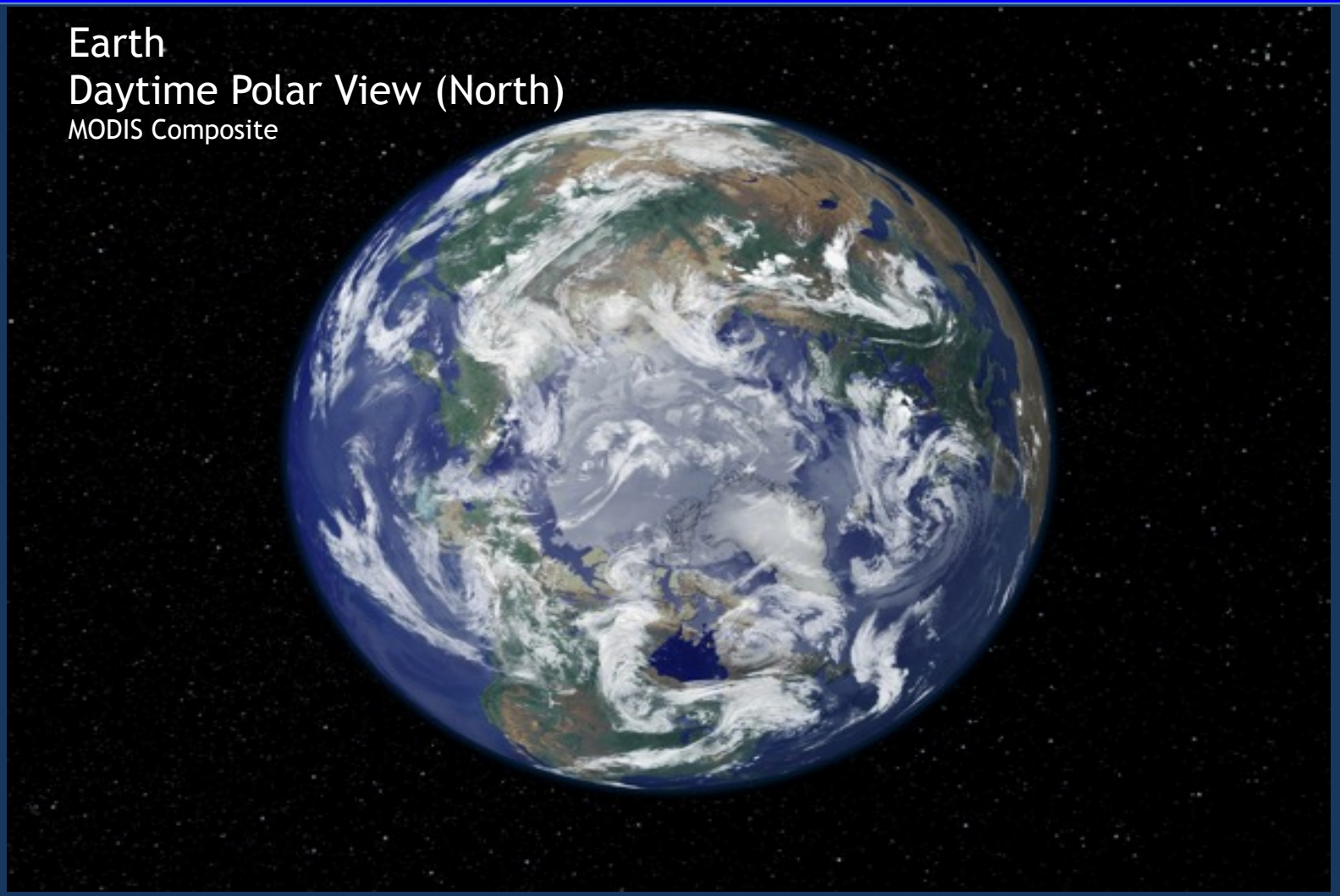
Urbanization and the Sustainable Human Enterprise



MARC IMHOFF - UMD's Earth System Science Interdisciplinary Center (ESSIC)

Urbanization - as a process - impacts ecosystems directly and indirectly at global, regional, and local scales

Earth
Nighttime Polar View
(North)
DMSP/OLS Composite

How do we address the complex interactions between the human and natural Earth systems in such a way that we can better determine our own destinies?

What is 'Sustainability' in the Context of Urbanization?

- SUSTAINABLE: Oxford English Dictionary
  - Definition: *Able to be maintained at a certain rate or level*
- What rate or level of services and resources (ecosystem or otherwise) are required to support urban metabolisms?
  - Food, water, energy, fabrication…
  - *Simple question with complex answers!*

Urban Metabolism Will Have Significant Global Ecosystem Impacts (Rates)

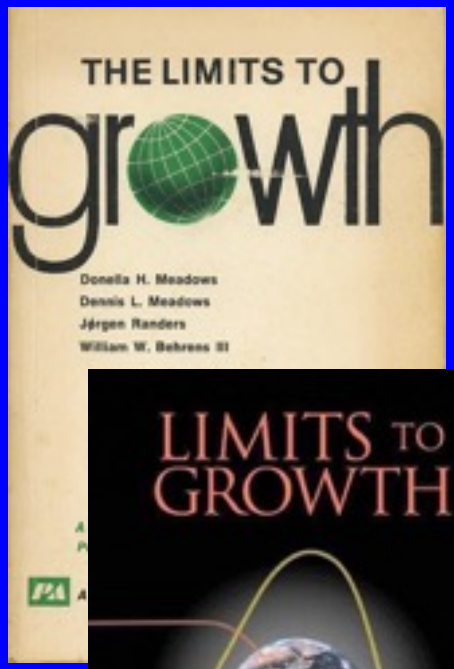
Global Population likely to reach 11B by 2100

