National Trust

Section 2: Places

Monitoring Using Remote Sensing

Monitoring using remote sensing – introduction

Remote sensing to monitor the impacts of climate change is a rich area of study, with a well-developed and ever-growing research base and literature.

For our purposes, it is helpful to think about the use of remote sensing in two distinct categories: monitoring and hazard warning. Monitoring means looking for short- or long-term variations in environmental characteristics which may signify climate-driven change. Hazard warning involves near real-time recording or observing environmental variables that can help to identify tipping points when potential hazards are likely to be triggered.[1]

Hazard warning

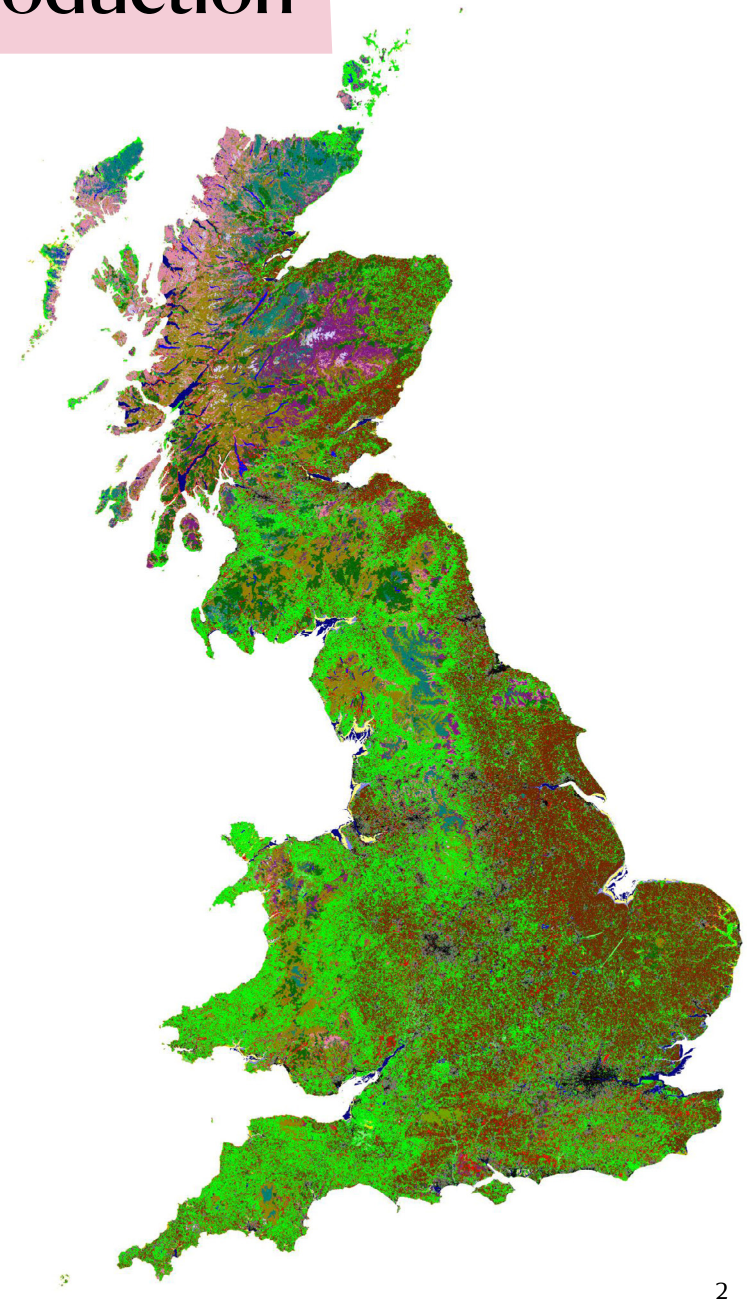
Hazard warning requires the identification and documentation of environmental characteristics that indicate an approaching problem. For example, this might be extreme weather conditions which are likely to lead to flooding or an increased risk of wildfire during dry periods. Hazard warning at scale is complex and resource intensive, so many hazard warning systems are maintained by government agencies such as the Met Office in the UK, or pan-governmental consortia, such as the European Forest Fire Identification System, maintained by the European Space Agency (ESA) for the European Union.

