Natural England Research Report NERR044

Valuing land-use and management changes in the Keighley and Watersheddles catchment

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Summary

This case study provides an *ex-ante* assessment of different land use and management scenarios for the Keighley Moor and Watersheddles catchment.

The scenarios were developed in consultation with a group of partners with interest or influence in land management of the catchment, as part of the 'Delivering Nature's Services Programme' – the upland ecosystem service pilots.

The aim of this assessment is to provide a 'first-cut' valuation estimate for the ecosystem services provided under different land use and management interventions and compare these with the potential costs. The approach follows the recently published Value Transfer Guidelines (eftec 2010) which are now regarded as best practice for these sorts of assessments.

Two scenarios were developed: 1) an 'improve' scenario where investments are made to deliver a greater range of ecosystem services through habitat restoration and more sympathetic land management interventions; and 2) a 'decline' scenario depicting future ecological decline in the catchment due to a general withdrawal of public investment in land management and applying only the minimum environmental regulations.

The scenarios were spatially mapped and key habitat changes quantified (both in terms of extent and quality). The likely changes in ecosystem services was then assessed and quantified where possible against a counter-factual (or baseline). Service changes that were quantified include: carbon storage and sequestration and changes in water quality. It was not possible to quantify potential changes in biodiversity, access and recreation, flood risk management and provisioning services.

However, despite not being able to physically quantify some service changes, it was still possible to estimate the value of some of them using value transfer techniques. Values derived by Christie *et al* (2011) and the National Ecosystem Assessment (NEA) / Department for Energy and Climate Change (DECC) were used to provide value estimates for changes in biodiversity and carbon in the catchment. Yorkshire Water (and United Utilities) provided estimates of potential changes in water treatment costs stemming from possible changes in the level of dissolved organic carbon (DOC) and pesticides. Changes in water treatment costs were added to both Christie *et al* and NEA/DECC values to two separate value estimates (see Table i).

Initial costs for each scenario were estimated using HLS cost data. All costs and benefits were discounted using standard HM Treasury discount rates and assessed over a period of 25 years.

Table i Present value costs, benefits, net present values and benefit/cost ratios over 25 years (discounted at 3.5%)[1]

Scenario	PV benefits	PV costs	NPV	BC ratio
Improved (NEA/DECC Values)	£9,475,000	**-£3,204,000**	£6,271,000	2.96
Decline (NEA/DECC Values)	**-£8,400,000**	£1,614,432	**-£6,786,000**	**-5.20**
Improved (Christie *et al* Values)	£4,206,404	**-£3,204,000**	£1,002,404	1.31
Decline (Christie *et al* Values)	**£3,207,860**	£1,614,432	**-£1,656,400**	**-2.03**

[1] Two separate values estimates are provided: 1) using Christies *et al* values combined with Water Company valuations; and 2) NEA/DECC values combined with Water Company valuations

Table i presents net present values (NPV) over 25 years and benefit/cost ratios for the improved and decline scenarios. Using the NEA/DECC values, the NPV for the improved scenario is around £6.27 million (the amount society would gain where the investments in the catchment made) and for the decline scenario it is -£6.77 million (the amount society would lose were all spending withdrawn and regulations reduced to the absolute minimum). The benefit/cost ratios tell a slightly different story. For the improved scenario, for every £1 spent in the catchment, society benefits by £2.96. Conversely, for the decline scenario every £1 **not** spent in the catchment, society stands to lose an estimated £5.20.

Using values from the Christie *et al* study, the differences between benefits and costs is much smaller. For every £1 spent in the catchment, society would benefit by only £1.31. Conversely, for every £1 **not** spent in the catchment, society stands to lose £2.03.

Even without the inclusion of possible access and recreation benefits or changes in flood risk, the analysis appears to provide a convincing case for investment in the catchment, particularly if the NEA/DECC figures are used.

The analysis has deliberately been cautious in estimating potential benefits (and costs under the decline scenario). In addition, sensitivity analysis has been undertaken for some of the key variables to test the significance of certain assumptions and the values used. This suggested a relatively high level of confidence that benefit / cost ratios are greater than one, significantly so in the majority of cases. The exception was where the very lowest benefit values were used combined with the highest cost estimates.

Overall, the analysis demonstrates that the Value Transfer Guidelines provide a useful framework to quantitatively assess some of the main ecosystem service changes in the Keighley Catchment and could usefully be applied to other such case studies in the future.

Improvements could be made to this particularly case study through further work to assess:

a) Potential changes in flood risk management under the different scenarios;
b) Potential changes in access and recreation which, given the Pennine Way goes through the catchment, could be significant; and
c) Potential changes to provisioning services (specifically those from agriculture). These have not been analysed in any detail. Whilst not expected to be significant in cost/benefit terms, there are likely to be important distributional impacts that need to be taken into consideration.

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1 Background and context

1.1 This case study provides an *ex-ante* assessment of different land use and management scenarios for the Keighley Moor catchment. The scenarios were developed in consultation with a group of partners with interest or influence in land management of the catchment, as part of the '*Delivering Nature's Services Programme*' – the upland ecosystem service pilots.

1.2 The aim of the assessment is to provide a 'first-cut' valuation estimate for the ecosystem services provided under different land use and management interventions and compare these with the potential costs. These possible interventions are the result of 2 different future scenarios: an 'improved' (or 'invest') scenario; and a 'decline' (or 'don't invest') scenario.

1.3 The Keighley and Watersheddles catchment (here after referred to as Keighley catchment) is located in the centre of the South Pennines National Character Area in the county of West Yorkshire. It is approximately 4,348ha in area. It is a rural catchment with only 8%, or 353ha, classified as urban. The entire catchment is designated as a Less Favoured Area (LFA) and the dominant land use is extensive sheep farming, although the catchment is an important area for drinking water supply. The catchment has high conservation value with 38% of the area being designated as of national (Sites of Special Scientific Interest) and EU importance (Special Protection Areas and Special Areas of Conservation). This conservation interest is largely centred around the blanket bog and upland heath habitats and associated birds. The high wildlife value of the catchment and large area of semi-natural habitat is reflected by a very high uptake of agri-environment schemes. In 2009 43% of the catchment was in Environmental Stewardship schemes; this represents a net total of 1859ha and a total spend of more than £1.7m over the duration of the various schemes. In addition there are still a number of classic scheme agreements in place; in total 57% of the catchment was under some form of environmental management in October 2009.

1.4 Underpinning this economic assessment is the 'Narrative and Baseline Assessment' for the Keighley pilot area. This Baseline Assessment document provides much more detailed information on a range of ecosystem services in both the National Character Area and specifically within the focal catchments, of which Keighley is one. Readers are referred to this document for further information and spatial mapping of different services.

1.5 The approach followed in this case study – indeed for all the Ecosystem Service Pilots – follows the recently published Value Transfer Guidelines which are now regarded as best practice (eftec, 2010).

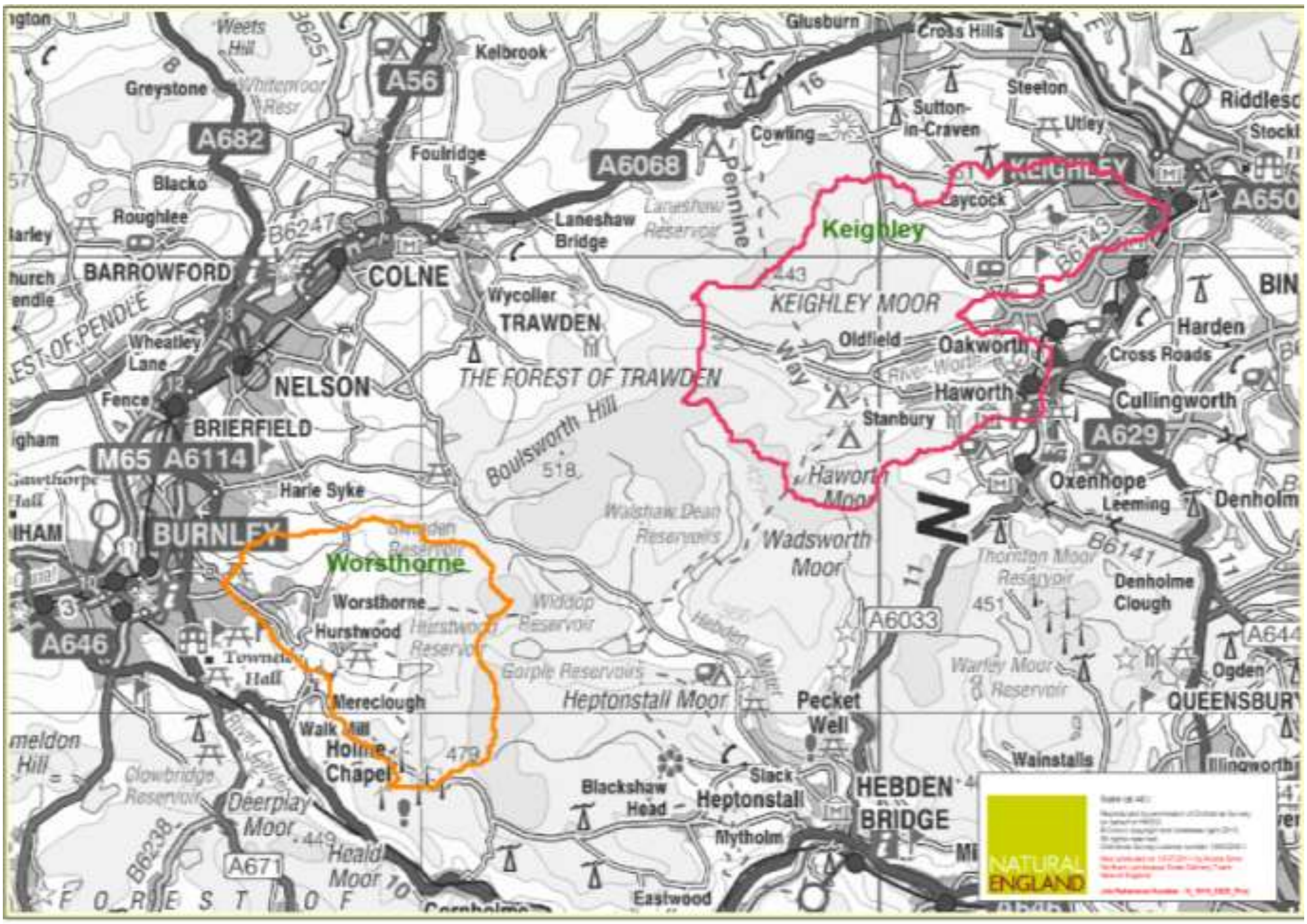


Figure 1 Location and boundaries of the Keighley & Watersheddles catchment (also shown is the Worsthorne catchment which is the subject of a separate valuation assessment)

2 How will changes in land management and land use in the catchment affect economic values?

What are the goods and services being valued?

2.1 The Keighley catchment currently provides a range of ecosystem services to a range of different beneficiaries. Changes in the levels of these services will affect the value people derive from the catchment, whether they use it directly (direct-use value) or indirectly (indirect-use value). Even where people don't 'use' the catchment at all, they may still derive benefits from it in the form of non-use values, such as through the value of knowing biodiversity is being enhanced and protected.

2.2 Just under half (42%) of the catchment (1835ha) is moorland habitat dominated by blanket bog and associated mosaics of drier upland heath, wet flushes and seepages. The predominance of peat in the catchment means that regulating services such as carbon storage and sequestration and water quality regulation are important in the area. Yorkshire Water operates several reservoirs in the catchment. The benefits derived from these services are primarily in the form of direct and indirect use values.

2.3 There is also significant wildlife interest. A high percentage of the catchment is designated as SSSI, 37.5% (1631ha). The international significance of this wildlife resource is reflected in the same area also being designated as both a Special Area of Conservation (SAC), and a Special Protection Area of Protection (SPA) under the EU Habitats and Birds directives respectively. Non-use values are therefore likely to be an important component of the analysis.

2.4 The Pennine Way runs through the catchment suggesting that recreational activities (direct-use value), specifically walking, are important. A significant area of the moorland is managed for grouse shooting and this activity is an important driver for land management within the catchment.

