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Understanding, Modeling, and Valuing Ecosystem Services

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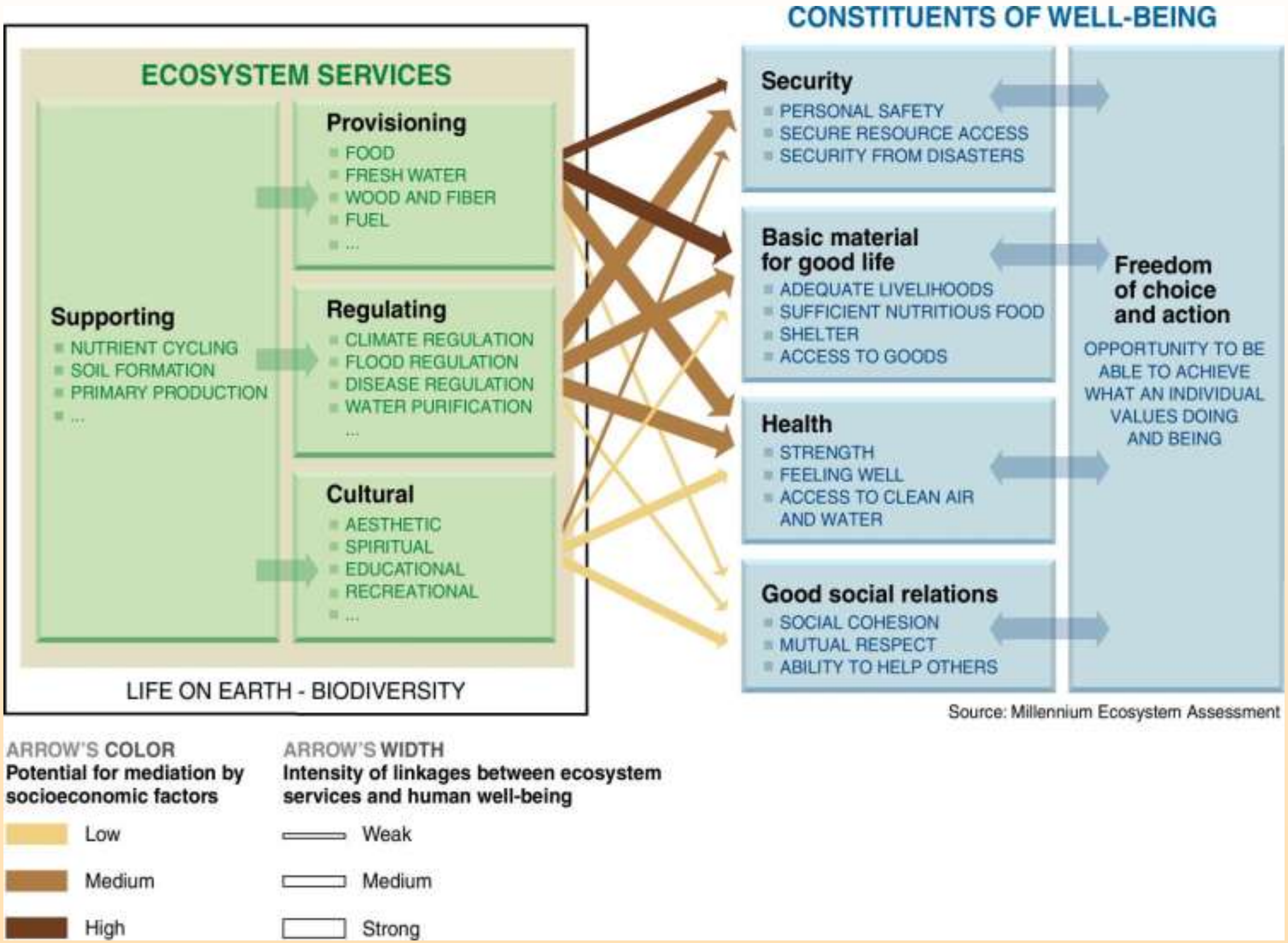
Ecosystem Services: the benefits humans derive from ecosystems



Four levels of ecosystem service analysis:

Basic value transfer - assumes values constant over ecosystem type (e.g. Nature paper global assessment - New Jersey study)

Expert modified value transfer - adjust values for local ecosystem conditions with expert opinion surveys (e.g. Puget Sound study)

Statistical value transfer - build statistical model of spatial and other dependencies (e.g. Liu et al. Coastal and Near-shore example)

Spatially Explicit Functional Modeling incorporating valuation. e.g.

Statistical (Hurricane protection)

Dynamic Systems (Patuxent, GUMBO, MIMES)

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

Table 2. Categories of ecosystem services and economic methods for valuation.

Ecosystem service	Amenability to economic valuation	Most appropriate method for valuation	Transferability across sites
Gas regulation	Medium	CV, AC, RC	High
Climate regulation	Low	CV	High
Disturbance regulation	High	AC	Medium
Biological regulation	Medium	AC, P	High
Water regulation	High	M, AC, RC, H, P, CV	Medium
Soil retention	Medium	AC, RC, H	Medium
Waste regulation	High	RC, AC, CV	Medium to high
Nutrient regulation	Medium	AC, CV	Medium
Water supply	High	AC, RC, M, TC	Medium
Food	High	M, P	High
Raw materials	High	M, P	High
Genetic resources	Low	M, AC	Low
Medicinal resources	High	AC, RC, P	High
Ornamental resources	High	AC, RC, H	Medium
Recreation	High	TC, CV, ranking	Low
Aesthetics	High	H, CV, TC, ranking	Low
Science and education	Low	Ranking	High
Spiritual and historic	Low	CV, ranking	Low

AC, avoided cost; CV, contingent valuation; H, hedonic pricing; M, market pricing; P, production approach; RC, replacement cost; TC, travel cost.

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.

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 Farber, Monica Grasso, Bruce Hannon, Karin Limburg, Shahid Naeem, Robert V. O'Neill, Jose Paruelo, Robert G. Raskin, Paul Sutton & Marjan van den Belt

*

The services of ecological systems and the natural capital stocks that 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, this must be considered a minimum estimate. Global gross national product total is around US$18 trillion per year.

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

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**

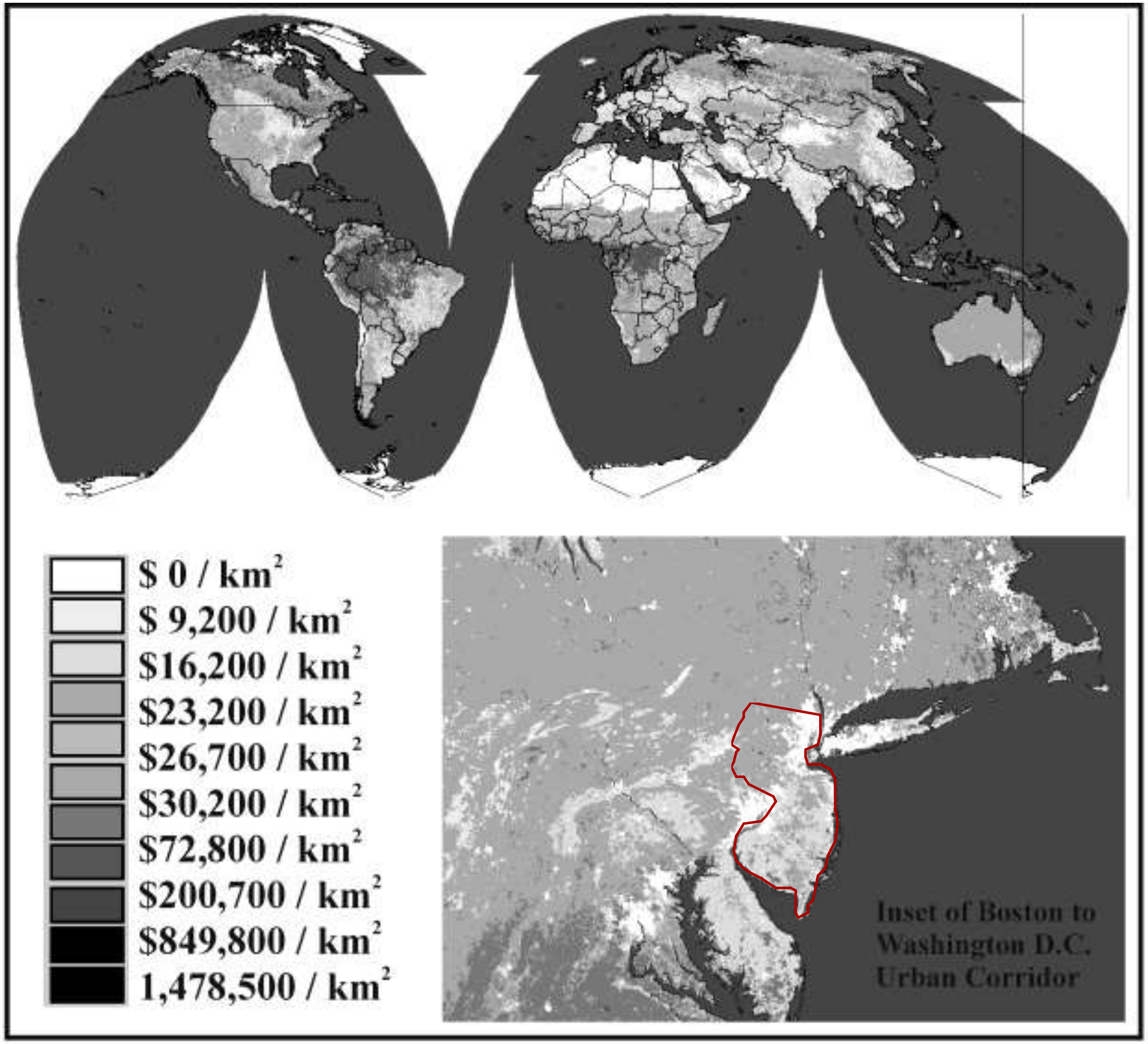


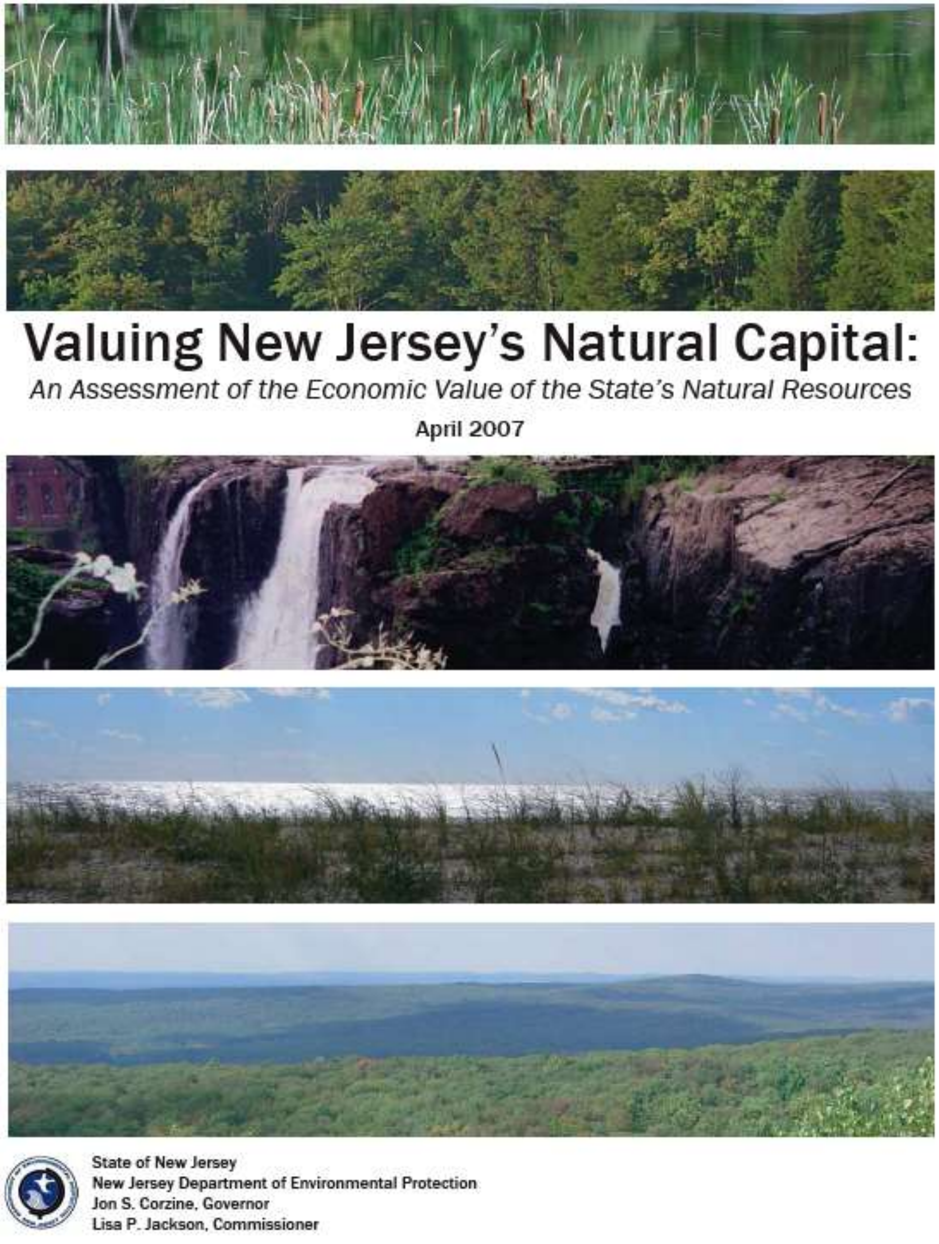
Figure 3: Global Map of Non-Marketed Economic Activity (ESP) arising from Ecosystem Services and derived from Land Cover at 1 km^2 (For National Totals See Table 1)

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

http://www.nj.gov/dep/dsr/naturalcap/



The Value of New Jersey's Ecosystem Services and Natural Capital

Robert Costanza
Matthew Wilson
Austin Troy
Alexey Voinov
Shuang Liu
John D'Agostino

Gap Analysis (Type A)

Ecosystem Service	Land Use: Fresh Wetland	Salt Wetland	Estuary	Open Fresh-water	Beach	Riparian Buffer	Forest	Cropland	Urban Green-space	Pasture
Gas & climate regulation							2		2	
Disturbance prevention		2			2	1				
Water regulation	1								1	
Water supply	5		3	5		7				
Soil retention & formation										1
Nutrient regulation										
Waste treatment		1								
Pollination								2		
Biological Control										
Refugium & wildlife conservation	1	4	2			1	4			
Aesthetic & Recreational	5	3	3	9	4	7	9	1	1	1
Cultural & Spiritual		1			1	1				

Total Filled Cells: 32/120 = 27%

Total Estimates: 93

Average Estimates per cell: 2.9

Gap Analysis (Types A-C)

Ecosystem Service	Land Use: Fresh Wetland	Salt Wetland	Estuary	Open Fresh-water	Beach	Riparian Buffer	Forest	Cropland	Urban Green-space	Pasture
Gas & climate regulation	*1						2		2	*1
Disturbance prevention	*1	*3	*1		2	1				
Water regulation	*2			*1					1	*1
Water supply	*6		3	5		7				
Soil retention & formation							*1			*2
Nutrient regulation			*1							
Waste treatment	*1	*2					*1			*1
Pollination								2		*1
Biological Control			*1				*1			*1
Refugium & wildlife conservation	*2	*5	*3			1	4			
Aesthetic & Recreational	*6	3	*4	*10	4	7	*10	1	1	*2
Cultural & Spiritual	*1	1	*1		1	1	*1			

* Indicates reference added from Costanza et. al. (1997)

