TEXAS A&M UNIVERSITY
AGRICULTURE & LIFE SCIENCES
DEPARTMENT OF ENTOMOLOGY

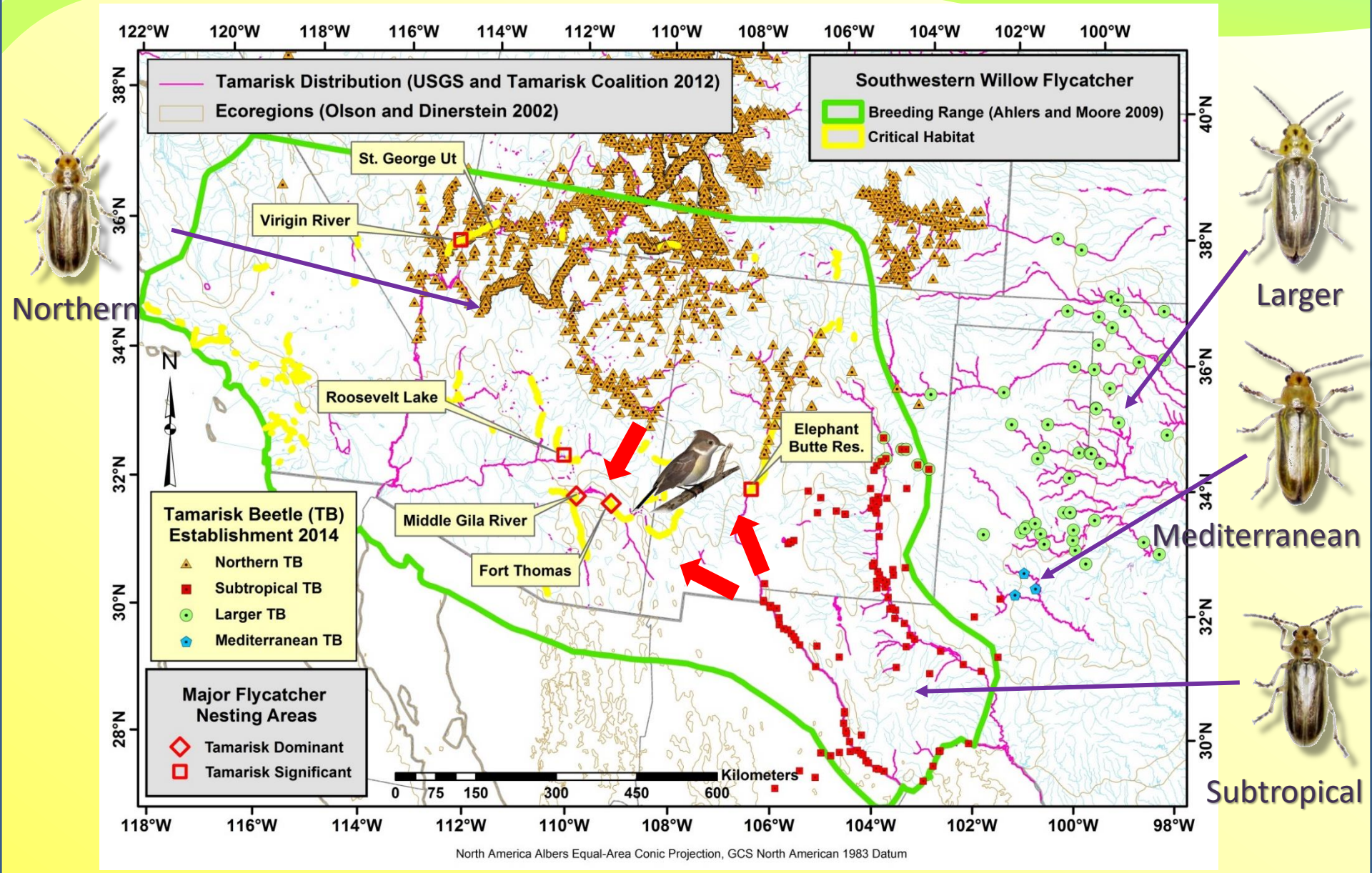
KEL
KNOWLEDGE ENGINEERING LABORATORY

Planning Site Restoration of Southwestern Willow Flycatcher Habitat with High Resolution (1m) Flycatcher Niche Models Incorporating Classification of Tamarisk, Willow & Cottonwood from Aerial Imagery

JL Tracy, RN Coulson,
Texas A&M University

17th Annual RiversEdge West
Riparian Restoration Conference
5 February, 2019
Phoenix, Arizona

Flycatcher and Tamarisk Beetle Ranges- 2014



Northern

Larger

Mediterranean

Subtropical

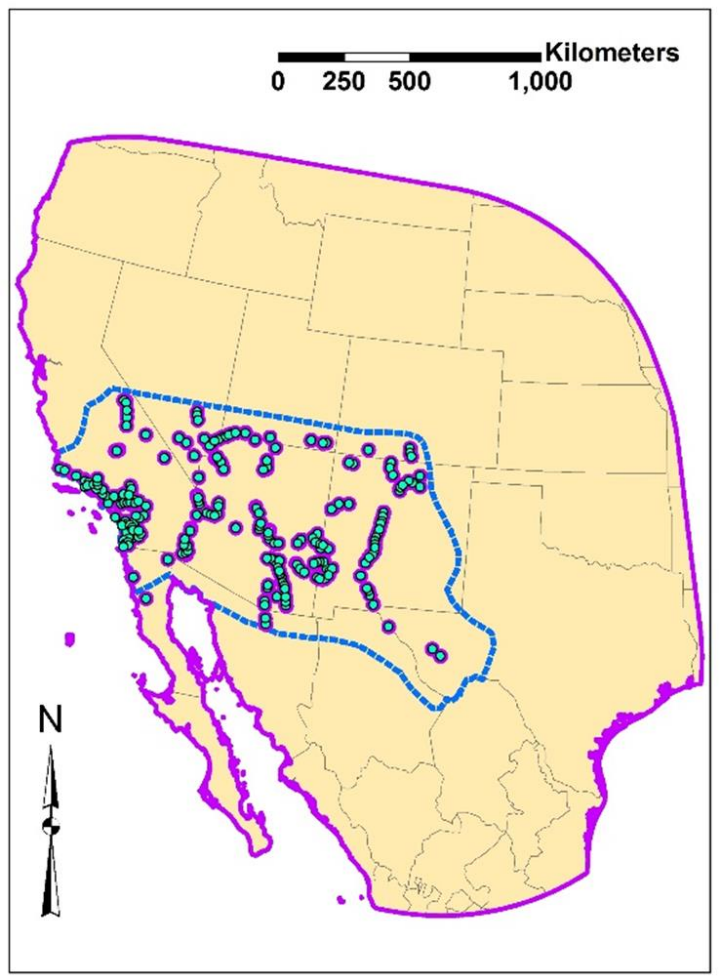
Effect of tamarisk beetle defoliation on federally endangered SW Willow Flycatcher, St. George, UT

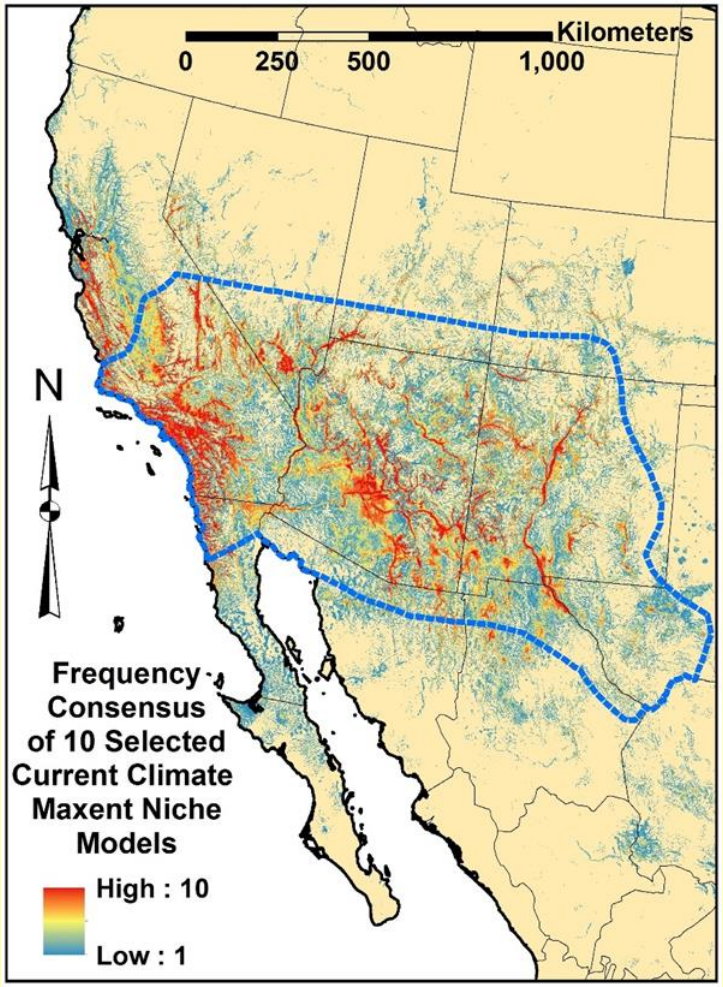
- First year of complete defoliation -2009
  - Nest success of 13%; = 75% drop from typical 54% nest success
- Second year of complete defoliation - 2010
  - Nesting sites switched to primarily willows
  - Nest success of 30%

Rapid Tamarisk beetle defoliation

(McLeod 2011)

Southwestern Willow Flycatcher
Coarse Resolution (1km)
MaxEnt Ecological Niche Model
(Tracy et al. in prep.)

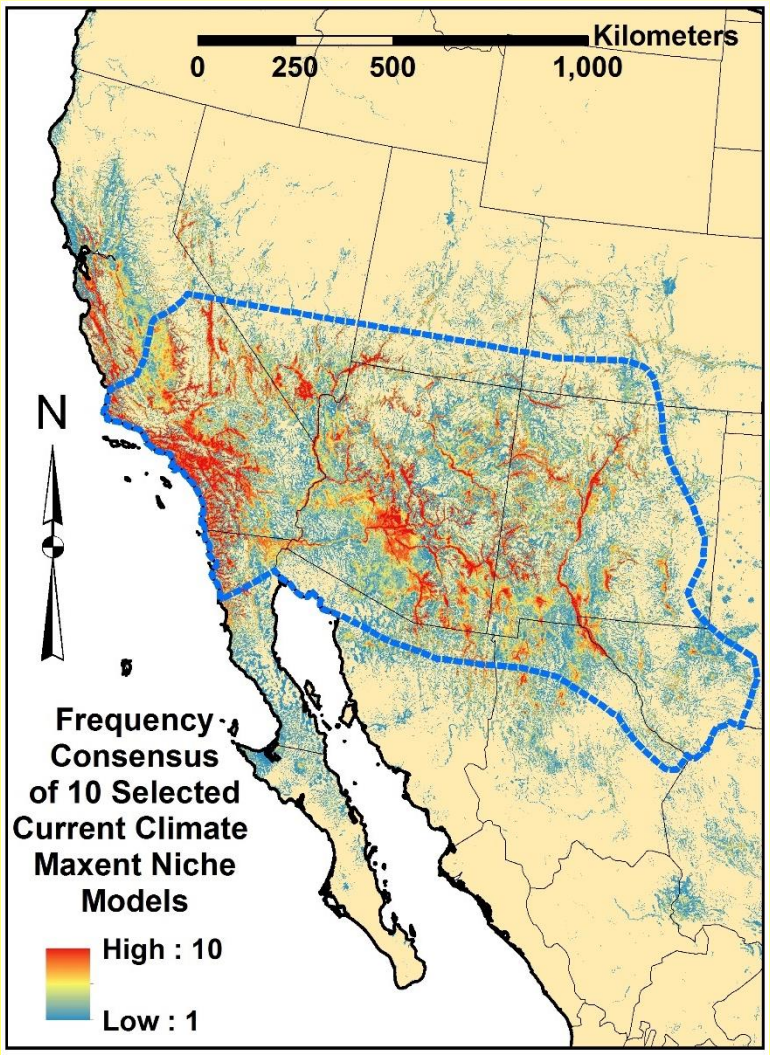




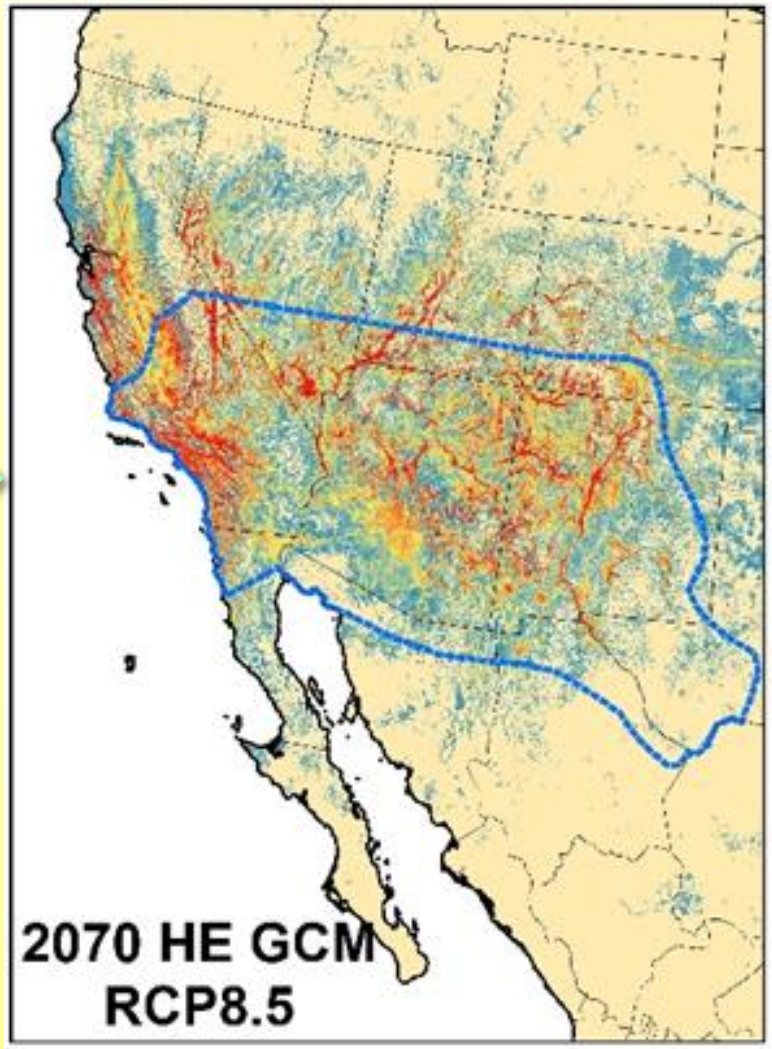
Southwestern Willow Flycatcher MaxEnt Ecological Niche Model

(Tracy et al. in prep.)

Historical

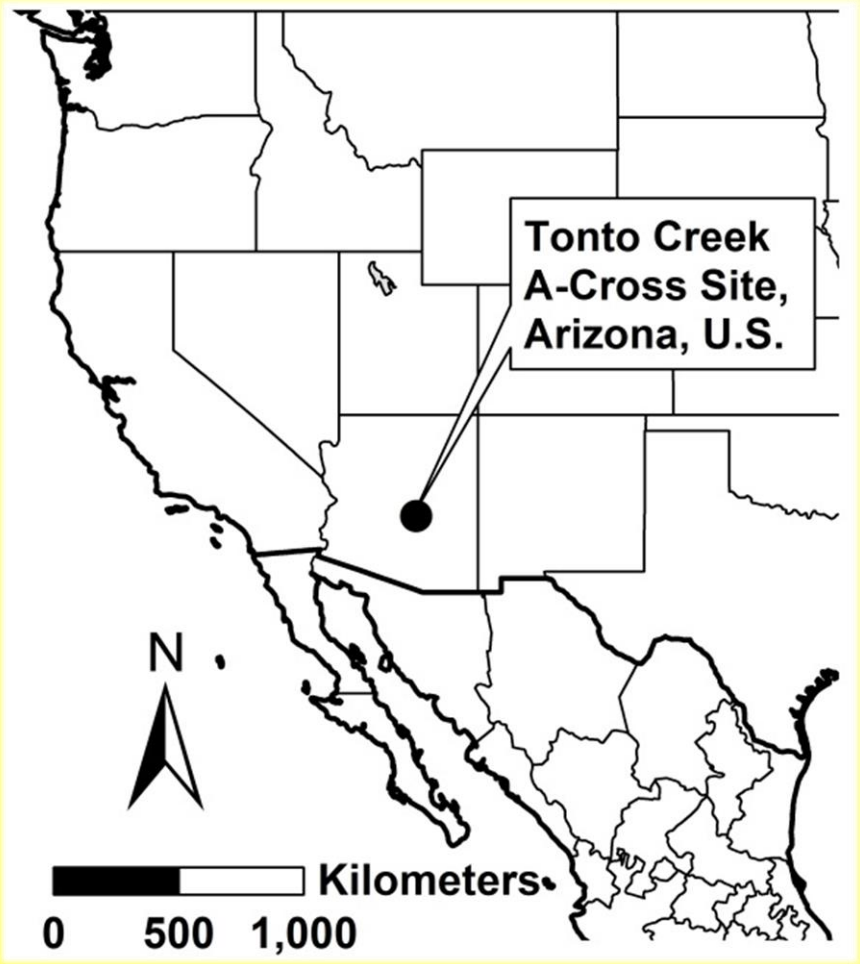


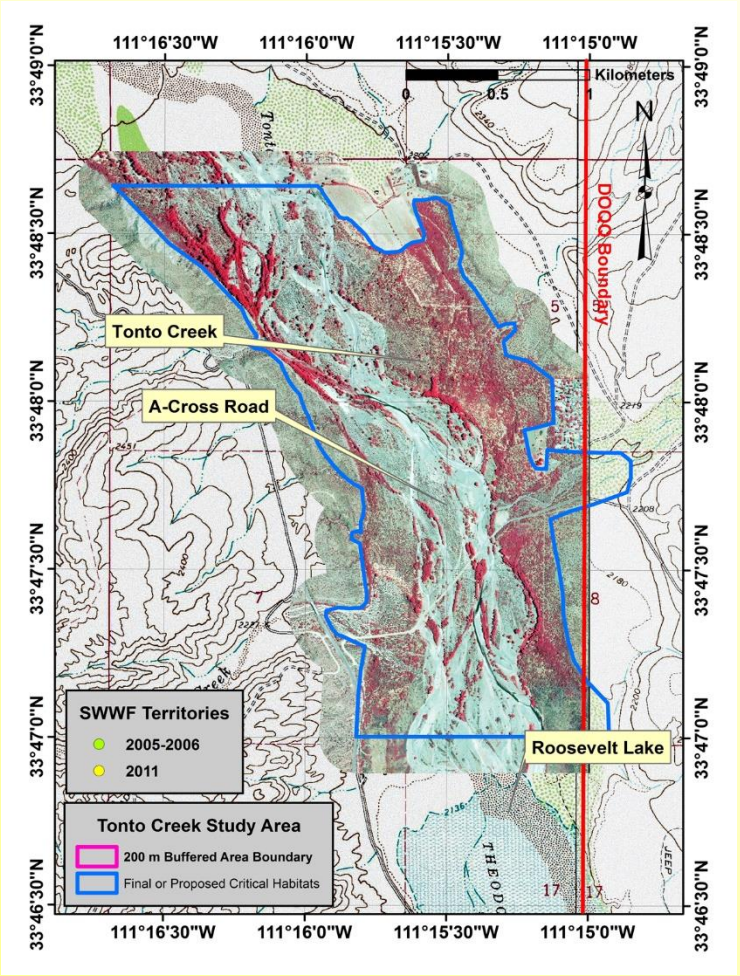
Future 2017 High CO_2



High Resolution (1 m) Random Forest Classification of Tamarisk, Willows, and Cottonwood using Random Subset Feature Selection

