Can Earth's Plants Keep Up With Us?
Satellite View of Global Demand on Products of Photosynthesis

Marc Lee Imhoff NASA's Goddard Space Flight Center

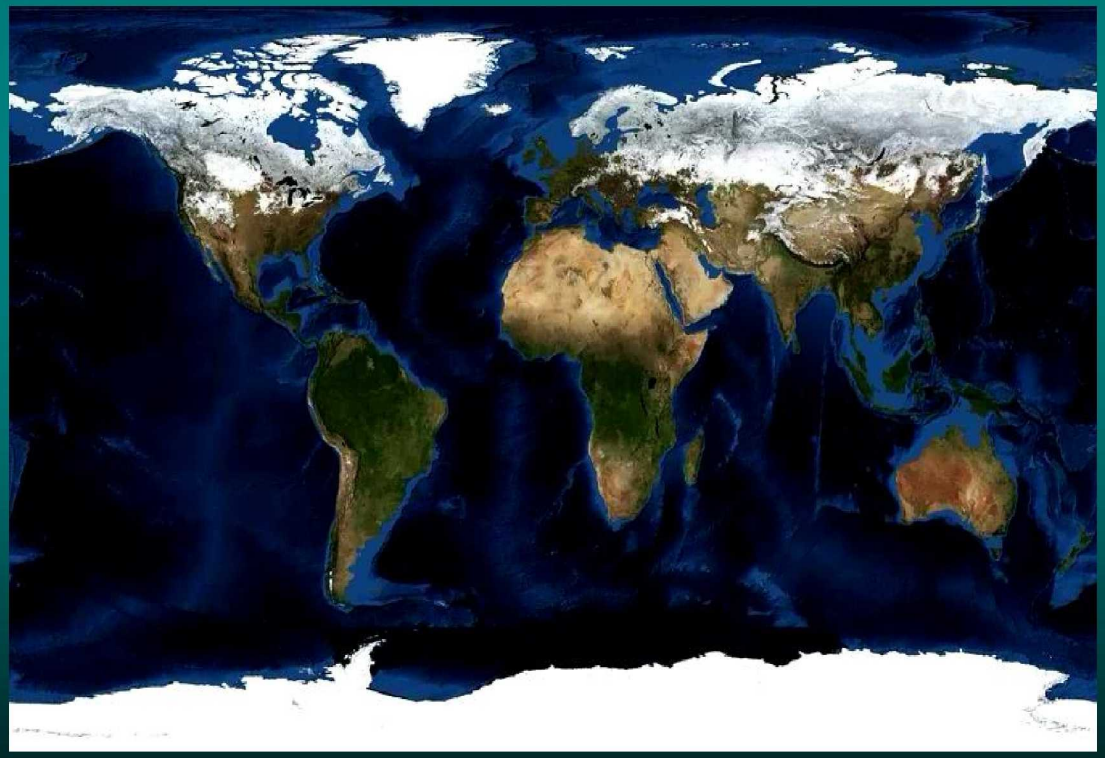
2008 Science-Technology Centers (ASTC)
International Action on Global Warming (IGLO)

The Great Transformation

The current land surface little resembles what existed 10,000 or even only 3,000 years ago

Human Quest for Food, Fiber, and Fuel

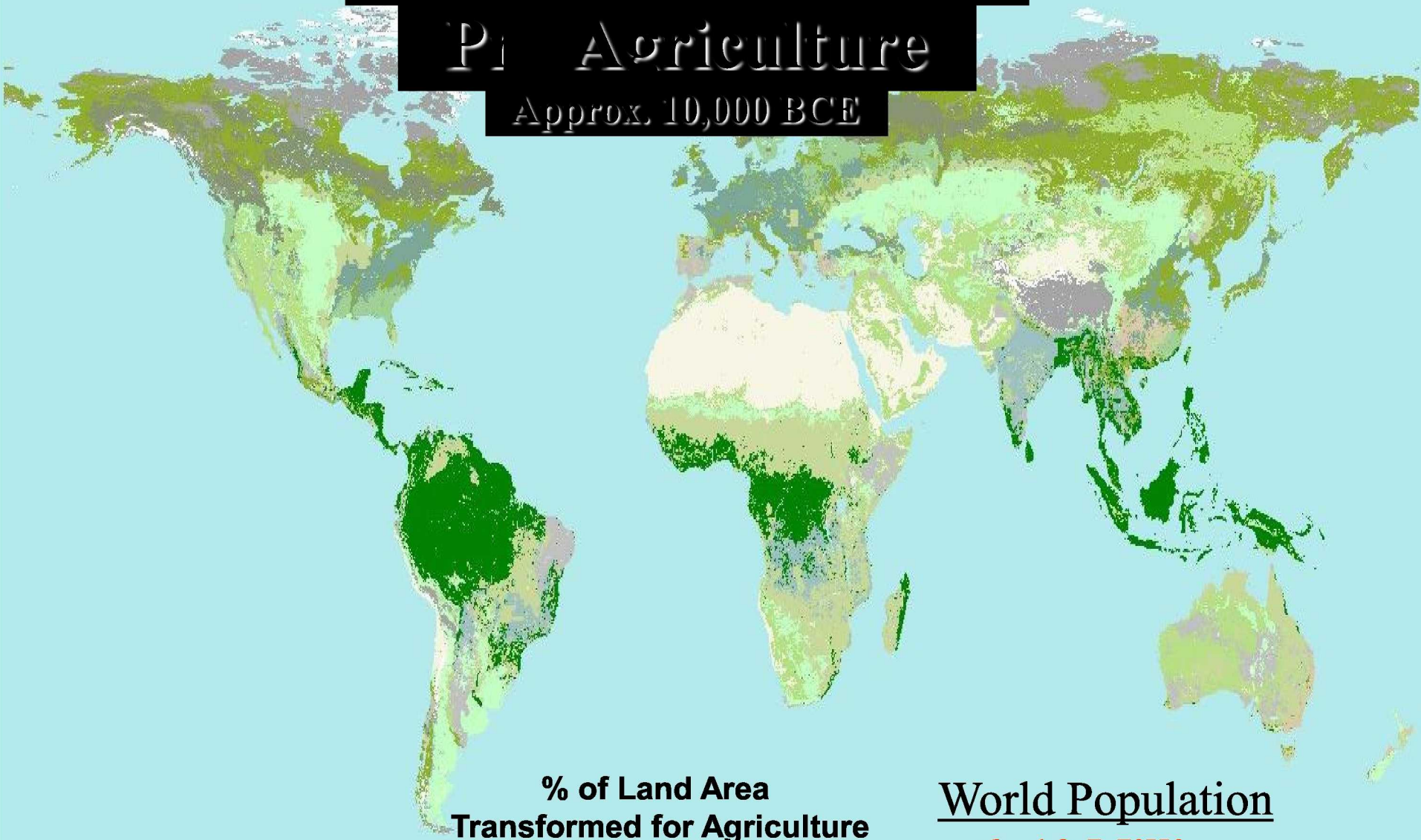
- Fire for ecosystem management
- Grazing
- Deforestation
  - Building material, and Fuel for heating, cooking, salt production, metal smelting
- Agriculture
- Urbanization