Post-event monitoring

Monitoring applications use remote sensing to identify and record environmental conditions over time. In many instances, the trigger for monitoring may be a hazard event, which may or may not be anticipated; for example, assessing damage to woodland after a storm or recording the extent of destruction caused by wildfire.

Long-term condition monitoring

Over a longer time scale, monitoring using remote sensing seeks to identify and document environmental change, the significance of which may not always be apparent at the time of recording. This might include changing vegetation vigour over multiple growing seasons, changes in land use that may threaten buried archaeological remains, land movement or deformation in the elevation of buildings. The scope of long-term monitoring is almost limitless and there will usually be one or more remote sensing techniques suitable for almost any situation.



[1] See Introduction to Climate Change Adaptation https://www.into.org/app/uploads/2024/11/0.-Introduction-to-climate-change-adaptation-Nov-2024.pdf

Image credit: UKCEH Landcover Plus 2024 Earth observation derived land cover mapping for Great Britain (© National Trust. Landcover Plus data © UKCEH https://doi.org/10.5285/4dd9df19-8df5-41a0-9829-8f6114e28db1).

Why monitor using remote sensing?

Remote sensing is the science and technology of examining and determining the characteristics of objects and material remotely. Use of remote sensing technologies offers many benefits to supplement or replace other means of recording.

Scale

Remote sensing technologies are easily scalable. Satellite observation of the Earth documents landscape conditions over hundreds of square kilometres in a single image. Systems, such as the ESA Sentinel satellites,[2] provide repeat coverage of most of the Earth's surface on a 3 to 5-day cycle. Commercial systems, such as Planet's PlanetScope satellites, provide daily high-resolution coverage of most of the Earth. Many technologies can be easily scaled from a modest area (a single property or farm unit) to much wider inter-site surveys using the same sensor package.

Efficiency

Remote sensing is a highly efficient and cost-effective means of generating environmental insight. Many systems collect data automatically all the time and require no intervention from potential end users other than access to the desired data. Many products from remotely sensed data are developed by government agencies; for example, habitat and landcover mapping in the UK, which is updated annually.

Insight

Remote sensing offers the potential to gain multiple levels of insight from a single source of data. For example, satellite acquired multispectral data, such as that from the Sentinel 2 satellites, can be used to determine vegetation vigour, vegetation and sediment moisture, and waterborne hazards, such as algae blooms or sediment plumes. It can also be used to assess the impact of hazards, such as flooding, storm and wildfire.

Automation

Remotely sensed data is digital, which means that it offers many opportunities for automation of collection, processing and delivery. Cloud-based platforms, such as Sentinel Hub (for ESA Sentinel data), allow users to develop applications that can automatically process new data as it arrives, and deliver analysis and insight into web-based mapping onto the desktops of end-users.

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[2] The Sentinel satellites form part of the European Space Agency's Copernicus Earth Observation programme. Sentinel 1 and 2 satellites provide radar (S1) and optical (S2) remote sensing of the Earth's surface at a high repeat cadence (every 3 to 5 days) and high spatial resolution. Additional Sentinel satellites provide more specialised sensing relating to oceans (Sentinel 3) and atmospheric monitoring (Sentinel 5). https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Introducing_Copernicus

[3] Radar (radio detection and ranging), detects the reflection of an electromagnetic pulse to determine the distance of objects from the sensor and some of their characteristics.

[4] Lidar (light detection and ranging), detects the reflection of a highly collimated laser pulse to measure the distance of objects from the sensor.

Remote sensing explained

Platforms

Similar technologies may be deployed on a variety of platforms ranging from satellites in Earth orbit to piloted aircraft. Different platforms offer different scales and resolution of collected data – from landscape scale low resolution (from orbit) to small area high resolution (from aircraft and drones). Data from some platforms is collected constantly and is made available freely; some data, however, may need to be purchased.

Sensors

Remote sensing platforms can deploy one or more sensors. A sensor may be simply a camera on a drone or aircraft, taking photographs of the landscape in the visible spectrum. More sophisticated multispectral sensors, which look beyond the visible spectrum, record data in multiple discrete spectral bands.

Active and passive

Sensors can be divided into those which are active and passive. Active sensors emit an energy source which is reflected, and the nature and intensity of the reflection recorded (such as radar[3] and lidar[4]). Passive sensors record the reflected energy from the sun, or thermal energy emitted by materials.