Total Filled Cells: 50/120 = 42%

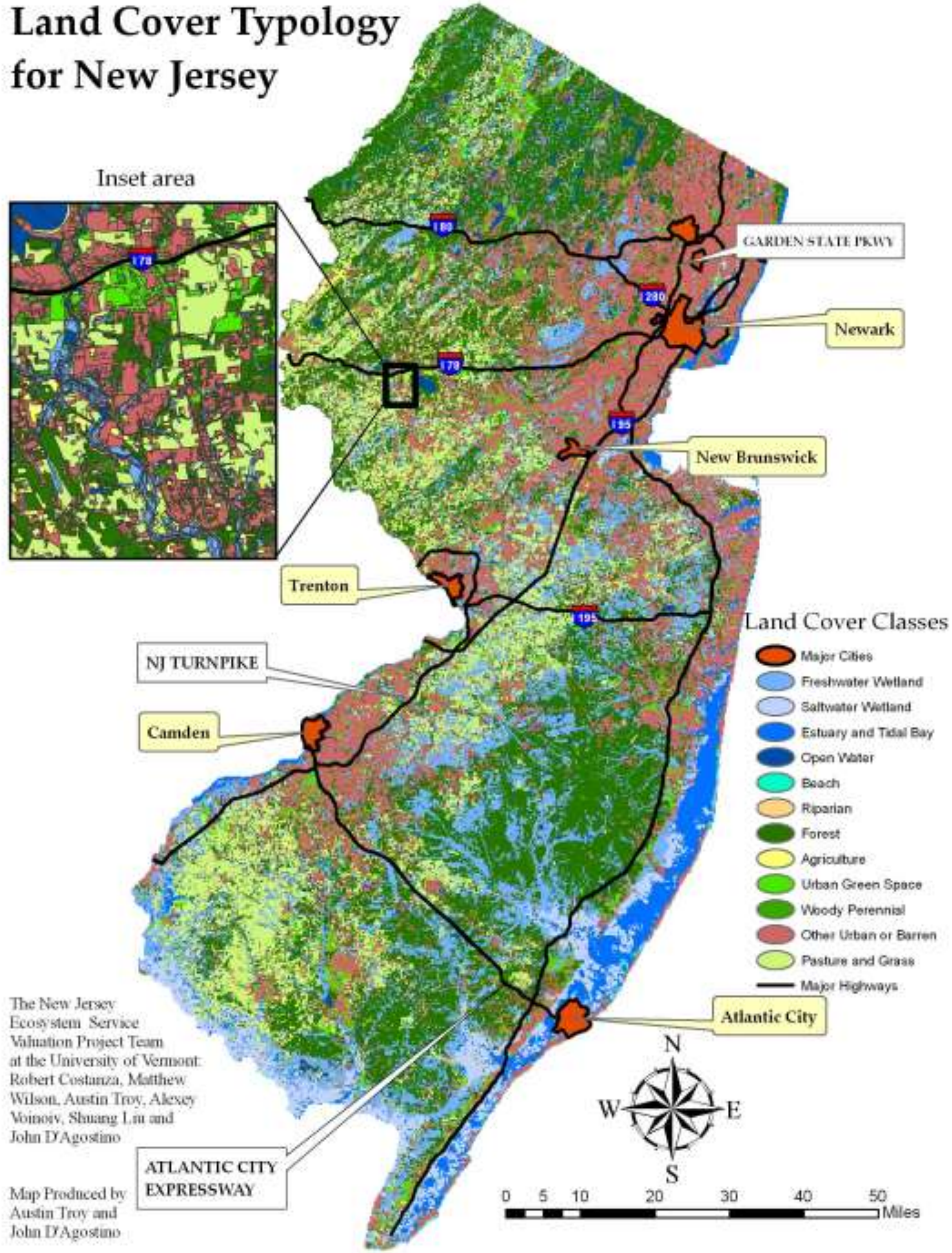
Total Estimates: 125

Average Estimates per cell: 2.5

Values by Ecosystem for the New Jersey Study

Ecosystem	Acreage	ESV Flows per acre (all studies used) 2004 $/ac/yr	ESV Flows Totals (all studies used) MM 2004 $/yr
Forested wetland	633,380	$11,568	$7,327
Estuary and tidal bay	455,700	11,653	5,310
Forest (excl. wetlands)	1,465,668	1476	2,163
Unforested wetland	181,099	11,568	2,095
Saltwater wetland	190,520	6,131	1,168
Cropland	546,261	866	473
Urban greenspace	169,550	2,473	419
Coastal shelf	299,835	1,299	389
Beach and dune	7,837	42,149	330
Open fresh water	86,232	765	66
Riparian buffer	15,146	3,382	51
Pasture/grassland	127,203	77	10
Barren land	51,796	0	0
Urban (developed)	1313946	0	0
	5,544,173	**$3,572**	**$19,802**
PV (3% in perpetuity)		**$119,067**	**$660,067**

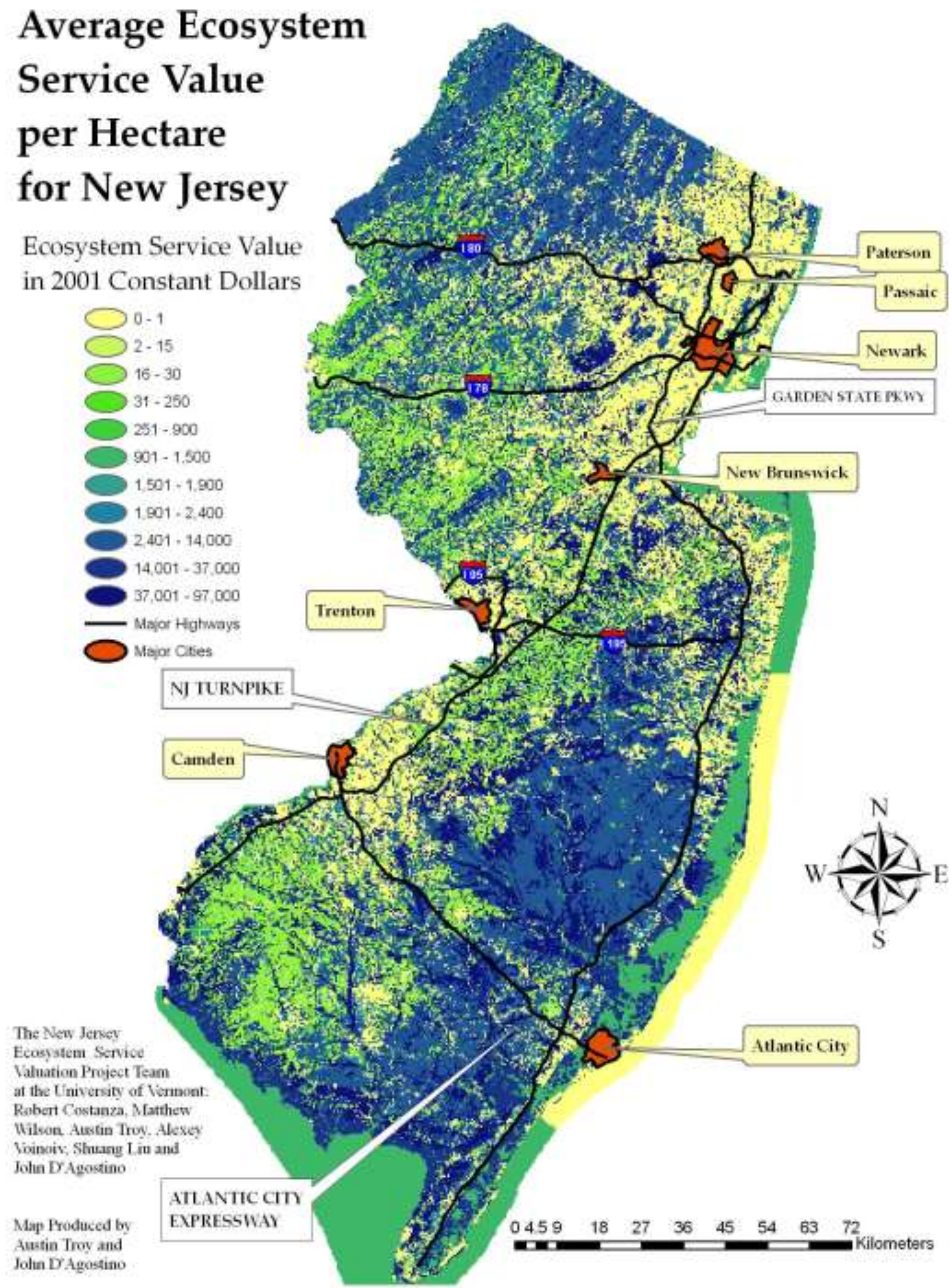
Land Cover Typology for New Jersey



Valuation of New Jersey's Natural Capital and Ecosystem Services

Contract # SR04-075

New Jersey Department of Environmental Protection



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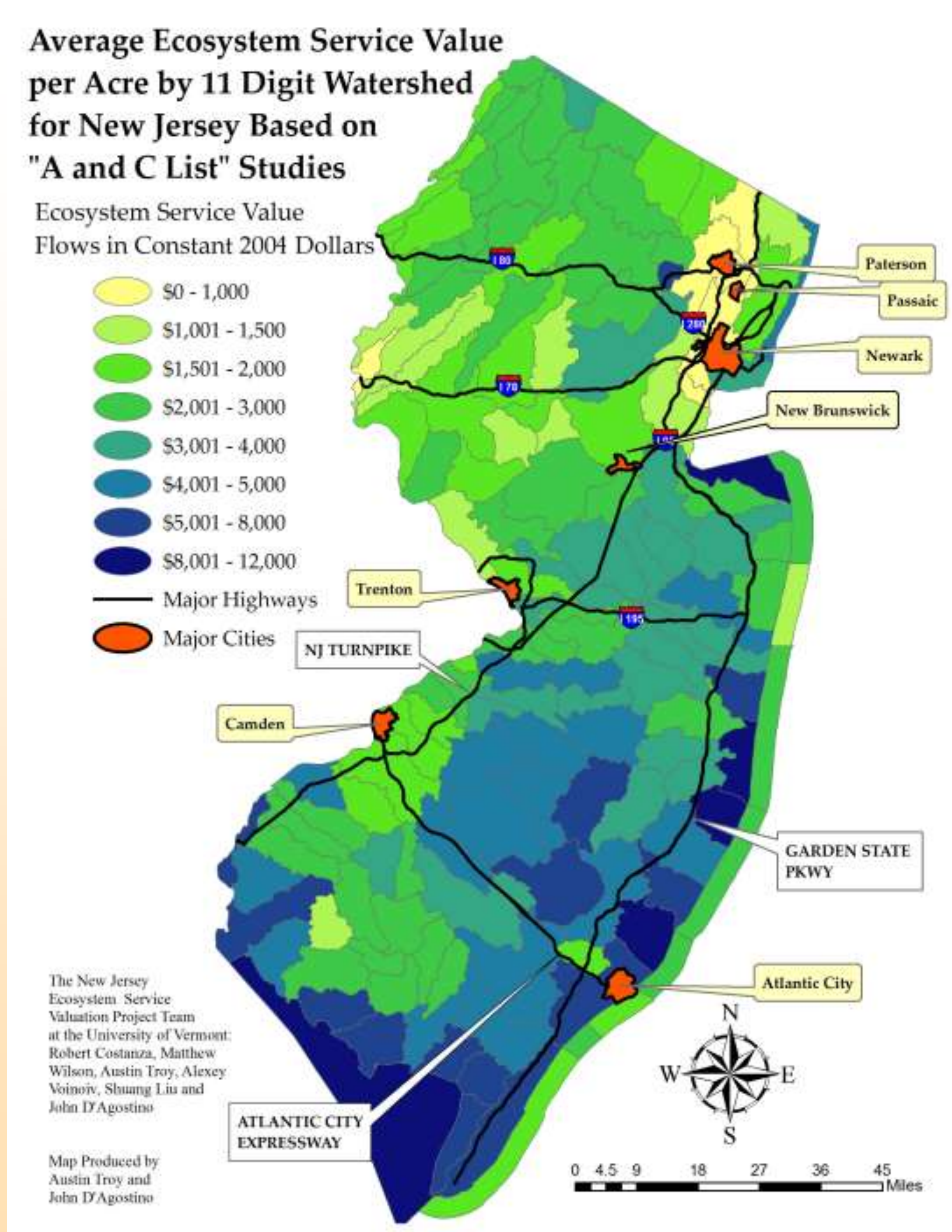


EcoServices classified according to spatial characteristics

1. Global-Non Proximal (does not depend on proximity)

- **1&2. Climate Regulation**
  - Carbon sequestration (NEP)
  - Carbon storage
- 17. Cultural/Existence value

2. Local Proximal (depends on proximity)

- *3. Disturbance Regulation/ Storm protection*
- 9. Waste Treatment
- 10. Pollination
- 11. Biological Control
- 12. Habitat/Refugia

3. Directional Flow-Related: flow from point of production to point of use

- 4. Water regulation/flood protection
- 5. Water supply
- 6. Sediment regulation/Erosion control
- 8. Nutrient regulation

4. In situ (point of use)

- 7. Soil formation
- 13. Food production/Non-timber forest products
- 14. Raw materials

5. User movement related: flow of people to unique natural features

- 15. Genetic resources
- 16. Recreation potential
- 17. Cultural/Aesthetic

From: Costanza, R., 2008. Ecosystem Services: Multiple classification systems are needed. *Biological Conservation* 141:350-352

Gund Institute for Ecological Economics University of Vermont

A META-ANALYSIS OF ECOSYSTEM SERVICE VALUATION IN COASTAL AND NEAR-SHORE MARINE ECOSYSTEMS

Shuang Liu, David Stern and Matthew Wilson

Meta-analysis

- 122 observations from 40 CV studies
- Y: WTP in USD2006/(household year)
- Xs: 3 categories 50 variables
- The estimated model

$$Ln\,(y) = a + Xcbc + Xmbm + Xqbq + u$$

Commodity consistency

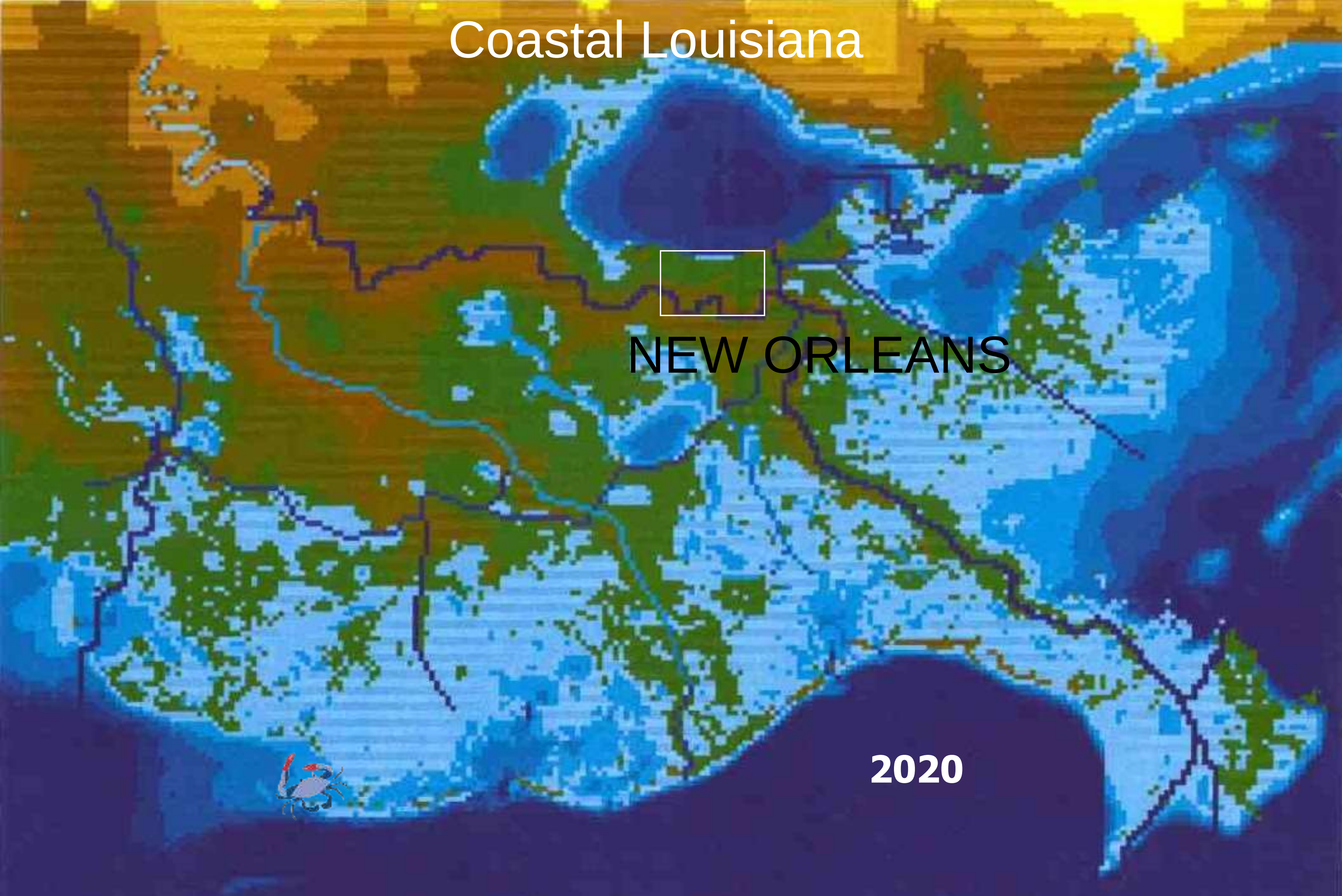
Methodology consistency

Quality consistency (publication year & primary data only?)

