Natural Capital Restoration Project Report

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Geoff Bright
ONS, UK

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Heartfelt thanks goes to my wife, Rita, for proofreading and suggestions, along with massive moral support!
Finally, most gratitude is due to my God, who, despite the setbacks, has supplied my needs[1] – to Him be all the glory!

[1] Philippians 4:19

Contents

Summary

Introduction (Chapter 1). This report forms the action for the first part of the project 'Natural Capital Project and Environmental Protection Expenditure' (Grant agreement no. 05121.2015.001-2015.546). The grant was made for a project with two strands – Ecosystem Accounting and Environmental Protection Expenditure; this report concerns the first distinct strand.

This part of the project began early in 2016, but due to a number of unavoidable obstacles and an expansion of its aims, a completion date of October 2017 was agreed. The project had two key deliverables: the production of a roadmap for work to produce an asset and risk register relating to the potential for natural capital restoration in the UK, and two pilot studies from which practical applications would emerge and be implemented and more widely-applicable issues arising would be investigated.

The roadmap is intended to show how a subsequent project, running from 2017 to 2020, will incorporate information gathering for a register, building the asset register, and developing the physical and financial accounts. Additionally, the findings of the pilot are presented, along with issues specific to that area or habitat and those of wider application, and the implications of these will be highlighted.

The planned register covers, not only asset condition, amount and spatial distribution, along with value, but also the services, trends in asset condition and capacity, degradation (including thresholds) and restoration (past, current and planned or potential activity and costs), and also feasibility and, if possible, prioritisation.

This project involved a substantial review of literature, particularly that concerned with ecosystem restoration, data collection, spreadsheet modelling, and discussion with a large number of individuals, representing government, academia, consultancy and practitioners.

Ecosystem restoration (Chapter 2): Ecosystem restoration is: 'the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed' (SER, 2004). Restoration has support in Europe generally, and within the UK specifically: for instance, in two the Aichi Targets (CBD, 2011), the EU Biodiversity Strategy (EU, 2011), and voiced by the UK NCC (2014).

In order to record the state of the country's ecosystem assets in terms of their extent, condition and spatial configuration and the ecosystem services flowing from them, the development of a risk, or asset and risk, register has been proposed (NCC, 2014). This would particularly help to highlight those habitats and areas where degradation is occurring and where restoration and improvement would be most beneficial.

To build a register and provide information for project, as well as aggregate assessments, detailed information on restoration activities and costs is required, as well as on ecosystem condition and ecosystem services (ES). Yet, although a good deal of data exists, there are problems in terms of their specificity, form and availability.

The chapter goes on to discuss the recognition of where restoration is needed, the identification and measurement of degradation, the types of restoration activities and costs, and the conceptual and practical issues associated with restoration costs. The use of restoration costs in ecosystem accounts is also discussed, with a more detailed coverage of the use of restoration costs in ecosystem asset valuation presented in Appendix E.

Ecosystem condition services and restoration – concepts and application (Chapter 3): This chapter provides a conceptual foundation for the pilot studies in the subsequent two chapters. The links between ecosystem condition, ecosystem services and restoration are explored and applied to peatland, the context of the pilot studies. The logic chain below represents those links.

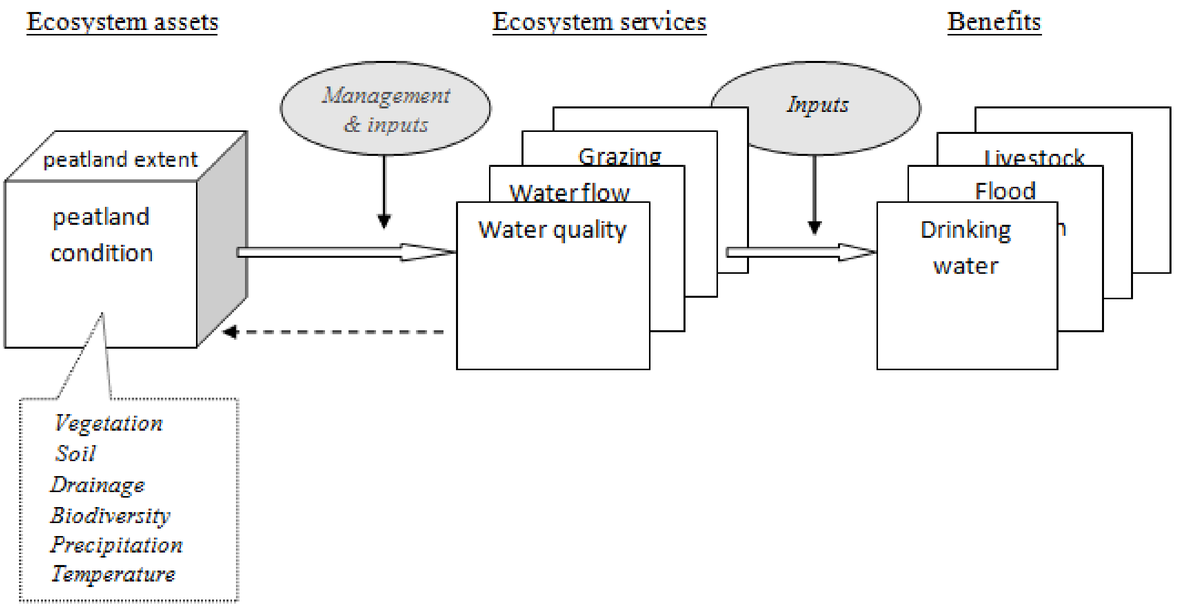
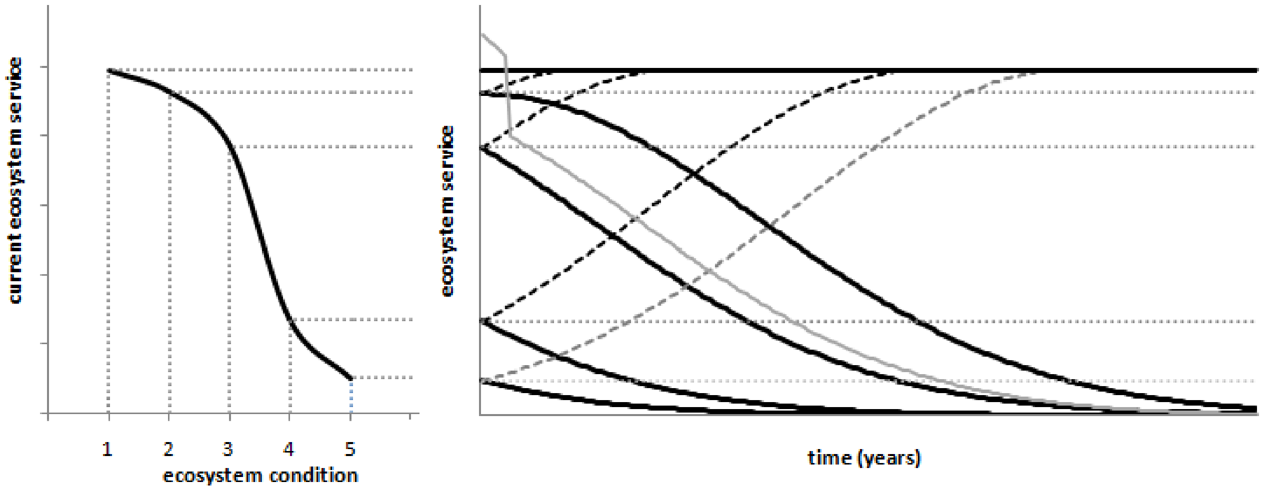


Fig. S.1 Logic chain focussing on ecosystem condition, services and benefits for peatland

Ecosystem services are closely related to the state of the ecosystem asset – its extent, condition and spatial configuration. On a unit-area basis, ecosystem condition and future management are key determinants of the pattern of ecosystem services into the future. Depending upon the objective, multiple indicators of ecosystem condition can be measured but, for specific purposes, summary indicators have been proposed; this is the case for peatland.

Conceptually, the pattern of ecosystem service flows over time can be linked to current condition, with deterioration, maintenance or restoration occurring dependent on the future management of the ecosystem asset, although restoration may not be possible if a threshold has been exceeded. Figure S.2 illustrates this – where condition gives rise to a stream of ES which may deteriorate, or, if managed appropriately, be maintained or be restored, with a consequent feedback to subsequent condition over time.



Key: Right-hand graph lines show ES flow following different starting condition categories from left-hand graph. Black curves/lines – business as usual (bau); thick dotted lines – restoration; fine dotted lines – maintenance; grey curve – ES unsustainably extracted.

Fig. S.2 Changing ecosystem condition and degradation and restoration of ecosystem services

Although, in practice, these relationships are more vaguely understood, the time-based pattern of restoration activities and costs, as well as of benefits, can be predicted for a site in a particular current condition. In fact, valuing assets on the basis of the expected stream of costs and benefits depends on such predictions.

Multiple ecosystem services are likely to arise during restoration, and beyond; these might be complementary, competitive or supplementary. The physical flows of each ecosystem service should be estimated and valued.

The comparative streams of costs and benefits for 'business as usual' and restoration can then be analysed for accounting and cost-benefit analysis purposes.

Pilot study 1 (Chapter 4): The Exmoor Mires Partnership, a project in operation for more than ten years and covering more than 3000 hectares, aims to restore degraded peatlands and promote regeneration of moorland bog vegetation. Figure S.3 shows the area within which the project is sited.

After outlining the extent and condition of the ecosystem asset represented by the project, ecosystem benefits (grazing, water provision, reduction in greenhouse gas [GHG] emissions, flood alleviation, biodiversity, recreation and educational opportunities) are, where possible, estimated and recorded costs are presented, with future ES flows predicted.

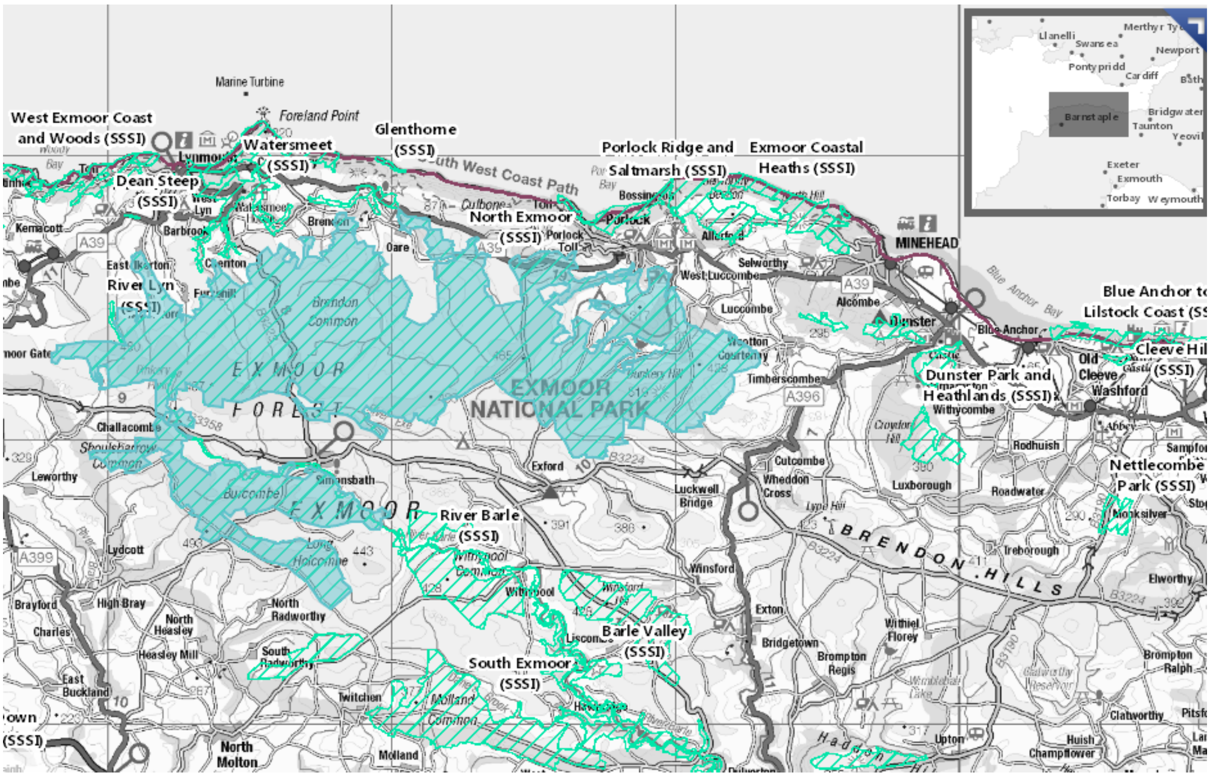


Fig. S.3 Map of Exmoor showing North Exmoor SSSI Source: Natural England (2017)

A summary asset and risk register is produced as are ecosystem accounts, following the pattern of Figure S.4. However, as restoration is underway, rather than hypothetical, this is covered as the upper line, while the situation which would have existed if ‘business as usual’ (bau) had continued is represented by the lower accounts.

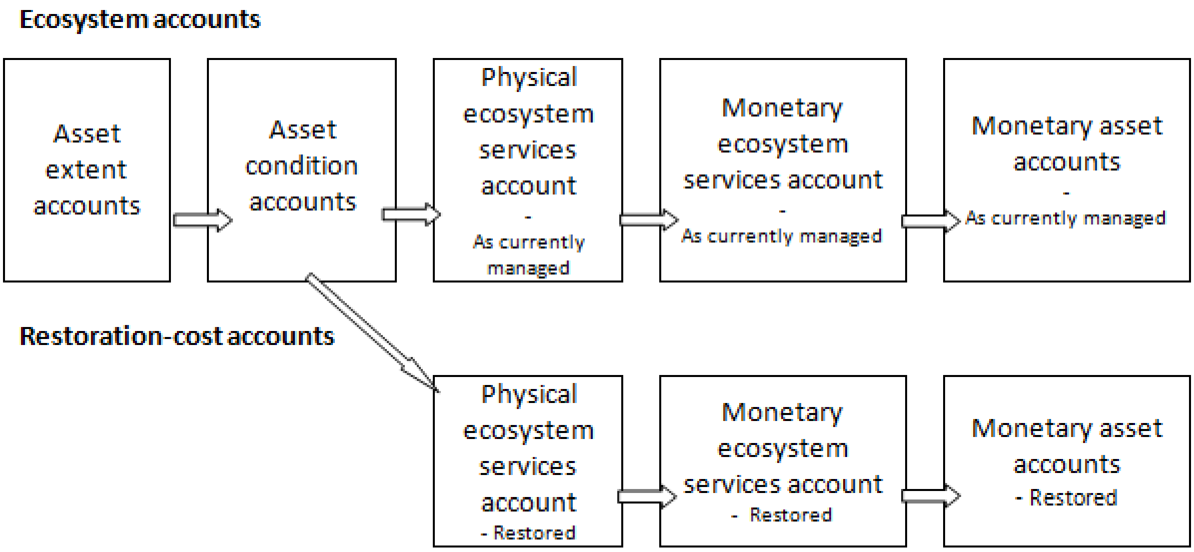


Fig. S.4 Ecosystem accounts with and without restoration

A cost-benefit analysis (CBA) is the final piece of financial analysis: a benefit:cost ratio (BCR) of 8.9 is estimated for a 100-year lifetime and, along with the further sensitivity analysis, suggests that the project is worthwhile on this measure.

In carrying out this study a number of issues with specific and general relevance arose and are listed.

Pilot Study 2 (Chapter Five): This chapter mirrors, for another peatland project, the previous chapter, but on low-lying fenland: the Wicken Fen Vision project. Instigated in 1999, the project aspires to eventually cover 5,300 hectares, although the analysis here focussed on 479 ha. of former agricultural land. Figure S.5 shows the project area.

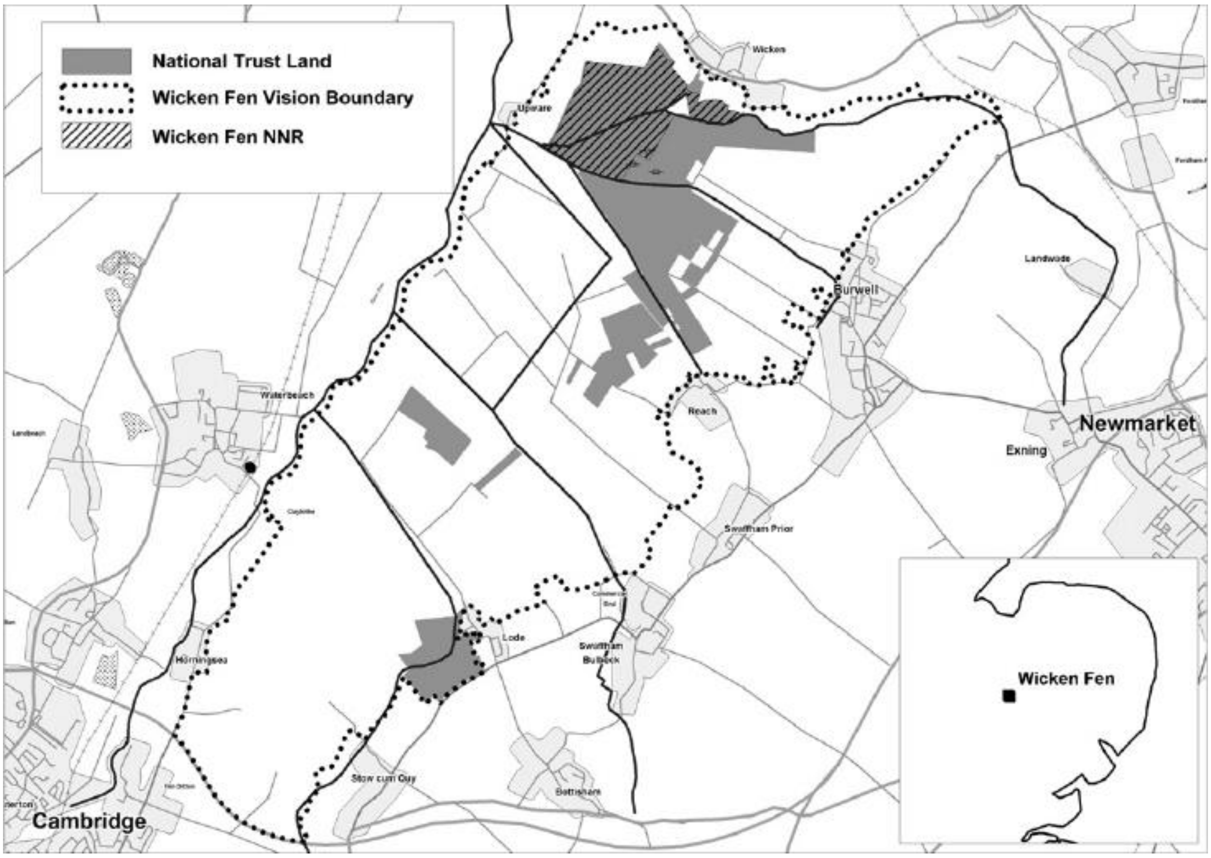


Fig. S.5 The Wicken Fen Vision area

The project aims to encourage habitats beneficial to wildlife, provide access for people, with local involvement, and influence policy development.

Again, condition was tabulated and ES (grazing, GHG emission reduction, flood alleviation, biodiversity and recreation) were estimated. Cost data were available, albeit less detailed than in the first study. An asset and risk register was constructed, followed by ecosystem accounts and a CBA. A BCR of 6.3, with the accompanying sensitivity analysis, indicated a positive result.

Both studies highlighted some key issues, particularly: the importance of good recording of costs as well as monitoring ES; the need to recognise off-site effects, as well as influences from adjacent sites; the importance of flexibility in objectives and management; the effort involved and the positive effects of good engagement with stakeholders; and the proper appreciation of time and time-scales.

Issues arising (Chapter 6): From the literature review, discussions and pilot studies, a large number of issues arose. These were gathered into three approximate groupings: objectives, benefits and costs; recording and accounting; and policy and decision making, as Figure S.6 illustrates.

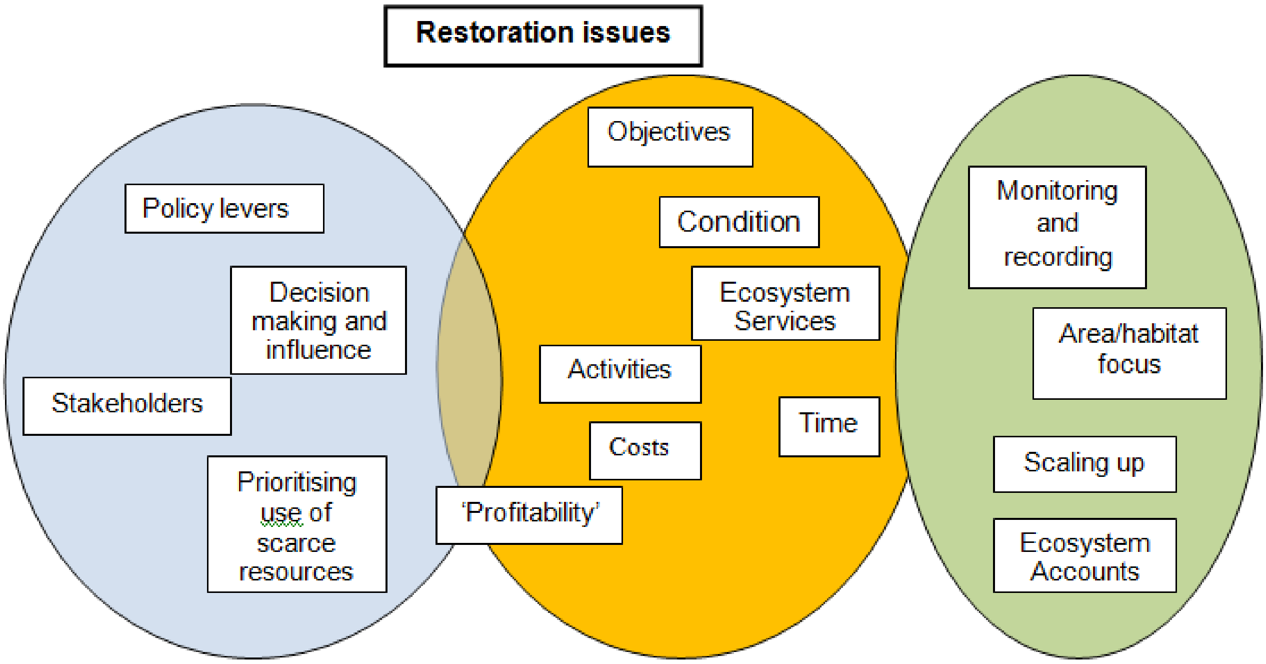


Fig. S.6 Grouped restoration issues

Amongst the many issues, attention is particularly drawn to the following:

- The links between ecosystem condition, ecosystem services (and trade-offs between them) and restoration activities, and their pattern over time, are not clearly understood
- Restoration costs information, although much exists, is widely scattered, incomplete, in different forms and can be poorly recorded and difficult to retrieve.
- Monitoring of ecosystem services, although not directly a cost of restoration, is common, but can be expensive.
- Scaling up is possible, but a high degree of uncertainty will surround current estimates due to insufficiency of data.
- Time plays a massive part in all aspects of restoration.
- Ecosystem accounts can incorporate restoration costs, but there remains some disagreement regarding the part they should play.
- The quality of the planning and implementation of policies influences the degree to which they work in favour of, or against, restoration.
- The central part that people play in policy implementation, in general, and restoration, in particular.

Recommendations (Chapter 7): Following on from the issues in the previous chapter, a substantial number of recommendations are made. The key recommendations are:

1. Ecosystem condition, ecosystem services, and restoration activities and changes over time are linked (Figure S.7) – this needs to be better understood

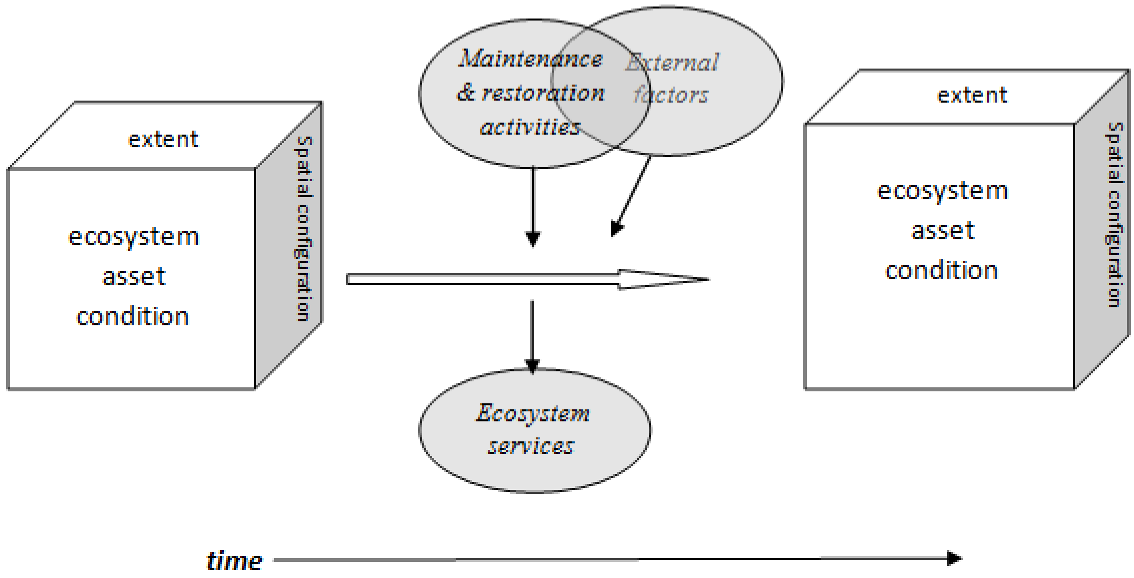


Fig. S.7 Ecosystem condition, restoration activities and ecosystem services

2. These elements, in physical and financial terms, need to be recorded and brought together for the common good – potentially at a UK and EU level. A database would cover ecosystem condition, extent and spatial configuration, ecosystem services, restoration, maintenance and bau activities and costs, grant rates, and monitoring activities (all with timings), categorised according to sub-habitat and other characteristics as well as condition. ONS/Defra would be a logical initial repository or coordinator of this for the UK; Eurostat could carry out the same role for EU/Europe, and these bodies could be responsible for the production of recording guidelines.
3. Scaling up to the aggregate could initially involve the construction of asset and risk registers by habitat, and these would be revised as the database expanded and 'average' and modelled figures emerged. Uncertainty should be recognised and evaluated – confidence intervals will narrow as the database improves.
4. Restoration costs have a place in ecosystem accounts – directly if restoration is underway, but only as parallel accounts if hypothetical, although the latter is still subject to debate; a paper on this would be helpful.
5. Recognising the time element is paramount– time in the consideration of ES flows, time for restoration activities and monitoring, the need to consider changes in values over long periods, the need to commit funding for long periods, and need to assign a sufficiently long lifetime in asset valuation and project appraisal[2].

Two further points arise:

6. EU, government and agency policy may have a major influence on restoration decisions, but requires careful planning and implementation. The redesign of CAP and Brexit provide opportunities.
7. Collaboration between agencies, between specialists and between practitioners and researchers bears fruit!

[2] And the related decisions about discount rates.

A Roadmap for Work on UK Natural Capital Restoration (Chapter 8): A summary asset and risk register is presented (Table S.1), while a more detailed template, showing the presentation of information by habitat and characteristics for the whole habitat, underlain by the disaggregated data at lower geographical levels shown in Appendix D.

Table S.1 Asset and restoration register summary

	Urban	trend	Enclosed farmland	trend	Semi-natural grassland	trend	Woodlands	trend	Mountains, moorlands & heath	trend	Freshwater (open waters, wetlands, floodplains)	trend	Coastal margins	trend	Marine	trend
Asset																
extent (m.ha.)	1,465	↑	11,539	↓	3,274	↑	2,879	-	2,734	↓	1,435	↑	56	↓	309	↑
condition																
soil (type, moisture, nutrients)			83 N bal.	↑												
species composition (bird index**)			48	↓			62	–			85	↑				
vegetation							633 m.m3	↑								
hydrology											32µg/l ammon.	↑				
carbon							3781 mtCO2	↑								
certified area (m.ha.)			2.59	↑			1.38	↑								
access*							70%	↑								
spatial configuration																
ecosystem services																
provisioning																
food			42.5 m.t.	–							2045 t.fish	↓				
fibre							13.7 m.m3	↓								
energy (Gwh)			5648 solar	↑											4889 wind	↑
water (m.m3)			119	↓							4709	↓				
peat											589.6 th.t.	↓				
regulating																
GHG reduction							14 mtcCO2	↓								
air quality (th.t.)			786.2	↓	164	↓	315.5	↓	127.1	↓	52.8	↓	2.35			
flood protection																
cultural																
recreation (m.hrs.)			131.4	↓			351.2	↑			296	↓				
education (th visits)			230.1	↑							59.7	↑				
supporting																
pollination																
biodiversity																
Asset																
degradation																
proximity to threshold																
restoration																
extent																
time																
cost																
benefit																
change of use																
extent																
cost																
benefit																

* population with access to 20 hectares of wood within 4 km
** indices specific to habitat

The roadmap is designed to parallel the ONS Natural Capital Account Roadmap and has been formulated taking account of an evaluation according to three factors: 'value', 'risk' (habitat quality and direction of change), and 'facility' (availability and ease of obtaining data). Table S.2 presents the roadmap and has four main elements – overview/reviews; broad habitat coverage; restoration database; and an overall asset and risk register for the UK. Guidelines would also be produced to support the development of the database.

Table S.2 Restoration roadmap

	2018	2019	2020	2021	2022	2023	2024	2025
Overview/review of possibilities and priorities								
Broad habitat coverage								
Peatland	Eurostat already support obtained							
Mountains, moorlands & heath	Eurostat already support obtained							
Enclosed farmland								
Woodlands								
Freshwater (open waters, wetlands & floodplains)								
Urban								
Semi-natural grassland								
Coastal margins								
Marine								
Restoration database								
Asset and risk register								
Guidelines								

Note: for habitats, grey shaded areas denote **scoping and an initial register**, dark upward sloped hatch – **more detailed register**, lighter horizontal hatch – **gap filling and updating**. For other lines the grey shaded areas denote specific tasks or elements being built up over time.

The successful implementation of this roadmap depends upon resources being made available, collaboration and appropriate staffing. The outcomes of the implementation of this roadmap will help decision makers at national and supra-national levels as well as those involved in restoration at a site level.

Conclusions (Chapter 9): Seven concluding points are made:

1. The project objectives have been met, with two pilot studies completed and a roadmap produced.
2. A national (and European) database bringing together restoration, ES and state-of-ecosystem data from disparate sources is recommended.
3. ONS and Defra should take the lead in putting the roadmap into effect.
4. Time has a wide range of implications and must be woven into thinking about ecosystem restoration.
5. Restoration costs can, at least, provide useful supplementary information in ecosystem accounts, but may also have a place in the 'mainstream' accounts themselves. Further debate is needed. The issue of ecosystem disservices deserves further consideration too.

6. Restoration policies (and those affecting restoration) need to be carefully designed and implemented - with agency collaboration and good stakeholder engagement (with losers as well as winners considered). The CAP and Brexit offer opportunities for the development of meaningful restoration policy.
7. With collaboration and support, a good deal of progress on producing habitat-based asset and risk registers and building up a valuable database for the UK can be made by 2020 and beyond.

Chapter 1 Introduction

The project – proposal

This report forms the action for the first part of the project 'Natural Capital Project and Environmental Protection Expenditure' (Grant agreement no. 05121.2015.001-2015.546) - full details are provided in Appendix A. The grant was made for a project with two strands – Ecosystem Accounting, and Environmental Protection Expenditure. The report that follows concerns only the first part, namely Ecosystem Accounting; the report for the second strand has already been submitted as it was a separate piece of work.

The project officially commenced on 1st November 2015, but due to a number of unavoidable obstacles, the project has run the full 24 months agreed at the outset.
For the Ecosystem Accounting section of the grant, two stages were envisaged, as follows:
'Stage 1 (4 to 6 months) Planning and scoping the project. The area of development is completely new, the scoping of the entire project (not just the 12 month work) will be critical to the success of the project. Data sources and corresponding analytical resource needed will have to be determined. Two pilot areas will be identified and negotiations carried out to facilitate study in those areas'.

Stage 1 was completed by the end of 2016 with a report provided in December 2016: this is reproduced in Appendix B.

The proposal for Stage 2 was:
'Stage 2 (6 - 8 months) A detailed roadmap will emerge from stage 1. Two basic pilot registers will be built where practical applications will emerge and be implemented and more widely-applicable issues arising will be investigated.'

At the end of this second stage a final report was to be published. This document, with the linked appendices, constitutes that report. According to the grant submission (amended – see Appendix A) the final report would contain the reports of two pilot studies as well as a roadmap, thus:
'The final report will outline, via a roadmap, how a subsequent project, running from 2017 to 2020, will incorporate information gathering for a register, building the asset register, and developing the physical and financial accounts. The timetable will take account of variation between ecosystems for which information is more readily available and comprehensive, and those for which the data gaps are more widespread and for which further data collection and modelling will be required. Additionally, the findings of the pilot will be presented, along with issues specific to that area or habitat and those of wider application, and the implications of these will be highlighted.

The planned register covers, not only asset condition, amount, spatial distribution and capacity, along with value, but also the services, trends in asset condition and capacity, degradation (including thresholds) and restoration (past, current and planned or potential activity and costs) but also feasibility and, if possible, prioritisation. Physical accounts and financial estimates will be produced.'

Ecosystem restoration

Ecosystem restoration is the activity or process of activities which are undertaken to bring the condition and the services provided by an ecosystem or site to some previous, more favourable, level, where this is still feasible. It has been defined as:
"The process of actively managing the recovery of an ecosystem service that has been degraded, damaged or destroyed as a means of sustaining ecosystem resilience and conserving biodiversity." (CBD, 2011)

Not all ecosystems or sites within them might be regarded as needing restoration, and there is disagreement regarding the position to which the ecosystem should be returned. Nevertheless, there is a good deal of interest in determining where degradation has occurred and where restoration might be most beneficial.

A more detailed discussion of ecosystem restoration is provided in Chapter Two.

What was done

Phase 1 consisted of planning and scoping the project. This involved a substantial literature and restoration data search, with over 200 references collected (available on request); the collection continued through the second phase too. Experts in the field were also contacted with visits made and telephone meetings held with 22 people; summaries of the conversations are presented in Table 1 below, while more complete details are presented in Appendix C. Again, these meetings were continued into Phase 2. Meetings with other experts were also planned, but either the individual could not attend or time did not allow.

Consideration of potential pilot habitats and sites was also undertaken , with a decision taken on the resulting two. Additionally, conceptual modelling and papers were produced, some of which have been incorporated in this report.

In Phase 2, information was collected on the pilot sites with visits made to the two sites, and discussions held with site and project management and researchers. From this, along with information collected elsewhere, spreadsheets for developing the analysis were constructed and the reports on the pilots studies were produced.

For the roadmap, cognisance needed to be taken of the ongoing work on ONS and Defra on the UK Natural Capital accounts and discussions were held concerning these and their links to the restoration work. The roadmap was then constructed, looking at the factors affecting the work on eight general habitats as well as other, cross-cutting work.

Table 1 Contact details

contact	organisation	sector	Nature of meetings*	dates
Jawed Khan	DfT – formerly ONS	Government department	face-to-face	July 2016
Ian Dickie	Eftec	Consultancy	face-to-face	July 2016
Chris White Petrina Rowcroft	AECOM	Consultancy	face-to-face	Sept. 2016
Rocky Harris Colin Smith	Defra	Government department	face-to-face	2016-17
Roy Haines-Young	Nottingham University	Consultancy/academic	face-to-face	July 2016
Stephen King	UNEP-WCMC	International organisation	telephone	Nov. 2016
Richard Haw Pat Snowdon Rachel Edwards Rebecca Isted Miranda Winram	Forest England/ Forestry Commission	Government-related organisation	telephone	July, Sept., Nov. 2016, Sept. 2017
Martin Lester	Wicken Fen Vision Project/National Trust	Non-government organisation	face-to-face	Nov. 2016
Francine Hughes	Anglia Ruskin University	Academic	face-to-face	Nov. 2016
Morag Angus	Exmoor Mires Partnership/	Non-government organisation	face-to-face	Nov. 2016
David Smith	South-West Water	Private company	face-to-face	Nov. 2016
Chris Dodds	Scottish Government	Government department	telephone	Jun. 2017
David Robinson	Centre for Ecology and Hydrology	Government-related organisation	telephone	Feb. 2017
Kerry Turner	CSERGE, University of East Anglia	Consultancy/academic	telephone	Jun.2017
Flemming Ulf-Hansen	Natural England	Government-related organisation	telephone	May 2017
Ken Bradley	Department of Agriculture, *Environment* and Rural Affairs in *Northern Ireland*	Government department	telephone	Aug. 2017
Neil Paull Caryn LeRoux Steve Spode	Welsh Assembly Government	Government department	face-to-face	Jun.2017
Steve Prior	Forest Carbon	Consultancy	email	Jan. 2017
Andrew Moxey	Pareto Consulting	Consultancy	email	Jan.2017
Anton Steurer	Eurostat	International organisation	telephone	Jan. 2017

*Note: Email correspondence was also carried out with all of those listed – some of it considerable!

Choice of Pilot studies

During phase 1 of the project consideration was given to which habitats or sites should be chosen as the pilot studies. It was quickly realised that covering a complete ecosystem would be too onerous and homing in on a particular site would still facilitate consideration of the approach to be taken in constructing and asset and risk register and the accounts dealing with restoration, as well as bringing up issues which would have specific as well as general application.

Initially, a woodland site was sought, given the researcher's expertise, the size of the habitat and the recoding practices, especially within public-sector forestry in the UK. However, after discussions, it appeared that it would not be possible to obtain cost data explicitly referring to restoration, so this avenue was abandoned. Instead, peatland was chosen, given its importance, particularly to GHG emissions and potential sequestration, but also because it has been the focus of a good deal of restoration activity and research. Furthermore, although the project had originally aimed for one pilot study, the focus on two peatland, but very different sites would enable valuable comparisons to be made.

Thus, a moorland, blanket bog site in the south-west of England – the Exmoor Mires Partnership, and a low-lying, fenland site in the east of England, the Wicken Fen Vision, were chosen.

Structure of report

In the following sections of the report, Chapter Two provides more detail about ecosystem restoration and how it relates to ecosystem accounting, with further discussion of the latter in Appendix E. Next, in Chapter Three, prior to discussing the pilots, it is necessary to explain and justify the approach taken, looking at the link between ecosystem condition and services. Chapters Four and Five report on the two pilot studies. From these pilot studies, a number of issues have come to the fore, and these, combined with other points arising from the wider research and discussions, are presented in Chapter Six. This leads to recommendations in the following chapter. The roadmap is presented in Chapter Eight with supporting material. The final chapter offers the Conclusions, completing the report.

Given the considerable amount of material produced during the project, it would be confusing to present this in the body of the report, so there are a number of appendices which allow the reader to go into greater detail. The spreadsheets underpinning the numerical results presented for the pilot studies in Chapters Four and Five are being provided separately as Excel files.

Chapter 2 Ecosystem Restoration

What is restoration?

In order to gain an understanding of natural capital restoration it is helpful first to define natural capital and then outline its environmental economics accounting context.

> **Natural Capital**: "the elements of nature that directly or indirectly produce value to people, including ecosystems, species, fresh water, land, minerals, the air and oceans, as well as natural processes and functions." (NCC, 2014)

Within the environment, ecosystems are the areas in which the natural resources interact as a functional unit to provide environmental structures, processes and functions.

> **Environment**: "From a stock perspective - all living and non-living components that comprise the bio-physical environment, including all types of natural resource and the ecosystems within which they are located. From a flow perspective – the source of all natural inputs to the economy – including natural resource inputs (minerals, timber, fish, water) and other natural inputs absorbed by the economy (solar and wind, air for combustion)." (UN, 2012b)
>
> **Ecosystems**: "Areas containing a dynamic complex of biotic communities and their non-living environment interacting as a functional unit to provide environmental structures, processes and functions. The dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit." (CBD, 2003)

From the perspective that these ecosystems provide a stream of services to society, the spatial areas containing biotic and abiotic components and other characteristics that function together are defined as ecosystem assets. These assets are measured in terms of their condition and extent and thence their capacity.

> **Ecosystem assets**: "spatial areas containing a combination of biotic and abiotic components and other characteristics that function together. (UN, 2012b). Measured by **condition** and **extent**. Also, **capacity**." (UN, 2015)
> **Ecosystem condition**: "the overall quality of the ecosystem, as expressed through a set of indicators expressing ecosystem composition and/or functioning (e.g. species diversity or net primary production)."
> **Ecosystem capacity**: "The ability of the ecosystem to generate an ecosystem service under current ecosystem conditions and uses at the maximum level that does not lead to degradation of ecosystem condition." (Hein, Obst *et al*, 2015)

Ecosystems provide a basket of services, which can be characterised as: provisioning (products that can be harvested or extracted); regulating (regulation of biological, hydrological and climate processes) and cultural (non-material benefits of ecosystems). A further category, supporting services (such as formation of soils), is sometimes also used. (Ecosystem Services, 2017)

> **Ecosystem services**: "Contributions of ecosystems to benefits used in economic and other human activity (UN, 2012b). OR the direct or indirect contributions that ecosystems make to the well-being of human populations (both intermediate and final services." (Barbier, 2012)

Both physical and monetary measures of ecosystem assets and services may be produced. Monetary valuation of flows of ecosystem services - is normally based on the exchange value (UN, 2011) of the annual net benefits arising from those services. The valuation of assets (stocks) is usually based on the present value of the discounted stream of net benefits of those services, although valuation in terms of replacement costs may be utilised in certain circumstances.

If the condition and extent, and hence capacity, of a country's or region's ecosystem assets is maintained (or enhanced), then the potential stream of services[3] will be maintained (or increased) and, *ceteris paribus*, so will the valuation[4]. For a renewable ecosystem asset, the service will then be sustained throughout its assumed lifetime.

However, if the value of the expected future stream of services derived from an ecosystem asset declines as a result of changes in ecosystem extent and condition (arising from human activity) this is known as ecosystem degradation and valuation has to be adjusted accordingly.

Ecosystem degradation: "Declining trend in value of expected service flows due to decline in ecosystem condition and capacity/ reduction in ecosystem capacity to and production of ecosystem services." (Defra, 2017)

This will normally be accounted for by the change in value of the ecosystem asset calculated as the change in the net present value between the start and the end of the period. However, depending, *inter alia*, upon assumptions about actions to be taken to deal with this, the valuation based on the discounted value of benefits may need to be replaced by the total costs of preventing damage or of rectifying harm, if this is lower[5]. Note that, only the decline in value resulting from human activities is classed as 'degradation' – other impacts from external shocks or supply-demand shifts are not included, but will be recorded elsewhere. Consequently, changes in the values of ecosystem service flows may mask the impact of degradation. This underlines the importance of assessing degradation using physical asset and service indicators, as well as monetary value.

If degradation has occurred, several courses of action (or inaction) are available. Ecosystems may display ecological resilience, being able to recover to their former state, although this may take a substantial amount of time (NCC, 2014). If decision makers have a 'weak sustainability' perspective, at the extreme believing that all forms of capital are substitutable (Aronson, Ch2, 2007), then the ecosystem service(s) may be replaced by manufactured capital, without the perceived need to restore the ecosystem asset. However, if the perspective is one of 'strong sustainability'. in which different forms of capital are complementary but, after a point, not substitutable (Helm, 2016), then active restoration of the ecosystem is required.

Ecosystem restoration: "The process of actively managing the recovery of an ecosystem service that has been degraded, damaged or destroyed as a means of sustaining ecosystem resilience and conserving biodiversity."
"The return of an ecosystem to its original community, structure, natural complement of species and natural functions." (CBD, 2011)

If ecosystem asset capacity is to be actively restored so that the stream of ecosystem services is to be maintained or returned to some previous level, then actions will need to be taken to rebuild the capacity of the ecosystem asset. These actions will incur costs which are known as maintenance or restoration costs – the former being those required to return the ecosystem asset to its condition (or, its capacity) at the start of the accounting period, the latter more general, in the sense that it concerns the return of the asset to its condition at some earlier time. (Hein, Edens and Bagstad, 2015).

[3] Depending, of course, upon the demand for/use of the services.
[4] note that value may fall because of price.
[5] The means of dealing with degradation and restoration in environmental-economic accounts is discussed further in appendix E.

There are a number of issues which arise when considering the restoration process:

- The ecosystem asset may have reached, or approached, a point, the threshold or, slightly different, the tipping point, beyond or below which it is not longer feasible to undertake restoration activities, i.e. the asset is not recoverable.

Threshold: "The point at which (below which) the decline in status accelerates and/or becomes difficult to reverse. A discontinuity whereby a small change in a driver exerts the largest change in an attribute or state of an ecosystem, typically abrupt." (NCC, 2014b) .
Tipping point: "a point at which an (ecological) system experiences a qualitative change, mostly in an abrupt and discontinuous way" (Jax, 2012)

- The condition to which the asset is to be restored, known as the target level, can be based on an earlier level, known as the reference point. This may be the ecosystem condition at the start of the accounting period, that a set number of years ago, that prior to some human-induced change (such as the Industrial Revolution) or its pristine state. In an accounting sense, in the same vein as with depreciation of human-produced assets, restoration to the condition or capacity at the start of the year might be considered. On the other hand, some campaigners would recommend restoration to an earlier level. Contrariwise, some would argue that restoration to some previous level might not be either desirable or feasible (Dickie, 2016). As Helm suggested, 'recognising that there is no Arcadia to get back to, any restoration plan has to start with where we are rather than where we would like to be' (p.209) and '…there is no going back.' (p.111). Hughes (2016) concurred, noting that it might not be possible, certainly within a limited period, of restoring habitats which had undergone a great deal of human intervention, to an earlier state. These commentators suggest that the focus should be on ecosystem improvement or enhancement, with the target level being based on a desired future asset condition/capacity without necessarily referring to an earlier level.

Ecosystem enhancement: "The increase or improvement in ecosystem asset due to economic and other human activity." (UN, 2012b)

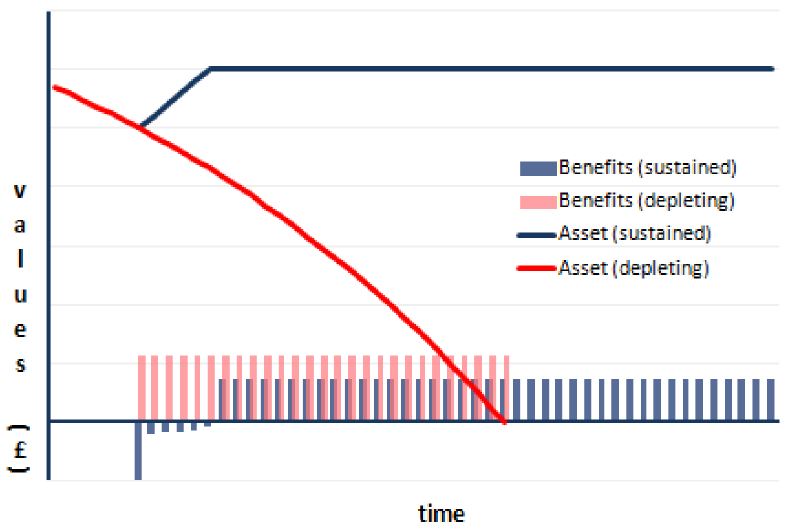
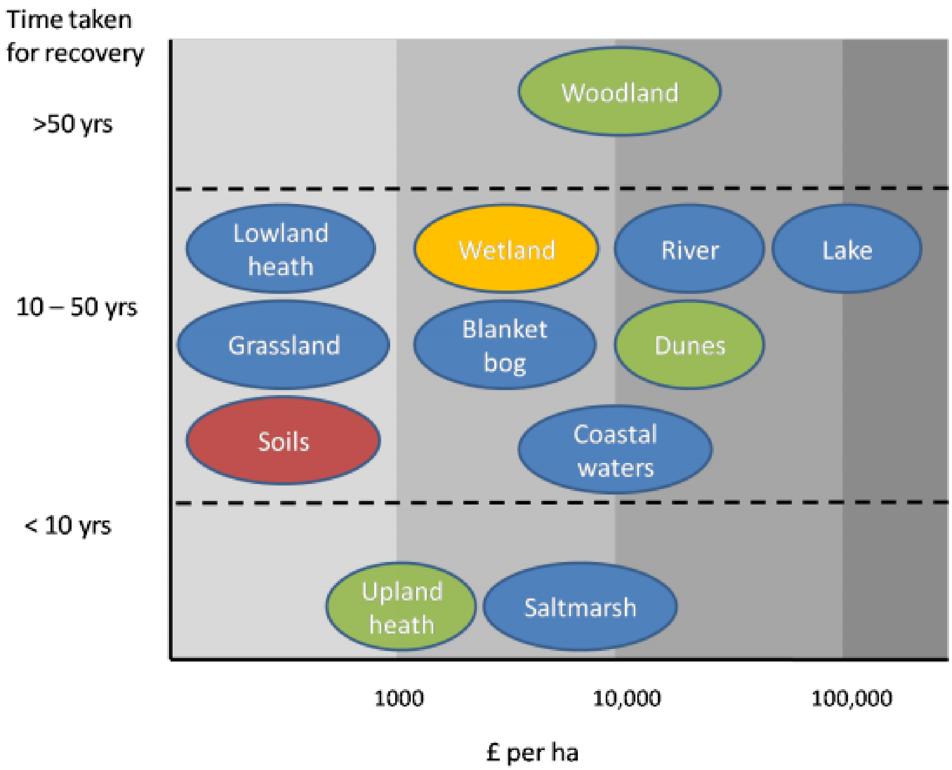


Fig. 2.1 Degradation and restoration – effects on asset stock and benefit flows

The differing pattern of services and the changing asset value for restoration compared to degradation of an ecosystem is illustrated by an example in Figure 2.1. The red bars denote the annual (net) values of the service flows for an asset experiencing degradation, while the red line shows the asset value eventually falling to zero. The blue bars show the effect of restoration activities, with costs exceeding benefits for a number of years until a sustainable level is reached. The blue line shows recovery of the asset value until it reaches a stable level.

- It might be feasible to undertake activities and incur restoration costs over one year which would bring about immediate restoration of the ecosystem asset to its condition and capacity at the start of the year. However, more commonly, restoration will take place over a number of years, in some cases a considerable period of time, as Figure 2.2 indicates..



Note: restoration is highly location and context specific so these are indicative only. Colours denote confidence in the evidence: Red= low agreement, limited evidence; Amber = low agreement much evidence; Green = high agreement limited evidence; Blue=high agreement, much evidence.

Fig. 2.2 Recovery and cost for restoration in different habitats (from NCC, 2014)

- Restoration may be feasible, but the costs may outweigh the perceived benefits, so it may not be worthwhile or it may not be deemed to be the best use of scarce resources. Thus, a register of restoration costs alone is not sufficient – to evaluate the profitability of a particular restoration activity within a particular ecosystem or landscape, cost-benefit analysis would be needed. As Helm 2015, suggests in this regard, ‘scarce resources need to be directed to where the marginal benefits are greatest’ (p.207).

- Hypothetical restoration costs are not deemed to be appropriate in Environmental-Economics Accounts (SEEA [6]), both within the Central framework and the Experimental Ecosystem accounts (UN, 2012a, 2012b), and in recent documents (UN, 2015; 2017). The asset valuations for the balance sheet will tend to be constructed from the present values of the flow of services, or by utilising damage or avoidance-based valuations and cost and benefit flows will be based on actual costs incurred and the actual and estimated exchange values of the ecosystem services.

[6] System of Environmental-Economic Accounting

Only when restoration costs are actually incurred will they be incorporated in the accounts. In such instances restoration costs actually expended will be part of gross value added in the accounts (Hueting, 2013; Appendix E). Furthermore, as some of the costs of restoration may be in the form of opportunity costs (the benefits foregone by not doing certain things such as delaying the harvesting of trees or restricting cattle grazing) they will not appear in the accounts. Thus, Obst, Hein and Edens (2015) state that the utilisation of restoration costs in accounting is not appropriate, and Obst and Vardon (2014) suggest that using restoration costs in the asset valuation (assuming such costs will be incurred and the asset restored over the future) is not realistic as it may not happen. However, not all have agreed (Mayer, 2013; Steurer, 2017), while the report of the 'Pimlico' meeting in 2013 (ONS, 2013) suggested that: "restoration cost estimates could provide some useful information for policy assessment and could be included separately" and Helm, in a letter to ONS on behalf of the NCC in 2014 advised, "An estimate of the potential restoration costs to maintain natural capital is essential and the committee is firmly of the view that this needs to be calculated as part of the national natural capital accounting framework." (Helm, 2014). The latest SEEA Technical Recommendations draft (UN, 2017) supports such use of restoration estimates, albeit not as part of the formal ecosystem accounts. Nevertheless, there are dissenting voices and, as Appendix E suggests, there may be some justification for the use of restoration costs in the ecosystem accounts themselves in certain circumstances.

- Calculation of ecosystem asset values is often based on the discounted expected stream of net benefits occurring over the accounting lifetime of the asset. In the absence of evidence to the contrary, such estimates tend to be based on the assumption that recent costs and benefits will persist, as Edens and Hein (2013) suggest – current management practices should be assumed. However, if a restoration plan has begun to be implemented, then it can be argued that the restoration costs, and the likely restoration impact on services, should be used to calculate the asset values.

What is required?

A comprehensive register of the current position (assets – extent, condition and capacity, services, capital maintenance charge, etc.), costs and benefits across all habitats and areas would be ideal. A range of information on restoration is needed for decision makers – from a figure for the total cost of maintaining or restoring ecosystem assets at the national level to the specific activities, costs and timings of restoration within a particular site. Furthermore, although these costs in themselves would be valuable, a more comprehensive database would be of greater value. This could comprise a register of ecosystem assets (physical and financial aspects), services, trends, highlighting degradation, the proximity to thresholds and the risks of crossing them, restoration reference positions and targets, options and associated restoration activities, with timings, and costs. Compiling such a register is likely to be an extremely onerous task.

A more pragmatic alternative approach might, therefore, be pursued. The NCC (2014) and its chair suggested that the focus should be on those assets and services most at risk (Helm, 2015). Nevertheless, although this could constitute a useful starting point, the roadmap should aim for a more detailed register, albeit being cognisant of the importance of timely interventions in those habitats most at risk.

Support for restoration information

Although a great deal of work has been carried out on the benefits of ecosystem assets and services, and their valuation, the study of restoration appears to be lagging somewhat. Nevertheless, the need for information on restoration costs has been propounded by many influential voices.

The Convention on Biological Diversity meeting in Nagoya, Japan, in October 2010 established the ‘Aichi targets’, numbers 14 and 15 of which particularly involve restoration:
Target 14 Ecosystems that provide essential services “By 2020, Ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable;
Target 15 – Ecosystem restoration and resilience. By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15% of degrade ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.” (CBD, 2011)

Similarly, the European Union established a target to: “halt biodiversity and ecosystem service loss by 2020, to restore ecosystems insofar as is feasible, and to step up the EU contribution to averting global biodiversity loss” (IEEP,2013): To achieve this target the EU 2020 Biodiversity Strategy includes six interrelated sub-targets and further supporting actions. Target 2 states that: “By 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15% of degraded ecosystems.” (EU, 2011)

In the UK, the Natural Capital Committee (2014) has recommended that: “Restoration efforts, therefore, need to be sustained and underpinned by long term commitment”, and its chairman, in a letter to the ONS in 2014, stated that: “An estimate of the potential restoration costs to maintain natural capital is essential and the committee is firmly of the view that this needs to be calculated as part of the national natural capital accounting framework.” (Helm, 2014)

And, to quote Helm (2015) again, “To enhance the natural capital environment to increase for the next generation requires restoration” and “we can do much better by improving those natural capital assets that have additional economic benefits if they are restored and enhanced, and thereby yield a higher level of sustainable economic growth.’” (Helm, 2015, pp.10-11)

Uses of restoration information

Information on restoration activities and costs will help the prioritisation of investments, the guidance for policy direction and to facilitate informed decisions at the aggregate, regional, and local levels. In particular, understanding of the reference costs and their timing will assist in answering such questions as: “What are we spending now, what do we need to spend, what will be the impact, and is it worth it?” at macro and micro as well as levels in between. Of course, to carry out such CBA, benefit values are needed, so these figures will also be required for such decisions to be made.

In ecosystem accounting, discussed above and in Appendix E, restoration costs will not normally be used, although this is not universally accepted. Nevertheless, once the restoration or enhancement process has been instigated, these costs will appear in the financial flows as well as in the valuation based on future costs and benefits. Furthermore, as discussed above, there is a good deal of interest in presenting restoration 'accounts' alongside their SEEA counterparts.

How do we determine where restoration is needed?

By definition, restoration is carried out in situations in which the ecosystem and its services have been degraded, damaged or destroyed, so this is where restoration activities would normally be undertaken. However, it is not enough to simply identify where degradation has occurred: given scarce resources, some degree of prioritisation will need to be put in place. This can be based on an assessment of the asset's proximity to thresholds or tipping points, the future losses which would occur if this point was reached, and the risk of this occurring. Thus, NCC (2014) and Mace *et al*. (2015) developed a risk register for England, the latter authors suggesting that such a register would serve, "to highlight the areas of greatest concern and to focus future monitoring and data gathering." (Mace *et al*., 2015, p.651)

It should also be noted that activities to improve an ecosystem may not be targeted only at degraded sites, but may also be carried out where ecosystem improvement or enhancement is seen to be relatively beneficial. Again, this is where a cost-benefit analysis can be used to evaluate options.

How do we identify and measure degradation?

If restoration is to be directed to sites at which degradation has occurred, how should degradation be measured and target sites identified? As degradation relates to declining ecosystem condition and capacity and the flow of ecosystem services, these are the aspects which need to be measured.

For the NCC's risk register, the results are largely based upon 'existing knowledge and expert judgement'[7]. However, this was effectively a prototype and a more complete evaluation of degradation needs to be founded on a more substantial evidence base. Chapter 8 presents a roadmap for the production of an asset and risk register for the UK.

Ecosystem assets and the services which they provide are, obviously, closely intertwined; and both may be measured. The condition and capacity of the asset stock determine the volume of services that can be sustainably removed or harvested from it. Rarely, however, are we considering only one service which flows from the particular ecosystem asset. Thus, for instance, woodlands provide timber, carbon sequestration, water quality and flood prevention services as well as recreation and other cultural values. Consequently, when gauging degradation from a service perspective, we need to evaluate the changes in all of the services, and weight them in some way.

To evaluate asset condition and capacity different indicators may be available to the different ecosystems – soil organic matter, soil nutrient content, biomass, age structure of trees, volume and

[7] More recent examples of risk registers are available, for example: McVittie *et al* (2017 and SNH (2017).

quality of water, other vegetation indices, species mix, water quality as well as various biodiversity indicators. Adverse changes in these indicators, when taken together will help to determine whether degradation has been occurring. Data on ecosystem extent will also be important, but the effect of movement of land use from one ecosystem type to another will depend upon the services which the different land uses provide.

Services can be measured in physical units of those flows – tonnes of grain, cubic metres of timber, tonnes of sequestered carbon and percentage dissolved organic carbon (DOC), for example. These services can also be valued monetarily and the basket of services arising from that particular ecosystem asset can then be combined, and the asset value is usually derived as the combined stream of the net values of the various service flows discounted to the present. However, as Appendix E discusses, because degradation is only one factor that can affect service valuation – external natural shocks can influence yields and price changes affect the unit values. Furthermore, the particular ecosystem's different services might not move in the same direction – in which case degradation might be particularly difficult to identify. However, if the monetary values assigned to those services reflect their relative values to society, then, *ceteris paribus,* changes in the asset value can be used (carefully) to identify degradation.

The many indicators (Maes *et al*, 2015 identify 327) vary in their difficulty of measurement and availability. DeFries and Pagiola (2005) identified three main sources of data for assessing ecosystem extent and condition: remote sensing and geographical information systems (GIS), natural resource and biodiversity inventories and other indicators of ecosystem condition. For the quality, quantity and spatial distributions of services they suggested that the above inventories and ecosystem models were key. For provisioning services, for those which are marketed, yield and output figures tend to be available. For regulating services models tend to be employed, although these are based on measurements at specific sites, while for cultural services, few measures are available apart from those for recreation, which tend to be based on visitor data supported by sample surveys.

Two final points should be made here: first, for evaluating service flows it is gauge the extent to which the current year is representative and the likely trend of these flows into the future. The risk register approach is potentially valuable, but whether used to determine an aggregate picture or to identify specific sites, there is a need for more disaggregated data, however garnered, to facilitate more accurate modelling and more informed evaluation.

What are restoration activities and costs?

With degraded ecosystems and sites identified, the next step is to determine what restoration work should be undertaken and how much it is likely to cost. Restoration costs will differ according to the habitat and the specific characteristics and problems of the site. However, activities and their associated costs can be allocated to a few general categories (specific examples for different habitats are presented in the Annex**)** listed below and tabulated in Figure 2.3:

- Initial investments/up-front costs. Initially, there may be substantial investments in terms of materials, equipment and staff inputs. These may last for only one period, but may extend for a number of years

- Ongoing costs – some costs, such as mowing, thinning, fertilising and maintenance, recur annually for the early part of a project or throughout its length. Activities may be similar to those previously carried out, but with some alterations and some extra (or reduced or less-intensive) tasks. Note that harvesting activities may change.
- Managing and monitoring costs – costs, often largely involving staff, may be incurred to manage the resource and monitor progress.
- Periodic maintenance and harvesting costs & reinvestments.
- Opportunity costs – often, restoration will restrict the activities which were previously occurring, and would continue to occur, on the site, such as grazing or harvesting. Off-take may be reduced in early years and may have to continue in this way or be compensated by greater off-take later. These costs will not be part of the cash flow (except insofar as the stream of benefits may be reduced) once the restoration project is underway, but will come into the calculation when comparing the 'with' and the 'without' perspective in a CBA. Note that there might also be costs incurred (and benefits enjoyed) by parties other than those at whom the project is directed, yet failure to take them into account can compromise the project's evaluation.

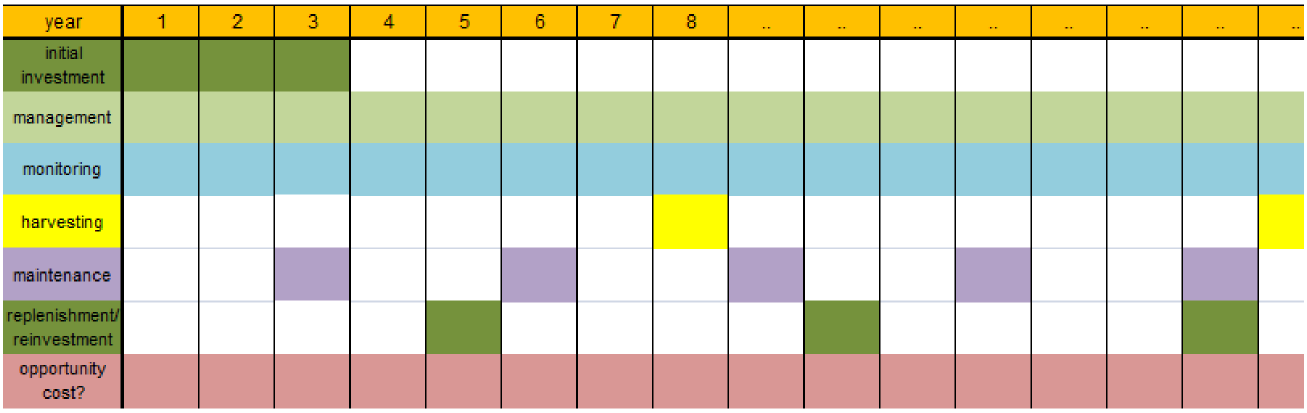


Fig. 2.3 Template showing possible pattern of restoration costs by type and year.

