



OPEN EO TOOLS

for terrestrial vegetation and wetland function recovery analysis to support ecosystem and biodiversity restoration projects

GEO BON Montreal

Dr. Andy Dean, Hatfield

Tools & models for biodiversity monitoring

12 October 2023



WHAT IS PEOPLE-ER?

- Financed by ESA under Earth Observation Science for Society (EO4Society) of FutureEO-1
- Objective to develop innovative high-quality EO-based application products, indicators and methods, targeting high-priority R&D areas
- **Ecosystem Restoration** is one of four related Pioneer projects
- Commenced in October 2022 - completion by March 2024
- Working with “Early Adopters”
- Following FAIR Principles

EARLY ADOPTERS & DEMONSTRATION SITES

- Canada – Society for Ecosystem Restoration
- Finland – Luke
- CAR – African Parks
- Vietnam – IUCN
- Romania – INCDS



See: www.people-er.info

PEOPLE-ER TOOLS

- Work with large volumes of EO data and EO data time series
- Make use of reference sites or reference time periods
- Widespread application beyond site-specific contexts
- Complement ER initiatives and guidelines
- Accessible – users do not need a background in remote sensing or computer science

Findable

Accessible

Interoperable

Reusable

VEGETATION SPECTRAL RECOVERY

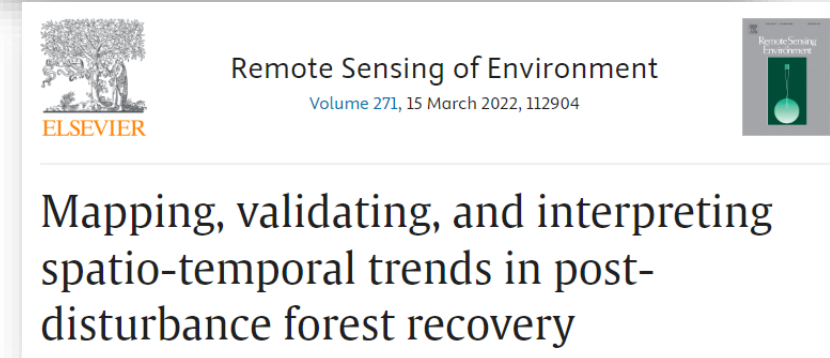
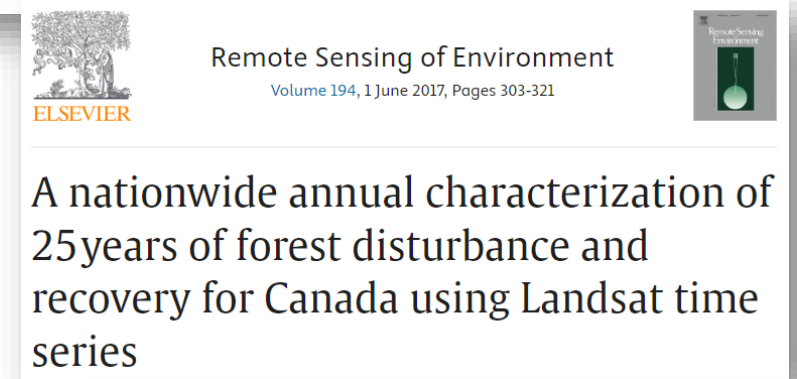
Lead:

- **Integrated Remote Sensing Studio / Dr. Nicholas Coops**
- **Department of Forest Resources Management**
- **University of British Columbia**

Support: Hatfield & VTT

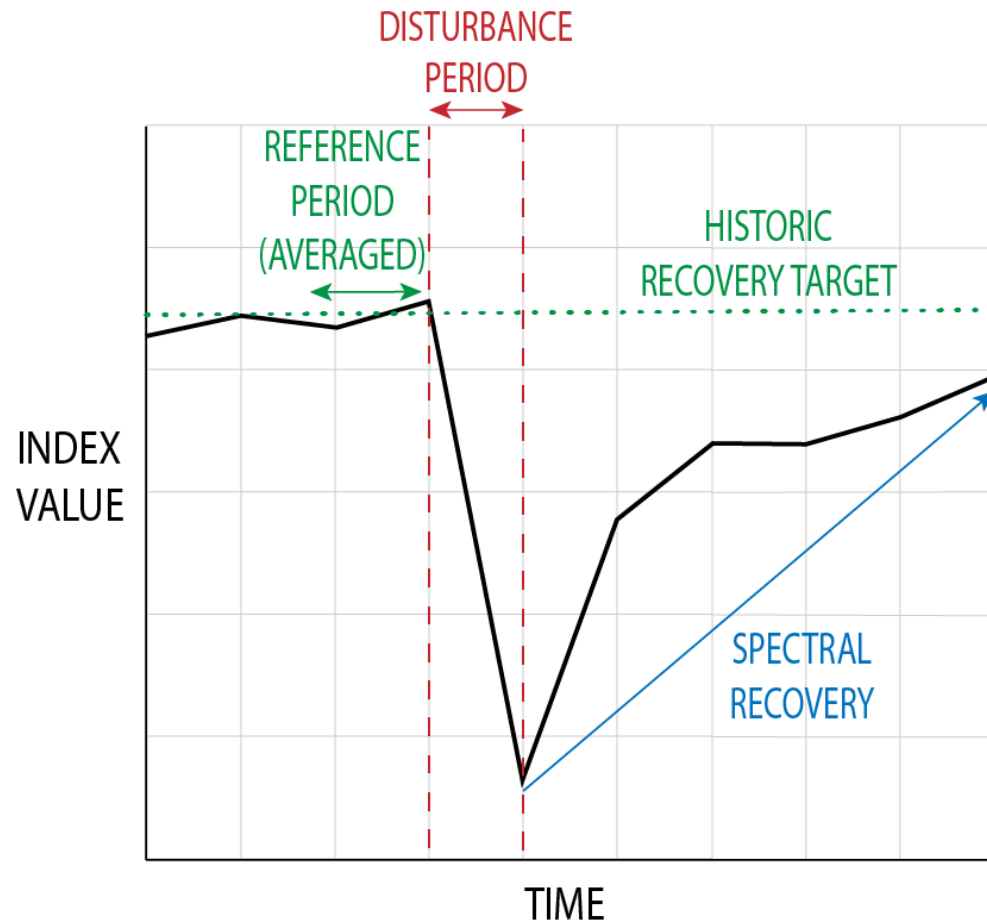
CONCEPT/BASIS

- EO time series have a proven capability to detect vegetation cover, vigour & density
- Vegetation indices (VIs) commonly used for land cover change and vegetation health analyses
- **Spectral Recovery** method demonstrated in research publications (Coops + Canadian Forest Service)
 - Assessment of recovery following a disturbance and/or management intervention
 - Suite of recovery metrics, e.g., years to recovery (Y2R), R80%, etc

