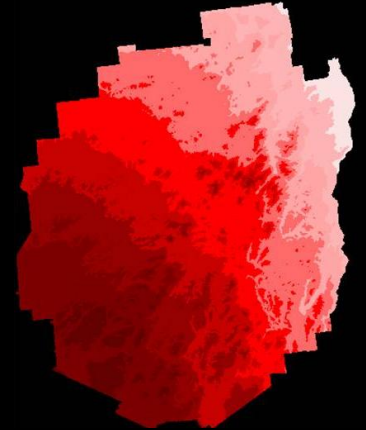


Alternative Ways to Understand and Assess the Impacts of Atmospheric Pollutants

Capturing the Value of Ecosystem Services



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Capturing the Value of Ecosystem Services

- Evolution of “Ecosystem Services”
- Role of Modeling
- Cases
 - Climate Change & Disturbance Regulation
 - Human Impact & Recreation Amenities
- ES & NYSERDA

Evolution of Ecosystem Services

Stock-Flow

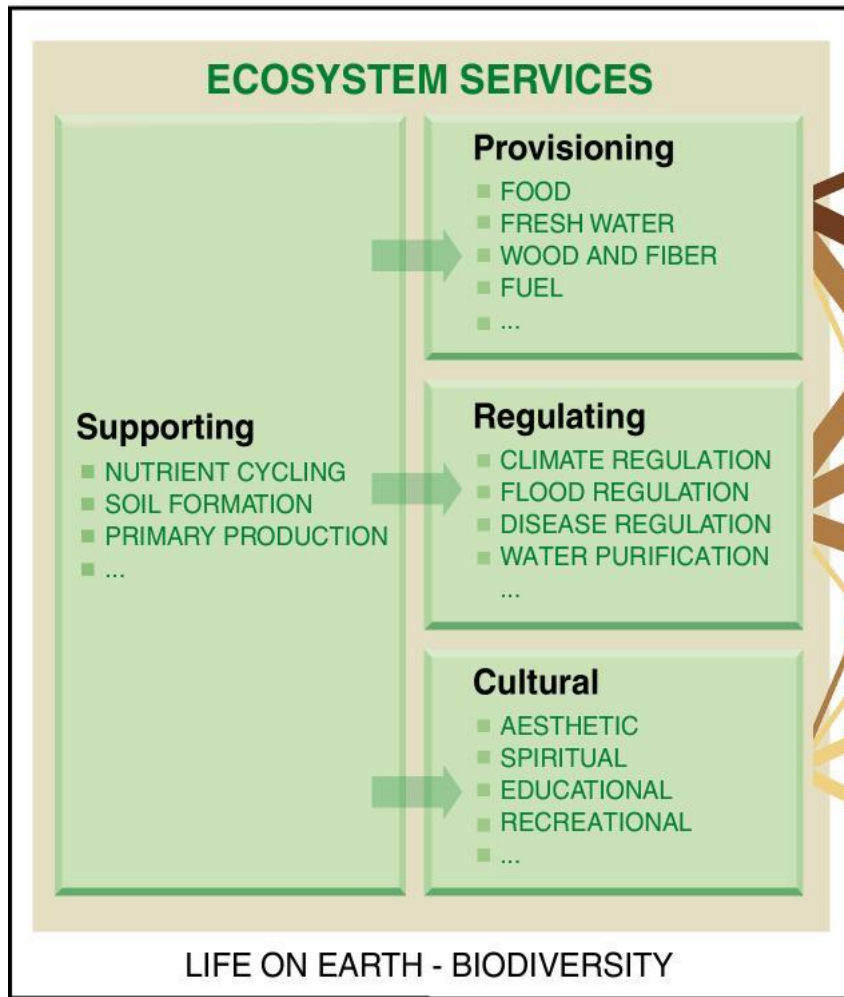
vs.

Fund-Service

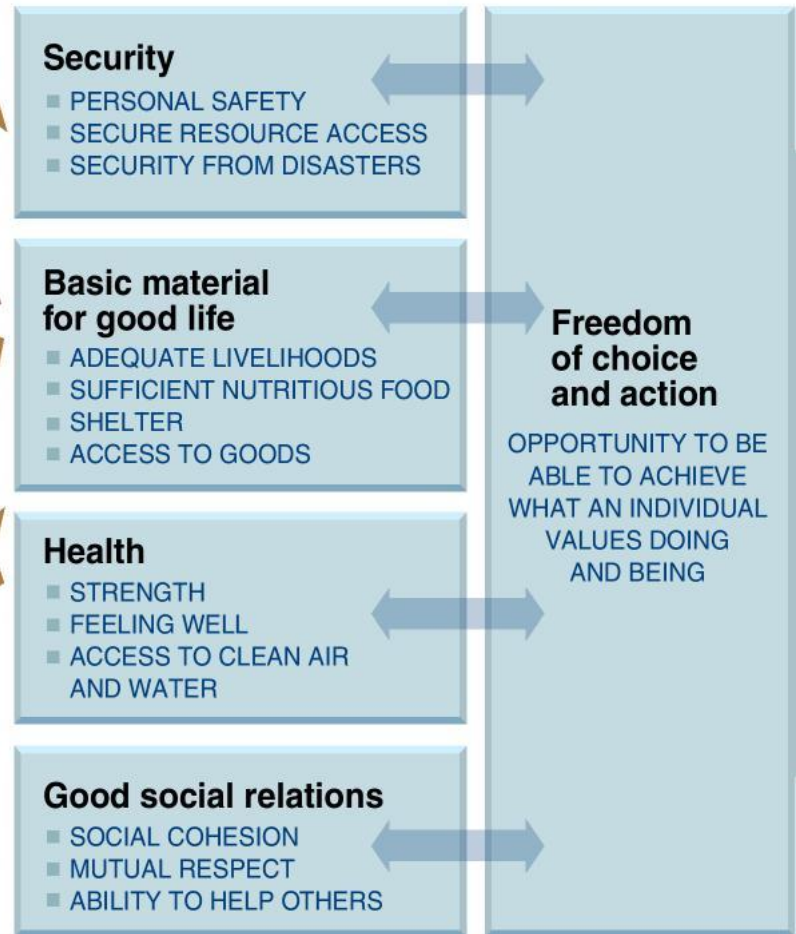


ECOSYSTEM SERVICES	ECOSYSTEM FUNCTIONS
Gas regulation	Regulation of atmospheric chemical composition.
Climate regulation	Regulation of global temperature, precipitation, and other biologically mediated climatic processes at global, regional, or local levels.
Disturbance regulation	Capacitance, damping 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.

Source: Costanza et al., "The Value of the World's Ecosystem Services and Natural Capital," *Nature* 387: 253-260, 1997.



CONSTITUENTS OF WELL-BEING



Source: Millennium Ecosystem Assessment

ARROW'S COLOR
Potential for mediation by socioeconomic factors

- Low
- Medium
- High

ARROW'S WIDTH
Intensity of linkages between ecosystem services and human well-being

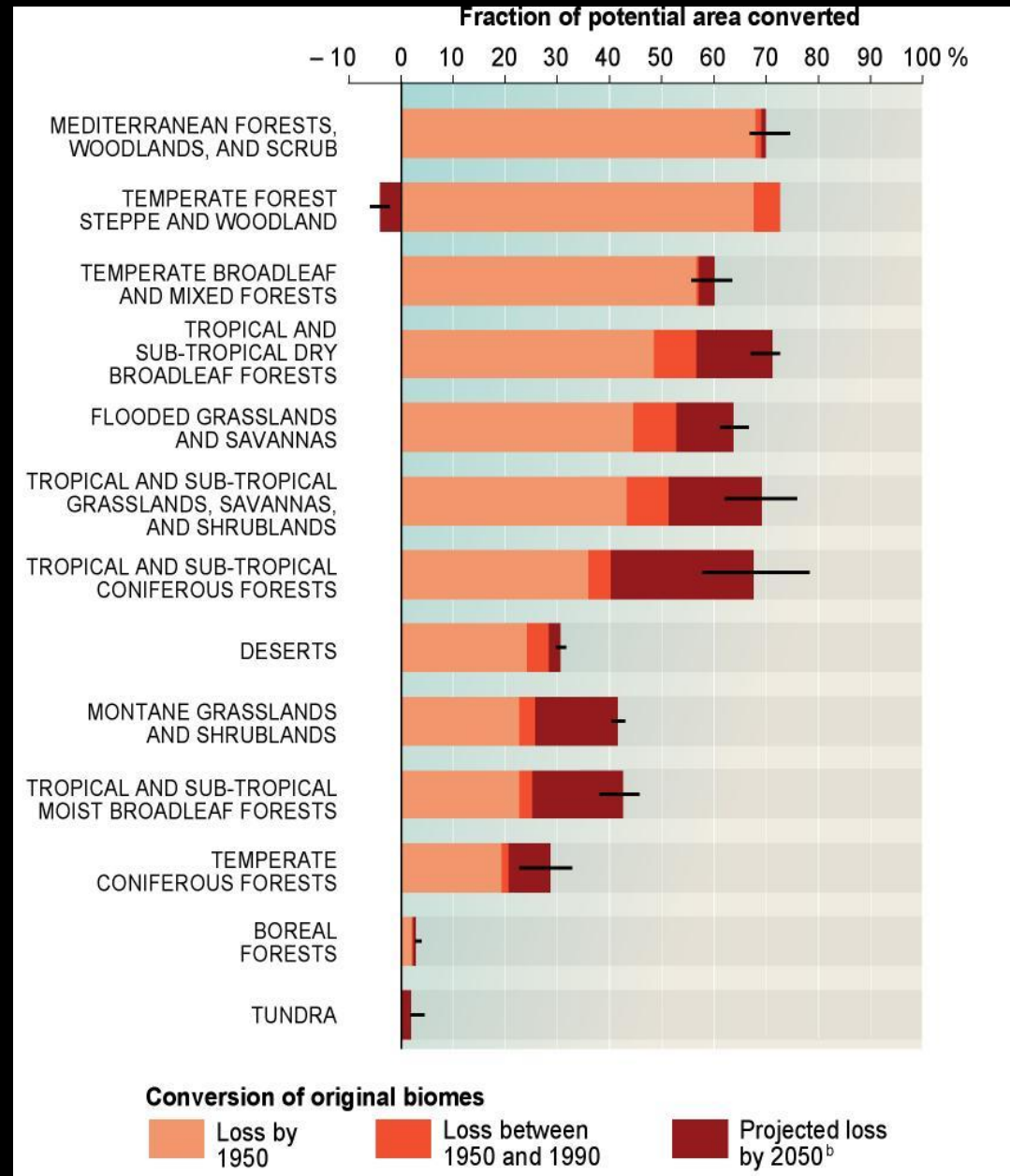
- Weak
- Medium
- Strong

Millennium

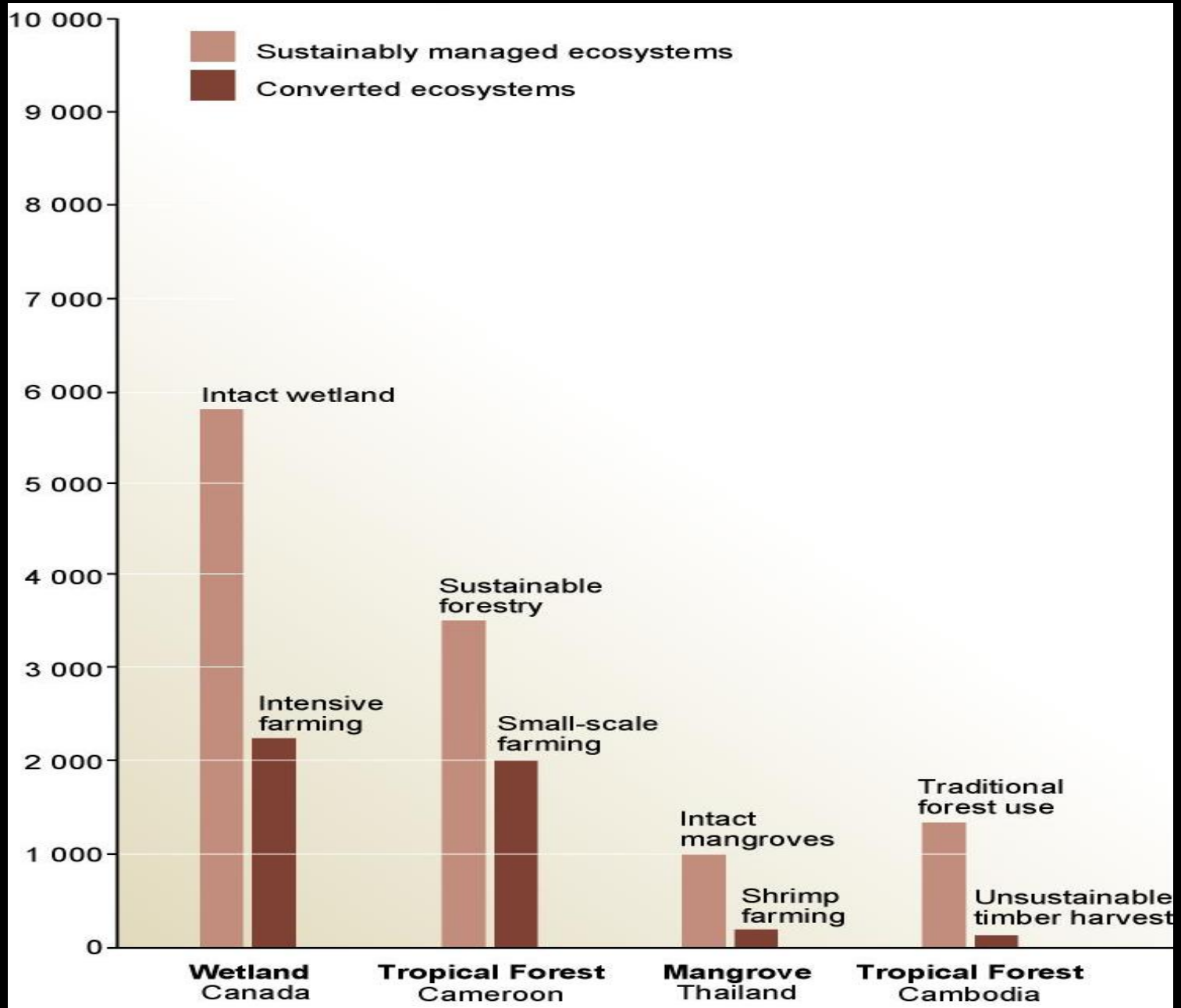
Ecosystem

Assessment

- 5-10% of the area of five biomes was converted between 1950 and 1990
- More than two thirds of the area of two biomes and more than half of the area of four others had been converted by 1990



Net Present Value
(\$/hectare)



Source: Millennium Ecosystem Assessment

Role of Modeling

Three Levels of Modeling

1. Scoping Models

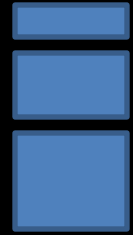
High generality, low resolution, broad participation by all stakeholder groups.

