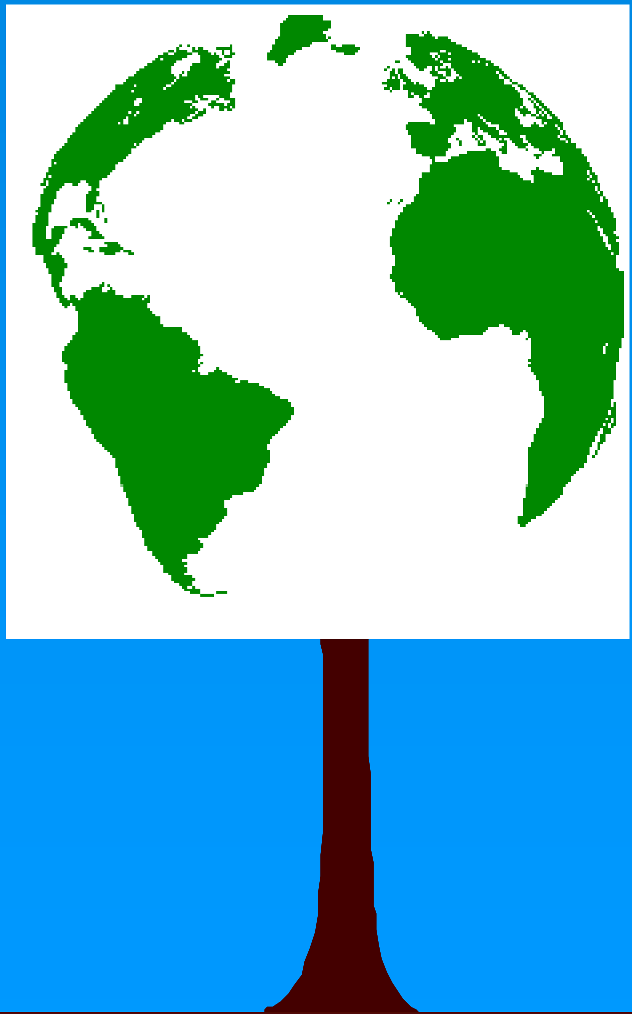
# Ecological Economics: Creating a Sustainable and Desirable Future




Robert Costanza

Gordon Gund Professor of Ecological Economics
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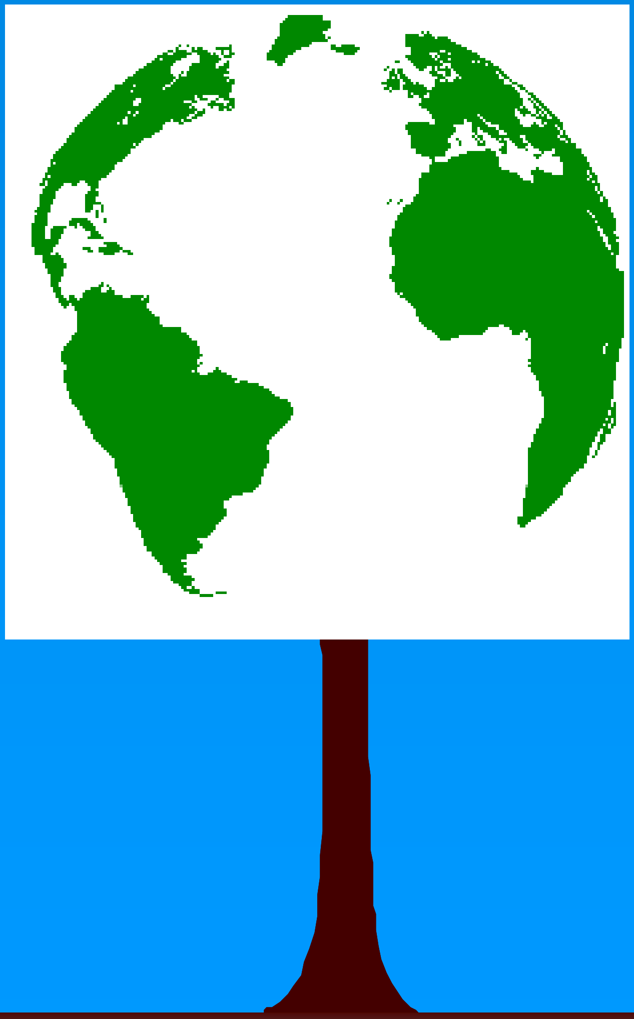
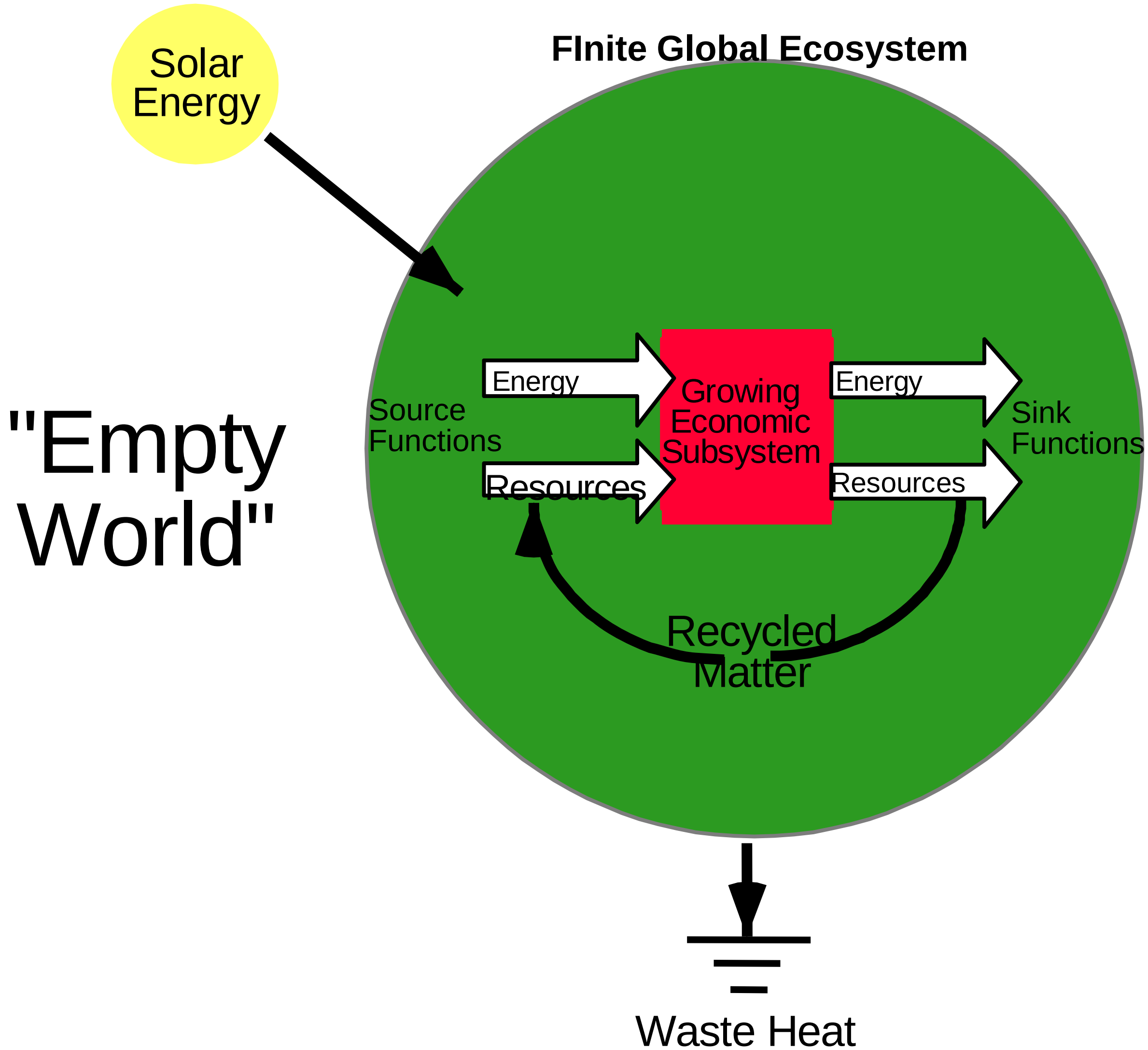
Burlington, VT 05401

**http://www.uvm.edu/giee**

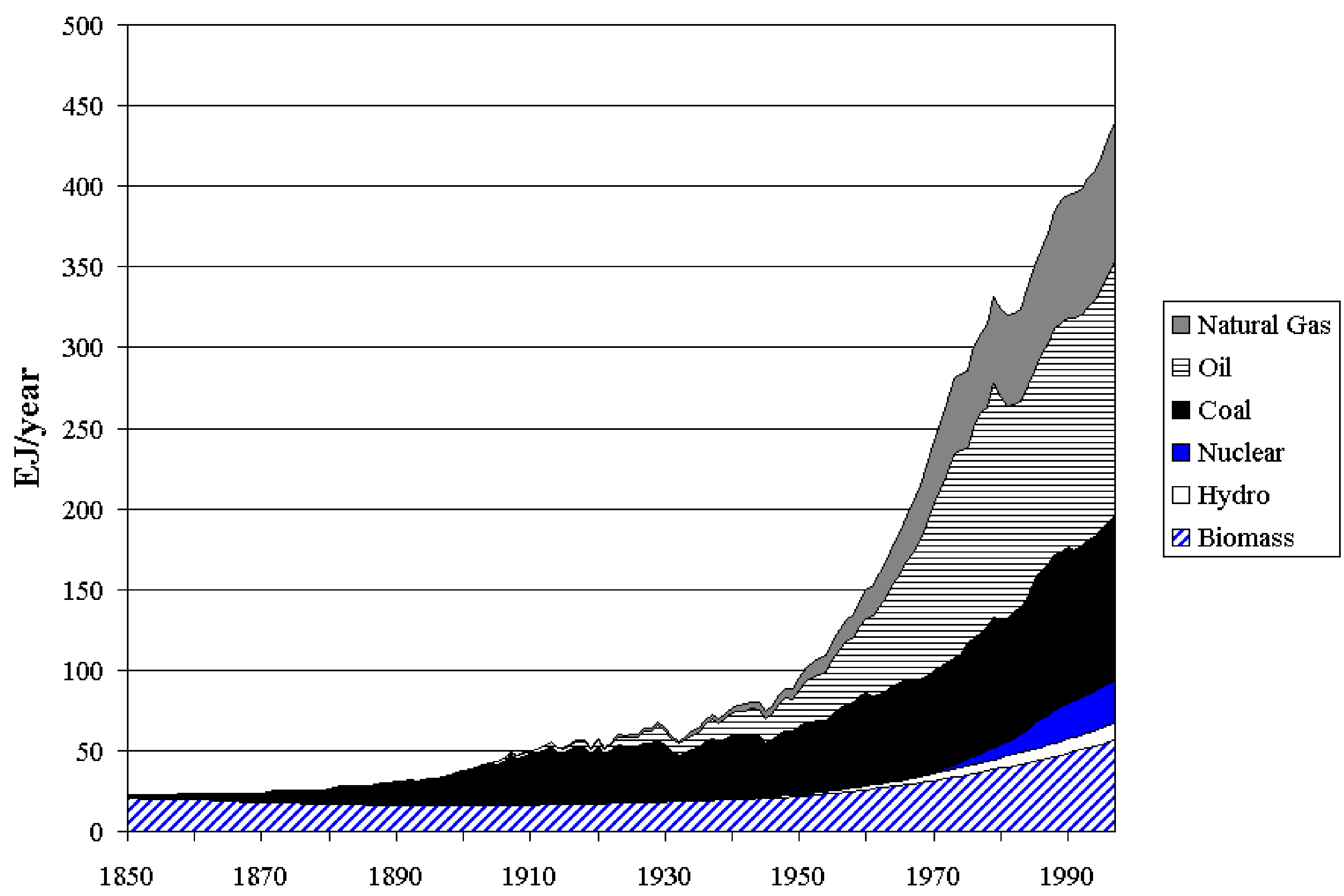
# Practical Problem Solving Requires the *Integration* of:

- Vision
  - a. How the world works
  - b. How we would like the world to be
- Tools and Analysis
  - appropriate to the vision
- Implementation
  - appropriate to the vision




FInite Global Ecosystem
Solar Energy
"Empty World"
Source Functions
Energy
Resources
Growing Economic Subsystem
Energy
Resources
Sink Functions
Recycled Matter
Waste Heat

# World Primary Energy Supply by Source, 1850-1997



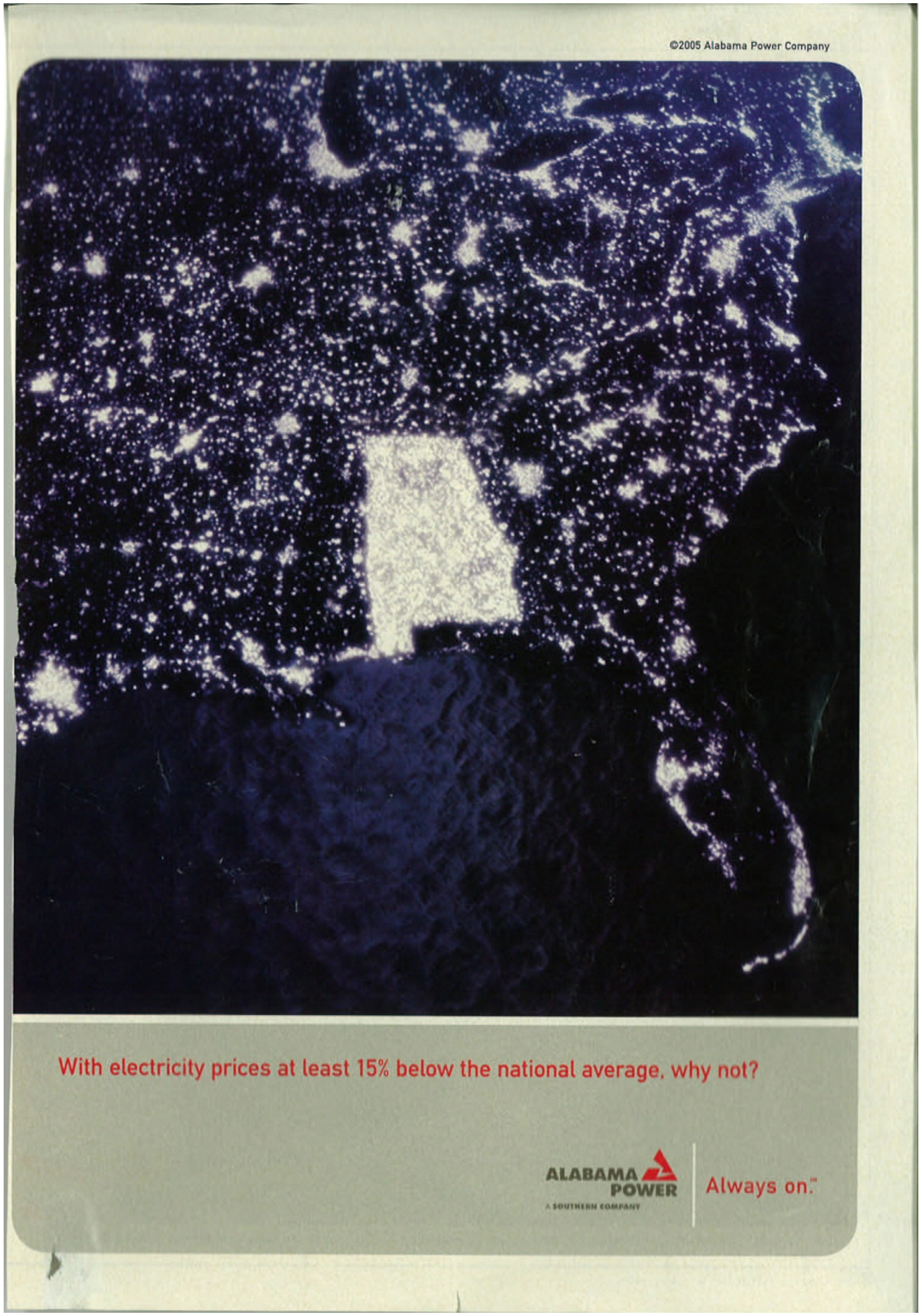
# Anthroposphere

QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

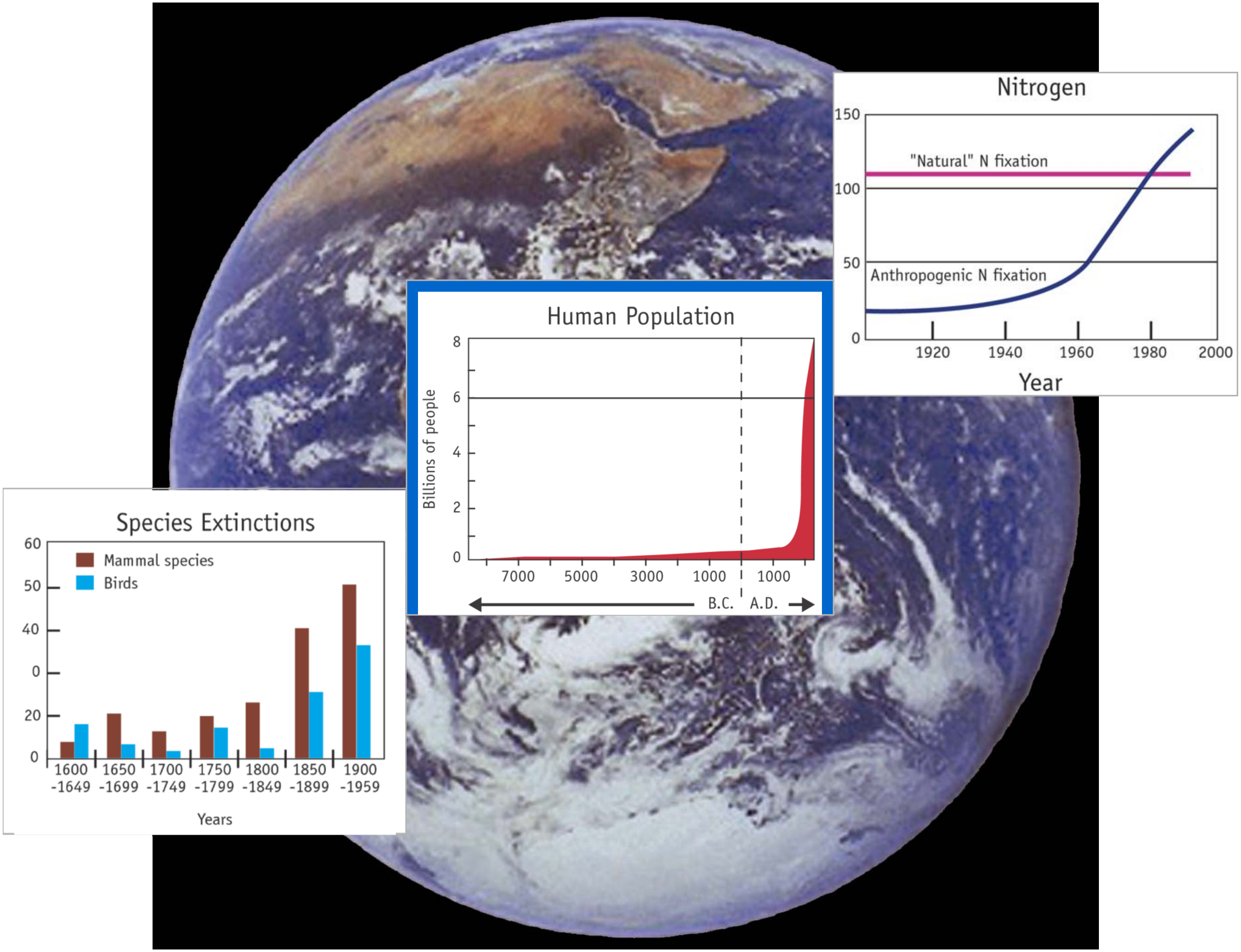
Marc
Imhoff

Biospheric
Sciences
Branch

NASA

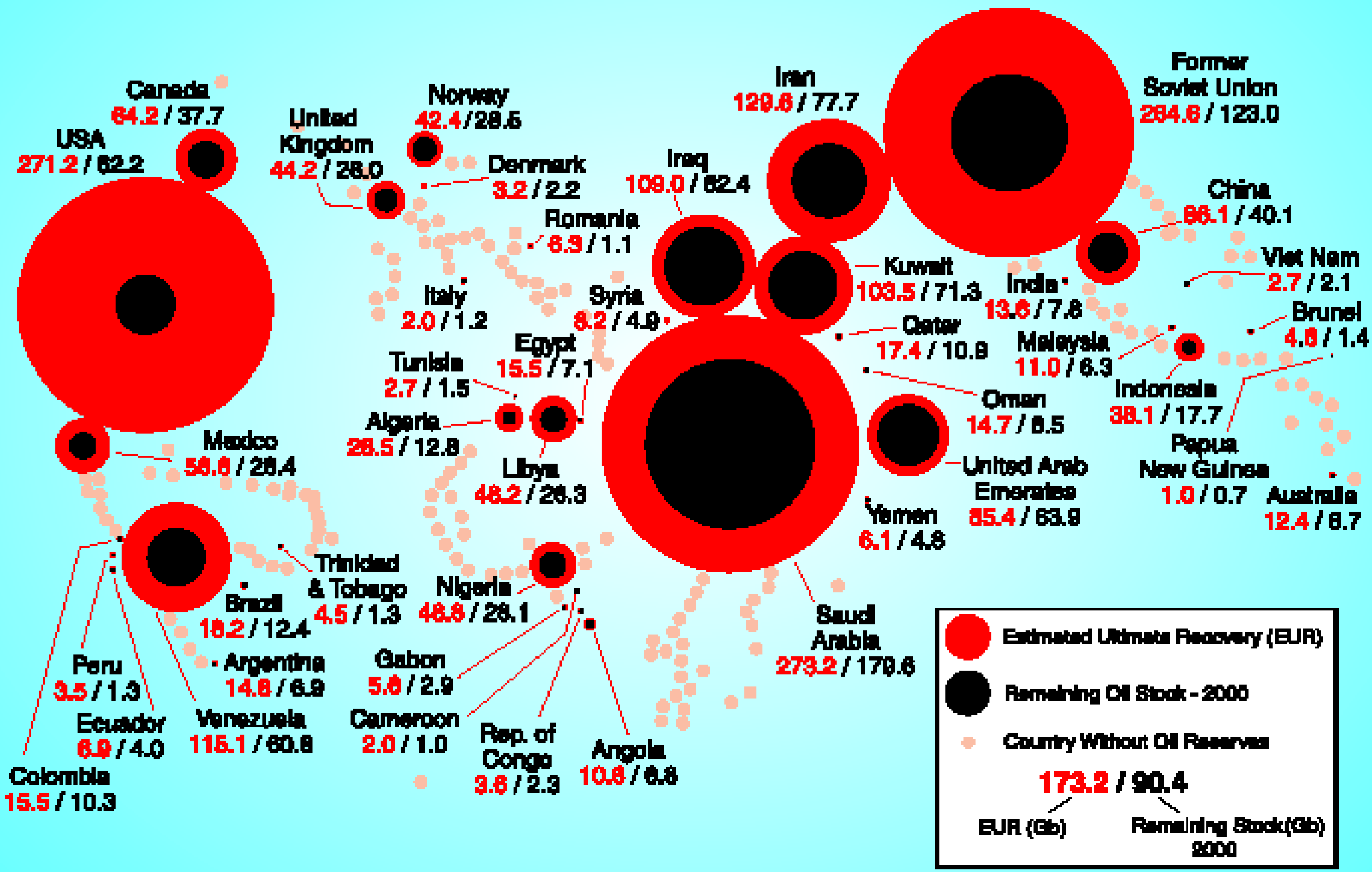



# Empty World Energy Planning?



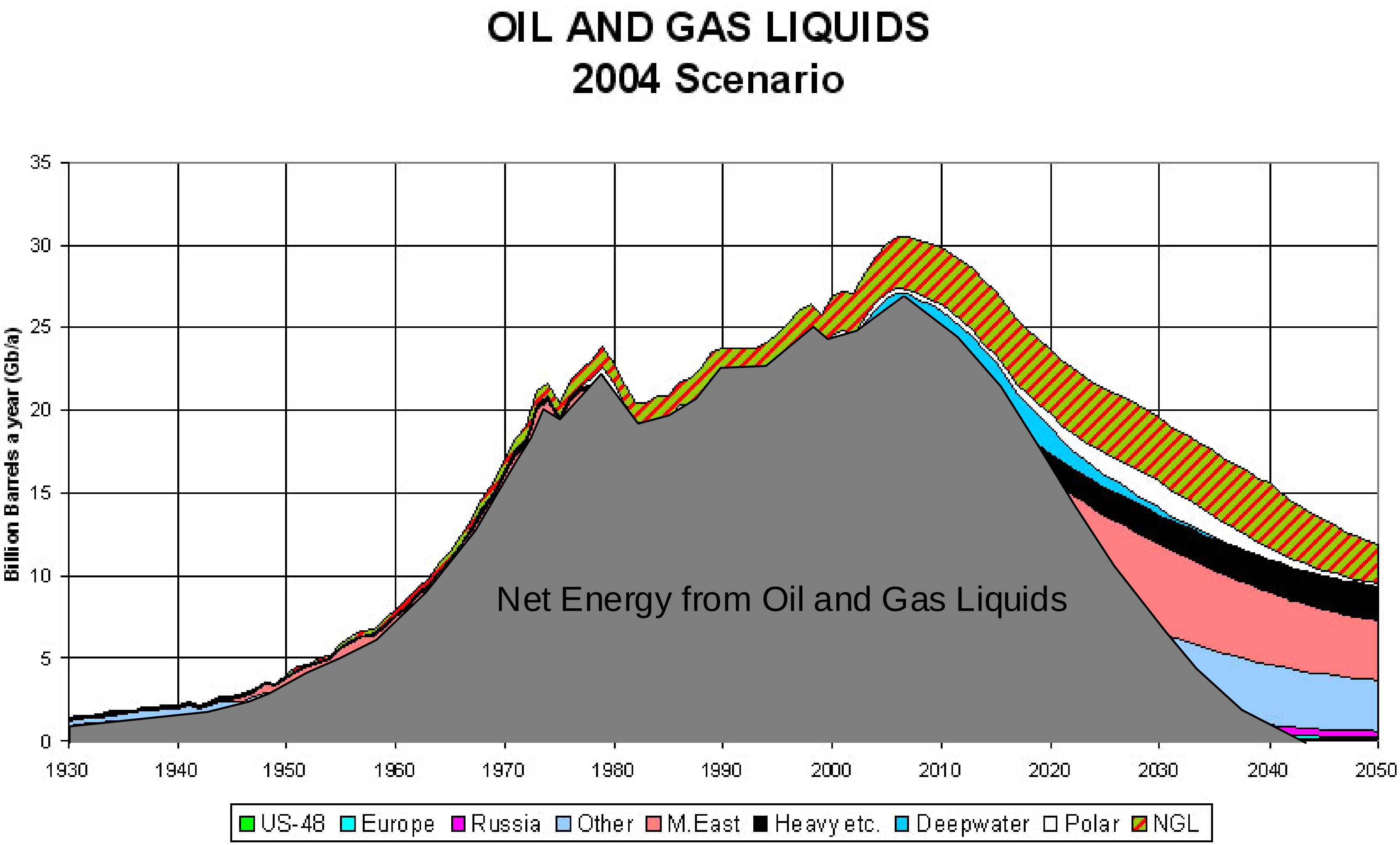

**The Challenge: Sustainable Management of an Ever-Changing Planet**

# Estimated World Oil Ultimate Recovery (EUR) and Remaining Stocks - 2000




From: *The World Petroleum Life-Cycle*, Richard C. Duncan and Walter Youngquist,

OIL AND GAS LIQUIDS 2004 Scenario
Updated by Colin J. Campbell, 2004-05-15



# EROI/Net energy definitions

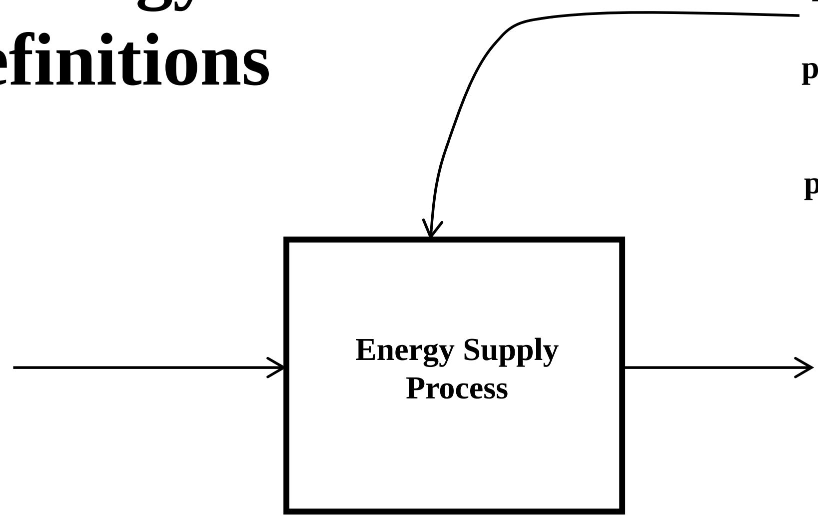
**B**

**Energy embodied in all feedbacks necessary to discover, extract or capture, process and deliver the energy, plus any external costs of the process (i.e. damage to ecosystem services)**

**Obviously, "B" is the most difficult one to estimate. It can be divided into 4 "tiers" of increasing comprehensiveness:**

**Tier 1** (direct energy feedback only),
**Tier 2** (tier 1 plus embodied in capital)
**Tier 3** (tier 2 plus embodied in labor and government services)
**Tier 4** (tier 3 plus damage to ecosystem services and other external costs)

**C**
**Energy input**




**A**
**Gross energy delivered to point of use**

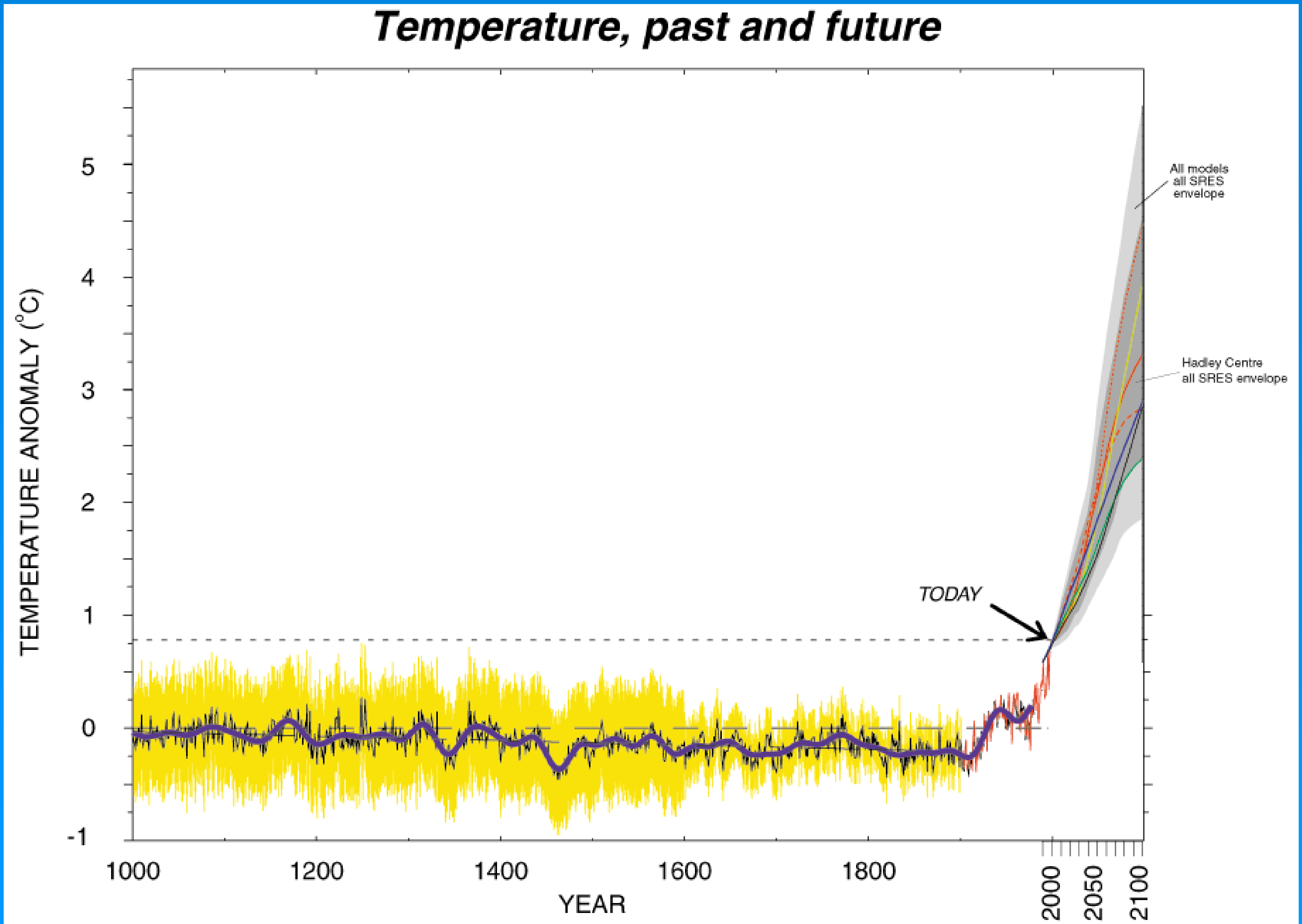
**"A" can be tricky if there are joint products (i.e. biodiesel and silage)**

