Natural capital trade-offs in afforested peatlands:

Evidence synthesis and needs for the future of peatland forestry and forest-to-bog restoration.

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Peat and peatlands

Peat is the partially-decayed remains of plants, accumulated over time as a thick organic soil. A peatland is a location where the depth of peat reaches a certain criterion, typically around 30-50cm, but precise definitions vary, even within the UK (1, 2). Peat develops in wet locations where plant production exceeds decomposition (3). These conditions can be found in a variety of climatic regimes. Peatlands are most abundant across the boreal and low Arctic domains where peat blankets large areas of North America and northern Eurasia (4). The UK lies on the southern edge of this zone. However peatlands are also abundant in the tropics and occur in some locations even in arid climates. With the exception of city states it is probable that some area of peat occurs in almost every country of the world.

The UK is a very peat-covered country. Based on Montanarella et al's (5) analysis of the European Soil Database, almost 11% of the UK land surface is peat-covered and other estimates place this proportion even higher (6). Peatland is found across the UK but particularly in the north and west. Peat is extensive in the moors of southwest England, through the uplands of Wales, along the length of the Pennines, scattered across Northern Ireland and throughout much of Scotland. The most extensive peatland areas are in Scotland: the Flow Country of Caithness and Sutherland, the Western Isles, and Dumfries and Galloway where peatland can be the dominant landscape. Considerable areas of peat are also found in the UK Overseas Territories, particularly the Falkland Islands (7).

Peatland ecosystem services and natural capital

The specific conditions which cause peatlands to develop lead to several attributes which are distinct from other ecosystems and ultimately to differences in the ecosystem services provided. The Millennium Ecosystem Assessment (8) categorises ecosystem services in terms of provisioning, regulating, supporting and cultural ecosystem services. These categories are used as a framework to introduce peatland ecosystem services and natural capital (Fig. 1).

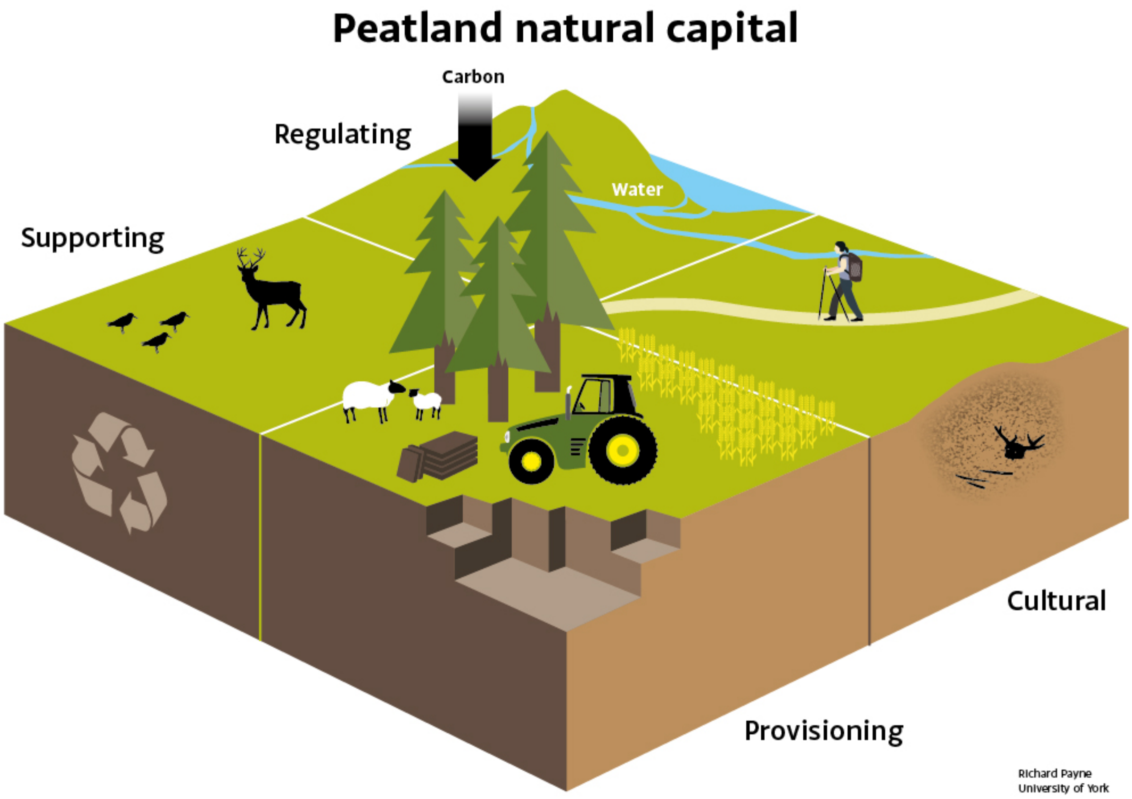


Fig. 1. Key forms of peatland Natural Capital and peatland ecosystem services. Categorisation of ecosystem services is non-exclusive, for instance water could also be considered as a provisioning service.

Regulating

Peatlands provide a range of important regulatory services. The role of peatlands in cooling the climate currently has a particularly high profile. In the time they have existed, peatlands have slowly accumulated carbon in the form of peat. As peat is roughly 50% carbon by dry weight and peatlands have accumulated many metres of peat around the world, this carbon store is very significant. Estimates of global peat carbon storage are around 400-600 GtC, approaching the pre-industrial carbon content of the atmosphere (9-11). The rate of carbon fixation by peatlands is slow compared to more productive ecosystems but because a proportion of that carbon is retained, on millennial timescales peatland carbon sequestration has been significant. Since the last glacial, peatlands have significantly cooled the global climate (10). However disturbance by human activity, particularly drainage, can cause carbon to be released at far more rapid rates than it was accumulated (12). Avoiding such loss of carbon is a key motivation for peatland conservation and management.

While carbon storage is the regulating service which has attracted most widespread attention, peatlands are also important for water (13). A large proportion of the UK's drinking water passes through peatland catchments and peat has an important role in water quality. Degraded peatlands can lead to discoloured drinking water, imposing a significant cost on water companies (13). Peatlands can trap nutrients and metals from water, improving water quality downstream but when degraded can also release these back to water courses (14). Peatlands are also important in regulating a more constant water supply.

Provisioning

Provisioning services of peatlands include their uses for agriculture, forestry and fuel. In the uplands of Britain agricultural uses have typically encompassed sheep grazing, grouse shooting and deer stalking. In the lowlands, arable agriculture on drained peatlands is widespread, particularly in the fens of eastern England (15). Peat continues to be cut for horticultural uses at many sites across the UK, although increasingly horticultural demand for peat is met by imports (2). Peatlands have also been cut for fuel, both on a domestic scale and industrially. Traditional hand-cutting of peat has been widespread historically and is still practised, particularly in the Western Isles (16). UK peatlands have been widely used for forestry, the key focus of this report. Many of these provisioning functions are extractive in nature and most are not sustainable in the long-term, degrading the peatland's ability to deliver other categories of ecosystem services. Due to their destructive nature some would not consider these functions to be ecosystem services, but they are undeniably forms of natural capital.

Cultural

Peatlands are also significant for the cultural ecosystem services they provide. As some of the UK's most extensive wild spaces, peatland landscapes are important areas for recreation (17). The peat-covered moorlands of the Peak District are central to one of the UK's most visited national parks. Peatlands are also important for the record of the past they contain. Some of the UK's most iconic archaeological finds, from the Lindow Man bog body to the Mesolithic headdresses of Star Carr, were unearthed from peat (18). Perhaps less obvious but arguably as important as these iconic large finds is the role of peat in preserving a record of past landscapes through the preserved remains of tiny microfossils such as pollen grains (19). Less tangible but far from least important, peatland landscapes have an important role in shaping the 'sense of place' in the landscape (20). From Islay Whisky to the Hound of the Baskervilles and the Kinder Trespass, peaty landscapes have an important role in the culture and history of Britain.

Supporting

Supporting ecosystem services of peatlands are the functions of the ecosystem which allow it to provide the other, more immediately apparent, ecosystem services. These include functions such as nutrient cycling, peat accumulation and biodiversity. Peatland biodiversity is particularly important. Peatlands often have lower total species numbers than other habitats but the species they host are often specialists, adapted to the unusual acidic/wet/nutrient poor conditions of peatlands. Therefore, although peatlands have fewer species than other habitats they contribute disproportionately to overall landscape biodiversity.

Collectively the provision of these ecosystem services and the values they underlie constitute the key natural capital of peatlands. The key topic of this report is how this natural capital is affected by afforestation.

Peatland afforestation

Around the world many areas of peatland are naturally forested. Across the boreal and sub-Arctic zones large areas of peatland in North America and Eurasia are covered with taiga forest. In the tropical peatland zone many peatlands are covered with broad-leaved trees and the true extent of peat is only beginning to become evident (21). This is not the case in the UK where the majority of peatland is currently treeless with the exception of deliberate plantation.

As an extensive land area of Britain, peatlands had long been considered a potential location for forestry and attempts to plant trees on UK peatlands go back to at least the 18th century (22). In the second half of the twentieth century, technical innovations such as better ploughs made large-scale afforestation a realistic prospect (22, 23). Desire for secure domestic timber supplies and to promote economic activity and employment in remote regions of Britain made forestry expansion a political imperative. Research by the Forestry Commission explored how timber crops could be produced on peat soils, testing a range of species and ultimately settling on conifer species from western North America (24). Afforestation was further accelerated by a favourable tax regime which made afforestation financially attractive for many investors. Between the late 1940s and early 1990s (but particularly in the 1970s and 1980s) large areas of UK peatland were ploughed and planted with conifers (22).

Trees could not be directly planted into peat surfaces for the same reasons which probably lead to the absence of trees on UK peat naturally: the peat surface is too wet and the nutrient levels too low. To allow trees to prosper these constraints needed to be removed. Deep drains were dug to lower the water table and the surface was ploughed to provide drier sites for tree planting. Planting was often accompanied by fertilisation with P, sometimes in combination with N and K to remove nutritional constraints on tree growth. Most afforestation involved two non-native species: either Lodgepole Pine (*Pinus contorta*) or Sitka Spruce (*Picea sitchensis*). Sitka is the more economically valuable crop but is the less tolerant of waterlogging. The two were often planted in combination with the aim that Lodgepole would prove a nurse crop to facilitate Sitka growth (25).

Into the 1980s there began to be increasing public concern about peatland afforestation, particularly in the UK's largest peatland area: the Flow Country (26). Campaigns by conservation organisations highlighted the impact of forestry, particularly on breeding birds. Media attention such as David Bellamy's documentary 'Paradise Ploughed' brought further public attention to the issues. The Nature Conservancy Council became a strong advocate for peatland conservation publishing two highly-influential reports (27) and the debate became increasingly heated (23, 26). In 1988 the tax incentives which promoted afforestation were abolished by the government which led to new plantations slowing to a trickle. New afforestation of peatland was essentially halted by Forestry Commission guidance against the plantation of deep peat (28).

There is no universally-recognised figure for the proportion of UK peatland which is currently tree-covered as data sources are fragmented and bedevilled by definitional issues around peat and peatland. Many datasets also do not differentiate deliberately afforested peat from peat with secondary tree growth and sites with natural tree presence. In England the figures for tree-covered peat appear to be around 9% of blanket bogs, 92% of raised bogs and 32% of fens (29). The JNCC quantify afforested peatland cover in England as around 33,156 ha afforested, 19,748 ha 'wooded' and 4818 ha 'scrub' (2). In Wales the overall figure appears to be around 15% (30) and Habitat Survey of Wales data shows considerable conifer cover on peat and organo-mineral soils, particularly in the uplands of mid- and South Wales (2). In Northern Ireland, data from the Northern Ireland Peatland Survey and Landcover Map 2000 show scattered conifer plantations occurring widely on peat (2). Scotland is the most extensively peat-covered nation of the UK and also has the most widely forested peat, particularly in the southwest, West Highlands and Far North (2). A recent assessment indicates that 17% of Scottish deep peats are forested; this amounts to 150,000 ha of which 91% is under conifers and 87% is blanket bog (31). In a JNCC analysis of ground cover and soil organic carbon data from the GB-wide Countryside Survey dataset roughly 15% of highly organic soils (SOM >65% in top 15cm) have tree cover (2). Tallis (32) gives an approximate figure of 3500 km^2 of afforested blanket mire (only) relative to a total cover of 22,500 km^2 (16%) , although the origin of these figures is unclear. In a survey of 56 points randomly-selected across UK mapped peat and surveyed, seven (12.5%) were forested (Payne et al. unpublished). The IUCN peatland programme suggest that 10.7% of UK peatlands have conifer cover and a further 1.6% have broadleaf cover (total 12.3%) but the source of these figures is not clear (33). Complex definitional issues around both 'peatland' and 'forest' mean that a precise figure for the proportion of UK peatlands which are afforested may never be produced but a reasonable current estimate seems to be that around 15% of UK peatlands are currently tree-covered and the overwhelming majority of this area is secondary, due either to direct planting or tree invasion of degraded peatland. Afforested peatland is found in all UK peatland areas but is particularly abundant in the Flow Country, Dumfries and Galloway, and Wales. By area, most afforested peatland is upland blanket bog but as a proportion of total area, lowland raised bogs may be most affected.

Future options

Draining a peatland and planting conifer trees on the surface fundamentally changes a peatland in many ways. Ditches lower the water table (12) while the tree canopy increases evapotranspiration and interception of rainfall. Water table draw-down may extend well beyond the margins of the plantation (6). Drains, plough furrows and cracks increase water through-flow. Typical peatland species are lost from the drying peat surface with those typical of wetter microhabitats lost first. As the canopy closes, light does not reach the understorey; there is a reduction in plant cover and a reduction in diversity of understorey vegetation. Needle litter accumulates, further impairing the growth of any remaining bog species. The drying of the peat and weight of the tree canopy leads to compression of the peat body and surface subsidence and may lead to peat cracking (22). These changes imperil many peatland ecosystem services and the underlying stock of natural capital.

New planting of trees on all but the shallowest peat has now effectively been prohibited (34). There are some concerns that with moves to encourage extensive planting of native species woodland and imperfect peat mapping, some peatland may incidentally be planted with trees. However it is generally clear that large-scale new peatland afforestation as seen in the twentieth century is a thing of the past. The critical questions now concern what should be done with current afforested peatlands. Many peatland plantations have reached the end of their first rotation or will do so this decade leading to questions around whether they should be re-stocked or not. The concerns which led to the end of new afforestation in the 1980s were particularly around biodiversity but the issues which will determine the future of afforested sites are broader and embedded in a natural capital framework.

There are three principle options: peatland restoration, restocking and continued forestry, or controversial 'middle way' options of disputed achievability.

1) Restoration

One option is to attempt to restore the afforested peatland system to its previous state, motivated by a view that peatlands in their natural state provide more valuable natural capital than peatlands used for forestry, particularly in terms of climate regulation and biodiversity. Large investments are currently being made in peatland restoration through UK public sector (agri-environment schemes, Peatland Action), European (LIFE) and third sector funding. Private sector investment also plays a role, particularly associated with wind-farm developments.

Over more than twenty years considerably progress has been made in the development of effective forms of forest-to-bog restoration. Such restoration involves two key interventions: felling trees and raising the water table. Tree removal can be undertaken in several different ways including felling to waste with trees left in situ, mulching *in situ*, conventional felling with removal and whole-tree harvesting. These alternative options reflect increasing thoroughness of tree removal but also increasing cost; methods such as whole-tree harvesting can require the use of skyline or helicopter extraction systems which can be very expensive. Tree-removal is a one-off intervention but ongoing removal of re-growth may also be required to prevent the site reverting to woodland. In parallel with tree-removal, raising the water table is achieved by blocking drains, and sometimes plough furrows, with dams, usually constructed of extracted peat. For very degraded sites, more intrusive work may be required, such as cell or contour bunding to retain water within the peatland (35). Restoration practice is continually developing; some relatively recent innovations include methods such as surface re-profiling and stump-flipping. In most cases vegetation is allowed to re-establish naturally but some trials have been conducted using plug-planting, brash spreading or the use of micro-propagated plant products to encourage plant species, particularly *Sphagnum* mosses (36).

The vast majority of UK forest-to-bog restoration has been conducted in the last 20 years and the majority in the last five so long-term success is currently unclear. Available results show rapid recovery of water table depth in many schemes (37). Vegetation recovery is also apparent with the vegetation of restored sites transitioning towards that of unafforested sites (37, 38).

2) Re-stocking for continued forestry

The second principle option is that currently afforested peatlands continue to be used for forestry. This option is frequently justified in terms of continued timber production capacity and economic benefits. Across all soil types there is currently a general presumption in policy that woodlands felled will be replaced by new tree planting, other than where this conflicts with other imperatives such as goals for biodiversity conservation and combatting climate change (34, 39). Policy specific to peatland forestry and re-stocking differs between the different nations of the UK but it is probable that many peatland plantations will be replaced at the end of the first rotation. In Scotland, policy is that sites are expected to be restocked if tree growth is strong (yield class 8 or greater), good tree growth can be expected on second rotation even in the absence of fertilizer and the site is not targeted for restoration (40). Re-stocking a site is unlikely to produce the drastic impacts of initial plantation but the longer-term consequences of multiple rotations of forestry are unclear (discussed further below).

3) Peatland Edge Woodland- a 'middle way'?

The final option is controversial. Current Scottish policy advocates the creation of 'Peatland Edge Woodland' in certain situations (40). This concept is essentially a 'middle way' envisioned to combine the best features of peatland and woodland including preserving the peatland carbon store while gaining some of the biodiversity and visual benefits of woodlands. The concept envisions low density planting of native species within their natural ranges, most likely combined with re-wetting of the peat surface. Perhaps a rationale for the policy is that current UK and Scottish policy both favours peatland restoration and, simultaneously, the increase in national forest cover (41). While these policies are not strictly exclusive, clearly the removal of trees for peatland restoration makes it harder to achieve an overall increase in forest cover. Peatland Edge Woodland is considered to be the favoured option where there is no presumption to restore a site post-felling, where tree growth is expected to be weak (less than yield class 8) and there is the potential for the cover of 'predominantly native' woodland with canopy cover >20% to be established.

This policy is much disputed. Opponents fear that rather than achieving the 'best of both worlds' vision, peatland edge woodland may actually be the 'worst of both worlds' with little or no biodiversity benefits , no timber production and continued loss of peat carbon. There are scientific concerns that trees on peat will prevent adequate re-wetting and lead to continued loss of peat carbon while trees do not grow sufficiently to compensate by additional carbon sequestration. There are also concerns that if not actively managed, trees will come to dominate and a Peatland Edge Woodland will become similar to other secondary woodlands on peat with a closed canopy and loss of peat carbon.