Global Land Cover

Pr Agriculture

Approx. 10,000 BCE

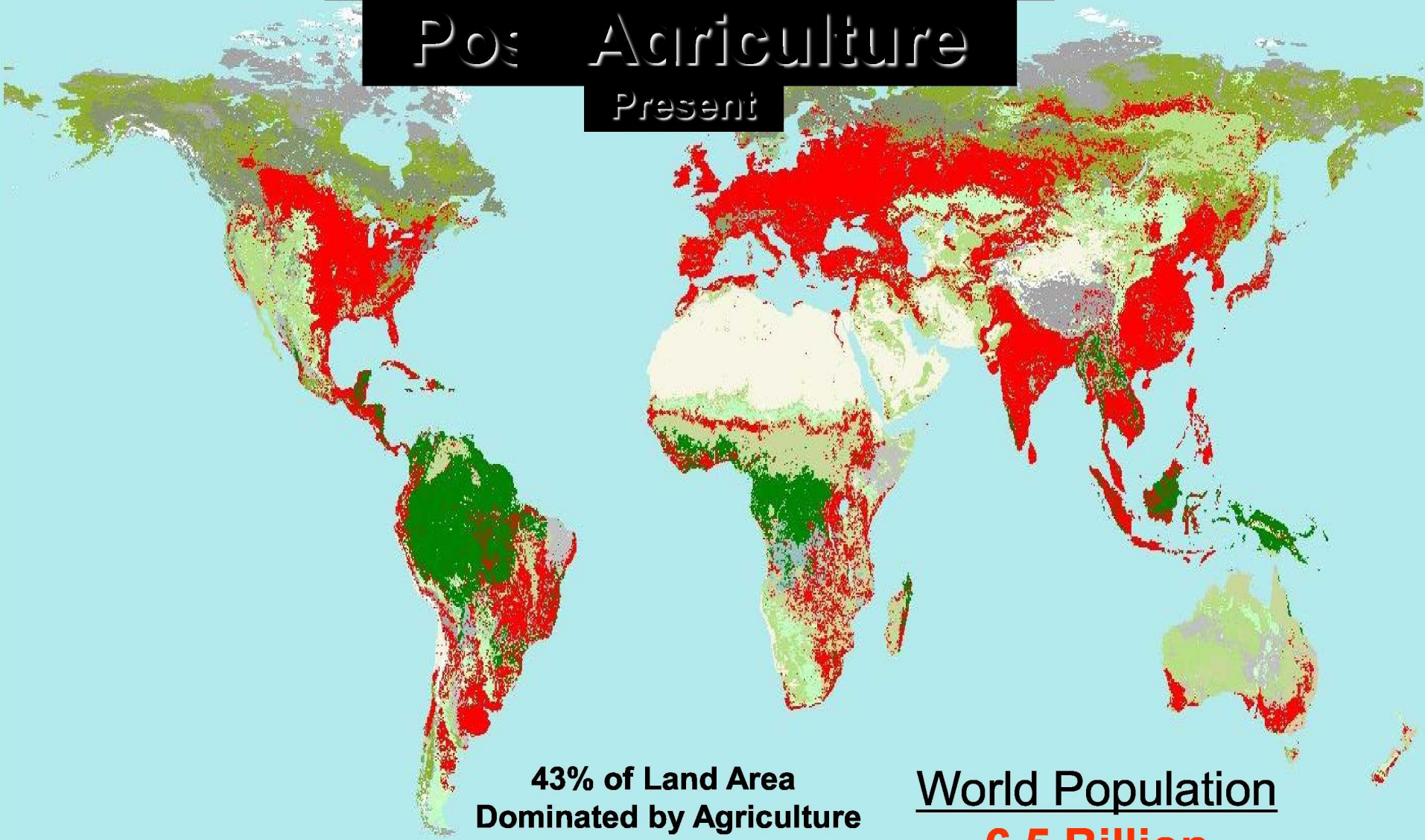


% of Land Area Transformed for Agriculture (Negligible)

World Population

6 -10 Million

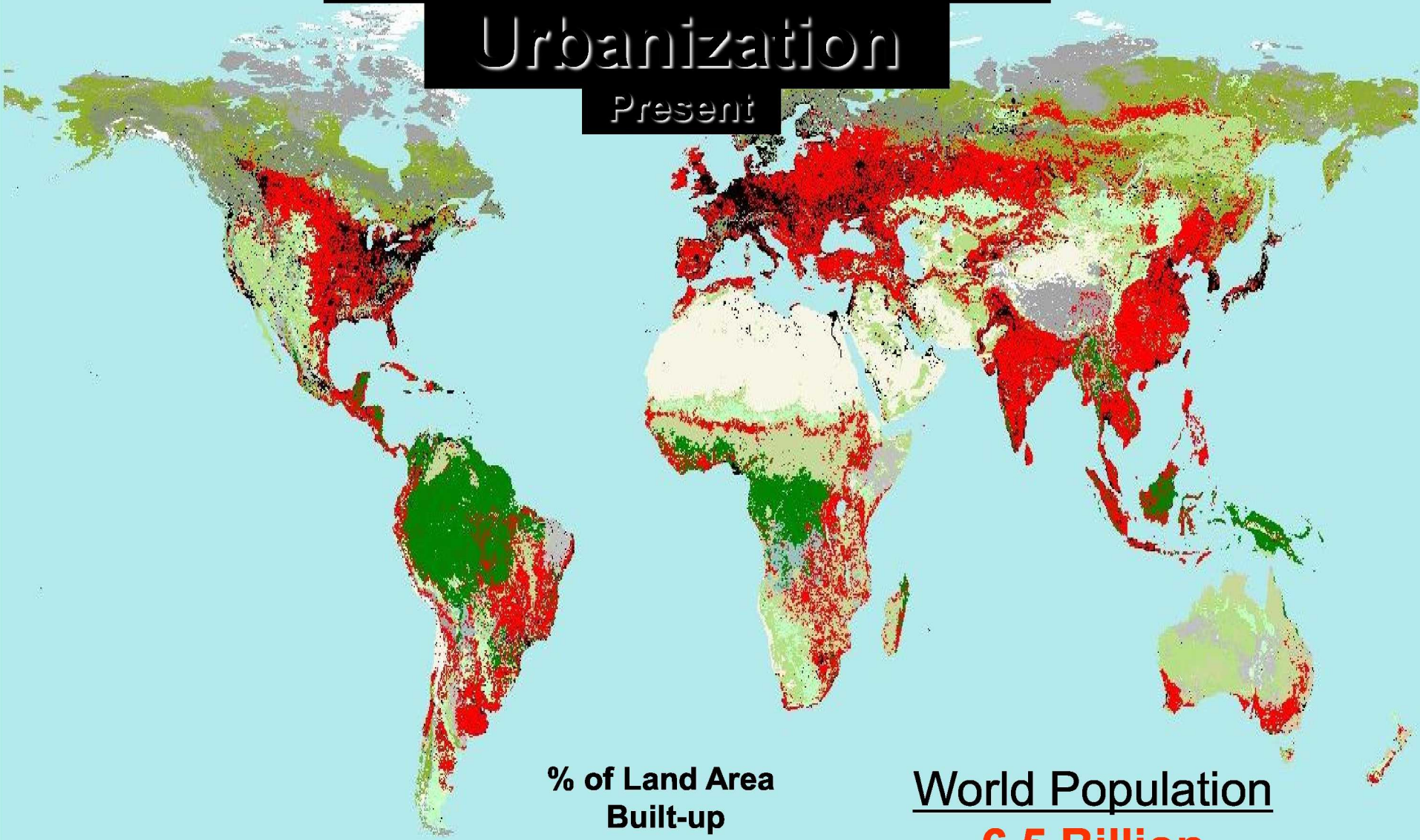
Global Land Cover
Pos Agriculture
Present



43% of Land Area
Dominated by Agriculture

World Population
6.5 Billion

Global Land Cover
Urbanization
Present



% of Land Area
Built-up
3 - 6%

World Population
6.5 Billion

Urbanization: One phenomenon, many processes

- Urban population, per capita consumption, and land transformation are *all* increasing simultaneously.
- How will we – as a species – deal with our own success?
- Can we recognize our impact on the environment and learn from it?
- Can we act in the general best interest?
- Will we use the incredible tools we have to address challenges before us?

OR…

Malthus's Dismal Theorem:

Thomas Malthus, a 19th Century economist, postulated that since human populations increase geometrically and food supplies grow arithmetically, human populations will undergo a cycle of growth and catastrophic decline.

