# Global Change: Its about more than just climate

## (Global limits to biological productivity and planetary resource boundaries)

Climate Change in the Great Lakes and Beyond
Michigan State University
April 2, 2014

Steven W. Running
NTSG, University of Montana

# First, I need some Michigan Street Cred
# [ Montana Fishing ]

# Carbon dioxide has risen by 36% since accurate measurements began in 1958

388 ppm (2008)

318 ppm (1958)

Mauna Loa Observatory on Hawai'i

# Climate Milestone: Earth's CO2 Level Passes 400 ppm

Greenhouse gas highest since the Pliocene, when sea levels were higher and the Earth was warmer.

*"The rise in $CO_2$ is proceeding so slowly that most of us today will, very likely, live out our lives without perceiving that a problem may exist"*

*Keeling CD, Harris TB, Wilkins EM, 1968. Concentration of atmospheric carbon dioxide at 500 and 700 millibars. J. Geophys. Res. 73:4511-28*

S. Running

# THE LIMITS TO growth

Donella H. Meadows
Dennis L. Meadows
Jørgen Randers
William W. Behrens III

1972

*A Report for THE CLUB OF ROME'S Project on the Predicament of Mankind*

A POTOMAC ASSOCIATES BOOK $ 2.75

# Human Appropriation of the Products of Photosynthesis

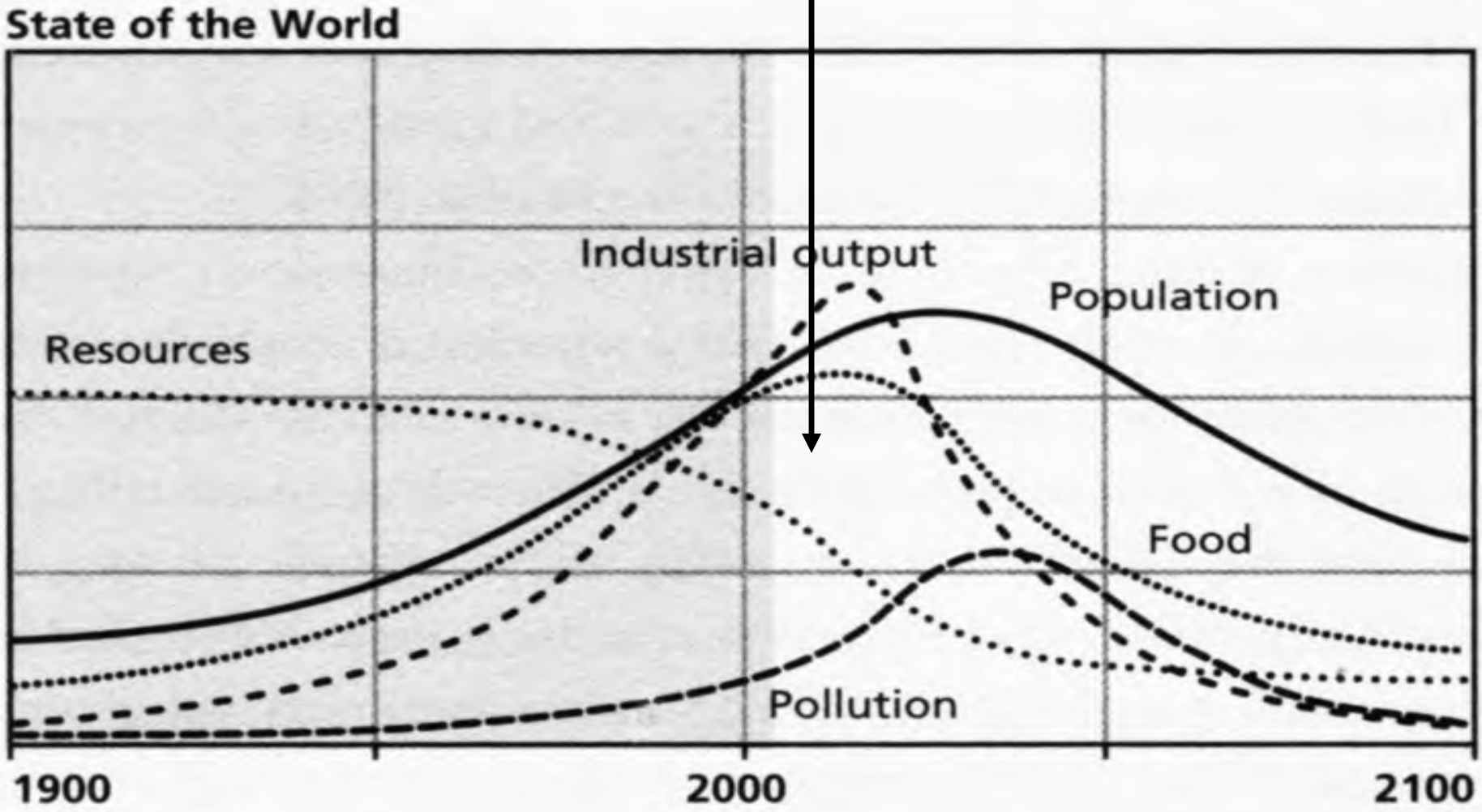
*Nearly 40% of potential terrestrial net primary productivity is used directly, co-opted, or foregone because of human activities*

Peter M. Vitousek, Paul R. Ehrlich, Anne H. Ehrlich, and Pamela A. Matson

# Human Domination of Earth's Ecosystems

Peter M. Vitousek, Harold A. Mooney, Jane Lubchenco, Jerry M. Melillo

# “Limits to Growth” Scenario in 1972 for 2012




From G. Turner, Global Env Change 18:397-411. 2008

# Global NPP 1983 version

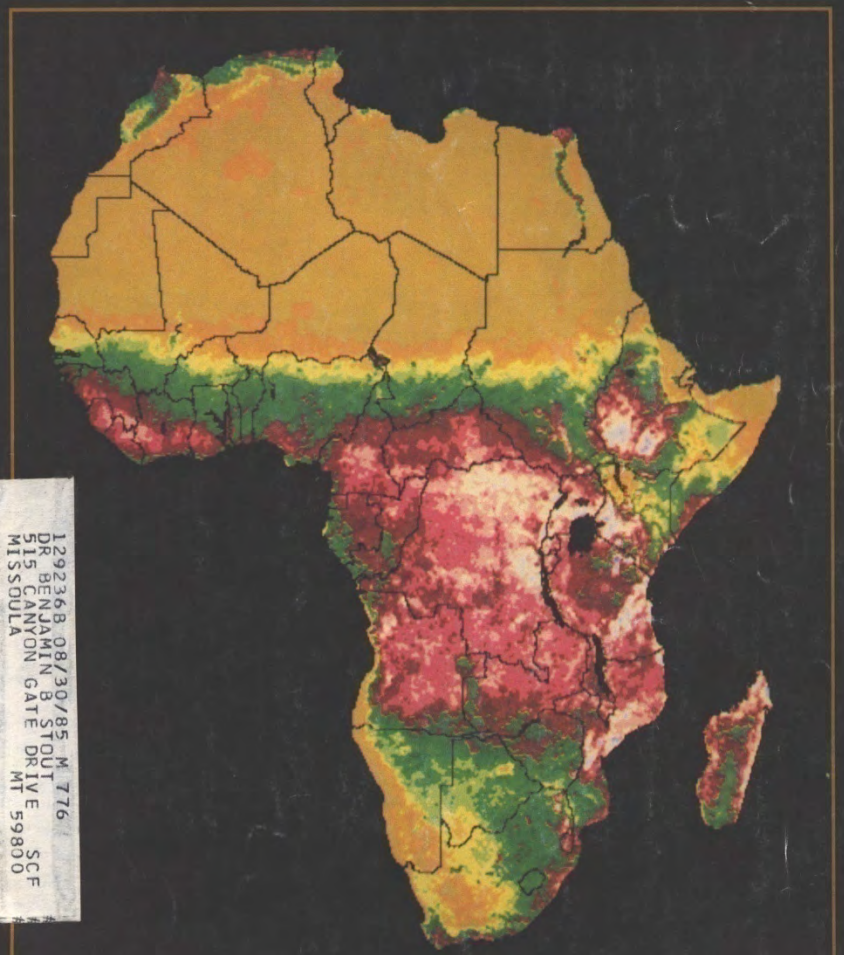



Fig. 2. Global distribution of NPP (× 10 gm C/m²/yr) at the tracer model resolution.

