

# ***Enhancing niche models for a riparian-dependent bird using multi-source vegetation data***

***A case study of habitat model accuracy for the yellow-billed cuckoo***

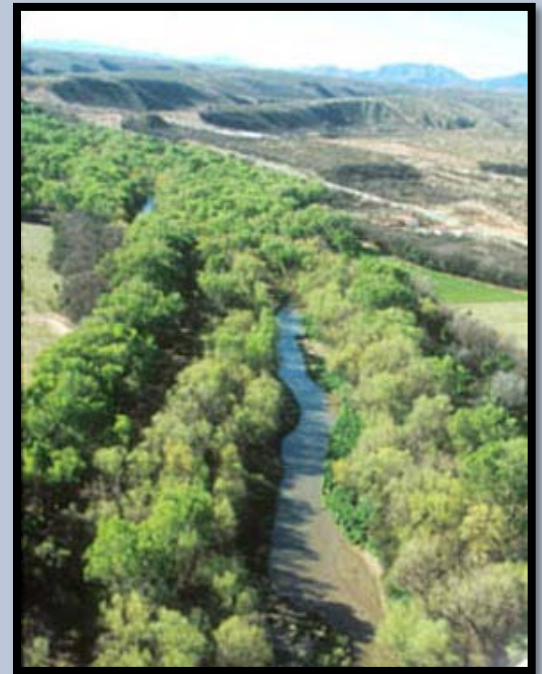


*Yellow-billed Cuckoo*  
Image source: David Speiser

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# Outline

- Research questions
- Yellow-billed cuckoo (YBCU)
- Issues with accuracy of riparian maps
  - Classification scheme, geographic scale, intended audience, etc.
- Research approach
  - Measure accuracy of existing riparian data
  - Aggregate multi-source riparian data sets
  - MaxEnt habitat models
- Results
  - Best model
  - Distribution of YBCU habitat in AZ
- Santa Cruz Watershed case study
  - Statewide vs. localized watershed



*The Santa Cruz River – north of Nogales*

*Image source: National Park Service*

*Photo by John Hoffman*

# Explanation of the Problem

- In the arid SW, riparian vegetation is habitat for a disproportionately large number of vertebrate species
- Riparian vegetation declination over past century due to drought, urbanization, damming, agriculture, etc.
- Riparian vegetation is notoriously difficult to map
- If we want to conserve, protect, restore, and to support biodiversity and prevent extinctions, we need accurate and consistent habitat maps

# Research Questions

- 1) Can we improve habitat model accuracy using multi-source/multi-scale vegetation data sets (geospatial)?
- 2) Where is YBCU habitat distributed in Arizona?
- 3) Which vegetation/land cover riparian data set is most accurate: national, regional, or statewide?

# Western Yellow-billed cuckoo (*coccyzus americanus*)

- Found in riparian woodlands and forests
- A neotropical migrant bird
  - Winters in South/Central America
  - Summers in western United States
- Breeds during June and July in western riparian forests
  - Threatened due to habitat loss
- Listed under Endangered Species Act as “Threatened”, up for potential listing in 2013



Yellow-billed Cuckoo  
Image source: [planetofbirds.com](http://planetofbirds.com)

# Issues Mapping Riparian Habitat

- Riparian areas are narrow, linear, and of small areal extent
  - 30 X 30 Meter pixels
- Mapping of riparian plant communities
  - Range from dense forests to mixed savanna/scattered trees
  - Dynamic and vulnerable to immediate changes (dams, urban water use, floods, and fire)
- Intended audience of mapped data
  - Urban management vs. natural resources management



0 m 300 m

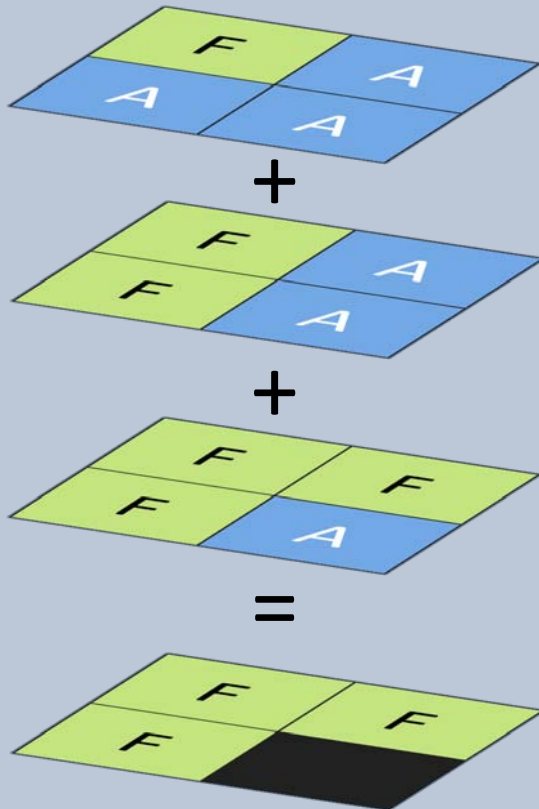
# Vegetation/Land Cover Data

- Three geographic **scales** of input data
  - **National:** National Land Cover Dataset (NLCD) (30 m)
  - **Regional:** Southwestern Regional Gap Analysis Project (SWReGAP)(30 m)
  - **State:** Arizona Game and Fish Department Riparian Dataset (AZGF) (polygon) (converted to 30m)
- Five riparian classes
  - Forest, Mesquite, Invasive, Agriculture, and Wetland
- Thematic Resolution
  - NLCD 3 riparian classes
  - SWReGAP 5 riparian classes
  - AZGF 5 riparian classes

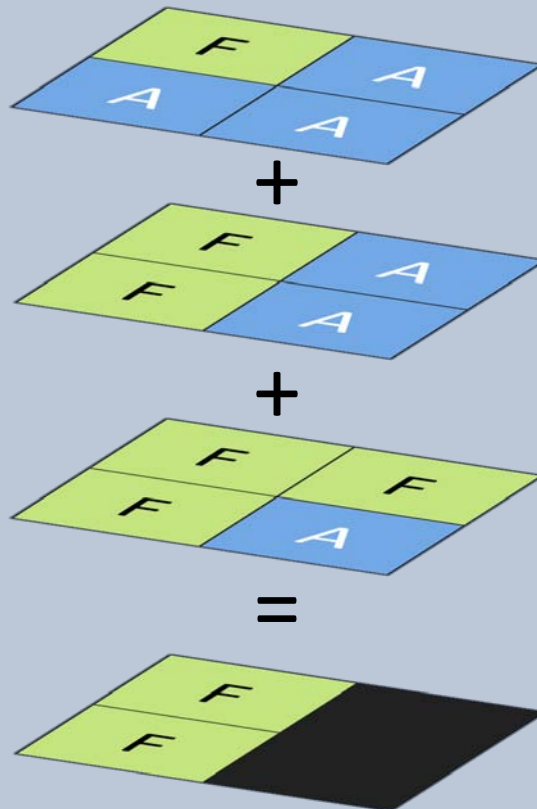
# Aggregate Data Sets

- Three levels of agreement – combination of vegetation/land cover data sets
  - 1) Liberal (no agreement necessary, largest areal extent)
  - 2) Moderate (agreement between two or more, medium areal extent)
  - 3) Conservative (agreement between all, smallest areal extent)