Tonto Creek A-Cross Site, Arizona

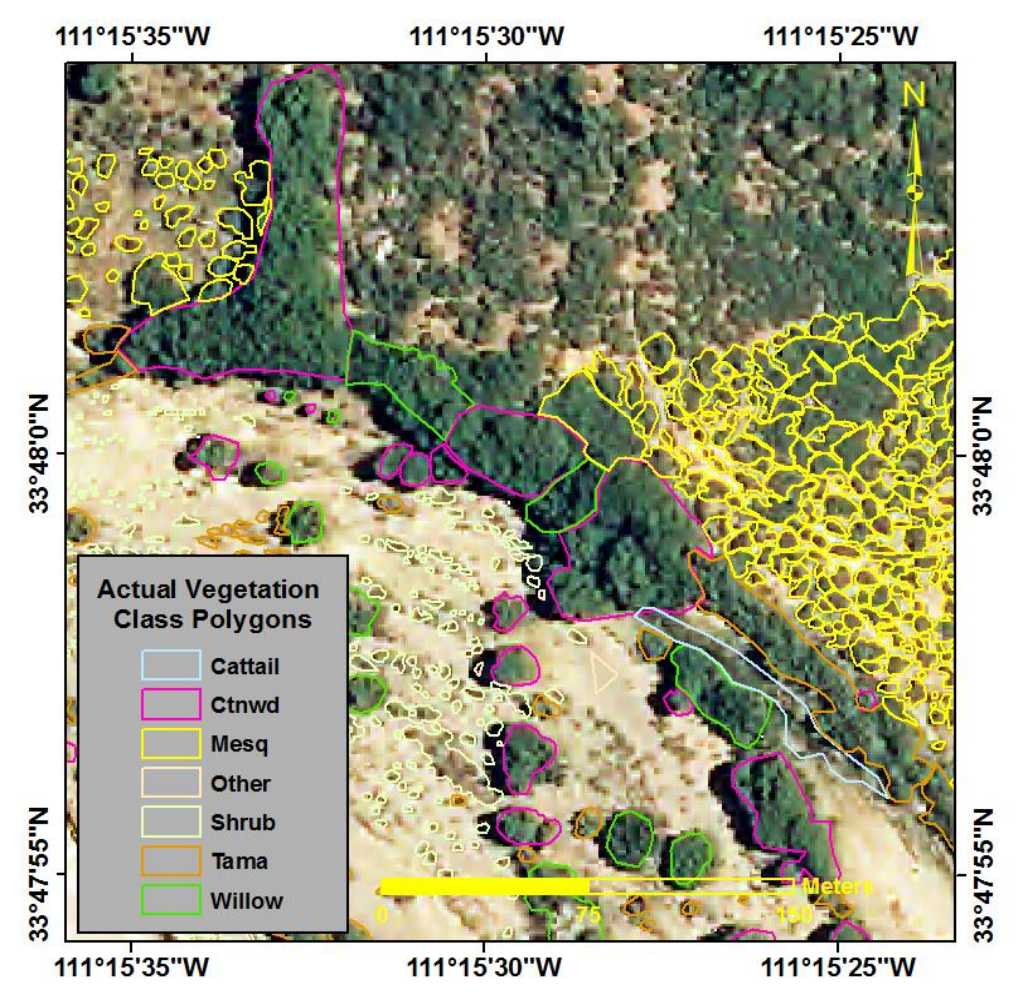




Random Forest Classification using Random Subset Feature Selection

6 June, 2013, leaf on USDA National Agricultural Imagery Program Digital Orthophoto Quarter Quad (NAIP DOQQ)

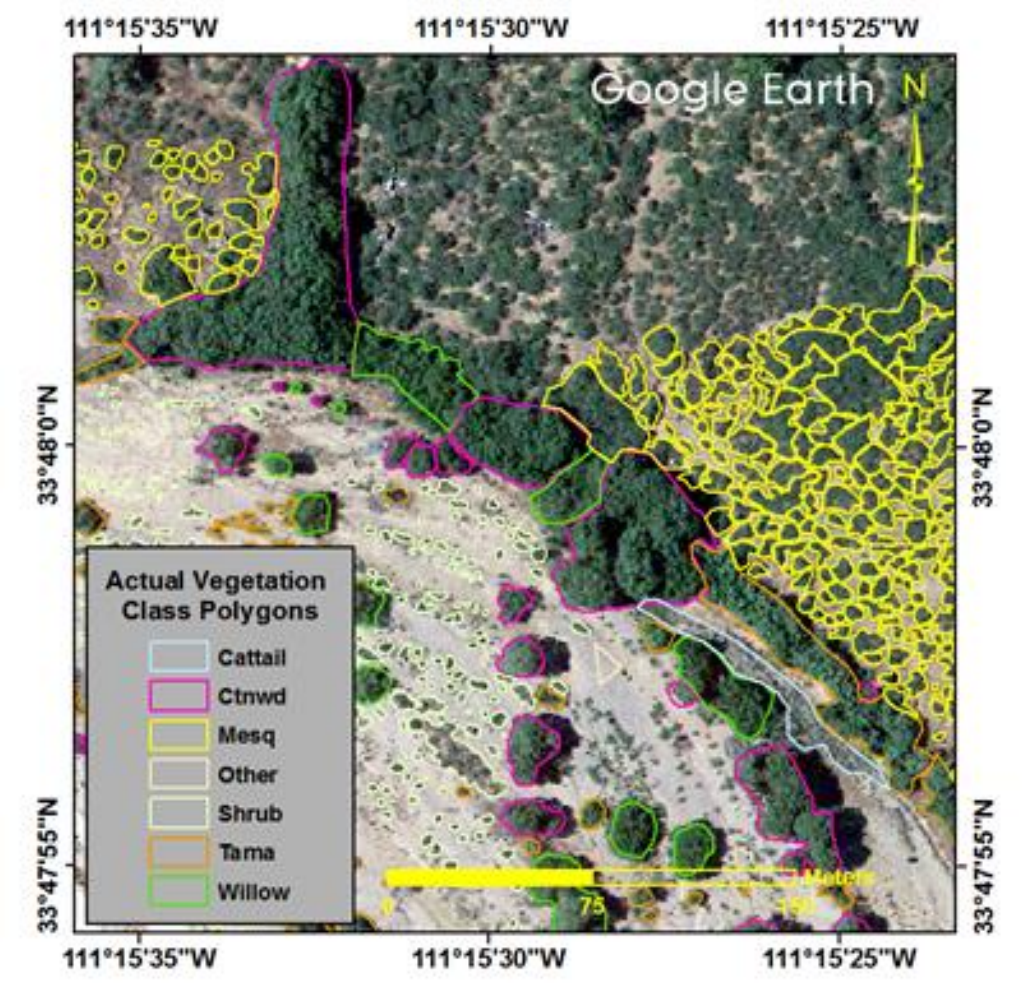
Red
Green
Blue
NIR



Random Forest Classification using Random Subset Feature Selection

5 June, 2012, leaf on Google Imagery

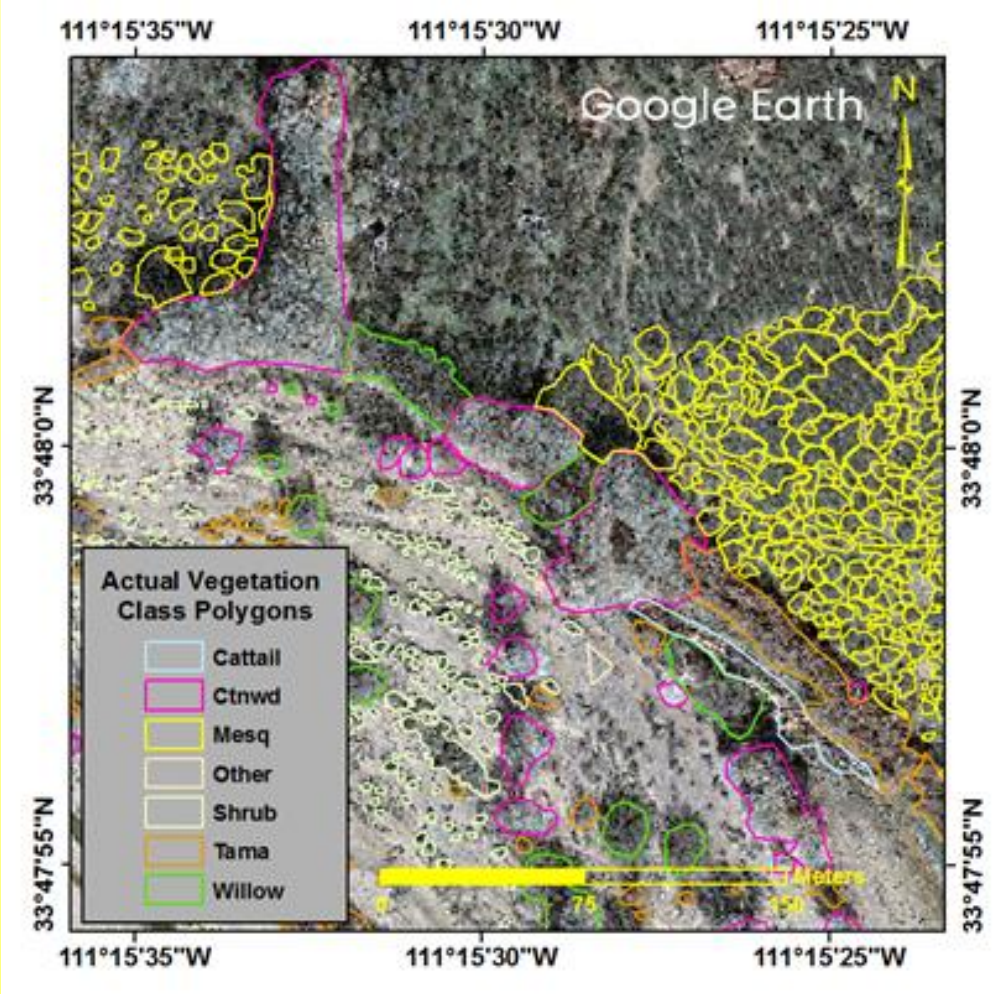
Red
Green
Blue



Random Forest Classification using Random Subset Feature Selection

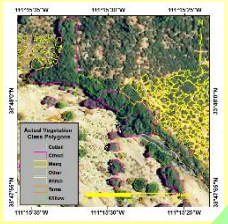
7 January, 2014, leaf off Google Imagery

Red
Green
Blue

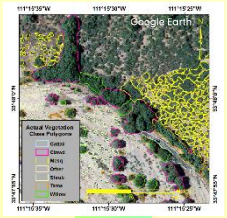


Random Forest Classification using Random Subset Feature Selection

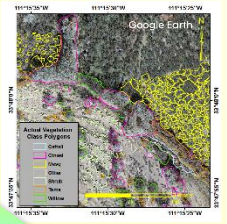
6 June, 2013, leaf on USDA DOQQ



5 June, 2012, leaf on Google Imagery



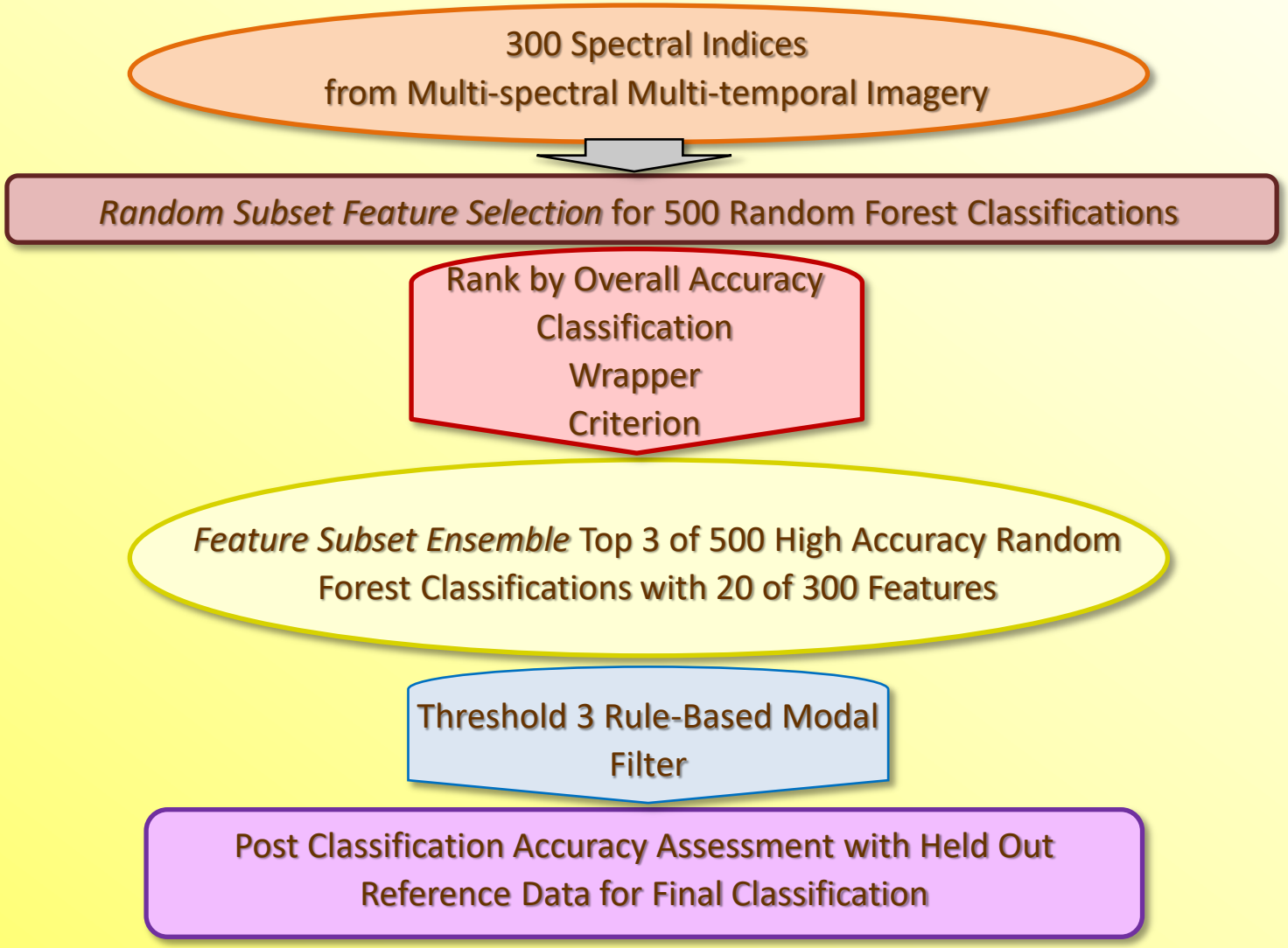
7 January, 2014, leaf off Google Imagery



300 Spectral Indices

- **10 Spectral Bands** (e.g., Blue June 1012, *BLUEJN12*)
- **70 Spectral Band Texture Indices** (e.g., Red Jan 2014 2nd Order Dissimilarity Texture in 17x17 window, *REDJA14-2DIS17*)
- **100 Single Pixel Spectral Indices** (e.g., Blue Red, Green Added Band Normalized Difference Index 2012; (Blue + Red – 2Green)/(Blue + Red + 2Green); *BRGANDI12*)
- **120 Single Pixel Spectral Index Texture Indices** (e.g., Red Blue Normalized Difference Index 2012 2nd Order Variance Texture in 17x17 window; (Red + Blue)/(Red – Blue); *RBNDI12_2VAR17*)

Random Forest Classification using Random Subset Feature Selection

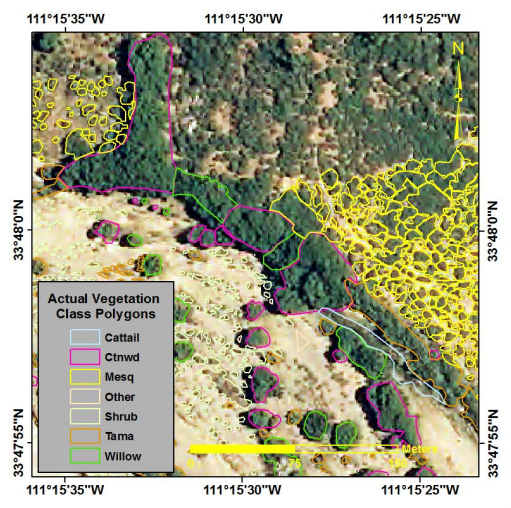


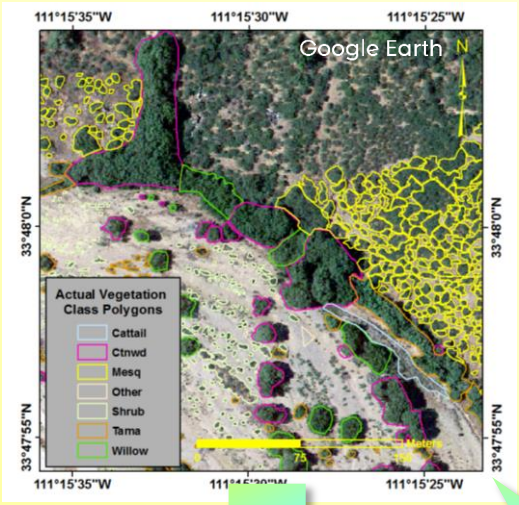
Random Forest Classification using Random Subset Feature Selection

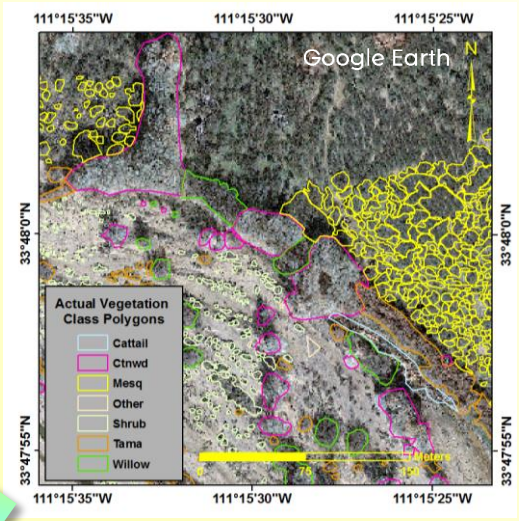
6 June, 2013, leaf on USDA DOQQ

5 June, 2012, leaf on Google Imagery

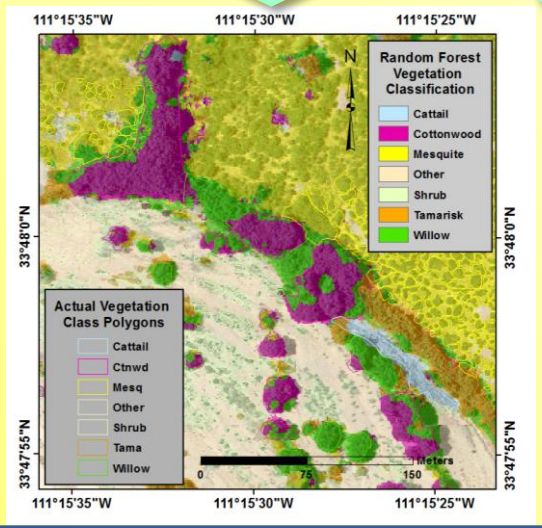
7 January, 2014, leaf off Google Imagery





