Use of Peat Depth Criteria: Accounting for the Lost Peatlands

Summary

- Definitions of peat around the world have historically been based on exploitation potential for commercial peat extraction or agricultural purposes, rather than being derived on the basis of hydrology, ecology, biodiversity or other non-exploitative ecosystem services. This has given rise to mapping exercises and policy decisions underpinned by an exploitation-focused system of definitions which are increasingly at odds with modern recognition of, and commitment to, holistic ecosystem functioning and services.

- Understanding how peat is formed and its associations with water and peat-forming habitat enables more comprehensive assessment and mapping of peatlands. Conversely, classifications based on historical data sets using minimum peat depth thresholds result in 'shallower' peatland areas being excluded from policy making and land management decisions. Such areas nevertheless continue to be substantial carbon stores, are often vital to the wider ecology and hydrological function of connected deeper peat deposits, and often have their own distinctive biodiversity as part of important areas of transitional habitat.

- Achieving climate change and biodiversity objectives requires a more inclusive approach, i.e., peatland classification and mapping that better recognises ecological and hydrological function and status, and therefore reflects the full potential of peatland values. To meet climate change goals, as much peat carbon stock as possible needs to be secured, including that contained in shallower peats.

- There is an urgent need to examine the 'lost peatlands', currently excluded from policies that rely on peat depth thresholds, and to assess the implications for strategic peatland objectives. Whilst it is appropriate for policy and regulation to define the areas to which they apply, we encourage that consideration is first given to the full extent of peatland. Rather than attempt to define a peatland using policy alone, regulation should start with a science-based definition, and then explain any constrained application of that policy to specific aspects of peatland management.

- It is recommended that a UK-wide definition of peat and peatland environments, focused on their sustainable and wise use, is agreed.

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Introduction

Throughout history, until the final decades of the 20th century, the idea of peat being a resource for exploitation was the dominant one. As such it was drained, extracted as fuel and horticultural growing medium, or converted to agricultural production, forestry, or urban development. Peatland was only considered as a useful resource when converted into something else (Joosten and Tanneberger, 2017). Consequently, many descriptions and definitions developed during this time relate to values for the exploitation of peatlands. Since the end of the 20th century, not only has increasing evidence emerged regarding the scale of peatland habitat loss across the world, but there is a growing awareness of the consequences arising from such loss (Joosten and Clarke, 2002; Leifeld *et al*., 2019).

Peatlands are acknowledged for the significant level of ecosystem services they provide when in their natural or restored state, while conversely, peatland degradation has given rise to increasingly serious levels of concern – not least over the climate consequences of releasing huge quantities of stored peatland carbon into the atmosphere (Page *et al*., 2002; Evans *et al*. 2016; UNEP, 2022). This has brought about a re-examination of the ways in which peatlands are described and defined, with a much greater focus on peatlands as living ecosystems, particularly as ecosystems capable of delivering a wide range of ecosystem services when in their natural state.

Defining 'peat' and 'peatland' is thus important: the presence of peat is often now a lynchpin for land use policy. For example, climate change and biodiversity objectives require measures of peatland area and its condition. In forestry, the presence of peat on a site will trigger additional survey and either halt planting or prescribe how any planting should occur (Scottish Forestry, 2021), while windfarm developments must undertake development impact assessments on any peatland present (Energy Consents Unit Scottish Government, 2017).

Different policies relating to peat or peatland often define peat and peatlands in the context of the policy area and the risks which are being balanced. There is, however, a danger in relying on policy alone to determine how peatlands are defined, rather than adopting definitions derived from an understanding of peatland function. Risks to peatlands may be overlooked, or decisions made which are not based on adequate recognition of peatlands and their key role within the landscape. There is also a danger that definitions set for previous objectives may no longer be appropriate as drivers of policy, given current priorities and understanding. The collective impact of a policy-led approach could mean that large areas of peatland are in danger of being excluded from accurate accounting, funding and protection, as well as undermining strategic peatland and wider environmental objectives.

What is peat and how is it formed?

Peat is an aggregation of dead plant matter that has resisted complete decomposition, specifically as a result of waterlogging, whether by groundwater, rain, fog or dew (rather than by desiccation, acidity or other means) and has accumulated in situ (Lindsay and Andersen, 2016; Lourenco *et al*., 2022). Peat is most commonly categorised as a soil because it accumulates as a surface layer which covers the underlying ground. While all soils are a continuum of mineral and organic surface deposits, peat is distinctive because it lies at one extreme end of this continuum, having a much higher proportion of carbon-rich organic matter than any other soil type; sometimes consisting almost entirely of organic plant matter. An area possessing such an accumulation of material is termed a peatland, and this remains the case, whether or not the area continues to support peat-forming conditions or peatland vegetation.

Organic plant material preserved specifically by waterlogging typically accumulates over time. Consequently, peatlands display a continuum of depths from initial thin layers to deposits of 15 m or more (Lindsay, 2010). Peat thickness may vary for several reasons, including date of peat initiation, slope, water chemistry and climate. In the natural, untouched scenario, waterlogging unites all parts of a peatland with different depth profiles into a hydrologically connected entity. A further key distinction resulting from in situ accumulation is that peat displays a chronological sequence of accumulation, preserving both a record of its development as well as a chronological sequence of other materials which may have been preserved within the peat.
All soils are a mixture of mineral and organic matter in differing proportions. The mineral content of peat can vary substantially depending on the conditions under which the peat is formed. Bog peatlands are maintained in

waterlogged condition solely by direct precipitation in the form of rain, snow, fog, mist, or dew, with little or no groundwater influence. Fens fed by calcareous springs may have a high calcium content, and floodplain fen peat may have significant pulses of mineral solids added during flood events. In nations such as Japan and Iceland, there may also be very substantial inputs of volcanic ash (Fujita *et al*., 2009). However, peat soil is fundamentally distinguished from other soil types by its relatively high content of organic matter, which may range from 30% to virtually 100%, making peat a uniquely carbon-dense soil.

