

# Ecosystem Services Analysis of Climate Change and Urban Growth; The Santa Cruz Watershed Ecosystem Portfolio Model (SCWEPM)



Laura M. Norman,  
Nita Tallent-Halsell,  
Bill Labiosa,  
Katie Hirschboeck,  
Matt Weber,  
Amy McCoy,  
James Callegary,  
Floyd Gray,  
Charles van Riper,  
Hans Huth,  
Francisco Lara-Valencia,  
and Joe Marlow

U.S. Geological Survey  
U.S. Environmental Protection Agency  
The University of Arizona  
The Sonoran Institute  
Arizona Department of Environmental Quality Office of Border Environmental Protection  
Arizona State University

# Location Map



Legend

- US-Mexico Border States
- Borderland Watersheds

110°40'0"W

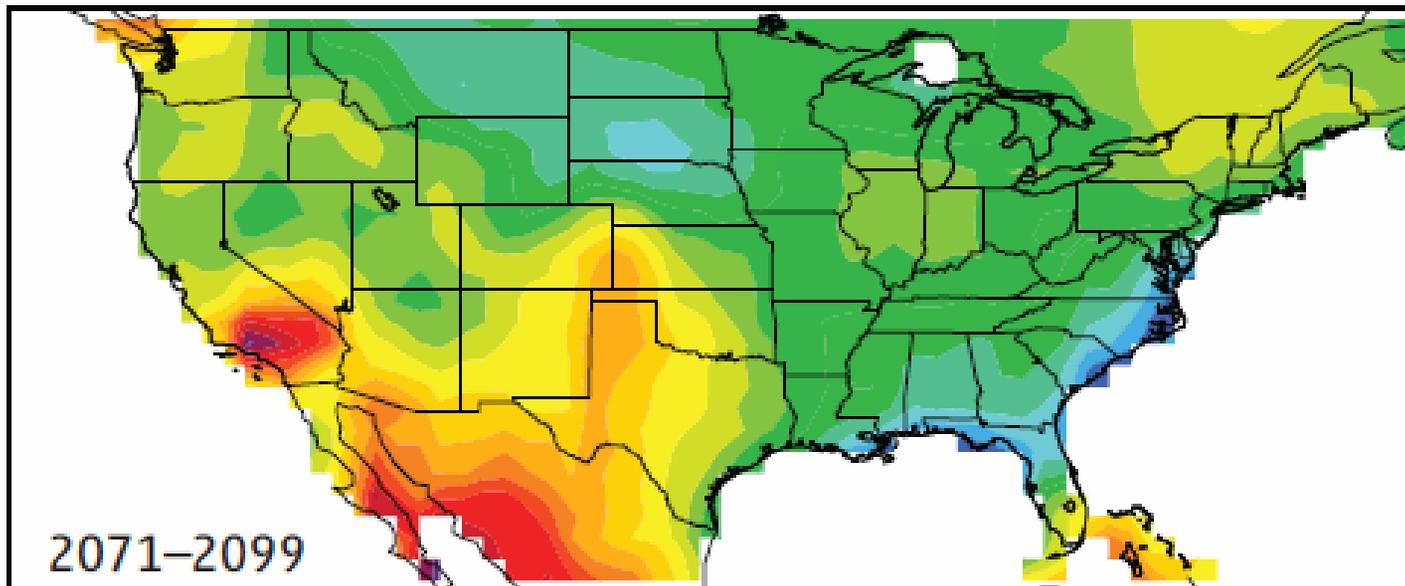




*Photo by Amy McCoy*

# Climate Change

- According to a climate-change-model consensus, the most severely affected region of the United States will stretch across the Southwest from southern California to west Texas and intensifies even more over northern Sonora, Mexico and most responsive (reds and yellows) to the strengthening greenhouse (Kerr, 2008)



2

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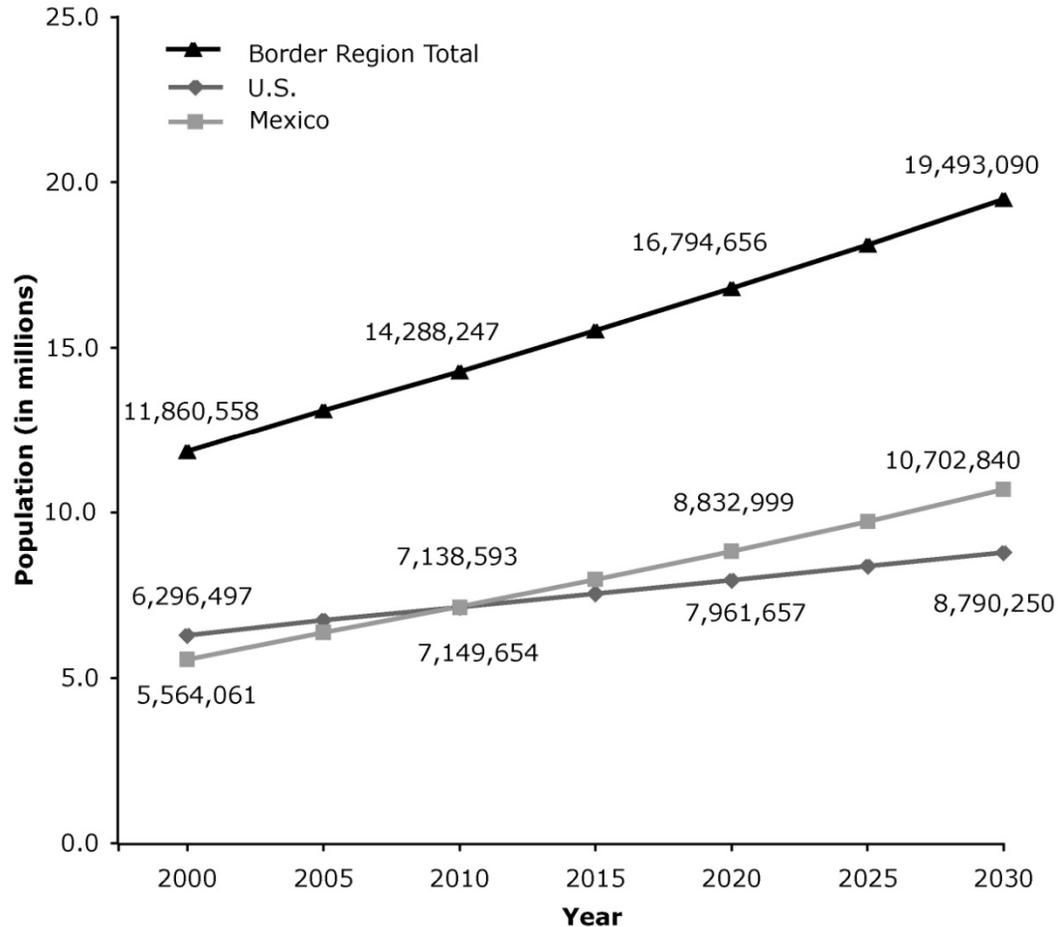
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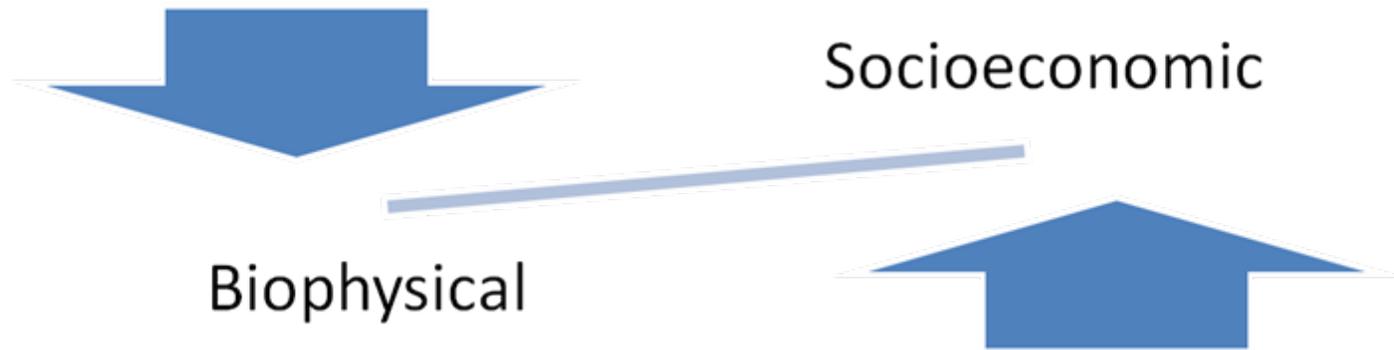
Relative Responsiveness

