Riparian vegetation monitoring with remote sensing

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Phil Davis (USGS), Joshua Caster (USGS), Paul Grams (USGS), Barbara Ralston (USGS)
Talk Outline

• 2013 Overflight image mosaic

• Long-term riparian vegetation changes 1964 to 2013

• Remote sensing of tamarisk changes and tamarisk beetle impacts 2009 to 2013
2013 Overflight Image Mosaic

Timeline:

• Acquisition – Memorial Day weekend 2013
• Image mosaic complete – December 2015
• Image mosaic dataset publication – 2016
• Riparian vegetation mapping and other analyses of data mosaic for Triennial Workplan studies – Fiscal years 2015, 2016, & 2017
2013 Overflight Image Mosaic

Details:

• 4 Image Bands – Blue, Green, Red, Near Infrared
• Pixel Resolution – 0.20 meters
• 215 GB un-compressed storage size
• 144 Image Scenes cover the Colorado River from Lake Powell (15.8 miles upstream of Lees Ferry) to Lake Mead (281.1 miles downstream of Lees Ferry)
  – 270 river miles and 285.7 km² of river/riparian/upland area
• Registered to 2009 overflight image mosaic for change detection
  – Error (horizontal positional accuracy) is < 30 cm
2013 Image Mosaic Examples

Slough in Glen Canyon - River Mile -12.0 to -12.4
2013 Image Mosaic Examples

Little Colorado River Confluence-
River Mile 61.8
2013 Image Mosaic Examples

2013 National Canyon – River Mile 167
2009 National Canyon – River Mile 167
2013 Image Mosaic Examples

Paria Beach 2013 – River Mile 1.2
2013 Image Mosaic Examples

Kanab Creek 2013 – River Mile 144.0
Talk Outline

- 2013 Overflight Image Mosaic
- Long-term riparian vegetation changes 1964 to 2013
- Remote sensing of tamarisk changes and tamarisk beetle impacts 2009 to 2013
Monitoring long-term riparian vegetation changes

• In FY2015 published long-term riparian vegetation changes from analysis of imagery from 1964 to 2009


• In this presentation, I’ll extend the analysis of changes from 1964 to 2013
Long-term riparian vegetation changes - methods
Long-term riparian vegetation changes

- methods

• Analyze by 5 “zones” of the historical riparian area inundated by discharges:
  • 8,000 to 25,000 ft³/s
  • 25,000 to 31,000 ft³/s
  • 31,000 to 45,000 ft³/s
  • 45,000 to 97,000 ft³/s
  • 97,000 to 210,000 ft³/s
Discharge (m³/s)

Percentage of time equalled or exceeded

- 97,000 ft³/s
- 8,000 ft³/s
- 25,000 ft³/s
- 31,000 ft³/s
- 45,000 ft³/s
- > 97,000 ft³/s
- > 45,000 ft³/s
- > 31,000 ft³/s
- > 25,000 ft³/s
- > 8,000 ft³/s
- > 2747 m³/s
- > 1274 m³/s
- > 878 m³/s
- > 708 m³/s
- > 226 m³/s

Elevation Zone

- 1921-1965
- 1965-1973
- 1973-1984
- 1984-1992
- 1992-2002
- 2002-2004
- 2004-2005
- 2005-2009
- 2009-2013
Long-term riparian vegetation changes 1964 to 2009

Sankey et al., 2015

Zone 1: 8,000 to 25,000 ft³/s
Zone 2: 25,000 to 31,000 ft³/s
Zone 3: 31,000 to 45,000 ft³/s
Zone 4: 45,000 to 97,000 ft³/s
Zone 5: 97,000 to 210,000 ft³/s
Long-term riparian vegetation changes 1964 to 2013

- results

Zone 1: 8,000 to 25,000 ft³/s
Zone 2: 25,000 to 31,000 ft³/s
Zone 3: 31,000 to 45,000 ft³/s
Zone 4: 45,000 to 97,000 ft³/s
Zone 5: 97,000 to 210,000 ft³/s
Monitoring long-term riparian vegetation changes - summary

