Investigating Ecosystem Services in the Arid Southwest

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Office of Research and Development

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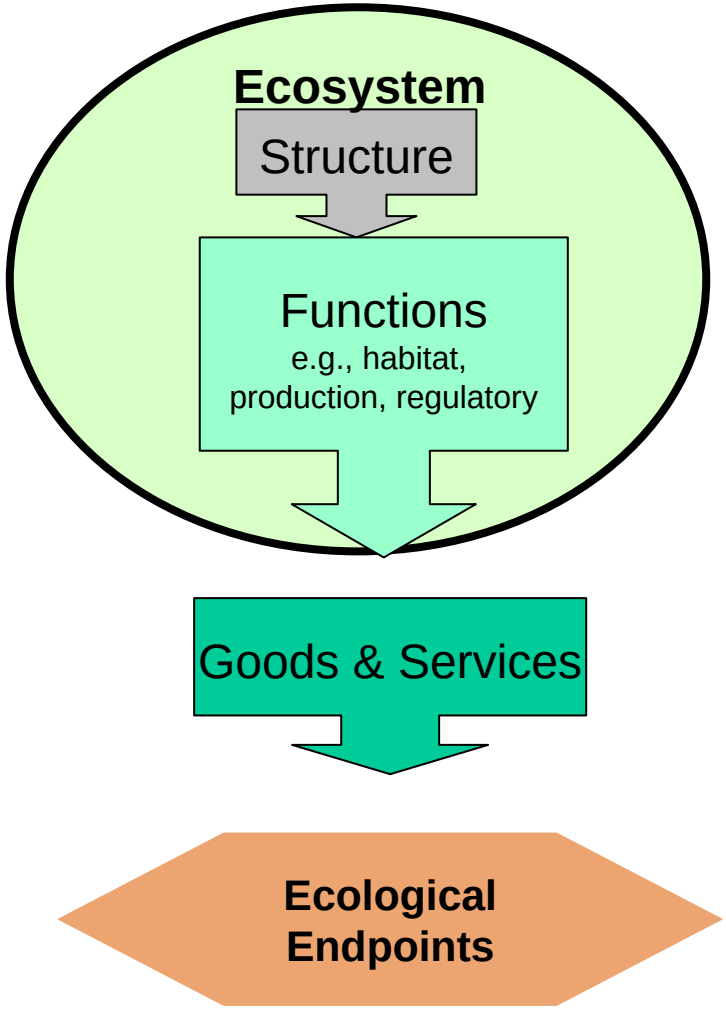
What is an ecosystem service?

- Ecosystem services are the benefits and goods that people receive from the environment.[1]
- The things or characteristics of nature *directly valued by humans*." [2]
- Goods: water, food, timber
- Services: flood protection, pollination
- Benefits: health, well being (cultural, spiritual), economics

[1]*Millennium Ecosystem Assessment 2005*.

[2]*Kroeger and Casey 2007*



Physical and spatial aspects of an ecosystem

Interactions among organisms and the physical environment

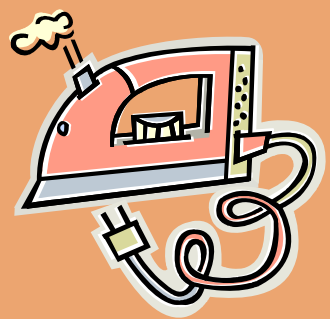
Ecological Endpoints

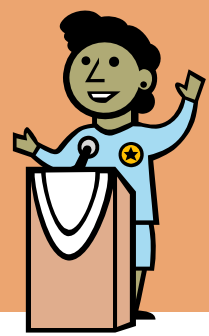
•Biophysical measure, indicators (IBI, habitat suitability rankings, tissue burdens, DO, nitrate, phosphorus, etc) that are…

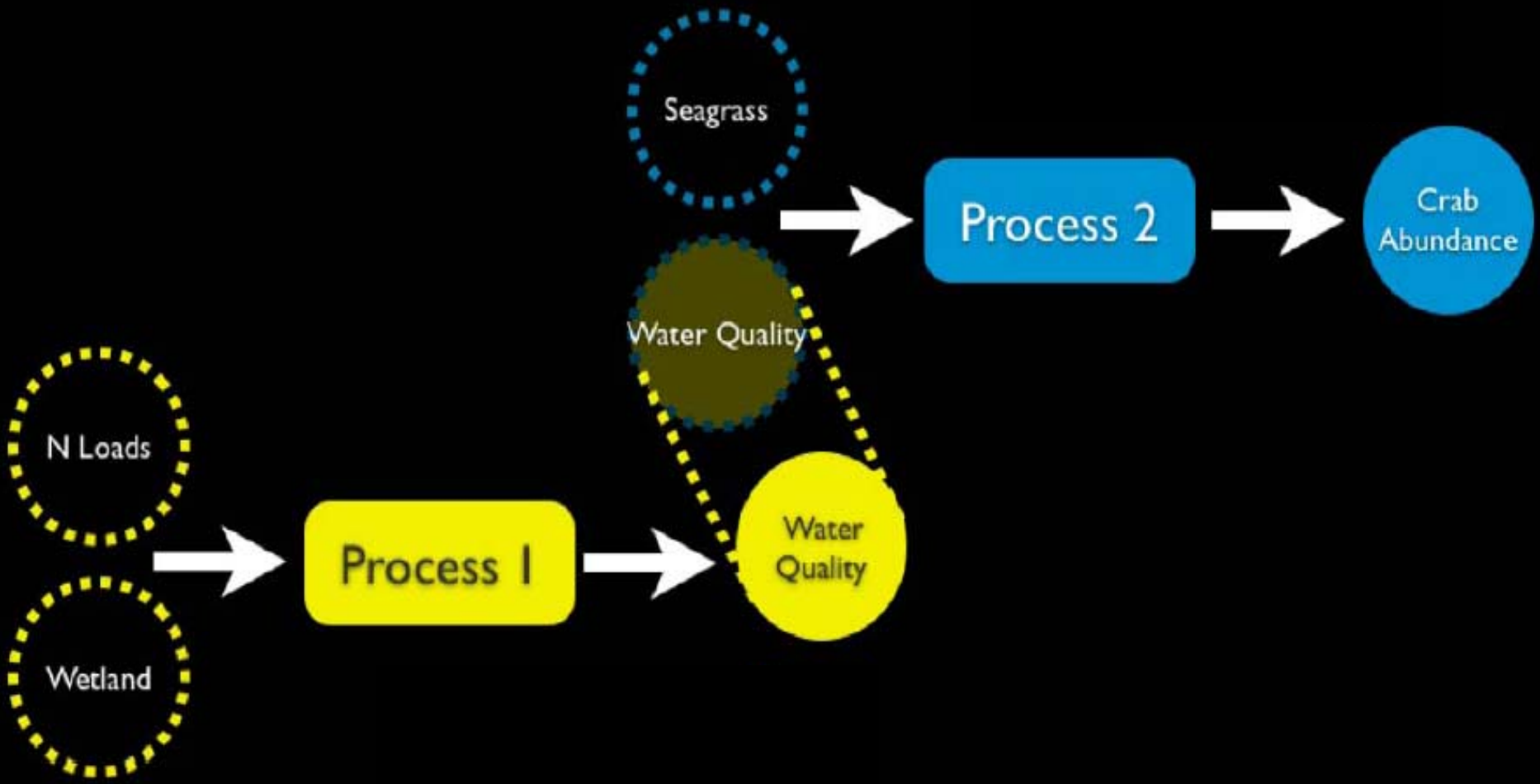
•Easy for non-scientist to interpret

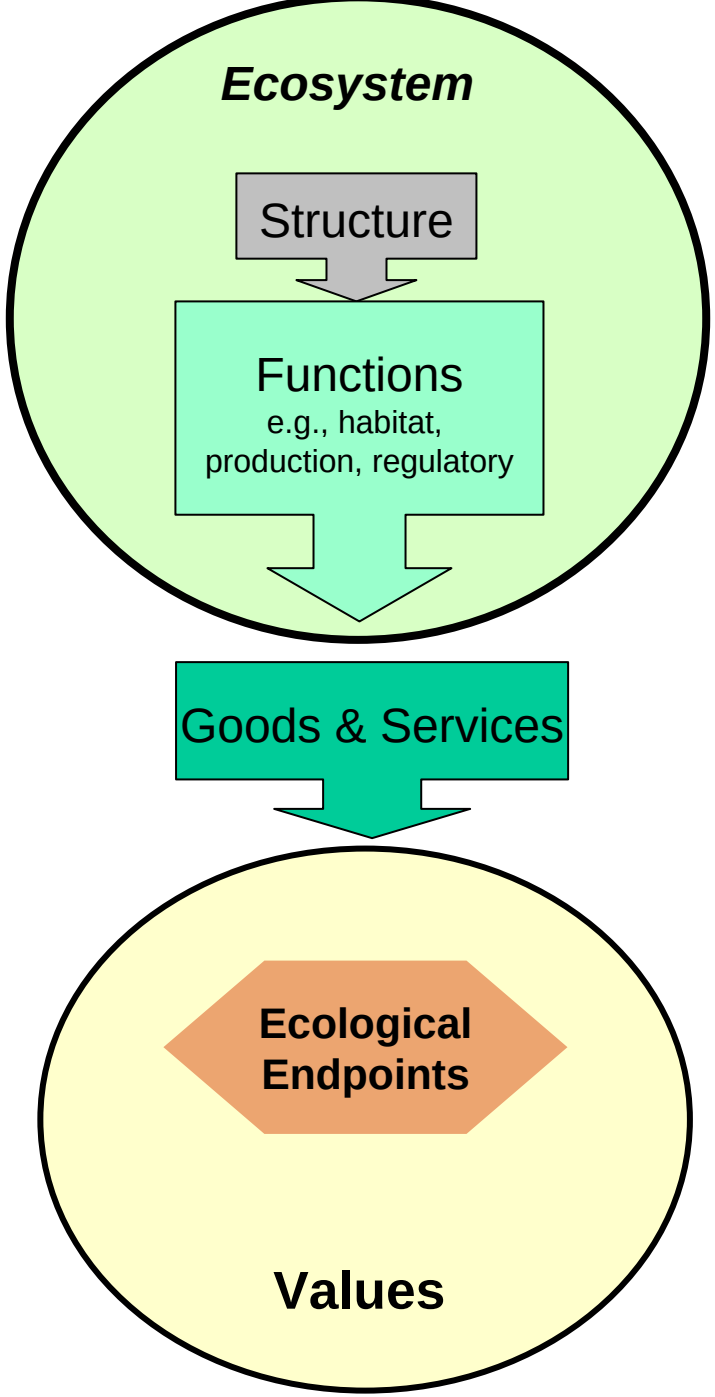
•Directly or tangibly used by users, enjoyers, caretakers, decision makers…