2.5 Given that farming and sporting interests are the predominant land-use activity, provisioning services such as food and fibre also need to be considered. There are an estimated 149 farm businesses within the Keighley catchment, employing approximately 182 people. 54 of those businesses are classified as upland hill farming which together support an estimated 14,228 sheep and lambs (Agriculture Census Data 2008). There are also 10 dairy farms. The vast majority of the land area is designated as a Severely Disadvantaged Area, 3,636ha (83.6% of the catchment), a further 713ha (15% of the catchment) is designated as a Disadvantaged Area. The average size of farm holdings is at 189.3ha and may reflect the mixture of lowland and upland farming systems.

Who is affected by the changes in different ecosystem services?

2.6 There is limited information on the populations affected by potential changes in the ecosystem services from the area. The population of Keighley catchment itself is small – and is likely to be a lot less than the estimated population of the Worth Valley Ward (15,546) which covers most of the catchment (ONS 2011). However, the population within a 50km radius of the catchment is estimated at over 6,120,000[2]. This reflects the proximity of a number of large urban areas.

2.7 The population affected by changes in ecosystem services will vary significantly by service. For example, beneficiaries of possible water quality improvements are end water users who are linked to this service via water companies. Yorkshire Water serves approximately 1.9 million households in the region but it is not possible to estimate the precise number of water customers reliant on Keighley catchment specifically. For carbon storage and sequestration, the benefit is arguably the global population because reduced greenhouse gas emissions can only be assessed in terms of the global climate system. For biodiversity (non-use values), it is appropriate to consider the national (England) population or possibly the northern region around the pilot area.

2.8 As will be explained later in the report, it has not been possible to value some ecosystem service changes in monetary terms. For those services where it has been possible, value transfer techniques have been used that do not require an assessment of the affected population (for example per ha values have been transferred rather than per person or per household). This partly reflects the 'first-cut' nature of the valuation estimates which are primarily for illustrative purposes only. More detailed future analysis would require an in-depth look at potential beneficiaries and affected populations.

[2] Hand drawn polygon using **http://sedac.ciesin.columbia.edu/gpw/wps.jsp**

3 What are the likely changes in ecosystem services resulting from proposed land use and management interventions in Keighley catchment?

3.1 This case study seeks to assess the benefits (and costs) of two different land use and management scenarios in the Keighley catchment. The two scenarios (detailed in Annex 1) can be summarised:

1) 'Improve' (or 'invest') – where investments are made to deliver a greater range of ecosystem services through habitat restoration and more sympathetic land management interventions, ie managing land and water to maximise multiple ecosystem service provision.
2) 'Decline' (or 'don't invest') – depicting future ecological decline in the catchment due to a general withdrawal of public investment in land management and applying only the minimum environmental regulations, for example, no Environmental Stewardship, little protection for high value biodiversity sites beyond statutory minimum, liberal use of pesticides, more burning, more wildfires and over-grazing.

3.2 Both of these scenarios are assessed against a counter-factual (or baseline) scenario, ie what might be expected to happen in the catchment if the current situation and policies are held constant and extrapolated into the future.

3.3 Table 1 details the main habitat types and areas for the different scenarios (including the current situation). The habitat changes represent land management interventions proposed by the wider project steering group and informed estimates of the likely changes under the two scenarios and the counter-factual. In actual fact, our analysis indicates that there would be very little change between the current situation and the counter-factual.

Table 1 Main habitats types and areas under different scenarios for Keighley catchment

Habitat type (ha)	Current	Counter-factual	Improved	Decline
Deep peat intact	43.4	43.4	1287	0.0
Degraded bog	1224.4	1219.6	0.0	1055.7
Bare peat (severe burn)	19.1	23.9	0.0	231.32
Flush & Mire	57.2	57.2	57.2	57.2
Upland heath (12 y burning)	281.8	281.8	0.0	140.5
Upland heath (16 y burning)	0.0	0.0	354.0	0.0
Acid Grassland	165.0	165.0	115.0	305.5
Bracken	44.4	44.4	22.0	65.6
New Woodland	0.0	0.0	131.2	0.0
Managed native woodland	108.4	108.4	108.4	87.4
Reservoirs	37.6	37.6	37.6	37.6

Table continued...

Habitat type (ha)	Current	Counter-factual	Improved	Decline
Improved grassland - low	1217.0	1217.0	1086	1217.0
Improved grassland - high	692.2	692.2	692.2	692.2
PMG & Rush	0.0	0.0	0.0	0.0
Upland hay meadows	0.0	0.0	0.0	0.0
Urban	353.3	353.3	353.3	353.3
Total	**4243.8**	**4243.8**	**4243.8**	**4234.2**
Unaccounted for (ha)	**-104.5**	**-104.5**	**-104.5**	**-105.1**
Unaccounted for (%)	-2.4%	-2.4%	-2.4%	-2.4%

Overview of habitat changes and ecosystem services under the 'improved' scenario

3.4 Interventions under the 'improved' scenario are expected to result in the following three key changes from the counter-factual scenario in the catchment:

1) Restored blanket bog – there will be 1244ha of blanket bog restored to favourable condition. This will be created by restoring approximately 1220ha of degraded bog, and 24ha of severely burnt bog in addition to maintaining 43ha that is currently 'intact'.
2) Favourable management of upland heath – approximately 354ha of upland heath will be favourably managed (under a 16 year burning rotation: longer rotation than at present). This is achieved by bringing: a) 282ha of existing upland heath into favourable management; b) 50ha of acid grassland back to upland heath; and c) 22ha of bracken into heathland management.
3) Planting of new native woodland – under the counter-factual scenario, the catchment has approximately 108ha of managed native woodland. An additional 131ha of new native woodland is proposed, mainly along gills, rivers and streams.

The three major habitat changes under the improved scenario are likely to lead to changes in a number of ecosystem services in the catchment. These are outlined in Table 2 below (see Figures 2 and 3 for example maps developed as part of the opportunity mapping exercise and Figures 3 and 4 for illustrative photographs).

Table 2 Changes in ecosystem services on Keighley Moor under the 'improved' scenario

Habitat	Changes in ecosystem services	Quantification (physical terms, not value)
Blanket Bog – 1244 ha 'intact' (or improving towards favourable condition)	**Carbon storage and sequestration** – bogs in good condition sequester carbon from the atmosphere. However, it is likely to take a number of years, following restoration, for the bog to start actively sequestering carbon. Methane emissions in the short-term after re-wetting are likely to be an important factor to consider when assessing GHG flux particularly as methane is a more potent GHG than carbon dioxide. The approach to quantifying the change in GHG flux has attempted to take account of this short term issue whilst reflecting the medium to long term benefits (see below).	**Yes**
	Improved water quality – this has been assessed separately by Yorkshire Water. Bringing this specific moorland area into favourable (biological) condition is likely to help slow (possibly stop) water colour problems becoming worse which should lead to postponement of capital solutions to meet water quality objectives. There could, therefore, potentially be some savings in water treatment costs. In addition to the water supply benefits, the restoration of blanket bog habitat may deliver ecological benefits to downstream rivers and streams though this has not been considered further in the analysis.	**Yes**
	Biodiversity – the restored area of moorland should lead to significant gains in biodiversity. At present large areas of the blanket bog are degraded through inappropriate drainage, grazing and burning. This management has resulted in a blanket bog habitat which is functionally impacted and has an impoverished flora and fauna. Overall the blanket bog is currently too dry and homogenous lacking the characteristic mosaic of different habitat types. Much of the moorland is therefore dominated by heather which is favoured by the dry conditions and burning practices. In addition, currently there are areas of bare peat which support no vegetation and have little value for invertebrates or other fauna. The proposed restoration will increase overall surface wetness favouring species more typical of intact blanket bog such as peat forming *Sphagnum* species, cotton grass (*Eriophorum* spp.) and other dwarf shrubs (crowberry, bilberry and cross-leaved heath). A more varied habitat structure will also benefit a range of bird species associated with the blanket bog – golden plover, dunlin and twite which use all parts of the moorland habitat mosaic through their life cycle. The South Pennines is particularly important for twite (*Carduelis flavirostris*) because the areas supports 1% of the British breeding population. Importantly, the proposed actions will restore the internationally designated areas into favourable condition.	**No**
	Food & Fibre (provisioning services) – some relatively small changes in these services are likely. The blanket bog improvements will in part be delivered through changing the grazing regimes; across the moorland area sheep grazing levels will be managed more appropriately and some limited cattle grazing will be introduced. The actual numbers of livestock will not increase significantly but there is the potential for an increase in agricultural outputs, particularly if this involves increased shepherding.	**?**

Table continued...

Habitat	Changes in ecosystem services	Quantification (physical terms, not value)
	Flood Regulation – restoring the blanket bog area could lead to reductions in flood risk in the catchment. There is some evidence that blocking drainage grips and reinstating a more natural blanket bog hydrology can modify the rate and volume of runoff at small scales (Holden, 2009) but this effect may not result in significant changes at the catchment scale. This is likely to be due to the complex interactions between grips, gullies and stream pathways for water flow and the fact that many upland streams have also been subject to physical modification; the effect of this modification may mask any benefit associated with changes to the blanket bog hydrology. More detailed modelling is required to determine any likely changes in flood regulation so for the purposes of this analysis, no change has been assumed.	**No**
	Access & recreation – the 'act' of bog restoration is unlikely to affect access and recreation significantly. It is therefore assumed that there is no impact on this service. Any additional interventions to promote access and recreation could be considered separately.	**No**
Upland heath 354 ha favourably managed	**Carbon storage and sequestration** – upland heathland, in good condition, is a potentially good store of carbon because it is largely formed on peat. Gains in this habitat could lead to carbon sequestration benefits, particularly if there is a managed transition from acid grassland which sequesters less carbon.	**Yes**
	Biodiversity – changes in management have the potential to improve the upland heath habitat for the benefit for both flora and fauna. The proposal is to change grazing patterns and intensity across the existing upland heath and to reduce the intensity and frequency of burning. This will have the effect of increasing the diversity of the vegetation and reducing the heather dominance. This should allow other dwarf shrubs (bilberry- *Vaccinium myrtillus*, crowberry - *Empetrum nigrum* and locally uncommon cloudberry - *Rubus chamaemorus*) to recolonise and create a more varied vegetation structure. By retaining periodic burning the characteristic red grouse (*Lagopus lagopus*) will still be supported but the longer rotations proposed will allow a more diverse habitat structure to develop benefiting a range of species.	**No**
	Food & Fibre – some relatively small changes in these services are likely. The improvements will in part be delivered through changing the grazing regimes; across the moorland area sheep grazing levels will be managed more appropriately and some limited cattle grazing will be introduced. The actual numbers of livestock will not increase significantly but there is the potential for an increase in agricultural outputs, particularly if this involves increased shepherding.	**No**

Table continued...