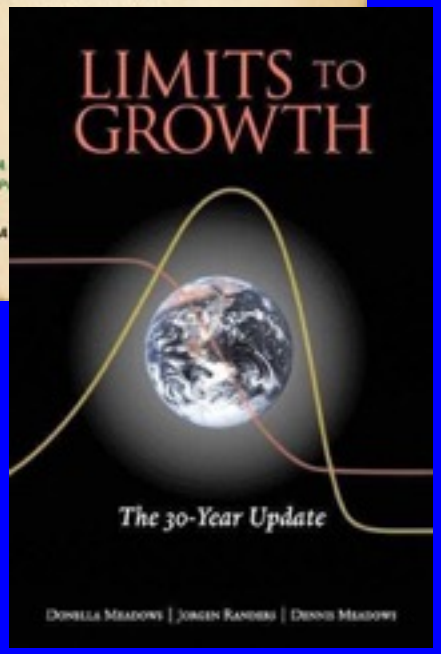
- 80% of which could be Urban

From: World Population Stabilization Unlikely This Century

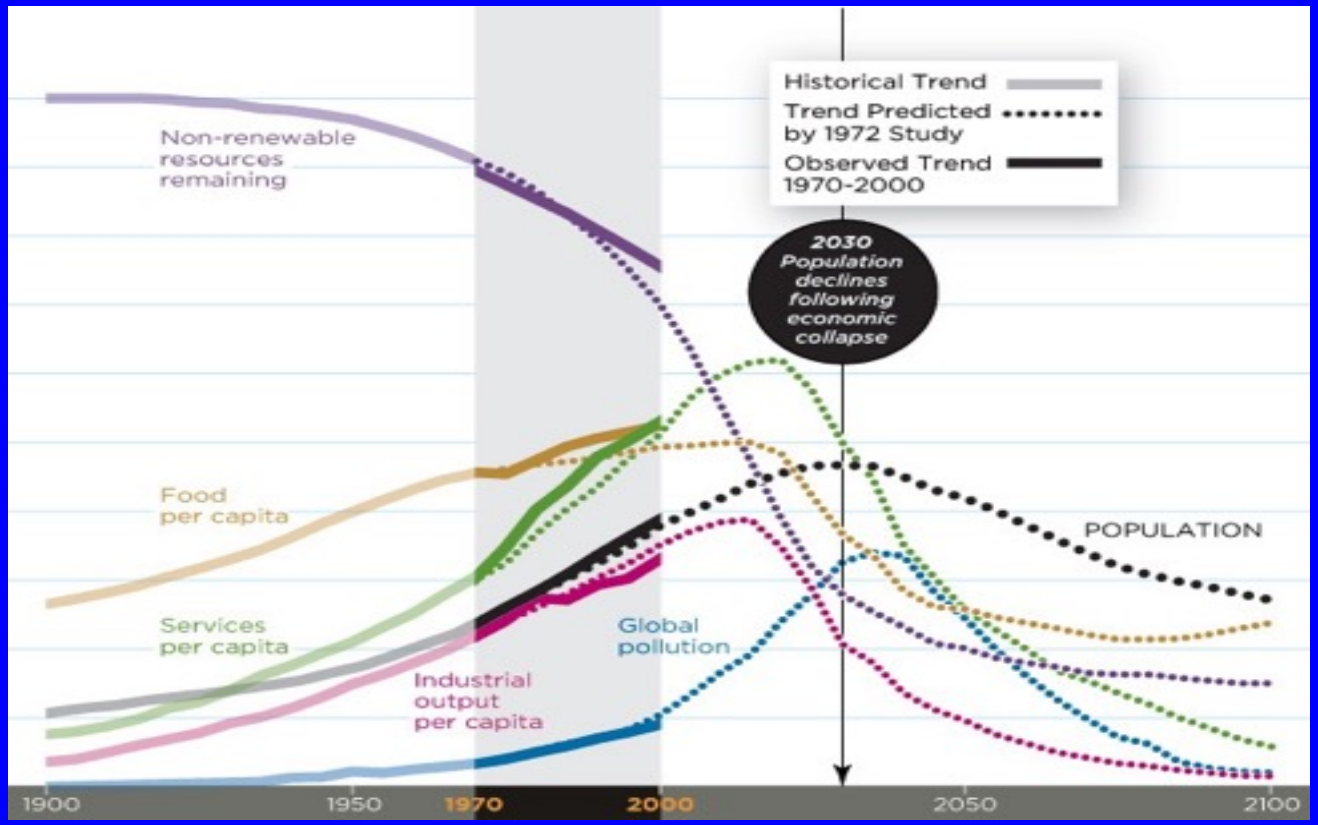
P. Gerland et al., 2014. Science (10 October 2014): Vol. 346 no. 6206 pp. 234-237

Urbanization, Development, Population and Economic Growth are Linked: Is there a Limit?





1972 MIT Model Predicts Half of Humanity to Be Culled in Post-Industrial Crash by 2030



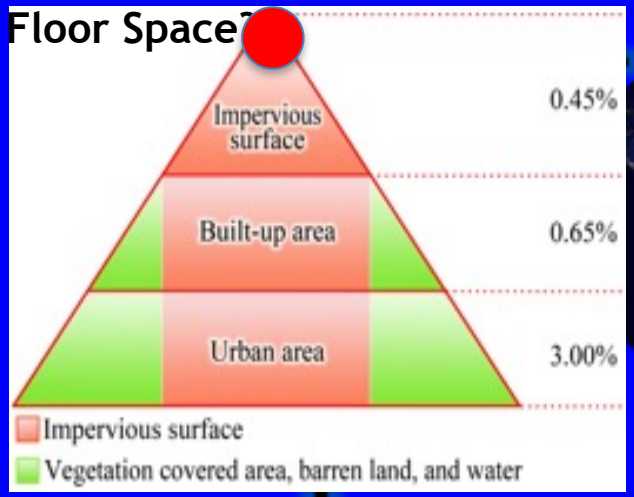
Compelling, but there is a lot missing here!