Not only will the tasks be different, *vis a vis* those carried out prior to the change to the restoration scenario, but the timing pattern may be altered, and this is important as it will affect the pattern of resource inputs and the time-based asset valuation.

How are these costs to be measured?

Although there are a number of sources of cost details for specific projects and manuals listing typical general costs, sources of accurate restoration costs are limited: as De Groot *et al* (2013) report, many of the costs are 'broad brush'. Similarly, IEEP (2013) noted, 'relatively few detailed data on habitat restoration costs are available in published literature' (p.231). Thus, compared to the number of restoration projects which might be carried out, there are a limited number of recent examples of restoration which has occurred, and for which cost data have been recorded separately. Furthermore, projects can be idiosyncratic and widely variable (Snowdon, 2016) so value transfer (using values from one location/context to another) may not be readily applicable.

As just mentioned, the restoration costs available tend to be either for specific projects or based on the standard costs derived from a number of projects or expert knowledge. Projected costs can also be estimated based upon the activities envisaged to be carried out, but these are also forecast, albeit physical rather than financial, and converting them to the latter also involves price estimation.

One area that is rather less fraught concerns situations in which grants or subsidies are available for asset holders to carry out preferred activities. In these cases, an exact cost can be determined for many of the activities involved. However, this only gives information of the cost to the grant provider, not to the unit carrying out the activities, and if the acting unit perceives the likely grant or subsidy to be below the cost which they will incur, the take-up of the desired restoration may be limited, while too generous a grant gives an inflated impression of the true cost.

To obtain more accurate data across habitats and sub-habitats, then an information-gathering exercise can be carried out to harvest data that has been or is being collected for projects, but is not published, or project managers can be encouraged to collect the required data. However, since no data register is likely to be comprehensive, modelling can be used to fill in the gaps. With the increasingly more widespread and expert use of GIS, satellite and other data, modelling is likely to be valuable in the construction of the register, albeit also relying on more and more ground-level data being available. Thus modelling and raw data collection go hand in hand. (Bateman *et al*., 2013 for example; Medcalf *et al*., 2014, indicate some of the potential)

There are, therefore, good prospects for the successful construction of a register of restoration costs. However, it must be borne in mind that this register is likely to be based upon past or current figures, so further estimation will be required to predict future restoration costs (even in real terms). Furthermore, as Snowdon (2016) has pointed out, such an exercise can be extremely expensive in time and resources. To gain a more accurate estimate of the restoration costs across all sites will take time and a considerable outlay, although satellite imagery, and GIS and Big Data techniques are becoming more powerful and accessible. Nevertheless, since policy-makers require timely information this may override accuracy, so a top-down approach may be more appropriate in certain circumstances. It is likely, therefore, that a two-pronged, bottom-up and top-down approach be advocated.[8] Others support this approach:
"The choices for the spatial level of the analysis depend on the purposes of the ecosystem accounting exercise. A highly aggregated approach would likely be sufficient for national level monitoring and integration with the SNA[9]. However, ecosystem accounting holds great potential for structuring information, communication and decision-support at a variety of scales and governance levels. To achieve these ends, and to take proper account of trade-offs across different services at local scales, spatially explicit accounts are needed" (Eftec, 2015a), and "The assessment of natural capital and efforts to restore it cannot be considered at a single scale. Rather, natural capital needs to be assessed and restored across scales (metamodel)." (Norgaard *et al*., 2007)

What about benefits?

Although the objective of this project relates to the costs of restoration, in order to evaluate a particular project and to compare with others, costs will need to be compared with benefits over the lifetime under consideration. Such data would be required for accounting and CBA purposes, so will need to be included in the asset and risk register, but cannot be given further attention here.

[8] Discussed further under 'Issues' in Chapter 6.
[9] The UN System of National Accounts

What work has been done on restoration costs?

Work on restoration costs can be reviewed in terms of conceptual and applied issues.

Conceptual issues

In the earlier UN publication on environmental-economic accounts, a complete chapter was devoted to degradation. Degradation gives rise to costs incurred to, 'prevent the damage or rectify the harm caused' (UN, 2003). However, restoration was only seen as one option amongst three, and the other two, incurring costs of halting the generation of residuals or of compensating for the damage caused, would be captured in standard national accounts, whereas potential, as opposed to actual, restoration costs would not.

Residuals: "Flows of liquid, solid and gaseous materials, and energy, that are discarded, discharged or emitted by establishments and households through processes of production, consumption or accumulation." (UN, 2012a)

Although more emphasis seemed to be given to these two other 'solutions' in addressing the problem of degradation, SEEA-CF (UN,2012a)[10] did give attention to the time dimension and the possibility that restoration might not be remedied immediately – the concept of ecological or environmental debt was introduced, in which damage costs built up over a period. Also, hypothetical restoration costs were seen as potentially useful, but only outside the direct scope of environmental-economic accounting; this has been recently reiterated (UN, 2017; Obst, 2017), but does not have universal support (Steurer, 2017).

In the 2012 manual (UN, 2012a) there was more attention to depletion - 'the fall in the value of a resource stock due to its use in productive activity' which, as it was concerned with individual resources rather than ecosystems, was narrower than degradation. It was the SEEA Experimental Ecosystem Accounting (UN, 2012b) manual which was more focussed on degradation than depletion. However, although there was attention to which economic actors the degradation should be allocated, discussion of restoration costs was limited.

In their input to the technical recommendations to the SEEA-EEA (Hein *et al*, 2015) discuss ecosystem capacity, 'the ability of the ecosystem to generate a basket of ecosystem services under current ecosystem condition and uses at the maximum sustainable yield that does not lead to a decline in the condition of the ecosystem.' (Hein *et al*, 2015, p.5) Degradation is evident in a sustained and significant decline in the condition and capacity of the ecosystem to generate the basket of services of over several years or more. It is important to measure physical changes and identify their drivers, rather than relying only on monetary measurement, as degradation may occur even when some services do not show a decline or when prices counterbalance physical reductions.

Dickie (2014) in a review of restoration evidence for the NCC, noted the complexity of the degradation/restoration issue. For any site or habitat there is the need to understand the initial state of the habitat (degree of degradation, species composition, abiotic variables, proximity to the

[10] UN SEEA – Central Framework

threshold), the restoration activities to be undertaken, the target state, whether this would be reached or exceeded, and the time frame for this process.

Dieter Helm published his ‘Natural Capital – Valuing the Planet’ in 2015 (Helm, 2015). In discussing the pursuance of a more optimal set of natural capital assets he suggested that restoration be part, but not the whole focus, since even non-degraded assets could be maintained or even enhanced, protected areas linked, and new habitats created as well as degraded ones restored. Although there was scope for small scale activities, restoration projects should be large in scale, thus: “A more optimal set of natural capital assets – is about large-scale, ambitious restorations, focussing on systems and infrastructures. It is about wide-ranging and integrated river, landscape and marine improvements considered in the round, rather than a series of smaller-scale projects, valuable though they are.” (p.202). Furthermore, generational restoration plans are needed for main assets, taking account of population and development pressure, geography and geology, alternative uses of natural capital.

In line with NCC (2014) and Mace *et al* (2015) Helm recognised that resources would best be focused on identifying the habitats and areas most at risk, rather than attempting to produce a comprehensive register from the outset. He suggests the identification of those ecosystems and assets close to thresholds and situations where there is most risk, albeit taking account of the opportunity-cost of the use of scarce investment resources: “Scarce resources need to be directed to where the marginal benefits are greatest.” (p.207)

Finally, Eftec (2016) in their work for WWF-UK, suggested that targeting should naturally be on currently less productive parts of current land uses, with relatively low opportunity costs (such as peatland, wetland on floodplains, lower grade woodland, saltmarsh on already-affected flood areas), areas which might become less favourable in their current uses under climate change. They also suggested more integration of government policies, and a better use of current subsidies to encourage the protection and improvement of natural capital.

Practical/applied issues

There are a substantial number of published sources of restoration costs data, some being review studies evaluating the work carried out and drawing conclusions from this, while others are more akin to manuals providing typical or average figures for various operations in different habitats. These publications range from manuals of costs, general and habitat-specific, through reviews with more detailed annexes to case studies and journal articles with some mention of restoration costs, to case studies of particular sites. Some publications report on the results of restoration activities, so costs are ex post, while others suggest the expected costs if for future restoration activities, ex ante.

According to IEEP (2013), “… there is a large amount of data on the costs of practical ecosystem maintenance and restoration costs, most notably from agri-environmental schemes as well as some nature conservation projects.” (p.15) and, referring to this and GHK (2006), Eftec (2015) reported: “There is well established evidence on the costs of managing land for nature conservation purposes and of ecosystem restoration.” (para. 2.4.3) Thus, there does appear to be a considerable amount of data available on restoration costs, but this cannot be said for all ecosystems: Dickie, 2014, remarked at the paucity of information for some habitats and IEEP, 2013, despite their earlier comment, stated, 'relatively few detailed data on habitat restoration costs are available in published literature.' p.231. Furthermore, information is much more limited on the actual costs incurred by specific projects.

For some situations, information on restoration activities and, particularly, costs is not publically available (CREW, 2013) because of its commercial sensitivity. An even greater reason for the shortage of data on actual costs incurred is the lack of specific records. Cost data may not have been recorded in such a way as to facilitate identification of such detail, may have been archived, but not in a readily-accessible form, or may simply not be available. This was the case for the second pilot study (Lester, 2016) as well as for Forestry Commission projects in general - Isted (2016) noted that the accounting system employed did not allow identification of restoration costs from amongst all other costs.

An additional problem is that although some authors appear to be using restoration cost data in their analyses, they do not always publish the details (Eftec, 2015; AECOM, 2015; Buckmaster *et al*., 2012) and Sutherland *et al*. (2014), although identifying almost 300 potential interventions across a range of habitats, did not present any cost data.

In other cases, cost information is presented, but it is in such an aggregated form that it is of limited use (North Pennines AONB, 2015; River Restoration Centre, 2011; Rayment, 2010). Glenk *et al*., (2014), in the context of peatland, commented, 'capital and management costs are rarely reported separately and monitoring costs seldom noted at all. In many cases, lack of cost data reflects the relative newness of projects where capital works have only been completed recently and on-going management has yet to be undertaken.'.

In many cases, average figures are presented, but it is seldom clear how these averages have been arrived at. Thus, Harlow *et al*. (2012) stated that they were using, "only indicative estimates of the costs…" and even in the, arguably, seminal work of de Groot *et al* (2013), which screened 20,000 publications and focussed on 95 cases, the costs were accepted as being 'broad brush'. In other cases, the data are presented as having more authority (EA, 2015; Matthews, 2012; Rayment, 2010; PDNPA, 2008). Some publications use a range of sources, which include some which are extremely general (EA *et al*, 2015, Hodder *et al*, 2010), whilst others appear to be more specific. Jacobs *et al* (2004) even categorise the reliability of their estimates, using terms, 'relatively reliable', 'not …particularly accurate' and 'very poor'!

Perhaps the majority of publications use grant rates (GHK, 2006; Artz,2012; Mathews, 2012; EA *et al*, 2015; Eftec, 2010) , which do represent the cost to the funding authority, but not to the operator, and they do not generally account for spatial variability. Nevertheless, these rates do allow for the reasonable estimation of the likely cost to the government or other agency and are often themselves based on consultation with practitioners: as Harlow *et al* (2012) suggest, they can be used as a proxy for the actual costs.

The authors of quite a number of publications consulted with experts: contractors, advisers and forestry commission staff (FC, 2016), site managers and landowners (Hodder *et al*, 2010), local stakeholders and expert knowledge (Harlow *et al*, 2012) and contractors (EA *et al*, 2015). Only a minority make use of the data from specific sites. The most accurate means of identifying the site-specific costs which have been incurred is via records or recall of those most closely involved. As discussed above, there are problems in accessing records, but some publications report figures based on discussion with site managers. Thus Graves and Morris (2013) and Peh *et al* (2014) report costs derived from such discussions at Wicken Fen, while PDNPA (2008), although reporting on averages for peatland restoration sites, does refer to a database of a substantial number of projects[11].

It may thus be concluded that, although there are a substantial number of publications in which restoration costs are available, they may not be very accurate. However, the importance of this depends upon their uses. As several authors point out, the figures presented are meant to be indicative. (EA *et al*, 2015; Shepherd *et al*, 1999; Harlow *et al*, 2012) This may be acceptable for upscaling and initial investment appraisal. However, restoration costs are site-specific and there is reportedly a good deal of variability between sites and interventions (Mathews, 2012) with the potential for 'generalisation' error. (Provins, 2014) Consequently, in order that dependable project decisions be made, and to improve the accuracy of the models that will be needed for providing a reliable estimate of aggregate restoration costs, more work is needed to derive accurate site-level costs. Although their conclusions may now appear somewhat pessimistic, these words from IEEP (2011) do highlight the continued need for much more detailed investigation: "This literature review has uncovered a limited number of cost estimates for delivering different environmental needs at different scales. The accuracy of these estimates is very variable and in many cases the assumptions that sit behind the calculation of the cost estimates are at worst unclear and at best extremely variable which makes any comparability of the data problematic. In addition, the estimates tend to be context-specific and not necessarily amenable to upscaling to the EU level." (para 3.2.5)

Although there is a good deal of information on restoration costs across habitats and activities, this cannot be said of timings. Although there is mention of approximate timings of restoration activities in some of the publications, nowhere was there detail of what activities occurred or would be expected to occur within specific years of the project. This is a fundamental shortcoming.

One final word of warning: despite the need for more work on identifying site-specific costs and timings, for future projects the need for adaptability has been underlined by several correspondents (Lester and Hughes, 2016) and by the NCC (2014) itself.

The Annex provides a table of some typical restoration cost categories and approximate timings from a selection of publications for eight broad habitats. Appendix G provides a comparative tabulation of the various classification systems for land use/habitats.

[11] The database reports a large range of characteristics, but is not complete for all sites.

Annex Summary of restoration cost types by habitats

Using a number of papers[12] which have reviewed the evidence on restoration costs the table below summarises by habitat and main category, and also provides indication of the time scales.

Table1 Typical restoration activities and costs by broad habitat.

Roadmap (ONS, 2015) - habitats	Urban environ ment	Enclosed farmland	Semi-natural grassland	Woodland	Mountains, moorland & heath	Freshwater wetlands	Coastal margins	Marine
initial/ early costs	tree planting; river, hard bank removal removing surface sealing	herbicide seeding grass buffers create bare patches hedgerow creation decanalisation shelterbelt planting	cut herbicide cultivate lime acidification (pine chipping, bracken litter) seed/reseed fertilise hedgerow restoration	fell/thin conifers remove invasives bracken control fencing herbicide cultivation planting	clear fell bracken clearance bulldoze burn strip soil/turf shallow cultivation fencing seeding/reseeding	Wetlands: remove trees remove invasives coppicing sedge cutting remove degraded peat/ strip soil peat reprofiling dyke creation & restoration drain/ditch/gully blocking fencing establish reedbed planting (sphagnum,…) Water bodies: natural recovery after catastrophic event barrier/weir removal de-embankment reconnect side channels/ weirs/sluices re-meander add fish pass dredge diversion of effluent liming	remove/realign sea defences/walls excavation/re-excavation of lagoons/pools/creeks reprofile/ create islands channel widening/narrowing control/block flows/maintain weirs construct breakwaters drain blocking deep plough turf strip tree & invasive removal remove algal bloom fencing plant	Investment in management and clean-up resources

[12] Sources: Maskell. *et al.* (Dec. 2014); Natural England (2014b); Eftec (2015); IEEP (2013)

ongoing/ sporadic costs	Tree husbandry and management	maintain conservation headland natural regeneration maintain grass buffers land/soil management changes (planting times, organic, controlled fertiliser application, fallows) grazing management haymaking boundary maintenance plant undercrops/winter cover	natural regeneration graze conservation headland feature management grazing management	natural regeneration woodland management remove invasives replanting thinning bracken control reduce fertiliser	graze natural regeneration grazing regulation/management bracken clearance	Wetlands: grazing management maintain/landscape ditches& pools control weeds sedge cutting irrigation coppicing hydrological management reed cutting bird management cease burning Water bodies: natural recovery control riparian invasives	remove algal bloom graze grazing management	implementing/policing quota transitional support clean-up
opportunity costs (what has to be foregone)		**reduced cropping & grazing intensity** less fertiliser less intensive reduced grazing intensity move to hay from silage organic fallows	**reduced grazing intensity** stop fertilising *reduce intensity (grazing & forage)*	**higher management costs & delayed timber income** fallowing = delay replanting	**reduced or excluded grazing** remove/reduce livestock cease burning	**reduced or excluded grazing and commercial water abstraction** reduce grazing intensity cease burning reduce grouse-rearing capacity reduce abstraction	**reduce fishing intensity**	**reduced catch**
timescales		some short-term improvements in 1-5 yrs, hedgerows 30 years+ *	some short-term improvements in 2-5 yrs, full restoration 60-100 years or more*	initial improvements in 5-10 years, canopy closure 20-30 years, full restoration 100 year+ or never*	some short-term improvements in 2-5 yrs, other improvements 10-15 years and much longer*	some early improvements 2-20 yrs, other improvements 15-25 yrs, more complete restoration can take 80 years*	some early improvements 1-3 yrs, other improvements >10 yrs*	

Many studies state that the period of the study was not of sufficient length to enable the measurement of longer timescales.

Chapter 3 Ecosystem Condition, Ecosystem Services and Restoration – Concepts and Application

Summary

This paper explores the links between ecosystem condition, ecosystem services and restoration, and applies this to peatland, the context of the pilot studies. It is intended to provide a background to and support the approach taken in those studies

The supply of ecosystem services is determined by ecosystem extent, condition and spatial configuration, along with management and external influences. On a unit-area basis ecosystem condition, future management and external factors are the main determinants of the pattern of ecosystem services into the future.

Depending upon the objective, multiple indicators of ecosystem condition can be measured, but for specific purposes summary indicators have been proposed; this is the case for peatland.

The pattern of ecosystem service flows over time can be linked to current condition, with deterioration, maintenance or restoration occurring dependent on the future management of the ecosystem asset, although restoration may not be possible if a threshold has been exceeded.

Although data are limited, the time-based pattern of restoration activities and costs, as well as of benefits, can be predicted for a site in a particular current condition.

Multiple ecosystem benefits are likely to arise during restoration, and beyond; these might be complementary, competitive or supplementary. The physical flows of each ecosystem service should be estimated and valued, taking account of these interactions.

The comparative streams of costs and benefits for 'business as usual' and restoration can then be analysed for accounting and cost-benefit analysis purposes.

Introduction

This paper aims to provide a conceptual background to the links between the state of the ecosystem asset, the ecosystem services (ES) flowing from that asset, and the restoration activities and costs necessary to improve the state of the asset and hence the services which it generates. This is then applied to peatland as the ecosystem within which the two pilot studies lie. It is, thus, intended to provide the background to, and support, the approach taken in those studies. Further background material was provided in the interim project report (Bright, 2016): this will be referred to but largely not repeated here.

Although the volumes of the different services emanating from an ecosystem will be based on the extent and condition of the ecosystem, on a unit area basis, of these, it is the condition which will be the major determinant, although the pattern of use will also influence the services which are utilised, as Figure 3.1 illustrates.

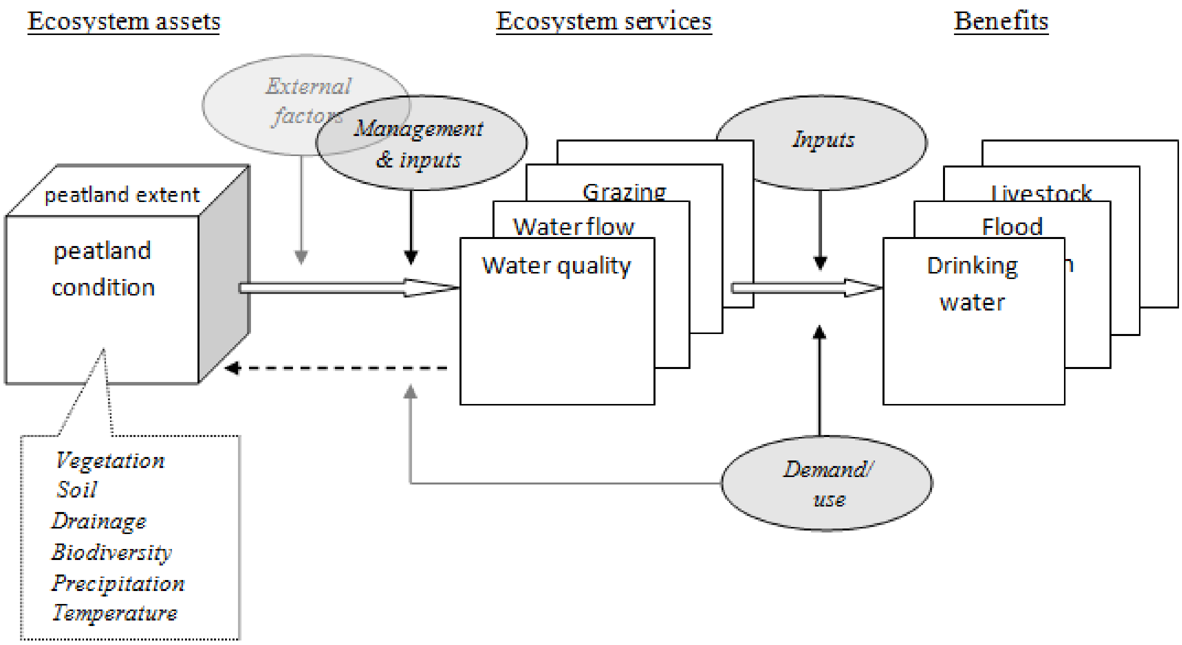


Fig. 3.1 Logic chain focussing on ecosystem condition, services and benefits for peatland

The present and future condition will be affected by its previous condition, how it is managed (and the other inputs which are applied to it), and external factors, such as climate change and changes in adjacent ecosystems. Additionally, the ecosystem services which are drawn from an ecosystem will also influence its future condition.

What we are particularly concerned with here is how condition is measured and the interlinkages between current and future ecosystem condition and services. Layered onto this is the part that restoration plays in this relationship, and how the whole can be applied to our pilot studies. The extent to which these findings can be applied more generally will be considered later

Condition indicators

To determine the extent, degree and type of restoration appropriate and even whether restoration is necessary or feasible, the condition of the ecosystem asset needs to be evaluated. This applies for a particular site and thence, by aggregating for all sites within each ecosystem. The future streams of ecosystem services flow from the ecosystem, so the level and pattern of these flows will depend upon the condition of the habitat:

Ecosystem condition … underpins the capacity of an ecosystem asset to generate ecosystem services and hence changes in ecosystem condition will impact on expected ecosystem service flows' (Vardon, 2014, p9)

Ecosystem condition: "The overall quality of the ecosystem, as expressed through a set of indicators expressing ecosystem composition and/or functioning (e.g. species diversity or net primary production)." (Obst *et al*, 2015)

"The physical, chemical and biological state of an ecosystem at a particular point in time." (EU, 2016, p.43)

Condition can be measured in a number of ways and how it is measured will depend on the ecosystem service of concern or should match critical pressures on condition (Bright, 2016; EU, 2016). However, for ecosystem accounting, condition measurement is likely to relate to the capacity of the asset to generate the most valuable bundle of ecosystem services. The number of indicators of condition will vary, as Hein *et al* (2015) suggest. A single indicator may be suitable for gauging the asset's capacity for generating a certain level of production of a number of ecosystem services; on the other hand, multiple indicators might be needed for just one ecosystem service. Maes *et al* (2015) identified 327 indicators, although not necessarily relating to only one service!

The Experimental Ecosystem Accounting framework (EC, 2013) lists water, soil, vegetation, biodiversity, carbon and nutrient flows as key characteristics which should be used to determine ecosystem condition indicators, Bonnett *et al.* (2011), in a restoration context, suggest biota, hydrology and biogeochemistry, while Defra (2017) lists seven broad dimensions of condition for which single or bundles of indicators might be devised. These are: volume, biodiversity, soil, ecological condition, spatial configuration, access and management practices, although not all of these aspects are relevant in all cases and can be specific to the particular ecosystem (EC, 2012; EU, 2016). The problem then emerges – how can a conglomerate indicator be devised to measure overall condition when the different sets of indicators are so different? It is possible to produce such an indicator by generating an average across all measures, in simple terms or using some predetermined weighting. On the other hand, it has been suggested and shown that some indicators are correlated, so that one indicator can be a proxy for several. (Smyth *et al*, 2015) Certainly, within the broad dimensions it may be acceptable to utilise single measures to represent the whole; for biodiversity, for instance, trends in keystone (Defra, 2017) or iconic (Smyth *et al*, 2015) species may be used. Conversely, it may be preferable to present all of the indicators in the form of a dashboard, although, this can make the process of determining where restoration is most appropriate more complex. Nevertheless, just what indicator or set of indicators is used depends upon the purpose to which it or they are to be put, and EC (2013) suggest that it is not likely that one set of indicators will be appropriate for all ecosystems.

For peatland, some institutions advocate the use of more general sets of indicators which can be applied across ecosystems (Maskell *et al*., 2014). Thus, in England, the Environment Agency, for SSSI's and SAC's, (JNCC, 2016) uses a seven-category scale (see Table 1 below) ranging from fair/maintained to destroyed. This overall measure is based on biodiversity, vegetation, soil and human intervention indicators derived from expert views as well as scientific measurement (pers comm. Ulf-Hansen, 2017). However, it has been found useful to produce scales specifically for peatland, such as those proposed by Birnie and Smyth (Smyth, M. *et al*, 2015), JNCC and IUCN. Due to the interest in peatland restoration for its impact on greenhouse gas (GHG) emissions, the Peatland Code (Reed *et al*., 2013) has a scale with six categories, one of which is split, although (Smyth *et al*, 2015, closely following Birnie and Smyth's model) suggested that, in practice, the split category be merged to produce five divisions, and, for carbon emissions/sequestration purposes, only four would be used – there being no GHG figures put forward for 'pristine' (see condition-service link later). This allies with EU (2016), who suggest that the number of categories be limited to between three and five. Table 3.1 provides a comparison of these indicators.

In Table 3.1, the peatland condition categories have been set out under the seven Natural England (SSSI) divisions, in an attempt to show equivalence. Further, in the light of descriptions given in the texts referred to, an estimate has been made of where the threshold might lie[13].

Threshold: "Point at which (below which) the decline in status accelerates and/or becomes difficult to reverse. A discontinuity whereby a small change in a driver exerts the largest change in an attribute or state of an ecosystem, typically abrupt." (NCC, 2014)

"A point or level at which new properties emerge in an ecological, economic, or other system, beyond which the system then behaves differently." (NCC, 2013)

Tipping point : "A point at which an (ecological) system experiences a qualitative change, mostly in an abrupt and discontinuous way." (Jax, 2016)

These peatland condition categorisations are generally designed for sites which might still be designated as peatland. However, in many sites, management and usage has lead, often over a long period, to the land now being classified into another ecosystem. Much of fenland England is now classified as farmland, while other areas have become woodland, grassland or heathland. (Chapman *et al.,* 2015) Thus, recognising the change of use, Lindsay and Immirzi *(1996*) have classified, particularly raised bogs, into nine categories of known use, covering primary, secondary and archaic.

For the purposes of the Exmoor Mires case study the five-division scale (Smyth *et al*, 2015 above) will be used, while for Wicken Fen, categorisation will take account of changed land use. (James Hutton Institute, 2015) When further work is carried out toward the production of whole habitat and national ecosystem accounting of restoration, further consideration will have to be given to whether these are the appropriate means of scoring condition. In the current study, the (adjusted) Peatland Code, five-point scale, is advantageous because it has been associated with differing emissions/sequestration levels and because the other service of high apparent value, water quality and consistency, is likely to be correlated with this.

[13] Smyth *et al*, 2015 suggest that sites in the 'actively eroding category are unlikely to have the potential of return to the near-natural category due to modified hydrology.

Table 3.1 Ecosystem (peatland) condition categories

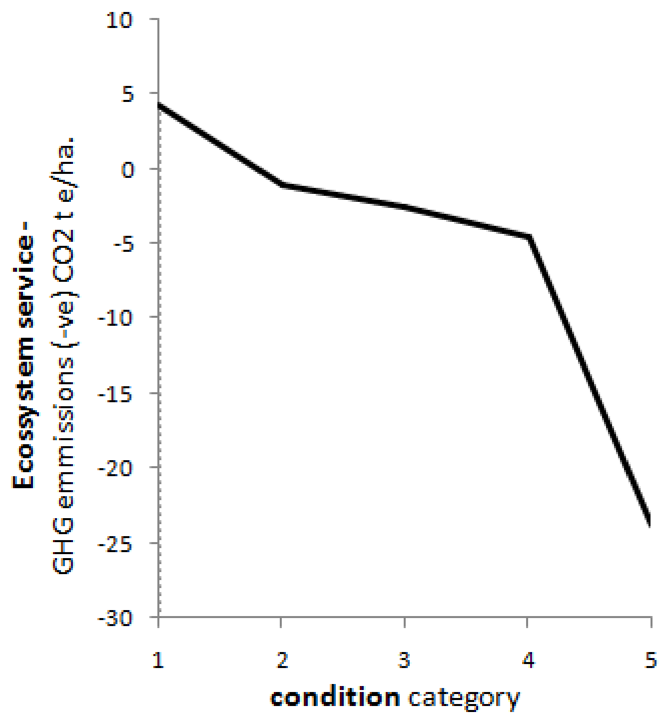
<table>
<tr><td>source</td><td>ref/notes</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td colspan="2">6</td><td>7</td></tr>
<tr><td>NE - SSSI</td><td>Brunea, & Johnson, 2011</td><td>favourable - maintained</td><td>favourable - recovered</td><td>unfavourable - recovering</td><td>unfavourable - no change</td><td>unfavourable - declining</td><td colspan="2">partially destroyed</td><td>destroyed</td></tr>
<tr><td>JNCC</td><td>Evans et al, 2011; Medcalf et al, 2014</td><td colspan="2">1. active</td><td colspan="2">2. degraded</td><td>3. bare</td><td colspan="2">4. archaic</td><td>5. wasted</td></tr>
<tr><td>Peatland Code Metrics</td><td>Smyth et al, 2015</td><td>1. pristine/ naturally functioning</td><td>2. near natural</td><td colspan="4">3. modified</td><td>4. drained</td><td>6. actively eroding</td></tr>
<tr><td>Peatland Code</td><td>Lunt et al, 2010; Buckmaster et al, 2012</td><td>1. pristine</td><td>2. near natural</td><td colspan="3">3. modified - degraded</td><td>4. modified - highly degraded</td><td>5. drained</td><td>6. actively eroding</td></tr>
<tr><td></td><td>description</td><td></td><td>no fire little trampling no bare</td><td colspan="3">some fires bit grazing little bare</td><td>freq bare patches fires, grazing sphagnum</td><td>within 30m grips</td><td>extensive bare past peat cutting</td></tr>
<tr><td>Birnie & Smyth</td><td>Smyth et al, 2015; Bain et al, 2011</td><td>1. intact</td><td></td><td colspan="3">2. moderately degraded</td><td>3. highly degraded</td><td>4. eroded</td><td>5. artificially drained</td></tr>
<tr><td></td><td>peat forming</td><td>intact</td><td></td><td colspan="3">reduced</td><td>lost</td><td>lost & mass being destroyed</td><td>reduced and possibly lost</td></tr>
</table>

threshold?

Condition and ecosystem services

The services generated by an ecosystem asset are dependent upon the three aspects mentioned earlier – extent, condition and spatial configuration, further influenced by management and external factors such as air pollution. (Bright, 2016) From a particular site, the services per unit area will be determined by its condition, management and external factors[14].

Condition indicators, because they tend to be ordinal, will be correlated with values of current services, but there is not necessarily a linear relationship between them. Thus, the left-hand graph in Figure 3.3 shows a hypothetical relationship between ecosystem condition and current services, whereas Figure 3.2 illustrates the relationship between the five adjusted Peatland Code categories shown in Table 1 above with the possible GHG emissions associated with them.[15]



Source: Worrall *et al*, 2011; Natural England, 2010; Smyth *et al*., 2015

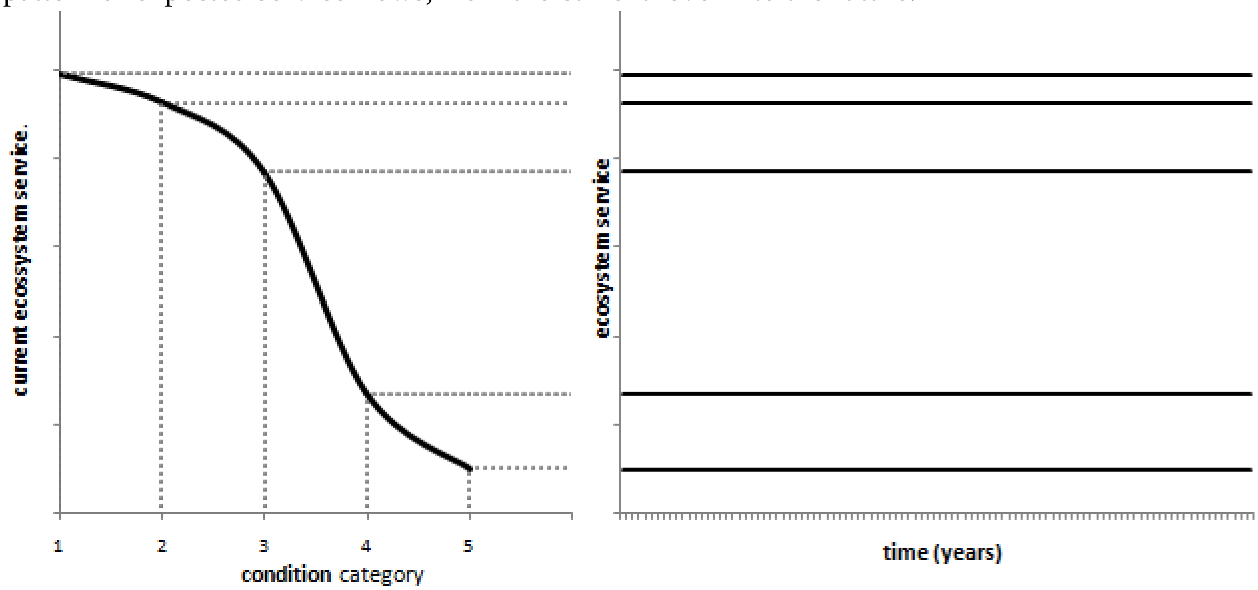
Fig.3.2 Peatland ecosystem categories and GHG fluxes

[14] The discussion here, and following, implies a deterministic relationship between ecosystem condition and ecosystem services. However, in practice the relationship can only be determined with a degree of uncertainty.

[15] Although the emissions/sequestration associated with pristine condition 1 is taken from a different source to that of categories 2-5.

Condition and future ecosystem services

A specific condition category will be associated with, not only the current service generated[16], but also the expected pattern of flows into the future, although this will also be dependent upon ongoing management and other factors (Obst *et al*, 2015; EC, 2013). For renewable assets the pattern of future service flows may be constant, rising, or falling. (Defra, 2017) If condition is maintained as a result of continued levels of management and other inputs[17], *ceteris paribus*, ecosystem services will also remain constant. (EC, 2013) This is the case if the condition of the ecosystem or site is pristine or near natural, but may also pertain if the ecosystem has been degraded but its condition is managed to maintain it at that level, albeit at a level below potential. Figure 3.2 illustrates this: the left-hand graph shows the link between categories of ecosystem condition and current ecosystem services, while the right-hand side shows the pattern of expected service flows, from the current level into the future.



Key: Right-hand graph lines show ES flow following different starting condition categories from left-hand graph.

Fig. 3.3 Ecosystem condition and constant ecosystem services

Sites whose condition and management suggest that they will be maintained can be described as sustainable. Even sites of inferior condition, but which are expected to be maintained, may also be classified in this way despite having the potential to generate a higher level of ecosystem services, albeit necessitating improved management and other resource inputs.

Environmental sustainability: "The dynamic equilibrium by which the environmental functions remain available for future generations (for renewable - regenerative capacity remains intact; non-renewables – substitutes developed)." (Hueting, 2013)

[16] As Figure 6 indicates, services derived may exceed the current sustainable capacity of the ecosystem, but this is only possible in the short term

[17] This may involve use of inputs and direct management in the site and/or deliberate avoidance of use of the ES, so that off-take is limited. For instance, grazing animals might be excluded from the site. In this case, rather than a direct cost, it is opportunity costs incurred.

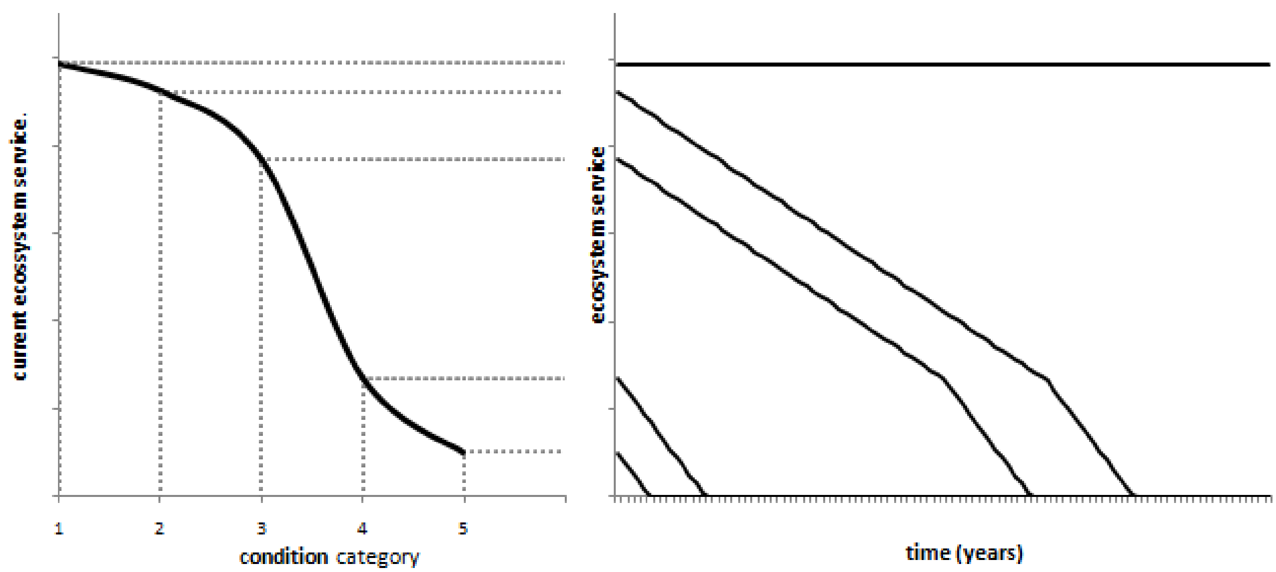
However, the ongoing management of a site may not be sufficient to maintain the ecosystem services into the future, the condition will deteriorate and, with it, the flow of future ecosystem services. As Obst *et al.* point out: "Degradation of the ecosystem would be reflected in declines in ecosystem condition and a reduction of the ecosystem's ability to generate ecosystem services over time." (Obst *et al.*, 2015, p.5)

Ecosystem degradation: "A declining trend in the value of expected service flows due to decline in ecosystem condition and capacity/reduction in ecosystem capacity to and production of ecosystem services."

"A decline in an ecosystem asset over an accounting period." (EC,2012)

Ecosystem service degradation: "For *provisioning services*, decreased production of the service through changes in area over which the services is provided, or decreased production per unit area. For *regulating* and *supporting services*, a reduction in the benefits obtained from the service, either through a change in the service or through human pressures on the service exceeding its limits. For *cultural services*, a change in the ecosystem features that decreases the cultural benefits provided by the ecosystem." (Brown *et al.*, 2011)

The straightforward assumption about the pattern of future ecosystem services may be that they move in a linear fashion (Dickie, *et al.*, 2014), although this is unlikely to be realistic (except in the case of non-renewable resources[18]) since it could lead to extremely high or zero services in the future. In this context, changes of slope may be shown to occur – thus, thresholds and tipping points are envisaged as points at which the straight line drastically changes slope, as the right-hand graph in Figure 3.4 shows.



Key: Right-hand graph lines show ES flow following different starting condition categories from left-hand graph.

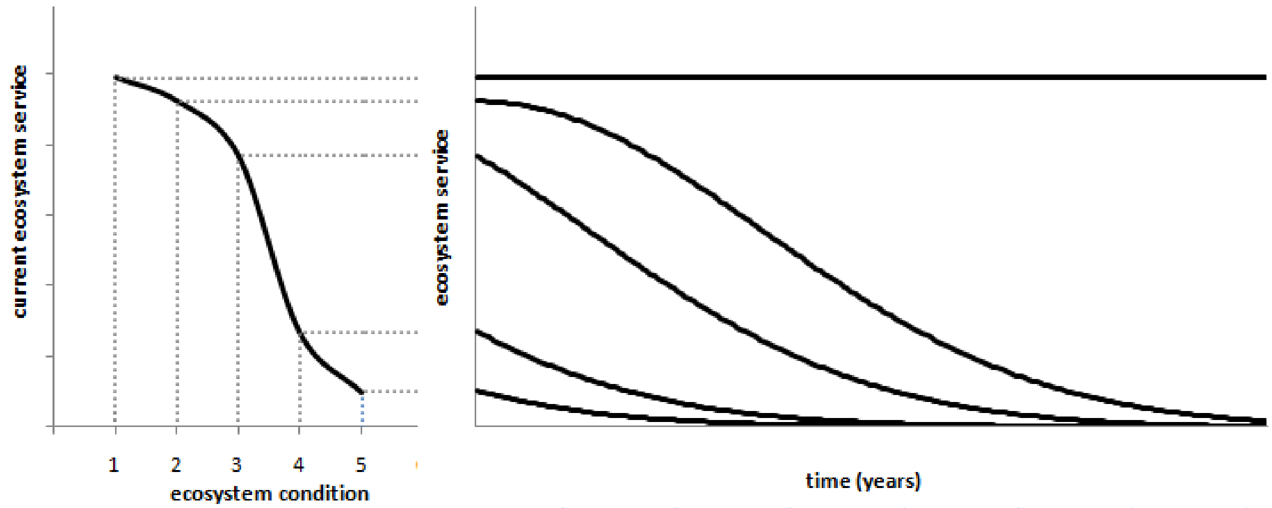
Fig. 3.4 Ecosystem condition and linear ecosystem service flows

In reality, future service flow patterns are likely to be curvilinear. (Mace, 2014; Provins, 2013; EC, 2013) Thus, Figure 3.5 implies that, once condition deteriorates from a pristine condition, there is an initial gradual decline in services, which increases in pace as deterioration

[18] Even then, as condition and services decline, the cost of extracting or providing the services may increase and so their exploitation may slow.

accelerates, but then slows as a high degree of degradation is reached. The actual shape of such curves, including their time-based pattern, is important for, *inter alia*, ecosystem accounting and so deserves further ecosystem and site-specific study.

The level of services arising from a site in pristine condition may be seen here as the maximum sustainable.



Key: Right-hand graph lines show ES flow following different starting condition categories from left-hand graph.

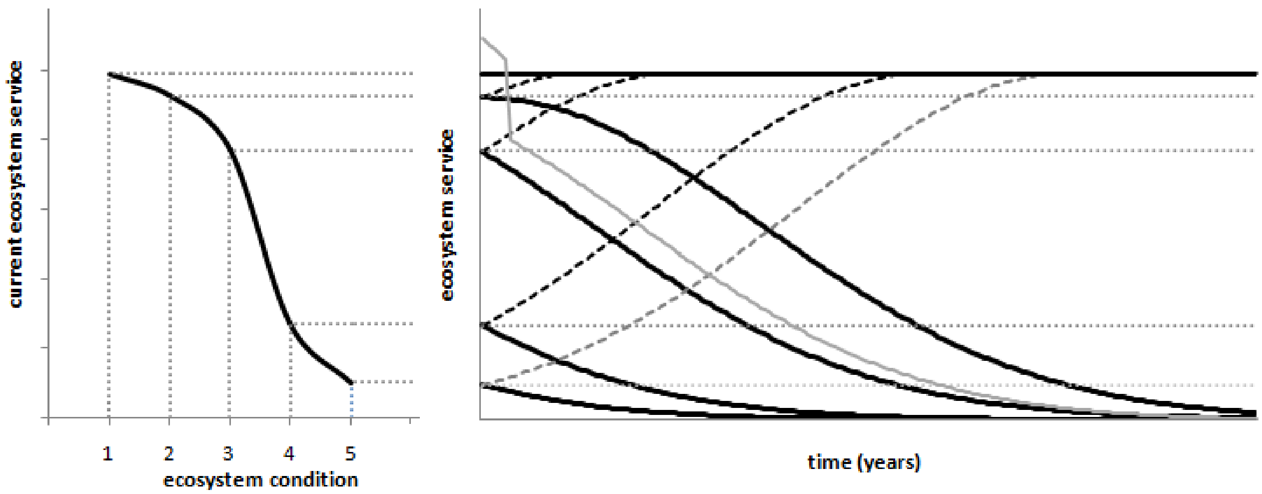
Fig. 3.5 Changing ecosystem condition and non-linear decline of ecosystem services

The current services being derived may, for a time, exceed those that are sustainable given the current condition – such would be the case for provisioning services for which the off-take exceeded annual production. But as the level of ecosystem services is above what is currently sustainable, this could not be maintained and condition would quickly deteriorate as would services (as the light grey solid line in Figure 3.6 illustrates). Timber felled earlier than its optimal economic rotation length, would be an example here, with future negative impacts on timber production as well as other services. However, it is conceivable that a higher sustainable level can be achieved, and this is particularly the case if external factors, such as climate change, have acted favourably upon a site, so that it may be able, in the future, if managed appropriately, to generate higher levels of ecosystem services than it did in its earlier, undisturbed, reference state.

Ecosystem capacity: "The ability of the ecosystem to generate an ecosystem service under current ecosystem conditions and uses at the maximum level that does not lead to degradation of ecosystem condition." (Hein *et al*, 2015)

"The ability of the ecosystem to generate an ecosystem service under current ecosystem conditions and uses at the maximum yield or use level that does not negatively affect the future supply of the same or other eco services." (UNEP, 2015)

On the other hand, it may be possible, if the management effort is sufficient, to enhance the condition of the site and so increase the service flows in the future, although it is likely to take longer to restore, the more degraded the site is in the first place (see thick dotted lines in Figure 3.6) and the return path to earlier condition may exhibit hysteresis – following a different pattern to that which it followed to reach its current condition. However, there may be sites of severely degraded peat which have passed their threshold or tipping point and cannot feasibly be restored, and the deterioration might inexorably worsen.



Key: Right-hand graph lines show ES flow following different starting condition categories from left-hand graph. Black curves/lines – business as usual (bau); thick dotted lines – restoration; fine dotted lines – maintenance; grey curve – ES unsustainably extracted.

Fig. 3.6 Changing ecosystem condition and degradation and restoration of ecosystem services

Note that a maintained site is expected to remain in its current category, whereas sites which are not maintained or undergo improved management can be expected to move into inferior or superior categories respectively over the future, which then generate lower/higher ES. Thus, future services will grow or decline in accordance with the ecosystem condition – and this will be dependent upon the management and resource input, as well as external factors, including climate change. In Figure 3.5, in the right-hand graph, moving down the ES curve associated with ecosystem condition three from the left-hand graph, takes us, over time, to a lower point associated with ecosystem condition four, i.e. ecosystem condition, under current management, is expected to decline from its current level of three, to four, which gives rise to a lower level of ES at a later time point, followed by ecosystem condition five and lower levels of ES further into the future.

There are situations in which deterioration in condition can even lead to negative ecosystem services – peatland degradation and consequent GHG emissions being an example of this, as Figure 3.1 illustrates. Restoration will then lead to a reduction in disservices, rather than an improvement in services, although eventually the site could move into positive service provision (carbon sequestration rather than emissions, for instance). The disservices element of an ecosystem will be dealt with elsewhere than in the ecosystem accounts – the impact of this will be analysed for the pilot studies.

Restoration, condition and ecosystem services

The aim of ecosystem restoration is, as the term and definitions suggest, to return the ecosystem to an earlier, preferred state.

Ecosystem restoration: "The return of an ecosystem to its original community, structure, natural complement of species and natural functions" (CBD, 2011*)*

"The process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed" (*SER, 2004*)

"The return of an ecosystem to its original community structure, natural complement of species, and natural functions." (Lammerant *et al*., 2014)

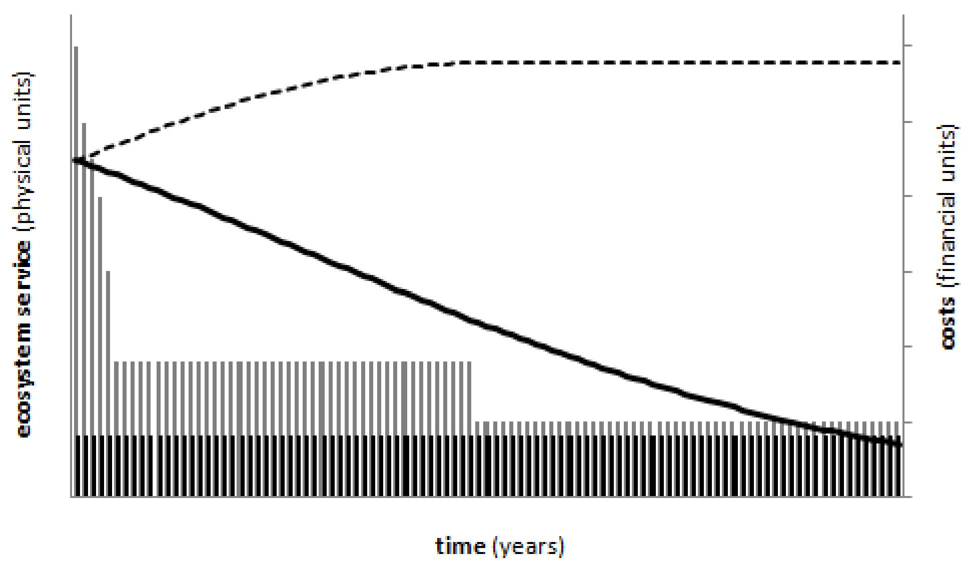
This aimed-for state is known as the target condition, and the earlier position which forms the target is the reference condition. (EC, 2012) How far back the reference point should be is open to debate: some would look to a 'pristine' state, focussing on pre-Industrial Revolution conditions or earlier (Defra, 2017), while others would take a point shortly after the Second World War or perhaps 30 years ago or, in an accounting sense, the condition at the start of the accounting period. (UNEP, 2015) Others have suggested that the pristine state may be unknown, undesirable or unreachable (Moors for the Future Partnership, 2008; Hughes *et al*, 2011; EC, 2012), particularly as environmental influences are no longer the same, and 'improvement', rather than 'restoration' might be a better term. (Dickie, 2016) As Helm has suggested: "Recognising that there is no Arcadia to get back to, any restoration plan has to start with where we are rather than where we would like to be." (Helm, 2015, p.209)

This debate is of some consequence since having an agreed, common time point to determine reference and thence target conditions can be useful for comparisons of progress. However, for decision makers, it does not matter so much what the reference point is, as long as target conditions are seen as realistic, allowing reasonable estimates to be made to compare the costs and benefits of business as usual and restoration scenarios. The more ambitious the target, the longer is it likely ot be before the desired as conditions are met, and time scales can be substantial. (Bright, 2016; NCC, 2014; Green *et al*., 2015)

If a process of restoration is successfully implemented then condition is likely to improve and thence the flow of services. As noted above, however, the pattern of recovery may exhibit hysteresis, following a different, and possibly slower, upward path than its previous downward path. (Glenk *et al*, 2014) Possible restoration curves are shown in the right-hand side graph in Figure 3.5. If, however, the asset has been allowed to degrade a great deal, it may not be possible to implement a programme of restoration, and the asset condition and the services it provides can be expected to degrade further over the following years, although there may be a levelling off at a very poor level of condition, associated with a very low level of ecosystem services or even disservices (GHG emissions from degraded peatland, for instance). The light-grey dotted line on the right-hand side of Figure 3.5 indicates that such restoration may not be feasible, or may take a very long time.

If restoration is planned to take place at a particular location, the relationship between current condition and the flow of current and future ecosystem services indicates the points in time at which improved condition categories are reached and the timing of reaching the target condition and service flow. This will also determine the expected timing at which restoration inputs and hence costs can cease and the project will change to a maintenance mode, with likely lower maintenance costs. Although this does not provide the pattern of restoration costs, only the end point, movement into improved condition categories can be estimated and those different condition categories will necessitate different restoration activities in terms of intensity and timing. For example, moderately degraded peat may require only the limitation of grazing and burning, while restoration of drained peat will require more expensive drain or grip blocking and subsequent maintenance. Thus, as linking condition to service flow facilitates estimation of ecosystem benefits, linking condition with restoration activity patterns facilitates estimation of costs – both restoration and maintenance.

Figure 3.7 provides an example comparing the ecosystem services and costs which might arise when two different management approaches are followed. The current ecosystem service (arising from the current ecosystem condition) is denoted by the point on the x-axis from which the continuous line (business as usual - bau) and dotted line (restoration) emanate. For bau ecosystem services deteriorate as the ecosystem deteriorates, with costs (dark bars) remaining at a low level, reflecting the relatively low input of management and associated resources. If, on the other hand, restoration is undertaken, ecosystem services are expected to rise until the target condition is reached, after which they stabilise. To achieve this, relatively large costs are incurred in the first few years (light bars), followed by lower, but substantial, costs in subsequent years. Once the stable ecosystem services flow is achieved, costs required to maintain ecosystem condition (i.e. no longer restoration, but maintenance, costs) are lower, albeit above bau costs.



Key: black line – ecosystem services (ES) under business as usual (bau) scenario; dotted line – ES under restoration scenario; black bars – costs under bau scenario; grey bars – costs under restoration scenario

Figure 3.7 Service benefits and costs under business as usual and restoration scenarios

The types of restoration activities, costs and timings were discussed in Chapter 2.

Given the flows of ecosystem services and costs, which approach is most profitable or preferable from the viewpoint of the asset holder or society, respectively, depends upon the values applied to the ecosystem services flows and the discount rates applied. This enables a cost-benefit analysis (CBA) comparing the two approaches to be made.

Such a comparison will help to determine whether restoration is worthwhile from the perspective of the ecosystem asset holder and society (a conclusion which, if market and social prices and discount rates do not align, may not be the same). Furthermore, if the threshold or tipping point has been exceeded, then restoration may no longer be feasible. In a peatland context, the condition classification would suggest that this generally occurs around categories 4 and 5, where peat is classed as archaic, wasted or lost. (Smyth *et al*, 2015)

Thus, linking ecosystem condition to the current and future flows of ecosystem services provides a means, not only of estimating the stream of benefits derived from a particular site, but also of estimating the restoration costs likely to be incurred, and the increased benefits arising. Although information on costs and timings is limited, by making use of a combination of value transfer techniques, with particular use of geographical information systems (GIS) and expert opinion, as the UK's Natural Capital Committee has done (NCC, 2014) along with sensitivity analysis, valuable guidance can be provided for policy makers and others in the meantime (Smyth *et al*, 2015; DeFries and Pagiola, 2005).

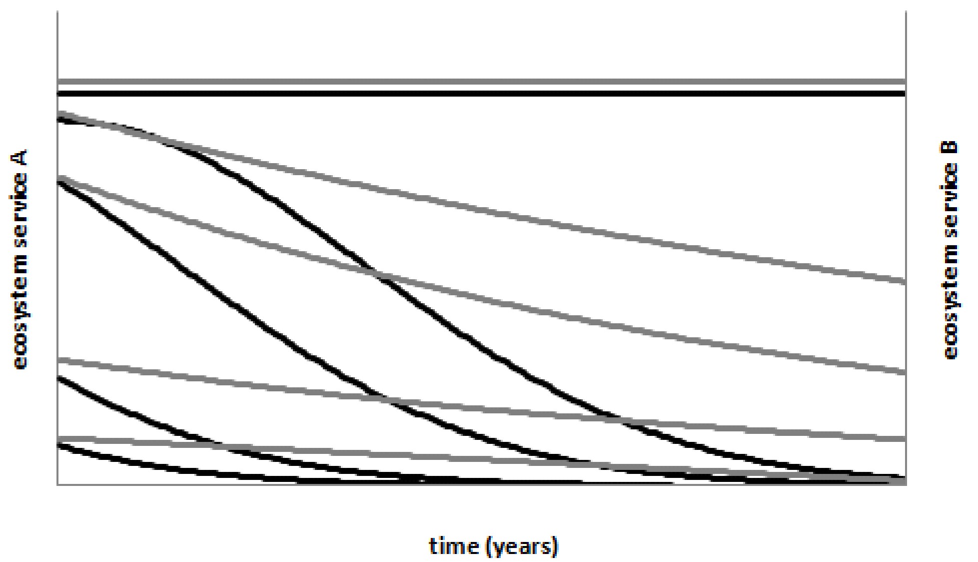
Single or multiple ecosystem services

So far the discussion has proceeded (along with the accompanying figures) as if there were only one ecosystem service arising from the ecosystem, while, in fact, several ecosystem services are likely to be generated. If the services are all positively correlated, which can often be the case with regulating services (such as CO_2 and water quality in peatland) then the single curve can be representative. However, if services do not move together under a specific regime of management of an ecosystem asset, and this can be particularly the case between provisioning services or between these and regulating services, then the ES curves shown earlier can instead be taken to represent the combination of the services.

In practice, this issue needs to be dealt with in more detail. In physical terms it is possible to represent the flows of the different services separately (as with the graph in Figure 8, using different axes for two ecosystem services), even if they do not follow the same patterns[19]. In this case, the services can then be combined employing value as the common factor – the total

[19] In fact, higher levels of condition may represent (especially current) higher levels of some ecosystem services, but lower levels of others – good condition fenland may be linked to superior levels of biodiversity and water quality, but poor levels of crop production, for instance. This depends, of course, on the indicators of condition used. In fact, it is feasible that different condition measures be used for different ecosystem services, with differing periods of time of moving between the different sets of measures.

value over time of the bundle of ecosystem services can be used, based on the exchange values or other accounting valuations of each of the ecosystem services, both currently and predicted for the future: The curves in Figures 3.6 (right-hand graph), 3.7 and 3.8 can thus be taken as representing the values of the bundle of ecosystem services.



Key: black line – ecosystem service A; grey line – ecosystem service B

Fig. 3.8 Ecosystem service flows – differing patterns for services A and B

The extent to which the different ecosystem services generated by an ecosystem asset vary according to different conditions, management and other resource inputs, and over time needs to be understood in order to evaluate the bau or restoration options. In economic terms, in their generation or production the different ecosystem services may be termed complementary, if they tend to be positively correlated, competitive, if the increase of one tends to be at the expense of a reduction in the other, or supplementary, if generation of more of one has no impact on the amount of the other. Consequently, at least in certain situations, biodiversity changes and GHG amelioration may be complementary, crop production and flood protection may be competitive, and wind energy and grassland productivity may have a supplementary relationship. In fact, the relationship between two ecosystem services can exhibit each of the three characteristics depending on how management and resources are deployed. For further discussion of the interrelationship between ecosystem services see the Annex.

If there is an understanding of the relationship between current condition and the current flow of ecosystem services, then this is the starting point for the estimation of the comparative benefits of continuing ‘business as usual’, i.e. a continuation of the current management of the site, relative to restoration. However, not only is understanding of the expected pattern of the flow of services into the future required, but also of the likely costs involved – the amounts and timings. Although this is a difficult task, it is not one which solely falls to those calculating restoration effects – even on the assumption of the continuation of ‘business as usual’ necessitates the estimation of the future flow of ecosystem services, and even just assuming that the services will continue at the same level (Figure 3.2) must be justified as much assuming an improvement or deterioration (Figure 3.5). However, as Green *et al* (2015) and

James Hutton Institute (2015) suggest for peatland, there is a great deal of uncertainty about future flows under current and alternative management regimes. So, not only should the degree of uncertainty be evaluated, but attention to the sensitivity to the assumptions should also be given.

Extent and spatial configuration influences on restoration

Although in a unit area context ecosystem condition is the key aspect to consider, in order to understand the overall impact of restoration, ecosystem extent and spatial configuration also need attention. These aspects will be discussed for both pilot studies.

Applying the ecosystem condition-ecosystem services relationship in the pilot studies

For the pilot studies, estimated restoration activities, costs and timings (as well as benefits) will be compiled for the relevant condition categories and applied to their specific circumstances. Although the evidence on timings is limited due to the relative infancy of restoration work (Smyth *et al*, 2015; JNCC, 2006; Bright, 2016), estimates are available from published sources (Lunt *et al*, 2010; Bonnett *et al*, 2009; Chapman *et al*, 2012b) as well as on-site practitioners.

Table 2 Tabulation of figures to be derived for the pilot sites

	Amounts, values & timings ➔	
	Current position	Future
Extent		
Condition		
Restoration:		
- Activities		
- Costs[20]		
- Ecosystem services		
○ Provisioning		
○ Regulating		
○ Cultural		

For each site, using actual and estimated data from the site managers, the spatial extent and current condition will be tabulated. Restoration activities, costs and timings will be derived based on condition, and current and expected ecosystem service flows, in physical and value terms will also be estimated. For those areas for which the land-use and ecosystem classification has and will change as a result of the restoration work, there will be account taken of the changing extent as well as condition. This is particularly the case for the Wicken Fen Vision Project where some of the area is being restored from cropland to fen.

[20] Chapter 2 discusses the types of costs expected. Of these, opportunity costs would not be included directly in the ecosystem accounts relating to the restoration activity, but would be present in a cost-benefit analysis.

From this information, and alongside cost and ecosystem services estimates for the bau scenario, ecosystem accounts will be produced and CBAs carried out..

Concluding remarks

The link between current ecosystem condition and the flows of ecosystem services for 'business as usual' and restoration scenarios enables prediction of benefits and costs, and thence construction of accounts and CBAs to take place, albeit with the necessary cognisance of the degree of uncertainty.

In a peatland context, summary condition indicators are available and will be used in the pilot examples. However, the limitations of using such summary indicators need to be evaluated, as does the feasibility of this approach for other ecosystems.

The relationship between the ecosystem condition and ecosystem services is expected to be positive, but may be negative in some cases. Also the relationship between the various ecosystem services generated may be complementary, competitive or supplementary, and the future flows of each may follow differing patterns, so this needs to be given consideration.

Information and data on restoration costs (and resulting benefits) are limited, so the uncertainty surrounding estimates should be taken into account.