Monitoring using remote sensing – our visitors

Visitor numbers and behaviour can be affected by the impacts of climate change and extreme weather.

Periods of hot weather mean that visitors seek places where they can stay cool, either through the presence of water or shade. Wet weather also affects visitor behaviour and can lead to impacts such as the compaction of ground in car parks and footpaths, which causes increased standing surface water, run-off and erosion. Visitors seeking to avoid waterlogged pathways may create new desire lines across the landscape and these can impact fragile habitats or archaeological remains.

ESA Sentinel satellites and NASA Landsat data can be used to calculate land surface temperature at a scale of tens of metres; for example, to identify persistently hot areas where the introduction of shade may benefit visitor comfort. Newly available commercial satellites are likely to increase both the scale and frequency of such data, which will make it of even greater use.

Airborne lidar data can serve as a source for detailed modelling of solar insolation – a measure of how much sunlight is received by a particular location. Such models can identify problematic areas of excessive heating and enable the beneficial impacts of interventions to be modelled.

Sentinel 2 satellite data can be used to identify variations in sediment and vegetation moisture. Mapping such variations over time can help to identify areas prone to both the impacts of excessive heat (very dry) and excessive moisture (very wet and so vulnerable to flooding and visitor-initiated erosion).

Airborne data, such as aerial photography, lidar and hyperspectral imagery can identify issues, such as erosion of footpaths, and can be used to examine change over time to highlight problem areas and the origin of persistent problems. Drones can capture photography, lidar and multispectral images and can be used in planned programmes of assessment; for example, to determine the impacts of interventions and to document flooding, landslips or other unexpected damage to landscape and habitat.

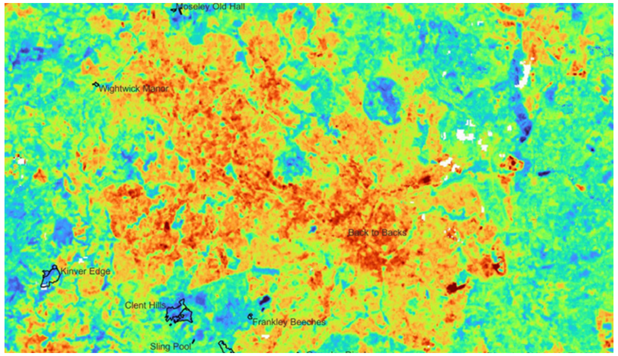


Image credits: top, urban heat island mapping for Birmingham, derived from Landsat 8 land surface temperature data (© National Trust. Landsat imagery courtesy of NASA Goddard Space Flight Center and U.S. Geological Survey); middle, aerial view of Avebury Manor and estate after the flood in January 2024, Wiltshire (©National Trust Images/James Dobson); bottom, desire lines creating erosion on the coastal saltmarshes at Stiffkey, Norfolk, visible on aerial photography (© National Trust. Data © 2025 NNRCMP).

Monitoring using remote sensing – climate hazards

Changes in climate can increase the frequency and severity of natural hazards, and precipitate entirely new factors that affect the landscape.

Wildfire

The increasing prevalence of wildfires in the UK and elsewhere is attributed partly to an increase in temperature; a significant portion, however, also stems from anticipated decreases in relative humidity. While most wildfires in the UK are the result of human action, elsewhere – particularly in remote areas – natural factors such as lightning strike may also play a part.

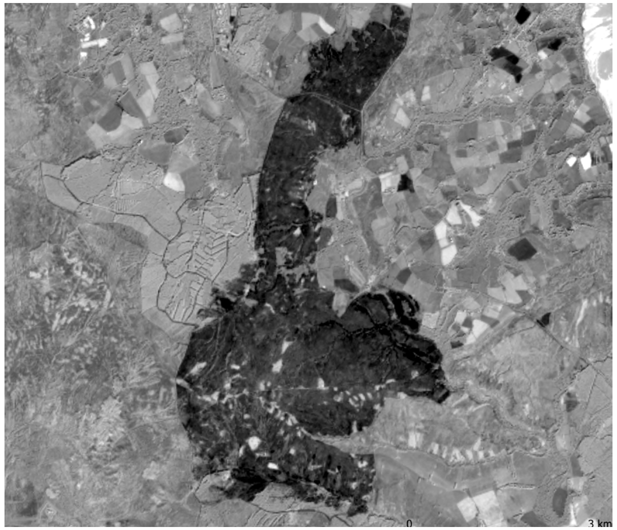


Image credit: Sentinel 2 satellite data Normalised Burn Ratio showing the burn scar of the 1600ha 2025 fire on Langdale Moor, North Yorkshire (© National Trust. Contains modified Copernicus Sentinel data 2025).