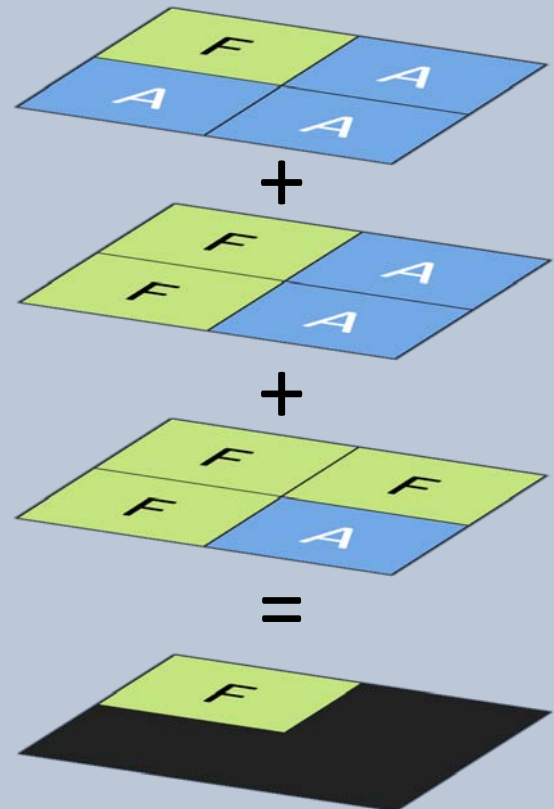
**Liberal**



**Moderate**

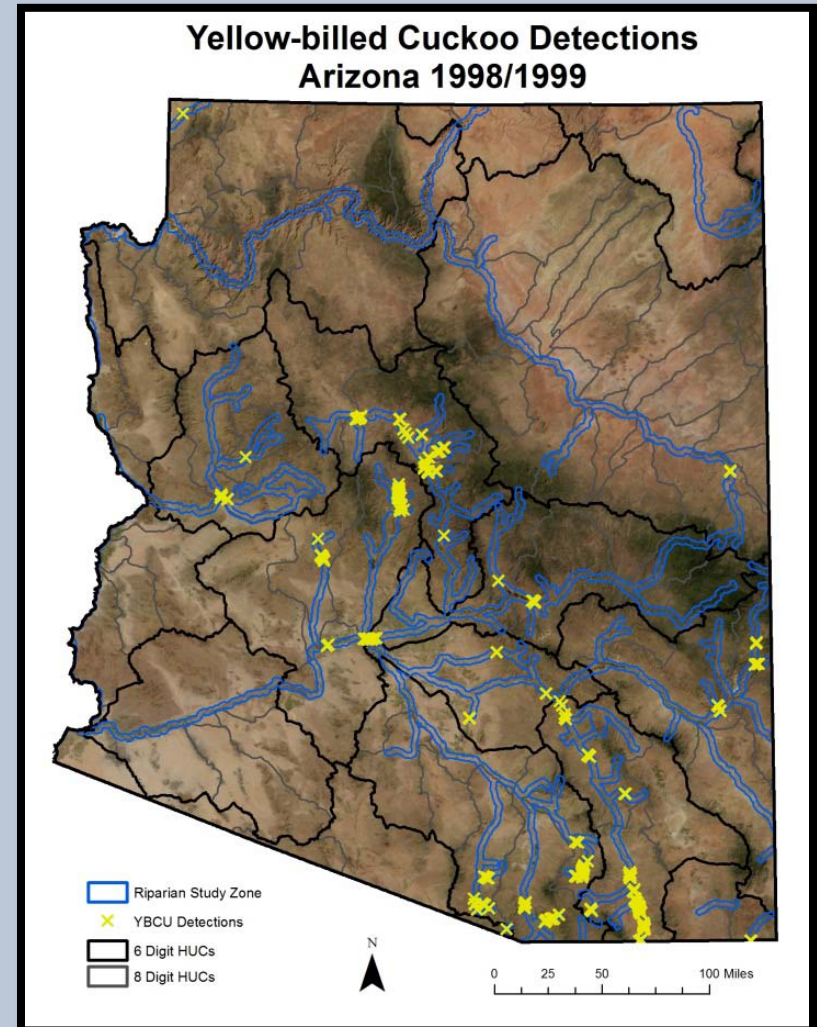


**Conservative**



# Developing Habitat Model

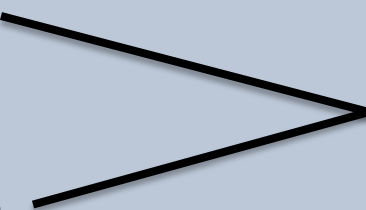
- Presence/absence YBCU observations field-collected for Arizona in 1998 and 1999 (n=479)
- 4 kilometer diameter buffer surrounding major perennial and intermittent rivers and riparian habitat
- Constant input variables (30 meter data)
  - Digital Elevation Model (DEM)
  - Topographic Position Index (TPI)
  - Normalized Differential Vegetation Index (NDVI)
- Focal Statistics – 480 m radius focal window
  - The amount of habitat type in 72 hectare area
  - Both input and aggregate data sets



# Habitat Model Layers

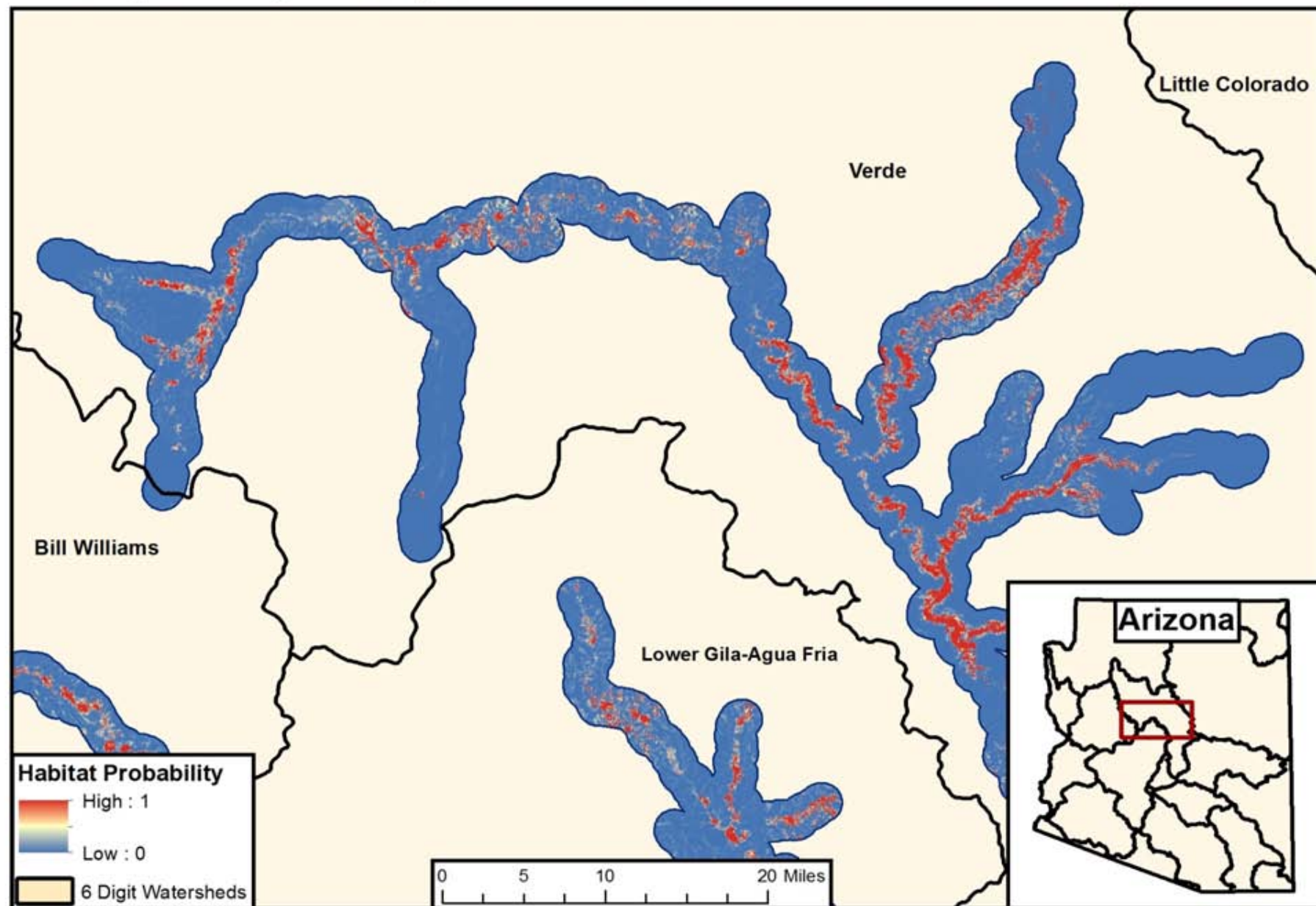
| Constant Input Variables                                                                                                                            | Land Cover Data Sets    | Aggregate                    |
|-----------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|------------------------------|
| DEM                                                                                                                                                 | AZGF Forest 480         | Conservative Forest 480      |
| Topographic Position Index 480                                                                                                                      | AZGF Agriculture 480    | Conservative Forest          |
| NDVI                                                                                                                                                | AZGF Mesquite 480       | Conservative Agriculture 480 |
| NDVI 480                                                                                                                                            | AZGF Wetland 480        | Conservative Agriculture     |
|  <p><i>Yellow-billed Cuckoo</i><br/>Image source: Jack Revare</p> | AZGF Invasive 480       | Conservative Mesquite 480    |
|                                                                                                                                                     | AZGF Full               | Conservative Mesquite        |
|                                                                                                                                                     | SWReGAP Forest 480      | Conservative Wetland 480     |
|                                                                                                                                                     | SWReGAP Agriculture 480 | Conservative Wetland         |
|                                                                                                                                                     | SWReGAP Mesquite 480    | Conservative Invasive 480    |
|                                                                                                                                                     | SWReGAP Wetland 480     | Conservative Invasive        |
|                                                                                                                                                     | SWReGAP Invasive 480    | Moderate Forest 480          |
|                                                                                                                                                     | SWReGAP Full            | Moderate Forest              |
|                                                                                                                                                     | NLCD Forest 480         | Moderate Agriculture 480     |
|                                                                                                                                                     | NLCD Agriculture 480    | Moderate Agriculture         |
|                                                                                                                                                     | NLCD Wetland 480        | Moderate Mesquite 480        |
|                                                                                                                                                     | NLCD Full               | Moderate Mesquite            |
|                                                                                                                                                     |                         | Moderate Wetland 480         |
|                                                                                                                                                     |                         | Moderate Wetland             |
|                                                                                                                                                     |                         | Moderate Invasive 480        |
|                                                                                                                                                     |                         | Moderate Invasive            |
|                                                                                                                                                     |                         | Liberal Forest 480           |
|                                                                                                                                                     |                         | Liberal Forest               |