Habitat	Changes in ecosystem services	Quantification (physical terms, not value)
New native woodland 131 ha	**Carbon storage and sequestration** – increase in sequestration and storage likely through new tree growth. During the period over which benefits have been assessed it is unlikely that new woodland will be managed or that timber or woodfuel will be extracted. As such any carbon sequestered is considered to be stored within the woodland.	**Yes**
	Biodiversity – there are likely to be modest gains in biodiversity as a result of the new planted woodland. The new woodland is likely to be planted in the moorland fringes and in stream valleys. This woodland will have both direct biodiversity benefits providing habitat for a range of birds and small mammals and potentially indirect benefits through improved stream water quality; many areas earmarked for new woodland planting are vulnerable to erosion and are therefore sources of sediment to watercourses. These benefits are likely to be fairly limited during the early years of planting and are not possible to predict with any confidence.	**No**
	Food and fibre – new planting is likely to increase opportunities for wood fuel. There may be minor costs in terms of reduced land for livestock grazing but once established, new woodland may provide valuable shelter for stock.	**No**
	Access & recreation – though there is a strong body of evidence to suggest that woodland has a higher recreation value than farmland, the new woodland area is small and likely to be spread out along the gills and valley bottoms. Therefore, it is unlikely to generate an increase in visit numbers to the area. It may, however, lead to improved visitor enjoyment. In the absence of more detailed information, this potential change in service is assumed to be zero.	**No**

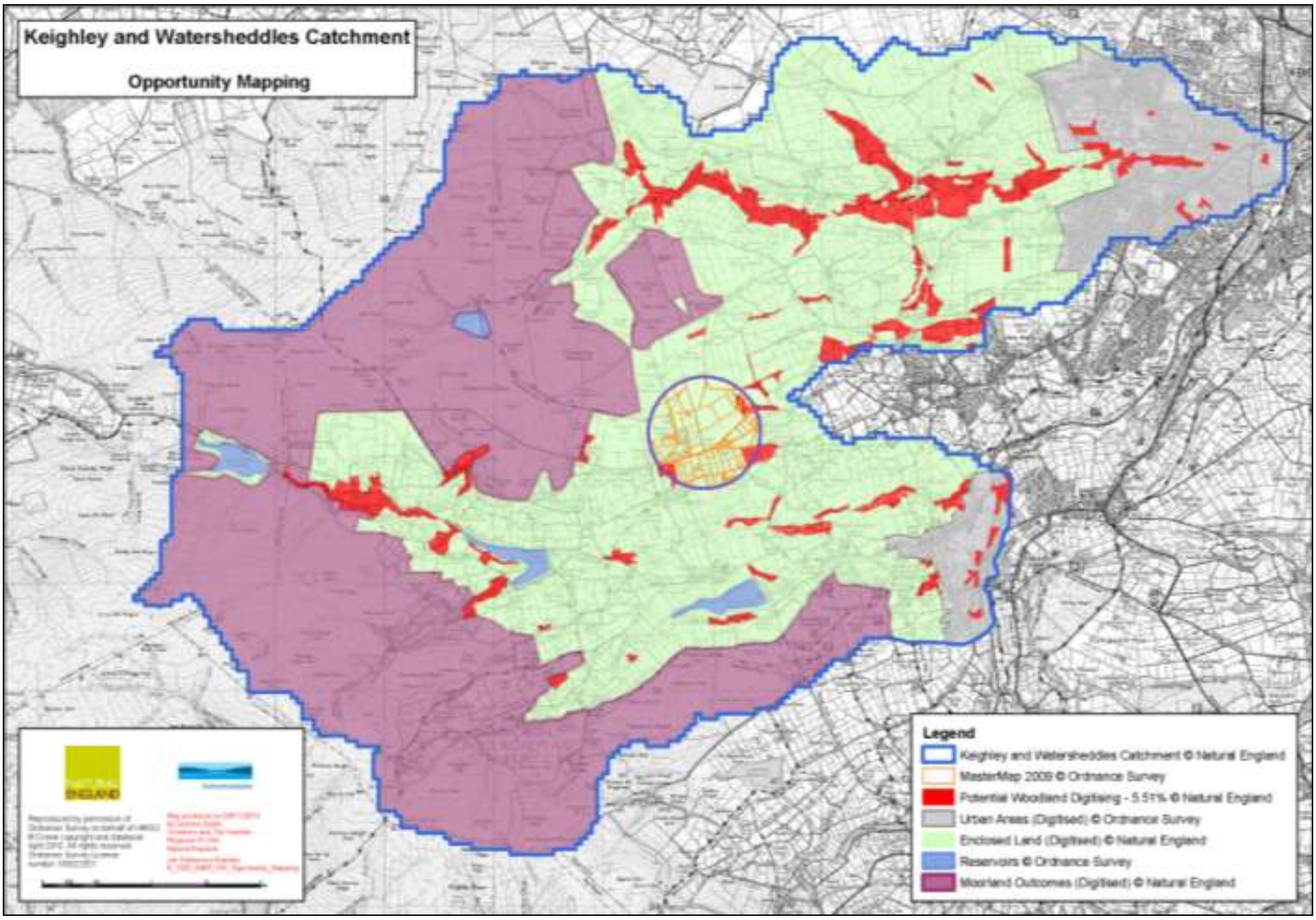


Figure 2 Keighley Catchment Opportunity Mapping

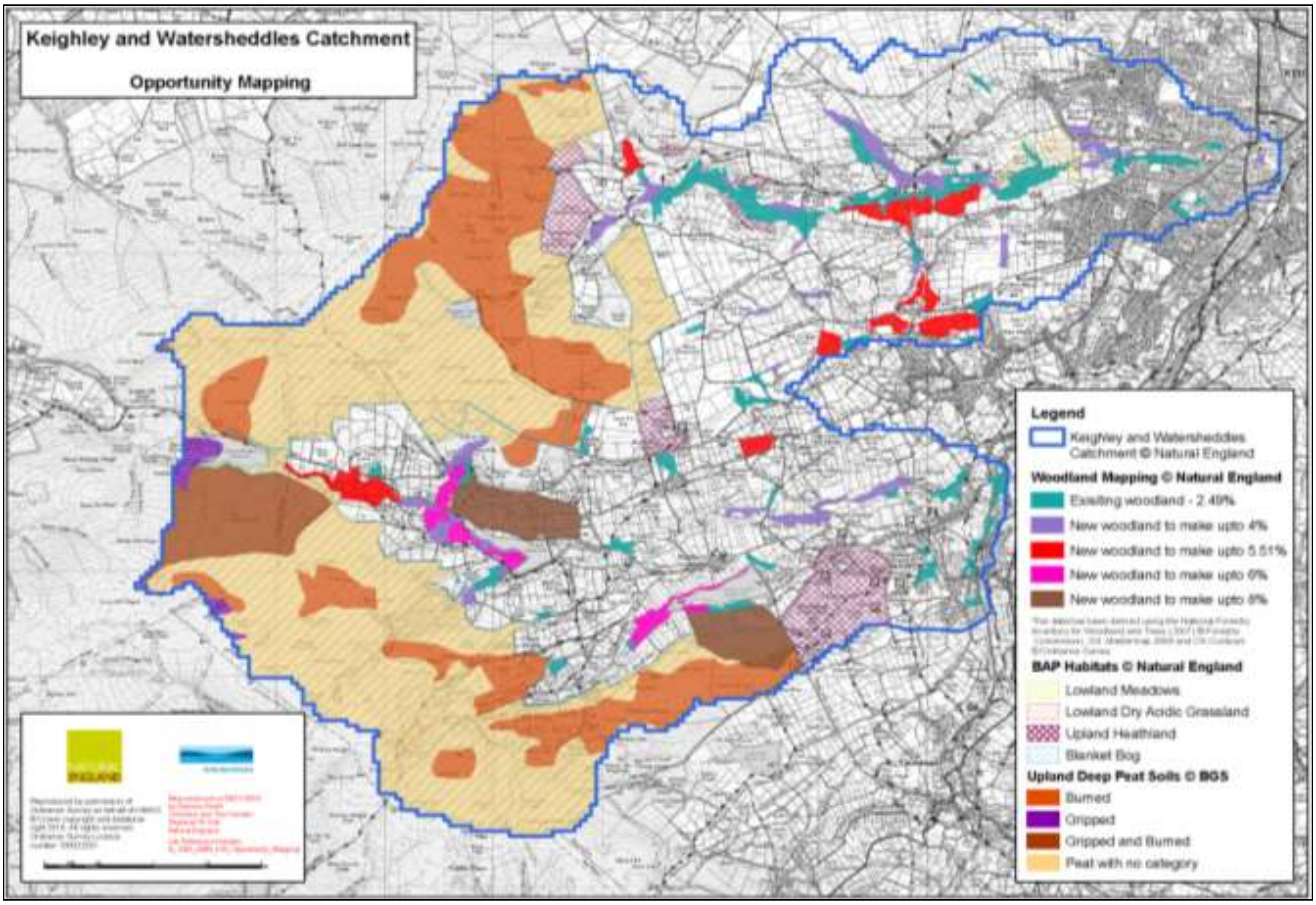


Figure 3 Keighley Catchment Opportunity Mapping; woodland and BAP priority habitats

Overview of habitat and ecosystem service changes under the 'decline' scenario

3.5 Interventions (or lack of) under the 'decline' scenario are likely to result in the following changes from the counter-factual scenario in the catchment:

1) The condition of bog habitat is likely to degrade even further. 'Intact' blanket bog (-43ha) is likely to become 'degraded' and a significant proportion of degraded bog (-164) is likely to become 'bare peat' (see Table 1).
2) The area of upland health is likely to shrink significantly by around 140ha (50%) with none of it being managed favourably in 16 year burning rotations. The loss of this habitat will most likely result in conversion to acid grassland, losing much of its biodiversity interest.
3) The area of bracken will increase by around 50% in size, from around 44ha to around 65ha.
4) The area of managed native woodland is likely to fall by around 20%, from 108ha to around 88ha.

3.6 Though the changes under this scenario are expected to be relatively small in land-use terms, the impact on ecosystem services is likely to be more pronounced. These changes, most of which are negative, are described in Table 3 (see Plates 1 and 2 for illustrative photographs).

Table 3 Changes in ecosystem services on Keighley Moor under the '**decline**' scenario

Habitat	Change in ecosystem services	Quantification (physical terms, not value)
Blanket Bog (-43ha intact to degraded,-164ha degraded to bare peat)	**Carbon storage & sequestration** – further deterioration of the blanket bog condition through over-grazing,intense and frequent burning is likely to increase the rate of carbon loss from peat soils. The increase in the area of bare peat is particularly significant because once vegetation cover has been lost the peat will rapidly be eroded by the action of wind and water; this has been assumed to represent a loss of stored carbon.	**Yes**
	Water Quality – assessed separately by Yorkshire Water. Continuing degradation of this moorland area is likely to aggravate water quality problems (specifically DOC levels) thus bringing forward the need for capital solutions. Under these circumstances, water treatments costs are likely to increase. In addition high dissolved and particulate organic carbon loads have the potential to have ecological impacts on instream ecology though these effects have been little studied.	**Yes**
	Biodiversity – further degradation in the condition and increases in the area of bare peat will impact negatively on biodiversity. For example, continued drainage and short rotation burning will continue to dry out the peat surface and favour heather dominance as well as leading to erosion of the peat. Species which are favoured through these conditions such as red grouse and golden plover may increase in number but there are likely to be further declines in other bird species such as twite, dunlin and waders such as curlew and lapwing. The blanket bog is likely to become more homogenous in both structure and species composition with an associated reduction in niches for rarer species. In some areas heavy grazing and intensive burning may lead to grass, rather than heather, dominance and extensive cover of dense grasses such as mat grass *Nardus stricta* and purple moor-grass *Molinia caerulea*.	**No**
	Food & Fibre – some relatively small changes in these services are likely. In the short term the increase in agricultural intensity may lead to increases in agricultural outputs. However, given the relatively marginal nature of the moorland habitat these are unlikely to be significant.	**?**
	Flood regulation – further degradation of the blanket bog area is likely to affect the water storage capacity of the moorland area and change the speed at which water moves down through the catchment. More detailed modelling is required to assess whether this would affect flood risk positively or negatively and how large any affect would be. So for the purposes of this analysis, no change has been assumed.	**No**
	Access & recreation – the impact here is likely to depend on the extent of degradation. Up to a point, the condition of the blanket bog is unlikely to affect access and recreation significantly. However, if the blanket bog dries out significantly and becomes more prone to (wild) fire, this could result in the area becoming 'unusable' (either closed to public access or simply not a preferred area for use). In other words, a threshold effect is possible which could result in abrupt cessation of recreational services (for example, on Bleaklow in the Dark Peak where erosion has effectively reduced access or at least made it difficult in some areas). This is an extreme scenario but nevertheless important. However, for the purposes of this analysis, the impact on recreational services is assumed to be zero, both in terms of visitor numbers and values.	**No**

Table continued...

