Monitoring Framework for Upland Hardwood and Grassland Restoration:
Integrating Innovative Spatial Technology

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and

Robin Tillitt
(US Geological Survey, Columbia Environmental Research Center)

May 11, 2016
DOI National Restoration Workshop
## GUHM Partners

(Grassland and Upland Hardwood Monitoring)

### Project Partners:

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<thead>
<tr>
<th>US Department of the Interior</th>
<th>US Department of Defense</th>
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<tr>
<td>US Fish and Wildlife Service</td>
<td>US Army Corps of Engineers</td>
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<tr>
<td>Crab Orchard National Wildlife Refuge</td>
<td>US Army Engineer Research and Development Center</td>
</tr>
<tr>
<td>Kathleen Burchett, Refuge Manager</td>
<td>Heather Theel, Research Biologist</td>
</tr>
<tr>
<td>Mike Coffey, CERCLA Program</td>
<td>Warren Lorentz, Chief, Environmental Processes and Engineering Division</td>
</tr>
<tr>
<td>Leanne Moore, CERCLA Program</td>
<td>Molly Reif, Research Geographer</td>
</tr>
<tr>
<td>David Jones, Fire Management Program</td>
<td>Nathan Beane, Research Forester</td>
</tr>
<tr>
<td>Case Bryan, Biology Program</td>
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<tr>
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<tr>
<td>Office of Policy Analysis</td>
<td>Office of Restoration and Damage Assessment</td>
</tr>
<tr>
<td>Kristin Skrabis, Economist</td>
<td>Restoration Support Unit</td>
</tr>
<tr>
<td></td>
<td>David Ross, Restoration Biologist</td>
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<tr>
<td>Columbia Environmental Research Center</td>
<td>National Inventory and Monitoring Applications Center</td>
</tr>
<tr>
<td>Robin Tillitt, Ecologist</td>
<td>John Stanovick, Mathematical Statistician</td>
</tr>
<tr>
<td>Jo Ellen Hinck, USGS NRDAR Coordinator</td>
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</tbody>
</table>

Keith Grabner, Forest Ecologist
Overview

- Background
  - Universal Metrics vs. Goal Based Objectives
- Project Questions
- Approach
- Monitoring Framework for Upland Hardwoods and Grasslands
  - Traditional Field Surveys vs. Innovative Spatial Technology
- 2016/2017 Field Sampling Plan
The need/importance of restoration monitoring is well documented (Hooper et al 2016)
Restoration Science Support Need
Restoration Science Support Need

- Restoration Science is trending towards the concept of Universal Metrics (Baggett et al. 2014)
  - Lack of monitoring data
  - Unclear restoration goals/objectives
  - Therefore, unable to assess population changes
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Lack of change detection = Unsuccessful Restoration
Utility of Universal Metrics

- Systematic Assessment of Basic Restoration Performance
- Consistent
- Comparable
- Simplified, Reduces burden
- May not adequately address goal-specific performance
Definitions (Baggett et al 2014)

- **Universal metrics**: Metrics and variables that should be sampled for each habitat-specific restoration project.

- **Goal-based Metrics**: Metrics that are specific to ecosystem service-based restoration goals and should be sampled for projects citing that particular restoration goal.
GUHM Project Questions

- What are common measures and/or metrics in the literature to monitor the basic performance of upland hardwoods and grassland restoration projects?
  - Traditional Field Based
  - Remote Sensing
- What are the advantages/disadvantages (precision, level-of-effort, etc.) between common monitoring metrics?
GUHM Project Approach

Phase 1 (2015/2016):
- Literature Review
  - Traditional Field Based
  - Remote Sensing
- Draft Monitoring Frameworks for Upland Hardwood and Grassland Restoration Projects
- Field Sampling Plan

Phase 2 (2016/2017):
Monitoring Framework

Objective:
- To develop habitat-specific restoration monitoring frameworks that provide universal metrics for evaluating restoration performance at varying levels of precision.

