Satellite Supported Estimates of Human Rate of NPP Carbon Use on Land: Challenges Ahead

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Key Findings

- Global requirement for land-based photosynthetic plant material rose from 20 to 25 percent from 1995 to 2005
- First measurement of this trend shows both population growth and per capita consumption are driving increase.
- By 2050 humans will require more than 55% of the photosynthetic production on land if people consume as much per person as N. Americans do now.
- Trend has huge implications for food security regionally and may require land management at planetary scale.
- Satellite-supported approach provides an updatable wall-to-wall assessment of human demands on Earth's annual photosynthetic production on land.

Why NPP?

Net Primary Production (NPP)

NPP is the "Common Currency" for Climate Change, Ecological, & Economic Assessment.

NPP is the amount plant material produced on Earth.

It is Earth's "Bio-Engine" - the primary fuel for Earth's food web.

NPP can be measured in terms of Carbon

Photosynthesis withdraws CO_2 from the atmosphere and fixes it in plant tissue. Photosynthesis and fate of vegetation biomass are important in carbon exchange between atmosphere and biosphere (global climate change).

Demand for NPP strongly influences land use/land cover change and land management policy.

Agricultural versus 'natural systems' - Conflicting needs; energy production versus conservation of biodiversity

Definitions for this Study

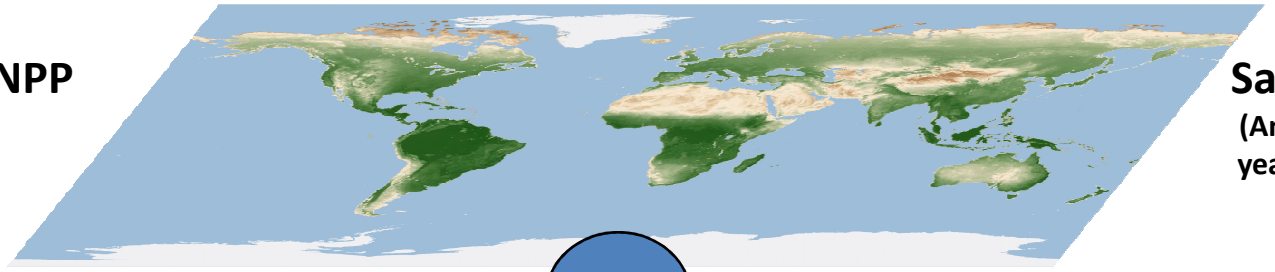
- NPP “supply” is the annual amount of vegetation produced on land in terms of elemental carbon.
- NPP “demand” is the mount of NPP required on the landscape to generate the food, fiber, and bio-fuels reported by the UN Food and Agriculture Organization on an annual basis.

These two definitions are matched so that they are comparable using a satellite supported estimate of global NPP (supply).

Creating the Balance Sheet: Can the Earth Keep Up?

Land-based Vegetation Carbon Balance (NPP)

Planetary NPP Supply



Satellite Data
(Annual and multi-year NPP averages)

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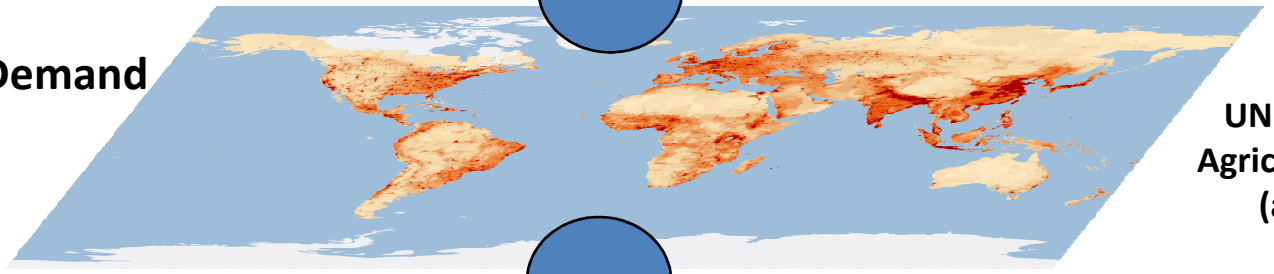
Human NPP Demand



UN Food and Agriculture Data (annual)

