Remote sensing of tamarisk beetle (*Diorhabda carinulata*) impacts along the Colorado River in Grand Canyon National Park and Glen Canyon National Recreation Area

Temuulen "Teki" Sankey[1], Ashton Bedford[1], Joel B. Sankey[2], Barbara E. Ralston[3], Laura Durning[1,2], and Nathaniel Bransky[1]

[1]School of Informatics, Computing, and Cyber Systems, Northern Arizona University
[2] Grand Canyon Monitoring and Research Center, Southwest Biological Science Center, U.S. Geological Survey, Flagstaff, AZ USA
[3]Office of Science Quality and Integrity, U.S. Geological Survey, Flagstaff, AZ USA

Tamarisk and Tamarisk Beetle (*Diorhabda carinulata)*

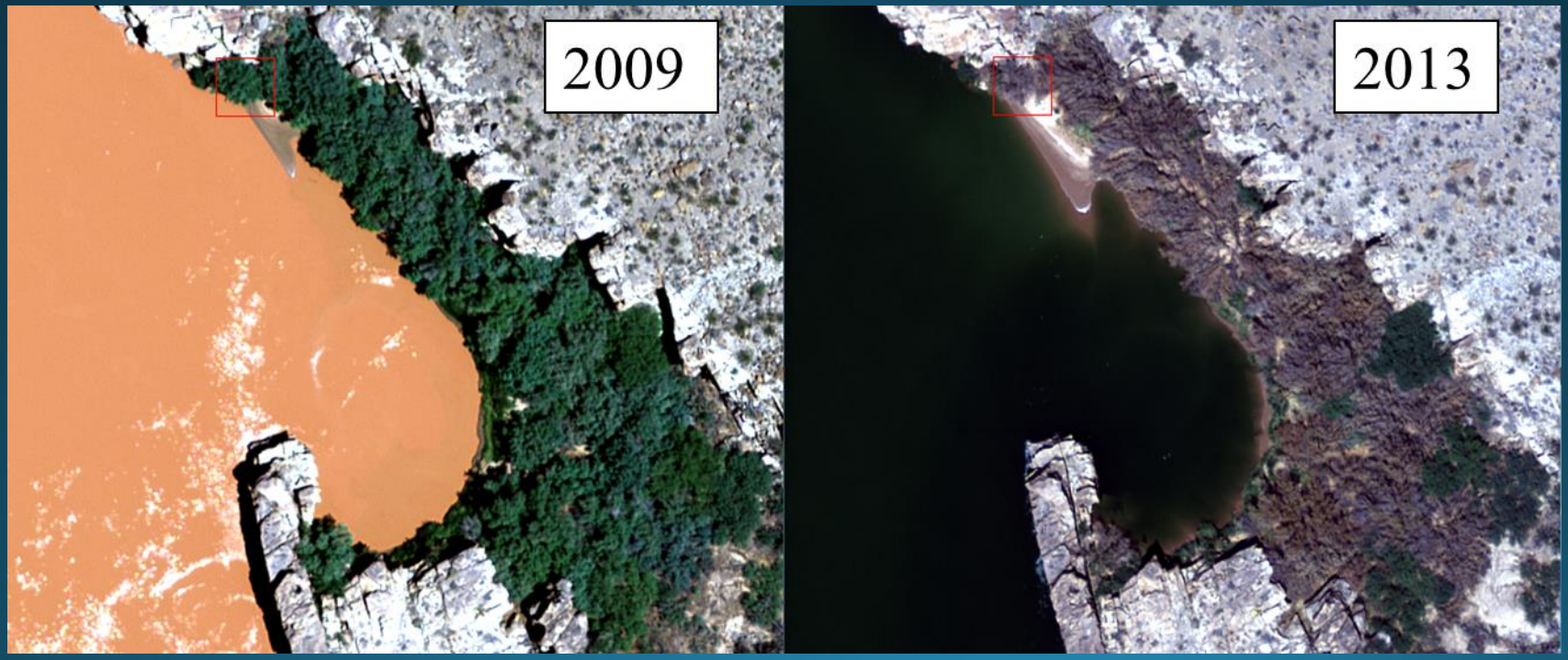
- Tamarisk in the US since 1800s
- Beetle introduced in 2001
  - CO, UT, WY, NV, CA, TX
- Arrived in Colorado River, AZ in 2009
- Larvae and beetle life states prey on tamarisk leaves
- Repeated defoliation events can weaken or kill tamarisk

Impacts from beetle

- Recreational experience
- Hydrological processes
- Carbon nutrient cycling
- Change in vegetation community and structure
  - Unclear if native vegetation will regenerate naturally?
- Risk to birds, such as endangered willow flycatcher from habitat loss?

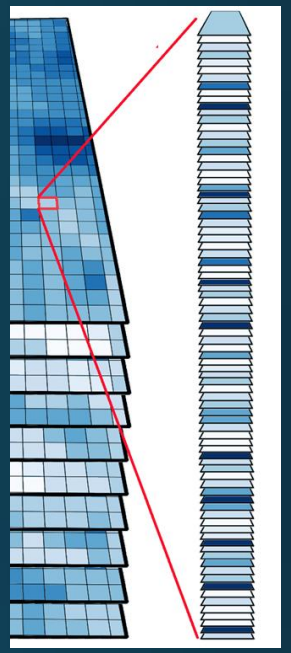
Remote Sensing of Beetle Impacts

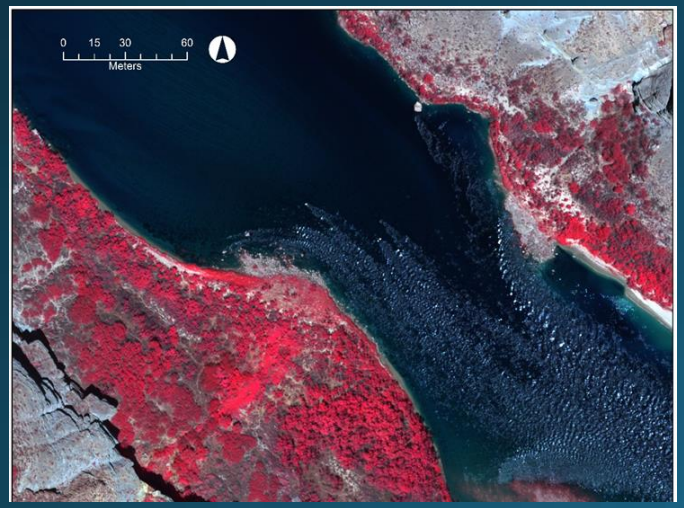
- Operates on a large scale and remote areas
- Allows detection of beetle effects on tamarisk
  - Pre-beetle image, 2009
  - Post-beetle image, 2013
- Both 2D spectral and 3D lidar data can be used

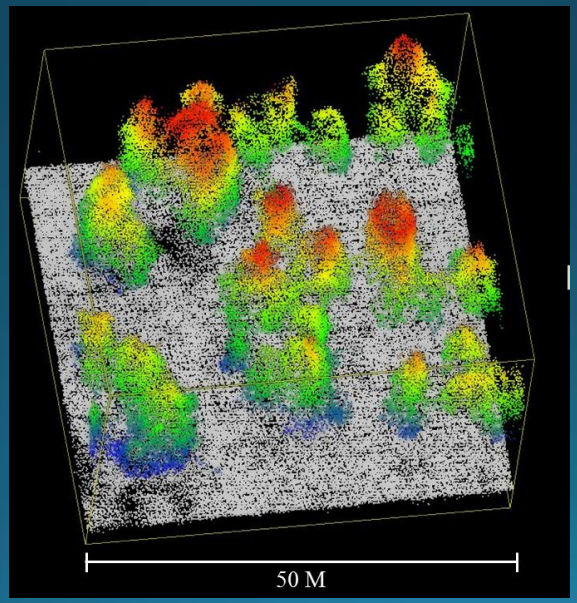


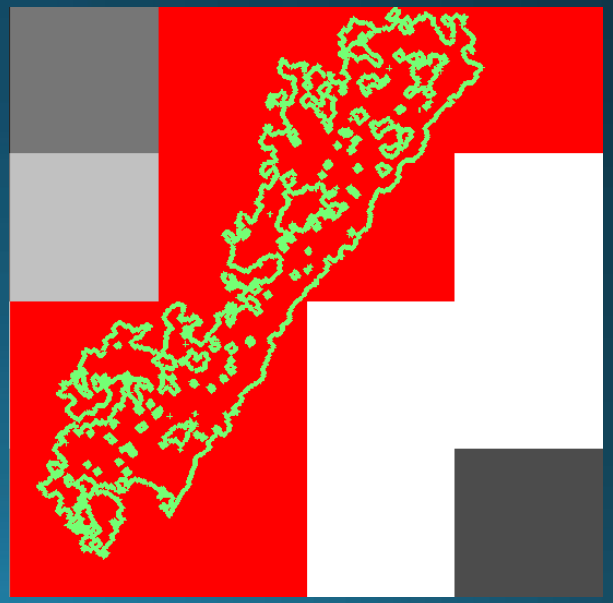
Study Objectives

1) Airborne multispectral remote sensing analysis
   - 2009 Pre-beetle imagery
   - 2013 Post-beetle imagery
2) Airborned lidar data analysis
   - Aboveground biomass estimates
   - Leaf biomass estimates
3) Satellite remote sensing analysis