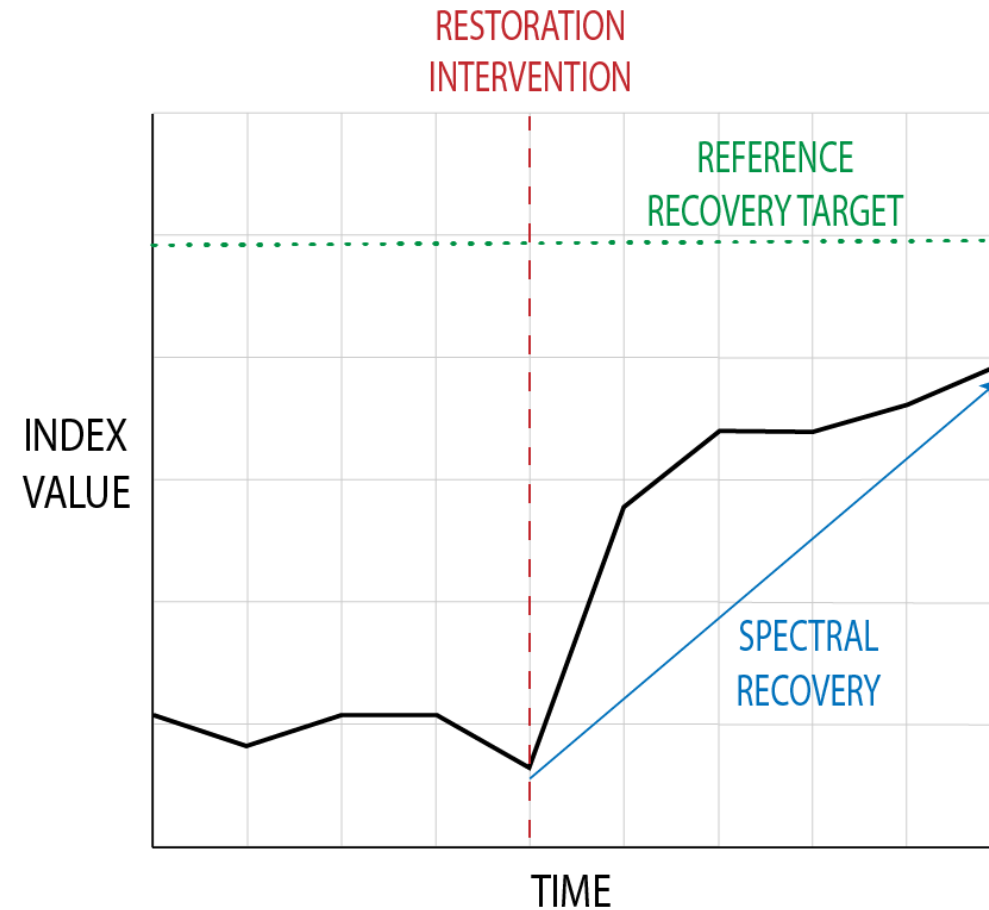


CONCEPT – SPECTRAL RECOVERY

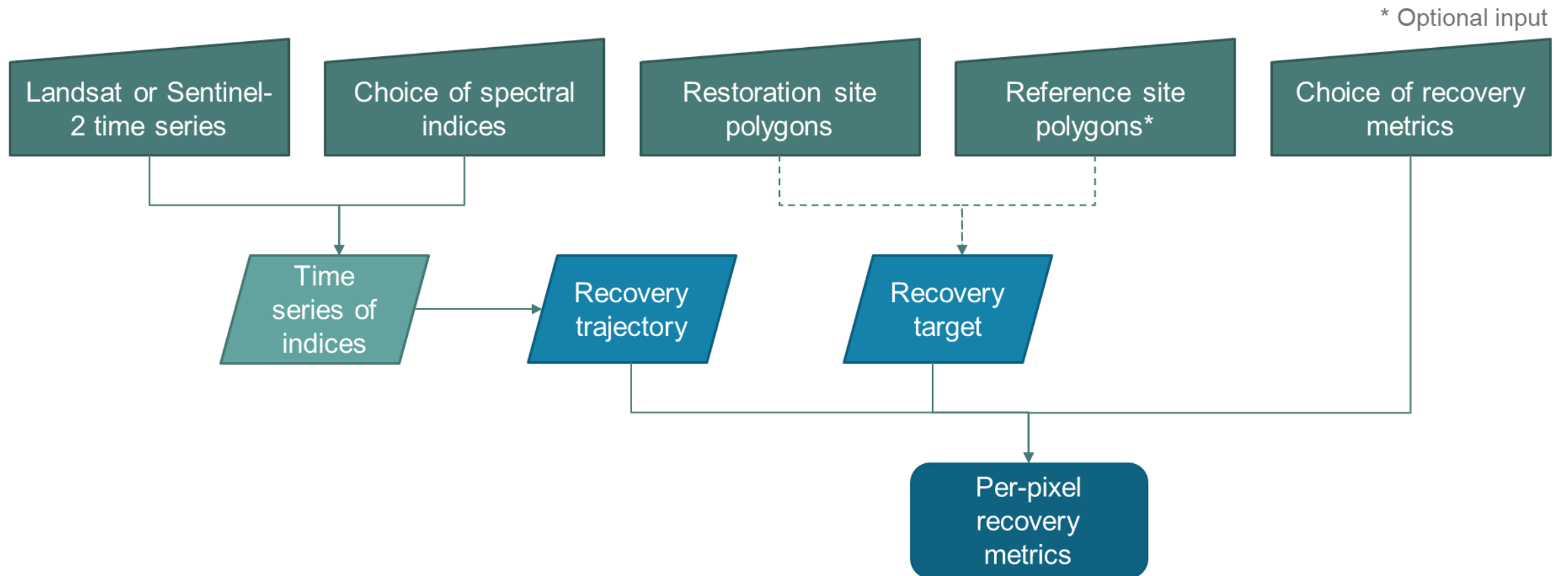
HISTORIC RECOVERY TARGET



REFERENCE RECOVERY TARGET

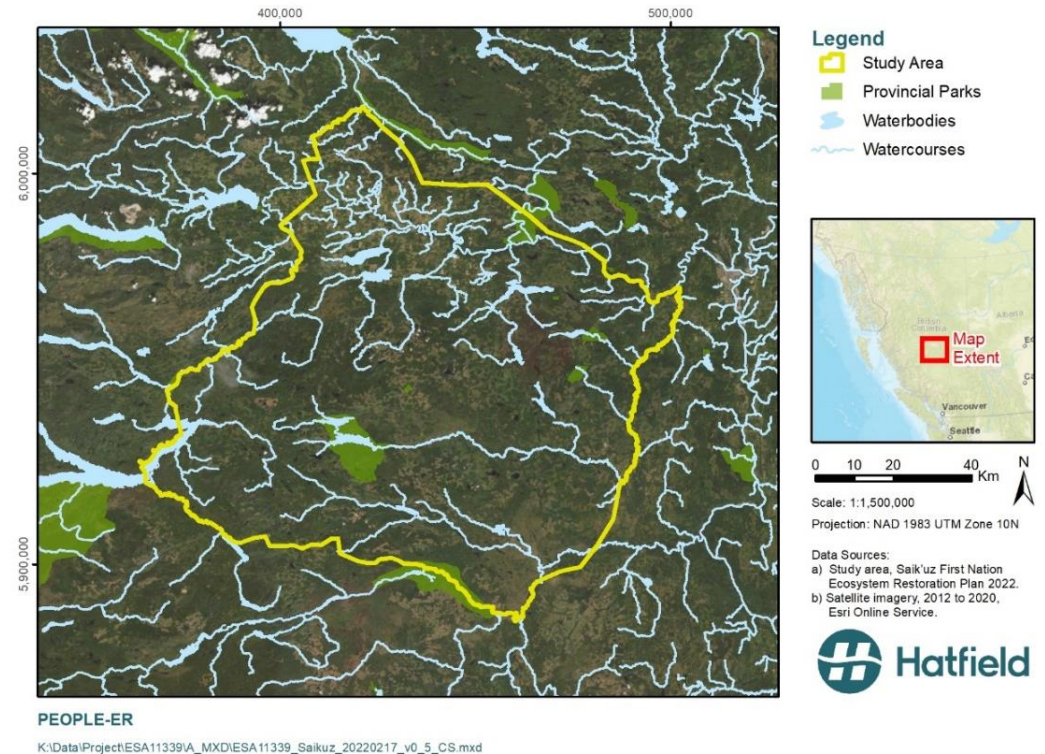


APPROACH - TOOL



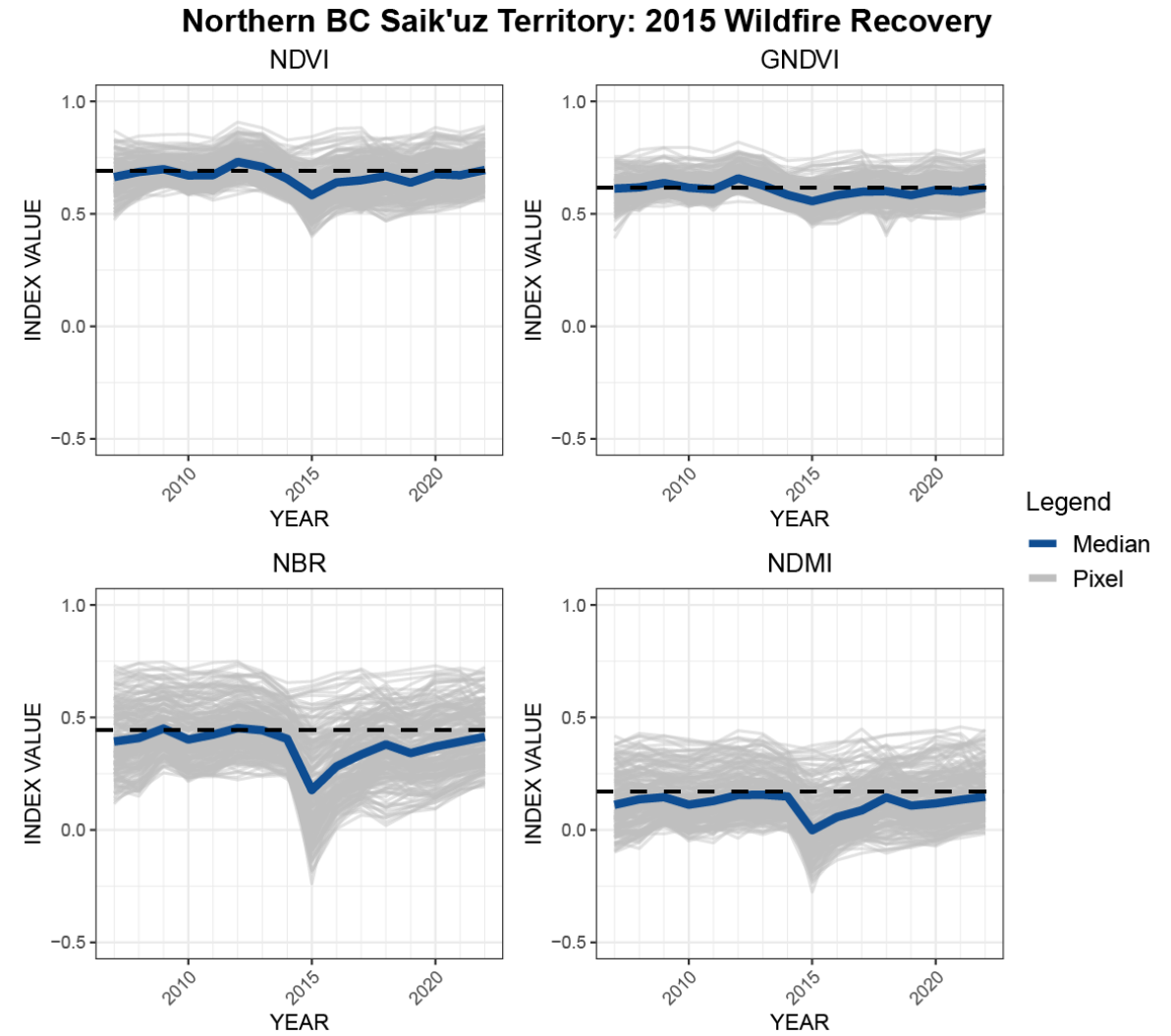
NORTHERN BC – FOREST RECOVERY FOLLOWING HARVESTING, WILDFIRE, & INSECT DAMAGE

- North Central Interior Plateau, BC
- Forests mostly lodgepole pine (*Pinus contorta*) and spruce (genus *Picea*)
- Habitat degradation and damage for key wildlife species through cumulative effects of human and natural processes:
 - Resource development, intensive forestry, mountain pine beetle and other pests, wildfire.



EXAMPLE RESULTS (1/2)

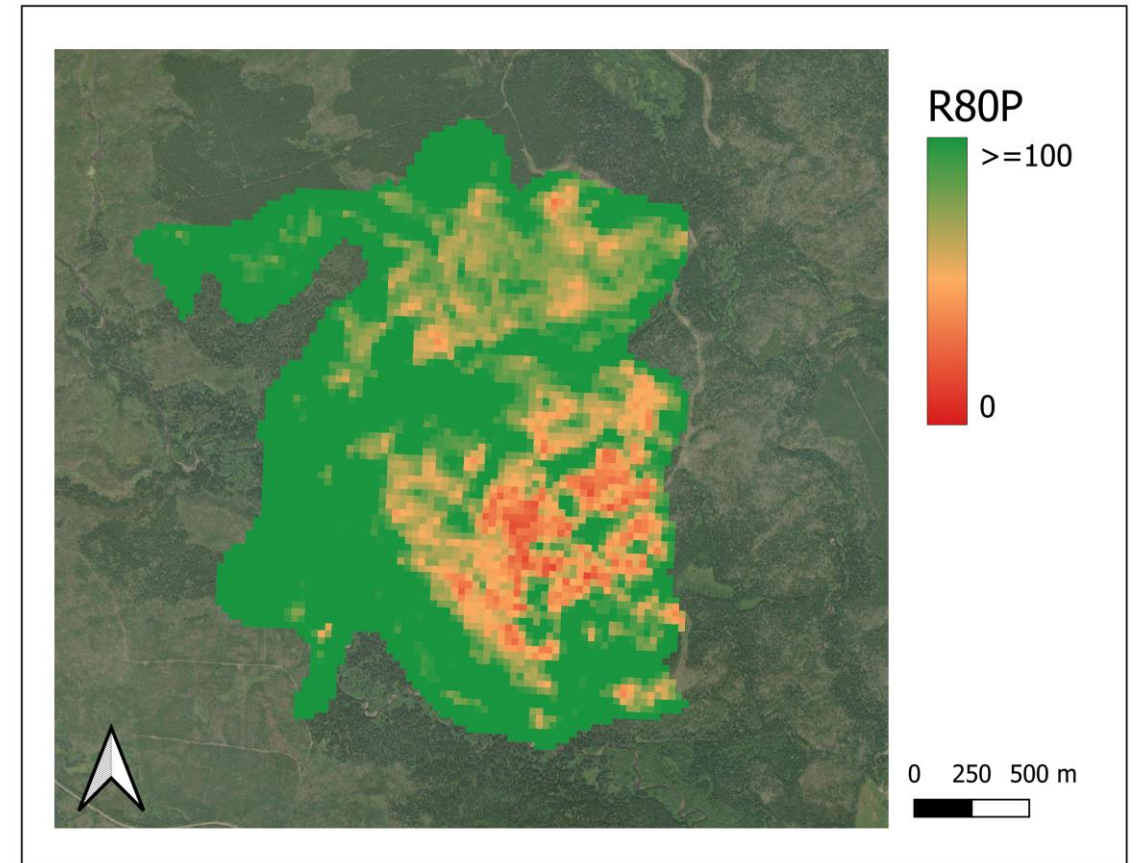
- 2015 wildfire disturbance (423 ha area)
- Multiple indices (NDVI, GNDVI, NBR, NDMI) and a historical recovery target
- Visualize spectral trajectories for multiple spectral indices within the restoration polygon



EXAMPLE RESULTS (2/2)

- Raster outputs for each spectral index and recovery metric combination (e.g., NBR and R80P)
- Visualize spatial recovery trends and variation within the restoration site
- Allows for the identification of areas that may need further management

Northern BC Saik'uz Territory:
2015 Wildfire Recovery using NBR



NEXT STEPS

- Complete use cases in Canada, Finland, and Romania
- Validation with local datasets
- Evaluation of utility with early adopters

Validation Expectations

- White et al. 2022
doi.org/10.1016/j.rse.2022.112904
- Lidar-derived benchmarks of canopy cover (>10%) and height (>5 m) used for validation.
- 87% and 97% of recovered harvest and wildfire samples achieved one of the benchmarks.

