ANALYSIS OF THE COSTS AND BENEFITS OF ALTERNATIVE SOLUTIONS FOR RESTORING BIODIVERSITY

Final report to Defra December 2010

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Defra Competition Code: WC0758/CR0444

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Acknowledgements

This project would not have been possible without the input provided by the case study representatives. In particular, for Ennerdale, Gareth Browning (Forestry Commission) and Rachel Oakley (National Trust); for Great Fen, Chris Gerrard (The Wildlife Trust for Bedfordshire, Cambridgeshire, Northamptonshire and Peterborough); for Heather and Hillforts, Helen Mrowiec (Denbighshire County Council); for Knepp, Charlie Burrell (Knepp Castle Estate); and for Pumlumon, Clive Faulkner (Montgomery Wildlife Trust), Liz Lewis-Reddy (Montgomeryshire Wildlife Trust) and Estelle Bailey (Montgomeryshire Wildlife Trust). They have spent time in providing data, their expertise, and discussions about their sites, for which we have been very grateful.

There are also numerous other people who have kindly helped with providing information for the case studies. For Ennerdale, these included Jenny Butler (Natural England) and Simon Webb (Natural England); for Frome, Andy Pollard (Dorset Wildlife Trust) Johnny O'Brien - RSPB, Arne, Deer management, Ian Danby, (BASC), Michael Ndeze (Forestry Commission); for Great Fen, Alan Bowley (Natural England); for Heather and Hillforts, Heledd Wyn Jones (Countryside Council for Wales); for Knepp, Theresa Greenaway (Ecological Consultant) and Henri Brocklebank (Sussex Records Centre); for Pumlumon, Stephen Hughes (Montgomeryshire Wildlife Trust), Jerry Pritchard (Forestry Commission), James Harvey (Statkraft Energy Ltd), Carol Fielding (Countryside Council for Wales) and David Webb (West Wales Water). Gwion Aeron (Welsh Assembly Government) was also a great help in providing agri-environment scheme data for the Welsh sites and Ewan Mackie and Charene Winbow (Forestry Commission) in providing standard timber values.

At Bournemouth University, several people have also assisted with the project. Special thanks go to Chris Moody and Mark Dover. Jennifer Morgen provided information on GI. We would also like to thank Jon Finch at CEH for his input to the flood mitigation assessment for the case studies.

Finally, we would like to thank the project steering group for their guidance.

Contents

1. Introduction and background

The potential benefits of implementing biodiversity conservation at a landscape-scale are increasingly recognised[1], with the aim of developing a more dynamic landscape, with greater resilience to environmental change. The integration of environmental, economic and social factors is essential for effective evaluation of such a landscape-scale approach and this recognition of multi-functionality is essential in incorporating an ecosystems approach into policy making[2].

This view as strongly stated in a recent review of England's wildlife sites, which concluded that a "step change" is needed in conservation with a new 'restorative approach" which rebuilds nature (Box 1, (Lawton 2010)[3]. They recommend the establishment of Ecological Restoration Zones (ERZs) to "operate over large, discrete areas within which significant enhancements of ecological networks are achieved, by enhancing existing wildlife sites, improving ecological connections and restoring ecological processes".

> Box 1. Concluding remarks from the 'Making Space for Nature Review', Lawton et al 2010.
>
> England's collection of wildlife sites, diverse as it is, does not comprise a coherent and resilient ecological network even today, let alone one that is capable of coping with the challenge of climate change and other pressures.
>
> The evidence is equally compelling that *Making Space for Nature* to establish such a network will make efficient use of scarce land and resources, and deliver many benefits to wildlife and people.

So this research explores whether a landscape-scale approach to conservation management or restoration can offer net benefits in relation to more locally targeted site-based approaches in terms of the provision of ecosystem services and biodiversity conservation.

Stakeholder-defined scenarios were developed with partners to compare the benefits for people and biodiversity for a range of case study sites in England and Wales that are subject to existing or planned schemes for landscape-scale conservation[4]. The scenarios were and developed with partners to compare the landscape scale approach with a site-based conservation management approach.

The scenario building process involved iterative consultation to map relevant features of the current landscape and to visualise the projected landscape in 2060. The date was given to help to focus the visualisation and enable evaluation of the landscape-scale approach in terms of management aspirations, based on locally relevant expert opinion, in a spatial context.

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[1] NE (08), State of the Natural Environment; WT(06) Living Landscapes, Environment Strategy Wales
[2] Defra (07), Securing a Healthy Natural Environment
[3] Lawton et al (2010) *Making Space for Nature: a review of England's wildlife sites and ecological network*. Report to Defra.

[4] see Appendices for details on the case study sites.

The output of this project is a timely accompaniment to the recent 'Making space for nature review, (Lawton 2010) and will complement parallel initiatives such as the UK National Ecosystem Assessment, which will report in early 2011, informing on the ecosystem benefits to society across the whole of the UK.

1.1 Typology of landscape scale conservation initiatives

Conservation management will always include aspects of landscape-scale planning and implementation, and in reality there is a considerable range of initiatives within the UK that have been dubbed landscape-scale in their approach. For example, 76 partnership projects are identified by Butterfly Conservation as landscape-scale and these vary from single large sites to even larger areas, such as Dartmoor, differentiated by multiple ownership (Bulman 2008). An even greater variety of approaches are frequently placed under the 'landscape scale' umbrella in the literature. For instance, examples of landscape-scale approaches to reducing biodiversity loss in (Rands et al. 2010) include trans-boundary conservation (e.g., the Great Limpopo Transfrontier Park), payments for environmentally sensitive farming (such as under the Farm Bill in the United States or in the Agulhas National Park in South Africa), and large-scale habitat creation and restoration, as seen, for example, in the Oostvaardersplassen project in the Netherlands.

Therefore we needed a working definition of the 'landscape-scale approach' to differentiate it from other approaches. Levitt (2004) suggests that (1) such initiatives should encompass some regional system of interconnected properties; (2) such efforts are in some way organized to achieve one or several specific conservation objectives; and (3) various landowners and managers within a given conservation region cooperate or collaborate in some concrete fashion to achieve those objectives. Even within this definition there are a variety of management approaches varying by area of region encompassed, partnership activity, range of ownership and many other factors.

There will be a continuum of decreasing inter-site management coordination from large single site management to management focussed on small single sites (Figure 1). There is a clear dichotomy between landscape-scale initiatives in which management of the entire landscape is undertaken, versus those initiatives that focus on particular sites or habitat patches, but attempt to address landscape-scale patterns and processes (e.g. through restoration of habitat networks). These different types of landscape-scale intervention were explored through selection of appropriate case studies.

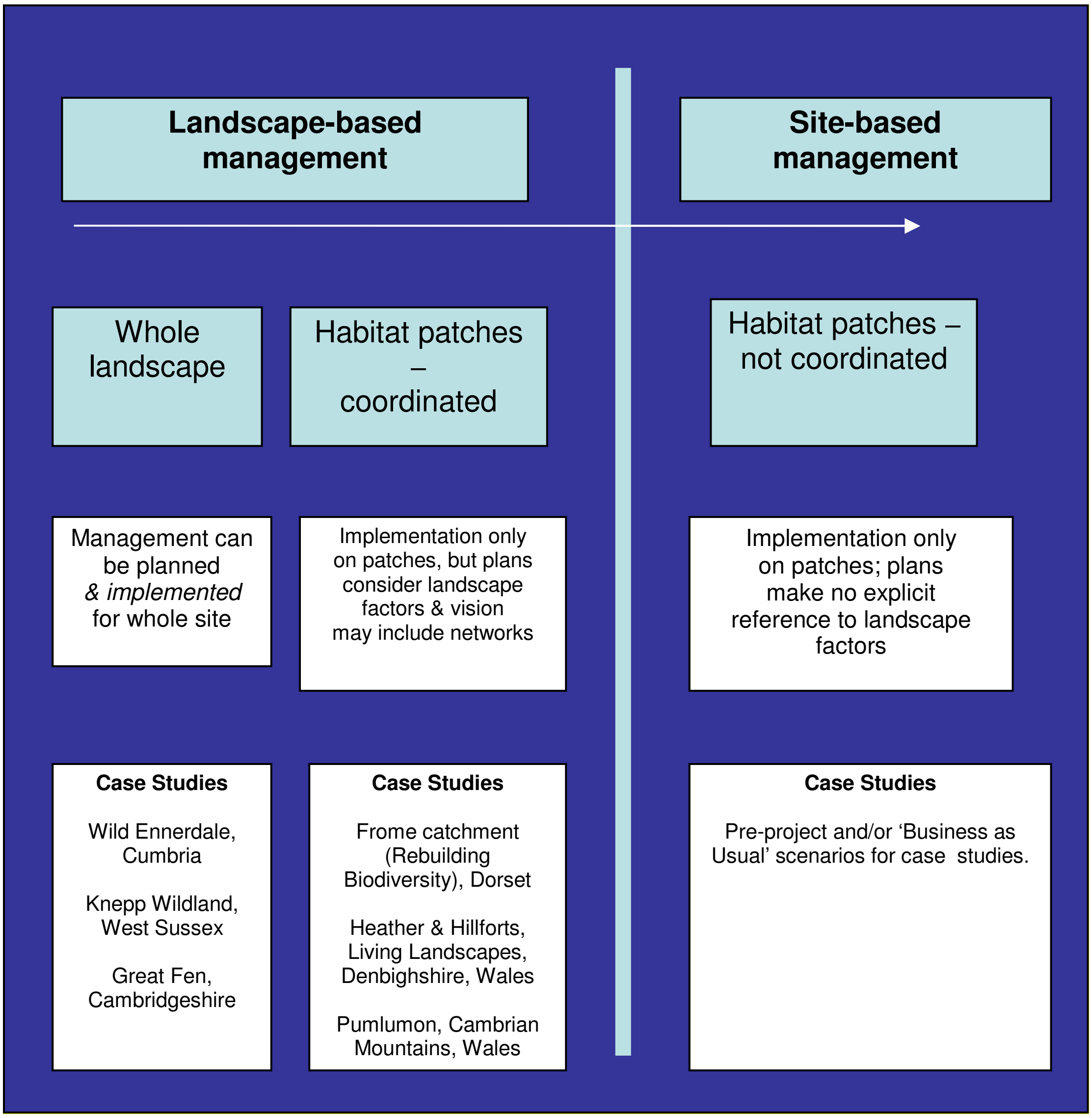

Figure 1 Typology of landscape-scale biodiversity conservation.

