Environmental Applications for Earth Observation Data

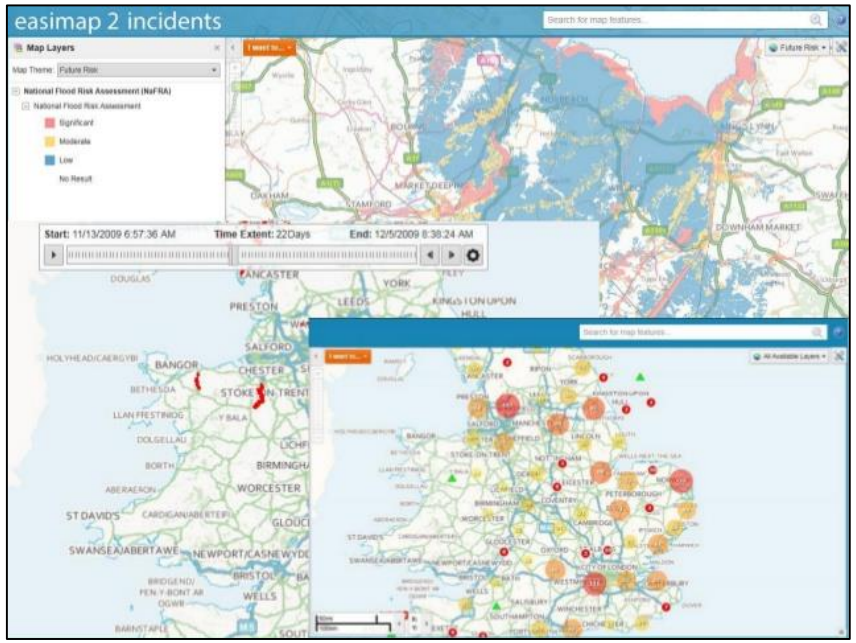
JNCC

Copernicus

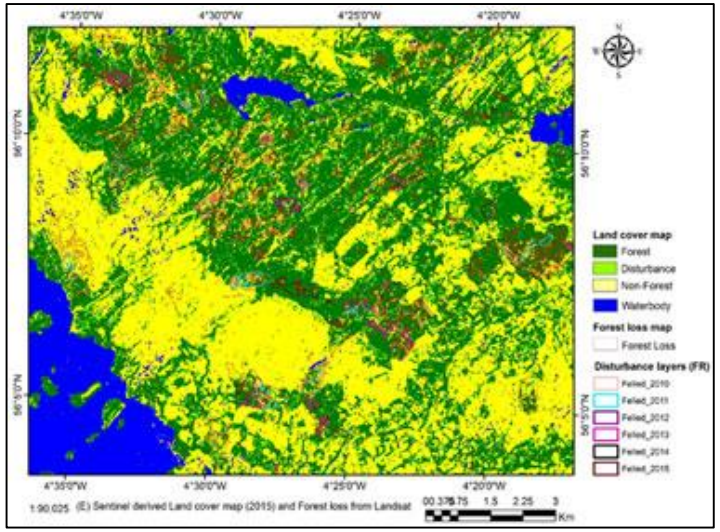
Framework Partnership Agreement for Copernicus User Uptake

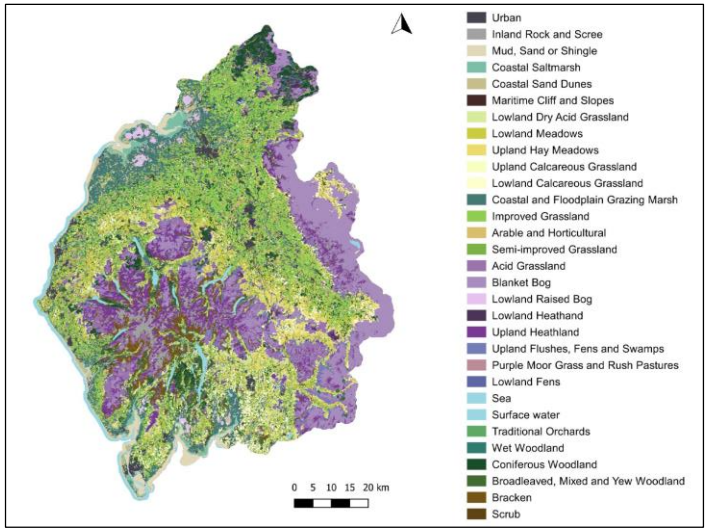
Satellite earth observation data can help to deliver environmental policy in two ways:

Visualisation of imagery to support routine operations



Data analyses including modelling and near-real-time change detection





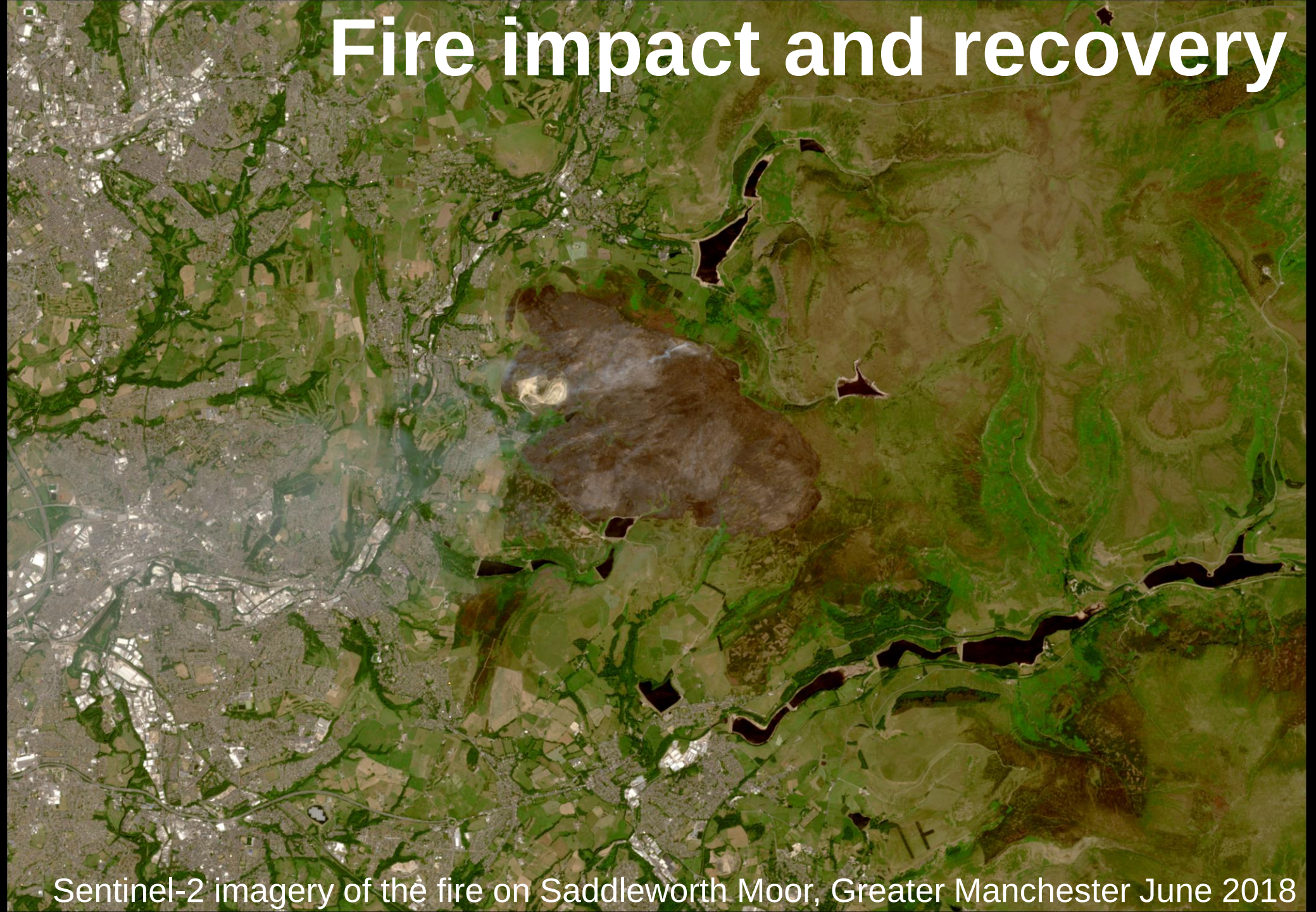
Visualisation

What can (and can’t!) we see in satellite imagery?

Sentinel-2 imagery (June 2018)
10 metre resolution

ESRI World Imagery
0.5 metre resolution

Fire impact and recovery

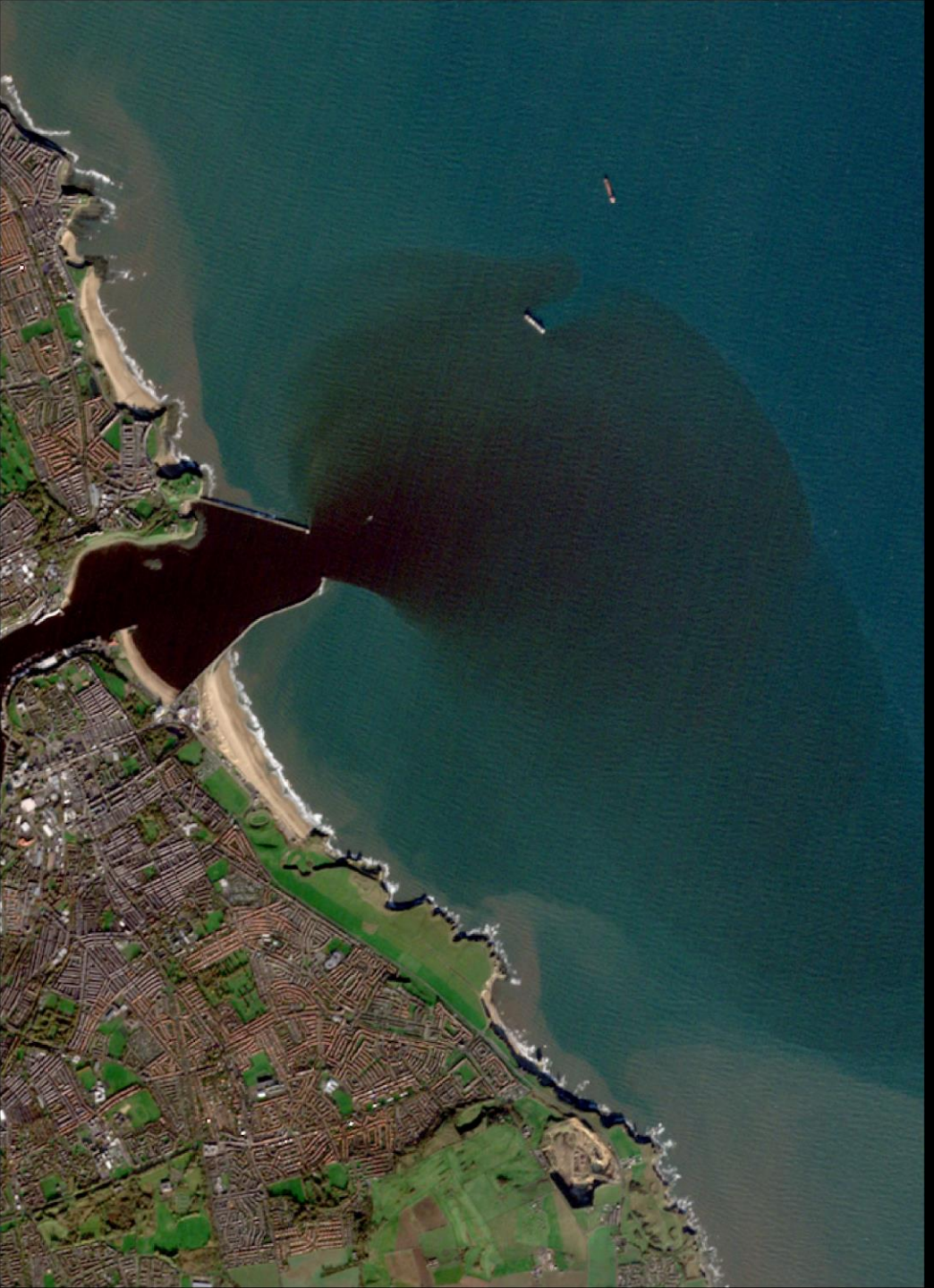


Sentinel-2 imagery of the fire on Saddleworth Moor, Greater Manchester June 2018

Plankton blooms

Sentinel-2 imagery of a coccolithophore bloom in the English channel June 2020

River sediment plumes



Sentinel-2 imagery of the River Tyne (November 2019) and the Bristol Channel (March 2020)

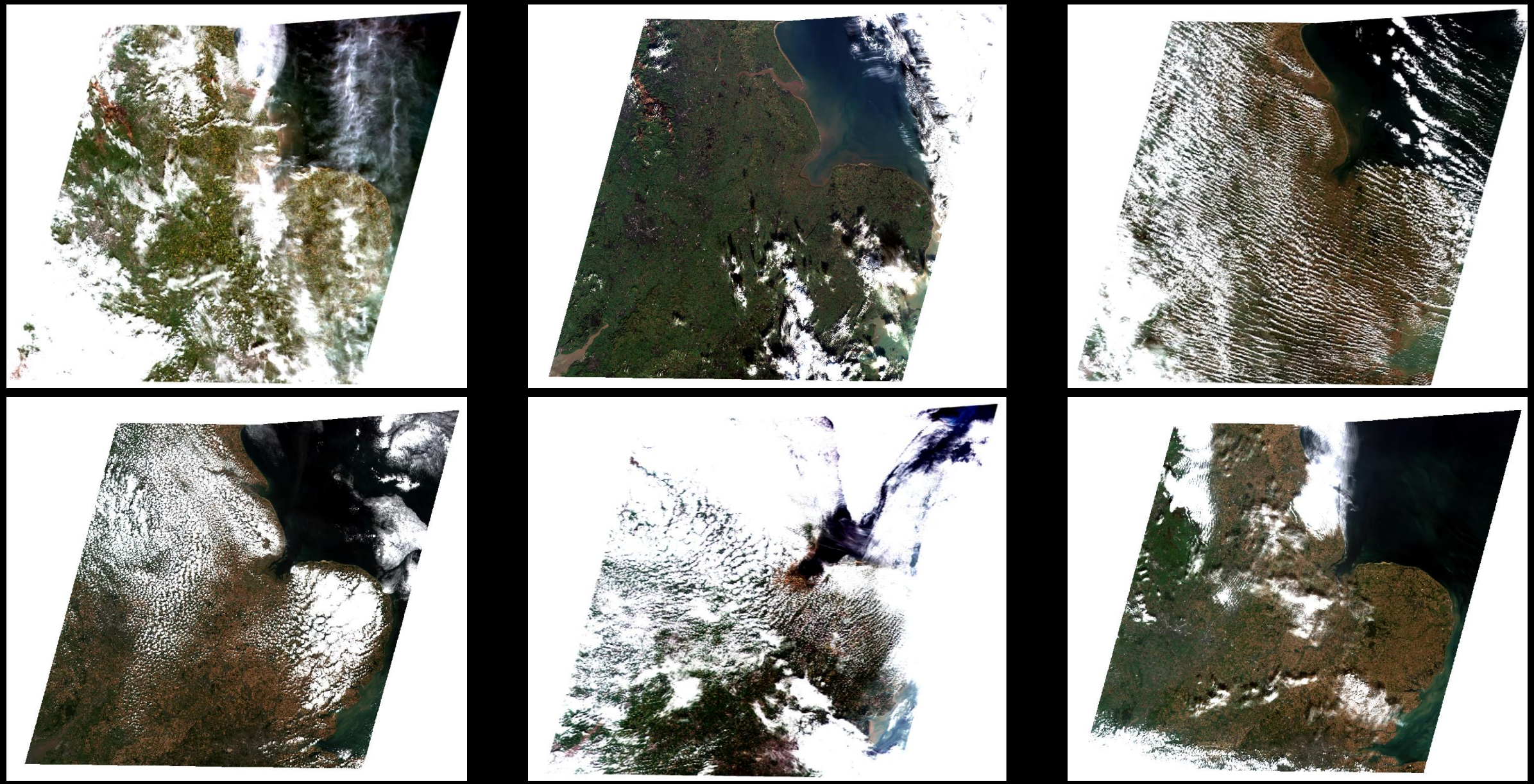
Urban areas and bare ground

False colour Sentinel-2 imagery of Edinburgh and the Firth of Forth in summer 2019

Changing land use and water levels

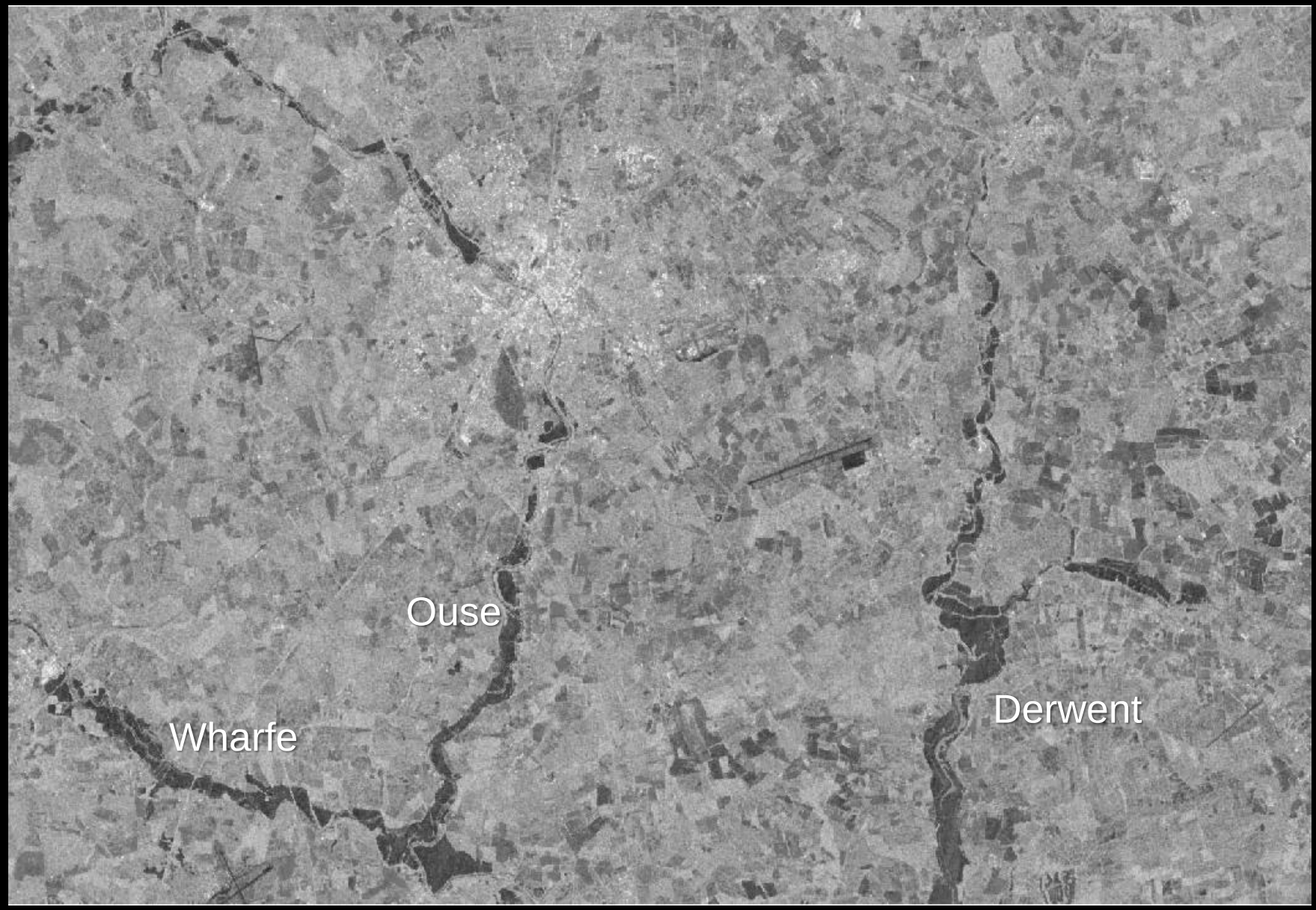
Sentinel-2 imagery of North Yorkshire 2019-2020

…but sometimes you can’t see much!