- •Households
- •Recreators
- •Ranchers
- •Farmers
- •Planners and politicians





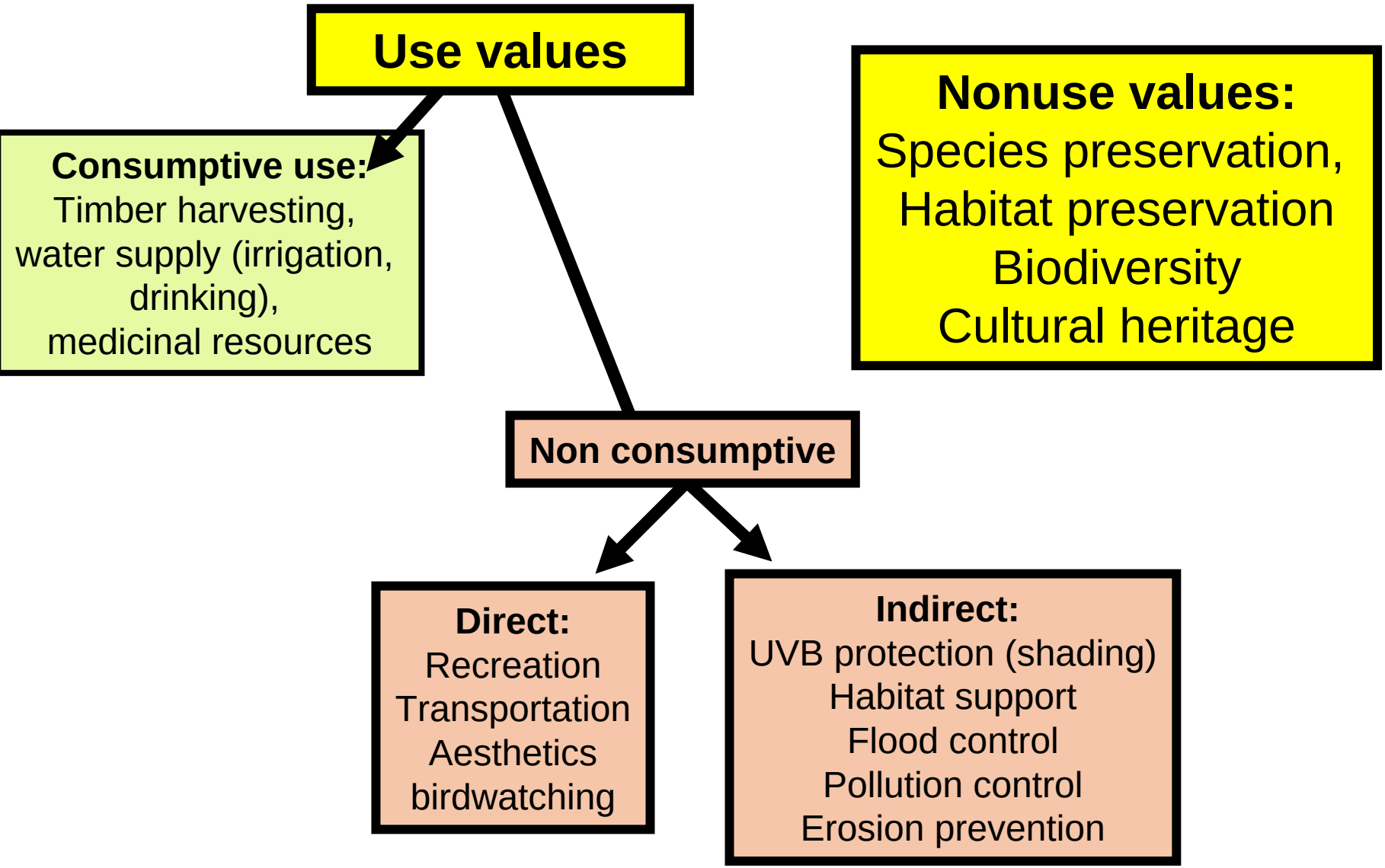

Seagrass
Process 2
Crab Abundance
Water Quality
N Loads
Process 1
Water Quality
Wetland

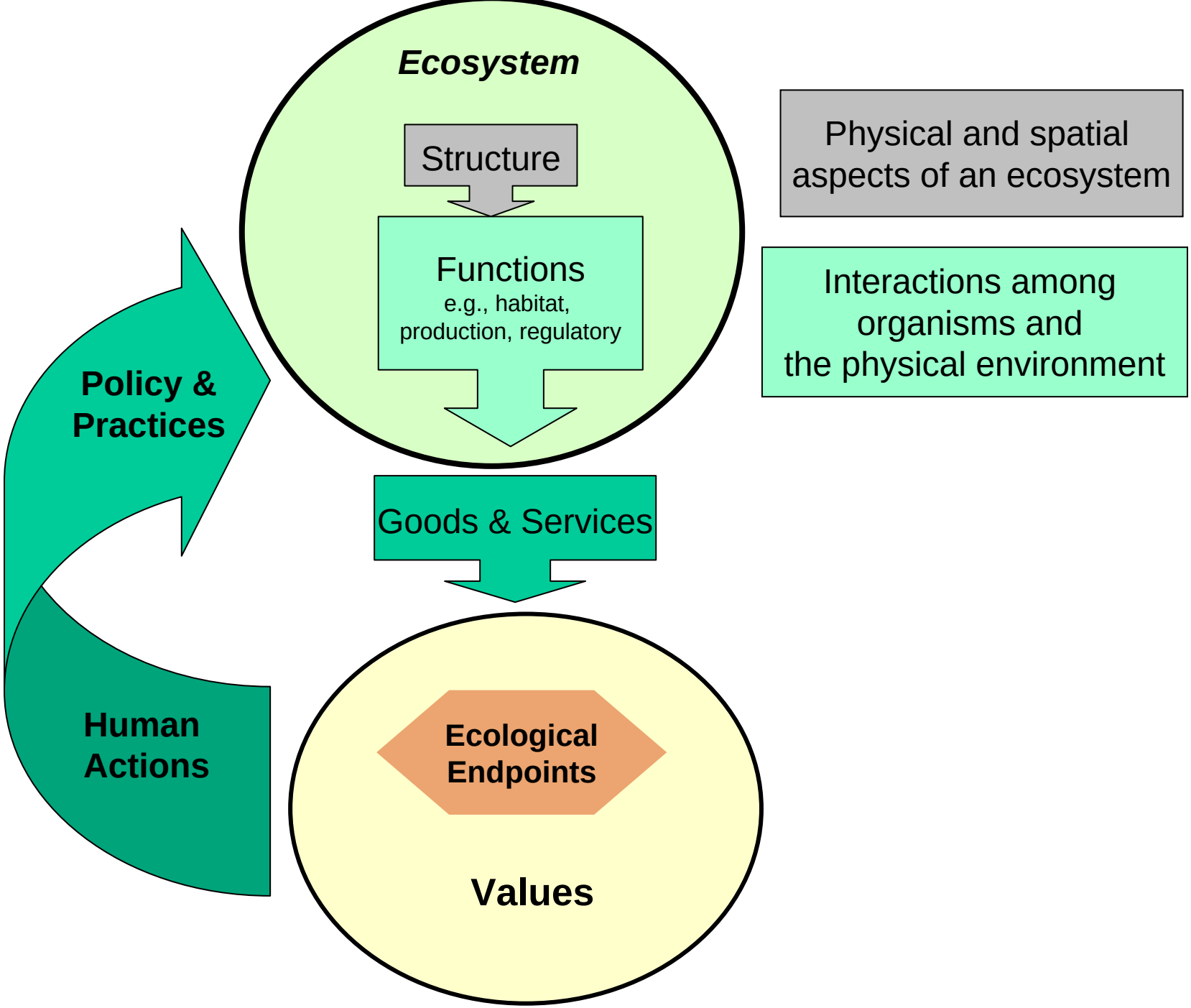


Physical and spatial aspects of an ecosystem

Interactions among organisms and the physical environment

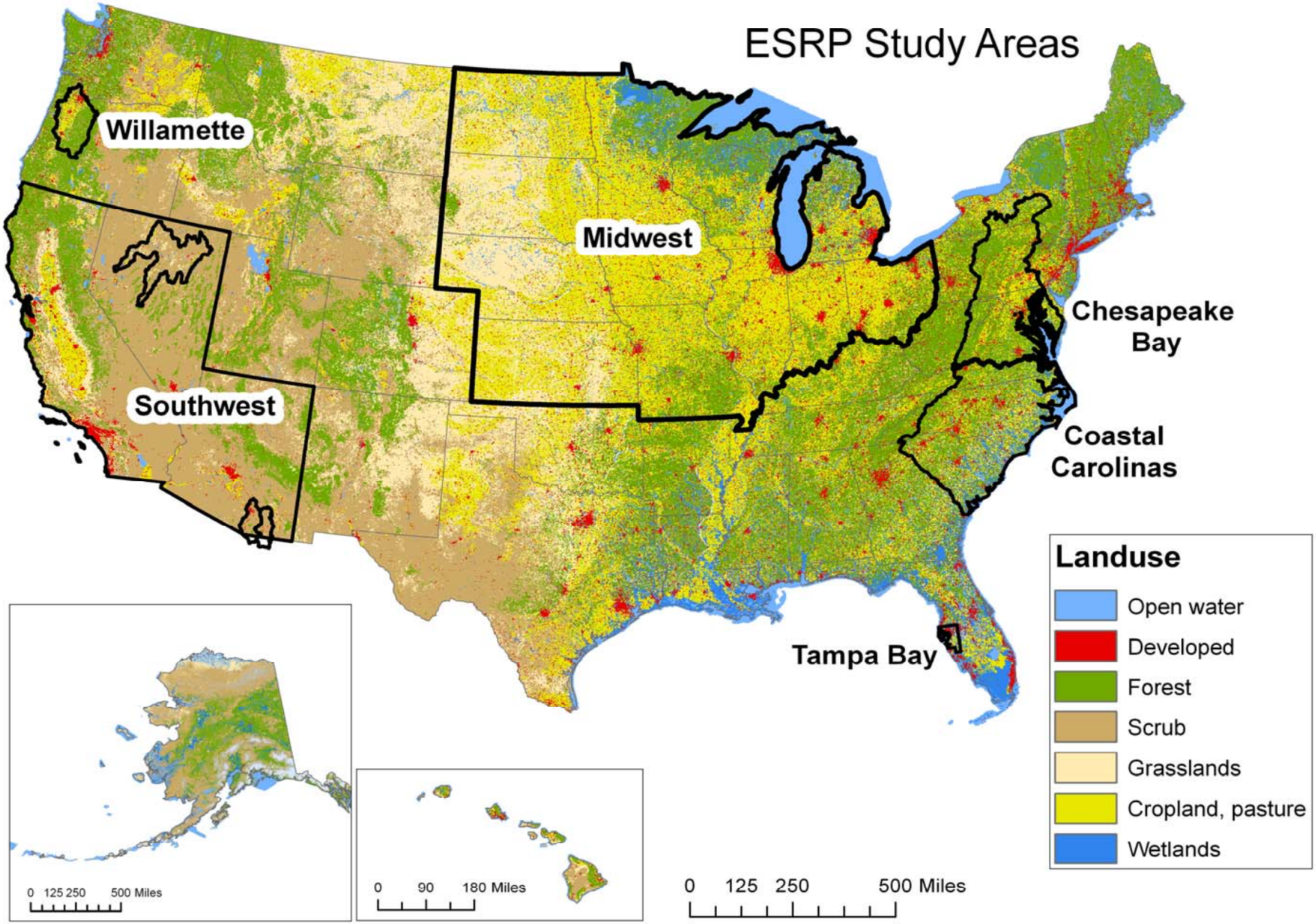
VALUES: Economic, constructed preferences, Community-based, Attitudes/judgments, Bio-ecological, Energy based