NASA's MODIS and VIRS satellites[5] detect active fire locations in near real time and can be particularly useful in identifying fires in remote, rarely visited areas. Gauging the impact of wildfires in remote, physically challenging environments can be difficult. Sentinel satellite imagery is frequently used to assess the impact of wildfires. The commonly used Normalised Burn Ratio (NBR) shows post-fire variations in vegetation and soil moisture, and biomass. It yields a clear visualisation of the extent and intensity of burning, which can aid assessment of fire impact and assist in immediate post-fire planning and remediation.

Sentinel satellite data can provide quick and easy near real-time insights into changing risks at a useful operational scale. For example, measurements of vegetation moisture using Sentinel 2 satellite data can help identify areas of very dry vegetation that are at an increased risk of ignition. This enables interventions such as increased on-site monitoring or even the closure of some areas to public access.

Ground movement

Ground movement caused by extreme weather can be a significant risk to buildings, structures and wider landscapes. Intense summer heat may lead to surface shrinkage, while excessive moisture from intense rainfall can lead to the swelling of some sediments and, in extreme cases, to landslips. Natural landscape features, such as cliffs, can also be vulnerable to extreme heat and moisture, which can accelerate erosion and lead to catastrophic collapse.

Remote sensing can provide data which allows the monitoring of surface movement and, in some cases, aid prediction of catastrophic events. Sentinel 1 satellite data, which is available in processed form through the European Ground Motion Service (EGMS), can determine surface movement at the millimetre scale.

Higher spatial resolution Sentinel 1 satellite derived ground motion data, with a wider coverage, is available commercially on demand from various providers, and includes up-to date-analysis of the latest data. Commercial providers offer bespoke alert services; for example, to identify land movement and notify users in near real time. Airborne lidar can also provide information on ground movement and rates of erosion with high precision, and at a high spatial resolution (usually with elevation values at a spatial resolution of 1 or 2m). Comparison of multiple years of survey data can identify changes in ground level associated with erosion or accretion of material.

The European Forest Fire Information System (EFFIS),[6] developed by the European Commission for Europe, the Middle East and north Africa, uses remotely sensed data from the Copernicus Sentinel satellite constellation. A variety of modelling algorithms generate daily situation maps and plot the potential impacts of wildfire on population, the environment and economic activity.

European Ground Motion Service[7] can show an average trajectory of change, both vertical and lateral, over a timespan usually ranging from mid–2015 (the launch of the Sentinel 1 satellite system) to near present.

Note that as of 2025, the latest processed data is for December 2023. Additional data is added annually in batches.

[5] MODIS (Moderate Resolution Imaging Spectroradiometer) and VIRS (Visible Infrared Imaging Radiometer Suite) are satellite-deployed sensors systems which provide frequent low-resolution images of the Earth's surface generating a range of analytical products, including near real-time detection of the thermal signature of fires).

[6] EFFIS - Welcome to EFFIS

[7] https://land.copernicus.eu/en/products/european-ground-motion-service

Monitoring using remote sensing – the natural environment

Vegetation

Earth observation satellites are particularly suited to monitoring vegetation character. Multispectral sensors, such as that deployed by the Sentinel 2 satellites, can be used to automatically generate vegetation metrics such as the Normalised Difference Vegetation Index (NDVI), a measure of vegetation vigour, and other metrics such as vegetation moisture and leaf area index. Although somewhat limited by its spatial scale, its frequency of collection, coverage (global every 3 to 5 days) and free availability make it an essential first stop for vegetation monitoring at scale.

Similar indices can be produced using higher resolution commercial imagery (such as PlanetScope, which has daily global coverage at 3m) or even using aircraft or drone deployed sensors.

Image-based remote sensing is helpful for determining some vegetation characteristics, but vegetation structure is best determined using active techniques such as radar or lidar.

