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

Complementary approaches to including humans:

- as stakeholders constructing and interacting with the model

- as decision makers (agents) internal to the model

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

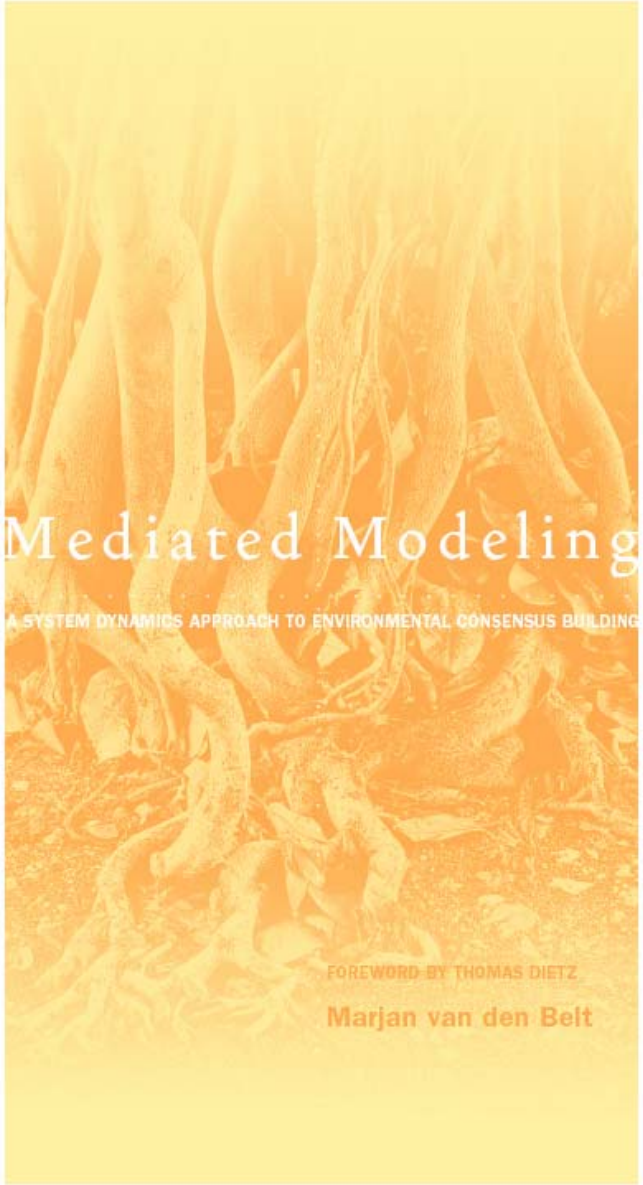
more detailed and realistic attempts to replicate the dynamics of the particular system of interest with the emphasis on calibration and testing.

