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Correlation of the flooding regime with the presence of Solidago gigantea over the valleys of Narew and Vistula in Poland

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ORIGINAL ARTICLE

The more we do, the less we gain? Balancing effort and efficacy in managing the *Solidago gigantea* invasion

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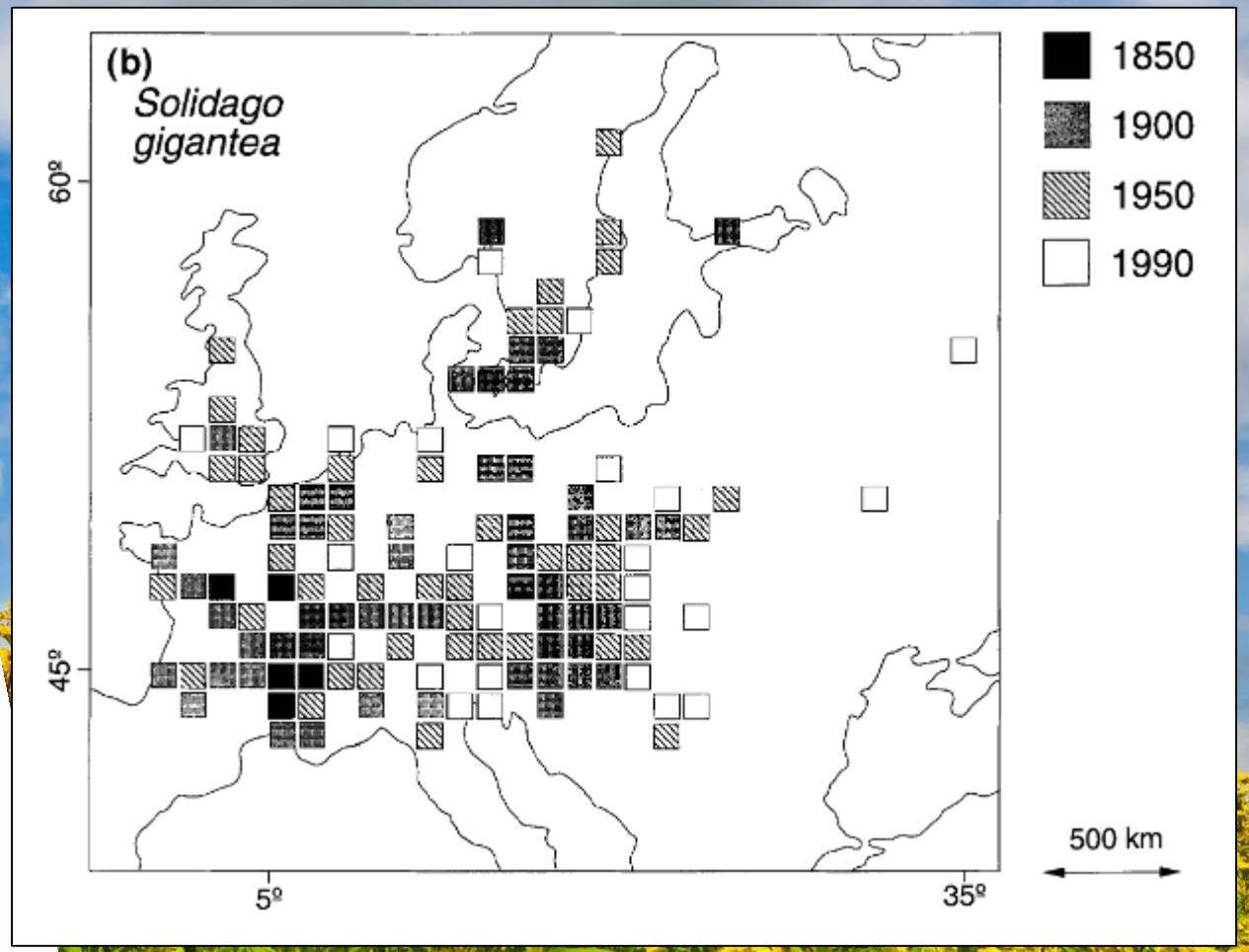
Abstract

Developing invasive plant management strategies is an important task in modern ecology, conservation biology and land management. *Solidago gigantea* is considered a problematic invader in Europe and Asia, where it forms dominant stands that can decrease species diversity. There is, therefore, an urgent need for effective management to reduce *S. gigantea* infestations and their negative impacts. We examined the efficacy of multiple approaches to *S. gigantea* management in Hungary. In our study, we evaluated the effect of several long-term management techniques such as grazing, mowing and periodic flooding on the invader's density as well as native community diversity. In addition, we investigated the short- and long-term effects of mowing combined with other treatment options, to estimate the influence of increased management intensity. Our results indicate that all tested management techniques had negative impacts on *S. gigantea* density. Short-term mowing did not appear to improve species diversity in the resident community; however, all long-term options improved species diversity. Moreover, combining treatments with mowing varied in its effectiveness; mowing once increased the efficacy of flooding, but decreased the efficacy of grazing, while mowing twice decreased efficacy of flooding. We suspect this is due to the increased intensity of disturbance, which does not allow for the natural recovery of communities, and after management ceases, invasion is able to re-occur. Our results indicate that for effective management, we need to combine management options which act via different mechanisms, leading to cumulative positive effects on the resident community when applied at moderate levels.

KEYWORDS
biodiversity, invasive species, long-term management, physical weed control, weed control

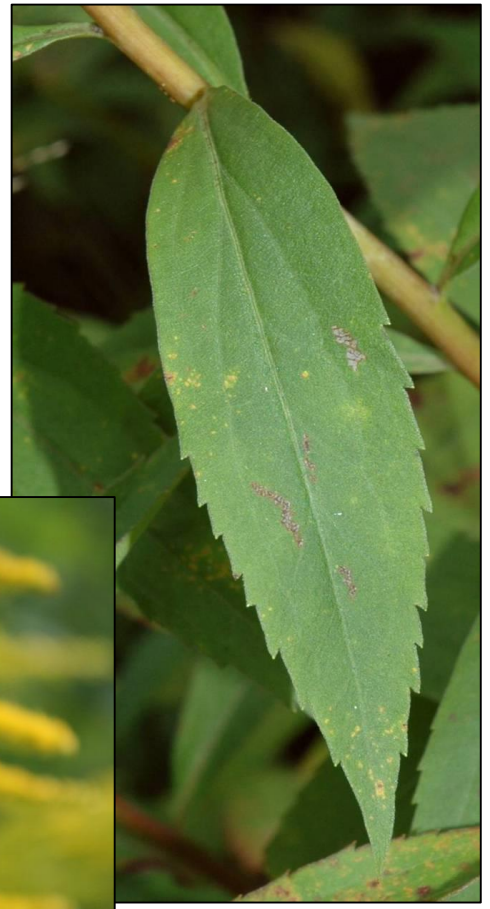
1 | INTRODUCTION

Invasive plant species can be a major factor in causing biodiversity loss (Pyšek et al., 2004). Land use change and cultivation/ livestock practices, together with rapid increases in population and the transportation of goods, have opened new ways of introducing organisms onto new continents. Invasive plant species are now colonising habitats independently of their natural dispersal



Solidago gigantea

Solidago gigantea, commonly known as **giant goldenrod**, is a tall and imposing flowering plant belonging to the aster family (*Asteraceae*).
It is native to North America and demonstrates invasive behaviour in Poland and throughout Eastern Europe.



Invasive tendencies

- **Rapid growth and reproduction:** *Solidago gigantea* is a vigorous growing plant, capable of spreading rapidly through its extensive rhizomatous roots.
- **Thrives in disturbed habitats:** Outcompetes native vegetation and colonises accessible open spaces.
- **No primary consumers or diseases:** *Solidago gigantea* is not commonly consumed by herbivores due to its bitter taste and tough foliage.
- **Competes with native plant species for resources:** Displacement of native vegetation reduces biodiversity and can negatively impact native wildlife that depends on specific plant species for food or habitat.

Objective

Identifying areas potentially endangered by the invasive species' spread

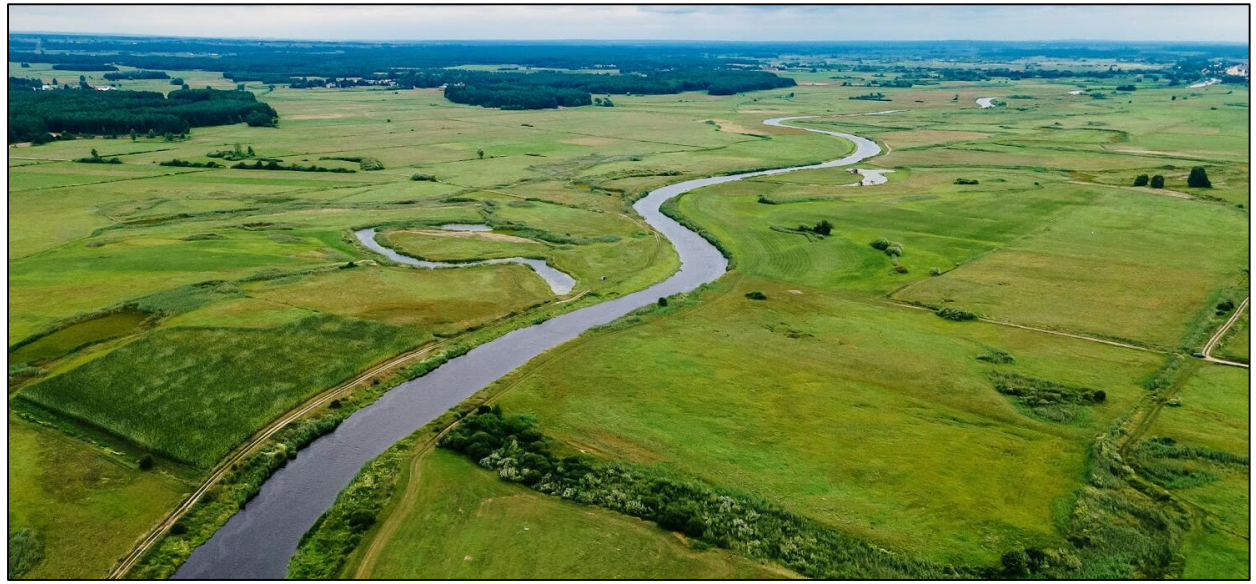
- Use of Sentinel-2 (S-2) time series for mapping of *Solidago gigantea* extent
  - Evaluation of phenological patterns of *Solidago gigantea* as input data to the classification
  - Evaluation of the efficiency of mapping using various input dataset derived from S-2 time series
  - Evaluation of satellite imagery detection limitations using drone images

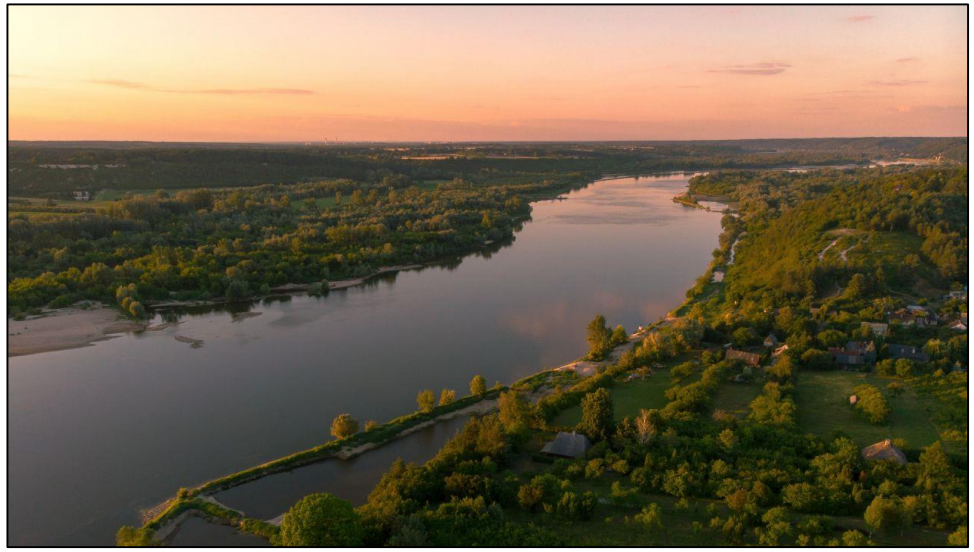
Study area

The **Narew** river valley is characterized by diverse wetland ecosystems:

- floodplains
- inland marshes
- meadows
- oxbow lakes
- high biodiversity

It is home to numerous plant and animal species, including **rare and endangered** ones.

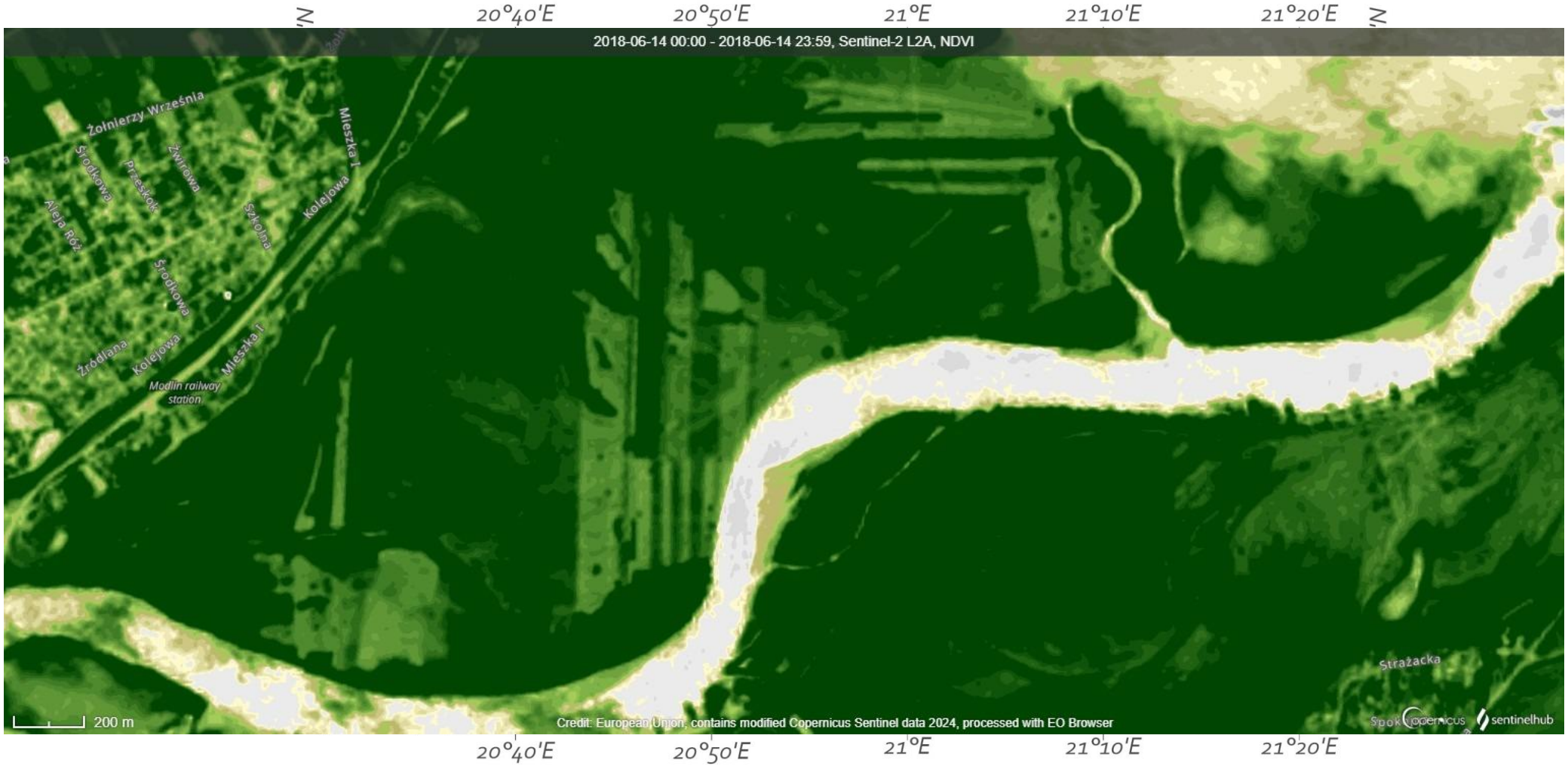




The **Vistula** river

- the longest river in Poland
- flowing through the country from south to north, it is an **important ecological corridor**
- supporting various habitats and species.

Study area


N
20°40'E
20°50'E
21°E
21°10'E
21°20'E
2018-06-14 00:00 - 2018-06-14 23:59, Sentinel-2 L2A, NDVI
Żołnierzy Września
Środkowa
Przeskok
Żwirowa
Mieszka I
Kolejowa
Szkolna
Aleja Róż
Środkowa
Źródlana
Kolejowa
Mieszka I
Modlin railway station
Strażacka
200 m
Credit: European Union, contains modified Copernicus Sentinel data 2024, processed with EO Browser
sentinelhub

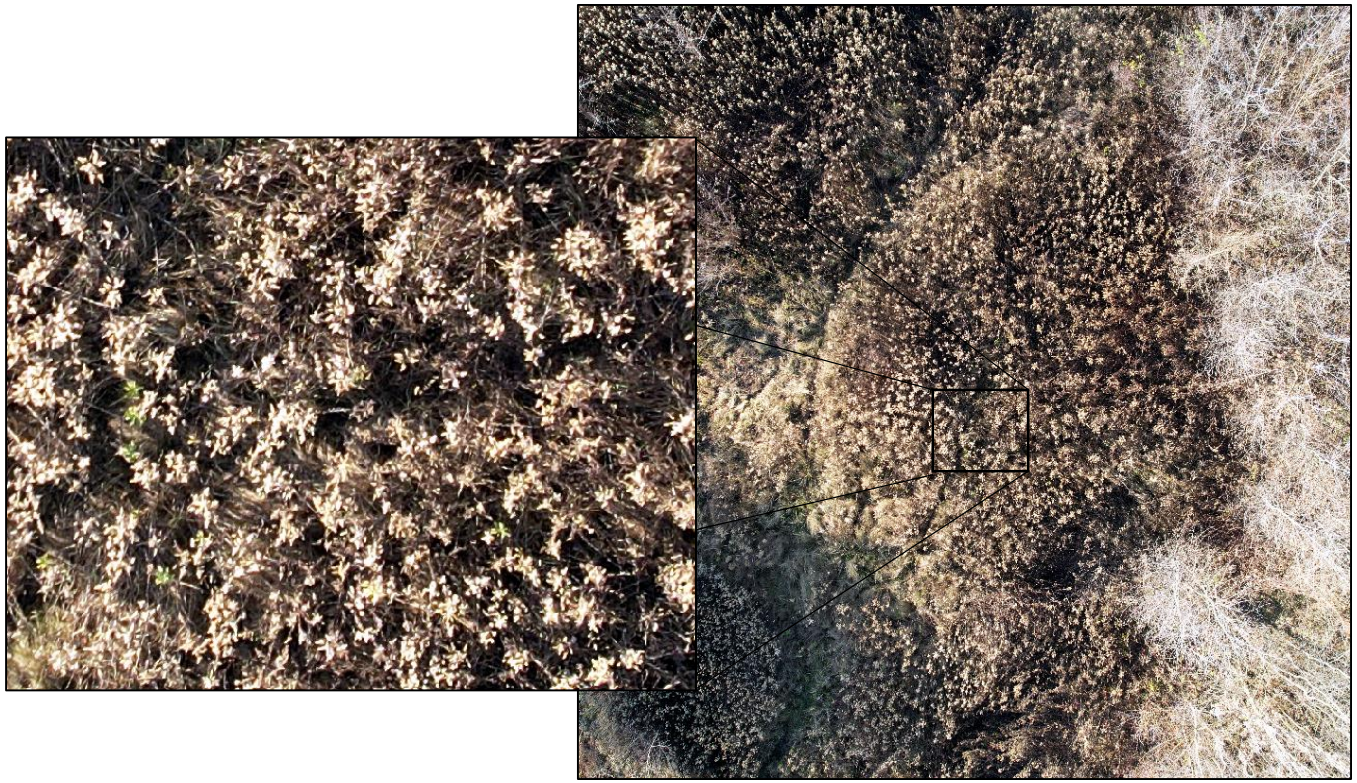
Reference data - Field survey

250 reference points were collected in May 2022 across the valleys using a GNSS receiver.

Points were collected on patches larger than 10x10 meters situated in open areas (not under tree canopy) to make sure they will be visible on satellite image of Sentinel-2.

Reference data - Drone survey

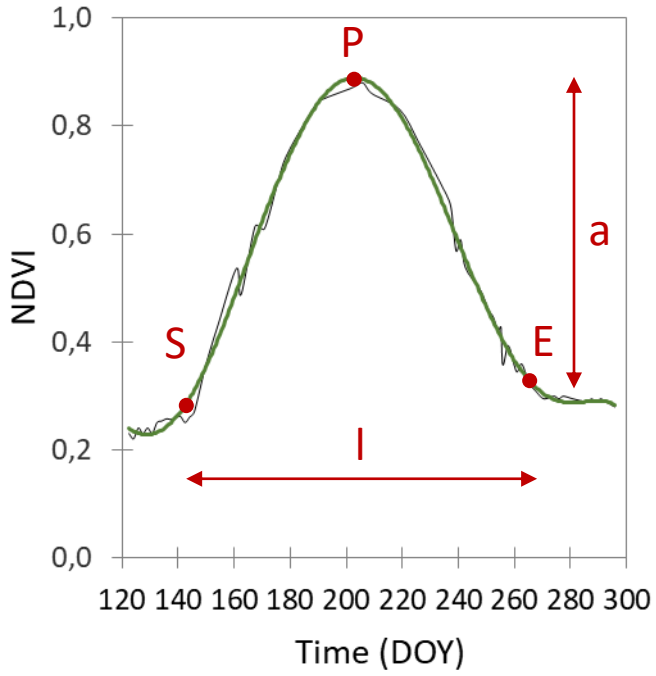
- 300 geolocated images were collected using an UAV in November 2022 to capture the presence of the species under the canopy of leafless deciduous trees.



Phenology metrics

Phenology Metrics algorithm utilizes a Time-Series NDVI images to detect:

- Start of Season: the date of onset of photosynthetic activity
- Peak of Season: the date when the ecosystem shows its maximum photosynthetic activity or leaf area
- End of Season: the date at which the leaf area or photosynthetic activity starts to decrease rapidly



S: Start of Season

E: End of Season

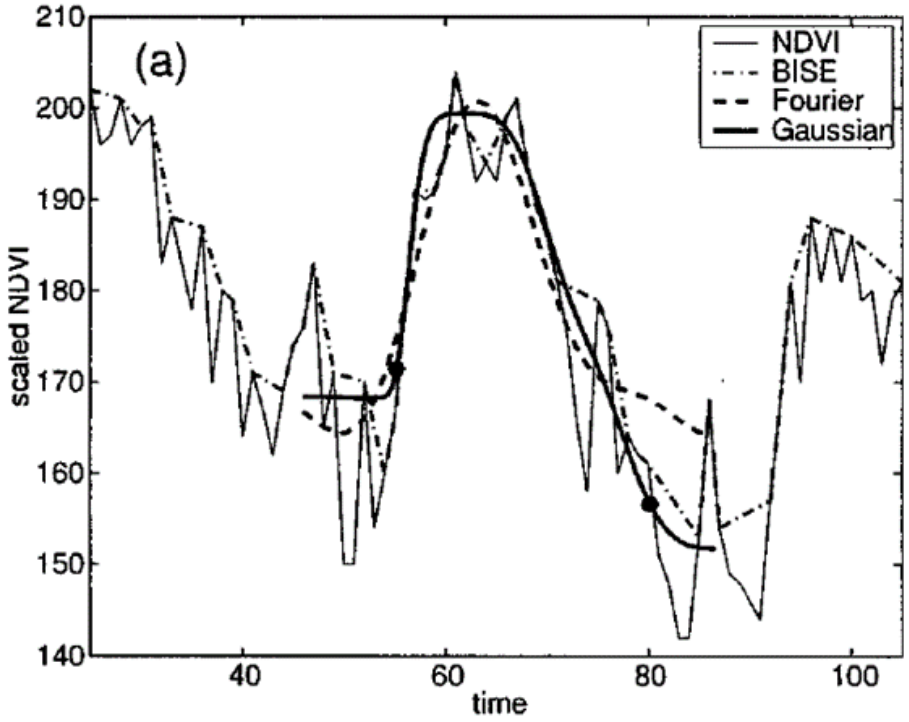
P: Peak of Season

l: length of Season

a: amplitude

S-2 Phenology metrics calculation

Phenology Metrics module uses the Phenex package to generate the smoothed NDVI curve with the Fast Fourier transform methods



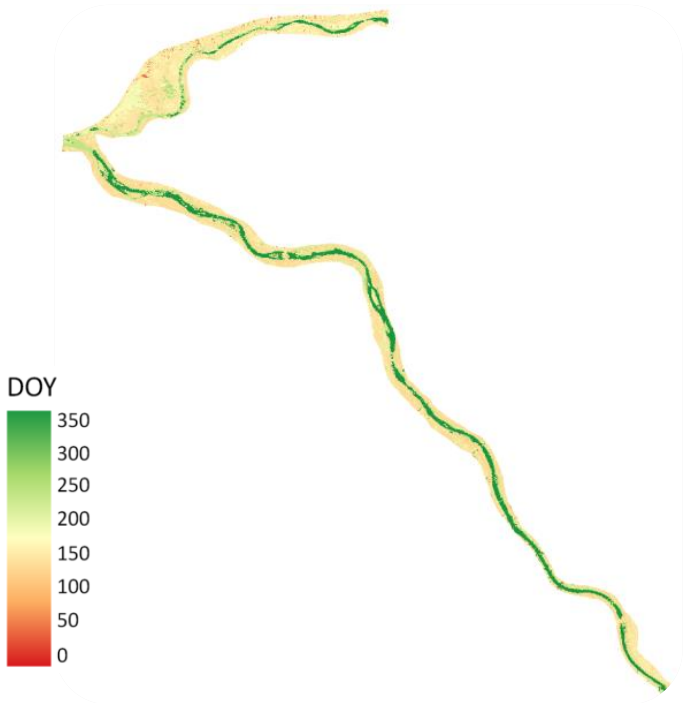
Jonsson P., E. L. (2002). Seasonality Extraction by Function Fitting to Time-Series of Satellite Sensor Data. IEEE Transactions on Geoscience and Remote Sensing, 40(8), 1824-1832

S-2 Phenology metrics map

Results for the season 2020-2021, utilizing 15 Sentinel-2 NDVI images

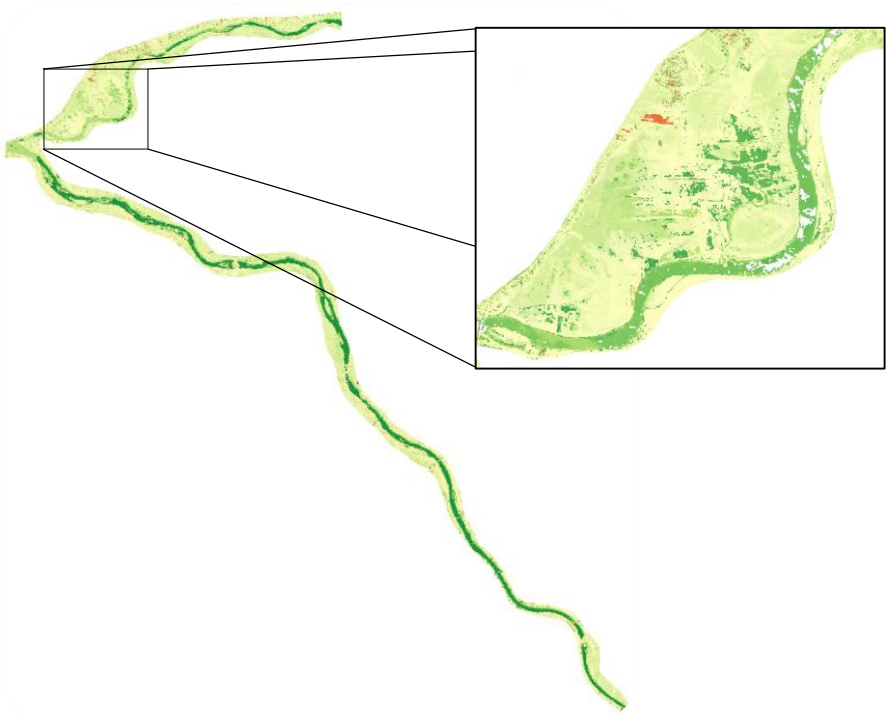
Start of the season

Day of the year when the green-up occurred



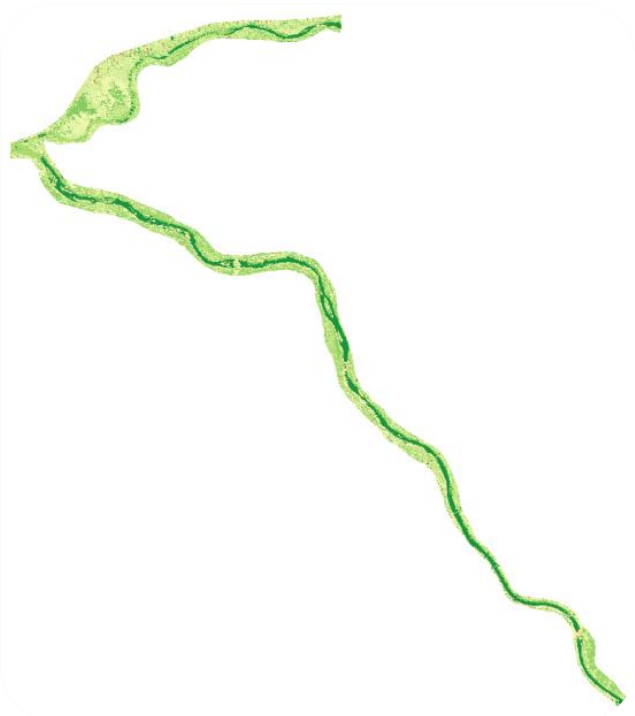
Peak of Season

Day of the year when the maximum NDVI value occurred



End of Season

Day of the year when the senescence occurred



Solidago gigantea fraction – drone images classification

- Creation of ortophoto based on drone images
- Tree canopy masking using LIDAR data
- Division of orthophoto into 10 × 10 m scenes using the pixel grid derived from Sentinel-2 satellite images
- Classification of fraction of *Solidago gigantea* based using the MAGICK package

no *Solidago gigantea* in the image

50-60% coverage

90-100% coverage

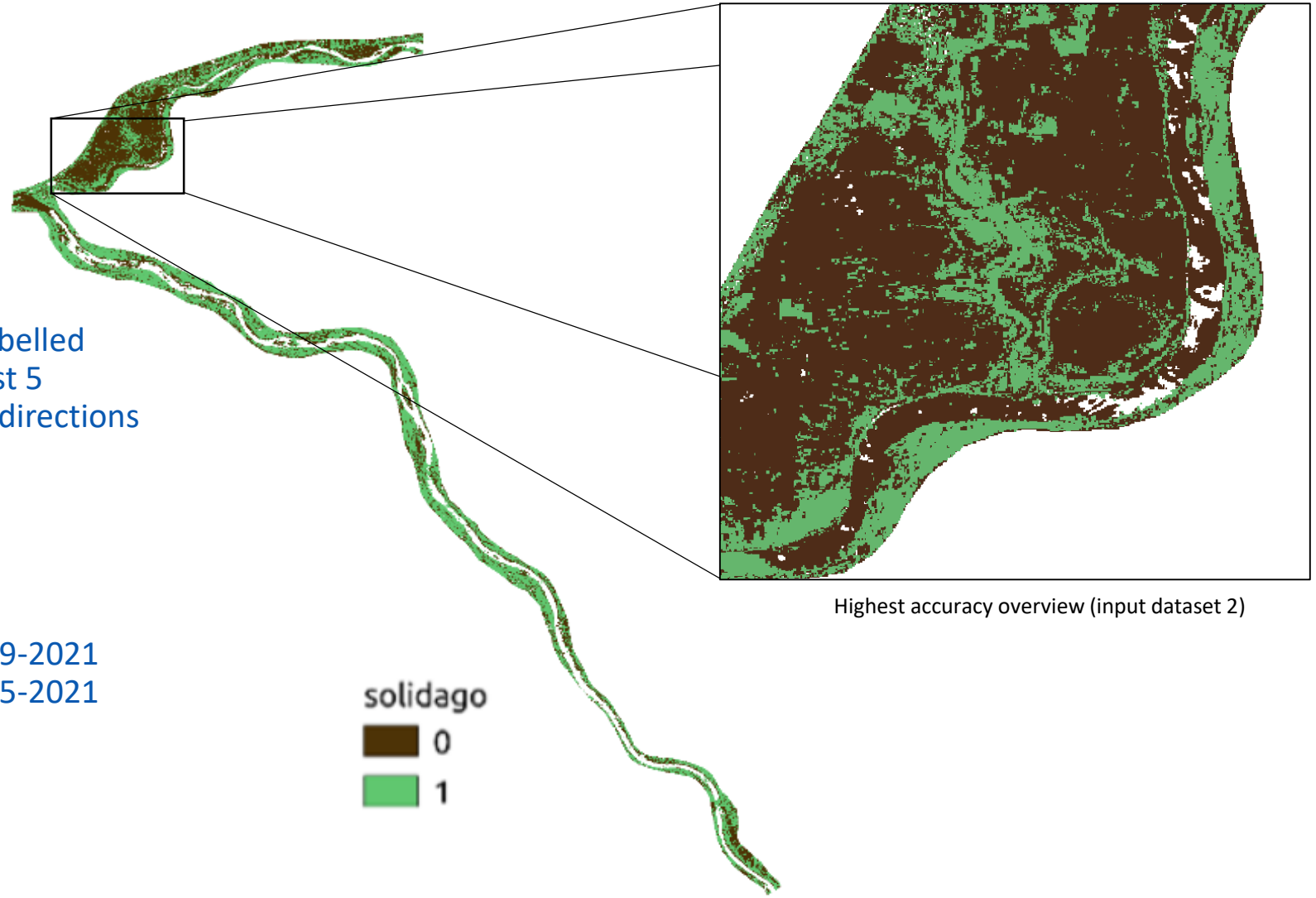
S-2 Classification

Available Input Data:
- Phenology Metrics 3 bands
- Sentinel-2 Level-2A 9 bands

Target:
- 141 points from the area of interest labelled with 1 in case *Solidago* expands at least 5 meters away from the point across all directions
- 84 points without *Solidago*

Input datasets:
1. 3 phenology metrics bands
2. 3 phenology metrics bands and 9 of 09-2021
3. 3 phenology metrics bands and 9 of 05-2021

Classifiers:
1. Random Forest (RF)
2. Support Vector Machine (SVM)



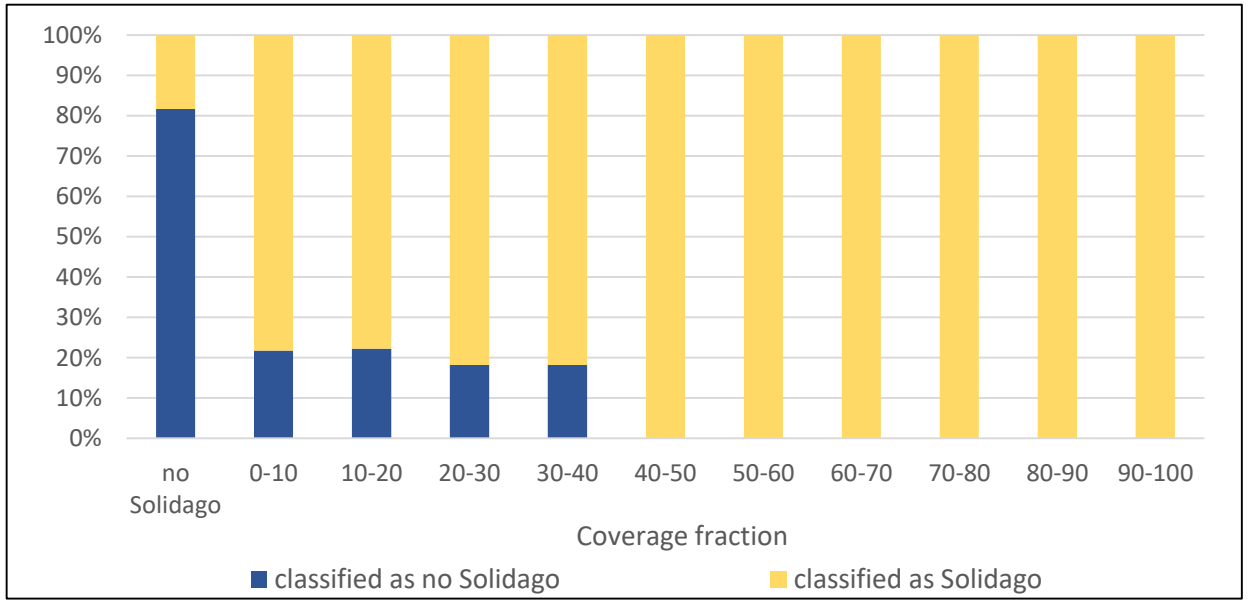
Highest accuracy overview (input dataset 2)

Detection limits

Input dataset	Random Forest	SVM
1	76%	71%
2	83%	79%
3	75%	68%

Across the various input dataset alternatives used (1-3), which achieved a range of 10-fold cross-validation accuracies between 68% and 83% (considering any of SVM and RF approaches), the best of them are 79% and 83% when phenology metrics were synergistically used with the spectral bands corresponding to the blooming season (input dataset 2).

Coverage fraction of *Solidago* higher than 50% all pixels of Sentinel-2 images were classified properly. For coverage ranging from 10% to 40%, around 80% of pixels were correctly classified. For the drone images where *Solidago* was not detected at all, an overestimation of about 20% occurred in the Sentinel-2 classification.



Flood detection workflow

Orbit level

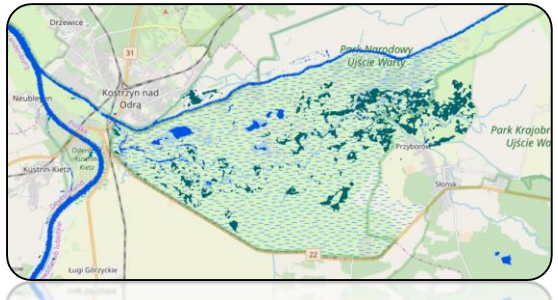
- Input S-1 data (t1-t2)
- Image pre-processing
- Change-detection
- Flood classification
- Masking
- Input auxiliary data (riparian zones) (land cover)

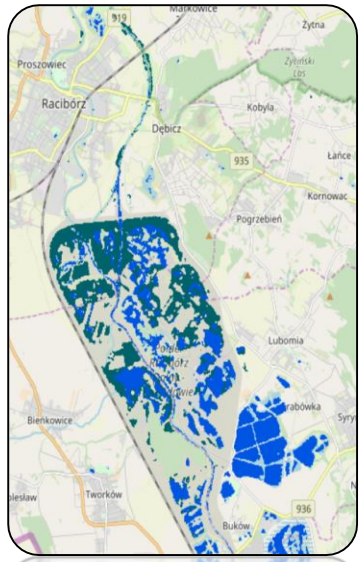
Country level

- Mosaicking
- Temporal reclassification
- Country-wide map updating

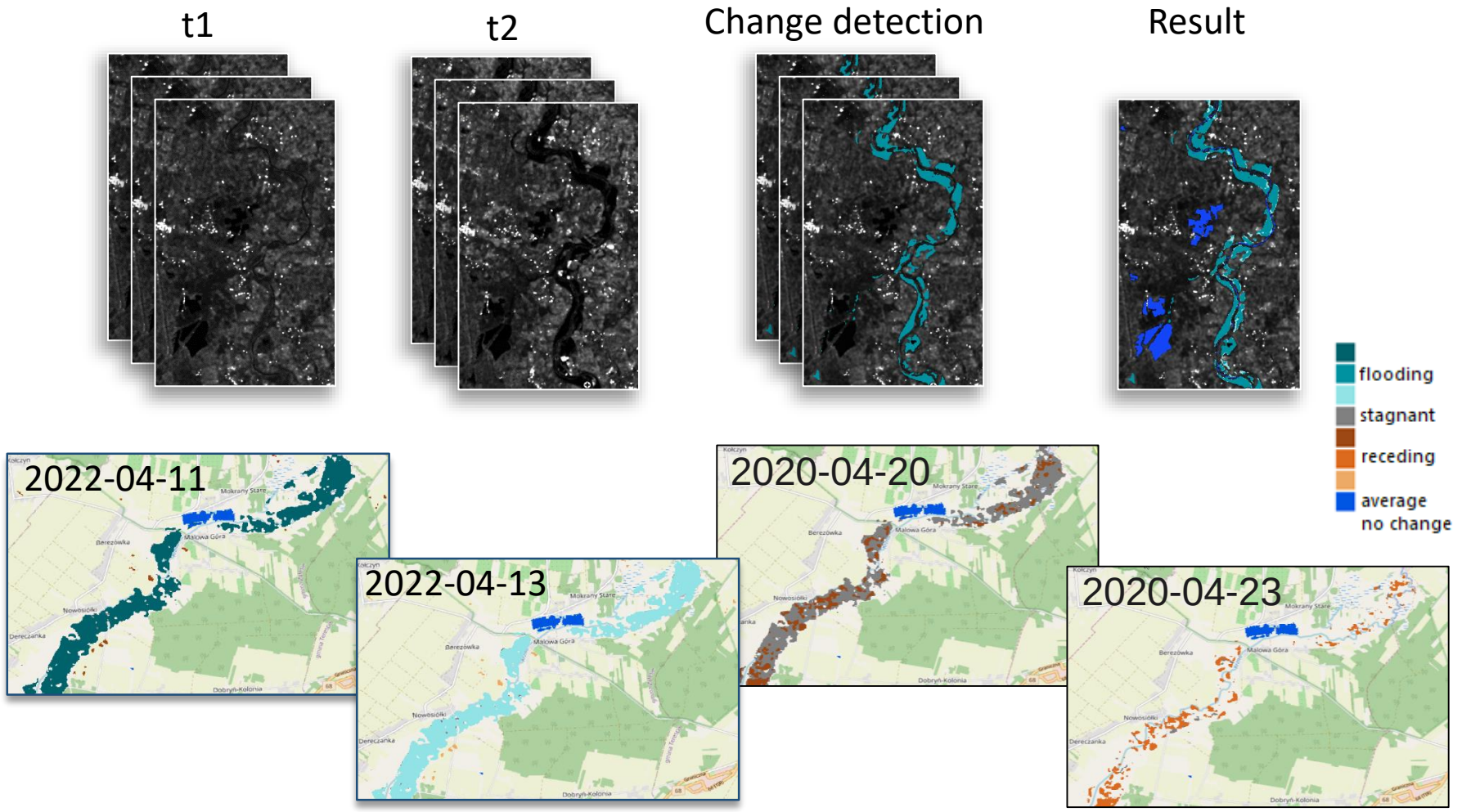
Geoportal publication

- Different functionalities for various stackholders

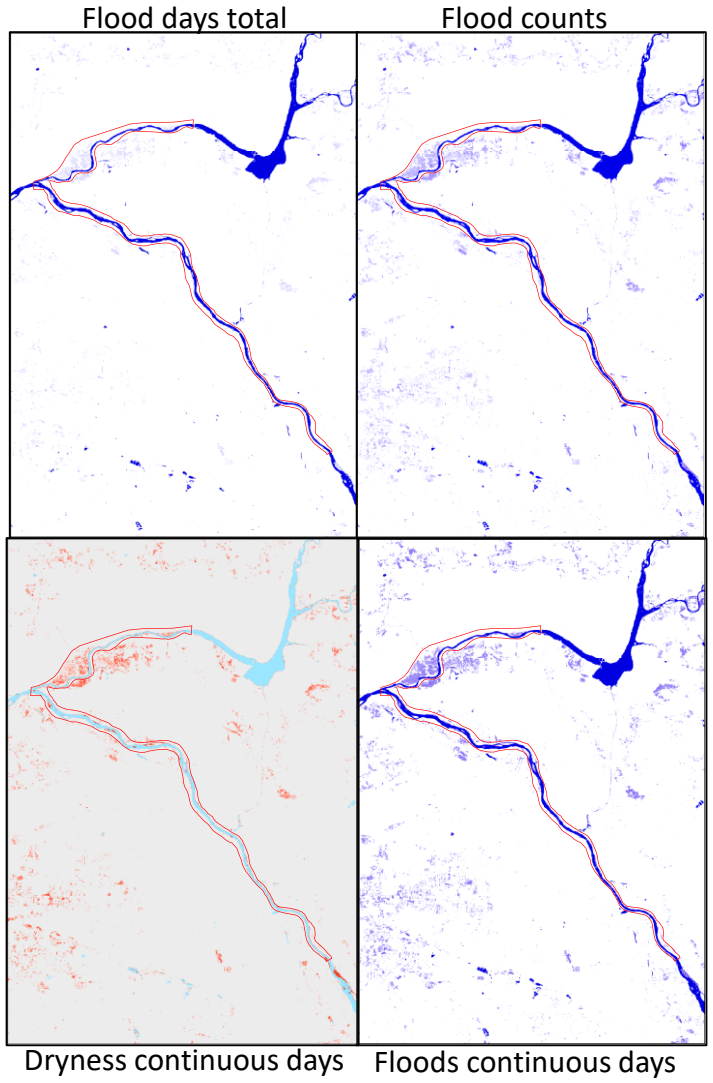


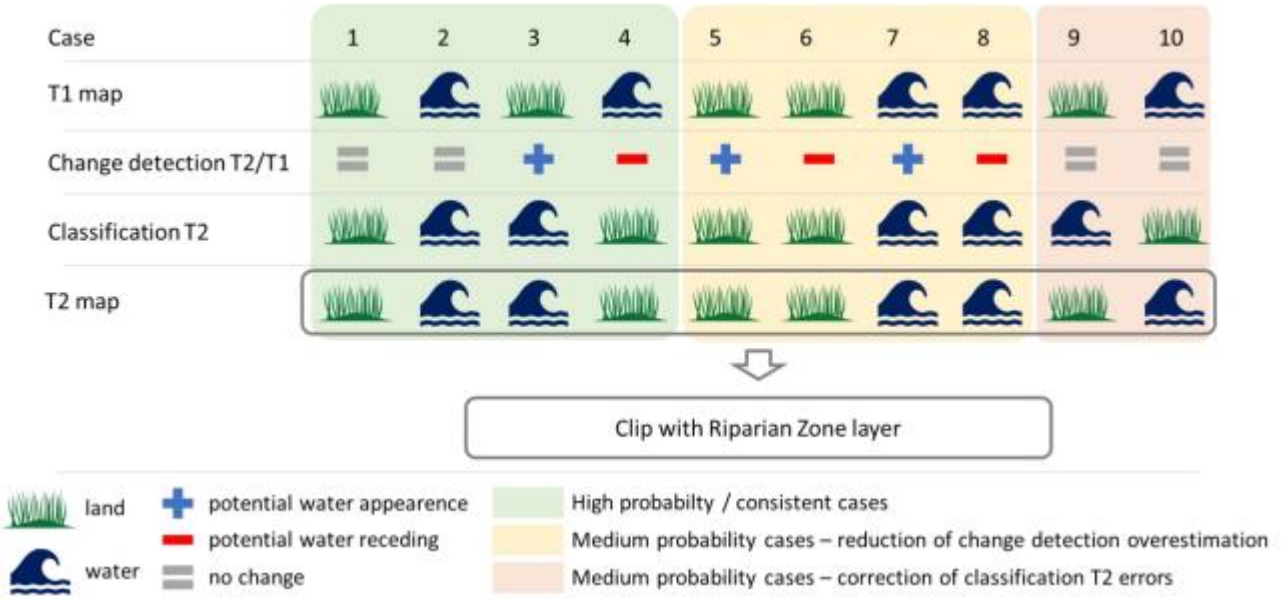


Flood detection workflow



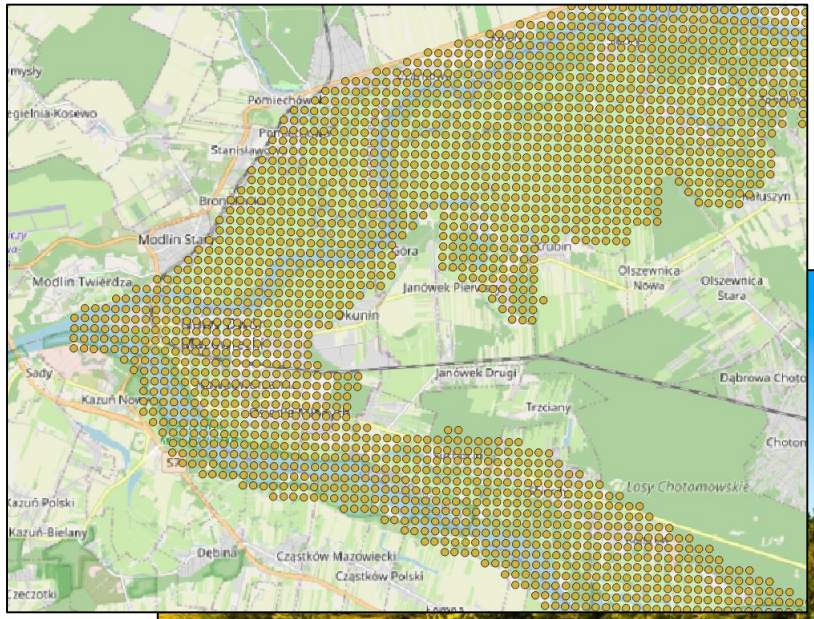
