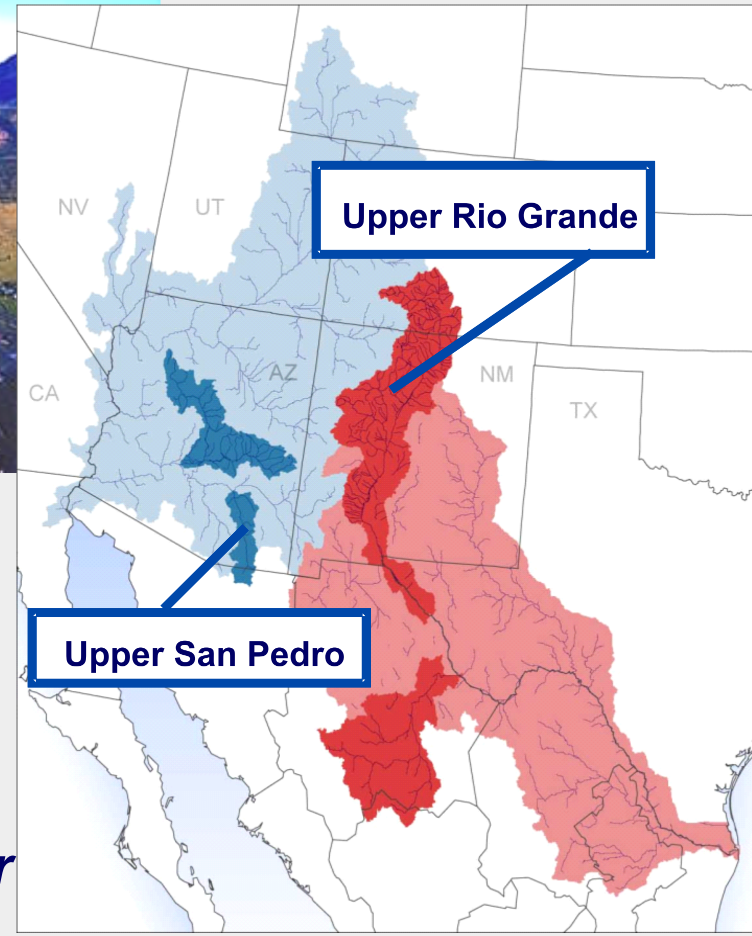
Ecosystem Valuation in Southwest Riparian Areas



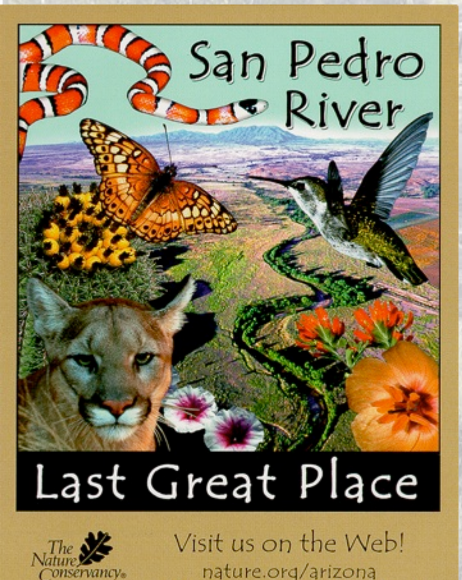
David Goodrich - USDA-ARS, Tucson, AZ
David Brookshire – Univ. of New Mexico
Craig Broadbent – Illinois Wesleyan Univ.
Investigators from multiple projects and over 50 Institutions, Agencies, and NGO 's

OVERVIEW

- **Background and building the scientific foundation**
- **Integration of science with decision-makers**
- **Ecosystem Services (ESS) – and non-market valuation methods**
- **Framework for science and policy integration for ecosystem valuation**
- **Riparian ecosystem services valuation study in the San Pedro and Rio Grande**
- **Conclusions and lessons learned**

The Water Resources Management Challenge in the San Pedro Basin

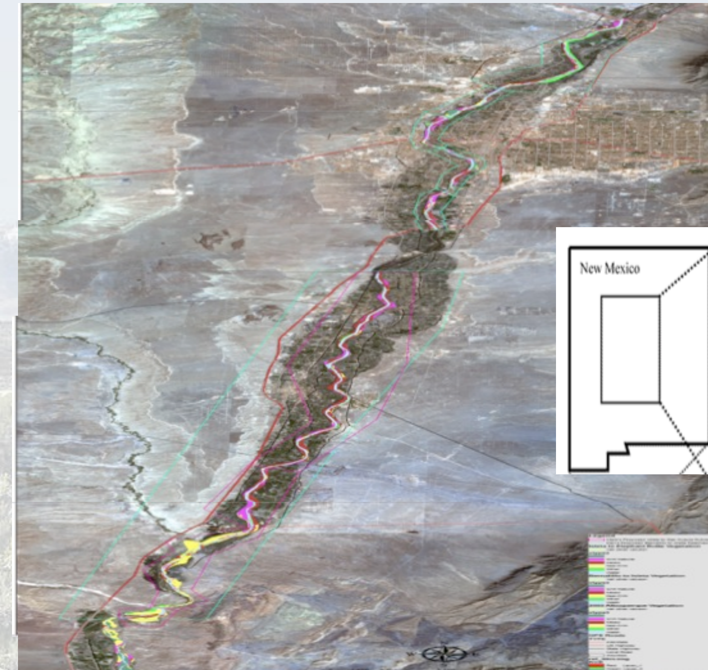
- Ft. Huachuca – largest employer in S. Arizona (Economic impact to AZ > $2B/yr) – only one of two locations in the world with a "clean" EM spectrum for communication tests
- Cananea Mine: 2-3% world's copper
- One of world's most ecologically diverse areas – 1st Congressionally designated National Riparian Conservation Area
- Groundwater is predominant source of water for human use and is a key factor in sustaining the riparian habitat



Santa Cruz R. near Tucson

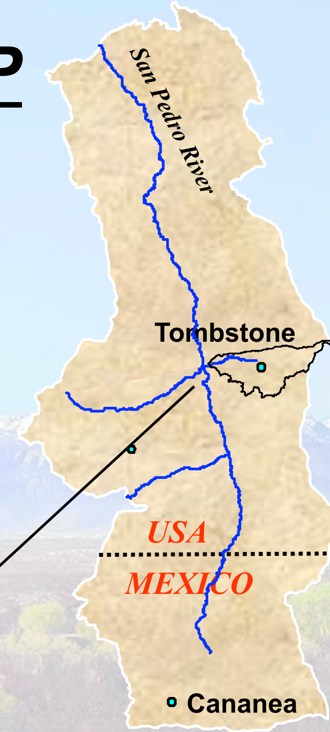
The Water Resources Management Challenge in the Middle Rio Grande

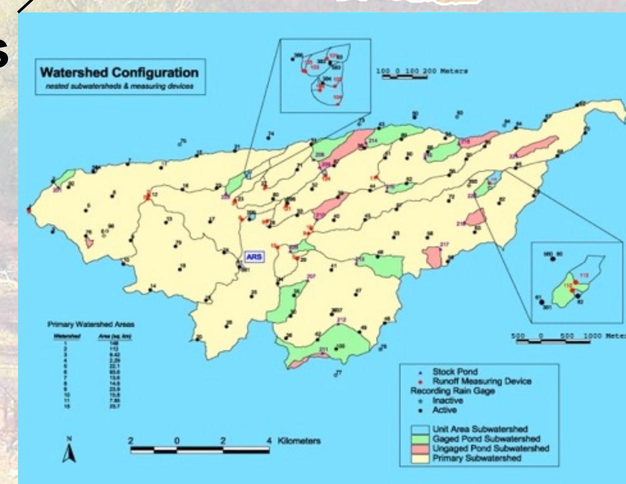
- Highly regulated – few natural large floods for cottonwood/willow recruitment
- Irrigation return flows maintain a relatively shallow groundwater table
- Many reaches choked with invasive salt cedar and Russian olive resulting in fire being the dominant factor in shaping the riparian area
- Mechanical thinning and fire are being used to remove invasive plants
- Pole planting of cottonwoods for restoration with continued understory thinning



Evolution of Research / Partnerships in the SP

- *USDA - ARS Walnut Gulch Experimental* Watershed (1953-Pres. Physical / watershed science)
- *MONSOON'90, WALNUT GULCH '92, NASA-EOS* ('88-'99 - Interdisciplinary – physical science)
- *SALSA Program* ('93-'00 Interdiscplinary physical and biological science – begin outreach & integration)
- *Upper San Pedro Partnership* ('98-Pres.- Work and plan research directly with elected officials and resource managers)
- *SAHRA NSF Science and Technology Center* ('00-'10 - Add economics, social & scenario science, education to all of the above)
- *AGAVES – Assessment of Good And Valuation of Ecosystem Services*





RIPARIAN WATER USE

Simple Question:

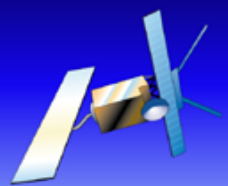
How much water does the riparian vegetation use and where does it come from ?

Riparian Ecosystems Processes

(AFM – Nov. '00)

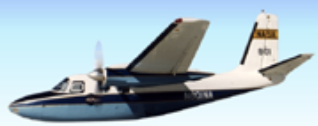
Semi-Arid Land-Surface-Atmosphere Program SALSA

Coordinated Measurements for Water Source and Exchange conducted during the SALSA Program



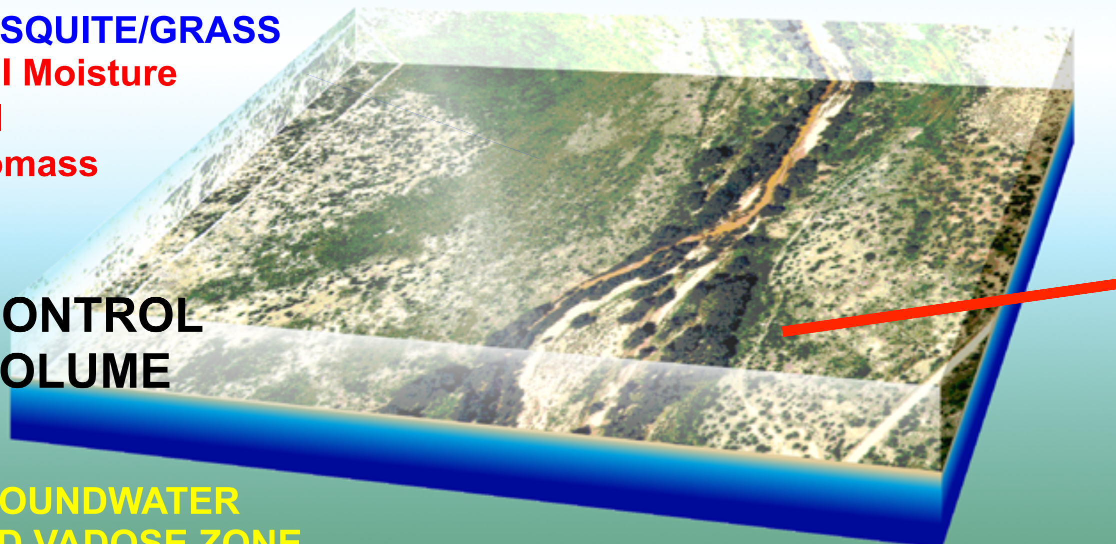
REMOTE SENSING

NEAR-SURFACE ATMOSPHERIC LAYER
Surface Met/Flux Stations
Scintillometer, LIDAR, SODAR



SAN PEDRO RIVER
Stage/Discharge
Dye Tracer Dilution
Bank Conductance

MESQUITE/GRASS
Soil Moisture
LAI
Biomass



GROUNDWATER
AND VADOSE ZONE
Deep Wells
Piezometers
Isotopes

RIPARIAN FOREST GALLERY
Sapflow, LAI, Stomatal Conductance
Leaf Carbon Isotope, Plant Water Isotope
Photosynthetic Rate

Interdisciplinary and Public Integration

ATMOSPHERIC SCIENCES

SURFACE WATER & UNSATURATED ZONE HYDROLOGY

ECOLOGY/BIOLOGY

GROUNDWATER HYDROLOGY, GEOPHYSICS

Upper San Pedro Partnership

A consortium of 21 agencies, NGOs and private firms established in 1998 that cooperate in the implementation of comprehensive policies & projects to assist in meeting the water needs of the Upper San Pedro.

