Character Area Climate Change Project NE117R

Climate Change Impact Assessment and Response Strategy: Shropshire Hills Character Area

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Shropshire Hills Character Area

View from Stiperstones to Long Mynd

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Further information
This report can be downloaded from the Natural England website: www.naturalengland.org.uk. For information on Natural England publications contact the Natural England Enquiry Service on 0845 600 3078 or e-mail enquiries@naturalengland.org.uk

Summary

Introduction

Natural England is working to deliver a natural environment that is healthy, enjoyed by people and used in a sustainable manner. However, the natural environment is changing as a consequence of human activities, and one of the major challenges ahead is climate change.

Even the most optimistic predictions show us locked into at least 50 years of unstable climate. Changes in temperature, rainfall, sea levels, and the magnitude and frequency of extreme weather events will have a direct impact on the natural environment. Indirect impacts will also arise as society adapts to climate change. These impacts may create both opportunities and threats to the natural environment.

Natural England and its partners therefore need to plan ahead to secure the future of the natural environment. One way in which we are doing this is through the Character Area Climate Change Project.

The project aims to identify the local responses required to safeguard the natural environment and our enjoyment of it. In the pilot phase we are focussing on four of the 159 'Character Areas' in England, one of which is the Shropshire Hills. The others are Cumbria High Fells, The Broads, and Dorset Downs and Cranbourne Chase.

This report provides the detailed findings from the pilot project. The summary leaflet is also available on our website at www.naturalengland.org.uk. It:

- identifies significant natural environmental assets;
- assesses potential climate change impacts on these assets; and
- puts forward potential adaptation responses.

What we learn from the four pilot projects will be used to extend the approach across England as part of our aim to build a healthy and resilient natural environment for the future.

About the project

The objective of the Character Area Climate Change Project is to ensure that when decisions on the future of places like the Shropshire Hills are made, proper account is taken of impacts on the natural world, as well as on communities and their livelihoods. It is not Natural England's role, or intention, to take such decisions, but to initiate debate on the impacts of climate change on the natural world, so that well informed decisions about its future can be taken.

Communities and their livelihoods are vital considerations in the development of any future strategy to respond to climate change. This leaflet does not attempt to cover these issues, not because they are unimportant, but because our role is primarily in relation to the natural environment.

Ensuring a strong, healthy, diverse and inclusive society that lives within environmental limits is the key objective of sustainable development. Natural England seeks to contribute to this through its management of the natural environment. We recognise that environmental and social solutions need to proceed in tandem. Informed by this report, we will consult communities, other organisations and Government to find approaches that deliver successful and long-term adaptation to climate change.

Taking action to respond to climate change will also depend on the cooperation of those who own and manage the land. We do not take that cooperation for granted and are aware that many measures would require appropriate incentives. At this stage we do not intend to pursue the mechanisms of change, but to explore with others potential responses which are feasible and acceptable in principle.

Significant natural assets

The most significant biodiversity assets found in the Shropshire Hills include:

- European dry heaths that contain features transitional between lowland heathland and upland heather moorland. The Stiperstones is regarded as an outstanding example of European dry heath and further extensive areas occur on the Long Mynd.
- Old Sessile Oak Woods with Holly and Hard Fern – the Stiperstones and the Hollies contains an area of this habitat that is regarded as nationally important.
- Other nationally important habitats are semi-improved and unimproved grasslands on acidic soils, and lowland meadows.
- A number of species, protected under the EC Habitats Directive including River Water Crowfoot, Otter, White Clawed Crayfish, Lesser Horseshoe Bat, Dormouse, and Brook Lamprey.
- BAP priority species, including Otter, Water Vole, Red Grouse, Merlin, Curlew and Lapwing.

The majority of the Character Area falls within the Shropshire Hills Area of Outstanding Natural Beauty (AONB). Significant landscape assets include:

- moorland on the Stipesrtones, Long Mynd and Clee Hills;
- unimproved semi-natural grassland across much of the area;
- ancient and semi-natural woodland, adding variety to the landscape scene;
- rivers and streams with associated lines of alder trees that are prominent features in the landscape;
- Varied geology. The Shropshire Hills has a more varied geology than any other area of comparable size in Britain. Recognised as a classic area for geological study, the Shropshire Hills contain many sites of national and international importance for their geological features. Many of the pioneering geological investigations were carried out in south Shropshire and Series names such as Wenlock and Ludlow define internationally accepted periods of geological time.
- historic environment features, including prehistoric earthworks, extraction sites, veteran trees, deserted medieval villages, traditional orchards and associated planned farmsteads, historic field boundary patterns and prehistoric plus Romano-British crop mark complexes.

The Character Area is widely used for recreation and tourism. It possesses a number of access and recreation assets including:

- An extensive network of public rights of way totalling 2,407km and including popular routes such as the Offa's Dyke National Trail, Jack Mytton Way and the Shropshire Way;
- Over 6,000 ha of open access land, much of which coincides with some of the best heathland on the Stipertsones and Long Mynd;
- rivers used for angling and providing income to local landowners;
- rugged uplands, popular for off-road cycling;
- Sustrans cycle routes;
- open access land and certain routes that are popular for horse riding;
- areas such as the Long Mynd, that are well used by educational groups undertaking environmental field work..

The most significant ecosystem services provided by the Shropshire Hills, from which we all benefit, include:

- the soils and geology which underpin all the agricultural enterprises in the area;
- water resources, which are key to agriculture and important for human and animal health;
- food and fibre products from its farming, fisheries and forestry enterprises;
- recreation, tourism and education opportunities, which are abundant throughout the Shropshire Hills;
- the Stiperstones and Long Mynd have important roles to play in holding water during peak rainfall events and helping to provide flood protection for Shrewsbury and other towns down stream in the river Severn Catchment;
- maintenance and expansion of the heathland and woodland network is contributing towards climate regulation by locking up carbon from the atmosphere, there is much potential for futher network expansion.

Likely impacts of climate change on the Shropshire Hills
Evidence from the UK Climate Impacts Programme (2002) shows that the climate in the Shropshire Hills over the coming century is likely to become warmer and wetter in winter and hotter and drier in summer. In addition, rainfall intensity will probably increase.

The most significant impacts of climate change on the Shropshire Hills are predicted to be:

- a change in the species and communities that make up habitats;
- changes in the timing of seasonal events like flowering, breeding and migration;
- more frequent droughts, which could result in crop failures and very low river levels affecting river biodiversity;
- increased erosion in winter, resulting in more nutrients being washed into rivers;
- an increase in fire risk particularly on areas of heathland such as the Stiperstones and Long Mynd as outdoor recreation becomes more popular and visitor numbers grow;
- intense storm events are likely to happen at a greater frequency which means that habitats will struggle to recover from any damage they cause. This potentially will have the greatest impact in wooded areas such as Wenlock Edge.

- a loss of mature trees in the landscape as these succumb to extended droughts and more severe storms;
- differences in the ability of woodland species to adapt to a longer growing season;
- an increase in the popularity of shaded areas such as woodland for recreation as temperatures rise ;
- Increased risk of heat stroke and sunburn as average summer temperatures increase and peak temperature events become more frequent;
- an increase in visitor numbers;
- a reduction in water resources available for agriculture, recreation, potable water supply and habitats;
- changes in the viability of some crop varieties and livestock breeds that are less able to cope with drought conditions;
- damage to historic buildings and structures such as earthworks, caused by an increase in soil erosion during peak rainfall events.

It is important to remember that climate change will not be the only change over the coming century. Changes in farming systems, the economy, population patterns and cultural values will also affect the natural environment of the Shropshire Hills. Indeed, climate change may have a greater impact on natural assets through changes in agriculture than through direct biophysical impacts. Changes to the types and varieties of crops, sowing dates, irrigation, pests, diseases and soil erosion are all likely. This report does not try to assess these, although they will have significant implications for the area and any proposed adaptation measures.

Adaptation options
Responding to the impacts of climate change requires adaptation to prevent natural environment assets and the social and economic benefits that they provide being lost. There are a number of adaptation responses that could be employed within the Shropshire Hills:

- Improve the condition of existing habitats to improve their resilience and expand their extent.
- Restore and create habitats by extending existing areas of semi-natural habitat and creating new areas. Extending existing habitat networks is recommended as the best way to safeguard the greatest number of species.
- Ensure structural diversity within new and existing habitats, to ensure there is a wide variety of microclimates;
- Identify research needs and commission appropriate studies to build adaptive capacity.
- Be aware of and plan for potential future catastrophic events such as the emergence of new pests and diseases. These could have significant impacts on agriculture and wildlife.
- Provide shade and drinking water at tourist attractions and recreation sites.
- In the wider landscape, promote a variety of tree species to eventually replace existing mature trees and safeguard against susceptibility to drought and storms.
- Re-establish pollarding regimes in historic parklands to reduce the susceptibility of veteran trees to storm damage.

- Record and rescue some structures and known archaeology, where at extreme risk, as a safeguard against total loss of features through climate change impacts.
- Regularly monitor and manage important geological sites to ensure that exposures remain visible.
- Manage catchments to reduce rainfall run off from land in the upper catchment by maintaining or establishing appropriate land cover and thus safeguarding downstream features from risk of flooding.
- Adopt sensitive farming methods - leaving vegetated buffer strips around fields and not leaving fields bare, so that run off of potentially harmful sediments is reduced.
- Use the spatial planning system to maintain adequate land for the natural environment.

Next steps

This report on how climate change is likely to affect the natural environment of the Shropshire Hills Character Area, and the adaptation responses required, is a significant first step but cannot be conclusive. It provides an indication of what may happen, but the future impacts of climate change are still uncertain and are partly dependent upon the amount of greenhouse gases that society releases and how much is released by natural feedback loops from the environment (one of our biggest unknowns).
When identifying adaptation actions, existing strategies, policies and initiatives need to be considered. Some actions defined as climate change adaptation are already occurring under a different name and it may be possible to modify existing programmes to provide a mechanism for delivering adaptation. An example of this is the planned incorporation of climate change adaptation into Natural England's Environmental Stewardship Scheme.

Natural England is now working on:

- an implementation plan, which may include a demonstration project. Natural England will work with local partners to ensure that this dovetails with existing initiatives;

- Learning from the pilot process to assess likely climate change impacts and the required adaptation strategies for other Character Areas both regionally and nationally.

The future of the Shropshire Hills depends on the actions we all take today to reduce our greenhouse gas emissions. This combined with decisions we make about managing our landscapes to adapt to unavoidable climate change will determine whether we continue to have a high-quality landscape that is cherished and respected by all.

Technical report

Contents

1. Introduction

Natural England is working to deliver a natural environment that is healthy, enjoyed by people and used in a sustainable manner. However, the natural environment is changing as a consequence of human activities such as development and climate change. Natural England is therefore developing plans to secure the future of the natural environment. One way in which Natural England is achieving this is through the Character Area Climate Change Project. Four Character Areas have been selected. These Character Areas represent a range of landscape types across England, (see Figure 1.1).

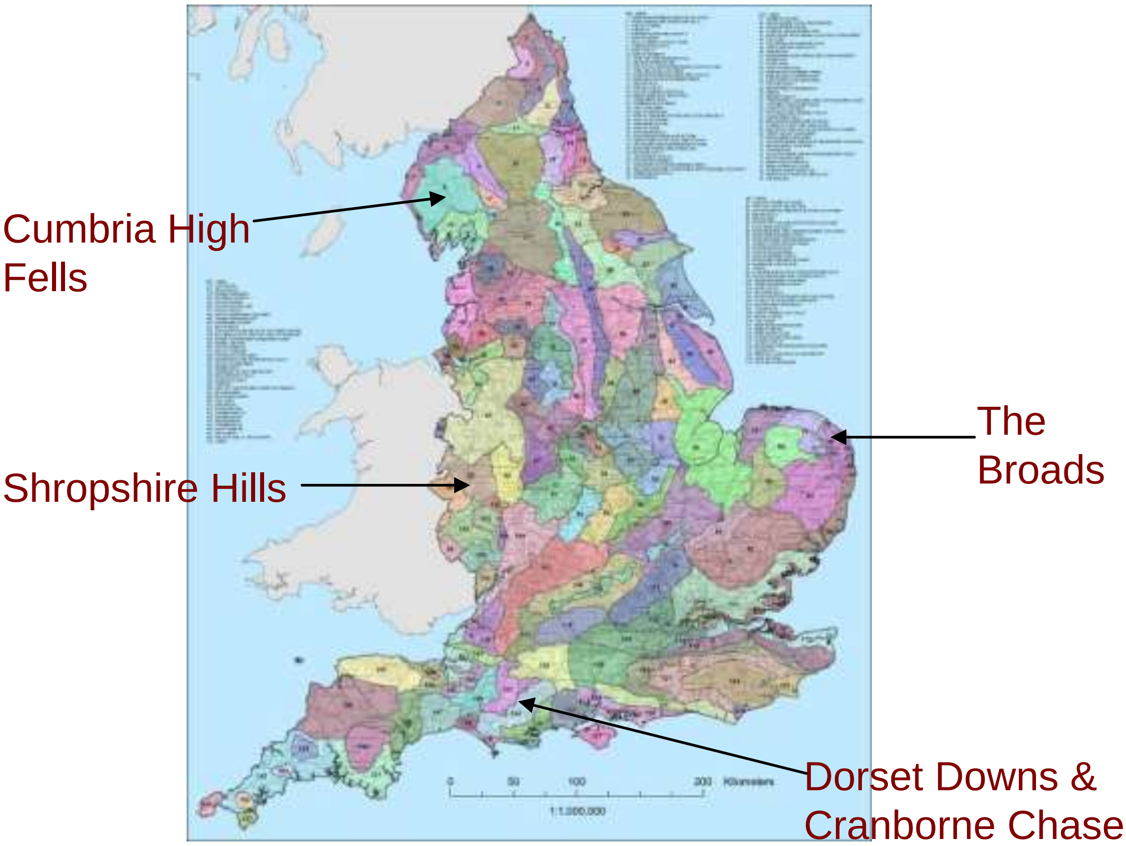

Figure 1.1 the four character areas used in the climate change pilot project

The project has three main elements, which form this report:

- identification of significant natural environmental assets;
- assessment of potential climate change impacts; and
- development of responses to adapt to the impacts.

The project has involved national habitat experts and local staff with knowledge of the Shropshire Hills Character Area.

A list of significant natural environmental assets has been complied from which the Shropshire Hills Character Area specific impacts of climate change have been identified. The impacts constitute a 'do nothing' option for the future, ie assume no response. Subsequently, detailed responses to each impact are presented.

Mitigation of climate change is not included in this report; other projects are addressing this within Natural England. Future work is planned that will assess the contribution that adaptation measures can make to mitigation strategies within the Character Areas.

This report is structured as follows:

- Section 2: Background to Character Area - brief description of the Character Area and the important natural environmental assets.
- Section 3: Impacts – identification of direct and indirect climate change impacts based on bioclimatic data for the Character Area.
- Section 4: Adaptation – identification of response strategies and assessment against 'good adaptation' principles.
- Appendix 1: Project methodology.
- Appendix 2: Briefing on socio-economic scenarios.
- Appendix 3: Main tables.
- Appendix 4: Landscape case study of historic farmsteads in the Shropshire Hills

2. Background to the Character Area

Box 2.1 Key features of the Shropshire Hills Character Area

- **European dry heaths** that contain features transitional between lowland heathland and upland heather moorland.
- Old Sessile Oak Woods with Holly and Hard Fern and Upland Mixed Ashwood.
- Other nationally important habitats are semi improved and unimproved grasslands on acidic soils, and lowland meadows.
- A number of species, protected under the EC Habitats Directive including River Water Crowfoot, Otter, White Clawed Crayfish, Lesser Horseshoe Bat, Dormouse, Brook Lamprey.
- BAP priority species including Otter, Water Vole, Red Grouse, Merlin, Curlew and Lapwing.
- 52,643ha of the Shropshire Area of Outstanding Natural Beauty falls within the Character Area.
- Landscape features include: moorland; unimproved semi-natural grassland; ancient and semi-natural woodland; rivers and streams; and geological features.
- Historic environment assets include: prehistoric earthworks on unenclosed moorland; extraction sites associated with mineral workings; areas of ancient field patterns and veteran trees; shrunken and deserted medieval villages, traditional orchards and associated planned farmsteads; and small-scale prehistoric and Romano-British crop mark complexes.
- Water resources – reservoirs, major aquifers and catchments.
- Flood plains provide natural protection from fluvial flooding.
- The majority of agriculture in the upland areas of the Shropshire Hills is sheep and some cattle grazing.
- The unique geological interest of the area is a significant educational asset.
- 52,643ha of the Shropshire Area of Outstanding Natural Beauty falls within the Character Area.
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- Water resources – reservoirs, major aquifers and catchments.
- Flood plains provide natural protection from fluvial flooding.
- The majority of agriculture in the upland areas of the Shropshire Hills is sheep and some cattle grazing.
- The unique geological interest of the area is a significant educational asset.
- 2,407 km of public rights of way and 6,220 ha of CROW Open Access land.
- Angling is an important recreation activity in the Shropshire Hills.
- The rugged upland terrain makes the area popular for mountain biking and off-road cycling but there are also a number of sus-trans cycle routes crossing the Character Area.
- Extreme sports are becoming increasingly popular.
- The Character Area possesses a number of significant attractions including The Wrekin, Wenlock Edge, Long Mynd and Stiperstones.

2.1 Location

The Shropshire Hills are bounded by the Shropshire, Cheshire and Staffordshire Plain to the north and the Severn Valley and Mid Severn Sandstone Plateau to the east. To the south-east lies the Teme Valley, on the edge of the Herefordshire Plateau, and to the south-west the Clun and North West Herefordshire Hills (see Figure 2.1).

Figure 2.1 Shropshire Hills Character Area boundary

2.2 Significant natural environmental assets

2.2.1 Biodiversity

Internationally important assets
The Stiperstones and the Hollies Special Area of Conservation (601 ha), designated under the EU Habitats Directive is an example of **European dry heaths** that contains features transitional between lowland heathland and upland heather moorland. The site also includes Annex I habitats, principally **Old Sessile Oak Woods with Holly and Hard Fern in the British Isles**.

A number of species, protected under the EC Habitats Directive, occur in the area including river water crowfoot *Ranunculus fluitans,* for which the UK holds 20 per cent of the global population, otter and white clawed crayfish, present in tributaries of the River Teme. White clawed crayfish is a globally protected species, listed in the Red Data List of endangered species of the International Union for the Conservation of Nature (IUCN). Other species include lesser horseshoe bat; dormouse, which is present in a number of semi natural woodlands in the area and brook lamprey.

Nationally important assets

The Character Area contains 3,676 ha of Sites of Special Scientific Interest (SSSI) in some **63** sites and around 7,921 ha of BAP habitat (the aggregated habitat inventory from which this figure is drawn requires review and updating, so this is not an accurate figure).

Heathland (upland and lowland) is a nationally important habitat feature. Extensive areas are present on the Long Mynd (see Figures 2.2 and 2.3), Stiperstones, Catherton Common and Brown Clee Hill. The Shropshire Hills contains 1.5 per cent of the national resource of upland heath and 0.7 per cent of the national lowland heath resource.

The Shropshire Hills holds a significant area of unimproved and semi-improved grasslands.

A number of BAP priority species occur in the Shropshire Hills. Species include otter; water vole; red grouse, which is on the southern edge of its range here; merlin; curlew and lapwing.

Locally important assets

The Shropshire BAP lists a number of locally important species, see Table 2.1.

There are a number of iconic species which the Shropshire Hills Character Area is known for. Theses may not be the most important species in terms of conservation interest (although they often are) but those which are popularly considered as representative of the area. Iconic species in the Shropshire Hills include buzzard, curlew and raven.

Picture 2.1 View east from the Stiperstones

Picture 2.2 Heathland on the Long Mynd

Table 2.1 Locally important BAP species

Classification	Species
Birds	Barn Owl Curlew Dipper House sparrow Lapwing Ring ouzel Snipe Yellowhammer
Plants	Black Poplar Green-winged orchid
Mammals	Brandt's bat Brown long-eared bat Daubenton's bat Leisler's bat Natterer's bat Noctule bat Serotine bat Sopranno pipistrelle Whiskered bat
Invertebrates	Club-tailed dragonfly Dingy skipper Grizzled skipper Grayling Small Pearl Bordered Fritillary
Fish	Atlantic Salmon Lamprey (brook and river)

2.2.3 Access and recreation

There are 2,407 km of public rights of way in the Shropshire Hills Character Area including a number of circular walks. The area is crossed by numerous bridleways and is popular with horseriders.

6,220 ha of land in the Character Area is CROW Open Access land. In addition to CROW access land, much Forestry Commission and National Trust owned land is open to the public.

Angling is a significant recreation activity in the Shropshire Hills. There are a number of rivers in the Character Area, including the River Severn, which are used for angling.

The rugged upland terrain makes the area popular for mountain biking and off-road cycling but there are also a number of sus-trans cycle routes crossing the Character Area. National Cycle Routes 44 and 45 and Regional Route 31 run through the Character Area.

Extreme sports are becoming increasingly popular and there are a number of activity centres including GoApe and rock climbing.

Areas such as the Long Mynd, that are well used by educational groups undertaking environmental field work.

The Character Area possesses a number of significant attractions including Wrekin, Coalbrookdale, Long Mynd and Axton Scott. The unique geological interest of the area also draws visitors to the Shropshire Hills. There are a number of attractive market towns and the Ludlow food festival is a significant visitor attraction.

2.2.4 Landscape and geodiversity

Sixty five per cent, or 52,643ha of the Shropshire Hills Area of Outstanding Natural Beauty (AONB) falls within the Character Area. The Natural Area profile for the Shropshire Hills describes five key conservation features in the Character Area:

- **Moorland**: Heathland, mire and flush, acid grassland and bracken, rock faces and scree;
- **Unimproved semi-natural grassland**: Neutral, calcareous, and wet grassland;
- **Ancient and semi-natural woodland**: Ash-elm-oak stands, western sessile oak and alder woods;
- **Rivers and streams**: Headwater streams, brooks and rivers, with associated riparian habitats;
- **Geological features**: Precambrian and Lower Palaeozoic stratigraphy and periglacial features. The Shropshire Hills contain many sites of national and international importance for their geological features. Many of the pioneering geological investigations were carried out in south Shropshire and Series names such as Wenlock and Ludlow define internationally accepted periods of geological time.

The Shropshire Hills form an area of great geological variety with distinctive landscape features such as the steep-sided ‘whaleback’ or ‘hogback’ (Toghill 2006) hills. The Long Mynd is a dissected plateau and the Wenlock Edge area is described as ‘scarp and vale' hills of open moorland interspersed with settled, cultivated valleys (Toghill 2006).

The Shropshire Hills are dominated by a series of south west to north east running ridges, scarps and intervening valleys. The principal features of which are the volcanic Stapeley Hill, the quartzite Stiperstones, the Precambrian shales of the Long Mynd plateau (see Figure 2.3), the volcanic Stretton Hills, the limestone ridge of the Wenlock Edge and the sandstone and limestone Clee Hills capped by a dolerite sill which is quarried for roadstone. Distributed across the area are many smaller, steep and rounded hills. The hills are topped by a mixture of bare open grassland or open moorland.

On the hill slopes there are patchworks of small pasture fields, often with woodland on steeper slopes. The hill slopes grade into gentler slopes characterised by arable and pasture land. In these areas there is often a strong presence of trees in hedgerows and alongside water courses. Isolated veteran trees in parkland and remnants of apple and damson orchards are present in the landscape.

There are scattered farmsteads in the dales and sheltering valleys, with larger settlements confined to the A49 corridor. Villages and hamlets are distributed across the area. Some areas are characterised by small fields with squatter settlements. Farmsteads on roadsides and in common edge settlements make an especially significant contribution to the character of the Shropshire Hills.

The area exhibits great diversity in its historic environment interest. The earliest evidence for human occupation comes from the burial monuments of the Bronze Age and less understood boundary and settlement earthworks on the undisturbed, unenclosed land. Iron Age hill fort settlements are common and characteristic of the hilly, much fought over, Welsh Marches. Under arable cultivation, more ordinary pre-Roman and Roman settlements are observed, suggesting this extends into improved pastures. There are areas of particularly coherent medieval field patterns with associated earthwork mottes, settlement sites and historic farmstead complexes within the Character Area.

Common-edge settlements sprung up from the 16th century onwards, often as “squatter” settlements due to new populations mixing small-scale “crofting” with the then burgeoning industrial activities. The more recent agricultural history of the area is mixed farming, with cattle and sheep rearing the mainstay of hill farms. Intensification, leading to enclosure of rough moorland, began inthe 18th century, with remaining areas such as Clunton Heath part of a much planned transformation in the 20th century. There is little ‘designed’ landscape.

There are 172 Scheduled Ancient Monuments (SAMs), covering 197 ha, in the area, including Offa's Dyke, which is associated with the Offa's Dyke Path National Trail. Most farmsteads have significant historic value, some of which is recognised through Listing. The Historic Environment Record contains several thousand more undesignated sites.

2.2.5 Ecosystem Service Assets

Human beings benefit from processes or structures within ecosystems that give rise to a range of goods and services called ‘ecosystem services’ (POST 2006). The

Millennium Ecosystem Assessment grouped ecosystem services into four broad categories (UNEP 2006):

- Supporting services - such as nutrient cycling, oxygen production and soil formation. These underpin the provision of the other ‘service’ categories.
- Provisioning services - such as food, fibre, fuel and water.
- Regulating services - such as climate regulation, water purification and flood protection.
- Cultural services - such as education, recreation, and aesthetic value.

Although not a service in itself, the geology of the Character Area underpins others including soils and hydrology. Soils in the Character Area are mainly freely draining acid loamy soils, slightly acid loamy and clayey soils with impede drainage and slowly permeable seasonally wet acid and loamy clay soils.

There are a number of rivers in the Character Area which are a source of water for potable supply, agriculture, recreation and the natural environment. The River Clun, River Teme, River Rea, River Severn all cross the Character Area.