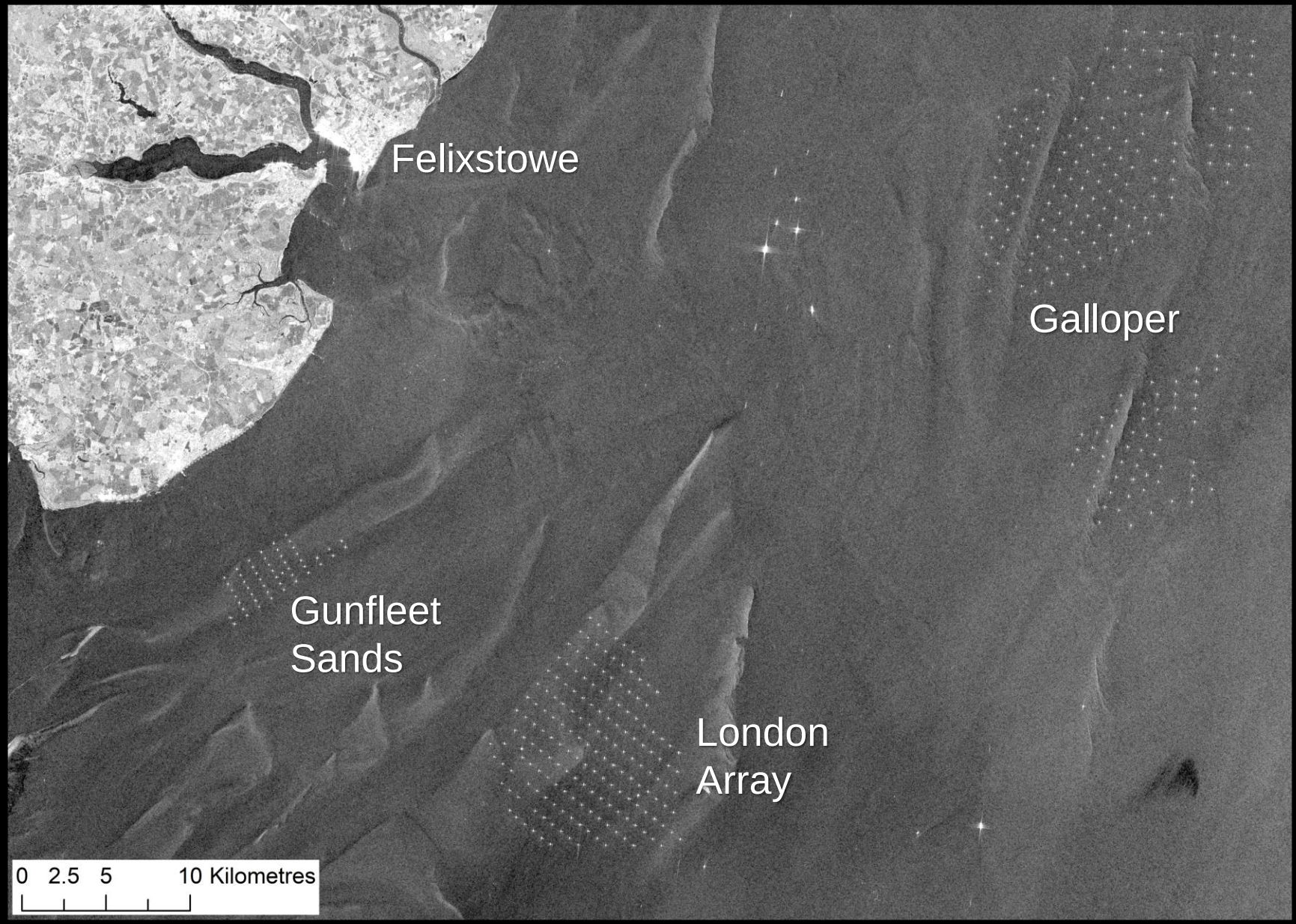
Sentinel-2 imagery of the east coast of England on various dates in 2016

Flooding



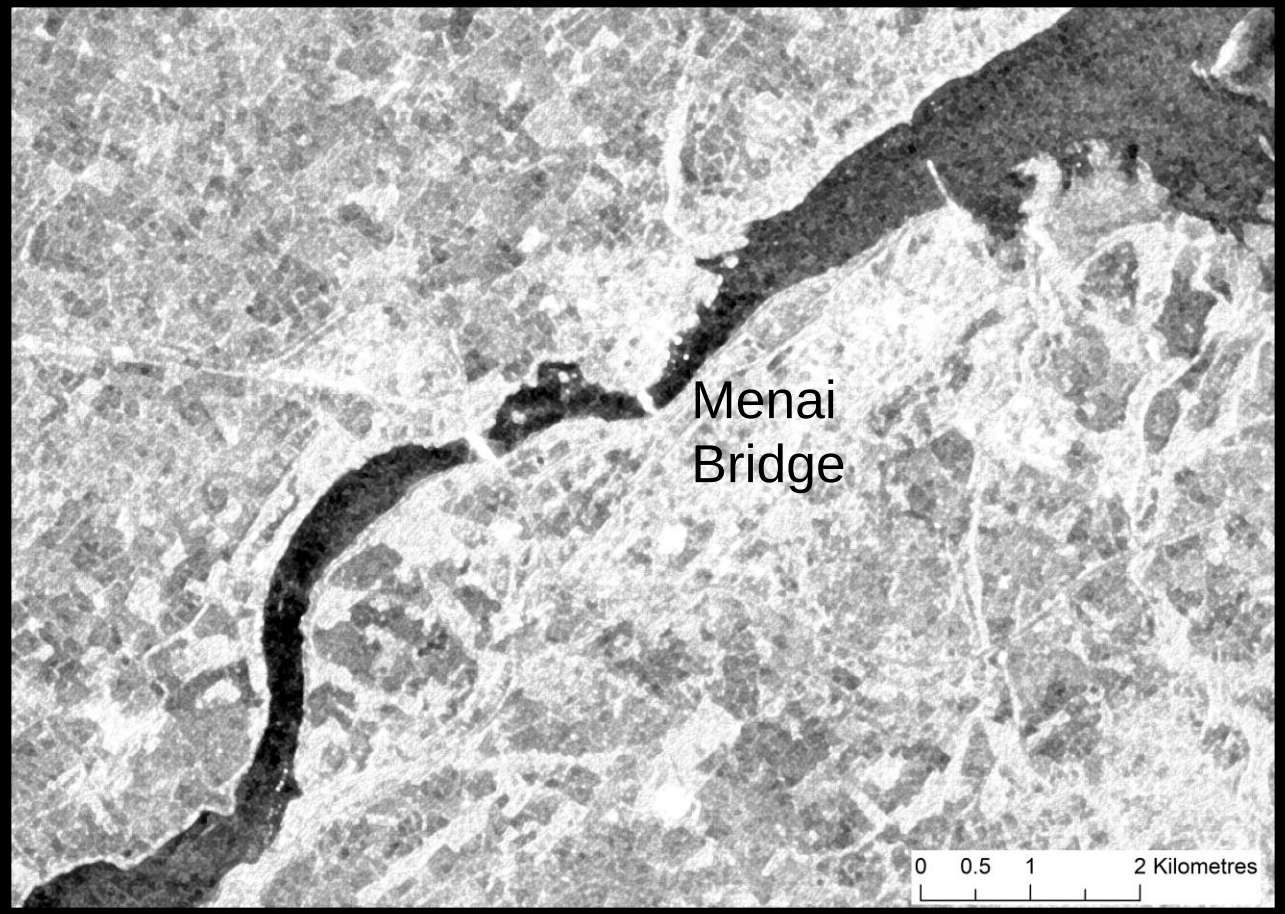
Sentinel-1 imagery of York on the 29th July 2019 and 15th February 2020

Offshore windfarms and vessels

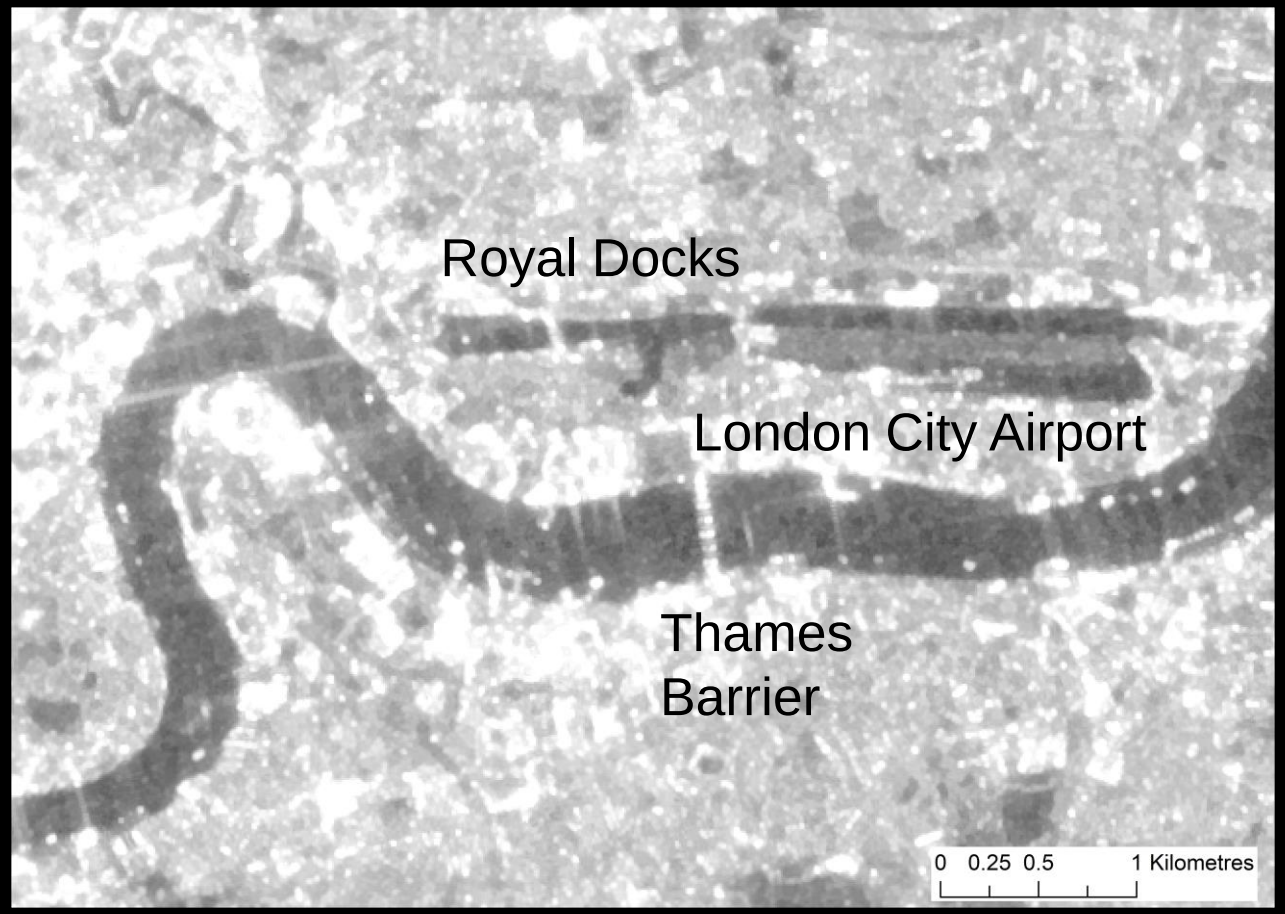


Sentinel-1 imagery of the North Sea off the coast of Essex and Suffolk, September 2020

Urban areas and infrastructure

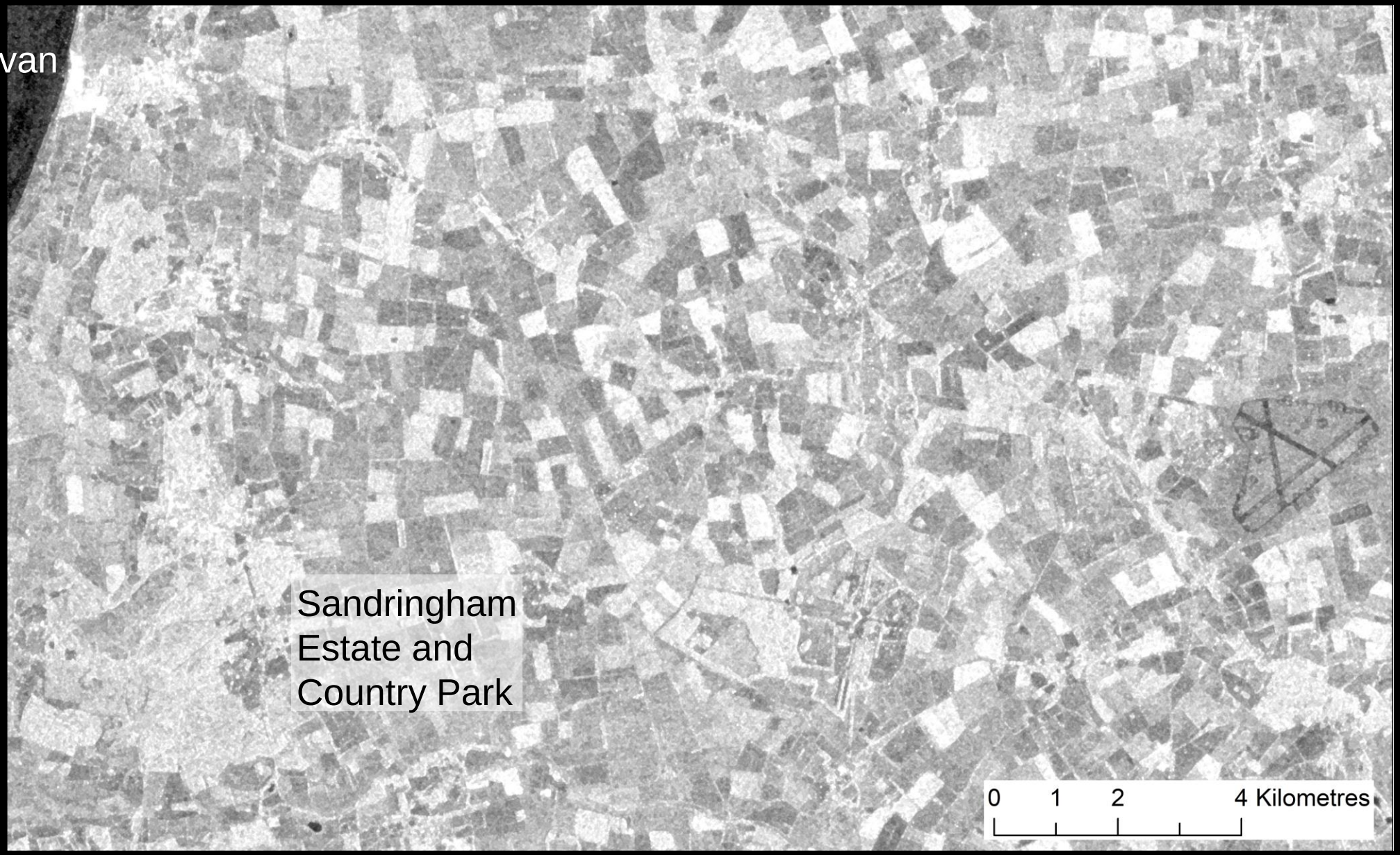


Sentinel-1 imagery of the Menai Straits
September 2020



Sentinel-1 imagery of central London
September 2020

Agriculture and woodland



Sentinel-1 imagery of Norfolk, September 2020

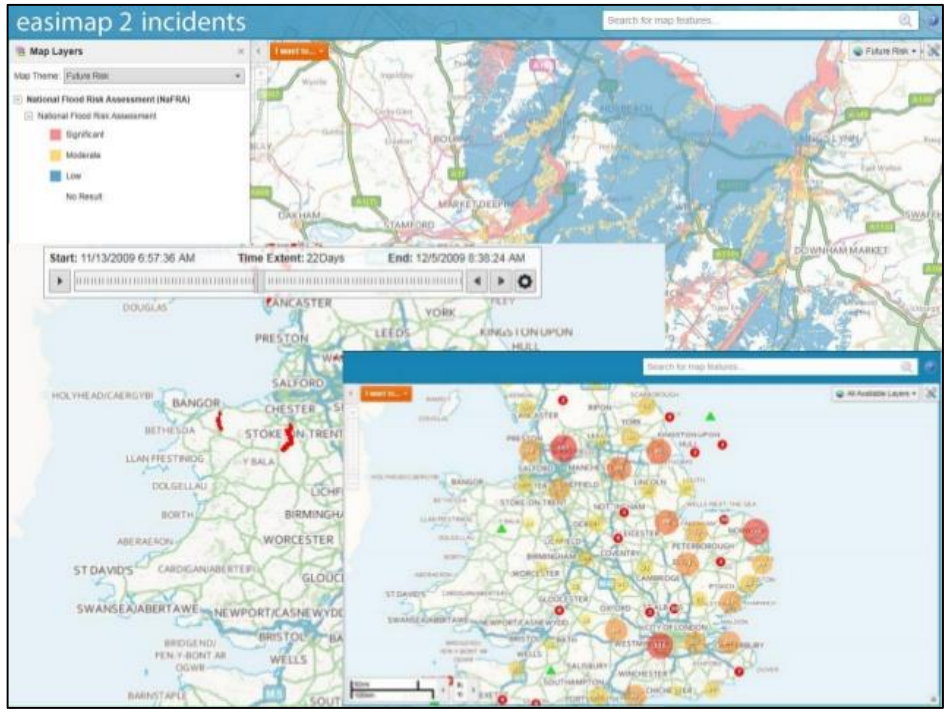
Visualisation case study

Department for Environment Food & Rural Affairs

Environment Agency

EasiMap

- The Environment Agency's primary web-GIS application.
- Used by 10,000 staff.
- Over 3,000 users per day on average.



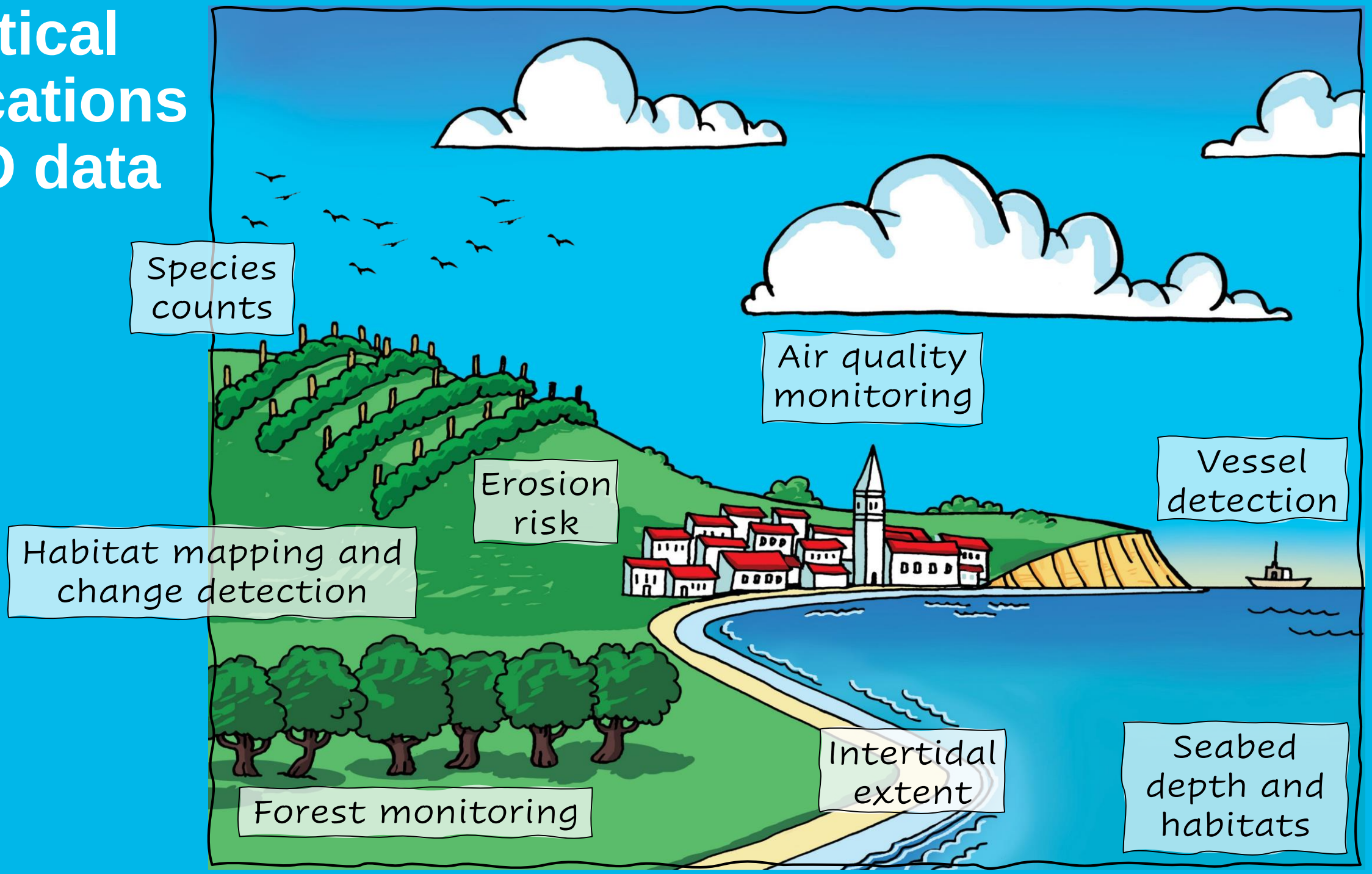
Integrating EO Data Service with EasiMap

- Defra and EA are working to integrate Sentinel-2 imagery into EasiMap using EODS web services.
- Visualisation alongside other spatial data and EO-derived products (e.g. flood maps) to inform operations.