Members

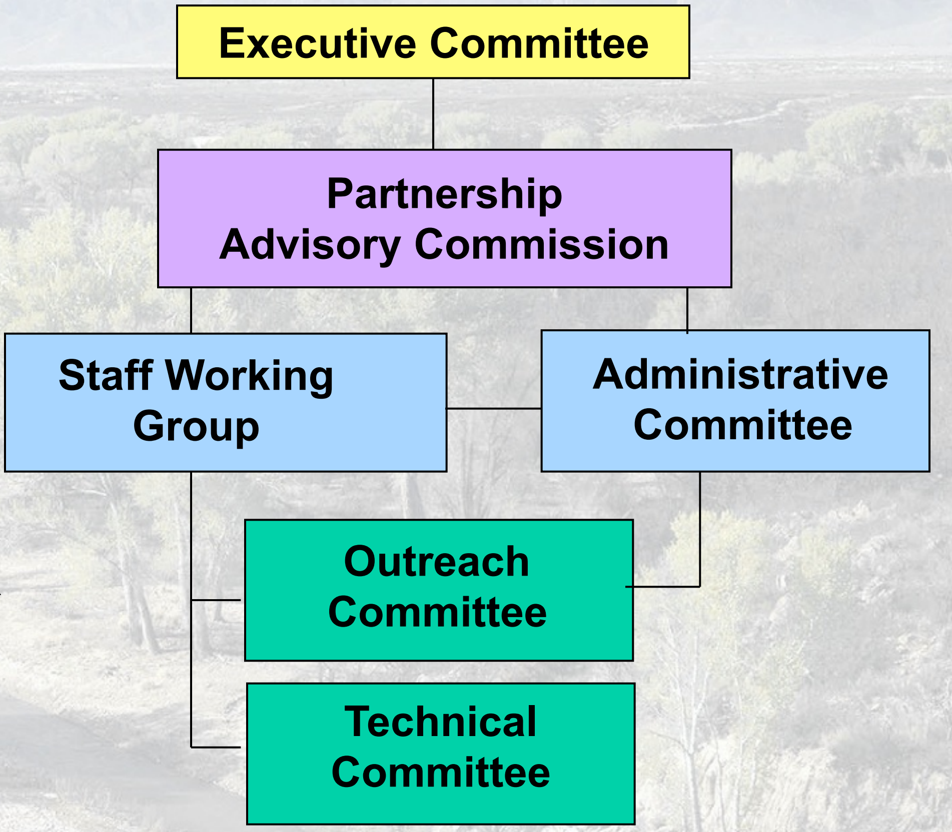
Local: Bisbee, Huachuca City, Sierra Vista, Tombstone, Cochise County, Hereford NRCD

State: AZ Dept. of Water Resources, State Land Department, ADEQ, AZ Assoc. of Conservation Districts

Federal: ***USDA-ARS-SWRC, USGS***, USFS, BLM, Ft. Huachuca, National Park Service, US Fish & Wildlife Service, BOR

NGOs: TNC, Audubon

Private: Bella Vista Water Company



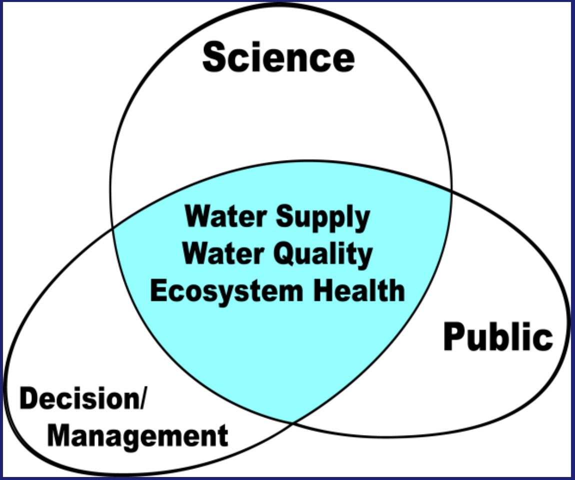
What does "Partnership" mean?

- Working together to gather and share data, information, and ideas
- Lending political / institutional support for each other's projects
- Identifying and leveraging funding resources

Integration of research into USPP

- Research is ***designed and planned*** with the USPP
- Regular USPP committee meetings (~2 days/month)
- Research plans reviewed / approved by multiple USPP committees
- Frequent oral and written research updates to USPP

"This effort is a step beyond the traditional science-stakeholder technology transfer to that of a true partnership where research is planned and conducted specifically to meet the needs of decision makers and resource managers"



Several Major Research Results and Tools

- **Basin characterization, land cover change, alternative futures and SW Modeling**
- **Quantify basin recharge**
- **State of the art Groundwater Model**
- **Quantify riparian water needs and riparian functional condition classes**
- **Downscaling of Global Change Model results**
- **Decision Support Model developed with USPP which also defined plausible alternative management decisions**

These efforts provided the physical and ecological scientific foundation for informed ecosystem service valuation & resulted in numerous peer-reviewed pubs

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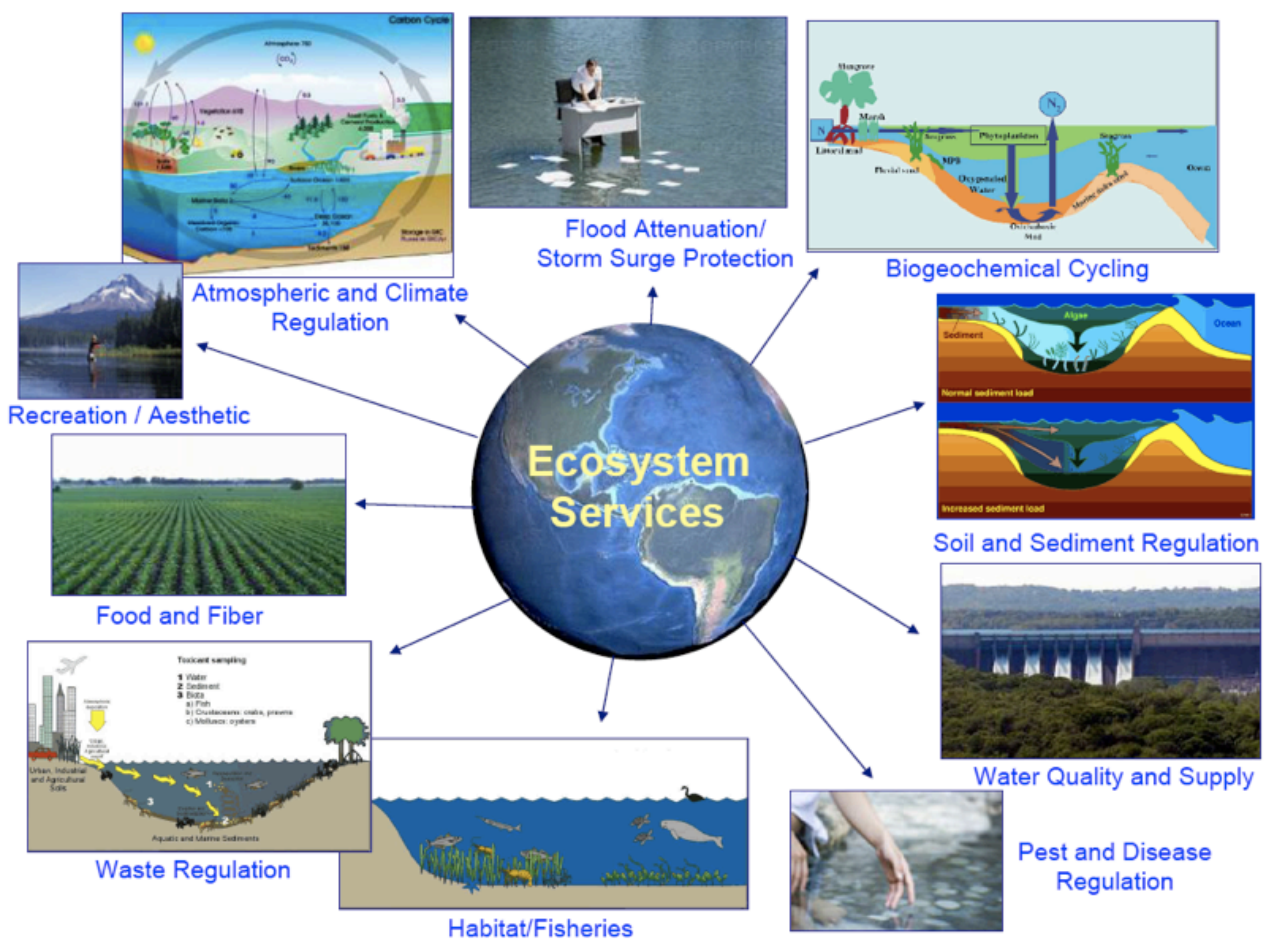
ECOSYSTEM SERVICES (ESS)

- **Ecosystem/watershed processes that support human well-being (early 1980s)**
- **UNEP Millennium Ecosystem Assessment (MEA) - define ESS as benefits people obtain from ecosystems and humans are fundamentally dependent on them**
- **Formalized within the 2008 Farm Bill – Secretary of Agriculture will:**
  - **Establish science-based methods to measure the environmental benefits of land management to support ESS markets**
  - **Establish a Federal Environmental Services Board (ESB) to promote scientifically and economically sound methods to quantifying the benefits of ESS and set ESS research priorities**



Ecosystem Services
Atmospheric and Climate Regulation
Flood Attenuation/ Storm Surge Protection
Biogeochemical Cycling
Soil and Sediment Regulation
Water Quality and Supply
Pest and Disease Regulation
Habitat/Fisheries
Waste Regulation
Food and Fiber
Recreation / Aesthetic
Carbon Cycle
Algae
Sediment
Ocean
Normal sediment load
Increased sediment load
Phytoplankton
Toxicant sampling
1 Water
2 Sediment
3 Biota
a) Fish
b) Crustaceans: crabs, prawns
c) Molluscs: oysters
Urban, Industrial and Agricultural Soils
Aquatic and Marine Sediments

Ecosystem Service Types

Supporting services

Nutrient cycling
Net primary production
Pollination & seed dispersal
Habitat
Hydrologic cycle

Regulating services

Gas regulation
Climate regulation
Disturbance regulation
Biological regulation
Water regulation
Waste regulation
Nutrient regulation
Soil retention

Provisioning services

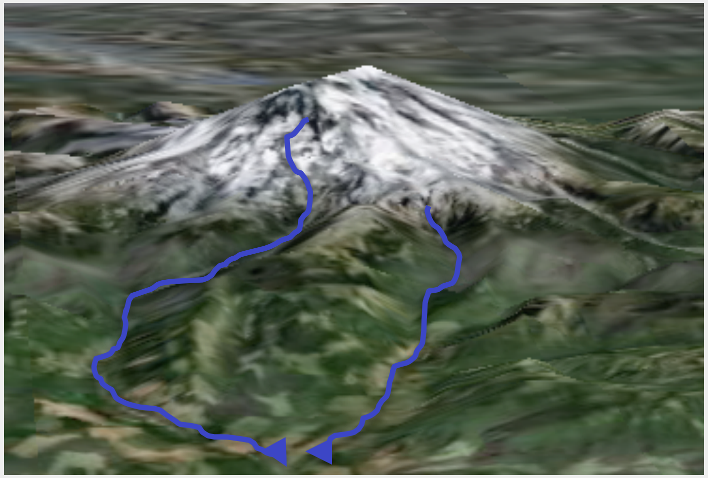
Water supply
Food
Raw materials
Genetic resources
Medicinal resources
Ornamental resources