Flood plains in the Shropshire Hills Character Area provide natural protection from fluvial flooding. Floodplains and wetland habitats also have a role to play in moderating water quality.

The majority of agriculture in the upland areas of the Shropshire Hills is sheep grazing and some cattle grazing. Shooting, hunting and fishing are existing recreational activities in the Shropshire Hills but there is potential for commercial fisheries.

The Shropshire Hills is an important area for tourism, see Section 2.3.3. Many of the recreation and tourism assets also have value as an educational resource. There are a number of field study and visitor centres in the Shropshire Hills. The unique geological interest of the area is also a significant educational asset.

The natural environment provides an important climate regulation function. Carbon is stored in soils, particularly peat soils, and biomass. The UK uplands are estimated to store 5 billion tonnes of carbon (RSPB undated**). There is a significant carbon store in the Shropshire Hills Character Area in organic soils and biomass.**

2.2.6 All assets

An initial list of the more significant natural environmental assets has been compiled (see Table 2.2). Figures 2.4 to 2.6 illustrate the location of these assets within the Shropshire Hills Character Area.

Table 2.2 Significant natural environmental assets in the Shropshire Hills Character Area

Type of asset	Assets
Biodiversity	Wet woodland Upland Oakwoods Upland Mixed Ashwoods Mixed Deciduous Woodland Ancient and Semi Natural Woodland Ancient Replanted Woodland Conifer Woodland Historic Parks and Gardens Lowland Calcareous grassland Lowland Dry Acidic Grassland Upland Dry Acidic Grassland Upland and Lowland Heathland Lowland hay meadows Purple Moor Grass and Rush Pasture Reedbeds Floodplain Grazing Marsh Rivers and Streams
Access and Recreation	Visitor destinations - 'honeypots' e.g. Stiperstones, Long Mynd, Wenlock Edge, Ludlow. Public Rights of Way and long distance footpaths e.g. Offa's Dyke Path, Jack Mytton Way, Shropshire Way Bridle ways Cycle tracks and national routes Open Access Land Rivers e.g. River Clun, River Teme, River Rea, River Severn Activity centres Geological trails, Wrekin Education site
Landscape, Geodiversity and Historic Environment	Varied geology and landforms with some of the oldest rocks in England. Dominant bare topped and open moorland topped ridges and hills Smaller, steep sided, rounded hills Semi natural vegetation, providing texture in the landscape Small fields on lower hill slopes Numerous trees in lower lying areas in boundaries and along watercourses Woodland on steep hillsides and in valleys Numerous veteran and historic trees in some areas Prehistoric earthworks on unenclosed moorland and hills Squatter settlements associated with historic mineral extraction sites Traditional orchards and associated planned farmsteads Below ground field archaeology Vernacular buildings and structures Scattered historic hamlets and villages There are an estimated 1875 surviving or partially surviving historic farmsteads in the Character Area (2072 if smallholdings are included)
Ecosystem services	Provision of food and fibre – Farming, fishing and forestry Soils and geology Water resources – potable and non potable Recreation and tourism Cultural and spiritual values Educational resources Flood protection Water quality Climate regulation

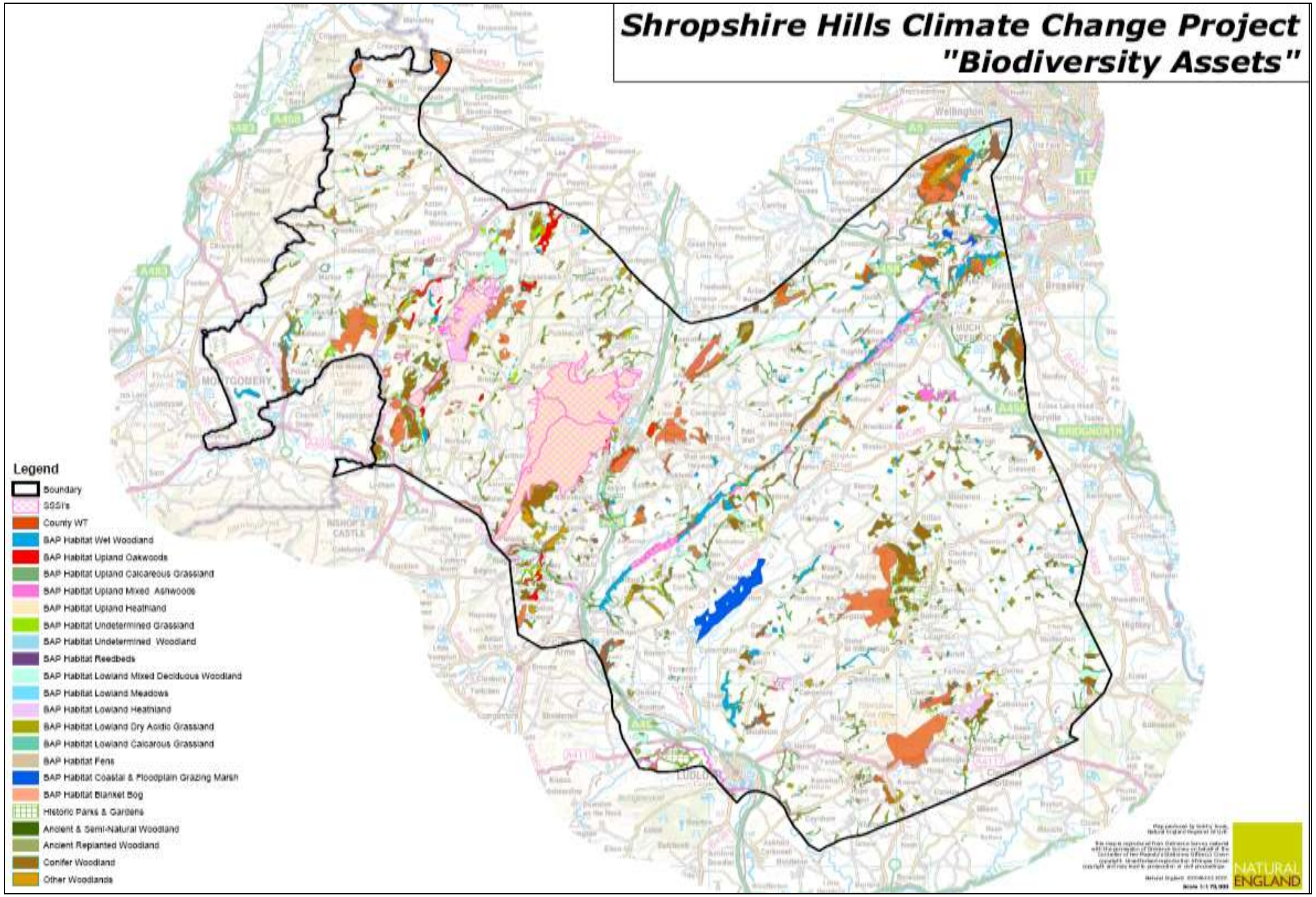


Figure 2.2 Significant Biodiversity Assets in the Shropshire Hills Character Area

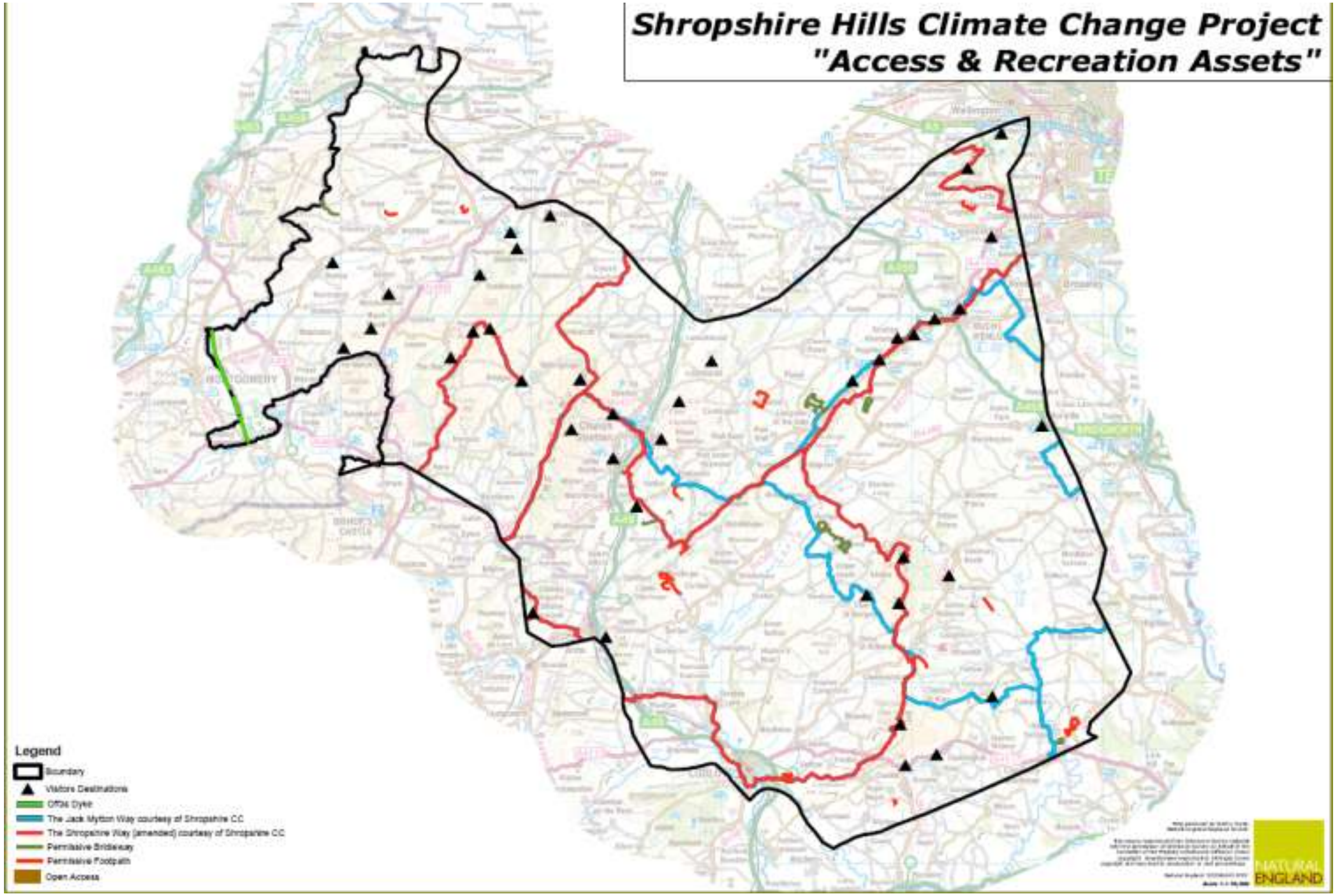
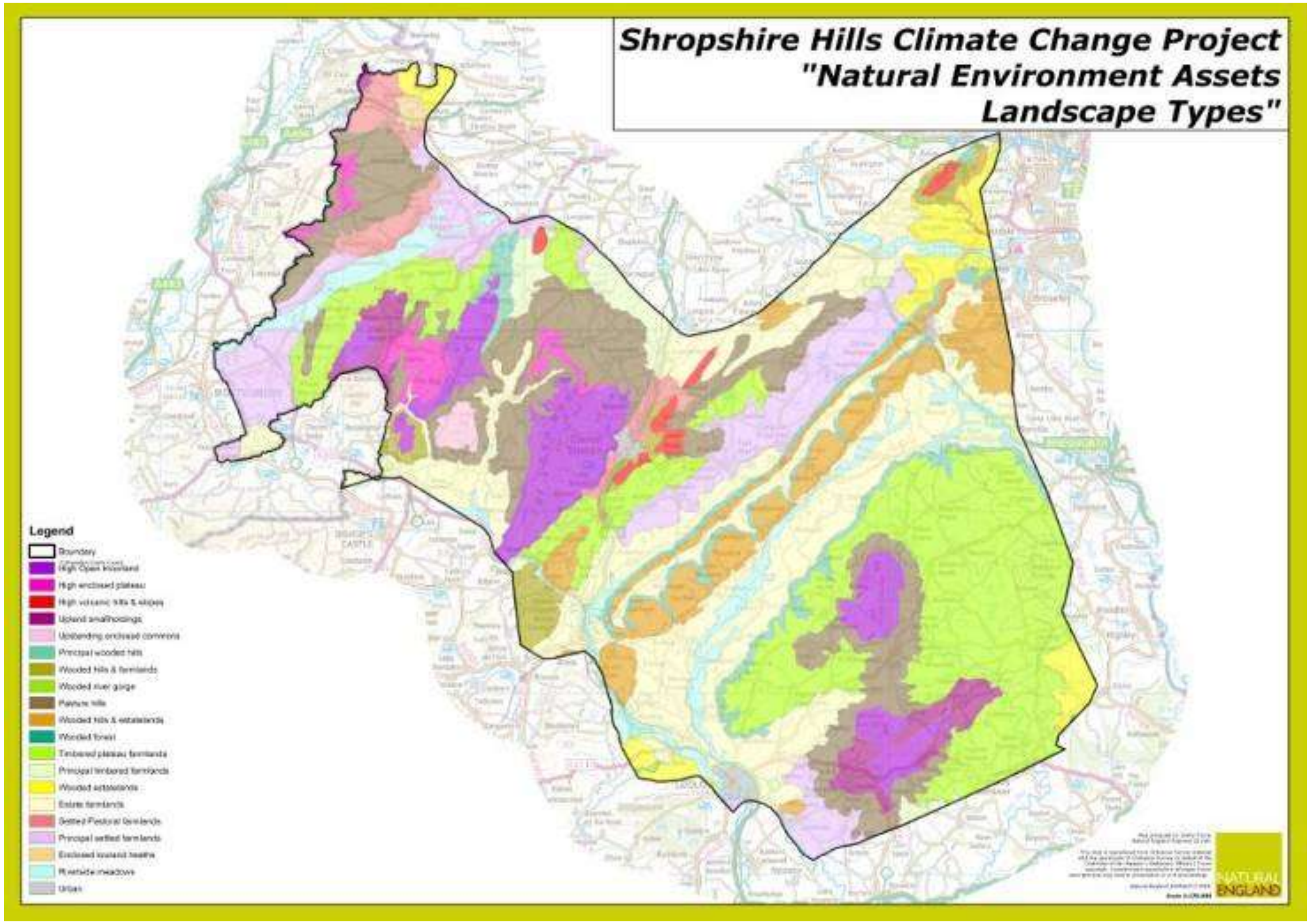


Figure 2.3 Significant Access and Recreation Assets in the Shropshire Hills Character Area



Acknowledgement: Shropshire County Council

Figure 2.4 Landscape Types in the Shropshire Hills Character Area

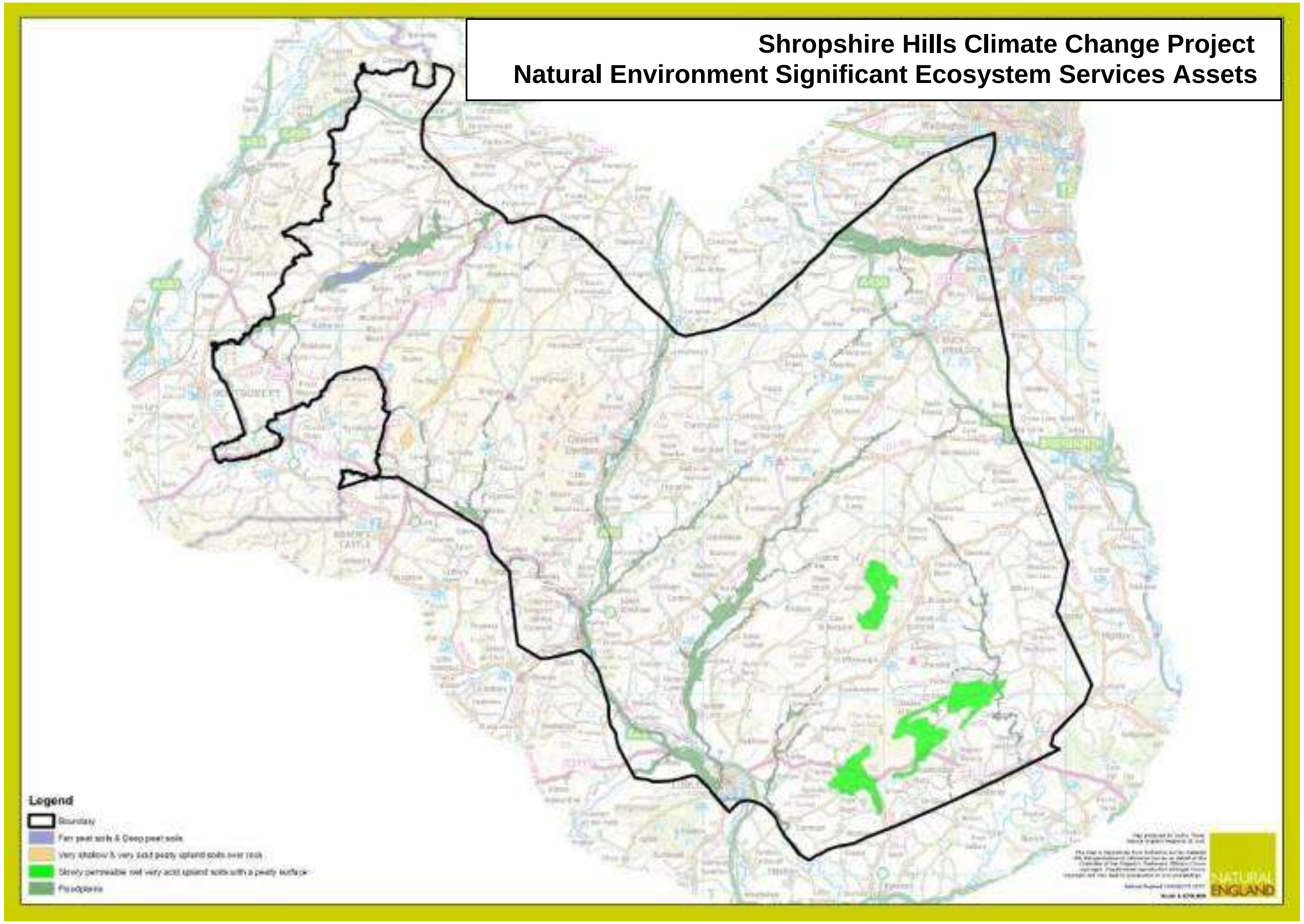


Figure 2.5 Significant ecosystem services assets

3 Impacts

Box 3.1 Key impacts of climate change on Shropshire Hills Character Area

- The main biophysical impact of climate change will be a change in species and communities that make up a habitat.
- Changes in temperature will have phenological effects which are likely to affect community composition (e.g. changes in the timing of events, such as the onset of spring).
- A decrease in summer rainfall may lead to more frequent droughts which could affect wet woodland and other wetland habitats.
- An increase in winter rainfall may increase erosion in winter, resulting in more nutrients being washed into rivers.
- A consequence of an increase in temperature and a decrease in rainfall in summer is an increase in the risk of fires in the Shropshire Hills Character Area. The impacts of fires on biodiversity are not necessarily all negative, although more frequent and/or more severe fires would almost certainly be damaging to biodiversity.
- Storms can have a positive impact on some aspects of woodland biodiversity but an increasing frequency of storm events may reduce their ability to recover.
- Changes in agricultural practices as a result of climate change may have a greater impact on biodiversity than direct biophysical impacts.
- Woodland based recreation is likely to increase in popularity as people seek shade in the hottest months.
- Under conditions of climate change, the hazardous season for outdoor recreation could shift to the summer.
- An increase in visitor numbers may have negative impacts on wildlife and landscape and the visitor opportunity must be carefully managed to prevent it becoming a threat.
- Bracken and scrub are likely to grow faster under climate change and become more competitive.

Exposed, upland sites are preferred for locating on-shore wind farms; hence the Shropshire Hills Character Area could be favoured for wind turbine development.

- The use of the natural environment for energy generation is likely to lead to conflict with landscape and biodiversity interests and will be another pressure on land use.

Box 3.1 Continued

- The types of crops and livestock supported by the Shropshire Hills may be different; current crops may not be able to persist under hotter, drier conditions but new, drought tolerant crops may thrive.
- The impacts of climate change are likely to exacerbate existing pressures in the Character Area. It is possible that the combined effects of climate change and other pressures will exceed the ability of species to adapt to new conditions, or to survive the combination of impacts.
- A change in species and community composition may have an effect on the delivery of current conservation targets which include definitions of 'good quality' and 'favourable' condition' of habitats. These targets have often not been devised with climate change impacts in mind.

In order to identify appropriate adaptation actions it is necessary to first define why adaptation is necessary and what we are adapting to. This involves identifying the impacts of climate change on the significant natural environmental assets of interest, in this case the significant natural environmental assets of the Character Area.

3.1 Bioclimatic Data

3.1.1 Observed climate

In anticipation of the next set of UKCIP scenarios of climate change for the UK, due to be published at the end of 2008, a report detailing observed climate for the UK for two 30 year periods, 1961 – 1990 and 1971 – 2000, has been issued (Jenkins *et al*. 2007). This report presents observed data on the climate variables to be included in the UKCIP08 scenarios. The observed climate between 1961 – 2000 for the Shropshire Hills is summarised in Table 3.1.

Between 1961 and 2000 some warming has been observed in the Shropshire Hills Character Area. Warming is particularly marked in the summer and winter records with an annual average increase of 0.4 to 0.5°C. The observed precipitation record shows an increase in autumn and winter rainfall between the two thirty year periods.

3.1.2 Climate change

The UKCIP02 scenarios project the impacts of climate change under a range of emissions scenarios for the UK (Hulme *et al*., 2002). Scenarios for three different timeslices are presented, representing the average climate over 30 year periods centred on the 2020s, 2050s and 2080s. The climate changes projected to the 2020s are similar across all scenarios; this is because changes in the short term are dictated by past Greenhouse Gas (GHG) emissions. Climate changes beyond the next few decades depend on future emissions, but even the low emissions scenario represents an acceleration of climate change when compared to changes that have occurred in the 20th century The scenarios are based on a UK Met Office General Circulation Model (GCM), coupled to a Regional Climate Model (RCM) which allows impacts to be projected on a local to regional scale.

The bioclimatic data used in this project is taken from the HADRM3 model, a regional climate model with a 50km^2 resolution. The data have also been compiled for different emissions scenarios; high and low emissions, based on the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES). The UKCIP high emissions scenario corresponds to the A1 scenario (see Appendix 2 for further explanation of socio-economic scenarios). Table 3.2 gives the bioclimatic data for the Shropshire Hills Character Area.

Table 3.1 Observed climate of the Shropshire Hills area

Climate variable		Observed climate 1961 - 1990	Observed climate 1971 - 2000	Change 1961-1990 to 1971-2000
Temperature	Annual mean	8 – 10 °C	8 - 10°C	0.2 – 0.3°C
	Spring mean	6 – 8 °C	6 – 10 °C	0.3 – 0.4°C
	Summer mean	14 – 16 °C	12 – 16 °C	0.2 – 0.4 °C
	Autumn mean	8 – 10 °C	8 – 10 °C	-0.1 to 0.2 °C
	Winter mean	2 - 4 °C	2 – 6 °C	0.4 – 0.5 °C
Precipitation	Annual mean	450 - 700mm	700 - 1000mm	-2 to +5%
	Spring mean	100 - 260mm	100 180mm	-5 to +5%
	Summer mean	100 - 260mm	100 – 180mm	-5 to +5%
	Autumn mean	180 - 260mm	180 – 260mm	+5 to+10%
	Winter mean	180 - 260mm	180 - 260mm	+5 to +10%
Wind speed	Annual mean	No data	7 – 14 knots	NA
	Spring mean	No data	7 – 10 knots	NA
	Summer mean	No data	2 – 10 knots	NA
	Autumn mean	No data	1 – 10 knots	NA
	Winter mean	No data	7 – 14 knots	NA
Relative humidity	Annual mean	79 – 85 %	79 – 82 %	-1.2 to -0.6 %
	Spring mean	76 – 82 %	76 – 79 %	-0.9 to -0.6 %
	Summer mean	76 – 79 %	76 – 79 %	-1.5 to -0.9 %
	Autumn mean	82 – 88 %	82 – 85 %	-0.9 to -0.6 %
	Winter mean	85 – 88 %	85 – 88 %	-0.9 to -0.6 %

Source Jenkins *et al*. 2007

Table 3.2 demonstrates that the Shropshire Hills Character Area is likely to experience warmer, drier summers and warmer, wetter winters in future. However, these changes in mean temperature and total rainfall are not the only changes we can expect. It is likely that there will also be change in extreme temperatures and rainfall events; for example, an increase in heat waves and storms, although the confidence associated with predictions of storms is low. It is important to note changes in extremes as they are likely to have significant impacts on the natural environment.

Table 3.2 Bioclimatic variables for Shropshire Hills Character Area

Climatic Variable	Annual average value for Shropshire Hills Character Area					
	2020s		2050s		2080s	
	High	Low	High	Low	High	Low
Change in absolute maximum temperature	1.44 ºC	1.21 ºC	3.43 ºC	2.16 ºC	5.95 ºC	3.07 ºC
Change in absolute minimum temperature	0.72 ºC	0.61 ºC	1.71 ºC	1.08 ºC	2.97 ºC	1.53 ºC
Change in minimum temperature expected over 20 years	0.96 ºC	0.81 ºC	2.31 ºC	1.44 ºC	4.01 ºC	2.06 ºC
Change in growing degree days >5ºC	294	245	753	456	1340	667
Change in mean temperature of the coldest month	No data	0.59 ºC	1.67 ºC	1.05 ºC	2.90 ºC	1.49 ºC
Change in mean temperature of the warmest month	No data	0.94 ºC	2.71 ºC	1.68 ºC	4.88 ºC	2.40 ºC
Change in total potential evapotranspiration	No data	21.2%	62.5%	38.4%	113.7%	55.4%
Percentage change in moisture availability	-47.9%	-40.2%	-116.4%	-72.3%	-207.1%	-103.5%
Change in total precipitation	-3.3%	-2.7%	-7.8%	-4.9%	-13.4%	-6.9%

A visual summary of the major changes in rainfall and temperature expected in the West Midlands is provided in Figure 3.1.

