The Moorland Change Map

This Technical Information Note (TIN) has been prepared to help inform you about the development of the Moorland Change Map.

Natural England are increasing our use of earth observation to map and monitor for a range of reasons across England. One of the tools we have developed for this is the Moorland Change Map (MCM) which identifies change, such as burning and cutting, across heather dominated areas in uplands. This is an annually produced map from satellite data which is currently monitoring ~2,000 Km², across 10 uplands in England, such as the North York Moors shown in Figure 1.

Figure 1 - Sentinel 2 of the North York Moors, 27/03/2020.

We have developed this approach as from looking at the increasing amounts of satellite data available it became clear that burns (whether wildfires or managed) can be seen in this data. In particular through the increased amount of optical satellite data coming from the European Space Agency's (ESA) Sentinel 2 satellites.

These S2 satellites pass over every 4-5 days, sometimes it's cloudy, but often burns are done on clear days when weather is settled. This means we often get to see smoke plumes (Figure 2) and fire fronts directly and even when we miss them because the satellite passes over say the following morning or several days later, the site of the burned area is very clear. So in reality we are confident that during the course of the season the areas being burnt will reveal themselves to us and we can monitor their extent and distribution.

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Figure 2 - Left: Smoke Plume of 4 neighbouring fires on 06/02/2020. Right: Smoke plumes from 2 fires on 31/12/2019.

These S2 datasets have a pixel size of 10 – 20m, and this level of detail means we are able to see burns / cuts which are over ~30m wide. The pattern of rotational burns can be seen visually in the imagery, especially when comparing images from before and after the burns (Figure 3) or with a difference calculation. It is this burn scarring and ability to compare images from before and after the managed burn season that has allowed us to develop a process to monitor moorland change, including from burning.