Globally, there is more carbon stored in the world's known peatlands (597.8 Gt C) (Leifeld and Menichetti, 2018) than there is in all the world's vegetation combined (496.6 Gt C) (Scharlemann *et al.*, 2014), and almost twice the amount stored in the world's forest above-ground biomass (362 Gt C) (Pan *et al*., 2013). Because peat occurs as a continuous mat across the ground surface, even shallow depths of peat can equal or exceed the total carbon storage per hectare of other ecosystems, including tropical rainforest (see Figure 1).
In theory, any plant material can form peat, as long as it is waterlogged. Across the globe a variety of plant species, including trees, do form peat, but in practice such peat-forming species are almost entirely those which are adapted to the very particular environment and habitat conditions of a natural living peatland.

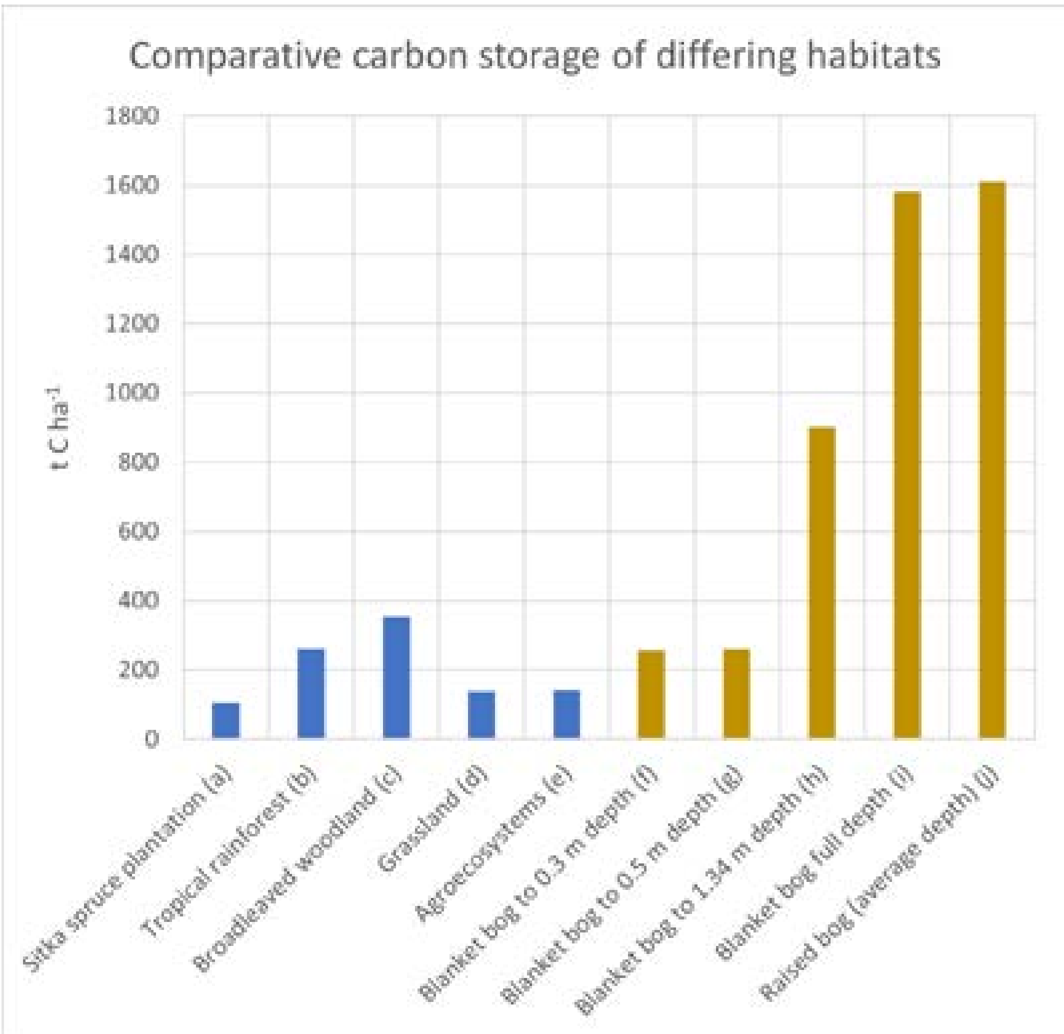

Figure 1. *Quantity of stored carbon per unit area (hectare) in various ecosystems. Data from: (a) Morison* et al. *(2012) for 80-year rotation, including carbon added by plantation to existing soil carbon stock; (b) Sullivan* et al. *(2017) with % soil carbon added based on Blais* et al. *(2005); (c, g, i, j) Gregg* et al. *(2021); (d) White* et al. *(2000); (f) Crouch and Chandler (2021); (h) Smith* et al. *(2009).*

What is peatland?

The Ramsar Convention defines peatlands as "ecosystems with a peat deposit that may currently support a vegetation that is peat-forming, may not, or may lack vegetation entirely" (Ramsar, 2002). The key feature of this definition is that any area of land with a surface layer of peat can be considered a peatland, regardless of its condition. This is also reflected in the definition offered in the 2022 UNEP Global Peatlands Assessment that states "land with any thickness of in situ peat is a peatland". Together, these mean that any area currently accumulating peat, or which has done so in the past, can be considered a peatland.

A 'mire', on the other hand, is a wetland supporting at least some vegetation that is normally peat-forming and is generally applied to peatlands which are still in a sufficiently undisturbed state currently to support a vegetation assemblage normally associated with peat formation (Lindsay, 2016; Joosten *et al*., 2017). The term does not, however, require peat to have actually formed. This is because there are some highly valued mire systems where high calcium levels, or permafrost conditions, have prevented significant peat accumulation. Mires and peatlands thus overlap to a considerable degree, but there are many peatland areas devoid of any peat-forming vegetation and there are some mires without any peat.

Sometimes a peatland might be referred to as 'active'. This comes from interpretation of the EU Habitats Directive list of priority habitats. It is used to describe bog habitats that are "still supporting a significant area of normally peat-forming vegetation" (European Commission DG Environment, 2013) and would thus also be classed as mires. Critically, the EU definition also allows for a site to be referred to as active if peat formation has come to a temporary standstill, for example after a fire or a drought.

How are peatlands classified?

