Characterizing Water Demand: Ecosystems

Christopher Scott

Research team

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- José Luis Moreno, students - *Colegio de Sonora*
- Hans Skov-Petersen - *University of Copenhagen, Denmark*

Arid region riparian corridors

- **Important class of social-ecological systems (SESs)**
  - valuable ecosystem services
  - vulnerable to changing water demand and land-use
  - vulnerable to climate change and variability
  - high levels of recreational and human migration usage
- **SES structures and functions**
 - collapse and reorganization – periodic w/ multiple equilibria
- **Cross-scale SES responses**
  - from within and outside the watershed
  - crucial influence of transborder context

Study watersheds

- Sonoran Desert, grassland, desert scrub, riparian forests, upland oak-conifer forests
- Climate: monsoon-dominated Río Sonora, bimodal precipitation – San Pedro
- Urban growth, military, mining, ranching
- San Pedro Riparian National Conservation Area (SPRNCA); Ajos-Bavispe Reserve
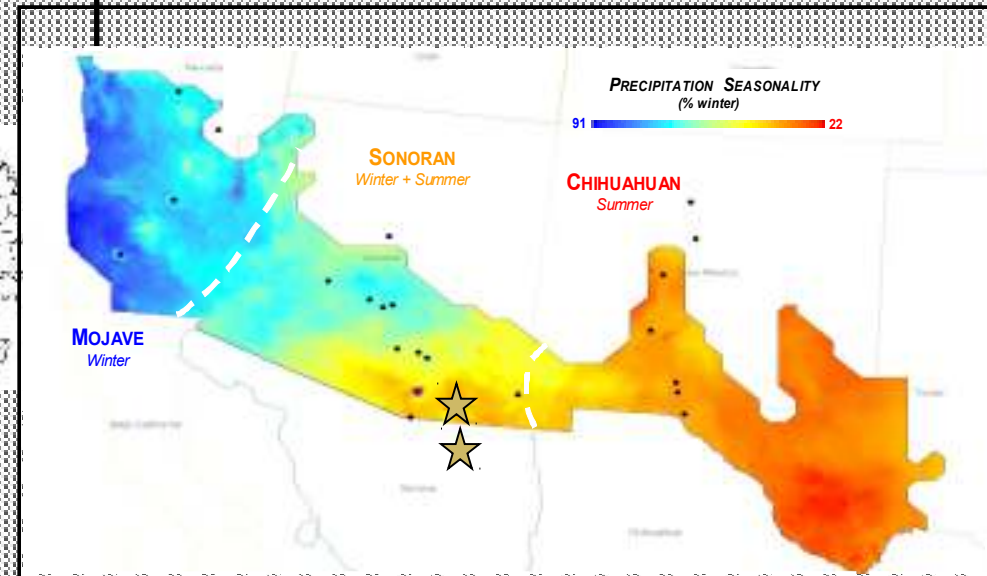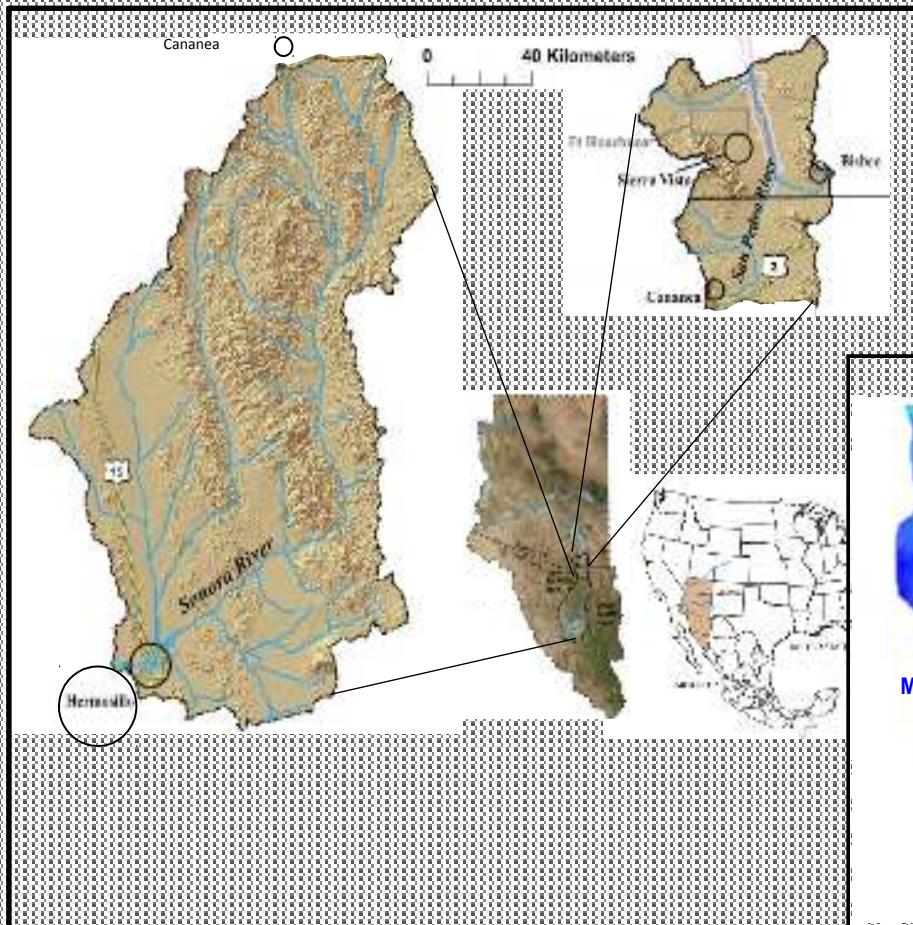
Río San Pedro - Mexico

Photos: L. House-Peters

RESERVA FORESTAL NACIONAL Y
REFUGIO DE FAUNA SILVESTRE
AJOS-BAVISPE

CONANP

San Pedro River – U.S.

Click to edit Master text styles
Second level
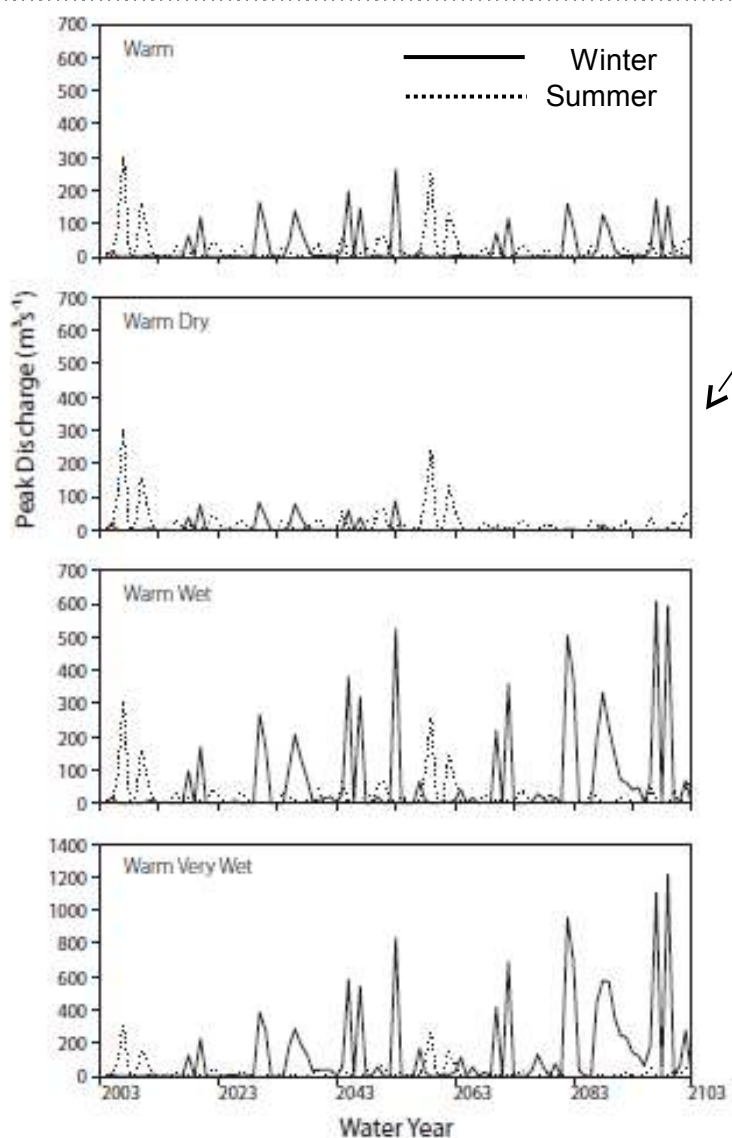- Third level
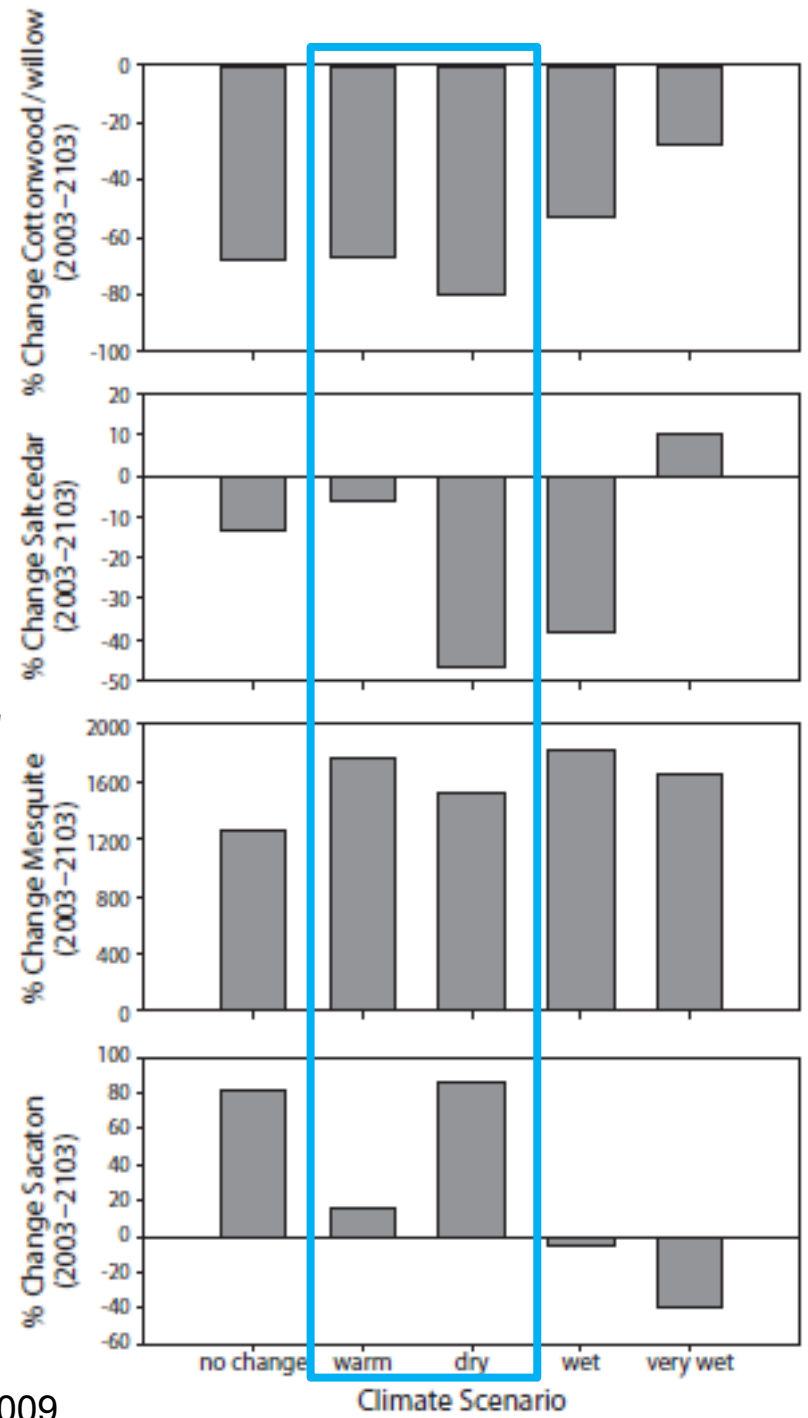 - Fourth level
    - Fifth level