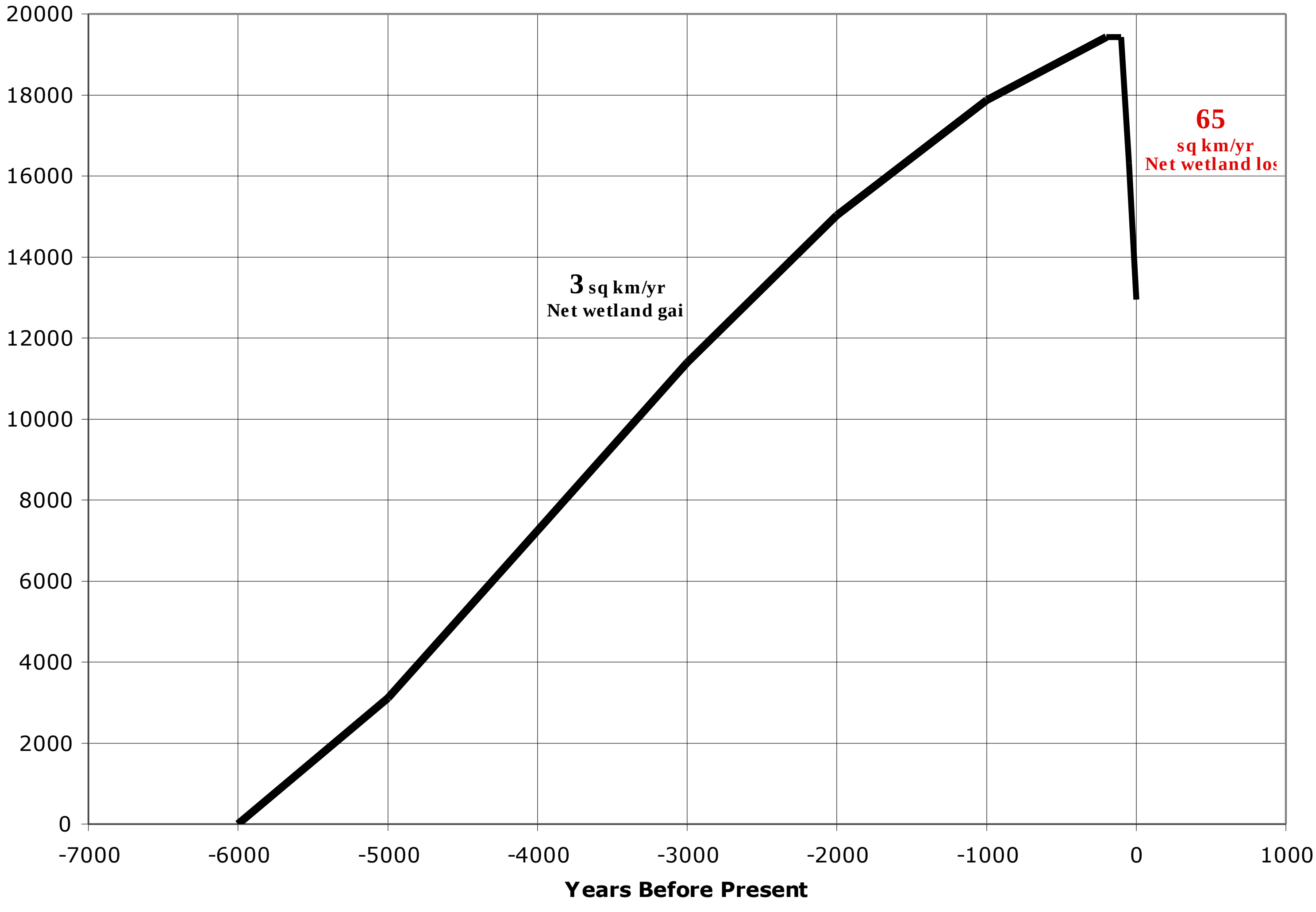
Meta-regression

- Ordinary Least Squares (OLS) model
- Stepwise regression, 25 explanatory variables left ($P<0.1$), df = 96, RATS software
- **Adjusted R^2 = 79.4%**
- Passed heteroscedasticity test but residuals are not normally distributed, though both factors were taken into account when running the model

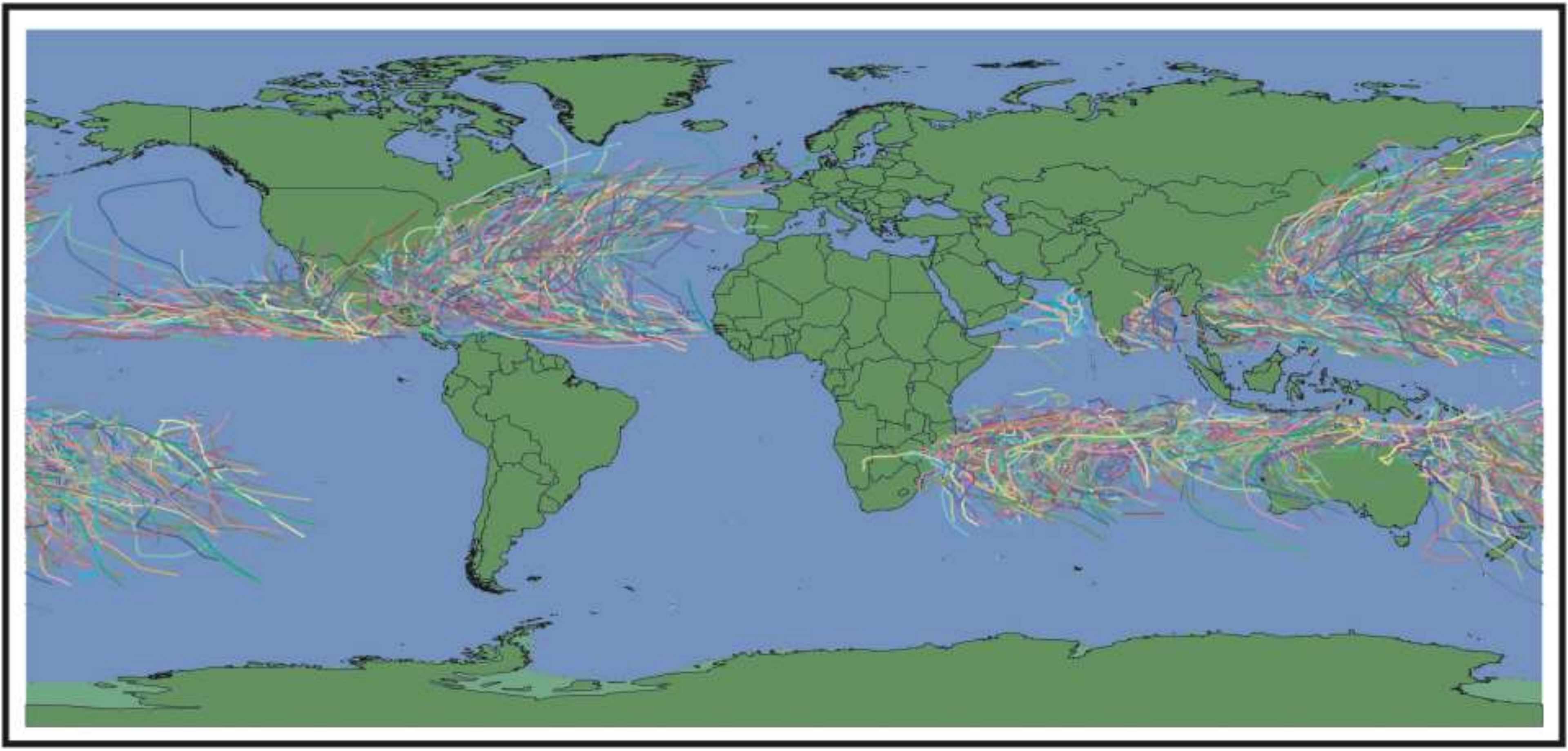
Picture taken by an automatic camera located at an electrical generating facility on the Gulf Intracoastal Waterway (GIWW) where the Route I-510 bridge crosses the GIWW. This is close to where the Mississippi River Gulf Outlet (MRGO) enters the GIWW. The shot clearly shows the storm surge, estimated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



Past and Projected Wetland Loss in the Mississippi Delta (1839 to 2020)



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.



Global Storm Tracks 1980 - 2006

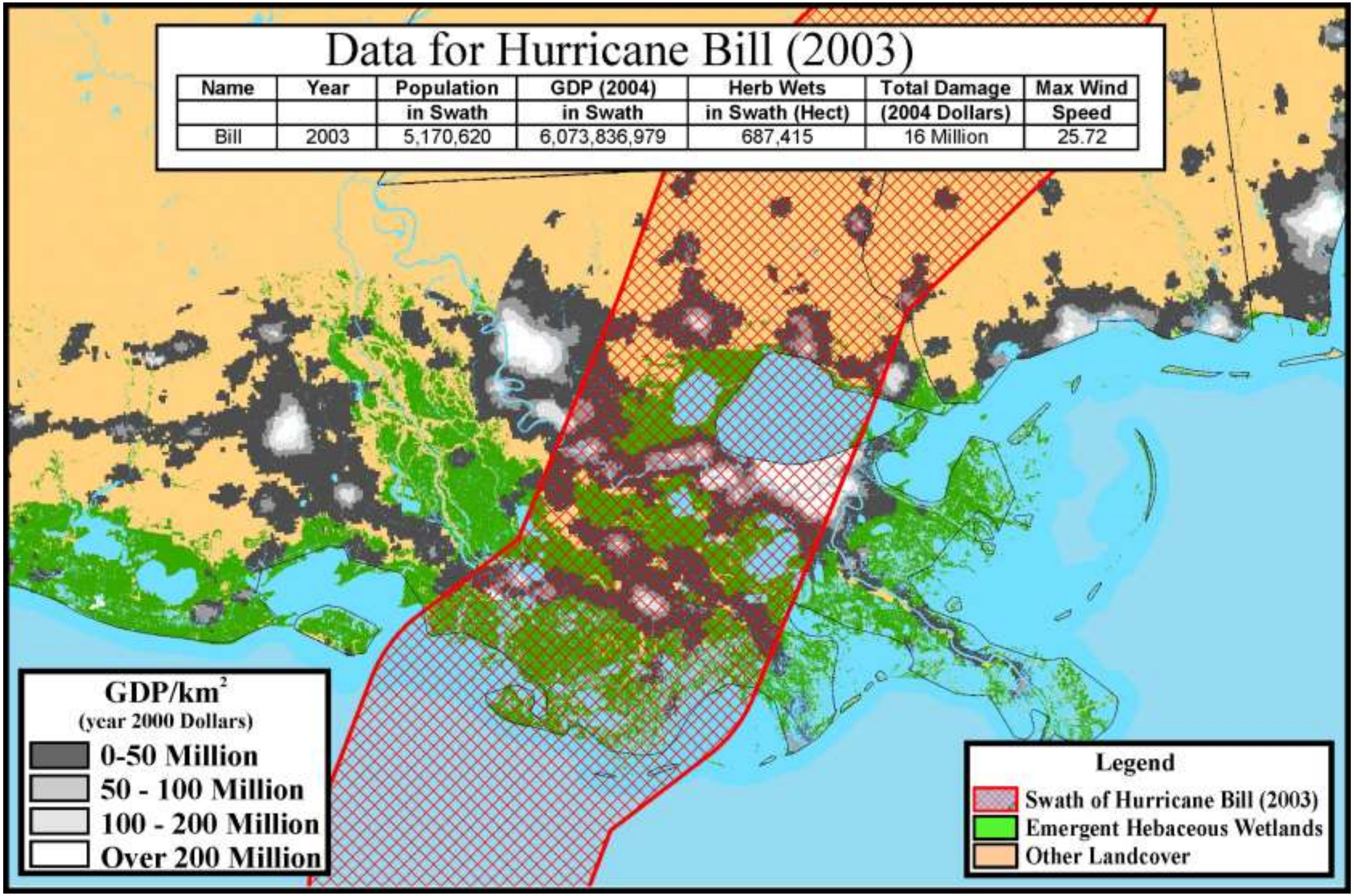


Figure 1. Typical hurricane swath showing GDP and wetland area used in the analysis.

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*

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

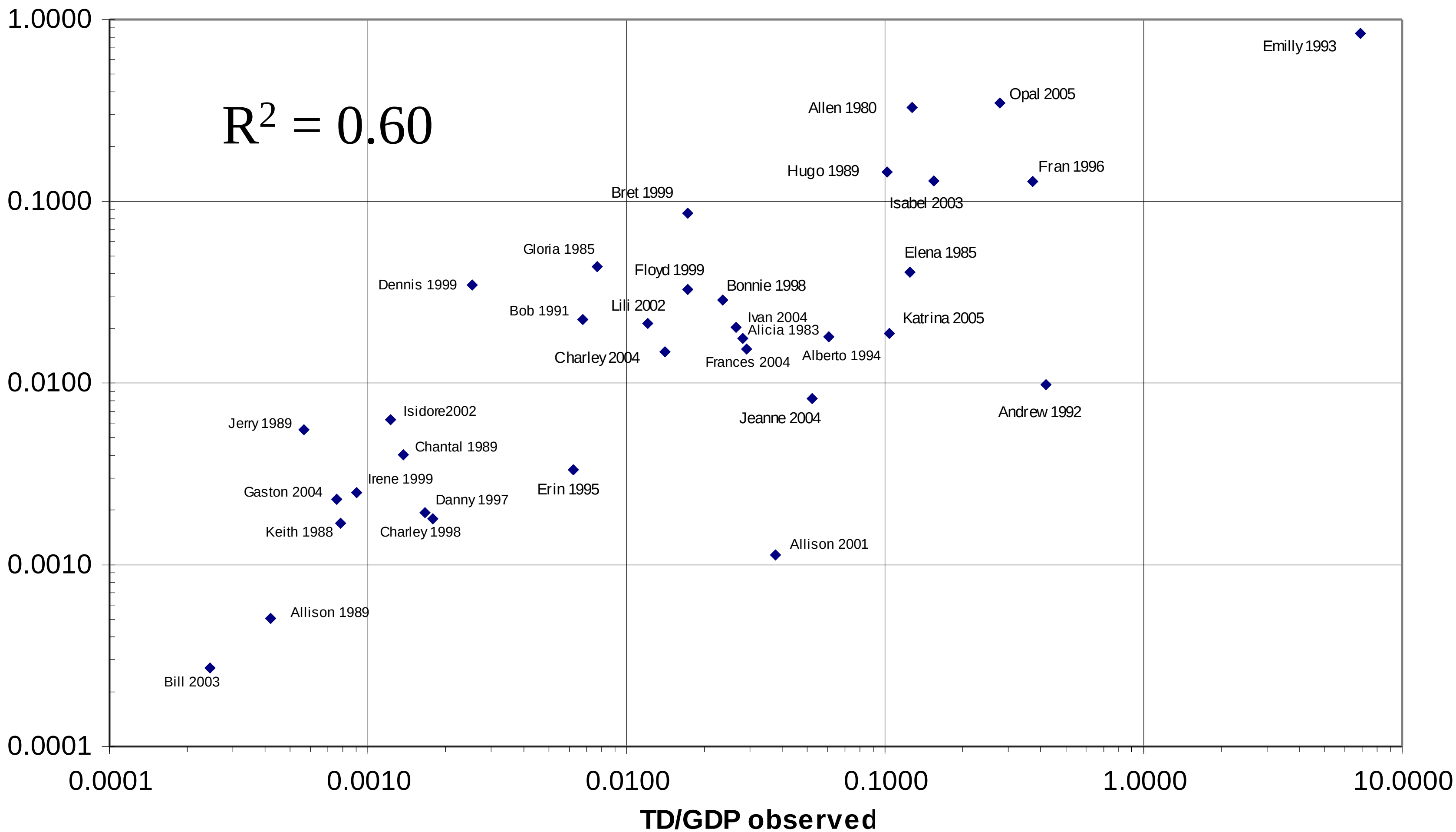
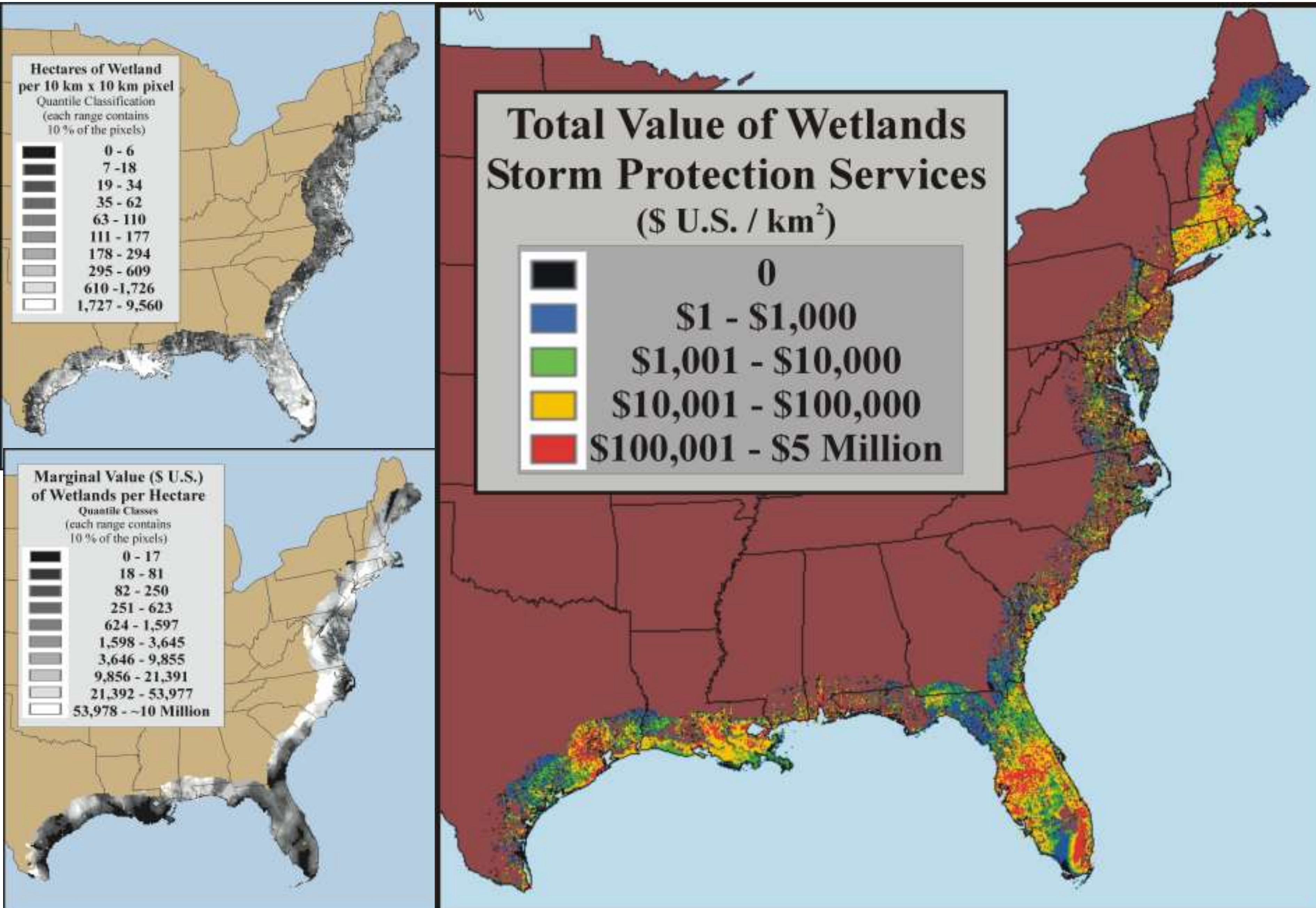


Figure 2. Observed vs. predicted relative damages (TD/GDP) for each of the hurricanes used in the analysis.