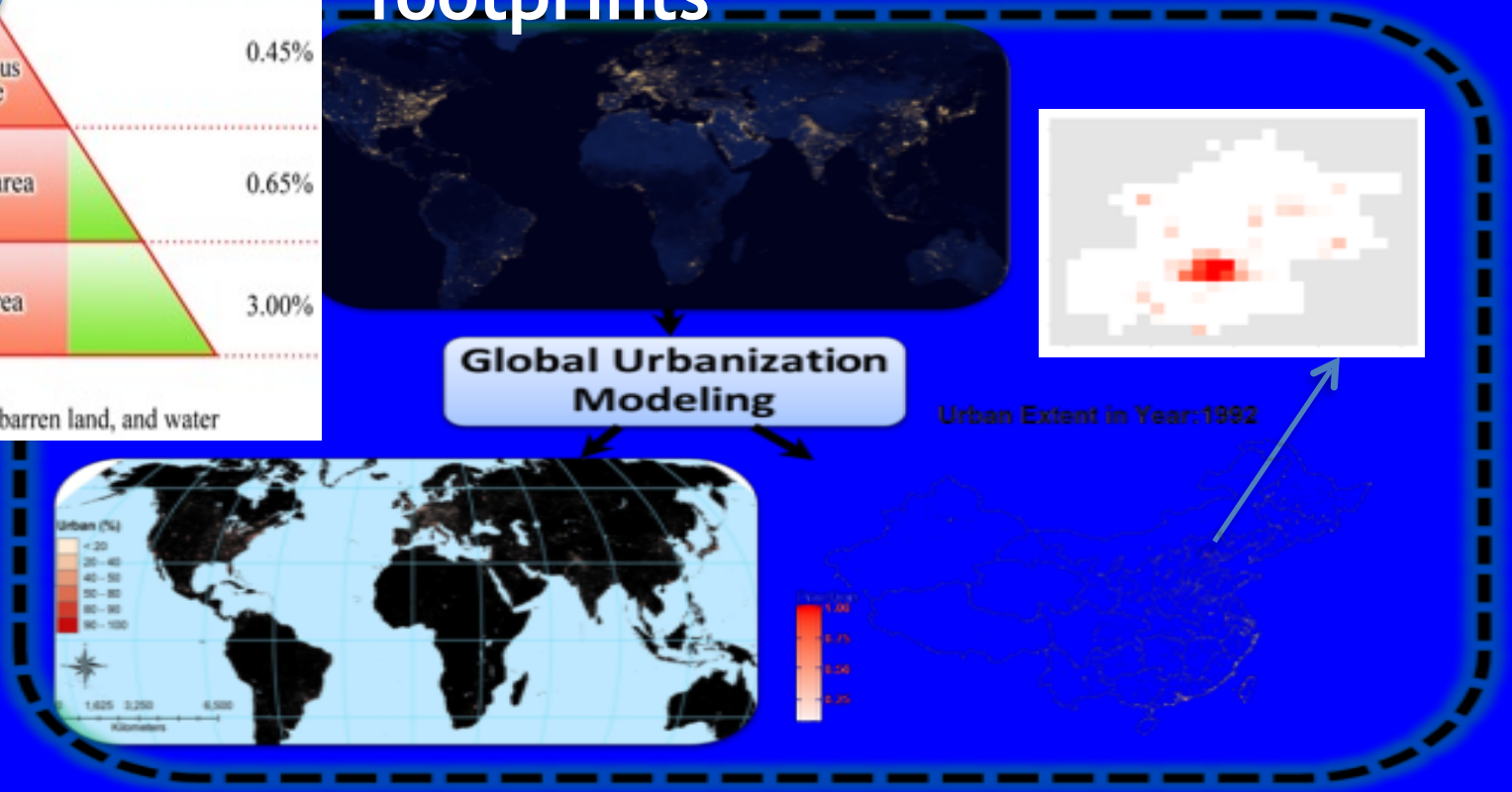
Approaches for Assessment

- **Footprint** – Area contextualization
- **Rate based** – Input versus Output
- **Predator Prey** - Interactive
- **Integrated Assessment** – Couples approaches linking human and natural systems dynamically.