25 January 1985 • Vol. 227 • 4685 $2.50

# SCIENCE

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE






NASA Technical Memorandum 85841

# Land-Related Global Habitability Science Issues

Land-Related Global Habitability
Sciences Working Group

JULY 1983

25th Anniversary
1958-1983

NASA

# Driving ecosystem models with satellite data, concept for NASA Global Habitability, 1983

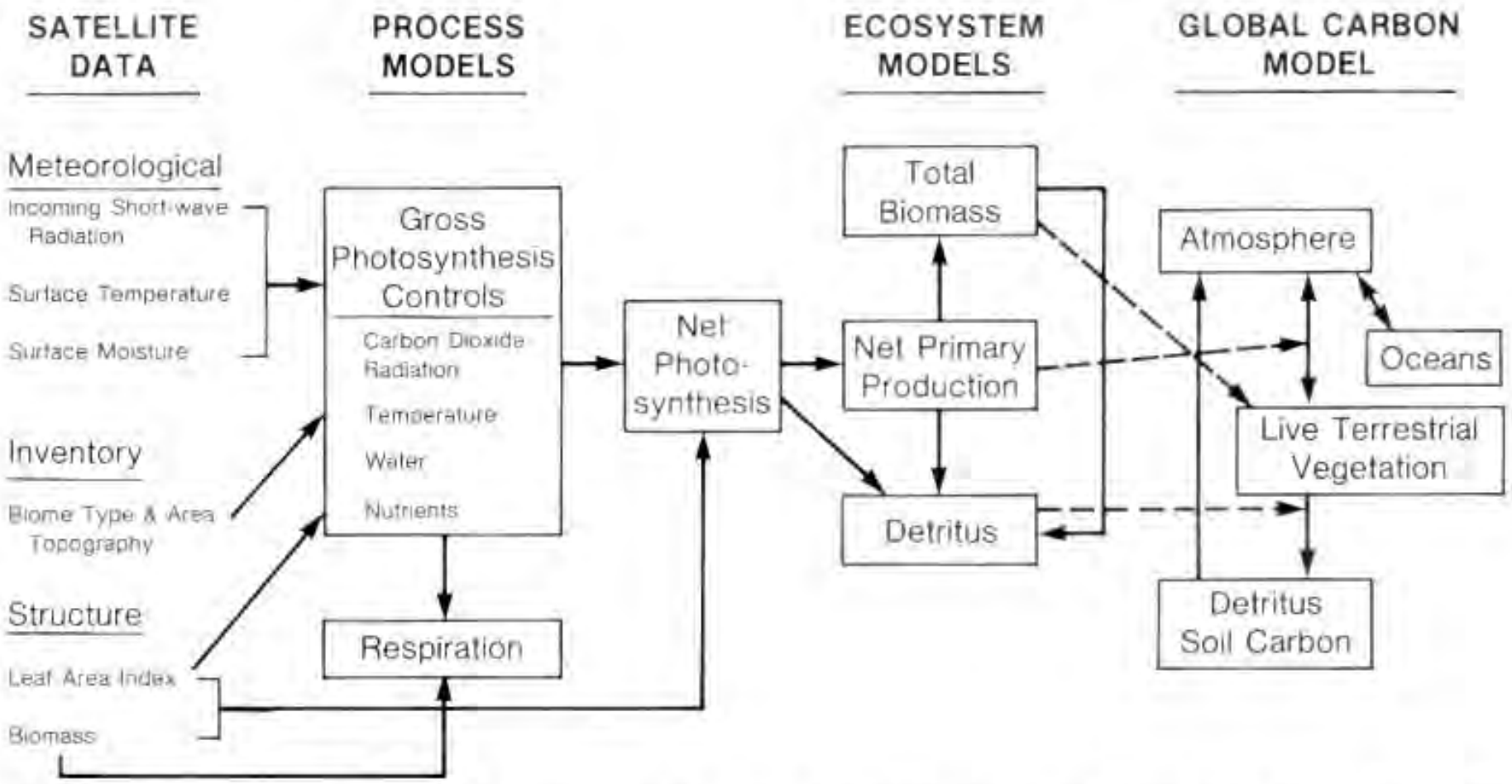
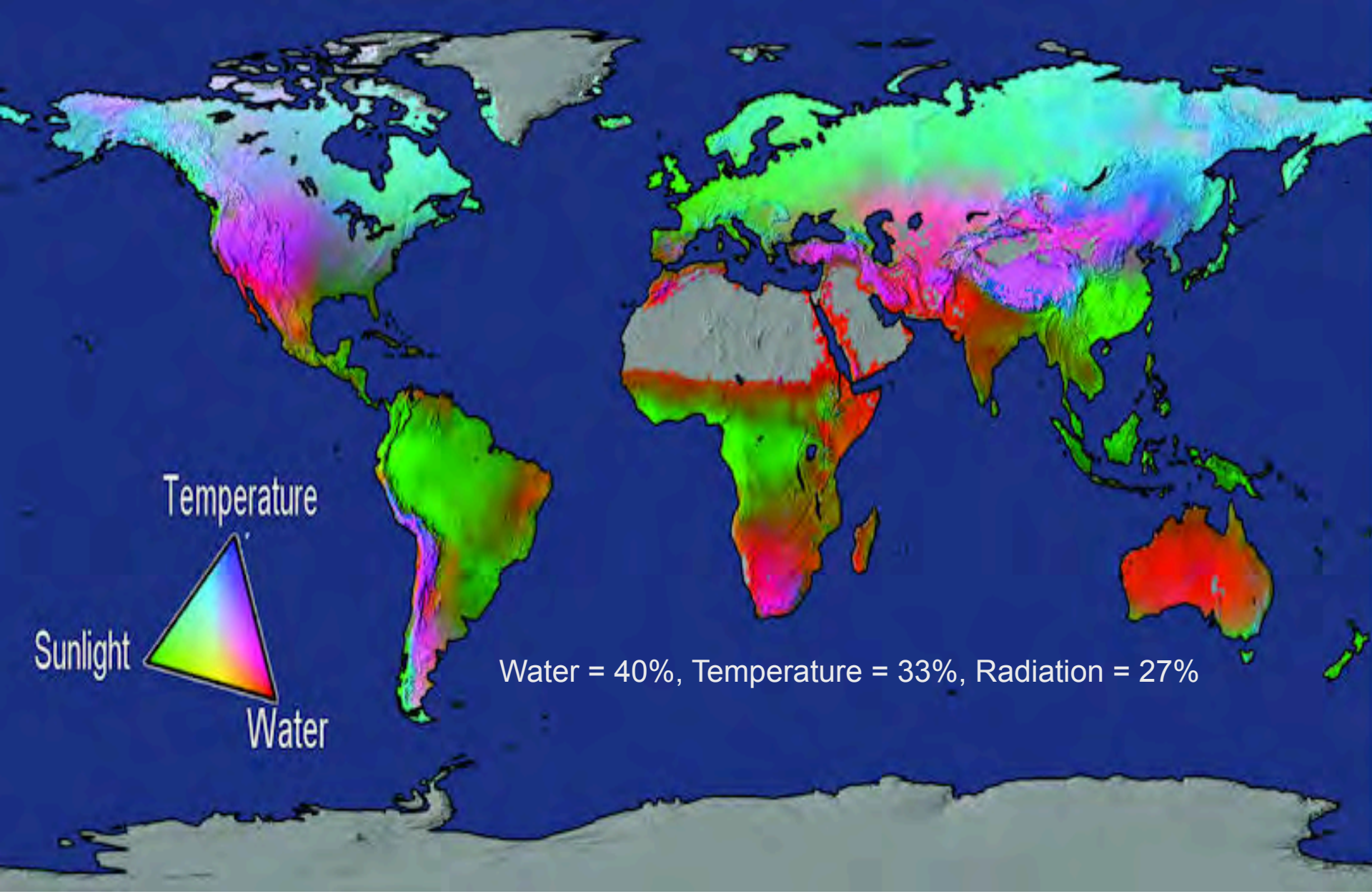
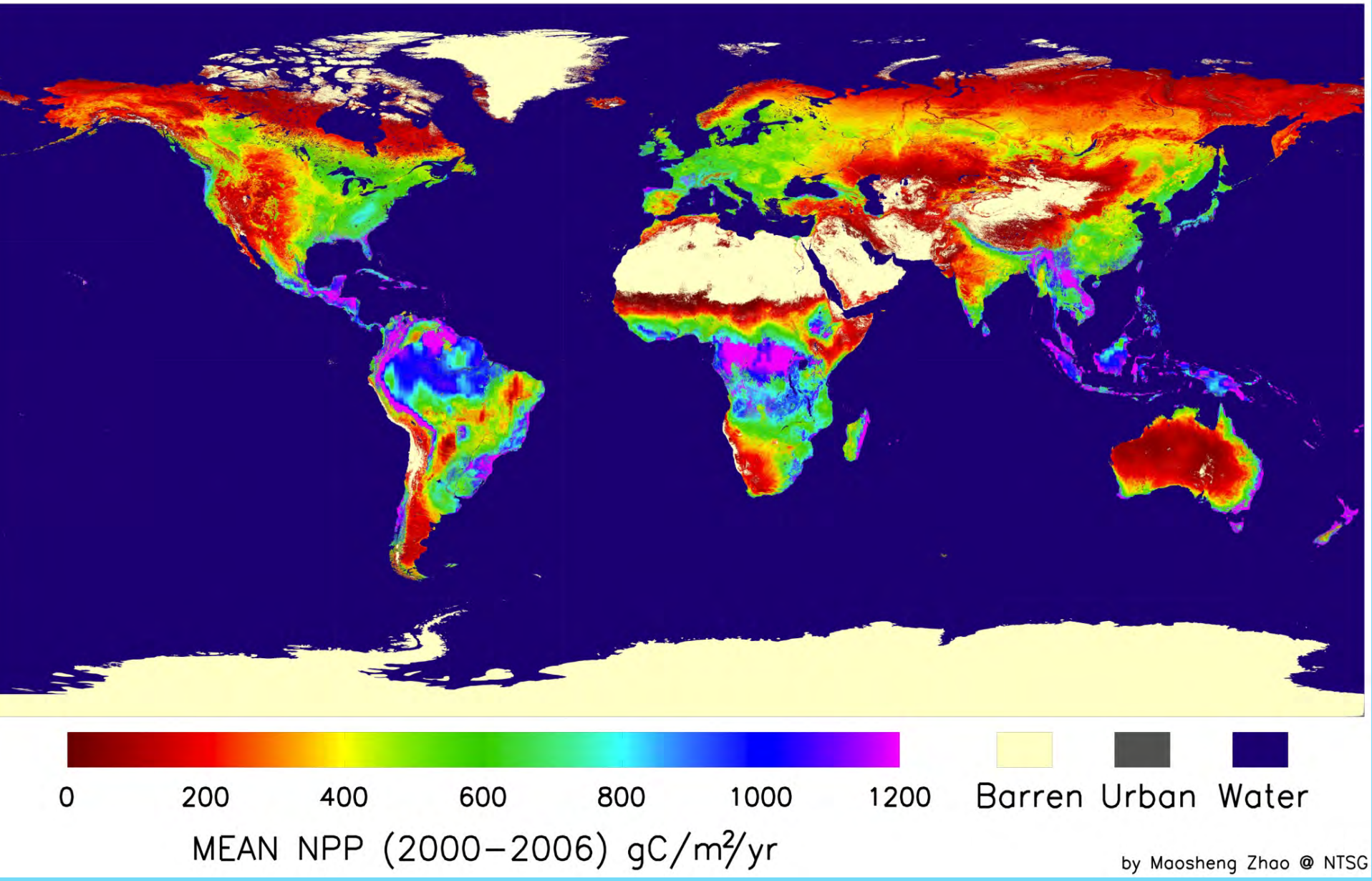



**Figure 2. Organizational diagram of a proposed model of net primary production for a coniferous forest. All driving variables are derived from satellite data. Potential linkages to a global carbon model are shown by dashed lines (Running, 1984).**




*Potential limits to vegetation net primary production based on fundamental physiological limits by solar radiation, water balance, and temperature (from Churkina & Running, 1998; Nemani et al., 2003; Running et al., 2004).*

# Terrestrial NPP = Planetary Boundary??




Zhao and Running. *Science* 329: 940-043 (2009)

