The squelchy bogs of Scotland and East Anglia must be carefully managed, protected, and monitored if the UK is to meet its obligations to curb climate change, according to research as part of the UK Soil Security Programme.

They might not look very special at first glance, but peatlands provide some of the most fertile agricultural land in the UK, and they store huge amounts of carbon and water, reducing greenhouse gas emissions and flood risk. But these natural services are lost as peat soils degrade due to drainage and erosion.

The UK’s biggest carbon store

Peatlands are formed in waterlogged soils, where the lack of oxygen prevents microbes from decomposing dead plants and animals. This makes the soils incredibly rich in organic matter, meaning peat bogs are packed full of carbon. Peat holds one third of all the carbon stored in soils – a quantity roughly equivalent to all the carbon dioxide (CO₂) currently present in the atmosphere. Keeping that carbon in the soil will be crucial for mitigating climate change.

Peat bogs come in two main types – lowland ‘fens’ bogs and upland ‘blanket’ bogs. Fens dominate the East Anglian countryside but are also found in Scotland, northeast England and Northern Ireland. Blanket bogs cover around 2.25 million hectares in the UK and are found predominantly in Scotland and northwest England.

People have drained these waterlogged soils to plant crops or graze sheep but doing so exposes the organic matter to microbes as well. Dormant microbes reawaken and start eating the peat from the inside out, releasing carbon back into the atmosphere. As a result, damaged peatlands account for 5.6% of global greenhouse gas emissions.

Restoring and maintaining these precious ecosystems will be crucial for the UK to meet its component of the EU commitment to the Paris Agreement. “The peatlands are one of our most effective ways of storing carbon”, said Nicholle Bell, a research fellow at the University of Edinburgh.

Blanket bog in Forsinard, Scotland. Damaged peatlands release greenhouse gases into the atmosphere and contribute to climate change.
Intensive and extensive grasslands harbour different soil communities. Opportunistic microbes dominate in intensively managed systems.

**Lowland Peatlands**

Draining the carbon-rich lowland peatlands has provided us with extremely fertile agricultural land, particularly in East Anglia’s fen peatlands. These super-productive fields provide the majority of our salad vegetables - an industry valued at £1.2 billion a year. But these prized soils are rapidly degrading – consumed by microbes and blown away by the wind.

People began using pumps to drain the fen peatlands in the 17th century. Since then 90% of the original area has been converted to cropland or grasslands, and estimates suggest that the soil is vanishing at a rate of 1–2 centimetres a year. “I would say that it is the most unsustainable place in the whole of the UK in terms of agriculture”, said Davey Jones, a soil scientist at Bangor University.

Jones and his team analysed soil samples from 13 fen peatbogs in the UK and found that the depth of the water table had a big influence on how much CO\(_2\) and other greenhouse gases were being exchanged between the air and the soil. Experimenting on blocks of turf, they found that raising the winter water table to 50cm – 60cm below the surface reduced CO\(_2\) emissions by more than two-thirds.

**Striking the right balance**

However, keeping the water table high throughout the year had a major impact on crop yield, so most farmers couldn’t afford to do it year-round. Instead, the team suggest raising the water table in winter and lowering it again in the summer, which reduces CO\(_2\) emissions without harming lettuce yield. To strike the perfect balance, farmers should raise the water table by 1m in winter. If this strategy were rolled out across all of the UK’s peatlands, it would cut CO\(_2\) emissions by 4.3 megatons a year, Jones says.

**Upland Peatlands**

They superficially look quite similar, but peatlands in the uplands are a totally different animal. Known as ‘blanket bogs’, upland bogs aren’t nutrient-rich like the lowland bogs in East Anglia, making them poor for agriculture. Instead, these bogs have been drained for sheep grazing and forestry. But whether you drain a bog for agriculture, forestry or livestock, the result is the same - the soil compacts, air and gases are squeezed out, and microbes begin breaking down the stored carbon.