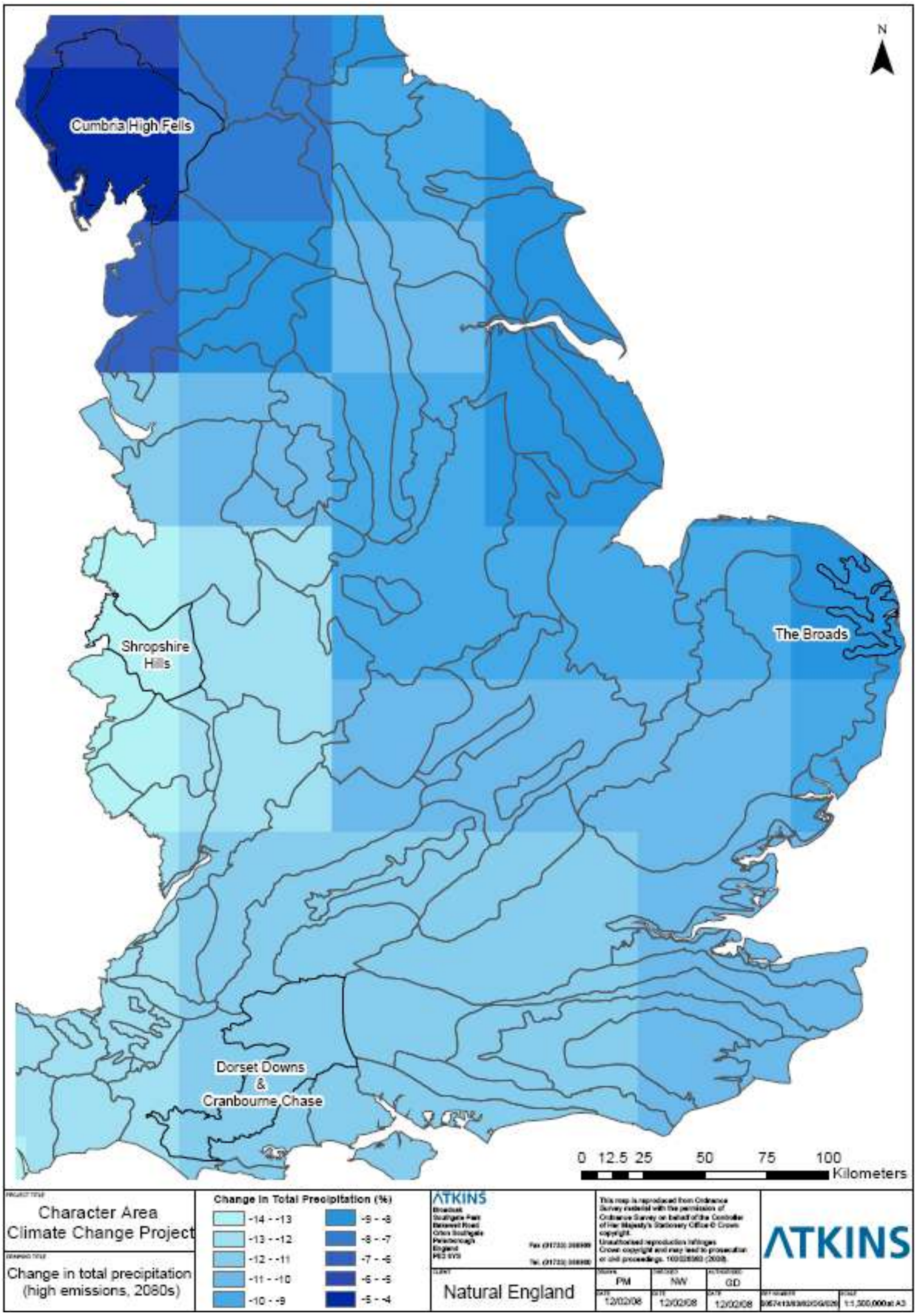


Figure 3.1a Projections of changes in bioclimatic data (2080s high emissions) a) total precipitation

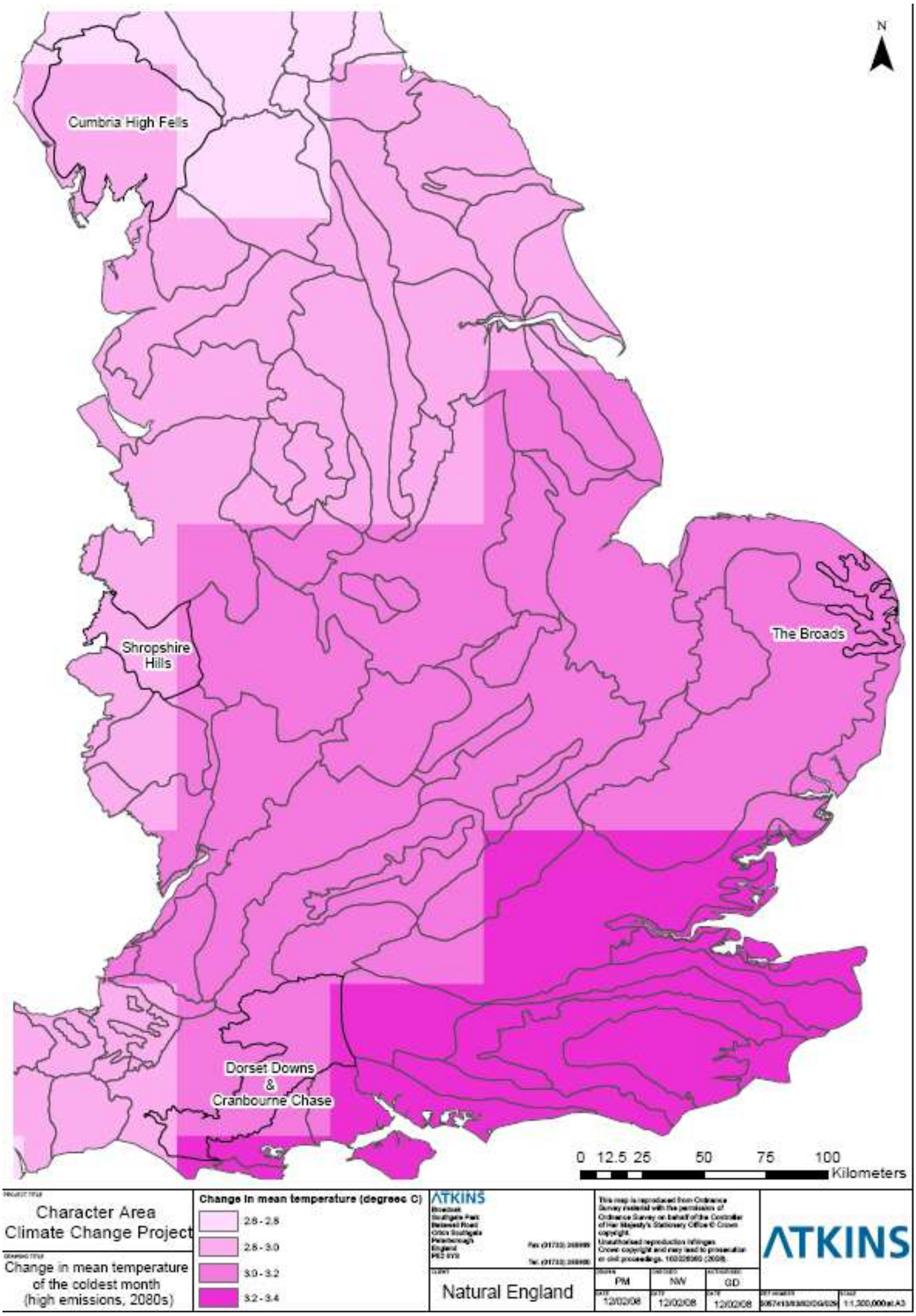


Figure 3.1b Projections of changes in bioclimatic data (2080s high emissions) b) change in mean temperature of the coldest month c) change in temperature of the warmest month

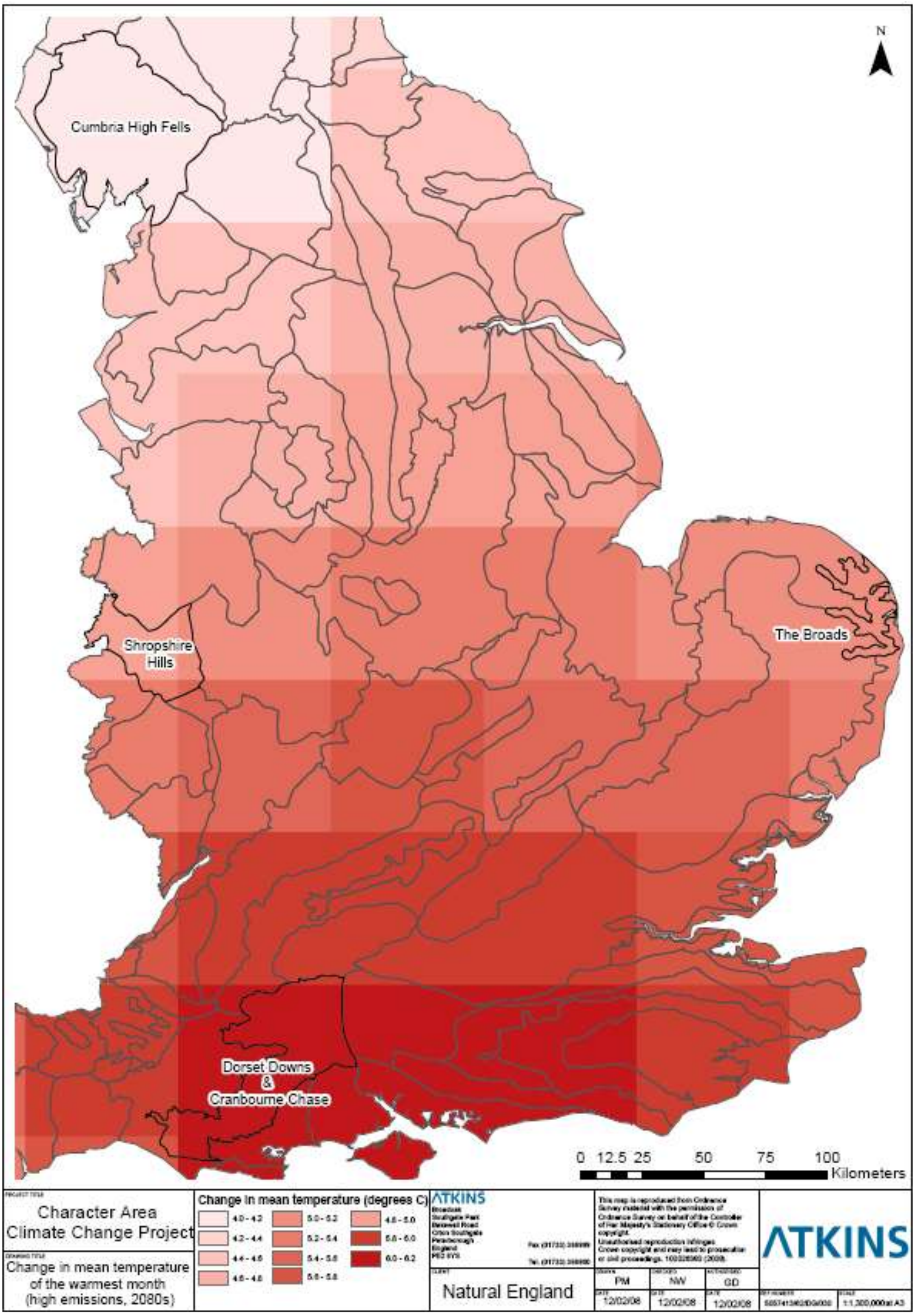


Figure 3.1c Projections of changes in bioclimatic data (2080s high emissions) c) change in temperature of the warmest month

3.2 Types of impacts

Climate change will not be the only pressure on natural environments in the future; other impacts will be felt through socio-economic change. The Shropshire Hills Character Area is heavily influenced by agriculture and changes in agricultural practices are likely to have a significant impact on its species, habitats and landscapes. Changes in agriculture could be driven by climate change, such as crop switching to more drought tolerant plants or increasing intensification due to the failure of harvests in other parts of the world. These would be classified as indirect impacts of climate change on the Character Area. However, shifts in agriculture may occur regardless of climate change, for example fluctuations in crop prices or shifts in consumer demand for certain products. Such changes would be classified as socio-economic impacts. These changes, whether climate induced or not, would significantly impact on the natural environment of the Shropshire Hills Character Area. In reality direct, indirect and socio-economic impacts are closely related. This project focuses mainly on the direct biophysical impacts of climate change on the more significant natural environmental assets in the Character Area. Where significant impacts have been identified (such as those related to agricultural change in the face of climate change) these have been highlighted.

The interaction of climate change and other, socio-economic pressures adds another source of uncertainty to predictions of future impacts. However, the direct impacts of climate change are also subject to uncertainty due to socio-economic change. The future will be different and we cannot predict what it will be like. Socio-economic scenarios provide internally consistent descriptions of potential futures. The impacts of climate change will be mediated by the socio-economic scenario that prevails at the time; changes in attitudes and behaviour towards the natural environment and conservation will alter the nature of the impacts.

Whilst it is important to bear in mind that the future will be different, in order to identify impacts in this project, an assumption that the socio-economic scenario that prevails in future will be broadly similar to that which we currently experience has been made. In identifying impacts, only one emissions scenario (high) for the 2080s has been used to indicate a direction of travel. The full range of bioclimatic data presented in Table 3.1 has not been used. This project has not adopted a formal scenario based approach, nor does it provide an integrated assessment as these are very complex. However, adaptation strategies will be tested against socio-economic futures to determine how robust they are to different scenarios. For further information about socio-economic scenarios, see Appendix 2.

3.3 Impacts on significant natural environmental assets in the Character Area

The broad climate changes projected in the UKCIP02 scenarios and the bioclimatic data given in Table 3.2, along with published research, was used to identify the impacts on the significant natural environmental assets in the Shropshire Hills. Whilst there is some uncertainty over the nature of climate change, and its detailed impacts, this report brings together the best available information on impacts based on the latest science and expert judgement. From this understanding, an initial set of responses has been defined (see Section 4). Table A3.1 in Appendix 3 identifies the climatic changes pertinent to the significant environmental assets and the likely impacts, which are discussed further below.

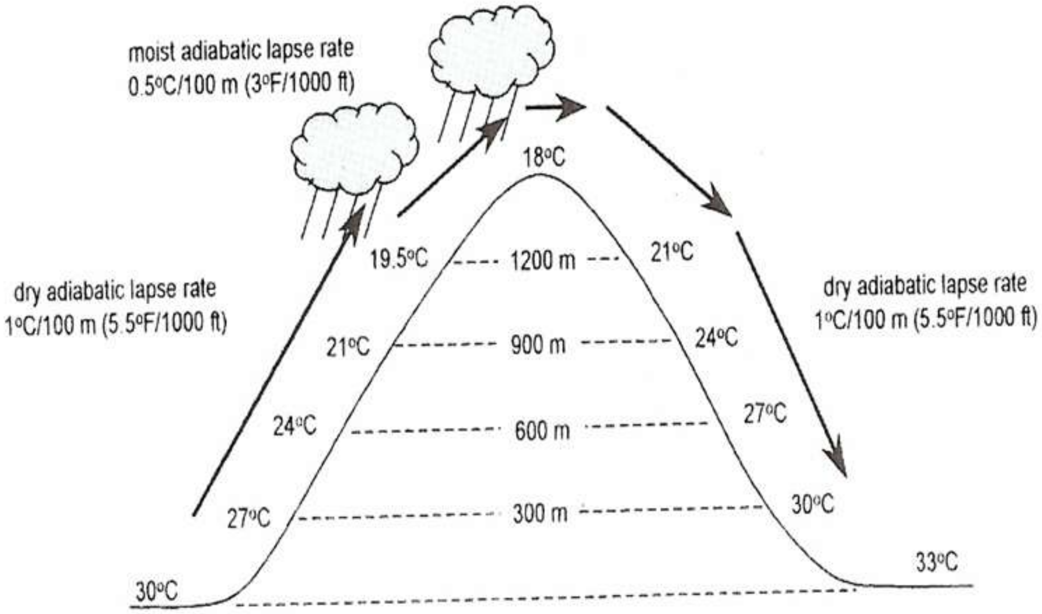
3.3.1 Impacts on biodiversity assets

Direct impacts

The main biophysical impact of climate change will be a change in species and communities that make up a habitat. Results from the Monarch study (Walmsley *et al*. 2007) which assessed the likely change in bioclimatic envelope for a number species, indicate that certain species will gain suitable climatic space in the north and west of the UK whilst losing it in the south. Table A3.1 in Appendix 3 contains details of habitat specific species composition changes but broadly speaking climate change will force species to move upwards (if there is higher ground available) and to the cooler north facing slopes (if they are available), (see Box 3.2). Species will move as suitable climate space changes; in some cases space will remain in the Character Area but will be present in different locations, in other cases suitable climate space will disappear and in other cases new climate space will appear. Within each case the species composition of the habitats will change and the significance of the change on the ecosystem will depend upon the different niche, or role, occupied by the different species that either move in or out of the habitat. Some changes may be significant simply because the species is seen as being significant to the Character Area whilst others may be significant due to the changes they have on the functioning of the ecosystem. It can be useful to look at neighbouring Character Areas to assess which species may move in.

Box 3.2 Change in suitable climate space

As air rises, the pressure it experiences decreases and it expands. As it expands, energy is released and consequently the temperature of the air falls. As a rule of thumb, for every 100m air rises, its temperature drops by 1ºC; this is the dry adiabatic lapse rate (see Figure 3.2). As a result of increasing temperatures at ground level, species will move upwards, if they are able, in order to find the temperature to which they are adapted. There is already observational evidence of this effect occurring; Hickling *et al*. (2006) report that a wide variety of vertebrate and invertebrate species have moved northwards and uphill in Britain over approximately 25 years. This phenomenon is more pronounced in the Alps with certain species observed to be moving 23.9m upwards per decade (Parolo and Rossi 2007). In addition to moving upwards, species will move across valleys to north facing slopes as the temperature on south facing slopes exceeds that which they can tolerate (see Figure 3.3). There is also evidence of species moving in response to topographic influence on micro-climate; Davies *et al*. (2006) report the changing slope and aspect preferences of silver-spotted skipper in response to climate change.



Source; Hopkins, from Bonan 2002

Figure 3.2 Adiabatic lapse rate

Box 3.3 Habitat Networks

The England Habitat Network (EHN) illustrates the existing networks of woodland, grassland, heathland and mires and bogs present in England. A current working definition by Catchpole (2007) of a habitat network is “a habitat network is made up of current statutory sites and sites listed on habitat inventories and surrounding land that is potentially permeable to the species present in the habitat of interest”. Different types of land use, in-between patches of semi-natural habitat, will have different levels of permeability for different species; the network joins up those sites which are separated by potentially permeable habitat or land use.

To maintain the same degree of biodiversity in the face of climate change, more habitat is required. With regard to the EHN there is a need to prioritise habitat creation action (highest priority action at the top):

- Subject to 'ground truthing', aim to maintain the existing mapped EHN for its value as an aggregated area of existing habitat patches;
- Consider extensions/additions to the habitat patches, including the expansion of pinch-points, within the EHN;
- Expanding existing habitat patches in networks outside the current EHN;
- Expand small isolated patches in 'hostile' environments.

Compositional changes are likely in a number of the key asset habitats in the Shropshire Hills for example including:

- Changes in wet woodland ground flora, particularly in mossy “dingle” woodlands in valley bottoms (see Figure 3.2).
- Shifts in the relative contributions of the sub-types of upland ash, for example, there is potential for expansion of the ‘dry’ forms down slope on warmer sites, this will be influenced by how water is controlled geologically/hydrologically.
- Certain acid grassland species are predicted to lose climate space by 2080.

As some species are likely to lose climate space, others will gain it. Not all the species gaining climate space are welcome; climate change may increase the number of non-native and invasive species. In most cases we will have to accept their presence but in others they may require changes in management. Examples identified from the Shropshire Hills include:

- Invasion of oak woods by beech leading to loss of ground flora.
- Increase in ruderal annual grassland species at the expense of perennials, leading to a change in species composition.

Changes in temperature will have phenological effects which are also likely to affect community composition. For example, it is predicted that temperature changes may cause certain lowland hay meadow species to flower or set seed earlier in season. Phenological changes are already being observed in the UK; earlier arrival of birds and butterflies in the spring have been recorded (Sparks *et al*. 2001) and tree leaf appearance in Surrey has been found to be 10 days earlier in the 1990s than the 1980s (Sparks *et al*. 2001). Changes in phenology are another cause of community compositional change as changes in the relative timing of events has knock on effects for other species in the community. There is currently uncertainty over the impact of temperature change on heather beetle in the Shropshire Hills. An increase in temperature may increase the abundance of heather beetle, with negative effects on the condition of upland heather. However, changes in phenology may also increase the abundance of heather beetle as the lifecycles of the heather beetle and its natural predator, a wasp *Asecodes mento* become less connected.

Picture 3.1 Dingle woodland

Picture 3.2 Veteran trees in Burwarton Park

As well as temperature changes, climate change will alter rainfall patterns which will impact on species and habitats. A decrease in summer rainfall may lead to more frequent droughts which could severely affect wet woodland and other wetland habitats, as well as veteran trees (see picture 3.1). This in turn would lead to changes in associated species and change in landscape character.

Purple moor grass and rush pasture, along with all wetland habitats, is also vulnerable to a drop in the water table in summer. Purple moor grass and rush pasture could also be damaged by an increase in flooding in winter due to more rainfall and more frequent storm events.

Climate change may increase the rate of physical processes such as erosion in the Shropshire Hills Character Area. An increase in winter rainfall may increase erosion in winter, resulting in more nutrients being washed into rivers. This will exacerbate nutrient loading from other sources including agriculture. An increase in erosion will also increase the sediment load of lakes and rivers, impacting on freshwater ecosystems. An increase in nutrient loading in summer combined with a reduction in summer rainfall will lead to low flows, increaseing the likelihood of eutrophication occurring.

Air quality can be impacted by climate change and there may be consequent impacts on biodiversity. Concentrations of low level ozone are predicted to increase as temperatures warm. Ozone pollution can affect biodiversity; beech and birch are sensitive to ozone and studies of ozone effects on grassland communities have reported changes in community composition (Morrissey *et al*. 2007). Other habitats, such as wetlands, heaths, montane and inland rock habitats are poorly studied although there is some evidence that montane habitats and bogs are sensitive to ozone (Morrissey *et al*. 2007).

A consequence of an increase in temperature and a decrease in summer rainfall is an increase in the risk of fires in the Shropshire Hills Character Area. Whilst burning is already used as a management practice during the winter months, an increase in unplanned and uncontrolled fires would pose a risk to the heathland habitat of the Character Area. Lower plant assemblages are at risk as they are vulnerable to the impacts of fire. Dry woodlands have also been identified as potentially at risk. Whilst summer fires are often very damaging as they damage seeds and roots, the impacts of fires on biodiversity are not necessarily all negative. Spring fires tend to flash across the surface (assuming the ground is wet) and vegetation regeneration is usually quite rapid. In some instances where fires are quite small and occur in areas where scrub reduction is desired they can turn out to be beneficial. However, controlled burns are much preferred.

An increase in the frequency and intensity of storms may have a negative impact on biodiversity assets. Woodlands and isolated trees are at particular risk of high winds associated with storms. Storms can have a positive impact on woodland biodiversity but an increasing frequency of storm events may reduce their ability to recover. Flash floods can also damage vegetation and cause soil erosion. An increase in the frequency of intense storm events may reduce the ability of habitats to recover.

An increase in temperature and growing degree days will lengthen the growing season. This may be beneficial to some species which can adapt to a longer growing season, oak,for example, but detrimental to those such as ash that can not. Differences in the ability of woodland species to adapt to a longer growing season will be another cause of community composition change. Overall, it is likely that an increase in the length of the growing season will be beneficial for trees.

Indirect impacts

In addition to direct effects of climate change, the biodiversity of the Shropshire Hills Character Area will be impacted by impacts of climate change on other sectors that interact with biodiversity. The key sector in the Shropshire Hills Character Area is agriculture. Changes in agricultural practices as a result of climate change may have a greater impact on biodiversity than direct biophysical impacts. For example, increasing the area of cultivation in response to longer growing seasons and the development of new crops may negatively impact on the amount of permanent and semi-natural grassland as arable farming moves up-hill.

Reduced grazing patterns may have a short term positive effect on a number of habitats such as grazed woodlands and inappropriately or intensively grazed upland heaths and grasslands. However, in the longer term some of these habitats need active grazing management. The loss of management skills and supporting agri-business infrastructure is another important consideration in the need to maintain flexibility as climate change constraints alters land management.

Agriculture also affects the permeability of the landscape, preventing migration of species along habitat networks (see Boxes 3.2 and 3.3). Creation and extension of biodiversity-friendly networks will be constrained by the presence of intensive agricultural land uses impermeable to species. These indirect impacts of climate change will be mediated by the prevailing socio-economic scenario in the future (see Appendix 2) and the state of agricultural economics is hard to predict.

In addition to agriculture, recreation can have impacts on biodiversity and landscape in the Shropshire Hills Character Area. The potential impacts of an increase in tourism and recreation on biodiversity in the Shropshire Hills are identified in Section 3.3.2.