All classification systems are developed for specific purposes. A geologist may simply wish to record the presence of a superficial deposit such as peat, while an agricultural soil scientist may wish to classify organic soils according to their potential fertility and ease of drainage. Every classification system makes use of descriptors which have been selected to provide information relevant to the objectives of the particular classification system. Some peatland descriptors, such as mineral content or dry bulk density, may be common across multiple classification systems, some may be unique to specific classification systems, while others may employ similar terms but have quite different meanings for these terms.

Peatlands have been subject to a multiplicity of classification systems, descriptors, and terminology, but for present purposes the most relevant are hydrology, nutrient status, habitat type, vegetation, topography, and peat characteristics such as humification and organic and mineral content (Lourenco *et al*., 2022). In an ecological context, the most fundamental classificatory distinction recognised is that between bog and fen. Bog peatlands are maintained in waterlogged condition solely by direct precipitation in the form of rain, snow, fog, mist or dew with little or no groundwater influence, while fen peatlands are maintained in a waterlogged state largely by groundwater and focused surface water inputs. Damaged peatlands blur this distinction, generally either in the direction of more fen-like conditions, or towards non-peatland conditions in the form of, for example, permanent grassland, heathland, carrot fields or plantation forest.

When peatlands are considered on a landscape scale, all bog systems in their natural state are accompanied by fen systems, either around their margins or as a network of surface water and groundwater fens dividing the bog environment into more or less distinct units. Thus, when entire landscapes are cloaked in peat to form a 'blanket mire landscape', this landscape represents a peatland complex consisting of blanket bog units fed only by precipitation, interspersed with, and interconnected by, a mosaic of fen units fed by a variety of sources such as springs and seepages.

Blanket mire landscapes represent the most extensive form of peatland in the UK, dominating large swathes of the uplands, though blanket peat can also be found at sea level in the north and west of Scotland (Lindsay *et al*., 1988). Such peat covered landscapes form because the climate is cool, constantly humid and has regular cloud cover or hill fog; conditions which encourage peat formation to cloak all but the steepest slopes in variable thicknesses of peat. However, popular perception of the uplands are not as peat covered landscapes but as 'moorland'. This term is widely understood as wild, open, mostly gently rolling hills, but is more of a cultural concept than a habitat description (Simmons, 2003). However, by subsuming the peatland ecosystem under this broad cultural term there is the danger, frequently realised, that 'moorland' management will fail to take into account the particular characteristics and sensitivities of such peatlands, leading to degradation of their condition and the benefits and services they provide.

Moorland

Moorland is a term that is usually applied to uncultivated upland landscapes which are typically dominated by peat soils. It is, however, an umbrella term that includes a variety of habitats, from blanket bog to upland grasslands and heaths. As moorland covers such a broad range of habitats and soil types, the term is not helpful in making detailed decisions regarding management, research and policy.

Carbon, water and biodiversity functions vary depending on the specific habitat type, underlying soils and water regime. Within the mosaic of habitat types that can comprise a moorland, individual habitats can give an indication of underlying conditions (e.g., blanket bog on deep wet peat and heath on well-drained mineral soils). However, land management can influence habitats, so they no longer reflect natural conditions. Heathland vegetation, for example, can occur on deep peat soils formerly dominated by blanket bog vegetation if the peatland habitat has been damaged by draining or burning.

In such cases, heathland vegetation is an indicator of degraded peatland condition, and if external influences were controlled, the site could naturally return to a more favourable hydrological state supporting a functioning blanket bog ecosystem. Elsewhere, heath occurs naturally on slopes too steep for peat formation.

Rather than applying a generalised approach to moorland management, effective decision-making depends on:

- recognising the many differing components of the moorland landscape;
- understanding their differing sensitivities and management requirements;
- identifying the impacts of past land use management on these various components.

Mapping and definitions

Minimum depth and % organic matter

In order to create a map, it is first necessary to create mapping categories, which in turn requires clear definitions for every mapping category based on the purpose for which the mapping is being undertaken. In the case of peatlands, the most pressing question for a variety of sectoral interests over the years has been the desire to identify the presence and extent of peat, primarily for exploitation.

Mapping of the UK's geological resources in the 19th century led to peat being mapped by the British Geological Survey as a 'superficial deposit' with a minimum depth of 1 m. However, the first attempt to precisely define the actual nature of peat was in the 1920s by engineers; namely, as an organic soil containing between 20-100% organic material and an ash content of <80% (Lourenco *et al*., 2022). In the 1930s, the 2nd International Congress of Soil Science defined peat as an organic soil 50 cm deep containing <35% ash content (i.e., at least 65% organic matter) and covering an area >1 ha (Wüst *et al*., 2003).

During and following World War II, the Scottish Peat Committee focused on surveying exploitable peat resources, and their work fed into the Soil Survey of Scotland, which adopted a definition of peat that required a minimum depth of 50 cm (Lilly *et al*., 2015). The Soil Survey of England and Wales was also initiated in the immediate post-war period, but it was more focused on agricultural potential, and thus adopted a definition of peat based on a minimum depth of 40 cm – considered to be the maximum ploughing depth. These two definitions persist to the present day and dictate government policy in relation to peat, as well as influencing the views and actions of many stakeholders. In contrast, definitions of peat that were not exploitation-based began to develop in the latter half of the 20th century.

In the 1970s, as part of a global mapping exercise, the Food and Agriculture Organisation of the United Nations (FAO) and the United Nations Educational, Scientific and Cultural Organisation (UNESCO) defined histosols (another term that can have several meanings, and in this case an umbrella term for organic soils including peat) as soils with an organic carbon content (typically half that of the organic matter content) of >12-18%. This was later updated to include organic layers of 10 cm or more overlying rock or ice, as well as areas with at least a 60 cm thickness of moss fibres or 40 cm of other dead plant matter (FAO, 2015).