# Urban Growth

**Medium Population Projection**



*Photo by Pamela Nagler*

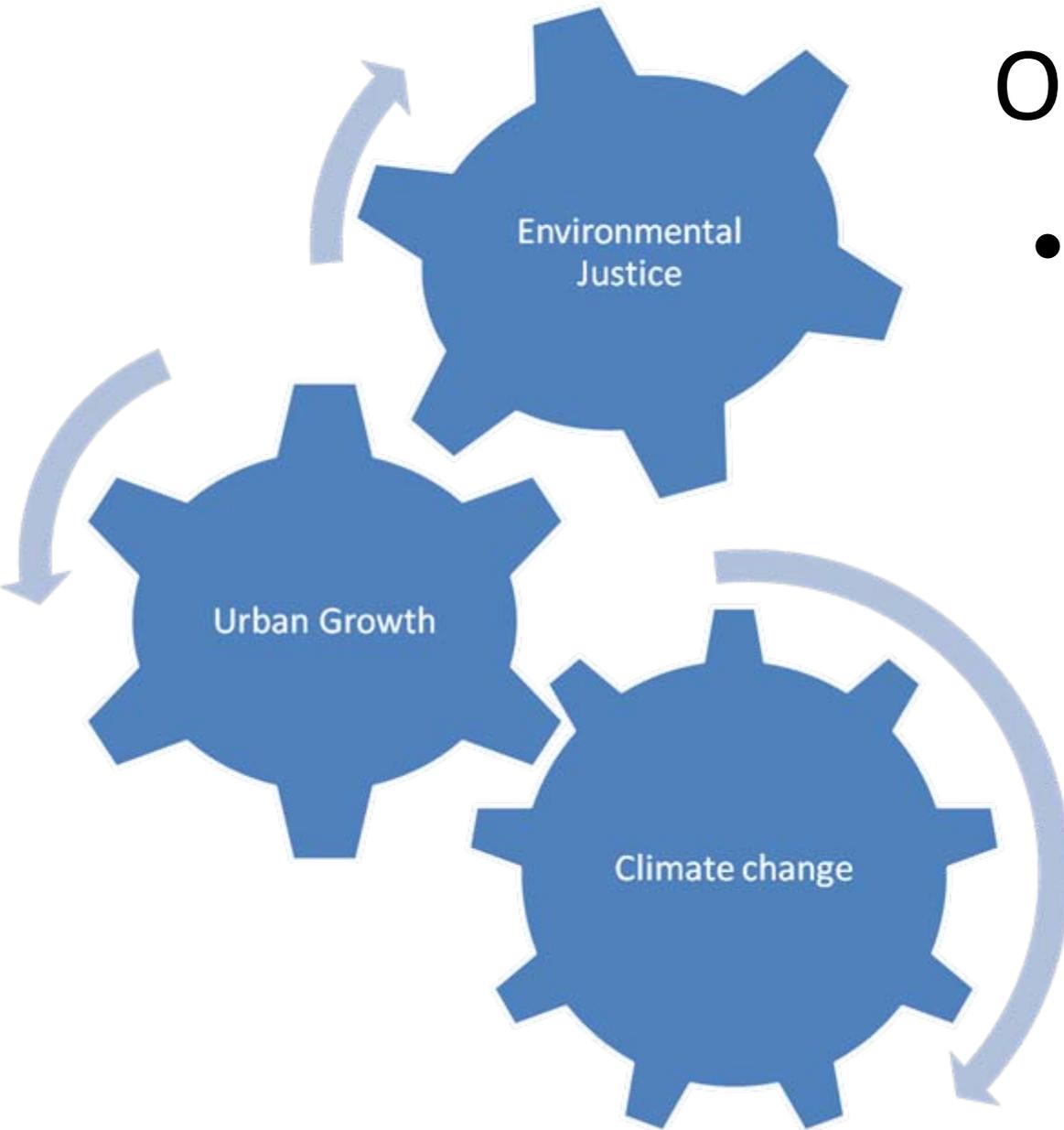


- Our *challenge* is to bridge the knowledge of the biophysical and socioeconomic processes supporting the provision of ecosystem services.

# Ecosystem Services

...the transformation of a set of natural assets (soil, plants and animals, air and water) into things that we value...

- Pollination
- Fulfillment of people's cultural spiritual and intellectual needs
- Insect pest control
- Maintenance and regeneration of habitat
- Provision of shade and shelter
- Prevention of soil erosion
- Maintenance of soil fertility & soil health
- Maintenance of healthy waterways
- Water filtration
- Regulation of river flows and groundwater levels



## Objective

- Develop binational protocol to recognize ES in economic markets, government policies, and land management practices.

# Documented Phenology

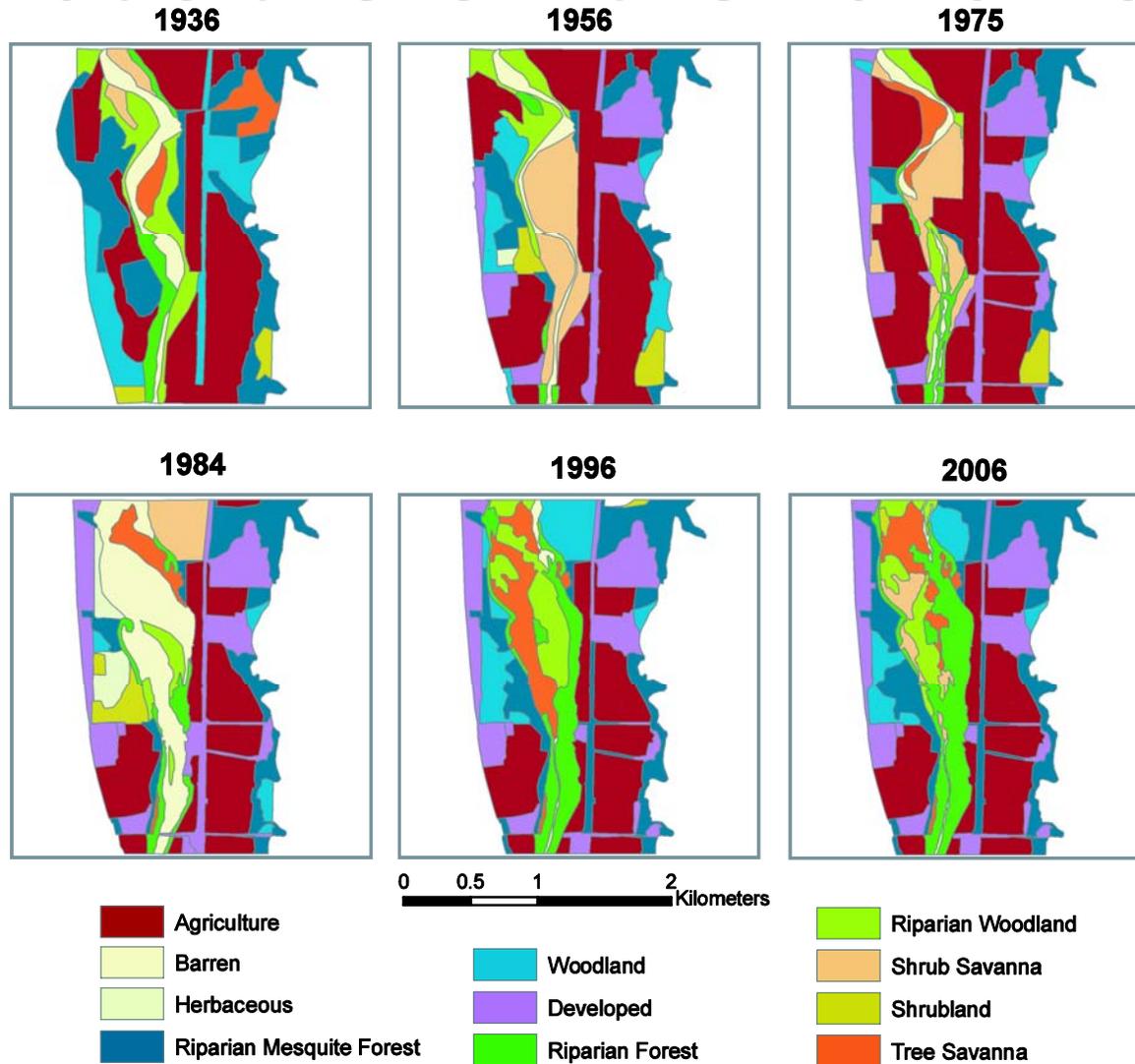
- Use documented recurring plant and animal life cycle events, or phenophases in the SCW, such as leafing and flowering, maturation of agricultural plants, emergence of insects, and migration of birds in response to historic climate patterns...



predict the future.