## With A, B, and C all converted to energy of the same quality:

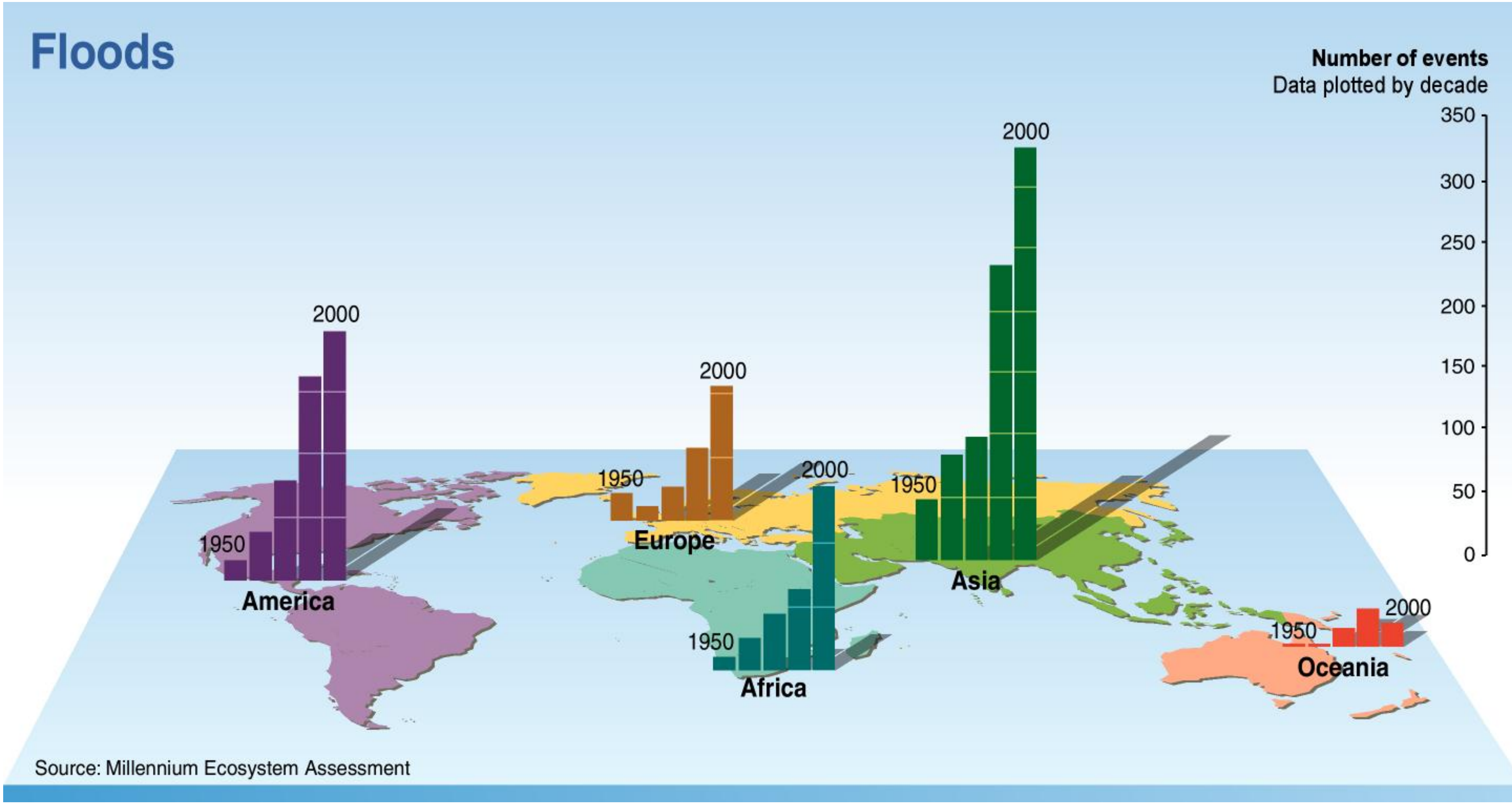
**Energy Return on Investment (EROI) = A/B**
**Net Energy = A - B**
**Energy Capture Efficiency = A/(B+C)**
**Energy Payback Time = time for flow of A to equal lump sum of B**

# Atmosphere

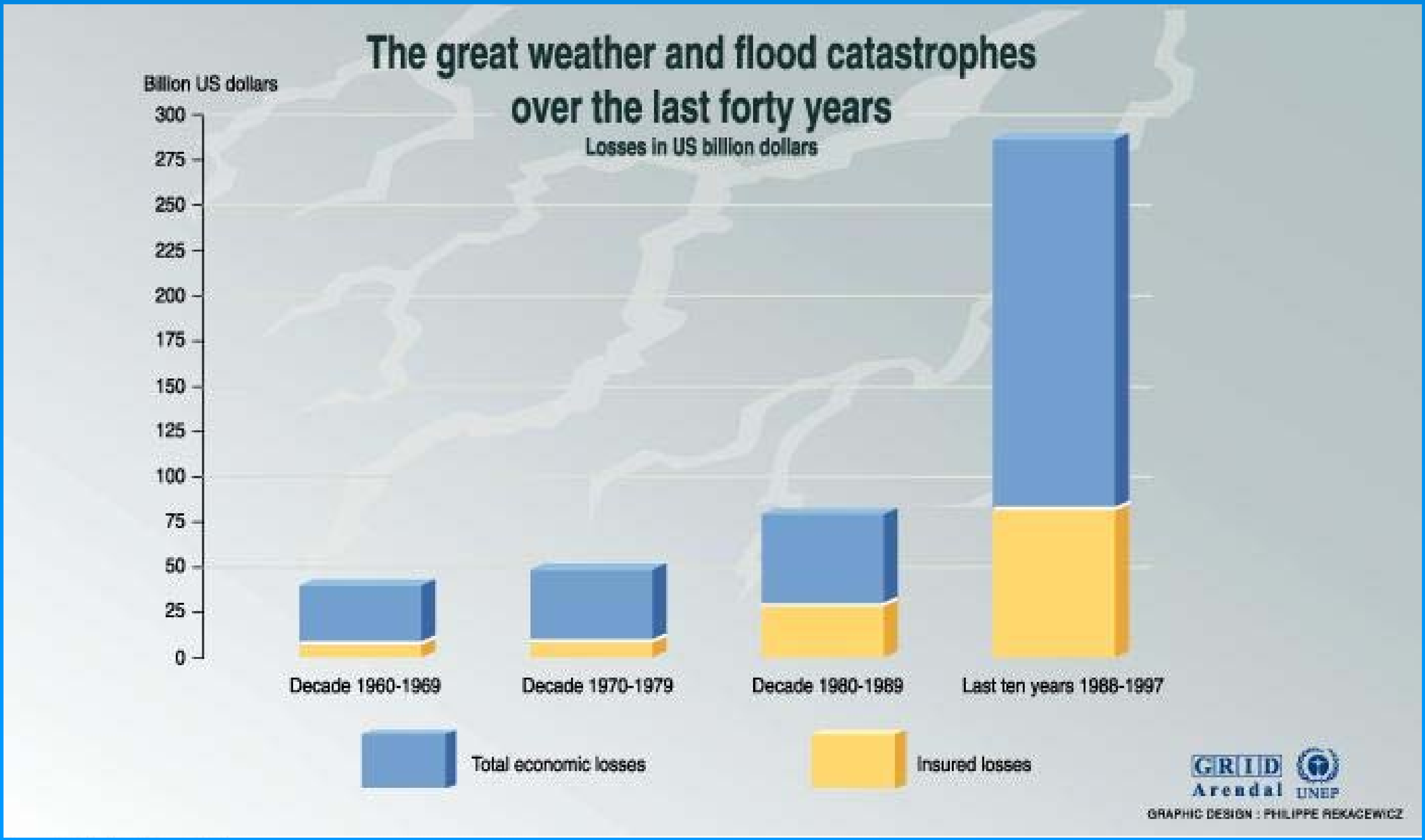
QuickTime™ and a
decompressor
are needed to see this picture.


Temperature, past and future
TEMPERATURE ANOMALY (°C)
5
4
3
2
1
0
-1
1000
1200
1400
1600
1800
2000
2050
2100
YEAR
TODAY
All models
all SRES
envelope
Hadley Centre
all SRES envelope

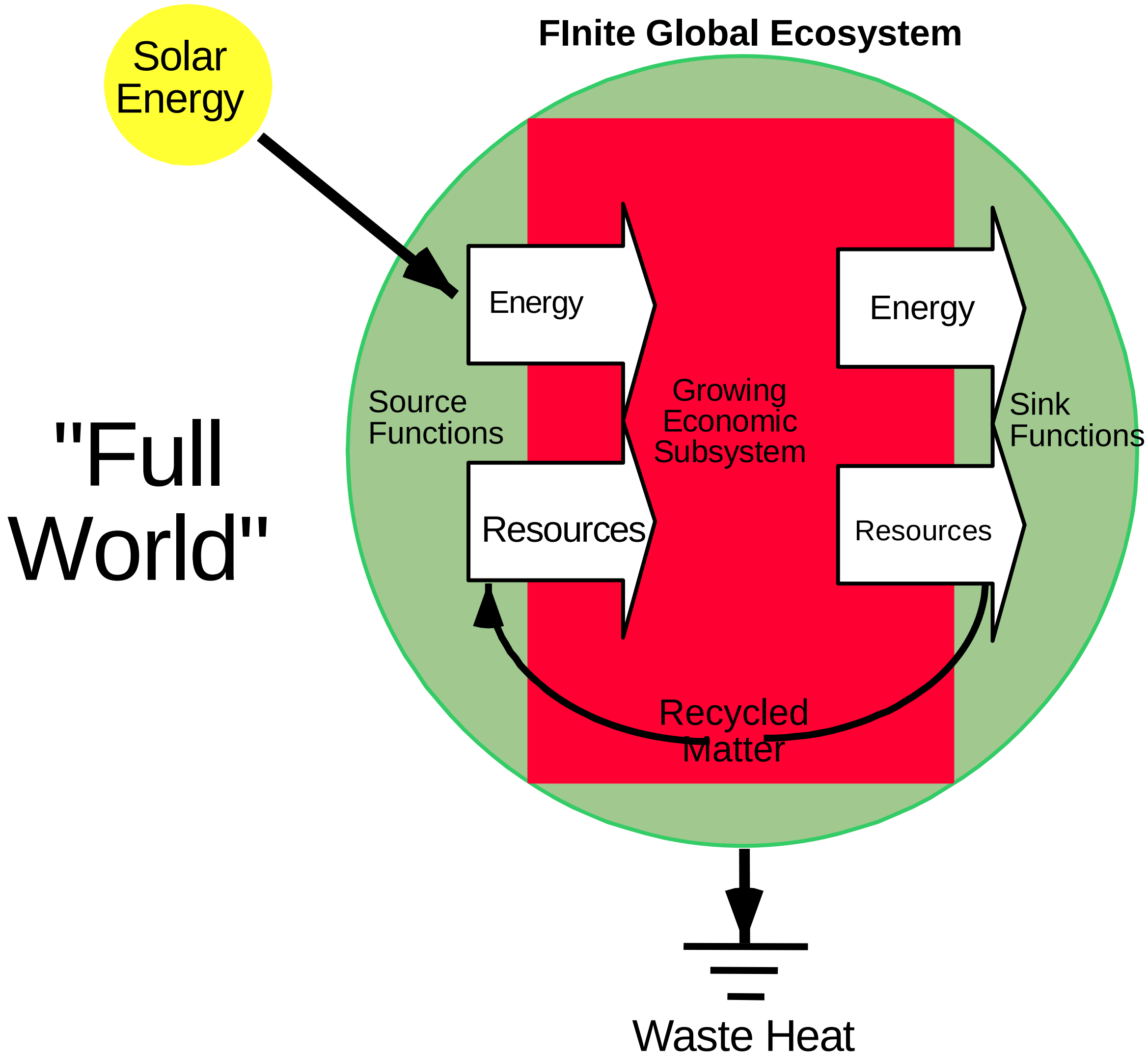
APRIL 3, 2006
www.time.com AOL Keyword: TIME
SPECIAL REPORT GLOBAL WARMING
TIME
BE WORRIED. BE VERY WORRIED.
Climate change isn't some vague future problem—it's already damaging the planet at an alarming pace. Here's how it affects you, your kids and their kids as well
EARTH AT THE TIPPING POINT
HOW IT THREATENS YOUR HEALTH
HOW CHINA & INDIA CAN HELP SAVE THE WORLD—OR DESTROY IT
THE CLIMATE CRUSADERS


Floods
Number of events
Data plotted by decade
350
300
250
200
150
100
50
0
1950
2000
America
1950
2000
Europe
1950
2000
Africa
1950
2000
Asia
1950
2000
Oceania
Source: Millennium Ecosystem Assessment

# Weather-related economic damages have increased



Hurricane Katrina approaching Louisiana coast



"Full World"
Solar Energy
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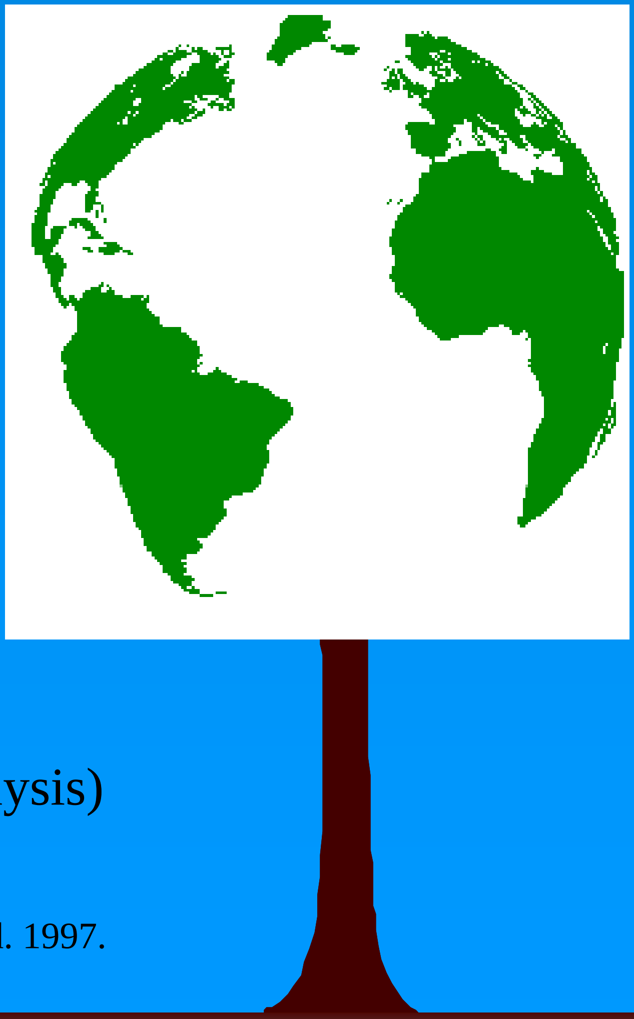
Waste Heat

# Ecological Economics

*oikos* = "house"
*logy* = "study or knowledge"
*nomics* = "management"

Literally: *management of the house (earth) based on study and knowledge of same*



## Integrated Questions/Goals:

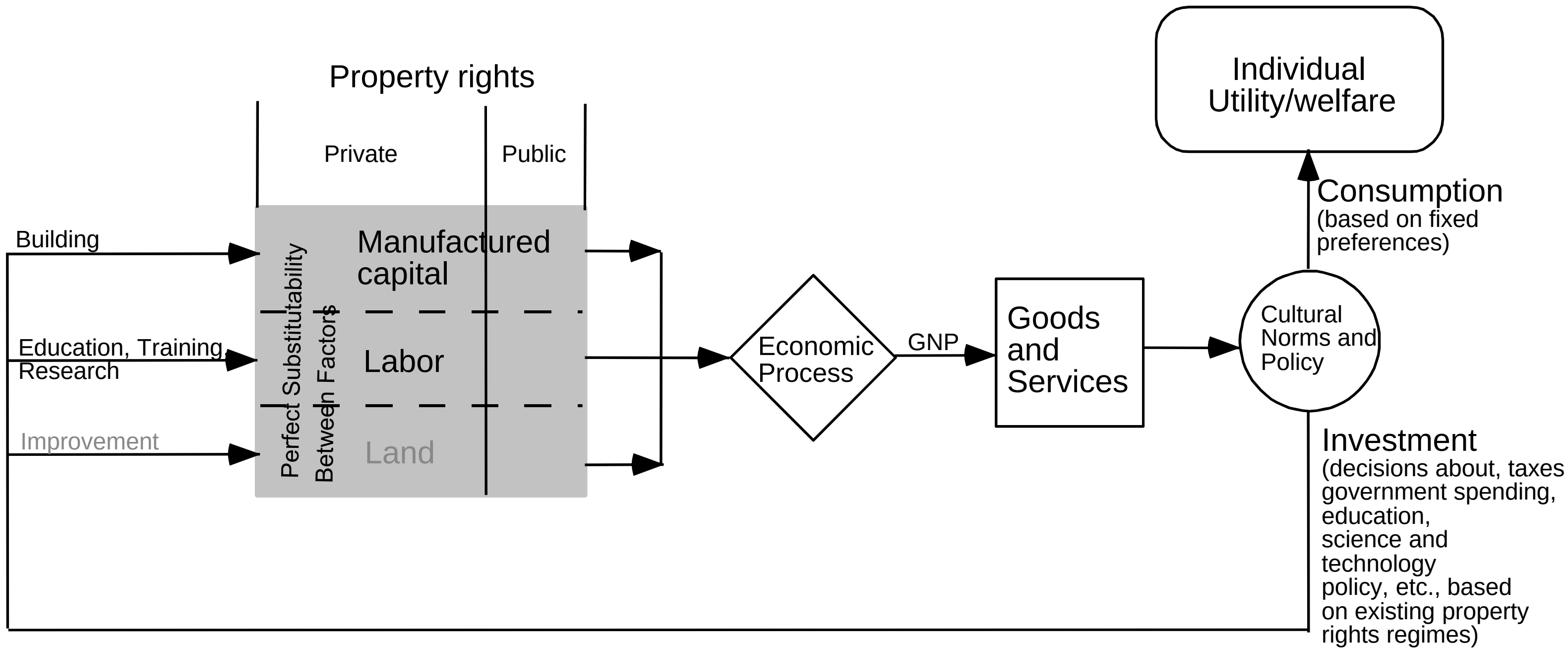
- Ecologically Sustainable **Scale**
- Socially Fair **Distribution**
- Economically Efficient **Allocation**

## Methods:

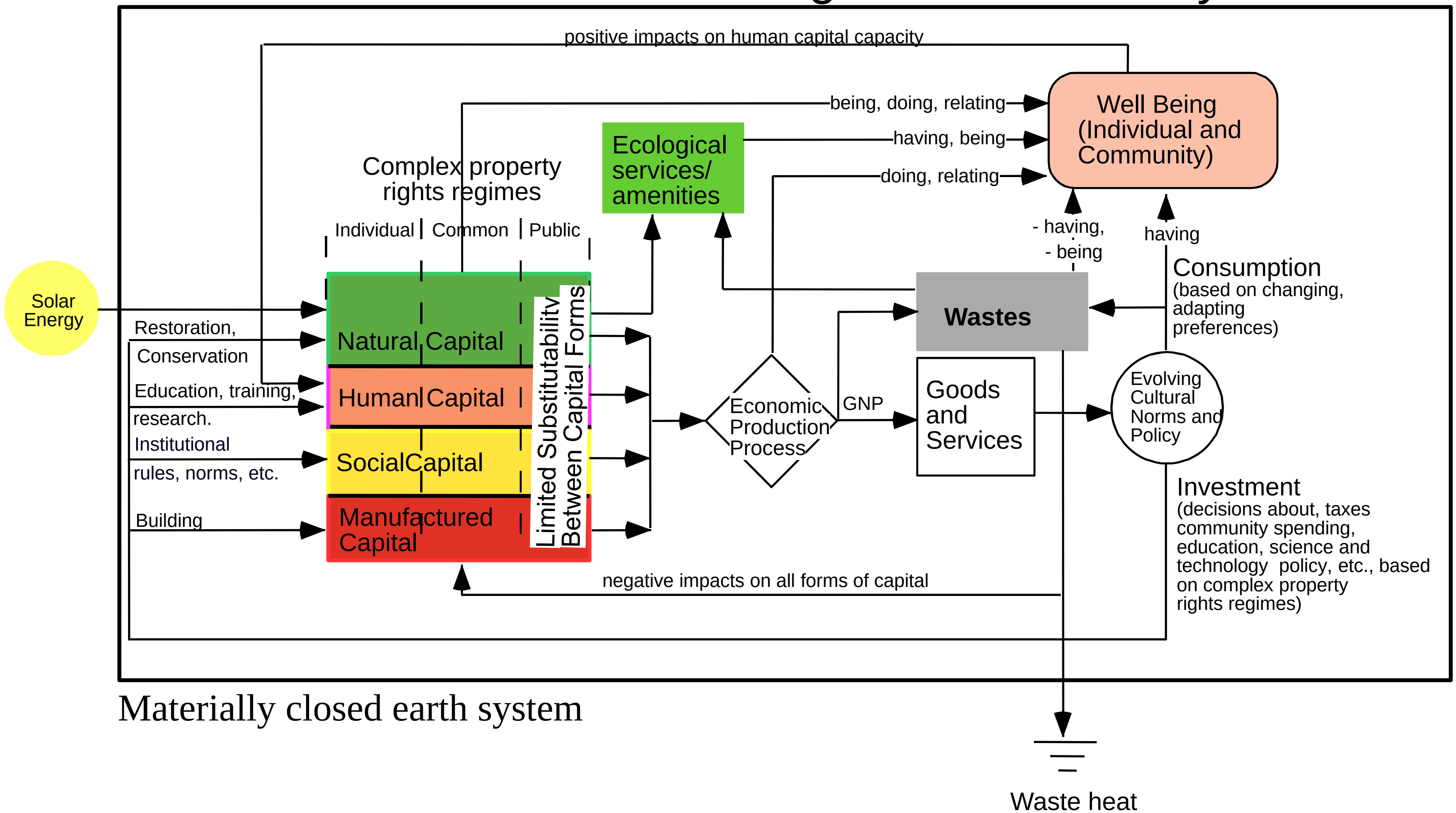
- Transdisciplinary **Dialogue**
- **Problem** (rather than tools) **Focus**
- **Integrated Science** (balanced synthesis & analysis)
- Effective and adaptive **Institutions**

See: Costanza, R., J. C. Cumberland, H. E. Daly, R. Goodland, and R. Norgaard. 1997. An Introduction to Ecological Economics. St. Lucie Press, Boca Raton, 275 pp.

# ”Empty World" Model of the Economy



# “Full World” Model of the Ecological Economic System




From: Costanza, R., J. C. Cumberland, H. E. Daly, R. Goodland, and R. Norgaard. 1997. An Introduction to Ecological Economics. St. Lucie Press, Boca Raton, 275 pp.

# Beyond the Confrontational Debate on the Environment

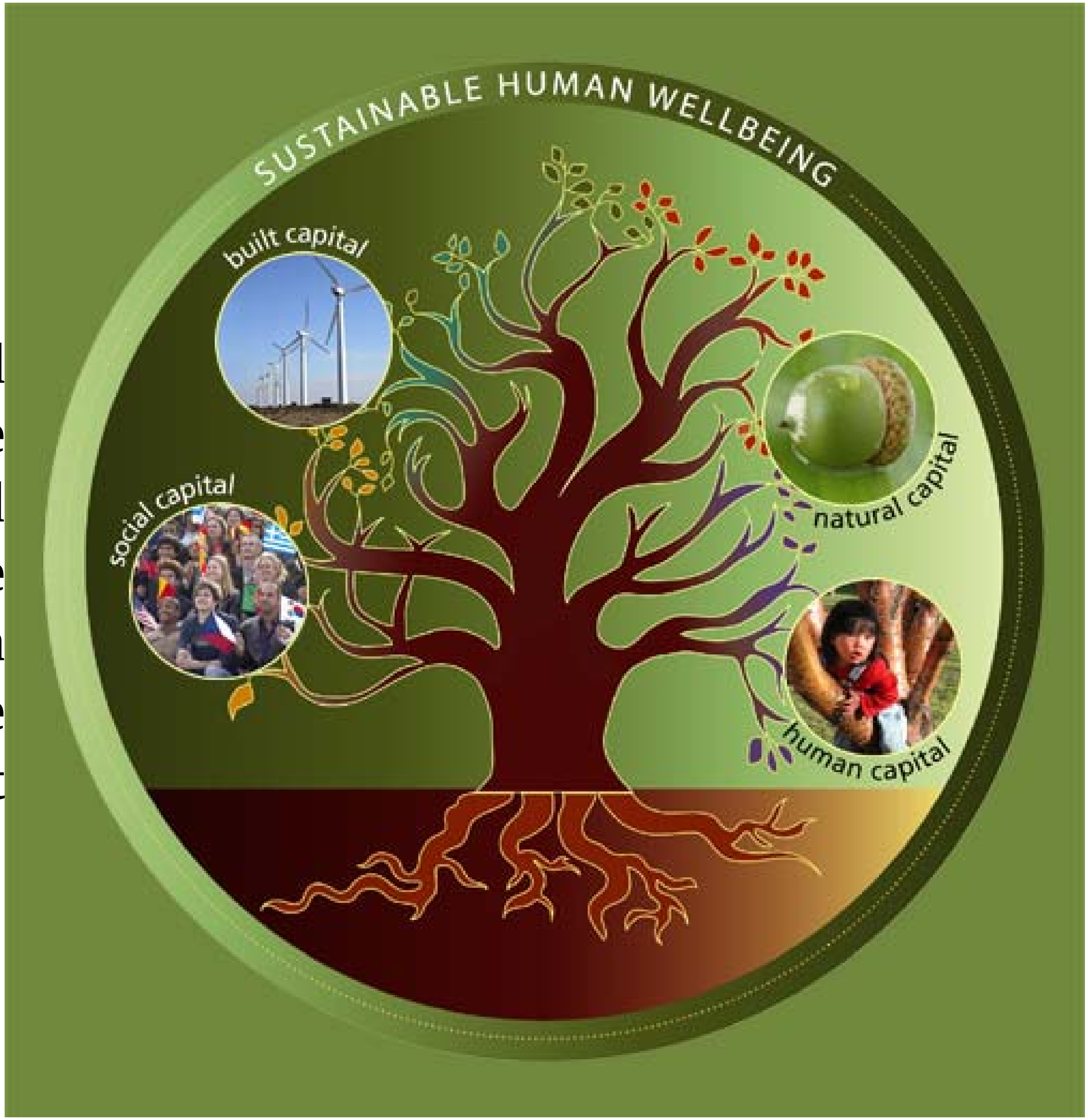
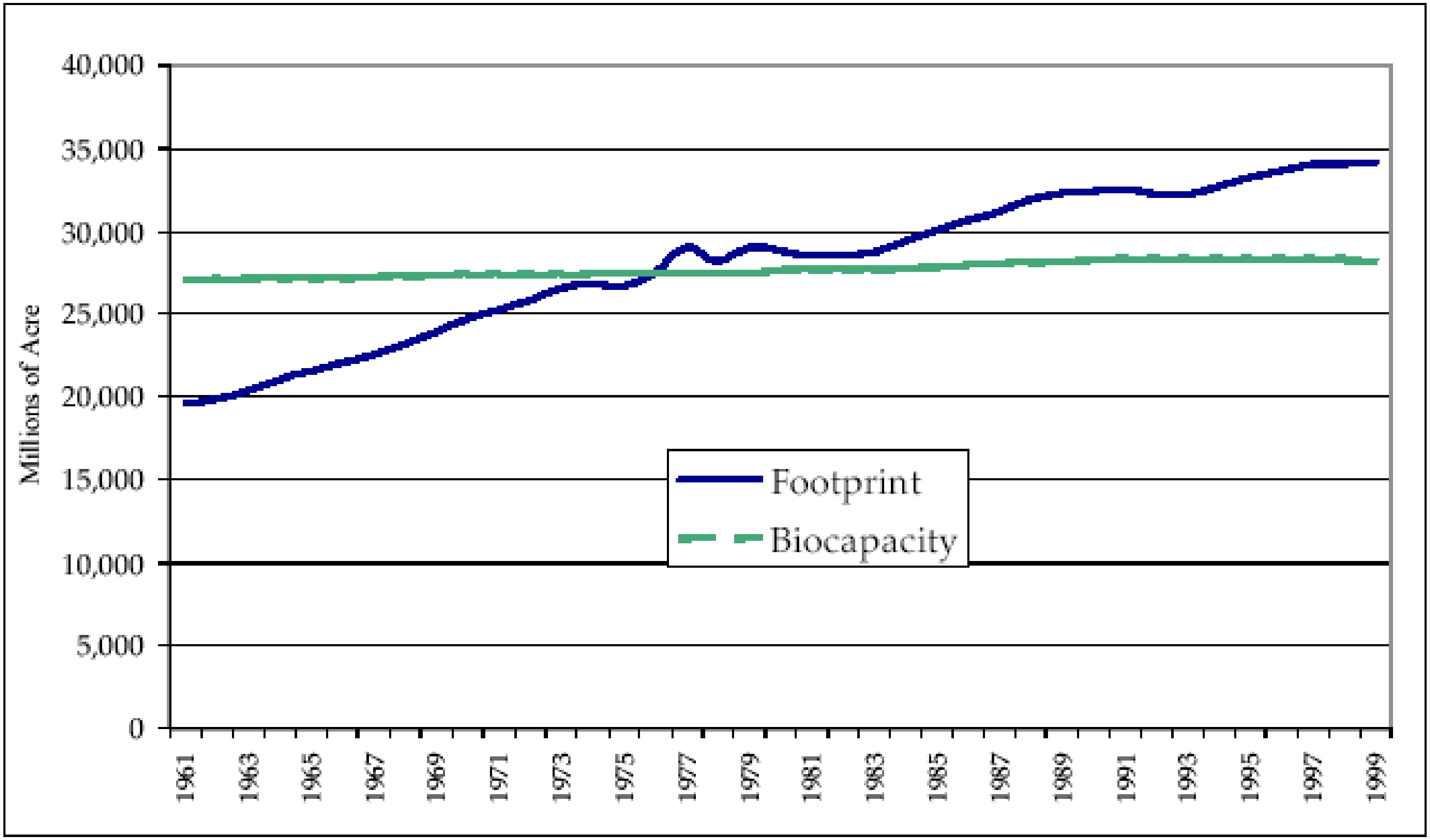


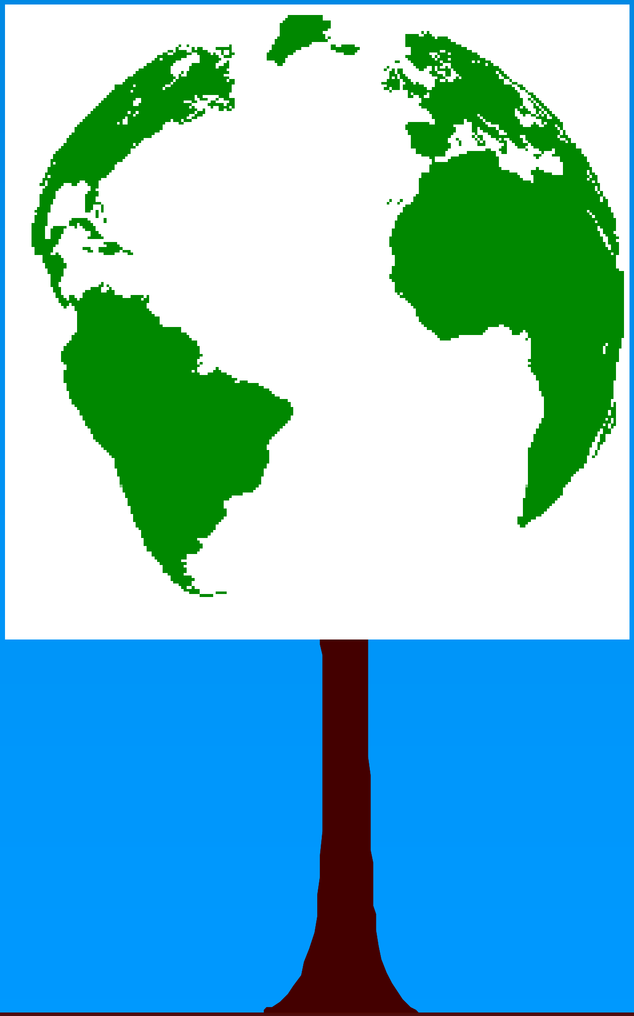
**ILLUSTRATION 1:**

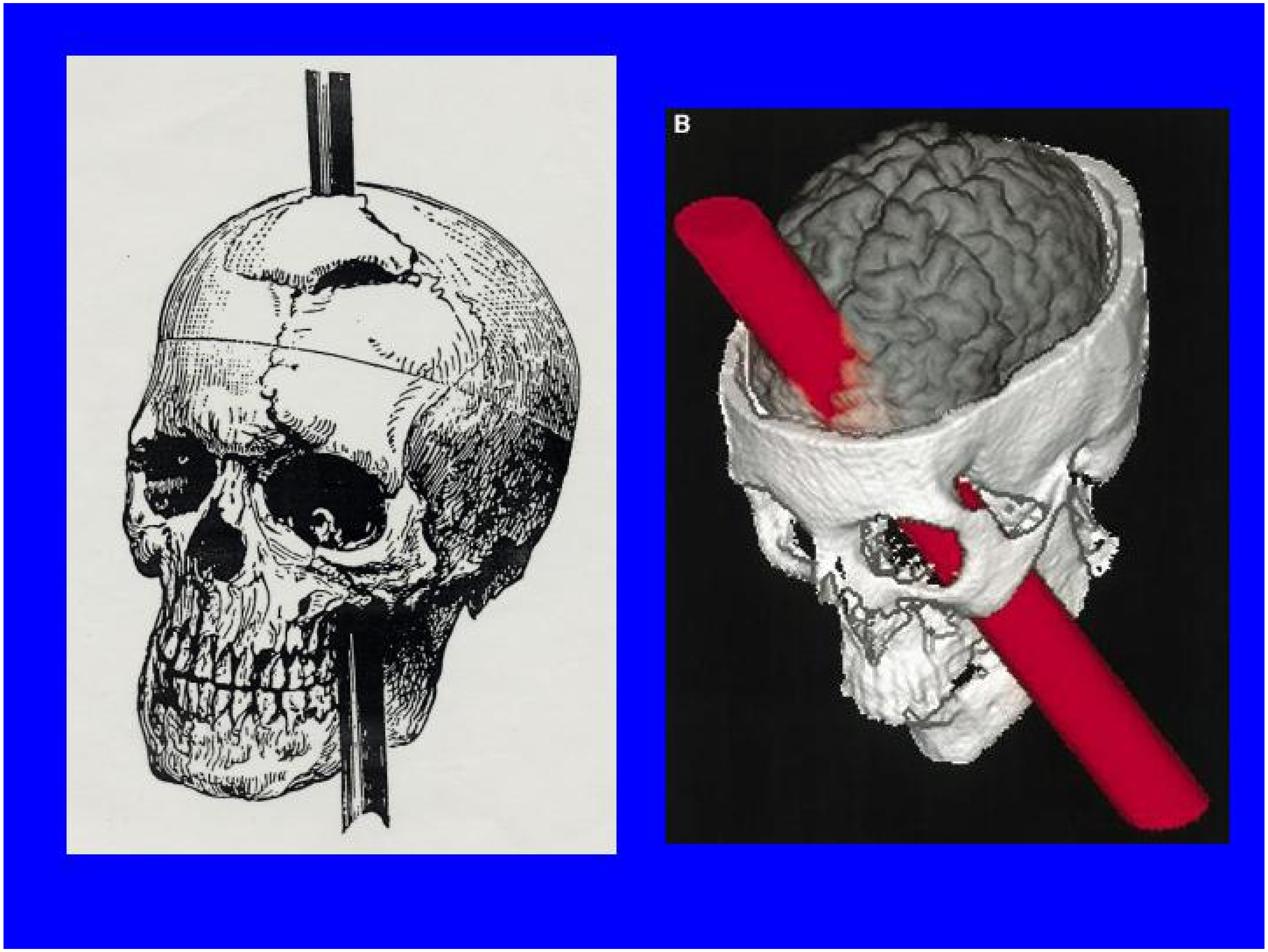
## HUMANITY'S TOTAL FOOTPRINT 1961-2000



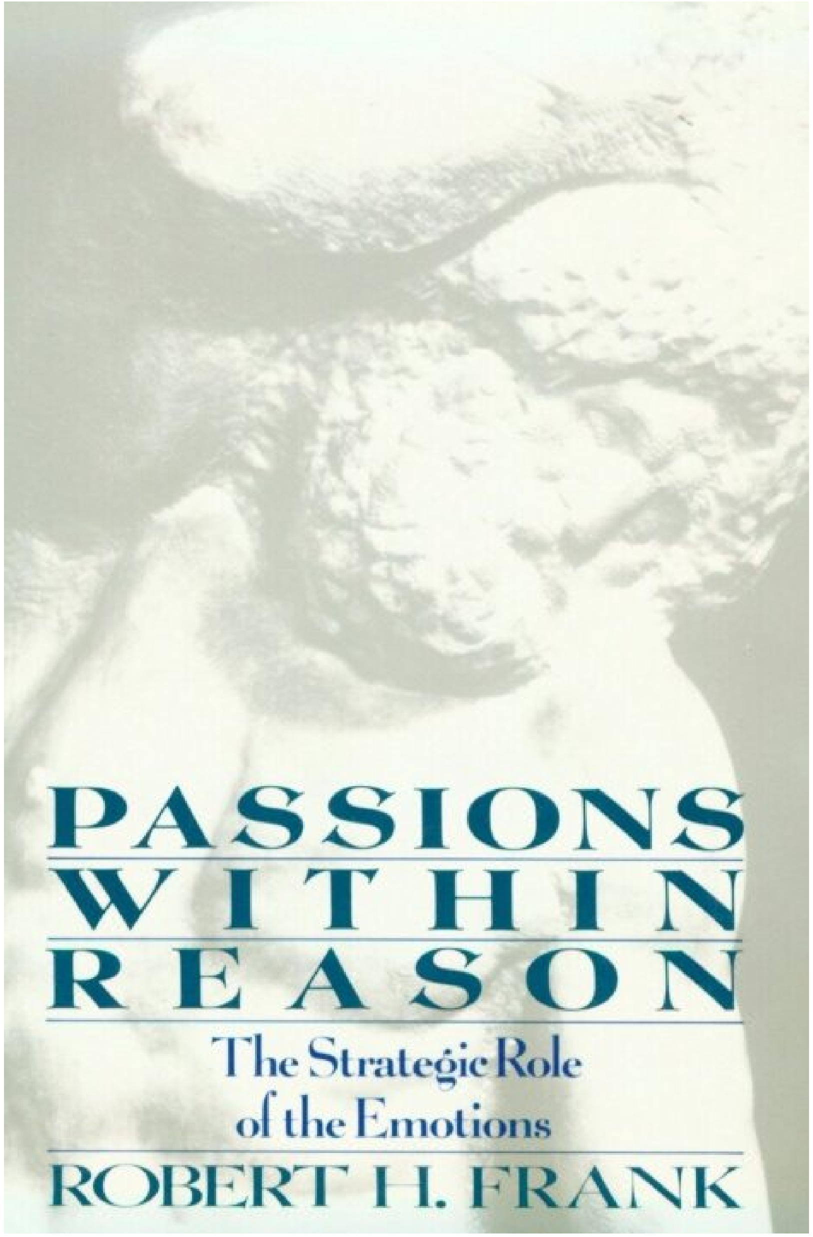
# More realistic vision of human behavior