WETLAND FUNCTION RECOVERY TOOLSET

Lead

- **Hatfield**
- **Vancouver, Canada**

Support: IUCN Vietnam

MEKONG DELTA – RESTORING FLOODPLAIN CONNECTIVITY

- Initiative to re-naturalize a large area within Vietnam’s upper Mekong Delta
- Transition away from a third annual rice crop into nature-based solutions of flood-based agriculture
- Mitigate extreme floods and droughts
- Challenges:
 - Dynamic timing of flood pulse
 - Complex water-vegetation interactions
- Study area - An Giang Province

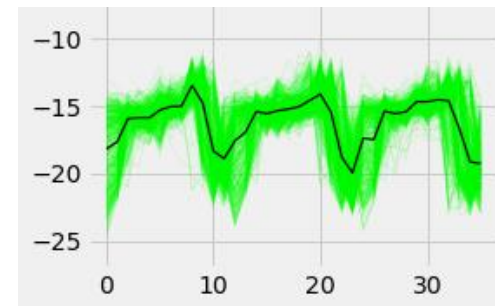


CONCEPT/BASIS

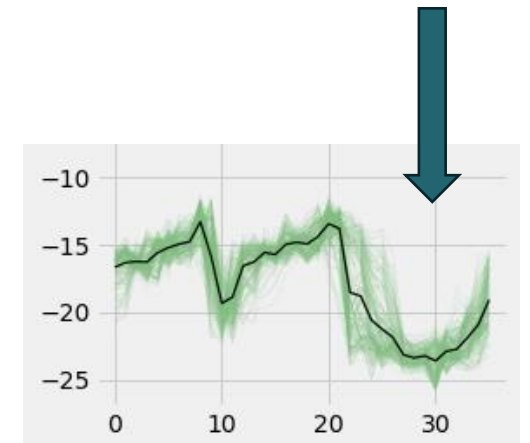
- S1 time series proven capability to detect **surface water** and **flooded vegetation**
- Full S1 time series have distinctive temporal patterns that can be associated with a wetland function
- Assess similarity of time series of restored areas to target functions