Cultural services

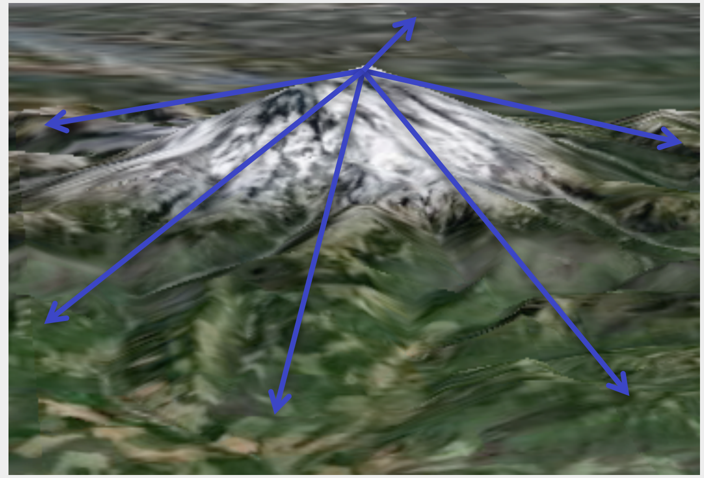
Recreation
Aesthetic
Science & education
Spiritual & historic

Geography Matters

(services provided in one place may provide benefits in another place)

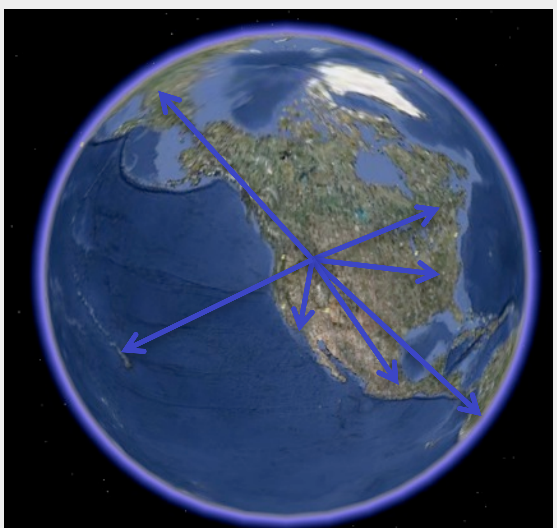


Hydrologic services



Aesthetic viewsheds

Recreation, flood regulation, many ecosystem goods

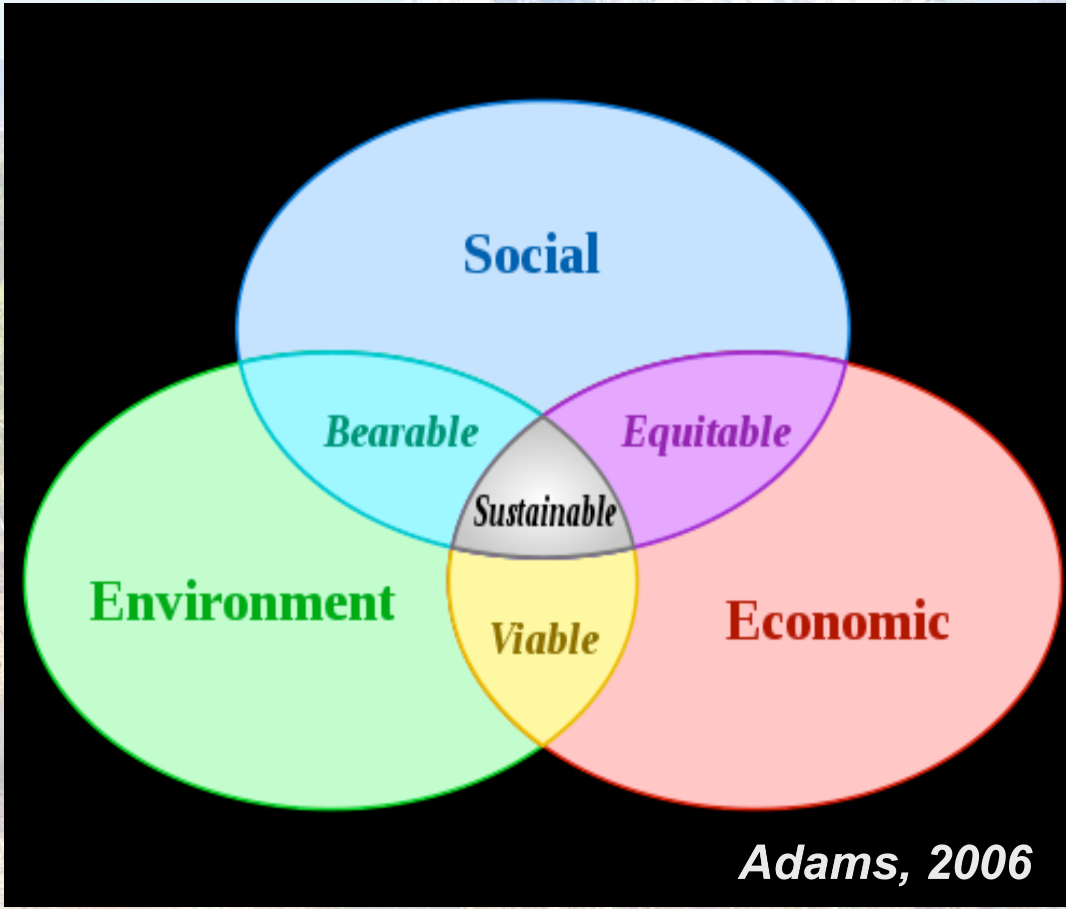


Carbon sequestration, some cultural values

Recreation, aesthetic proximity, some cultural services

Sustainability and Valuation of ESS

- Many definitions – "Reconciliation of environmental, social equity and economic demands" (2005 World Summit)
- Does the lack of measureable values for ESS lead to their overexploitation?
- Will monetizing ESS help decision-makers better weigh the costs and benefits of management and investment actions?



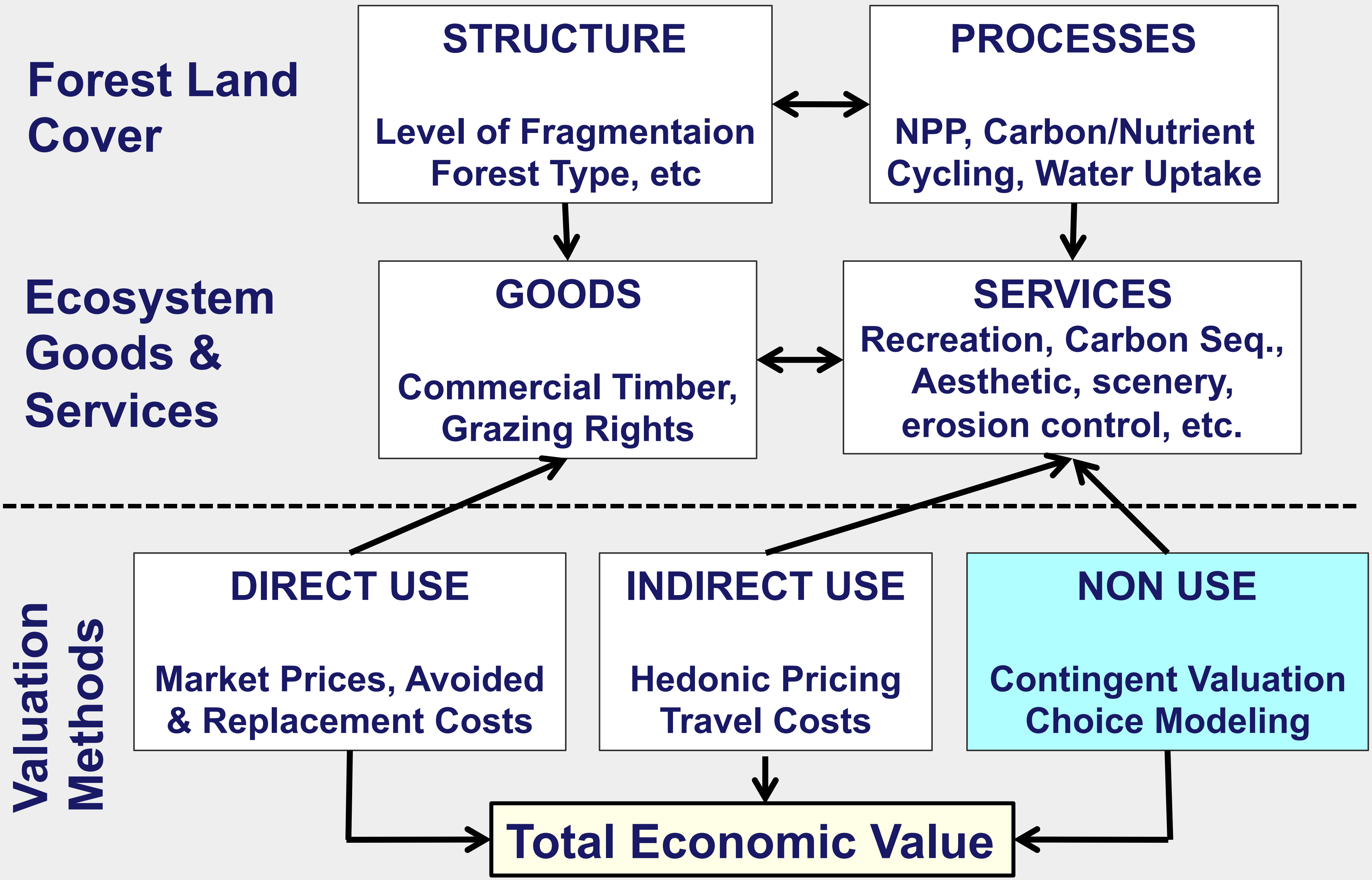
The Political & Economic Problem

- **Who benefits and who loses?**
  - **Protect the ecosystem:**
    - **Winners: the public (all of us)**
    - **Losers: landowners who could make money with extractive use**
  - **Degrade the ecosystem:**
    - **Winners: private property owner(s)**
    - **Losers: the public (all of us)**
- **One solution: legal rights to ecosystems and their services (<u>propertization,</u> not privatization)**
- **How do we value ecosystem services ?**

The Valuation Problem

	Excludable	***Non-Excludable***
Rival	*Market Good:* cars, houses, land, oil, timber	*Open Access resource:* Oceanic fisheries, timber etc. from unprotected forests, waste absorption capacity
Non-rival	*Club or toll good* patented information, toll roads, country clubs	*Pure Public Good:* Information, most ecosystem services, e.g. climate stability, coastline protection, life support functions, etc.

Structure, Function, & Total Economic Value



* Adapted from Turner (2000)

ESS VALUATION TECHNIQUES

- Two well developed stated preference techniques (surveys)
  - Contingent Valuation (CV)
  - Choice Modeling (CM)
- CV: Asks individuals to explicitly state their willingness to pay for a proposed change in a single ecosystem attribute
- CM: Ask the person to compare “current conditions” of a bundle of ESS relative to an “alternative condition”
  - Repeat this decision multiple times
- Yields marginal dollar values for changes in attributes
- Attributes maybe spatially lumped or distributed

Contingent Valuation Example

Current Condition

Alternate Condition - 1

Alternate Condition - 2

Ask: How much are you willing to pay for Alt. #1 over CC?

How much for Alt. #2 over CC?

How much for Alt. #2 over Alt. #1 ?