In the 21st century, whilst arguing for the preservation and protection of peat as a nature and climate critical resource, Jooston and Clarke (2002) proposed a definition which defined peatlands as having >30% organic material (as dry weight) and a minimum depth of 30 cm. A later definition provided by Joosten *et al*. (2017) retains the requirement for 30% organic material but drops the concept of a minimum depth. Indeed, in that same volume, which describes the peatlands of every nation in the Continent of Europe, 17 of the 49 nations do not use a minimum depth threshold in defining peatland, 26 nations (including Russia) use 30 cm or less and only six nations use depth thresholds of 40 cm or more. Meanwhile, Loisel *et al*. (2017) in a global review of northern peatland carbon stocks state that "peatlands are characterized by a water-saturated soil layer consisting of at least 30% (dry mass) organic material. Most definitions require a minimum peat thickness of 30 cm for an ecosystem to be considered a peatland".

A minimum depth threshold in defining peat thus has a demonstrably long history of use and has obvious advantages when surveying for the purpose of creating a map. When the prime focus of such mapping was for the purposes of exploitation or development, particular thresholds could be determined by requirements arising from the proposed means of exploitation: peat shallower than 50 cm is not suitable for commercial extraction, whilst peat shallower than 40 cm can be turned and mixed with underlying mineral by the plough. Modern requirements, however, cannot so easily be met by using a simple depth threshold: moss-generated surface roughness which slows flood peaks may require a moss carpet only a few centimetres thick; peat soils of only 30 cm are still sufficiently carbon-rich to exceed the emissions of many other habitats if destroyed, and peatland margins are often biodiversity hotspots because they represent transition zones between differing habitats.

As a consequence, there is an increasingly widespread move away from minimum depth thresholds when defining peat and a move towards the use of % organic matter as a key indicator (Joosten *et al*., 2017). This results in greater alignment with definitions for all other soil types, because % organic matter is a standard measure for all soils, whereas a minimum depth threshold is not. It also more clearly places peatlands on the spectrum of % organic matter and helps to highlight, in a way that a depth threshold does not, the extraordinary quantity of carbon stored in peat soils when compared with other soil types.

Figure 2. *A fragment of dried peat, with a 20p coin to indicate scale.*

Use of % organic matter also makes more sense than setting an essentially arbitrary depth threshold if one considers what is illustrated in Figure 2. The object positioned next to the 20p coin consists almost entirely of organic matter and is quite evidently 'peat' – there is no other term that could sensibly be applied to this material – yet it measures only ~5 cm on its longest axis. For a material to be recognised as peat, there is clearly no inherent requirement for it to attain a particular depth beyond a centimetre or so.

While a depth threshold is undoubtedly one of the simpler metrics to obtain in the field when surveying to create a map of peat, Joosten *et al*. (2017) instead select >30% organic matter as their sole determinant, observing that "30% is a practical criterion, because

between 8% and 30% it is impossible to assess the organic matter content manually in the field.”
They further observe that even a minimum peat thickness of 30 cm excludes many sub-arctic and sub-alpine mires. They do, however, acknowledge that the widespread use of a 30 cm depth threshold has “a practical background, both from an ecological (most roots are found in the uppermost 30 cm of soil) and from an agricultural point of view”.

UK Soil Survey classifications and mapping

Current UK policy and planning regarding peat is based on definitions provided by the various UK National Soil Surveys, in all cases derived from post-war drivers of exploitability and land capability and thus employing a minimum depth threshold of 40 cm for England and Wales and 50 cm for Scotland and Northern Ireland, as shown in Figure 3. However, in terms of mapping the peat resource based on these criteria, the picture is more complicated.

In England and Wales, and in Northern Ireland, the Soil Surveys adopted an approach used in the USA whereby soil types are named after the ‘type’ site from which a particular soil ‘series’ is first identified and described. In contrast, the Soil Survey of Scotland adopted the Canadian approach of recognising soil ‘associations’ based on soil drainage characteristics (Hallett and Deeks, 2012). The two approaches are not readily interchangeable and thus present challenges when generating a consistent UK-wide map. Both approaches do recognise categories equivalent to the deep-peat World Reference Base class of ‘histosol’, but it is in the classification and mapping of other peatland conditions that complications arise.

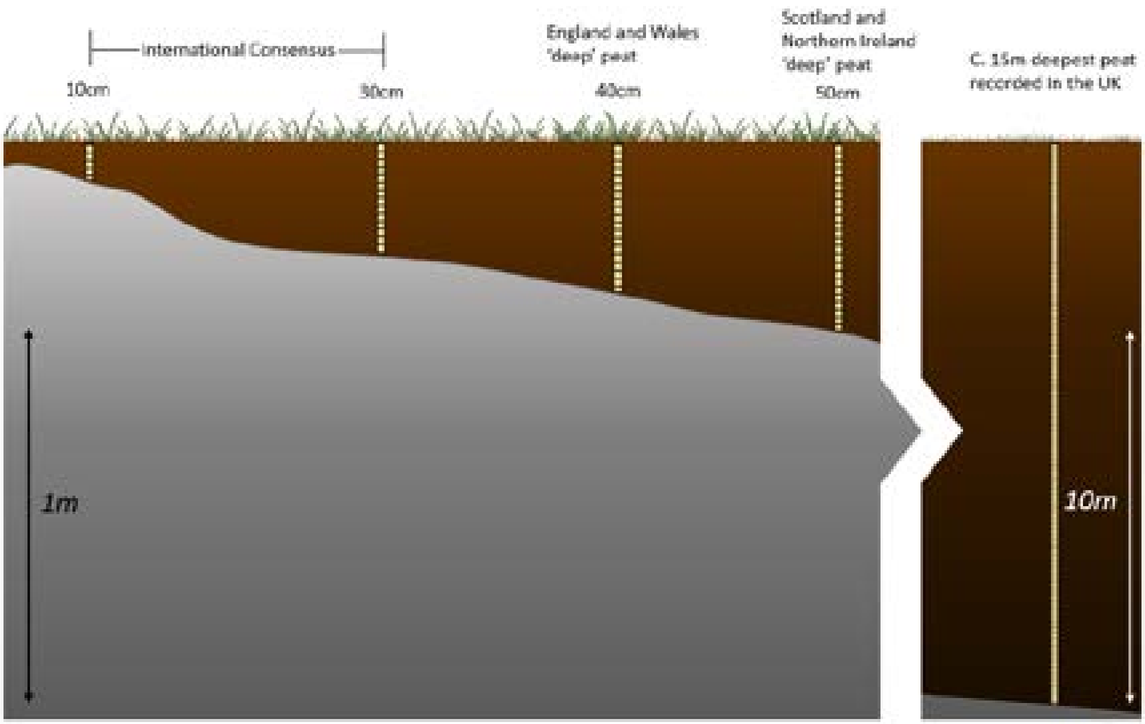

__Figure 3.__ The differing uses of minimum peat depth to define ‘peat’ as employed by the Soil Surveys of England, Wales, Scotland (and Northern Ireland), as well as the threshold range more widely adopted internationally, together with an indication of the deepest peat recorded for the UK.