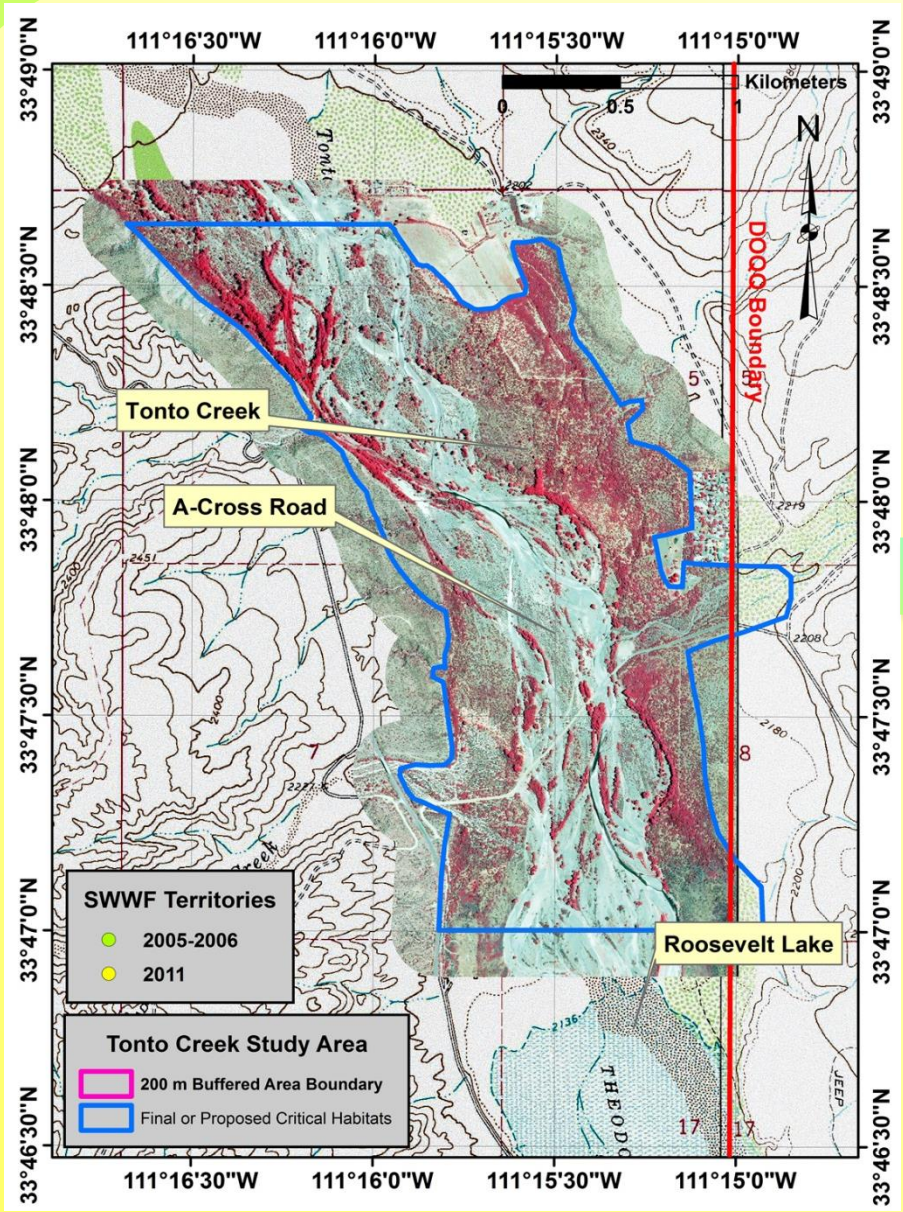


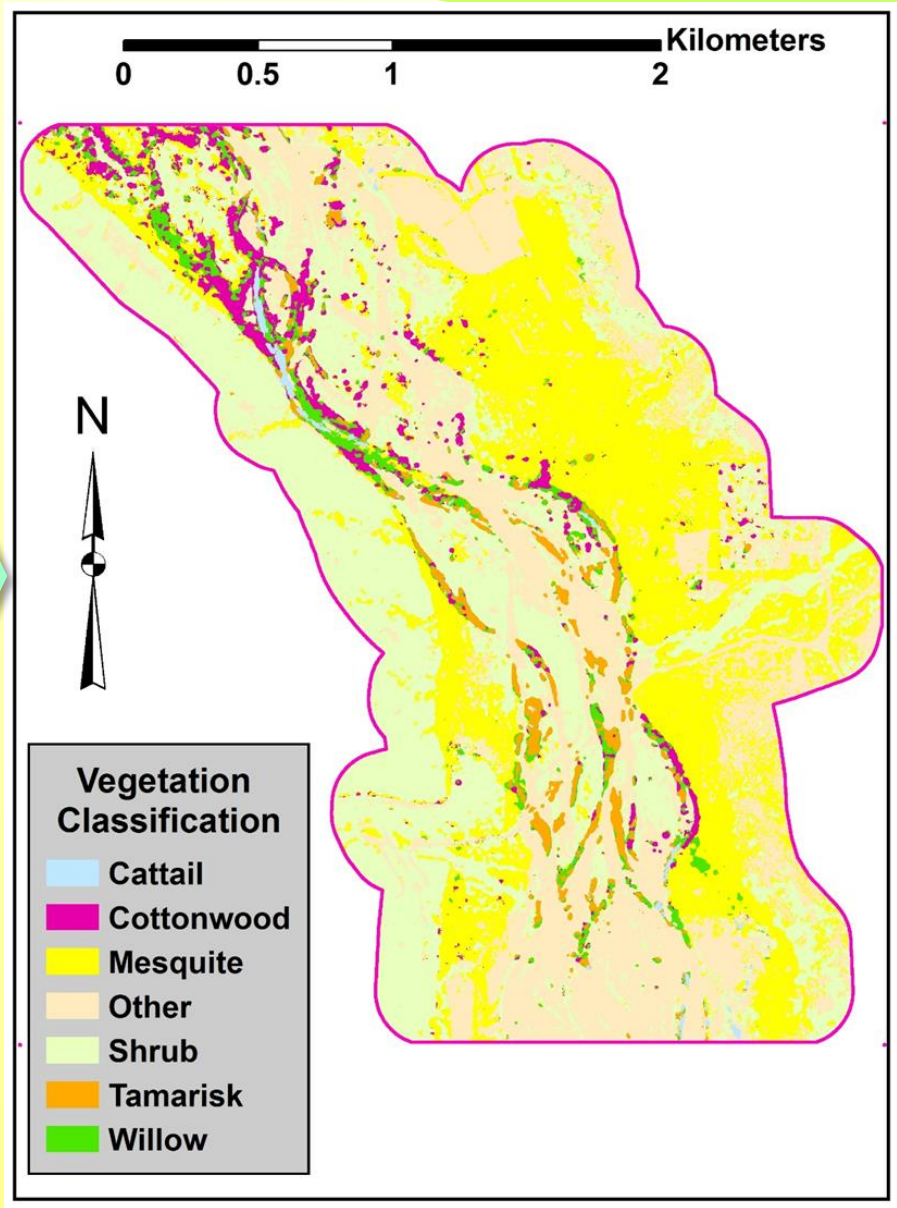
Majority Vote Feature Subset Ensemble for Top Accuracy 3 of 500 Random Forest Classifications using Random Sets of 20 of 300 Spectral Indices



Threshold 3 Rule-Based Modal Filter (Modification of Adaptive Majority Filter by Kim (1996)

Random Forest Classification using Random Subset Feature Selection





Riparian Vegetation Classification Accuracy

Confusion Matrix for Riparian Vegetation Classification

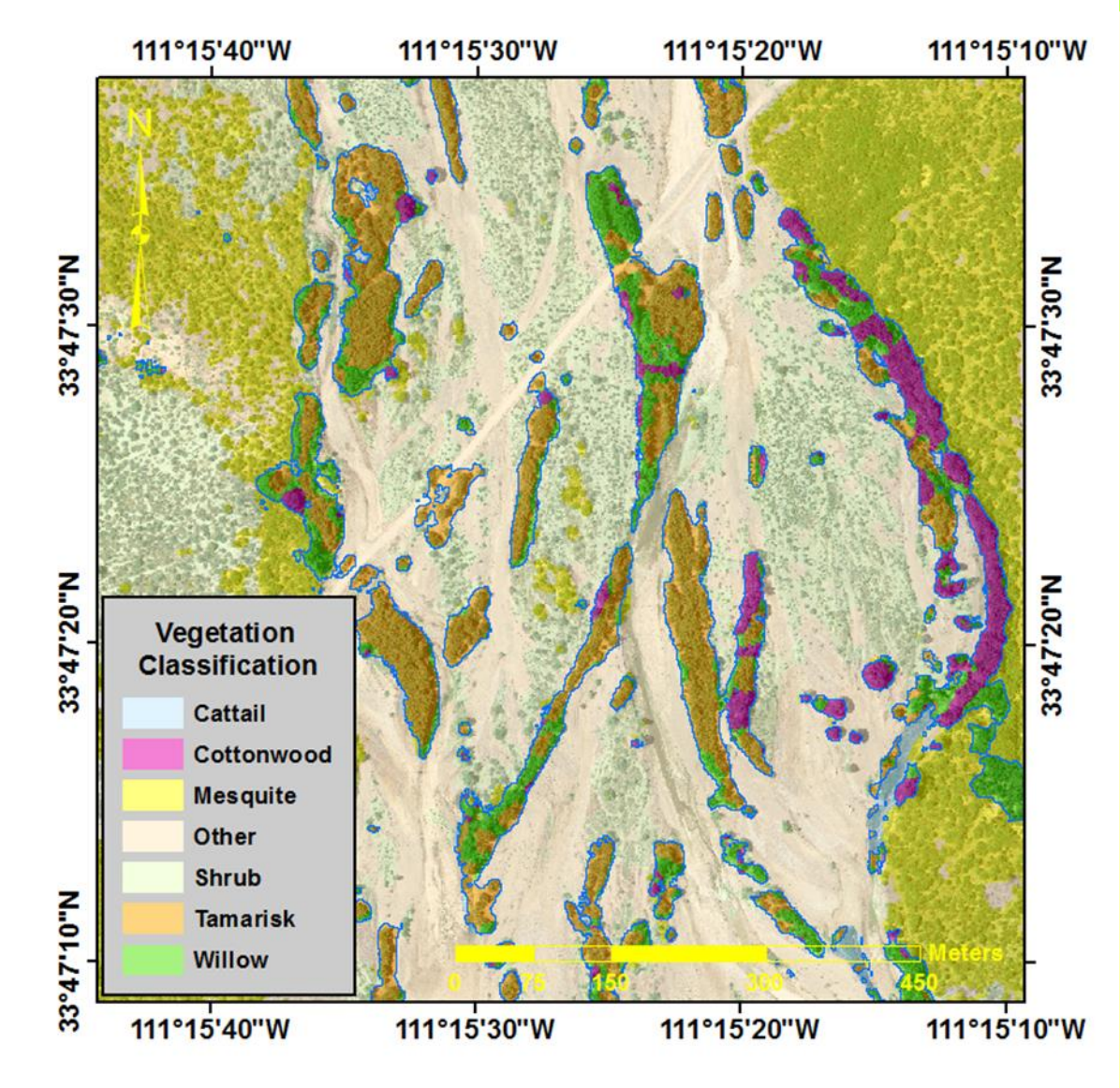
		Reference Data								
		Cattail	Fremont Cottton-wood	Velvet Mesquite	Other	Shrub	Tamarisk	Good-ding's Willow	Total	User's Accu-racy
Classification Data	Cattail	24	0	0	1	0	0	0	25	0.96
	Fremont Cottton-wood	0	27	0	2	0	0	1	30	0.90
	Velvet Mesquite	0	1	28	1	1	0	0	31	0.90
	Other	0	0	0	71	0	0	0	71	1.00
	Shrub	0	1	1	7	24	0	0	33	0.73
	Tamarisk	2	2	0	1	0	27	2	34	0.79
	Goodding's Willow	1	0	1	3	0	4	21	30	0.70
	Total	27	31	30	86	25	31	24	222	254
	Producer's Accuracy	0.89	0.87	0.93	0.83	0.96	0.87	0.88	254	222/ 254= 0.87

Overall Accuracy: 0.87

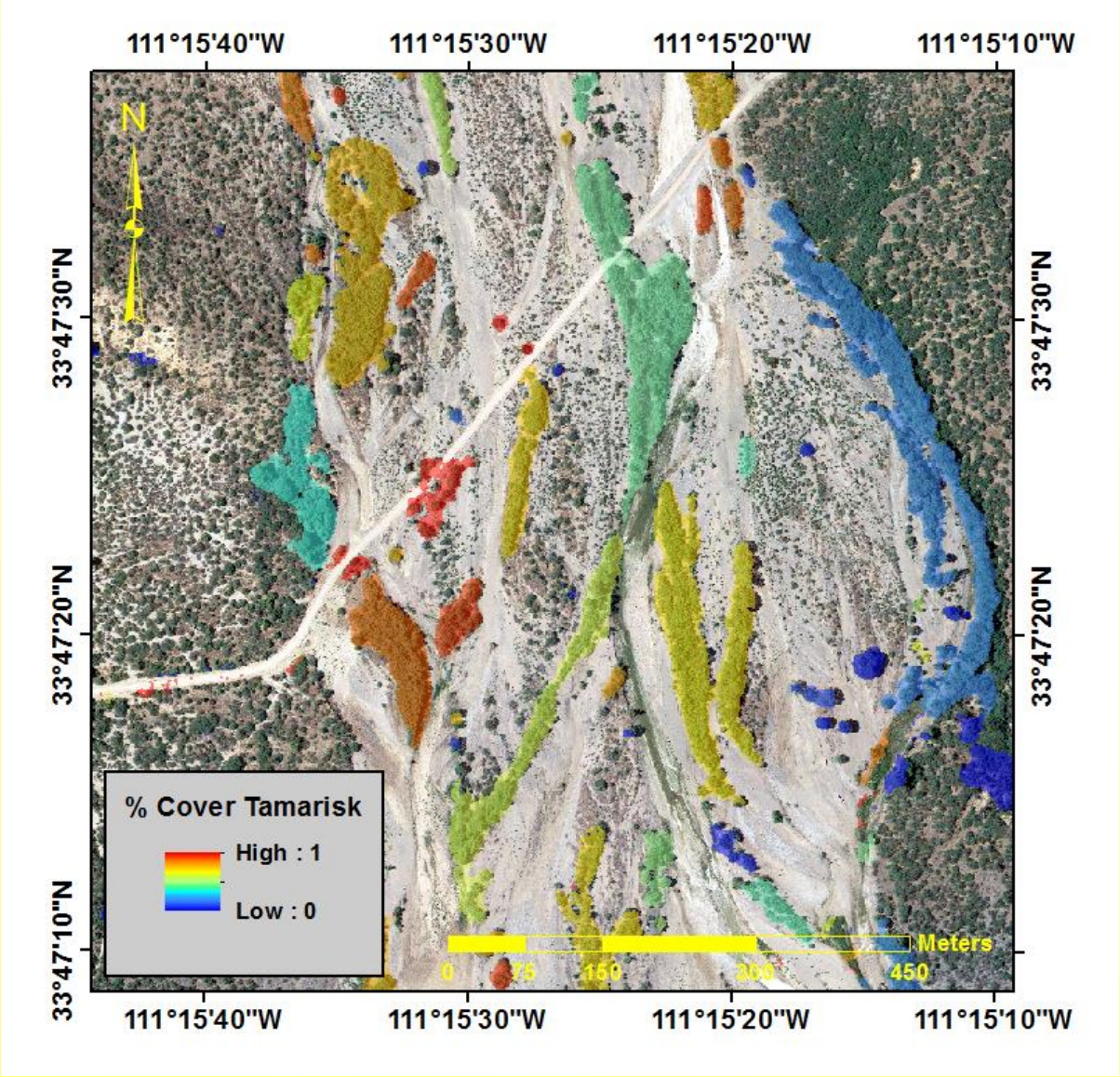
Kappa: 0.85

Overall TSS: 0.75

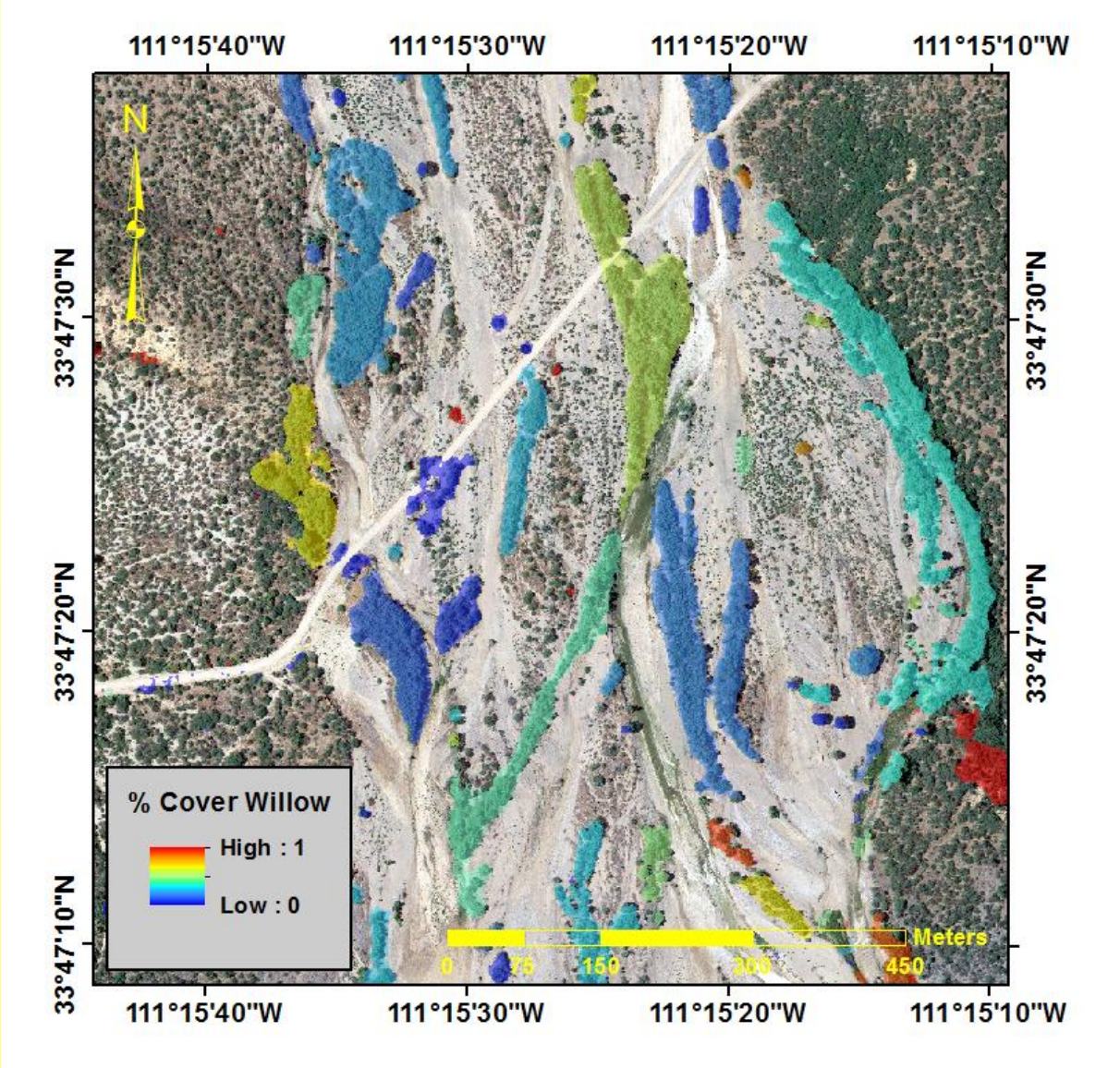
Classified Patches of Tamarisk/Willow/Cottonwood Riparian Woodlands



