UK National Ecosystem Assessment

Understanding nature's value to society

Synthesis of the Key Findings

Coordinating Lead Authors: Robert Watson and Steve Albon

Authors: Richard Aspinall, Mel Austen, Richard Bardgett, Ian Bateman, Pam Berry, William Bird, Richard Bradbury, Claire Brown, James Bullock, Jacquie Burgess, Andrew Church, Sue Christie, Ian Crute, Linda Davis, Gareth Edwards-Jones, Bridget Emmett, Les Firbank, Alastair Fitter, Chris Gibson, Rosie Hails, Roy Haines-Young, Louise Heathwaite, John Hopkins, Martin Jenkins, Laurence Jones, Georgina Mace, Stephen Malcolm, Ed Maltby, Lindsay Maskell, Ken Norris, Steve Ormerod, Juliet Osborne, Jules Pretty, Chris Quine, Shaun Russell, Lucy Simpson, Pete Smith, Megan Tierney, Kerry Turner, René van der Wal, Bhaskar Vira, Matt Walpole, Andrew Watkinson, Tony Weighell, Jonathan Winn and Michael Winter.

Extended Writing Team: UK NEA Chapter Lead Authors and Contributing Authors

Acknowledgements: The UK National Ecosystem Assessment (UK NEA) is funded by Department for Enviroment, Food and Rural Affairs (Defra), Natural Environment Research Council (NERC), Economic and Social Research Council (ESRC), Northern Ireland Environment Agency (NIEA), the Scottish Government, the Countryside Council for Wales (CCW) and the Welsh Assembly Government (WAG). The economic analysis was in part funded by the ESRC Social and Environmental Economic Research (SEER) into Multi-Objective Land Use Decision Making project (Funder Ref: RES-060-25-0063) at CSERGE, University of East Anglia. The UK NEA is an accredited project within the Living With Environmental Change (LWEC) partnership.

Suggested Citation: UK National Ecosystem Assessment (2011) The UK National Ecosystem Assessment: Synthesis of the Key Findings. UNEP-WCMC, Cambridge.

Designed by: NatureBureau, Newbury

Printed by: Information Press, Oxford

UNEP promotes environmentally sound practices globally and in its own activities. This publication is printed using vegetable-based inks, on paper from sustainable forests including recycled fibre. Our distribution policy aims to reduce UNEP's carbon footprint.

Table of Contents

Cross reference to the UK National Ecosystem Assessment Technical Report is designated by (TR X.Y) which indicates the relevant chapter (X) and section (Y) of the Technical Report.

The UK National Ecosystem Assessment

Synthesis of the Key Findings

Foreword

The UK National Ecosystem Assessment (UK NEA) provides a comprehensive overview of the state of the natural environment in the UK and a new way of estimating our national wealth. It shows how we have under-valued our natural resources. Valuing them properly will enable better decision making, more certain investment, new avenues to wealth creation and jobs, and greater human well-being in changing times ahead.

Our wealth as a nation and our individual well-being depend critically upon the environment. It provides us with the food, water and air that are essential for life and with the minerals and raw materials for our industry and consumption. Less obviously, it provides the processes that purify air and water, and which sequester or break down wastes. It is also in our environment where we find recreation, health and solace, and in which our culture finds its roots and sense of place. Scientists refer to these services that our environment provides as 'ecosystem services', recognising that it is the interaction between the living and physical environments that deliver these necessities.

Yet we tend to take this largely for granted. While we pay for some ecosystem services like food and fibre, we are often unaware of the importance of others such as natural water or air purification, and would be alarmed at the cost of providing these artificially. This under-estimation of the value of natural processes in economic terms means that we take inadequately informed decisions on how to use these resources. The result is pollution, the loss of species and ecosystems and damage to the processes we need, with real economic costs to either recover them or provide artificial alternatives.

With ever increasing pressures on these natural resources, partly from growing populations but still more from growing levels of individual consumption, it is essential that we learn to take account of the full value of ecosystem services in our decision making. By doing so, we cannot only protect what we have and repair damage where needed, but harness these resources more effectively to generate wealth and well-being. The UK NEA represents a first attempt to assess our stocks of natural ecosystem resources, their state and the trends in their development.

This ground breaking assessment has been adopted by the partnership that I chair, of Government, Devolved Administrations, Research Councils and other bodies (22 in all) who form the *Living with Environmental Change Partnership* (LWEC). The aim of LWEC is to ensure that decision makers in government, business and society have the knowledge, foresight and tools to mitigate, adapt to and benefit from environmental change.

