June 2021 Webinars
Monitoring Ecological Restoration with Imagery Tools (MERIT)

**Webinar Logistics:**

- The webinar will begin at 12:00 pm CDT.
- To access the audio select “Call Me” – this is the preferred option to reduce feedback.
- If you are unable to connect via the “Call Me” feature,
  - Dial: 1-844-800-2712
  - Access: 199 565 7227#
Webinar Instructions

• All lines are muted.

• Submit questions or comments in the Chat Box to “Everyone”.

• The webinar is being recorded and will be shared following the meeting.
Monitoring Ecological Restoration with Imagery Tools (MERIT): Python-based decision support tools integrated into ArcGIS for satellite and UAS image processing, analysis, and classification

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Kristofer Lasko is a Research Geographer with the Data Signature and Analysis Branch (DSAB) at ERDC GRL. His research efforts have included: agricultural fire characterization, synthetic aperture radar and remote sensing algorithm development, and machine learning for land cover mapping. He has previously served as an adjunct professor at the University of Maryland. Prior to joining ERDC, he was a DoD SMART program scholar and worked at the University of Maryland on interdisciplinary NASA funded research with field work in South/Southeast Asia.

Sean Griffin is a Physical Scientist with the DSAB branch at ERDC GRL. His recent research efforts have included: UAS remote sensing, deep learning for land cover mapping, high resolution building and feature extraction, ecological applications in vectorborne diseases and much more. Prior to joining ERDC, his ~20 years of work and research experience included: the Peace Corps, and work with non-profits, academia, industry, and other government agencies such as NGA.
• GRL’s ArcGIS Tool suite
  • Description of capabilities
    • Python-based custom toolboxes in ArcGIS Pro
  • Example Walk-throughs
    • Tool installation
    • UAS Image Processing
    • Sentinel-2 Image acquisition
    • Image Pre-processing (cloud composite, image stacking)
    • Image automated classification
    • Region time series statistics (Burned Area application)
    • Mapping of a flood event
  • Discussion and questions
Ecosystem Management and Restoration Research Program

The central repository for ERDC/USACE ecosystem restoration efforts, research, and related products and tools

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Focus Areas

- Multi-objective Restoration
- Inland Resource Management
- Coastal Resilience & Function
- T & E and Invasive Species Management
- Modeling & Decision Making Tools
- Ecological Infrastructure
Tech Transfer and tool distribution

• Ecological Management and Restoration Research Program (EMRRP) that finished in September 2020

• Tools/software are available publicly on https://emrrp.el.erdc.dren.mil/ and then navigate to the “Resources+” section and the “Models”

• **An additional minor update will be soon made to the software hosted on the website**
Capabilities

• Tools are integrated into ArcGIS Pro to enable processing of satellite or UAS imagery for use in ecosystem assessments
• Tools are fast, easy to install and user-friendly.
• Features include: Sentinel-2 image downloading, conversion to surface reflectance, cloud compositing, image stacking, area time series analysis, environmental indices, UAS block adjustment and orthomosaicking
UAS Capabilities

EMRRP MERIT

Open-source Version
NodeOpenDroneMap
Docker Container
Custom GUI

ArcMap Desktop Version
ArcPy
Mosaic Database, Block Adjustment, Color Balancing
Custom ArcGIS Toolbox GUI

ArcGIS Pro Version
Orthomapping Workspace
Block Adjustment, Color Balancing, etc.
ArcGIS Pro Workflow

Output: DSM, DTM, Point Cloud, Ortho image, 3D texture* (*open source version)
UAS Tool: NodeODM

1. Start OpenDroneMap Docker Instance
2. Open OpenDroneMap Browser Instance
3. Stop/Reset OpenDroneMap Docker Instance
Products: Colorbalanced Orthomosaic and DTM

*Any output from NodeODM can be generated
Demonstration #1: UAS/Drone imagery processing and derivative product generation
Instructions

• From the EMRRP website, download the data files to your computer

• Read the “Readme_First” document. Then right click on “MERIT.exe” and select “Run as administrator”. Follow the instructions presented. A black command line window will popup, allow this to complete (about 4-5minutes) before closing out and finishing the install.

• This setup will add the MERIT ArcGIS Pro toolbox directly into your ArcGIS Pro AND it will install the “MERIT” custom anaconda python libraries into ArcGIS Pro

• Read over the “MERIT_UserDocumentation” file as well as the technical report (online) for more information about the tools.
Demonstration #2: Installing MERIT onto your computer, and overview of tools in ArcGIS Pro
While Sentinel-2 imagery may be coarser resolution than UAS, it provides advantages in some respects:

- Repeat overpass of data collection (e.g. every 6-12 days) enables change detection, phenology curve mapping, etc., global availability
- Is free and scientifically validated
- Multispectral imagery has higher spectral resolution than most UAS systems, which enables better differentiation of land surface phenomena.