- No change or small decrease in vegetated area in all zones from 2009 to 2013
- However, long-term trend is vegetation increase in zones inundated by discharges less than 45,000 ft³/s
- 2013 data doesn’t alter statistical importance of predictors (Sankey et al., 2015)
  - Vegetation decoupled from river hydrology in zones inundated by discharges > 97,000 and possibly > 45,000 ft³/s; vegetated area decreases due to rainfall drought
  - Vegetated area increases in zones below 45,000 ft³/s with (i) elevated baseflows that make more water available to plant roots, and (ii) lower frequency and magnitude of peak flows/floods
- How do we explain the 2009 to 2013 changes in zones below 45,000 CFS? HFE deposition and shoreline changes? Rainfall drought?
Brown and defoliated Tamarisk in 2013 due to Tamarisk Beetle impacts.
Talk Outline

- 2013 Overflight Image Mosaic
- Long-term riparian vegetation changes 1964 to 2013
- Remote sensing of tamarisk changes and tamarisk beetle impacts 2009 to 2013
Tamarisk
(*Tamarix spp.*)

- **History**
  - In the US since 1800s
  - Decorative species
  - Invasive species

- **Biology**
  - Salt cedar
  - Tap-root

- **Management**
  - Dominant in the Southwest
  - Spread rate: 20 km/year
  - Expensive mechanical control
Tamarisk Beetle
(Diorhabda carinulata)

- **Biology**
  - Natural predator of the shrub
  - Eats the leaves
  - Tamarisk defoliation
- **History of Introduction**
  - Asia
  - Texas- early 2000s
  - Utah- 2005
  - Found in Grand Canyon NP and Glen Canyon NRA in 2009
Objectives and Methods

- Map area and biomass of green and defoliated tamarisk - new remote sensing for monitoring tamarisk and beetle impacts
  - Change detection of multispectral imagery
    - What percent of green tamarisk in 2009 was defoliated in 2013?
  - Glen Canyon, Kanab Creek, National Canyon (3 reaches)
  - Ashton Bedford, M.S. Thesis NAU, Defending Spring 2016
- Fusion of multispectral imagery with lidar data
  - Quantify and map spatial distribution of biomass of total, green-leaf, and defoliated leaf (litter) tamarisk in 2013
  - Glen Canyon (one reach)
What percent of green tamarisk in 2009 was defoliated in 2013?

(Bedford, M.S. Thesis)

<table>
<thead>
<tr>
<th>Reach</th>
<th>Percent of Tamarisk Vegetation</th>
<th>Total Area (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glen Canyon (Glen Canyon Dam to Lees Ferry)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green</td>
<td>76 %</td>
<td>20,005</td>
</tr>
<tr>
<td>Defoliated</td>
<td>24 %</td>
<td>9,053</td>
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<td>88 %</td>
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<td>Defoliated</td>
<td>12 %</td>
<td>2,893</td>
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Spatial distribution of tamarisk biomass

(Sankey et al., manuscript in review)
Remote sensing of tamarisk and defoliation - summary

• Biomass maps in Glen Canyon
  • 8.68 kg/m² mean total above ground tamarisk biomass
  • 0.52 kg/m² mean total above ground tamarisk “green leaf absent” (i.e., litter) biomass
    • 4,300 kg of tamarisk leaf biomass potentially shed within the riparian area of Glen Canyon

• Practical utility of the maps and data:
  • Future monitoring of defoliation and beetle impacts
  • Planning for vegetation management
    • Identify locations of widespread defoliation for vegetation removal
    • Estimate biomass that would need to be removed mechanically, or consumed (fuel) by prescribed fire
    • Tamarisk and defoliation relative to inundating flows
Thanks for listening!
Acknowledgements
Summary