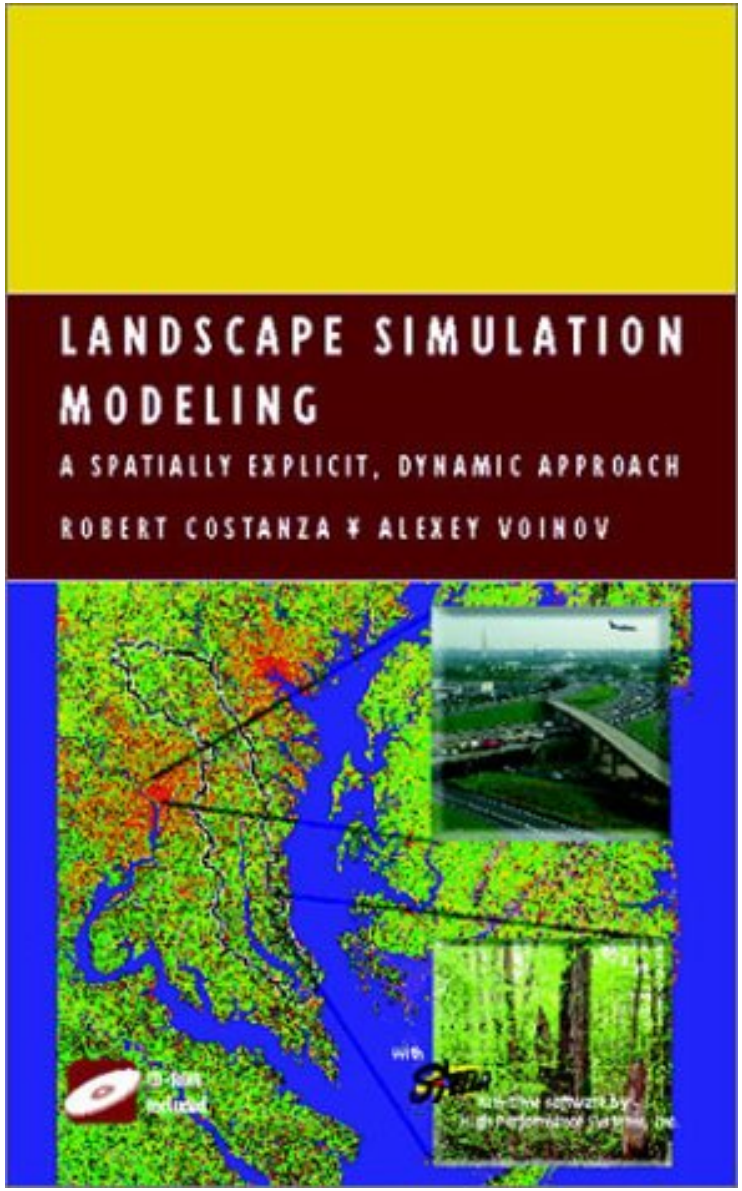
3. Management Models

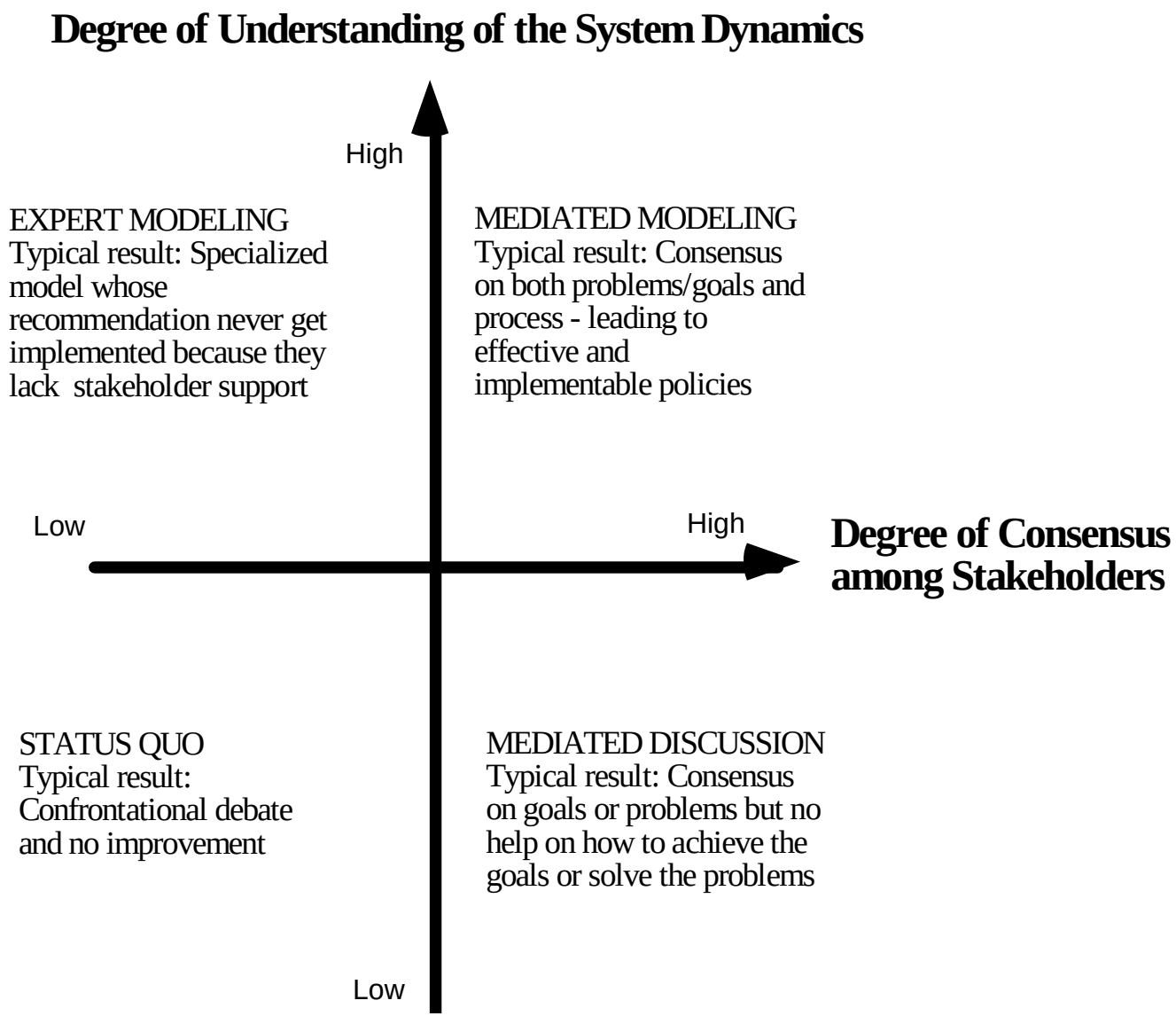
medium to high resolution models based on the previous two stages with the emphasis on producing future management scenarios - can be simply exercising the scoping or research models or may require further elaboration to allow application to management questions

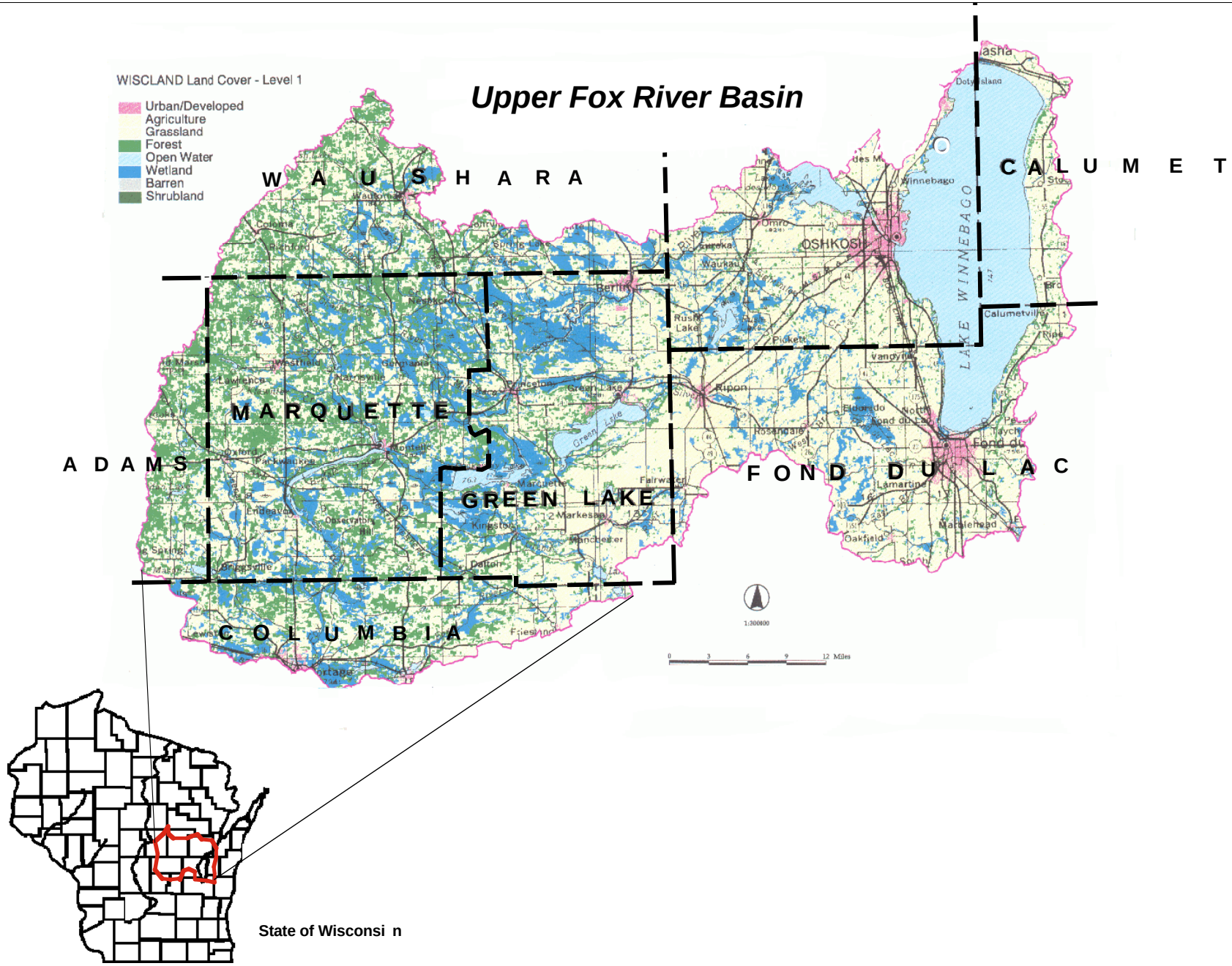
Increasing Complexity, Cost, Realism, and Precision