Minimal Scientific Foundation Required

Choice Modeling Example - Riparian Preservation

Attributes	Riparian Vegetation	% Time SW Is Present	Bird Type/Pop. Attributes	
Alternate Condition - 1		< 60%		Bundle #1
Current Condition		> 60% < 95%		Bundle #2
Alternate Condition - 2		> 95%		Bundle #3

- Attributes across bundles are NOT independent
- Need science ( ) to describe dependence of attributes in a bundle
- Note there are costs associated with lost ESS
- Decisions points: 1) do nothing 2) maintain CC 3) improve CC
  - different construction/conservation measures with each decision

Riparian Restoration / Preservation (R/P)

- **Now add a decision or action that will alter ecosystem attributes**
- **The costs ($$) associated with restoration are often well defined (e.g. USCOE efforts in the Middle Rio Grande)**
- **Non-market ESS benefits of restoration can be defined in $$ with <u>Choice Modeling</u> & <u>Contingent Valuation</u>**
- **This enables a $$ to $$ comparison of market-based costs to non-market based benefits**

Restoration is occurring ….
(To the tune of ~$1Billion/yr)

… is it worth the cost? What is it worth to preserve a functioning riparian system?

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ASSERTION

- **Valuation studies are typically conducted in the absence of integrated science information and a realistic decision framework because**
  - **Targeted scientific research is lacking, or**
  - **Studies have not been designed to inform the valuation questions**
  - **A strong linkage between scientists and decision makers is lacking**
- **Addressing these issues requires – TIME**
  - **Trust between scientists and decision-makers – essential**
  - **Interdisciplinary / interagency partnerships (research enterprise)**
- **While we may not be able to afford to do this everywhere we have to do it extremely well in some places and test transferability and the limits of valuation in locations with less science & information**
- **This foundation is essential for scientifically based ecological valuation as no single agency or Univ. has the depth & breadth to do it alone (=> 50 Institutions, Agencies, and NGO's)**

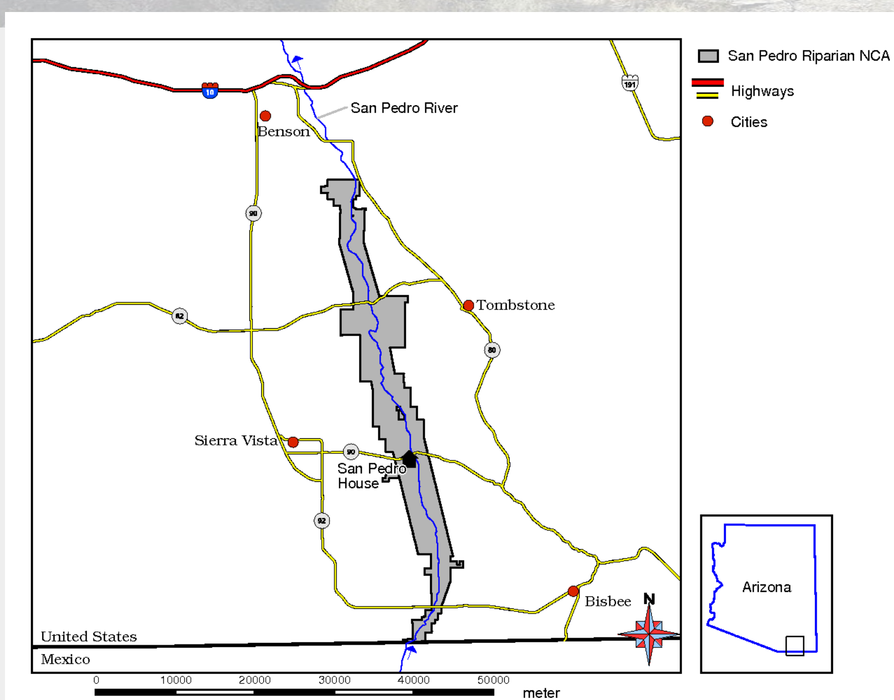
San Pedro River & Middle Rio Grande

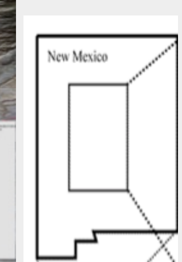
- Flows north from Cananea Mexico to the Gila River in Arizona
- San Pedro Riparian National Cons. Area
  - 40 miles in length
  - 56,000 Acres
- A semi-arid flyway for resident and migratory birds
- Riparian vegetation consists of:
  - Cottonwood
  - Salt Cedar
  - Mesquite
  - River Grasses

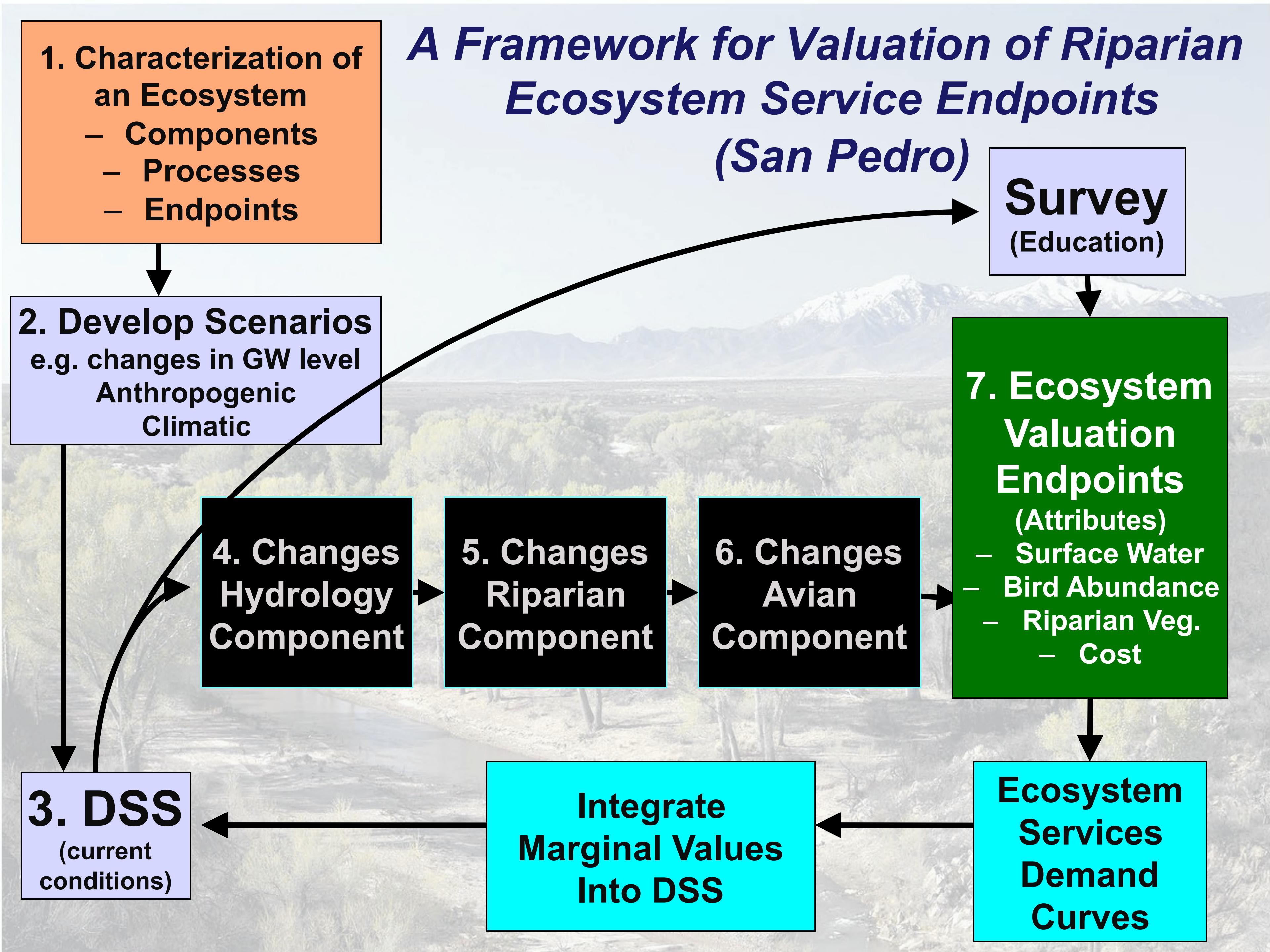
Preservation

- Stretch of river from Cochiti Dam to San Acacia gage
  - Approximately 40 miles of river
  - Includes the Rio Grande State Park and Bosque del Apache
- Habitat for birds
  - 277+ year round, 146+ migrants
  - Acquired data set from Hawks Aloft
- Riparian Vegetation consists of:
  - Cottonwood
  - Salt Cedar
  - Russian olive
  - River Grasses

Restoration






A Framework for Valuation of Riparian Ecosystem Service Endpoints (San Pedro)
1. Characterization of an Ecosystem
– Components
– Processes
– Endpoints
2. Develop Scenarios
e.g. changes in GW level
Anthropogenic
Climatic
3. DSS
(current conditions)
4. Changes Hydrology Component
5. Changes Riparian Component
6. Changes Avian Component
Survey
(Education)
7. Ecosystem Valuation Endpoints
(Attributes)
– Surface Water
– Bird Abundance
– Riparian Veg.
– Cost
Ecosystem Services Demand Curves
Integrate Marginal Values Into DSS

1. Characterization of an Ecosystem
– Components
– Processes
– Endpoints

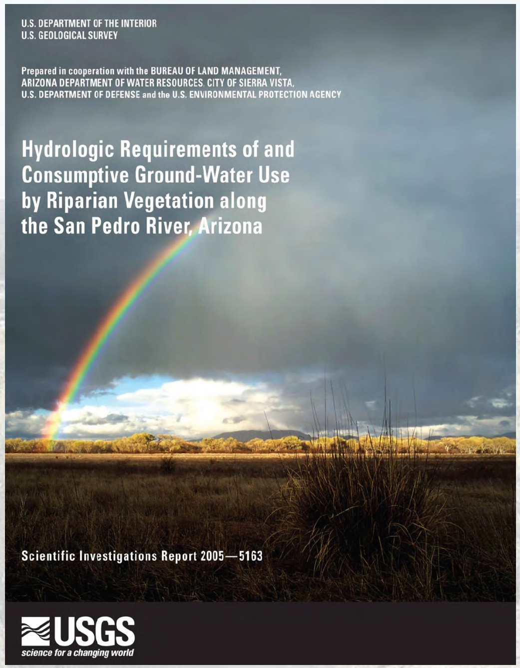
Why it is important to connect decisions to changes in ESS with science-based process models for valuation?

- **Market Goods –**
  - Enter a supermarket and pick a good off of the shelf – What can you read about it? Details!!
- **Non Market –**
  - Walk through the forest - what do you know about it?
    - The forest is pretty etc, but doubtful one knows the mix of vegetation, birds, groundwater levels etc., and what might change the mix
    - Without this information cannot decide what you prefer from one area to another
  - What is needed is science driven ecosystem attribute endpoint "bundles" describing ecosystem services
    - Endpoints are directly related to human welfare measure, not typical science measures (e.g. not "Dissolved O" or "TDS" but "miles SW")
    - Drivers of change clearly defined,
    - Represent marginal change of attributes

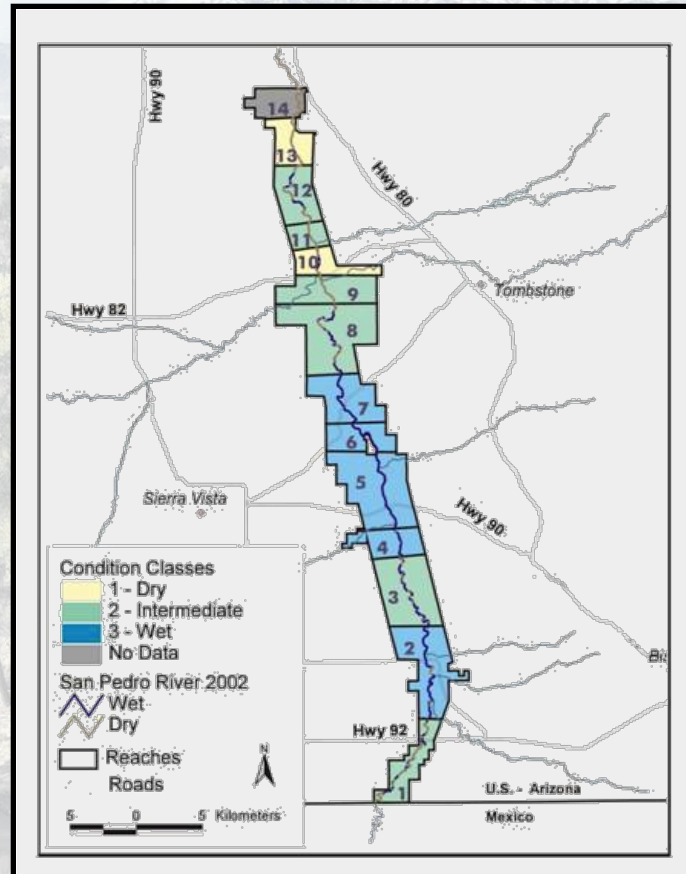
Riparian Water Needs Report

1. Characterization of an Ecosystem
- Components
- Processes
- Endpoints

- New estimates of total riparian ET
- Develops condition class model which relates classes to hydrologic metrics
- Each condition class is reflective of different levels of ecosystem functional capacity



Leenhouts, J. M., Stromberg, J.C., and Scott, R.L., eds., 2006, USGS Scientific Investigations Report 2005–5163, 154 p.