Multi-tiered Mapping Methods Critical for Analyses

System for consistent purpose-based mapping of urban footprints



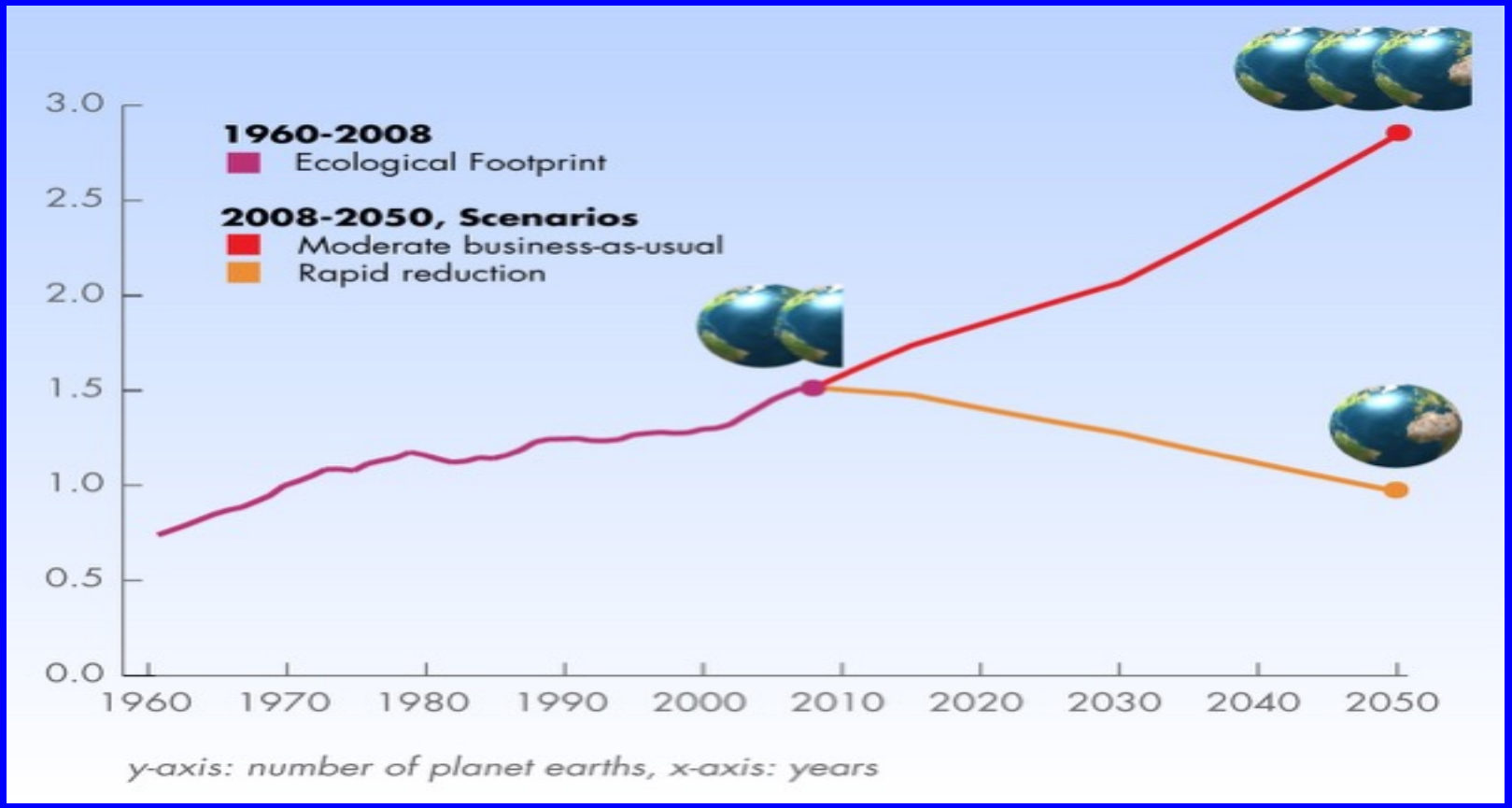


Yuyu Zhou - PNNL's Joint Global Change Research Institute

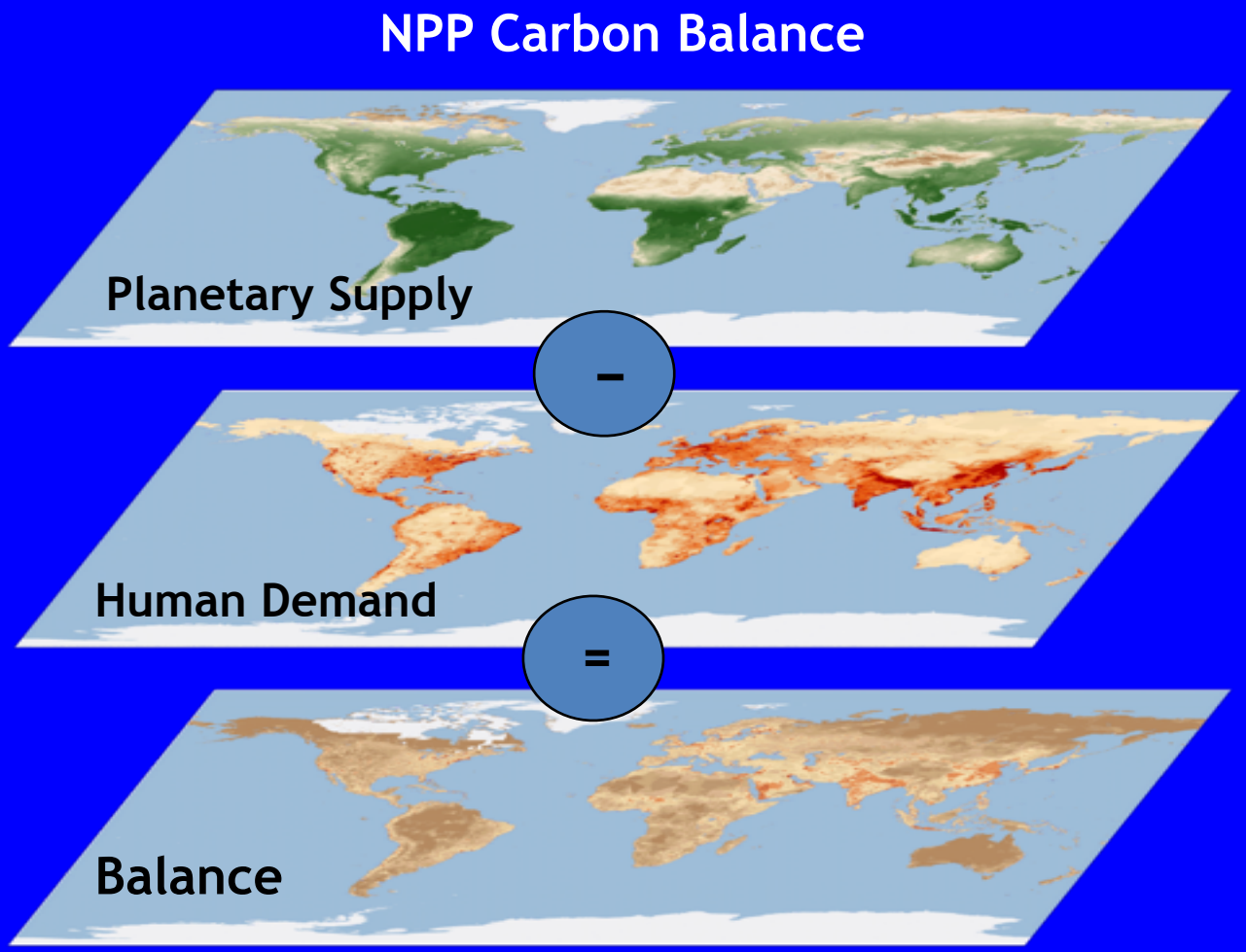
Liu, Z., C. He, Y. Zhou, J. Wu, . *Landscape Ecology*,2014

Human Footprint Analyses

GLOBAL FOOTPRINT NETWORK
http://www.footprintnetwork.org/en/index.php/GFN/page/world_footprint/