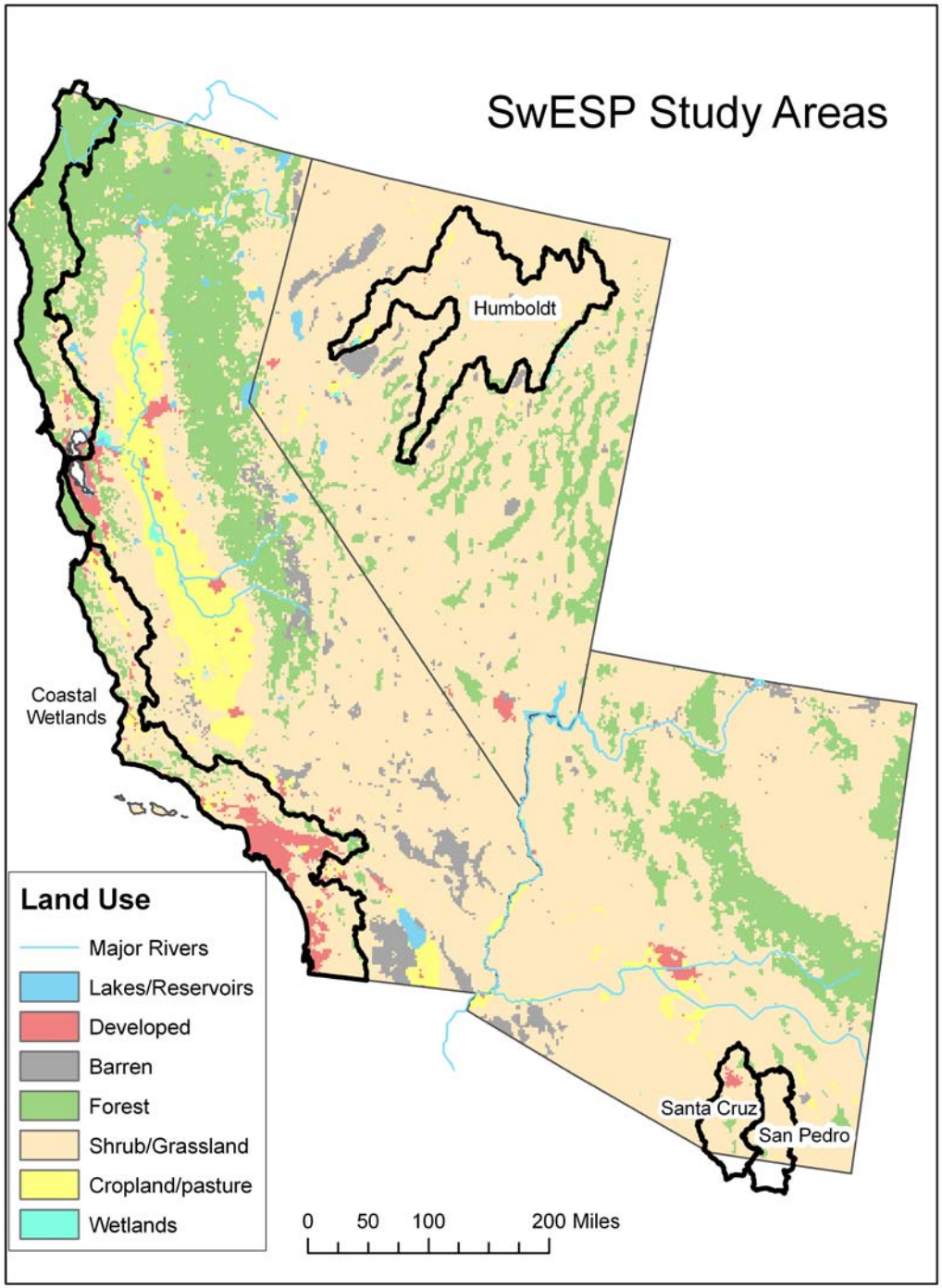

Ecosystem
Structure
Functions
e.g., habitat,
production, regulatory
Physical and spatial
aspects of an ecosystem
Interactions among
organisms and
the physical environment
Policy &
Practices
Goods & Services
Human
Actions
Ecological
Endpoints
Values

Ecosystem Services Approach

- To promote good decision making, policy makers require information about how and how much ecosystems contribute to society's well-being.
- An understanding of the services and valuation (non-monetary and monetary) of an ecosystem which can be integrated into management, policy, and planning relevant to that ecosystem

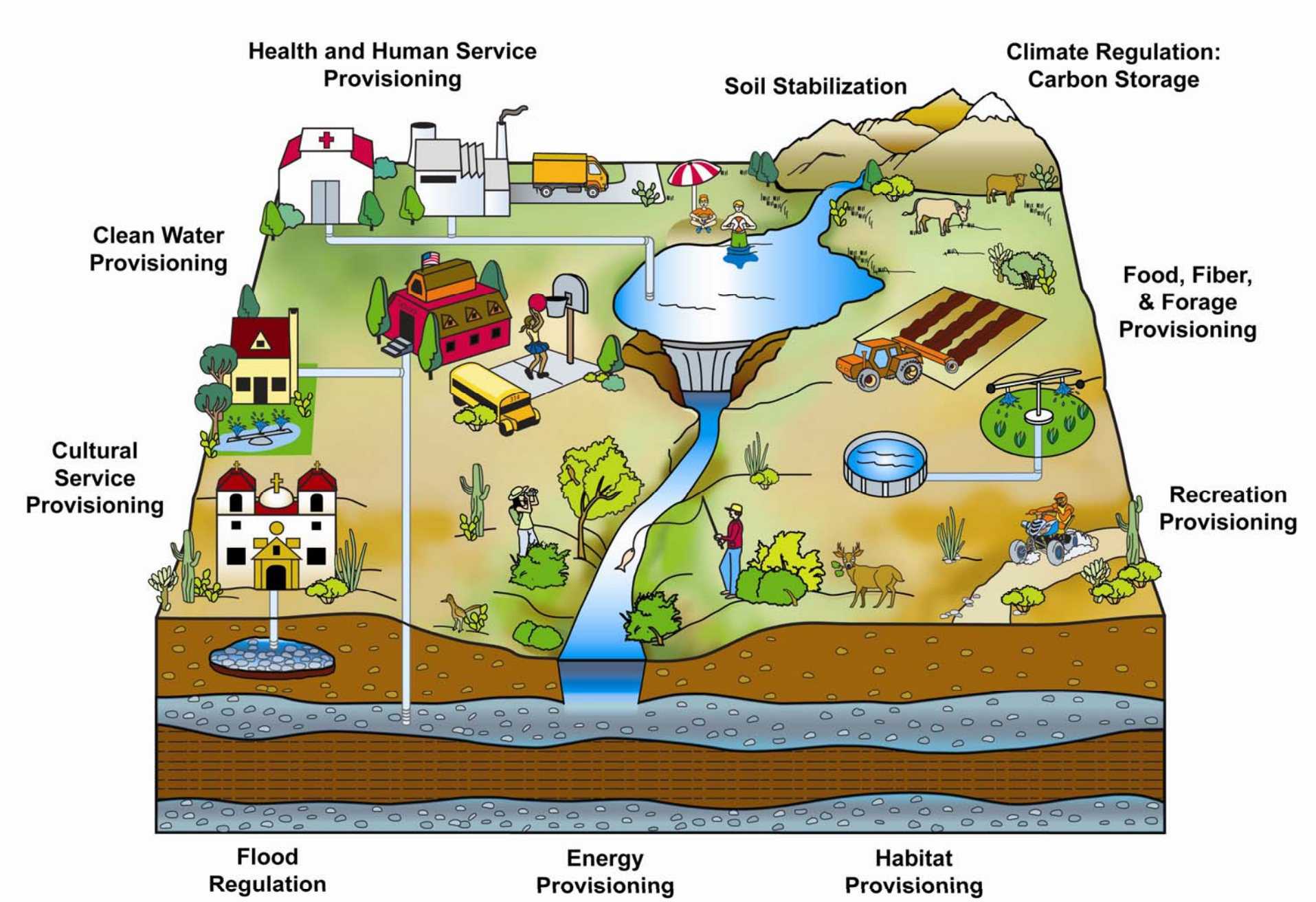

ESRP Study Areas
Willamette
Midwest
Chesapeake Bay
Southwest
Coastal Carolinas
Tampa Bay
Landuse
Open water
Developed
Forest
Scrub
Grasslands
Cropland, pasture
Wetlands
0 125 250 500 Miles
0 90 180 Miles
0 125 250 500 Miles

Coastal & Upland Wetlands



Great Basin Rangeland

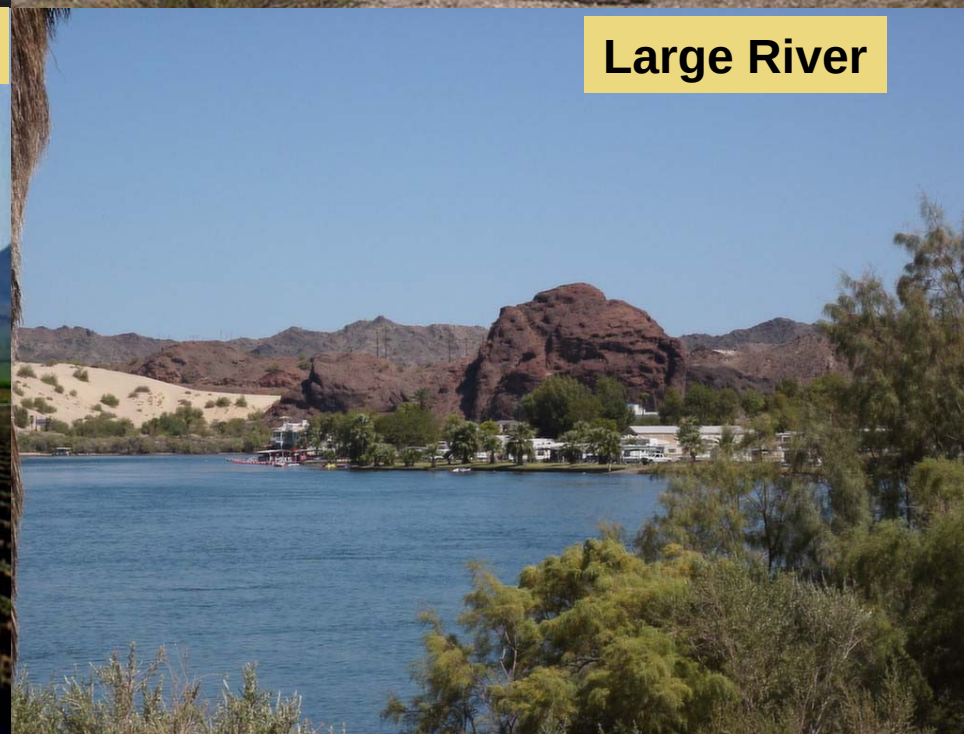
Southern Arizona Borderlands


Health and Human Service Provisioning
Soil Stabilization
Climate Regulation: Carbon Storage
Clean Water Provisioning
Food, Fiber, & Forage Provisioning
Cultural Service Provisioning
Recreation Provisioning
Flood Regulation
Energy Provisioning
Habitat Provisioning