Habitat	Change in ecosystem services	Quantification (physical terms, not value)
Upland Heath (-140ha)	**Carbon storage and sequestration** – upland heathland, in good condition, can be an important store of carbon. However, increasing burning, increased grazing and further drying out is likely to lead to carbon losses from the peat underlying the heath. This intensive management is likely to lead to greater erosion, grass dominance (*Nardus stricta* and *Molinia caerulea*) and acid grassland is known to sequester less carbon than upland heath.	**Yes**
	Biodiversity – in common with the blanket bog habitat, the increased intensity of management is likely to lead to declines in biodiversity value. Heavy grazing and burning will favour heather and could lead to a change in habitat to acid grassland, This habitat shift is likely to lead to lower plant species diversity because the resulting habitat will be much more homogenous and will not be suitable for moorland bird species such as twite.	**No**
	Food & Fibre – some relatively small changes in these services are likely. In the short term the increase in agricultural intensity may lead to increases in agricultural outputs. However, given the relatively marginal nature of the moorland habitat these are unlikely to be significant.	**No**
Managed Native woodland (-20ha)	**Carbon storage & sequestration** – Small reductions in woodland area is likely to impact negatively on carbon storage but it is not possible to assess the likely magnitude of the reduction. Equally without knowing what might happen to any timber of wood from the woodland it is not possible to determine whether this represents a carbon loss.	**No**
	Biodiversity – Small losses in biodiversity would result through the loss of woodland habitat. As woodland is relatively rare within the landscape already there are few areas which support flora and fauna typical of wooded areas.	**No**
	Food & fibre – marginal negative changes in wood fuel, for example, could be expected. Likely to be very small so assumed to be zero.	**?**
	Access & recreation – No impact access or recreation is anticipated.	**N/A**

Plate 1 Black Hill (Peak District) in March 2006 before restoration started

An illustrative example of severely degraded / bare peat from Black Hill which would become much more prevalent in the Keighley catchment under the 'decline' scenario.

© Yorkshire Water

Plate 2 Black Hill in 2010, four years after restoration

An example of restored blanket bog from Black Hill which is illustrative of the restoration envisaged under the 'improved' scenario for Keighley.

Quantifying changes in ecosystem services

3.7 As indicated in the tables above, it has not been possible to quantify, in physical terms, the likely changes in all ecosystem services for each of the scenarios. However, for certain services it has been possible using certain assumptions.

3.8 Changes in **soil carbon** have been estimated using a model developed by Natural England (based on earlier work by Couwenberg *et al* (2008)) which predicts GHG flux of both CO_2 and methane in tonnes per hectare per year for different restored habitat types. The model was used to estimate GHG changes for the blanket bog with a simpler analysis used for heathland changes. Detailed information and assumptions used in the analysis are presented in Annex 2. Under the improved scenario, restoration of blanket bog is estimated to take 2-3 years during which time, no carbon gains are assumed. The conversion from acid grassland to upland heath is assumed to take 5 years with no benefits therefore assumed for this period. Under the decline scenario, the loss of 'intact' bog is assumed to take place over 5 years and the loss of degraded bog to bare peat assumed to happen over 10 years. Losses of carbon have been calculated to reflect this, converted into CO_2e and then adjusted to reflect the level of transmission into the atmosphere. This final step is an important assumption. Whilst the evidence is unequivocal that peat is being lost from the upland systems, much less is known about where it ends up and critically whether (and when) it makes its way into the atmosphere as CO_2. To reflect this uncertainly, it has been assumed that only 50% of the peat lost through erosion is oxidised and therefore makes its way into the atmosphere with the other 50% essentially being transported and effectively buried in other systems (reservoirs / estuaries). This issue is picked up further in the sensitivity analysis. Finally, where the bog is degraded so severely it become bare peat, the loss of carbon from vegetation has also been estimated.

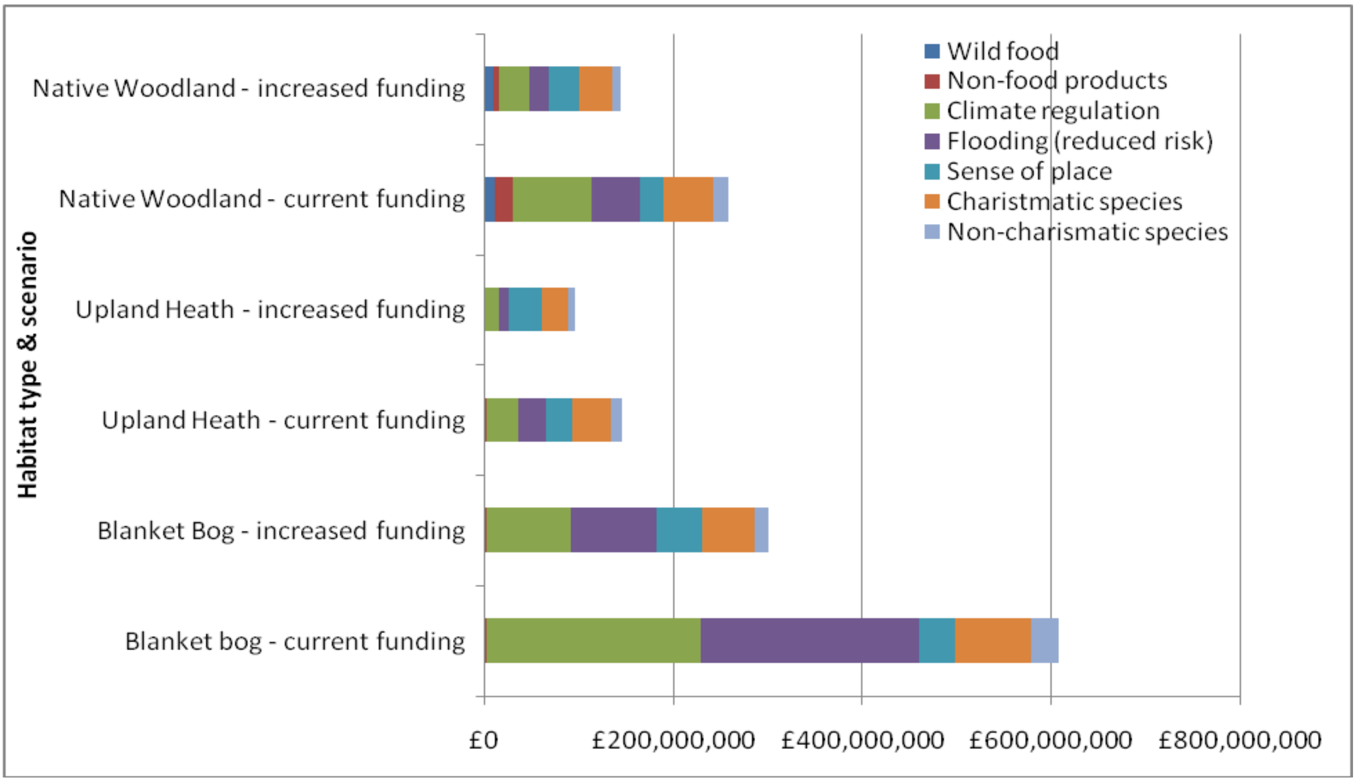
3.9 Possible changes in water quality were assessed by Yorkshire Water. In the absence of more detailed data specific to the Keighley catchment, 6 possible trend lines were developed for water quality reflecting the counter-factual, improved and decline scenarios and a pessimistic, central and optimistic scenario for each (ie 9 scenario combinations in total). The trends range from a situation where DOC plateaus in 2020 (best case) to a worst case where it increases by 50% (plus increases in pesticides). Details of the approach are provided in Annex 3.

3.10 Changes in woodland carbon have been estimated using the Forestry Commission Carbon Lookup Tables (**www.forestry.gov.uk/forestry/INFD-8JUE9T**). Assumptions have had to be made about species planted, spacing, yield class, management and growth period. An error adjustment has also been applied in line with the guidance. Full details are provided in Annex 4.

4 Identification and selection of monetary valuation evidence

4.1 There is a wide range of monetary valuation evidence upon which to draw for the value transfer exercise. It should be noted that the analysis in this report is very much a 'first-cut' and partly influenced by the value transfer methodology chosen. A more sophisticated and detailed valuation may be possible in future.

4.2 **Two different approaches** have been used to provide a range of value estimates for the benefits. The **first approach** involved transfering (largely unadjusted) values for different UKBAP habitat types using Christie *et al* (2011). This recently completed stated preference valuation study quantifies and values the benefits associated with delivery of UK BAP habitat targets. It does so for two different funding scenarios which broadly match the improved and decline scenarios considered in this assessment: 1) increased funding to deliver all UK BAP targets (improved scenario); and 2) maintaining current funding levels (ie complete withdrawal of funding being the counter-factual – decline scenario). The study uses a choice experiment to generate values for changes in seven ecosystem services (as detailed in Figure 4) for all 19 priority habitats. The aggregated UK values of these services for each of the main 3 habitats relevant to the Keighley catchment are presented in Figure 4.



Source: Christie *et al* (2011)

Figure 4 Aggregated UK annual values for blanket bog, upland heath and native woodland habitats under an 'increased funding' (improved) and 'current funding' (decline) scenario (See paragraph 4.2 for details)

4.3 As Figure 4 illustrates, wild food and non-food products make up a very small proportion of estimated total value. By far the biggest proportional contributions are made from climate regulation, reduced flood risk and charismatic species. 'Sense of place' is also important – proportionally much more so under the 'increased funding' scenario which makes intuitive sense.

4.4 The aggregate values illustrated in Figure 4 for each funding scenario were converted into per ha per year values as presented in Table 4. The values were adjusted further so that they only take account of the ecosystem services relevant to Keighley catchment as identified above. Specifically, this involved removing the flood risk management benefits because these remain very uncertain in the context of the pilot area. The values in the adjusted column in Table 4 have been used in the value transfer exercise. They have been applied to the land-use and management changes envisaged in Keighley catchment to provide a very rough approximation under each of the 'improved' and 'decline' scenarios.

4.5 Note that the per ha values are higher under the decline scenario than they are under the improve. This is consistent with economic theory in that people tend to value marginal losses in welfare more than they value marginal gains. In other words, the Christie *et al* study shows that people are willing to pay more to conserve what currently exists (ie avoid losses in biodiversity) than they are to secure gains from current levels.

Table 4 Values per hectare per year for habitat types under the improve and decline scenarios

Habitat & scenario	Value (£/ha/year) 2010 prices	Adjusted (£/ha/year) 2010 prices
Blanket Bog – 'Improved' scenario	£136	£94
Blanket Bog – 'Decline' scenario	£275	£170
Upland Heath – 'Improved' scenario	£96	£84
Upland Heath – 'Decline' scenario	£148	£118
Native Woodland – 'Improved' scenario	£136	£117
Native Woodland – 'Decline' scenario	£244	£195

4.6 Although the transfer of these values is broadly defensible, there are a number of problems likely to lead to errors. Firstly, the Christie *et al* study methodology is controversial. It has pioneered the development of what it calls a 'weightings matrix' (a kind of Delphi technique based on opinions from site conservation officers) to determine the likely changes in ecosystem services from different BAP habitat types as their condition changes. This approach has been criticised for not drawing on the scientific literature to validate the judgements of those that took part in the exercise.

4.7 Secondly, the 'increased' and 'current' funding scenarios used in the study do not match exactly to the 'improved' and 'decline' scenarios developed for the Keighley catchment, though they are probably reasonable approximations. Thirdly, the Christie *et al* work values carbon through the choice experiment and does not use DECC guidelines (see below). Values (per tonne & per ha) as transferred in this case study appear to be much lower. Finally, the values presented in Table 4 are UK averages. They have not been adjusted, for example, for possible differences in income (a significant determinant of willingness-to-pay) between the Keighley area and the national average. This can be remedied through future iterations.

4.8 The **second approach** has instead drawn on a wider range of valuation literature to identify values for the specific service changes expected in the Keighley catchment. Effectively, each service that could be valued was quantified and valued separately, and then aggregated as explained below.

4.9 Changes in carbon storage and sequestration were valued using DECC carbon valuation guidelines (DECC 2009) which provide detailed guidance on *values per tonne for* CO_2e *for non-traded carbon*. These were used to value the expected changes in carbon sequestration and GHG emissions (for example, methane) under each scenario.

4.10 A *treatment cost approach* was adopted to value possible changes in water quality from the catchment. This analysis was undertaken separately by Yorkshire Water (see Annex 3) for differing possible future trends in dissolved organic carbon (DOC) and pesticides.

4.11 Biodiversity non-use values can be quantified and valued in a number of ways. For example, estimates per household per year are available from other studies which could then be aggregated to a relevant population (see eftec, 2010). Instead, emerging results from the National Ecosystem Assessment (NEA) (forthcoming) were used. The NEA has adapted a recent meta-analysis of wetland valuation studies by Brander *et al* (2008) for UK wetlands (which includes blanket bog habitats). It calculates that inland wetlands which provide good quality biodiversity habitat generate a value of approximately £454 per hectare per year more than those which do not offer that habitat.