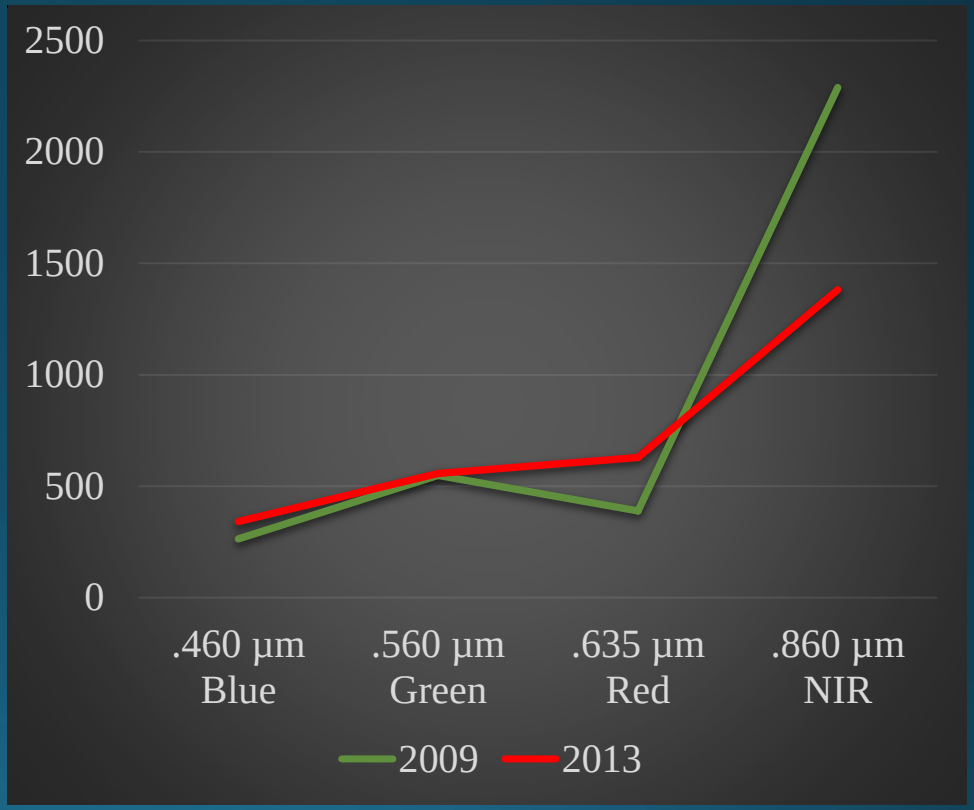
Objective 1: Imagery

- Airborne imagery provided by USGS Grand Canyon Monitoring & Research Center

- 20 cm spatial resolution

- Four bands:
  - blue (0.46 µm)
  - green (0.56 µm)
  - red (0.63 µm)
  - near-infrared (NIR) (0.86 µm)

- May 2009: Pre-beetle image
- May 2013: Post-beetle image



Objective 1: Kanab Creek – 232 km downstream of Lees Ferry in Grand Canyon

2009

2013

Objective 1: Paria Beach – at Lees Ferry in Grand Canyon

2009

2013

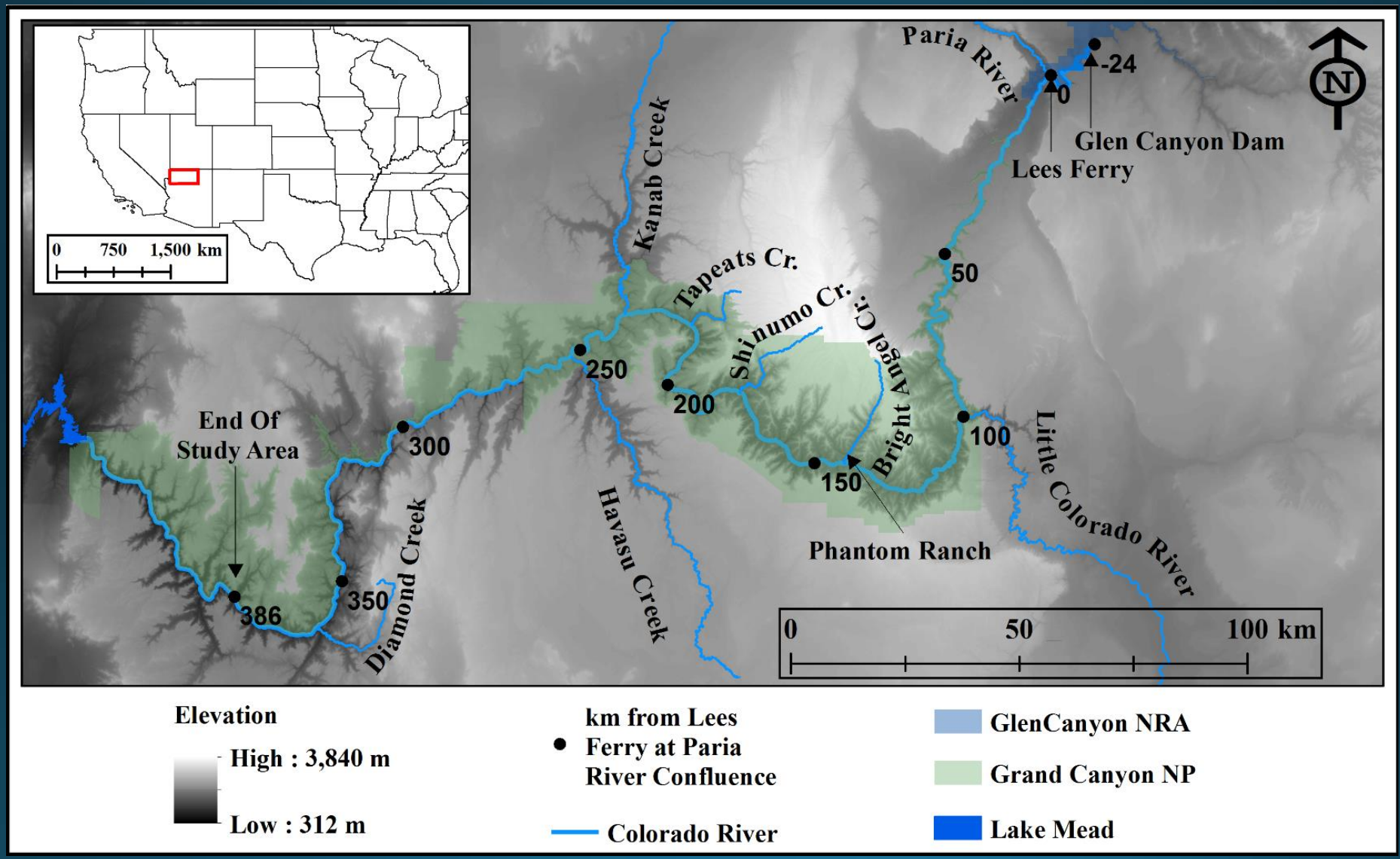
Objective 1: Multispectral image analysis

- Map areas of green and defoliated tamarisk
    - 2009 tamarisk cover
    - 2013 tamarisk cover

