

Proxies of Functional Recovery in Restored Peatlands



Image Credit: Jack Brennand

Peatland restoration is recognised as a central pillar of UK environmental and climate policy, as outlined in the Environmental Improvement Plan (EIP)¹. Progress against EIP goals is tracked through the Environmental Indicator Framework (EIF)², which uses a suite of indicators to assess environmental change across habitats, including peatlands. Within this framework, peatland restoration is evaluated using surface-based indicators³.

These indicators are widely used to assess restoration success, determine favourable condition status⁴, and support estimates of carbon savings⁵. Existing frameworks rely on observable surface characteristics, such as vegetation composition, erosion extent, and surface wetness, as proxies for hydrological recovery and reduced greenhouse gas emissions⁶.

Surface proxies also underpin statutory monitoring and carbon finance mechanisms, including carbon savings estimates used by the IUCN UK Peatland Code⁵. By linking visible surface change to assumed emissions reductions, they provide a scalable and accessible basis for evaluating restoration outcomes and issuing carbon credits. Their widespread use reflects their ease of measurement, repeatability, and compatibility with field surveys and remote sensing approaches.

However, peatland function is governed by sub-surface structure, rather than surface condition⁷. Hydrological regulation, gas exchange, and long-term carbon storage are controlled by the size, organisation, and efficiency of peat pore networks beneath the surface^{7,8}.

These structural properties regulate water retention, oxygen availability, and the balance between carbon accumulation and loss, yet remain poorly represented within surface-based assessment frameworks.

Consequently, surface indicators may not reflect whether restored peatlands are functioning in ways that support sustained carbon benefit. While some surface proxies respond to restoration, their relationship with sub-surface recovery has not been demonstrated. Improving understanding of how surface condition relates to sub-surface structure and function is therefore critical for strengthening restoration assessment, reducing uncertainty in carbon claims, and improving confidence in peatland restoration outcomes.

Overview

This brief demonstrates how surface-based indicators used to assess peatland restoration relate to sub-surface structure and function.

1. Peatland assessment frameworks rely on surface proxies to infer restoration success and potential carbon savings, yet these indicators do not account for sub-surface structure and function.
2. Evidence shows some surface indicators demonstrate clearer links to sub-surface recovery than others, although disconnects remain.
3. Surface pH and redox potential profiles are examined in relation to surface condition and sub-surface pore network structure, exploring their potential as biogeochemical proxies of functional recovery.

This brief draws on research from Brennand, J. (2025), *Evaluating UK Blanket Peatland Restoration: Structure, Function, and Net Carbon Benefit*, undertaken as part of an ERDF-funded ECO-I NW PhD project within the Institute of Science and Environment at the University of Cumbria. Sub-surface 3D X-ray micro-computed tomography research was supported by the National Research Facility for Lab X-ray CT (NXCT) through EPSRC grant EP/T02593X/1.

Sub-surface structural analysis across restored blanket peatlands shows visual improvements at the surface do not always correspond to functional recovery at depth. Comparisons between surface condition, including vegetation composition, indicator species cover, and physical degradation extent, and pore network size, organisation, and efficiency reveal variability beneath sites that appear similar when assessed using surface indicators alone, with implications for hydrological regulation, gas exchange, and carbon function (Figure 1).