Policy benefits

- Protecting people from impacts of flooding.
- Targeting regulatory and enforcement activities e.g. relating to agricultural practices.
- Informing waste crime activities.

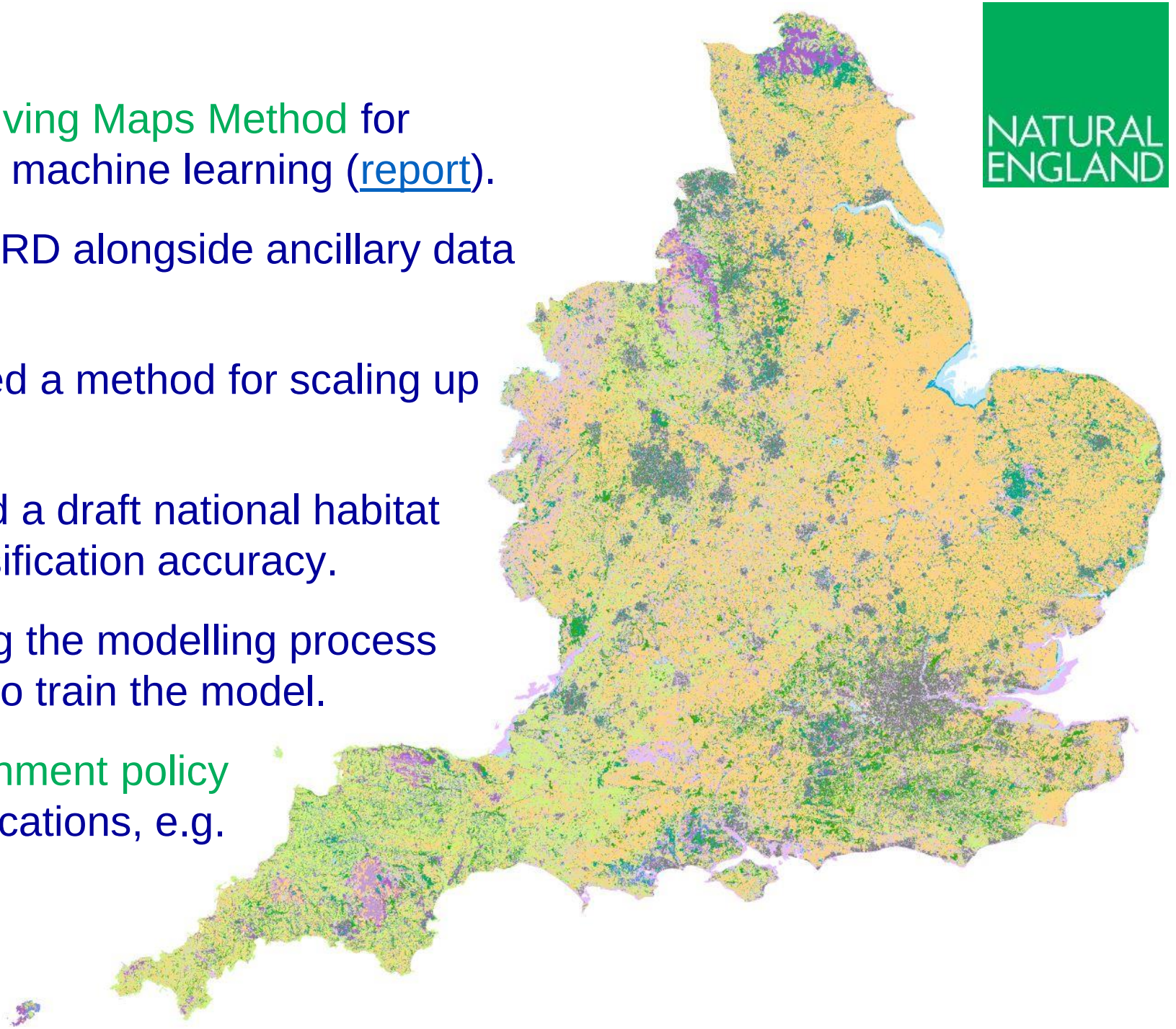
Analytical applications for EO data



Habitat
Mapping

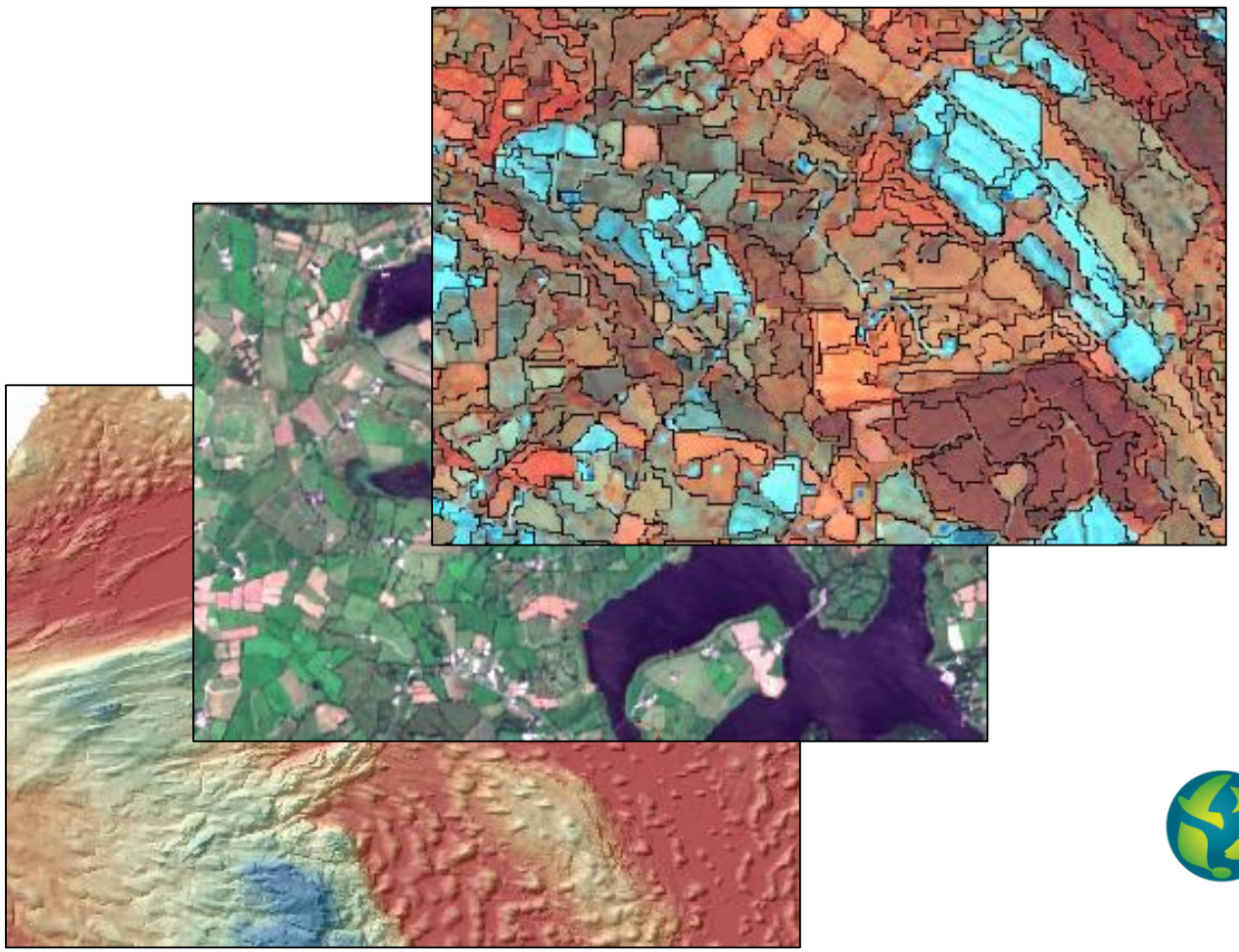
Habitat Mapping

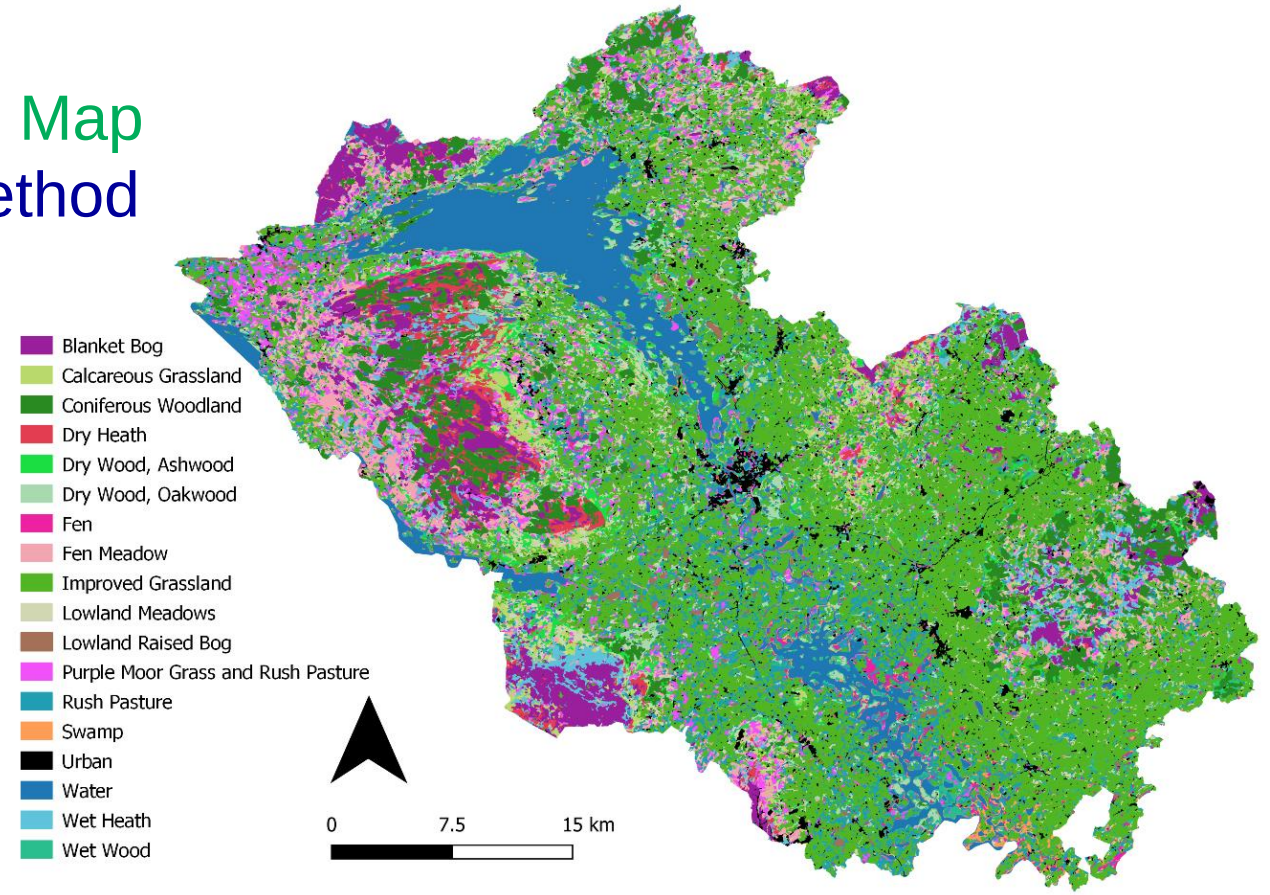
- Natural England developed the Living Maps Method for classifying habitats using EO and machine learning (report).
- Uses Sentinel-1 and Sentinel-2 ARD alongside ancillary data e.g. climate layers.
- Living England Phase 1 developed a method for scaling up the Living Maps approach.
- Living England Phase 2 produced a draft national habitat map with 78% probability of classification accuracy.
- Living England Phase 3 is refining the modelling process and gathering more habitat data to train the model.
- Developed to support agri-environment policy delivery but has many other applications, e.g.
  - Reporting on indicators
  - Site condition assessments
  - Biodiversity Net Gain
  - Nature Recovery Networks



Habitat Mapping

JNCC and the Northern Ireland Environment Agency are collaborating to produce a Living Map of Northern Ireland using the Living Maps method developed by Natural England.





Seasonal Sentinel-1 and Sentinel-2 derived habitat map of Fermanagh

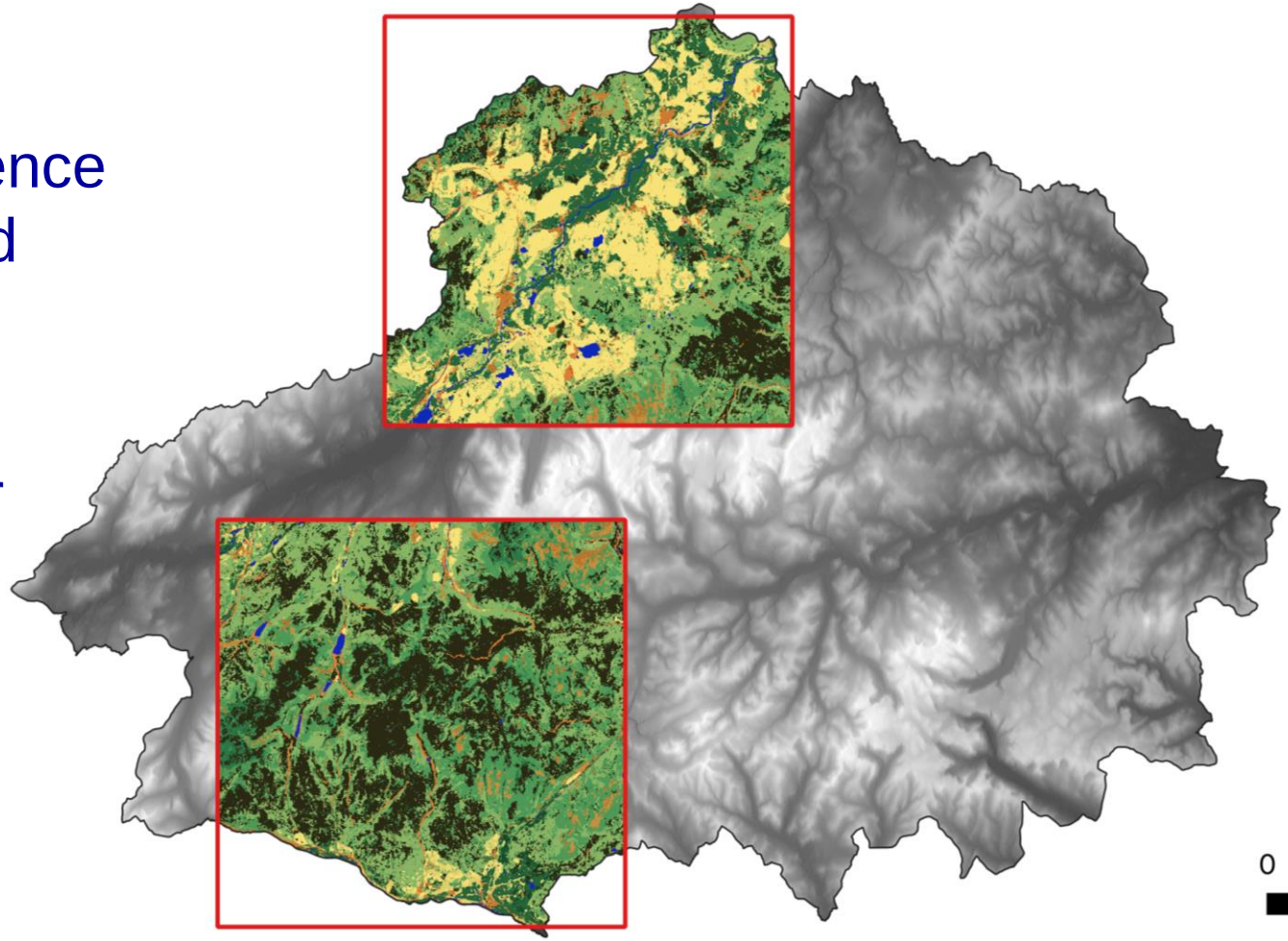
JNCC

NIEA Northern Ireland Environment Agency
www.daera-ni.gov.uk

Habitat Mapping

Nature.Scot and Space Intelligence are producing a satellite-derived EUNIS Level 2 map of the Cairngorms National Park.

This will be used as an input for Natural Capital Asset Index calculations.



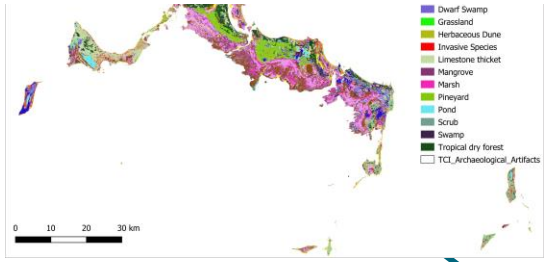
NatureScot
Scotland's Nature Agency
Buidheann Nàdair na h-Alba

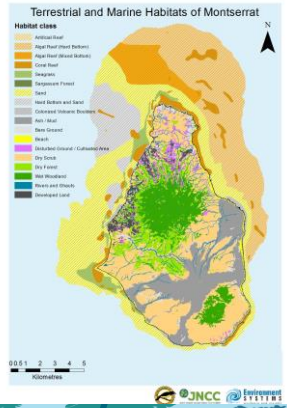
SPACE INTELLIGENCE

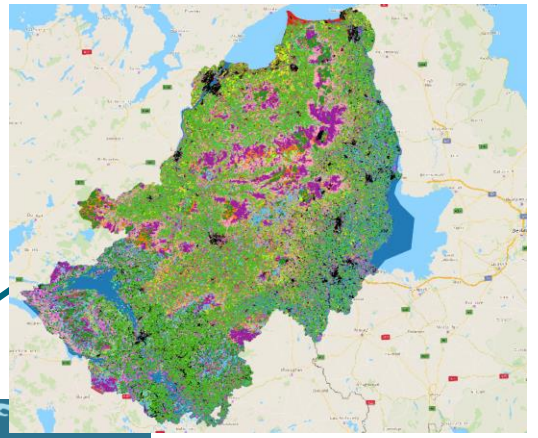
EUNIS Habitat Classification

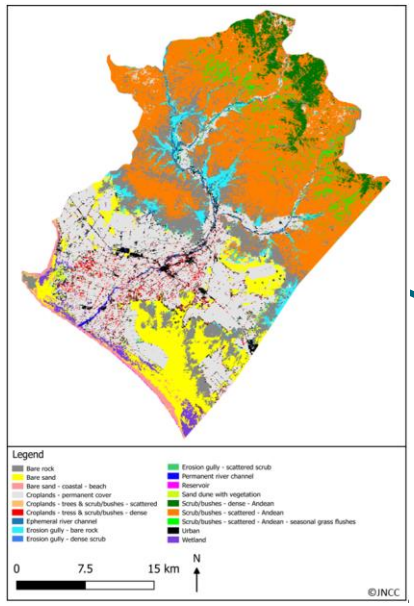
- Surface waters
- Raised and blanket bogs
- Valley mires
  poor fens and transition mires
- Base-rich fens and calcareous spring mires
- Dry grasslands
- Mesic grasslands
- Alpine and subapline grasslands
- Woodland fringes and clearings and tall forb stands
- Arctic alpine and subalpine scrub
- Temperate and mediterranean-montane scrub
- Temperate shrub heathland
- Riverine and fen scrubs
- Broadleaved deciduous woodland
- Coniferous woodland
- Mixed deciduous and coniferous woodland
- Lines of trees
  small anthropogenic woodlands
  recently felled woodlands
  early-stage woodland and coppice
- Screes
- Inland cliffs rock pavements and outcrops
- Manmade surface (buildings and roads)
- Other bare surface

