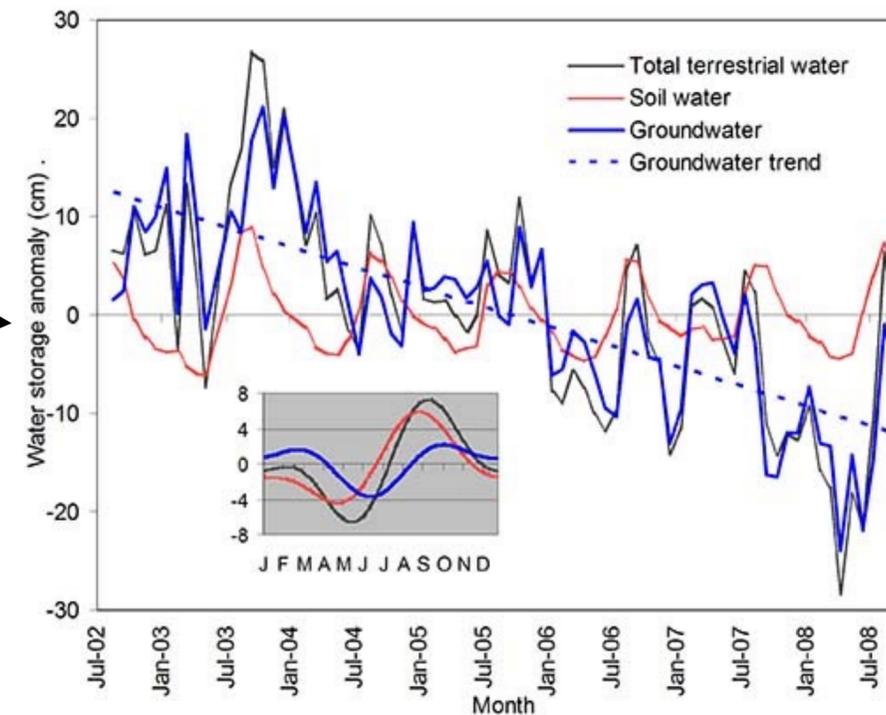
## GRACE Quantifies Massive Depletion of Groundwater in NW India

The water table is declining at an average rate of 33 cm/yr

GRACE is unique among Earth observing missions in its ability to monitor variations in all water stored on land, down to the deepest aquifers.

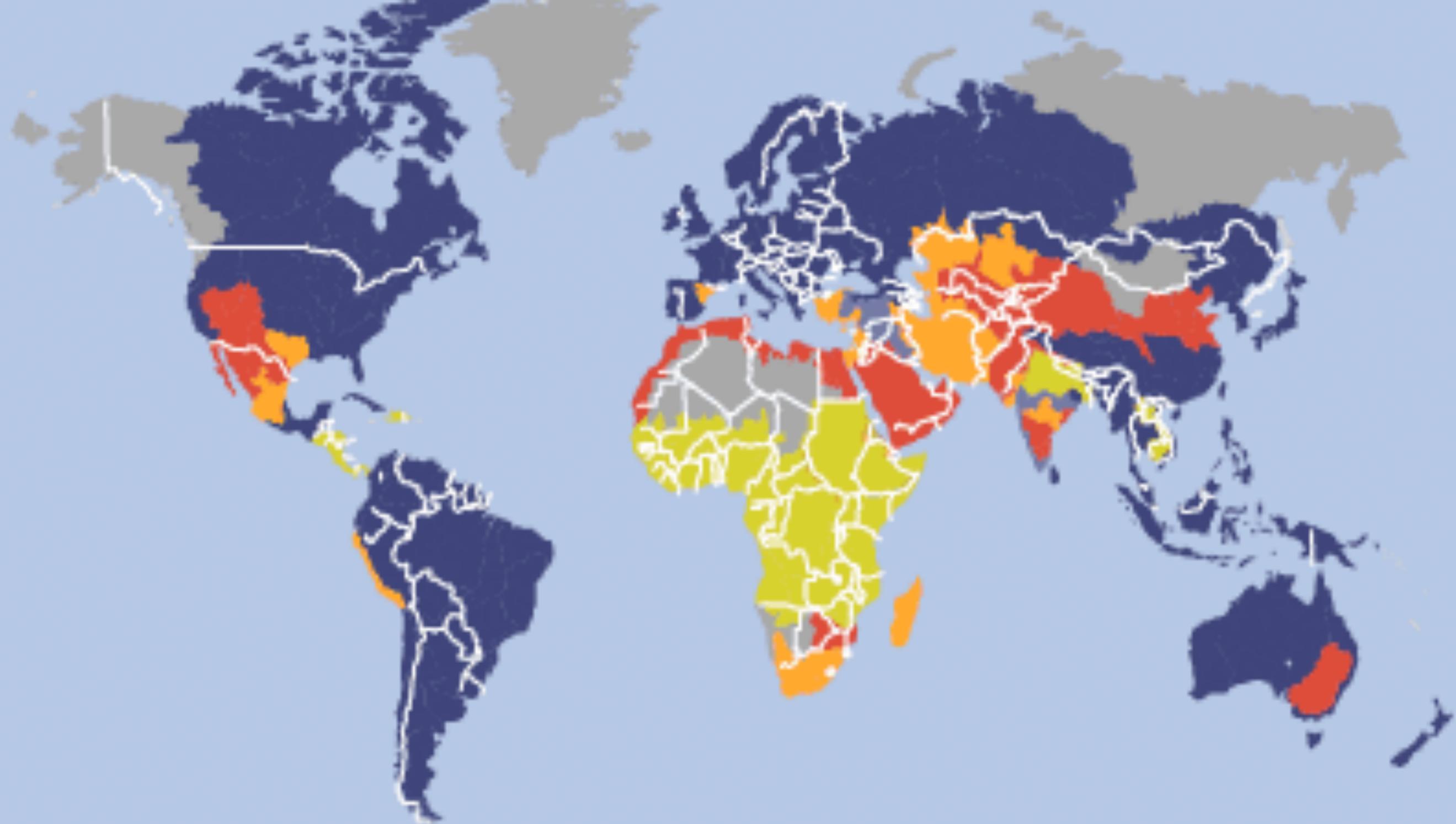


Trends in groundwater storage during 2002-08, with increases in blue and decreases in red. The study region is outlined.



Time series of total water from GRACE, simulated soil water, and estimated groundwater, as equivalent layers of water (cm) averaged over the region. The mean rate of groundwater depletion is 4 cm/yr. Inset: Seasonal cycle.

***During the study period, 2002-08, 109 km<sup>3</sup> of groundwater was lost from the states of Rajasthan, Punjab, and Haryana; triple the capacity of Lake Mead***