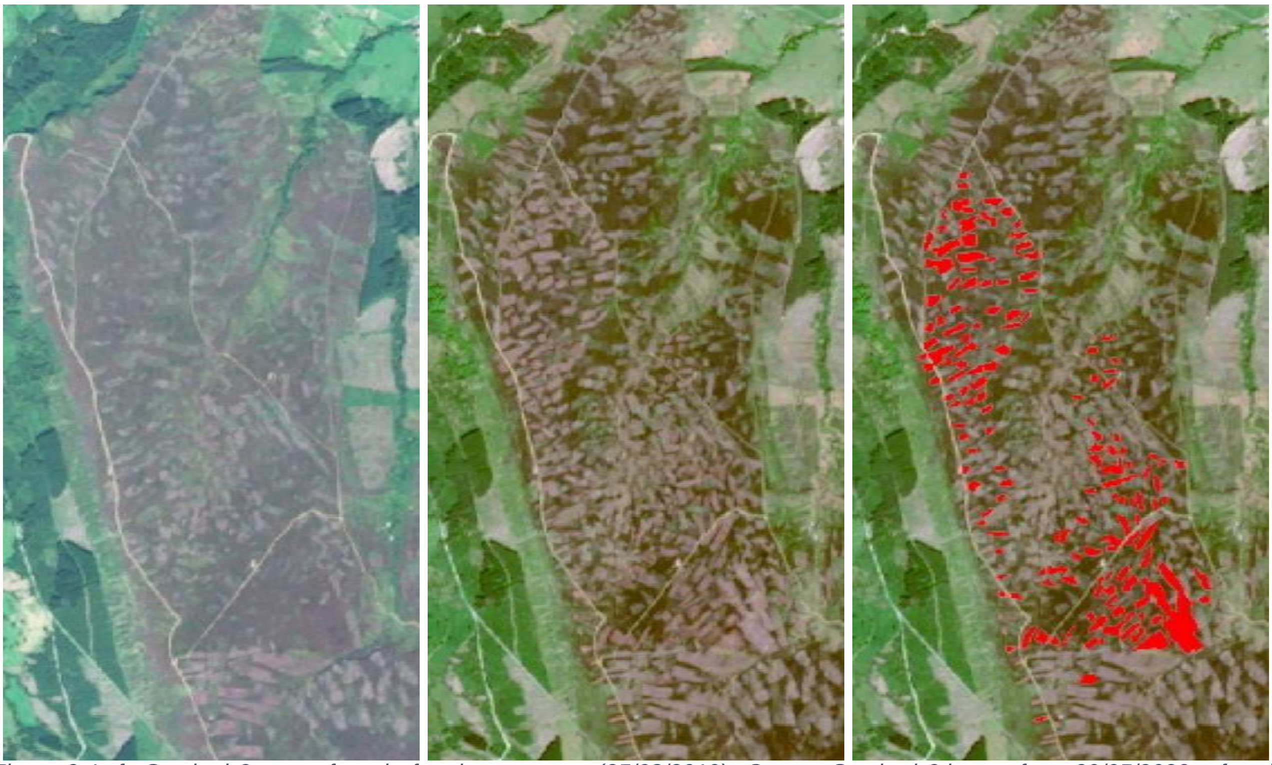

Figure 3: Left: Sentinel 2 scene from before burn season (25/08/2019), Centre: Sentinel 2 image from 29/05/2020, after the managed burn season & Right: Identified change (Red) from between these two dates.

Through the use of these techniques in 2018-19 burn season we identified ~135km² of change for these 10 upland areas, with an accuracy of 87%. Then in the 2019-20 burn season we identified ~ 65 km² of change for these uplands, with an accuracy of 95% nationally. The process to achieve these results and validate them are described further below.

The MCM is undertaken primarily through the Python and R scripting language. These access a variety of modules, the majority of which are open source. The analysis uses Sentinel 2 Analysis Ready Data from the Defra Earth Observation Data Service (EODS), a dataset showing Heather dominated habitat, and training data collected from visual assessment of the Sentinel 2 imagery. Then for validation we use a combination of field data collected by Natural England's local and national teams, showing point data of heather (Building, Mature or Degenerate) and Change (Burnt Heather or Cut Heather) and further data collected from visual assessment of the Sentinel 2 imagery.

The analysis takes Sentinel 2 imagery for before and after the burn season. Due to cloud conditions though, which are especially problematic in the uplands, this can be a couple of months before the burn season starts or after the burn season finishes. As such the change identified will not have necessarily have happened within the managed burn season.

The before and after Sentinel 2 imagery are then compared to create a dataset showing the difference in NDVI between them (Figure 1). The NDVI (Normalised Difference Vegetation Index) is a standard and commonly used EO vegetation index, which is a proxy for vegetation productivity. Negative values show a decrease in the vegetation index, which effectively shows a decrease in vegetation productivity. If heather is removed by burning or cutting vegetation productivity (and NDVI value) will be significantly reduced. Within the Heather Mask and timings of imagery used, observed significant decreases will mainly be due to burning or cutting. Neutral or positive NDVI change values indicate healthy or unchanged vegetation, either at the same state of phenology as the previous year, or with an increased state of productivity.