Hydroperiods

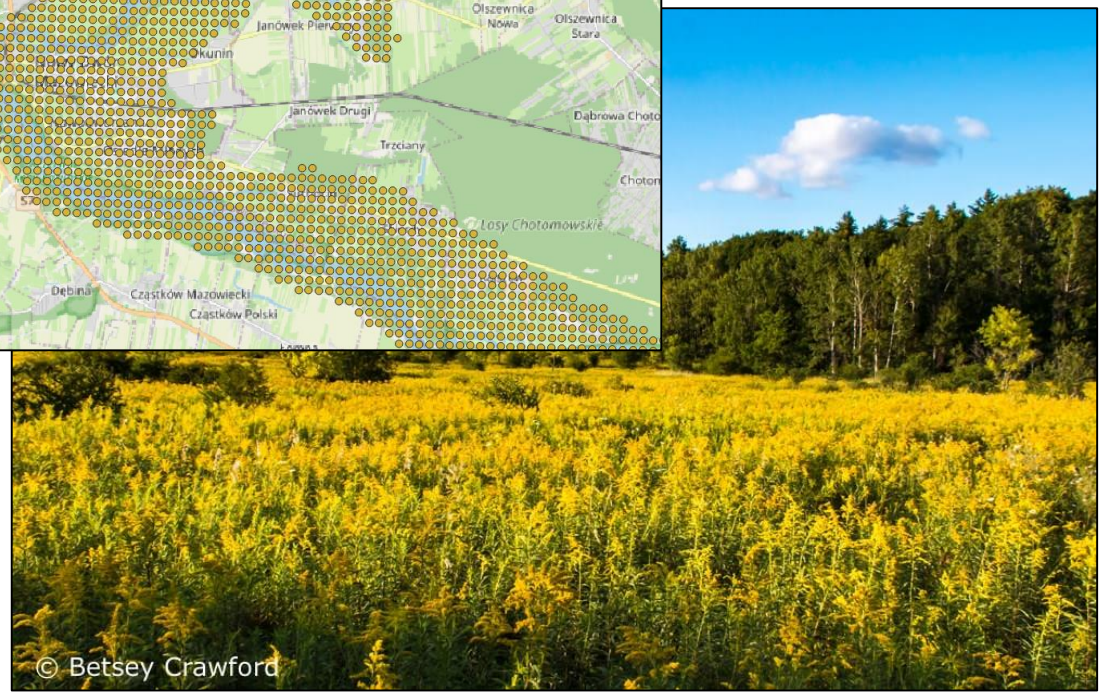




Regression Model

- Periods of **continuous dry days** positively impact the spread of Solidago gigantea, meanwhile **continuous days of flooding** and **total days of floods** inhibit the reproduction of the plant.
- The method is highly dependent on **data availability**.





EnviLink

Thank you for attention!