Riparia

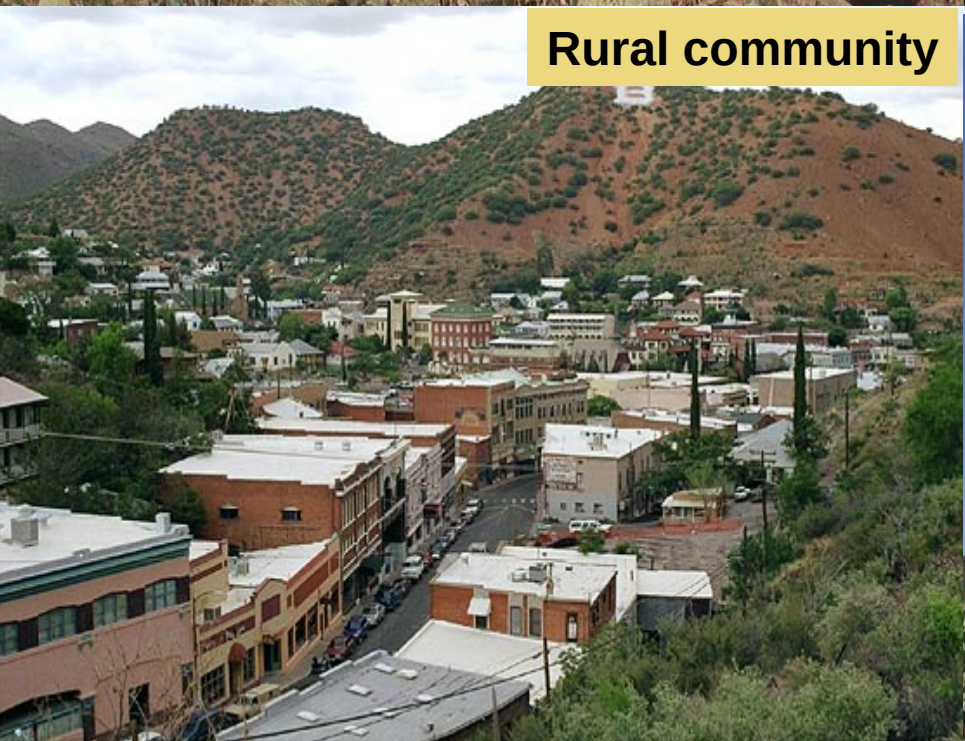

Mojave Desert


Dry Land Agriculture


Large River

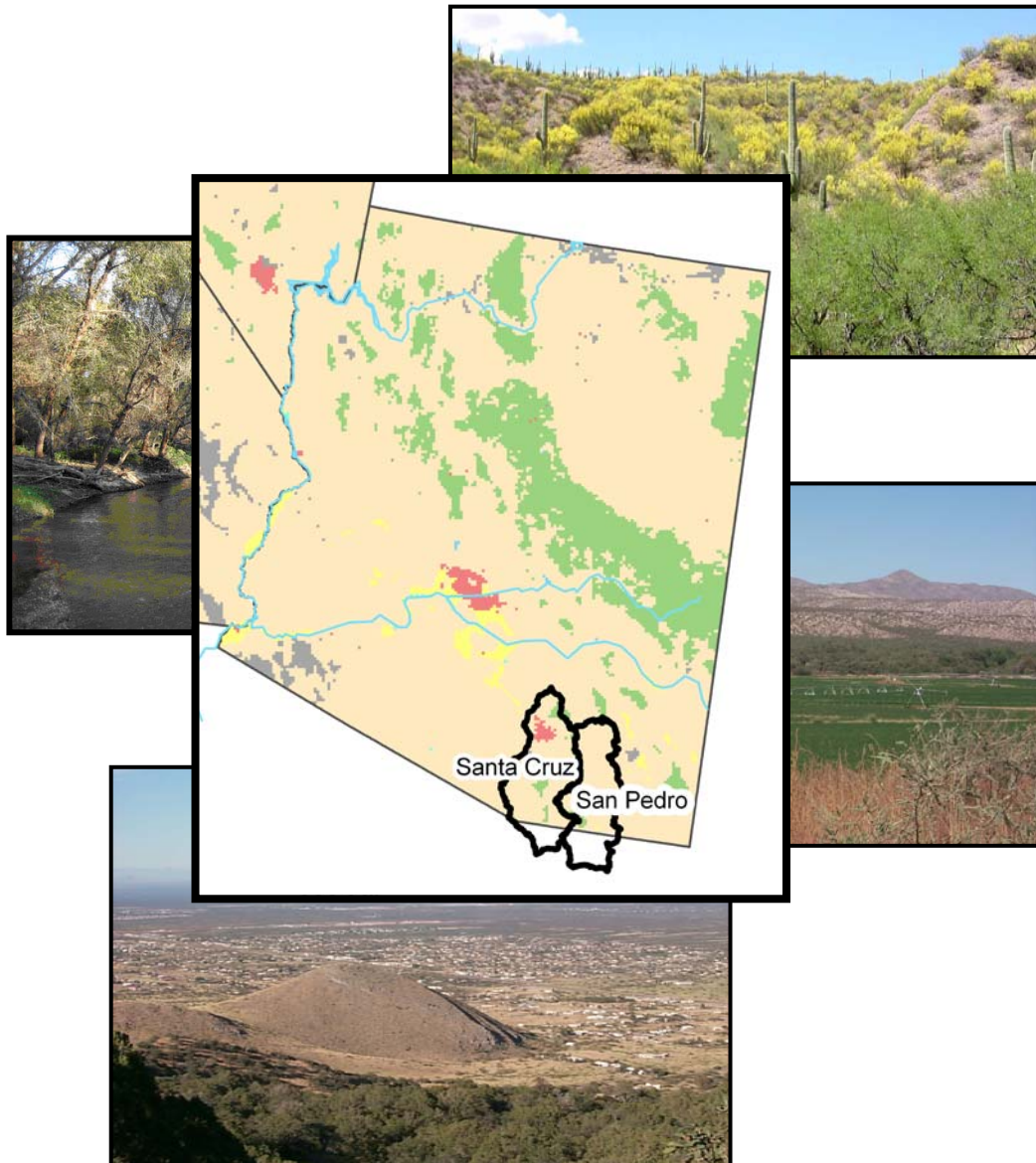

Rangeland


Exurban Residential


Rural community


Cultural

Santa Cruz and San Pedro Watersheds

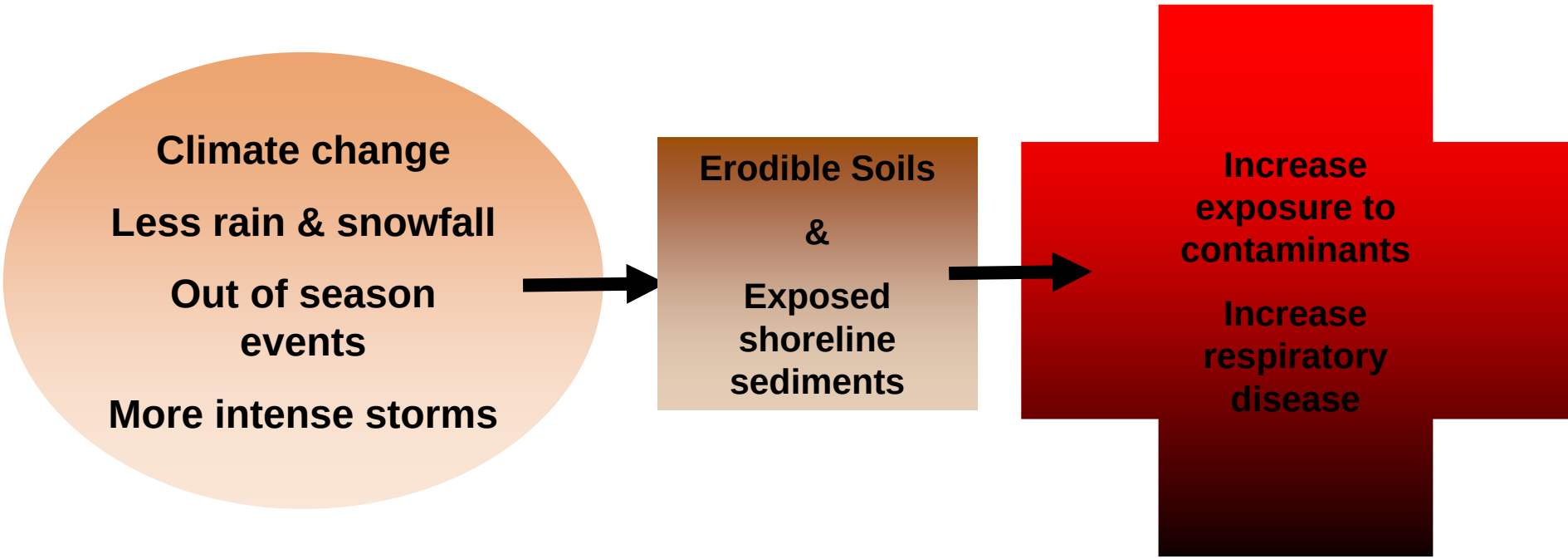


THE BURNING QUESTION?

Determine how to identify, characterize, quantify and map the ecosystem services &

Linkages among service endpoints and human health and well-being.

- **What are the consequences of land use change caused by:**
  - **Drought**
  - **Urban expansion / contraction**
  - Agricultural/range intensification / reduction
  - Mineral/resource extraction
  - Alternative energy production
  - Water resource development
- **on Arid and Semi-Arid landscapes**
- How are the natural and novel ecosystems affected and what impact might occur to the services derived from them
  - **Riparia – clean water, habitat provisioning, cultural (recreation, spiritual, aesthetic), carbon sequestration**
  - **Shrub and grasslands – clean water, habitat provisioning, recreation, carbon sequestration, livestock forage**
  - **Forest – clean water, habitat provisioning, cultural (recreation, spiritual, aesthetic), carbon sequestration, fuel, fiber, air purification**
  - **Urban – habitat provisioning, cultural, human services,**
  - **Agriculture/livestock – food provisioning**
- And what are the impacts on human health and well-being


Climate change
Less rain & snowfall
Out of season events
More intense storms
Erodible Soils
&
Exposed shoreline sediments
Increase exposure to contaminants
Increase respiratory disease

Ecosystem Services	Biophysical Supply	Value of Ecosystem Services
Clean water for human consumption	Water flow across landscape & water import across landscape	Market value of water availability
Water for irrigation		Market value of crop/agriculture production
Water for reservoirs		Market value of energy production
Water flow through run-of-river power stations		Market value of energy production
Crop / agriculture production	Crop and Agriculture Production	Market value of crop / agricultural production
Environmental quality, natural capital, amenities, fees, and tourism/recreation	Environmental quality and natural capital stock	Total consumer surplus of all visitors
Terrestrial carbon storage and sequestration	Terrestrial carbon storage and sequestration	Social benefits of avoided carbon emissions
Habitat to native fauna (wildlife, fish, and birds)	Species Richness	Market value of ecotourism, hunting, and fishing. Non market value
Cultural / aesthetic attributes of the landscape	Cultural / aesthetic attributes of the landscape	Non market value

(modified from Tallis & Polasky 2009)

Tools

- Integrated Valuation of Ecosystem Services and Tradeoffs Tool - InVEST (Natural Capital Project)
- Ecosystem Portfolio Model – EPM

Decision-maker questions

- What places provide the most ecosystem services?
- How would a proposed dam or logging project affect different ecosystem services and biodiversity?
- What landscape pattern would optimize ecosystem services now and under likely scenarios?
- Who should pay whom under a proposed PES program, and how to scale it up?

ANSWERS:

landscape-scale, multi-service assessments

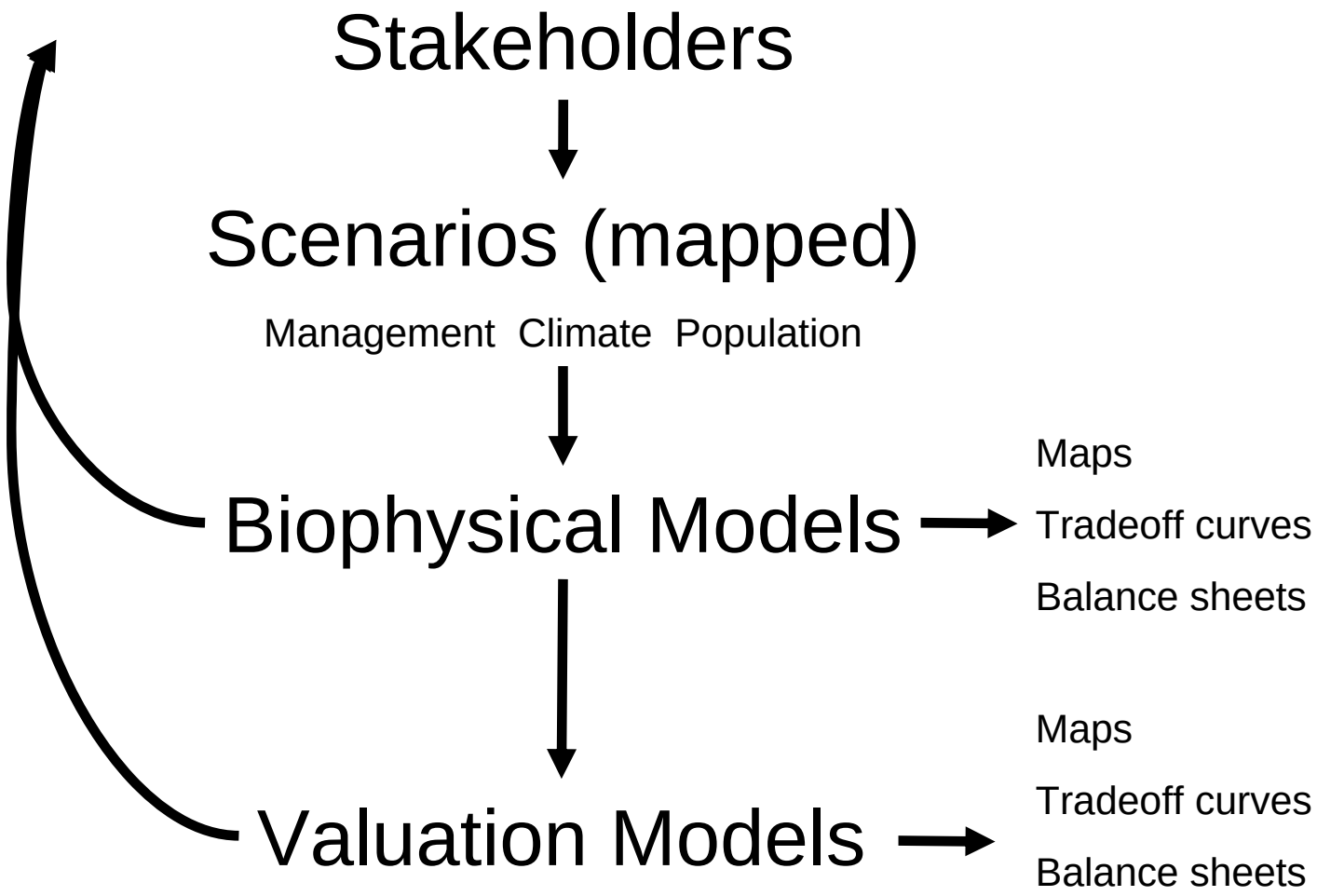
The Natural Capital Project

Make conservation economically attractive

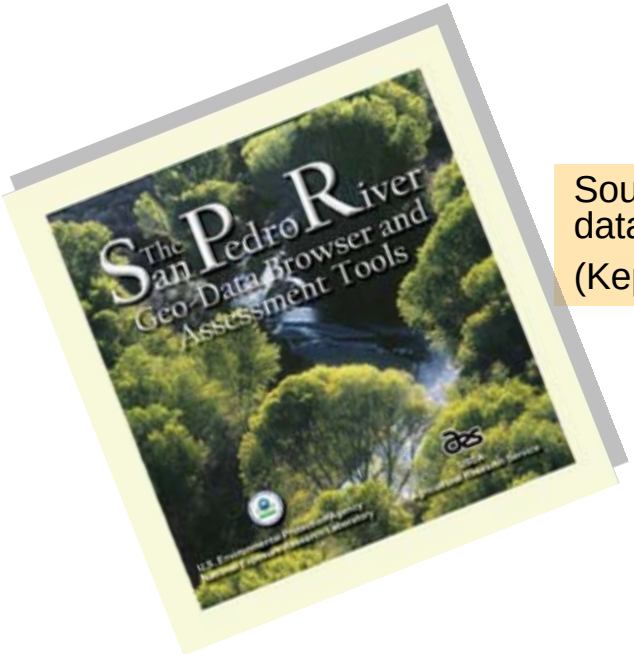
- Develop science and policy tools to address ecosystem services
- Apply tools in important places
- Support policies to maintain / pay for services
- Change the way ecosystems are viewed

InVEST

InVEST

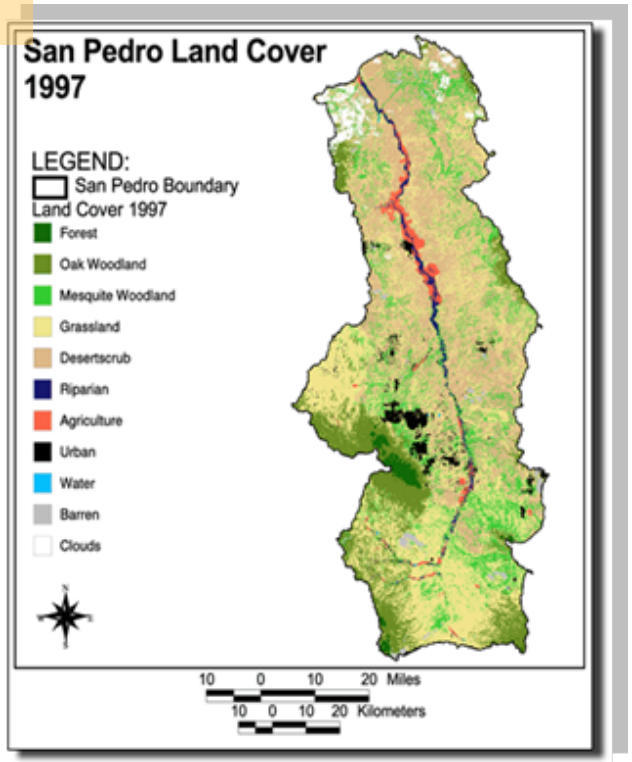

Stakeholders
Scenarios (mapped)
Management Climate Population
Biophysical Models
Maps
Tradeoff curves
Balance sheets
Valuation Models
Maps
Tradeoff curves
Balance sheets

Assessment of Goods and Valuation of Ecosystem Services (**AGAVES**)



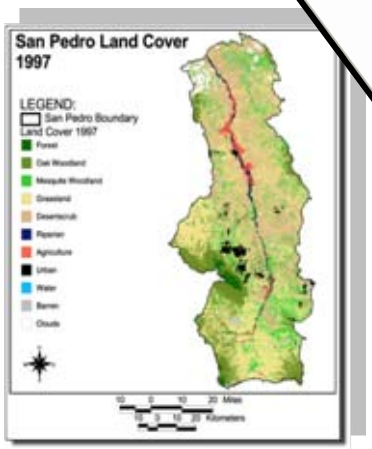
Source for input data

(Kepner et al 2003)

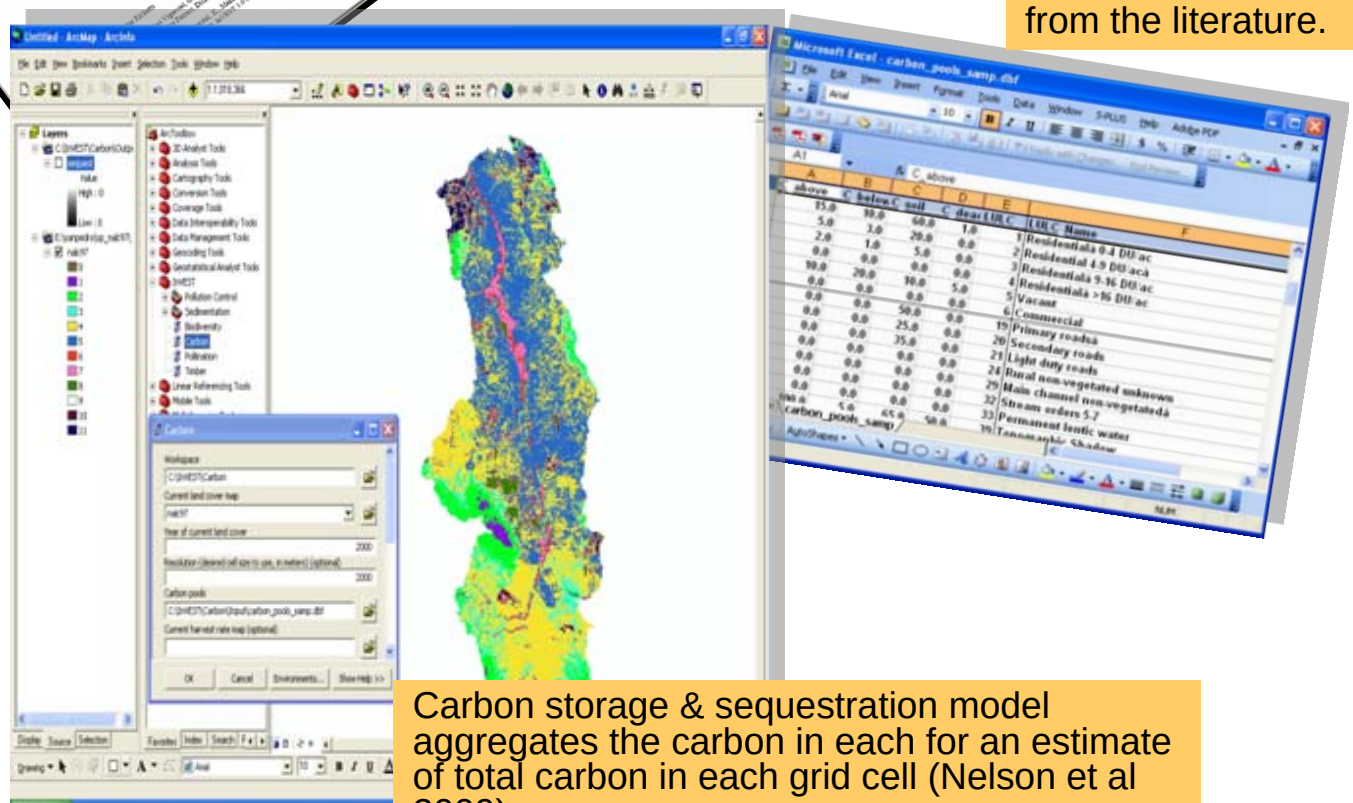


Sample input land cover

Tallis et al 2008



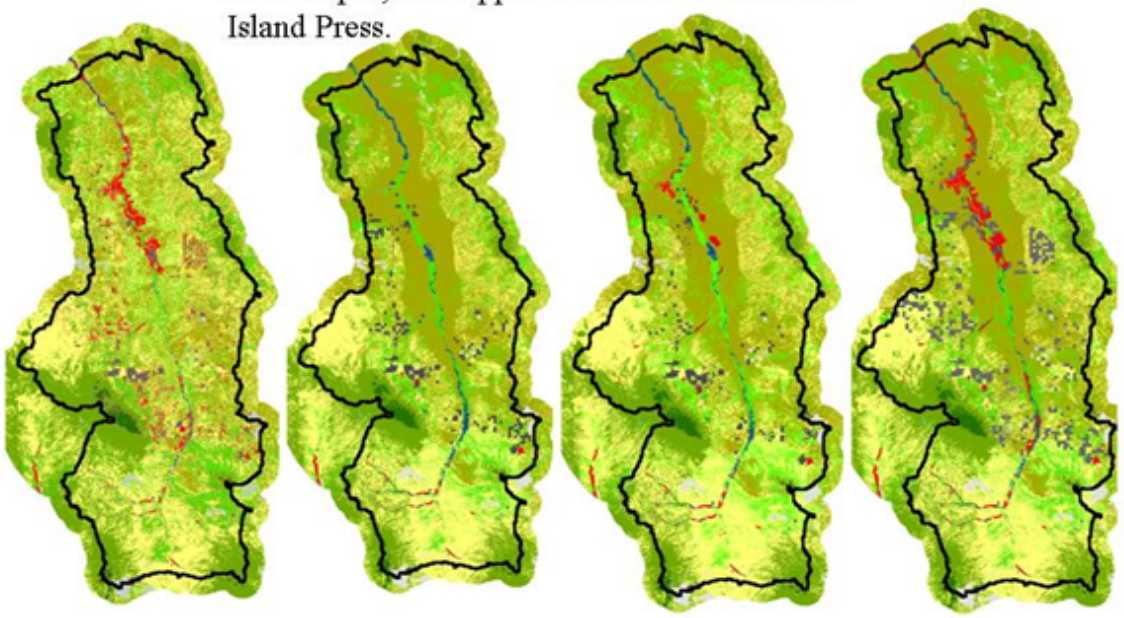
Database of estimated amount of carbon pools in each LULC derived from the literature.



Carbon storage & sequestration model aggregates the carbon in each for an estimate of total carbon in each grid cell (Nelson et al 2009).

Land Cover (2000-2020)

Steinitz et al. 2003. Alternative Futures for Changing Landscapes, The Upper San Pedro River Basin. Island Press.



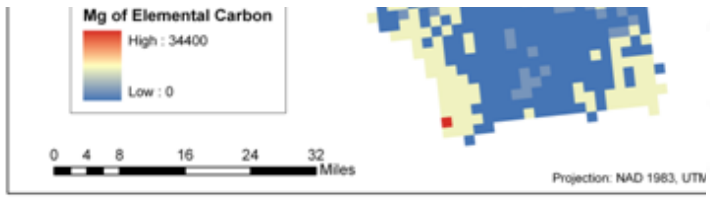


Table 1. Scenarios for future urbanization of the Upper San Pedro River Basin in the year 2020.

CONSTRAINED	Assumes lower population (78,500 inhabitants) than presently forecast for 2020. Development is concentrated in mostly existing developed areas (i.e., 90% urban). Removes all irrigated agriculture within the river basin.
PLANS	Assumes population increase as forecast for 2020 (95,000 inhabitants). Development is in mostly existing developed areas (i.e., 80% urban and 15% suburban). Removes irrigated agriculture within a 1-mile buffer zone of the river.
OPEN	Assumes population increase is more than the current 2020 forecast (111,500 inhabitants). Most constraints on land development are removed. Development occurs mostly into rural areas (60%) and less in existing urban areas (15%). Irrigated agriculture remains unchanged from current policy except for prohibiting new expansion near the river.