3.3.2 Impacts on access and recreation assets

Direct impacts

Whilst potentially the greatest impact on access and recreation assets might be due to a perceived increase in visitor numbers (an indirect impact of warmer conditions) there are a number of direct impacts of climate change on recreation assets. Potentially the most significant for the Shropshire Hills is an increase in fire risk. Should a fire occur, there is the potential for severe damage to recreation assets such as historic sites and valued landscapes. The greatest risk will be associated with areas of heathland and grassland, particularly on the Long Mynd, Clee Hills area and The Stiperstones which attract the highest visitor numbers.

Another direct impact of climate change on access and recreation is an increase in flood risk. There is potential for disruption to the rights of way network and other visitor attractions (including urban areas) due to flooding. An increase in standing water on footpaths and other rights of way may also lead to more rapid erosion. Overall though this is likely to be a sporadic, short term impact that is unlikely to lead to long term closure or inaccessibility of areas.

Woodland based recreation is likely to increase in popularity as people seek shade in the hottest months and there will be an opportunity to develop visitor facilities at woodland sites. However, tick-borne diseases such as Lyme disease may become more prevalent in woodland areas as warmer temperatures allow rapid development between tick stages (HPA 2008). However, there is no simple correlation between temperature and incidence of Lyme disease, other factors such as agricultural and wildlife management practices and increased exposure may be responsible for an increase in cases (HPA 2008).

Hotter, drier summers may also lead to more incidences of heatstroke and other heat related illnesses. Currently, winter is seen as the high risk season for outdoor recreation. Under conditions of climate change, the hazardous season for outdoor recreation could shift to the summer and more people may need to be rescued due to heat stroke and heat exhaustion.

A further consequence of warmer temperatures in water environments is an increase in pests such as midges. This could reduce the attractiveness of the area to visitors. Possibly more serious is the potential for the re-introduction of vector borne diseases such as malaria. The Health Protection Agency (HPA) has mapped malaria suitability under recent climate and a range of future climate scenarios illustrating the number of months introduced mosquitoes could persist in the UK. Under the 2080s medium-high emissions scenario, the risk of malaria transmission is predicted to increase in the West Midlands (HPA 2008).

Indirect impacts

The indirect impacts of climate change on recreation assets in the Shropshire Hills Character Area are due to an assumed increase in visitor numbers as a response to an increase in temperature. Visitor numbers may also increase as UK-based holidays become more popular than overseas destinations which “carbon pricing” may make too expensive or where temperature rises have made the local climate too uncomfortable. Whilst this assumption may be valid under the current socio-economic scenario, this may not be the case under alternative scenarios where people have different attitudes towards the environment and nature conservation has different objectives. The assumption that visitor numbers would increase has been made in this report and in Table A3.1 in Appendix 3.

A rise in temperature and the consequent rise in visitor numbers can be seen as an opportunity or a threat for the Character Area. In terms of recreation and enjoyment of the natural environment, climate change may present an opportunity. Currently, there are generally fewer visits to the Shropshire Hills in winter than in spring or summer although the busiest week for recreation in Cardingmill Valley is between Christmas and New Year. The impact of climate change may be to extend the tourist season as the autumn and spring months become popular. This may benefit the tourism industry which traditionally is very seasonal. However, an increase in visitor numbers may have negative impacts on wildlife and landscape and the opportunity must be carefully managed to prevent it becoming a threat. A number of potential negative impacts of an increase in visitor numbers can be identified including:

- Even greater congestion at ‘honeypot’ sites or on popular rights of way leading to a reduction in visitor experience and wilderness quality.
- Increase in litter, noise and pollution.
- Greater pressure on water resources and sewage treatment works.
- Increased demand for visitor infrastructure, for example accommodation and resources,
- Congestion on transport infrastructure, for example roads, car parks and trains .
- Increased disturbance to sensitive wildlife.

An increase in visitor numbers may reduce the wilderness quality associated with the Shropshire Hills Character Area.

3.3.3 Impacts on landscape, geodiversity and historic environment assets

Direct impacts

Changes in the elements and patterns that shape landscape character have an impact on the overall quality of the countryside (CQC, undated). As Table 3.3 demonstrates, climate change will directly impact on the landscape of the Shropshire Hills. Whilst the characteristic species that make up some habitats may be different, broad habitat types will persist (for example woodland) thus landscape character will often persist. Mature and veteran trees and orchards may be particularly at risk of drought and storm damage due to climate change. This, in combination with the effects of repeated soil shrinkage and wetting, may result in these trees being lost from the landscape. This is likely to be a significant impact for the Shropshire Hills, as hedgerows, infield trees and lines of trees along watercourses are important components of the landscape. At particular risk are the characteristic lines of alder trees along watercourses in valleys and on lower lying land. It is anticipated that Phytophthora root disease will become increasingly prevalent in warmer conditions, killing may alders. There are also signs that the disease may spread to other species of trees and shrubs. Disease weakened trees are easily dislodged and river sections may become choked causing bank erosion and affecting water quality.

In addition to changes to existing assets, new features may become more prominent within the landscape. Bracken and scrub are likely to grow faster under climate change and become more competitive. Without management they could dominate parts of the landscape more than they do at present. This would alter landscape character, but may be an acceptable change if it does not occur on a wide scale. However, an increase in bracken and scrub in the landscape is often detrimental to historic environment and geodiversity assets as it obscures access to and visibility of earthwork archaeology and periglacial landscapes.

The geology of the Shropshire Hills is an important environmental and educational asset, given the wide variety of rock types and long history of study. Many of the processes that contribute to the deterioration of important geological sites will be accelerated, such as vegetation growth, increased rates of erosion and mass movements. This will lead to the need for more intensive management.

An increase in the rate of physical processes and extreme weather events could impact on the soils and geomorphology of the Character Area as active or static geomorphological features will change. For instance, an increase in the rate of fluvial processes could lead to river channel migration and consequent impacts on the landscape. There is potential for new exposure of geological features from an increase in mass movement There is a risk that soils and Quaternary (Ice Age) sediments will be more easily lost through increased erosion due to climate change. These processes are likely to be accelerated during extreme events which are forecast to become more common. This will impact on the historic environment of the Shropshire Hills Character Area as our most recent environmental history and archaeology are preserved in this layer. There is also a risk that demands for river defences to protect land, could mask important geological features.

An increase in the rate of fluvial processes could lead to river channel migration and consequent impacts on the landscape. Slope stability could be reduced by climate change. An increase in winter rainfall may lead to more mass movement. Drying of clay soils in summer may also lead to cracking and subsidence.

Climate change will impact on historic environment features.. Many historic and veteran trees will be susceptible to drought, winter waterlogging and increased severity of storms. Earthworks, such as Offa’s Dyke, Iron Age hill forts and motte and bailey mounds may be damaged by increased erosion, caused by prolonged winter rain, and exposure of soil in prolonged droughts. Where trees are growing old on earthworks, and with changes in hydrology and soils, they may be more susceptible to wind-blow, with consequent significant damage caused by upturned root plates. Below ground archaeology such as sites known from cropmarks, will also be susceptible to increased erosion caused by extreme rainfall events, as would historic bridges, weirs and mill structures in gullies, streams and rivers.

The Shropshire Hills stock of vernacular buildings and structures is particularly characteristic. These may be at particular risk from extreme storm event damage and subsidence, leading to a loss of landscape character. Traditional working farm buildings are particularly vulnerable to changes in weather patterns, especially those that result in increased rainfall and storm events - see the case study at Appendix 4.

The Shropshire Hills Character Area exhibits a number of characteristics of robustness to climate change (see Box 3.4). Whilst the extent of permeable networks is not great (see Figure 4.1 above), the Character Area benefits from significant topographic variation; the Character Area possess extensive high open moorland and high volcanic hills and slopes as well as more gently sloping whale-back hills. There are many land cover types within the Character Area; the biodiversity asset map for the area lists sixteen different BAP habitats and five woodland and other tree habitats. The range of habitats also leads to a range of vegetation types. Therefore the Shropshire Hills Character Area has the potential to be robust to climate change although the current paucity of networks could constrain its ability to adapt to climate change.

Indirect impacts

It is likely that the indirect impacts of climate change on agriculture could have a greater impact on the landscape of the Shropshire Hills Character Area than any direct impacts. Changes in agricultural production in response to climate change will alter the appearance and character of the landscape. For example, re-intensification of agriculture due to improved growing conditions and newly viable crops may result in loss of woodland and grassland habitats. Conversion of land to arable would result in the loss of grassland and hay meadows, affecting sheep farming on the uplands.

Vegetation growth is likely to increase with warmer temperatures leading to changes in grazing regimes. For example, summer drought may reduce the biomass available for grazing driving some areas into agriculturally marginal status. This could lead to abandonment of this land, with consequent change in its character as scrub, bracken and rough grassland grows in place of formerly well grazed grassland. However, biomass for grazing may be more abundant in winter. Alternatively, rising commodity prices might lead to intensification of areas that are currently marginal, as better prices may make it feasible to farm such areas.

Box 3.4 Resilience and robustness to climate change

When evaluating the impacts of climate change on landscapes, the terms robust and resilient are potentially useful. However, there are subtle differences between the terms. Resilience is defined in the climate change literature as '*the ability of a system to recover from the effect of an extreme load that may have caused harm*' (UKCIP 2003) whilst robustness is defined as '*the ability of a system to continue to perform satisfactorily under load'* (UKCIP 2003). In terms of climate change and the natural environment, a resilient landscape can be thought of as one that can recover following an extreme climate event (such as a storm or flood) although recovery may not be to the same condition as it was in prior to the event. Recovering from climate change will involve a shift in state; recovery to the status quo will not be sustainable in the long term.

A robust landscape can be thought of as one that continues to function under the stresses caused by prolonged changes in temperature and rainfall. In order to continue functioning a robust landscape must posses the ability to change in response to climate change e.g. species need to be able to move. A robust landscape is likely to possess extensive, permeable habitat networks and exhibit heterogeneity within and between habitats. I particular it will contain a wide range of micro-climates in each habitat type. Landscapes robust to climate change are likely to possess the following features:

- high permeability;
- variation in topography – slope, aspect and height;
- soil diversity;
- numerous land cover types;
- diverse and structurally varied vegetation; and
- diverse water regimes.

An indirect impact on the landscape would be engineered solutions to reduce the impact of extreme events such as floods and mass movements. These could impact on the landscape character and geodiversity of the area. Disrupting natural processes can often result in other unforeseen impacts on the landscape.

Climate change mitigation policy may also have impacts on the landscape of the Character Area. Currently, UK climate and energy policy supports the development of wind power in response to climate change. Exposed, upland sites are preferred for locating on-shore wind farms; hence the Shropshire Hills CA and nearby areas, particularly in Wales, could be favoured for wind turbine development. Some people currently perceive there to be a problem with vertical communication structures in the landscape, wind turbines may exacerbate this. Mitigation policy also favours the growth of energy crops. The implications of this on landscape are uncertain, but could lead to re-intensification of some areas, in valleys and flood plains

Table 3.3 Impacts of climate change on landscape

Landscape feature	Impact of climate change
In-field and riverside trees including veteran trees	Drought, severe storm and disease may significantly deplete mature trees in the landscape.
Semi natural features that contribute texture to the landscape –	Agricultural land that is currently marginal may be subject to intensification as rising commodity prices make farming more economically viable leading to the loss of semi-natural habitat in the

Landscape feature	Impact of climate change
heathland, unimproved grassland	landscape.
Vernacular buildings and structures	Extreme storm events may lead to damage and structural collapse of buildings and structures, leading to loss of historic fabric, particularly historic buildings, mills and bridges.
Geodiversity	Mass movements and erosion from increased heavy rainfall events. Potential for new exposure of geologic features from mass movement. Increased vegetation growth and weathering/talus accumulation obscuring geological features. Loss of access to internationally important geologic resource.
Archaeological earthwork monuments: hillforts, motte & baileys, Offa's Dyke.	Severe storms and prolonged winter rain may increase erosion and damage through poaching, and wind-blow of trees. Resulting in erosion and structural decline of monuments.
Below ground field archaeology	Severe storm events and prolonged rain may erode soils, leading to loss of Romano-British crop mark complexes.

3.3.4 Impacts on ecosystem services

Direct Impacts

Table A3.4 in Appendix 3 identifies the significant ecosystem services offered by the Shropshire Hills Character Area. Climate change will have a direct impact on the ecosystem services provided by the Shropshire Hills Character Area (see Table A3.4). Ecosystem services are potentially vulnerable to the impacts of climate change as they are not always valued.

Reduced summer rainfall and more intense rainfall events will impact on the water resources available for agriculture, recreation, potable water supply and habitats. Increased demand as a result of hotter, drier conditions and population growth in surrounding areas will compound this issue, potentially resulting in a supply-demand deficit.

An increase in flooding frequency and magnitude will impact on water quality. High run-off events can lead to sewerage overflows and pollution incidents, as experienced during the Summer 2007 floods. An increase in flooding may also compromise the potable water resource. An increased risk of contamination from heavy metals and hydrocarbons arises from flood water inundation of underground storage tanks. Flooding can also have a detrimental affect on soil resources, causing an increase in erosion but also longer term damage to soil structure.

An increase in the occurrence of wildfires may have an impact on water quality. This is a particular concern for water companies as it increases their processing costs. Wildfires can also lead to more rapid soil erosion.

An increase in the rate of physical processes could impact on the soils and geology of the Character Area. There is a risk that soils will be more easily lost through increased erosion due to climate change**.** There are parts of the Character Area where soils are already thin; these areas may be particularly susceptible to erosion and are likely to become increasingly marginal as the climate changes. This will impact on the geodiversity and historic environment of the Shropshire Hills Character Area as our most recent history and archaeology are preserved in this layer.

Climate change presents an opportunity for agriculture; longer growing seasons may increase productivity but farmers may need to be willing to switch to alternative crops. The types of crops and livestock supported by the Shropshire Hills may be changed by climate change; current crops may not be able to persist under hotter, drier conditions but new, drought tolerant crops may thrive.

However, climate change may also threaten agriculture in the Shropshire Hills Character Area. Summer drought (although not as severe as in other Character Areas) may affect productivity. It is also likely that new pests and diseases will be present in the Shropshire Hills Character Area as a result of warmer conditions.

Forestry may be impacted by an increase in storms and diseases. Increased wind throw of trees and more prevalent pests and diseases such as the processionary moth may reduce the commercial viability of forestry.

Recreation and tourism will both be directly affected by climate change. With the predicted warmer, dryer climate in the spring and summer, the Shropshire Hills Character Area may become more attractive as a tourist destination and visitor numbers are likely to increase. Recreation is also likely to increase in the Character Area under warmer, drier conditions. The risk of fire, particularly on heathland areas, threatens to reduce the attractiveness of the area to visitors.

Natural resources are increasingly being exploited for energy generation. An increase in sunshine hours in the Shropshire Hills Character Area could increase the opportunity for solar power generation. Exposed, upland sites are preferred for locating wind turbines and there could be opportunities to exploit this resource. In addition, a longer growing season may favour the growth of energy crops in the valleys and lowlands. There is an opportunity to produce wood fuel in the Character Area. The use of the natural environment for energy generation is likely to lead to conflict with landscape and biodiversity interests and will be another pressure on land use within the Character Area.

An increase in soil erosion and loss of biomass as a result of climate change may impact on the climate regulation function of ecosystems. Carbon can be released into streams in sediment forms, giving water a brown colour, increasing water treatment costs (RSPB undated).

Indirect Impacts

Indirect impacts of climate change will also be felt by ecosystem services. The recreational and tourism services offered by the Character Area are at risk of being negatively impacted by an increase in visitor numbers. As well as an increase in recreation and tourism, the use of the Character Area for outdoor educational purposes is likely to increase as conditions become warmer and drier. Trampling and footpath erosion are likely consequences of an increase in visitors. An increased human presence in the landscape will also result from an increase in visitor numbers and this may negatively affect the attractiveness of the Character Area for recreation and tourism. A further impact of an increase in visitor numbers is increased pressure on water resources and infrastructure, exacerbating direct climate impacts (see Section 3.2.2 above).

3.3.5 Socio-economic impacts

Socio economic change will have an impact on the biodiversity, access and recreation and landscape assets of the Shropshire Hills Character Area. Changes in agriculture and recreation are hard to predict as there is no certainty over which socio-economic scenario will prevail in the future (see Appendix 2). The Character Area project has not adopted a formal scenario based approach to assessing the socio-economic impacts of climate change, nor does it provide an integrated assessment of them as they are highly complex. Instead, it is assumed that conventional development (mainly World Markets with aspects of other scenarios) will prevail.

Table A3.5 in Appendix 3 provides some examples of socio-economic impacts, which could affect the species, habitats, landscapes and recreational function of the Shropshire Hills Character Area. This is based on knowledge of socio-economic changes, informed by current trends and drivers (for example, the Water Framework Directive; European and UK Climate Change Programmes) and the futures literature (e.g. Evans *et al*. 2004; LUC *et al*. 2006; OST, 2002; UKCIP, 2001).

Potential changes in the agricultural sector are likely to have the most significant impact on the Shropshire Hills Character Area. There is currently an Environmentally Sensitive Area Agreement for the Shropshire Hills which is due to end in five years time. Once this agreement comes to an end, there will be an opportunty for farmers to switch grassland to potatoes or other arable crops. This would have an impact on the landscape and biodiversity of the Character Area.

One important socio-economic change may be a shift in consumer demand towards more organic and local produce. This growth in demand for organic products is already being seen and is likely to continue in future as people become more concerned with where their food comes from and how it is produced. This socio-economic change could have benefits for biodiversity; a reduction in pesticide use may increase invertebrate populations which will have a beneficial impact on bird species. In addition, a reduction in the use of artificial fertilisers will have benefits for water quality.

There are a number of potential socio-economic changes envisioned in Table A3.5 that would have detrimental effects on the natural environment. Whilst climate change policy could drive an increase in energy generated from renewable sources such as wind and biomass, socio-economic changes could have a similar effect. An increasing oil price and concerns over security of energy supply may lead to an increase in renewable energy, putting pressure on the landscape of the Shropshire Hills through installation of wind turbines or growth of energy crops. Increasing petrol costs will also impact place pressure on quarries given then increasing cost of transporting aggregates.

Growth in population in the West Midlands would put further pressure on the Shropshire Hills as demand for housing, transport and other infrastructure would increase. Whilst the designated areas may be protected from development, other areas within the Character Area may be further fragmented by development.

As can be seen from the discussion above, climate change is not the only, or necessarily most important, driver of change in the Shropshire Hills Character Area. The impacts of climate change are likely to exacerbate existing pressures in the

Character Area. It is possible that the combined effects of climate change and other pressures will exceed the ability of the natural environment to adapt.

3.3.6 Policy implications

A change in species and community composition may have an effect on the delivery of current conservation targets which include definitions of 'favourable' condition' of habitats. Under current, static definitions of 'favourable condition', species and community compositional changes may make it more difficult to meet targets as climate changes. As climate changes, habitats with species compositions currently occurring outside the Shropshire Hills, may well become the norm within the Character Area In addition, a potential increase in non-native and invasive species may threaten the delivery of conservation objectives.

4. Adaptation

Box 4.1 Key adaptation responses

When defining adaptation actions consider existing schemes, strategies and levers.

- Improving the condition and extent of existing habitats will increase their robustness to climate change.
- Habitat restoration and creation will be required to address multiple sources of pressure.
- Creating a wide range of micro-climates, within habitat types, will provide structural diversity with the most opportunities for species to survive.
- It will be necessary to work with other organisations to adapt to climate change.
- Increasing the diversity of riparian habitats.
- Creation of new areas of habitat.
- Identifying research needs and commissioning appropriate studies is an early step towards building adaptive capacity that should increase the effectiveness of strategies when implemented.
- Be aware of future potential catastrophic events that may occur as a result of climate change such as the emergence of new pests and diseases.
- A common impact across all habitat types is the likelihood of species and community compositional changes and there is a need for policy to reflect this.
- The provision of shade and drinking water at tourist attractions will be important.
- Implementation of a tiered fire warning system.
- Fire prevention needs to take a two pronged approach; hazard management (for example vegetation management) and risk management (for example education, enforcement and access restrictions).
- Recreation networks can be linked to biodiversity networks. Habitat creation which is designed to accommodate access and recreation needs can be beneficial, as people can be managed to prevent them causing damage to sensitive biodiversity.
- Link access and recreation responses with development in the urban areas closest to the Character Area.
- Provide and promote attractive circular walks close to urban areas.

Box 4.1 Continued

- Plant a variety of species as eventual replacements for existing mature trees, avoiding those susceptible to drought.
- Re-establish pollard regimes to reduce susceptibility to storm damage.
- Where archaeological features are likely to be lost to climate change impacts, a record should be made of field patterns, structures and known archaeology.
- Include regular monitoring and management of important geological sites to ensure that exposures remain visible, or alternatively, allocate resources for clearance of exposures on a more regular basis than now.
- Ensure that the important stock of vernacular farmstead buildings is maintained and not allowed to fall into serious disrepair.
- Manage catchments in a more holistic manner;
- Sensitive farming methods including leaving vegetated buffer strips around fields and not leaving fields bare, will contribute to water resources and water quality.
- Sustainable Urban Drainage systems can be used to intercept and store water.
- Rural payments may need to be tied to the provision of ecosystem services.
- Use the spatial planning system to safeguard ecosystem services and provide for a wide range of flexibilities to cope with the impacts of climate change.

Based on the impacts identified in Section 3, a list of adaptation responses for the Shropshire Hills has been complied (see Table A3.2, Appendix 3). These have been informed by Hopkins *et al*. (2007), who present guidelines for conserving biodiversity in a changing climate (see Box 4.2). The adaptation responses have been tested against more generic criteria of effectiveness (see Section 4.3).

When defining adaptation actions, existing schemes, strategies and levers should be considered. Some actions defined as climate change adaptation may already be occurring under a different name or it may be possible to modify an existing programme to provide a mechanism for delivering adaptation. Climate change adaptation needs to be ‘mainstreamed’ into existing Natural England plans and policies such as Higher Level Stewardship and SSSI monitoring. It will also be necessary to identify projects led by other organisations which could be used as a vehicle to deliver climate change adaptation.

It should be recognised that there may be policy, economic or other constraints to delivery of some actions; these are identified in Table A3.2. Additionally, some of the actions identified may not have a delivery mechanism at present. At this stage, all potential adaptive actions are included despite known constraints.

Box 4.2 Guidelines for conserving biodiversity in a changing climate, Hopkins et al (2007)

- Conserve existing biodiversity:
  - Conserve protected areas and other high quality habitats.
  - Conserve range and ecological variability of habitats and species.
- Reduce sources of harm not linked to climate.
- Develop ecologically resilient and varied landscapes:
  - Conserve and enhance local variation within sites and habitats.
  - Make space for the natural development of rivers and coasts.
- Establish ecological networks through habitat protection, restoration and creation.
- Make sound decisions based on analysis:
  - Thoroughly analyse causes of change.
  - Respond to changing conservation priorities.
- Integrate adaptation and mitigation measures into conservation management, planning and practice.

4.1 Adaptation Response in Shropshire Hills Character Area

4.1.1 Biodiversity responses

Guideline 1 - Conserve existing biodiversity;

- *Conserve protected areas and other high quality habitats;*
- *Conserve range and ecological variability of habitats and species*

The impacts of climate change will be felt most in habitats which are already degraded or in poor condition. **Improving the condition of existing habitats will be an important adaptation response.** A number of management practices are suggested in Table A3.2 that aim to maintain and enhance current significant natural environmental assets in the Character Area through adaptive management. Adaptive management involves modifying existing management practices in the face of uncertainty, in this case due to climate change. The approach involves making a change to an existing management practice and monitoring the results to ensure the response is effective.

As a result of monitoring, the management practice may need to be reviewed again. Examples of adaptive management in the Shropshire Hills Character Area include:

- Altering stocking rates on grazed grasslands to respond to an increase (or possibly a decrease) in biomass productivity.
- Reviewing heathland burning plans to take account of an increased frequency of fires.

- Altering hay cutting date to respond to phenological changes (e.g. changing growing seasons).
- Management of heathlands to account for an increase in the rate of heather growth.

Adaptive management has a number of advantages over more radical adaptation options. It is relatively inexpensive as it is already an ongoing process which needs modification rather than a step change in approach to management. It is also a flexible approach and that should be able to quickly respond to change, assuming change is gradual. Adaptive management is useful in dealing with those impacts which are uncertain as the response can be altered on an iterative basis depending on the results.

There is a risk of employing 'knee jerk' reactions to the impacts of climate change, based on current management regimes; for example, responding to an increase in heather beetle damage on heathland by increasing burning. This can have a negative effect on other aspects of the Character Area; in this case, increased burning will result in a uniform age structure of heather which is detrimental to biodiversity. Impacts may be more complex than first thought, in this example, there is uncertainty over the effect of heather beetle as it may be naturally controlled by predators which also become more abundant due to climate change. This is an issue that will need more research.

There should be a focus on reducing barriers to biodiversity movement and preventing fragmentation of core sites. Buffer strips can be used around core sites to reduce the impacts of intensive agricultural land use and prevent the site becoming isolated in an intensive agricultural landscape.

Guideline 2 - Reduce sources of harm not linked to climate
Climate change may be the 'tipping point' that prevents the Character Area from recovering from the in-combination effects of all sources of pressure. In addition, the legacy of past sources of pressure on the natural environment may restrict the ability of the Character Area to adapt to climate change. It is thus vitally important that efforts are made to address other sources of pressure in order that habitats are more robust to climate change.

Indirect impacts of climate change on the Character Area will be felt through changes in agricultural practice and recreation (see Section 4.1.2). A number of adaptive management responses listed above can be used to respond to changes in agriculture but the main tool currently available for ensuring the maintenance of the natural environment in the face of agricultural change is agri-environment schemes. There is an environmentally sensitive area agreement in the Shropshire Hills which ends in 2012; this will be an opportunity to introduce a new scheme that is designed to deliver climate change adaptation. A number of responses identified in Table A1.2 can be delivered through environmental stewardship schemes.