The choice between these three principle options represents complicated trade-offs between alternative forms of financial and natural capital. Decision-making needs to encompass divergent interest groups with very different perspectives on the underlying issues. It is unlikely that the future will see a single option across all UK afforested peat. The financial imperatives mean that restoration of all afforested peat in the UK to open bog is improbable in the near-to-medium term. Meanwhile, it is similarly unlikely that all peatland plantations will be restocked with the same non-native conifers. The future is likely to see a patchwork of alternative options but how site decisions should be made is difficult and disputed.

This report

This is a contentious subject area and it is clear that optimum decision making requires the best available evidence. This report aims to identify the key questions of concern to stakeholders, briefly summarise the current state of evidence and identify priorities for the future.

The first aim was to identify the most important questions for the community. Prioritisation exercises of this nature can be valuable for policy-makers to shape a research agenda which meets their needs; for research funders to guide research in applied directions which meet stakeholder requirements and to individual researchers to improve the 'impact' of their research (42). This project followed the example of other studies which have attempted to identify 'key questions' in subjects such as conservation biology (43), environmental policy (44) and palaeoecology (45). We consulted a wide group of stakeholders in order to identify a number of focal research questions which the community consider to be of critical importance to determining the future of peatland forestry. In this report we then use these questions to structure a discussion of key issues, the currently-available evidence and future needs.

METHODS

In designing the study we aimed to follow the key principles of Sutherland et al. (42) of openness, inclusivity and democracy. Our study comprised five phases: i) recruitment of participants; ii) an open call for questions; iii) editing of submitted questions; iv) prioritisation of questions by participants, and v) compilation of the final list of questions. Our study design differed from many previous similar exercises in being conducted solely online. This was partially determined by cost and time-scale but has the advantage of being a more democratic option. Online participation imposes no requirements for organisers to make *a priori* decisions about invited participants, makes no financial or other constraints on participant involvement, ensures complete anonymity if desired and all participants are able to make an equal contribution without the risk of discussions being dominated by a few individuals. Outputs from an online study are also arguably more likely to reflect a participant's true thoughts and beliefs than outputs from an in-person debate and discussion. Previous studies have found online survey responses to open-ended questions tend to be both more detailed (46) and include more self-disclosure (47) than alternatives. Disadvantages may include the possibility of biasing the sample towards respondents with desk-based roles and available time.

In inviting participants we aimed to solicit the opinions of all relevant parties with a stake in the debate about the future of afforested peatlands including commercial interests, public bodies, charitable organisations and research providers. We first assembled a list of email addresses of known interested parties. These included commercial forestry companies and forest managers; Forestry Commission representatives; peatland conservation managers; peatland specialists in national agencies; scientists active in this research area; environmental consultants; land owners;

land managers and private companies such as water supply and wind-farm companies. In addition we also included all members of three previously-established groups of representatives: the Scottish National Peatland Committee; the Scottish National Peatland Research and Monitoring Group and the authorship team of the IUCN Commission of Inquiry chapter on forestry. This list comprised 124 individuals or organisations. The list included participants from across the UK but with an acknowledged bias towards Scotland as the nation of the UK with the most extensive afforested peat. To avoid interested parties being overlooked participants were encouraged to forward the survey to others and the project was publicised on social media (Twitter), an approach which has been utilised in other similar studies (45).

Our open call for questions (the 'first stage survey') was made using an online form which was designed to be clear, simple and quick to complete. The survey posed only two questions, the first of which was simply designed to assess the representativeness of the population sampled by asking participants to select their employer or interest in afforested peatlands within a range of options. The second question asked participants to nominate what they considered to be the key research questions using the wording 'When deciding the future of afforested peatlands, what is the most important outstanding question?' (Appendix I). The survey was anonymous and participants were provided with a participant information sheet which detailed the context to the study and how the data would be used (Appendix II). A briefer summary of this information was included in the form itself and the solicitation email. The study design and materials were approved by the Ethics Committee of the Environment Department, University of York.

Not all questions submitted in an exercise of this nature will be useful in the form in which they are submitted so an editing phrase is typically required. Some questions may be too vague to be directly answerable; some may be off-topic; the answers to some may already be known but not to the contributor. Sutherland et al. (42) propose the following general principles for useful output questions from studies of this nature: (i) answerable through a realistic research design, (ii) that have a factual answer that does not depend on value judgments, (iii) that address important gaps in knowledge, (iv) of a spatial and temporal scope that reasonably could be addressed by a research team, (v) not formulated as a general topic area, (vi) not answerable with 'it all depends', (vii) except if questioning a precise statement should not be answerable by yes or no, (viii) if related to impact and interventions, contains a subject, an intervention, and a measurable outcome. Guidance on these principles was provided to contributors as part of the participant information sheet however many submitted questions did not meet some or all of these requirements. Other common issues included statements not phrased in the form of a question or questions which included an extensive preamble. The editorial revisions stage was also an opportunity to address replication of questions, another consequence of an open call for contributions. One of the disadvantages of an online-only study is that unlike workshop approaches these editorial changes cannot realistically be made collectively.

In this study we opted for an editorial approach which was transparent, but facilitated. Editorial changes were made by the project team to improve question formatting and remove replication which would otherwise lead to 'dilution' of votes between multiple similar questions. We first allocated all the submitted questions to one of eight themes (Appendix III). We then attempted to identify unique topics within these themes and reformulated questions to address these topics using wordings from the original submissions when possible. We aimed to avoid multiple very similar questions but to preserve all unique topics present in the original submitted questions. We aimed to preserve all topics present in the original questions with the exception of off-topic submissions, questions which primarily reflected value-judgements rather than evidence-needs and questions which were so broad that they covered all the key themes without the scope to offer a suite of questions. All these changes were itemised and the edits communicated to participants as part of the invitation for the second stage of the survey.

Participants were invited for the second stage through the same combination of a targeted email list and an open call using social media. The second stage survey had a similar structure to the first. All participants were asked their background and to confirm they had a professional interest in the subject of afforested peat/peatland forestry/forest-to-bog restoration. Participants were then asked to select up to five of the nominated questions which they considered most important. These questions were randomly shuffled to avoid order bias in results (48, 49). Details of both surveys are included in Appendix I-III. The first stage of the survey was open for 10 days and the second for 13 days; previous studies suggest that these periods are sufficient to expect most likely respondents to reply (46). Finally we tallied all votes and identified the questions with greatest support within the community. There is a danger in interpreting results simply in terms of numbers of votes cast as the sample is unlikely to be perfectly representative and different sectors may employ differing numbers of people; that more people are employed by a sector does not make the views of that sector more valid. We therefore also considered sector-by-sector results where sufficient votes were cast to draw meaningful conclusions.

RESULTS

Overview

In the first stage of the survey, 126 questions were submitted by 87 contributors, although not all of these contributors may have been unique. The full list of submitted questions is included in Appendix III. The span of questions was broad, ranging from the very general to the very specific. Particularly common topics identified at this stage were changes in greenhouse gas budgets with restocking and restoration (29 submissions) and compensatory planting for plantations removed for restoration (10 submissions). These 126 submitted questions were edited to 29 questions reflecting unique topics. Details of these edits and justification for changes made are included in Appendix IV. Inevitably this process was subjective and some nuance intended by the original contributors may have been lost; however we consider that the nominated questions successfully captured the key themes from the submissions.

In the second stage of the survey 68 participants cast 323 votes. One of these participants and one of these votes was excluded on the basis of answering ‘no’ to the question asking participants to confirm a professional interest in the subject. We consider the number of participants in the study to be a substantial sample of those with relevant professional interests in the subject. Relative to the initial invitation list the response rate was 55%, although an unknown proportion of respondents may have derived from social media and email forwarding by invitees. Participants represented a wide span of interest groups and respondents were not dominated by any one sector (Fig. 2). The most frequent 'background' categories selected were forestry, governmental/statutory bodies, research organisations and third sector conservation groups. There was broadly similar representation amongst question contributors (first stage) and voters (second stage) with a somewhat greater proportional representation from forestry amongst question contributors and from third sector conservation organisations amongst voters. Comparatively fewer questions were nominated and votes cast by participants who selected the 'other private sector' or 'land owners/managers' categories. A small minority of votes were cast by participants who preferred not to specify their background or felt it was not represented amongst the options provided.

It is difficult to know what would constitute a truly representative sample of those with professional interests in the subject matter. We suspect that our sample is broadly representative with perhaps a slight under-representation of those in the private forestry sector. There was little clear relationship between the number of initially submitted questions on a topic and the number of votes cast in the second stage (Figure 3) with the exception that the single most frequent topic in the first stage (greenhouse gas budgets with restocking and restoration) was also the most-frequently voted category in the second stage.

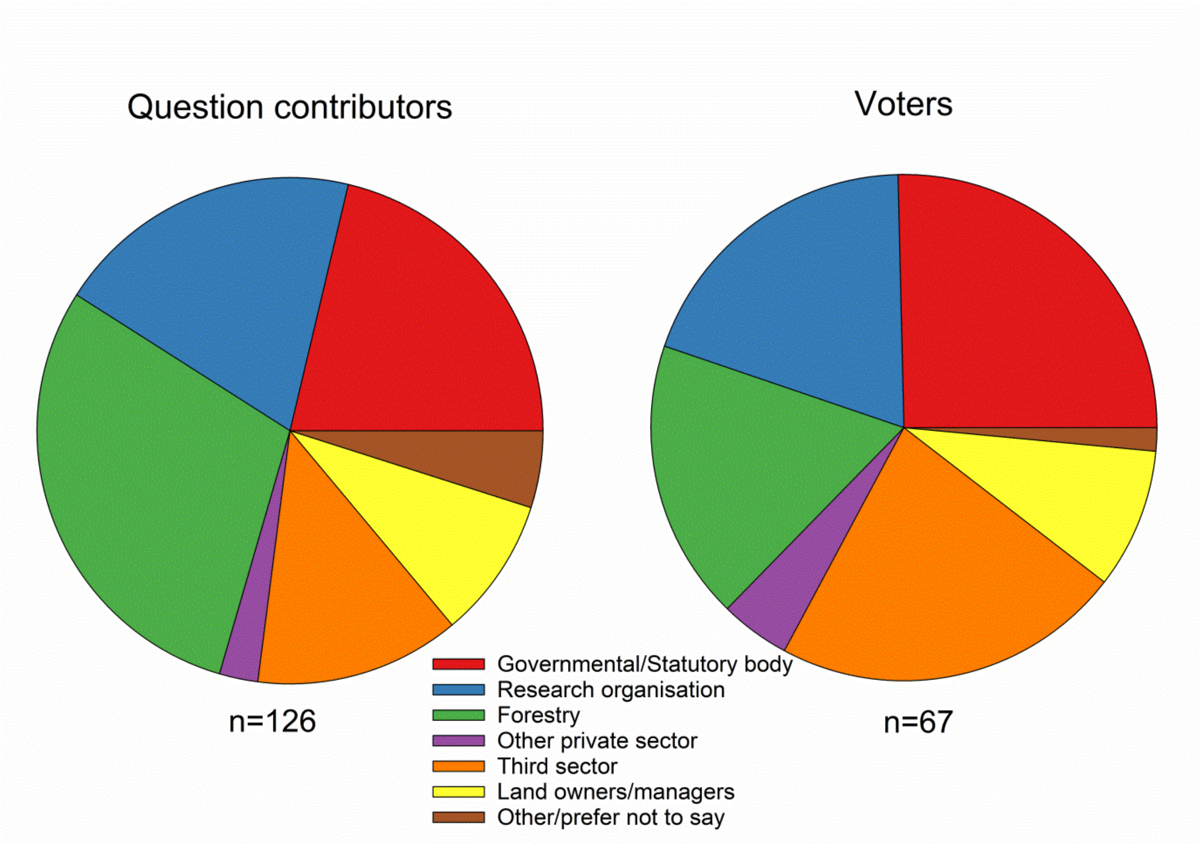


Fig. 2. Sector representation of initial question contributors and voters in second stage survey.

Table 1. Nominated questions and full votes. Five most voted questions highlighted in bold.

Code	Question	Votes
NQ-GH1	**How does the greenhouse gas budget of a peatland change with initial afforestation, restocking or restoration?**	20
NQ-GH2	How long will it take for the carbon from felled peatland plantations to be returned to the atmosphere?	1
NQ-GH3	How do alternative forest management practises affect greenhouse gas balance?	7
NQ-GH4	How far beyond a plantation does forestry affect the greenhouse gas balance of unplanted peatland?	8
NQ-GH5	**How does the greenhouse gas balance of peatland forestry differ between deep and shallow peat and compare to forestry on mineral soils?**	21
NQ-GH6	How appropriate are current emission factors for UK afforested peat?	12
NQ-GH7	How does greenhouse gas balance of afforested peat vary with forest yield class?	7
NQ-GH8	How does the peatland greenhouse gas balance change across multiple rotations of forestry?	13
NQ-G1	**What is the financial value of natural capital in natural and afforested peatlands and how does this change with restoration?**	18
NQ-G2	Is knowledge of peatland extent, depth and carbon stock adequate to make policy decisions on the future of afforested peatland?	10
NQ-R1	Is it possible to restore afforested peatlands to naturally functioning systems and how long will this take?	15
NQ-R2	**What are the limits to the achievability of forest-to-bog restoration in terms of factors such as peat condition, depth and site extent?**	18
NQ-R3	How should afforested peatland sites be prioritised for restoration and when is the best time to restore?	14
NQ-R4	How can restoration sites be optimally managed to ensure rapid recovery of natural peatland functioning?	15
NQ-F1	Should peatland plantations removed be compensated by additional forestry on mineral soils, where should these plantations be located and what are the opportunities and costs of doing this?	12
NQ-F2	How can timber be harvested from peatlands with minimal environmental disturbance?	6
NQ-F3	If replanting on peatland is not allowed should private sector investors be financially compensated and how could this be achieved?	2
NQ-F4	How can afforested peatlands be made as natural as possible?	5
NQ-F5	How could private sector landowners be incentivised to restore afforested peatlands and would this be desirable?	10
NQ-F6	**Is it possible to have trees on peat without loss of biodiversity and carbon storage?**	20

NQ-F7	What are the economic benefits of forestry on peat and how do these compare to restoration and forestry on mineral soils?	7
NQ-F8	How does forestry yield relate to peat depth?	2
NQ-C1	How will climate change affect the sustainability of forest-to-bog restoration?	11
NQ-C2	How will climate change affect peatland forestry?	10
NQ-B1	How will biodiversity recover with forest-to-bog restoration in the long-term?	12
NQ-W1	How will the water quality of peatland catchments be affected by continuing forestry or restoration?	16
NQ-W2	How do afforested peatlands and peatland restoration affect downstream flood risk?	14
NQ-W3	How does peatland hydrology change with afforestation and restoration?	8
NQ-O1	Why are naturally forested peatlands so rare in the UK, were they more abundant in the past and would understanding their decline help us better manage current afforested peatlands?	12
NQ-O2	Could the planting or maintenance of peatland forests be justified to mitigate erosion?	1

Table 2. Most popular questions, as voted by four sectors with highest voter numbers.

Sector	Question	Votes
Other governmental or statutory bodies (government, national nature conservation bodies, environmental regulators etc.).	How do afforested peatlands and peatland restoration affect downstream flood risk?	7
Research organisation or university.	How does the greenhouse gas budget of a peatland change with initial afforestation, restocking or restoration?	6
Forestry Commission or private sector forestry industry.	What is the financial value of natural capital in natural and afforested peatlands and how does this change with restoration?	7
Charitable conservation organisation.	How will biodiversity recover with forest-to-bog restoration in the long-term?	8

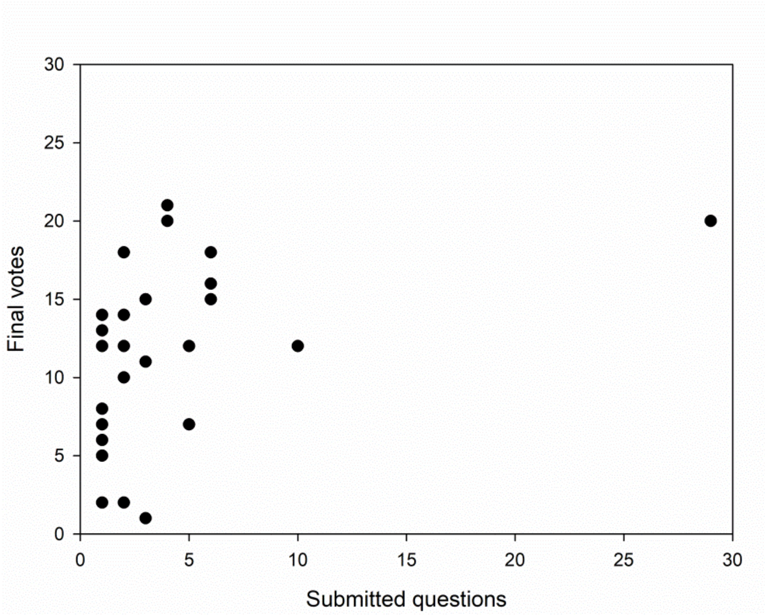
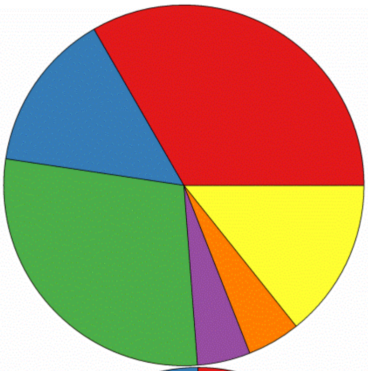


Figure 3. Submitted questions on topics versus number of votes for resulting nominated questions arising from those topics.

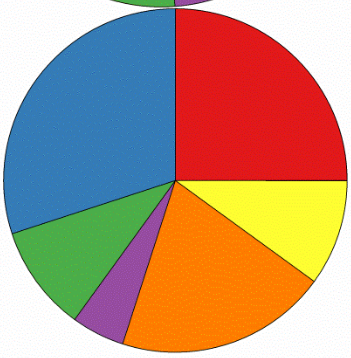
Key questions

All nominated questions received votes. The most voted question and the equal second most voted question were both on the theme of greenhouse gases: NQ-GH5 (How does the greenhouse gas balance of peatland forestry differ between deep and shallow peat and compare to forestry on mineral soils?) and NQ-GH1 (How does the greenhouse gas budget of a peatland change with initial afforestation, restocking or restoration?). The other three questions in the top five were NQ-F6 (Is it possible to have trees on peat without loss of biodiversity and carbon storage?), NQ-R2 (What are the limits to the achievability of forest-to-bog restoration in terms of factors such as peat condition, depth and site extent?) and NQ-G1 (What is the financial value of natural capital in natural and afforested peatlands and how does this change with restoration?). We consider these five to be the key questions identified by the participants but other questions on topics such as water quality (NQ-W1), restoration achievability/time-scale (NQ-R1), management (NQ-R4), prioritisation (NQ-R3) and flood risk (NQ-W2) also attracted considerable support. In terms of the eight general themes we identified in the submitted questions, the most votes were assigned to the themes of greenhouse gases (total votes 89), forestry (total votes 64) and restoration (total votes 62) with other topics receiving considerably fewer (≤38). This general voting pattern parallels that for individual questions with two of the most highly voted questions assigned to the greenhouse gases theme and the next two questions assigned to forestry and restoration respectively. Results strongly suggest that questions around greenhouse gases and consequent climate forcing are believed to be of paramount importance to the community.