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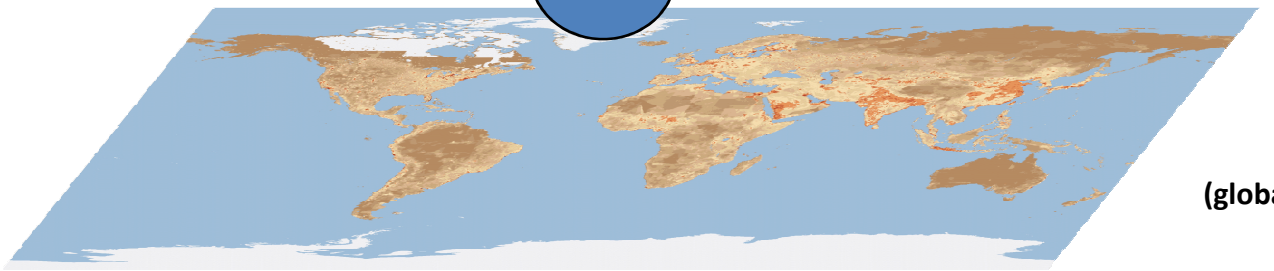
Balance



Result
(global and regional balances)

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

NPP "Supply"

Earth's Current Terrestrial Production

Vegetation biomass in terms of carbon (Above and Below Ground)

28 years of Satellite Observations

AVHRR (1982-2009) at (0.25x0.25 degree horizontal resolution)

MODIS 1km 2000 - 2009

Vegetation Indices from satellite estimate leaf area over time

Terrestrial Carbon Models

Carnegie Ames Stanford Approach – CASA

Biome BGC

Models combine satellite vegetation indices and climate data to calculate NPP in gC/m^2 [above & below ground].

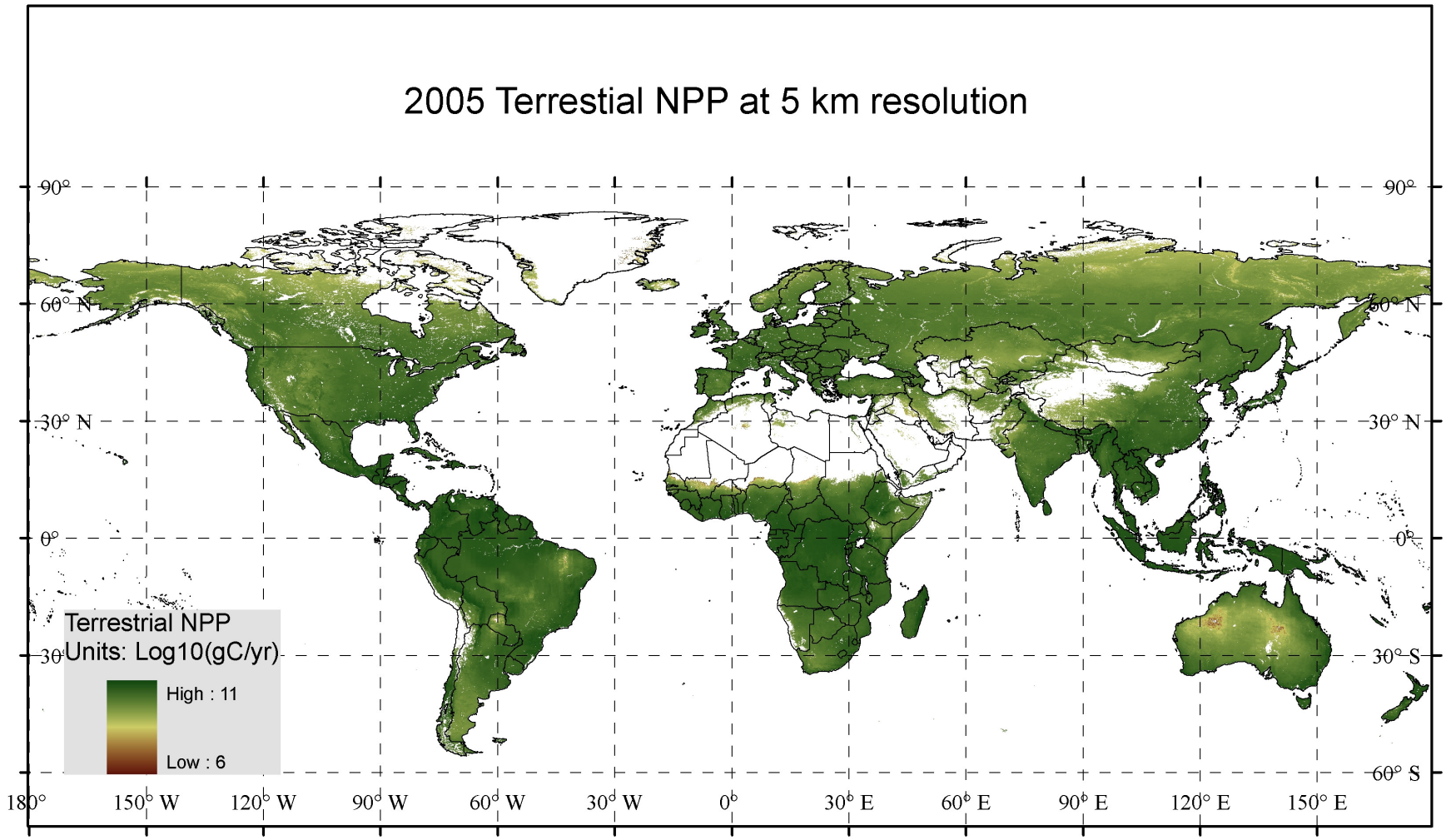
NDVI + vegetation map → FPAR (0.4-0.7mm)