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

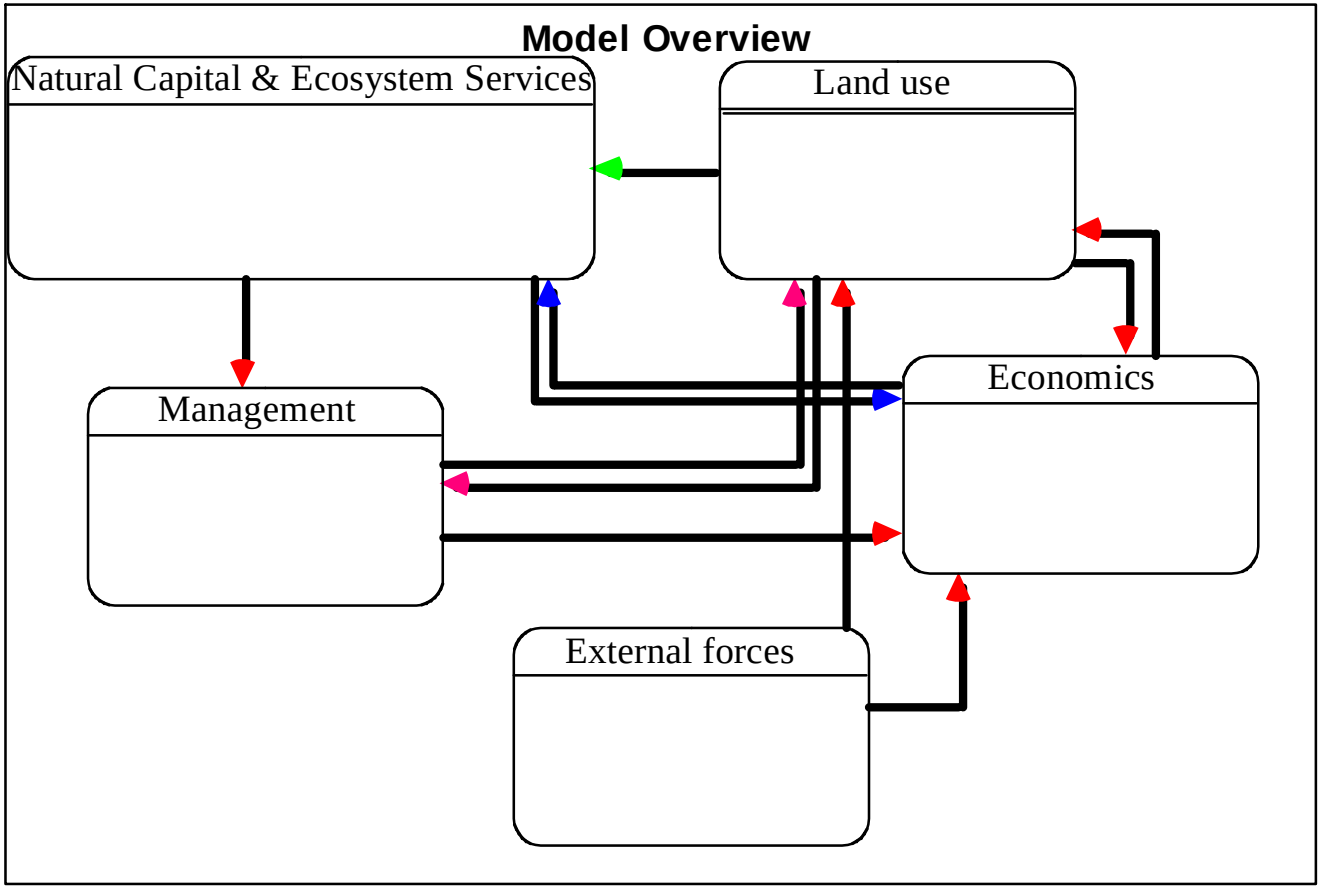

Mediated Modeling
A SYSTEM DYNAMICS APPROACH TO ENVIRONMENTAL CONSENSUS BUILDING
FOREWORD BY THOMAS DIETZ
Marjan van den Belt


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

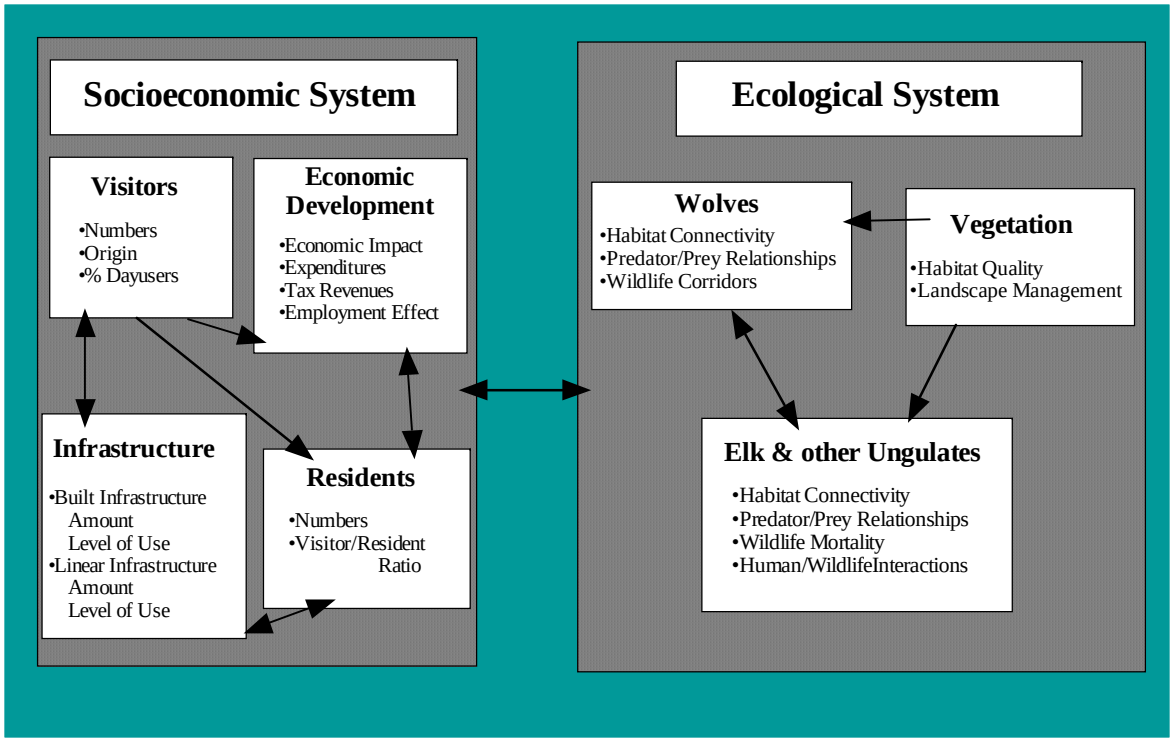

Degree of Understanding of the System Dynamics
High
EXPERT MODELING
Typical result: Specialized model whose recommendation never get implemented because they lack stakeholder support
MEDIATED MODELING
Typical result: Consensus on both problems/goals and process - leading to effective and implementable policies
Low
High
Degree of Consensus among Stakeholders
STATUS QUO
Typical result: Confrontational debate and no improvement
MEDIATED DISCUSSION
Typical result: Consensus on goals or problems but no help on how to achieve the goals or solve the problems
Low