■ Little or no water scarcity

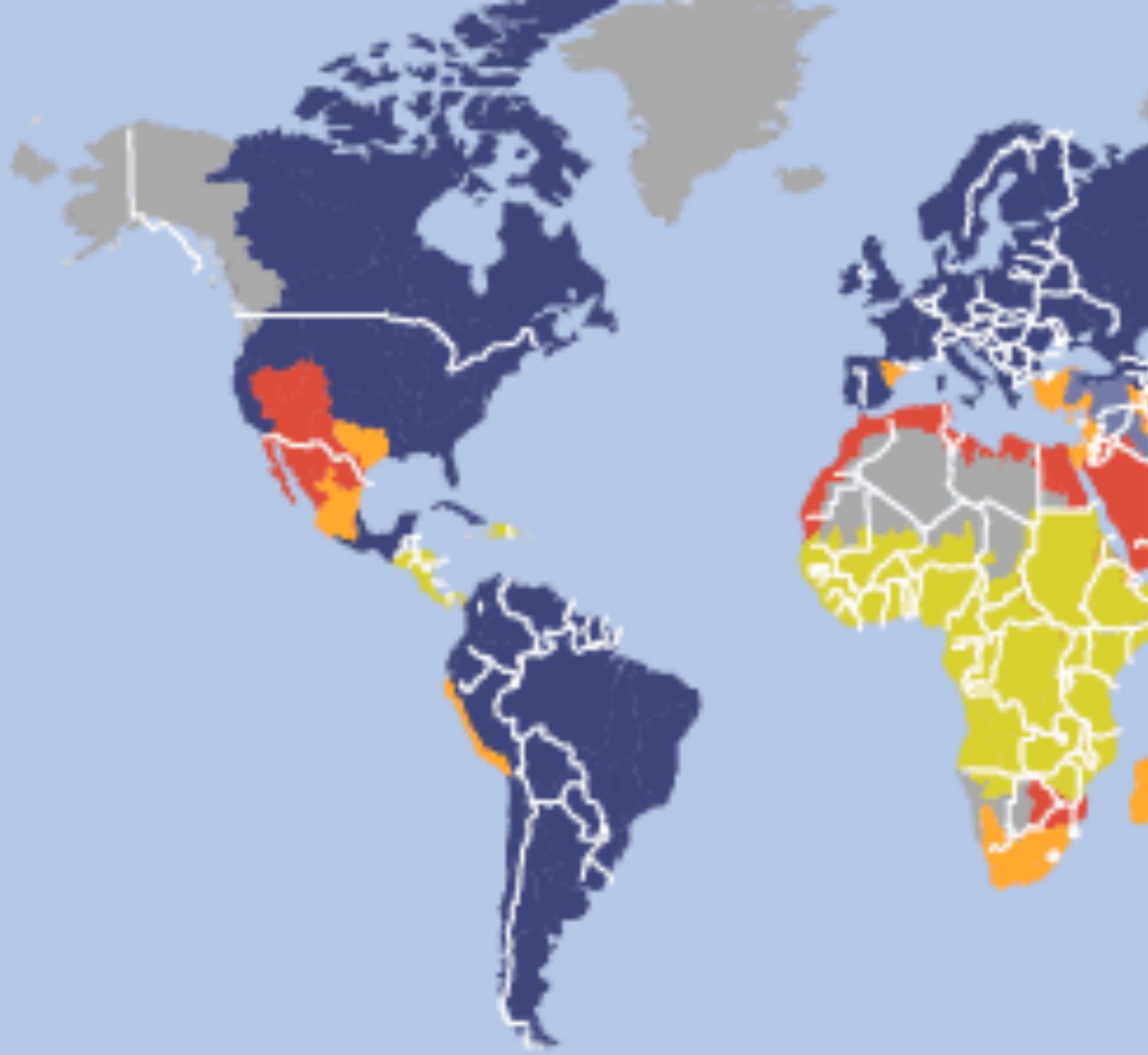
■ Not estimated

■ Approaching physical water scarcity

■ Physical water scarcity

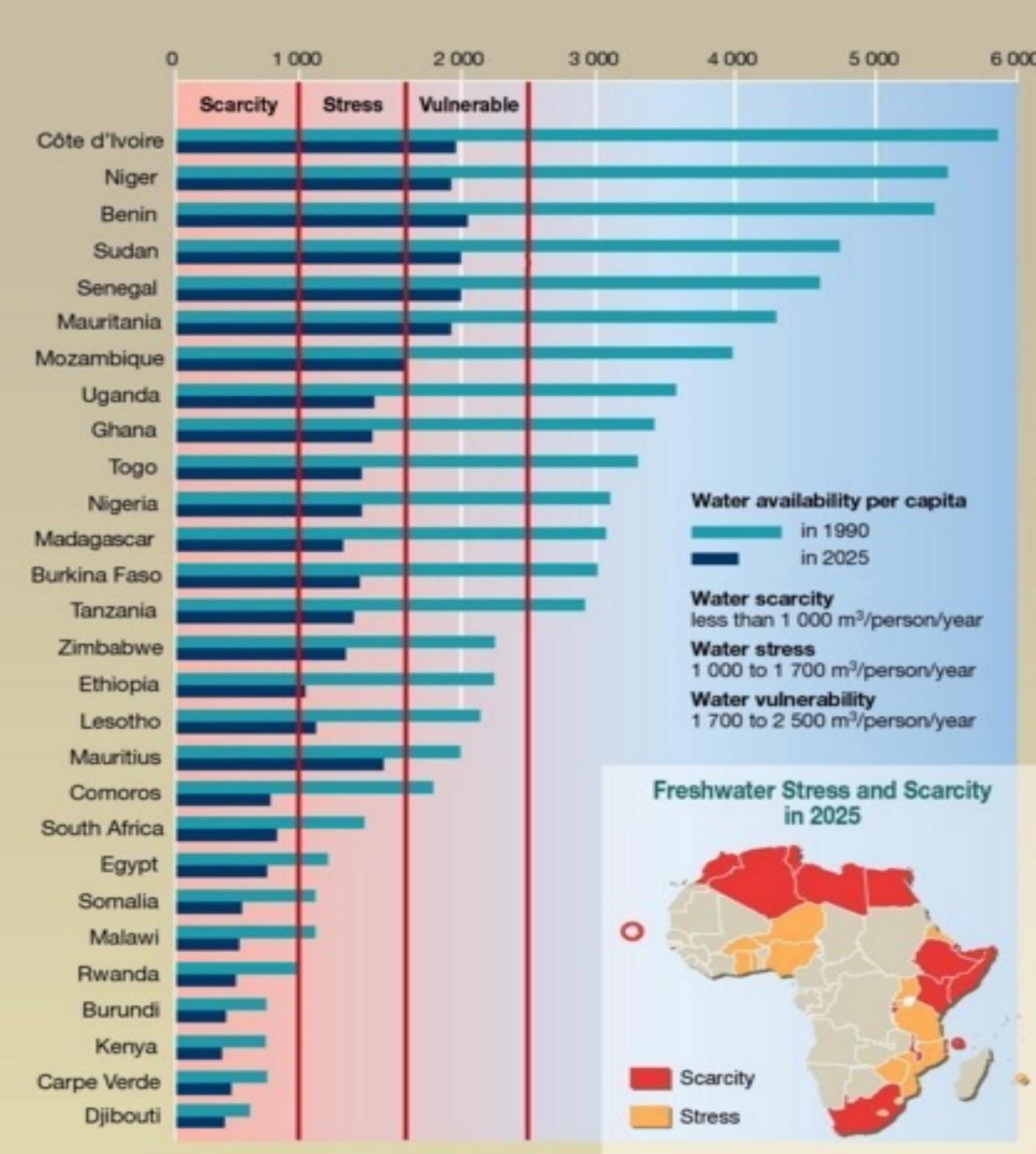
■ Economic water scarcity

Source: International Water Management Institute



■ Little or no water scarcity    ■ Not estimated  
■ Physical water scarcity    ■ Economic water scarcity

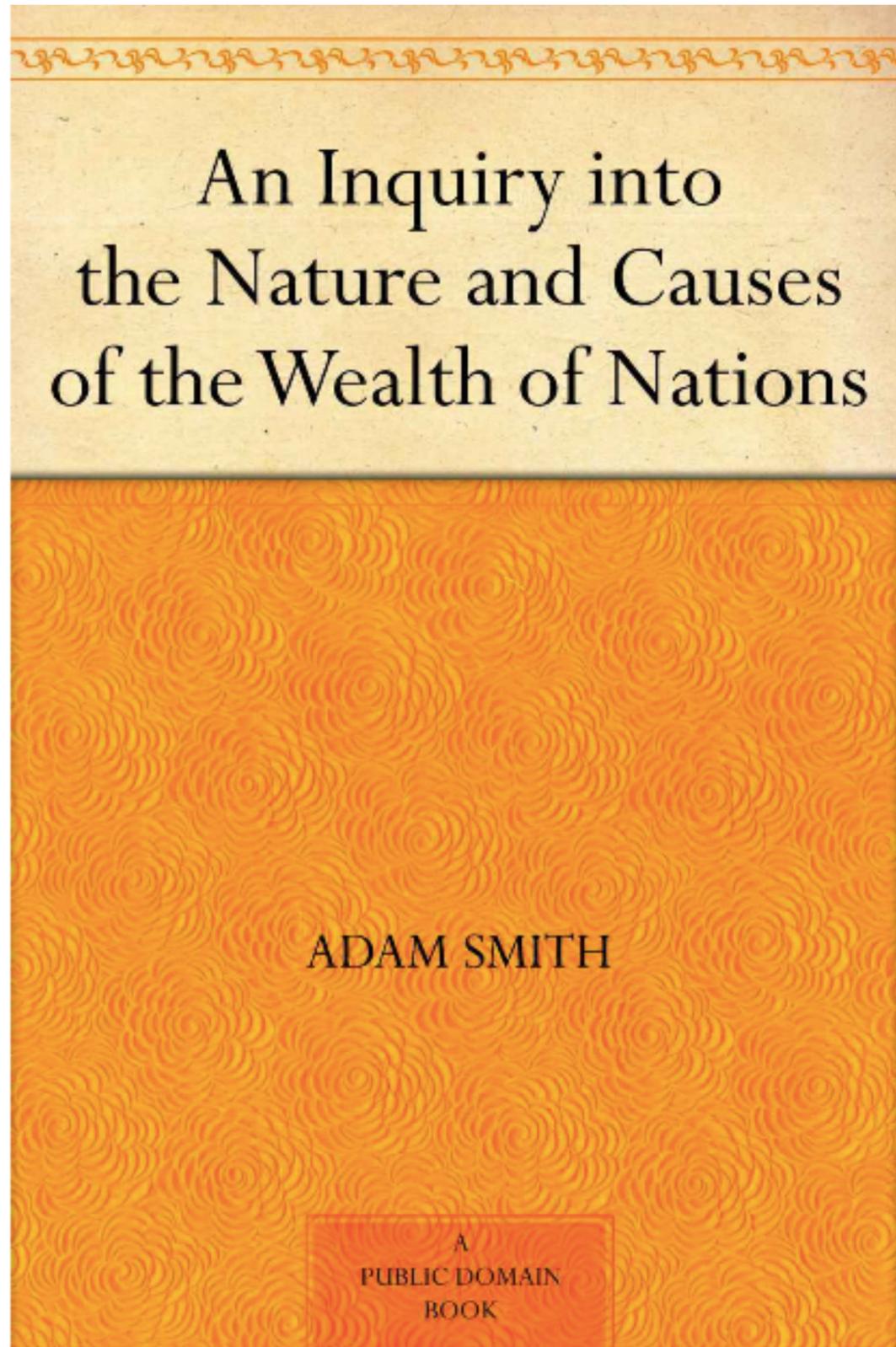
Source: International



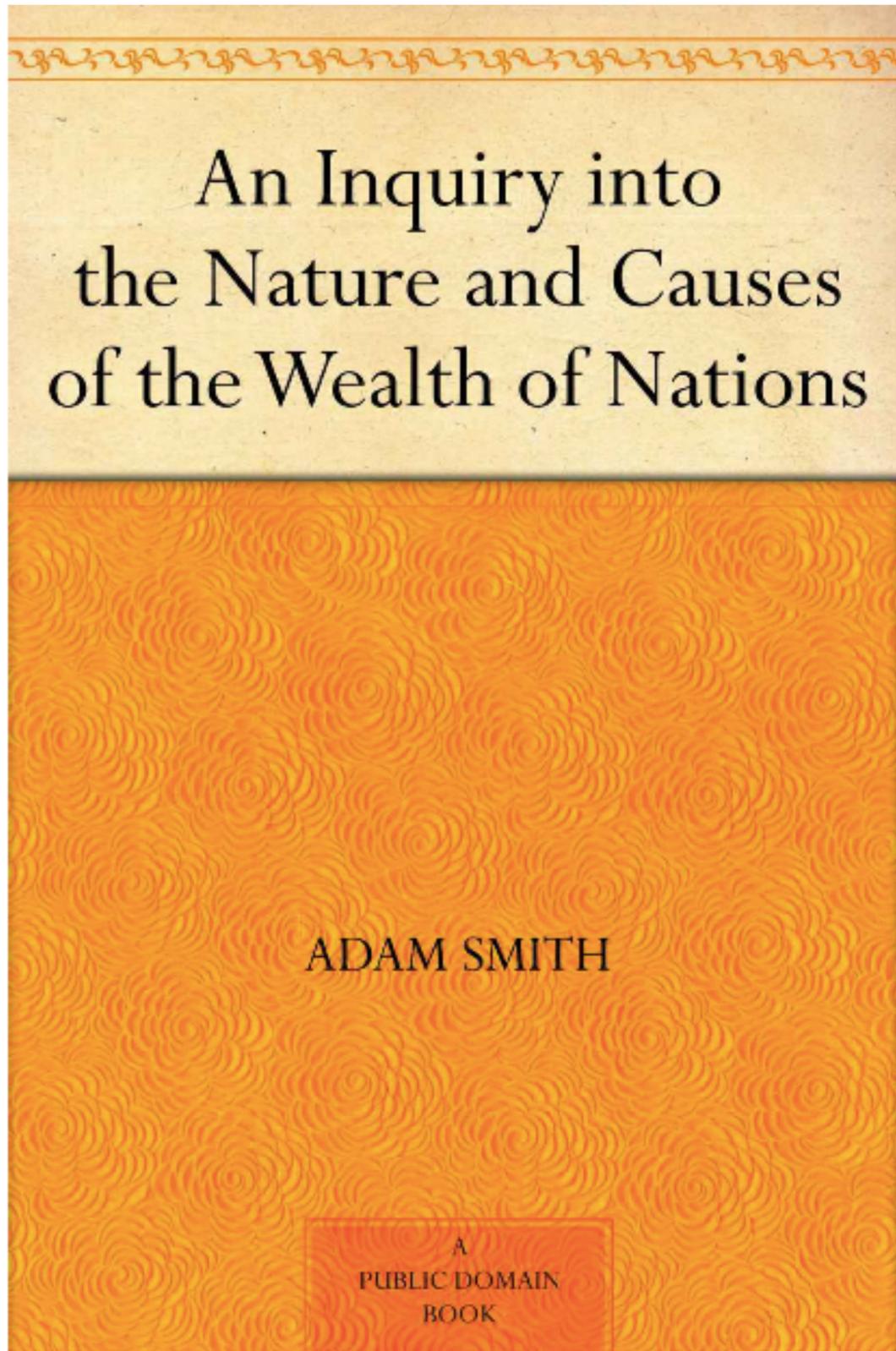
Source: United Nations Economic Commission for Africa (UNECA), Addis Abeba; Global Environment Outlook 2000 (GEO), UNEP, Earthscan, London, 1999.