Photo by Amy McCoy

# What's there—then and now?



Villarreal\*, M.L., S. Drake, S. E. Marsh, and A. McCoy, 2009 In Review, The Influence of Wastewater Subsidy, Flood Disturbance and Neighboring Land Use on Current and Historical Patterns of Riparian Vegetation in a Semi-arid Watershed, submitted to Ecosystems.

# Habitat requirements

- may relate to foraging for food,
- protection from enemies,
- reproduction,
- or a combination of all three factors.

\* Being able to predict changes in habitat is often the first step in predicting impacts on the species or community of concern.



*Photo by Brian Anderson*

# Climates affecting Habitats

- By adapting potential scenarios of climate regimes, can make predictions regarding how the plants and animals will react (migrate, deplete, multiply??) ....



Gray  
Hawks &  
Other  
Raptors  
Nest



*Photo by Amy McCoy*

# Biodiversity

- Biodiversity is the variation of life forms within a given ecosystem and is often used as a *measure* of the **health** of biological systems.
- Will changing climates - habitats

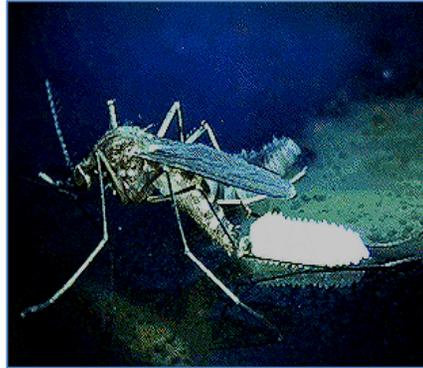
impact biological health?



*Photo by Miguel Villareal*

# Habitats and Human Health?

Mosquito vectors  
Culex species



VIRUS



Dead - end Hosts



VIRUS



VIRUS



Avian reservoirs



Another impact from warmer temps are spreading of vectors, including the very efficient disease spreader, the mosquito.

With warming, the vector is spreading to new environments. Mosquitoes are efficient carriers of viruses also

# HEALTH EFFECTS OF CLIMATE CHANGE



*Temperature Rise*<sup>1</sup>  
*Sea level Rise*<sup>2</sup>  
*Hydrologic Extremes*

<sup>1</sup> 3°C by yr. 2100

<sup>2</sup> 40 cm “ “

IPCC estimates

*Patz, 1998*

**Urban Heat Island Effect**

Heat Stress  
Cardiorespiratory failure

**Air Pollution & Aeroallergens**

Respiratory diseases, e.g., COPD & Asthma

**Vector-borne Diseases**

Malaria  
Dengue  
Encephalitis  
Hantavirus  
Rift Valley Fever

**Water-borne Diseases**

Cholera  
Cyclospora  
Cryptosporidiosis  
Campylobacter  
Leptospirosis

**Water resources & food supply**

Malnutrition  
Diarrhea  
Toxic Red Tides

**Mental Health & Environmental Refugees**

Forced Migration  
Overcrowding  
Infectious diseases  
Human Conflicts

# Vulnerability

- **Urban** groups, including **poor**, elderly, **marginalized**
- Children < 5 years old (challenged gastrointestinal/diarrheal, food shortages, and means to escape extreme weather events)
- Those who depend on subsistence **farming** or whose traditional food sources
- Those with **weak health systems**
- Those living in **drought prone** regions
- **Socioeconomics...**



*Colonias* are neighborhoods that demonstrate infrastructure deficiencies, poor quality housing, high levels of poverty, and a disproportionate concentration of Hispanics



- Property: net assessed valuation -- the taxable value of residential, commercial, industrial properties and utilities – is critical for financing county services such as public health services and bonds for public transportation improvements.
- “The Border” itself; laws, institutions, and decision-making processes are unresponsive, complicate their problems, and impede cooperation due to binational nature
- Differential exposure of some populations to harmful chemicals, pesticides, and other toxins

# Environmental Justice



*Photo by Hugo Rodriguez-Gallegos*

Donelson (2006) developed an index of deprivation to delineate areas of greatest housing, social, and poverty stress.

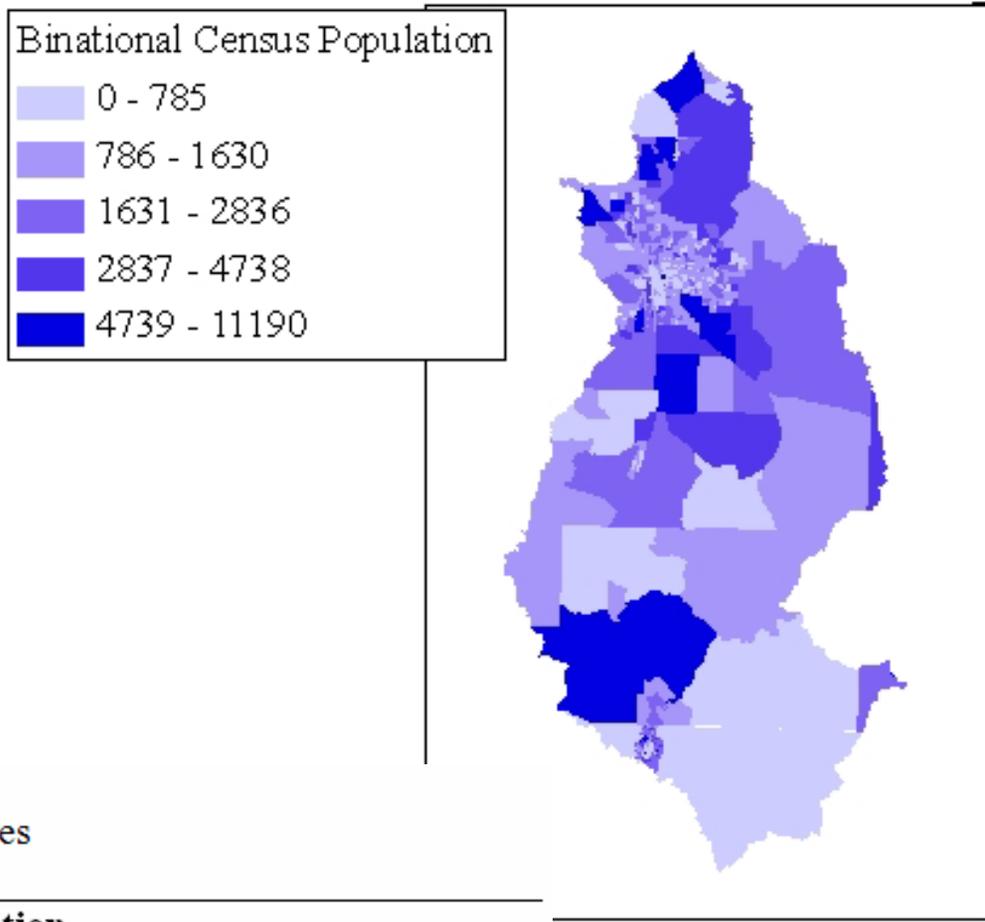


Table 1. Variables Entering Deprivation Indices

| Poverty                                      | Variable Description<br>Social         | Housing                 |
|--|--|-------------------------|
| 1] No. persons below 50 % median area income | 1] Different residence in past 5 years | 1] Median housing value |
| 2] Persons below poverty                     | 2] Household structure                 | 2] Lack of plumbing     |
| 3] Median per capita income                  | 3] No vehicle available                | 3] Age of housing       |
| 4] Median family income                      | 4] Dependency ratio                    | 4] Vacant units         |
| 5] Ratio of income inequality                | 5] Occupation                          | 5] Seasonal housing     |
| 6] Ratio of middle incomes                   | 6] Linguistic isolation                | 6] Overcrowding         |
|  | 7] No high school diploma              |                         |
|  | 8] Foreign born population             |                         |
|  | 9] Unemployment rate                   |                         |

# Environmental Economics

- Goal: “Potential Pareto Improvement”
- Economists then search for inefficiencies, issues where managing the environment differently could lead to higher net benefits for society as a whole.
- Nonmarket valuation studies is a part of these analyses, such as the value of increased biodiversity.
- But, how might environmental choices affect one group more than another?