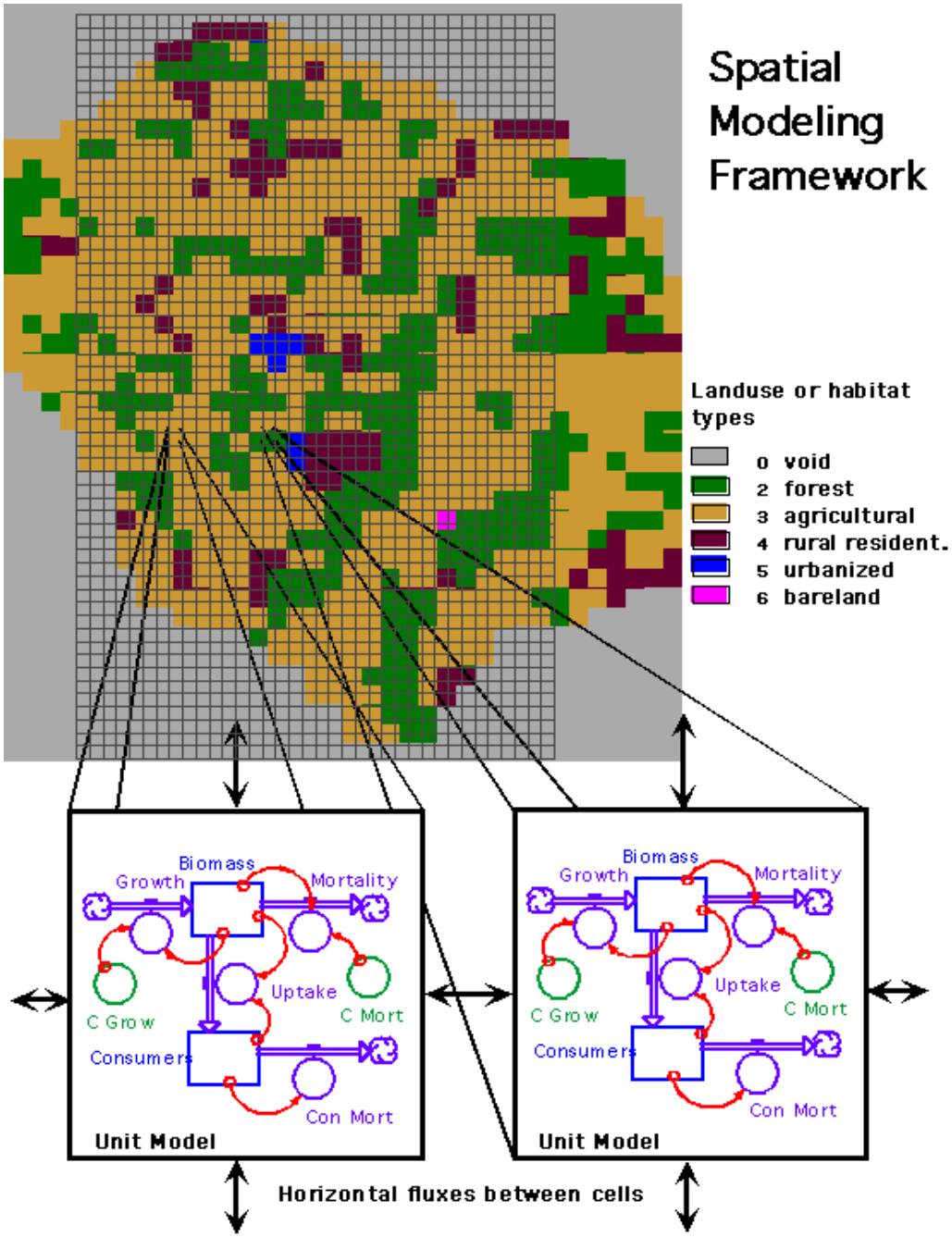

Upper Fox River Basin
WISCLAND Land Cover - Level 1
Urban/Developed
Agriculture
Grassland
Forest
Open Water
Wetland
Barren
Shrubland
W A U S H A R A
C A L U M E T
M A R Q U E T T E
A D A M S
G R E E N L A K E
F O N D D U L A C
C O L U M B I A
LAKE WINNEBAGO
OSHKOSH
State of Wisconsi n

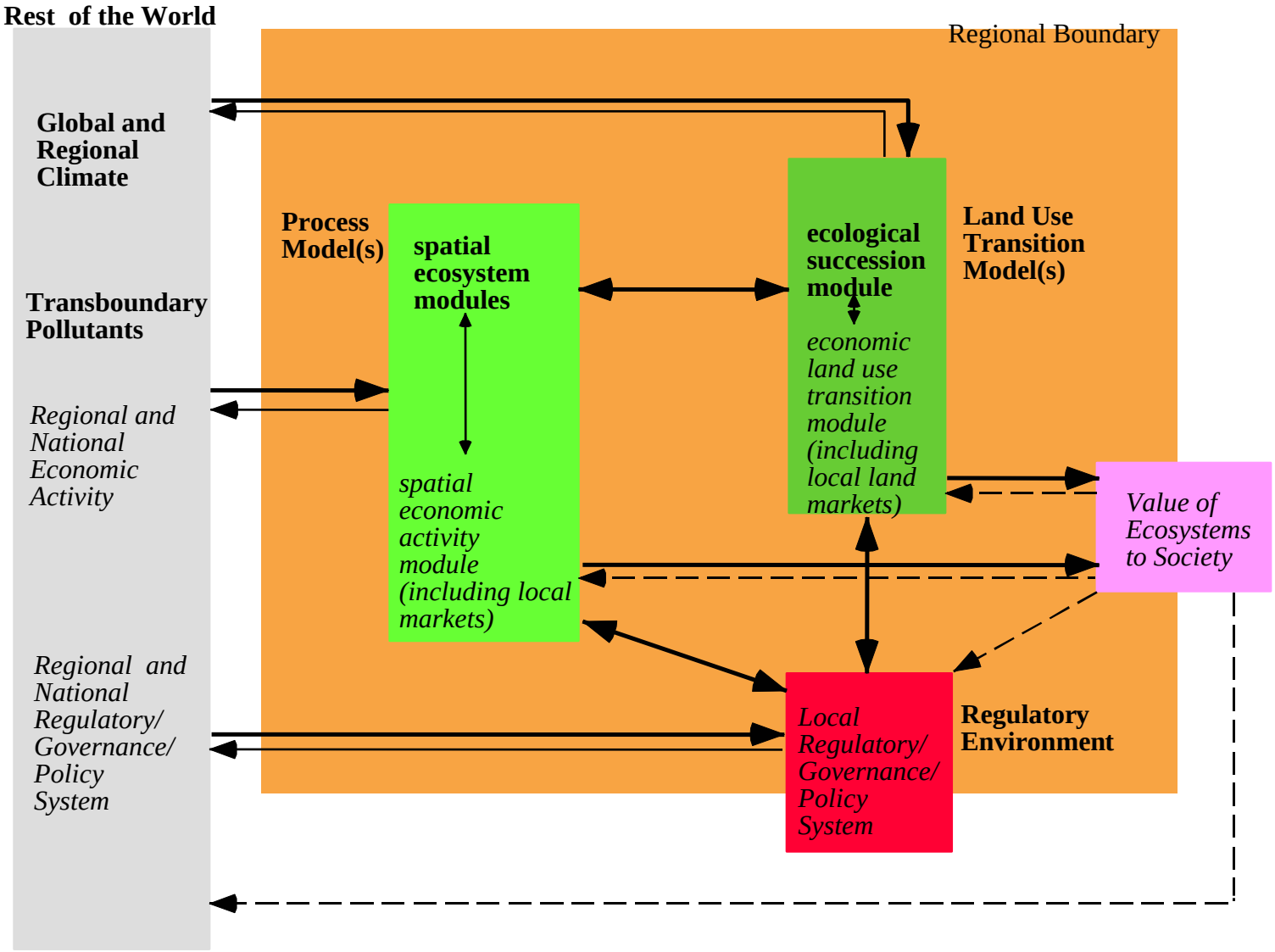
Upper Fox River Watershed Model Conceptual Overview
(Model Facilitated by Marjan van den Belt)