PERSPECTIVES

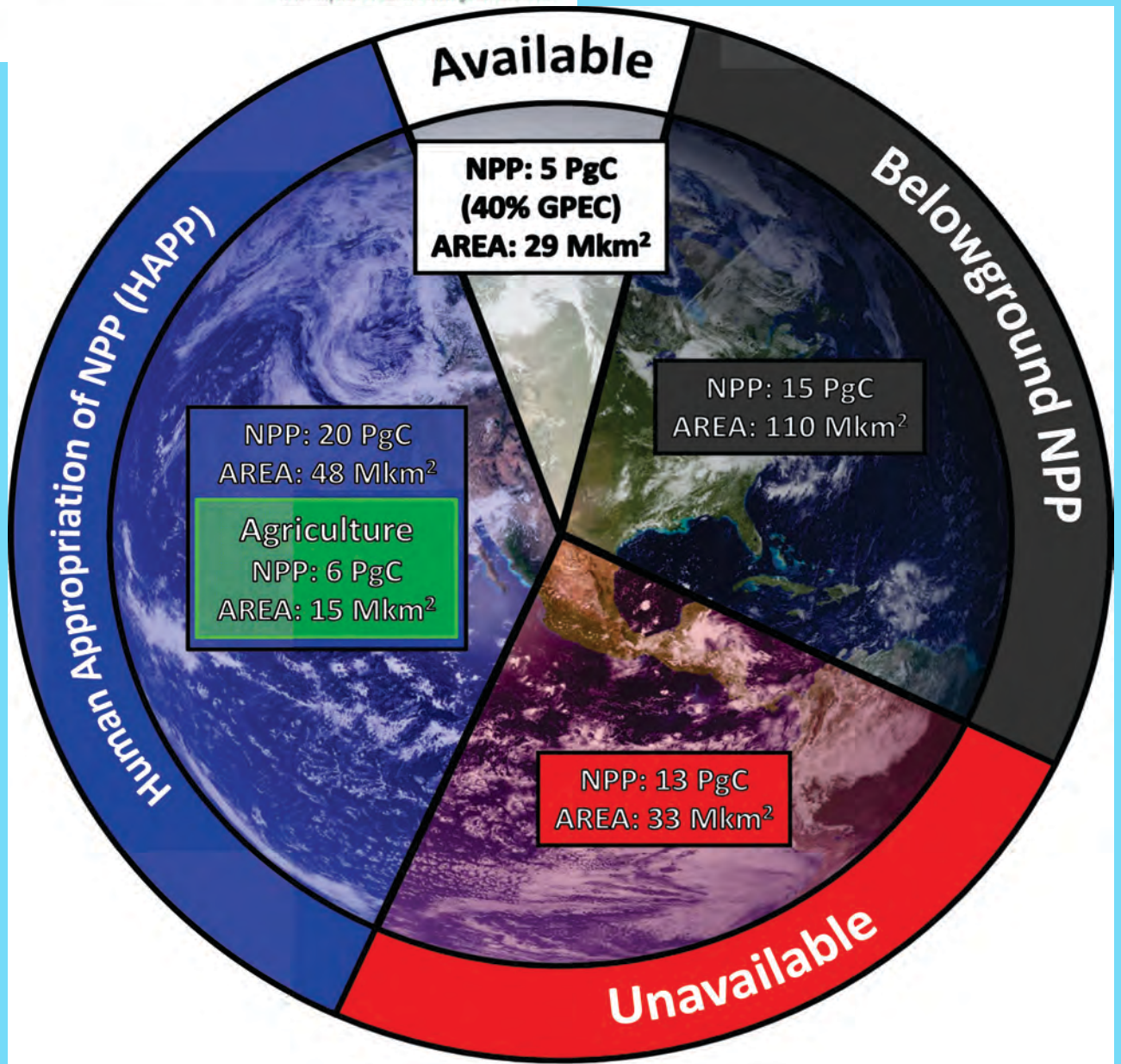
ECOLOGY

# A Measurable Planetary Boundary for the Biosphere

Steven W. Running

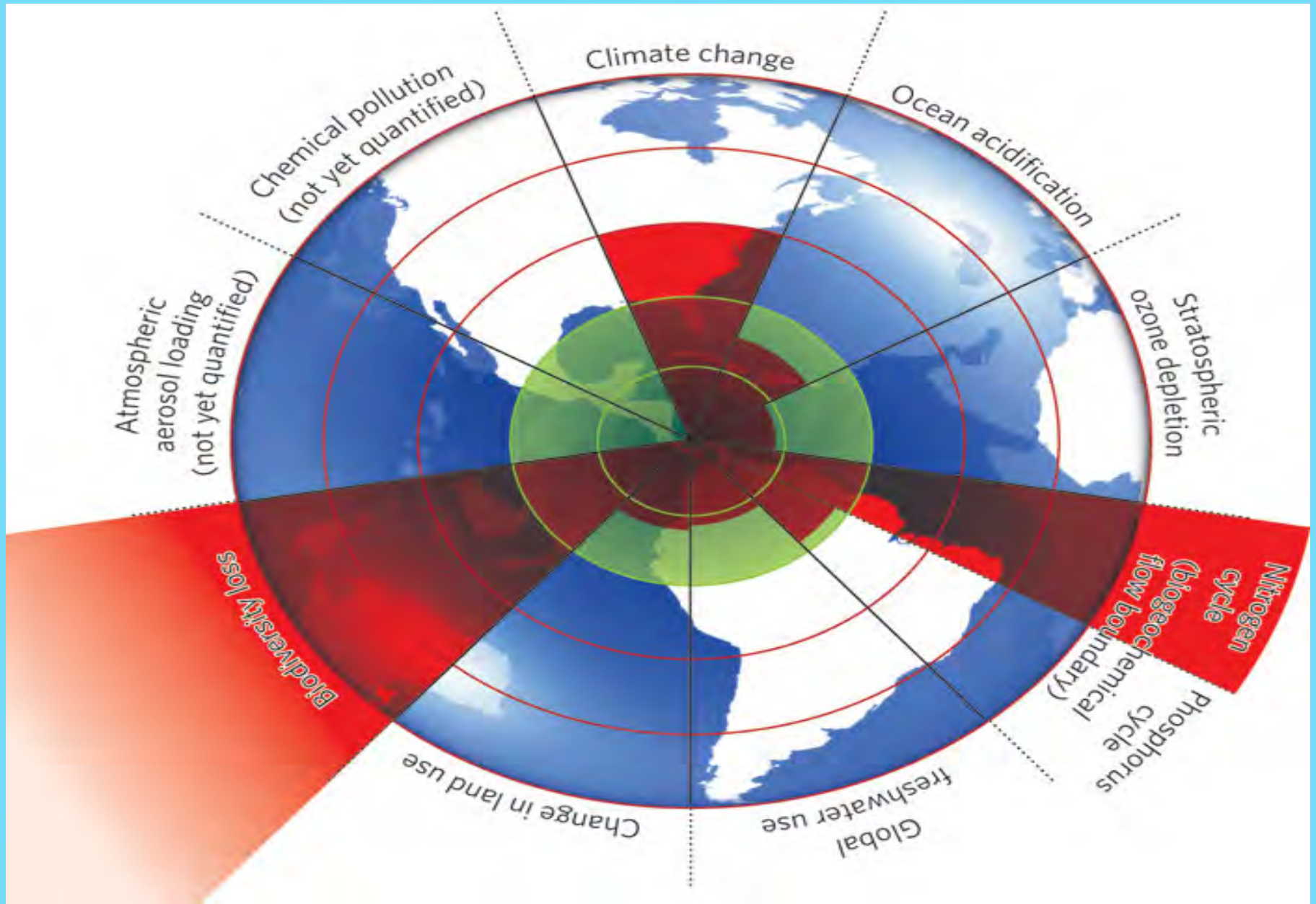
Terrestrial net primary (plant) production provides a measurable boundary for human consumption of Earth's biological resources.

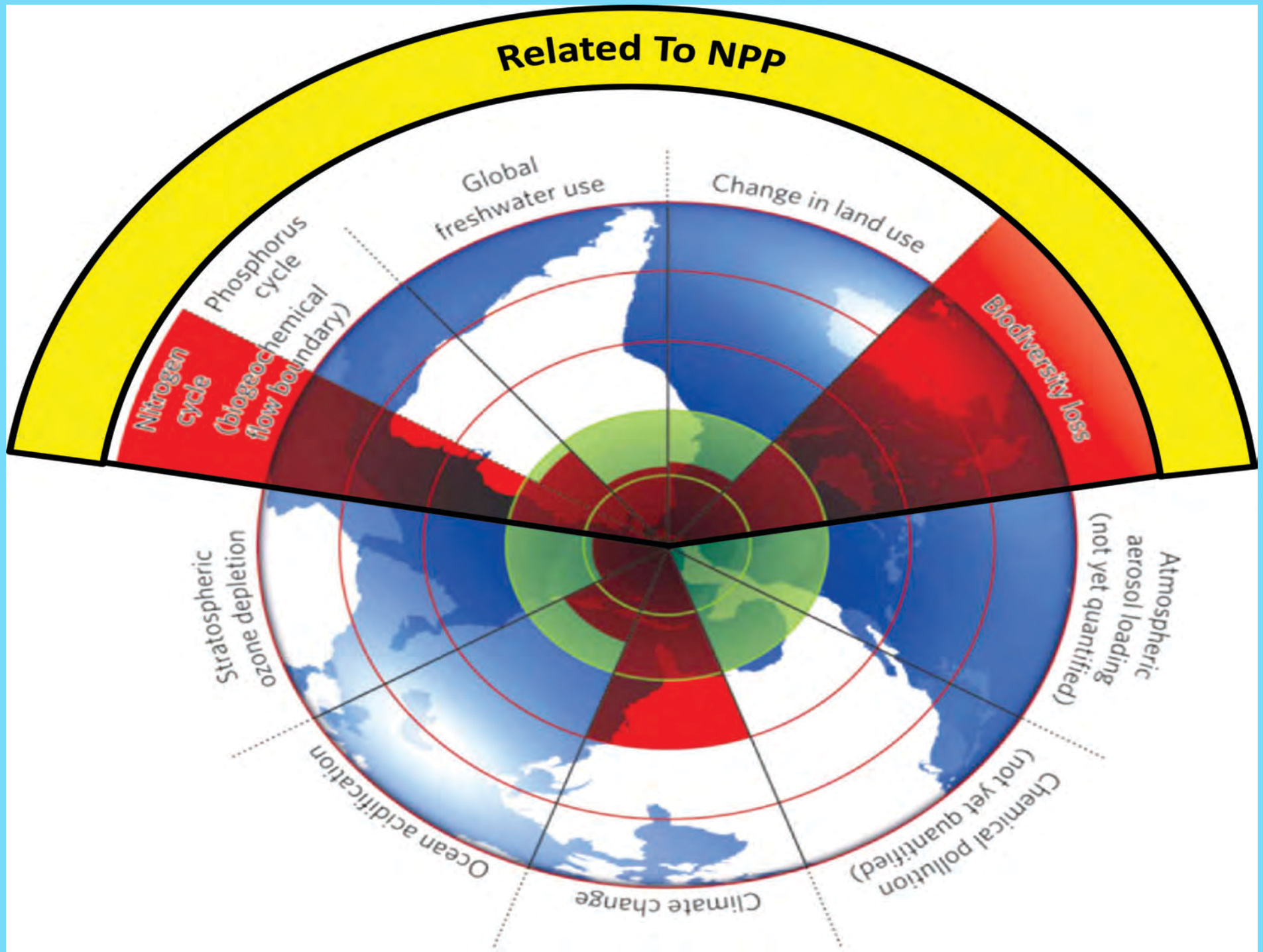
From Running, SW. *Science* 337 p1458-1459, 2012



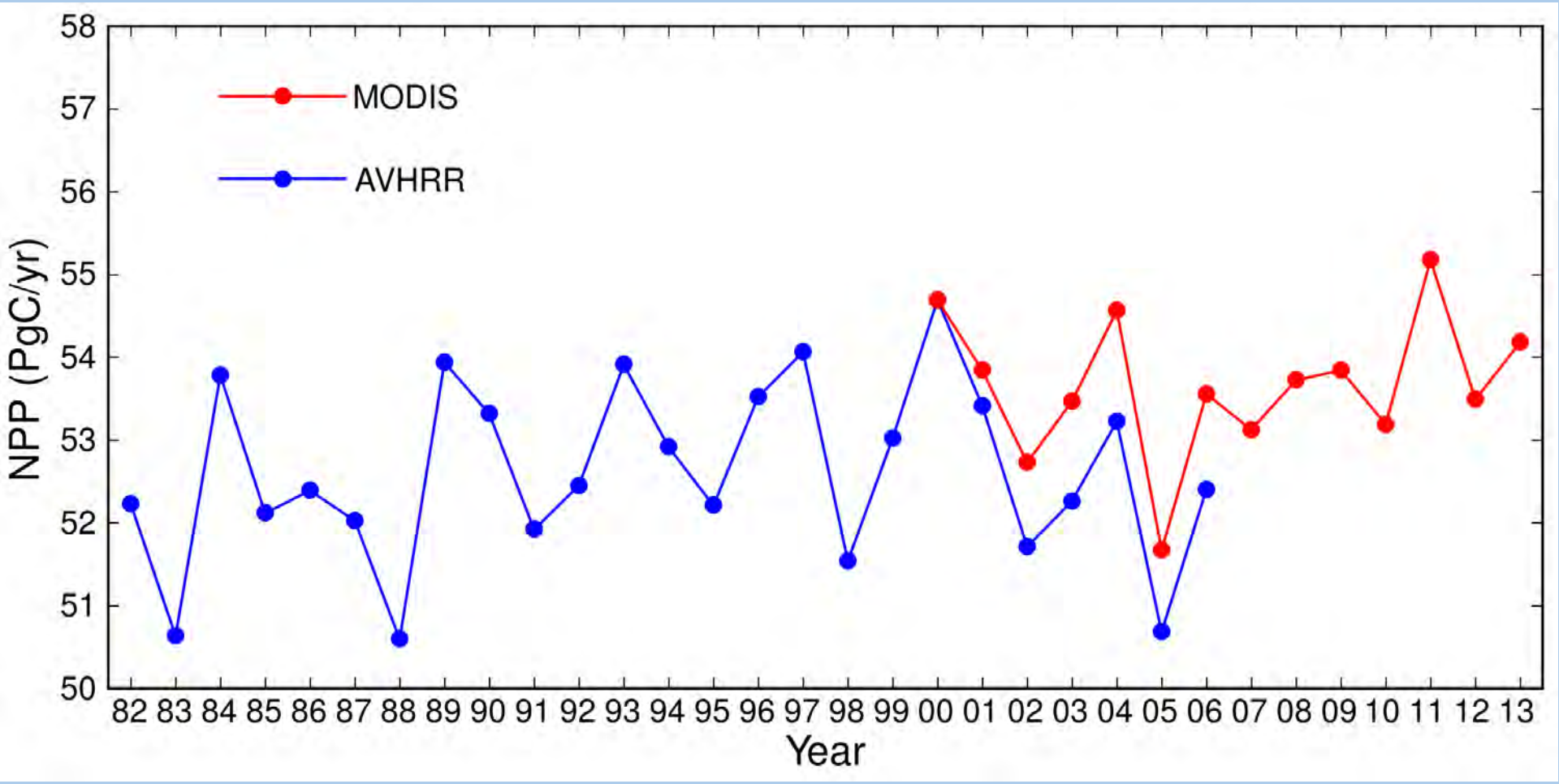
# PLANETARY BOUNDARIES

Rockstrom et al. *Nature* 2009




Related To NPP
Global freshwater use
Change in land use
Phosphorus cycle
Nitrogen cycle (biogeochemical flow boundary)
Biodiversity loss
Stratospheric ozone depletion
Atmospheric aerosol loading (not yet quantified)
Ocean acidification
Chemical pollution (not yet quantified)
Climate change