<table>
<thead>
<tr>
<th>Sentinel-2 bands</th>
<th>Central wavelength (μm)</th>
<th>Resolution (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 1 – Coastal aerosol</td>
<td>0.443</td>
<td>60</td>
</tr>
<tr>
<td>Band 2 – Blue</td>
<td>0.490</td>
<td>10</td>
</tr>
<tr>
<td>Band 3 – Green</td>
<td>0.560</td>
<td>10</td>
</tr>
<tr>
<td>Band 4 – Red</td>
<td>0.665</td>
<td>10</td>
</tr>
<tr>
<td>Band 5 – Vegetation red edge</td>
<td>0.705</td>
<td>20</td>
</tr>
<tr>
<td>Band 6 – Vegetation red edge</td>
<td>0.740</td>
<td>10</td>
</tr>
<tr>
<td>Band 7 – Vegetation red edge</td>
<td>0.783</td>
<td>20</td>
</tr>
<tr>
<td>Band 8 – NIR</td>
<td>0.842</td>
<td>10</td>
</tr>
<tr>
<td>Band 8A – Vegetation red edge</td>
<td>0.865</td>
<td>20</td>
</tr>
<tr>
<td>Band 9 – Water vapour</td>
<td>0.945</td>
<td>60</td>
</tr>
<tr>
<td>Band 10 – SWIR – Cirrus</td>
<td>1.375</td>
<td>60</td>
</tr>
<tr>
<td>Band 11 – SWIR</td>
<td>1.610</td>
<td>20</td>
</tr>
<tr>
<td>Band 12 – SWIR</td>
<td>2.190</td>
<td>20</td>
</tr>
</tbody>
</table>

Figure 5: Comparison of spatial resolution between VHR airborne and HR spaceborne imagery at Hog Island site.
Automated Sentinel-2 Image Acquisition

Integration with ArcGIS Pro

Custom Tool output

Sentinel-2 Multispectral Imagery (10m, 20m)
Demonstration 3 & 4: ESA’s data repository for Sentinel-2 imagery; Acquiring Sentinel-2 Imagery from ESA directly within ArcGIS Pro
Image Pre-processing

After downloading imagery, continue to Use EMRRP Image Processing tools to:
1. Convert imagery to surface reflectance (optional)
2. “stack” or combine imagery from 2 dates into a single file.

Once imagery is in surface reflectance format and combined into a single file, it’s ready for automatic image classification tool...

<table>
<thead>
<tr>
<th>Sentinel Band</th>
<th>Date</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1 Blue</td>
<td>Winter</td>
<td>Surface Reflectance</td>
</tr>
<tr>
<td>B2 Green</td>
<td>Winter</td>
<td>Surface Reflectance</td>
</tr>
<tr>
<td>B3 Red</td>
<td>Winter</td>
<td>Surface Reflectance</td>
</tr>
<tr>
<td>B4 Red Edge</td>
<td>Winter</td>
<td>Surface Reflectance</td>
</tr>
<tr>
<td>B5 Veg Red Edge</td>
<td>Winter</td>
<td>Surface Reflectance</td>
</tr>
<tr>
<td>B6 Red edge</td>
<td>Winter</td>
<td>Surface Reflectance</td>
</tr>
<tr>
<td>B7 Near-IR</td>
<td>Winter</td>
<td>Surface Reflectance</td>
</tr>
<tr>
<td>B8 SWIR-1</td>
<td>Winter</td>
<td>Surface Reflectance</td>
</tr>
<tr>
<td>B9 SWIR-2</td>
<td>Winter</td>
<td>Surface Reflectance</td>
</tr>
<tr>
<td>B10 Blue</td>
<td>Summer</td>
<td>Surface Reflectance</td>
</tr>
<tr>
<td>B11 Green</td>
<td>Summer</td>
<td>Surface Reflectance</td>
</tr>
<tr>
<td>B12 Red</td>
<td>Summer</td>
<td>Surface Reflectance</td>
</tr>
<tr>
<td>B13 Red Edge</td>
<td>Summer</td>
<td>Surface Reflectance</td>
</tr>
<tr>
<td>B14 Veg Red Edge</td>
<td>Summer</td>
<td>Surface Reflectance</td>
</tr>
<tr>
<td>B15 Red edge</td>
<td>Summer</td>
<td>Surface Reflectance</td>
</tr>
<tr>
<td>B16 Near-IR</td>
<td>Summer</td>
<td>Surface Reflectance</td>
</tr>
<tr>
<td>B17 SWIR-1</td>
<td>Summer</td>
<td>Surface Reflectance</td>
</tr>
<tr>
<td>B18 SWIR-2</td>
<td>Summer</td>
<td>Surface Reflectance</td>
</tr>
</tbody>
</table>
Demonstration 5: Conversion of Sentinel-2 Radiance (L1C) to Surface Reflectance (L2A)

Demonstration 6 & 7: Sentinel-2 single date image composite/stack; Sentinel-2 two date image composite/stack
Cloud free composite generation

• With any satellite imagery, clouds are an issue. By using several dates of imagery, cloudy areas can be removed or reduced.
Automated wetland area mapping with satellite imagery