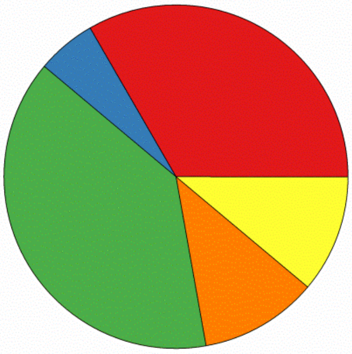
Given that our participants are a partially self-selecting sample of unknown representativeness we also note three questions which received considerable support but were not ultimately the most highly voted. Of the four sectors most well-represented by the respondents, two voted most strongly for questions not included in the overall top five (Table 2). Amongst third sector conservation organisations there was strong support for question NQ-B1 (How will biodiversity recover with forest-to-bog restoration in the long-term?). Amongst governmental and statutory bodies there was support for question NQ-W2 (How do afforested peatlands and peatland restoration affect downstream flood risk?). Given that the different sectors cannot be assumed to have been sampled equally we consider these questions important. The topic which was nominated second most frequently in the question nomination stage was compensatory planting for peatland restoration, with 10 questions assigned to this topic. This topic appeared to be a particular priority for the forestry sector, which was somewhat less-strongly represented in the second stage survey. The nominated question arising from the submissions (NQ-F1) received moderately strong support (12 votes) but not sufficient to place in the top five nominations. However, on the basis of the first stage we feel that this topic has support within the community.



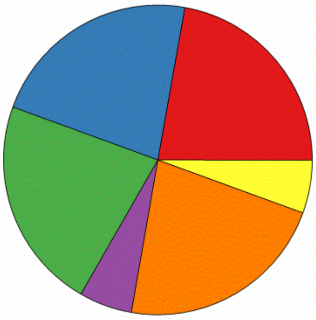
How does the greenhouse gas balance of peatland forestry differ between deep and shallow peat and compare to forestry on mineral soils?



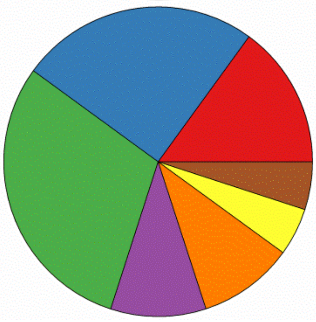
How does the greenhouse gas budget of a peatland change with initial afforestation, restocking or restoration?



Is it possible to have trees on peat without loss of biodiversity and carbon storage?



What are the limits to the achievability of forest-to-bog restoration in terms of factors such as peat condition, depth and site extent?



What is the financial value of natural capital in natural and afforested peatlands and how does this change with restoration?

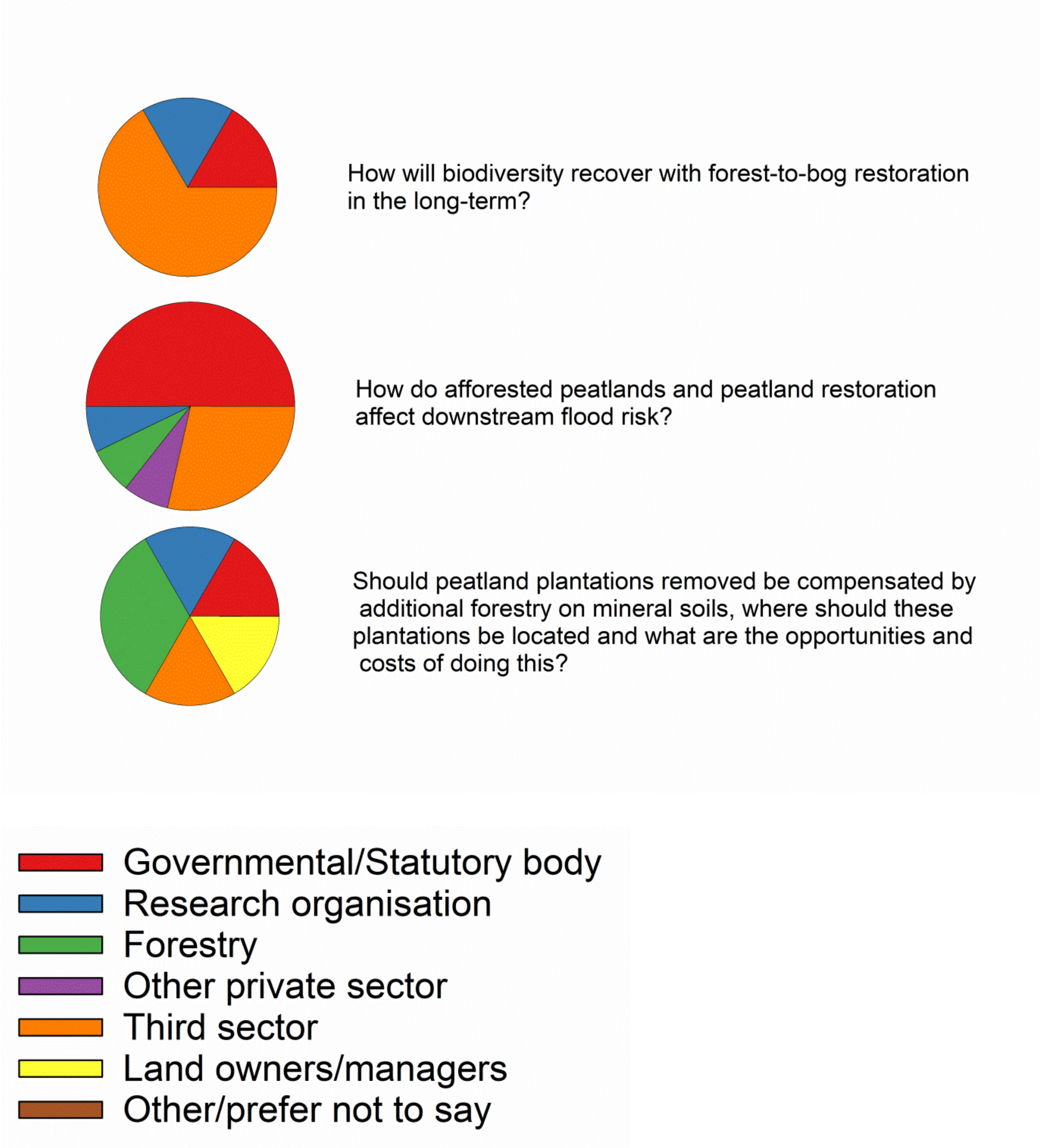


Fig. 4. Voting distributions for five most highly voted questions and three questions identified as of additional importance. Symbols sized diameter proportional to total votes, colour schemes as above.

DISCUSSION

Below we discuss the 5+3 key questions identified. Given the small scale of this project comprehensive review is not possible but we aim to outline the general state of evidence and make contributions where feasible. The length of discussion for different questions varies, largely due to the extent of established knowledge and/or our ability to make contributions. This should not be taken as any judgment on the importance of the questions.

Five key questions.

How does the greenhouse gas balance of peatland forestry differ between deep and shallow peat and compare to forestry on mineral soils?

How does the greenhouse gas budget of a peatland change with initial afforestation, restocking or restoration?

Context and voting:

These were the first and equal second most voted questions with 21 and 20 votes respectively. We opt to discuss the two collectively as, although distinct, they closely overlap. Both questions consider the greenhouse gas budget of forestry on peat and future management options.

The first question (NQ-GH5) addresses differences between forestry on deep and shallow peat and between forestry on peat and mineral soils. Originally-submitted questions such as SQ-119 (What are the GHG emissions from planting forestry on shallower 10-40cm peat soils?) addressed the difference in greenhouse gas budget between shallow and deep peat soils. The context to this is criteria which mean that 'deep peats' are considered different to 'shallow peats' in terms of use for forestry. Consequently, shallow peats generally receive much less protection with new areas still potentially being afforested. Submitted questions such as SQ-125 explicitly addressed the validity of thresholds delineating such categories. Other submitted questions incorporated a comparison to mineral soils (e.g. SQ-124). The voting contribution for this question was broadly similar to the overall sector split with a higher proportion of voters from the forestry and landowner/manager groups and smaller proportion from third sector conservation groups.

The second question (NG-GH1) addresses change in greenhouse gas budget with initial afforestation and then the principle future options of either restocking or restoration. These issues were raised frequently in a number of forms amongst the submissions. Many submitted questions were phrased in terms of carbon stock or carbon flux, and some made reference to specific flux terms such as dissolved organic carbon (DOC) or methane (CH_4). Most submitted questions were phrased in terms of carbon but other greenhouse gases such as N_2O can occasionally be non-trivial components of the greenhouse gas budget (50). Both these nominated questions are phrased in terms of greenhouse gas balance but should perhaps be considered in terms of total radiative forcing as some research has suggested significant changes in albedo with forestry or restoration (51). The first question is phrased in terms of the greenhouse gas budget of peatland forestry whereas the second question is in terms of an individual peatland. It is important to recognise that the overall impact on climate of a choice between restoration and restocking cannot be answered solely by studies of peatland carbon budget as the timber supply chain introduces wider factors.

State of current evidence:

We will address the second question first.

Current knowledge allows a reasonable assessment of many of the processes which affect the greenhouse gas budgets of peatlands with afforestation and restoration (52). These are summarised in Fig. 5.

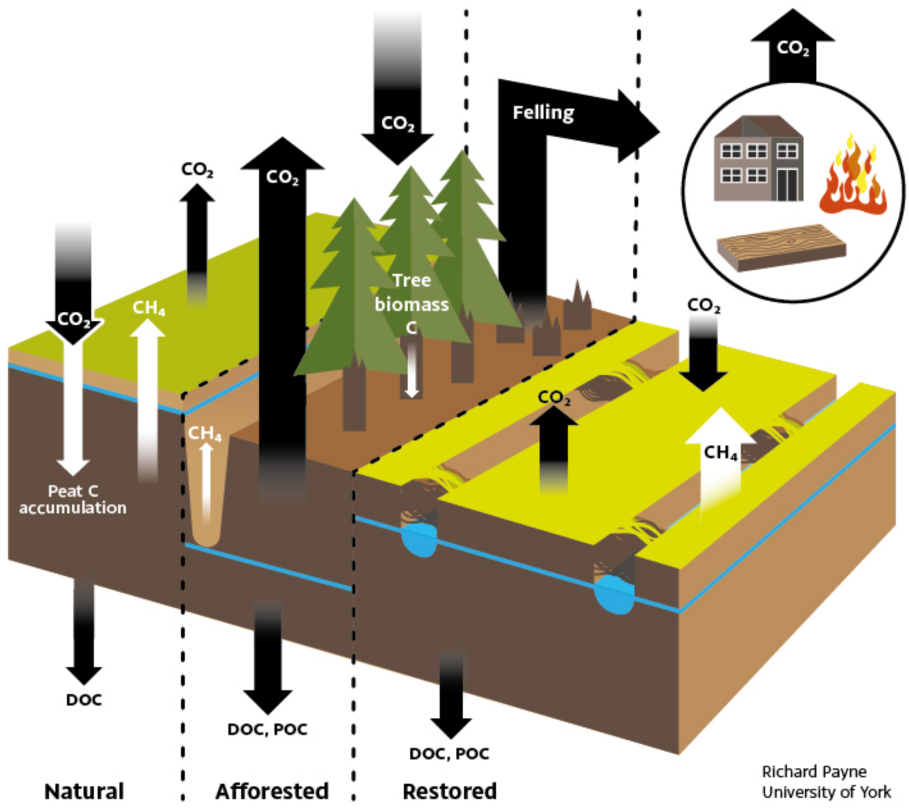


Fig. 5. Conceptual diagram of key carbon cycle pathways and changes with peatland afforestation and restoration.

Considerable loss of carbon can be expected to have occurred during initial ground preparation and planting, although as new afforestation on deep peat is no longer permitted (40) this is difficult to quantify. Ploughing will have directly exposed deep, anoxic (catotelm) peat to oxidation in plough-throw ridges and large fluxes of dissolved and particulate carbon are likely to have occurred as plant material and exposed peat were disaggregated and decomposed. Longer-term water table drawdown will have exposed a greater depth of peat to oxidative decomposition, leading to carbon loss (12). There is a well-understood positive correlation between peatland water table depth and CO_2 efflux (18) and it is highly likely that afforestation will have increased CO_2 production and DOC loss. The scale of this change and its long-term trajectory will partially depend on the wetness of the site, fertility and the degree to which drains are maintained. A corollary of increased CO_2 emission from peat drained for forestry is a likely reduction in CH_4 emission. By increasing the depth of the oxic layer, water table drawdown increases the available space for CH_4 to be oxidised by methanotrophic bacteria. The decline of typical bog species following drainage will often also reduce the abundance of plants with aerenchyma which are disproportionately important in channelling CH_4 to the atmosphere (19) (although these species can sometimes be locally abundant in plough furrows). While there is likely to be some trade-off in greenhouse warming potential between the effect of increased CO_2 efflux plus increased aquatic carbon loss, and reduced CH_4 efflux, in most sites the CO_2 released from the peat will overwhelm the reduction in CH_4. Afforested peatlands will cease the accumulation of new peat which may become important in the long-term. Although most attention has focussed on fluxes of carbon, other factors may also be important. Some forested peatlands can be substantial sources of N_2O (50), forestry may reduce albedo and change micro-climate.

The net effect of afforestation on carbon fluxes from the peat itself is likely to be carbon loss implying climate warming. However, this will be at least partially offset by carbon fixation by the trees themselves (Fig. 6). The carbon fixation potential of a conifer crop is considerably greater than that of typical low-growing bog species (mostly bryophytes, graminoids and dwarf shrubs) and a mature conifer crop contains more carbon than typical bog vegetation (although the latter may be non-trivial (6)). Tree planting will also lead to some carbon input into the peat in roots and litter, although this is likely to be overwhelmed by increased losses. Tree growth is, however, strongly dependent on the nature of the peatland site: in drier sites with more nutrient supply (as is typical of Fennoscandian fens) growth will be much stronger than in wet sites with few nutrients (such as most Scottish blanket bogs). Overall, afforestation will tend to increase the carbon stock aboveground and reduce the carbon stock belowground. It is currently unclear whether carbon fixation by the trees counteracts probable carbon loss from the peat and how this varies spatially and temporally. However, plantations on peat will ultimately be felled so the future climatic consequences of afforested peatlands will actually depend on the fate of this timber. If it is left to rot or immediately burned then the carbon will be returned to the atmosphere rapidly. In this case then even if tree growth does compensate for carbon loss from the peat the net effect may be climatic warming. The argument is less clear if the timber is used for longer life-time products such as construction when it may take a century or more for the carbon to be returned to the atmosphere.

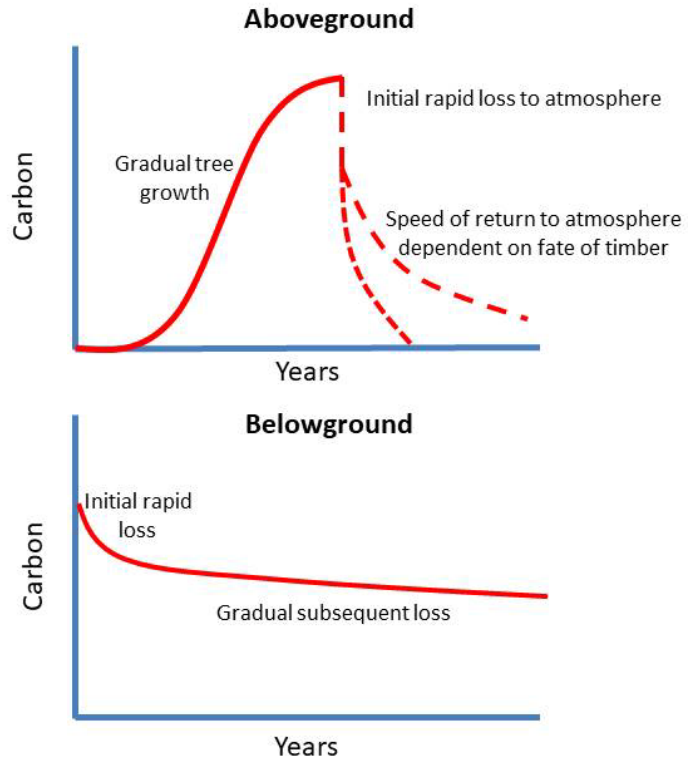


Fig. 6. Conceptual diagram of probable change in peatland carbon stock with afforestation below and aboveground. Results are indicative and scales of the two plots are arbitrary and not the same.

Nationally, the most significant destination for felled timber is sawmills, implying a reasonably slow return to the atmosphere, while destinations such as fuel and pulp mills (implying more rapid release) represent less than a quarter of the total (Fig. 7)(53). However this overall picture is unlikely to be representative for timber derived from peatland plantations. There is no established national data and it is not currently possible to draw general conclusions.

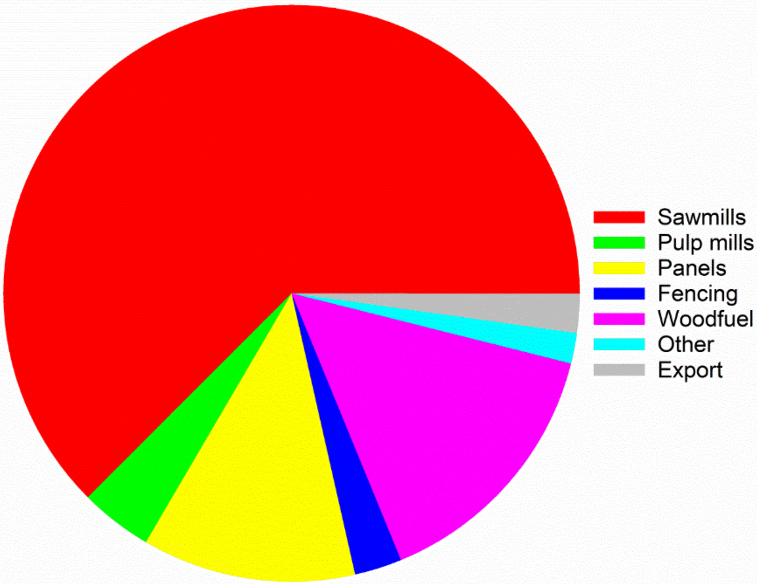


Fig. 7. UK timber deliveries in 2016, data from (53).