"State of the San Pedro"

Allows prediction of change in riparian condition class with GW changes predicted by the GW / DSS models

2. Develop Scenarios
e.g. changes in GW level
Anthropogenic
Climatic

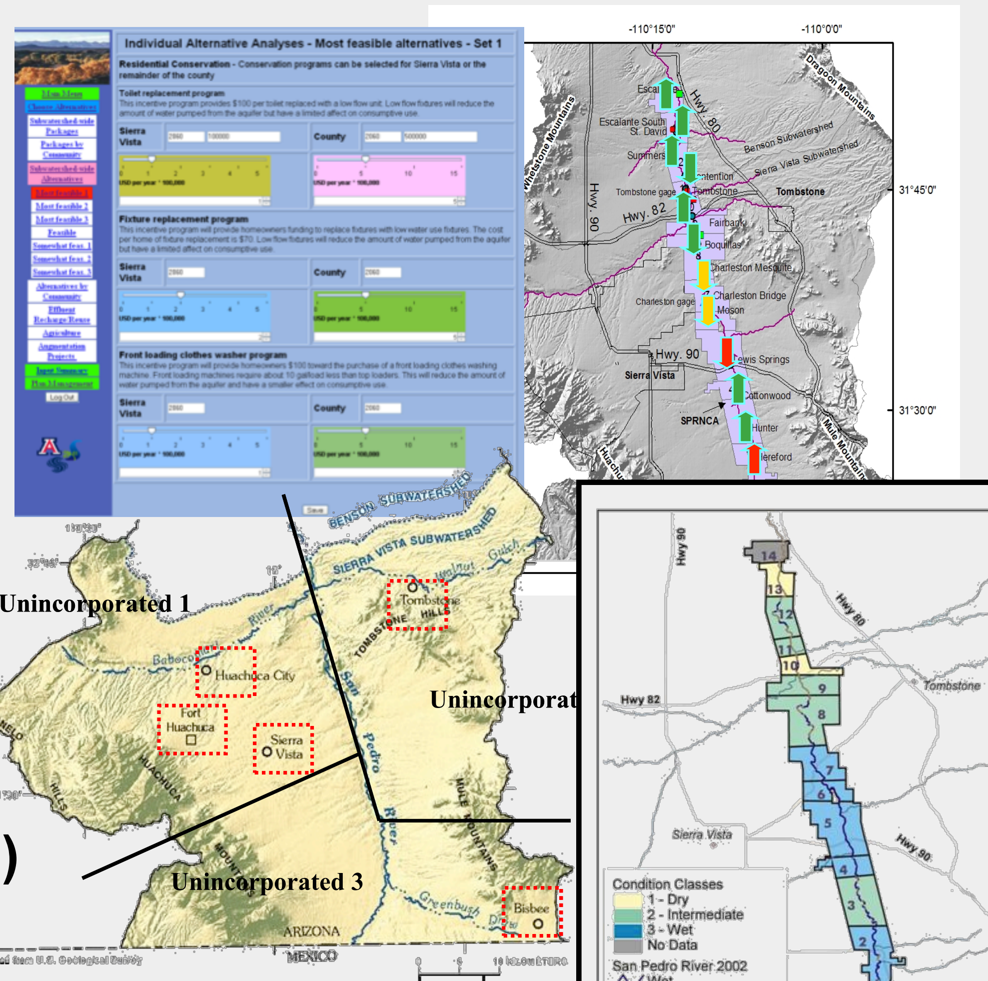
What Alternative Water Polices are Available for the San Pedro ?

- **INFRASTRUCTURE CHANGES**
  - location of subdivisions and groundwater wells
  - recharge basins
- **WATER AUGMENTATION**
  - increase the amount of water in the basin by piping it in from other regions
- **WATER CONSERVATION**
  - decrease the consumption of water in the region
- **Climate Changes**

3. DSS

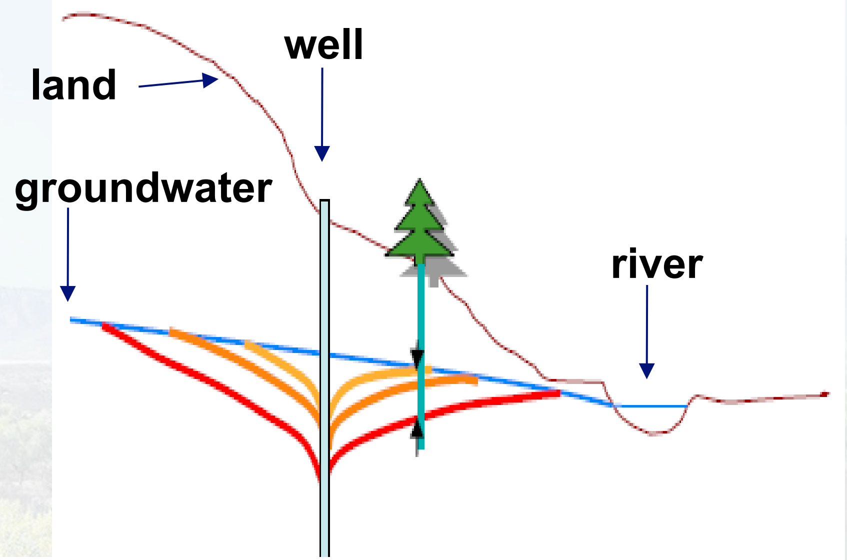
DSS Tool – House & Integrate the Science

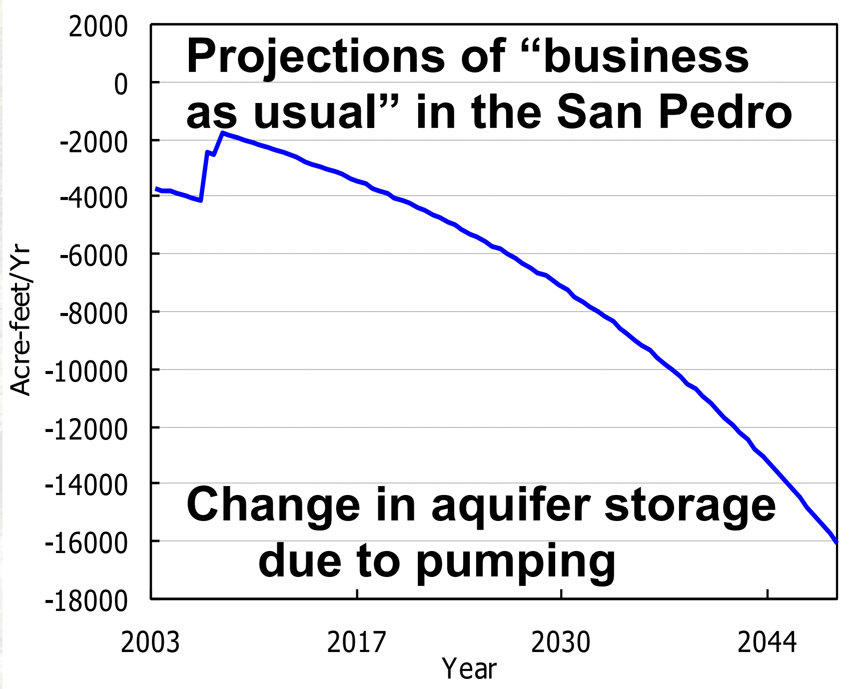
- <u>San Pedro DSS:</u> Provide an operational DSS to the USPP to illustrate & evaluate the costs / benefits of conservation, augmentation, and recharge alternatives (A "House" to hold and summarize the science)
- Incorporates multiple factors
  - USGS groundwater model
  - Surface water supply
  - Groundwater storage
  - Residential/commercial water uses (infrastructure, well location)
- Simulations up to 50 years
  - Can vary (e.g.):
    - populations
    - location of recharge basin
    - location of future wells
- Generates alternative futures (adaptive management scenarios)



Decision Support System (DSS)

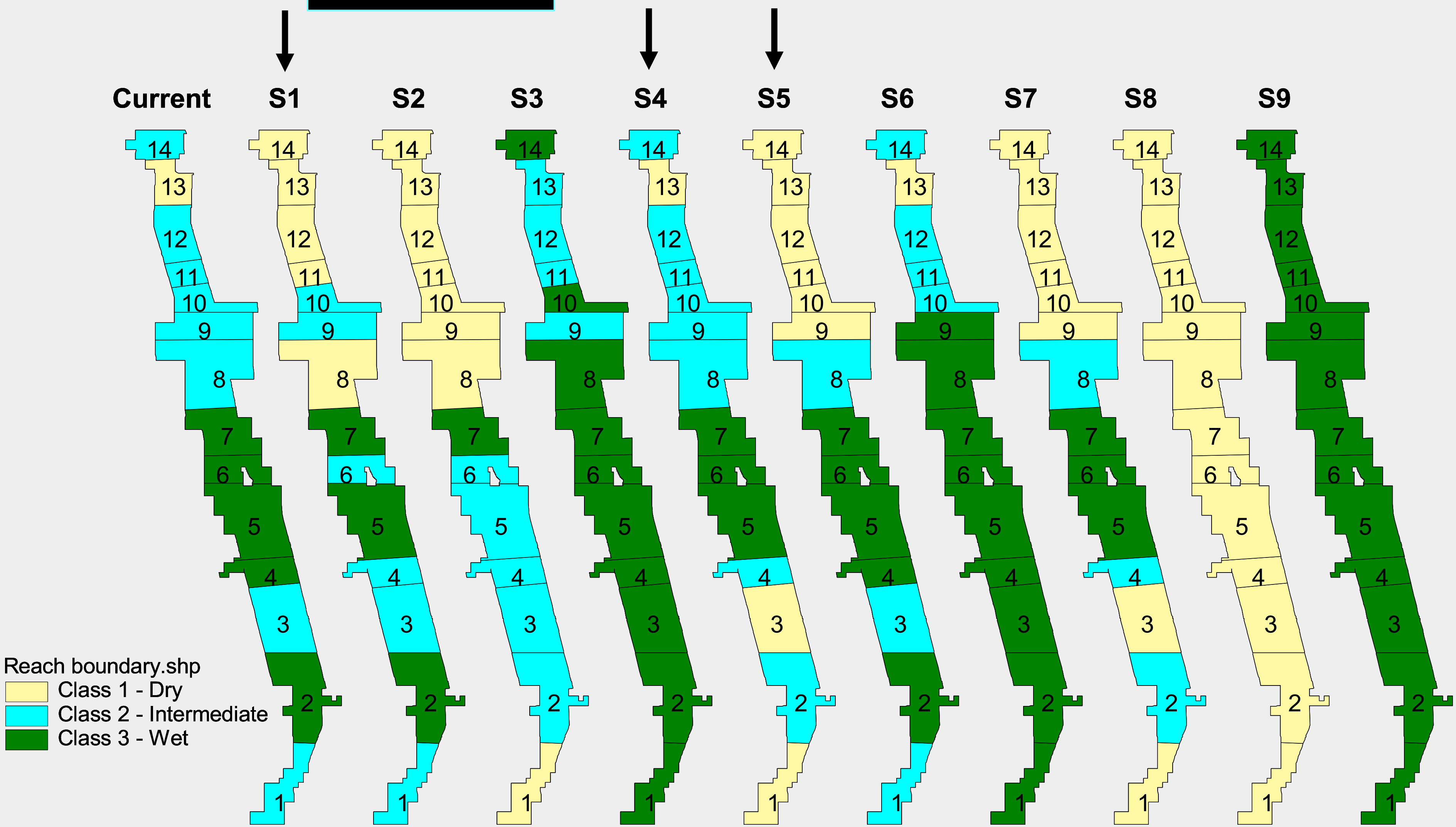
- **Sample Scenarios**
  - Scenario 1
    - 0.5 m uniform decline in groundwater
  - Scenario 4
    - Continued and increased spatially designated agricultural pumping
    - new developments in unincorporated areas
  - Scenario 5
    - Increasing spatial cone of depression impacts in the Sierra Vista, Ft. Huachuca, and Huachuca City with impacts toward the lower Babocomari and Northern SPRNCA