4.12 The £454 per ha per year value is the average of the biodiversity wetland non-use value where the habitat currently exists. The NEA goes on to develop marginal values – ie the value for an additional unit of new wetland with good quality biodiversity habitat. This is estimated at £304 for inland wetlands and is the amount used in the value transfer exercise. However, it is likely to cover both the ‘improved’ and ‘decline’ scenario. To use the full value in both scenarios would risk significant overestimation. In the absence of more evidence on the relative split in biodiversity gains and losses between the scenarios, an even split has been assumed – so the per ha per year gain in moorland biodiversity value under the improved scenario is valued at £152. The loss under the decline scenario is -£152.

4.13 Flood risk management and changes in access and recreation have not been valued in monetary terms for the reasons explained above.

5 Estimating the monetary value of ecosystem service changes in the Keighley catchment

5.1 The valuation exercise has been undertaken in a separate spreadsheet. Readers are advised to look at that for more detail. The time frame for the assessment is 25 years, using standard HM Treasury discount rates (3.5%). Key assumptions are explained below.

5.2 Restoring blanket bog (re-wetting) will lead to significant biodiversity improvements as described above. However, this will not happen immediately and it is likely to take several years before typical bog vegetation (ie sphagnum species) returns. Equally, as the blanket bog degrades under the decline scenario, biodiversity losses will not be immediate. Accordingly, no biodiversity gains (losses) have been assumed in the first 5 years but thereafter 'full biodiversity gains' have been assumed. These are simplifying assumptions but considered appropriate for the purposes of this analysis by experts in Natural England and Yorkshire Water.

5.3 Similar assumption have been made when profiling likely carbon gains and losses (see **paragraph 3.8**).

5.4 Numerous assumptions have been made in estimating possible changes in dissolved organic carbon (DOC) and pesticides. These are explained in detail in Annex 3. The central estimate has been used for the initial aggregation with lower and upper bound estimates being considered as part of the sensitivity analysis.

5.5 Table 5 provides estimates of the present value (PV) for changes in services under the 'improved' and 'decline' scenarios using the **Christie *et al* (2011) values**. The decline scenario is estimated to result in increased costs (negative benefits) in the region of £3.03 million pounds over a 25 year period – much of this being accounted for by declines in water quality. Conversely, the improved scenario is estimated to deliver benefits in the region of £3.57 million pounds over the same period of time.

5.6 Table 6 provides estimates of the present value (PV) for changes in services under the 'improved' and 'decline' scenarios using **NEA & DECC values as well as incorporating changes in estimated water treatment costs**. Under both scenarios, carbon benefits and costs dominate, accounting for nearly £5 million of the overall £9.5 million under the improved scenario and -£3.2 million of the overall -£8.4 million under the decline scenario.

Table 5 Estimated present value (PV) benefits of scenarios for Keighley Catchment using Christie *et al* (forthcoming) values (25 years)

Scenario	Habitat Type	Value (£)	ha	Value/year	PV benefits (25yrs)
Decline	Bog	-£170	168	-£28,560	-£353,724
	Upland Heath	-£118	140	-£16,520	-£204,605
	Native Woodland	-£195	88	-£17,160	-£212,532
	Water Quality[3]	-	-	-	-£2,500,000
	Present Value				**-£3,270,860**
Improved	Bog	94	1244	£116,936	£1,448,286
	Upland Heath	84	354	£29,736	£368,289
	Native Woodland	117	131	£15,327	£189,829
	Water Quality[4]	-	-	-	£2,200,000
	Present Value				**£4,206,404**

Table 6 Estimated present value (PV) benefits of scenarios for Keighley catchment (25 years)

Ecosystem Service	Improved Scenario	Decline Scenario
Biodiversity (non-use)	£2,342,000	-£2,297,000
Carbon change (woodland)	£1,599,000	-
Carbon change (blanket bog)	£3,285,000	-£3,188,815
Carbon change (heathland)	£49,310	-£121,000
Water quality (reduced treatment costs)	£2,200,000	-£2,510,000
Flood Risk Management	-	-
Recreation & Access	-	-
Total Benefits (PVB)	**£9,475,000**	**-£8,400,000**

Note that values may not sum exactly due to rounding

Additional carbon benefits

5.7 In addition to the benefits described above, there are further carbon benefits (and potentially costs) that should be accounted for in the analysis (but are not in this case – figures presented for illustration only). Both the construction and operation of water treatments works can be very energy intensive. Yorkshire Water estimates that embodied carbon in a typical MIEX water treatment plant is likely to be around 1147 t/ CO_2e. By improving water quality in the catchment and (hypothetically) avoiding the need for an additional treatment works, the value of avoided embodied carbon emissions is estimated at £59,650 (using DECC 2011 non-traded carbon values). Using the non-traded price of carbon for 2035 (the final year of the timeframe for this analysis), the value of avoided emissions rises to approximately £118,000.

[3] UU & Yorkshire Water analysis

[4] UU & Yorkshire Water analysis

Costs

5.8 As with the benefits, it is only possibly to provide indicative estimates of the costs of the scenarios. Broadly speaking, costs fall into three categories:

- **Capital costs** (typically one-off costs around habitat restoration or infrastructure);
- **Management costs** (typically annual costs associated with particular land management practices); and
- **Opportunity costs** – costs to private land owners and managers in terms of forgone income.

5.9 Strictly speaking, there is a fourth category of costs – changes in water quality treatment costs which have been included above in the analysis of benefits (ie negative costs) and not in the costs section. However, the most important issue is not necessarily where they go, but that they are counted only once in the assessment.

5.10 Again, as for the benefits, the costs are presented for the whole catchment (ie they are gross costs) – they have not been adjusted to take account of the HLS agreements (for example) that are already in place. Currently, 18.5% of the catchment is covered by such agreements so the values presented below are likely to over-estimate actual costs on the ground.

5.11 Table 7 presents a summary of potential costs using 3 different approaches: 1) using national averages for Environmental Stewardship schemes (HLS); 2) using individual HLS option payment rates and then aggregating over the catchment; and 3) using current average HLS payment rates for the pilot area and extrapolating to the whole catchment. All costs have been assessed over 25 years, using standard HM Treasury discount rates (3.5%).

5.12 Cost estimates for option 2 are based on Environmental Stewardship payments rates[5] and the England Woodland Grant Scheme (EWGS)[6] – using both as a proxy for actual cost.

5.13 As Table 7 illustrates, using national average costs provides the highest estimate at a little over £5.7 million over 25 years. Using HLS options to construct more tailored measures for the catchment reduces the cost estimates to approximately £3.2 million, of which over half are capital costs associated with blocking grips and gullies, re-seeding bare peat and woodland planting. Using approach 3 (current catchment average costs) provides estimates between the two at approximately £4.3 million. For the purposes of the analysis that follows, approach 2 is arguably most appropriate because it is tailored specifically to need. Ideally, a bespoke and detailed cost mapping exercise would be undertaken across the whole of the catchment but this is beyond the scope of this initial report.

5.14 The costs for the decline scenario (which will effectively be savings – ie money not spent on Environmental Stewardship schemes) are estimated at around £1.61 million (in present value terms). This is in effect the lifetime value of the all stewardship agreements in the catchment.

5.15 The sensitivity analysis section later in the report examines the how the situation changes when assumptions about the costs are varied.

[5] HLS handbook reference

[6] **http://www.forestry.gov.uk/forestry/infd-6dcegu**

Table 7 Cost estimates improved and decline scenarios (PV over 25 years)

Approach	Capital cost	Annual cost	Total
Improved Scenario			
1. National average costs	-	-	£5,733,000
2. Option payment rates	£1,902,000	£1,302,000	£3,204,000
3. Catchment average costs	-	-	£4,276,000
Decline Scenario			
Current ES spend in catchment	-	-	£1,614,000

Calculating net present values

5.16 Table 8 presents net present values (NPV) over 25 years and benefit/cost ratios for the improved and decline scenarios. Using the NEA/DECC values, the NPV for the improved scenario is around £6.27 million (the amount society would gain where the investments in the catchment made) and for the decline scenario it is -£6.77 million (the amount society would lose were all spending ceased and regulations reduced to the absolute minimum). The benefit/cost ratios tell a slightly different story. For the improved scenario, for every £1 spent in the catchment, society benefits by £2.96. Conversely, for the decline scenario every £1 **not** spent in the catchment, society stands to lose an estimated £5.20.

5.17 Using values from the Christie *et al* study, the differences between benefits and costs is much smaller. For every £1 spent in the catchment, society would benefit by only £1.31. Conversely, for every £1 **not** spent in the catchment, society stands to lose £2.03.

Table 8 Net present values and benefit cost ratios

Scenario	PV benefits	PV costs	NPV	BC ratio
Improved (NEA/DECC Values)	£9,475,000	**-£3,204,000**	£6,271,000	2.96
Decline (NEA/DECC Values)	**-£8,400,000**	£1,614,000	**-£6,786,000**	**-5.20**
Improved (Christie *et al* Values)	£4,206,404	**-£3,204,000**	£1,002,404	1.31
Decline (Christie *et al* Values)	**£3,270,860**	£1,614,000	**-£1,656,860**	**-2.03**

5.18 Even without the inclusion of possible access and recreation benefits or changes in flood risk, the analysis appears to provide a convincing case for investment in the catchment, particularly if the NEA/DECC figures are used.

6 Sensitivity analysis

6.1 The analysis above already provides some sensitivity analysis around the carbon and biodiversity values as it stands. Even using the Christie *et al* values and mid-range cost estimates, benefit-cost ratios are greater than 1 (or -1). However, if the upper bound cost estimates (the national average scheme costs) are used in the improved scenario, then the benefit/cost ratios fall to 1.65 for the NEA/DECC values and to 0.73 for the Christie *et al* values, meaning that costs are greater than benefits for the latter. However, the likelihood of this is very low and it should be noted that this involves using the highest costs and a very low (almost worse-case scenario) estimate for the benefits.

6.2 Another key area of uncertainty relates to reductions in water treatment cost. United Utilities and Yorkshire Water stress the significant uncertainties around possible DOC levels following restoration or virtual abandonment of the catchment from a conservation perspective. Their analysis suggests that cost savings for the improved scenario could range between £0 to £3.9 million over 25 years (see Annex 3). Altering this variable and using the NEA/DECC values suggests that the PV benefits in the improved scenario could range between £7.3m (water treatment cost savings = £0) to £11.2 million (water treatment cost savings = £3.9 million). Under such circumstances benefit/cost ratios are 2.27 and 3.49 respectively. This demonstrates that even if water quality treatment cost reductions are zero, the benefits of investment in the catchment still significantly outweigh costs.

6.3 The situation is different, however, using the Christie *et al* values. Because biodiversity and carbon benefits are significantly lower, water treatment cost savings of around £1.2 million are needed for a benefit/cost ratio of 1 (ie for the investments to break even). This is entirely plausible since this level of potential water treatment cost saving falls towards the lower end of the range provided by Yorkshire Water.

6.4 The range of water treatment costs under the decline scenario is -£2.57 million to -£1.02 million. Using these values in the analysis, using both NEA/DECC and Christie *et al* values still results in benefit/cost ratios of more than -1 (ie for every £1 **not** spent on conservation (taken away) society will lose more than £1 (range £1.10 - £5.26).

6.5 As discussed in **paragraph 3.8**, carbon losses have been valued using DECC guidelines which, in turn, are for tonnes of CO_2e emitted into (or removed from) the atmosphere. Whilst we are fairly confident that the rate of peat erosion from the catchment under the decline scenario is plausible (indeed, we've taken an average from different recent studies carried out in the South Pennines), what we are much less sure about is the proportion of those losses that would enter the atmosphere and critically when that might be. In our analysis, we have simplistically assumed that only 50% of the peat lost from the catchment under the decline scenario enters the atmosphere (and further assumed that happens almost immediately upon loss). Emerging evidence suggests that between 30-35% of DOC will be emitted into the atmosphere with a much higher proportion entering the atmosphere from POC (Particulate Organic Carbon). From a valuation perspective, this is a key assumption and needs to be tested. One extreme case could see zero carbon emissions into the atmosphere as the peat is gradually eroded, implying that all the peat and carbon leaving the catchment is somehow locked safely into other terrestrial (and possibly marine) systems. Clearly that will not be the case. Another extreme could see all peat (both in DOC and POC) entering the atmosphere. Again, this is an unlikely scenario and in the absence of further information, the 50/50 split has been assumed.