Annex Representing ecosystem service relationships using a possibility frontier approach

The relationship between ecosystem services can be illustrated using the economist's production possibility frontier, adapted for the idiosyncrasies of the ecosystem context[21] - we can term this the ecosystem service possibility frontier (ESPF)[22]. The relationship between two ecosystem services, for a certain current condition and pattern of management and resource input is shown in Figure 3.9 below.

The curve represents the possible combinations of the flow of discounted streams of ecosystem services (ES) C and D, given a starting ecosystem condition and a fixed amount of management and other resources. It shows the frontier of possible ES combinations; combinations inside the curve would be possible, but 'technically inefficient', while points beyond the curve could not be reached, given the current condition and the given resource inputs[23]. The curve between the y-axis and point X is positively sloped, denoting a complementary relationship between ES C and D; between points X and Y the negative slope denotes a competitive relationship and between point Y and the x-axis, a supplementary relationship[24].

[21] The incorporation of multi-period flows is based on Bright (2007).

[22] As noted earlier with regard to the ecosystem condition-ecosystem services relationship, so also here with the ecosystem services-ecosystem services relationship – in practice, the predicted relationship will be subject to uncertainty.

[23] This ties in with the discussion of the potential and capacity of an ecosystem asset in EC(2013) paragraphs 2.32 and 2.33.

[24] If ES are produced in 'tandem'(paragraph 2.32, EC, 2013) they are complementary throughout, rather than just over a range.

Different points or ranges along the ESPF could represent different management approaches, showing greater emphasis on ES C relative to D – greater attention to, and resource focus on, certain provisioning, rather than regulating or cultural services, for instance.

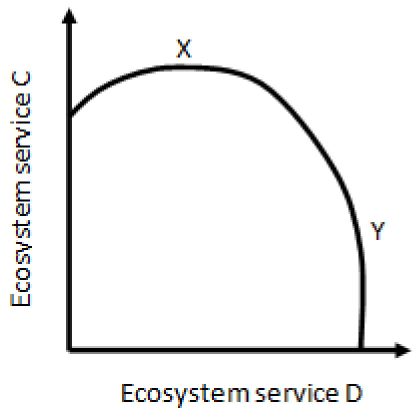


Figure 3.9 The ecosystem service possibility frontier

The frontier can be deemed to represent what would actually be generated by the ecosystem. However, if the resources were not used with greatest efficiency it might be possible to generate greater combinations – this is shown in Figure 3.10 below- the solid line representing what would be expected to be achieved – the 'actual', while the dotted line represents 'capability'. If actual ES generated by an ecosystem are below 'capability', i.e. if the solid is closer to the x-axis than the dotted line, this would imply that 'technical' inefficiency exists.

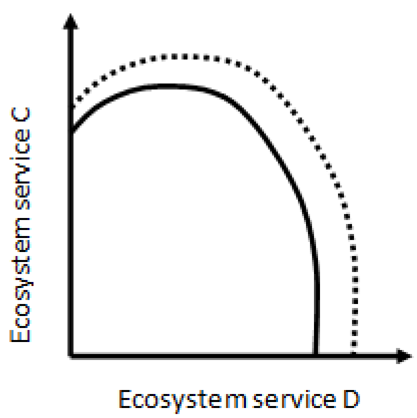
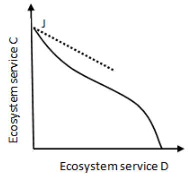


Fig. 3.10 ESPF – actual and capability

The most (economically) efficient combination of ES would occur in Figure 3.11 where the line whose gradient is the ratio of the values[25] of the two ES is tangential to the ESPF[26]. If market prices are used, the solid grey line is the appropriate 'isoreveneue' line, which produces a combination of ES at point F. However, if market prices do not represent society's valuation, perhaps because of inefficient markets, taxes and subsidies, public goods and

[25] Expected values for the period covered.

[26] There may be situations in which the convexity, or even concavity, is such that a 'corner solution' would be optimal (e.g. point J in diagram below) – with all of one ES and none of the other.



This may occur for small or homogeneous sites, but is less likely as the size and viability increases.

externalities, the ratio of values from the viewpoint of society may be shown by the gradient of the dotted line. In this case the appropriate combination of ES would occur at point G. Here a greater emphasis of management and other limited resources on ES D would result in a greater discounted flow of D and less of C, than if market prices determined the profit maximising outcome at point F. These differing optima illustrate the possibility that private decisions regarding the management of ecosystems may lead to the generations of ES combinations which differ from those which society might choose, but also how policies which alter the returns from different ES may alter behaviour.

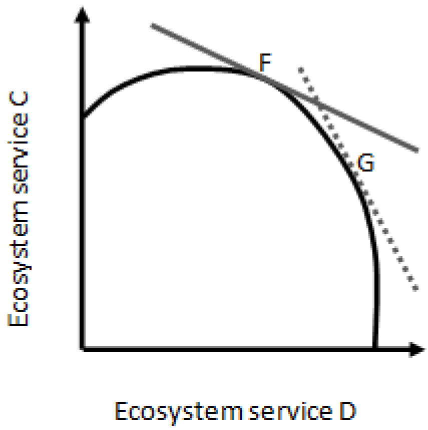


Fig. 3.11 ESPF and isoreveneue lines

For a superior ecosystem condition and/or a greater management and resource input[27]the ESPF would tend to move away from the origin, but not necessarily uniformly; the grey dotted lines illustrate this in Figure 3.12. The optimum combination of ES C and D would move from point H to I[28].

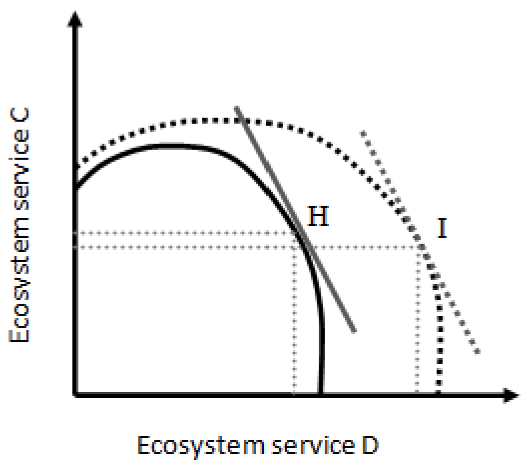


Figure 3.12 ESPF and isoreveneue lines

Thus, as condition improves relative optimum combinations of ES may alter – the flows of some ES may even decline – grazing and hunting services may decline, for instance, when upland peatland condition is restored, while regulating services will increase.

[27] In this case, the sum of discounted costs

[28] Note that the isoreveneue lines have the same gradient, the one further from the origin denoting increased revenue.

Chapter 4 Pilot Study 1 – Exmoor Mires Partnership

Contents

Introduction

The following paper forms part of a one-year, Eurostat-funded study of Natural Capital restoration costs. The study aims were to produce a roadmap covering asset registers and restoration cost estimates for all UK ecosystems by 2020, as well as two pilot studies illustrating the approach and issues arising. This paper reports on the first of these pilot studies, namely the Exmoor Mires Partnership.

The paper outlines the project and then proceeds to present the underlying information on the ecosystem asset, services and restoration costs. Next, this information is used to construct an asset and risk register, a set of physical and financial ecosystem accounts, and a cost-benefit analysis to appraise the economic value of restoration. The issues, specific and general, which arose, and concluding remarks complete the report.

Project description

The first restoration activity of the Exmoor Mires Partnership (EMP) (formerly the Exmoor Mires Restoration Project) commenced in 2006, although minor restoration works had taken place since the late 1990’s. The project covers more than 3000 hectares of Exmoor in the

South-West of England and is a partnership between the Exmoor National Park Authority, South-West Water [29], Environment Agency, Natural England, Historic England and representatives from the local farming and general community, with the wider involvement of, and collaboration with, the local community and universities[30]. Between 2006 and 2015, ditch blocking and other restoration work was instigated over more than 2,000 hectares of peatland, with a further 1,000 hectares planned by 2020.

The Exmoor National Park, designated in 1954, is one of 15 such national parks across the UK, and covers almost 700 km^2. The moor itself is a dissected plateau, much of it over 300 metres. A substantial amount of the area has also been designated as a Site of Special Scientific Interest (North Exmoor SSSI) and a Special Area of Conservation under the EC Habitats Directive (Exmoor Heaths SAC) (Fig. 4.1). About half of the EMP project is within the SSSI. Much of the land is in public ownership (including 60% owned by the National Park Authority), with the remainder in private hands.

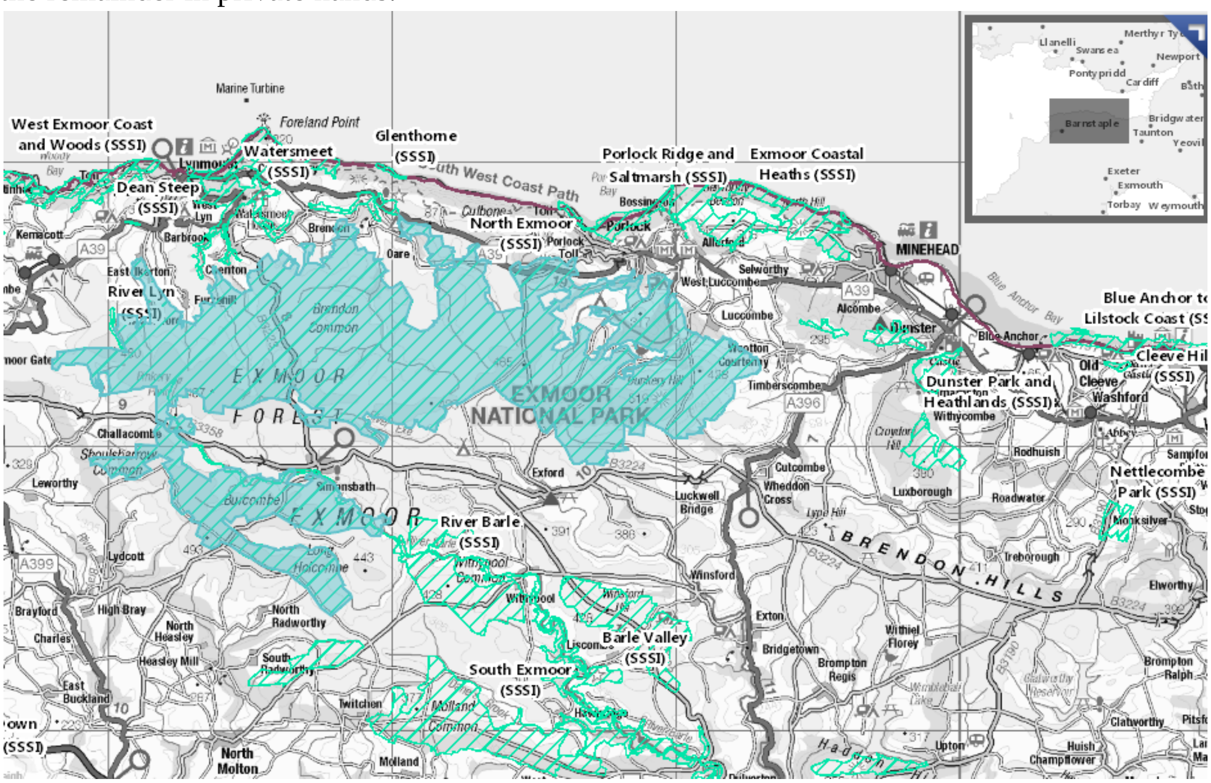


Fig. 4.1 Map of Exmoor showing North Exmoor SSSI
Source: Natural England (2017) https://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=S1006541

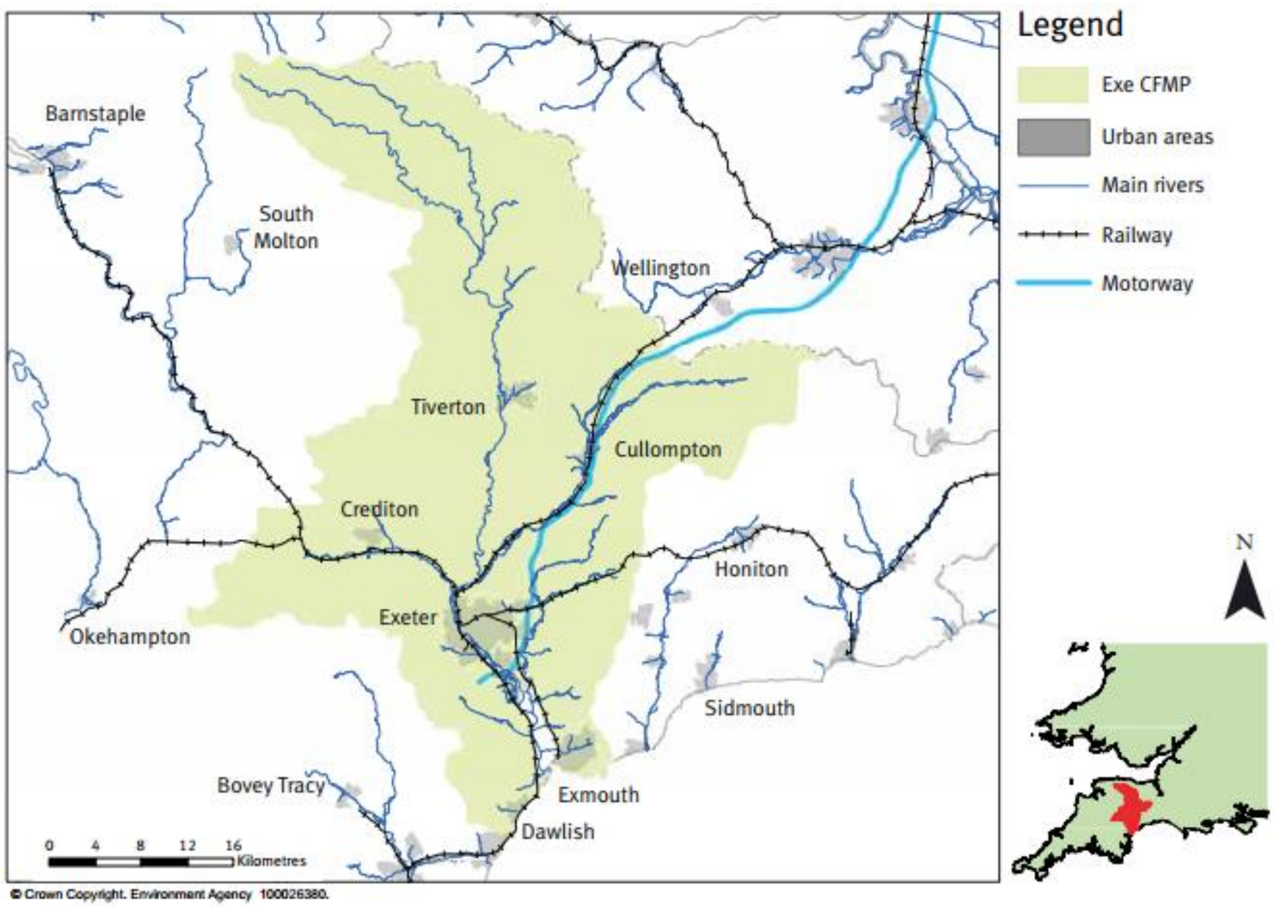
The ecology of the shallow peat (averaging 0.3 m.) covering much of the moorland area has been altered considerably over several centuries, with peat cutting for fuel and a wide network of ditches dug and vegetation burnt around two hundred years ago in an effort to improve agriculture. This was exacerbated in the twentieth century as governments subsidised further development for livestock farming. Although bare peat is not a problem on Exmoor, as it is on

[29] A water company
[30] Principally, the University of Exeter, but others, such as Bristol, Plymouth and Royal Holloway, have been involved.

Dartmoor and other northern peatland areas, the past land management has dried the peatland out, leading to the habitat being dominated by *Molinia caerulea* (purple moor grass) to the detriment of *Sphagnum* and other peatland-associated plants and habitat.

Because of its southerly position with rainfall averaging 1800-2600mm p.a. and mild temperatures (ref 139) Exmoor is seen as an important site for evaluation of the early effects of climate change.

The Exmoor Mires Partnership was set up to, "restore degraded Exmoor peatlands on a landscape scale and to promote the regeneration of moorland bog vegetation" (Bonnett, *et al*, 2011), in order to improve the storage, supply and quality of freshwater, reduce harmful greenhouse gas (GHG) emissions, improve biodiversity, enhance the understanding and mitigate for the historic environment, whilst look to monitor landscape change and opportunities for enhancement within that. The project has involved a considerable amount of ditch blocking (mostly peat blocks), supported by a wider moratorium on burning instigated by Natural England.



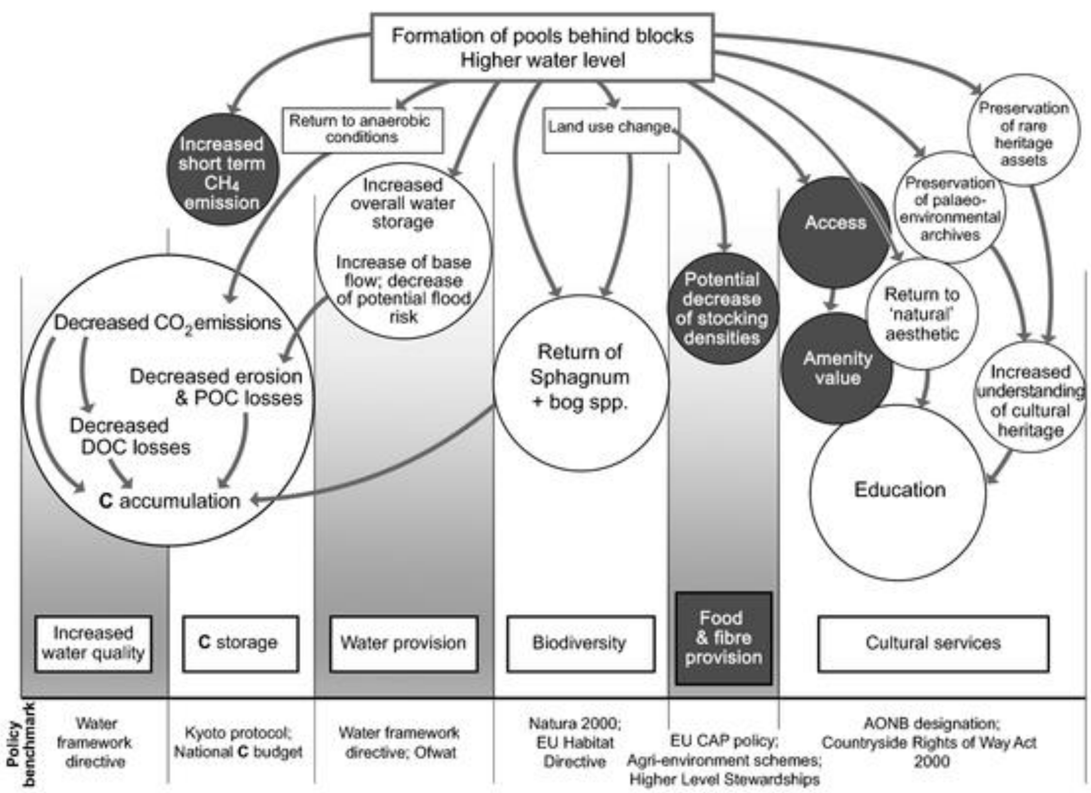
Notes: the EMP project area covers the watershed in the top third of the map. CFMP: Catchment Flood Management Plan
Source: Environment Agency (2012)

Fig. 4.2 Map showing the Exe watershed

Because of the important water benefits, and its obligations under the Water Framework Directive, South West Water has invested substantial funds in the project and is closely involved in monitoring, not only water quality and flow, but also carbon emissions, grazing effects and biodiversity. Other public institutions, particularly Natural England and the Environment Agency, are heavily involved with monitoring and provision of funds.

A wide range of benefits are expected from restoration: Grand-Clement et al (2013) provided a helpful diagram to show the beneficial effects of grip blocking – this is shown in Figure 3.

As with any such project there will be beneficiaries and losers. In this case, the benefits of reduced emissions of greenhouse gases (GHG) will accrue to the global population, both present and future, while the water-related benefits will occur to water users and residents and businesses downstream. Biodiversity enhancement will have multiple beneficiaries, not just those living locally. If the changes improve the recreation experience, then consumers of recreation - those resident locally as well as visitors – will benefit (although they would suffer if recreation was hindered by the project). Similarly, with educational opportunities – it is likely that local schoolchildren will benefit most, but visiting students will also gain. On the negative side, to the extent that grazing is reduced, then local farmers and landowners will lose out, as will those involved in hunting.



Note: size of circles reflect likely impact and colouring – light/dark – denotes positive and negative impacts respectively
Source: Grand-Clement et al (2013)

Fig. 4.3 The impacts on ecosystem services of restoration by drain blocking in South-West England

The author paid a site visit in late 2016 with the two key stakeholders responsible for management of the project, with later discussion with the Natural England representative with responsibility for the project. During the summer of 2017, the author set up a calculation spreadsheet in consultation with key stakeholders.

Project ecosystem asset and ecosystem services calculations

The asset and risk register, accounting and cost benefit analysis (CBA) calculations were based on existing data and a number of assumptions. Where possible, the data and assumptions used information directly from the project; otherwise, the references to other sites or more general information were used.

A spreadsheet was constructed to deal with each aspect of the calculations in order to produce the register, ecosystem accounts and a cost-benefit analysis. Figure 4 illustrates the structure of the spreadsheet.

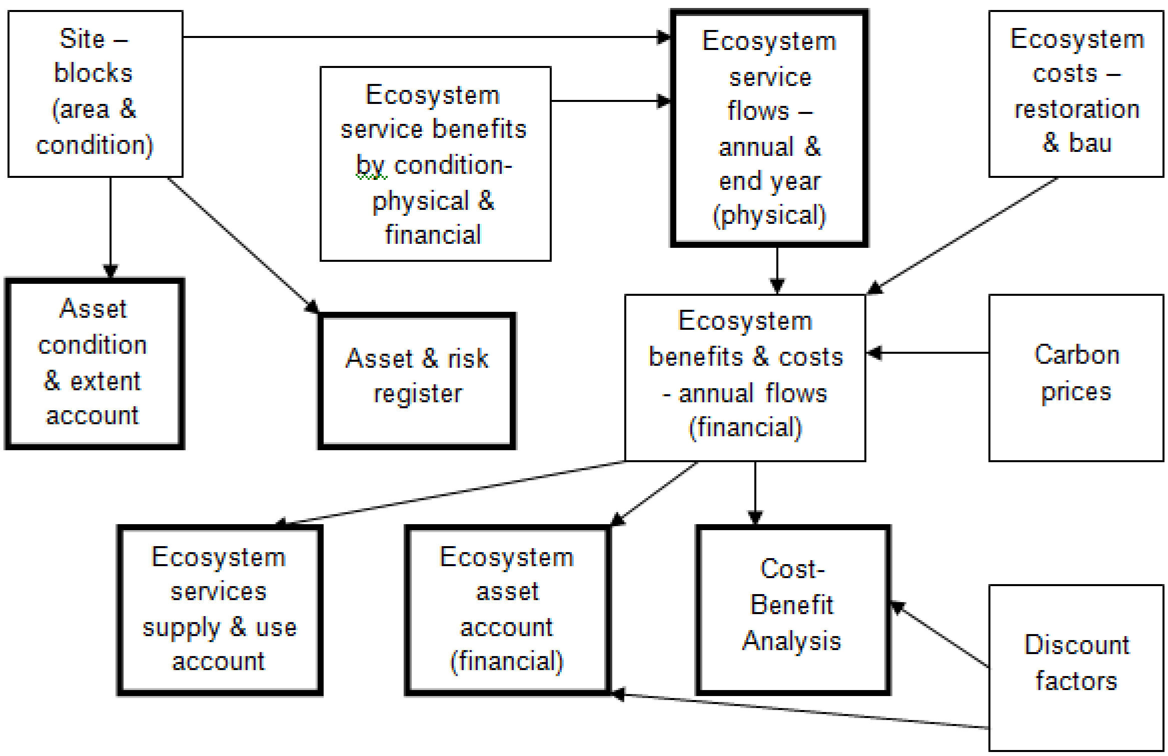


Fig. 4.4 Spreadsheet structure

The build up of information in the spreadsheet begins with the worksheet represented by the textbox on the top left-hand side of the diagram, with the final outputs shown in those boxes with bold borders. The elements of the spreadsheet, including the sources of the data, assumptions made and calculations are explained below.

Extent and condition

Restoration began in 2006, with blocks of land of differing sizes brought into the restoration activities each year, with a total of 2,638 hectares to be included by 2020.

According to Natural England (2017) the bulk of the sites within the North Exmoor SSSI were classified as ‘unfavourable – recovering’, which the condition-services concept paper for this study (Chapter 3) correlated with the Peatland Code condition category as ‘4. Drained’ or ‘3. Modified’, with the suffix added here - ‘under restoration management’. After consultation with the management of EMP, it was agreed that the sites covered by the project should be classified as ‘unfavourable’ and ‘unfavourable – recovering’, depending upon whether restoration had been begun, and this was converted to ‘drained’ and ‘drained- recovering’ under the Peatland Code classification. Thus, at the various stages of the project, the areas in each category are shown in Table 4.1 below, illustrating the development of the project, from 2005 when the 2,638 project hectares were unrestored, to the whole area under restoration by 2020, with 410 ha. project to move to the, superior, ‘modified’ category. Each year, restoration has begun (and is planned, to 2020, to begin) on new blocks of land, while the condition of those already under restoration is expected to improve, with some reaching ‘modified condition by 2020.

Table 4.1 Project areas by Peatland Code and Natural England condition categories (ha.)

condition	*1*	*2*	*3*	*4*	*4*	*5*	*total*
	pristine	nr natural	modified	drained - recovering	drained	actively eroding	
WFD	High	High	Good	Moderate	**Poor**	Bad	
NE	favourable - maintained	favourable - maintained	favourable - recovered	unfav. - recovering	unfavourable	unfav. - declining/ partially destroyed	
2005	0	0	0	0	2638	0	2638
2006	0	0	0	2573	65	0	2638
2015	0	0	0	1506	1132	0	2638
2016	0	0	65	1472	1101	0	2638
2017	0	0	139	1949	550	0	2638
2020	0	0	410	2225	0	0	2638

Note: WFD – Water Framework Directive; NE – Natural England

Using stakeholder expertise and references, the time expected within each category as restoration proceeded was then determined, with the spreadsheet designed to model either stepped changes from one category to the next or a graduated transition. Thus, imagine that the land categorised as ‘4. Drained’ underwent restoration and, under this process, it took ten years for the land to move to the next, improved, category. In this scenario the benefits could be envisaged as remaining as those for this category for ten years when they would change to those for ‘3. Modified’: this can be termed a ‘stepped’ approach. Alternatively, they could be expected to increase in an upwardly-sloped straight line from the level for category ‘4’ to that of category '3' over the ten years[31]: the 'sloped' approach. Similarly, if drained-category land was deemed to degrade over time, rather than be maintained at that level, then this would occur in either a stepped or graduated fashion.

The initial times regarding movement between condition categories are shown in Table 4.2 below. However, due to uncertainty regarding these timings, the spreadsheet was designed to facilitate the evaluation of the effects of varying these timings.

Table 4.2 Years taken to change between condition categories for restoration and degradation

	years between conditions			(from one stage to the next)		
Peatland Code	1	2	3	4	4	5
	pristine	nr natural	modified	drained - recovering	drained	actively eroding
NE	favourable - maintained	favourable - maintained	favourable - recovered	unfav. - recovering	unfavourable	unfav. - declining/ partially destroyed
recovering						
stage wise		50	40	10		
cumulative		100	50	10		
degrading						
stage wise					1000	
cumulative					1000	

Angus (2017) suggested the time for improvement regarding reduced carbon emissions and *Molinia caerulea* (purple moor grass) domination is 7-10 years, with more fundamental change only beginning to appear at this time. Other studies (Eftec, 2015) support this, with more substantial improvement likely to take a considerable time. For un-restored sites, further deterioration may occur and there is some evidence of this (Angus, 2017).

Ecosystem service benefits

The benefits arising from each ecosystem service were specified according to the ecosystem condition, as discussed in the methodology paper. It is not claimed that the list of benefits is exhaustive; these are shown in Table 4.3

Physical asset flows were converted into financial terms using grazing livestock gross margins, straw costs, carbon prices[32], and visitor opportunity costs[33].

Although grazing activity might be expected to be limited once restoration has been underway for some years, Angus (2017) reported that 'levels on Exmoor have not reduced since any

[31] Of course, as Chapter 3 discusses, they could be modelled as rising in a curvilinear fashion. However, for ease of modelling this has not been attempted in the spreadsheet.
[32] DECC (2016)
[33] Sen *et al* (2011); Phillips (2017)

restoration works have taken place. Grazing will continue; some recent evidence shows that bog habitat brings in greater diversity of herb species which could enable grazing to go on for a longer period of time compared to *Molinia*-dominated grasslands that are there now'. Even should change occur, it is likely to be slower in this area of shallow peats than has been experienced in other areas where deep peat prevails. Furthermore, in current drained environments, grazing is not currently seen as hazardous for livestock.

Table 4.3 Ecosystem service yields for each category

Condition	Units	1	2	3	4	5
		nr natural	modified	drained - recovering	drained	actively eroding
Ecosystem service						
Provisioning						
Grazing[34]	Livestock units/ha.	0.06	0.06	0.06	0.06*	0
Mowing[35]	Adjusted tonnes/ha.	0	0	0	0.92*	0
Hunting		0	0	0	0	0
Water provision[36]	Savings £/ha.	20.4	6.0	3.0	0.0	-6.6
Regulating						
GHG[37]	CO2e t/ha	2.69	-1.08	-2.54	-4.54	-23.84
Flood prevention[38]	Savings £/ha.	5.8	5.8	4.8	0.0	-3.6
Biodiversity		na	na	na	na	na
Cultural						
Education		na	na	na	na	na
Recreation[39]	Visitors/ha.	29.25	29.25	29.25	29.25	21.94

Note: na – not available; * for inferior condition only limited mowing and grazing is feasible, and the same for mowing for superior condition.

In some areas farmers mow the *Molinia* for use as a substitute for winter bedding. This is not expected to be feasible once restoration occurs.

The values of changes in water quality are based on changes in the levels of dissolved organic carbon (DOC) in the water as a result of improvement or deterioration in peatland condition

[34] Moxey (2014), Angus and Smith (2017), Harvey and Scott (2016), SAC Consulting (2017). In improved condition, grazing may not be appropriate, and for inferior conditions productivity would be very low. However, Angus (2017) believes that, for this site, grazing would continue as condition improved.

[35] Angus figures and variable costs and coverage assumptions. For other conditions, assumptions as above

[36] Based on watershed share of rainfall and water treatment costs – Grand-Clement (2013), Met Office (2017) and South-West Water (2015).

[37] James Hutton Institute (2015), Brazier (2017), Eftec (2015), Moxey and Moran (2013), Grand-Clement (2013 & 2015).

[38] CECA(2016), Environment Agency (2016), Brazier (2017), Grand-Clement (2013), and assumption of 25% cost increase with further degradation. Further explanation of the method is provided in the annex.

[39] Freeman and Stephens (2015), Mills et al (2010), Grand-Clement (2013), Phillips (2017), ENPA (2010). Assuming no change with improvement, but 25% decline as condition deteriorates

(Smyth *et al*, 2015), an estimate of the volume of water derived from the project area as a proportion of the total water supply, and the costs of water treatment. (SWW, 2015)

Degraded peatland is a source of carbon emissions; this worsens considerably when peatland reaches a poor condition, but improves as condition improves, although this is expected to take place over a long time scale (Smyth et al, 2015; Eftec, 2015; Grand-Clement et al, 2013, 2015). It is expected that greenhouse gas emissions (GHG) will continue until peatland approaches pristine condition – only then is carbon sequestration likely to begin. This is problematic in an ecosystem accounting context as ecosystem disservices are dealt with differently to services and, as a consequence, viewing restoration accounts against those for 'business as usual' can give a distorted comparison. Nevertheless, reductions in emissions (as opposed to an increase in sequestration) as a result of restoration will be viewed as a benefit in cost-benefit analysis. The spreadsheet takes account of expected changes in GHG emissions and transition times between peatland condition.

Drain blocking is expected to change the pattern of water flow from the project area and help in reducing downstream flooding risk. The changing impact as a result of condition change was calculated based upon predicted change in flow and the costs of flood prevention in the major urban centre (Exeter) within the Exe watershed. References and further explanation are provided in a footnote to Table 4.3 above and in the Annex.

Beneficial changes in biodiversity are seen to be an important part of restoration in this context, but values were not readily available for this, or other ecosystem services, such as education, so no figures have been used in the analysis.

Recreation is a valuable service provided by Exmoor National Park (ENPA, 2010), but although values were estimated for this analysis, it was not clear what effect restoration would have, so these benefits were assumed to be constant for improving condition. However, if the peat deteriorated to 'actively eroding' it was assumed that recreation benefits would fall by 25%.

Ecosystem restoration and related costs

Extensive restoration costs were provided by the site management as were the timings. However, as these costs covered the period from 2006 to 2015, the GDP deflator was used to convert costs to 2016. Budgeted and expected costs and timings were also elicited for future years. Details are listed in Table 4.4.

The major initial activity was the damming of the man-made drains[40], which involved machinery – low ground-pressure diggers and dumper trucks, labour, materials ie wooden posts and planks, metal steels for any bridge/access improvements works, and transportation of machinery to sites.

[40] In the north of England these drains can be termed 'grips', but not in the south-west!

GHG, hydrological, agricultural and biodiversity monitoring was carried out as well as a survey of archaeological evidence, and monitoring continues. This is expensive, not only in terms of investment in equipment, but also labour (including partial funding of three PhDs). In a sense, this monitoring element of the costs should not be included in the valuation of restoration, although Angus (2107) argues that these are a vital element of restoration: 'survey and monitoring work is a crucial element to the restoration work. Without it we would not have the scientific evidence to understand and demonstrate the change brought about by ditch blocking.' Further, with regard to the historic environment survey, 'we would not have been able to undertake any restoration without the initial survey work and ongoing monitoring', so 'monitoring work is as crucial as the practical work on the ground'. The analysis was carried out both with and without these costs.

Table 4.4 Restoration costs and timings

operation	Cost (£/ha./yr.)	start yr.	period (yrs.)
ditch blocking	265.9	1	1
management	66.6	1	20
monitoring equipment	30.0	1	1
monitoring other	52.7	1	5
archaeological survey	26.2	2	5
education	2.5	2	5
volunteer maintenance - pre-2017	77.2	1	5
volunteer maintenance -post-2016	51.2	6	5
maintenance once restored to modified	0.0	10	40
maintenance once restored to near natural	0.0	50	50
maintenance once restored to pristine	0.0	100	300

General maintenance was carried out by volunteers. However, to account for the value of their input fairly, information on the cost, if their labour had had to be paid for, was provided by the project management. Later in the cycle, more intense machine-based maintenance would also be carried out.

The costs of management of the project – staff, offices, transport and related costs have been included in the accounts and analysis.

Additionally, information was elicited concerning costs which could be expected if the restoration activity had not been instigated – termed here, 'business as usual' or bau.

Based on Table 4.5 the pattern of costs can be determined: this is presented in Figure 4.5a on a per hectare basis (inflation-adjusted costs) for the first fifteen years. Note that the largest costs occur early in the project as damming and investment in monitoring equipment occurs. Although costs decline in later years, in order to continue and eventually maintain condition, costs are likely to be incurred into the long term.

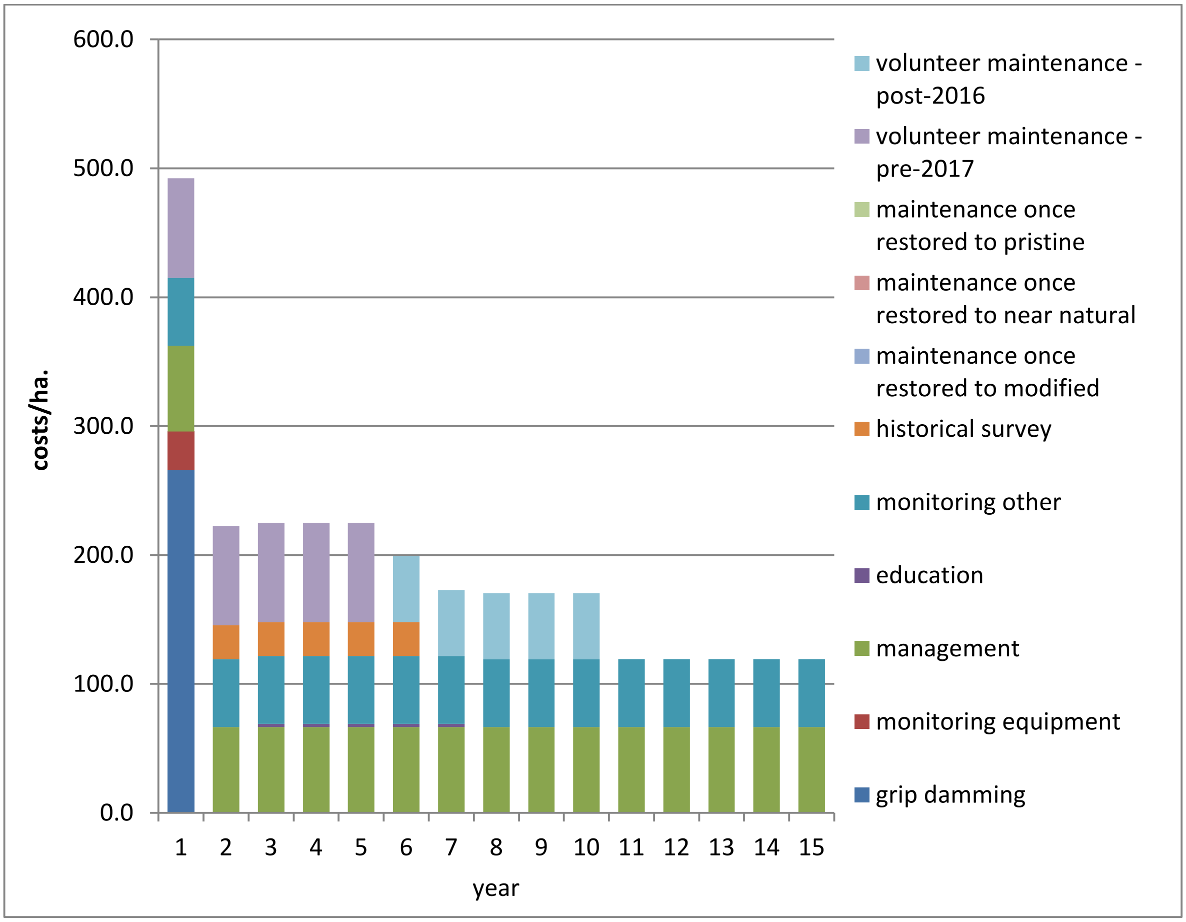
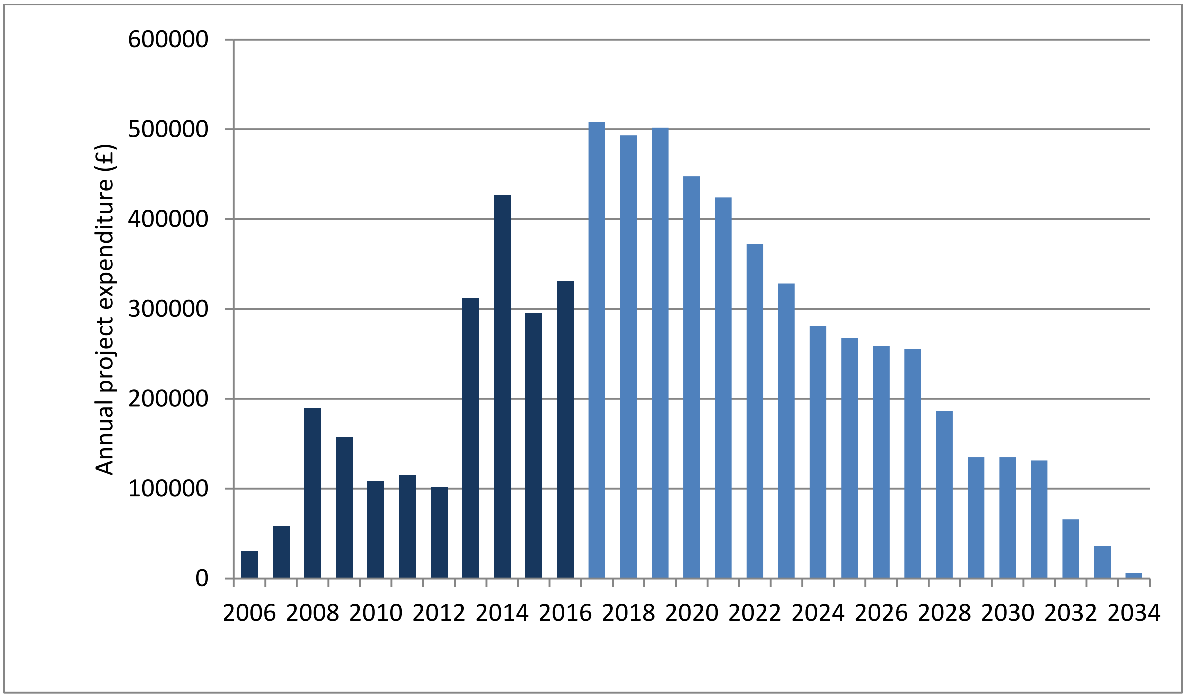


Fig. 4.5a Restoration and associated costs (per hectare)

Figure 4.5b shows the costs for the project as a whole until 2034. Costs build up as more plots are brought into the restoration process, but plot sizes differ, so the overall pattern is not smooth. After 2020, no more areas are added.



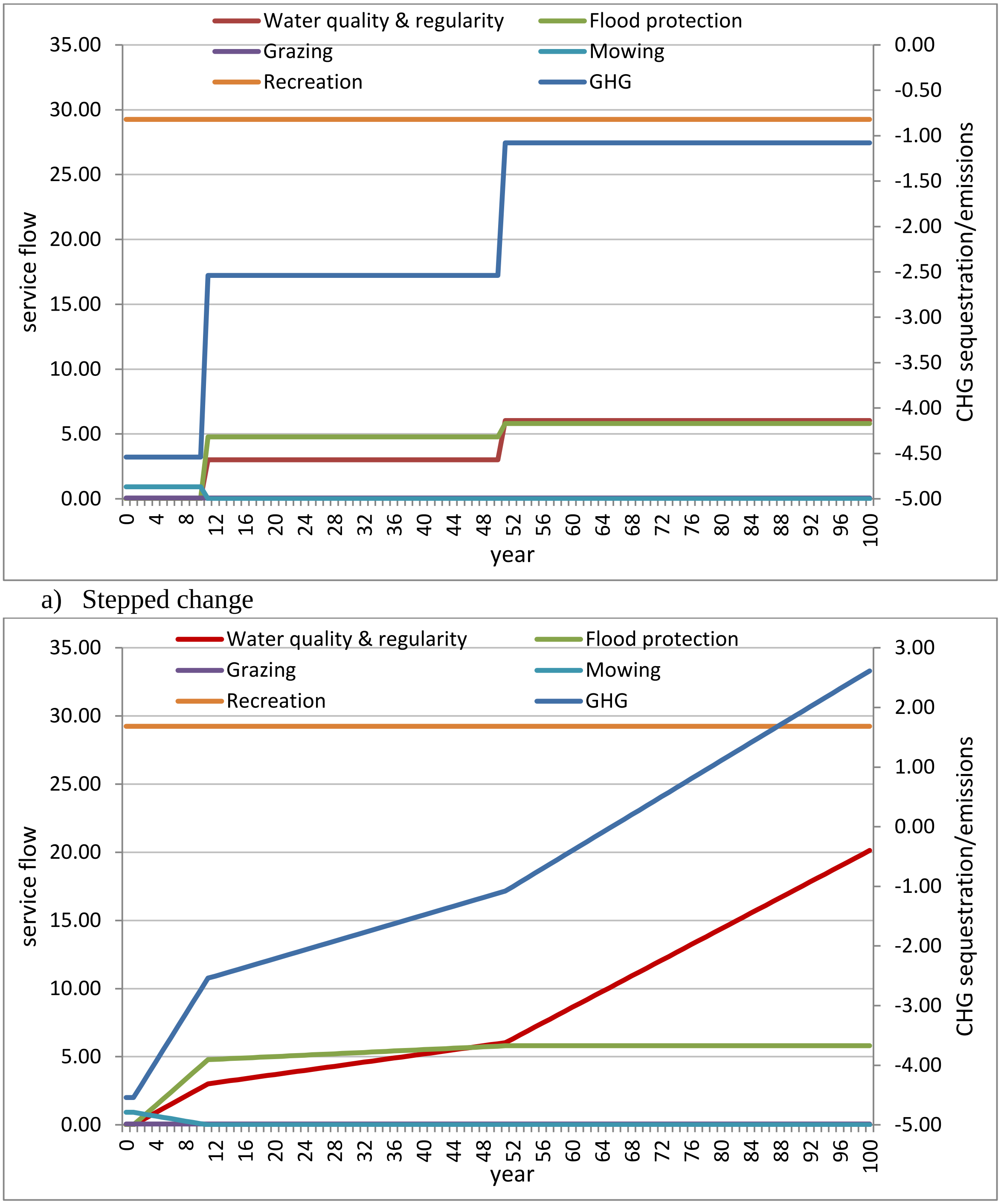
Note: dark blue bars denote costs already incurred, light blue – predicted costs.

Fig. 4.5b Restoration and associated project costs

Ecosystem service flow pattern

Based on the estimated timing of movement between condition categories (Table 4.2) and the levels of services for each condition category (Table 4.4), the annual flow of services was modelled. Depending upon the assumption of stepped or sloped change the pattern differed: Figures 4.6a and 4.6b illustrate, for stepped and sloped transformation between categories respectively, the flows of services for the first 100 years.

Both graphs show the change in environmental services as a site moves from one condition to the next. For grazing and mowing there is a reduction as site restoration proceeds, while recreation is assumed to be constant. Other services show an increase.



a) Stepped change

b) Sloped change

Figure 4.6 Ecosystem service flows as condition changes – a) stepped b) sloped change

Asset and risk register

The register presented in Table 4.5 below was constructed following McVittie *et al* (2017) and NCC (2016).

Although the land can be classed largely as shallow peat, in terms of land cover, it would be classified as ‘mountains, moorlands and heath’ (MMH) according to the UK National Ecosystem Assessment or, despite the absence of shrubs and bushes, as ‘shrubland, bushland and heathland’ as classified by a number of other systems, while land-use type moves from ‘rough grazing’ to ‘land used for restoration of environmental functions’, despite grazing still occurring (albeit at a somewhat reduced intensity).

Table 4.5 Asset and risk register

		opening 2006	closing 2016	change	trend
extent and type of land cover					
Shrubland, bushland, heathland/MMH	ha.	2638	2638	nc	-
Semi-natural grassland	ha.	0	0	nc	-
land use type					
1.1 Agriculture - rough grazing		97.5%	41.7%	-55.8%	↓
1.1 Agriculture - permanent pasture		0.0%	0.0%	nc	-
1.2 Forestry		0.0%	0.0%	nc	-
1.6 Land used for maintenance and restoration of environmental functions		2.5%	58.3%	55.8%	↑
significant land ownership and management					
owners					
Exmoor National Park Authority (ENPA)		64.9%	64.9%	nc	-
National Trust		0.5%	0.5%	nc	-
Private		34.6%	34.6%	nc	-
managers					
ENPA tenant		64.9%	64.9%	nc	-
private tenancy		9.1%	9.1%	nc	-
owner occupier		26.0%	26.0%	nc	-
condition					
Natural England					
unfavourable		97.5%	41.7%	-55.8%	↓
unfavourable - recovering		2.5%	58.3%	55.8%	↑
Peatland Code					
drained		97.5%	41.7%	-55.8%	↓
drained - recovering		2.5%	55.8%	53.3%	↑
modified		0.0%	2.5%	2.5%	↑
spatial configuration					
contiguous		largely	largely	nc	-
ecosystem services					
provisioning					
grazing		✓	✓		↓
hunting		✓	✓		↓
water		✓	✓		↑
regulating					
greenhouse gas reduction		✓	✓		↑

flood protection	✓	✓	↑
biodiversity	✓	✓	↑
cultural			
recreation	✓	✓	↑
education	✓	✓	↑
wildlife	✓	✓	↑
what managed for			
peatland restoration	✓	✓	↑
grazing	✓	✓	↓
hunting	✓	✓	↓
major dependencies			
grazing linked to other farm pastures			
hunting over wide area - project area is a part			
downstream watershed			
potential thresholds/tipping points			
drained/unfavourable peatland, if unimproved, could irretrievable condition			
assets valued of local and national importance			
ENPA popular recreation/tourism destination			
archaeological remains			
rare plants and insects under threat – sphagnum mosses, round-leaved sundew, black darter, common hawker			
such shallow peats in southern UK provide useful exemplar for study of early climate change impact.			
risks (L,H,VH - low, high, very high risk)			risk trend
food	L	L	-
clean water	VH	VH	↓
equable climate	VH	VH	↓
hazard protection	VH	VH	↓
wildlife	H	H	↓
recreation	L	L	-

The fact that two-thirds of the land is in public ownership, with the remainder owned and managed privately is likely to influence the way in which the project proceeds. On the one hand, influencing private owners, rather than dictating, is likely to involve encouraging, persuading, incentivising. However, even for publicly-owned land, introducing and maintaining the objectives of the project will require a good deal of careful negotiation as those given the responsibility for decision making for this land will be subject to influence by the tenants and other influential people and organisations.

Land condition, with much of the area being within the North Exmoor SSSI, was classified as unfavourable, but has moved into the recovering category as restoration has extended. Similarly, under the Peatland Code, the land would be likely to fall into the drained category, and would continue in this general class (albeit now recovering) until it reached modified status – some of this is assumed to have occurred by 2016.

The productivity of the site in terms of grazing and hunting is limited and may fall as restoration proceeds. However, all other services are expected to improve.

The peatland area within the project is not isolated – different areas are within wider farm holdings and the whole feeds into the Exe and other watersheds, so consideration needs to be given to the implications of this. Also the site is part of a wider, popular recreation and tourist area with aesthetic value. Restoration is expected to have positive biodiversity effects, particularly for certain species.

It is likely that even in the absence of restoration the tipping point for this ecosystem will not have been reached, although without maintenance it may be that further deterioration would take place, eventually reaching the threshold. Nevertheless, in terms of certain ecosystem services, the site could be considered at high risk, although the restoration process is likely to begin to reduce this.

Ecosystem accounts

Following SEEA-EEA (2013) the normal set of ecosystem accounts would be as shown below in the upper part of Figure 4.7. If restoration was not actually being implemented, it would be helpful to produce a parallel set of accounts to illustrate accounts if restoration were to be instigated.

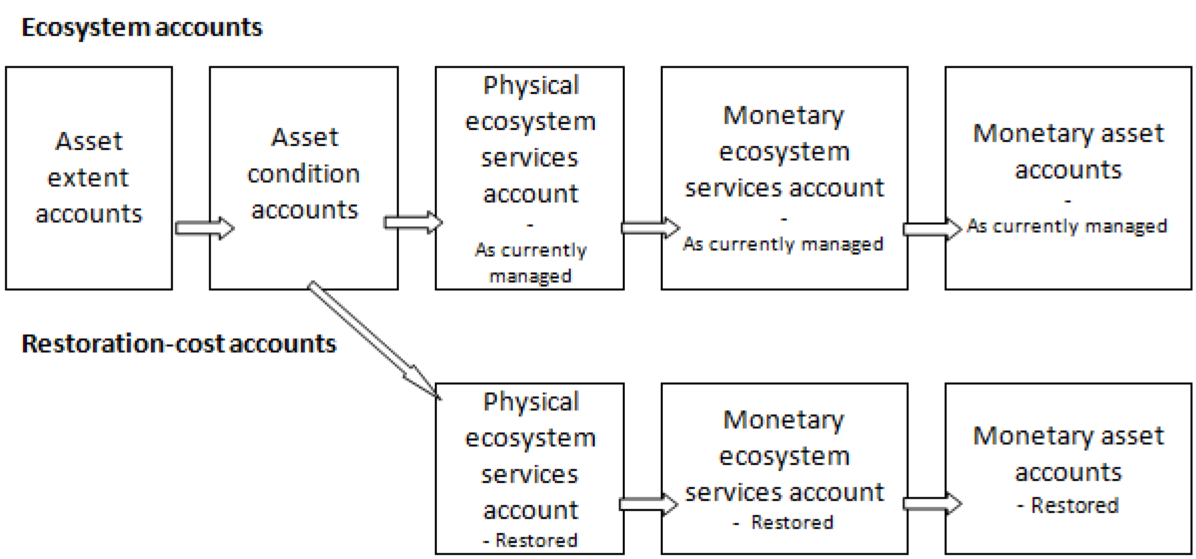


Fig.4. 7 Ecosystem accounts

In this study, however, the opposite has been done – the restoration process has been instigated, so the upper set of accounts, in fact, constitute the restoration case, while the lower set show what would have been expected if no restoration had taken place, or was planned – here this is termed ‘bau’. Despite the accounts here being in the ‘reverse order’, so to speak, they still allow comparison of restoration against bau.

The spreadsheet was designed to produce each of these accounts, with two parallel sets produced – those including restoration and those for bau (assuming no restoration were to take place) – these could be termed the ‘actual’ (what interventions had actually happened and were intended to happen) and the ‘hypothetical’ (what might have happened otherwise). In the accounts below, to avoid confusion, only ‘the ‘actual’ accounts are presented, except in the case of the ecosystem asset account (financial), where the ‘’hypothetical’ (bau) is also presented alongside.

Asset extent and condition accounts

In this case, the asset extent and condition accounts can be combined. The opening period is taken as 2006, the year in which restoration was started in the first block, while the closing year is taken as the most recently completed year, 2016. Details are presented in Table 4.6.

Table 4.6 Asset extent and condition accounts

	1	2	3	4r	4	5	**total**
	pristine	nr natural	modified	drained recovering	drained	actively eroding	
	fair - maintained	fair - recovered	unfair-recovering	partially destroyed	partially destroyed	destroyed	
	favourable	favourable - recovered	unfavourable recovering	unfavourable recovering	unfavourable		
Opening stock - 2006	0	0	0	65	2573	0	**2638**
additions to stock							
regeneration - natural	0	0	0	0	0	0	**0**
regeneration - via human activity	0	0	65	1472	0	0	**1537**
reclassification	0	0	0	0	0	0	**0**
reductions of stock							
reductions due to extraction/harvest	0	0	0	0	0	0	**0**
reductions due to human activity	0	0	0	65	1472	0	**1537**
catastrophic losses – human activity	0	0	0	0	0	0	**0**
catastrophic losses – natural events	0	0	0	0	0	0	**0**
Closing stock - 2016	0	0	65	1472	1101	0	**2638**

The project area of 2,638 ha. was in an unrestored condition in 2005, all blocks being classified as ‘drained’ or ‘unfavourable’. By the end of 2006, restoration had begun on one block of 65 ha., and this was now classified as ‘drained (recovering)’ or ‘unfavourable – recovering’. By the closing year of these accounts, 2016, restoration was underway on 11 blocks, covering

1,537 ha., with the first of these blocks moving into the 'modified' category. Four blocks, 1,101 ha., remained in 'drained' or unfavourable' condition at that time.

Ecosystem service accounts (physical)

The annual physical[41] flows of ecosystem services for 2016 are presented in Table 4.7; note that it is not claimed that the list of services is exhaustive.

Table 4.7 ES service (physical) accounts – year end 2016

ecosystem services	unit	Total (excluding negatives)	*per ha.*	Total (including negatives)
provisioning				
grazing	GLU	158	*0.06*	158
mowing	tonnes	1704	*4.3*	1704
hunting	£	na	*na*	na
water quality & regularity	£	2369	*0.90*	2369
regulating				
GHG	CO2et	0	*-3.94*	-10406
flood protection	£	3753	*1.42*	3753
biodiversity		na	*na*	na
cultural				
education		na	*na*	na
recreation	visitors	77158	*29.25*	77158

The flows which should be included in the ecosystem account are those under the heading 'total (excluding negatives)' since the GHG emissions of -10406 tonnes of CO2 equivalent should be included elsewhere in the environmental accounts (ref). Nevertheless, they are included in the final column for reference.

Ecosystem services financial supply and use table

Table 8 shows the supply of ecosystem services, shown on the right as emanating from the ecosystem, while these flow to (uses) on the left hand side – although some regulating services also flow back into the ecosystem.

Note here that the value of GHG is zero in the table. In fact, for 2016, despite restoration having been in train for 10 years, the peat will still be producing emissions; only much later, when condition improves to 'near natural', will net sequestration take place. The environmental emissions accounts should deal with the emissions not included here, although it is unclear

[41] In some cases here the services are measured in financial terms at the outset.

whether this is currently the case. The other zero values are merely because a calculation for these services has not taken place.

Also, GHG and biodiversity will contribute to industrial production and human health, both within the economy and elsewhere and will add to the stock which will provide services in the future.

Table 4.8 Ecosystem services financial supply and use table – 2016 (£/yr.)

SUPPLY	Type of economic unit				Ecosystem		
	Industry	Households	Accumulation	Rest of World	…	Mountain, moorland & heath	…
ecosystem services							
provisioning							
grazing						46794	
mowing						11355	
hunting						0	
water quality & regularity						2369	
regulating							
GHG						0	
flood protection						3753	
biodiversity						0	
cultural							
education						0	
recreation						81634	

USES	Type of economic unit				Ecosystem		
	Industry	Households	Accumulation	Rest of World	…	Mountain, moorland & heath	…
ecosystem services							
provisioning							
grazing	46794						
mowing	11355						
hunting	0						
water quality & reg.	2369 →						

regulating								
GHG	0							
flood protection	3753							
biodiversity	0							
cultural								
education		0						
recreation		81634						

Ecosystem asset account (financial)

The financial account showing the value of the ecosystem assets at the start and the end of the period is shown in Table 4.9. The asset value at the start and end of the period was the sum of the costs and benefits for each of the blocks for each year, discounted using the British Government ‘Green Book’ (HMT, 2016) discount rates – ranging from 3.5% for the first 30 years, falling in steps to 1% for cash flows beyond 300 years. The discounting period was 100 years, although the calculation was also carried out for 300 years.

Again, following the SEEA-EEA (2013), the calculations are presented excluding emissions, but then also showing the effect of including the emissions, for reference. Also, the figures for the ‘hypothetical’ case of bau are presented on the right hand side.

Table 4.9 Ecosystem asset account (financial)

£	restoration		bau	
	Without negative GHG	*With negative GHG*	Without negative GHG*	*With negative GHG*
Opening stock @ 2006	1619817	*-15617901*	4100801	*-49947487*
Additions to stock				
Regeneration - natural	0	*0*	0	*0*
Regeneration – human activity	2213665	*2902975*	0	*0*
Reclassifications	0	*0*	0	*0*
Total additions to stock	2213665	*2902975*	0	*0*
Reductions in stock	0	*0*	0	*0*
Reductions -extraction	0	*0*	0	*0*
Reductions – human activity	0	*0*	25480	*14436286*
Catastrophic less –human activity	0	*0*	0	*0*
Catastrophic losses – natural	0	*0*	0	*0*
Total reductions in stock	0	*0*	25480	*14436286*
Revaluations	0	*0*	0	*0*
Closing stock @ 2016	3833482	*-12714926*	4075321	*-64383773*

* Note that only the negative GHG are excluded – smaller negative value for water and flooding have been included here.

Between 2006 and 2016 the asset value increased substantially. The is was due to: the onset of benefits from GHG sequestration becoming 10 years closer, and hence discounted by 10 fewer years; carbon price having an increasing trend; reaching the increasing benefits of flood prevention and increased water quality sooner, and the initial damming costs for the first 10 blocks being sunk, that is, in the past. If GHG emissions are included then the asset value is negative, although, for the same reasons as before, the value is improved substantially over the period.

For the ‘hypothetical’, bau scenario, the exclusion of the negative GHG values leads to this giving superior asset values because of the positive early benefits from mowing and grazing and absence of the restoration costs. Nevertheless, even here a fall in the asset value occurs over the period. Once the negative values from the GHG emissions are taken into account, there is a negative asset value in 2006 and this becomes substantially worse by 2016.

There is an issue here, however: because under the SEEA accounting conventions, the negative, disservice values of GHG emissions are excluded from ecosystem accounts, but appear to be included in the UN-defined ‘air emission account’ (UN, 2012, para. 3.243), although to which sector such emissions should be allocated is not made clear, particularly as there is no ‘natural world’ sector. (Harris, 2017) Furthermore, if such peatland-related emissions are excluded from the ONS air emission account delivered to Eurostat: they only appear to be included in the bridging tables (ONS, 2017).

Comparison of the ‘actual’ restoration asset valuations with the ‘hypothetical’ bau figures, when negative GHG values are excluded, would suggest that bau is superior to restoration, whereas inclusion of GHG emissions in the accounts and in the cost-benefit analysis indicates otherwise.

However, the 2006 and 2016 valuations are based on differing patterns of carbon prices, so the effect of price and volume change has not been separated. If the calculations are made using the same carbon price patterns in 2006 as in 2016, then the effects can be separated, with the results shown in Table 4.10

Table 4.10 Ecosystem asset account (financial) – nominal terms

£	restoration		bau	
	Without negative GHG	*With negative GHG*	Without negative GHG	*With negative GHG*
Opening stock @ 2006	1619817	*-15617901*	4100801	*-49947487*
Additions to stock				
Regeneration - natural	0	*0*	0	*0*
Regeneration – human activity	2269161	*8595115*	0	*0*
Reclassifications	0	*0*	0	*0*
Total additions to stock	2269161	*8595115*	0	*0*
Reductions in stock	0	*0*	0	*0*
Reductions -extraction	0	*0*	0	*0*
Reductions – human activity	0	*0*	25480	*2800900*
Catastrophic less –human activity	0	*0*	0	*0*
Catastrophic losses – natural	0	*0*	0	*0*
Total reductions in stock	0	*0*	25480	*2800900*
Revaluations	-55496	*-2527757*	0	*-11635385*
Closing stock @ 2016	3833482	*-12714926*	4075321	*-64383773*

The volume effects are, therefore, shown to be much larger when negative values are included with restoration, although smaller with bau. The exclusion of the negative GHG values obscures much of the effect.

Cost: Benefit Analysis

Following the discounting procedure noted in the previous section, but taking a one hectare example using unit benefits and weighted-average cost, the discounted values were calculated for the site under restoration compared to the situation if no restoration had occurred (business as usual – bau). The results are presented in Table 4.11.

Table 4.11 Cost-Benefit Analysis

discounted £/ha.	restoration		bau		difference	
	benefits	costs	benefits	costs	net benefit	B:C ratio
100 years	-4063.8	2132.8	-23072.5	0.0	16876.0	8.9
300 years	-2041.1	2132.8	-28038.3	0.0	23864.3	12.2

Although the discounted net benefit of the restoration project is negative, due to the long period of GHG emissions before the onset of sequestration, this is much superior to the result if no restoration is carried out. In fact, the Benefit: Cost ratio (BCR) is extremely high – nearly 9 for the one hundred-year analysis, rising to 12 when the analysis is extended to 300 years.