The issue is even further complicated by the role of timber in the supply chain. Timber may compete with fossil fuels as a fuel source and with materials such as concrete, steel and plastics in manufacturing and construction. Domestic UK timber production may avoid the need for timber imports with the transport emissions that implies. This whole supply-chain view is important but makes the ultimate calculation a very complicated one.

A particularly important factor in comparing the climate forcing of natural and afforested peatlands is the time-scale under consideration (Fig. 8). In the period immediately after ploughing, afforested peatlands are almost certain to exert a stronger warming effect on climate than natural peatlands as peat is exposed and decomposes. As the trees grow to maturity this may be more finely balanced with increasing sequestration in the tree canopy. In the longer-term, greenhouse warming potential will depend on the fate of timber and how long it takes to be returned to the atmosphere. In their natural state peatlands will keep slowly accumulating carbon until either the next glaciation or some hypothetical limit to peat growth is reached (54). By contrast, afforested peatlands will probably keep gradually losing carbon from peat with every forestry rotation and carbon stored in timber is inherently less secure; even timber used for construction will *eventually* return to the atmosphere. The productivity of future rotations of forestry is uncertain. First rotation forestry has been supported by fertilisation and extensive ground modification which are unlikely to be repeated; subsequent rotations may see weaker tree growth and reduced carbon sequestration. At some stage it is almost certain that a point will be reached whereby the carbon being gradually lost from the peat is not balanced by carbon in tree biomass and timber products. Therefore on a suitably-long timescale (centuries) it is very probable that unafforested peatlands are ultimately better for climate.

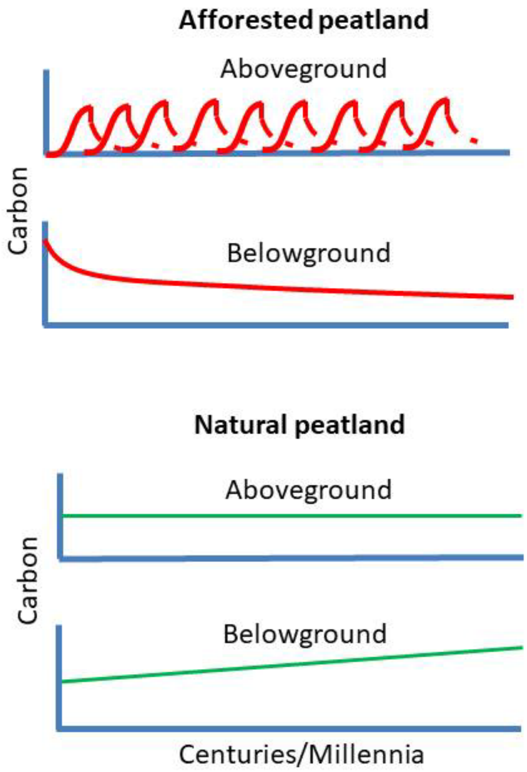


Fig. 8. Long-term comparative change in aboveground and belowground carbon stock in natural and afforested peatlands. The plot of aboveground carbon in forested sites assumes future rotations follow similar trajectories to first rotations but it is not clear if this will be the case and there are reasons to suppose weaker growth in the future.

In terms of restoration there is a similar lack of data but it is possible to theorise the likely mechanisms. Removal of trees will remove a large pool of above-ground carbon but the fate of this carbon will depend on subsequent timber usage. From conversations with conservation managers it anecdotally appears that a substantial proportion of timber removed during restoration projects goes to short-lifetime uses such as fuel while a relatively small proportion is of sufficient quality for long-lifetime uses such as construction, but there is no national data. Some tree material (in some cases *all* tree material) may remain on the surface of the peatland after restoration, where it will decompose, releasing carbon. The process of felling and peat dam construction is likely to lead to some short-term increase in CO_2 flux due to disturbance of surface peat and decomposition of tree material. In the longer-term it can be expected that raising the water table will substantially reduce CO_2 emissions due to reduction in the oxic depth. This may be partially off-set by increased emissions of CH_4 particularly in the early stages of re-wetting, and where species with aerenchyma such as *Eriophorum angustifolium* become abundant (52). As peatland vegetation becomes re-established this will begin to accumulate carbon and at some stage should lead to new peat formation. These processes are reasonably well-understood but currently poorly-quantified and there is particular uncertainty regarding temporal changes.

The first question specifies differences between forestry on peat and forestry on mineral soils and between forestry on deep and shallow peat. Forestry on mineral soils is known to represent net carbon sequestration: there is substantial carbon accumulation in the trees and this will more than outweigh any carbon loss from soils which, depending on the previous land use, may even experience an increase in carbon content (55). This compares to peatlands where carbon accumulation in trees may or may not outweigh carbon loss from soils. It is clear that in terms of climate change mitigation, forestry on mineral soils is more effective, although the scale of the difference is currently difficult to quantify due to fundamental uncertainties around the greenhouse gas budget of afforested peat. The second element of the question addresses differences between forestry on deep and shallow peat. There has been no direct study of this topic and answers are likely to partially reflect what exactly is meant by deep and shallow peat. In the shallowest peat, tree roots may penetrate below the peat into the underlying substrate. In shallow peat the stock of peat carbon will be smaller but as most losses occur near the surface this does not necessarily equate to reduced losses. On balance, it appears probable that afforestation of shallow peats may be less harmful to peatland carbon stock than afforestation of deep peats, but there is little direct evidence (31).

<u>Future evidence needs</u>:

There is currently no clear answer to the basic question of whether planting trees on UK peatlands ameliorates or exacerbates climate change and certainly not to secondary questions such as the differences between deep and shallow peats. A particularly important evidence gap is measurements of the whole system greenhouse gas budgets for afforested peatlands. There is currently no published ecosystem-scale flux monitoring dataset for any UK afforested peatland. This data can only be obtained from aquatic flux monitoring paired with eddy-covariance systems, which are both cost and labour-intensive. Such monitoring has now commenced at one site in the Flow Country but it will take several years to produce a data series of suitable length to make policy proscriptions and this monitoring is currently un-replicated. Particular uncertainty surrounds carbon losses in the initial planting phase when large fluxes most likely occurred. Fluxes through this phase cannot be easily quantified as new planting on unafforested peat is not taking place. One way to address this is to undertake carbon-stock comparison studies which integrate all loses or gains of carbon over time and so avoid the short-termism inherent in flux studies. However such studies cannot disaggregate alternative carbon forms and pathways so there may even be a case for ploughing and planting a small area of natural peat in order for measurements to be undertaken (although doing so would be controversial). In terms of restoration there is a basic need for flux measurements from a range of sites and a range of time-periods. The chronosequence approach has particular advantages to allow a pseudo-time-series to be produced rapidly.

Is it possible to have trees on peat without loss of biodiversity and carbon storage?

Context and voting:

This question was the equal second most voted option with 20 votes. The voting pattern in terms of sector backgrounds was similar to the overall mix but with higher proportional representation from the forestry sector and lower representation from research organisations and third sector conservation organisations. The nominated question arose from submitted questions with themes around whether trees on peat are intrinsically undesirable in terms of key forms of natural capital. The question touches on themes of native species woodland on peat (mentioned by questions SQ-22 and SQ-60) and the Peatland Edge Woodland concept (discussed above and referenced by question SQ-21). The key issue at stake is whether it should be assumed that peatland forestry is always 'a bad thing' in terms of biodiversity and carbon storage or whether some model might be possible whereby valued features of open bogs could be retained while also having tress. If such a model were possible it would clearly be attractive to some stakeholders.

State of current evidence:

At some level the answer to the question is already known: it *is* possible to have trees on peat without loss of biodiversity and carbon storage. Forested peatlands are widespread around the world, with coniferous trees across the boreal realm and with broadleaved trees in the tropics. These peatlands actively accumulate carbon and host high value biodiversity. Even in the UK, trees do occur on peat in some lowland fen systems and river valleys ('wet woodlands') and a few fragments of seemingly-natural pine bog woodlands more similar to boreal forested peatlands occur in isolated areas, principally in eastern Scotland (56). These naturally-wooded peatlands (albeit rare) do host valued biodiversity with bog woodlands being a priority habitat under the annex 1 of Habitat Directive (57). They also appear to accumulate peat and carbon, although there is limited primary data. Palaeoecological evidence implies that trees on peat may once have been prevalent in the UK (58) and there are open questions regarding the causes of the decline of these woodlands. So, to some extent the question can be answered 'yes', however the intent with the question is probably more specific. The key issue is not whether wooded peatlands which both accumulate carbon and have biodiversity value *can exist* but whether they can be *created*. The Peatland Edge Woodland concept in Scotland is based on an assumption that this *is* possible, but this remains very controversial. Two central issues are water table and feedbacks. UK peatlands in their natural state are too wet for most tree species to grow but lowering the water table leads to the likelihood of carbon loss: is there a middle ground in which trees can grow but peatland functions are retained and carbon continues to be sequestered as peat? Secondly, trees on peat are not a passive component of the ecosystem. Trees tend to increase rainfall interception, increase evaporation and increase transpiration, all of which will tend to dry the peat surface. There is a risk that this leads to a feedback whereby the presence of trees on peat leads to the surface drying, leads to more trees, leads to carbon loss and loss of valued species (59). Whether optimum conditions could be found which avoid these risks is very unclear and continuing active management would probably be required to maintain a balance. In relation to biodiversity there is also uncertainty and this will ultimately come down to which elements of biodiversity are of interest. For many wading birds it is clear any trees on the peat surface will be negative, whereas birds which require a low density 'fringe woodland' such as black grouse, hen harrier and nightjars might benefit.

Future evidence needs:

There is unlikely to be a simple answer to this question but several avenues could help address this theme. There is a need for a better understanding of naturally afforested peatlands in the UK as our only current model of ecosystems successfully achieving both long-term peat accumulation and tree cover. What are the conditions which have allowed trees to persist on these sites without major negative consequences? How does their carbon accumulation compare to open sites? Has tree cover been continuous or intermittent? This could be addressed both by looking at the present ecology and distribution of such sites and temporally, looking at the palaeoecological record of their development. The development of Peatland Edge Woodland pilot sites also allow for the possibility to test whether a balance between tree cover and peat drying is achievable. Close monitoring of pilot sites, including carbon flux measurements, will be required before the policy can be rolled-out without the risk of substantial negative consequences.

What are the limits to the achievability of forest-to-bog restoration in terms of factors such as peat condition, depth and site extent?

Context and voting:

This question was the joint fourth highest-ranking question with 18 votes; voting patterns by sector very closely matched the overall sample. The question wording reflects themes of the limits to peatland restoration raised by submitted questions such as SQ42 and SQ7. Specifically, the nominated question is worded to encompass issues such as the minimum restorable area (mentioned by SQ7), shallow peats (SQ7) and cracked peats (SQ7). The subtext to this is perhaps a mood of increasing ambition in terms of peatland restoration. The IUCN peatland programme's recent draft peatland strategy increases the aim of its overarching restoration goal to achieving 2 million hectares of peatland in good condition, under restoration agreements and being sustainably managed by 2040 (33). Meeting such ambitious targets may not be possible simply by focusing on the relatively easy-to-restore 'low hanging fruit' and may require more challenging sites to be tackled.

State of current evidence:

Considerable progress has been made in the development of effective methods for peatland restoration. A 'standard suite' of methods is reasonably well-established and novel approaches are continually being developed. Most of this progress has been made on a trial-and-error basis by individual restoration managers and this knowledge has largely been communicated through informal and semi-formal networks. The topic of limits to peatland restoration has been discussed in many forums for those interested in peatland restoration. It is probably the case that most peatlands degraded by afforestation are capable of restoration, at least in narrow terms of preventing rapid peat oxidation, as long as some peat remains and sufficient time is allowed. The most challenging situation has arguably been very cracked peats but even here methods have been developed which appear effective (35). Perhaps more important than what is technically possible is what is economic and practicable and here there is greater uncertainty.

Future evidence needs:

The development of restoration methods will probably proceed as it has done thus-far based on incremental innovation by individual managers reflecting accumulated collective experience. The most important need is probably for better monitoring of restoration outcomes which is currently very fragmented and ad hoc, impairing ability to conclusively establish the optimum methods. There is also a need for mechanisms to ensure that best practice developed is successfully communicated to others. Such mechanisms partially exist: the IUCN UK peatlands programme has a particularly important role as a forum for discussion and a dissemination pathway. However there is considerable room for more formal synthesis.

What is the financial value of natural capital in natural and afforested peatlands and how does this change with restoration?

Context and voting:

This question was the joint fourth most highly ranked question by project participants (18 votes). In term of sector contributions, this question was particularly frequently selected by participants from the forestry and 'other private sector' categories. The theme of natural capital was inherent in many of the submitted questions including questions which explicitly focussed on the financial value of this natural capital (e.g. SQ114). The question, as formulated, addresses the value of natural capital in natural and afforested peatlands and the change in this with restoration. The broader context to the question reflects increasing interest in the natural capital concept amongst policy-makers and attempts to place financial value on this capital under alternate options.

State of current evidence:

Peatlands provide many ecosystem services, some with obvious monetary value. Other services such as the cultural services would be particularly difficult to assign a monetary value. We are aware of little research which has attempted to financially value ecosystem services and natural capital in UK peatlands. Perhaps the easiest of the services to value is carbon storage as there are established carbon markets and valuations. BEIS produces a set of carbon values for policy evaluation in the UK ; for 2018 based on the 'central' series this price is £4.19 t eCO_2^{-1}(60). A probable minimum estimate for the carbon stock of UK peatlands is around 3000 MtC (6). Converting carbon to CO_2 equivalents and applying the BEIS carbon price gives a 'back of the envelope' valuation of at least £46 bn, equivalent to roughly 2.5% of UK gross domestic product (61). The majority of this natural capital is unlikely to be quickly gained or lost. One valuation exercise for England values the risk of degraded peatland to an equitable climate at £70-210M per year (62). England contains in the order of 10-20% of UK peatland so, were all UK peatlands similarly degraded to those of England, this value might be up to ~£2.1 bn per year. These figures are very approximate and other ecosystem services are even more difficult to value. There is little extant data on valuation of other peatland ecosystem services and certainly not within the context of peatland forestry and forest-to-bog restoration. In the context of peatland restoration, Martin-Ortega et al. (20) consulted publics in Scotland on the perceived value of peatland restoration, arriving at a range of £127-414 ha^{-1} yr^{-1} for benefits to carbon, water and wildlife. Moxley and Moran (63) provide perhaps the most comprehensive assessment of the economics of peatland restoration, investigating a range of scenarios and concluding that in the majority of cases, carbon emissions savings are likely to be sufficient to justify restoration. However this study also found that results were very sensitive to assumptions around future emissions changes and these assumptions are particularly uncertain for afforested peatlands.

The economic value of forestry is somewhat clearer. Forestry is a major UK industry, valued at over £8.5 bn and ranked 18th of UK industries (64). The forestry sector supports 16,000 jobs with a further 137,000 in wood processing and many more in the wider supply chain (53). Much of this employment is in rural, low population regions, some of which have limited alternate options. However the proportion of this economic activity which relates to specifically to peat is unclear given that few data-sources disaggregate forestry on peat from forestry on mineral soils. A ball-park estimate (based on (6, 53)) is that maybe a fifth of UK forestry by area is on peat. This would imply that the economic value of peatland forestry is in the region of £1.7 bn but this is likely to be an over-estimate given that peatland forestry is generally less productive than forestry on mineral soils.

Although there is little direct data, it is very probable that forestry on peatland is less economically productive than forestry on mineral soils. There are two dimensions to this: the yield of the timber and the value of the timber produced. Peat is a sub-optimal soil for commercial forestry as a consequence of which upland peatlands were amongst the last areas to be widely developed for conifer forestry in the UK. Key issues include low nutrient content, weak structural strength and, particularly, waterlogging. There is a strong positive correlation between deeper water tables and greater tree growth; even in the relatively-tolerant Lodgepole Pine, height growth with a water table around 30cm may be double that with a water table of 10cm (65). Sitka Spruce grown on peat soils has a consistently poorer yield than on mineral soils (66). Windthrow is also an important factor affecting economic returns from peatland plantations through direct loss of timber and by making harvesting difficult and impairing site management and thinning (67). Peat has a lower shear strength than mineral soils and windthrow is more frequent and widespread in peatland plantations than mineral soils (67). Windthrow is a particularly issue in wetter sites with water tables nearer the surface where root plates may be very shallow (68). As windthrow probability increases with tree maturity (69) windthrow concerns may lead to plantations being harvested before they reach full term.

The second dimension to economic valuation is the value of the timber produced. One of the most useful publicly-available sources on the timber value is the dataset compiled by the consultancy firm Bidwells (70, 71). These reports detail standing sales value of private sector conifer timber sold between October 2016 and September 2017. The dataset is contributor-reported and far from complete but provides a useful current snap-shot. The data represent felling for a range of reasons (including thinning) and clearly includes many sites felled before full-term. As for most forestry data the Bidwells dataset does not disaggregate forestry on peat from that on mineral soils. However, considering the data for sites containing at least one of the two most widely planted species: Lodgepole Pine and Sitka Spruce a few observations can be made (Fig. 9). Firstly it is clear that the sale price of Lodgepole Pine (mean £13.87 m^{-3}) is considerably less than both Sitka Spruce (mean £23.62 m^{-3}) and all conifers in the dataset (£20.42 m^{-3}). This is significant because while Sitka has been planted widely on both mineral soil and peat, Lodgepole is a species which has predominantly been planted on peat. The mixture of Sitka and Lodgepole in the same site -which was a particular feature of planting on peatland sites- has a value of £2.40 m^{-3} less than pure Sitka. The only site in the dataset explicitly noted to be on deep peat (a mixed Sitka/Lodgepole site in Dumfries and Galloway) had a harvesting value of £20.57 m^{-3}, around the middle of the market. The dataset highlights that the prices achieved can be extremely variable. The dataset records sites as being easy or difficult to harvest: of the sites containing Sitka and Lodgepole sites classified as 'easy' returned an average of a third more than sites classified as 'difficult' (£22.88 m^{-3} vs £17.08 m^{-3}). Characteristics of peatland plantations such as wet ground conditions and wind-throw mean they are likely to often be more difficult to harvest than sites on mineral soils. Finally it is notable that several sites in the database are recorded as yielding low returns due to inaccessibility and distance to markets. These are factors which are likely to apply disproportionately to peatland sites many of which occur in relatively remote regions. Taken overall the dataset cannot directly cast light on afforested peatland but does clearly demonstrate that attributes of many peatland forests such as a disproportionate abundance of Lodgepole Pine and being difficult to harvest lead to lower returns compared to other forest sites in terms of the value of the timber produced. These data are expressed in terms of timber value but the more meaningful comparison would be in terms of land area. Average planting densities vary but, for instance, Anderson and Peace (2017) (37) give data for three sites with a mean live stem density across three plantations of 2462 ha^{-1} which when applied to the Bidwells dataset value for all conifers implies a mean value of a fraction under £24,000 ha^{-1}.