PHILIPPE REKACEWICZ  
MAY 2002





*Published in 1776*



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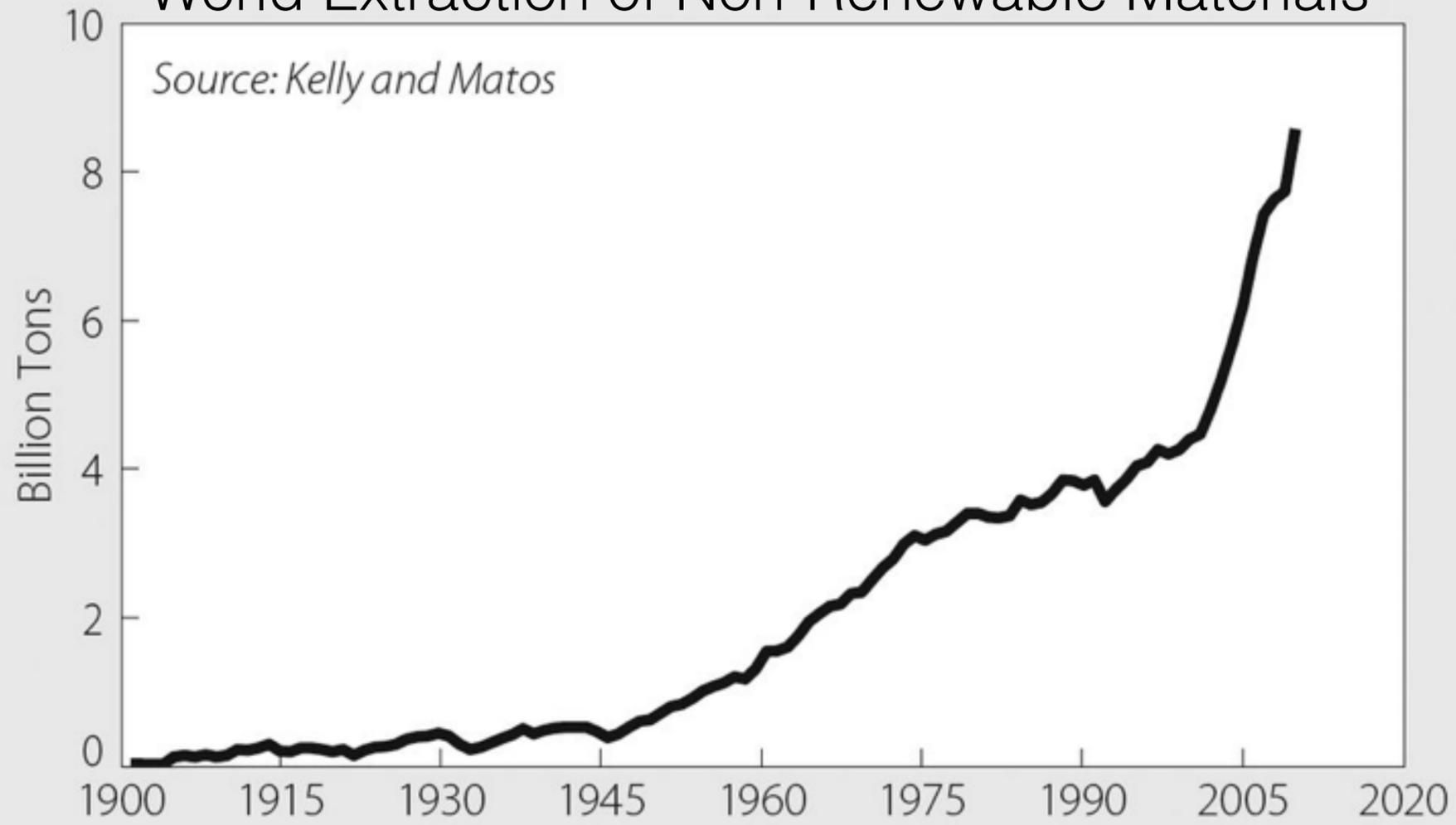
The current mainstream model of the global economy is based on a number of assumptions about the way the world works, what the economy is, and what the economy is for. These assumptions arose in an earlier period, when the world was relatively empty of humans and their artifacts. Built capital was the limiting factor, while natural capital was abundant. It made sense not to worry too much about environmental “externalities,” since they could be assumed to be relatively small and ultimately solvable. It also made sense to focus on the growth of the market economy, as measured by gross domestic product (GDP), as a primary means to improve human welfare. And it made sense to think of the economy as only marketed goods and services and to think of the goal as increasing the amount of these that were produced and consumed.

The Worldwatch Institute. State of the World 2013: Is Sustainability Still Possible? (Kindle Locations 2921-2927). Island Press. Kindle Edition.



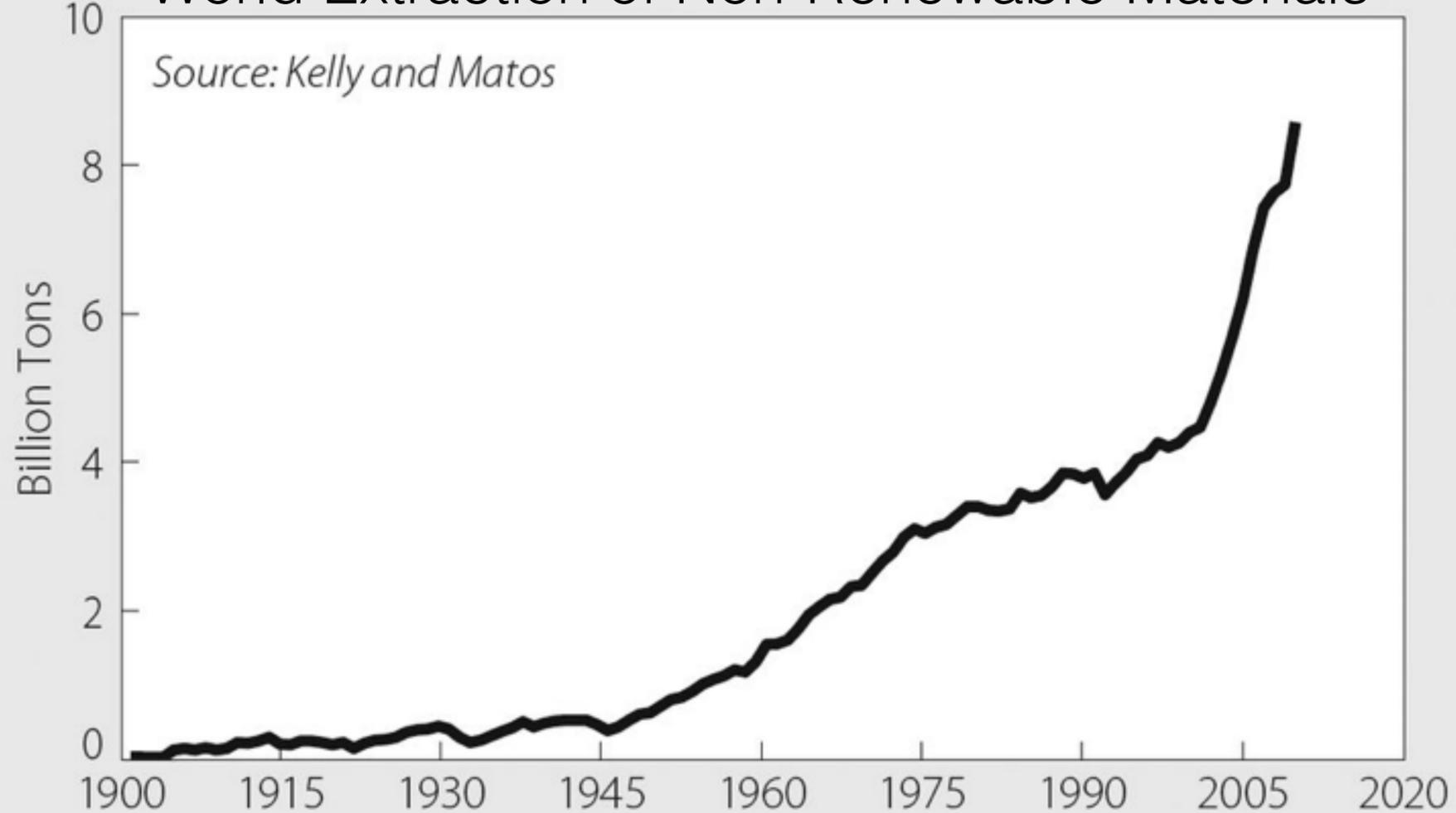
## World Extraction of Non-Renewable Materials

Source: Kelly and Matos



## World Extraction of Non-Renewable Materials

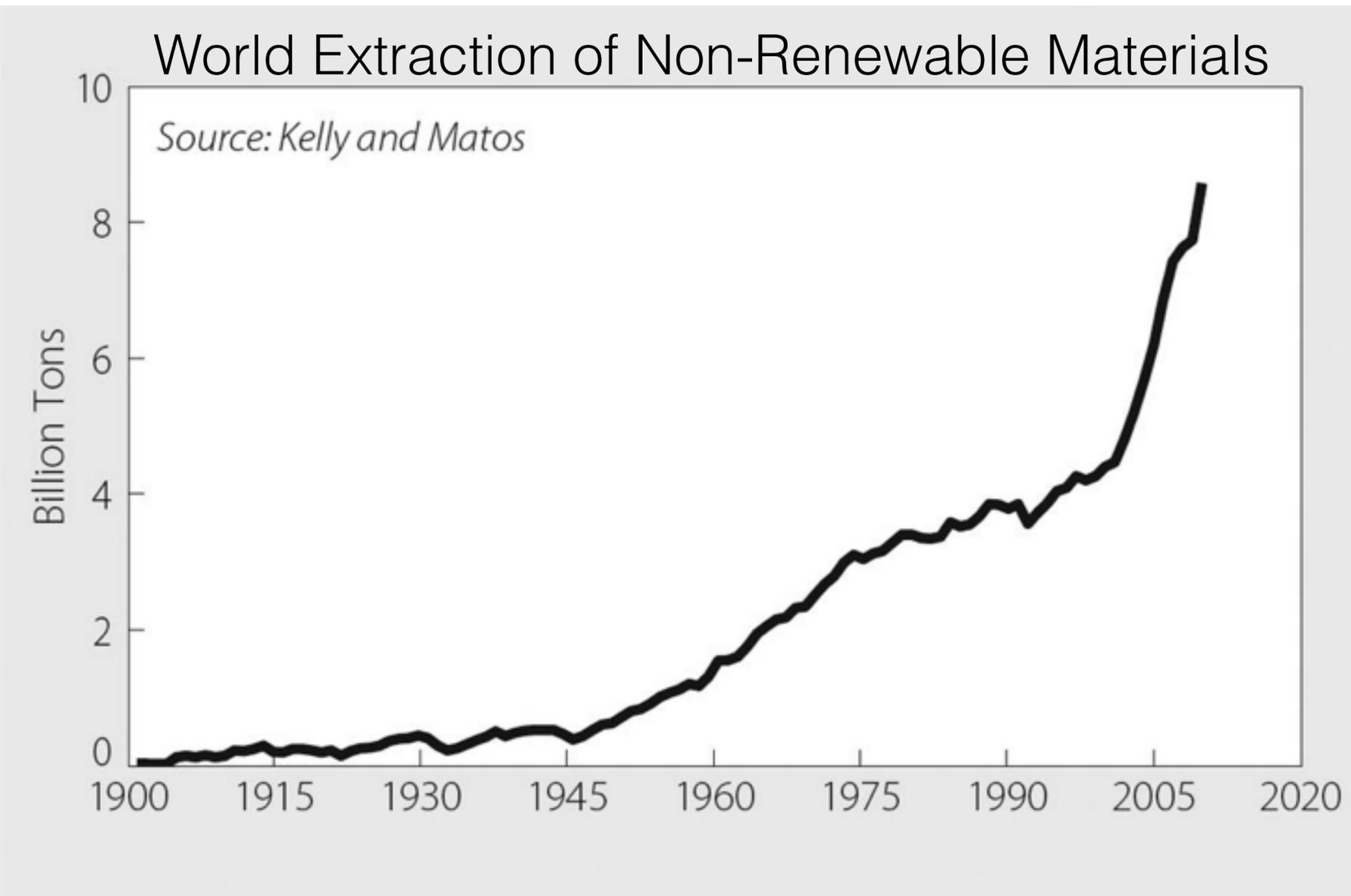
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In 2008, people around the world used 68 billion tons of materials, including metals and minerals, fossil fuels, and biomass. That is an average of 10 tons per person— or 27 kilograms each and every day. That same year, humanity used the biocapacity of 1.5 planets, consuming far beyond what the Earth can sustainably provide.