A more equitable community in which we live, work, and play, can lead to a community with fewer class tensions and a *higher quality of life.*

# Public Survey

- A public survey is planned to collect information on how residents of the watershed value the SCR.
- Ultimately the goal is to identify physical attributes related to the river that are the most important to the public to be used as 'indicators' of the river resource.
- These attributes are by definition ES that contribute to public benefits.

# SI -- Upper Santa Cruz River Health Assessment

- To identify components of river health that can be monitored on an annual basis and that can demonstrate if and how the river is changing over time.
- Goal is to communicate this information to the public, land managers, and policy makers with the aim of deepening a dialogue about conservation and management actions on the river.
- This provides a means of presenting both current status, and future changes in aquatic and riparian condition for a general public readership.
- The variables used in the health assessment form a hypothesis for river attributes that may be used in the survey (i.e. “Biodiversity”).

# Water Provisioning



# SCWEPM Website Mock-up

- To visualize the end-product, we have developed a full-sized scale model of the structure, to be used for demonstration, study, and/or testing.
- The Binational Features, Counties, and International Boundary are coming from the Web Map Service (WMS) is a standard protocol for serving georeferenced map images over the Internet that are generated by a map server using data from the U.S. - Mexico Border Environmental Health Initiative (BEHI) GIS database

The screenshot displays a web-based GIS application. At the top left is the USGS logo with the tagline "science for a changing world". To the right are links for "USGS Home", "Contact USGS", and "Search USGS". The main title is "Santa Cruz Watershed Ecosystem Portfolio Model (Prototype)". The map shows a central watershed area in green and yellow, overlaid on a pink background representing the international boundary. Major roads like I-19, I-10, and SR-77, 82, 83, 90, 92 are visible. A dashed black line indicates the international border. On the right, a "Layers" panel is open, showing "General Data" with checked options for "Roads", "Hydrology", "Santa Cruz Watershed", "International Boundaries", "Counties", "Population Density", and "Hillshade". Under "Base Imagery", "Landsat 7 (543 bands)" is selected. Below the map is a "Point Info Results" section, currently empty. At the bottom, there are navigation controls (zoom in, zoom out, home, full screen, etc.), latitude and longitude fields, and a scale bar in miles (0 to 48). The footer contains links for "Accessibility", "FOIA", "Privacy", and "Policies and Notices", along with the "U.S. Department of the Interior | U.S. Geological Survey" logo and the "USA.gov" logo.

USGS  
science for a changing world

USGS Home  
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Santa Cruz Watershed Ecosystem Portfolio Model (Prototype)

Layers

General Data

- Binational Features
- International Boundaries
- Roads
- Counties
- Hydrology
- Population Density
- Santa Cruz Watershed
- Hillshade

Base Imagery

- Landsat 7 (543 bands)
- Orthoimagery (Landsat in certain areas)
- None

Point Info Results

Lat: Lon:

MI

0 12 24 36 48

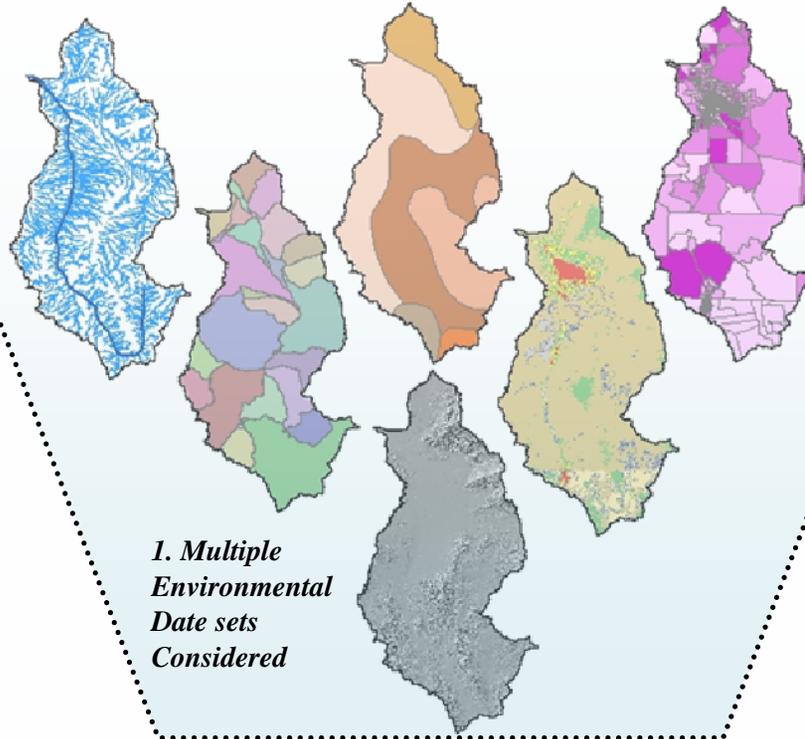
Accessibility FOIA Privacy Policies and Notices

U.S. Department of the Interior | U.S. Geological Survey  
URL: <http://lcat.usgs.gov/sflorida/sflorida.html>  
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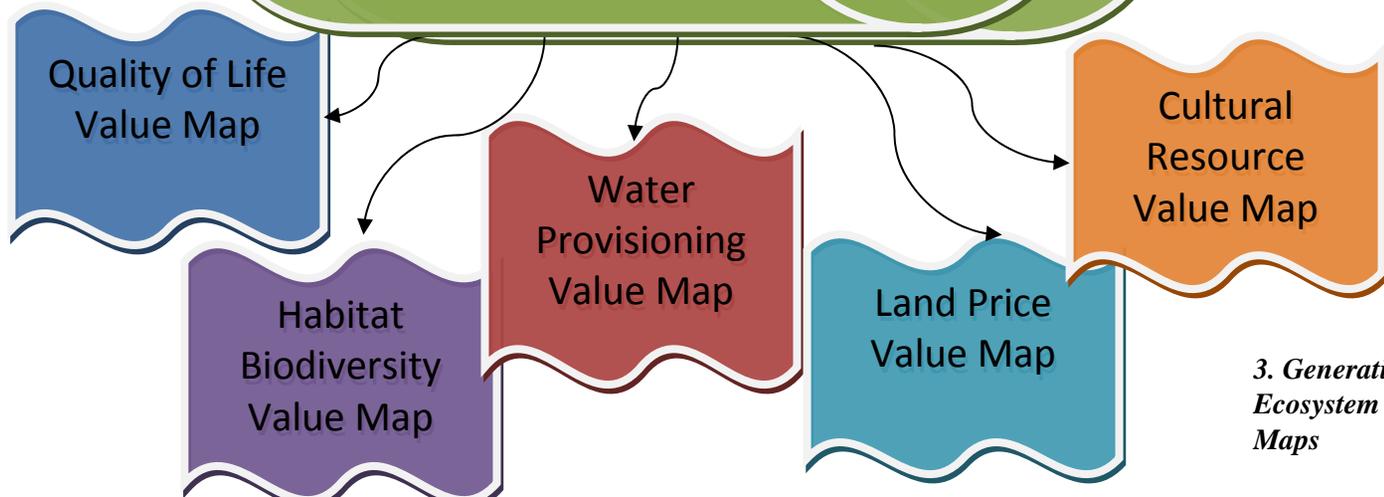
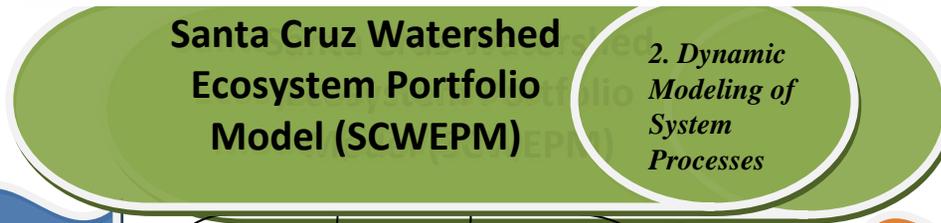
USA.gov  
Take Pride in America



Users?