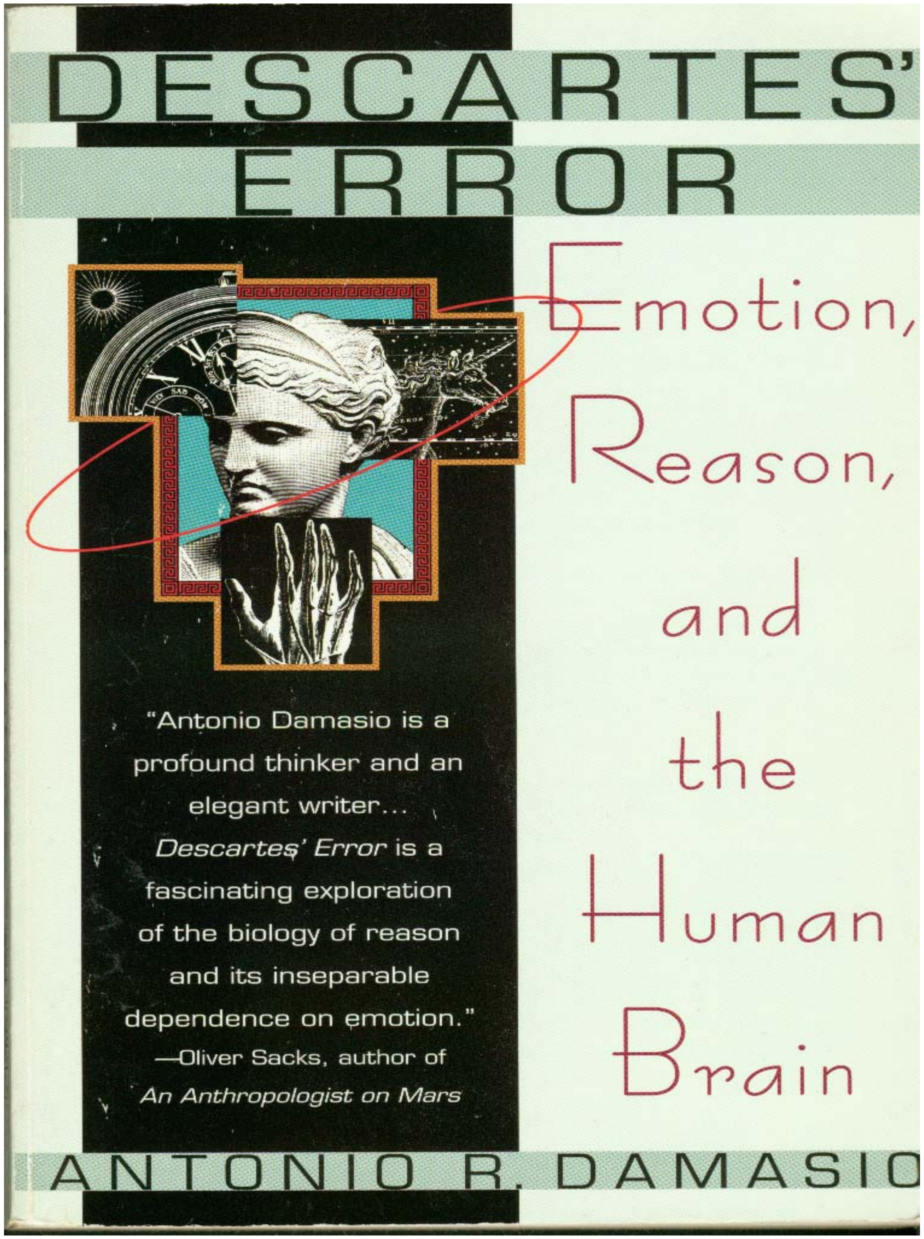
- Multiple motivations
  (personality types, culture, etc.)
- Limited knowledge and "rationality"
- Evolving preferences
- Satisfaction based on relative, rather than absolute, consumption, plus a host of "non-consumption" factors
- Central role of emotions in decision-making and evading social traps
- Embedded in multiscale, complex, adaptive, systems





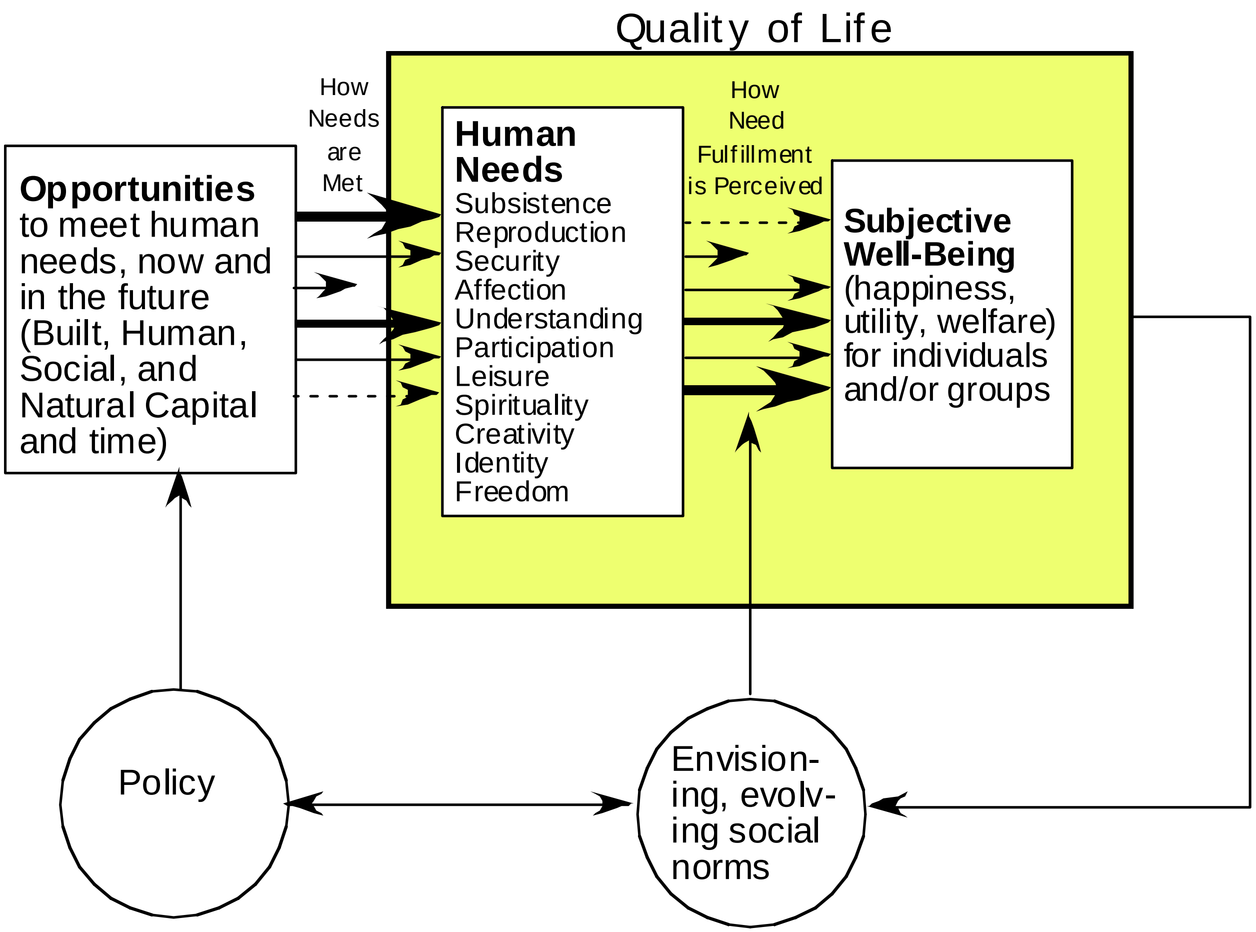

Phineas Gage




**We devote a huge chunk of our brains to recognizing faces and reading other people's emotions and intentions. This is essential to allow social capital to form and to build rules and norms that can avoid free rider problems and other social traps.**

# Quality of Life (QOL) as the interaction of human needs and the subjective perception of their fulfillment, as mediated by the opportunities available to meet the needs.




From: Costanza, R., B. Fisher, S. Ali, C. Beer, L. Bond, R. Boumans, N. L. Danigelis, J. Dickinson, C. Elliott, J. Farley, D. E. Gayer, L. MacDonald Glenn, T. Hudspeth, D. Mahoney, L. McCahill, B. McIntosh, B. Reed, S. A. T. Rizvi, D. M. Rizzo, T. Simpatico, and R. Snapp. 2006. Quality of Life: An Approach Integrating Opportunities, Human Needs, and Subjective Well-Being. *Ecological Economics* (in press).

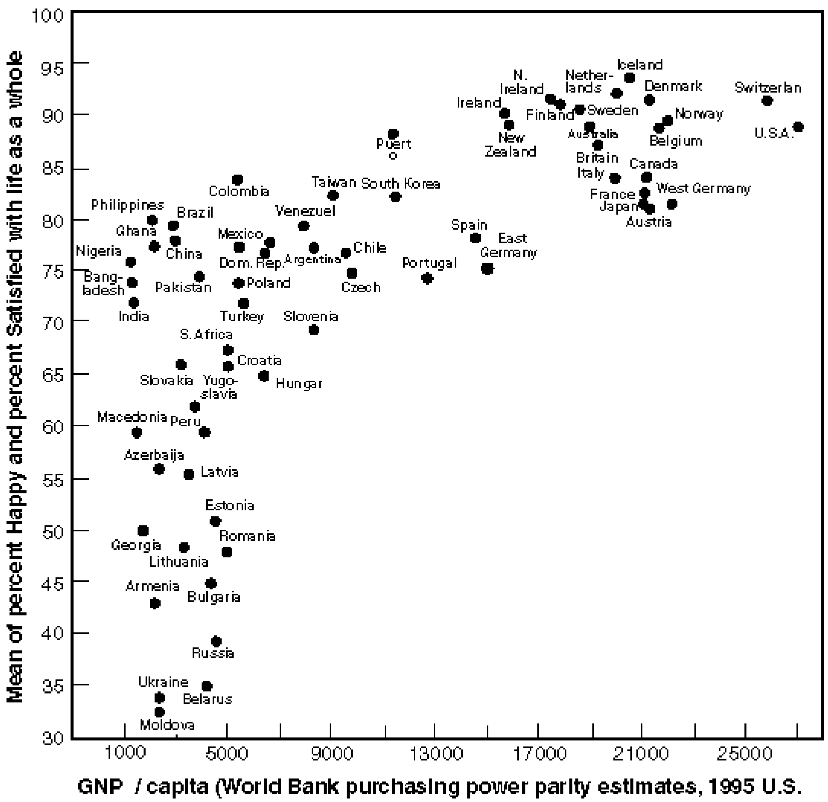
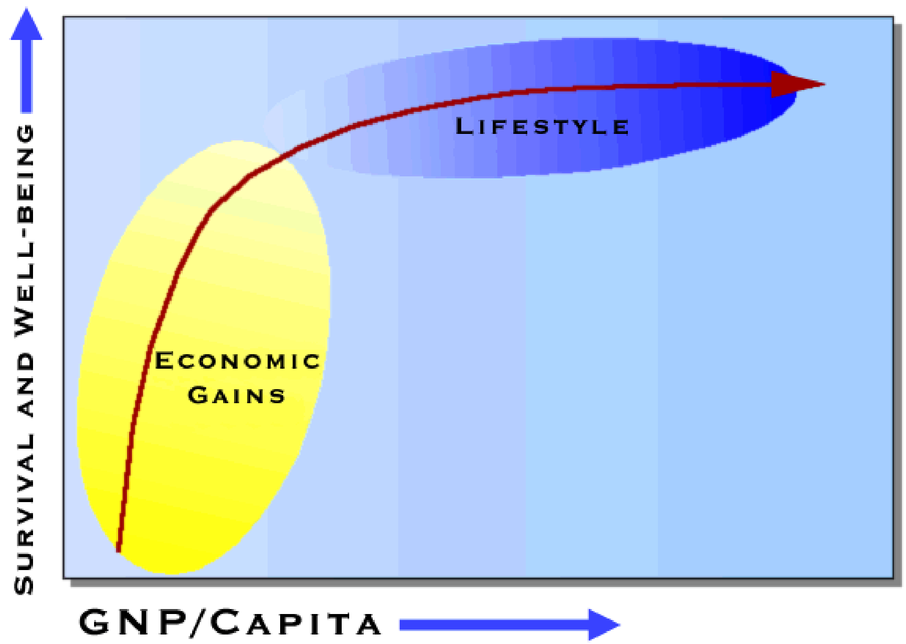
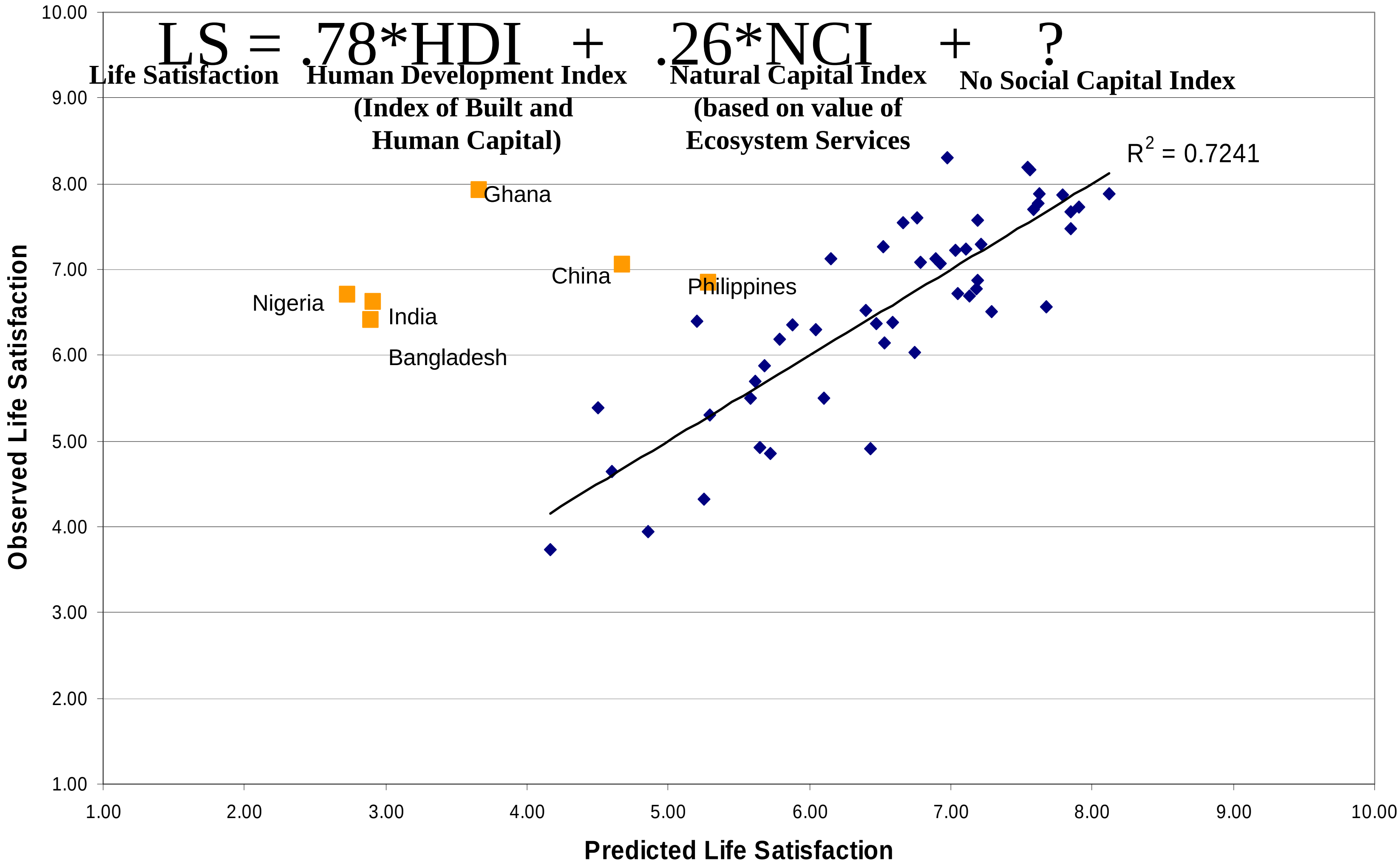



**Figure 2.** **Subjective well-being by level of economic development.**
Source: World Values Surveys; GNP/capita purchasing power estimates from World Bank, World Development Report, 1997.
R = .70 N = 65 p < .0000



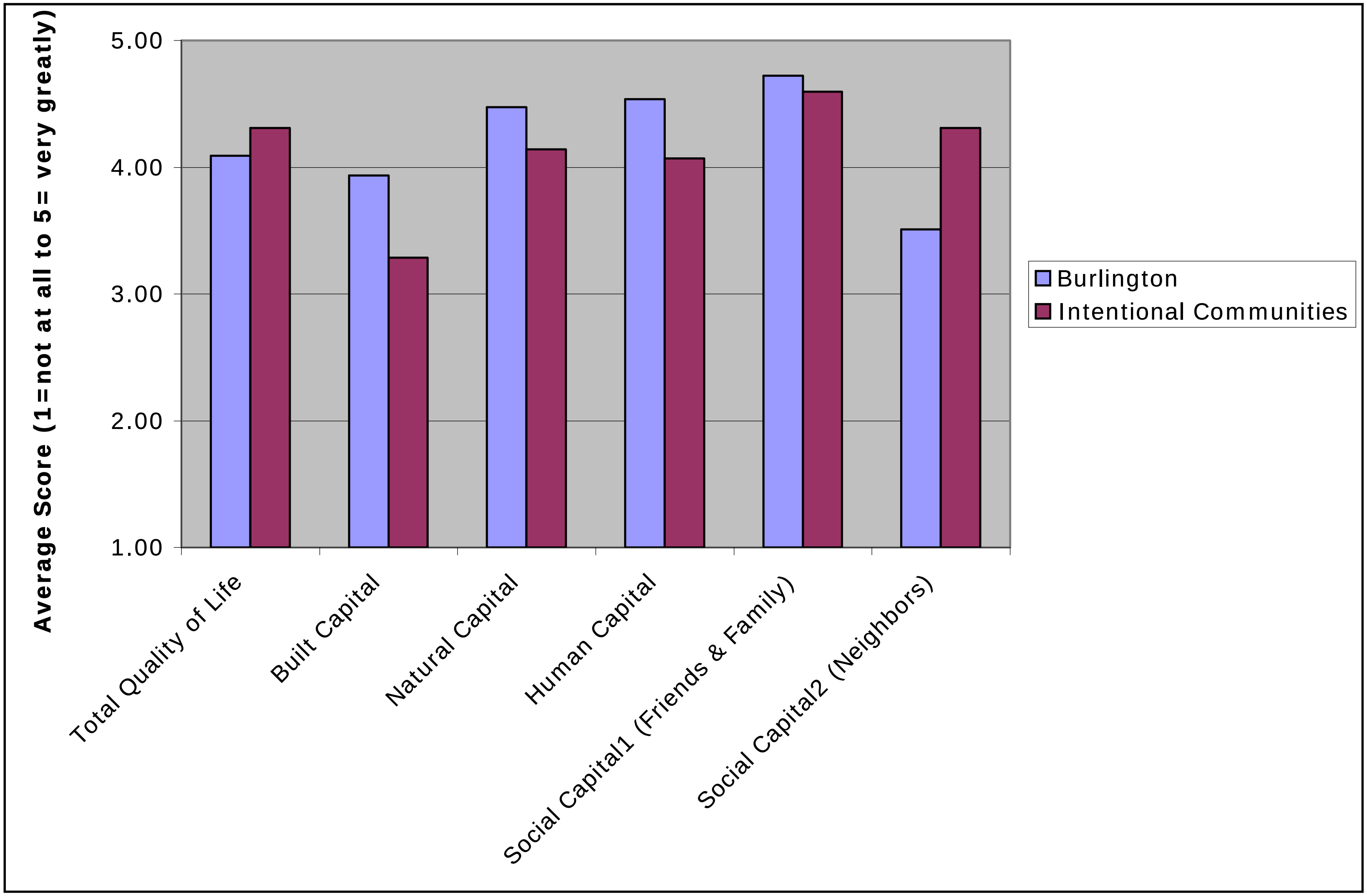

Source: R Ingelhart, 1997

**Observed Life Satisfaction versus Predicted Life Satisfaction**




**Predicted Life Satisfaction (LS)**

From: Vemuri, A. W. and R. Costanza. 2006. The Role of Human, Social, Built, and Natural Capital in Explaining Life Satisfaction at the Country Level: Toward a National Well-Being Index (NWI). *Ecological Economics* (in press).




From: Mulder, K., R. Costanza, and J. Erickson. 2006 The contribution of built, human, social and natural capital to quality of life in intentional and unintentional communities. *Ecological Economics* (in press)

A range of goals for national accounting and their corresponding frameworks, measures, and valuation methods

| Goal | Economic Income: Marketed | Economic Income: Weak Sustainability | Economic Income: Strong Sustainability | Economic Welfare | Human Welfare |
|---|---|---|---|---|---|
| Basic Framework | value of marketed goods and services produced and consumed in an economy | 1 + non-marketed goods and services consumption | 2 + preserve essential natural capital | value of the wefare effects of income and other factors (including distribution, household work, loss of natural capital etc.) | assessment of the degree to which human needs are fulfilled |
| Non-environmentally adjusted measures | **GNP** (Gross National Product) **GDP** (Gross Domestic Product) **NNP** (Net National Product) | | | **MEW** (Measure of Economic Welfare) | **HDI** (Human Development Index) |
| Environmentally adjusted measures | **NNP'** (Net National Product including non-produced assets) | **ENNP** (Environmental Net National Product) **SEEA** (System of Environmental Economic Accounts) | **SNI** (Sustainable National Income) **SEEA** (System of Environmental Economic Accounts) | **ISEW** (Index of Sustainable Economic Welfare) | **HNA** (Human Needs Assessment) |
| Appropriate Valuation Methods | Market values | 1 + Willingness to Pay Based Values (see Table 2) | 2 + Replacement Costs,+ Production Values | 3 + Constructed Preferences | 4 + Consensus Building Dialogue |

From: Costanza, R., S. Farber, B. Castaneda and M. Grasso. 2001. Green national accounting: goals and methods. Pp. 262-282 in: Cleveland, C. J., D. I. Stern and R. Costanza (eds.) The economics of nature and the nature of economics. Edward Elgar Publishing, Cheltenham, England

*The gross national product does not allow for the health of our children, the quality of their education, or the joy of their play. It does not include the beauty of our poetry or the strength of our marriages; the intelligence of our public debate or the integrity of our public officials. It measures neither our wit nor our courage; neither our wisdom nor our learning; neither our compassion nor our devotion to our country; it measures everything, in short, except that which makes life worthwhile.*

Robert F. Kennedy, 1968

*Some would blame our current problems on an organized conspiracy. I wish it were so simple. Members of a conspiracy can be rooted out and brought to justice. This system, however, is fueled by something far more dangerous than conspiracy. It is driven not by a small band of men but by a concept that has become accepted as gospel: the idea that all economic growth benefits humankind and that the greater the growth, the more widespread the benefits.*

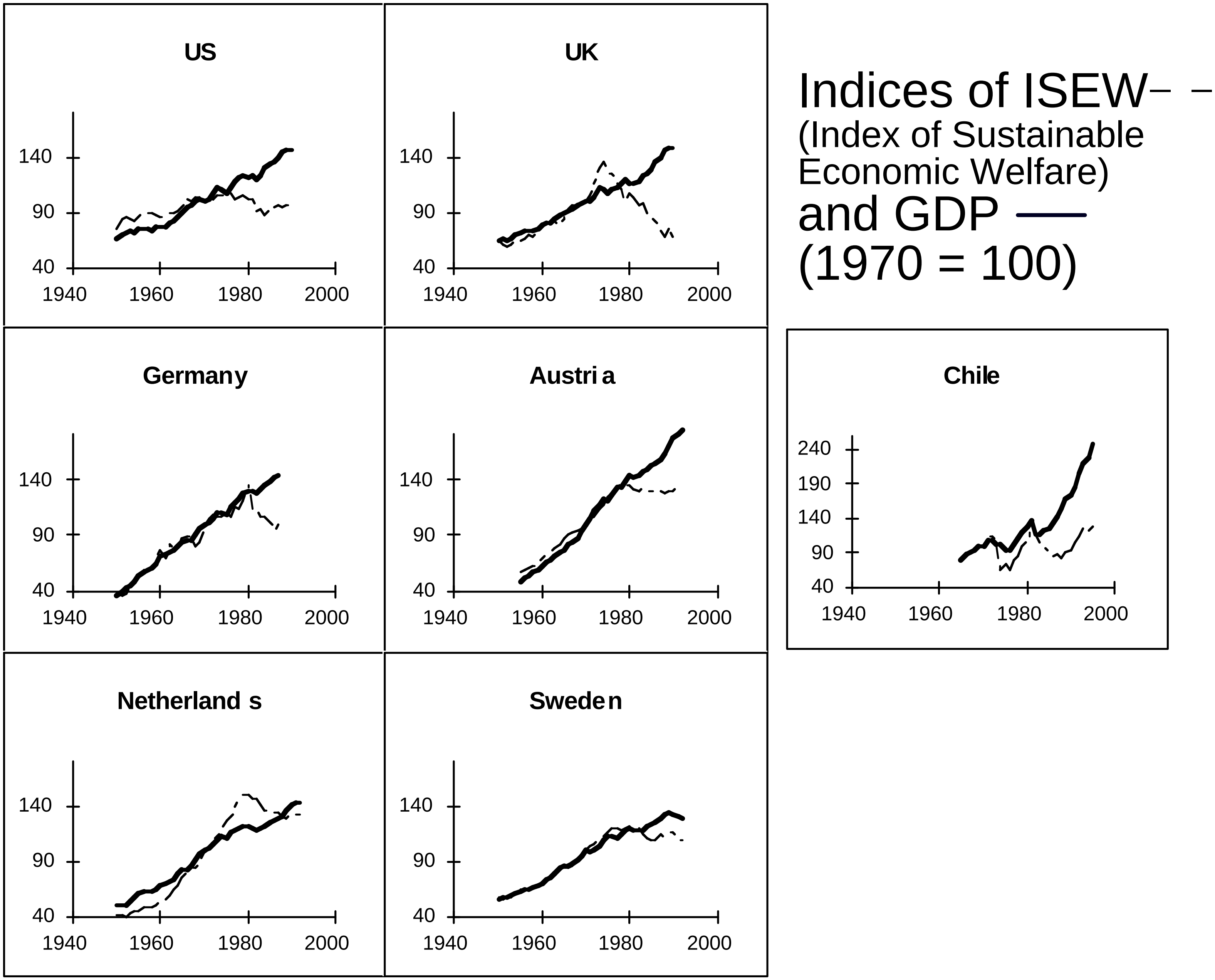
John Perkins, Confessions of an Economic Hit Man, 2004

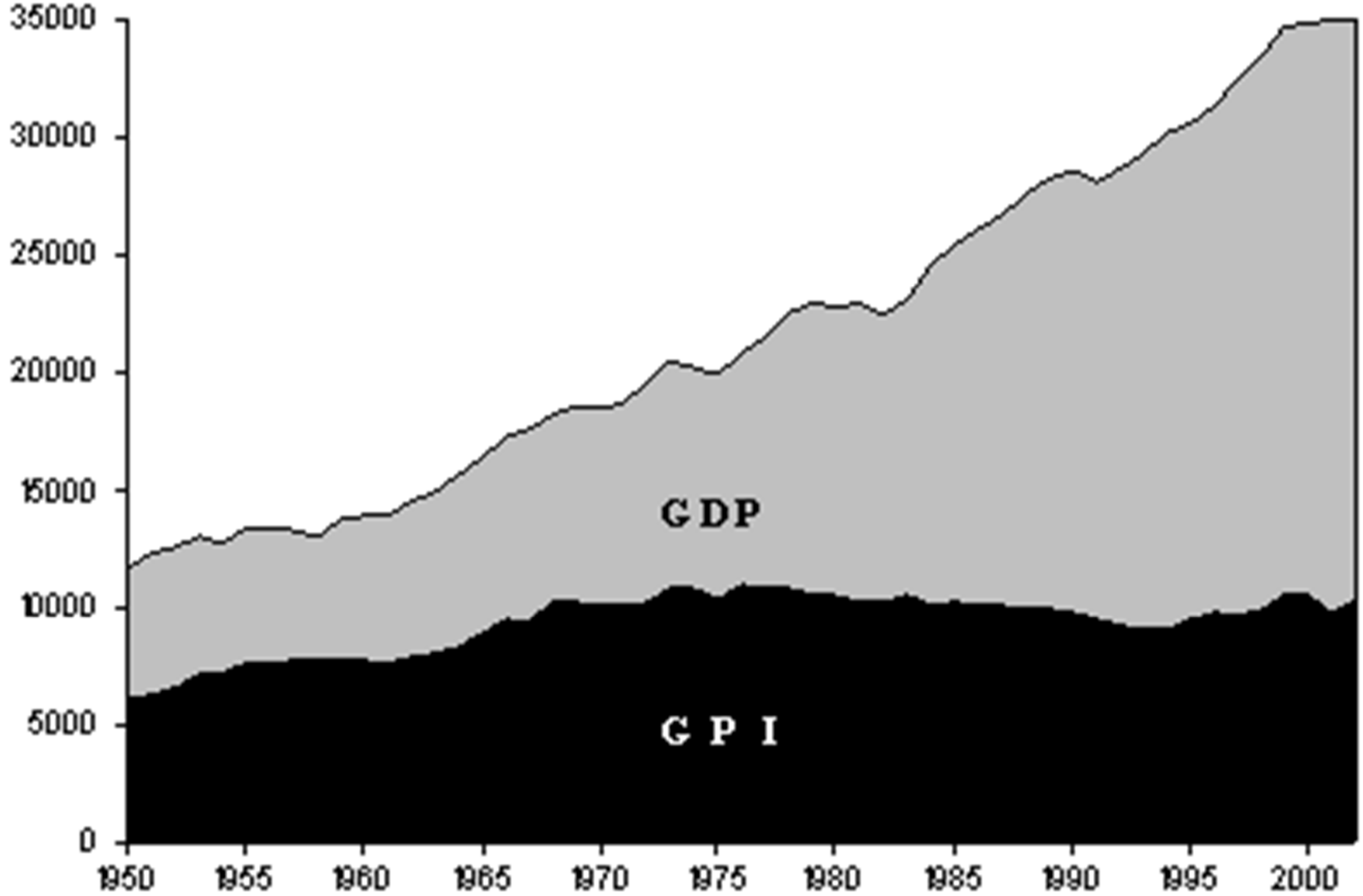
GDP measures marketed economic activity, not welfare
ISEW (Index of Sustainable Economic Welfare) or
GPI (Genuine Progress Indicator) are intended to be better approximations to economic welfare, since they adjust for:

- Income distribution
- Value of Social Capital
- Value of Natural Capital
- Value of Non-Marketed Household Work
- and other things…

# ISEW (or GPI) by Column

Column A: Personal Consumption Expenditures
Column B: Income Distribution
Column C: Personal Consumption Adjusted for Income Inequality
Column D: Value of Household Labor
Column E: Value of Volunteer Work
Column F: Services of Household Capital
Column G: Services Highways and Street
Column H: Cost of Crime
Column I: Cost of Family Breakdown
Column J: Loss of Leisure Time
Column K: Cost of Underemployment
Column L: Cost of Consumer Durables
Column M: Cost of Commuting
Column N: Cost of Household Pollution Abatement
Column O: Cost of Automobile Accidents
Column P: Cost of Water Pollution
Column Q: Cost of Air Pollution
Column R: Cost of Noise Pollution
Column S: Loss of Wetlands
Column T: Loss of Farmland
Column U: Depletion of Nonrenewable Resources
Column V: Long-Term Environmental Damage
Column W: Cost of Ozone Depletion
Column X: Loss of Forest Cover
Column Y: Net Capital Investment
Column Z: Net Foreign Lending and Borrowing