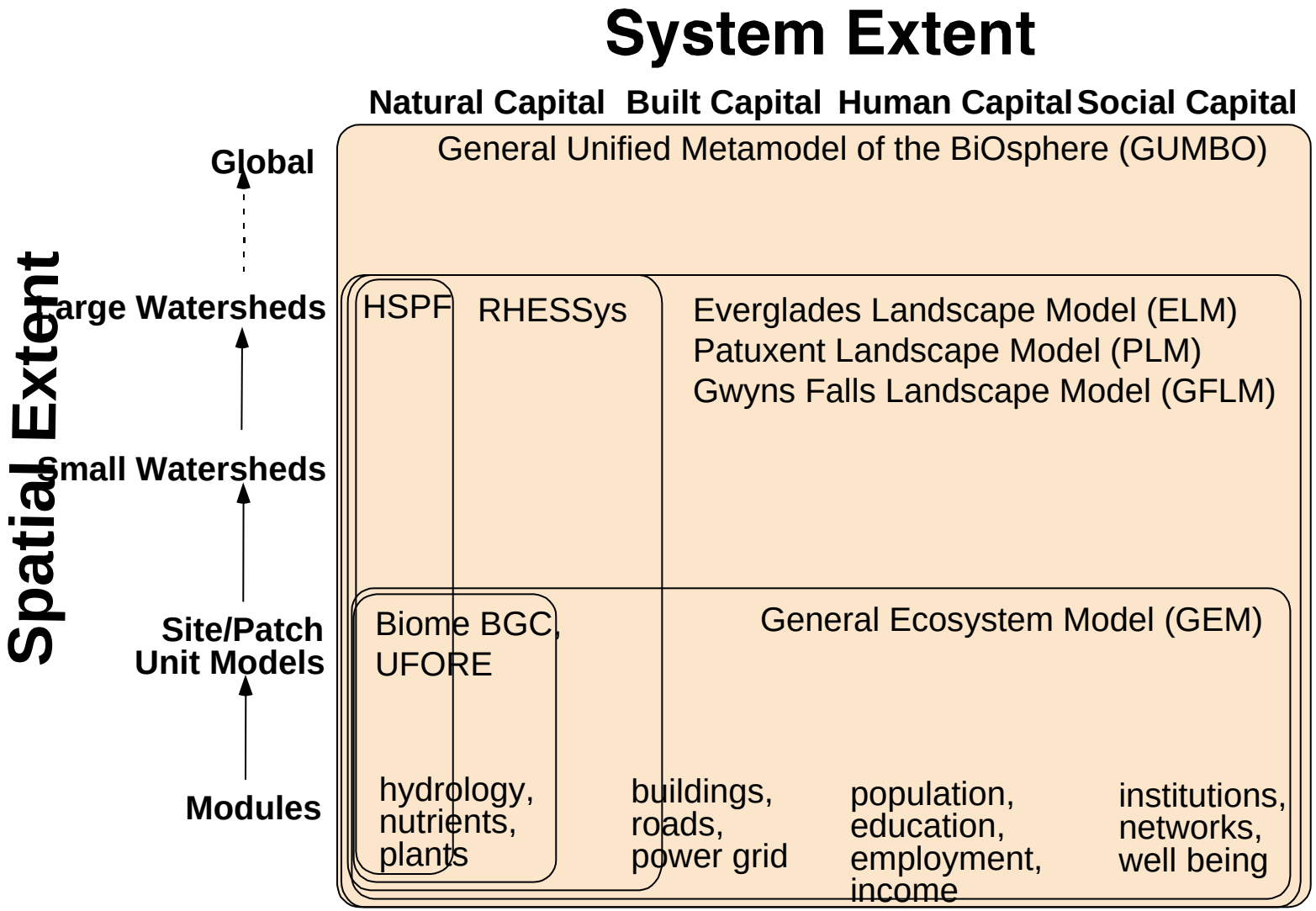
Conceptual Schematic of the Banff-Bow Valley Futures Model *(Facilitated by Laura Cornwell)*




Spatial Modeling Framework
Landuse or habitat types
0 void
2 forest
3 agricultural
4 rural resident.
5 urbanized
6 bareland
Biomass
Growth
Mortality
Uptake
C Grow
C Mort
Consumers
Con Mort
Unit Model
Biomass
Growth
Mortality
Uptake
C Grow
C Mort
Consumers
Con Mort
Unit Model
Horizontal fluxes between cells



Integrated ecological economic modeling and valuation framework.



Suite of interactive and intercalibrated models over a range of spatial, temporal and system scales (extents and resolutions)

Modeling Coastal Landscape Dynamics*

Jay F. Martin, G. Paul Kemp, Hassan Mashriqui, Enrique Reyes, John W. Day, Jr.