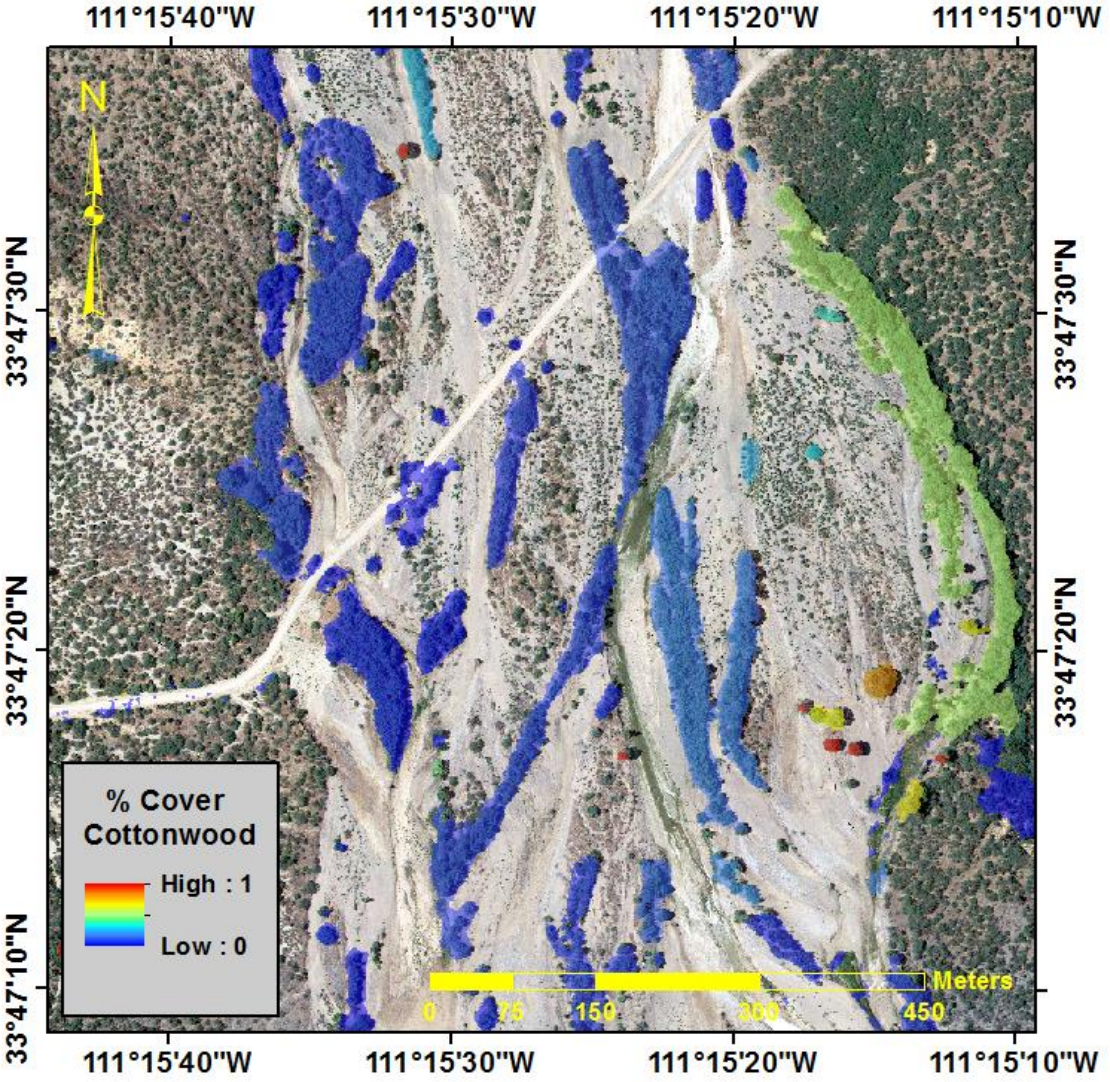
Percent Tamarisk per Riparian Woodland



Percent Willow per Riparian Woodland

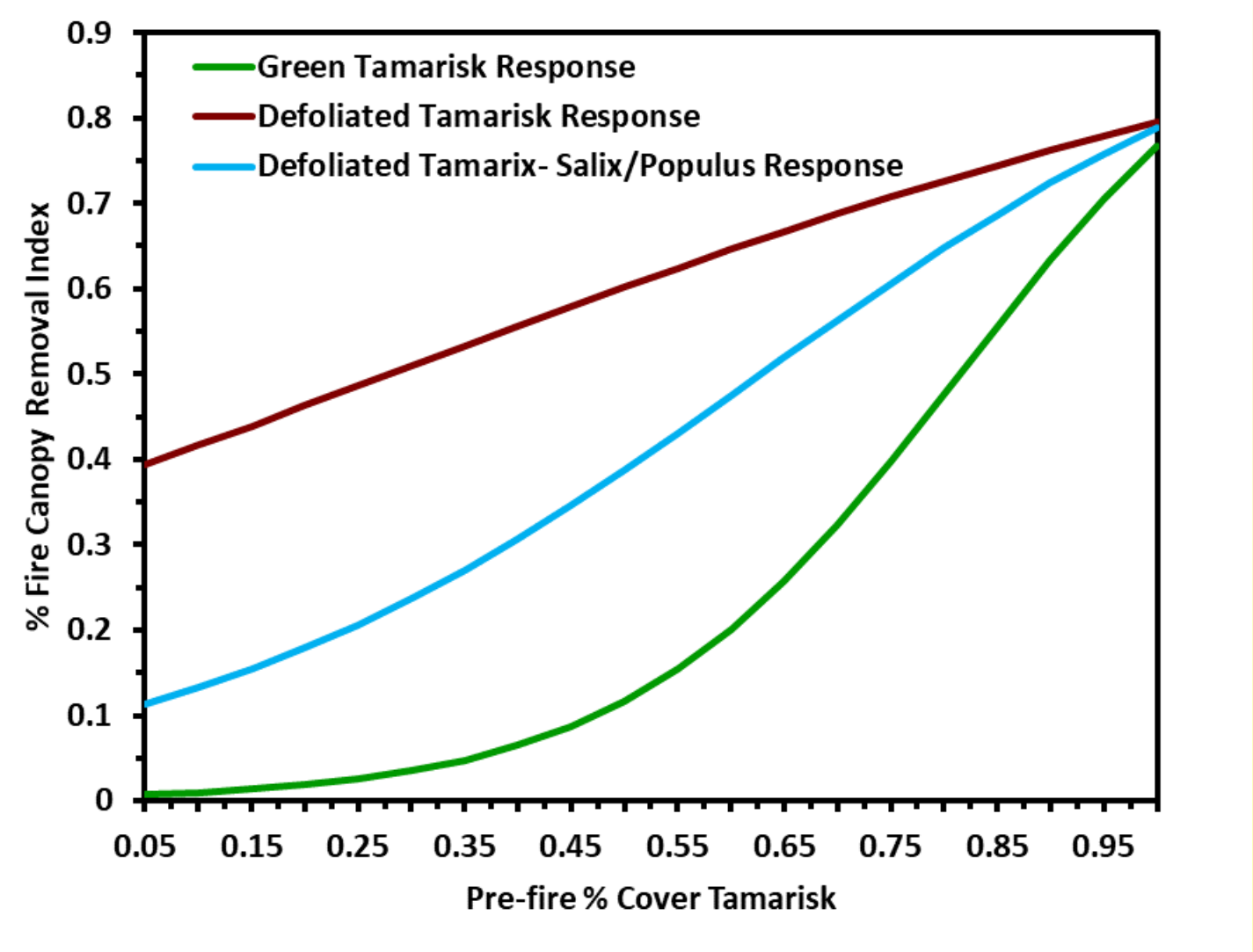


Percent Cottonwood per Riparian Woodland

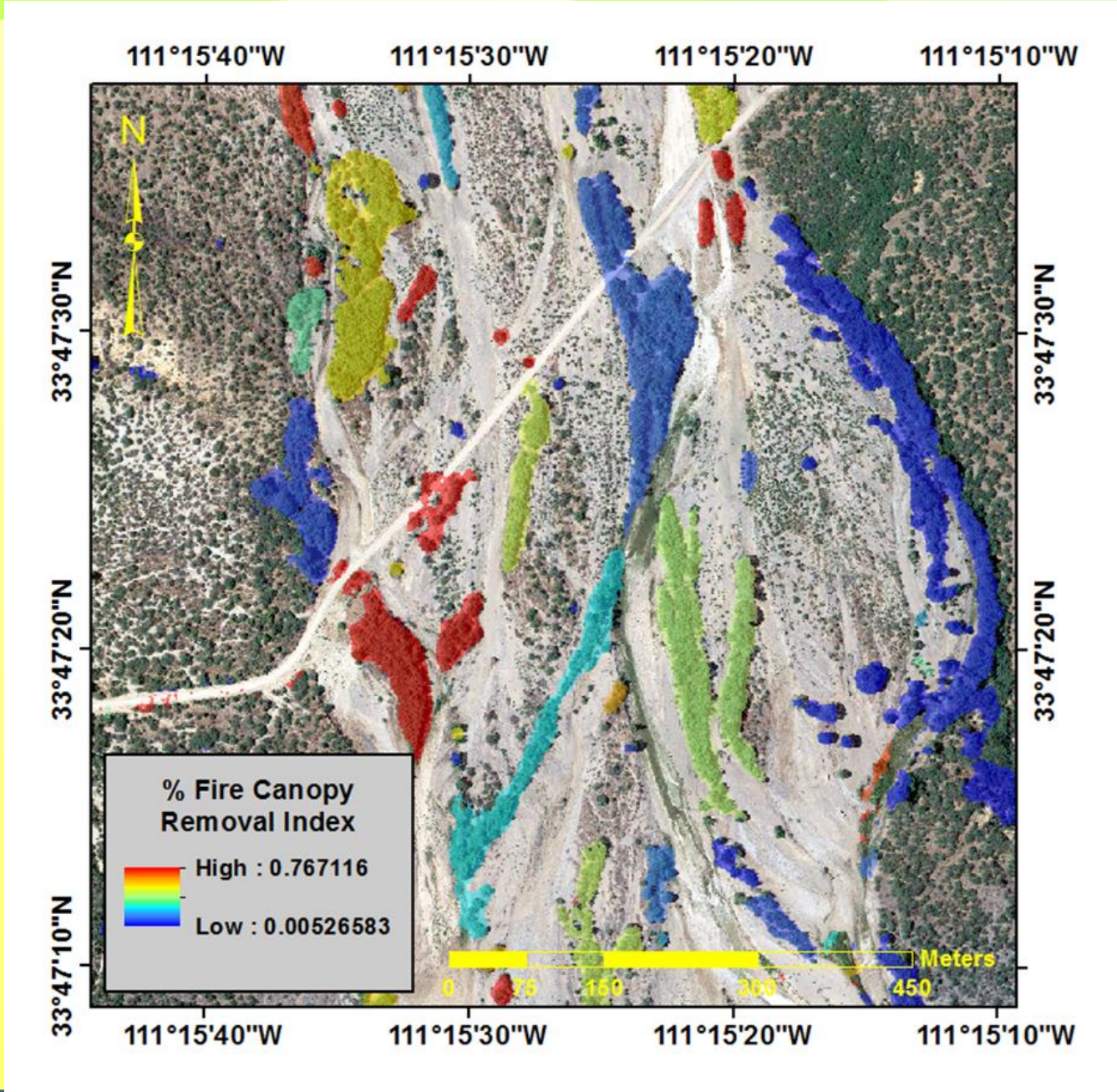


% Fire Canopy Removal Index versus Pre-Fire % Cover Tamarisk

(Gail Drus)

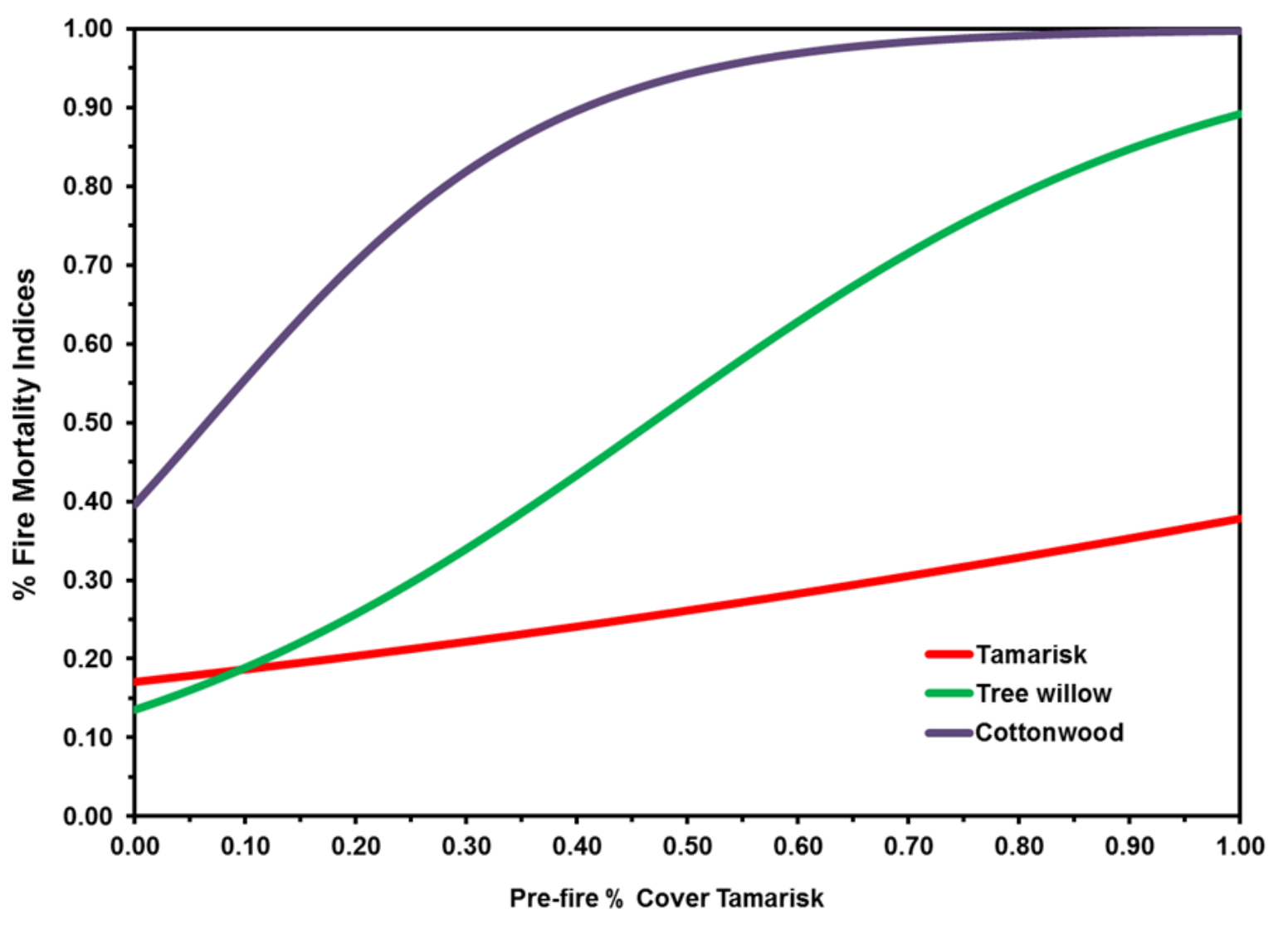


% Fire Canopy Removal Index – with Beetle Defoliation



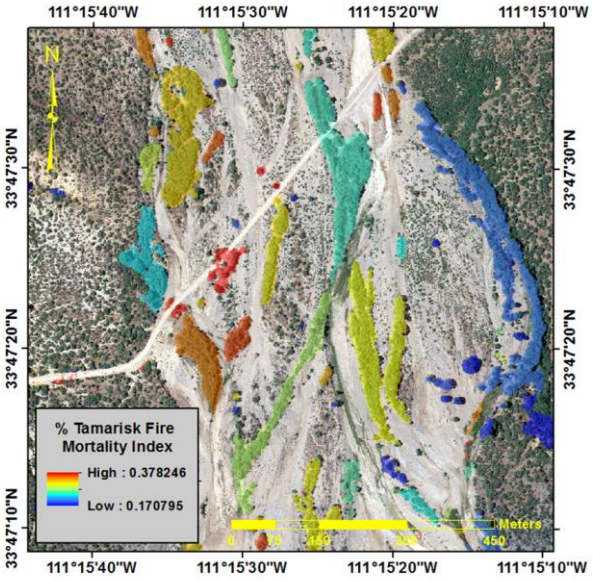
% Fire Mortality Index versus Pre-Fire Cover Tamarisk

(Gail Drus)