1998-1999

"Malthus might be right"

NY Times/Science Times 12/8/98

Will Humans Overwhelm the Earth? The Debate Continues

By MALCOLM W. BROWNE

PHILADELPHIA, Dec. 4 — Two hundred years ago the Rev. Thomas Robert Malthus, an English economist and mathematician, anonymously published an essay predicting that the world's burgeoning human population would overwhelm the Earth's capacity to sustain it.

Malthus's gloomy forecast, called "An Essay on the Principle of Population As it Affects the Future Improvement of Society," was condemned by Karl Marx, Friedrich Engels and many other theorists, and it was still striking sparks last week at a meeting in Philadelphia of the American Anthropological Society. Despite continuing controversy, it was clear that Malthus's conjectures are far from dead.

Among the scores of special conferences organized for the 5,000 participating anthropologists, many touched directly or indirectly on the Malthusian dilemma: Although global food supplies increase arithmetically, the population increases geometrically — a vastly faster rate. The consequence, Malthus believed, was that poverty and the misery it imposes will inevitably increase unless the population increase is curbed.

This contention has prompted endless debate. Malthus's critics, especially the utopians of his time, have argued that man's ingenuity will always keep pace with population growth by finding improved ways to produce food.

Recent assaults on Malthusian pessimism have cited the success of the "Green Revolution" launched in the 1950's and 1960's by Dr. Norman Borlaug and his associates in developing high-yield strains of rice and wheat.

But the scientific descendants of Malthus argue that feeding the world's masses is only part of the problem. Just as dangerous, they contend, is the omnivorous consumption of nonrenewable resources, the irreversible destruction of habitats and species, the fouling of the air and seas and consequent changes in climate, and many other effects of the growing human horde.

One of the symposiums held at last week's meeting was so controversial that a conference with the same title had been banned from the 1994 meeting of the American Association for the Advancement of Science on the grounds (according to its organizer, Dr. Warren M. Hern, a Colorado physician and epidemiologist) that "You may not ask that question."

Feeding the masses is just part of the problem, some say.

The question, posed as t the symposium, was this: Human Species a Cance Planet?"

Dr. Hern, the director of tion clinic in Boulder, Colo nearly a decade ago that a satellite views of urban cer en over a period of years striking similarity to image cerous tissue (particularly ma) invading the healthy s ing tissue.

In his presentation last w Hern argued that in many the world the increase i numbers is rapid and unco that it invades and destroys and that by killing off many it reduces the differentiati ture. All of these features c acteristic of cancerous tu said.

This assessment was a by another member of the p Lynn Margulis of the Univ Massachusetts, Boston, known for her conauthorshi other highly controversial known as the "Gaia Hypoth

The Gaia idea, the brainchild of an English theorist, Dr. James E. Lovelock, and Dr. Margulis, who is a microbiologist, is that the entire Earth deploys feedback mechanisms to maintain an environment hospitable to life. In this it resembles a gigantic living organism, proponents of the idea believe.

Life on Earth has survived many crises, including mass extinctions caused by the impacts of asteroids and comets, Dr. Margulis said, and life will continue despite the threats created by humanity — but with reduced diversity.

She agreed with the notion that the human race is a kind of self-destructive cancer.

"For millions of years the Earth got along without human beings," she said, "and it will do so again. The only question is the nature of the human demise that has already begun."

Dr. Margulis quoted a line from

Bettman Archives

The Rev. Thomas Robert Malthus

from 1.9 to 2.1 percent, largely because of Hispanic immigration.

All the speakers at the symposium had expected vigorous criticism from the audience of anthropologists, but were surprised to encounter few strongly negative comments.

"Arguments over the accuracy of Malthus's views, future population trends and the Earth's carrying capacity are never-ending and never resolved," one speaker said. "Many people prefer to just forget about the big questions involved, and get on with their lives."

At another symposium held at last week's meeting participants were asked to address the question "Was Malthus Right?" None of the panelists called Malthus's assessment of the grim consequences of overpopulation wrong, although some argued that he had some details wrong.

"Most biologists would say that Darwin's work was mostly correct

REMEMBER THE NEEDIEST

2002-2004

"Malthus is wrong"

Time Magazine Special Millennium Issue, Nov. 1999

2005

"Malthus might not be wrong - but we don't want to know"

Science

AAAS Magazine News STKE SAGE KE Careers Collections

Current Issue Previous Issue Science Express Science Products

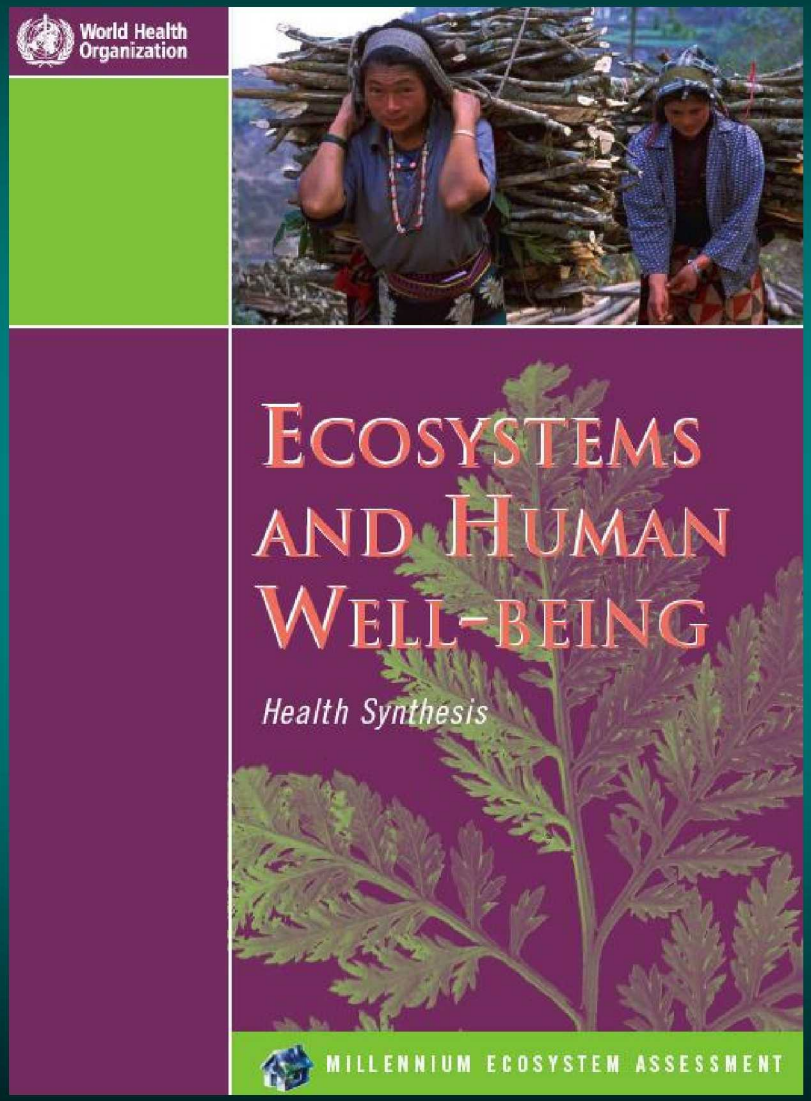
Science 1 July 2005:
Vol. 309. no. 5731, p. 102
DOI: 10.1126/science.309.5731.102

NEWS

Will Malthus Continue to Be Wrong?