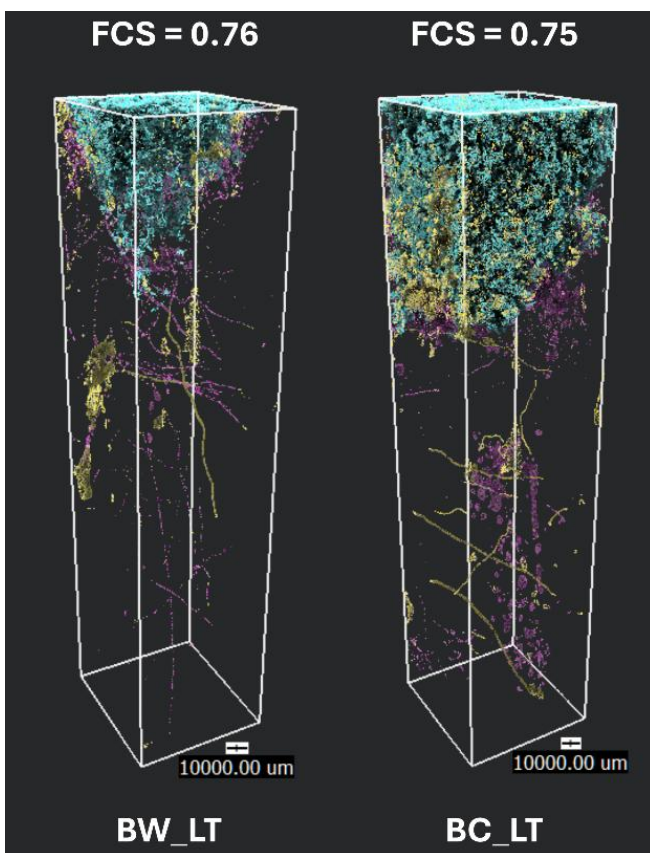


Figure 1: Surface favourable condition scores (FCS; 0.00 = unfavourable, 1.00 = favourable) for two locally turved peat cores (BW_LT: ~10y/o; BC_LT: ~5y/o), shown alongside 3D μ CT renderings of sub-surface pore network structure. Networks are classified as atmosphere-connected (blue), laterally connected (orange), isolated (purple), illustrating contrasting sub-surface structure beneath similar surface conditions.

Surface pH (acidity) and redox potential (anoxia) profiles show relationships with both surface condition and sub-surface indicators of functionality. Higher surface pH relative to degraded baselines aligns with peat-forming species and atmosphere-connected pore networks capable of surface water uptake and retention (Figure 2a). Declining redox potential with depth reflects reduced oxygen availability and pore networks supportive of water

retention and carbon accumulation within the catotelm, while increased redox values at depth are associated with laterally connected drainage pore networks and persistence of perched water tables (Figure 2b). Notably, redox potential appears to delineate the permanently saturated catotelm rather than the position of the water table alone, highlighting its potential as a low-cost proxy for identifying zones of lower and higher carbon loss risk within the peat profile.