Target functions

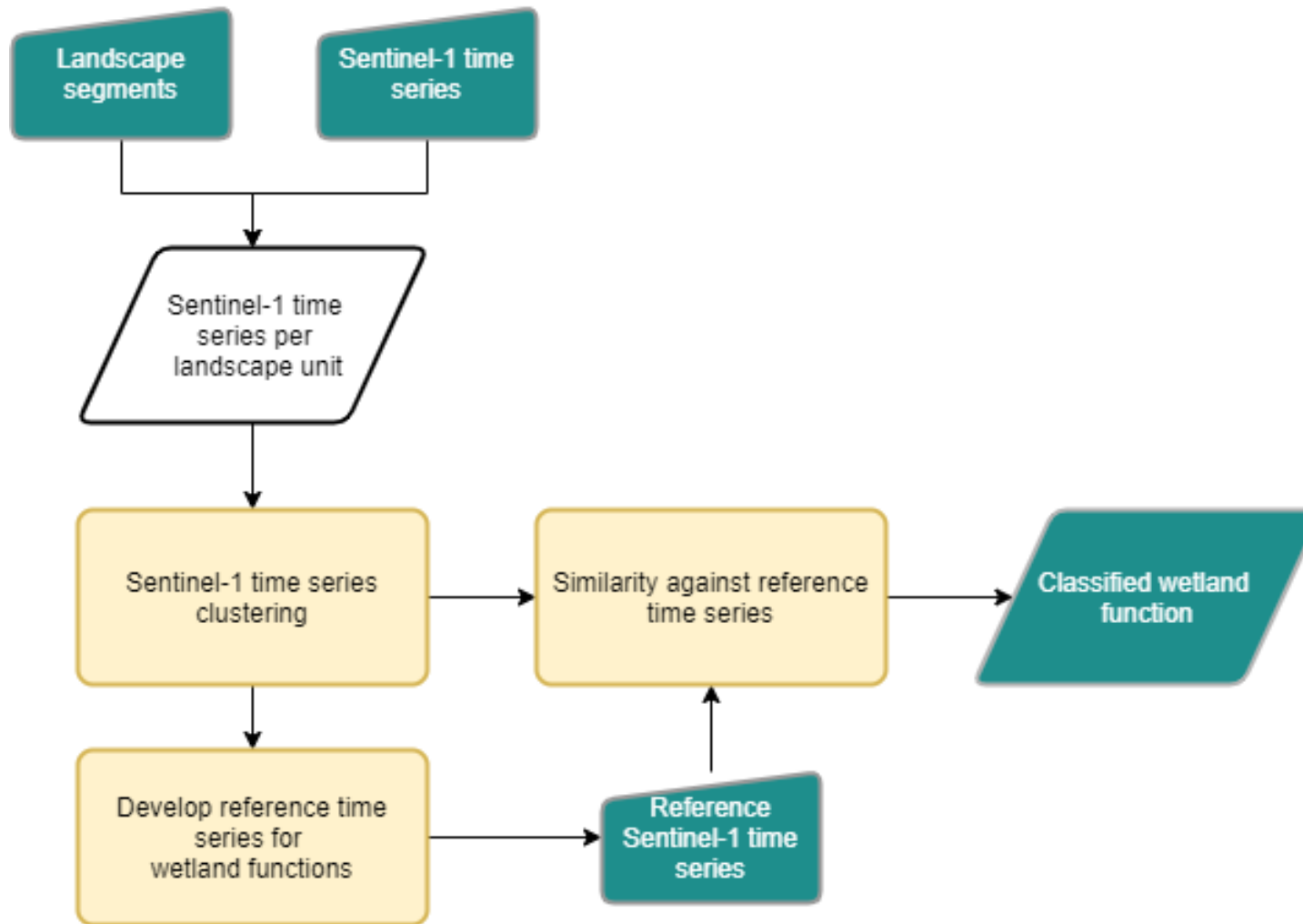
Isolated from floodplain



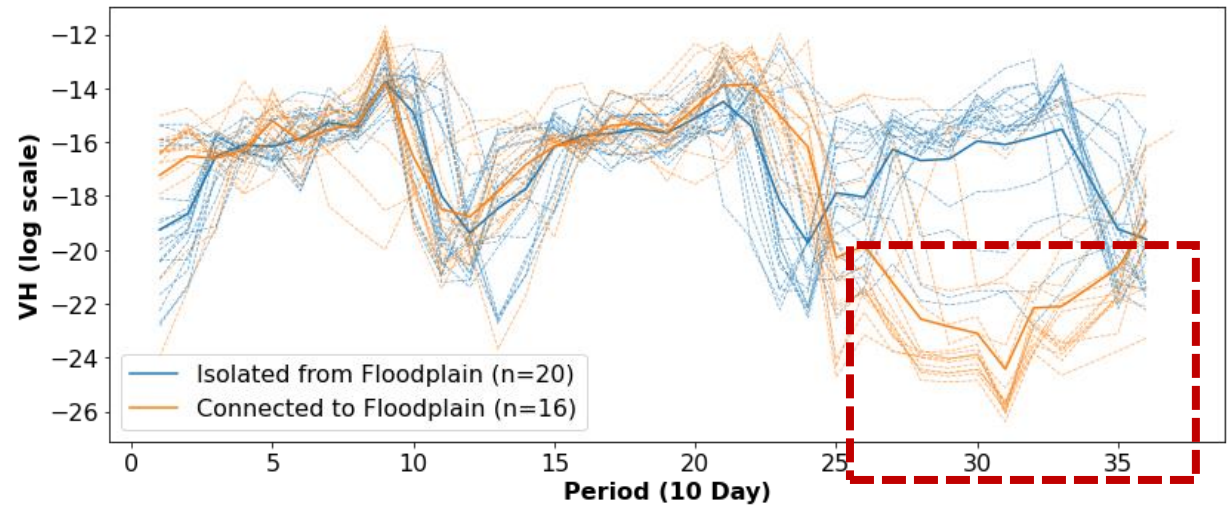
Connection to floodplain



APPROACH – PEOPLE-ER TOOL



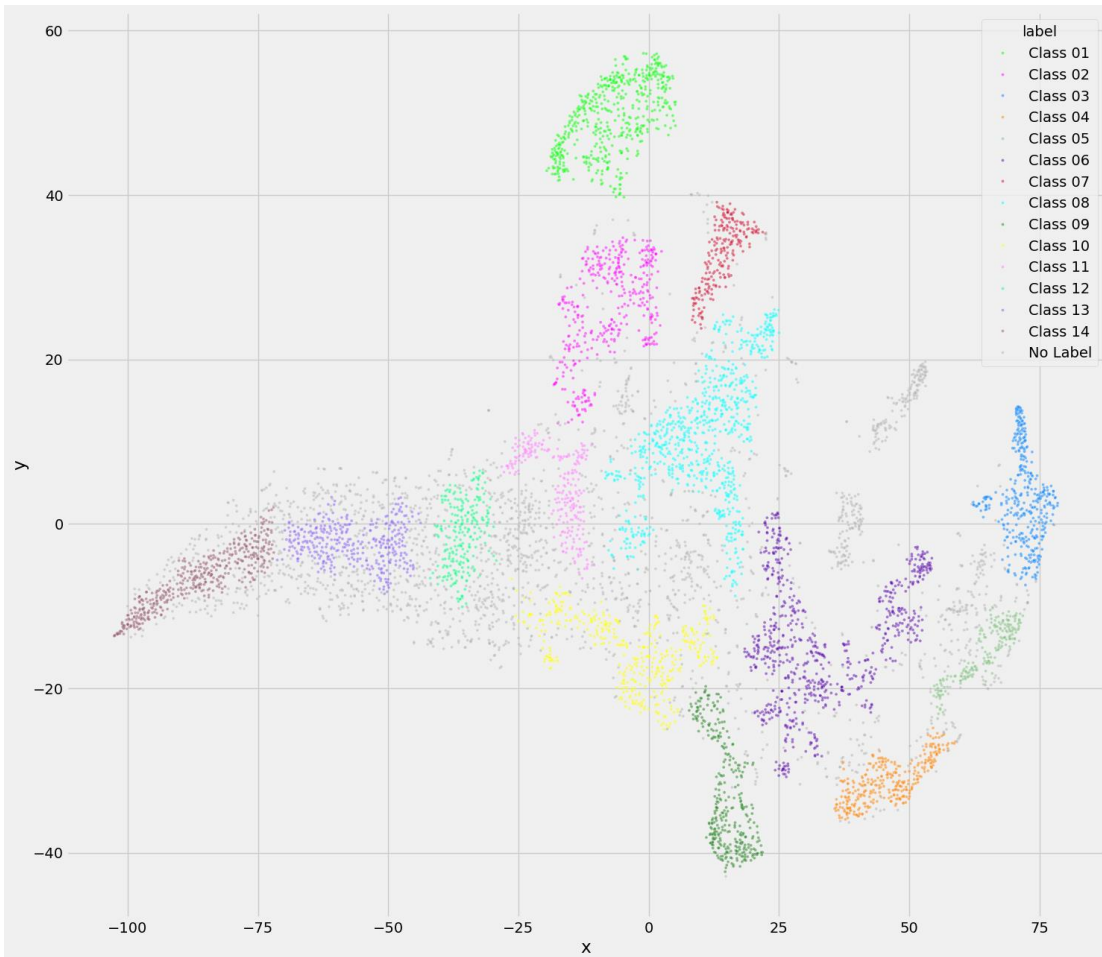
APPROACH – BUILD S1 REFERENCE TIME SERIES



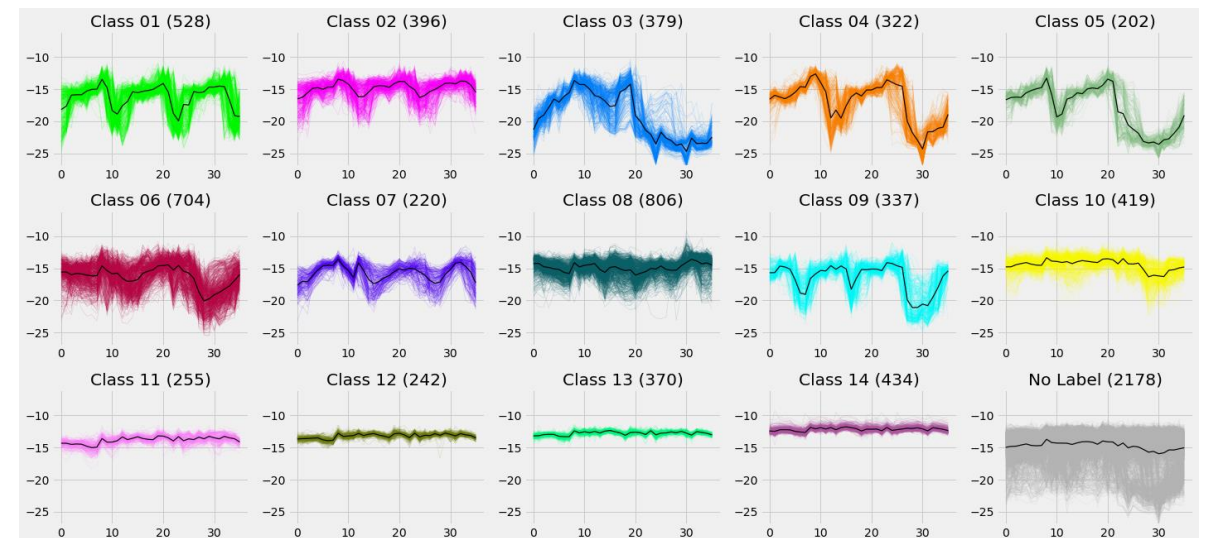
Natural 'flood pulse'
function

APPROACH – CLUSTERING

t-SNE Map



- t-SNE to project time series into 2D map for visualization
- HDBSCAN to identify clusters on t-SNE map
- Reference time series based on the average backscatter value

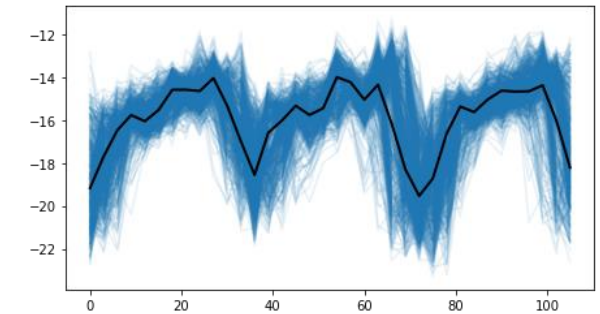
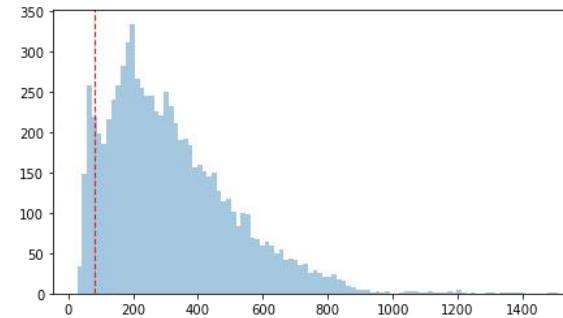


APPROACH – SIMILARITY-BASED CLASSIFICATION

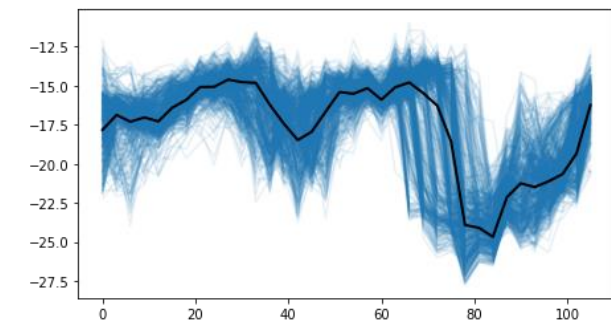
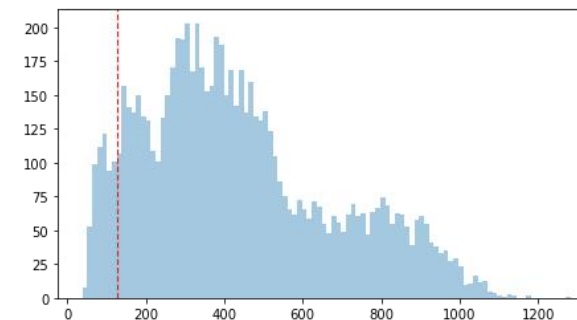
- Fieldwork to label the reference time series
- Dynamic Time Warping (DTW) to measure similarity
 - advantage: tolerance in time lag
- DTW distances are calculated for landscape unit time series against reference time series
- Landscape units are assigned to the wetland type with most similar temporal profile



Similarity measure - reference profile **Isolated from Floodplain**



Similarity measure - reference profile **Connected to Floodplain**

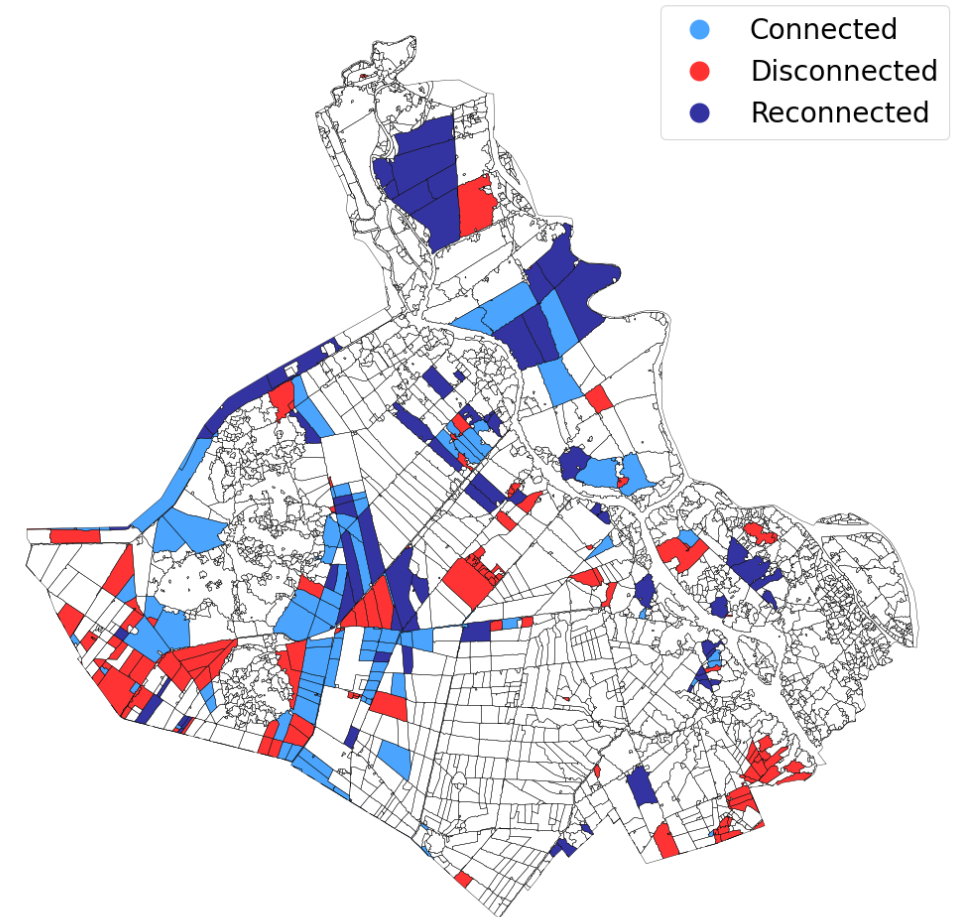


EXAMPLE RESULTS

Type	# Landscape Unit	Total Area (km2)
Connected	113	281.32
Disconnected	142	229.20
Reconnected	80	295.61

Year	# Landscape Unit	Total Area (km2)
2018	255	510.52
2022	193	576.93
Change	-62	+66.40 (+13%)

Change in floodplain connectivity 2018-2022



Change in floodplain connectivity 2018-2022

NEXT STEPS

- Validation of Mekong Delta classification (IUCN fieldwork ongoing)
- Use Case Summary
- Evaluation with IUCN

Future opportunities:

- Scaling up the analysis for the entire Delta for monitoring transition
- Testing of the tool/method in other wetland ecosystems
- Testing of the tool for other applications, e.g., vegetation phenology

K-NEAREST NEIGHBOUR PREDICTION

Lead:

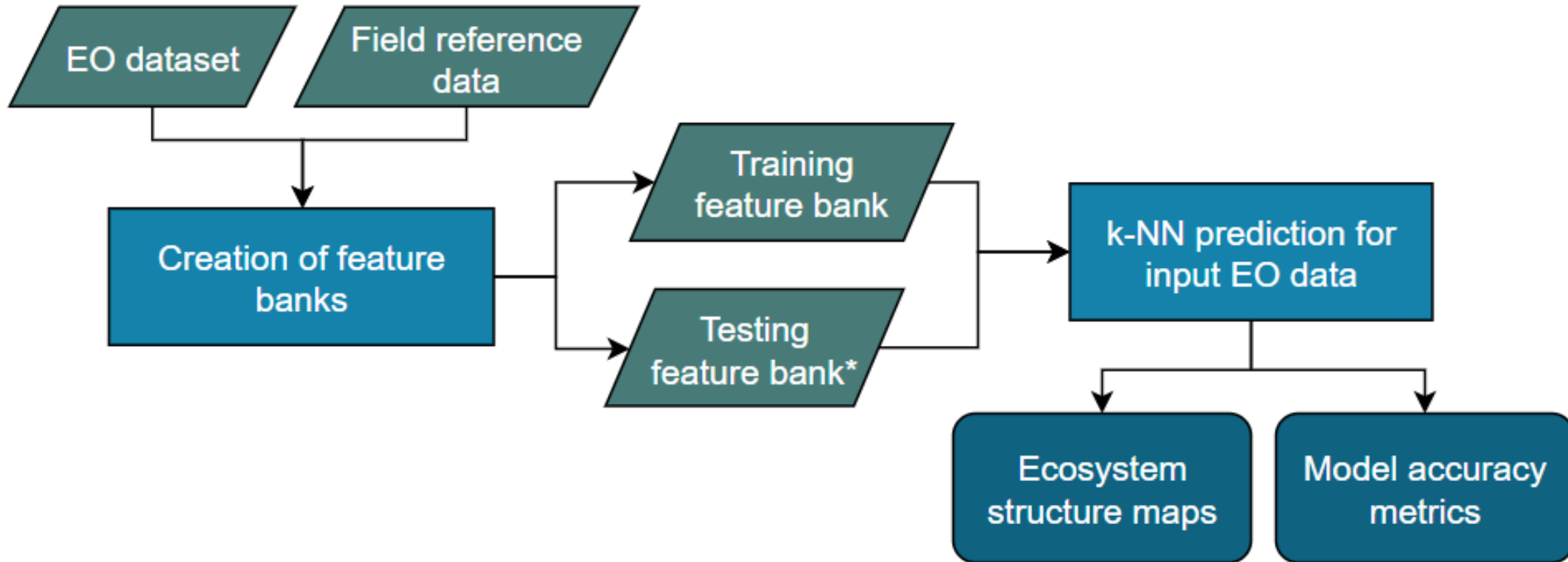
- **VTT Technical Research Centre of Finland**