FPAR + solar surf. Irradiance → IPAR

IPAR + light use efficiency → NPP rates (g m^{-2})

Climate drivers (Temperature, Precipitation, etc.)

Planetary NPP “Supply” on Land 2005



2005 MODIS Derived NPP in Log10 Grams Carbon per year (Total = 51.6 PgC)

NPP Global "Demand"

"Demand" = the amount of NPP Required to generate the food, fiber, and wood-fuels reported in FAO annually.

Source: UN-FAOSTATS (United Nations Food and Agriculture Statistical Database)

Country level - spatially constrained

Product Specific

Vegetal Foods, Livestock-based Products, Wood, Paper, and Fiber.

Domestic Supply = Production + Imports – Exports

Bio-agronomic modules estimate landscape NPP from data

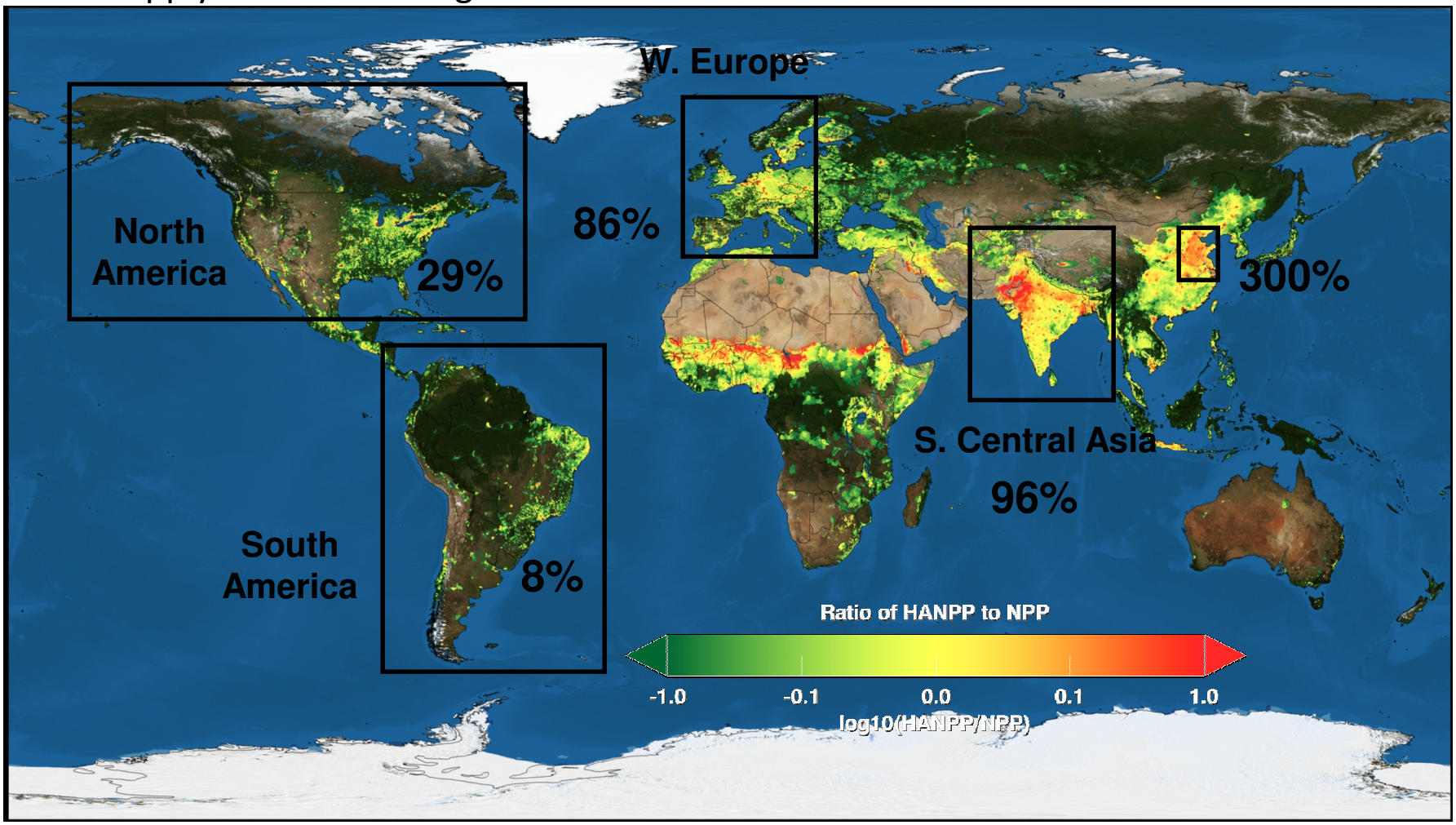
Back-calculate the NPP required "in the field" in grams Carbon.