1.2 The case studies

The case studies were selected because they have either implemented or planned a landscape-scale management approach. Three were distinct sites with single ownership or close collaboration between small numbers of owners. The remaining case studies were landscape visions where implementation would occur on patches but these were seen in the management vision as part of a wider landscape with potential for inter-patch connectivity (Figure 2). A range of landscape types were selected to explore the implications of the differences in management approaches within different circumstances: these included uplands, fenland and lowland farmed landscape (Table 1) and were situated across several regions of England and Wales (Figure 2).

Figure 2. Location of each case study

Table 1. Characteristics of the case study sites

Case study site	**Area (ha)**	**Tenure**	**Landscape**	**Scenarios**
Frome catchment, Dorset	48,295	Forestry Commission, Dorset Wildlife Trust, RSPB and others.	The principal habitats are chalk river reaches of the Frome, bordered by coastal & floodplain grazing marsh and former water meadows with scattered fragments of swamp, fen and wet woodland. Around the edges of the floodplain there are habitats such as lowland heath, valley mire, semi-natural deciduous woodland and natural grasslands, along with deciduous and coniferous plantation woodlands. Agriculture is the predominant landuse in the flood plain.	*Landscape vision:* Living Landscapes: A regional approach to landscape-scale planning for habitat restoration developed by the South West Wildlife Trusts, which aims to ensure the long-term conservation of all priority wildlife habitats in the SW, by defining ecologically functional fragments at the landscape scale (referred to as strategic nature areas, SNAs) where habitat restoration should be delivered in the future. The SNAs and their land-use type have been identified in a map, called 'Nature Map', which identifies the location of biodiversity restoration actions and is designed to inform strategies for sustainable development. *Pre-project:* Frome catchment current landscape without the Nature Map.
Great Fen Project, Cambridgeshire	3,700	Bedfordshire, Cambridgeshire, Northamptonshire and Peterborough Wildlife Trusts, Huntingdonshire District Council, Natural England and the Environment Agency.	Lowland fenland. Two fen nature reserves surrounded by drained fenland converted to arable land.	*Lanscape vision:* Restoration of over 3,700 hectares of fenland from arable land, between Huntingdon and Peterborough. The project will connect Woodwalton Fen National Nature Reserve with Holme Fen National Nature Reserve, and halt the deterioration of these reserves *Pre-project:* Continued isolation of Woodwalton Fen National Nature Reserve and Holme Fen National Nature Reserve, with arable land separating them. The fens will continue to lose their peat soils so that much of the peat in the project area will be gone in 50 years.

Case study site	Area (ha)	Tenure	Landscape	Scenarios
Heather and Hillforts, Denbighshire, North Wales	2,982	National Trust, RSPB, Forestry Commission, Countryside Council for Wales, Denbighshire County Council.	An open windswept landscape with long, high ridges broken by a series of summits and often with long spurs, creating a gentle rolling landscape with broad vistas. Heather and bracken are dominant, together with bilberry and gorse.	*Landscape vision:* An overarching strategic approach to restore and maintain the upland historic and natural heritage as a sustainable landscape. A key aim of the project is to enhance the quality of the heather moorlands through better management and understanding, demonstrating sustainable agriculture in harmony with a landscape of outstanding historic and biodiversity value;. *Pre-project/Business-as-usual:* Continuing decline and poor condition of a significant amount of the heather moorland due to the lack of appropriate management.
Knepp Estate, West Grinstead, West Sussex	1,400	Charles Burrell, Knepp Castle Estate.	An estate in lowland England, previously with in-hand and let farmland, including arable, livestock and woodland. The main habitats are grassland, woodland, including wood pasture / parkland, and scrub.	*Landscape vision:* Restoration of the estate to its pre-intensive agriculture state, through 'rewilding', with minimal management. Grazing by herds of deer, cattle, pigs and horses will occur across the whole Estate, with the vegetation managed by teeth, not machines. *Pre-project:* Pre-implementation of the rewilding project: intensive farming, including arable and livestock, and woodland.
Pumlumon Project, Cambrian Mountains, Mid Wales	40,000	Welsh Wildlife Trusts, Forestry Commission, Countryside Council for Wales, the Environment Agency, Powys County Council, Ceredigion County Council, water utilities companies.	A complex mosaic of locally, nationally and internationally important habitats and species, such as dry and wet dwarf-shrub heath, blanket bog, unimproved acid grassland and a number of oligotrophic lakes. Agriculturally improved grassland, broadleaved woodlands and forestry plantations are also characteristic features of the area.	*Landscape vision:* Creation of landscape solutions that will address climate change, diffuse pollution, flooding, habitat loss and species decline by establishing ecosystems management; enabling the farming community to have a sustainable future through the sympathetic and sustainable management of natural capital; encouraging economic activity through the promotion of enhanced natural assets; and empowering communities to address environmental issues through sustainable environmental management. *Pre-project/Business-as-usual:* Continuing loss or degradation of upland habitats due to intensive

Case study site	Area (ha)	Tenure	Landscape	Scenarios
				land use activities, including over-grazing by sheep, which has induced soil compaction, resulting in diffuse pollution and increased flooding of the lowland areas
Wild Ennerdale, Ennerdale Valley, Lake District	4,300	Forestry Commission, National Trust, United Utilities.	Mountains, rocky outcrops and scree, large, diverse woodlands, rivers, a lake and some of the most highly valued flora and fauna in the country.	*Landscape vision:* Shift away from economic productivity as the primary output, with a move towards lower input, more sensitive management whereby natural processes are given a greater hand in determining how the valley will evolve in the future. *Pre-project/Business-as-usual:* Based on management practices prior to implementation of the rewilding project (2001).

1.2.1 Urban landscape management

An urban case study based on a Green Infrastructure (GI) initiative was considered, but the natural and cultural environments in rural areas differ radically from urban areas. Accordingly, the core method employed in this research, exploring potential land cover changes brought about by landscape scale projects, is not directly transferable to the study of GI in towns or cities. This is partly because large scale changes in land cover are unfeasible in the urban environment and so much of the GI emphasis tends to be on improving the quality and accessibility of the existing resource. Therefore, an approach relying solely on changes in broad habitats would be likely to severely underestimate the potential benefits.

Nevertheless, the growing prevalence of such GI themes merits inclusion in this report so alternative approaches in urban areas were approached by reporting on selected current GI schemes to give a qualitative assessment of the potential for these initiatives to deliver cost effective enhanced ecosystem benefits and also on the key policy influences (section 5). The assessment was based on consultation with key representatives of each scheme and recently published or draft documents[5].

2. Building the alternative scenarios

2.1 Introduction

The alternative scenarios were developed to represent different management approaches for each case study site. Each case study site was visualised in at least two scenarios (1&2) and a third scenario was created where feasible.

1. **Pre-project scenario** – land cover before the start of the landscape project (i.e. site-based conservation).
2. **Landscape-scale scenario** – the expected land cover in 2060 assuming successful implementation of the landscape-scale project.
3. **'Business-as-Usual' future scenario** – visualisation of the future without the landscape-scale initiative.

At all sites, the landscape-scale management visions were either in their early stages or yet to be developed, so visualisation of future scenarios was achieved by spatially projecting the landscape that is hoped to develop by 2060, should the landscape scale management strategies be successfully implemented. This process varied between case studies, but for the majority, the management goals had not been spatially developed so a unique process of mapping the possible future landscape was developed, based on the strategies and assumptions of the management vision, and guided by local knowledge.

Where possible, we worked with representatives at case studies to develop alternative scenario maps to represent what would happen if the landscape scale project was not implemented. These were future **'Business-as-Usual' scenarios**. This was more challenging than development of the 'Landscape-Scale' scenarios because there were no

[5] SE Dorset GI: Evidence and Opportunities Study (Land Use Consultants 2010), Liverpool GI Action Plan (Draft), Liverpool City Region Green Infrastructure Framework: Technical Document and Evidence base (Draft).

strategy documents or project plans on which to base the scenario. Nevertheless, for some sites (e.g. Ennerdale) it was possible to create this projection. We also built pre-project scenarios in all cases for consistency between the sites.

2.2 Creating scenario maps

The scenarios were created in collaboration with case study representatives: full methods, maps and characteristics of each scenario are given in Appendix 1. The pre-project scenarios were made by reference to existing vegetation survey, such as Phase 1 or NVC survey or remotely sensed land cover data. Mapping the future scenarios then involved modification of the existing maps using a combination of management plans or strategy documents, where available, and expert opinion.

Three scenarios (Pre-project, Business –as-usual and Landscape-scale) were created for the Ennerdale, Pumlumon and Heather and Hillforts case studies. For instance, the Ennerdale scenarios were developed from an NVC survey modified using local knowledge and planning documents. The future scenarios reflected differences in forest management. For the Landscape-scale alternative, the Wild Ennerdale Stewardship Plan was applied with extensive felling and minimum intervention regeneration leading to an increase in broadleaved and mixed woodland in place of conifer woodland along with other habitat changes (Figure 3).

In contrast, the Ennerdale Business-as-usual scenario showed a future where commercial forestry operations were assumed to continue. The maps were modified to simulate felling and restocking using Forestry Commission Forest Design Plans with the assumption that these plans would have been implemented if the Wild Ennerdale project had not been realised. This resulted in an increase in broadleaved woodland, but not as great as under the Landscape-scale scenario, a decrease in heath (Figure 3). In addition to the broad habitat visualisation, tree species detail was added to enable greater accuracy of timber valuation (see Appendix 1 for full details).