Sample output

To estimate carbon sequestration over time, the model will be applied to current landscape and future scenarios and the difference in storage will be calculated.

WHAT'S NEXT:

- Refine scenarios through stakeholder input
- Explore literature and expert input for input data
- Generated biophysical, economic and cultural outputs as available in or complimentary to InVEST.
- Explore using InVEST output in decision support framework such as Ecosystem Portfolio Model (currently being developed in an adjacent watershed, the Santa Cruz, by US EPA, USGS and other partners).
- Compare with other ESRP community based studies.

- This work builds from several prior and on-going efforts. The InVEST Modeling and Mapping tool is the product of the Natural Capital Project, a joint venture among The Woods Institute for the Environment at Stanford University, The Nature Conservancy, and World Wildlife Fund.
- The geospatial data contained within the San Pedro Data Browser have been acquired from a number of sources including the Arizona State Land Department (Arizona Land Resources Information System), Instituto del Medio Ambiente y el Dasarrollo Sustainable del Estabado de Sonora (IMDES), U.S. Department of the Interior (e.g., U.S. Bureau of Land Management and U.S. Geological Survey), U.S. Environmental Protection Agency, and others. The Alternative Futures were developed by Kepner et al (2004) and C. Steinitz et al (2005). We thank these researchers and agencies who readily made data and research available to us.

AGAVES InVEST contributors

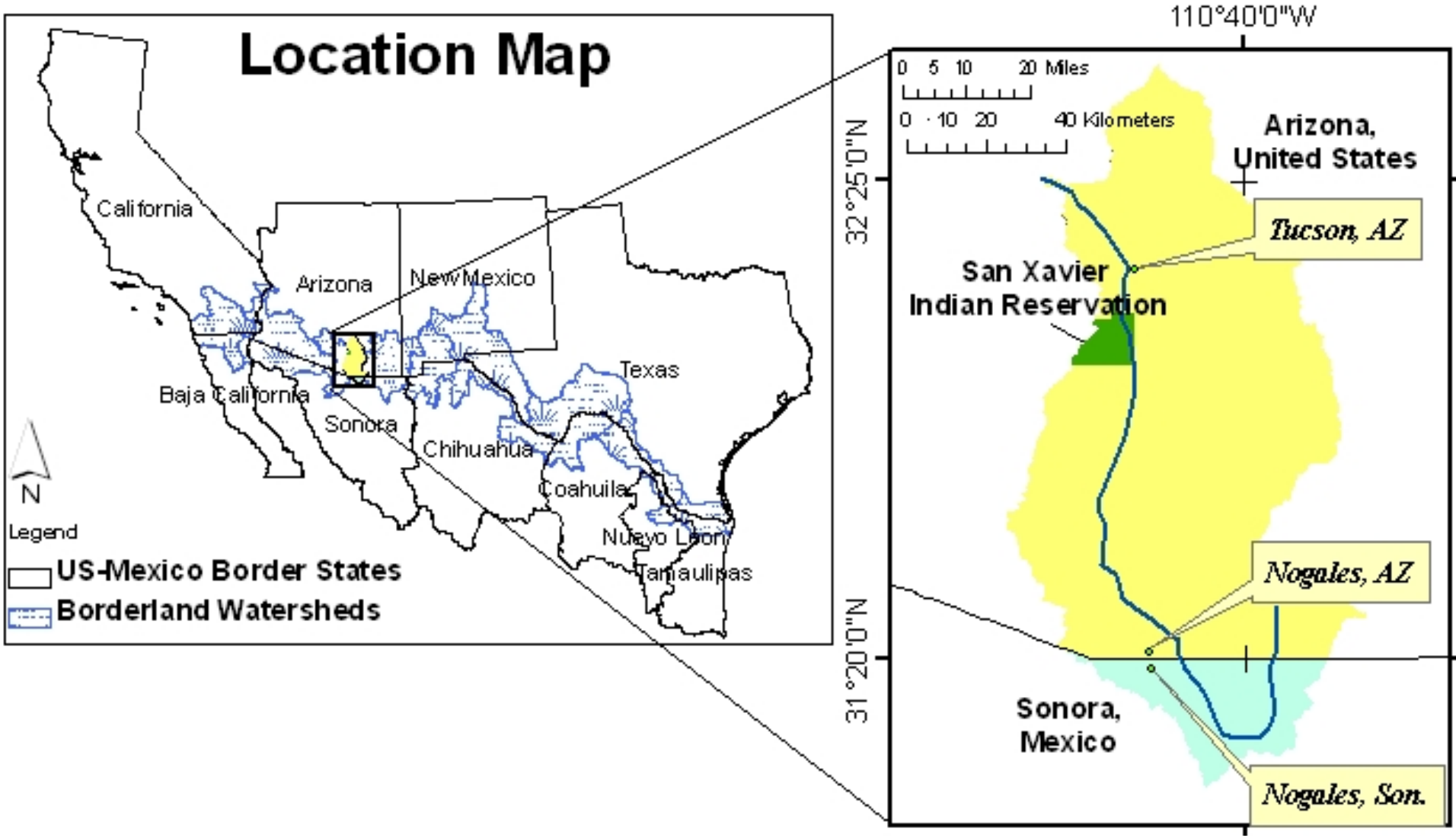
- US Environmental Protection Agency
- The Nature Conservancy
- Upper San Pedro Partnership
- US Department of Interior
- US Bureau of Land Management
- US Fish and Wildlife Service
- US Geological Survey
- USDA Agricultural Research Service
- University of Arizona
- University of New Mexico

San Pedro Riparian National Conservation Area

The Ecosystem Portfolio Model

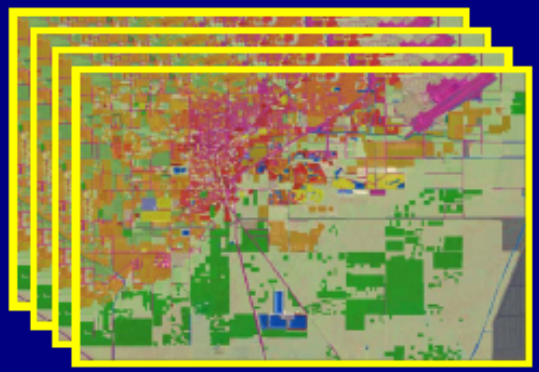
- Incorporating ecosystem values into land use planning decision support in South Florida
- Multi-criteria evaluation (ecological, economic, quality-of-life
- End user driven (Tribes, Stakeholders, Land use planners – US and Mexico, Land Trusts, Federal Managers, Water Managers)
- US Mexico Border Environmental Health Initiative Dataset

Santa Cruz Watershed Ecosystem Portfolio Model



How the EPM works …

1. Multiple land use plans considered



Model-based characterization of outcomes

2. Evaluated against multiple criteria

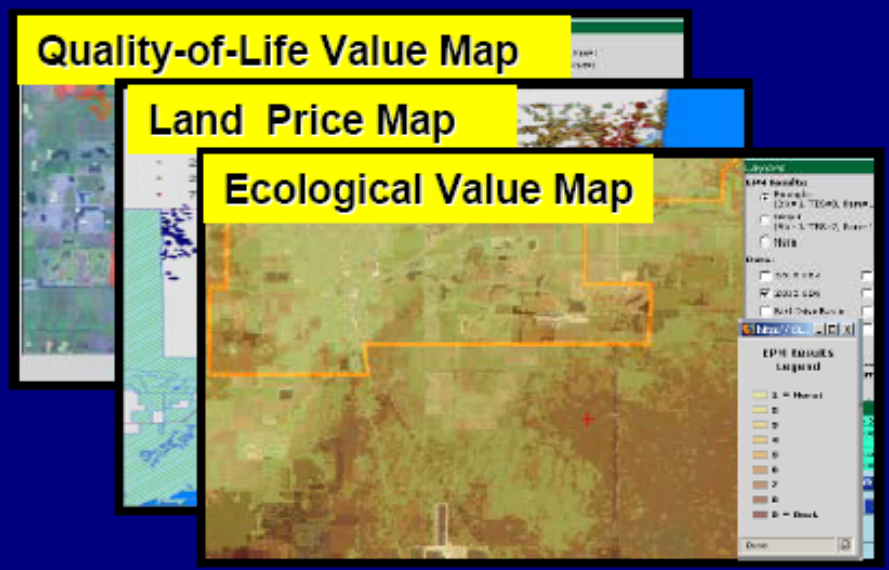
Ecological Value Model

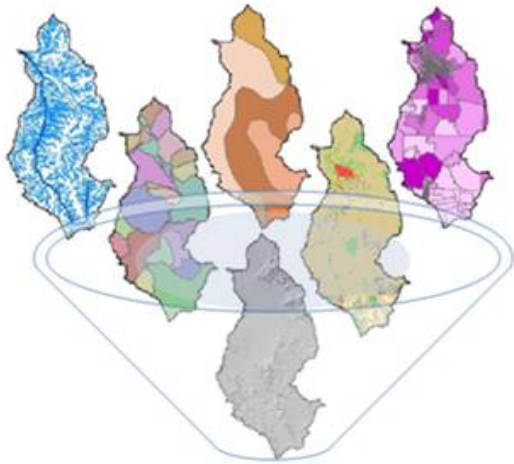
Land Price Model

Quality-of-Life Indicators

Multi-attribute utility valuation

3. Value maps combine user-elicited value judgments and criteria scores





Data Input to Environmental Models

Hydrological	Land Use	Habitat	Quality of Life
Discharge, Evapotranspiration, Runoff, Water Yield, Sediment Yield, Precipitation, Steady and Nonsteady Flow of Groundwater through Aquifers	Urban land use change (Spontaneous growth, New Spreading Center Growth, Edge Growth, and Road-Infleunced Growth); Impervious Areas	Threatened and Endangered Species, Rare and Unique Habitat, Biodiversity, Fragmentation and Patterns, Ecological Restoration	Deprivation Index, Preferences, Public Values for Change, Property Values, and Property Tax Revenues

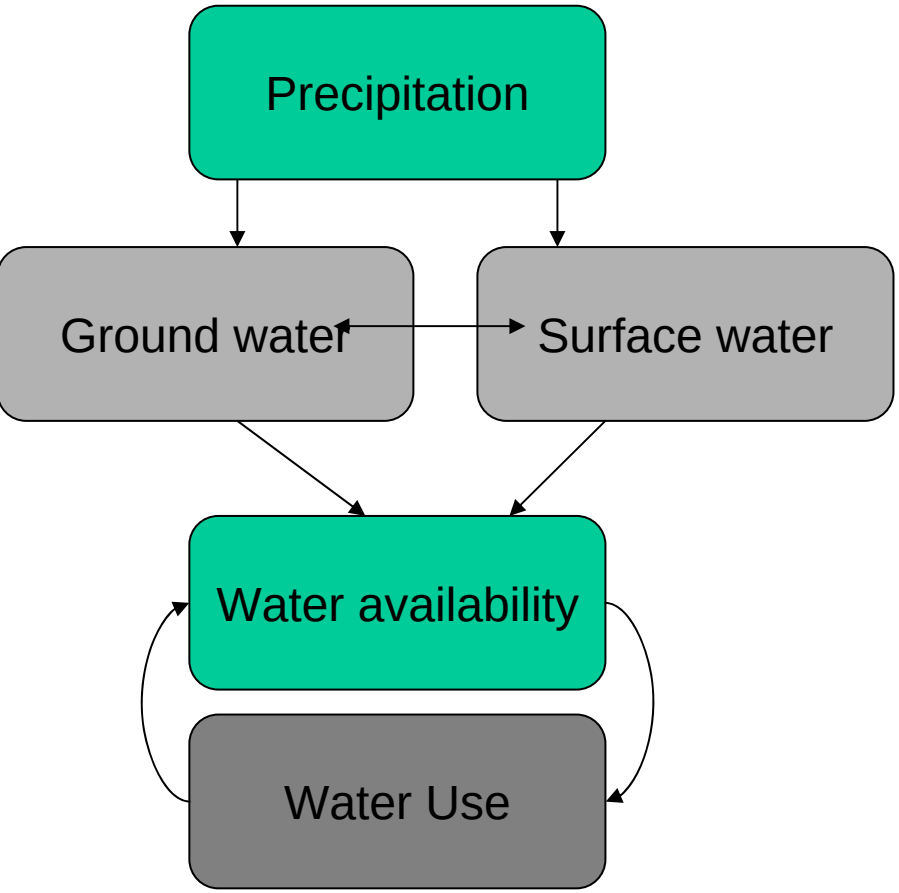
Results of models are converted to potential Criterion