Río Sonora

Río Bavispe
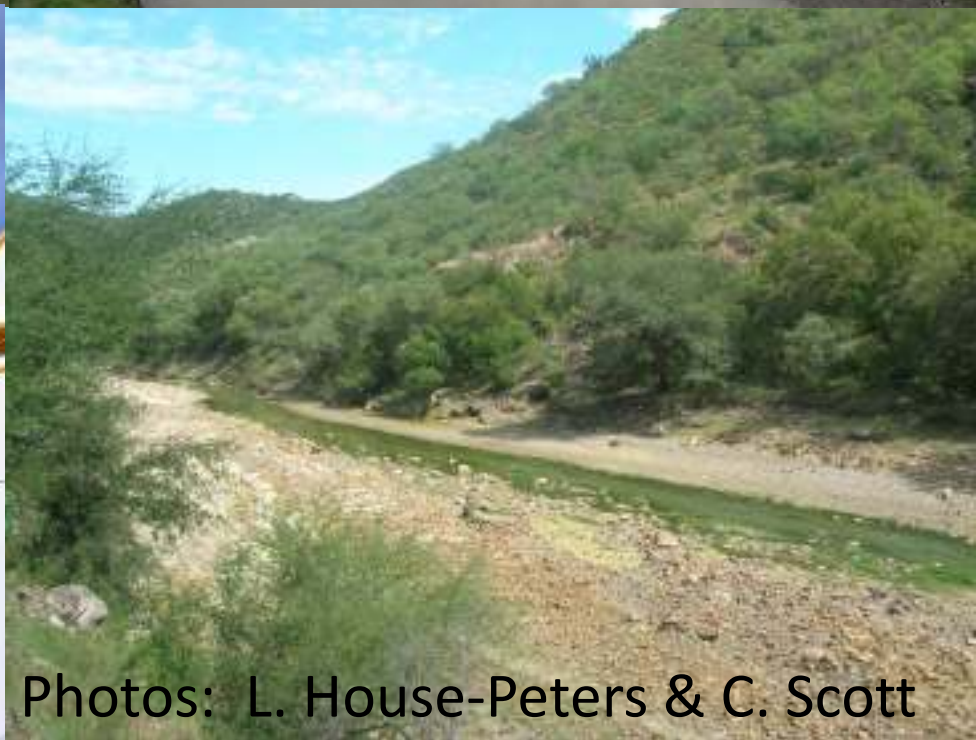
Photos: L. House-Peters & C. Scott

Ecohydrologic response to climate change

Modeled Seasonal Flow Peaks
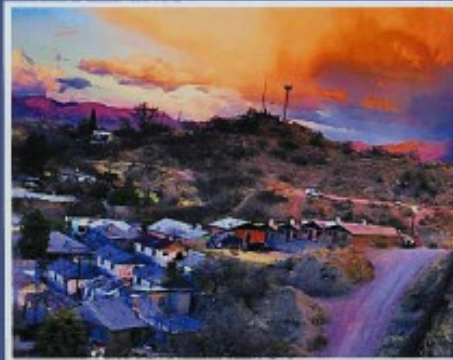
Simulated Cover Change

Dixon MD et al. 2009
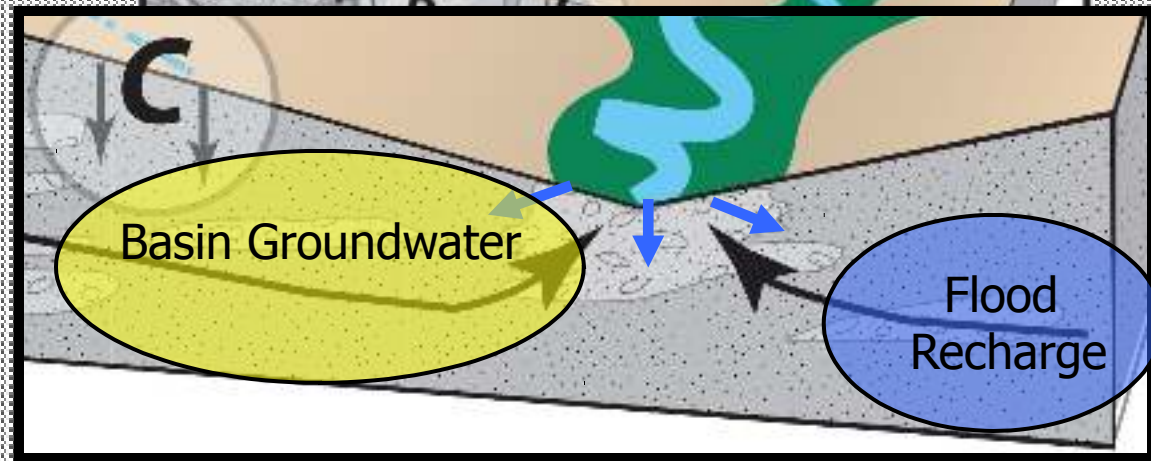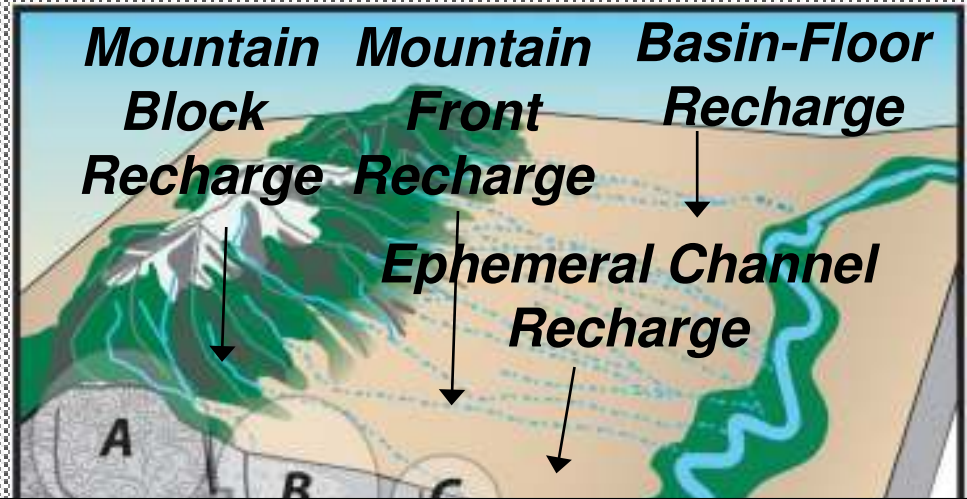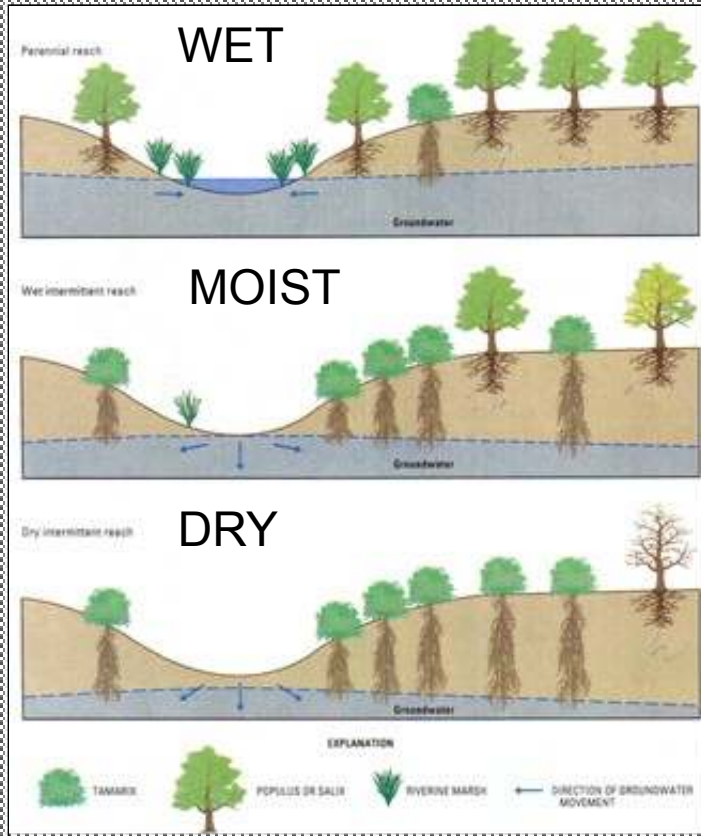
Social and institutional response to climate change