General Approach:
- Compilation of Universal Monitoring Metrics
- Tiered Precision (3 levels)
- Traditional Field Based vs. Remote Sensing
- Universal Environmental Metrics
- Universal Human Use/Recreation Checklist
Using the literature, the team is developing a tiered framework with the following kinds of information:

**Upland Hardwood Site**

<table>
<thead>
<tr>
<th>Metric Type</th>
<th>Calculated Metrics</th>
<th>Field Collected Data</th>
<th>Methodology (plot size, distribution, and number of samples will be determined by consultation with statistician)</th>
<th>Level of Effort (estimates for field personnel hours and/or data processing hours)</th>
<th>Sampling Guidelines</th>
<th>Precision (determined by confidence required/desired by practitioner and restoration objectives)</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tier One (Universal Metrics for all Hardwood Restoration)</td>
<td>1-Structural Metrics 2-Compositional Metrics 3-Ecosystem Service Metrics</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

The tiers represent increasing levels of precision to meet the wide range of NRDAR needs. For example:

- **Tier 1.** Structural and compositional metric for trees is % cover
- **Tier 2.** # Trees/Hectare, Basal Area/Hectare (m²/ha), and snag Density (# snags/ha)
- **Tier 3.** Tier 2 plus survival
Why Integrate Remote Sensing?

- Role of RS has increased with the advent of new sensors, improved technology, decreasing costs, and global increases in protected land area.

- Increased need for rapid and remote ways to examine the effectiveness of restoration strategies.

- Spatial measurements can be used to quantitatively assess restoration objectives in four main areas: 1) habitat extent and landscape structure, 2) habitat degradation, 3) biodiversity, and 4) threats/pressures.
Remote Sensing Examples

Medium Resolution Sensors
5-30 m

Applications
• Broad-scale land cover or habitat type/pattern
• General biodiversity or species richness
• Rapid change detection or loss/gain
• Seasonal/multi-year changes
• Overall forest extent clearance/regeneration
• Overall degradation or disturbance from fire grazing, drought, etc,
• Broad biophysical estimates from band ratios (NDVI, etc)
• Landscape metrics (landscape and class level), such as fragmentation
Remote Sensing Examples

Detailed habitat abundance to assess potential project impacts for restoration planning

- High resolution satellite imagery provided through internal agency agreement

<table>
<thead>
<tr>
<th>Wetland Impacts</th>
<th>S10/40</th>
<th>S2/48</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ashley River forested wetlands</td>
<td>1.52 acres</td>
<td>1.36 acres</td>
</tr>
<tr>
<td>Ashley River marsh wetlands</td>
<td>10.86 acres</td>
<td>13.16 acres</td>
</tr>
<tr>
<td>Cooper River forested wetlands</td>
<td>89.65 acres</td>
<td>126.37 acres</td>
</tr>
<tr>
<td>Cooper River marsh wetlands</td>
<td>177.57 acres</td>
<td>179.53 acres</td>
</tr>
<tr>
<td>Total</td>
<td>231.60 acres</td>
<td>323.72 acres</td>
</tr>
</tbody>
</table>

Detailed species mapping in a restored blog complex

Knoth et al. (2013)
Remote Sensing Examples

**Active Sensors**

**Lidar and Radar**

**Applications**
- Detailed vegetation structure, biomass, and height characteristics
- Combined with imagery for improved species identification
- Assist with biophysical estimates, detailed 3-D, height, LAI, biomass, age, succession, regeneration, and composition

### Lidar products:
- Ground surface, canopy surface, and canopy height models, and intensity images

- **Vegetation**
  - 22 (out of 44) species occupancy increased with increasing heterogeneity
  - Two (out of 44) species occupancy decreased

- **Canopy heterogeneity**
  - Species richness increased
  - Bat activity and occurrence increased

- **Canopy vertical distribution**
  - Two species (out of two) increased abundance and/or occupancy with increasing vertical distribution
  - Species diversity increased