*Assadourian, 2013*

# Role of Economy



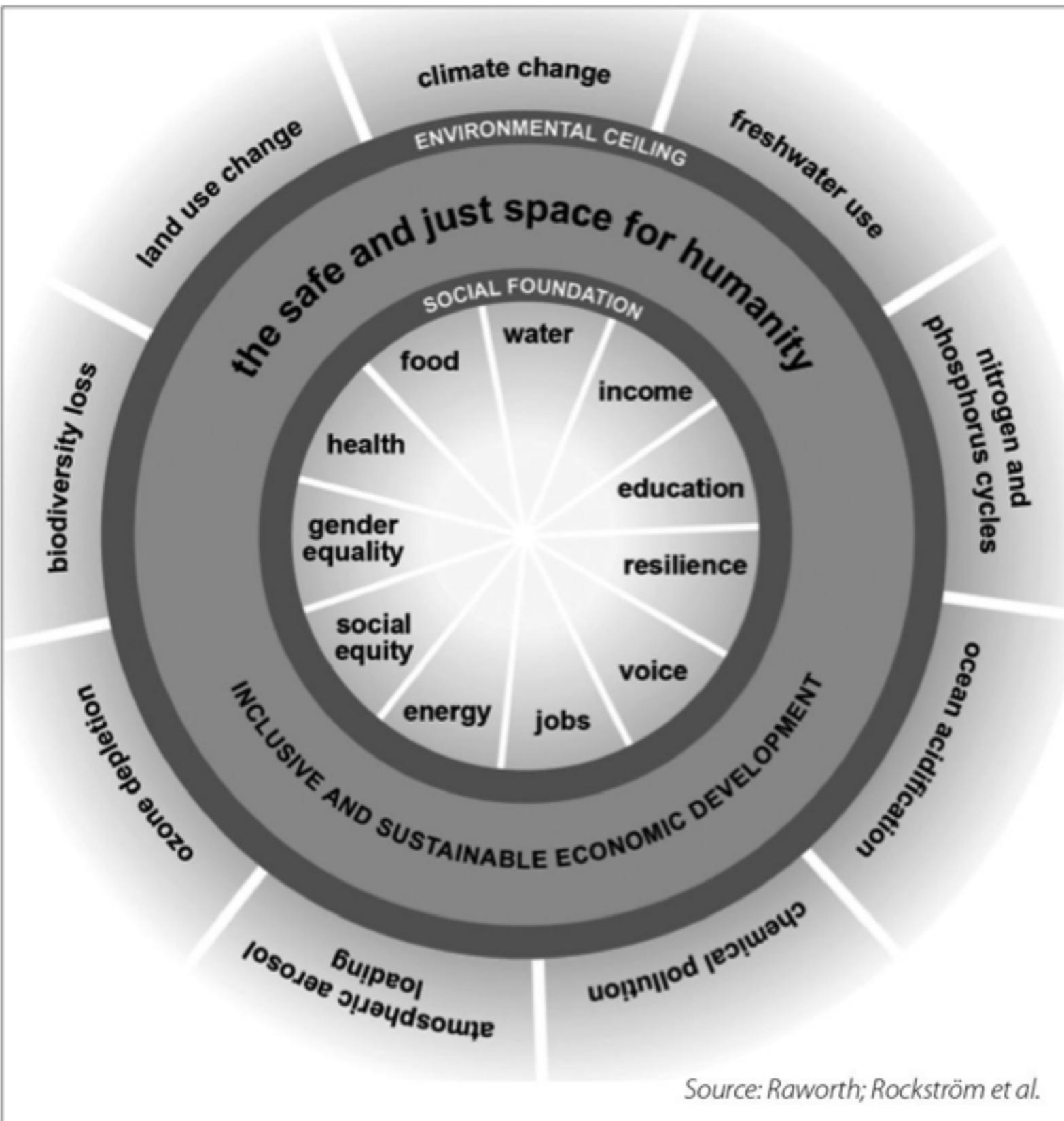
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The urban population in the developing world will double by 2030. The implications are staggering. One is that we have 20 years to build as much urban housing as was built in the past 6,000.

*Reinhard Goethert, School of Architecture and Planning, MIT, 2010.*

# Role of Economy

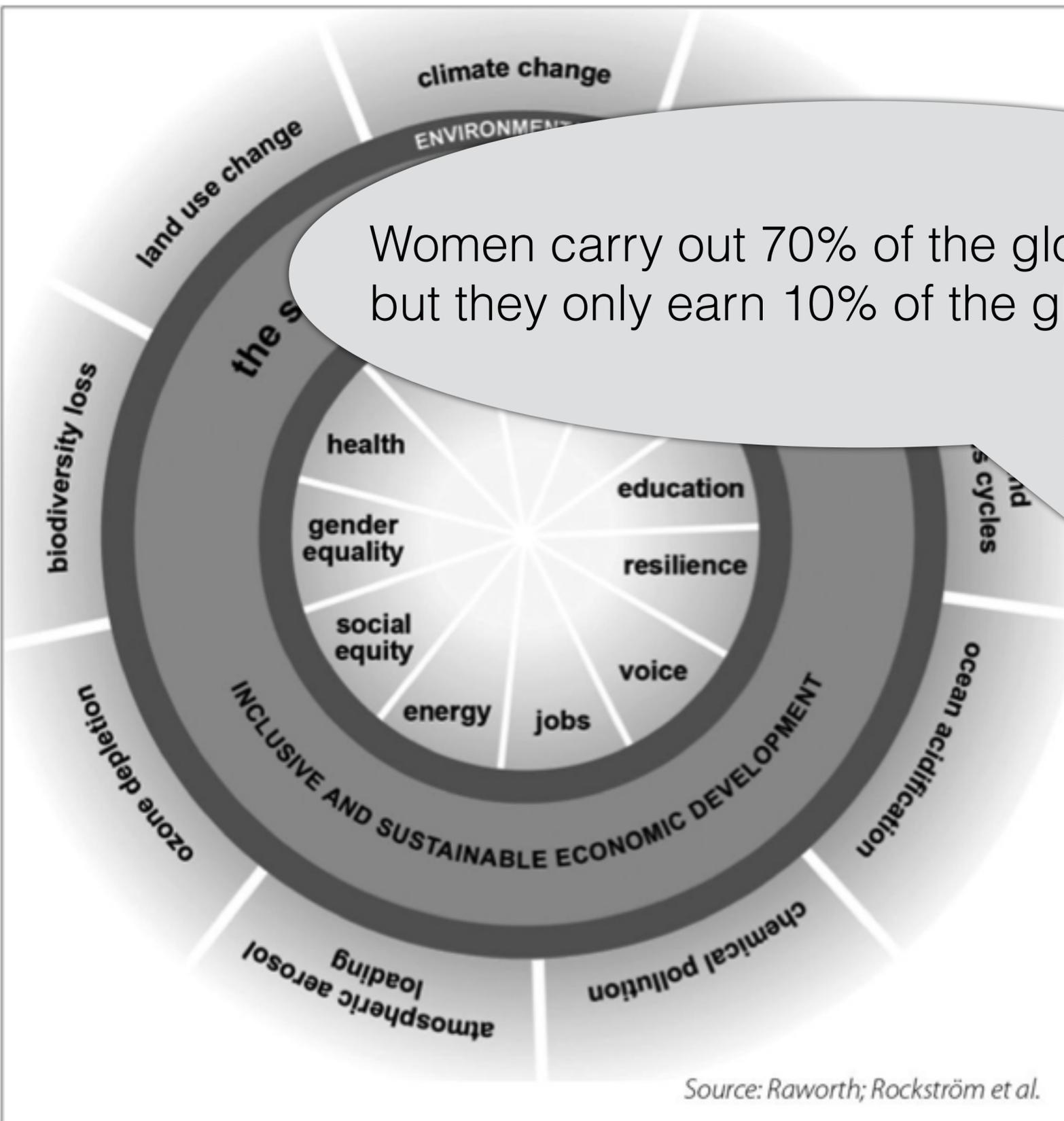


Social Foundation	Illustrative Indicators of Global Deprivation	Share of Population (percent)	Year
Food security	Population undernourished	13	2010–12
Income	Population living below \$1.25 (purchasing power parity) per day	21	2005
Water and sanitation	Population without access to an improved drinking water source	13	2008
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Health care	Population without regular access to essential medicines	30	2004
Education	Children not enrolled in primary school	10	2009
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Energy	Population lacking access to electricity	19	2009
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Gender equality	Employment gap between women and men in waged work (excluding agriculture)	34	2009
	Representation gap between women and men in national parliaments	77	2011
Social equity	Population living in countries with significant income inequality	33	1995–2009
Voice	Population living in countries perceived (in surveys) not to permit political participation or freedom of expression	To be determined	
Jobs	Labor force not employed in decent work	To be determined	
Resilience	Population facing multiple dimensions of poverty	To be determined	

Source: See endnote 8.

# Role of Economy

Women carry out 70% of the global work hours but they only earn 10% of the global salary

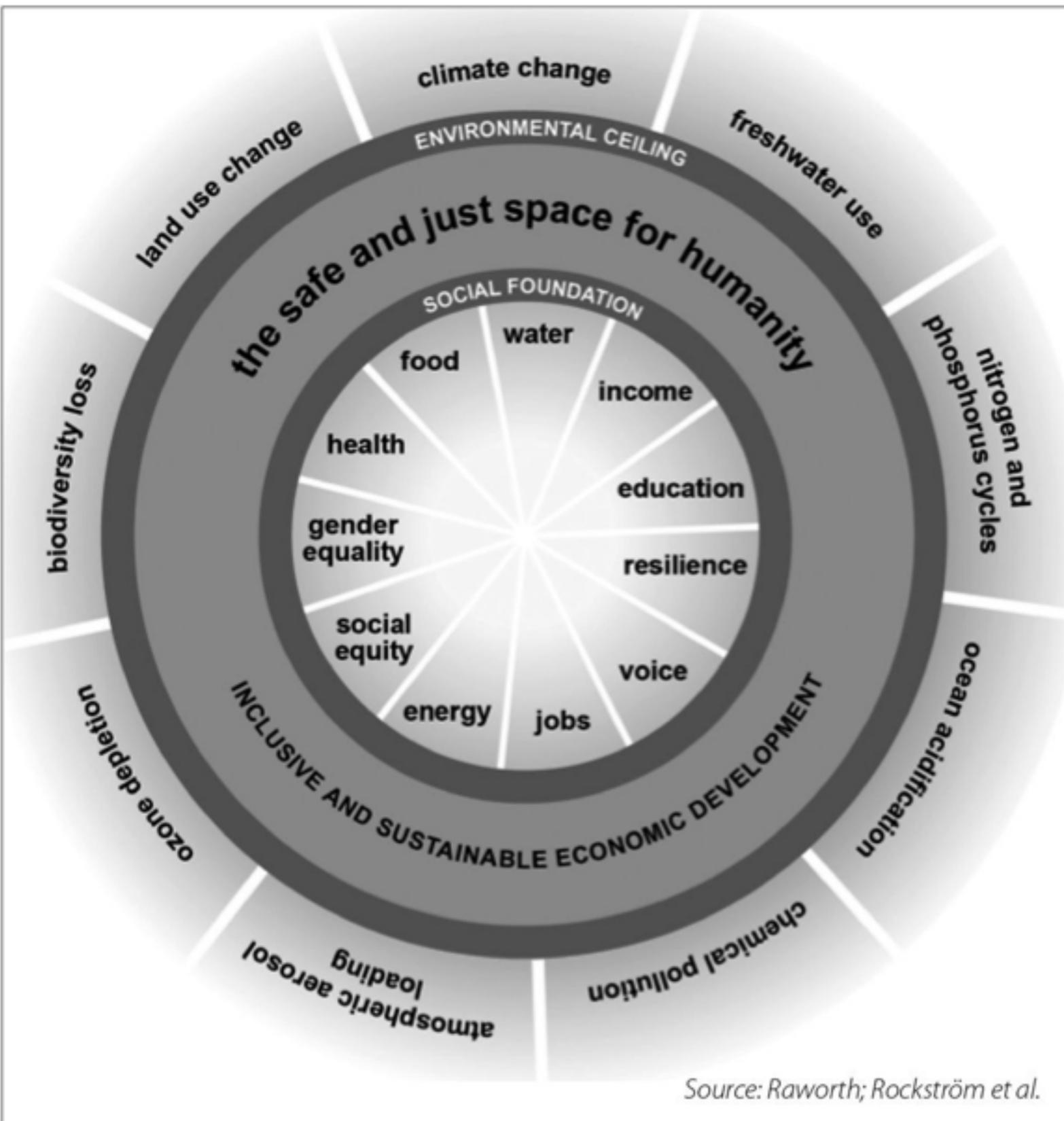


Source: Raworth; Rockström et al.