2. Research Models

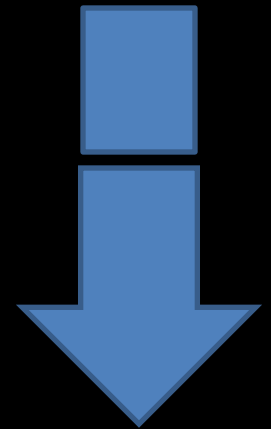
More detailed and realistic attempts to replicate the dynamics of a particular system of interest, with emphasis on calibration and testing.

3. Management Models

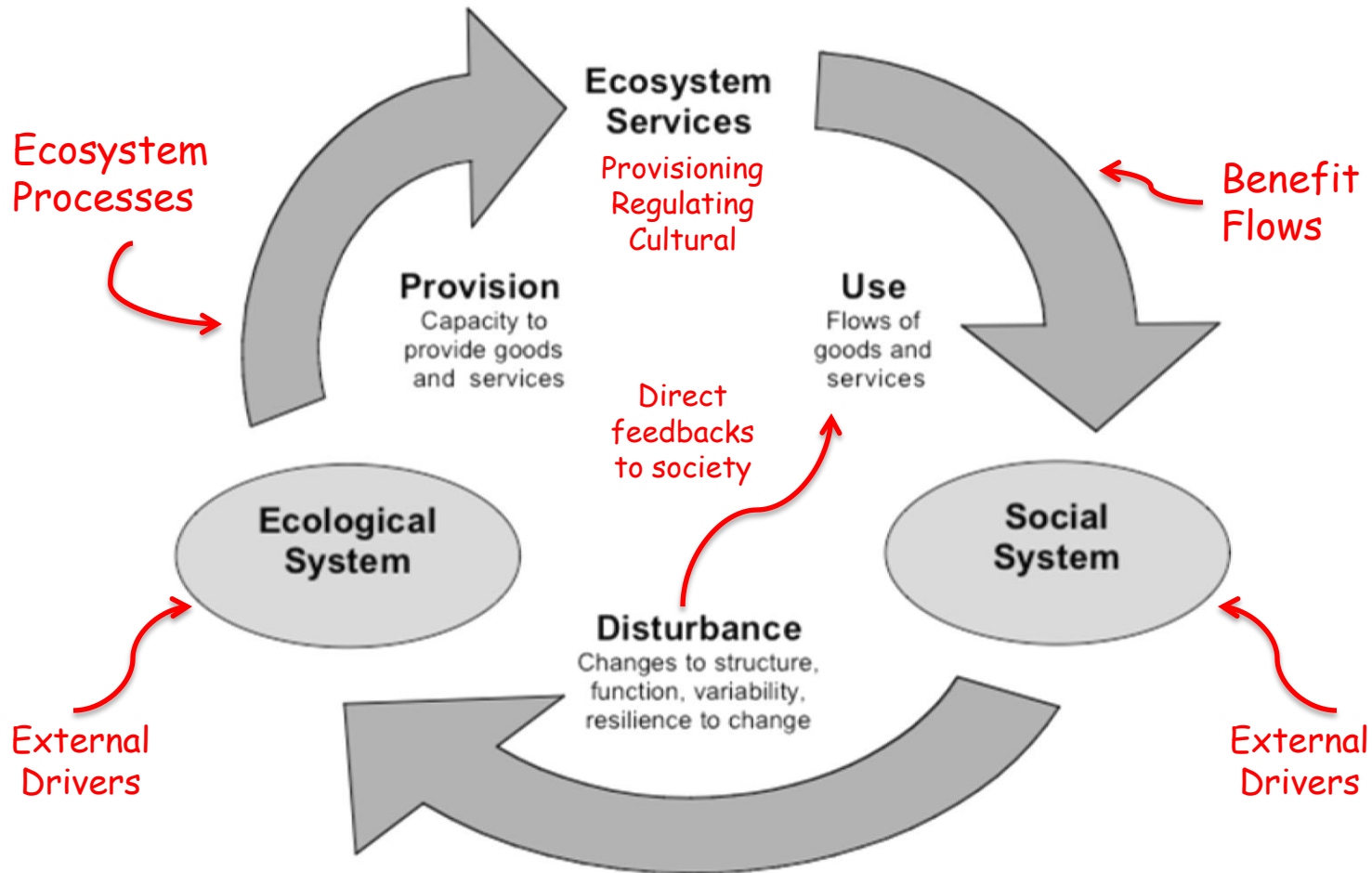
Medium to high resolution. Emphasis on producing future management scenarios. Can be exercising #1 or #2, or require further elaboration to apply management questions.



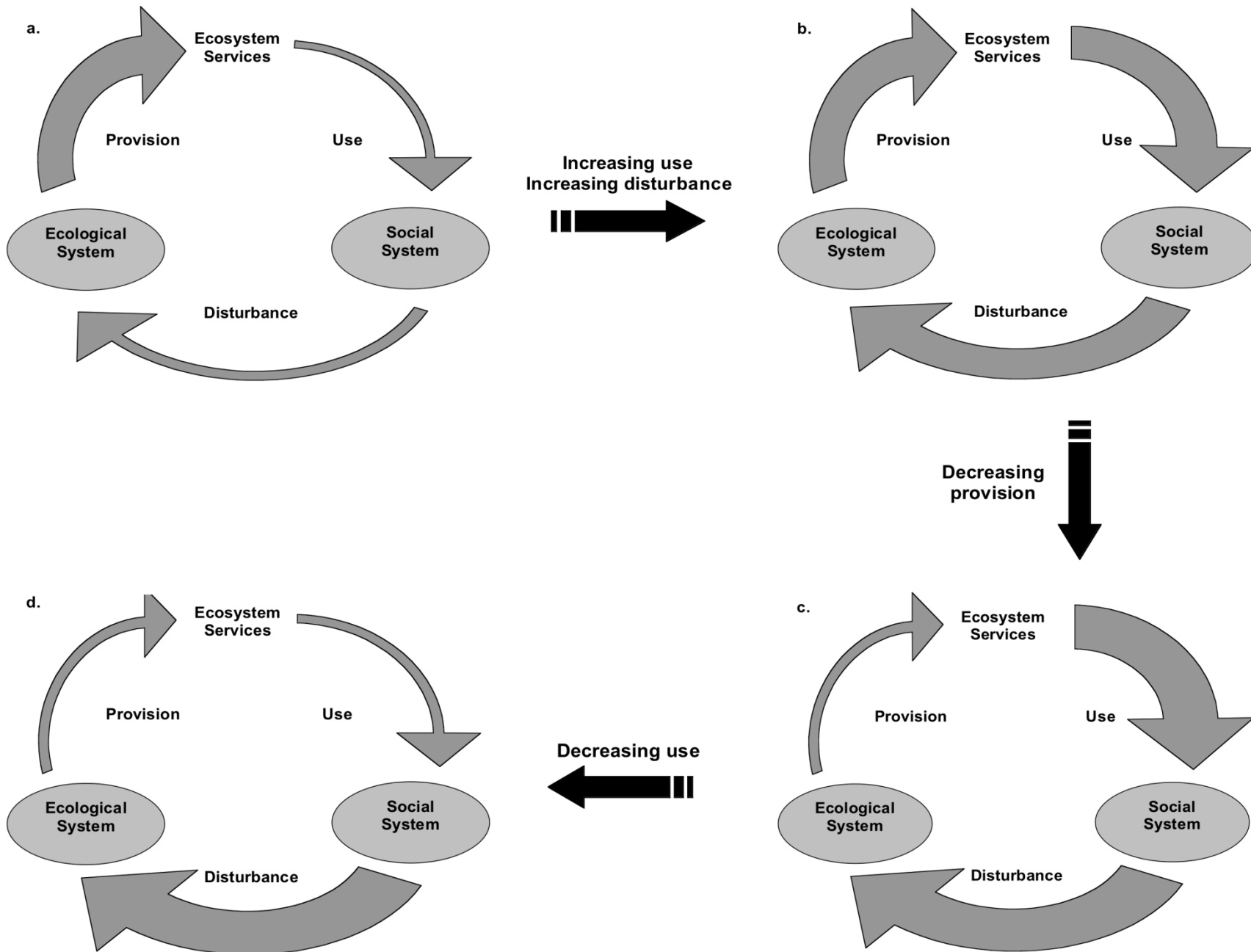
Increasing
Complexity,
Cost, Realism,
and Precision



A systems framework for ES assessment...



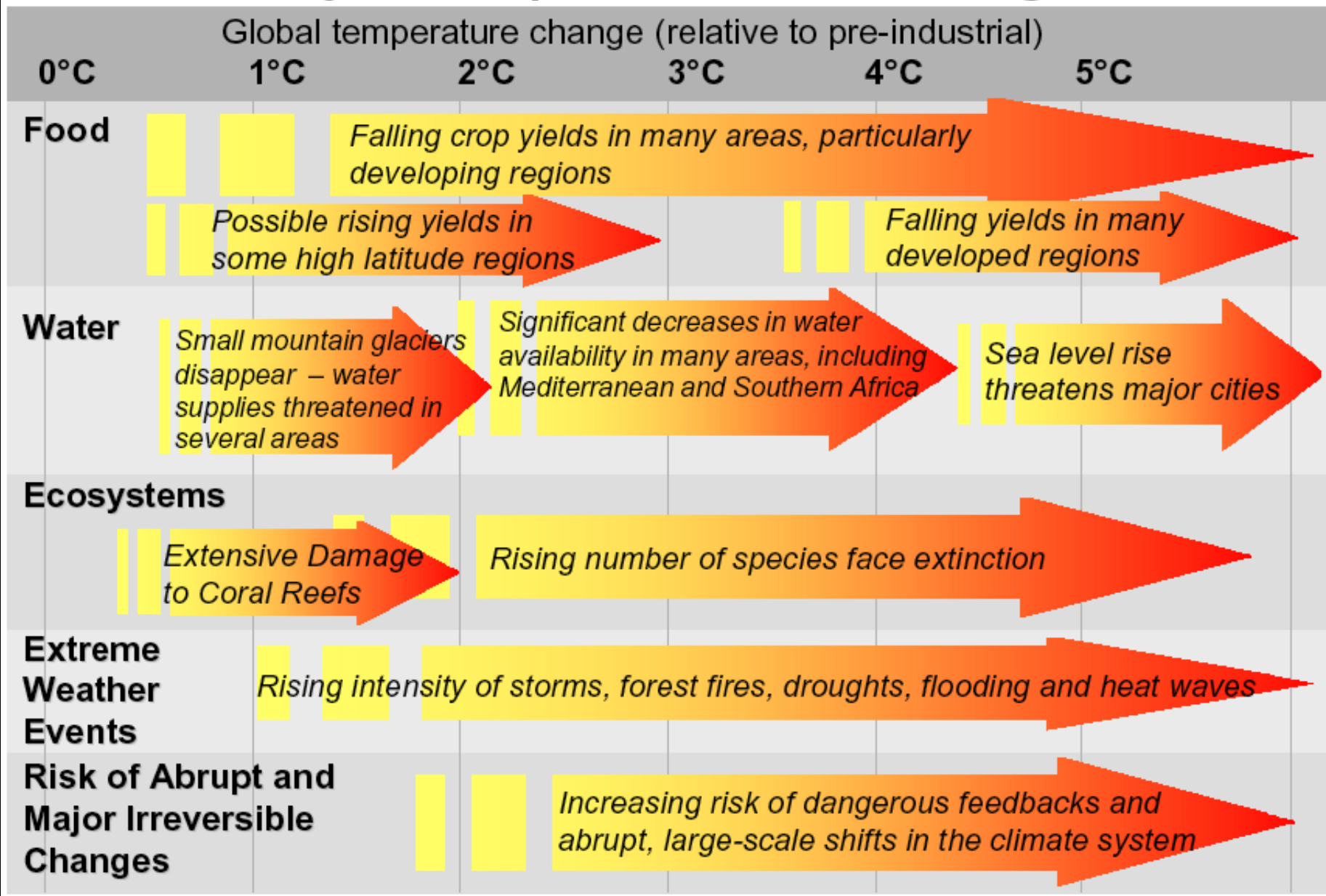
Beier et al. (2008) Ecosystems



Cases

Climate Change & Disturbance Regulation
(Scoping Model)