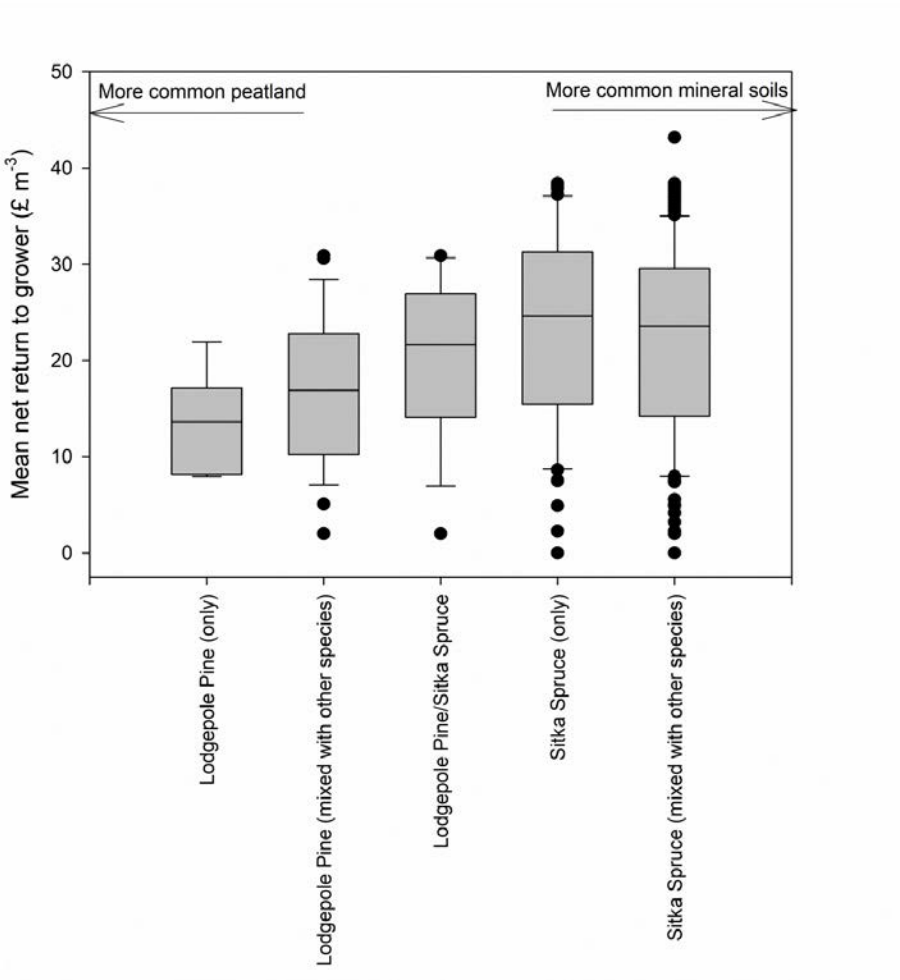


Fig. 9. Forestry financial value: mean net return to grower based on data from (70, 71) for private conifer forestry 2016-2017. Bars show prices for most abundant species grown on peatlands.

It is also worth briefly considering the financial cost of restoration. There is a limited body of publicly-available data on this topic, with the most extensive compilation being that associated with the Peatland Action programme in Scotland (72). The key costs of peatland restoration are those of forest-removal and drain blocking. Both appear to be highly variable depending on the nature of the sites, methods used, location etc. Most records for the cost of drain blocking imply cost between £500-1500 ha^{-1}. Most records for the cost of tree-felling are in the range £2000-4000 ha^{-1} but this is both very context (site/method) dependent and unless trees are felled to waste/mulched is likely to be offset (entirely/in-part) by the value of the timber. These constitute the core costs, but far from the only cost of restoration works. Scrub and re-growth control is likely to be an on-going cost, particularly in drier sites. Sites are likely to require ongoing monitoring and there are also administrative costs involved (e.g. felling licenses). More intensive restoration methods (e.g. cell bunding) can be far more expensive and much restoration work does not represent a one-off intervention but rather the initiation of a longer-term process. Although highly variable, it is clear that the cost of forest-to-bog restoration is considerable and represents one of the more-expensive forms of peatland restoration.

Table 3. Previously-reported costings for restoration works and data assembled for this study. Figures as reported in original sources, figures in square brackets adjusted for inflation to 2017. σ= standard deviation.

Projects	Intervention	Cost	Source
Projects funded by Peatland Action programme (Scotland)	Drain-blocking Forest removal (harvesting) Forest removal (mulching)	Mean of £879 (σ=906) ha^{-1} (14 records) Mean of £2996 (σ=3720) ha^{-1} (7 records) £2425 ha^{-1} (1 record)	
Older Scottish projects	Whole tree removal incl. helicopter extraction (Langlands Moss) Fell to waste (Halsary/Braehour) Fell to waste (Flanders Moss) Whole tree harvesting (incl. skyline extraction) Furrow damming (full range dependent on slope and interval)	£9000 ha^{-1} (net cost) [£14,670] £630 ha^{-1} [£1027] £1100 ha^{-1} [£1793] £2800 ha^{-1} [£4564] £4000-61,000 ha^{-1} [£6520-99,434]	
Fenns, Whixall and Bettisfield Mosses NNR (lowland raised bog, England and Wales)	Tree removal Bunding Scrub control (likely to need two rounds)	~£4200 ha^{-1} minus receipts ~£4000 ha^{-1} ~£750-1000 ha^{-1}	Daniels (pers. comm.)
Forest Enterprise Scotland Peatland Action sites (may overlap with sites listed above)	Tree removal (harvesting machines) Chainsaw felling/packing Mulching Ditch blocking	£1500 ha^{-1} (1 record) £1836 ha^{-1} (9 records) £2983 ha^{-1} (5 records) £528 ha^{-1} (12 records)	McKee (pers. comm.)

Scottish Power Renewables sites (blanket bog restoration associated with windfarm construction)	Mulching (no longer widely practised) Post-felling ground smoothing Regeneration control Tree felling Ditch and furrow blocking	£4-8000 ha^{-1} ~£1000 ha^{-1} ~£100 ha^{-1} (highly variable) Highly variable, net cost depends on variable income from timber. ~£450 ha^{-1} (variable)	Robson (pers. comm.)

Future evidence needs:

The question posed cannot be answered with current knowledge. It is clear that the natural capital of peatlands is considerable, but the financial value is unclear. Quantifying this is a considerable challenge, but not impossible. The most challenging element of the question is change with afforestation and restoration. Addressing this element of the question would necessitate addressing other questions considered elsewhere in this report. We cannot currently place a value on change in climate forcing or flood risk (for instance), simply because we do not currently know how these things will change. A robust answer to this question would require a broad-scale improvement in knowledge of the impacts of peatland forestry and consequences of restoration. For this reason the question is probably the single most challenging of those proposed here.

Other questions with support.

The questions above were the most highly-ranked by participants in the second-stage survey, but we consider that voting by specific sectors and in the first-stage justify consideration of three further questions.

How will biodiversity recover with forest-to-bog restoration in the long-term?

Context and voting:

This question received 12 votes in the second stage survey, placing it as the 12th most highly-ranked question in the voting. However the question was the most popular question with third sector conservation organisations with this group constituting the majority of voters. The theme of biodiversity was present in many of the originally submitted questions with many having similar wording; this was the sole question on biodiversity put forward to the second stage. Biodiversity is one of the most frequently-cited justifications for peatland restoration and this question focuses particularly on long-term changes.

State of current evidence:

It is clear that afforestation leads to considerable impacts on peatland biodiversity. The process of drainage, often also associated with fertilization, leads to partial removal of the specific conditions which peatland biota have evolved to. New species are likely to establish in vacated niches but these are typically not peatland specialists and many are of a ruderal character and not conservation priorities. Afforestation often leads to the loss of *Sphagnum* mosses which have particular importance due to their role as keystone species (73) which acidify their environment and produce recalcitrant plant litter which promotes peat development. In a national study of 56 selected randomly selected sites with peat we found that the sites with conifer planting had lower mean plant species richness and *Sphagnum* cover than open sites (Payne unpublished data). While this trend was non-significant (Mann Whitney P=0.1) it is still very notable given that the open sites included many which were also degraded through burning or agricultural usage.

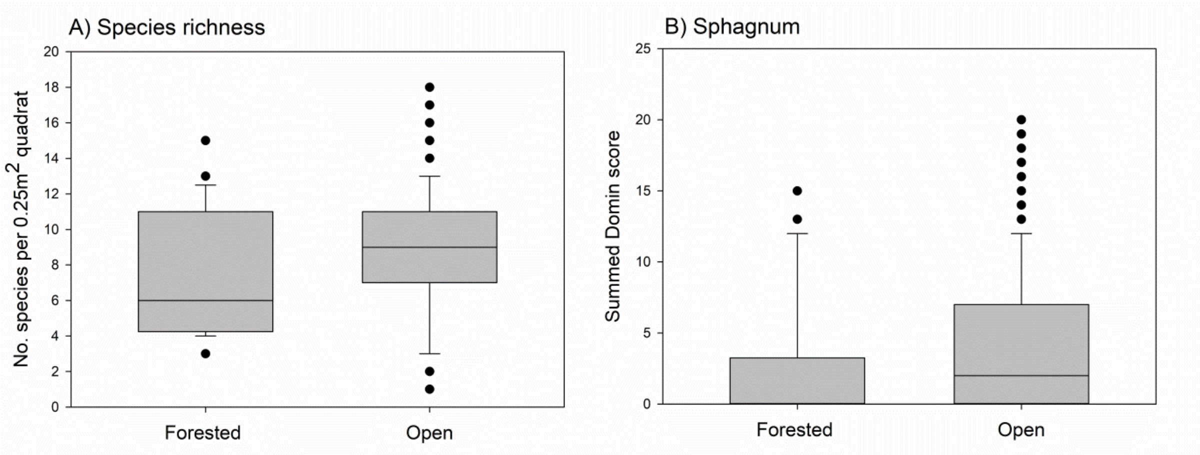


Fig. 10. Difference in species richness (A) and abundance of the ecosystem engineer *Sphagnum* (B) in 224 quadrats from 56 sites (7 forested) randomly selected solely on the basis of being mapped to contain peat.

Impacts of afforestation are likely to extend across multiple trophic levels. The impacts of peatland forestry on birds are particularly well-known and extend considerably beyond the boundaries of the plantation itself (27, 74). Impacts have been demonstrated in other groups from microbes to insects (75, 76). It is possible that some species of conservation value may benefit from trees. For instance Pine Marten can be quite abundant in peatland conifer plantations in northern Scotland and degraded drained peat with secondary growth of deciduous trees at the Humberhead peatlands is a habitat for Nightjar (L. Ryan, University of York, pers. comm.). However, it is generally accepted that the balance of impacts is negative; a loss of biodiversity of conservation value.

Evidence for recovery with restoration to-date is fragmented, partly because much data collected is not in the public domain. Available evidence suggests that as peatlands re-wet typical bog plant species do re-establish (37, 38, 77). However, more than twenty years after the earliest restoration projects all restored sites remain considerably different from unafforested sites. The trajectory of recovery varies with some sites showing much more rapid recovery than others and recovery in some sites stalling (38). Recovery is typically slower in drier microhabitats such as plough-throw ridges and more rapid in wetter microhabitats such as furrows. Ongoing management is also likely to play an important role in trajectory of change with tree re-growth often rapid in drier sites and the potential for dominance by non-target species such as *Molinia caerulea*. Recovery towards conditions typical of open peatlands has been demonstrated at multiple trophic levels (75, 76), but information on groups other than plants is scant. More data is available from other types of peatland restoration and this suggests that re-wetting is likely to lead to recovery in biodiversity (13).

Future evidence needs:

The question can be considered to have two components: recovery over the ~20 year time-span when forest-to-bog restoration has been undertaken and recovery further into the future; the former is more tractable. There is a clear need for the impacts of current peatland restoration on biodiversity to be monitored. This can be problematic given that many restoration funders do not require (or even allow) funding to be allocated to monitoring. A related issue is that much data which is collected is not disseminated more widely. In this respect, stakeholder fora (such as the meetings of the IUCN peatland programme) and outlets such as Conservation Evidence (www.conservationevidence.com) may have important roles. Most monitoring of post-restoration recovery focusses on peatland plants and there is a risk that other important elements of biodiversity may be overlooked. Although plant communities are of paramount importance, future monitoring needs to consider other components of biodiversity as well.

The question wording specifies 'the long-term' and predicting changes further into the future is much more challenging. One approach is to identify 'early indicators' which may provide near-term signs of longer-term success. However, ultimately, predicting change many decades into the future can only be achieved by modelling the system. While several models of peatland function are available and many of these incorporate elements of peatland biota (often at least plant functional types), predicting long-term biodiversity changes is beyond the ability of any current model and would require the development of specific tools. Climate change (the subject of other nominated questions) poses additional challenges to such predictive modelling given that impacts on peatlands are probable but outcomes highly uncertain.

How do afforested peatlands and peatland restoration affect downstream flood risk?

Context and voting:

This question received 14 votes in the second stage survey, placing it as the 9th most highly voted question. However the question was the single most popular question amongst the group of stakeholders from governmental and statutory organisations, with this group constituting 50% of the total voters for the question. In the original submissions this theme was only proposed by a single participant (question SQ126: Under different magnitudes of rainfall events (low, medium and high) do afforested peatlands increase or decrease downstream flood risk?). The nominated question addresses the effect of alternative management options (forestry or restoration) on flood risk. Part of the context to the popularity of the question probably relates to interest in UK policy in Natural Flood Management (NFM) with several NFM pilot schemes incorporating peatland restoration elements (78).

State of current evidence:

We are aware of little research directly addressing this issue, particularly in the UK context of forestry primarily on otherwise-open blanket bogs. Planting trees on peat modifies the (eco)hydrological system in many ways and some processes are clear. Drainage lowers the water table considerably relative to undrained peat. The forest canopy increases both rainfall interception and evapotranspiration. Drains and plough furrows drastically increase the surface channel capacity of a peatland. Compression, de-watering and oxidation increases peat bulk density and reduces hydraulic conductivity. Subsidence leads to sinking of the peat surface. Peat cracking may lead to the development of macro-pores and soil pipes (79). However, the net effect of these changes is not currently clear. A Scandinavian study (80), found that drainage of naturally-forested peatlands generally reduced peak flow but the highest peak flows might be increased. However such results are not directly transferable to the UK context due to the intrinsic differences between UK and Fennoscandian peatlands and peatland forestry. There is even greater uncertainty as to the effects of restoration, which may partially reverse the initial impacts of forest planting (raised water table, removed tree canopy etc.) but lead to sites which in the short-to-medium term are still considerably different from natural peatlands.

Future evidence needs:

Given the general lack of extant evidence on this issue, evidence needs are considerable but tractable. A large body of river flow data is collected routinely and is publicly available (81). Many of these records will encapsulate phases with both peatland afforestation and forest-to-bog restoration within catchments. Hydrological models are well-developed and their parameterisation to address the question is an achievable challenge. A large quantity of relevant data already exists. There is unlikely to be a single, simple answer to the question so site and catchment-specific studies are likely to be required.

Should peatland plantations removed be compensated by additional forestry on mineral soils, where should these plantations be located and what are the opportunities and costs of doing this?

Context and voting:

This question received 12 votes in the second stage survey, ranking as the tenth most voted questions. However the underlying theme of compensatory planting was the second most frequent in the original submissions, particularly amongst contributors from a forestry background. Given that ten question submissions addressed this topic and that forestry participants appear to have been better represented in the first stage than second we consider that this topic has support. The sector distribution of voters shows particular popularity amongst forestry sector participants and amongst land owners/managers. The question arises from numerous original submissions which raised the question of whether removal of peatland plantations should/would/could be replaced by additional 'compensatory' planting and how/where this could be achieved. This appears to be motivated particularly by concerns that peatland restoration imperils timber supply, the economic value of forestry, shifting forestry production onto other valuable habitats either nationally or internationally, and concerns around the role of timber as a carbon store.

State of current evidence:

Nationally there are targets to increase forest cover, in the UK to 12% by 2060 and in Scotland (the most peat-rich nation) to 25% by 2050 (41). These targets are currently voluntary but the policy landscape is currently dynamic and Brexit is likely to lead to many changes. Although peatland restoration often has similar carbon/climate motivations to forest expansion, restoring forested peatlands to open systems makes such targets harder to achieve. Peatland forestry represents a comparatively small proportion of total UK timber production but there are concerns that restoration imposes a negative pressure on production capacity, particularly given that projections already indicate a notable decline in production by the 2030s (82). These concerns are both about the economic effect and the wider consequences. There are concerns that any shortfall in domestic demand may be met by greater imports which may have higher carbon footprint due to transportation costs and could come from countries with lower environmental standards. There are also concerns that reduced timber supply could lead to timber being replaced by alternative materials with high carbon footprints (e.g. replacement of wood by concrete in construction). There is therefore interest in the idea of compensatory planting- that forestry removed from peatland is replaced by new forestry elsewhere. The carbon balance implications of forestry on peat are currently unclear whereas forestry on mineral soils can generally be expected to increase overall carbon storage. Peatland restoration combined with compensatory planting therefore offers the possibility for a clear increase in overall landscape carbon storage. Peatland forestry generally leads to lower yields of lower quality timber than forestry on mineral soils so the area of compensatory planting required to achieve the same carbon storage and timber production would probably be less than the area of forestry removed.

Future evidence needs:

The question addresses whether compensatory planting is desirable, which partially reflects value judgments beyond the scope of evidence alone. However some of the opportunities and challenges are clear. One clear challenge recognised by the question is where compensatory planting would occur. Trees were planted on peatland in large part because the land was cheap and available. There is no ready supply of alternative land for new forestry and new planting on mineral soils may conflict with other economic land-uses. A second clear challenge is cost: acquiring new land for compensatory planting would impose considerable costs. Another challenge is the environmental impacts of additional planting and the risks this potentially poses to other semi-natural habitats; this is a key concern for some conservation organisations (83). Compensatory planting has been touched on by a number of reports (34, 40) but we are not aware of any systematic assessment of whether compensatory planting is desirable and how this might be achieved. From this project it appears that there is some stakeholder support for more detailed consideration.