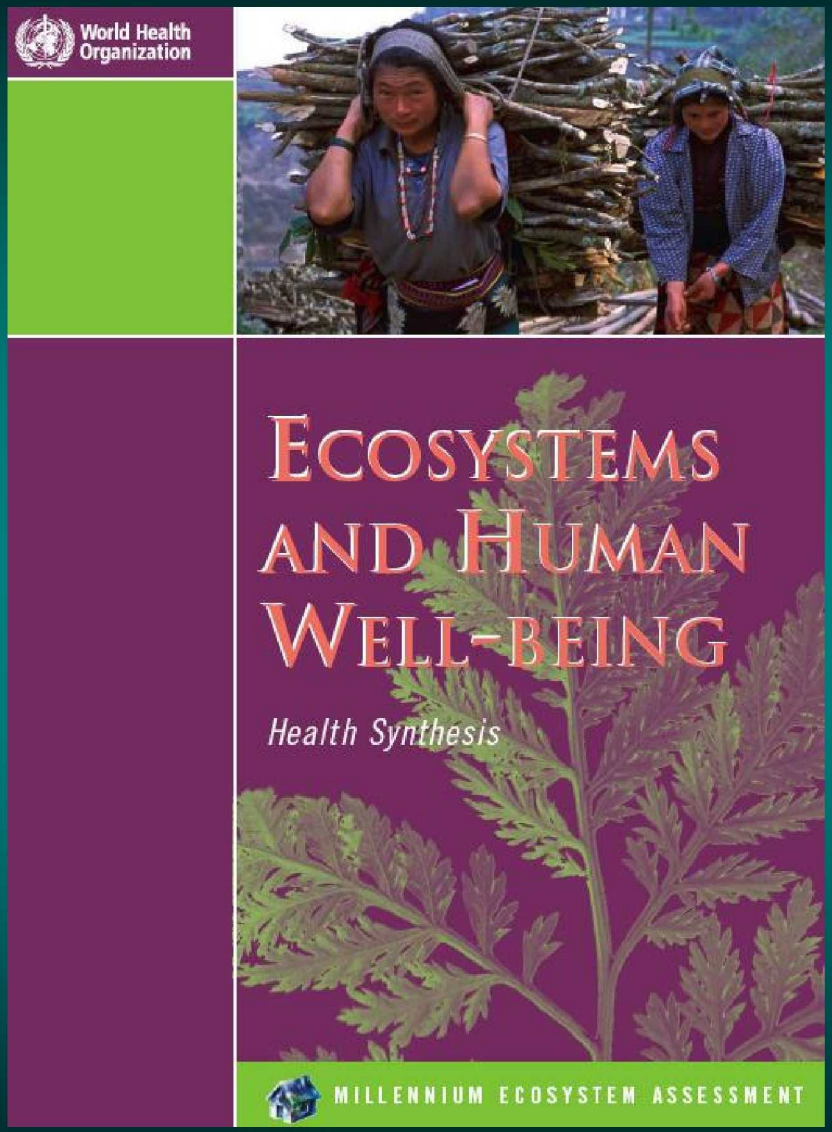
Erik Stokstad

MILLENNIUM ECOSYSTEM ASSESSMENT



In the 200 years for which we have reliable data, overall growth of consumption has outpaced increased efficiencies in production processes.

Economic growth tends to increase consumption and the projected growth in the next 45 years is 200 - 400%.



Demand for food is projected to grow by 70-80% and water by 30-85%.

Food security is not achieved under any of the MA scenarios by 2050.

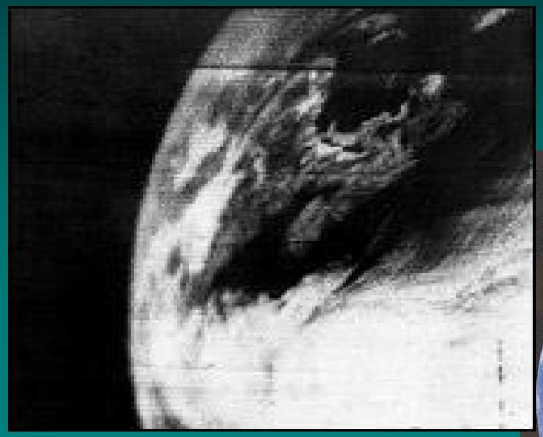
2007 Commodity Price Index

The Economist commodity-price index
2000=100

	Nov 20th	Nov 27th*	% change on one month	% change on one year
Dollar index				
All items	210.3	212.2	−1.3	+14.4
Food	197.8	201.8	+3.8	+30.8
Industrials				
All	226.5	225.6	−6.5	−0.2
Nfa†	175.1	176.1	+1.2	+30.5
Metals	254.6	252.6	−9.1	−8.3
Sterling index				
All items	154.5	155.4	−1.4	+7.6
Euro index				
All items	131.6	132.0	−4.2	+1.2
Gold				
$ per oz	793.25	812.75	+3.6	+27.8
West Texas Intermediate				
$ per barrel	99.07	94.42	+4.9	+55.2

*Provisional †Non-food agriculturals.

Closing the Earth System: We've Come A Long Way



TIROS
April 1, 1960
700 km Altitude

Apollo 17
Dec.7, 1972, 45,000 km from Earth,
70mm Hasselblad, 80mm lens

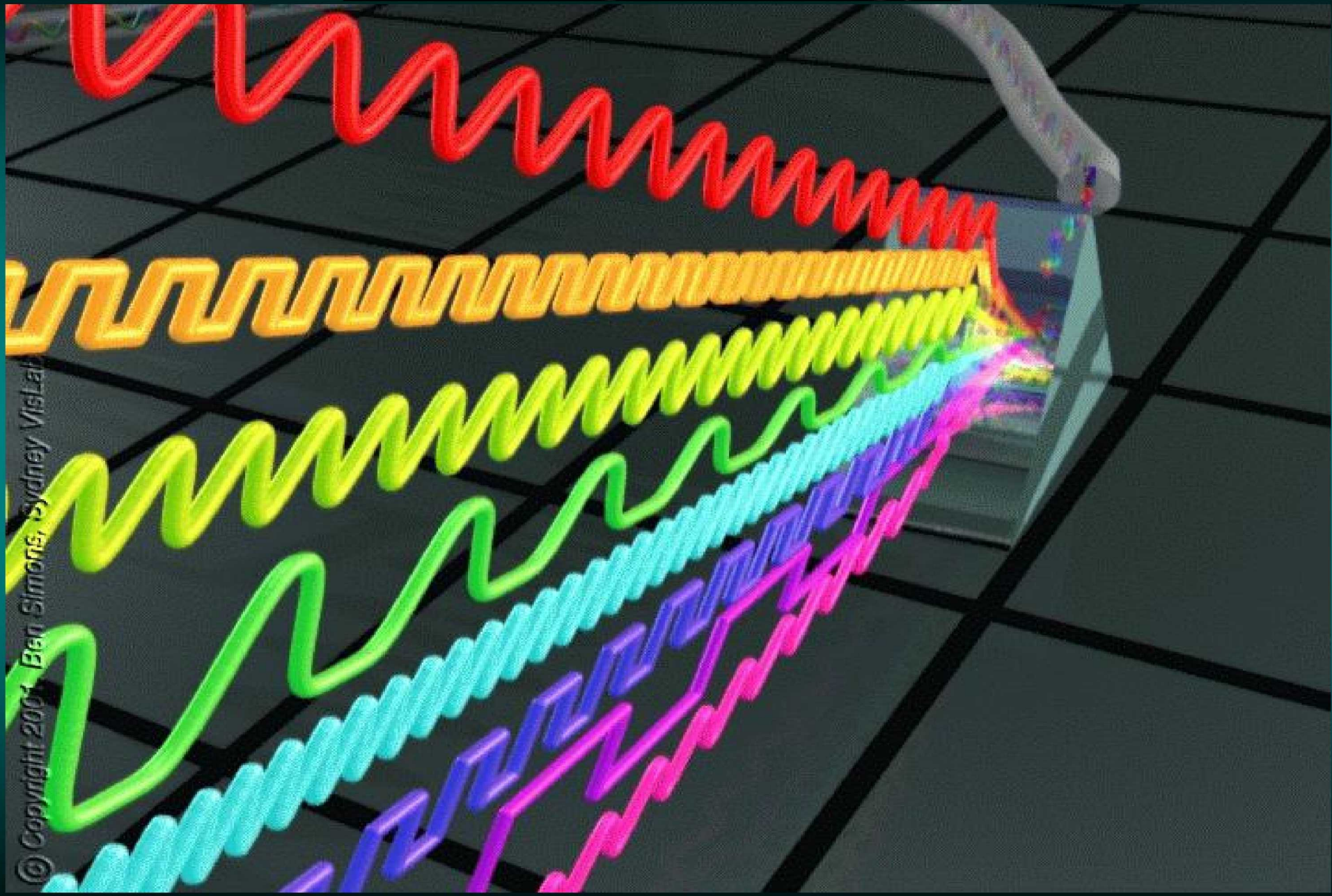
Blue Marble
EOS Terra/Aqua 2000 -

World Community - Earth Observation satellite datasets
land, ocean, sea-ice, clouds, urban lights,topography