**The rise and fall of bogs**

As spongy peat soils gain and lose water, gases or organic matter, the surface gradually rises and falls - like slow-motion waves on the ocean. While testing a novel technique for remotely monitoring peatlands (see Box 1), environmental scientist David Large, from the University of Nottingham, discovered an unexpected pattern in the height Scottish peat bogs that could help scientists monitor their health from a distance.

Large and his colleagues found the seasonal timing of the rises and falls depends on the type of vegetation present, which is known to be a good indicator of the health of a bog. Wet, healthy peatlands tend to be dominated by mosses, and reach their peak height in mid-winter, whereas drier peatlands tend to be covered in heather and peak in early spring. This discovery could help scientists diagnose peat soils remotely.

**Molecular soldiers defend soil carbon**

Mosses also seem to be crucial for protecting the peat. “Carbon is stored within the peatlands because there are some soldier molecules . . . that prevent the decomposition of the peat bog by switching off all the microbial decay pathways”, said Bell. The soldiers are thought to be phenolic compounds, produced by mosses such as Sphagnum to protect themselves against hungry herbivores. Phenols are bitter tasting, so animals don’t like to eat them. But they also turn off microbial enzymes - known as hydrolases - that would otherwise break down organic matter. The antibacterial activity of phenols even made Sphagnum a popular as a disinfectant in the 19th century.

Microbes do have a defence against this onslaught – an enzyme called phenol oxidase – but it is disabled when oxygen levels are low. Draining the bog allows oxygen in and kills the moisture-loving mosses, so the supply of soldier molecules dries up too. But Bell and her colleagues discovered that an army of molecules is coming back after restoration that could protect peatland carbon. Chemical tests for these molecules could become a regular part of monitoring the recovery of degraded peatlands.
Nicholle Bell’s team compared the chemistry of peat soils at different states of degradation and restoration to track the return of compounds like phenols as the soil recovers.
A toolbox for monitoring peatland recovery

Scientists are now equipped with a whole toolbox of methods to insure that investments in peatland restoration are being used effectively - from new chemical tests, all the way to satellite monitoring of whole landscapes. This will prove essential as the UK’s peatlands, and the 584 million tonnes of carbon they hold, start to become a top priority for governments in search of practical ways to tackle the climate emergency.

Tracking the success of peatland restoration schemes using radar. Government agencies may have invested hundreds of millions in restoring peatlands but they face challenges in monitoring the success of these schemes over the enormous areas involved. Large and his team trialled a new satellite-based monitoring technique for land managers and policy-makers that could allow them to “cost-effectively validate the success of their investments,” said Large.

The satellite-mounted radar system known as ‘interferometric synthetic aperture radar’ (InSAR) is able to visualise the motion of the peatlands allowing scientists to remotely monitor their health – a task that was once laborious and extremely expensive. Satellite-borne monitoring techniques like InSAR are “giving us a whole new scientific view of the peatland and peatland processes”, said Large.

Just like radar navigation devices, InSAR works by bouncing microwaves off the surface of the ground and calculating the distance. The team found the technique was 78% accurate to measurements on the ground. Its only downfall was when soils moved up or down very dramatically, such as in 2018 when severe droughts caused the peat to drop 3cm in just 6 days, exceeding the technical limitations of the equipment.

Implications & Recommendations

- Bare peat soils are vulnerable to erosion but vegetation can protect top soil and rebuild nutrients, so planting cover crops on cultivated peatlands could help protect them against natural erosion and extreme weather events.
- Carbon dioxide emissions from peatland soils are affected by the depth of the water table, so raising the water table in cultivated peatlands over the winter can reduce emissions without negatively affecting crops.
- Prolonged droughts disrupt microbial communities in upland peat soils, and climate warming makes these communities more vulnerable. Shrubs can help buffer soil fungi against these extreme weather events, so minimising grazing pressure could make peatland microbes more resilient.
- Sphagnum mosses are found on healthy peatlands and release compounds into the soil that protect carbon from being consumed by hungry microbes, and these protective compounds can be measured slowly returning to recovering peat soils, so monitoring chemical changes could help evaluate peatland restoration programmes.

References