MICCI

Moorland Indicators of Climate Change Initiative

2013
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Moorland Indicators of Climate Change (MICCI) 2013

National Science and Engineering week 2013 sparked the sixth year of the Moorland Indicators of Climate Change Initiative (MICCI) (see Appendix 1 for map of MICCI sites). During a particularly wintry spring twelve secondary schools across England and Wales, led by the Peak District National Park’s Learning and Discovery Team, explored their local moorlands, collecting valuable scientific data, with the aim of investigating the connection between moorlands and climate change.

Between the 8th March and 18th May 2013 twelve schools collected environmental data across fourteen moorland sites in the Peak District (4), Northumberland (3), North York Moors (2), Exmoor (2) and Brecon Beacons (3) National Parks. This data included information about the site (altitude), its hydrology (water table height and river water pH), soils (pH, soil surface water pH, temperature, organic content, moisture content and peat depth) and vegetation.

Using these data we can monitor the health of moorlands, pick up on changes, for example in plant communities, investigate what might be driving these changes and calculate how much carbon these peat soils contain. Monitoring these changes over time helps us understand how important conserving these areas are, especially when thinking about how they might change in the future as well as the impact changing moorlands might have on future climate change.

How deep is your peat?

Peat is formed over long periods of time as dead plants and animals (carbon rich organic matter) slowly decay in a waterlogged environment. Peatlands are a globally important land-based carbon store, holding carbon that could otherwise be released into the environment in other forms and exacerbate global climate change. UK peatlands are currently the UK’s largest terrestrial carbon sink so it is important that we are able to identify if and how they are changing.

Comparing peat depth data over time will help us understand how much carbon is being lost from moorlands into the atmosphere and downstream environment. Once peat, and the carbon it is made up of (see next section), erodes from peatlands it can cause wide reaching issues including effecting the quality of drinking water, flood risk and future changes in our climate.

This year the deepest peat deposits (6.12m) were recorded at Trefil Quarry (Waun Nant Ddu) in the Brecon Beacons by students from Brecon High School (see Fig. 1). Taking the mean average between this measurement (calculated from twelve individual peat measurements on a 30m² grid) and those taken by Crickhowel High School (3.70m), Trefil Quarry has the deepest mean recorded peat depth (4.91m) of any of the nine sites measured across England and Wales during this years MICCI project (see Table 1). Sites in Northumberland National Park recorded the second deepest peat deposits recorded, with both Padon Hill (4.20m) and Steng Moss (3.56m) measuring over 3.00m of peat (Fig. 1 & Table 1). Deep peat ( > 0.50 m) was recorded at all but one of the moorlands investigated beyond the Brecon Beacons and Northumberland, ranging from 1.98m at Burbage North to 0.59m at Wessenden Head, both in the Peak District. Shallower peat (mean depth of 0.41m) was recorded on Danby Moor, North York National Park.

Peat depth can differ between samples taken very close together. Figure 1 shows two samples taken within 10m of each other at Burbage North that differ by 0.20m. Identifying areas of deep peat, which often occur in relatively small areas, such as basins (containing depths of more than 8m), as
well as areas of relatively shallow peat which are often spread across larger areas, is essential to accurately estimate the importance of peat across the UK.

![Figure 1: Mean peat depth calculated from 12 samples at sites across the Peak District (purple), Northumberland (light blue), North York Moors (red), Exmoor (green) and Brecon Beacons (dark blue) National Parks.](image-url)
Since 2008 MICCI has been collating a database of peat depth measurements including sites in England, Scotland and Wales (see Fig.2), showing small scale differences in peat depths across the UK.

![Figure 2: Peat depth measurements taken across MICCI sites 2008 - 2013.](image)

**How much carbon does peat contain?**

Peat soils are made up of decaying plant and animal matter and so have a high soil organic matter (SOM) content of which approximately 50% is organic carbon, making them an important carbon store. To investigate how much carbon our peat soils contain (which could otherwise be lost to the environment) we can calculate the carbon content of small soil samples that were collected using the equation below (Hiederer et al., 2011)).

\[
SOC_s = SOC_c \times BD \times LD \times 10^2 (t \ ha^{-1})
\]

where

- **SOCs**: total amount of soil organic carbon to given depth (t ha⁻¹)
- **SOCc**: soil organic carbon content for given depth (%) calculated from soil organic content samples (%) x 0.50 (correction factor for estimating soil organic carbon form soil organic content averaged from 0.52 (Lindsay, 2010) and 0.48 (Evans, M. personal communication for peat soils in the Peak District).
- **BD**: dry bulk density (g cm⁻³)
- **LD**: Depth of soil layer (m)
Table 1: Calculating the total amount of soil carbon in a given depth of peat at our sample sites.