6.6 Assuming no carbon enters the atmosphere, benefit cost ratios fall significantly under the decline scenario for NEA/DECC values, from -5.2 to -3.05 (ie for every £1 **not** spent in the catchment, society stands to lose an estimated £3.05, down from £5.20). So even if carbon is eliminated from the calculations altogether, the evidence suggests that removing funding from the catchment would still lead to significant societal costs.

6.7 Conversely, assuming that **all the lost carbon** makes its way into the atmosphere, the benefit cost ratio rises to 7.18 (ie for every £1 **not** spent in the catchment, society stands to lose an estimated £7.18).

6.8 In summary, the analysis suggests that in the majority of cases, the returns from investing in habitat restoration in the catchment are potentially significant with benefit/cost ratios significantly exceeding 1. Only where the absolute worse-case scenario is assumed would benefit/cost ratios fall below this level.

7 Conclusion

7.1 The Value Transfer Guidelines provide a useful framework to quantitatively assess some of the main ecosystem service changes in the Keighley Catchment and could usefully be applied to other such case studies in the future.

7.2 It has only been possible to value potential changes in carbon, water quality and biodiversity. Assessing these three services alone has required fairly significantly levels of data and effort. One of the biggest challenges was translating the implications of potential land-use and land management through to potential changes in ecosystem services. This required close working between economists and natural scientists as well as close working between Natural England and Yorkshire Water in particular.

7.3 Given the uncertainties associated with linking land use and land management changes to changes in ecosystem services and the limited evidence in this area, a number of assumptions have been made. These assumptions have been documented and in general we have estimated potential benefits in a precautionary way. There is some potential to change these assumptions and hence to generate different results and conclusions. However, we have discussed the assumptions and approaches with internal and external experts and are therefore confident that these are defensible even if others might reach slightly different conclusions about the magnitude, if not the direction, of changes. There are a number of research initiatives underway to begin to address some of these knowledge gaps and it is hoped that better tools will be available in the near future.

7.4 The use of scenarios seemed to work well (decline and improve, both compared to a counter-factual scenario). However, more than two scenarios would have proved difficult to work.

7.5 Improvements could be made to the case study through further work to assess:

a) Potential changes in flood risk management under the different scenarios;
b) Potential changes in access and recreation which, given the Pennine Way goes through the catchment, are likely to be significant; and
c) Potential changes to provisioning services (specifically those from agriculture). These have not been analysed in any detail. Whilst not expected to be significant in cost/benefit terms, there are likely to be important distributional impacts that need to be taken into consideration.

7.6 However, limiting the assessment to just carbon, water quality and biodiversity, the analysis suggests that there are likely to be significant societal gains under the ‘improve’ (restoration) scenario. For every £1 spent, society is likely to benefit by an estimated £3. These finding are in line with other recent studies to estimate the wildlife and landscape benefits of Environmental Stewardship (Boatman *et al* 2010).

7.7 Equally, under a decline scenario, there are likely to be significant losses as the condition of the blanket bog deteriorates and wider conservation investments are not made in the catchment. For every £1 **not** spent (saved), society is likely to lose an estimated £6.61, with the highest level of losses being estimated at over £9.12.

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Annex 1 Definitions of scenarios

Scenario 1 – Improve

In the '**improve**' (or 'invest') scenario, it has been assumed that necessary investments are made in the Keighley and Watersheddles Catchment to deliver a greater range of ecosystem services through habitat restoration and more sympathetic land management interventions. A consultative, desk-based assessment was undertaken of the potential land use and management changes required to maximise multiple ecosystem service provision. In many ways, this scenario represents an 'optimal' theoretical land use and management scenario that would in turn deliver an optimal level of social welfare gains. A very ambitious and well resourced (HLS) delivery plan would be needed to realise the assumed changes.

Scenario 2 – Decline

In the '**decline**' scenario it has been assumed there will be little or no regulatory or government interventions for land management. We have assumed that land managers have no access to agri-environment schemes (but are still supported through a single farm payment type mechanism) and therefore intensify their activities to maximise financial returns. As water companies generally own only a small part of the catchment and this land is tenanted, we have little direct control over land management practice and rely on working with landowners and tenants to achieve mutually beneficial solutions. In this scenario we would assume that the landowner/tenant does not wish to work with us and simply aims to maximise commercial returns for provisioning services such as farming (grouse, livestock).

This will mean:

- No environmental stewardship schemes;
- Minimal protection of sites for biodiversity, for example, South Pennines SSSI/SAC/SPA (ie little beyond statutory protection);
- Minimal protection of archaeological or landscape features (ie little beyond statutory protection);
- Pesticides, herbicides & livestock welfare treatments use increased;
- Intensification of managed burning (potential increase in wildfires);
- Over-grazing leading to loss of biodiversity interest, soil compaction and localised erosion;
- Increased small scale drainage and increased track-way construction on blanket bog; and
- Decreased investment in farm infrastructure increases the amount of source pollution.

Based on the current available evidence, these land management practices are very likely to cause increased peat degradation and erosion, increasing colour concentrations. In turn this will result in increased operational costs as well the need to invest earlier in capital solutions such as treatment works.

Annex 2 Quantifying and valuing peat related carbon in the ecosystem services pilots

By Stewart Clarke, Matthew Shepherd & Julian Harlow, Natural England

This note describes the methods and approaches adopted to quantify and value changes in carbon storage and flux as a result of land management changes proposed in the ecosystem services pilots. All of the land management changes proposed have the potential to change carbon (and other greenhouse gas) fluxes but some of these are difficult to quantify because there is insufficient information, other changes are considered to be small and therefore unlikely to greatly influence values. Four different habitat changes (which are themselves the result of a range of management changes) are considered here: 1) restoration of blanket bog; 2) deterioration of intact blanket bog; 3) further deterioration of blanket bog to bare peat; and 4) conversion of upland heath to acid grassland. These represent the major moorland habitat changes in the pilots.

Restoration of blanket bog

Background

Each of the three pilot projects includes proposals to restore upland blanket bog through blocking grips, ceasing or reducing the frequency of burning, re-vegetating bare peat or changing grazing intensities. The value of intact and functioning blanket bog as a store of carbon is well established (Natural England, 2008); damaged or degraded bog represents a source of carbon to the atmosphere as previously stored carbon is released. Restoration of blanket bog, largely through re-wetting has consequently been advocated as a means of preventing this loss and reinstating the potential for further carbon sequestration from the atmosphere. However, there is some evidence that re-wetting results in increased methane release to the atmosphere offsetting any potential short term benefits of restoration. As methane is 25 times more potent than carbon dioxide as a greenhouse gas (GHG) this could be significant.

Restoration and methane release

Methane flux from peatlands is highly variable in both space and time (see summaries by Bussell *et al*., 2010; Lindsay, 2010) and tends to be associated with areas of recently flooded vegetation. Restoration by grip-blocking and re-wetting creates areas of wetter and flooded vegetation and hence areas for methane release. However, where water is shallow, and conditions suitable, areas of open water can be rapidly colonised by aquatic *Sphagnum* species and eventually peat-forming *Sphagnum* which forms an aerobic layer at the surface, which is likely to contribute to oxidation of methane generated. For the purposes of the ecosystem service pilots economic valuation work we have assumed that over the 25 year period the area of open water declines rapidly due to colonisation by *Sphagnum* and water table changes. Figure A shows a hypothetical trajectory of change over the 25 year period following restoration; it shows a decline in open water area and an overall re-wetting of the blanket bog surface with an increasing proportion of the area functioning as 'low ridge' habitat with near-surface mean water tables.

Modelling GHG balance

Following the assumed trajectory of habitat change shown in Figure A it was possible to predict the GHG balance over time. A simple 'model' was developed to calculate GHG flux for each time step (1 year) in the valuation period. The model was based on the work of Couwenberg *et al*. (2008) which relates carbon dioxide and methane flux to water table depth based on data from a range of European peatlands. The model simplifies a restored blanket bog system into 3 "compartments" with different water table regimes – representing dry bog with low mean water table (-20cm), re-wetted bog or filled in ponds with near surface mean water table (-5cm) and areas of open shallow water (+5cm). The data presented in Couwenberg *et al* (2008) were used to predict flux of both CO_2 and methane in tonnes per hectare per year. Methane emissions were multiplied by 25, to reflect their larger global warming potential. The balance of the 3 water table regimes during the hypothetical restoration trajectory was used to estimate overall greenhouse gas flux from the restored peatland in tonnes CO_2-equivalent per hectare per year.