3. DSS (current conditions) → **4. Changes Hydrology Component**

Alternative Groundwater Scenarios



4. Changes Hydrology Component → 5. Changes Riparian Component

Riparian Model

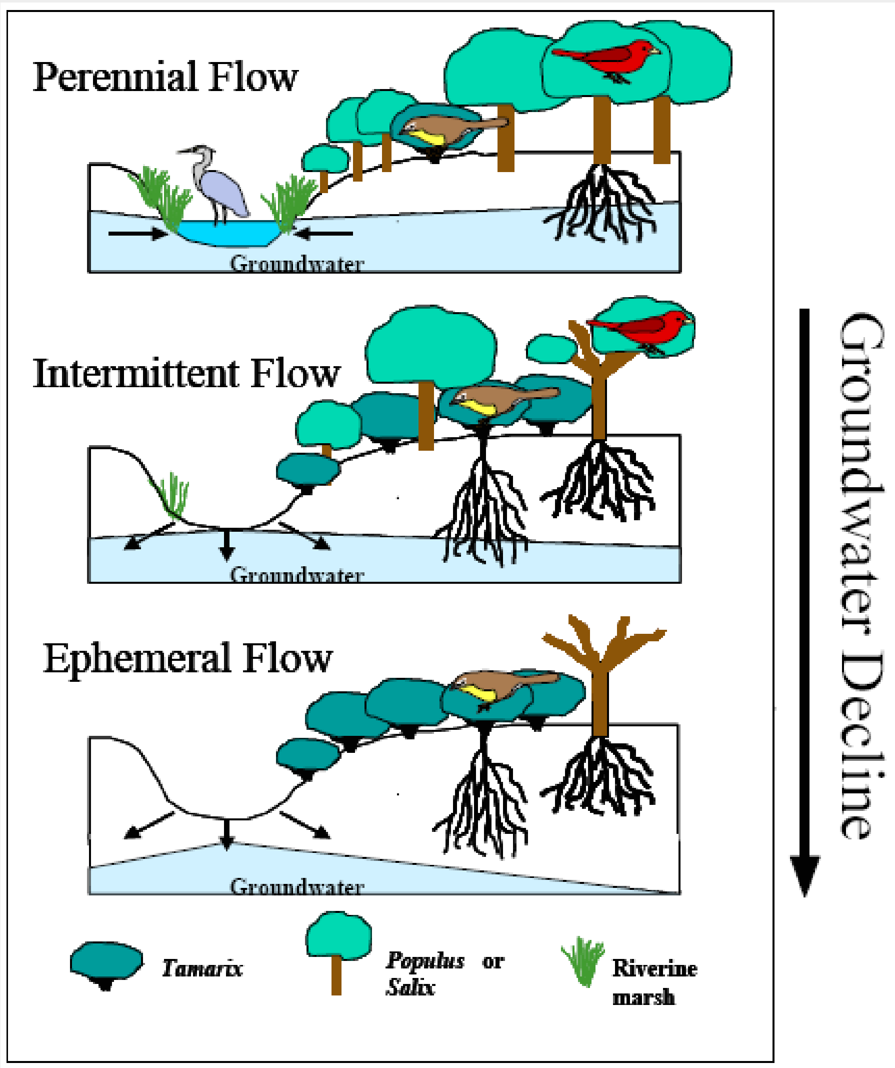
- **The model places reaches of the river into one of three condition classes:**
  - **Based on 9 bio-indicators (e.g. types of plants) which are sensitive to changes in hydrology.**
- **Each current condition class (e.g. situation today) is reflective of different levels of ecosystem functional capacity.**
- **Model is inside DSS and is used to track changes in the abundance of each class over time, based upon ground water level changes:**
  - ***Dry* : 73% Tamarisk, 10% Cottonwood-Willow**
  - ***Intermediate:* 21% Tamarisk, 63% Cottonwood-Willow**
  - ***Wet:* No Tamarisk, 89% Cottonwood-Willow**

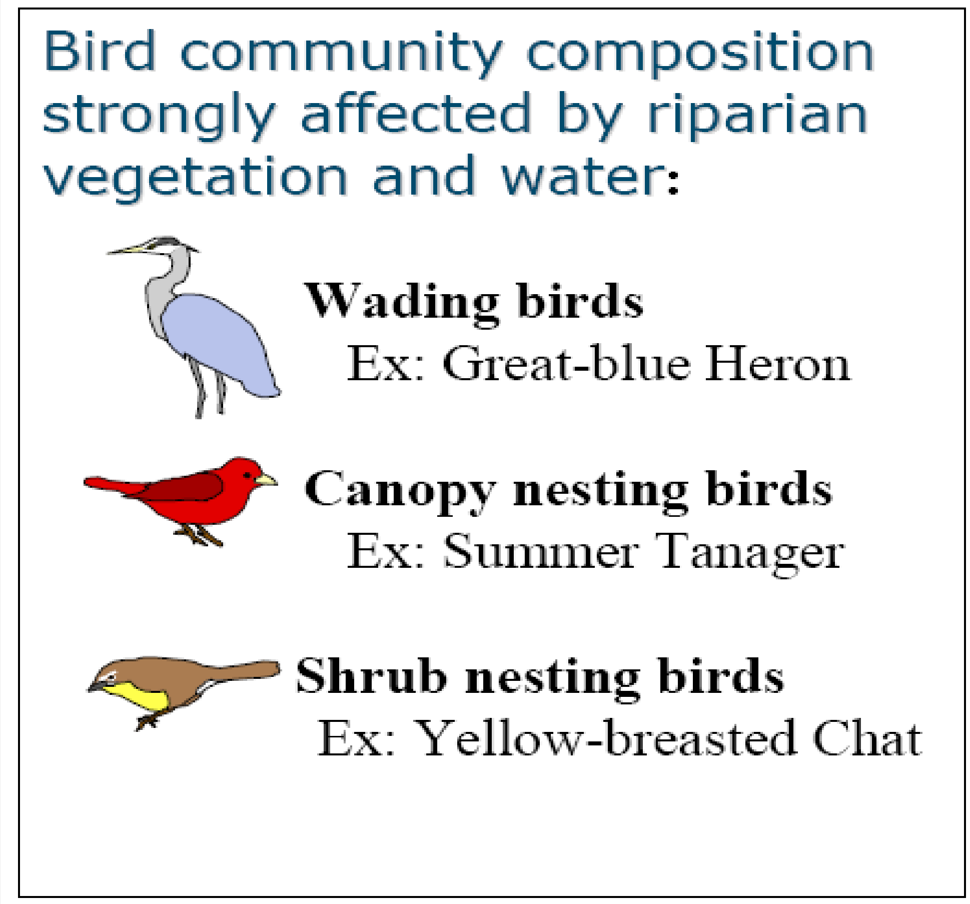
Cottonwood-Willow

Tamarisk

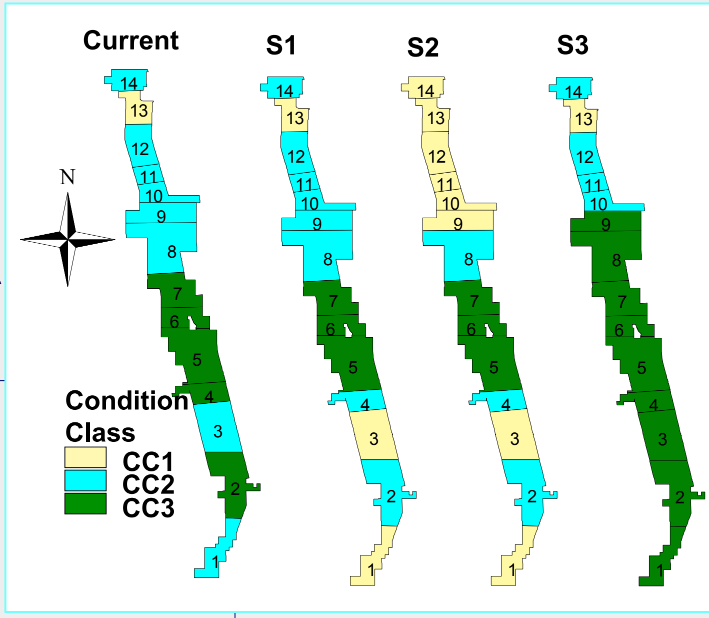
5. Changes Riparian Component → 6. Changes Avian Component