Projected Impacts of Climate Change







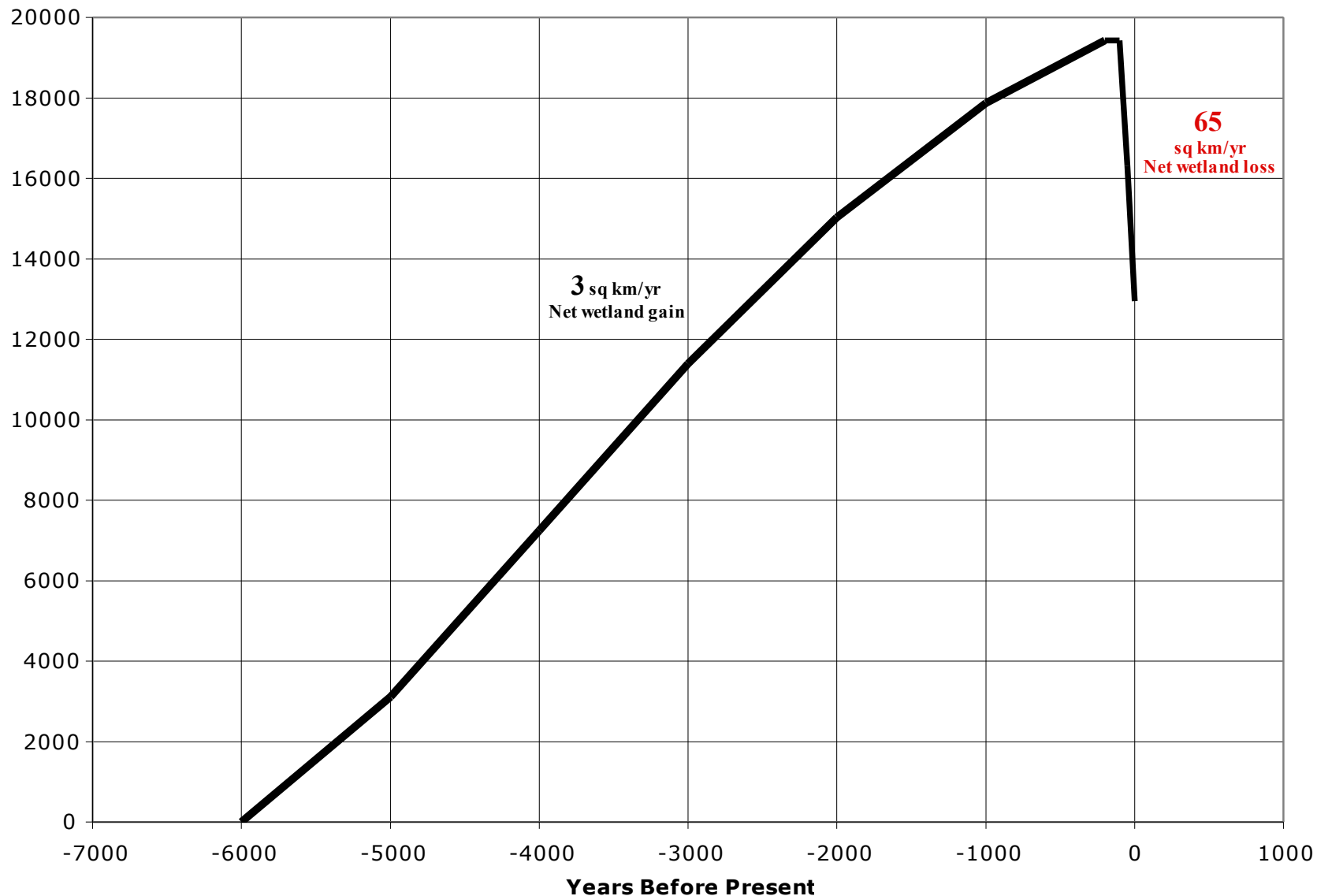
Picture taken by an automatic camera located at an electrical generating facility on the Gulf Intracoastal Waterway (GIWW) where the Route I-510 bridge crosses the GIWW. This is close to where the Mississippi River Gulf Outlet (MRGO) enters the GIWW. The shot clearly shows the storm surge, estimated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

Coastal Louisiana

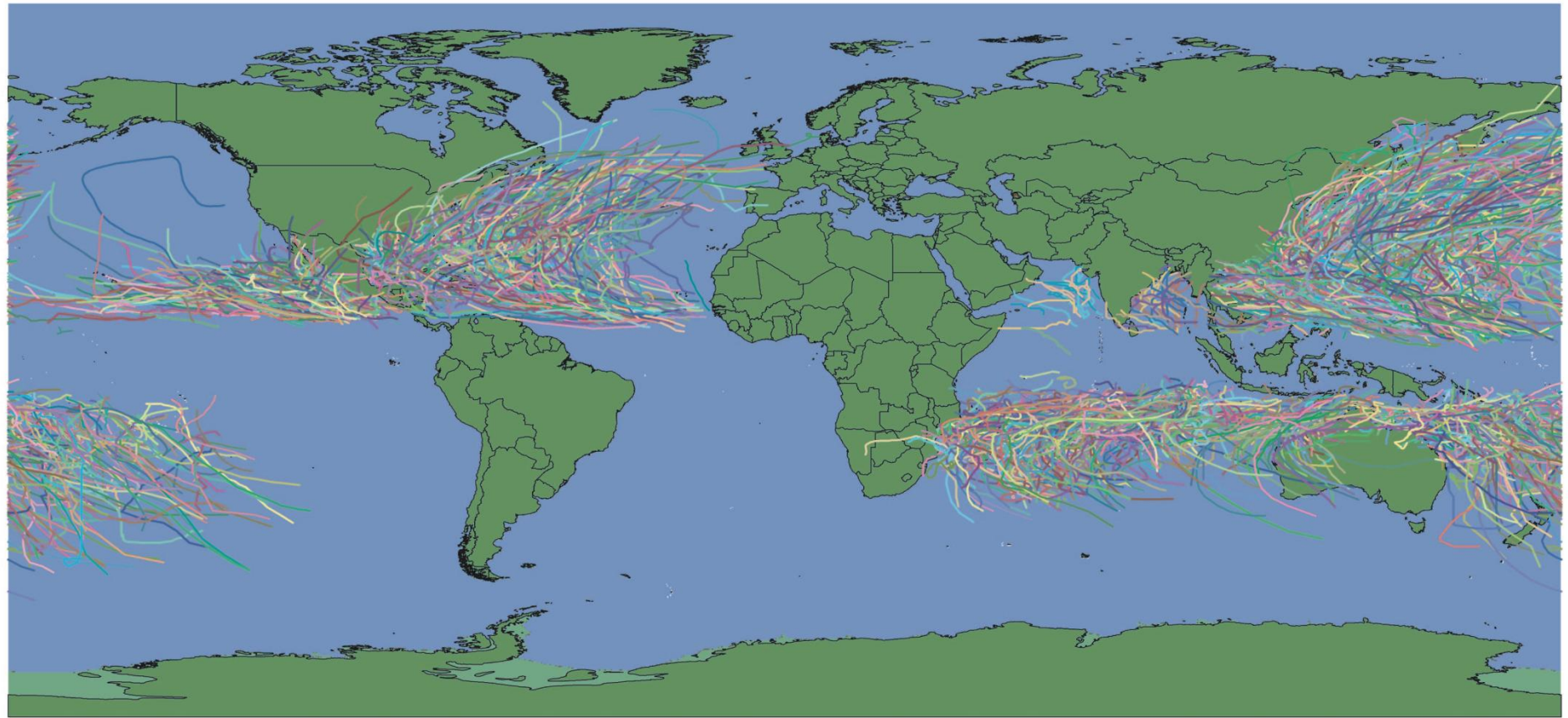
NEW ORLEANS



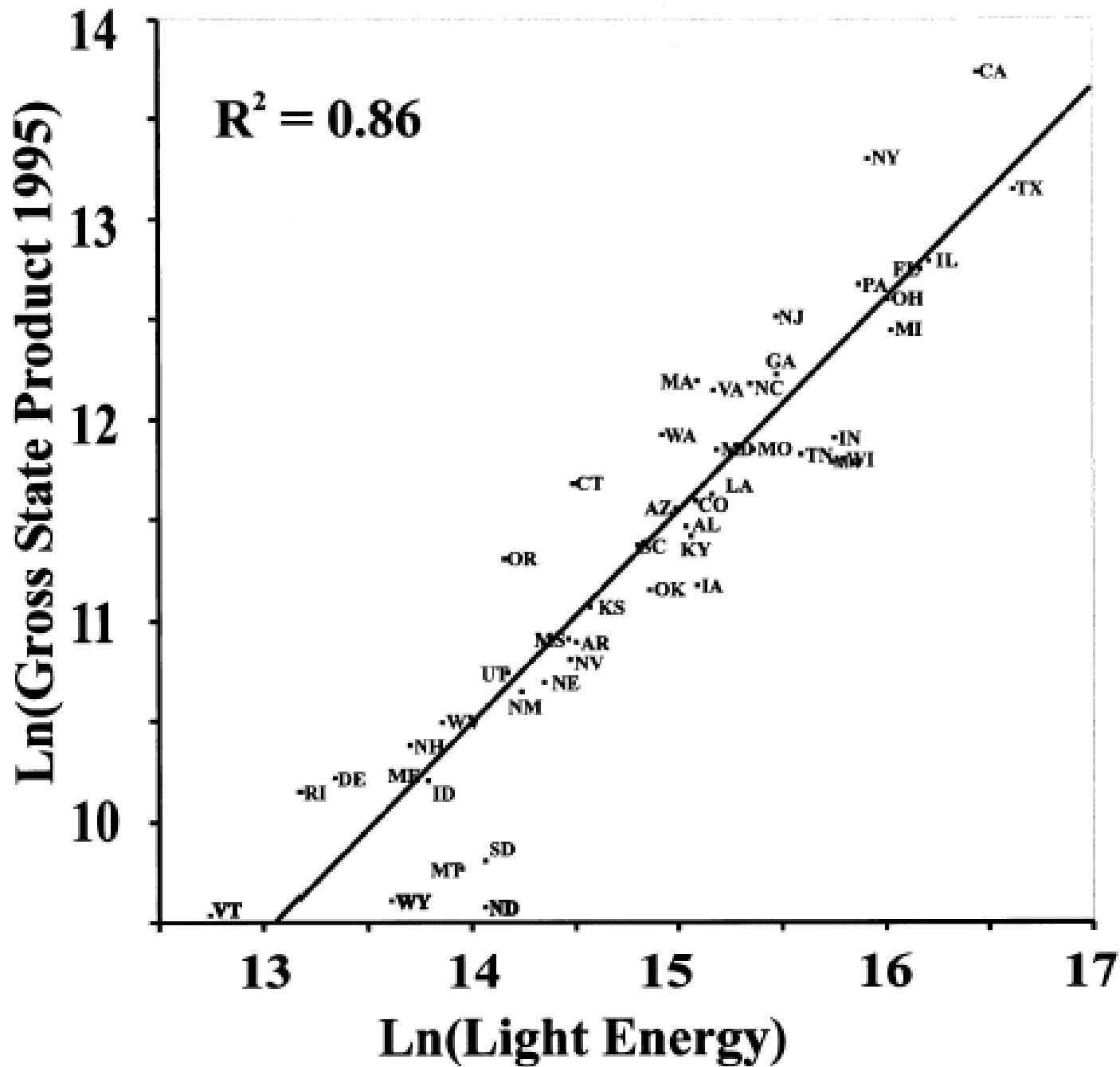
Past and Projected Wetland Loss in the Mississippi Delta (1839 to 2020)



History of coastal Louisiana wetland gain and loss over the last 6000 years, showing historical net rates of gain of approximately 3 km²/year over the period from 6000 years ago until about 100 years ago, followed by a net loss of approximately 65 km²/yr since then.