- **Canopy height**
  - Chick mass increased in blue tits, decreased in great tits, was climate dependent for great tit chick mass (increased in warm springs, decreased in cold springs) with increasing height
  - Native to exotic species ratio increased with increasing height
  - Species richness (forest species richness increased, scrub species richness decreased)
  - 21 (out of 49) species abundance and/or occupancy increased with increasing height
  - Nine (out of 49) species abundance decreased
  - Species diversity increased
  - Bat activity and occurrence increased

- **Canopy cover**
  - Native to exotic species ratio increased with increasing cover
  - Species diversity increased
  - 11 species (out of 23) increased abundance and/or occupancy with increased cover (horizontal extent and foliage density)
  - Six species (out of 23) decreased abundance and/or occupancy with cover

- **Understory density**
  - Species diversity increased with increasing density
  - 12 (out of 34) species increased abundance and/or occupancy with increasing understory density
  - Seven (out of 34) species decreased abundance and/or occupancy with increasing understory density
  - Foraging bat abundance decreased with increasing density

- **Horizontal structure**
  - Two species (out of two) preferred intermediate or mixed levels of horizontal structure
  - Species richness increased with increasing patch diversity

- **Contiguous forest**
  - Native to exotic species ratio increased with larger forest patches
  - One species (out of one) preferred larger forest patches

- **Topography**
  - Species richness decreased with increasing elevation

- **Elevation**
  - Species richness decreased with increasing steepness

**Radar backscattering and intensity to characterize riparian vegetation properties: size, orientation, and structure**

(Dufour et al., 2013)
Remote Sensing for Restoration Ecology: Application for Restoring Degraded Ecosystems
(authors Reif and Theel, submitted to IEAM April 2016)

<table>
<thead>
<tr>
<th>Platform</th>
<th>Sensor, Type</th>
<th>Sensor</th>
<th>Spectral Bands (NM)</th>
<th>Spatial Resolution (M)</th>
<th>Swath Width (KM)</th>
<th>Revisit (Days)</th>
<th>Operator</th>
<th>Cost</th>
<th>Applications/Metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium Resolution Spaceborne</td>
<td>Optical - Multispectral</td>
<td>Landsat-8</td>
<td>1-7, 9 (435-2294), Pan 8 (503-676), 10-11 (1060-1251)</td>
<td>15, 30, 100 (Pan, MS, TIR)</td>
<td>185 KM</td>
<td>16 days</td>
<td>USGS</td>
<td>Free</td>
<td>Broad-scale land cover or habitat type/pattern, general biodiversity/species richness, rapid change detection or loss/gain, season change/multi-year changes, overall forest extent/clearance/regeneration, overall degradation or disturbance from fire, grazing, drought, etc, broad biophysical estimates (NDVI, NPP, LAI etc), landscape metrics (landscape and class level), such as fragmentation</td>
</tr>
<tr>
<td>Medium Resolution Spaceborne</td>
<td>Optical - Multispectral</td>
<td>Indian Remote Sensing-PS (IRS-7D) also called Resourcesat-1 and 2</td>
<td>3 (520-860), 4 (520-1700), Pan (500-850)</td>
<td>5, 20, &amp; 60 (Pan, MS)</td>
<td>70, 141 &amp; 740 KM</td>
<td>5 days</td>
<td>Indian Space Research Organization</td>
<td>1700-4500 EUR/scene</td>
<td></td>
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<tr>
<td>Medium Resolution Spaceborne</td>
<td>Optical - Multispectral</td>
<td>SPOT-7</td>
<td>4 (455-890), Pan (450-745)</td>
<td>1.5-2.5, 6-10 (Pan, MS)</td>
<td>60 KM</td>
<td>1-5 days</td>
<td>Sattish Dhawan Space Center</td>
<td>Some archives free; $32/KM</td>
<td></td>
</tr>
<tr>
<td>Medium Resolution Spaceborne</td>
<td>Optical - Multispectral</td>
<td>Sentinel-2A</td>
<td>13 (400-2400)</td>
<td>10 (0.5-2.5, 6-10, 60 (b1, 9, 10, 11)</td>
<td>290 KM</td>
<td>10 days</td>
<td>ESA</td>
<td>Available Oct 2013/Free</td>
<td></td>
</tr>
<tr>
<td>Medium Resolution Spaceborne</td>
<td>Optical - Multispectral</td>
<td>RapidEye</td>
<td>5 (400-850)</td>
<td>6.5</td>
<td>77 KM</td>
<td>1 day</td>
<td>Blackbridge</td>
<td>0.99/1.05 EUR/KM</td>
<td></td>
</tr>
<tr>
<td>Medium Resolution Spaceborne</td>
<td>Optical - Multispectral</td>
<td>TERRA ASTER</td>
<td>11 (520-2430)</td>
<td>15 (VNIR), 30 (SWIR), 90 (TIR)</td>
<td>60 KM</td>
<td>16 days</td>
<td>NASA RSE</td>
<td>Fine-scale land cover, habitat type/pattern, some species mapping (homogenous areas), composition/abundance/distribution (homogenous areas), indicators of biodiversity/species richness (homogenous areas), detailed degradation or disturbance (some invasive species, pest attacks, fire, grazing, etc), individual feature delineation (e.g. tree crowns), more detailed biophysical estimates (NDVI, NPP, LAI etc) such as with WV-2 and 3 (higher spectral resolution), and landscape metrics (landscape, class, and patch level)</td>
<td></td>
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</table>
2016/2017 Field Sampling Plan