In particular, the upland landforms of England, Wales and Northern Ireland are mostly (but by no means always) large ‘whale-back’ massifs which encourage deep peat to form across their broad plateau summits, with peat gradually shallowing downslope towards the intervening valley floors (see Figure 4a). In such landscapes, the shallower peat forms wide halos round the centres of deep peat and the relevant soil series for such ground can be readily identified and, if considered appropriate, added to the peatland inventory.

Whilst there are whale-back landforms in the Scottish uplands, there are many blanket mire areas where the landform is much more complex (see Figure 4b). The Soil Survey of Scotland approach to such areas involved creating a large number of soil ‘complexes’ based on distinct landform units, each of which contained a number of different soil types, often including peat. A soil complex might thus be described as containing, for example, ‘peaty podzols, humus-iron podzols, some gleys and peat’.

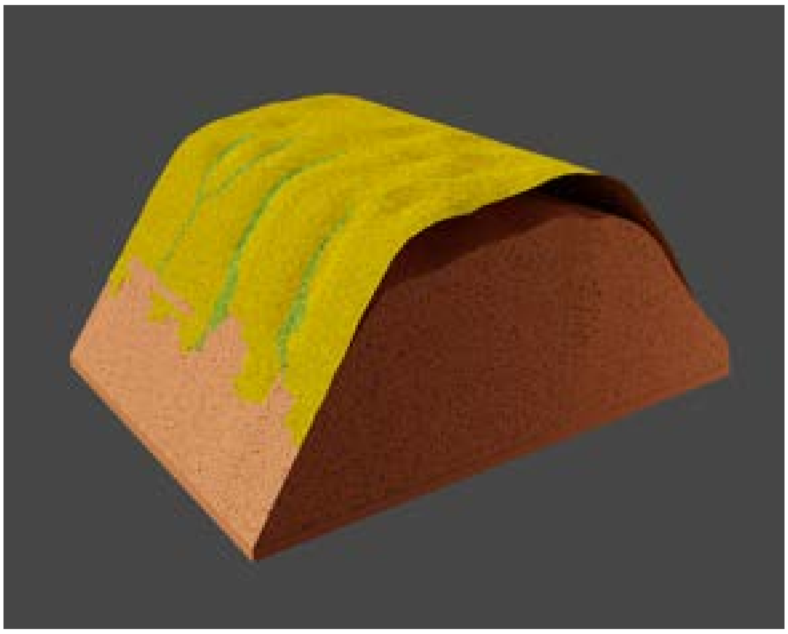

Figure 4a. *Typical 'whale-back' blanket mire of the Pennines, with the deepest peat dominating the broad plateau summit while a steadily diminishing thickness of peat cloaks upper parts of the hill-slope. Underlying mineral ground is shaded speckled pink. Blanket bog is shaded speckled gold while integral fen areas, often also giving rise to shallower peat, are shaded speckled green.*

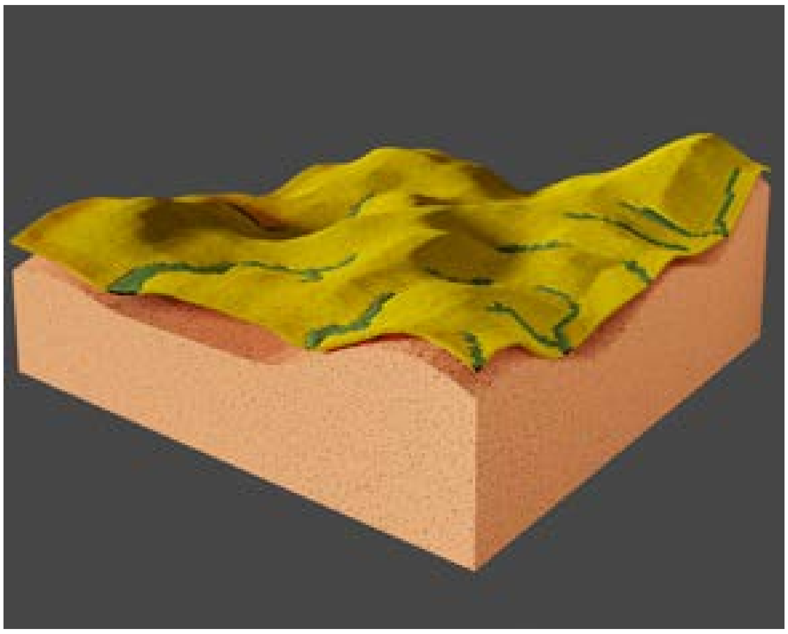

Figure 4b. *Characteristic undulating and complex terrain commonly found in northern and western Scotland. The blanket mire surface is shaded speckled gold, while integrated fen components within the mire complex are shaded speckled green. The underlying mineral ground is shaded speckled pink. Peat thickness varies over quite short distances, with deeper peat forming over basins, level ground and broad plateau summits while shallower peat forms across the slopes of underlying mineral ground.*

In addition, within the Soil Survey data across all four nations there are also soil series or soil associations describing peat soils which have depths less than the critical threshold and which are not therefore identified explicitly as 'peat'. These 'peaty soils' are ignored if only the strictly-defined 'peat' classes are used to map the peat resource. The consequences of this for policy can be seen in the 2011 Joint Nature Conservation Committee (JNCC) report 'Towards an assessment of the state of UK peatlands'. This report specifically maps and collates data for both deep peat and peaty soils across the UK, the extent of which are given in Table 1, while the mapped distribution is shown in Figure 5.