# Maximum Entropy Model (MaxEnt)

- Presence only species habitat probability model
  - Categorical and continuous data
  - 6 Models
    - 3 Aggregate Data Sets
    - 3 Land Cover Data Sets
- 
- Constant input variables  
and YBCU detections
- Withheld 120 detection points for validation
  - Determined the best model by using thresholds (quartiles) of MaxEnt probabilities (0.0-1.0) to classify the MaxEnt raster

# Maximum Entropy Model - Moderate Aggregate

Habitat probability for the yellow-billed cuckoo



# Validation of Data

50 random points for each class (forest, mesquite, invasive, wetland, and agriculture) for each data set



Aravaipa Canyon



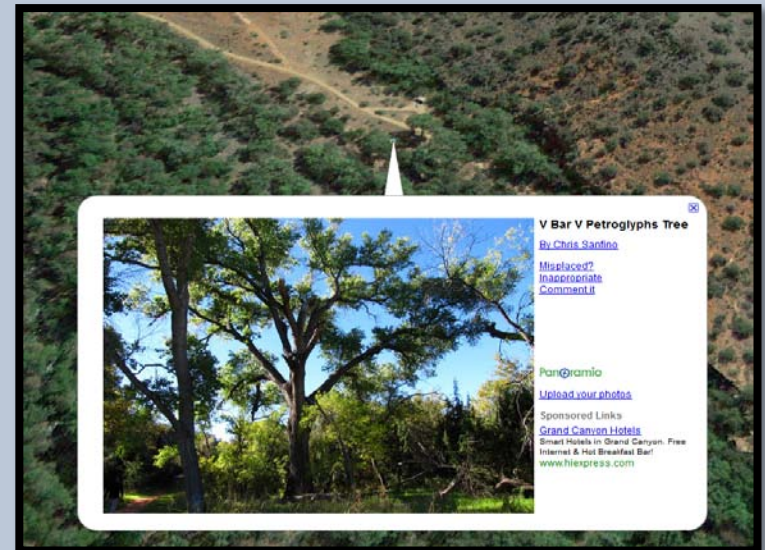
Colorado River



Salt River



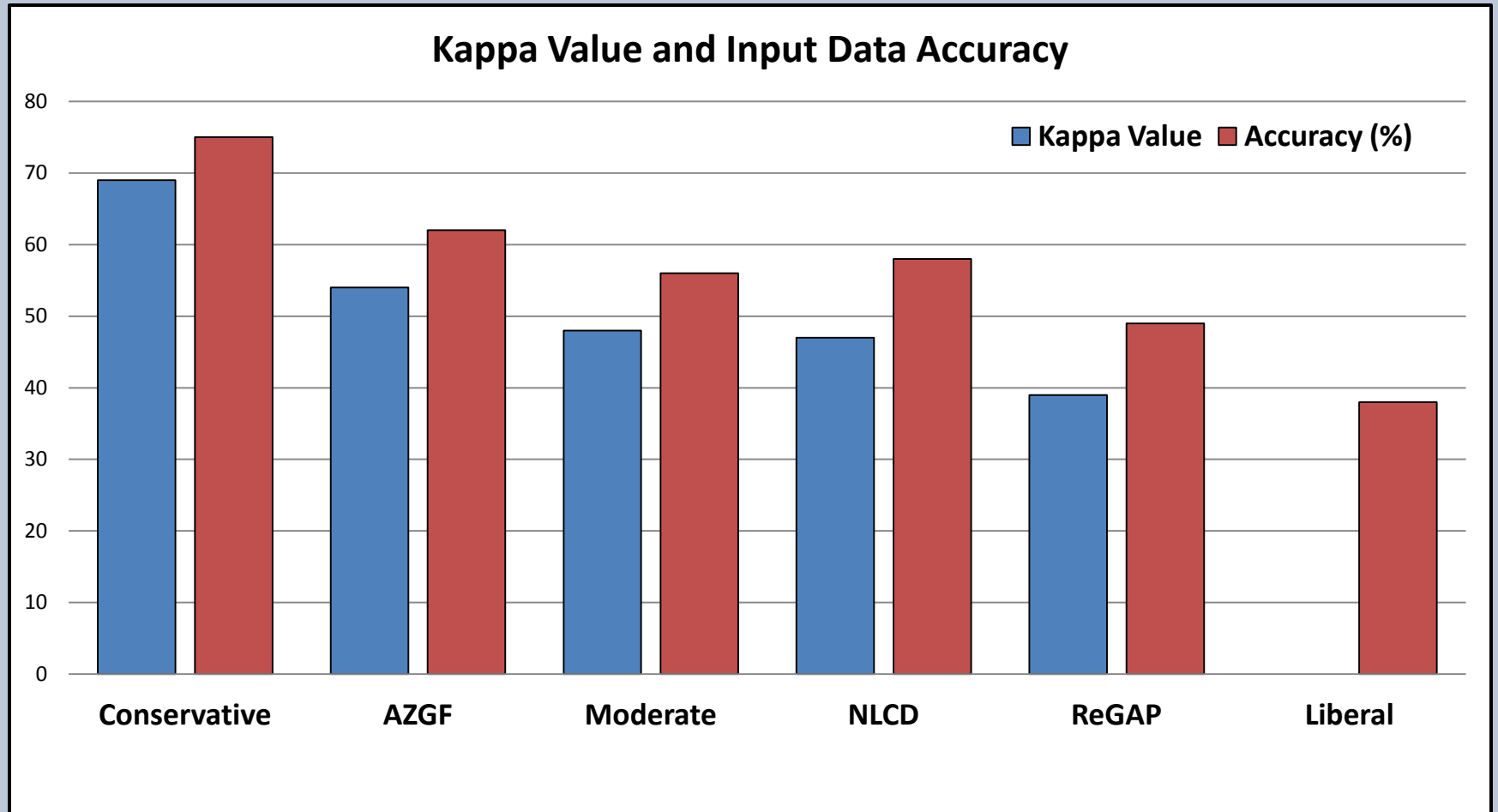
Verde River

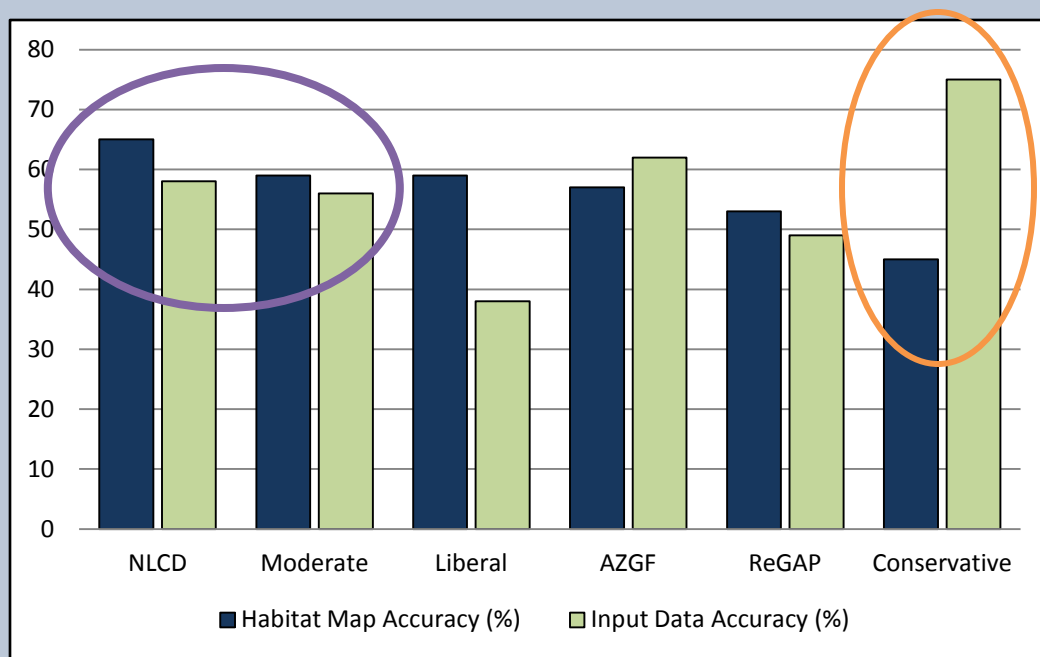


Verde River

Source: Google Earth

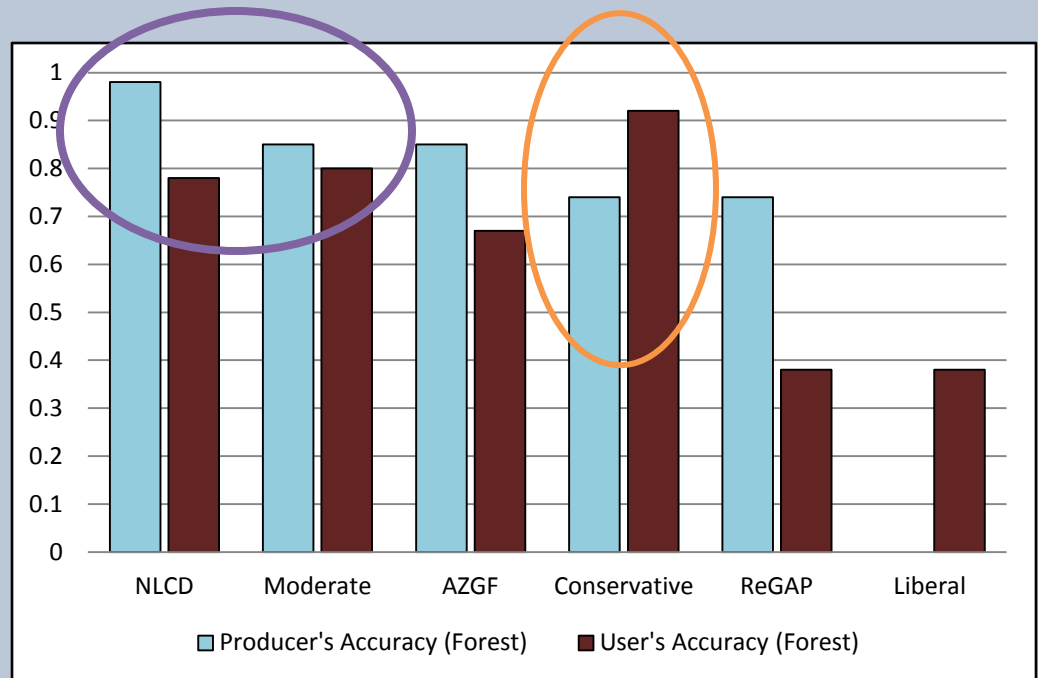
# Accuracy of Input Data Sets

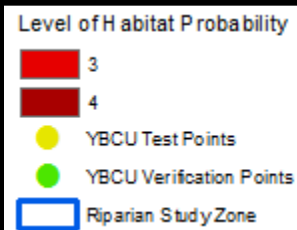
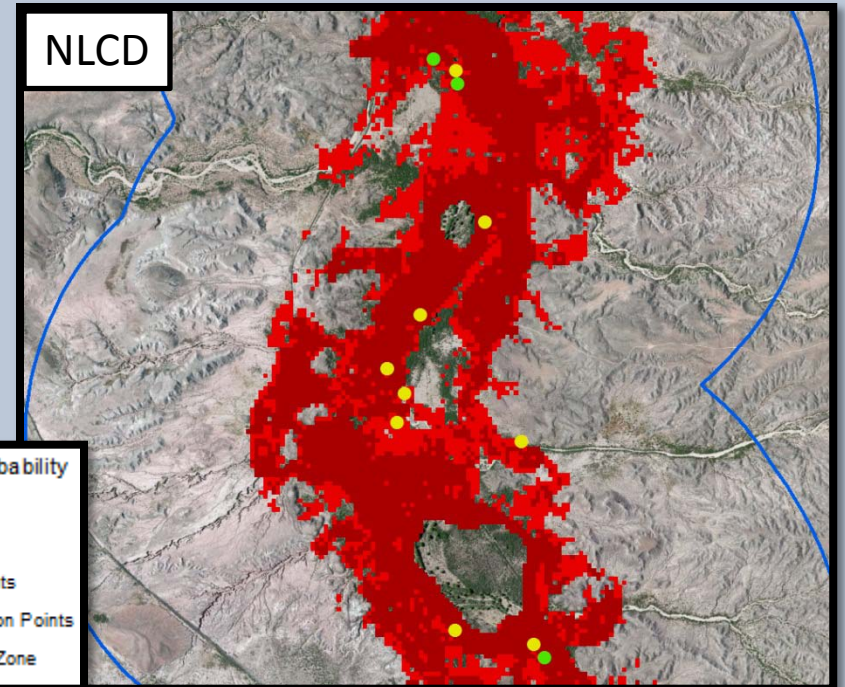
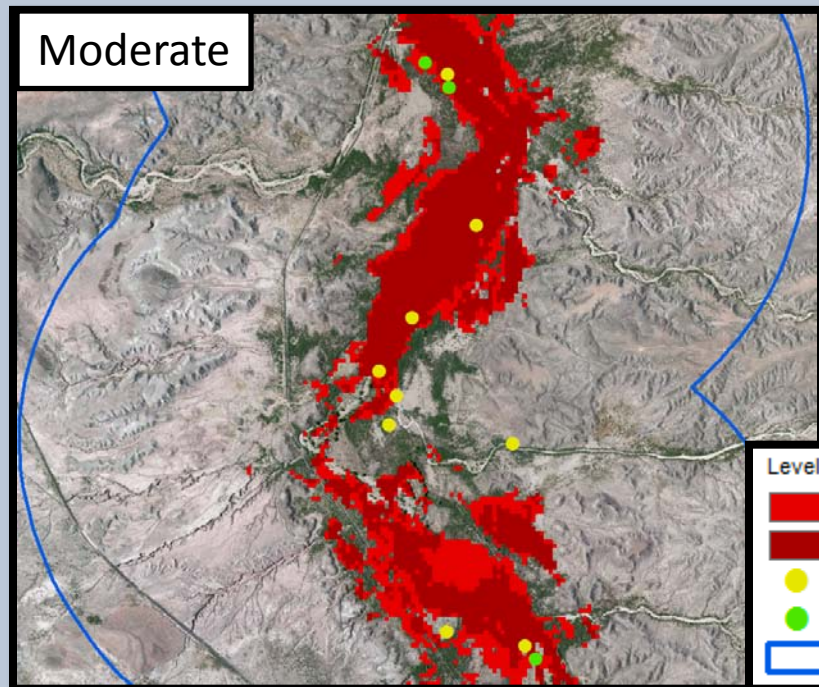
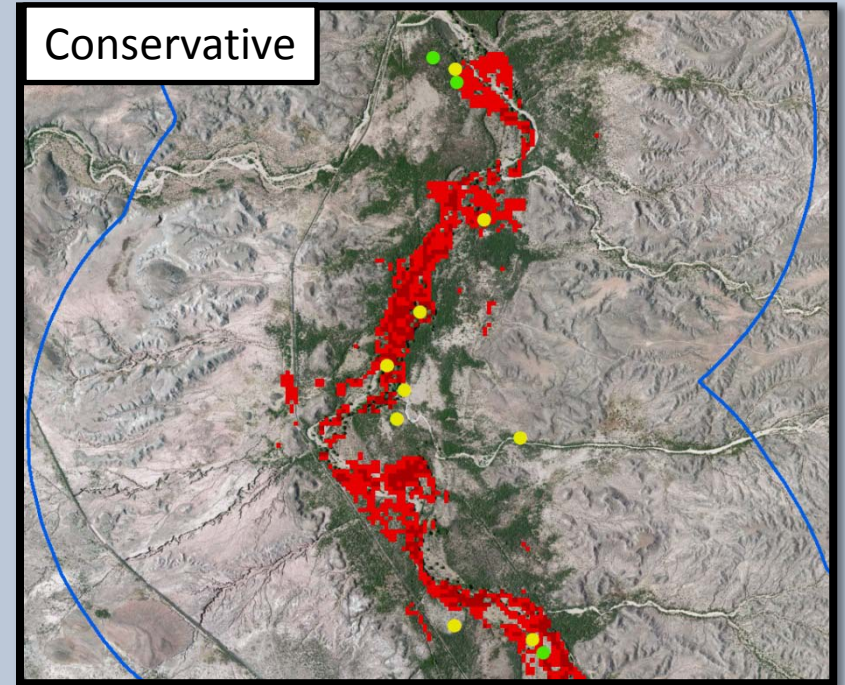
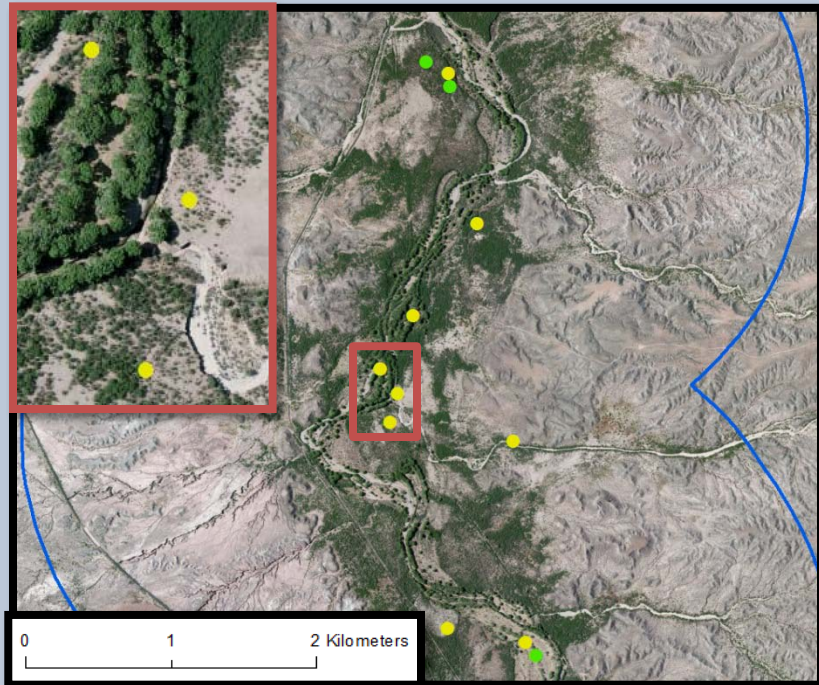