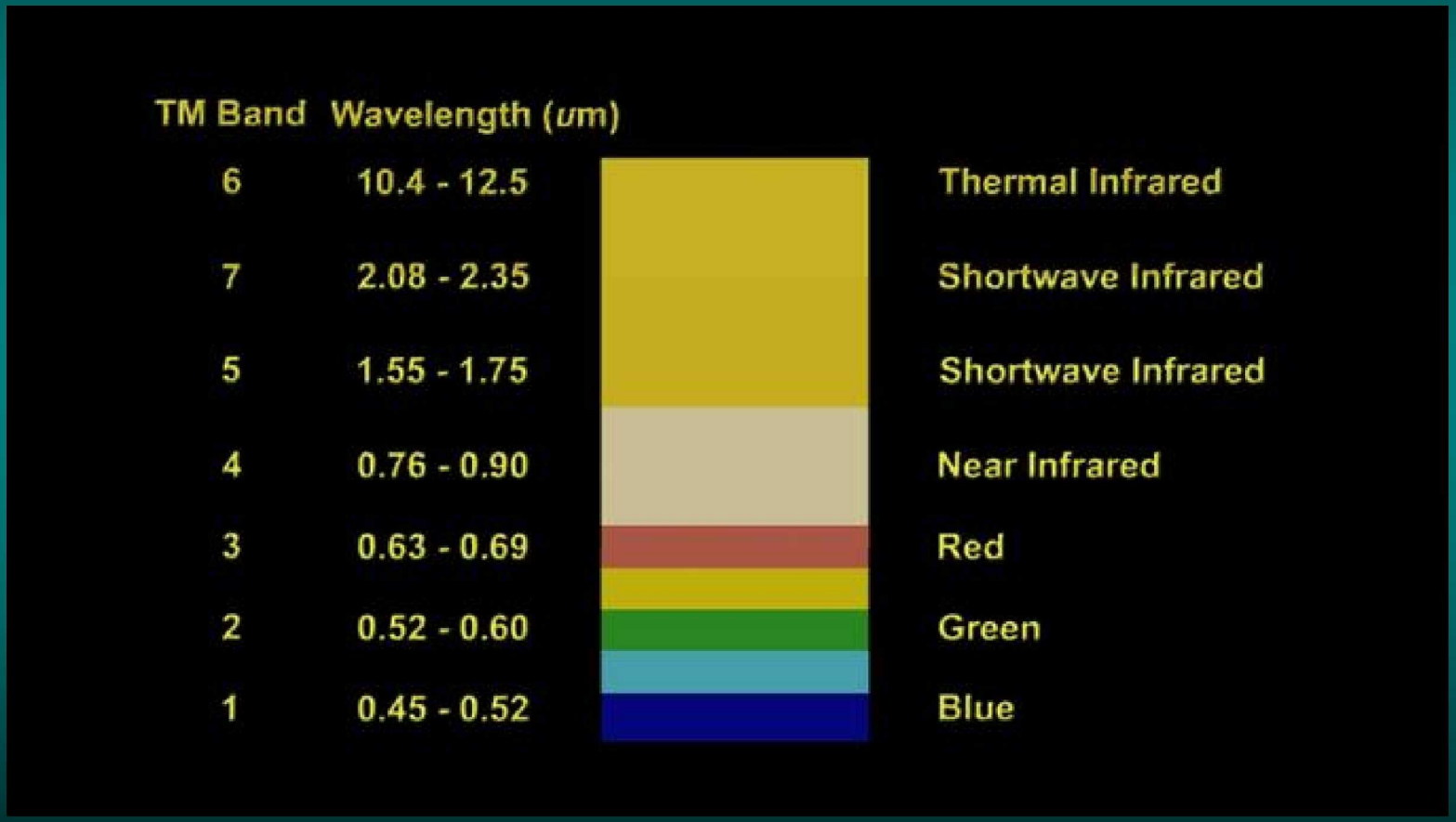
Credits: Reto Stöckli, Rob Simmon and MODIS science team