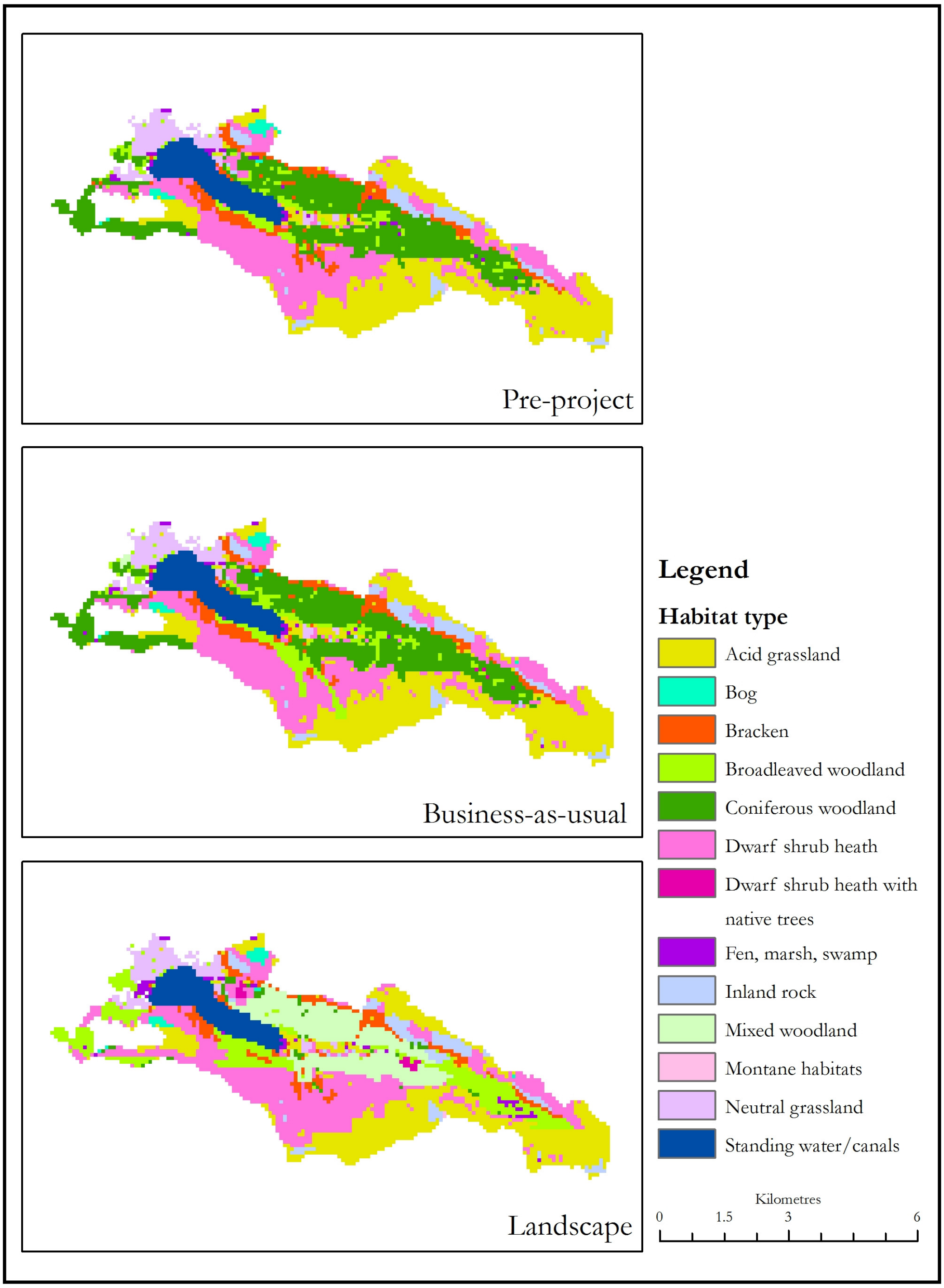

Figure 3. Differences in land cover for each scenario in Wild Ennerdale

Two scenarios were created for the Great Fen and Knepp Wildlands projects, as initial consultation indicated that suitable information was available for the Pre-project and Landscape-scale scenarios only. In both cases, the pre-project scenario was based on existing survey, either field or remotely sensed, with some modification where necessary. For the Great Fen, the Pre-project scenario consisted of isolated fenlands with arable land separating them. In the Landscape-scale scenario, these fens were connected through land purchase and restoration to replace arable and horticultural land with neutral grassland, fen, marsh and swamp. The scenario was based on a project vision map provided by the Great Fen project, giving projected vegetation development in NVC classes and informed by topology and water levels (Figure 4).

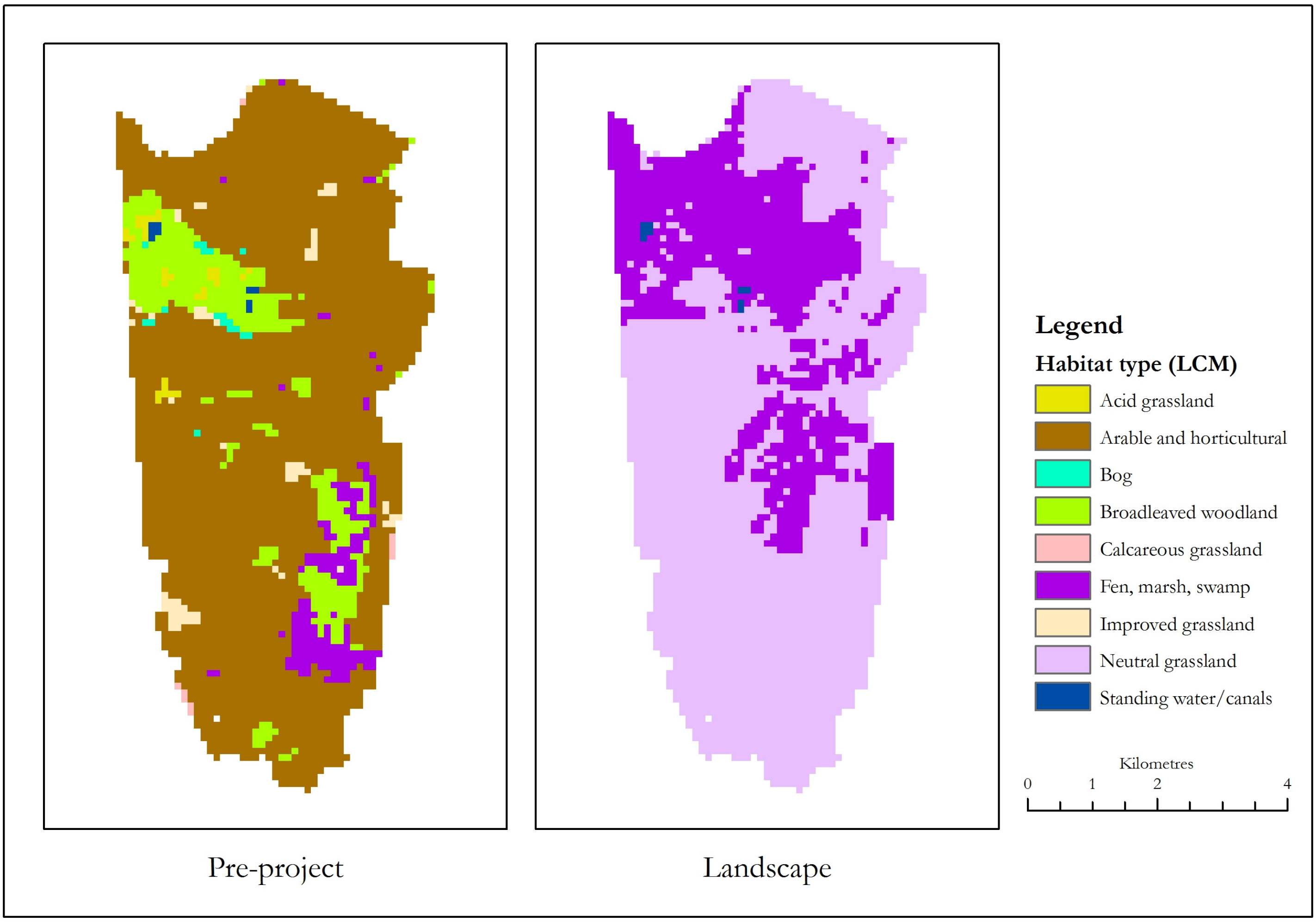

Figure 4. Differences in land cover for each scenario in the Great Fen.

For the Frome catchment case study, a Pre-project scenario was generated using the CEH Land Cover Map 2000 (LCM2000) along with alternative futures reflecting three interpretations of a regional strategy, the South West Nature Map (Brenman 2005). Biodiversity restoration targets of the Strategic Nature Areas (SNAs) in the South West Nature Map were used to guide simulation of land cover conversions by extending existing habitat patches in a GIS buffering process (Figure 5).

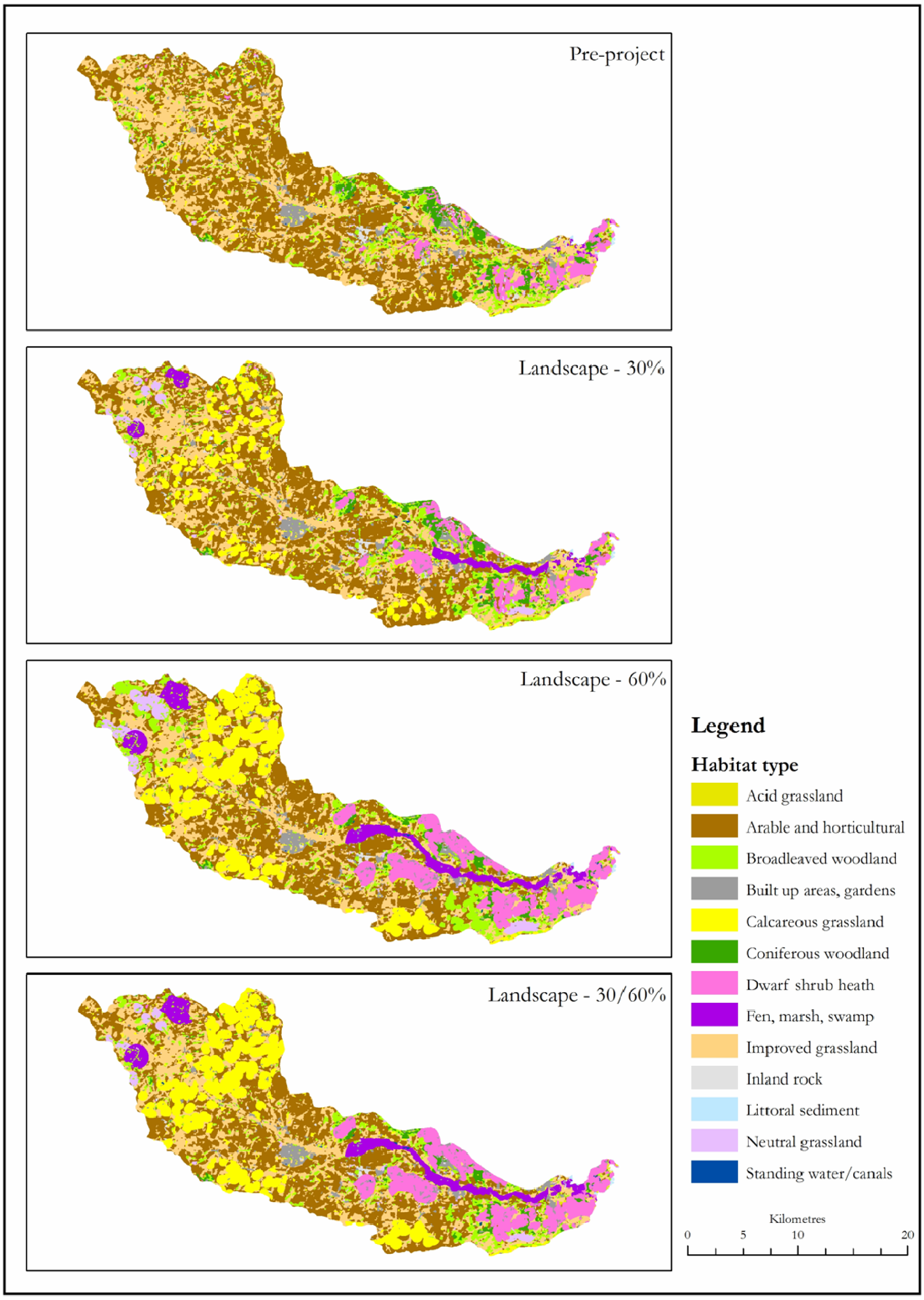

Figure 5. Differences in land cover for each scenario in the Frome catchment. Priority habitats were extended by 30%, 60% or a combination of these two based on priority.

3. Evaluating the alternative scenarios

3.1 Framework for valuation of ecosystem services

The framework for valuation of ecosystem services used in this project was developed through literature review and consultation with representatives of each of the case studies in a 'Benefits scoping exercise'. The latter was designed to assess the perceived importance of each of the ecosystem services under the different scenarios of future management.

3.1.1 Introduction to the valuation of ecosystem services

The ecosystem services approach has been widely embraced, recognising the need to link ecosystem functioning and human welfare, but numerous complications have been observed. These include typology of services, the requirement for marginal valuation, the scale of geographical area over which the valuations are assessed, non-excludability (the need to avoid double counting), and the time period over which the valuations occur (e.g. Balmford et al. 2008; de Groot et al. 2009). Hence, this is a rapidly growing research area, with considerable current activity in the UK, Europe and beyond[6], and all methods must be interpreted in view of their limitations. Pursuit of standard methodology, in any case, is likely to be futile, as arguably, the methods used should focus on fitness for purpose, in the context of the ecosystems in question and the human decision context, rather than seeking to conform to existing classification schemes (Fisher et al. 2008).

Lack of data is currently a challenge, and it is for this reason that many evaluations are based on transferred or proxy values (benefits transfer) with accompanying loss of accuracy (Eigenbrod et al. 2010). However, for research based on comparing differences in service provision, this becomes less problematic.

For this valuation exercise, we have adopted the following general principles:

- Mixed methodology, using locally informed empirical data where available, and proxy values based on land use where locally derived information is not available.
- Methods are based on recent best practice, and modified in some cases to produce novel indices, where no suitable method had been developed to date.
- Selection of ecosystem services with discrete 'end benefits' in order to minimise the risk of double counting. In other words services such as soil provision – which are necessary for provisioning services, were not valued, following the approach advocated by Balmford et al. (2008).

3.1.2 Scoping the perceived benefits

In order to integrate local knowledge into the design of the framework, a consultation process was carried out during the first contact with the case studies. A template for scoping the benefits from each site was modified from the Rapid Assessment Methodology of the Natura 2000 toolkit (Kettunen *et al* 2009) and was sent to representatives asking them to assign a value between 0 and 5 to indicate the importance

[6] E.g. NEA, TEEB, The Natural Capital Project (USA)

of ecosystem services at their sites under the different scenarios (see Appendix 2). The results show a range of importance of different benefits as they are perceived across the sites, and importantly, show that the representatives can envisage large changes following implementation of their landscape visions (Figure 6). Notably this reflects opinion and is useful for determining the way in which the vision is hoped to produce benefits and may be quite different from valuations based on indices or monetisation.

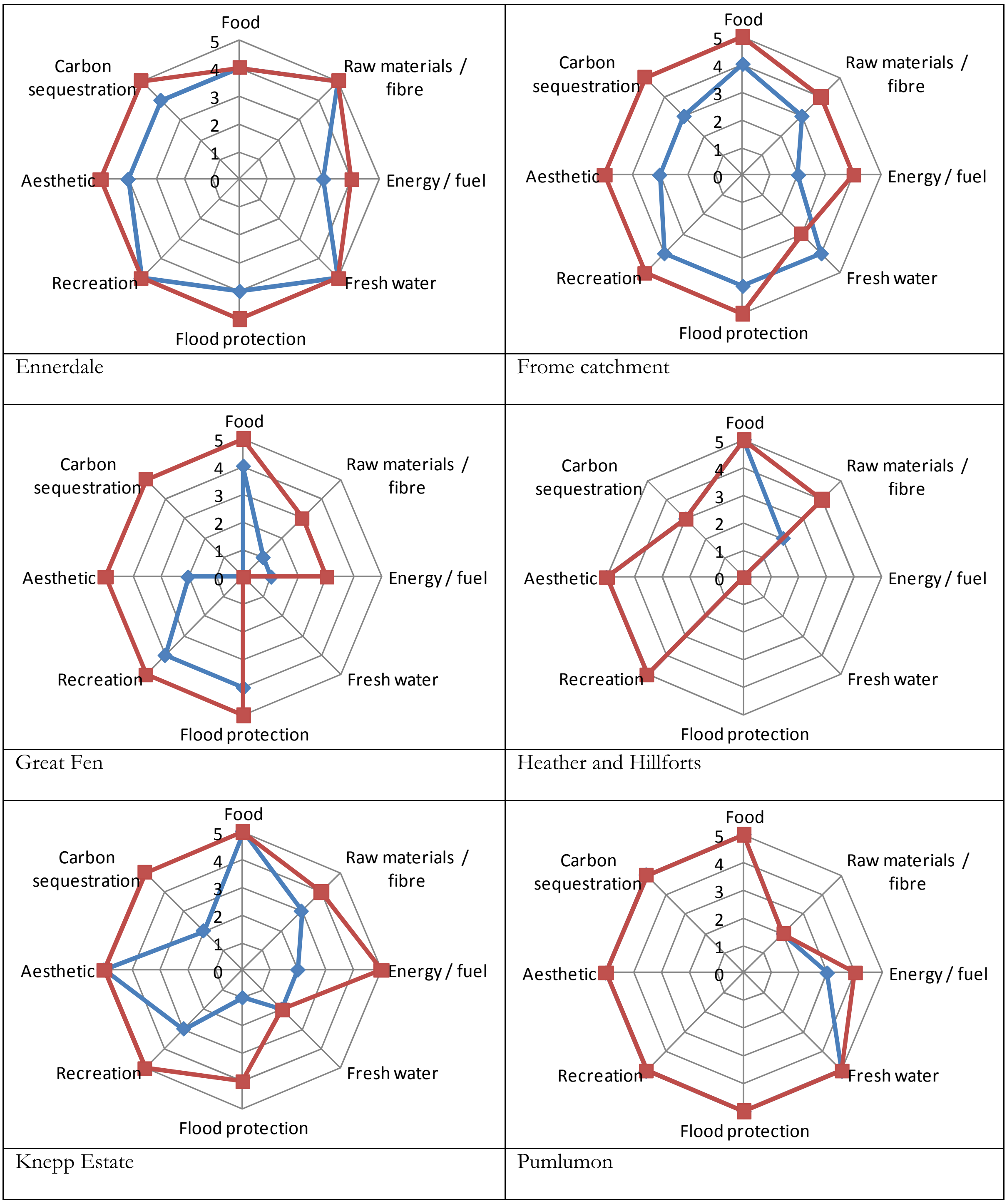

Figure 6. Importance scores for the selected ecosystem benefits from a case study scoping consultation: scores range from 0 (not relevant) to 5 (very high importance). **Red** indicates the score for the Landscape-scale scenario and **blue** a Business-as-usual scenario.

3.1.3 Benefits included in the framework

The project specification, literature review, and scoping study all informed the selection of a subset of key ecosystem services for valuation (Table 2). These services were investigated for their potential for valuation in the case studies except where they were assigned a score of 0 in the scoping exercise. This was the case for the Great Fen where water provision was not valued and Heather and Hillforts where water provision and energy/fuel were not valued.

Table 2. Selected ecosystem services for valuation at the case study sites.

Ecosystem Services	
Food	Cultivated crops, wild foods, livestock, fish and game.
Fibre/raw materials	Timber, plant fibre (such as straw), animal skins and leather, wool.
Fuel/energy	Renewable fuel products or renewable energy: woodfuel, biofuel crops, hydroelectricity.
Fresh water provision	Provision from reservoirs and aquifers for domestic consumption, industry or agriculture. Water quality is included through effects on production costs. NB Small-scale non-marketed use may occur. This use may be reflected in other services e.g. reduction of food production costs by irrigation.
Flood protection	Influence of the site in mitigating downstream flood risk.
Nature-based recreation/ tourism	Opportunities provided by the landscape: walking/hiking, horse riding, cycling/mountain biking, rock climbing, nature-watching, fishing/angling, boating, water sports (canoeing etc.), swimming, camping, picnicking, air sports (hang-gliding etc) and hunting/game shooting.
Aesthetic benefits	Characteristics of the landscape that are of aesthetic value to people.
Carbon	Carbon storage/sequestration capacity of land-cover types. *Carbon storage* is the amount of carbon stored in vegetation (above and below ground); therefore, an avoided flow of carbon into the atmosphere, and c*arbon sequestration* is the net annual rate of atmospheric carbon added to existing biomass carbon pools (absorbed from the atmosphere by plants).
Biodiversity	
	Biodiversity protection and enhancement: area of priority habitat and habitat connectivity for species of conservation interest.

3.1.4 Benefits not included in the framework

Certain benefits were considered for valuation but their inclusion rejected for this study. These were:

(i) *Knowledge*. This benefit might be represented by opportunities for education and research. Although it can be relatively easily evaluated for current situations (e.g. Pugh & Skinner 2002), it is difficult to estimate the value of this service for future scenarios, and difficult to map.

(ii) *Property*. Although property values can be affected by the presence of a site, it is very difficult to determine what these values may be under the future scenarios and to isolate the influence of the site from other factors that can influence property prices.

(iii) *Spiritual/ cultural wellbeing*. This benefit can be particularly subjective and difficult to value without a primary valuation study. It is also included to some extent in some of the other categories that have been included, such as aesthetic benefits and tourism/recreation, which may inspire a sense of spiritual wellbeing.

(iv) *Supporting services*. These services are required for the supply of all other services e.g. Soil retention is essential for the provisioning services. Therefore valuation would result in double counting.

3.2 Valuation approaches for ecosystem services

Approaches to valuation were developed with reference to the literature and with necessary modifications for the case studies depending on data availability. Full details of the development of the approach, and application in each case study, are given in Appendix 1.

3.2.1 Food, Raw materials /Fibre, and Fuel / Energy

These three benefit categories were assessed using market price because they are tangible goods with observed or estimated market prices. The approach has been widely adopted and advocated (Chan et al. 2006; Christie et al. 2008; Kettunen et al. 2009a; Natural England 2009a; Nelson et al. 2009; Pascual et al. 2010). There are a number of caveats to be considered when using market price and these are considered in Appendix 1.