- Habitat map accuracy
  - Percentage of validation points that fell with high probability habitat
- Input data accuracy
  - Accuracy of the original input data set

- The Producer's Accuracy
  - Errors of omission
- The User's Accuracy
  - Percentage of forest accuracy points that were correctly classified





# Which was the best model?

1) NLCD was the most accurate MaxEnt model

- High habitat map accuracy
- High producer's accuracy value

2) Moderate Aggregate (MA) was the second most accurate MaxEnt model

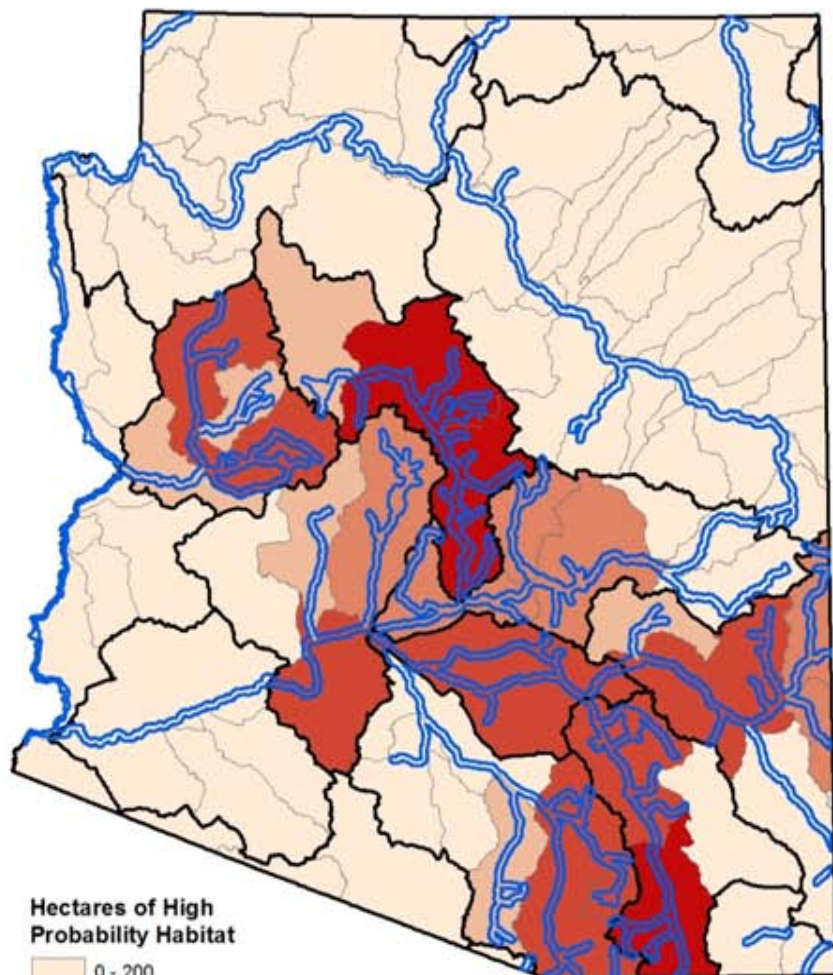
3) NLCD Model has the ability to overestimate based on a greater spatial extent of forest class