Coastal Ecology Institute
Louisiana State University

No Action Plan: MDM

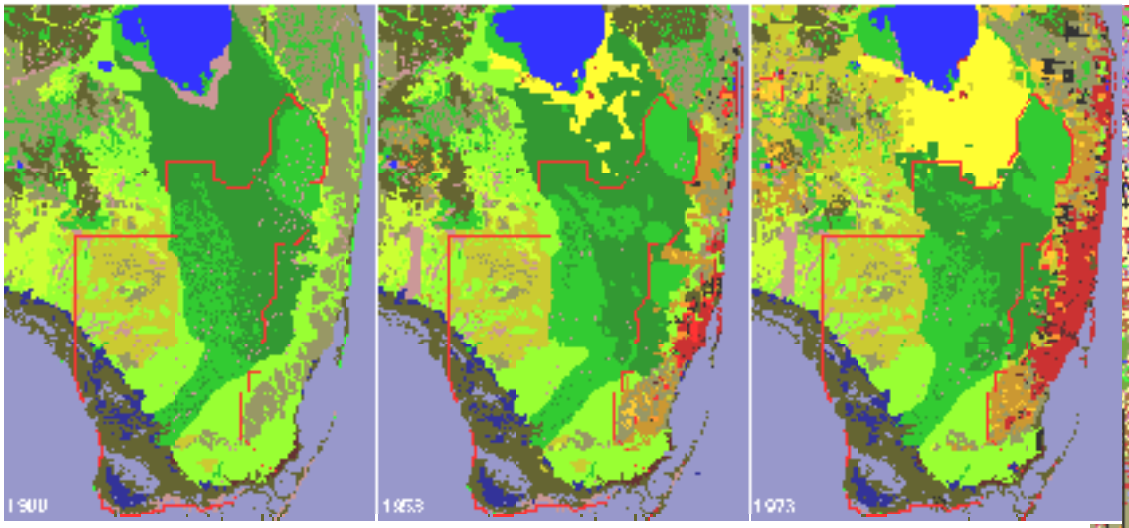
1988 USFWS Map

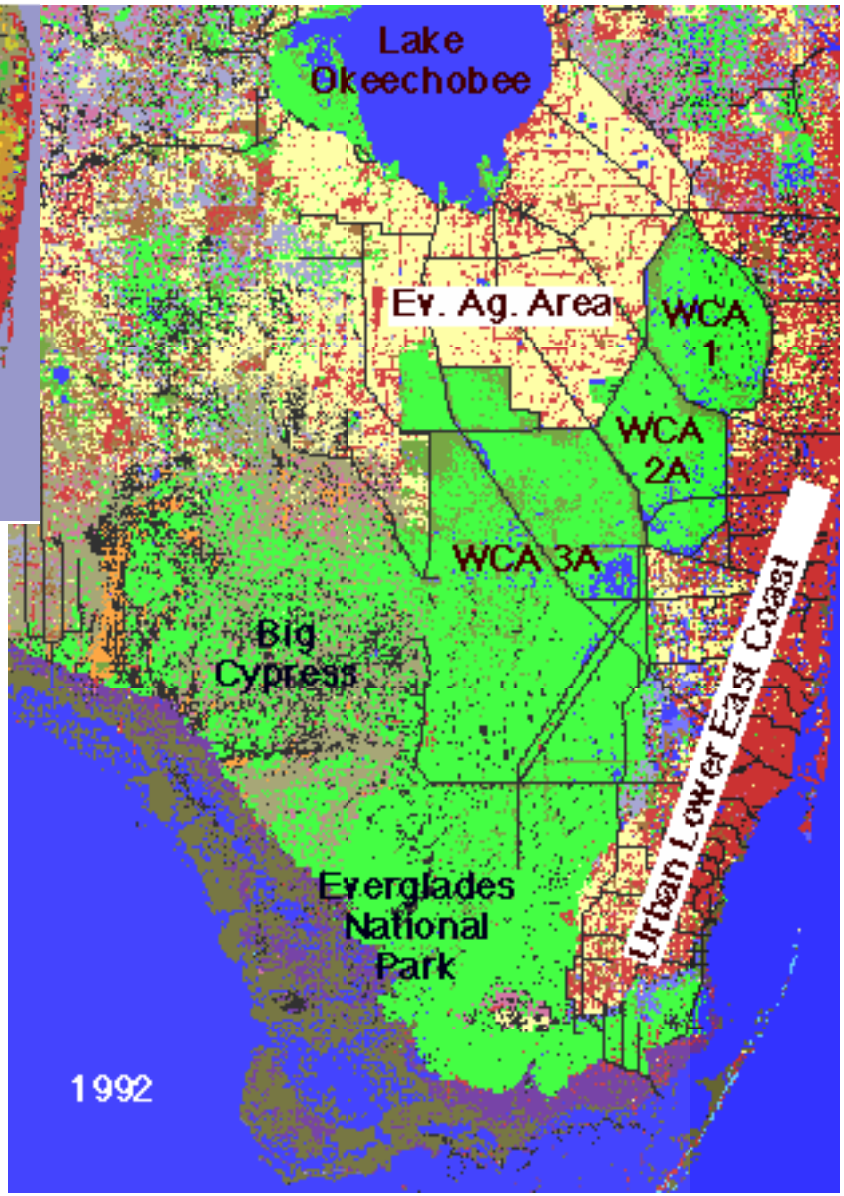
2058 No Action Plan MDM

Habitat Coverage (km²)

	Swamp	Int. Marsh	Fresh Marsh	Brackish Marsh	Salt Marsh	Open Water
Initial Conditions (1988)	461	219	727	674	76	646
No Action Plan (2058)	460	298	1414	159	54	6237

* Building on work originally reported in **Costanza, R., F. H. Sklar, and M. L. White. 1990.** Modeling coastal landscape dynamics. *BioScience* 40:91-107.





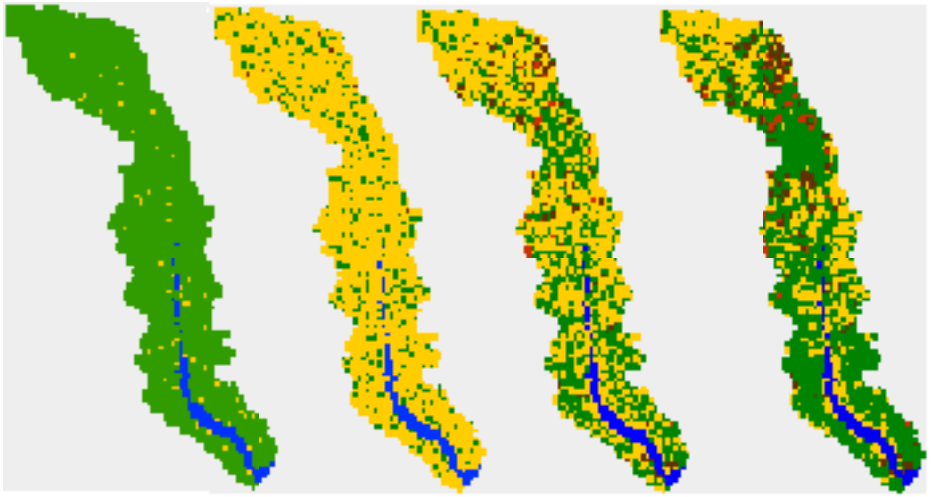
The Everglades Landscape Model (ELM v2.1)

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

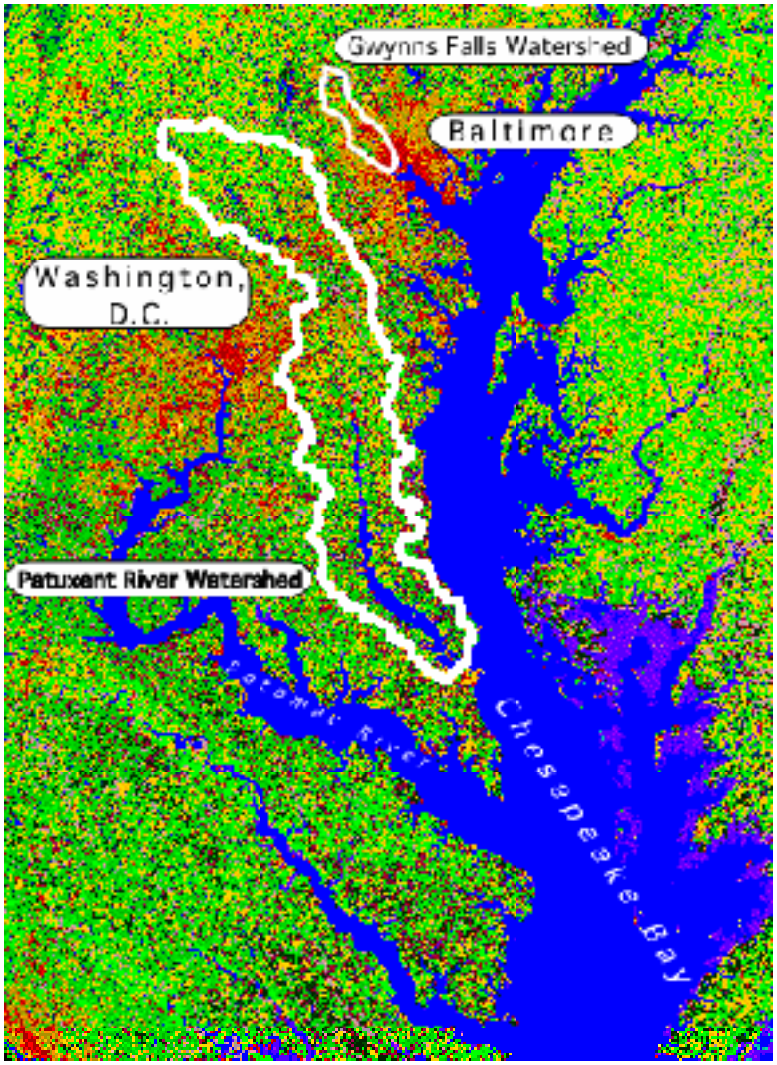
The ELM is a regional scale ecological model designed to predict the landscape response to different water management scenarios in south Florida, USA. The ELM simulates changes to the hydrology, soil & water nutrients, periphyton biomass & community type, and vegetation biomass & community type in the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