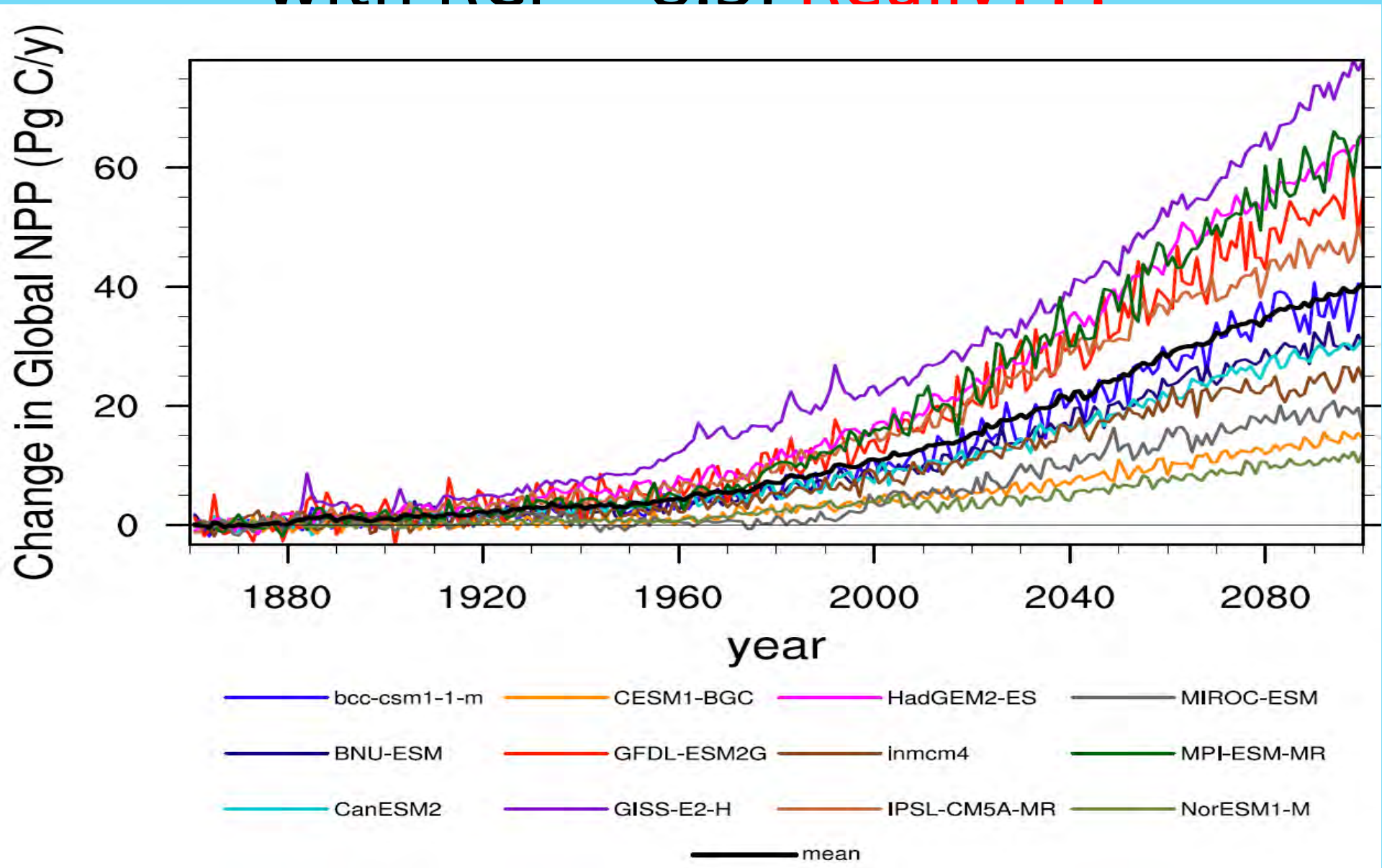
# Global Terrestrial Net Primary Production (1982-2013)



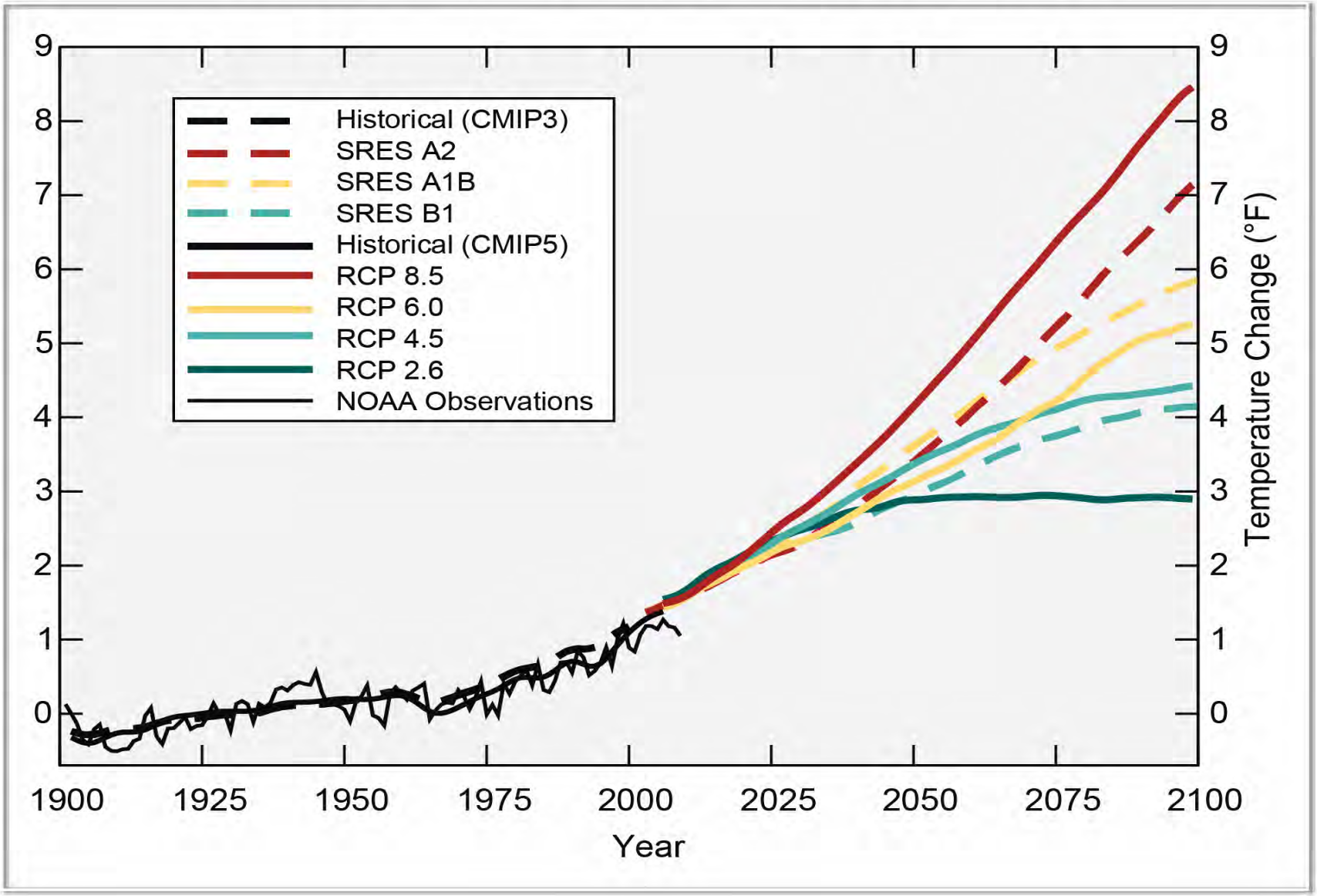

+/- 1Pg or about 2%

Nemani et al 2003, Zhao and Running 2010

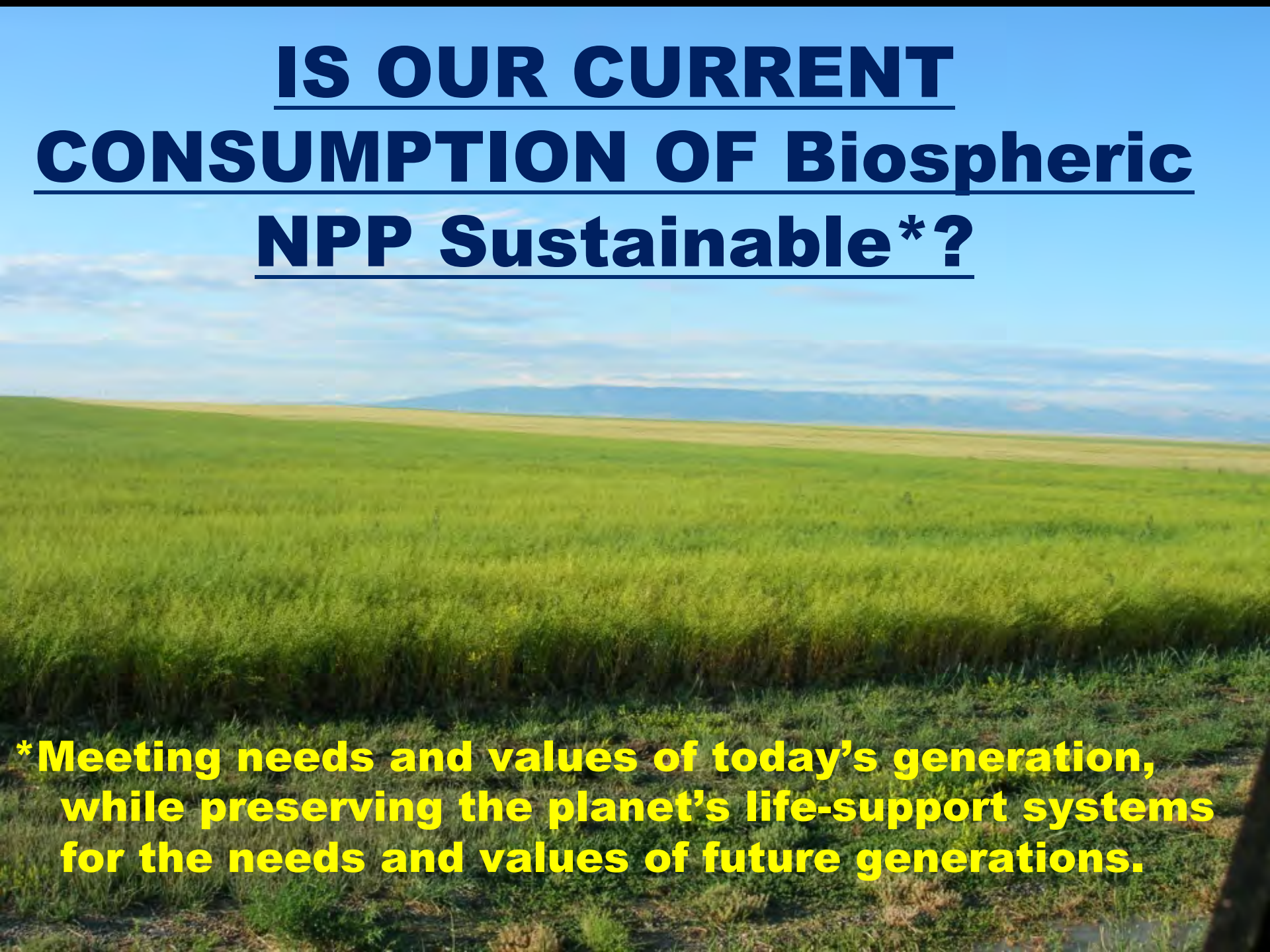
# CMIP5 Projections of Global NPP with RCP = 8.5. Really???



# Average Global Temperature Projections



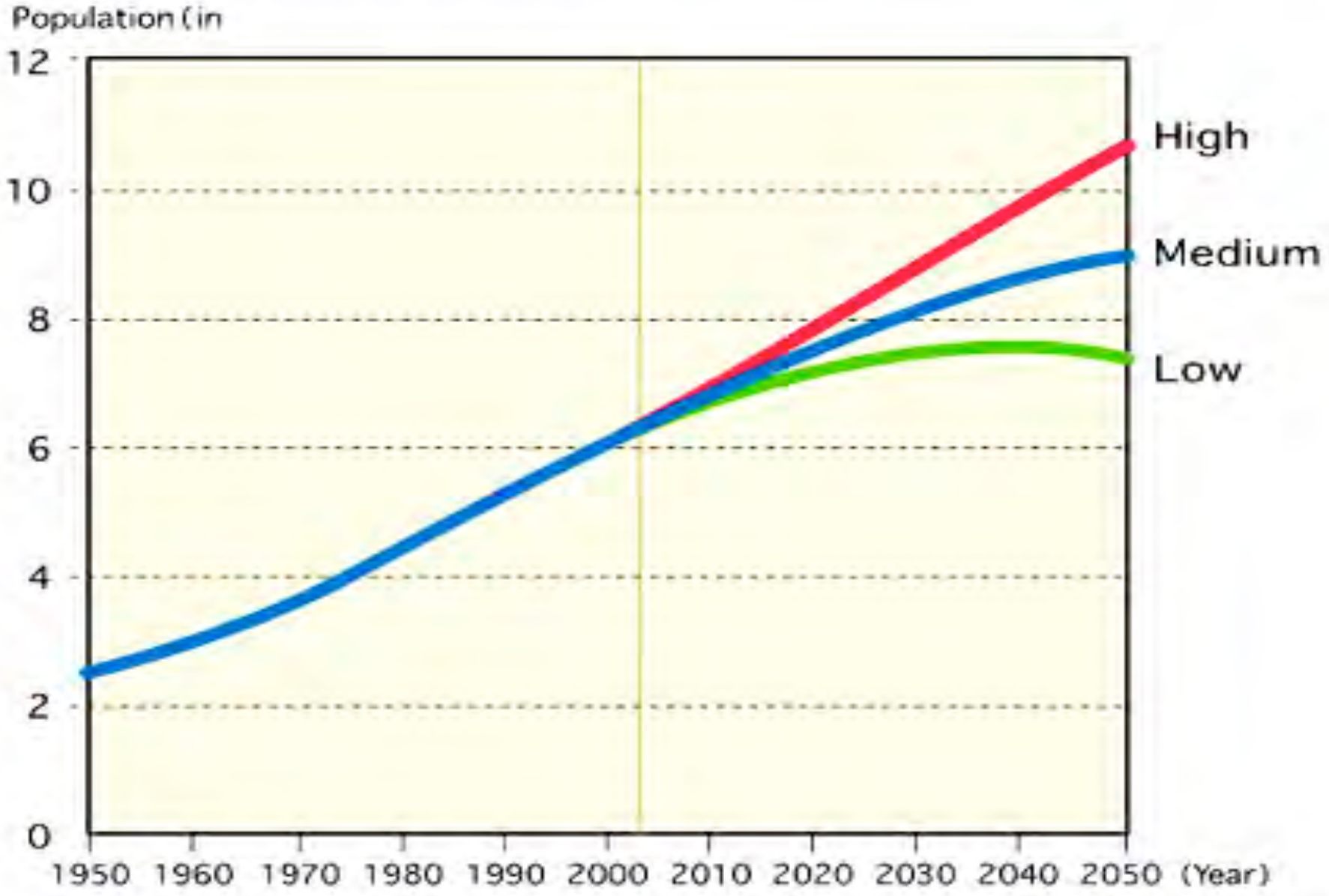
# IS OUR CURRENT CONSUMPTION OF Biospheric NPP Sustainable*?