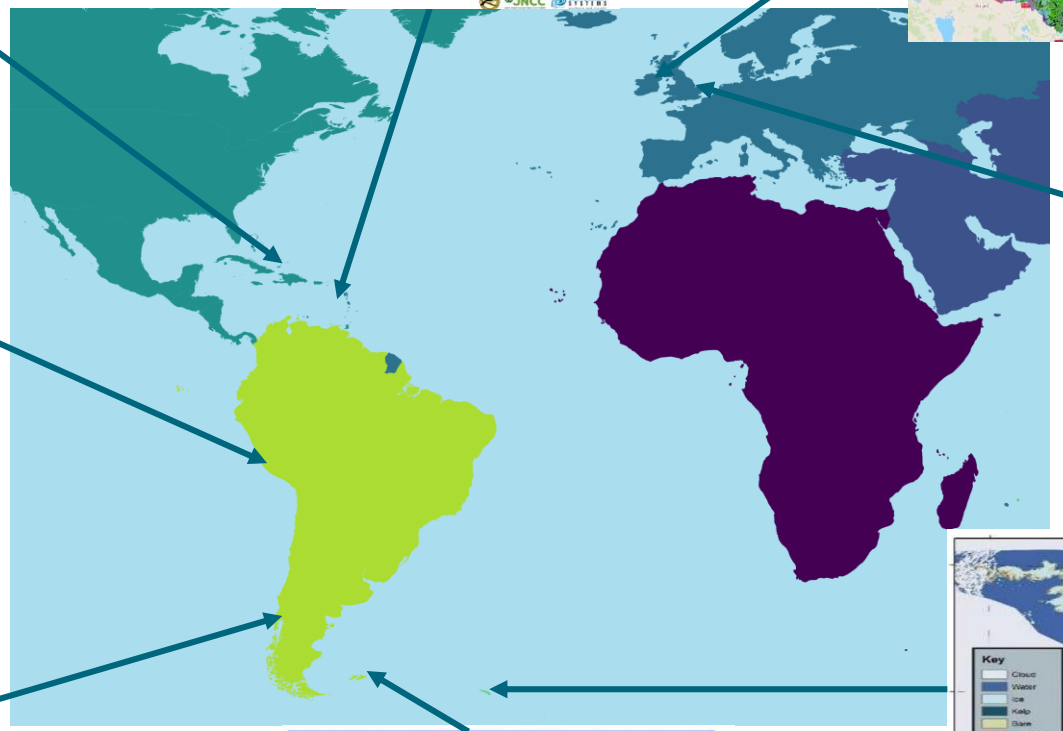
Habitat Mapping

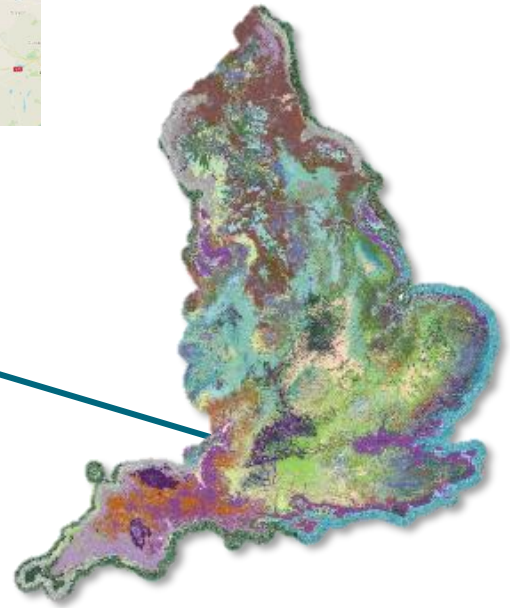


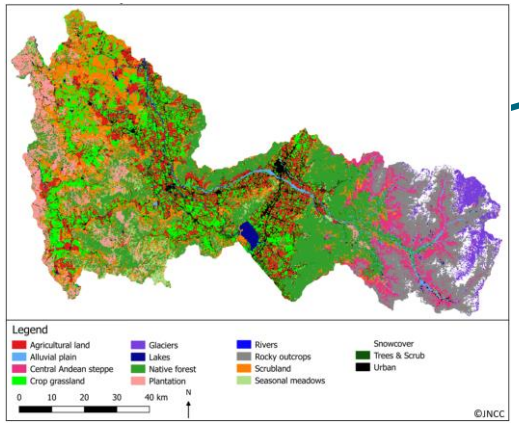


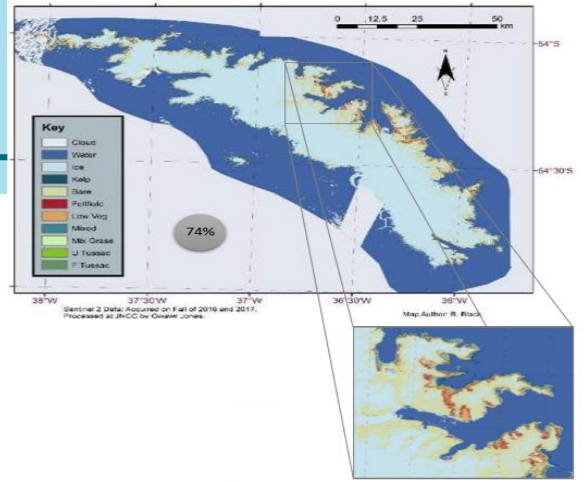








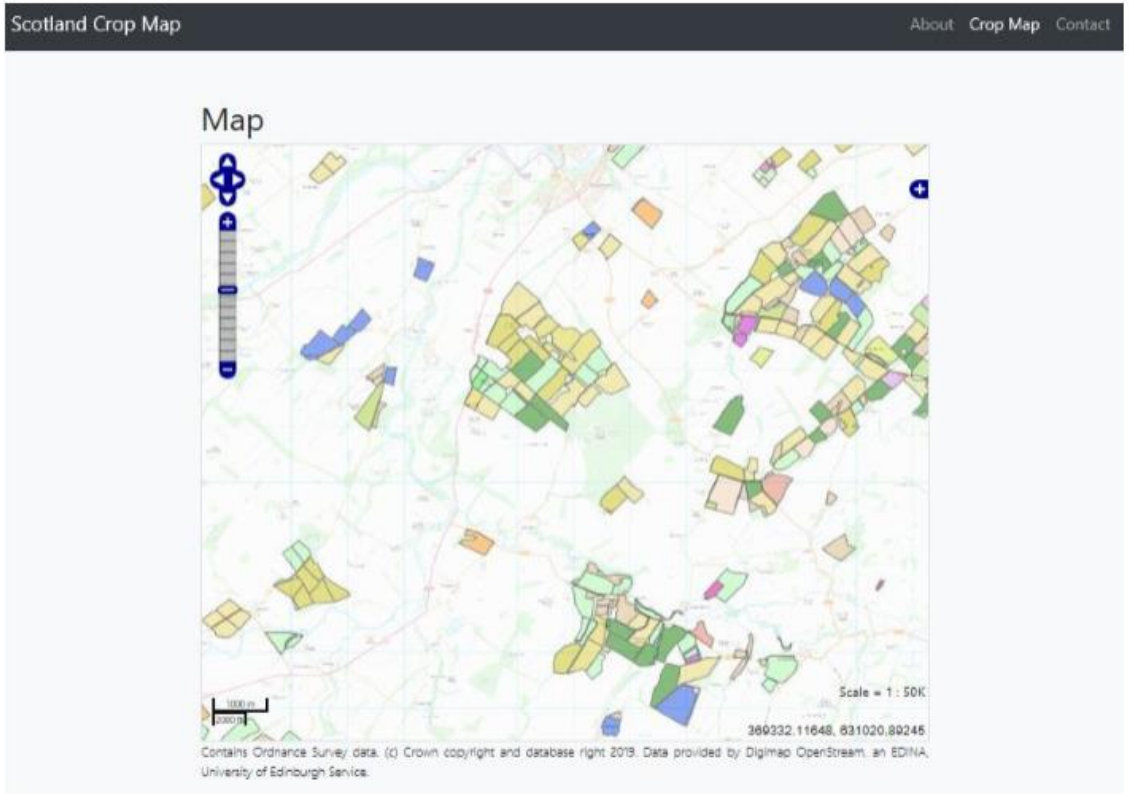




Crop Mapping

Sentinel-1 and Sentinel-2 ARD are being used with ancillary datasets to produce an up-to-date Crop Map of Scotland.

This is a valuable tool for agricultural and environmental policy makers and regulatory bodies.



EDINA THE UNIVERSITY of EDINBURGH

Scottish Government
Riaghaltas na h-Alba
gov.scot

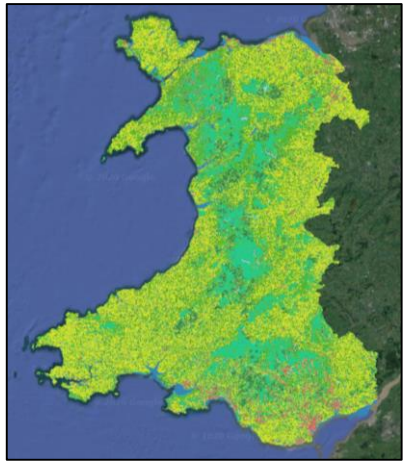
RESAS
Rural & Environmental Science and Analytical Services

JNCC

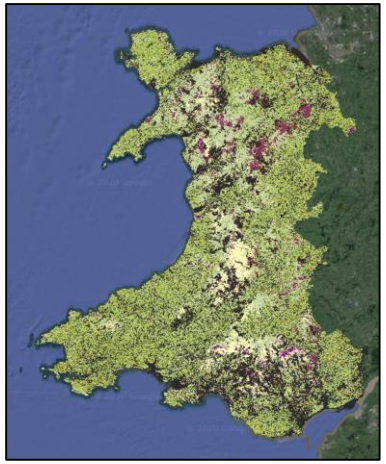
Habitat Mapping (and more!)

- Living Wales is a research project aiming to significantly advance the use of EO data in Wales and internationally.
- An open system encouraging collaboration and engagement from all sectors across a multitude of users.
- Pro-active approach emphasizing use of EO for sustainably managing, using, conserving and restoring landscapes.
- Spatial outputs to address key environmental and social issues.
- Quantitative biophysical data to assess change and trends.
- Detailed, high resolution land cover and habitat classifications.

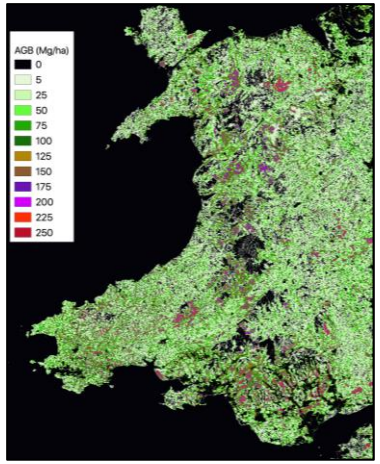
Land cover classifications



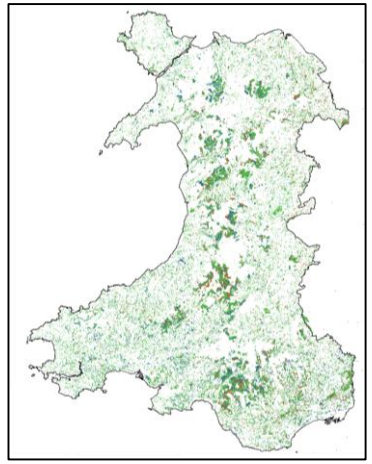
Dominant plant species



Above ground biomass ~ carbon



Changes in canopy cover 2005 - 2015

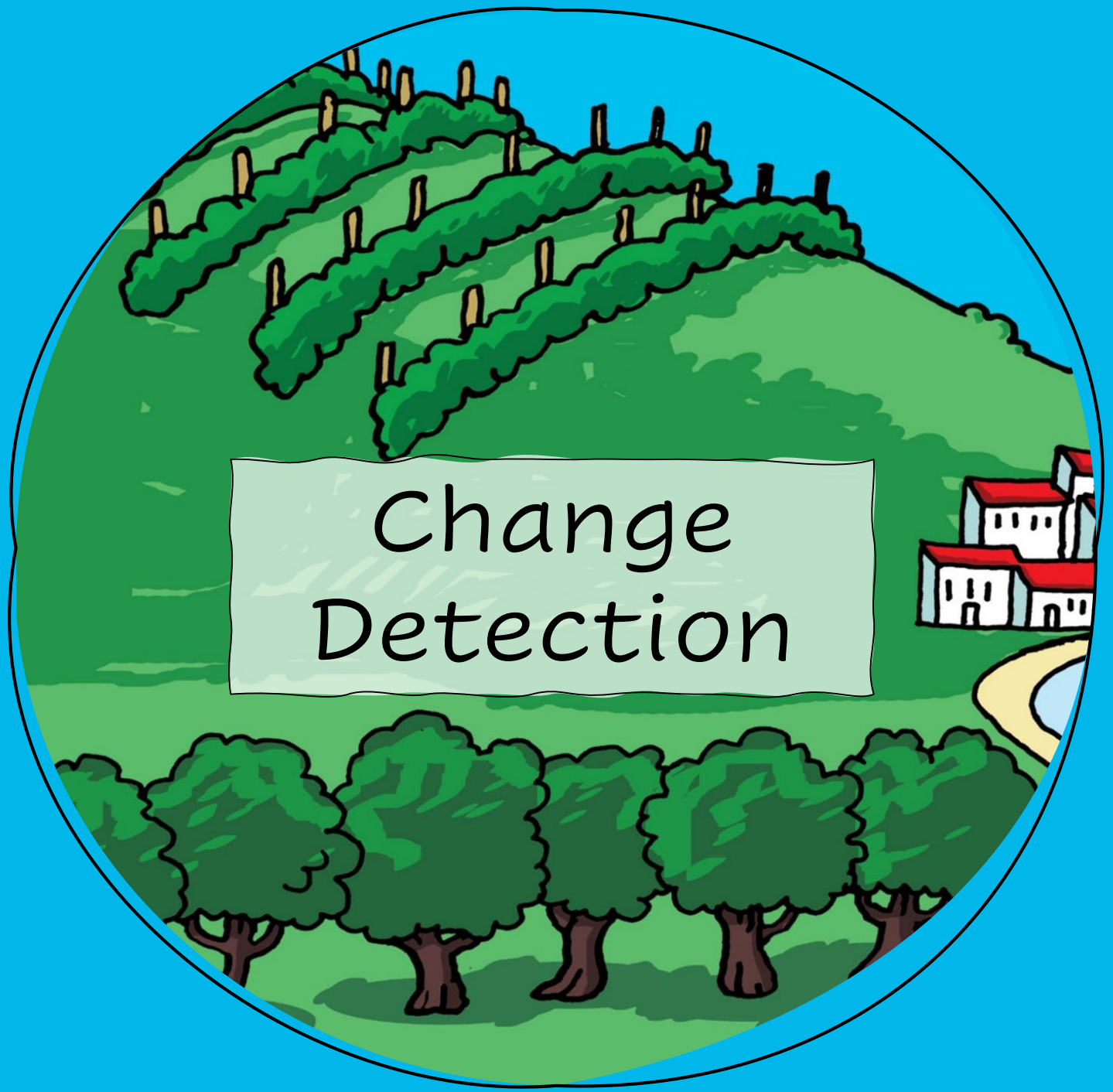


https://wales.livingearth.online/

LIVING WALES

1872 PRIFYSGOL ABERYSTWYTH UNIVERSITY

Llywodraeth Cymru
Welsh Government


Change
Detection

Change Detection

- EO-derived habitat mapping is becoming well established, but evidence on habitat condition and change over time is lacking.
- JNCC developed a web-based app enabling use of Sentinel-1 and -2 ARD to detect change in habitats and historical landscape features.
- Natural England, Historic Environment Scotland, Nature.Scot and Natural Resources Wales are testing it at eight pilot sites across the UK.
- Feedback from end-users will inform development from proof of concept to national-scale operational application.
- Decision-support tool could reduce costs and improve policy delivery through effective targeting of survey and management resources.

Chang

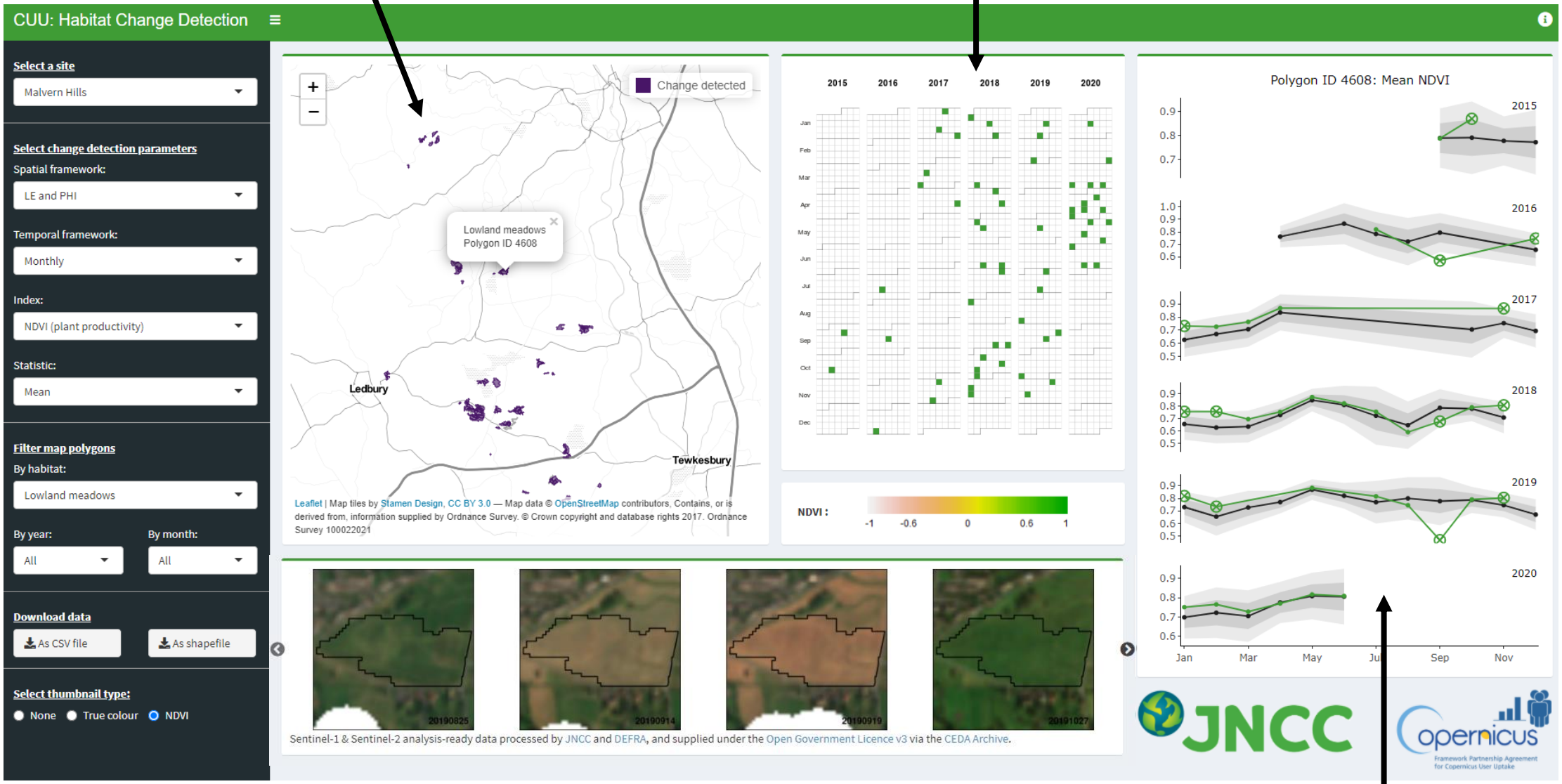
Polygons whose index value exceeds the mean index value for the habitat by >1 standard deviation.

Dates of imagery used to generate index values.

Filters

- Site
- Months or seasons
- Index
- Statistic
- Habitat

Download data as .csv or shapefile.