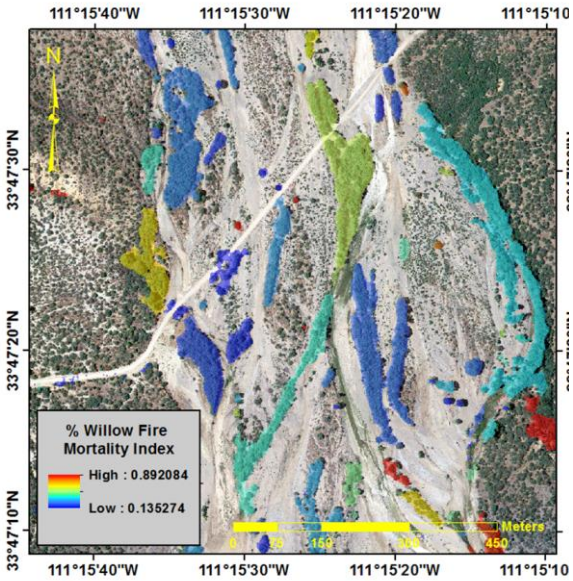


% Fire Mortality Indices

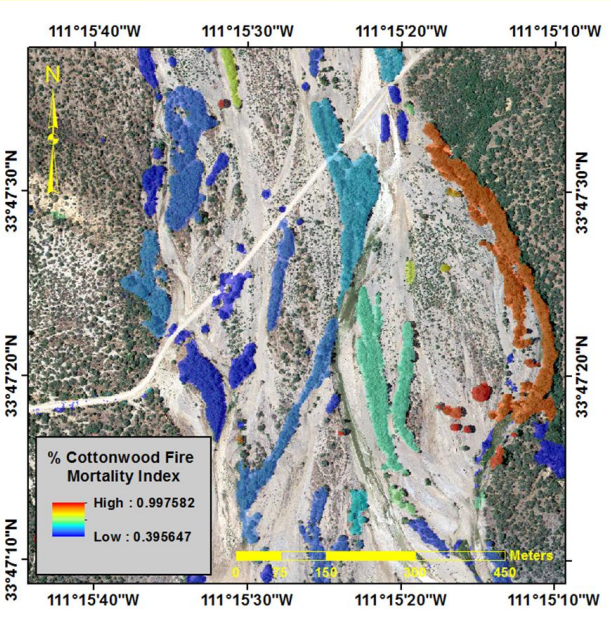
Tamarisk Mortality



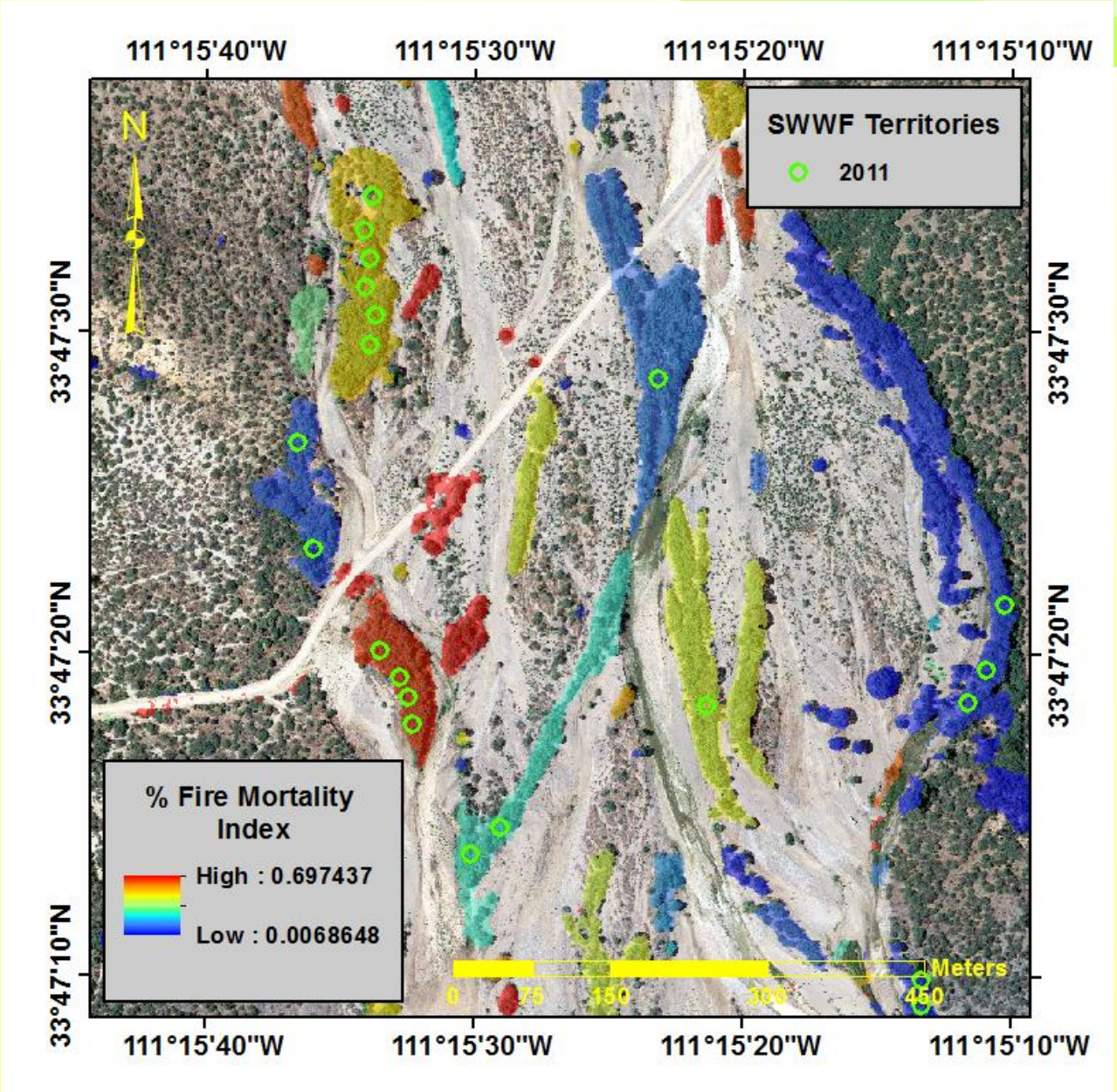
Willow Mortality



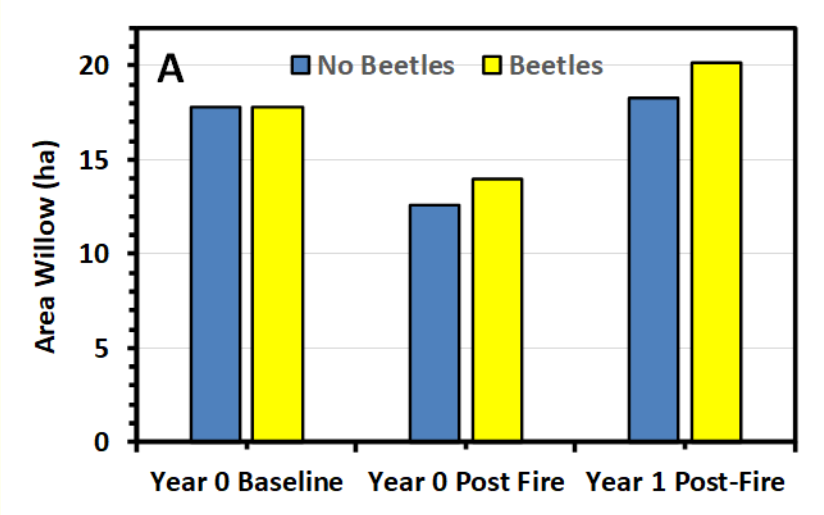
Cottonwood Mortality

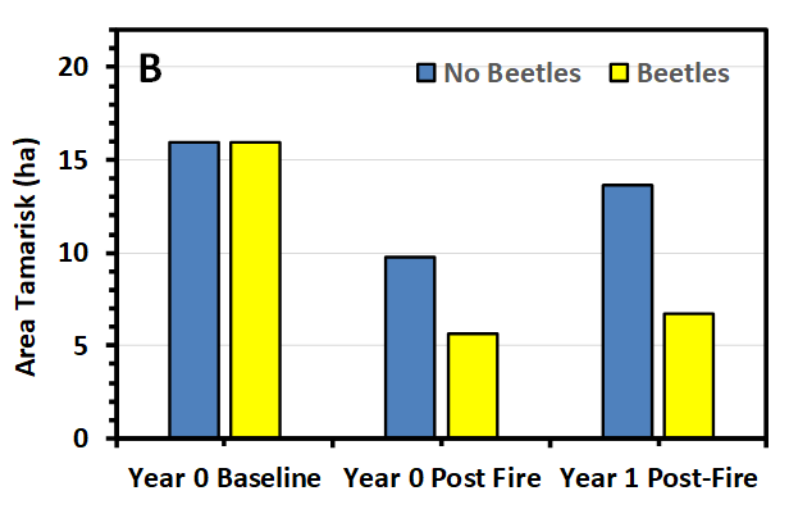


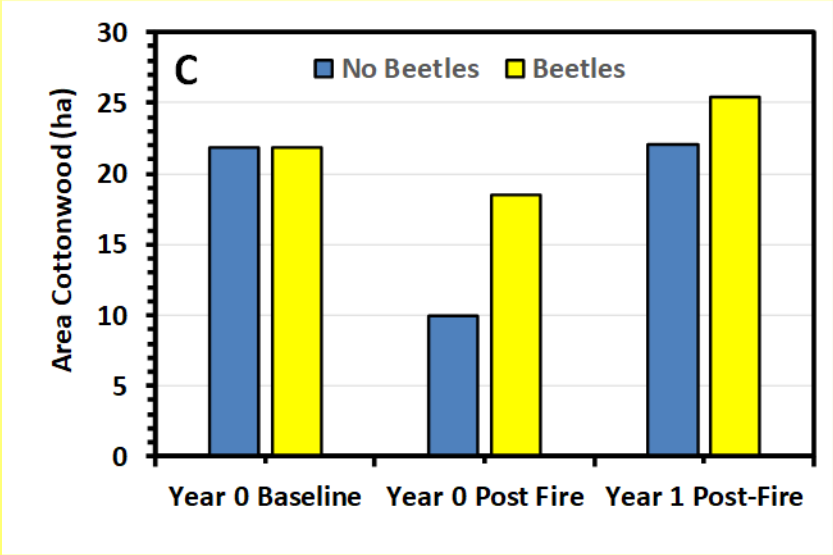
% Fire Mortality Index

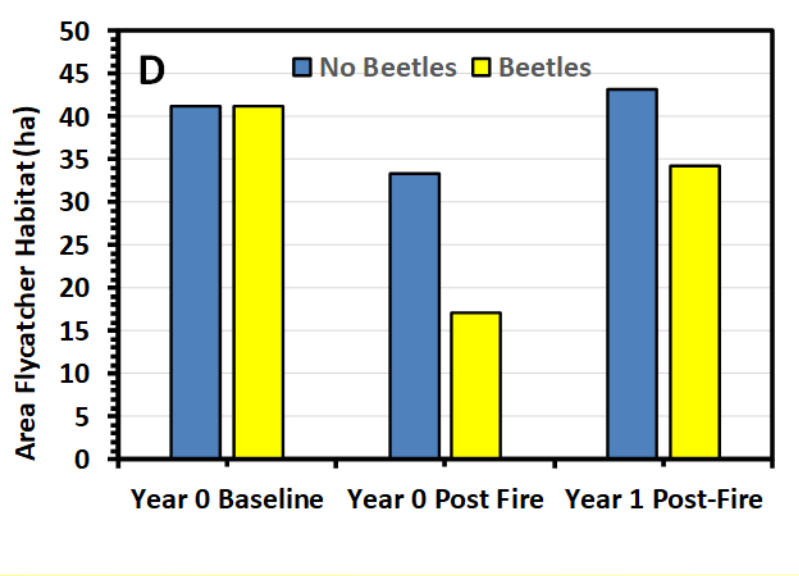


Area Riparian Woodland at Zero and One Years Post Fire

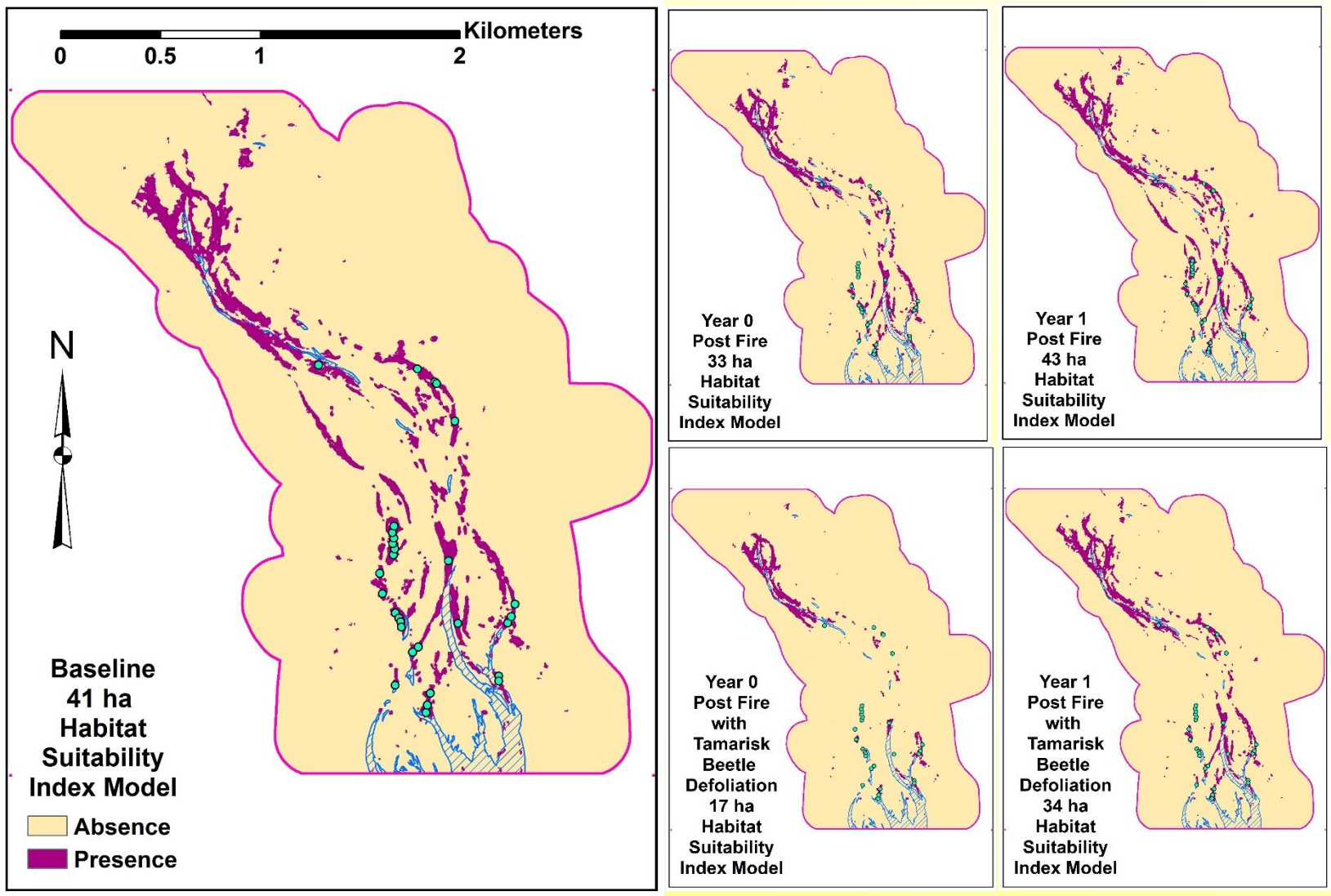




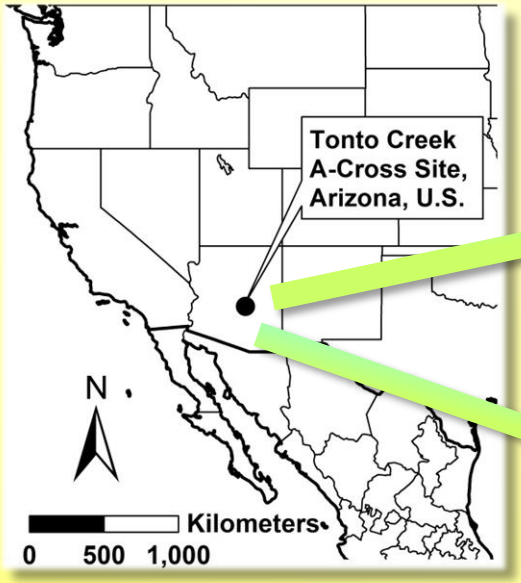


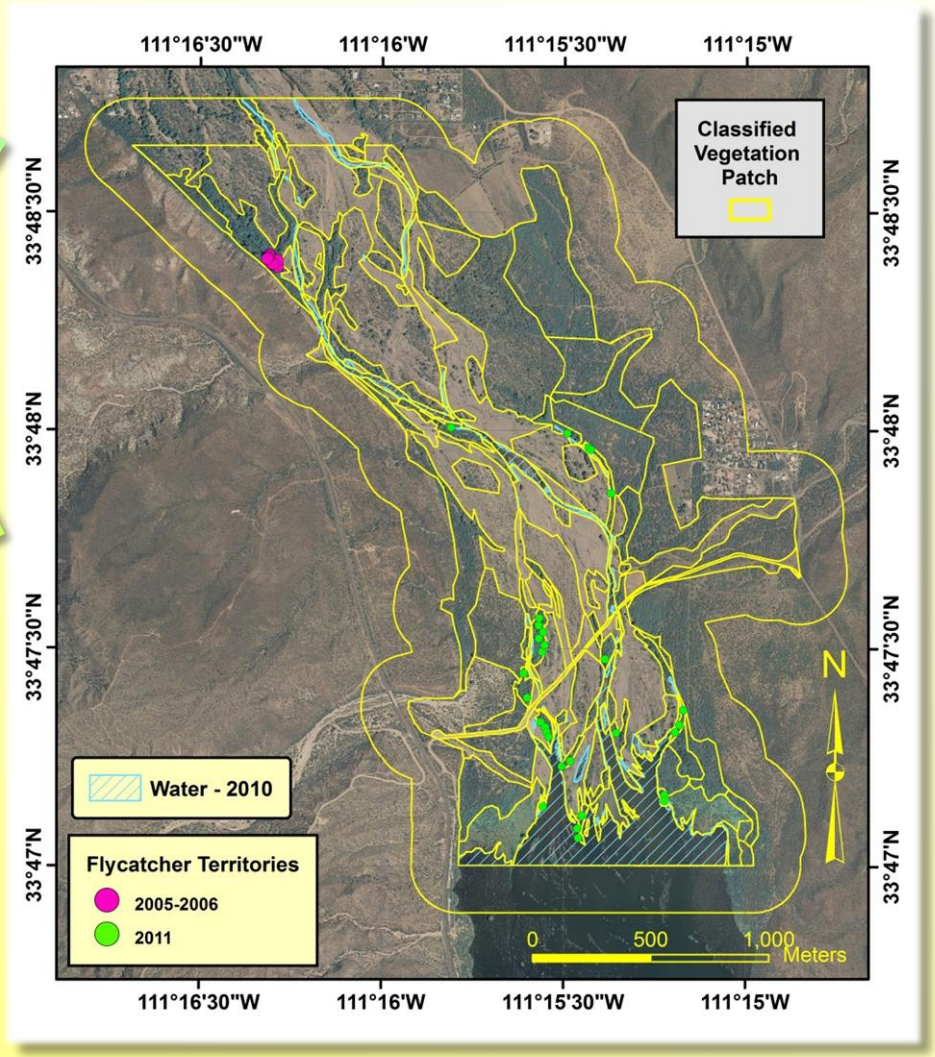


Area Flycatcher Habitat at Zero and One Years Post Fire



Southwestern Willow Flycatcher
High Resolution (1m) Habitat Suitability Index Model
Tonto Creek A-Cross Site, AZ



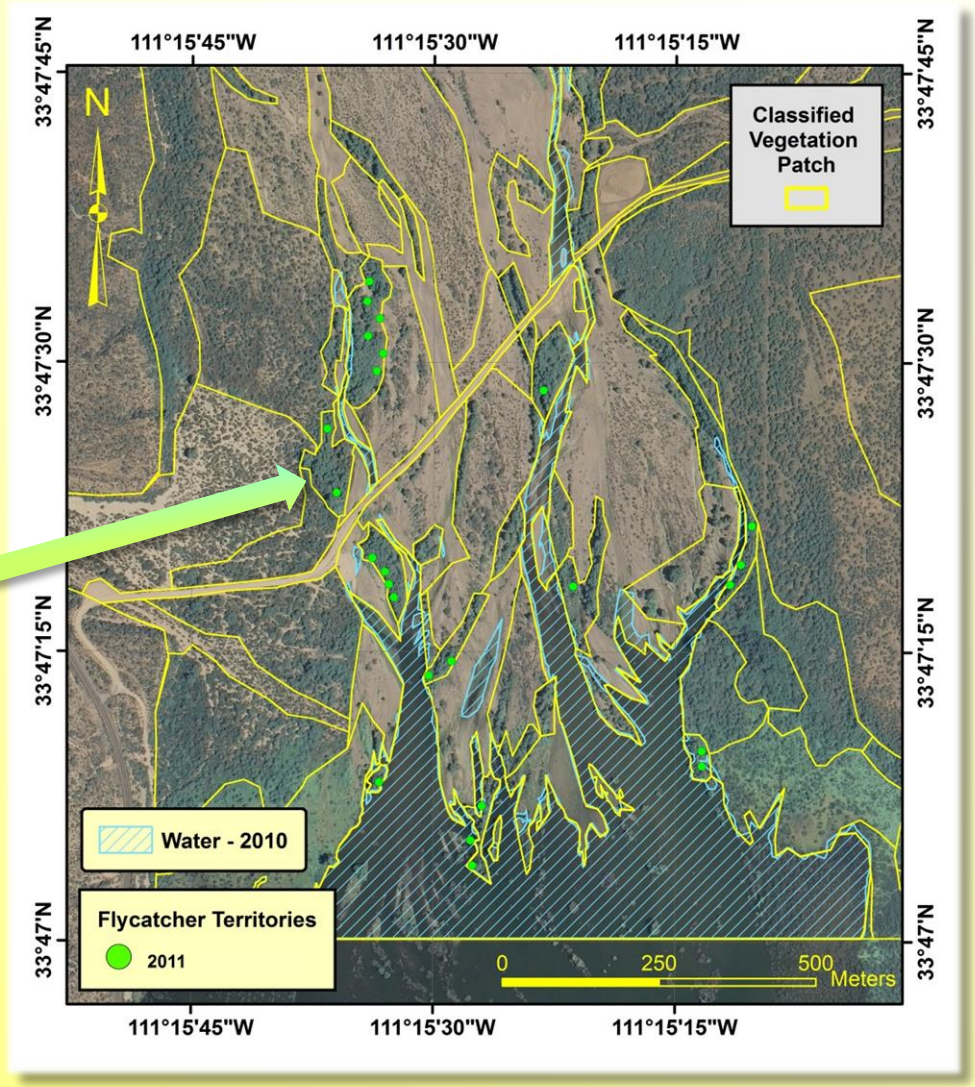


- 30 flycatcher territories in 2011; 100 random absence sites selected
- 335 ha, 3.5 km reach
- Tamarisk 10–90 % cover in woodland patches

Ground Survey of Riparian Woodland Patch Location, Composition and Height

- Tamarisk dominates 13 (43%) of 30 patches with flycatcher territories

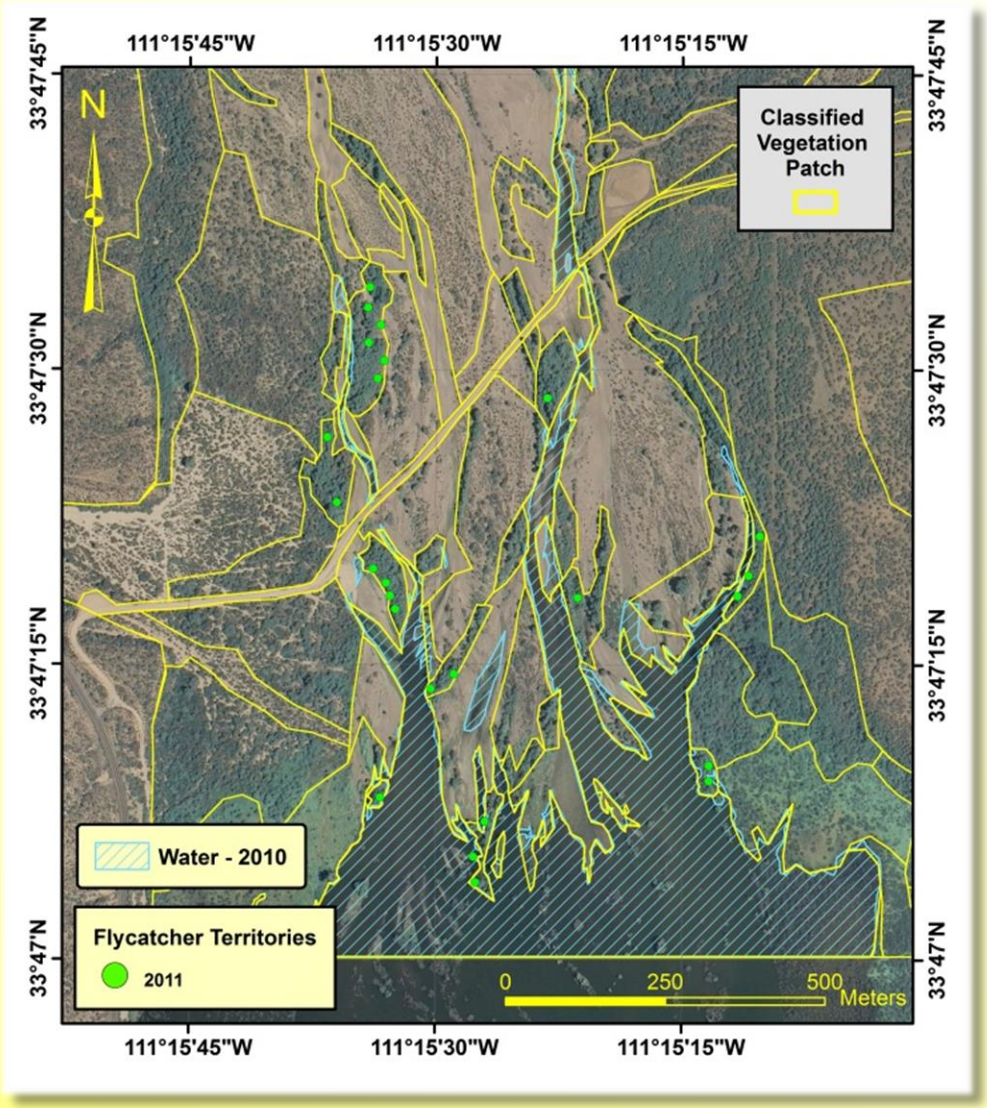
Tamarisk in patch used by flycatchers at Tonto Creek, AZ in 2011