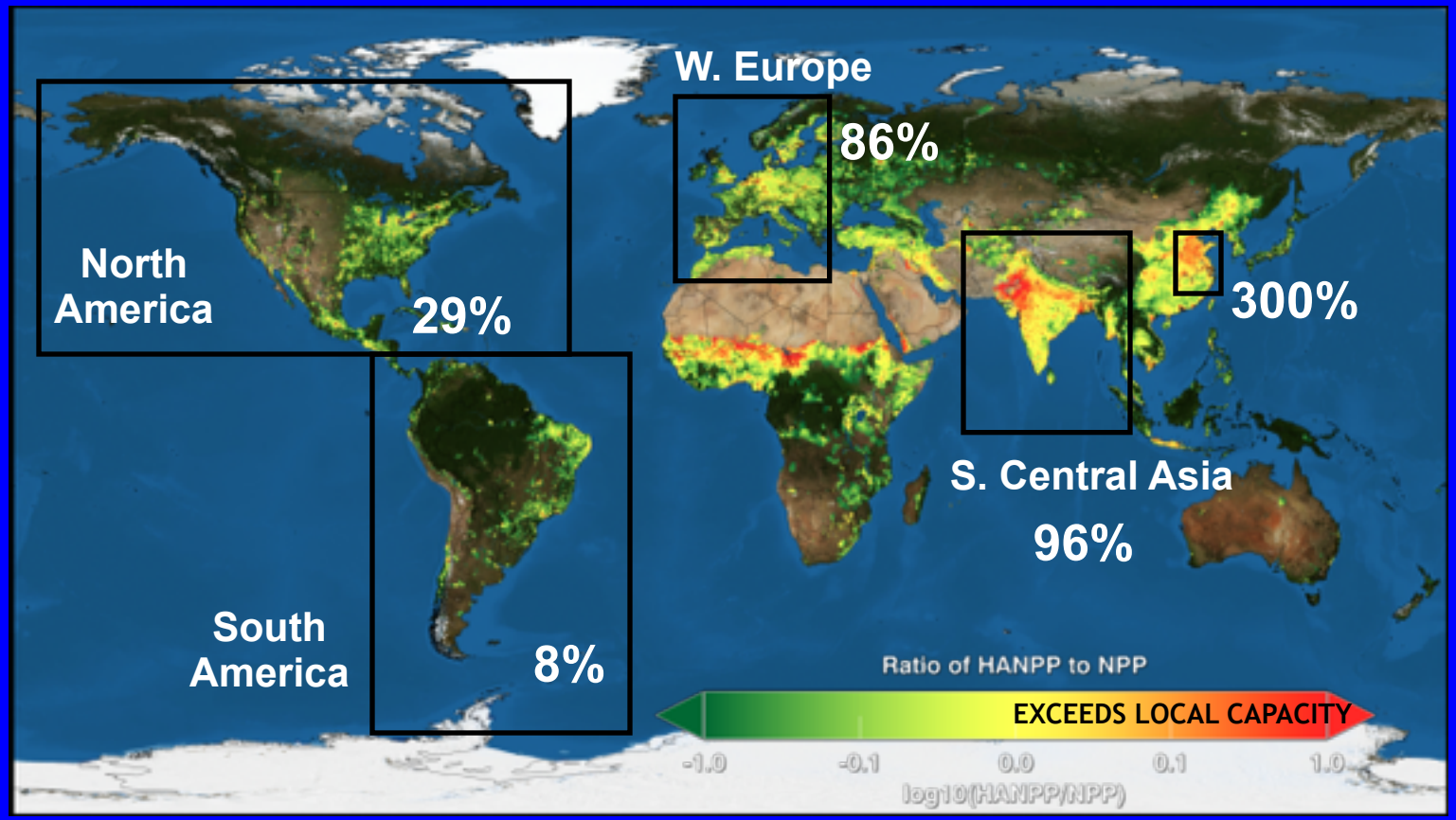
RATE Based Assessments: Human 'Appropriation' of NPP (HANPP)



M. L. Imhoff et al., Nature 429, 870, 2004
M. L. Imhoff et. al., JGR, VOL. 111, 2006

Rate of Human Appropriation of NPP: Requirement as % of Terrestrial Supply

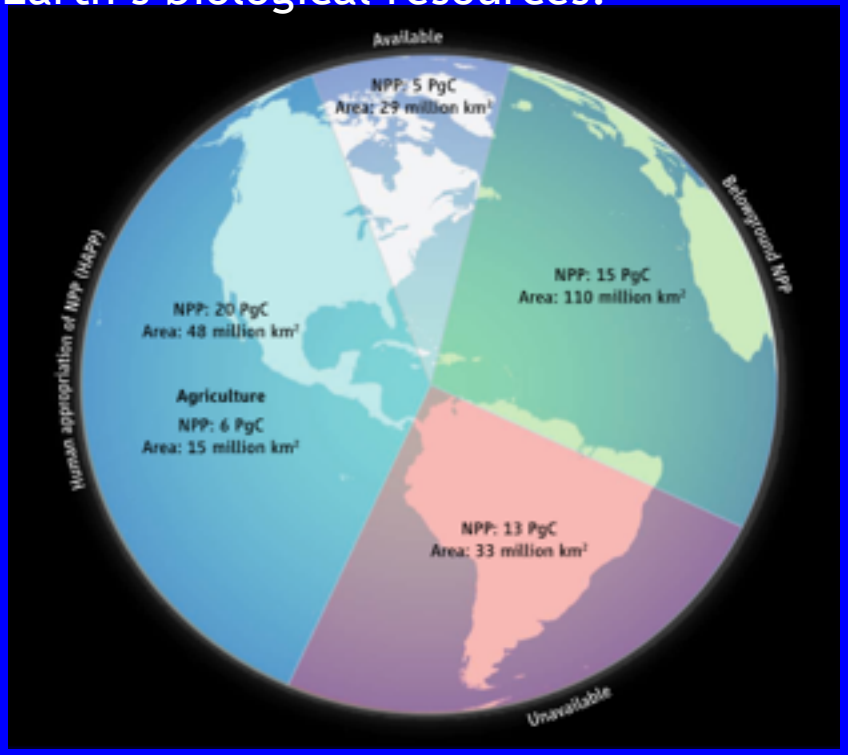
Some regions exceed their local capacity by many times.
Food security dependent on trade.