Hectares of Wetland
per 10 km x 10 km pixel
Quantile Classification
(each range contains
10 % of the pixels)
0 - 6
7 -18
19 - 34
35 - 62
63 - 110
111 - 177
178 - 294
295 - 609
610 -1,726
1,727 - 9,560
Marginal Value ($ U.S.)
of Wetlands per Hectare
Quantile Classes
(each range contains
10 % of the pixels)
0 - 17
18 - 81
82 - 250
251 - 623
624 - 1,597
1,598 - 3,645
3,646 - 9,855
9,856 - 21,391
21,392 - 53,977
53,978 - ~10 Million
Total Value of Wetlands
Storm Protection Services
($ U.S. / km²)
0
$1 - $1,000
$1,001 - $10,000
$10,001 - $100,000
$100,001 - $5 Million

•A loss of 1 ha of wetland in the model corresponded to an average $33,000 (median = $5,000) increase in storm damage from specific storms.

•Taking into account the annual probability of hits by hurricanes of varying intensities, the annual value of coastal wetlands ranged from $250 to $51,000/ha/yr, with a mean of $8,240/ha/yr (median = $3,230/ha/yr)

• Coastal wetlands in the US were estimated to currently provide $23.2 Billion/yr in storm protection services.

From: Costanza, R., O. Pérez-Maqueo, M. L. Martinez, P. Sutton, S. J. Anderson, and **K. Mulder**. 2008. The value of coastal wetlands for hurricane protection. *Ambio* 37:241-248

Integrated Modeling of Humans Embedded in Ecological Systems

- **Intelligent Pluralism (Multiple Modeling Approaches), Testing, Cross-Calibration, and Integration**
- **Multi-scale in time, space, and complexity**
- **Can be used as a Consensus Building Tool in an Open, Participatory Process**
- **Acknowledges Uncertainty and Limited Predictability**
- **Acknowledges Values of Stakeholders**
- **Evolutionary Approach Acknowledges History, Limited Optimization, and the Co-Evolution of Human Culture and Biology with the Rest of Nature**

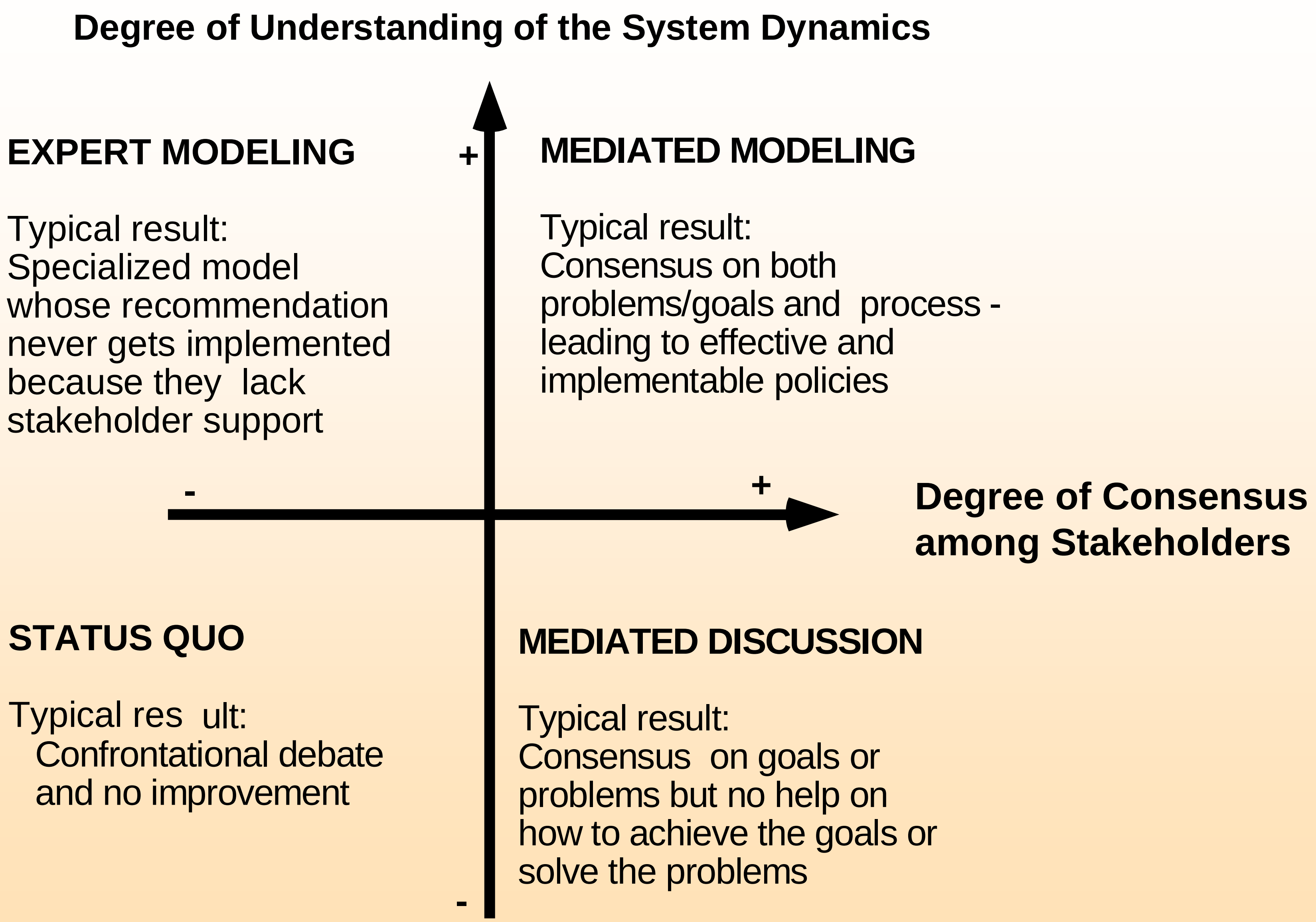
Three complementary and synergistic ways to include humans in integrated models:

1. **As "stakeholders" and active participants in the model conceptualization, development, construction, testing, scenario development, and implementation processes.**

2. **As "players" of the models where the model is used as both a decision aid and as a research tool to better understand human behavior in complex valuation and decision processes.**

3. **As "agents" programmed into the model based on better understanding of their goals and behavior gleaned through 1 and 2.**

Major opportunities exist to enhance acceptance of ecosystem service models for decision-making by clients, especially local and state governments through *participation*



From: Van den Belt, M. 2004. Mediated Modeling: A System Dynamics Approach To Environmental Consensus Building. Island Press, Washington, DC.

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.

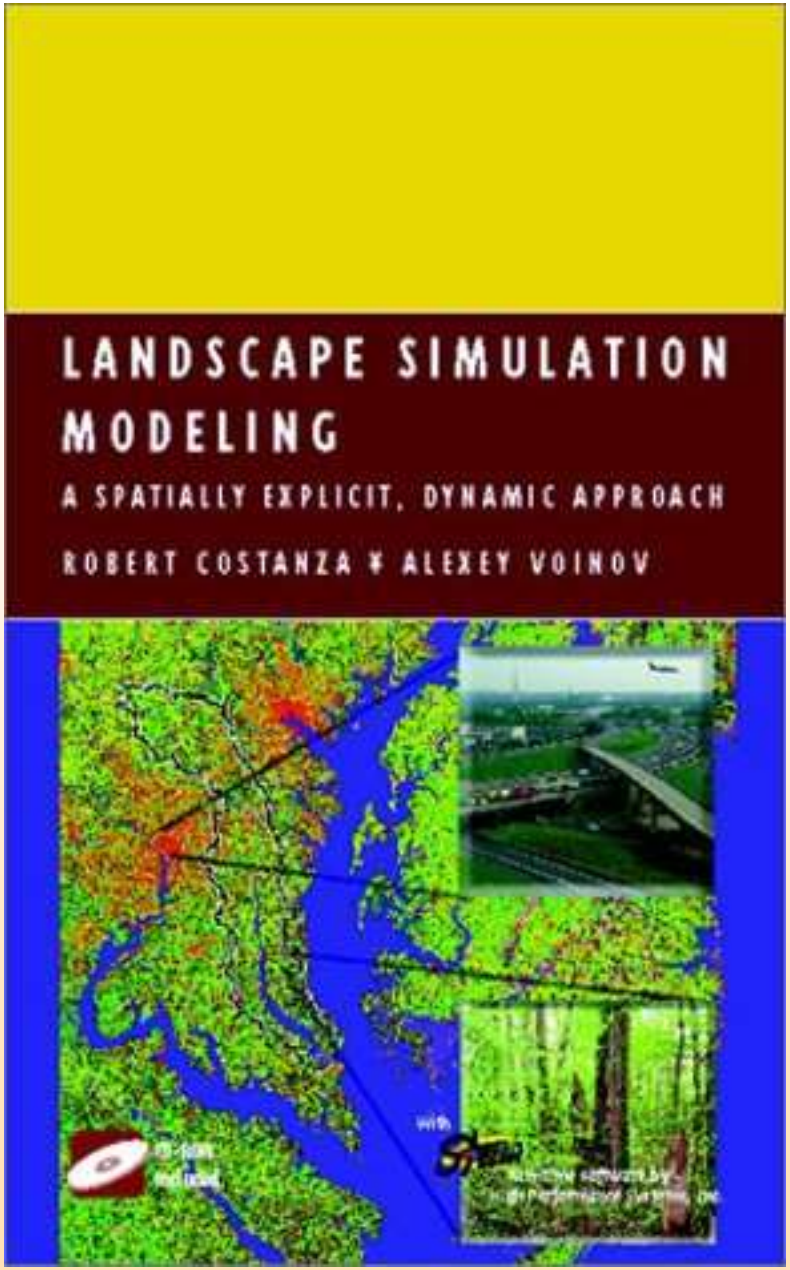
3. Management Models

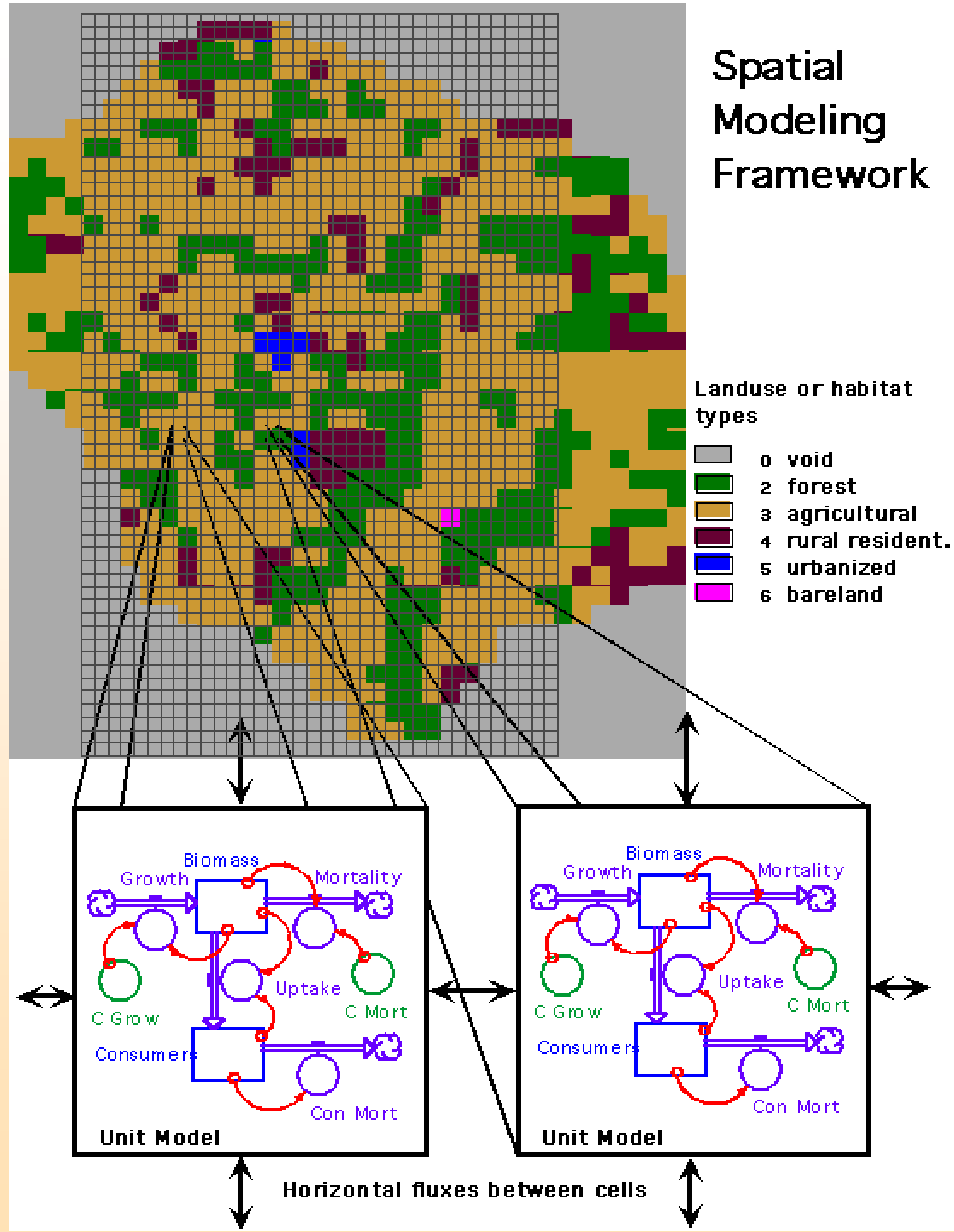
medium to high resolution models based on the previous two stages with the emphasis on producing future management scenarios - can be simply exercising the scoping or research models or may require further elaboration to allow application to management questions

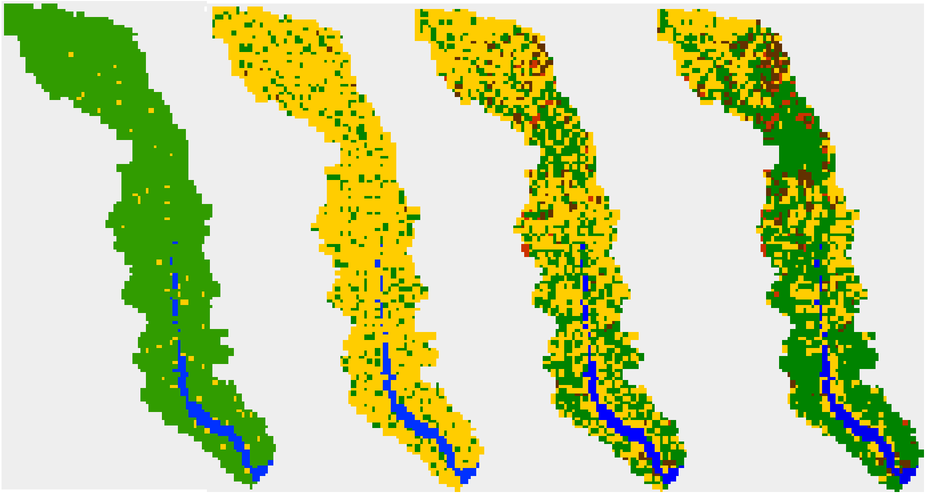
Increasing Complexity, Cost, Realism, and Precision