Adapting Across Boundaries: Climate Change, Social Learning, and Resilience in the U.S.–Mexico Border Region

Margaret Wilder,* Christopher A. Scott,[†] Nicolás Pineda Pablos,[‡] Robert G. Varady,[§] Gregg M. Garfin,[¶] and Jamie McEvoy[#]
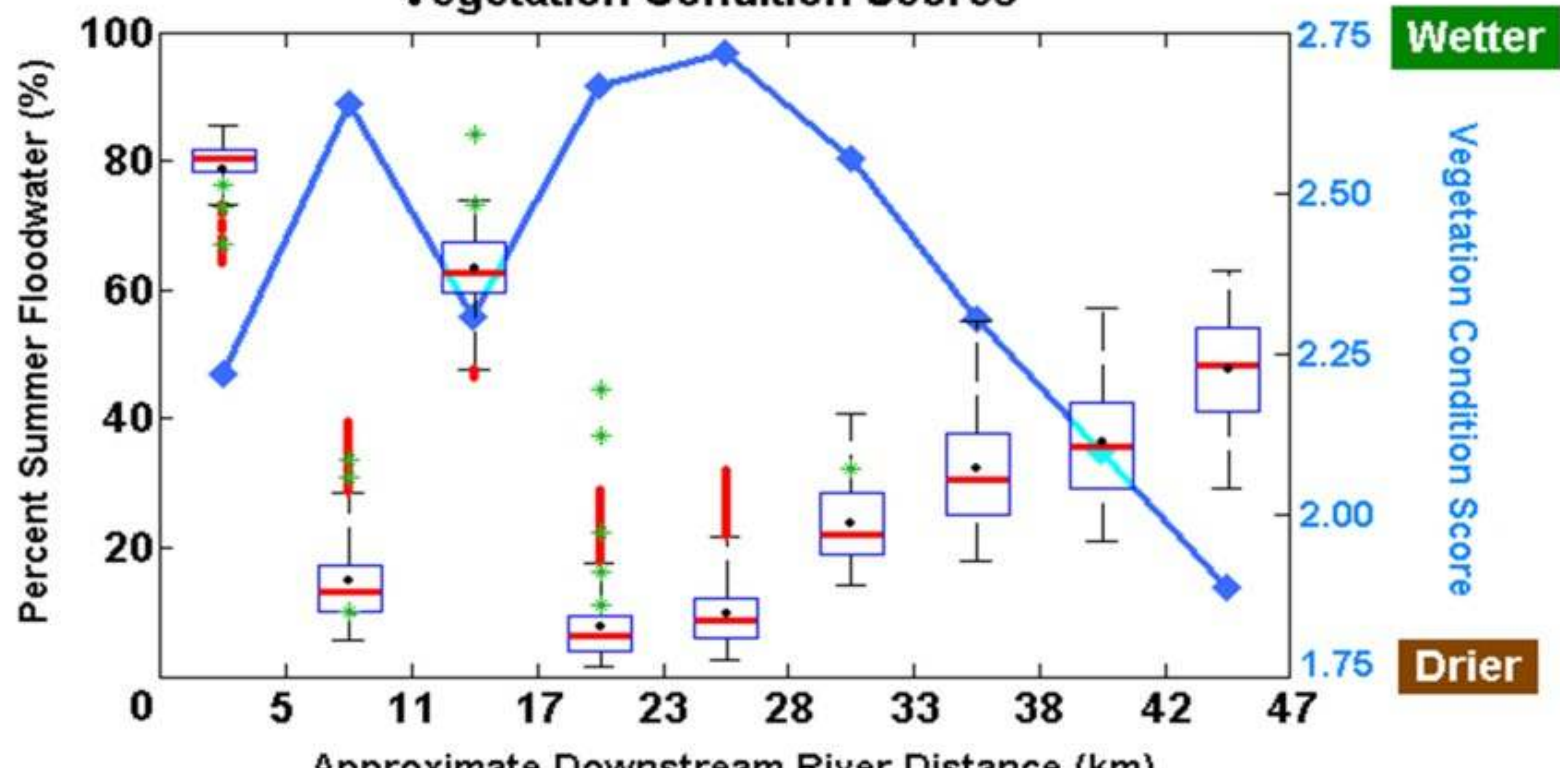
Annals of the Association of American Geographers, 100(4) 2010, pp. 917–928 © 2010

Wilder, M., et al. (eds) 2012. Moving Forward from Vulnerability to Adaptation: Climate Change, Drought, and Water Demand in the Urbanizing Southwestern United States and Northern Mexico - Casebook. Udall Center for Studies in Public Policy. University of Arizona, Tucson.
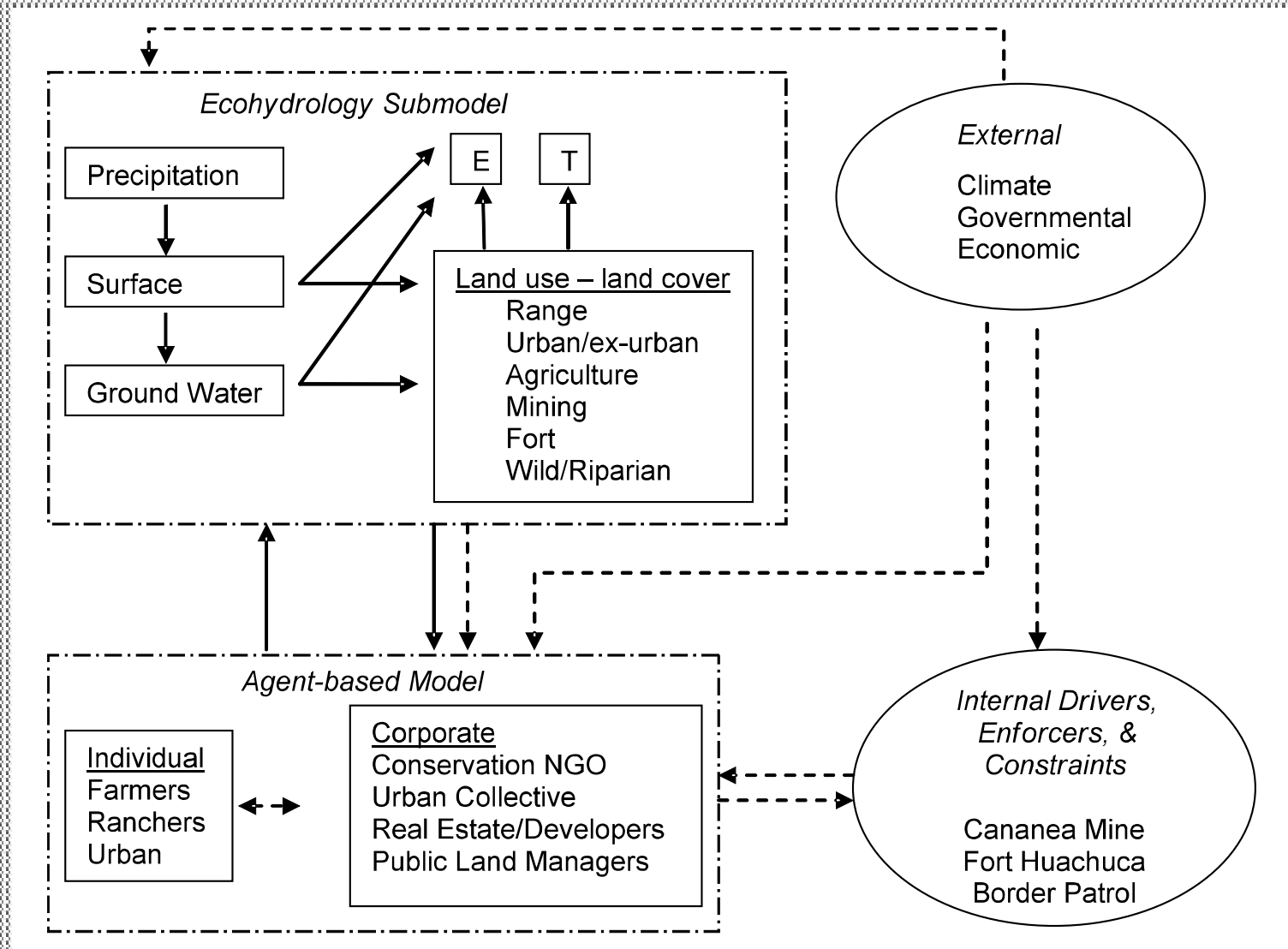
Sources of groundwater and streamflow

WET

MOIST

DRY

Mountain Block Recharge

Mountain Front Recharge

Basin-Floor Recharge

Ephemeral Channel Recharge

Basin Groundwater

Flood Recharge

Percent Summer Floodwater in Riparian Groundwater / Vegetation Condition Scores

Socio-Ecological System Approach

Ecohydrology Submodel

Precipitation

Surface

Ground Water

E   T

Land use – land cover
Range
Urban/ex-urban
Agriculture
Mining
Fort
Wild/Riparian

External
Climate
Governmental
Economic

Agent-based Model

Individual
Farmers
Ranchers
Urban

Corporate
Conservation NGO
Urban Collective
Real Estate/Developers
Public Land Managers