Global Storm Tracks 1980 - 2006



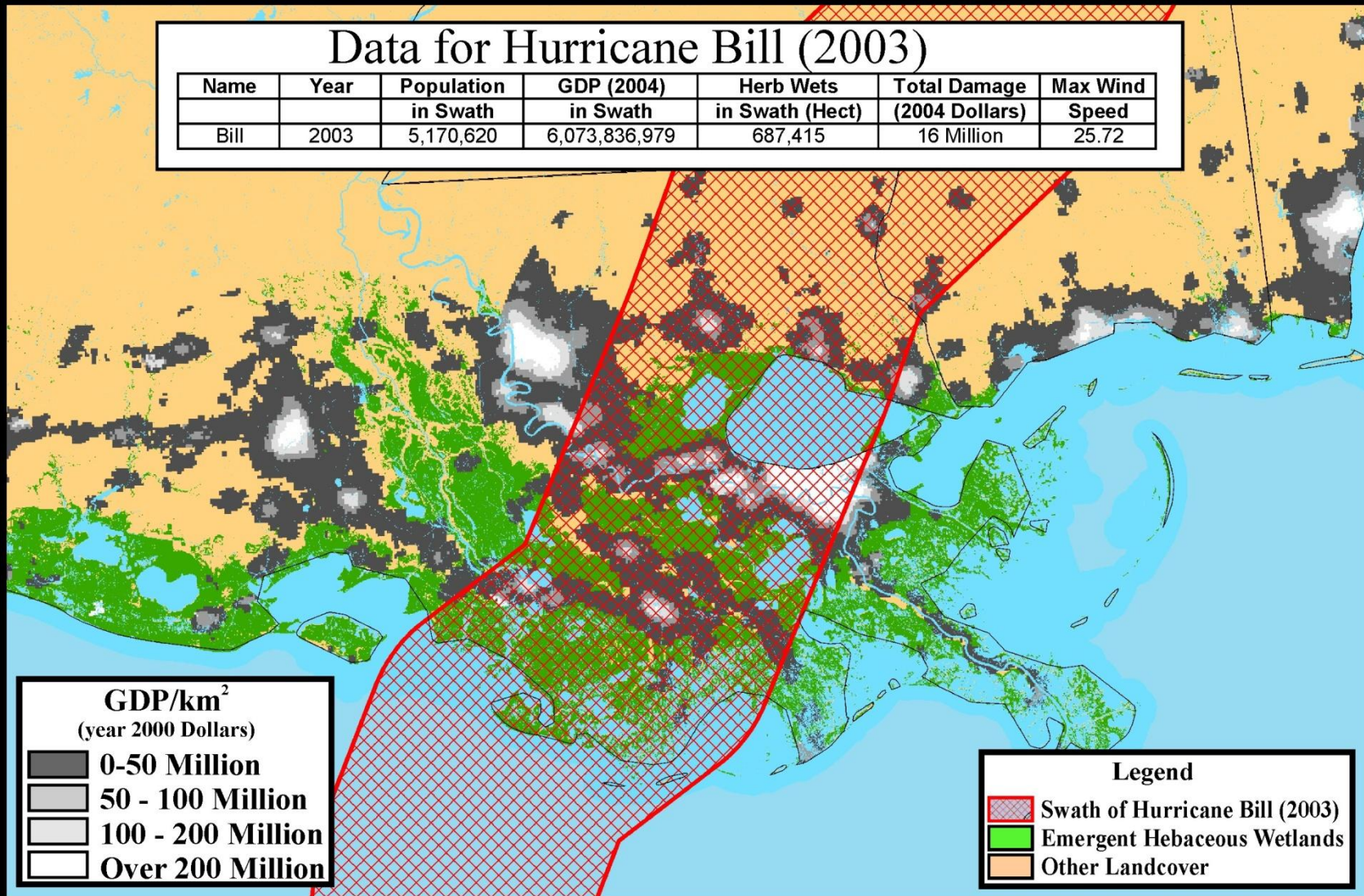


Figure 1. Typical hurricane swath showing GDP and wetland area used in the analysis.

The value of coastal wetlands for hurricane protection

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

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

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

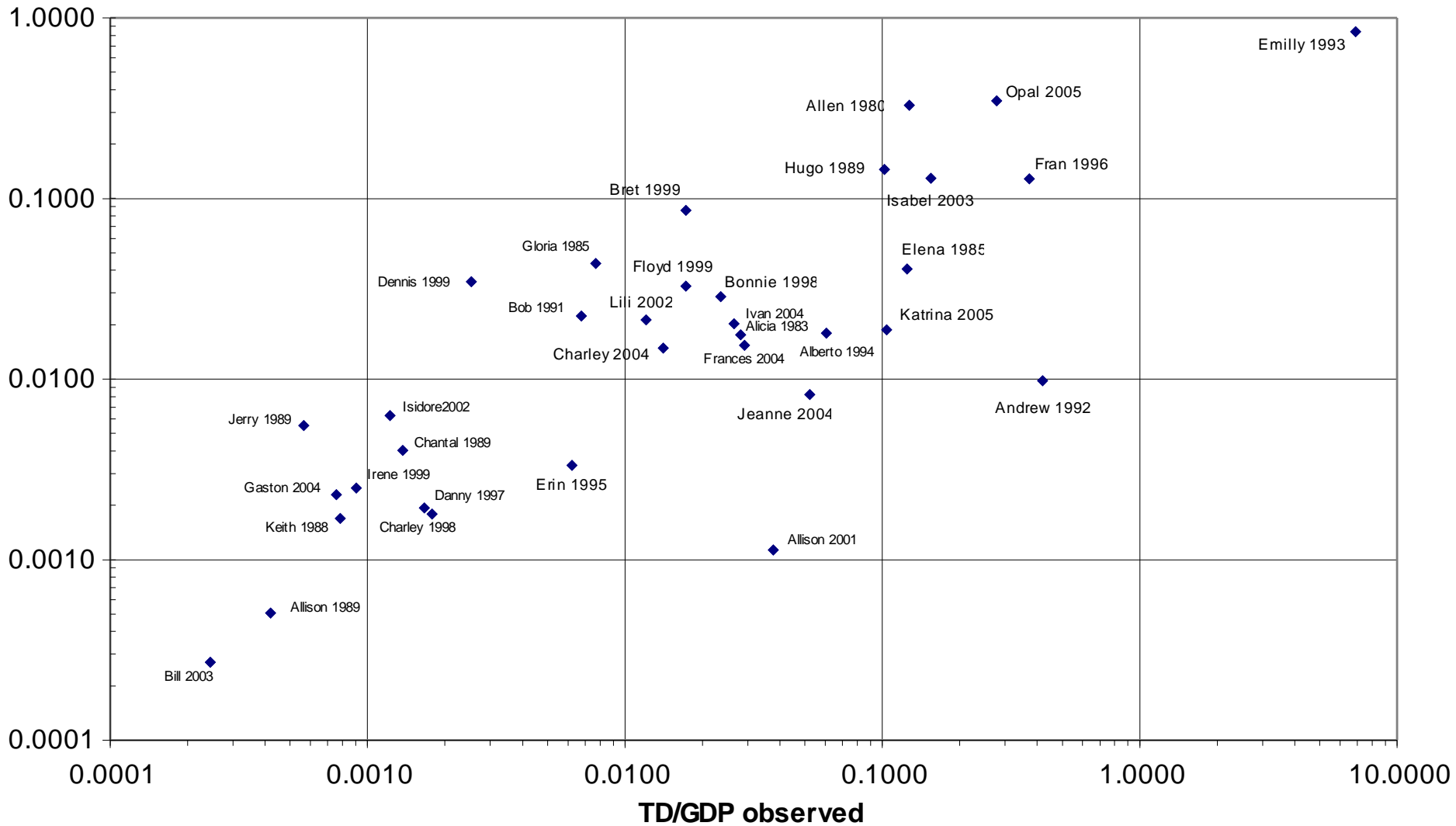
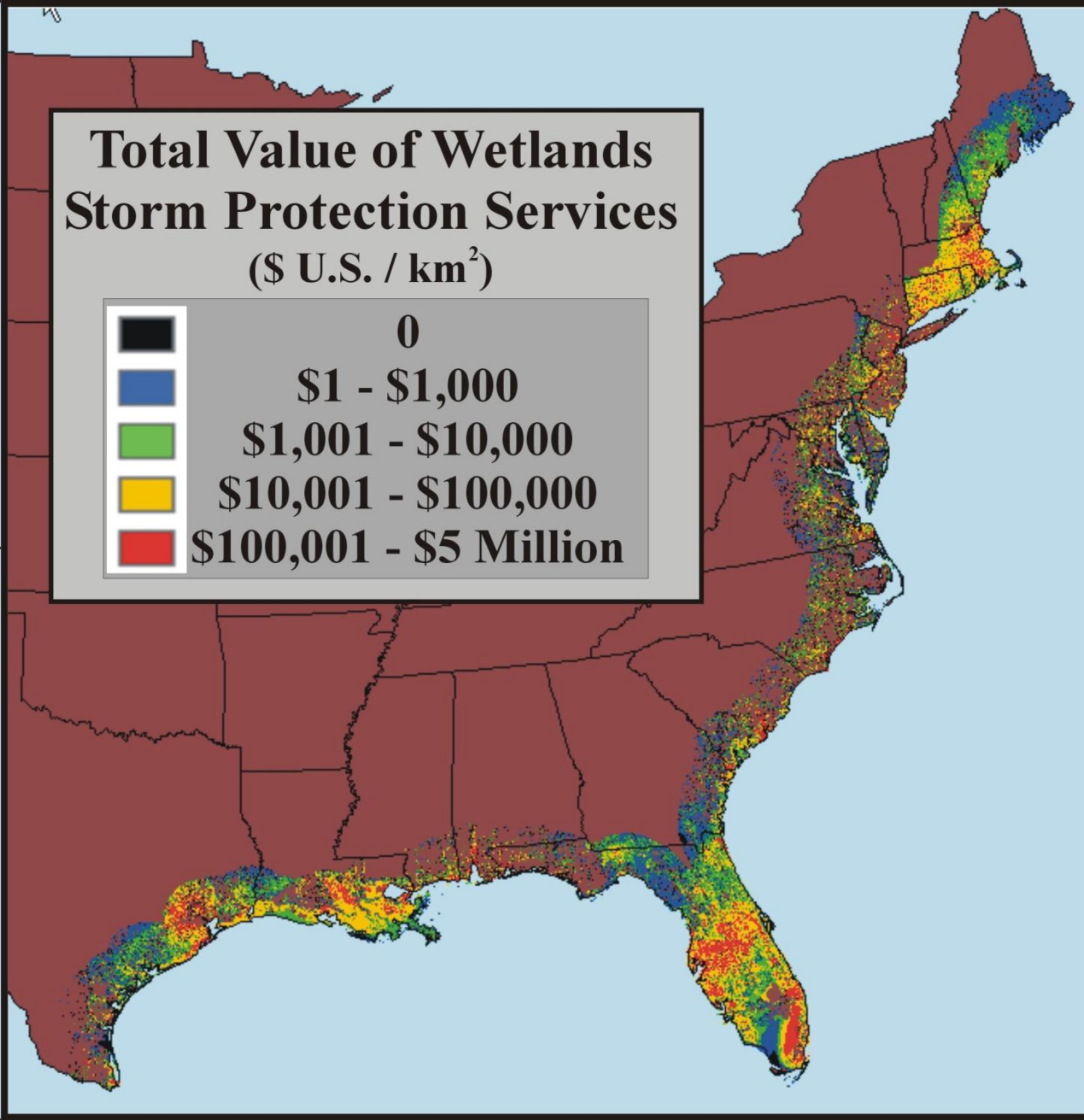
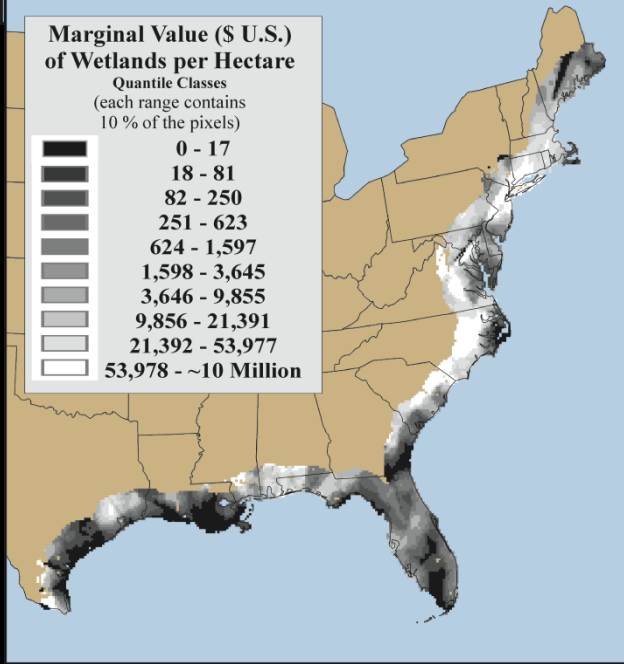
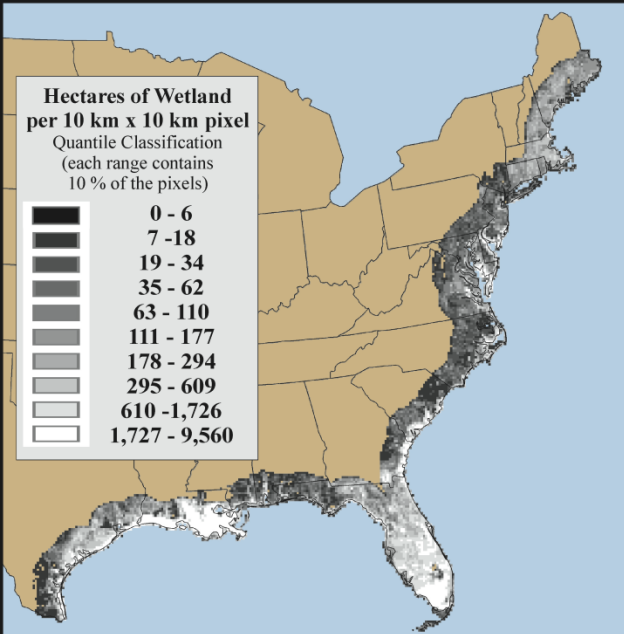


Figure 2. Observed vs. predicted relative damages (TD/GDP) for each of the hurricanes used in the analysis.