*1. Multiple Environmental Data sets Considered*



*3. Generation of Ecosystem Service Value Maps*

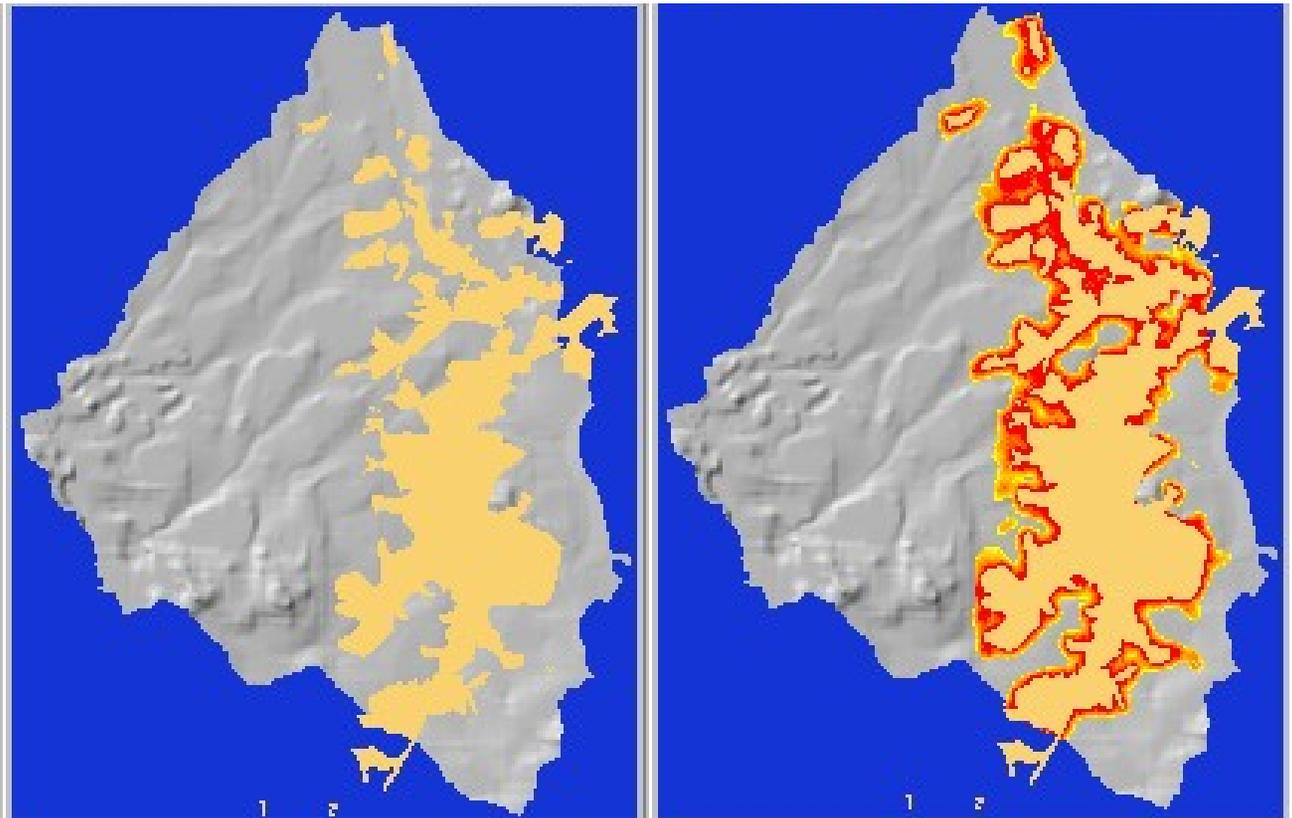
# Website DSS dynamically simulates scenarios – coupling existing models with similar inputs

- i. **SLEUTH**, to simulate variations and predictions of urban-growth
- ii. **SWAT** (Soil & Water Assessment Tool) to estimate impacts of land management practices on water quantity and quality in complex watersheds
- iii. **ATtILA**, to calculate landscape characteristics, riparian characteristics, human stressors and physical characteristics and/or **FRAGSTATS**, to computes several statistics for each patch and class in the landscape.
- iv. Southwest Regional Gap Analysis Project **Animal Habitat Models** Data?
- v. **NatureServe** tool, for synthesizing data when not readily available
- vi. **MODFLOW**, a 3D Finite-Difference Groundwater Flow Model
- vii. **InVEST** (Integrated Valuation of Ecosystem Services and Tradeoffs), models for carbon sequestration, pollination of crops, managed timber production, water pollution regulation and sediment retention for reservoir maintenance, and a biodiversity model.

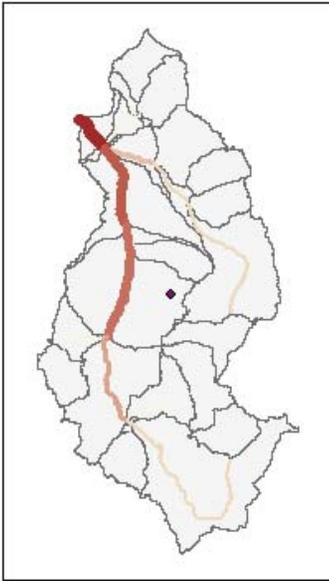
# SLEUTH Urban Growth Model

## *Predicted 27-Years Growth to 2030*

| Probability Range | Color        |
|-------------------|--------------|
| 0- 50%            | Black        |
| 50- 60%           | Yellow       |
| 60- 70%           | Light Yellow |
| 70- 80%           | Orange       |
| 80- 90%           | Dark Orange  |
| 90- 95%           | Red-Orange   |
| 95- 100%          | Red          |

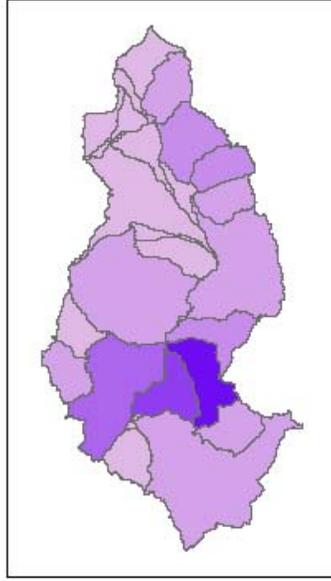


# SWAT



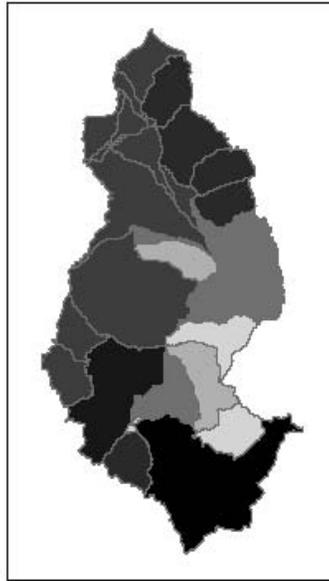
## Legend

### Channel Discharge (m<sup>3</sup>/day)



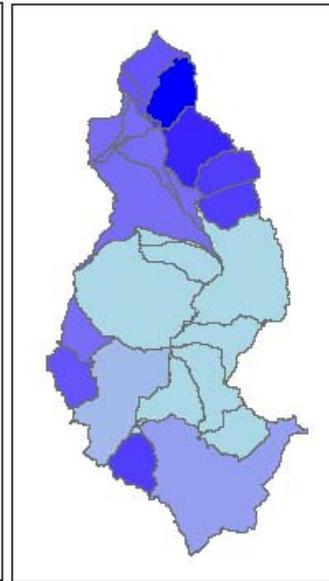
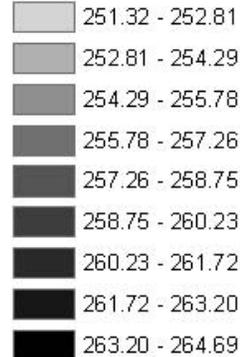
## Legend