On the basis of the annual values per hectare, converting the lump-sum, net-benefit figures from Table 4.11, to an annuity, for a 100-year lifetime the figure is £584.7, while for 300 years it is £765.4.

The sensitivity of these results to changes in some of the main assumptions is shown in Table 4.12 and Figure 4.7.

Table 4.12 B:C ratios - sensitivity

			change from base	
	100 yrs	300 yrs	100 yrs	300 yrs
base - sloped changes	**8.9**	**12.2**	**0%**	**0%**
base - stepped changes	5.0	7.3	-45%	-40%
base - no monitoring costs	19.2	26.3	116%	116%
50% reduction in GHG benefits	4.5	6.1	-51%	-51%
20 yrs to moderate	7.8	11.0	-13%	-10%
double years to next category	6.5	9.1	-27%	-26%
halve years to next category	13.0	16.2	46%	34%
double years to next category/no monitoring	14.0	19.6	59%	62%
maintenance costs continue at same level	5.9	7.8	-34%	-36%

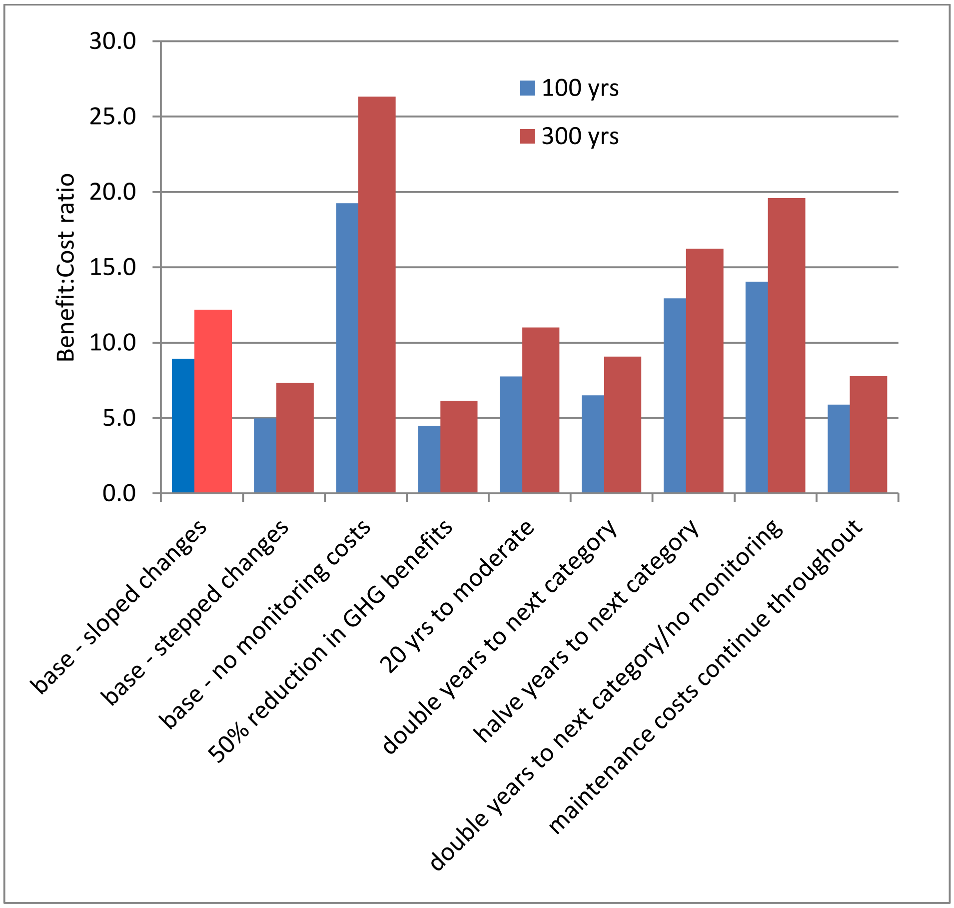


Fig. 4.7 B:C ratios – sensitivity

Relaxing the assumption of a sloped transition reduces the BCR substantially, although it could be argued that the base assumption is the more realistic. Monitoring costs could be argued as separate from the analysis – extracting these from the appraisal more than doubles the BCR. GHG benefits make up the bulk of the value of benefits, so halving them, not surprisingly, halves the BCR.

The importance of the time intervals between reaching condition categories is shown by increasing the time to reach moderate condition and halving and doubling each of the time intervals. The effect is considerable, although the BCR's remain high, and when monitoring is excluded he BCR's exceed the base figures by more than 50%. Finally, if maintenance costs continue at the same level once superior condition categories are reached the BCR falls by about one-third.

The study by de Groot (2014), with global coverage of 225 studies, calculated BCR's ranging from 3 for coral ecosystems, to 75, for grassland., albeit using 'broad brush' cost data and a 1% discount rate. If the spreadsheet is re-run using such a rate the 100 and 300 year BCRs increase to 27.6 and 68.1.

Issues

This is a project in which restoration has already begun, so the costs already expended are known with reasonable precision, but those expected in future years are not, with uncertainty increasing further into the future. This also applies to the benefits and the timing of both. Although there is some literature available which can be used in the estimation of future costs and benefits, since the widespread practice of restoration is relatively novel, examples of later-stage restoration are limited. The timing of changes to condition and thence levels of services is particularly uncertain. Nevertheless, sensitivity analysis can be used to measure the impacts of a range of values.

Costs under a 'no restoration' scenario are needed to provide a counterfactual, particularly when undertaking a CBA. However, there do tend to be figures more readily available for these circumstances. Thus, for example, grazing costs and benefits are available in the form of gross margins, whilst 'net margins' should take account of overhead costs.[42]

Records of costs have been well-maintained for this project. However, this is not the case for all such restoration sites, and, even here, records of the non-restored scenario are limited. Furthermore, restoration tends to occur on sites seen as valuable or special, so here records will have tended to be and continue to be, relatively well kept (if not always available – see Wicken Fen pilot study, Chapter 5). (Bradley, 2017) Consequently, upscaling may be difficult – the limited number of sites and the 'special sites only' applicability of the examples making modelling for both special and 'ordinary' sites, problematic. This is exacerbated by the likelihood that the condition of the 'ordinary', non-restored sites may be inferior. This is not an insurmountable problem, but it does suggest that aggregation or use of 'average' data for other potential sites will be subject to a greater degree of uncertainty.

Getting local stakeholders on board is important for project success, but has taken a good deal of time and resources of project managers here. It must be borne in mind that for some the *status quo* is, or appears to be, preferable to restoration, since the benefits and loses accrue to different stakeholders. However, subsidies can be used (as here) to compensate those apparently losing out.

Following on from this, subsidy payments influence stakeholder behaviour. How they are designed and used is likely to play a substantial part in take-up and success of restoration, particularly where a substantial proportion of the land is under private ownership. But this also opens up the debate about who should pay for restoration.

The water company involved in this project, South West Water (SWW), is strongly incentivised to support this project – it is likely to yield cost savings for water treatment in the long term and may add to catchment resilience and help to assure supplies against climate change effects. Furthermore, water companies also have duties under the NERC and CROW[43]

[42] Gross and net margins can be criticised, but alternatives can be calculated. See Bright (2003**)**
[43] The Natural Environment and Rural Communities *Act* (2006) and the Countryside and Rights of Way *Act* 2000.

Acts to help deliver environmental outcomes in catchments from which they abstract. These are set out in the Environment Agency's Natural Environment Programme for the Water Industry (WINEP) and the Exmoor restoration is supported by EA with additional funding, as well as being a requirement on SWW via this programme. Finally, in SWW's consultations on the 2010-15 and 2015-20 business plans customers indicated a willingness to pay for catchment management and peatland restoration, which gives rise to a regulatory requirement to deliver this work. Linked to this, the economic regulator of the water delivery sector in England and Wales, OFWAT, requires the company to monitor and report on progress under its output delivery incentives (ODI). Less formally, being involved with good environmental outcomes is beneficial to SWW in terms of its public relations and external stakeholder management. Important policy lessons can be learned here with regard to the involvement of the private sector in restoration.

This project employs certain gulley-blocking techniques, but there are several others available which are used elsewhere.

Exmoor may be regarded as a special case, with its southerly position and shallower peat – this makes its results less applicable elsewhere, but also makes it useful for prediction of climate-change effects.

Using the results to scale up to ecosystem level is difficult, but the more cases for which costs can be compiled, the more they will facilitate more accurate aggregate figures to be compiled or modelled.

For water companies, and for the assessment of impacts on water quality and flooding, catchments may be more appropriate. Smith (Angus and Smith, 2016) noted that water treatment was necessitated, not only by the organic matter resulting from peatland in the headwaters, but also dirty water and pesticides emanating from farms further downstream.

The results are sensitive to changes in the assumptions about levels of benefits and costs, timings and discount rate. Nevertheless, restoration appears to be worthwhile, although the bulk of the value of the benefits is in the form of public, rather than private, goods. The latter point has implications for policy and stakeholder incentives for restoration.

Monitoring costs make up a substantial proportion of the costs of restoration. Who should bear these, and whether they should be included in evaluation of such projects is open to question.

As discussed in the annex to the concept paper preceding this pilot study report, and illustrated here, ecosystem services may follow different, even opposing, trends as condition improves or deteriorates.

Under SEEA, the reduction of disservices, such as GHG emissions, should not be included in ecosystem accounts. This means that comparing an accounting picture of restoration with that of bau, as in Table 4.9, may give a misleading picture. Additionally, although the change in disservices should be picked up elsewhere in the accounts, in a UK context these do not appear to be being picked up, apart from under LULUCF (Land Use, Land use Change and Forestry) in the ‘bridging’ accounts. Further, although Carbon accounts (ONS, 2016) have been produced for the UK, conceptual work (Vardon, 2014) seems to neglect the accounting for emissions reductions (as opposed to sequestration). The latest SEEA Technical Recommendations feature this statement: “While the emissions themselves are not ecosystem service flows, the loss of carbon from storage may be considered a reduction in the services provided by the associated ecosystem assets. However, further discussion is needed to determine the precise nature of any ecosystem services and possible approaches to measurement and valuation.” (UN,2017)

Conclusions

An asset and risk register, ecosystem accounts and cost-benefit analysis have been successfully conducted for the Exmoor Mires Partnership.

The success of this analysis depended upon the cooperation and help of the project management, and the success of the project itself has depended upon the cooperation of the stakeholders.

The BCR suggests a promising project, although a large proportion of the services is in the form of non-market benefits, and this has important policy implications. Additionally, monitoring is important in determining the outcomes of the project, but its costs are substantial and how these are paid for is another policy-related issue.

Under the environmental-economic accounting framework, with GHG emissions values excluded, the financial asset accounts appear to favour bau over restoration, although the cost-benefit analysis suggests otherwise. Further, it is unclear where in the wider accounts, negative values would appear.

The project illustrates the wider issues, that activity, cost and benefit data availability, and scaling up, need to be addressed.

Annex Flood protection cost avoidance

Given that Exeter is the main population centre affected by floods from the Exe watershed, and a substantial part of the project area is within the catchment[44], the cost of the Exeter Flood Prevention Scheme was converted to an annuity of 30 years (using 3% discount rate).

Then the share of the rainfall affecting the whole watershed was calculated approximately, breaking the watershed into large segments and applying the annual rainfall affecting each of these areas.

[44] According to Angus (2017), about 50% of the project is within the Exe catchment.

The annual flood prevention costs to each ha. of the project were next apportioned. A statement from an Exeter University report on the project, that damming (i.e. restoration) reduced the amount of water leaving the site by 2/3. On this basis the costs were reduced the costs by proportion once the next (improved) condition category was reached.

The spreadsheet shows full details of the procedure. However, a hypothetical example will help with understanding; an illustration is provided in Table 4.13 below. The first section shows the conversion of the cost of flood fences (net discounted cost) to an annual equivalent. Water flow calculations are calculated by breaking the watershed (upstream of the area in danger of flooding) into blocks and multiplying the areas of these by the average rainfall, for a particular period, in that area. This is totalled to give 740 m3. However, flooding would only be a problem for water volumes above a certain level; so the surplus over this base is the amount over which the flooding cost has to be shared.

Table 4.13 Flooding cost saving example

Flood defence costs				
cost of defences		£40,000,000		
lifetime of defences		20 years		
interest rate		3.5%		
annual cost (annuity)		£2,814,443		
Water flow calculations				
watershed areas				water volume m3
(upstream of pop'n centres)		area (km2)	rf (mm)	rf * area
	I	600	500	300
	II	350	1000	350
	III	50	1800	90
	total	1000		740
floods occur if water flow >				40
surplus over flood base (volume of water flow causing flooding)				700
		area (km2)	rf (mm)	rf * area
project (sited in area III)		18	1800	32.4
Potential savings				
annual cost per flood surplus unit		£4,020.63	/m3	
project water flow reduction		33%		10.7 m3
annual cost savings				£42,989

Note: the spreadsheet method, for simplicity, effectively assumes that all flows lead to flooding.

The volume of water contributed by the project site is then calculated in the same way as for the whole. Finally, savings are calculated by first deriving the cost per m3 by dividing the annual cost by the 'surplus over the flood base'. This number is then applied to the volume of water which would be held back as a result of restoration to give the total annual savings.

Chapter 5 Pilot Study 2 – Wicken Fen Vision project

Contents

Introduction

The following chapter forms part of a one-year, Eurostat-funded study of Natural Capital restoration costs. The study's aims were to produce a roadmap covering asset registers and restoration cost estimates for all UK ecosystems for the period 2018-2020, as well as two pilot studies illustrating the approach and issues arising. This paper reports on the second of these pilot studies, namely the Wicken Fen Vision project

The paper outlines the project and then proceeds to present the underlying information on the ecosystem asset, services and restoration costs. Next, this information is used to construct an asset and risk register, a set of physical and financial ecosystem accounts, and a cost-benefit analysis to appraise the economic value of restoration. The issues, specific and general, which arose, and concluding remarks, complete the chapter.

Project description

The second study area is situated in the vast low-lying fenland area covering 38509 sq km in East Anglia in the east of England (Peh *et al*, 2014). Although containing an extensive area of deep peat, this has been severely degraded over several centuries. From the early seventeenth century fen peats began to disintegrate as the large-scale straightening of rivers, erection of wind pumps and digging of a network of drains began, funded by speculators and using

expertise from the Netherlands. The eel trapping and sedge cutting (for thatch) in these wetlands was replaced by digging of the peat for fuel ('turf cutting') and intensive cropping. The demand for peat as fuel fell with the onset of the Industrial Revolution, but the intensive cropping of the fertile peatland continues: Morris *et al* (2010) estimate that, of the 131,000 ha. of rich fens, 75% are cropped, although much of the deep peat has been severely depleted. Only 20% of the area consists of deep peat and 79% of the soils are classified as 'wasted peat'. Yet the Fens continue to make a considerable contribution to the UK's cereal and vegetable production. A major recent report suggests that:
'lowland peats in England and Wales are major sources of UK GHG emissions…
…lowland peats under intensive arable agriculture in England are probably the UK's largest land-use derived source of carbon dioxide (CO2) emissions.' (Evans *et al* (2017)

Nevertheless, some pockets have been retained as undrained reed and swamp, and designated as Sites of Special Scientific Interest (SSSI), EU Habitats Directive Special Areas of Conservation (SAC), Royal Society for the Protection of Birds (RSPB) preserved or Wetlands of International Importance (RAMSAR). The designation of these protected sites often overlaps.

Furthermore, and despite the severe loss of peat depth and volume, the East Anglian fens are seen as still having great potential for the reduction of GHG emissions. Thus, Evans *et al* (2017) suggest: 'Conservation-managed lowland fens appear to be among the most effective carbon sinks per unit area in England and Wales'. Consequently, a number of projects aimed at restoration of other areas of the Fens have been instigated, by government agencies or by non-government organisations with government support.

In 1899, land at Wicken Fen was first acquired by The National Trust, a non-government organisation with the aim of preserving heritage sites in the UK, having already attracted the attention of entomologists at Cambridge University. The Wicken Fen National Nature Reserve (NNR) is now an SSSI, SAC and RAMSAR site covering 254 ha, most of which has never been drained, although some was derelict reed and swamp, which had been drained, ploughed and farmed between 1939 and 1953. Natural England has designated roughly half of the area as in 'favourable' condition, with the other half 'unfavourable- recovering' (Natural England, 2017). The National Trust subsequently acquired further land and in 1999 established the Wicken Fen Vision, 'a strategy to create a 53 square kilometre nature reserve for wildlife and people in Cambridgeshire' (National Trust, 2017). Over a one-hundred year period the area is expected to grow to 5300 ha, running from the NNR, south-westwards to Cambridge (see Figure 5.1). So far, including the NNR, 930 ha. have been acquired, including the NNR, but restoration has not yet begun throughout; for this study 479 hectares of land, formerly in agricultural use, is the focus of the analysis since specific data has been published.

The objectives of the Vision (as opposed to that for the NNR alone) are to:
"greatly expand space for wildlife and people; encourage habitats that benefit wildlife; provide access and encourage local people to be involved in the work, learn continually from

experience and influence policy development at national and international level." (National Trust, 2017)

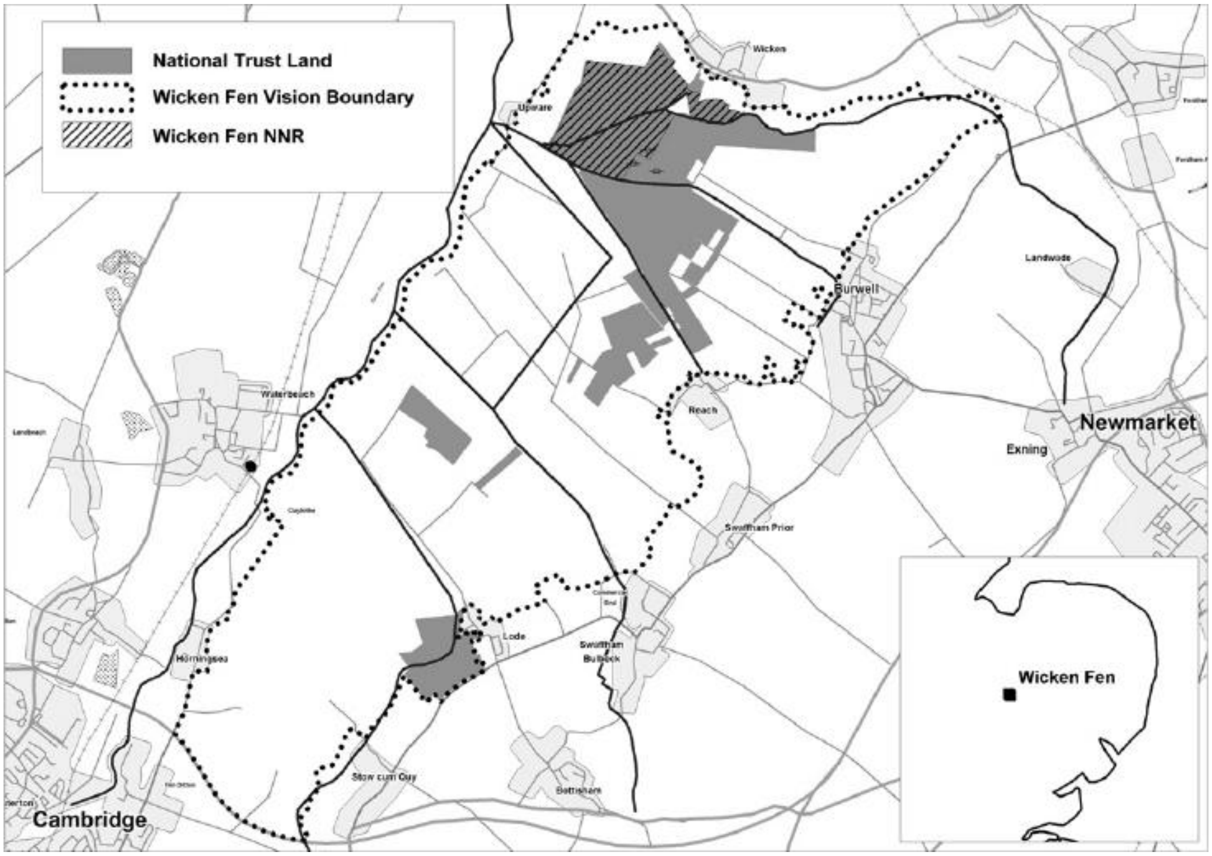


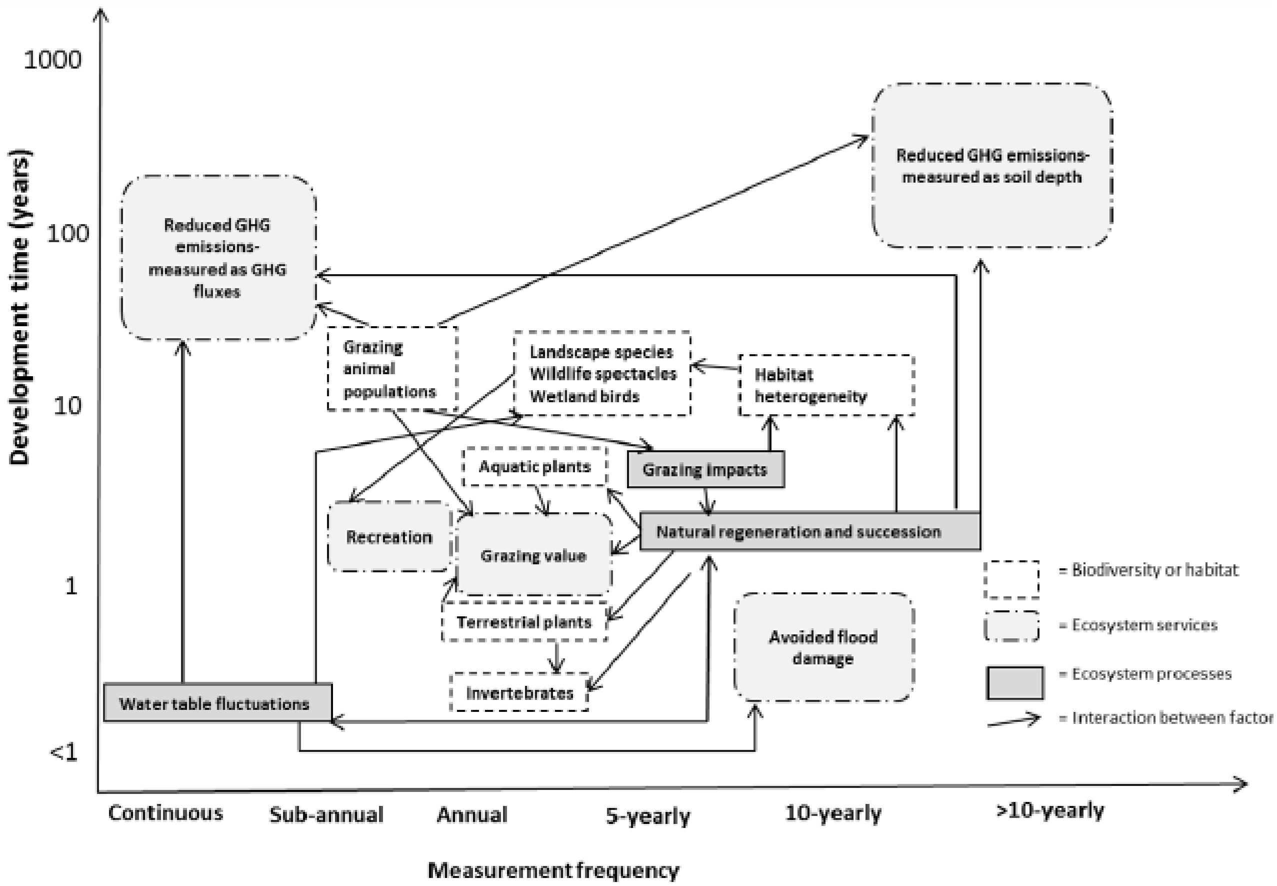
Fig. 5.1 The Wicken Fen Vision area

The project focuses on biodiversity, people and ecosystem services, loosely in that order, and has no end point or intent to restore the site to a former state. Rather, the aim is to re-establish natural processes and to allow them to function ("let nature take its course"), and to be dynamic and not prescriptive, although the management does have certain obligations regarding cross-compliance under High-Level Stewardship of the agri-environment scheme administered by the government,, including control of invasive weeds near to adjacent farms. (Lester and Hughes (2016) A great deal of monitoring of various aspects of project outcomes is carried out (Hughes *et al.,* 2016); Figure 5.2 illustrates this.

Unlike some other fen projects, which have had quite 'heavy' intervention, this project tends to be low key. No major capital works are undertaken, but fencing is carried out, field drains are blocked, and 'clean' water (not containing agricultural run-off) is abstracted from the higher level canalised rivers (lodes). The land itself is then 'engineered' using extensively grazing livestock (Highland cattle and Konik ponies), supported by some commercial grazing.

The measurable benefits of this project, which have been estimated here, cover income from grazing livestock, reduced carbon emissions (and eventually sequestration), recreation, with visitors from the locality[45], the rest of the UK and beyond, and prevention of flooding of nearby farmland and residential accommodation. Biodiversity improvements, although not measured here, are seen as a key to the success of this project.

The cost, or opportunity-cost, in terms of what benefits are likely to be foregone by changing from the cropping land use, are the farming income[46], as well as the visitor numbers, although these would be smaller than the numbers attracted when restoration is underway.



Source: Hughes *et al*, 2016.

Fig. 5.2 Conceptual diagram of monitoring within the Wicken Fen Vision project

Project ecosystem asset and ecosystem services calculations

The asset and risk register, accounting and cost benefit analysis (CBA) calculations were based on existing data and a number of assumptions. Where possible, the data and assumptions used information directly from the project; otherwise, the references to other sites or more general information were used.

[45] There are also educational visits by local schools and universities, but these have not been included in the evaluation.

[46] not including the subsidies, which constitute transfer payments, as do the agri-environment payments when restoration occurs,

A spreadsheet was constructed to deal with each aspect of the calculations in order to produce the register, ecosystem accounts and iterations of the cost-benefit analysis. Figure 5.32 illustrates the structure of the spreadsheet.

The build up of information in the spreadsheet begins with the worksheet represented by the textbox on the top left-hand side of the diagram, with the final outputs shown in those boxes with bold borders. The elements of the spreadsheet, including the sources of the data, assumptions made and calculations are explained below.

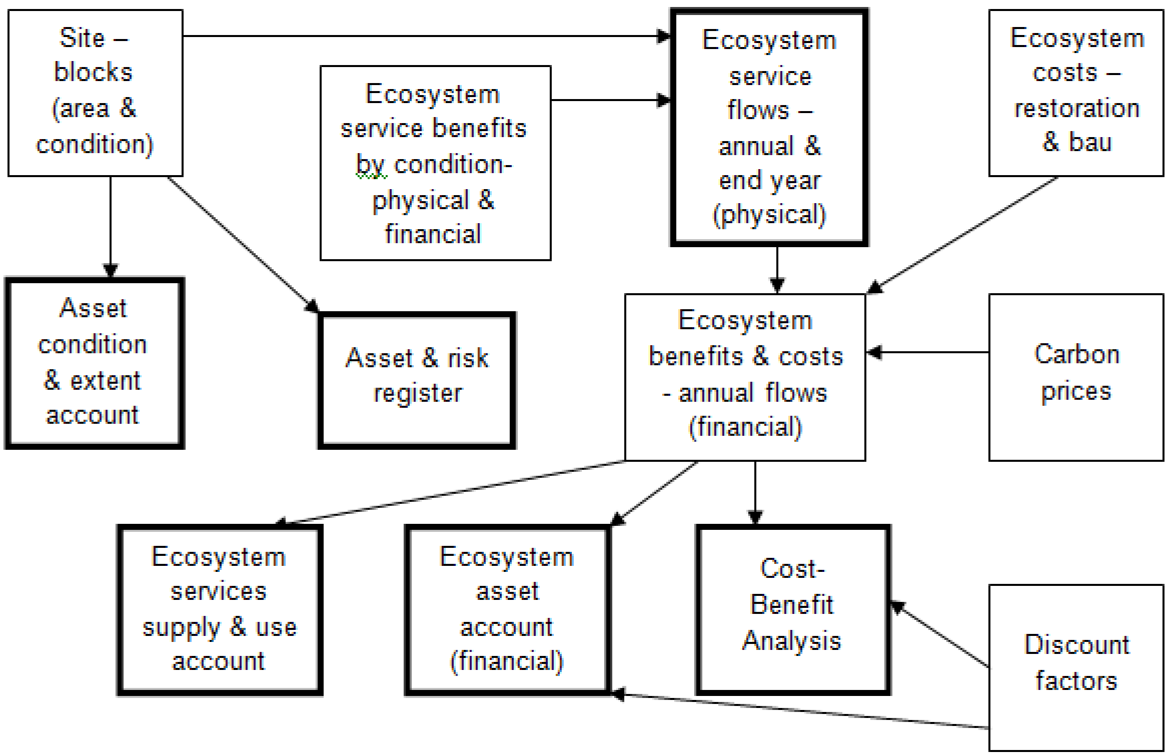


Fig. 5.3 Spreadsheet structure

Extent and condition

Unlike the first pilot, the Exmoor Mires Partnership, here the 479 ha. block is considered as a whole, with restoration beginning throughout in 1995. Although the Peatland Code does not yet have a calibrated condition categorisation for fenland[47], the same format has been used here as in the first pilot. The land under cropping would have been considered archaic peat, but could be classed here as 'drained', which remains as 'drained' for the initial period of restoration, but is termed here 'drained – recovering' which ties in with the Natural England category of 'unfavourable – recovering'. As restoration improves condition the land is

[47] Work is currently in train: http://www.iucn-uk-peatlandprogramme.org/commission-inquiry/call-experts/fen

expected to move into the ‘modified’ or ‘favourable – recovered’ category, and eventually becomes ‘near natural’.

Table 5.1 Project areas by Peatland Code and Natural England condition categories (ha.)

condition	*1*	*2*	*3*	*4*	*4*	*5*	*total*
	pristine	nr natural	modified	drained - recovering	drained	actively eroding	
WFD	High	High	Good	Moderate	**Poor**	Bad	
NE	favourable - maintained	favourable - maintained	favourable - recovered	unfav. - recovering	unfavourable	unfav. - declining/ partially destroyed	
year							
1995	0	0	0	479	0	0	479
2016	0	0	479	0	0	0	479

In Table 5.2, the stagewise time periods show the number of years for the site to move to improved condition categories. Although Lest and Hughes 2016) suggested that restoration improvements could become apparent within one or two years, they did suggest that other aspects could take 80 or more years. Furthermore, Peh *et al* (2014) outlined ecosystem service benefits as apparent at the time of the study, which was 6 years from the start. Consequently, 16 years has been taken as the time to reach ‘drained – recovering’ and 80 years to ‘modified’, with a further 100 years to ‘near natural’ state.
Evans et al (2017) suggest that in some fen areas, peat will deteriorate over 100 years: this period has been taken as the time to reach lower condition status. Yet, just as restoration tends to be a very long process, so degradation can be rapid: according to Hughes at el (2016) – ‘carbon sequestration in re-wetted peat soils is very slow, measurable over decadal time frames. Loss of drained peat soils (and stored carbon) occurs rapidly’.

For all of these periods, sensitivity analysis has been carried out to evaluate the impact of longer and shorter time assumptions on the benefit-cost ratio.

Table 5.2 Years taken to change between condition categories for restoration and degradation

years between conditions			(from one stage to the next)		
Peatland Code	2	3	4	**4**	5
	nr natural	modified	drained - recovering	drained	actively eroding
WFD	High	Good	Moderate	**Poor**	Bad
NE	favourable - maintained	favourable - recovered	unfav. - recovering	unfavourable	unfav. - declining/ partially destroyed
<u>recovering</u>					
stage wise	100	64	16		
cumulative	180	80	16		
<u>degrading</u>					
stage wise					100
cumulative					100

Ecosystem service benefits

Physical yield data were not readily available for ecosystem services, except for GHG emissions/sequestration and recreation, so financial figures have been provided in Table 5.3 in their absence.

Grazing revenue was taken from Peh *et al* (2014) and converted to a per hectare basis, and converted from \$2011 to £2016; this revenue was expected to continue throughout the restoration process. Cropping revenue was similarly taken from the above reference and converted to £2016/ha.; this revenue would only occur in the unrestored situation and would be expected to decline as condition deteriorated.

GHG estimates on CO2 equivalent tonnes provided in Peh et al (2014) with further evidence in Hughes *et al* (2016), were in line with those used in the Peatland Code. GHG emissions would occur for cropping, and these would worsen over time, while emissions would eventually change to sequestration under restoration, although this would take a considerable time. The carbon prices used in the studies referred to above were not used; instead, mirroring the practice for the first pilot study, the DECC (2017) carbon price time series was used.

Table 5.3 Ecosystem service yields for each category

Condition	Units	2	3	4	4	5
		nr natural	modified	drained - recovering	drained	actively eroding
Ecosystem service						
Provisioning						
Grazing[48]	£/ha.	82.31	82.31	82.31	0	0
Cropping[49]	£/ha.	0	0	0	1401.03	700.51
Regulating						
GHG[50]	CO2e t/ha	0.64	0.64	-1.69	-4.85	-23.84
Flood prevention[51]	Savings £/ha.	33.1	33.1	33.1	0.0	0.0
Biodiversity		na	na	na	na	na
Cultural						
Education		na	na	na	na	na
Recreation[52]	Visitors/ha.	67.7	67.7	67.7	31.2	15.6

48 Peh et al (2014)

49 As above. Cropping costs have been included in the analysis, but are combined with cropping benefits in the benefit-cost ratio. These are both assumed to halve once a more degraded condition is reached.

50 Peh et al (2014) report Co2 equivalent emission and sequestration rates by condition which fit quite closely to those in Smith et al (2015).

51 The flooding cost savings reported in Peh et al (2014) are likely to continue as condition improves, abut have been assumed to remain constant.

52 Peh et al (2014) report recreation benefits based on a survey of visitors and their expenditure. However, the resulting estimates are around 7x those of the more widely-accepted MENE survey (Phillips, 2017). Thus the value per visitor figures are taken from the latter (for freshwater sites) while th evictor numbers have been taken from the former. However, Peh et al values have been included in the BCR sensitivity.

Note: na – not available;

Flood prevention data were again converted from Peh et al (2014) and, in the absence of other data, assumed to remain constant as condition improved.

The recreation value data provided by Peh *et al* (2014) and Hughes et al (2016) included on-site expenditure, so the MENE survey value per visit data (Phillips, 2017) were combined with the visitor numbers derived from the former.

Although other ecosystem services were identified (education, biodiversity, existence values) and considered valuable (Hughes, 2016; Hughes *et al*, 2016) it was not possible to measure them here.

Ecosystem restoration and related costs

Table 5.4 lists the categories of costs, their amounts and timings. Although detailed costs had been recorded, earlier records had been archived and project management did not have time to set out the costs and timings, so costs had to be taken from Peh *et al*. (2014). Maintenance costs may include monitoring costs but it has not been possible to separate these. Nevertheless, as reported in Chapter Four, these can be argued as being a necessary part of restoration.

Additionally, estimates have been made for the costs which could be expected if the restoration activity had not been instigated – termed here, 'business as usual' or bau. Peh et al (2014) based the cropping costs foregone on average figures for the area from a survey of local farming practices.

Table 5.4 Restoration costs and timings

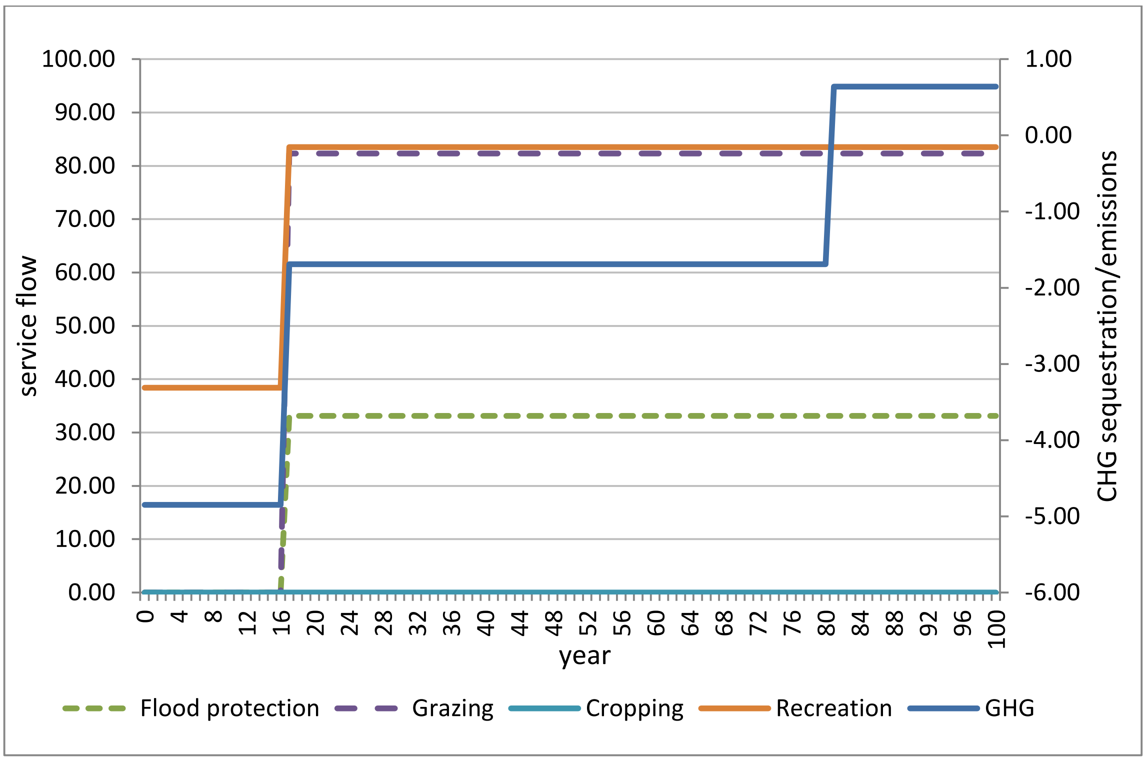
operation	Cost (£/ha./yr.)	start yr.	period (yrs.)
Initial investment	1595.27	1	2-3*
maintenance	127.90	1	16
maintenance once condition improved	127.87	16	300

Note: Initial cropping costs for bau are £1039.28/ha., falling to half this once degraded condition is reached

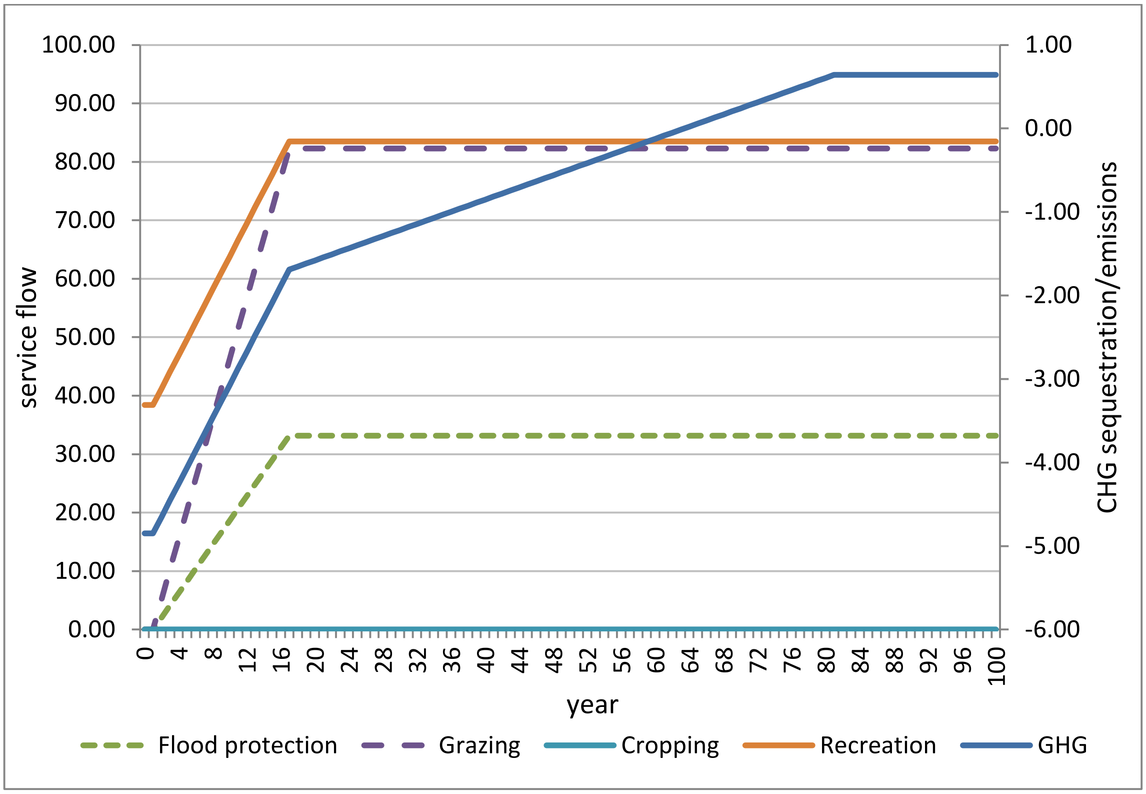
Mention is made of the inclusion of the costs of land purchase in Peh et al (2014), but it is unclear whether the figures which they present include this (it would be expected to be substantial if the land purchased had been used for cropping). However, it would not be appropriate here to include either the cost of land purchase or rental in either ecosystem accounts or cost:benefit analysis: for the former, because the calculations are effectively covering the return to the asset, or the land which the asset occupies, and that is what the rental value is, so there would be double counting; for the latter because the value of the land, is measured by its opportunity-cost, i.e. the return in its next alternative use, and the land cost or rent is the proxy for this, so again, double counting would ensue.

Ecosystem service flow pattern

Based on the estimated timing of movement between condition categories (Table 5.2) and the benefit values derived from Table 5.3 (along with carbon prices from DECC, 2017) the graphs in Figures 5.3 a and b have been derived. Figure 5.3a shows the pattern of benefits if they are assumed to continue at the same level until the new condition is reached (stepped change), while 5.3b shows the pattern if it is assumed that there is a sloped transition between each category. The patterns are similar for degradation to worse condition. As chapter three argues, ecosystem benefits are likely to show a curvilinear pattern as a site moves between condition categories; the sloped transition as illustrated in Figure 5.3b is closer to this than the stepped pattern, and this is preferred here.



a) Stepped change



b) Sloped change

Fig. 5.3 Ecosystem service flows as condition changes – a) stepped b) sloped change

Thus, the assumption on which the base calculations have been made is of a sloped transition although the sensitivity of the results is tested by also running the spreadsheet assuming a stepped transition.

Asset and risk register

The register presented in Table 5.5 below was constructed following McVittie *et al* (2017) and NCC (2016).

If the register had been constructed for a starting point just prior to restoration, then there would have been a change of land cover, land use type and one aspect of condition. However, 1995 signals the start of restoration so, by the end of that year, all land was classified as such, and this did not change over the 21 years until 2016. Nevertheless, if Peatland Code condition categories are adopted, it is assumed that, over the period, the land condition will have changed from 'drained – recovering'[53] to 'modified'.

However, there is change occurring in the provision of ecosystem services. It is suggested here that grazing will remain stable, although there is some recent evidence of variation in this, although this seems to be down to grazing licence fees and available commercial stock

[53] The 'recovering' suffix has been added by the author to indicate land for which the condition is improving.

numbers rather than productivity (Hughes et al, 2016). Regulating and cultural services are expected to show gradual improvement – GHG emissions to fall and eventually become sequestration, biodiversity and wildlife to expand, and recreation to increase. The likely changes to flood prevention are not well understood, and the figures are here kept constant once restoration is in train. On the other hand, cropping revenue ceased once the restoration began.

Table 5.5 Asset and risk register

		opening 1995	closing 2016	change	trend
extent and type of land cover					
cropping land in restoration to fen	ha.	479	479	nc	-
cropping land	ha.	0	0	nc	-
land use type					
1.1 Agriculture - cultivation		0.0%	0.0%	0.0%	-
1.6 Land used for maintenance and restoration of environmental functions		100.0%	100.0%	0.0%	-
significant land ownership and management					
owners					
National Trust		100.0%	100.0%	nc	-
condition					
Natural England					
unfavourable		0.0%	0.0%	0.0%	-
unfavourable - recovering		100.0%	100.0%	0.0%	-
Peatland Code					
drained		0.0%	0.0%	0.0%	-
drained - recovering		100.0%	0.0%	0.0%	↓
modified		0.0%	100.0%	0.0%	↑
spatial configuration					
contiguous		largely	largely	nc	-
ecosystem services					
provisioning					
grazing		✓	✓		-
cropping		✗	✗		-
regulating					
greenhouse gas reduction		✓	✓		↑
flood protection		✓	✓		↑
biodiversity		✓	✓		↑
cultural					
recreation		✓	✓		↑
education		✓	✓		↑
wildlife		✓	✓		↑
what managed for					
fenland restoration		✓	✓		-
grazing		✓	✓		-

biodiversity	✓	✓	-
major dependencies			
possible influences on/of adjacent farmland and drainage as these deteriorate			
available clean water from 'lodes'			
peatland sufficiently intact to lead to expected GHG improvements			
good local relationships			
potential thresholds/tipping points			
drained/unfavourable/wasted/archaic peatland, if unimproved, could be in irretrievable condition			
assets valued of local and national importance			
Wicken NNR valued for landscape, biodiversity and recreation. This extra area expected to add to the attractiveness.			
Rare wildlife under threat			
risks (L,H,VH - low, high, very high risk)			risk trend
food from cropping	H	H	↑
food from grazing	L	L	↓
equable climate	VH	VH	↓
hazard protection	L	L	↓
biodiversity	H	H	↓
recreation	L	L	↓

This cut-down register also records risks, dependencies and externally-valued assets. The success of the project and its wider effects will depend upon the interaction with the surrounding area, a region of heavily cropped land and idiosyncratic drainage and stream flow. It is also dependent upon the quality of the underlying peatland – much local peat is wasted and this will affect the feasibility of restoration. And, as Dickie (2016) and Haines-Young (2016) pointed out, 'buy-in' of local, as well as external, stakeholders can have decisive implications. The value of the Wicken Fen NNR is much appreciated, but with the expansion of the area, while welcomed by ornithologists and other visitors, those gaining income from the alternative land use and others affected, may not have a favourable attitude.

Risks to the project involve the loss of crop output, which is, of course, high. This might only have a marginal impact for a project such as this, but it is a major issue for more extensive land restoration in where highly productive systems are being replaced. Other risks will be likely to fall, with the most important being climate change, followed by biodiversity.

Ecosystem accounts

Following SEEA-EEA (2013) the normal set of ecosystem accounts would be as shown below in the upper part of Figure 5.4. If restoration was not actually being implemented, it would be helpful to produce a parallel set of accounts to illustrate accounts if restoration were to be instigated.

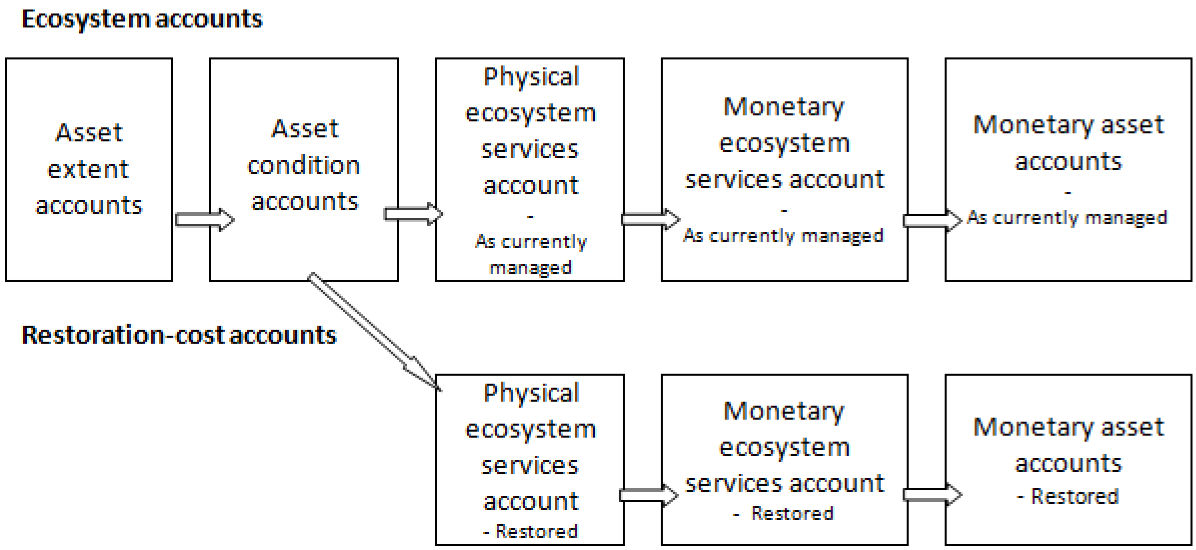


Fig. 5.4 Ecosystem accounts

In this study, however, the opposite has been done – the restoration process has been instigated, so the upper set of accounts, in fact, constitute the restoration case, while the lower set show what would have been expected if no restoration had taken place or was planned – here this is termed 'bau'. Despite the accounts here being in the 'reverse order', so to speak, they still allow comparison of restoration against bau.

The spreadsheet was designed to produce each of these accounts, with two parallel sets produced – those including restoration and those for bau (assuming no restoration were to take place) – these could be termed the 'actual' (what interventions had actually happened and were intended to happen) and the 'hypothetical' (what might have happened otherwise). In the accounts below, to avoid confusion, only 'the 'actual' accounts are presented, except in the case of the ecosystem asset account (financial), where the ''hypothetical' (bau) is also presented alongside.

Asset extent and condition accounts

In this case, the asset extent and condition accounts can be combined. The opening period is taken as 1995, the year in which restoration was started, while the closing year is taken as the most recently completed year, 2016. Details are presented in Table 5.6.

As the area is being taken as a whole, there are not a multiplicity of changes occurring between the opening and closing points. Once restoration began in 1995, the condition could be taken as moving from 'unfavourable' to 'unfavourable-drained'. By 2016, following more than twenty years undergoing restoration, the area would still be ‘unfavourable- recovering’ but moves into ‘modified’ if the Peatland Code applied here.

Table 5.6 Asset extent and condition accounts

	1	2	3	4r	4	5	**total**
	pristine	nr natural	modified	drained - recovering	drained	actively eroding	
NE	favourable - maintained	favourable - maintained	favourable - recovered	unfav. - recovering	unfavourable	unfav. - declining/ partially destroyed	
Opening stock - 1995	0	0	0	479	0	0	**479**
additions to stock							
regeneration - natural	0	0	0	0	0	0	**0**
regeneration - via human activity	0	0	479	0	0	0	**479**
reclassification	0	0	0	0	0	0	**0**
reductions of stock							
reductions due to extraction/harvest	0	0	0	479	0	0	**479**
reductions due to human activity	0	0	0	0	0	0	**0**
catastrophic losses – human activity	0	0	0	0	0	0	**0**
catastrophic losses – natural events	0	0	0	0	0	0	**0**
Closing stock - 2016	0	0	479	0	0	0	**479**

Ecosystem service accounts (physical)

The annual physical[54] flows of ecosystem services for 2016 are presented in Table 5.7. Although the emissions of GHG are expected to fall as a result of the restoration activities, because emissions are continuing, albeit at a lower level, environmental-economic accounting (UN, 2012a; 2012b) excludes such disservices.[55] Nevertheless, to illustrate their contribution, GHG have been included in the right-hand column of the table, a negative sign indicating emissions – for the bau scenario, instead of the 722 tonnes of CO2 (equivalent) emissions, the spreadsheet model suggests that there would be an estimated 4,322 tonnes produced.

Table 5.7 ES service (physical) accounts – year end 2016

ecosystem services	unit	Total (excluding negatives)	*per ha.*	Total (including negatives)
provisioning				
grazing	£	39425	*82.31*	39425
cropping	£	0	*0*	0

[54] In most cases here the services are measured in financial terms at the outset.
[55] Emissions should be included in the emissions accounts (Harris, 2017)

regulating				
GHG	CO2et	0	*0*	-722
flood protection	£	15872	*33.14*	15872
biodiversity		na	*na*	na
cultural				
education		na	*na*	na
recreation	visitors	32451	*67.75*	32451

Ecosystem services financial supply and use table

Table 5.8 shows the supply of ecosystem services in financial terms[56], shown on the upper right as emanating from the ecosystem, while these flow to uses on the lower left hand side – although some regulating services also flow back into the ecosystem.

Table 5.8 Ecosystem services financial supply and use table (£/yr., 2016)

SUPPLY	Type of economic unit				Ecosystem		
	Industry	Households	Accumulation	Rest of World	:	Open wetlands	:
ecosystem services							
provisioning							
grazing						39425	
cropping						0	
regulating							
GHG						0	
flood protection						15872	
biodiversity						na	
cultural							
education							
recreation						40001	

USES	Type of economic unit				Ecosystem		
	Industry	Households	Accumulation	Rest of World	:	Open wetlands	:

[56] financial figures from earlier years have been inflated using the GDP deflator.

ecosystem services						
provisioning						
grazing	39425					
cropping	0					
regulating						
GHG	0					
flood protection	15872					
biodiversity	na					
cultural						
recreation		40001				

The ecosystem supplies services which are then used by different economic units: grazing services are transformed by 'industry' into products, while regulating services often benefit a range of economic actors, even those outside the borders of the country. Recreation is consumed by households, from within the UK and by external visitors ('rest of the world'). No separation between economic units was attempted here.

Ecosystem asset account (financial)

The financial account showing the value of the ecosystem assets at the start and the end of the period is shown in Table 5.9. The asset value at the start and end of the period was the sum of the costs and benefits for each of the blocks for each year, discounted using the British Government 'Green Book' (HMT, 2016) discount rates – ranging from 3.5% for the first 30 years, falling in steps to 1% for cash flows beyond 300 years. The discounting period was 100 years, although the calculation was also carried out for 300 years.

Again, following the UN (2012b), the financial calculations for the ecosystem asset in Table 5.9 are presented excluding emissions, but then also the effect of including the emissions is shown for reference. Also, the figures for the 'hypothetical' case of bau are presented on the right hand side.

With the exclusion of GHG emissions, the accounts show an increase, via regeneration resulting from human activity, from £0.72 mill. To £1.11 mill. If emissions are included, the initially-negative valuation of -£0.58 mill. becomes positive by the end of 2016, at £0.50 mill. The comparison with the bau picture excluding omissions may seem unfair – it appears that the asset value would be higher, albeit falling from £4.76 mill. to £3.03 mill. as expected future crop revenues decline. The 'with emissions' account shows the bau moving from -£15.44 mill. to -£25.41 mill. The source of the change is denoted as a reduction due to human activity.

Table 5.9 Ecosystem asset account (financial)

£	restoration		bau	
	Without negative	*With negative*	Without negative	*With negative*

	GHG	*GHG*	GHG	*GHG*
Opening stock @ 1995	727218	-580809	4756440	-15439636
Additions to stock				
Regeneration - natural	0	0	0	0
Regeneration – human activity	384909	1084999	0	0
Reclassifications	0	0	0	0
Total additions to stock	384909	1084999	0	0
Reductions in stock				
Reductions -extraction	0	0	0	0
Reductions – human activity	0	0	1723007	9969254
Catastrophic less –human activity	0	0	0	0
Catastrophic losses – natural	0	0	0	0
Reclassifications	0	0	0	0
Total reductions in stock	0	0	1723007	9969254
Revaluations	0	0	0	0
Closing stock @ 2016	1112127	504190	3033433	-25408890

In Table 5.9, however, the 1995 and 2016 valuations are based on differing patterns of carbon prices, so the effect of price and volume change has not been separated. If the calculations are made using the same carbon price patterns in 1995 as in 2016, then the price and volume effects can be separated, with the results shown in Table 5.10

Table 5.10 Ecosystem asset account (financial) – nominal terms

£	restoration		bau	
	Without negative GHG	*With negative GHG*	Without negative GHG	*With negative GHG*
Opening stock @ 1995	727218	-580809	4756440	-15439636
Additions to stock				
Regeneration - natural	0	0	0	0
Regeneration – human activity	399643	2335950	0	0
Reclassifications	0	0	0	0
Total additions to stock	0	0	0	0
Reductions in stock				
Reductions -extraction	0	0	0	0
Reductions – human activity	0	0	1723007	794797
Catastrophic less –human activity	0	0	0	0
Catastrophic losses – natural	0	0	0	0
Reclassifications	0	0	0	0
Total reductions in stock	0	0	0	0
Revaluations	-14734	-1250951	0	-9174457
Closing stock @ 2016	1112127	504190	3033433	-25408890

The volume effects are, therefore, shown to be much larger when negative values are included with restoration, but not so with bau. The exclusion of the negative GHG values obscures much of the volume effect with restoration, but the price effect with bau.

Cost: Benefit Analysis

Following the discounting procedure noted in the previous section, but taking a one hectare example using unit benefits and costs, the discounted values were calculated for the site under restoration compared to the situation if no restoration had occurred (business as usual – bau). The results are presented in Table 511.

The benefit of the restoration project was taken as the present value of the stream of restoration benefits (including 'negative' income from emissions) less the present value of the stream of bau net benefits. To determine the benefit:cost ratio, the figure from the previous sentence was divided by the discounted restoration costs, using the British Government's 'Green Book' discount rates (HMT, 2017).[57]

Table 11 Cost-Benefit Analysis (£/ha)

	net benefits bau	benefits restoration	bens rest- net bens bau	costs bau	B:C ratio
100 yrs	-30784.8	2248.8	33033.5	5232.0	6.31
300 yrs	-46758.6	3151.0	49909.6	5528.2	9.03

The benefit:cost ratio (BCR) is strongly positive at over 6 for 100 years and 9 for 300 years, but it is wise to evaluate the sensitivity of the results to changes in key variables. The results of this are shown in Table 5.12 and Figure 5.5.

On the basis of the annual values per hectare, converting the lump-sum, net-benefit figures from Table 5.11, to an annuity, for a 100-year lifetime the figure is £963.2, while for 300 years it is £1,423.4.

Table 5.12 B:C ratios - sensitivity

			change from base	
	100 yrs	300 yrs	100 yrs	300 yrs
base - sloped changes	**6.3**	**9.0**	**0%**	**0%**
base, high recreation	8.1	10.9	28%	21%
recreation values growing	6.4	9.2	1%	2%
cut crop yield to half in 25 yrs	10.8	13.3	72%	47%
50% reduction in GHG benefits	3.9	6.4	-38%	-29%
halve C prices	2.6	4.0	-58%	-55%
double years to improved condition	3.9	6.4	-38%	-29%
halve years to improved condition	6.8	9.5	8%	5%
stepped changes	0.2	3.2	-97%	-64%
1% discount rate	15.8	28.0	150%	210%

[57] Different means of presenting the discounting results could have been used; the result concerning whether the project was worthwhile would be the same (Bright, 2011).

Positive changes, such as using the recreation values from Peh *et al* (2014) , increasing the recreation numbers with population, halving the time it takes for condition to improve, as well as devaluing the opportunity-cost (the value of the alternative land use, namely cropping) has an expectedly positive impact on the BCR, albeit not great. Negative changes – reducing GHG benefits, halving carbon prices and doubling the years for condition improvement, have negative changes, although the BCR remains positive.

Two other changes are notable – if the transition from one condition to the next is stepped, effectively making the time period before improvements are felt much longer, does reduce the BCR considerably – to only 0.2 for 100 years, although 3.2 for 300 years. Using a lower discount rate of 1% throughout, to mirror that used by de Groot *et al* (2013) increases the BCR a great deal –into line with the range of ratios found by them.

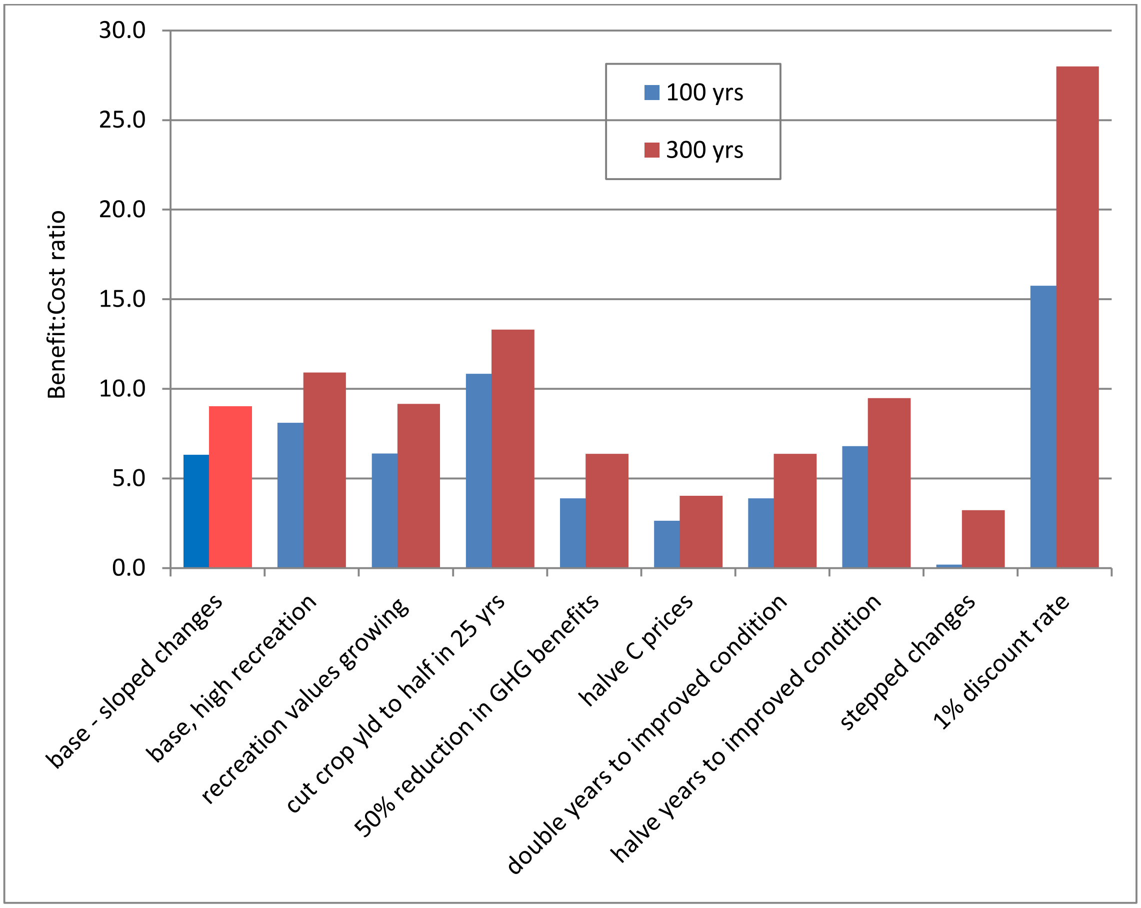


Fig. 5.5 B:C ratios – sensitivity

Issues

- The future pattern of activities, costs and benefits and the transition from one condition, and hence flow of services, to the next, is only predicted, and due to the relative infancy of many projects, guidance from other projects is limited.
- Fen/peatland 'restoration' projects differ widely in their approach (heavy/limited engineering and prescription/direction) and costs – due to characteristics and philosophy, as well as their characteristics.
- With discounting, because restoration costs tend to be heavily 'front-loaded', especially with initial heavy engineering, this has a substantial negative impact on measures of economic favourability; assuming a long project life favours projects with delayed and long-term benefits.
- Considerable funding is being expended for the project, yet nobody seems to have previously carried out a detailed economic appraisal[58]. It would seem to be an important task – why has it not been done? It may be because the future is seen to be so uncertain, or because the project is seen as experimental, or because the biodiversity benefits are deemed to be much higher than any costs. Furthermore, analysis should be carried out in a manner which yields defensible results, highlighting the need for group expertise ranging from ecology to economics, to be applied.
- Will fixed/specific/prescribed objectives give sufficient flexibility and resilience in the face of climate change and other external factors? Will objectives need to change? What objectives are appropriate?
- Considerable effort was being made to monitor biodiversity, yet no value was applied. Difficult to measure services should not be ignored.
- Monitoring costs can be considerable and, due to the lengthy time scales involved, long-lasting. As with Exmoor Mires, such costs are seen as necessary in order to gain a better understanding of the levels and patterns of ecosystem services arising from the site. Two questions arise here – will funders be willing to support the monitoring work for the long term; and to what extent should monitoring costs be considered part of restoration?
- Projects have <u>not</u> tended to enumerate costs to facilitate cost-benefit analysis or comparison across projects. Much effort is often expended on measuring ecosystem service outcomes, with considerable research interest in these, whilst costs seem to be the poor relation, with less apparent interest in publishing and analysing them.
- It may not be possible to return to a pre-intervention state, certainly not for a long time, and it may not be desirable to do so.
- Buy-in of, and relationships with, local stakeholders, as well as those further afield, is an important consideration and can take up a good deal of the time of project staff. There will be winners and losers in any project and all must be given consideration. (Dickie, 2016; Haines-Young, 2016)
- Because of the exclusion of GHG emissions, ecosystem accounts can give an unfavourable impression of a restoration project *vis a vis* bau. Thus, it is advisable to first use discounted cash flow (DCF) to help in evaluating the economics of a restoration project.