<table>
<thead>
<tr>
<th>National Park</th>
<th>School</th>
<th>Site</th>
<th>Mean peat depth (m)</th>
<th>Soil organic carbon content (%)</th>
<th>Bulk density (g/cm)</th>
<th>Total soil carbon to a given depth (tonnes per hectare)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PeakDistrict</td>
<td>Honley High</td>
<td>Wessenden Head</td>
<td>0.59</td>
<td>39.00</td>
<td>0.12</td>
<td>277.49</td>
</tr>
<tr>
<td>PeakDistrict</td>
<td>New Mills</td>
<td>Burbage North</td>
<td>1.84</td>
<td>48.50</td>
<td>0.12</td>
<td>1071.97</td>
</tr>
<tr>
<td>PeakDistrict</td>
<td>King Egbert School</td>
<td>Burbage North</td>
<td>2.12</td>
<td>44.00</td>
<td>0.12</td>
<td>1119.36</td>
</tr>
<tr>
<td>PeakDistrict</td>
<td>The Long Eaton School</td>
<td>Cowper stone</td>
<td>1.03</td>
<td>49.50</td>
<td>0.12</td>
<td>610.34</td>
</tr>
<tr>
<td>Northumberland</td>
<td>Dr Tomlinson, Rothbury</td>
<td>Padon Hill</td>
<td>3.75</td>
<td>49.75</td>
<td>0.12</td>
<td>2238.75</td>
</tr>
<tr>
<td>Northumberland</td>
<td>Dr Tomlinson, Rothbury</td>
<td>Steng Moss</td>
<td>3.56</td>
<td>47.50</td>
<td>0.12</td>
<td>2030.63</td>
</tr>
<tr>
<td>Northumberland</td>
<td>Dr Tomlinson, Rothbury</td>
<td>Albion Outdoors</td>
<td>Padon Hill</td>
<td>4.66</td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Yorkshire</td>
<td>National Park Apprentices</td>
<td>Danby Moor</td>
<td>0.63</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>North Yorkshire</td>
<td>Caedmon School</td>
<td>Danby Moor</td>
<td>0.19</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exmoor</td>
<td>Dulverton Middle School</td>
<td>Pinkworthy</td>
<td>1.26</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exmoor</td>
<td>Lynton and Southmead Schools</td>
<td>Pinkworthy</td>
<td>1.36</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brecon</td>
<td>Brecon High School, Brecon</td>
<td>Trefil Quarry</td>
<td>6.12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brecon</td>
<td>Crickhowel High School</td>
<td>Trefil Quarry</td>
<td>3.70</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Brecon</td>
<td>Ysgol Maesydderwen</td>
<td>Black Mountain</td>
<td>1.76</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Peat < 0.15m deep = estimated dry bulk density of 0.06 g cm⁻³. > 0.15m deep = 0.12 g cm⁻³

Based on the measurements that schools provided in 2013, the total amount of soil carbon contained at the given depth of each site varied from 277.49 tonnes per hectare (t ha⁻¹) at Wessenden Head in the Peak District to 2238.75 t ha⁻¹ at Padon Hill in Northumberland. Whilst this is a relatively crude method of calculating the amount of carbon stored in peat soils it highlights that even relatively shallow deep peats (e.g. 0.59m at Wessenden Head) are carbon rich and are important carbon stores on a national and global scale (Fig. 3).