Overall Conclusions

This report has two principle aims: to identify the questions of greatest concern to stakeholders and to summarise the current evidence and future needs around these questions (within the limits of what is possible in a small project). It is clear that particular evidence-needs surround the greenhouse gas budgets of afforested and restored peatlands. Current knowledge allows mechanisms to be theorised but no robust answer to even the basic question of 'does planting trees on peat exacerbate or ameliorate climate change'- this is clearly a key future evidence need. Other issues of concern to stakeholders include restoration, biodiversity, natural capital valuation and flood risk, while themes not present in the final selection of questions but still with considerable support include water quality and the impacts of climate change.

Decisions about the future of afforested peatlands will reflect trade-offs between many of these factors and decisions around the prioritisation of alternative forms of natural capital and financial capital go beyond evidence alone. For biodiversity conservation there is a strong imperative for restoration. For immediate reasons of financial capital and timber security there is an imperative for restocking. For carbon emission avoidance the case is nuanced but in the long-term there is likely to also be a case for peatland restoration. The survey results demonstrate a considerable range of stakeholder views and perspectives which will need to be balanced in future decision-making.

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Appendix I. Survey details.

QUESTIONS RESPONSES 40

When deciding the future of afforested peatlands, what is the most important outstanding question?

This survey forms part of a research project funded by the Natural Environment Research Council's Valuing Nature Programme on afforested peatlands. We would like to hear your views on evidence needs for the future of UK afforested peatlands. We would simply like to know what information you/your organisation would find most useful for the future; what key question or questions would you like researchers to answer? Your suggested questions can be on any aspect of afforested peatland including forest-to-bog restoration. You can nominate as many or as few questions as you wish. This survey will have two stages: in the first stage we are inviting an open call for questions; in the second stage we will ask participants to vote on the relative importance of those questions.

For further information or to be added to the mailing list for the second phase please contact Dr Richard Payne (richard.payne@york.ac.uk). A document detailing the background to the project and how the information will be used is available on request. In brief: replies are anonymous, no information will be collected other than that you directly supply and all reporting will be in aggregate, participation is entirely optional but very much appreciated. Thank you for your interest.

Who is your employer / what is your interest in afforested peatland? (please select the closest match) *

- Research organisation or university.
- Charitable conservation organisation.
- Forestry Commission or private sector forestry industry.
- Private sector land owners or land managers.
- Other private sector organisation (consultancies, utilities etc).
- Other governmental or statutory bodies (government, national nature conservation bodies, environmental regulators e
- Other or prefer not to say.

When deciding the future of afforested peatlands, what is the most important outstanding question?

Long-answer text

When deciding the future of afforested peatlands, what is the most important outstanding question? Phase II.

This survey forms part of a research project funded by the Natural Environment Research Council's Valuing Nature Programme on afforested peatlands. We would like to hear your views on evidence needs for the future of UK afforested peatlands. In the first phase of the survey a large number of questions were submitted by the community which we have edited for clarity and consistency and to remove duplicates. In this second phase we would now like your help to prioritise these edited questions. Please vote for up to five of the questions below.

For further information about the study please contact Dr Richard Payne (richard.payne@york.ac.uk). A document detailing the background to the project and how the information will be used is available on request. In brief: replies are anonymous, no information will be collected other than that you directly supply and all reporting will be in aggregate, participation is entirely optional but very much appreciated. Thank you for your interest.

*Required

I confirm that I have a professional interest in UK afforested peatlands or forest-to-bog restoration and will only complete this form once. *

- ○ Yes
- ○ No

Who is your employer / what is your interest in afforested peatland? (please select the closest match) *

- ○ Research organisation or university.
- ○ Charitable conservation organisation.
- ○ Forestry Commission or private sector forestry industry.
- ○ Private sector land owners or land managers.
- ○ Other private sector organisation (consultancies, utilities etc).
- ○ Other governmental or statutory bodies (government, national nature conservation bodies, environmental regulators etc).
- ○ Other or prefer not to say.

Which are the most important questions for the future of afforested peatlands? Please select up to five options.

- ☐ How does the greenhouse gas balance of peatland forestry differ between deep and shallow peat and compare to forestry on mineral soils?
- ☐ Could the planting or maintenance of peatland forests be justified to mitigate erosion?
- ☐ Is knowledge of peatland extent, depth and carbon stock adequate to make policy decisions on the future of afforested peatland?
- ☐ How does greenhouse gas balance of afforested peat vary with forest yield class?
- ☐ How appropriate are current emission factors for UK afforested peat?
- ☐ Is it possible to restore afforested peatlands to naturally functioning systems and how long will this take?
- ☐ How will the water quality of peatland catchments be affected by continuing forestry or restoration?
- ☐ How will climate change affect peatland forestry?
- ☐ If replanting on peatland is not allowed should private sector investors be financially compensated and how could this be achieved?

Appendix II. Participant information sheets.

Natural Capital Trade-offs In Afforested Peatlands

Why we are doing this?

This data collection is part of a project to synthesise evidence around afforested peatlands and their future management. The project is funded by the Natural Environment Research Council through their Valuing Nature programme (http://valuing-nature.net/). To identify where the focus should be and guide future research we are keen to get the opinions of stakeholders on the key open questions. The project won't be able to provide definitive answers to all questions but aims to establish the current state of knowledge and guide where future, more detailed, research is required.

Who are we sending this to?

We are interested in the opinions of everybody with a stake in the future of peatland forestry and afforested peatlands in the UK. We are sending this request to a wide variety of participants with a professional interest in forestry, peat and peatlands. These include people in the Forestry Commission, private forestry industry, peatland conservation organisations, statutory bodies, land owners and land managers. Assembling a definitive list of such people is, of course, difficult so please feel free to forward this to others inside or outside your organisation who might have a view on the subject. In some cases we have sent this request to generic organisational email addresses and we would be grateful if you could forward this to whoever would be most appropriate within your organisation. If you have received this invitation but do not work on afforested peatland (e.g. you work on forestry but only on mineral soils or on peatlands but not afforested peatlands), please ignore this invitation. For this survey we are only interested in the views of people with professional interests in this subject matter, not members of the public (which is not to say that we think public views are unimportant). The project is about the situation in the UK so we are only looking for participants from the UK or with interests in UK peatlands. Participation is entirely optional, you are free to participate or not as you wish. Once you have contributed it will not be possible to remove your contribution as responses will not be identifiable to an individual contributor.

What do we want you to do?

We want to identify the most important open questions where answers are needed in order to shape the future of afforested peatlands. What evidence would help your organisation plan for the future of peatland forestry or forest-to-bog restoration? What questions would you like researchers to address? The project is funded through a funding scheme that focuses on 'natural capital' which in this context would include issues like carbon storage, biodiversity, water quality etc. However we are also interested in broader considerations including the economics of forestry on peat. You can nominate as many or as few questions as you wish.

How will the process work?

This will be a *two-stage process*. In the first stage we are making an open call for questions to everybody we have identified as potentially having an interest in this topic. Please enter your responses using the link provided. The form simply contains a box where you can enter what you think are the most important question(s). The survey is anonymous and we will not collect any data about you which you do not directly provide (we won't log IP addresses or any other identifying information). To allow us to assess the representativeness of respondents the form includes a box which asks you what type of organisation you represent; please choose the closest match. If you would rather not say, the form also includes a 'prefer not to say' box. We will collate the questions you nominate to take forward into the second round. At this stage we will edit questions for clarity and consistency of formatting and will combine questions which are the same or similar to avoid replication. We expect to take all questions which meet our criteria through to the second stage of voting but reserve the right to remove or edit any questions. In the second stage we will ask the same group of contributors to vote on all of the nominated questions. We will distribute a second online survey and ask you to vote for the questions you consider most important. You *can* vote for your own questions but please only vote once. When this is complete we will collate all the results and identify the questions which are considered to be the highest priorities by the community.

What makes a good question?

Sutherland et al. (2011 Methods Ecol Evol) propose the following features which would constitute a useful question: (i) answerable through a realistic research design, (ii) that have a factual answer that does not depend on value judgments, (iii) that address important gaps in knowledge, (iv) of a spatial and temporal scope that reasonably could be addressed by a research team, (v) not formulated as a general topic area, (vi) not answerable with *it all depends*, (vii) except if questioning a precise statement should not be answerable by *yes* or *no* (i.e. not 'is X better for biodiversity than Y'), (viii) if related to impact and interventions, contains a subject, an intervention, and a measurable outcome. We believe these are useful principles for this study.

What will we do with the information?

We will use this information to help understand what stakeholders view as the most important questions for the future of afforested peat. We have been commissioned to write a report on this work for the NERC Valuing Nature programme which will be made available on their website. We also intend to use this information to help guide the ongoing IUCN commission of enquiry on UK peatlands and may write academic papers using the results. If you provide us with an email address we will be happy to keep you informed about these outputs. The role of contributors will be acknowledged in all outputs but the requirement for anonymous responses means this will necessarily be on a collective basis.

Having problems with the form?

Our experience suggests that google forms may be blocked by some institutional IT systems. If you have this problem you can provide your information directly by email: just send your answer to the question 'When deciding the future of afforested peatlands, what is the most important outstanding question?' to Dr Richard Payne at richard.payne@york.ac.uk Information submitted in this way will clearly not be anonymous on receipt but will be otherwise treated as for other responses.

Any questions?

If you have any questions which are not covered by the information above please contact Dr Richard Payne on richard.payne@york.ac.uk.

Natural Capital Trade-offs In Afforested Peatlands

Part 1: Participant information.

Why we are doing this?

This data collection is part of a project to synthesise evidence around afforested peatlands and their future management. The project is funded by the Natural Environment Research Council through their Valuing Nature programme (http://valuing-nature.net/). To identify where the focus should be and guide future research we are keen to get the opinions of stakeholders on the key open questions. The project won't be able to provide definitive answers to all questions but aims to establish the current state of knowledge and guide where future, more detailed, research is required.

Who are we sending this to?

We are interested in the opinions of everybody with a stake in the future of peatland forestry and afforested peatlands in the UK. We are sending this request to a wide variety of participants with a professional interest in forestry, peat and peatlands. These include people in the Forestry Commission, private forestry industry, peatland conservation organisations, statutory bodies, land owners and land managers. Assembling a definitive list of such people is, of course, difficult so please feel free to forward this to others inside or outside your organisation who might have a view on the subject. In some cases we have sent this request to generic organisational email addresses and we would be grateful if you could forward this to whoever would be most appropriate within your organisation. If you have received this invitation but do not work on afforested peatland (e.g. you work on forestry but only on mineral soils or on peatlands but not afforested peatlands), please ignore this invitation. For this survey we are only interested in the views of people with professional interests in this subject matter, not members of the public (which is not to say that we think public views are unimportant). The project is about the situation in the UK so we are only looking for participants from the UK or with interests in UK peatlands. Participation is entirely optional, you are free to participate or not as you wish. Once you have contributed it will not be possible to remove your contribution as responses will not be identifiable to an individual contributor.

What do we want you to do?

We want your help to identify the most important open questions where answers are needed in order to shape the future of afforested peatlands. What evidence would help your organisation plan for the future of peatland forestry or forest-to-bog restoration? What questions would you like researchers to address? The project is funded through a funding scheme that focuses on 'natural capital' which in this context would include issues like carbon storage, biodiversity, water quality etc. However we are also interested in broader considerations including the economics of forestry on peat.

This is a two-stage process. In the first stage we asked participants to nominate questions. In the second we now want participants to vote on the most important of these questions. Using the link provided please vote for up to five questions which you consider most important. The survey is anonymous and we will not collect any data about you which you do not directly provide (we won't log IP addresses or any other identifying information). To allow us to assess the representativeness of respondents the form includes a box which asks you what type of organisation you represent; please choose the closest match. If you would rather not say, the form also includes a 'prefer not to say' box.

What happened to my question?

When you look at the second stage questions you will probably find that they do not include the question you submitted in its original form. We received a lot of questions in the first round, many of them quite similar. In order to give a reasonable number to vote on we needed to combine lots of questions. We first allocated all the questions to one of eight themes (Table 1 below). We then attempted to identify unique topics within these themes and reformulated questions to address these topics using wordings from the original submissions when possible. This was a difficult process and the decisions we have made are inevitably subjective. In the sections below you can find all of the submitted questions, our identified topics and justification for our decisions. Wherever there has been a choice to be made we have often opted for broader questions over more specific questions as previous research has shown that broader questions often attract more support in the voting phase of processes like this. It is inevitable that some nuance intended by original contributors may have been lost in this editorial process but we think we have captured all of the key themes somewhere in the resulting nominated questions. We have done our best at what proved to be quite a challenging task.

What will we do with the information?

We will use this information to help understand what stakeholders view as the most important questions for the future of afforested peat. We have been commissioned to write a report on this work for the NERC Valuing Nature programme which will be made available on their website. We also intend to use this information to help guide the ongoing IUCN commission of enquiry on UK peatlands and may write academic papers using the results. If you provide us with an email address we will be happy to keep you informed about these outputs. The role of contributors will be acknowledged in all outputs but the requirement for anonymous responses means this will necessarily be on a collective basis.

Any questions?

If you have any questions which are not covered by the information above please contact Dr Richard Payne on richard.payne@york.ac.uk.

[Part 2 of this sheet was as per appendix III and IV, omitted here for brevity]

Appendix III. Submitted questions, full list.

Table 1. Full list of submitted questions, themes, comments and related nominated questions.

#	Submitted question [theme]	Nominated questions	Comments
SQ1	Starting from unplanted, deep peat (>0.5m deep blanket bog), how do the carbon budgets compare between between leaving it as open, active peatland, with appropriate management to keep it active, and planting it with commercial woodland managed through normal commercial planting and felling cycles. [GHG]	NQ-GH1	
SQ2	What is the net GHG balance of tree removal from deep peat sites over different time horizons, and how do different removal and restoration strategies affect this balance? [GHG]	NQ-GH1 and others	
SQ3	The main question about the future of afforested peatlands is whether when reforested they will have substantial positive GHG balance both above and belowground? [GHG]	NQ-GH1	
SQ4	The other question will be if the afforested peatlands are prioritised for restoration, can they become carbon sink in the long term? [GHG]	NQ-GH1	
SQ5	How long will it take for forest-bog restoration to turn previously afforested peatlands back to healthy bog? [Restoration]	NQ-R1	
SQ6	Time it will take to restore the hydrology, vegetation and chemistry of the site post deforestation [Restoration]	NQ-R4, NQ-W3	
SQ7	Establishing the most appropriate pace of forest removal for maximum restoration potential including addressing the issue of scale - ie the minimum restorable area. [Restoration]	NQ-R2, NQ-R3	
SQ8	Do peatlands restored from formally afforested peatlands sequester more or less carbon as afforested peatlands? [Restoration, GHG]	NQ-R1	
SQ9	or What level of valued biodiversity do peatlands restored from former afforested peatlands have compared to intact peatlands? Sorry two equally important questions [Biodiversity]	NQ-B1	
SQ10	At what pace can we expect de-forested and restored peatlands to return to natural functioning ? [Restoration]	NQ-R1	

SQ11	Is it possible and desirable to maintain current Scottish and UK government forestry cover targets if afforested peatlands are not restocked once commercial plantations on peatlands reach maturity and are felled? If so, which parts of the UK should be afforested to compensate for lost forestry cover from formerly-afforested peatlands and what impacts would these changes in the distribution of forestry cover have on biodiversity, terrestrial carbon storage and flooding? [Forestry]	NQ-F1	Includes multiple components
SQ12	Whether restoring afforested peatlands back to an active peatland habitat brings great ecosystem benefits than continuing to use them for forestry [Restoration]	Multiple questions	Very general phrasing and implied value judgments
SQ13	The global demand for forest products will triple by 2050, (WWF Chapter 4 Forest Products), the UK is the world's 2nd biggest importer of forest products. The UK is one of the least forested countries in Europe, and new woodland creation is at a 30 year low. How will the UK sustainably meet its future requirements for timber? [Forestry]	Indirectly NQ-F1	Includes preamble. Lack of peatland focus.
SQ14	What is the best long term result for the atmosphere in terms of carbon dioxide and other greenhouse gases? [GHG]	NQ-GH1, NQ-GH2	
SQ15	With a secondary question being what is the best outcome from a local species diversity point of view? [Biodiversity]	NQ-B1	Not entirely clear phrasing (is the question just about best outcome or about the probability of achieving that?). The 'best outcome' can presumably be quite easily defined: a perfectly natural peatland.
SQ16	In the 1970's the viability of commercial conifer planting on peatland was researched, and proven, by the Forestry Commission in consultation with the Nature Conservancy Council. On the strength of the evidence private sector funding for peatland planting, was actively encouraged with Government support, to promote the development of a strategic timber resource to benefit the National economy. Question : If replanting on peatland is to be denied, how are private investors going to be compensated for the loss in value of their investment? [Forestry]	NQ-F3	Preamble.
SQ17	[NA]	NA	No question submitted.
SQ18	The ability of afforested peatlands to be restored to an 'active' state and the carbon balance of this transfer. [Restoration]	NQ-R1, NQ-GH1	Not phrased as question.

SQ19	Concerned that woodland removal is net loss, i.e. there is no requirement for compensatory afforestation elsewhere in Wales [Forestry]	NQ-F1	Not phrased as question.
SQ20	What is the contribution of ongoing carbon storage and product substitution by harvested wood use, especially in cascading value chains, to the net GHG and resource efficiency balance of afforested peatlands? [GHG]	NQ-GH2	
SQ21	What are the real (i.e. measured, empirical) ecological, carbon and economic trade-offs between the three main options (restoration, PEW or re-stocking)? [General]	Indirectly NQ-G1	Implies value judgements which are beyond the scope of a research project.
SQ22	How to make afforestation as natural as possible. How can we promote natural colonization and how to promote natural woodland succession? [Forestry]	NQ-F4	Not clear how this relates to commercial forestry.
SQ23	What is the long-term goal for the habitat and what type of trade-offs are we willing to consider? [General]	Not taken forward	Implies value judgements which are beyond the scope of simply evidence.
SQ24	[NA]	NA	No question submitted.
SQ25	[NA]	NA	No question submitted.
SQ26	In Wales I believe that the responsibility for the decision to restore or not should lie with NRW, since they issue a conditional or unconditional felling licence on the land prior to felling. There should be a fund to compensate landowners for not restocking their woodland and aid for carrying out restoration work on the peat. Otherwise the landowner is faced with devalued land, unless they restock at their own expense which is what is happening. I believe peat condition surveys should be carried out by NRW as well, on land they have issued an unconditional felling licence on, post felling. There are too many incentives for a landowner or their agent to find that the site is not restorable. There is no incentive for landowners to restore the peat and if they want to, then they are devaluing their land. In my experience most of the deep peat areas in private ownership are being re-stocked with 100% Sitka spruce. Peat restoration in the public sector should definitely be followed by acquisition of additional planting land. [Forestry]	NQ-F3, NQ-F5 and indirectly NQ-G2	Not phrased as question. Preamble. Multiple points.