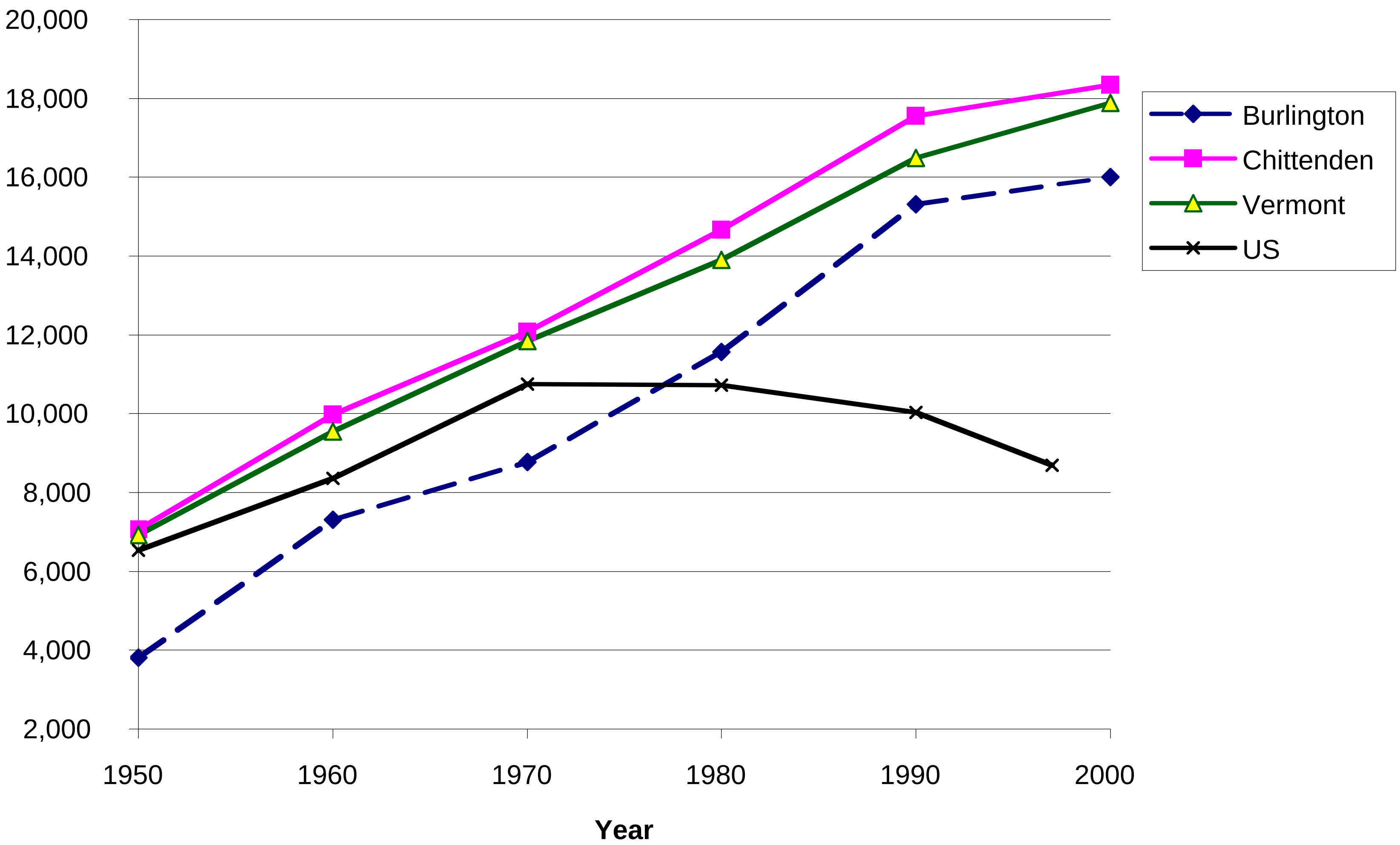

Indices of ISEW
(Index of Sustainable Economic Welfare)
and GDP
(1970 = 100)
US
UK
Germany
Austri a
Chile
Netherland s
Sweden
140
90
40
240
190
1940
1960
1980
2000




**Gross Production vs. Genuine Progress for the US, 1950 to 2002**

(source: Redefining Progress - http://www.rprogress.org)

# Genuine Progress Indicator (GPI) per capita




From: Costanza, R. J. Erickson, K. Fligger, A. Adams, C. Adams, B. Altschuler, S. Balter, B. Fisher, J. Hike, J. Kelly, T. Kerr, M. McCauley, K. Montone, M. Rauch, K. Schmiedeskamp, D. Saxton, L. Sparacino, W. Tusinski, and L. Williams. 2004. Estimates of the Genuine Progress Indicator (GPI) for Vermont, Chittenden County, and Burlington, from 1950 to 2000. *Ecological Economics* 51: 139-155

| ECOSYSTEM SERVICES | ECOSYSTEM FUNCTIONS |
|---|---|
| **Gas regulation** | Regulation of atmospheric chemical composition. |
| **Climate regulation** | Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global, regional, or local levels. |
| **Disturbance regulation** | Capacitance, damping and integrity of ecosystem response to environmental fluctuations. |
| **Water regulation** | Regulation of hydrological flows. |
| **Water supply** | Storage and retention of water. |
| **Erosion control and sediment retention** | Retention of soil within an ecosystem. |
| **Soil formation** | Soil formation processes. |
| **Nutrient cycling** | Storage, internal cycling, processing, and acquisition of nutrients. |
| **Waste treatment** | Recovery of mobile nutrients and removal or breakdown of excess or xenic nutrients and compounds. |
| **Pollination** | Movement of floral gametes. |
| **Biological control** | Trophic-dynamic regulations of populations. |
| **Refugia** | Habitat for resident and transient populations. |
| **Food production** | That portion of gross primary production extractable as food. |
| **Raw materials** | That portion of gross primary production extractable as raw materials. |
| **Genetic resources** | Sources of unique biological materials and products. |
| **Recreation** | Providing opportunities for recreational activities. |
| **Cultural** | Providing opportunities for non-commercial uses. |

From: Costanza, R. R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, S. Naeem, K. Limburg, J. Paruelo, R.V. O'Neill, R. Raskin, P. Sutton, and M. van den Belt. 1997. The value of the world's ecosystem services and natural capital. *Nature* 387:253-260

# Focus: Consequences of Ecosystem Change for Human Well-being

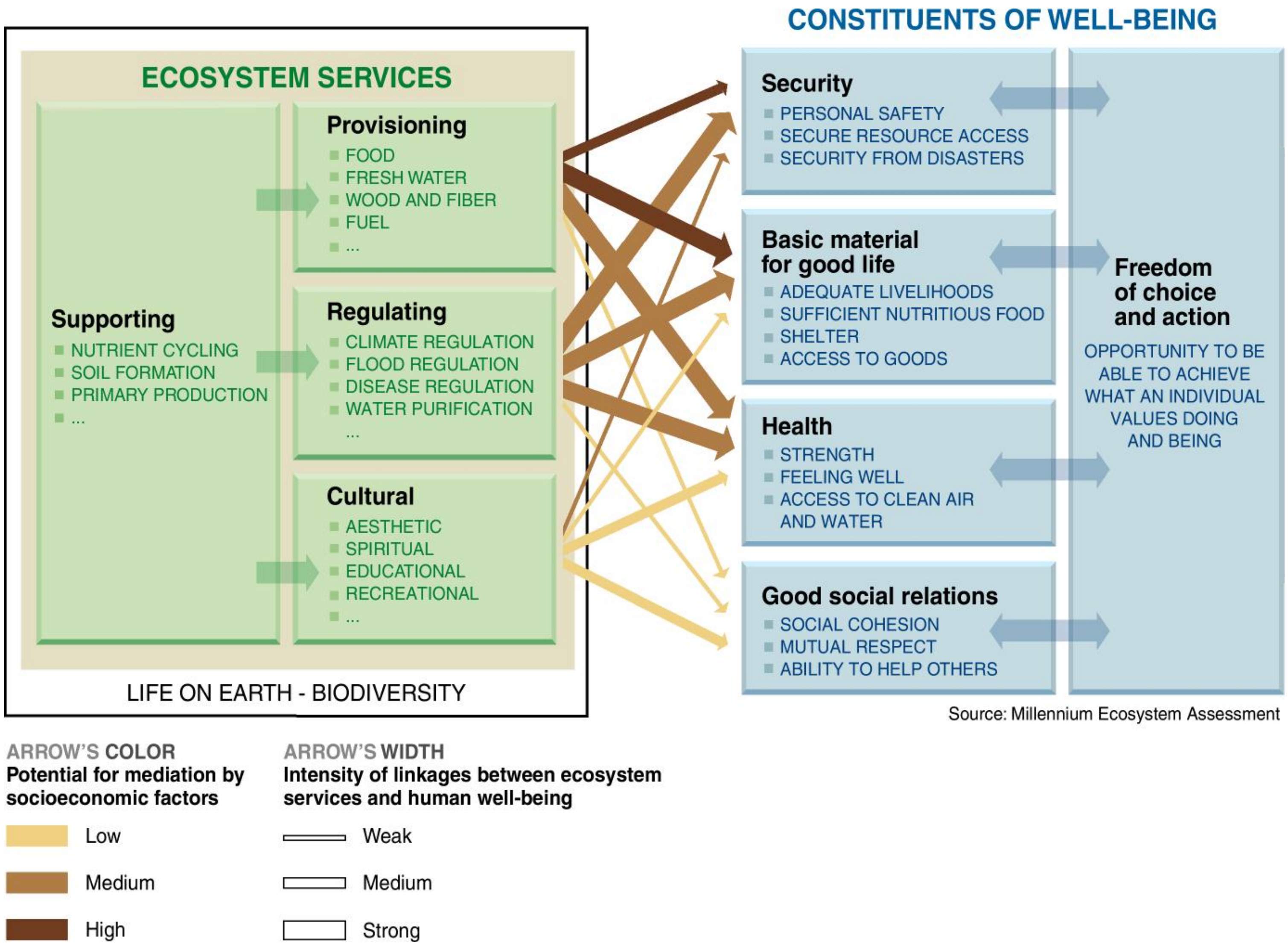
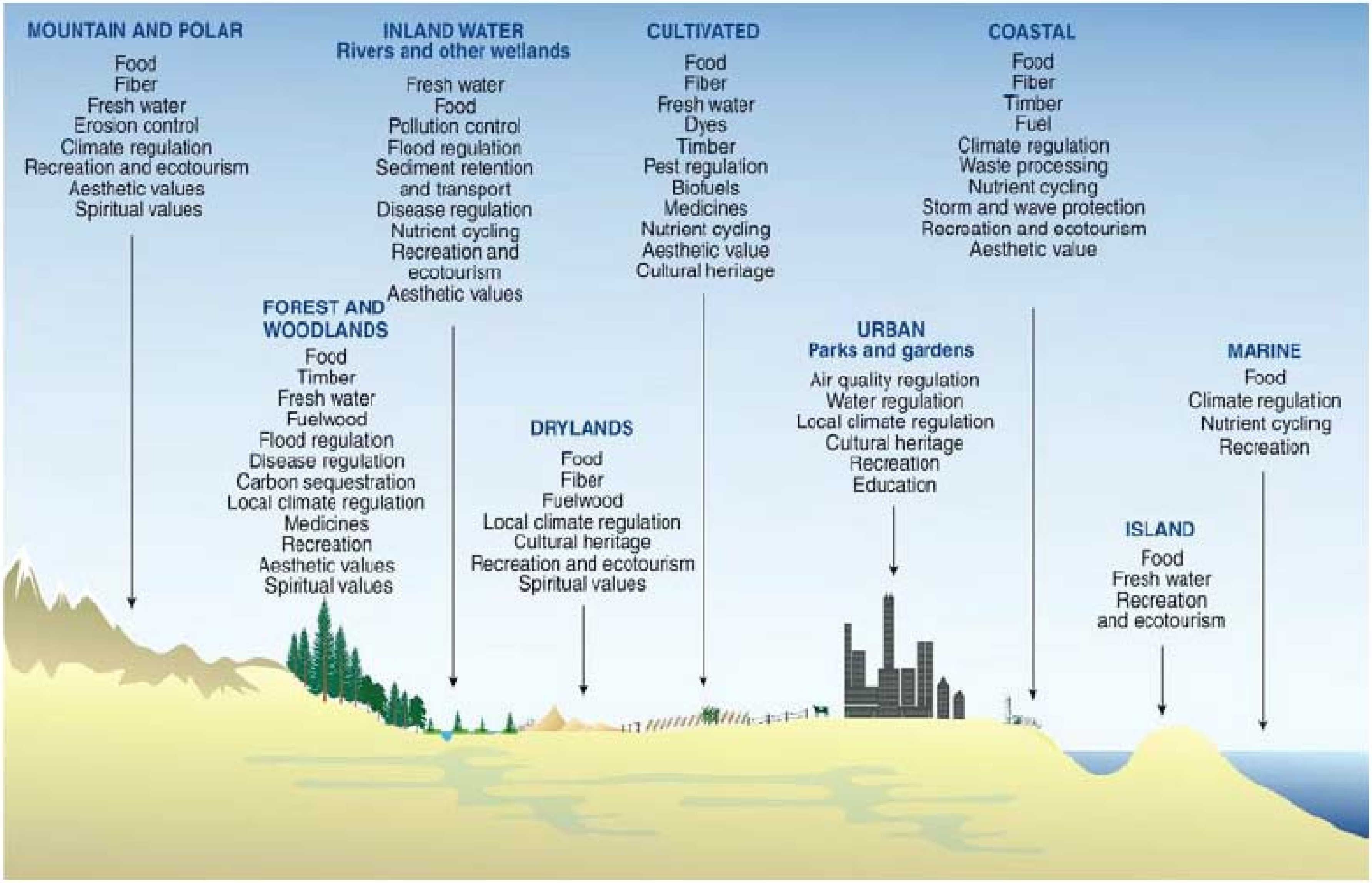


*Table 1. Ecosystem functions and services.*

| Ecosystem functions and services | Description | Examples |
|---|---|---|
| *Supportive functions and structures* | Ecological structures and functions that are essential to the delivery of ecosystem services | See below |
| Nutrient cycling | Storage, processing, and acquisition of nutrients within the biosphere | Nitrogen cycle; phosphorus cycle |
| Net primary production | Conversion of sunlight into biomass | Plant growth |
| Pollination and seed dispersal | Movement of plant genes | Insect pollination; seed dispersal by animals |
| Habitat | The physical place where organisms reside | Refugium for resident and migratory species; spawning and nursery grounds |
| Hydrological cycle | Movement and storage of water through the biosphere | Evapotransporation; stream runoff; groundwater retention |
| *Regulating services* | Maintenance of essential ecological processes and life support systems for human well-being | See below |
| Gas regulation | Regulation of the chemical composition of the atmosphere and oceans | Biotic sequestration of carbon dioxide and release of oxygen; vegetative absorption of volatile organic compounds |
| Climate regulation | Regulation of local to global climate processes | Direct influence of land cover on temperature, precipitation, wind, and humidity |
| Disturbance regulation | Dampening of environmental fluctuations and disturbance | Storm surge protection; flood protection |
| Biological regulation | Species interactions | Control of pests and diseases; reduction of herbivory (crop damage) |
| Water regulation | Flow of water across the planet surface | Modulation of the drought–flood cycle; purification of water |
| Soil retention | Erosion control and sediment retention | Prevention of soil loss by wind and runoff; avoiding buildup of silt in lakes and wetlands |
| Waste regulation | Removal or breakdown of nonnutrient compounds and materials | Pollution detoxification; abatement of noise pollution |
| Nutrient regulation | Maintenance of major nutrients within acceptable bounds | Prevention of premature eutrophication in lakes; maintenance of soil fertility |
| *Provisioning services* | Provisioning of natural resources and raw materials | See below |
| Water supply | Filtering, retention, and storage of fresh water | Provision of fresh water for drinking; medium for transportation; irrigation |
| Food | Provisioning of edible plants and animals for human consumption | Hunting and gathering of fish, game, fruits, and other edible animals and plants; small-scale subsistence farming and aquaculture |
| Raw materials | Building and manufacturing<br>Fuel and energy<br>Soil and fertilizer | Lumber; skins; plant fibers; oils; dyes<br>Fuelwood; organic matter (e.g., peat)<br>Topsoil; frill; leaves; litter; excrement |
| Genetic resources | Genetic resources | Genes to improve crop resistance to pathogens and pests and other commercial applications |
| Medicinal resources | Biological and chemical substances for use in drugs and pharmaceuticals | Quinine; Pacific yew; echinacea |
| Ornamental resources | Resources for fashion, handicraft, jewelry, pets, worship, decoration, and souvenirs | Feathers used in decorative costumes; shells used as jewelry |
| *Cultural services* | Enhancing emotional, psychological, and cognitive well-being | See below |
| Recreation | Opportunities for rest, refreshment, and recreation | Ecotourism; bird-watching; outdoor sports |
| Aesthetic | Sensory enjoyment of functioning ecological systems | Proximity of houses to scenery; open space |
| Science and education | Use of natural areas for scientific and educational enhancement | A "natural field laboratory" and reference area |
| Spiritual and historic | Spiritual or historic information | Use of nature as national symbols; natural landscapes with significant religious values |

**From:** Farber, S., R. Costanza, D. L. Childers, J. Erickson, K. Gross, M. Grove, C. S. Hopkinson, J. Kahn, S. Pincetl, A. Troy, P. Warren, and M. Wilson. 2006 Linking Ecology and Economics for Ecosystem Management: A Services-Based Approach with Illustrations from LTER Sites. *BioScience* 56:117-129.

# Ecosystem Services and Land Cover Types



# Biosphere

QuickTime™ and a
decompressor
are needed to see this picture.

Sea-viewing Wide Field-of-View Sensor (SeaWiFS)
data on marine and terrestrial plant productivity

## Valuation of ecosystem services based on the three primary goals of efficiency, fairness, and sustainability.

| Goal or Value Basis | Who votes | Preference Basis Required | Level of Discussion Required | Level of Scientific Input | Specific Methods |
|---|---|---|---|---|---|
| **Efficiency** | *Homo economius* | Current individual preferences | low | low | willingness to pay |
| **Fairness** | *Homo communicus* | Community preferences | high | medium | veil of ignorance |
| **Sustainability** | *Homo naturalis* | Whole system preferences | medium | high | modeling with precaution |

from: **Costanza, R. and C. Folke. 1997**. Valuing ecosystem services with efficiency, fairness and sustainability as goals. pp: 49-70 in: G. Daily (ed.), Nature's Services: Societal Dependence on Natural Ecosystems. Island Press, Washington, DC, 392 pp.

# Example Valuation Techniques

•**Avoided Cost** (AC): services allow society to avoid costs that would have been incurred in the absence of those services; flood control provided by barrier islands avoids property damages along the coast.

•**Replacement Cost** (RC): services could be replaced with man-made systems; nutrient cycling waste treatment can be replaced with costly treatment systems.

•**Factor Income** (FI): services provide for the enhancement of incomes; water quality improvements increase commercial fisheries catch and incomes of fishermen.

•**Travel Cost** (TC): service demand may require travel, whose costs can reflect the implied value of the service; recreation areas attract distant visitors whose value placed on that area must be at least what they were willing to pay to travel to it.

• **Hedonic Pricing** (HP): service demand may be reflected in the prices people will pay for associated goods: For example, housing prices along the coastline tend to exceed the prices of inland homes.

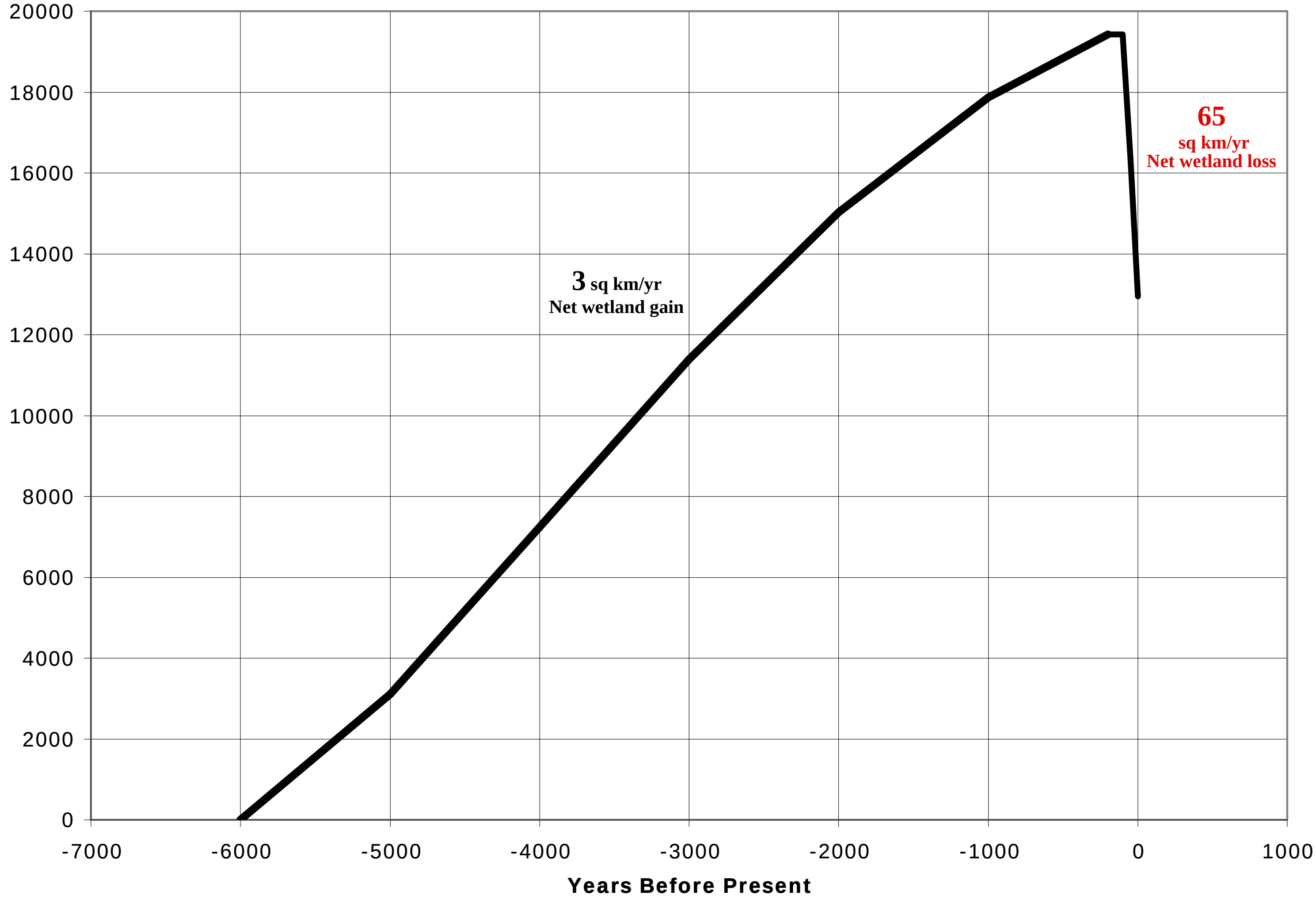
•**Marginal Product Estimation** (MP): Service demand is generated in a dynamic modeling environment using production function (i.e., Cobb-Douglas) to estimate value of output in response to corresponding material input.

•**Contingent Valuation** (CV): service demand may be elicited by posing hypothetical scenarios that involve some valuation of alternatives; people would be willing to pay for increased preservation of beaches and shoreline.

•**Group Valuation** (GV): This approach is based on principles of deliberative democracy and the assumption that public decision making should result, not from the aggregation of separately measured individual preferences, but from *open public debate.*

Hurricane Katrina approaching Louisiana coast

Picture taken by an automatic camera located at an electrical generating facility on the Gulf Intracoastal Waterway (GIWW) where the Route I-510  bridge crosses the GIWW.  This is close to where the Mississippi River Gulf Outlet (MRGO) enters the GIWW. The shot clearly shows the storm surge, estimated to be 18-20 ft. in height..




History of coastal Louisiana wetland gain and loss over the last 6000 years, showing historical net rates of gain of approximately 3 $km^2$/year over the period from 6000 years ago until about 100 years ago, followed by a net loss of approximately 65 $km^2$/yr since then.

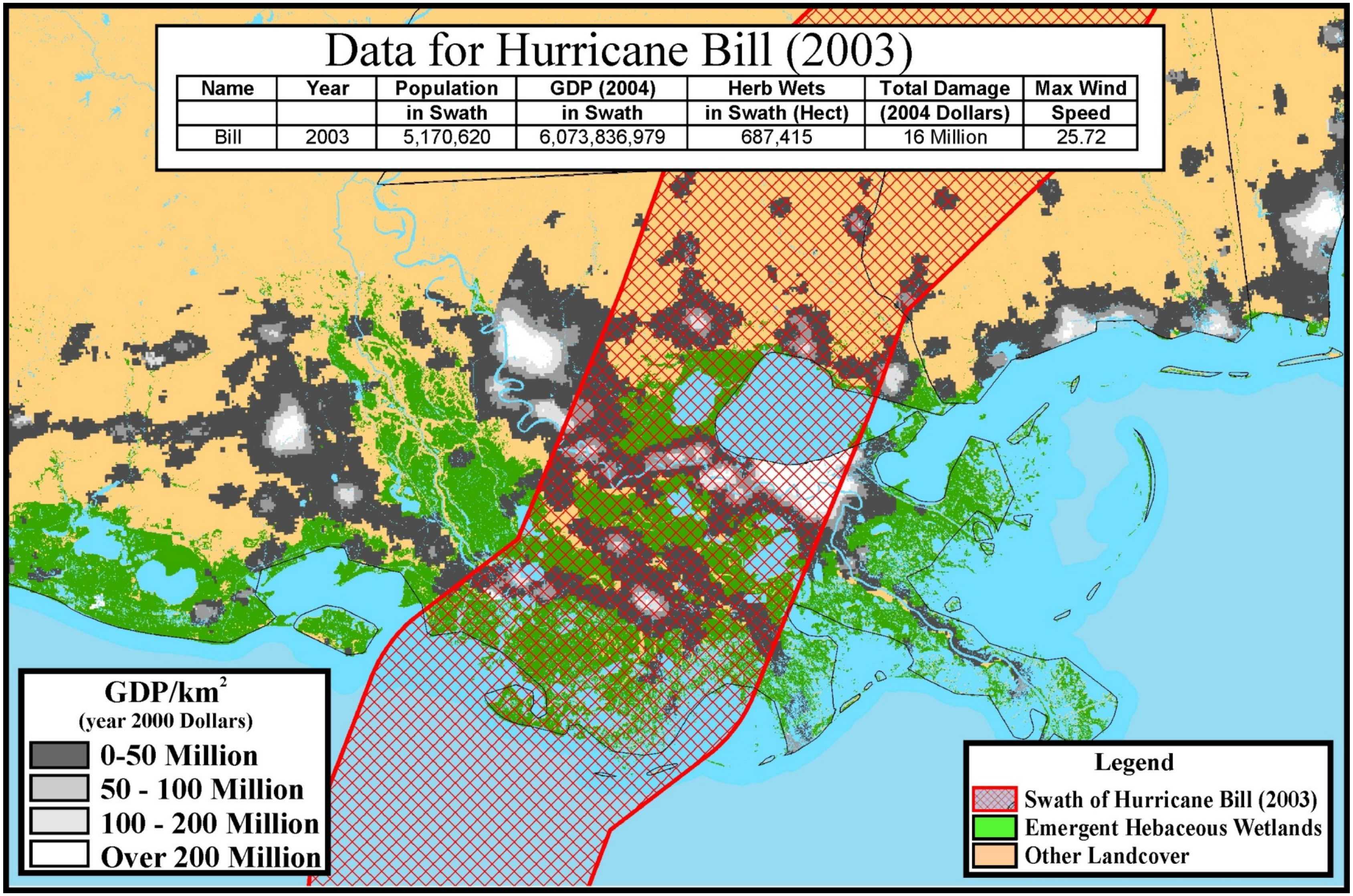



Figure 1. Typical hurricane swath showing GDP and wetland area used in the analysis.

# The value of coastal wetlands for hurricane protection

$$\ln(TD_i / GDP_i) = \alpha + \beta_1 \ln(g_i) + \beta_2 \ln(w_i) + u_i \qquad (1)$$

Where:

$TD_i$ = total damages from storm i (in constant 2004 $US);

$GDP_i$ = Gross Domestic Product in the swath of storm i (in constant 2004 $US). The swath was considered to be 100 km wide by 100 km inland.

$g_i$ = maximum wind speed of storm i (in m/sec)

$w_i$ = area of herbaceous wetlands in the storm swath (in ha).

$u_i$ = error

**Predicted total damages from storm *i***

$$TD_i = e^{\alpha} * g_i^{\beta_1} * w_i^{\beta_2} * GDP_i$$

**Avoided cost from a change of 1 ha of coastal wetlands for storm *i***

$$\Delta TD_i = e^{\alpha} * g_i^{\beta_1} * \left((w_i - 1)^{\beta_2} - w_i^{\beta_2}\right) * GDP_i$$

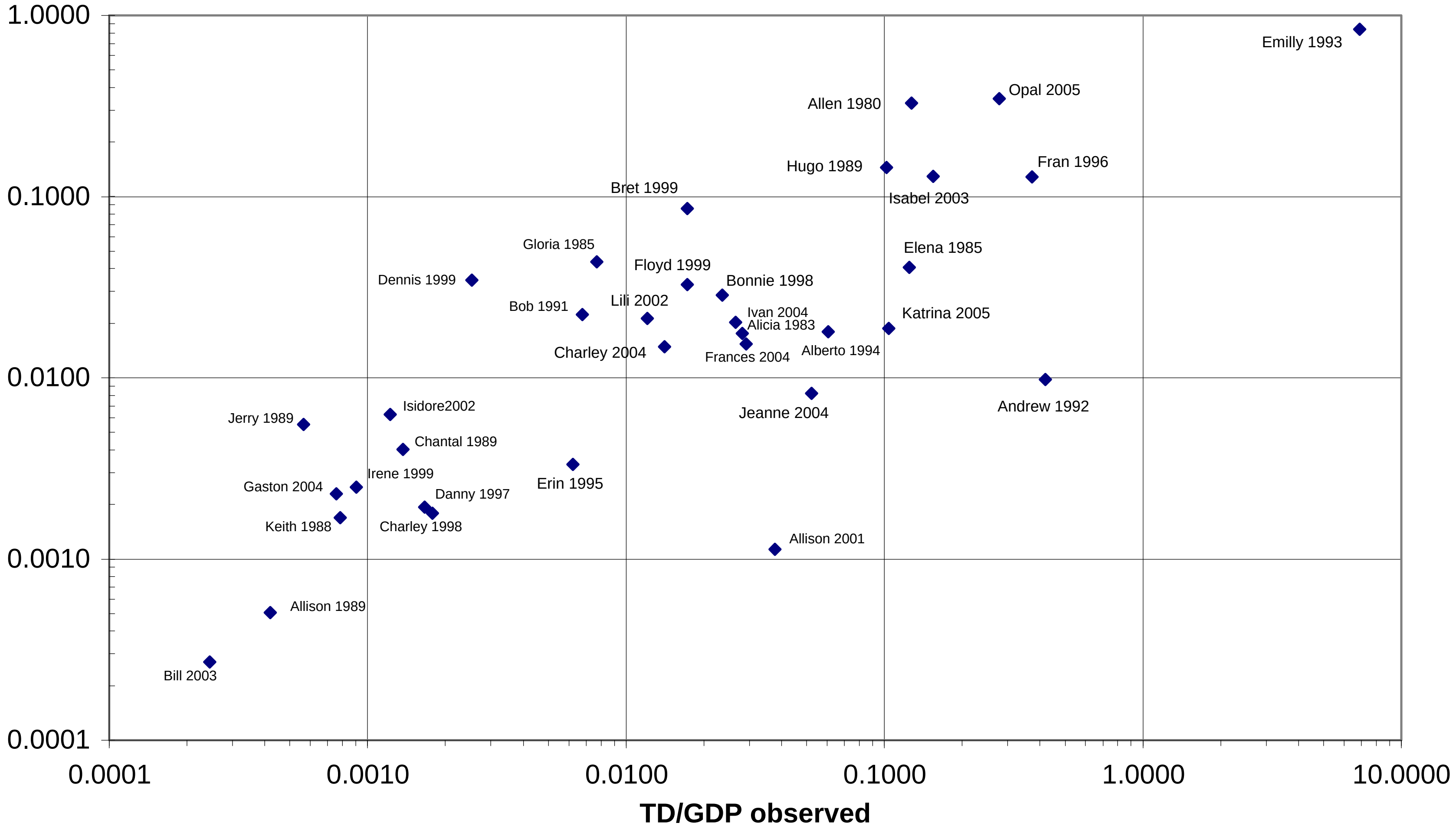



Figure 2. Observed vs. predicted relative damages (TD/GDP) for each of the hurricanes used in the analysis.