Refine flycatcher Habitat Suitability Index Model for Tonto Creek A-Cross Site, AZ

Five Habitat Suitability Index variables (1 m res)

- Percent cover tamarisk/ willow/cottonwood at 2–10 m height(*SI1*)
- Patch area (*SI2*)
- Vegetation height (*SI3*)
- Distance to water (*SI4*)
- Nest tree defoliation (*SI5*) susceptibility



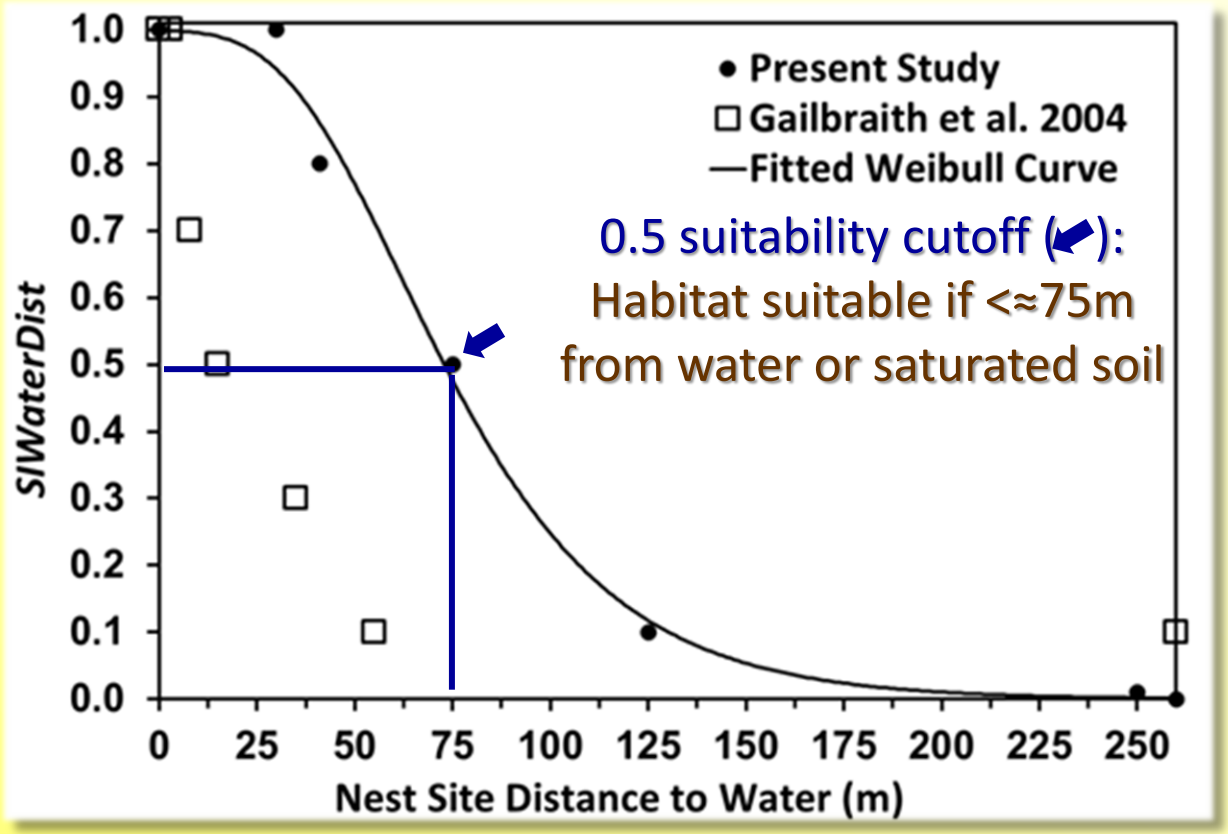
Flycatcher HSI calculation

$$HSI = SI1 \times SI5 \times \sqrt[3]{SI2 \times SI3 \times SI4}$$

(Tracy et al. in prep.)

Flycatcher Habitat Suitability Index Model-
Estimating Suitability Index Curve of Distance to Water

- Step 1: Assemble univariate statistics from literature field data
- Step 2: Estimate suitability variables from field data statistics
- Step 3: Fit appropriate curve to estimated suitability variables

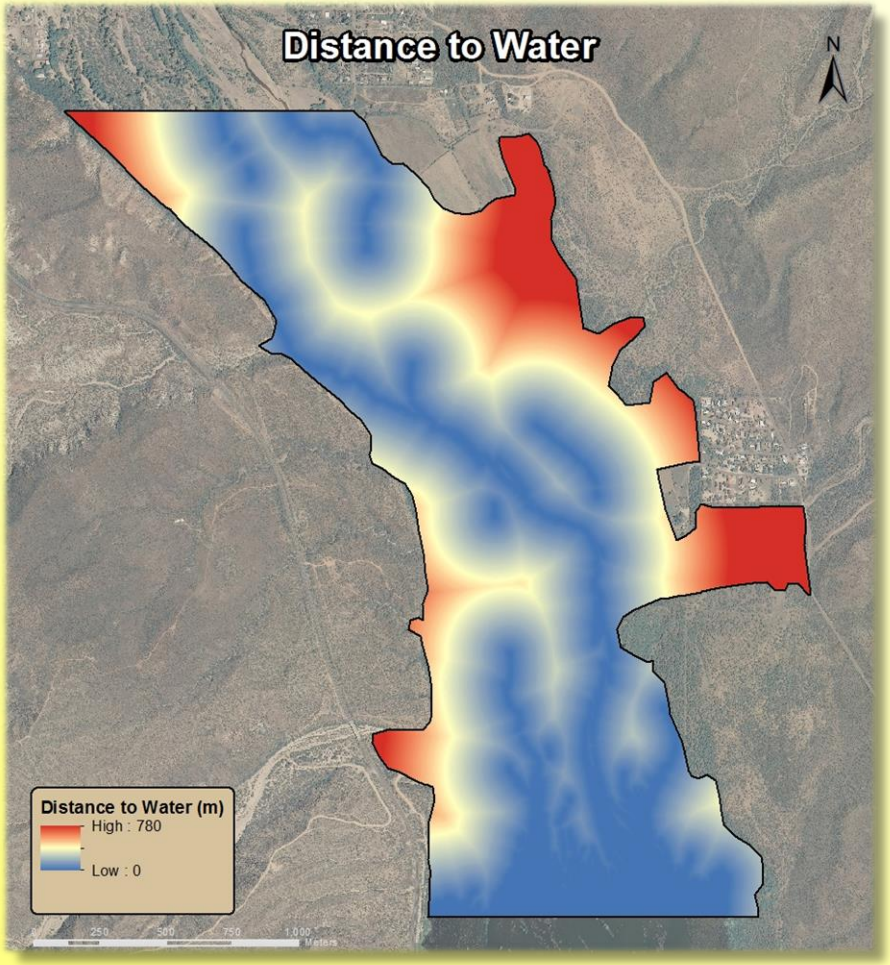


Fitted Weibull curve:

Suitability = 1 - e -1*((x+914501849.9222)/914501911.6335)**-30042543.2241

Flycatcher Habitat Suitability Index Model-
Estimating Suitability Index Curve of Distance to Water

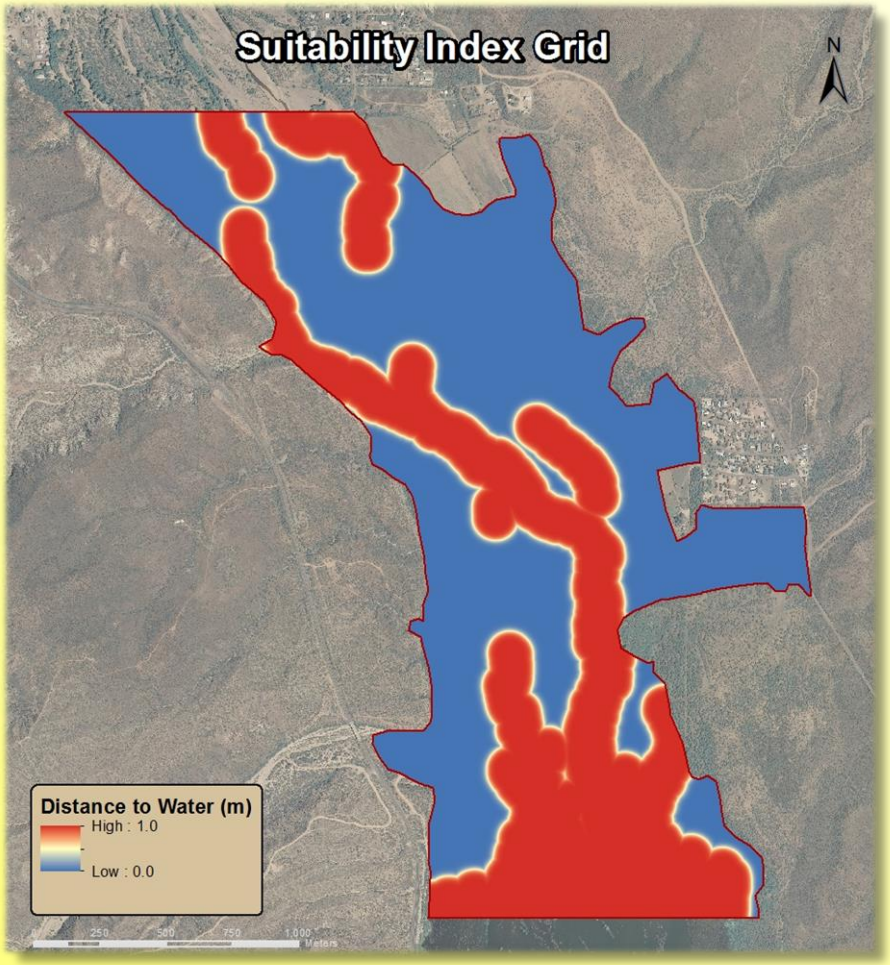
- Step 4: Calculate distance to water grid for study site (1 m res)



(Tracy et al. in prep.)

Flycatcher Habitat Suitability Index Model-
Estimating Suitability Index Curve of Distance to Water

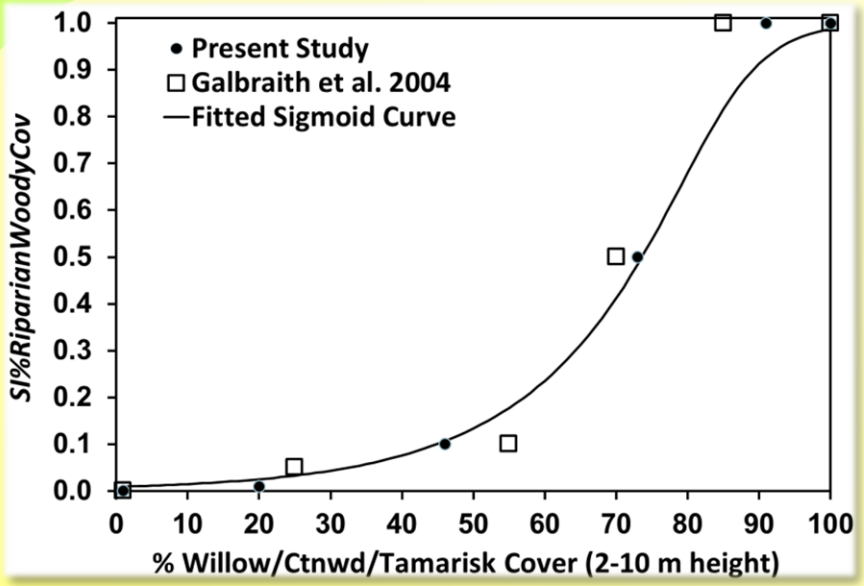
- Step 5: Apply suitability curve formula to distance to water grid and calculate suitability index grid *SI4*- distance to water



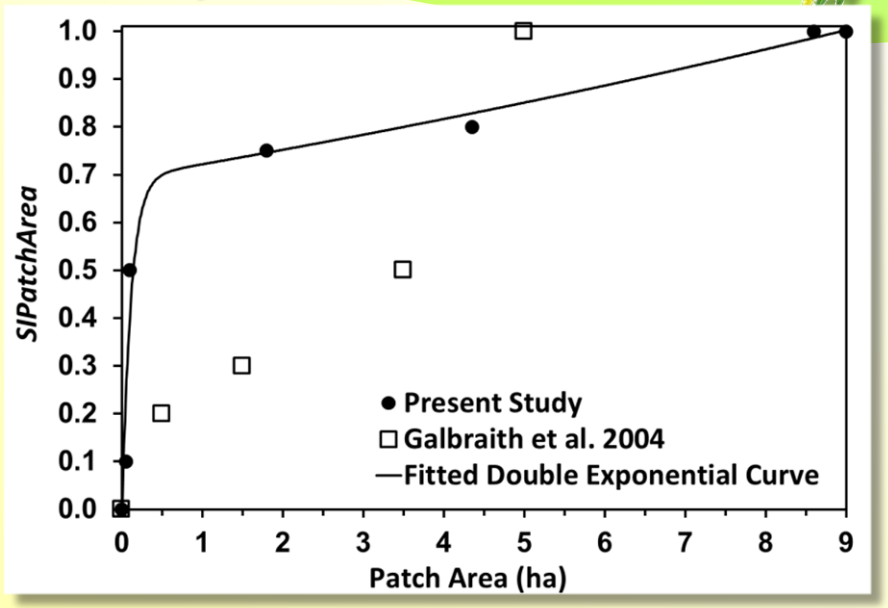
(Tracy et al. in prep.)

Flycatcher Habitat Suitability Index Model

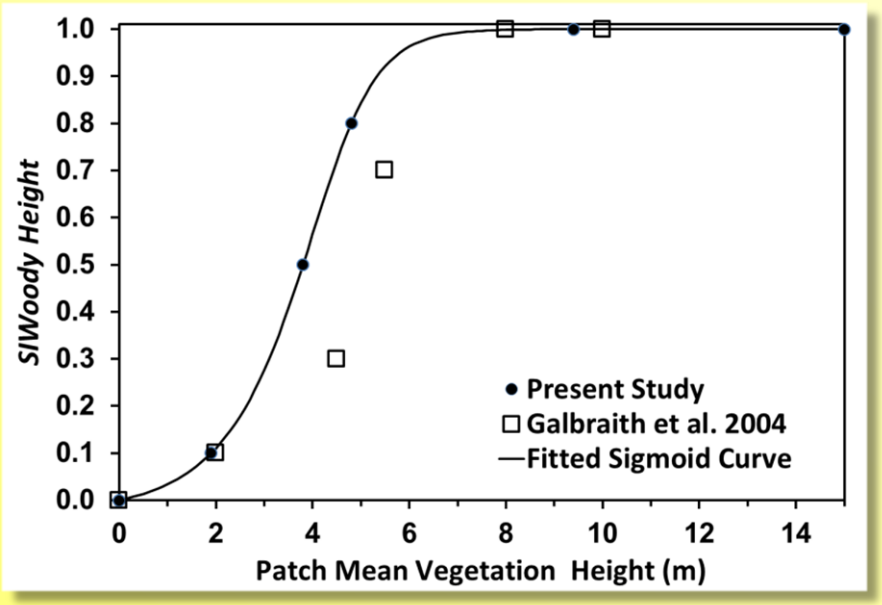
Patch-based Suitability Indices



% Cover Willow/ Cottonwood/Tamarisk at 2–10 m Height Index



Patch Area Index



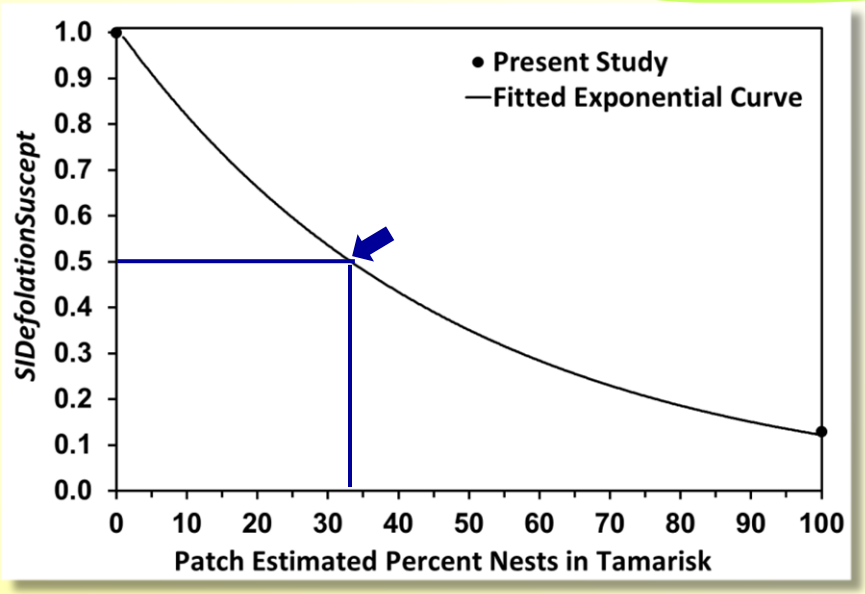
Patch Mean Vegetation Height Index

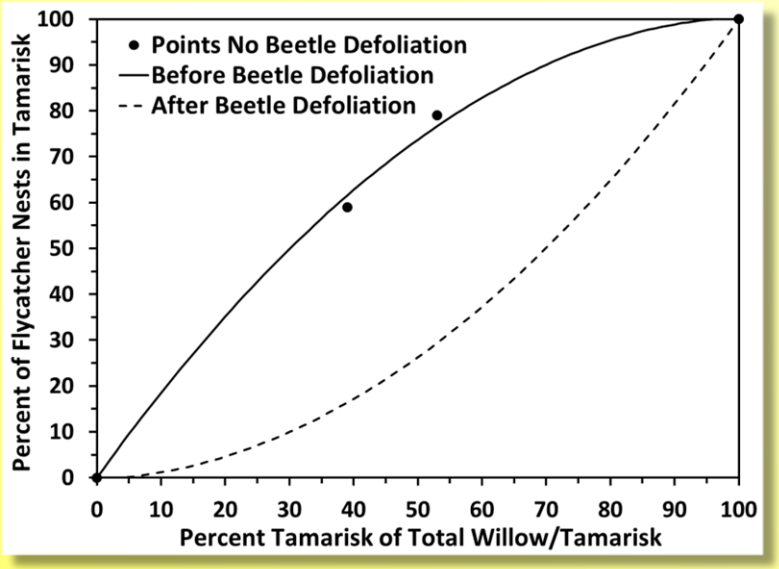
Flycatcher Habitat Suitability Index Model