It can be seen from Table 1 that in all cases except for Northern Ireland, the soil units identified as peaty soils account for a substantially greater area than the soil units identified as peat – in Wales, dramatically so. For the UK as a whole, the peat soil category represents just 41% of the total peat and peaty soil area. Figure 5 reveals that in terms of distribution of these two soil groups, the picture in England and Northern Ireland is indeed largely as shown in Figure 4a, where the shallower peats form a halo around areas of deeper peat. This is also true for Wales, but inclusion of peaty soils adds considerable areas of ground in south and west Wales. In the case of Scotland, there is a clear geographical trend, with deeper peat dominating central and northern parts of Scotland, while shallower peats predominate across the west of the country, reflecting the type of peat-draped landscape shown in Figure 4b.

	England	Wales	Scotland	Northern Ireland	UK totals
Peat	679,926	70,600	2,326,900	206,400	**3,283,826**
Peaty Soils	738,618	359,200	3,461,200	141,700	**4,700,718**
Country totals	**1,418,544**	**429,800**	**5,788,100**	**348,100**	**7,984,544**

Table 1. *Area totals (ha) for peat and peaty soils derived from soil survey mapping (JNCC, 2011).*

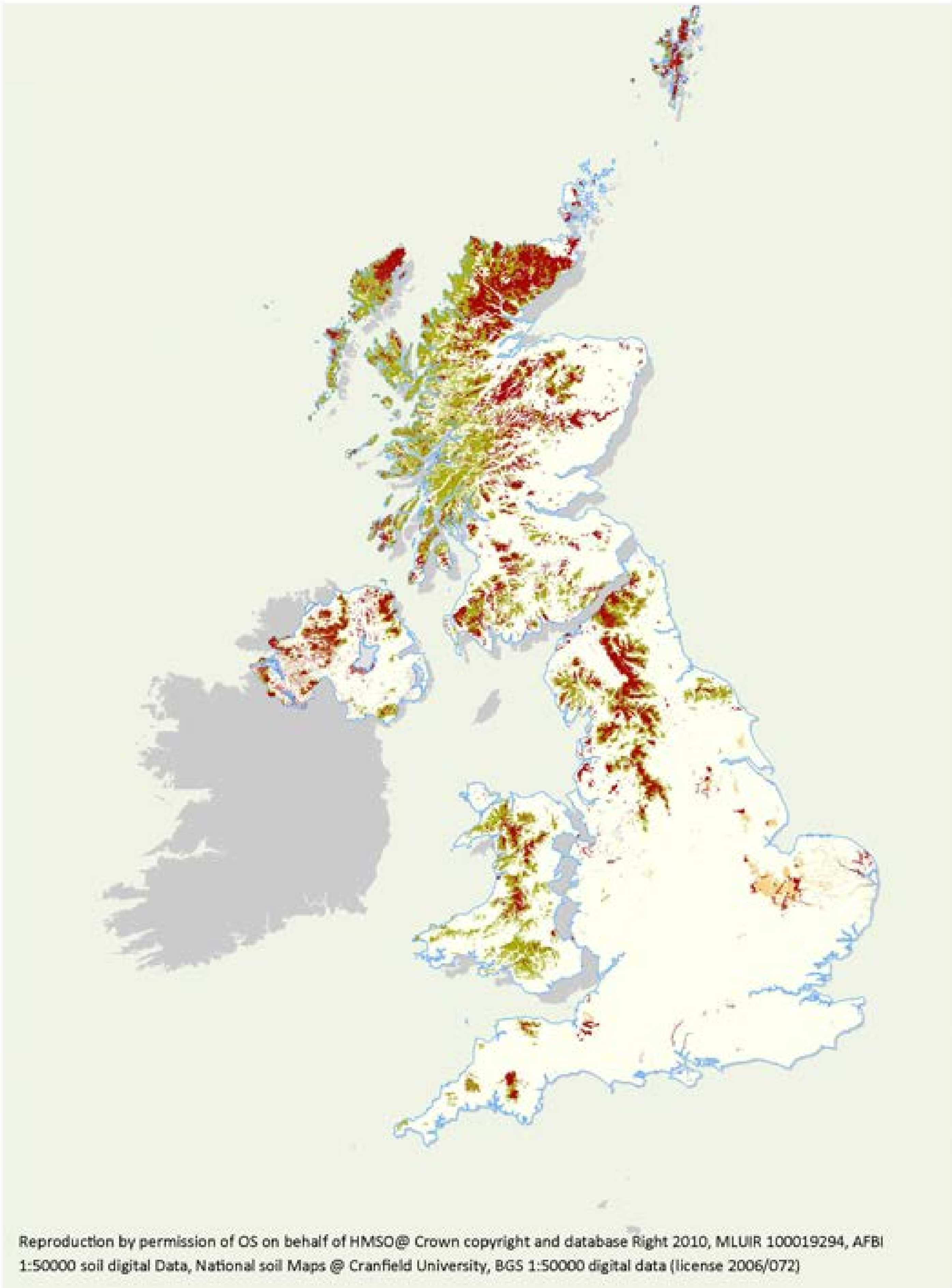

Figure 5. *Map of deep peat (continuous coverage, red), shallow peat soils (mosaic peatland habitat, green) and wasted deep peat soils (yellow) in the UK, derived from National Soil Survey data. Peat soils are those exceeding 50 cm in Scotland and Northern Ireland, and 40 cm in England and Wales. Peaty soils are those soil classes which are either shallower than these depth thresholds, or may be deeper but occur as pockets within complex landforms (JNCC, 2011). A more recent map using data from the BEIS 'Implementation of an Emissions Inventory for UK Peatlands' (Evans* et al.*, 2017) can be found in the 'The State of UK Peatlands: an Update' (Artz* et al.*, 2019), showing the extent of UK peatlands, but the older map has been used here to demonstrate the areas of peat excluded by minimum depth criteria.*

It is possible to compare these figures with those in the policy-focused report to the former Department for Business, Energy and Industrial Strategy ‘Implementation of an Emissions Inventory for UK Peatlands’ (Evans *et al*., 2017) – see Table 2.