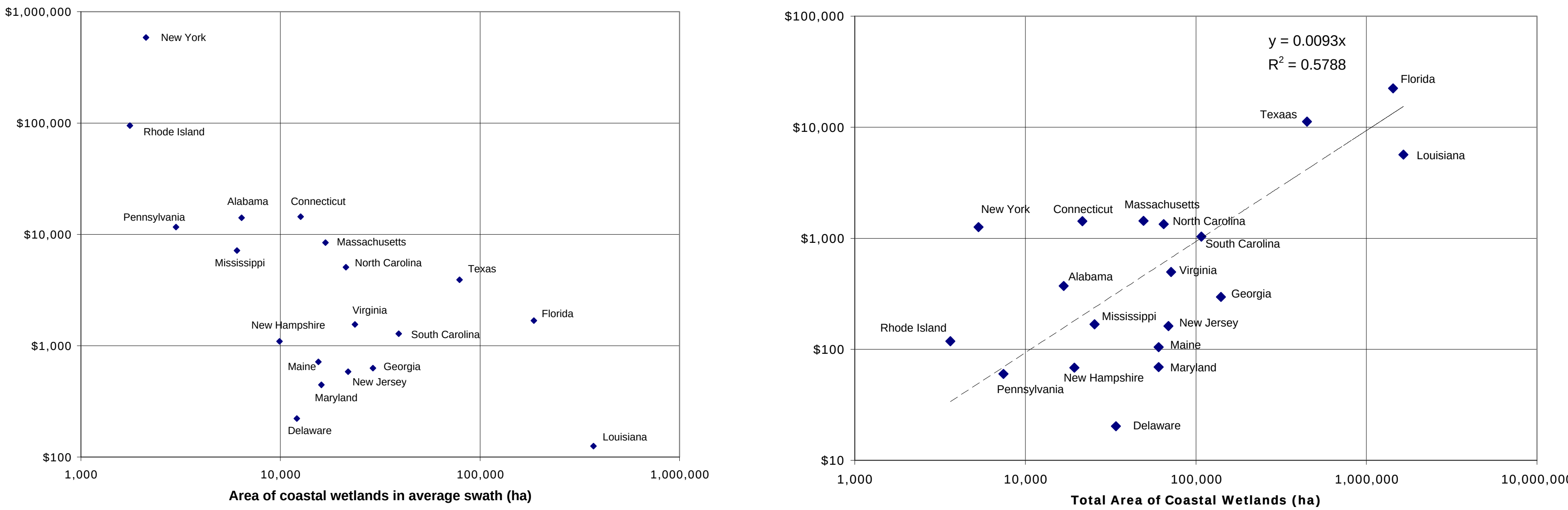
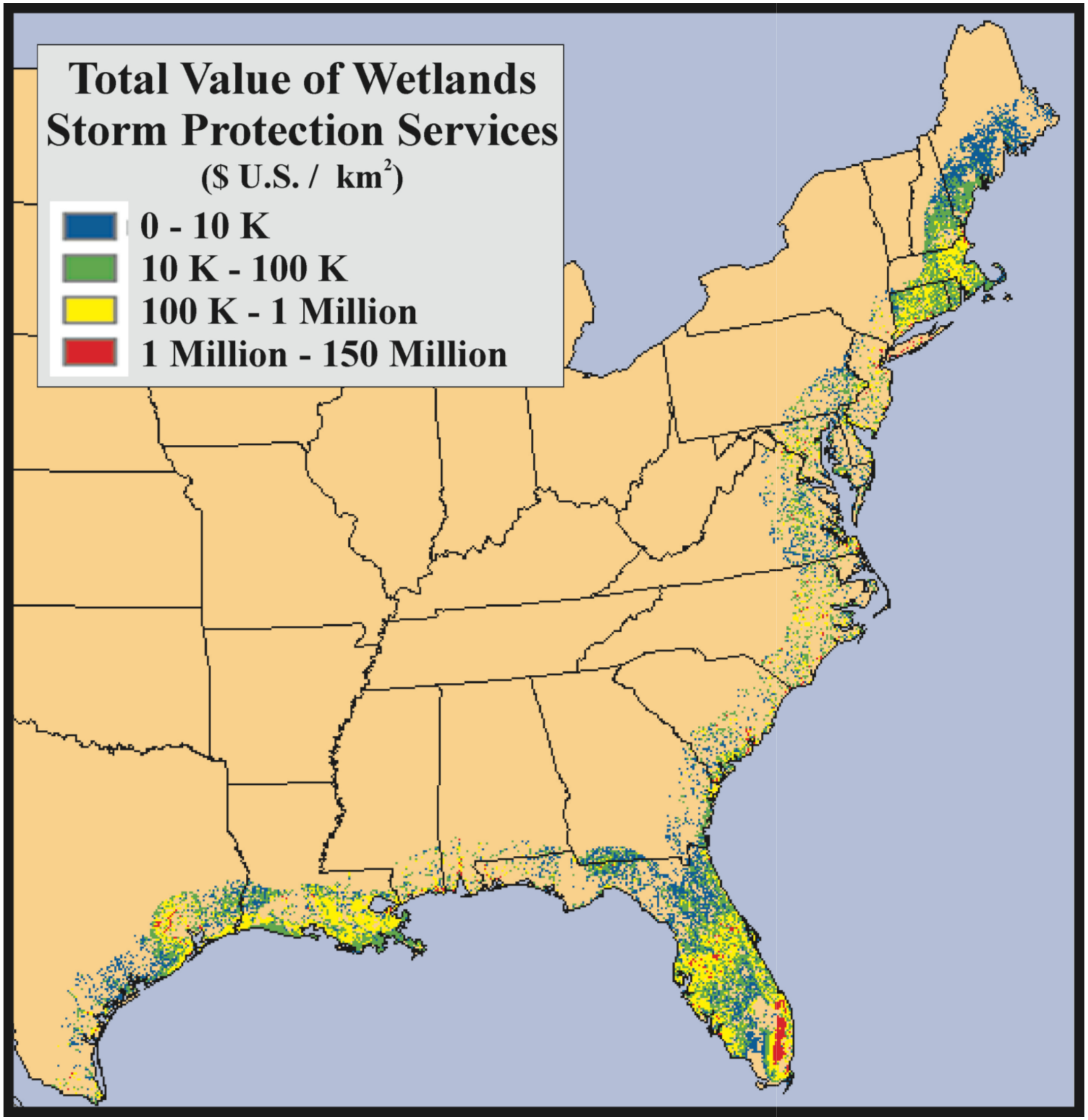
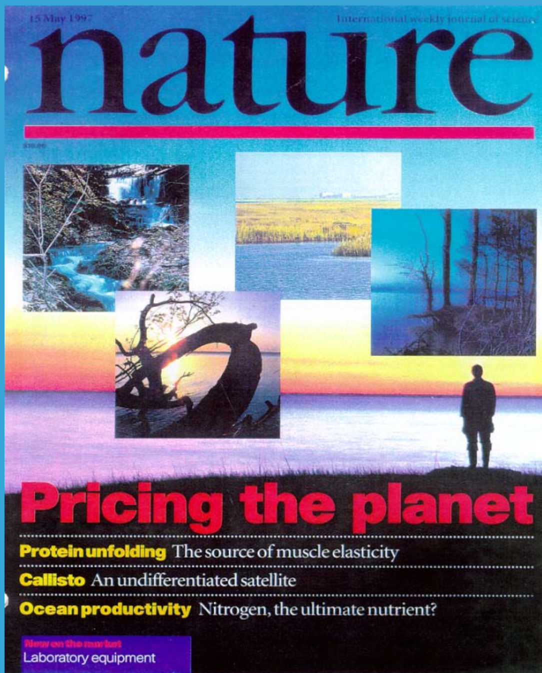



Figure 3. Area of coastal wetlands (A) in the average hurricane swath vs. the estimated marginal value per ha ($MV_{sw}$) and (B) in the entire state vs. the total value ($TV_s$) of coastal wetlands for storm protection



Total Value of Wetlands
Storm Protection Services
($ U.S. / km$^2$)
0 - 10 K
10 K - 100 K
100 K - 1 Million
1 Million - 150 Million




This is the 2nd most cited article in the last 10 years in the Ecology/Environment area according to the ISI Web of Science.

NATURE |VOL 387 | 15 MAY 1997 **253**

**article**

# The value of the world's ecosystem services and natural capital

**Robert Costanza*†, Ralph d'Arge‡, Rudolf de Groot§, Stephen Farberk, Monica Grasso†, Bruce Hannon¶, Karin Limburg#ı, Shahid Naeem**, Robert V. O'Neill††, Jose Paruelo‡‡, Robert G. Raskin§§, Paul Suttonkk & Marjan van den Belt¶¶**

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*¶¶ Ecological Economics Research and Applications Inc., PO Box 1589, Solomons, Maryland 20688, USA*

**The services of ecological systems and the natural capital stocksthat produce them are critical to the functioning of the Earth's life-support system. They contribute to human welfare, both directly and indirectly, and therefore represent part of the total economic value of the planet.We have estimated the current economic value of 17 ecosystem services for 16 biomes, based on published studies and a few original calculations. For the entire biosphere, the value (most of which is outside the market) is estimated to be in the range of US$16–54 trillion ($10^{12}$) per year, with an average of US$33trillion per year. Because of the nature of the uncertainties, thismust be considered a minimum estimate. Global gross national product total is around US$18 trillion per year.**

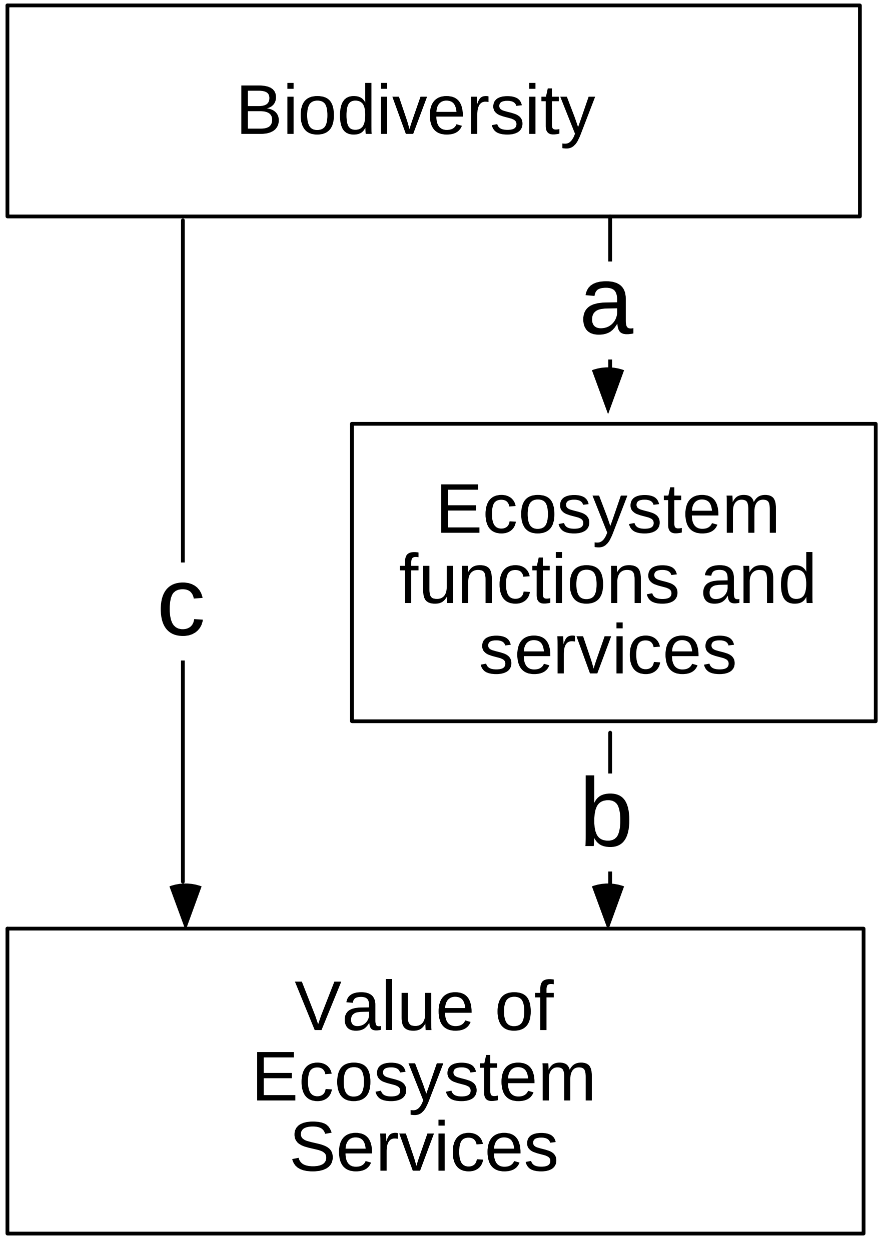
# Summary of global values of annual ecosystem services (From: Costanza et al. 1997)

| Biome | Area (e6 ha) | Value per ha ($/ha/yr) | Global Flow Value (e12 $/yr) |
|---|---|---|---|
| **Marine** | **36,302** | **577** | **20.9** |
| Open Ocean | 33,200 | 252 | 8.4 |
| Coastal | 3,102 | 4052 | 12.6 |
| Estuaries | 180 | 22832 | 4.1 |
| Seagrass/Algae Beds | 200 | 19004 | 3.8 |
| Coral Reefs | 62 | 6075 | 0.3 |
| Shelf | 2,660 | 1610 | 4.3 |
| **Terrestrial** | **15,323** | **804** | **12.3** |
| Forest | 4,855 | 969 | 4.7 |
| Tropical | 1,900 | 2007 | 3.8 |
| Temperate/Boreal | 2,955 | 302 | 0.9 |
| Grass/Rangelands | 3,898 | 232 | 0.9 |
| Wetlands | 330 | 14785 | 4.9 |
| Tidal Marsh/Mangroves | 165 | 9990 | 1.6 |
| Swamps/Floodplains | 165 | 19580 | 3.2 |
| Lakes/Rivers | 200 | 8498 | 1.7 |
| Desert | 1,925 | | |
| Tundra | 743 | | |
| Ice/Rock | 1,640 | | |
| Cropland | 1,400 | 92 | 0.1 |
| Urban | 332 | | |
| **Total** | 51,625 | | **33.3** |

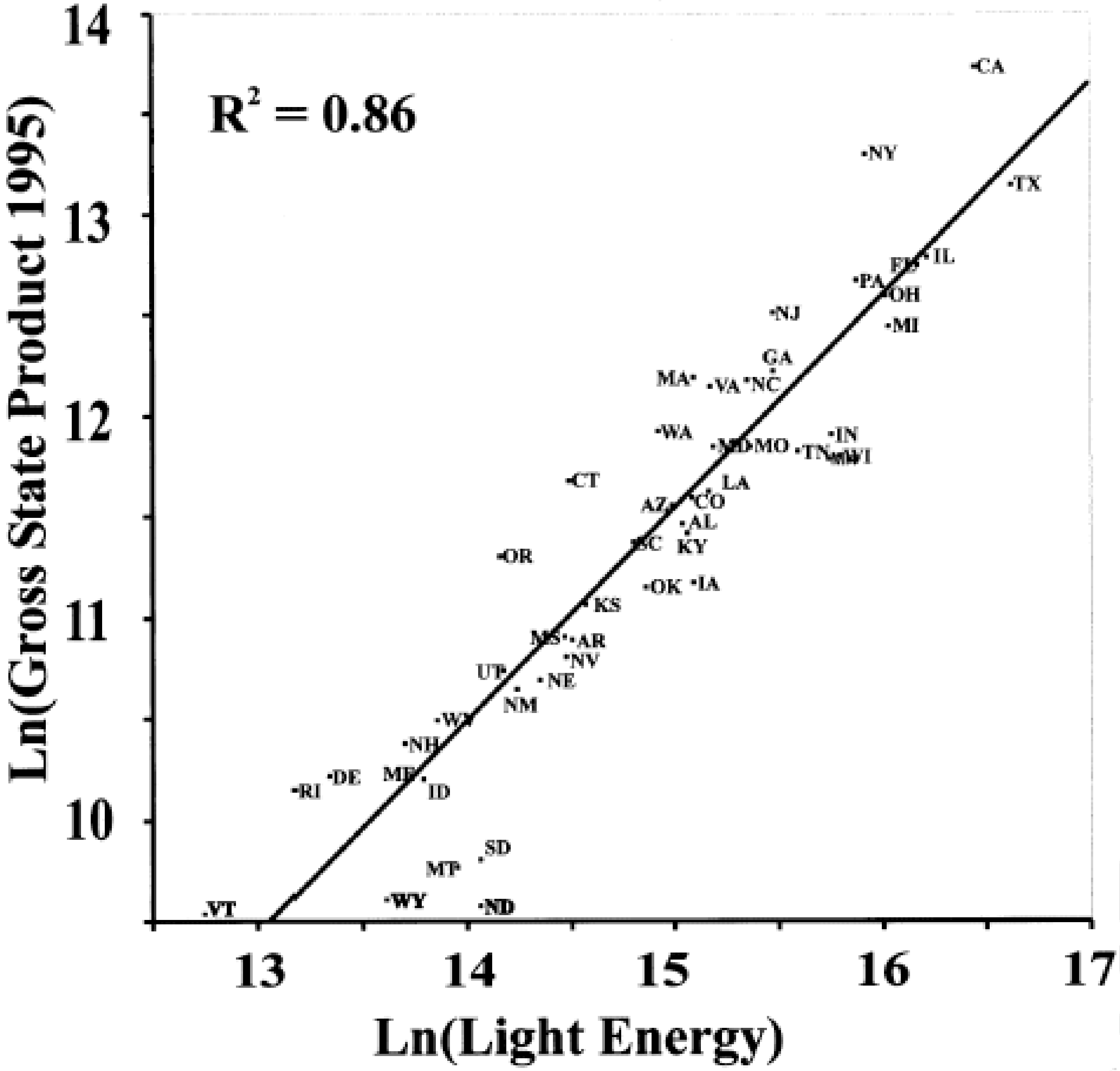
## Problems with the *Nature* paper
### (as listed in the paper itself)

1. **Incomplete (not all biomes studied well - some not at all)**
2. **Distortions in current prices are carried through the analysis**
3. **Most estimates based on current willingness-to-pay or proxies**
4. **Probably underestimates changes in supply and demand curves as ecoservices become more limiting**
5. **Assumes smooth responses (no thresholds or discontinuties)**
6. **Assumes spatial homogeneity of services within biomes**
7. **Partial equilibrium framework**
8. **Not necessarily based on sustainable use levels**
9. **Does not fully include “infrastructure” value of ecosystems**
10. **Difficulties and imprecision of making inter-country comparisons**
11. **Discounting (for the few cases where we needed to convert from stock to flow values)**
12. **Static snapshot; no dynamic interactions**

**Solving any of these problems (except perhaps 6 which could go either way) will lead to larger values**




**Linkages Between Biodiversity and the Value of Ecosystem Services**



R² = 0.86
Ln(Gross State Product 1995)
Ln(Light Energy)
14
13
12
11
10
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14
15
16
17
CA
NY
TX
IL
FL
PA
OH
NJ
MI
GA
MA
VA
NC
WA
IN
MD
MO
TN
WI
CT
LA
AZ
CO
AL
SC
KY
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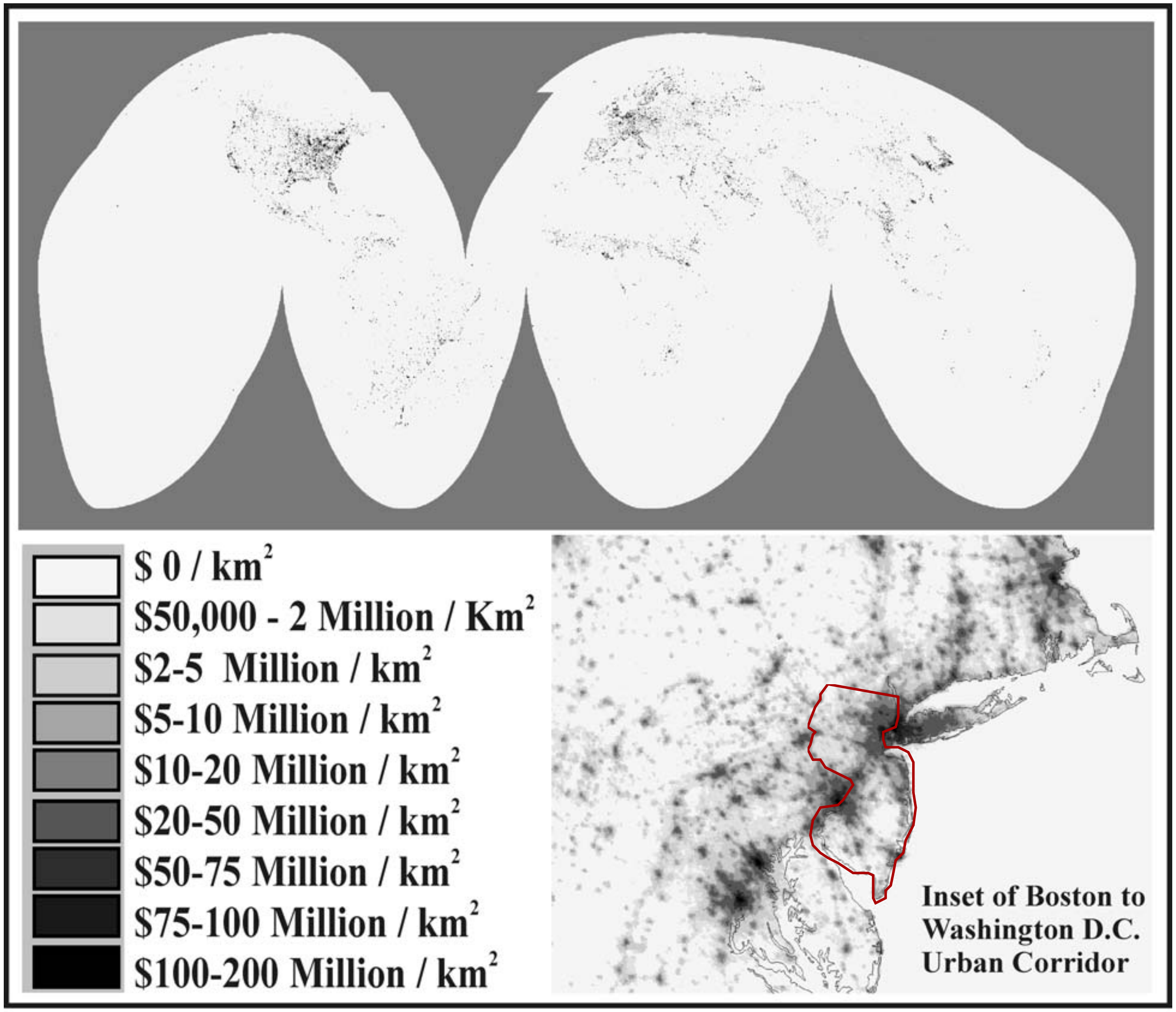



**Figure 2: Global Map of Marketed Economic Activity as measured by Nighttime Satellite Image proxy**

**From:** Sutton, P. C. and R. Costanza. 2002. Global estimates of market and non-market values derived from nighttime satellite imagery, land use, and ecosystem service valuation. *Ecological Economics* 41: 509-527

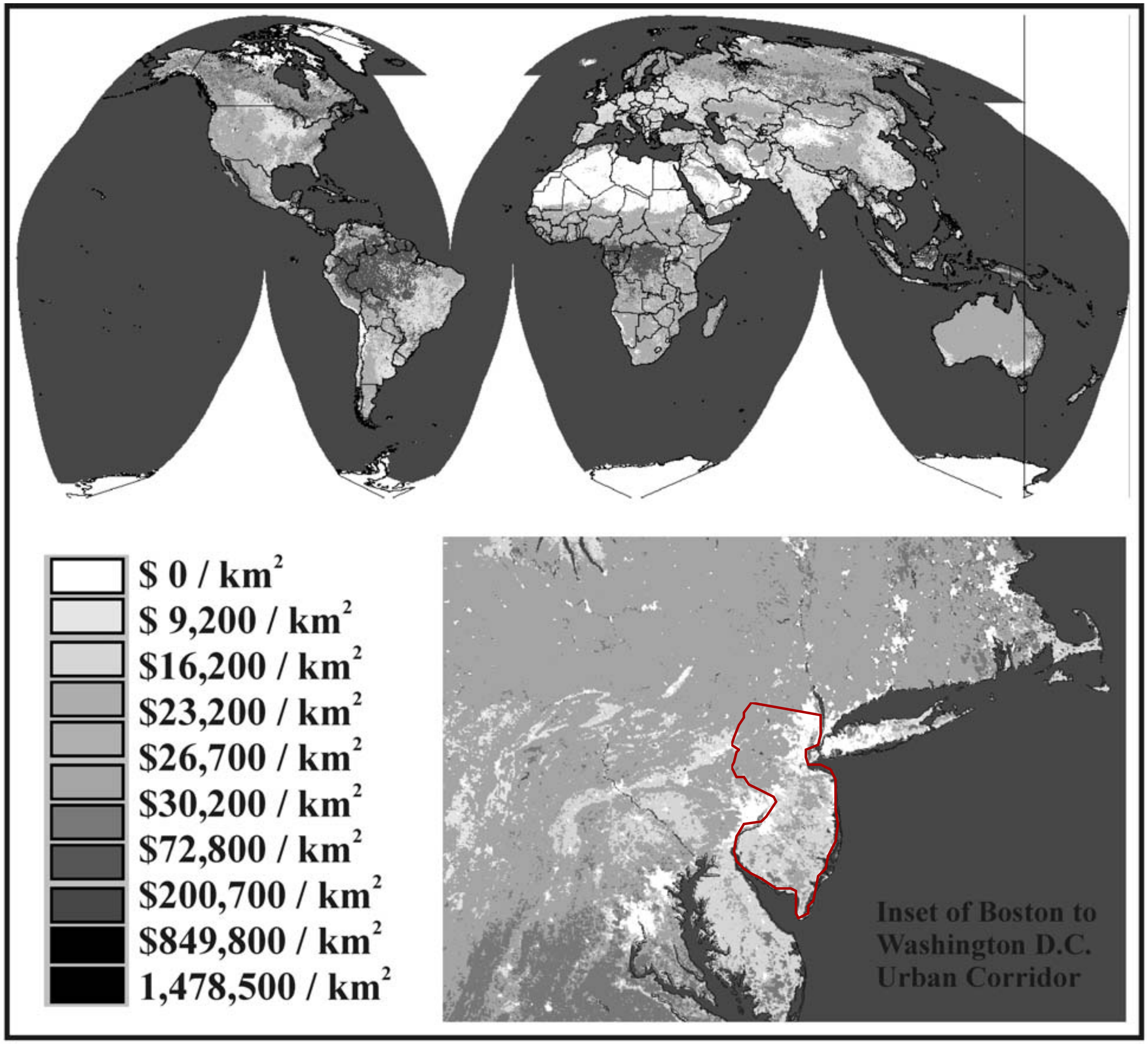


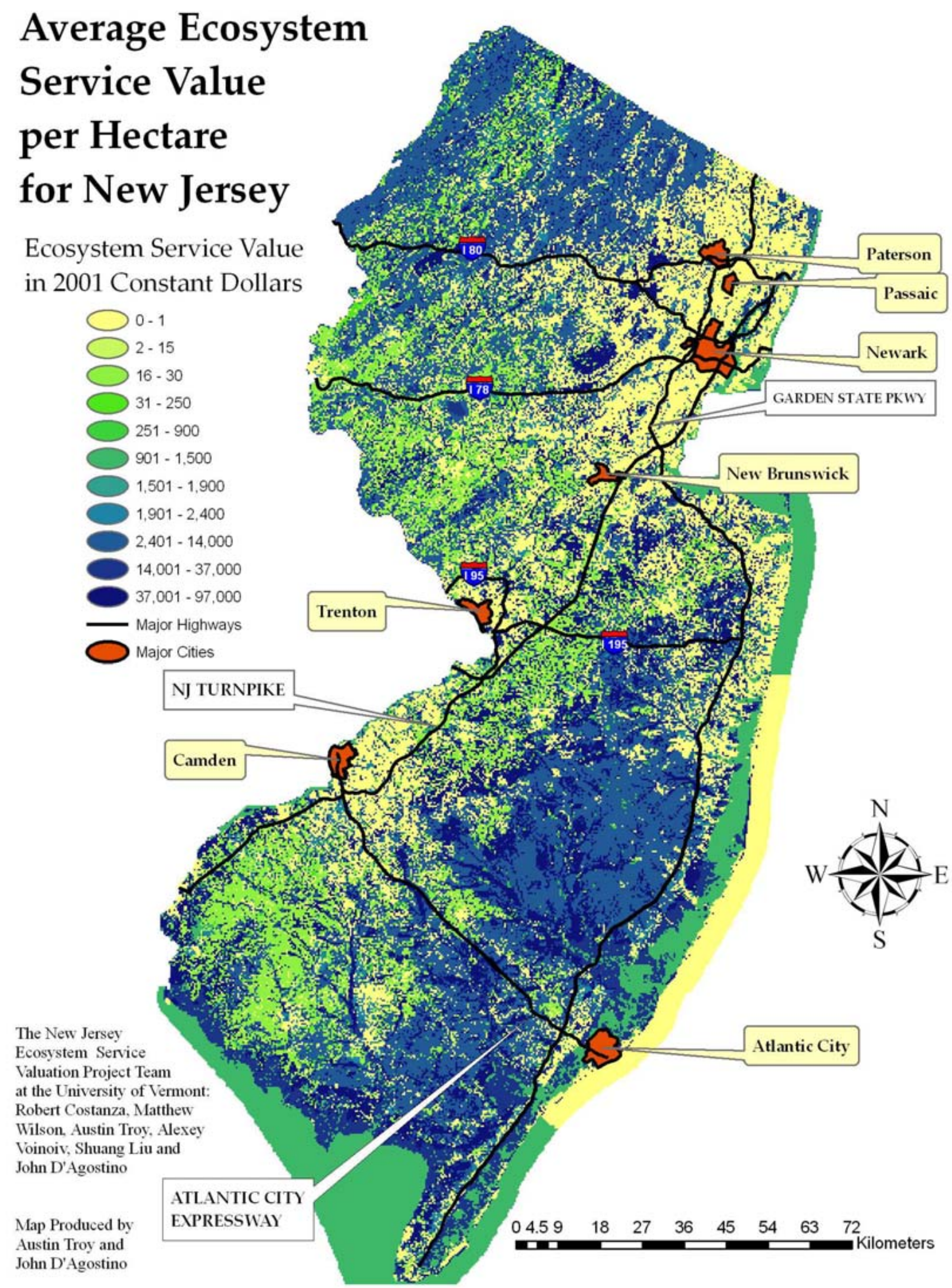

**Figure 3: Global Map of Non-Marketed Economic Activity (ESP) arising from Ecosystem Services and derived from Land Cover at 1 km$^2$ (For National Totals See Table 1)**