[58] Peh et al (2014) have produced an analysis, but this is limited.

- The project involves, and depends upon, positive collaboration between non-government organisations, government-related organisations, academics and project managers.

Conclusions

- Although cost data was limited and aggregated, and benefit data also had shortcomings, it was possible to build the asset and risk register, ecosystem accounts and DCF. Sensitivity analysis enabled the evaluation of some aspects of uncertainty.
- For all scenarios, the BCR is positive – suggesting that the project is, economically, worthwhile.
- Detailed and readily-retrievable recording of costs is important for evaluation of the project and for sharing across the restoration community.
- Much effort is being expended on measuring ecosystem services. This is potentially of great value to the research community, but as with costs, it needs to be disseminated in a form of value to restoration decision makers elsewhere. Attempts are being made, not least for peatland (Bonnett, *et al*., 2011; Evans *et al*, 2011; PDNPA, 2008); pushing ahead with this is strongly recommended.
- Monitoring can be expensive, but, although not directly part of the restoration itself, is an important and, many would argue, a necessary component of restoration.
- Information on restoration activities, costs and benefits needs to be stored and made available as a resource for the restoration community.
- It may not be feasible to measure all ecosystem service outcomes. Although improvements in this regard would be helpful, focus on those which are likely to have the greatest impact is advisable.
- Cooperation between the various stakeholders is important – and this includes ‘losers’ as well as ‘winners’.

Chapter 6 Issues arising

From the earlier chapters as well as discussions held with various individuals (see Appendix C), a large number of issues have arisen, issues of relevance not only for the pilot studies but more widely for the UK and EU.. In an attempt to give some order to the presentation, these issues have been allocated to a number of headings and these grouped into three broad areas – application objectives, benefits and costs; recording and accounting; and policy and decision making, as shown in the diagram below (Figure 1). The issues will be discussed under those headings for each of the broad areas; some sub-topics appear under more than one heading, which may underline their importance.

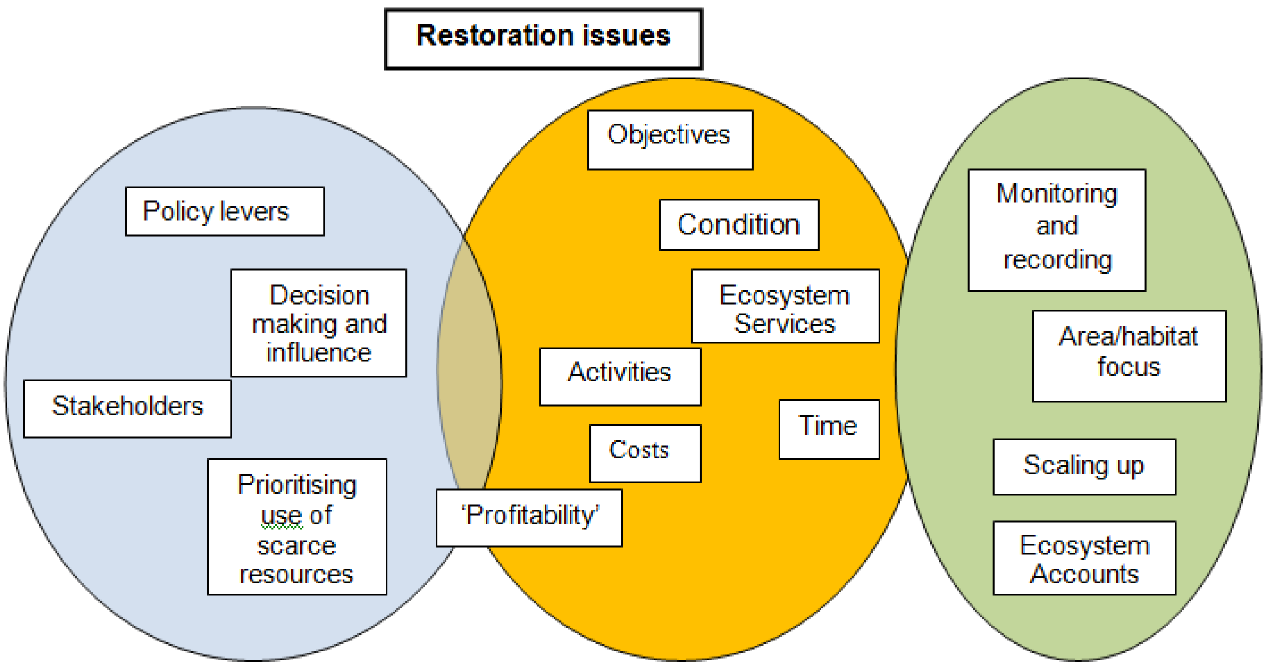


Fig. 6.1 Grouped restoration issues

Application objectives, benefits and costs

Objectives

- Opinions vary regarding the reference point to which the project should be targeted, and even whether the pristine condition could be reached or even desirable, given that conditions have changed. Some suggest that 'improvement', rather than 'restoration' should be the aim.
- Some practitioners suggest that it is important that project objectives should be flexible, and might need to be reassessed in the light of experience.
- Restoration objectives need to take account of changing demands into the future.

- Those involved in projects seem to favour strong sustainability, with restoration ensuring that future options are left open.

Ecosystem Services

- Despite this study focussing on restoration costs, the ecosystem services (ES) arising are obviously important. As the annex to chapter three highlighted, different ecosystem services within a habitat or site will follow differing change patterns and may even move in opposing directions. Thus, account needs to be taken of trade-offs. Again, as the annex to chapter three indicated, 'corner solutions' are rarely optimal - it may not be wise to restore or change the land use for a whole area, farm or site.
- Restoration often involves change of quality rather than change of extent – restoration of farmland may involve edge strips, hedgerows and pockets of meadow and woodland, rather than wholesale change[59].
- Not all services are readily measured or estimated. Should we attempt to cover all, even the difficult-to-measure ones, or just those which are likely to be most important? Biodiversity deserves particular attention – of substantial consequence but easily neglected in measurement terms due to these difficulties.
- Future user demand and its effect on services and their value should be borne in mind
- There is limited understanding of the links between ecosystem condition, the restoration activities and costs, the ES which would ensure, and the timings of these.

Condition

- Understanding the links between ecosystem condition and ecosystem services (both current and future) will help in gauging restoration needs and impacts.
- Measures of condition are manifold, albeit falling within grouped headings. Can we use one or a few condition indicators or a summary indicator for restoration plans and do we need such an indicator relevant to all ecosystems or can they be specific?
- The quality of condition data varies, with different approaches to measuring condition depending partly upon their envisaged uses.

Activities

- Restoration can be carried out in different ways, from heavy engineering to laissez-faire. This will depend upon a number of factors and will affect the costs and outcomes.

[59] Although there is probably much that could be done to improve the supporting services of the most productive land without having to reduce its provisioning services , such as less soil damaging cultivation techniques and more accurately targeted use of pesticides and fertilisers.

Costs

- Recording of costs is vital for project appraisal and wider use, but may be poor or difficult to separate from other costs or difficult to retrieve.
- Costs incurred may be available, but their relevance for estimation of future costs must be evaluated.
- Costs tend to be site specific and the quantity, provenance and accuracy of 'average' costs is often unclear and poor and limited.
- Future costs may fall – as new methods become available and expertise is gained. Economies of scale are also likely.
- Despite the problems with obtaining cost data there is a good deal of knowledge of costs - amongst large businesses (such as water companies), and NGO's, agencies and consultants closely involved in projects (such as Wildlife trusts) in the UK and within the rest of the EU.
- There have been, and are, attempts to collate costs data, but these are not held in one place and form. Much more effort seems to be going into collection of data on the ecosystem services arising from restoration than the costs involved (e.g. ESMERELDA).
- In order to evaluate the 'profitability' of restoration, the costs of maintaining and costs of 'business as usual' (bau) are also needed for comparison. In addition, it has been suggested that maintenance costs may be the opportunity costs of not getting the highest rate of subsidy,
- There is a good deal of data on grant rates and standard costs for grant applications – these do not represent the actual costs of restoration, but are often used as proxies for them.
- Naturally, much of the focus of restoration projects has been on special sites. How would the costs involved differ for non-special sites?

Time

- Restoration often takes a long time, so needs to be evaluated over a long period.
- Because of up-front costs, discounting over short periods is likely to favour bau., so appropriate lifetimes are important.
- Furthermore, high discount rates will militate against long-gestation restoration.
- Activities, costs, services and values are unlikely to remain the same, particularly over such long periods. Assumptions about trends need to be justified, including assuming that current values will remain.
- The future is uncertain – uncertainty needs to be acknowledged and evaluated.
- Some ES may be in decline; on the other hand, factors, such as technology, may improve yields.
- Climate change effects on ES need to be predicted. Some sites can help to give an early indication of these (this has been suggested for Exmoor Mires).
- To assist in gauging the impact of uncertainty, a base case can be presented supplemented by sensitivity analysis.

'Profitability'

- Different measurement methods (e.g. exchange or welfare values) may be appropriate depending upon the objective of the calculations.
- Using discounted cash flow (DCF) the two pilot studies appear to be worthwhile – 'profitable'. Other studies give positive results for many and varied restoration projects.

Recording and accounting

Monitoring and recording

- Monitoring of impacts of the project, particularly of ES, tends to be expensive. It might be argued that this is not strictly a cost of restoration, but it is also argued that it is necessary.
- It is not clear who should pay for monitoring –those undertaking the restoration may not be so concerned about measuring its impacts if they are simply responding to an incentive. Should those who want to know the outcome, pay for monitoring?
- Some grant schemes have been criticised for measuring uptake rather than output/outcomes.
- To reduce the cost of monitoring and encourage support, 'citizen monitoring' has been advocated and used (e.g. counting butterflies).

Area focus

- Restoration activities and its effects may not be confined to one field, forest stand, site, ecosystem or habitat, but cross boundaries. Measurement will therefore have to cover a wider area, such as a farm, instead of a field, a forest instead of a stand, or a catchment instead of a project. This can be particularly true of linear features. This can be a question of scale or of area affected.

Scaling up

- Currently, there is limited information on costs and benefits to facilitate the development of a representative picture of a whole habitat..
- Scaling up from site to a national ecosystem or habitat level presents considerable difficulties: geographic variability is such that each site might be unlike any other, so that restoration costs and the ES and their values might be site-specific. So assuming that cost and values (transfer values) can be used to gross up might lead to widely inaccurate

aggregates, not only suggesting restoration costs much higher or lower than reality, or wrongly indicating the most cost-effective areas for restoration.

- Past or current costs and benefits might not be indicative of those in the future - there may be economies of scale achievable if restoration were to be taken up much more widely; or unit restoration costs or returns might be less favourable as we move from 'cherry-picked' sites to those less appealing.
- Solutions have been put forward: records need to be collected from as many sites, representative of the range of situations, as possible; using a variety of data from satellite imagery, GIS, agriculture data, business data, and big data could help to fill gaps, particularly using statistical techniques ; or producing general estimates based on key factors, such as grade of land (condition), proximity to people, and whether upstream of heavily populated areas.
- Although modelling might be feasible, it could require vast amounts of data and be expensive.
- Would a two-pronged approach be more suitable – using a 'quick and dirty' ('top down') approach for aggregate estimates and a database to help those planning and evaluating particular projects?

Ecosystem accounts

- Although disservices are included within SEEA accounts, they are excluded from ecosystem accounts, which can give a confusing picture
- Certain disservices can be missed from the overall SEEA accounts!
- There continues to be argument about the inclusion of restoration costs in ecosystem accounts. There is agreement that they should be included if restoration is underway or intended, but those updating the SEEA-EEA suggest that hypothetical restoration costs should be excluded, while there is still a body of opinion which supports their inclusion in some circumstances – and this seems to be supported in the worked example .
- Nevertheless, there is agreement that appending details of hypothetical restoration costs can be useful, if not in formal accounts, then in parallel or satellite accounts.

Policy and decision making

Policy levers

- How should actions be brought about? By nudging, incentivising or directing?
- To what extent should subsidies and taxes be used to encourage restoration and discourage degradation? Should there be payment for environmental services or taxes for damage or both. One cited European scheme involves requiring compensation for degradation as urbanisation of greenfield sites occurs.
- Who should pay for restoration?

- Coordination of management of grant schemes does not always take place, agencies do not always collaborate and coverage can overlap.
- Grant schemes can work against restoration (such as agri-environment schemes and moorland restoration).
- Grants and subsidies can be too rigid in terms of prescriptions and time periods.
- Wording can be off-putting rather than persuasive (e.g. the use of the term degradation, rather than ‘ protect’ or ‘improve’ – Dickie, 2016)
- Grant schemes seem to have often measured outcome not uptake so the effects have not been real but superficial
- Cross-compliance standards may be too weak.
- Inadequate attention to size/scale may lead to undesired consequences.
- Targeting of schemes to particular areas or actors may be beneficial, but raises other issues.
- The use of auctioning for subsidies may lead to areas with lower opportunity costs being brought forward, which may lead to more optimal outcomes when resources are limited.
- Attention has not always been paid to those stakeholders who lose out when restoration schemes are implemented.
- Brexit provides threats and opportunities. This includes the extent to which CAP funds are replaced and how they are used (still only for agricultural landowners, for instance).
- It has been suggested that too much focus has been given to technocentric rather that sociocentric solutions and decision making.

Decision making and influence

- Those who own the assets may be those who make the decisions about its use. However, control and powerful influence on decisions can be exercised by others – government, tenants, interest groups. Even decisions about land under public ownership can be heavily influenced by interest groups.
- Land owners and other asset decision makers may have short term interests (e.g. covering up-front costs) or long term perspectives (passing on to children).
- Those who are likely to gain or have gained from restoration and those who lose will have opinions and may have influence on the success of the project or policy.

Stakeholders

- Local people may not be part of a project, but will have a stake.
- Involving stakeholders can be time-consuming and expensive, but is necessary
- Collaboration between stakeholders influences success. This includes that between government departments, agencies and specialists (accountants, economists, ecologists and even specialists within these areas. Dodds (2017) suggested the Strategic Research Programme in Scotland as a positive example.
- Technocentric solutions may take precedence over sociocentric decisions

- Sufficient notice may not be taken of those who are likely to lose from a project. Dickie (2016) quoted: 'pay more attention to the people who lose out.'

Use of resources/scarce resources

- Resources are limited – not all restoration will be possible.
- How do we determine which restoration to select (where is effort justified, and how much?) and the order of priorities?

Considering these issues and the earlier findings, a number of recommendations are presented in the next chapter.

Chapter 7 Recommendations

Following on from the previous chapter, and using the same headings, a number of recommendations are offered. These have application at sub-national, UK, European and wider levels.

Application objectives, benefits and costs

Restoration objectives

- Although determination of the target condition should take account of some past, 'reference' condition, it is not always helpful, feasible or necessary to use that term. Rather, ecosystem 'improvement' might be a better term.

- Due to changing circumstances, objectives may need to be flexible.

Condition

- More work is needed to improve understanding of the link between ecosystem condition and ecosystem services, including the effect of maintenance and restoration activities over time: Figure 7.1 illustrates this relationship.

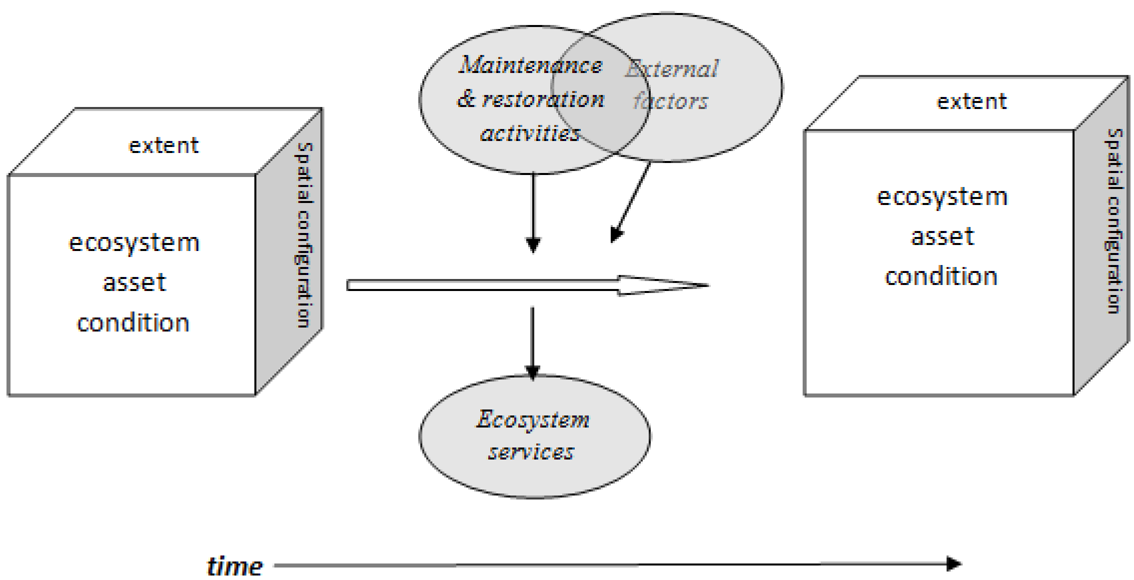


Fig. 7.1 Ecosystem condition, restoration activities and ecosystem services

- Amongst the many indicators of ecosystem condition, agreement of a set of key indicators would be helpful for recording and linking with information on ecosystem capacity and appropriate restoration activity.
- Improved coverage of data on ecosystem condition is needed, particularly for those areas not given special attention (i.e. not SSSI or SAC sites).

Ecosystem services

- It might not be possible to measure or estimate all ecosystem services: those services likely to be most important need to be measured, but those seen as peripheral or difficult-to-measure should not be completely neglected.
- Not all ecosystem services will grow as restoration is implemented; as Chapter Three explains – ES may be competitive rather than complementary or supplementary. The implications of such trade-offs need to be evaluated, on a local as well as a wider scale. For instance, for restoration of fenland from arable – if this took place on a wider scale, would it have national and international implications? Moreover, in the case of trade-off, the optimum solution may well involve a combination of ES, as Figure 7.2 illustrates[60].

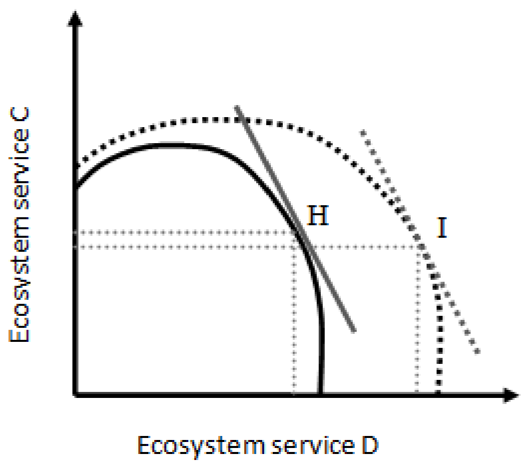


Fig. 7.2 Optimum ES combinations with restoration sifting of ESPF (taken from Chapter 3)

- Estimates of future ES should be produced, taking account of changing conditions, and not simply carrying forward past costs, unless this is justified.
- Unless actual costs are used, some estimate of the effect of uncertainty should be provided.

Activities

- Restoration activities can differ, even for similar sites with similar condition – the rationale for these different approaches and their implications need to be understood and recorded

[60] The Annex to Chapter Three provides more detail to this argument.

- The cost of restoration is made up of the volume of the physical activity and its unit cost; so attention must be paid to the physical, not just the financial

Costs

- 'Average' costs need to be improved – 'broad brush' is unsatisfactory!
- 'Average' costs can be helpful – for producing aggregate values as well as for estimating likely costs for a specific site. To produce better averages, costs need to be gathered, not only by habitats, sub-habitats and sub-categories, if possible, but also by other factors e.g. (location, size) and condition. This also applies to ES.
- To help with evaluation, we also need maintenance and bau (carrying on as we are) costs
- Grant rates do help as proxies for actual costs – these too need to be gathered.
- Modelling of costs could help to fill gaps, and may not be as difficult as that for ES outcomes.

Time

- Restoration takes time, so sufficient time needs to be given – for projects, for project funding, for evaluation of project effects, for project appraisal lifetimes. Thus, some changes to ES may be quick, some take a considerable time, and some ES may worsen before they improve – this needs to be recognised.
- The estimated time series of costs and ES should take account of changes in influencing factors such as climate change, technology, population and demand over the short, medium, long and very long term.

Evaluation -'Profitability'

- Data and information on bau (counterfactual) should be collected to assist in the appraisal of projects and policies
- Acknowledgement of and some assessment of uncertainty will help to give an appreciation of the sensitivity of estimates.

Recording and accounting

Monitoring and recording

- Recording of costs as well as outcomes is vital. It should be clear, consistent, detailed, time-related and retrievable
- Information should be recorded by habitat, sub-habitat and other relevant geographical features and by condition. It needs to link condition, costs and services and to incorporate time.
- Guidelines should be produced to help those involved in collecting and recording data

- A database should be constructed and continually added to. This would be beneficial, not only on a UK, but also on a Europe-wide scale, and be made widely available. For this, a consistent, uniform (but not straitjacket) approach should be agreed and encouraged
- There are many disparate individuals and organisations who have data and expertise which could be used to build up the database
- The cost of monitoring is not a direct cost of restoration, but is vital for understanding. This should be recorded and included in project analysis.

Area focus

- Agreement needs to be reached on the appropriate geographical area and scale for recording restoration data – unit area, site, catchment, area, linear feature.

Scaling up

- More data, with wide coverage and suitably recorded would help in making aggregate estimates more accurate
- Gaps in the data need to be identified and filled
- Asset and risk registers should be constructed by habitat
- It will take time and expense to achieve accuracy, but decision-makers need timely information. To facilitate this, a multi-pronged approach could be taken: for each habitat, restoration potential could be scoped and an initial asset and risk register constructed. Simultaneously, more and better recording encouraged (and guidelines produced), a database could be built up, gaps filled, improved and more-detailed 'averages' calculated, and modelling carried out.
- Resource shortages suggest that focus should be on areas likely to yield the greatest benefit.

Ecosystem accounts

- Parallel to the ecosystem accounts, accounts showing hypothetical restoration-costs should be produced, as Figure 7.1 illustrates.

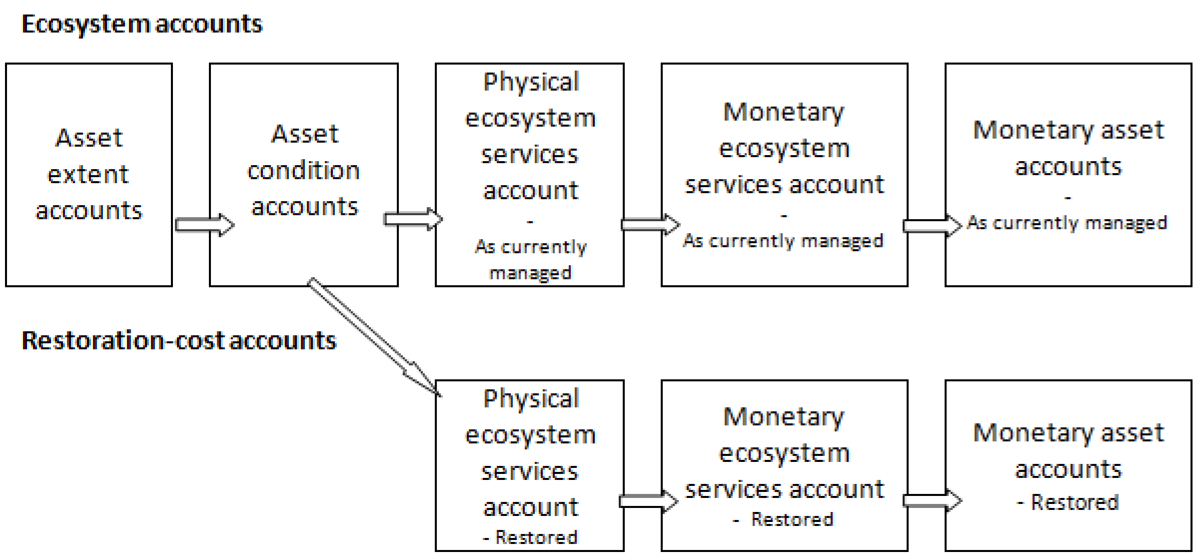


Fig. 7.3 Parallel ecosystem and restoration-cost accounts (copied from Fig. 4.7)

- Where restoration is being carried out, its costs should be included in the ecosystem accounts
- The argument for excluding hypothetical restoration costs from the valuation of ecosystem assets is not universally accepted, so more debate is needed
- Although corporate and national accounts differ, there are similarities. The above debate could usefully consider the differing approaches to ecosystem asset valuation in these.
- A paper setting out the debate, with modelled examples, would help those involved and those needing explanation!
- The clear inclusion of ecosystem disservices in the UK's national environmental-economic accounts should be ensured.
- The exclusion of ecosystem disservices from the ecosystem accounts, can be misleading: appraisal of restoration should ensure that changes in disservices as well as changes in services, are accounted for.

Policy and decision making

Policy levers

- Policy making should involve careful planning and should take account of who makes decisions about, and who is affected by, restoration (winners and losers). Policy makers need to decide who should pay, which approach or combination of levers they wish to use – to nudge, incentivise and disincentivise and/or to direct, the likely impacts of which should be appreciated. Incentives should focus on outcomes, not solely on uptake, and should not have unintended consequences. Funds may be best targeted and not necessarily universal; auctioning could be considered. The phraseology used can be encouraging or off-putting or worse – words matter and this should be recognised in grant and project literature and in verbal communication.

- Overlap between policies should be avoided
- Beware of technocentric policies and solutions – a sociocentric approach, not ignoring technical aspects, is advocated by people with a depth of experience.
- The Common Agriculture Policy of the EU involves substantial funding. Those funds, within the EU or for the UK following Brexit, provide an opportunity for a major restoration drive.

Stakeholders

- Collaboration is vital – between agencies, stakeholders and individuals - in policy-making, policy delivery and recoding of policy effects. Further, as this researcher has learned from the pilot studies and discussions, this means collaboration between experts, from economists to ecologists, and practitioners.
- Restoration is likely to produce winners and losers – the latter should not be forgotten.
- Involving people in decisions and communicating with the various actors can be time-consuming and expensive, but produces rewards – decision makers and managers should take time to listen and take note.

Use of resources/scarce resources

- Given limited resources, their use in restoration will involve determining priorities, so careful evaluation of costs and benefits and weighing up the opportunity-cost is necessary.
- Consequently, good records, not only of costs, but also of the related benefits, must be available not only to support judgements about the past, but also to assist in evaluating future plans.

Key recommendations

From this long list of recommendations some key themes can be identified and these are listed below:

1. Ecosystem condition, ecosystem services, and restoration activities and changes over time are linked (Figure 7.1) – this needs to be better understood.
2. These elements, in physical and financial terms, need to be recorded and brought together for the common good – potentially at a UK and EU level. Records would cover ecosystem condition, extent and spatial configuration, ecosystem services, restoration maintenance and bau activities and costs, grant rates, and monitoring activities (all with timings), categorised according to sub-habitat and other characteristics as well as condition. Such a database could be created and added to over time from a host of sources. ONS/Defra would be a logical initial repository or coordinator of this for the UK, Eurostat carry out the same

role for EU/Europe. These bodies could be responsible for the production of guidelines for the recording of these data.

3. Scaling up to the aggregate could initially involve the construction of habitat asset and risk registers, which would be revised as the database expands and ‘average’ and modelled figures emerge. Uncertainty should be recognised and evaluated – confidence intervals will narrow as the database improves.
4. Restoration costs have a place in ecosystem accounts – directly if restoration is underway, but only as parallel accounts if hypothetical, although the latter is still subject to debate; a paper on this would be helpful.
5. The importance of time cannot be overstressed – time in the consideration of ES flows, time for restoration activities and monitoring, the need to consider changes in values over long periods, the need to commit funding for long periods, and need to assign a sufficiently long lifetime in asset valuation and project appraisal.[61]

Two further points arise – they are not of direct relevance to this project’s objectives, but are worth mentioning because of their importance:

6. EU, government and agency policy may have a major influence on restoration decisions, but requires careful planning and implementation.
7. Collaboration between agencies, between specialists and between practitioners and researchers bears fruit, so should be encouraged!

[61] And the related decisions about discount rates.

Chapter 8 A Roadmap for Work on UK Natural Capital Restoration

The construction of an asset register will provide the underpinning for the study of natural capital restoration. This will cover the ecosystem assets as well as ecosystem services, by ecosystem or habitat, and then identify restoration costs and benefits. A key objective of this project is to produce a roadmap for the development of such a register by 2020.

Register contents

The register will need to identify and estimate both the current levels of and trends in: assets – extent, condition and spatial configuration; ecosystem services – volumes and values; degradation and proximity to thresholds; and the activities, costs and benefits of restoring degraded assets. It would also be valuable to identify potential improvements as well as restoration and changes of land use to improve services. Table 8.1 provides a snapshot of a summary of such a register – a more detailed form is presented in Appendix D.

Register compilation

In the UK a good deal of work has already been carried out to produce natural capital accounts, and more is planned. Consequently, for several of the broad habitats data are already available on assets and ecosystem services, with more scheduled, as resources allow, over the next three years. For these cases, the information on the assets and ecosystem services will be available. For those areas lacking this information, it is sensible here not to plan for the work to complete the top part of the table, but to schedule the work within the topic of this project to be completed following once that initial asset and ecosystem services work has been carried out.

To gather the information on degradation and restoration in order to complete the register a series of steps can be followed:

1. Identify the habitats and areas within them where condition is poor and/or is deteriorating, and proximity to thresholds
2. For each condition category within each habitat, collate data on the activities, costs and timings if restoration is to be implemented.
3. Similarly, collate data on the stream of benefits, their values and their timings, in each of these categories, if restoration takes place.
4. Use the cost and benefit information to determine the total expected costs and benefits of restoration, the timings, and areas exhibiting the greatest financial (net) benefit[62].
5. Aggregate these for each condition category and each habitat.

[62] Bearing in mind the difference between public and private costs and benefits, and the likelihood that not all benefits will be measured.

In addition, further steps might be taken to also calculate costs and benefits of improvement and change of use, enabling these to be brought into the prioritisation process.

Table 8.1 Asset and restoration register summary

	Urban	trend	Enclosed farmland	trend	Semi-natural grassland	trend	Woodlands	trend	Mountains, moorlands & heath	trend	Freshwater (open waters, wetlands, floodplains)	trend	Coastal margins	trend	Marine	trend
Asset																
extent (m.ha.)	1,465	↑	11,539	↓	3,274	↑	2,879	-	2,734	↓	1,435	↑	56	↓	309	↑
condition																
soil (type, moisture, nutrients)			83 N bal.	↑												
species composition (bird index**)			48	↓			62	–			85	↑				
vegetation							633 m.m3	↑								
hydrology											32µg/l ammon.	↑				
carbon							3781 mtCO2	↑								
certified area (m.ha.)			2.59	↑			1.38	↑								
access*							70%	↑								
spatial configuration																
ecosystem services																
provisioning																
food			42.5 m.t.	–							2045 t.fish	↓				
fibre							13.7 m.m3	↓								
energy (Gwh)			5648 solar	↑											4889 wind	↑
water (m.m3)			119	↓							4709	↓				
peat											589.6 th.t.	↓				
regulating																
GHG reduction							14 mteCO2	↓								
air quality (th.t.)			786.2	↓	164	↓	315.5	↓	127.1	↓	52.8	↓	2.35			
flood protection																
cultural																
recreation (m.hrs.)			131.4	↓			351.2	↑			296	↓				
education (th visits)			230.1	↑							59.7	↑				
supporting																
pollination																
biodiversity																
Asset																
degradation																
proximity to threshold																
restoration																
extent																
time																
cost																
benefit																
change of use																
extent																
cost																
benefit																

* population with access to 20 hectares of wood within 4 km
** indices specific to habitat

This process may seem straightforward, but a number of difficulties may arise, albeit not insurmountable:

- Records might not be available to provide a sufficiently detailed picture – this can be the so for a number of reasons. It may be, for instance, because of commercial sensitivity, record keeping for different purposes, or simply lack of records. Furthermore, scaling up from a limited number of sites needs to be carried out with regard to the specificity of each site. Nevertheless, geographical information systems, modelling and using information from similar sites (value transfer) can help to overcome some problems (Provins, 2013).
- Habitat condition information might be geographically limited and there might not be agreement about the link between the various indicators of condition and the ecosystem services arising.
- The costs and benefits of restoration partly depend upon scale and accessibility, so these need to be taken into account in the compilation
- The accuracy of the aggregate figures will depend upon how detailed the data are which underpin them. It will help if the broad habitats are broken into lower levels and data brought together for each of these.
- However, even then there is likely to be a good deal of variability between sites. Consequently, the more sites for which information can be garnered, the better. In many cases, 'average'[63] figures or subsidy rates have been used to fill data gaps; this is acceptable if no better data are available, but is likely to be subject to a wide error margin. Scaling up from lower levels has to be done with care, but scaling to sub-levels, modelling, and use of expert judgement can assist.
- Sites for which data are available may be non-typical. For instance, in the UK, much of the restoration data available for some habitats may be from sites of special scientific interest (SSSI) or similar conservation sites. Scaling up to include non-special sites is then problematic.

In order to obtain a 'library' of information and to help in identifying gaps, the construction of a database is suggested. This was partially attempted in this project, for peatland, so gave some insights. For the future, information from articles, reports and accounts could be collected for all habitats and tabulate types of activities, costs and timings as well as characteristics of the site and condition. Although here specific to the UK, appropriate published and expert information from other countries should also be solicited. This database would be built up alongside the habitat-specific work and provide a source of data for the former as well as indicating where further data gathering was needed; its format will be determined as part of future work.

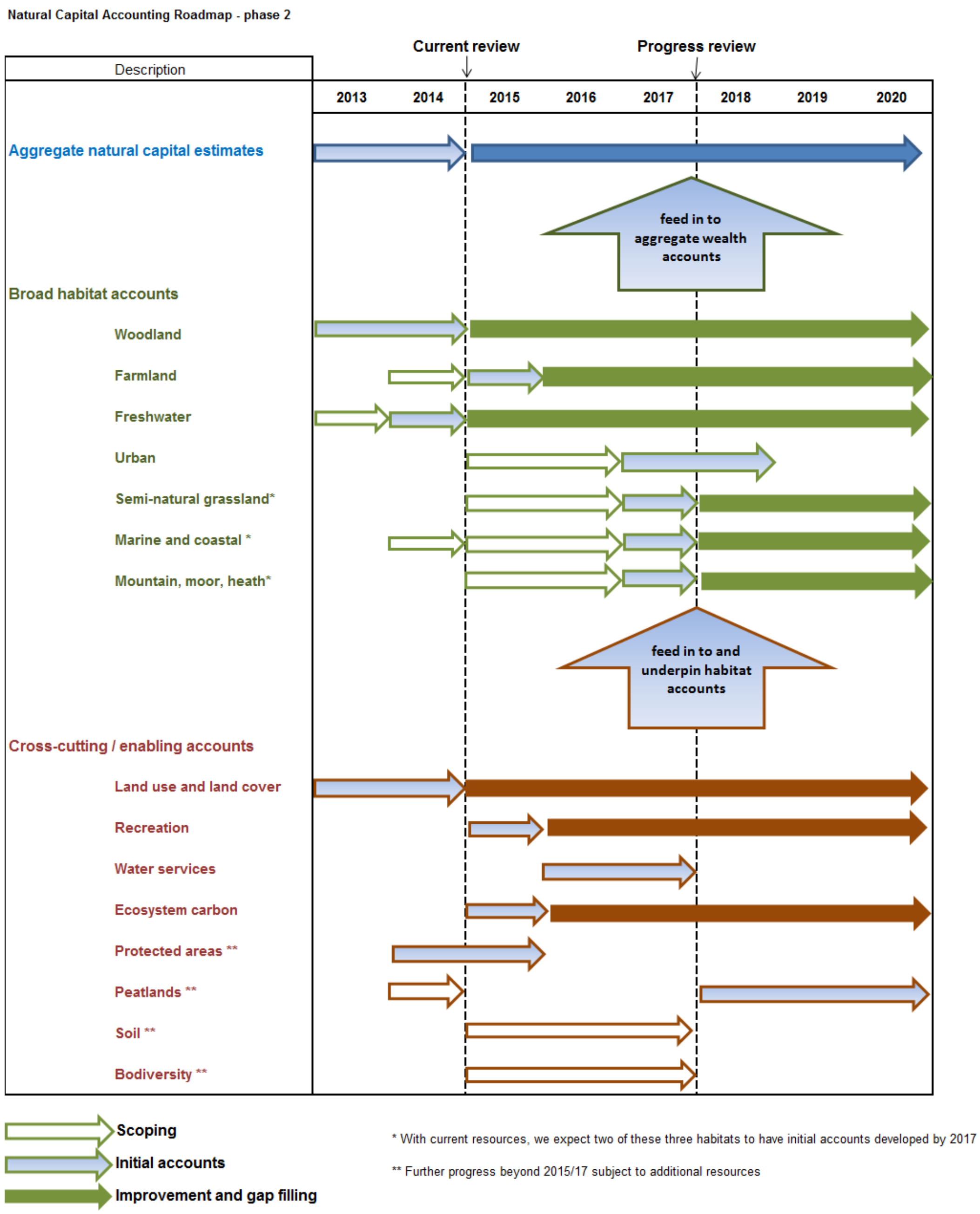
Register roadmap

The roadmap must specify the work to be undertaken, its dependencies, timing and order, and should also make clear the resource requirements.

[63] Although these 'averages' seem to be more 'expert predictions' based on experience in a number of projects.

In determining the structure of the proposed roadmap for the restoration work in the UK, the first factor to consider is the ongoing work being carried out by ONS, in collaboration with the UK government's Department of Food, Environment and Rural Affairs (Defra). An updated Natural Capital Accounting Roadmap (reproduced below as Table 8.2) was published in 2015 and is currently being further updated.

Table 8.2 ONS Natural Capital Accounting Roadmap



Source: ONS (2015)

The work that has already been carried out will furnish data concerning assets and ecosystem services, while the current and planned future work will provide further information at a later stage. The first line of Table 8.3 provides an evaluation of the completeness of the work on each of the eight broad habitats. Farmland and Woodland accounts have been completed as have those for freshwater, although the peatland element of these is limited. A scoping study for Mountains, moorlands and heath (MMH) has taken place and work will now proceed further due to a Eurostat grant. The urban habitat is receiving detailed attention, but is complex, while for semi-natural grassland (SNG), coastal and marine only scoping studies have taken place. Due to this partial dependency, it is sensible to stagger the restoration work to tie in with this.

With the state of, and plans for, the natural capital accounts work in the UK as a foundation, three key factors under the headings of: value, risk and facility are considered[64]. Table 8.3 below codes various aspects of these three factors referring, particularly, to Mace (2014) and NCC (2014) supplemented by the author's own evaluation.

'Value' can be viewed in terms of the current valuation of assets and the services which are provided by them and then the benefits that might be generated if restoration were to occur. Of course, against this, must be set the costs, including the opportunity cost - what might be foregone when restoring[65]. Thence the likely size of the net benefits can be predicted. As far as the assessment in terms of value is concerned, it would appear that there is considerable restoration potential for MMH and freshwater for restoration of bogs and fens, although for the latter, this could mean loss of farm production. Reducing (or optimising) farming intensity could also reap substantial benefits, particularly given the wide expanse of this habitat, and even conversion to other land uses (to wood, fen or wetland), although, again the opportunity cost of lost agricultural production deserves consideration, particularly in the light of Brexit and a move away from the Common Agricultural Policy[66]. Restoration of woodlands could arguably provide improvements to air quality and GHG sequestration, although even greater benefits might be obtained by extending woodland close to urban areas. Within urban areas, restoration or improvement might involve increasing the tree and greenery cover, although the opportunity cost of any land diverted from alternative uses must be costed. Marine and semi-natural grassland may have considerable potential for restoration and improvement, but this needs further research, as does the coastal margins habitat.

The 'risk' factor is here gauged in terms of the quality of the habitat and its direction of change. The areas deemed most at risk are deemed to be the bogs and fen areas within MMH and freshwater, as well as urban areas. Marine has suffered in terms of fish and vegetation stocks, so could also be vulnerable, while farmland is, in some areas, a major source of water pollution and unrestrained run-off.

The final factor concerns the 'facility', the availability of and ease with which information, both physical and financial, about current and restoration activities, can be obtained, and how

[64] see Mace (2014) ; NCC (2014); SNH (2017); McVittie A., et al (2017) Summary; UN (2012b).

[65] As discussed in the Annex to Chapter 3, as ecosystem improves the patterns of ecosystem services arising over time may not only diverge, but may also move in opposing directions – some services will grow, others may decline.

[66] Dickie (2016) ha suggested that the opportunity cost may not be so high if areas in poorer agricultural condition were targeted.

long development of the register for the habitat is likely to take. No habitat is seen as being well served in terms of restoration data, but, physical asset and ecosystem service information for farmland, woodland and freshwaters is reasonable, partly due to the natural capital accounting work which has been completed so far. For farmland and woodland, data on values can be seen as having more detail, although this is linked to subsidy rates and closer government involvement. So it can be expected that Farmland, Woodland and Freshwater asset and restoration registers can be developed most speedily, although this, and the confidence in the outcome, will depend on a number of factors, including resources made available, work being undertaken elsewhere and collaboration with other organisations. The complex urban habitat will take longer, and SNG, marine and coastal margins will be dependent upon the natural capital work on these habitats and on resource availability.

Table 8.3 Evaluation by broad habitat of existing accounts, value, risk and facility.

	Urban	Enclosed farmland	Semi-natural grassland	Woodlands	Mountains, moorlands & heath	Freshwater (open waters, wetlands, floodplains)	Coastal margins	Marine
Existing accounts								
Value								
Current value	recreation	farm produce	GHG, wildlife	air, water, floods, GHG, recreation	water, floods, GHG, recreation	water, GHG, recreation	recreation	fish
Potential benefit					bogs	fens		
Restoration cost *(& opportunity cost)*	*foregone land use*	*lost farm production*		Timber↓ GHG↑		*foregone farm production*		
Net benefit of restoration	?	If conversion to woods /fen						
Risk								
Sensitivity to human (and other?) influences								
Threshold proximity								
Condition/ES trends								
Ease/difficulty/timing								
Physical data – assets, ES, condition (availability/coverage)								
Values								
Restoration data								
Potential time needed for development								

Low risk, positive benefits, positive or neutral trend, information available	Medium risk, medium benefits, negative trend, limited information available	High risk/ low benefits, strongly negative trends, weak information	Low value or low costs

Before setting out the roadmap proposals, there is one other consideration. Peatland, which was the focus of the two pilot studies, does not fall into one of the eight broad habitat categories, although within the 23 LCM sub-categories, this seems to be covered by the two – ‘fen, marsh and swamps’ and ‘bogs’. Nevertheless, even then all peatland in the UK would not be covered by these categories since much of the blanket bog lies within the MMH and woodland categories, and a considerable area of fenland is now classified as farmland. Eftec (2015) produced a useful diagram to illustrate this – Figure 8.1.

Thus, information on peatland will be needed to feed into the register for other habitats and restoration considerations may involve taking land back to peatland from other current habitats. So, although it has not been possible to give a great deal of attention to peatlands in the work carried out so far on Natural Capital Accounts, this will have to change for the restoration work. Fortunately, since the pilot studies for the current project have involved different types of peatland, they have prepared the ground for a more aggregated study of this area, and Eurostat has recently agreed to assist with funding.

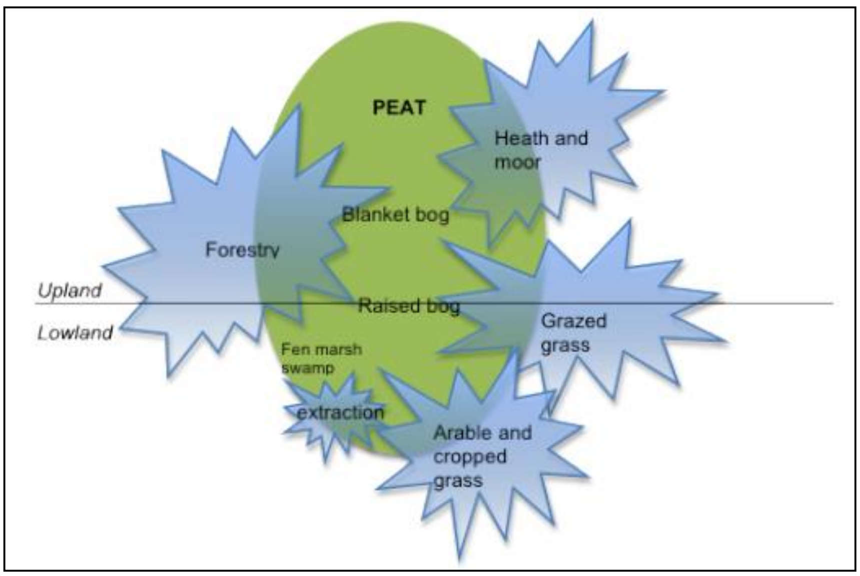


Fig. 8.1 Peatland and habitat overlaps Source: Dickie,, *et al* (2015)

The restoration roadmap has been constructed in the light of these considerations of existing accounts, value, risk and facility, and is presented in Table 8.4. The roadmap has three elements, with a fourth arising from these:

- **overview/review of possibilities and priorities**, to take stock and scan the future at the start of the project and at strategic points;
- **broad habitat** coverage – for each habitat, scoping the task and producing an initial **register**, developing a more detailed register, and further updating and filing in gaps;

- **restoration database** – as the work develops a database covering condition, the restoration activities, costs and timings as well as the benefits arising for sites within habitats and sub-habitats. Modelling references will also be recorded. This database will be informed by and inform the habitat tasks being conducted.
- an **overall asset and restoration register**, which will bring together the information from the habitat work and, like the database, will be updated as new information becomes available.

Additionally, **guidelines** will be produced to assist those who are involved in recording restoration activities and costs and to encourage common approaches to recording the information.

It is assumed that the restoration project will be overseen by the manager of the natural capital accounts process, although, given its potential importance for policy-makers, appointing a manager with sole responsibility for this project might be advisable. Further staffing would be a senior research officer and an economic assistant, with additional input from Defra. The project would be boosted if staff with existing expertise were appointed and further training provided. Should additional resources be made available, this would allow extra staff to be appointed within ONS or Defra and sub-contracting of some work to external experts to be funded, facilitating the possible acceleration and further development of the timetable.

Table 8.4 Restoration roadmap

	2018		2019		2020		2021	2022	2023	2024	2025
Overview/review of possibilities and priorities											
Broad habitat coverage											
Peatland	Eurostat already	support obtained									
Mountains, moorlands & heath	Eurostat already	support obtained									
Enclosed farmland											
Woodlands											
Freshwater (open waters, wetlands & floodplains)											
Urban											
Semi-natural grassland											
Coastal margins											
Marine											
Restoration database											
Asset and restoration register											
Guidelines											

Note: for habitats, grey shaded areas denote **scoping and an initial register**, dark upward sloped hatch – **more detailed register**, lighter horizontal hatch – **gap filling and updating**. For other lines the grey shaded areas denote specific tasks or elements being built up over time.

The timeliness of the more detailed work (hatched in Table 8.4) will be dependent on ONS and Defra, with government support, showing a willingness to underwrite the project. Should the staffing resources be limited to those mentioned above, then the production of more-detailed registers or initial registers for less-prioritised habitats will be delayed. However, since areas where restoration is feasible will not be ubiquitous, and general priority areas are likely to be identified at an early stage, the volume of work may not turn out to be as onerous as might first appear.

Although the roadmap was originally intended to cover the period between 2018 and 2020, it is felt that it would not be realistic to timetable coverage of all habitats within that period. Consequently, Table 8.4 does present the plans for that period, but extends the timetable to 2025.

Outcomes

The outcomes from the project will be in the form of:

- An early overview of possibilities and priorities
- Initial and then more detailed documents focussed on assets and restoration registers for each broad habitat, with further detail for sub-habitats and areas within these
- Periodic reviews of progress, possibilities and priorities (in 2020 and 2025)
- A database, with increasing breadth and depth, of habitat condition, its links to ecosystem services and their trends, restoration activities, costs and timings and the ensuing benefits - useful for producing aggregates as well as detailed estimates for site-specific restoration projects
- An asset and restoration register, as summarised in Table 8.1, of potential use for, *inter alia*, policy makers
- Guidelines on the recording of restoration activities, costs and timings as well as the ecosystem service outcomes.

Conclusions

A roadmap for the production of an asset and restoration register and associated documentation has been developed for the period 2018-2025.

A certain level of staff resourcing has been assumed, but the success of the project will depend upon the support and commitment of the ONS, Defra and others.

The outcomes of this project will help decision makers at national and supranational level as well as those implementing restoration at a site level.

Chapter 9 Conclusions

Project objectives: The aims of this project were to produce a roadmap for the development of an asset and risk register to 2020, focussing on potential restoration activity and its costs, supported by two studies piloting the suggested. These aims have been achieved: in carrying out the two pilot studies a conceptually-underpinned method has been developed, registers, ecosystem accounts and project appraisals have been produced, issues have arisen and lessons for the delivery of the roadmap have been learnt. Furthermore, although the history of restoration examples is short, in certain situations restoration does appear to be worthwhile; and the two pilot studies the Exmoor Mires Partnership and the Wicken Fen Vision, support this view. A roadmap, to 2020, with an extension to 2025, based on stated criteria, and linked to the NCC Roadmap, has been set out.

Database: Recording of restoration activities and costs by site, in a common and available form, would be valuable both for scaling up and for evaluation of new and existing sites. There is a good deal of knowledge across agencies, individuals, scientists and practitioners, but it needs to be gathered together for the use of all. To provide a more complete understanding, linked information on condition and ecosystem services should also be recorded. Additionally, monitoring costs should be included as, although not directly a cost of the restoration itself, they are vital for increasing understanding of the restoration process. The construction of UK and Europe-wide databases could provide a valuable resource. Guidelines would help to give consistency and meaning to the recording of this information.

Roadmap: Much needs to be done to develop an understanding of restoration across habitats, along with the links between ecosystem condition, services and restoration (as well as maintenance and bau) activities. Besides the development of a database, the roadmap presented here which will facilitate the building up of an asset and risk register in stages. To reap the full benefits of this, the wholehearted support of and collaboration between ONS, Defra and related agencies will be necessary. Given the joint role which ONS and Defra have played in coordinating the approach to the measurement of natural capital in the UK, it is logical for them to also take the lead in the parallel, restoration work.

Time: Time is a key element. With ecosystem restoration, careful account needs to be taken of time: the long periods required for restoration; the pattern of restoration activities and ecosystem services over time; how costs and benefits are likely to change over time; discounting for a sufficient lifetime; time to build understanding. On a people level, project implementers and monitors need to be prepared for long-term involvement, and policy-makers and politicians need to show patience and commitment – to be ‘in it for the long haul’!

Ecosystem accounts: Restoration costs can provide useful supplementary information alongside ecosystem accounts. However, there is unfinished debate regarding their use in the mainstream accounts, along with the presentation and impact of disservices.

Restoration policy-making: Policies need to be carefully designed and implemented - with agency collaboration and stakeholder engagement (with potential losers as well as gainers considered). The CAP (and Brexit) offers an opportunity for meaningful restoration policy which could help to bring about desired changes.

The future: With collaboration and support, a good deal of progress on producing habitat-based asset and risk registers and building up a database for the UK can be made by 2020, but, like restoration itself, it is a long-term task, and therefore needs long-term support.

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Appendix A Grant agreement details

The grant was made for a project with two strands – Ecosystem Accounting and Environmental Protection Expenditure. This report concerns the first part, namely Ecosystem Accounting; the report for the second strand has already been submitted as it was a separate piece of work.

Due to health problems of the author and suggested improvements to the project, amendments were made to the initial plan of work and its timings. This appendix therefore, has two parts: the first provides details of the initial project agreed at the outset; the second presents the amendments as finally agreed.

Initial grant application details

EUROSTAT GRANT FOR 2015
EUROSTAT UNIT: E.2 – ENVIRONMENTAL STATISTICS AND ACCOUNTS; SUSTAINABLE DEVELOPMENT
OBJECTIVE[67]: 05.1.21; 05.1.22; 05.1.23 – PROVIDE ENVIRONMENTAL ACCOUNTS AND CLIMATE CHANGE RELATED STATISTICS
TITLE: ENVIRONMENTAL ACCOUNTS 2015

Date of first application: 29 May 2015
Date of the modified version:

SUMMARY OF THE APPLICATION
Title: Natural Capital & Environmental Protection Expenditure
Identity of the applicant: James Evans
Duration (in months): 12 months
Total estimated cost (in €): 122,440.25
Requested grant (in €): 85,708.18
Percentage of the requested grant (co-financing): 70 per cent
Pre-financing payment: Not applicable

[67] (Priority) objective as indicated in the Annual Work Programme (AWP)

III. INFORMATION ON THE ACTION(S) FOR WHICH THE GRANT IS REQUESTED

1 DESCRIPTION OF THE ACTION
Title: Natural Capital Project & Environmental Protection Expenditure

a) Description of the general and specific objectives that the action aims to achieve:

Specify also related indicators to assess the action's achievements and expected impact, if possible.

The Eurostat have invited bids for Environmental Accounts, the closing date for which is 30 May 2015. Among eligible bid criteria are Environmental Protection Expenditure Accounts (EPE) and Ecosystem Accounting. The UK initially intended submitting two grant applications for these pieces of work, advice from Eurostat indicated that a combined grant application would be preferred.

Ecosystem Accounting

ONS, in partnership with Defra have been working on a Natural Capital Accounting project. We have been developing both the physical and monetary asset accounts. The monetary asset accounts are estimated by valuing the benefits that these assets provide over their life and then discounting them into today's money by using an appropriate discount rate.

This project is split in to two phases. Phase 1 was completed in March 2015. Phase 2 of this project will run from 2015 through 2020 with another review scheduled for 2017. The following accounts will be divided between ONS and Defra. Semi Natural Grassland, Mountains, moorlands & Heaths, Coastal Margins, Urban Environment, Cross Cutting Soil Accounts and Cross Cutting Water Accounts. All of this information and more can be found at: http://www.ons.gov.uk/ons/guide-method/user-guidance/natural-capital/index.html. All of this work is scheduled and costed and will go ahead.

However, the value of assets and flows of benefits (the work that ONS is currently undertaking) is only one key component of the policy advice. The other, equally important for policy application, is to estimate the potential cost of replacing natural capital if they are depreciated. This information will help the policy makers to prioritise investment and make informed decisions. This requires developing a comprehensive register of natural capital, record how much value is lost over a time period and then estimate how much it will cost to restore them and the resources required to improve them. The importance of this component of Natural Capital Accounting has been championed by renowned international experts, for example Professor Dieter Helm. It is for this work, which ONS would like to apply for funding to implement.

Environmental Protection Expenditure

Following significant development, ONS is now in a position to fully comply with the Environmental Goods and Services (EGSS) component of regulation 691/2011. The ability to deliver major improvements to this regulation were heavily dependent on the provision of quality improvement funding. The funding received by Eurostat supported a programme of activities, including coordination with experts in the Netherlands, this has now resulted in comprehensive compliance.

Another large component of the regulation, namely the Environmental Protection Expenditure (EPE) Account, has yet to be developed. At the time of writing, the UK are not fully compliant with the EPE component. Moreover, previous submissions of EPE (via the voluntary joint Eurostat/OECD questionnaire) have delivered the bare minimum.

The quality underpinning the source of data for EPE expenditure by business is low. For example, the survey which provides the data achieves a responding sample of circa 20%. This results in difficulties where any interpretation of the data are attempted (e.g. year-on-year comparisons). To complicate matters further, it is looking increasing likely, the Department for Environment, Food and Rural Affairs (DEFRA), who currently provide this information on business EPE will cease to continue the survey. If ONS is to be able to comply fully with the regulation by 2017, action is urgently required to:

(a) Review and assess the appropriateness of all current data sources.

(b) Develop data sources to comply with the additional requests of the amended EPE regulation.

(c) Develop data sources to replace the DEFRA survey.

b) Description of the action (on the basis of the main activities foreseen) and where it will be implemented

Each workstream will be undertaken within the Office for National Statistics, specifically the Environment Branch.

Ecosystem Accounting

The 12 month action will have two distinct stages:

Stage 1 (4 to 6 months) Planning and scoping the project. The area of development is completely new, the scoping of the entire project (not just the 12 month work) will be critical to the success of the project. Data sources and corresponding analytical resource needed will have to decided.

Stage 2 (6 – 8 months) A detailed roadmap will emerge from stage 1. An initial and basic pilot register build will be undertaken in stage two where practical applications would emerge and be implemented, albeit in relation to particular ecosystems or particular parts of the country.

The final report will outline how a subsequent project will incorporate information gathering for a register in year 1. Building the asset register in year 2. Develop the physical accounts in year three. Additionally, it will outline the findings of the pilot.

The project will be responding to one of the main recommendations within the UK State of Natural Capital report.

The work will allow the UK to build its capability in the area and assist member states going forward..

The work is policy relevant because it provides information on the cost that is required to replace or maintain an environmental asset. The Natural Capital Committee, who advise the UK Government, has emphasised this aspect in every report it has published.

This successful study could lead to accounts which would help to provide information on where to direct investment. Along with accounts based on benefit approach, these accounts will provide a comprehensive picture of natural capital in the UK. This will help to make a comparison - for example, should investment be diverted to those assets which provide more benefits but expensive to maintain? Or to those critical assets that provide lower benefits but are expensive to maintain.

Environmental Protection Expenditure

The work will be undertaken within the Office for National Statistics, specifically the Environment Branch.

The 12 month action will have three distinct stages:

A review of the current status of all data sources feeding the UK submission of EPE. The review will consider current sources underpinning both the public and business sector expenditure components and evaluate the strengths and weaknesses of these different sources.

Identification and development of new data sources to comply with additional requirements of the EPE regulation. This stage will utilise information gathered at stage one to identify the most suitable sources of EPE data. It will consider both survey and administrative data.

An analysis of the impact that ceasing the DEFRA survey will have on the UK's ability to comply fully with the regulation, and alternate data sources developed if possible. This stage will comprise sensitivity testing and evaluate the recommendations put forward before informing a decision which will ensure the UK become fully compliant.

c) Organisation of the project management:

The applicant should provide a detailed description of the organisation of the action and of the implementation phase, specifying arrangements for monitoring, supervision, risk management and if an affiliate is involved which part of the action will be carried out by the affiliate.

Where subcontracting[68] **is envisaged** please **provide its justification and specify in particular, the tasks to be subcontracted, the selection procedure used** and, if known,the contractor's name (in particular if an existing framework contract is used).

If the applicant (and affiliate) has to conclude contracts in order to carry out part of the action, the recourse to the award of contracts must be justified having regard to the nature of the action and what is necessary for its implementation. The description of the action (see Part III.1.c) must include information on the role, activity and responsibility of each subcontractor. Rules have already been foreseen in the financial regulation and the standard grant agreement where implementation of an action requires the award of procurement contracts (see Articles I.10.2 and II.9.2). It is assumed that the beneficiary (and his affiliate) is competent for carrying out and managing directly the major part of the action. Situations where a beneficiary simply acts as intermediary must be avoided. In any case the beneficiary is sole responsible for the whole action and for compliance with the provisions of the agreement. Note and take into account that Eurostat should not have direct contact with the subcontractor(s) during the implementation of the action.

The justification of subcontracting part of the action is particularly sensitive and important within the framework of grants restricted to the NSIs and other national authorities, due to their acknowledged responsibilities for the development, production and dissemination of European statistics. The justification must be substantiated in this respect.

All projects within the ONS Environment Branch are implemented using Prince 2 principles,

[68] *Entities which are NSIs or other national authorities according to Article 5 of regulation 223/2009 cannot be, in principle, proposed as (sub) contractors pre-identified in the application. See also Guide for applicant. If necessary, the participation of such entities could be envisaged as co-beneficiaries of the action. If a co-beneficiary is envisaged, please contact the person mentioned in the invitation letter in order to be provided the appropriate forms and documentation for the multi-beneficiary grant agreement for an action.*

these projects will be no exception.

The Natural Capital project manager will report progress to the Natural Capital Project Board, who themselves report to the Natural Capital Committee, who themselves, report to HM Treasury.

The EPE project manager will report progress to a board made up of policy making department thought to be Defra and BIS at this time.

For both projects there will be appropriate Prince 2 documentation and reporting tools to implement the projects.

d) Arrangements for monitoring/supervision during the operation and foreseen risks about the implementation:

The applicant should provide effective explanations about the supervision of the action and should state the presence of any possible risk in the implementation of it, and how it could affect the objectives and outcomes of the action or how it could be mitigated.

Please provide a **curriculum vitae** of the [key] staff member(s) [coordinating the action], ilustrating his/her competence, expertise, leadership quality and authority required by the action tasks.

I will be overseeing the work of this project. Previously I have successfully attained a grant to develop the Environmental Goods and Services. The resulting outputs have been very beneficial and won praise from Eurostat.

e) Sustainability of the project's achievements:

The applicant should explain how the sustainability will be secured after the completion of the action. It can include considerations about different dimensions of sustainability: financial, economics, institutional (structures which would allow the results of the action to continue), environmental, policy, etc (if applicable, depending upon the provisions of the basic act).