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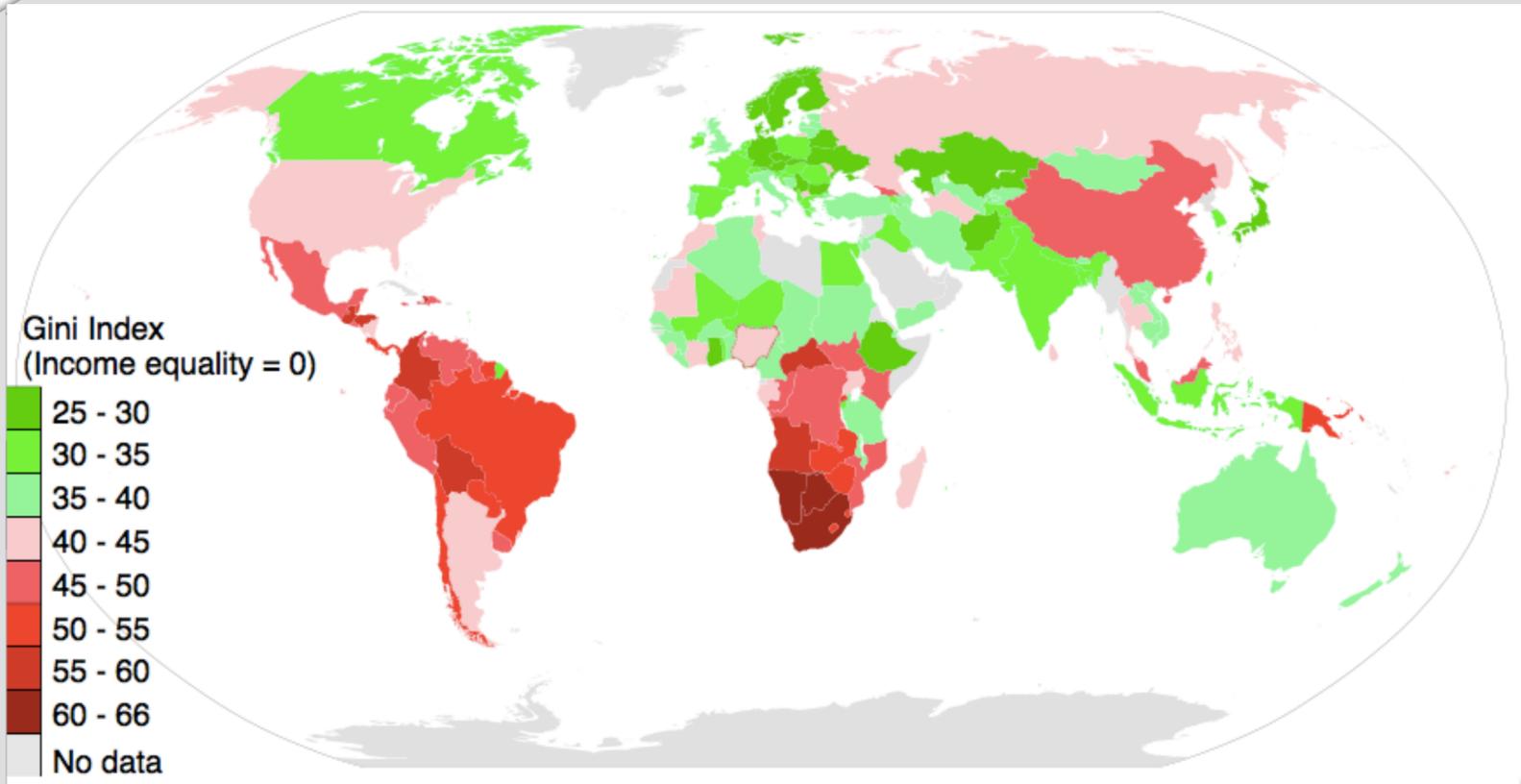
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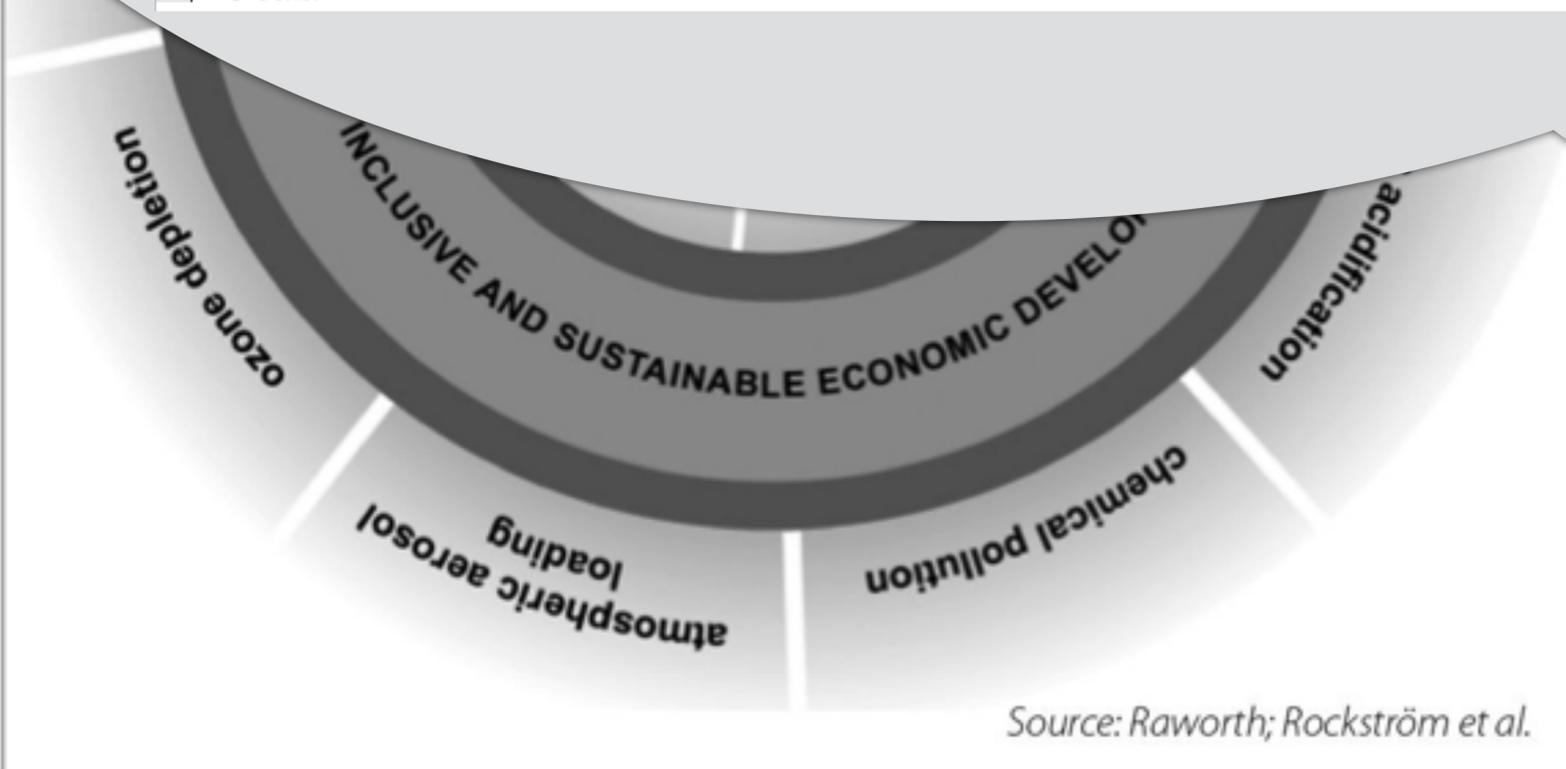
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### Illustrative Indicators of Global Deprivation