Internal Drivers, Enforcers, & Constraints

Cananea Mine
Fort Huachuca
Border Patrol

Ecological Resilience

- Ability to absorb disturbances, change and reorganize, but still have the same basic structure and functioning
- Reflects adaptive capacity of a system - includes the ability to learn from the disturbance

1902 1951 2003

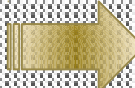Rob Wu, Santa Rita Experimental Range
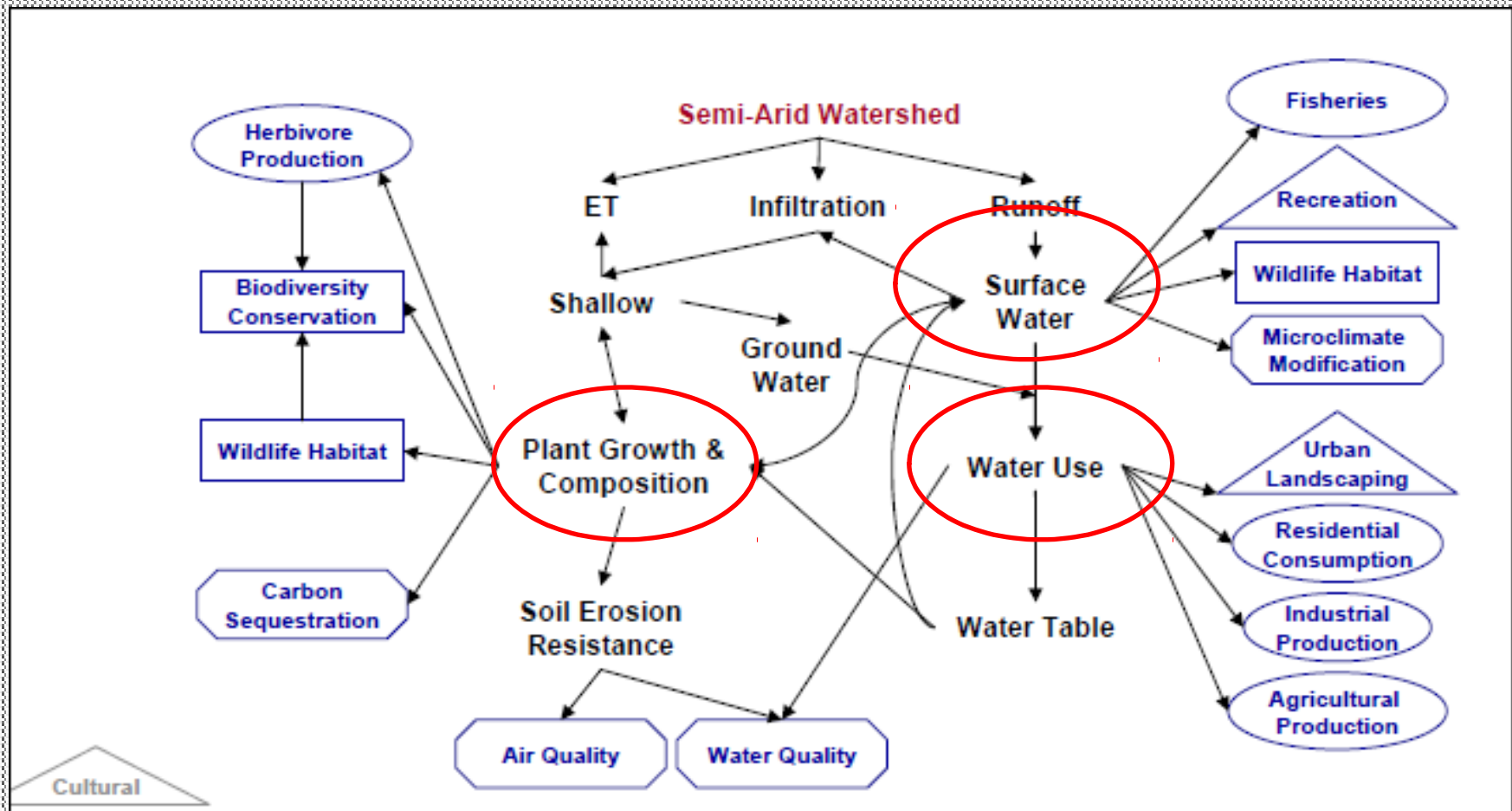
Research design & methods

- Eco-hydrological dynamics
  - Land-cover/land-use modeling
  - Ecosystem physiological metrics
  - Ecosystem service modeling
  - Characterize sources and variability of recharge
  - Quantify pumping and surface withdrawals
  - Estimate hydrologic state over time, link to ecological conditions
- Social-institutional dynamics
  - Documentary analysis
  - Institutional analysis
  - Semi-structured interviews and focus groups
  - Workshops

Hypothesis

Crossing thresholds can lead to collapse and reorganization of riparian systems:

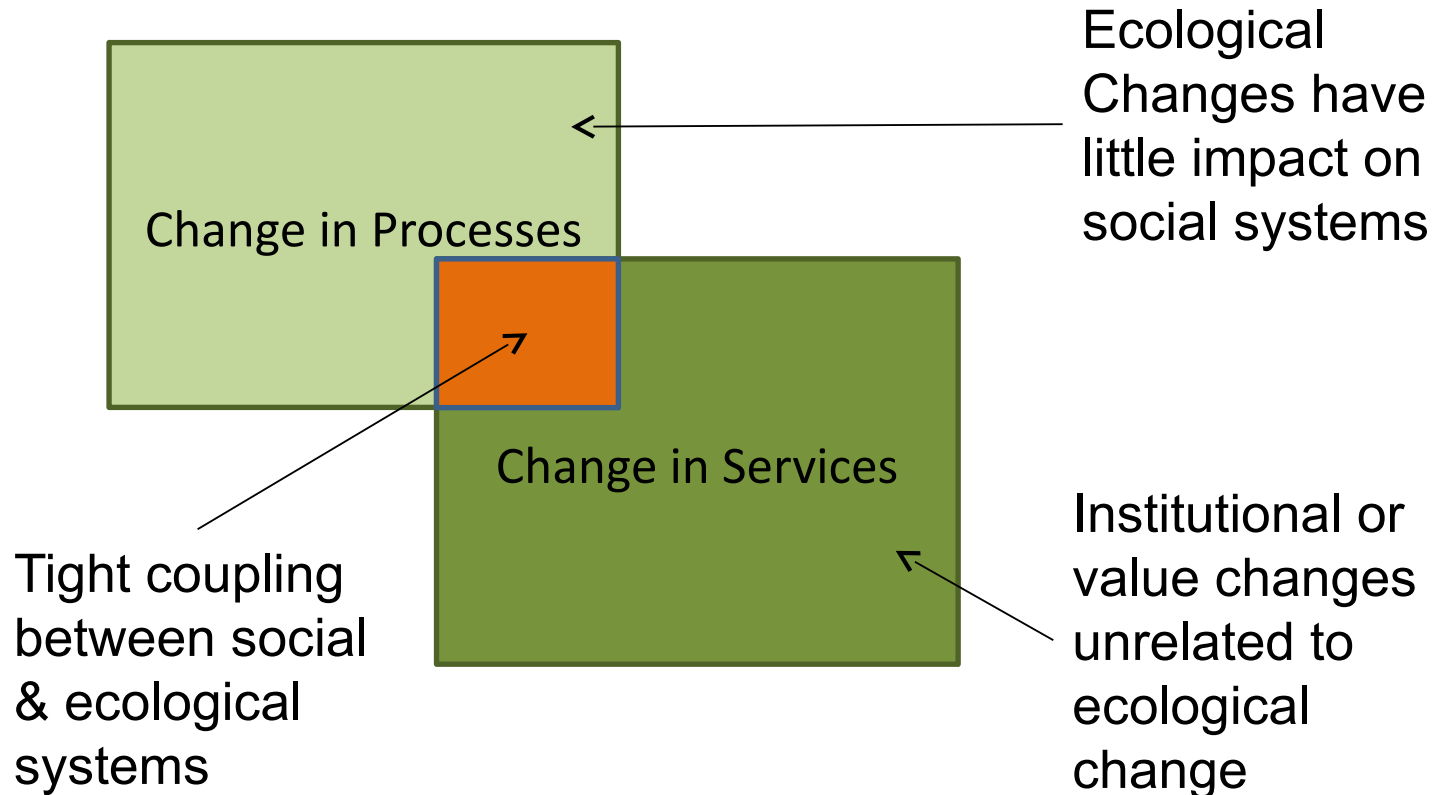| Component	Example
ecological communities	
stream-aquifer interactions	native cottonwood, willow threatened by mesquite
water management	declines in shallow groundwater intercept streamflow
institutions	land and water conservation do not counteract effects of growth
	agents' decision space influenced in manner that enhances or reduces risk of crossing thresholds

Plant community composition thresholds

Community Dominance

Drier ⟶ Wetter

Lite and Stromberg. 2005. *Biol. Cons.* 125:152-167

Ecosystem services are linked to water

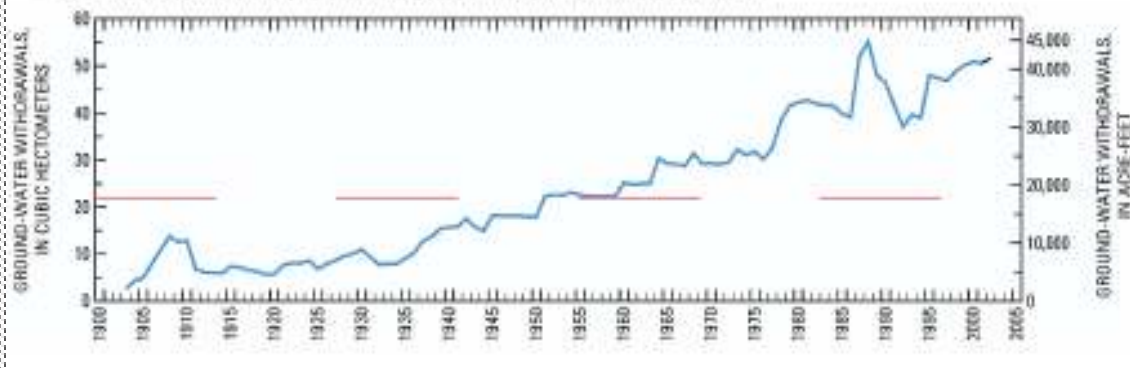USGS Assessment of Goods and Valuation of Ecosystem Services (AGAVES)