- **Objectives:**
  - Evaluate the utility of the draft universal monitoring framework for grassland and upland hardwood restoration,
  - Identify low-cost remote sensing technologies to monitor grassland and upland hardwood restoration performance,
  - Compare traditional field-based surveys and remote sensing technology metrics for assessing performance of grassland and upland hardwood restoration,
  - Document costs (level-of-effort) associated with executing all tiers in the decision framework including field and data processing labor, travel, and any indirect costs, and
  - Develop universal field sampling data collection forms for restoration practitioners to ensure basic data are being collected.
Study Site

Study Site:

- Crab Orchard National Wildlife Refuge, IL
- 43,890 ac
- 4 primary purposes: Wildlife Conservation, Agriculture, Industry, and Recreation

https://www.fws.gov/uploadedFiles/general%20refuge%20map.pdf
## CONWR Restoration Sites

<table>
<thead>
<tr>
<th></th>
<th>Forest</th>
<th>Grassland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total # CONWR Sites</td>
<td>204</td>
<td>18</td>
</tr>
<tr>
<td>Restoration Implementation Completed</td>
<td>102</td>
<td>15</td>
</tr>
<tr>
<td># Primary Restoration</td>
<td>17</td>
<td>4</td>
</tr>
<tr>
<td># Compensatory Restoration</td>
<td>85</td>
<td>11</td>
</tr>
<tr>
<td>Mean Area (ac)</td>
<td>9.6</td>
<td>29.4</td>
</tr>
<tr>
<td>Min. Area (ac)</td>
<td>0.6</td>
<td>2.5</td>
</tr>
<tr>
<td>Max. Area (ac)</td>
<td>54.5</td>
<td>112.1</td>
</tr>
<tr>
<td>Standard Deviation (ac)</td>
<td>10.5</td>
<td>27.9</td>
</tr>
</tbody>
</table>
Sampling Design

- For each habitat type, 4 sites for each ‘treatment’:
  - Primary Restoration (NRDA contaminated sites)
  - Compensatory Restoration (ag prior land use)
  - Reference
- Use similar size sites (~ avg site size +/- 1 SD)
- At least 5 plots per site, additional RS Ground Truth info as necessary
- Implement and collect data from each tier (1-3) at each plot to characterize site
Expected Products

- GUHM Field Data Report
- Final Monitoring Framework Report following field testing
- Level-of-Effort (costs) associated with each tier for field and RS
- Universal Field Sampling Data Collection Forms
Acknowledgements

DOI Office of Restoration and Damage Assessment (ORDA)
Restoration Support Unit (RSU)
GUHM Team