Avian Model: As riparian changes occur, so goes avian changes

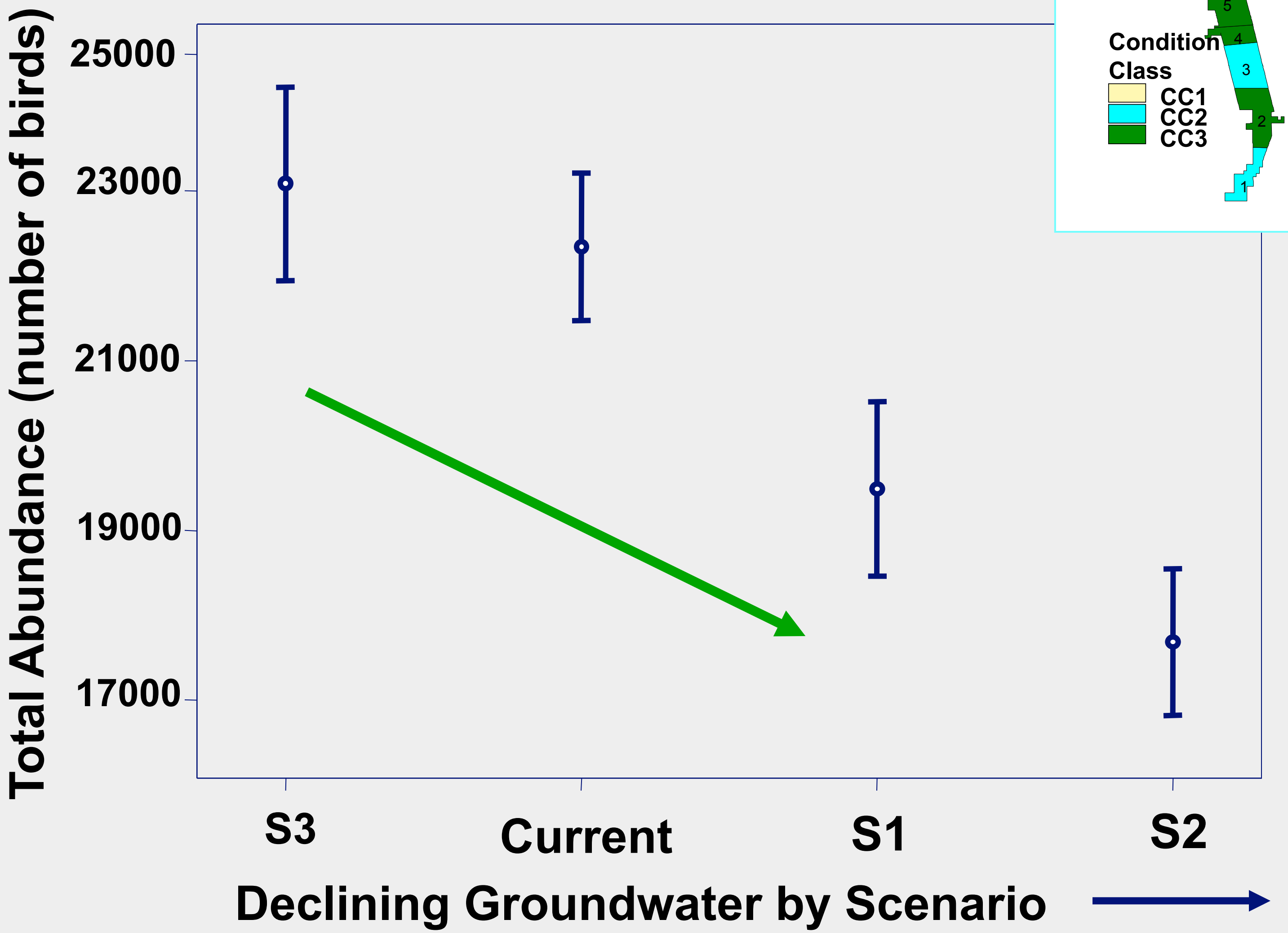




5. Changes Riparian Component → 6. Changes Avian Component



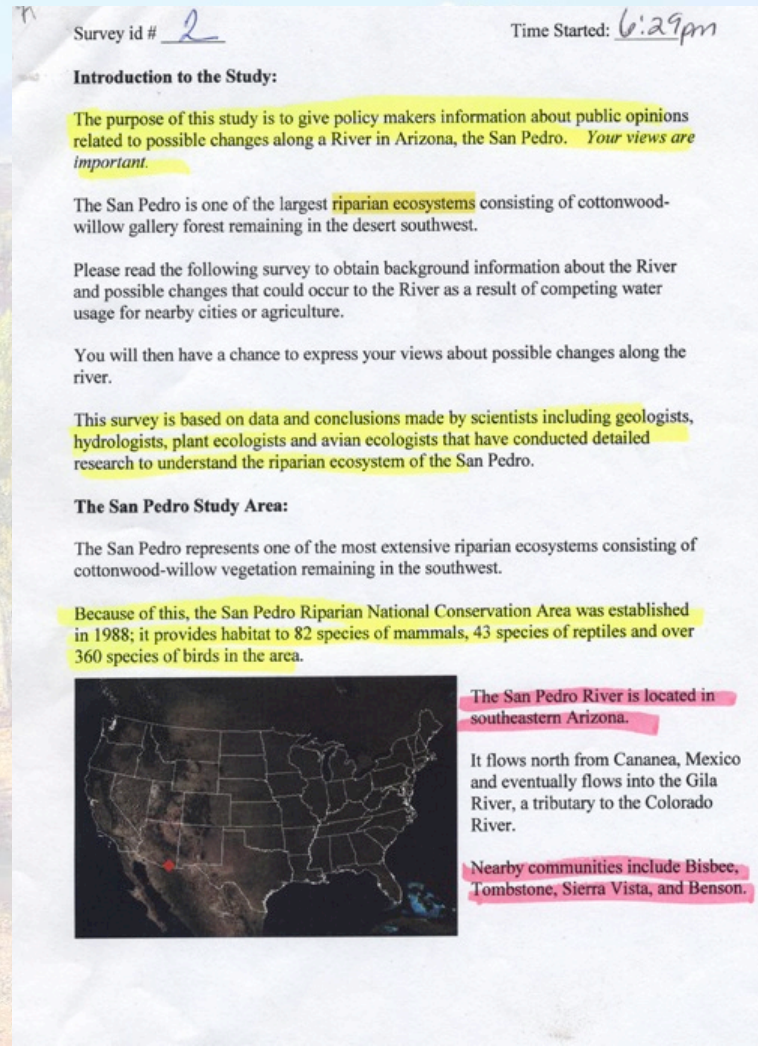
Migrating Bird Abundance Changes



Survey
(Education)

Focus Groups

- **12 focus groups conducted over 18 months**
- **Written/oral feedback about different ecosystem end-products and presentation preferences – lots of information presented**
- **Focus Group Feedback**
  - **Wanted less information!**
  - **Changes in visual material**
  - **Indicated what information was most useful**
  - **Wanted melded information (e.g. GW, veg, birds presented together)**
- **Result: Ecological end-products, grounded in science that are comprehensible to survey participants**



Survey id # 2 Time Started: 6:29pm

Introduction to the Study:

The purpose of this study is to give policy makers information about public opinions related to possible changes along a River in Arizona, the San Pedro. *Your views are important.*

The San Pedro is one of the largest riparian ecosystems consisting of cottonwood-willow gallery forest remaining in the desert southwest.

Please read the following survey to obtain background information about the River and possible changes that could occur to the River as a result of competing water usage for nearby cities or agriculture.

You will then have a chance to express your views about possible changes along the river.

This survey is based on data and conclusions made by scientists including geologists, hydrologists, plant ecologists and avian ecologists that have conducted detailed research to understand the riparian ecosystem of the San Pedro.

The San Pedro Study Area:

The San Pedro represents one of the most extensive riparian ecosystems consisting of cottonwood-willow vegetation remaining in the southwest.

Because of this, the San Pedro Riparian National Conservation Area was established in 1988; it provides habitat to 82 species of mammals, 43 species of reptiles and over 360 species of birds in the area.

The San Pedro River is located in southeastern Arizona.

It flows north from Cananea, Mexico and eventually flows into the Gila River, a tributary to the Colorado River.

Nearby communities include Bisbee, Tombstone, Sierra Vista, and Benson.

Survey
(Education)

7. Ecosystem Valuation Endpoints

– Surface Water
– Bird Abundance
– Rip Veg.

Content

– Site Intro and discussion of future scenarios
– Attributes details for each site: a) Water b) Rip Veg c) Bird abundances
– Current conditions - pictorial
– Explain proposed water use programs for the SP and MRG mechanical management San Pedro background
– *Contingent valuation* question

WTP for improvement (restoration)

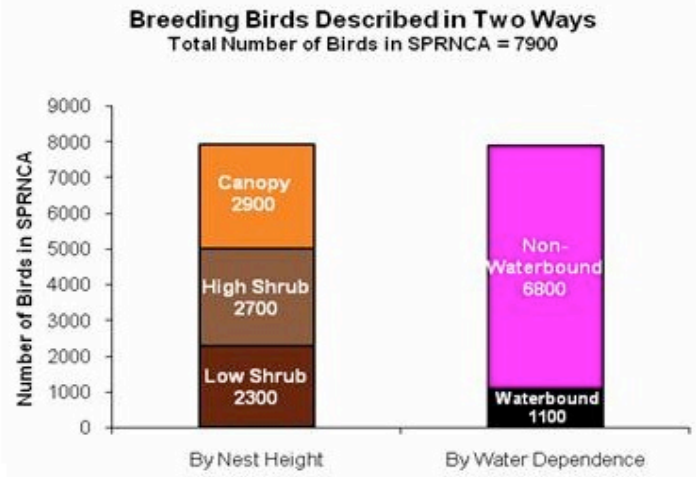
WTP to avoid degradation (Preserv.)

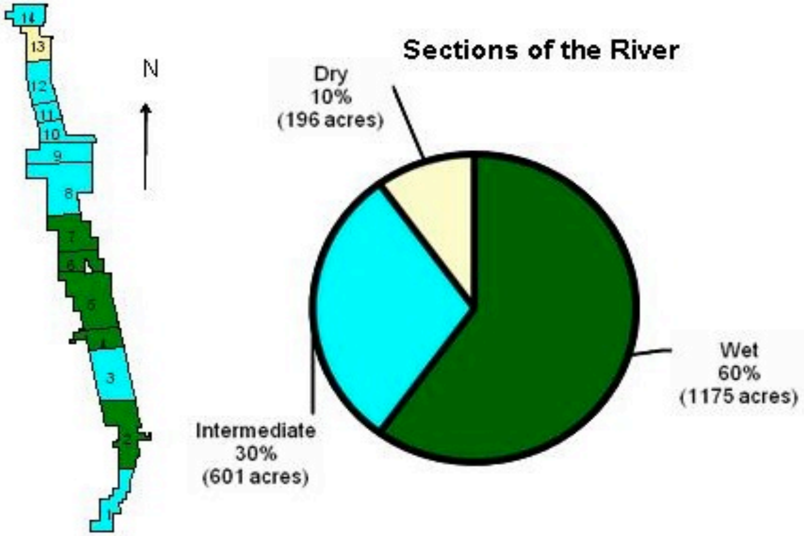
– Demographic info and visitation questions

Current Conditions

Miles of Surface Water = 31

Migratory Birds = 19,000

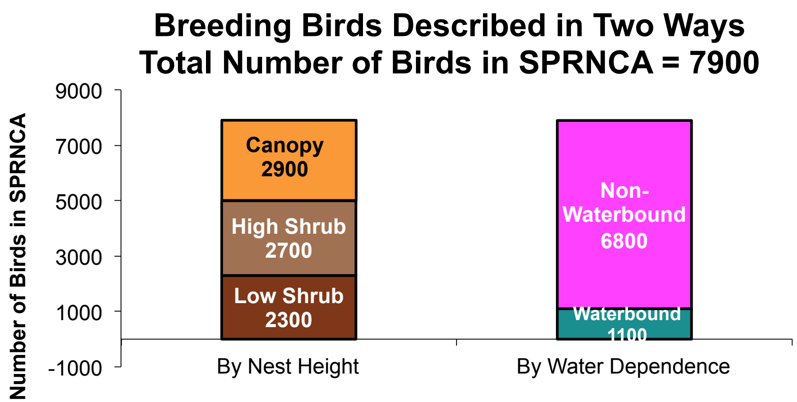


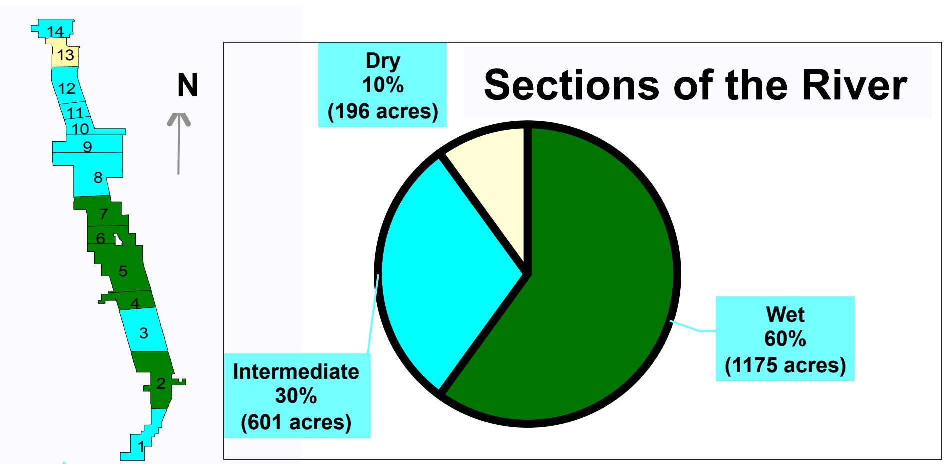


- Sent 4,500 in AZ (~13% return)
- 3,500 in New Mex. (~17% return)

WTP to Avoid Degradation (Preservation)

Current Cond. (CC)