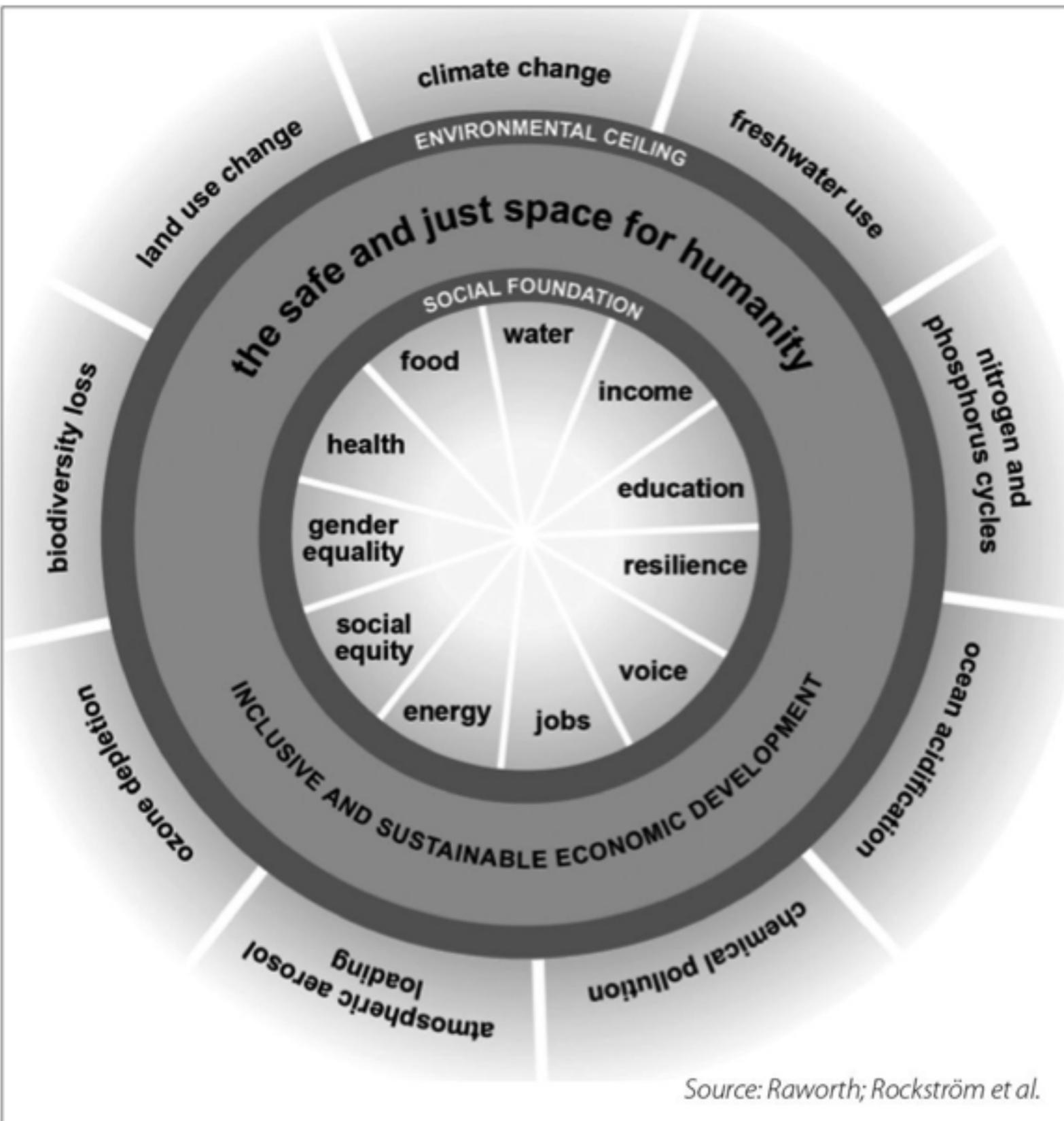
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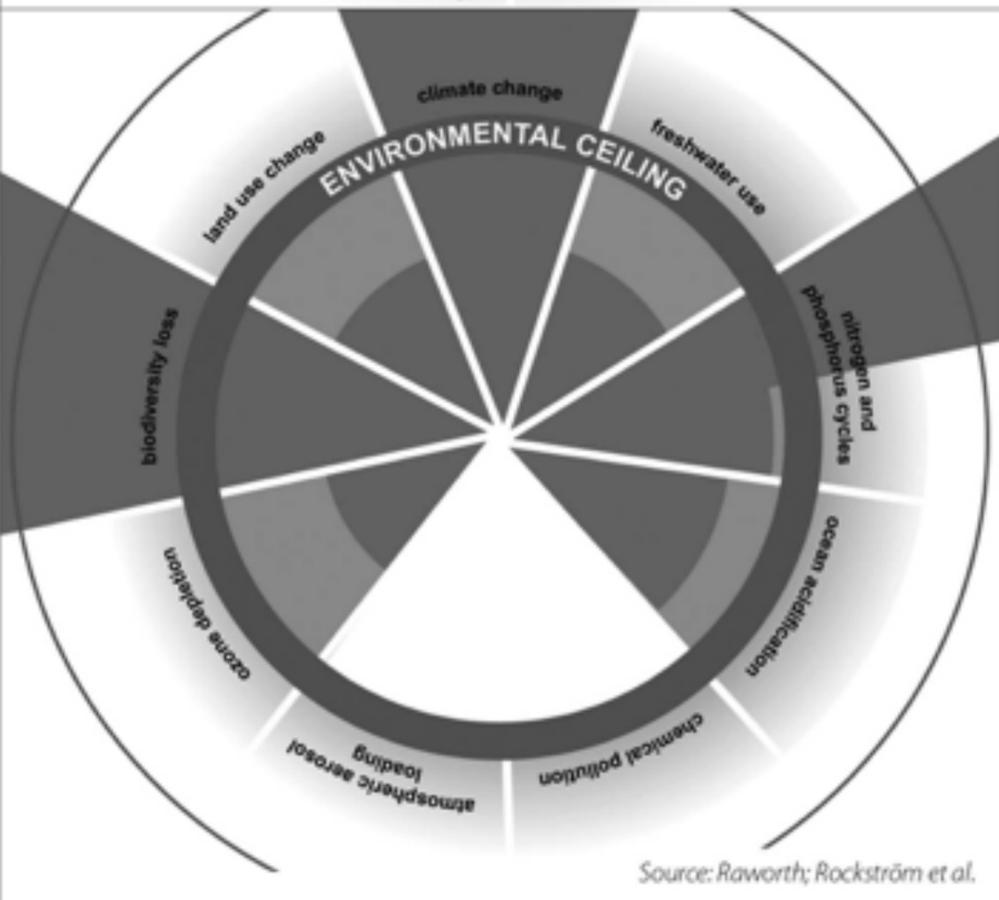
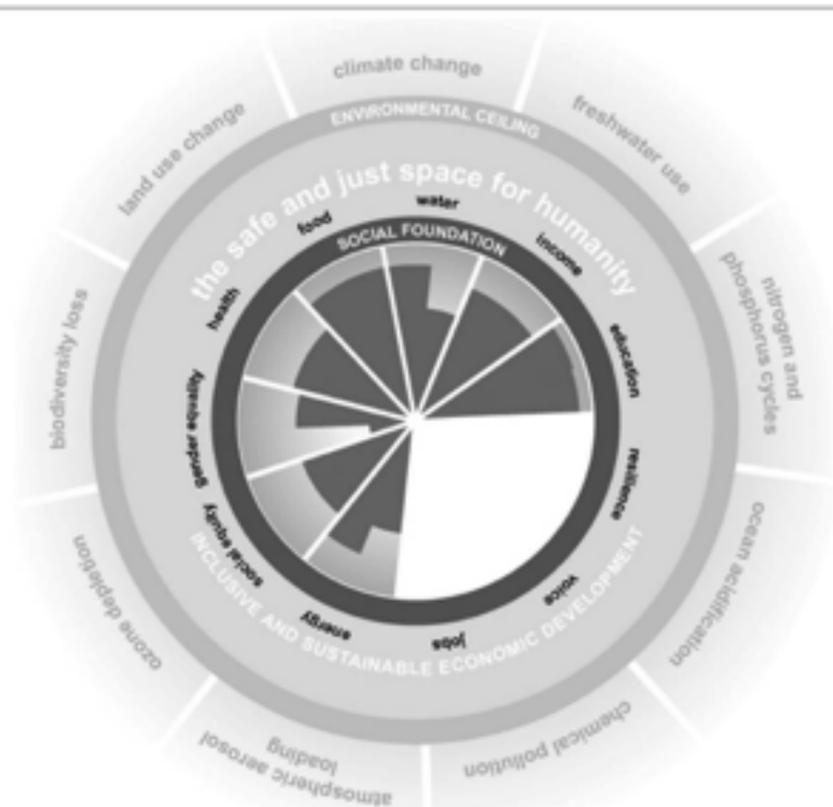


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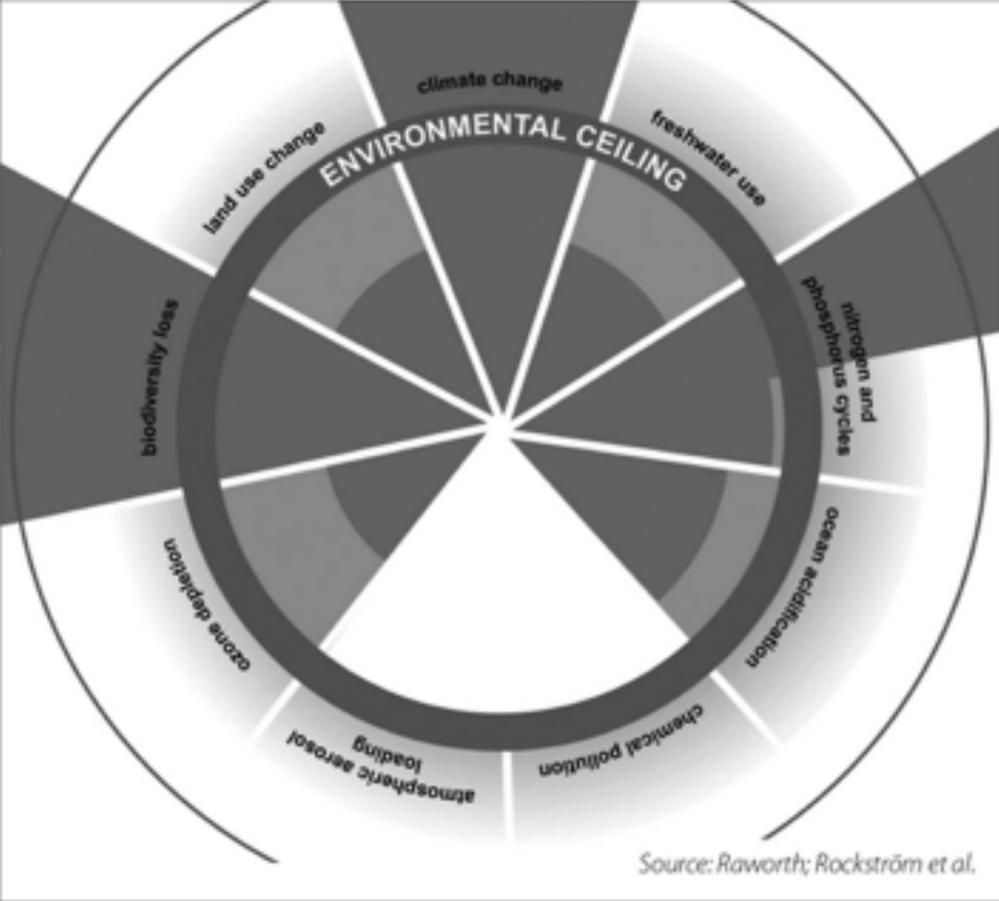
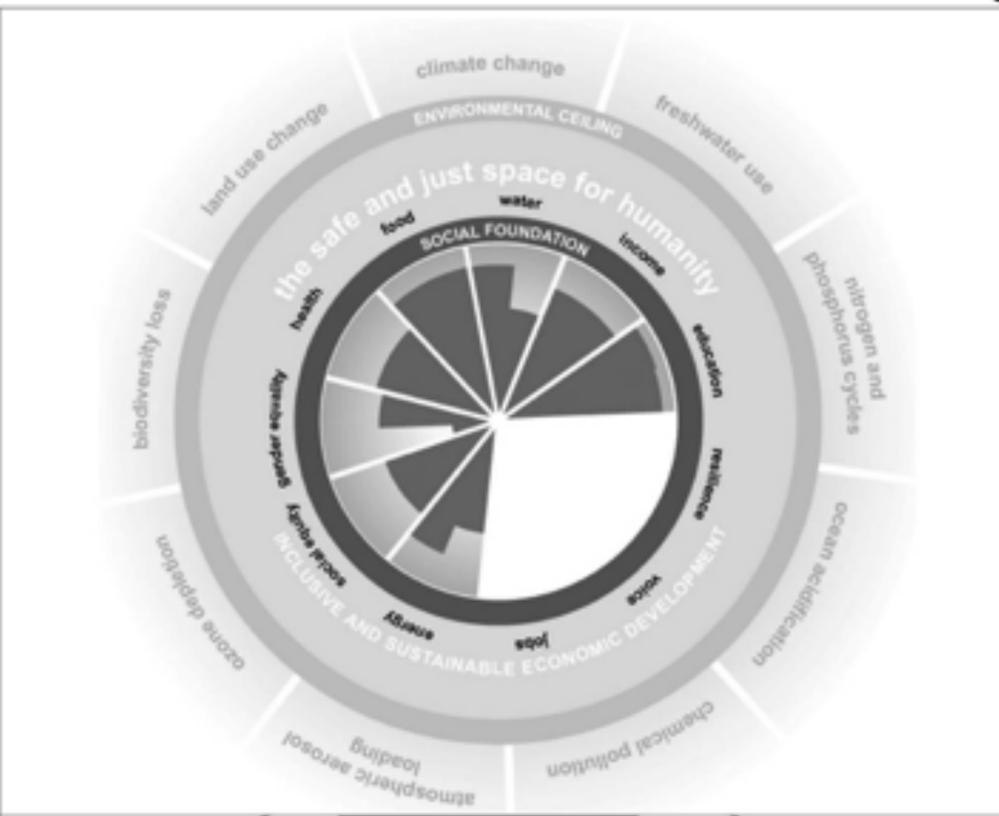


Source: Raworth; Rockström et al.