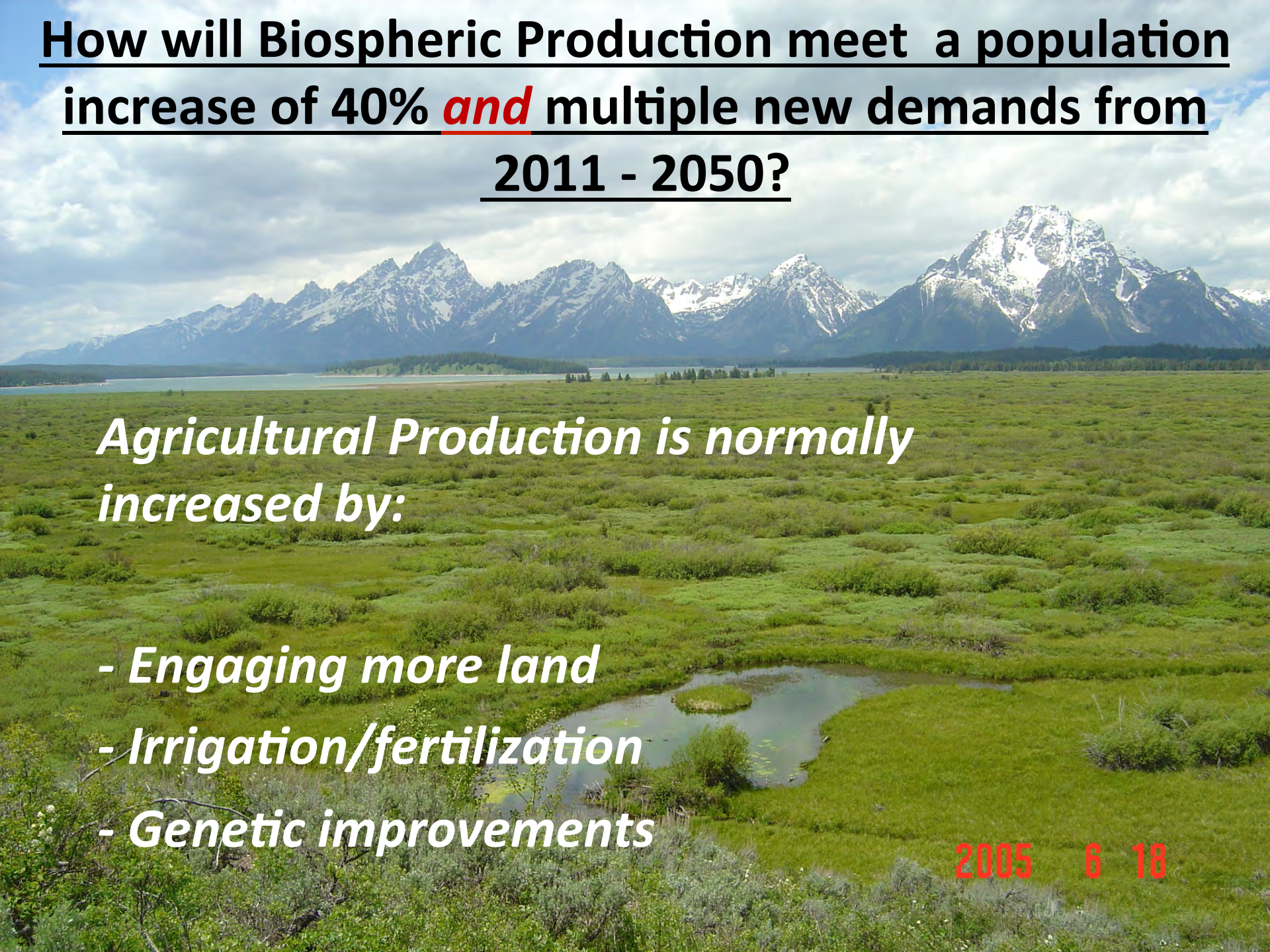
*Meeting needs and values of today's generation, while preserving the planet's life-support systems for the needs and values of future generations.