- Wetland area land cover type mapping. Model will currently work in Southern and Eastern US, and non-arid, non-snow environments.
- Input: Winter and summer Sentinel-2 imagery
- Leverages: Machine learning, open-source python libraries integrated into ArcGIS interface

EMRRP ArcGIS Pro toolsuite

Tool: Download Sentinel-2 imagery

Tool (optional): pre-process image to surface reflectance

Tool: Cloud free composite and image stacking for 2 dates

Tool: Wetland area land cover type classification

- Sentinel-2 imagery
- Land Cover Type Classification

Sentinel-2 imagery

Land Cover Type Classification

- Permanent Water
- Barren Land
- Evergreen Forest
- Deciduous Forest
- Vegetated Wetlands
- Wetland Forest
- Cropland
- Low Vegetation
- Temporary water
- Built-up
Different land covers exhibit unique spectral signatures captured by the multiple wavelengths in the imagery.

These unique signatures can be very similar to one another and difficult to differentiate. Machine learning algorithms enable us to distinguish a unique signal with high accuracy for each land cover type.

**Support Vector Machine (SVM)**

- Multidimensional decision boundary that maximizes value difference between classes
- SVM is updated during training based on predicted/observed class and associated cost value. Update to the gradient improves the classifier.

Compatibility with Sentinel-2 (20m) or Landsat 8 (30m)
1. Run ‘two date sentinel-2 classification tool’ in ArcGIS Pro
2. Enter tool parameters
   1. Your “stacked” sentinel-2 image combining winter and summer dates
   2. Create an output folder to save your classified land cover map
3. Output will produce a classified image. The tool will take 3-4 minutes for a landsat-8 image, and about 5-7 minutes for sentinel-2 image.
Demonstration 8: Sentinel-2 two date automatic land cover classification
1. Run ‘Remove clouds...’ tool in ArcGIS Pro
2. Enter tool parameters
   1. Your “PIXELQA.tif” layer for landsat-8 winter image (this file is in the original landsat-8 surface reflectance folder)
   2. Your “PIXELQA.tif” layer for landsat-8 summer image
   3. The automatic classified land cover image
   4. The folder where you want to save the output.
3. The new file will remove cloudy areas from the image, they will just be white, no-data pixels (as seen in example image).
Derive environmental indices such as Normalized difference water index (NDWI), bare soil index, burned area index, etc.

Just input a data folder and the tool will compute indices for MULTIPLE files, multiple dates, --saving you time and effort on image processing.
Ensemble Supervised Classifier

- Pre-process imagery using our tools
- Create your own classification of your phenomena of interest (e.g. burned area)
  - (1) Any satellite or UAS imagery
  - (2) user-generated polygons representing each region of interest.
  - (3) optionally, environmental indices derived from our tools for enhanced classification
- Combine 3 classifiers into a single map for higher-accuracy results.
Ensemble Supervised Classifier

Atmos. Correction and cloud masking

Environmental Indices (NDVI, NDSI, etc.)

Ensemble Supervised Image Classification

- Imagery and derived indices
- RF, SVM, Max Like, etc.
- Ensemble Classifier
- Classification map and pixel agreement
Ensemble Supervised Classifier

Supervised Classification Result (Ensemble Classifier)

Pixel Agreement/Classifier Confidence

Your own UAS or satellite imagery and ROI polygons

SVM
Random Forest
Maximum likelihood

Ensemble model

Image classification AND classification “confidence”

Tree
Low Veg
Agriculture
Urban
Agroforestry
Water

Green
Blue
Yellow
Orange
Red

All agree
2 agree
None agree
Time series of regional statistics

Multiple dates of Environmental Indices (NDVI, NDSI, etc.)

October 15 2019
November 15 2019
December 15 2019
January 15 2020

Study site 1

Study site 2

EMRRP ArcGIS Pro Tool

Merged, tabular output
Time series of regional statistics

Monthly Burned Area Data

Shapefile of each state of interest

EMRRP GIS Region Analysis Tool
Demonstration 9: Time series of region/study site statistics (multitemporal zonal statistics)
Surface water mapping

**Input:** Sentinel-2 20m imagery from .SAFE folder (L2A)

**Process:** Water map is created based on a random forest classifier using automatically created training points selected from an ensemble of spectral indices with quality checks

**Output:** 20m Water map

**Task:** Map flooded area of our district/zone by running the tool twice. Once using an image from pre-flood date (e.g. February) and once using imagery from the flood date (e.g. May). Then, compute the difference between the two images to observe surface water dynamics/flooding.

![Date 1 imagery](image1)

![Date 2 imagery](image2)
Surface water mapping

Sentinel-2 Imagery

Sentinel-2 Imagery + Output layer
Demonstration 10: Mapping surface water area changes after a flood event
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Questions & Answers

Please post any questions to the “CHAT”.

Missed the last webinar?

June 15th

Topic: Model to Assess Species and Habitat Migration Due to Climate Change

Dr. Jacob Jung and Ms. Christina Saltus

POSTED: