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

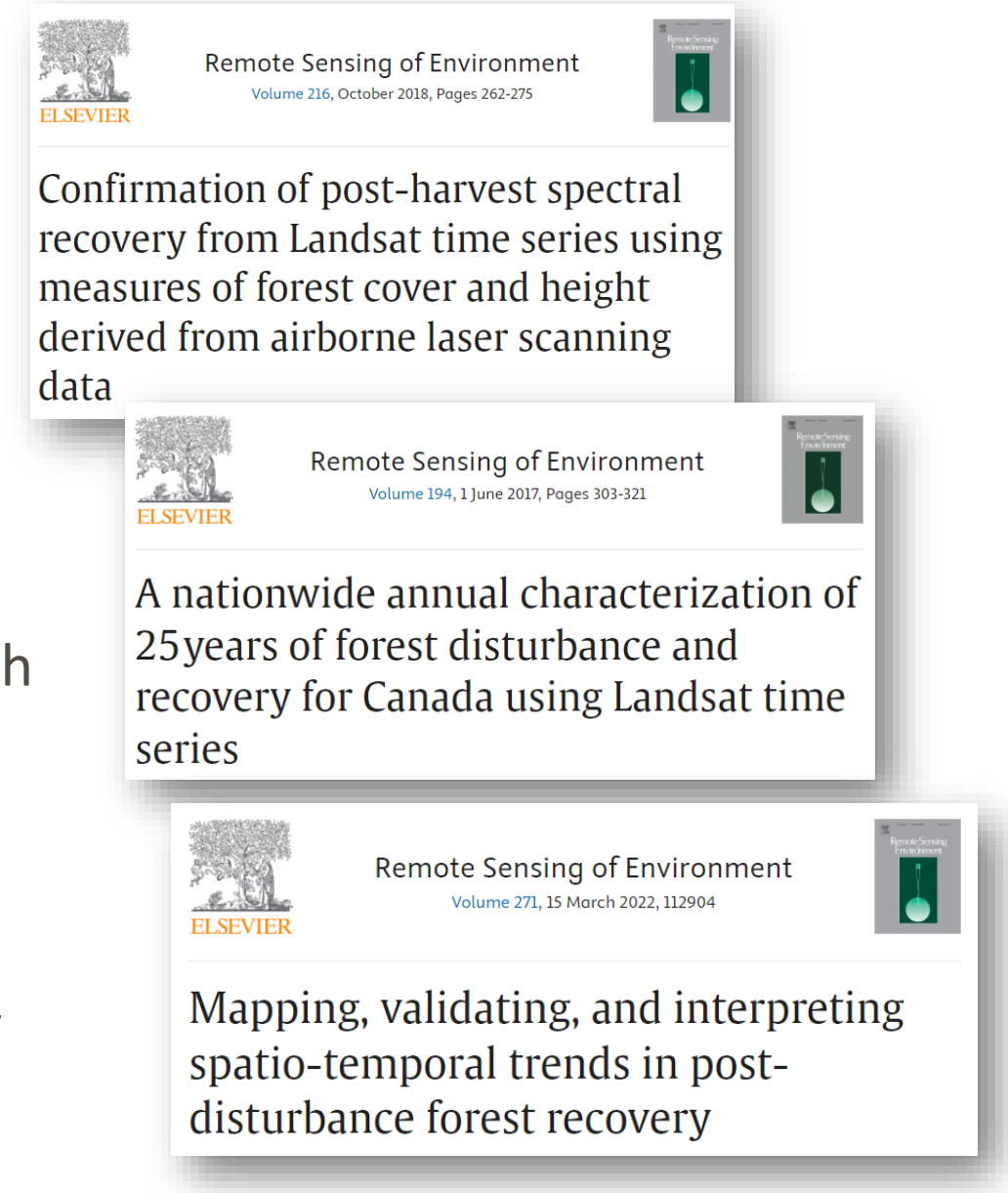
Lead:

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

Support: Hatfield & VTT

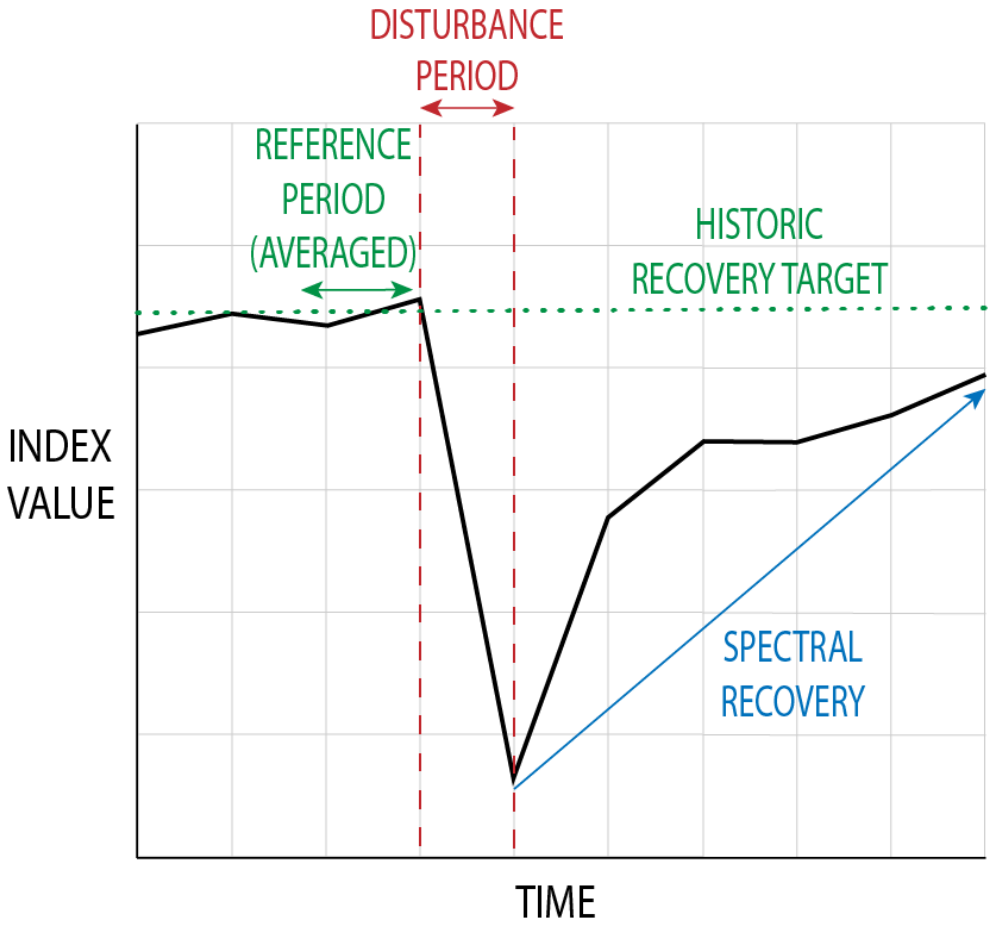
CONCEPT/BASIS

- 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

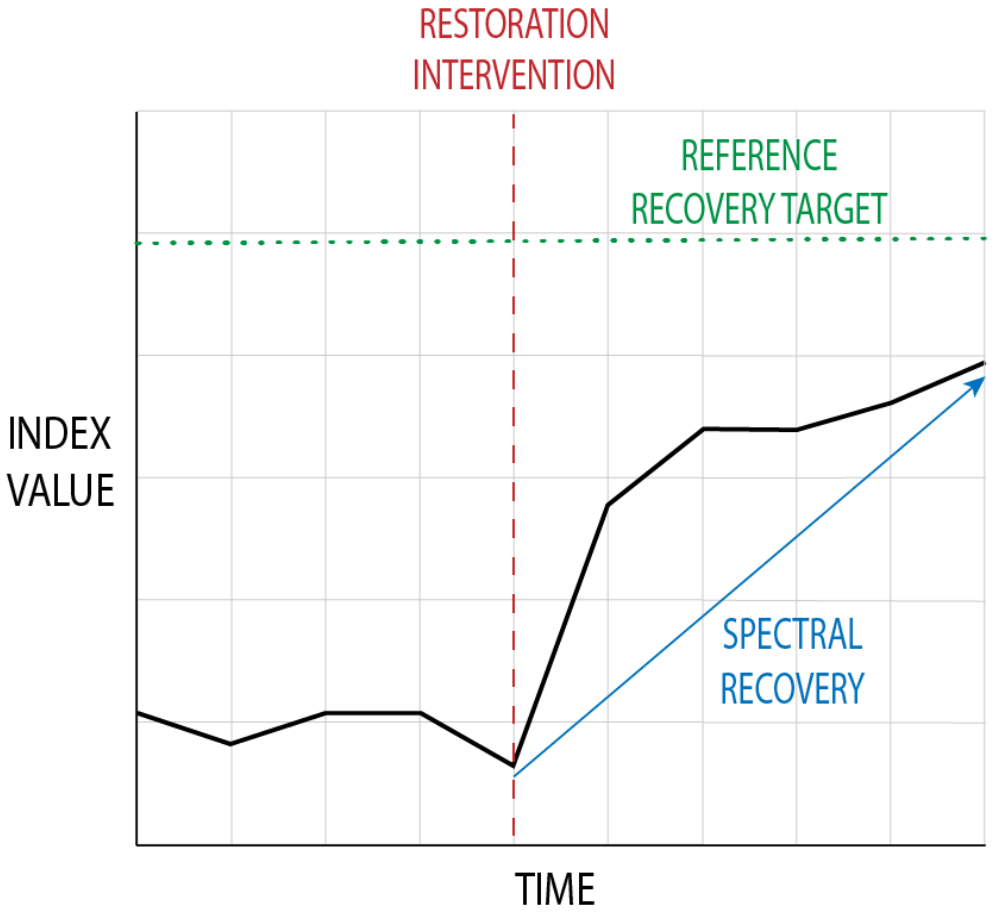


CONCEPT – SPECTRAL RECOVERY

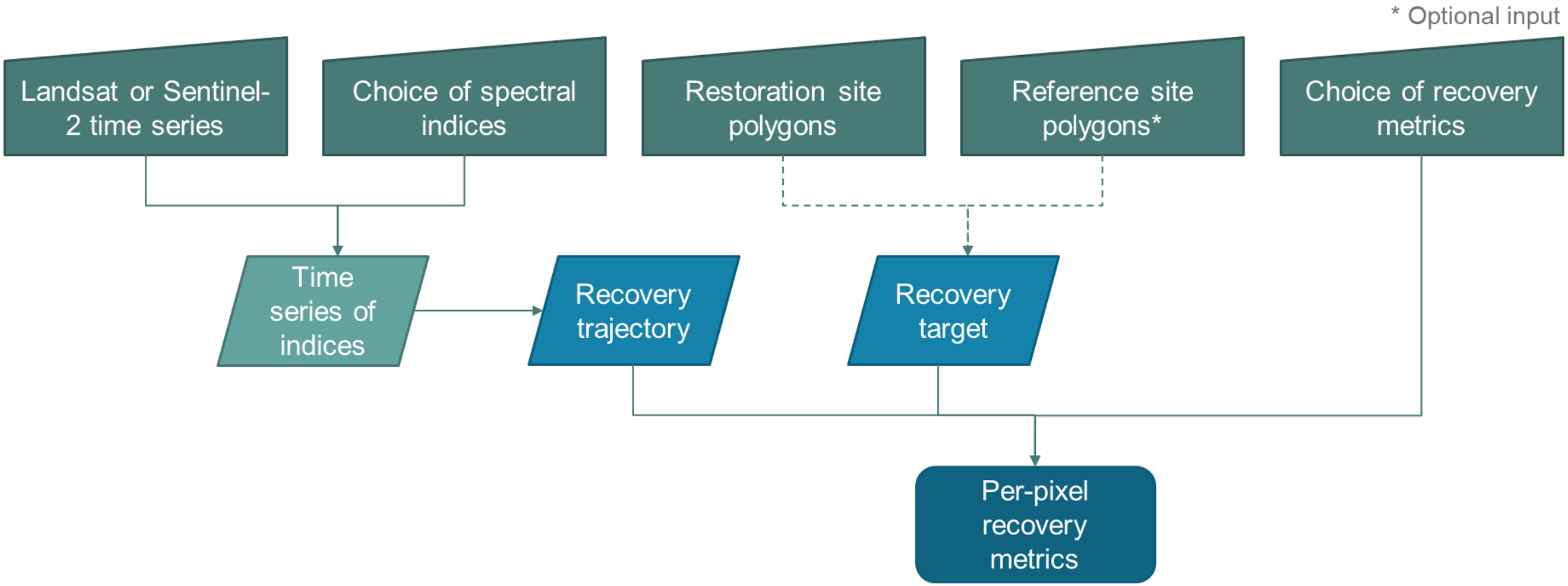
HISTORIC RECOVERY TARGET



REFERENCE RECOVERY TARGET

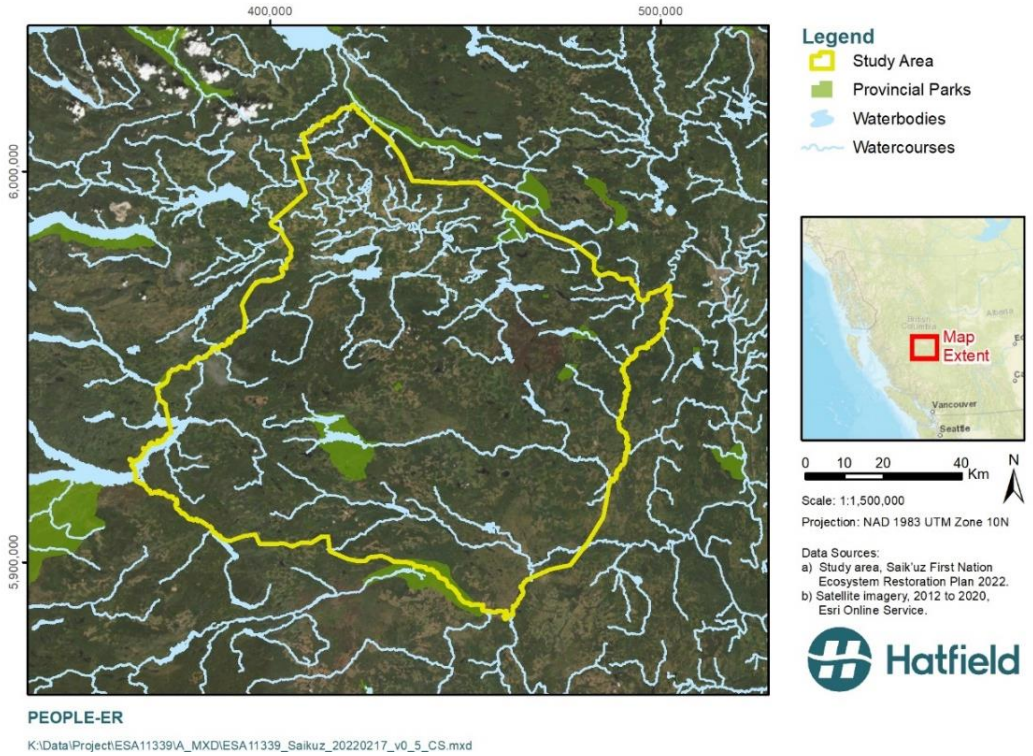


APPROACH – TOOL



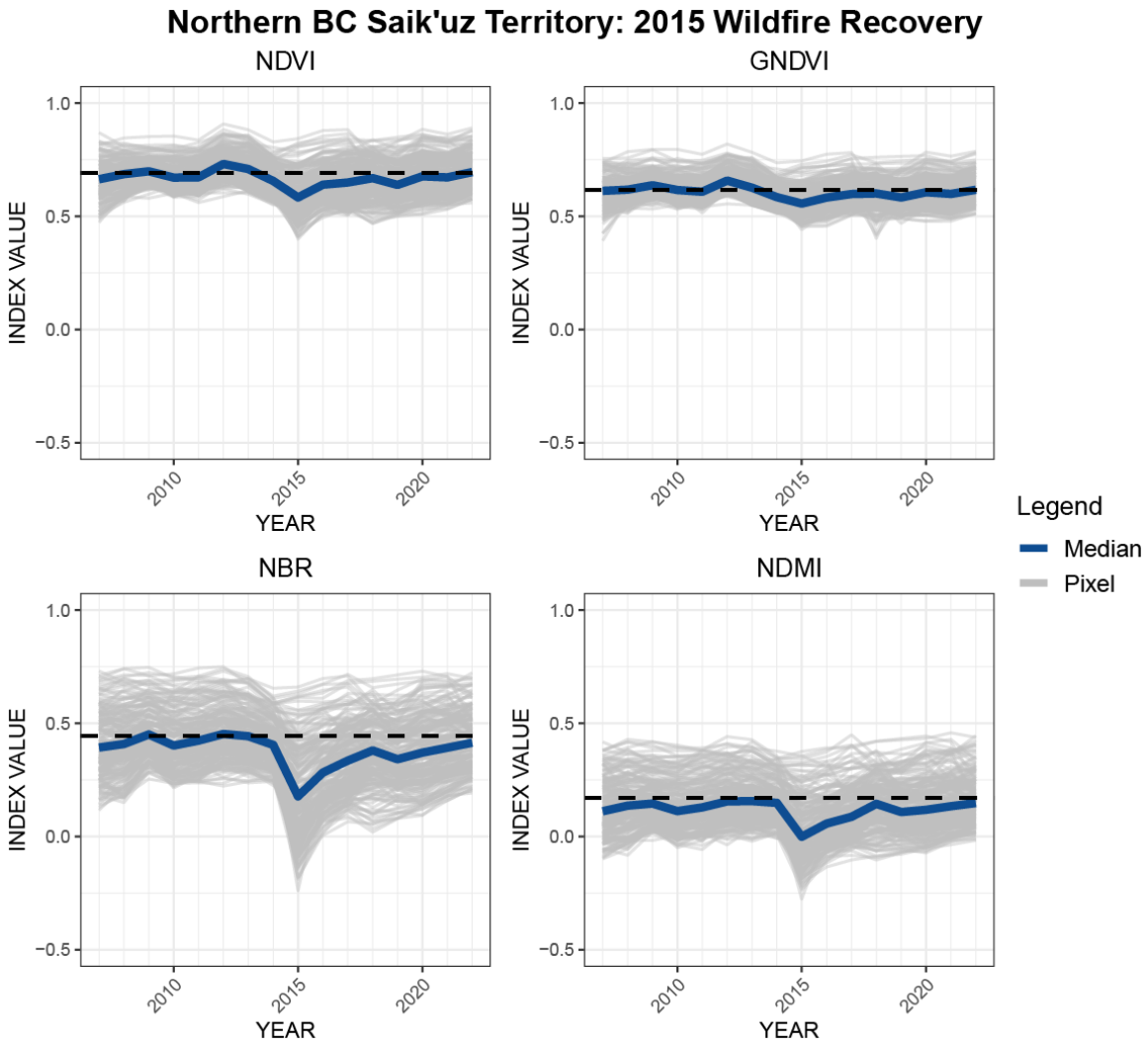
NORTHERN BC – FOREST RECOVERY FOLLOWING HARVESTING, WILDFIRE, & INSECT DAMAGE

- 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)

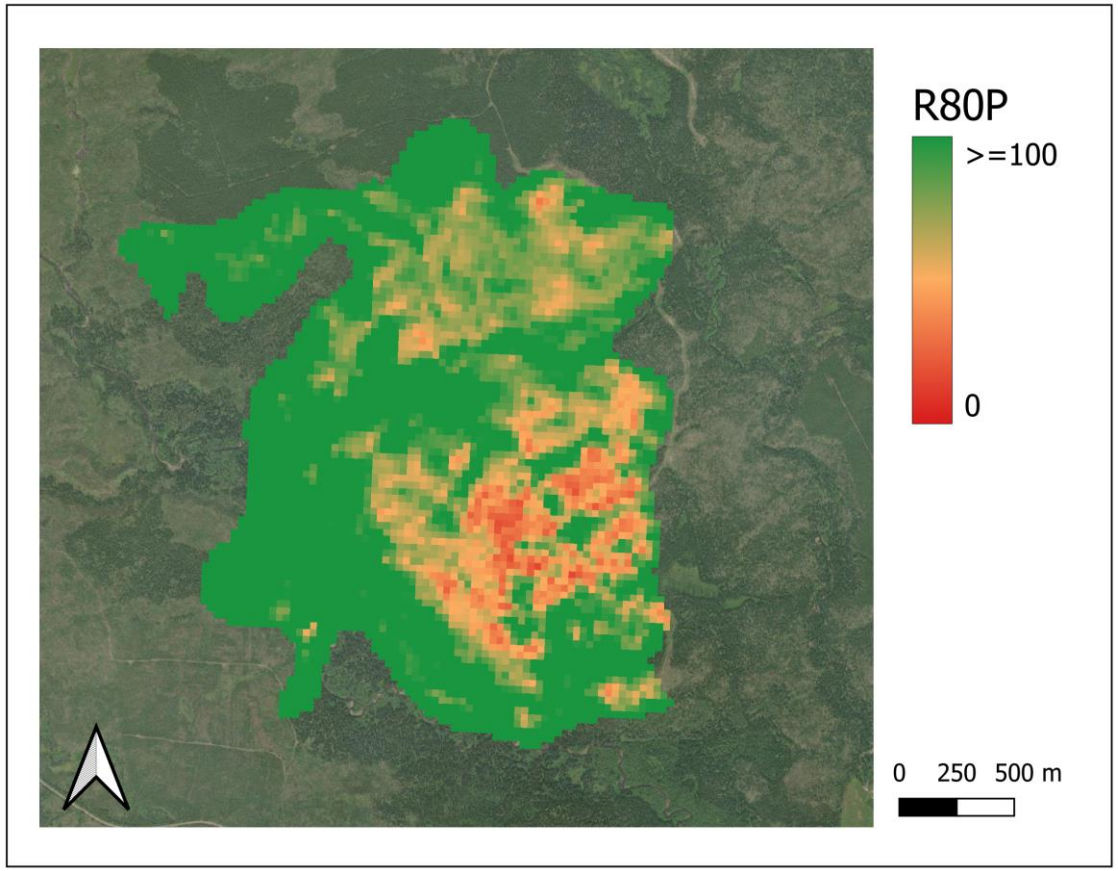
- 2015 wildfire disturbance (423 ha area)
- Multiple indices (NDVI, GNDVI, NBR, NDMI) and a historical recovery target
- Visualize spectral trajectories for multiple spectral indices within the restoration polygon



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

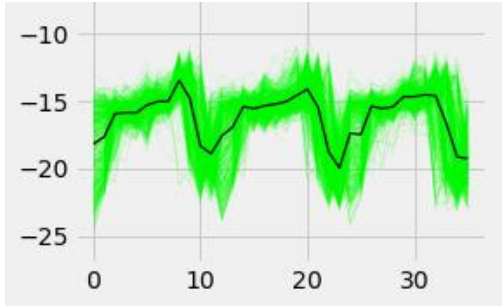
- Initiative to re-naturalize a large area within Vietnam's upper Mekong Delta
- Transition away from a third annual rice crop into nature-based solutions of flood-based agriculture
- Mitigate extreme floods and droughts
- Challenges:
  - Dynamic timing of flood pulse
  - Complex water-vegetation interactions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

CONCEPT/BASIS

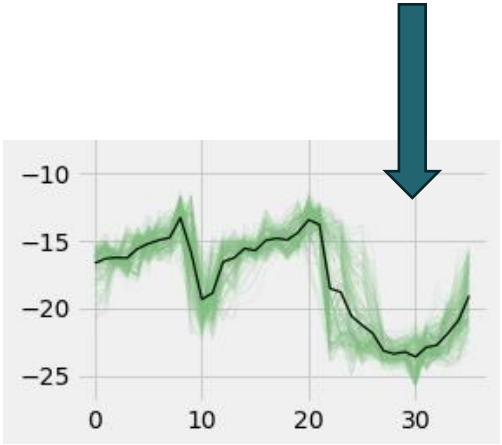
- S1 time series proven capability to detect **surface water** and **flooded vegetation**
- Full S1 time series have distinctive temporal patterns that can be associated with a wetland function
- Assess similarity of time series of restored areas to target functions

Target functions

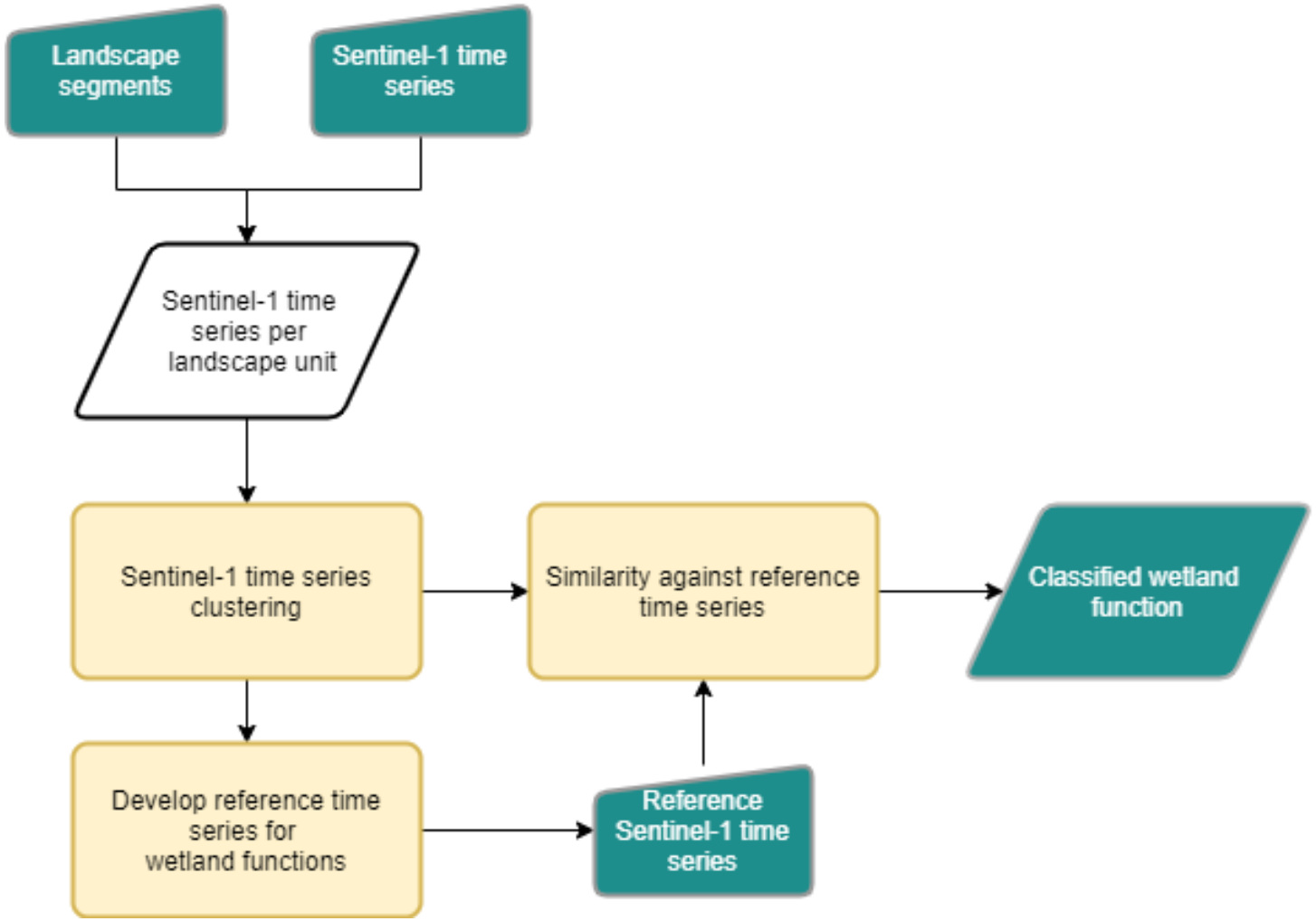
Isolated from floodplain



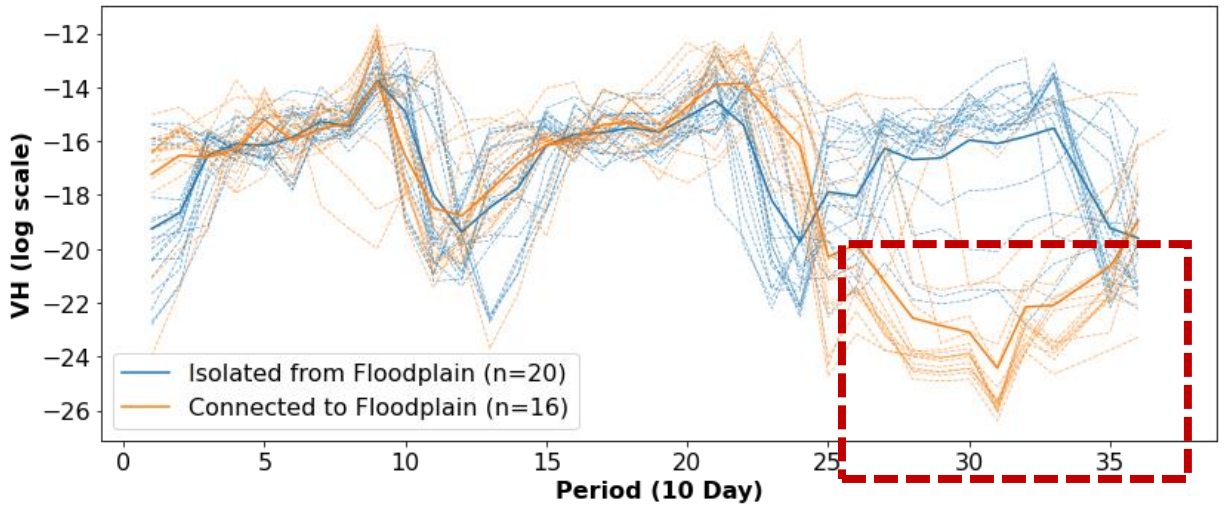
Connection to floodplain



APPROACH – PEOPLE-ER TOOL



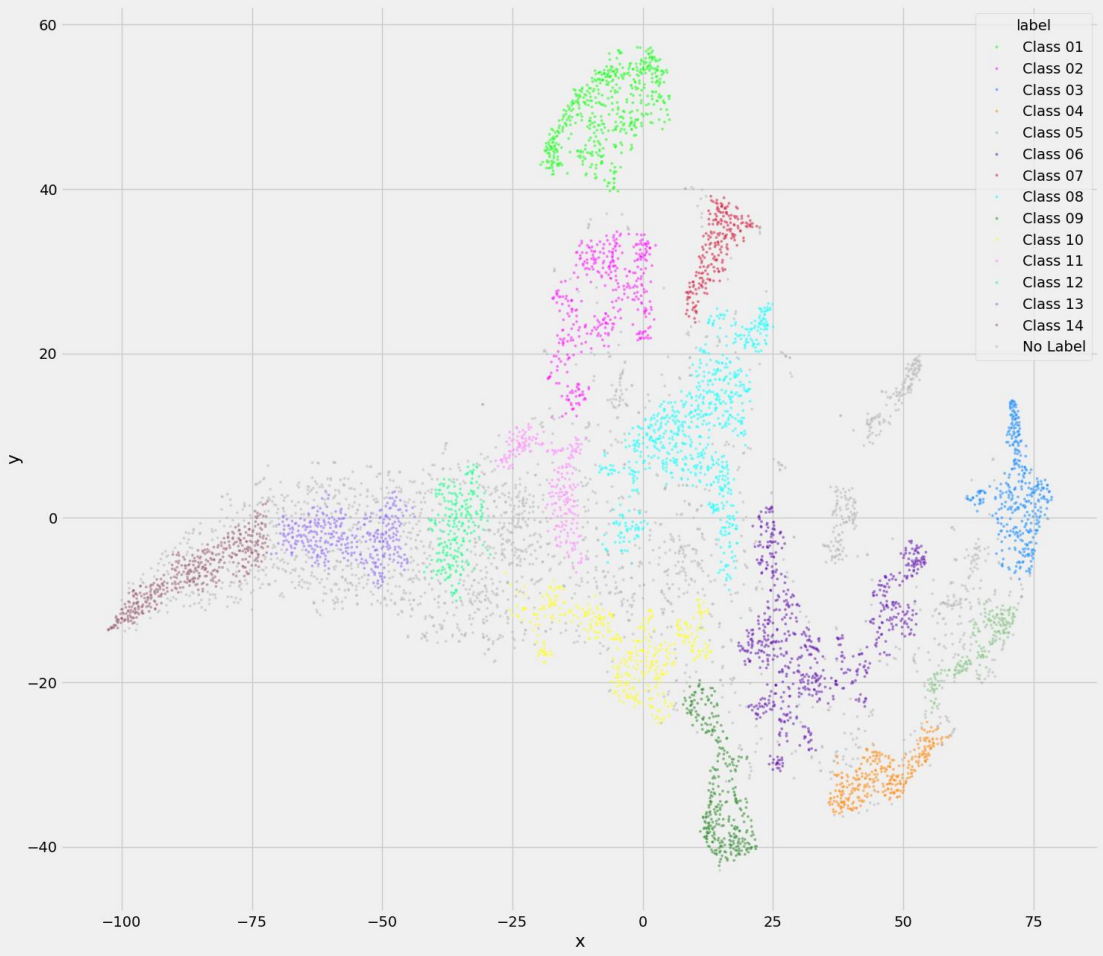
APPROACH – BUILD S1 REFERENCE TIME SERIES



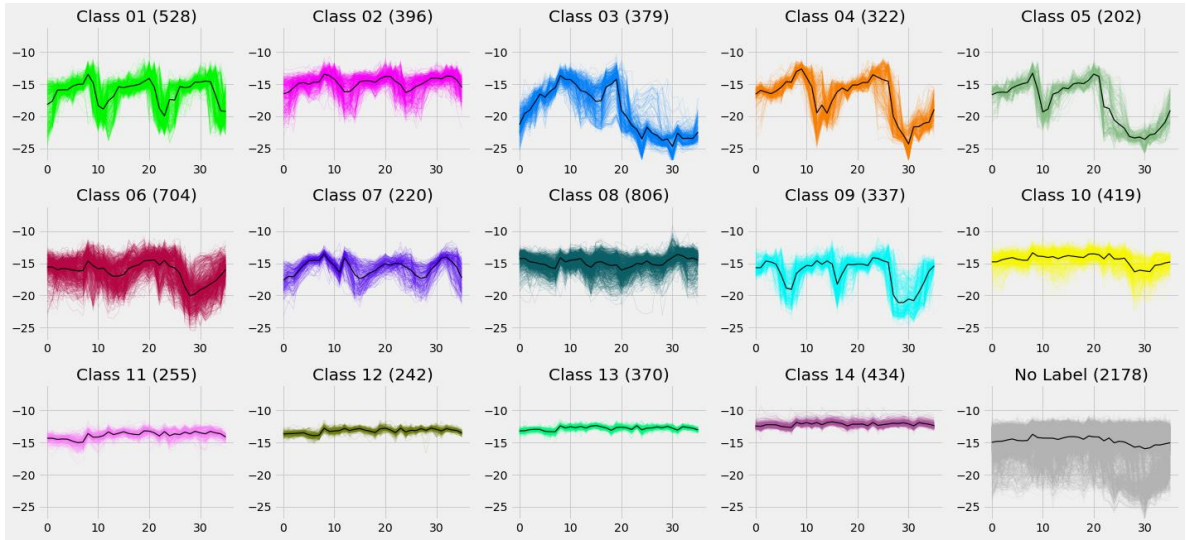
Natural 'flood pulse' function

APPROACH – CLUSTERING

t-SNE Map

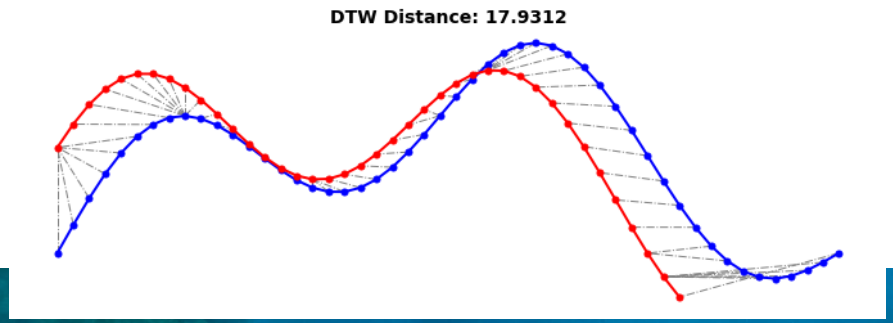


- t-SNE to project time series into 2D map for visualization
- HDBSCAN to identify clusters on t-SNE map
- Reference time series based on the average backscatter value

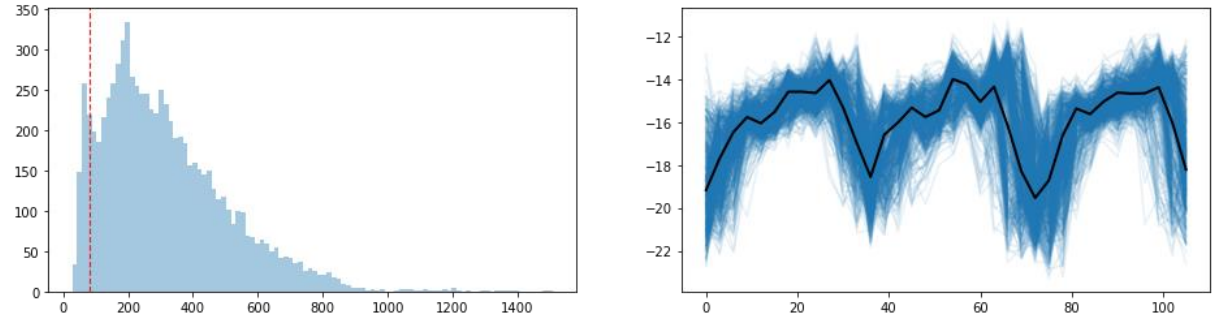


APPROACH – SIMILARITY-BASED CLASSIFICATION

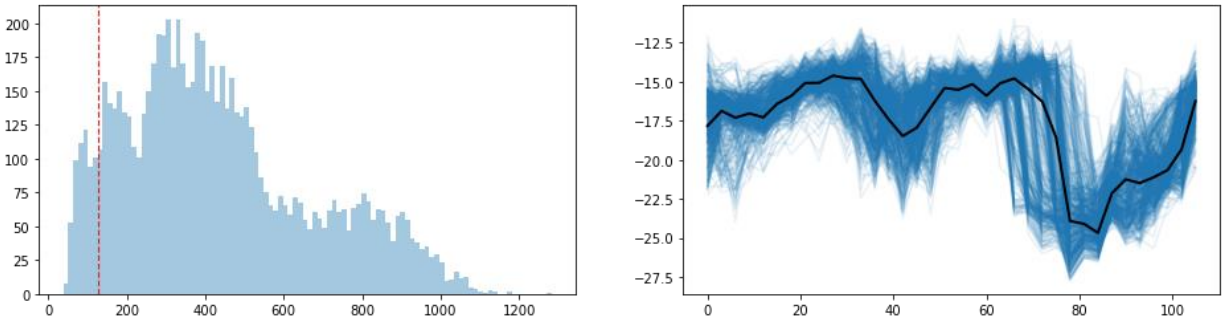
- Fieldwork to label the reference time series
- Dynamic Time Warping (DTW) to measure similarity
  - advantage: tolerance in time lag
- DTW distances are calculated for landscape unit time series against reference time series
- Landscape units are assigned to the wetland type with most similar temporal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



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



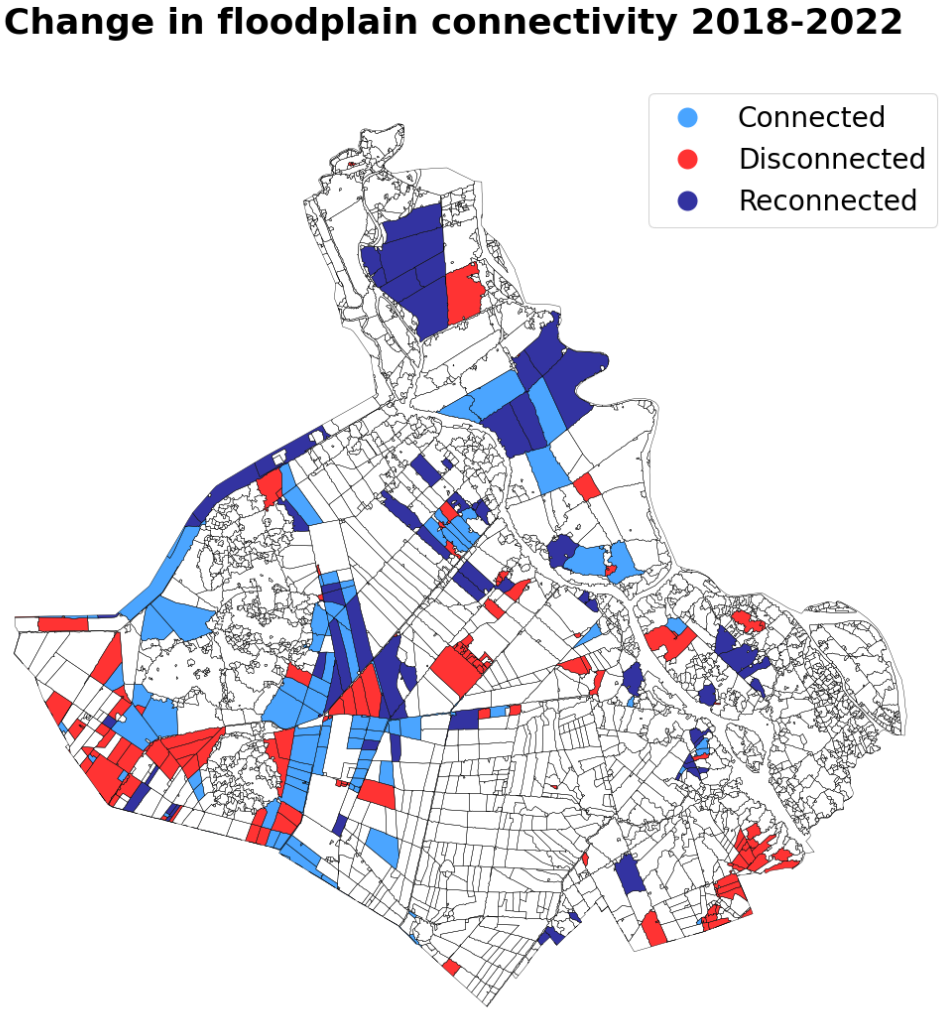
Similarity measure - reference profile **Connected to Floodplain**



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

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:

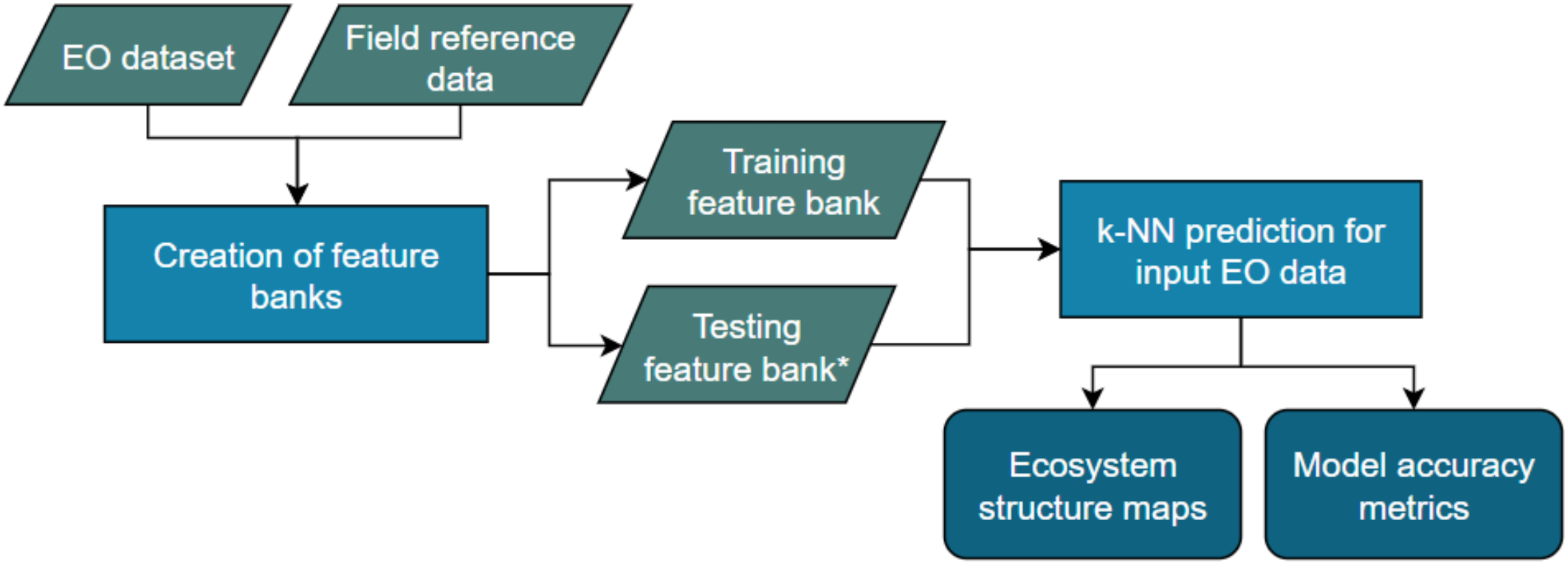
- **VTT Technical Research Centre of Finland**

Support: Hatfield

CONCEPT/BASIS

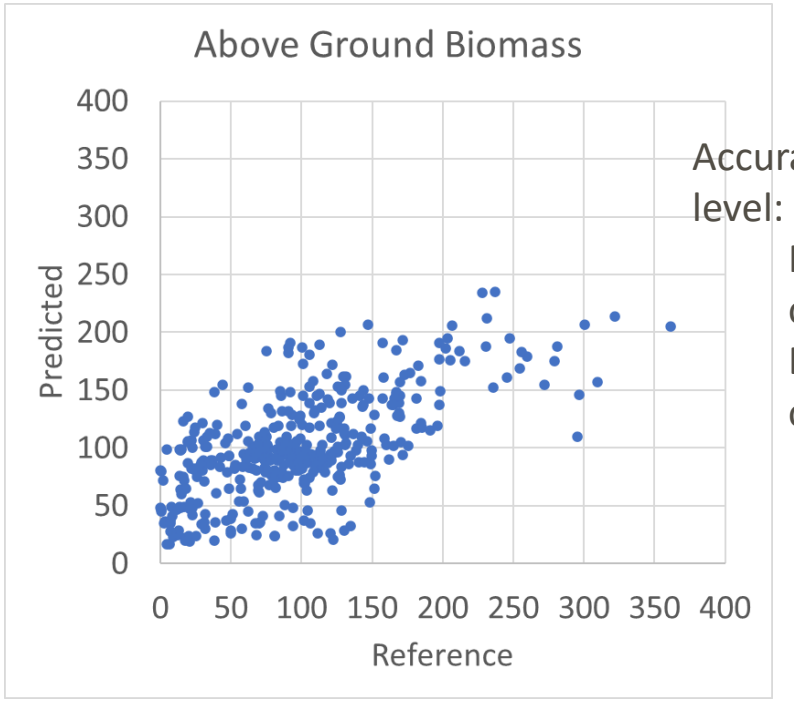
- K- Nearest Neigbour (k-NN) prediction is widely used in EO based forest and environmental monitoring
- As a support for the Spectral Recovery tool, the k-NN tool provides a way to evaluate the ecosystems' status (e.g., in the form of forest structural variable development)
- Users may wish to:
  - 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)



Accuracy metrics at pixel level:

RMSE 45,63 t/ha
or 45,06 % of mean
Bias -0,89 t/ha
or -0,88 % of mean

Above Ground Biomass 0 t/ha 250

ACCESSING THE TOOLS

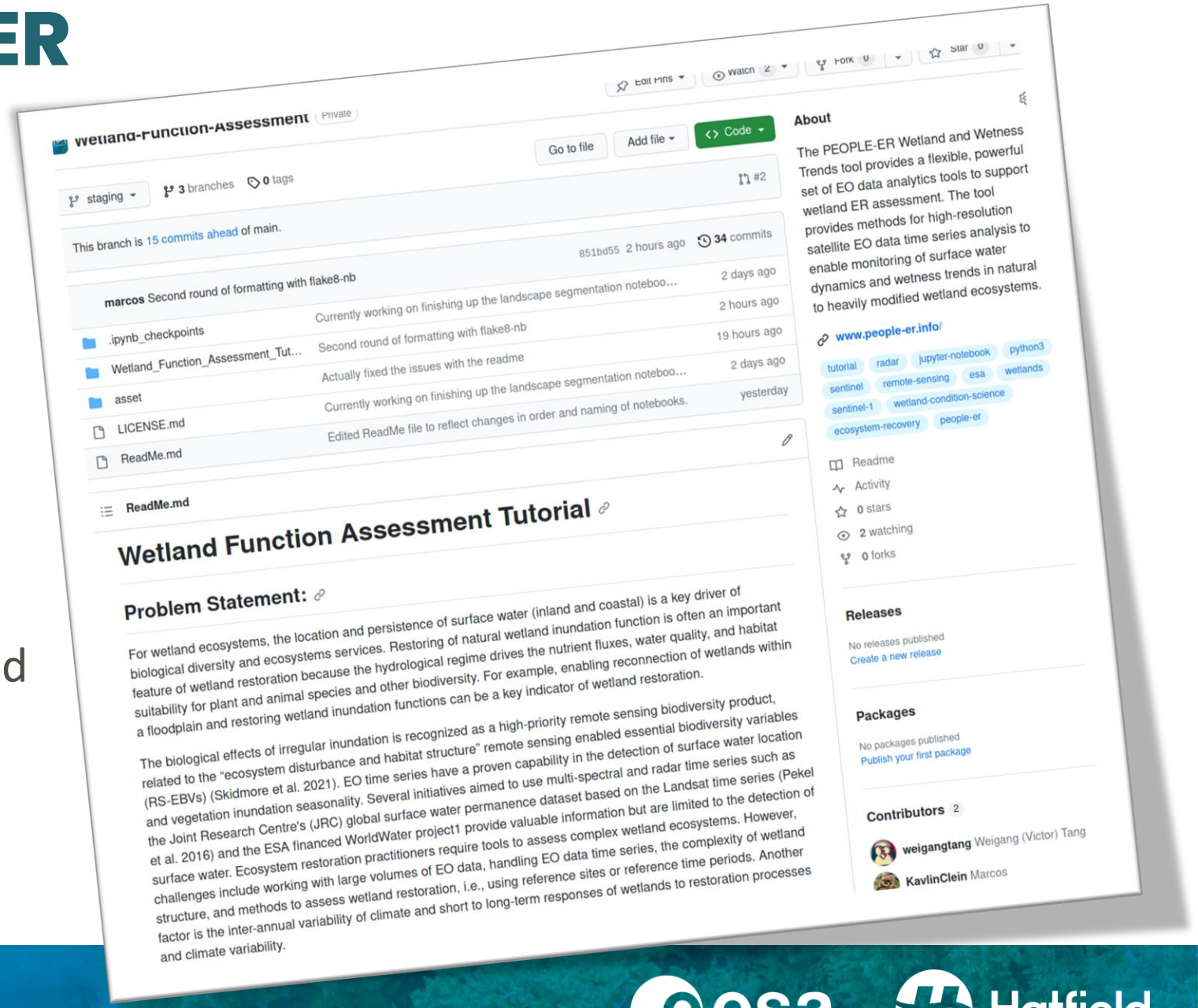
- GitHub
- Notebooks
- Documentation
- Forestry Thematic Exploitation Platform (Forestry TEP)

GITHUB – PEOPLE-ER

Two Public Repositories:

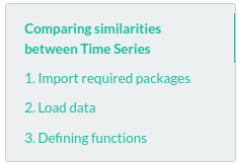
- Spectral Recovery
- Wetland Function Assessment