Recreation has also affected the biodiversity of the Shropshire Hills. An increase in visitor numbers due to warmer temperatures will exacerbate impacts due to recreation. Education of visitors through interpretive signing and other forms of information may reduce this pressure.

Habitat restoration and creation will be required to address these multiple sources of pressure. In addition to responding to the direct impact of climate change, this will allow other issues such as habitat fragmentation due to agricultural intensification and recreation to be addressed. The greater the area of well connected, good quality habitat, the more resilient the landscape will be to the impacts of climate change and other pressures.

There are a number of existing projects operating in the Shropshire Hills that although primarily designed to address other pressures, can also be used to deliver climate change adaptation. It will be necessary to work with partner conservation and other organisations to adapt to climate change through projects such as Back to Purple and Plantations on Ancient Woodland Sites. There are also planning opportunities that can be used to address the pressure of population growth in the area. The Regional Spatial Strategy and Local Development Framework could be opportunities to articulate and strengthen the position of the natural environment in Shropshire in the face of a growing population.

Guideline 3 - Develop ecologically resilient and varied landscapes:

- *Conserve and enhance local variation within sites and habitats;*
- *Make space for the natural development of rivers and coasts*

Increasing the heterogeneity of existing habitats will increase their robustness to climate change. In particular the creation of a wide range of micro-climates within habitat types will provide the wide range of opportunities for species to grow and live in, see Box 4.3. Responses such as planting a mixture of woodland trees and increasing riparian shading through floodplain planting would be good examples of a method of increasing heterogeneity within habitats and networks. When planting new trees, it will be important to identify species which are likely to tolerate the predicted changes in temperature and rainfall.

An important theme that underlies many of the following biodiversity responses, relates to the way that many plants and animals respond to change, by moving to situations that offer more suitable conditions for them. Some species may be able to adjust to climate change by expanding the range of vegetation types they occupy, or by moving from one type of vegetation to another. Similarly, species may be able to move up slope or around aspects in order to occupy areas providing suitable microclimates (Hopkins *et.al.* 2007). Providing variation within habitats is thus important in adapting to climate change. For example, recent studies of the silver-spotted skipper *Hesperia comma* have revealed a change of habitat, so that it now breeds in cooler, taller grasslands than previously was the case. (Davies *et al*. 2006). Box 4.3 describes some examples of differing micro-climates that could be created within habitats.

Box 4.3 Examples of situations that provide a range of micro-climates

- Grassland with short sward and grassland with long sward.
- Wetland on relatively free draining areas prone to desiccation and wetland on more waterlogged areas, less prone to desiccation.
- Open woodland rides and rides with dappled or full shade.
- Semi-natural habitat on a range of slope and aspect. Microclimate varies considerably with slope and aspect. At sites with varied topography species adversely affected by higher temperature and summer drought on south-facing slopes may be able to move to cooler, more humid north facing slopes. Quite small differences in topography, for example on different sides of a hillock may provide the topographical variation required if the magnitude of change is not too great.

Box 4.3 Continued

- Woodland containing high, medium and low canopy structure.
- Transitional habitats, such as scrub between grassland and woodland, increases variability of habitats and microclimates.

Increasing the diversity of riparian habitats has been identified as an important response to climate change in freshwater habitats. Increasing the variety of micro-climates within riparian habitats, through planting of wet woodland and development of fen and scrub on floodplains will improve the ability of freshwater systems to adapt to climate change.

Guideline 4 - Establish ecological networks through habitat protection, restoration and creation
In addition to maintaining existing habitats, a number of responses (see Table A1.2) advocate the extension of existing habitats and the creation of new areas. This is the fourth of the Hopkins *et al.* (2007) guidelines (see Box 4.2). The extent to which plants and animals can move in order to adapt to the effects of climate change will be an important factor in their continued persistence at specific locations (Catchpole 2007) thus increasing the area of suitable habitat is likely to aid the conservation of species. Increasing the area of habitat is worthwhile because larger populations are less likely to become extinct from random events. In order to maintain the same degree of biodiversity in the face of climate change, more habitat is required. One way to do this is to extend the existing habitat network in the Shropshire Hills Character Area (see Box 4.3).

To date, habitat network maps have been created for three of the habitats present within the Shropshire Hills Character Area: woodlands, grasslands and heathlands (see Figure 4.1). Currently, the heathland and woodland networks are the most extensive in the Shropshire Hills Character Area. A significant heathland network is found in the Long Mynd area with others to the north and west of the Long Mynd and around Brown Clee Hill. There are a number of scattered woodland networks with the most significant found in the north east of the Character Area between and around Much Wenlock and Wellington. Grassland networks are more limited with an area to the north west of Long Mynd and an area south of Brown Clee Hill (see Figure 4.1).

There is a need to increase the extent of habitat networks (and the range of micro-climates within these extended areas) within the Shropshire Hills Character Area in order to increase robustness of the landscape to climate change. The extent to which plants and animals can move in order to adapt to the effects of climate change will be an important factor in their continued persistence at specific locations (Catchpole 2007). Habitat networks will be extended at the habitat scale through maintenance of existing high quality habitats, habitat restoration and re-creation.

However, expansion of ecological networks cannot prevent loss of some locally occurring species due to climate change, it can only reduce the number of species lost and there is a danger of spending resources re-creating habitats that will not be sustainable under a changed climate. The process of impact and adaptation response identification should assist in minimising the risk of this occurring. Similarly, habitat re-creation targeted at specific species may not be an effective response if the species is likely to be lost as a result of climate change. An example is Red Grouse, a bird currently at the southern edge of its range in the Shropshire Hills Character Area. Red Grouse are less likely to persist in their current location, but conversely, species such as the Dartford Warbler, which appears to be moving northwards, may arrive on the Long Mynd heathlands. Although Red Grouse may be publicly perceived as a 'iconic' species for the Shropshire Hills Character Area, it may not be efficient to manage suitable habitat purely for this species as this will not be sufficient to prevent its decline. It will however be desirable to manage the heather moorland habitat where Red Grouse are found for the whole range of species which are found there

There may also be physical constraints to habitat creation, e.g. a lack of suitable soil conditions on which to recreate for instance, lowland calcareous grassland. In addition the challenge of securing suitable land that could be used for habitat recreation should not be underestimated.

Guideline 5 - Make sound decisions based on analysis:

- *Thoroughly analyse causes of change*
- *Respond to changing conservation priorities*

Responding to the impacts of climate change may be hindered by incomplete information. For example, in order to respond to the impact on woodland of a decrease in summer rainfall, research into local hydrology is required. The fifth Hopkins *et al*. (2007) guideline for adaptation states that sound decisions should be based on analysis**.** Identifying research needs and commissioning appropriate studies can be seen as an early step towards building adaptive capacity that should increase the effectiveness of strategies when implemented.

A direct impact of warmer conditions is an increase in the prevalence of pest and diseases within the Character Area. A common response across all habitat types is the need to be aware of future potential catastrophic events that may occur as a result of climate change such as the emergence of new pests and diseases. This response requires ongoing monitoring of species and habitats at the same time as preparing contingency plans. It is important that lessons from previous events such as the decline of White Clawed Crayfish, the storm of 1987 and Dutch Elm disease are learnt and that past experience is used to inform the development of future management responses. One of the main lessons to learn is that woods can recover very well without a lot of intervention after storms. We can also look to other locations with similar climates to that which England may experience in future to identify potential threats.

Guideline 6 - Integrate adaptation and mitigation measures into conservation management, planning and practice.

A common impact across all habitat types is the likelihood of species and community compositional changes and there is a need for policy to reflect this. Changing conservation objectives may require a radical shift in the current paradigms of conservation; species not currently considered native to the region may have to be favoured and the attitude towards alien and invasive species may have to change. Currently, species such as beech and holly are seen as negative invaders which reduce the available space for more highly valued native species. However, if native species are no longer viable under conditions of climate change, attitudes towards non-natives may have to change. It is possible that species currently considered of low conservation value in the UK, and worse, invasives, may become so rare in their native habitat that the UK inherits a responsibility to conserve them. One example of this is beech woodlands which may no longer thrive in southern England, but potentially could in western and northern England (Wesche *et al.* in press).

4.1.2 Access and recreation responses

Direct impacts

In addition to the indirect impacts caused by an increase in visitor numbers, a number of direct impacts of climate change on access and recreation in the Shropshire Hills can be identified. An increase in summer heat related illnesses may be significant and the area should ensure that is has an up-to-date heat wave contingency plan. The provision of shade and drinking water at tourist attractions will be important.

An increase in fire risk could be caused directly by hotter drier summers but is also influenced by visitor behaviour. Whilst the baseline fire risk is low, the risk will increase as summers become warmer and driers. There is uncertainty over the best way to respond to an increased fire risk in areas frequented by visitors. There is an argument that excluding people from an area can reduce the risk of a fire occurring. However, the counter argument is that by closing areas, fire is less likely to be detected if it does occur.

There are a number of potential strategies for responding to the risk posed to recreation by fire, mainly focusing on raising awareness and fire prevention including a tiered warning system. This will raise people's awareness of the level of fire risk and encourage them to adjust their behaviour accordingly. Natural England already uses a Fire Severity Index provided by the Met Office. This works on 10km square grids across England and Wales to facilitate restrictions on open access land. The possibility of extending this scheme to cover all land in Character Areas at risk of wildfires could be investigated. The success of this scheme will depend on public awareness that it exists and what measures to take at different levels of risk. Land managers may be able to learn lessons from other places which use a similar system including National Parks in Australia and the south of France. Knowledge about communicating risk may also be available from the Environment Agency's experience with its tiered flood warning system.

A tiered fire risk warning system on its own will not prevent fires: it is a response to an increased risk of severe fires. The majority of wildfires in this country are either started accidentally or maliciously by people or result from controlled burns getting out of control. Fire 'prevention' therefore, needs to take a two pronged approach; hazard management (for example vegetation management) and risk management (for example education, enforcement and access restrictions).

Whilst preventing fires occurring is the primary objective of a fire risk reduction strategy, limiting the damage caused by fire when it does occur is also important. It is important that the response to fire outbreaks is quick, appropriately equipped and co-ordinated. There is now an England Wildfire Forum which looks at this issue (members include the Fire Service, Forestry Commission and Natural England). There is existing good practice in this area including the Peak District National Park Fire Operations Group which co-ordinates a fire plan (includes communication protocols, lists of contacts and who has the key for locked moorland gates) which enables quick mobilisation of personnel and off road equipment including that belonging to private land owners and managers. Training is also run through the fire operations group, including working with helicopters.

Flooding is another direct impact of climate change on recreational assets. However, this is only likely to impact on recreational access for relatively short periods of time, whilst areas are under water. Presently, at times of flood, visitors choose not to use areas affected, outside of flood events, the resources are available, so it is not envisaged that any response is required. Footpath erosion may be exacerbated by increased rainfall in winter. Silt traps could be installed to catch eroded material and return it to the footpath. This would prevent additional sediment reaching water courses.

Woodland areas are likely to become increasingly popular for recreation as temperatures warm. Increased access to woodlands should therefore be provided. Work to increase woodland habitat networks will help to increase the area of woodland that could be made available for access purposes. There are significant woodland assets, close to the Shropshire Hills, in neighbouring character areas, for example Mortimer Forest and Severn Gorge woodlands.

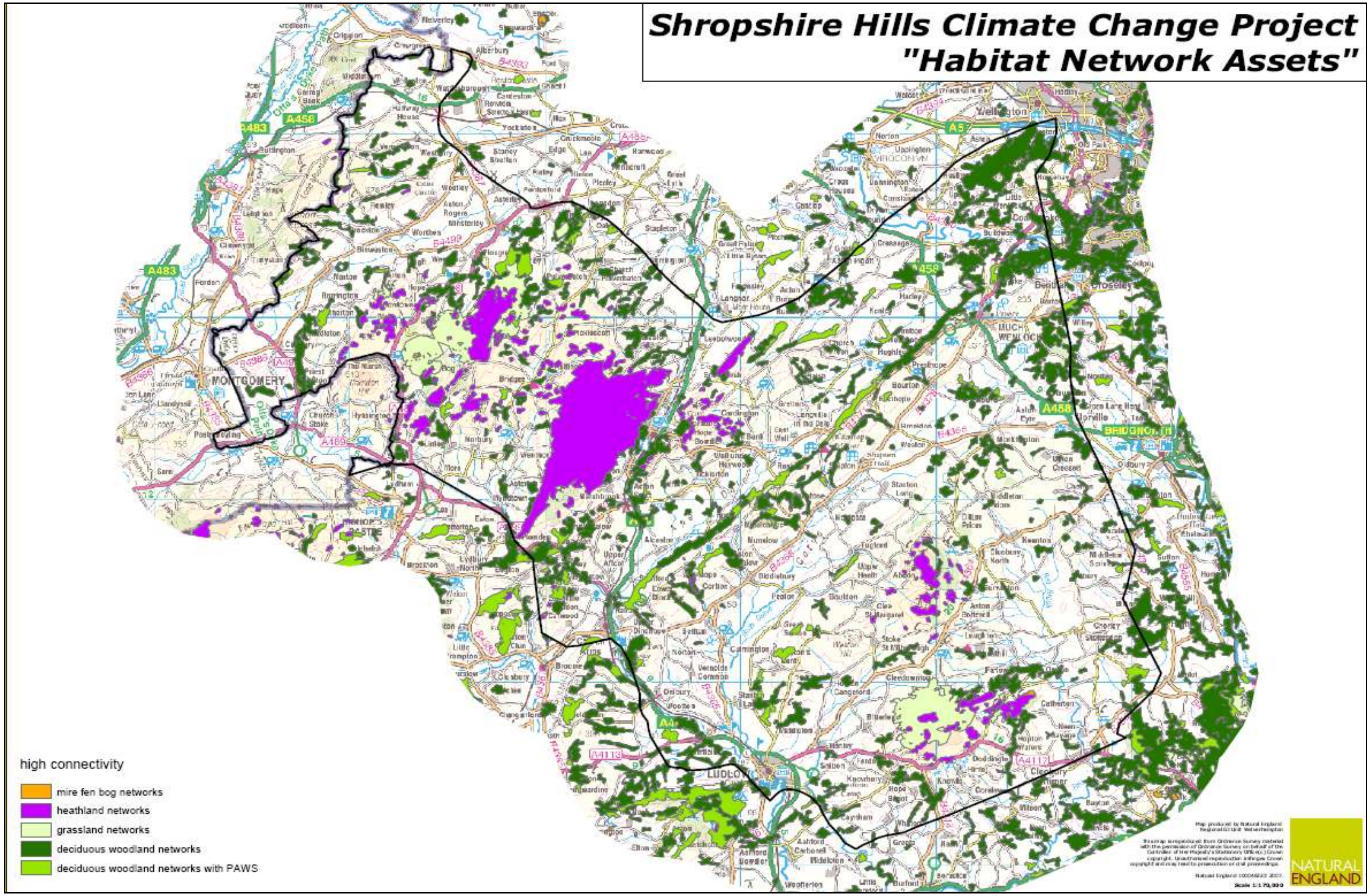


Figure 4.1 Habitat networks in the Shropshire Hills Character Area

Indirect impacts

The most significant impact of climate change on access and recreation is likely to be an increase in visitor numbers. This can be seen as an opportunity for recreation as more people will be able to enjoy the countryside. However, this opportunity may present risks to significant natural environmental assets if it is not managed correctly. The suggested responses to an increase in visitor numbers are thus aimed at reducing negative impacts and ensuring recreation and tourism can continue within the Character Area in a way that is sustainable.

A principle of visitor management is dispersal, or spreading the impact of an increase in visitor numbers across the Character Area. Burden sharing is a generic adaptation to climate change which can be applied to recreational assets in a natural environment. Currently, certain elements of the Shropshire Hills Character Area are considered most desirable to visitors and there is a high demand for access and recreational services. These ‘honeypots’ include the Stiperstones, Wenlock Edge, Brown Clee and the Long Mynd and certain popular rights of way. If demand for recreation increases it is likely that these sites and routes will reach or exceed their carrying capacity. In response to this, it is suggested that alternative sites and routes are publicised in an attempt to spread demand throughout the Character Area. However, dispersal of visitors may create more problems than it solves, particularly in terms of biodiversity impact. It may be better to concentrate visitors at honeypot sites with existing visitor facilities. The need for quiet refuges for sensitive wildlife in upland areas will need to be maintained. Strategies designed to widen access should be accompanied by a risk assessment to ensure sensitive habitats are not being put at risk.

Action to increase areas of semi natural habitat, proposed under biodiversity responses above, will provide more space for wildlife to disperse into. To some extent this will mitigate the impacts of increased visitor numbers on the existing biodiversity resource. Recreation networks can be linked to biodiversity networks. Habitat creation which is designed to accommodate access and recreation needs can be beneficial, as people can be managed to prevent them causing damage to sensitive biodiversity.

It will be important to link any access and recreation responses with development in the urban areas closest to the Character Area. An advertising campaign based in the urban areas which serve as a gateway for visitors, may help to promote attractions closer to centres of population and reduce the number of people in sensitive areas for biodiversity. The concept of ‘sustainable tourism’ should be promoted to visitors through interpretive signs and access and recreation promotion.

Another technique would be to provide and promote attractive circular walks close to urban areas, thus reducing the numbers of people in the more sensitive parts of the Character Area and reducing the need to travel for recreation. In order to avoid congestion, pollution and other negative impacts of a possible in vehicle movements within the Character Area, it is likely that improvements to public transport facilities will be needed. Some public transport aimed at tourists and visitors already exist, for example the Stiperstones Shuttle bus service. This initiative could be extended and integrated with other modes of transport, including the railways serving gateway destinations to the Character Area.

4.1.3 Landscape responses

Creating new areas of habitat or extending existing ones will have an impact on the landscape of the Character Area. Whilst habitat creation will be undertaken at the local scale, the aggregate impact of habitat creation may change the appearance of the Character Area at the landscape scale. However, whilst there is uncertainty over exactly what will be created (as habitats will change due to climate change) it is unlikely that the habitats created will be radically different from those that exist currently and will not dramatically change the landscape character.

The significance of the landscape impact can only be determined by understanding the context in which changes have occurred. It will be necessary to monitor changes in landscape character to enable informed decisions about necessary adaptive responses to be taken. The Countryside Quality Counts (CQC) analysis concluded that increasing the amount of woodland in the Character Area through planting of small sites has enhanced the landscape (CQC, undated), thus it could be expected that an increase in small areas of woodland as a response to climate change would also be viewed favourably. Similarly, restoring arable land to grazing and grasslands is viewed as a positive landscape change and there is a vision to increase the amount of unimproved grassland throughout the Character Area. The CQC does recognise scrub and bracken encroachment as potential threats to existing landscape character, but on a limited scale this is unlikely to be considered as a threat to overall character, and could contribute to textural patterns that reinforce existing landscape character. Scrub and bracken expansion is something that could be exacerbated by climate change but could also be reduced through upland habitat creation and management as a response to climate change.

Trees have been identified as a landscape feature that may be impacted by climate change. In response it will be necessary to plant a wide variety of species as eventual replacements for existing mature trees, avoiding those susceptible to drought. In the wider landscape consideration could be given to the use of trees, presently considered as alien to the area, (e.g. beech, sweet chestnut and sycamore), for planting as potential replacements for species that may no longer be able to cope with changing conditions. In woodlands, one practical action to respond to changing species composition of woodland habitats may be to trial different strains to ascertain which strains might grow successfully in future. It could also be possible to start a programme of selectively breeding from existing varieties to develop better adapted varieties.. This will also help to increase the heterogeneity of the landscape, increasing its robustness to climate change.

Mature trees are at particular risk form an increase in the frequency and intensity of storms. It may be necessary to manage the succession of planted trees to ensure that a storm event does not clear all trees from the landscape. Another response would be to re-establish pollard regimes to reduce susceptibility to storm damage. Hedgerow trees in particular require active management through pollarding.

There are a number of features of the historic environment that have been identified as at risk from the impacts of climate change. Once an archaeological feature is gone, it is gone forever. This fact reinforces the need for a robust approach to the identification of key historic environment issues within Character Area response strategies, early liaison with relevant organisations and careful consideration of measures that may affect the historic environment resource. For some features of the historic environment, where mitigation of impacts is impractical, the course of action should be to record those sites and features whilst they are still visible. It may be possible to implement localised management for special cases but this will be determined on a site-by-site basis. In extreme circumstances, where remediation is impractical and where it is accepted that an historic feature will have to be lost from the landscape, it will be necessary to take a record and rescue approach.

The significance and integrity of important historic assets can be threatened by poorly designed adaptation responses. An integrated approach is therefore required when assessing potential adaptation within this Character Area. For example:

- Planting of woodland needs to take account of other environmental assets that may be damaged from such planting, including historic environment and geological features.
- Altering the number of grazing animals in response to increased grass growth can lead to poaching and erosion of archaeological remains.

Historic farmstead buildings make an important contribution to the character of the Shropshire Hills landscape and are seriously at risk from climate change impacts. Severe storms in particular could send buildings into rapid decline. It will be important to ensure that historic farmstead buildings are regularly maintained. The preference is to maintain historic farmsteads in their unconverted state rather than convert them for residential or business use. See the case study in Appendix 4.

Conserving and managing the geodiversity of the Shropshire Hills will need to include regular monitoring and management of important geological sites to ensure that exposures remain visible. Space should be allowed for natural physical processes and for active landforms to change and migrate.

4.1.4 Ecosystem Service response

Climate change will impact on the ecosystem services provided by the Character Area and effective responses must be employed to protect them. Table A3.4 suggests potential responses to impacts on ecosystem services in the Shropshire Hills Character Area. Many of the responses described under biodiversity, access and recreation and landscape responses will have multiple benefits in preserving ecosystem services and can therefore be described as win-win solutions.

In addressing impacts on water resources and water quality it will be necessary to manage catchments in a more holistic manner. Management practices upstream have impacts downstream. In response to reduced water availability it would be beneficial to increase water storage capacity within the catchment and to reduce the rate of overland flow. This can be done through planting of wet woodland on floodplains and reducing the area of bare ground. This also has benefits for flood protection as water takes longer to reach the channel, thus avoiding high peak loadings. However, there is a risk that fallen branches could block bridges during flood events. Habitat restoration and creation as a response to climate change impacts on biodiversity will be beneficial in enhancing water resources in the Character Area as it increases the vegetated area in the catchment.

In response to water shortages, farmers may need to increase their capacity for on-farm water storage. Sensitive farming methods including leaving vegetated buffer strips around fields and not leaving fields bare will contribute to water resources and water quality. Some farmers may need to consider storing water in reservoirs; there has been some experience of this in the potato farming sector in the area. Creation of more reservoirs would change the appearance of the landscape. Precision farming methods using Geographic Information Systems to target irrigation may also help reduce the water demand of agriculture.

Water storage will also be necessary in urban areas. Sustainable Urban Drainage systems can be used to intercept and store water. This has multiple benefits in terms of water resources and flood risk reduction as water reaches rivers more slowly, reducing the risk of flash floods.

Soil erosion may be exacerbated by climate change. It will be necessary to maintain vegetation cover to avoid loss and increase the organic content of soils. Minimum tillage practices could also help protect the most sensitive soils.

Farmers will need to be aware of the potential for new crops and livestock. Livestock will be impacted by climate change and farmers may have to adapt their practices. An increase in summer temperature may mean that farmers need to provide shade for their stock. Shade can be provided by trees which would have a beneficial impact on landscape. There may also be an impact on livestock feed crops and new species may become viable in future. Farmers may also be affected by new pests and diseases which could threaten their livelihood. In the same way that awareness of pests and diseases affecting natural and semi-natural habitats and species will be an important response to climate change impacts on the natural environment (see Section 4.1.1), it will be important in the agricultural sector.

Climate change may provide an opportunity for forestry. Climate change is likely to improve the growing conditions for commercial tree species. The market for wood fuel may also increase as people switch to low carbon sources of energy. There are opportunities in the Shropshire Hills to bring neglected woodland back into management. Increasing tree cover will have multiple benefits for soil retention, water quality, provision of shade and reduction of flood risk.

Responses to an increase in tourism and recreation are addressed in Section 4.1.2. These responses are also pertinent to an increase in visitor numbers due to an increase in demand for outdoor education.

Many of the measures outlined above will have benefits for climate regulation. Strategies to increase biomass and retain organic soils in the Character Area will have a benefit for carbon storage.

4.1.5 Response to other socio-economic impacts

Climate change is not the only driver of change in the natural environment; pressure also comes from socio-economic change. Table A3.5 in Appendix 3 sets out responses to the likely socio-economic impacts. Climate change may be the ‘tipping point’ that prevents the Character Area from recovering from the in-combination effects of all sources of pressure. In addition, the legacy of past sources of pressure on the natural environment may restrict the ability of the Character Area to adapt to climate change. It is thus vitally important that efforts are made to address other sources of pressure in order that habitats are more robust to climate change (see Box 4.4).

Habitat restoration and creation is a response that is already required to address multiple sources of pressure, such as fragmentation of habitats by agricultural intensification and development. The need for this response is heightened by the added impact of climate change. The greater the area of good quality habitat, the more robust and resilient the habitats and overall landscapes will be to the combined impacts of climate change and other pressures.

As many of the socio-economic impacts will be felt through an increase in development pressure (for housing, transport, wind turbines etc) the main response is to use the spatial planning system to control development and retain adequate land for the natural environment. It has already been identified that more habitat is needed in order for the natural environment to adapt but there will be competing pressures for land. Whilst there is no certainty over what the natural environment will look like under conditions of climate change, it is certain that more land will be required. The spatial planning and landscape designation systems must be used to control development to help ensure that land is available in future for the extension of networks.

4.1.6 Policy responses

Many of the responses designed to protect ecosystem services can be delivered by farmers. In order to promote sustainable farming methods, rural payments may need to be tied to the provision of ecosystem services. There are also a number of existing schemes which can be tied to climate change adaptation including Catchment Sensitive Farming and the Water Framework Directive Programme of Measures.