User-elicited value judgments and criteria scores are combined to generate

Ecosystem Service Value Maps

Fulfillment of people's Cultural and Spiritual needs	Maintenance and regeneration of habitat	Maintenance of healthy waterways	Prevention of soil erosion	Provision of shade and shelter	Regulation of river flows and groundwater levels

Water Provisioning



Tools
Estimate and manipulate

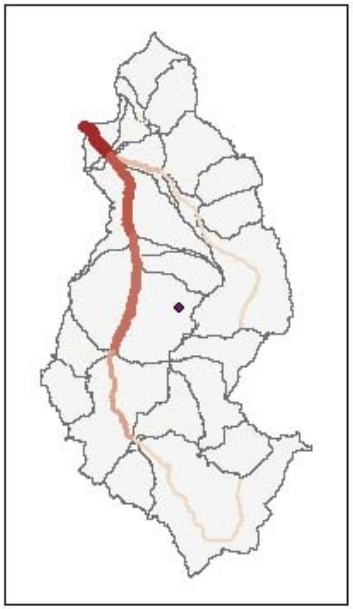
Climate change model

Groundwater Availability Models

Interaction Models

Surface-water Models

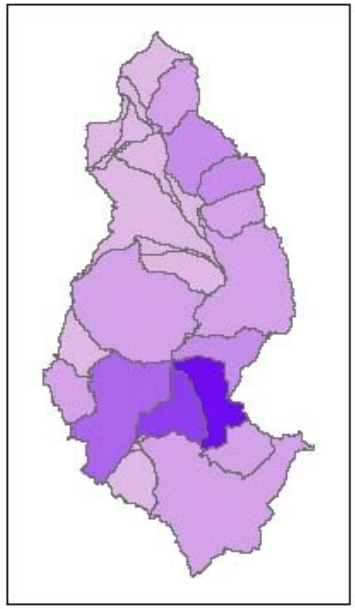
Water use models



Legend

Channel Discharge (m3/day)

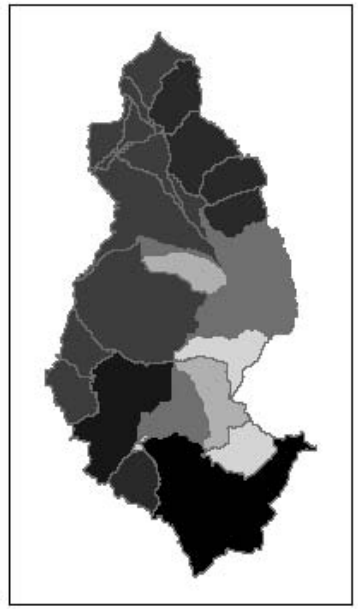
- 5,726.59 - 47,647.10
- 47,647.10 - 89,567.62
- 89,567.62 - 131,488.13
- 131,488.13 - 173,408.64
- 173,408.64 - 215,329.15
- 215,329.15 - 257,249.66
- 257,249.66 - 299,170.18
- 299,170.18 - 341,090.69
- 341,090.69 - 383,011.20
- 0.0



Legend

Sediment Yield (tons/ha)

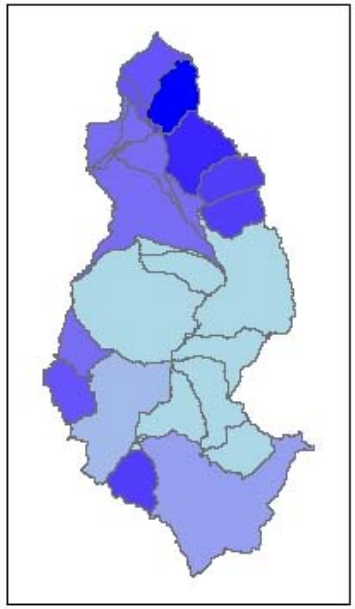
- 0.00 - 6.13
- 6.13 - 12.26
- 12.26 - 18.40
- 18.40 - 24.53
- 24.53 - 30.66
- 30.66 - 36.79
- 36.79 - 42.92
- 42.92 - 49.05
- 49.05 - 55.19



Legend

Evapotranspiration (mm)

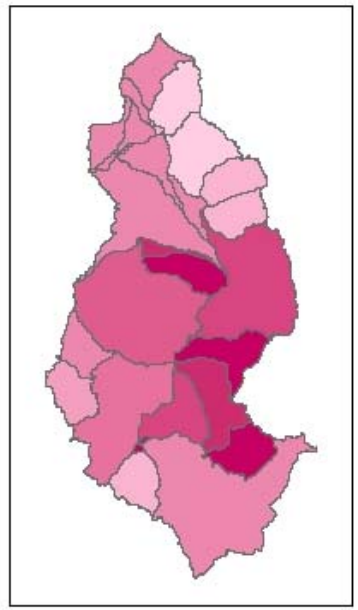
- 251.32 - 252.81
- 252.81 - 254.29
- 254.29 - 255.78
- 255.78 - 257.26
- 257.26 - 258.75
- 258.75 - 260.23
- 260.23 - 261.72
- 261.72 - 263.20
- 263.20 - 264.69



Legend

Percolation (mm)

- 0.67 - 2.48
- 2.48 - 4.28
- 4.28 - 6.09
- 6.09 - 7.89
- 7.89 - 9.70
- 9.70 - 11.50
- 11.50 - 13.31
- 13.31 - 15.11
- 15.11 - 16.92



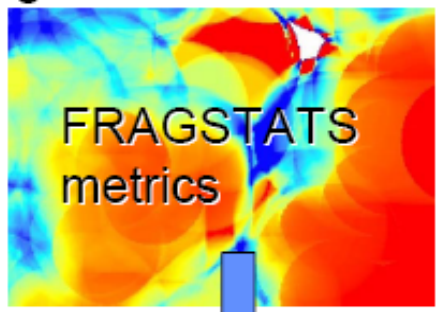
Legend

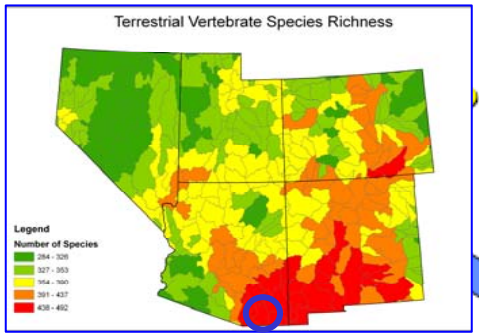
Surface Runoff (mm)

- 8.99 - 12.08
- 12.08 - 15.16
- 15.16 - 18.25
- 18.25 - 21.34
- 21.34 - 24.42
- 24.42 - 27.51
- 27.51 - 30.60
- 30.60 - 33.68
- 33.68 - 36.77

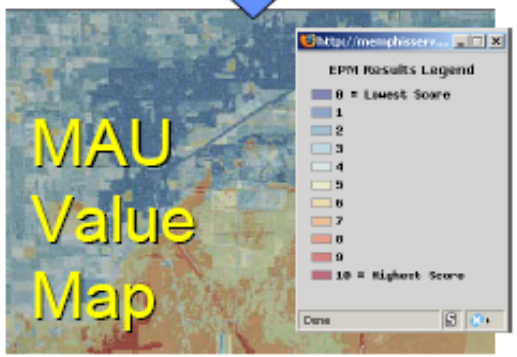
Ecological Value Model

Fragmentation & Patterns Criterion





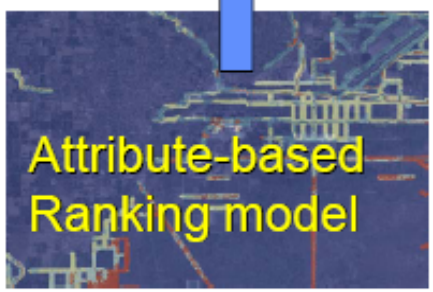
Biodiversity Potential Criterion



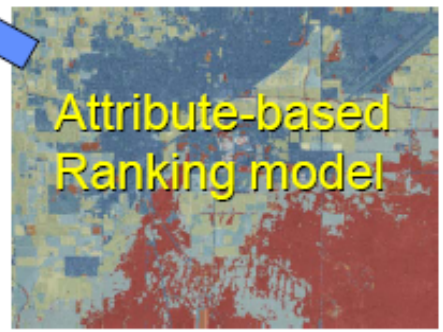
Cell-wise Aggregate "Ecological Value"