M. L. Imhoff et al., Nature 429, 870, 2004
M. L. Imhoff et. al., JGR, VOL. 111, 2006

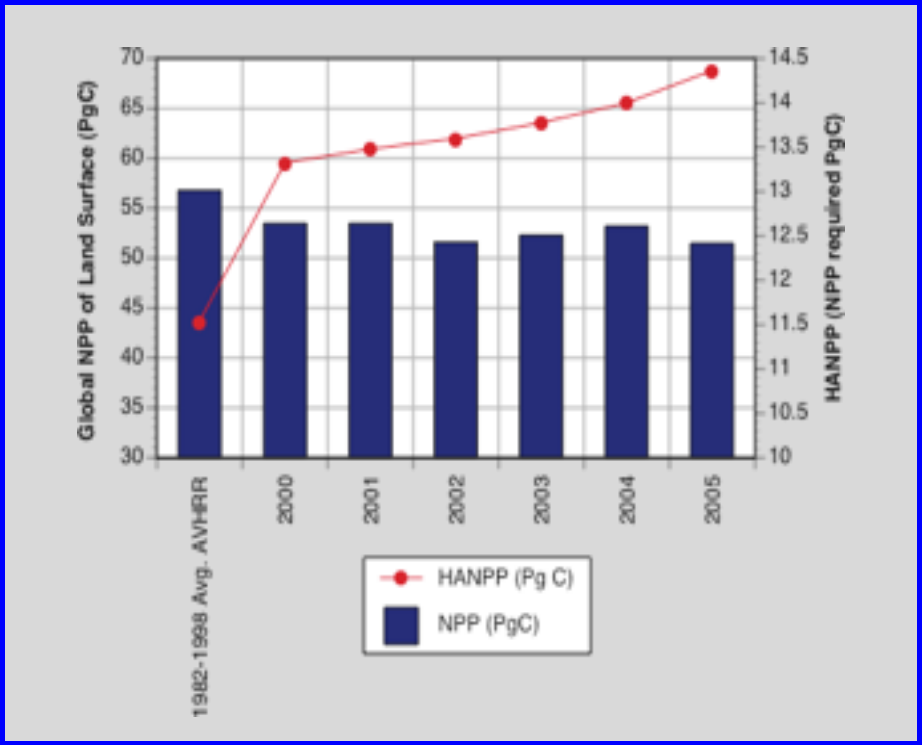
Will human consumption of primary plant production soon reach its limits?

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



S. Running: 21 SEPTEMBER 2012 VOL 337 **SCIENCE**

Satellite observations of planetary NPP "Supply" shows no trend but human "Demand" is rising



Rate -Based Area-Change Analyses

Annual NPP Lost or Gained Going from a pre-urban to a post urban world

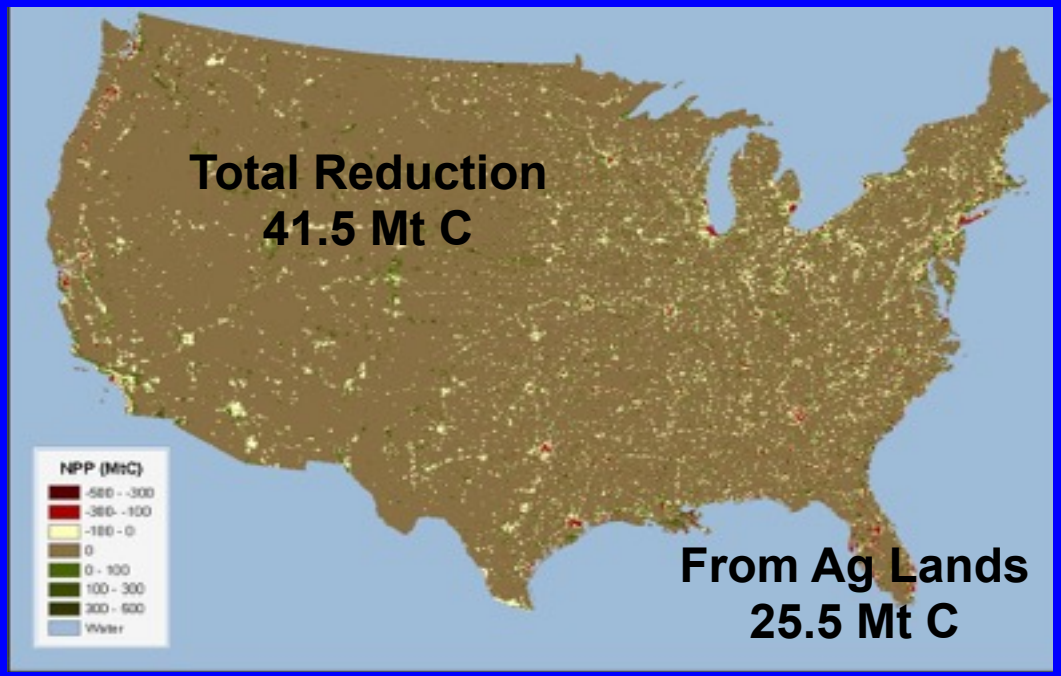
Urbanization and NPP

- NPP decreased 41.5 M tons C / year.
- Roughly offsets 300 years of agricultural development.

Location, Location, Location.
Most Urbanization is taking place on the most fertile lands

Reduction of NPP may have biological significance:

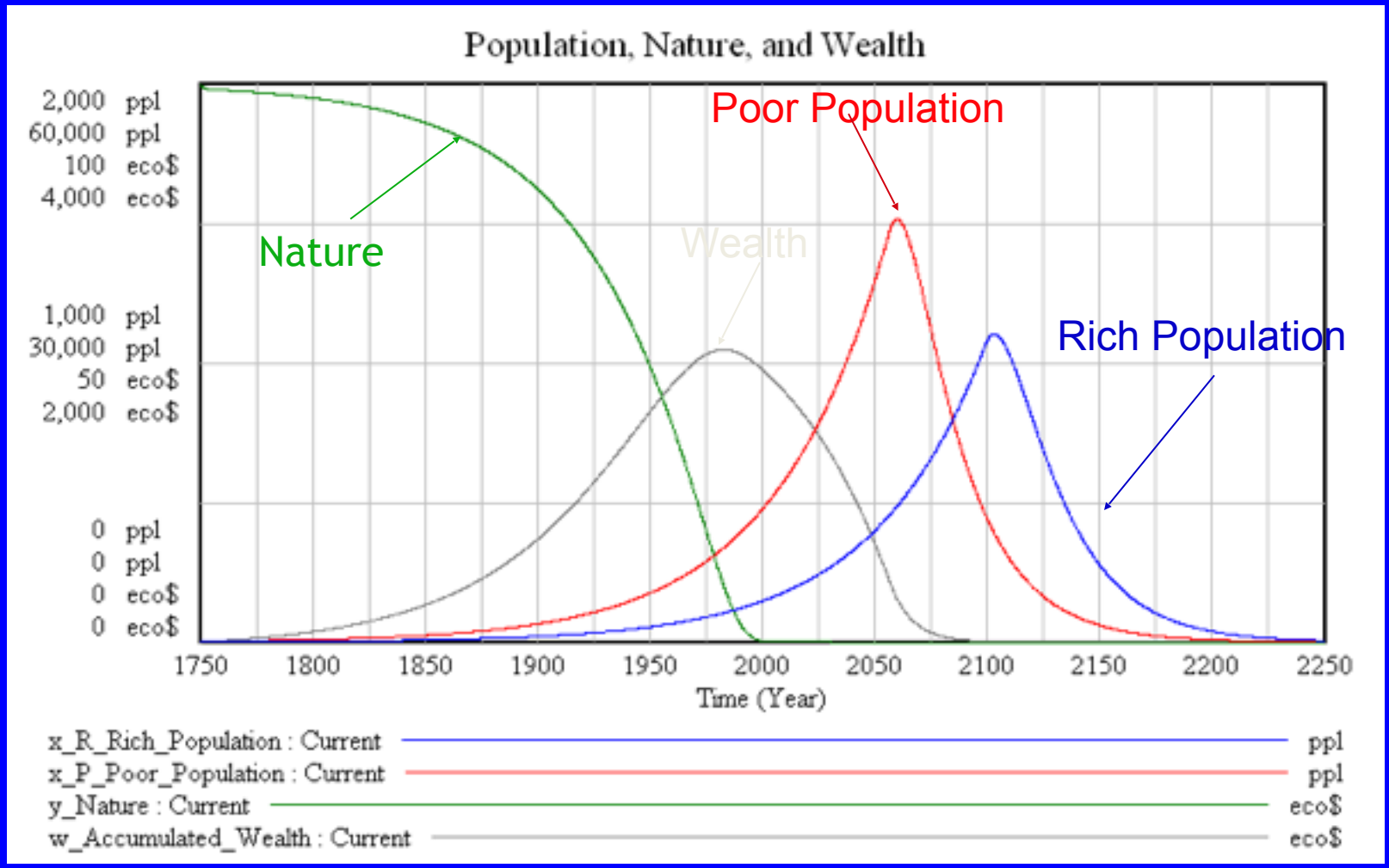
Calibrated DMSP Data and MODIS NPP



M. Imhoff et al., RSE 89 (2004) 434-443

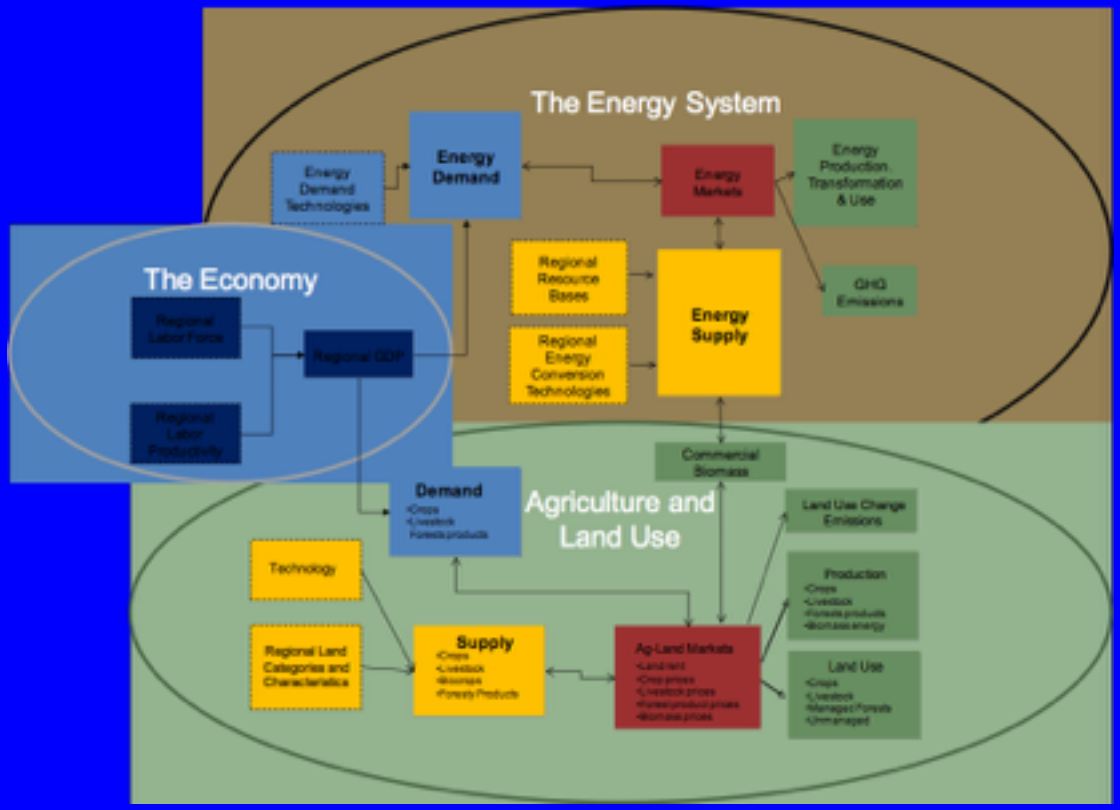
Coupled Modeling Approaches: Human and Nature Dynamical model (HANDY)

Rich
Poor
Nature
Wealth



Montesharrei, Rivas, and Kalnay, *Ecol. Econ.*, 101 (2014) 90-102

Integrated Assessment – PNNL's Global Change Assessment Model (GCAM)