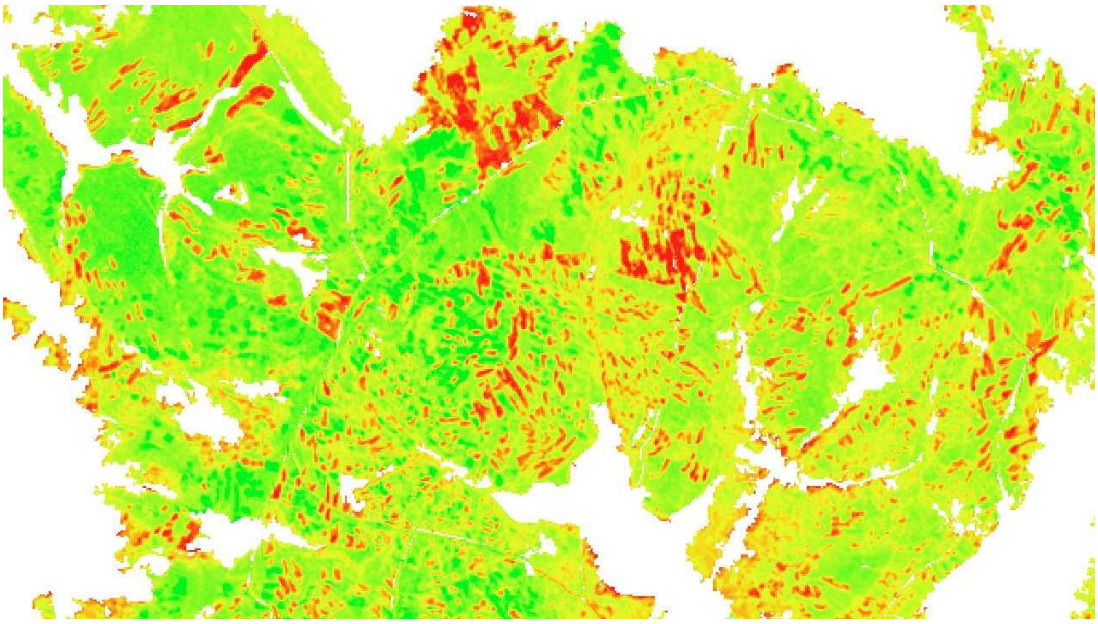

Figure 4 -Difference in Normalised Difference Vegetation Index (NDVI) between the Baseline and Recent Period. Green to Red Colour Ramp with Green being a positive change and Red a negative change in NDVI Difference.

From this NDVI difference dataset we can make an assessment of areas thought to have changed, i.e. due to burning or cutting, during the burn season. This is achieved through applying a threshold value to separate the NDVI Difference into No Change or Change. This threshold value is set through evaluation of the training data through a number of models. These are the General Linear Model (GLM) (run twice with different settings), Generalised Additive Model (GAM) and Gradient Boosted Model (GBM). These alongside the median threshold value from across the models, can be visualised through a graph of the model curves (Figure 2).

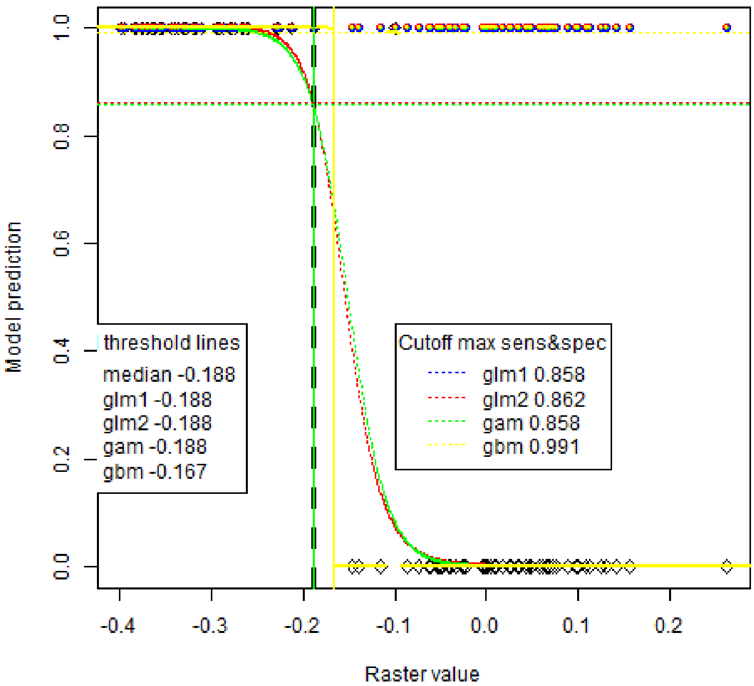

Figure 5 - Graphical representation of the model curves and threshold values identified from each. The Median value is then shown as the vertical black dashed line.

This Median threshold value is then applied to the NDVI difference dataset. Any values below this threshold value are thought to be heather which was burnt or cut over the burn season. Values above the threshold are then considered heather which has not been actively managed during that burn season and is actively growing. This could be heather at any other stage of the heather lifecycle, such as pioneer, building, mature or degenerate.