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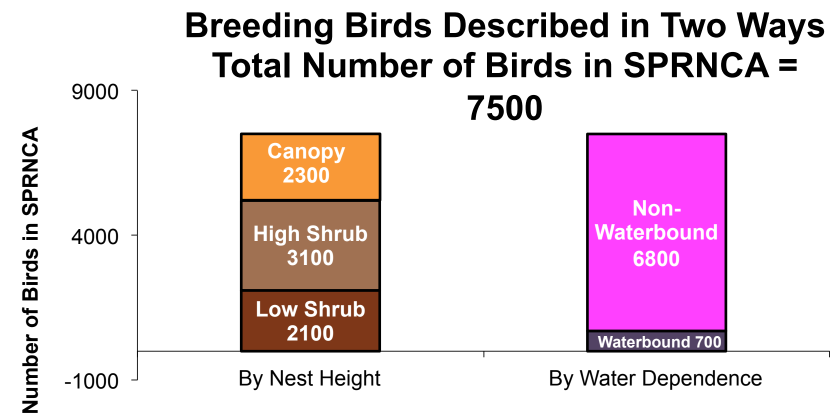
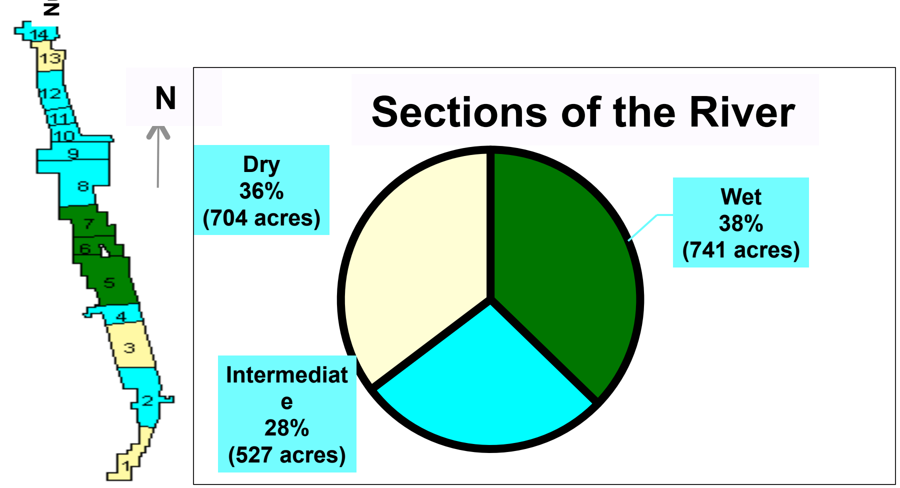




- **Contingent Valuation (CV) - WTP for an ecosystem endpoint (marginal dollar values for the incremental changes presented in the survey)**
- **Choice Modeling (CM) is being done with different surveys**

Survey Responses

- In addition to demographics, three questions (Provides insight into what type of WTP values are estimated)
  - Have you visited the site?
    - For San Pedro less than 1/3 visited the site
    - For MRG more than 2/3 visited the site
  - Do you plan on visiting the site?
    - For San Pedro about 50% yes, 50% no
    - For MRG about 2/3 yes, 1/3 no
  - Are you a birder?
    - For San Pedro about 27%
    - For MRG about 30%

- The relatively low visitation of SP indicates the WTP reflects non-use values while the MRC reflects consumptive use value

Willingness To Pay (WTP) Estimates

	Preservation	Restoration
	San Pedro Estimates	
Mean WTP	52.42*	49.71**
Std. Error	15.98	26.82
No. Obs.	378	391
State Wide	$335M	$318M
	MRG Estimates	
Mean WTP	-58.63	61.88*
Std. Error	53.65	25.25
No. Obs.	408	429
State Wide	------	$127M

** * Denotes significant at the 10% & 5% levels

2010 Census: Pop. AZ 6,392,017 Pop. NM 2,059,179

2002 USACOE study Est. MRG restoration ~$50 - $100M

Benefit Transfer (BT)

- **BT uses the incremental monetary value of an environmental good calculated at one study site and transfers that value to another site (*this estimate for the SP to MRG and for the MRG to the SP is in process*)**

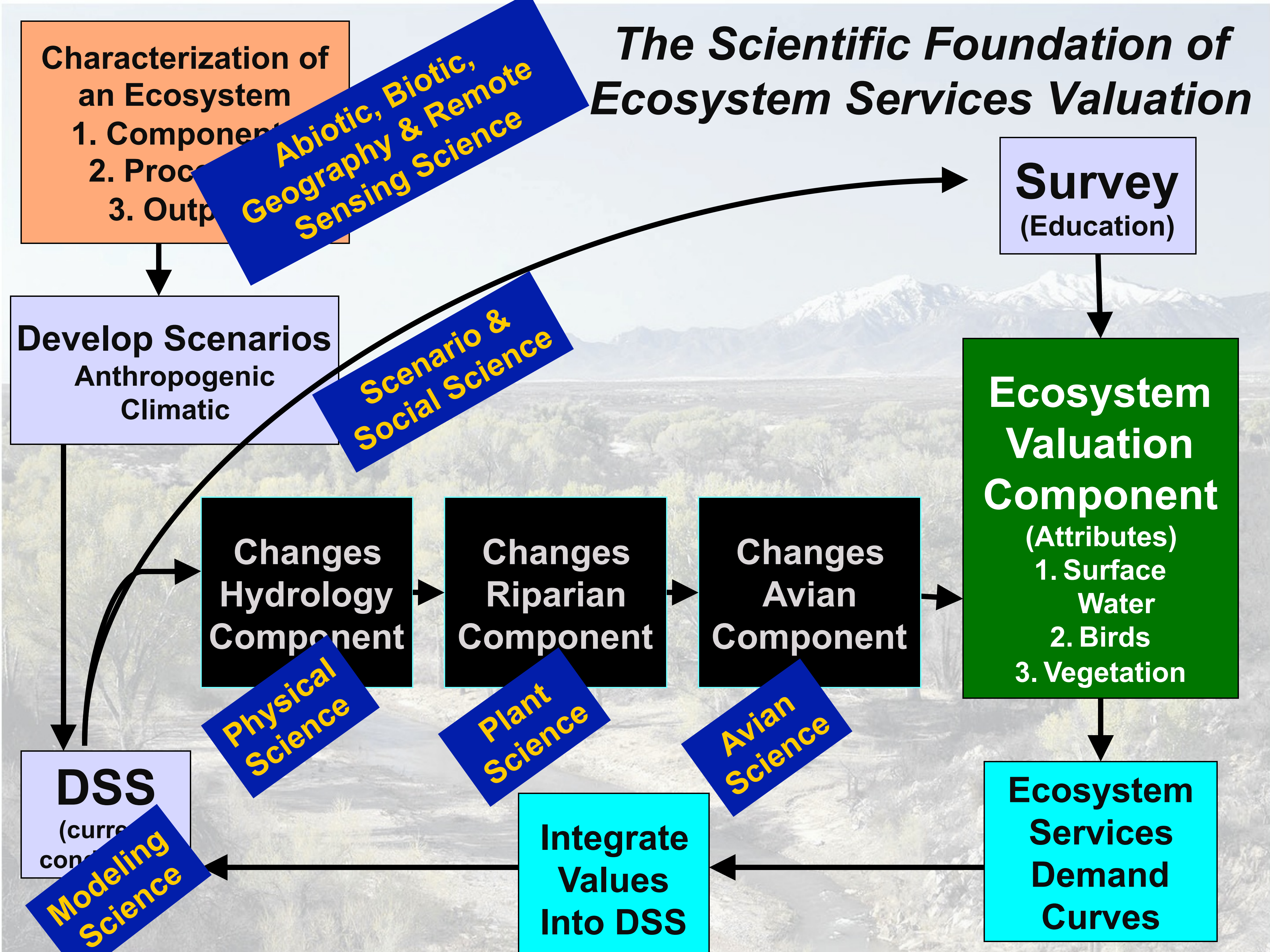
- **The relative science information between the "study and transfer sites" has typically not been a focus – How confident are we that all the science is transferrable to another location (e.g. Florida – not likely)?**

Ultimate Goal: Create a system to value any semi-arid southwestern area

- Environmental Drivers
  - Hydrologic regimes
  - Geomorphic regimes
  - Water quality, fire, climate and anthropogenic changes
- Vegetation
  - Need a taxonomy of riparian ecosystems
  - Use empirical data to determine the changes to the environmental drivers
- Birds
  - Determine how birds respond to a large set of physical drivers
  - Use a meta-analytic dataset to determine changes of birds to environmental changes

Verde River, AZ

Big Bend NP, TX


The Scientific Foundation of Ecosystem Services Valuation
Characterization of an Ecosystem
1. Component
2. Proc
3. Outp
Abiotic, Biotic, Geography & Remote Sensing Science
Survey
(Education)
Develop Scenarios
Anthropogenic
Climatic
Scenario & Social Science
Ecosystem Valuation Component
(Attributes)
1. Surface Water
2. Birds
3. Vegetation
Changes Hydrology Component
Changes Riparian Component
Changes Avian Component
Physical Science
Plant Science
Avian Science
DSS
(curre
con
Modeling Science
Integrate Values Into DSS
Ecosystem Services Demand Curves

Common Ground Across Disciplines

Basic Understanding → ***Discipline Complexity Scale*** → ***State of the Science***

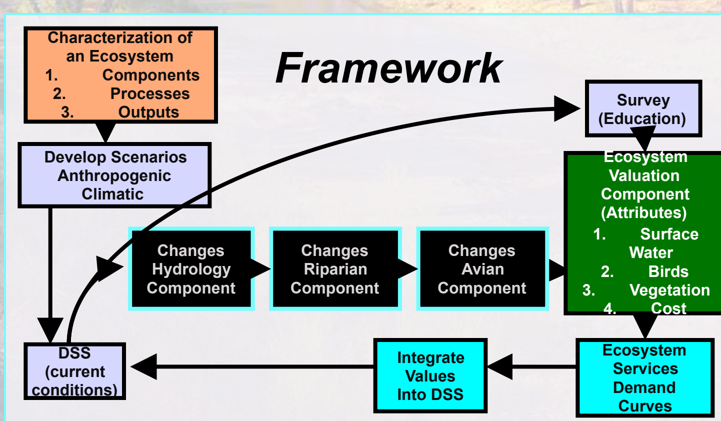
Stakeholder Readiness & Decision Support

Hydrology

Riparian Ecology

Avian Dynamics

Economics



Common level of understanding and consistent supporting data for valuation surveys

Overall Conclusions

- We must work in partnership with policy and decision makers to develop realistic scenarios for valuation
- ‘Basic science’ models can be integrated into social science surveys to obtain WTP estimates
- Coupling realistic decision scenarios with interdisciplinary science can:
  - Provide a scientifically defensible link between cause (a policy or decision) and effect (a change in an ESS)
  - Create ES end-products understood by lay respondents
  - Is necessary to obtain accurate values for ESS
- Result in better environmental policy by knowing, more quantitatively, how ecological goods change with decisions, and how these changes are perceived by society
- Science-based ESS valuation is essential to level the playing field in decisions impacting ecosystems and move toward sustainability

Lessons Learned

Building the Scientific-Decision Foundation for ES Valuation:

- **Requires substantial investment and *TIME* (much longer than the typical 3 – 5 year grant period)**
  - **Time to understand the basics of other disciplines**
  - **Time to identify a common level of complexity to enable interdisciplinary coupling**
  - **Time to build trust with decision-makers**
  - **Time to develop comprehensible surveys conduct them**
- **It's hard and expensive work – understandable why there is often a heavy reliance of using benefit transfers from others studies for ESS valuation studies**
- **While we can't afford to do this everywhere it needs to be done very well in some places with transferability tests so the limits of valuation in locations with less science & information can be defined**

Next Steps

- **Choice Model Valuation for SP and MRG**
- **Analyze Benefit Transfer to/from SP and MRG**
- **NSF Water Sustainability and Climate Project:**
  - **Tom Meixner et al.:** ***Climate and Population Change and Thresholds of Peak Ecological Water: Integrated Synthesis for Dryland Rivers***
- **NSF Coupled Natural Human Systems Project:**
  - **Chris Scott et al.:** ***Strengthening Resilience of Arid Region Riparian Corridors - Ecohydrology and Decision-Making in the Sonora and San Pedro Watersheds***

Thank You

Questions

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