- 8.68 kg/m²: mean total above ground tamarisk biomass
- 0.52 kg/m²: mean total above ground tamarisk “green leaf absent” (i.e., litter) biomass
  - 4,300 kg: potential tamarisk leaf biomass potentially shed over the riparian zone within Glen Canyon
- Practical utility of the maps and data:
  - Planning for vegetation management
    - Identify locations of high degree of defoliation for vegetation removal treatments
    - Estimate amount of biomass that would need to be removed either mechanically, consumed as fuel in a prescribed fire
    - Identify areas of high degree of defoliation that are within the HFE flood stage
PERS paper intro with methods

• Research Objectives
  • Develop a remote sensing method to estimate total aboveground tamarisk biomass as well as leaf-only tamarisk biomass using lidar and existing allometric relationships,
  • Demonstrate how the fusion of lidar and multitemporal, multispectral imagery can be used to monitor the effects of green leaf biomass defoliation,
  • Quantify the uncertainties associated with the above estimates in a robust manner that accounts for each of the key sources of uncertainty in riparian biomass estimates.

• Paper in review

• Methods
  • Fusion of lidar (2013) and multispectral imagery (2009 and 2013) from overflights: Glen Canyon Dam to ~6 miles upstream of Lees Ferry
  • Use multispectral imagery to map tamarisk
  • Use lidar allometry to estimate tamarisk biomass
  • Use change detection of multispectral imagery with lidar-derived biomass to estimate biomass of total, green-leaf, and defoliated leaf (litter) tamarisk in 2013
Summary
2013 Overflight Image Mosaic

Details:

• During mosaic preparation remove “smear” (mechanical error) from the data.
  
  – Smear could not be removed in less than 0.24 km² or 0.09% of the total image area
2013 Image Mosaic Examples

Inner Gorge - River Mile 81.2
2013 Image Mosaic Examples

Submerged Sand at 182mile Camp – River Mile 182.8
Methods

- Overflight Multispectral Image Mosaics
  - 2009: Pre-beetle image
  - 2013: Post-beetle image
  - 2009:2013 (Pre/Post Comparison)
- NDVI (Normalized Difference Vegetation Index)
  - 2009
  - 2013
  - 2009:2013
- 3D Lidar images
  - 2013
  - Vegetation height
  - Canopy volume and biomass density
Methods

- Overflight Multispectral Image Mosaics
  - 2009: Pre-beetle image
  - 2013: Post-beetle image
  - 2009:2013 (Pre/Post Comparison)

- NDVI (Normalized Difference Vegetation Index)
  - 2009
  - 2013
  - 2009:2013

- 3D Lidar images
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Remote sensing of tamarisk defoliation

- Research Question
  - What percent of green tamarisk in 2009 was defoliated in 2013?
- M.S. Thesis (Ashton Bedford), Northern Arizona University, defense Spring 2015
- Three reaches
  - Glen Canyon (19.6 miles from Glen Canyon Dam to 3.6 miles downstream of Lees Ferry)
  - Kanab (From 134.6 to 155.7 miles downstream of Lees Ferry)
  - National (From 158.6 to 180.5 miles downstream of Lees Ferry)
- Methods
  - Image classification of tamarisk in 2009
    - Glen Canyon Tamarisk Classification accuracy = 87 %
    - Kanab Tamarisk Classification accuracy = 83 %
    - National Tamarisk Classification accuracy = 72 %
  - Change detection vegetation greenness indices from 2009 to 2013
Remote sensing of tamarisk defoliation

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(Glen Canyon Dam to Lees Ferry) |                                |                 |
| Green                          | 76 %                           | 20,005          |
| Defoliated                     | 24 %                           | 9,053           |
| **Kanab**  
(RM 134.6 to 155.7)         |                                |                 |
| Green                          | 77 %                           | 4,047           |
| Defoliated                     | 23 %                           | 1,095           |
| **National**  
(RM 158.6 to 180.5)        |                                |                 |
| Green                          | 88 %                           | 21,727          |
| Defoliated                     | 12 %                           | 2,893           |
Remote sensing of tamarisk defoliation - Lidar Fusion - Tamarisk Biomass