EOS Satellite Fleet

Measuring the Energy

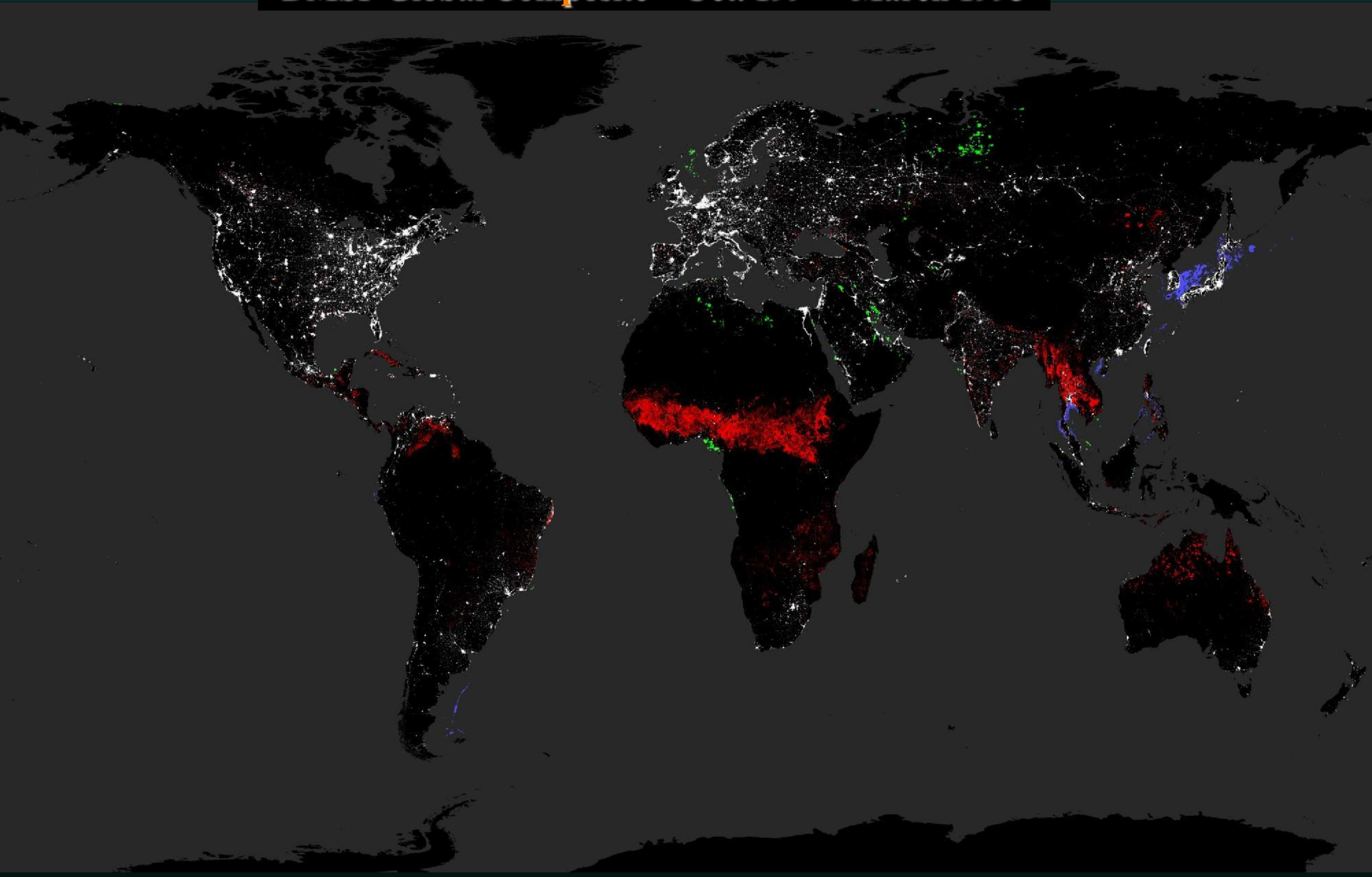


Local to Regional Scale: Multispectral View of San Francisco



Nighttime Lights of the World

DMSP Global Composite Oct. 1994 - March 1995



Global Scale Urban Assessment:

Defense Meteorological Satellite

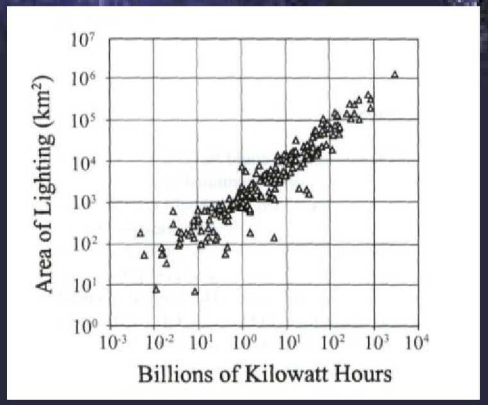
Operational Linescan System (OLS)

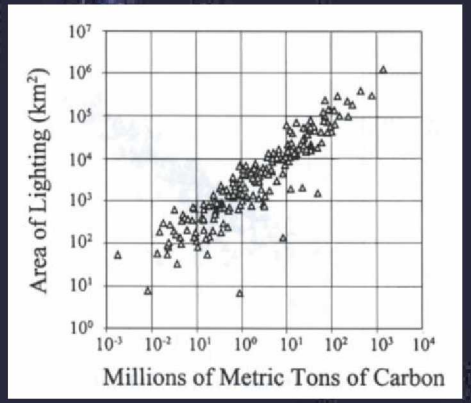
Relationship between urbanization and energy production, use, and carbon emissions

- 833 km, sun-synchronous, near circular, polar orbit.
- Nighttime data (PMT)
  - 0.47 - 0.95 um
  - 10^{-5} to 10^{-9} Watts per cm^2 per sterradian.
- Pixel resolution:
  - 2.7 km at low resolution(smooth mode).

DMSP/OLS

Area of Lighting vs Power Consumption and Carbon Emissions for 200 Countries





Elvidge et al. ISPRS, 2001

Urbanization and Productivity

Landcover change, consumption, and food and fiber production

Earth's "Bio-Engine"

Net Primary Production (NPP)

NPP is the amount plant material produced on Earth.

It is the primary fuel for Earth's food web.
Represents all available food and fiber.

NPP can be measured in terms of Carbon

(photosynthesis - CO_2 exchange between atmosphere and biosphere (global climate change).

Land use strongly impacts NPP

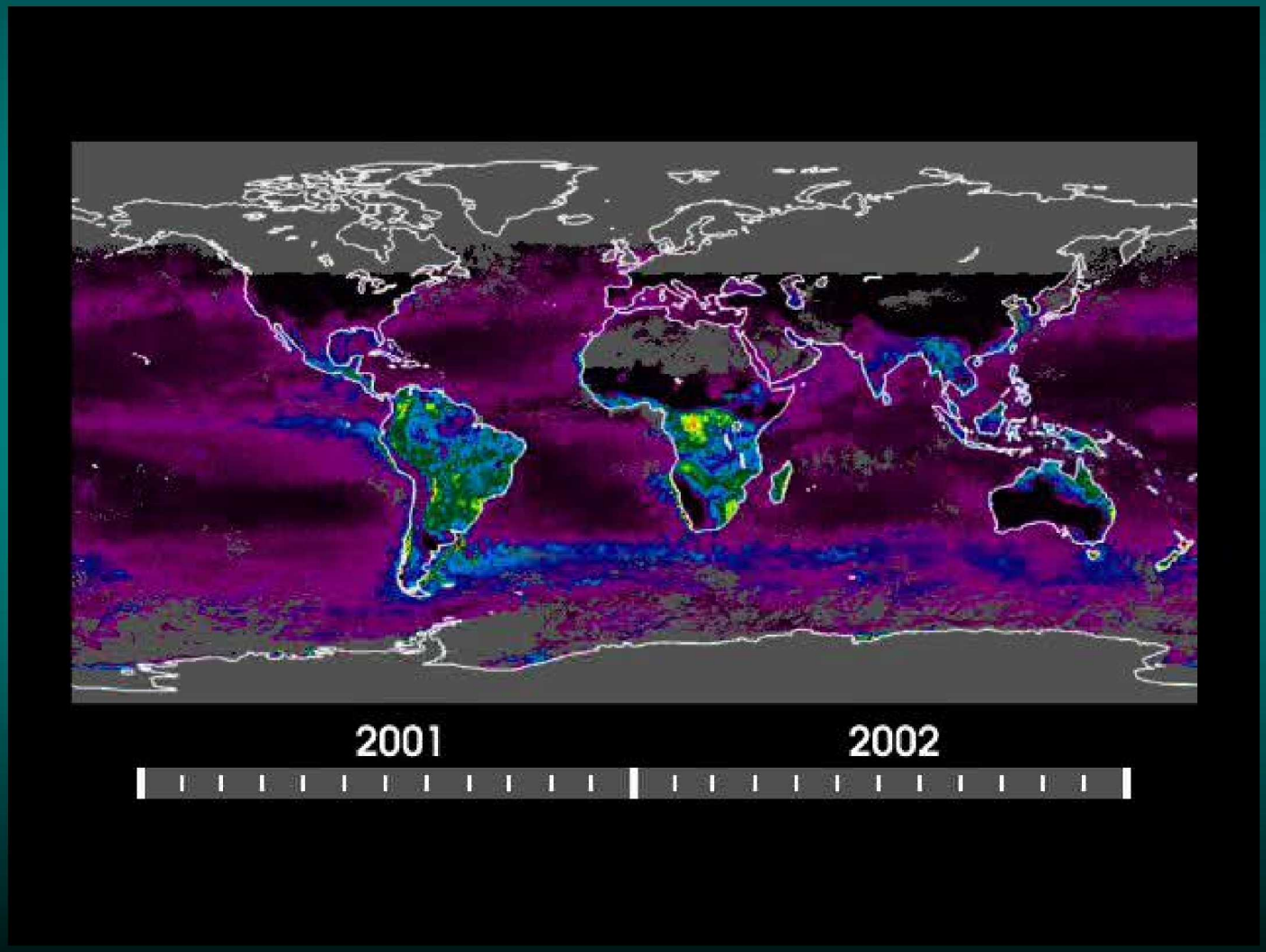
Humans require almost 20% of Earth's NPP capacity on land