Both the work streams outlined are valuable in their own right. The Natural Capital work is an essential first step in a much bigger project that 'may' be implemented depending on the results of the scoping study and pilot. The EPE development will become an important component of our expanding suite of Green Economy indicators, namely the Environmental Goods and Services, the Low Carbon and Renewable Energy Survey and the development of our Adaptation and Resiliance to Climate Change Survey.

Each workstream will make important contributions to the Sustainable Development Goals which ONS are also progressing within the same Division.

f) Combined survey (where applicable)[69]:

1. Is the EU survey combined with a national survey?

Yes ☐ No ☐ (No impact on the budget, *go to next part of appl. form)*

2. If YES: Can costs of each part (EU and national) be clearly identified?

No ☐ Yes ☐ (No impact on the budget, refer only to costs related to the EU part, *go to next part of appl. form*)

3. If NO, which case applies?

a) the EU survey is complemented by a national part Yes ☐ No ☐

[69] *To be used in case of surveys.*

b) the EU survey is combined with an existing national survey Yes ☐ No ☐

In both cases, only the costs generated by the EU part of the survey are "eligible" for EU funding. The costs related to the national part should be integrated in the budget as "ineligible".

4. What is the proportion (repartition key) between the eligible direct costs of the cost item(s) concerned?

EU……% / National……%

5. Please explain the criteria and the method used for the calculation of the repartition key (% split) in order to allow the Commission to evaluate its appropriateness.

To be completed:

2 PLANNED DURATION OF THE ACTION (in months): xx

Please choose one of the following options:

Option 1: The action shall start the first day following the date the last party has signed the grant agreement

Option 2: Starting date: November /2016

LEGAL NOTICE

Applicants are informed that, under the Financial Regulation applicable to the general budget of the European Union, no grant may be awarded retrospectively for actions already completed, and that in the exceptional cases accepted by the Commission where applicants can demonstrate the need to start the action or work programme before the agreement is signed, expenditure eligible for financing may not have been incurred before the grant application was lodged.

Shall your action begin before the grant agreement is signed? No

If yes, you have to provide below a justification which demonstrates the need to start the action before the grant agreement is signed: *(to be completed)*

The work will not begin before the agreement has been approved and signed, but if possible, we would like to begin the work prior to November.

2.(a) TIMETABLE TO CARRY OUT EACH STAGE OF THE ACTION SHOWING MAIN DATES AND EXPECTED RESULTS FOR EACH STAGE

Milestones/ Deliverables / Tasks / Results / Reports	Timetable

Date	Natural Capital Milestone	EPE Milestone
November 2015	Planning and scoping the project. The area of development is completely new, the scoping of the entire project (not just the 12 month work) will be critical to the success of the project. Data sources and corresponding analytical resource needed will have to decided.	A review of the current status of all data sources feeding the UK current submission of EPE. Are the most appropriate data sources being used, are there more suitable data sources that could be used.
December		
January 2016		
February		Development of new data sources to comply with additional requirements of the EPE regulation.
March	A detailed roadmap will emerge from stage 1. An initial and basic pilot register build will be undertaken in stage two where practical applications would emerge and implement, albeit in relation to particular ecosystems or particular parts of the country.	
April		
May		An analysis of the impact the ceasing of the DEFRA survey will have on the UKs ability to comply fully with the regulation, and develop alternate data sources or methodologies.
June		
July		
August 2016		
September 2016	Circulate report to NCC Committee	Circulate report to Project Board
October 2016	Submit report to EU.	Submit report to EU.
Final technical report on implementation of the action and financial statement	60 days following the closing date of the action	

Final amendment to agreement

Timetable is attached.

EUROPEAN COMMISSION
EUROSTAT

Directorate E: Sectoral and regional statistics

AMENDMENT No 2

TO GRANT AGREEMENT No 05121.2015.001-2015.546

The European Union ("the Union"), represented by the European Commission ("the Commission"), which is represented for the purposes of signing this amendment by **Marcel Jortay, Director of Directorate E, Eurostat**,

of the one part, and

Office for National Statistics
Cardiff Road
UK – NP10 8XG Newport

("the beneficiary"), represented for the purposes of signature of this amendment by **Glenn Everett, Director**

of the other part

Having regard to Agreement No 05121.2015.001-20015.546 concluded between the Commission and the beneficiary on 26/10/2015 ("the agreement"), last amended by Global amendment signed on 26/04/2016.

Whereas the beneficiary has requested the Commission to extend the above agreement,

HAVE AGREED AS FOLLOWS:

Article 1

- Clause 1.2.2 of article 1.2 is replaced by the following clause as follows:

The action shall run for **24 months** as of **01/11/2015** ("the starting date"). The above period shall be determined on the basis of calendar days.

- Modification of Annex I

  Annex I – Description of the action annexed to the present amendment is modified.

The modifications take effect on the date on which the amendment enters into force.

Article 2

All the other provisions of the agreement shall remain unchanged and shall continue to apply for the new period of duration indicated in Article 1 of this amendment]

Article 3

The present amendment shall form an integral part of the agreement and it shall enter into force on the date on which the last party signs.

SIGNATURES

For the beneficiary
Glenn Everett
Director

Signature

Done at Newport on

For the Commission
Marcel Jortay
Director

Signature

Done at Luxembourg on

In duplicate in English

.

ANNEX I

DESCRIPTION OF THE ACTION

1 DESCRIPTION OF THE ACTION

Title: Natural Capital Project & Environmental Protection Expenditure

a) Description of the general and specific objectives that the action aims to achieve:

The Eurostat have invited bids for Environmental Accounts, the closing date for which is 30 May 2015. Among eligible bid criteria are Environmental Protection Expenditure Accounts (EPE) and Ecosystem Accounting. The UK initially intended submitting two grant applications for these pieces of work, advice from Eurostat indicated that a combined grant application would be preferred.

Ecosystem Accounting

ONS, in partnership with Defra have been working on a Natural Capital Accounting project. We have been developing both the physical and monetary asset accounts. The monetary asset accounts are estimated by valuing the benefits that these assets provide over their life and then discounting them into today's money by using an appropriate discount rate.

This project is split in to two phases. Phase 1 was completed in March 2015. Phase 2 of this project will run from 2015 through 2020 with another review scheduled for 2017. The following accounts will be divided between ONS and Defra. Semi Natural Grassland, Mountains, moorlands & Heaths, Coastal Margins, Urban Environment, Cross Cutting Soil Accounts and Cross Cutting Water Accounts. All of this information and more can be found at: http://www.ons.gov.uk/ons/guide-method/user-guidance/natural-capital/index.html. All of this work is scheduled and cost and will go ahead.

However, the value of assets and flows of benefits (the work that ONS is currently undertaking) is only one key component of the policy advice. The other, equally important for policy application, is to estimate the potential cost of replacing natural capital if they are depreciated. This information will help the policy makers to prioritise investment and make informed decisions. This requires developing a comprehensive register of natural capital, record how much value is lost over a time period and then estimate how much it will cost to restore them and the resources required to improve them. The importance of this component of Natural Capital Accounting has been championed by renowned international experts, for example Professor Dieter Helm. It is for this work, which ONS would like to apply for funding to implement.

Environmental Protection Expenditure

Following significant development, ONS is now in a position to fully comply with the Environmental Goods and Services (EGSS) component of regulation 691/2011. The ability to deliver major improvements to this regulation were heavily dependent on the provision of quality improvement funding. The funding received by Eurostat supported a programme of activities, including coordination with experts in the Netherlands, this has now resulted in comprehensive compliance.

Another large component of the regulation, namely the Environmental Protection Expenditure (EPE) Account, has yet to be developed. At the time of writing, the UK are not fully compliant with the EPE component. Moreover, previous submissions of EPE (via the voluntary joint Eurostat/OECD questionnaire) have delivered the bare minimum.

The quality underpinning the source of data for EPE expenditure by business is low. For example, the survey which provides the data achieves a responding sample of circa 20%. This results in difficulties where any interpretation of the data are attempted (e.g. year-on-year comparisons). To complicate matters further, it is looking increasing likely, the Department for Environment, Food and Rural Affairs (DEFRA), who currently provide this information on business EPE will cease to continue the survey. If ONS is to be able to comply fully with the regulation by 2017, action is urgently required to:

(a) Review and assess the appropriateness of all current data sources.

(b) Develop data sources to comply with the additional requests of the amended EPE regulation.

(c) Develop data sources to replace the DEFRA survey.

b) Description of the action (on the basis of the main activities foreseen) and where it will be implemented

Each workstream will be undertaken within the Office for National Statistics, specifically the Environment

Branch.

Ecosystem Accounting

Stage 1 (4 to 6 months) Planning and scoping the project. The area of development is completely new, the scoping of the entire project (not just the 12 month work) will be critical to the success of the project. Data sources and corresponding analytical resource needed will have to be determined. Two pilot areas will be identified and negotiations carried out to facilitate study in those areas.

Stage 2 (6 - 8 months) A detailed roadmap will emerge from stage 1. Two basic pilot registers will be built where practical applications will emerge and be implemented and more widely-applicable issues arising will be investigated

The final report will outline, via a roadmap, how a subsequent project, running from 2017 to 2020, will incorporate information gathering for a register, building the asset register, and developing the physical and financial accounts. The timetable will take account of variation between ecosystems for which information is more readily available and comprehensive, and those for which the data gaps are more widespread and for which further data collection and modelling will be required. Additionally, the findings of the pilot will be presented, along with issues specific to that area or habitat and those of wider application, and the implications of these will be highlighted

The planned register will cover, not only asset condition, amount, spatial distribution and capacity, along with value, but also the services, trends in asset condition and capacity, degradation (including thresholds) and restoration (past, current and planned or potential activity and costs) but also feasibility and, if possible, prioritisation. Physical accounts and financial estimates will be produced

The project will be responding to one of the main recommendations within the UK State of Natural Capital report. The work will allow the UK to build its capability in the area and assist member states going forward. The work is policy-relevant because it provides information on the cost that is required to replace or maintain an environmental asset. The Natural Capital Committee, who advise the UK Government, has emphasised this aspect in every report it has published.

This successful study could lead to accounts which would help to provide information on, not only the aggregate costs of maintaining and enhancing ecosystem assets, but also where to direct investment. Along with accounts based on a benefit approach, these accounts will provide a comprehensive picture of natural capital in the UK. This will help to make a comparison - for example, should investment be diverted to those assets which provide more benefits but expensive to maintain? Or to those critical assets that provide lower benefits but are expensive to maintain

Environmental Protection Expenditure

The work will be undertaken within the Office for National Statistics, specifically the Environment Branch.

The 24 month action will have three distinct stages:

A review of the current status of all data sources feeding the UK submission of EPE. The review will consider current sources underpinning both the public and business sector expenditure components and evaluate the strengths and weaknesses of these different sources.

Identification and development of new data sources to comply with additional requirements of the EPE regulation. This stage will utilise information gathered at stage one to identify the most suitable sources of EPE data. It will consider both survey and administrative data.

An analysis of the impact that ceasing the DEFRA survey will have on the UK's ability to comply fully with the regulation, and alternate data sources developed if possible. This stage will comprise sensitivity testing and evaluate the recommendations put forward before informing a decision which will ensure the UK become fully compliant.

c) Organisation of the project management:

All projects within the ONS Environment Branch are implemented using Prince 2 principles, these projects will be no exception.

The Natural Capital project manager will report progress to the Natural Capital Project Board, who themselves report to the Natural Capital Committee, who themselves, report to HM Treasury.

The EPE project manager will report progress to a board made up of policy making department thought to be Defra and BIS at this time.

For both projects there will be appropriate Prince 2 documentation and reporting tools to implement the projects.

d) Arrangements for monitoring/supervision during the operation and foreseen risks about the implementation:

I will be overseeing the work of this project. Previously I have successfully attained a grant to develop the Environmental Goods and Services. The resulting outputs have been very beneficial and won praise from Eurostat.

e) Sustainability of the project's achievements:

Both the work streams outlined are valuable in their own right. The Natural Capital work is an essential first step in a much bigger project that 'may' be implemented depending on the results of the scoping study and pilot. The EPE development will become an important component of our expanding suite of Green Economy indicators, namely the Environmental Goods and Services, the Low Carbon and Renewable Energy Survey and the development of our Adaptation and Resiliance to Climate Change Survey.

Each workstream will make important contributions to the Sustainable Development Goals which ONS are also progressing within the same Division.

2 PLANNED DURATION OF THE ACTION (in months): 24

Starting date: 1st November 2015

2.(a) TIMETABLE TO CARRY OUT EACH STAGE OF THE ACTION SHOWING MAIN DATES AND EXPECTED RESULTS FOR EACH STAGE

Date	Natural Capital Milestones (original)	Natural Capital Milestones (revised)	EPE Milestones (original)	EPE Milestones (revised)
Nov. 2015	Phase 1 Planning and scoping the project. The area of development is completely new, the scoping of the entire project (not just the 12 month work) will be critical to the success of the project. Data sources and corresponding analytical resource needed will have to be decided.		Phase 1 A review of the current status of all data sources feeding the UK current submission of EPE. Are the most appropriate data sources being used, are there more suitable data sources that could be used.	
Dec. 2015				
January 2016				
February 2016		Phase 1	Phase 2 Development of new data sources to comply with additional requirements of the EPE regulation.	Phase 1 A review of the current status of all data sources feeding the UK current submission of EPE. Are the most appropriate data sources being used, are there more suitable data sources that could be used.
March 2016	Phase 2 A detailed roadmap will emerge from stage 1. An initial and basic pilot register build will be undertaken in stage two where practical applications would emerge and			
April 2016				
May 2016			Phase 3	Phase 2

June 2016	implement, albeit in relation to particular ecosystems or particular parts of the country.	Phase 1 (contd.) Planning and scoping the project. The area of development is completely new, the scoping of the entire project (not just the 12 month work) will be critical to the success of the project. Data sources and corresponding analytical resource needed will have to be decided. Pilot possibilities will be investigated and negotiated. Investigate accommodation of SEEA to restoration costs.	An analysis of the impact the ceasing of the DEFRA survey will have on the UKs ability to comply fully with the regulation, and develop alternate data sources or methodologies.	Development of new data sources to comply with additional requirements of the EPE regulation.
July 2016				
August 2016				Phase 3 An analysis of the impact the ceasing of the DEFRA survey will have on the UKs ability to comply fully with the regulation, and develop alternate data sources or methodologies.
September 2016	Circulate report to NCC Committee		Circulate report to Project Board	
October 2016	Submit report to EU.		Submit report to EU.	
November 2016				
December 2016				Circulate report to Project Board
Jan. 2017		Phase 2 A detailed roadmap will be designed. Two basic pilot registers (for particular ecosystems or areas) built and practical applications will emerge and issues will be investigated.		Submit report to EU.
Feb. 2017				
March 2017				
April 2017				
May 2017				
June 2017				
July 2017				
Aug. 2017				
Sept. 2017				
Oct. 2017				
Nov. 2017		Circulate draft report to Eurostat & NCC		
Dec. 2017		Submit final report to EU.		
Final technical report on implementation of the action and financial statement			60 days following the closing date of the action	

Appendix B Interim Report – 'ONS Natural Capital Restoration[70] study'

The study

In February 2016, in line with the Government White Paper[71] and NCC recommendations[72][73], reiterated at the last NCC meeting in July[74], ONS began a one-year study of natural capital restoration funded by Eurostat. The dual aims are to develop a **roadmap** through **to 2020** for the construction of a comprehensive **register** of **degradation** and potential **restoration** activities and costs across the UK and to produce a **pilot**, for a particular area or habitat, to illustrate how the register might be developed and draw out issues which need to be considered.

The 12-month study is split into two stages: the first, of 4-6 months, involves planning and scoping the project and determining the identity of the pilot. The following 6-8 months will be taken up with the production of the detailed roadmap and completion of the pilot. The final report will present the roadmap and the findings of the pilot, both in terms of the specific results as well as lessons learned for the wider project.

Funding for the study commenced in January 2016, but because of staffing logistics, there has been a delay of approximately four months, so a proposal is being put to Eurostat that the project be extended into 2017. Stage 1 is now projected to be completed in December, with the draft roadmap and final report available for comment in June/July 2017.

The register

At this stage it is envisaged that the register will effectively be three dimensional - as the diagram below illustrates.

For each habitat (urban, woodland,…), the characteristics will be tabulated. These will cover the assets, their extent and condition, valuations, changes and trends, the services which those assets provide (provisioning, regulating, cultural and supporting, both current levels and changes in them, identification of degradation and proximity to thresholds, and restoration in terms of reference and target condition, restoration activities and restoration costs, with timescales,. However, although an aggregate result for each land cover/ecosystem functional unit (LCEU) or habitat is required, this is most accurately constructed from spatially-disaggregated information, ranging across basic spatial units (BSU), land cover/ecosystem functional unit (LCEU), sites of special scientific interest (SSSI), national park, watershed, region or country. Furthermore, having detailed disaggregated data is valuable in its own right since this can be used for practical policy application.[75]

[70] 'The process of actively managing the recovery of an ecosystem service that has been degraded, damaged or destroyed as a means of sustaining ecosystem resilience and conserving biodiversity' (*CBD, 2011*)

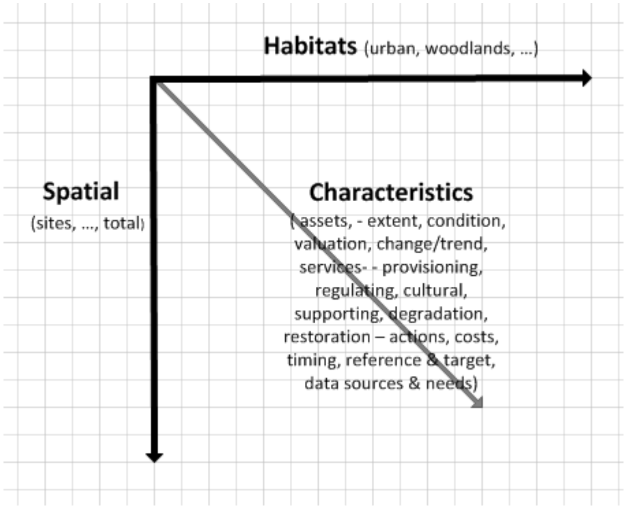
[71] The Natural Choice: Securing the Value of Nature. June 2011. 'We can make progress towards restoring nature's systems and capacities and the government wants this to be the first generation to leave the natural environment of England in a better state than it inherited.'

[72] The State of Natural Capital: Restoring our Natural Assets. NCC, March 2014'Restoration efforts… need to be sustained and underpinned by long-term commitments.'

[73] Letter to ONS from NCC February 2014. 'an estimate of the potential restoration costs to maintain natural capital is essential and the committee is firmly of the view that this needs to be calculated as part of the national natural capital accounting framework'

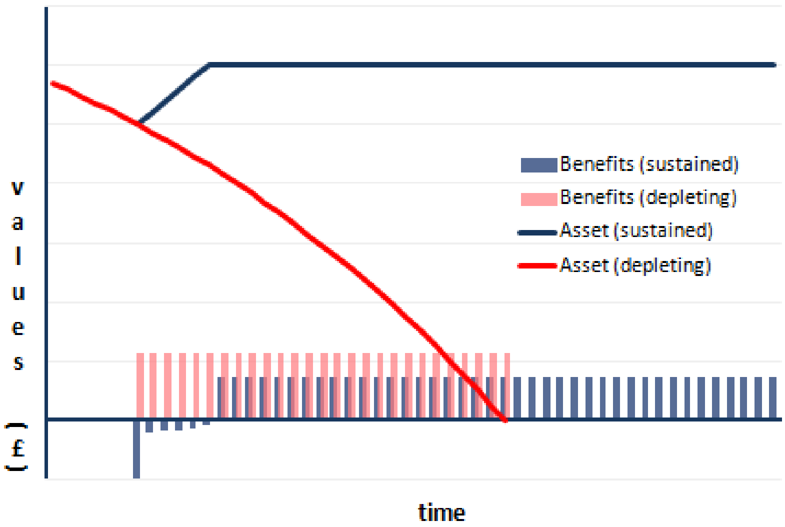
[74] NCC, Third meeting, 12th July 2016. 'Georgina Mace reiterated that the government's goal is to leave the environment in a better state than it is now. To achieve this, we need to do more than just hold back decline. We also need to enhance and restore.'

[75] 'Developing UK Natural Capital Accounts: Woodland Ecosystem Accounts,-report for Defra, March 2015, Eftec. 'The choices for the spatial level of the analysis depend on the purposes of the ecosystem accounting exercise. A highly aggregated approach would likely be sufficient for national level monitoring and integration with the SNA. However, ecosystem accounting holds great potential for structuring information, communication and decision-support at a variety of scales and governance levels. To achieve these ends, and to take proper account of trade-offs across different services at local scales, spatially explicit accounts are needed'



Restoration costs, as detailed in the Annex, include initial capital investments (such as planting, fencing, dam construction or dam breaching) as well ongoing management costs and inputs (replanting, fertilising, thinning). There will also be opportunity costs, in the form of reductions in the activities which would otherwise have taken place on the site (although this may be dealt with in comparative cost benefit analysis).

The diagram illustrates a restoration scenario, with net benefits substantially below those of the business-as-usual pattern in the early years of the intervention (illustrating initial and ongoing restoration costs and reduced benefits) while the asset recovers/improves, but continuing beyond the point at which the asset would otherwise be completely degraded.



This project will draw on the work that has already been carried out to produce roadmap aimed at the construction of a more complete register of restoration activities and costs.

Pilot register

Although an aggregate picture with complete spatial coverage will be required for the project, this is likely to be constructed from disaggregated sources of data, which are useful in their own right for modelling and policy application purposes. Furthermore, although it would be helpful for the pilot to constitute an exemplar for a complete habitat, due to time and resource limitations it will only be possible to carry out a sufficiently thorough investigation for one area. Although it would be beneficial to take account of habitat interactions within the context of a landscape, watershed or national park, this is likely to be too onerous. A number of options are being considered, but, for a number of reasons, including the expertise of the researcher, it is likely that a forest site will be chosen. This is will be an area providing multiple ecosystem services and one which has already undergone a degree of restoration intervention. [*it has not been* *possible to pursue the forestry option; the aim is now for two pilots based on upland bog and lowland fen, and work on these has begun*]

Progress and next steps

We are effectively four months into the study. So far, an initial review of literature, both conceptual and applied, has been carried out, a study timetable, with milestones, constructed and a number of internal and external[76] meetings have been held, with more planned over the next few months. Also over this period the scope of the project will be determined and negotiations will take place to agree on the pilot site and information requirements. Stage 2 is planned to commence in January.

Issues arising

Although there are likely to be a number of further issues arising and lessons learned to be reported at the conclusion of the study, several issues have already come to the fore, namely:

- Gaps, in terms of spatial coverage, are likely to remain even after a thorough data gathering exercise and, because of the idiosyncrasies of the sites for which data will be available, there will be drawbacks in applying the results from elsewhere to the gap sites. However, **gap filling** will be possible by sponsoring the collection of data for those gap sites, by extrapolation from UK or similar sites elsewhere or by modelling (as has already been used in the Bateman *et al.* work, for example);
- Restoration may not be feasible in all situations, if the **threshold/tipping point** has been reached – but it is important that these cases be identified;
- Which **reference point** is taken will influence the degree of restoration required. The **target condition** may, in fact, not be a past reference point but a level that is seen as feasible or an improvement in the light of changes in the ecosystem or changing needs;
- Much restoration relates to change in **quality/condition** rather than scale/quantity: change within land use rather than change of land use;
- Impacts are unlikely to be linear and static over the course of the restoration project: the likely **pattern of growth or decline** in the inputs and outputs needs to be estimated;
- Once implemented **monitoring** is important and **adaptive strategies** are likely to be sensible;
- Because of degrees of confidence in the precision of the restoration cost estimates, **sensitivity analysis** and presentation of possible **scenarios** will be valuable;
- Having a register of restoration costs is not sufficient for decision making. These should be set alongside the benefits and the alternative uses of the habitat and the trade-off evaluated**;**
- Restoration costs may have to be **best estimates**, although restoration activity that has been carried out already for this or similar sites can inform these;
- Although not specifically within the remit of the project drawing out the **policy implications** of the restoration activities identified will need to be spelled out
- Similarly, although not specifically within the objectives of the study, how this restoration-costs approach fits within the **SEEA accounting** and the **CBA approaches** should be considered.*[now accepted as part of the investigation]*.

[76] Richard Haw, Rebecca Isted, Rachael Edwards (Forestry Commission), Ian Dickie (Eftec), Rocky Harris, Colin Smith (Defra), Jawed Khan (former ONS), Roy Haines-Young (Nottingham University), Francine Hughes, (Anglia-Ruskin University)

Annex Summary of restoration costs types by habitats

Using a number of papers[77] which have reviewed the evidence on restoration costs the table below summarises by habitat and main category, and also provides indication of the time scales.

Roadmap (ONS, 2015) - habitats	Urban environ ment	Enclosed farmland	Semi-natural grassland	Woodland	**Mountains, moorland & heath**	Freshwater wetlands	Coastal margins	Marine
initial/ early costs	tree planting; river, hard bank removal removing surface sealing	herbicide seeding grass buffers create bare patches hedgerow creation decanalisation shelterbelt planting	cut herbicide cultivate lime acidification (S, pine chipping, bracken litter) seed/reseed fertilise hedgerow restoration	fell/thin conifers remove invasives bracken control fencing herbicide cultivation planting	clear fell bracken clearance bulldoze burn strip soil/turf shallow cultivation fencing seeding/reseeding	Wetlands: remove trees remove invasives coppicing sedge cutting remove degraded peat/ strip soil peat reprofiling dyke creation & restoration drain/ditch/gully blocking fencing establish reedbed planting (sphagnum,…) Water bodies: natural recovery after catastrophic event barrier/weir removal de-embankment reconnect side channels/ weirs/sluices re-meander add fish pass dredge diversion of effluent liming	remove/realign sea defences/walls excavation/re-excavation of lagoons/pools/creeks reprofile/ create islands channel widening/narrowing control/block flows/maintain weirs construct breakwaters drain blocking deep plough turf strip tree & invasive removal remove algal bloom fencing plant	Investme nt in manage ment and clean-up resource s

[77] Sources: *Restoration of Natural Capital: Review of Evidence*. Maskell, L. *et al.* (Dec. 2014); *Microeconomic evidence for the benefits of investment in natural capital, 2*. Natural England (2014); *Economic case for investment in natural capital in England*. Eftec (Jan. 2015);*Air and Urban Appendix* (in the previous publication); *Marine Appendix* (previous publication) *Estimate of financing needs to implement target 2 of the EU Biodiversity Strategy*. IEEP (2013)

ongoing/ sporadic costs	Tree husbandry and management	maintain conservation headland natural regeneration maintain grass buffers land/soil management changes (planting times, organic, controlled fertiliser application, fallows) grazing management haymaking boundary maintenance plant undercrops/winter cover	natural regeneration graze conservation headland feature management grazing management	natural regeneration woodland management remove invasives replanting thinning bracken control reduce fertiliser	graze natural regeneration grazing regulation/management bracken clearance	<u>Wetlands</u>: grazing management maintain/landscape ditches& pools control weeds sedge cutting irrigation coppicing hydrological management reed cutting bird management cease burning <u>Water bodies</u>: natural recovery control riparian invasives	remove algal bloom graze grazing management	implementing/policing quota transitional support clean-up
opportunity costs (what has to be foregone)		**reduced cropping & grazing intensity** less fertiliser less intensive reduced grazing intensity move to hay from silage organic fallows	**reduced grazing intensity** stop fertilising *reduce intensity (grazing & forage)*	**higher management costs & delayed timber income** fallowing = delay replanting	**reduced or excluded grazing** remove/reduce livestock cease burning	**reduced or excluded grazing and commercial water abstraction** reduce grazing intensity cease burning reduce grouse-rearing capacity reduce abstraction	**reduce fishing intensity**	**reduced catch**
timescales		some short-term improvements in 1-5 yrs, hedgerows 30 years+ *	some short-term improvements in 2-5 yrs, full restoration 60-100 years or more*	initial improvements in 5-10 years, canopy closure 20-30 years, full restoration 100 year+ or never*	some short-term improvements in 2-5 yrs, other improvements 10-15 years and much longer*	some early improvements 2-20 yrs, other improvements 15-25 yrs, more complete restoration can take 80 years*	some early improvements 1-3 yrs, other improvements >10 yrs*	

- Many studies state that the period of the study was not of sufficient length to cover more complete restoration effects

Appendix C Contact meeting reports

Notes from the meetings with those listed in Chapter 1, Table 1, in the order of the table.

Meeting – Jawed Khan 14th July 2016

Agenda

- Was NCC-driven (Colin Mayer – we've done benefits, why not costs? – do you allow deplete or restore to ref condition?)
- This major work – cost approach – need to know if depleting or not - if threshold – define this. (who is expert to define this? NCC done some work.
- Heat gone out? Nat cap has gone somewhat generally, Rocky likes the NPV approach. If FC is supportive of restoration and Eurostat quite interested + approval of funding shows they are interested. UN like but accept data difficult to obtain, but do need a cost when do CBA.

Concepts

- Reference date – no agreement e.g. when is data available from? 25 yrs = one generation (how defend to period chosen – think about defending. WB did 25 yrs … or 50 yrs.
- Policy questions arise when do CBA – asking question, should you be spending money on this – rather than as an accounting question.
- What is reference condition, what is threshold?
- Opp costs not included in accounts.

Project

- It may take a long time to set up a database Even doing register takes time.

Pilot

- Start - do a pilot – forestry? If have problem here, when data rich, what problems will others have? Pilot – country, region or a forest in S Wales.
- First, what assets are we talking about? Need database (e.g. forests) – who owns, what's av value, how calc depreciation, (depletion – how calc and allocate value?), inventory. How many trees – who own, what life, how depreciate, how record? If straight line how decide where threshold – some may be below, some above Should we restore? How much will it cost|? What is opp cost? E.g. wetlands –if depleting – do you replace totally? How much cost? Cf cost v benefit
- one area-many habitats, many areas-one habitat, one area-one habitat
- Pilot gives issues for others. got to be able to complete in one year
- Forest area with particular problems – issues will arise as dig in and put monetary value.
- FC may be sustainably managing – do private do the same?
- Localised is more accurate and can gross up to some extent. This is a pilot and for learning lessons For pilot don't do aggregate.
- Aggregate up on general assumption that this case study is representative.

Contacts

- FC – Sheila Ward/ (statistics) Richard Hew (econ) [Pat Snowdon] also Forest Research (Vivian…?)
- Eftec – good on econ. bad on accounting , application

Meeting – Ian Dickie, Eftec – 8th July 2016

A Policy/plans/agenda

- NCC relaunch last night
- Julian Harlow re. 25 yr plan
- Agenda hasn't changed much (White Paper – leave environment in better condition – Ian 'but how much better?')
- Last night - Environment Agency/Natural England/Forestry Commission to be reorganised into 14 regions, eventually merged as one organisation.
- NCC remit is England
- At relaunch – key for society is – what's the costs of maintaining and the cost of restoring - so that society can decide- economics data and cultural and other choices come in to the decision.

B what is real restoration

- Urban development likely to continue onto Greenfield sites – damage – should we seek compensation for this?
- If 'offsets' approach – tie compensation to types and cause of damage (offsets not well received) or
- General compensation approach – if society/planning authorities approve x houses, assess damage and work out compensation (e.g. in German Länder)
- Some call the latter 'restoration' but not the former. ????
- Real restoration isn't compensation, but net gain (some think compensation could crowd out genuine restoration, but long way off!)
- NGOs State of Nature' report (2013/14) focussed on biodiversity (and B action plans, BAPs, existed for some time – but patchy – reedbeds got emphasis, semi-natural grassland little?) e.g. freshwater wetland – weigh up effect using grade of land, proximity to people , whether upstream (so people benefit downstream from better water quality) (but land available for these improvements may be limited – can't do around railway line, etc.). Gives welfare benefits – but these not covered in env accounting terms. Say set target of 100k ha. Could produce account of amount and condition of wetland but some 'levels' farmed not v. intensively so not necessarily a change of land use. Rather **change in quality – hard to detect** .

C Level – aggregate or micro

- NCC looking at high level but expect localised implementation – i.e. get on with it at local level (e.g. Bristol, Birmingham plans). Environment Agency/Natural England/Forestry Commission to be reorganised into 14 regions, eventually merged as organisation.
- Implementation/local effects fragmented, so difficult to measure for aggregate picture.

C* How decide/calculate where?

- There isn't a systematic way of this is what/where we're restoring as most effort goes into degradation ...
- Worth exploring satellite imagery – woodland account – should be about tree cover, proximity to people and ecosystem services.
- Ian did ag. study for WWF based on Nix – 12% of land area could be restored but only lose opp cost of 4% of ag. production (over 25 years)
- Paper on tree cover in London mapped against antidepressant prescriptions – used data on tree cover (Ian to send)

D Measurement costs

- See measuring quality in B above.
- Linked to C above – there may be a more efficient way of estimating effects – opportunity cost may be lower than seems at aggregate level e.g. farmers may get good yields this year, but climate change may flood more often and some land will need to be abandoned(note, should we, therefore, look at changes over time rather than assume RR =today's value?)
- Base on baseline assumptions with some sensitivity analysis
- May know costs/ha. On average and if multiply up, government says that is miles too high – unrealistic and puts off politicians. But there can be **efficiencies** in terms of **right location** (and the extra benefits, like recreation, that that area can provide more of, and **economies of scale** (say going from 100 to 300ha. can have big effect on management costs).
- How pick up quality in this framework – may be no land use change, but quality change? In 'Investment...' they used existing mapping of peatland restoration linking to higher populated catchments (water companies know best for local targeting as they weigh up their infrastructure costs)
- Difficult to set up land-use options – timber production can cover maintenance costs, other benefits on top of this (any payment to produce these?). He says a lot of maintenance costs are often the opportunity costs of not being in receipt of the highest rate of production subsidy. Long-term system reliant on production subsidy.
- **Tree cover** (using satellite imagery) can be more useful than woodland data.
- **GIS & Satellite imagery** – Cranfield work on mapping driveways and spoil modelling shows how data can be used.
- Restoration paper has much on biodiversity, less on other - plucking figures a bit.
- In 'Investment' paper each chapter looked at the economies of scale, etc. Different approach in each one – benefits and cost – include opportunity costs – sensitivity analysis.
- Environmental challenges - caveats – ask actors (Nat. England, …) – what data will you give to monitor quality?

D* Reference condition

Deep green is for going back to pristine. Need to be practical/pragmatic. =This can be threatening to the agricultural community implying big land use change. Get lost in acrid arguments.

Better wording is ‘protect and improve’. ‘Degradation’ puts off farmers. Beware divisive language. Even current baseline targets such as about restoring biodiversity, can still take account of historical factors (e.g. nightingale important for centuries) even though data and case use the current baseline.

E Data sources

- For study of Investment… or Restoration… (Dickie papers – which?) Graham Tucker – esp. Evelyn Underwood (IEEP) had spreadsheet of areas and costs, etc.

F encouraging actions/incentives

G Pilot?

- Baseline for 1 habitat, then case study (e.g. Manchester) – and how will the data change as investments are made (c.f. how data has changed over the last few years) – and how could this be automated to give measure of change across the whole country.
- Urban green space – challenge of playing fields and individual trees (highest value but worst data; *cf* peatland strong case, but lots of data/info.)

OR

- Pilot areas of NCC (to be announced – marine (Lyme Bay), River catchment (Lake District), City (Manchester?) (Manchester Green Infrastructure Strategy, useful planning data may exist).

- If look at, say, agriculture – frame it on a catchment . A lot happening with Environment Agency & Water Framework directive – target, but nothing to coordinate management efficiently – expect farmers to do it off their own bat (with grants). |What is the benefit to society if we coordinate this? – not always clear at present. How habitats interact (in catchments) is important.
- Maybe (see catchments above) not much actual land use change will occur/be visible/be needed, but lots of qualitative changes which could be important (e.g. farms – edge strips, borders, hedges, fertiliser,…).
- How pick up these **qualitative changes** systematically? Management agreements (but often short term and no compulsion to keep restoring beyond the 5-year agreement.
- NCC remit is England.

H Policies

- May have target areas in advance with fixed prices – but can be too clumsy and expensive. Can be cheaper if auction and go for most suitable areas (lower quality, liable to flooding – lower opportunity cost), create some kind of market where people have incentive to bring poorer areas forward.
- Some landowners do have future generations/stewardship attitude, which can help.
- A good local way of targeting is important – not top down edict.
- Need assumptions on efficiency (**see RSPB guy Ausden in ‘Investment...’ paper*****)
- Scales/sizes – small can be v. beneficial [e.g. recreation], but costlier than large scale.
- Targeting important
- See conceptual below
- **Wording** – ‘improve’ better than ‘restore’
- **Gainers and losers** (see World Forum on Natural Capital in Edinburgh, Nov. 2015) – guy who had been big in env. area advised, one key lesson – **‘pay more attention to the people who lose out.’**
- Hard to make a case for the benefits, so can ensure by raising the standards of cross-compliance – so pay for the good, and ensure actors don’t do the bad.
- Key challenge is to **monitor the changes** and see if what was wanted is happening! People are scared of change , especially if not monitored as whether change occurs can be disputed (and **time lag** before beneficial effects, e.g. nutrients in soils – stored for ages so no increase in water quality for ages – decade+).

I Conceptual

- Investments in natural capital should show an increase in productive capacity of services useful to people, whereas agri-environment 5-year agreement can be surface-level – not a good investment because it should make the habitat/site healthier, more resilient regarding provision of benefits for humans.
- Natural Capital potentially non-renewable (if beyond threshold) if agriculture loses species diversity (would take thousands of years if could restore), soil structure, … - but if looked after can be self-sustaining.

J Corporate

- Corporate natural capital accounting – compares characteristics of conventional balance sheet cf natural capital assets.
- Often in England in agriculture falling yield or increasing fertiliser costs so asset needs to be shown as falling in value.

K report, roadmap

- Fill gaps using satellite data or GIS/land use data and integrate subsidy information (Netherlands combine habitat data, agricultural data and business survey).
- Be careful with language – NCC remit is England. Some areas of England more relevant to extrapolate elsewhere (e.g. NW England to S. Scotland). Do analysis for England (unsure about what extrapolate from this).

L Timeliness/time

25 yrs is period when investments take place, but benefits and maintenance costs occur longer into the future (Climate Change Act – more independence of political influence). But now intergenerational targets so it could be useful (feasible?) to look at longer periods.

Meeting: Chris White, Petrina Rowcroft AECOM 9th September 2016

Their work:

1. Ecosystems services assessment IFC performance standards (standard 6 – bio ecosystems services
2. Environmental valuation for decision support tools (CBA, …) – water companies incorporate environmental and social values. Some initial PES
3. Market & payments for ecosystem services (Defra best practice guide) – water companies – SW Water, SCAMP
4. Natural capital accounting. Ecosystem accounts for 6 protected areas in E&S (they have accounts person in their team – Rosie). ONS work on pollutants to air. Natural Capital assets check for Kent CC

Pre- Natural Capital Protocol companies nervous of innovation re nat cap accounting but also not wanting to be left behind What are the others doing?' approach

Restoration costs – big businesses have a better handle – aware of costs and benefits. National Grid strategy – they have partners – wildlife trusts doing the actual restoration work so they know the costs – looking at their non-operational estate (a liability – zero book value – seek to derive community value). Making a business case for this.

Chris suggested – For aggregate – **headline** ~~damage~~ restoration costs. For **disaggregated** – more detailed – regression model (me e.g. restoration costs=f(size of area, difficulty of access, state of degradation, what land doing now, need to separate/fence off from surrounding area/what is around it,…)

Green Book is firm on proportionality – what is the nature of the question/how material is it? Determines if go for a broad brush or specifics approach (e.g. they did for noise) – don't put in more effort than is justified.

Ecosystem assessments – too costly to collect data unless already collected. 80-90% was publicly available (e.g. cultural value of Lake District). Defra was keen for them to be experimental. Lots of data but quality of asset indicators problematic - inconsistently collected, different spatial areas, , everyone did things differently and not consistently across time to enable measurement of change. They did compile registers of potential sources of data.

Costs to restore? Issue is no market where these activities are bought and sold or recorded. If database with people bidding via centralised restoration broker would be good (feasible?) e.g woodland carbon broker – what is costs to plant trees, etc. FC register through Woodland Carbon Code? Natural England reference tables about what farmers claim for fencing, etc.?

They interviewed 1,200 farmers about attitudes to planting – but not costs.

Ask – **what is the purpose**? What do they want/will they do with the results – headline or disaggregate.
Peatland restoration – Mark Reid at Newcastle Uni – he would know. Peatland Carbon Code.
Ethiopia forest restoration – CBA potential carbon and water/dams value cf planting costs and opportunity costs.
Priority if short of time, scarce resource.
Optimisation model would be useful – if limited funds, then do x amount of this and y of that.
Restoration=rehabilitation of mined or quarry sites with picture of what like previously or rewilding – but little idea of original state – reference point.

Kielder Forest lynx introduction. Restoring farmers say to 700 years ago. Improvement better that going back to something way back to establish more diversity or C storage.

Timing of restoration costs – they'll ask Rosie.

Will Richardson – their friendly local forester! Also Pat Snowden (FC)

Meeting – **Defra** – **Rocky Harris** and **Colin Smith** – 6th July 2016

The topic

- Heat has gone out of this – Colin Mayer has shifted his view: he realises (?) his former view is not viable. However, research on SEEA by UN has accepted the need for this, albeit not priority. And FC are still supportive (see Forest Estate England accounts about to come out) . Also, NCC broad thrust still no net loss – restoration to where we are now (start of period/year?) and enhance what we have got.
- Colin Mayer – capital maintenance costs – NCC would like ONS to produce data showing 'maintenance cost of natural capital is 'x', whereas actually spend 'y', and getting worse.'
- Need – what we need to spend vs. what we are spending
- Atkinson says we need costs as well as benefits.
- (Rocky) national-level issues are different
- Pat Snowdon (FC) said (restoration costs) had policy relevance.

Aggregate or disaggregated?

NCC want aggregate

Nitty gritty for localised information – don't spend too long on this

Tabulating restoration costs

- (Colin) systematic look at habitats – what would restoration and maintenance costs be?
- Can you restore?
- Try a few scenarios/examples with logic chain (like Obst and Atkinson [Vardon?]).
- What's driving the change?
- Include - what we need to spend vs. what we are spending
- Explore issues on each habitat
- (Colin) on a per hectare basis

Evidence – data sources

- UK-NEA?
- Central Highlands (?) – Victoria, Australia
- Forest Estate England – natural capital accounts (next week)
- Natural woodlands – no maintenance costs – can it just be left to regenerate (via scrub, secondary forest)? (except fencing/keeping livestock out)
- Eftec – peatland, woodland
- Eftec – this is what was actually spent.
- (13 yrs ago ONS tried resource accounts)
- CEFAS accounts – know how much we spend on fish management.
- Water – Environment Agency and OFWAT (some or all of their costs?)
- Natural England doing work on nature reserves (SSSI's? – to which they assign quality/condition grading) – setting up scenarios (Rebecca Clark)
- Biodiversity Action Plans (10 yrs ago) (BAPs) had costs of restoration
- SDG – Nature Target – Scotland?
- RPA
- Urban – Birmingham done stuff- NCA-based – not yet published (results?)
- NCC work on investment with NPV's (Colin to send material)
- River restoration

Types of costs

- Environment protection expenditure (EPE) – are restoration costs similar re. SNA? *Environmental products are goods and services that are produced for the purpose of preventing, reducing and eliminating pollution and any other degradation of the environment (environmental protection - EP) and preserving and maintaining the stock of natural resources and hence safeguarding against depletion (resource management - RM).* *http://ec.europa.eu/eurostat/statistics-explained/index.php/Environmental_goods_and_services_sector*
- What about future restoration costs?
- (Rocky) so many variations in restoration costs – could do in different ways, over differing time periods, in different areas,… - make it quite unmeasurable (?).
- (Rocky) Trade-offs – who gains, who loses, who owns?
- Do we/can we integrate with existing accounts *(Rocky seems to think not possible)*

- Are maintenance costs likely to increase over time?
- Value of the degradation – one accounting approach is to measure degradation (equivalent of depreciation) – not the same as restoration cost.
- Can you restore? E.g. ash tree disease – no change in extent – can we replace with ash or does it have to be something else?
- Conceptual issues re. restoration – concepts of what costs we are looking at.
- Resource management (planting, thinning, …)- Eurostat have done some work on this.
- Marston (former head Defra) opined – public spending on biodiversity not outcome-oriented – pure estimates of spend not helpful alone as can be ineffective/effective depending on, *inter alia*, management regime.

Can we integrate restoration costs with existing accounts?

- Current spending is 'x' – part of broader environmental accounts – amount you need to spend is separate – not strictly part of accounts

Choice of pilot

Woodland – as most data- maybe take whole habitat and also home in on one location.

What is reference condition?

Lots of views

Timescales

Are maintenance costs likely to increase over time?

Reporting

To get steer from NCC

(apart from producing roadmap, etc.)

- What are messages we want to give? - initial findings –
- high level aggregate indicator (national level stuff gives strategic direction)
- nitty gritty – detail for sub-areas – local decision making - can they use the same concepts and data? *Don't spend too long on this*.
- Try a few scenarios/examples with logic chain (like Obst and Atkinson[Vardon?]). Incl. what's driving the change.
- Interim report – help pull out generic issues.
- Pilot - Woodland – as most data- maybe take whole habitat and also home in on one location.
- Engage NCC early on - is my thinking right? Conceptual issues re. restoration – concepts of what costs we are looking at.

Meeting – **Roy Haynes-Young** 21st July 2016-07-22

<u>Stock and condition</u>

He was been working on:

Environmental Accounts (KIP-INCA project wit EU (Anton Steier) – the want stock and condition for key assets.
JNCC working on condition, Eur Env Agency working on stocks for pan-European ecosystem accounts.
ESMERELDA Project (2020 Biodiversity Programme – target of 15% restoration of green infrastructure – but 15% of what and what constitutes restoration) – Natura sites (lot in unfavourable conservation status).

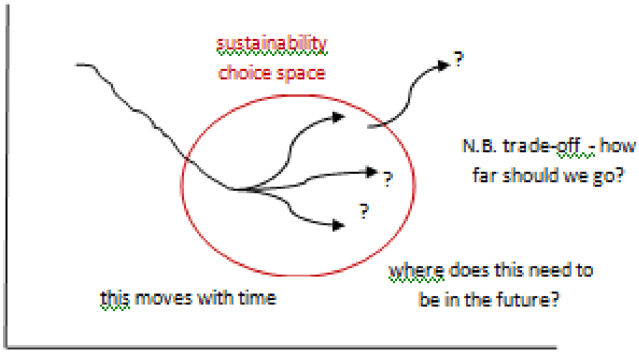
Ian Dickie lots done on module 1 of NEA follow-up (see website) (was a Defra project did scoping study then follow-on for NEA. Likely to have to use that – not move way – lot done already. They seemed to start to put together a way of doing it, but getting data on specifics was problematic.

Countryside Survey (CEH work) – next round would be 2018 (if done, don't seem to be investing in this). NEA largely used their classification, much of their data came from CS as did input to Eftec stock and change in broad habitats. Did **stock** and **condition**. There was stock loss, but most of degradation was re. condition That's the **nut to crack**. Will make progress if operationalise those condition meanings and types – ecological description (e.g. like 4 status measures for SSSI's such as 'favourable conservation status'), but not tied in with ecosystem services – needs to be broader, looking at the functions of these systems (it works for peatlands where straightforward key measures like sphagnum being active)

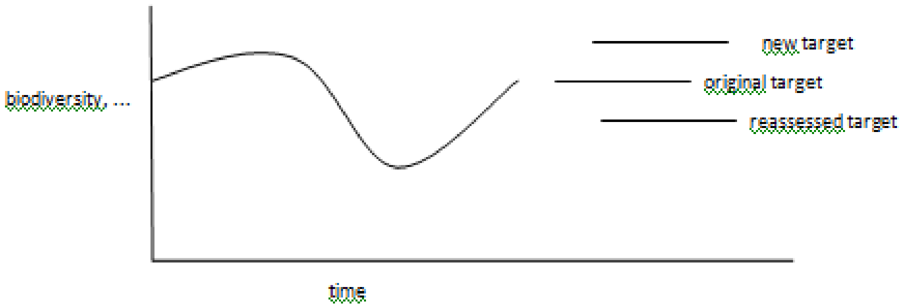
<u>Cascade model</u>

Cascade model (Routledge Handbook of Ecosystem services, Potschin et al, 2016, p.26 diagram) – going from ecosystems condition to services through to consumer – supply of services and demand – the latter means that restoring to some previous level may not be appropriate if growing demand. E.g. amount of flood protection. So does notion of

restoration make sense?- landscapes always changing – look at future levels of need. E.g. Blue-Green Cities initiative not about restoration but improving.
CICES (last was v4.3 20130 common hierarchical classification of services – how can we describe the final services – breaking up provisions, regulating and cultural (book Table 3.1) – now they're working on how measure and is it exhaustive? Need to look at supporting or intermediate services & integrity of those assets. (which assets at risk?)
But to assess risk need to look at rhs – who is at risk, what values to put on the risks.
Trade-off
Note **trade-off** – e.g. skylarks vs. agric. – need to bring back (up) to sufficient level, but not too much.



Re. Trade-offs - Social values need to be included as well as economic, and cover collective values (e.g. as expressed via RSPB) Now argue that look not just at money but health, social, moral – broader range of metrics could be brought to bear. Decisions not usually based just on money – e.g. political. Multi-criteria decision tools people trying to use – particularly in local situations – scoring, with peoples' views. Not unique to environment – e.g. schools, - citizens' juries (health with NICE) – weighing evidence. It's about governance – how we do planning – are we prepared to invest in it? (putting resources into planning authorities, etc.). How we come to a decision – moved from technocentric to socio-centric
Restoration/improvement
Restoration/improvement – adaptive strategy – may find don't get to the level wanted so reassess – discover reality as implement – governance – punters may not accept – don't want failure.



People-centred
Swiss did sustainable flood plain management – was canalised, wanted to open up to allow flooding, modellers reckoned no effect, people didn't want but accepted compromise – implement, but if reaches x point then something would be done. – Adaptive.

Worked with West Country Rivers Trust – restore land to improve water quality. SW Water money to give farmers – sat with them and asked where, with maps, agreed where to focus – zones of potential agreement.

He involved with Defra agri-env scheme re. hedges – had it improved landscape character? Blind rating of quality of those in and out of scheme. Hard to tell if improved. **Monitoring** is a problem – often measure uptake rather than outcome. Monitoring using citizen science – **citizen monitoring**. And what people value using social media – how many pix on this site, locating devices – where people go and how long stay. LSE **mappiness** from mobile – where they are and how happy – green space impact. May feed into assessment of risk and CBA apart from economics.
Pilot –

- peat is good but everyone goes for this
- Coastal setback equally good – taking down sea wall on E Coast (Kerry Turner) – balance between flood alleviation and costs of maintaining and benefits of taking down (coastal margins into wetlands [fen, mash, swamp])
- Restoring Caledonian Forest in Scotland.
- The National Forest (Nottingham, Stoke, Rugely,..) – is it restoration? From 6% to 30% forest cover (20 yrs in its 20%) – lots of data on costs and benefits – '**everyday landscapes'** **,** several habitats

Landscapes

- England 159 landscape character areas – over years evolved to become 'national character areas' (website) – what do they give, what are threats/risks and opportunities, drivers for change in future. How about landscapes and the assets? Mosaics of Land type/habitats (e.g. Lake District was overgrazed..)

- Could ask questions – what does it give, what does it need, but using landscapes (Sussex Downs NP or other new NP's or New Forest – lot of data))(lot of work on economic benefits of NPs)

- Landscapes – within ecosystem services based on 'place-based approach'. Services exists as bundles and bundles attached to places & values & beneficiaries vary from place to place (Table 11.2 in the book)

Question – what land/habitat classes do EU use? See what they regard as an asset – cf our habitats. Check EU stuff – would a pilot on changing land cover be helpful? Think how we would identify undesirable trends in stocks and <u>condition</u> accounts.
CORINE (new satellites will give more frequent, more variables, but coarser images – GEMS)

My project –

- Take one of the land cover categories – have a map of where they are (take all >2ha. polygons which are woodland – identify which are conifer, ancient woodland ... – how are they changing and what are the risks (Woodland Trust recently did something on ancient woodlands under threat) - get ???? process and identify characteristics which make it important and which drivers for change. Could do it for woodlands, peatlands (most of these are in SSSIs so monitor condition). Countryside Survey seems to have been halted because of funding.
- Landscape characterisation in Wales was sophisticated (NERC-BESS Cambrian Mountains [biodiversity programme case studies], DURESS project did scenarios [Isobel Durance, Cardiff] – review other work, have they taken a landscape or habitat approach – have they been better able to look at trade-offs , assign values to assets. Scenarios – extent to which restoration occurred and what they have regarded as trade-offs, If ask 'are these things at risk?' look at scenarios ands counterfactual of not doing anything.

- Partly been through this with eftec and NEC – could this be applied at a European scale? Their interest is to show – is it peculiar to UK re data availability that not applicable to European scales? Let's take something that would be regarded as an asset at European scale. E.g. CORINE would regard x as an asset – then if did in this way, how could apply across board? E.g. peatlands, woodlands. How would be measured/captured in accounts at European level (see CORINE map for England would cover this –show how bring info together for this
- The setback one would be easier as lots of studies done.
- Case study – Flow Country - conifers planted earlier felled/taken out and bog/pool system (from 21ha bought by RSPB in mid-90s to 2200 ha.) –land had been cheap for tree planting, cos marginal land, but realised that host of wading birds of European significance affected (political move to stop because of Nature Conservancy Council (NCC – so influential that Maggie broke up!) influence restored to improve dunlins (proxy for other birds too) (RSPB) . They did lot of work on dunlins decline with afforestation (had 70's data, used GIS) (**Nature** paper – incl. Mark Avery)

Sustainability – about not closing our options for the future

Paradigm is utilitarian - must make a case for nature – must help people.

NCC was more concerned with economics rather than ecology.

Stern with Climate, TEEB with environment

90's project – Countryside Quality Counts – is countryside changing and does it matter? (characterised 4 – as was, declining, improving from decline, total change)

Phone meeting: Steve King, **UNEP-WCMC**, Cambridge 17th November 2016

Accounting

SEEA-EEA – could sit alongside in a combined presentation – restoration cost accounts, showing liabilities, what invest to achieve

Approach:

Habitat OR cross-cutting OR different spatial areas OR location

Each of these has been done;, scoping studies – by broad habitat classes; cross-cutting re. key ecosystem services, e.g. carbon, accounts; protected area

Directs how to start thinking about the issue

Following broad habitats ties in with the Risk Register of NCC – makes most sense.

Degradation – NCC **risk matrix** – traffic light system – where the benefits are tailing off/decline in quantity/quality or condition/right places, which services or capacity to deliver them is being reduced – **configuration**/extent. Gives idea of where and what. e.g. forestry near urban, chemical quality of river course. Challenge is understanding what is degradation – indicators – baseline of where want to be and how far and how achieve. Quantify this.

Roadmap

Important to be aware of cross-boundary

Integrate maintenance/restoration costs with different accounting approaches

Habitat-wise is best, but how do these communicate with spatial and cross-cutting?

Case studies

Difficult on a number of levels – baseline which you are trying to achieve; current condition

e.g. Freshwater accounts – chemical ecological status, transfer into treatment costs –volume of contaminants, ongoing leaching

Ecological cost/restoration cost approach in Quickstart publication (John Louis Webber) – CBD, European Environment Agency complimentary thinking re. restoration costs and ecosystem accounts (**check**)

His thoughts on most important approach:

1. Prioritisation exercise most important first step (link to NCC) – reposition that work – informing the targeting of where restoration analysis should focus
2. How information on current sets of accounts currently available can be used to infer what costs of restoration are required and the likely benefits it would generate
3. Lead to another prioritisation exercise – trying to establish costs of restoration in obvious wins – when most benefits for least costs – meta-analysis of data already brought together.
4. How integrate with other accounts/ how apply the methodology in a discrete area or bottom-up approach or how could integrate with cross-cutting accounts.

Politics – seems willingness to carry on with the policies.

Meeting (telephone) Richard Haw, Forestry Commission. 20th July 2016

Didn't seem to think restoration needed in forestry!

Restoration and degradation – he thinks of peatland.

Carbon sequestration may be declining with the ageing of the woodland planted in the 70's (no longer youthful and fast growing). Wonders whether planting targets have sequestration factored in for the future.

Idea of replacing with broadleaves – will put me in touch with forester (UK Forest Standard does not allow monoblock planting)

Lots of FC colleagues agree that longer rotation length good for C but trade-off with commercial rotation since owners do not benefit from the C. If incorporated C sequestration into rotations would be extended, But move to broadleaves would be strongly challenged at FC as conifers can show a wide range of benefits.

Restoration could be reforesting land or bringing unmanaged woodland back into management

DECC C valuation estimation – value to society of reduced C emissions – analysis – may be better not to fell at all.
Forest Research (Vadim Saraev – Northern Research Station) – tool to analyse trade-offs re timber, C and windthrow risk = prototype with Sitka and one yield class.

Bateman *et al* producing a tool re recreational benefits of planting close to urban areas.

Meeting (telephone) **Pat Snowdon**, Head of Economics & Climate Change, Forestry Commission, Edinburgh
0300 067 5211 pat.snowdon@forestry.gsi.gov.uk 15th November 2016

Standard costs exist for grant applications – fencing, tree shelters, etc. – could be the basis for a hypothetical pilot

Restoration – what does it mean? Can be just improving/better condition or restore to woodland, or SSSI's into better conditions

Defra costs study re. meeting BAP targets – lots on costs
Only option if don't do specific project
Problem is costs are hugely site-variable (standard costs produced to get round this) [me - but, by definition, then, aren't standard costs likely to be wildly inaccurate?]

Register – do pilots but register standardised?

Top-down approach –
Define what restoration is going on
If knew had to restore, say, 50k ha. Across England
Bottom-up great in theory, but massive modelling capacity or loads of data, transfer values or representative sample of sites
e.g. FC trying to estimate economic value of woodland re. flood risk. Env Agency – consultants- modelling – how many sites need to be looked at in order to get a feel for the national picture? Now going for another approach – Top-down – categorise water catchments and communities at risk.

Need summary –x ha of moorland, y ha of woodland need restoration (or improvement – or is that going too far as my task is big enough as it is?) Improvement - planting woodland on moorland degraded by agriculture?

C sequestration is tricky – carbon sequ value varies depending on tree age structure, so over next 20 years, lots of felling so sequ will go down
Difference between optimisation and degradation – perhaps longer rotations would improve, but ….

In UK forestry, both restoration & improvement taking place - The Forest estate will spend money on restoration.
Moving land use – some would say enhancement/improvement.
Nationally, 2 key policy aims:
Plant more
Improve management – grants available & indicators (re. targets – on FC England website)

Private forestry – Woodland Carbon Code – set up standard and engaged with a lot of planting projects at local level – planting on unused or ag land (see FC website) – Woodland Carbon Code (WCC) – website lists project developers who know of a lot of projects (James Hepburn-Scott, Steve Prior).

Meeting (telephone) Rachael Edwards, Head of Strategy and Insight, Forest Enterprise, Forestry Commission England, 620 Bristol Business Park | Bristol | BS16 1EJ
0300 067 4019 | Mobile 07867372567 rachael.edwards@forestry.gsi.gov.uk 2nd September 2016

I explained my study and that I was looking for data on restoration costs (had happened or in process) and that Rebecca had mentioned Northants.

Northants – ancient semi-natural woodland. Part of England Biodiversity Strategy to increase semi-naturalness scores – PAWS areas – what % of cover is natural >80%, 50-80%,… Records of naturalness over time. Not records separated re. specific costs for these *vis a vis* bau – same accounting codes and not separated by stand, just district level.
Maybe woodland SSSI's may have been recorded differently – she will look into.
National Forest – restoration from open-cast sites? Initially done by Land Restoration Trust so no cost data.

Problem re accounting codes re restoration vs. ongoing management. Also restoration work gradual – as get to end of one rotation…

They see natural capital account as way of articulating and comparing proposals. Getting data on which they can have confidence is problem . C OK but not water and air quality.

CAP (we discussed funds post Brexit) – maybe study large landowner getting woodland management grant – Forest Services deals with these. Might get some average costs.

Rachael deals with:
Nat Cap – production of first account and development of the account and how can use in strategic decision making and how manage the resources
Strategic direction for next 10 years
Management info and data – that they need to tell them if what doing is working and impact how do differently.

Meeting (telephone) Rebecca Isted, Principal Adviser - Natural Environment, Forest Services, Forestry Commission England, 620 Bristol Business Park | Bristol | BS16 1EJ 29h July 2015
0300 067 4035 | Internal VOIP 4035 | Mobile 07776 245076 rebecca.isted@forestry.gsi.gov.uk

Woodland change in asset/service flow value: view of whether decline depends on your definition of natural capital. If you mean available timber or carbon, probably not in that timeframe. If, instead, look at less easily measured ecological services – nitrogen deposition in soils (some baseline site data from Bunce Project 1974 then surveyed again in 2000) – of native woodlands (much in SSSIs), but this not commercial woodlands
Have qualitative dataset – woodland condition as a whole – National Forest Inventory – gives conifer/broadleaved, etc and data for 1 ha. plot samples – lots of measurements of all woodland types – can measure change, including woodland quality.

It would be new thinking to equate woodland quality measures to natural capital accounts – 'defining 'natural assets'. Depends on how you want to measure natural capital. NEA had a lot on woodland – the services and established results. Where do they have restoration costs for?
PAWS – plantation of ancient woodland sites - a lot of ancient woodland sites replanted with conifers. Short term carbon loss with felling but produce timber and give better quality C sequ. As soil quality improves – water management properties similar but quality improves. Flood prevention esp relates to impact on soil of change – more organic matter and rooting (although takes time).
Lots of sites (rural development regulation RDR grant aid) transfer conifer to broadleaves . Takes time – to canopy closure (15 yrs), but this doesn't change everything – some elements persist for > 1 rotation.. Takes longer on disturbed (ag.) soil but PAWS sites often little disturbed (one ploughing?). Clear fell biomass and soils emit.
(experts C emission – Mark Broadmeadow, econ. – Pat Snowdon)
Other ecosystem services/benefits – because it's challenging don't ignore other aspects – otherwise only partial results , e.g. landscape quality – people want things to stay that way.
NEA-follow up Phase 1 identified full range but Phase 2 – more focus on easily understandable.

Within Public Forest Estate good data on what tree cover was, what volume of timber came off (standing sales by volume).
Pilot – one district – Northants District? – done most of restoration already, clear felled. Lot off restoration by natural regeneration..
Big site is Fine Shade (nr Kettering). They reported on restoration work (found a lot of heritage material – Roman villa and remains)

Broadleaves vs conifers – often latter are new planting so moving to broadleaves might not be advantageous – no driver for this – a balance needs to be struck and importance of timber supplies – massive negative downstream processing and employment) if softwood production were cut.
Forest estate is 18% of forest resource in England but produces disproportionate amount of timber into forestry sector. Can be unintended consequences. Can't start with blank sheet of paper. Also, as 80% private ownership can't make people do things – when fell can only say must plant like for like, only if SSSI can you require actions 'in public interest'. (rural development regulation RDR, focuses on water and biodiversity)
Brexit opportunity using CAP funds (although trade deals will cost some of this) – could use for land managers (not just farmers) with requisite cross-compliance.
Good if could get CLG and Defra working together.