SQ27	If the peatland is already afforested is it really peatland any more? However if afforested it is likely to be commercial or at least commercial in its planning stage . That has not always followed through in the management of such areas. The most important question is how can the timber be harvested with minimum damage whilst using an assessment (tools) to decide where it is possible to restore active bog life and where alternate tree/plant life might enhance active bog management for natural capital advancement. [Forestry, Restoration]	NQ-F2, NQ-R3	The first part is answerable with current knowledge: peatland is defined by a minimum peat depth, unless forestry has caused the loss of sufficient peat depth to fall below this threshold afforested peatlands will remain peatlands.
SQ28	the change in the level of provision (and associated societal value) of the change of the ecosystem services generated by the change on the ecosystem (i.e. the modification of the ecosystem from forest to bog) [General]	NQ-G1 and multiple others	Not phrased as question. We find this too general to be easily addressable with a research project as it encompasses both all ecosystem services and their societal value.
SQ29	What are the long-term consequences of restoring peatland for biodiversity and other ecosystem services besides maintaining carbon stocks? [Biodiversity, Restoration]	NQ-B1	
SQ30	Why are almost all UK blanket bogs except those that have been afforested largely treeless? [Other]	NQ-O1	
SQ31	What do the results of GHG and carbon flux measurements on afforested peatlands so far tell us? [GHG]	NQ-GH1	Not specific (tell us about what? why).
SQ32	What does the evidence tell us about recovery of bog ecosystems (flora and fauna, not functioning) after forest-to-bog restoration? [Biodiversity]	NQ-B1	Phrased in terms of current evidence rather than future needs.
SQ33	What are the benefits and costs (in a non-monetary sense, i.e. disbenefits) of afforesting peatlands and of forest-to-bog restoration? [General]	Multiple questions	Very general in scope. Could be a sole output.
SQ34	What can we say about how the sheltering effect of open woodland would affect ongoing erosion in blanket bog? [Other]	NQ-O2	Context not entirely clear.
SQ35	What role(s) can the restoration of afforested peatlands play in fighting the carbon crisis of the 21st century? [GHG]	NQ-GH1	
SQ36	Under what circumstances does forestry on peatland have a net climate cooling effect? [GHG]	NQ-GH1, NQ-GH2	
SQ37	What role(s) can the growing of trees on peatland play in fighting the carbon crisis of the 21st century? [GHG]	NQ-GH1, NQ-GH2	

SQ38	When further clearance of afforested peatland areas occur is the same area of land going to be made available to re-plant. [Forestry]	NQ-F1	
SQ39	Before deciding whether to take radical action to destroy an existing use of land with a peat component in the soil, careful consideration should be given to the existing benefit pertaining to the current use and the net effect of its destruction. Of course peatland (is this defined here?), has many values both to the particular species which it supports (as do deserts), and its capacity to lock up carbon. However notice should be taken of the values of the existing forest with its own particular species and its ability to provide a rapid and continuing take-up of CO2 into perpetuity, particularly in the case of structural timber where it is a replacement for concrete and steel. Every case should of course be taken on its merits and where a decision is taken to restore a peat bog then there will be a price paid in terms of profitable production and a compensatory area of new forest should be part of the process. [Forestry, Restoration]	Indirectly NQ-GH2, NQ-F1, NQ-R3	Not phrased as question. Preamble.
SQ40	[NA]	NA	No question submitted.
SQ41	How will climate change affect peatlands [Climate]	Indirectly NQ-C1, NQ-C2	Not specific to afforested peatlands.
SQ42	In obtaining a felling license, if peat depth qualifies as "deep peat" ie over 50cm depth then re-stocking after felling will not be required if the peat is shown to be capable of restoration. If peat is shallower or badly cracked, then restocking will be required. However very often it is possible to restore peat-forming communities on much shallower peat, if original hydrological conditions can be restored. Indeed peat obviously must have initially formed on sites with no peat at all.. Should this 50cm limit be re-visited? [Restoration]	NQ-R2	Preamble.
SQ43	The benefits of the natural capital accrued [General]	NQ-G1?	Not phrased as question. Not specific- natural captial benefits of what?
SQ44	Will there be an overall net reduction in carbon emissions following forest to bog restoration and over what timescale will this occur? [GHG]	NQ-GH1, NQ-GH2	
SQ45	Is it ever possible to have trees on peat without loss of ecosystem services we value (carbon storage, biodiversity etc)? [Forestry]	NQ-F6	

SQ46	What are the short- and long-term consequences of peatland forestry and restoration for water quality? [Water]	NQ-W1	
SQ47	Why are forested peatlands so rare in the UK, were they more abundant in the past and would understanding their decline help us better manage current afforested peatlands? [Other]	NQ-O1	Multiple inter-related questions.
SQ48	How do the carbon benefits of peatland restoration vary based on the timescale under consideration and how different are the 10year, 100year and 1000year pictures? [Restoration, GHG]	NQ-GH1	
SQ49	How can we prioritise peatland sites for restoration to maximise carbon retention? [Restoration, GHG]	NQ-R3	
SQ50	Is it possible to finance peatland restoration through private-sector investment and how could this be achieved? [Restoration, Forestry]	NQ-F5	
SQ51	Over the next 100 years, what will be the net carbon loss/gain resulting from continued exploitation v. restoration of peatland for: a) agriculture b) windfarms c) forestry d) horticulture e) other development? [This question should help prioritise funding and attention for peatland restoration] [Restoration, GHG]	NQ-R1 (element 'c' only)	Not specific to afforested peatlands.
SQ52	Are new woods being planted to compensate for the lost land due to peatlands? Peatlands are a 'single' event for carbon capture and also water retention, whereas trees can be grown and felled many times, thus increasing carbon capture and water retention many times over; so any increase in peatlands needs to allow for new tree plantations as any damage to the peatlands (e.g. increase in temperature which causes peatlands to dry out) in the future will create an increase in the release of carbon retention and water losses. [Forestry, GHG]	NQ-F1	Opinion.
SQ53	Is it economically viable and responsible to replant trees on peatlands? [Forestry]	Indirectly NQ-F7 and several other questions.	Responsible' implies value judgements beyond the scope of a research project.
SQ54	What is the long-term, whole life cycle, carbon and nutrient balance of afforested peatlands (their supporting and regulating value), what is their contribution to wider ecosystem biodiversity (inclusive of edge effects, their intrinsic value) and how do these balance against the socio-economic value (production and cultural value), of the forestry crop. [General]	Multiple questions	Broad in scope covering multiple ecosystem services, biodiversity and socio-economics. 'Balance' implies value judgements beyond the scope of evidence alone.
SQ55	Peatland restoration [Restoration]	NQ-R1?	Not phrased as a question.

SQ56	how afforestation of peatlands will affect on peatlands vegetation composition, decompose process and GHG exchange? [General]	NQ-GH1 etc	General. Phrasing implies new afforestation which is not likely.
SQ57	How can we pragmatically achieve a win-win-win-win-win outcome: carbon + water quality + flood + landscape + wildife? [General]	Multiple questions	A general question covering multiple ecosystem services. Wording presumes that such a solution is possible.
SQ58	The big unknown (in terms of research data) is how much peat/carbon is being lost from the system... (down the ditches and into the air); [GHG]	NQ-GH1	Not phrased as question.
SQ59	and the extent to which drained forested peatland causes acidic rivers and peaty water supplies. [this and above submitted by one contributor but considered two questions] [Water]	NQ-W1	Not phrased as question.
SQ60	For forestry planting proposals there is a prohibition against conventional (sitka) planting on areas where peat depths are greater than 50cm. Current prohibitions relate only to sites considered a priority for habitat restoration on ecological grounds. Sites with deep peat (>50cm) could be restored for open peatland habitat, bog woodland/scrub (peatland edge habitat), and native woodlands where site would support tree growth. [Forestry, Restoration]	Not taken forward	Phrased as opinion not question. No clear evidence need.
SQ61	1. Will the overall benefits we are trying to create / maintain through management of afforested peatlands be achieved given projected climate change; [Climate]	NQ-C2	Assumes consensus over benefits.
SQ62	2. Will the overall benefits we are trying to create / maintain through peatland restoration still be achieved given projected climate change; [Climate]	NQ-C1	Assumes consensus over benefits.
SQ63	3. How different tree species suitable for growing on peat will change their behaviours, impacts and benefits under projected climatic conditions; [Climate]	NQ-C2	Slightly awkward wording.
SQ64	4. What are the economics involved in managing afforested peatlands and how the compare with peatland restoration; [Forestry]	NQ-F7	
SQ65	5. Can we quantify the ecosystem services provided by forests and low-density woodland on peatlands in different areas; [General]	NQ-G1 and several others indirectly	General in scope (all ecosystem services). As currently worded answerable with yes/no response (yes this is possible).
SQ66	6. In carbon sequestration AND storage terms can we identify the most effective land management. [GHG]	NQ-GH1	

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SQ67	We need carbon data on afforested peatland soils using total soil/peat depth, not just the top 1m (because the top 1m is constantly subsiding/disappearing) (FC's research only looks at the peat surface. The UK needs data on the total peat) [General]	NQ-G2	Phrased as opinion not question.
SQ68	When restoring forest-to-bog how does site area, peat depth, % of site that was afforested, proximity to other peat masses and average ground water depth correspond with the recovery rate of bog specialist biodiversity (e.g. Sphagnum cover and species diversity). [Restoration]	NQ-R1, NQ-R4, NQ-B1	
SQ69	What work is required to secure an appropriate and sustainable hydrological regime on the site [Restoration]	NQ-R4	Not clear on context- presumably restoration sites?
SQ70	What future state (given climate change) is best in terms of generating a range of ecosystem services? [General]	Multiple questions	General in scope (multiple ecosystem services). Somewhat unclear what is meant by future state (presumably continuing forestry or restoration).
SQ71	Should trees be removed to facilitate bog restoration? [Restoration]	Not taken forward	Unclear phrasing, can be read as either 'when we are restoring bogs do we need to remove trees' (to which the answer is presumably 'yes') or 'should we restore forested sites to bog?'. If the latter then it is unclear what evidence is needed to make this decision.
SQ72	As the number of forest rotations increases, the potential to restore the underlying and adjacent peatland decreases. What are the financial and environmental costs of forest establishment, fertilizing, harvesting, transporting and processing over multiple rotations, and is forestry on peatland financially and environmentally sustainable in the long term? [Forestry]	Indirectly NQ-R3, NQ-F7 and several others.	Includes preamble and assertion. Encompasses multiple themes.
SQ73	In a changing climate, with increasing pest and disease problems, how do intact peatlands and afforested peatlands compare in the long term (100 years plus) with regard to their	NQ-GH1	

	carbon balance, taking management activities into account? [GHG]		
SQ74	What is the ultimate fate of timber harvested from peatland plantations and what implications does that have for carbon balance? [GHG]	NQ-GH2	
SQ75	Taking into account the likely impact of climate change on both peatlands and forests, on what types of afforested peatland is the rate of carbon sequestration by the trees likely to exceed the rate of carbon loss from the peat, and how is this affected by the type of forest management practised (eg. rotation length, methods of ground preparation for restocking)? [Forestry, Climate]	NQ-GH3, NQ-GH1, NQ-C1, NQ-C2	Wording assumes that at least in some afforested peatlands tree carbon sequestration will exceed peat carbon loss- disputed.
SQ76	To what extent was carbon lost from peat through afforestation, and can ongoing carbon loss be effectively halted? [GHG]	NQ-GH1	
SQ77	Where restoration of peatlands involves the removal of forestry then there should be a specific programme for that area of forestry to be replaced elsewhere. That replacement should not be lost in the general planting target of the government but should be conditional rather like conditions attached to a felling licence. The outstanding question should be where will compensatory planting occur? [Forestry]	NQ-F1	Extensive preamble, phrased as opinion.
SQ78	What is the cumulative effect of several rotations of commercial conifers on peatland - is it sustainable, or damaging the peat/soil ecosystem? [Forestry]	Indirectly several questions including NQ-GH8.	Not entirely clear what is meant by either 'sustainable' or 'damaging'- in different contexts these terms may have different meanings.
SQ79	how to best to restore them to active peatlands [Restoration]	NQ-R4	Not phrased as question.
SQ80	1) What are the effects of afforestation and reforestation on peaty soil C stocks and GHC fluxes for the range of peaty soils, forest types and ages encountered in the UK. [GHG]	NQ-GH1	
SQ81	2) What are the effects of typical thinning and clearfell practice on peaty soil C stocks and losses, and on soil GHG fluxes. [GHG]	NQ-GH3, NQ-F2	
SQ82	3) Is it possible to restore afforested peat land to a fully functional bog ecosystem? [Restoration]	NQ-R1	
SQ83	4) What will be the typical bog vegetation community in a plus 2, plus 3 or plus 4 degree world? [Climate]	NQ-C1, NQ-C2	Not phrased in terms of afforested peatland.

SQ84	5) Is there a role for tree cover to protect/maintain peat soils? [Other]	NQ-O2	
SQ85	6) What are likely to be the impacts of climate change on the peatland if it is restored (i.e. is restoration sustainable in the long term)? [Climate]	NQ-C1	
SQ86	What is likely to be the GHG balance of a site under different options for future management, given the fertility of the site and planned future water table level? [GHG]	NQ-GH1	
SQ87	Additional questions - How will the water quality in the catchment be affected under the different management options, as short and long term response given use of specific restoration techniques? [Water]	NQ-W1	
SQ88	Can a generic method be applied to these questions for individual sites using available site specific information, and with an estimate of uncertainty in the outcome? [Other]	Not directly taken forward	Not entirely clear what a 'generic method' would be or aim to achieve.
SQ89	1) What are the effects of afforestation, harvesting and reforestation on peaty soil C stocks and GHC fluxes for the range of peaty soils, forest types and ages encountered in the UK? [GHG]	NQ-GH1	
SQ90	2) Is it possible to restore afforested peat land to a fully functional bog ecosystem? [Restoration]	NQ-R1	
SQ91	3) Is there a role for tree cover to protect/maintain peat soils? [Other]	NQ-O2	
SQ92	4) What are likely to be the impacts of climate change on the peatland if it is cleared of tree cover (i.e. is restoration sustainable in the long term)? [Climate]	NQ-C1	
SQ93	5) Where will land for compensatory woodland creation be sourced from to off-set the loss of woodland area and the reduction in multiple benefits which accompany that woodland (market and public benefits)? [Forestry]	NQ-F1	
SQ94	Drained afforested peatland, when compared with undrained, unafforested releases more carbon dioxide, nitrous oxide and dissolved carbon (DOC), but less methane. Whilst the soil may be a substantial source of CO2 especially for nutrient rich peatlands, the better tree growth after drainage provides a larger C sink, which is likely to provide an overall net GHG sequestration benefit. The long-term GHG balance of afforested bogs is still the area with most uncertainty. The key knowledge gap is whether restoration felling is warranted prior to commercial rotation length, or would be better delayed until normal operational practice - current evidence suggests that maintenance of forest cover to the point of commercial felling is likely to be the best net GHG	NQ-GH1, NQ-R3	Phrased as statement (incl. opinion) not question

	management approach but this is where evidence is required. [GHG]		
SQ95	The key decision should be based on knowledge of the quality and type of the afforested peat resource, and concerns when, if restoration (or cessation of commercial forest activity I.e. another forest rotation) is considered the best course of action, the intervention should occur? Current evidence is scant, and does not adequately cover all GHG's, but suggests that management until the end of a commercial rotation is likely the best approach if forest productivity is such that an economic timber return will occur. Premature felling should be considered in priority habitat areas and where forest productivity is poor (approximately yield class 8 Sitka spruce) [GHG]	NQ-R3	Phrased as statement not question.
SQ96	Quantify the net loss of GVA and number of jobs lost per Ha by forest removal on peatlands, per country. [Forestry]	NQ-F7	Not phrased as question.
SQ97	A comparison of the volume per Ha/year of carbon sequestration by peatlands and forests on peatlands over one rotation of trees, i.e. 30 years and a comparison of the volume per Ha/year of water sequestration by peatlands and forests on peatlands over one rotation of trees, i.e. 30 years [GHG, water]	NQ-GH1 and NQ-W2 indirectly	Not phrased as question.
SQ98	The reduction in timber production in terms of M3 forecasted by deforestation on peatlands, per country. [Forestry]	Indirectly NQ-F7	Not phrased as question.
SQ99	What are the reasons why compensatory planting of new forests to offset forests lost to peatland restoration has not happened despite the requirements under other strategies to do so, and what needs to be done to rectify that. [Forestry]	NQ-F1	
SQ100	the area of new forests planted specifically as compensatory planting for forests lost to peatland restoration as required by UKFS, per county. [Forestry]	NQ-F1	Not phrased as question. Arguably not very helpful.
SQ101	How can a robust process be implemented which ensures compensatory forest planting for trees already removed, and removed in future, so that peatland restoration does not continue to result in deforestation? [Forestry]	NQ-F1	

SQ102	What is the impact of afforestation on the soil carbon storage capacity and greenhouse gas budget of peatlands? [GHG]	NQ-GH1	
SQ103	What are the long-term impacts on carbon balance of peatland afforestation? [GHG]	NQ-GH1	
SQ104	What are the economic timber benefits of trees on bogs versus trees on non peat soils? [Forestry]	NQ-F7	
SQ105	Determine the hydrological and vegetational impact of existing plantations and restocking plantations on deep peat – what are the right methods for capturing the full effect on peatlands including shifts in Sphagnum structure/composition, subsidence, long term effect on hydrological stability. [General]	Multiple questions	Question encompasses multiple distinct themes treated seperately elsewhere. Not totally clear what is meant by 'The right methods for capturing'.
SQ106	Examine the overall land use carbon scenarios of a)planting trees on non-peat soils plus conservation/restoration of peatland versus b) planting/re-planting trees on peatland – what is the optimal overall land use carbon scenario? Is it healthy trees in the right place and healthy bogs rather than compromising both tree growth and peatland condition through planting on peat? Water and biodiversity outcomes could also be assessed. [GHG]	NQ-GH1, NQ-GH2	Multiple inter-related questions.
SQ107	what is the best overall natural capital / climate change based return on investment made? [General]	Multiple questions	General in scope and could imply value judgements between different forms of natural capital.
SQ108	Can functioning peatland habitat by restored/re-created? [Restoration]	NQ-R1	
SQ109	Is the extent on the peatland understood and has the depth of peat been mapped sufficiently to make an informed opinion as to whether the forestry is having a detrimental impact on the function of the peatland [General]	NQ-G2	
SQ110	1. What loss rates for Soil Organic Carbon (SOC) are associated with different types of cultivation techniques for peatland restock sites? Purpose: To help identify cultivation techniques that minimise loss of SOC when restocking forests on peatland sites. [GHG]	NQ-GH3	
SQ111	2. How does moisture content of peat soils affect rates of loss of SOC? Purpose: To improve understanding of the variability of peat soil types and their capacity to release SOC following disturbance. [GHG]	Not taken forward	Not specific to afforested sites.