	Condition	System State	Provisioning Services	Regulating Services	Supporting Services	Cultural Services	Multi-sectoral Tradeoffs
Natural	Winter rain dominance of annual precipitation decreases	• Flow regime in river • ESA litigation	↔	↓	↓	↓	Low
	Annual precipitation overall decreases	• Flow regime in river • Riparian ground water • ESA litigation	↓	↓	↓	↓	Medium
	Mesquite cover increases	• Grassland cover • Transpiration increases	↔	↓	↔	↔	Low
Anthropogenic	Riparian groundwater levels decreases	• Mesquite vs. Cottonwood /Willow cover • Species richness	↓	↓	↓	↓	Medium
	Urban cover in the watershed increases	• Groundwater levels decline • Surface runoff increases	↓	↓	↓	↓	High
	Increased water use by Cananea Mine	• Flow regime in river • Water quality	↓	↓	↓	↓	High
	Fort H. closes or missions are reduced	• Flow regime in river • Groundwater levels increase	↑	↑	↑	↑	High
	Water Supply Augmentation to Sierra Vista and SPRNCA	• Flow regime in river • Groundwater levels increase	↑	↑	↑	↑	High

Linking Traits to Ecosystem Services

Change in Processes

Change in Services

Ecological Changes have little impact on social systems

Institutional or value changes unrelated to ecological change

Tight coupling between social & ecological systems

Upper San Pedro River

Groundwater Withdrawal (1900-2005)

SPRNCA Designation (1988)

Pre-1988

Post-1995

Rio San Miguel
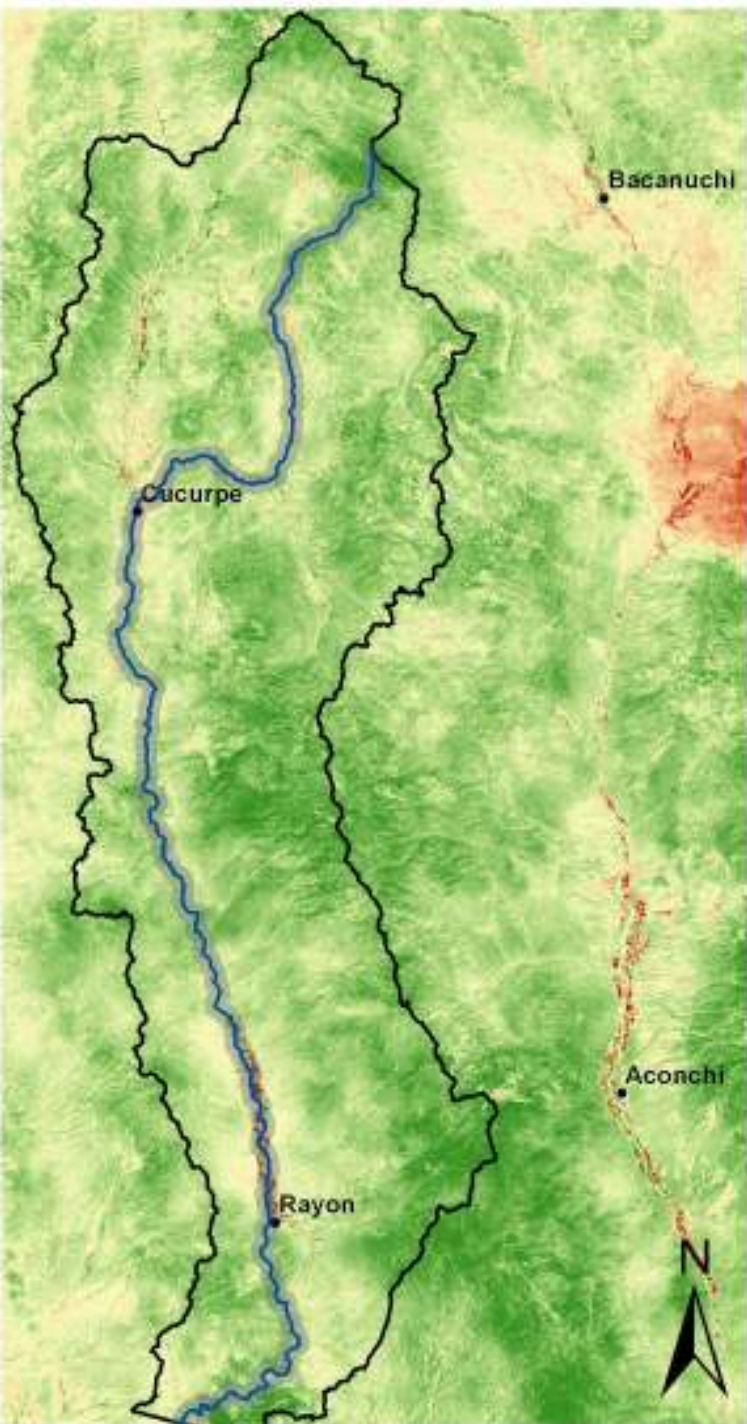
Small Dam

Acequia

Agricultural fields between Rayon and Cucurpe

Agricultural fields adjacent to the river

Data
Landsat Imagery

1984	May 3
1990	May 4
	October 11
1994	May 15
	October 22
1999	May 13
	October 4
2005	May 13
	October 20
2010	May 11
	October 2

Methods
Landsat Imagery

NDVI=

$$\frac{(\rho nir - \rho red)}{(\rho nir + \rho red)}$$

Unsupervised Classification

🟦	Water
🟪	Irrigated Agriculture
🟩	Woodland
⬜	Barren
🟩	Forest
🟨	Desert Scrub
🟧	Grassland
⬜	Urban/Cleared Land
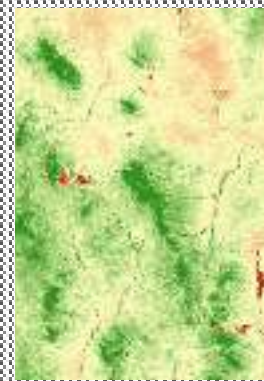
Normalized Difference Vegetation Index (NDVI)

Pre-Monsoon (May)

Post-Monsoon (Oct.)