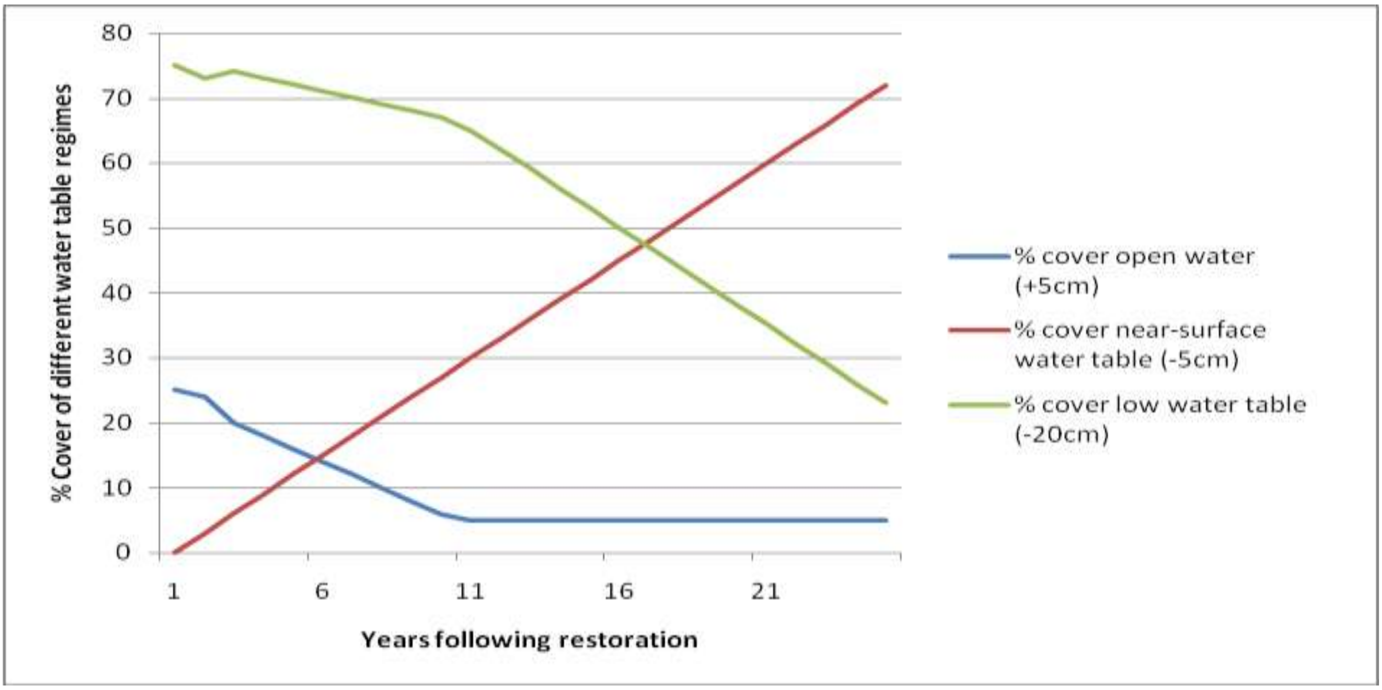

Figure A Habitat change over time following restoration

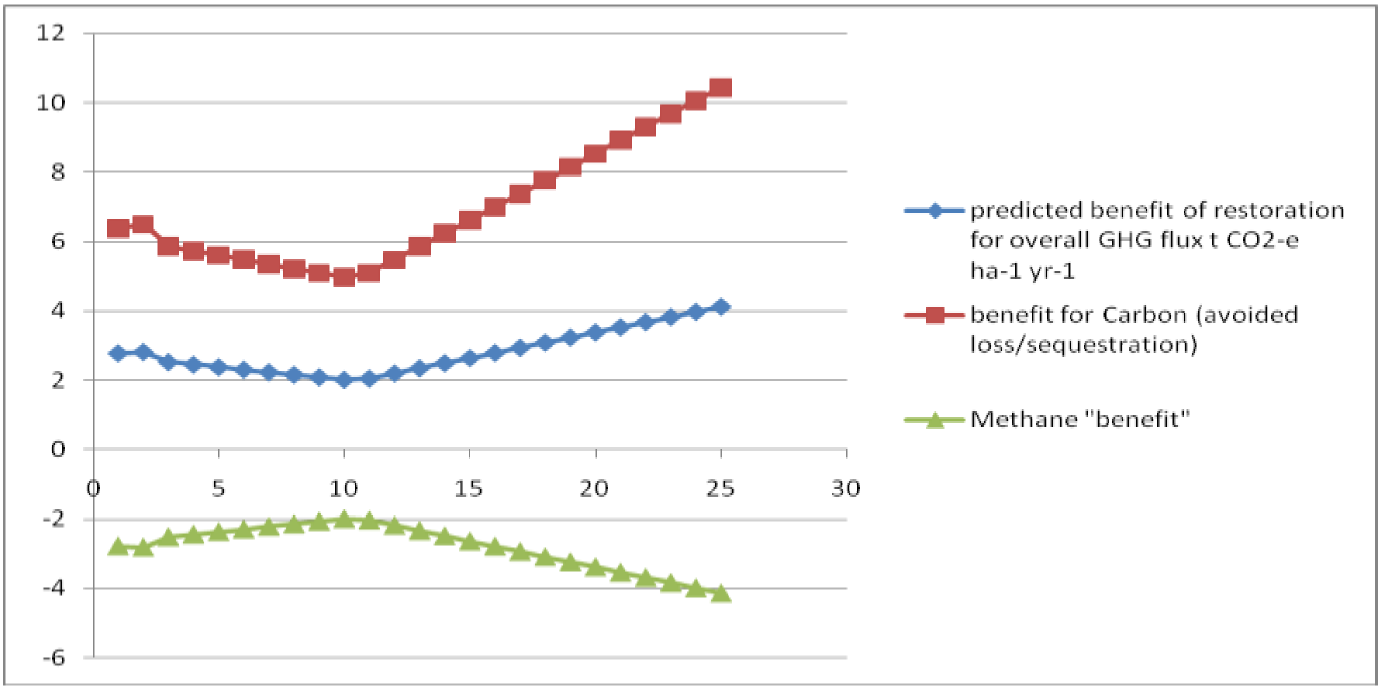

Figure B CO_2e benefit of blanket bog restoration

Clearly the model outlined applies once restoration has taken place and restoration works may take some time. For the purposes of the valuation exercise it was assumed that restoration would take place in years 1 and 2 with no carbon benefit in these first two years. The trajectories shown in Figures A & B were therefore applied from the end of year 2. This is considered conservative as changes to the blanket bog hydrology will begin as soon as restoration takes place.

Deterioration of intact blanket bog

Future scenarios which predict changes in management or intensification of land use have the potential to degrade the condition of habitats, therefore there was a need to quantify the resulting changes in carbon flux. Values were taken from a table in the peatland carbon report (Natural England, 2010) which compiles values of carbon flux associated with different habitat condition; these values were derived from the scientific literature.

The report quotes figures of -4.11 tonnes CO_2-e ha^{-1} yr^{-1} for intact blanket bog and 2.56 tonnes CO_2-e ha^{-1} yr^{-1} for degraded systems. Change in carbon flux associated with the deterioration of intact blanket bog was assumed to be the difference between these two figures. As deterioration will occur over a period of time, the loss of habitat was spread over the first five years of the valuation period.

Deterioration of blanket bog to bare peat

Further deterioration of blanket bog as a result of more frequent and intense burning, over-grazing and erosion has the potential to lead to a loss of vegetation creating areas of bare peat. The flux values used for deterioration of intact bog are not appropriate here because losses to the atmosphere from bare peat are fairly insignificant. However, bare peat is subject to erosion (water and wind) and oxidation so losses of peat (and associated carbon) can be significant.

An average erosion rate for bare peat (20mm yr^{-1}) was determined from a series of surface retreat rates given in Evans and Warburton (2007); the average was calculated from nine values given from different studies in the South Pennines. The carbon associated with this peat loss was based on the figure of 47kg per m^3 (Cannell *et al*., 1993 quoted in Lindsay, 2010). It was assumed that the bare peat was created gradually over a ten year period. As this bare peat creation also results in a loss of vegetation which itself contains significant carbon an additional carbon loss was included; a value of 10 tonnes C per ha was used (value for degraded bog with vascular plants cf. sphagnum; Lindsay, 2010). As all of these figures are expressed as tonnes Carbon, they were converted to CO_2e quantities, using a multiplication factor of 3.67, to enable valuation.

In addition, it was recognised that not all of the CO_2e quantities leaving the catchment would enter the atmosphere (or if they do, when that might be). Emerging evidence suggests that only 30-35% of dissolved organic carbon (DOC) will enter the atmosphere. The percentage for particulate organic carbon (POC) is likely to be much higher. Recognising this, it was assumed that only 50% of the CO_2e quantities released from bare peat would enter the atmosphere. This 50/50 split reflects an even split between 1) zero atmospheric emissions (which is very unlikely) and 2) 100% transmission to the atmosphere (which again is unlikely since some of the peat is likely to be locked away in other systems (for example, reservoirs and ultimately coastal or marine systems).

Conversion of upland heath to acid grassland

The final upland habitat change involves a shift from upland heath to grassland as a result of intensification of agriculture (over-grazing, nutrient additions). The draft Natural England report on carbon associated with land management (Alonso, Weston & Gregg, in prep) includes values from the scientific literature for changes in carbon (or other GHG) resulting from a change in one habitat to another. Values are given for a change between improved upland heath and improved grassland (from Dawson and Smith, 2007; Ostle *et al*., 2009); a value of 1 tCO_2-e $ha^{-1}yr^{-1}$ was adopted as the mid-point of the range quoted. It was assumed that the change to grassland would occur gradually over a ten year period.

Carbon valuation

The additional carbon sequestered or lost as a result of restoration or habitat changes was valued using per tonne values for CO_2e non-traded carbon from the DECC carbon valuation guidelines (DECC, 2009). The overall 'net present value' was calculated for the 25 years using a discount rate of 3.5%.

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Annex 3 Valuation of catchment management for water quality, case study of keighley moor and watersheddles catchment

By Alex Scott, Yorkshire Water

Introduction

Keighley Moor and Watersheddles reservoirs and the catchments that feed them deliver approximately 8 to 10 megalitres per day (mld) into the water treatment system, supplying customers in part of the South Pennines region.

Yorkshire Water owns Keighley Moor and there is a shooting tenancy agreement on the moor resulting in long term grouse moor management on this catchment. Yorkshire Water does not own the Watersheddles catchment which is also managed for grouse shooting.

Colour

Over the past two decades, raw water quality has shown demonstrable deterioration in the Keighley Moor and Watersheddles catchments mainly due to the increased concentrations of colour. A substantial programme of research has been carried out to determine the causes of the colour increase. The colour is generated by the microbial breakdown of peat within the upland catchments and this breakdown is affected by land management practises which change peat hydrology.

Without intervention in the catchment, significant increases in raw water colour concentrations are projected to continue and will result in additional treatment to ensure that customers receive high quality drinking water. The process to treat higher colour levels involves increasing the chemical dosing and where colour concentrations reach a certain limit, as a last resort, new and expensive treatment solutions must be built (MIEX plants). MIEX would only be installed if all other more cost-effective solutions have been exhausted. In addition to the initial capital cost, MIEX is an energy intensive solution that greatly contributes to other operational cost and carbon footprint of the treatment process.

Catchment management to restore peat hydrology and reduce colour production at source offers a more sustainable alternative to traditional treatment processes.

If this approach is successful, we will see the upwards colour trend gradually decelerate and eventually plateau, which will result in deferring capital spend on a new MIEX treatment plant and also reduce the amount of chemicals required to meet DWI standards.

The main objective of this approach is to deliver a sustainable solution to the colour problem and minimise the bills for our customers.

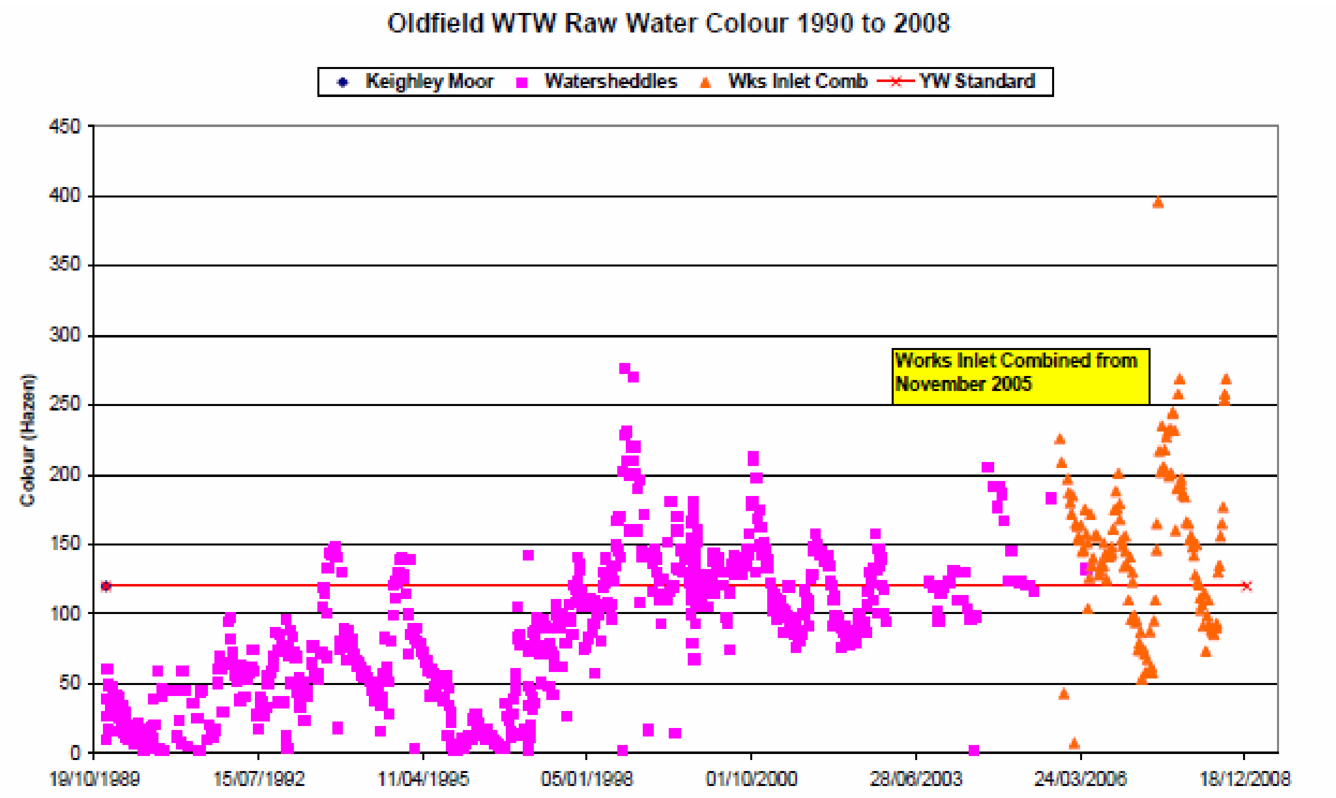

Figure C Graph of raw water colour trend

Yorkshire Water are investigating a series of catchment management techniques to stabilise the colour levels currently observed in the catchment run-off and are delivering a 5 year pilot study in the catchment as part of their Water Colour Remediation Strategy. This strategy includes measures to improve biodiversity in the catchment.

Until the results of this pilot study are available and can provide more robust evidence to determine the efficacy of catchment land management interventions, various colour trend lines have been put forward based on current evidence.

Pesticides

YW does not currently have a pesticide problem in the Keighley Moor and Watersheddles catchments however, the methodology allows for this to be included in the future to enable transfer to different catchment areas (for example Worsthorne Moor owned by United Utilities) or to simulate land management scenarios which would introduce pesticides.