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

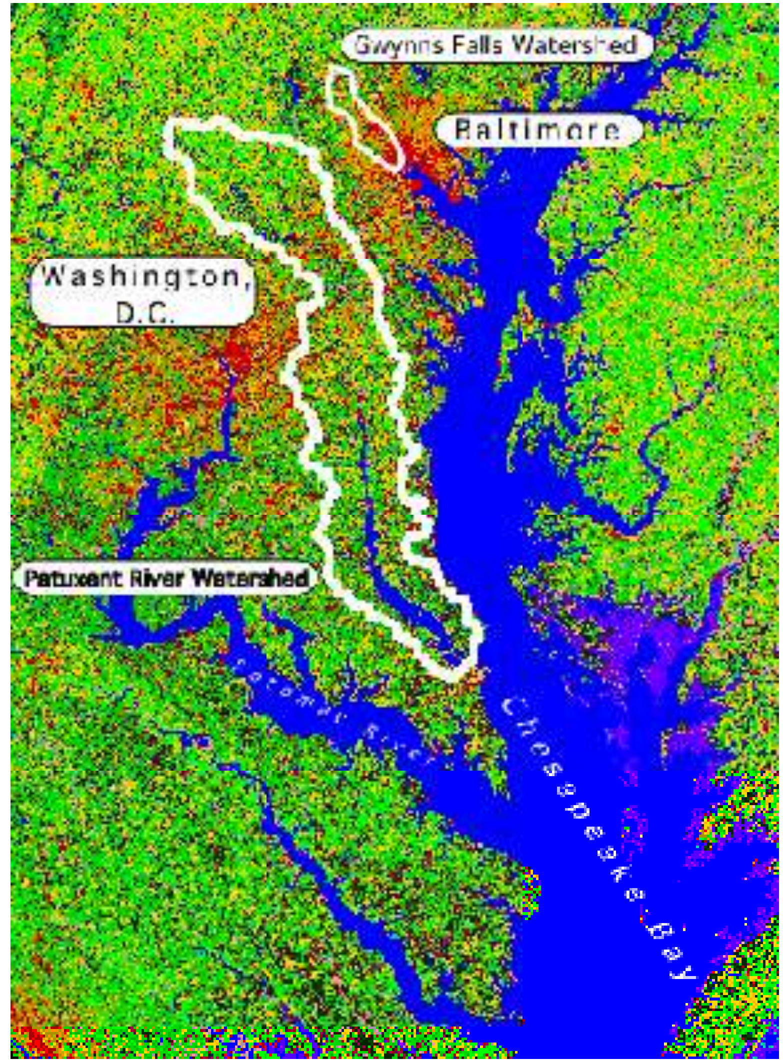
Spatial Modeling Framework







	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

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.

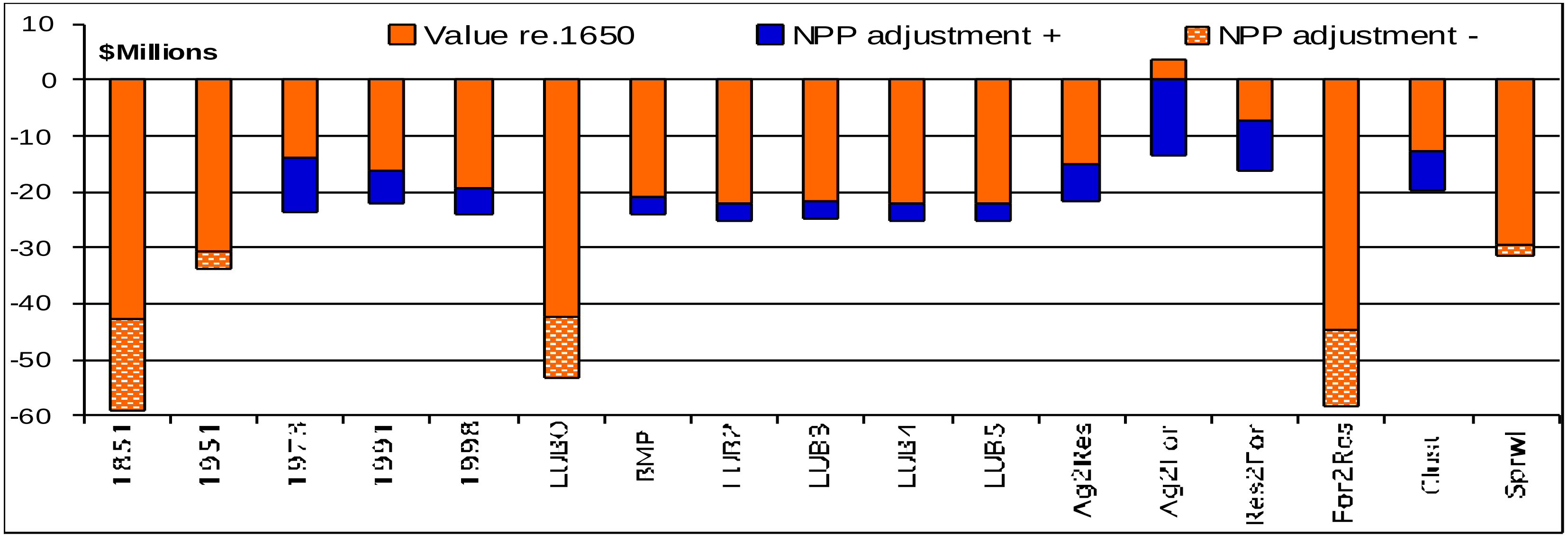
Patuxent Watershed Scenarios*

		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

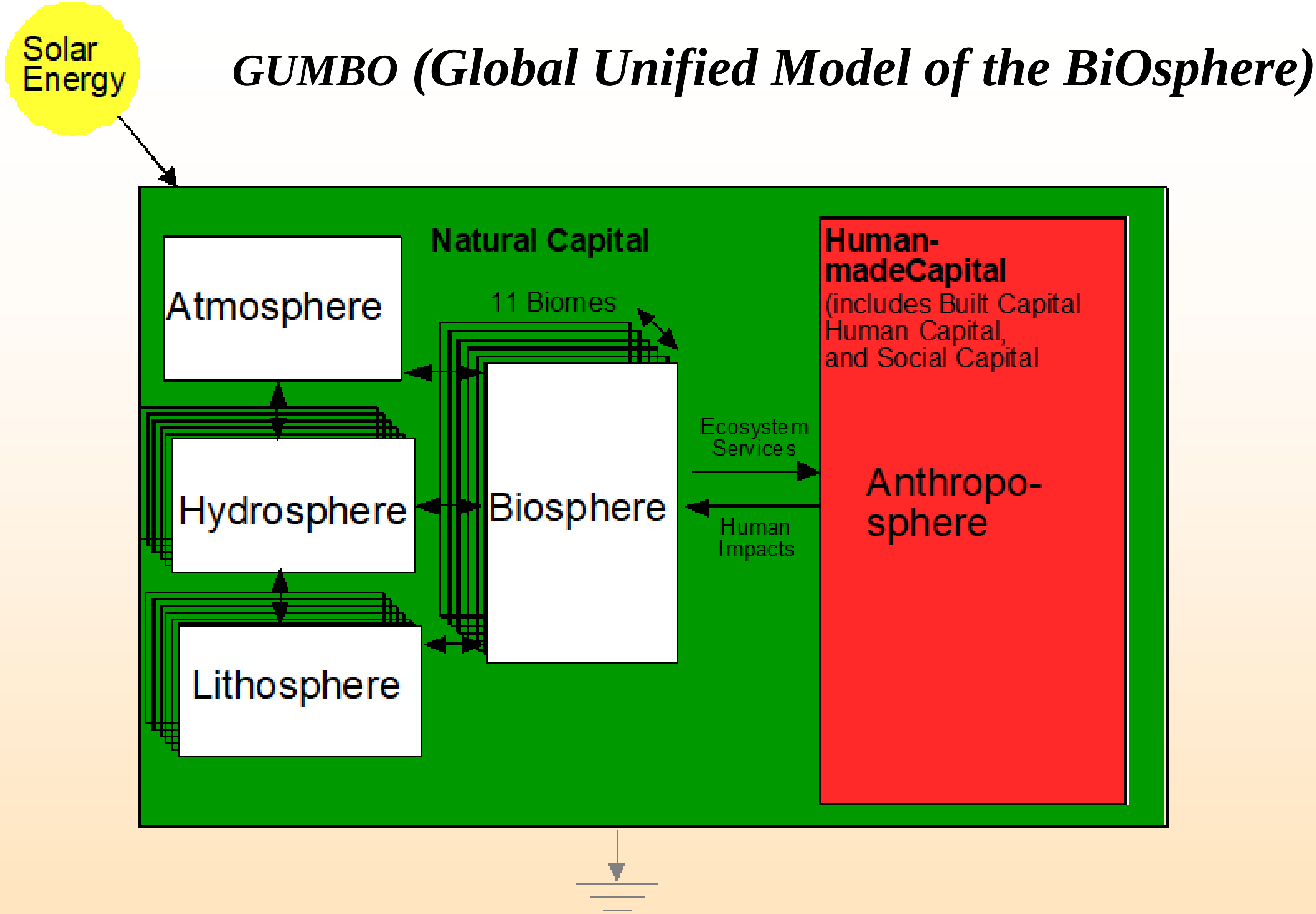
* From: Costanza, R., A. Voinov, R. Boumans, T. Maxwell, F. Villa, L. Wainger, and H. Voinov. 2002. Integrated ecological economic modeling of the Patuxent River watershed, Maryland. *Ecological Monographs* 72:203-231.

Results

Ecosystem service value by scenario in the Patuxent watershed



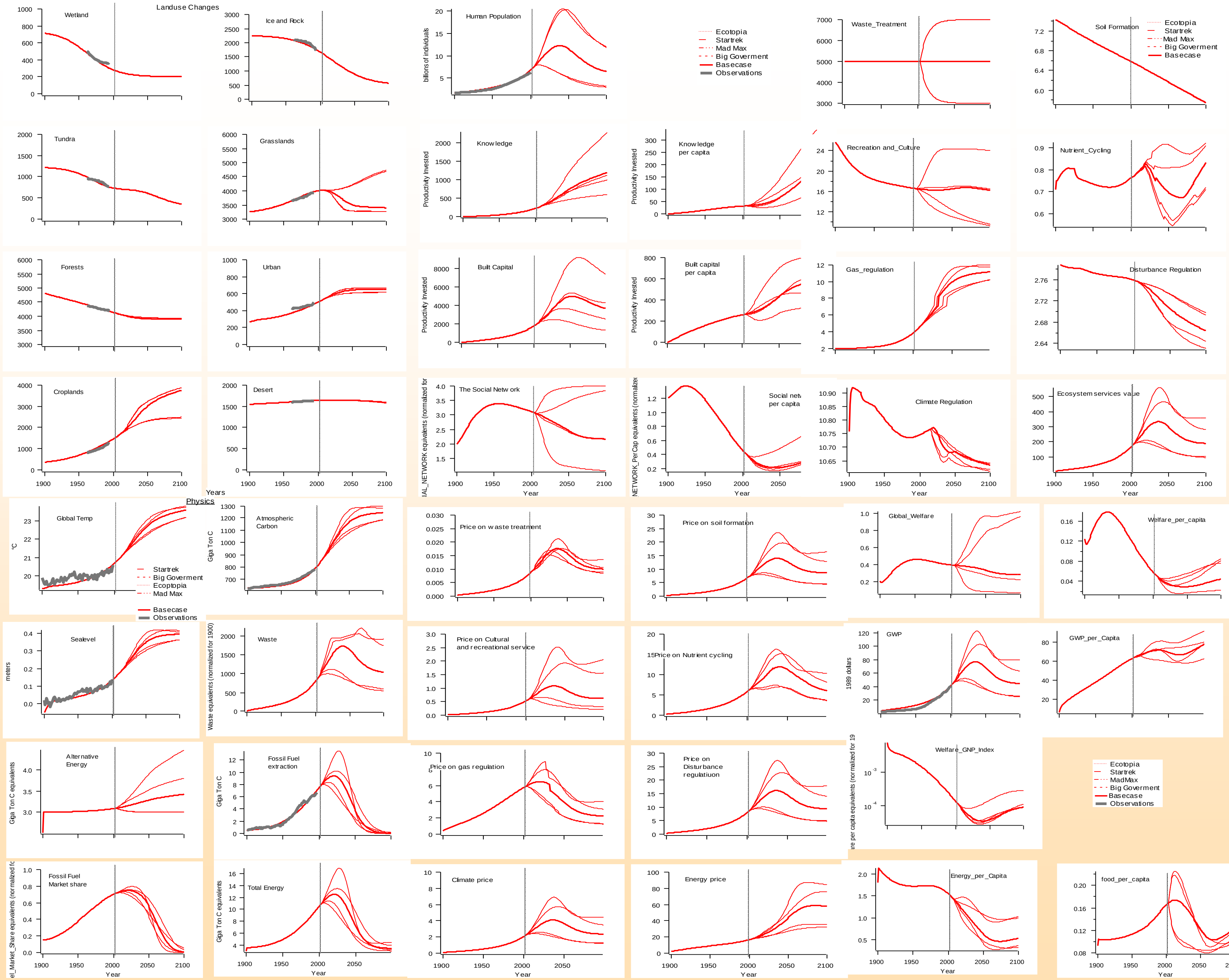
GUMBO (Global Unified Model of the BiOsphere)



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

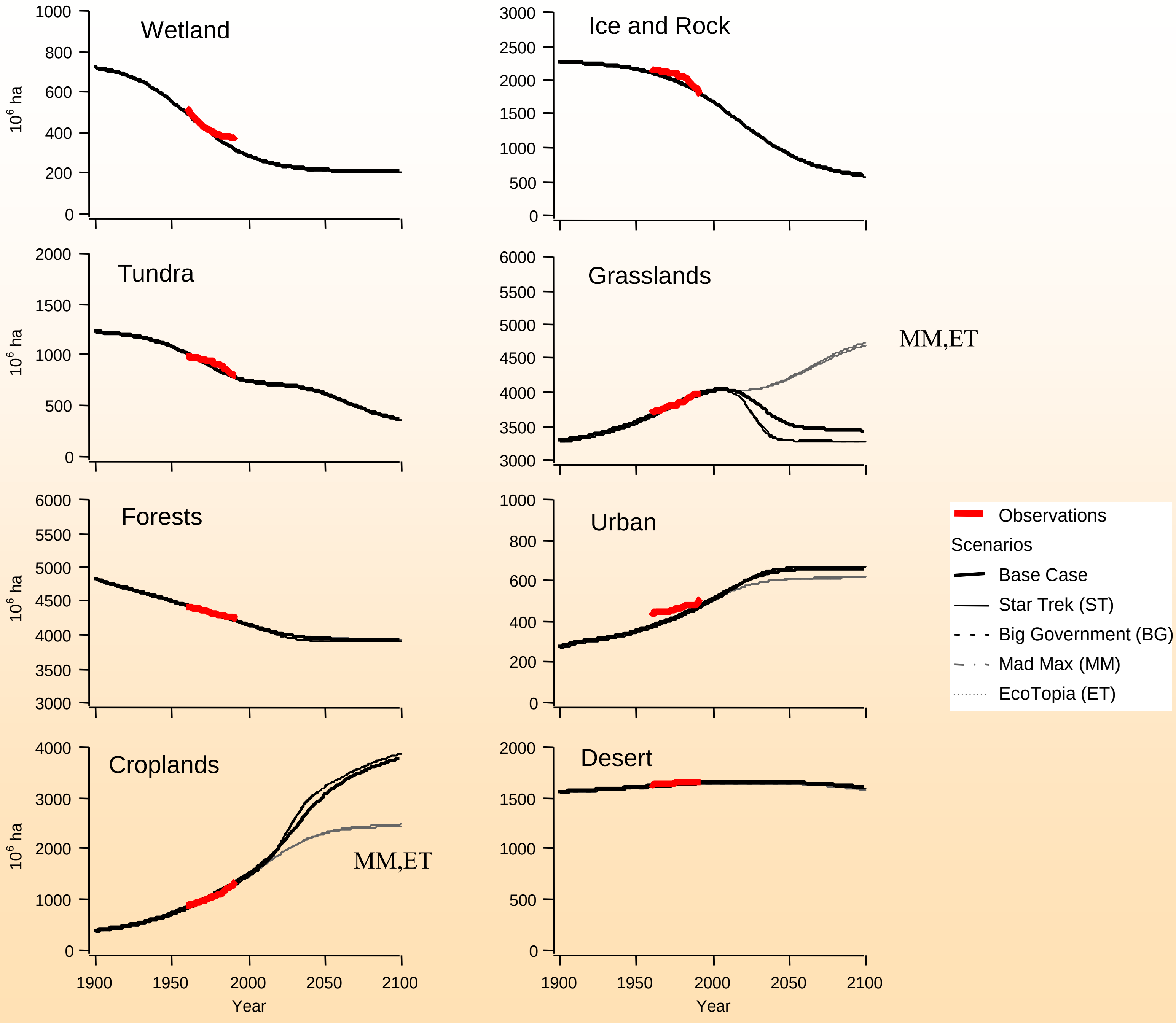
Global Unified Metamodel of the BiOsphere (GUMBO)