4) MA model is the best overall model

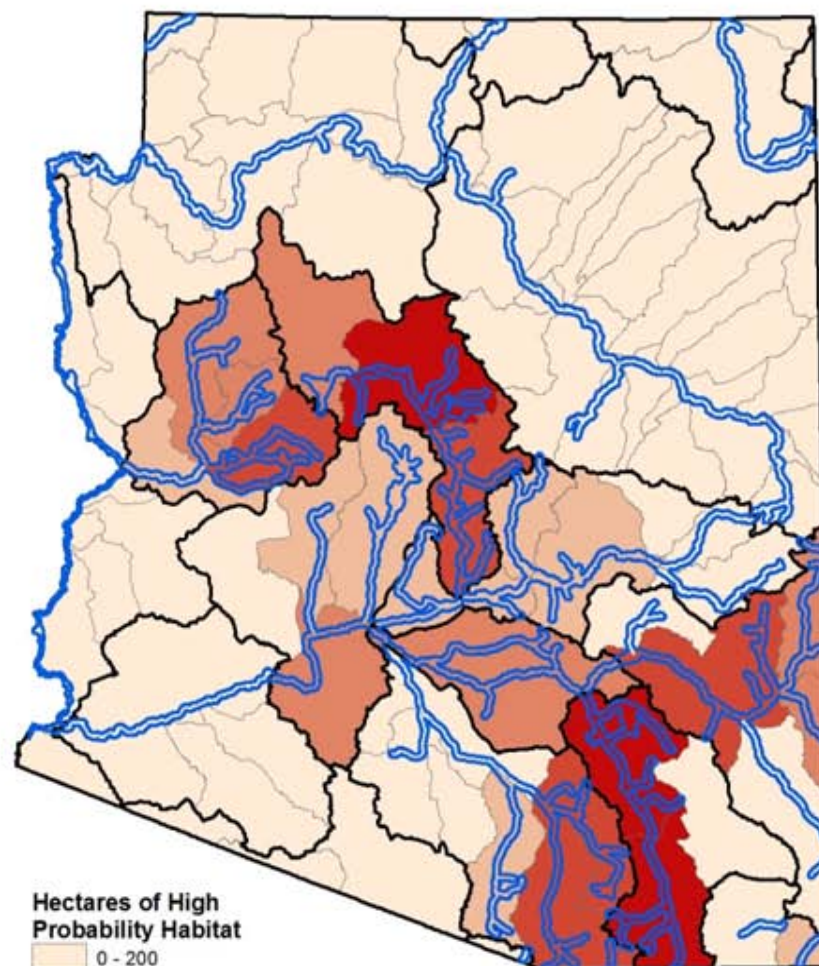
- Greater thematic resolution (includes forest, mesquite, invasive classes)
- High producer's accuracy value

| Habitat Spatial Extent            |                                                |
|-----------------------------------|------------------------------------------------|
| Model                             | Square Kilometers of High Probability Habitat* |
| <b>NLCD</b>                       | <b>387</b>                                     |
| SWReGAP                           | 364                                            |
| Conservative                      | 342                                            |
| <b>Moderate</b>                   | <b>324</b>                                     |
| Liberal                           | 303                                            |
| AZGF                              | 256                                            |
| *MaxEnt Probability Value 0.5 - 1 |                                                |

# A. Hectares of High Probability Habitat per 8 Digit HUC - MA Model



# B. Hectares of High Probability Habitat per 8 Digit HUC - NLCD Model



# NLCD vs. MA

## NLCD

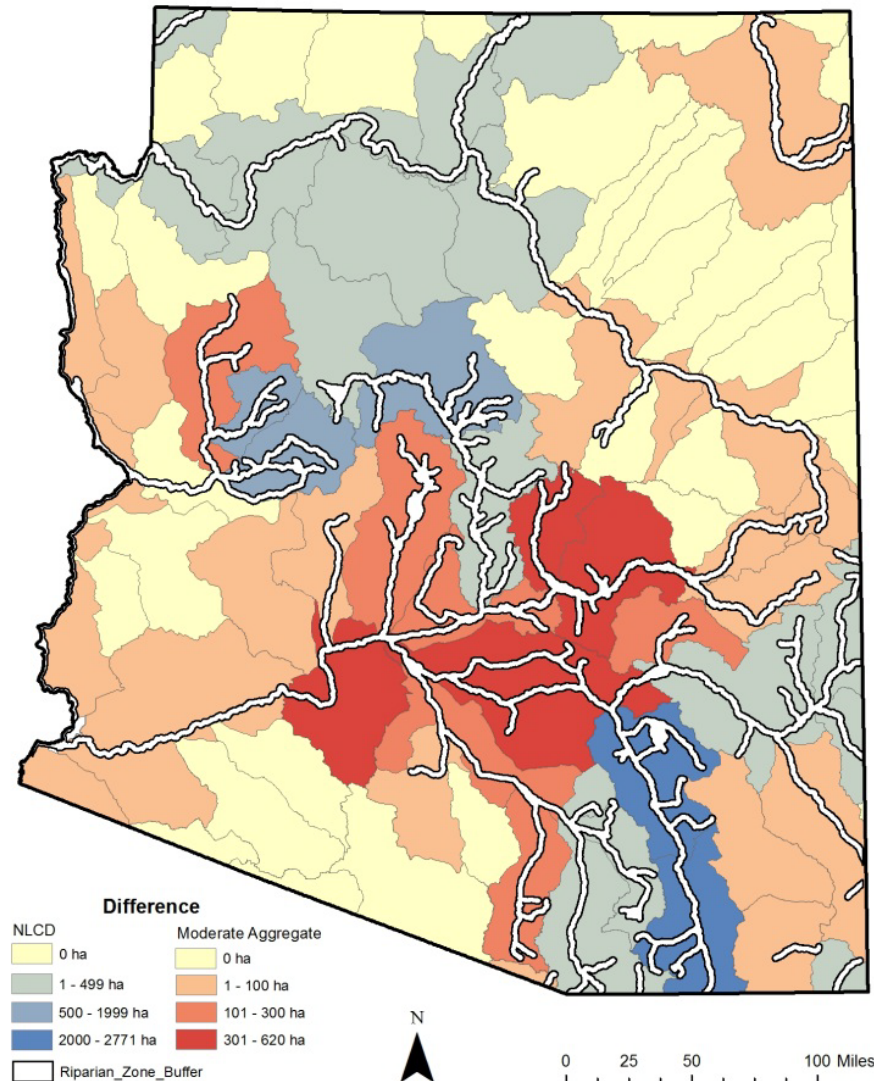
| Variable    | Percent contribution | Permutation importance |
|-------------|----------------------|------------------------|
| nlcd_for480 | 63.2                 | 8.9                    |
| dem_final   | 10.8                 | 50                     |

## MA

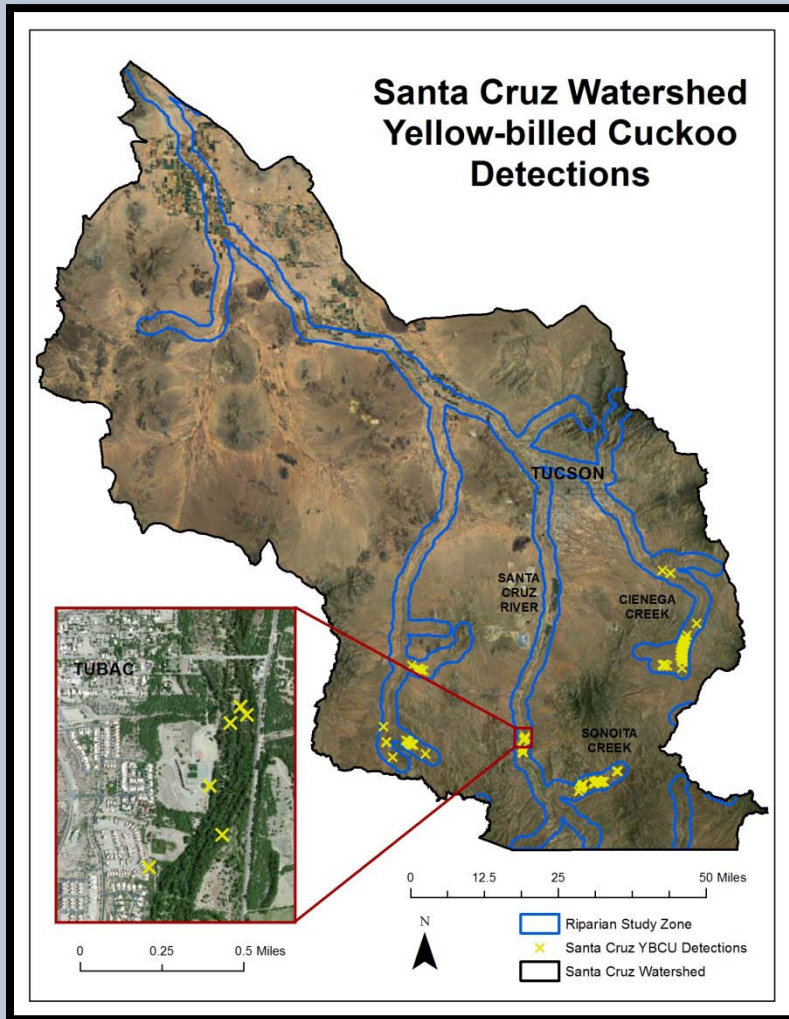
| Variable    | Percent contribution | Permutation importance |
|-------------|----------------------|------------------------|
| ndvi_480    | 23.5                 | 2.9                    |
| mod_for480  | 16.7                 | 9.8                    |
| dem_final   | 15.7                 | 57.1                   |
| mod_mesq480 | 9.9                  | 6.3                    |

- Forest drives the NLCD model
  - More prominent on the San Pedro, Santa Cruz, and the Verde
- The MA model has a greater contribution of variables
  - Mesquite/Invasive is not mapped by NLCD and is more present on the Salt and Gila Rivers

## Moderate Aggregate vs. NLCD Difference in Hectares



# YBCU Models of the Santa Cruz Watershed (SCW)



- Used both the NLCD and MA to develop habitat model for just SCW
  - YBCU detections in SCW ( $n = 139$ ) mostly on the upper Santa Cruz River, Cienega Creek, and Sonoita Creek
- Compared to SCW habitat from statewide NLCD and MA models

# What is driving each model?

## 1) Location of bird detections

- Statewide vs. Santa Cruz Watershed
- What vegetation classes are found in each location?