Support: Hatfield

CONCEPT/BASIS

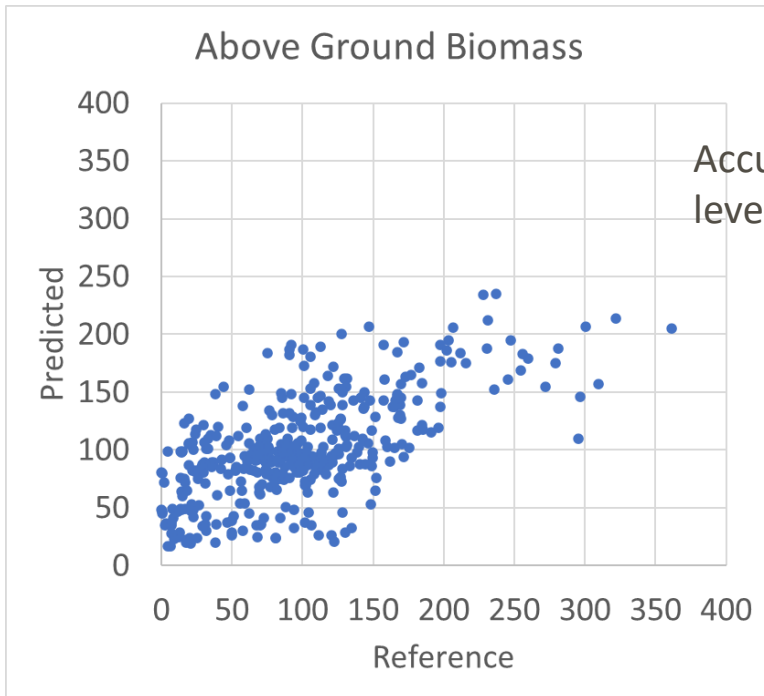
- K- Nearest Neighbour (k-NN) prediction is widely used in EO based forest and environmental monitoring
- As a support for the Spectral Recovery tool, the k-NN tool provides a way to evaluate the ecosystems' status (e.g., in the form of forest structural variable development)
- Users may wish to:
 - Know the pre-restoration characteristics of the ecosystem
 - Monitor the development of ecosystem characteristics during the restoration process
 - Compare ecosystem characteristics in the restoration area and in ecosystem outside the restoration area

APPROACH – PEOPLE-ER TOOL



EXAMPLE RESULTS

- Above Ground Biomass prediction 2022 in an area that experienced wildfires in 2014 (Northern BC Saik'uz Territory)



ACCESSING THE TOOLS

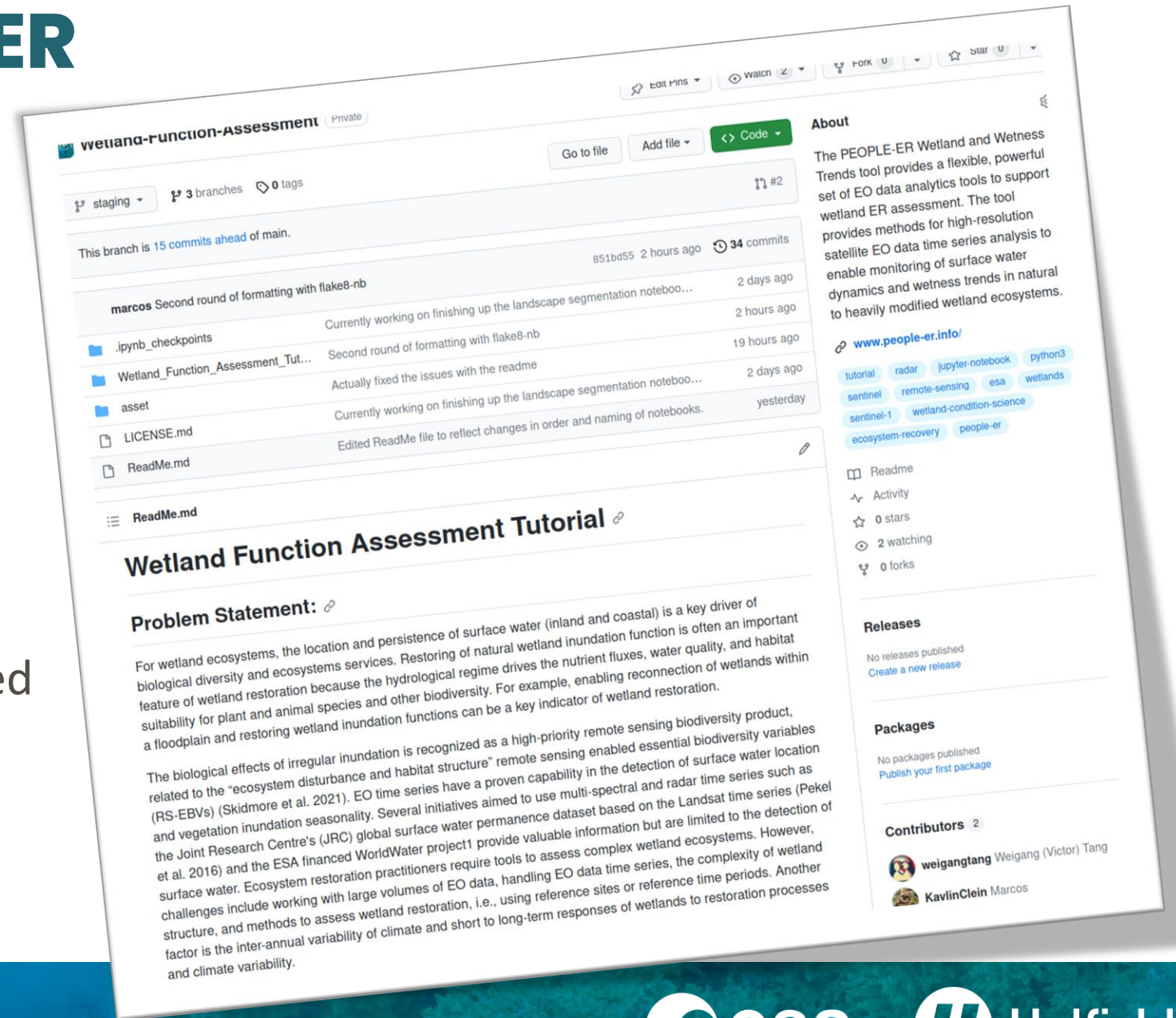
- **GitHub**
- **Notebooks**
- **Documentation**
- **Forestry Thematic Exploitation Platform (Forestry TEP)**