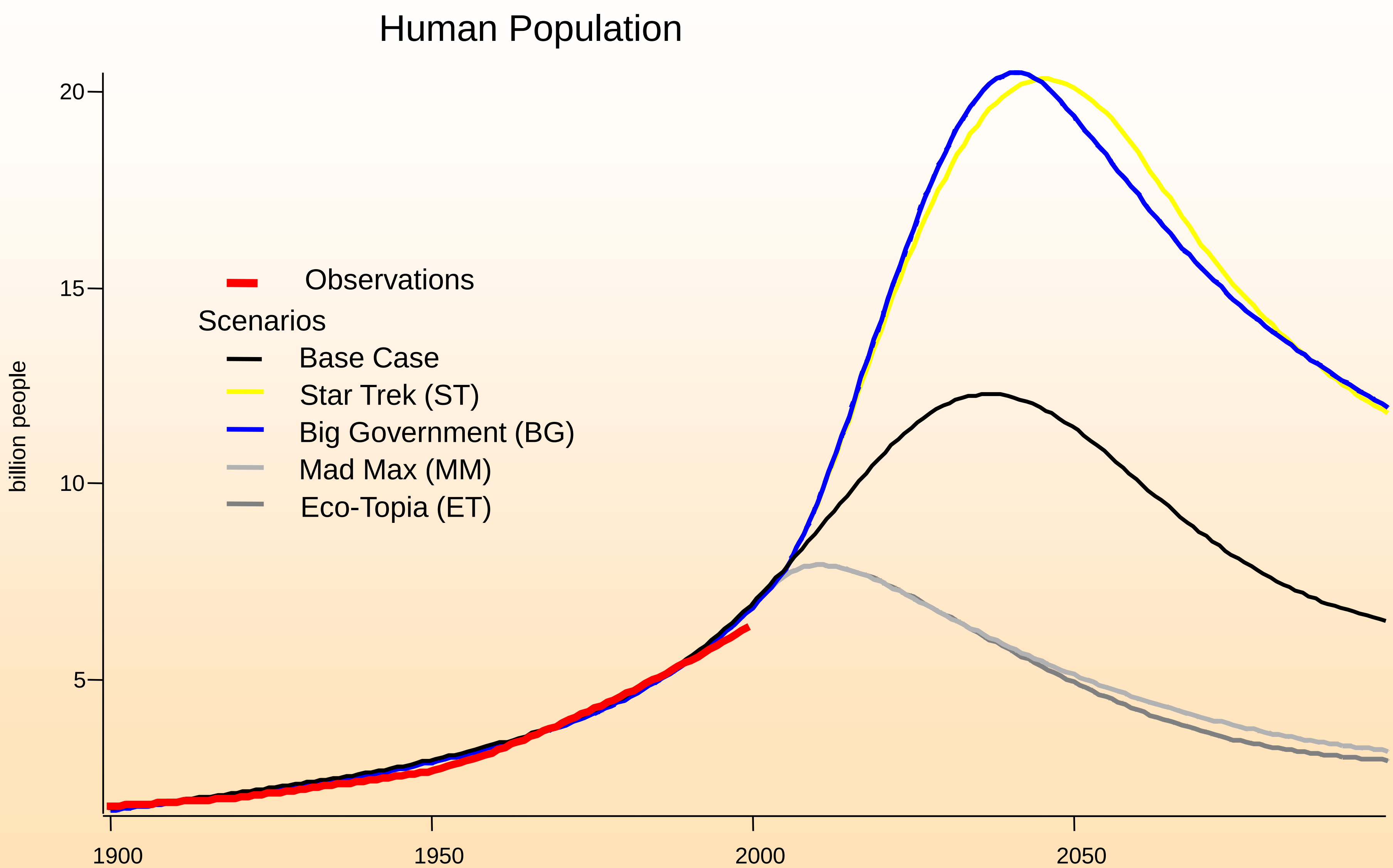
- was developed to simulate the integrated earth system and assess the dynamics and values of ecosystem services.
- is a "metamodel" in that it represents a synthesis and a simplification of several existing dynamic global models in both the natural and social sciences at an intermediate level of complexity.
- 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

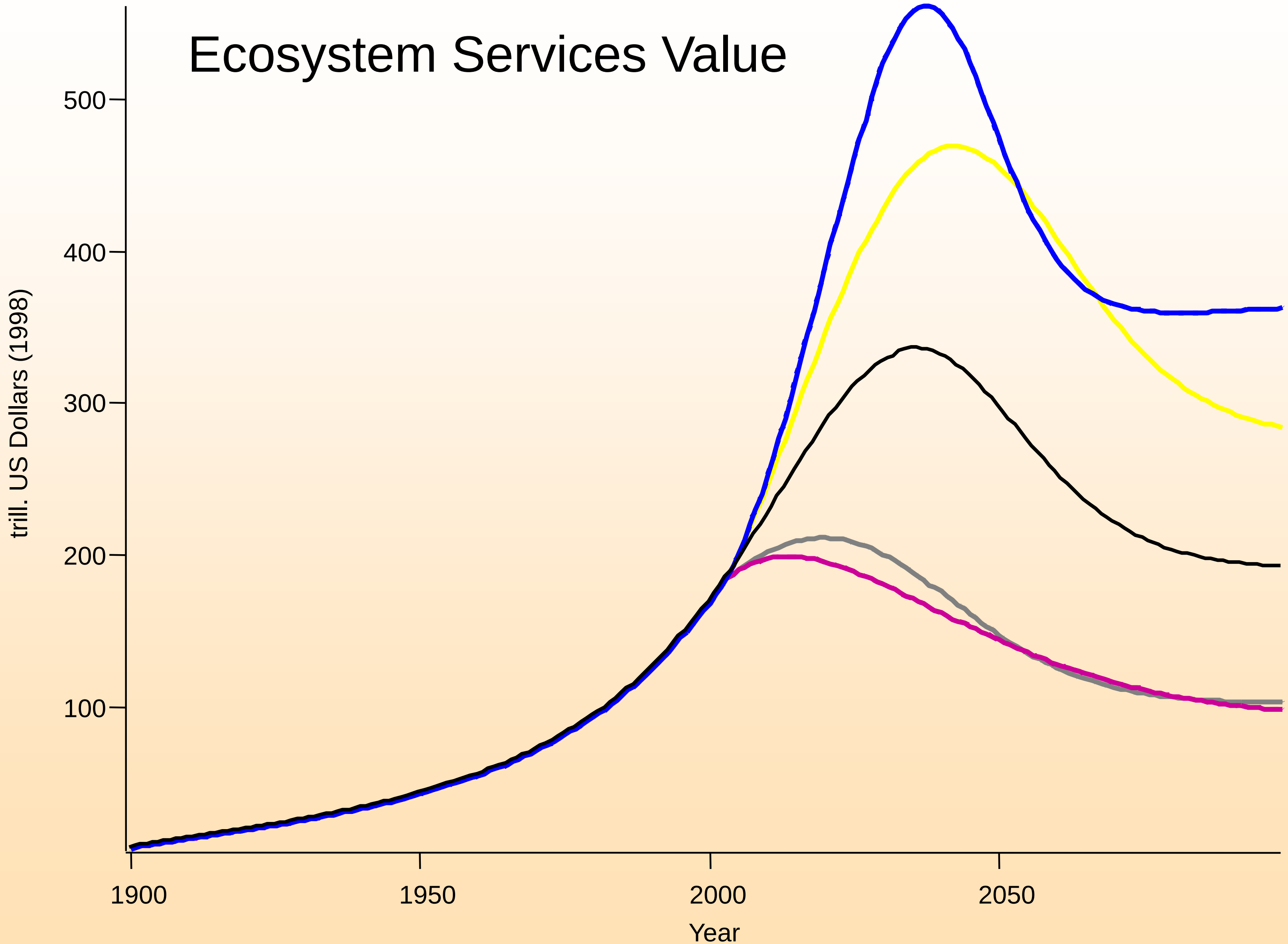


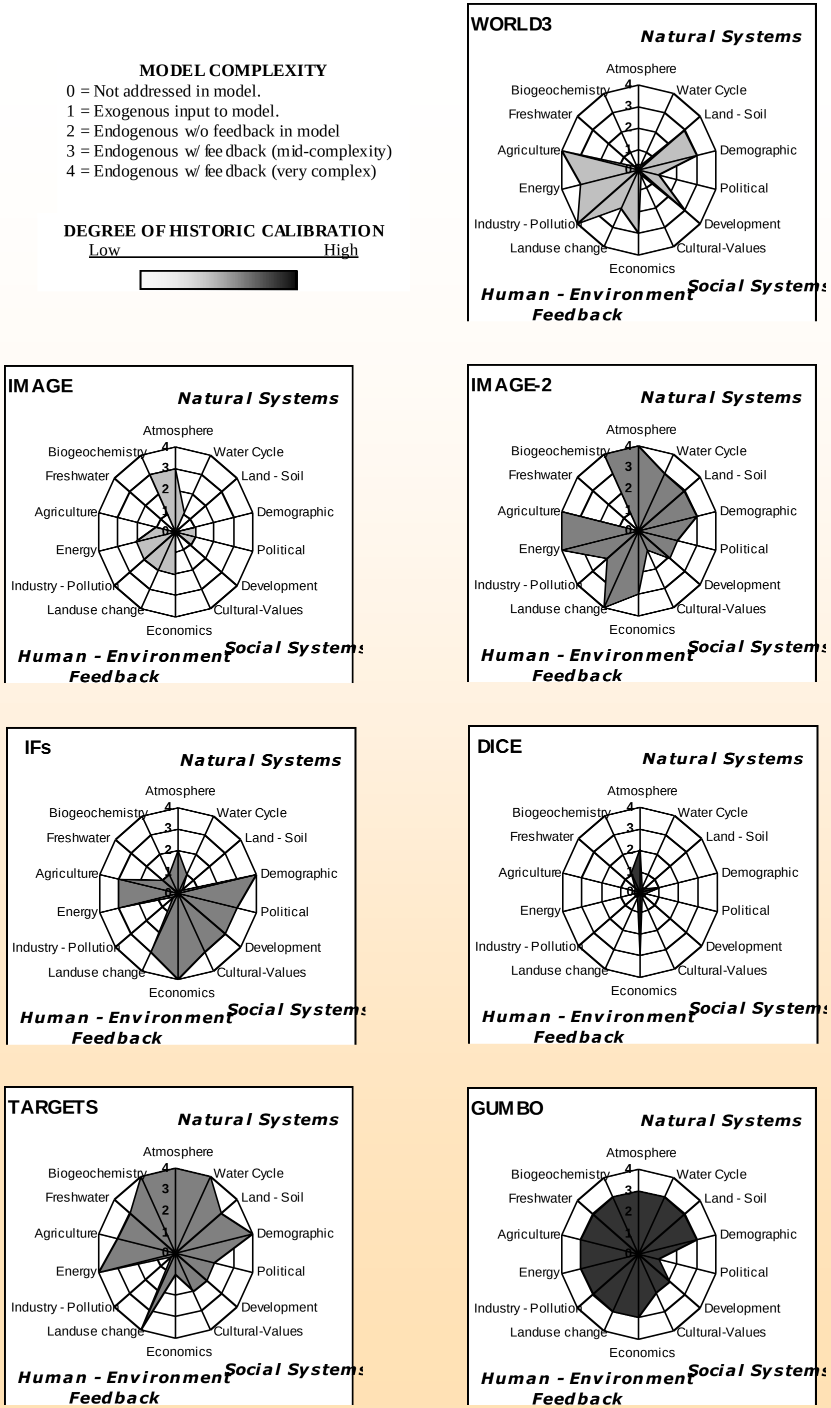
Landuse Changes
Wetland
Ice and Rock
Human Population
billions of individuals
Ecotopia
Startrek
Mad Max
Big Goverment
Basecase
Observations
Waste_Treatment
Soil Formation
Tundra
Grasslands
Knowledge
Productivity Invested
Knowledge per capita
Recreation and_Culture
Nutrient_Cycling
Forests
Urban
Built Capital
Built capital per capita
Gas_regulation
Disturbance Regulation
Croplands
Desert
The Social Netw ork
Social netw per capita
Climate Regulation
Ecosystem services value
Years
Year
Physics
Global Temp
°C
Atmospheric 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
Ecopia
Startrek
MadMax
Big Goverment
Basecase
Observations
Fossil Fuel Market share
Total Energy
Climate price
Energy price
Energy_per_Capita
food_per_capita

Landuse Changes




Human Population
billion people
20
15
10
5
1900
1950
2000
2050
Observations
Scenarios
Base Case
Star Trek (ST)
Big Government (BG)
Mad Max (MM)
Eco-Topia (ET)


Ecosystem Services Value
trill. US Dollars (1998)
500
400
300
200
100
1900
1950
2000
2050
Year



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. Pp 417-446 in: Costanza, R., L. J. Graumlich, and W. Steffen (eds.). Sustainability or Collapse?: An Integrated History and future Of People on Earth. Dahlem Workshop Report 96. MIT Press. Cambridge, MA.

Multiscale Integrated Models of Ecosystem Services (MIMES)

www.uvm.edu/giee/mimes

Project Goals

Outcome 1. A suite of dynamic ecological economic computer models specifically aimed at integrating our understanding of ecosystem functioning, ecosystem services, and human well-being across a range of spatial scales.

Outcome 2. Development and application of new valuation techniques adapted to the public goods nature of most ecosystem services and *integrated with the modeling work*

Outcome 3. Web-based delivery of the integrated models & results to a broad range of potential users.

Major Accomplishments:

- **Global network** of collaborators (> 100, 14 countries)
- **Collaborative development of models** (MIMES) including biophysical dynamics and valuation
- **Initial results and ongoing applications** at calibration sites (Global, Vermont, Amazon, PNW, Mexico, Marine)
- **Web sites** for collaboration, education, and model delivery
- **Publication of results** in multiple venues
- **Commitments for applications** to multiple sites around the world

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Collaborative Model Development

Meetings:

October 2006, Burlington, VT

March, 2007, Costa Rica

June, 2007, Seattle

July, 2007, Burlington, VT

October 2007, New Hampshire

November 2007 Burlington, VT

December 2007 Brazil

Gund Institute for Ecological Economics
University of Vermont

University of Vermont

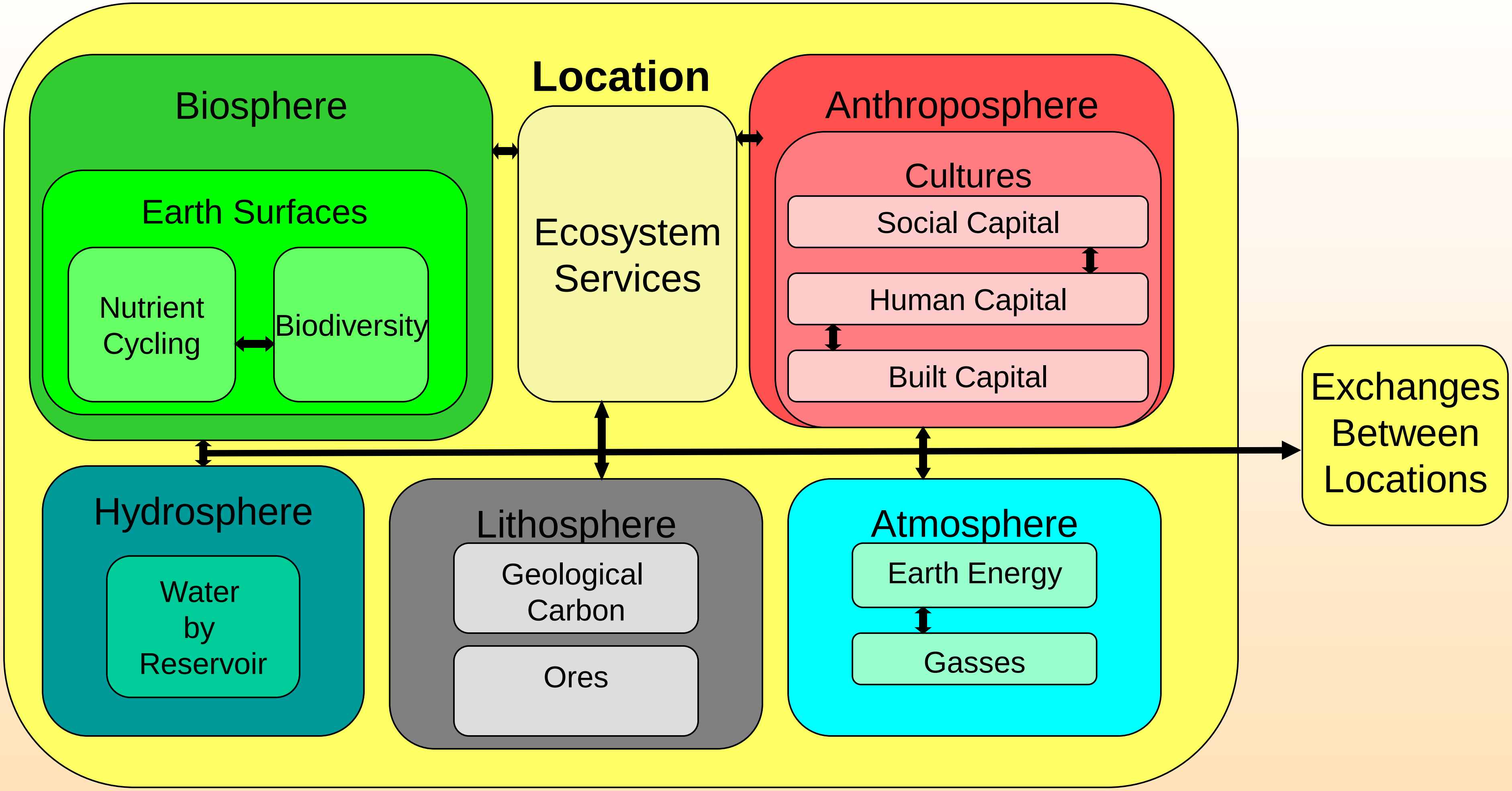
Austin Troy	Faculty
Robert Costanza	Faculty
Roelof Boumans	Faculty
Serguei Krivov	Faculty
Amos Baehr	Graduate Student
Eric Garza	Graduate Student
Galen Wilkerson	Graduate Student
Gary Johnson	Graduate Student
Juan Alvez	Graduate Student
Karim Chichakly	Graduate Student
Kenneth Bagstad	Graduate Student
Mark Gately	Graduate Student
Robin Kemkes-Wengell	Graduate Student
Shuang Liu	Graduate Student
Valerie Esposito	Graduate Student
Azur Moulaert	Project Manager
Anju Dahiya	Modeling Expert
Ernie Bufford	Spatial Analysis Laboratory
Jarlath O'Neil-Dunne	Spatial Analysis Laboratory
Sean McFaden	Spatial Analysis Laboratory
Eneida Campos	Gund Fellow, Brazil
Joe Roman	Gund Fellow
Guy Derry	Web Developer

External Participants & Current Partners

Cutler Cleveland	Boston University
Les Kaufman	Boston University
Giselle Samonte Tan	Conservation International, DC
Keith Alger	Conservation International, DC
Miroslav Honzak	Conservation International, DC
Rodrigo Moura	Conservation International, Brazil
Rosimeiry Portela	Conservation International, DC
Brett Bryan	CSIRO, Australia
So-Min Cheong	University of Kansas
David Batker	Earth Economics, Seattle
Ken Lindeman	Florida Institute of Technology
Kathy Hibbard	National Center for Atmospheric Research
Robert Muetzelfeldt	Simulistics
Jasper Taylor	Simulistics
Hal Mooney	Stanford University
Ralph Seppelt	UFZ, Germany
Paul C. Sutton	University of Denver
Steve Farber	University of Pittsburgh
Trista Patterson	USDA Forest Service, Juneau AK
Rudolf deGroot	Wageningen University
Ademar Romeiro	Unicamp, Brazil
Paolo Sinisgalli	Embrapa, Brazil
Luis Steinle Camargo	Brazil
Maria Ramos Fasabien	Brazil
Wilson Rotatori Correa	Brazil
Daniel Caixeta Andrade	Brazil
Wilson Cabral Sousa	Brazil
Colin Beer	State University of New York ESF
Marcos Amend	Conservation Strategy Fund, Brazil
Denis Ojima	Colorado State University
Fred Sklar	South Florida Water Management District
Dan Childers	Florida International University
Paul West	The Nature Conservancy
Belinda Morris	The Nature Conservancy
Richard Howart	Dartmouth College
Brett Bryan	CSIRO
Charles Hopkinson	Woods Hole Marine Biological Laboratory
Kenneth Mulder	Green Mountain College
Robin Naidoo	World Wildlife Fund

MIMES

Multi-scale Integrated Models of Ecosystem Services



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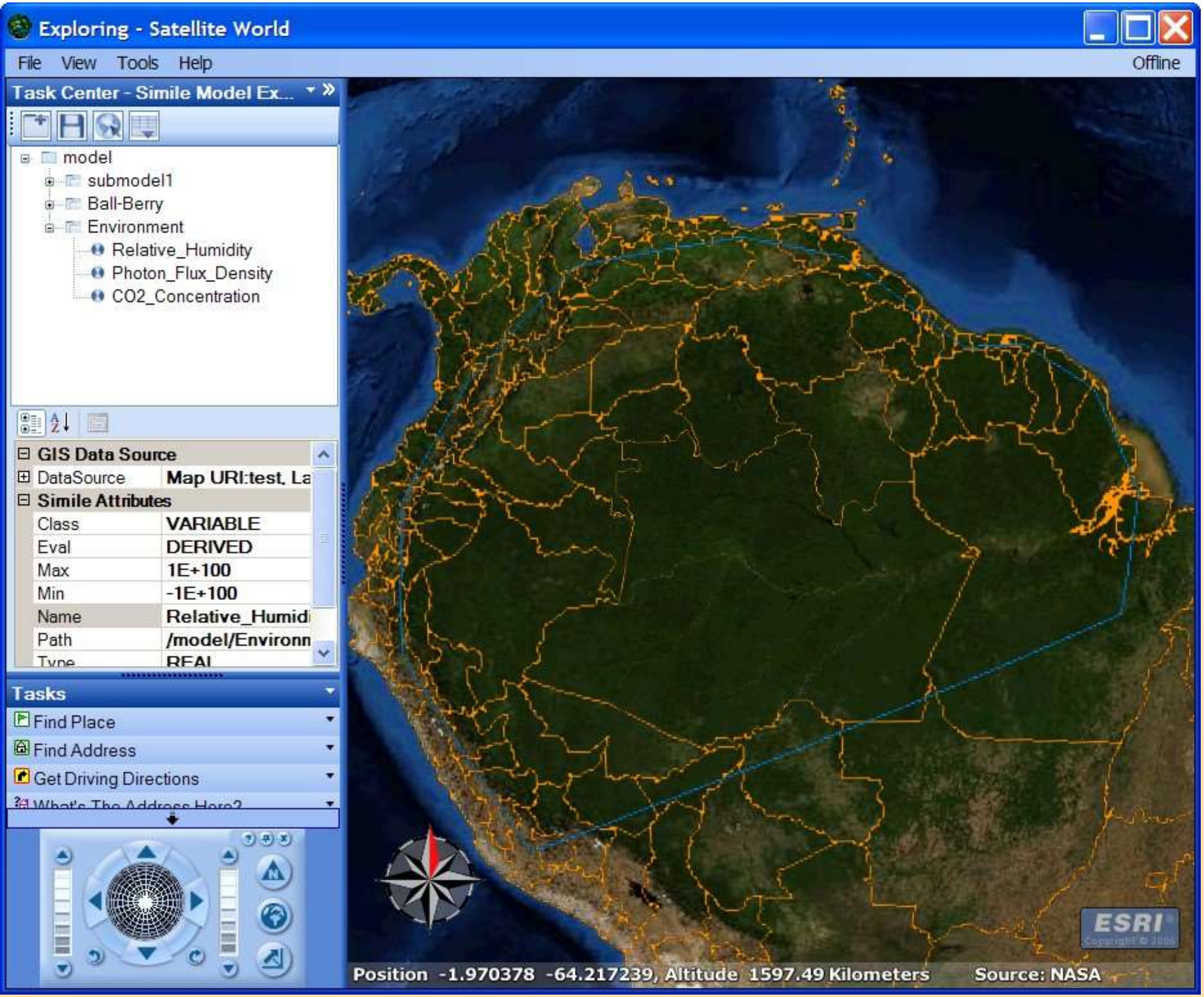
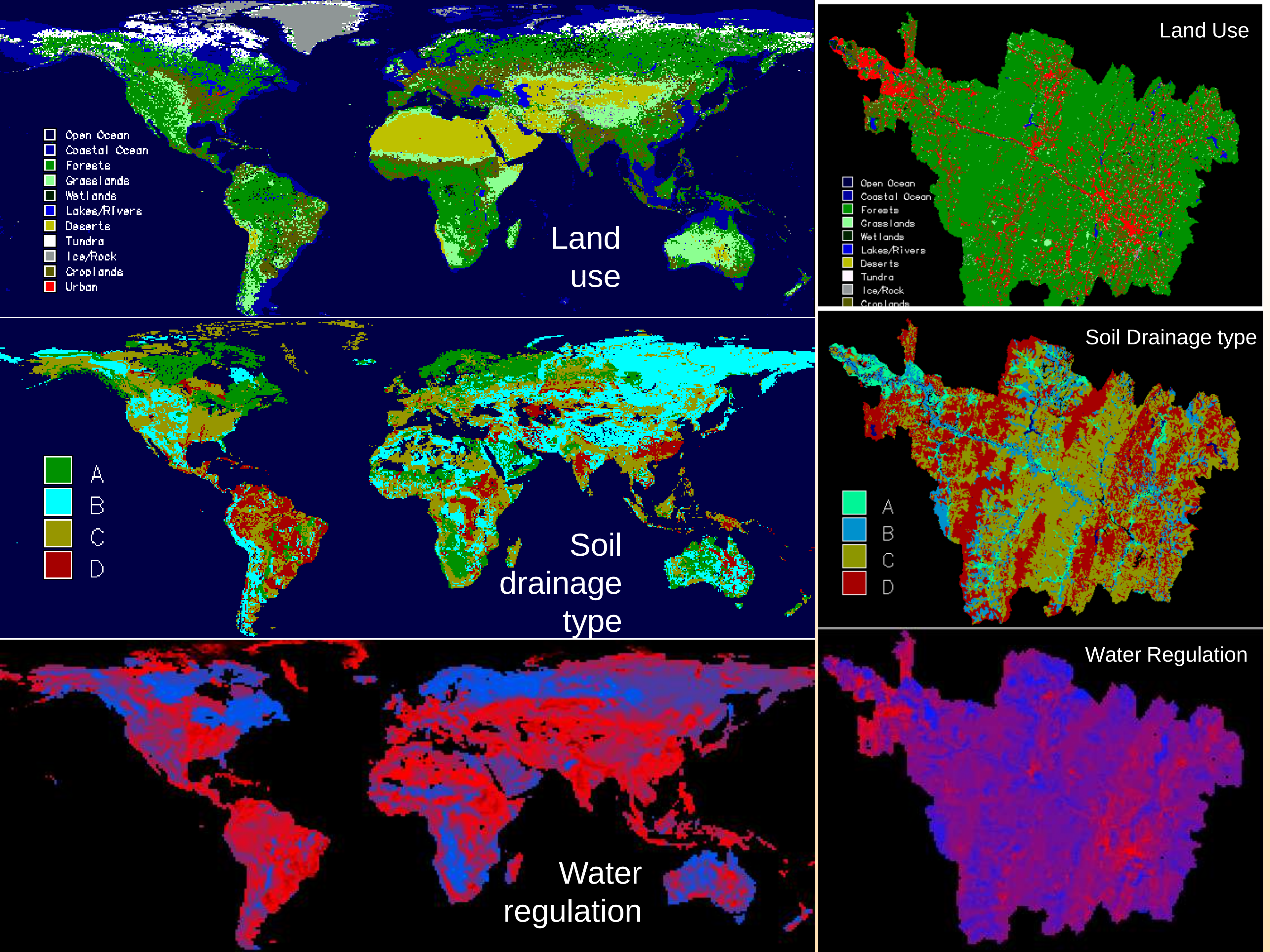
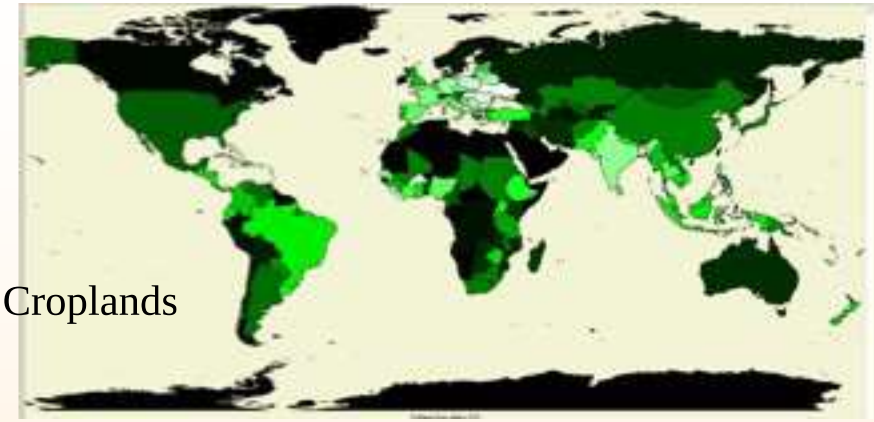
Ability to select specific areas to model at variable spatial and temporal resolution, in their global and regional context

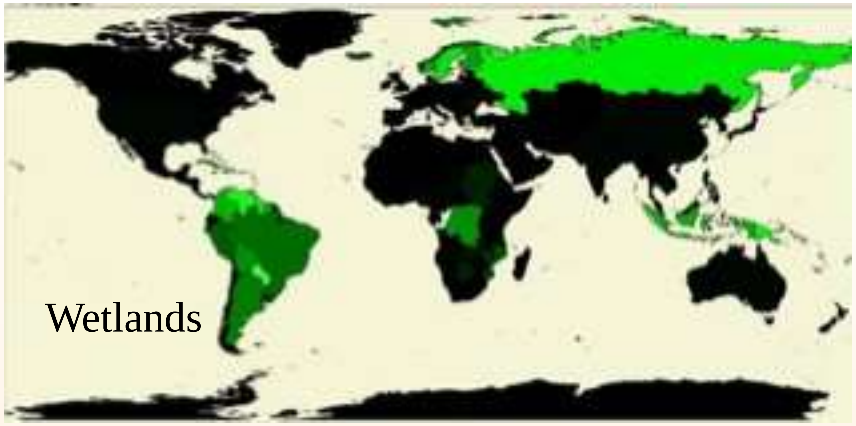


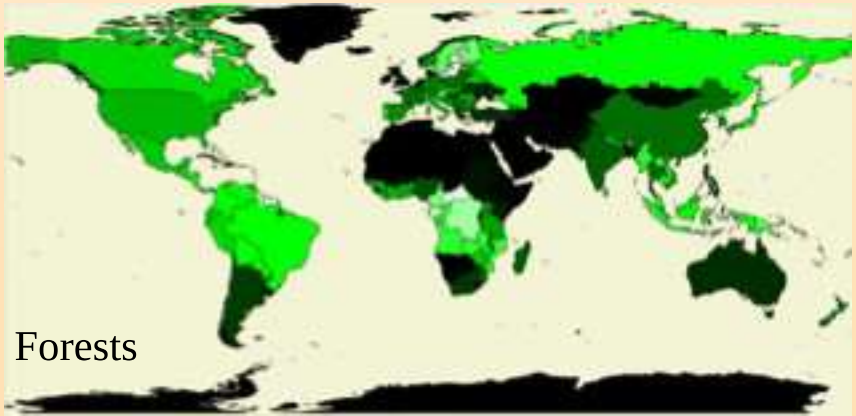
A range of calibration sites used by project partners to test model applicability and performance. These include in the first phase: Amazon, Pacific northwest, Winoski watershed, Vermont, and Global

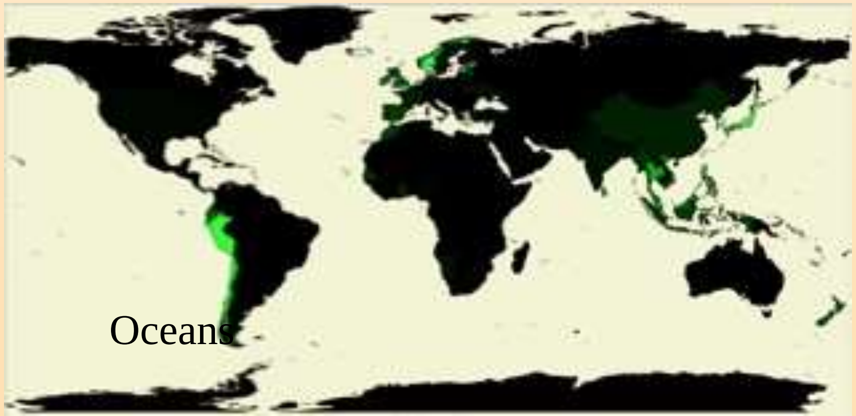

Open Ocean
Coastal Ocean
Forests
Grasslands
Wetlands
Lakes/Rivers
Deserts
Tundra
Ice/Rock
Croplands
Urban
Land use
Land Use
Open Ocean
Coastal Ocean
Forests
Grasslands
Wetlands
Lakes/Rivers
Deserts
Tundra
Ice/Rock
Croplands
A
B
C
D
Soil drainage type
Soil Drainage type
A
B
C
D
Water regulation
Water Regulation

