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.

- 318 ppm (1958)
- 388 ppm (2008)

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”

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
Fig. 2. Global distribution of NPP ($\times$ 10 gm C/m²/yr) at the tracer model resolution.
July 1982 Green Leaf Density
Land-Related Global Habitability
Science Issues

Land-Related Global Habitability
Sciences Working Group

JULY 1983
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??

A Measurable Planetary Boundary for the Biosphere

From Running, SW. Science 337 p1458-1459, 2012
Global Terrestrial Net Primary Production (1982-2013)

Nemani et al 2003, Zhao and Running 2010

+/- 1Pg or about 2%
CMIP5 Projections of Global NPP with RCP = 8.5. Really???
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

Global Arable Land and % of Ag Land

Millions of Hectares


UNEP Data
Global Water Supply Threat

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

Vorosmarty et al Nature 2010
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

IF MORE LAND AREA IS NOT AVAILABLE, MORE IRRIGATION WATER IS NOT AVAILABLE, MORE FERTILIZER USE POLLUTES THE BIOSPHERE, AND BIOENERGY CONSUMES ANY “EXCESS” NPP.

THEN NPP MAY BE A PLANETARY BOUNDARY THAT IS BEING APPROACHED.
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.
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

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
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 greenhouse gases until it was shut down at the end of 2013.
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)

Bioenergy Potential:
\(~ 425 \text{ EJ } \text{yr}^{-1}\)

(Gritsevskyi & Schrattenholzer, 2003)
Capacity for Bioenergy Production (estimated by ecologists)

Current GBP Estimates

Smith et al. (2012)

Available

Harvest Residuals

Global Primary Energy Consumption 2009

Unavailable

Low Range

Beringer et al. (2010)

Erb et al. (2009)

Campbell et al. (2008)

Medium Range

IPCC (2011)

High Range

UN (2009)

WBA (2009)

Hoogwijk et al. (2005)

Smeets et al. (2007)
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%)

Growth rates 2011–2012:
- China: 5.6%
- USA: -4.0%
- EU28: -1.6%
- India: 7.4%

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Source: CDIAC Data; Le Quéré et al 2013; Global Carbon Project 2013
The “Climate Problem” cannot be solved without a re-orientation of society goals and priorities.

When will global economic growth hit a “Planetary Boundary”? 
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