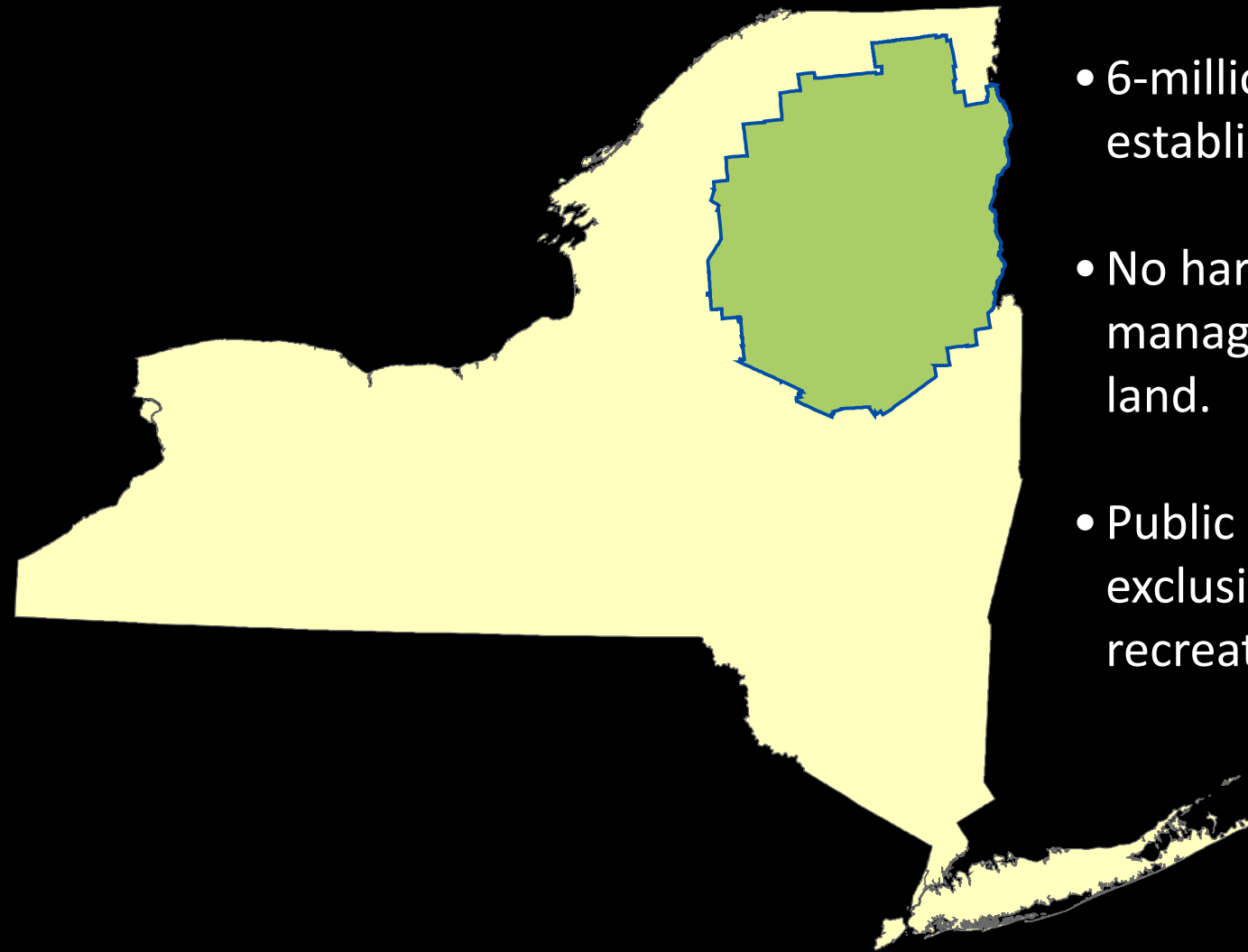
Costanza, R., O. Pérez-Maqueo, M. L. Martinez, P. Sutton, S. J. Anderson, and K. Mulder, “The value of coastal wetlands for hurricane protection,” *Ambio* 37:241-248, 2008.

- A **loss of 1 ha of wetland** in the model corresponded to an **average \$33,000 increase in storm damage** (median = \$5,000) 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 U.S. were estimated to currently provide **\$23.2 Billion/yr in storm protection services**.

Cases

Human Impact & Recreation Amenities
(Research/Management Model)

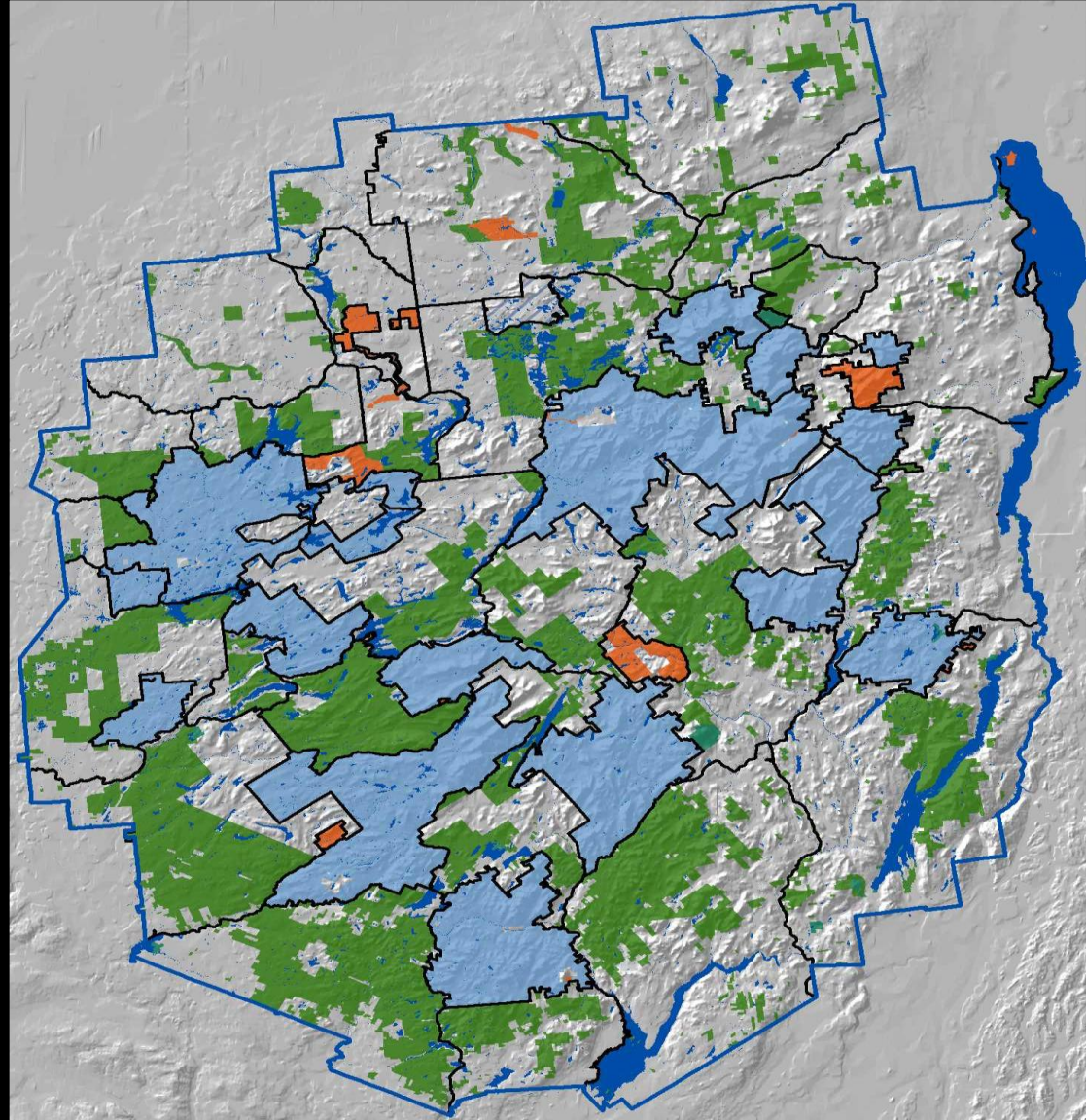
Adirondack Park

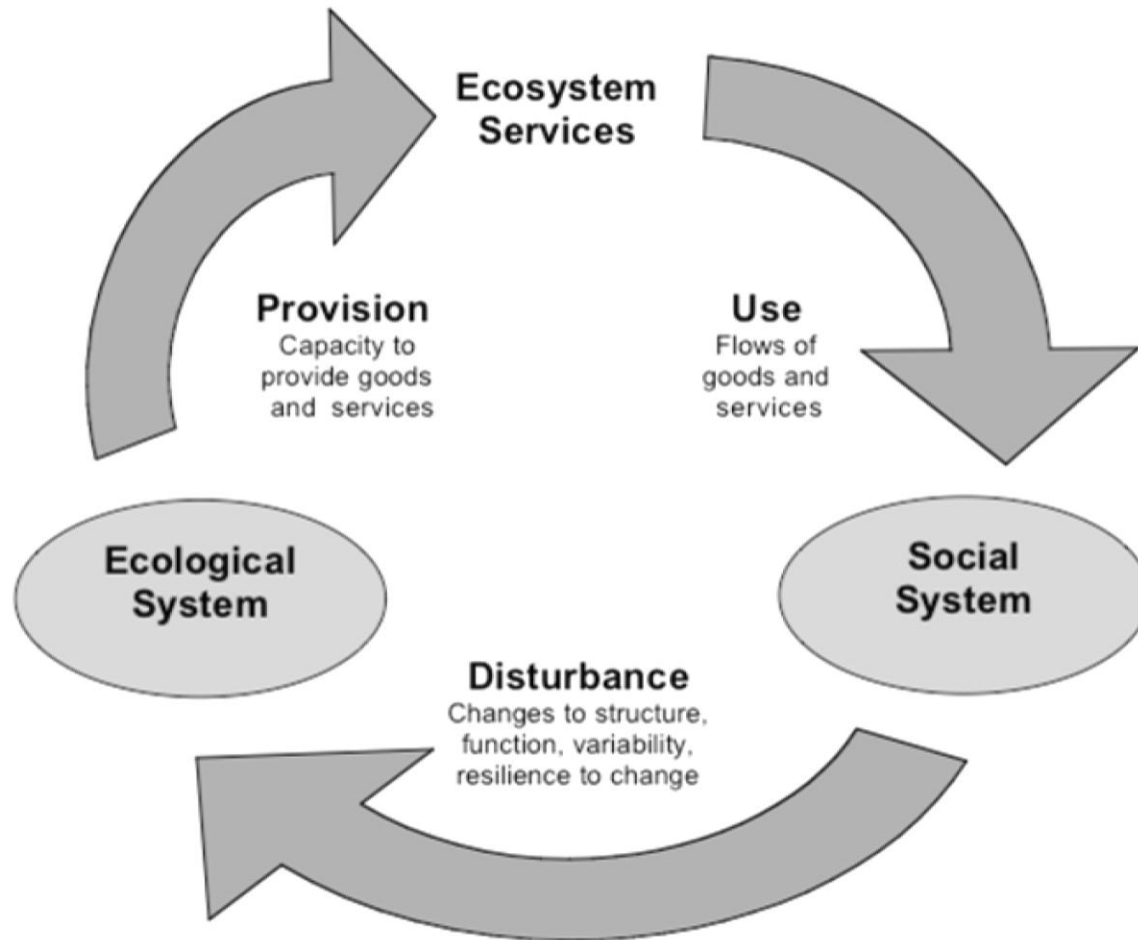


- 6-million acre state park, established in 1880s.
- No harvesting or timber management on public land.
- Public land managed almost exclusively for wilderness / recreation.

Adirondack Forest Preserve

- Matrix of mountains/lakes.
- Interspersed with a population of 131,000 (14 people/sq. mi.)
- Public land managed by NY Department of Environmental Conservation (DEC).
- 53 management units.
- Wilderness, Wild Forest, Primitive, Canoe, Intensive Use Areas