Separate parameterization for Developing and Industrialized countries

Applied to global map of population distribution on a Per Capita basis (source: CIESIN -Center for International Earth Science Information Network)

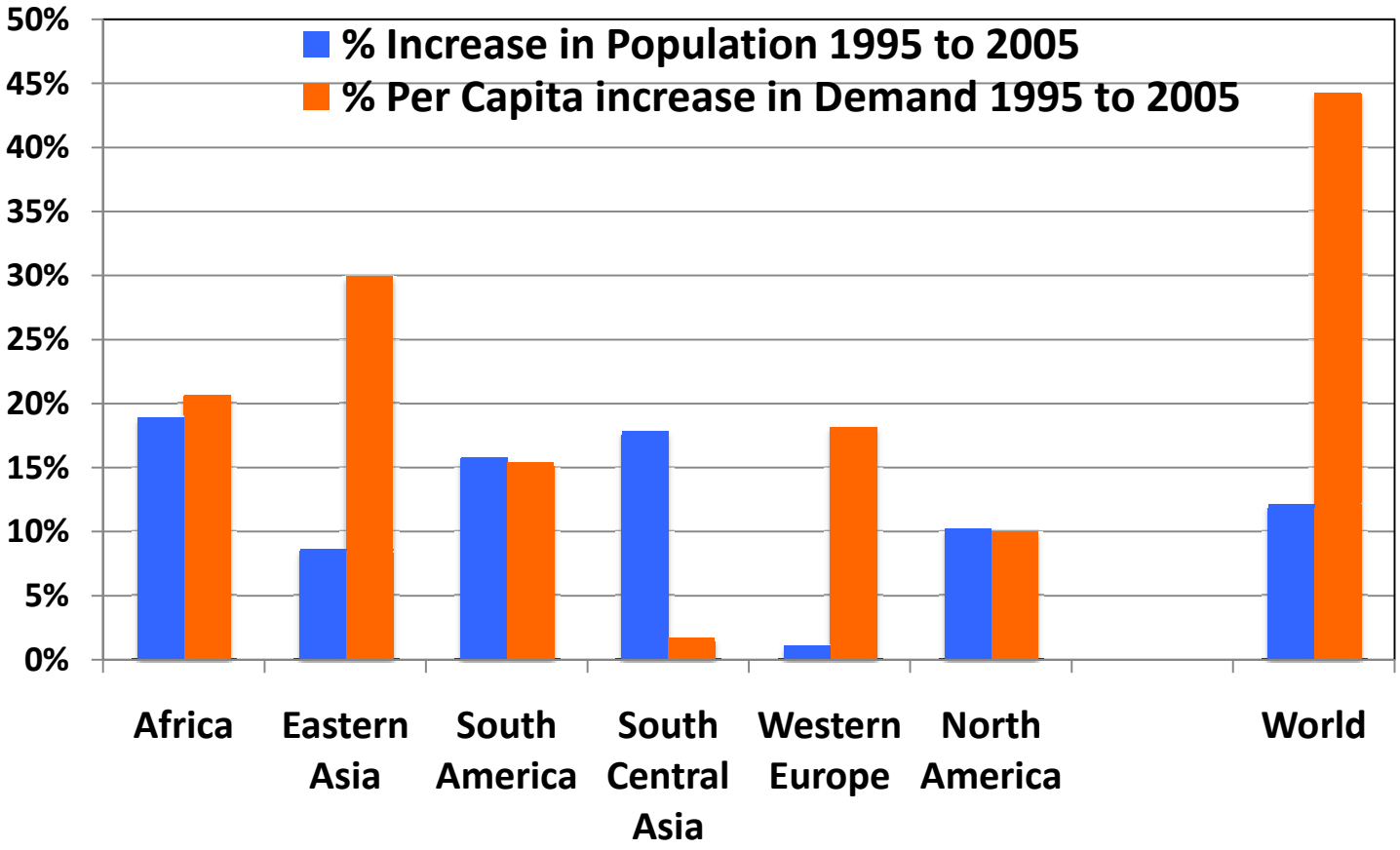
NPP Required by Humans as % of Supply (2005)