4.2 Assessment of responses against 'good adaptation principles'

When formulating a climate change response strategy is it necessary to assess options to ensure that they are going to deliver effective adaptation. Adaptation measures need to be fit for purpose. However, there are a number of difficulties in ensuring that a specific measure is fit (UKCIP 2007):

- Determining fitness is often only possible after the measure has been implemented.
- The desired outcome may be delayed, invisible or hidden due to the implications of other changes.

There is a risk of producing a list of responses but with no guide as to which will be most effective at delivering the required adaptation. UKCIP (2007) has published a set of guidelines to inform effective adaptation which can be used to assess responses to climate change (see Box 4.2). These guidelines build on the UKCIP Risk, Uncertainty and Decision Making framework (Willows and Connell 2003). Despite there being difficulties in defining a particular adaptation measure as being good, acceptable, or successful, there are principles of good adaptation that can be used to inform the selection process (UKCIP 2007). The UKCIP set of principles has evolved through practice and can be seen in Box 4.5.

The UKCIP principles suggest that good adaptation requires engagement of an informed community with a willingness and ability to adapt. They also suggest that good adaptation requires an understanding of, and the ability to articulate, the objectives of the required action; an understanding of adaptation measures, including their feasibility; and a desire and willingness to see continued success through responsive and appropriate adaptation. Furthermore, the suggestions of implementing appropriate adaptation options (adaptive, no/low regrets and win-win), avoiding inappropriate actions, and adopting a continuous improvement approach are consistent with the precautionary approach (UKCIP 2007).

Box 4.5 UKCIP (2007) guidelines for effective adaptation

- Work in partnership.
- Provide a balanced approach to climate and non-climate risks.
- Manage priority climate risks.
- Address risks associated with today's climate variability and extremes.
- Use adaptive management to cope with uncertainty.
- Recognise the value of no/low regrets and win-win adaptation options.
- Avoid actions that foreclose or limit future adaptation.
- Avoid actions that conflict with mitigation objectives.

In addition to the UKCIP adaptation guidelines, the Hopkins *et al*. (2007) guidelines (see Box 4.1) for conserving biodiversity in a changing climate provide a more tailored approach for assessing adaptation in the natural environment. It is useful to combine the generic elements of Hopkins *et al*. (2007) with the UKCIP guidelines to form a list of criteria against which adaptation options for the natural environment can be tested:

- Work in partnership with other organisations and individuals with similar objectives. Delivering effective adaptation responses will require cooperation between organisations and it is important to identify and engage stakeholders.
- Influence organisations that may have different primary objectives, but none-the-less can contribute to adaptation actions, so that they are aware of the issues and are encouraged to take action. For example utility companies with major landholdings.
- Address pressures other than climate change on the natural environment. As can be seen from Chapter 3 of this report, climate change will not be the only driver of change in the natural environment; agriculture, recreation and other socio-economic pressures will impact on the natural environment. It is important to identify adaptation responses that deal with these sources of pressure as well as climate change.
- Maintain and enhance existing natural environment assets through adaptive management. Effective adaptation will deal with uncertainty and one of the best techniques for doing this in the natural environment is through adaptive management. By a process of reviewing and altering responses with respect to new information on climate change, adaptation can be flexible and respond to uncertainty. This approach reduces the risks associate with being wrong, since it allows for incremental adaptation (UKCIP 2007).
- Recognise the value of no/low regrets (measures that are worthwhile whatever the extent of climate change) and win-win options (actions which have other social, economic or environmental benefits in addition to climate change adaptation).
- Avoid actions that foreclose or limit future adaptation. It is important that actions taken today will not compromise future adaptation.

- Avoid actions that conflict with mitigation objectives. Adaptation responses which will result in an increase in greenhouse gas emissions should be avoided.

In addition to these criteria, adaptation options should be screened against socio-economic scenarios to ensure they are robust to different futures. Each adaptation response listed in Table A3.2 has been assessed against these principles to gauge their effectiveness, see Table A3.3 in Appendix 3.

From Table A3.3 a number of particularly effective response strategies can be identified. These responses are flexible, no or low regret and do not conflict with mitigation. In addition they offer opportunities for partnership working, deal with climate and non-climate risks and offer solutions for current climate risks. The particularly effective responses in the Shropshire Hills Character Area are likely to be:

- Maintaining existing habitats through adaptive management.
- Adjust conservation objectives in SSSIs in response to change.
- Be alert to new pests and diseases.
- Improve understanding of Character Area hydrology.
- Reduce fragmentation of habitats by expanding core areas and by bridging barriers and pinch points.

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Appendix 1 Background and project methodology

There is little doubt that climate change is a reality and that it will pervade all areas of life. While there are impacts that are no longer avoidable, there is still time to develop adaptation techniques to cope with a changing climate, and mitigation strategies to limit the extent of further damage in the 21st century.

The Earth's climate is dynamic; the planet alternates between periods of glacial (cold) and interglacial (warm) conditions as part of its natural cycle (IPCC, 2001). While this is often altered by such events as large volcanic eruptions, the cycle is consistent. For the past 10,000 years the Earth has been in an interglacial period, which has provided a comfortable 15°C average surface temperature for mankind. However, there is substantial evidence that the impact of human activities has caused, and will continue to cause, a steady but significant increase in this average surface temperature.

The Earth is kept warm by certain gases in its atmosphere; gases such as water vapour, carbon dioxide (CO_2) and methane absorb outgoing radiation and re-emit it back to the Earth's surface. This has been described as the 'greenhouse effect', without which the Earth's surface would be approximately 33°C colder. Since the industrial revolution, mankind has consistently been adding to the greenhouse gases already in the atmosphere. Through burning of fossil fuels and changes in land use, the volume of greenhouse gases has increased from 270 parts per million volume (ppmv) in pre-industrial times to 379 ppmv in 2005 (IPCC, 2007). This far exceeds the natural range of the past 650,000 years (180 to 300 ppmv) as determined by ice cores (IPCC, 2007). This has caused an intensification of the greenhouse effect and a gradual warming of the Earth.

Addressing the challenges associated with climate change requires a 'two-pronged' approach; mitigation to limit the magnitude and rate of change and adaptation to deal with the residual impacts and opportunities. However, irrespective of the success of mitigation efforts, there will still be some degree of unavoidable climate change due to historic emissions of GHGs. Responding to the impacts of climate change requires adaptation. With respect to climate change, adaptation is thought of as 'an adjustment in natural or human systems to actual or expected climatic stimuli (variability, extremes and changes) or their effects, which moderates harm or exploits beneficial opportunities' (UKCIP 2007; 4). Adaptation requires effective measures directed at enhancing our capacity to adapt and at minimising, adjusting to and taking advantage of the consequences of climatic change.

The purpose of Natural England is to conserve, enhance and manage the natural environment for the benefit of current and future generations. In doing so, Natural England works towards the delivery of four strategic outcomes:

- A healthy natural environment: England's natural environment will be conserved and enhanced.
- Enjoyment of the natural environment: more people enjoying, understanding and acting to improve, the natural environment, more often.
- Sustainable use of the natural environment: the use and management of the natural environment is more sustainable.

- A secure environmental future: decisions which collectively secure the future of the natural environment.

Dealing with the specifics of climate change, as opposed to the generalities, is very challenging but Natural England believe it important to start working towards comprehensive, geographically specific assessments of the possible impact of climate change on the heritage of wildlife, landscapes and our enjoyment of them. Such assessments would then allow us to start identifying responses which would reduce the adverse impacts identified. Character Areas have been chosen as there is systematic comprehensive coverage of England and they are at a manageable sub-regional scale. The four pilot Character Areas are the start of the journey. The pilots aim to translate the emerging principles of climate change adaptation into specific actions.

The 4 pilots were chosen to illustrate a range of projected climate impacts:

- Cumbria High Fells (montane impacts).
- Shropshire Hills (typical fragmented landscape).
- Dorset Downs and Cranborne Chase (drought).
- The Broads (wetland, sea level rise).

The purpose of the project is to create climate change response strategies for each of the selected Character Areas based on national and local expertise. In each Character Area an initial list of the more significant natural environmental assets has been complied; other valued assets may exist, but this exercise attempted to select some of the most important. Based on this list, Character Area specific impacts of climate change have been identified. Subsequently, Character Area specific response strategies have been complied that aim to practically adapt the habitats and landscapes in question, to the identified impacts of climate change.

Project methodology
The basic methodology has been to:

1. Identify significant environmental assets in the Character Area.
2. Assess the projected nature of climate change by looking at biologically significant parameters such as precipitation.
3. Assess the impacts of the projected climate changes on the environmental assets.
4. Propose actions to minimise the adverse impacts.

The climate change responses are the result of dialogue between national experts and local staff within each Character Area. Figure A1 illustrates the method behind each Character Area report. Initially, national experts (in habitat types, species, landscape, access and recreation and geodiversity) were asked to fill in templates to identify the impacts of climate change on significant natural environmental assets.

The templates asked the National Experts to identify climate risks, as expressed by projected climate change. The nature of the effects generated by the risk were then identified; for example for arctic alpines the risk is an increase in temperature and the nature of the effect is that species are forced to higher altitude or north facing sites. The extent of the effect, both in terms of geographical variation and magnitude of change was then identified. The projected impacts column identified the biophysical impact of the risk on the asset in question, so for arctic alpines the impact is that species move upwards or are lost. Following identification of impacts, the national experts were asked to suggest practical action that could be taken to adapt to climate change. Any key assumptions made in the impact assessment or useful references are listed in the final column. Table A2.1 shows a worked example of the process for arctic alpine flora.

Table A1.1 Worked example of national expert template

Valued asset	**Risk**	**Nature of effects**	**Extent of effects**	**Projected impacts**	**Proposed responses**	**Key assumptions**
Arctic alpine plants	Increasing temperature	Forces them to higher altitude/north facing slopes	Amount of temp increase from bioclimatic data	Retreat to higher altitude or loss	Improve condition of existing habitat to maintain as long as possible	

These master templates were then sent to the regional offices containing each of the chosen Character Areas. Regional staff were then asked to collate the assets pertinent to the Character Area in question and construct a Character Area specific version of the template. At this point regional staff reviewed the information provided by the national experts and updated it to reflect the specificities of their Character Area. One Character Area held an internal workshop to complete this part of the process.

Once a draft Character Area template had been assembled, national experts and regional staff met at a workshop to discuss and refine them further. The output of the workshops were annotated Character Area templates to reflect discussion held and a second template detailing practical response strategies for adapting to climate change. In addition, cross cutting issues such as landscape and ecosystem services were discussed at the workshops.

The outputs form the Character Area workshops form the basis of the climate change response reports. Around these templates, a narrative has been written which captures discussions held during and after the workshops.

The detail of any action – by who, when, cost, feasibility etc is not covered at this stage – that would be for subsequent implementation plans, which will involve working with regional partners.

The concept of connectivity, and how fragmented landscapes might be adapted to be more resilient in the face of climate change, has been the subject of a separate, specialist workshop with external bodies. This is a potentially important element in the response strategies.

Subsequently, after the pilot project, consideration will be given to:

- Assessing, broadly, the cost of the responses advocated.
- Assessing the contribution to locking up carbon (mitigation) which the response strategies would deliver.
- Rolling out the production of the response strategies to further Character Areas deemed to be at risk from climate change.

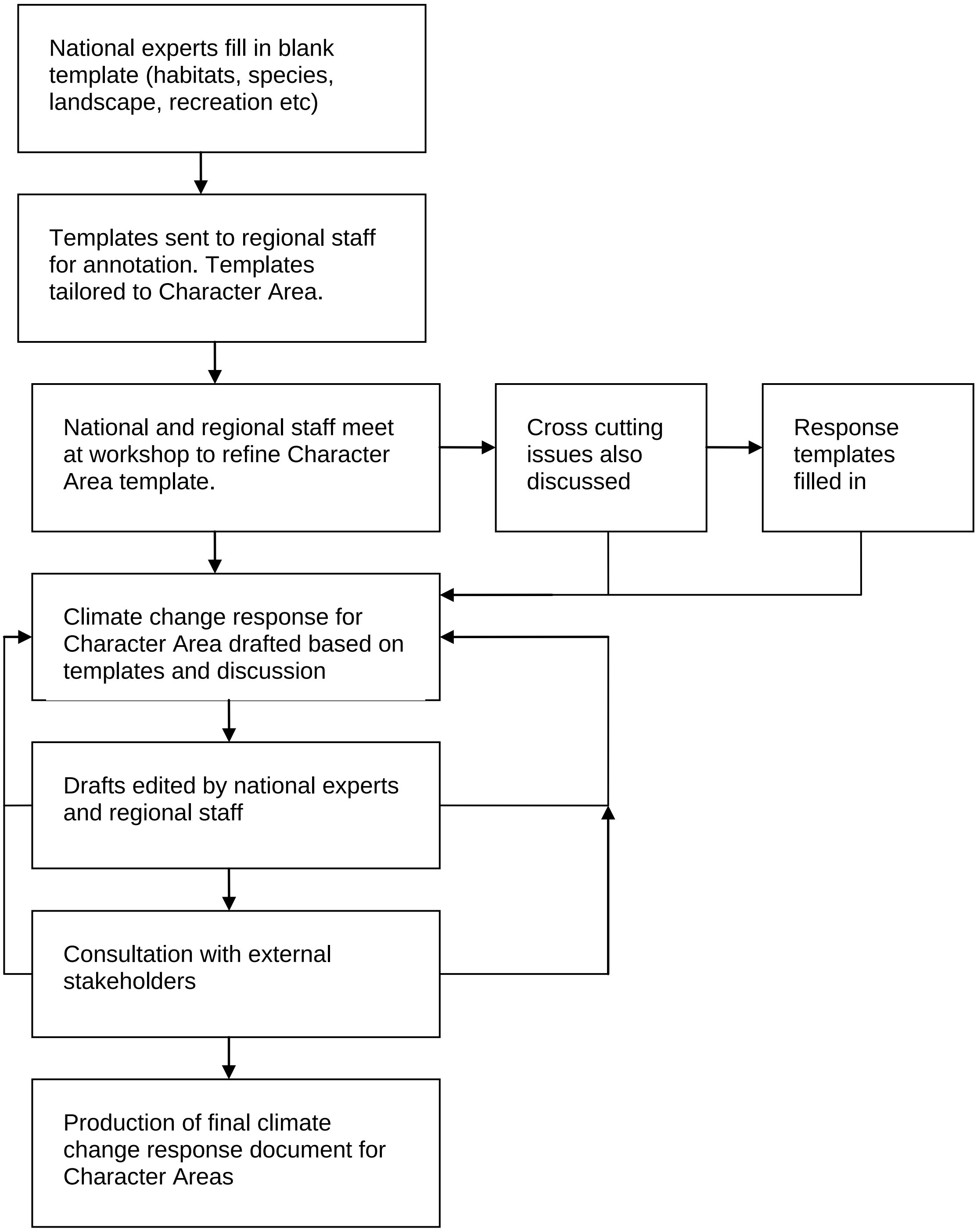


Figure A1.1 Flowchart showing project methodology

Appendix 2 Note on indirect climate change and socio-economic impacts

Socio-economic scenarios

Climate change will not be the only pressure on natural environments in the future. Other impacts will be felt through socio-economic change. Berkhout *et al*. (1999) identify five dimensions of socio-economic change:

1. demography and settlement patterns;
2. the composition and rate of economic growth;
3. the rate and direction of technological change;
4. the nature of governance; and
5. social and political values.

Given the deep level of uncertainty, traditional forecasting techniques are inappropriate. Instead, *scenarios* of socio-economic change are developed. Scenarios can be defined as:

> 'p*lausible, challenging and relevant sets of stories about how the future might unfold. They are generally developed to help decision-makers understand the wide range of possible futures, confront uncertainties and understand how decisions made now may play out in the future' (UNEP 2005).*

Scenarios attempt to capture the dimensions of change described above; however, the last two dimensions are somewhat less tangible than the first three. The nature of governance concerns the degree to which governance is at a global or local scale. Governance can be international and strongly integrated or local and highly autonomous. Social and political values refer to the degree of individualism and consumerism that prevails, as opposed to communism and conservation. A continuum exists between the two extremes of each dimension and these can be used to form a matrix in which potential future socio-economic scenarios sit (see Figure A2.1). Other dimensions of change are then applied within this framework.

A number of socio-economic scenario sets have been constructed by a number of organisations for a range of purposes. Figure A2.1 includes socio-economic scenarios constructed by UKCIP (2001), for use alongside climate change impact and adaptation assessments, and the scenarios from the Millennium Ecosystem Assessment (MEA) (UNEP 2005). Both scenario sets consider the impacts on biodiversity, which are summarised in Table A2.1.

Table A2.1 Socio-economic scenarios related to biodiversity

Global Orchestration • Conservation sites maintained and slowly expanded but designed for access • *Large-scale farming, GM crops* • *Urban sprawl and demand for 'managed landscapes'*	**Techno-Garden** • High priority to protection • Pressures from growing demand • *Low input farming and sustainable landscape management* • *Tight planning controls* • *Control of industrial pollution*
Order-from-Strength • Policy not strong enough to restrict development pressures • Little public concern about biodiversity • *Intensified farming, larger farms* • *Environmental pollution*	**Adaptive-Mosaic** • Strenuous efforts to preserve wildlife • Access demands • *Extensive and more diverse agricultural* • *Development controls*

Adapted from UKCIP, 2001, with scenarios names from UNEP, 2005. Indirect socio-economic impacts i.e. socio-economic impacts on other sectors but with implications for biodiversity are shown *in italics*.

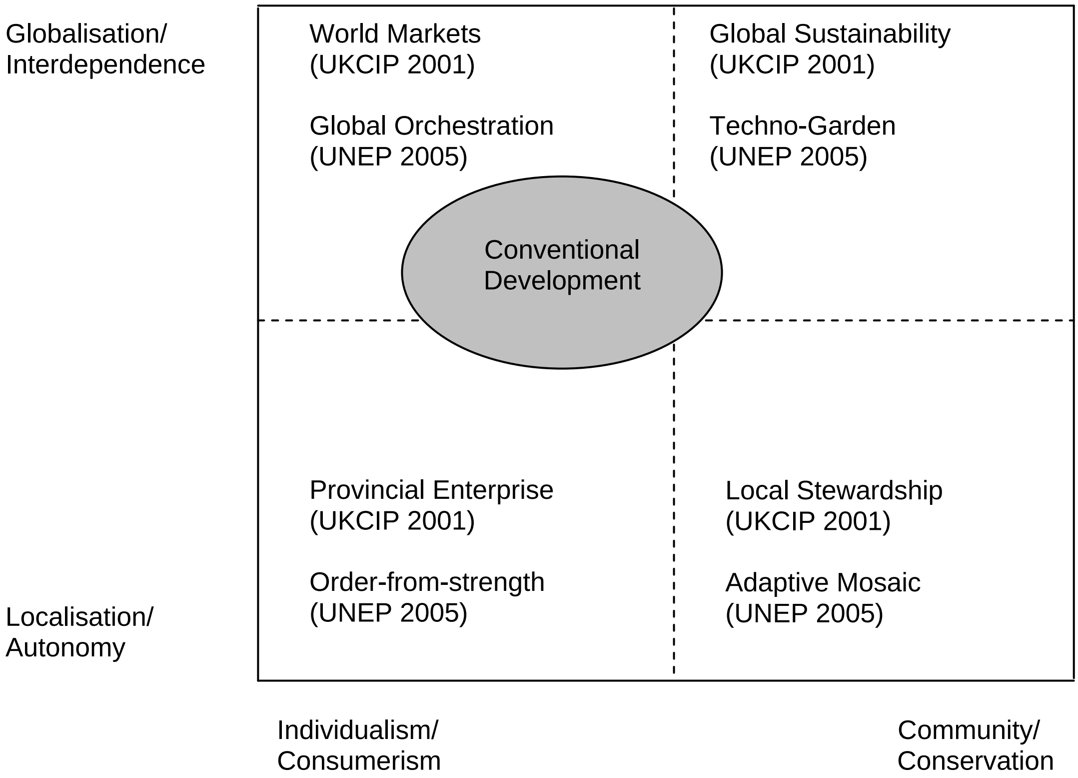
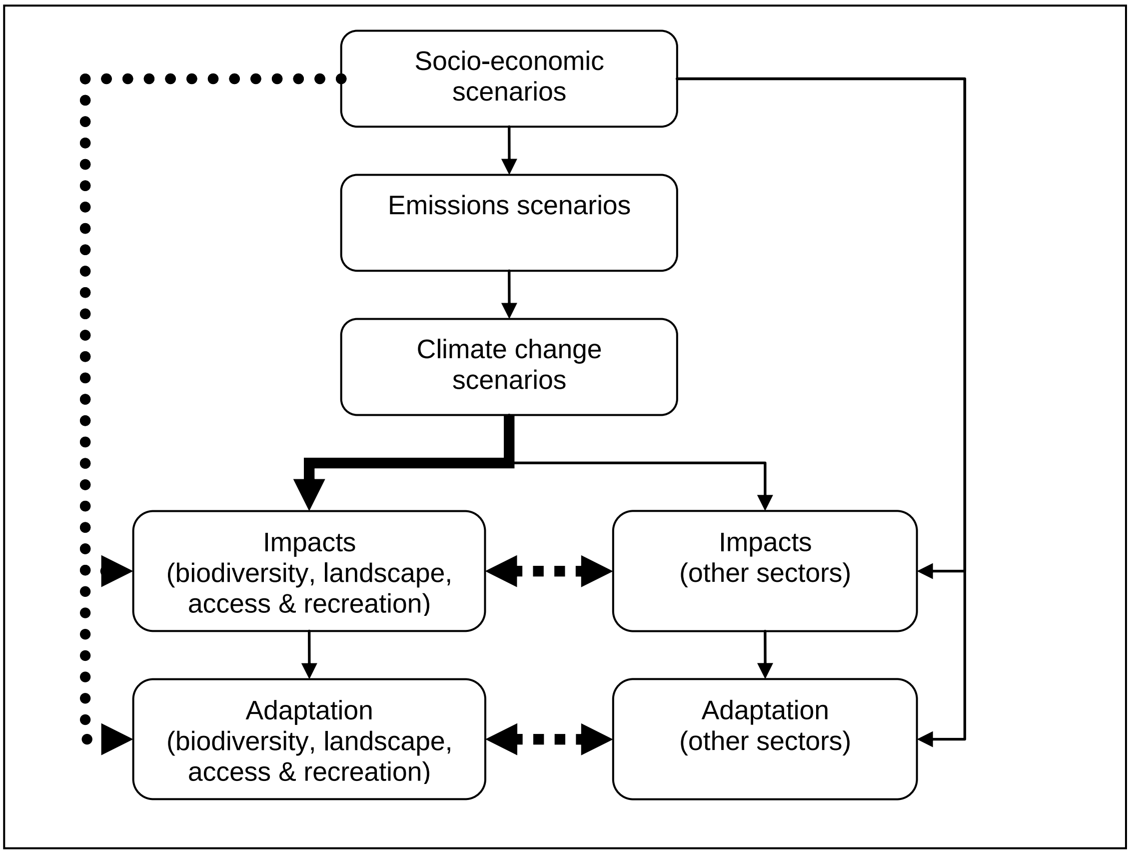


Figure A2.1 Socio-economic scenarios

Socio economic scenarios in climate change impact and adaptation assessment
We are increasingly used to working with climate change scenarios (such as those produced by UKCIP) to identify the direct and indirect impacts of climate change on assets of interest. These scenarios are informed by emissions scenarios (e.g. IPCC 2000) which are in turn driven by socio-economic scenarios (see Figure A2.2). Therefore the socio-economic scenarios not only directly and indirectly affect significant natural environmental assets; they also condition the climate change scenarios and resulting impacts. For this reason, socio-economic and climate change

scenarios are often linked e.g. World Markets with High Emissions, although alternative 'cross-over' scenarios can be employed.



Thick solid line = direct climate change impact on biodiversity etc; dashed line = indirect climate change and socio-economic impact on biodiversity etc; dotted line = socio-economic impact on biodiversity etc.

Figure A2.2 Role of socio-economic scenarios in climate change impact and adaptation assessment

Significance of socio-economic scenarios for the CA project

Climate change will directly affect valued assets in the Character Areas. The significance of the impacts of climate change will be mediated by the socio-economic scenario that prevails at the time; changes in attitudes and behaviour towards the natural environment and conservation will alter the nature of the impacts. For example, the priority attached to dealing with species loss will be dependent on what we perceive as 'valuable' in the natural environment.

In addition to direct impacts, climate change will also have an indirect impact through interaction of assets with other sectors. For example, many Character Areas are heavily influenced by agriculture. Changes in agriculture could be driven by climate change, such as crop switching to more drought tolerant plants or increasing intensification due to the failure of harvests in other parts of the world. These would be classified as indirect impacts of climate change on the Character Area. These indirect impacts will also be mediated by the prevailing socio-economic scenario at the time.

However, shifts in agriculture may occur regardless of climate change e.g. driven by fluctuations in crop prices or shifts in consumer demand for certain products. Such changes would be classified as socio-economic impacts. These changes, whether climate induced or not, would significantly impact on the Character Areas.

Table A2.2 Examples of direct, in-direct and socio-economic impacts

Type of impact	Examples
Direct climate change impact	• Increased stress due to drought • Phenological changes • Carbon dioxide fertilisation effect
In-direct climate change impact	• Increased visitor numbers in CA (due to an increase in temperature) • Reduction in water available for habitats (due to an increase in potable water demand)
Socio-economic impact	• Increase in invertebrate and bird species due to a shift towards organic farming • Development pressure in CA due to population increase

In reality direct, indirect and socio-economic impacts are closely related. The Character Area project focuses on the direct biophysical impacts of climate change on the significant natural environmental assets of the Character Area (and is noting the downstream policy impacts where they arise). Where significant indirect impacts have been identified (such as those related to agricultural change in the face of climate change) these have been included and classified as indirect.