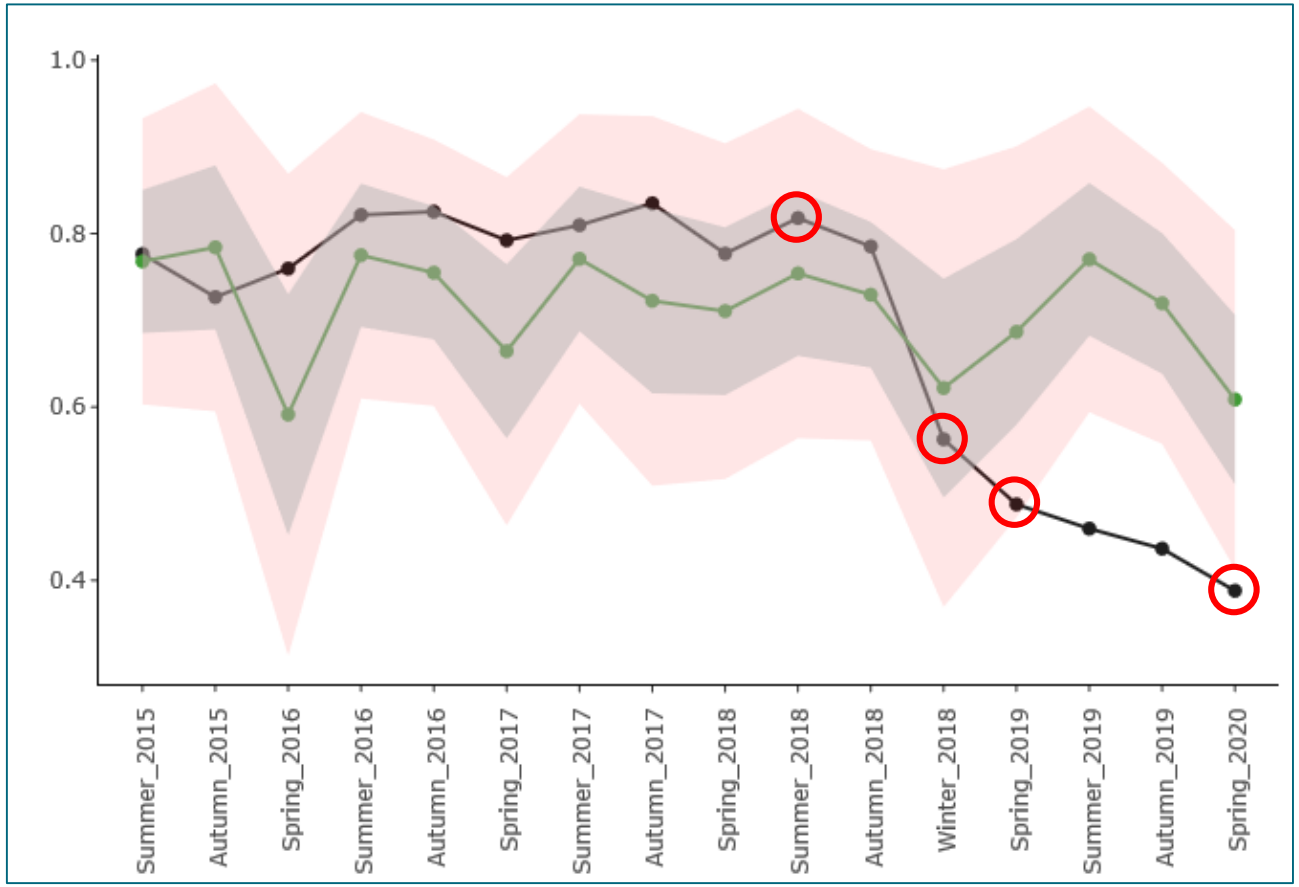
Thumbnails of imagery or indices.

Mean index value of selected polygon and all polygons of the habitat. Shaded areas = 1 and 2 standard deviations.

Change Detection

Example:

Coniferous woodland at Insh Marshes SSSI, Scotland.

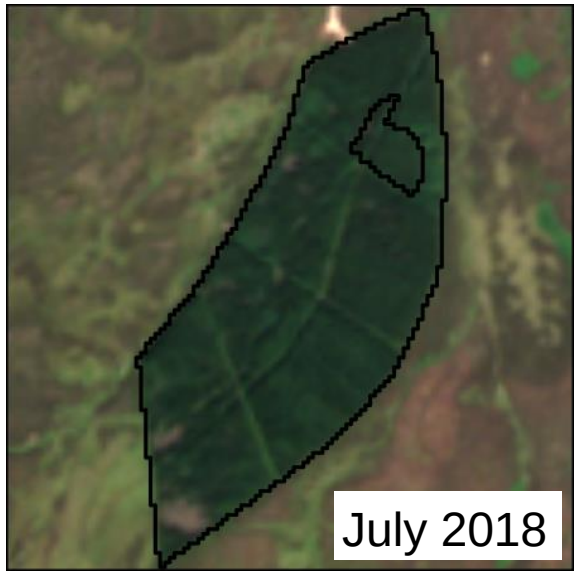


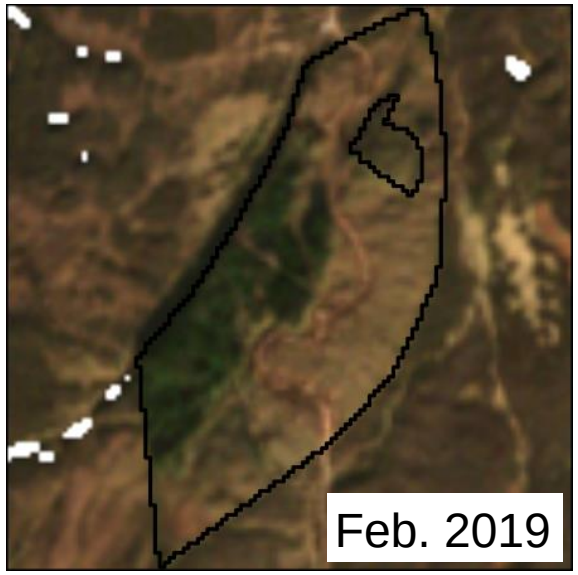
Black line: mean NDVI for selected polygon

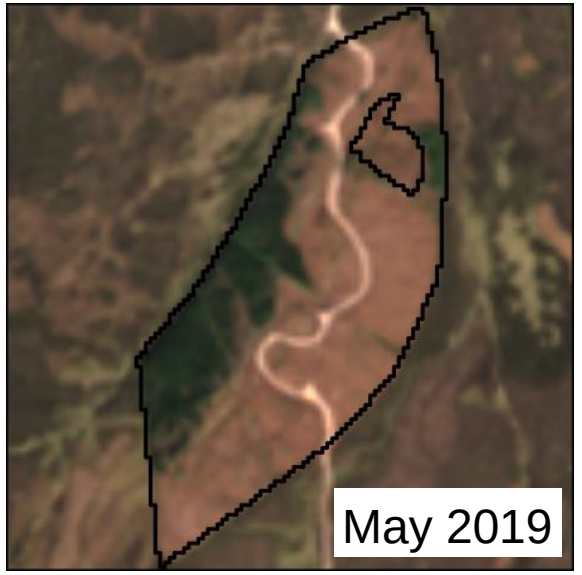
Green line: mean NDVI for all polygons of coniferous woodland

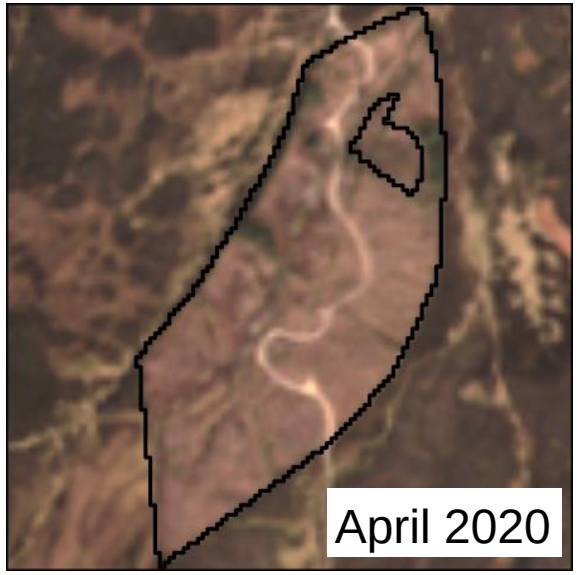
Grey band: 1 standard deviation

Pink band: 2 standard deviations





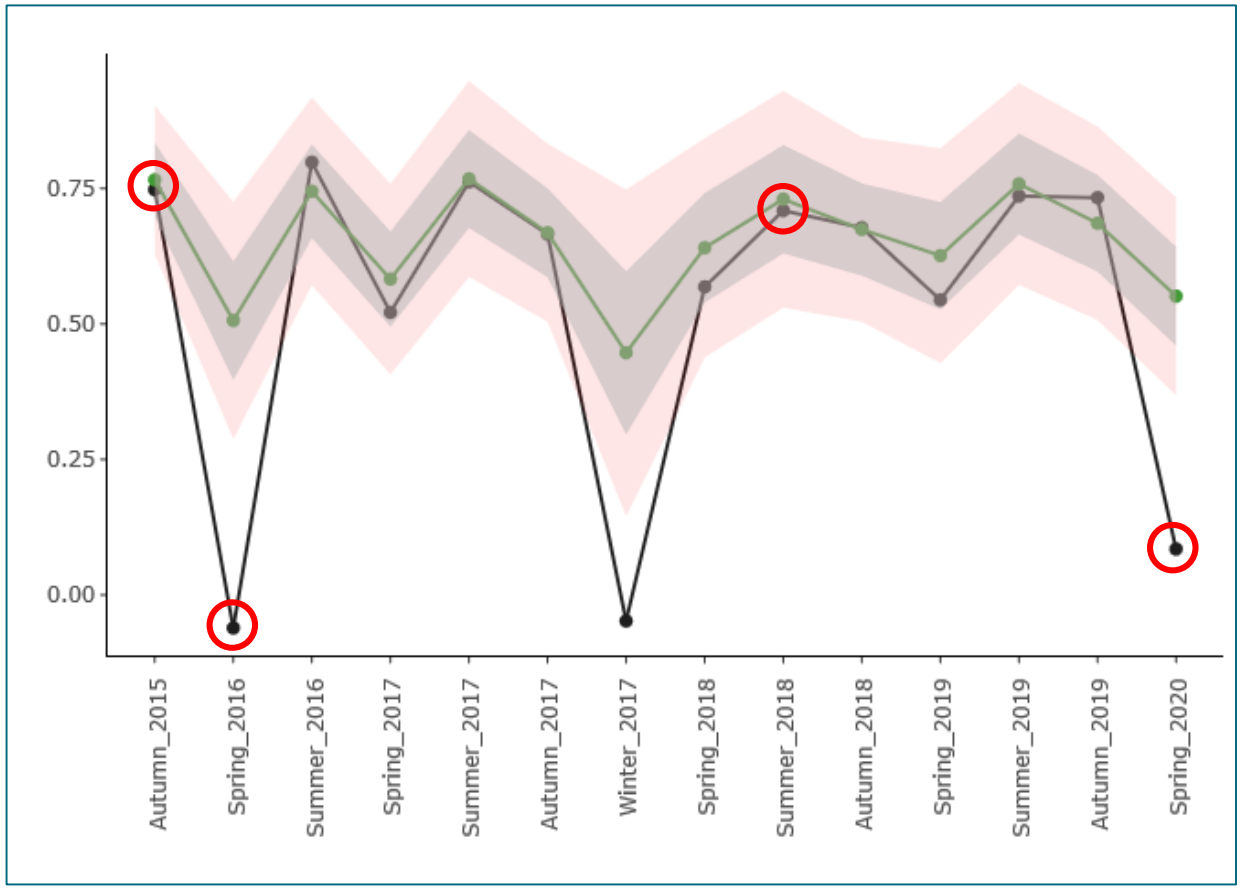




Change Detection

Example:

Temperate shrub heath at Insh Marshes SSSI.



Black line: mean NDVI for selected polygon
Green line: mean NDVI for all polygons of coniferous woodland
Grey band: 1 standard deviation
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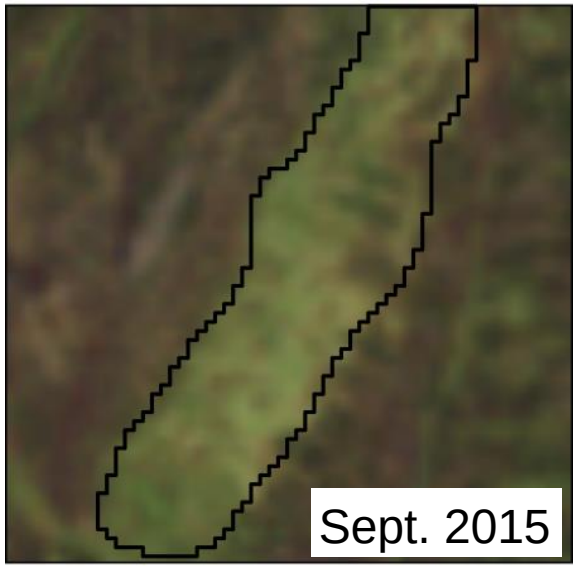
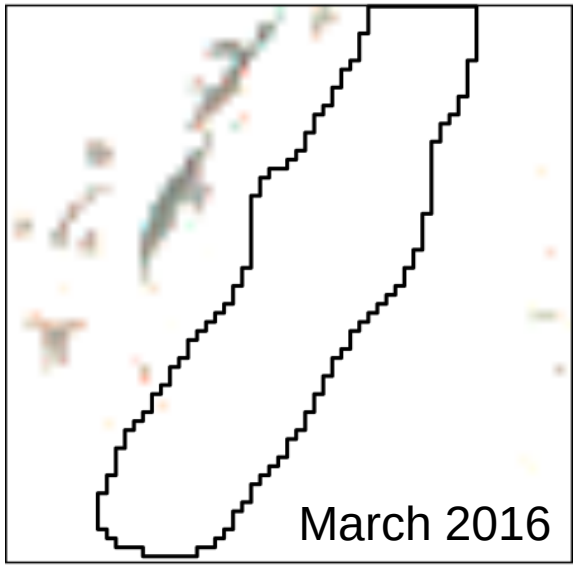
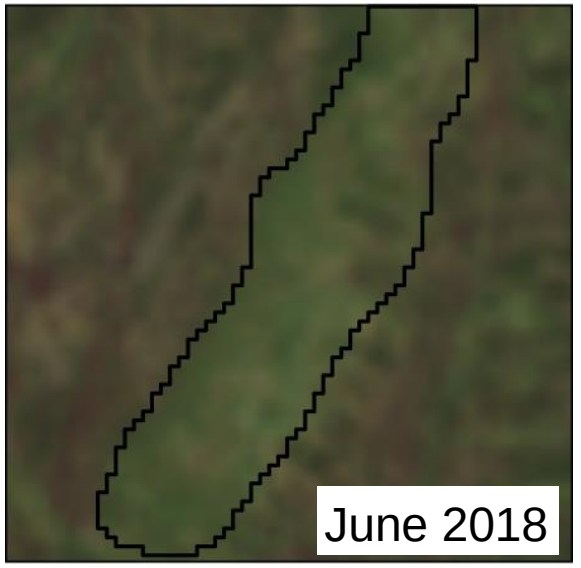
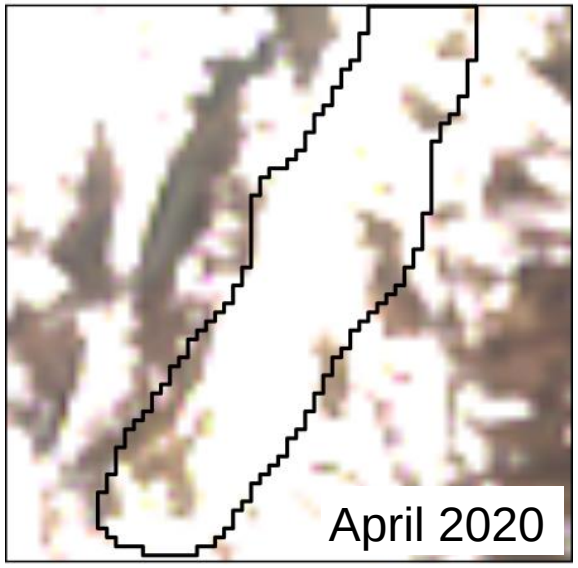








Erosion
Risk

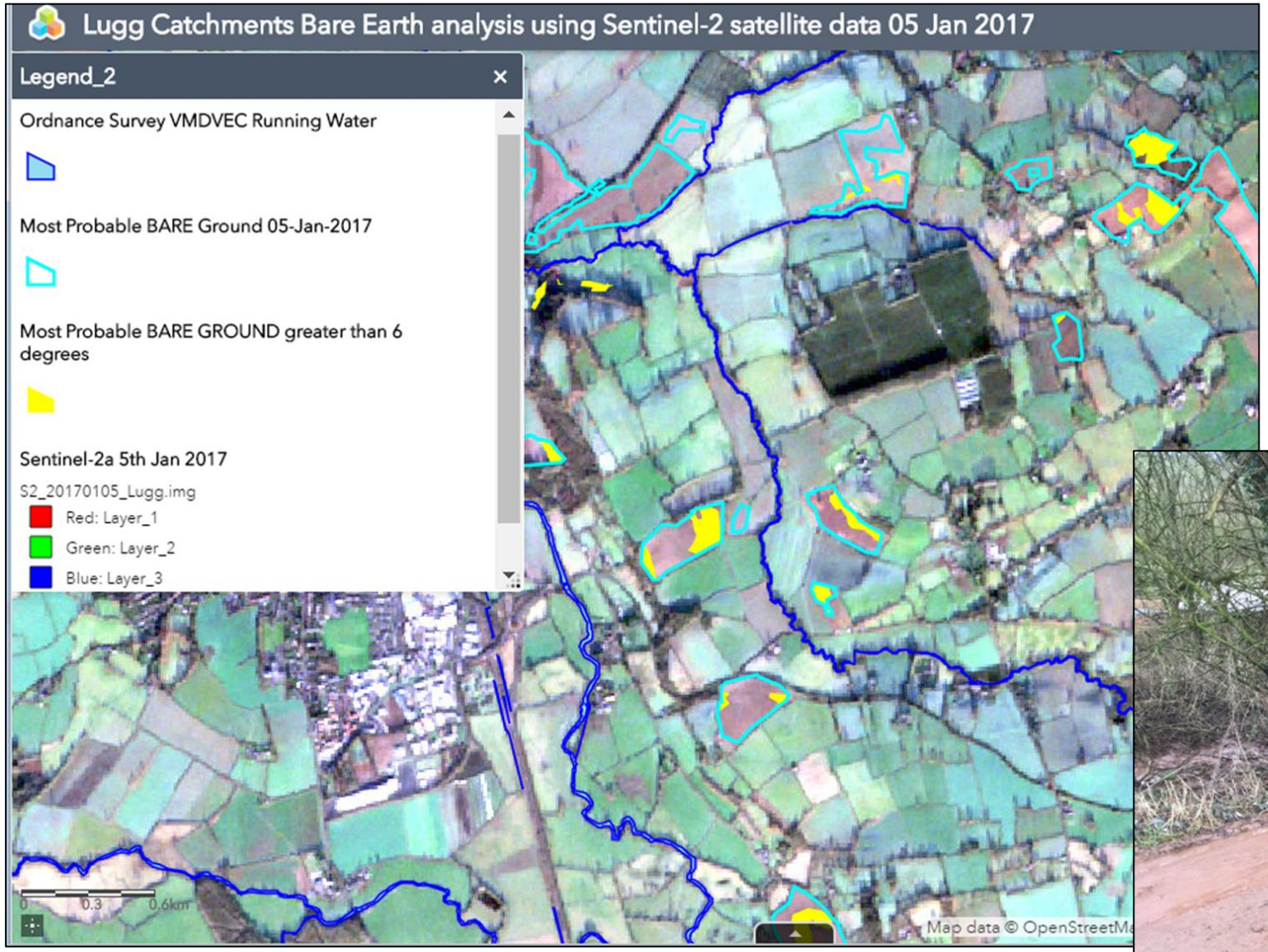
Erosion and water quality risk

Environment Agency's Agricultural Land Environmental Risk Tool (ALERT) predicts risk of erosion and run-off into water bodies.