3.2.2 Fresh water provision

Assessment of the value of fresh water provision was approached using observed market price with the ecosystem services reflected through reduction in processing costs (Kettunen et al. 2009a).

3.2.3 Carbon storage

As primary data were not available, carbon values were calculated using average values from ecosystems similar to those in the study area (Kettunen et al. 2009a), these were for habitat types in the south-west of England (Cantarello et al. in press).

3.2.4 Flood protection

The relationship between land cover and flood protection is complex, depending on many factors such as slope, soils, geology and rainfall (O'Connell et al. 2005; Orr et al. 2008). For this reason, valuation studies tend to either use qualitative descriptions of the potential changes in flood risk (Natural England 2009a) or may adopt a scoring system based on land cover type, such as that used by Collingwood Environmental Planning (2008) in their Green Infrastructure study.

In this study, a qualitative assessment was made for all sites and two novel methods for modelling land cover related flood risk were explored: (i) an index for overland flow based on the CEH Land Cover Map categories, (ii) a prototype model of flood risk based the Joint UK Land Environment Simulator (www.jchmr.org/jules/) for one study site.

Ideally, damage costs avoided would be used to value flood protection as such cost-based approaches have been successfully applied to estimate the value of ecosystems in regulating water runoff and controlling floods (Kettunen et al. 2009a) and the cost of flood damage is the currently recommended method for assessing physical damages from flooding events (Natural England 2009b). A new Defra project, BD 5005, will develop the rigorous valuation of flood protection benefits.

3.2.5 Recreation/tourism

This ecosystem service was assessed as market price represented by willingness to pay (WTP). Initial consultation indicated that WTP studies were not available for any of the case study sites so benefits transfer was used, based on studies that have implemented WTP for similar areas. This approach has been widely applied in recent studies: for instance, Natural England (2009b) used benefits transfer of WTP for valuing recreation in upland areas; Tinch and Provins (2007a) transferred WTP values and admission prices for their Wareham Managed Realignment case study; O'Gorman and Bann (2008a) took a similar approach in their wider study of England's terrestrial ecosystem services.

3.2.6 Aesthetic benefits

Aesthetic value was assessed using scores based on GIS indicators of aesthetic attributes of land cover types identified from the CPRE[7] Tranquility Mapping study (Jackson et al. 2008b). This study was selected because it was based on a substantial survey of UK public (4000 people) and the indicators used were spatially linked to aesthetic features.

3.3 Valuation approaches for biodiversity conservation

For consistency and comparability, suitable methods for valuing biodiversity benefits were sought in 'Biodiversity Indicators in your Pocket' (Defra 2009). The most suitable were the 'area of priority habitats' and 'habitat connectivity' so these two were included in this analysis. However, as the landscape-scale scenarios were created on the assumption of achievement of conservation objectives it is inevitable that areas of the priority habitats will increase. The most interesting feature may therefore be the relative increase of the different habitats.

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[7] Council for the Protection of Rural England

The ecological impact of the scenarios was addressed using Ecological Impact Assessment (EcIA) which applies scoring based on conservation priorities and habitat significance (Rouquette et al. 2009). These two criteria are determined by (i) assigning each land cover type to a category of conservation priority and (ii) calculating the proportion of the national and regional resource that the habitat represents (see Appendix 1).

The functional connectivity of priority habitats was approached by focussing on one of the case studies, Frome catchment, and employing method similar to the least-cost distance method developed by Watts *et al.* (2008b) to estimate the potential ease with which species could move between habitat patches (Defra 2009). Lack of empirical data on the 'costs' of moving through the landscape means that generic focal species had to be adopted, as in Watts et al (2008). The analysis was only really meaningful on the larger case studies: Frome catchment and Pumlumon and the latter could not be included because the use of habitat networks estimation in development of the landscape-scale scenario would introduce an unacceptable level of circularity to the analysis.

3.4 Assessment of costs

Costs include project implementation, running and opportunity costs. The estimation of costs needed to be addressed with a variety of approaches because some were closely associated with services and others applied across the case study sites.

Ecosystem services valued using market price were adjusted for costs by subtraction of production costs. Production costs were assessed separately for all other services. Implementation and running costs were estimated for the conservation work being carried out, or envisaged, in each scenario, based on consultation with case study partners and reference to known costs for habitat management. An exception was the Frome case study where costs had to be estimated using transferred values as collated costs were not available.

Opportunity costs from implementation of the different scenarios were integral to the valuation in this study. For example, if there was a reduction in food production under the landscape vision scenario compared to the business-as-usual scenario, this would be an opportunity cost.

4. Synthesis of results

Ecosystem services[8]
Recreation and aesthetic values increased in all of the landscape-scale scenarios (Table 3) and the monetary values of the envisioned recreational income were substantial in many cases (see Appendix 1). For instance, in the Great Fen, recreation was envisioned to increase by over 4000% giving a difference of over £3.3 million, and for Pumlumon, a

[8] Ecosystem service provision in the landscape-scale scenarios compared with either the pre-project or future business-as-usual scenarios are summarised in Table 3 in order to combine monetary and other benefits. Monetary estimates are given in summary sections for each case study (Appendix 1) and in the cost benefit section below.

very conservative estimate gave an increase from 1.7 to 1.9 million. These increases alone could in many cases compensate for losses in other services.

Carbon storage increased for all of the sites showing a particularly strong increase in Knepp where arable land was converted to habitat with much higher carbon storage values (Table 3). The exception was Heather and Hillforts and this simply reflected a loss of commercial forestry. Gains by habitat conversion were not feasible in this project as management was for improvement in condition.

It might be expected that the landscape-scale management, which implicitly moves away from intensification, would always lead to reductions in food production; however, in two of the case studies there was an increase in this service as grazing animals could still be marketed and they may be of higher meat value than those produced prior to the conservation initiative. Notably, even in projects such as the Great Fen, where large losses in food productivity would occur, this monetary loss from arable crops is vastly compensated for by the added and increased services. This compensation occurs even though not all services are included because they are not monetised (flood mitigation and aesthetic value for instance).

Production of fibre and raw materials is also reduced in most cases due to the loss of commercial forestry. In the Great Fen this is not the case, as reed production will be a major output. In other sites, additional services may be derived from forests in the future, such as increased demand for wood fuel. However, discussion with the case study representatives established that these aspects were too uncertain to include in the scenario assessment. Improvements in fresh water provision were not reflected in these case studies as the water quality, where relevant, was already high and so potential benefits such as drain blocking in peat to improve the colour of domestic water supply were not applicable.

Despite only partial monetisation of the benefits, there was a tendency for losses in some services to be (at least) compensated for by gains in others. There was a general trend for service provision to change from food and fibre to carbon storage and recreational value. However, there were notable exceptions where products such as reeds or premium meat were significantly increased.

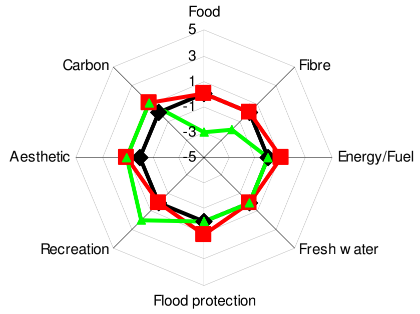
The qualitative assessment of flood mitigation potential indicated that there would be no change or an increase in potential for the landscape to alleviate flood risk. This was not supported in the one example case study in which a pilot model of flood mitigation risk was tested. The potential errors in both the qualitative assessment and the model mean that these results should be interpreted with caution. These methods are now being developed further by CEH in a new Defra project: BD 5005 "The provision of ecosystem services in the environmental stewardship scheme" (see also Conclusions).

Valuation of flood mitigation potential was identified as an area in particular need of further research.

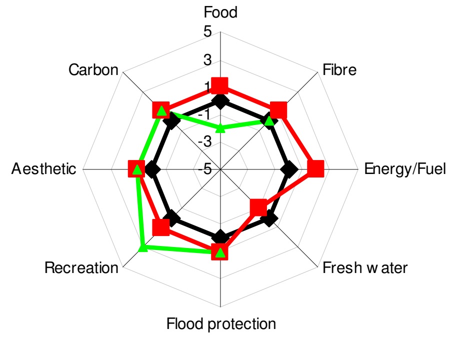
Carbon was by far the most significant service in terms of monetary values and very much dominated the total value of the benefits for each site. The differences in values for the lower, middle and upper carbon values (shown in the summaries for each project) illustrate the sensitivity of the method to these values and even when is the lower value would used an assessment based on monetary values rather than indices of direction of change would be very dominated by carbon. This may be partly due to a lack of monetisation of flood mitigation (which could potentially have very high values) but has also been noted by Birch et al (in press) in Latin America.

The monetised values were highly sensitive to, and dominated by, the value of carbon.

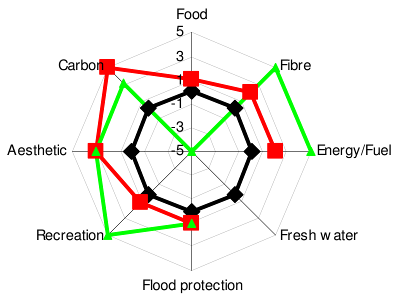
The data gathered from case studies revealed interesting differences between the results of the initial scoping exercise, where representatives were asked to score the 'significance' of ecosystem benefits at their sites, and their estimated monetary values. Higher values in the scoping exercise are likely to be due to differences between the hoped-for importance of services, such as timber or energy fuel crops, which 'should' have high value, as opposed to the current market realities. It also reflects aspirational development of sites that were not available for evaluation. The scoping exercise made it possible to record this view and to compare this with the scenario results (Figure 7).



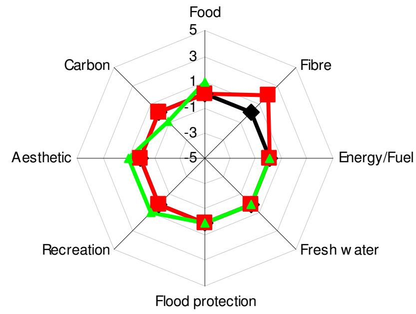
Ennerdale



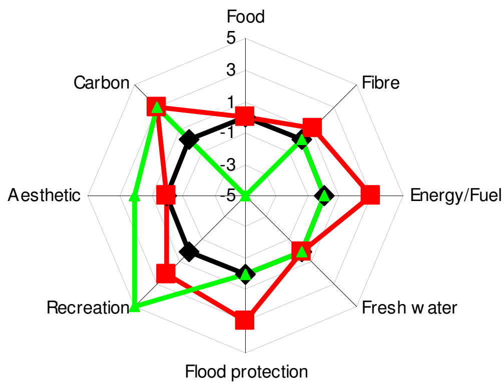
Frome catchment (30/60%)



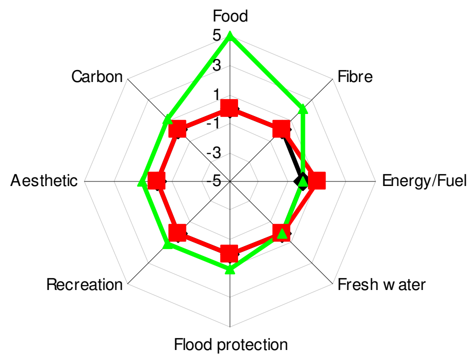
Great Fen



Heather and Hillforts



Knepp Estate



Pumlumon

Figure 7. Extent of change in service provision envisaged through the stakeholder scoping exercise (red) and the evaluation process (green). Percent change in the evaluation was applied by converting to scores where up to 20% = 1, up to 40% = 2 etc., and flood protection was given a nominal score of 1. The black line indicates 0 – no change.