Satellite radar, such as Sentinel 1, can produce low-resolution data on vegetation structure. However, airborne lidar is better suited to detailed assessment of structure and, with appropriate processing to generate estimates of above ground biomass, can support carbon accounting.

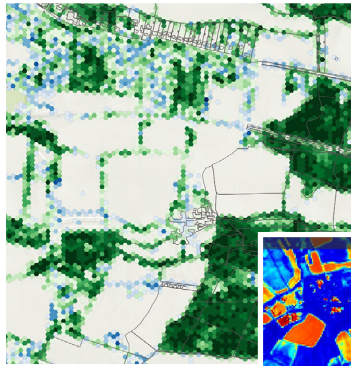
Finally, drone imagery can be useful to document the impact of extreme weather – for example, woodland damage caused by gales – especially as drones can be deployed quickly and relatively cheaply to collect such data.

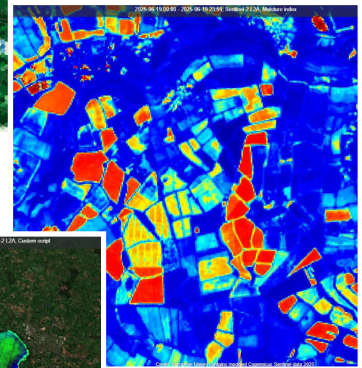
Inland water

At a catchment scale, detailed topographical data, such as that captured by airborne lidar, can provide the high-quality information required for fluvial modelling. This can range from the prediction of flood vulnerability to design improvements in the movement of water through the landscape. Lidar is also able to provide insight into relict fluvial features, such as past river channel locations, which can assist in designing floodplain restoration schemes. Lidar elevation and backscatter intensity data are often able to detect buried land drains, even when these have little or no surface expression.[8]

Earth observation satellites, such as Sentinel 1 and 2, can provide insight into the extent and severity of flood events at a landscape scale. Airborne remote sensing, particularly rapidly deployed drone imaging, can be useful in the aftermath of a flood event to map flood extent and damage; information which can feed into future flood management measures and may be essential for insurance purposes.

Sentinel 2 data can be used to assess sediment and vegetation moisture, a vital part of understanding catchment health, and can be processed to determine various aspects of water quality including turbidity, suspended sediment and the presence of cyanobacteria and chlorophyl A in algal blooms.[9]





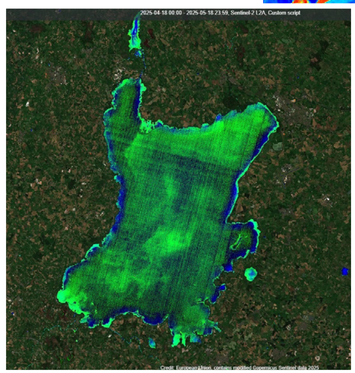


Image credits: top, lidar derived vegetation character mapping, Dorset (© National Trust. Contains Environment Agency information © 2022 Environment Agency and/or database right); middle, Sentinel 2 satellite data moisture index showing vegetation moisture in fields at Buscot Park, Oxfordshire, 19 June 2025 (© National Trust. Contains modified Copernicus Sentinel data 2025); bottom, Sentinel 2 image of Lough Neagh, Northern Ireland, 18 May 2025, processed to highlight suspended organic sediment and cyanobacteria chlorophyl A (© National Trust. Contains modified Copernicus Sentinel data 2025).

[8] Challis, K. and Howard, A., 2013. The role of lidar intensity data in interpreting environmental and cultural archaeological landscapes. Interpreting Archaeological Topography: 3D Data, Visualisation and Observation; Opitz, RS, Cowley, DC, Eds, pp.161-170.

[9] Kravitz, J., Matthews, M., Lain, L., Fawcett, S. and Bernard, S., 2021. Potential for high fidelity global mapping of common inland water quality products at high spatial and temporal resolutions based on a synthetic data and machine learning approach. Frontiers in Environmental Science, 9, p.587660.

Monitoring using remote sensing – cultural heritage

Archaeology

The direct physical impacts of extreme weather, such as flooding, accelerated erosion and tree throw, may cause physical damage to buried remains and surface earthworks. More subtle changes in the burial environment may cause physical and chemical changes that impact buried remains adversely; for example, through drying out of previously wet sediments due to increased dry summer days. Archaeology is also vulnerable to the impacts of human adaptation to changing climates; for example, through changes in land use or farming practice, or increases in summer water abstraction to irrigate crops.

