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A.I. Satellite Image insights for Natural Resource Management

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- A small introduction to remote sensing
- Natural Resource Management
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  - Example 2: Invasive Species Monitoring
  - Example 3: Tree colonization
- How to get started in geospatial monitoring

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Small introduction to remote sensing

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What is Remote Sensing?

Sensing from afar

- Remote sensing is where you collect information about an object without making physical contact with that object.

- In the context of geospatial analysis, that object is usually the Earth.

- Remote sensing also includes processing the collected information.

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What is Remote Sensing?

Aerial images for urban plannig

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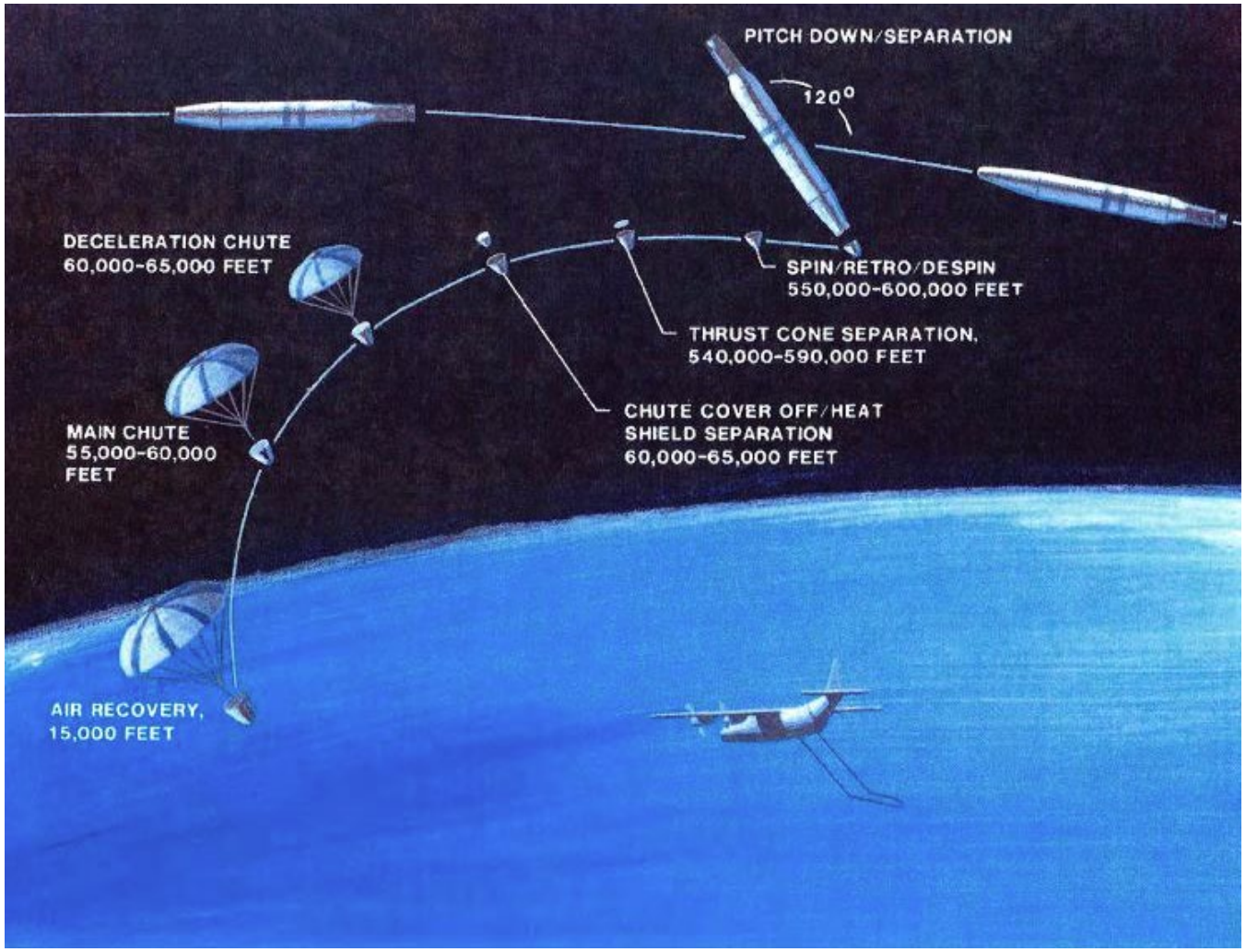
What is Remote Sensing?

The benefits of cold war



[Declassified satellite images]

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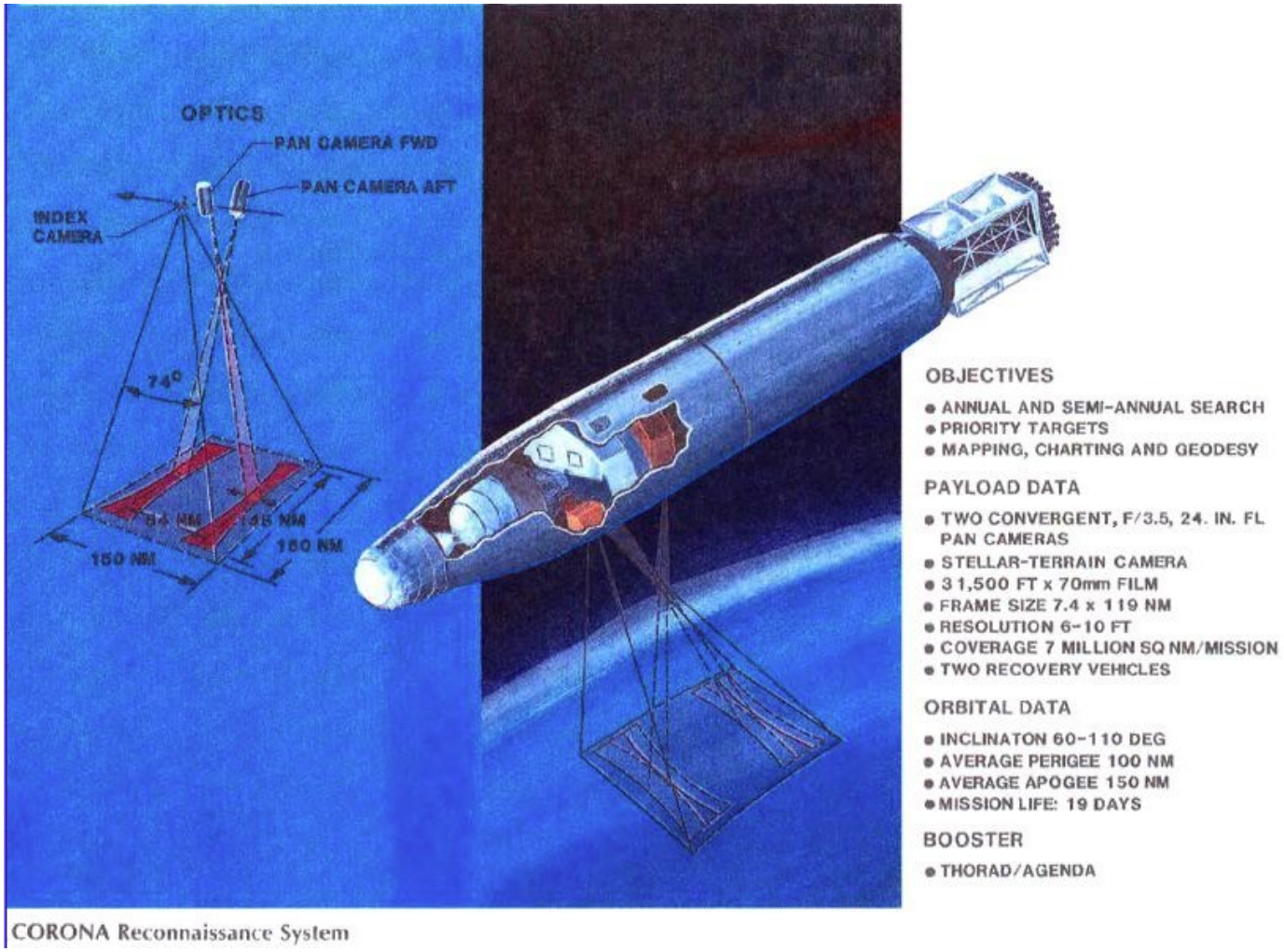
What is Remote Sensing?

The benefits of cold war



CORONA Reconnaissance System

[Declassified satellite images]

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What is Remote Sensing?

The benefits of cold war

[Declassified satellite images]

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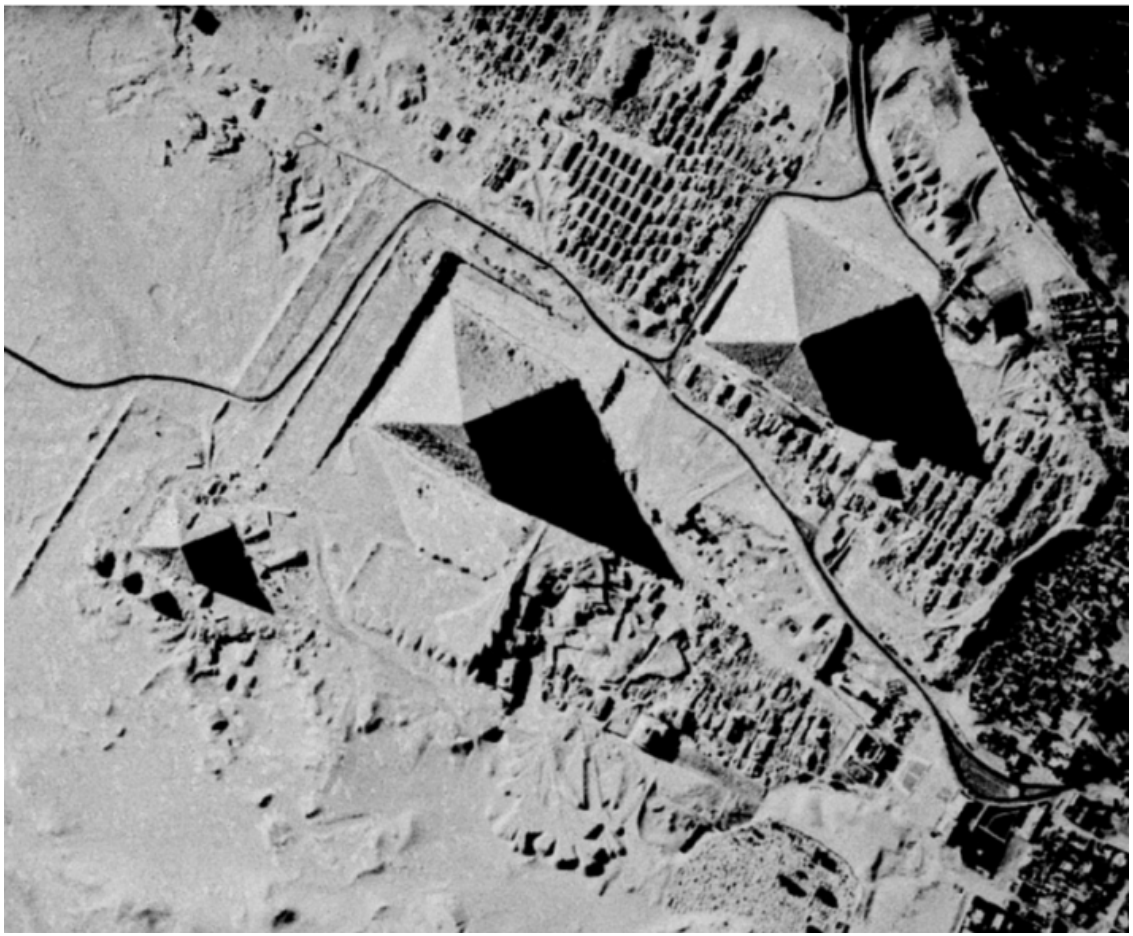
What is Remote Sensing?

The benefits of cold war



[Declassified satellite images]

What is Remote Sensing?

The Landsat program

- On July 23, 1972, NASA launched the **Earth Resources Technology Satellite** (**ERTS**). It was renamed as **Landsat 1**. The main sensor was the:
  - **Multispectral Scanner** (**MSS**). MSS captured four separate images at four different wavelengths of the light reflected from the Earth's surface.
- This sensor had several revolutionary capabilities. The first and most important capability was the first global imaging of the planet scanning every spot on the Earth every 16 days.

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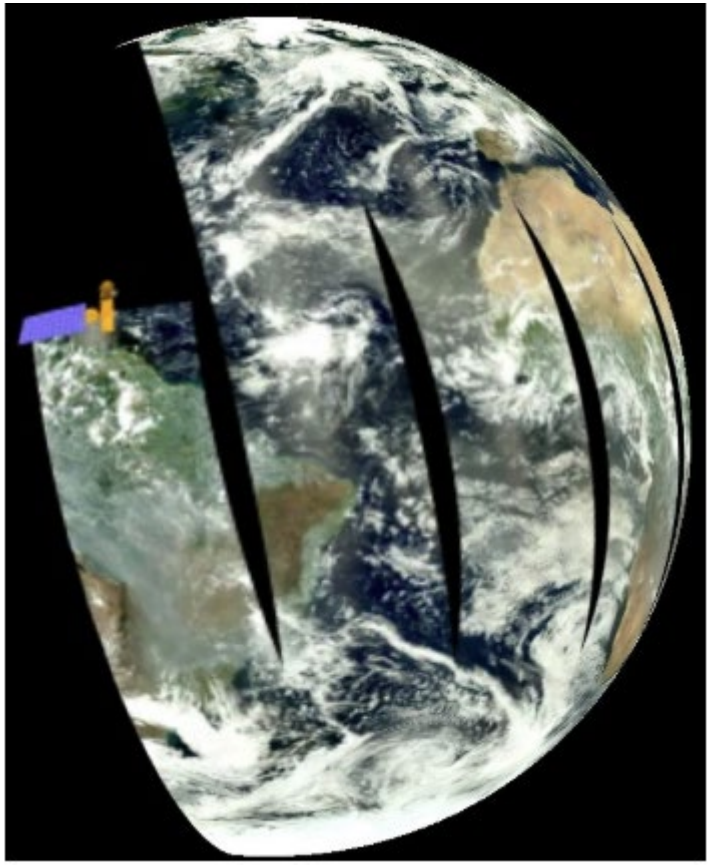
What is Remote Sensing?

The Landsat program



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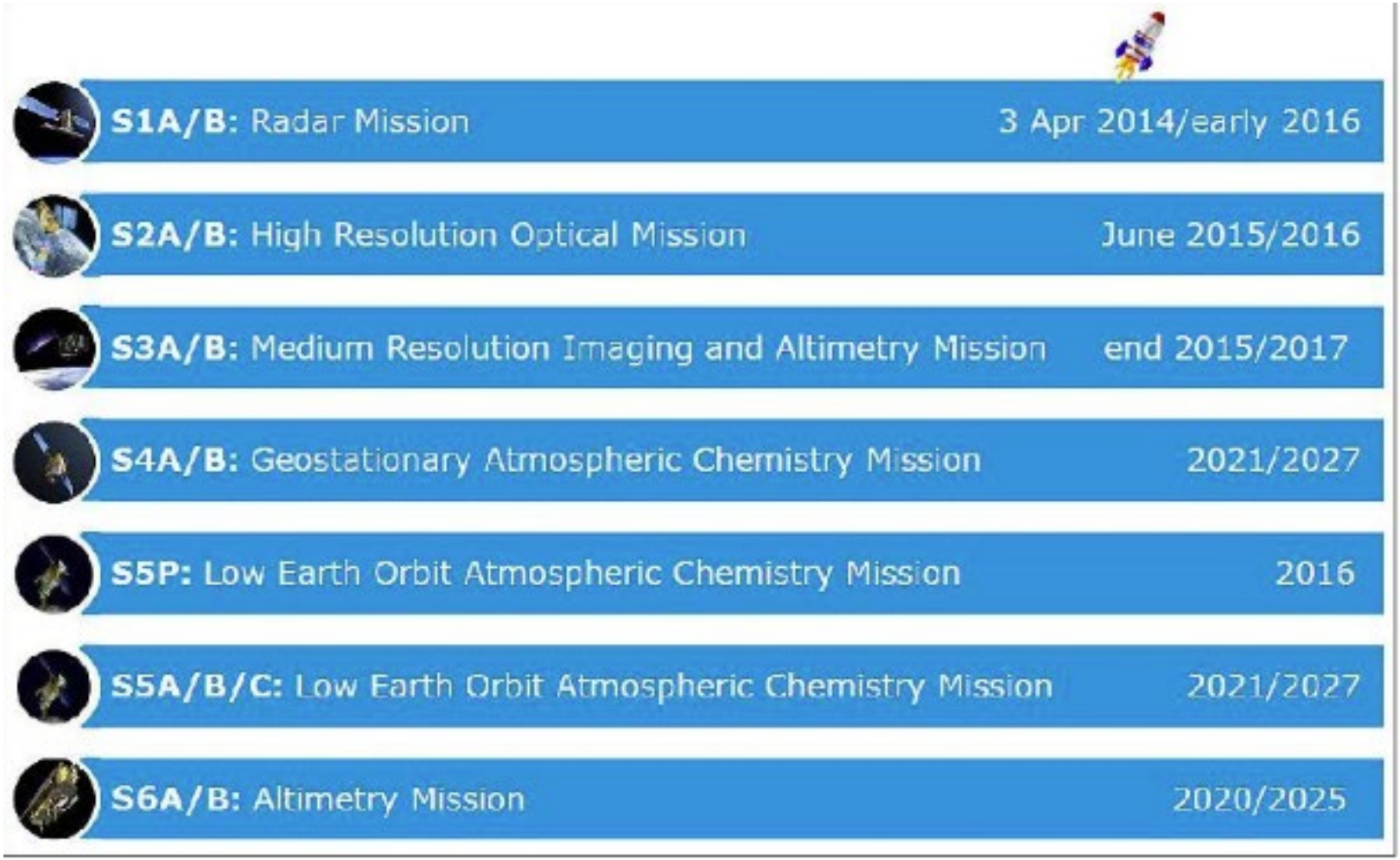
What is Remote Sensing?

The Copernicus program



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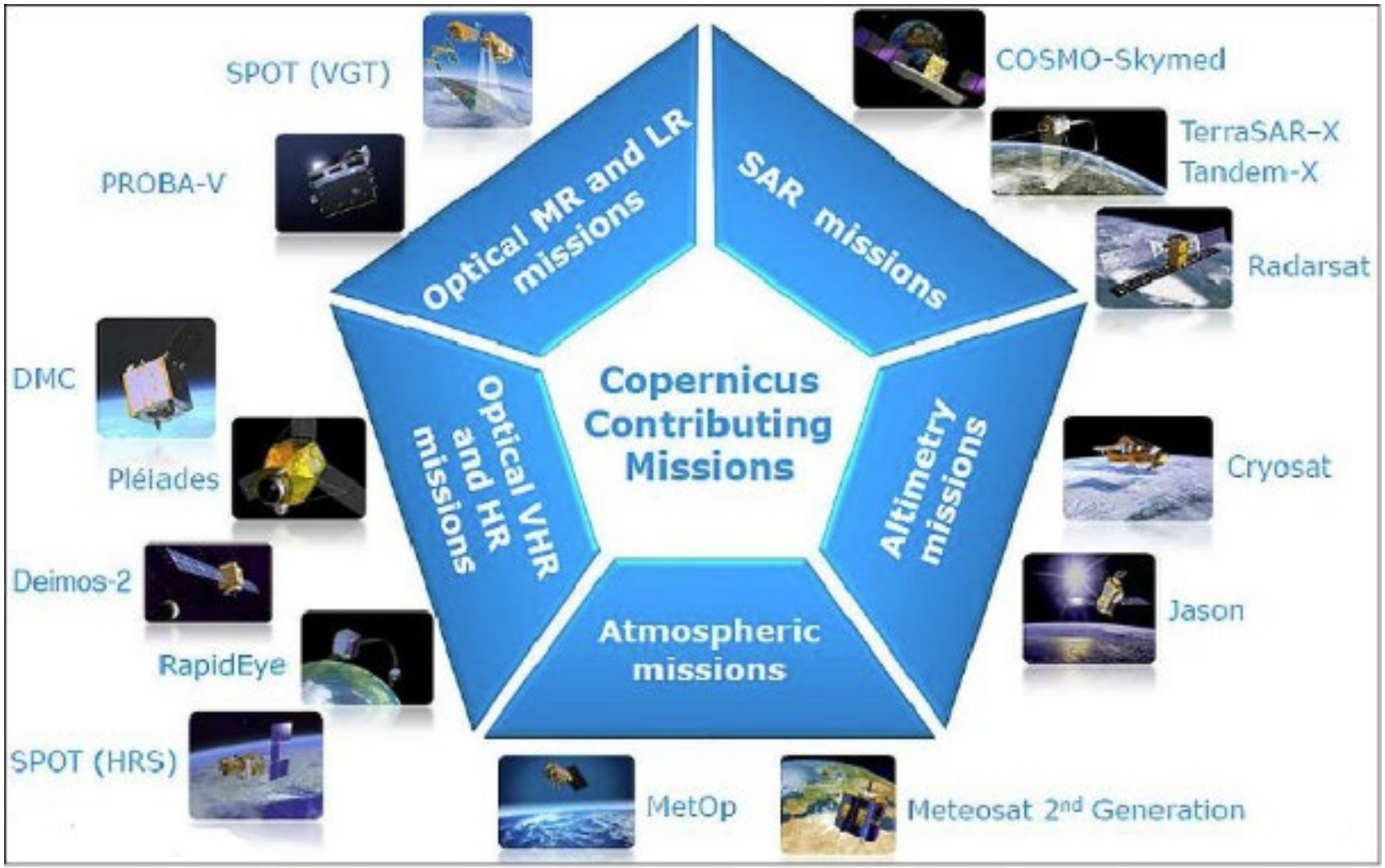
What is Remote Sensing?

The Copernicus program



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What is Remote Sensing?

Sentinel 2

10 metre spatial resolution:

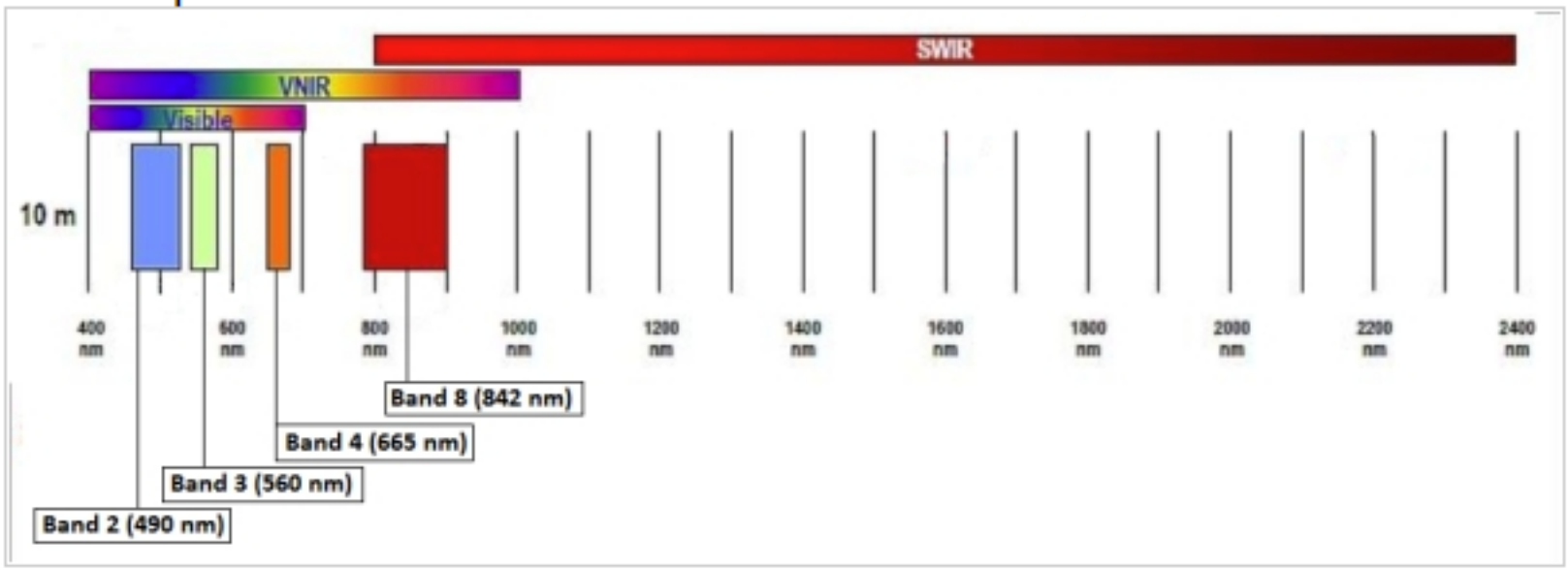

Figure 1: SENTINEL-2 10 m spatial resolution bands: B2 (490 nm), B3 (560 nm), B4 (665 nm) and B8 (842 nm)

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What is Remote Sensing?

Sentinel 2

20 metre spatial resolution:

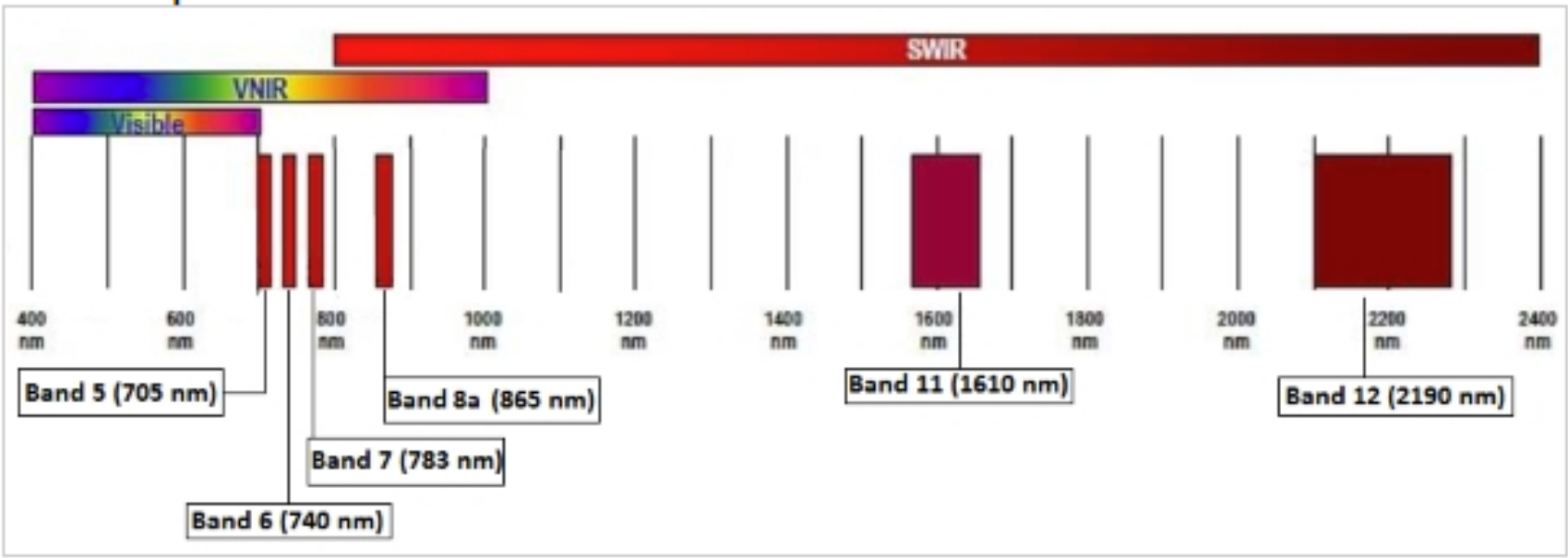

Figure 2: SENTINEL-2 20 m spatial resolution bands: B5 (705 nm), B6 (740 nm), B7 (783 nm), B8a (865 nm), B11 (1610 nm) and B12 (2190 nm)

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What is Remote Sensing?

Sentinel 2

60 metre spatial resolution:

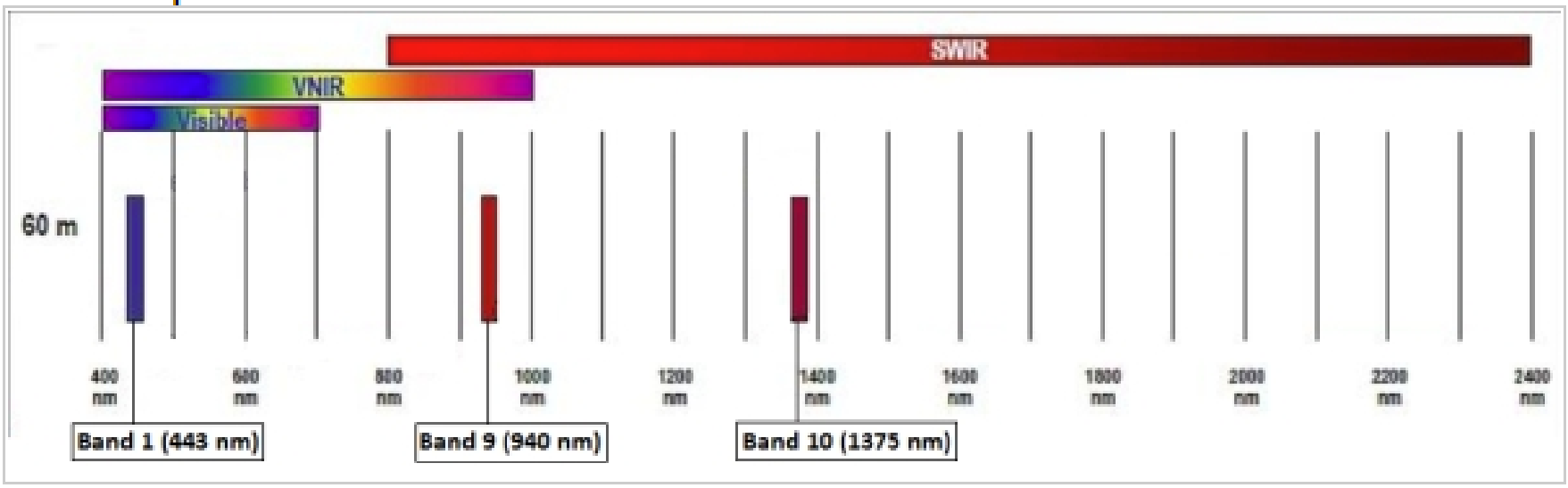

Figure 3: SENTINEL-2 60 m spatial resolution bands: B1 (443 nm), B9 (940 nm) and B10 (1375 nm)

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Raster Concepts

Sentinel 2 Band Math and Combinations

Name	Math	Usability
Color Infrared	B8, B4, B3	The color infrared band combination is meant to emphasize healthy and unhealthy vegetation. By using the near-infrared (B8) band, it's especially good at reflecting chlorophyll. This is why in a color infrared image, denser vegetation is red. But urban areas are white.

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Raster Concepts

Sentinel 2 Band Math and Combinations

Name	Math	Usability
Short wave infrared	B12, B8, B4	The short-wave infrared band combination uses SWIR (B12), NIR (B8A) and red (B4). This composite shows vegetation in various shades of green. In general, darker shades of green indicate denser vegetation. But brown is indicative of bare soil and built-up areas.

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Raster Concepts

Sentinel 2 Band Math and Combinations

Name	Math	Usability
Agriculture	B11, B8, B2	The agriculture band combination uses SWIR-1 (B11), near-infrared (B8) and blue (B2). It's mostly used to monitor the health of crops because how it uses short-wave and near infrared. Both these bands are particularly good at highlighting dense vegetation which appear as dark green.

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Raster Concepts

Sentinel 2 Band Math and Combinations

Name	Math	Usability
Geology	B12, B11, B2	The geology band combination is a neat application for finding geological features. This includes faults, lithology and geological formations. By leveraging the SWIR-2 (B12), SWIR-1 (B11) and blue (B2) bands, geologists tend to use this Sentinel band combination for their analysis.

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Raster Concepts

Sentinel 2 Band Math and Combinations

Name	Math	Usability
Bathymetric	B4, B3, B1	As the name implies, the bathymetric band combination is good for coastal studies. The bathymetric band combination uses the red (B4), green (B3) and coastal band (B1). By using the coastal aerosol band, it's good for estimating suspended sediment in water.

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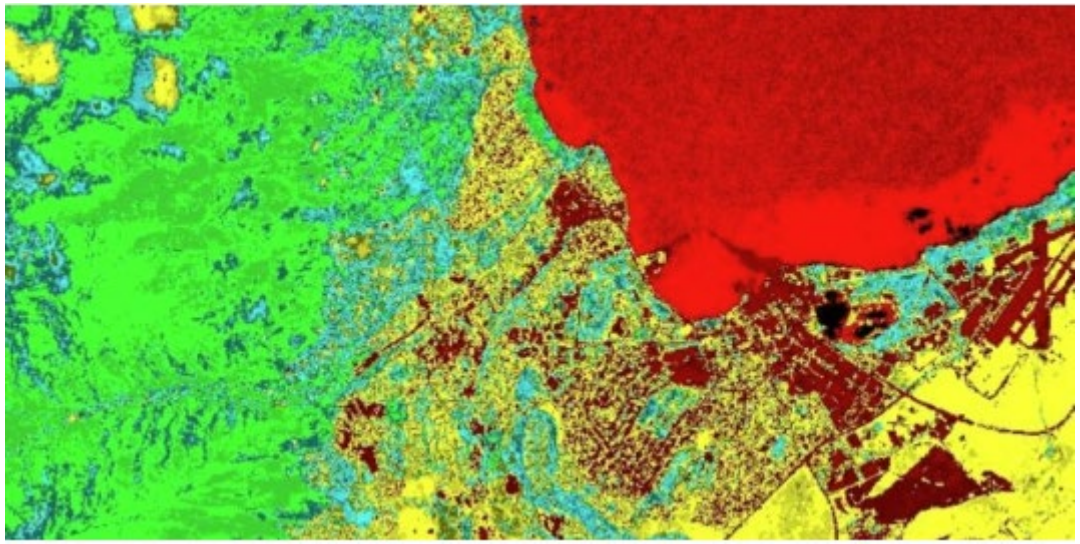
Raster Concepts

Sentinel 2 Band Math and Combinations



Name	Math	Usability
Vegetation Index	(B8-B4)/(B8+B4)	Because near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs), the vegetation index is good for quantifying the amount of vegetation. The formula for normalized difference vegetation index is (B8-B4)/(B8+B4). While high values suggest dense canopy, low or negative values indicate urban and water features.

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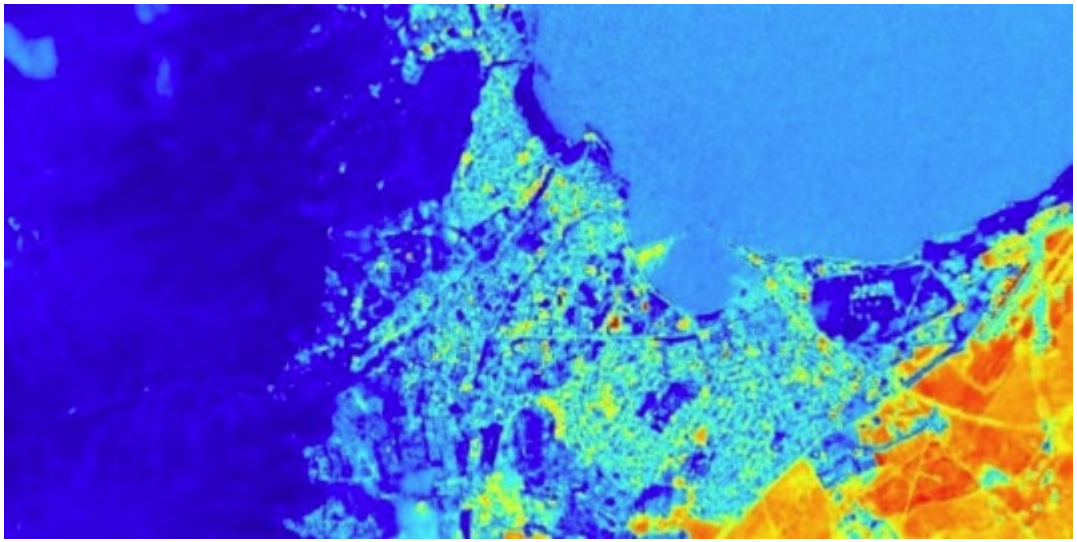
Raster Concepts

Sentinel 2 Band Math and Combinations



Name	Math	Usability
Moisture Index	(B8A-B11)/(B8A+B11)	The moisture index is ideal for finding water stress in plants. It uses the short-wave and near infrared to generate an index of moisture content. In general, wetter vegetation have higher values. But lower moisture index values suggests plants are under stress from insufficient moisture.

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Natural Resource Management

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Natural Resource Management

Leveraging geospatial datasets

- Thanks to the constant availability of satellite imagery we can monitor natural resources at a rate that we couldn't before

- However, as we shall see in the next examples, satellite datasets are not enough to perform automated and reliable management of natural resources such as:

  - Sustainable harvest rate estimation
  - Invasive species monitoring
  - Ecosystem processes prediction

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Example: seaweed monitoring

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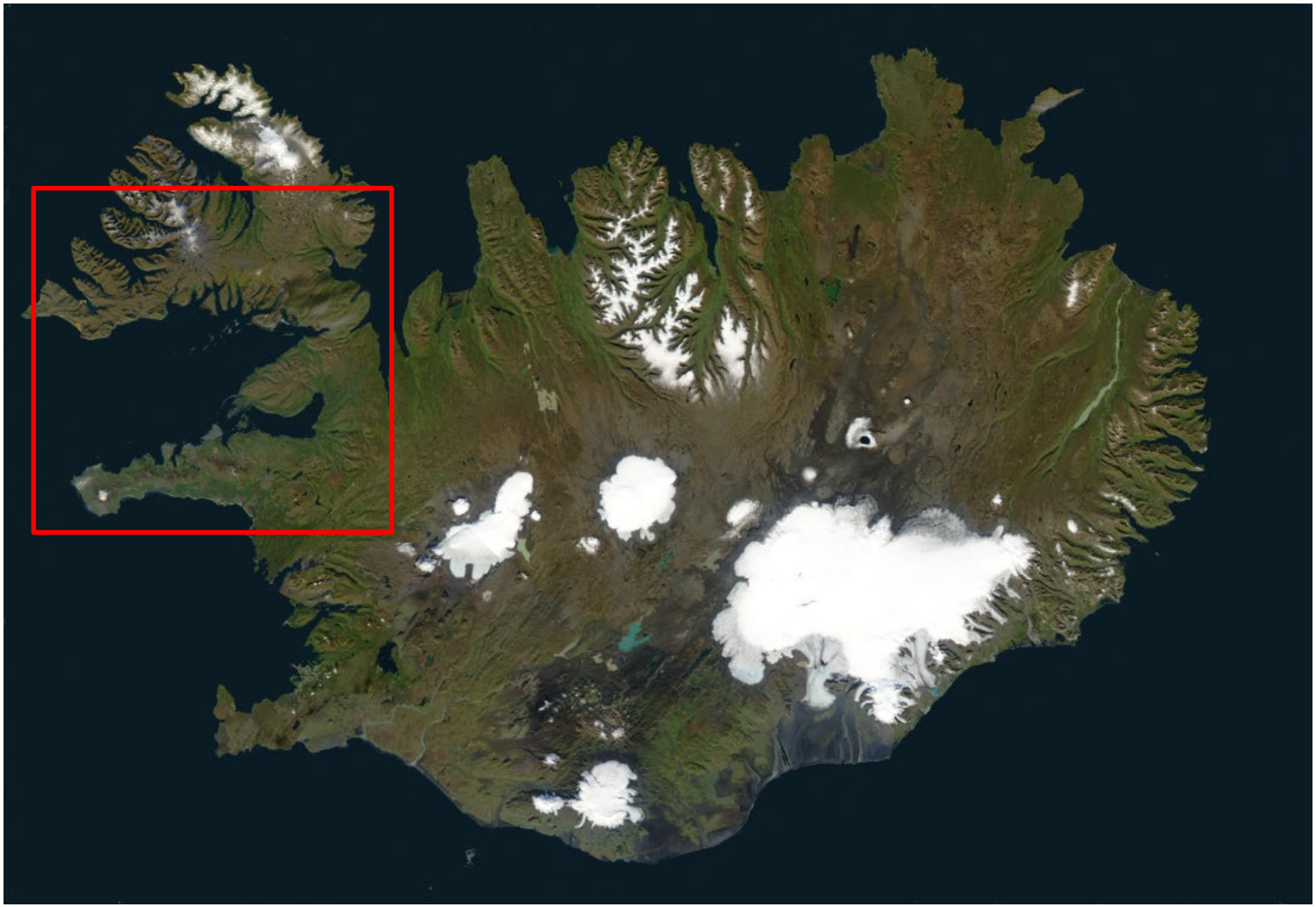
Seaweed Monitoring

Introduction



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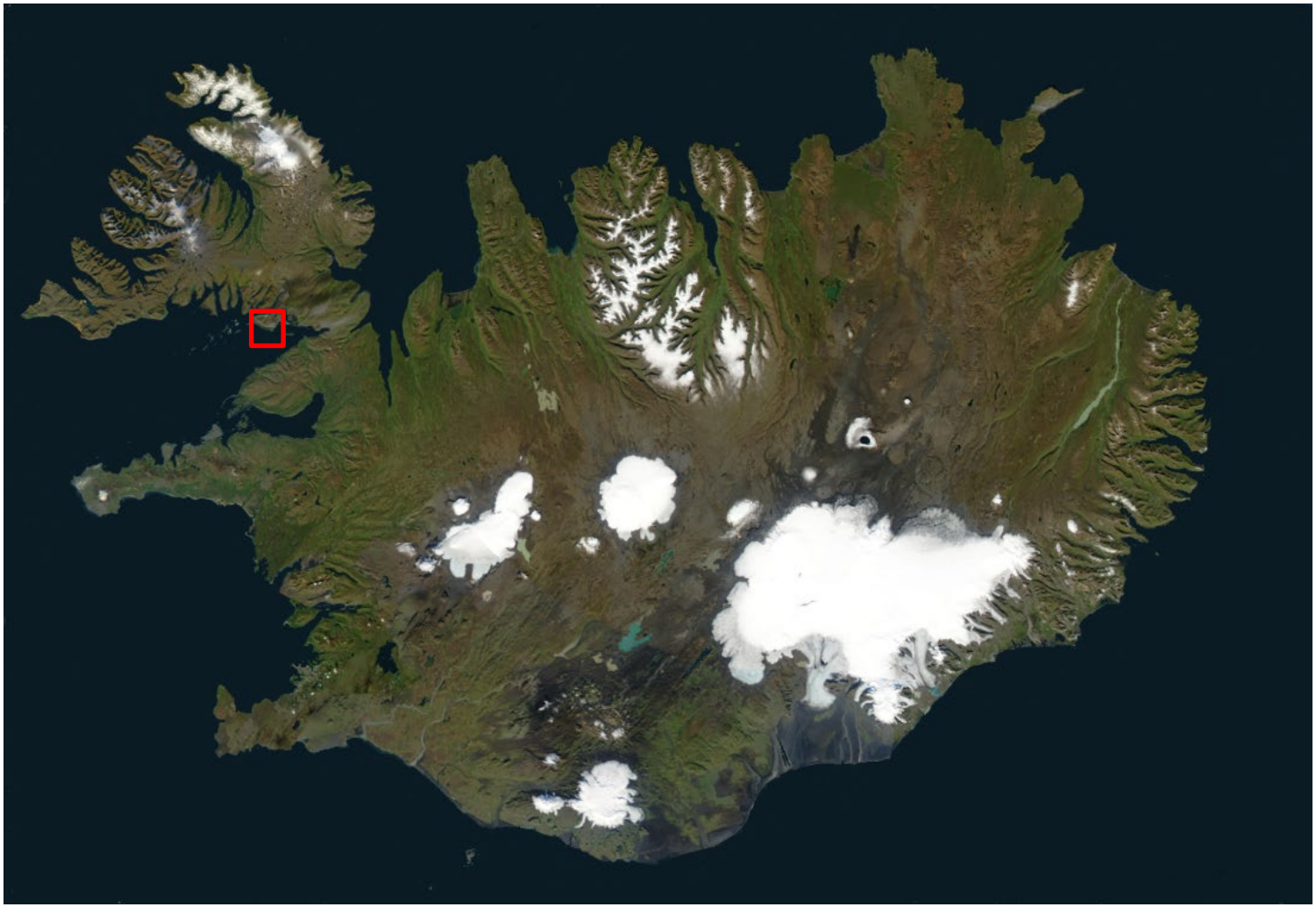
Seaweed Monitoring

Introduction



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Seaweed Monitoring

Introduction

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Seaweed Monitoring

Introduction

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Seaweed monitoring

Introduction: why?

- *Aschophyllum nodosum* is abundant on the Icelandic coasts, but is being harvested for animal feed amongst other uses

- Knowing the sustainable harvest rate is crucial to maintain the balance of the ecosystem

- In order to estimate those rates, researchers need to know the biomass present at the Icelandic shores

  - Traditionally, this account was done by manually digitizing high resolution airplane images and field estimates
  - It will take around 6 months to 1 year for a team of two to estimate the whole content

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Seaweed monitoring

Introduction: opportunity

- The idea of using a combination of remote sensing and AI was precisely to automate and ease the biomass estimation process

- As we shall see, thanks to the collected information and the dataset generated, biomass estimates can be performed now under a timeframe of just a couple of days

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Seaweed monitoring

Introduction: challenges

- The generation of the necessary dataset for this endeavor was not easy:
  - Short window of time for data collection only available during low tide
  - Limited optical satellite image due to cloud cover
  - SAR images limited by their pass at high tide peaks
  - Existence of more than one species of seaweed

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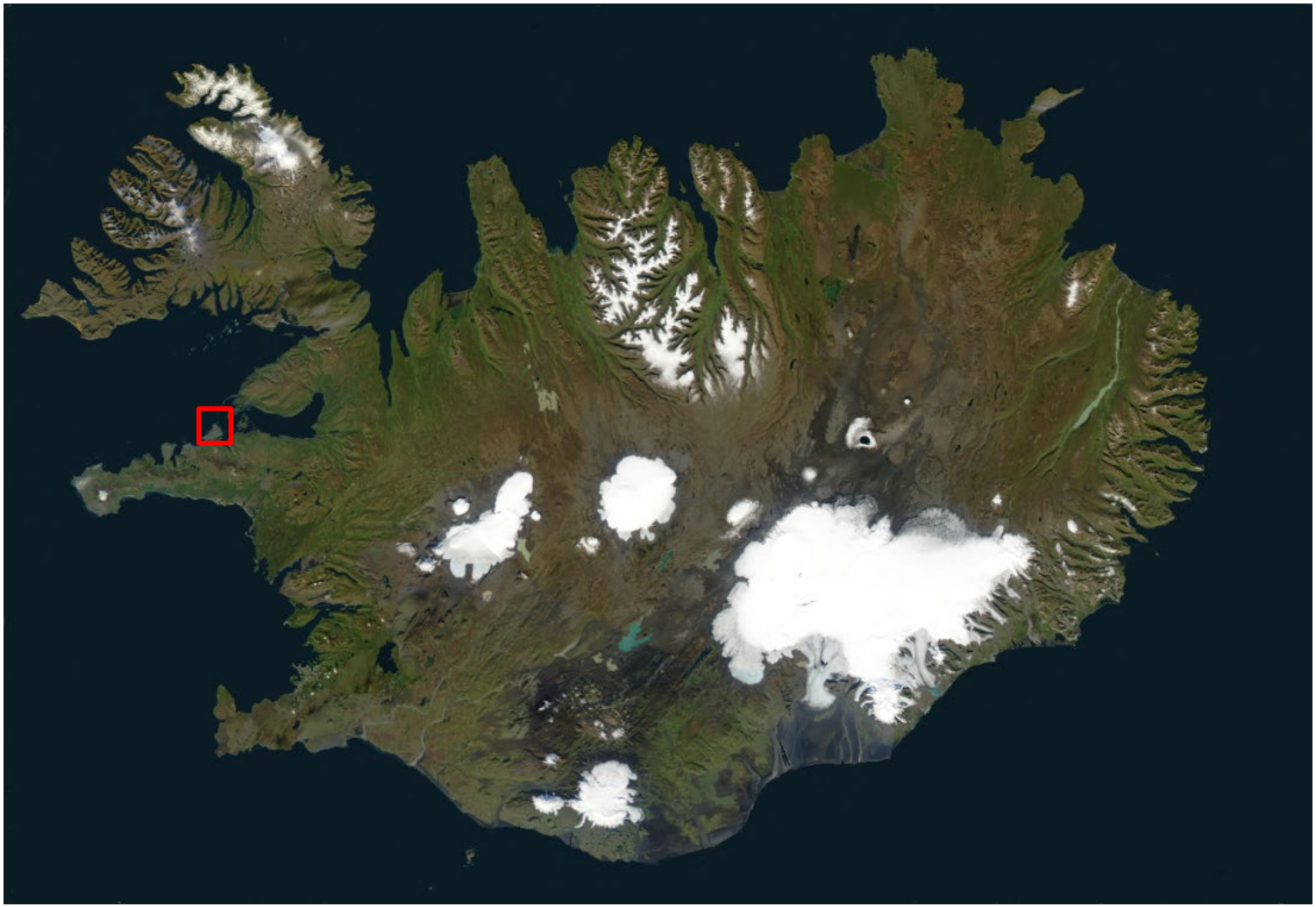
Seaweed Monitoring

Introduction



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Seaweed Monitoring

Introduction

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Seaweed Monitoring

Introduction

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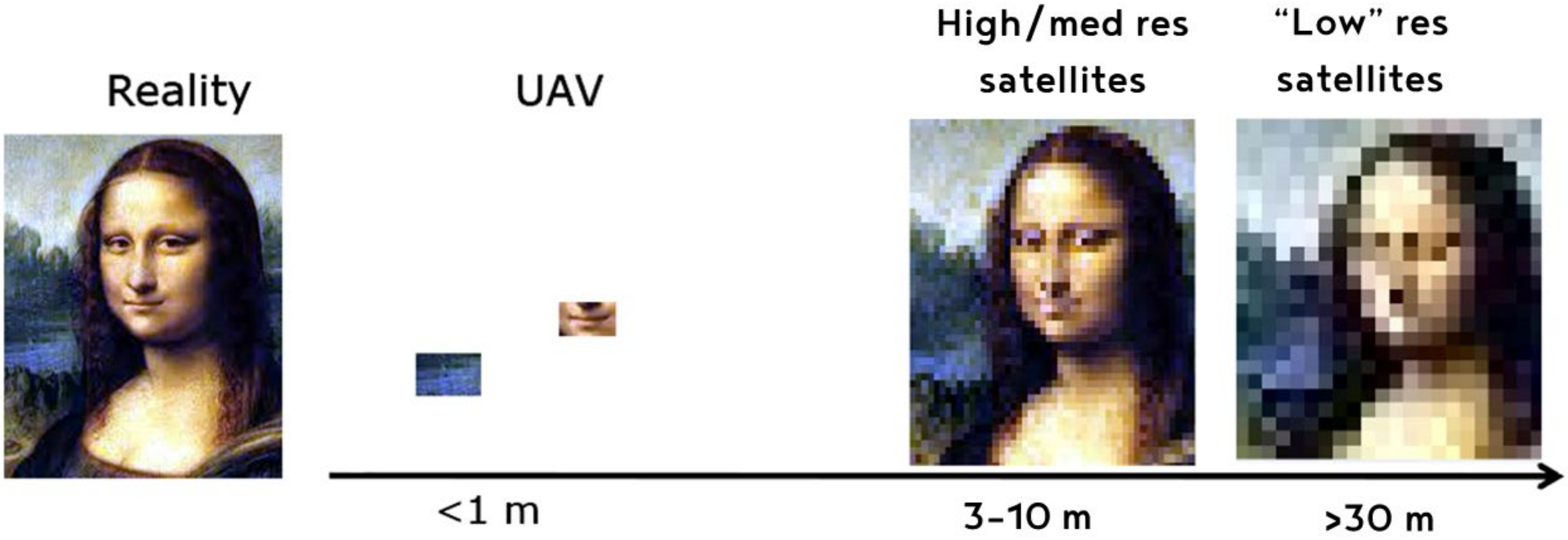
Seaweed Monitoring

Linking different spatial scales



- Ground truth
- UAVs
- Rapideye/Copernicus
- Landsat

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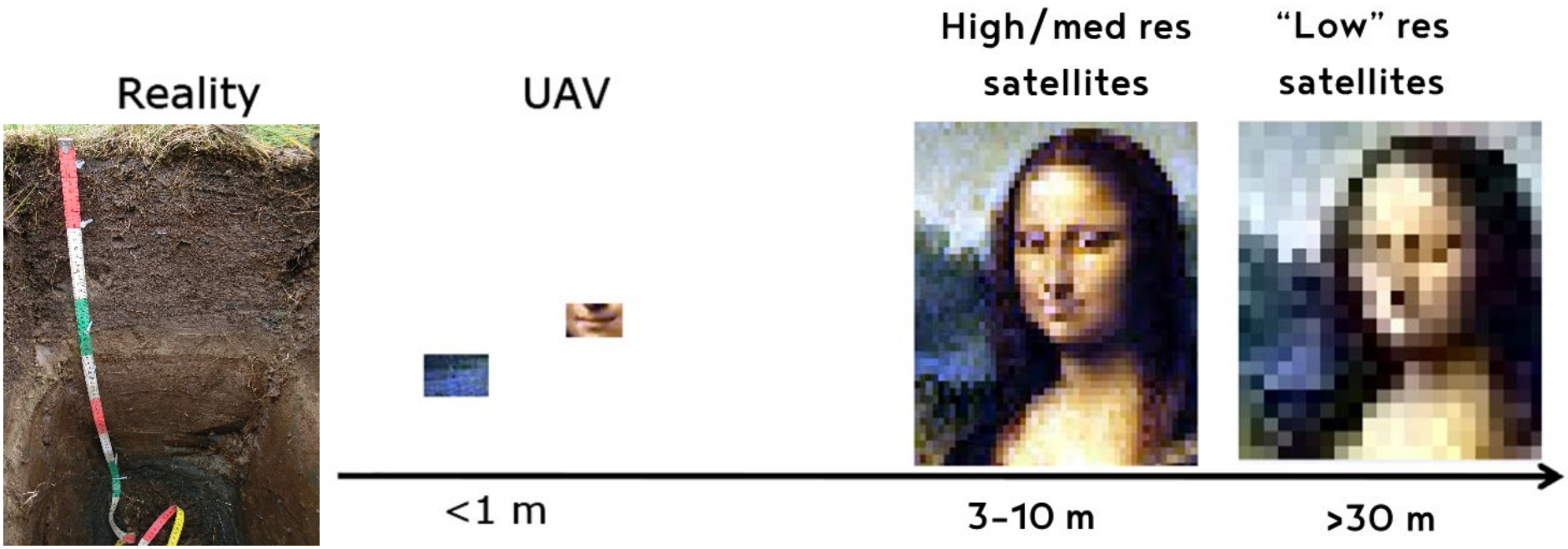
Linking different spatial scales



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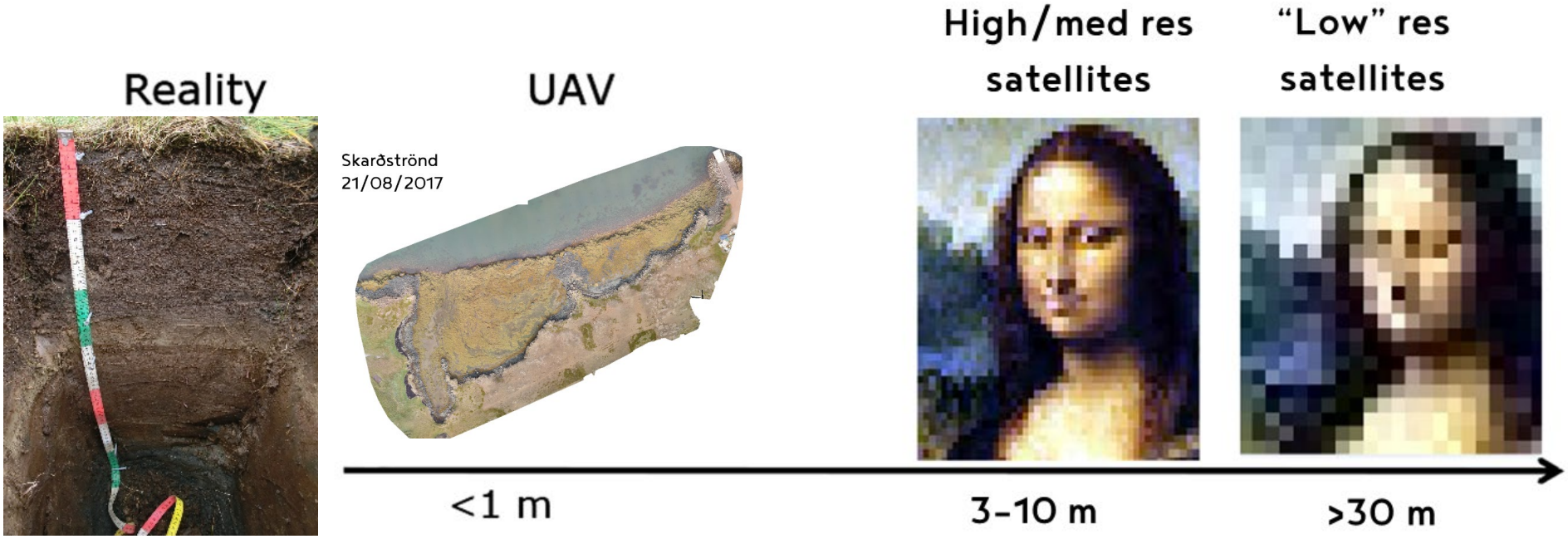

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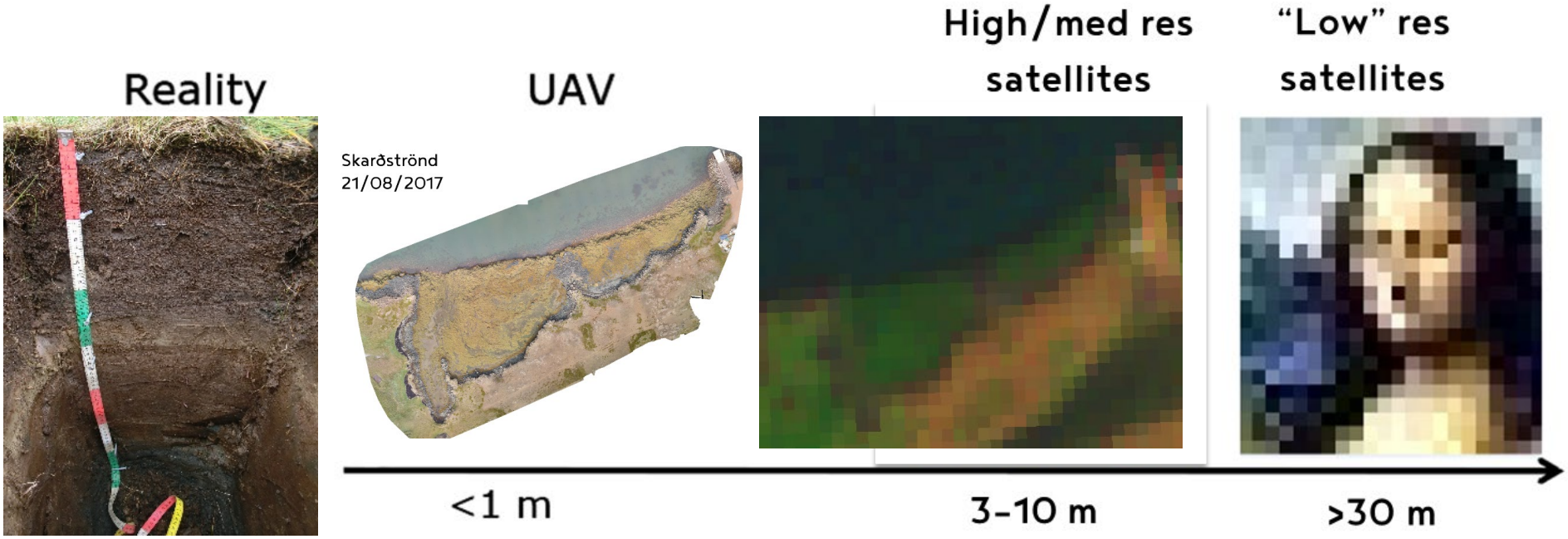

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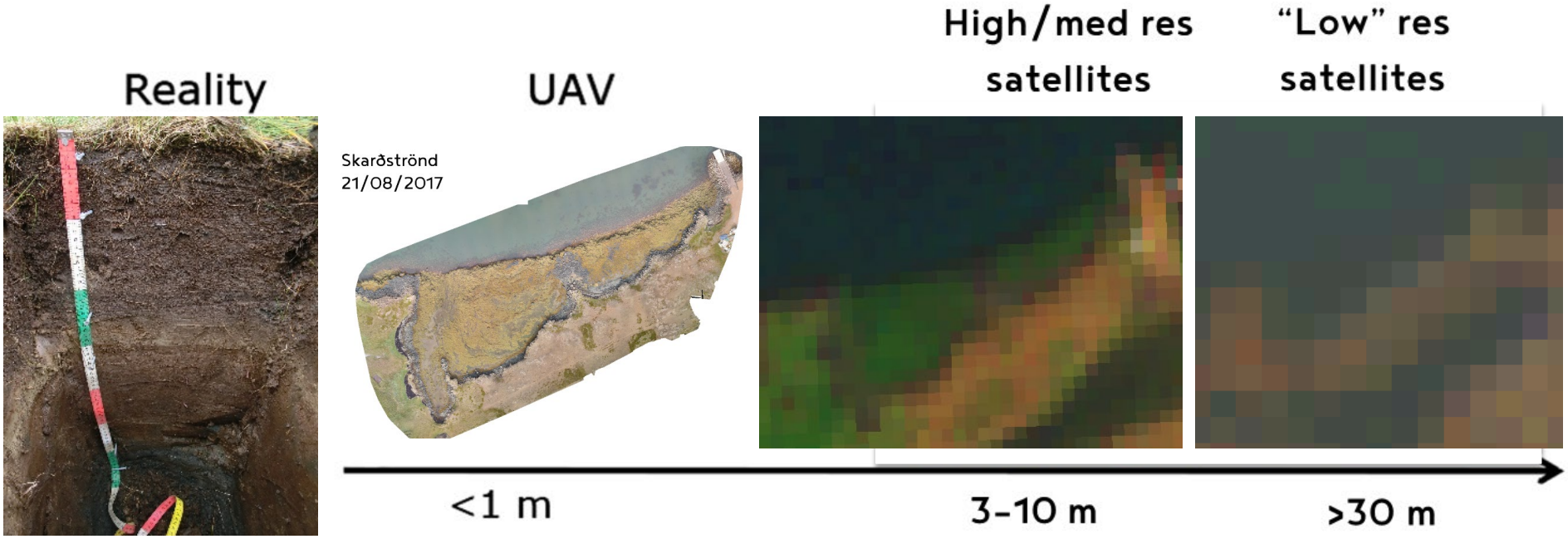
Linking different spatial scales



- Ground truth
- UAVs
- Rapideye/Copernicus
- Landsat

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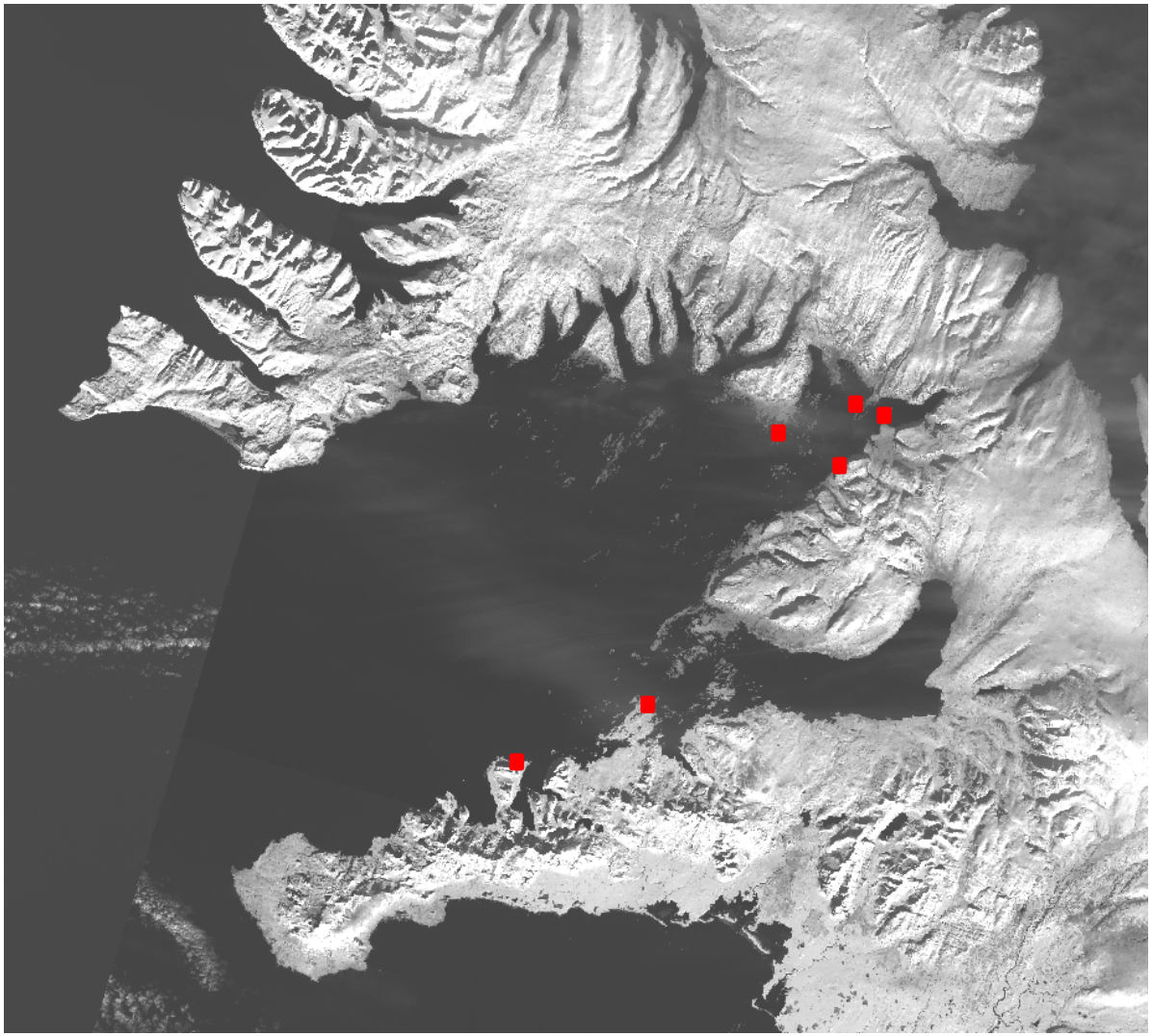
Seaweed Monitoring

Ground truth collection



- Scatter of ground truth points according to seaweed variability
- Biomass measures collected on site
- UAV multispectral images taken around ground truth collection points
- UAV taken during same date of satellite pass
- Huge challenge: sampling only at low tide

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Seaweed Monitoring

Ground truth collection

- Setting of permanent monitoring plots for drone flights
- During cloudy days (optical imaging covered by clouds) reliability on late passes of SAR

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Ground truth collection

- Accurate georeferencing of UAV images through rover-ground station GPS measurements

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Ground truth collection

- Challenging ground control setting
  - Quicksand
  - Mushy ground
  - Tide hours

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Seaweed Monitoring

Ground truth collection

- This reality turned into this image…

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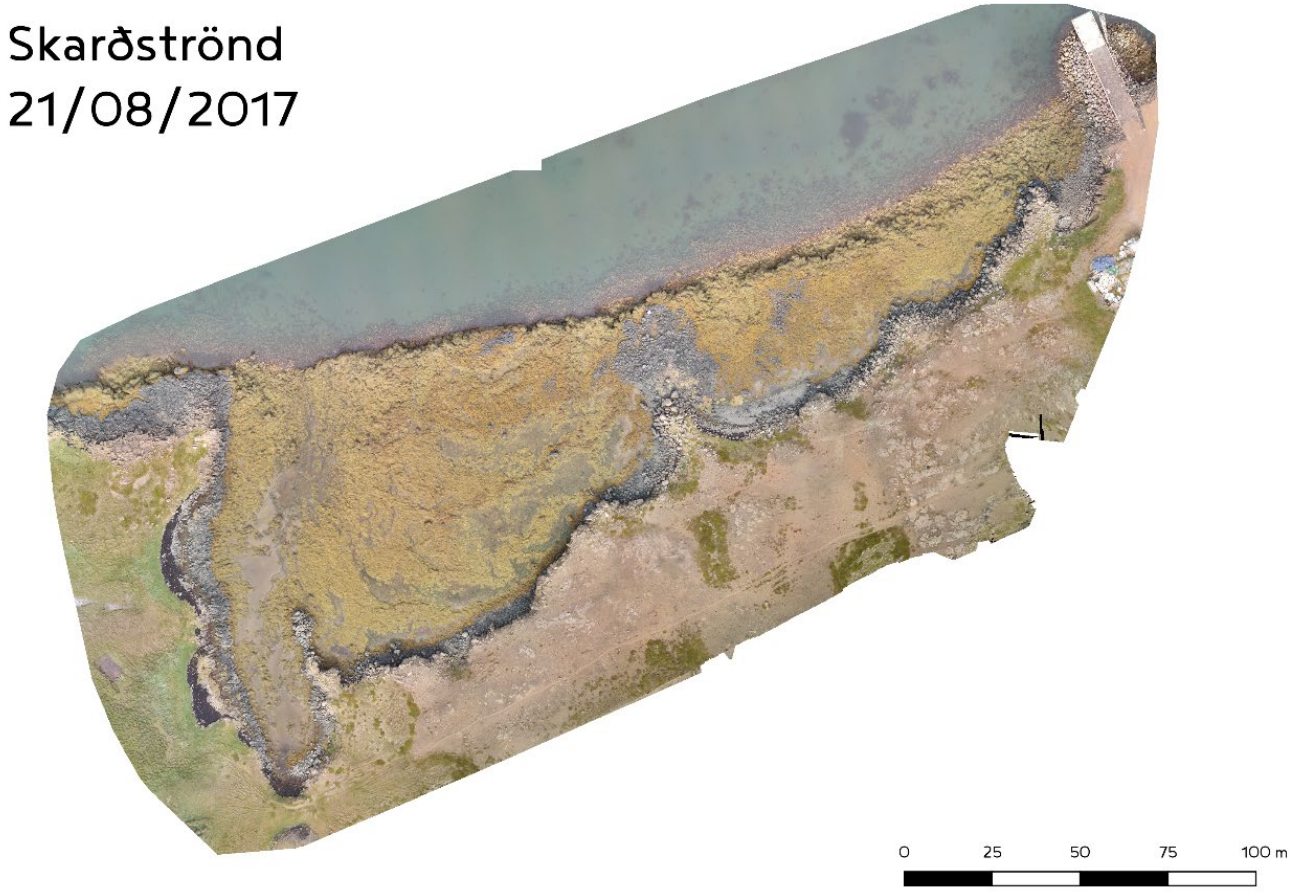
Seaweed Monitoring

Ground truth collection



- RGB image

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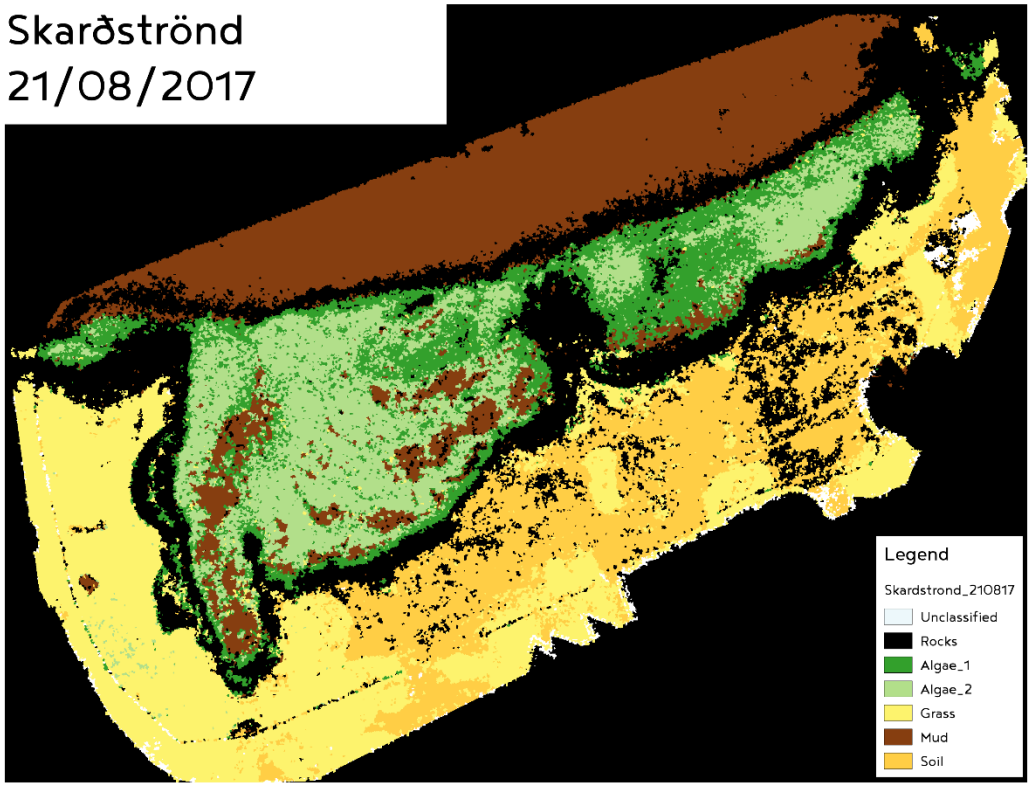
Seaweed Monitoring

Ground truth collection



- Classified image

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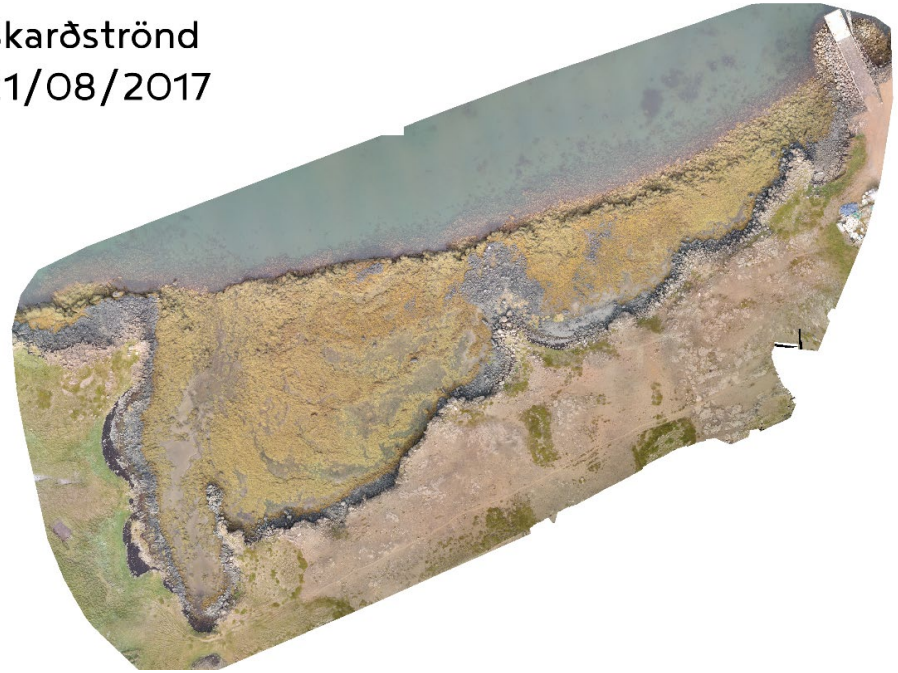
Seaweed Monitoring

Ground truth collection

Skarðströnd
21/08/2017



- The classification of the UAV images help to know the distribution of the two seaweed species found at the subpixel level
- This is handy for collecting the statistical distribution at the different collection sites

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Seaweed Monitoring

Upscaling

- The UAV images were taken as a ground truth to be passed to a neural network (UNET)
- Semantic segmentation was performed both over available datasets of the Landsat and Copernicus mission
- Test results were compared over manually digitized images

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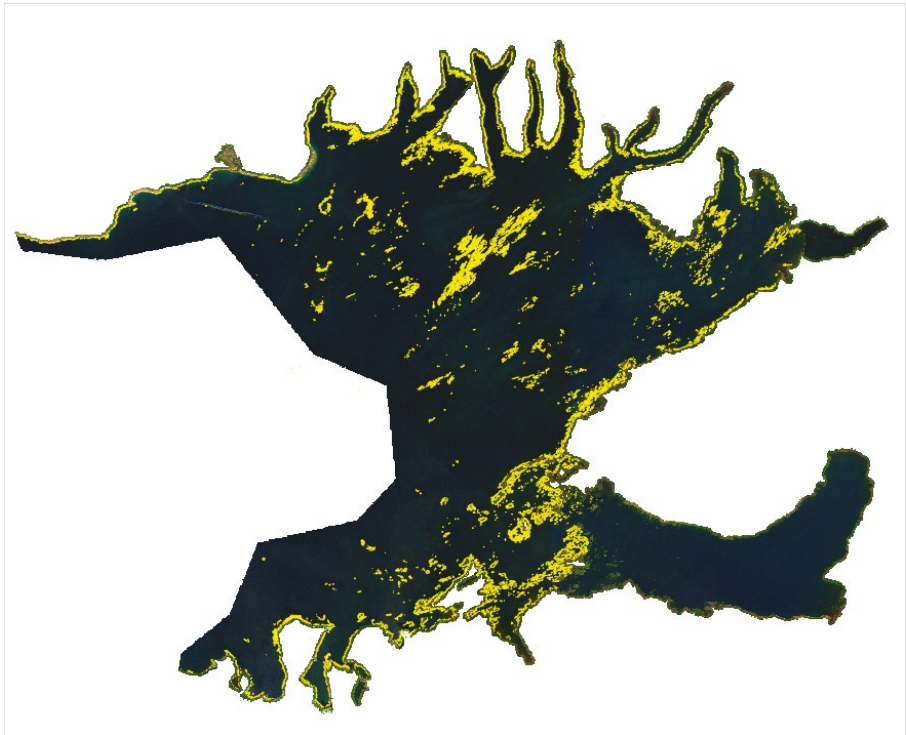
Seaweed Monitoring

Landsat



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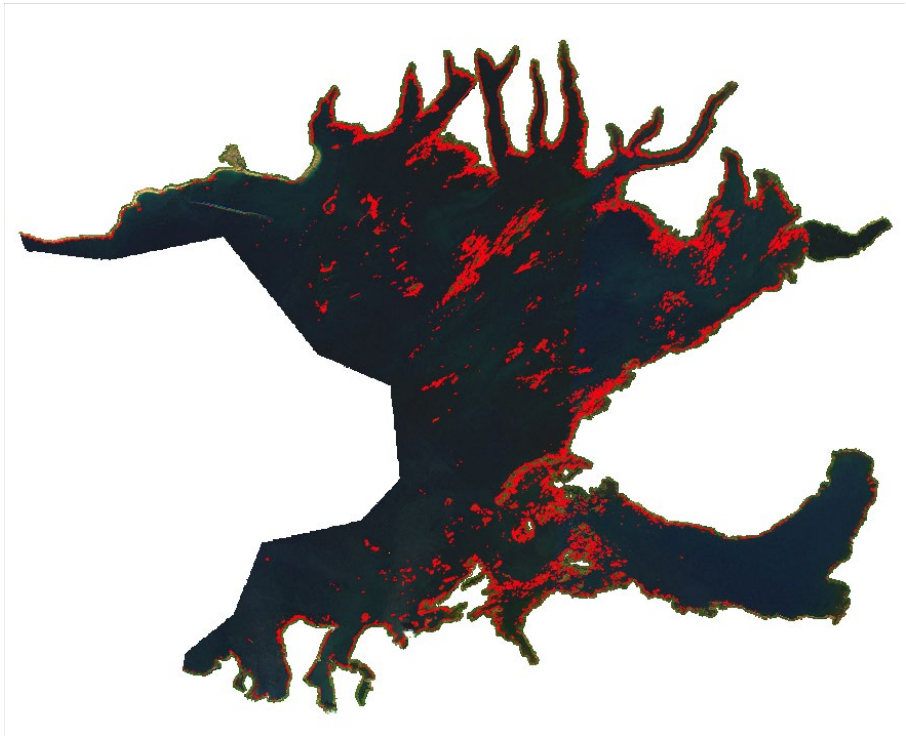
Seaweed Monitoring

Sentinel



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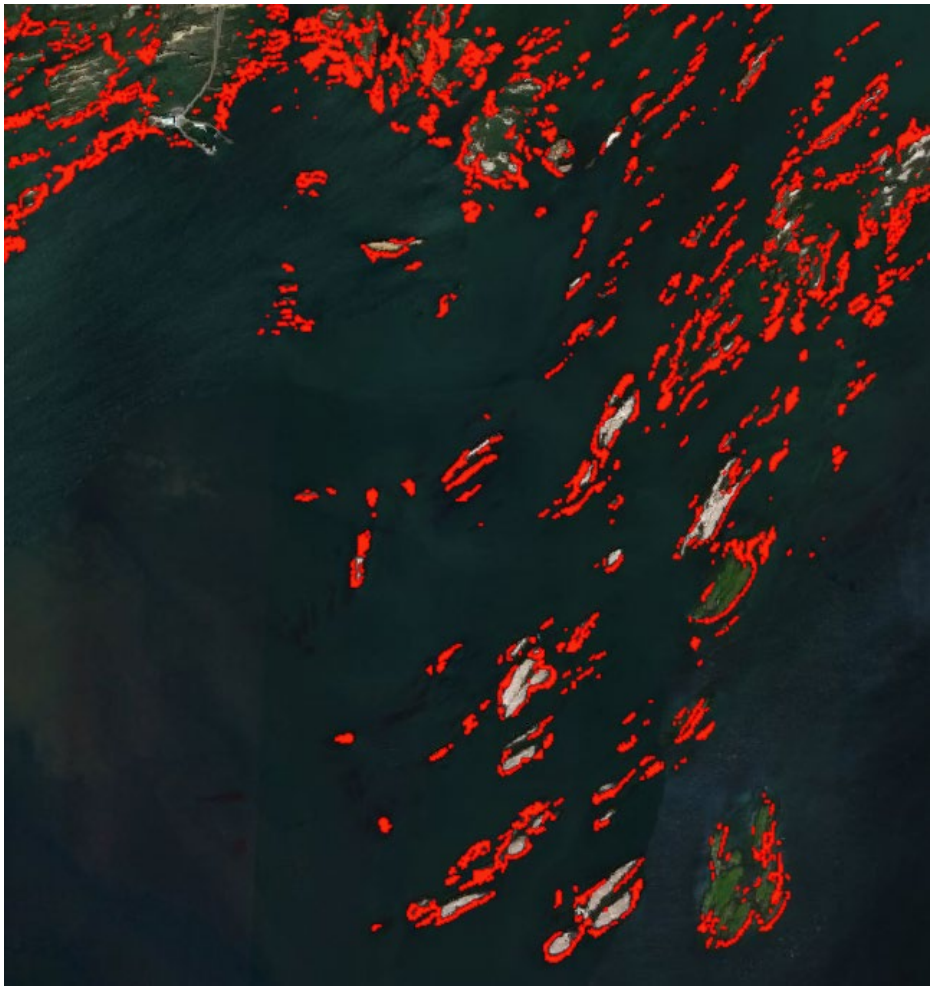
Seaweed Monitoring

Final results



- The total extension of seaweed was calculated at 130km2
- A further regression network was used to predict the **distribution and biomass** of both species for more accurate assessments
- Final accuracy was set at 89% compared to manual digitized images
- The total inference time for the whole country, counting conversion to polygon was set at 2 days max processing

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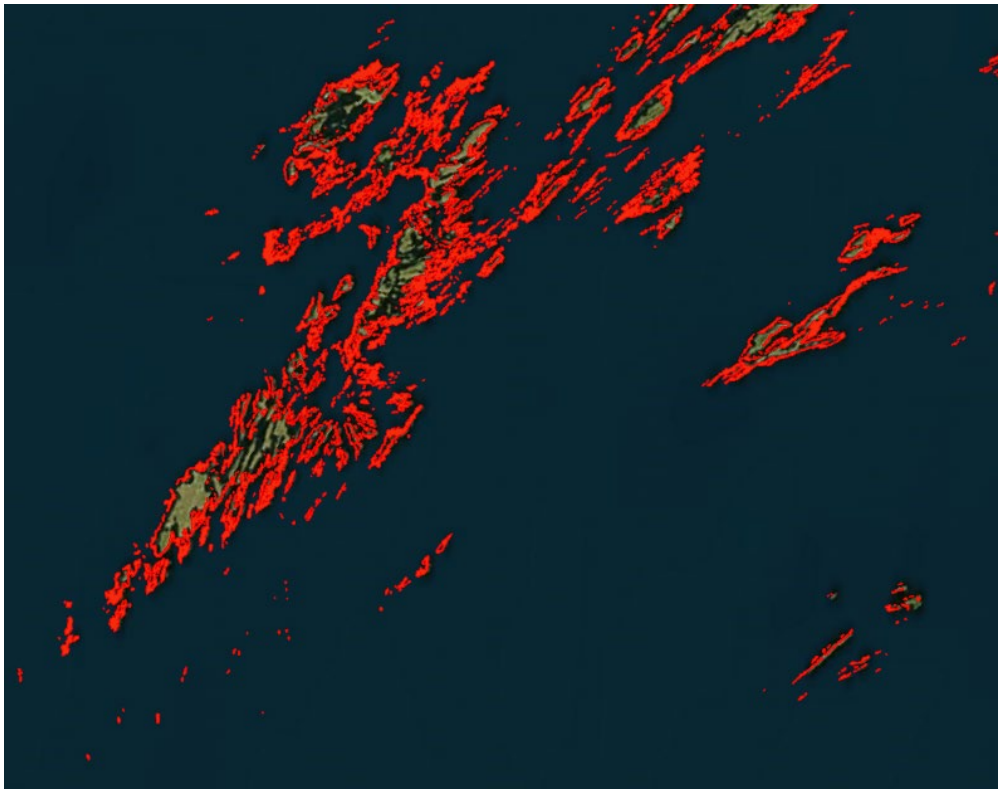
Seaweed Monitoring

Final results



- The marine research institute now has a tool to predict and assess biomass estimates over the whole country under a couple of days
- Previous ground truth campaigns are maintained to check the accuracy of the system and improve the model when necessary

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Example: invasive species monitoring

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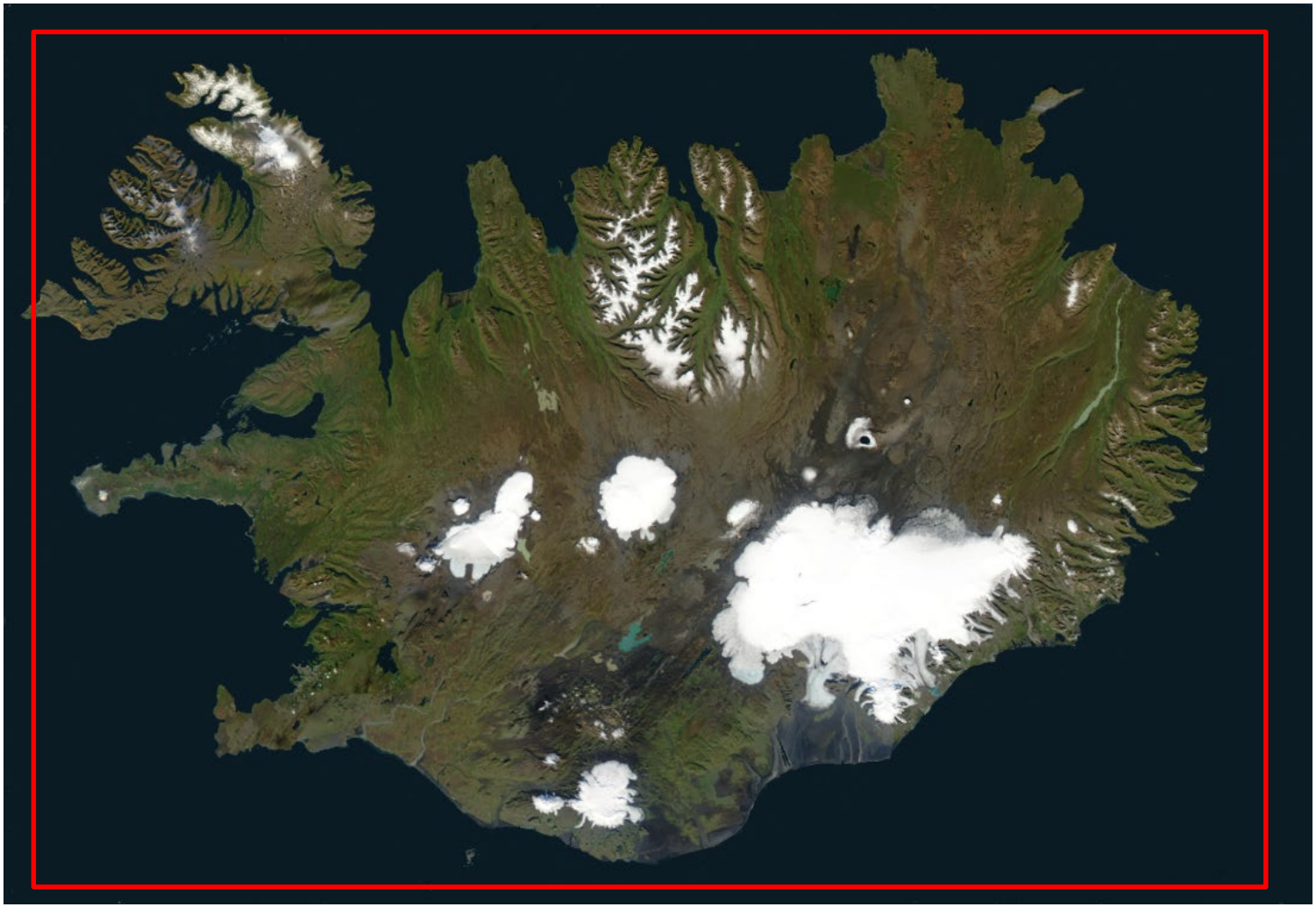
Invasive species monitoring

Introduction



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Invasive species monitoring

Introduction

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Invasive species monitoring

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Invasive species monitoring

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Invasive species monitoring

Introduction

Egill Bjarntsson

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Invasive species monitoring

Introduction: why?

- *Alaskan nootka lupin* was introduced in Iceland to combat desertification and soil loss

- After years of introduction the species is taking over the Icelandic landscape and displacing native vegetation due to their competitive advantage at fixing nitrogen

- The eradication is costly when the seedlings are spread and is easy to eradicate if taken early

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Invasive species monitoring

Introduction: opportunity

- The mapping of Lupine was usually done in a similar manner to the seaweed, through manual digitalization

- The task here was to create a model that could be used to assess current extent and detect new spreading locations

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Invasive species monitoring

Introduction: challenges

- The generation of the necessary dataset for this endeavor was not easy:
  - Lack of labelled datasets
  - Cloud coverage on new imagery
  - Fusion of optical and SAR imagery (in order to bypass the cloud issue)

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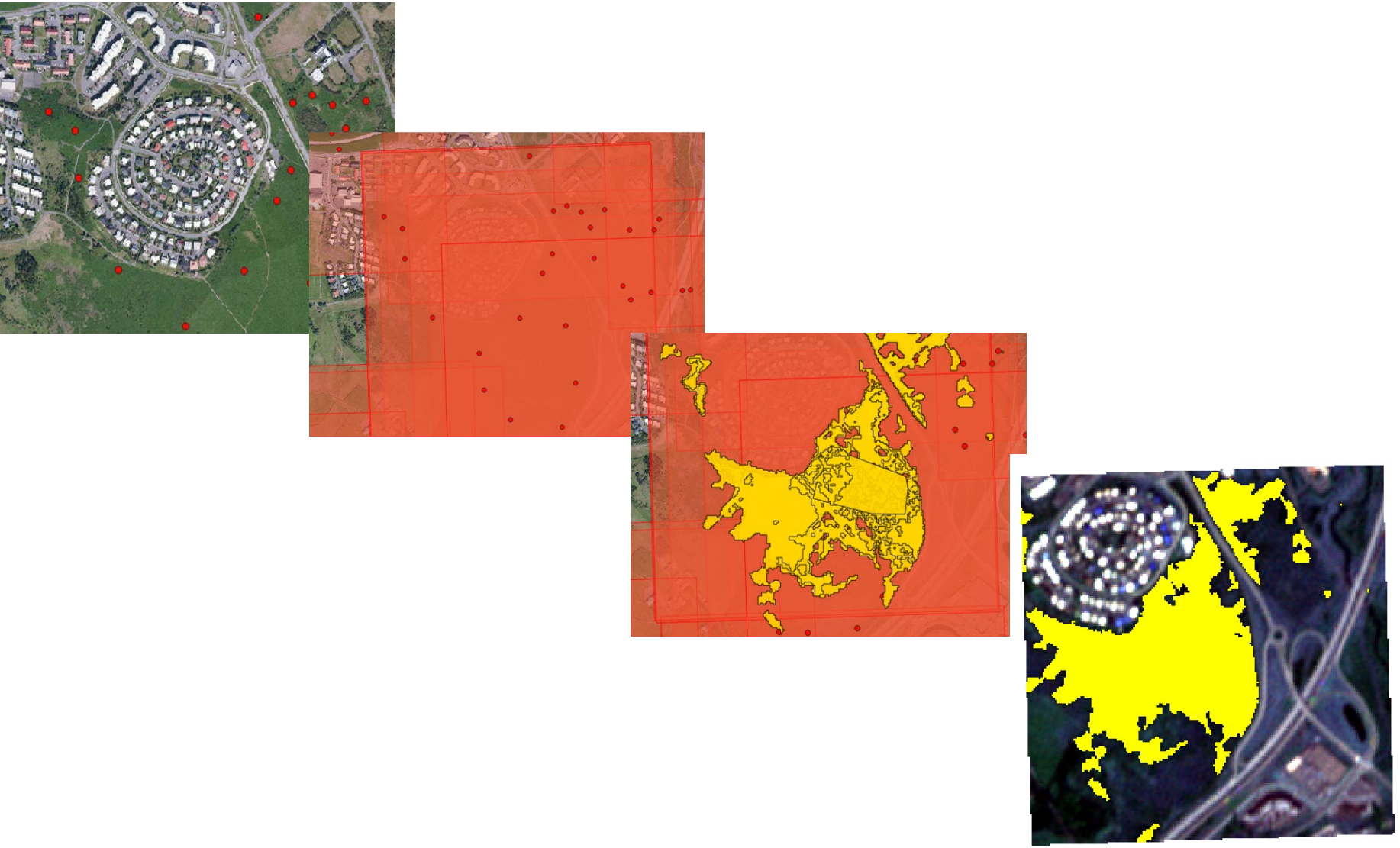
Invasive species monitoring

The generated dataset



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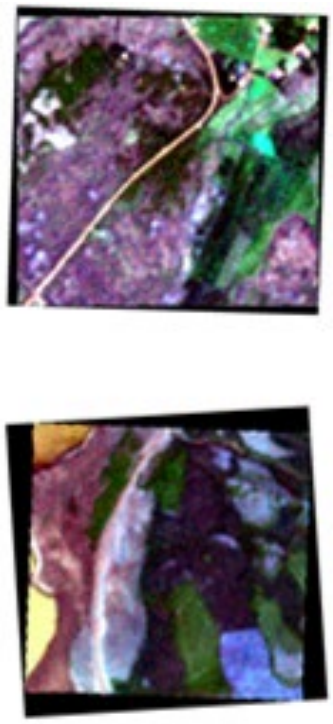
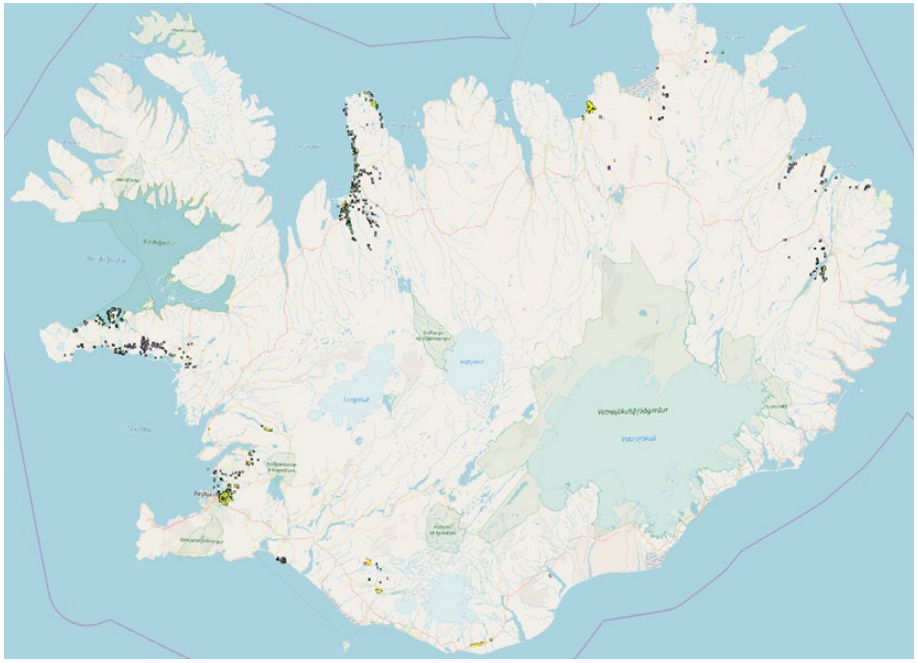
Invasive species monitoring

The generated dataset





- The final dataset was set at 746 tiles for training and 185 tiles for testing

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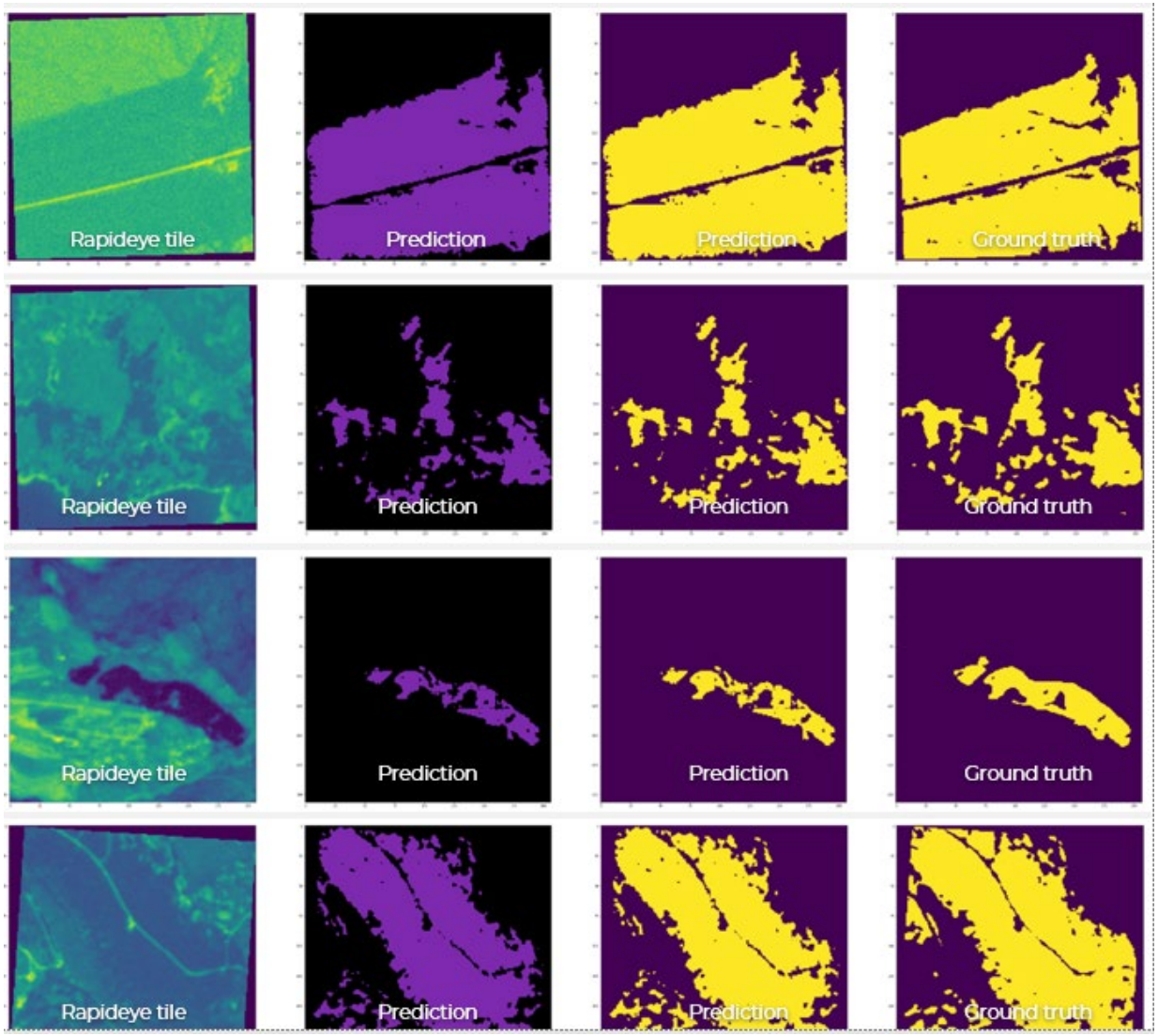
Invasive species monitoring

Usage of semantic segmentation networks



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Invasive species monitoring

Results

- With a GPU NVIDIA TESLA V100:
  - Total training time 12 hours
  - Total inference time (125 Rapideye images): 18 hours

- A total of 130km2 of Lupine detected over those images
- Model output saved as training labels for Sentinel1 and Sentinel2 imagery

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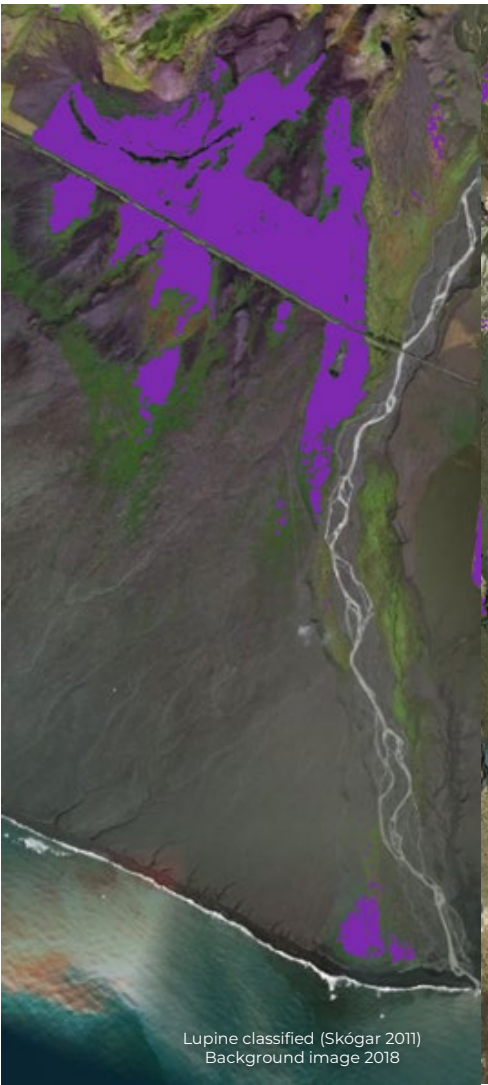
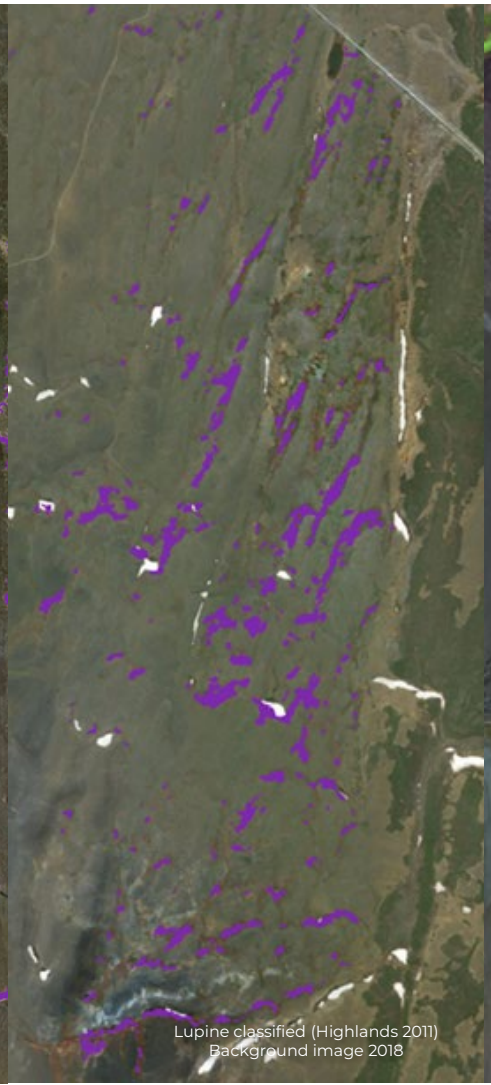
Invasive species monitoring

Results


Lupine classified (Skógar 2011)
Background image 2018


Lupine classified (Gunnarsholt 2011)
Background image 2018


Lupine classified (Highlands 2011)
Background image 2018


Lupine classified (Mýrdalssandur 2011)
Background image 2018

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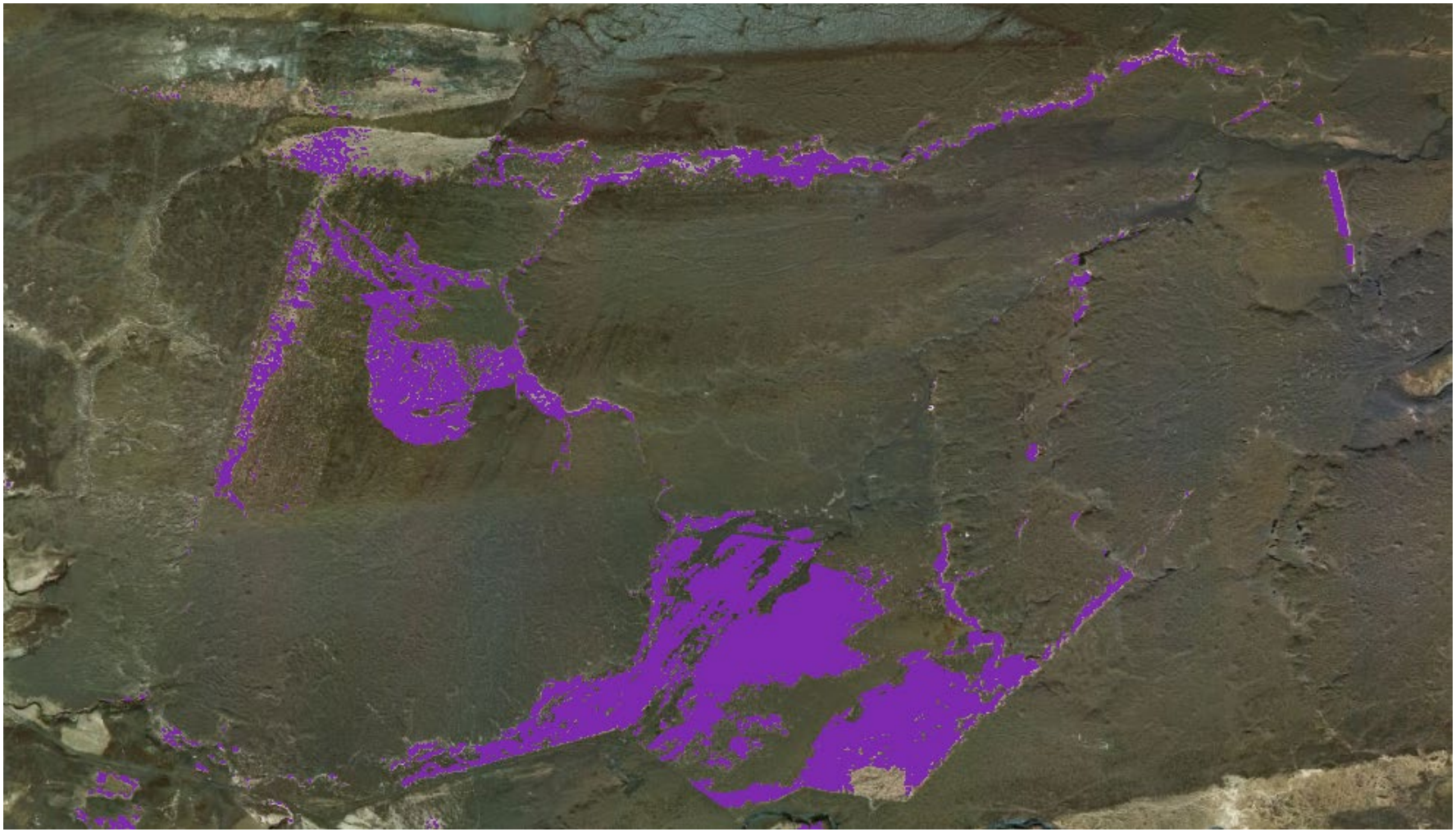
Invasive species monitoring

Results: Gunnarsholt (background image 2018)



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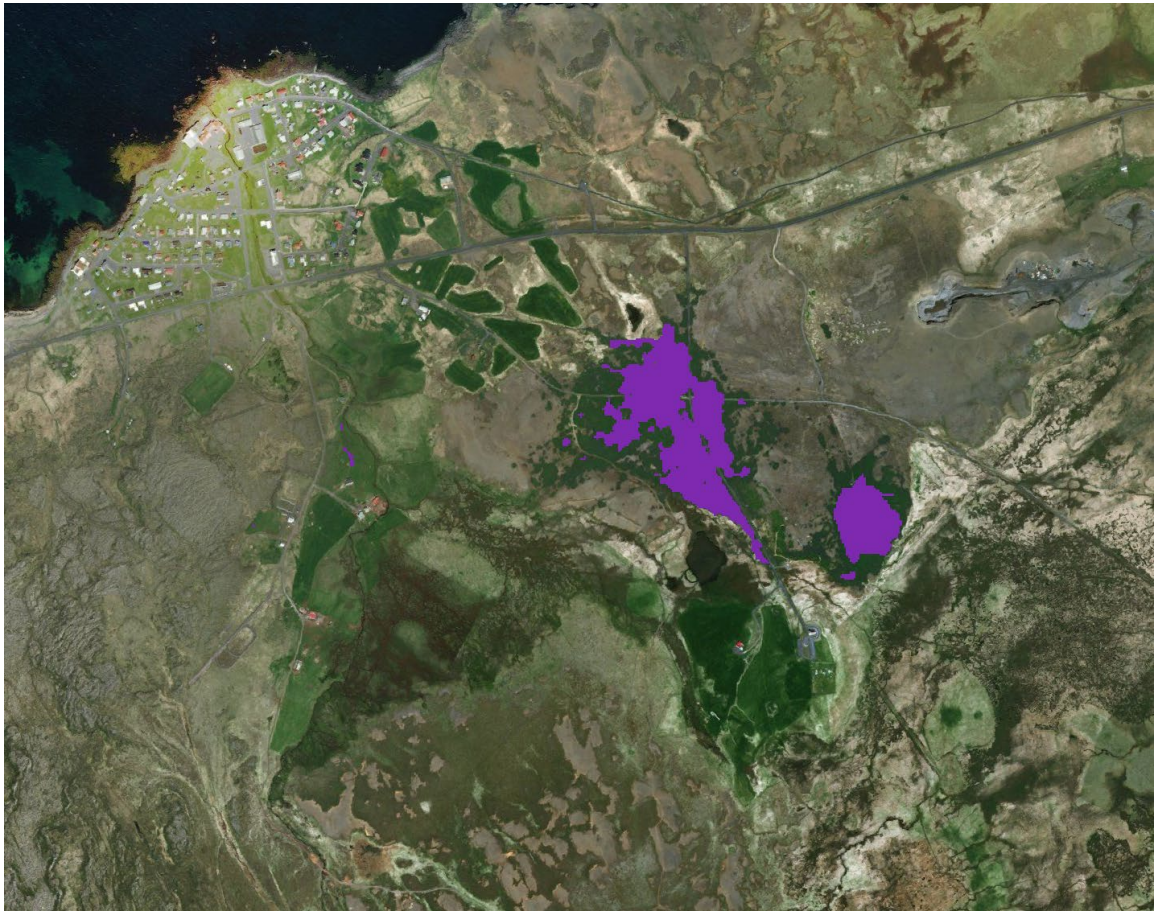
Invasive species monitoring

Results: Hellisandur (background image 2018)



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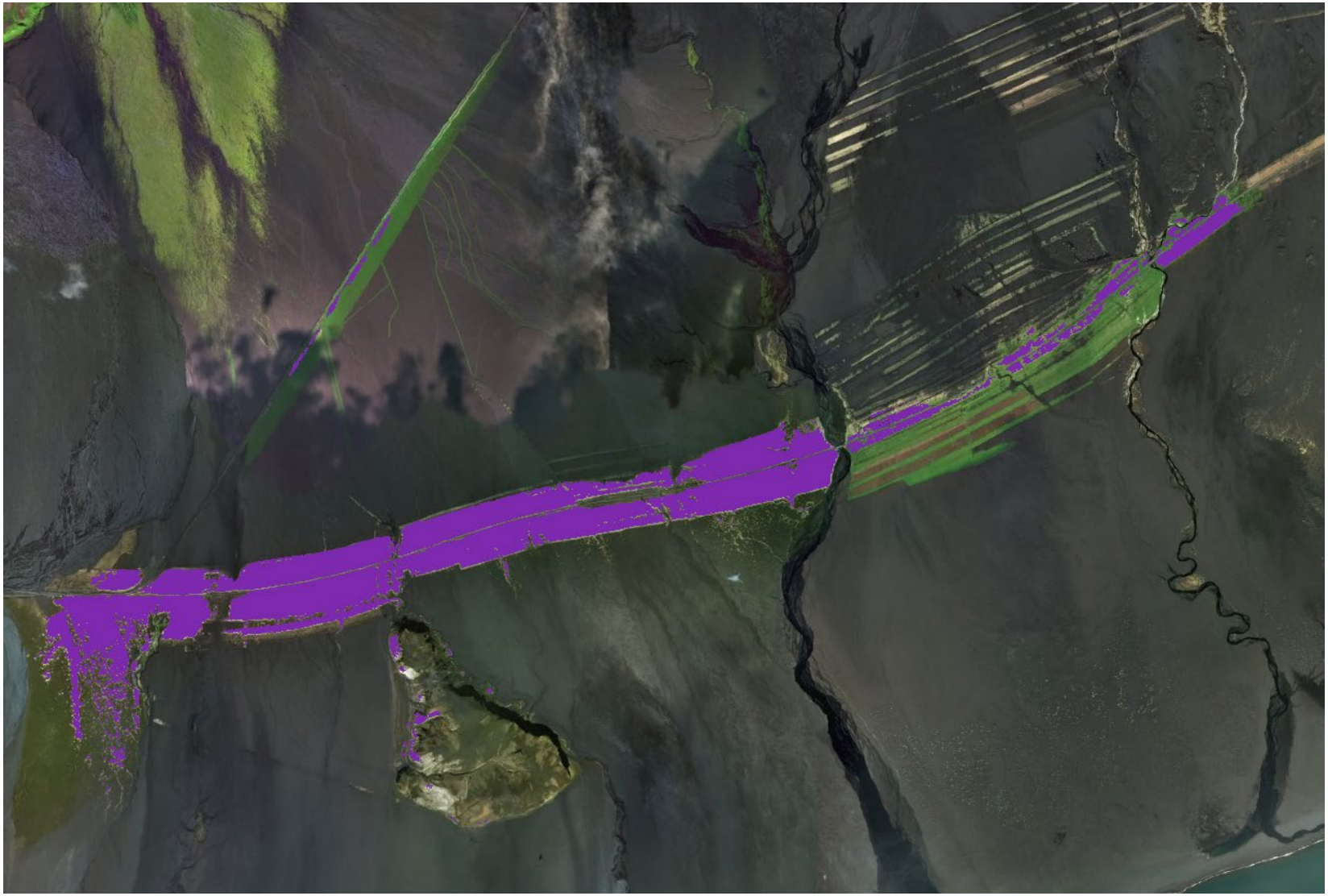
Invasive species monitoring

Results: Myrdalssandur (background image 2018)



Example: tree colonization

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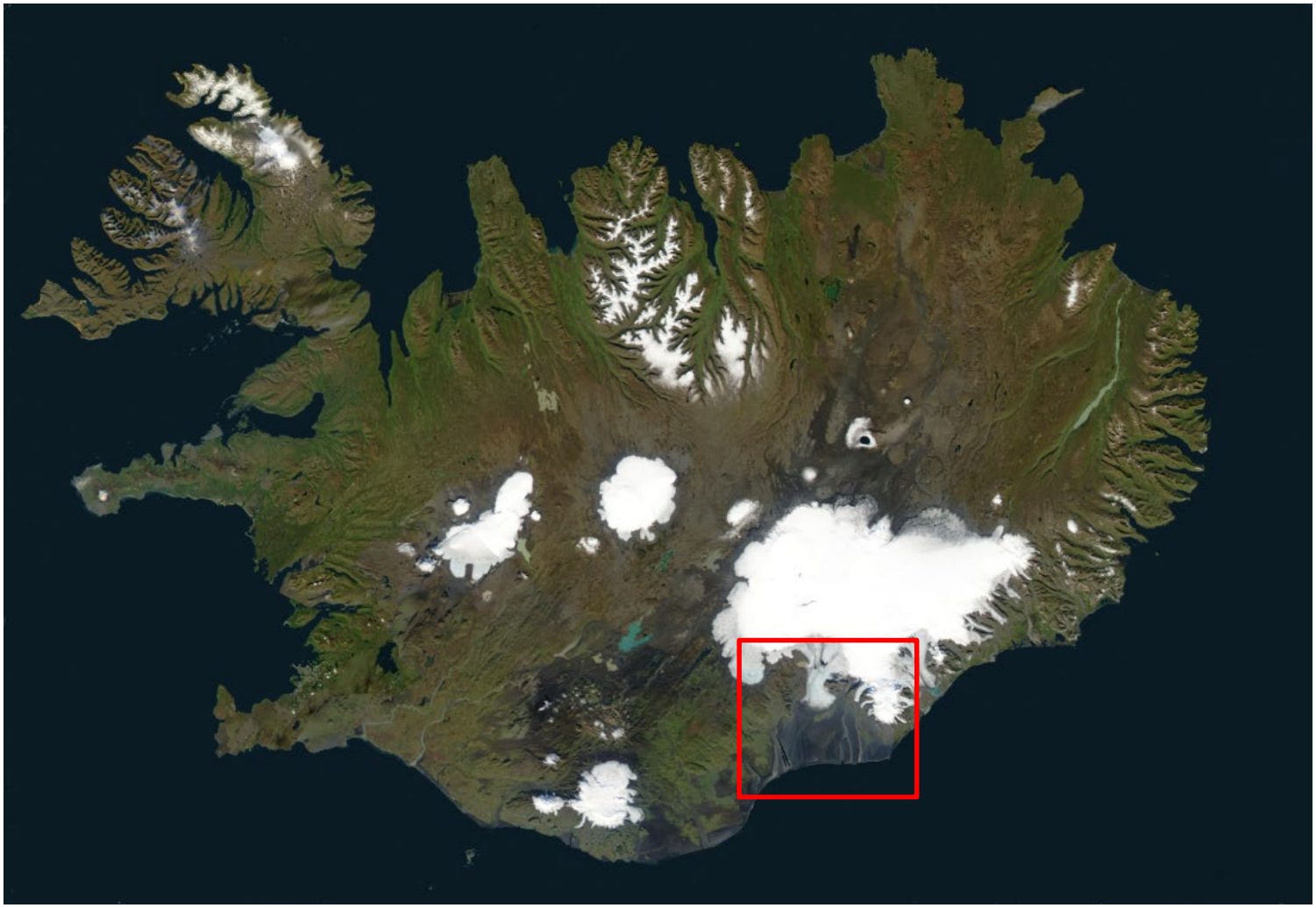
Tree colonization

Introduction



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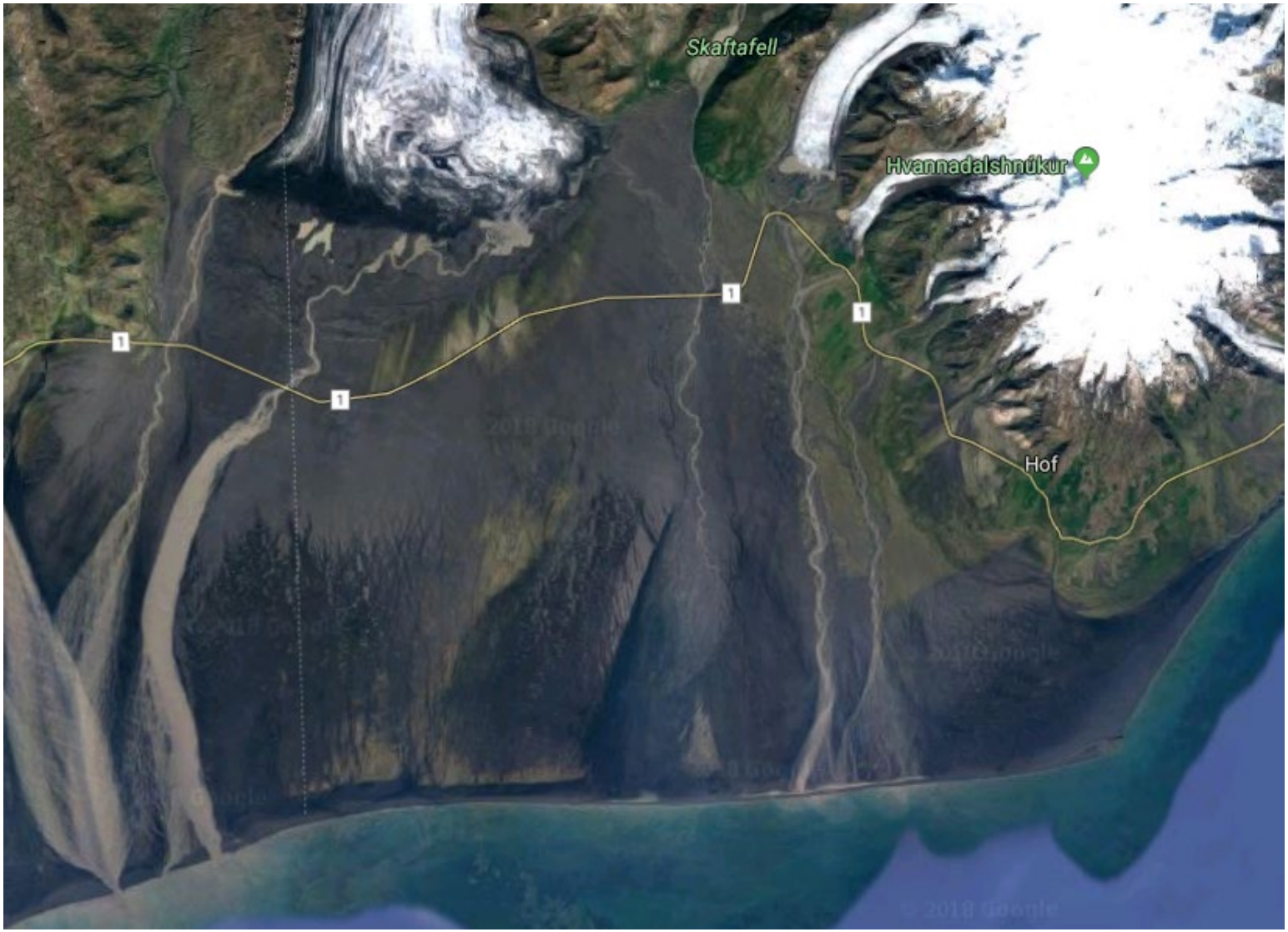
Tree colonization

Introduction



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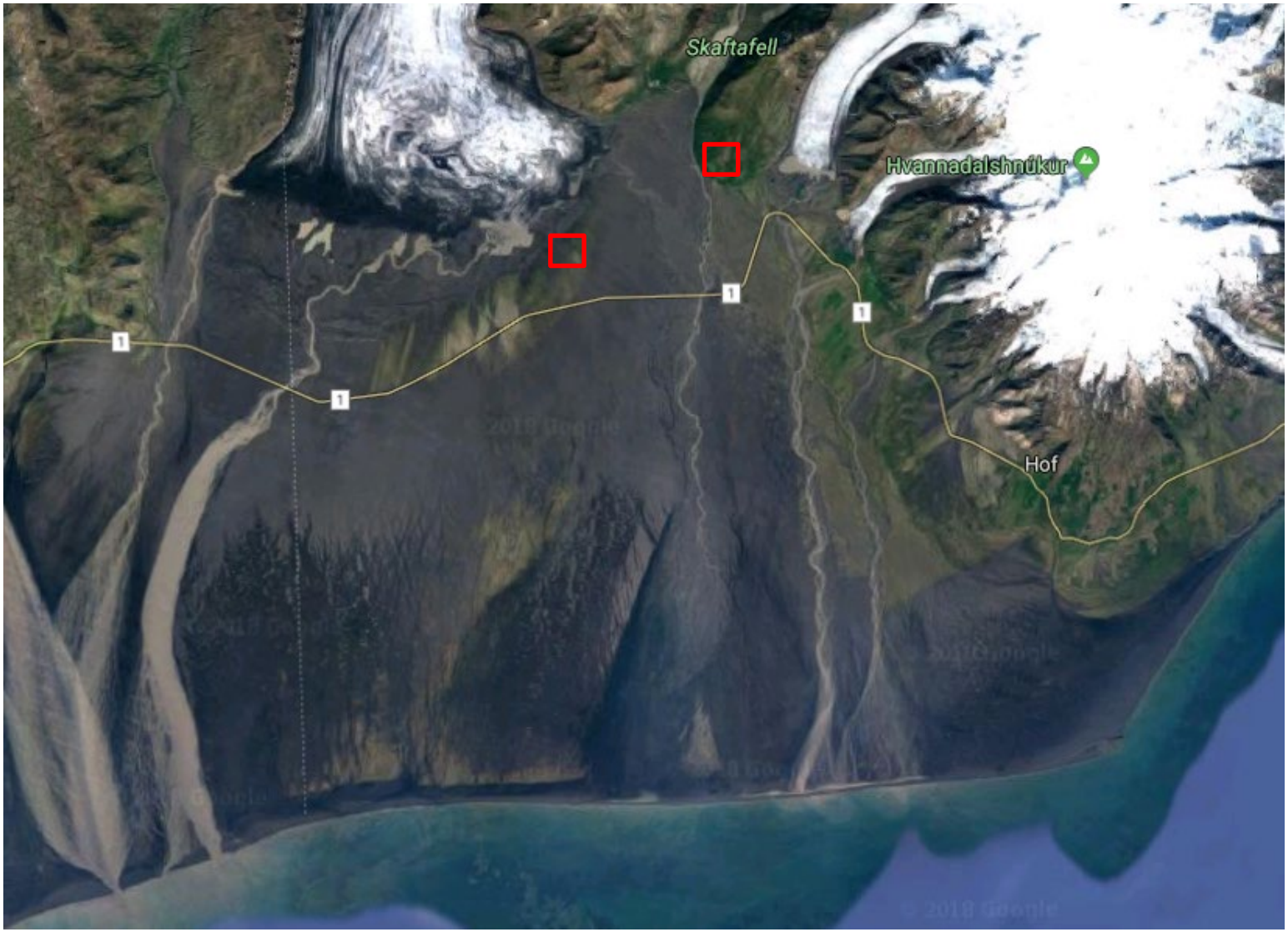
Tree colonization

Introduction



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Tree colonization

Introduction

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Tree colonization

Introduction: why?

- The glacial sandplains are a perfect place to study species colonization and settlement
- A growing trend of birch trees have been spotted related to the changes in glacial sandplains
- It was a perfect moment to study the colonization of birch trees and settling a model for their expansion

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Tree colonization

Introduction: opportunity

- The idea of using a combination of UAV and AI processes helped to undercover the density distribution as well as other spatially related variables

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Tree colonization

Introduction: challenges

- The generation of the necessary dataset for this endeavor was not easy:
  - The area is basically a very difficult area to access and prone to constant changing weather, so sampling is difficult
  - Limited UAV coverage
  - Non coherent dataset from a reflectance point of view
  - Total lack of label data

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Tree colonization

Introduction

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Tree colonization

Introduction

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Tree colonization

The dataset

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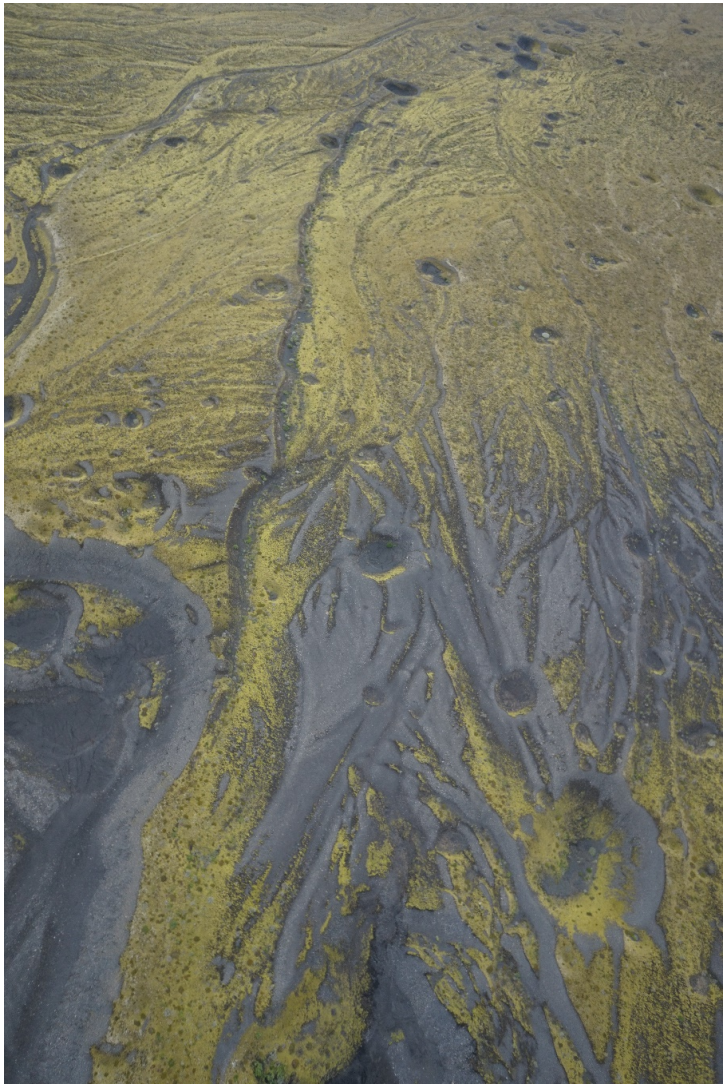
Tree colonization

The dataset



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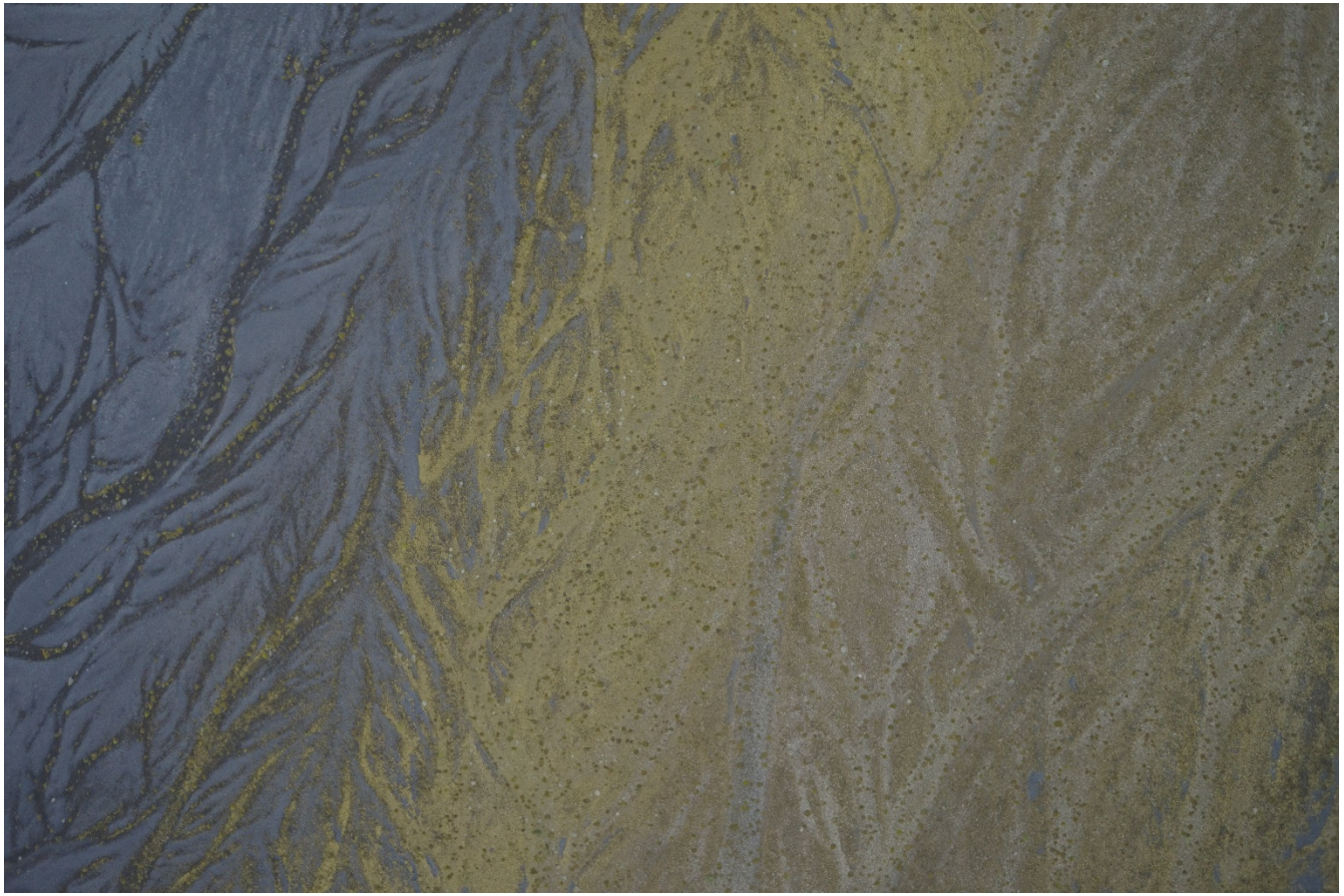
Tree colonization

The dataset



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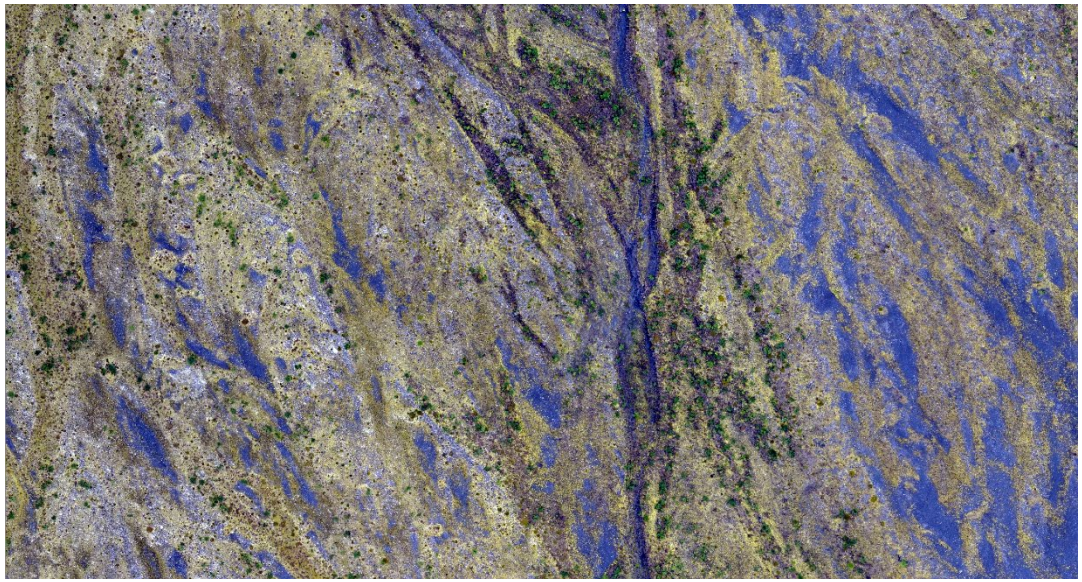
Tree colonization

The dataset



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Tree colonization

The dataset

- 5cm/pixel
- More than 130GB dataset
- Collected during summer with varying light conditions
- Only RGB imagery

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Tree colonization

Collection of tree GPS locations

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Tree colonization

Collection of tree GPS locations

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Tree colonization

Collection of tree GPS locations

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Tree colonization

Collection of tree GPS locations

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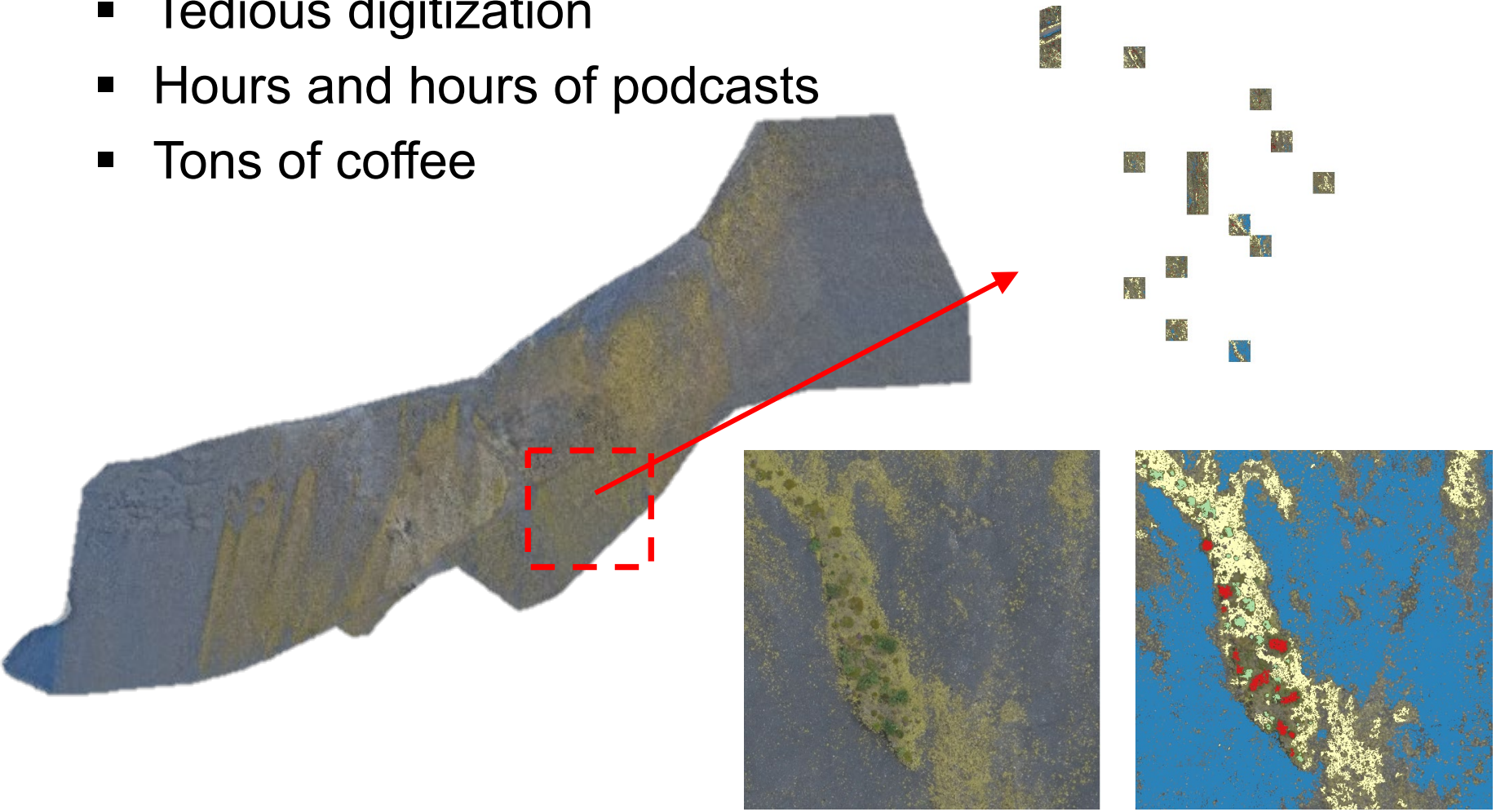
Tree colonization

The dataset

- Tedious digitization
- Hours and hours of podcasts
- Tons of coffee



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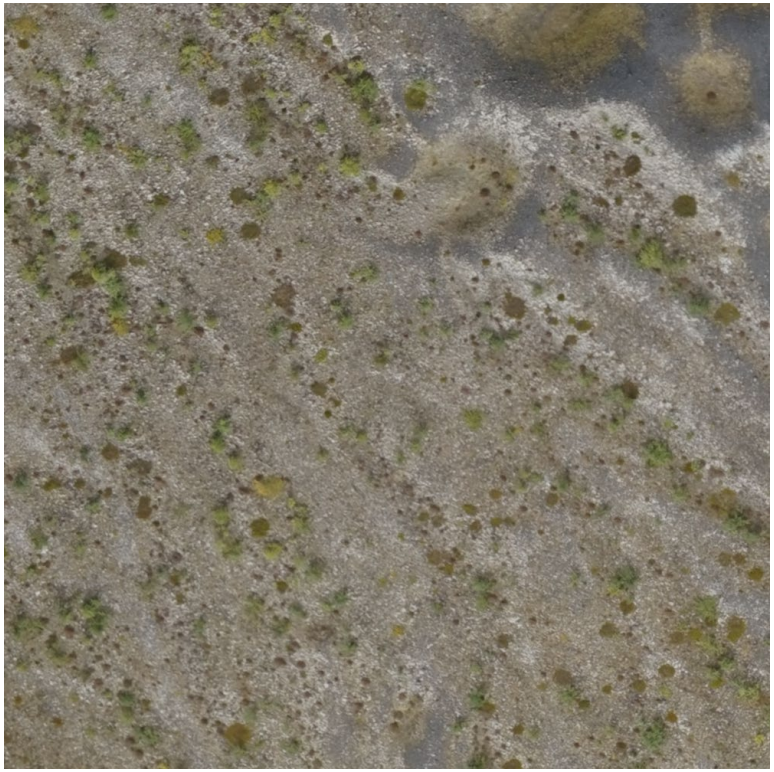
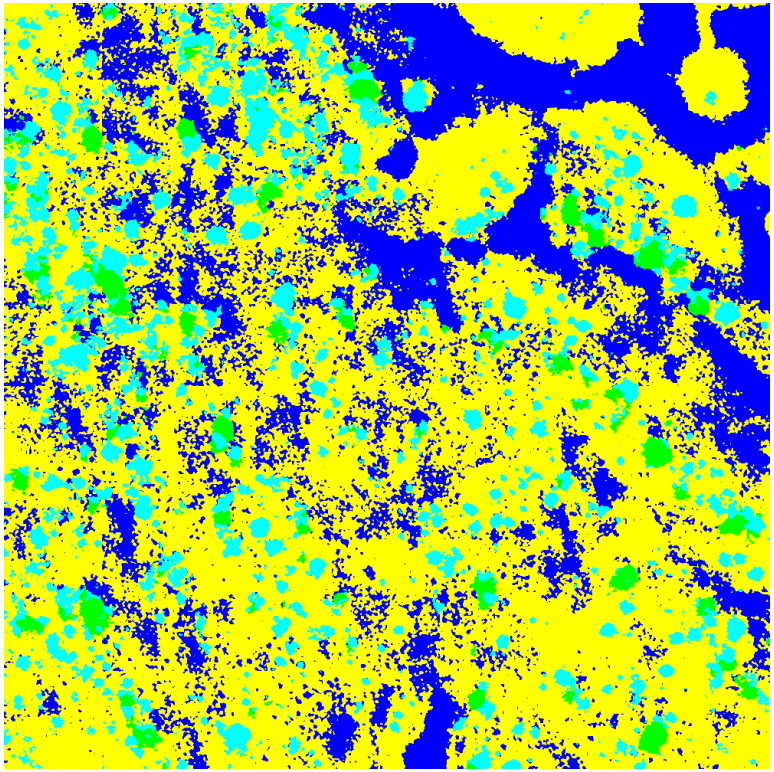
Tree colonization

Self CNN application





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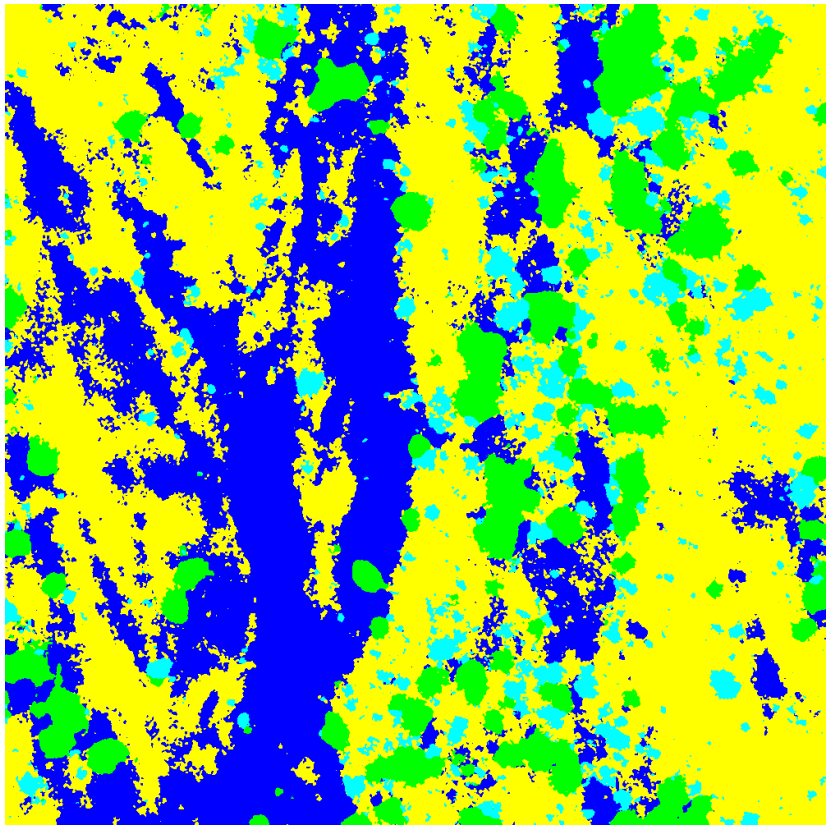
Tree colonization

Self CNN application



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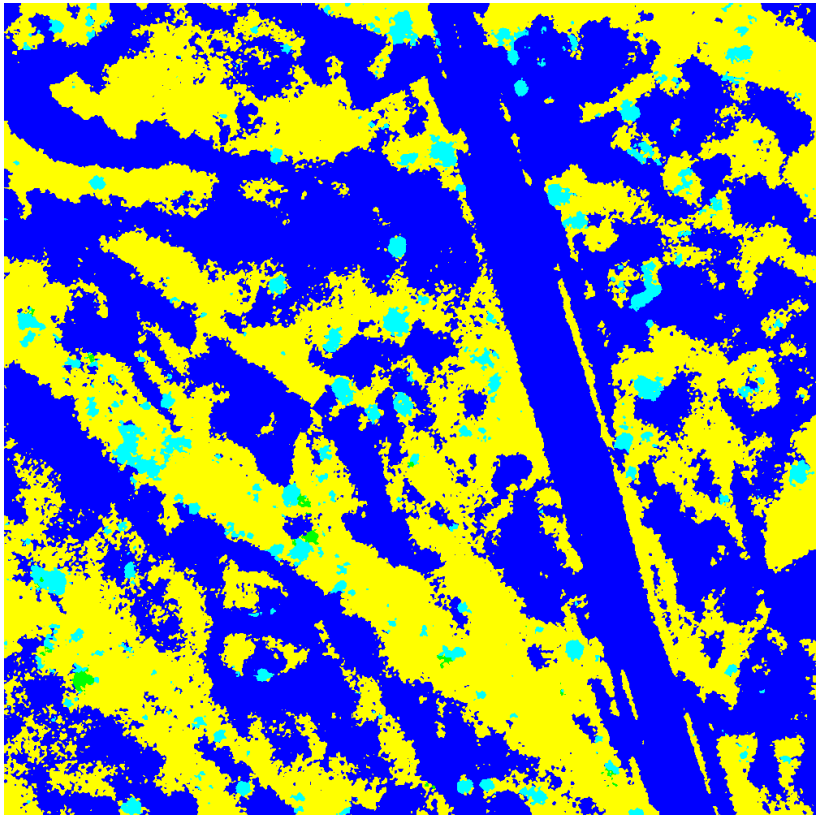
Tree colonization

Self CNN application



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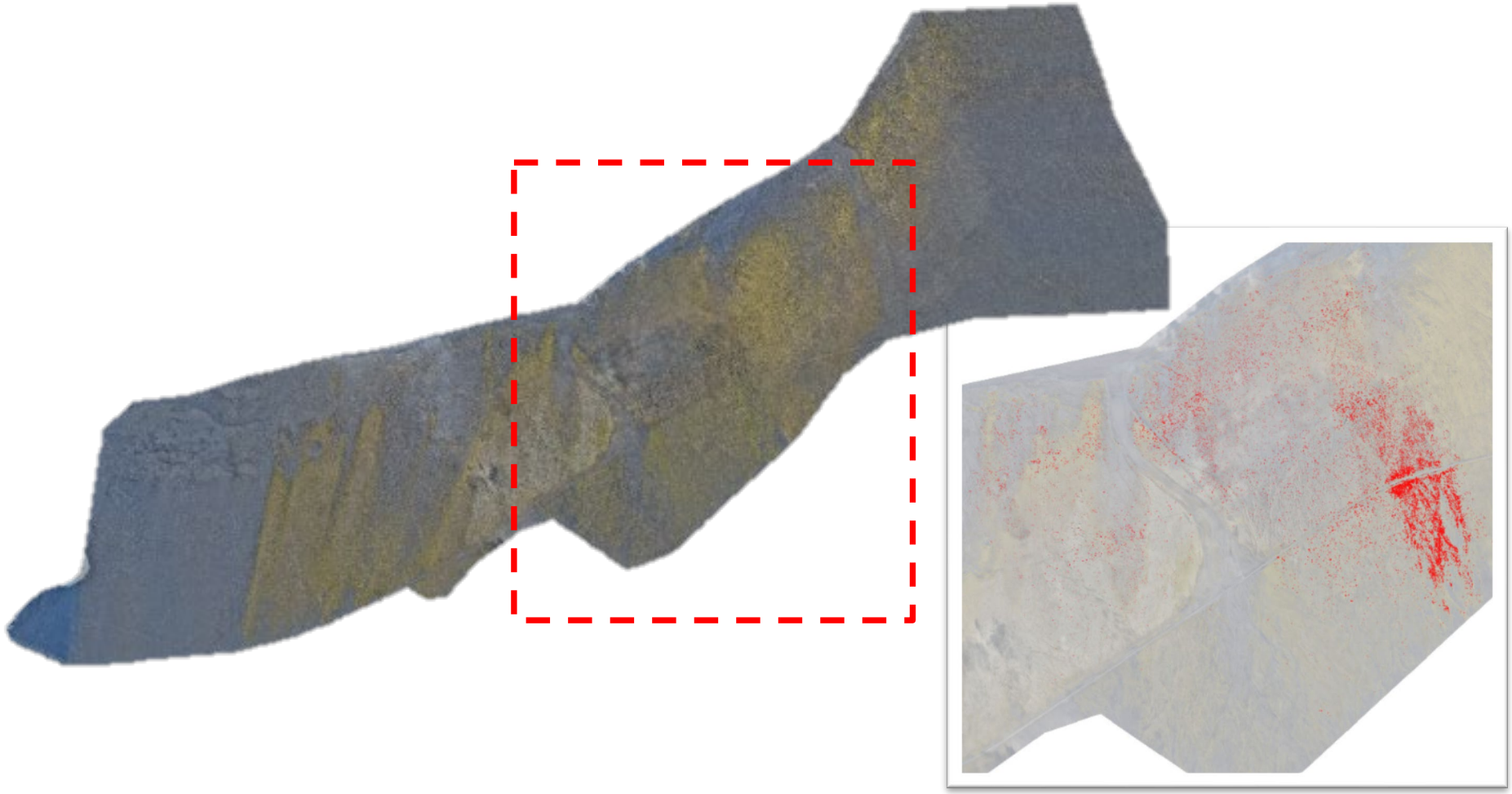
Tree colonization

Density derivation from detected trees



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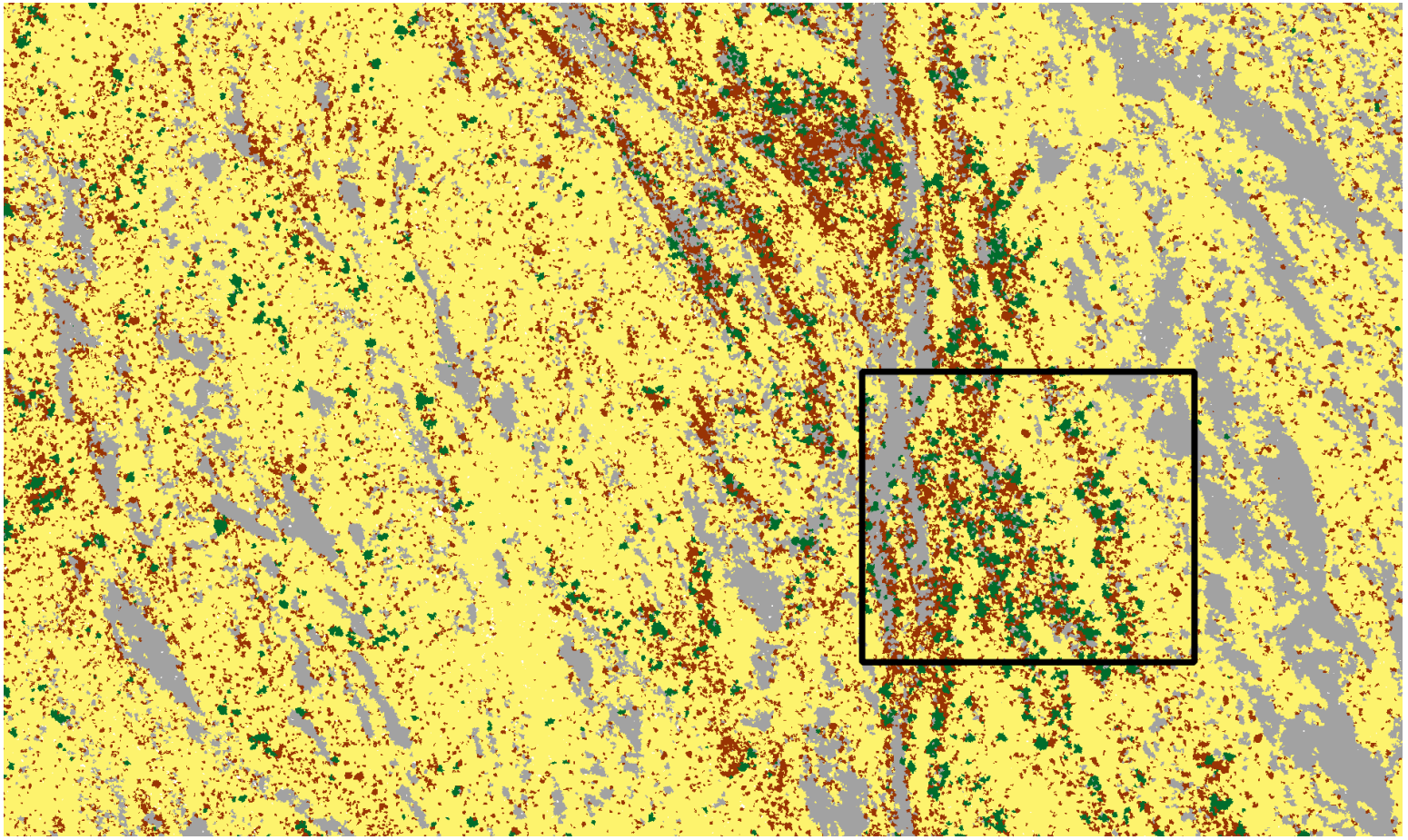
Tree colonization

Selection of further study areas based on density



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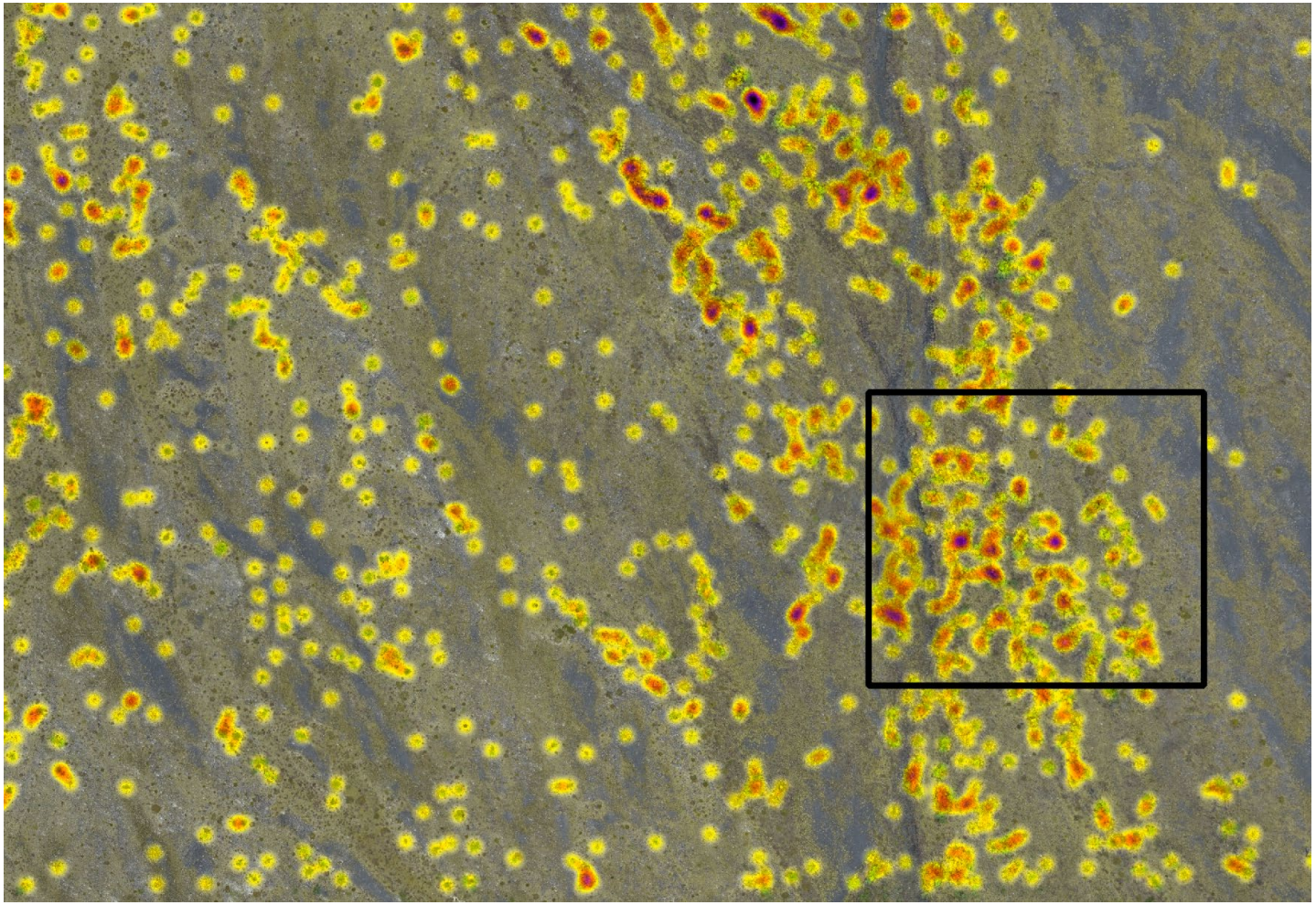
Selection of further study areas based on density



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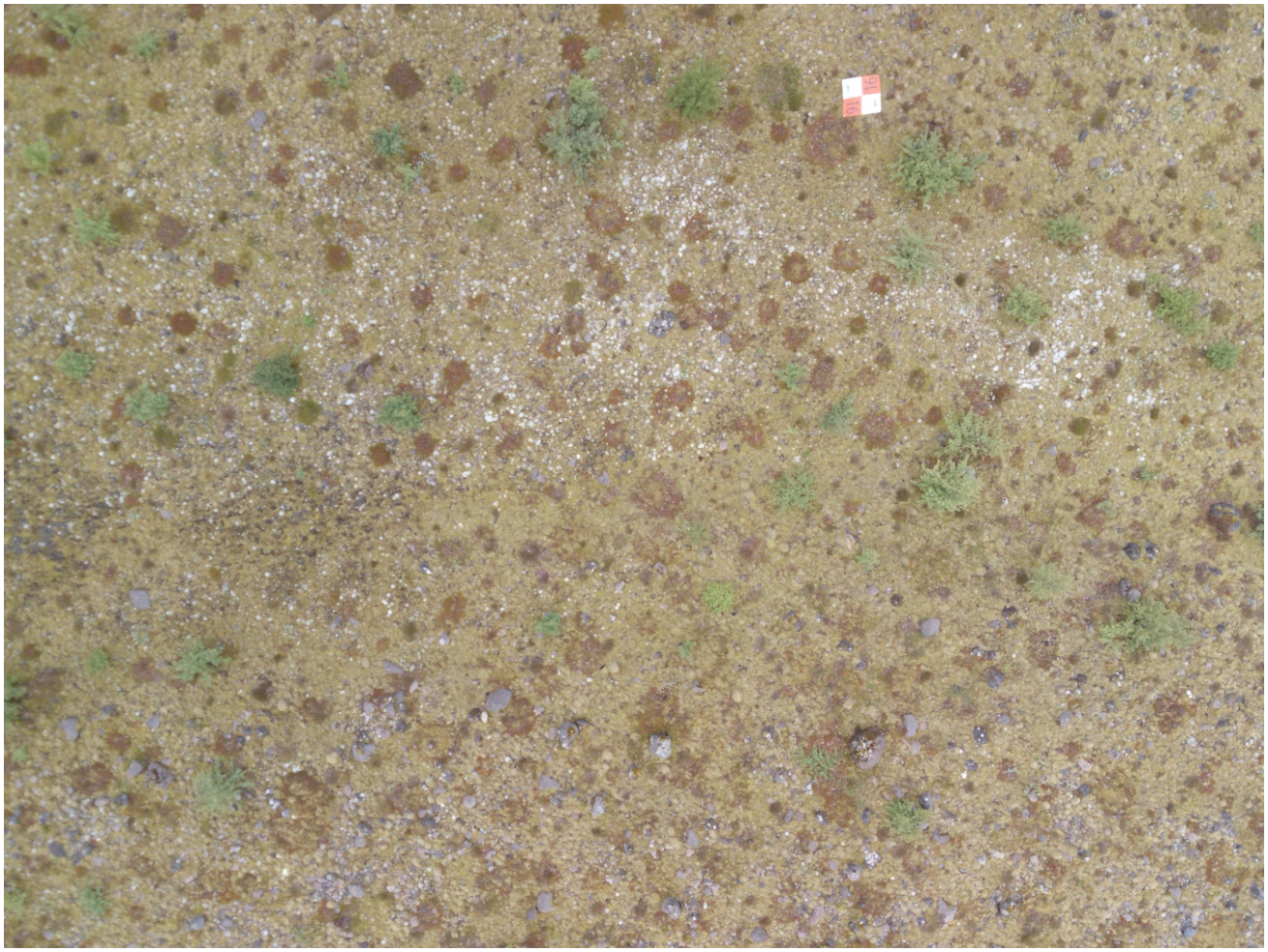
Tree colonization

Further ground control taking based on results



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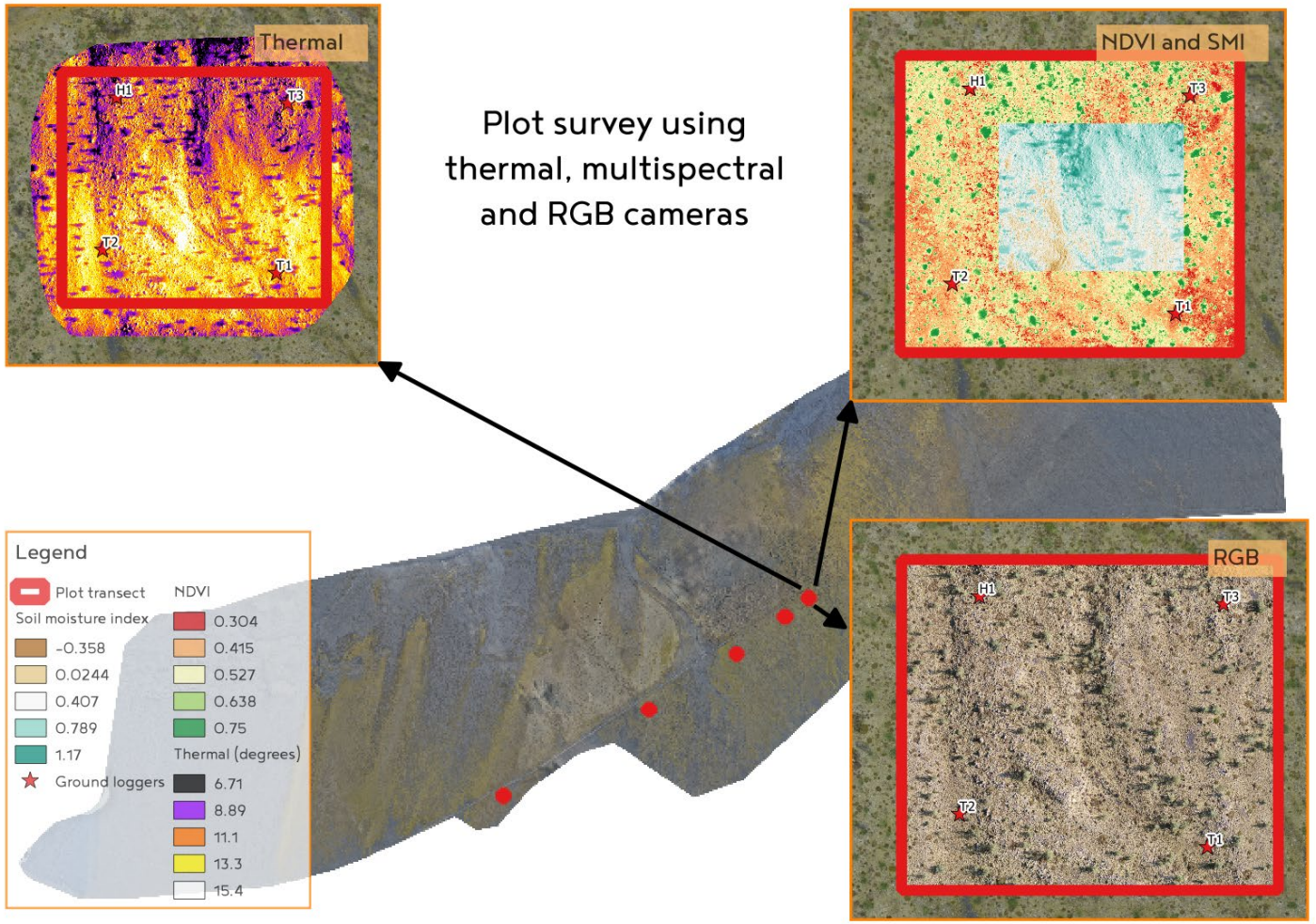
Tree colonization

Further study plots



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Tree colonization

Status

- Spatial distribution model corrected by local variables about to be released
- Papers on production
- Current realistic estimate applicable to the rest of the sandplain

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Parties involved in the presented research

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Parties involved

Research presented

	Seaweed	Lupine	Birch
Data Collection	Svarmi ehf & The Icelandic Marine Research Institute • Victor Pajuelo • Daniel Ben Yehoshua • Karl Gunnarsson • Julian Burgos	Svarmi ehf & Landgraedslan • Kristín Svavarsdóttir • Victor Pajuelo • Arna Björk Þorsteinsdóttir • Jóhann Thorarensen	Svarmi ehf & Landgraedslan & University of Iceland • Kristín Svavarsdóttir • Victor Pajuelo • Bryndís Marteinsdóttir • Gudrun Oskarsdottir • Þora Ellen Þorhasllsdottir • Tryggvi Stefansson • Sydney Gunnarsson • Daniel Ben Yehoshua • Hlynur Steinsson • Others.
Algorithm Development	• Victor Pajuelo	• Victor Pajuelo	• Victor Pajuelo
Project paid/funded by	The Icelandic Marine Research Institute	Landgraedslan	The Icelandic Innovation Grant

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Parties involved

Research presented

- Svarmi ehf:
  - https://svarmi.is/
- Landgraedslan:
  - https://land.is/
- Marine Research Institute:
  - https://www.hafogvatn.is/
- University of Iceland:
  - https://english.hi.is/university_of_iceland

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How to get started in geospatial monitoring

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Where to start?

Resources and more

- Copernicus Data:
  - https://scihub.copernicus.eu/
- Elevation data and other from Catalonia:
  - https://www.icgc.cat/Descarregues
- Essential Python libraries:
  - Fiona
  - Shapely
  - Rasterio
  - Geopandas

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Contact

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Contact

If you have any further questions about my research

- victor.pajuelo@bts.tech
- victor.fpm@gmail.com

- Also, I can put you in contact with people involved in the presented research if you are interested about the datasets or the applications

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