# Role of Economy

What, then, is the biggest source of stress on planetary boundaries today? It is the excessive consumption levels of roughly the wealthiest 10 percent of people in the world and the resource-intensive production patterns of companies producing the goods and services that they buy. The richest 10 percent of people in the world hold 57 percent of global income. Just 11 percent of the global population generates about half of global CO2 emissions. And one third of the world's "sustainable budget" for reactive nitrogen use is used to produce meat for people in the European Union, just 7 percent of the world's population.

*Raworth, 2013*

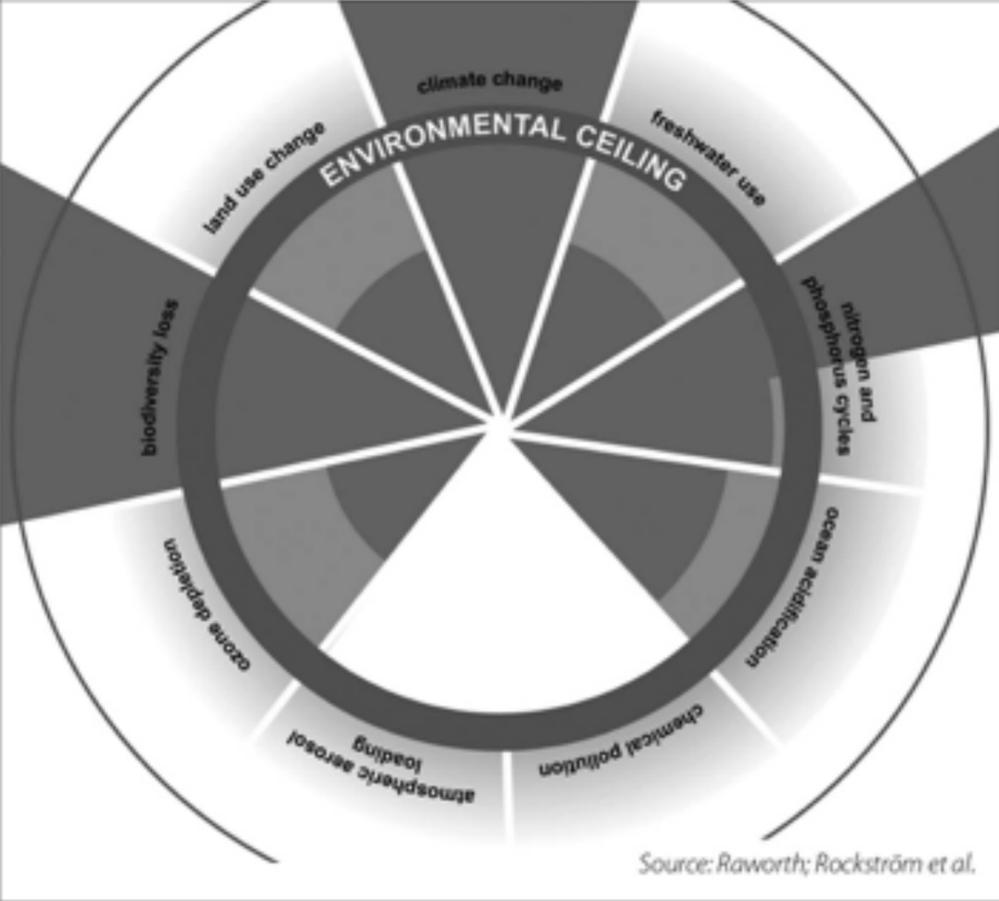
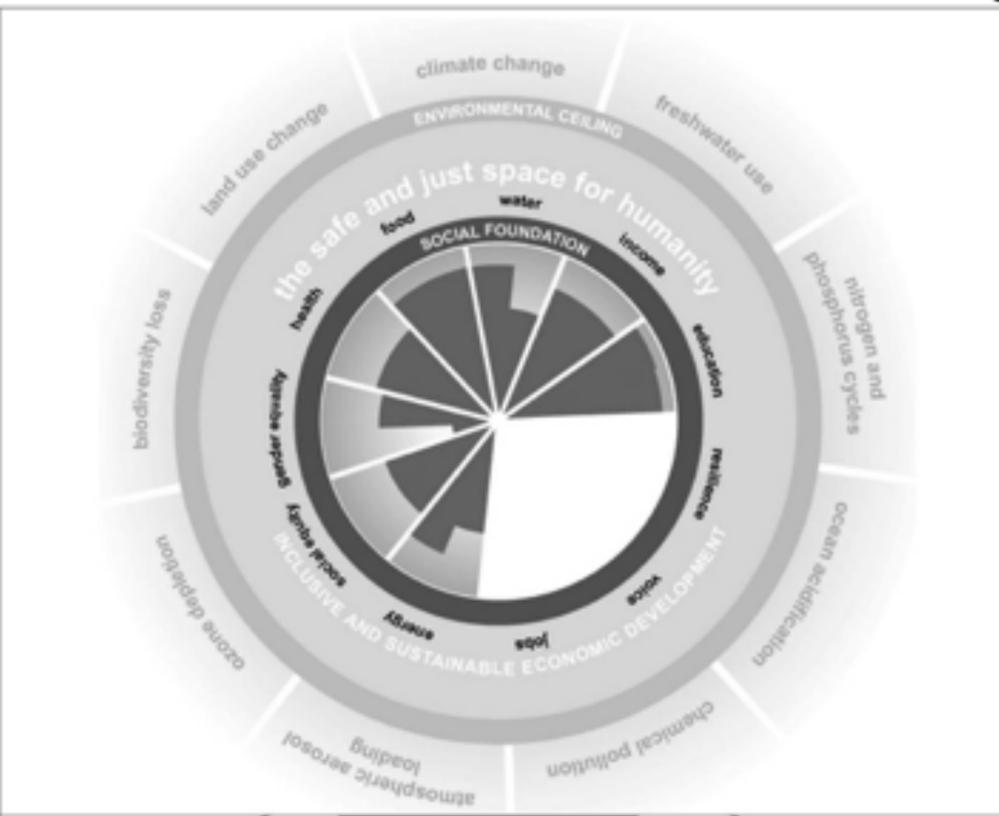


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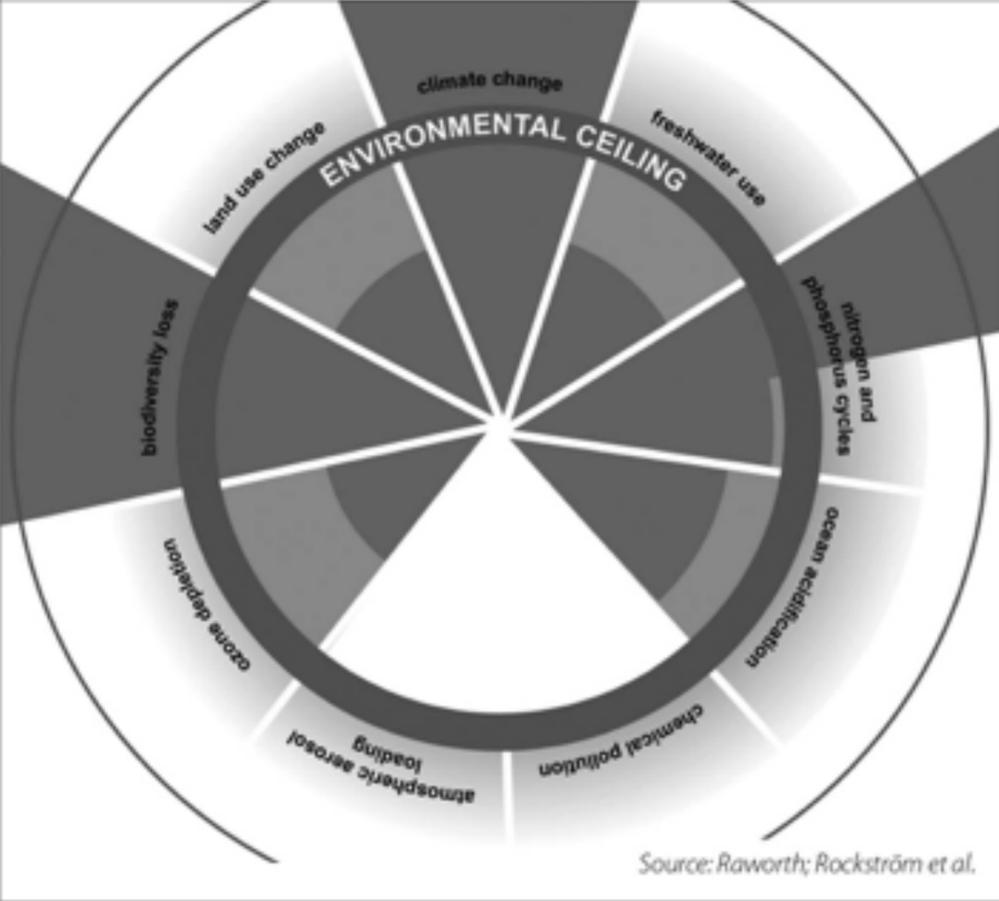
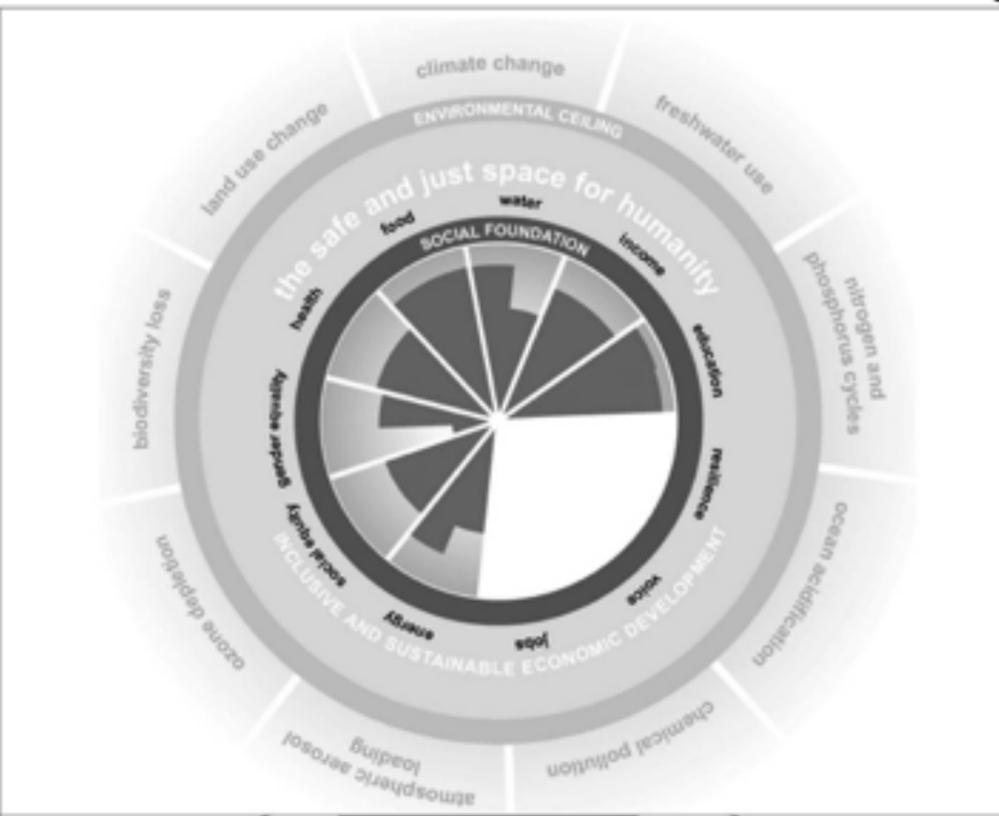
*Raworth, 2013*



Wealth Distribution:		
Top 1%:	Top 5%:	Top 10%:
2000 49.6%	2000 77.2%	2000 89.4%
2009 45.4%	2009 73.7%	2009 86.5%
2016 50.8%	2016 77.7%	2016 89.1%