Supply estimated using MODIS NPP - Demand From UNFAO and models



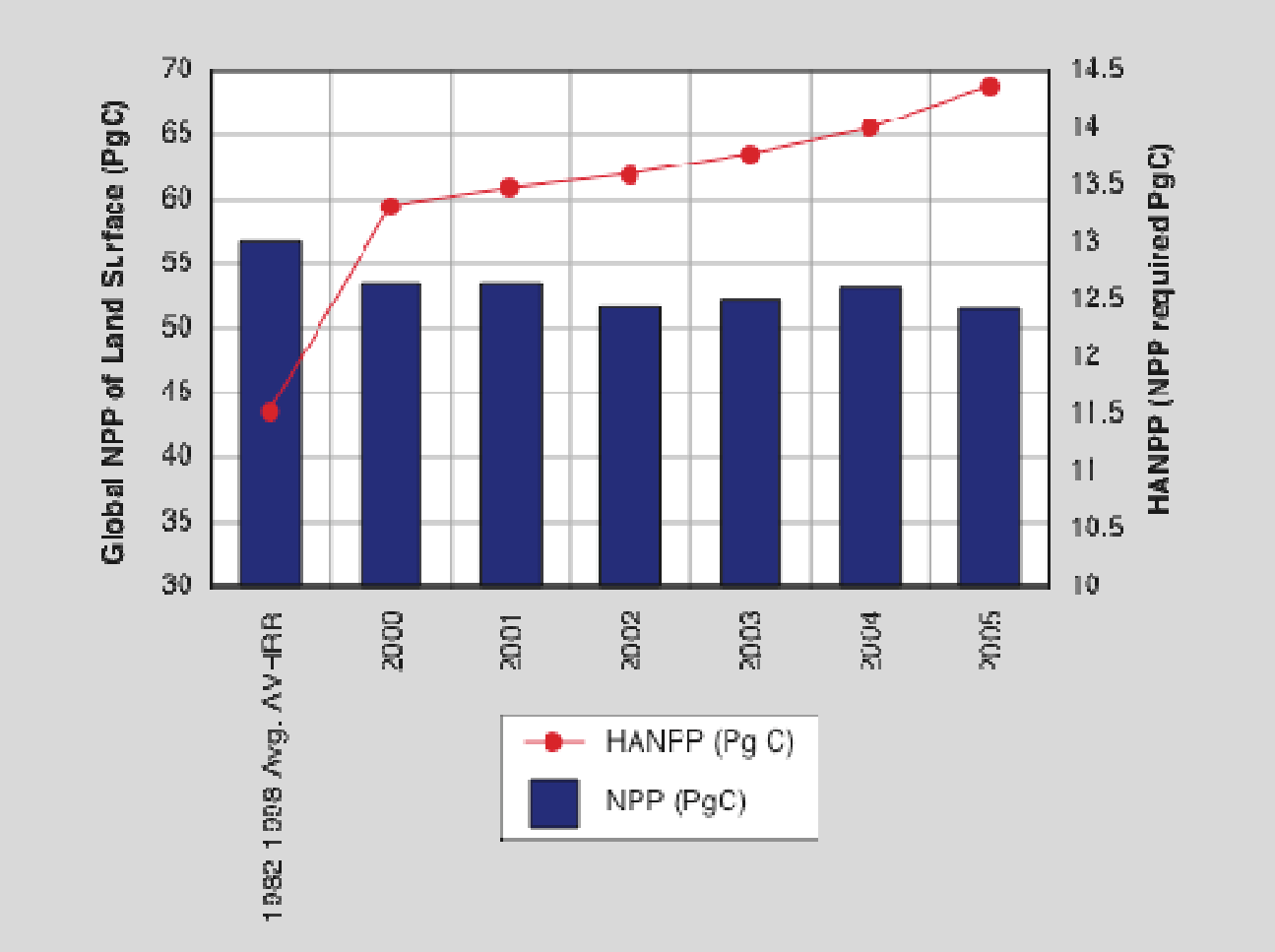
We are growing and consuming more per person