This report was commissioned “to develop and implement a new method for reporting greenhouse gas (GHG) emissions from peatlands in the UK’s emissions inventory”. The report specifically excludes peat soils less than 40 cm in England and Wales and peat soils less than 50 cm in Scotland and Northern Ireland. It does so by adopting the constrained definitions of peat employed by the various National Soil Surveys. Adopting such definitions has the effect of potentially excluding more than 50% of the peatland resource by land area from UK emissions reporting.

	England	**Wales**	**Scotland**	**Northern Ireland**	**UK totals**
Area of peat	495,828	90,050	1,947,750	242,622	2,776,250

Table 2. *Area totals (ha) for peat soils derived from a variety of sources but constrained by a minimum depth of 40 cm in England and Wales and 50 cm in Scotland and Northern Ireland (Evans* et al.*, 2017).*

Both the JNCC (2011) report and Evans *et al*. (2017) recognise a third type of peat soil for England, termed ‘wasted peat’. This is a term devised by agricultural interests to describe formerly deep peat deposits that have been heavily degraded to the point where the peat is now so thin that it becomes mixed with the underlying mineral layer during tilling, or areas where the peat has almost entirely vanished as a result of shrinkage, oxidative loss and wind-blow, increasingly exposing the underlying mineral ground (Evans *et al*., 2016). In effect, the carbon from these wasted peats has already been emitted to the atmosphere.

The JNCC (2011) report also recognises within England and Northern Ireland a fourth type of peatland soil which it terms ‘peaty pockets’ (see Figure 6). These may be thought of as analogous to some of the soil complexes devised by the Soil Survey of Scotland, where peat occurred as scattered features within physically complex landforms. Such areas are widely scattered across the south of England, extending all the way to the south coast.

These ‘peaty pockets’ serve to highlight the fact that the natural range of peatland habitats extends right across the UK. Although peat in the UK is generally thought of as a feature of the north and west, and particularly of the uplands, peatlands can be found throughout the UK’s lowlands. Even London possesses some *Sphagnum* peatlands, and many river valleys along the south coast of England continue to support remnants of peatland habitat. This is an important consideration for policy initiatives such as natural flood management, carbon emissions reductions, biodiversity targets and landscape recovery.

Impact of definitions on peatland mapping

It is easy to see the impact that minimum peat depth thresholds (and other mapping decisions) have on accounting for peatland extent by looking at the history of peatland estimates in the UK. In 2010's 'Peat Bogs and Carbon: A critical synthesis', peat estimates from the late 1960s to the time of publication were compiled (Lindsay, 2010). A dramatic and gradually increasing variation in estimates for peat extents was found, with a threefold increase from minimum to maximum estimates. There were also nation-specific trends, with peatland area in Scotland steadily increasing, and falling in England. These changes were attributed to differences in methodology (field survey or aerial image desk study), resolution of survey, and application of minimum depth thresholds to define the presence of peat. The latter of these in particular continued to constrain estimates of peatland area, and thereby maintain a fairly consistent minimum total extent, whereas the setting aside of a depth criterion drove large increases in estimates, as shallower peat deposits were documented and included. Overall, it was concluded that the probable extent of UK peatland lay somewhere between 1.5 million and 5 million hectares.

Since 2010, the disparity in area estimates has, if anything, increased (see Tables 1 and 2), almost entirely due to continued application of the minimum depth thresholds. At the same time, improved mapping identified more areas as peatland which may have been classified as other habitat types in previous mapping. The chapter on UK peatlands (Lindsay and Clough, 2017) within the most comprehensive review so far of peatlands in every European nation (Joosten, Tanneberger and Moen, 2017) also illustrates the increased difference in area totals which occur if depth thresholds are applied to peat data. Using a wide variety of data sources, including the JNCC (2011) report, Lindsay and Clough (2017) arrive at a UK total of 2,863,826 ha for peat using minimum thresholds, compared with a total area of 7,384,544 ha if these minimum thresholds are not applied.

Peatland definitions and policy

"Only what gets measured gets managed" (Klaus, 2015), but conversely, what is not measured is not then managed. The carbon content of even relatively shallow peat has already been highlighted in Figure 1, so potential exclusion of such ground from consideration may, for example, have substantial implications for UK emissions reporting and the UK's Nationally Determined Contributions (NDCs).

Carbon storage is nevertheless just one ecosystem service associated with peatlands. The Office for National Statistics (ONS) values peatlands at £888 million in terms of their function as suppliers of drinking water and £274 million in terms of peatland-related recreation (ONS, 2019). The highly distinctive biodiversity associated with the extreme environment of peat bogs, coupled with the often extremely rich biodiversity of fen peatlands, represents a major contribution to the UK's natural capital and offers much in terms of enhancing biodiversity targets.

Peatlands also offer flood-relief zones and, when in good condition, peatland-dominated catchments can spread flood peaks by adding significant surface roughness to the catchment terrain. The ONS estimates that if only 55% of UK peatlands were restored to good condition, the benefits in terms of reduced carbon emissions alone would be worth £45 billion to £51 billion.

All these benefits depend, however, on first recognising that an area is a peatland and therefore contributing to, or suitable for, such measures. The current policy focus only on peatlands which exceed 40 cm or 50 cm means that other land use policies continue to result in loss or degradation of areas which do not meet these thresholds – thresholds which have their origins in active exploitation of the UK's peat resources.

Current forest policy in some parts of the UK has recently undergone a significant change in terms of planting guidance and peat. Whereas previous guidance (Patterson and Anderson, 2000; Scottish Forestry, 2019) had recommended that peat deeper than 50 cm to 1 m should not be planted – thereby in effect pushing planting activities onto shallower peat soils – the latest guidance for England (Defra, Forestry Commission and Natural

England, 2022) states that planting grants will not be approved for peat deeper than 30 cm. From October 2021 in Scotland, as well as not permitting planting on peat deeper than 50 cm, any Forestry Grant Scheme application which includes medium and high disturbance soil cultivation techniques, such as ploughing on soils where peat depth exceeds 10 cm, will not be accepted, although low impact methods of tree planting on shallow peat will continue to be supported (Scottish Forestry 2021).