Patch-based Suitability Indices

Nest Tree Defoliation Susceptibility Index

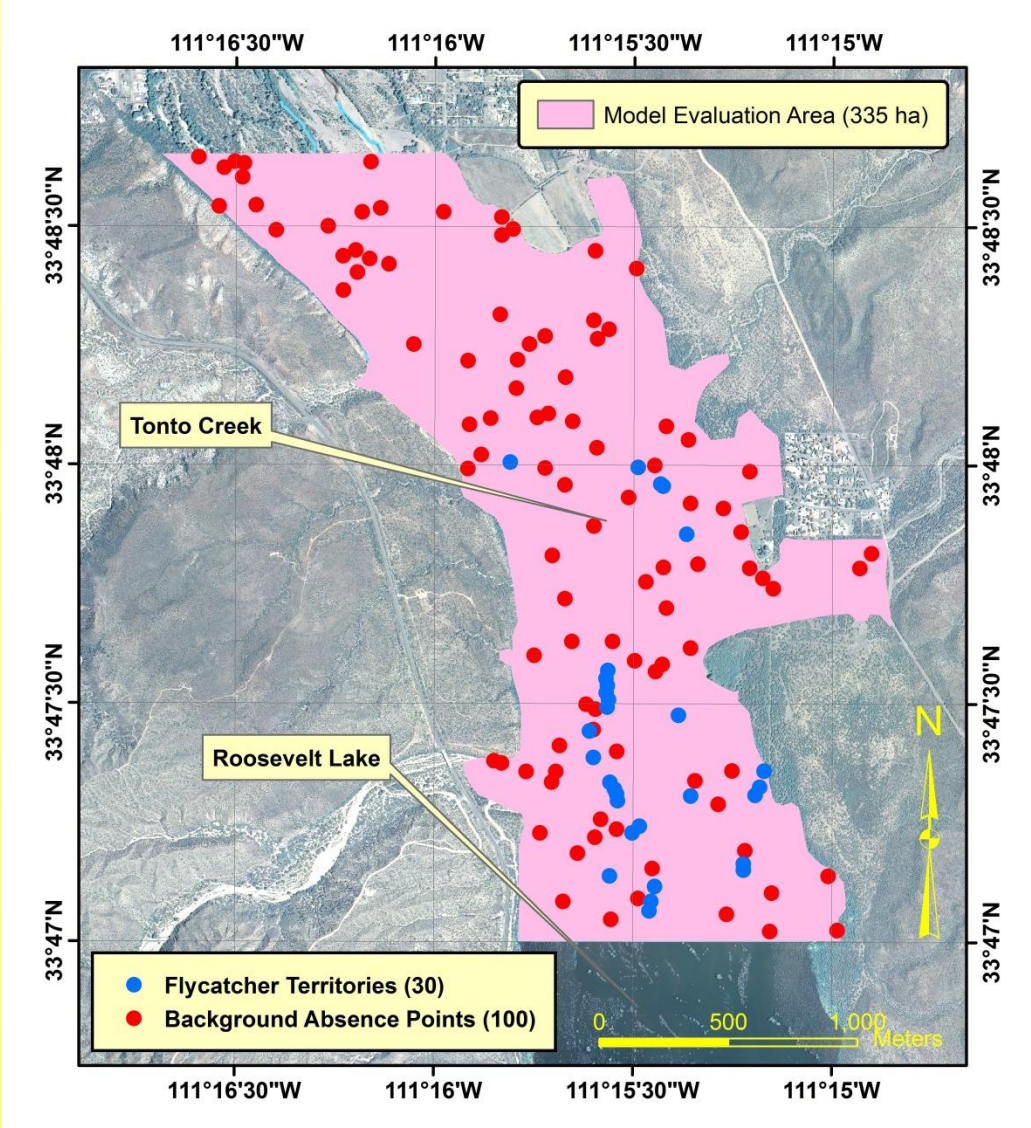
Habitat suitable if < ≈35% nests in tamarisk





Estimated Percent Nests in Tamarisk based on % Tamarisk vs. Willow

Flycatcher Habitat Suitability Index Model-
Evaluation Area with Presence/Pseudoabscence Data



(Tracy et al. in prep.)

Flycatcher Habitat Suitability Index Model and GLM Suitability Model

HSI

Suitability =
SI%Tamarisk/Willow
x (SIVegHeightMeters
x SIPatchAreaHa
x SIDistWatMeters)$^{1/3}$

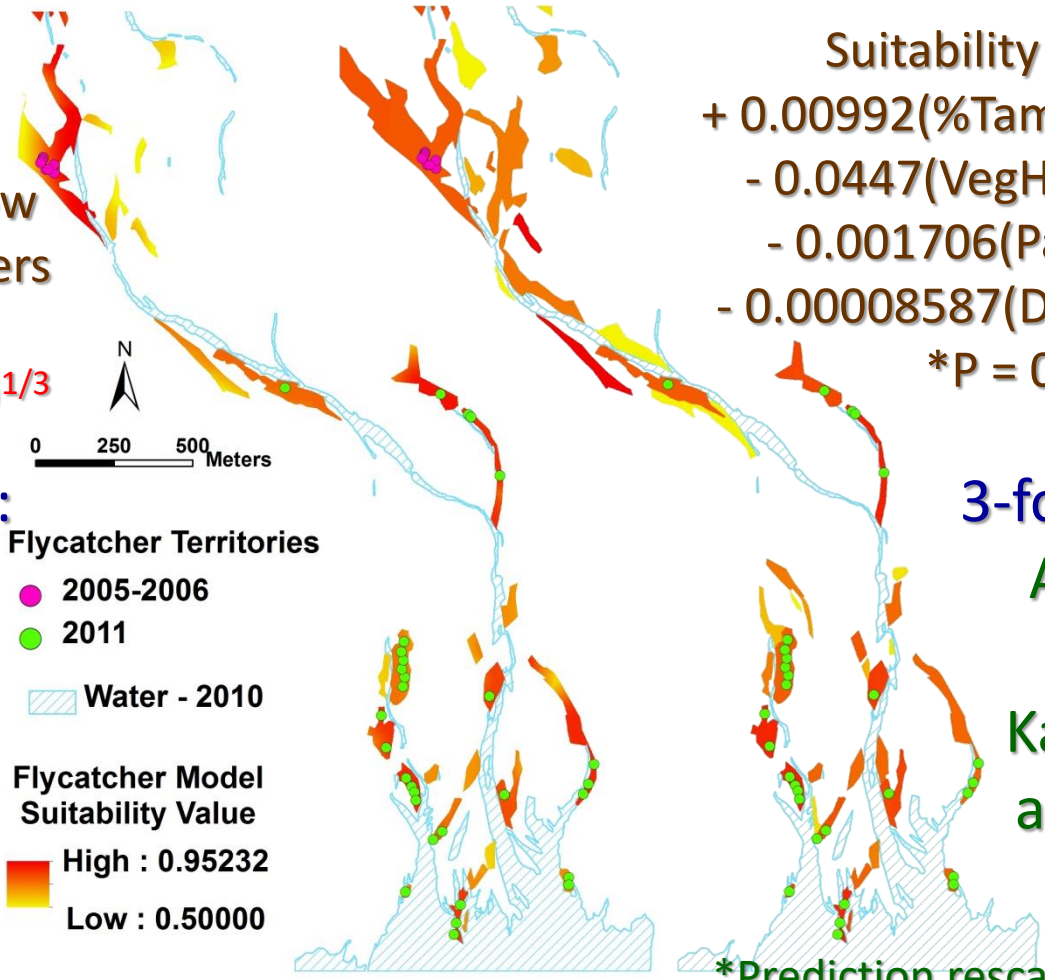
3-fold validation:
AUC = 0.98;
Maximum
Kappa = 0.92
at threshold
0.72

GLM*

Suitability = 0.1091
+ 0.00992(%Tamarisk/Willow*)
- 0.0447(VegHeightMeters)
- 0.001706(PatchAreaHa)
- 0.00008587(DistWatMeters)
*P = 0.001

3-fold validation:
AUC = 0.98;
Maximum
Kappa = 0.90
at threshold
0.78

*Prediction rescaled to match HSI



Baseline suitability (Y0), Tonto Ck, AZ

HSI vs. GLM Flycatcher Suitability Model Comparison

Baseline flycatcher suitable habitat projected by HSI and GLM models for Tonto Creek A-Cross Site, AZ.

Model	Threshold	Total Quantity Suitable Habitat (ha)	Mean Quality Suitable Habitat
HSI	≥ 0.50	19.1	0.77
GLM	≥ 0.50	31.8	0.76
% Difference		66%	1%
HSI	≥ 0.71*	13.2	0.82
GLM	≥ 0.78*	19.7	0.82
% Difference		49%	0%

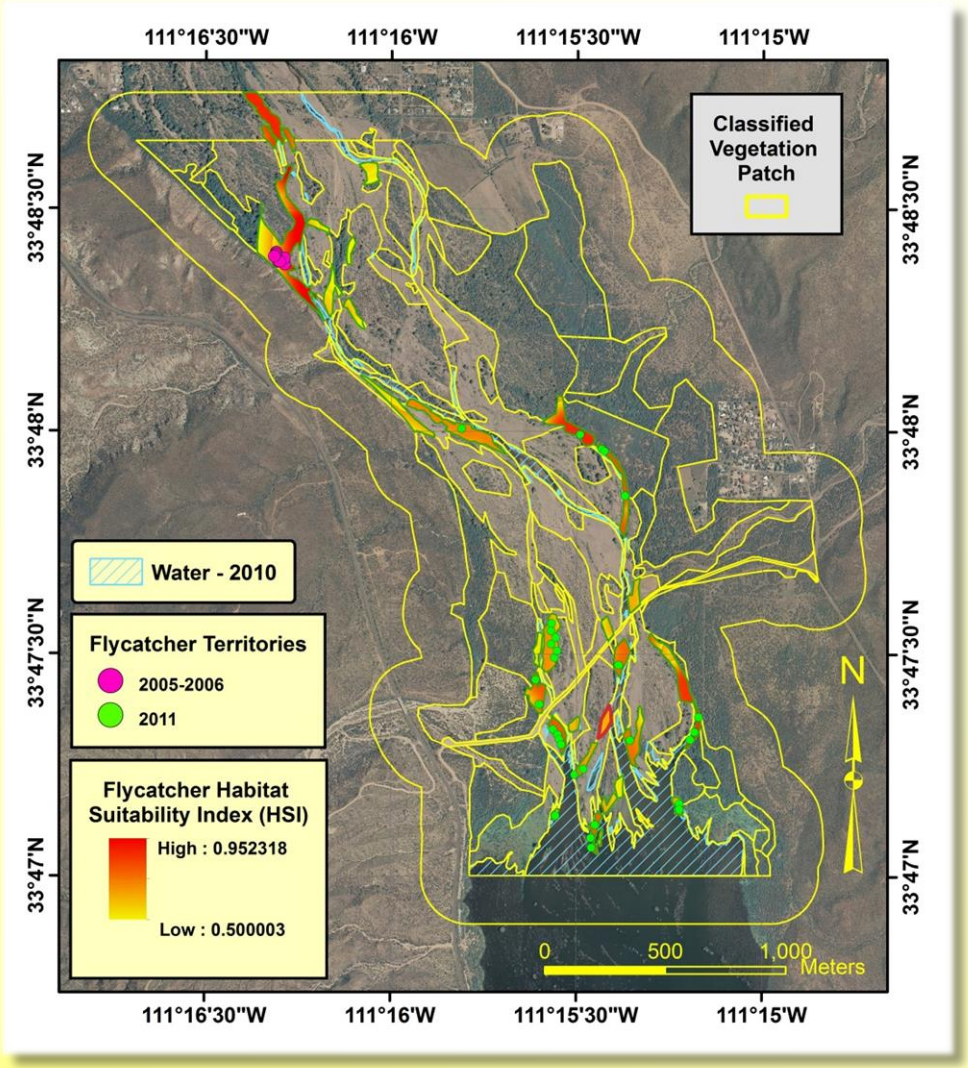
*Threshold maximizing kappa.

Flycatcher Habitat Suitability Index Model – *HSI*

Combine five suitability indices by weighted HSI formula to project baseline flycatcher habitat, Tonto Ck, AZ

Baseline HSI projections

- Suitable flycatcher habitat (≥ 0.5 *HSI*) (yellow/orange/red) projected at 19.1 ha
- Suitable habitat quality projected at 0.77 out of 1.0



Baseline Flycatcher Habitat, Tonto Creek, AZ

2011 mesoscale niche model - 30 m res. (Hatten et al. 2010)

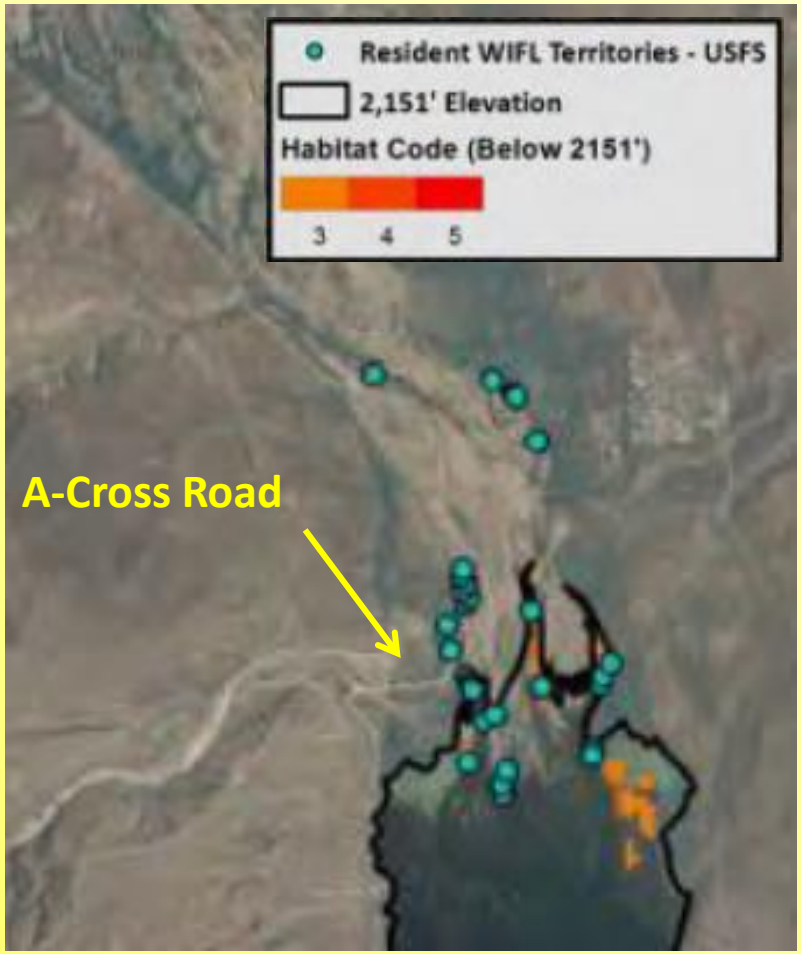
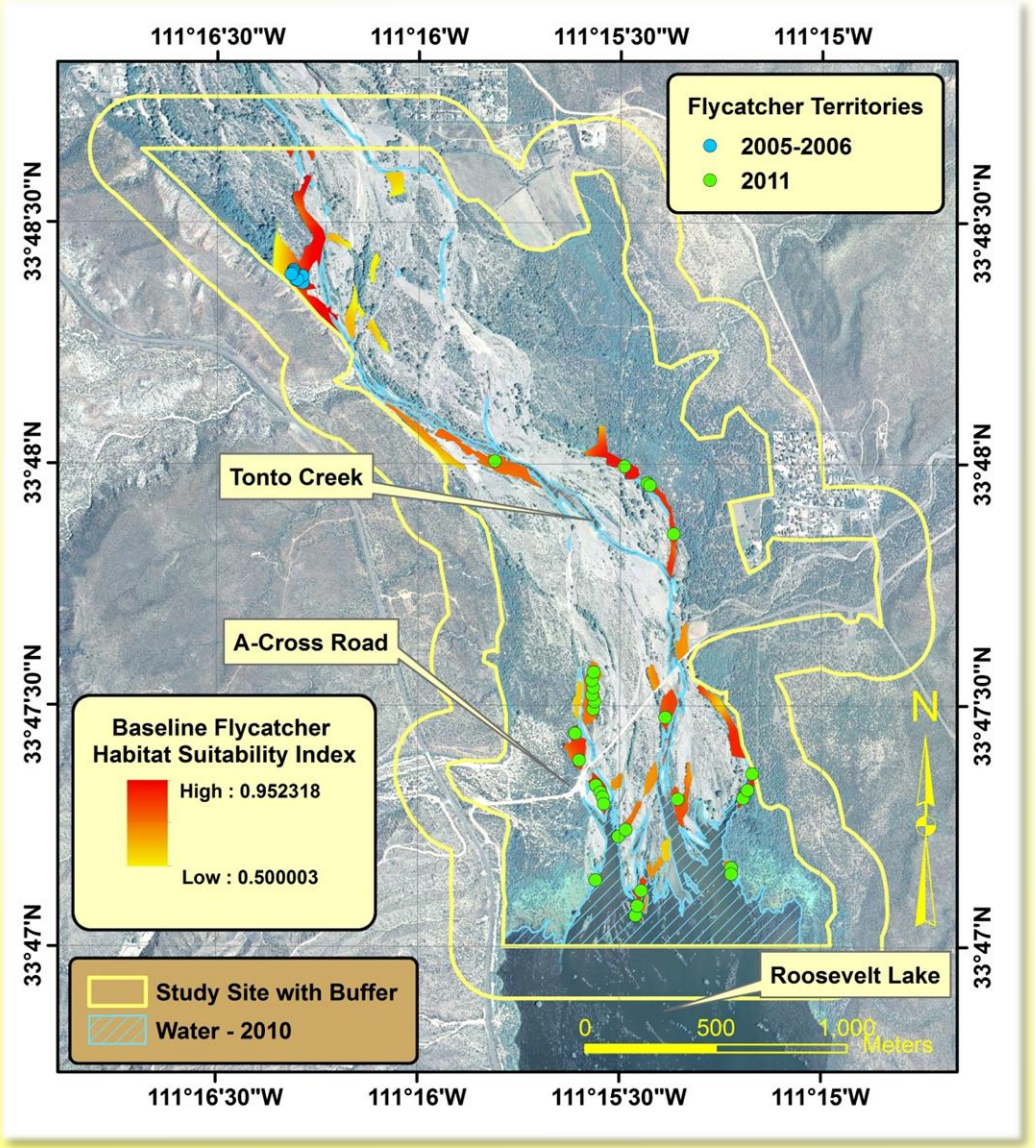


Fig. 6 (Valencia 2012)

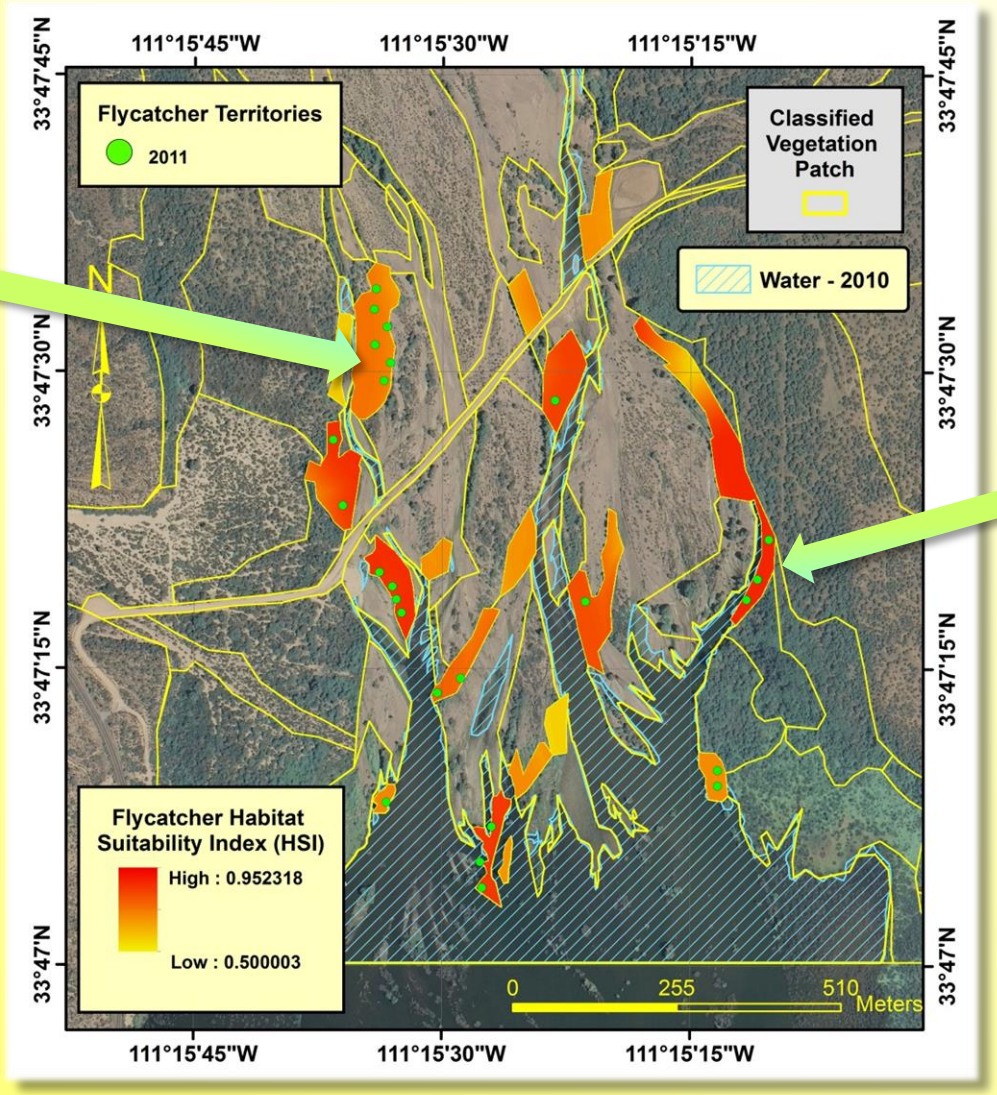
2011 microscale niche model - 1 m res. (current study)