Images from Sentinel 2 satellites can be used to monitor aspects of the burial environment, such as sediment and vegetation moisture, which can serve as a check on its integrity. Many of the remote sensing techniques and processes useful for landscape scale assessment of vegetation, water and land movement can also provide insight into climate impact on archaeology.

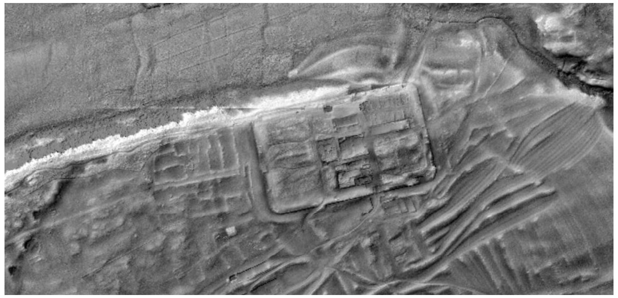
Archaeologists have a long history of using aerial imagery. Conventional aerial photography from aircraft or drones can help to identify buried and surface archaeology through changes in surface vegetation (cropmarks), sediment character (soil marks) and topography (shadow sites). These are all helpful in identifying archaeological remains which may be affected by climate change and human responses to these changes. Airborne lidar is particularly useful for identifying subtle traces of surface archaeology and repeat survey can determine changes that may impact archaeological remains; for example, modifications of land use or erosion caused by changing grazing regimes. Airborne lidar intensity can be a highly effective indicator of sediment moisture and is helpful to identify drainage features such as buried field drains.

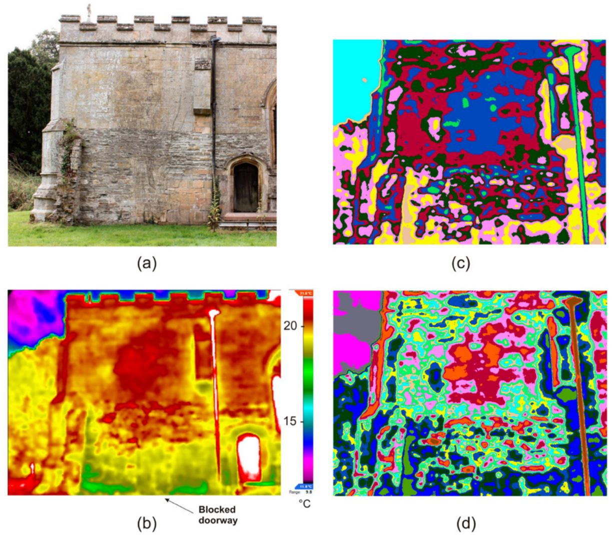
Built heritage

The direct sensing of building structures may include the use of techniques such as thermal imaging – either from handheld thermal infrared cameras or from drones – which can help to identify variations in fabric temperature that may be attributed to damp, water ingress or underlying structural flaws. Laser scanning, which provides very precise measurements, can help to identify structural issues that may be caused by climate and weather. Repeat scans, if undertaken correctly, can be used to identify structural movement. Backscattered laser intensity measurements, collected as part of the scanning process, can aid understanding of variations in building fabric which may affect resilience. It can also help to identify structural flaws such as cracks.

Remote sensing of the environment around buildings can assist in identifying the impact of water; for example, by highlighting areas of persistently damp ground or heat and by mapping variations in land surface temperature. Ground and structural movement, both vertical and lateral, can be determined to within millimetres using data from satellite radar. The impact of extreme weather events can be effectively identified using drone photography in the immediate aftermath of an event; for example, flooding, roof and other structural damage.

Image credits: top, lidar image of Housesteads Roman Fort, Northumbria (© National Trust); middle, view across the shingle towards the Pagodas at Orford Ness National Nature Reserve, Suffolk (© National Trust Images/Justin Minns); bottom, Kelham Church, Nottinghamshire, the exterior north wall of the chancel **(a)** under normal diffuse daylight conditions, as seen by the unaided eye; **(b)** in the thermal infrared with high-contrast LUT applied; **(c)** k-means clustering of the thermal image with eight clusters, and **(d)** k-means clustering of the thermal image with 16 clusters (From Brooke, C., 2018. Thermal imaging for the archaeological investigation of historic buildings. *Remote Sensing, 10* (9), p. 1401, Fig 8).