Table A2.3 Indirect impacts of climate change on significant natural environmental assets

Sector primarily impacted	Impact of climate change	How it might affect the natural environment
Agriculture, horticulture and forestry	Crop switching to more drought resistant crops Re-intensification due to failure of harvests elsewhere Increase in irrigation requirements	Landscape change Landscape change, reduced access to the natural environment, increase in diffuse pollution, species compositional change, reduction of network size Reduction in water available for habitats
Flood management	Reduction in condition of existing defences and risk of subsidence Increased risk of breach and overtopping of defences	Potential for habitat creation Change in land use Increased risk of inundation of sites
Water resources	Increase in demand, reduction in supply Increased storage requirements	Reduction in water available for habitats Potential for habitat creation
Transport	Subsidence Damage to infrastructure	Reduced access to natural environment
Retail	Increased opportunity for outdoor retail	Increase in recreation potential

Sector primarily impacted	Impact of climate change	How it might affect the natural environment
Leisure and tourism	Increase in visitor numbers	Increase in recreation activities in the natural environment Risk of overcrowding leading to loss of visitor experience, damage to footpaths, increased pressure on resources and infrastructure
Health	Increase in heat related illnesses	Reduced outdoor recreation in summer

The Character Area project has not adopted a formal scenario based approach, nor does it provide an integrated assessment as these are highly complex. Instead, it is assumed that conventional development (mainly World Markets with aspects of other scenarios) will prevail.

Table A2.4 provides some examples of socio-economic impacts, which could affect the species, habitats, landscapes and recreational function of the Character Areas. This is based on knowledge of socio-economic changes, informed by current trends and drivers (e.g. the Water Framework Directive; European and UK Climate Change Programmes) and the futures literature (e.g. Evans *et al*. 2004; LUC *et al*. 2006; OST, 2002; UKCIP, 2001).

Table A2.4 Socio-economic changes with potential to affect natural environment

Sector	Socio economic change	How it might affect natural environment
Agriculture, horticulture and forestry	Increase in demand for organic produce Changes in payments and subsidies	Increase in invertebrate and bird species Reduction in diffuse pollution Improve countryside stewardship Reduce monoculture
Flood management	Preference for 'soft defences' e.g. managed realignment Changes in flood defence budget (decrease) Changes in flood defences (increase)	Increase in inter-tidal and floodplain habitat creation potential Greater risk of inundation of valued assets – positive for some and negative for others Reduced risk of inundation of valued assets – positive for some and negative for others
Water resources	Increase in water metering Introduction of variable tariffs Increased pressure on water resources in growth areas due to population increase	Potential increase in water available for habitats as potable consumption reduces Potential decrease in water available for habitats in growth areas

Sector	Socio economic change	How it might affect natural environment
Energy	Increase in oil price resulting in switch to renewables Switch to nuclear energy	Negative landscape impact of wind turbines Risk of diffuse pollution, landscape impact
Buildings	Increase in new build rates to meet demand from population growth – urban expansion Demand for waterside locations	Pressure on land Diffuse pollution
Transport	Demand for new infrastructure – roads, railways, runways etc to meet growing demand	Habitat fragmentation, landscape impact. Positive impact on access to countryside
Manufacturing and industry	Shift of heavy industry to other parts of the world	Reduction in diffuse pollution, increase in sites available for habitat restoration and creation
Financial services	Demand for ethical investment increases	Increased financial support
Retail	Movement of retail out-of-town Increase in ethical shopping	Pressure on land Increased awareness of value of natural environment
Leisure and tourism	Increased demand for extreme sports Increased demand for eco-tourism	Increase in visitor numbers and demand for facilities and infrastructure Reverse some of the negative effects of previous tourism
Health	Increase in obesity	Increased potential to market the countryside as part of a healthy lifestyle
Defence	Terrorism	Heightened security measure required

Mitigation

Addressing the challenges associated with climate change requires a ‘two-pronged’ approach: mitigation to limit the magnitude and rate of change and adaptation to deal with the residual impacts and opportunities. In climate change literature, mitigation refers specifically to the reduction in greenhouse gas emissions (UKCIP 2003). Mitigation is often driven by policy e.g. the UK Climate Change Programme. In addition to direct and in-direct impacts of climate change, assets can be impacted by mitigation policy. Table A2.5 illustrates some potential impacts of mitigation policy on the significant natural environmental assets. Note that other mitigation actions e.g. individual, corporate or market-based may also affect assets, although they are likely to be of a similar type.

Table A2.5 Mitigation policy impacts on Natural England

Sector	Mitigation policy	How it might affect Natural England objectives
Agriculture, horticulture and forestry	Increase in biofuel production Increase carbon store in soils and biomass	Landscape change, increase in monoculture Habitat creation potential
Flood management	Support use of non-carbon intensive forms of flood defence	Habitat creation potential
Water resources	Reduce energy demand of water treatment	Diffuse pollution
Energy	Shift to renewable energy or nuclear	Landscape impact of wind turbines / new power stations
Transport	Renewable transport fuel Increase in public transport	Landscape change, increase in monoculture Shift in how people access recreational facilities, new infrastructure required
Manufacturing and industry	Burning of biofuels and CHP	Landscape change, increase in monoculture. Opportunity to capitalise on demand for waste organic products (e.g. wood chippings generated through reserve management)

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Appendix 3 Tables accompanying narrative

Table A3.1: Impacts on the significant natural environmental assets of the Shropshire Hills CA
Key
Indirect impacts are highlighted in italics
Policy impacts are underlined

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
1	BAP[1] Habitat wet woodland	Summer drought Summer temperature increase Higher intensity rainfall events	Drying out of rainfall-dependent sites in summer Possible increase in land for flood storage	Mainly a problem in the lowlands	1a. Changes in ground flora communities 1b. Potential opportunities for habitat creation on flood storage land 1c. Loss of condition of designated sites, failure to achieve Favourable Conservation Status on Annex 1 habitats, failure to meet HAP[2] targets	Key factor is availability of water, (ground water) for maintenance of this habitat. Need to research hydrology of Character Area and how it might change under climate change.
2	BAP Habitat Upland Oakwoods	Increased summer temperature Changed rainfall pattern	Changes in ground flora composition - probably no major losses of currently common species Some decline at margins of most bryophyte-rich types as modelled by *Dryopteris aemula,*	Occurs largely in the north and west. Effects likely to be greatest on south-facing slopes and towards the margins of its climate suitability, e.g. on the	2a. Individual rare species may increase or decrease 2b. Increased invasion of oakwoods by beech & holly 2c. Shifts in the relative contributions of the sub-types of upland oak, e.g. W11[5] versus	This is one of the types less likely to change significantly under climate change

[1] Biodiversity Action Plan.
[2] Habitat Action Plan.

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
			Changes in canopy tree competitiveness (particularly with respect to beech, currently considered non-native through most of this type) Changes in balance of woodland versus upland grass/moor under agricultural shifts	upland fringe.	W17 with implications for reasons for designation as SSSI[3]/ SAC[4]	
3	BAP Habitat Upland Mixed Ashwoods	Increased summer temperature Changed rainfall pattern	Changes in ground flora composition, but probably no major losses of currently common species Changes in canopy tree competitiveness (particularly with respect to sycamore and beech, currently considered non-native through most of this type)	Habitat is predominantly in the north and west. Effects likely to be most pronounced on south-facing slopes and at the southern margins of the range.	3a. Individual rare species may increase or decrease 3b. Shifts in the relative contributions of the sub-types of upland ash, e.g. potential for expansion of the 'dry' (W8g) forms down slope on hot sites; expansion of moist types (W8f) if rainfall increases humidity in ravines.	this is one of the types less likely to change significantly under climate change
4	BAP Habitat Mixed Deciduous Woodland	Summer drought Higher summer	Shifts in the competitive balance of major tree species Shifts in the regeneration patterns of trees (more	Widespread throughout the lowlands so even minor changes at	4a. Decline in woodland cover 4b. Increased threat of fire on driest sites	Relatively little consideration has been given to this type of woodland to date, even though it is the largest

[3] Site of Special Scientific Interest.
[4] Special Area of Conservation
[5]National Vegetation Classification reference

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
	Ancient & Semi Natural Woodland Ancient Replanted Woodland	temperature Changed rainfall patterns	regular masting?) Changes in the relative abundance of woodland species and communities, but probably no major changes in overall species pools Changes in landscape context because of changes in lowland agriculture Potential invasion/establishment of species from further south in Europe e.g. Holm oak.	individual sites will have significant cumulative impact. Effects likely to be most severe on dry south-facing slopes in south-east.	*4c. Increased impacts of agricultural practice on adjacent woodland* 4d. Individual rare species may increase or decrease 4e. Change in composition from invasive species <u>4f. Shifts in the composition of vegetations types or balance of types has implications for reasons for site designation</u>	single type.
5	Other Woodland	For all woodland types there is likely to be an increased risk from introduced pests and diseases but also from changes in the population dynamics of native species, e.g. outbreaks of winter moth.	Across all types there could be increased risks from effects of climate change on agricultural profitability leading to intensification of arable or improved grass in the lowlands and more stock in the upland; equally more emphasis on wood as an energy source could lead to impacts on woodland structures and conditions. For these effects there is a difficulty “drawing the line” in respect of impacts.		5a. Changes in ground flora communities 5b. Potential opportunities for habitat creation on flood storage land 5c. Loss of condition of designated sites *5d. Failure to achieve Favourable Conservation Status on Annex 1 habitats* *5e. Failure to meet HAP targets*	For all woodland types increasing the size of small blocks will increase resilience by increasing the potential species population sizes and buffering against current threats. The role of increasing connectivity with respect to climate change is uncertain, but where it increases local heterogeneity in terms of soils, aspect or altitude this is likely to be beneficial.
6	Historic Parks and Gardens Wood Pasture and Parkland	Increased summer drought	Increased rates of loss of existing veteran trees In addition to the above some models highlight the following possibilities:	Whole country potentially affected	6a. Loss of specialist associated species through loss of veteran tree habitat (primarily fungi, saproxylic invertebrates and lichens)[2] 6b. Loss of landscape quality through loss of	Main threat is assumed to be to the veteran tree population. However, changes in farming practice could affect both the sites and

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
			Increased windiness, increased frequency of extreme storms		old trees *6c. Agricultural intensification leading to improvement/ploughing of pasture element, clearance of scrub etc* 6d. Increased loss of mature trees to wind	the landscapes in which they sit as a consequence of climate change.
7	BAP Lowland Calcareous grassland and undetermined grassland – (Not a big habitat of interest in Shropshire Hills Character Area)	Increased summer temperature Wetter, warmer winters Longer growing seasons	Drought Increase in spring biomass and decline in summer biomass Increased risk of wildfires resulting in damage to lower plant assemblages.	Increased summer drought is likely to be a particular threat for those communities which already have a highly xeric character, notably CG9 on South and West facing slopes.	7a. Loss of/declining condition in parts of the SSSI/SAC series <u>7b. Continuing unfavorable conservation status for Annex 1 habitat</u> <u>7c. Difficulty in meeting lowland dry acid grassland HAP/BAP targets</u> 7d. Possible losses/declines of perennials due to die back through drought 7e. Increase and expansion of drought tolerant ephemerals 7f. Delayed succession, as gap formation in the sward will provide sites for colonisation of annuals, thereby enabling their persistence in the sward at the expense of perennials 7g. Loss of dominant species, including grasses is predicted in certain climatic models. 7h. Results from Monarch indicate that certain species will undoubtedly gain suitable climatic space in the North and West whilst losing it in the South (*Cirsium acaule, Blackstonia*	Responses of chalk/limestone communities to climate change will be related to the life-history attributes of the dominant species. Sensitivity of the majority of perennial grasses to increasing incidence and intensity of summer drought resulting in possible substantial shift in community composition towards more annularity.

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
					perfoliata, Helianthemum nummularia) but the ability of such species to successfully colonise newly suitable patches is likely to be constrained by dispersal ability.	
8	BAP Habitat Lowland Dry Acidic Grassland	Drier summers Increased temperatures and longer growing seasons Wetter winters	Summer drought may favour annual species over perennials Milder winters may reduce frost heaving characteristic of U1 vegetation especially in eastern England	Across the range of the habitat but effects may be more pronounced in SE & eastern England.	8a. SSSI condition may become "unfavourable". 8b. Difficulty in meeting lowland dry acid grassland HAP/BAP targets 8c. Community composition changes - may shift to favour southern temperate and Mediterranean continental elements in flora. Oceanic/sub-oceanic species may decline 8d. Certain acid grassland species are predicted to lose climate space by 2080 namely *Koeleria macrantha* (U1), *Erica cinerea* (U3), *Filago lutescens* (U1), and *Agrostis curtisii* (U3). The last named though is predicted to have high adaptability potential. 8e. Less summer forage available for livestock grazing *8f. Drier conditions may make agricultural areas less viable*	Change in community composition to favour stress tolerators and ruderals (especially annuals) (southern temperate/Mediterranean floral elements)
9	BAP Habitat Upland and Lowland Heathland (Treat upland and lowland	Warming	Increased above ground biomass Increased herbivory damage Slight increased flowering		9a. Negative for species depending on bare ground and open areas 9b. Increases in area damaged by heather beetle – could become more prolific if temperatures warm	The main papers dealing with impacts of climate change (drought and warming) on heathlands in the UK refer to an upland site in Wales, but they are the best info that

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
	heath as one entity in this Character Area - distinctions in Shropshire Hills are vague)		Less CO_2 allocated to soil Litter fall tended to decrease Increased spring leaching of nitrate Increased growth Decreased growth Acceleration of spring growth Upland character will give way to lowland character in a warming climate. Increase in wildfires		9c. Positive warming feedback as more CO_2 is released. Changes in soil chemistry. Possible impacts on soil fauna. 9d. Water pollution 9e. Changes in community composition; impact on insects 9f. Increased risk of wildfires resulting in damage to lower plant assemblages	exists.
10	Lowland hay meadows	Wetter winters Drier summers Increased temperatures and longer growing seasons	Higher water tables/increasing frequency and duration of flooding	Across the range of the community but drought effects may be more pronounced in SE England	10a. Temperature changes may cause certain species to flower/set seed earlier in season 10b. Wetter winters may lead to higher frequency/duration of high soil water tables/flooding events 10c. Higher water tables/increasing frequency and duration of flooding could potentially threaten the integrity of alluvial flood meadows as the component plants of the community are more prone to increasing wetness than to summer drought. 10d. SSSI condition will become "unfavourable".	The component plant species of the various lowland meadow types mostly belong to the southern temperate, widespread temperate and temperate biogeographical elements. This suggests that the three lowland meadow NVC types might be relatively resilient to climate change scenarios, especially those related to temperature

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
					10e. Difficulty in meeting lowland hay meadow HAP/BAP targets 10f. Continuing unfavourable conservation status for Annex 1 Lowland Hay meadow (MG4) habitat 10g. Changes in phenology of characteristic lowland meadow plant species may change significantly 10h. Increase in biomass – favour competitive species 10i. Stress tolerant species and ruderals increase	
11	BAP Habitat Purple Moor Grass and Rush Pasture	More severe summer drought episodes Wetter, warmer winters Longer growing seasons	Reduced summer rainfall predicted by some Prolonged inundation in winter	M22 is vulnerable given its southern and eastern distribution.	11a. M24 is vulnerable to reductions in watertable, flooding and dereliction 11b. Loss of/declining condition in parts of the SSSI/SAC series. 11c. Continuing unfavourable conservation status for Annex 1 habitat. 11d. Difficulty in meeting lowland dry acid grassland HAP/BAP targets 11e. Change in community composition - precise tolerances are not known but it can be speculated that this will lead to a loss of wetland interest and increased representation by 'dryland' species. 11f. Potential increase in spring biomass and decline in summer biomass	Responses of these *Molinia* and *Juncus* dominated communities to climate change will be related to the life-history attributes of the dominant species. There is a real paucity of any habitat specific evidence of likely impacts of climate change for this priority grassland type.

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
					11g. Decline in abundance and diversity of associated mosses, particularly sphagnum component (no evidence). 11h. A reduction in the water table will result in the loss of some mire species and 'M13 characteristic' species. 11i. Prolonged inundation in winter of stands of these communities in winter may shift them towards true fen or swamp communities.	
12	BAP Habitat Reedbeds	General issues as for other freshwater habitats	Coastal re-alignment and flooding		*12a. Loss due to coastal realignment and flooding* 12b. Increased frequency of flooding 12c. Increased silt loading 12d. Loss of breeding habitat for wetland bird species	
13	BAP Habitat Coastal and Floodplain Grazing Marsh	General issues as for other freshwater habitats	Similar issues to reedbed and floodplain fen. Potential for better storage of winter rainfall.		13a. Increased frequency of flooding 13b. Increased silt loading 13c. Loss of breeding habitat for wetland bird species	Much depends on management of rivers and floodplain and flood risk.
14	BAP Habitat Fen	General issues as for other freshwater habitats	Floodplain fens face same risks as reedbed. Basin fens (largely surface-water fed) may suffer drying in summer	Impact on ground-water dependent fens may vary depending on aquifer type and degree of winter recharge. Recent modelling suggests fens fed by chalk	14a. Increased frequency of flooding 14b. Increased silt loading 14c. Loss of breeding habitat for wetland bird species 14d. Increased risk of polluted run-off with	Fens encompass a very wide range of habitat types, all of which will respond to climate change in different ways.

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
				aquifers may be particularly vulnerable. Sandstone and limestone aquifers appear to be at less risk.	increased winter rainfall and extreme rainfall events.	
15	BAP Habitat Blanket Bog	Increasing Summer Temps	Changes in temperature, precipitation and evaporation.		15a. Increased summer soil droughtiness (higher moisture deficits) with natural/semi-natural ecosystems including drying of peat bogs/peat loss. 15b. Increased organic matter turnover and loss of soil carbon. This could lead to poorer soil structure, stability, topsoil water holding capacity, nutrient availability and erosion.	Soil moisture and temperatures are the key drivers to most soil processes. Changes in soil water fluxes may also feedback to the climate itself. The type of soil structure which develops under a particular climatic regime is important because it affects aeration, run-off, infiltration, percolation and drainage and hence associated vegetative cover/land use
16	Visitor destinations	Climate Change	Hotter weather may encourage people to take holidays in the UK/ become more active. Policy reduction in climate change gasses cost of travel increase	Attractive rural areas	*16a. Increase in visitor numbers* *16b. Problems particularly significant at holiday times on transport infrastructure* *16c. Possible reduction in travel to more remote areas as cost increases.* *16d. Socio-economic effects – increasing population and housing prices*	Assumes visitor numbers will rise with warming temperatures. Visitor behaviour will also be determined by socio-economic environment – attitudes to recreation, nature etc.

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
17	Public Rights of Way	Warmer temperatures, wetter winters	Hotter weather may encourage people to take holidays in the UK/ become more active.	Rights of Way network	*17a. Increase in visitor numbers. Increase in people using rights of way.* *17b. Congestion on popular routes.* 17c. Footpath erosion.	
18	Open Access Land	Climate change Warmer dryer periods	Fires Increased visitor numbers	Heathland & Moorland – fires All	18a. Large areas of potential fire damage - areas not available for recreation. Degraded or severely damaged *18b. Congestion – loss of visitor experience*. 18c. Erosion.	
19	Rivers	Increased winter precipitation and storminess	Increase in flash flooding	Rivers and low lying areas	19a. Increased flood risk to rights of way network. *19b. Increase in visitors to view floods* 19c. Increased erosion of wet paths	
20	Landscape: Semi-natural habitat features – heathland, grassland,	Prolonged summer drought, prolonged winter rains.	Change in viability of farming in marginal areas, leading to abandonment or inappropriate management. Scrub growth arising from abandonment of marginal land.	Throughout the Character Area in extensive areas of semi-natural habitat.	20 Loss of key textural features of heath and unimproved grasslands. Leading to homogenous – scrubland character.	
21	Traditional Orchards	England: Higher temps annual, seasonal (especially winter), max and min. South east greater increase than north west.	Change in dependent species ranges Longer growing season / greater woody species growth per year, Less favourable temperatures for winter chill requirements for fruit e.g. bud development Possible mortality / crop loss if orchards exposed to	Effects in north for fruit species ranges	21a Wider range of fruit species and varieties can be grown and range extension of some species further north e.g. walnut. Positive Reduced fruit crops due to warmer winters, and possible greater past and disease problems Mild Increased scrub growth in neglected orchards Moderate Changed climate conditions may impact on the viability of local varieties currently under cultivation.	Loss figures for traditional orchards (BAP proposal) and Norfolk orchard survey Scrub observations in Natural Englnad orchard surveys Apple yields in Kent negatively related to temps Feb-April, see Cannell et al (1989)15

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
		Increased seasonal precipitation and increased annual variation may increase flood frequency and waterlogging of soils.	prolonged flooding in growing season or waterlogged soils		21b Fruit species not suited to waterlogged soils. Some orchards located on floodplains. Loss and damage could affect crop yield but most importantly habitat for dependent species e.g. noble chafer location in orchard adjacent to River Severn Moderate	Apple variety Braeburn from 'warm growing' countries now more successful in UK (Webster & Biddlecombe, 2003)8 Rough comparisons of fruit species distributions show that some occur in warmer and drier climates in mainland Europe than the UK 4 Climate matching in Broadmeadow et al (2005) also used4. General observations on effects of climate on pests and diseases Broadmeadow (2005)2 and Broadmeadow (2002)3 MONARCH 3 species models used (Berry et al 2007)14 Species modelling and autecological research required. Waterlogged soils unsuitable for fruit trees according to Macer Wright (1960)10, Barden and Neilsen (2003)11, Webster & Biddlecombe (2003)8, Taylor (1949)12, Grubb (1949)13

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
22	Hedgerow, infield and riverside trees	England: Higher annual mean temperature Higher winter temperature Increased winter precipitation Increased annual precipitation variation Increase in extreme events e.g. storms	Some species may not be suited to warmer conditions, particularly when combined with summer drought (e.g.. beech). Dieback and death resulting Increased flooding and waterlogging. Prolonged saturation of river valley soli may kill some tree species. Significant numbers of trees may fall victim to windblow. Drought	Throughout the Character Area, but particularly on exposed slopes and hilltops. South east greater temperature increase than north west.	22 Decrease in presence of trees in the landscape.	Need references
23	Historic and veteran trees, including trees in designed parkland.	England: Higher annual mean temperature Higher winter temperature Increased winter precipitation Increased annual precipitation variation Increase in extreme events e.g. storms	Some species may not be suited to warmer conditions, particularly when combined with summer drought (e.g. beech). Dieback and death resulting Prolonged saturation of river valley soli may kill some tree species. Significant numbers of trees may fall victim to windblow.	Throughout the Character Area , but mainly in historic landscape types (parks and gardens, pre-1880s settlements, pre-1880s orchards, irregular squatter orchards, small assarts, large assarts with sinuous boundaries, small irregular fields, piecemeal enclosure, other small rectilinear fields) , and particularly in these areas on exposed slopes and hilltops.	23a Loss of veteran and historic trees in the landscape. 23b Some historically authentic new tree plantings may not be viable by the time they reach maturity	Need references Climate Change and the Historic Environment – Historic Environment – Local Management website.