### Sediment Yield (tons/ha)



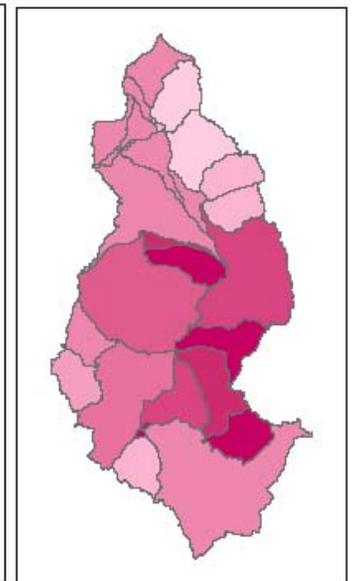
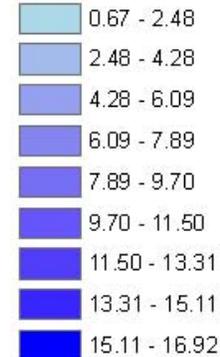
## Legend

### Evapotranspiration (mm)



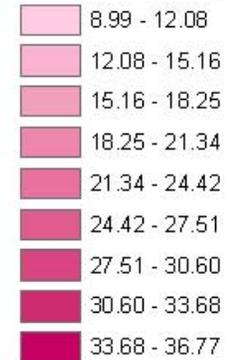
## Legend

### Percolation (mm)

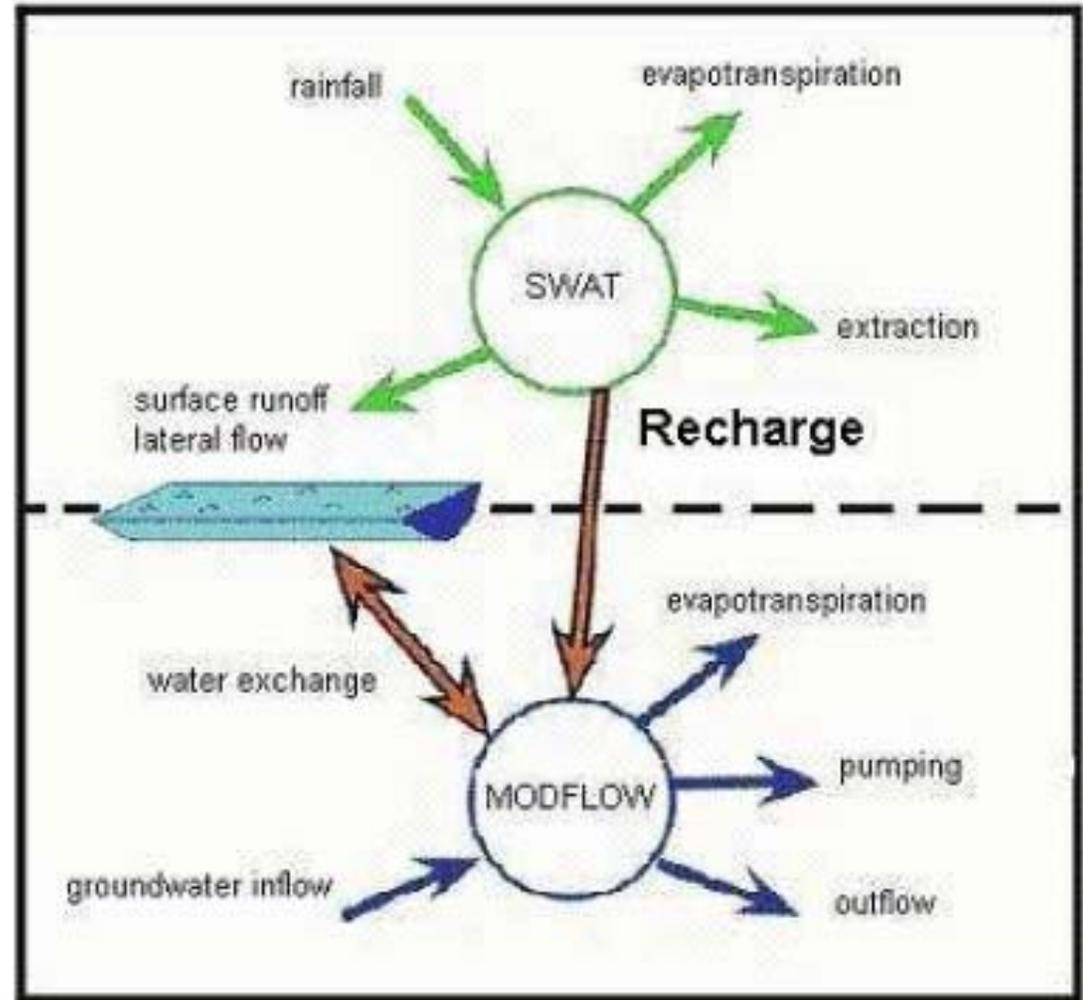


## Legend

### Surface Runoff (mm)



SWAT model to provide input to MODFLOW, so the two models can 'talk' and be interactive when "live".





## Southwest Regional Gap Analysis Wildlife Habitat Relationship

# Southwest Regional Gap Analysis Project Animal Habitat Models

<http://fws-nmcfwru.nmsu.edu/swregap/habitatreview/>

**ID** 2568      **Model Name** SWReGAP 554137  
**Taxa code (ITIS)** 554137  
**Scientific Name** *Asturina nitida*  
**Common Name** GRAY HAWK  
**Created By** jwynne      **Last Modified By** J Judson Wynne  
**Date** 6/18/2004 2:00:45 PM      **Date** 4/29/2005 5:05:03 PM

**Sensitive Data**

### Model Description

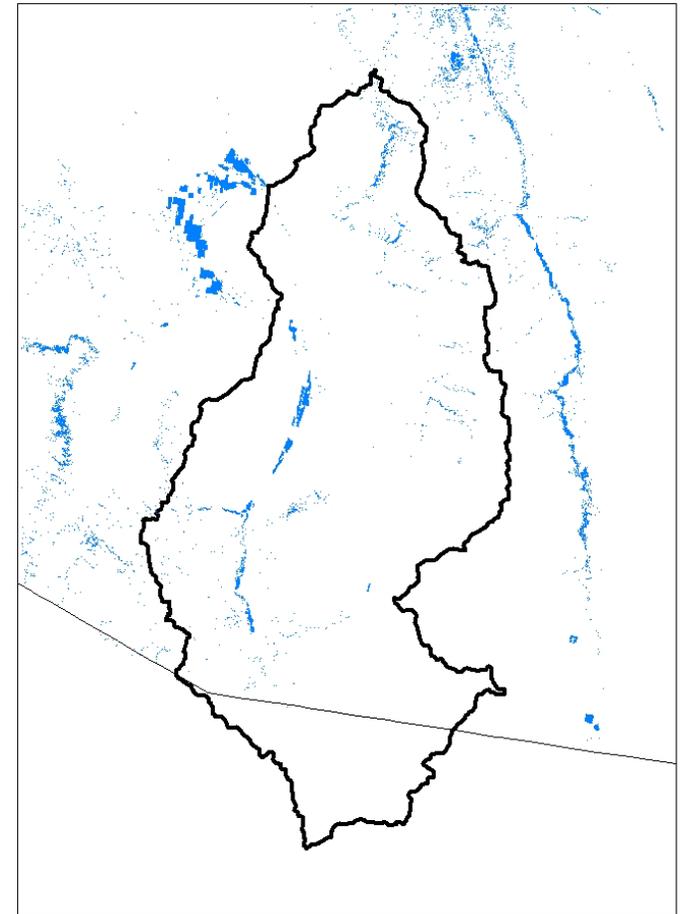
#### Background

**Model Considerations -** Vegetation is a mosaic of three types: large-diameter riparian forest (cottonwood) adjacent to mesquite bosque and large-diameter riparian forest (cottonwood) adjacent to agriculture.