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Case study: post-event monitoring

Slieve Donard

In April 2021, a significant wildfire devastated over 384ha of the Mourne Mountains in Northern Ireland; most of the affected area was within the National Trust's Slieve Donard estate. Remote sensing played a part in assessing the impact of the fire and its immediate aftermath by gathering information to help plan landscape scale remediation and by monitoring the recovery of the landscape over time.

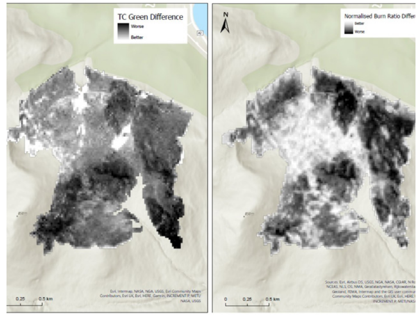
In the days immediately after the fire, Sentinel 2 satellite data was used to assess the extent of the fire's impact and the relative severity of burning across the affected area. Several Sentinel 2 indices were used, including the standard Normalised Burn Ratio and the less frequently used Tasseled Cap Transformation,[10] which calculates vegetation greenness and wetness. Comparison of imagery from immediately before and after the fire enabled scale comparison of the changes in the index values, which reflected the severity of the burning.

In the weeks after the fire, a team conducted a challenging high-resolution drone survey of the affected area. This provided highly detailed imagery which showed the impact of the burning and enabled a detailed digital surface model to be constructed. This showed the topography in 3D and allowed the calculation of vulnerability to factors such as the increased run-off from and erosion of newly bare ground. Together, this data assisted in the planning of a remediation programme. High-resolution lidar data was later collected from an aircraft mounted sensor. As well as a point in time record of the conditions of the land and vegetation structure, lidar formed a component of detailed modelling of fire vulnerability to assist in future landscape management planning.

After four years and immense effort by the National Trust team and its partners, and with financial support from the Department of Agriculture, Environment and Rural Affairs, the Slieve Donard landscape is well on the way to recovery. Sentinel 2 satellite imagery provides some evidence to document the success of the recovery efforts. Comparison of Normalised Difference Vegetation Index measurements from before and after the fire, and subsequently at annual intervals, shows the change from a healthy 'green' landscape to one dominated by bare ground and burnt vegetation with a gradual return to a more normal green state.[11]

[10] Tasseled cap transformation is a commonly used remote-sensing technique and has been successfully used in various remote sensing-related applications. T. Shi and H. Xu, 'Derivation of Tasseled Cap Transformation Coefficients for Sentinel-2 MSI At-Sensor Reflectance Data,' in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 12, no. 10, pp. 4038-4048, Oct. 2019, doi: 10.1109/JSTARS.2019.2938388

[11] Donard Nature Recovery Report. National Trust 2025. https://nt.global.ssl.fastly.net/binaries/content/assets/website/national/regions/northern-ireland/pdf/donard-nature-recovery-report-2025.pdf



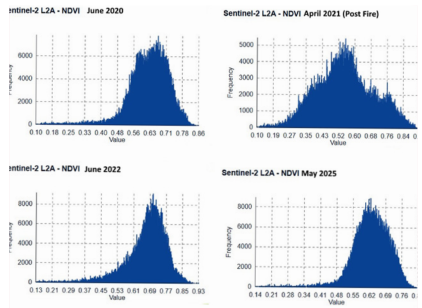


Image credits: left, Slieve Donard is the highest mountain in Northern Ireland and, together with its associated smaller peaks, forms the northern end of the Mourne Mountains (© National Trust Images/Joe Cornish); top, Sentinel 2 images showing the burn scar of the 2021 fire at Slieve Donard (© National Trust. Contains modified Copernicus Sentinel data 2025); bottom, histograms showing changes in NDVI (vegetation greenness) highlighting the impact of the 2021 fire and gradual landscape recovery (© National Trust. Contains modified Copernicus Sentinel data 2025).