# Work in Progress:

# Valuation of New Jersey’s Natural Capital and Ecosystem Services

**Contract # SR04-075**

**New Jersey Department of Environmental Protection**



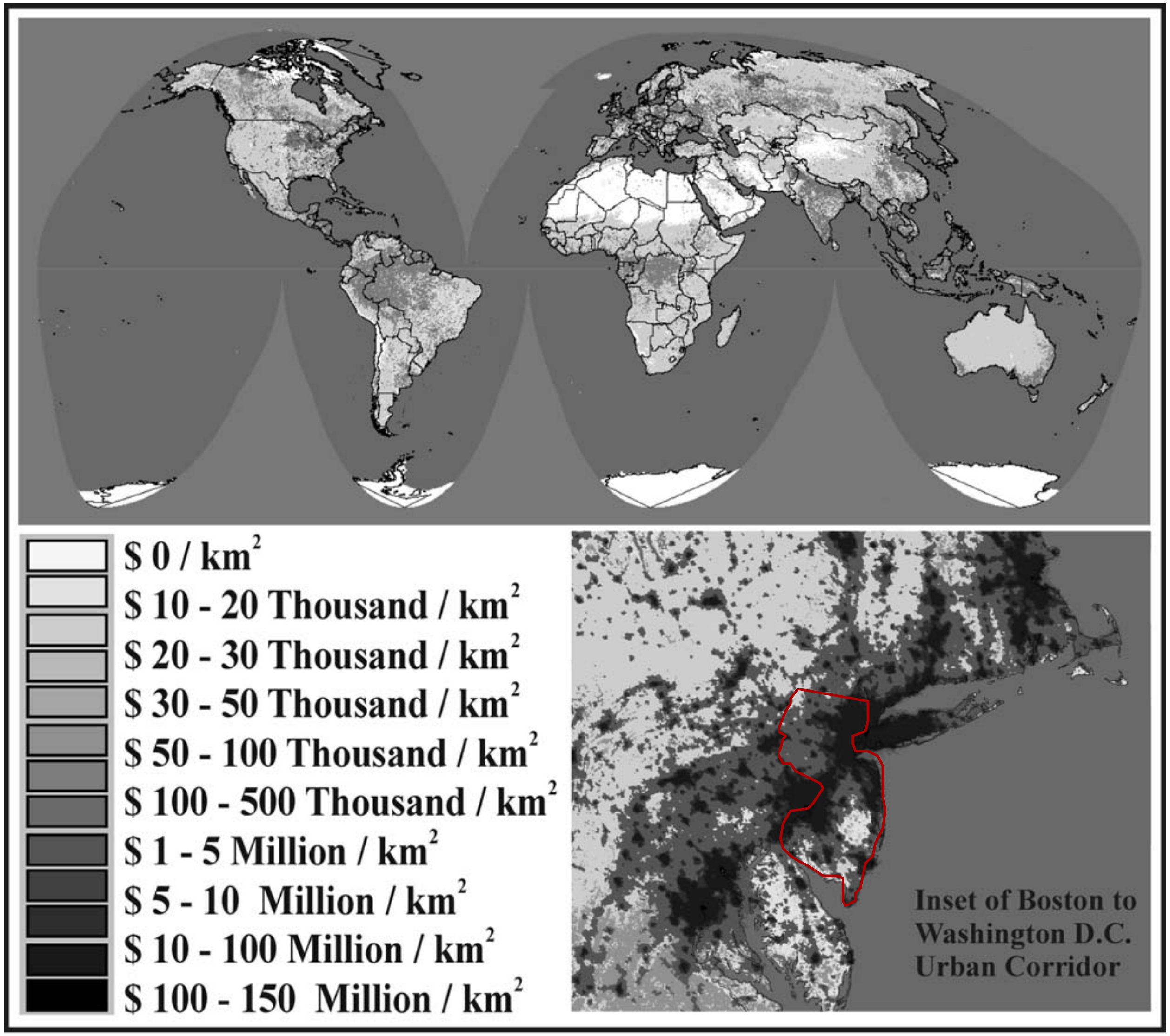



**Figure 4: Subtotal Ecological-Economic Product (SEP = GDP + ESP) at 1 km2 resolution (w/ inset Boston -DC)**

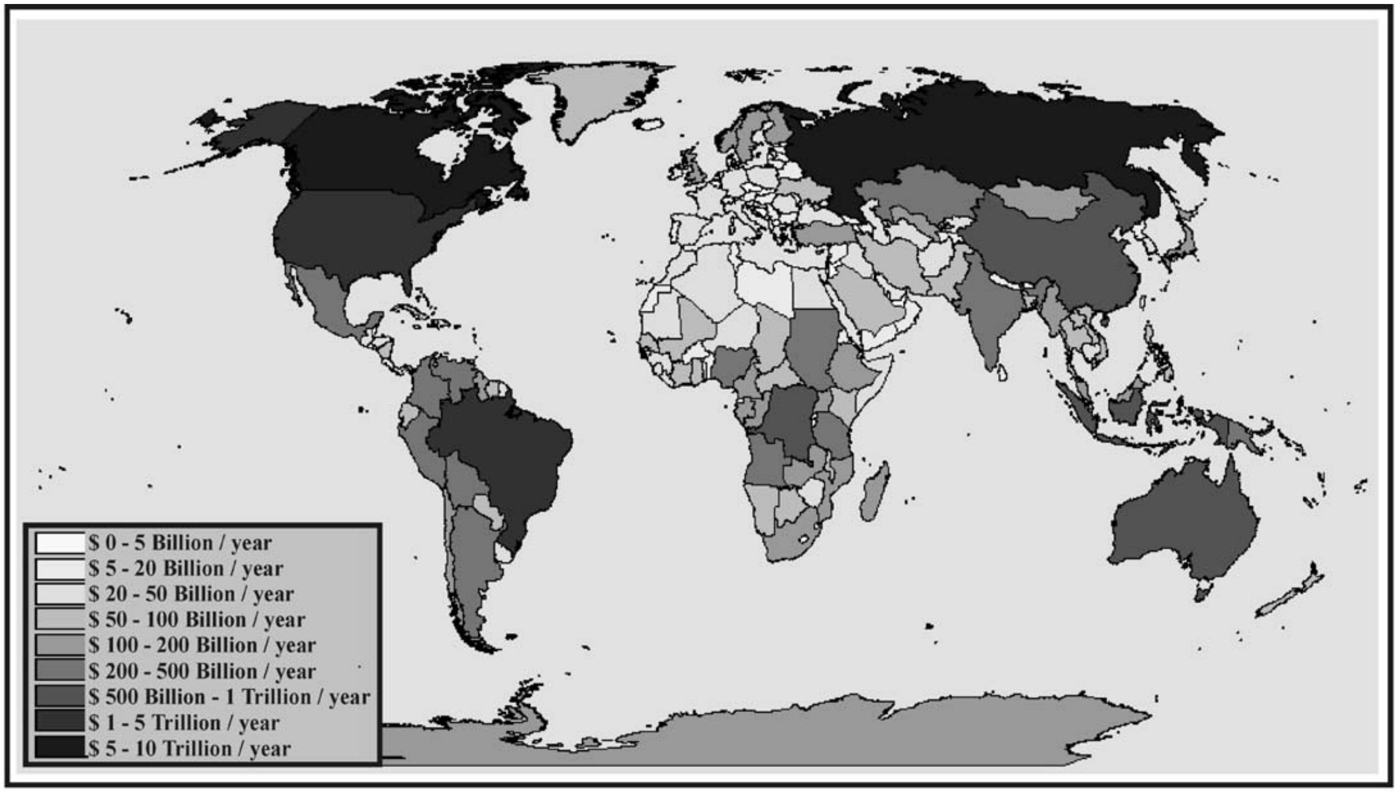



**Figure 5: Aggregated National Map (choropleth) of ESP (Ecosystem Service Product)**

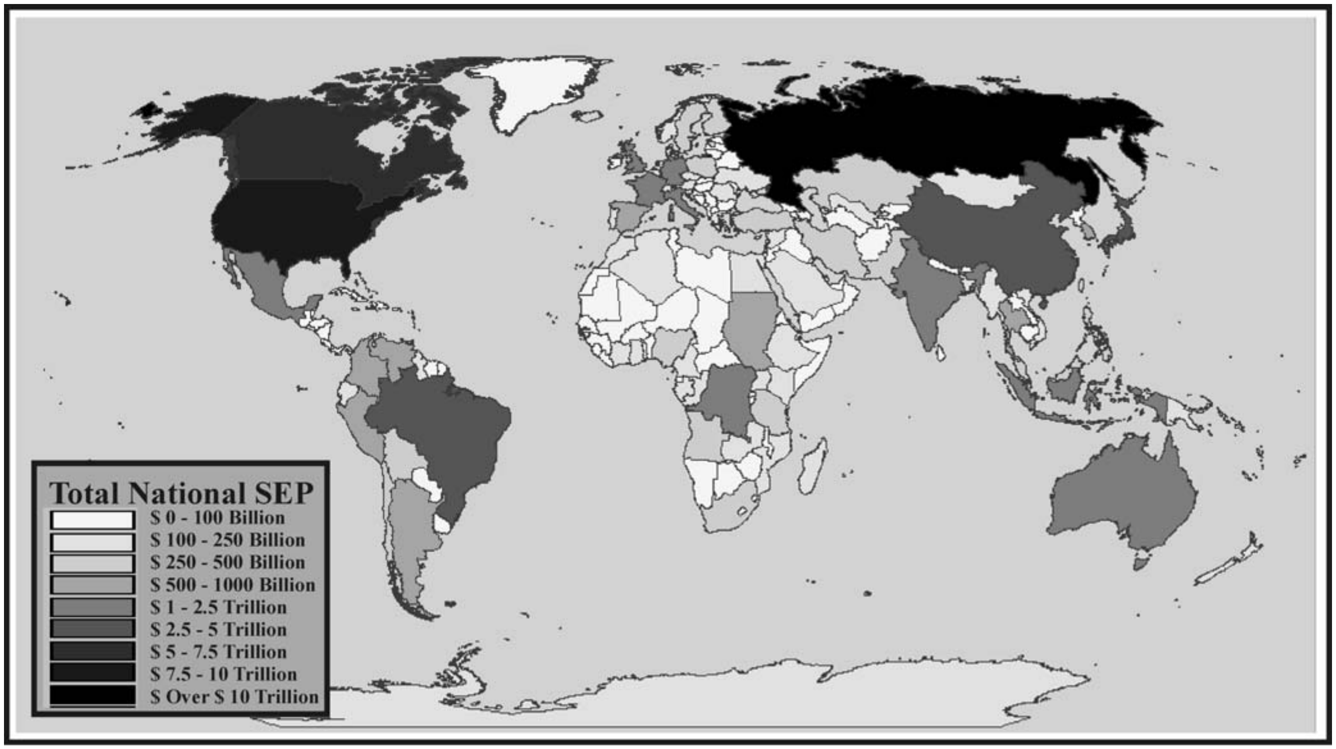



**Figure 6: Aggregated National Map (choropleth) of SEP (Subtotal Ecological-Economic Product)**

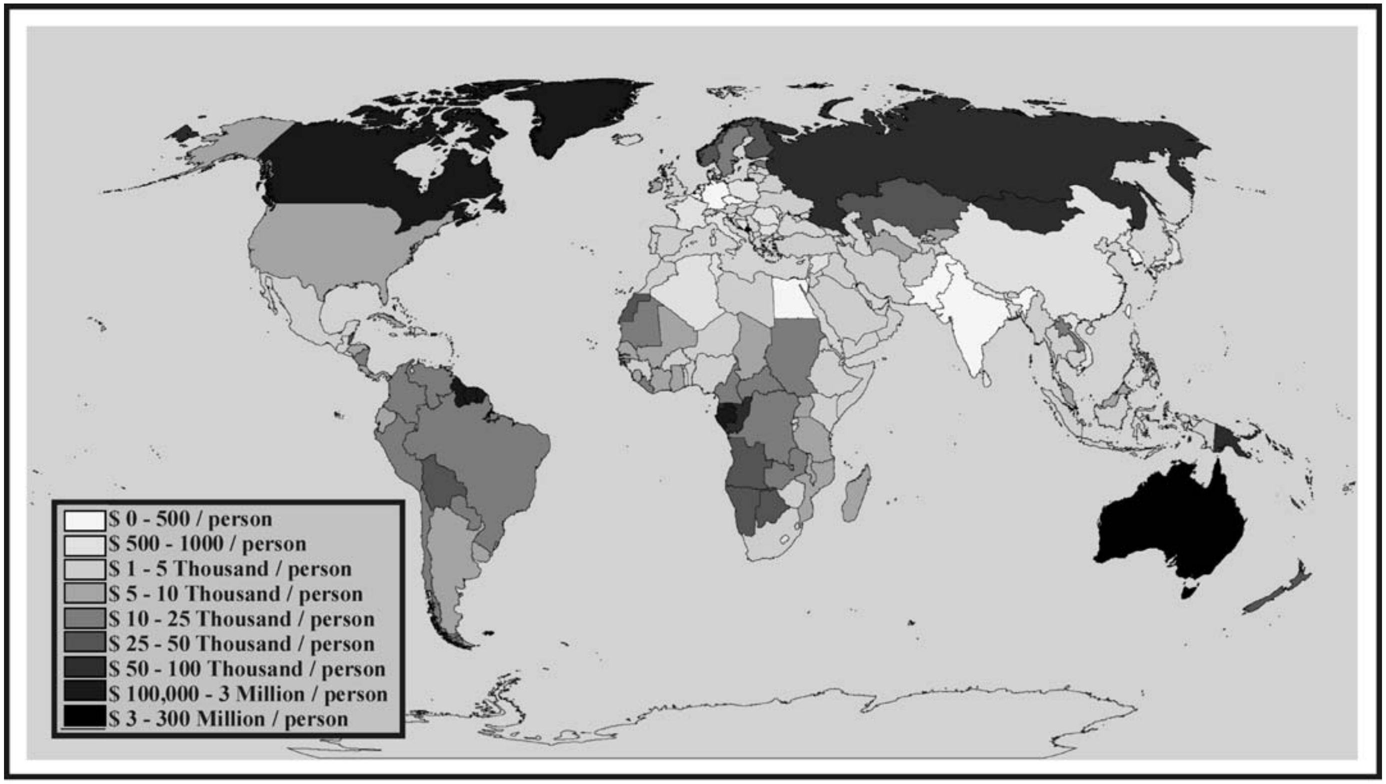
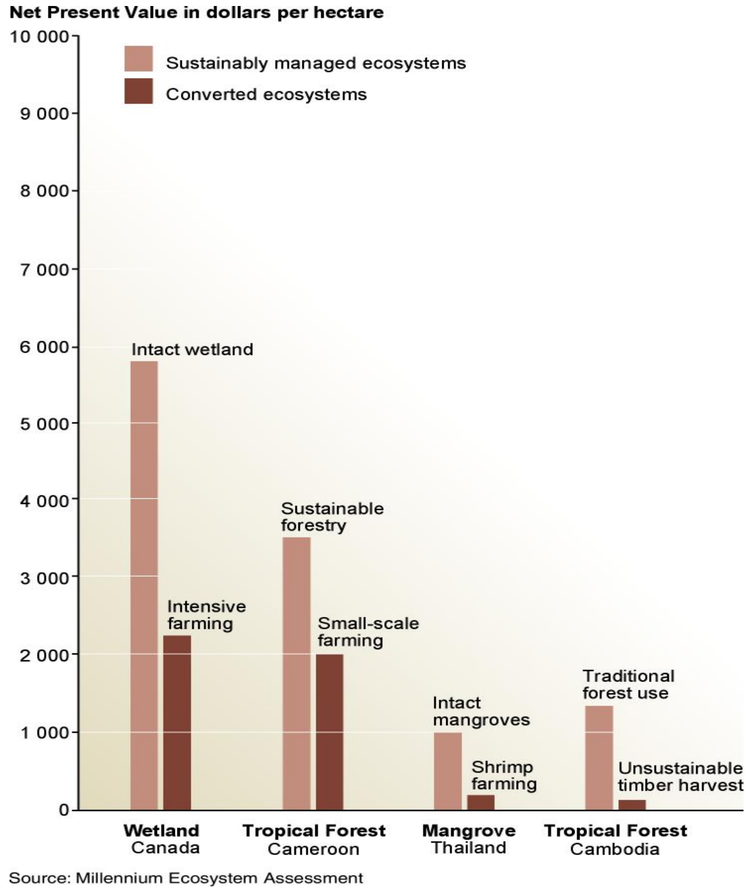



**Figure 7: Agrregated National Map (choropleth) of SEP/ Capita**

# Degradation of ecosystem services often causes significant harm to human well-being

- The total economic value associated with managing ecosystems more sustainably is often higher than the value associated with conversion
- Conversion may still occur because private economic benefits are often greater for the converted system



# Economic Reasons for Conserving Wild Nature

**Costs of expanding and maintaining the current global reserve network to one covering 15% of the terrestrial biosphere and 30% of the marine biosphere** = **$US 45 Billion/yr**

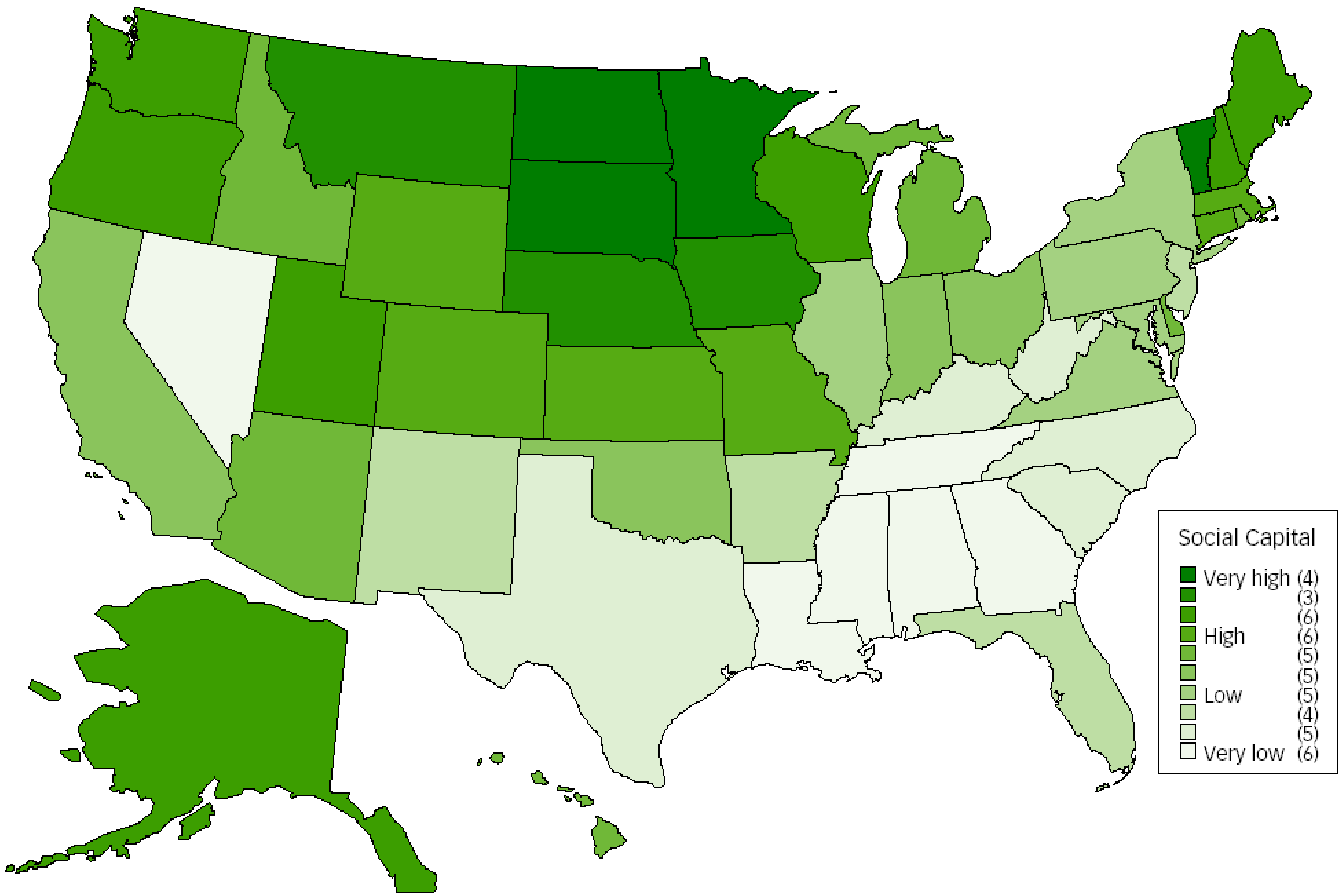
**Benefits (Net value* of ecosystem services from the global reserve network)** = **$US 4,400-5,200 Billion/yr**

***Net value is the difference between the value of services in a "wild" state and the value in the most likely human-dominated alternative**

# Benefit/Cost Ratio = 100:1

**(From:** Balmford, A., A. Bruner, P. Cooper, R. Costanza, S. Farber, R. E. Green, M. Jenkins, P. Jefferiss, V. Jessamy, J. Madden, K. Munro, N. Myers, S. Naeem, J. Paavola, M. Rayment, S. Rosendo, J. Roughgarden, K. Trumper, and R. K. Turner 2002. Economic reasons for conserving wild nature. *Science* 297: 950-953)

**Social Capital:** "Not Unto Ourselves Alone Are We Born."




From: R. Putnam, *Bowling Alone: The Collapse and Revival of American Community* NewYork: Simon and Schuster, 2000).

**FIGURE 7.4**

**Violent crime is rarer in high social capital states**

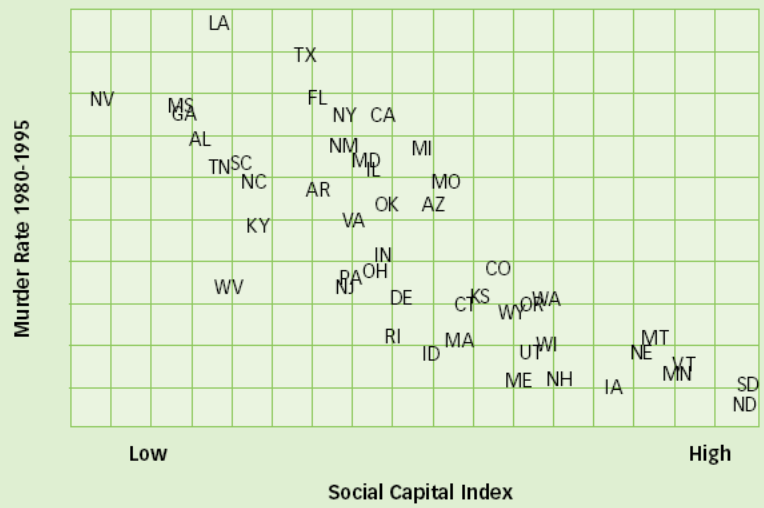



**FIGURE 7.3**

**Kids watch less TV in high social capital states**

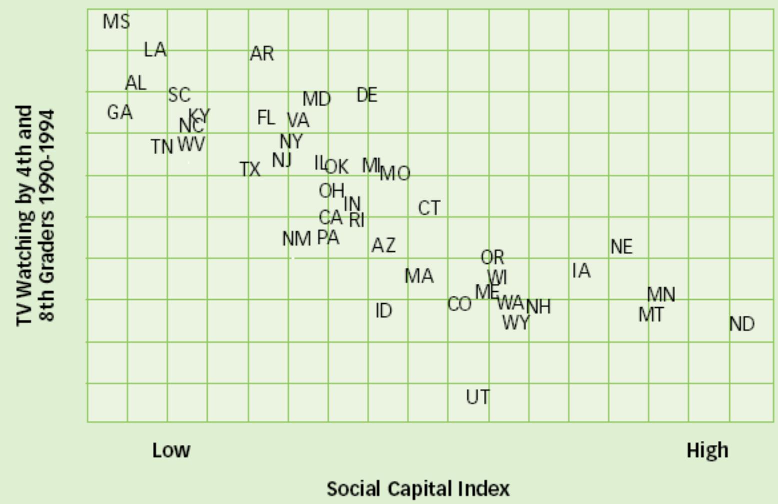



**FIGURE 7.1**

**Schools work better in high social capital states**

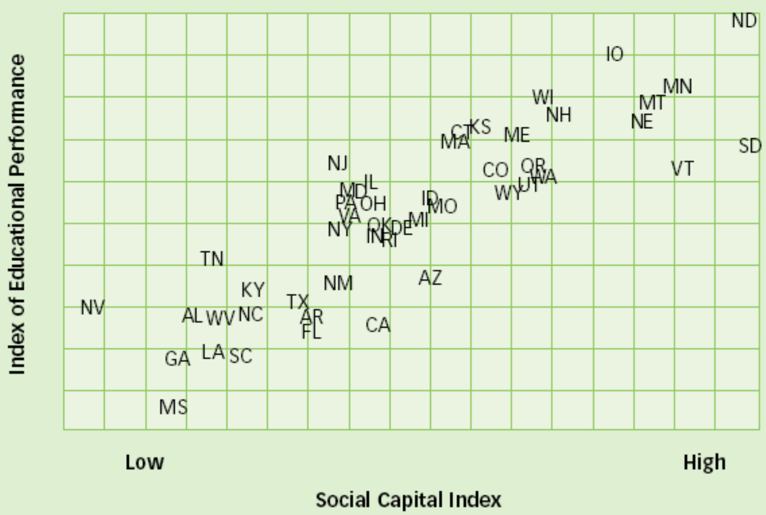
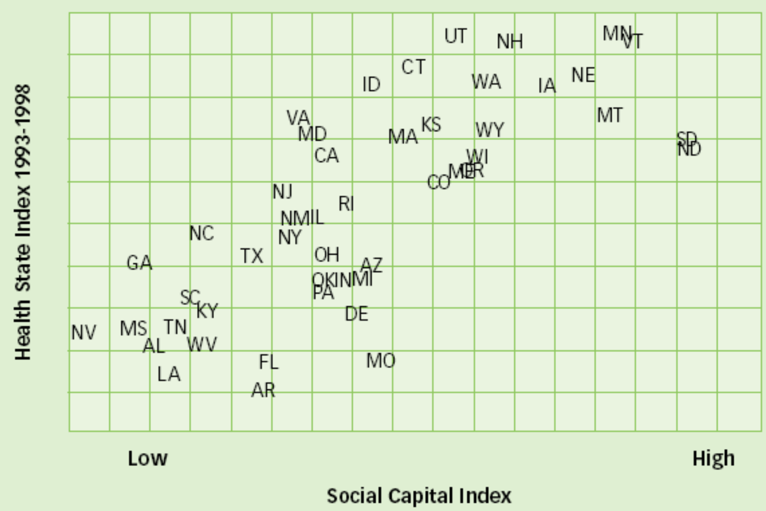



**FIGURE 7.6**

**Health is better in high social capital states**



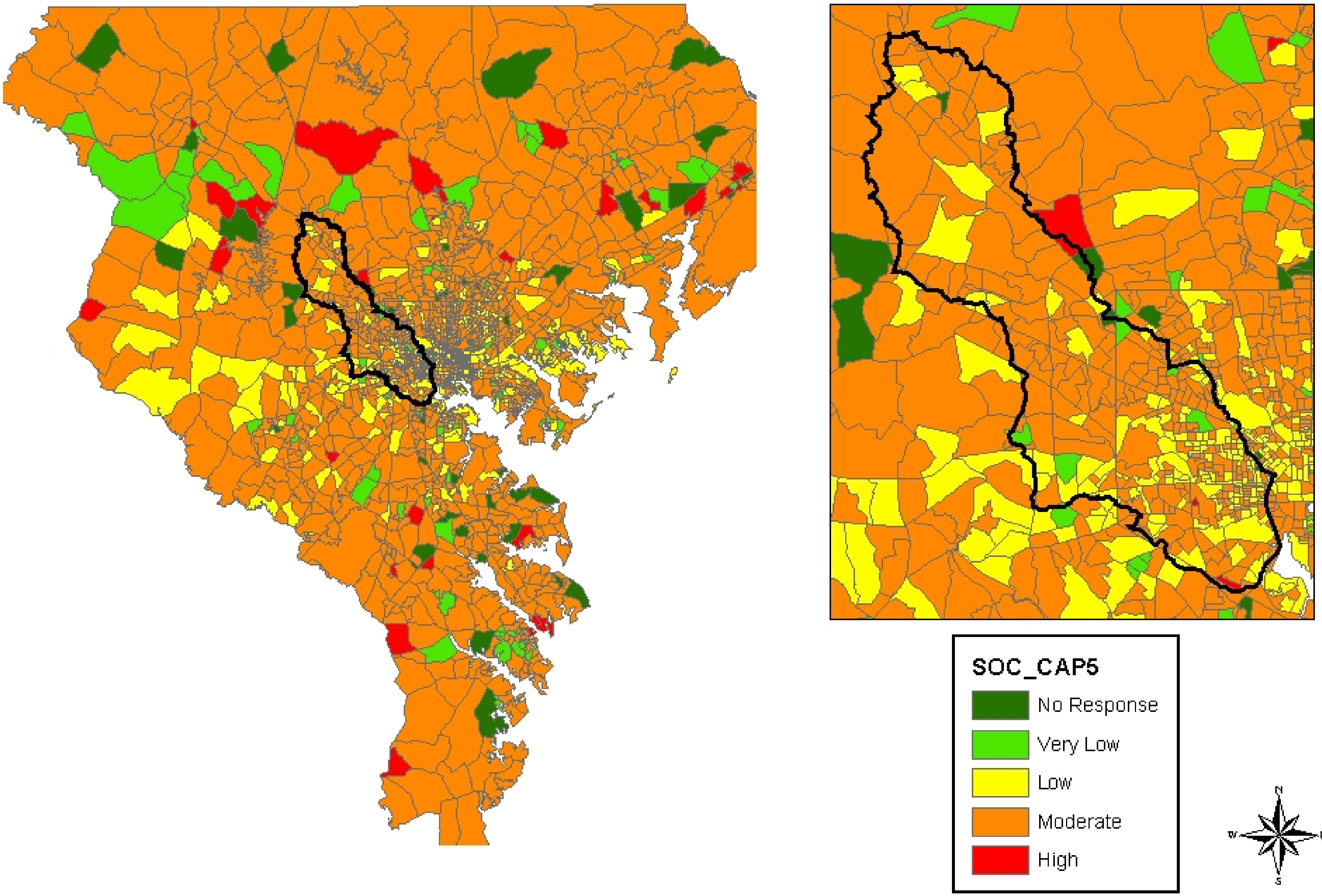
# Social Capital Survey Questions

work by: Morgan Grove, Bill Burch, Matt Wilson, and Amanda Vermuri
as part of the Baltimore Ecosystem Study: http://www.ecostudies.org/bes/

- People in the neighborhood are willing to help one another*
- This is a close knit neighborhood*
- People in this neighborhood can be trusted*
- There are many opportunities to meet neighbors and work on solving community problems*
- Churches or temples and other volunteer groups are actively supportive of the neighborhood*
- There is an active neighborhood association
- Municipal (local) government services (such as sanitation, police, fire, health & housing dept) are adequately provided and support the neighborhood's quality

* Included in Social Capital Index; Cronbachs alpha = .7758

# Social Capital Index by Census Block Group



# Integrated Ecological Economic Modeling

- Used as a Consensus Building Tool in an Open, Participatory Process
- Multi-scale, Landscape Scale and Larger
- Acknowledges Uncertainty and Limited Predictability
- Acknowledges Values of Stakeholders
- Simplifies by Maintaining Linkages and and Synthesizing
- Evolutionary Approach Acknowledges History, Limited Optimization, and the Co-Evolution of Humans and the Rest of Nature

# Three Step Modeling Process*

## 1. Scoping Models

high generality, low resolution models produced with broad participation by all the stakeholder groups affected by the problem.

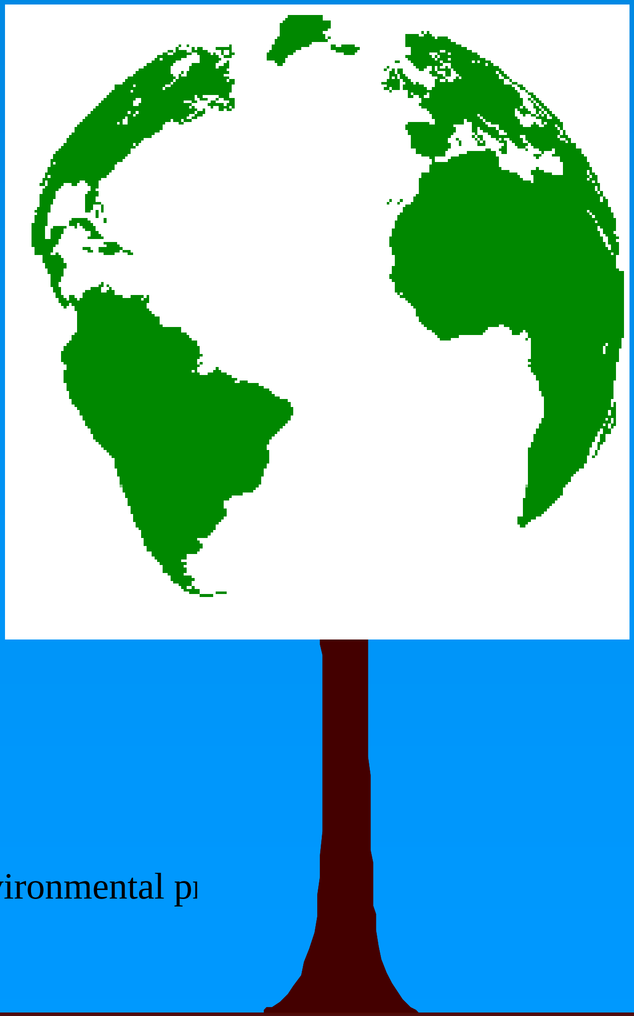
## 2. Research Models

more detailed and realistic attempts to replicate the dynamics of the particular system of interest with the emphasis on calibration and testing.

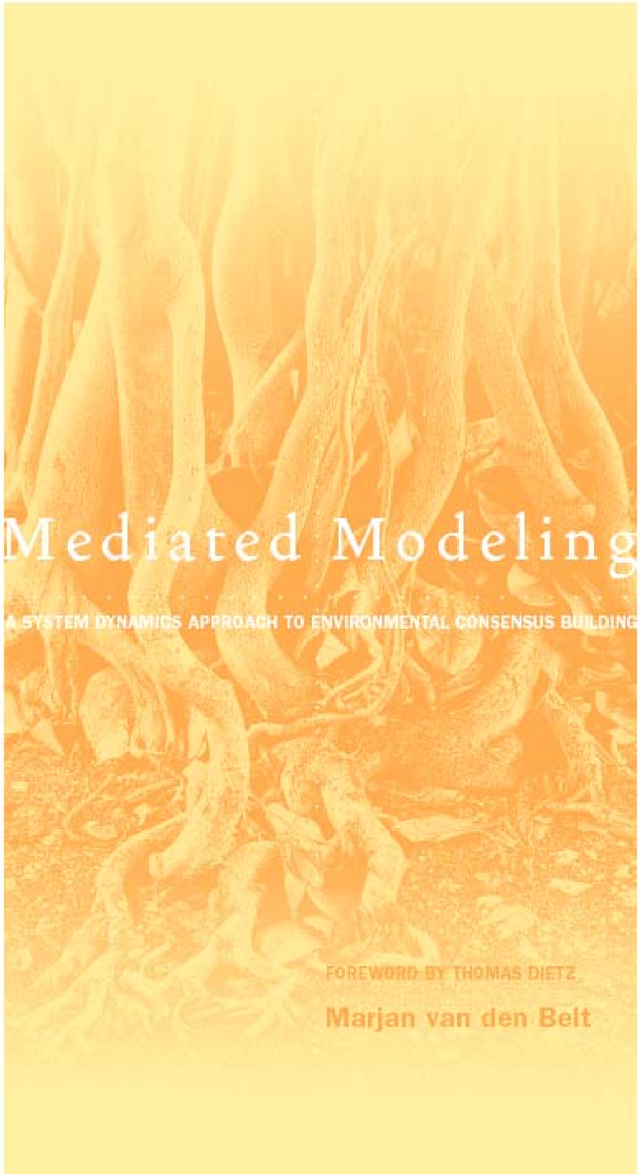
## 3. Management Models

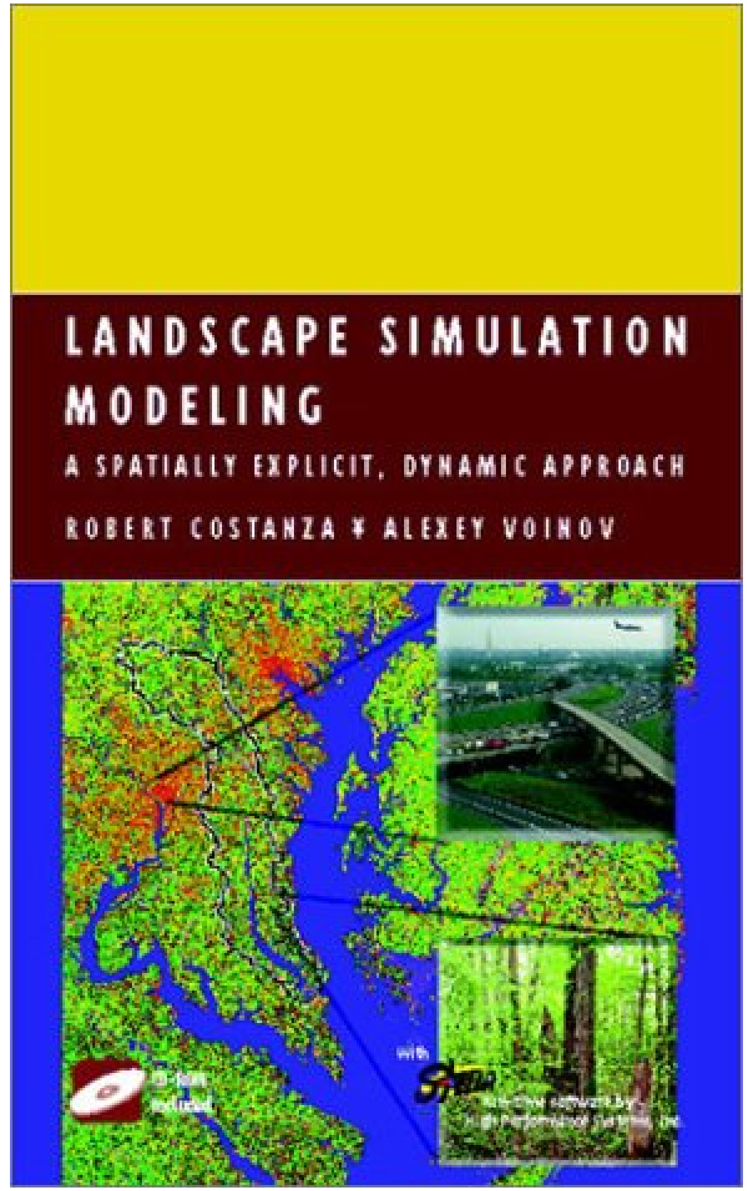
medium to high resolution models based on the previous two stages with the emphasis on producing future management scenarios - can be simply exercising the scoping or research models or may require further elaboration to allow application to management questions

Increasing Complexity, Cost, Realism, and Precision

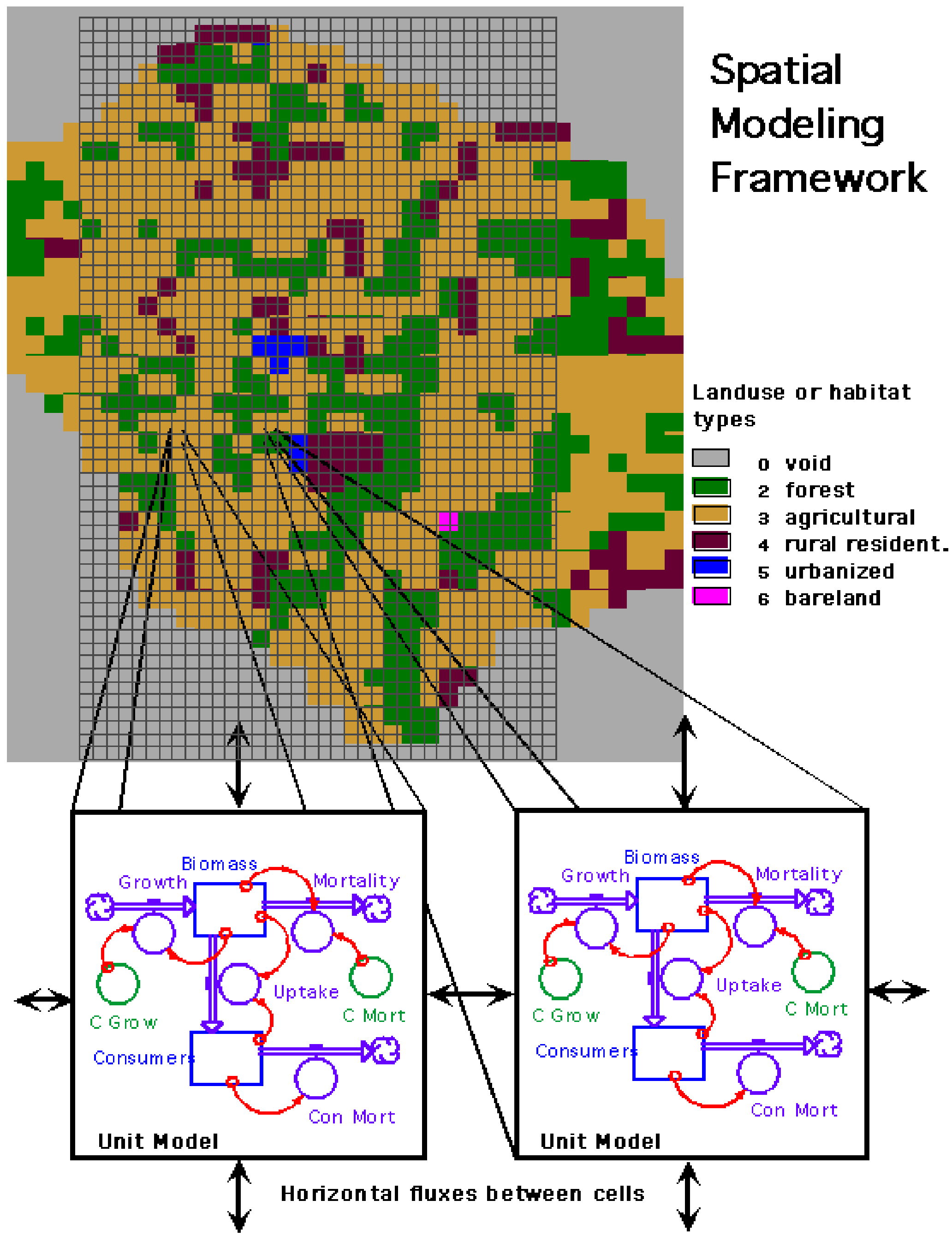


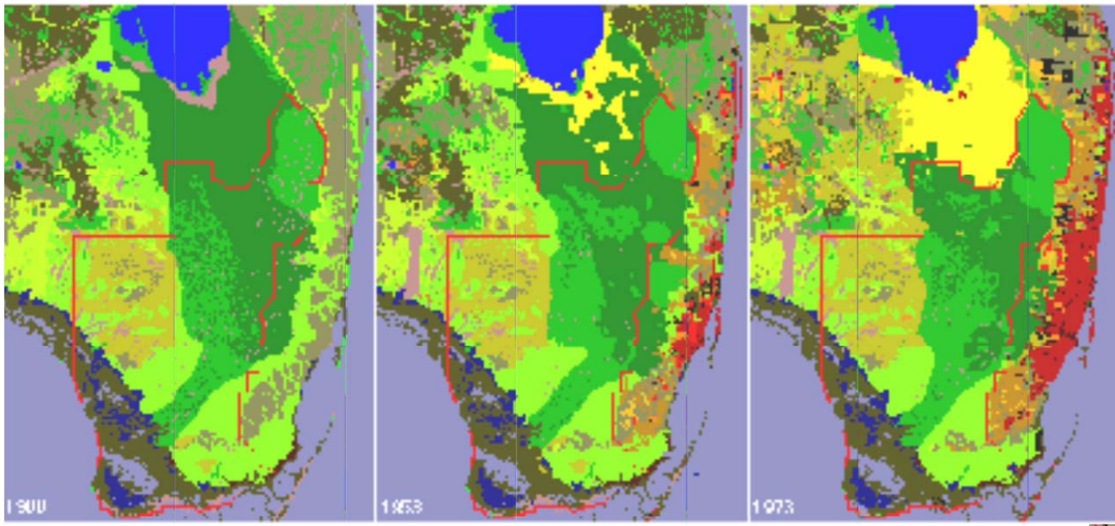
*from: Costanza, R. and M. Ruth. 1998. Using dynamic modeling to scope environmental p
and build consensus. *Environmental Management* 22:183-195.