Figure 1 United Nations World Population Projections, 1950-2050

Source: World Population Prospects



# How will Biospheric Production meet a population increase of 40% *and* multiple new demands from 2011 - 2050?



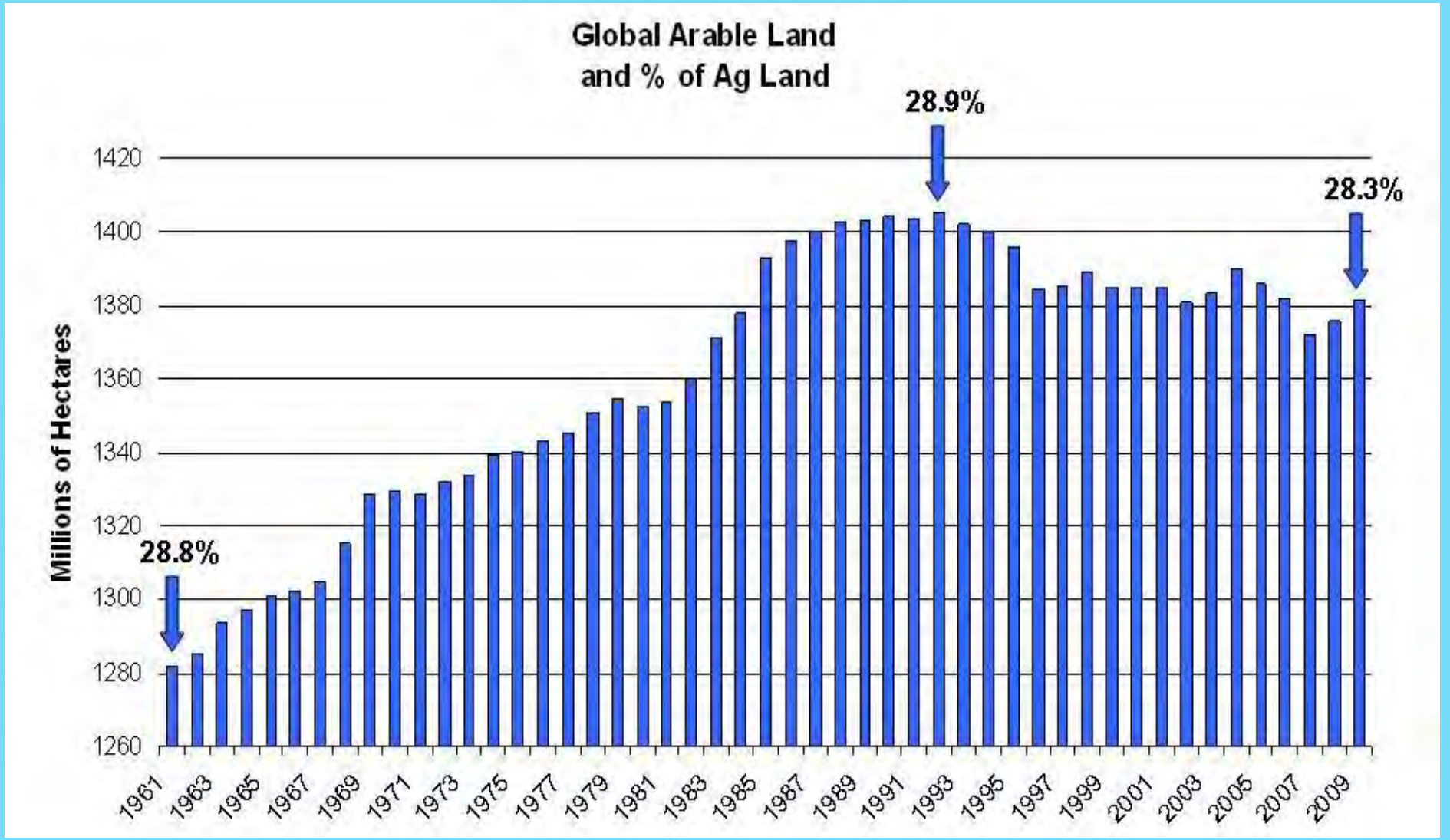

*Agricultural Production is normally increased by:*

*- Engaging more land*

*- Irrigation/fertilization*

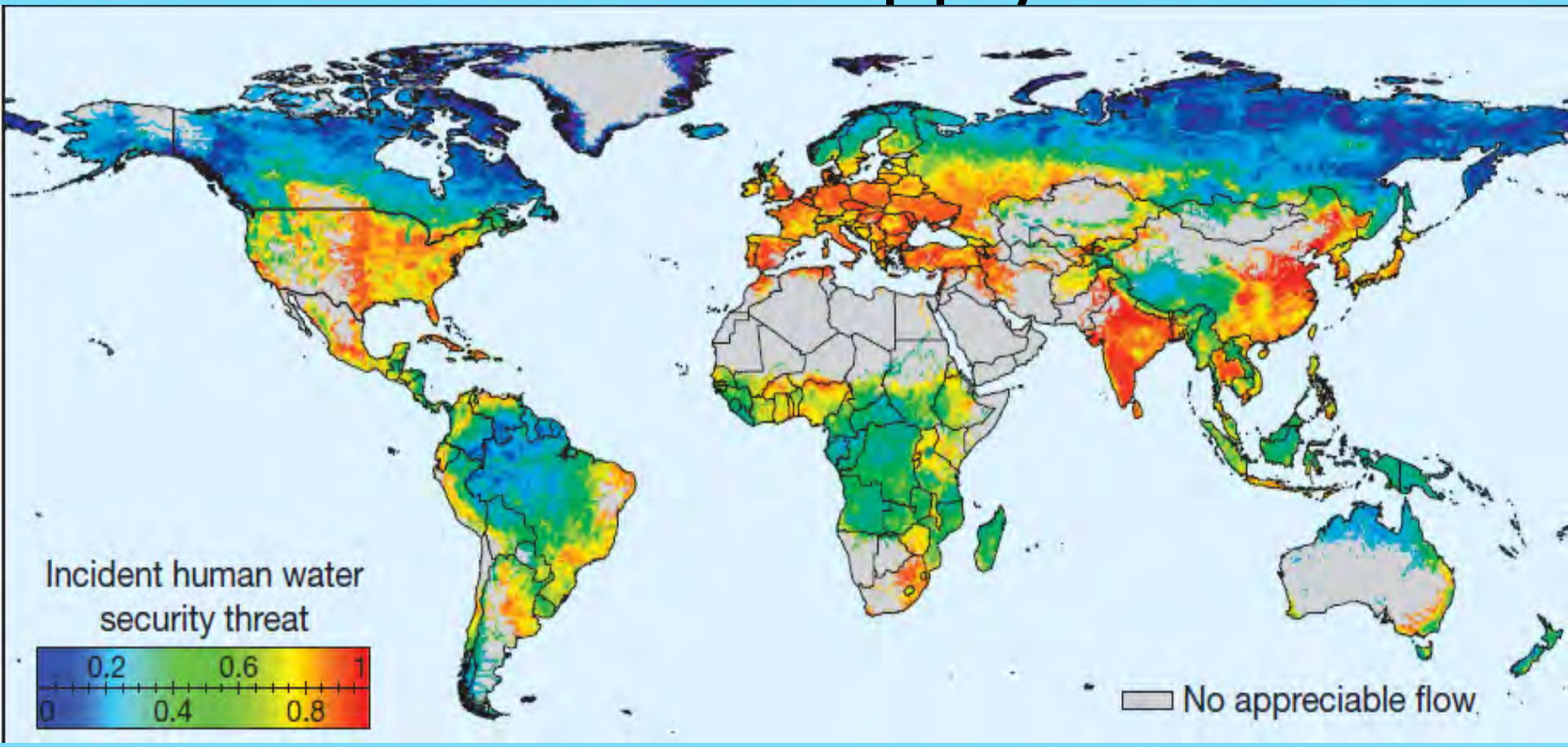
*- Genetic improvements*

# Land area is NOT increasing




UNEP Data

# Global Water Supply Threat



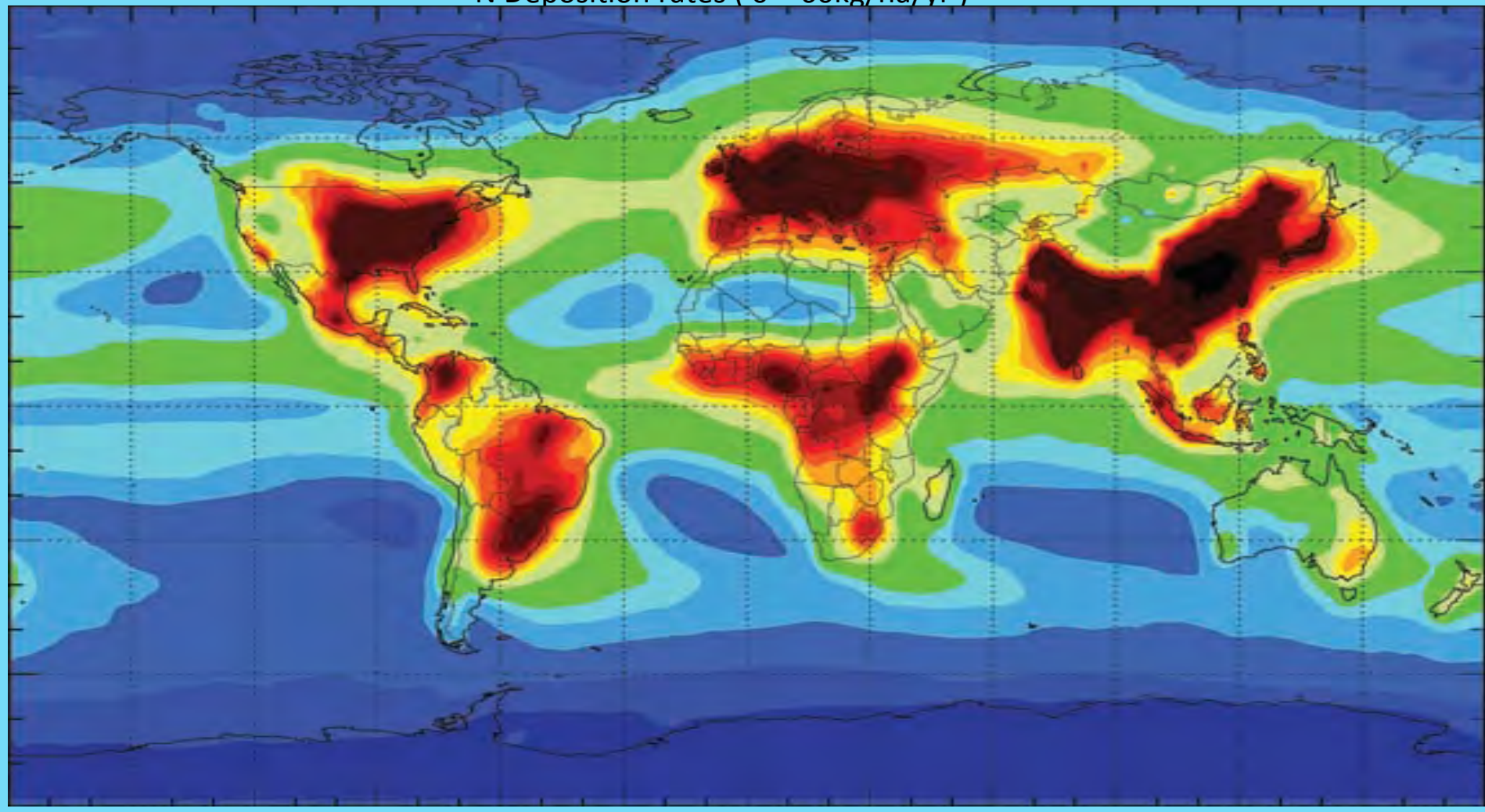

**Vorosmarty et al *Nature* 2010**

*The global percentage of dry areas has increased by about 1.74% (of global land area) per decade (11%) from 1950 to 2008.*

*Aiguo Dai. J.Geophysical Res 2011*

# Nitrogen Loading is already damaging the biosphere

N Deposition rates ( 0 – 60kg/ha/yr )

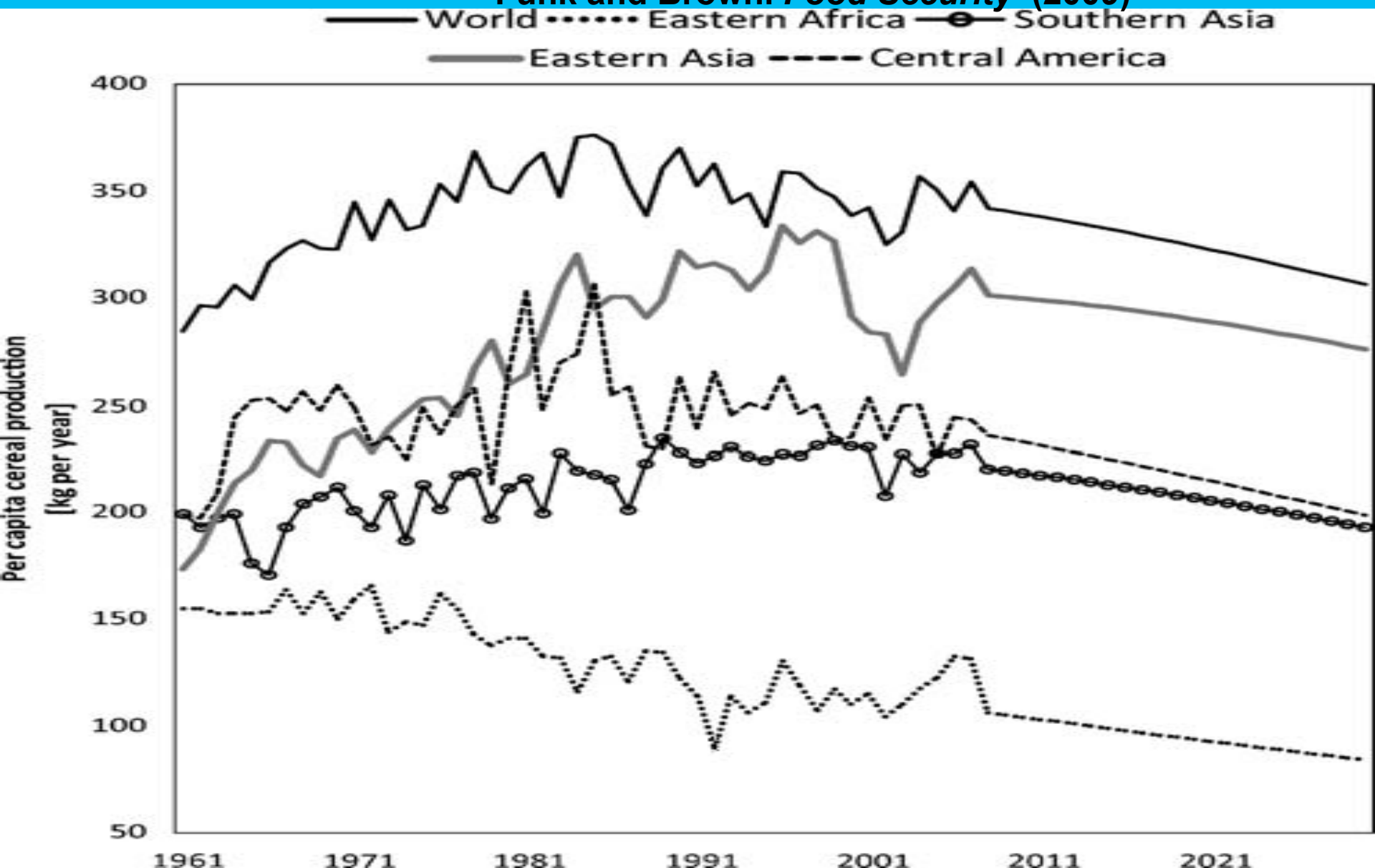


**Galloway et al. *Science* 2008**

# Per Capita Agricultural Production trends.

*Global 14% Per capita reduction projected by 2030*

**Funk and Brown. *Food Security* (2009)**




IF MORE LAND AREA IS NOT AVAILABLE,
MORE IRRIGATION WATER IS NOT AVAILABLE
MORE FERTILIZER USE POLLUTES THE BIOSPHERE
AMD
BIOENERGY CONSUMES ANY "EXCESS" NPP
THEN NPP MAY BE A PLANETARY BOUNDARY
THAT IS BEING APPROACHED
2007 6 8

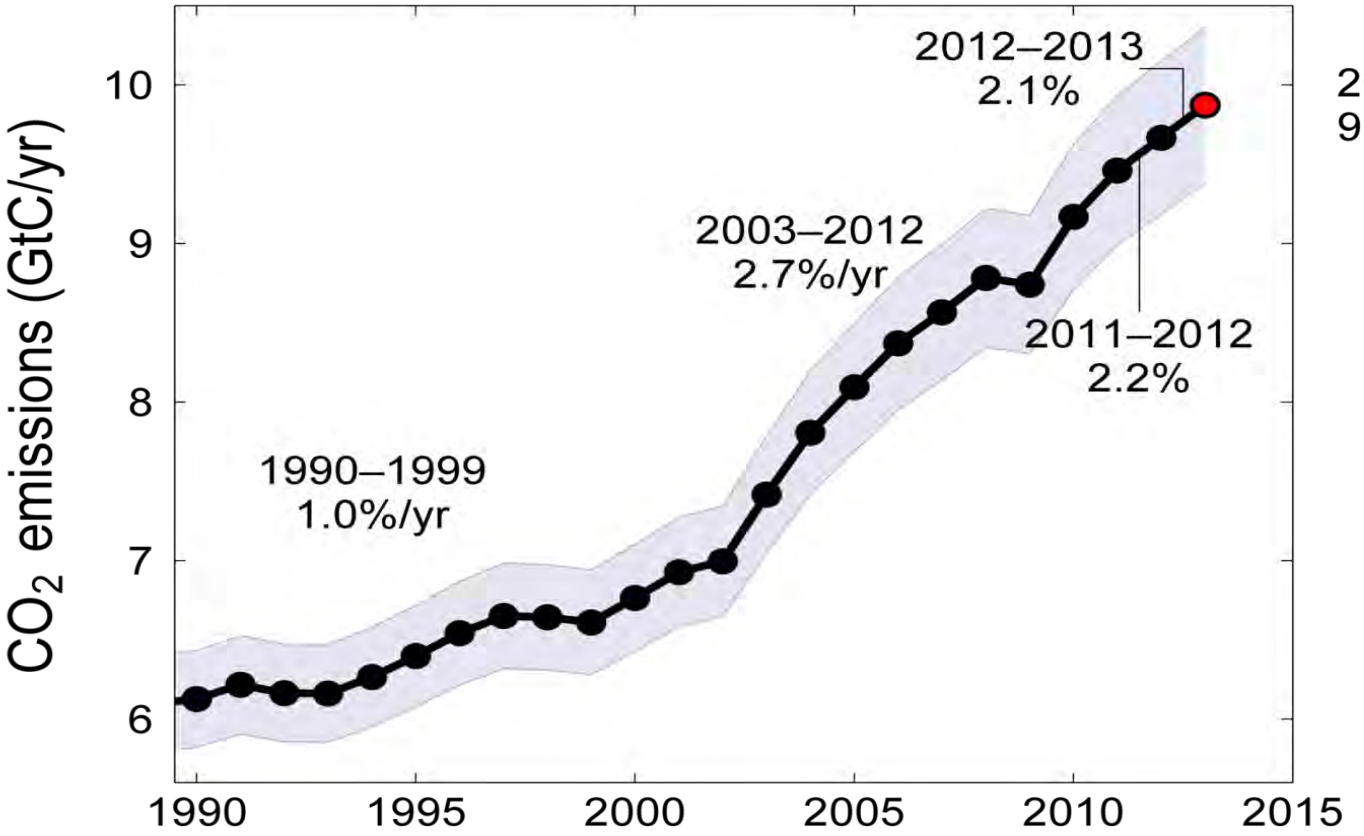
# The Anthropocene Era


GROWTH 1960 – 2000:
POPULATION: DOUBLED 2x
ECONOMY: SIXFOLD 6x
FOOD PRODUCTION: TWO AND A HALFFOLD 2,5x
USE OF FRESH WATER: DOUBLED 2x
CUTTING OF FOREST FOR PULP AND PAPER: THREEFOLD 3x
DAMMED RIVERS: FOURFOLD 4x
... DURING THE SAME PERIOD OF TIME THE EARTH HAS NOT GROWN A BIT.
seppo.net