Soil Organic Carbon (SOC) content has been estimated across the globe on a relatively coarse scale. Surveying the amount of organic carbon in our soils on a small scale, as MICCI did this year, we can monitor changes in soil organic carbon over time and in relation to environmental changes.
Figure 3: Estimated Peaty Soil Carbon content of the UK\textsuperscript{1} and a Global Carbon Map\textsuperscript{2} 

\textsuperscript{1} Natural England: NE257 England’s peatlands \url{http://publications.naturalengland.org.uk/publication/30021}

\textsuperscript{2} Scharlemann \textit{et al.} 2011

\textbf{How much carbon is being lost?} 

Healthy peatlands are an important land-based carbon store, transferring more carbon from the atmosphere to the ground than they release back into the environment. In healthy blanket bogs, the water table stays close to the surface, protecting peat that is already there and supporting vegetation that sequesters carbon (transferring carbon from the atmosphere to the ground). If the water table drops and the peat is no longer saturated, oxygen from the air gets into the peat and decomposition starts. This can tip the balance of peats role in the carbon cycle. Instead of storing carbon the soils release it into the atmosphere (as carbon dioxide and methane) and water courses (as Total Organic Carbon (TOC)), changing the peat from a carbon sink to a source (see fig. 4).

![Diagram of carbon fluxes in peat](image)

\textit{Figure 4: Basic atmospheric and fluvial carbon fluxes of peat (4).}

Taking water samples and analysing the amount of TOC within them gives an indication of the amount of carbon being lost from peat soils. Whilst it is important for organisations working to conserve peatlands (like \textit{Moors for the Future}) to monitor the movement of carbon and how it changes over time in relation to our works, water companies also use TOC measurements as an
indication of water quality. Removing carbon and other impurities from upland water supplies is an expensive process (£160,000 was spent in one year removing 11,500 tonnes of sediment from raw water in one catchment to meet drinking water standards (Courtesy of Severn Trent Water)), and with 70% of the water coming out of our taps in the UK coming from peaty uplands, the amount of carbon being lost to moorland streams has an impact on millions of people.

Figure 5: Carbon is lost from degraded, unstable bare peat (left) downstream (middle) and must be expensively removed at water treatment plants to meet drinking water standards (right).

TOC values recorded during this year’s MICCI project ranged from 2.8 mg/l at Black Mountain in the Brecon Beacons to 19 mg/l at Cowper Stone in the Peak District, with Castleton Pits on the North York Moors recording an average of 4.7 mg/l (see Fig.6). These sites represent relatively intact moorland with good vegetation cover and no more than 15% bare ground. TOC values from degraded peat sites show significantly higher levels of carbon being lost (e.g. mean 31.0 mg/l from Kinder Edge, Peak District) than from intact sites (e.g. mean 8.0 mg/l Ashop, Peak District).

The amount of carbon in moorland streams depends not only on the condition of the surrounding peat but also on the time of year and weather; less carbon is transferred in water when there is less rain. We would expect to see variation from samples within and between sites taken on different days after different weather events, as is evident in the MICCI data.
Figure 6: Total Organic Carbon (TOC) measures from upland streams in the Brecon Beacons (dark blue), North York Moors (red) and Peak District (purple) National Parks during MICCI 2013.

Water tables

Some of the early MICCI sites in the Peak District now have six years of water table measurements. 50% of measurements recorded water tables within 10.0cm of the ground surface and 75% were within 20.0cm (Fig. 7). Compared with data from other sites the majority of MICCI data suggest consistently wet conditions expected of healthy moorland environments (Allott et al. 2009). Water tables react to weather events such as droughts and storms, showing variability at different times of year as well as variation at different sampling locations at the same site, making direct comparison of data between different points across years inappropriate.

A drop in water table heights was seen across several sites in 2011 perhaps a result of particularly dry weather compared to other years. Historic weather data from the Met Office (3) confirms that only 12.4mm of rain fell in March and 11.2mm in April 2011 compared to 56.4mm, 44.2mm and 98.8mm in the previous three Marches and 32.6mm and 63.4mm in the following two, accounting for notable drop in water tables in 2011 samples (Fig.7).

Figure 7: Water table measurements from MICCI sites (2008 – 2013).
Water table levels are strongly linked to the condition of peat (i.e. whether organic matter forms peat or whether peat dries out and erodes) and influence the vegetation growing on it. High average water tables are found at intact sites whilst lower water table conditions are found eroded sites. As erosion takes place, which in itself can be driven by exceptionally dry conditions such as artificial drainage, the water table drops (Fig. 8). On functioning peatlands with water tables close to the surface (<15cm) the water table falls slower and remains closer to the ground surface in response to dry weather than drier, eroded sites (Allott et al. 2009). Intact peatlands are therefore more able to deal with short term weather events and longer term changes in climate than those in poorer condition.