She will speak to colleagues in FC – ask where best source of information and get the project principle sorted with senior person
Me to send outline – where is project going , what for and info needs..
Go to their team meeting in Bristol?

FC natural capital Accounts - published soon

Meeting (telephone) Miranda Winram, Head of Strategy and Insight, Forest Enterprise
Mob: 07901 102831, Tel: 0300 067 4625 (New number in 2017)
620 Bristol Business Park; Coldharbour Lane, Bristol BS16 1EJ
miranda.winram@forestry.gsi.gov.uk 19th September 2017

(Rachael Edwards stood in for Miranda while she was on maternity leave. The latter commissioned the 1st NC account from Eftec, ,which was delivered while she was away).
I explained my project and gave a rough definition of restoration. We discussed reference point and what was included in restoration, cf with 'improvement', and interest in restoration – I said arose from NCC.
She expressed interest in seeing pilots – to see what is possible to achieve.
Referring to Rachael Edwards' statement about difficulty in obtaining separate restoration costs, Miranda is sure that she will have inquired about what information was available.
FE is weak on peatland impacts, so would like to see my pilot report(s), in confidence.
May be opportunity for me to discuss/work with them on Forestry restoration.
Bogs – Wendy (their accountant). Interest in seeing if can find practical ways to apply NC to land management decisions.
Me to send peatland condition-ES model refs and list key people.

Discussed FC Natural Capital account. – the 3.67 issue of C cf CO2 and apparent low figure for bog emissions (p22).

Email 20th Sept 2017
Geoff, I've looked through this paper, and the others you sent, with great interest. I am afraid I haven't got any useful input to you I don't think, but the Pilot Study has prompted lots of thoughts for me about what we could do with woodland in a similar way looking at alternative land uses (which is what I was hoping when I asked you for this!).
Couple of questions initially –
1. Where did you get your flood benefit values for peatland from? There isn't one available for woodland as far as I am aware – is peatland flood impact much more advanced?
2. Would you be able to share your spreadsheet for this work at all (either now or later) as I'd be interested to see how complex the modelling is.

Reply
Miranda,
Thanks for getting back to me, and pleased that it has sparked some thoughts!
To answer your questions:
1. I get the impression that flood benefits data are extremely limited. However, although I was looking at restoration costs, I needed to estimate benefits for the CBA. So I engaged in my own, rough and ready calculations!
Given that Exeter is the main population centre affected by floods from the Exe watershed, I used the cost of the Exeter Flood Prevention Scheme and converted this to an annuity of 30 years (using 3% discount rate). I then worked out (very

roughly) the share of the rainfall affecting the whole watershed*. And so apportioned the annual flood prevention costs to each ha. of the project. I then took a statement from an Exeter Uni report on the project that damming (i.e. restoration) reduced the amount of water leaving the site by 2/3, so reduced the costs by this once the next (improved) condition category was reached. (the spreadsheet facilitated varying the assumption that condition **jumped** to the next category after x years, to one in which the change occurred gradually [**sloped**])
2. I'd be happy to share the spreadsheet - in confidence again - I'll ask permission. It's rather a mess at present, but I intend to tidy it for Eurostat. The spreadsheet is large, but the modelling isn't that complex - it just looks that way.
Regards, Geoff
* just weighted big blocks of the watershed by the annual rainfall received there, by the differing rainfall for each block received by there.
Email
Hi Geoff – Very impressed that you came up with your own flood figure – I've heard lots of people spending lots of time explaining why its not possible to come up with one up until now!
There is some work (in a fairly limited way) about to happen with Forest Research on quantifying the impact of woodlands on flooding, but its going to look at only a couple of the factors that impact on it. But it's a start. That may be of interest to you when its published (work not actually started yet) so I will forward when it eventually emerges, likely spring next year I think.
Great on the model – just as and when you feel able would be great – modelling always looks hellish complicated when its someone else's work I find….
Miranda

Meeting (on site**): Martin Lester**, **Francine Hughes** **Wicken Fen Vision Project** 28th November 2016
Wicken Fen Countryside Manager - Martin.Lester@nationaltrust.org.uk
Animal and Environmental Biology Department, Anglia Ruskin University - francine.hughes@anglia.ac.uk

Martin:
Establishing costs – each bit of field is treated differently. Objective to re-establish a set of processes and let nature take its course. Low key approach regarding capital costs, fencing maintenance and in-hand grazing (also some tenanted grazing). Livestock are doing the engineering. Do have obligations re. cross-compliance (incl. weeds [e.g. ragwort], zoning plans near where others with crops & livestock; not such a concern in the middle of the project area.)[78] All Vision land is within the agri-environment scheme (High Level Stewardship), but this is difficult as it is a targeted scheme and this project is not conventional! Natural England have been persuaded to amend what they expect to achieve – making the scheme fit the project.
Objectives change – biodiversity, difficult to measure, but do monitor how it's developing (like an observatory of change). The NNR has to be managed for certain objectives, but the Vision area is more dynamic.
He can report how much it costs to manage the livestock. But costs cover two distinct areas – the NNR (the old fen), which uses a lot of the resource, and the new part of the site. Initial costs – initial capital works (land-use conversion costs); operation costs of restoration work
Methods they are using may not work at another site.
They are in communication with other projects – Wild Ennerdale Partnership (Lake District, United Utilities, FC, etc.) and Weald (Sussex, Knepp Castle Estate Wildland project, private owner – Charlie Burrell) – re-establishment, but looking forwards, not back.
Francine:
Biodiversity assets change all the time – instead of increasing certain species, accept that some arrive and some disappear – biodiversity is dynamic.
Different ways of converting - other fen projects (Lakenheath [RSPB], Great Fen[79] [NE, EA, LA]) involved much heavier intervention - with consequent much greater conversion costs (and carbon emissions arising from the digging!). Each project may have differing objectives. Here the aim is for more resilient ecosystems/habitats with the expectation that species might come and go – the projects provide stepping stones within an overall landscape in the light of climate change. Ecosystem targets concern function rather than prescribed assemblage of species (except for rare [IUCN Red list] species in danger of extinction.

[78] 'What was GAEC 11 (control of weeds) and 12 (agricultural land which is not in agricultural production) have been removed. Instead, as part of the BPS eligibility rules, this agricultural land will need to be maintained so that it is kept clear of dense scrub.' Cross-compliance handbook v2
[79] Woodwalton Fen and Holme Fen = National Nature Reserves (NNRs), but vision covers much larger area.

Can’t get back to some pristine state.
Martin:
We don’t expect massive handouts.
Rather than being prescriptive of what they want to achieve, aim for a naturalistic hydrological regime – e.g. stop drainage – in the early years abstract water (from high level carriers [lodes] coming from limestone in the east – clean water, not ‘dirty water’ from agriculture) into the project area, tend to put in a sluice (in case of burst bank, etc. emergency – for Internal Drainage Board) but not drain. Tend to be pragmatic, relaxed and patient. Habitats that develop tend to be novel as they are derived from former agricultural land.
Lakenheath prescriptive and heavily engineered, but no comparative study seems to have been done.
Disadvantage of the Wicken Fen regime is that it takes longer – some benefits within one year, but dramatic benefits (e.g. appearance of big flocks of corn bunting), although can be seen within 2 years, can take 80 years or more.
Encouraging and protecting specific species can be very expensive. Why is this done – people like to see (e.g. cuckoo), but not vital. Species changes are tied in with ecosystem functions.
Objectives – from day 1 have struggled to find the language for what they do. Aim to make space for the old fen – ‘give it some space’ Three aims: **biodiversity**, **people**, **ecosystem services**.

1. **Biodiversity** – was the starting point. , but became are of people-countryside disconnect – lack of SSSI’s, AONB, etc. – SE England black hole - , so created opportunities for people (Wild Camp, on a Denmark model for scouts, etc.
2. **People** – give locals a stake via a community liaison forum, and help with community issues – local cycle routes, assist parishes with issues/support
3. **Ecosystem services** – over last 8-10 years – knew of benefits, but previously had not time! E.g. reedbeds clear up some agricultural run-off (water cleansing), Uni of Leicester doing some work on CO_2, cycle routes help well-being & health

   Never consciously scored these, but for Martin the order would be 1, 2, 3.

Martin knew from the start that successors may not be able to draw on the sort of funds a 5,000 ha. project would require in terms of what other conservation projects have done. Looking at large projects (e.g. Serengeti and Yellowstone) they haven’t attempted to engineer a great deal of change. In their approach people nearby can take advantage straight away and with climate change we don’t know what is going to happen – big expenditure on infrastructure may not be worthwhile.
Reedbeds are part of the NNR/SSSI with clear conditions for them to attain. They monitor, but minimise management so that they don’t degrade. They have also developed their own reedbeds. In late 19^{th} Century peat was cut for turf. Areas that were grazed in the late 50’s/early 60’s became commercial reedbeds. But reeds were low quality and expensive to harvest. Keystone species – reed leopard moth habitat was damaged by regular cutting.
Grazing: in-hand – Highland cattle and Konik ponies – bovine & equine eating/digesting patterns symbiotic (rip, ruminate for 18hrs; continuous grazing)

<u>History</u>

Gentlemen Adventurers (Duke of Bedford,…) (speculators) (1630 on) put money into projects to straighten rivers and drain and make money from the fens with windmills to pump water out. Cornelius Vermeyden and others did the engineering work. Some locals opposed (they had strips of land and engaged in eel trapping, wildfowling, sedge for thatch). But Industrial Revolution changed markets so livelihood damaged and land fell into disrepair. Cut for turf up to late 19^{th} century. 1895 Uni of Cambridge entomologists bought land at Wicken to collect insects, then 2.5 ac. by NT in 1895. WWII wanted for bombing range but buckthorn alder twigs good for fuses so not pursued. 1920/30s Godwin and Tansey at U of Camb researched here and Sweden – from this came ‘ecology’ and ‘conservation’. Post war rough grassland but reed recognised as important habitat.
The Farm in the Fens. Alan Bloom; *Adventurers’ Fen*. Eric Ennion

<u>Costs</u>

1. No two areas have been the same in terms of costs
2. Older costs have been archived – difficult to access and analyse
3. **Current costs** of each activity are available
4. Martin will think about, for each project (acquisition), **what** was done and **when** (even if rough and ready) (covering – what was done (if anything) initially prior to ‘engineering’, what capital works were carried out [reprofiling, blocking], fencing, livestock purchase, livestock management, monitoring [including proportion of time of managerial and other staff], other running costs; also income from grazing rents).

<u>Areas</u>

First land acquired 1899

Areas	ha.

SSSI- never drained	169
Derelict reed and swamp (drained, ploughed, farmed 1939-53)	116
Acquired cropland (1995?-2011)	550
Total (doesn't sum!)	792

Issues/points of which to be aware

- Spatial differences - each area differs re. **characteristics**
- Fen/peatland 'restoration' projects differ widely in their **approach** (heavy/limited engineering and prescription/direction) and **costs –** due to **characteristics** and **philosophy**.
- Discounted measures – initial heavy engineering (hence, costs) has a substantial negative impact, considering long life favours projects with delayed & long-term benefits
- Climate change and other external factors - will fixed/specific/prescribed objectives give sufficient flexibility and resilience/ will objectives need to change? So what objectives are appropriate?
- Valuing the benefits of biodiversity
- Can't return to a pre-intervention state, certainly not for a long time
- Projects have not tended to enumerate costs to facilitate cost-benefit analysis or comparison across projects.

Meeting (on site) Morag Angus, David Smith Dulverton, 24th November 2016 **Exmoor Mires Partnership**

Morag Angus Exmoor Mires Partnership Manager, 7-9 Fore Street, Dulverton, Somerset, TA22 9EX, mangus@southwestwater.co.uk Tel direct line: 05601181602 Tel mobile: 07827283893 www.exmoormires.org.uk

Dr. David M. Smith Upstream Thinking and Environment Manager, South West Water: Peninsula House, Rydon Lane Exeter, Devon EX2 7HR Direct line 01392 443219 Mobile 07824 460274 **www.upstreamthinking.org.uk**

Both SWW employees since 2006

SSW responsibility for water supply (and water quality) and waste water (not all water companies have this responsibility). Flooding concerns them, LA's and Environment Agency.

2010-15 Business Plan(water companies have to do this, including 5 year AMP – Assets management Plan)
SSW's Upstream Thinking – this project became part of this umbrella, aimed at looking after the catchments and water quality.
Damaged peatland – lots of things/methods possible for restoration. Here they have done ditch blocking. They are pretty good at knowing the costs

Dartmoor – bare peat map – due to grazing, burning and shelling, and peat excavation for fuel and industrial use. (distilled for naphthalene (tar camphor – mothball stuff). Ditches for draining plus natural development of gully system as peat mass breaks up. To reinstate peat would costs £1m for <100ha. And stakeholder management problems.
South Pennines peatland – degraded mainly due to industrial pollution

Problem on Exmoor – ditches in 18th/19th century – Knight family (purchased in 1818?) improving agriculture – draining and setting fire. More from **sphagnum** to grass (& *Molinia* caerulea (*purple* moor-grass) (clear correlation with peat quality). No bare peat on Exmoor.
Aim – to restore to functional hydrological system – raised water table with sphagnum (which is 98% water) which is a living skin which protects the underlying peat. Freshwater supply and store, C sequestration and helps biodiversity – creating habitat. Benefits to SWW – water quality (lower treatment costs) (less dissolved organic matter –DOC – brown), sustained supply – manage water so gives base flow and can abstract for longer (resilience) as get water from surface flow(reservoirs and rivers), ensure long term supply (resilience planning).
Natural Environment Programme (Env Agency, Ofwat, water companies) – obligations (incl under Water Framework Directive) (and other stuff – sewage works, etc.) on habitat and biodiversity drivers. SWW do peatland restoration on land they don't own – can work out costs and outcomes.

United Utilities – SCAMP project , 2010 – they own and manage SSSIs purely for Natural England's condition assessments.

Mires Project – on the 2,000 ha. About 60% owned by national park Authority (half is SSSI). Natural England say must improve habitats.
Stakeholders – reps - National Park – manage moorland, but no restoration plan; Natural England (CAP moorland payments) – help pay capital works; Environment Agency (under WFD) – funded some research and capital works; Historic England - archaeo and paleo ecology; reps from NGO's and farmers.
Landowner & tenant have a say on each bit of land with a restoration plan for each.

SWW have invested heavily on measuring water quality, C-sequestration and storage, water flow – measure (via flume) water flow and C emissions.

NB Duchy has Nat Cap chapter
North Pennines AONB (Chris Woodley-Stewart) local nature partnership[p with other protected areas– Northern Chain – Investment Plan

Also lower down – dirty farm water – trying to get farmers to do more – from CAP payment often contributes (Pillar I to Pillar II). SSW could use those funds with farmers better.

SSW has targeted question 'what the customer wants' in the business plan. Ofwat – pleasing them – innovative/cost saving/status – want short term evidence – pushing an open door – they want catchment management, Osborne agenda re. deregulation though free market economy.
Emilie (at Exeter Uni) looking at financial benefit of water treatment re. treating moorland, farm costs – sediment and silt disposing of, pesticides, dirty water, DOC.

Sheffield- -Severn-Trent Water – water treatment works upgrading re. Ladybower res. drop off of DOC is very slow, even after 10 yrs not really showing.

SWW – Exe water taken out near Tiverton (Allers – Bolham) and Exeter (Pynes), use pumped storage at Wimbleball res.

East of England – Rutland – water quality – slug pellets from cereal cropping – metaldehyde – goes straight through water treatment works – have to shut down when it's present and bring in water from elsewhere. Big fuel costs to pump water round.
East &south water companies have problem with pesticides.

SWW biggest electricity user in SW with pumping round the system. Avoidance management

My contribution – will help if give convincing argument for institutions doing natural capital plans (can do it for bits, but not watersheds, etc. Exmoor National Park Plan (60% of the moorland) doesn't have this plan. David wants more in the business plan about natural capital – my use as case study helps.

Dartmoor – major landowner is the Duchy.

Thinking that another PhD could look at what landscape interventions in the last 10 yrs and the effects – on biodiversity, fish stocks (Atlantic salmon were common in Exmoor waters – big decline as indicator.

Long time for effects. Little/no baseline evidence – so have to do backward modelling. So can't say cost:benefit ratio is x because of long time scale & lack of research/
Economist 65:1 ratio – they don't use anymore ?
WTP exercise done elsewhere in SSW David says thinks 'we should do this catchment management' – the more evidence he has the better. Most of the information is in Dulverton – not downloadable in Exeter.

Fen peat Great Fen restoration project (Holme Woodwalton?)
More alkaline (ph7) not acid moorland peat, derived from reeds/rushes vegetation
Landscape was drained and farmed intensively – oxidation is main loss and soil loss via vegetables takeoff and wind erosion (friable soils when drained)
Black peat, but clays coming through – carbon emissions rate is <u>massiv</u>e
e.g Holm Post – steel column driven in from Great Exhibition

IUCN Peatland Code only qualify if can prove you're not exporting carbon emissions – can't be something that would happen anyway.

Telephone conversation _ **Chris Dodds, Scottish Government** 14th June 2017
Head of Environment and Rural Analysis Unit. 0131 2445417 chris.dodds@gov.scot

Peatland restoration good in Scotland – not v expensive and decent C benefits

Had quick read of paper – lot makes sense, including need for CBA, and not aiming for a given level of historical quality. Need check what's benefit – may let degradation increase in some areas or improve/dramatic increase in others – at margins.

Work going on in Scotland:

1. Strategic Research Programme – lots of £ - strategic science and social science research in one clutch – Natural Assets – to identify geographical natural assets register and their state – like a Scottish risk register – but a question on how much detail. Looking at transfer values form other studies.
2. Some peatland modelling as part of above (depth, quality) – recent work for Scotland's Climate Plan (Jan 17?) – trying to optimise most cost effective way of reducing C emissions – mostly an energy model with envelopes for reductions in each area (peatland and waste – connected but outside the model?). Modelling time profile for carbon gains? http://www.gov.scot/Topics/Environment/climatechange/meetingemissionstargets/climate-change-plan
3. Natural Asset register sort of work at SRUC (follow on from SAC) – with cash from 1 above. http://www.hutton.ac.uk/sites/default/files/files/research/srp2016-21/RESAS_srp141_NAR_NCA_ELPEG_Briefing.pdf
4. SNH – economist constructing a Natural Capital Asset Index – different types of land and different attributes – overall index. http://www.snh.gov.uk/docs/B814140.pdf
   Excellent – v positive and helpful!

- He will email me contact.
- Me email them and CC Chris.

Dr D.A. Robinson Soils, Land & Ecohydrology, Centre for Ecology & Hydrology Environment Centre Wales
Deiniol Rd, Bangor, Gwynedd, LL57 2UW United Kingdom Tel: +44 (0)1248 374534
email: davi2@ceh.ac.uk<mailto:davi2@ceh.ac.uk> web: http://www.ceh.ac.uk/

Feb 2017

David,

It is a pity that we missed each other when you were here meeting Emily last week. I hope it's OK - Emily passed on your paper to me - and I have a few questions.

I am working on restoration but came to appreciate that in order to understand where restoration was needed we will have to look at degradation and hence condition. My two pilots are Wicken Fen and Exmoor Mires, so peat is of particular interest. Not being a scientist (I used to lecture at Bangor, by the way, in farm/forest/development economics/management/accounting!) I do not understand the reason for the apparent exclusion of peat from your paper's coverage - would you mind spelling it out for me?

Another couple of picky questions/comments:

line 17 - 'tree covered soils are associated with the highest carbon stocks' - what about peatland?
line 68 - soils definition - so what about peat with depths well in excess of 2m?
line 219 - do I take this to mean that soil formation is imperceptible from an annual or even 100 year accounting perspective?
line 237 - trafficking - as it only occurs for clear fell and, possibly, thinning - so only a few times in the rotation for a particular stand, is it likely to be such an issue?
line 255 - I can see that the difference would be so much given that this is a 20,000 fold increase in area
line 314 - is it <u>the</u> important issue, rather than one of the main issues?
This paper is very interesting - I found the setting out of condition metrics particularly helpful.
Kind regards, Geoff

DR Reply

Hi Geoff,

Thanks for responding. Peat is included (organic), what amazes me is how much peat is under trees, not in the UK but in much of the rest of Europe. I call peat organic soil because it's not possible to tell what's peat and what are other thick organic soils as the data is not good enough (no depth). We used the EU peat map to identify the organic soils. I should probably make this a little more obvious.

Soil formation is about 1.5 tonnes per ha per year and erosion losses, for sustainability, should remain at a similar scale or below. The problem is they don't, they are higher which means we are mining arable soil. But we need a mass balance, of production vs erosion to fully understand gains and losses.

Soil erosion from plantation forests is at least an order of magnitude higher than from native, perhaps several orders.

Hope this helps, it'd be good to catch up at some point, I will undoubtedly have another visit.
David.

Meeting _ Professor **Kerry Turner, CSERGE, UEA** 16th June 2017 Also Silvia r.k.turner@uea.ac.uk
Centre for Social and Economic Research on the Global Environment.

They doing two projects for KIM-INCA:

1. Trying to offer pragmatic way forward between accountants and economists with Policy makers in the middle. Paper- Synthesis Report on Natural Capital Accounting - draft just commented on by INCA partners (Get report? Conact Jakub.wejcher@ec.europa.eu & Laure.ledoux@ec....
2. Rome people – pollution and recreation

INCA partners in this – WCMC, Cambridge – ES indicators & risk thresholds; Institute ofr European Env policy – London & Brussels – policy makers and their requirements
This work due to finish end Dec 2017- may renew for extra years

Restoration – to what reference position? I answered re. pristine (pre Ind Rev, 1950, …) target near natural state, start of accounting period (year)
He said: diverging opinions as far as they can see. **ONS position that restoration costs not equivalent to depreciation; Eurostat believes that they are equivalent.** We take the nuanced position – 3 approaches:

1. Could extend SNA but restricted by rules = exchange values
2. Satellite accounts – ancillary only to formal accounts but not bound by strict accounting rules
3. Welfare accounts (a la Dasgupta).

We would say restoration accounts fit into approach 2. National Income accounts designed to measure consequences of changes in economic activity- for this, can go beyond exchange values and cost-based data. If in your value-based method it doesn't work then exclude from 1, but include in 2.

In the report they have tables for types of cost analysis that could be used in 1, 2 or 3. If used in a particular context – e.g. if no exchange values welfare-based data (survey data using WTP), could used monetised value in restoration costs. They are trying to help policy makers – effect on environment if economy goes up or down – need some handle on that. They are trying to argue with different partners, saying 'what are we trying to do here?' OK, we may not be able to modify the account in 1, but can get stuck in a loop. Instead ask, 'what information don't we have but need if the question is, the economy increases by x%, what is the effect?' We are applied economists, concerned with policy.

Another debate – a lot in EU interested in welfare accounts – here we would have a whole series of data, including survey-based data. Pragmatism – **hypothetical** restoration costs acceptable here – in 2 (or is it 3? – me)

I asked about cost data being do broad brush and scaling up. GIS should definitely be used. Difficult to say without looking at the studies and the level of significance and uncertainty. No technical answer to this (he said, 'didn't they partition restoration costs into real and hypothetical? [I haven't seen this])

Telephone conversation _ **Flemming Ulf-Hansen, Natural England, Bridgewater)** 18th May 2017
Responsible for Exmoor, SSSI's/ag environment stuff. Ecologist in NCC/Eng Nature/Nat Eng 28yrs
(U Bradford, W. Ontario, Liverpool)
<u>Condition - Blanket Bog</u>
Exmoor different – shallower peat than – definition 0.4 or 0.5m peat but Mires peat depth maps (Masters student did) some >1m in few places, generally quite thin (10-20-30 com) – possible reasons – drainage from 18th century (steam ploughing and hand digging small ditches) – restoration plans show dense network of small drains, 8-9 yds apart theorising that the areas between would dry out. Research over last 20-30 years suggests ditches can influence up to 6m – so they were clever! Also herringbone network of bigger ditches from 1950's, some linked up with existing drainage – dried out the peat and stopped from increasing in depth (sphagnum can give 1-2mm/yr growth on peat depth over 100's of years). Burning for new growth – bring animals over summer from before 1800's with gates – graziers paid to graze – damaged/destroyed the sphagnum moss and CAP headage payments led to higher stock numbers.

On the flattest area (the Chains) – centre of Exmoor Forest (royal hunting area), peat up to 2.5m and 100-200 ha up to 1m deep. Won't get deep on slopes and Exmoor isn't a wide plateau and rainfall not as great as N Scotland where peat down to sea level. Within SSSI's last 20 years regular burning management more or less stopped. Molinia is an indicator that the water table is not close to the surface as it can't tolerate lack of oxygen in its root system Restoration by reversing drainage and stopping burning (certain seeds sensitive to burning can then improve the vegetation) – should be able to increase peat depth over many years. To judge vegetation – peat-forming vegetation on the surface and lack of negative factors – some reflected in their condition indicators – e.g. mosses and cotton grasses too much Molinia presence of drains. NE looks at attributes – factors illustrating diversity score (>5-6 species), positive and negative (rushes) indicators. Otherwise you could look at peat depth, water table depth (although fluctuates),… Some not easily measured and included in international sites (SAC's) and SSSI's so may want air quality (such as nitrogen) at greater than critical loads which will cause negative change (e.g. 5-15kg/ha exceed ed in large parts of the uplands.. Climate change – blanket bogs form if about >150 wet days/year.
My measures (Peatland Code, etc) are of peat itself rather than vegetation – his attributes are why they designated them SSSI's – vegetation. One could introduce physical structure attributes – bare ground, eroding peat not more than drainage ditch every 10m,… - indicators of poor state of soil or hydrology.
Air pollution in the Peak district has a big effect – sphagnum couldn't grow but since Clean Air Act and post Industrial Revolution and sulphur levels falling (acid rain),improved but increased cars increased nitrogen and intensive farming meant increased ammonia bad,. Things tending to go down but cars increasing. Some research showed that high N can benefit some species (purple moor grass- Molinia in Holland), but heather and sphagnum intolerant.
How you assess depends upon your perspective. NE for SSSI's look at vegetation, but also affected by other factors – soil nutrients, hydrology, air quality, management factors – ranges from quadrat ($2m^2$) to regional level. For SSSI's established monitoring – common standards monitoring (JNCC) at UK level (although each country interprets a bit differently) – related these to SSSI's and SAC sites – condition at a habitat and species level e.g. wet heath – attributes – where x% of sample show the habitat is in favourable condition (e.g. a moor or bog) – scale applied varies by country – England is assessed on a management basis – say, 30 site units have blanket bog (BB), but not all sites are BB. If some attributes are not met – too much bare peat, too much drainage, not enough sphagnum, they then ask, is management in place and therefore 'improving (recovering), or not changing (no change) of declining (say 10/20 quadrats were bare, 6 yrs later 15/20 bare). Also categorise as damaged (e.g. illegal ploughing, outwintering cattle, BB changed to grassland due to fertiliser) or destroyed. When they measure a block of moorland (a unit and its condition, it may have BB, valley mires,… - the condition for the unit as a whole is measured from the poorest..
NE are thinking how they might streamline recording – should they record BB across the site as a whole (more like Scotland where they have more extensive areas) (APIS.co.uk – pollution indicator system)
GIS – could record summary results for each BB using spot measurement for say, 20 ha. Doesn't work quite like that at the moment. Used to measure every 6 years, now 7-8 years but based on risk (he could dig out results but would take a couple of days and each site wouldn't be measured at the same year)
Peatland Code and EA measurement of quality of peatland soils (Matthew Shepherd of NE – has done GIS [coarse] mapping of quality of peatland soil) can get at very coarse level from satellite imagery – can be done pretty quickly – only measuring one or two aspects – not vegetation.

<u>Correlation</u> – expect unfavourable condition reflected in vegetation (and that ditches <10m) – e.g. if only 3 species of attribute indicator are present this wouldn't show in the satellite map.

<u>Condition change</u>
Unfavourable in current state (e.g. cos have bare ground or <6 species). If in a scheme so positive trajectory then = recovering, as they are doing something about it. If old drainage could be stable, unless indicators show drains eroding and soil erosion so = declining.
Note ES could be favourable for water but unfavourable for biodiversity. There is some correlation and even functional relationship – C and water, but maybe not air pollution. May be from past conditions. Can categorise as 'under threat' – maybe not evidence of air pollution but if overall critical load excessive, then problem. (IPENS improvement programme for English Nature sites – for each SAC site identify main factors and what can …? Table at England level)

<u>Tipping point</u>?
e.g. landowner asks for funds for scheme but heavy grazing, drainage, burning (active eroding, heavy burning with wide bare ground, poaching, sphagnum carpet damage with ag weeds [buttercups]) – NE may not pay if indicate it is not stable but declining

Exmoor almost all BB in SSSI, Dartmoor only some not in. (JNCC report 445 Table 6). Maybe less notified as SSSI as move up north, specially Scotland.
NE has generally used ownership boundaries.

ES – competitive in BB?
Ag- grazing intensity vs biodiversity (may increase a bit at first as give small scale diversity, although BB's don't necessarily need grazing). Flooding – shallow vegetation – storm flow runoff slows but in winter bog not sponge as mostly full but if water table lower (Mires/Exeter Uni research) shows lag of flood unless drains well connected drainage network – and poss reduce peak.

Restoration
Different costs for different condition? Favourable – low – wetter land for farmer. His experience on Exmoor – most is ditch network (Knight small drains 1 spade wide and dense, later ag drainage – herringbone small to large) but each site is different – site-dependent
Mires did keep costs although project team costs not allocated nor archaeo survey costs (note price regulation rounds of OFWAT – PR09 and PR14). Spreadsheet had about £490/ha. hydrologically-restored areas.

Time scales
After capital works, what further ongoing costs? Agri-environment moorland schemes are 10 years. Moorland rewetting supplement to keep ditch blocks maintained although seems to more compensate for reduced grazing (£12/ha/yr) – calculated on the latter.. Mires and NE no more than 15 years. He knows that some ditch blocks need maintenance over the first 4-5 years, but drains tend to disappear. In long term aim to restore natural hydrology but may be some underground cracks/rooting from when dry, giving 'peat pipes' 5-30 years expect sphagnum growth, peat growing and closed drains so not maintenance. Complete restoration can take 10s or even 100 years.
Holden (Leeds) recent paper on burning (2015) showed effects on water table and storm flow, especially worst storms.

Ken Bradley, NI government. Ken.Bradley@daera-ni.gov.uk Meeting 24th August 2017
Ni just starting on the journey – starting blocks re. Natural Capital (NC) – only given ministry approval in January. Talked to produce scoping paper (not ye done) – have researched via internet, Birmingham workshop, onto NC Forum, spoke to Paul Leinster and Scot Wildlife Trust (Jonny Hughes) who are doing urban study on Stirling. He's interested in pilot studies to demonstrate the NC concept in non jargon.

This area also involved in env policy – habitats (EU directive)- they've finished the definition process , and know actions to be taken, but need to manage it. Now a major programme to develop plans for main sites.

Fermanagh (Cuilcagh Mountain -blanket bog) – employed Ulster Wildlife Trust to do management plan and they are keen to do a NC pilot because it has many aspects – tourism, pollution, recreation,.

Role to assist higher level decision making

Main data are on protected sites, but planning decisions often relate to ordinary areas and need to understand env effects on these. So limited. e.g calculation of compensation of env in other areas for new road

Discussed fact that habitats may have lower value because degraded yet potentially higher value.

He's also involved with Ireland NC forum – includes NGO's, govt., LA, business (Bord Na Mona) and electricity company.

Ammonia (livestock farms and chicken production) big env problem in NI.

NC easily seen as new kid on block by green welly brigade!

CAP – new Env Farming Scheme (through RDP) post Countryside Management Scheme. In past no monitoring of net env benefit. EFS = discretionary payment with single payment scheme (nb if too much heather in uplands didn't get payment so lot of burning!!) EFS was Jan-Mar but only 400 farmers. 2nd tranche will occur. Will evaluate/monitor.

Brexit – little thought. Defra takes lead. What needs to change not detrimental to future trade agreements – focus on trade deals. Border – 5 counties border the south and 300 road crossing#

Traditional conservation efforts haven't worked and decisions often detrimental. Want ot better inform.
Have had attitude – any development is good development, the troubles hindered this, would get planning permission unless something badly wrong. How bend the rules, how get round, not apply to me!

Meeting _ **Neil Paull, Economist, Welsh Assembly Government** 8th June 2017
Also Caryn LeRoux and Steve Spode, ecologists (Emily Finney unable to attend) neil.paull@wales.gsi.gov.uk

Steve – Arcadia report – Scottish model 4 stages – Aichi targets 15%, Wales likely to use their model
SONAR – elaborated on NCC approach – **resilience** factors (Land Use Consultants (LUC) did - expert judgement comprehensive risk register for Wales – broad (and narrow?) habitats – 4 principle measures as in Environmental Acts Wales has specifics in Env Act to maintain resilience of systems- value, ES delivery.

*****Neil – information for one site not necessarily transferrable – picking off major sites, major issues in the risk register. So broad brush for aggregate, more specific for sites.

Steve - Glas Tir monitoring and evaluation programme 300 km sq sites – env indicators – want people to discuss the science – valuing useful but not the only show in town – other ways of measuring worth – social values, value of benefits

Caryn – costs of restoration – for x input the benefits will increase y

Neil – economists value environment, problem is bringing together scientific & risk & uncertainty. He's not formally involved in developing the account but interested in what ONS is doing. Hoping to contribute and gain understanding.

Steve – we'd like to be more involved – Emily Finney linked to NCC. Cath Raymond (leads on Env side) and Emily. He is ecological adviser in the department.

Caryn – Steve's been involved in restoration target for CBD- 15%

Steve – we've been, with the Env Act, duty of NRW & WAG (biodiversity to NERC ???) to maintain harmony & resilience and… services they provide – managed to incorporate resilience into legislation. Lot of work on ES and valuation, little on resilience, keen on restoration. Attributes – similar to Lawson Review – 1 Connectivity[80], 2. Diversity, 3. Size, 4. Condition – test these 4 (also interested in adaptability) – then more able to resist/adapt to climate change. Pools biodiversity & condition.

Don't aggregate – can't tot up but can use for any space and scale – the better these things are the better. Idea is the benefits provided by these though paid for cos people want and pay for.
Wellbeing of Future Generations Act – 1 goal is resilient Wales. Emily's work part of Env Act – leads on policy – priorities for government and others to achieve resilience.

How Wales achieve if government can't/won't pay?
PES, CAP – replace – this project would provide useful information on how best to spend what you get. Desire not to go down same road (as CAP?)

Neil - *****Treasury view ag – want to shift to pay for env goods not area payment – Defra less clear. Tension between targets and paying for externalities. WAG (minister) has active round table for rural affairs – cross-cutting group with strong consensus – continue producing high quality product.

Caryn - Nat Res policy applies across WAG – there's discussion of what different departments can do to restore.

[80] Although can be bad re invasive species

Steve - Been probing farmers' unions – aimed at landowners and NGOs.
RSPB – Migneint costing

Neil - To what extent are grants reflective of actual costs? Suspect lots of env projects differ re recording financial info. – why not pro forma to make uniform without overburdening – if they already do the collection anyway.

Emily role is NR policy and env act – evidence base, policy priorities, implementing for NR Wales – they oversee, also biodiversity p[policy, priority species (Env Act section 7)
Cath Raymond – Env Science

Natural Resources Wales – State of Natural Resources
http://naturalresources.wales/evidence-and-data/research-and-reports/the-state-of-natural-resources-report-assessment-of-the-sustainable-management-of-natural-resources/?lang=en
Glastir Monitoring and Evaluation Programme portal
https://gmep.wales/

Stephen Prior and Andrew Moxey

Stephen Prior Director Forest Carbon Ltd Abbey Road Business Centre
Abbey Road Durham DH1 5JZ sdp@forestcarbon.co.uk
t: 0191 395 2956 f: 0191 395 2946 m: 07737 740 020

Dr Andrew Moxey Pareto Consulting 29 Redford Avenue Edinburgh EH13 0BX
apmoxey@pareto-consulting.co.uk Tel: +44 (0)131 441 1029 Mob: 0774 967 9301

I am currently working on a natural capital restoration study, and am homing in on two exemplars in peatland areas. Therefore, the Defra report (NR0165) carried out under the auspices of Crichton, was of some interest to me. I then came across the above neat and very interesting tool, and looking at its properties discovered the author a 'Prior', so assumed it was you - I hope it is!
I have a few questions about the spreadsheet, which I'd be grateful if you could answer (or pass on to colleagues):
From GAB Jan 2017
1. Discounting - this has not been done and is justified in the spreadsheet. However, I would be grateful for more explanation as to why expenditures - up-front with some capital works and then ongoing for some time - and benefits, again building up over a long period -do not need to be discounted
2. Linked to this, what assumptions are you making about the build-up of benefits, particularly as with peatland there can be different stages, but generally a very long period for 'full' restoration?
3. It is helpful that you allow the user to put in their own figures. What would you say about the 'accuracy' of the guide costs? (I didn't see a reference to these in the project report)
4. You have 4 condition categories, with a very wide range of emissions; I see that these are based on some careful fieldwork and analysis. However, the emissions range is very wide and comments in the report highlight the variability and likely improvement over time ('wide ranges of emissions' p.15; need for 'age of the site since restoration as an additional factor…' p.17; 'extremely high variability of GHG flux measurements' p.17). This question should not detract from the view that this is a very high quality and valuable piece of work, but what would you say about confidence intervals we should put on the values for each condition category and the build-up over the restoration period (this links to points 1 and 2)?
Geoff

SP reply
You have come to one of the right places - Andrew Moxey and I completed the financial analysis work package (WP2) together and I've cc'ed him here.
My answers/comments below in red, Andrew's in blue.
Best,
Steve

1. Discounting - this has not been done and is justified in the spreadsheet. However, I would be grateful for more explanation as to why expenditures - up-front with some capital works and then ongoing for some time - and benefits, again building up over a long period -do not need to be discounted

THE MAIN REASONS ARE STATED IN THE SPREADHSEET. SO FAR ALL OF OUR MORE THAN 100 WOODLAND CARBON PROJECTS HAVE BEEN SOLD EX-ANTE, MEANING WE HAVE TAKEN ALL OF THE PAYMENT TODAY FOR FUTURE CARBON AND FUTURE LIABILITIES (BUT MOST OF OUR COSTS HAVE BEEN TODAY). WE HAVE ESTIMATED THE FUTURE LIABILITY ELEMENT AND ARE INVESTING ACCORDINGLY. WOODLANDS LEND THEMSELVES TO THIS MODEL BECAUSE THE CARBON WILL BE A LONG TIME COMING. IN THE CASE OF PEATLANDS THE SAME WILL PROBABLY OCCUR (UNLESS THERE IS A PROJECT DEVELOPER WITH DEEP POCKETS) DUE TO THE FRONT LOADING OF COSTS AND THE NEED FOR INSTANT FINANCE. (IN FACT IN THE ONLY PEAT CARBON PROJECT IN THE UK TO DATE WAS AN EX-ANTE SALE). THERE IS, THO', ALSO A CASE FOR PERIODIC EX-POST SALES (AS PEAT RESTORATION DELIVERS INSTANT CARBON SAVINGS), AND IF THAT WERE TO OCCUR THEN PRICES AT THE TIME OF THE SALE WOULD NEED TO AT LEAST MIRROR COSTS. THIS WAS INTENDED ONLY TO BE A PRACTICAL TOOL DESIGNED TO GIVE PROJECT DEVELOPERS ENTERING A CONFUSING MARKET A ROUGH IDEA OF WHETHER THEY HAD SOMETHING WORTH PURSUING. INCLUDING DISCOUNT FACTORS (WHICH TO ME IN ANY CASE CAN BE A "TELL ME WHAT YOU WANT THE ANSWER TO BE AND I'LL GIVE YOU THE DISCOUNT RATE" KIND OF THING) SEEMED UNNECESSARILY CONFUSING.

ALONGSIDE THIS PRACTICAL CASE FOR AVOIDING CONFUSING INVESTORS, THERE IS ALSO THE (PHILOSOPHICAL) DEBATE ABOUT THE APPROPRIATENESS OF DISCOUNTING WHEN BENEFITS ARE EXTREMELY DURABLE - AS DISCUSSED AT LENGTH BY THE LIKES OF COLIN PRICE AND IN THE STERN REPORT. WE DIDN'T ENGAGE WITH THIS EXPLICITLY, BUT IT DOES PROVIDE AN ALTERNATIVE JUSTIFICATION FOR USING A ZERO DISCOUNT RATE ON BENEFITS.

2. Linked to this, what assumptions are you making about the build-up of benefits, particularly as with peatland there can be different stages, but generally a very long period for 'full' restoration?

WE HAVE ASSUMED LINEAR BENEFITS - AS THE BIGGEST GAIN IS THE AVOIDANCE OF CARBON LOSS WHICH IN MOST CASES CAN BE ASSUMED TO BE LINEAR. I KNOW CRICHTON WOULD LIKE TO REFINE THIS FURTHER.

DIFFERENT FUNCTIONAL FORMS FOR THE EMISSION TRAJECTORY WERE EXPLORED WITH COLLEAGUES AT THE JAMES HUTTON INSTITUTE, BUT A LINEAR APPROXIMATION WAS SHOWN TO REASONABLY ACCURATE (AND EASIER TO HANDLE) - BUT FUTURE REFINEMENTS MIGHT STILL BE POSSIBLE. REDUCTIONS IN EMISSION LOSSES CAN BE ACHIEVED PRETTY QUICKLY - ACTUAL NEW SEQUESTRATION TAKES MUCH LONGER.

3. It is helpful that you allow the user to put in their own figures. What would you say about the 'accuracy' of the guide costs? (I didn't see a reference to these in the project report)

THE GUIDE COSTS ARE BASED ON EVIDENCE GATHERED FROM PROJECTS ACROSS THE UK OVER THE PAST TEN YEARS OR SO. ALTHOUGH A DEGREE OF JUDGEMENT HAS HAD TO BE EXERCISED IN COMPILING THEM (E.G. REPORTING FORMATS ARE NOT CONSISTENT ACROSS PROJECTS), THEY HAVE BEEN TESTED AGAINST THE VIEWS OF SELECTED RESTORATION EXPERTS AND THE VIEWS OF PARTICIPANTS IN WORKSHOP TESTING OF THE FINANCIAL TOOL ITSELF. AS SUCH, WE ARE CONFIDENT THAT THAT ARE AN ACCURATE GUIDE TO TYPICAL COSTS - ALTHOUGH IT IS MADE CLEAR THAT LOCAL CIRCUMSTANCES DO NEED TO BE TAKEN INTO ACCOUNT AND COSTS MAY BE DIFFERENT IN SOME CASES (E.G. ACCESS BY ROAD OR HELICOPTER MAKES A HUGE DIFFERENCE TO THE COSTS OF MATERIALS).

4. You have 4 condition categories, with a very wide range of emissions; I see that these are based on some careful fieldwork and analysis. However, the emissions range is very wide and comments in the report highlight the variability and likely improvement over time ('wide ranges of emissions' p.15; need for 'age of the site since restoration as an additional factor…' p.17; 'extremely high variability of GHG flux measurements' p.17). This question should not detract from the view that this is a very high quality and valuable piece of work, but what would you say about confidence intervals we should put on the values for each condition category and the build-up over the restoration period (this links to points 1 and 2)?

THIS WP WAS COMPILED BY CRICHTON CARBON CENTRE.

OTHERS (E.G. CHRIS EVANS AT BANGOR, REBEKKA ARTZ AT JHI) HAVE CONTINUED TO WORK ON THIS (SOME RESULTS WERE SUMMARISED AT THE IUCN CONFERENCE AT SHREWSBURY IN

DECEMBER) AND WOULD BE BETTER PLACED THAN US TO COMMENT ON CONFIDENCE INTERVALS. HOWEVER, SOME ECONOMIC SENSITIVITY ANALYSIS WAS UNDERTAKEN IN AN EARLIER REPORT TO THE ASC OF THE CCC (SEE SECTION 2 OF HTTPS://WWW.THECCC.ORG.UK/WP-CONTENT/UPLOADS/2013/07/FINAL-REPORT-SRUC-ASC_-4-JULY_ASC-FINAL-9-JULY-2013_CLEAN.PDF [1]).

GAB reply
Thanks again for the information.
I do understand your wariness that discount rates can be manipulated to give the answer required and the danger of confusing users (but are you not dealing with businesses, many of which would be likely to have an appreciation of this?). However, I still have some concerns about the absence of discounting. I'm sure you will agree that whether to discount and the appropriate discount rate depend upon from whose perspective the appraisal is being made.

If it is the investing business, then, if they wish to know what the cost and net benefit would be in present terms, then discounting would be appropriate and their opportunity cost of capital would arguably be the appropriate rate (Ok, it can be difficult to estimate this beyond a few years ahead).

The argument about discounting or not (or alternative discounting formulae) is not one for business, but for society (and the government on their behalf). Although, after working alongside him for many years, I have some sympathy for the arguments put forward by Colin Price, the Treasury Green Book* gives the current perspective accepted by the government, which is to discount conventionally (albeit with stepped rates).
Cheers,
Geoff
* with a recent review which has included natural capital supporting the continued use of discounting

SP & A Moxey reply
Further to Andrew's last comment.
This isn't really a standard investment decision, or a model designed to analyse a project with that in mind.

Some observations from the UK domestic carbon market to date:
* For a business considering buying carbon credits then the expenditure is not treated as an investment in future benefit but current year spend for current year (or very short term) benefit. What I mean by this is that typically businesses will buy carbon credits annually, for that year's carbon footprint (or maybe a little into the future). In terms of UK peat or woodland projects it's highly likely that most or all of the actual carbon savings at the project site will be not be delivered until long into the future, but for the purposes of the business buying the credits the 'benefit' occurs today, on the planting of the woodland or the restoration of the peatland. I know this goes against carbon orthodoxy at its purest, but (a) as businesses are engaging in voluntary actions then we cannot be prescriptive (and we do not want to cause them to take no action at all, or to invest in less locally useful carbon projects elsewhere in the world), and (b) the credits are not being claimed against any current statutory obligations.
* For a landowner, to date, the motivation has (mostly) been to get a project implemented, and therefore the focus has been on the short term (up front capital to implement the woodland/peatland restoration, and no net loss of cash flow in the first few years). There are forestry carbon projects we have worked on where the landowner is a large investor planting a commercial forest and interested in IRR an NPV, and in those cases we use the appropriate tools and rates.
* The standard investment situation - someone invests some money in something that will only pay off over a long period with uncertain prices, demand and so on just does not apply. Roughly speaking, from the planting of the final tree at a woodland carbon project, for example, the credit buying business has its benefit in full (doing something about their carbon footprint for the current year), and the landowner has their benefit in full (the woodland is planted). For the standard investment model to apply here we would need something like the following: an investor spending lots of money now on a new woodland or peat restoration, with a view to selling the credits/benefits that arise in the future _only as they arise - _ie ex-post credits._ _This would satisfy the carbon purist. In that case, and in respect of woodland carbon for example, that investor would not have anything worth selling until year 25, and the bulk after year 35. Obviously there are some investors with that horizon, but there's a high degree of risk attached (will there even be a carbon market in 25 years, who on earth could predict prices with so little current data?). In any case the market as it currently configured works (new woodlands get created, benefiting business, landowner and society). Peat carbon will more readily lend itself to the standard model as there are annual benefits from year 1, but as there has only ever been one peat carbon transaction in the UK (as opposed to hundreds in UK woodland carbon) so again that would take an

investor with a high appetite for risk. (In fact we're about to do just that - privately invest in a peatland restoration - but with an expectation that we would sell the carbon ex-ante in the short term).
* You may wish to value the benefits to society of these new projects, and discount the fact that many of those benefits occur in the future, but that's not what this model was aimed at.

I'd be happy to talk this through with you on the 'phone. Also - it'd be good to hear a lttle more about your study.
Best,
Steve

GAB reply
Thanks both for explaining. This will help in my understanding of the situation/market for which you are providing the tool. This has helped me to see how this is not a standard investment decision for the carbon-credit buying business. However, I am still a bit puzzled about the use of the stream of costs and benefits in the spreadsheet. And what are the costs and benefits which the landowner will encounter?

My final comments were not intended to provide an argument for discounting in this context, but as a response to Andrew's point about the philosophical debate on discounting - it's easy to get carried away! (Andrew, thanks for that link)

I'm attaching a recent (informal) progress report on my project - I'd appreciate any comments you might have.
Kind regards,
Geoff

SP reply

The costs and revenues in the spreadsheet are those typically borne by the landowner (or their agent); they will incur the costs in implementing the project, and recover them in the form of the various potential revenues (one of which is the sale of carbon credits to a **business). The tool was designed with landowners and NGOs (eg RSPB) in mind, to help them figure out whether or not they had a project that was financially feasible, and that would qualify for additional** ecosystem services payments (e.g carbon).

A Moxey reply

Morning Geoff,Your summary looks pretty good.

The types of on-going costs likely to be incurred are described in the text of the accompanying main report and also in the SRUC report to the ACC of the CCC. However, as your quote from Glenk et al. stresses, there is a lot of uncertainty around the precise costs likely to apply at a specific site - hence the financial tool suggests "typical" values but allows users to substitute their own. In the SRUC report (see also the attached paper based on the report) we attempted to handle this uncertainty by sketching-out different combinations of different cost elements and inviting the restoration community to comment on the plausibility of different scenarios. Although we didn't get much feedback, nothing contradicted the range of values collated over the past six to seven years in my repeated attempts to help the IUCN estimate costs (see here for my latest commentary on opportunity costs http://www.iucn-uk-peatlandprogramme.org/sites/www.iucn-uk-peatlandprogramme.org/files/Andrew%20Moxey%20Assessing%20the%20opportunity%20costs%20of%20peatland%20restoration%20revised%20v2.pdf).

Part of the uncertainty stems from genuine variation in site conditions (i.e. the degree of degradation and ease of access) and from innovation (i.e. practical experience has moved us up the learning curve and some costs have fallen; the use of drones may lower monitoring costs in the near future) but also from inconsistencies in how costs are reported. For instance, separate types of cost are not always separated explicitly and the specification of the ha denominator can be awkward where (e.g.) the length but not density of grips is reported or where the area actively restored is different to the area reported as affected due to hydrological connectivity.

None of the above addresses the point about discounting in the financial tool, but to rephrase Steve's comments I think it is fair to say that we considered it but decided it was an unnecessary additional complexity given the frontloading nature of the transaction and the highly speculative nature of future carbon values on the voluntary market (and indeed of future commodity prices and subsidy support levels, even more so given Brexit!). I'm not aware that any workshop or project users of the tool have asked about discounting, but if somebody requested it then I guess that it could be added into a future version.

I've copied my SRUC co-author Klaus in since he has been working closely with SNH on their Peatland Action programme of restoration in Scotland and may have some other thoughts on costs and benefits.
Andrew

Email conversations: Anton Steurer, Eurostat January 2017

Anton Steurer, Head of unit , Eurostat E2 – Environment statistics and accounts; sustainable development
Tel. +352 4301 37339 http://ec.europa.eu/eurostat/web/environment/overview Anton.Steurer@ec.europa.eu

Eurostat-funded project - Grant agreement 05121.2015.001-2015.546

In response to my informal report for Phase 1:
Having looked at the material I think this is coming along well. The material is a bit too condensed for me to be able to comment much but just some remarks:

- Clearly for restoration costs we have to separate actual from potential. The actual are real and an expression of society for the values involved as is the case for any other actually realised project (such as building an airport or school). Potential costs need to be handled with care but the strict way it is put in Obst may go too far: in fact the real point is that the least cost option must be used to value in these cases and often restoration costs are not least cost (there is also a theoretical argument held against restoration costs by environmental ecologists but if you want to be coherent with national accounts the point is least costs and nothing else I think) . To the extent they are least cost (or are a reasonable proxy) they can be used for valuation, including of depreciation.
- I think in other contexts registers (or data bases) of valuation study results have been set up for use in benefits transfer studies where the costs or benefits in one place can be transferred to other places (or generalised to cover wider areas). Maybe these data bases do include also restoration costs data. There may well be some EU funded research that could help with some data they already found – not sure but you may start with looking for OPERAs, OpenNESS and ESMERALDA projects.
- Case study areas are a good idea.

Administratively, I consider the files you sent as informal communication and not part of any deliverable under the amended grant agreement. The material will therefore not be registered with the agreement. If that assumption is not correct, please do clarify in the form foreseen in the grant agreement.

I responded with some queries:
Thanks for your response. On your remarks:
1. I presume your first point stems from my Annex 2. This annex was taken from a theoretical piece which I produced to try to help in Defra's preparation of their forthcoming Principles paper (but does represent some of my thinking on the issue as part of this project). This then concerns the question of whether restoration costs should be used in the SEEA accounts, and I take your points.

- However, do you agree that there are a number of practical difficulties of inclusion of restoration costs - some of which I listed in the annex?
[AS:] yes but other methods have their own problems
- Further, you say, ' often restoration costs are not least cost'; but if, in a strong sustainability scenario, restoration is foreseen as worthwhile, then the costs are expected to be lower than the benefits, so would not restoration costs be the least-cost option?

[AS:] :)) under <u>those</u> assumptions yes. In reality you have one of two cases: The government has decided that restoration shall be undertaken - then there is no question any more. Or the system has been run down and there is no such decision – then you need to know what options there are and what the costs and benefits are.

- Could you spell out for me, or refer me to a suitable publication regarding the 'theoretical argument held against restoration costs by environmental ecologists'?

[AS:] Maybe Google can help. Basic idea is that restoration costs do not reflect individual preferences for the benefits so they have no justification.

The inclusion of restoration costs in mainstream SEEA accounts is, however, not the main concern of this study. Rather, the register will present estimates of, and identify spatially, the activities and costs (and time scales) of restoration of degraded areas, and also facilitate the construction of aggregate estimates.

[AS:] Not sure I see the distinction. If you want to make a data base that allows values to be put, and that allows aggregates to be made, you presumably think of publishing the results and you should be able to answer whether this value align with the values as expressed in national accounts (similar to the issue of the recreational values in the UK estimate) – maybe not immediately but the question will come.

I will look for further restoration cost data in the areas you suggest - thanks for the pointers. If you have any more suggestions I would welcome them.

I appreciate that the report does not constitute a deliverable, but thought it would be helpful in marking the move to Phase 2 of the project, to give you an update on progress and to elicit feedback. I envisage that the deliverables will be the detailed roadmap, a report on the pilot studies and a report on the project with a discussion of issues, including consideration of the accommodation of restoration costs within the SEEA framework. Is that your understanding?

[AS:] I did not check the grant agreement. What that says about deliverables, applies.

KIP-INCA Knowledge Innovation Project on Integrated System for Natural Capital and Ecosystem Services Accounting in the EU

Project developed by a partnership of European Commission services (DG ENV, DG JRC, DG ESTAT, DG RTD) and EEA • Objective to strengthen the knowledge base for the implementation of the 7th EAP • Knowledge Innovation Projects (KIPs) have the ambition to address gaps in environmental knowledge, using an innovative approach • Feasibility and design phase until mid-2016, then if "go ahead" implementation phase until 2020

ESMERELDA (Enhancing ecoSysteM sERvices mApping for poLicy and Decision mAking)

Mapping and assessment of ecosystems and their services (ES) are core to the EU Biodiversity (BD) Strategy. They are essential if we are to make informed decisions. Action 5 sets the requirement for an EU-wide knowledge base designed to be: a primary data source for developing Europe's green infrastructure; resource to identify areas for ecosystem restoration; and, a baseline against which the goal of 'no net loss of BD and ES' can be evaluated.

In response to these requirements, ESMERALDA aims to deliver a flexible methodology to provide the building blocks for pan-European and regional assessments. The work will ensure the timely delivery to EU member states in relation to Action 5 of the BD Strategy, supporting the needs of assessments in relation to the requirements for planning, agriculture, climate, water and nature policy. This methodology will build on existing ES projects and databases (e.g. MAES, OpenNESS, OPERAs, national studies), the Millennium Assessment (MA) and TEEB. ESMERALDA will identify relevant stakeholders and take stock of their requirements at EU, national and regional levels.

The objective of ESMERALDA is to share experience through an active process of dialogue and knowledge co-creation that will enable participants to achieve the Action 5 aims. The mapping approach proposed will integrate biophysical, social and economic assessment techniques.

OPERAs Operational Potential of Ecosystem Research Applications

OPERAs is a European research project that is helping to put cutting edge ecosystem science into practice. Composed of scientists, researchers and practitioners from 27 different organisations the project seeks to help stakeholders to apply the ecosystem services and natural capital concept into practice.

OpenNESS OPERATIONALISATION OF NATURAL CAPITAL AND ECOSYSTEM SERVICES

OpenNESS aims to translate the concepts of Natural Capital (NC) and Ecosystem Services (ES) into operational frameworks that provide tested, practical and tailored solutions for integrating ES into land, water and urban management and decision-making. It examines how the concepts link to, and support, wider EU economic, social and environmental policy initiatives and scrutinizes the potential and limitations of the concepts of ES and NC.

Mapping and Assessment of Ecosystems and their Services - MAES

The Biodiversity Strategy outlines a number of targets and precise actions to stop biodiversity loss. By mapping out and assessing the state of ecosystems and their services, we can help inform the policy decisions affecting the environment.

The Biodiversity Strategy called on Member States to map and assess the state of ecosystems and their services in their national territory by 2014, with the assistance of the European Commission. They must also assess the economic value of such services, and promote the integration of these values into accounting and reporting systems at EU and national level by 2020 (see Target 2, Action 5).

This specific action aims to provide a knowledge base on ecosystems and their services in Europe. It underpins the achievement of all 6 targets of the strategy and is also relevant to a number of other EU sectoral policies such as agriculture, maritime affairs and fisheries, and cohesion.

A coherent analytical framework has been developed (see first technical report 2013) to be applied by the EU and its Member States in order to ensure consistent approaches. It contributes to the ongoing discussion on the conceptual framework for sub-global assessments of ecosystems and ecosystem services under the Intergovernmental Platform on Biodiversity and Ecosystem services (IPBES). A second technical report (2014) proposes indicators that can be used at European and Member State's level to map and assess biodiversity, ecosystem condition and ecosystem services.

The third technical report (2016) is taking stock on Mapping and assessing the condition of Europe's ecosystems: Progress and challenges. The fourth technical report (2016) is on mapping and assessment of urban ecosystems and their services.

All Member States are actively involved in mapping and assessing the state of ecosystems and their services in their national territory. At EU level also, a lot of MAES-related activities are supported by the European Environment Agency and its Topic Centres, the Joint Research Centre, Eurostat, DG Research & Innovation.

Appendix D Detailed Asset and Risk Register

The diagrams below show a suggested structure of the asset and risk register for the UK. As Figure D.1 indicates, this would, in a sense, be in three dimensions: ecosystem/habitat on one axis, asset and ES characteristics in another, with a third providing details for different projects and areas, which would be aggregated to the whole.

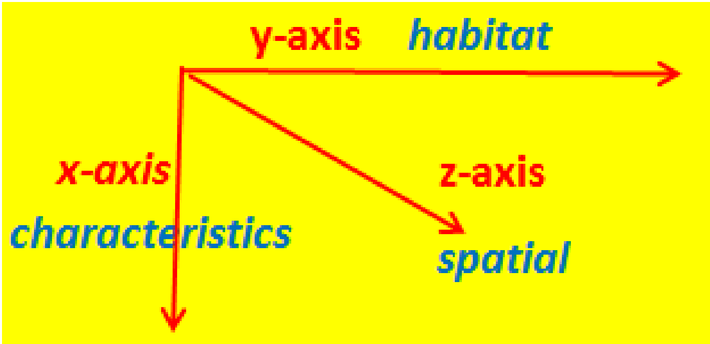


Fig. D. 1 Three dimensional format of register

The characteristics of the assets, ecosystem services and restoration activities and costs recorded by habitat as illustrated in figure 2. This can be recorded by areas within the habitat, allowing the information to be broken up by area – in terms of sub-habitat, catchment, area or project., as shown in Figure 3.

x-axis y-axis
characteristics habitat

	Urban	Enclosed farmland	semi-natural grassland	Woodlands	Freshwater (open waters, wetlands, floodplains)	Mountains, moorlands & heath	coastal margins	marine
Assets								
Extent								
Data sources on above (primary & secondary) (*incl coverage*)								
Condition (characteristics)								
Data sources on above (primary & secondary) (*incl coverage*)								
Capacity (see SEEA-EEA Technical Recommendations, 2015)								
Renewable/non-renewable								
Maintaining/ deteriorating (degradation)/Enhancing								
Services								
Provisioning								
Food								
Timber								
Fibres								
Energy								
Minerals								
Water								
Renewable energy								
Regulating								
GHG sequestration								
Air quality								
Flood protection								
Cultural								
Recreation								
Supporting								
Pollination								
Biodiversity								
Wildlife								

Degradation								
Nature of degradation								
Measures of degradation								
Data Sources (primary & secondary) (*incl coverage*)								
Valuation of degradation								
How value?								
Sustainable flow (how much lower or higher?)								
Restoration								
What might be restored/needs restoring?								
Publications citing specific restoration examples/results/data								
Priority areas for restoration (state area and source)								
Restoration method								
Physical inputs, impacts & time period over which restoration takes place								
cover opp. costs (but beware double counting)								
Restoration benefits								
(one year or several) and what delays?								
does anything change over time, and any delays?								
Restoration to what position – start of accounting period or earlier **reference** position?								
threshold (reached?) & safe limit								
Data sources (& coverage) on above (& discuss scaling feasibility)								
Priority/worthwhileness/practicality								
Possible/worth restoring?								
Data & research needs								

Fig. D.2 Register: habitat: characteristics dimensions

z-axis y-axis

spatial *habitat*

Roadmap (ONS, 2015) - habitats	Urban	Enclosed farmland	semi-natural grassland	Woodlands	Freshwater (open waters, wetlands, floodplains)	Mountains, moorlands & heath	coastal margins	marine
total UK								
Case study 1								
Case study 2								
Case study 3								
Case study 4								
Case study					peatland			
Case study								
Case study								
Case study								

Fig. D.3 Register: habitat: spatial dimensions

Notes and suggestions

The following lists notes and suggestions concerning the structure and detail of the register:

- Case studies may cover catchment, SSSI, national park, project, administrative area, country e.g. Wales), and one, some or all habitat categories. Or it might be for one habitat type for a region, county, country or UK.
- They may not cover the whole habitat category, but a sub-element, e.g. peatland, cereal-growing area, upland coniferous woodland.
- Case studies may overlap others (e.g. national park study cf study of all woodland or catchment).
- To improve accuracy/fine-tuning we should disaggregate results into different habitat categories (e.g. lowland cereals farming, cereals and roots, mixed farming, hill sheep, ...)
- Make results policy-oriented - amenable to producing figures overall and for specific projects or policies.
- Grossing up - Results might be grossed up (after and while looking at the effects of using data from different overlapping studies). For each line on the z-axis table, the total can be derived by taking the areas of each of the case studies, in each of the habitats and then assuming that the case study values apply to the total area of the habitat or sub-habitat represented by that case study. Thus, calculating a value per hectare for the habitat in that case study area and multiplying by the total area in the UK within that habitat type. If there is overlap between case studies then an 'average' should be applied, or the habitat be broken down into sub-categories and the case studies deemed to be representative of different sub-habitats. This needs to handled/evaluated carefully.
- What about non-representativeness of case studies? If hotspot or key area, then other areas likely to be of lower value or degraded. Note importance of breaking into habitat sub-categories - e.g. upland/lowland peat, or even further - Scottish upland peat/Welsh ..., peat <2000ft, >2000ft...
- How we view restoration depends on policy considerations - if we are bothered about an asset service (e.g. C-sequ.) we would want to consider all of the habitats which have these assets/produce these services.
- What is the policy about? - If it is environmental policy it will focus on the key environmental assets/services. The reason for focussing on one or several particular areas is that they have a particular concentration of those assets/services in which we are interested or could enhance those assets/services in which we are interested.
- Tasks: identification of data/information availability; spotting gaps; fill gaps by 1. extrapolation from elsewhere (UK or similar elsewhere), 2. modelling, 3. collecting new data.
- Types of restoration costs: costs of intervention - inputs/actions, limiting/halting current use,/benefits foregone (e.g. fencing off), normal costs (e.g. replanting - but can be replanting with something else), change of land use (opportunity cost), change of lifetime?
- NB length of time to restore and time horizon
- Fill in whole (extrapolate) from whatever limited data is available. As more detailed micro data becomes available, extrapolation can be more base don similar environments/habitats, features.