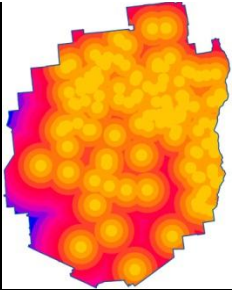




Beier et al. (2008) Ecosystems

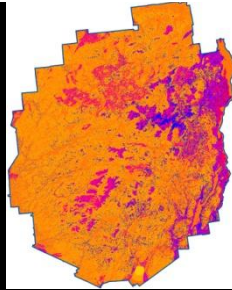
Provision Model

Distance to State
Threatened/Endangered
Animal Habitat



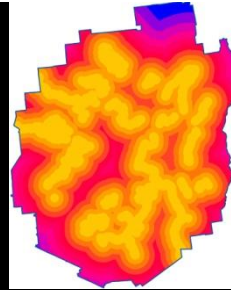
+

Ecosystem
Rarity



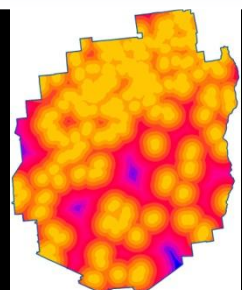
+

Distance to
exemplary aquatic
communities



+

Distance to
Megawetlands



Slice each raster into 20 equal-area classes

Add rasters together, slice into 10 equal-area classes

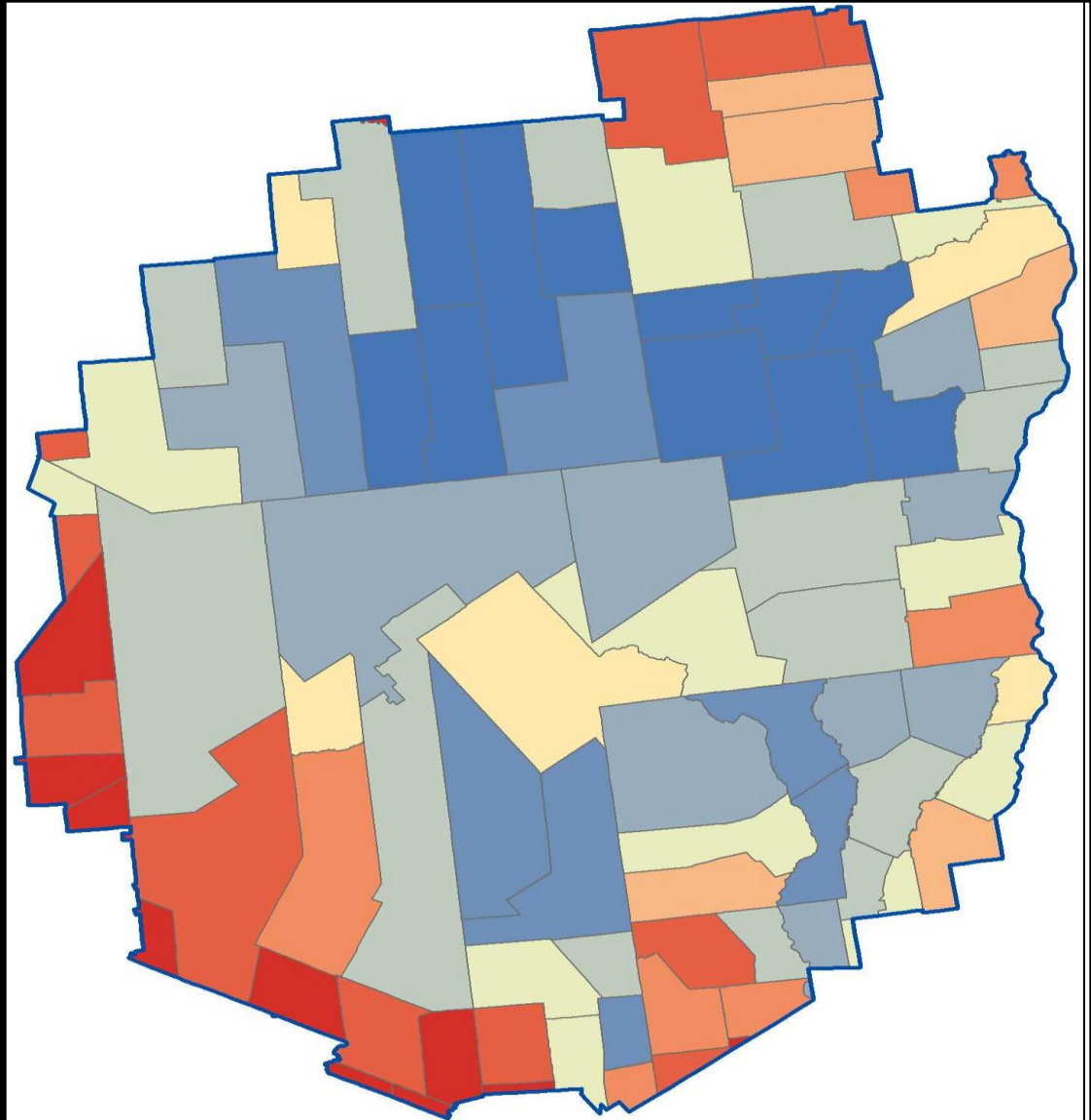
Provision Index

Provision Index

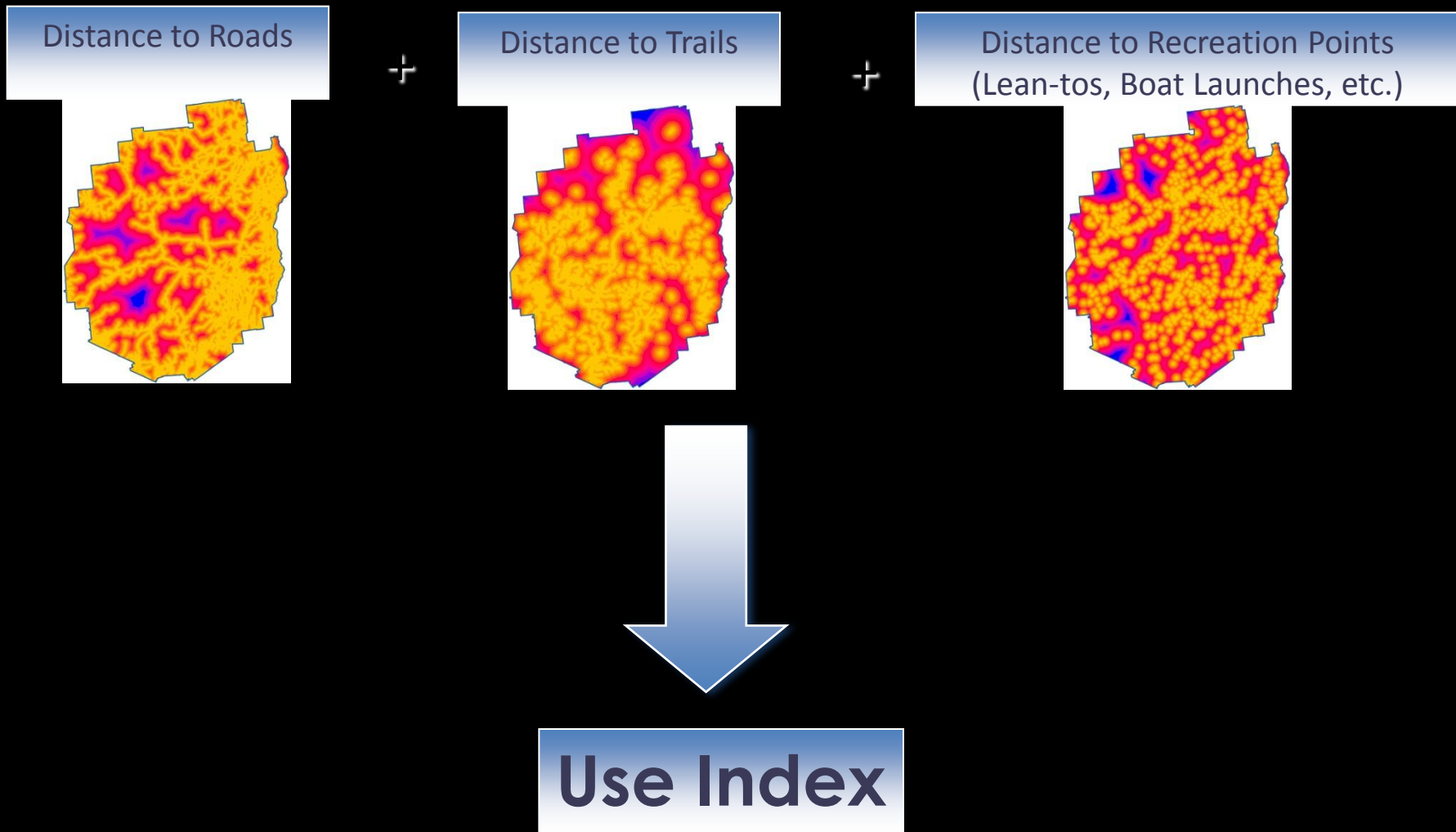
1-10 scale

Blue = High Provision

Red = Low Provision



Use Model

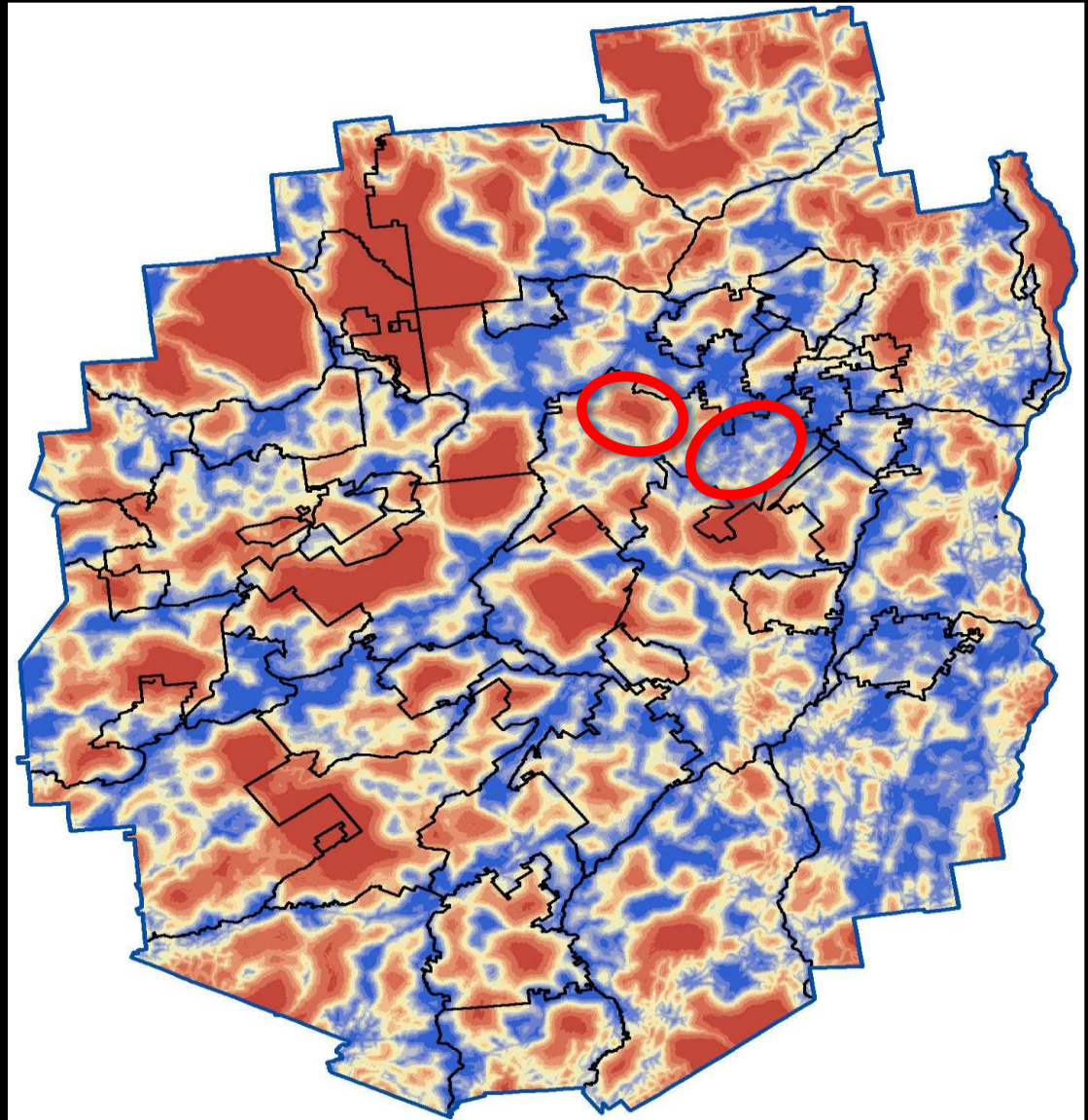


Use Index

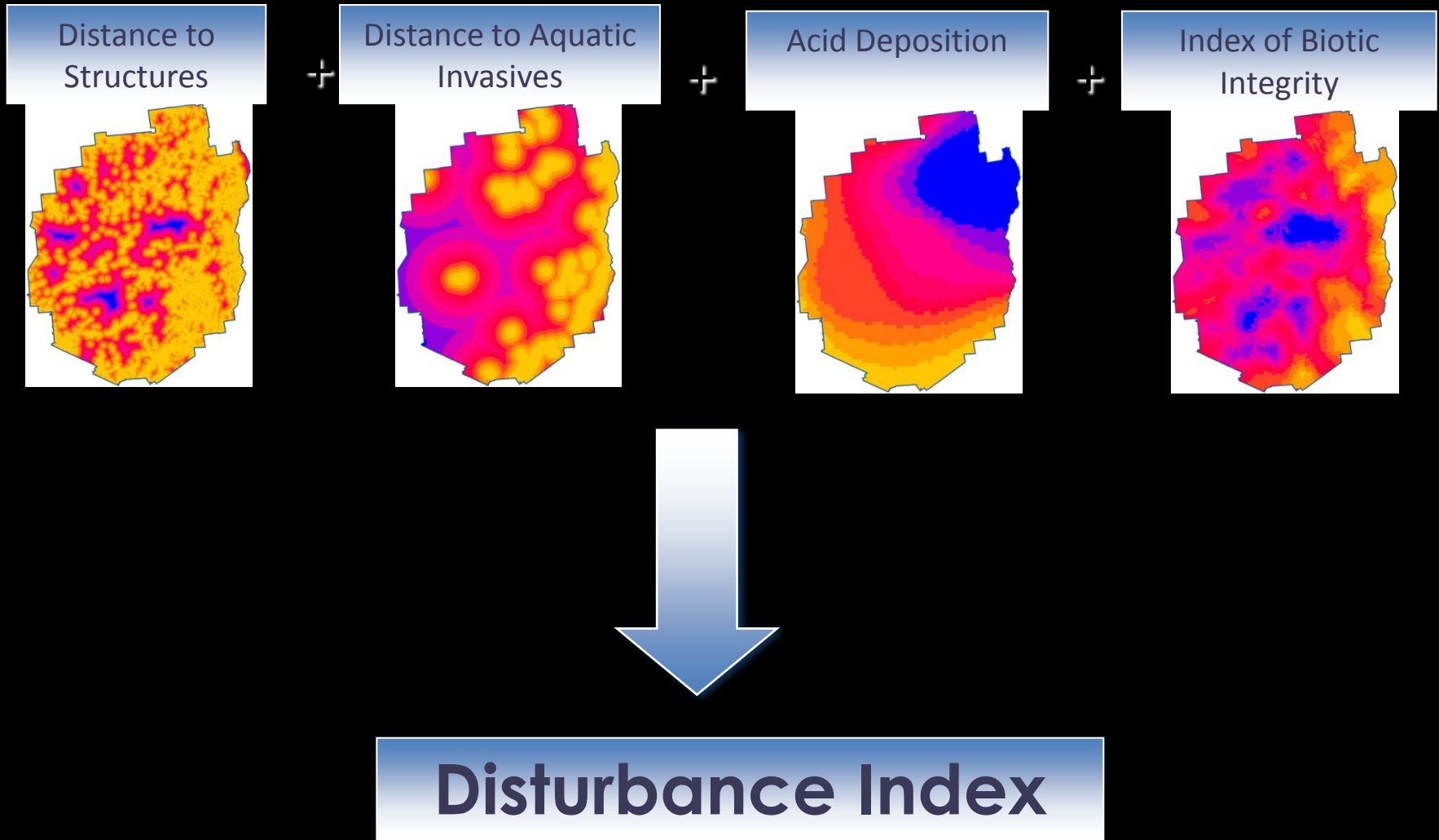
1-10 scale

Blue = High Use

Red = Low Use



Disturbance Model

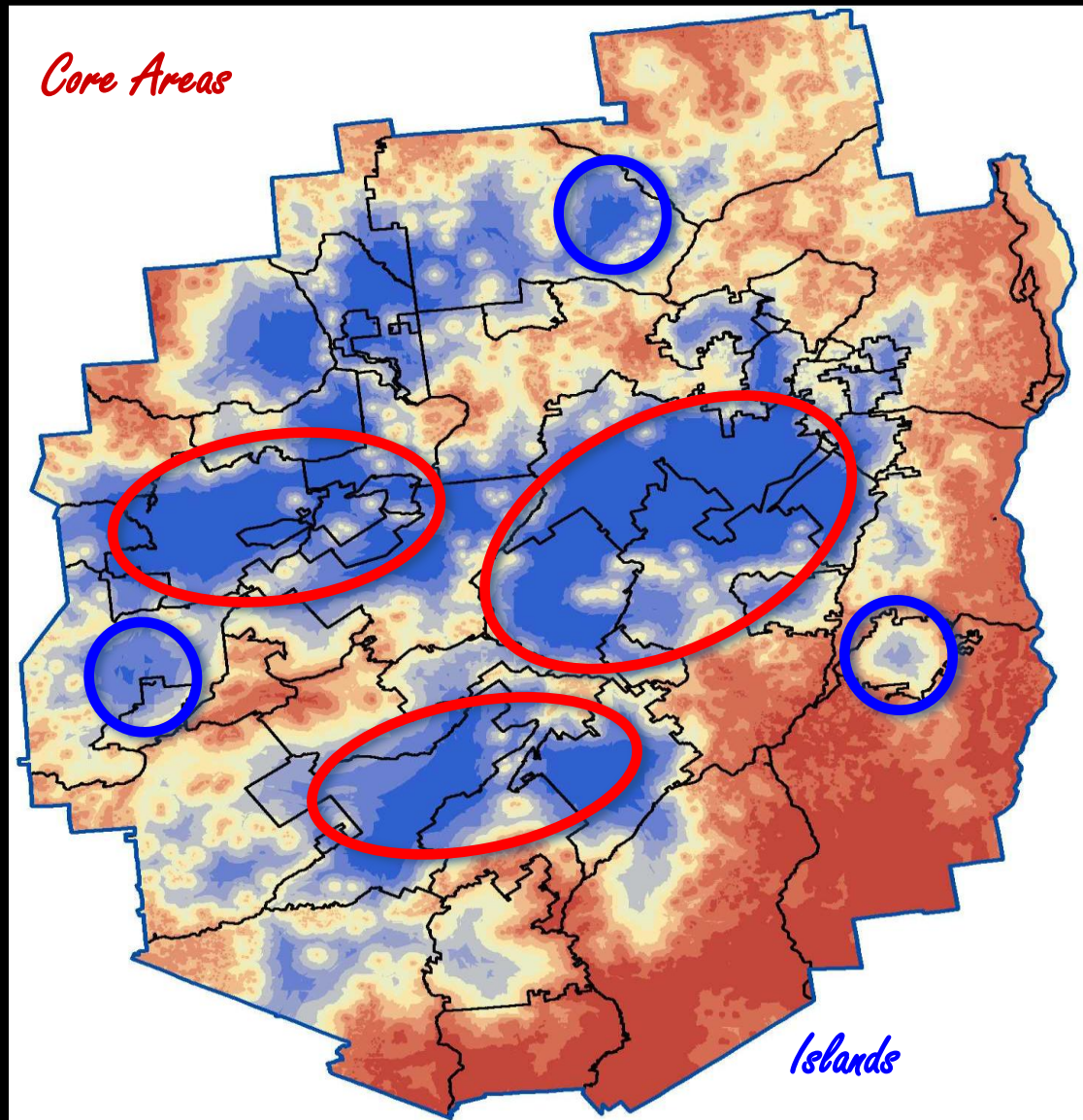


Disturbance Index

1-10 scale

Blue = Low Disturbance

Red = High Disturbance

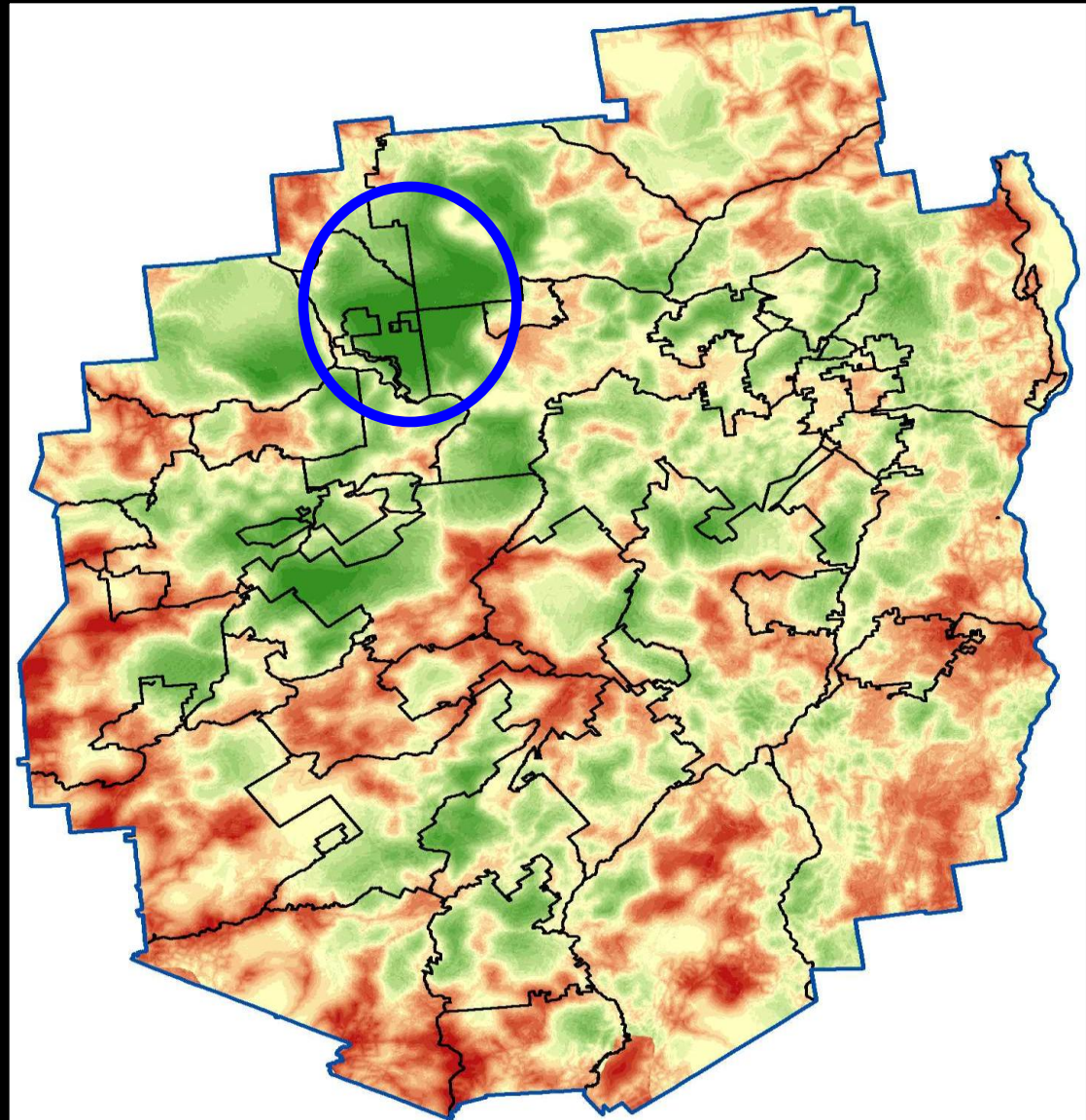


Combining rasters illuminates relationships between provision, use & disturbance

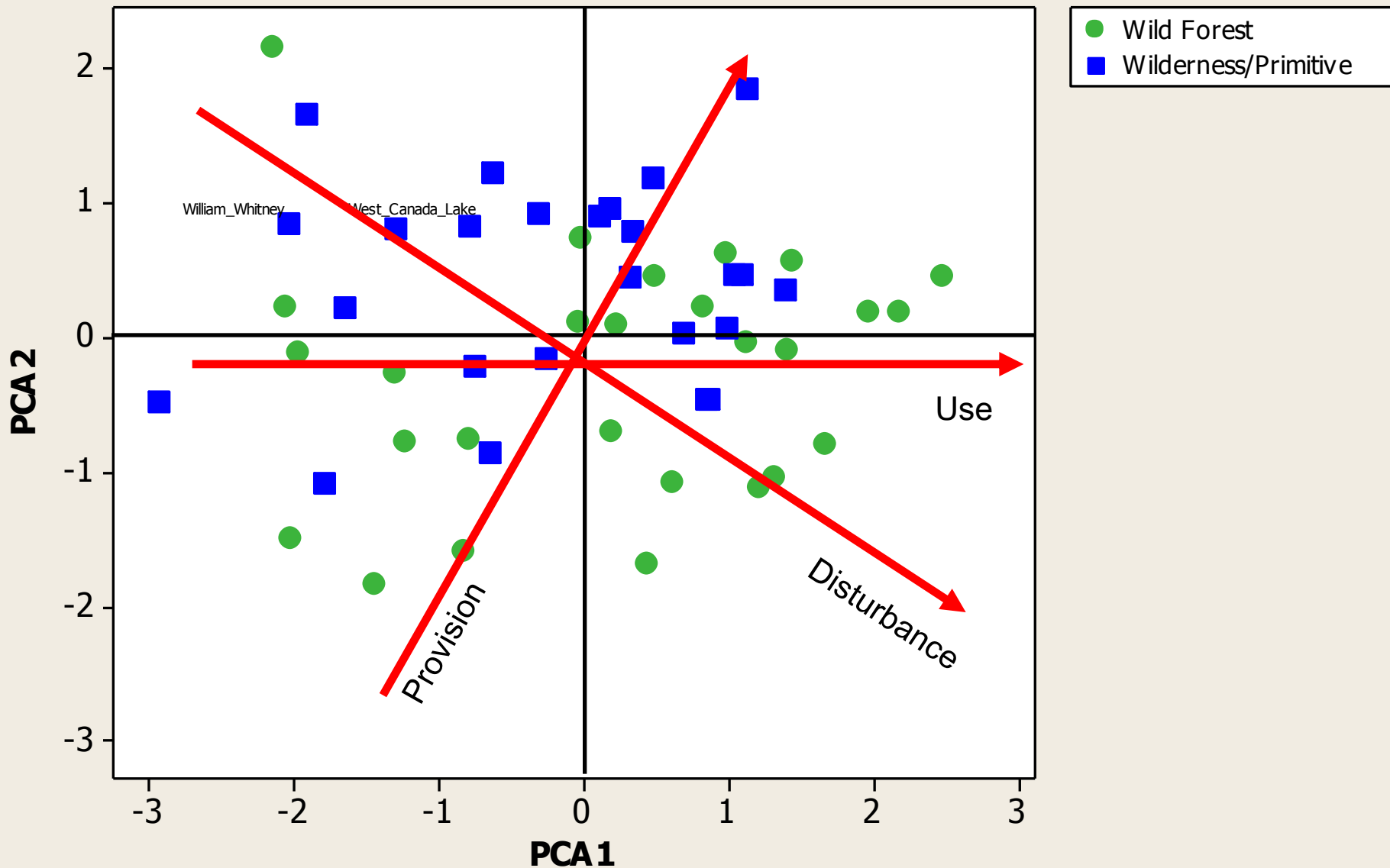
Provision *minus* Use

Green = High Provision,
Low Use

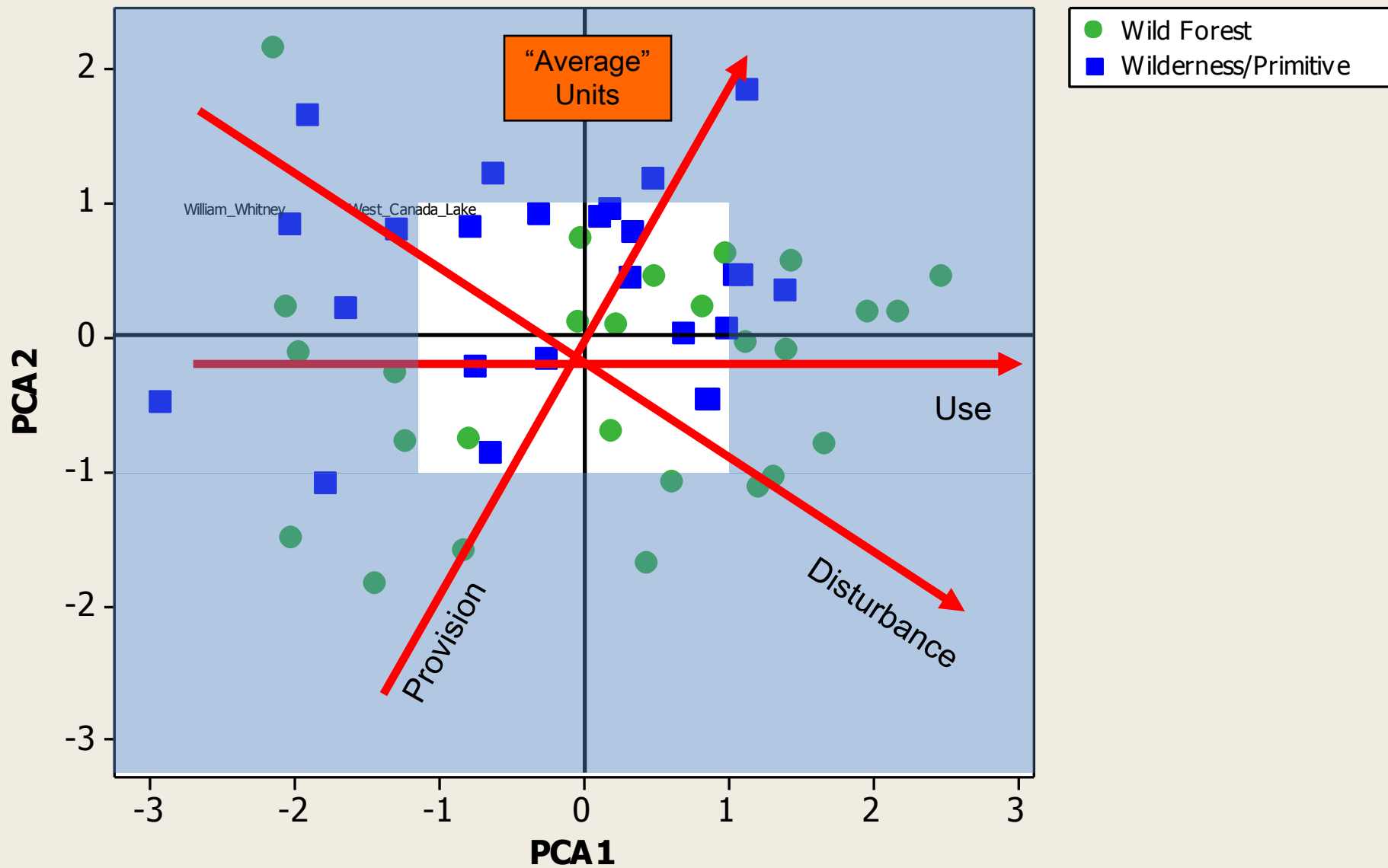
Red = Low Provision,
High Use



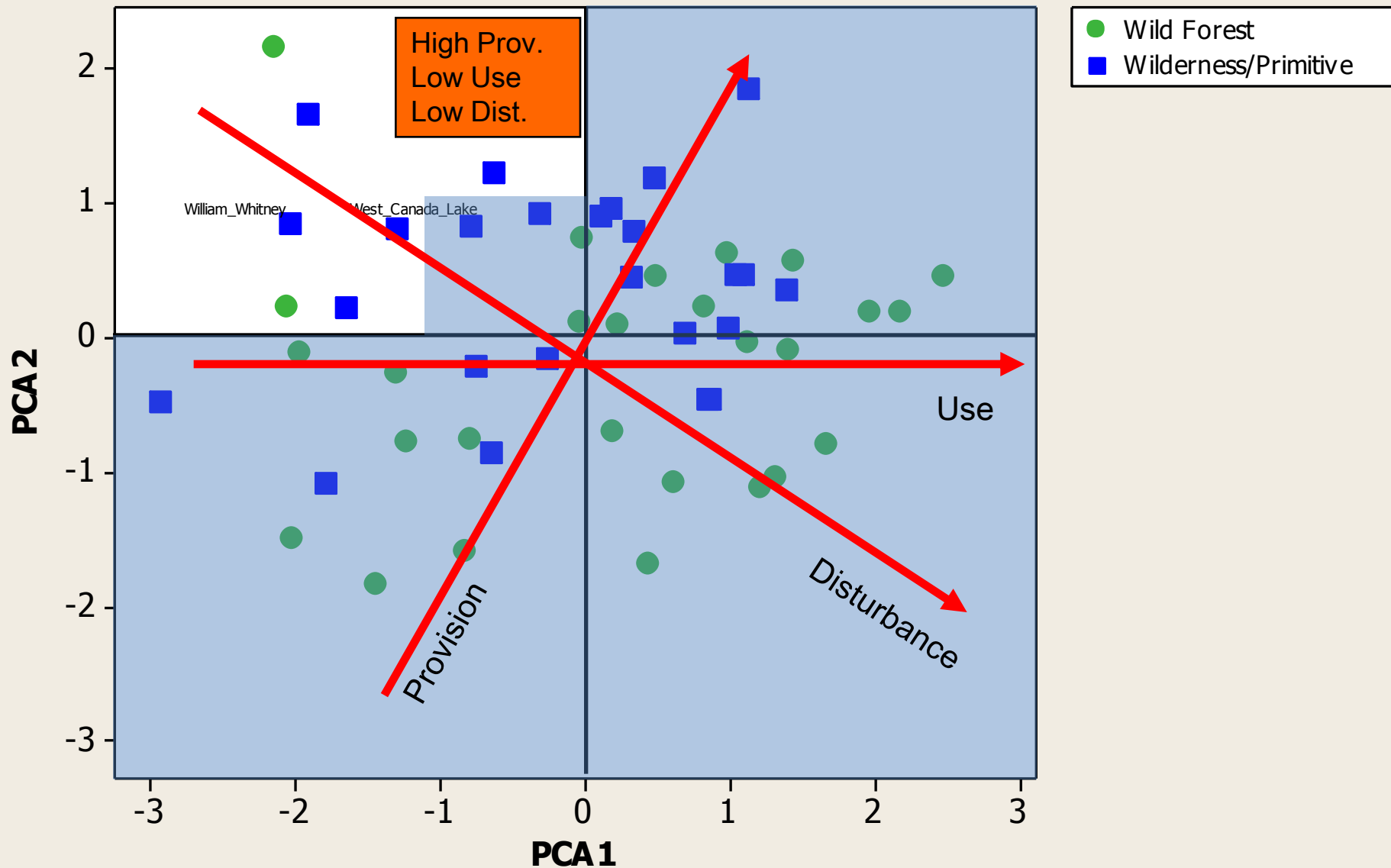
Using index scores to classify management units



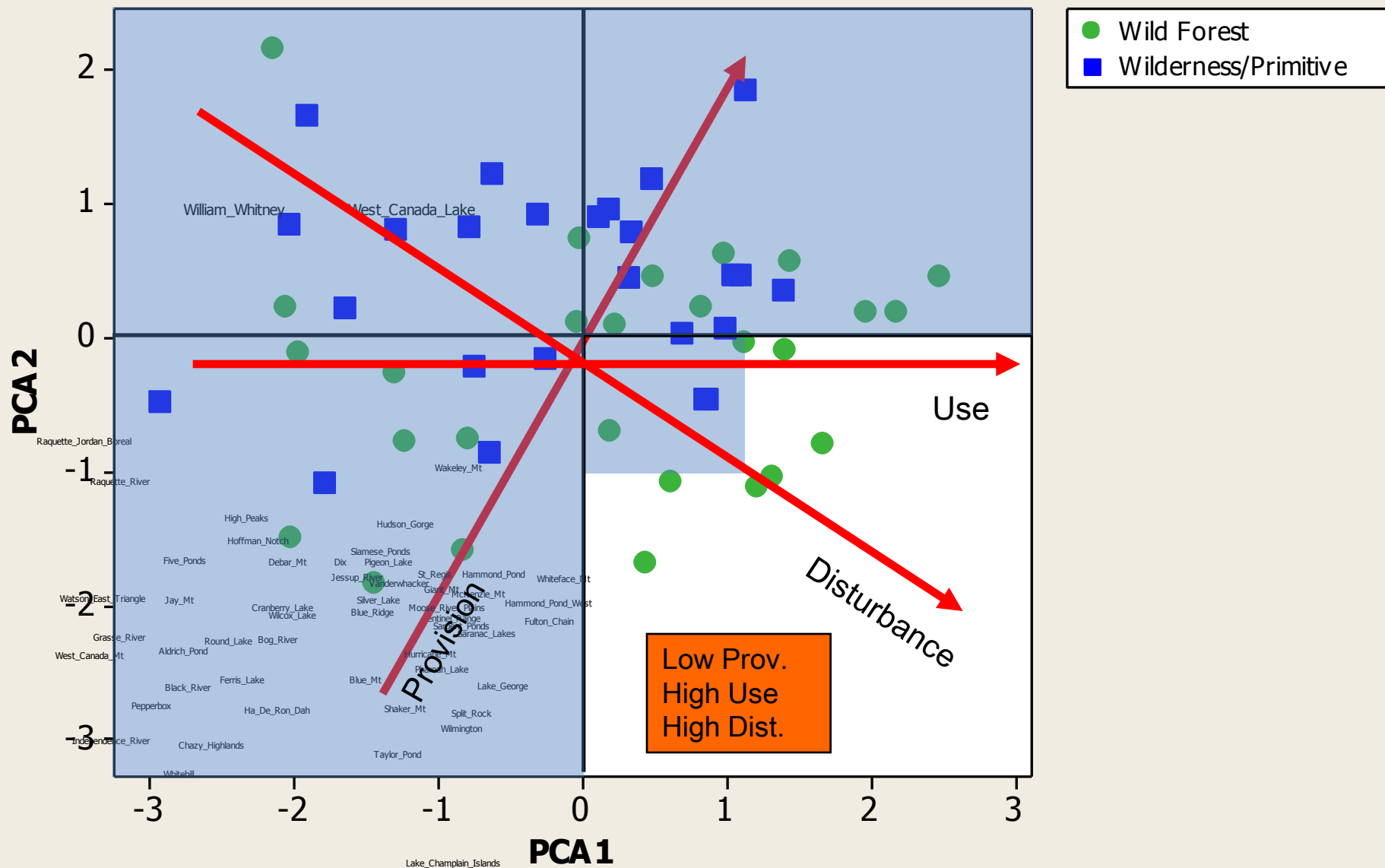
Using index scores to classify management units



Using index scores to classify management units



Using index scores to classify management units



ES & NYSERDA

Scoping → Research → Management