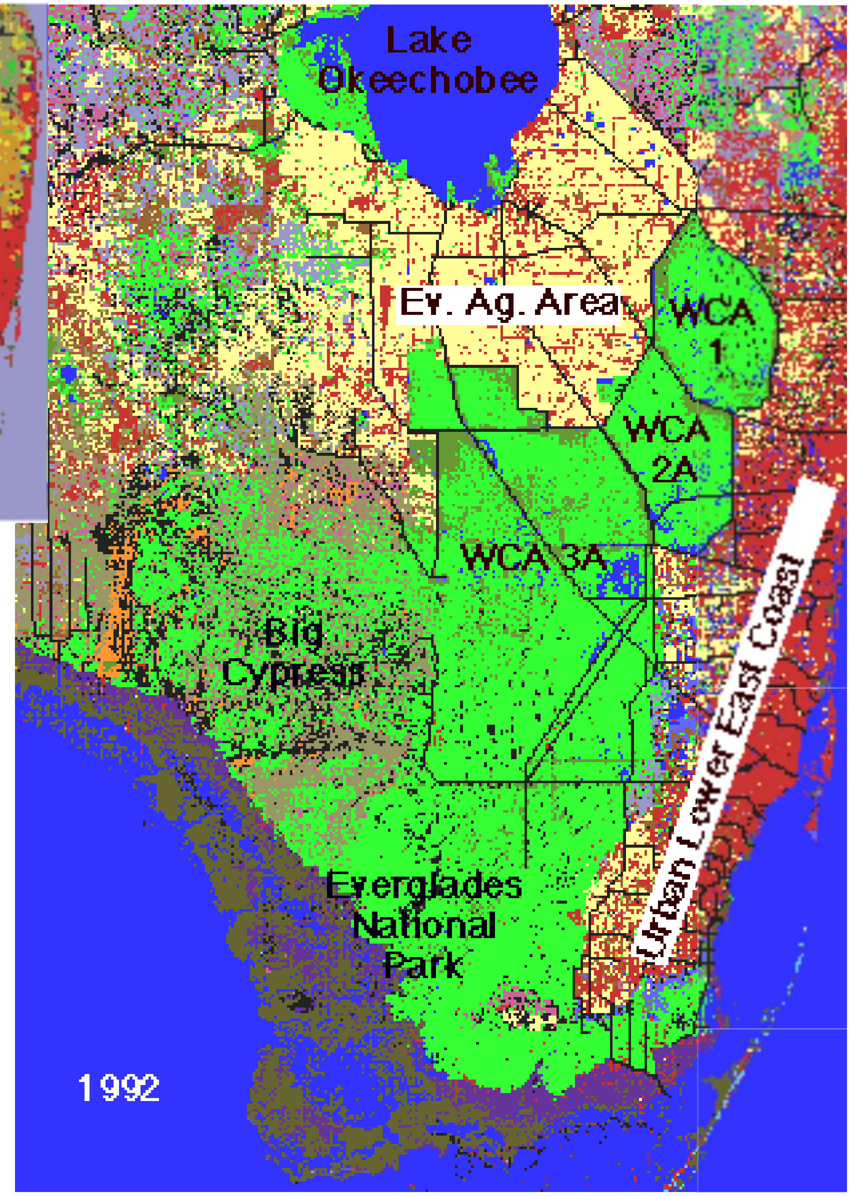

Mediated Modeling
A SYSTEM DYNAMICS APPROACH TO ENVIRONMENTAL CONSENSUS BUILDING
FOREWORD BY THOMAS DIETZ
Marjan van den Belt


LANDSCAPE SIMULATION MODELING
A SPATIALLY EXPLICIT, DYNAMIC APPROACH
ROBERT COSTANZA ¥ ALEXEY VOINOV
with

# Spatial Modeling Framework







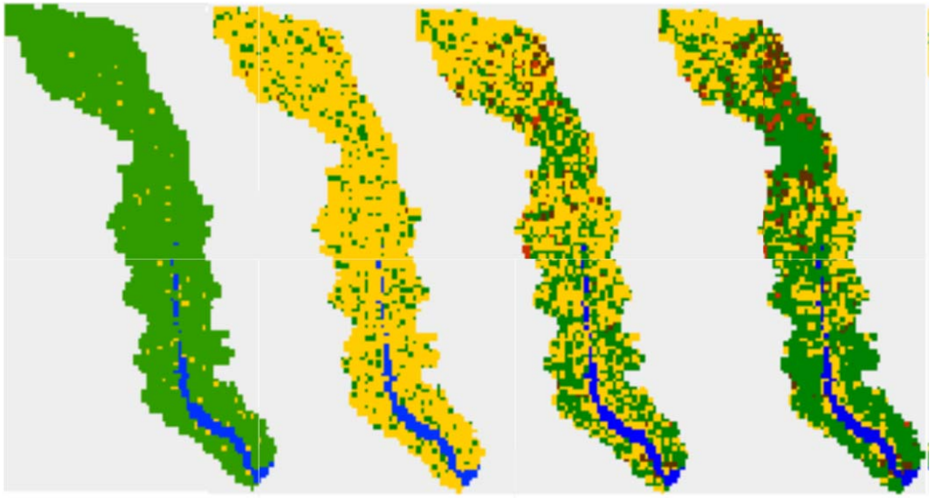

## The Everglades Landscape Model (ELM v2.1)

http://www.sfwmd.gov/org/erd/esr/ELM.html

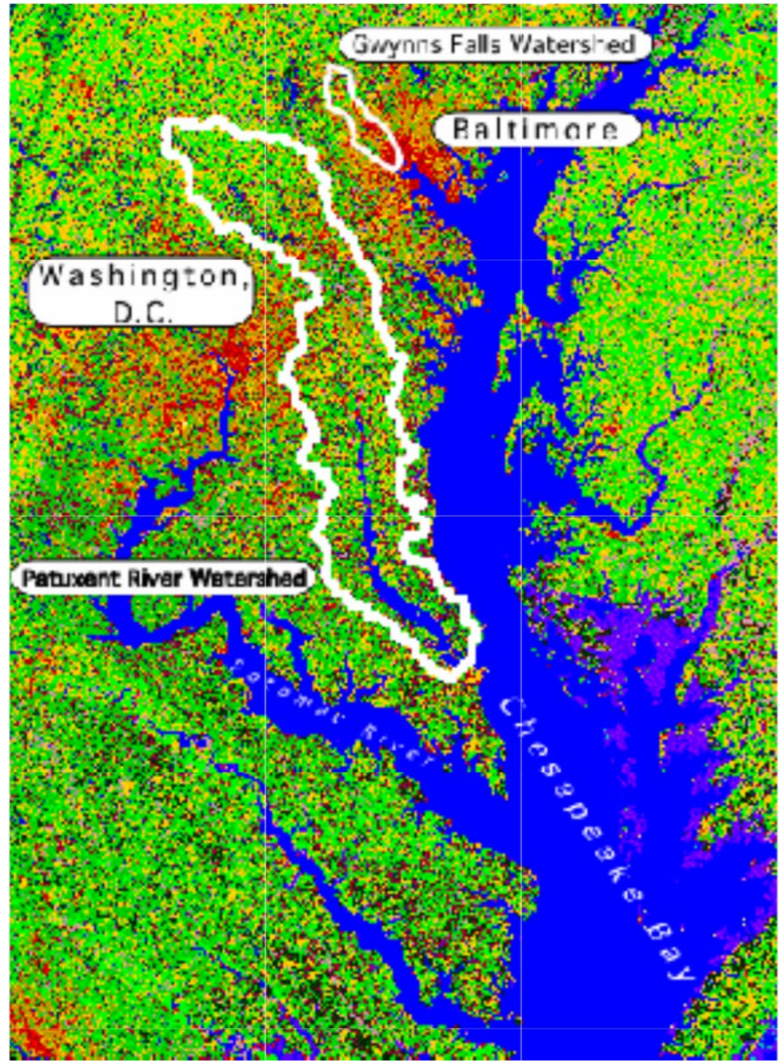
The ELM is a regional scale ecological model designed to predict the landscape response to different water management scenarios in south Florida, USA. The ELM simulates changes to the hydrology, soil & water nutrients, periphyton biomass & community type, and vegetation biomass & community type in the Everglades region.

**Current Developers**
**South Florida Water Management District**
H. Carl Fitz
Fred H. Sklar
Yegang Wu
Charles Cornwell
Tim Waring

**Recent Collaborators**
**University of Maryland, Institute for Ecological Economics**
Alexey A. Voinov
Robert Costanza
Tom Maxwell
**Florida Atlantic University**
Matthew Evett



| | 1700 | 1850 | 1953 | 1972 |
|---|---|---|---|---|
| Forest | 2386 | 348 | 911 | 1391 |
| Residential | 0 | 7 | 111 | 195 |
| Urban | 0 | 0 | 28 | 56 |
| Agro | 56 | 2087 | 1391 | 800 |




**The Patuxent and Gwynns Falls Watershed Model s (PLM and GFLM)**

http://www.uvm.edu/giee/PLM

This project is aimed at developing integrated knowledge and new tools to enhance predictive understanding of watershed ecosystems (including processes and mechanisms that govern the interconnect - ed dynamics of water, nutrients, toxins, and biotic components) and their linkage to human factors affecting water and watersheds. The goal is effective management at the watershed scale.

**Participants Include:**

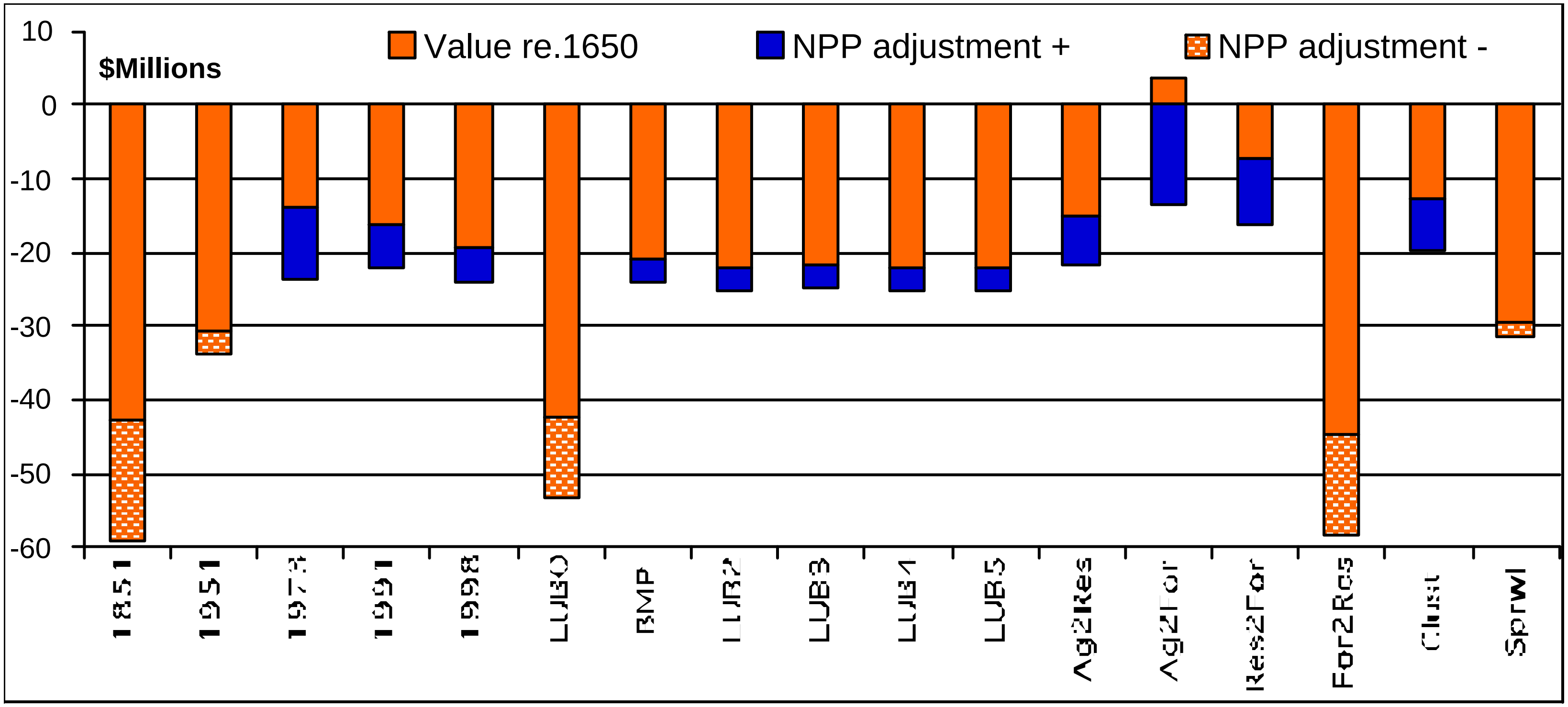
Robert Costanza
Roelof Boumans
Walter Boynton
Thomas Maxwell
Steve Seagle
Ferdinando Villa
Alexey Voinov
Helena Voinov
Lisa Wainger

# Patuxent Watershed Scenarios*

| | | Land Use | | | | Nitrogen Loading | | | | Nitrogen to Estuary | | | Hydrology | | N in GW | NPP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Forest | Resid | Urban | Agro | Atmos | Fertil | Decomp | Septic | N aver. | N max | N min | Wmax | Wmin | N gw c. | NPP |
| | **Scenario** | number of cells | | | | kg/ha/year | | | | mg/l | | | m/year | | mg/l | kg/m2/y |
| 1 | 1650 | 2386 | 0 | 0 | 56 | 3.00 | 0.00 | 162.00 | 0.00 | 3.14 | 11.97 | 0.05 | 101.059 | 34.557 | 0.023 | 2.185 |
| 2 | 1850 | 348 | 7 | 0 | 2087 | 5.00 | 106.00 | 63.00 | 0.00 | 7.17 | 46.61 | 0.22 | 147.979 | 22.227 | 0.25 | 0.333 |
| 3 | 1950 | 911 | 111 | 28 | 1391 | 96.00 | 110.00 | 99.00 | 7.00 | 11.79 | 42.34 | 0.70 | 128.076 | 18.976 | 0.284 | 1.119 |
| 4 | 1972 | 1252 | 223 | 83 | 884 | 86.00 | 145.00 | 119.00 | 7.00 | 13.68 | 60.63 | 0.76 | 126.974 | 19.947 | 0.281 | 1.72 |
| 5 | 1990 | 1315 | 311 | 92 | 724 | 86.00 | 101.00 | 113.00 | 13.00 | 10.18 | 40.42 | 1.09 | 138.486 | 18.473 | 0.265 | 1.654 |
| 6 | 1997 | 1195 | 460 | 115 | 672 | 91.00 | 94.00 | 105.00 | 18.00 | 11.09 | 55.73 | 0.34 | 147.909 | 18.312 | 0.289 | 1.569 |
| 7 | BuildOut | 312 | 729 | 216 | 1185 | 96.00 | 155.00 | 61.00 | 21.00 | 12.89 | 83.03 | 2.42 | 174.890 | 11.066 | 0.447 | 0.558 |
| 8 | BMP | 1195 | 460 | 115 | 672 | 80.00 | 41.00 | 103.00 | 18.00 | 5.68 | 16.41 | 0.06 | 148.154 | 16.736 | 0.23 | 1.523 |
| 9 | LUB1 | 1129 | 575 | 134 | 604 | 86.00 | 73.00 | 98.00 | 8.00 | 8.05 | 39.71 | 0.11 | 150.524 | 17.623 | 0.266 | 1.494 |
| 10 | LUB2 | 1147 | 538 | 134 | 623 | 86.00 | 76.00 | 100.00 | 11.00 | 7.89 | 29.95 | 0.07 | 148.353 | 16.575 | 0.269 | 1.512 |
| 11 | LUB3 | 1129 | 577 | 134 | 602 | 86.00 | 73.00 | 99.00 | 24.00 | 7.89 | 29.73 | 0.10 | 148.479 | 16.750 | 0.289 | 1.5 |
| 12 | LUB4 | 1133 | 564 | 135 | 610 | 86.00 | 74.00 | 100.00 | 12.00 | 8.05 | 29.83 | 0.07 | 148.444 | 16.633 | 0.271 | 1.501 |
| 13 | agro2res | 1195 | 1132 | 115 | 0 | 86.00 | 0.00 | 96.00 | 39.00 | 5.62 | 15.13 | 0.11 | 169.960 | 17.586 | 0.292 | 1.702 |
| 14 | agro2frst | 1867 | 460 | 115 | 0 | 86.00 | 0.00 | 134.00 | 18.00 | 4.89 | 12.32 | 0.06 | 138.622 | 21.590 | 0.142 | 2.258 |
| 15 | res2frst | 1655 | 0 | 115 | 672 | 86.00 | 82.00 | 130.00 | 7.00 | 7.58 | 23.50 | 0.10 | 120.771 | 20.276 | 0.18 | 1.95 |
| 16 | frst2res | 0 | 1655 | 115 | 672 | 86.00 | 82.00 | 36.00 | 54.00 | 9.27 | 39.40 | 1.89 | 183.565 | 9.586 | 0.497 | 0.437 |
| 17 | cluster | 1528 | 0 | 276 | 638 | 86.00 | 78.00 | 121.00 | 17.00 | 7.64 | 25.32 | 0.09 | 166.724 | 17.484 | 0.216 | 1.792 |
| 18 | sprawl | 1127 | 652 | 0 | 663 | 86.00 | 78.00 | 83.00 | 27.00 | 8.48 | 25.43 | 0.11 | 140.467 | 17.506 | 0.349 | 1.222 |

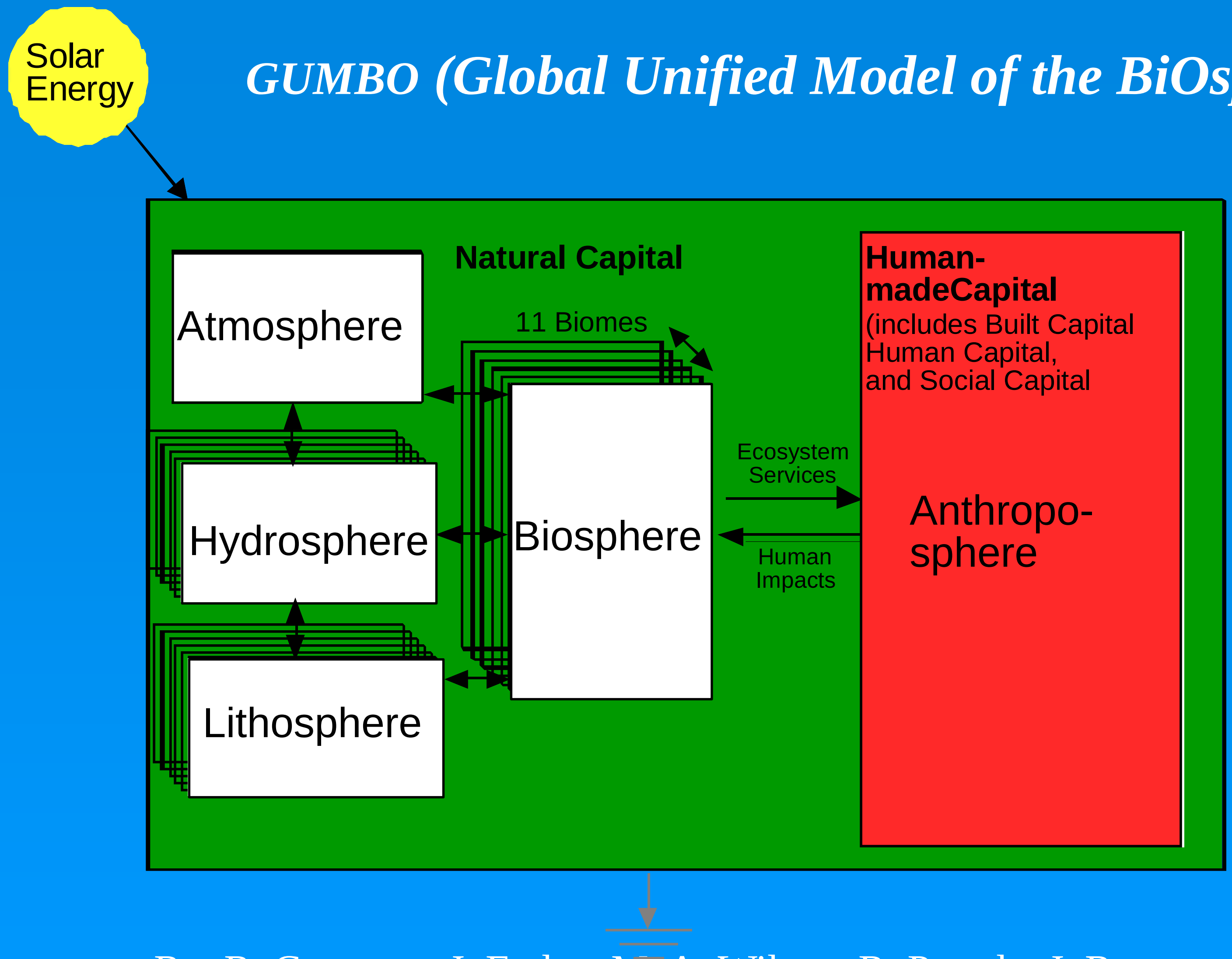
* From: Costanza, R., A. Voinov, R. Boumans, T. Maxwell, F. Villa, L. Wainger, and H. Voinov. 2002. Integrated ecological economic modeling of the Patuxent River watershed, Maryland. *Ecological Monographs* 72:203-231.

# Results




- Change in value of ecosystem services since 1650 calculated based on values estimated for different land use types (Costanza, et al., 1997). Further adjusted by NPP values calculated by the model. In some cases the NPP adjustment further decreased the ES value (-), in other cases it increased it (+).

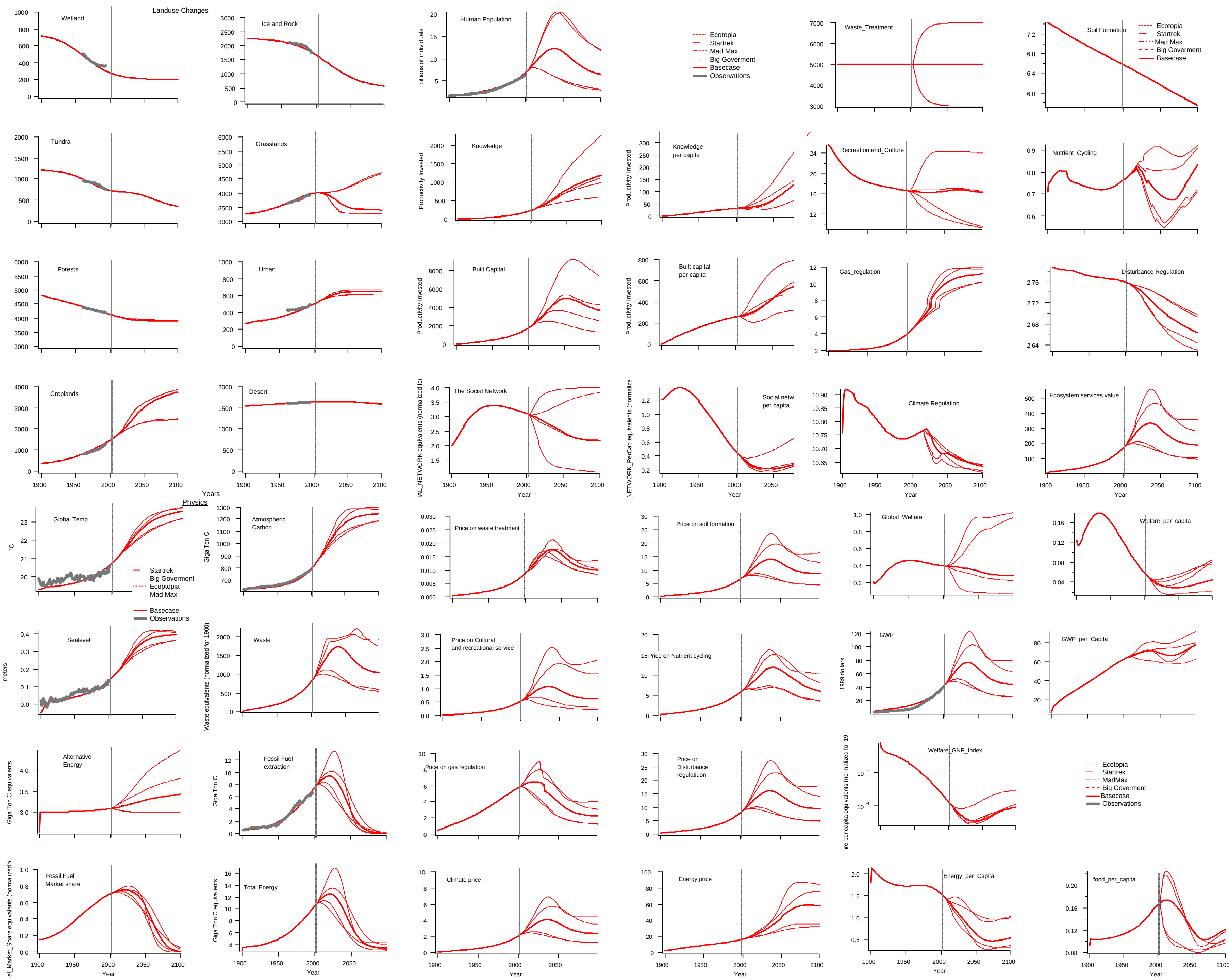
## *GUMBO (Global Unified Model of the BiOsphere)*




**From:** Boumans, R., R. Costanza, J. Farley, M. A. Wilson, R. Portela, J. Rotmans, F. Villa, and M. Grasso. 2002. Modeling the Dynamics of the Integrated Earth System and the Value of Global Ecosystem Services Using the GUMBO Model. *Ecological Economics* 41: 529-560

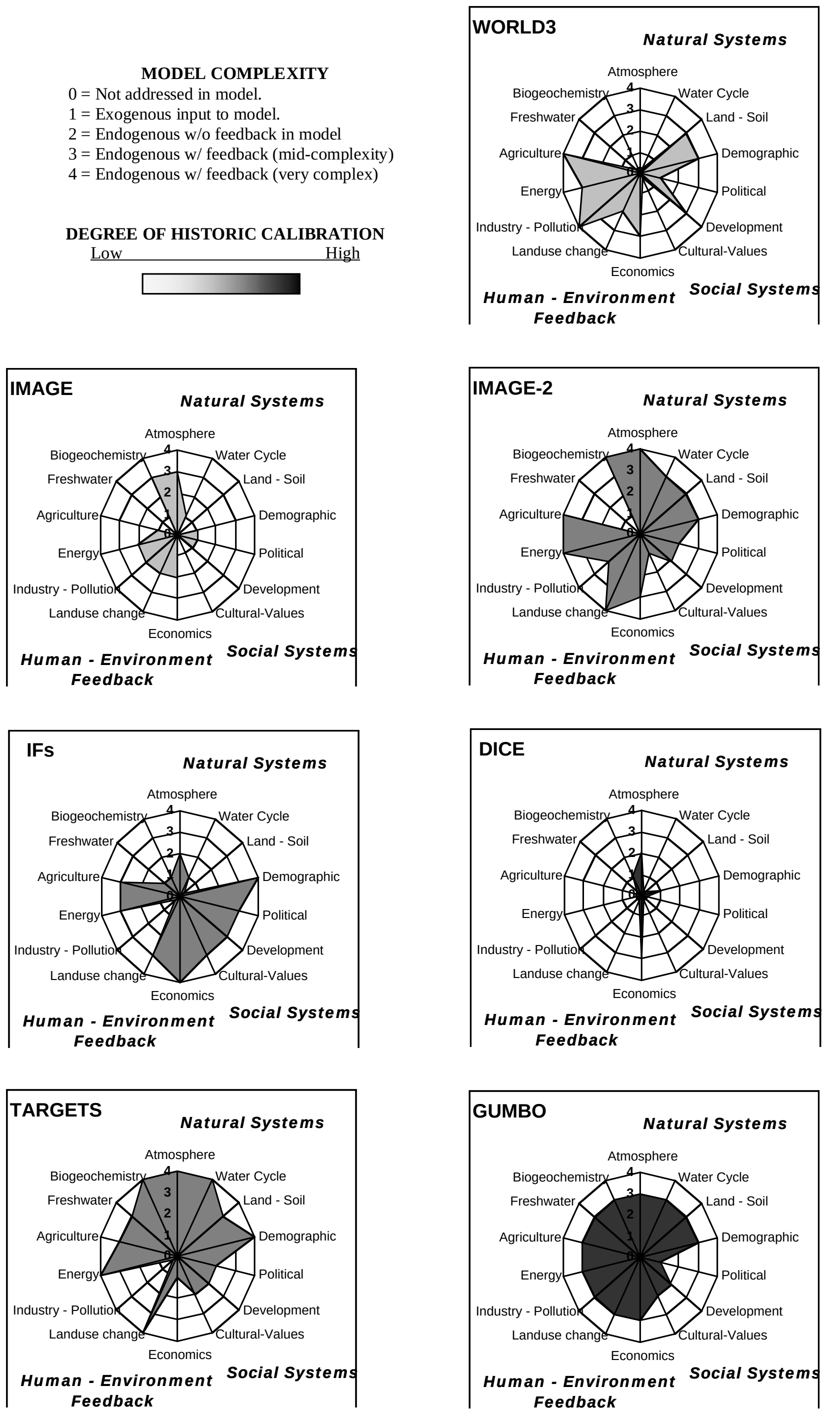
## Global Unified Metamodel of the BiOsphere (GUMBO)

- was developed to simulate the integrated earth system and assess the dynamics and values of ecosystem services.
- is a “metamodel” in that it represents a synthesis and a simplification of several existing dynamic global models in both the natural and social sciences at an intermediate level of complexity.
- the current version of the model contains 234 state variables, 930 variables total, and 1715 parameters.
- is the first global model to include the dynamic feedbacks among human technology, economic production and welfare, and ecosystem goods and services within the dynamic earth system.
- includes modules to simulate carbon, water, and nutrient fluxes through the *Atmosphere*, *Lithosphere*, *Hydrosphere*, and *Biosphere* of the global system. Social and economic dynamics are simulated within the *Anthroposphere*.
- links these five spheres across eleven biomes, which together encompass the entire surface of the planet.
- simulates the dynamics of eleven major ecosystem goods and services for each of the biomes


Landuse Changes
Wetland
Ice and Rock
Human Population
billions of individuals
Ecotopia
Startrek
Mad Max
Big Goverment
Basecase
Observations
Waste_Treatment
Soil Formation
Tundra
Grasslands
Knowledge
Productivity Invested
Knowledge per capita
Recreation and_Culture
Nutrient_Cycling
Forests
Urban
Built Capital
Built capital per capita
Gas_regulation
Disturbance Regulation
Croplands
Desert
The Social Network
Social netw per capita
Climate Regulation
Ecosystem services value
Year
Years
Physics
Global Temp
°C
Atmosperic Carbon
Giga Ton C
Price on waste treatment
Price on soil formation
Global_Welfare
Welfare_per_capita
Sealevel
meters
Waste
Waste equivalents (normalized for 1900)
Price on Cultural and recreational service
Price on Nutrient cycling
GWP
1989 dollars
GWP_per_Capita
Alternative Energy
Giga Ton C equivalents
Fossil Fuel extraction
Price on gas regulation
Price on Disturbance regulatiuon
Welfare_GNP_Index
Ecotopia
Startrek
MadMax
Big Goverment
Basecase
Observations
Fossil Fuel Market share
Total Energy
Climate price
Energy price
Energy_per_Capita
food_per_capita

# GUMBO Conclusions

- To our knowledge, no other global models have yet achieved the level of dynamic integration between the biophysical earth system and the human socioeconomic system incorporated in GUMBO. This is an important first step.
- Historical calibrations from 1900 to 2000 for 14 key variables for which quantitative time series data was available produced an average $R^2$ of .922.
- A range of future scenarios representing different assumptions about future technological change, investment strategies and other factors have been simulated
- Assessing global sustainability can only be done using a dynamic integrated model of the type we have created in GUMBO. But one is still left with decisions about *what* to sustain (i.e. GWP, welfare, welfare per capita, etc.) GUMBO allows these decisions to be made explicitly and in the context of the complex world system. It allows both desirable and sustainable futures to be examined.
- Ecosystem services are highly integrated into the model, both in terms of the biophysical functioning of the earth system and in the provision of human welfare. Both their physical and value dynamics are shown to be quite complex.
- The overall value of ecosystem services, in terms of their relative contribution to both the production and welfare functions, is shown to be significantly higher than GWP (4.5 times in this preliminary version of the model).
- “Technologically skeptical” investment policies are shown to have the best chance (given uncertainty about key parameters) of achieving high and sustainable welfare per capita. This means increased relative rates of investment in knowledge, social capital, and natural capital, and reduced relative rates of consumption and investment in built capital.