## 2) Most important MaxEnt Variable

- Which variable has the greatest contribution to the model

## 3) The accuracy/validity of the model

- The MaxEnt AUC value
- NLCD = 0.948; MA = 0.941

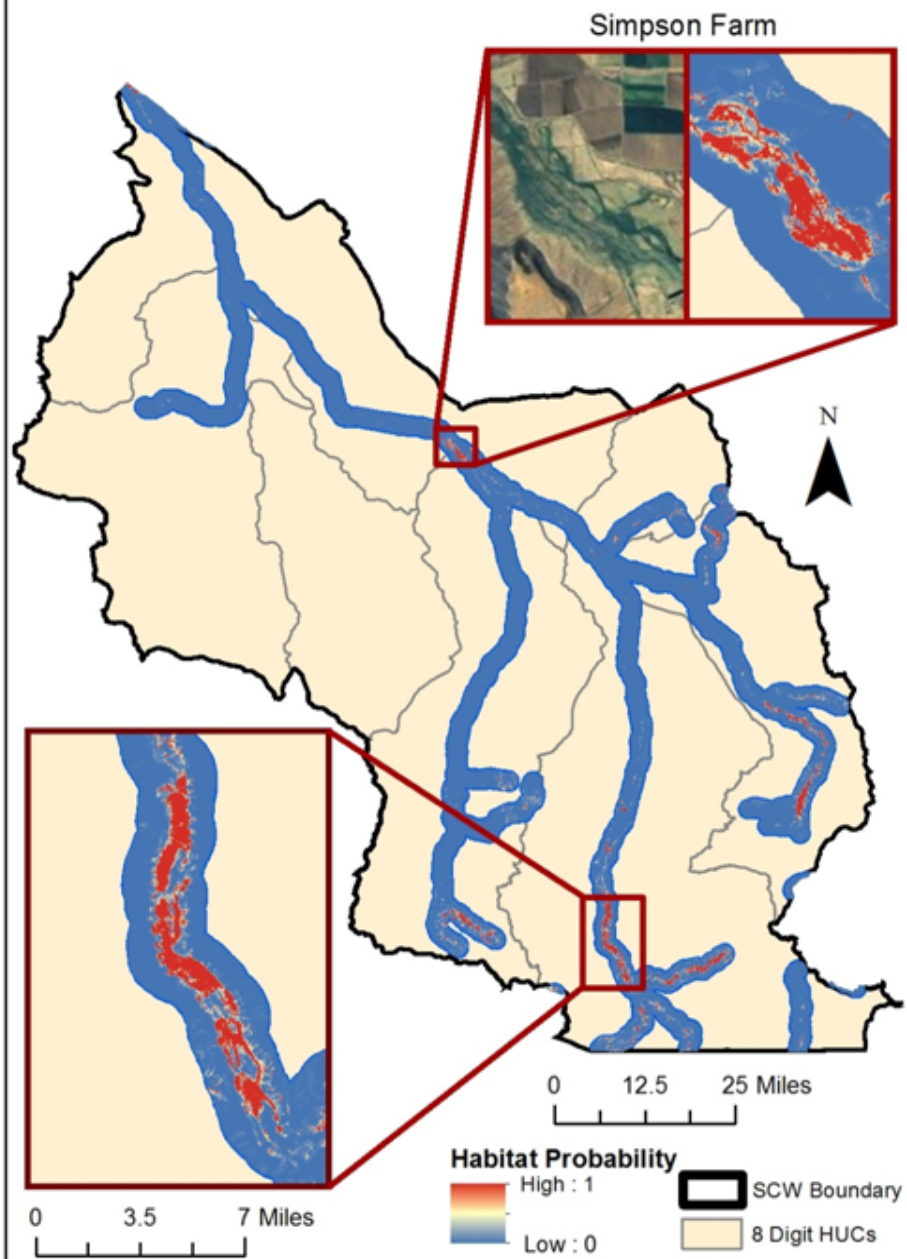
| Variable        | Percent contribution | Permutation importance |
|-----------------|----------------------|------------------------|
| nlcd_for480     | 42.6                 | 18                     |
| dem_final       | 20                   | 45.3                   |
| nlcd_full       | 14.3                 | 7.7                    |
| tpi_480         | 7.9                  | 7.8                    |
| ndvi_final      | 5.7                  | 9.8                    |
| nlcd_ag480      | 4.9                  | 6                      |
| ndvi_480        | 3.4                  | 4.4                    |
| nlcd_wet480     | 1.1                  | 0.9                    |
| santa_cruz_mask | 0                    | 0                      |

Santa Cruz NLCD Model

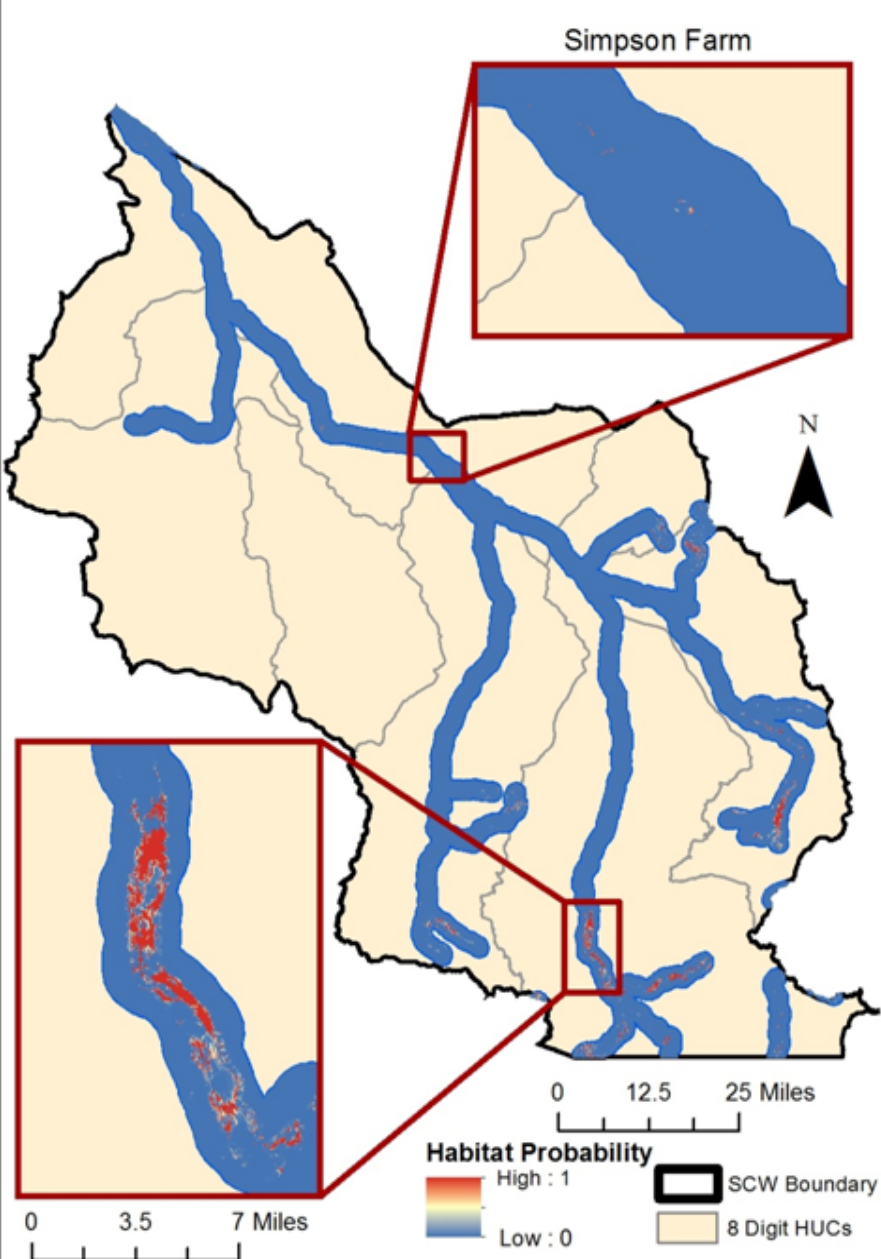
| Variable        | Percent contribution | Permutation importance |
|-----------------|----------------------|------------------------|
| mod_mesq480     | 21.8                 | 1.4                    |
| dem_final       | 21.8                 | 82.2                   |
| mod_for480      | 16.3                 | 0                      |
| ndvi_final      | 9.4                  | 3                      |
| mod_forest      | 7.6                  | 0.4                    |
| ndvi_480        | 5                    | 4.1                    |
| tpi_480         | 4.8                  | 4                      |
| mod_invas480    | 3.9                  | 1.2                    |
| mod_ag480       | 3.9                  | 2.2                    |
| mod_wet480      | 2.4                  | 1.3                    |
| mod_mesquite    | 2.3                  | 0.1                    |
| mod_agriculture | 0.6                  | 0                      |
| mod_invasive    | 0.2                  | 0                      |
| mod_wet         | 0                    | 0                      |
| santa_cruz_mask | 0                    | 0                      |