GITHUB – PEOPLE-ER

Two Public Repositories:

- Spectral Recovery
- Wetland Function Assessment

- K-Nearest Neighbour to be added



NOTEBOOKS & DEMO DATASETS

Comparing similarities between Time Series

1. Import required packages
2. Load data
3. Defining functions

- Wetland Function Assessment
 - 5 related notebooks/tutorial
 - Example outputs from each notebook for running the final 3 notebooks
- Spectral Recovery
 - 1 notebook/tutorial
 - Example dataset in Northern British Columbia to test the tool

The combination of the two plots, provides the information necessary to a practitioner in order to fine tune the threshold they plan to use.

```
In [34]: ts_array = df_ts.values
ref_array = df_ref.loc["Class 01"].values

d = calculate_dtw(ts_array, ref_array, 7, 4)

thr = 160
idx = d < thr

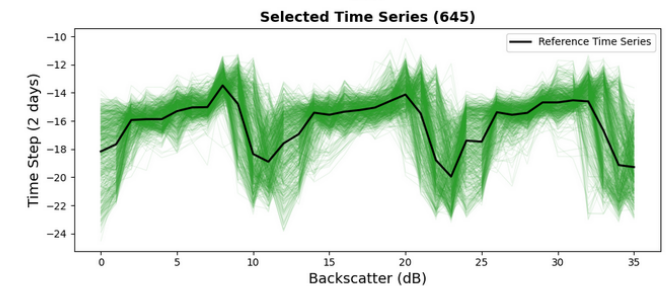
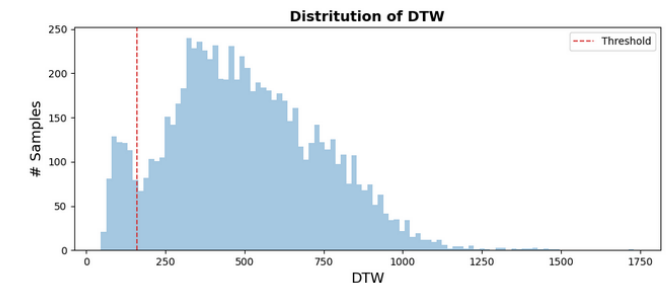
df_ts_sel = df_ts.iloc[idx, :]
n_sel = df_ts_sel.shape[0]

fig, axes = plt.subplots(2, 1, figsize=[9, 8])

axes[0].hist(d, bins=100, alpha=0.4)
axes[0].axvline(thr, color="tab:red", linestyle="dashed", lw=1.2, label="Threshold")
axes[0].set_xlabel("DTW", fontsize=14)
axes[0].set_ylabel("# Samples", fontsize=14)
axes[0].set_title("Distribution of DTW", fontsize=14, fontweight="bold")
axes[0].legend()

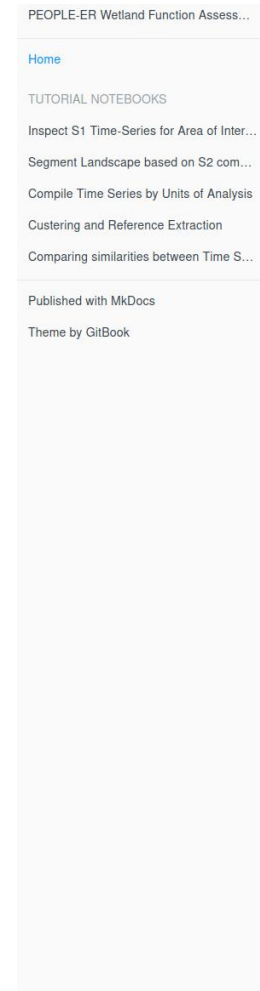
axes[1].plot(df_ts_sel.values.T, color="tab:green", lw=0.8, alpha=0.1)
axes[1].plot(ref_array, color="k", lw=2, label="Reference Time Series")
axes[1].set_xlabel("Backscatter (dB)", fontsize=14)
axes[1].set_ylabel("Time Step (2 days)", fontsize=14)
axes[1].set_title("Selected Time Series (645)", fontsize=14, fontweight="bold")
axes[1].legend()

fig.tight_layout()
```



DOCUMENTATION

- Published using GitHub Pages
- <https://PEOPLE-ER.github.io/Spectral-Recovery>
- <https://PEOPLE-ER.github.io/Wetland-Function-Assessment>
- You will find:
 - Tutorials
 - Technical Documentation
 - User Guide



Welcome to the PEOPLE-ER Wetland Function Assessment Tutorial!



Problem Statement:

For wetland ecosystems, the location and persistence of surface water (inland and coastal) is a key driver of biological diversity and ecosystems services. Restoring of natural wetland inundation function is often an important feature of wetland restoration because the hydrological regime drives the nutrient fluxes, water quality, and habitat suitability for plant and animal species and other biodiversity. For example, enabling reconnection of wetlands within a floodplain and restoring wetland inundation functions can be a key indicator of wetland restoration.

The biological effects of irregular inundation is recognized as a high-priority remote sensing biodiversity product, related to the "ecosystem disturbance and habitat structure" remote sensing enabled essential biodiversity variables (RS-EBVs) (Skidmore et al. 2021). EO time series have a proven capability in the detection of surface water location and vegetation inundation seasonality. Several initiatives aimed to use multi-spectral and radar time series such as the Joint Research Centre's (JRC) global surface water permanence dataset based on the Landsat time series (Pekel et al. 2016) and the ESA financed WorldWater project¹ provide valuable information but are limited to the detection of surface water. Ecosystem restoration practitioners require tools to assess complex wetland ecosystems. However, challenges include working with large volumes of EO data, handling EO data time series, the complexity of wetland structure, and methods to assess wetland restoration, i.e., using reference sites or reference time periods. Another factor is the inter-annual variability of climate and short to long-term responses of wetlands to restoration processes and climate variability.

Tutorial Objective:

FORESTRY TEP

- User friendly interface
- K Nearest Neighbour tool integrated – Early adopter testing ongoing
- Spectral Recovery Toolset integration ongoing

The image displays two screenshots of the forestry tep web application. The top screenshot shows a map of Southeast Asia with a pink polygon overlaid on Myanmar, Laos, and Thailand. The interface includes a top navigation bar with options like Explorer, Developer, Manage / Share, Helpdesk, My Account, and Logout. A left sidebar contains a 'Mission' section with 'Sentinel-1' selected, and a 'Product date' range from 01-01-2019 to 31-01-2019. Below this is an 'ADI' section with a polygon identifier and a 'Processing level (S-1)' dropdown set to '1'. The bottom of the map shows 'RESULTS: SENTINEL1', 'DATABASKETS', 'JOBS', and 'MESSAGES (2)'. The bottom screenshot shows the 'kNearestNeighbours' tool configuration window. It has a 'Workspace' section with 'Advanced Mode' checked. The tool description states: 'Predicts forest properties or other user specified ground variables using k Nearest Neighbours (KNN) algorithm.' The 'Input image(s)' section contains a text area with a file path: 'ftp://refData/514/Stana_de_Valle_2019-L2A-NBR-N/DVI.tif'. Below this is the 'Input image name pattern' field. The 'Training data file' section contains another file path: 'ftp://refData/514-PEOPLE_ROM_L2A_NBR_N/DVI-Training-without_SP.csv'. The bottom of the tool window shows a 'RESULTS' section with a job ID '139804', status 'COMPLETED', and a label 'Romania kNearestNeighbour example3'. It lists inputs and outputs, including file paths for training data and the resulting product. A 'Filters' panel on the right shows a list of jobs with their IDs, labels, and start times.



THANK YOU!

CONTACT:

adean@hatfieldgroup.com
www.people-er.info