- Change detection of pre- and post-beetle multispectral imagery

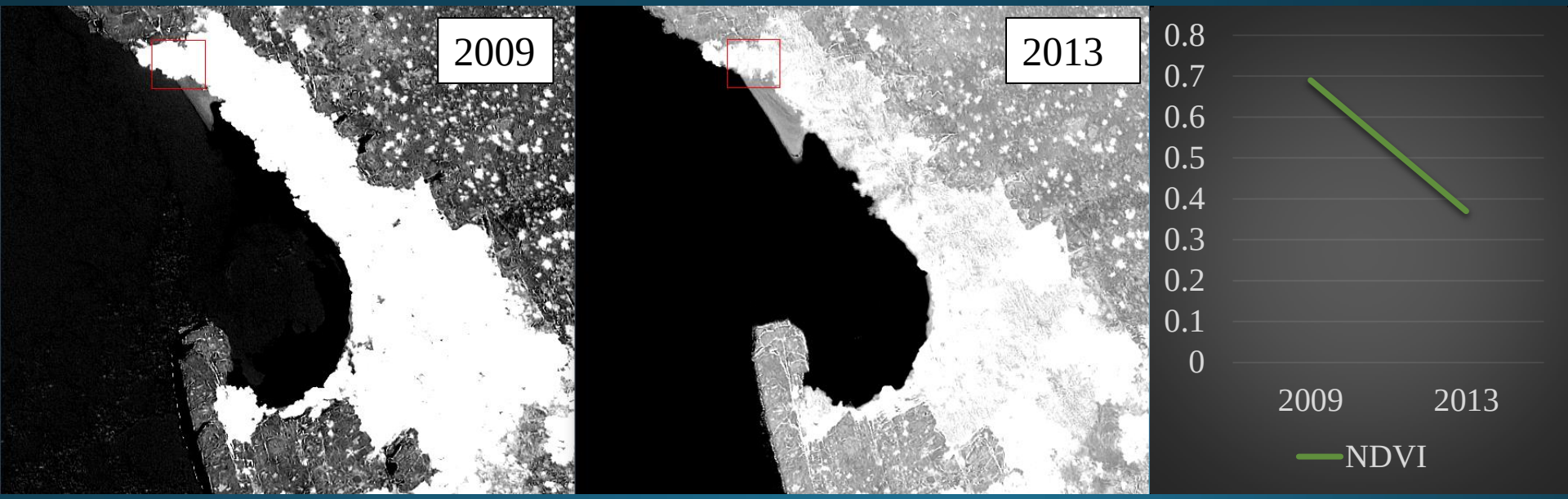
Bedford, A. "Remote Sensing of Tamarisk (Tamarix spp.) defoliation by the Tamarisk Leaf Beetle (Diorhabda carinulata) along the Colorado River in Arizona " M.S. Thesis. Northern Arizona University, May 2016

Objective 1 - Study Area: 412 km of Colorado River



Objective 1 - Methods

- Mahalanobis Distance classification
- Change detection (2009 to 2013)
- Normalized Difference Vegetation Index (NDVI)

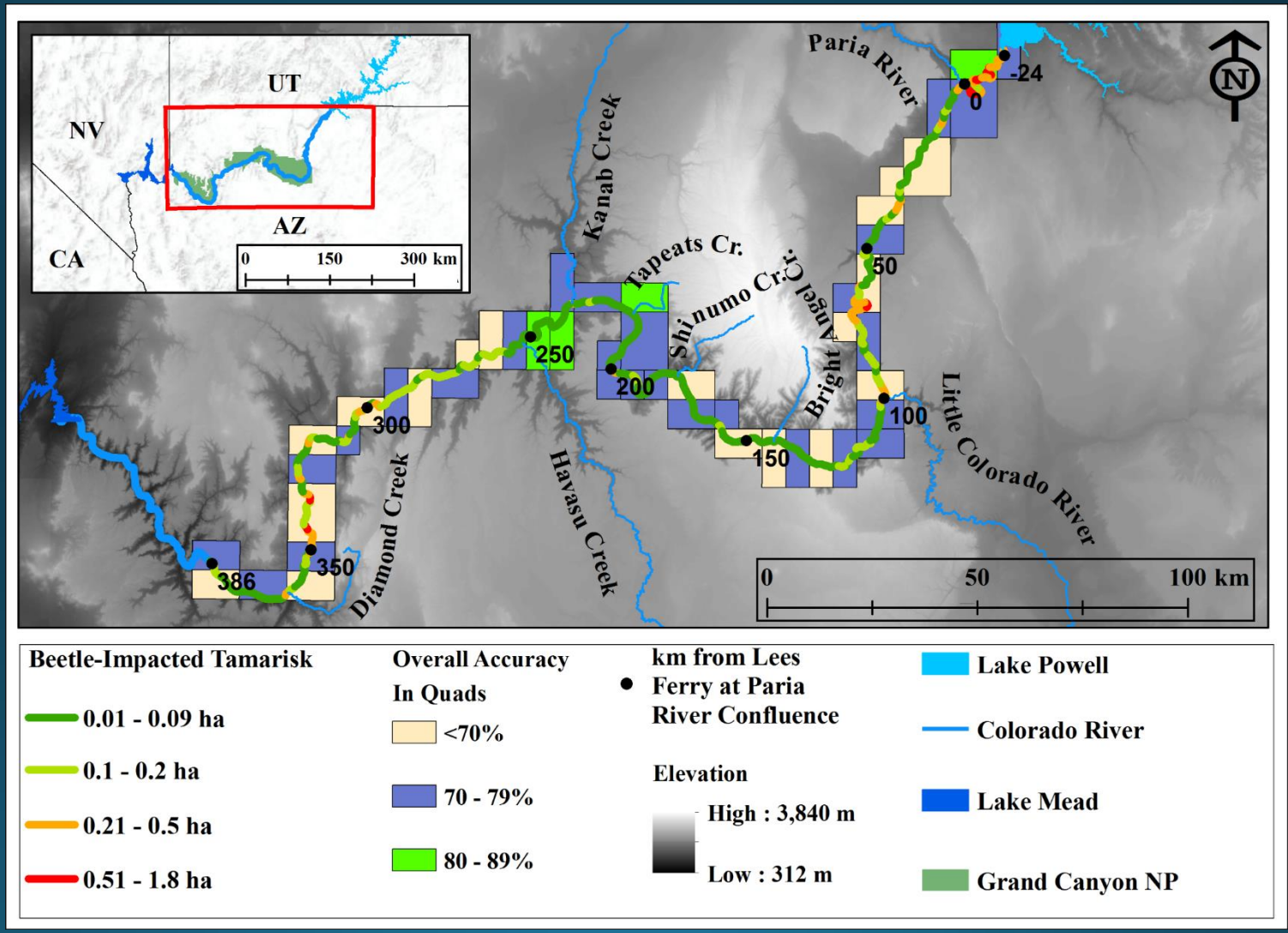


Objective 1 - Results

Total Tamarisk Area: 214 ha

Beetle-Impacted Area: 32.1 ha (15%)

Overall accuracy: 74%

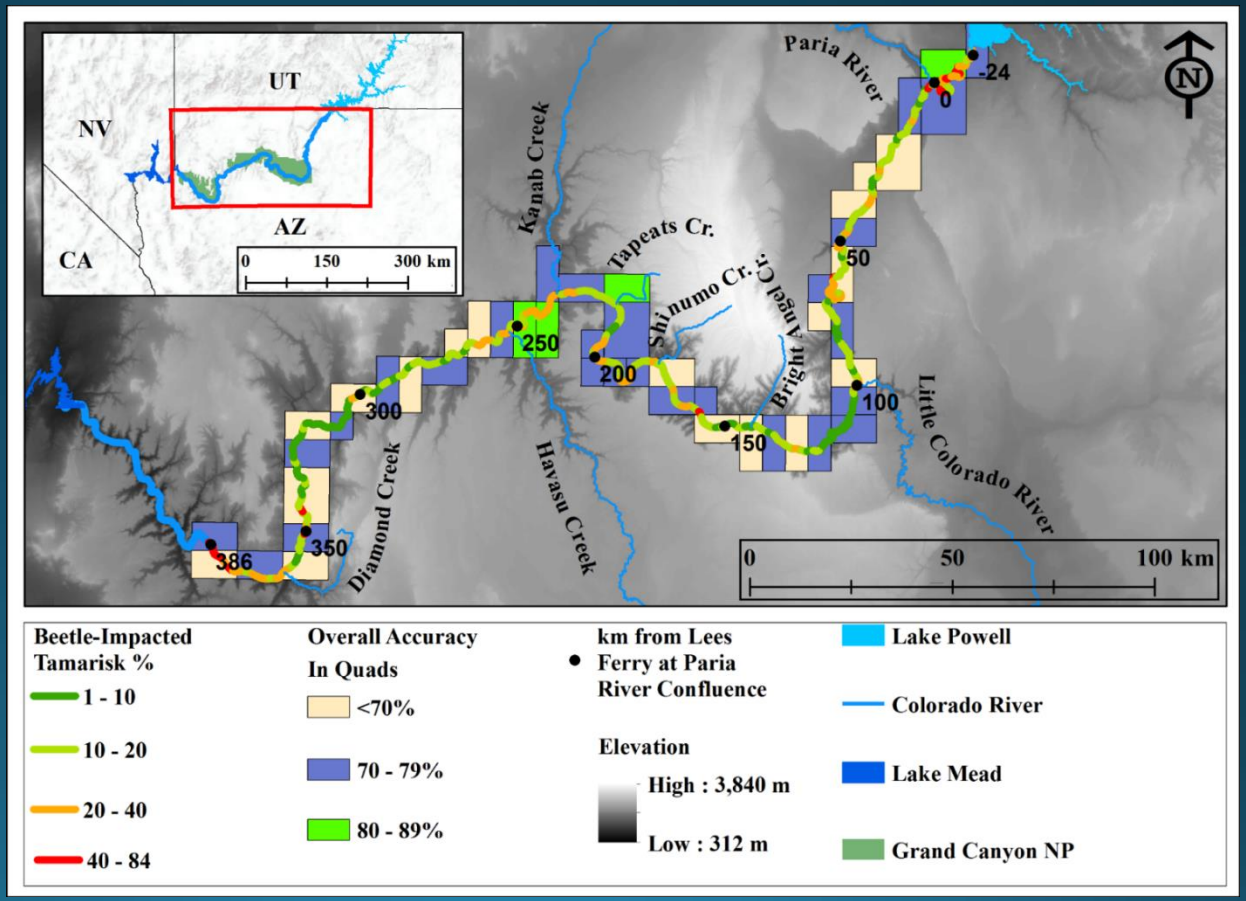


Objective 1 - Results

Beetle impact is spatially variable:

- 182 (71%) reaches: <20% canopy impacted
- 58 (23%) reaches: 20 – 40%
- 16 (6%) reaches: 40-84%

Heavily impacted reaches:
Glen Canyon,
Marble Canyon,
Western Grand Canyon

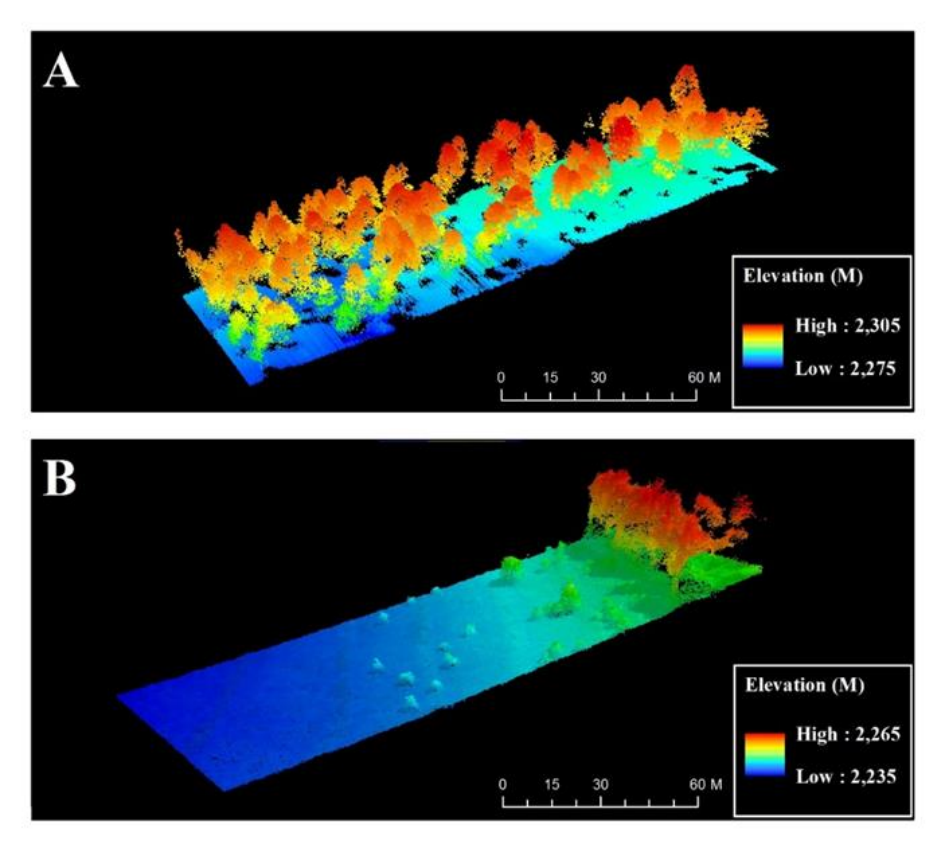


Objective 2 - Study Area

Objective 2 - Data and Methods

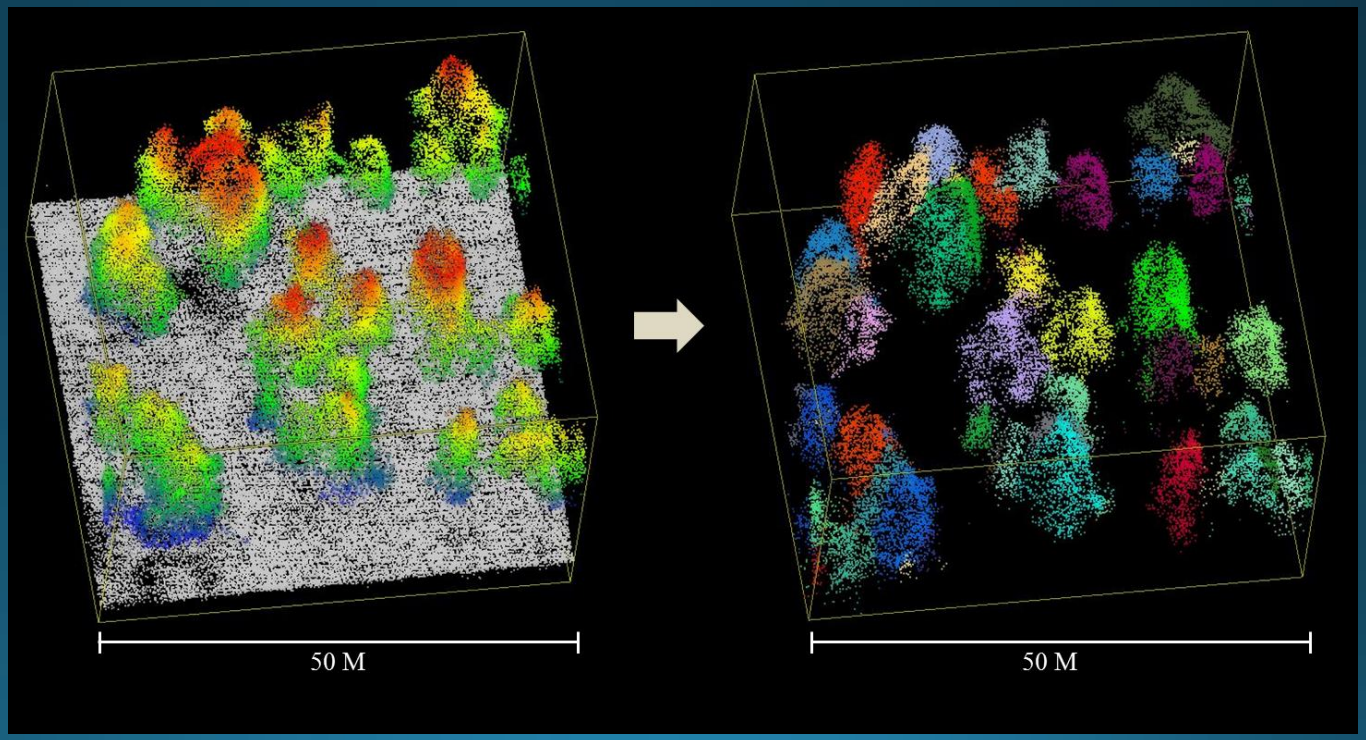
- Change detection map: 2009-2013

- Determine tamarisk biomass with lidar and allometric relationships



Objective 2 - Data and Methods

- Lidar point density of 100 points/m^2
- The lidar points classified: vegetation versus ground returns
- A canopy height model: only canopies >3 m in height
- The canopy height model segmented to delineate individual tree canopies

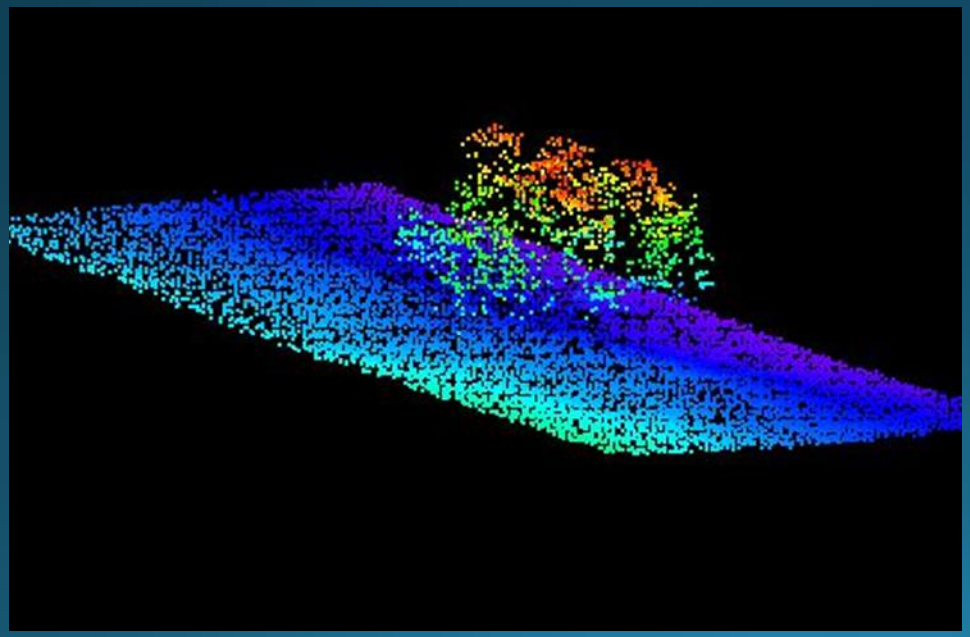


Objective 2 - Data and Methods

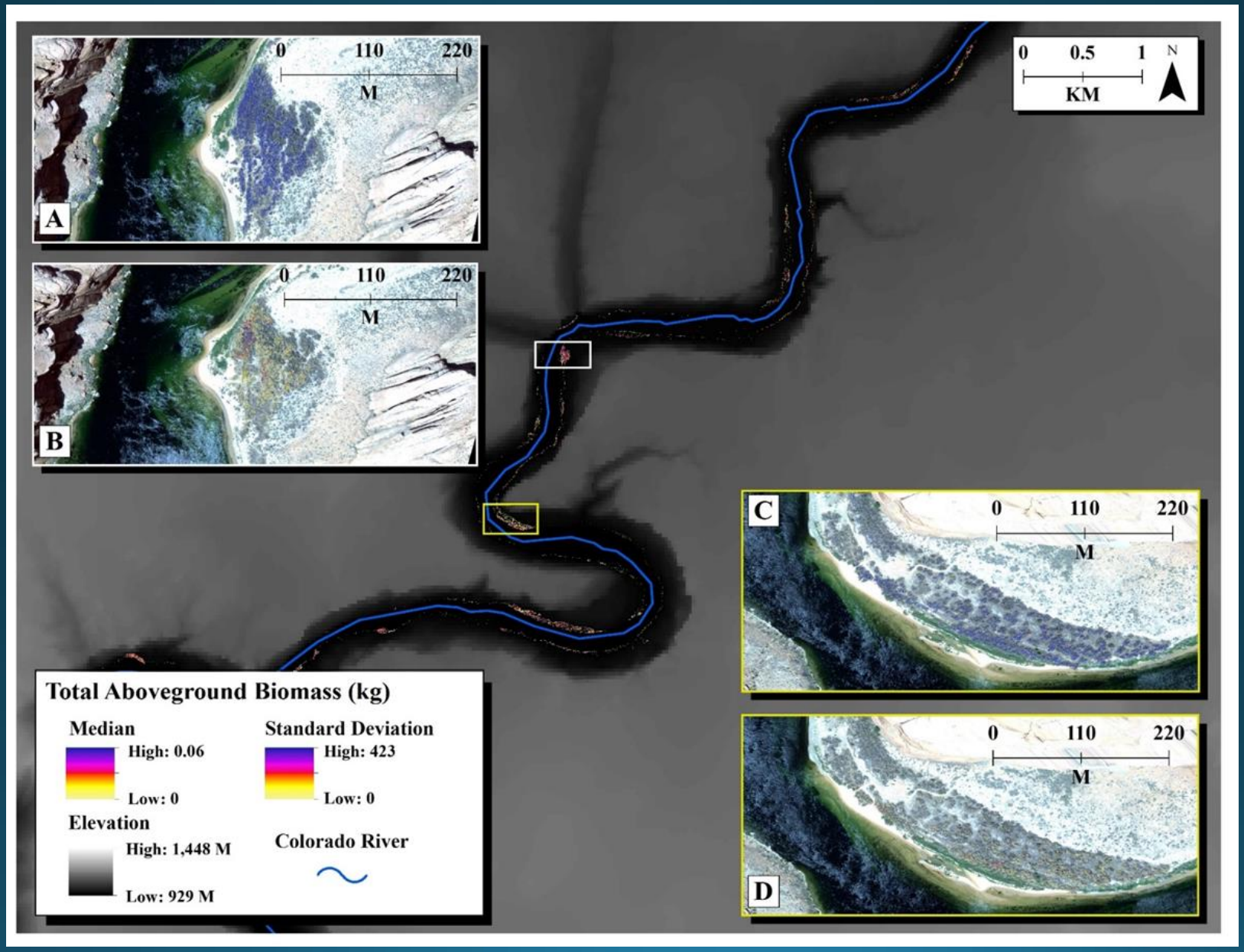
- Total aboveground tamarisk biomass (TAGB) was estimated using the canopy height (HT) and canopy area (CA) estimates (Evangelista et al., 2007):

$$\mathbf{Log_{10}(TAGB) = -1.1993 + 1.1090\ Log_{10}(CA) +}$$

$$\mathbf{0.8595\ (HT) - 0.0927\ (HT)^2}$$



Objective 2 – Tamarisk biomass: mean = 8.7 kg/m^2 (SD = 17.6)



Objective 2 - Data and Methods

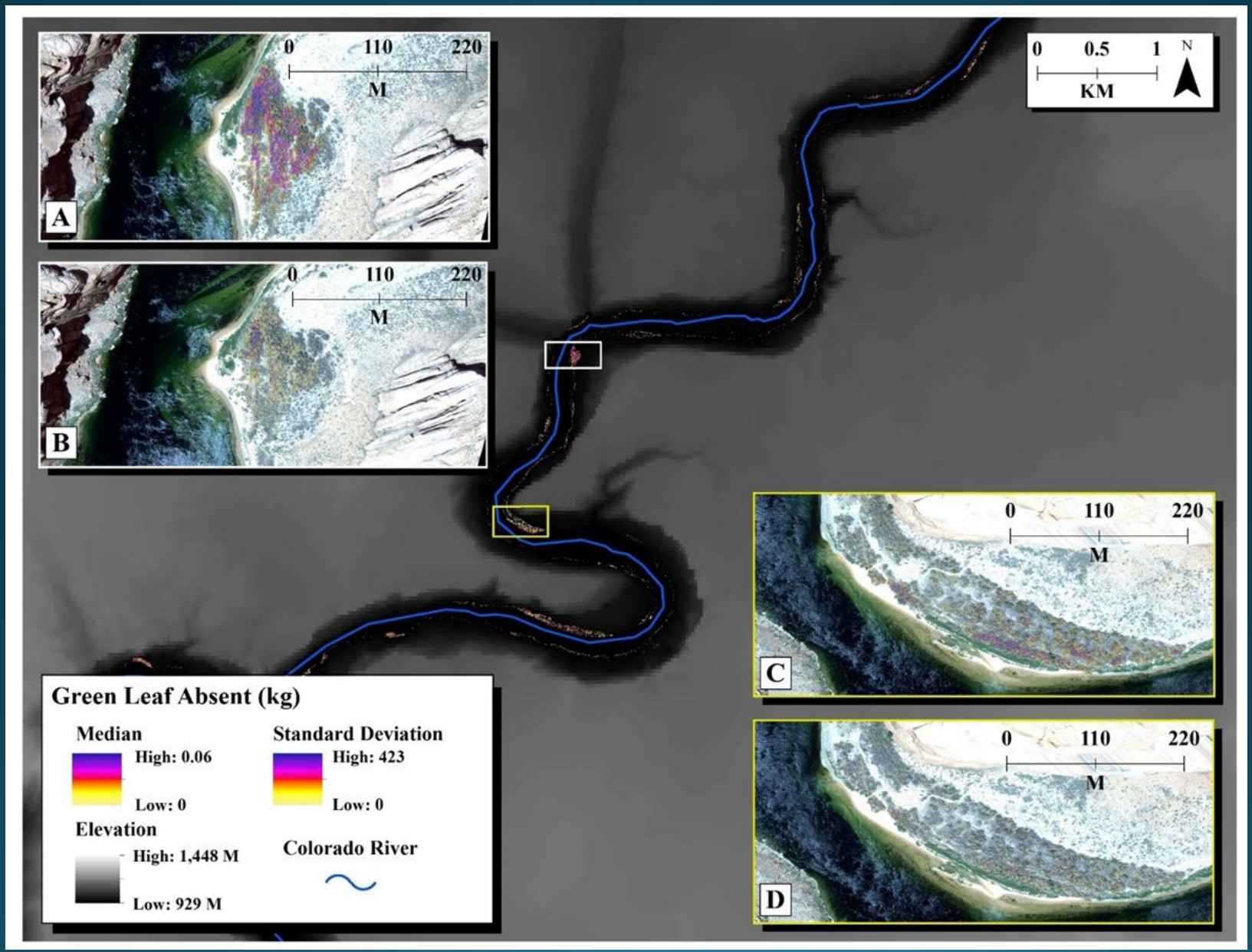
- The proportion of TAGB that was green biomass remaining on the canopy after beetle defoliation was estimated as:

  TAGBglpresent = 0.335 * 0.093 * TAGB

- The proportion of the green leaf biomass lost from the canopy due to defoliation was estimated as:

  TAGBglabsent = 0.665 * 0.093 * TAGB

Objective 2 – Tamarisk biomass: mean loss = 0.5 kg/m^2 (SD = 1.12)



Objective 2 - Summary

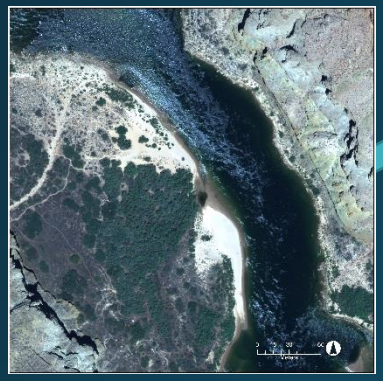
- Tamarisk biomass loss
  - 25,692 kg leaf biomass lost across the entire study area
  - 313 kg of available Nitrogen in the leaves shed

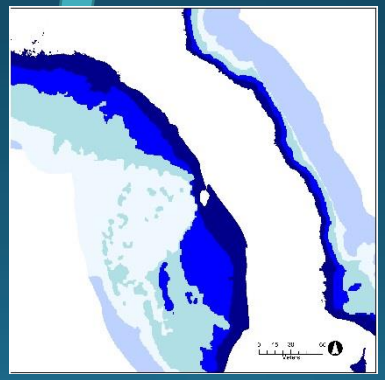
Objectives 1 & 2: Summary

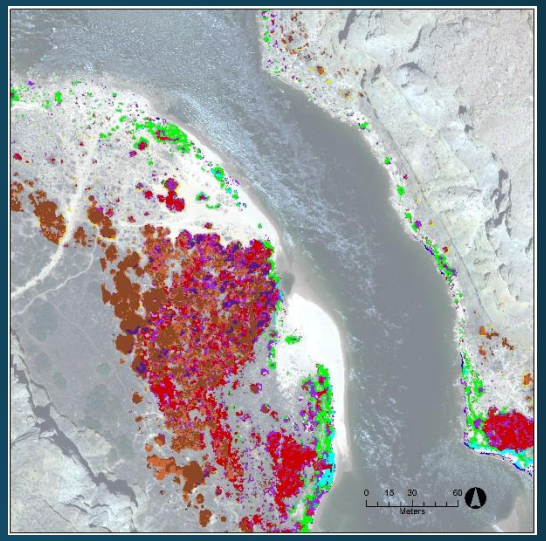
- Practical utility of the maps and data:
  - Identify locations of widespread defoliation for vegetation removal
  - Estimate biomass that would need to be removed mechanically, or consumed (fuel) by prescribed fire

Objectives 1 & 2: Summary

Image classification

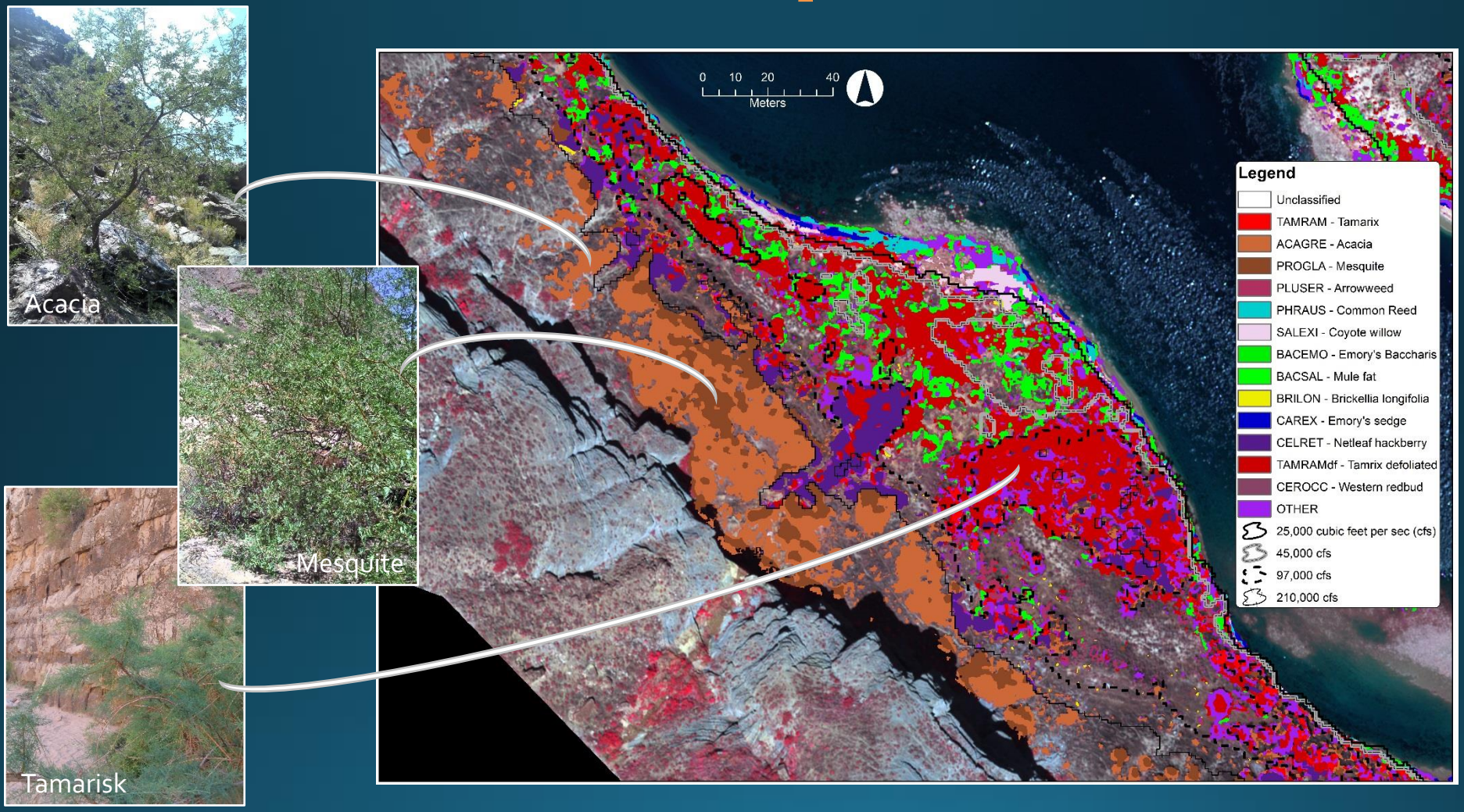




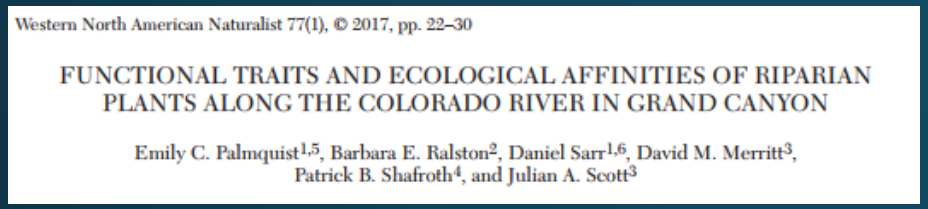


Durning et al., 2019.