Ecosystem	Focal Impacts of Acidic Deposition	Ecosystem Services	Service Type	Direct Beneficiaries	Potential Data Sources
Forest Ecosystems	Sugar Maple	Forest Products	<i>Provisioning</i>	Industry/Communities	USDA FIA, ESFPA, Cornell Coop Extension, NYSEDA EMEP, forest parcel data (NYS)
		Scenic Amenities	<i>Cultural</i>	Communities/Tourism	USDA FIA, Lodging Tax Revenues, AATV, Tourism Industry
		Ca Regulation	<i>Regulating</i>	Supports All ES	USGS, NYSEDA EMEP, ADK Critical Loads Project, scientific publications and reports
	Forest Composition & Productivity	Forest Products	<i>Provisioning</i>	Forest Industry	USDA FIA, ESFPA, forest parcel data (NYS)
		Carbon Sequestration	<i>Regulating</i>	Supports All ES	USDA FIA, USGS, scientific publications, technical reports
	Biodiversity	Wildlife Viewing	<i>Cultural</i>	Communities/Tourism	NYS DEC, scientific publications, technical reports
		Ecosystem Resilience	<i>Supporting</i>	Supports All ES	NSRC, Natural Heritage, WCS, ADK Critical Loads Project, publications
Surface Waters	Water Quality	Drinking Water	<i>Provisioning</i>	Human Health	ALSC, ADK Critical Loads Project, AATV, municipal water usage, publications, reports
		Recreation	<i>Cultural</i>	Communities/Tourism	NYS DEC, APA, AATV, Tourism Industry
	Fisheries	Food Production	<i>Provisioning</i>	Human Health	NYS DEC, USFWS, scientific publications and reports
		Recreation	<i>Cultural</i>	Sport-Fishing	NYS DEC, USFWS, scientific publications and reports
	Biodiversity	Ecosystem Resilience	<i>Supporting</i>	Supports All ES	ALSC, Natural Heritage, WCS, publications and reports