San Pedro River
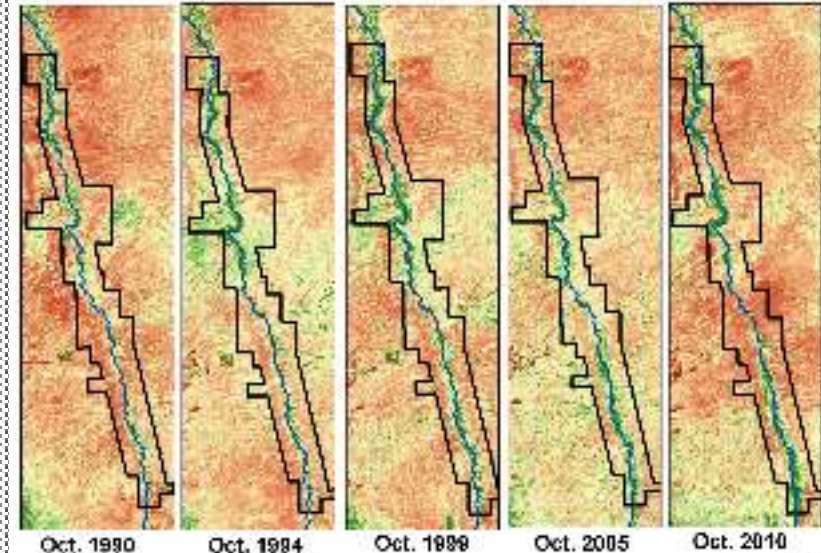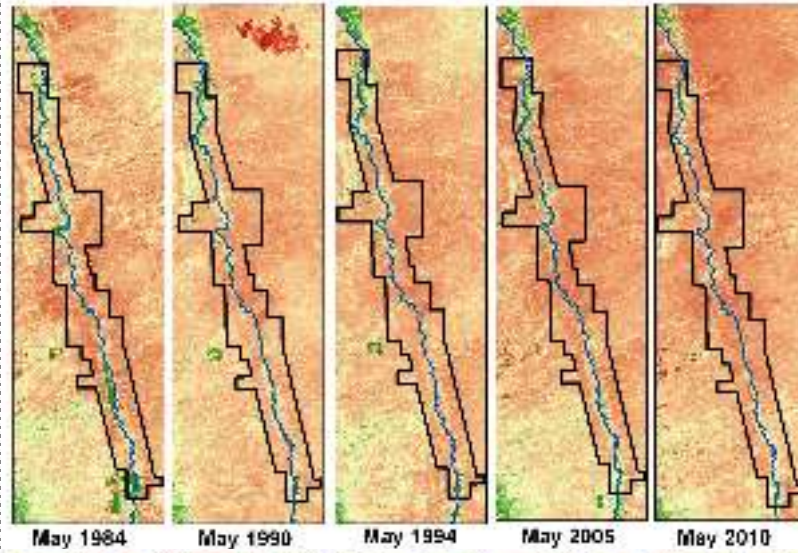
Rio San Miguel
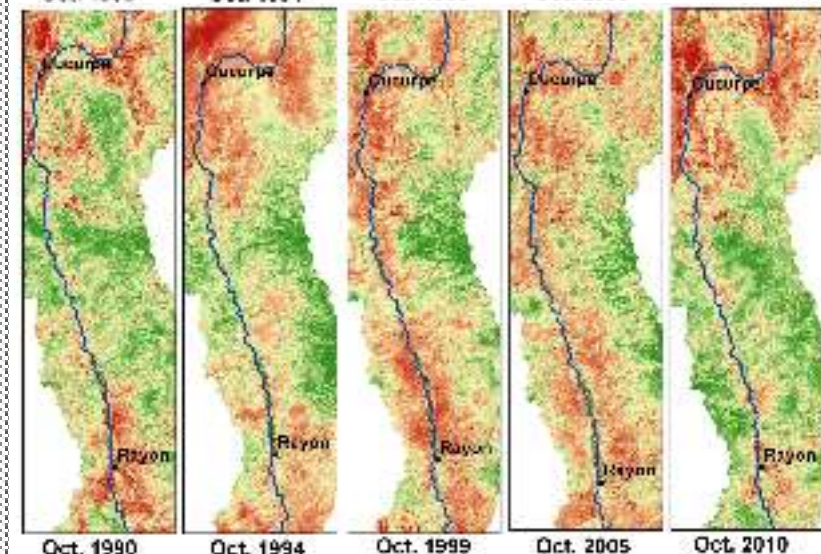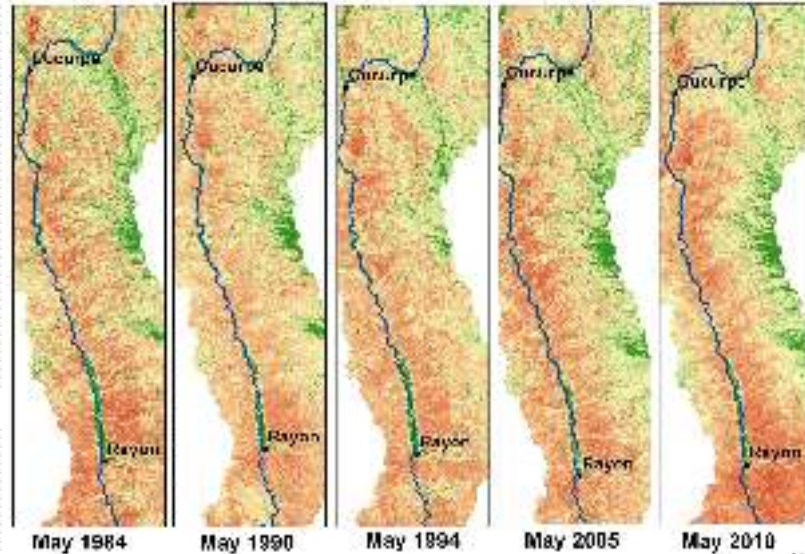
San Pedro River Land Cover (5km Riparian Buffer) 1984-2010
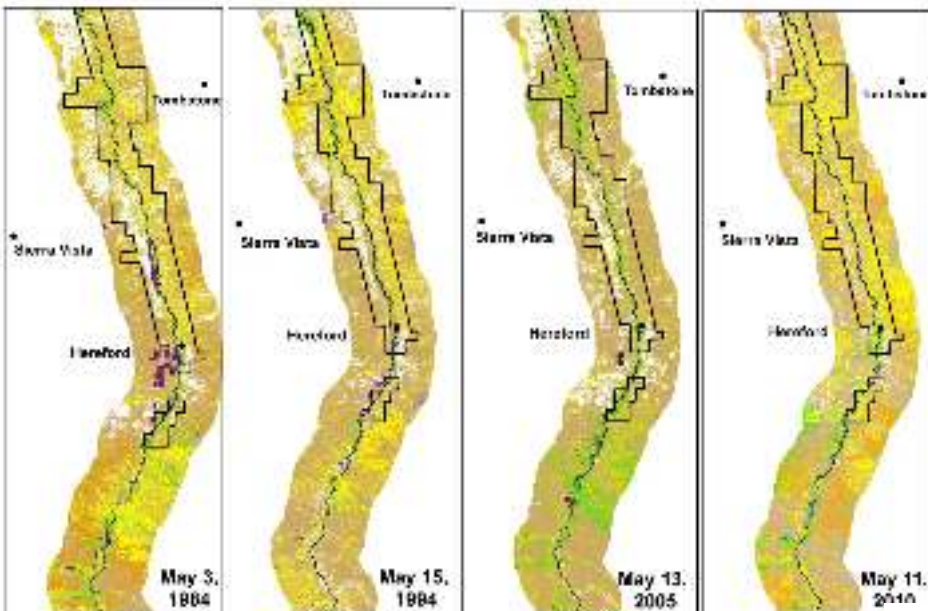
Land Cover Change Pre-Monsoon

May: 1984, 1994, 2005, 2010

Rio San Miguel Land Cover (5km Riparian Buffer) 1984-2010
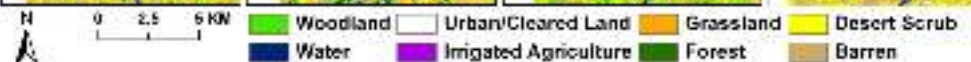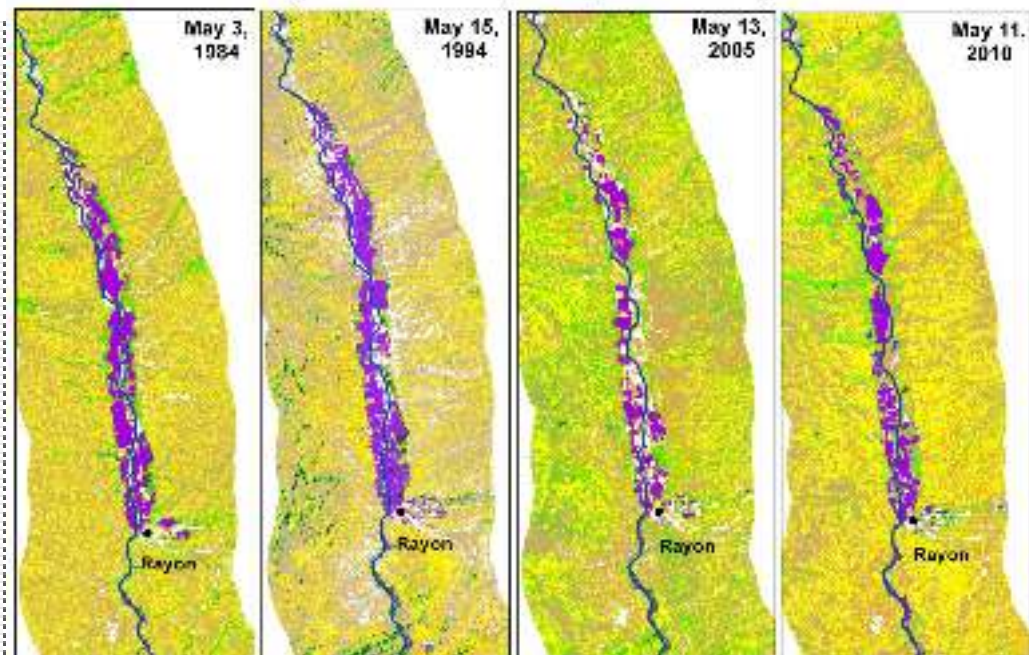
Condition		Provisioning Services	Regulating Services	Supporting Services	Cultural Services
Winter rain decreases under climate change	SP RN CA	⟷	↓	↓	↓
	Rio San Miguel	↓	↓	↓	↓

Modeling Coupled Natural-Human Systems

Models provide:

-a better understanding of CNH systems

-a method to examine future conditions of proposed ecohydrological and societal changes

-an interactive tool non-experts and experts can use to understand impacts of human disturbances

Challenges in Modeling CNH Systems

or

How to turn this…   *into this…*
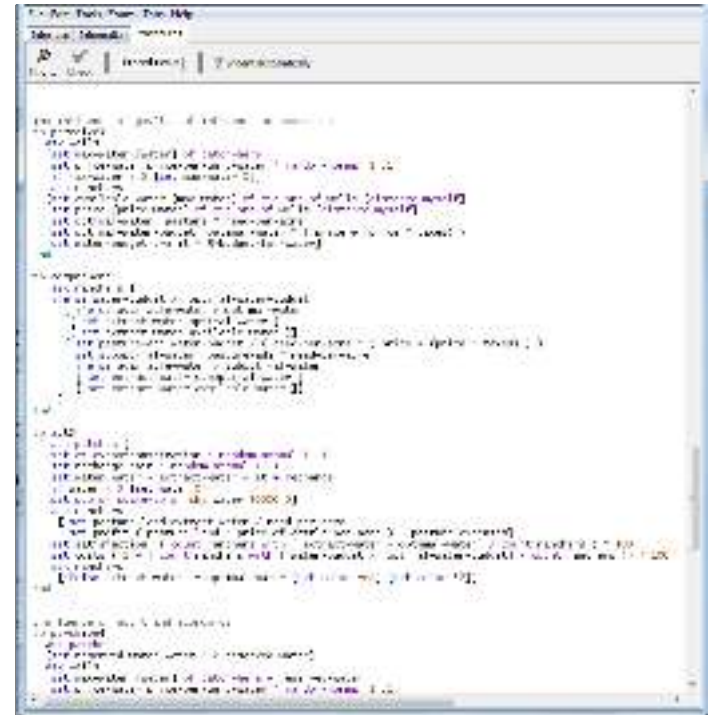
Modeling CNH Systems