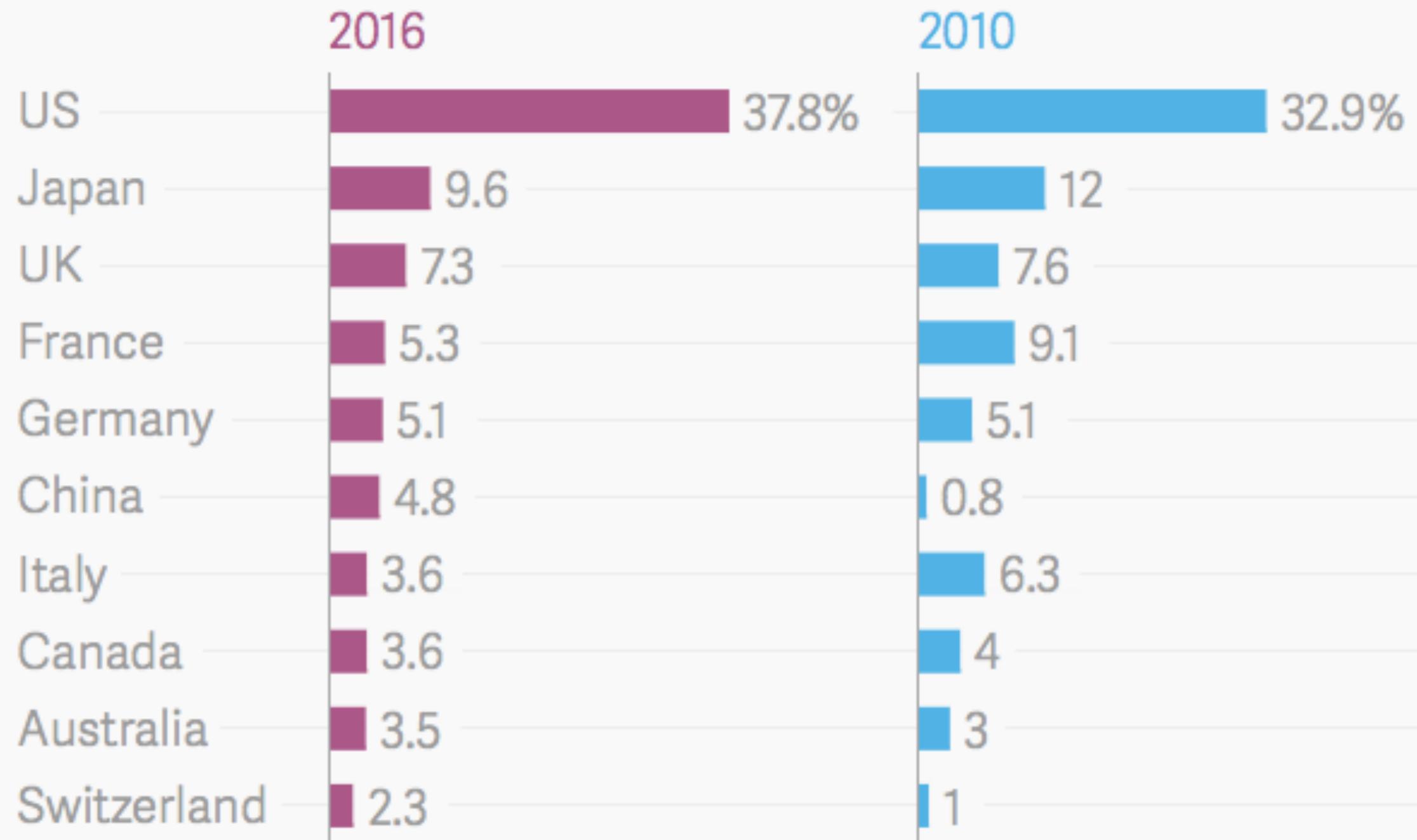
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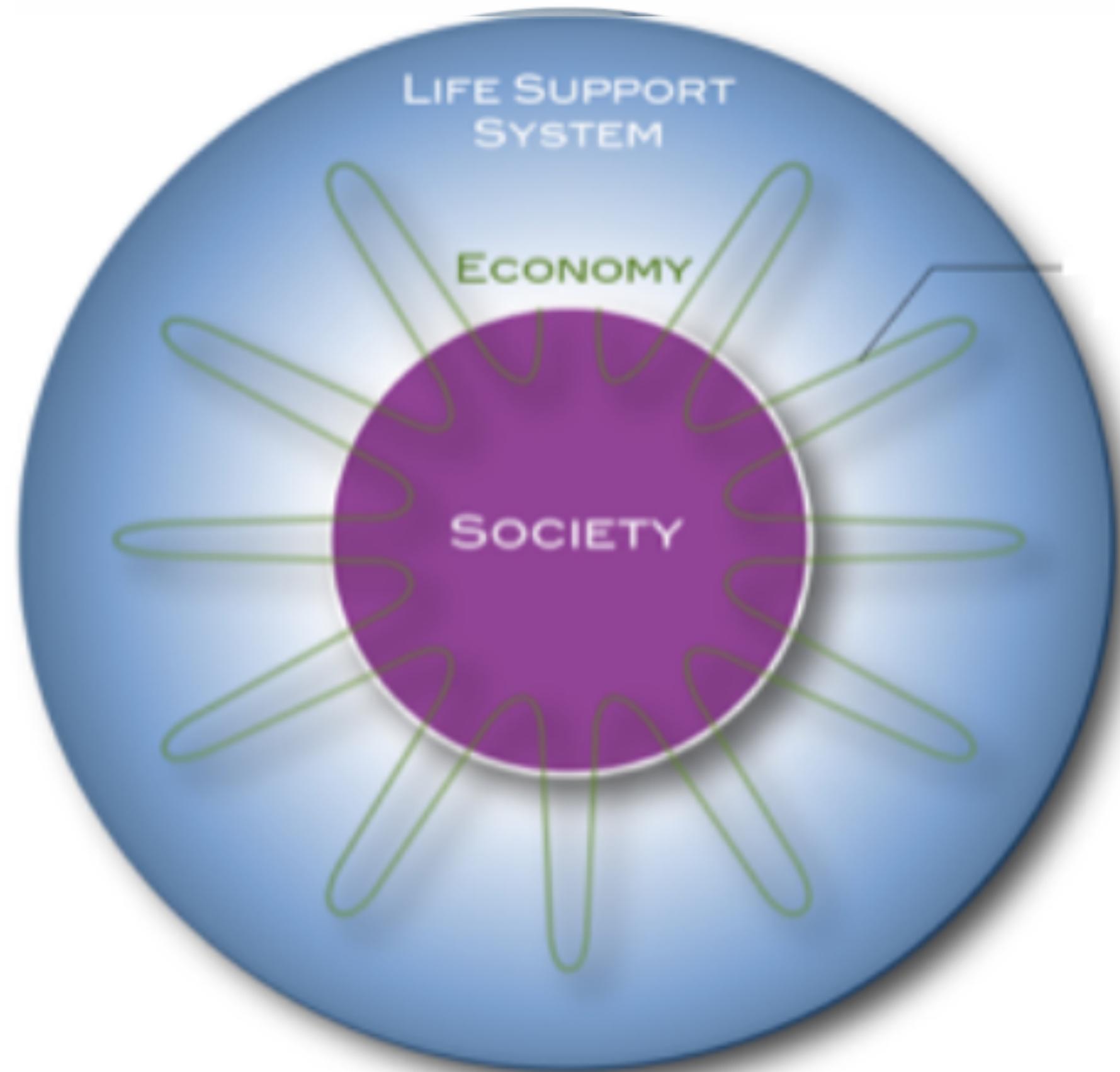
## Share of membership in world's richest 1%, top 10 countries



# Role of Economy

“Sustainable Development is a 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.”

*Griggs et al., 2013*

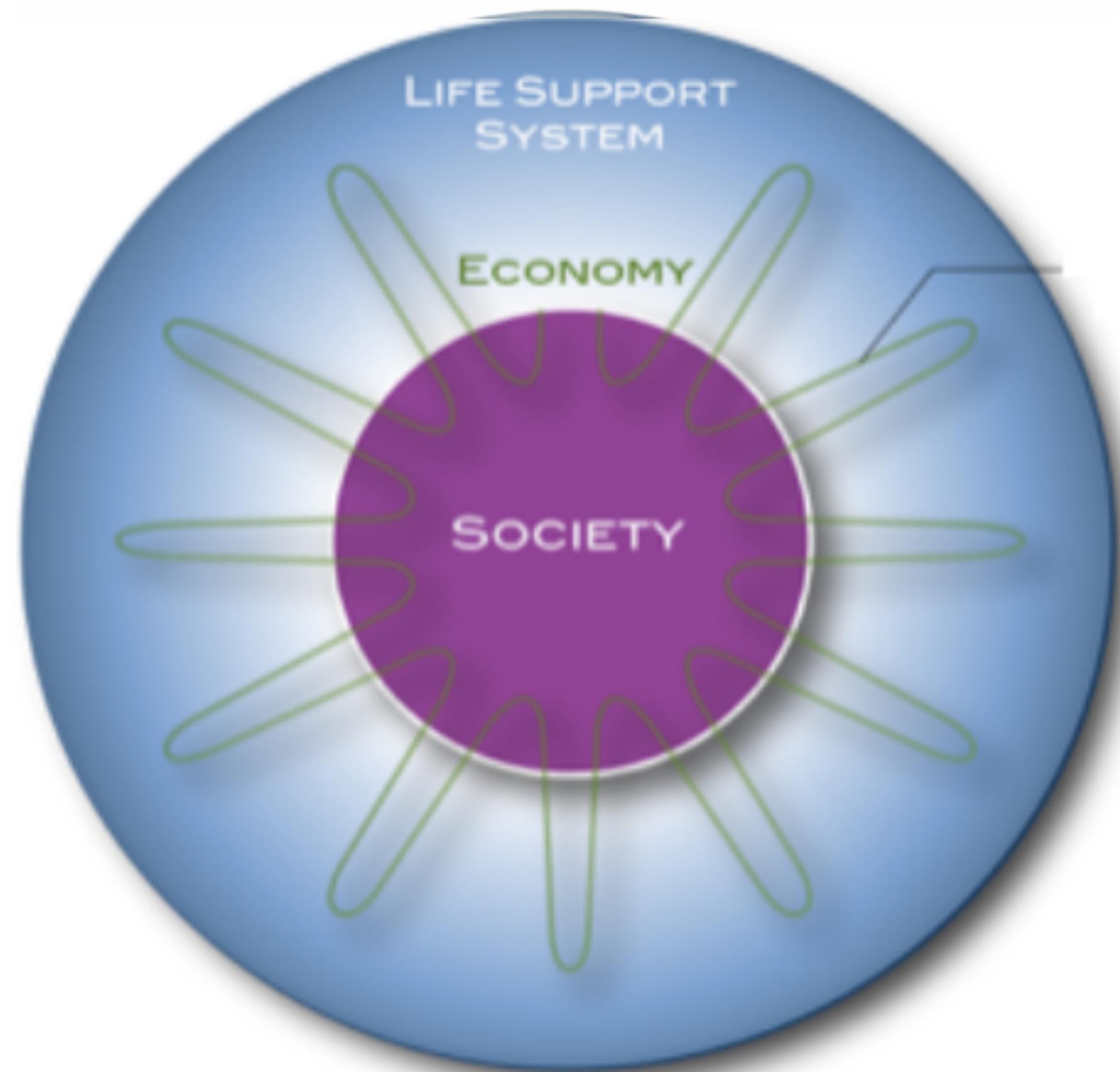


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