Threatened & Endangered Species Criterion

Rare & Unique Habitats Criterion



Water Quality Buffer Potential Criterion

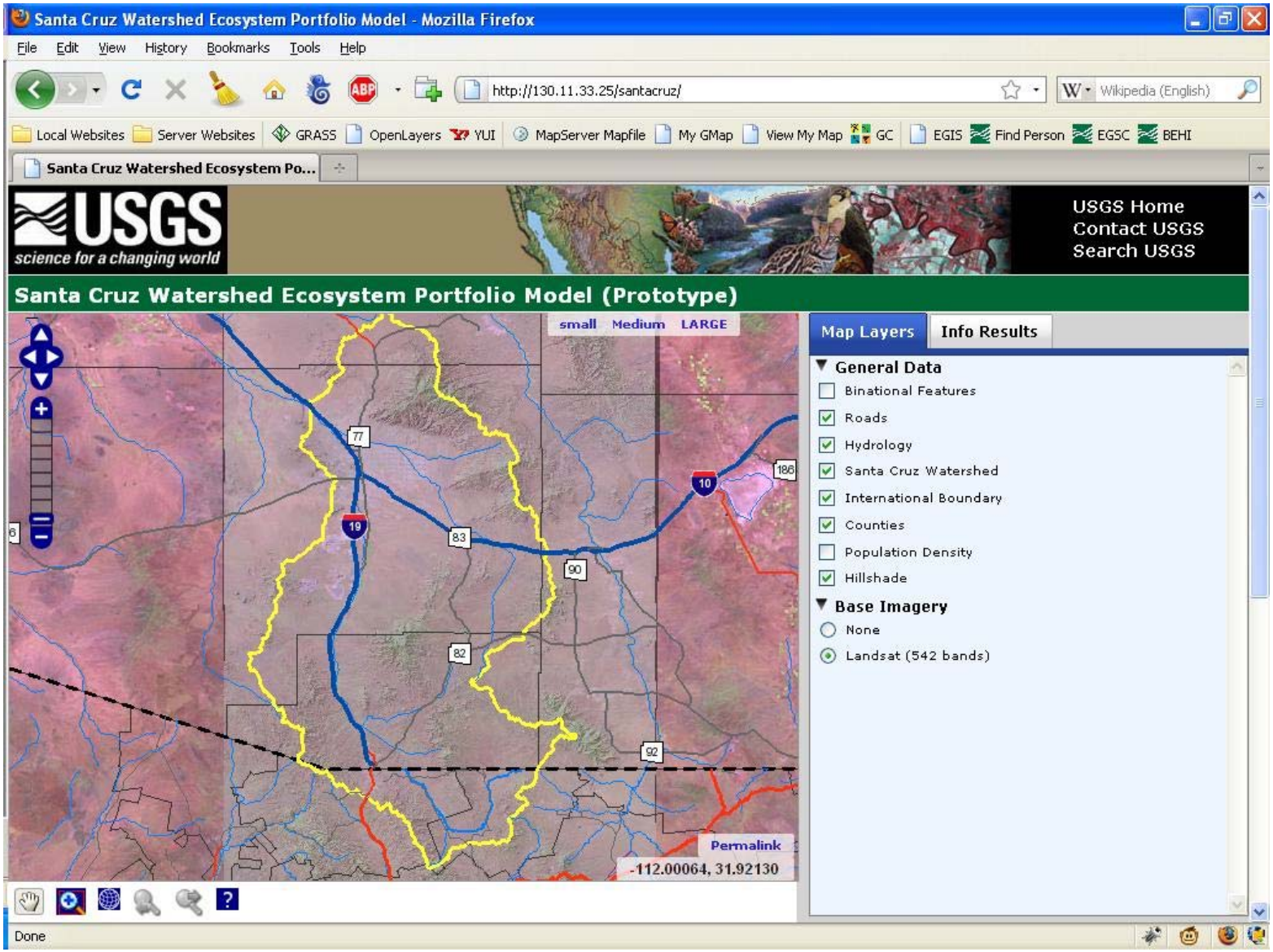


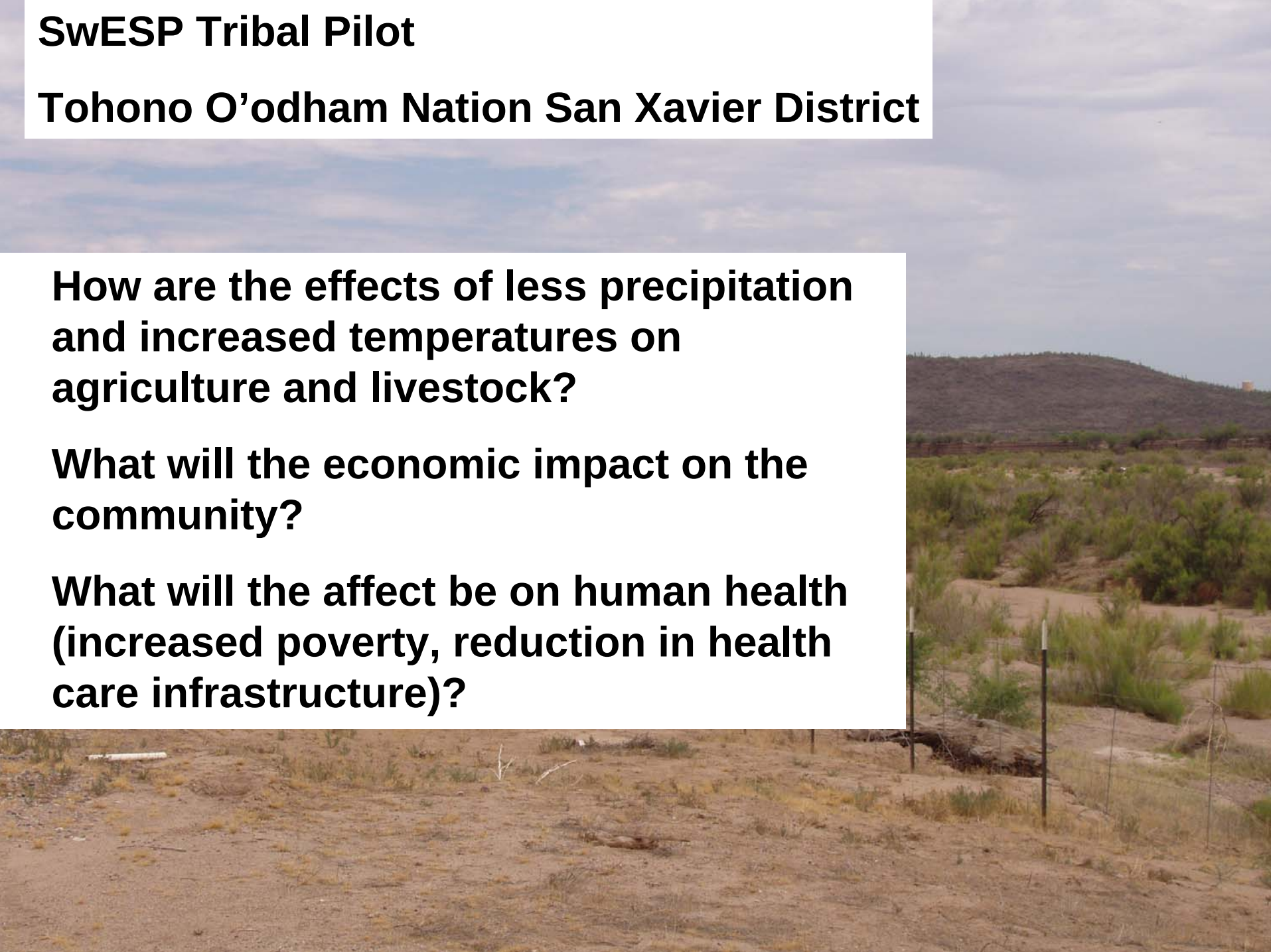
Restoration Potential Criterion

OTHER MODELS / TOOLS THAT WILL FEED THE SCWEPM

- Analytical Tools Interface for Landscape Assessments ATtILA
- SLEUTH Urban Growth Model
- GAP Habitat Models

Santa Cruz Watershed Ecosystem Portfolio Model Web Interface





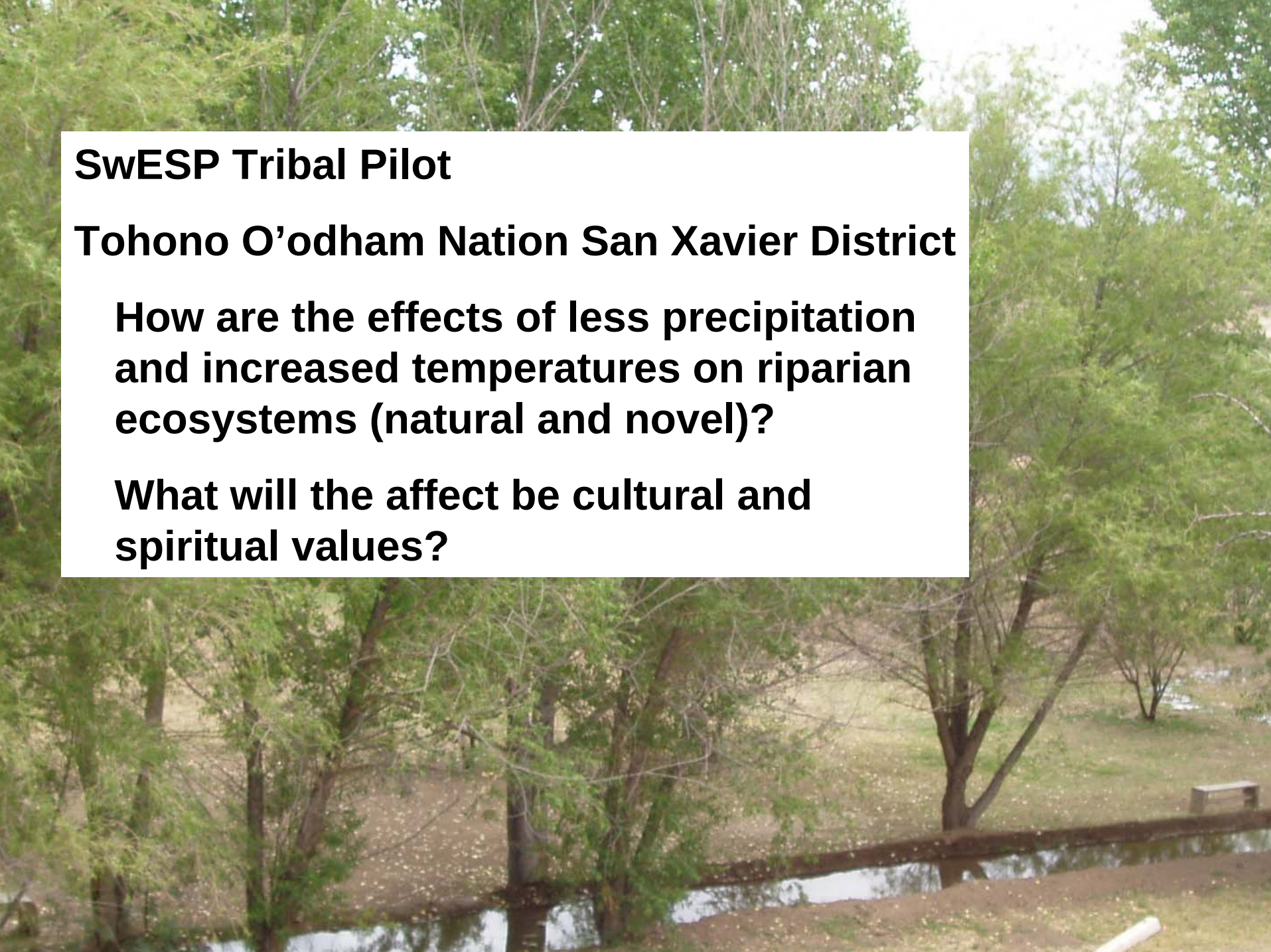
SwESP Tribal Pilot

Tohono O'odham Nation San Xavier District

How are the effects of less precipitation and increased temperatures on agriculture and livestock?

What will the economic impact on the community?

What will the affect be on human health (increased poverty, reduction in health care infrastructure)?



SwESP Tribal Pilot

Tohono O'odham Nation San Xavier District

- **How are the effects of less precipitation and increased temperatures on riparian ecosystems (natural and novel)?**
- **What will the affect be cultural and spiritual values?**

Goal: Research and Methods to be relevant and transferable to other Nations

Santa Cruz Watershed Ecosystem Portfolio Model contributors

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- EPA Region IX (Robert Hall, Jared Vollmer, Sam Ziegler)
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- Arizona State University (Francisco Lara-Valencia)
- The Nature Conservancy (Brooke Gebow and JB Miller)
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Comments
Questions
Interest
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WATER

Ecosystem Service	Indicators / (measurement units)	Models	Ecological Endpoints	Service Endpoints
Water provisioning	Volume/timing % impervious surfaces Per capita use	SWAT, AGWA, MODFLOW, GFLOW, etc	Water quantity – groundwater / surface water	Water supply Benefits Municipal Agricultural Industrial Producer Profits Household costs Municipal utility costs Food, Fiber, Fuel Production
			Recharge	Recreation (fishing, boating, etc.)
	Aquatic and terrestrial species diversity, Native species richness, Functional Type, T & E species		Resilience, Restoration, Biodiversity	Existence Values
Clean water provisioning	Drinking water quality indicators (TDN, Chl*a*, TP, DO, TSS, total fecal coliform, *E. coli*, etc.)	SWAT		Human quality of life
Flood Risk Reduction		SWAT, other	Base flow maintenance	Flood Damage Avoided Value of property protected

LAND & SOIL

Ecosystem Service	Indicators / (measurement units)	Models	Ecological Endpoints	Service Endpoints
Land quality provisioning	Soil organic matter, water filtration, nutrients, LIDAR	STATSG2, SSURGO,	Sustainable land management, biodiversity	Livestock Productivity (yields)
	Vegetative cover, Species richness, functional types	NDVI, NLCD, LandFIRE, NASS, Forest production Model		Economic outputs
	Land quality indicators (nutrient balance, yields, land use diversity & intensity),			
	Soil contaminants (concentrations)		Sustainable land management, biodiversity	Forest Products
	Microbial biomass, soil enzymes			Timber production Economic outputs
			Agriculture, biodiversity	Farm Productivity (yields)
		Terrestrial Carbon Models (InVEST),	Carbon sequestration (plant biomass, Soil C)	Climate Regulation
		SWAT		C trading credits
		Habitat suitability Models (USFWS), GAP	Biodiversity,	Existence Values, Rare species existence/persistence, Ecosystem resilience/persistence,Recreation, (Hiking, Hunting, Birding, etc.), Tourism related jobs

AIR

Ecosystem Service	Indicators / (measurement units)	Models	Ecological Endpoints	Service Endpoints
Air quality provisioning	Ozone, NOx, SOx, Particulate Matter2.5, VOCs	CMAQ-NLCD/MODIS	Air quality	Visual Aesthetic Services
			Visibility	
			AGI – air quality index	Health Effects/ Economic Benefits
				Premature mortality incidence
				Value of lost life
				Lost work days
				Hospital admissions & associated costs (etc)