# Fossil Fuel and Cement Emissions

Global fossil fuel and cement emissions: 9.7 ± 0.5 GtC in 2012, 58% over 1990

● Projection for 2013 : 9.9 ± 0.5 GtC, 61% over 1990



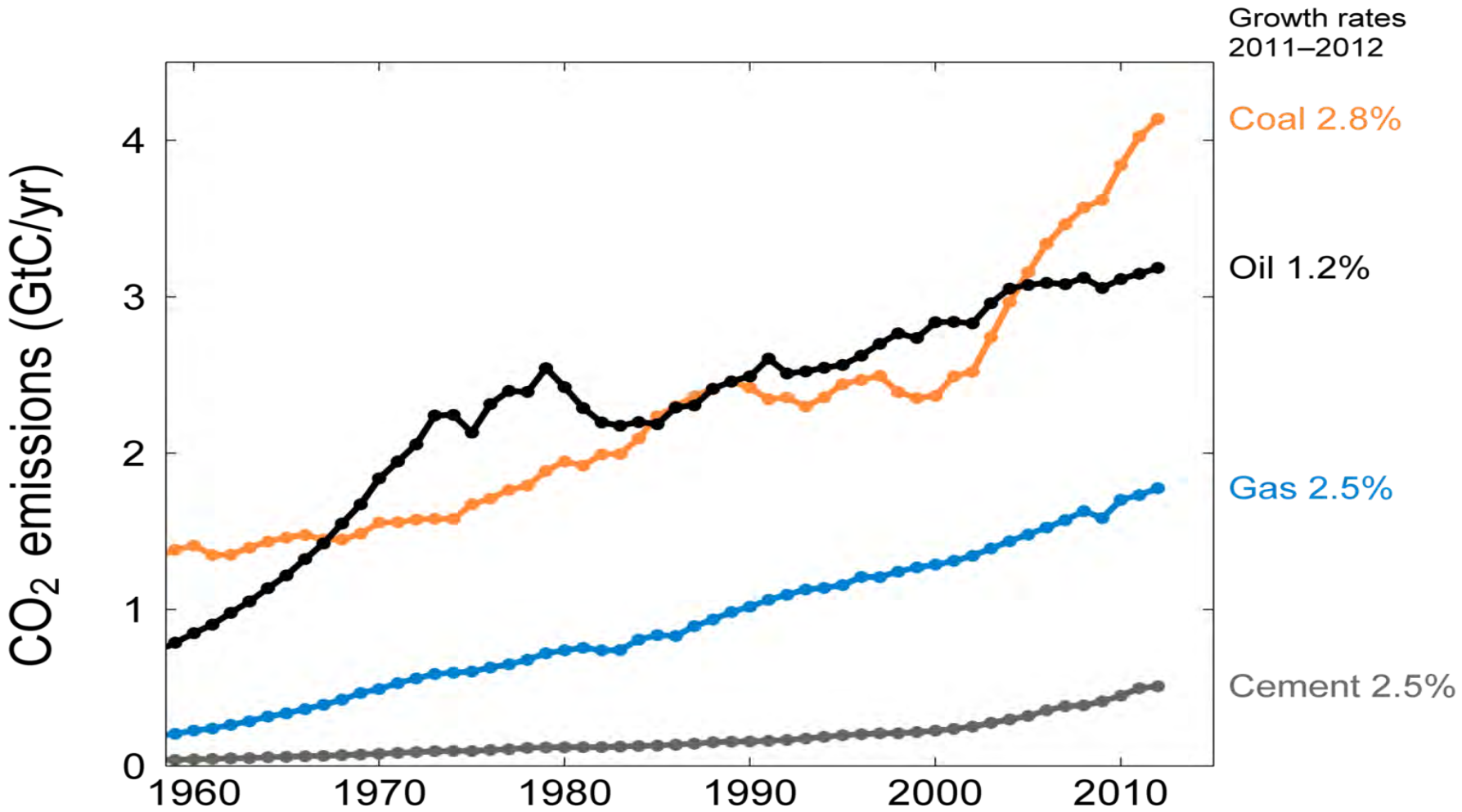

Uncertainty is ±5% for one standard deviation (IPCC "likely" range)

With leap year adjustment: 2012 growth rate is 1.9% and 2013 is 2.4%

Source: Le Quéré et al 2013; CDIAC Data; Global Carbon Project 2013

# Emissions from Coal, Oil, Gas, Cement

Share of global emissions in 2012:
coal (43%), oil (33%), gas (18%), cement (5%), flaring (1%, not shown)




With leap year adjustment in 2012 growth rates are: coal 2.5%, oil 0.9%, gas 2.2%, cement 2.2%.

Source: CDIAC Data; Le Quéré et al 2013; Global Carbon Project 2013

# Alberta Tar Sands… Is This next?

***But they wouldn't dig it, if we didn't buy it***

GREAT LAKES ECHO



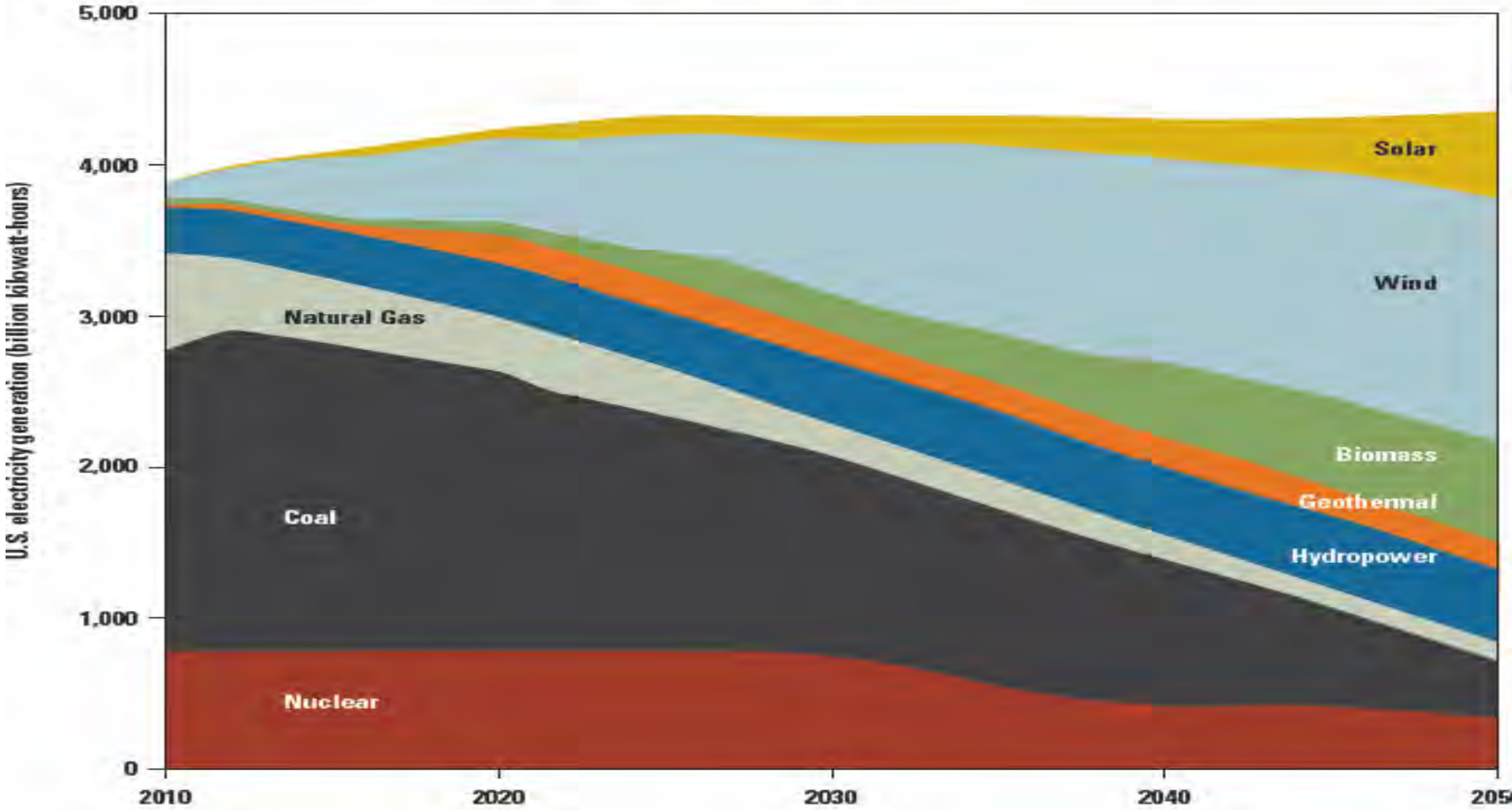
# Ontario shuns coal; will other provinces follow?

MAR 24 2014 RJ WOLCOTT NO COMMENTS



The Nanticoke Generating Plant in Nanticoke, Ontario, was one of Canada's highest emitters of green house gases until it was shut down at the end of 2013

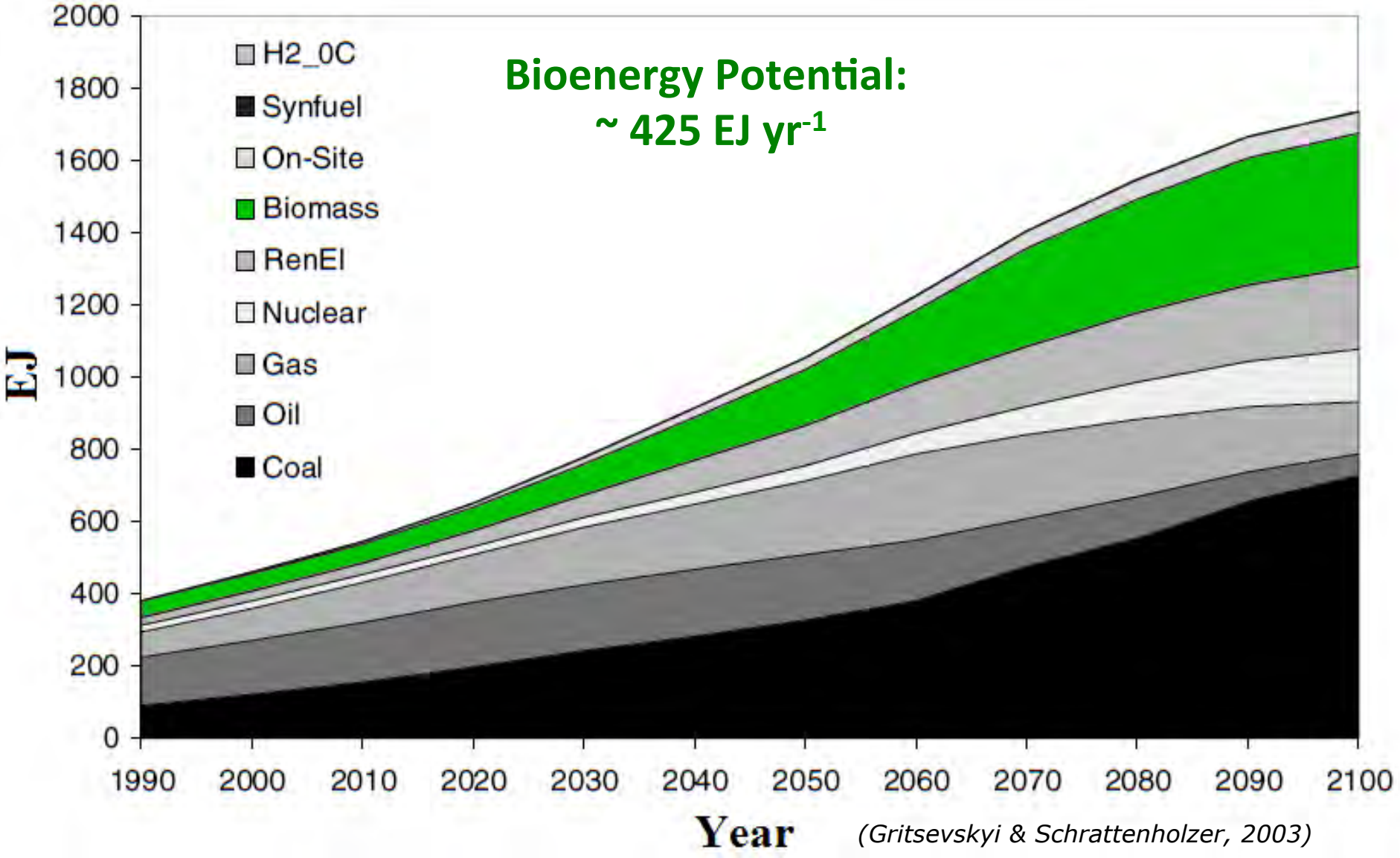
## Figure 4. Renewable energy could provide 80 percent of U.S. electricity by 2050.