It combines:

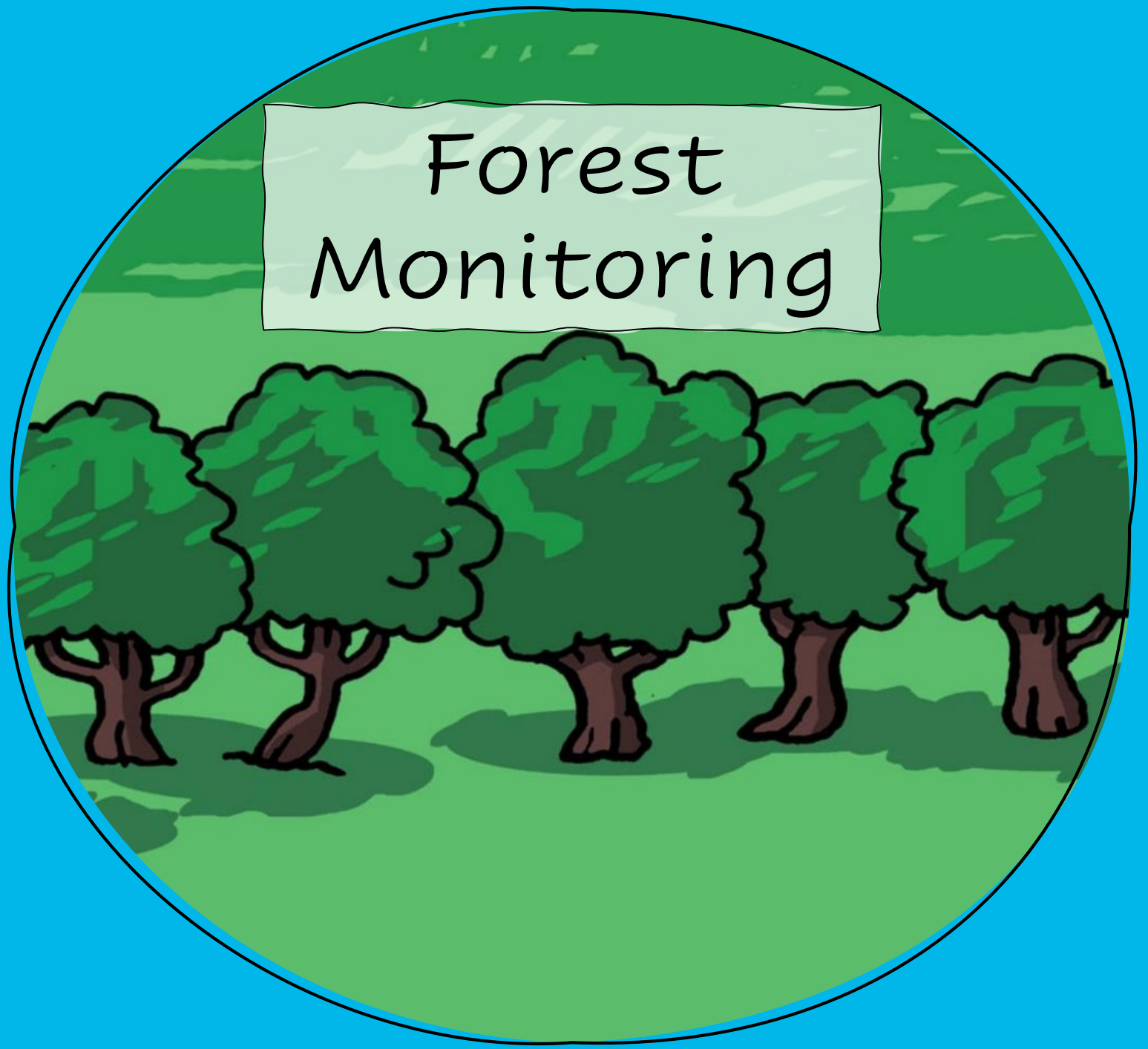
- Flow pathways
- Mini sub-catchments / watersheds
- Slope
- Bare soil information
- Recent crop information
- Fine scale elevation data
- Recent satellite imagery

Erosion and water quality risk



The Soil Patrol app uses Sentinel-2 imagery to highlight areas of bare ground.

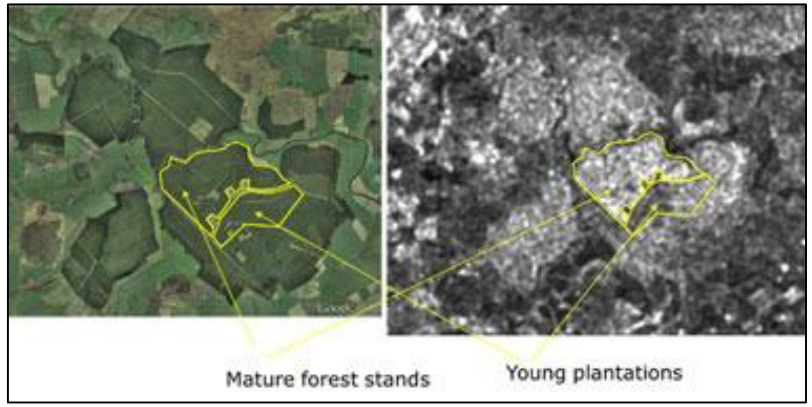
This helps the EA's Environment Officer to target field visits more effectively.

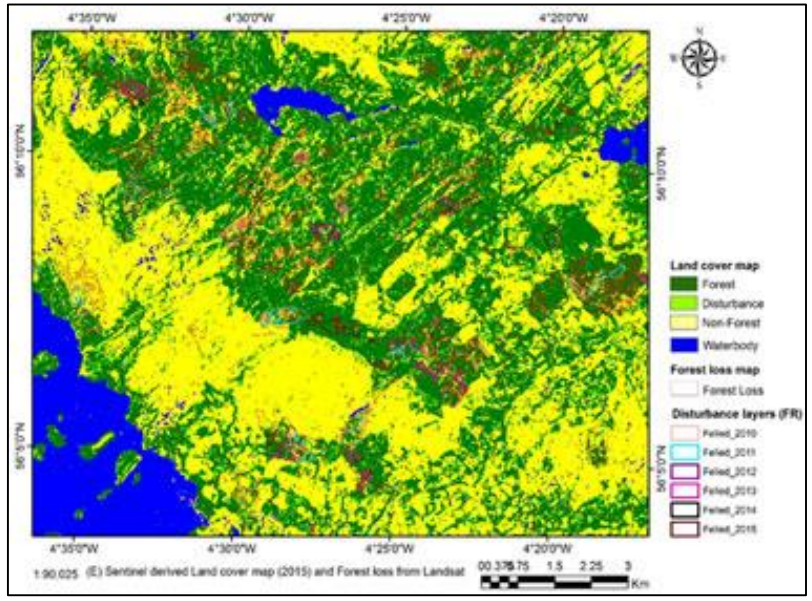

Forest
Monitoring

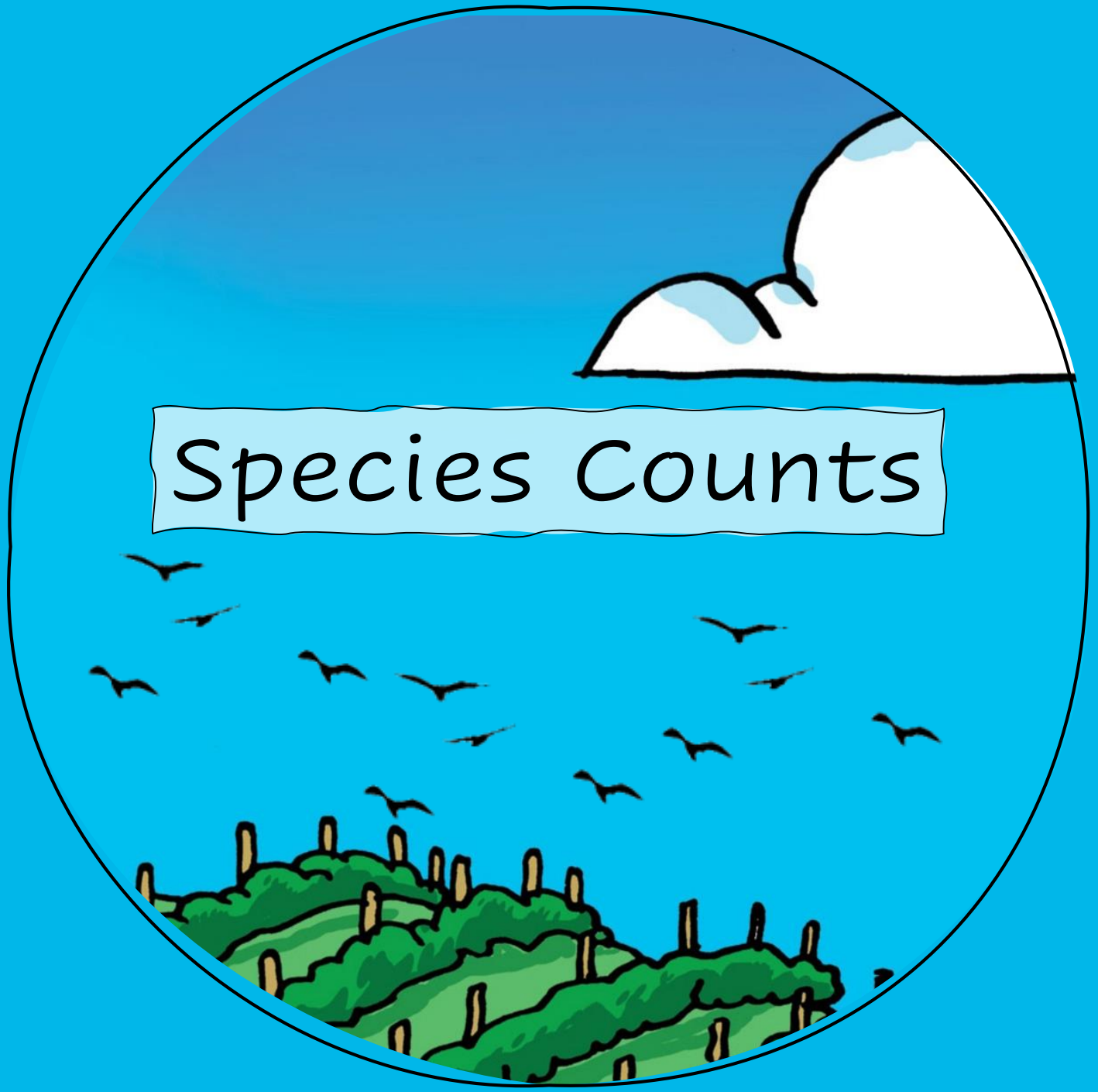
Forest Monitoring

Forest Research

- Forest Research use Sentinel-1 and Sentinel-2 ARD to:
  - update the National Forest Inventory
  - classify woodland e.g. mature stands, young plantations
  - detect change in near real-time e.g. storm damage, logging
  - detect and monitor trees outside of woodland
- Automated analysis maximises benefits of Copernicus frequent revisit times.
- Enables more efficient use of resources by targeting site visits more effectively.
- Helps to improve understanding of carbon stocks, natural capital and ecosystem services.






Species Counts

Species Counts

Natural England use a fixed wing drone to photograph breeding bird colonies without disturbing them.

NATURAL ENGLAND

Belmont Reservoir – Gull Colony 18 May 2017

Species Counts

Natural England use a fixed wing drone to photograph breeding bird colonies without disturbing them.

Automated image analysis enables fast and accurate counts.

There are 3,099 gulls in this image!

NATURAL ENGLAND

Belmont Reservoir – Gull Colony 18 May 2017

Species Counts

Species can be detected and potentially counted using very high resolution commercial satellite imagery.

Potential benefits

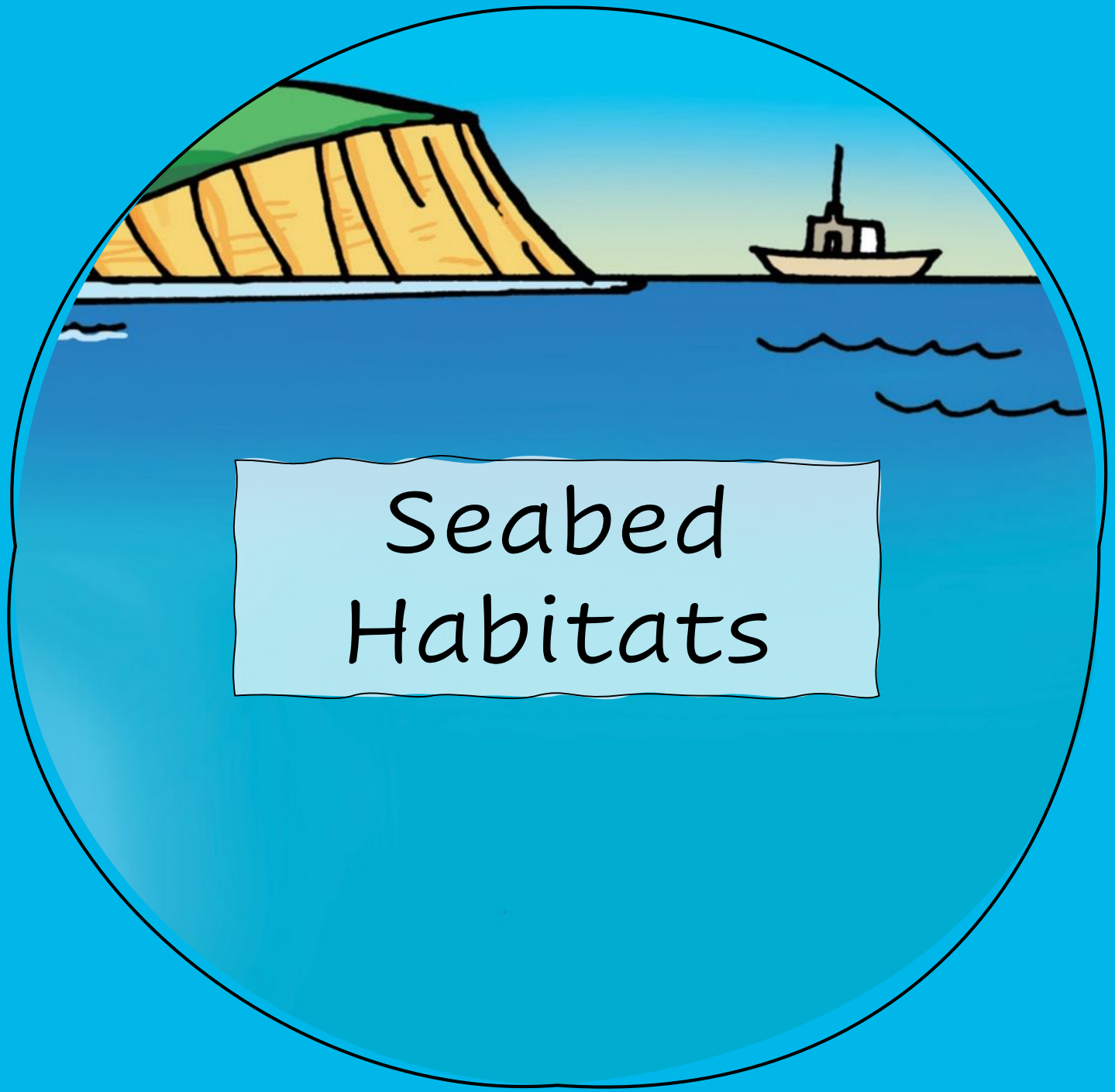
- Access remote locations
- Increase spatial and temporal survey coverage
- Monitor cryptic species e.g. deep divers
- Fill gaps to improve distribution modelling

Limitations

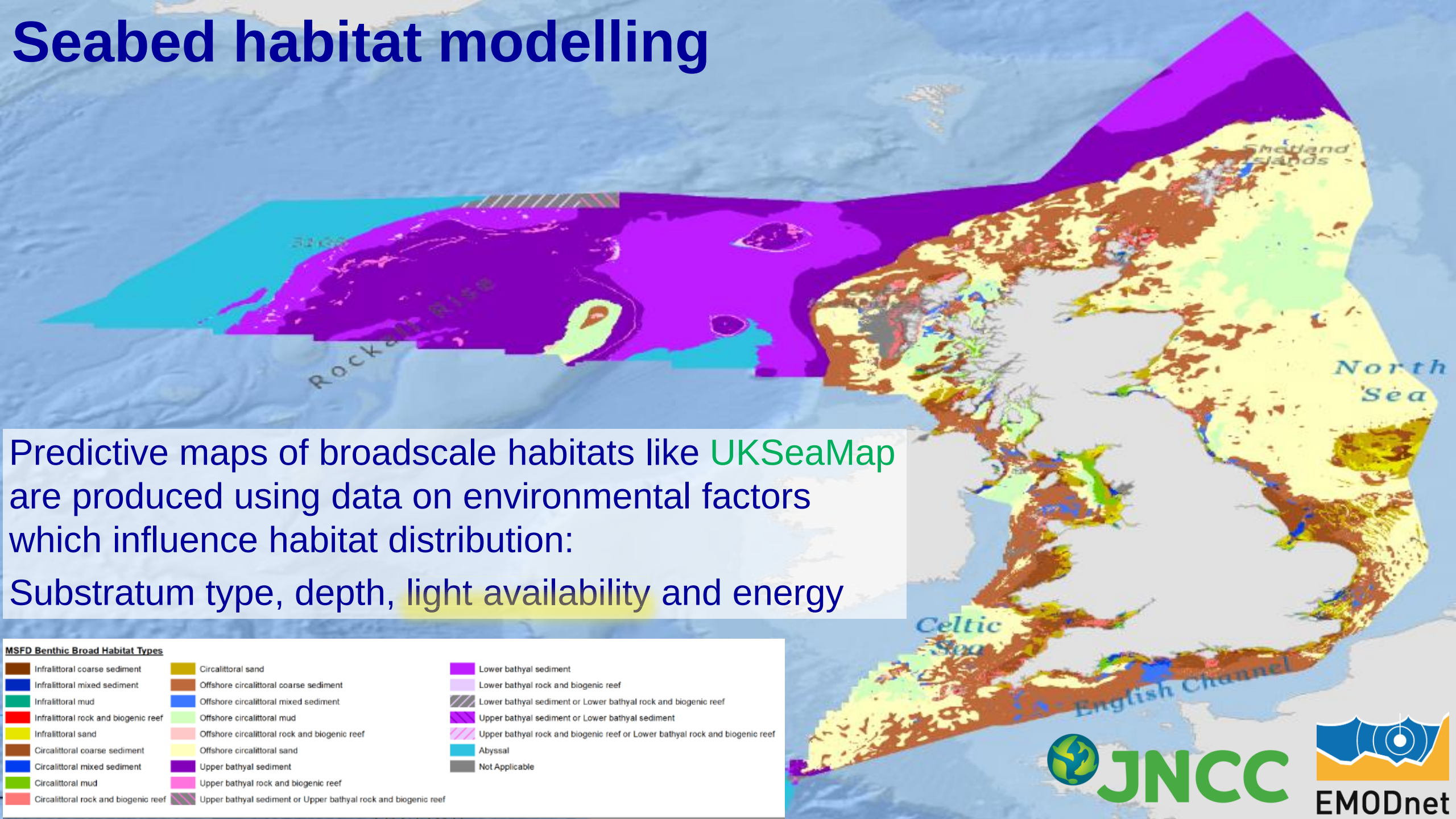
- Cost of required resolution data
- Size of animal that is detectable
- Species ID challenging
- Weather constraints
- Ground-truthing of remote data can be difficult

Fin Whale © Digital Globe (Maxar)

Emperor penguin colony at Cape Roget © Digital Globe (Maxar)


Seabed
Habitats

Seabed habitat modelling



Predictive maps of broadscale habitats like UKSeaMap are produced using data on environmental factors which influence habitat distribution:

Substratum type, depth, light availability and energy

MSFD Benthic Broad Habitat Types

- Infralittoral coarse sediment
- Infralittoral mixed sediment
- Infralittoral mud
- Infralittoral rock and biogenic reef
- Infralittoral sand
- Circalittoral coarse sediment
- Circalittoral mixed sediment
- Circalittoral mud
- Circalittoral rock and biogenic reef
- Circalittoral sand
- Offshore circalittoral coarse sediment
- Offshore circalittoral mixed sediment
- Offshore circalittoral mud
- Offshore circalittoral rock and biogenic reef
- Offshore circalittoral sand
- Upper bathyal sediment
- Upper bathyal rock and biogenic reef
- Upper bathyal sediment or Upper bathyal rock and biogenic reef
- Lower bathyal sediment
- Lower bathyal rock and biogenic reef
- Lower bathyal sediment or Lower bathyal rock and biogenic reef
- Upper bathyal sediment or Lower bathyal sediment
- Upper bathyal rock and biogenic reef or Lower bathyal rock and biogenic reef
- Abyssal
- Not Applicable

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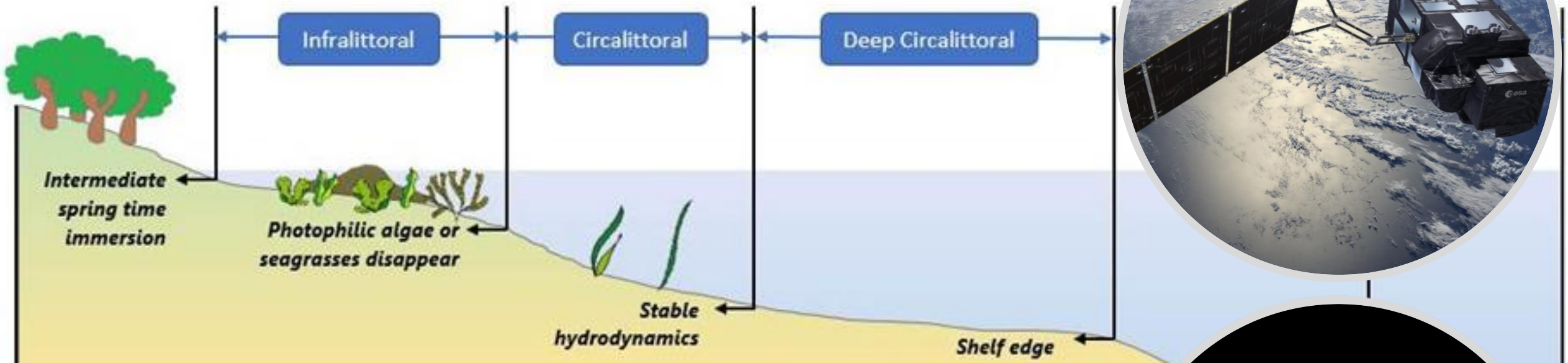
EMODnet