- K-Nearest Neighbour to be added



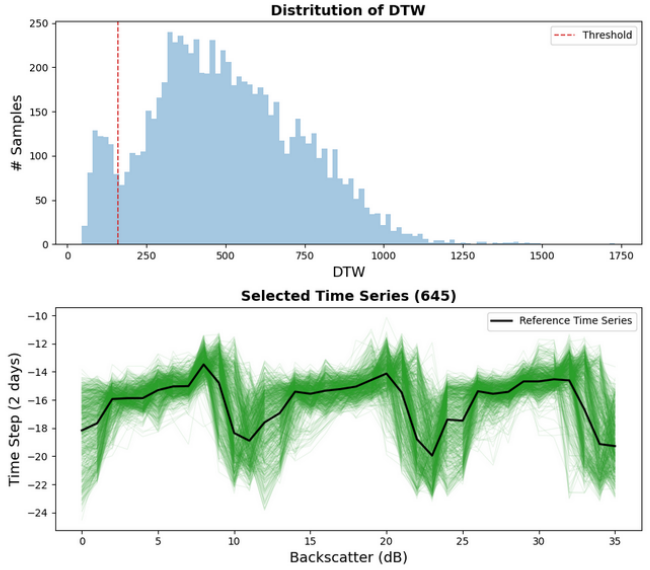
NOTEBOOKS & DEMO DATASETS

- 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



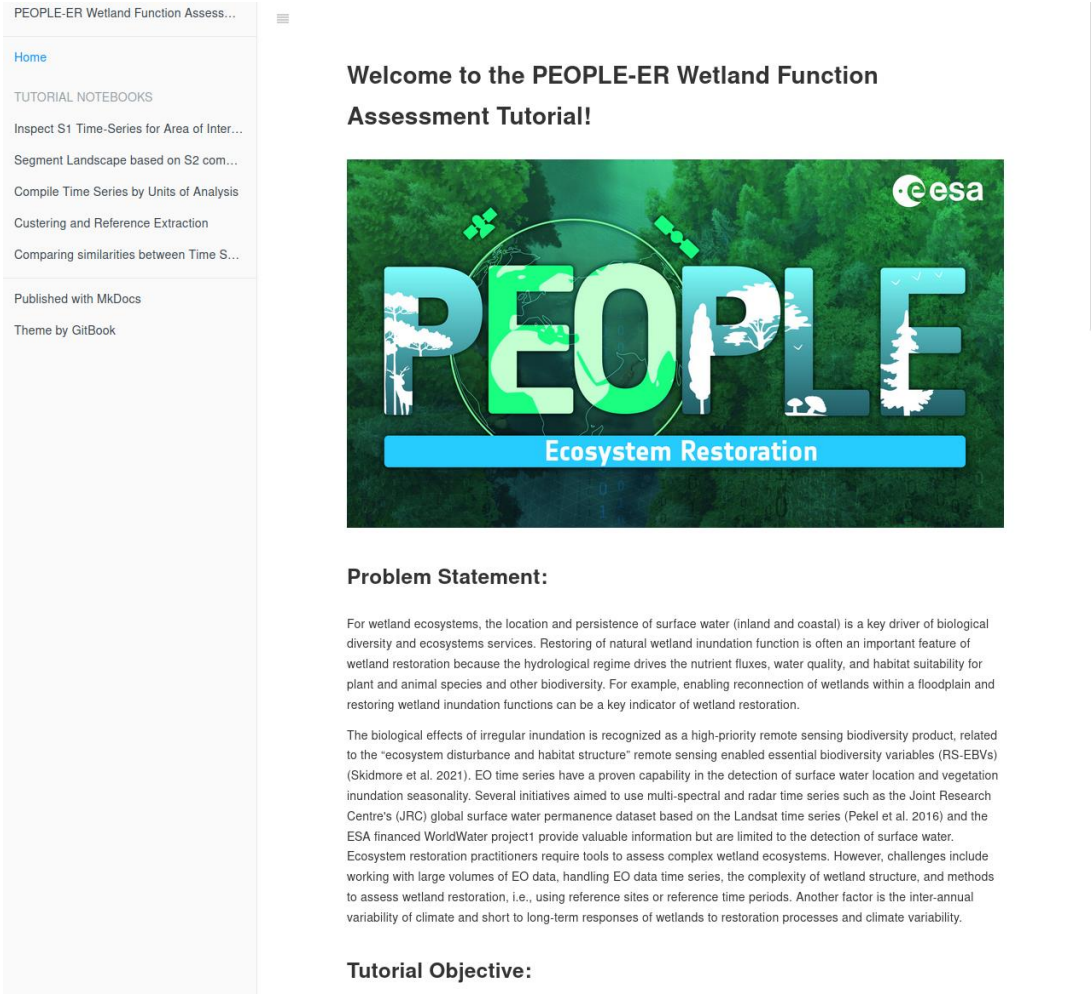
The combination of the two plots, provides the information necessary to a practitioner in order to fine tune the threshold they plan to use.

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="--",
                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(f"Selected Time Series ({n_sel})", fontsize=14,
                  fontweight="bold")
axes[1].legend()

fig.tight_layout()
```



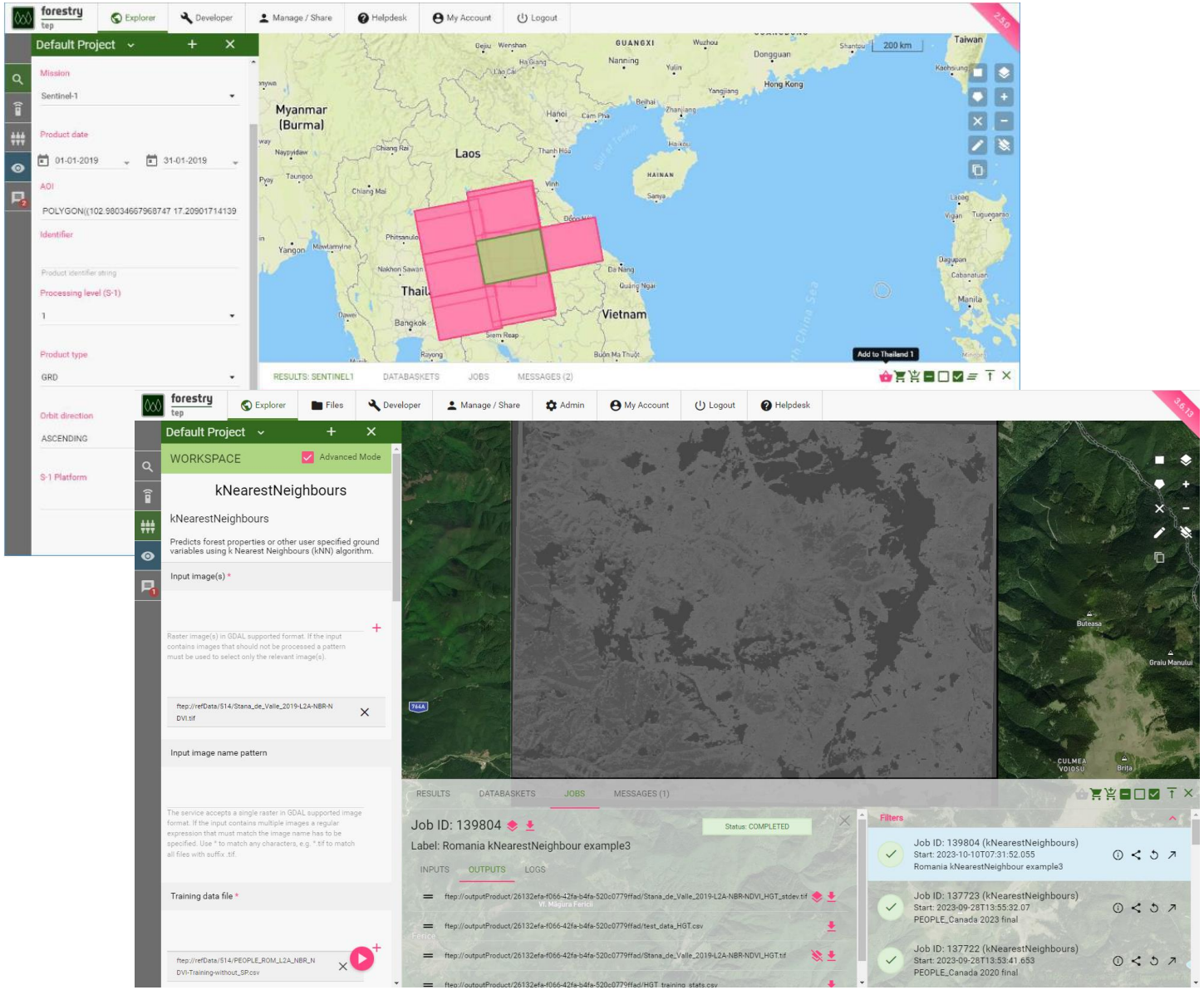
DOCUMENTATION

- 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



FORESTRY TEP

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



THANK YOU!

CONTACT:

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