**A 2012 study by the National Renewable Energy Laboratory found that renewable energy technologies available today could supply 80 percent of U.S. electricity in 2050, while meeting demand every hour of the year in every region of the country. Under this scenario, wind and solar facilities would provide nearly half of U.S. electricity that year.**

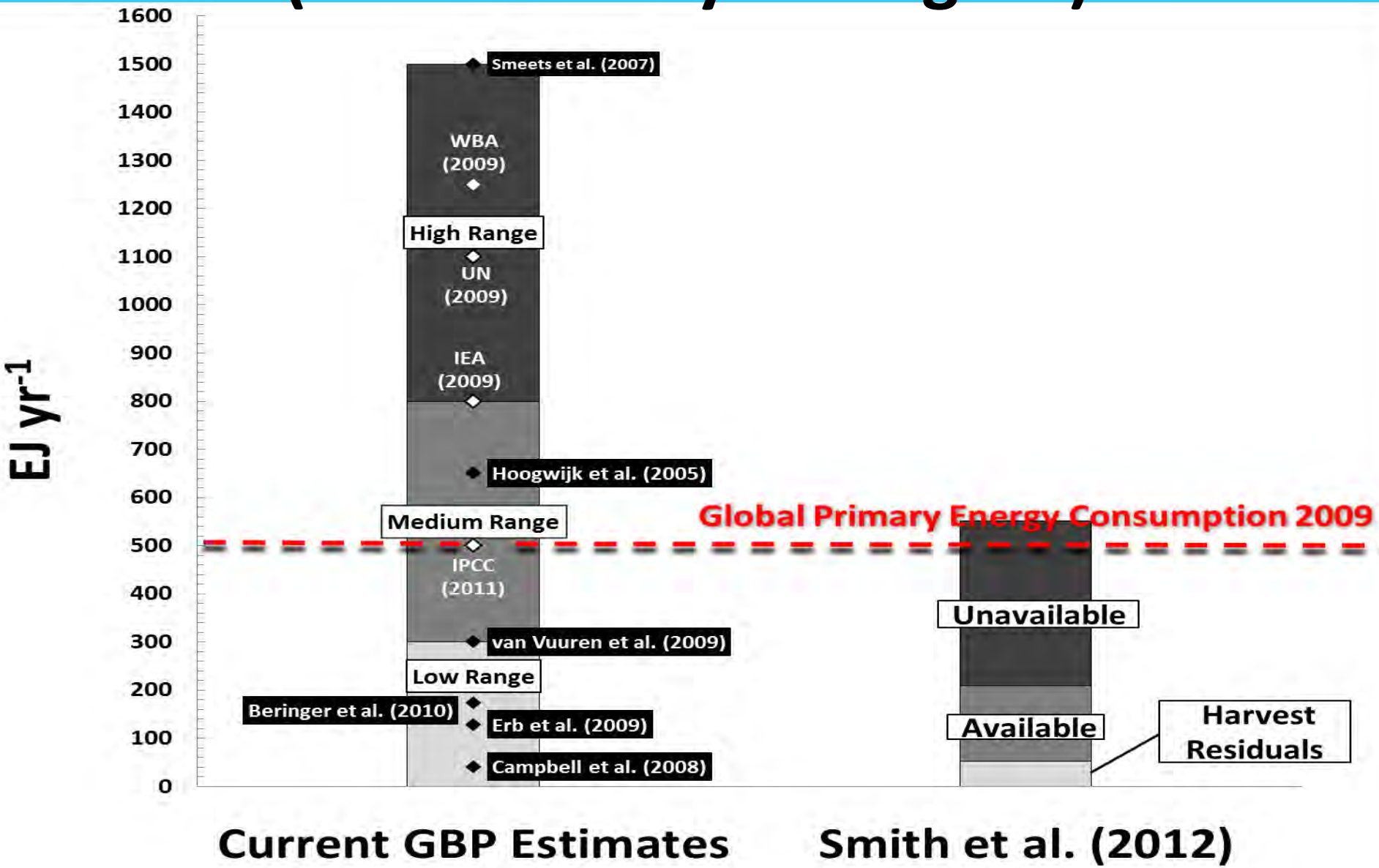
Source: NREL 2012.

# Future Bioenergy Potential (estimated by economists)




*(Gritsevskyi & Schrattenholzer, 2003)*

# Capacity for Bioenergy Production (estimated by ecologists)



BloombergBusinessweek
News From Bloomberg





Bloomberg News

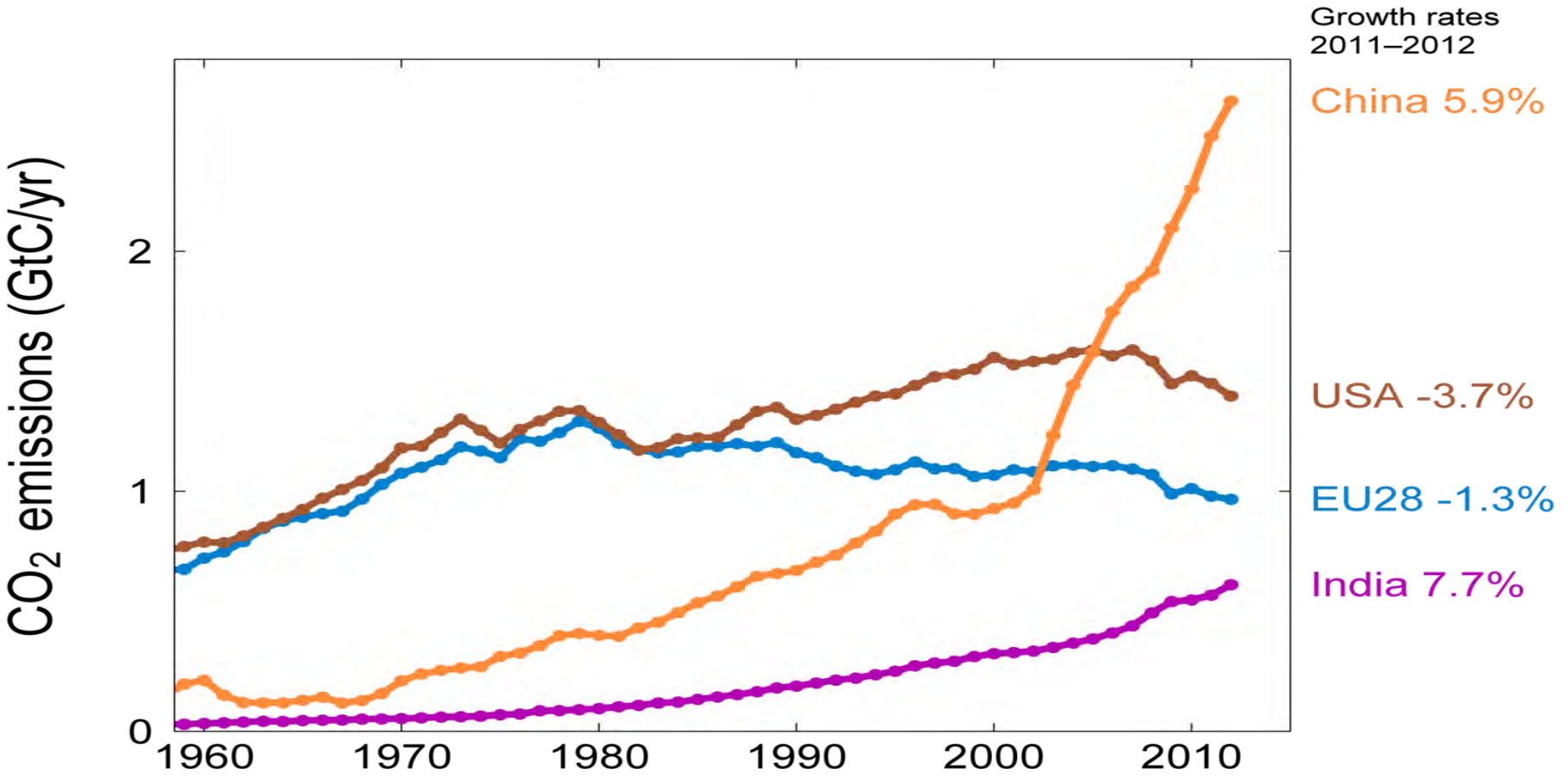
# How Much Hot Air do the UN Climate Treaty Talks Produce?

By Alex Morales | November 20, 2013



# Top Fossil Fuel Emitters (Absolute)

Top four emitters in 2012 covered 58% of global emissions
China (27%), United States (14%), EU28 (10%), India (6%)




With leap year adjustment in 2012 growth rates are: China 5.6%, USA -4.0%, EU -1.6%, India 7.4%.

Source: CDIAC Data; Le Quéré et al 2013; Global Carbon Project 2013

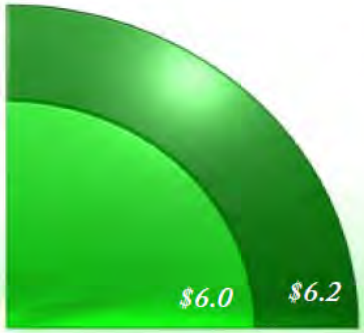
# Federal Subsidies *(2002-08)*

**FOSSIL FUELS**
$72.5 billion

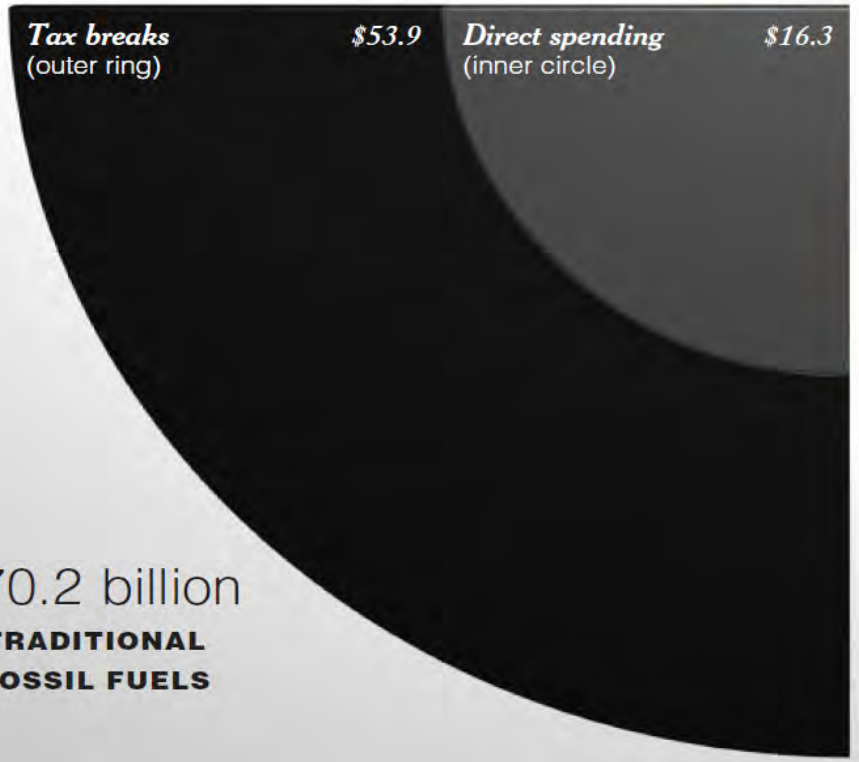
**RENEWABLE ENERGY**
$29.0 billion

$2.3 billion
**CARBON CAPTURE AND STORAGE***


$12.2 billion
**TRADITIONAL RENEWABLES**




*all subtotals in $ billions*




$70.2 billion
**TRADITIONAL FOSSIL FUELS**


$16.8 billion
**CORN ETHANOL****

***The "Climate Problem" cannot be solved without a re-orientation of society goals and priorities***

**When will global economic growth hit a "Planetary Boundary"?**

# COMMENT

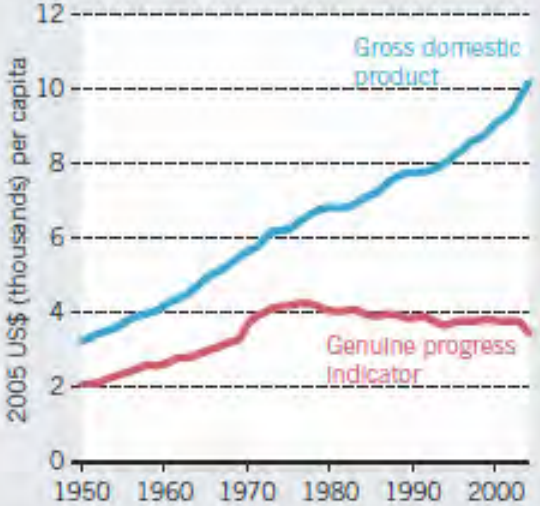



ILLUSTRATION BY PETE ELLIS/DRAWGOOD.COM

# Time to leave GDP behind

Gross domestic product is a misleading measure of national success. Countries should act now to embrace new metrics, urge **Robert Costanza** and colleagues.

Constanza et al., Nature January 2014



**THE MOST DISTANT IMAGE OF EARTH EVER TAKEN, *1 BILLION KM***

**WE BETTER NOT SCREW THIS PLANET UP**