Population and Affluence Drive Demand



Demand – NPP Carbon (land vegetation)

NPP (no trend) - HANPP is rising



1982-1998 baseline NPP from AVHRR
NPP for 2000-2005 from MODIS
HANPP (all years) UN FAO and models (Imhoff et al. 2004)

Conclusions

We use a satellite-supported methodology to estimate the amount of Earth's land-based NPP (carbon from land vegetation) that is required for food, fiber, and fuel.

Previous work showed that - as of 1995 - humans required 11.5 Pg of NPP Carbon - approximately 20% of the total generated on land.

The same methodology applied to 2005 data shows that the human NPP demand has increased to 14.6 Pg C – about 25% of the amount generated on land that year.

Increases are due to both population growth and larger per capita demand for products of photosynthesis.

Globally Earth's production capacity in the form of NPP-Carbon shows no trend varying only slightly year to year due to climate and weather

Regionally, NPP varies widely putting some populations at higher risk

Population growth and increases in per capita demand could result in the human need for 55% of the NPP carbon on land by 2050 with major implications for land management policy.

Supplemental Slides

10 Years of Changes in Regional NPP Carbon Supply & Demand

REGION	1995 / 2005 Population (millions)	1995 / 2005 Per capita NPP (MTC)	1995 / 2005 NPP demand (Pg C)	BASELINE NPP Supply (Pg C)	1995 / 2005 Demand (% Supply)
Africa	742 / 882	2.08 / 2.51	1.55 / 2.21	12.50	12.4% / 17.7%
Eastern Asia	1400 / 1520	1.37 / 1.78	1.91 / 2.71	3.02	63.2% / 89.7%
South America	316 / 366	3.11 / 3.59	0.98 / 1.31	16.10	6.1% / 8.1%
South Central Asia	1360 / 1603	1.21 / 1.23	1.64 / 1.97	2.04	80.4% / 96.6%
Western Europe	181 / 183	2.86 / 3.38	0.52 / 0.62	0.72	72.2% / 86.1%
North America	293 / 323	5.4 / 5.94	1.58 / 1.92	6.67	23.7% / 28.8%
World	5690 / 6378	1.58 / 2.28	11.54 / 14.55	56.80	20.3% / 25.6%

Foundations for Earth System Stewardship

Session B31 Wed AM 2006 (Moscone West)

8:20 **Earth-System Resilience** and Thresholds *I. Fung*
8:40 Changing Climate for **River Systems** *D. P. Lettenmaier*