Using what we have termed 'standard', or nationally available, monetary values for some services, such as meat or timber, may be necessary where local data are difficult to access, and this approach is sometimes advocated for comparing sites. Use of such proxy values is commonplace in the study of ecosystem services and may be combined with locally derived data to represent values e.g. (Birch In press). However, results from our case studies, particularly Ennerdale and Pumlumon, showed the major differences in valuation that can occur between generalised values and the local values. The generalised values failed to account for variation in the product itself, local market forces and costs of production. This was particularly evident for timber values which vary greatly depending on the ease of access for harvest and also beef production where the value is very dependent on the specific source (see Tables 9 and 10 in Appendix 1). For the production of timber in Ennerdale, the difference between local and standard values was sufficient to require separate notation on the summary chart (Table 3). The standard values (denoted by the first arrow) show a large decline in timber production on implementation the landscape-scale scenario but when local values are used, the reduction is less marked. The importance of this type of context sensitive in valuation of ecosystem services is increasingly recognised (Eigenbrod et al. 2009; Nelson et al. 2009).

Although proxy values are generally far more easily available than empirically derived local values, and their use may be advocated to enable comparisons, they should be used with caution, as major differences in valuation can accrue. The development of more context-sensitive approaches should be encouraged.

Table 3. (opposite page). Summary of changes in ecosystem services under alternative scenarios. EN is Ennerdale, FR is Frome, GF is Great Fen, HH is Heather and Hillforts, KN is Knepp, PM is Pumlumon. For Frome, LS 30 is Landscape 30% , LS 60 is Landscape 60%, and LS 30/60 Landscape 30/60% PP is minus pre-project. ↑ indicates an increase of greater than 50%; ↗ indicates an increase of less than 50%; → indicates no change; ↘ indicates a decrease of less than 50%; ↓ indicates a decrease of greater than 50%; NA indicates that the service was not valued at a site, and grey that this scenario was not produced. Grey arrows are used for flood protection, as this was based on a qualitative assessment. It should be noted that the total monetary value does not include aesthetic or biodiversity.

Ecosystem service	Landscape minus Pre-project					Landscape minus Business-as-usual					Business-as-usual minus Pre-project					LS 30 - PP	LS 60 - PP	LS 30/60 - PP
	EN	**GF**	**HH**	**KN**	**PM**	**EN**	**GF**	**HH**	**KN**	**PM**	**EN**	**GF**	**HH**	**KN**	**PM**	**FR**	**FR**	**FR**
Food	↓	↓	↗	↓	↗	↘		↗		↗	↘		↗		→	↘	↘	↘
Fibre/raw materials	↓↘	↑	NA	NA	↘	↓↘		NA		↘	↘		NA		→	→	→	→
Fuel/energy	NA	NA	NA	NA	→	NA		NA		→	NA		NA		→	NA	NA	NA
Fresh water provision	→	NA	NA	NA	→	→		NA		→	→		NA		→	NA	NA	NA
Flood protection	→↘	↗	→	→	↗	→↘		→		↗	→↘		→		→	↗	↗	↗
Recreation	↗	↑	↗	↑	↗	↗		↗		↗	→		→		→	↑	↑	↑
Aesthetic	↗	↗	↗	↗	↗	↗		↘		↗	↘		↗		↘	↗	↗	↗
Carbon storage	↗	↗	↘	↑	↗	↗		↘		↗	↗		↘		↘	↗	↗	↗
Biodiversity – ECIA score	↗	↗	→	↗	↘	↗		→		↘	→		→		→	↗	↗	↗
Biodiversity – BAP area	↗	↑	↗	↑	↑	↗		↗		↑	↗		↗		↘	↑	↑	↑
Total monetary value	↗	↗	↘	↑	↗	↗		↗		↗	↗		↘		↘	↗	↗	↗

Biodiversity
The impacts of the landscape-scale scenarios on biodiversity were explored using three methods: change in area of habitat, change in the index for Ecological Impact Assessment (EcIA) and change in landscape connectivity.
Increases in habitat areas were inevitable because the scenarios were created to represent the successful achievement of the landscape-scale projects (Appendix 6). The percentage change in BAP habitat is understandably very large in some scenarios and reflects the nature of the project, aspirations of the project partners and assumptions about pre-project conditions. The potential impact of the increases in area aspired to in the case studies would provide major contributions to, or exceed, national targets for many current BAP habitats (Figure 8). However, there are trade-offs between management for specific BAP habitats, with losses of some to enable expansion of others indicated both by the mapping with project partners (e.g. Ennerdale) and the modelling of strategic nature areas (Frome catchment) (Appendix 6). Spatial realisation of these trade-offs is only possible through scenario mapping, such as carried out for this project, and should be a useful planning tool for future projects.

Trade-offs between habitats can be usefully explored through scenario mapping and constitute a useful planning tool for landscape-scale projects.

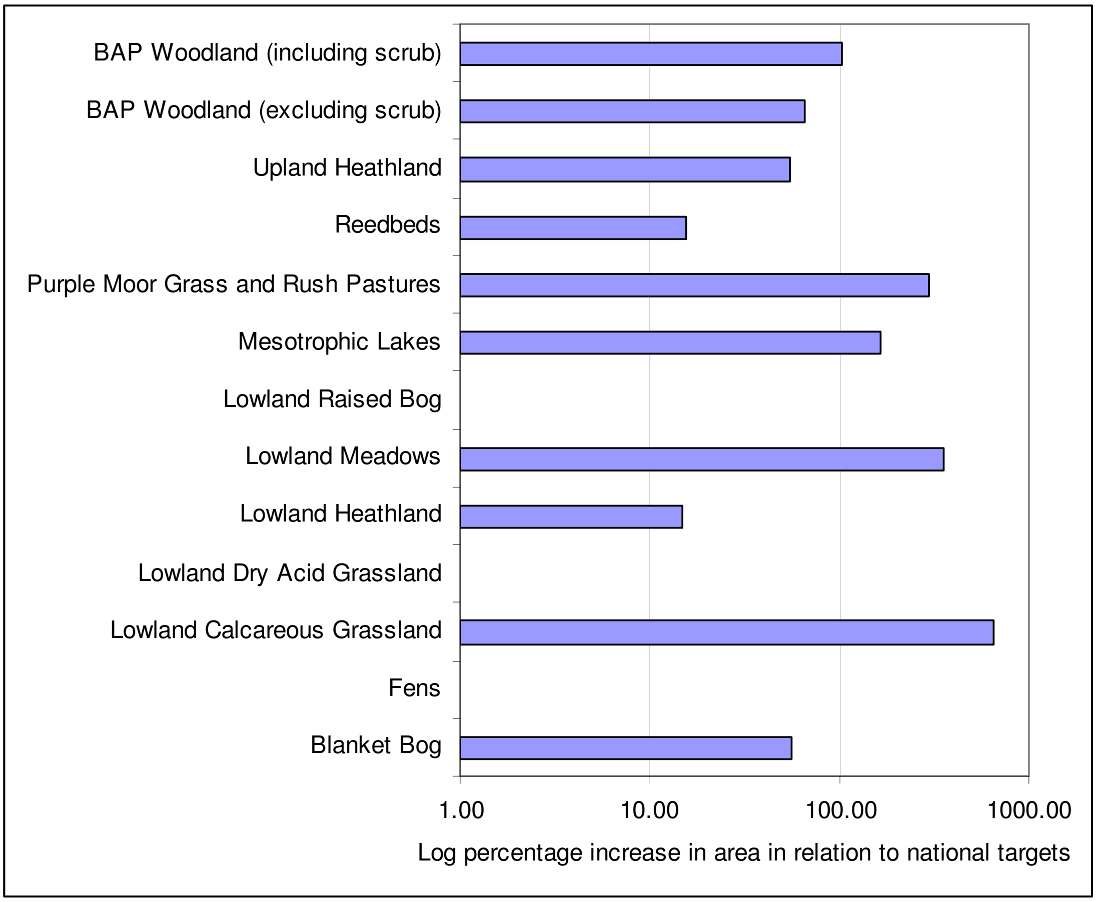


Figure 8. The increase in area from Pre-project to Landscape-scale scenario as a percentage of national targets for England and Wales. Data are combined for all case studies. Note that three priority habitats do not have bars as these reduced under the Landscape-scale futures.

The EcIA score was employed to put the impact of the restoration in the context of regional and national priorities, with the aim of developing a decision making tool. There were limitations to the method. For instance, the scores were sensitive to the accuracy and completeness of data on regional and national habitat area. Woodland scores had to be combined due to this issue. So EcIA methods may have potential for further application as national and regional inventories of habitats are improved. The percentage change in score for each case study gave an indication of the difference between the pre-project and landscape scale scenarios in relation to national priorities (Table 4). Even if there was a large increase in area for a given habitat, this would not necessarily translate to a large increase in EcIA score if it was not a significant increase in the context of the national resource.

So for the Frome strategic nature areas and Knepp castle a large benefit in terms of meeting the national priorities is indicated; whereas smaller, or even negative, effects are indicated in other cases. This outcome needs to be interpreted with caution as the EcIA does not take into account limitations in terms of what habitats it is *possible* to restore in each site and also for the reasons outlined above. Increases in EcIA that were smaller than might be expected given the large area of restored habitats, reflected trade-offs between habitats, or in some cases was an artefact of the level of detail in the future scenario mapping. For Ennerdale, and especially Heather and Heathlands, the proportional change in BAP habitat was small but improved *condition* was expected in the future scenarios. The EcIA method could be improved by incorporating condition as well as area if being applied to observed change. It would not have been helpful in this case as improved condition would be inevitable in the vision scenarios.

The significance of the habitat restoration, as indicated by an EcIA score, was increased where restoration converted land with low conservation value. Low or negative scores should be interpreted with caution.