![Image](image.png)

**Figure 8:** Conceptual model of local water table drawdown associated with gully erosion (Allott et al, 2009).

**Moorland Indicators of climate change: Vegetation**

Plants are good indicators of biodiversity and environmental change. Differences in vegetation communities can be due to climate, soil condition, air pollution, and hydrology as well as interactions between these factors. By monitoring changes in vegetation we can begin to assess the impact of climate and land use change on moorlands over time.

By looking at the number and type of plant species in an area we can define the type of habitat we are looking at and gain an indication of its condition. Active, undamaged peatlands support a suite of vegetation types adapted to wet, peat forming conditions. Bog peatlands (hydrated by rain water and so naturally nutrient poor) have characteristic bog vegetation associated with them. Blanket and raised bogs are characterised by bog mosses (*Sphagnum* species), sedges (e.g. cotton grasses), dwarf shrubs (including heather and bilberry) and broad-leaved grasses such as purple-moor grass (5).

Whilst all vegetation has the potential to form peat under the right conditions, *Sphagnum* mosses are key peat forming vegetation because of their water retaining structures and growing patterns, and as such are good indicators of functioning blanket bog habitat. *Sphagnum* species were present at all sites, making up between 7 – 29 % (Wessenden Head – Cowper Stone) of vegetation cover within quadrats (Fig. 9). The most northern sites (Padon Hill and Steng Moss in Northumberland) are
dominated by Cotton grasses, *Sphagnum* moss and heather, indicative of bog vegetation. Bilberry, a dwarf shrub common on blanket bog was also present (3% mean cover) at Steng Moss.

Castleton Pits on the North York Moors, south of Northumberland, was dominated by narrow-leaved grasses (24%), including meadow grasses more commonly found on grazing land than bog or heathland. *Sphagnum* mosses make up a fifth (19%) of the vegetation cover with cotton grasses (18%), rushes (13%) and other mosses (12%) also present in large proportions. Whilst the presence of *Sphagnum* moss, dwarf shrubs and cotton grasses are indicative of bog habitat the coverage of narrow-leaved grasses (often associated with shallow peaty soils) may indicate a history of heavy grazing (5).

The three sites in the Peak District (Burbage North, Cowper Stone and Wessenden Head) show a variety of vegetation communities. Heather dominated Burbage North quadrats (45%) with narrow-leaved grasses accounting for the second largest proportion of cover (16%). A dominance of common heather on deep or shallow peats may be indicative of upland heath vegetation, often associated with “drainage, rotational burning, grazing and air pollution” (5). Cowper Stone indicates more of a grassland community than bog or heathland with narrow and broad leaved grasses representing 56% of vegetation cover. The remaining cover is however composed of *Sphagnum* moss (29%), star moss (5%) and heather (10%), which on peat soils of over 0.50m is suggestive of disturbed moorland. Heather, other dwarf shrubs and cotton grasses were noticeably absent from Wessenden Head records. Non-specified plant species (others) represented the largest proportion of vegetation cover (36%) suggesting this site’s vegetation community differs from the characteristic range of bog vegetation assemblages and is either heavily disturbed or verging on a different moorland fringe habitat.

Both Breaccon Beacon sites had a large proportion of narrow and broad leaved grasses recorded. Dwarf shrub and cotton grasses were also less dominate in the vegetation cover of these moorlands. The most southerly site (Pinkworthy, Exmoor National Park) showed the greatest diversity of vegetation types. Dominated by *Sphagnum* and other mosses with cotton grasses, heather, herbs (sorrel, tormentil and bedstraw) and grasses (narrow and broad-leaved) (see Fig. 10) also recorded, indicative of bog vegetation.