9:00 to 9:15 PANEL DISCUSSION

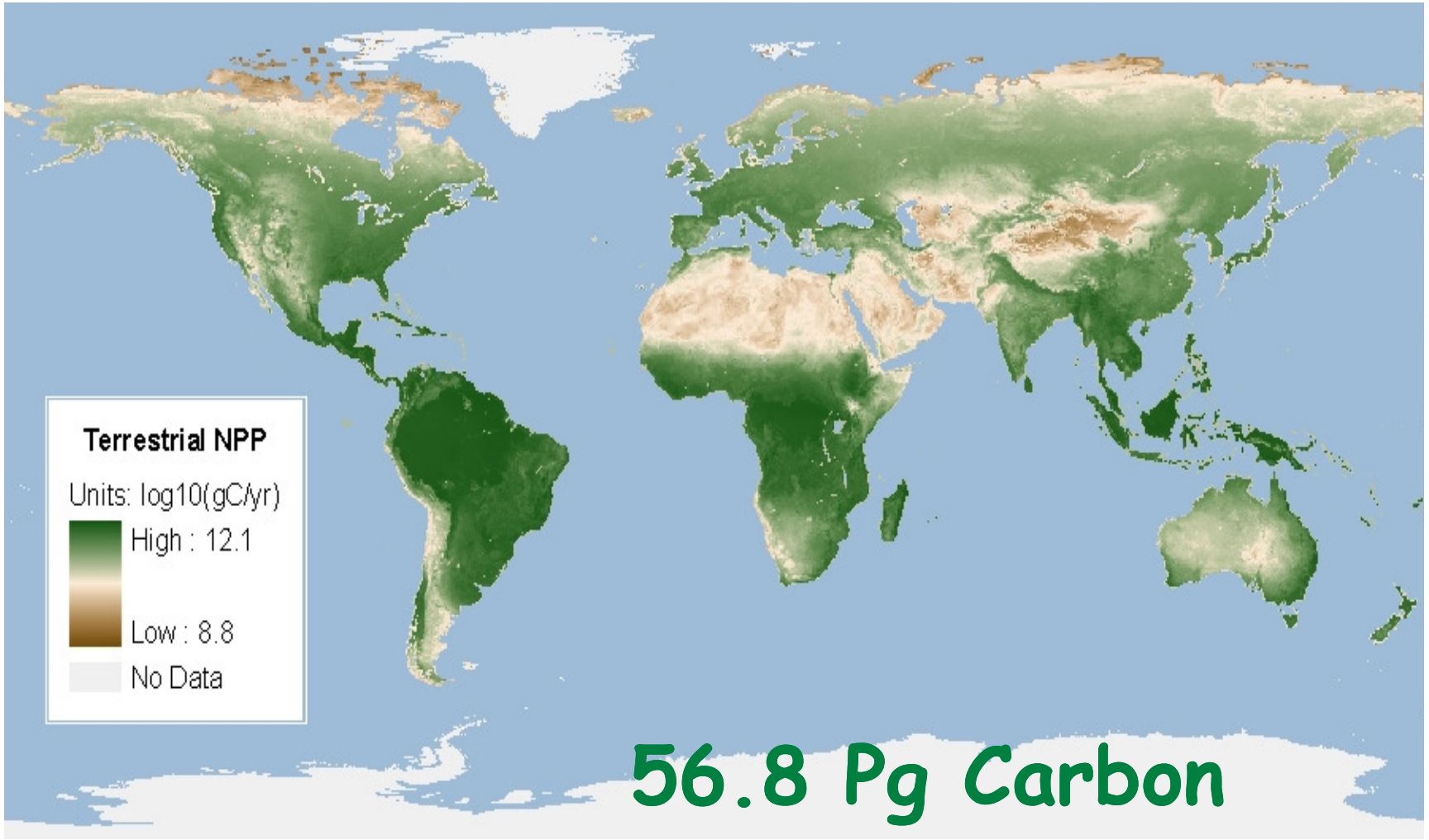
9:15 **Feeding 9 Billion** While Sustaining the Earth System *J. A. Foley*

9:30 Human Rate of NPP **Carbon Use** on Land: *M. L. Imhoff; L. Bounoua; P. Zhang; R. E. Wolfe*

9:45 **Sustainability** in a Rapidly Changing World *F. S. Chapin; M. E. Power; S. Pickett; R. B. Jackson; D. Carter; J. W. Harden*

Poster Session B43B Thursday Afternoon Moscone South

Planetary NPP "Supply" on Land
18 Year AVHRR Baseline (Average)



AVHRR Average (1982 – 1999)

So, what do we do?

Don’t Panic

Avoid the extremes - Doomsday and Denial are poor choices

Use our best tools - address the issue.

Past attempts failed because the system could not be “closed”

Treat Earth as a system

Satellite technology enables this perspective for the 1st time in human history