- must re-envision a dynamic system as a series of feedbacks
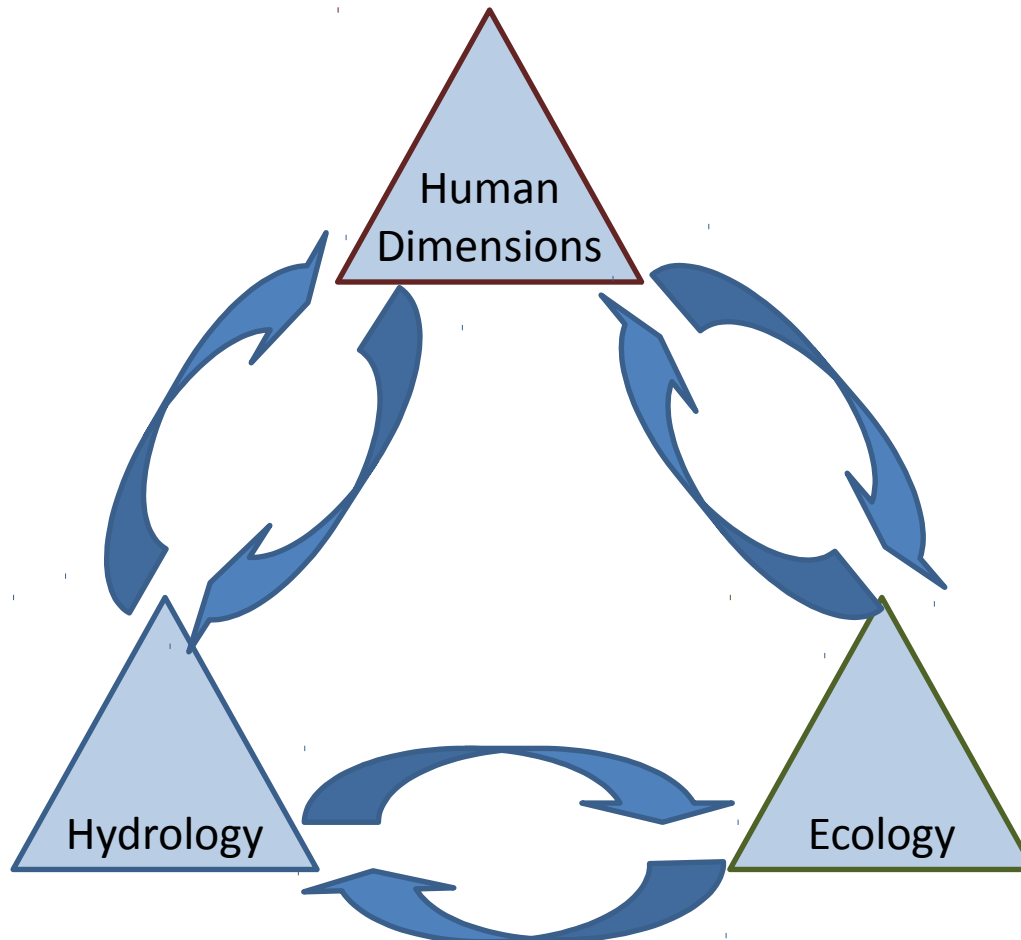
Modeling CNH Systems

- Determine how the different components interact
  What changes?
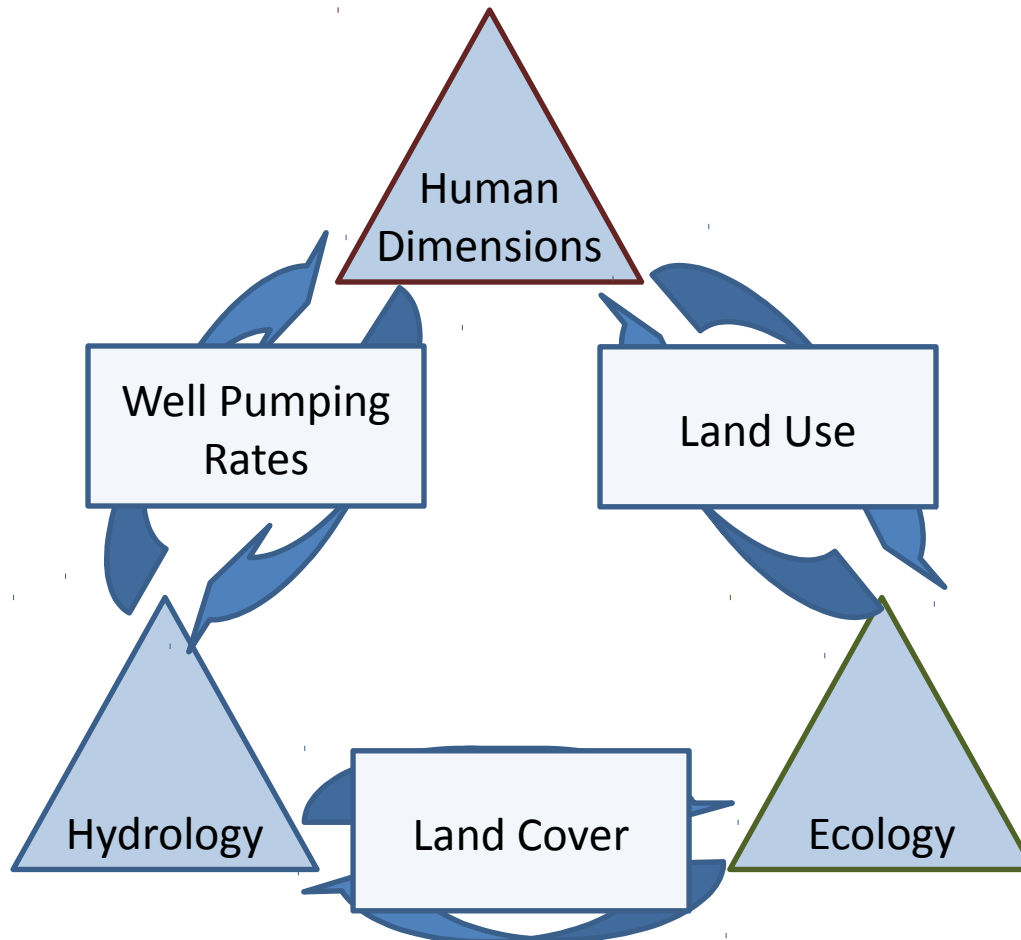
Modeling CNH Systems

- *Now to get this into a computer…*
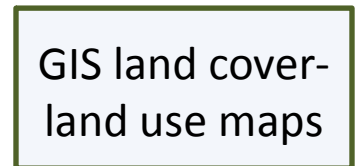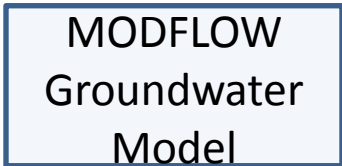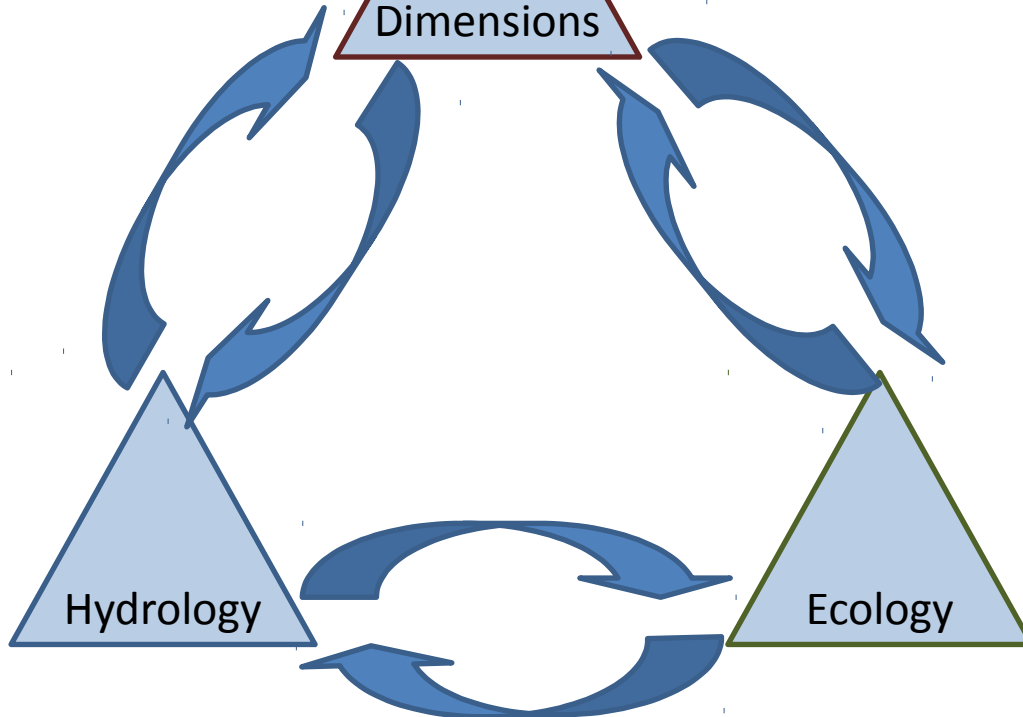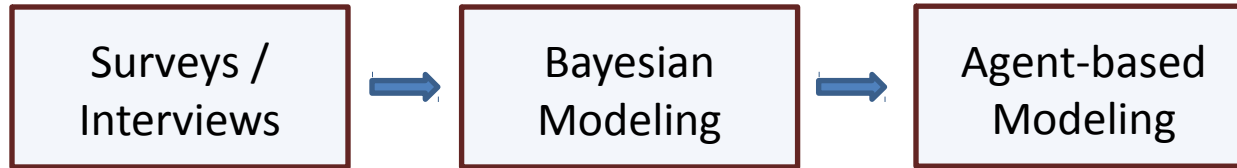
Modeling CNH Systems