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

Earth's Breath of Life

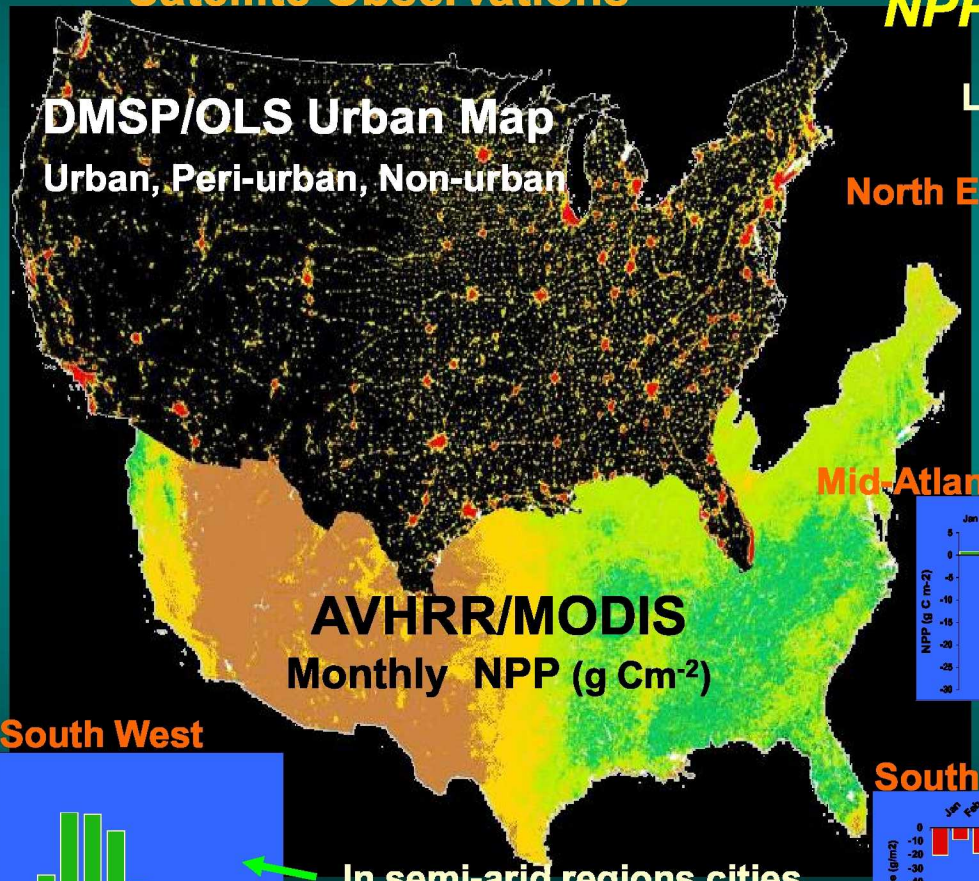
Global Biological Productivity Land and Ocean

MODIS (Terra and Aqua Satellites)



Urbanization and NPP: US Examples

Satellite Observations



NPP and Local Climate:

Urban Heating Extends Length of growing season locally in cold climates.

North East

Mid-Atlantic

Winter NPP gain negated in peak season by reduced vegetation and heat stress.

South West

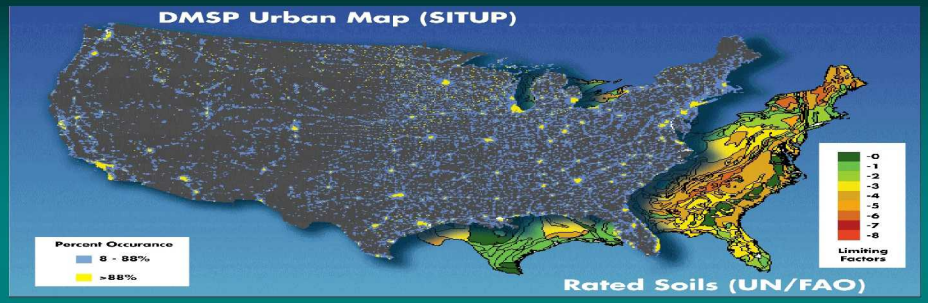
In semi-arid regions cities enhance NPP relative to surrounding areas

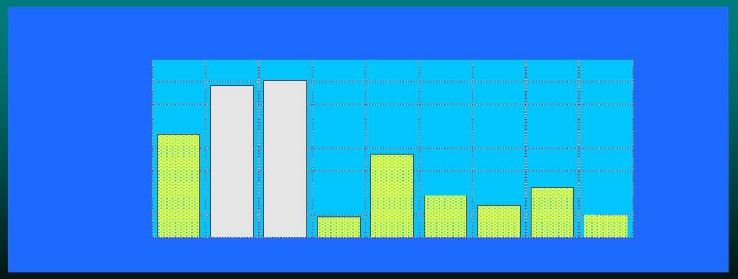
South East

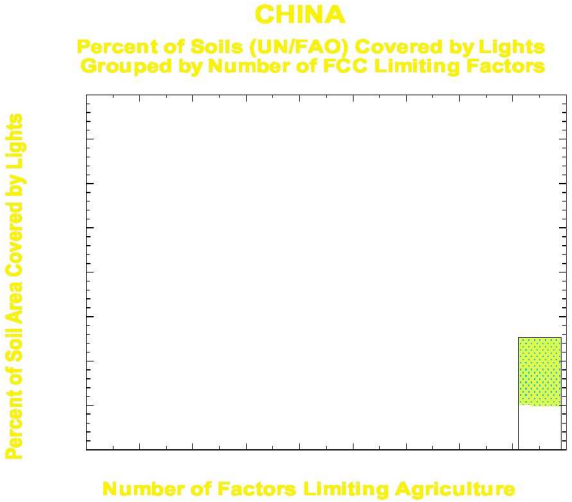
Seasonal Offset diminishes in tropics

Imhoff et al., RSE, 89, 2004

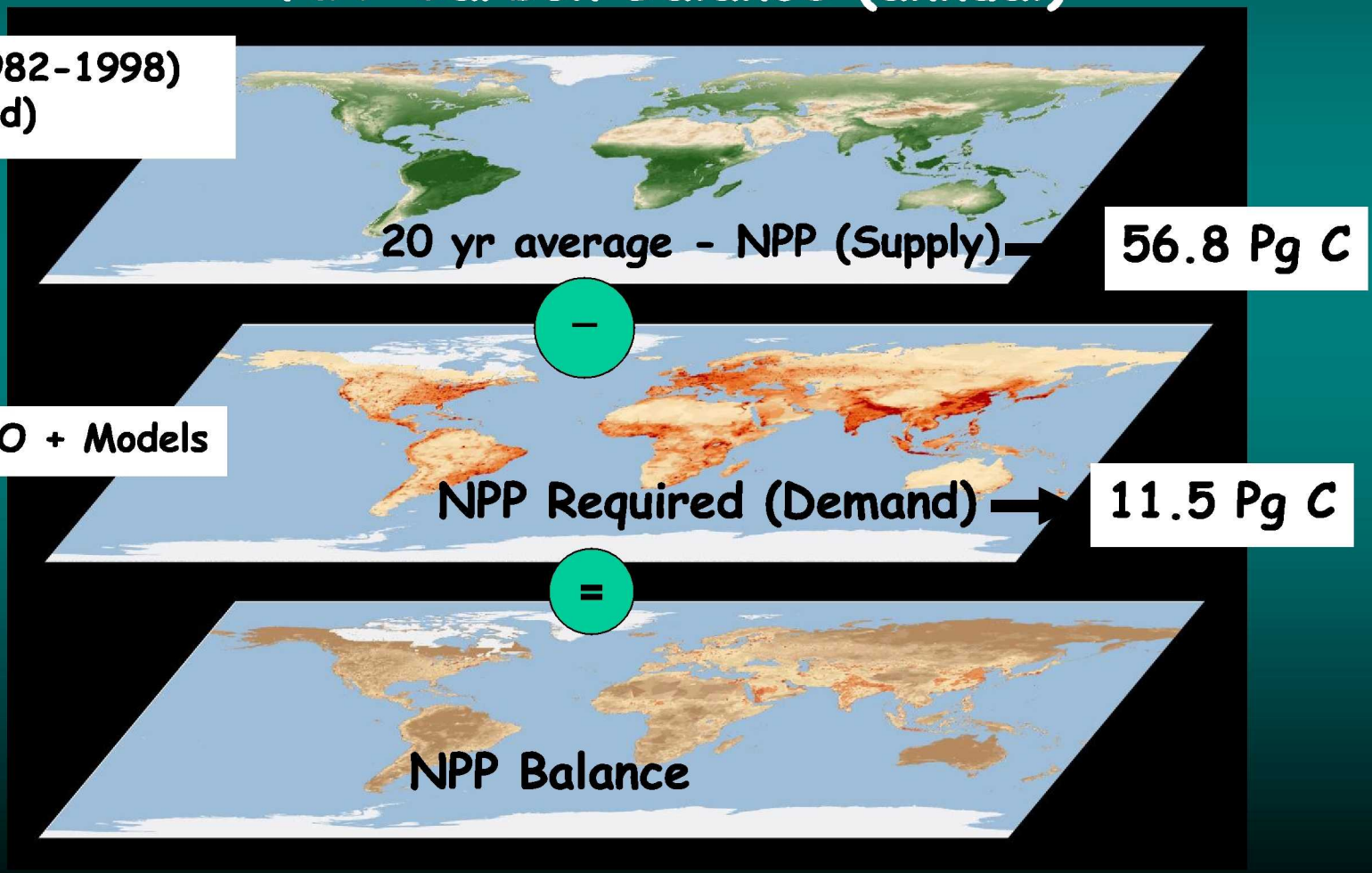
Urbanization and Soil Fertility Capability Class