Santa Cruz MA Model

# A. Habitat Probability for the SCW MA Statewide Model



# B. Habitat Probability for the SCW MA Santa Cruz Watershed Model



# Arizona and the SCW

- Accuracy vs. spatial distribution
  - Less available information in a localized model
- SCW Models have a smaller spatial extent of high probability habitat
- The statewide model is the better model for determining high probability habitat for the cuckoo
  - Simpson Farm



*Tucson Audubon Society – Simpson Farm*

# Conclusion

- Can we improve niche modeling using multi-source vegetation data sets?
  - Yes! For the most part..
  - The NLCD model was good but has potential errors with overestimating the high probability habitat
  - NLCD has loss of thematic resolution (3 classes)
  - MA has a full suite of classes (5 classes)
- There are ways to improve the model results
  - Improved mapping and classification
  - Improved observations and distribution of field detections
- Based on the model, to protect this important neotropical migrant, we need to protect these areas
  - Tucson Audubon Society Simpson Farm success story

Yellow-billed cuckoo and avian species richness

Sampling:

- 1. Vegetation
- 2. Avian point count
- 3. Cuckoo stop count
- Count

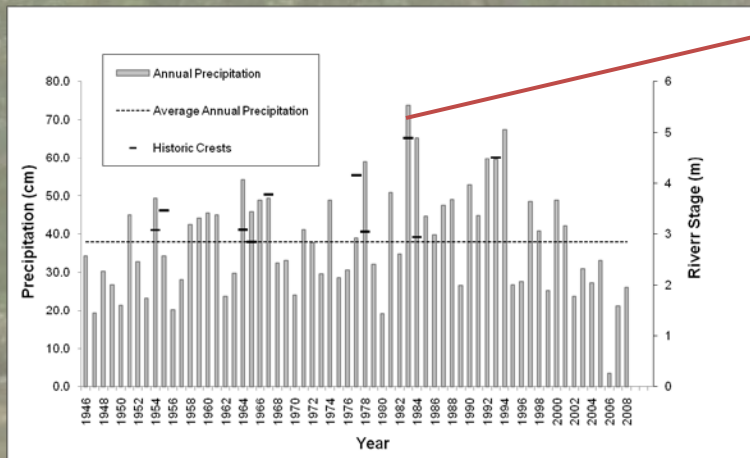
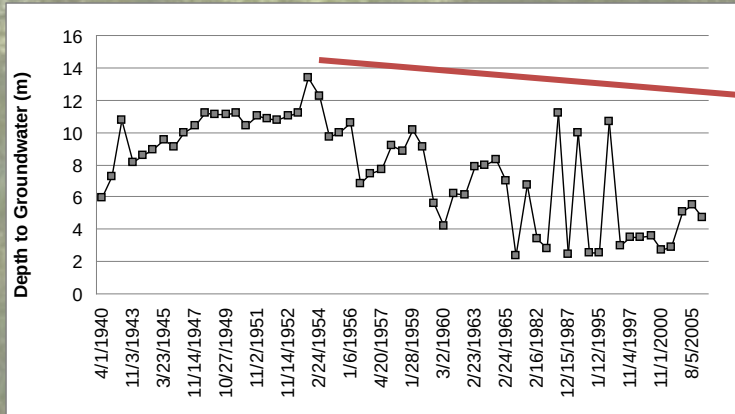


|               | Percent Catchment                                                                                                                                                                                                                                                                                             |      |       |        |        |        |        |        |        |        |        |
|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-------|--------|--------|--------|--------|--------|--------|--------|--------|
|               |                                                                                                                                                                                                                                                                                                               | 1-5% | 6-10% | 11-20% | 21-30% | 31-40% | 41-50% | 51-60% | 61-70% | 71-80% | 81-90% |
| Forest        | Cottonwood-Goodding Willow Forest<br>Cottonwood-[Velvet Mesquite-Elderberry] Forest<br>Velvet Mesquite Forest<br>Velvet Mesquite-[Elderberry-Netleaf Hackberry] Forest<br>Velvet Mesquite-Catclaw Acacia Forest<br>Tamarisk Forest                                                                            |      |       |        |        |        |        |        |        |        |        |
| Woodland      | Cottonwood-Goodding Willow Woodland<br>Cottonwood Woodland<br>Cottonwood-Goodding Willow-Tamarisk Woodland<br>Cottonwood-Velvet Mesquite Woodland<br>Velvet Mesquite Woodland<br>Velvet Mesquite-Netleaf Hackberry Woodland<br>Velvet Mesquite-Elderberry Woodland<br>Velvet Mesquite-Catclaw Acacia Woodland |      |       |        |        |        |        |        |        |        |        |
| Shrubland     | Velvet Mesquite Shrubland<br>Velvet Mesquite-Catclaw Acacia Shrubland<br>Catclaw Acacia-White Thorn Acacia Shrubland<br>Hymenoclea Shrubland<br>Seep Willow Shrubland<br>Tamarisk Shrubland                                                                                                                   |      |       |        |        |        |        |        |        |        |        |
| Tree Savanna  | Cottonwood/Native Grass Tree Savanna<br>Cottonwood/Amaranth Tree Savanna<br>Elderberry/Amaranth Tree Savanna<br>Velvet Mesquite/Native Grass Tree Savanna<br>Velvet Mesquite/Amaranth Tree Savanna<br>Velvet Mesquite/Tumbleweed Tree Savanna<br>Tamarisk/Amaranth Tree Savanna                               |      |       |        |        |        |        |        |        |        |        |
| Shrub Savanna | Velvet Mesquite/Mixed Herbaceous Shrub Savanna<br>Baccharis/Amaranth Shrub Savanna<br>Baccharis/Grass Shrub Savanna<br>Hymenoclea/Mixed Herbaceous Shrub Savanna                                                                                                                                              |      |       |        |        |        |        |        |        |        |        |
| Herbaceous    | Grass Herbaceous<br>Amaranth Herbaceous<br>Forbs Herbaceous<br>Unknown Herbaceous                                                                                                                                                                                                                             |      |       |        |        |        |        |        |        |        |        |
| Barren        | Cottonwood-Goodding Willow Strand<br>Shrub Strand<br>Herbaceous Strand                                                                                                                                                                                                                                        |      |       |        |        |        |        |        |        |        |        |

Avian Richness

Yellow-billed cuckoo

# Models of riparian vegetation response to groundwater & climate conditions



Build scenarios depicting changes in avian ecosystem services related to climate and flooding