-Incorporate the influence of exogenous factors
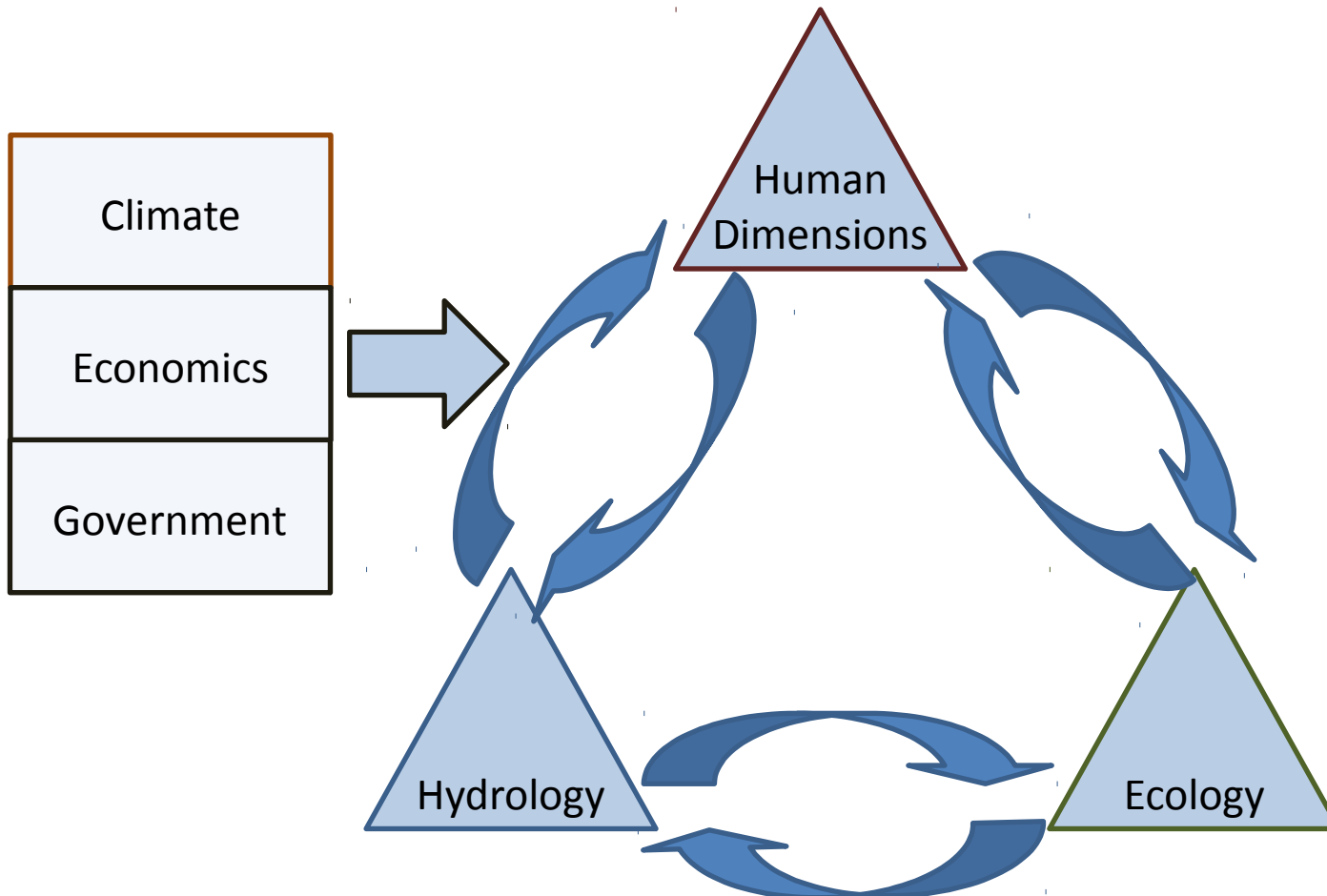
Bayesian Belief Networks

- Parameterize workshop results in probability functions

- Build probability functions for decisions and drivers

- Simulate probabilities in ABM using scenarios
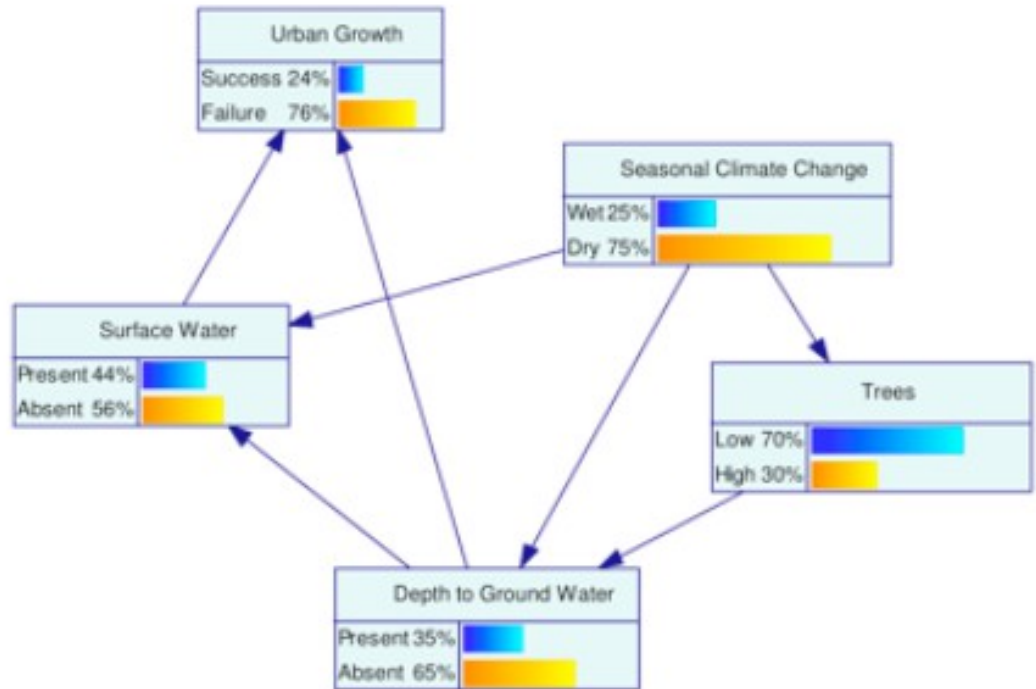
Figure 3. Example network model for riparian trees

Probability-Impact Matrix for scenarios

		Potential for impact on SES	
		Low	High
Probability of Occuring	Low	**High-value, low-water crops replace grains**	**Ft. Huachuca closure**
	High	**Rapid invasion of non-native grasses**	**Drought frequency increases with climate change**

Integration in agent-based model (ABM) & coupled decision-support system (DSS)
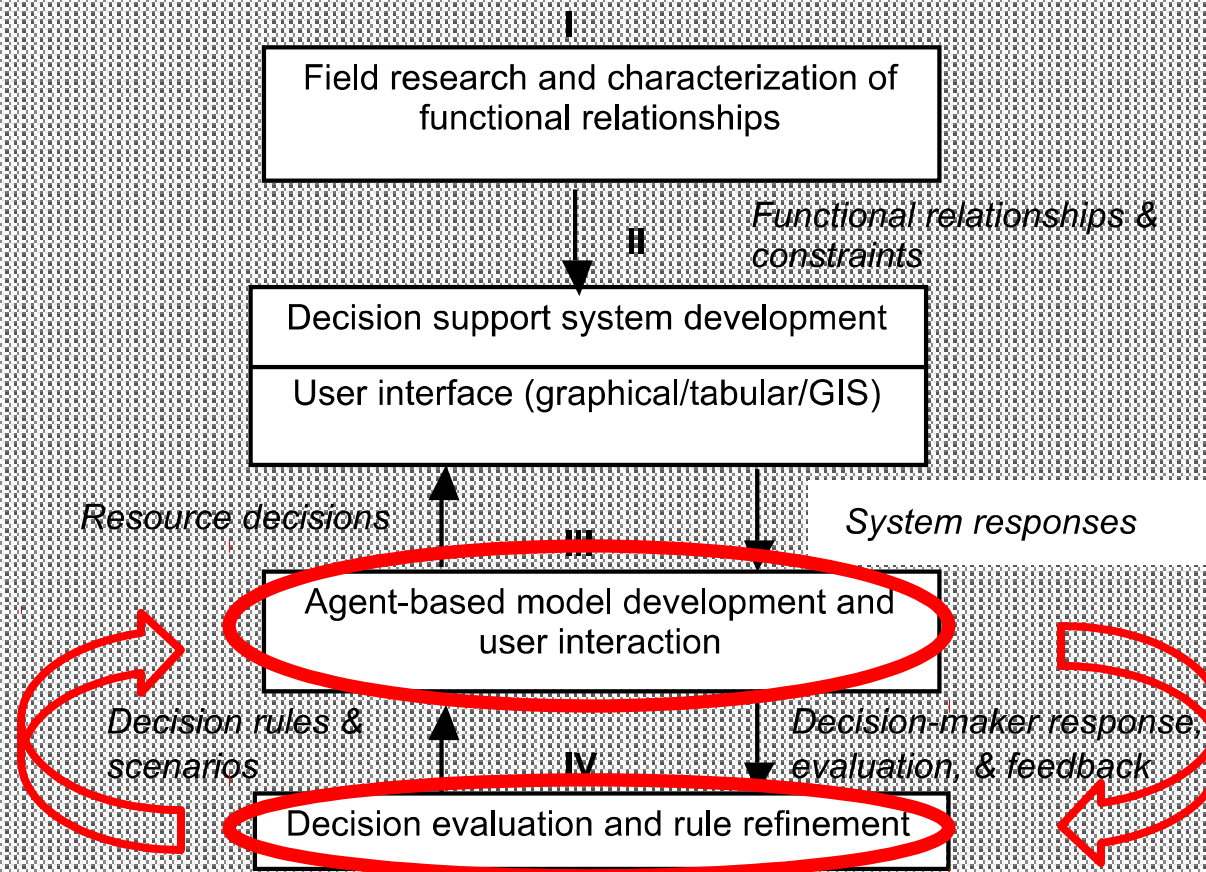
Figure 4. Schematic of model design

Thanks

http://udallcenter.arizona.edu/wrpg/cnh/

http://riparianres.blogspot.com/