Amoeba diagram of complexity with which Integrated Global Models (IGMs) capture socioeconomic systems, natural systems, and feedbacks

(from Costanza, R., R. Leemans, R. Boumans, and E. Gaddis. 2006. Integrated global models. Dahlem Workshop on Integrated History and future of People on Earth (IHOPE). (in press)

# Four Visions of the Future

| World View & Policy | | Real State of the World: **Optimists Are Right** (Resources are unlimited) | Real State of the World: **Skeptics Are Right** (Resources are limited) |
|---|---|---|---|
| **Empty World Vision** | **Technological Optimism**<br>Resources are unlimited<br>Technical Progress can deal with any challenge<br>Compitition promotes progress; markets are the guiding principle | **Star Trek**<br>Fusion energy becomes practical, solving many economic and environmental problems.<br>Humans journey to the inner solar system, where population continues to expand<br>(mean rank 2.3) | **Mad Max**<br>Oil production declines and no affordable alternative emerges.<br>Financial markets collapse and governments weaken, too broke to maintain order and control over desperate, impoverished populations.<br>The world is run by transnational corporations.<br>(mean rank -7.7) |
| **Full World Vision** | **Technological Skepticsm**<br>Resources are limited<br>Progress depends less on technology and more on social and community development<br>Cooperation promotes progress; markets are the servants of larger goals | **Big Government**<br>Governments sanction companies that fail to pursue the public interest.<br>Fusion energy is slow to develop due to strict saftey standards.<br>Family-planning programs stabilize population growth.<br>Incomes become more equal.<br>(mean rank 0.8) | **EcoTopia**<br>Tax reforms favor ecologically beneficent industries and punish polluters and resource depleters.<br>Habitation patterns reduce need for transportation and energy.<br>A shift away from consumerism increases quality of life and reduces waste.<br>(mean rank 5.1) |

from: Costanza, R. 2000. Visions of alternative (unpredictable) futures and their use in policy analysis. *Conservation Ecology* 4(1):5. [online] URL: **http://www.consecol.org/vol4/iss1/art5**

# Millennium Ecosystem Assessment Scenarios

## TechnoGarden

Globally connected world relying strongly on environmentally sound technology, using highly managed, often engineered, ecosystems to deliver ecosystem services, and taking a proactive approach to the management of ecosystems in an effort to avoid problems.

## Order from Strength

Regionalized and fragmented world, concerned with security and protection, emphasizing primarily regional markets, paying little attention to public goods, and taking a reactive approach to ecosystem problems.

## Global Orchestration

Globally connected society that focuses on global trade and economic liberalization and takes a reactive approach to ecosystem problems but that also takes strong steps to reduce poverty and inequality and to invest in public goods such as infrastructure and education.

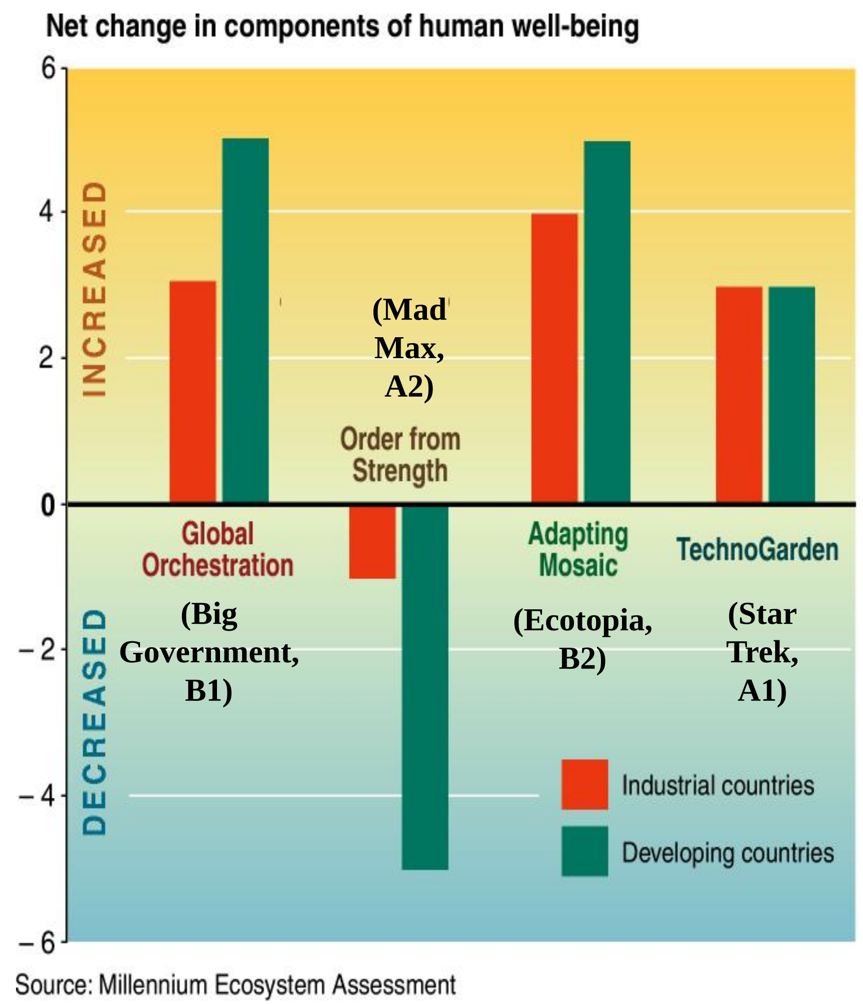
## Adapting Mosaic

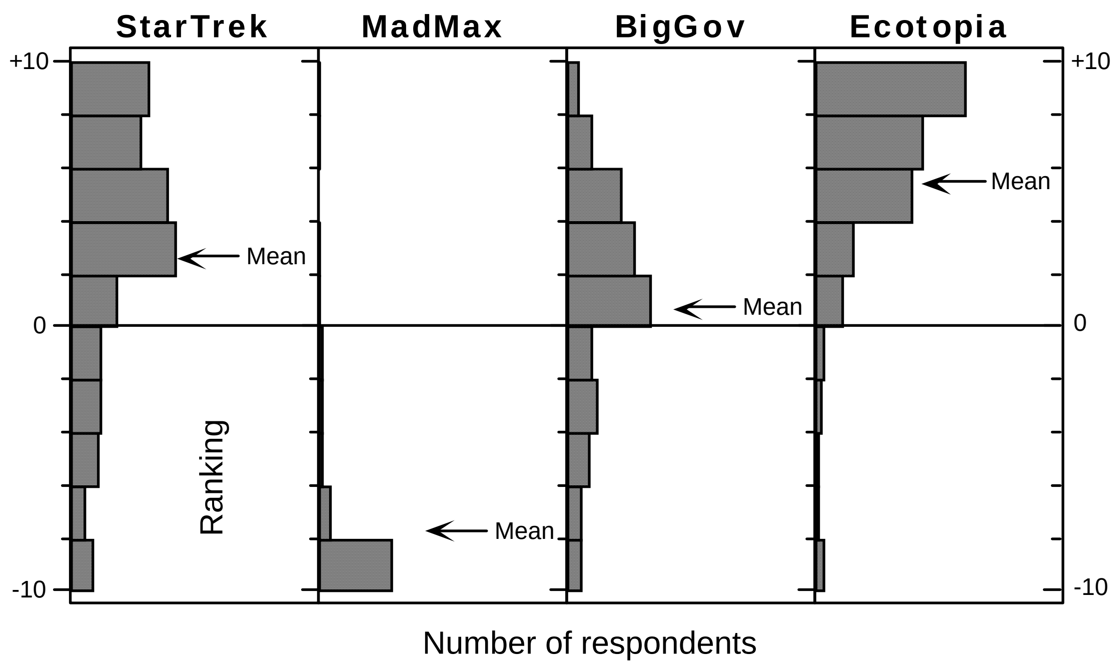
Regional watershed-scale ecosystems are the focus of political and economic activity. Local institutions are strengthened and local ecosystem management strategies are common; societies develop a strongly proactive approach to the management of ecosystems.

# Changes in human well-being under Millennium Assessment scenarios

- In three of the four MA scenarios, between three and five of the components of well-being (material needs, health, security, social relations, freedom) improve between 2000 and 2050

- In one scenario (*Order from Strength)* conditions are projected to decline, particularly in developing countries




StarTrek
MadMax
BigGov
Ecotopia
+10
0
-10
Mean
Ranking
Number of respondents

# Envisioning a Sustainable and Desirable America

## The vision so far (see http://www.uvm.edu/giee/ESDA)

**World View**

- Humans as a part of nature
- Steady state, ecological economy
- Goal quality of life rather than consumption

**Natural Capital**

- Protected as essential life support
- Depletion heavily taxed

**Built Capital**

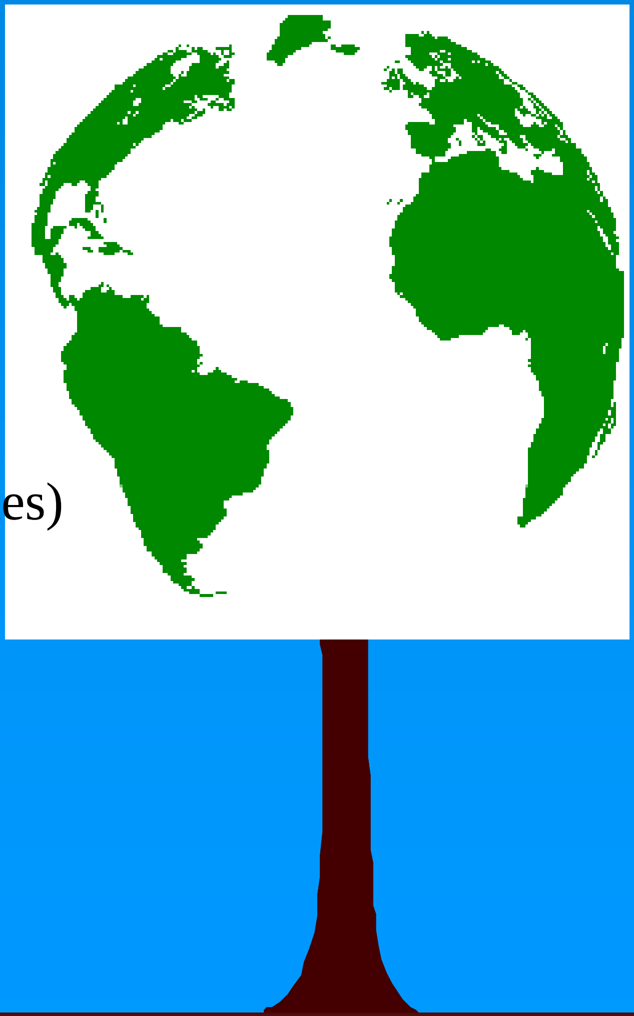
- Runs on renewable energy and natural capital
- Emphasis on quality rather than quantity
- Small communities rule (both within and outside cities)

**Human Capital**

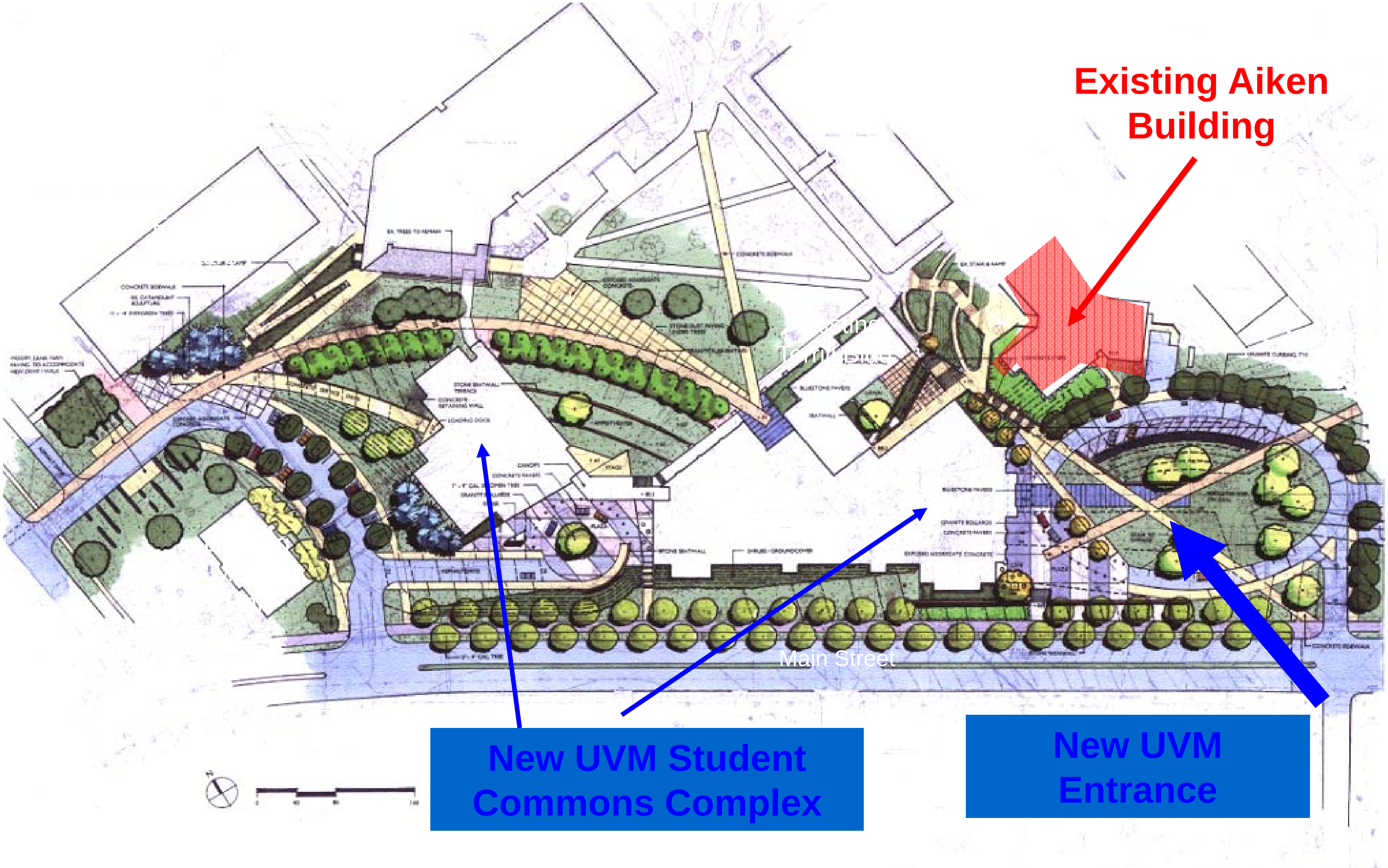
- Balance of synthesis, analysis, and communication
- Meaningful, creative work and leisure
- Stable populations

**Social Capital**

- A primary source of productivity and well-being
- “Strong” democracy

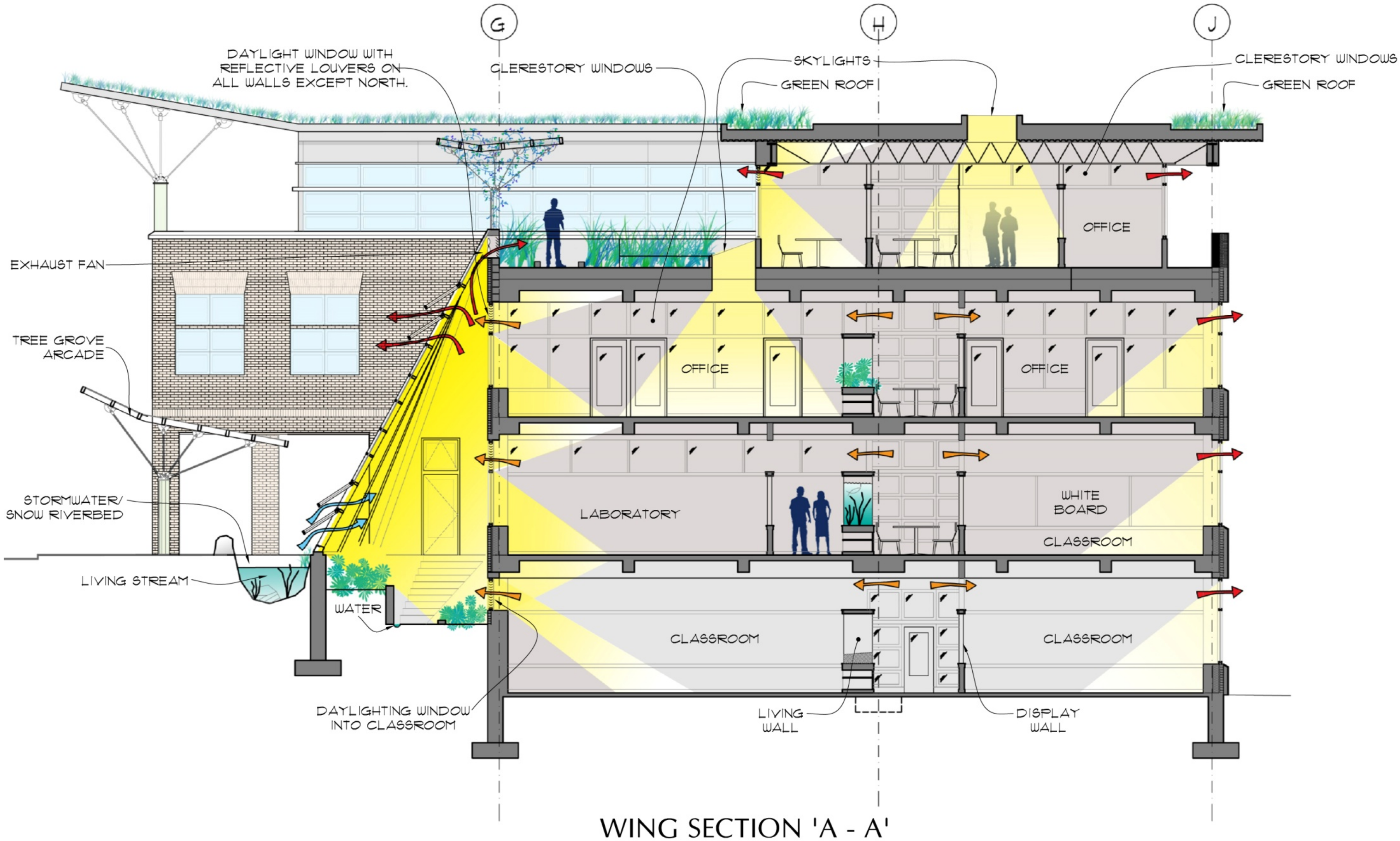


# Building the Environmental University



*The*
**UNIVERSITY**
*of* **VERMONT**

## The Rubenstein School
**of Environment and Natural Resources**



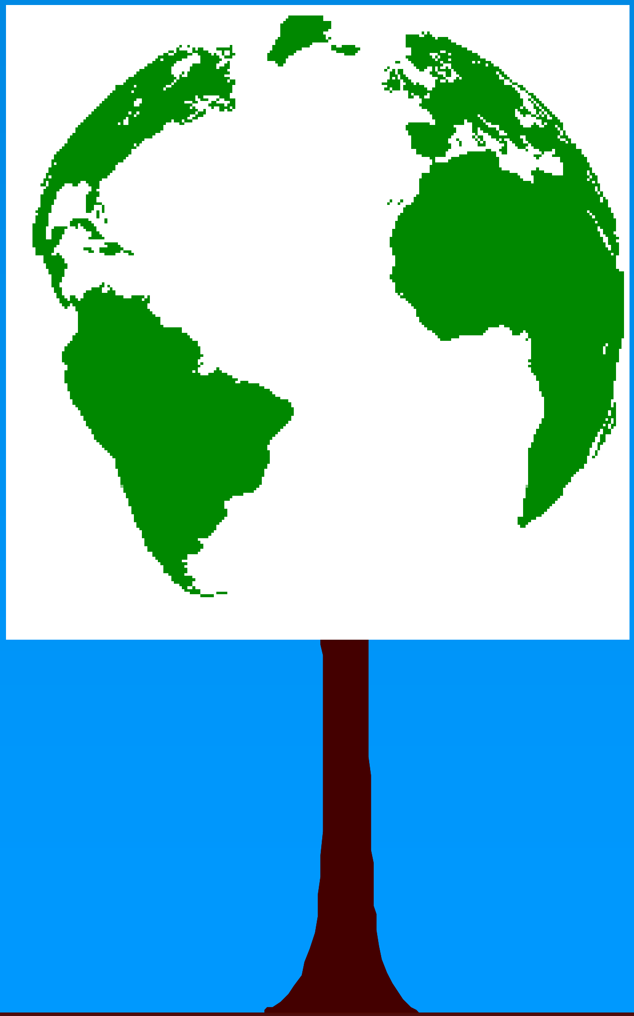

# Goal: building (as) an ecosystem

**producing a net positive contribution to built capital, human capital (education), social capital (community interactions) and natural capital (ecosystem services)**


**Intentional communities (co-housing, ecovillages, etc). as attempts to balance built, human, social, and natural capital to enhance sustainable quality of life**

# The Big Challenge:

# Create a *shared* vision of a sustainable and desirable future

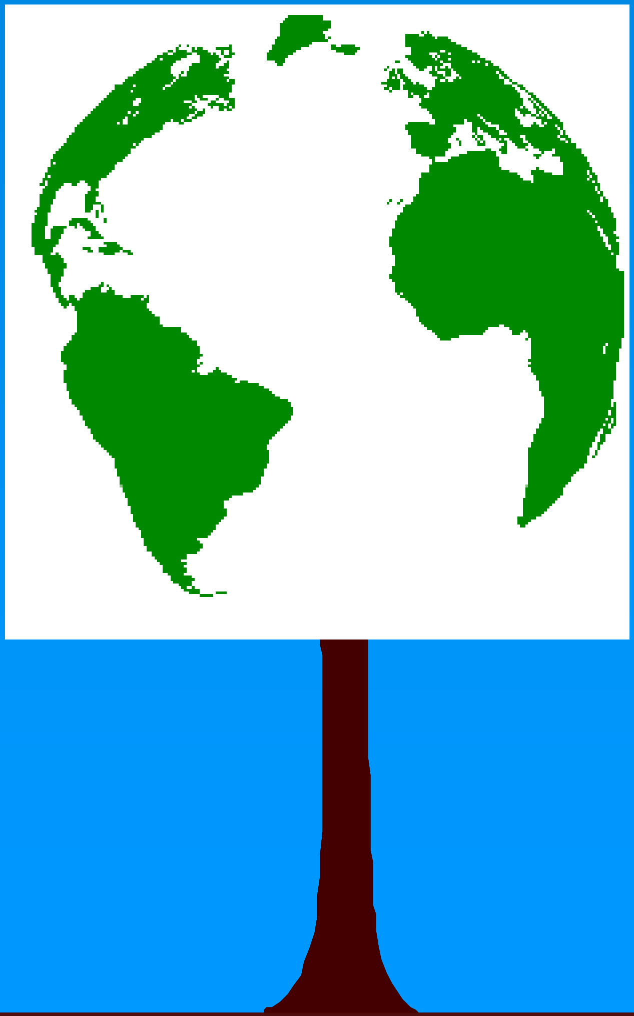


# Some Implications for Policy and Implementation:

## Making the Market Tell the Truth

## Dealing with Uncertainty: Changing the Burden of Proof

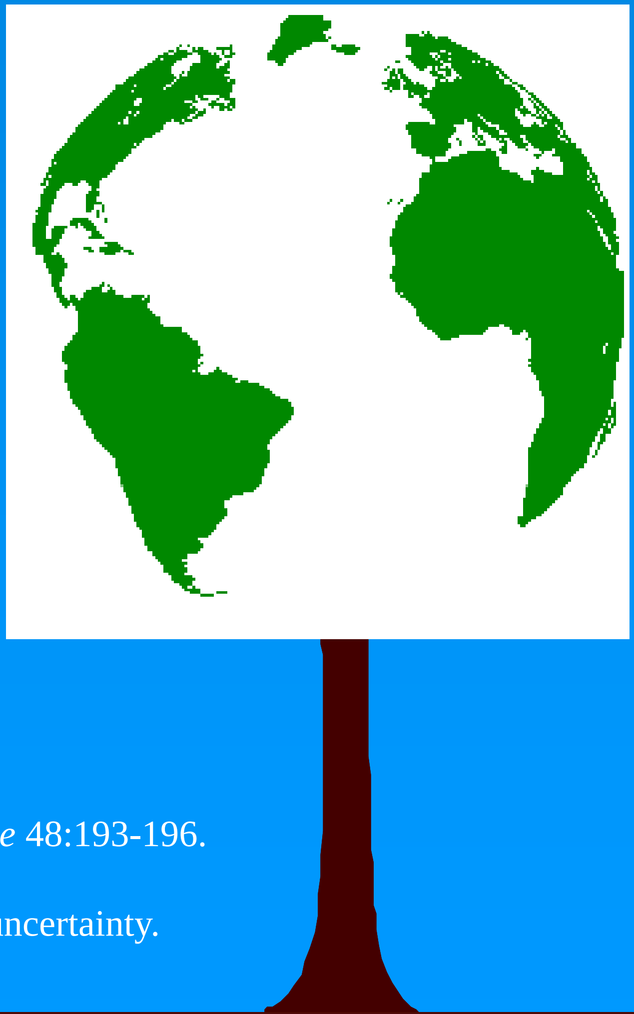
## Sustainable Trade



# Making the market tell the truth

**In general, privatization is NOT the answer, because most ecosystem services are public goods. But we do need to adjust market incentives to send the right signals to the market. These methods include:**

- **Ecological tax reform (tax bads not goods, remove perverse subsidies)**
- **Full cost pricing (i.e. www.trucost.org) linked to investment fund management**
- **Ecosystem service payments (a la Costa Rica)**
- **Conservation easements and concessions (a la Conservation International)**
- **Environmental Assurance bonds to incorporate uncertainty about impacts (i.e. the Precautionary Polluter Pays Principle - 4P)**



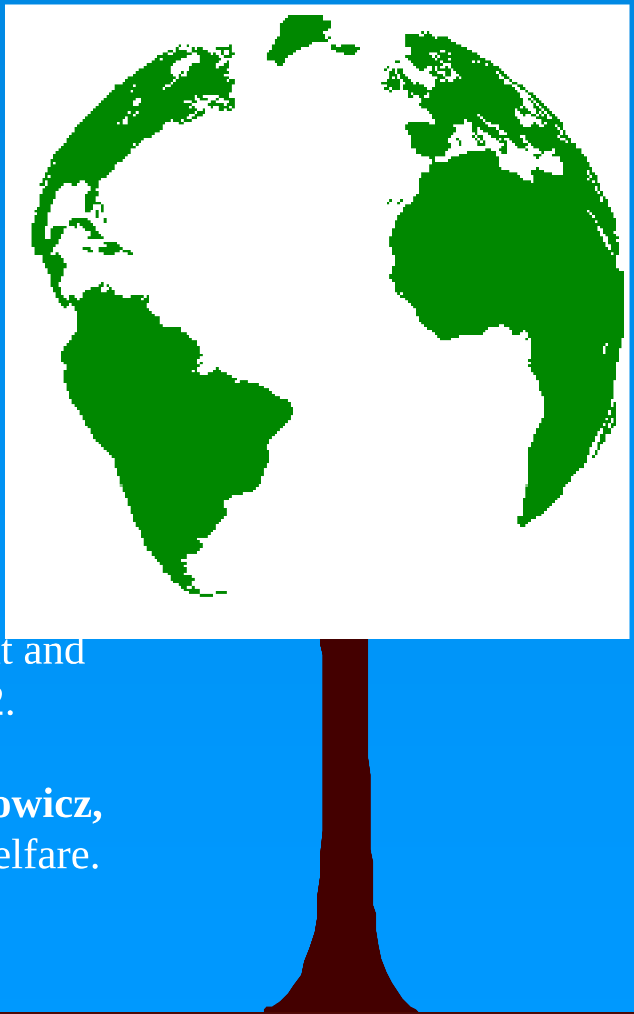

**See:**

**Bernow, S., R. Costanza, H. Daly, et. Al.. 1998**. Ecological tax reform. *BioScience* 48:193-196.

**Costanza, R. and L. Cornwell. 1992.** The 4P approach to dealing with scientific uncertainty. *Environment* 34:12-20,42.

# Sustainable Trade:

**Remove environmental and labor externalities FIRST (via the previous methods) THEN allow trade to occur. This will allow trade to create real, socially beneficial gains, rather than mislabeling externalized costs as benefits of trade.**

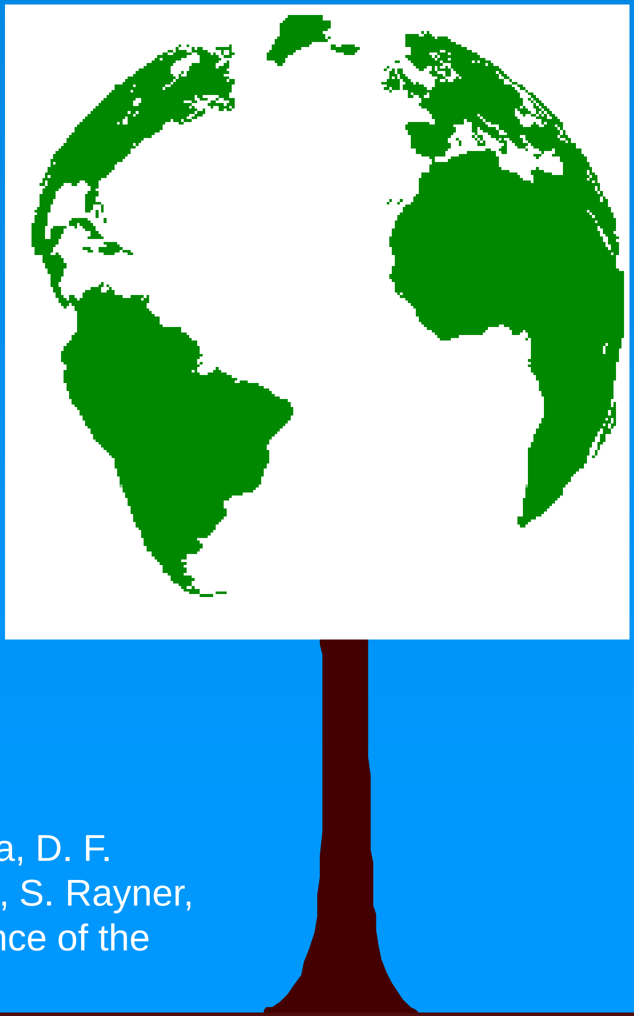


**See: Ekins, P., C. Folke, and R. Costanza. 1994**. Trade, environment and development: the issues in perspective. *Ecological Economics* 9:1-12.

**Costanza, R., J. Audley, R. Borden, P. Ekins, C. Folke, S. O. Funtowicz, and J. Harris. 1995**. Sustainable trade: a new paradigm for world welfare. *Environment* 37:16-20, 39-44.

# Lisbon Principles of Sustainable Governance:

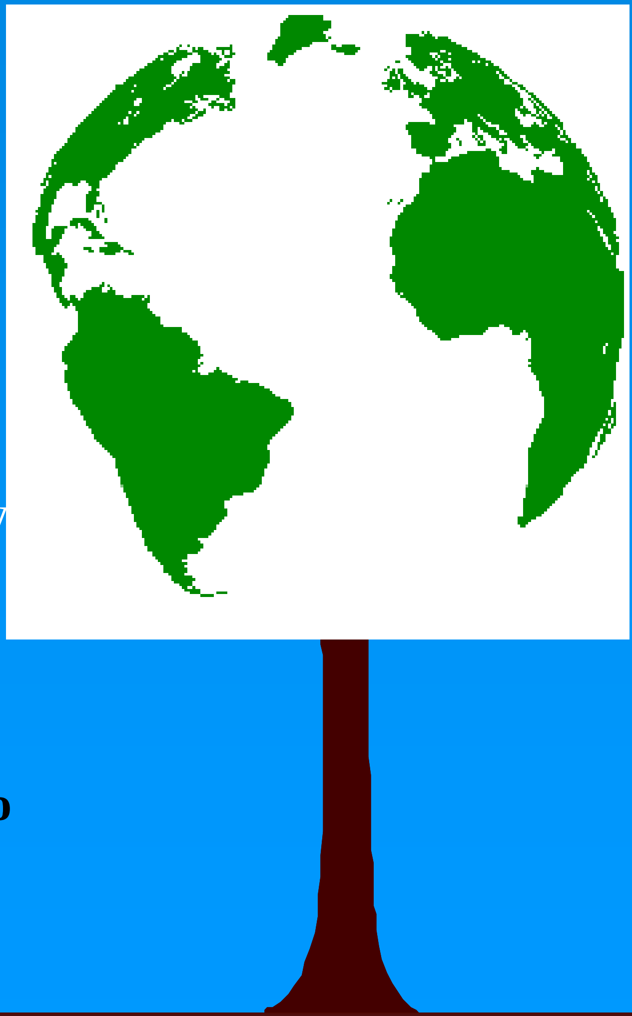
1. Responsibility Principle
2. Scale-Matching Principle
3. Precautionary Principle
4. Adaptive Management Principle
5. Full Cost Allocation Principle
6. Participation Principle



**From:** Costanza, R. F. Andrade, P. Antunes, M. van den Belt, D. Boersma, D. F. Boesch, F. Catarino, S. Hanna, K. Limburg, B. Low, M. Molitor, G. Pereira, S. Rayner, R. Santos, J. Wilson, M. Young. 1998. Principles for sustainable governance of the oceans. *Science* 281:198-199.

# Conclusions:

- The environment is not a luxury good.  Ecosystem services contribute to human welfare and survival in innumerable ways, both directly and indirectly, and represent the majority of economic value on the planet, especially for the "poor".
- Ecosystem services, and the natural capital stocks that produce them, have been depleted and degraded by human actions to the point that the sustainability of the system is threatened.
- A Sustainable and Desirable Earth (Ecotopia/Adapting Mosaic) scenario would **increase** the sustainable quality of life of people on earth significantly over a Business as Usual scenario.
- A sustainable and desirable future is both possible and practical, but we first have to create and communicate the **vision** of that world in compelling terms.  **We have to design the future.**



# Surprise Washington! US is already halfway to Kyoto!

(from: Fisher, B and R. Costanza. 2005. Regional commitment to reducing emissions. *Nature* 438:301-302

| | Population (thousands) | % of Total US Population | Gross Product 2003 (billions) | % of Total GDP |
|---|---|---|---|---|
| **Current Adopters** | | | | |
| California*** | 35,484 | 12.19% | 1,446 | 13.26% |
| Connecticut* | 3,483 | 1.20% | 172 | 1.58% |
| Maine* | 1,306 | 0.45% | 41 | 0.38% |
| Massachusetts* | 6,433 | 2.21% | 297 | 2.73% |
| New Hampshire* | 1,288 | 0.44% | 49 | 0.45% |
| New Mexico** | 1,875 | 0.64% | 57 | 0.52% |
| New York* | 19,190 | 6.59% | 822 | 7.53% |
| Rhode Island* | 1,076 | 0.37% | 40 | 0.36% |
| Vermont* | 619 | 0.21% | 21 | 0.19% |
| Subtotal | 70,755 | 24.31% | 2,945 | 26.99% |
| **Probable Adopters** | | | | |
| New Jersey | 8,638 | 2.97% | 397 | 3.64% |
| Oregon | 3,560 | 1.22% | 120 | 1.10% |
| Washington | 6,131 | 2.11% | 245 | 2.24% |
| Subtotal | 18,329 | 6.30% | 763 | 6.99% |
| **Possible Adopters** | | | | |
| 25 US Municipalities | 12,774 | 4.38% | 1,673 | 15.34% |
| **Totals** | | | | |
| Current Adopters | 70,755 | 24.31% | 2,945 | 26.99% |
| SUM (Current, Probable, Possible) | 101,859 | 34.99% | 5,381 | 49.32% |
| **United States** | 291,000 | | 10,911 | |

*Pledged 10% reduction, below 1990 levels by 2020

** Pledged 10% reduction, below 2000 levels by 2020

*** Pledged to reach 1990 levels by 2020

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.