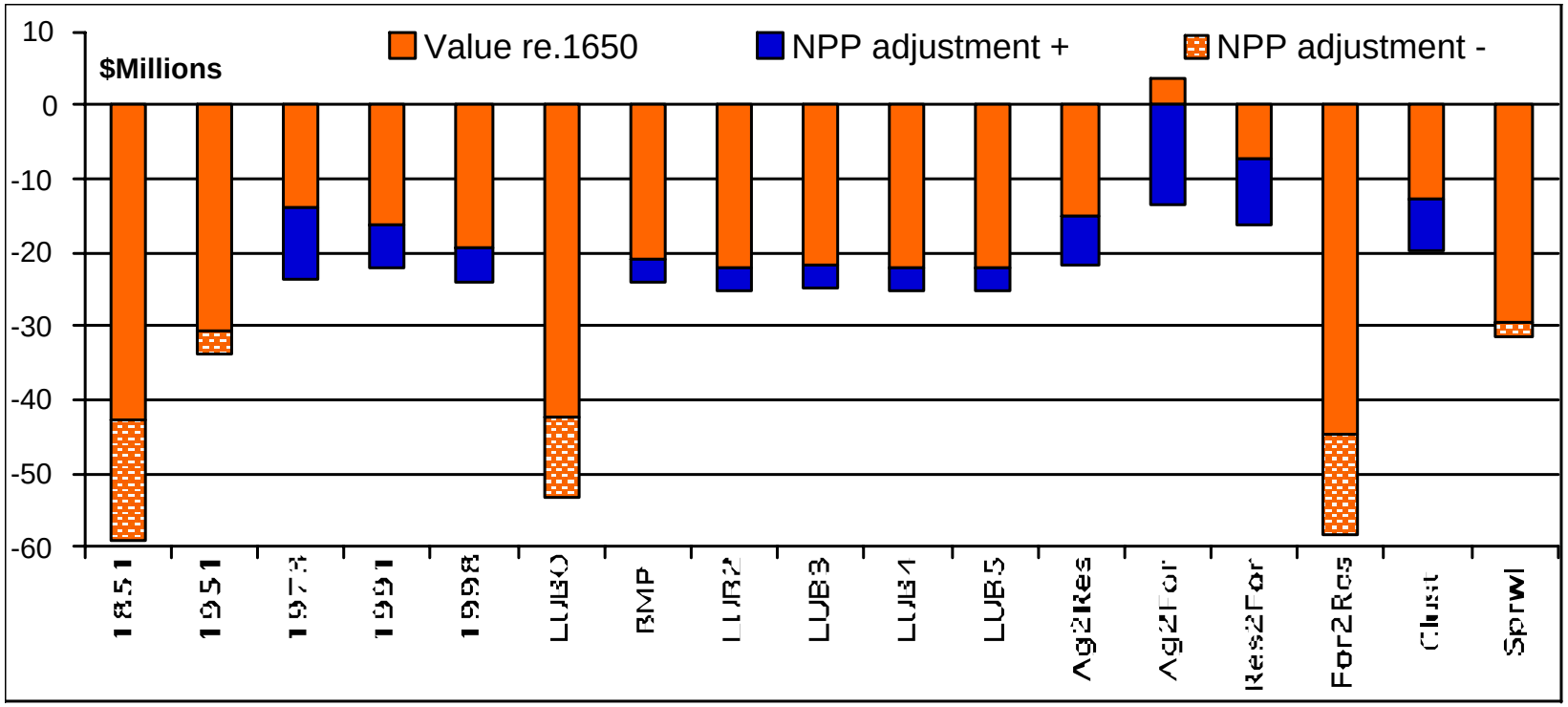
Participants Include:
Robert Costanza
Roelof Boumans
Walter Boynton
Thomas Maxwell
Steve Seagle
Ferdinando Villa
Alexey Voinov
Helena Voinov
Lisa Wainger