In terms of managed burning, current policy in Scotland is that 'peat' should not be subject to such activity because it is acknowledged as a 'sensitive habitat', but it is only defined as 'peat' if it is more than 50 cm deep (NatureScot, 2021). Meanwhile in England, managed burning is subject to licence (because it is recognised as potentially harmful) only on protected sites where the peat depth is greater than 40 cm (Defra, 2021). As a consequence, throughout Scotland and England, managed burning continues to be carried out on peat less than 50 cm deep.

In terms of thin peats, wasted peats and peaty pockets, the peat often now exists only as remnant thin layers because the peat has been physically removed, as in the case of domestic peat cutting or commercial peat extraction, or because of continued drainage and sometimes burning which has led to much of the original peat thickness being lost - either to the atmosphere through oxidation, or into streams and rivers as particulate organic carbon (POC) and dissolved organic carbon (DOC). Policies which do not recognise such areas as peatland inevitably risk loss of opportunities to restore peatland habitats through peatland restoration funding and thus, perversely, encourage permanent conversion of such areas to forms of land cover other than peatland.

Currently a minimum depth criterion is applied to many policies and schemes designed to protect peatlands around the UK. Although recognising that depth can be useful in this context, providing a cut-off for various activities that cause harm to peat soil and habitats, there is a danger that a fixation on depth could exclude extensive areas of often forgotten and sensitive shallower peatlands. With the current constrained definitions of peat and peatland, based on peat depth, an area in the UK at least as large as the currently recognised area of 'deep peat' is currently being defined as 'not peat' and therefore risks being managed in a way that is harmful to all its peatland characteristics and services. In carbon storage alone, the *Sphagnum* layer in these areas can contain as much carbon as plantation forest (Lindsay 2010).

Although the climate crisis encourages focus on the carbon content of peatland systems, the acknowledged biodiversity crisis requires that policy identifies ways of both maintaining and restoring biodiversity, as well as addressing policy areas which may currently be acting as a perverse incentive to continued loss of important biodiversity hot-spots. Transitional habitats are recognised as important hot-spots for biodiversity because they combine elements of differing habitat conditions (Smith *et al.*, 2001). In the case of peatlands, these transitions may occur in many different settings:

- as the transition from the deep peat of the mire expanse to the thinning peat of the mire margin;
- thinning peat transitioning to mineral ground on hill slopes;
- the transition from bog to fen habitat within a blanket mire landscape, where often the fen peat is shallower because water movement and solutes encourage decomposition (as shown in Figures 4a and b);
- the transition from mineral ground to the lagg fen surrounding a lowland raised bog.

Too often, these transitional areas have 'fallen between the cracks' because they have been invisible, lying at the margins of the main areas attracting focus and action. There is a real need to refocus attention upon the *whole* ecosystem complex, with all its connections and transitions.

A policy that only focuses on, and manages for, parts of an ecosystem without recognising all the essential components and connections of the entire system risks causing harm across the system as a whole if essential supporting structures are allowed to degrade or be lost. Deeper peats almost never end abruptly, but instead grade into shallower peat, then into mineral ground. Given that peatland systems are wetlands and essentially large water bodies held within an organic medium, these margins are vital parts of the interconnected whole in much the same way that one part of a lake is indivisible from the rest of the water body. Where policy retains a focus only on deeper peats, it obscures the view of peatlands as this integrated system. Policy should instead overtly address the fact that peatlands are integrated wetland systems which cannot be successfully maintained, managed or restored if only parts of the system are acknowledged. Fundamentally, a peatland does not end until the mineral begins, although even then, the system may have ecological connections which extend far beyond the peat itself.

Knowledge gaps and recommendations

The current focus on deeper peat deposits means that there has been limited data collection on the greenhouse gas fluxes and carbon balance of shallower peats. This means that despite being a significant area of land cover and carbon store, they cannot currently be included in the Peatland Code, unless they are integral to a deeper peat unit and used to be deeper.

Given the UK's commitment to a range of international environmental treaties focusing increasingly on whole ecosystem management and the full spectrum of ecosystem services, it is important that UK peatland inventory and policy move away from historical peatland definitions based on the perspective of resource exploitation, and instead embrace a view of peat and peatlands more in tune with current thinking on ecosystems and the environment.

We recommend that there should be a broader awareness in policy of the importance of shallower peat deposits in their own right as transitional habitats and refuges for biodiversity. This should also include their role in the wider functioning of a hydrologically connected landscape and their substantial carbon store. Definitions based on depth thresholds reflect earlier perceptions of peatlands as places to be exploited, whereas today's national priorities and international obligations encourage focus on whole ecosystem approaches, together with key transitions and connections with other habitats.

If not included within policies aimed at improving the current condition of the UK's peatlands, the essential peatland character and ecosystem services of shallower peats risk being lost by default through conversion to other habitat types. Shallower peats therefore merit specific attention and recognition, to be approached sensitively and with nuance, not merely by prospective developers, but also within peatland conservation and restoration programmes, because established definitions have also influenced the thinking of such programmes. The question should be asked whether reliance on a single criterion such as depth is appropriate for addressing today's complex land management challenges, and if it is compatible with our conservation and restoration goals. Other criteria, such as the hydrological integrity of a peat unit within the landscape, should be given greater attention.

There is a need for continued peatland mapping and data collection to ensure that all stakeholders are fully aware of the presence and importance of shallower peats. Although the extent of deeper peat around the UK is now reasonably well known, there remains uncertainly over the amount and extent of shallower peat deposits. Given that shallower peats are more easily mistaken for other non-peat habitats, and that they are more easily converted from peatland habitats to other land uses, there is a real risk that without such policy realignment, vital parts of the UK's natural capital might be lost through neglect and oversight, rather than by intention.

It is recognised that incorporating shallower peat areas into policy-making brings challenges for land use planning, as such peatland can be extensive. At present, however, such areas are simply excluded from policy decisions with little or no assessment of their significance. Adopting a broader definition that recognises shallower peatlands does not prevent policy making, but allows it to be made rationally. Government policy can and should be made in the full knowledge of the impacts on peatlands and peatland services.

The International Union for the Conservation of Nature (IUCN) UK Peatland Programme exists to promote peatland restoration in the UK and advocates the multiple benefits of peatlands through partnerships, strong science, sound policy and effective practice.

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iucnpeat

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