Seabed habitat modelling

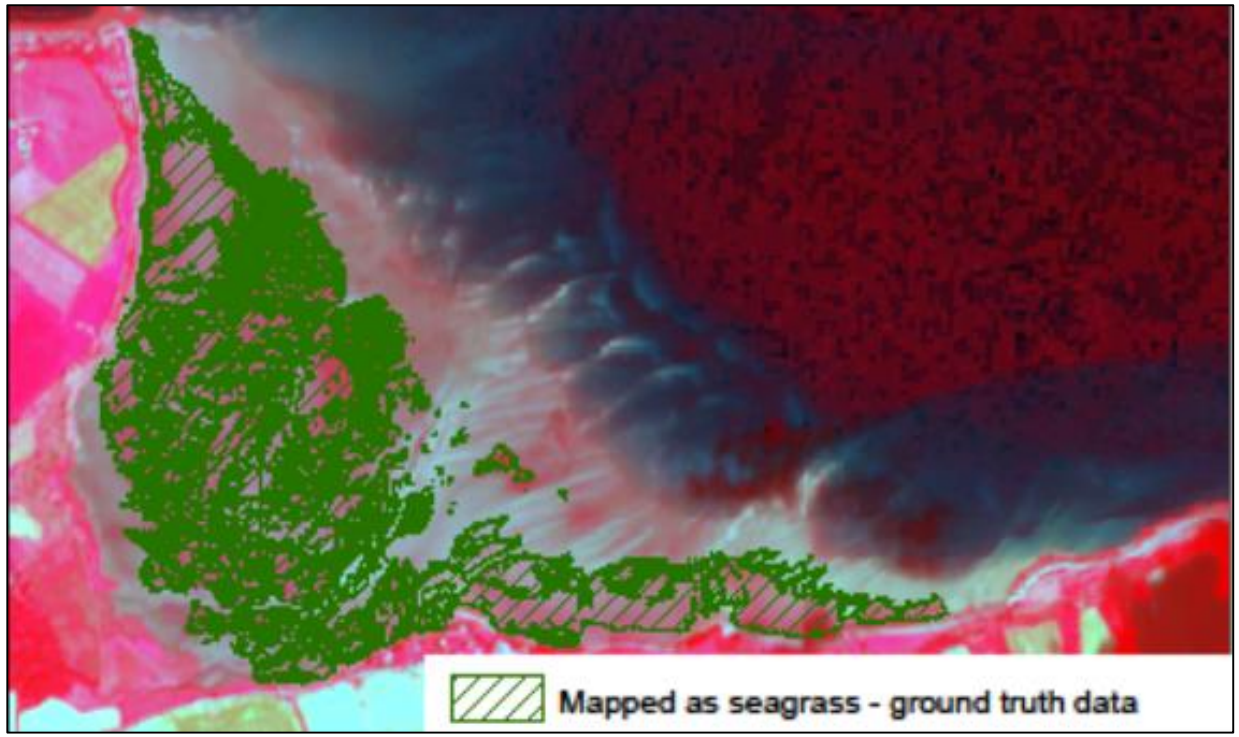


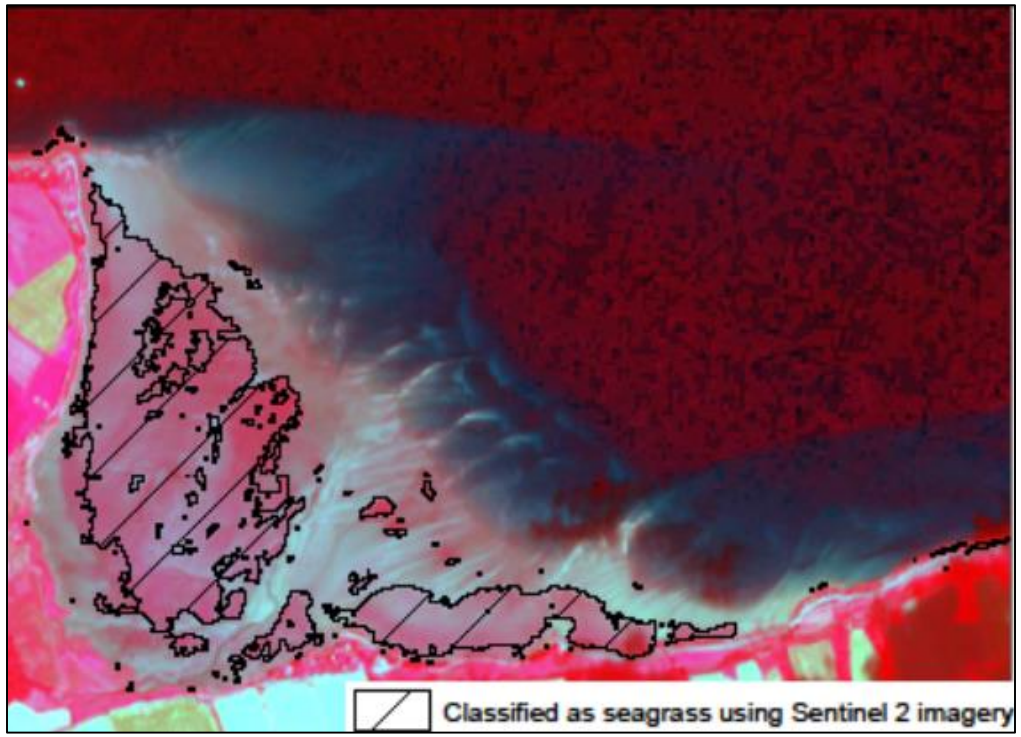
Light availability at the seabed strongly influences the distribution of species communities. It is calculated from

- Photosynthetically Available Radiation (PAR) at the sea surface.
- Light attenuation in water (K_{dPAR}).
- Depth to seabed

Light availability maps can be derived from ocean colour sensors e.g. ENVISAT MERIS or Sentinel-3 OLCI.

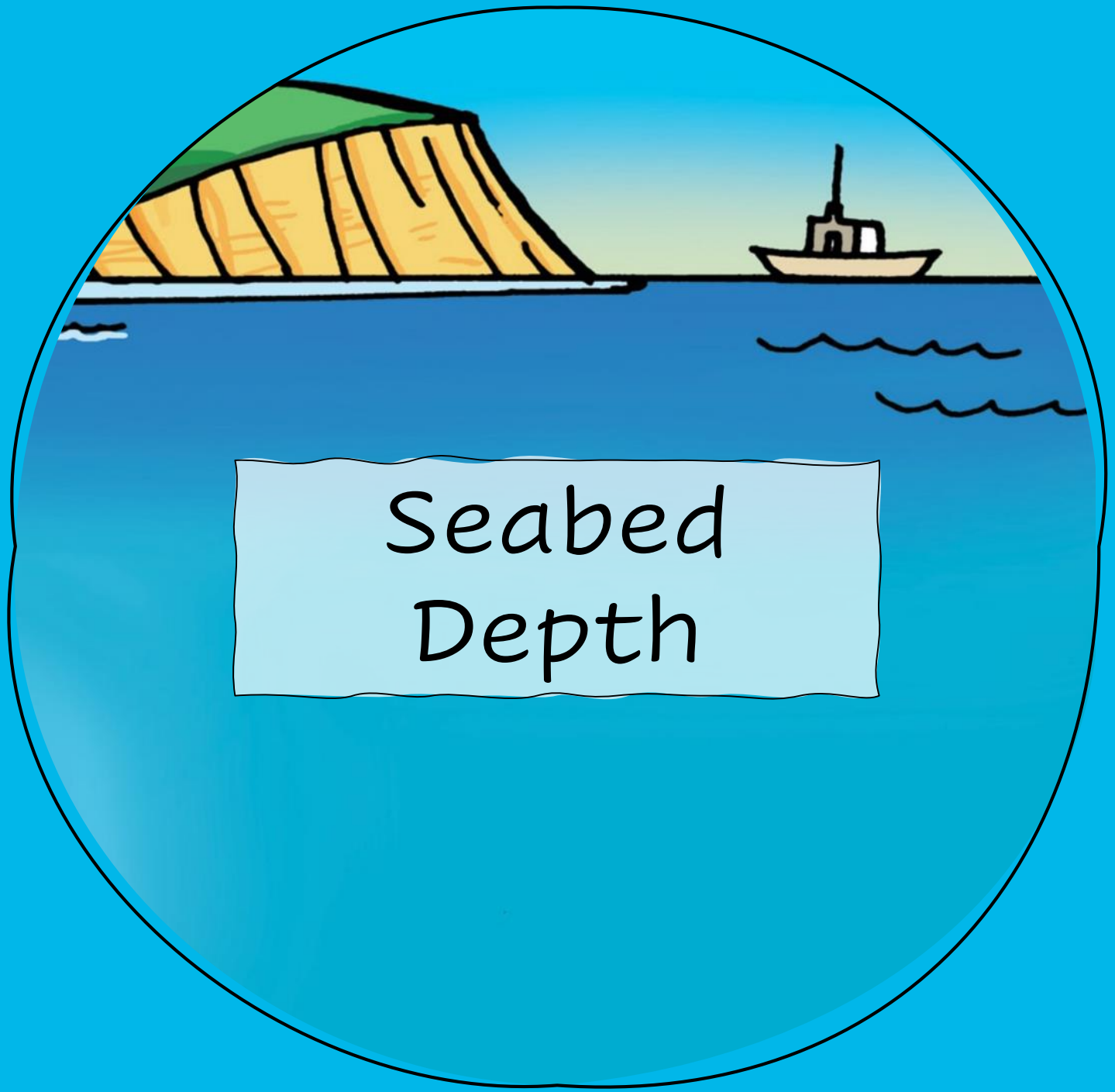
Seagrass Mapping





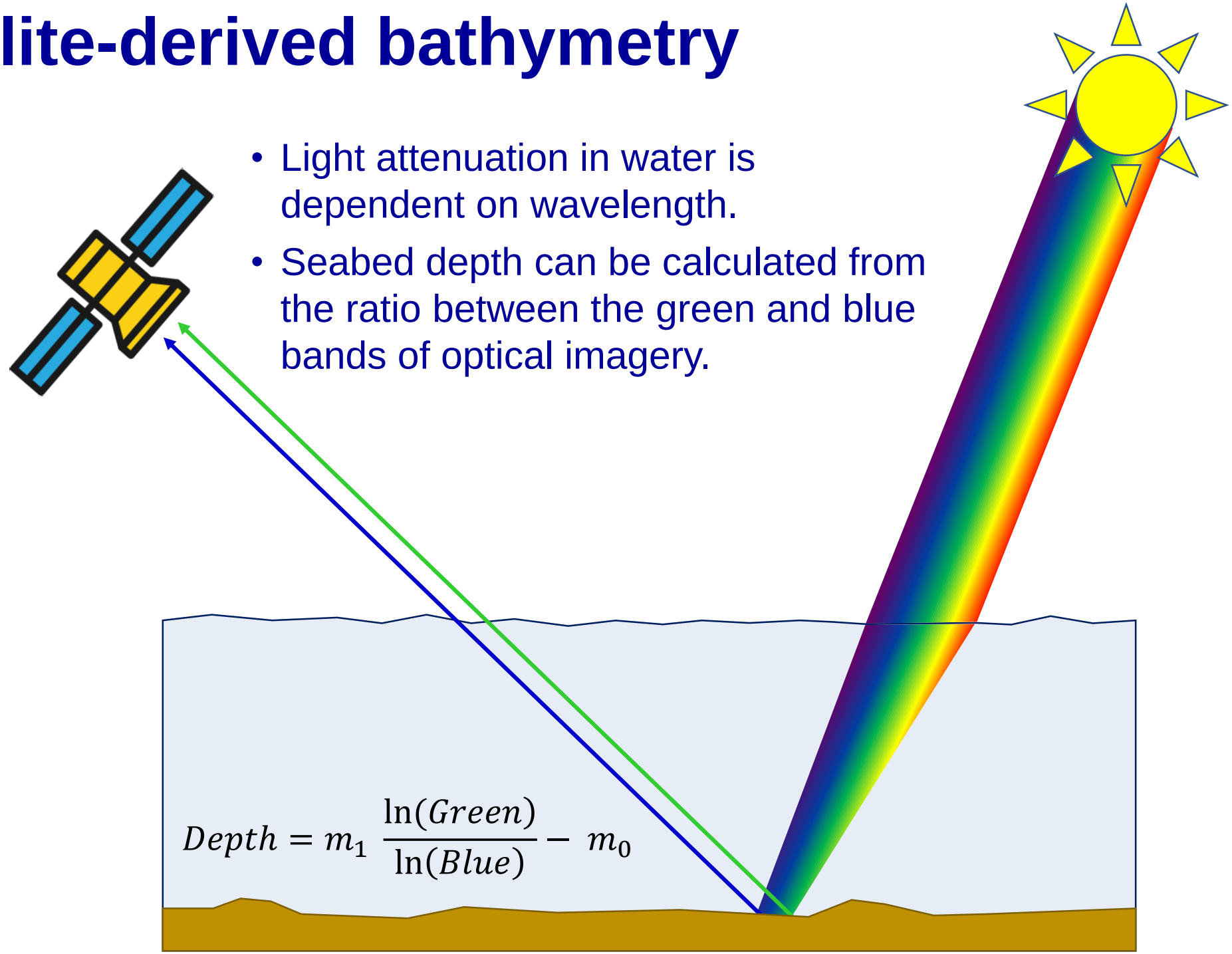
- Seabed habitats can be mapped through analysis of optical imagery, e.g. using machine learning approaches trained by ground truth data.
- Nature.Scot use Sentinel-2 ARD with ancillary datasets to map intertidal seagrass.
- In clear waters, subtidal habitat maps (e.g. coral reefs) can be produced through analysis of optical imagery.

Contains modified Copernicus Sentinel data 2019, processed by JNCC. Contains SEPA data © Scottish Environment Protection Agency and database right 2019. All rights reserved. © Scottish Natural Heritage. GIG joblog ID 88296

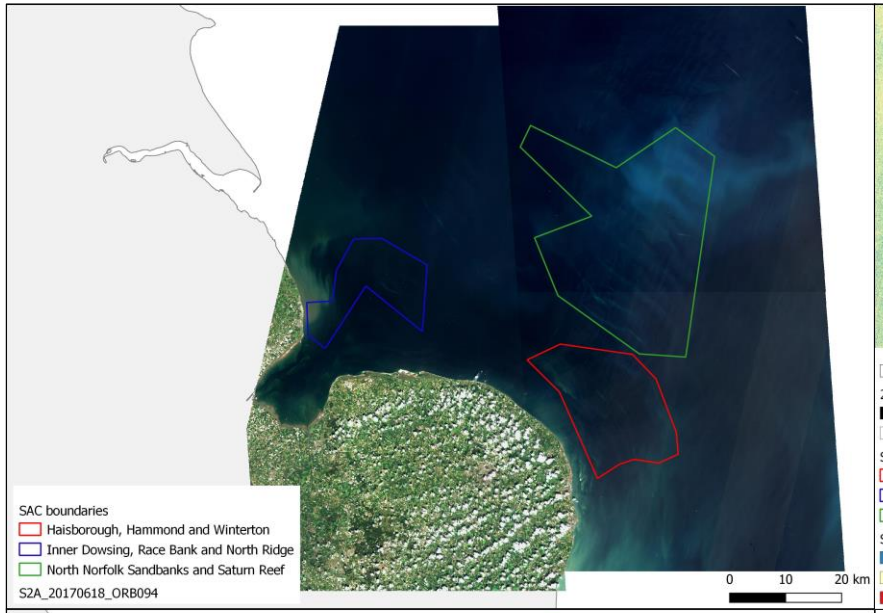

Seabed
Depth

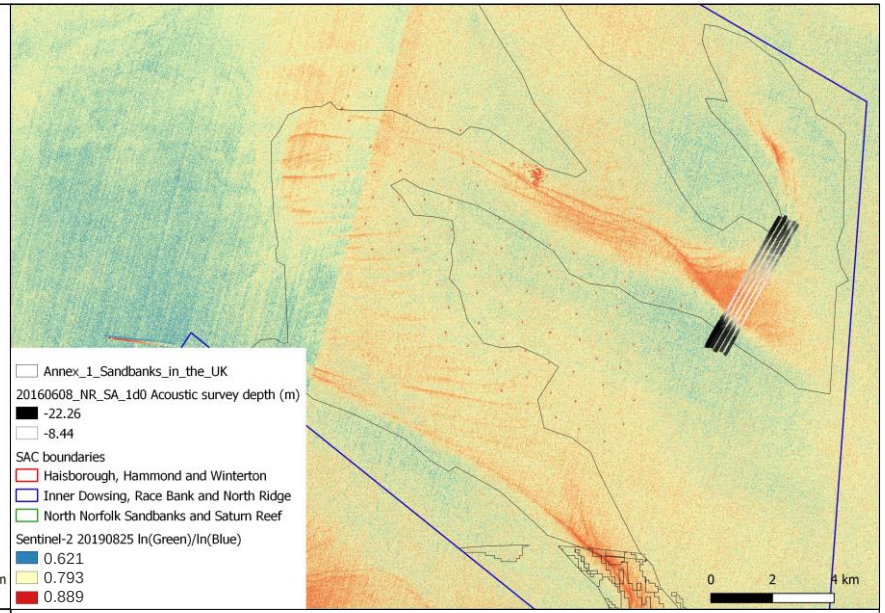
Satellite-derived bathymetry

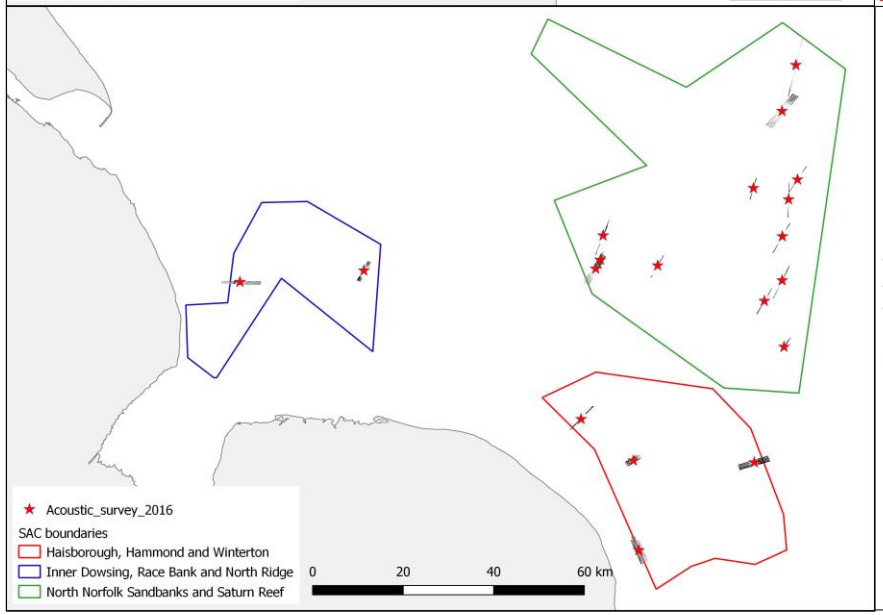
- Light attenuation in water is dependent on wavelength.
- Seabed depth can be calculated from the ratio between the green and blue bands of optical imagery.

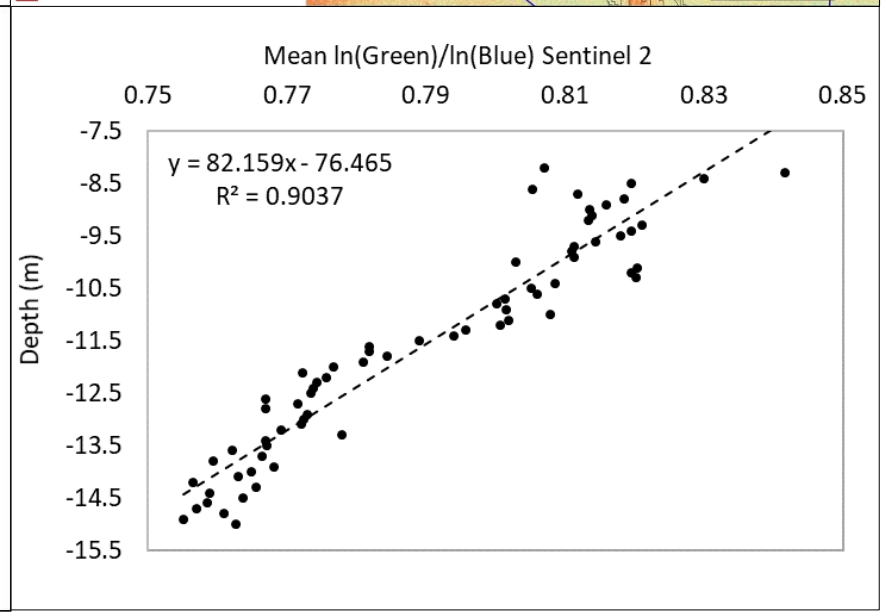


Monitoring subtidal sandbanks









Special Areas of Conservation in North Sea designated for sandbanks.