Ref	Asset	Risk	Nature of risk effects	Extent of Effects	Projected Impacts	Key Assumptions
24	Designed parkland – man made water features	Increase in extreme events e.g. storm events	Increased erosion and flash flood events may lead to structural collapse of water features and silting up.	In certain historic parklands within the Character Area .	24 Loss of important designed water features in parklands.	
25	Earthworks	Prolonged winter rainfall Extreme storm events	Poaching of earthworks by livestock running on saturated soils. Increased erosion where earthworks are exposed and have poor vegetation cover. Wind blow of trees on earthworks.	Offa's Dyke, hillforts, motte and bailey earthworks throughout the Character Area .	25a Erosion and significant structural decline of historic earthwork features. 25b Windblown trees in particular will damage earthworks, as the upturned root plates lift and disturb significant sections of earthwork.	
26	Below ground field archaeology	Extreme storm events, prolonged winter rainfall.	Erosion of soils covering below ground archaeology	Throughout the Character Area , particularly on slopes and sensitive soils.	26 Loss of historic fabric – prehistoric and Romano-British crop mark complexes.	
27	Vernacular buildings and structures – traditional farm buildings, mills and bridges	Extreme storm events, prolonged winter rainfall. Prolonged summer drought conditions Flooding.	Damage to buildings and structures. Erosion of footings.	Throughout the CA	27 Loss of historic fabric – traditional buildings, vernacular bridges and mills.	References for storm event increase and severity

Table A3.2: Responses to climate change impacts in the Shropshire Hills CA

Key
Policy responses are underlined

Asset	Impact Ref	Response strategy	Priority	Timing	Cost	Extent to which impact dealt with by response	Responsibility	Barriers
Grassland	8a	Maintain best practice management through adaptive management e.g. grazing levels	High	Immediate	Low – adapt existing management	Effective if delivered through targeted agri-environment schemes	Natural England, landowners, farmers	Agricultural economics, physical constraints
	7d 7f 7g 7h 8c 8d	Habitat re-creation or restoration	Medium	Ongoing	Medium to High	Effective if targeted towards habitats that will be sustainable under climate change conditions. Effective to target resources towards habitats or species that will not persist. Calcareous grassland creation will be constrained by soil types.	Natural England, landowners, NGOs, Environment Agency (for floodplain habitats)	Funding, Agricultural economics, Unsympathetic landowners
	7a 7b 7c 8a 8b 10d 10e 10f	Changing conservation objectives to accept changes in species and community composition	High	Immediate	Low	Will need monitoring to determine effectiveness	Natural England	Political resistance
	10a 10g 10i	Alter hay cutting date	High	Immediate	Low – adapt existing management	Effective but will require monitoring to find optimum date. Can be delivered through agri-environment schemes	Natural England, farmers	

Asset	Impact Ref	Response strategy	Priority	Timing	Cost	Extent to which impact dealt with by response	Responsibility	Barriers
Heathland	9a 11f	Manage grazing - maintain appropriate stocking level	High	Immediate	Low – adapt existing management	Effective – requires monitoring to ensure effectiveness	Natural England, landowners	Agricultural economics
	9f	Adjust burning regime	High	Immediate	Low – adapt existing management	Partly depends on heather beetle life cycle and interactions with natural predators.	Natural England	
Woodland	1a 4a 5a 6a	Maintain existing habitat including around sites	High	Ongoing	Medium – already a management priority	Effective. Requires countryside monitoring	Natural England	
	1a 4a 5a 6a	Increase size of small woodland sites	High	Immediate	Medium	Effective – increases habitat network and connectivity. Proven response.	Natural England, local authority planning departments, farmers, Forestry Commission	Development pressure Agricultural economics
		Be alert to potential new pests and diseases	High	Immediate	Medium	Requires ongoing monitoring on the ground	Natural England, reserve managers	
	2a 2b 2c 3b 4d 4e 4f 5c 5d 5e	Build in flexibility in conservation objectives to accommodate vegetation shifts e.g. beech, sycamore, holly.	High	Immediate	Low – likely to reduce cost of management	Will need monitoring to determine effectiveness.	Natural England	Political resistance
	6d	Crown works on existing trees where this helps improved the root: crown ratio	Medium	Ongoing	Medium	Only effective on small scale – too many trees for it to be a widespread response	Natural England, land managers, Forestry Commission	

Asset	Impact Ref	Response strategy	Priority	Timing	Cost	Extent to which impact dealt with by response	Responsibility	Barriers
	2a 2b 2c 4e	Replacement cohorts of trees with species likely to tolerate predicted future climates	Medium	Ongoing	Low	Will require monitoring to ensure effectiveness	Natural England, Forestry Commission	Conservation policy, objection to non-native species
	1a 1b 5b	Improve understanding of hydrology in the CA	Research need	Immediate	Low	Will allow targeted adaptation response that is likely to be more effective	Natural England, Environment Agency	
Access and recreation	16a 16b 17a 17b 17c 18b	Dispersal – promotion of more sustainable attractions, routes, different types of tourism etc.	High	Immediate	Low	Will require monitoring of visitor numbers and route usage	Natural England, National Trust, highways authorities	Public perception of honeypot sites
	17a 17b 17c	Introduce circular walks from urban areas	Medium	Immediate	Low	Will require monitoring of visitor numbers and route usage	Natural England, highways authorities, walkers groups	
	16b 16c	Sustainable public transport provision	Medium	Immediate	High	Uncertain – depends on condition of infrastructure. Will require monitoring of user numbers.	Natural England, public transport providers	High cost
	18a	Fire risk warning system – red, amber, green displayed throughout CA	Medium	2020s	Medium	Effectiveness depends on awareness	Natural England	Public understanding of problem
	18a	Education on fire risk and how to reduce it – training for land managers, visitor information boards, leaflets etc.	High	2020s	Low	Behaviour will need modifying, fire wardens to enforce guidelines may be necessary	Natural England, land managers	Human behaviour
	18a	Provision of equipment to tackle fire	Medium	2020s	Medium	Will require training in use of equipment	Natural England	
	19a 19c	Relocate infrastructure at risk of flooding	Medium	Immediate	Medium	Effectiveness depends of awareness of new routes	Natural England, landowners, highways authorities	Suitable locations

Asset	Impact Ref	Response strategy	Priority	Timing	Cost	Extent to which impact dealt with by response	Responsibility	Barriers
Landscape	20	Continue with existing conservation strategies, which should be revised using an adaptive management approach.	High	Ongoing	Low – medium, adapt existing management, and possibly also offer incentive.	Effective if land managers are willing to continue to manage marginal land. May require ES or other incentives.	Natural England, AONB unit, local authority, landowners, farmers	Agricultural economics, funding availability
	21a & b	Trial different traditional varieties (preferred) or new varieties to ascertain which varieties might grow successfully in future. Selectively breed from existing varieties to develop better adapted varieties. Plant a range of varieties to partly future-proof crops. Maintain support for orchard planting and restoration.	Medium	Ongoing	Medium – to high.	Will need monitoring to determine success.	Natural England, NGOs, Regional Development Agency, farmers, smallholders. Local food interests.	Agricultural economics, trade prices.
	22	Plant a wide variety of species as eventual replacements for existing mature trees. Avoid species that are susceptible to drought E.G. beech. Re-establish pollard regimes to reduce susceptibility to storm damage. .	High	Ongoing	Low - Medium, low particularly if timber from pollards can be sold.	Effective, but will require long term monitoring in order to establish which trees can cope best with changed climate.	Natural England, local authorities, NGOs, Tree Wardens, landowners, farmers	Availability of incentives, market for pollard timber. Availability of volunteers to act as tree wardens for a monitoring programme.

Asset	Impact Ref	Response strategy	Priority	Timing	Cost	Extent to which impact dealt with by response	Responsibility	Barriers
	23a & b	Re-establish pollard regimes where this would reduce susceptibility to storm damage. Establish new pollards. Plant different species as replacements for existing mature trees, choosing species that are better able to cope with changed climate conditions.	High	Ongoing	Medium	Effective, but will require long term monitoring in order to establish which trees can cope best with changed climate.	Natural England, local authorities, NGOs, Tree Wardens, landowners, farmers	Availability of incentives, market for pollard timber. Availability of volunteers to act as tree wardens for a monitoring programme.
	24	Maintain dams and other features in good structural condition	Medium	Ongoing	High	Effective	Natural England, English Heritage, Environment Age ncy. Landowners.	High cost of capital works
	25a 25b	Maintain vegetative cover – avoid putting livestock on land when saturation is likely to be a problem; apply appropriate stocking levels to reduce physical impact on earthworks. Remove trees from earthworks. Try to replace these trees as a landscape feature by replanting elsewhere, off earthworks.	Medium	Immediate	Medium	Effective – eliminates a significant cause of earthwork destruction.	Natural England, English Heritage, Landowners, farmers.	Landscape value of mature trees on some earthworks.
	26	Introduce minimum tillage practices, particularly on sensitive soils. Introduce and/or maintain good soil resource protection measures.	High	Immediate	Low	Effective	Natural England, English Heritage, landowners.	Agricultural economics.

Asset	Impact Ref	Response strategy	Priority	Timing	Cost	Extent to which impact dealt with by response	Responsibility	Barriers
	27	Prioritise maintenance, so that high value structures that are most at risk/in worst repair, receive support urgently.	High	Immediate	High	Effective, but resources are unlikely to be able to deal with all structures requiring attention.	Natural England, English Heritage, farmers, landowners, highways authorities (for historic bridges on rights of way)	Financial resources.

Table A3.3: Assessment of responses against 'good adaptation principles'

Response	Work in partnership	Address climate and non-climate pressures	Adaptive management to deal with uncertainty	Low/no regrets and win-win options	Future adaptation	Conflict with mitigation	Robust to socio-economic scenarios
Maintain existing habitats	Landowners, farmers	Deals with habitat fragmentation, protects from agricultural and development pressures	Response can be delivered through adaptive management	No regrets. Win-win for ecosystem services – improves water resource availability, quality and flood protection.	Improves scope for future adaptation	Potential synergy with mitigation – increase carbon storage capacity	Future biodiversity will depend on the diversity we conserve today even if it is different. Value of habitats may change under different scenarios.
Habitat re-creation or restoration	Landowners, NGOs, Environment Agency (for flood plain habitats)	Deals with habitat fragmentation, protects from agricultural and development pressures	Swap certainty for uncertainty – don't know exactly what habitats will thrive. Limited value in recreating habitats which will not be sustainable under climate change	Potential for regret if habitat is re-created based on current composition. Win-win for ecosystem services – improves water resource availability, quality and flood protection.	Can improve scope for future adaptation if flexible over what habitats are created	Potential synergy with mitigation – increase carbon storage capacity	Value of habitats may change under different scenarios. May have a different emphasis between conservation and recreation.
Changing conservation objectives	No	Can be used to deal with invasives and non-native species	Must be flexible in response to uncertainty	Low regret	Must remain flexible in order to have no impacts on future	No interaction with mitigation	Attitude to conservation may be different. Value placed on

Response	Work in partnership	Address climate and non-climate pressures	Adaptive management to deal with uncertainty	Low/no regrets and win-win options	Future adaptation	Conflict with mitigation	Robust to socio-economic scenarios
					adaptation		habitats and species may be different. May be greater or lesser emphasis on recreation over conservation.
Alter hay cutting date	Farmers		Adaptive management therefore allows flexibility in the face of uncertainty	Low regret	No impact on future adaptation – adaptive management therefore flexible / reversible	No interaction with mitigation	Will be mediated by changes in agriculture sector
Manage grazing level	Landowners, farmers, graziers	Can be used to deal with changes in agricultural economics – shift towards arable cultivation	Adaptive management therefore allows flexibility in the face of uncertainty	No regret	No impact on future adaptation – adaptive management therefore flexible / reversible	Increased stocking levels may increase methane emissions	Will be mediated by changes in agriculture sector
Adjust burning regime	Land managers, farmers	Can be used to deal with heather beetle (already a problem) and to manage age of heather	Adaptive management therefore allows flexibility in the face of uncertainty	Low regret	No impact on future adaptation – adaptive management therefore flexible	Increase in burning will produce more CO_2 emissions	

Response	Work in partnership	Address climate and non-climate pressures	Adaptive management to deal with uncertainty	Low/no regrets and win-win options	Future adaptation	Conflict with mitigation	Robust to socio-economic scenarios
Extend existing sites	Landowners, NGOs, Environment Agency (for flood plain habitats)	Deals with habitat fragmentation, protects from agricultural and development pressures	Swap certainty for uncertainty – don't know exactly what habitats will thrive. Limited value in recreating habitats which will not be sustainable under climate change	Low regret – although possible regret if based on existing composition. Win-win for ecosystem services – improves water resource availability, quality and flood protection.	Can improve scope for future adaptation if flexible over what habitats are created	Potential synergy with mitigation – increase carbon storage capacity	Value of habitats may change under different scenarios. May have a different emphasis between conservation and recreation.
Be alert to potential new pests and diseases	Farmers, Forestry Commission, NGOs	Pests and diseases can arrive independently of climate change – e.g. through import of plants	Response robust to uncertainty – don't need to know what new pests and diseases are	No regret. Win-win for ecosystem services – agriculture also affected.	Beneficial impact on future adaptation	No interaction with mitigation	Useful information regardless of socio-economic scenario
Crown works on existing trees where this helps improved the root: crown ratio	Reserve managers	Assists in control of succession and maintenance of biodiversity		Low regrets	No impact on future adaptation	Reduced biomass carbon store	Socio-economic scenarios unlikely to affect response

Response	Work in partnership	Address climate and non-climate pressures	Adaptive management to deal with uncertainty	Low/no regrets and win-win options	Future adaptation	Conflict with mitigation	Robust to socio-economic scenarios
Replacement of trees with a mix of species	Land managers, NGOs	More resilient to pests and diseases	May not be robust as uncertainty over which species will thrive	Potential regret if species chosen not sustainable – requires research.	No impact on future adaptation if flexible	Potential synergy with mitigation – increase carbon storage capacity	Value of species may change under different scenarios. Attitudes towards non-natives and invasives may change.
Improve understanding of hydrology in the CA	Environment Agency	Assists in understanding of other sources of water resource Character Area e.g. abstraction. Assists in understanding flood risk.	Important knowledge regardless of uncertainty	No regret. Win-win for ecosystem services – potential for improving water resource availability.	Beneficial impact on future adaptation	No interaction with mitigation	Useful information regardless of socio-economic scenario
Dispersal of visitors	Highways authorities, local authorities, tourist board	Alleviates existing pressure on honeypots	Robust to uncertainty over visitor levels	No regrets. Win-win for ecosystem services – maintains attractiveness of area for visitors.	No impact on future adaptation	No conflict with mitigation	Sensible regardless of socio-economic scenario. May see a decrease in visitor numbers.
Circular walks from urban areas	Highways authorities, local authorities, tourist board	Alleviates existing pressure on popular routes	Robust to uncertainty over visitor levels	No regrets Win-win for ecosystem services –	No impact on future adaptation	No conflict with mitigation	Robust to uncertainty over visitor levels. May see reduction in

Response	Work in partnership	Address climate and non-climate pressures	Adaptive management to deal with uncertainty	Low/no regrets and win-win options	Future adaptation	Conflict with mitigation	Robust to socio-economic scenarios
				maintains attractiveness of area for visitors.			visitor levels.
Sustainable public transport provision	Public transport providers, local authorities	Alleviates congestion	May not be viable under scenarios of lower visitor numbers	No regrets Win-win for ecosystem services – maintains attractiveness of area for visitors. Assists in dealing with socio-economic change - reduces demand for infrastructure developments.	No impact on future adaptation	Benefits for mitigation	May not be viable under scenarios of lower visitor numbers
Fire risk warning system		Alerts visitors to planned burning as part of management regime	Robust to uncertainty over visitor levels	No regrets. Win-win for ecosystem services – maintains attractiveness of area for visitors	No impact on future adaptation	Benefits for mitigation if fires prevented	Sensible regardless of socio-economic scenario.
Education on fire risk	Tourist board	Reduces risk of accidental burn caused by visitor behaviour	Robust to uncertainty over visitor levels	No regrets	No impact on future adaptation	Benefits for mitigation if fires prevented	Sensible regardless of socio-economic scenario.

Response	Work in partnership	Address climate and non-climate pressures	Adaptive management to deal with uncertainty	Low/no regrets and win-win options	Future adaptation	Conflict with mitigation	Robust to socio-economic scenarios
Provision of equipment to tackle fire		Reduces risk of accidental burn caused by visitor behaviour	Robust to uncertainty over visitor levels	No regrets	No impact on future adaptation	Benefits for mitigation if fires prevented	Sensible regardless of socio-economic scenario.
Relocate infrastructure at risk of flooding	Highways authorities, Environment Agency		Robust to uncertainty over visitor levels	Low regrets. Win-win for ecosystem services – reduce flood risk.	No impact on future adaptation	No conflict with mitigation	Robust to uncertainty over visitor levels. May see reduction in visitor levels but still valid approach.

Table A3.4 Impacts on ecosystem service and suggested responses

Category	Ecosystem Service	Impact of Climate Change	Response	Key assumptions
Provisioning services	Water resources	Lower summer flows - less water available for agricultural abstraction, recreation and habitats Increased overland flow during high intensity events – less groundwater recharge	Catchment management – improving permeability of surfaces through planting, creation of wet woodland, SUDS etc Demand management Switch to more drought resistant plants On farm water storage	Increases in efficiency could limit problem of low water availability in summer
	Provision of fibre and fuel - farming	Changes to livestock / crop viability New pests and diseases affects crops and livestock Summer drought – higher agricultural water demand	Crop / livestock switching Improvements in water management – on farm storage, reduced surface run-off, increase infiltration rates Be aware of new pests and diseases Tie rural payments to delivery of ecosystem services	Genetically modified crops so not become popular – current species could remain viable if genetically modified
	Provision of fibre and fuel – forestry	Longer growing season – opportunity Wind blow Increase in falling branches Disease	Bring neglected woodland back into management Review species choice for new woodland – drought tolerant species	
	Provision of fibre and fuel – fisheries	Change in species supported, spawning time and location	Monitor species change Restoration of riparian habitat – provision of shade	

Category	Ecosystem Service	Impact of Climate Change	Response	Key assumptions
Cultural services	Recreation	More opportunities – increased visitor numbers *Risk of increase in congestion, footpath erosion, trampling* Risk of fire on heathland	Fire action plans Improve recreational infrastructure where appropriate Identify vulnerable areas	Assumes increase in visitor numbers with increase in temperature. Assumes conventional development prevails.
	Tourism	More visitors (esp. in shoulder months) *Increased risk of congestion, footpath erosion, trampling* *Greater pressure on resources – accommodation, transport infrastructure, water etc*	Fire action plans Improve recreational infrastructure where appropriate Identify vulnerable areas Education Infrastructure vs. protection (debate needed)	Assumes increase in visitor numbers with increase in temperature. Assumes conventional development prevails.
	Education	*Increased demand for field studies*	Change in curriculum	Assumes increase in visitor numbers with increase in temperature.
Supporting services	Soils	Quaternary deposits could be lost through erosion – impact on historical environment as they contain recent history	Improvement in soil and vegetation management Increase soil organic matter Changes in agricultural practice – minimum tillage Limiting visitor numbers in sensitive areas	

Category	Ecosystem Service	Impact of Climate Change	Response	Key assumptions
	Geology	*Access issues if widespread habitat creation in response to climate change* Change in fluvial processes	Ensure access to geological features (may conflict with habitat extension and creation programmes)	
Regulating services	Flood protection	Increase in flood risk – greater winter rainfall, more overland flow, more storm events *Impact on infrastructure – roads, rail, isolated communities etc*	Catchment management – improving permeability of surfaces through planting, creation of wet woodland, SUDS etc Habitat creation opportunity from flood defence works – flood storage areas, managed realignment Temporary closure / diversion of rights of way Increase vegetation cover	
	Water quality	Diffuse pollution – less dilution due to lower flows Increase in nutrient loading due to increase in visitor numbers and potential agricultural re-intensification.	Vegetation and soil management to achieve potable water improvements Vegetation buffer strips around fields Reduce nutrient input to water bodies Management of slurries and manure – swales and silt traps	
	Climate regulation	Drying out of peat soils and loss of vegetation – release of carbon dioxide	Soil protection measures Increase biomass cover Biowaste fertiliser	

Table A3.5 Socio-economic impacts and responses in Shropshire Hills CA

Sector	Socio economic changes	Impact on Shropshire Hills CA	Response	Key assumptions
Agriculture, horticulture and forestry	Increase in demand for organic produce Changes in payments and subsidies	Increase in invertebrate and bird species due to reduction in pesticides used Reduction in diffuse pollution Improved countryside stewardship Reduce monoculture	Extension of the habitat network through habitat creation on arable field margins	Assumes conventional development. Demand for organic and local produce would be highest under Local Markets
Water resources	Increase in water metering Introduction of variable tariffs Increased pressure on water resources due to population increase	Potential increase in water available for habitats as potable consumption reduces Potential decrease in water available for habitats	Wetland habitat creation and restoration Resist development in areas of water stress through the water resource and spatial planning system	Assumes water demand grows as population grows. Greater water efficiency may reduce per capita consumption.
Energy	Increase in oil price and concern over security of supply	Switch to renewable - negative landscape impact of wind turbines and biofuels	Resist inappropriate structures on the landscape through spatial planning system Strengthen landscape designations in Shropshire Hills Character Area	Increase in oil price and concern over security of supply could lead to increase in nuclear power rather than renewables
Buildings	Increase in new build rates to meet demand from population growth and urban expansion	Pressure on land	Resist development in sensitive areas through spatial planning system Strengthen landscape designations in Shropshire Hills Character Area	Assumes UK population will increase

Sector	Socio economic changes	Impact on Shropshire Hills CA	Response	Key assumptions
Transport	Demand for new infrastructure – roads, railways, runways etc. to meet growing demand	Habitat fragmentation, landscape impact. Positive impact on access to countryside	Resist development in sensitive areas through spatial planning system Improve public transport access to Character Area – reduce demand for travel	Assumes conventional development and limited use of public transport.
Leisure and tourism	Increased demand for outdoor activities – walking, cycling, gliding Increased demand for eco-tourism	Increase in visitor numbers and demand for facilities and infrastructure Reverse some of the negative effects of previous tourism	Visitor dispersal Education	
Health	Increase in obesity	Increased potential to market the countryside as part of a healthy lifestyle – increase number of people enjoying the countryside	Market the countryside as part of a healthy lifestyle	Assumes conventional development – lifestyles may change to be less sedentary

Appendix 4 Landscape Case Study of Historic Farmsteads in the Shropshire Hills

This adaptation strategy provided an opportunity to retrieve baseline information on the condition of the traditional farm building resource within the Character Area in order to gauge the possible effects of climate change and explore the most effective adaptation strategies that Natural England could employ. The survey was an opportunity to explore the implications of the West Midlands region emerging from another recent survey as having the greatest percentage of listed buildings in poor structural repair.

A field-based condition survey was commissioned by Natural England and carried out by Mercian Archaeology over Easter 2008 (Mercian Archaeology PJ209), assessing 85 farmsteads selected from 4 representative areas of the Character Area's varied landscape.

Assets
Key features:
Combining analysis of preliminary results from Shropshire's Historic Farmstead Characterisation against this condition survey sample area data, it has been possibly to extrapolate the survey results up to Character Area level. There are an estimated 1875 surviving or partially surviving historic farmsteads in the Character Area, rising to 2072 if smallholdings are included (Andy Wigley *pers comm*.).

The diversity in landscape and historical use of that landscape is highlighted by the different farmstead types across the sample study areas, from cottages and former smallholdings of squatter settlements to out-farms and courtyard farms.

Farmsteads on roadsides and in common edge settlements make an especially significant contribution to the character of the Character Area.

The Countryside and Community Research Institute reported that below 39 per cent of listed farm buildings had been converted to residential or non-farming use in the Character Area, whilst between 21-35per cent were derelict. This survey indicates a higher conversion rate and towards the higher end rate of dereliction. Of the working buildings surveyed, most were in a condition requiring some restoration and maintenance to ensure their survival, with some in a very poor condition. Further findings are that:

- More than half are now out of agricultural or associated use, but are generally kept in very good condition (condition A).
- Around 25 per cent of buildings require maintenance or some restoration to prevent decline (condition B). These are almost overwhelmingly in agricultural use.
- A small proportion (5per cent) of farmsteads exhibit obvious structural failure and appear to require a significant repair programme – almost all are in agricultural use (condition C).

Impacts on the asset
Direct impacts of climate change
Increased numbers of extreme weather events, or prolonged rainfall events are thought to potentially pose the greatest direct threat to the condition and ultimately the survival of the traditional farm buildings resource throughout the Character Area.

Those assessed as requiring maintenance or some 'restoration' attention to preserve their historic character, i.e. those maintained in agricultural use, are most threatened. Once storm damage is left unchecked, and water ingress occurs, damage to key structural components (walls and roof timbers) is extremely likely to occur.

Traditional working farm buildings are particularly vulnerable to changes in weather patterns, especially those that result in increased rainfall and storm events

Indirect effects of climate change

The historical development of the Character Area landscape tells us that human behaviour and use of the landscape will change in response to a changing climate. Changes in recreational pressure and the desirability of this landscape may lead to an increased desire to convert more traditional farm buildings for residential or leisure use. Changes in farming economies may be a driver to adapt traditional farmsteads for different, compatible or non-compatible uses.

Key adaptation responses

Those buildings most at threat from increased intensity or frequency of severe weather events need an adaptation response. As their condition deteriorates further, with structural decay to roof timbers and occasional structural cracks, the cost of remedial works will make intervention progressively more expensive.

Accepting that traditional farm buildings in their unconverted state make the biggest and most coherent contribution to an understanding of the farmed landscape is a pre-requisite to deciding what policies to adopt in response to climate change. As a lead in delivery of the European Landscape Convention, Natural England would most likely adopt this position statement as part of a balanced approach to the changing resource.

Natural England's role in an adaptation strategy will focus on the continued conservation of traditional farmsteads in agricultural use to maintain their valued contribution to landscape character.

Since 1996, the British Government has implemented incentive schemes for the conservation of historic farm buildings in their landscape, accessing European Commission funds through various rural development programmes. While the Environmentally Sensitive Areas Scheme has initiated restoration schemes for traditional farm buildings in the Shropshire Hills, some assessment of the current Environmental Stewardship Scheme and its possible role in an adaptation strategy is worthwhile in this context.

Agri-environment schemes form the lynchpin of Natural England's response to some anticipated effects of climate change on the traditional farm building resource.

Environmental Stewardship (ES) provides incentive for the maintenance and restoration of traditional farm buildings, the former, accessible to all, pays £2/sqm ground floor area p.a. for maintaining buildings in a waterproof and weatherproof condition. For the purposes of this survey, those are buildings recorded in condition A. For buildings in a fairly weatherproof condition, but requiring some attention to small items of 'failure', equivalent to condition B in this survey, the funds available over the period of an ES Agreement is proving a significant driver for 'up-front' investment to attain eligible status.

The ES 'Maintenance of Traditional Farm Buildings Option' is a popular incentive for owners of working traditional farm buildings and is ideal for making the resource resilient to a changing climate. Consideration should be given to the costs of applying this option to all buildings in eligible condition across the Character Area as a key response strategy.

Restoration schemes available under Higher Level Environmental Stewardship Scheme (HLS) are funded at 80% and targeted at those more vulnerable and historically valuable buildings that contribute to landscape character and provide an obvious public benefit. They are mostly applied to buildings identified in this survey as in condition C, or B where there are 'hidden'

problems such as structural failure and fatigue in roof nails. HLS provides a suitable route for bringing the most vulnerable traditional farm buildings into a condition that makes them resilient to a changing climate.
Restoration options should be proactively focussed on the most vulnerable sections of the resource through enhanced targeting.

Further work
The survey results warrant more in-depth analysis to quantify the some additional preliminary conclusions and answer some of the following questions:

- Explore the probable link between farmsteads surviving at a higher altitude (and thus a more harsh environment) seemingly being appreciably in a worse condition (condition C).
- There appears to be no relationship between condition and farmstead ‘type’, suggesting that all farmstead types are experiencing the same vulnerability (at least to their condition),.
- Some farm building types, especially those associated with the common-edge settlements, seem to have suffered from the highest rates of conversion. What would that mean for determining significance of a surviving example?
- What would be the costs involved in applying the available Environmental Stewardship options to the necessary farmsteads in the sample areas and across the wider Character Area?
- An assessment of the landscape benefits against the cost of higher rates of take-up of ES Maintenance and restoration options.