SQ112	3. How does yield class of sitka spruce relate to varying peat depth? Purpose: To identify threshold site types where higher yield class crops achieve a positive carbon balance by absorbing CO2 and accumulating SOC because of litter accumulation at a higher rate than SOC loss due to cultivation disturbance of peat soils. [Forestry]	NQ-F8	
SQ113	4. How does the carbon footprint of commercial forest crops compare to the potential loss of SOC through cultivation of peatland sites when the use of the timber products produced is considered as an alternative to other construction materials like steel and concrete? Purpose: To improve understanding of the overall carbon balance of commercial forests growing on peatland soils. [Forestry, GHG]	NQ-GH1, NQ-GH2	
SQ114	5. Under a range of peat depths and yield classes, what is the natural capital value in pounds sterling of, • Undisturbed peatland, • Undisturbed peat that will be newly afforested, • Undisturbed peat that will be newly afforested, • Undisturbed peat that will be newly afforested,• Undisturbed peat that will be newly afforested,• Restocking of previously afforested peat, [General]	NQ-G1	Multiple inter-related questions.
SQ115	6. How do rates of loss of soil organic carbon (SOC), as a result of forestry cultivation work, vary between new planting sites and restock sites that have been previously cultivated? [GHG]	NQ-GH1 indirectly	
SQ116	Peatlands, particularly blanket bog and 'intermediate' mire, are one of the few UK natural habitats that are significant in terms of their contribution to global biodiversity. The majority, particularly those in England, are highly degraded with major loss of characteristic biota. The richest remaining bogs in England are those in the Border Mires, where over 20,000 ha of peat is still planted with conifer crops reducing biodiversity directly, and indirectly through drainage, edge effects, loss of transitional habitats etc. How can the UK seriously claim to be doing its bit for global biodiversity while these and other areas of peat remain under crops, and remaining non-designated areas of bog are still threatened with habitat destruction through planting of conifer crops? [Biodiversity]	Indirectly NQ-B1	Specific in focus. Opinion. Not phrased in terms of evidence needs.
SQ117	Is rapid deforestation of peatlands the best solution for peatland restoration? [Restoration]	NQ-R3	Unclear phrasing as regards ultimate aim of restoration. If aim is restoration in itself (as currently phrased) then question can be answered simply by 'yes'.
SQ118	What is the GHG emissions of 2nd & 3rd rotation forestry on deep peat soils [GHG]	NQ-GH1, NQ-GH8	

SQ119	What are the GHG emissions from planting forestry on shallower 10-40cm peat soils? [GHG]	NQ-GH5	
SQ120	How do UK afforested peatlands emissions differ from current tier 1 & tier 2 emissions factors that were mostly produced from Scandinavian & European data? [GHG]	NQ-GH6	
SQ121	What growth class of tree is needed to equal the emissions being released from afforesting peat soils at all depth 10cm upwards? [GHG]	NQ-GH7	
SQ122	What are the long term implications of peatland afforestation on the water chemistry of water courses draining the peatlands when compared with non-afforested peatlands? [Water]	NQ-W1	
SQ123	A number of forestry plantation on peat also affect the hydrology of the peatland sites beyond the actual forestry plantations. This drying and drainage associated with the forestry means carbon emissions can extend outwards. How large is this affect in terms of GHG emissions and distance from the plantation that is being impacted? [GHG]	NQ-GH4	Preamble.
SQ124	In its recent report, the Committee on Climate Change also state, Gaps to meeting the fourth and fifth carbon budgets remain. These gaps must be closed. Where woodland is planted on peat the emissions gains are negligible and so much lower than planting on areas away from carbon rich peat soils. What is the gain in emissions from planting away from peat when compared to planting on both shallow and deep peat soils? [GHG, forestry]	NQ-GH5	Preamble. Opinion.
SQ125	The UK Forestry's Standards (UKFS) Forests and Climate Change (and both Soils and Biodiversity) Guidelines: consider the balance of benefits for carbon and other ecosystem services before making the decision to restock on soils with peat exceeding 50 cm in depth. Is this 50 cm still the correct figure or would a 40 or 30 cm be more in keeping with the science? What are the ecosystem service trade offs of planting on peat inc. DOC etc., emissions? [GHG, forestry]	NQ-GH5 and many others	Preamble. Final clause is very general.
SQ126	Under different magnitudes of rainfall events (low, medium and high) do afforested peatlands increase or decrease downstream flood risk? [Water]	NQ-W2	

Appendix IV. Question reformulation undertaken.

Below we outline the key themes we identified in the responses and explain our decision-making.

Theme: Greenhouse gases [GHG].

This theme encompasses all questions related to carbon/greenhouse gases (GHGs) and climate forcing in terms of afforested peatlands. This was the most numerous category with many questions submitted similar and general in scope making the editorial process challenging. We ultimately opted for one general question encompassing these responses and then a sequence of more-specific questions reflecting other points made.

Key topics were:

1) Greenhouse gas budgets and change with restocking or restoration (a very large number of questions).

2) Fate of timber and implications for carbon budget (SQ20, SQ74, SQ113).

3) Forest management and GHG balance (SQ81).

4) Edge effects and GHG balance (SQ123).

5) Variability in GHG balance with peat/soil type/depth (SQ124, SQ121, SQ119, SQ125).

6) Emission factors (SQ120).

7) Variability in GHG balance with forestry yield (SQ121).

8) Changes through multiple forestry rotations (SQ118).

Questions put forward:

NQ-GH1. *How does the greenhouse gas budget of a peatland change with initial afforestation, restocking or restoration?*

This is the question which incorporates the largest number of other submitted questions. While there is considerable variability in the wording we have taken the view that all these questions go towards the same fundamental issue and have therefore combined. We have opted to phrase the question in terms of greenhouse gases (following e.g. SQ2, SQ20) to be more general than simply carbon. We have opted to phrase in terms of a greenhouse gas budget rather than a carbon stock (e.g. SQ29) as the latter is largely inherent in the former. We have opted not to differentiate different flux terms such as methane (e.g. SQ94), CO_2 (e.g. SQ14), N_2O (SQ94) or aquatic carbon (e.g. SQ125, SQ58) for the sake of a simple question wording and to avoid the need for multiple closely-related questions.

NQ-GH2. *How long will it take for the carbon from felled peatland plantations to be returned to the atmosphere?*

This question relates to themes around the fate of timber and the implications of this for carbon balance (contributions including SQ20, SQ74 and indirectly SQ113). While this question could arguably be considered a component of that above, the research required to address it is quite distinct and therefore warrants separate inclusion. Wording used is edited from SQ74.

NQ-GH3. *How do alternative forest management practises affect greenhouse gas balance?*

This question addresses submitted questions around forest management practises such as thinning. This theme is most apparent in SQ81 but is alluded to by other questions (e.g. SQ86). While this theme could be considered to be already incorporated in question NQ-GH1 we feel it goes towards a more general issue of whether alternative forest management would make a difference to climate forcing.

NQ-GH4. *How far beyond a plantation does forestry affect the greenhouse gas balance of unplanted peatland?*

This question comes from SQ123, here re-worded to be shorter and more general.

NQ-GH5. *How does the greenhouse gas balance of peatland forestry differ between deep and shallow peat and compare to forestry on mineral soils?*

This question goes towards two themes in the submitted questions: the difference between GHG balance of forestry on peat and mineral soils (e.g. SQ124) and the variability in GHG balance with peat depth (e.g. SQ124, SQ121, SQ119, SQ125). Arguably the two are distinct but given that these points are closely-related and were made by a relatively small number of question contributors we have considered it better to combine.

NQ-GH6. *How appropriate are current emission factors for UK afforested peat?*

This question abbreviates that proposed in SQ120

NQ-GH7. *How does greenhouse gas balance of afforested peat vary with forest yield class?*

This question slightly generalises from that proposed in SQ121.

NQ-GH8. *How does the peatland greenhouse gas balance change across multiple rotations of forestry?*

This question addresses themes around GHG changes through second, third etc. rotation forestry in questions such as SQ118. We waivered when deciding whether this theme was already sufficiently apparent in NQ-GH1, but ultimately decided that a separate question was warranted.

Theme: General questions.

This category encompasses questions which have a general scope and could not be easily categorised to one of the other classes. We found this the most difficult category to deal with. Ultimately many questions were not put forward to phase II on the basis that: 1) they encompass value judgements (e.g. 'is it better to have carbon storage or biodiversity'?) and therefore go beyond evidence needs per se; 2) the answers are dependent on answers to other nominated questions, or 3) they are sufficiently broad in scope that they could be the *only* question whereas our intention is to identify a suite of questions. That questions have not been put forward is not a judgement on whether the questions are valid or important but a judgement on whether they are helpful for the purposes of this exercise.

Key topics were:

1) Natural capital valuation (SQ21,SQ28,SQ43,SQ65,SQ17,SQ114 and others).

2) Peat depths/carbon stocks (SQ67/SQ109).

Questions put forward:

NQ-G1. *What is the financial value of natural capital in natural and afforested peatlands and how does this change with restoration?*

A common theme (explicit or implicit) in many of these questions is the economic value of natural capital in peatlands in alternative states. This is direct in the case of SQ114 and implied by many other questions. This question wording addresses the general topic.

NQ-G2. *Is knowledge of peatland extent/depth/carbon stock adequate to make policy decisions on the future of afforested peatland?*

A point made by questions SQ67 and SQ109 regards how well peat depth/extent/carbon stock is understood. While this point is arguably not specifically about afforested peatland because it has been made independently by two contributors we feel it important to carry through to the second stage.

Theme: Restoration

This category encompasses all questions on the general theme of restoration.

Key topics were:

1) Restoration achievability and time-scale (SQ10, SQ18, SQ54, SQ82, SQ90, SQ68 and others).

2) Restoration limits (SQ42, SQ7).

3) Restoration priorities (SQ117, SQ49).

4) Restoration practise (SQ69, SQ79, SQ71)

Questions put forward:

NQ-R1. *Is it possible to restore afforested peatlands to naturally functioning systems and how long will this take?*

This question combines the themes of achievability of restoration (SQ54, SQ18, SQ82, SQ90), particularly in terms of ecosystem function (SQ54, SQ10, SQ18, SQ82, SQ90), and the time-scales which will be required (SQ5, SQ6, SQ10, SQ68). By including time-scale the question also indirectly relates to questions which have made more specific points on similar themes (SQ6, SQ48).

NQ-R2. *What are the limits to the achievability of forest-to-bog restoration in terms of factors such as peat condition, depth and site extent?*

This question combines general themes of the limits to peatland restoration which are inherent in questions SQ42 and SQ7. The wording used incorporates peat depth (SQ42), area (SQ7) and 'condition' which is intended to generalise the point regarding cracking made by SQ42.

NQ-R3. *How should afforested peatland sites be prioritised for restoration and when is the best time to restore?*

This question incorporates questions of both when sites should be restored (e.g. SQ94, SQ95) and how the decision should be made about which sites to restore when (inherent in several questions). While these are somewhat different topics they are quite closely related as a decision on prioritisation of sites is likely to at least partially reflect the time since planting; we therefore consider a combined question most appropriate.

NQ-R4. *How can restoration sites be optimally managed to ensure rapid recovery of natural peatland functioning?*

This question indirectly develops from proposed questions SQ69, SQ79 and SQ71 but is somewhat broader in focus to encompass many of the specifics listed by questions such as SQ69 and (in a slightly different context) questions such as SQ6.

Theme: Forestry

This broad category includes topics related to continuing forestry and the economics of peatland forestry.

Key topics:

1) Compensatory planting for peatland restoration (SQ11, SQ19, SQ26, SQ38, SQ93, SQ99, SQ100, SQ101, SQ52, SQ39).

2) Timber harvesting (SQ27).

3) Financial compensation (SQ16, SQ26).

4) Naturallness (SQ22).

5) Incentives for peatland restoration (SQ26, SQ50).

6) Native trees on peat and 'middle way' options (SQ45 + SQ60, SQ22, SQ21).

7) Economic trade-offs (SQ53, SQ64, SQ96, SQ104, SQ72).

8) Forestry yield (SQ112).

Questions put forward:

NQ-F1. *Should peatland plantations removed be compensated by additional forestry on mineral soils, where should these plantations be located and what are the opportunities and costs of doing this?*

Many original questions raised this topic in a variety of different framings and wordings. In this question we have aimed to encompass the key themes of whether compensatory planting is desirable (SQ11), where it should be undertaken (SQ11, SQ77, SQ93) and the challenges and opportunities of doing this (SQ11, SQ93). We have opted for one question which addresses most of the key themes rather than splitting across several questions as we feel questions of 'why', 'where' and 'how' are closely linked.

NQ-F2. *How can timber be harvested from peatlands with minimal environmental disturbance?*

This issue is raised in question SQ27 and in the specific case of carbon by SQ110 and SQ115. The wording here is modified from SQ27. The nominated question is quite closely related to NQ-GH3 but differs in the focus on harvesting and all environmental disturbances, not simply carbon.

NQ-F3. *If replanting on peatland is not allowed should private sector investors be financially compensated and how could this be achieved?*

This question closely follows SQ16 with editing for clarity and generality. This theme also comes from SQ26.

NQ-F4. *How can afforested peatlands be made as natural as possible?*

This question directly follows the first clause of SQ22.

NQ-F5. *How could private sector landowners be incentivised to restore afforested peatlands and would this be desirable?*

This question follows the theme of incentives for restoration from SQ26 and also incorporates the theme of private sector investment for peatland restoration from SQ50.

NQ-F6. *Is it possible to have trees on peat without loss of biodiversity and carbon storage?*

This question goes towards the question of whether trees on UK peatlands are intrinsically undesirable in terms of key forms of natural capital. This theme is most apparent in SQ45 but also goes towards themes included in SQ60, SQ22 and the Peatland Edge Woodland concept (a Scottish FC policy) referenced by SQ21. The wording itself is an edited version of SQ45.

NQ-F7. *What are the economic benefits of forestry on peat and how do these compare to restoration and forestry on mineral soils?*

The question follows the 'economic benefits' theme of several questions (SQ53, SQ64, SQ96, SQ104). The wording aims to incorporate the comparisons to restoration made by SQ53 and SQ64 and to mineral soils made by SQ104.

NQ-F8. *How does forestry yield relate to peat depth?*

This question is simply a version of question SQ112 slightly edited to make more generic. This question is perhaps arguably answerable with current knowledge but clearly reflects a topic not incorporated in other questions and is therefore put forward to phase II on this basis.

Theme: Climate Change

This category encompasses all questions related to the impacts of climate change on (afforested) peatlands and peatland restoration, as opposed to the impacts of peatlands *on* climate which are included under the GHG category.

Key topics:

1) The impact of climate change on restoration (SQ62, SQ85, SQ92)

2) The impact of climate change on peatland trees and forestry (SQ61, SQ63).

Other questions under this category are not explicit to afforested peatlands and could apply to either or both of these points (SQ41, SQ83). Climate change is included as a modifier under several other proposed questions (SQ70, SQ73, SQ75) and could apply to many more but we prefer to keep as a distinct topic.

Questions put forward:

NQ-C1. *How will climate change affect the sustainability of forest-to-bog restoration?*

Our wording here combines the straightforward, but generic phraseology, of question SQ41 with the 'sustainability of restoration' theme from questions SQ85 and SQ92.

NQ-C2. *How will climate change affect peatland forestry?*

This question is a re-written form of question SQ63 which we hope is more easily readable. We have endeavoured to maintain the same key themes of climate change impacts on peatland trees and consequent envirionmental changes. While we could combine this question with that on restoration the proposer of questions SQ61-63 clearly felt them to be distinct topics so we keep separate here.

Theme: Biodiversity

This category encompasses all questions related to changes in species diversity. We considered that the questions submitted were fundamentally rather similar and therefore only nominated one question.

Key topics:

1) Recovery of biodiversity with restoration (SQ32, SQ29) and comparison to intact peatlands (SQ9). Other points in this category are thematically related (SQ15, SQ116).

Questions put forward:

NQ-B1. *How will biodiversity recover with forest-to-bog restoration in the long-term?*

This question essentially conflates SQ15, SQ32 and SQ29. We have retained the expression 'long term' from SQ29 as this seems the key uncertainty. We believe the comparison implied by SQ9 is inherent in the word 'recover'.

Theme: Water

This category encompasses all questions related explicitly to water as an output from peatlands.

Key topics:

1) Impact of forestry (SQ46, SQ59, SQ87, SQ122) and restoration (SQ46, SQ87) on water quality.

2) Flood risk (SQ126).

3) Site hydrology (SQ105 and others).

Questions put forward:

NQ-W1. *How will the water quality of peatland catchments be affected by continuing forestry or restoration?*

This question essentially conflates key features from SQ87 and SQ46. We consider that the specific aspects of water quality referred to by SQ59, the timescale issue referred to by SQ46 and the alternative restoration options referred to by SQ87 are inherent in the wording.

NQ-W2. *How do afforested peatlands and peatland restoration affect downstream flood risk?*

This question generalises submitted question SQ126. The submitted question does not include restoration but this seems an important point.

NQ-W3. *How does peatland hydrology change with afforestation and restoration?*

Several questions included reference to site hydrology and water table depth, although often as part of other issues (e.g. SQ105). We ultimately decided that given this was a relatively frequent theme a separate question was warranted.

Theme: Other

This category encompasses all questions which could not easily be encompassed in other categories.

Key themes:

1) Natural tree cover on UK peatlands (SQ30, SQ47).

2) Tree cover and erosion (SQ34, SQ84, SQ91).

Questions put forward:

NQ-O1. *Why are naturally forested peatlands so rare in the UK, were they more abundant in the past and would understanding their decline help us better manage current afforested peatlands?*

We consider that question SQ47 already incorporates the key points from SQ30. We have not edited the question but note that it is actually three conflated questions.

NQ-O2. *Could the planting or maintenance of peatland forests be justified to mitigate erosion?*

This question encompasses the key theme from questions SQ34, SQ84 and SQ91. The question has been phrased in terms of a concrete intervention 'planting or maintenance of peatland forests'.