Taking a baseline and establishing the change to the Environment

The baseline is simply a continuation of the current trend line and is represented by line A (see **Figure D**) assuming status quo for the existing land management practises.

The current trend line is an average for upland works in the South Pennines which are showing a colour increase due to peat degradation.

We have used a 25 year timescale to ensure that all of the costs and benefits are captured as completely as possible.

Each of the colour trend lines represents the likely outcomes of the various land management practices identified in the Scenarios A, B and C outlined below.

These scenarios have been drawn up by experts from Yorkshire Water and United Utilities with regard to published research.

Scenario A – Status quo

This scenario will inform the baseline trend as at April 2010.

Peat erosion after wildfire incidents has resulted in loss of peat depth of varying degrees across the moor and under current land management practises the concentration of colour in the catchment run-off is increasing over time. If current practises continue the likelihood is that the colour trend also continues upwards.

For a detailed assessment of the current condition of Keighley Moor please see *Keighley Moor Restoration Implementation Plan August 2010 (Penny Anderson Associates Ltd).*

Scenario B – Decline

In this scenario we have assume that there will be no regulatory or government intervention for land management. Yorkshire Water only owns part of the catchment, and this land is tenanted. Therefore YW has little direct control over land management practises and relies on working with landowners and tenants to achieve mutually beneficial solutions. In this scenario we would assume that the landowner/tenant does not wish to work with us and simply aims to maximise commercial returns for provisioning services such as farming (grouse, livestock).

This will mean:

- No stewardship schemes.
- Little or no protection of sites for biodiversity, for example, South Pennines SSSI/SAC/SPA.
- Pesticides applied liberally.
- Intensification of burning.
- Over-grazing.
- Increased occurrence of wildfire.
- Increased drainage and grips.

Based on the current available evidence, these land management practises are very likely to cause increased peat degradation and erosions thus increasing colour concentrations and this will result in increased operational costs as well the need to invest sooner in capital solutions such as treatment works.

Scenario C – Improve

This scenario is based on the interventions negotiated between YW, our tenants, landowners and Natural England as part of the AMP5 programme and YW colour pilot study on Keighley Moor only. Full detail available in the *Keighley Moor Restoration Implementation Plan August 2010 (Penny Anderson Associates Ltd).*

The 'improve' scenario approach is compatible with land management to improve biodiversity and will involve enhancement of blanket bog habitat.

Measures include:

- Grip blocking to raise the water table.
- Peat pipe blocking.
- Re-profiling of bare peat gullies.
- Reducing the dominance of heather through reduced burning and managed cutting.
- Changes to burn patterns.
- Managing the grazing levels.
- Continuing to discourage use of pesticides.

As the exact impact on colour trends from land management practises will only be known once the YW pilot study is complete, we have assumed three levels of confidence in the efficacy of the interventions to reduce colour which are categorised as:

- Pessimistic (X);
- Central (Y); and
- Optimistic (Z).

This gives us a nine box model (see Table A) and for each of the boxes a colour trend line can be estimated.

Table A The nine box model showing land management inputs and likely associated colour trend lines

Scenario description	**X** - Pessimistic	**Y** - Central	**Z** - Optimistic
1. Status quo	**Trendline B** 5% increase in DOC (with climate change impacts)	**Baseline A**	**Baseline A**
2. Decline	**Trendline D** 50% increase in DOC	**Trendline C** 30% increase in DOC	**Trendline B** 5% increase in DOC
3. Improve	**Baseline A**	**Trendline E** 15% decrease in DOC	**Trendline F** PLATEAU by 2020

Colour increase = % increase in DOC from trend line A in 2035

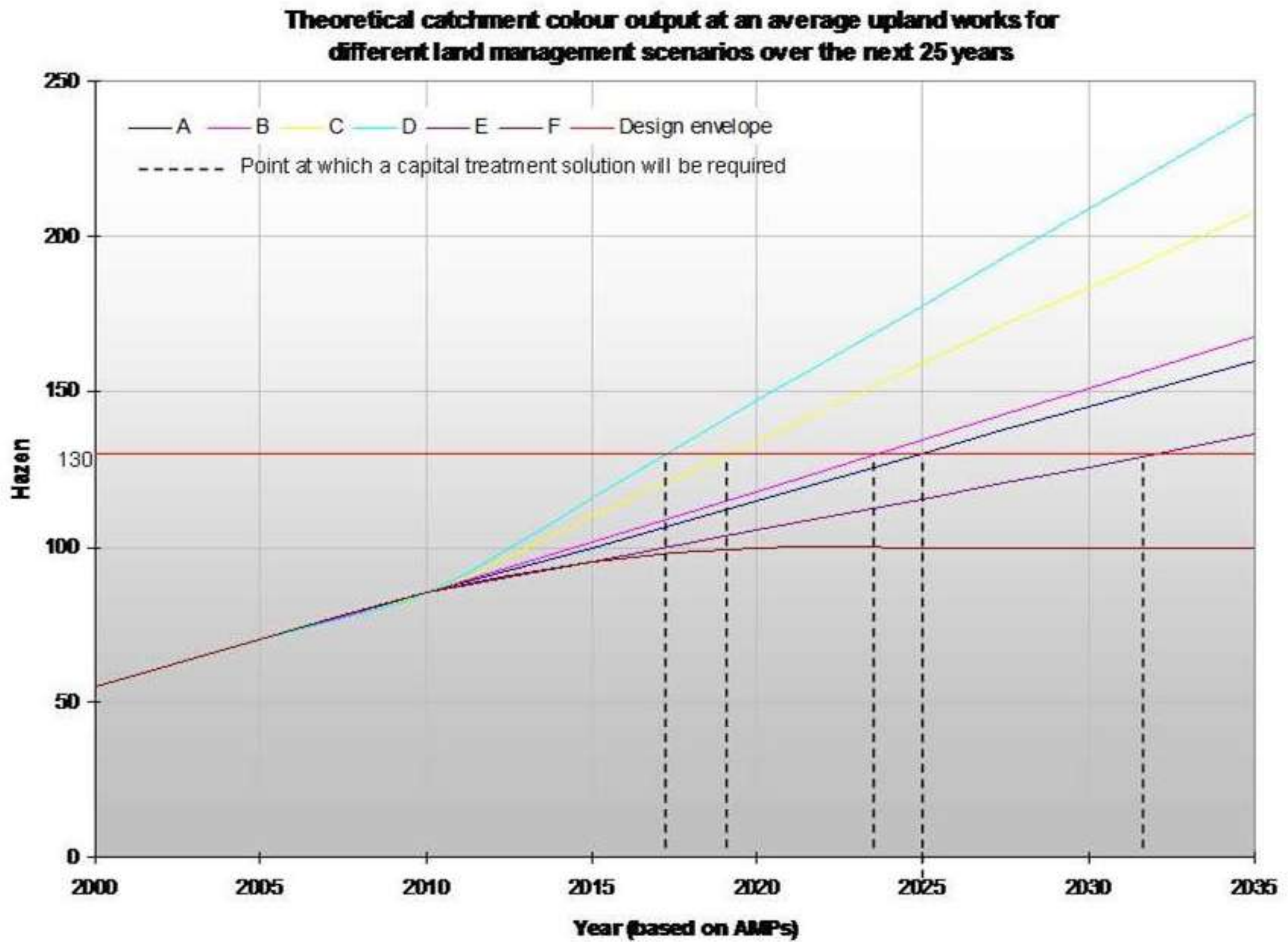

Figure D Graph showing predicted catchment colour output for each scenario at an average upland water treatment works

The nine scenarios can then be valued and the value of the change from the baseline under different conditions can be estimated.

Valuation Process

In this case study, there are difficulties associated with using the Total Economic Value (TEV) framework. Distortions of the water supply market due to the close regulation of the water industry are compounded by the Yorkshire Water grid system which transports water around Yorkshire to minimise treatment costs. This means that there is no discrete set of customers who would benefit from improvements in raw water quality, there is a risk of double counting and therefore the benefits are difficult to quantify accurately.

Consequently, we have adopted a cost based approach which is based on the capital and operational costs of meeting drinking water utility standards set by the DWI, the variable input being raw water quality. In this case, the benefit of successful land management intervention to reduce the upward trend in raw water colour is the cost avoided by deferring capital investment in MIEX and operational cost increases for chemicals (ie the cost of alternatives to good raw water quality).

The existence of a grid for raw water means that we have assumed the following process with no transfer of raw water to other works or between catchments:

Keighley Moor & Watersheddles Catchments → Reservoirs → Treatment works → Distribution → Customer

The following assumptions have been taken into account for the valuation process:

- The works is a generic three stage upland treatment works with standard processes and an average output of 10,000 cubic metres per day.
- If colour increases, the only change to the treatment process is the additional requirement for chemicals.
- Operational costs include chemical dosing only.
- The works always is compliant with DWI standards.
- No additional sludge costs are incurred from increased chemical dosing.
- Capital investment to build a MIEX treatment process at the works will occur just before when the works is predicted to fail (where the colour trend line crosses the design envelope line).
- It is a relative valuation which measures change from the baseline and is not an absolute measure.

Additionally, a discount rate has been applied to all capital investment to reflect the opportunity cost associated with having to invest earlier. Consequently, the costs of capital investment will be lower the longer that it can be deferred into the future[7]. The table below shows the range of values for each of the scenarios **relative to the Baseline A which is the Status Quo scenario**.

Table B Value changes associated with different land management scenarios and interventions

Comparison with the change from Baseline A	**X** - Pessimistic	**Y** - Central	**Z** - Optimistic
1. Status quo	Trendline B 5% increase in DOC	Baseline A	Baseline A
	-£16,644	£0	£0
2. Decline	Trendline D 50% increase in DOC Pesticides present	Trendline C 30% increase in DOC Pesticides present	Trendline B 5% increase in DOC Pesticides present
	-£2,569,302	-£2,509,734	-£1,016,644
3. Improve	Baseline A	Trendline E 15% decrease in DOC	Trendline F PLATEAU by 2020
	£0	£2,197,028	£3,878,026

[7] The discounted present value of a capital investment in 2035 is significantly lower that of a capital investment in 2015 due to the funds required for the capital investment in 2035 being available to be used elsewhere to earn a return in the interim

Conclusions

- Land management interventions to change peat hydrology have the potential to deliver significant benefits (cost avoidance) for catchment areas where colour concentrations are increasing.
- The interventions for water quality are compatible with activities that will also benefit biodiversity such as restoring blanket bog.
- Due to the complex nature of water treatment, the valuation process has had to be simplified and relies upon 'cost avoided' as a proxy for TEV. This needs to be carefully interpreted so as not to be misrepresented.
- This exercise is based on one small catchment in the South Pennines Region and it could be transferred to other upland catchments with similar characteristics.

Annex 4 Carbon associated with new woodland

By Stewart Clarke, Natural England

The following assumptions have been used to calculate the carbon sequestered and stored as a result of new woodland planting in the pilot areas.

The carbon values have been calculated using the Forestry Commission on line Carbon Lookup Tables (Version 1.2) **www.forestry.gov.uk/forestry/INFD-8JUE9T**.

The tables require a number of decisions and assumptions to be made about the nature of the planting and likely growth rates:

Species

As we are intending to plant mixed deciduous woodland, I have selected the SAB model (sycamore, ash, birch - mix or pure species) which is recommended for all mixed native woodlands.

Spacing

I have selected a spacing value of 2.5m which is the middle option. Keith Kirby (Woodland Principal Specialist) has suggested that this is appropriate for woodlands destined for production or for biodiversity focused planting.

Yield class

This is a measure of productivity and can be adjusted according to soil type etc. I have used class 4 in line with the FC guidance for native mixed woodlands (this has also been suggested independently by Keith).

Management

Two management options are presented. I have selected a 'no-thin' option on Keith's advice; it is unlikely that woodland in the locations we are promoting would be harvested in early years due to access and cost.

Growth period

I have used a 25 year period consistent with other valuation aspects.

Error adjustments

The FC model requires two adjustments to be made to the carbon values to reflect model uncertainty (20%) and a range of factors affecting the life and productivity of the woodland – 'permanence' (15% for low risk). The outputs of the model have then been converted to monetary values using DECC non-traded carbon values for the period (central estimate) with a discount rate of 3.5% applied.