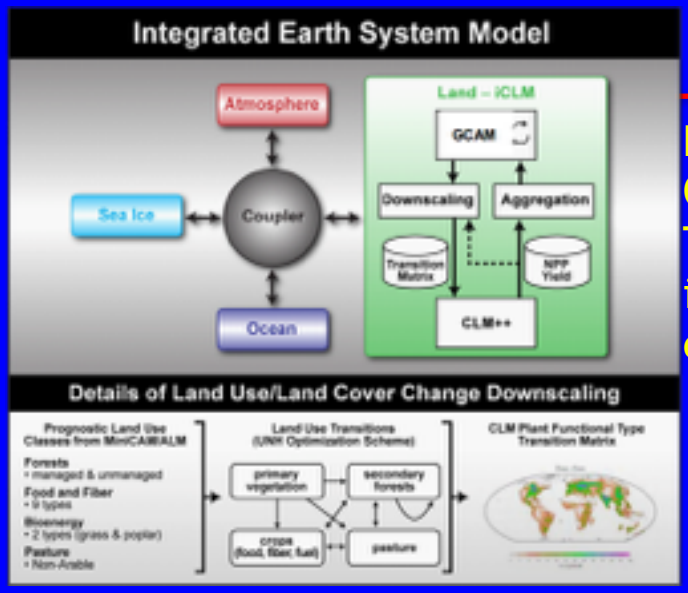


The GCAM human Earth systems

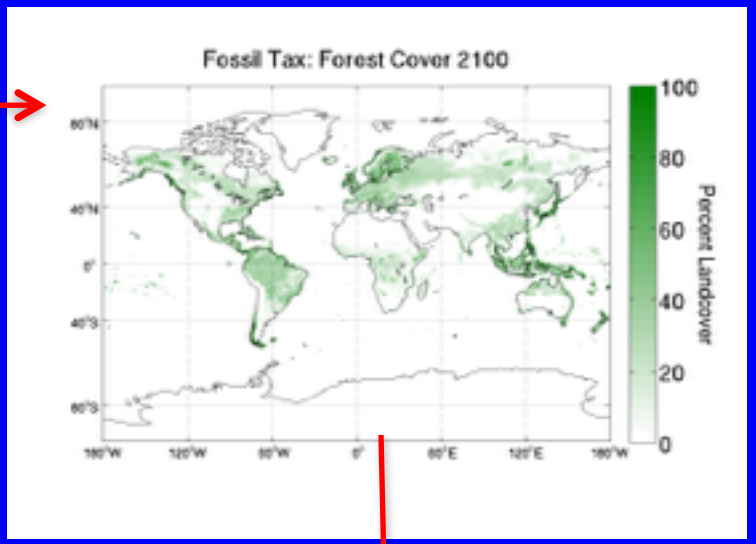
- **Open source model.**
- Dynamic-recursive model.
- **The GCAM human Earth systems model has Economic, Energy and Land-use systems.**
- Technologically detail.
- Emissions of 16 greenhouse gases and short-lived species: CO_2, CH_4, N_2O, halocarbons, carbonacious aerosols, reactive gases, sulfur dioxide.
- 151 Agro-Ecological Zones (AEZ)
- **Runs through 2095 in 5-year time-steps (time step is variable)**

Energy policy can have surprising feedbacks with land cover and climate forcing!

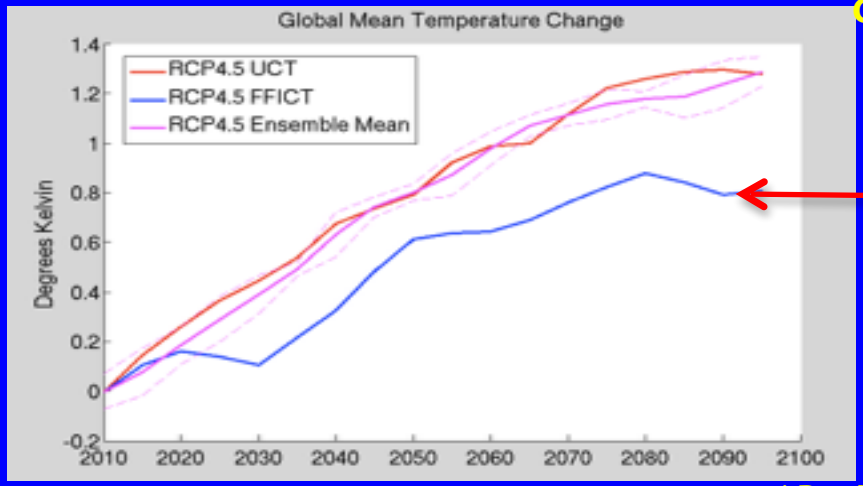
Taxation policy favoring biofuels raises food prices, decreases coal prices, accelerates deforestation, and slows down climate warming due to raised surface albedo.

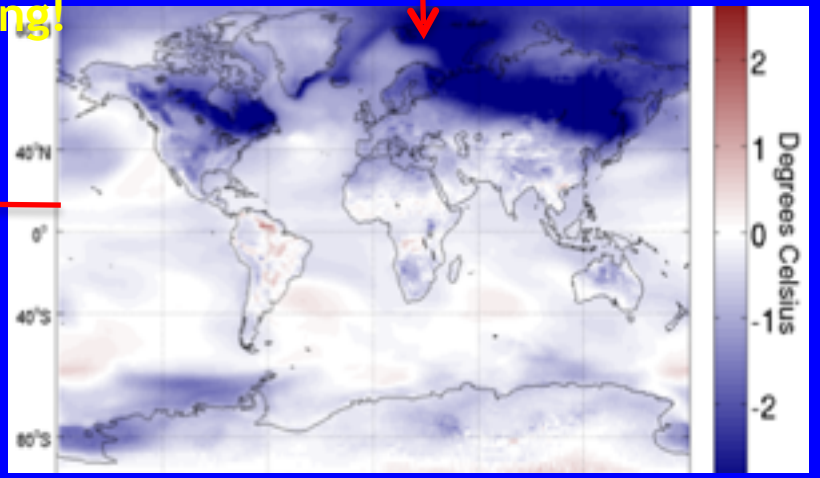


Fossil Fuel Only Carbon Tax resulted in nearly 50% deforestation



Higher albedo = cooling!





AD. Jones et al. 2012 - Journal of Climate, 26(11), 3657-3670.

Summary

- **The fate of the planet's ecosystems and the human enterprise are intertwined and strongly modulated by weather and climate.**
- **Population growth, development and urbanization are strongly linked.**
- **Policy matters! Sustainability of the urban enterprise must be considered at all scales from local to global and include human and natural systems interactions.**
  - Vegetation <=> albedo (climate change)
  - CO2 emissions <=> climate change <=> vegetation
  - Vegetation <=> water use, fossil fuel use <=> crops
  - Population <=> crops, food/capita <=> mortality
  - Population <=> food/capita <=> fisheries
  - Population <=> CO2 emission, pollution <=> atmosphere, land
  - Population <=> urban sprawl <=> loss of cultivated land
  - Technology <=> non-renewable resources <=> alternative resources
  - Policies <=> education, birth rate <=> pollution, emissions
  - Resource depletion <=> trade, resource conflicts
  - Population <=> CO2 emissions <=> climate change <=> vulnerability