Ecosystems (% Area)

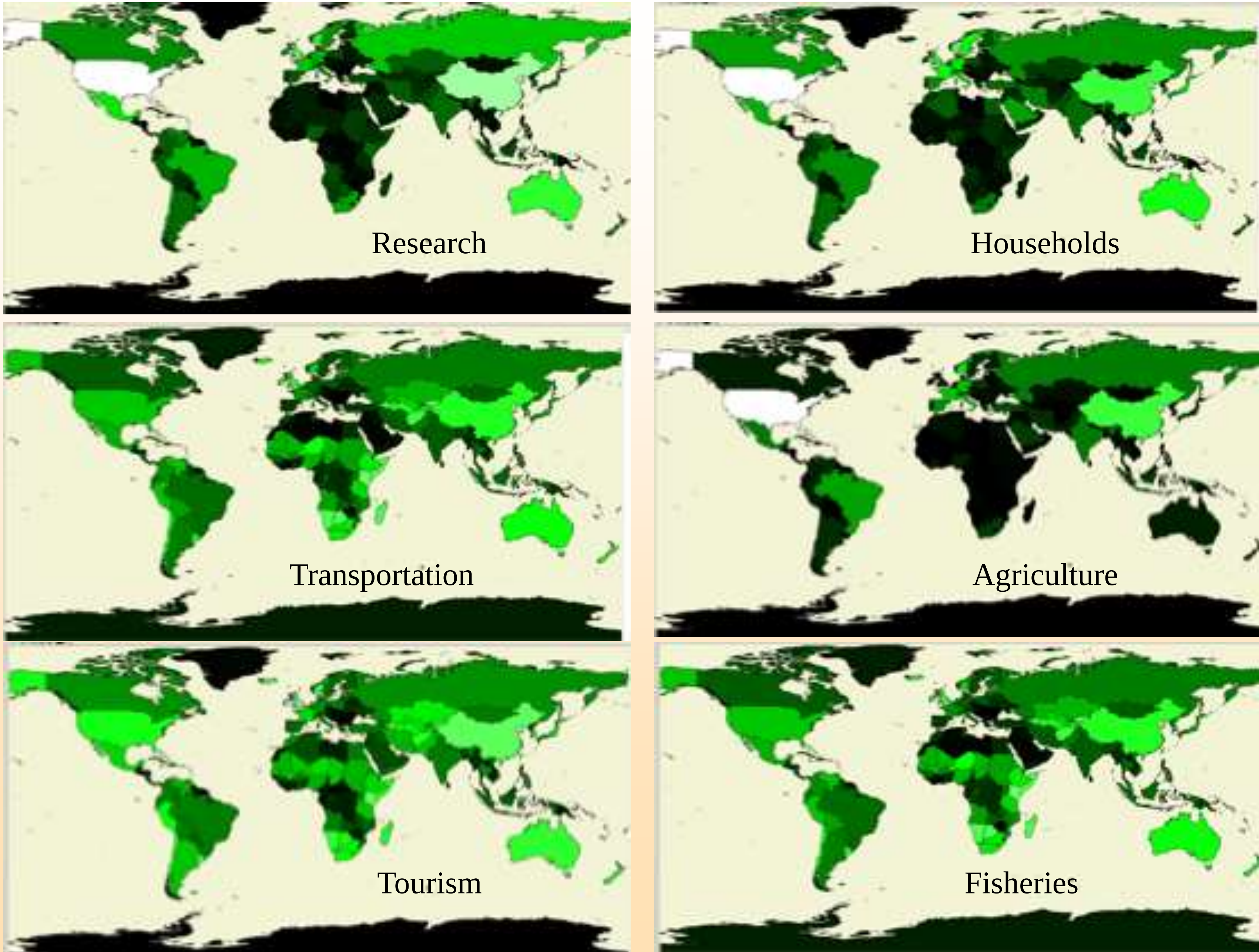




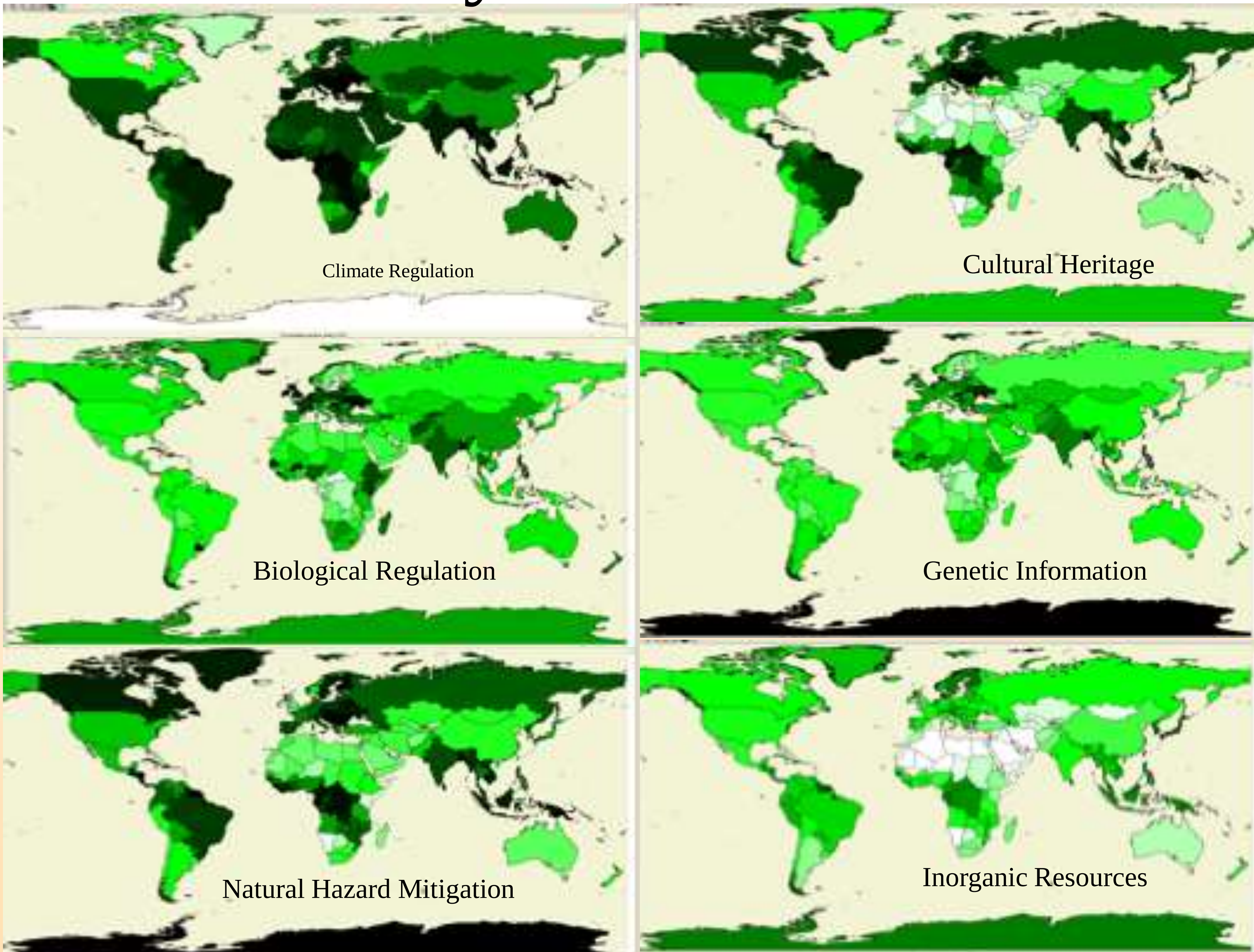




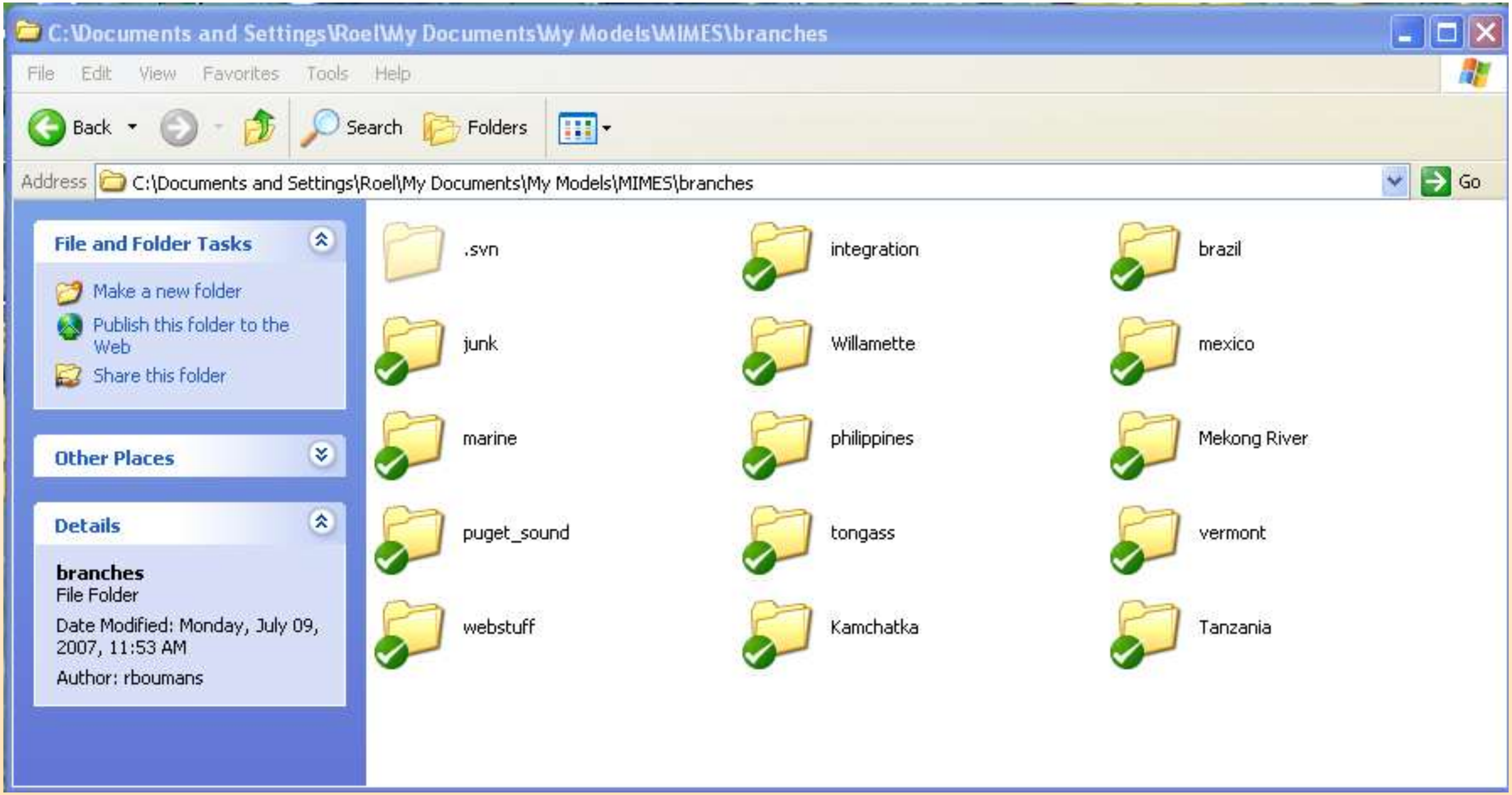
1990 economic production in $ PPP by country

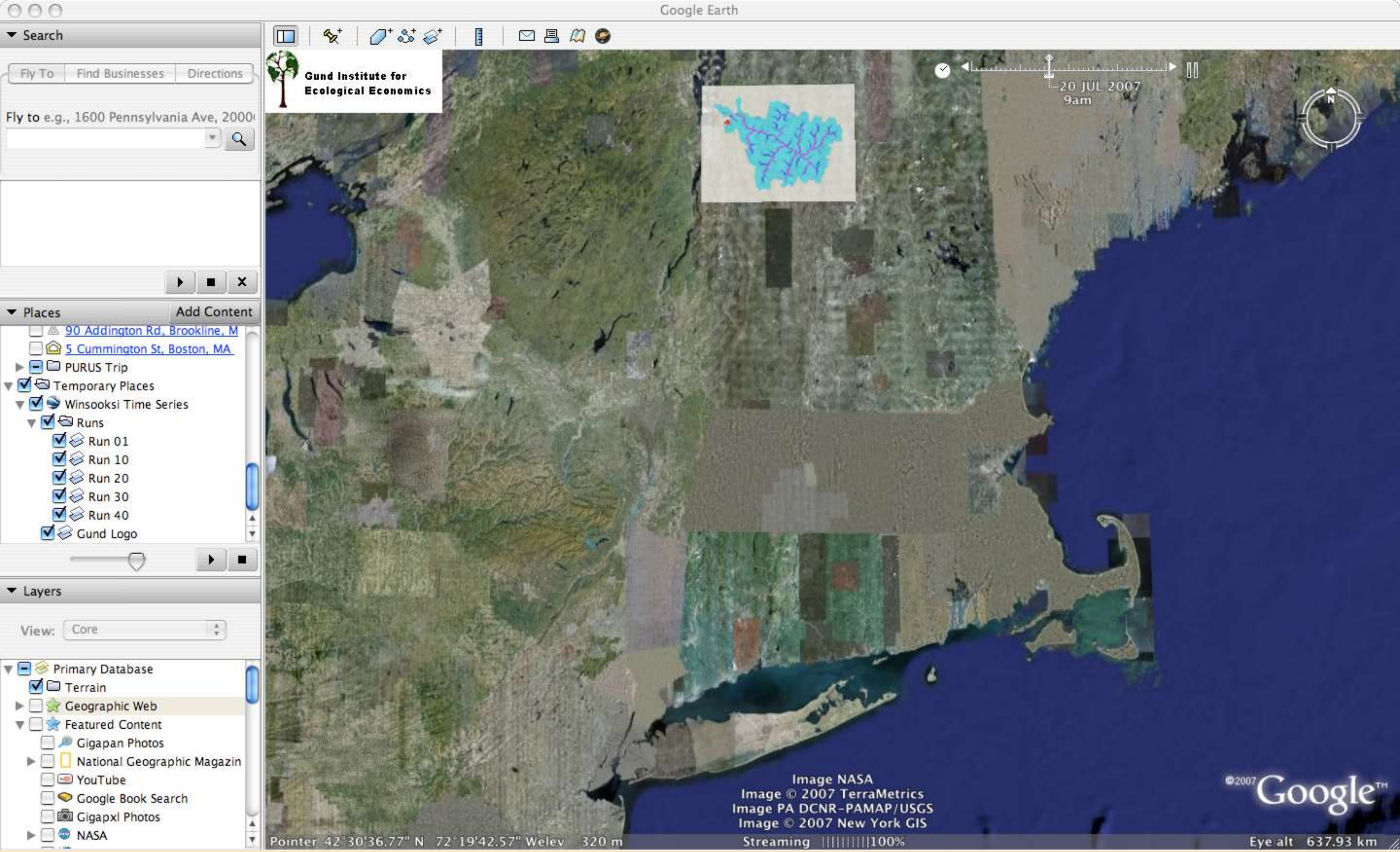


Ecosystem Services



Case studies under development




Google Earth
Search
Fly To
Find Businesses
Directions
Fly to e.g., 1600 Pennsylvania Ave, 2000
Places
Add Content
90 Addington Rd, Brookline, M
5 Cummington St, Boston, MA
PURUS Trip
Temporary Places
Winsooksi Time Series
Runs
Run 01
Run 10
Run 20
Run 30
Run 40
Gund Logo
Layers
View: Core
Primary Database
Terrain
Geographic Web
Featured Content
Gigapan Photos
National Geographic Magazin
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Ecological Economics
20 JUL 2007
9am
Image NASA
Image © 2007 TerraMetrics
Image PA DCNR-PAMAP/USGS
Image © 2007 New York GIS
©2007 Google
Pointer 42°30'36.77" N 72°19'42.57" W elev 320 m
Streaming 100%
Eye alt 637.93 km

MIMES Next Steps:

1. Further development and testing of MIMES

2. Application to a large number of sites around the world in support of PES systems, carbon trading, national accounting, etc. in collaboration with local partners

3. make MIMES a widely used, trusted, and evolving system for ecosystem service modeling and evaluation

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Thank You

Papers mentioned in this talk available at:
www.uvm.edu/giee/publications:

MIMES website at:
www.uvm.edu/giee/mimes