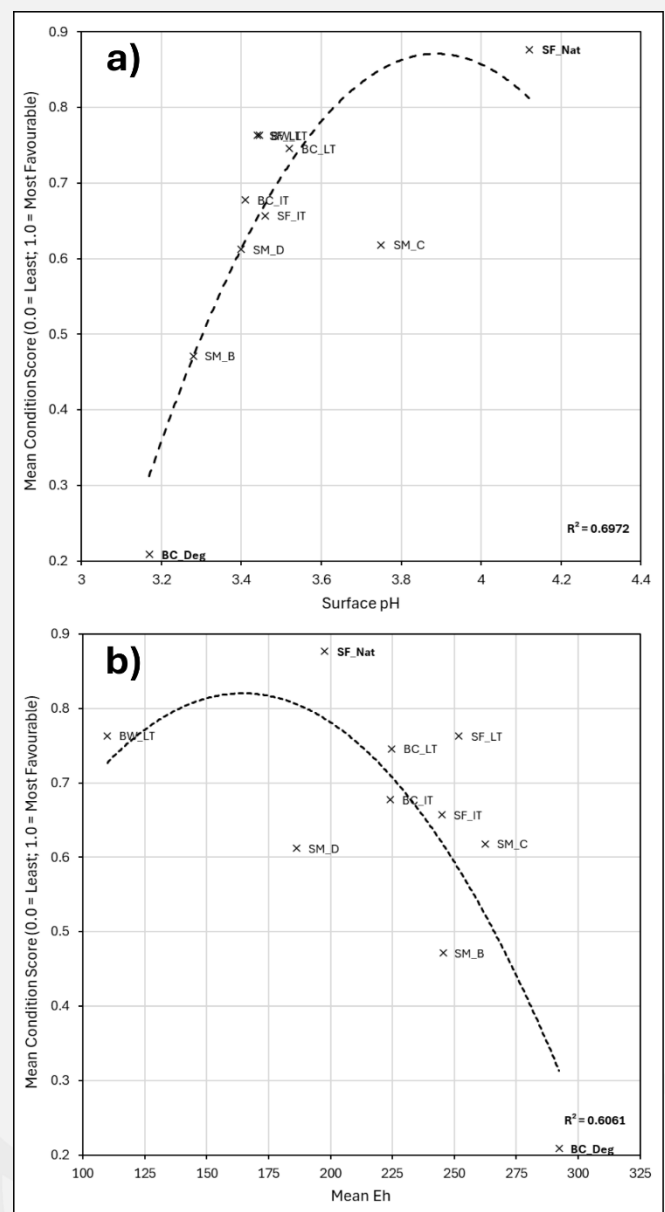


Figure 2: Mean surface favourable condition scores (FCS; 0.00 = unfavourable, 1.00 = favourable) versus surface pH (a) and mean redox potential (Eh) (b). Polynomial fits ($R^2 \sim 0.70$ and 0.61, respectively) indicate relationships between surface condition scores and underlying biogeochemical conditions.

Linking sub-surface structural and biogeochemical findings to surface features reveals contrasts between vegetation states. *Sphagnum*-dominated surfaces are associated with increased atmosphere-connected porosity, reduced lateral drainage, higher moisture, lower bulk density, and more anoxic conditions, reflected in higher pH and lower Eh. Bare peat is associated with a compact, hydrophobic surface, limited surface water uptake, and more oxic, acidic conditions at depth. Graminoid and vascular species dominance aligns with laterally connected drainage networks, promoting drier, oxic conditions, indicated by increased Eh (Figure 3).

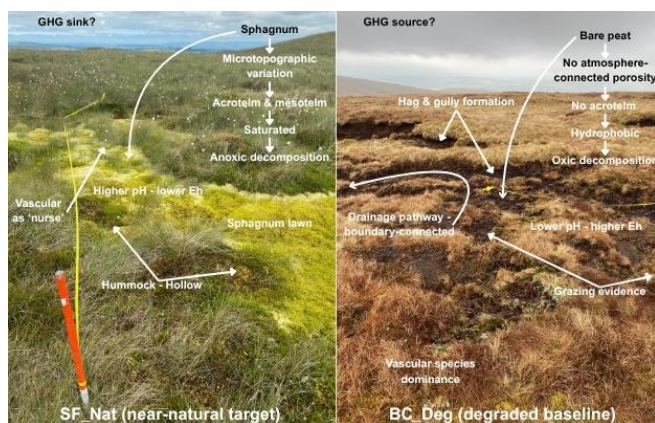


Figure 3: Contrasting surface vegetation states and associated sub-surface hydrological and biogeochemical conditions in near-natural (*Sphagnum*-dominated) and degraded (bare peat and vascular-dominated) blanket peat, illustrating links between surface indicators, pore network structure, and biogeochemical conditions.

Surface condition alone may overestimate functional recovery in restored peatlands. Integrating surface indicators with simple biogeochemical measures, such as pH and redox potential (Figure 4), provides a more robust basis for assessing sub-surface function and associated carbon benefit.



Figure 4: Accessible pH and Eh probing methods.

Key Findings

1. Restored peatlands with similar surface condition retain different sub-surface structure and function, indicating surface-based indicators alone do not reliably reflect functional recovery at depth.
2. Contrasting vegetation states are associated with distinct sub-surface pore network structures, with *Sphagnum*-dominated surfaces aligned with moisture-retentive, atmosphere-connected pore networks, and bare peat or vascular/graminoid dominance aligned with compacted or laterally connected drainage structures.
3. Surface pH and redox potential profiles show consistent relationships with both surface condition and sub-surface pore network structure, supporting their use as practical, low-cost proxies of functional recovery.

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Visit: <https://www.cumbria.ac.uk/study/academic-departments/institute-of-science-and-environment/policy-briefs/>

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