As individual sites, even those situated close to each other (e.g. in the Peak District (see Appendix 1), can support different types of moorland vegetation there is limited value comparing between them. We can however compare the vegetation recorded at the same sites, using the same methodology at the same location across different years, to monitor changes in vegetation communities over time, giving us an indication of the impacts of natural and man-made environmental changes, such as climate change and peatland restoration. As different plant species grow at different times of year and are effected differently by weather, sampling at different times of year (e.g. early March or mid-May) can be a significant source of variation.
Figure 9: Proportion of vegetation cover represented by different plants in 1m² quadrats (mean values) in Northumberland (Padon Hill & Steng Moss), North York Moors (Castleton Pits), Peak District (Burbage North, Cowper Stone & Wessenden Head), Brecon Beacons (Trefil Quarry & Black Mountain) and Exmoor (Pinkworthy) National Parks in 2013.

Six years’ worth of vegetation data is now available from some of the early MICCI sites in the Peak District (Fig 9) however as methodologies have evolved over the years early records show whether individual plants are present in a quadrat but do not indicate the proportion of the vegetation cover they represent. Figure 9 shows the proportion of quadrats in which heather (9a), bilberry (9b) and narrow-leaved grasses (9c) were recorded as present.

These data suggest that whilst heather cover has varied between years at individual sites the mean number of quadrats in which it is found hasn’t differed significantly since 2008 with the exception of Harland Brook (Fig. 9a). The proportion of heather cover at Harland Brook does appear to have decreased between 2008 – 2009 and 2011 -2012. Figure 9b shows the consistent coverage of bilberry at four out of five sites in the Peak District, remaining absent at three and maintaining approximately 30% coverage at Long Grain on Thurlston Moor. As the three sites without bilberry (which has been recorded at other sites in the Peak District) recorded do have peaty soils greater than 0.50m and have other dwarf shrubs (e.g. heather) present we would typically expect to see bilberry in some quadrats on healthy bog vegetation, perhaps indicating these areas have been heavily disturbed. The consistently high proportion of narrow –leaved grass cover on these deep peat sites (see figure 12c) supports the suggestion that these moorland sites have been influenced by land management activities such as drainage, burning and over-grazing (5). As mentioned above, the time of year and exact location of sampling must be considered before drawing conclusions from these data, the analysis of which may be explored further during MICCI 2014.
Continuing to monitor changes in the abundance and diversity of different plant types, along with other environmental indicators, year after year at the same locations in the same way can provide valuable information on how moorlands are changing in response to changes in climate and land management.

Figure 10: From top) Proportion of vegetation cover represented by; (a) heather (b) bilberry (c) narrow-leaved grasses between 2008 – 2013 at MICCI sites in the Peak District.

Figure 11: (from left) Sphagnum moss, cotton grasses and dwarf shrubs including bilberry and heather are indicative moorland vegetation.
Outcomes

It has been another successful year for MICCI. Together with the schools that took part we have continued to promote the need to protect the natural resources (such as water, soil and air quality) of moorlands in UK National Parks whilst providing learning opportunities to key rural and urban audiences, particularly young people, from surrounding urban areas.

With thanks to all the schools and students that took part.

Many thanks to MICCI sponsors:

**OPAL** and South West Water through the [Exmoor Mires Project](http://www.exmoormiresproject.org.uk) (2012)

**OPAL** and the East Midlands branch of the [British Association of Science](http://www.bas.ac.uk) (2011)


[Association of National Park Authorities](http://www.anpa.org.uk) (ANPA) and OPAL (2013)

Landowners:

There are many sites that have been used for MICCI projects across the different National Parks, and too many landowners to name them all, but their co-operation and encouragement has been vital to the project’s success, and we thank each and every one of them.

MICCI research support:

Dr Martin Evans of Manchester University kindly provided TOC analysis.

National Park staff from the Cairngorms, Dartmoor, Exmoor, Northumberland, North York Moors, Peak District, Norfolk Broads, New Forest, Pembrokeshire Coast, Brecon Beacons and Snowdonia.

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1 Drinking Water Inspectorate. Defra (2009) Drinking water safety Guidance to health and water professionals

http://publications.naturalengland.org.uk/publication/30021

3 Met Office Historic weather data: Sheffield
http://www.metoffice.gov.uk/climate/uk/stationdata/sheffielddata.txt (14/06/2013)


Appendix 1

MICCI sampling sites (2008 – 2013)