A further point to consider is that the scores for the landscape-scale future scenarios were based on the area of BAP habitat under the future scenarios as a percentage of the *current* national and regional resource figures. These figures are likely to be different in the future: if they increase then the habitat in the project area may not be as significant and the converse would be true if national and regional values decreased. The Lawton review (Lawton 2010) has called for "*more"* and *"bigger"* natural areas but priorities will need to be set in terms of restoration for specific habitats. This type of EcIA analysis may help to provide indications of how local and regional priority setting interacts with these priorities.

The EcIA enabled consideration of the restored scenarios in a wider context. This showed major differences between case studies in terms of the impact of the envisioned restoration. The utility of this method is currently limited by data incompleteness and other factors, however this approach merits further development as useful tool for testing the potential impacts of restoration plans.

Table 4. Summary of changes in EcIA score and total area of BAP habitat between the landscape-scale (LS) and pre-project (PP) scenarios. The EcIA scores are calculated using the UK (rather than England and Wales) as the national resource, and the Knepp and Pumlumon scores are calculated excluding scrub.

Case study site	PP EcIA score	PP total BAP habitat (ha)	LS EcIA score	LS total BAP habitat (ha)	% change in EcIA score: LS - PP	% change in BAP habitat: LS - PP
Ennerdale	3.4	1542	3.5	1979	3	28
Frome 30_60%	4.3	6934	5.2	18554	21	168
Great Fen	2	602	2.1	3634	5	504
Heather and Hillforts	4	1812	4	1902	0	5.0
Knepp	2.8	104	3.8	751	48	622
Pumlumon	4.7	9318	4.3	14920	-9	60

Finally, the impact of the scenarios on functional connectivity was investigated for the Frome catchment. Interestingly, the changes in connectivity did not always simply follow the greatest increase in area of the habitat network. For woodland species, although area reduced the number of networks also reduced, indicating greater connectivity. Thus, suitable spatial planning of habitat expansion can increase connectivity while allowing for trade-offs with other habitats.

Reduction in habitat fragmentation is key to the landscape-scale approach, and so the effects of the modelled scenarios for restoration were explored using the Frome catchment using the focal species approach to detect the number of habitat networks. This method was particularly useful for exploring the potential trade-offs between connectivity where several priority habitats exist within a landscape, as will often be the case. The method is dependant on the focal species concept and the indices of habitat permeability assigned to these 'species'. Although these are based on the literature and expert judgement, they would benefit from further development with empirical evidence at the species level. Recent tests of the sensitivity of methods to assess habitat connectivity have shown that these show " high sensitivity of the models to variation in buffer distance (i.e. maximum dispersal distance) and permeability of common landscape features" so that models using best estimates for these values should be interpreted with caution (Brouwers 2010).

There are promising developments in this area as empirical knowledge on indicator species is gained. For instance, our understanding of the permeability of agricultural landscapes to moths has recently been greatly improved, and macro-moths are good indicators for biodiversity (Merckx 2009). Detailed aspects of landscape structure, such as the presence of hedgerow trees, was found to be important in this case, and such studies will help point to landscape metrics that can be used to improve the evidence for functional connectivity in landscapes and to refine the permeability metrics.

Differences in functional connectivity can be usefully explored between future scenarios using the focal species approach. The Frome case study illustrated the usefulness for investigating trade-offs between connectivity where more than one priority habitat coincide in multifunctional landscapes. Advances in species specific knowledge are improving our ability to robustly understand landscape functionality and this should be a priority area for research.

Cost and benefits
The costs of conservation actions were derived from estimates provided by the site partners, apart from the Frome catchment, where such data were unavailable and estimates from published data on agri-envirionment scheme costs were used. The costs for the Knepp castle estate (Table 5) were unique, in that it was assumed that no conservation work would take place without the wildlands project. The amount used in this summary was taken as the specified costs rather than the total agri-environment grant (see also Appendix 1). For the other sites, some conservation work was ongoing in the pre-project scenario.

These differences in assumptions and methods should be considered when comparing costs between sites. Real differences do exist in terms of costs. For instance, where land acquisition is necessary, as in the Great Fen, the set up costs will reflect this and where large capital investment may also be required for works such as fencing or hydrological engineering in some sites. However, differences will also be caused by the variation between cost estimation methods between sites.

Table 5. Costs of conservation work estimated for each of the case study sites and showing the additional costs of implementing the landscape-scale scenario(s).

	Area (ha)	**Set up cost**	**Pre-project annual running cost**	**Landscape-scale annual running cost**	**Additional annual cost**
Ennerdale	4,300	73,000	64,064	84,064	20,000
Great Fen	3,700	50,000,000	315,083	470,000	154,917
Heather and Hill forts	2,982	26,883	23,751	205,312	181,561
Knepp Wildland	1,400	1,242,000	0	84,975	84,975
Pumlumon 2006-2010	30,000	253,000	1,449,319	1,506,199	56,880
Pumlumon 2011-2015	“	N/A	1,449,319	2,264,034	814,715
Frome LS_30	48,295	3,465,036	2,095,962	3,787,626	1,691,664
Frome LS_30-60	“	7,544,090	2,095,962	6,089,869	3,993,907
Frome LS_60	“	8,055,843	2,095,962	6,262,999	4,167,037

Cost benefit analyses were considered at the outset of this project to supply a neat method for summarising the policy choices for landscape-scale restoration. This approach can be used to provide a Net Social Benefit (Birch et al., 2010). However, this approach requires full monetisation and is acknowledged to be, as yet, subject to considerable uncertainty.

As an illustration for our sites a Benefit:Cost ratio for was calculated for Ennerdale. If the cost is compared to benefits over the 50 year period chosen to envisage the outcome of the Wild Ennerdale vision (2010-2060) the Benefit:Cost ratio is positive (13). This assumes that overall cost is the set up cost, plus the annual difference in running costs for 50 years (73,000 + (50*20,000) = £1,073,000) and that the benefits are the difference in stock in the year 2060 between Wild Ennerdale and the Business as Usual scenarios for the carbon and timber and the annual difference in revenue for food production and recreation (£14,371,734).. The positive outcome is highly influenced by the market price set for carbon, with very substantial differences resulting from the choice of value and this would also be the case for the other sites that were studied. If carbon is excluded, the Benefit:Cost ratio becomes negative (-0.01). However, the benefits are underestimated non-monetised benefits cannot be included.

As it was possible to use the two future scenarios for the Ennerdale example, discounting was not applied because the effects would equal out for both the scenarios. Calculation of these ratios for sites without a business-as-usual scenario would have required discounting to enable to compare present and future values. However, more complete and accurate monetisation would be required to make this exercise worthwhile.

The importance of including values that cannot be assessed in monetary terms should not be underestimated. This includes the intrinsic biodiversity value and the aesthetic value of landscape, as well as more subtle effects on long-term health and well-being, of users of the project areas. If a cost benefit analysis is required then it would be crucial to ensure that these factors can be included – either by converting all elements assessed to indices or by converting these elements to a monetary format. This aspect still requires a good solution.

5. Alternative approaches in an urban context

Application of the scenario creation method was not appropriate for the urban environment due to the inherent differences between the rural case study areas and the urban areas. In the former, land cover differences are extensive between scenarios; whereas, in the latter there are more likely to be changes in 'quality' of land cover or urban specific changes such as the development of green access routes.

Green Infrastructure in the UK

In the urban context, the current mode for development of landscape-scale initiatives is through strategies for Green Infrastructure (GI) which develops the living environment within *and between* urban, peri-urban and rural areas. Green infrastructure aims to develop a matrix of green spaces and networks to link these environments and achieve multifunctional goals for the enhancement of biodiversity and provision of ecosystem services. Structures such as green roofs and living walls have a role but much of the emphasis is in altering the status of existing parks and gardens and in improving access. Issues of human health, citizenship, social cohesion, recreation and education are particularly important in urban areas (Maas et al 2006). For the majority of UK citizens, the primary experience of biodiversity is in an urban setting and so enhancement of biodiversity in this setting has very important social as well as intrinsic value.

Understanding of the urban biodiversity resource has increased greatly in recent years, for instance in the meticulous recording of the biodiversity of urban gardens (e.g. Loram et al 2008) and the understanding of the potential functioning of greenways or habitat corridors in urban areas is an area of rapidly growing understanding. Although Angold et al (2006) did not find any evidence of the use of urban greenways for dispersal by plant or invertebrates, both Angold's study, and more recent work, emphasise the need to integrate understanding of functional connectivity to allow species movements in urban planning (Kong et al 2010).

The distinctive biophysical features of urban landscapes also lead to important functions for Green Infrastructure in mitigation of climate change impacts. The highly modified surface cover of urban areas leads to creation of urban heat islands and increased surface run-off of rainwater. Key changes include a loss of vegetation which reduces evaporative cooling and surface sealing which increases run-off. Importantly, climate change will amplify the effects of these distinctive features, hence the urgent need to develop suitable green infrastructure (Gill et al 2009).

There are now numerous Green Infrastructure initiatives in the UK, including the Green Infrastructure North West programme, part of the Natural Environment North West initiative, schemes in the North East [9], Yorkshire and Humber[10], East Midlands[11], West Midlands[12] and Thames gateway green grids[13].

Strategy development

Development of GI strategy requires an intensive early stage of mapping the existing resource and identifying the areas for investment in GI. Many regions of the UK have reached this stage and the challenge is now funding for implementation.

For instance, the strategy for SE Dorset[14] was initiated through a study to assesses the current state of GI in the area, look at priorities and suggest zones for development. The region considered in this strategy is very large and encompasses one of our other study areas (Frome catchment) from this report. While considering GI priorities the strategy emphasises links with other policy objectives such as SANG[15]s.

Further development of strategies has entailed a number of different approaches to map and quantify the multiple benefits required from the GI. For instance, the Liverpool Green Infrastructure Strategy group is currently working on a strategy action plan. In this, they used a qualitative assessment of the benefits supplied by the existing GI using a qualitative approach. They assigned values (generally 0 or 1) to 28 functions to assess the deliver of the 11 benefits in the typology established by the Natural Economy Northwest programme. This is work in progress. In the East Midlands mapping at a somewhat coarser scale was used to assess differences in 'public benefit' from potential investments in GI shown by the 'Public Benefit Recording System (PBRS) technique'.

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[9] See NE newsletter 2010 http://www.naturalengland.org.uk/Images/GIupdate_tcm6-11962.pdf

[10] Ecotec 2008 Green Infrastructure and the Regional Spatial Strategy for Yorkshire and the Humber: developing the evidence base. http://www.yhassembly.gov.uk/dnlds/Final%20GI%20Report.pdf

[11] http://www.tep.uk.com/strategies/green-infrastructure/green-infrastructure-in-the-east-midlands.html

[12] http://www.growingourfuture.org/wmwff/taskgroups/gip/plan_pros.htm

[13] Case study to develop tools and methodologies to deliver an ecosystem based approach - Thames Gateway Green Grids – Defra project NR0109.