The threshold value is calculated and applied separately to each upland area and burn season assessed. This is due to variations in the dates of before and after S2 imagery between uplands to get good cloud free coverage, phenology changes and subsequent differences in the NDVI difference. Using a threshold tailored to each upland with its own training data helps to improve the accuracy we get in this monitoring, although does also mean the process takes longer to produce the results.

Figure 6: Exmoor MCM 2018-19, Left: Sentinel 2 from 23/08/2019, Right: MCM results showing large burns.

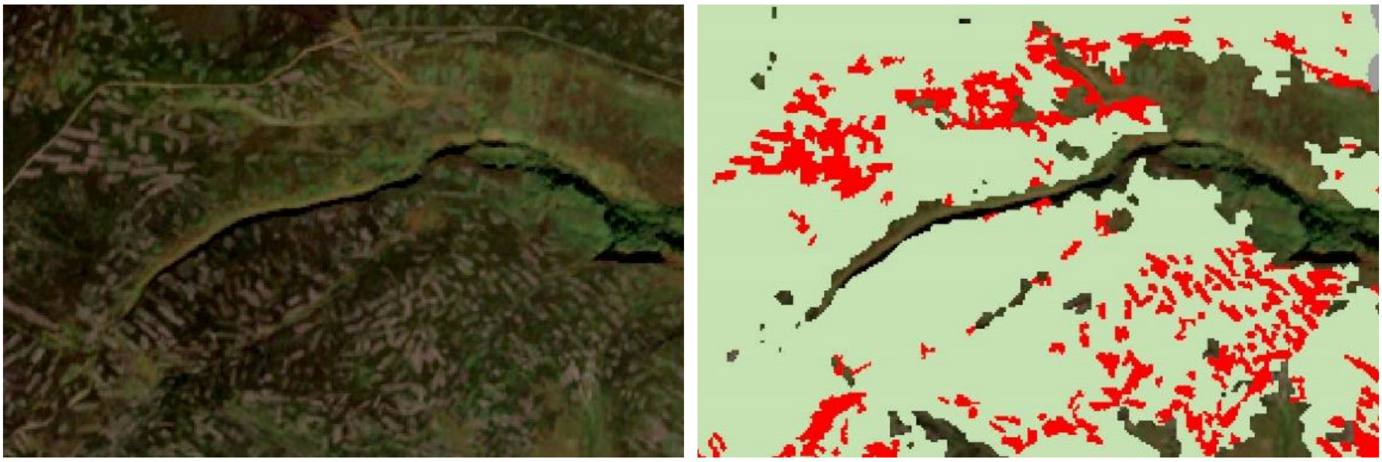

Figure 7: Peak District MCM 2018-19, Left: Sentinel 2 from 02/10/2019, Right: MCM results showing medium and small burns.

Validation for the Moorland Change Map happens in two ways, firstly through visual checks carried out at the end of the analysis. It is then followed by creation of an accuracy assessment using both field data collected by the area and national teams and validation data created from Sentinel 2 satellite data.

These datasets are then both used to create error matrices. They are used to create separate error matrices because we are able to create more validation data from Sentinel 2 data, then we achieve from actual field data and this could skew and hide genuine issues identifiable in the field data.

These error matrices (Table 1) show the accuracy of the User and Producer (the inverse to the error of Commission and Omission) for each class and provides an overall accuracy of the result.

Table 1 - Example Error Matrix showing the User and Producer Accuracy per class and the Overall Accuracy.

		User - Ground Data			
		No Change	Change	Total	Accuracy
MCM Producer	No Change	643	81	724	88.81
	Change	3	535	538	99.44
	Total	646	616	1262	
	Accuracy	99.54	86.85		

Overall Accuracy	93.34

This Overall Accuracy value is to enable us to be able to provide a level of confidence and trust in the monitoring. The specification for the accuracy of MCM is 80% as a minimum at each upland.

We have been developing this method over the past couple of years and now hope to produce it for each year going forwards.

This work is led by Evidence Earth Observation Service in the Chief Scientists Directorate. Contactable at: earth.observation@naturalengland.org.uk

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