Table 1. Research topics, organized by ecosystem, focal impacts of acidic deposition, ecosystem services, and direct beneficiaries; data sources are a partial list. USDA FIA - US Dept. of Agriculture, Forest Inventory & Analysis; NYSEDA EMEP - NY State Energy Research & Development Authority, Environmental Monitoring, Evaluation and Protection; ESFPA - Empire States Forest Products Association; AATV - Adirondack Association of Towns & Villages; USGS - US Geological Survey; NYS DEC - New York State Dept. of Environmental Conservation; NSRC - Northeastern States Research Cooperative; WCS - Wildlife Conservation Society; ALSC - Adirondack Lake Survey Corporation; APA - Adirondack Park Agency; USFWS - US Fish & Wildlife Service (Dept. of Interior)

Ecosystem	Focal Impacts of Acidic Deposition	Ecosystem Services	Service Type	Direct Beneficiaries
Forest Ecosystems	Sugar Maple	Forest Products	<i>Provisioning</i>	Industry/Communities
		Scenic Amenities	<i>Cultural</i>	Communities/Tourism
		Ca Regulation	<i>Regulating</i>	Supports All ES
	Forest Composition & Productivity	Forest Products	<i>Provisioning</i>	Forest Industry
		Carbon Sequestration	<i>Regulating</i>	Supports All ES
	Biodiversity	Wildlife Viewing	<i>Cultural</i>	Communities/Tourism
		Ecosystem Resilience	<i>Supporting</i>	Supports All ES

Ecosystem	Focal Impacts of Acidic Deposition	Ecosystem Services	Service Type	Direct Beneficiaries
Surface Waters	Water Quality	Drinking Water	<i>Provisioning</i>	Human Health
		Recreation	<i>Cultural</i>	Communities/Tourism
	Fisheries	Food Production	<i>Provisioning</i>	Human Health
		Recreation	<i>Cultural</i>	Sport-Fishing
	Biodiversity	Ecosystem Resilience	<i>Supporting</i>	Supports All ES