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

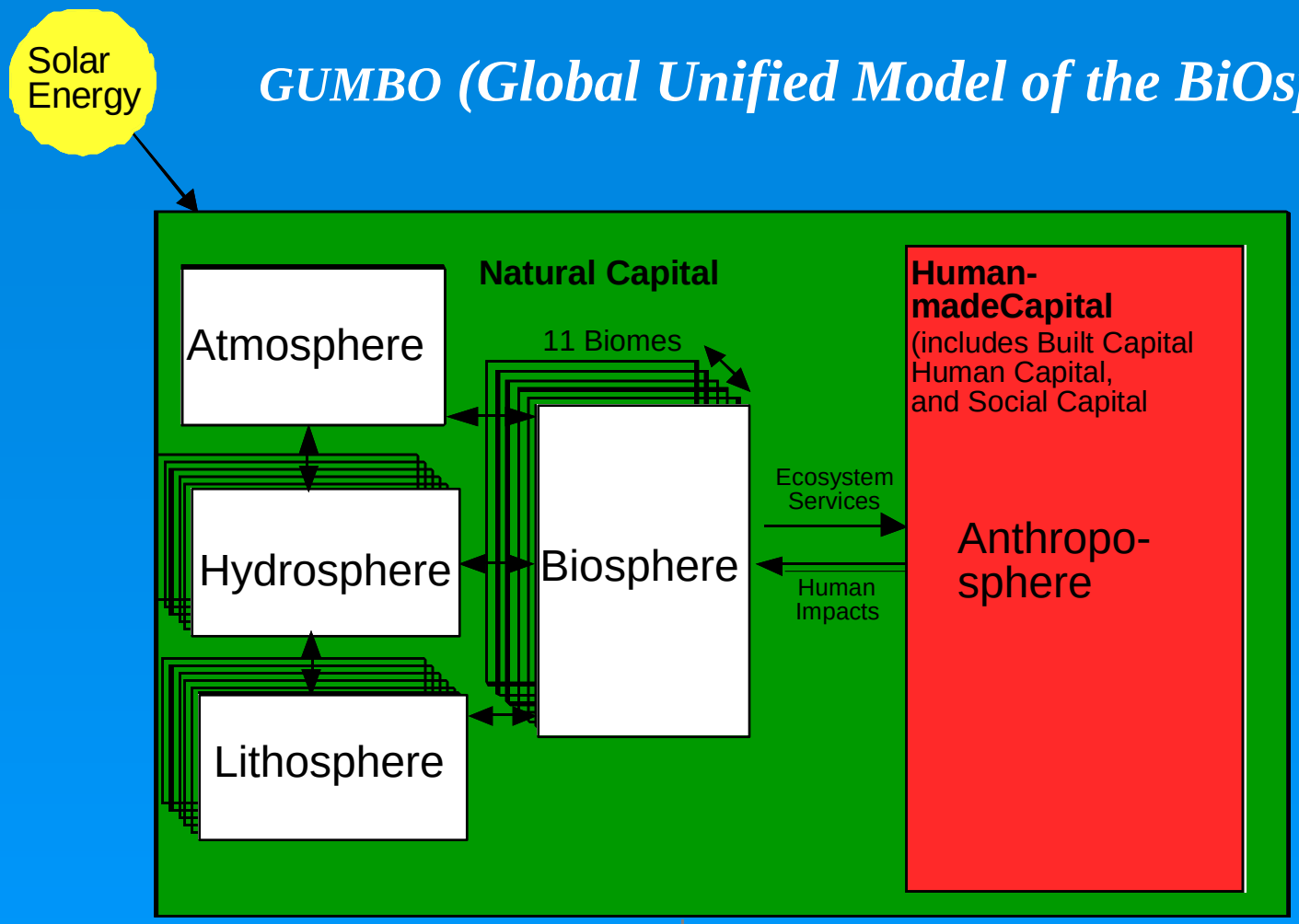
* From: Costanza, R., A. Voinov, R. Boumans, T. Maxwell, F. Villa, L. Wainger, and H. Voinov. 2002. Integrated ecological economic modeling of the Patuxent River watershed, Maryland. *Ecological Monographs* 72:203-231.

Results



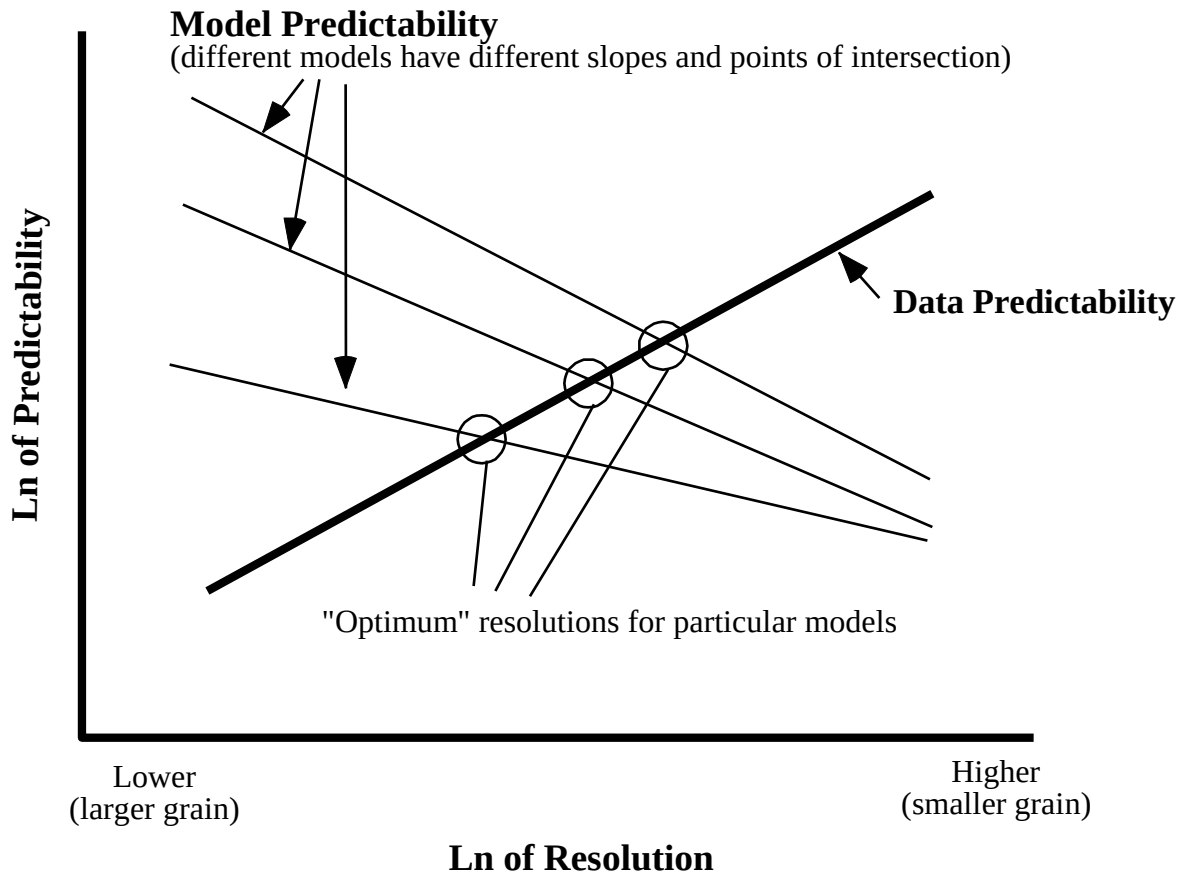
- **Change in value of ecosystem services since 1650 calculated based on values estimated for different land use types (Costanza, et al., 1997). Further adjusted by NPP values calculated by the model. In some cases the NPP adjustment further decreased the ES value (-), in other cases it increased it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

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

See also: Portella, R. R. Boumans, and R. Costanza. Ecosystem services from Brazil's Amazon rainforest: Modeling their contribution to human's regional economy and welfare and the potential role of carbon mitigation projects on their continued provision.



from: **Costanza, R. and T. Maxwell. 1994**. Resolution and predictability: an approach to the scaling problem. *Landscape Ecology* 9:47-57

Three basic methods for scaling

(after Rastetter et al. (1992) Ecological Applications)

1) partial transformations of the fine-scale mathematical relationships to coarse-scale using a statistical expectations operator that incorporates the fine-scale variability
(can be mathematically VERY cumbersome)

2) partitioning or subdividing the system into smaller, more homogeneous parts (*i.e.* spatially explicit modeling, individual agent based modeling)
(but what resolution should one use?)

3) calibration of the fine scale relationships to coarse scale data,
(if this data is available at the coarse scale!)

Integrated Modeling and Valuation: four options:

1. Values (prices) generated externally and used in the model
2. Model used as a tool for generating and displaying alternatives to value (i.e. via conjoint analysis or MCDA)
3. Model generates alternative non-preference based values (i.e. energy analysis, ecological footprint)
4. Valuation internalized in the model (i.e. CGM models, GUMBO)