Objectives 1 & 2: Summary – Riparian Species Map



Durning et al., 2018



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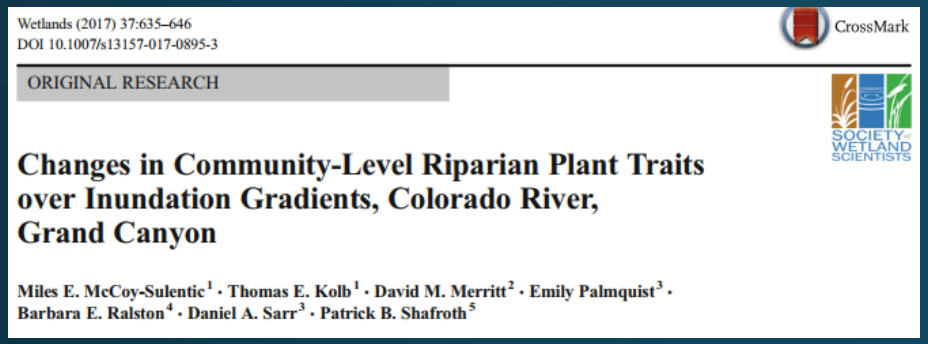
FUNCTIONAL TRAITS AND ECOLOGICAL AFFINITIES OF RIPARIAN PLANTS ALONG THE COLORADO RIVER IN GRAND CANYON

Emily C. Palmquist[1,5], Barbara E. Ralston[2], Daniel Sarr[1,6], David M. Merritt[3], Patrick B. Shafroth[4], and Julian A. Scott[3]



Wetlands (2017) 37:635–646
DOI 10.1007/s13157-017-0895-3

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ORIGINAL RESEARCH

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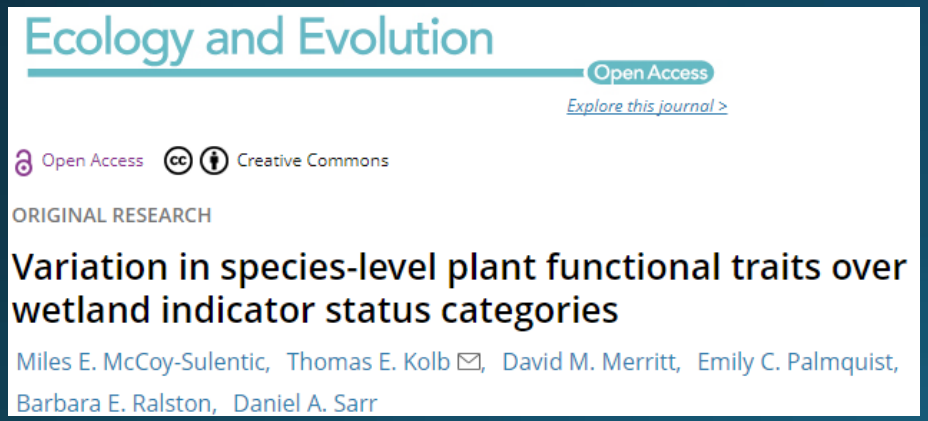
Changes in Community-Level Riparian Plant Traits over Inundation Gradients, Colorado River, Grand Canyon

Miles E. McCoy-Sulentic[1] · Thomas E. Kolb[1] · David M. Merritt[2] · Emily Palmquist[3] · Barbara E. Ralston[4] · Daniel A. Sarr[3] · Patrick B. Shafroth[5]



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ORIGINAL RESEARCH

Variation in species-level plant functional traits over wetland indicator status categories

Miles E. McCoy-Sulentic, Thomas E. Kolb ✉, David M. Merritt, Emily C. Palmquist, Barbara E. Ralston, Daniel A. Sarr

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Journal of Arid Environments

Available online 19 October 2017

In Press, Corrected Proof

Arid

Landscape-scale processes influence riparian plant composition along a regulated river

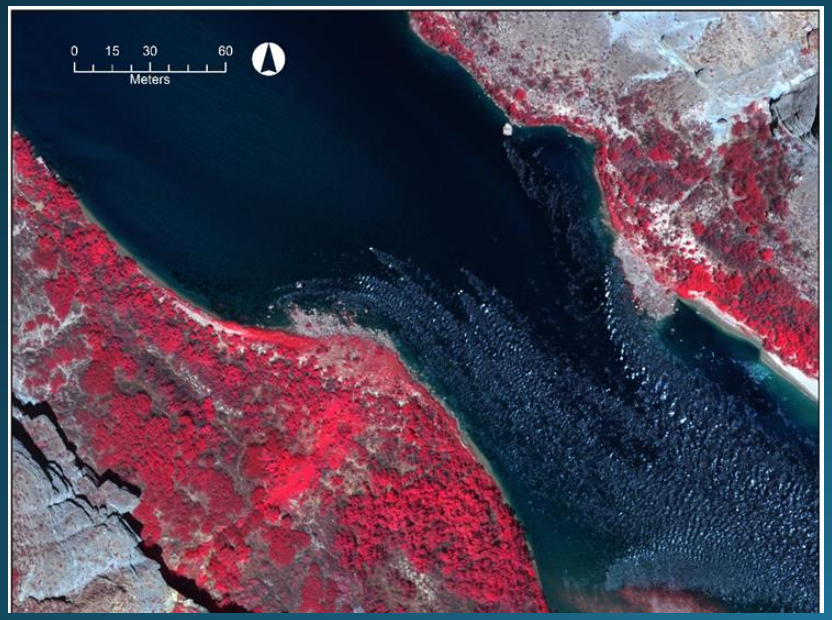
Emily C. Palmquist [a] ✉, Barbara E. Ralston [b] ✉, David M. Merritt [c] ✉, Patrick B. Shafroth [d] ✉

Objectives 1 & 2: Summary

- Remote sensing classification maps show **where** plants exist in the riparian area
- New work on Grand Canyon riparian vegetation functional traits (Palmquist et al., 2017a, b; McCoy-Sulentic et al., 2017a, b) and species distribution and niche modelling (Butterfield et al., in prep.), shows us **why** plants exist where they do in the riparian area, and can also help us predict where they will exist in the future

Objective 3: Scaling up

1) Currently ongoing project: Nat Bransky
2) Develop a new algorithm for satellite-based detection
3) Scaling up to a larger region
    Airborne multispectral image
    Field data from Levi Jamison and Matt Johnson
4) Scaling to higher frequency detection



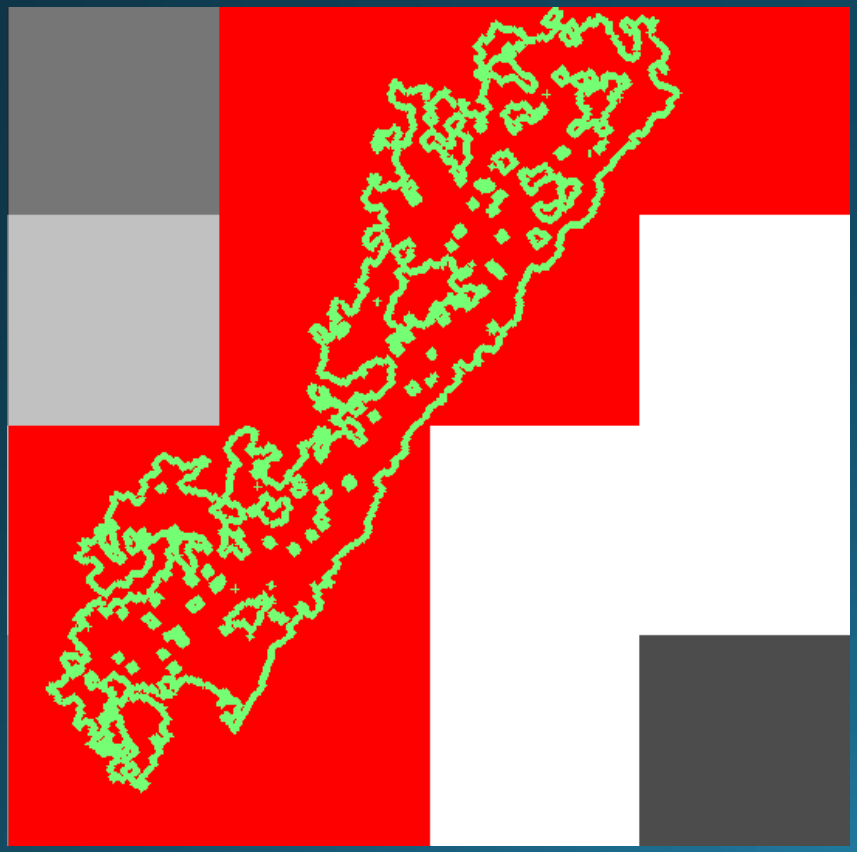
Objective 3: Satellite Remote Sensing

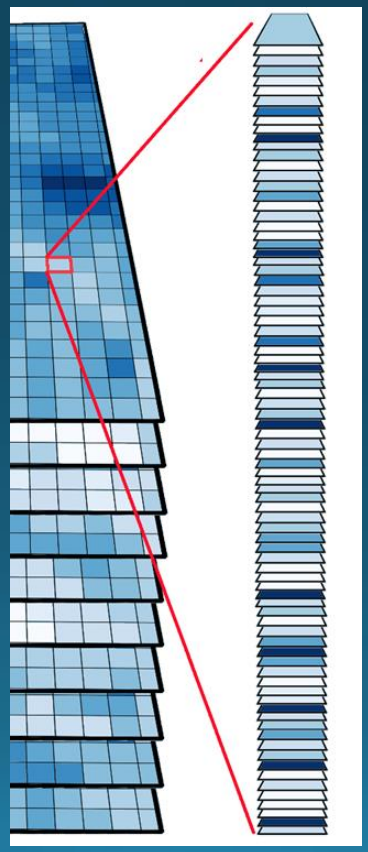
1) Satellite image:

Landsat image – 30 m pixels

Multi-temporal data: every 16 days

Identify sub-pixel defoliation

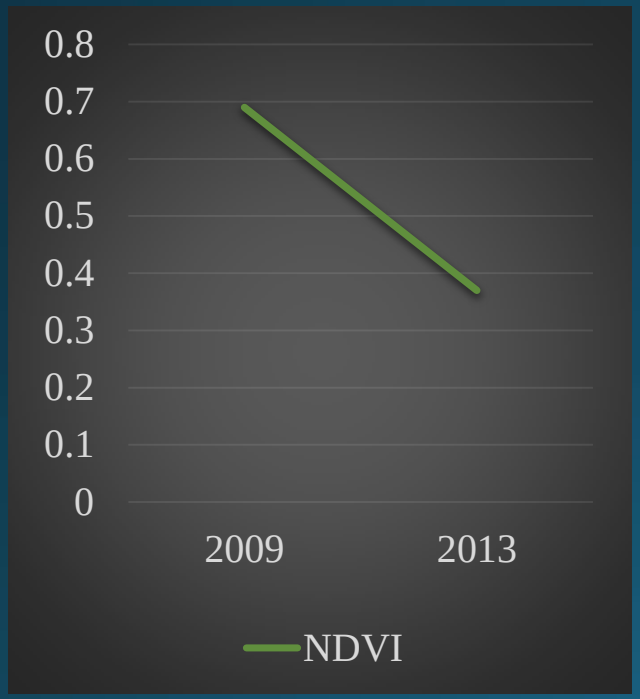


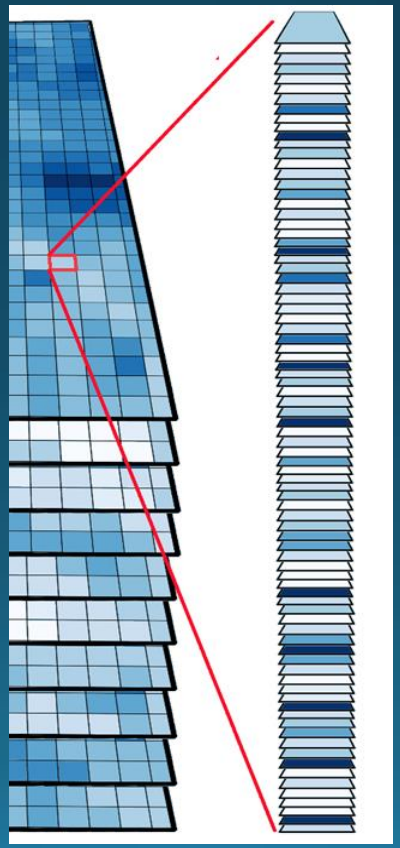


Objective 3: Satellite Remote Sensing

Important to identify locations of:

- Defoliation
- Total mortality

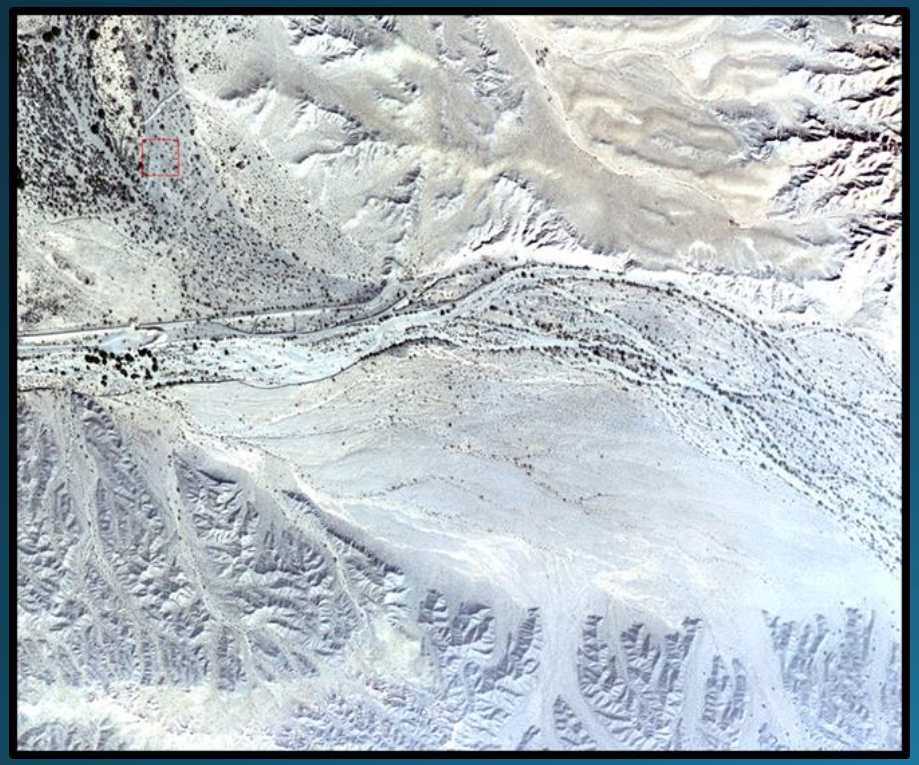


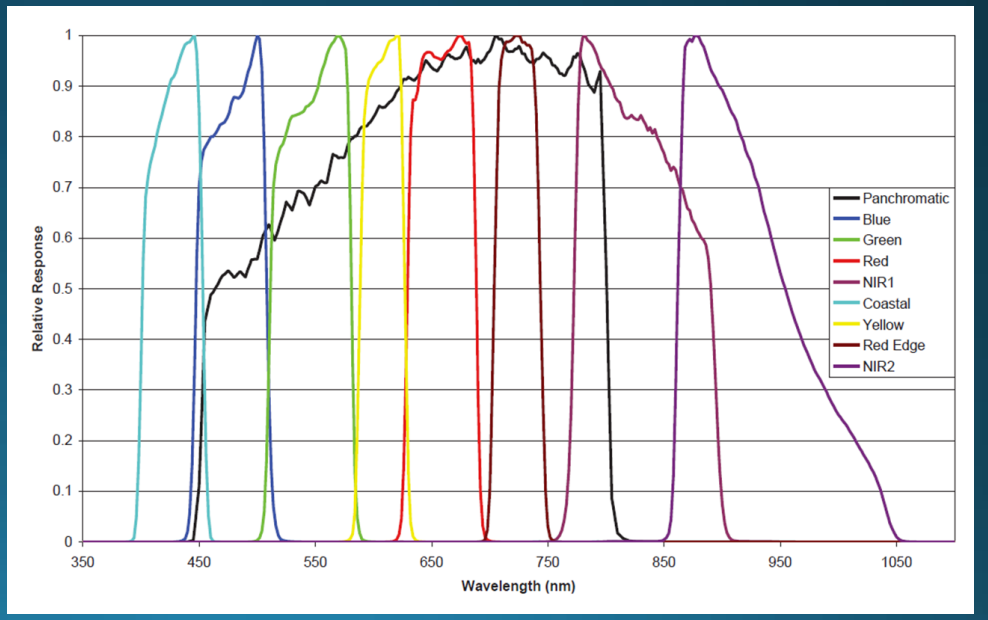


Remote sensing of tamarisk and defoliation: Future Work

Important to identify the most suitable image source:

- WorldView-2 and -3 satellite images
- Expensive commercial data
- But has 2.4m resolution and lower temporal frequency





Thanks for listening!

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•Bedford, A, Sankey, TT, Sankey, JB, Durning, L, Ralston, B, *in review at Ecological Indicators*, Remote sensing of tamarisk beetle (Diorhabda carinulata) impacts along 412 km of the Colorado River in the Grand Canyon, Arizona, USA

•Sankey, TT, Sankey, JB, Bedford, A, Horne, R, 2016, Remote sensing of tamarisk biomass, insect herbivory, and defoliation: novel methods and applications in the Grand Canyon region, Arizona, USA. Photogrammetric Engineering and Remote Sensing 82(8), pp. 645-652, doi: 10.14358/PERS.82.8.645