[14] LUC (2010) SE Dorset GI: Evidence and Opportunities.

[15] Suitable Alternative Natural Greenspaces.

A number initiatives at a national scale now exist, for instance, Liverpool is one of a group of cities in the CABE initiative "Sustainable Cities" http://www.cabe.org.uk/sustainable-cities , the city is also seen as potentially a leading local authority in delivering another CABE initiative, "Grey to Green".

6. Conclusions

The scenario comparisons between site-based and landscape-scale management suggest that considerable advantages can be envisaged through landscape-scale management, both for biodiversity conservation and for ecosystem services. This conclusion relies on many assumptions, including that the landscape-scale vision is achieved by 2060, and should be interpreted with this in mind. There are also numerous assumptions associated with the valuation of services, the monetary valuation of benefits implies that money will exchange hands, particularly if project costs are to be recouped or exceeded. However, there are currently no clear systems for payment for these benefits, so such comparisons should be taken as illustrative of the principle of benefits rather than necessarily indicating monetary gains.

One of the key strengths of the scenario approach adopted here is that it is suitable for providing the 'powerful narrative' needed to link biodiversity with sustainability and which is increasingly recognised as essential for ensuring that long-term landscape and habitat conservation goals are met[16]. Scenarios are also likely to be useful tools in the planning for Ecological Restoration Zones (ERZs), if that is implemented as recommended in Lawton et al. (2010). Such projections of landscape change enable decision makers to envisage the interaction of multiple benefits and the changes in these under different management regimes. In this research, the scenarios developed for the Frome demonstrated the utility of the tool for exploring alternative interpretations of regional conservation strategy and the impacts of this on costs and outcomes for biodiversity and ecosystem services. Projection of a business as usual future is more challenging than the landscape-scale future, because in addition to the uncertainties inherent in any future vision, in the BaU case there are not even any project visions or strategies to guide the scenario creation. The output for Pumlumon did however demonstrate that it is useful to explore these alternative scenarios, as the benefits, especially in the case of carbon, are more pronounced when the landscape vision scenario is compared to the alternative business-as-usual future due to likely degradation of habitat should land management continue as usual.

The responses below summarise the insights provided by the research including priorities and knowledge gaps related presented in response to the key questions posed by the project specification.

(i) *Is the contribution to UK BAP targets significantly affected by the landscape approach? Is it possible to adequately evaluate this question, and if not, what additional primary data collection is required?*

The scenarios approach essentially visualised the outcome of successful implementation of the landscape-scale projects and compared these to business-

[16] EASAC (09) Ecosystem services and biodiversity in Europe

as-usual. Hence, there are inevitable benefits in terms of increases in priority habitat. As landscape scale projects mature, the measurement of baseline data and appropriate monitoring of habitats and species is essential to confirm these outcomes. In addition to the increase in overall area of habitat, increases in the connectivity for movement of species across the landscape is integral, in the medium and long-term to achieving BAP targets and biodiversity conservation more generally in a dynamic landscape. Therefore, the further development of measures of connectivity especially in terms of functional connectivity for species is a prime concern. The methods adopted here, based on focal species (Watts et al. 2008a) are useful for exploring the potential impacts of alternative restoration options on biodiversity but are somewhat limited by a paucity of empirical data. Future work of this sort will be enhanced through availability of more and better data for the parameters such as permeability of the landscape for priority species and also indicator species (Brouwers 2010). Research to fill this knowledge gap, such as recent work on moth populations in an agricultural landscape (Merckx 2009) should be prioritised.

Encouragement of suitable monitoring works is a priority. A key knowledge gap is in understanding the functional connectivity of the landscape for species which can be addressed through research on priority and indicator species.

(ii) *How does the net cost of landscape scale approaches compare with more traditional approaches?*

The estimation of net costs as a monetary value was very challenging due to the many areas of uncertainty in the projection of the scenarios, and also in the assessment of ecosystem services, some of which were not feasible to monetise. Although a Benefit:Cost ratio was estimated for one project, this was not inclusive of all factors, and was highly sensitive to carbon values. The data were not suitable for generation of these values for all of the projects. Nevertheless, it was possible to see that increased provision of most services occurred in the landscape-scale scenarios and that even the incomplete benefits valuations would generally outweigh the costs. This effect was largely dependent on carbon values, and for this reason those sites which showed the greatest change in land-use had higher overall increases in value of ecosystem services.

Simplified representation of degree of increase or decrease in ecosystem services (e.g. Table 3) may be a more useful tool where highly uncertain data may obfuscate the results. Ideally though, development of further tools for a more complete assessment of services offers the possibility of more robust assessments bearing in mind that certain benefits such as aesthetic or intrinsic value, can never be accounted for using a quantitative approach.

The estimation of flood risk mitigation is an area in particular need for further development. The methodology developed to assess flood risk for the Ennerdale case study was a potentially useful way of interpreting trade-offs when looking at flood risk. However, the approach is very simplified, and is only suitable for low-level interpretation of the effects of land use and soil moisture retention indices. The main areas of uncertainty are the values ascribed to the retention index which are based on expert judgement, as little suitable data exist on moisture retention of land use types in their landscape context. The main challenge is to bring together these datasets with a flow model, so that cumulative downslope risk may be mapped. These ideas will be developed in a new Defra project: BD 5005 "The provision of ecosystem services in the environmental stewardship scheme". In addition, the FEH approach as outlined in Defra report FD2114/PR2 could be used alongside this approach to assess the flood risk.

Better still; an integrated approach that uses parallel methodologies to get a better understanding of the flood risk issues within a catchment should be pursued. Modelling at the fine scale would only really be possible once hydrological time series from ongoing projects become available, and the mapped surface features (such as buffer strips or blocked grips) are incorporated into the model inputs, e.g. via high resolution digital terrain models.

Increased provision of ecosystem services was predicted under the landscape-scale scenarios, and in many cases this appeared likely to compensate for the set-up and increased running costs. Notably, the valuations for ecosystem services were highly sensitive to carbon values and this might be balanced in future by more complete monetary valuation, particularly of flood mitigation potential.

(iii) *What are the costs of landscape scale approaches and how may they be offset?*

The costs of the landscape-scale approaches varied greatly between the projects both in scale of cost and its components. It included capital costs, such as fencing or engineering works for the alteration of drainage patterns, ongoing costs such as employment of a project officer. This variation was deliberately included in this assessment as a range of different landscape scale projects was selected in order to be as representative as possible of the types of initiatives included in this definition. Hence, sites under single ownership and discrete partnership projects were included as well as wider regions where only estimations of costs based on generalised restoration costs were possible.

The costs were assessed as the increase compared to a site-based alternative. Here, the additional costs were very sensitive to the assumptions made in most projects about the amount of land that might be included in agri-environment schemes without the landscape scale project. The need for integration of biodiversity enhancement with economic sustainability was a major theme in the management plans of the landscape- scale projects and it is the successful implementation of this vision that will be the key to offsetting costs. There is a strong view expressed by representatives working in the field that this integration is crucial to the long-term success of the projects.

Costs of the landscape-scale projects, in relation to site-based alternatives, are very site-specific and also may be dependent on assumptions about what type of conservation management occurs without the initiative. Offset of costs is also site dependent in detail but in general is approached through integration of conservation and economic objectives.

(iv) *Which are the preferable management options and how does this vary between landscapes?* Management options for landscape-scale projects are very much dependent on the environmental and social landscape. Two main themes can be identified from the research: (i) application of intensive restoration methodologies in a landscape context and (ii) reduced intervention management over a wider area. Most sites included an element of each of these aspects, such as (i) intensive works to rewet peatland or fen and (ii) extensive grazing over mixed habitats. As a rule the wilder upland landscapes, such as Ennerdale, have more scope for the dominance of reduced intervention options whereas the patchwork landscape of the lowlands is more amenable to targeting such as the whole landscape targeting of agri-environment schemes.

Management options in any one landscape-scale initiative will include a mixture of targeted intensive and reduced intervention options. The relative application of these will vary mainly in relation to location in either upland or lowland localities.

(v) *To what extent is it realistic to develop the landscape-scale approach further, and what are the potential policy instruments that could be used?*

The benefits for biodiversity and other ecosystem services envisaged by the scenarios endorse the support of his approach, assuming the successful implementation of the projects. To be *realistic,* the landscape-scale initiatives must be sustainable economically over the long term. The range of commercially exploited ecosystem services such as premium meat, reeds and recreation, that are planned or developed by the projects considered shows the way forward for integrating with the local economy. The domination of the combined benefits by carbon values suggests that support of many landscape-scale initiatives through carbon-offset potential should be considered, at the same time other benefits yet to be monetised effectively, such as flood mitigation, may also be future recipients of Payments for Ecosystem Services (PES). Other PES are already being practised in support of large scale restoration projects, such as the support of rewetting schemes by water companies[17].

Although these market forces should be encouraged as much as possible, it is also recognised that the market alone cannot be expected to deliver the full range of ecosystem services from a given landscape[18] and the overall challenge is to determine the optimum policy instruments for enhancing natural assets with economic and social sustainability. The projects examined here showed the key importance of agri-environment schemes in delivering landscape-scale projects. Suitably targeted the available resource has enormous potential for enabling the restoration of an ecologically functioning landscape - about £400 million each year is paid to England's land managers through AES (Natural England 2009c).

Many conservation NGOs (such as the Wildlife Trusts) have amassed, not only great expertise in targeting agri-environment schemes with an integrated

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[17] For instance rewetting mires on Exmoor supported by South West Water http://www.exmoor-nationalpark.gov.uk/mire

[18] LUPG Securing our common future through environmentally sustainable land management

landscape approach in mind, but also have invaluable insights and established connections with local farming communities. Further integration with research on functional connectivity and systematic monitoring, should suitable funding be available, will enhance these approaches. A key point emphasised by site representatives was the benefits of the landscape-scale approach in consolidating effort which should prevent lack of coherence and continuity in funding. Nevertheless, even for larger partnership projects, the lack of continuity in funding has been seen to have a negative feedback effect, discouraging confidence in funding for specific works.

Realistic landscape-scale initiatives will be well integrated with the local economy, and supported through appropriate policy instruments, to ensure that there is adequate sustainability for large temporal as well as spatial scale.

Appendices

Appendix 1 – Building and evaluating alternative management scenarios

Appendix 2 - Scoping the actual and potential benefits from ecosystem services

Appendix 3 - Details of the land cover reclassification

Appendix 4 – Search terms for UK willing to pay studies

Appendix 5 - UK willingness to pay studies

Appendix 6 - Change in extent of priority habitats under alternative case study scenarios

Appendix 7 – References