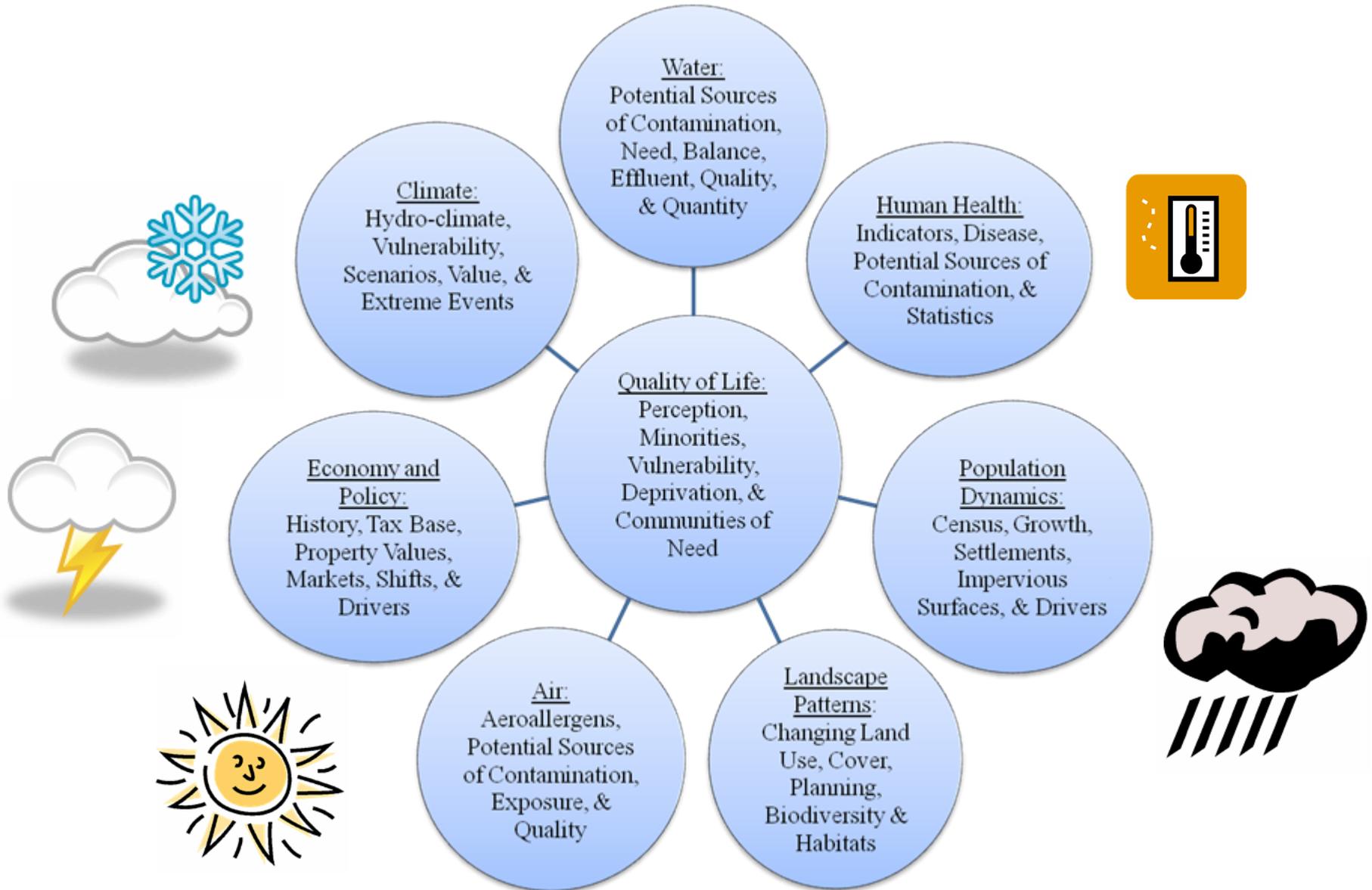
**Proximity to water:** GRHA is closely associated with riparian areas (Bibles et al. 2002). This seems to be a requirement tied to the availability of suitable nesting trees (large diameter cottonwoods) and not the actual presence of water or riparian areas for forage.

**Vegetation Type:** Well-developed cottonwood riparian woodlands and cottonwood-willow woodlands for nesting with adjacent mesquite bosques with open understory or farmland for hunting. Edison et al. (1995) describes habitat as "tall cottonwood riparian woodland." Bibles (1999) and Bibles et al. (2002) describe this species as being most common in riparian areas dominated by cottonwood with adjacent mesquite bosques. Cottonwood-willow riparian areas were second in use (Bibles 1999). Stensrude (1965) corroborates this in his observations of a pair of GRHA within riparian shrub habitat dominated by cottonwood and adjacent to farmland; however, this is based on an observation of an infinitesimal sample size ( $n = 2$ ).

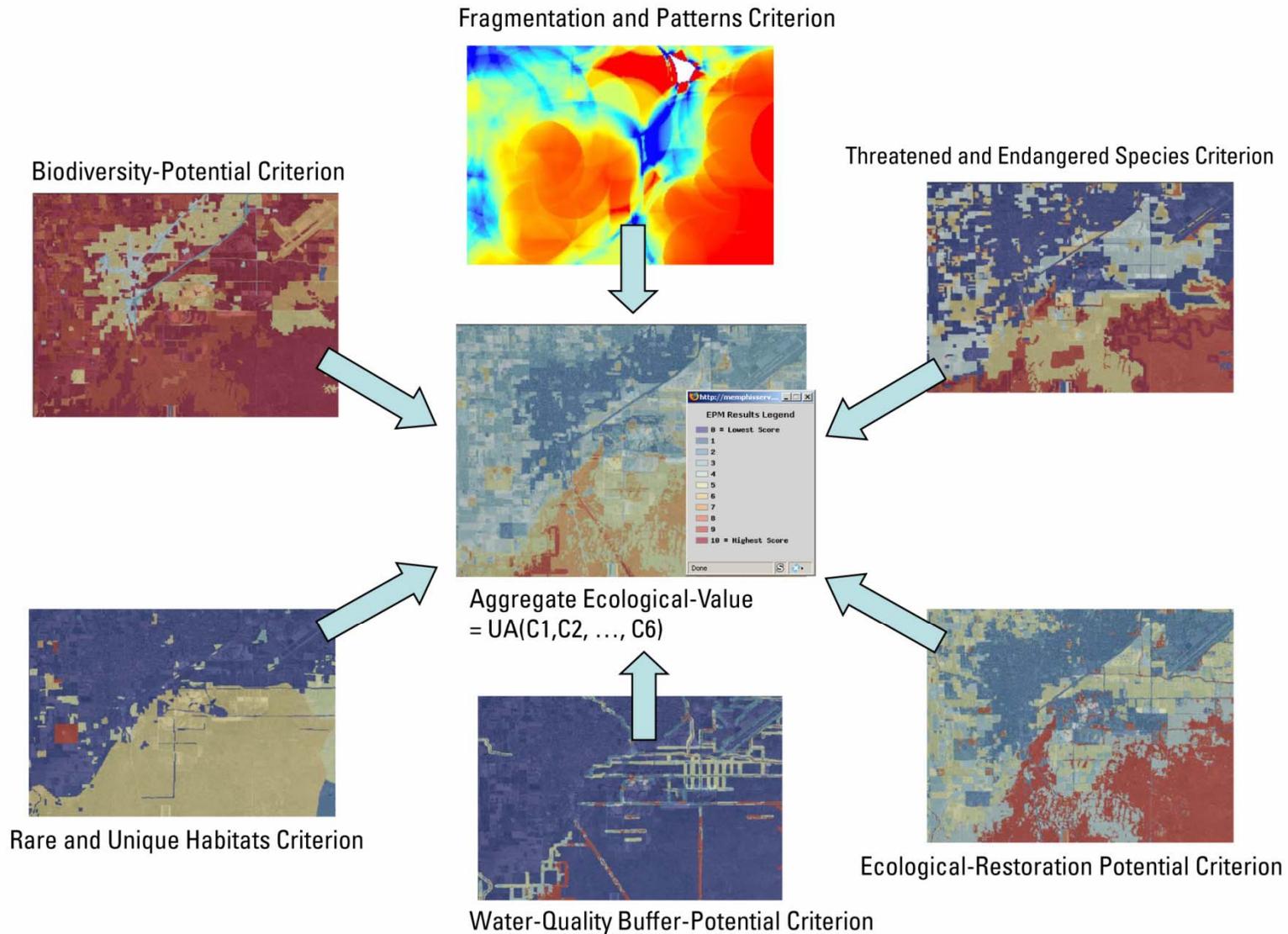
**Vegetation Structure:** Foraging ecology – Bibles (1999) asserts gray hawks may select habitat based on areas with the highest number of lizards and suggests areas with low horizontal mesquite cover are most important determinant for gray hawk habitat quality. This species forages in mesquite and cottonwood-willow forest and rarely uses other vegetation types (Bibles 1999). Mesquite bosques comprises a large portion (~54%) of home ranges and the majority of foraging locations (~80%; Bibles 1999). Stensrude (1965) found that his pair hunted mostly in mesquite bosques and cultivated fields. Mesquite cover tended to be higher at foraging sites when compared to random sites and horizontal cover was lower at foraging sites when compared to random sites (Bibles 1999). Males tend to select mesquite bosques with relatively open