Appendix E Ecosystem asset valuation under degradation and restoration

Ecosystem assets will generally be valued in terms of the present value of the stream of expected net benefits generated by them. For each service within the basket of services, this will be built up from the stream of expected physical units for each year of the presumed life multiplied by the expected prices or exchange values (net of costs), subsequently discounted. (UN, 2012b; para 5.120)

The annual volume of services and hence the benefit stream will depend upon the capacity of the ecosystem which, in turn, will be a function of its extent and condition. However, other influences, both physical (such as natural disasters) and financial (changes in external demand or supply conditions affecting the price) may also affect the value of the ecosystem services. If such changes occur, these will affect the valuation, but their effects will need to be separated in the asset account.

If future volumes and prices are not expected to be the same as those for the current year, commensurate adjustments need to be made, as SEEA-EEA Technical Recommendations (2015;para.9.39) imply: '*the derivation of NPV requires describing the likely future flows of ecosystem services*.'

If the ecosystem extent and condition, and hence the capacity are maintained, then, other things being equal, the benefit stream will be constant, as will the NPV, and the asset will be maintained and hence be sustained. Consequently, *ceteris parib*us, the change in the value of the ecosystem asset between the start and end of the accounting period will be zero. If, however, the asset is not maintained, degradation will occur, and the discounted asset value will fall between the start (opening value) and end (closing value) of the accounting period.

Although measurement of degradation is normally assumed to be dealt with via the change in the asset value in terms of the change in the present value of net benefit flows, an alternative approach has been proposed. When estimating the depreciation charge for man-made capital accountants will take the estimate of the lower of replacement cost and net value:

'The guiding principle of accounting for material capital is that it should be valued at the lower of the cost of replacement and its economic value (defined as the present value of the [net] (sic.) benefits derived from the services of the material capital.' (Mayer, 2013, p.5)

In a natural capital context, Mayer translates this practice to the valuation of ecosystem assets, suggesting that, particularly in a situation of strong sustainability, if the costs of replacement are less than the net present value of the benefits arising from the restoration of degraded assets, then the former should be used as the 'depreciation' charge. Consequently: *'On the balance sheet there is an entry not of the value of the assets but their cost of replacement or restoration.'* (Mayer, 2013, p.6)

An example of the use of 'hypothetical' restoration costs instead of the change in the asset's NPV is modelled in Annex 2 to this appendix, and the findings contribute to the points below.

As Mayer, and Annex 2 suggest, using the cost of replacement or restoration is conceptually preferable in circumstances in which restoration is shown to be worthwhile, there are substantial practical difficulties in its implementation:

- With charging for the depreciation of fixed capital assets, such as machinery, given the market for such items, it is possible to discover the price of a machine of the same age and condition if it were to be replaced at the end of the accounting period. It is thence straightforward to calculate the loss of value over that accounting period. With ecosystem assets such replacement may not be feasible as the asset is tied to a specific spatial area. Furthermore, although it might be possible to identify sites elsewhere with similar characteristics (or produce a transfer value or modelling-based value based on other sites), this would be difficult because the market for such assets is limited and site-specific.
- Alternatively, the replacement cost could be viewed in the sense of the cost of restoring the elements of the asset in situ. However, the use of potential restoration costs is not seen as appropriate in ecosystem accounting:

.'*… from an accounting perspective restoration costs should not be considered an estimate of the value of degradation.'* (Obst *et al*, 2015)

'Generally, restoration cost approaches are not well accepted by the environmental economic community…. who prefer to see degradation valued as the change in the value of the associated benefits and income flows, In accounting terms

as well, recent work suggests that restoration costs are not equivalent to what is undertaken in estimating depreciation of fixed capital. '(SEEA-EEA Technical Recommendations 2015; para.9.49)
'There is a range of concerns about the restoration costs approach.' (SEEA-EEA; para.6.35)

The following list provides some of the concerns expressed about the use of potential restoration costs in national accounts:

- They are not seen as equivalent to depreciation:

The use of restoration costs to value degradation does not provide an accounting equivalent to the measurement of the depreciation of produced assets (Obst, *et al*., 2015)
and
There is clearly attraction in the measurement of restoration costs. Indeed there are some very useful applications of this information… However, they should not be used as a proxy for accounting measures of degradation, given the ecosystems accounting developments of recent years. (Obst, et al., 2015)

- They are not equivalent to the value/cost of the degradation. The path and costs of restoration are unlikely to follow those of degradation (hysteresis).
- Estimation of restoration costs avoids subjective evaluations of likely future benefits but, as Mayer (2013, p.7) concedes, but it does involve subjective estimation of future costs, and is complex.
- Restoration can rarely be achieved within the accounting period even though it is convenient to assume that it can. Using such staggered costs in the balance sheet and monetary flows account would add further complexity. Further, this would indicate that the asset could not be restored within one accounting period to return the level of services to their start-of-period level. How this would be dealt with in the accounts would vary, depending upon whether the valuation was to be based on restoration to the start of the period or to some earlier period. If the former, then, as degradation continued each year the restoration cost would refer to a deteriorating starting asset value.
- As Annex 2 shows, calculating the restoration costs would involve estimating the annual excess of restoration costs over maintenance costs as well as the annual shortfall of expected benefits relative to those arising if the asset continued in maintained condition. This is complicated, but calculating the opening and closing NPVs as if restoration were going to occur can give the same result.
- As the pilot studies in Chapters 4 and 5 exemplify, assets undergoing restoration may continue to produce disservices (such as GHG emissions), albeit at lower levels than without restoration. As disservices are excluded from ecosystem accounts, the asset valuations and changes in them, could give a misleading picture.

In the light of the foregoing, it can be argued that restoration costs should be used, even if hypothetical, and there is support for this from some quarters. However, the main ecosystem accounting publications have, and continue to maintain otherwise: as Obst *et al* (2015) above and UN (2017) suggest, use of accounts based on hypothetical restoration costs do provide valuable information, but are not seen as appropriate for use in valuing ecosystem assets. As Obst and Vardon (2014; p.135) maintain:
'From a policy perspective, an important distinction must be made between accounting for changes in the value of assets and decisions that are taken to maintain or restore those assets. It is most certainly meaningful to understand the outlays required to restore an ecosystem to an alternative and better condition. This is a distinct investment decision that should be evaluated based on information about costs and potential benefits, including economic, social, and environmental outcomes. However, it should not be implied that these costs represent depletion or degradation in accounting terms.'

As far as degradation is concerned, then, accounts constructed according to SEEA conventions will cover degradation in terms of reduced annual service flows and their valuations and the declining asset values based on expectations, taking account of the impact of degraded ecosystem condition and capacity. Potential restoration costs will not be included in asset valuations unless a restoration policy has begun to be implemented and some restoration costs have already been incurred. Yet, as Annex 2 shows, up to the point beyond which restoration is no longer feasible, values of degrading assets calculated in this way will tend to be lower, while changes in values will be greater, than if hypothetical restoration costs were used. Nevertheless, there would be consensus that accounts constructed using restoration costs can usefully be used alongside the ecosystem accounts; this is illustrated in the two pilot studies[81]

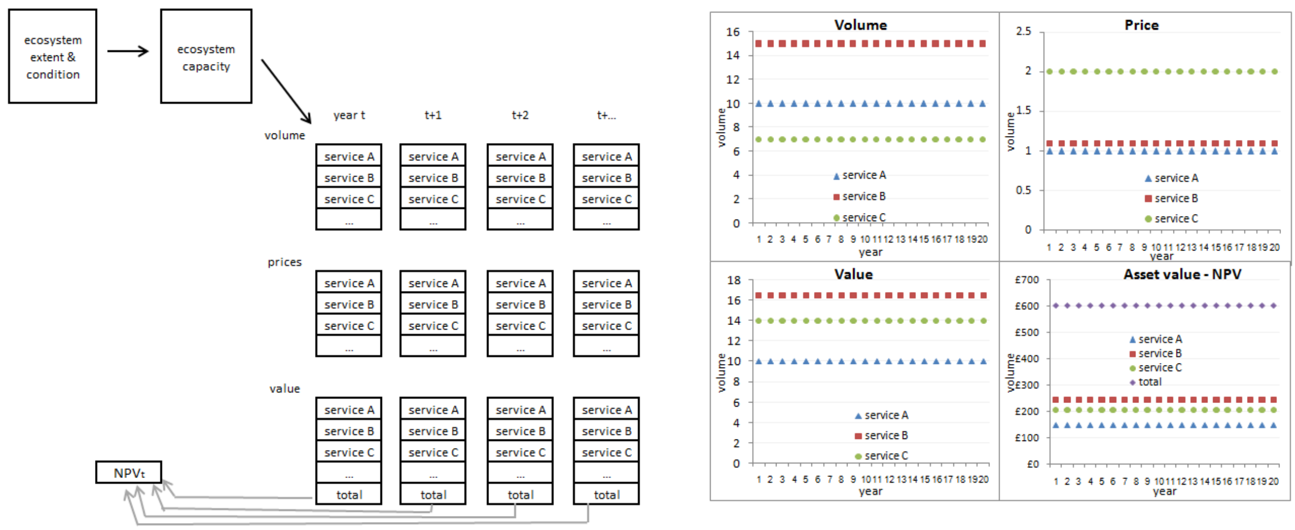
[81] Albeit, in reverse, in the sense that restoration is taking place, while accounts are also constructed on the basis of 'business as usual' – as if restoration had not occurred.

Annex 1 Modelling the effects on asset valuation of volume and price changes with multiple ecosystem services

To evaluate the change in ecosystem extent, condition and capacity and the consequent flow of services arising from them, it is helpful to compare the situation and expected flows at the start and end of the accounting period. Figure E.1 illustrates this approach, showing the evaluation at (a) time t and then at (b) time t+1.

In a scenario of expected stability and hence sustainability, the situations at t and t+1 should be the same. In this case, Mayer (2013) suggests that these do not need to be incorporated into national accounts as there is no change in asset value.

a)



b)

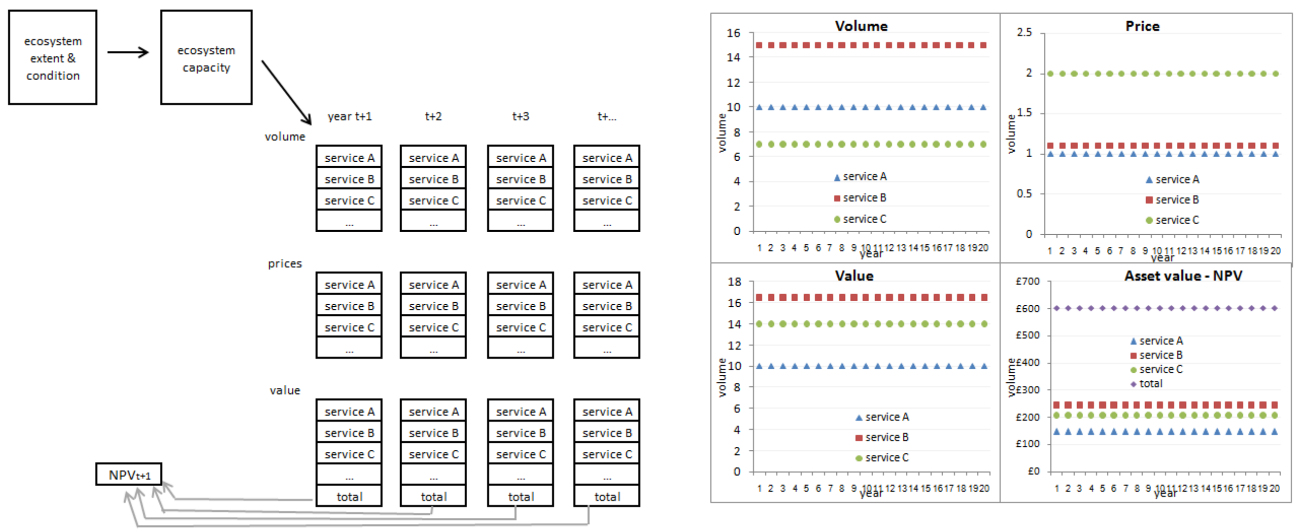


Fig. E.1 ‘No degradation’ scenario- a) at year t, and b) year t+1

If, however, services are removed in excess of recovery potential then, *ceteris paribus*, ecosystem condition and capacity will decline, leading to a fall in the expected stream of ecosystem services in the future, and a fall in the asset value (NPV) between one year and the next (here, between year t and year t+1). Figure 2 illustrates such degradation, variously defined as:

‘a real decline in an asset and its value from the declining quality of the asset’ (UN, 2003);
‘a decline in an ecosystem asset over an accounting period’ (UN, 2012b, para. 4.3.1);
‘the change in value of expected ecosystem service flows over an accounting period’ (UN, 2012b, para 6.33); and
‘a significant and sustained decrease in capacity to generate one or more eco services as a result of changes in eco condition.’ (Hein, *et al*., 2015)

In the first instance, evidence of ecosystem degradation should be exhibited by the declining condition and capacity of the ecosystem (UN, 2012b; Tables 4.3 & 4.4), as long as appropriate indicators are being measured. In terms of service flows, degradation would be evidenced, not only by a fall in physical volumes, but also by the decline in service and asset (NPV) values. Thus:

…ecosystem degradation would be measured as the decline in ecosystem capacity over an accounting period, or in other words, the decline in the ecosystem asset's ability to supply ecosystem services due to a decline in ecosystem condition. (UN, 2015; para 6.74)

In Figure E.2 the graphs show falling expected volumes and NPV's, signalling a decline in the asset value between the start and end of the accounting period.

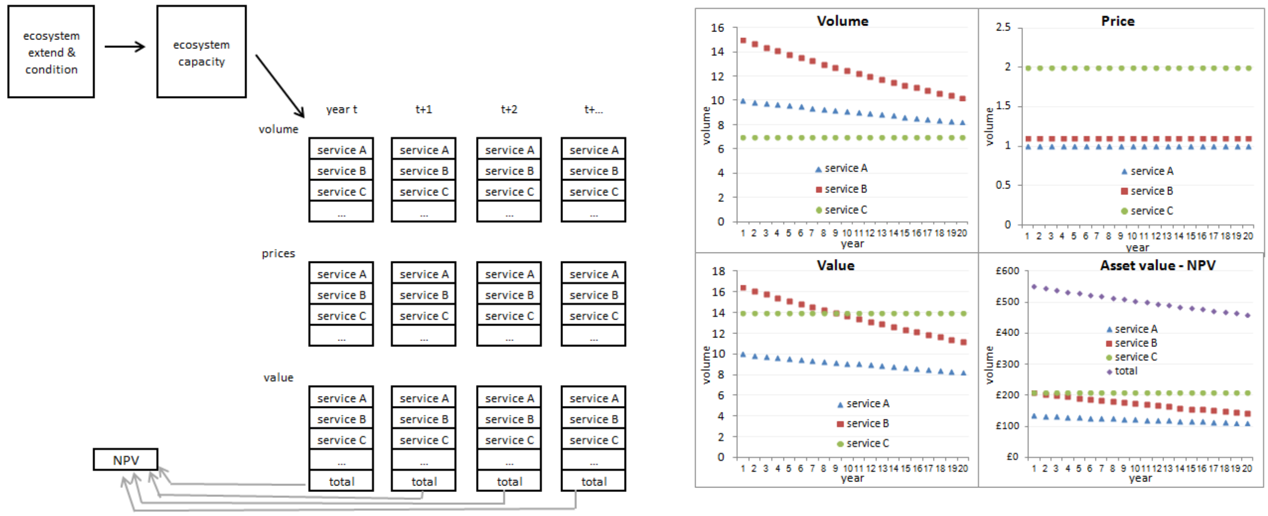


Fig. E.2 'degradation only' scenario

It is, however, only as a result of economic and human activity that degradation is deemed to occur. Therefore, if other changes were to occur, such as natural disasters or price change resulting from external shifts in demand and supply (as in Figure E.3 below), then these would obscure the degradation impact within service and asset values, although the impact, in this case, would still be shown in the ecosystem condition and capacity accounts as well as in the physical indicators of service volumes. The effects of the other changes would, however, have to be extricated from the asset valuation, thus:

The value of ecosystem degradation will be equal to the change in the net present value of an ecosystem asset, putting aside changes in value that are not due to economic and human activity. (UN, 2015; para. 9.47).

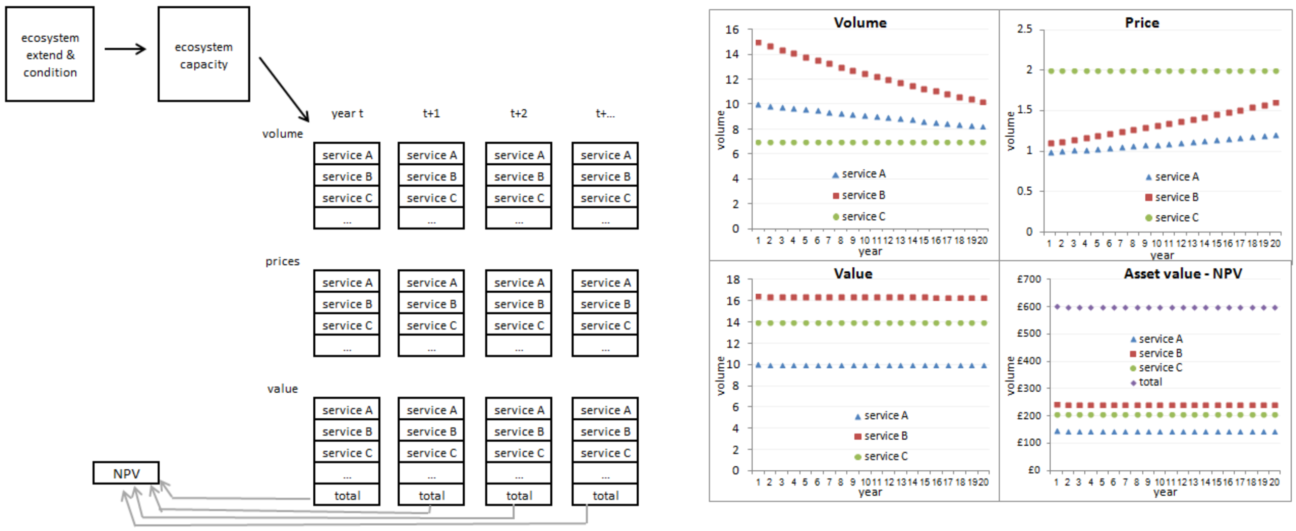


Fig. E.3 'degradation plus price change' scenario

Note that the value of the asset is derived from the several services that it provides. The ecosystem condition and capacity needs to be evaluated in regard to each of these. In the same vein, the annual volumes consumed of each of the services should be evaluated. However, although ecosystem services may often correlate positively, a scenario can be envisaged in which some services decline, while others increase. Figure E.4 illustrates this.

In this example, service C exhibits growth in annual volumes, while services A and B decline. Thus, the physical indicators of these services would reflect degradation and ecosystem condition and capability accounts would also do so if they contained appropriate indicators. However, the overall asset valuation (NPV) exhibits positive growth from one year to the next. Such an example illustrates that the characterisation of such an ecosystem is difficult – is it degrading? The definition of ecosystem degradation given above does not make this clear, nor does that on the measurement of degradation:
The most straightforward approach to measuring ecosystem degradation is as the change in value of expected ecosystem service flows over an accounting period. (UN, 2012b; para 6.33)

Thus, if the overall value of the asset does not decline, degradation may not be deemed to be occurring. Although examples such as that in Figure E.4 may not be common, this is feasible, and it does illustrate the importance of deriving appropriate values (prices) for each of the ecosystem services, since these determine the weight of each of the services within the basket provided by the ecosystem. If, however, one takes the Heins, *et al* .,(2015) perspective:
'Degradation involves changes in ecosystem condition due to human activity with a sustained and significant effect on the capacity to generate one or more ecosystem services.' (p.7),
then the scenario in Figure E.4 would be classified as illustrating a degraded ecosystem. Nevertheless, it is clear from this example that a tighter definition of ecosystem degradation is required.

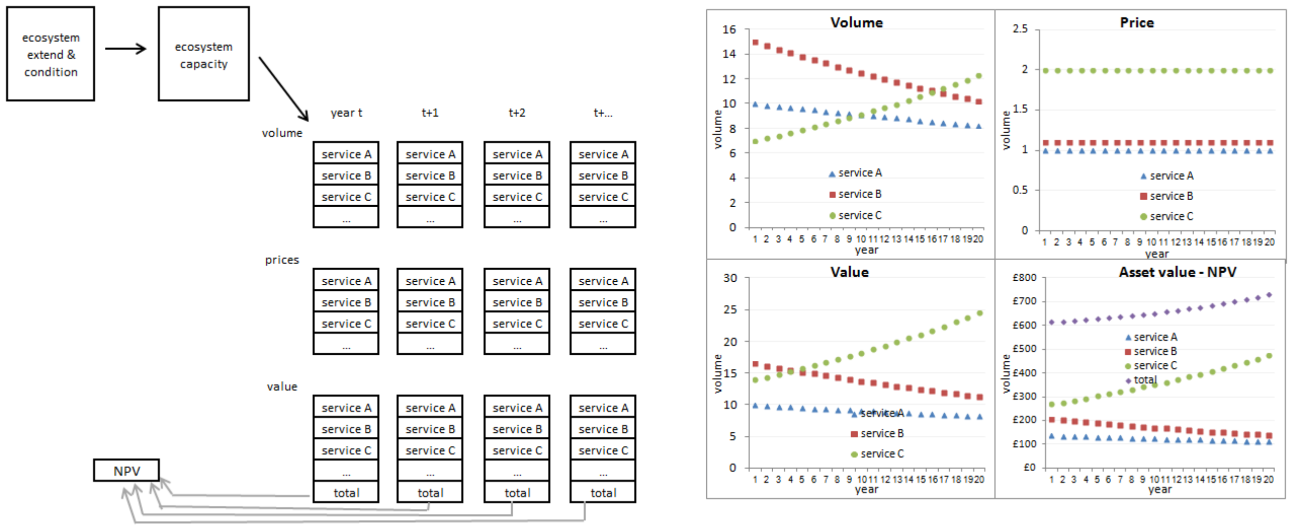


Fig. E.4 'partial degradation' scenario

One other problem when evaluating the effect of change between two accounting periods relates to the potential change in asset **extent** – some of the area might be lost (draining of bog for agricultural use, for instance), while there might be a gain elsewhere (blocking of drains to reclaim peatland). As a consequence, the difficulty in identifying degradation might be further complicated.[82] Nevertheless, if the indicator metrics either relate to disaggregated areas, or are expressed on a unit area basis, then this problem is eased. UN (2012b) paragraphs 4.3.2-4.3.4 and 6.3.3. touch on this.

Annex 2 Comparing the use of restoration costs instead of asset NPV change

As discussed above, it has been suggested (Mayer, 2013; Steurer, 2017) that the cost of restoring the ecosystem asset to its value at the start of the period should be used in place of the change in the NPV of the assets over the period when

[82] Also remember that a change in extent of one ecosystem will mean a countervailing change in the extent of another. So extent change will affect more than one ecosystem.

the former is lower than the latter. However, the SEEA-EEA and recent technical recommendations (UN, 2013;2017) recommend otherwise.

In order to assist the discussion, a simple example is presented. Assuming that initial annual ES amount to 100, an annual rate of degradation of ES of 5%, ES price of £0.3/unit, bau costs of £4, maintenance costs of £11 (at the 100 level of ES) and that, after a year of degradation it would take 2 years to restore the ES level (in a straight line), costing £14 a year. These assumptions would give rise to annual figures as shown in Table E.1.

Table E.1 Annual ES, benefits and costs for an ecosystem asset

year	1	2	3	4	5	6	7	8	9	10
Ecosystem services (ES)										
maintained level of ES	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
degrading ES	100.0	94.0	88.4	83.1	78.1	73.4	69.0	64.8	61.0	57.3
restored level of ES	100.0	94.0	97.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Benefits (£)										
maintained level of ES	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
degrading ES	30.0	28.2	26.5	24.9	23.4	22.0	20.7	19.5	18.3	17.2
restored level of ES	30.0	28.2	29.1	30.0	30.0	30.0	30.0	30.0	30.0	30.0
Costs (£)										
maintained level of ES	4.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0
degrading ES	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
restored level of ES	4.0	4.0	14.0	14.0	11.0	11.0	11.0	11.0	11.0	11.0

Based on these assumptions we obtain the financial ecosystem asset figures, for the end of year 1 and the end of year 2[83] shown in Table E.2. Three accounting approaches are taken – degradation is allowed to continue (bau) and the asset values exhibit the effects of this; restoration is assumed to take place, the one year's degradation taking two years to restore; and retaining the base asset value in the accounts for the opening and closing value, assuming maintenance of condition, even if this does not occur in practice, with the 'depreciation' figure based on the NPV of the expected net restoration costs calculated separately.

In the third example, the NPV of the discounted extra restoration costs relates not to the actual restoration costs but the excess of these costs over the maintenance costs; in Table E.1, for year 2, for example, this would be £11-£4, giving £7. Similarly, the discounted revenues shortfall takes the differences between the revenues until restoration is complete.

Table E.2 Ecosystem asset account (£)

scenarios	Degradation continuing (bau)	Restoration taking 2 years)	Asset value maintained
Opening asset value (NPV)	141	147	147
Closing asset value (NPV)	130	140	147
Change in asset value	**-10.3**	**-6.4**	**0.0**
Benefits for the year	28.2	28.2	28.2
Costs for the year	4.0	4.0	4.0
Ecosystem net financial flow	13.9	17.8	24.4
less discounted extra restoration costs	-	-	**-5.6**
Restoration-adjusted financial flow	-	-	18.6
Discounted revenues shortfall	-	-	**-0.9**
Restoration & benefit-adjusted financial flow	-	-	17.8

[83] It is assumed that cash flows occur just before the end of each period. Thus, the year 1 flows just before the end of year 1, and the asset valuations for year 1 refer to the end of that year.

The change in asset value is the common means by which the consumption of natural capital is calculated. This value is then used, with the net value of the flow of benefits and costs for the period, to determine the annual net financial flow. The key points to note are:

- The change in the asset value in the second, restoration, case (-£6.4) is not the same as the change in the discounted restoration cost (-£5.6). This is because the asset values also differ because benefits are reduced until restoration returns the asset, and thence ES, to the condition at the start. Consequently, the discounted restoration costs should not only take account of the difference between the maintenance and restoration costs, but also of the difference in revenues.
- Given that the change in asset value (and the above NPV of restoration costs adjusted for benefits) is lower for restoration than for bau (£6.4 cf £10.3) – which is the case when restoration is shown to be financially preferable to bau (allowing degradation to continue) (shown by the closing asset value) relative to bau, as is the case here – then, according to general accounting conventions, the former value should be used. Conversely, if restoration does not appear to be worthwhile, the change in asset value should be used.
- Because restoration to the level at the start of the period takes time, and in practice, often a considerable period of time, the use of this measure in place of change in asset value is complicated. This is exacerbated if this method is applied for more than one period with a degrading ecosystem asset, for on top of the restoration cost which has been applied for one year, further costs build up to take account of the further restoration. In this way, a substantial, and difficult to calculate liability is built up. However, as illustrated in Table E.2 (the third column of figures), the same value is arrived at by just estimating the closing NPV of the asset.
- It has been suggested that the use of the cost of restoration in the accounts should be the sum, rather than the discounted sum (Mayer, 2013). Thus, in the example above, rather than 6.4 (5.6+0.9, rounded) the figure would be 6.9 (6.0+0.9, rounded). Here, where the restoration only takes two years and the discounting period is ten years, the difference is small, but for long-term restoration and long discounting periods, the difference could be extremely large. Note also that the summed restoration cost would veer away from the figure derived from the discounted asset valuation (i.e. those in the second columnar set of figures in Table E.2).
- When a project involves ecosystem disservices, as in both pilot studies (Chapters 4 and 5), there would be further difficulties – would the NPV of the ecosystem asset be calculated with or without the disservices?
- The closing asset valuation is calculated as the opening valuation less the restoration (net, and with benefit effects). The opening valuation must, at some point, be calculated as the NPV of the asset if ES are maintained. Therefore, this method still relies on the NPV, albeit only at the start.

Appendix F Natural Capital & Environmental-Economic Accounts – Glossary of Terms

Abiotic services – ecosystem services don't include all environment flows – e.g. mineral & energy extraction and **space**. Often involve trade-offs between baskets of ecosystem and abiotic services (e.g. quarry *vs* ag. land)

Adjusted net saving (ANS) = **genuine saving** = national net saving adjusted for value of resource depletion and environmental degradation + education expenditure (proxy for human capital) (pp 18-19, *WB, The changing wealth of nations)(see Hartwick Rule below)*

Aichi targets - CBD meeting in Nagoya, Japan, in October 2010 - **Target 14** By 2020, **Ecosystems that provide essential services**. Ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable; **Target 15** – **Ecosystem restoration and resilience**. By 2020, ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15% of degrade ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification.
Assets – see **ecosystem assets, environmental asset**, and **natural capital assets**

BAT – best available technologies

Benefit transfer – using values from one location/context to another.

Biodiversity – the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part, this includes diversity within species, between species and ecosystems. (CBD in SEEA-EEA)

Biodiversity Action Plans (BAP) is an internationally-recognized program addressing threatened species and habitats and is designed to protect and restore biological systems. The original impetus for these plans derives from the 1992 Convention on Biological Diversity (CBD).

Basic spatial units (BSU) - smallest units for constructing aggregates.

Capability to generate eco services - the ability of the eco to generate provisioning services at a max sustainable level, irrespective of the implications for other eco services and irrespective of the implications for other eco services and irrespective of the potential legal, institutional, economic or other restrictions that constrain or prevent human uses of eco services. Bit different definitions for regulating and cultural services. (Hein, Edens, Bagstad, 2015, p.8)

Capital – Financial, Manufactured (man-produced fixed assets)**, Human, Social** (institutions, relationships, social networks, shared cultural beliefs,…), **Natural.**

Capital enhancement – 'improve' level of capital assets

CICES – Common International Classification for Ecosystem Services
Compensation *(p.146ff)* is what is paid for direct damage to natural capital from specific projects and developments.
Convention on Biological Diversity (CBD). Signed at Earth Summit, Rio in 1992 is a multilateral treaty. The Convention has three main goals: conservation of biological diversity; sustainable use of its components; and fair and equitable sharing of benefits arising from genetic resources. In other words, its objective is to develop national strategies for the conservation and sustainable use of biological diversity. It is often seen as the key document regarding sustainable development.

CORINE Land Cover (CLC) (**C**o-**or**dination of **In**formation on the **E**nvironment) is a geographic land cover/land use database encompassing most of the countries of the European Community (**C**o-**or**dination of **In**formation on the **E**nvironment)

CLC describes land cover (and partly land use) according to a nomenclature of 44 classes organised hierarchically in three levels (table 1). The first level (5 classes) corresponds to the main categories of the land cover/land use (artificial areas, agricultural land, forests and semi-natural areas, wetlands, water surfaces). The second level (15 classes) covers physical and physiognomic entities at a higher level of detail (urban zones, forests, lakes, etc), finally level 3 is composed of 44 classes.
CLC was elaborated based on the visual interpretation of satellite images (SPOT, LANDSAT TM and MSS). Ancillary data (aerial photographs, topographic or vegetation maps, statistics, local knowledge) were used to refine interpretation and the assignment of the territory into the categories of the CORINE Land Cover nomenclature.
The smallest surfaces mapped (mapping units) correspond to 25 hectares. Linear features less than 100 m in width are not considered. The scale of the output product was fixed at 1:100.000. Thus, the location precision of the CLC database is 100 m

Table F.1 CORINE Land Cover classification

Level 1	Level 2	Level 3
1. Artificial surfaces	1.1 Urban fabric	1.1.1 Continuous urban fabric
		1.1.2 Discontinuous urban fabric
	1.2 Industrial, commercial and transport units	1.2.1 Industrial or commercial units
		1.2.2 Road and rail networks and associated land
		1.2.3 Port areas
		1.2.4 Airports
	1.3 Mine, dump and construction sites	1.3.1 Mineral extraction sites
		1.3.2 Dump sites
		1.3.3 Construction sites
	1.4 Artificial, non-agricultural vegetated areas	1.4.1 Green urban areas
		1.4.2 Sport and leisure facilities
2. Agricultural areas	2.1 Arable land	2.1.1 Non-irrigated arable land
		2.1.2 Permanently irrigated land
		2.1.3 Rice fields
	2.2 Permanent crops	2.2.1 Vineyards
		2.2.2 Fruit trees and berry plantations
		2.2.3 Olive groves
	2.3 Pastures	2.3.1 Pastures
	2.4 Heterogeneous agricultural areas	2.4.1 Annual crops associated with permanent crops
		2.4.2 Complex cultivation patterns
		2.4.3 Land principally occupied by agriculture with significant areas of natural vegetation
		2.4.4 Agro-forestry areas
3. Forests and semi-natural areas	3.1 Forests	3.1.1 Broad-leaved forest
		3.1.2 Coniferous forest
		3.1.3 Mixed forest
	3.2 Shrub and/or herbaceous vegetation associations	3.2.1 Natural grassland
		3.2.2 Moors and heathland
		3.2.3 Sclerophyllous vegetation
		3.2.4 Transitional woodland scrub
	3.3 Open spaces with little or no vegetation	3.3.1 Beaches, dunes, sand plains
		3.3.2 Bare rock
		3.3.3 Sparsely vegetated areas
		3.3.4 Burnt areas
		3.3.5 Glaciers and perpetual snow
4. Wetlands	4.1 Inland wetlands	4.1.1 Inland marshes
		4.1.2 Peat bogs
	4.2 Coastal wetlands	4.2.1 Salt marshes
		4.2.2 Salines
		4.2.3 Intertidal flats
5. Water bodies	5.1 Continental waters	5.1.1 Water courses
		5.1.2 Water bodies
	5.2 Marine waters	5.2.1 Coastal lagoons
		5.2.2 Estuaries
		5.2.3 Sea and ocean

Counterfactual – what would have happened anyway (=baseline = WITHOUT). If this had not happened, or if that had happened, what would have been the result?

Damage – acute and obvious changes in an ecosystem *(SER, 2014*) [doesn't say if negative or positive changes!]

Degradation – real decline in asset and value from declining quality of asset. If occurs one period and not rectified so carried over to next – this accumulation = **environmental debt** (SEEA, 2003). Should debt be cleared over 1 or >1 yr?
Subtle or gradual changes that reduce ecological integrity and health *(SER, 2014).* Reflects the decline in the capacity of the ecosystem asset to provide services due to changes in its condition.(in Obst et al, 2015)
sustained, significant decline in eco condition affecting supply of eco services – time frame of several years or more. (so if recovers from disturbances within few years not = degradation. (p.7) Heins, Eden & Bagstad
a significant and sustained decrease in capacity to generate one or more eco services as a result of changes in eco condition. (Hein, Obst et al, 2015)

Degraded – the simplification or disruption of ecosystems and the loss of biodiversity, caused by disturbances that are too frequent or severe to allow natural ecosystem recovery in a relevant or 'reasonable' period of time. Generally reduces flows of ecosystem goods and services. *(IUCN, 2012).*

Defensive expenditure – monetary value on environmental damage which is prevented or rectified (SEEA, 2003)

Depletion (monetary) – value of resource stock falls due to its use in productive activity. Change in the value of an environmental asset due to extraction in excess of regeneration. Reduces an asset's ability to produce an income stream into the future. Equals change in asset value between start and end of year due to physical extraction.
Measured within broader concept of ecosystem degradation – not only using up of resources but also declines in capacity of ecosystems to generate other ecosystem services (e.g. air filtration). SEEA-EEA
(physical) decrease in the quantity of the stock of a natural resource over an accounting period that is due to the extraction of the natural resource by economic units occurring at a level greater than that of the regeneration (SEEA-CF, p.7)

Depletion-adjusted resource rent = net return to environmental assets. 'The measurement of resource rent provides a gross measure of the return to environmental assets. As for produced assets, it is relevant to consider the derivation of a net measure of the return by deducting depletion from resource rent, i.e depletion-adjusted resource rent. For produced assets, the equivalent deduction is for depreciation. This measure corresponds, in economic terms, to a net return to capital or net return to environmental assets. '(SEEA-CF 5.116)

Ecosystems – areas containing a dynamic complex of biotic communities and their non-living environment interacting as a functional unit to provide environmental structures, processes and functions. A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit. (CBD, 2003) Ecosystems have functions (e.g. nutrient recycling) but don't' provide benefits directly to humans, rather the ecosystem services arise at the point at which humans make use of them. (see **habitats**)
The UK NEA has defined ecosystems based upon recognised 'Broad Habitats' within the UK (Jackson 2000). In the UK and much of Europe, the classification of ecosystems can be considered as significantly overlapping with that of **habitats**. A definition of a habitat is an ecological or environmental area that is inhabited by a particular animal or plant species. UKNEA Chapter 2

Ecosystem Accounting an integrated approach to measure and monitor ecosystems , and the flow of services from ecosystems and economic and other activity in a way that is aligned with the SNA (Hein, Obst, et al, 2015)

Ecosystem Accounting Unit (EAU)

Ecosystem Assessment – UK National Ecosystem Assessment (UK NEA) was the first analysis of the UK's natural environment in terms of the benefits it provides to society and continuing economic prosperity. Part of the Living With Environmental Change (LWEC) initiative, the UK NEA commenced in mid-2009 and reported in June 2011, involving many government, academic, NGO and private sector institutions.

Ecosystem assets – spatial areas containing a combination of biotic and abiotic components and other characteristics that function together. (SEEA-EEA). Measured by **condition** and **extent**. Also, **capacity** (SEEA-EEA-Technical Recommendations, 2015, p.71)

Ecosystem capacity – ability of the eco to generate an eco service under current eco conditions and uses at the max level that does not lead to degradation of eco condition. (Hein, Obst et al, 2015); ability of the eco to generate an eco service under current eco conditions and uses at the max yield or use level that does not negatively affect the future supply of the same or other eco services (Obst in Tech Rec).

Ecosystem condition – overall quality of the eco, as expressed through a set of indicators expressing eco composition and/or functioning (e.g. species diversity or net primary production) . (Hein, Obst et al, 2015) Eco condition account only physical indicators (Hein, Obst et al, 2015)

Ecosystem degradation
Declining trend in value of expected service flows due to decline in ecosystem condition and capacity/ reduction in ecosystem capacity to and production of eco services.
Decline in an ecosystem asset over an accounting period (SEEA-EEA).

Change in present value (PV) not necessarily a sign of degradation/enhancement – may be due to change in demand or management access to encourage recovery of stock. But -ve **ΔPV** does, otherwise, show degradation.
Note time effects – lags
Costs need to be incurred to prevent damage OR rectify harm. Estimate effect on price of internalising costs of residuals OR measure residuals' damage (=negative benefit).
Value reductions in <u>sink</u> and <u>service</u> functions provided by the environment (SEEA, 2003). Often combine degree of emissions & costs/unit of amelioration – diminishing returns.
Cost-based valuation - avoid (refrain, substitute less damaging), capture emissions/make less harmful, restore – clean up.
Damage-based valuation – assess damage (dose-response; often re. health), then value – use prices or may use other wtp.
Valuing ecosystem degradation - two schools: Ideal is decline in value of eco system re loss of future services – so measure with prices and quantities for basket of services OR cost to **restor**e the condition (quality) at start. Restoration cost approach criticisms - need to assume asset owner wants restoration & doesn't reflect expected future uses of the ecosystem on which assessments of degradation are based. (Obst and Vardon, 2014, p.134; Obst *et al*, 2015)
Degradation cost (charge?) of assets – compare value at start less cost to replace as it stands at end. (Obst and Vardon, 2014, p.134) (but no expectation that owner will replace/pay this - so decline in value does not create a liability & if it doesn't reduce future services then need not charge).
Ecosystem service degradation: For *provisioning services,* decreased production of the service through changes in area over which the services is provided, or decreased production per unit area. For *regulating* and *supporting services,* a reduction in the benefits obtained from the service, either through a change in the service or through human pressures on the service exceeding its limits. For *cultural services,* a change in the ecosystem features that decreases the cultural benefits provided by the ecosystem. NEA – UNEP-WCMC

Ecosystem enhancement the increase or improvement in ecosystem asset due to economic and other human activity. From activities to restore or remediate an ecosystem asset. Systems have potential to regenerate (**thresholds**, **irreversibilities** & varying time horizons).

Ecosystem services – contributions of ecosystems to benefits used in economic and other human activity (SEEA-EEA). OR the direct or indirect contributions that ecosystems make to the well-being of human populations (both intermediate and final services. (*Barbier, 2012)*
Provisioning (products that can be harvested or extracted – crops, trees, fish, water supplies) – **regulating** (regulation of biological, hydrological and climate processes – climate, disease, hazard & noise regulation pollination, waste, air & soil detox and purification)– **cultural** services (non-material benefits of ecosystems – wild species diversity, , env spaces – aesthetic/inspiration, recreation/tourism, spiritual/religious). Also, **supporting services** (e.g. formation of soils).
'Many ecosystem services are location-specific – spatially-disaggregated accounts are likely to be far more policy-relevant and capable of identifying change. Hence, ideally nat. accounts should be built upon spatially-disaggregated data about local services. But … very data-intensive – most of this data has to be generated from modelling and remote sensing.' *(Harris, 2015, Introduction to Natural Capital Accounting in the UK)*

Table F.2 Ecosystem Service Categories

Section	Division	Group
Provisioning	Nutrition	Biomass
		Water
	Materials	Biomass, fibre
		Water
	Energy	Biomass-based energy sources
		Mechanical energy
Regulation &	Mediation of waste, toxics and other nuisances	Mediation by biota
		Mediation by ecosystems
	Mediation of flows	Mass flows
		Liquid flows
		Gaseous / air flows
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection
		Pest and disease control
		Soil formation and composition
		Water conditions
		Atmospheric composition and climate regulation
Cultural	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions
		Intellectual and representative interactions
	Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Spiritual and/or emblematic
		Other cultural outputs

CICES by Eur Env Agency
Note: Regulation = Regulation & maintenance

Ecosystem units (EU) - explicit accounting unit for ecosystem assets (UNEP-WCMC, 2015 – biodiversity accounts). Ecosystem Units - area representing a different type of ecosystem (based on land cover classes – artificial area, herb. Crops, woody crops, multiple/layered crops, grassland, tree-covered, shrub-covered, ,…. From CF T5.12) SEEA-EEA Tech Rec. 3.2.1

Environment – stock-wise = all living and non-living components that comprise the bio-physical environment, including all types of natural resource and the ecosystems within which they are located.
Flow-wise = source of all natural inputs to the economy – including natural resource inputs (minerals, timber, fish, water) and other natural inputs absorbed by the economy (solar and wind, air for combustion)

Environmental assets – the naturally-occurring living and non-living components of the Earth together constituting the bio-physical environment, which may provide benefits to humanity. (SEEA-CF, 2.17)

Environmental functions - **resource** functions (env materials used to produce g&s); **sink** functions (residuals emitted to env media [air, land, water] for assimilation (affect quality); **service** functions (**surviva**l functions, **amenity** functions).

Externalities – consequences for welfare of opportunity costs not fully accounted for in the price and market system (Bannock *et al*, 1988) - those who bear the cost not necessarily those who benefit. Lead to overexploitation (so social costs higher than private benefits). Can be positive externalities (e.g. carbon sequestration) – social benefits>private benefits). The unaccounted for consequences for others of actions taken by one or more persons. (Dasgupta, 2016)

Fens – peatlands which receive water and nutrients from groundwater and surface runoff & rainfall. (JNCC, 2006)

Flows – within economy = product flows; from environment to economy = natural inputs; from economy to environment = **residuals**

Grips - lines cut through moorland for drainage purposes (peatland) (JNCC, 2006). Drains – terms used I the north of England.

Habitat is an ecological or environmental area that is inhabited by a particular animal or plant species. (UK-NEA http://uknea.unep-wcmc.org). 'whilst the classification and management of habitats is centred on the populations of species of interest, the concept of an ecosystem is centred on the interactions between its components and its properties as a system.'
'The ecological or environmental area that is inhabited by a particular animal or plant species.' (UKNEA, Chapter 2)

Hartwick rule – simple rule of thumb for sustainable development for countries that depend for sustainable development on non-renewable natural resources: consumption can be maintained (i.e. sust. dev.) if rents from non-renewable resources are continuously invested rather than used for consumption. Can compare what capital would have been if invested since 1980 to actual produced capital. *(Hartwick, 1977 quoted in WB, the changing wealth of nations, p.9)*
Hotelling's rule – states that under certain market conditions, non-renewable resource rents will rise at the rate of the nominal discount rate as the resource becomes scarce. Under these circumstances, the value of the resource stock can be calculated simply as the unit resource rent times the size of the stock.(SEEA-CF, A5.17) [**not** Hotelling's **law**]

Hysteresis – rate or path to recovery differs from the path to degradation. A system displaying hysteresis exhibits a response to the increase of a driving variable which is not precisely reversed as the driving variable is decreased (ref lost). the path from state A to B (degradation) is different from the path from B to A (recovery) (Ocean Tipping Points, 2017).

IPENS – Improvement Programme for England's Natura 2000 sites.

Land cover – the observed physical and biological cover of the Earth's surface sand includes natural vegetation and abiotic (non-living) surfaces. (SEEA-CF). Classes: urban & associated developed areas, medium-large fields rainfed herbaceous cropland, medium-large fields irrigated herbaceous cropland, permanent crops/agriculture plantations, agriculture associations and mosaics, pastures and natural grassland, forest tree cover, shrubland/bushland/heathland, sparsely vegetated areas, natural vegetation associations & mosaics, barren land, permanent snow & glaciers, open wetlands, inland water bodies, coastal water bodies, sea. (SEEA-EEA)

LCEU – land cover/ecosystem functional unit. Based on ecosystem characteristics – land cover type, water resources, climate, altitude, soil type, ...

McKelvey diagram for coal or gas reserves

MENE – Monitoring Engagement with the Natural Environment by Natural England survey

Natura 2000 –Europe-wide most valuable and threatened species and habitats protected as part of >27k nature conservation areas. + Natura 2000 network. **Special Protection Areas (SPA)** & **Special Areas of Conservation (SAC)**. England 338 sites, 2.1m ha. If land or coast = SSSIs (=82% of SSSI area). **IPENS** – Improvement Programme for England's Natura 2000 sites.

Natural Capital – the elements of nature that directly or indirectly produce value to people, including ecosystems, species, fresh water, land, minerals, the air and oceans, as well as natural processes and functions. (NCC, 2014)
refers to the elements of nature that produce value or benefits to people (directly or indirectly), such as the stock of forests, mines, land, minerals and oceans, as well as the natural processes and functions that underpin their operation (NCC, April 13) = ecosystems, species, freshwater, land, minerals, air and oceans and natural processes and functions = natural – unproduced
Renewable (living species and ecosystems), **Non-renewable** (subsoil assets), **Replenishable** (atmosphere, potable water, fertile soils), **Cultivated** (crops, forest plantations)

Natural capital assets -

Natural inputs = all physical inputs that are moved from their location in the env as a part of an economic production process or are directly used in production (SEEA-CF)

Output – in national accounts – mainly …the value of g&s produced in order to be sold to other agents. Output at current prices is measured as sales+ change (+ or -) in inventories of finished products or work in progress (exclude holding gains)' OR those g&s that are produced within an establishment that become available for use outside that establishment, plus any g&s produced for own final use. [Lequiller & Blades]
Sales of extracted environmental assets at basic prices, includes all subsidies on products, excludes taxes on products. (within Resource Rent, para5.116, SEEA-CF)

PAWS – protection? of ancient woodland sites (Forestry Commission)

Planners' mitigation hierarchy – avoid, reduce, moderate & minimise, relocate, restore, offset.

Precautionary principle = "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. In this context the proponent of an activity, rather than the public, should bear the burden of proof. The process of applying the precautionary principle must be open, informed and democratic and must include potentially affected parties. It must also involve an examination of the full range of alternatives, including no action." - Wingspread Statement on the Precautionary Principle, Jan. 1998

Property rights = entitlements to exclusive use (excludable and rival) (able to prevent others from harming the assets and rivalry – my use precludes yours) = **private good** (theoretically – no externalities, rivalry – but many goods. services are public in an economic sense. Much renewable natural capital has bits of public goods and pollution externalities. (p.141)
Pollution taxes (and subsidies) change the prices in the market and hence the choices and incentives of companies and consumers. (p.160) – changing the price to internalise the externality. (p.164)
Public goods are not provided naturally by the market as non-excludable and non-rival.

Ramsey formula = time preference rate + growth of consumption x el of marginal utility + catastrophic risk rate

HMT Green Book SDR =	0.5%	+	2% x 1.0	+	1% = 3.5%
Stern Review (06) =	0.1%	+	1.3% x 1.0		= 1.4%
WB (06, 11) =	1.5%	+	2.5% x1.0		= 4.0%

Renewables – above the threshold – return in perpetuity at zero cost. **Non-renewables** – intergenerational – spread over all future generations – (Refs to Ch9, p.256)

Replacement cost = what it would cost to replace the value at the beginning less the value now.

Resilience (ecological) – the ability of disturbed systems to recover to their former state (NCC, 2014)

Residual = flows of liquid, solid and gaseous materials, and energy, that are discarded, discharged or emitted by establishments and households through processes of production, consumption or accumulation (p.25 SEEA-CF)

Resource Rent (annual)= Gross Output – Intermediate consumption – compensation of employees – consumption of fixed capital (produced assets) (so far = GOS), then – return to owner of produced assets = RR (note RR= return to owners of non-produced assets + resource depletion). Can calculate a **residual value**, **appropriation** (actual payments for), **access price** method. Brouwer *et al* (2009) call them **residual imputation** or **net rents.** 'The measurement of resource rent provides a gross measure of the return to environmental assets.
As for produced assets, it is relevant to consider the derivation of a net measure of the return by deducting depletion from resource rent, i.e **depletion-adjusted resource rent**. For produced assets, the equivalent deduction is for depreciation. This measure corresponds, in economic terms, to a net return to capital or net return to environmental assets. '(SEEA-CF 5.116)

'The measurement of resource rent provides a gross measure of the return to environmental assets. As for produced assets, it is relevant to consider the derivation of a net measure of the return by deducting depletion from resource rent, i.e depletion-adjusted resource rent. For produced assets, the equivalent deduction is for depreciation. This measure corresponds, in economic terms, to a net return to capital or net return to environmental assets. '(SEEA-CF 5.116). So RR=gross return to environmental assets= depletion +net return to environmental assets.

Restoration charge – capital maintenance charge

Restoration (maintenance) cost – return to condition at start of a/c period (to reference or target condition)
Damage based (activity-based allocation) or cost-based (avoidance costs) (receiver-based allocation). Note – time impact – benefits received/degradation occurred early, degradation costs felt later. Expenditure required to restore ecosystem to condition at beginning of accounting period (or to point pre-human intervention or 30 years ago, at least). Accumulated unpaid restoration cost=liability=ecological debt (but beware of double counting if Δ asset value shows this too.

Restoration - 'The process of actively managing the recovery of an ecosystem service that has been degraded, damaged or destroyed as a means of sustaining ecosystem resilience and conserving biodiversity' (CBD, 2011) (not v good definition?!). **Ecosystem restoration** – the return of an ecosystem to its original community, structure, natural complement of species and natural functions' (EU in Dickie, p.3)(CBD, 2011) 'the process of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed (*SER, 2002*). 'Any activity that integrates investment in and replenishment of natural capital stocks to improve the flows of ecosystem goods and services, while enhancing all aspects of human well-being'. not a great one! (p.5 Restoring Nat. Cap.[Aronson, J. et al.]- Chapter 1- restoring nat. cap.: definitions and rationale). 'Nat cap restoration activities include – 1. restoration & rehab of terrestrial and aquatic ecosystems 2. Ecologically sound improvements to arable and other lands that are managed for useful purposes 3. Improvements in the ecologically-sustainable utilisation of biological resources, and 4.establishment or enhancement of socio-economic activities and behaviour that incorporate knowledge awareness conservation and management of natural capital into daily activities.' (ugh!) *p.5* European Commission Biodiversity Strategy Impact Assessment: Ecosystem restoration: "The return of an ecosystem to its original community structure, natural complement of species, and natural functions". (Arcadis, 2014)

Restoring Natural Capital – **restoration** (an option when natural assets lost or severely impacted); **recovery** (restoring certain benefits, but if can't/not cost-effective to restore to natural state); **replacement** (use of another, built, capital) (NCC, 2014) (Aronson et al – see above p.5 talk about **restoration**, **rehabilitation** and **reallocation**)

Risk register a central repository for all risks identified by the project or organisation and, for each risk, includes information such as risk probability, impact, counter-measures, risk owner, etc. The risk register lists major risks to benefits from natural capital though the lens of the major land use types.
Risk no., risk description/event, responsible, impact (H/M/L), impact description, probability (H/M/L). timeline, status if response, completed action, planned future actions, risk status (open/closed/moved to issue) (NCC, 'the need for a long-term investment programme in NC?' 'Valuing our life support systems; Natural Capital Initiative, London, 7/11/14).

Rural Development Programme for England (RDP) – an EU funding instrument providing money to improve agriculture, the environment and rural life.

Soil - any material within 2m if the Earth's surface that is in contact with the atmosphere, excluding living organisms, areas with continuous ice not covered by other material, and water bodies deeper than 2m. World Soil Resources Reports FAO 2015

Special Areas of Conservation (SAC) – see Natura 2000 above.

Special Protection Areas (SPA) – see Natura 2000 above.

Sustainable Catchment Management Project (SCaMP) between United Utilities and RSPB.

System of Environmental-Economic Accounting (SEEA) – **Central Framework** (CF) – adopted as international standard by UN Stats Commission in 2012
- joint initiative EC, UN, FAO, IMF, WB, OECD
- is a multipurpose conceptual framework for understanding the interactions between the economy and the environment, and for describing stocks and changes in stocks of environmental assets.

From World Commission on Environment and Development (1987 – Brundtland Commission – *'Our Common Future*') and Agenda 21 document from 1st UN Conference on Environment and Development in Rio ('*Earth Summit'*)1992
1993 Handbook of National Accounting: Integrated Environmental and Economic Accounting (issued as a work in progress)- 'SEEA'.
1994 London Group on Environmental Accounting (under UNSC)
2003 Handbook of National Accounting: Integrated Environmental and Economic Accounting

System of Environmental-Economic Accounting (SEEA) – **Experimental Ecosystem Accounting** (EEA) – not a statistical standard
Measure condition and extent; land cover & land use
Understand and monitor contributions of ecosystems to economic activity [Hein] – contribute to economic production and household consumption.
Reference condition ('natural' or some base year?) – actual condition – target condition
Ecosystem service flows
Degradation, enhancement, conversion
NOT – natural inputs from mineral and energy resources & renewable energy.

Sustainability – weak/strong. Environmental sustainability = dynamic equilibrium by which the env. functions remain available for future generations (for renewable - regenerative capacity remains intact; non-renewables – substitutes developed). (Hueting, 2013).
Strong or weak sustainability – no change in any assets vs trade off against any other type of capital (too weak). (Helm, 2015)
Sustainable Development – development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987). See also **Hartwick rule**.

SNA scope – economic demonstrated? Resource

SEEA scope – sub-economic demonstrated? Resource

TEEB – the economics of ecosystems and biodiversity (UNEP)

TESSA – Toolkit for ecosystem site-based assessment. Rapid assessment tool of ecosystem services (Anglia-Ruskin & Cambridge Unis, UNEP, RSPB,…) – compares ecosystem benefits of alternative land uses.

Threshold – point at which (below which) the decline in status accelerates and/or becomes difficult to reverse. A discontinuity whereby a small change in a driver exerts the largest change in an attribute or state of an ecosystem, typically abrupt. (NCC, 2014) (see **tipping point** – not quite the same).
A threshold is a point or level at which new properties emerge in an ecological, economic, or other system, beyond which the system then behaves differently. For example. species diversity in a landscape may decline steadily with increasing habitat degradation to a certain point, then fall sharply after a critical threshold is reached. Human behaviour, especially at group levels, can exhibit threshold effects too. Limits (or environmental limits) on the other hand tend to be socially determined and can be defined as the point or range of conditions beyond which the benefits derived from a natural resource system are judged unacceptable or insufficient. NCC 1st report

Tipping point -"a point at which an (ecological) system experiences a qualitative change, mostly in an abrupt and discontinuous way" (Jax, 2012)

Total economic value (TEV) direct use, indirect use (value of clean air), option value (can take up in future), non-use value (existence, bequest, cultural value)
Revealed preference (hedonic pricing, travel cost)
Stated preference (WTP) – contingent valuation (specific), choice experiment (bundles)

Value added - GVA = value of output less value of intermediate consumption.

Value to the owner - minimum loss that a firm would suffer if it were deprived of an asset. RC – replacement cost; NRV – net realisable value; PV – present value. (Edwards *et al*, 1987)

Value of assets limited to those over which property rights can be enforced – these rights generate potential for stream of benefits. But this is in SNA – it may not be so for SEEA (Vardon, 2014).

Valuation methods
market prices that would have occurred if freely traded and exchanged. (Defra/ONS, 2014)

- Use
- Non-use
    - Consumptive use
    - Non-consumptive use
        - Direct
            - Travel cost
            - Stated preference
                - Contingent valuation
                - Choice modelling
            - Hedonic price
        - Indirect
            - Production function
            - Replacement cost
            - Stated preference (wtp) (wta?)
                - Contingent valuation
                - Choice modelling
            - Hedonic price

Value transfer – use of values from other areas/projects in different places but with similar attributes.

Valuing degradation

1. Cost-based (maintenance cost [SEEA '93])

- Avoid (prevent before happens)
    - Structural adjustment costs (need to be based
        - Refrain –reduce activities or abstain
        - Change production/consumption pattern
    - Abatement
        - Change technology/input substitution
        - Treatment costs - capture emissions & make less harmful
- Restore – clean-up (reverse once it has happened) – may be SNA 'actual' costs to decommission/rehabilitate/put back to former use. But may have to calculate hypothetical costs if least cost option, and may include mitigation/abatement of accumulated damage.

2. Damage-based (effect of overuse of environmental sinks). May be straightforward, or difficult (e.g. effect on health). WTP to be free of effects.

- Estimating damage done
    - dose-response model
- Revealed preference techniques
    - Market prices
    - Hedonic pricing (land & house values depend on characteristics
    - Travel cost method (direct travel costs, entrance fees, time costs getting to/from site.
- Stated preferences
    - Contingent valuation
    - Conjoint analysis/choice modelling

WAVES – wealth accounting and valuation of ecosystems (WB)

Wealth: Inclusive Wealth – 'The **inclusive wealth** index measures the **wealth** of nations by carrying out a comprehensive analysis of a country's productive base. That is, it measures all of the assets from which human well-being is derived, including manufactured, human and natural capital.' (IHDP-UNU, 2012), covered human capital, produced capital and natural capital (also measured health capital).

Comprehensive wealth - produced, natural and intangible (human, social & quality of institutions). Used **adjusted net savings** (depletion-adjusted net savings, WB's **Genuine Savings**) – gross national saving-depreciation of fixed capital – depletion of natural resources. = National net savings adjusted for value of resource depletion and environmental degradation plus education expenditure (proxy for human capital) (WB, 2011)

Appendix G Land cover/Habitat classifications

SEEA-EEA LCEU classes	urban & associated developed areas	medium-large fields rainfed herbaceous cropland	permanent crops agriculture plantations	pastures and natural grassland			forest tree cover		shrubland/bushland/heathland	open wetlands		barren land sparsely vegetated areas	inland water bodies	inland water bodies	coastal water bodies	sea	boundary & linear features *not in SEEA* ????
				pastures/ improved grassland	semi natural grassland (neutral, calcareous, acid, bracken) acid grassland	neutral grassland	broadleaved, mixed and yew	coniferous woodland					standing waters	flowing waters			
UK-NEA-based habitat classes	Urban	Enclosed farmland			Montane habitats & inland rock		woodland		Dwarf shrub heath (heather & heather grassland)	freshwater		Montane habitats & inland rock	freshwater		Coastal margins?	marine	
Countryside Survey broad habitats	Built-up areas	Arable & horticulture		Improved grassland			Broadleaved, mixed & yew woodland	Coniferous woodland	Dwarf shrub heath	Fen, marsh, swamp	bog	Montane habitats inland rock	Standing open waters	Rivers & streams			
Land Cover UK (ONS, 2015)	urban & associated developed areas	rainfed herbaceous crop	permanent crops	Pastures Semi-natural grassland			Broadleaved, mixed & yew woodland	Coniferous woodland	shrubland/bushland/heathland	open wetlands		Barren land/sparsely vegetated areas	inland water bodies		coastal margins		
CORINE Land Cover (CLC)	1. artifical sufraces	2.1 arable land	2.2 permanent crops	2.3 pastures 2.4 natural grassland			3.11 Broadleaved forest also 3.13 Mixed forest	3.12 Confierous forest also 3.13 Mixed forest	3.2 shrubland and/or herbaceous vegetative associations (except 3.2.1)	4.1 inland wetlands 4.1.1 inland marshes	4.1.2 peat bogs	3.3 open spaces with little or no vegetation (not 3.3.1)	5.1 continental waters 5.1.2 water bodies	5.1 continental waters 5.1.1 water courses	3.3.1 beaches, dunes & sand plains 5.2.1 coastal lagoons,	5.2.3 seas & oceans	
Roadmap (ONS, 2015) - habitats	Urban environment	Enclosed farmland			semi-natural grassland		Woodlands		shrubland/bushland/heathland	Freshwater (open waters, **wetlands**, floodplains)			Freshwater (**open waters**, wetlands, floodplains)		coastal margins	marine	