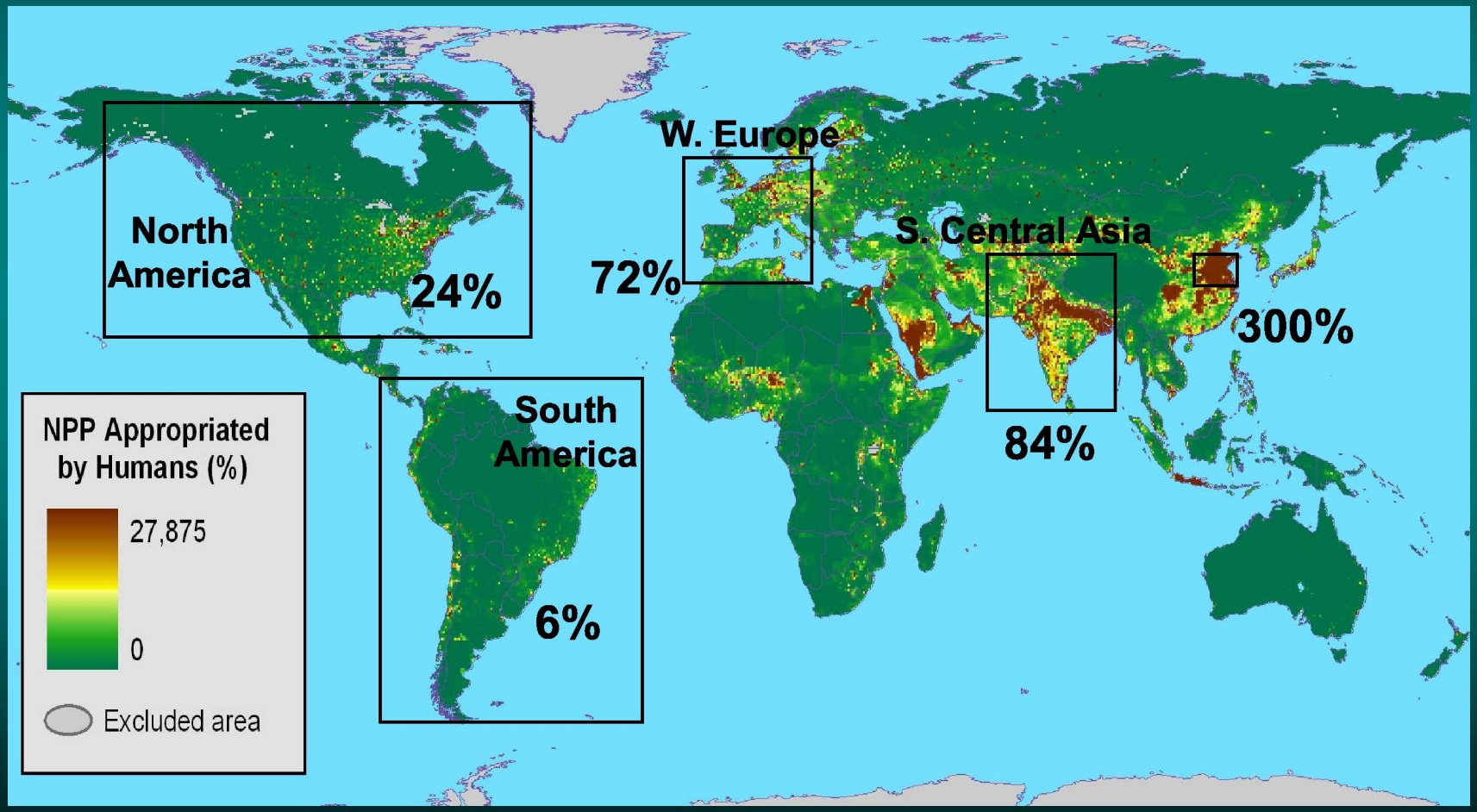


Human Consumption of NPP: Can the Earth Keep Up?



NPP Demand as % of Supply

Global NPP Demand is 20% of Total Supply (land)
There are large regional and local variations



Imhoff et al., *Nature*, vol. 429, June 24, 2004.

How HANPP Changes as a Function of: Population, Affluence, and Technology

I = PAT

- The ecological impact [**I**] of human activities involves population size [**P**], consumption levels [**A**, for "affluence"], and the technologies employed [**T**] (Holdren and Ehrlich, 1976).

Scenario	P*	A**	T***	HANPP (PgC)	
1	↑	–	–	17.42	31%
2	–	↑	–	20.19	36%
3	–	↑	↑	16.26 □	29%
4	↑	↑	–	31.59	56%
5	↑	↑	↑	25.5 □	45%

↑(increase), – (no change from the baseline 1995 intermediate estimate).

* Population increase from 5.69 Billion (global population in 1995) to 8.92 Billion (estimated global population in 2050; Ref 18).

** Affluence increase applies average *per capita* consumption of industrialized countries (in 1995) for all countries.

*** Technology increase applies technological efficiencies of industrialized countries (in 1995) to all countries.

† *Per capita* fuel wood use in developing countries reduced to average for industrialized countries in 1995.

Conclusions

The placement, structure, and style of development of urban places impact biological resources (food and fiber production), hydrology, and the thermal environment.

Earth's production capacity in the form of NPP-Carbon is a useful 'common currency' for environmental and economic assessment.

As urbanization increases so does consumption. Human NPP-C Demand is between 10% and 20% of planetary supply with large regional and local variation.

Technology, affluence, and population can interact in surprising ways.

Green technologies can reduce energy consumption, heat, and aerosol pollution to create livable cities.

Conservation does work to ameliorate impacts.

Partners and Contributors

- **Michael King** - EOS Project Science Office, NASA's Goddard Space Flight Center
- **Lahouari Bounoua** - NASA's GSFC
- **William Lawrence** - Bowie State University
- **Colby Loucks** and **Taylor Ricketts** - World Wildlife Fund
- **Randall Sharp** - Sharp & Diamond Landscape Architecture and Planning, Vancouver, BC, Canada
- **Dale Quattrochi** - NASA's Marshall Space Flight Center, Huntsville, Alabama
- **J. Marshall Shepherd** - University of Georgia
- **Robert Harriss** - Houston Advanced Research Center.
- The unbelievably great graphics artists at NASA's GSFC!