Sandbanks migrate at around 10m - 100m per year.

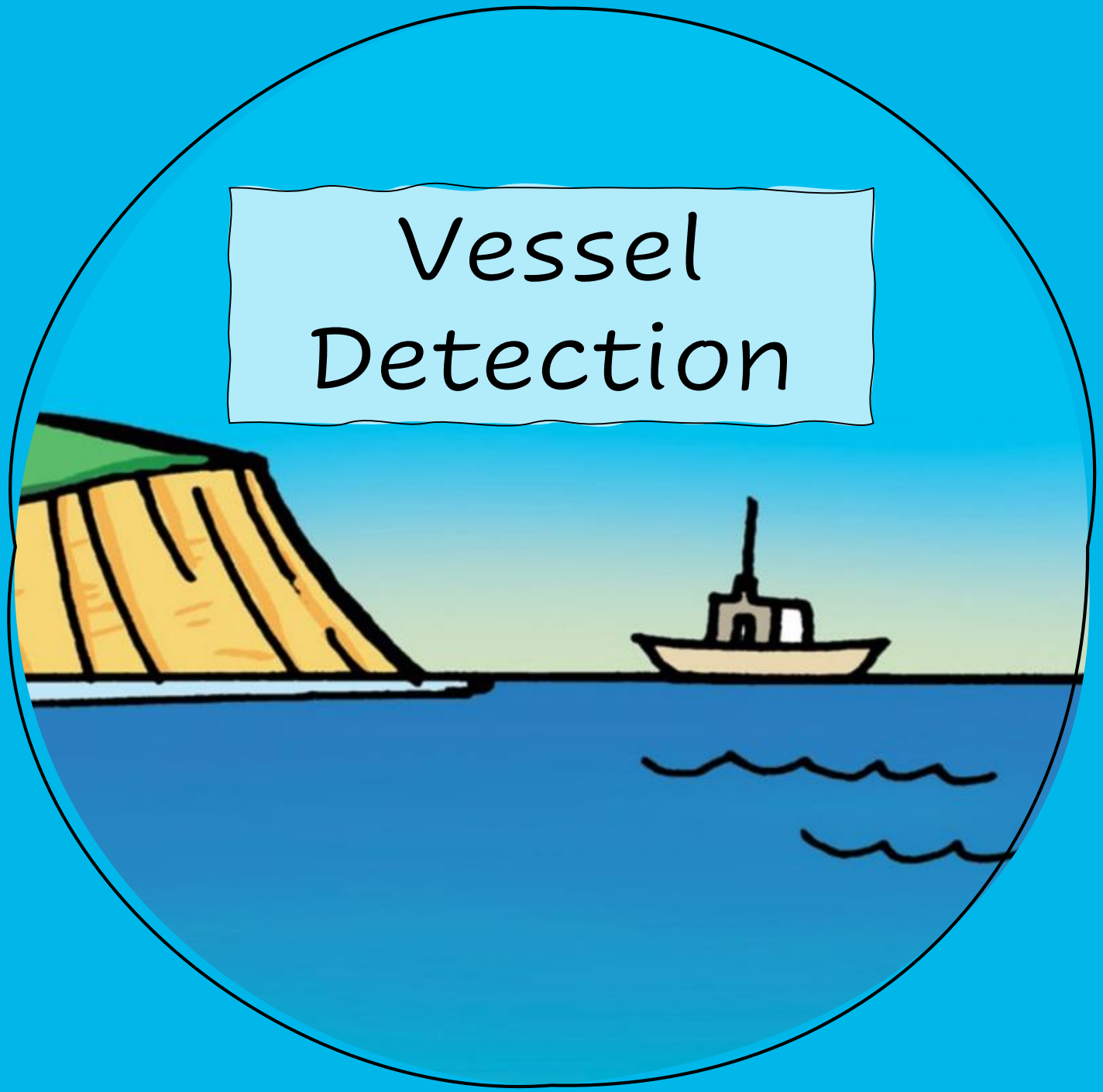
Monitoring by acoustic survey is expensive but sandbank crests can be detected using Sentinel-2 ARD.

Depth predicted using linear regression of the relationship between measured depth and ln(Green)/ln(Blue).

Mean accuracy 1.2m RMSE for depths above 15m.

Newcastle University JNCC

Vessel Detection

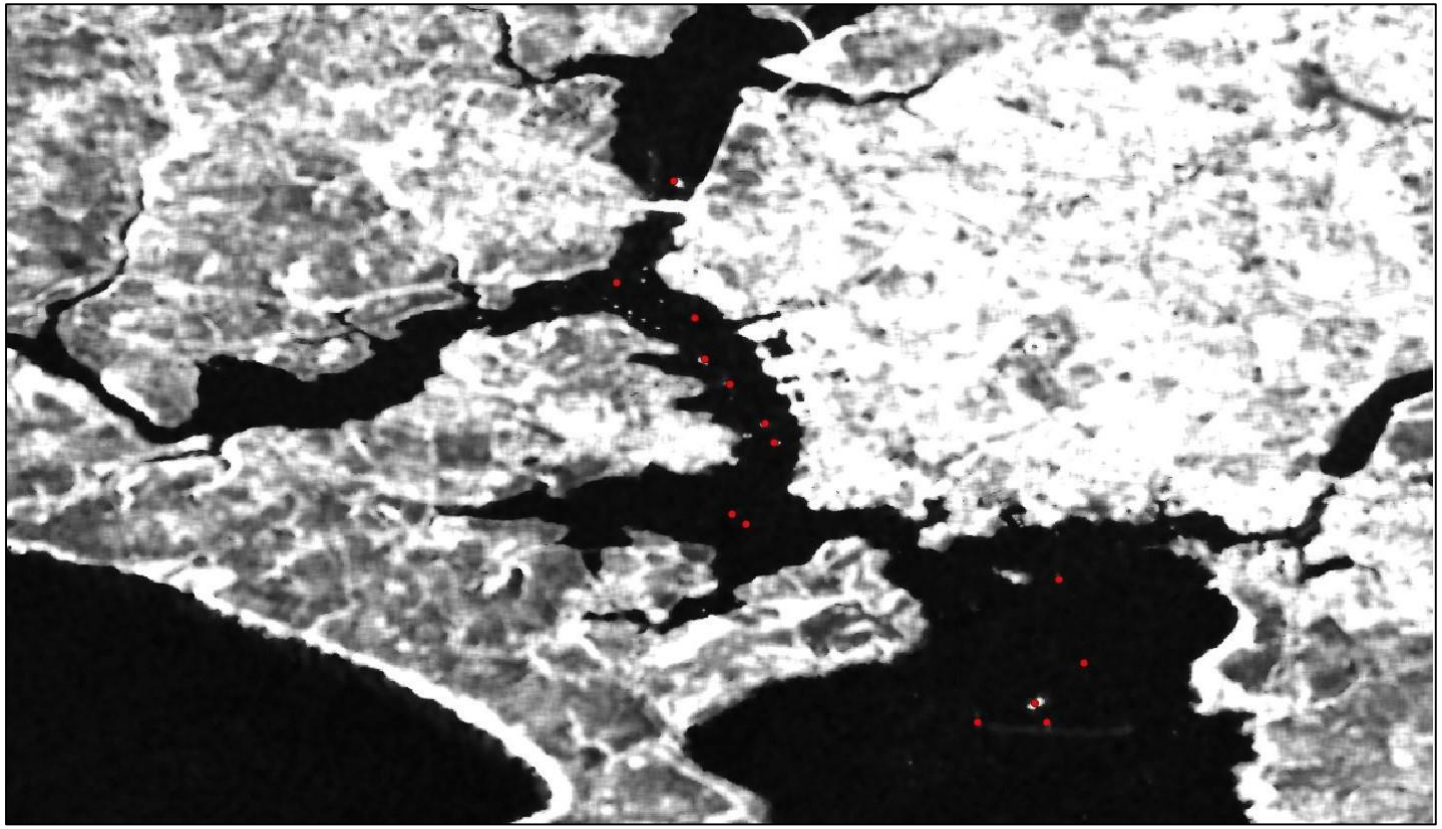


Vessel Detection

- Blue Belt Programme project – using Sentinel for marine monitoring around UK Overseas Territories.
- SCISYS (now CGI) developed Rapid Vessel Detection software in a user-friendly map-based portal.
- Sentinel-1 data can be an effective surveillance tool for illegal, unregulated and unreported (IUU) fishing activities.
- Vessels over 20m can be detected.
- Detections from satellite data can be correlated with Automatic Identification System (AIS) data from vessels.
- 'Dark' vessels, i.e. not transmitting AIS, can be detected.

SCISYS is now part of CGI

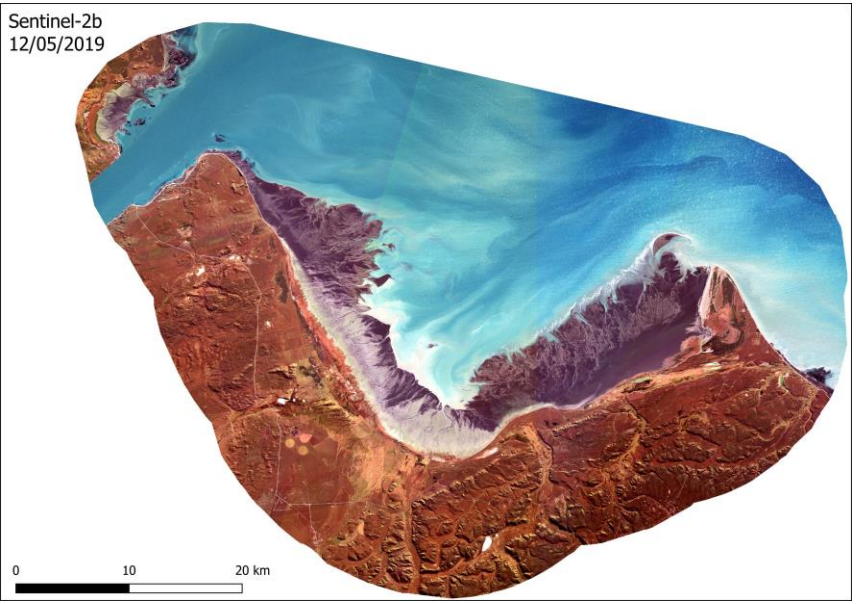
Marine Management Organisation



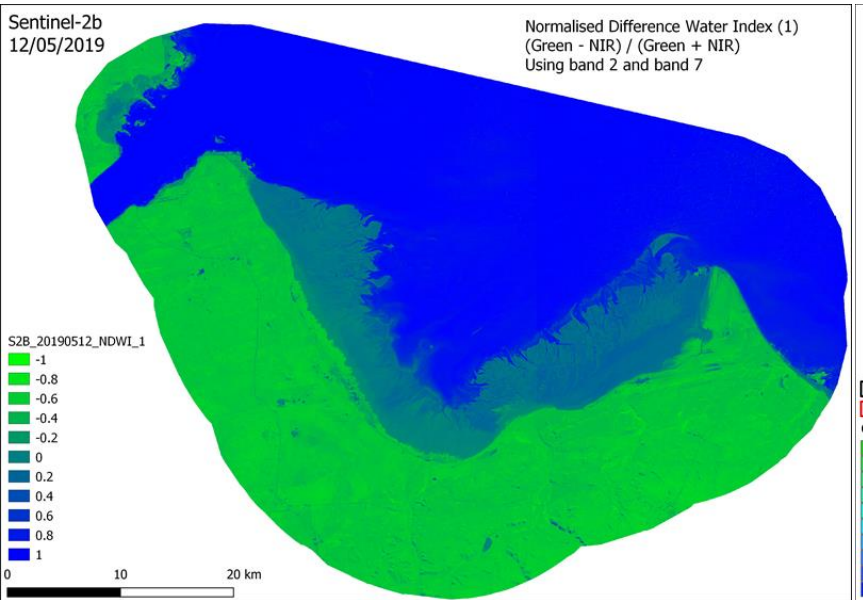
Sentinel-1 vessel detections over the Plymouth channel

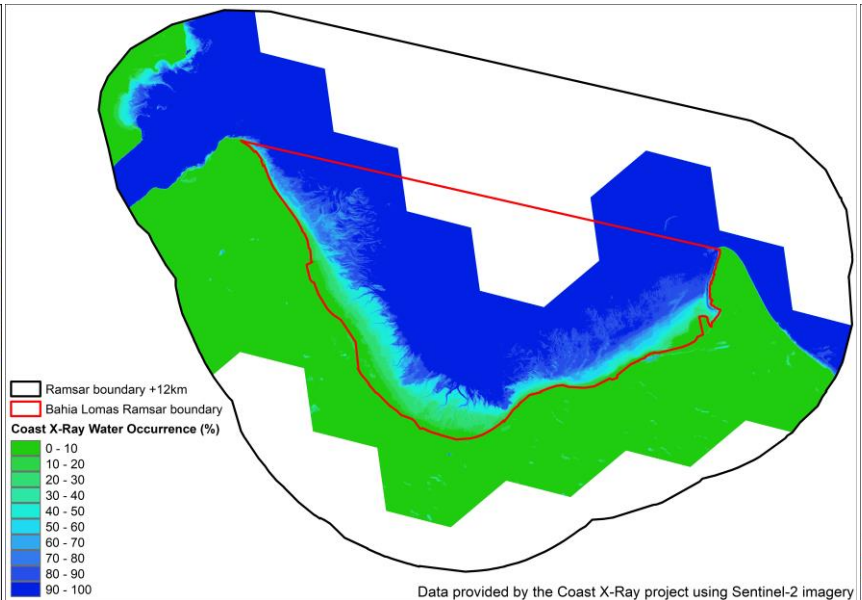
Intertidal
Extent

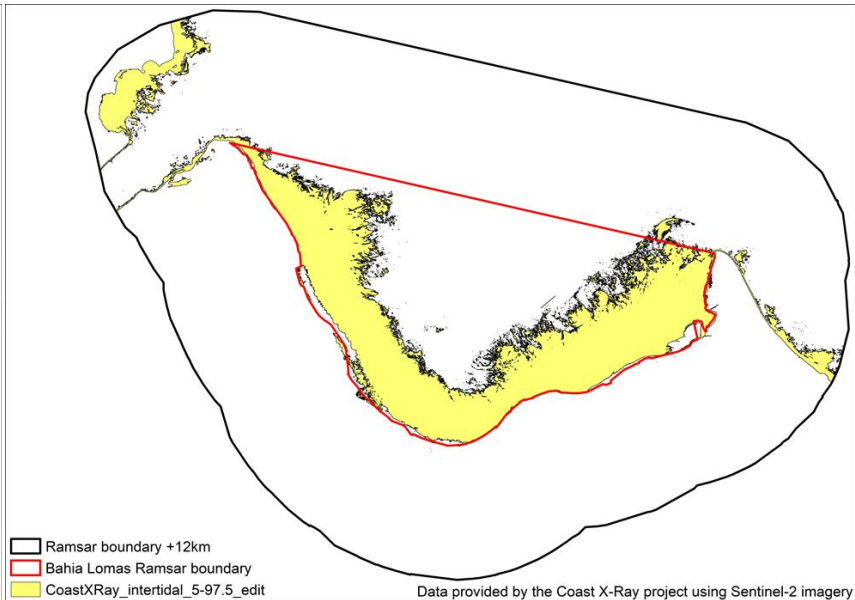
Mapping intertidal extent



- Method applied in UK and Bahía Lomas Ramsar site, Chile.
- Create normalised difference water index (NDWI) from green and near infrared bands of time-series Sentinel-2 imagery.
- Classify pixels as ‘water’ or ‘land’ based on NDWI values.
- Create raster with water occurrence values from 0% to 100%.
- Create a vector map of the intertidal area, i.e. pixels which are sometimes, but not always, water.







Air Quality
Monitoring

Air Quality Monitoring

Collaborative project to understand satellite measurements of air quality and greenhouse gases and how these can improve the Environment Agency's ways of working.

Case studies

- UK-wide ammonia measurements per month using Infrared Atmospheric Sounding Interferometer (IASI) MetOp-A satellite. Highest concentrations in March, April and May.
- Nitrogen dioxide concentrations identified over large point sources using Sentinel-5P Tropospheric Monitoring Instrument (TROPOMI).
- UK-wide methane plots generated, but no clear signals from landfill sites identified yet.

Workshop 29 September 2020

Sentinel-5P TROPOMI and other air quality products – potential applications to regulatory activities https://tinyurl.com/tropomi

Environment Agency

UNIVERSITY OF LEICESTER

National Centre for Earth Observation
NATURAL ENVIRONMENT RESEARCH COUNCIL

opernicus
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Other examples of uses for Sentinel-1 and 2 data

- Create productivity and wetness products to detect **changes in designated sites**
- Identify **woodland change** and update the FC's National Forest Inventory dataset
- Measure **natural capital metrics**: extent, quality and change
- Undertake **risk based management**
- Plan site visits, identify any **access issues** and likely routes and trails
- Map extent of macroalgae on mudflats in large estuaries during peak opportunistic growing season
- Identify areas of **bare/exposed ground**
- Detect changes over time in land holdings indicating where **compliance checks** may be advised
- Monitor urban fringe and link to ground deformation causes
- Detect **coastal changes** to inform about climate change
- Identify exact location of **felling activity** to be more accurate about timings and save time on site visits
- Detect potential areas of **diseased trees** to help direct field visits
- Provide local authorities with most recent information on the ground to assist with planning
- Assess stock and change in habitats across England to meet reporting requirements
- Overlay images with incident locations to identify areas at risk
- Monitor **peatland restoration**
- Identify winter born water ways to identify areas at risk and **improve flood defences**

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Crick Framework

- Framework developed by JNCC and Environment Systems for categorising how well EO techniques can identify habitats and features.
- Initiated in 2012 during the Making Earth Observation Work (MEOW) project.
- Categorised habitats in 5 tiers from 1 (likely to be classified solely using EO) to 5 (cannot be classified using EO).
- Currently being reviewed and updated to cover use of EO for habitat condition and change detection rather than simply habitat mapping.
- Keep an eye on our website for updates: https://jncc.gov.uk/our-work/the-crick-framework/

Tier diagram for the Crick Framework, categorising habitats based on the EO and ancillary data required to map them.

Resources

Code Sharing

A curated list on GitHub of code in various languages for manipulating and analysing Sentinel-1 and Sentinel-2 ARD.

https://github.com/jncc/s1-s2-ard-code-list

User Forum

Slack workspace for users of Sentinel-1 and Sentinel-2 ARD.

https://s1-s2-ard-users.slack.com/

Webinar

Webinar on code sharing and knowledge exchange for users of Sentinel-1 and Sentinel-2 ARD.

Thursday 24th September, 12:00 – 13:30

Registration: https://attendee.gotowebinar.com/register/5429883606638137612

Sentinel-1 & Sentinel-2 ARD code list

JNCC | Centre for Environmental Data Analysis | Department for Environment Food & Rural Affairs | Copernicus Framework Partnership Agreement for Copernicus User Uptake

A curated list supporting the use of Sentinel-1 and Sentinel-2 analysis-ready data (ARD) in the UK

Project Background

JNCC are leading a project to help people use Sentinel-1 and Sentinel-2 analysis-ready data (ARD) provided by the Defra EO Data Service and the CEDA Archive, with a particular focus on accessing data via API (application programming interfaces). As part of this project, we have set up a public repository for sharing code in any language for processing or analysing Sentinel-1 and Sentinel-2 ARD. We conducted a survey in July 2020 to gain a better understanding of user needs and inform the choice of code-sharing platform. Based on the survey results and subsequent discussion with the project team and partners, it was agreed that the best option was to set up this curated list on GitHub.

How to contribute

This list is a work in progress and we need your help to keep it up-to-date! If you have examples of code for selecting, downloading, manipulating or analysing Sentinel-1 or Sentinel-2 ARD, please add them to the list by making a pull request. See our contribution guidelines for details on how to do this.

Acknowledgements

Thank you very much to all the authors who have contributed their code to this list, and to Andrew Cutts for help with setting up the list. This project is funded by the Caroline Herschel Framework Partnership Agreement on Copernicus User Uptake.

Contents

| Tutorials and functions |

| Marine and Coastal Applications | Maerl monitoring | Satellite-derived bathymetry | Intertidal extent mapping

| Terrestrial Applications | Habitat Change Detection | Peatland Mapping | Upland mapping | Habitat mapping |

| GitHub accounts of relevant organisations | Other useful Earth Observation GitHub links |

Thank you!

Any questions?

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