# Ecosystem Services and Values



# Defining Aggregate (Ecological) Value Using a Multi-attribute Utility Function



Labiosa, William B., Bernknopf, Richard, Hearn, Paul, Hogan, Dianna, Strong, David, Pearlstine, Leonard, Mathie, Amy M., Wein, Anne M., Gillen, Kevin, and Wachter, Susan, 2009, The South Florida Ecosystem Portfolio Model; a map-based multicriteria ecological, economic, and community land-use planning tool: U.S. Geological Survey Scientific Investigations Report 2009-5181, 41 p.

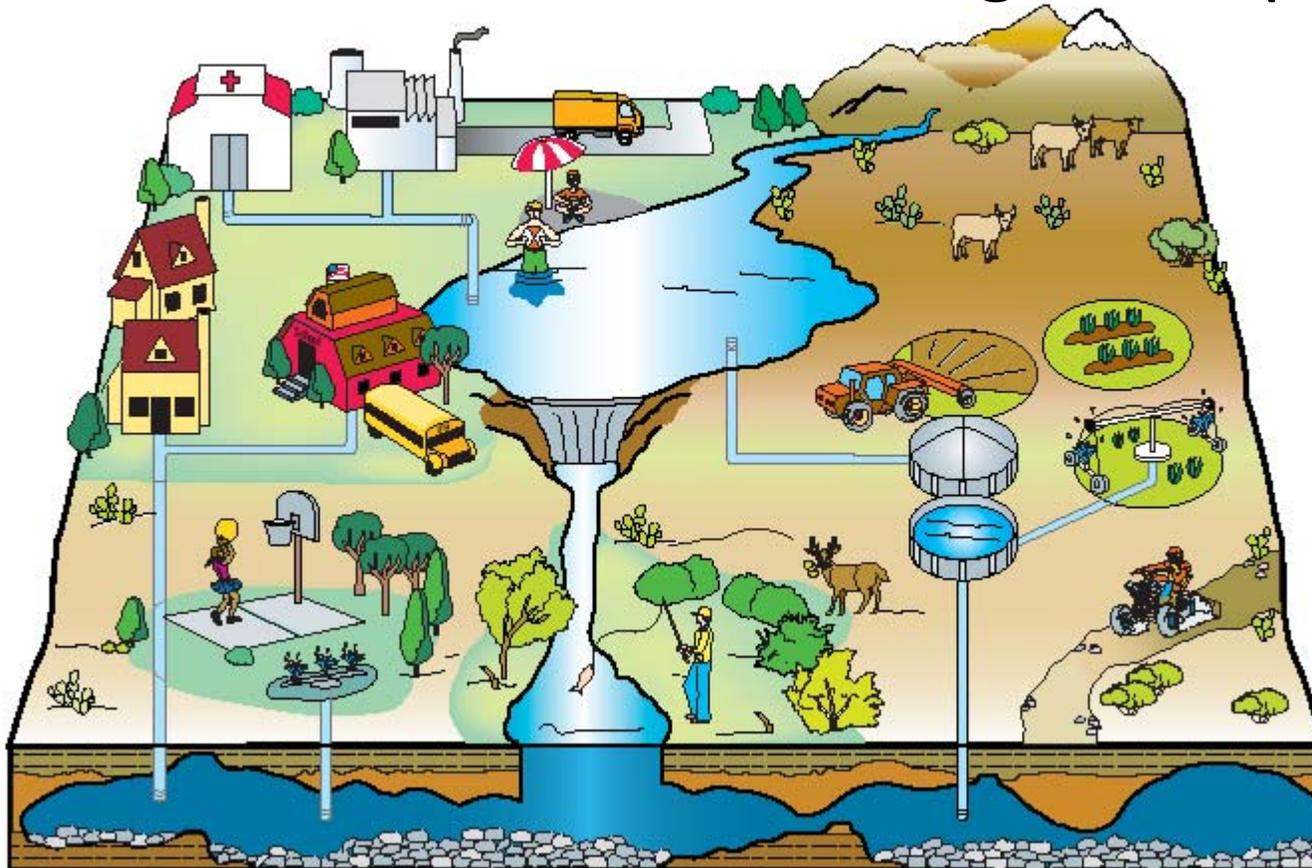
# Outreach: “Google Group” SCWEPM

## Folks

- Began June 25, 2009, as a group of people working to develop the Ecosystem Portfolio Model as a multidisciplinary platform for the Santa Cruz watershed.
- 61 members as of October 2, 2009, including representatives from: Arizona Department Emergency and Military Affairs (ADEMA), Arizona Department of Environmental Quality (ADEQ) Arizona Department of Water Resources (ADWR) Arizona Land and Water Trust (ALWT), Arizona State University (ASU), Bureau of Land Management (BLM), City of Nogales-Sonora, Friends of the Santa Cruz River (FOSCR), Global Community, International Boundary and Water Commission (IBWC), Santa Cruz County Flood Control, Sonoran Institute (SI), Sustainable Santa Cruz, The Nature Conservancy (TNC), Tucson Audubon Society (TAS), University of Arizona- Bureau of Applied Research and Anthropology (UA-BARA), University of Arizona-Geography, University of Arizona-Hydrology and Water Resources, US Army Corps of Engineers (USACE), US Department of Agriculture-Agricultural Research Station (USDA-ARS), US Environmental Protection Agency (EPA), US Geological Survey (USGS), and Watershed Management Group (WMG).

# Ideal

- Scientists and communities to learn together about how to deliver the right information to policy developers and decision makers to move towards more sustainable land management practices.



←Draft EPA  
Southwest Ecosystem  
Services Project logo.

## ***Points of Contact:***

USGS: Laura M. Norman (520-670-5510) and Bill Labiosa (206-220-4563)

EPA: Nita Tallent-Halsell (702-798-2567)

## ***Publications and Websites:***

- Information about the USGS Border Environmental Health Initiative (BEHI) and the Santa Cruz Watershed
  - <http://borderhealth.cr.usgs.gov/>
  - <http://borderhealth.cr.usgs.gov/PDFs/WR-website.pdf>
- USGS Ecosystem Portfolio Model (EPM) literature
  - <http://geography.wr.usgs.gov/science/sFloridaPM.html>
  - [http://sofia.usgs.gov/projects/index.php?project\\_url=gis\\_tool](http://sofia.usgs.gov/projects/index.php?project_url=gis_tool)
  - <http://geography.wr.usgs.gov/science/pugetPM.html>
- Description of the US EPA Ecosystem Services Research Program (ESRP):
  - <http://epa.gov/ord/esrp/>
  - <http://epa.gov/ord/esrp/quick-finder/southwest.htm>
  - <http://www.epa.gov/esd/land-sci/default.htm>
- Join our Google Group for more current information, post questions/discussions, and to interact with scientists or stakeholders:
  - <http://groups.google.com/group/scwepm-folks?hl=en>