Flycatcher Habitat Suitability Index Model – *HSI*

Projected baseline flycatcher habitat, Tonto Ck, AZ

Correctly projected flycatcher occupied patch of 75% tamarisk 25% willow

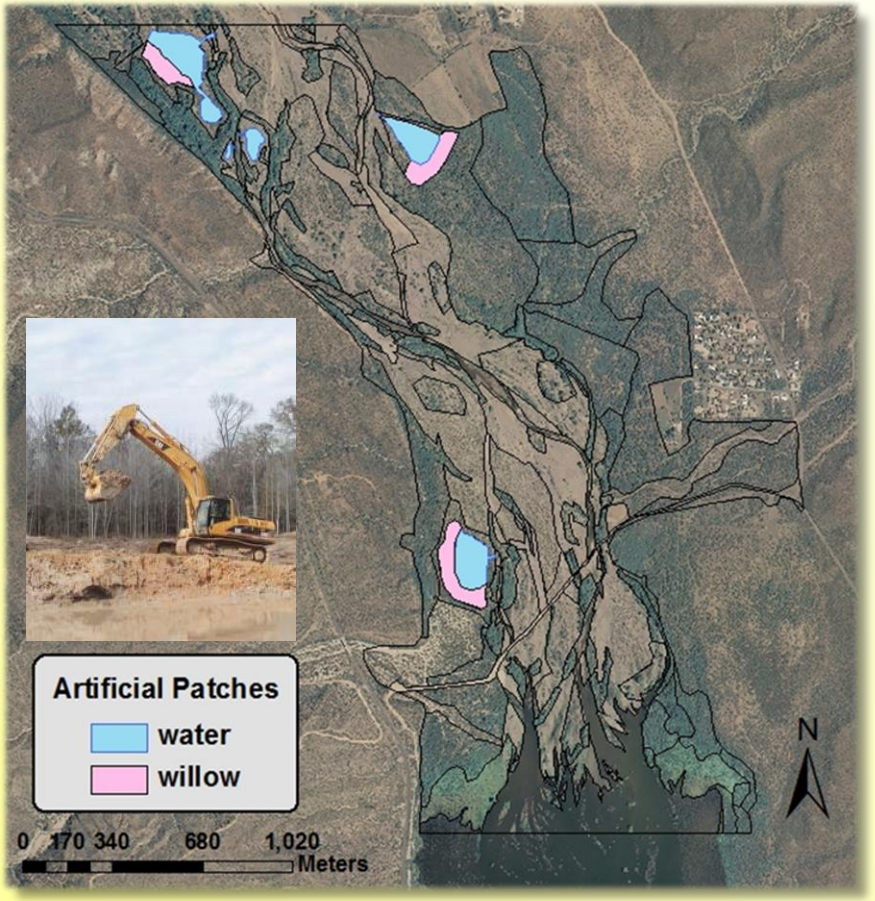


Correctly projected flycatcher occupied patch of 10% tamarisk 90% willow

Simulation flycatcher Habitat Suitability Index Model to assess beetle impact and restoration

Main assumptions for flycatcher HSI simulation models

- Tamarisk dieback due to beetles averages about 50% over a 3 yr period (based on data from Big Spring, Texas)
- Flycatchers switch nesting preference from tamarisk to willow after 1st yr defoliation
- Pole plantings of willows take three years to reach suitable heights for flycatcher nesting habitat

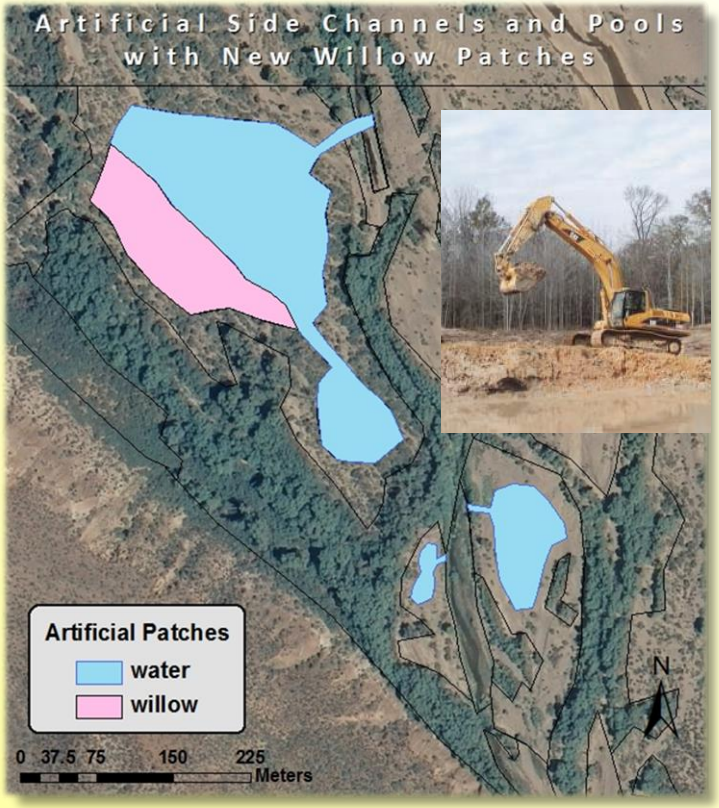


Year 3 simulated added artificial side channel pools and planted willow patches, Tonto Ck, AZ

Simulation flycatcher Habitat Suitability Index Model to assess beetle impact and restoration

Flycatcher HSI simulation model scenarios, Tonto Ck, AZ

- Year 0- baseline suitability
- Year 1- suitability with 100% beetle defoliation of tamarisk
- Year 3- suitability with beetle defoliation and 50% tamarisk dieback (including some willow regrowth)
- Year 3- suitability with beetle defoliation and dieback and 5 ha artificial willow patch creation and 8 ha pools

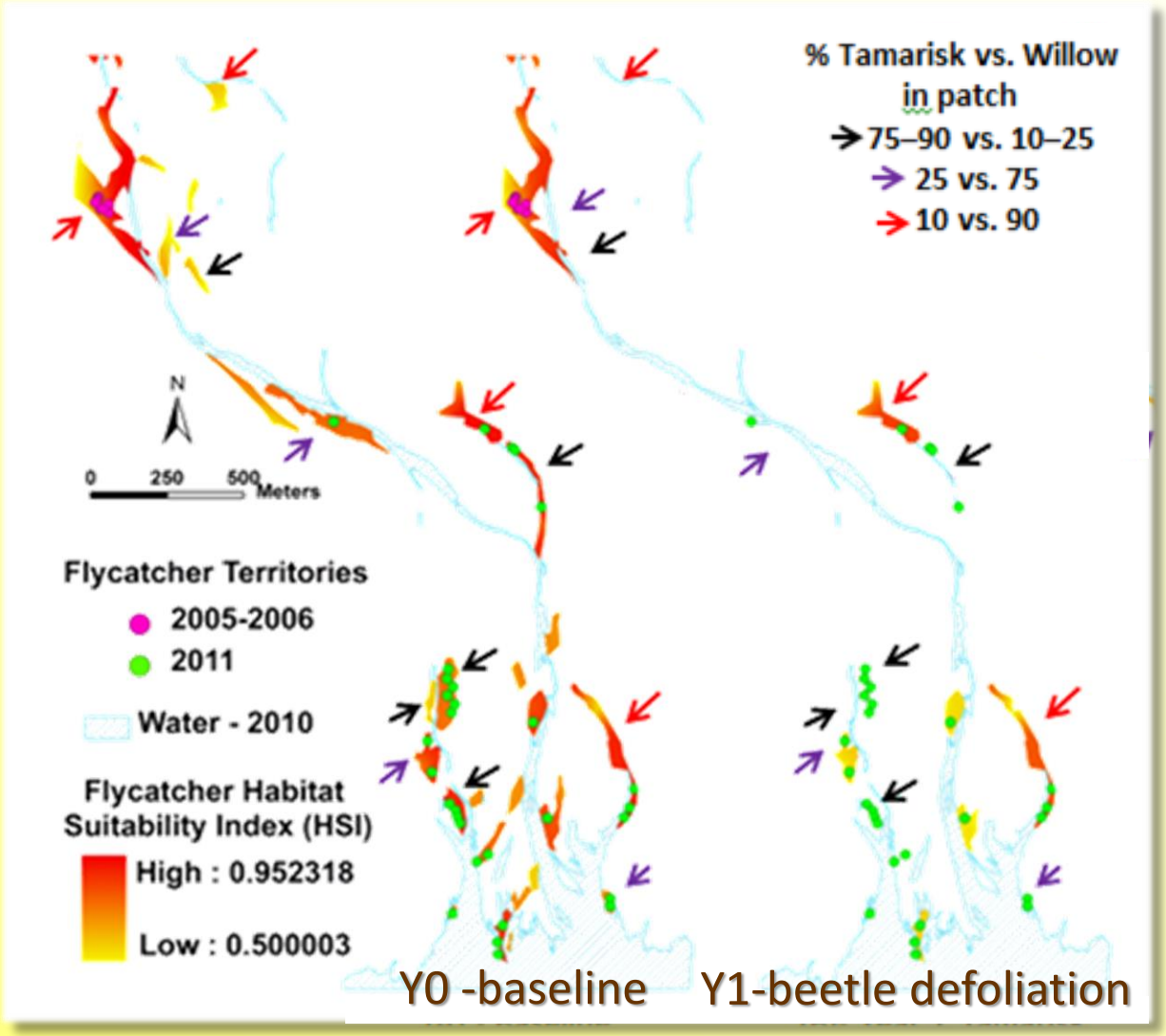


Year 3 simulated added artificial side channel pools and planted willow patches, Tonto Ck, AZ

Simulation flycatcher Habitat Suitability Index Model to assess beetle impact and restoration

Flycatcher HSI baseline (Y0) and Year 1 (Y1) simulation, Tonto Ck, AZ

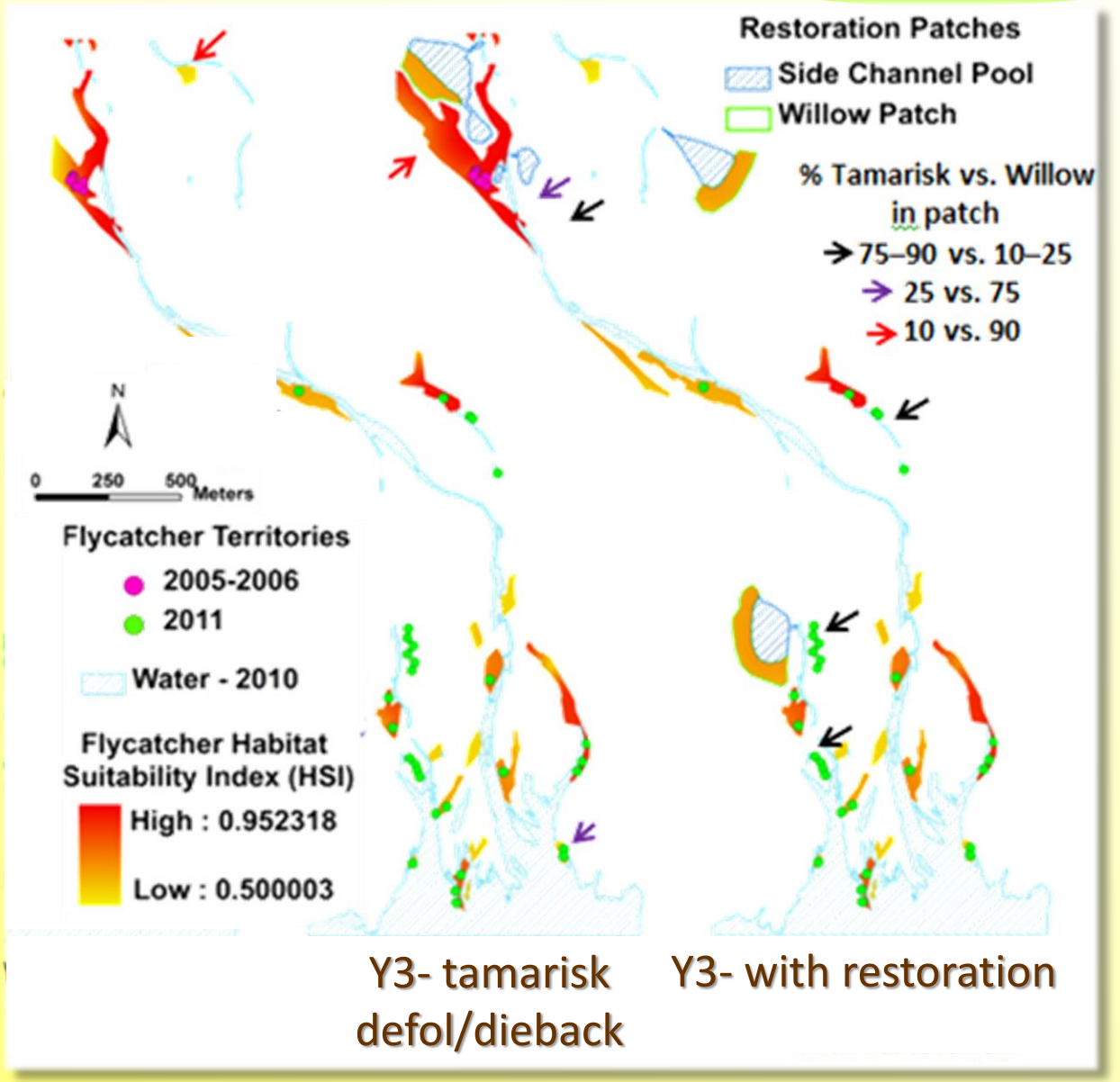
- In Year 1 of beetle defoliation, 56% loss of suitable flycatcher habitat, with a loss of 2/3 of suitable patches
- Most, but not all, patches lost are dominated by tamarisk



Simulation flycatcher Habitat Suitability Index Model to assess beetle impact and restoration

Year 3 simulations, Tonto Creek, AZ

- By Year 3 (Y3) of defoliation, only 25% of habitat is lost (not 56% as in Y1) due to flycatchers switching preference to willow.
- In Y3 with restoration of 5 ha willows, suitable habitat can be restored 22% above baseline Y0



Simulation flycatcher Habitat Suitability Index Model to assess beetle impact and restoration

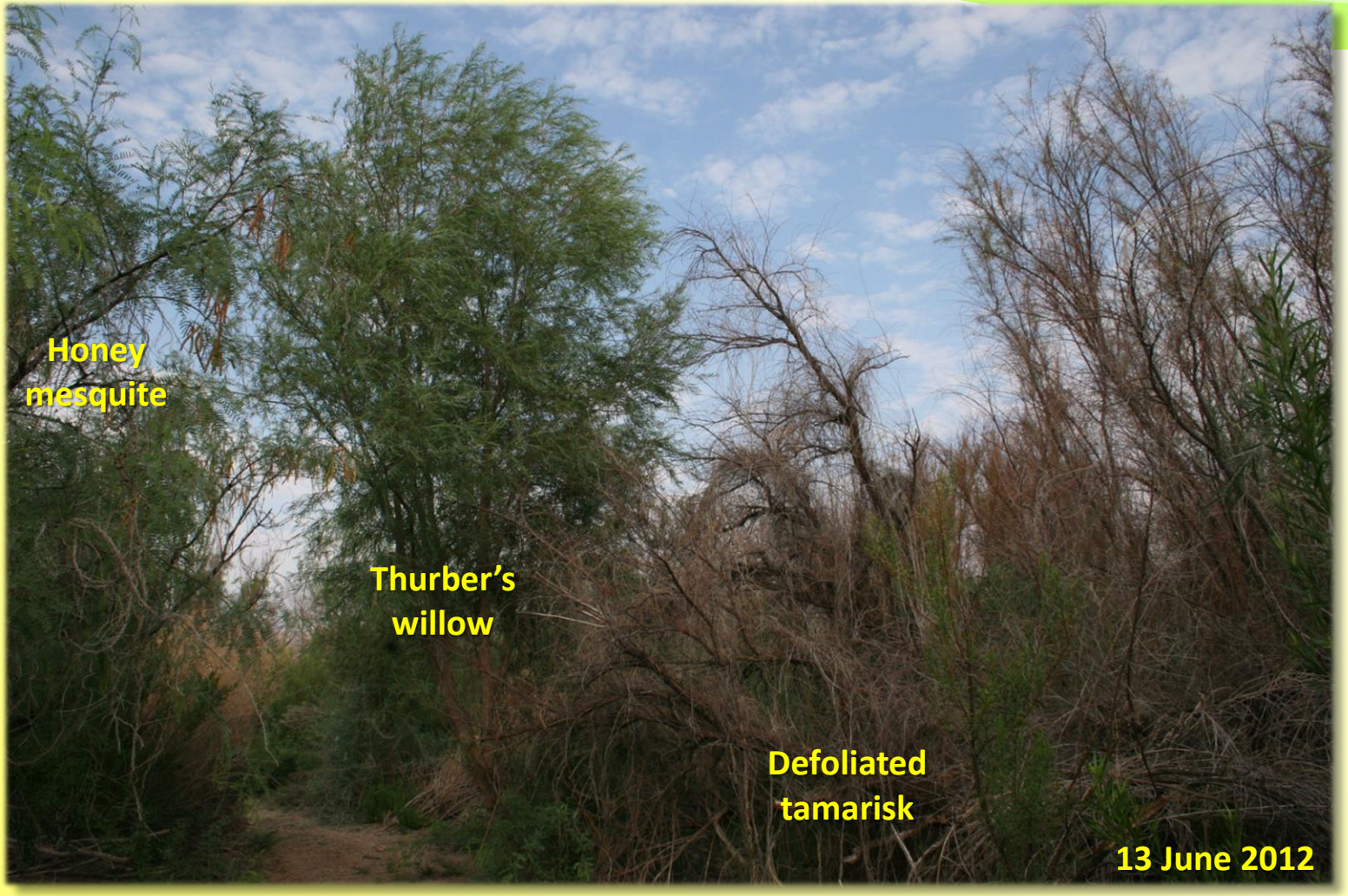
Projections from flycatcher HSI simulations

- Highest losses to flycatcher habitat may occur during the first year of tamarisk beetle defoliation
- Significant loss of flycatcher habitat suitability may occur in willow patches with as little as 10–25% tamarisk
- Addition of side channel pools with willow patches three years prior to arrival of beetles can potentially mitigate flycatcher habitat loss to tamarisk beetles
- Addition of pools next to existing willow stands can improve their suitability to flycatchers
- HSI simulations can guide timing, placement, and amount of pool/willow patches for habitat restoration

Acknowledgements

- Amy Ann Madara-Yagla, Forest Protection Officer, USDA Forest Service, Tonto National Forest, Tonto Basin Ranger District, Roosevelt, Arizona

Questions?



Forgotten River Reach, Rio Grande, Candelaria, TX