Funding for the UK NEA has brought together about 500 experts in the natural sciences, economics and the social sciences, under the chairmanship of Professor Robert Watson (Defra's Chief Scientific Advisor and Strategic Director of the Tyndall Centre at the University of East Anglia) and Professor Steve Albon of the James Hutton Institute (formerly the Macaulay Land Use Research Institute). This team has assembled and analysed an enormous body of published information about the UK environment and generated new tools for valuing it, in economic and non-economic terms; this is a world first. It provides for the first time, a coherent body of evidence about the state of our natural environment and the services it provides for each country in the United Kingdom. This can serve as the basis for thinking about how we want to use these services to best effect, for national wealth and national well-being, now and for our nation's children into the future.

Lord Selborne GBE, FRS

The Key Messages of the UK National Ecosystem Assessment

The natural world, its biodiversity and its constituent ecosystems are critically important to our well-being and economic prosperity, but are consistently undervalued in conventional economic analyses and decision making. Ecosystems and the services they deliver underpin our very existence. We depend on them to produce our food, regulate water supplies and climate, and breakdown waste products. We also value them in less obvious ways: contact with nature gives pleasure, provides recreation and is known to have a positive impact on long-term health and happiness.

Ecosystems and ecosystem services, and the ways people benefit from them, have changed markedly in the past 60 years, driven by changes in society. During the second half of the 20th Century, the UK's population grew by roughly a quarter to nearly 62 million, living standards greatly increased and technological developments and globalisation had major effects on behaviour and consumption patterns. The production of food from agriculture increased dramatically, but many other ecosystem services, particularly those related to air, water and soil quality, declined.

The UK's ecosystems are currently delivering some services well, but others are still in long-term decline. Of the range of services delivered in the UK by eight broad aquatic and terrestrial habitat types and their constituent biodiversity, about 30% have been assessed as currently declining. Many others are in a reduced or degraded state, including marine fisheries, wild species diversity and some of the services provided by soils. Reductions in ecosystem services are associated with declines in habitat extent or condition and changes in biodiversity, although the exact relationship between biodiversity and the ecosystem services it underpins is still incompletely understood.

The UK population will continue to grow, and its demands and expectations continue to evolve. This is likely to increase pressures on ecosystem services in a future where climate change will have an accelerating impact both here and in the world at large. The UK's population is predicted to grow by nearly 10 million in the next 20 years. Climate change is expected to lead to more frequent severe weather events and alter rainfall patterns, with implications for agriculture, flood control and many other services. One major challenge is sustainable intensification of agriculture: increasing food production while decreasing the environmental footprint.

Actions taken and decisions made now will have consequences far into the future for ecosystems, ecosystem services and human well-being. It is important that these are understood, so that we can make the best possible choices, not just for society now but also for future generations. Contemporary economic and participatory techniques allow us to estimate values for a wide range of ecosystem services. Applying these to scenarios of plausible futures shows that allowing decisions to be guided by market prices alone forgoes opportunities for major enhancements in ecosystem services, with negative consequences for social well-being. Recognising the value of ecosystem services more fully would allow the UK to move towards a more sustainable future, in which the benefits of ecosystem services are better realised and more equitably distributed.

A move to sustainable development will require an appropriate mixture of regulations, technology, financial investment and education, as well as changes in individual and societal behaviour and adoption of a more integrated, rather than conventional sectoral, approach to ecosystem management. This will need the involvement of a range of different actors – government, the private sector, voluntary organisations and civil society at large – in processes that are open and transparent enough to facilitate dialogue and collaboration and allow necessary trade-offs to be understood and agreed on when making decisions.

Summary of the UK National Ecosystem Assessment

The UK, its people and its ecosystems

- **The benefits that we derive from the natural world and its constituent ecosystems are critically important to human well-being and economic prosperity, but are consistently undervalued in economic analyses and decision making.**
- **Ecosystem and ecosystem services are constantly changing, driven by societal changes – demographic, economic, socio-political, technological and behavioural – which influence demand for goods and services and the way we manage our natural resources.**

The UK is a small, densely populated island nation, the first industrialised country in the world. Eighty per cent of its inhabitants live in towns and cities. For some of them the natural world is something 'out there', whose existence they may value, or not, but which apparently has little to do with their day-to-day lives. In fact, we humans are an integral part of the natural world, ultimately dependent on a functioning biosphere and its constituent ecosystems for our survival. At the most fundamental level, other organisms create a breathable atmosphere and provide us with the food vital to our existence, as well as fibre, timber and a host of other raw materials. Ecosystems are of huge importance in other, less immediately obvious ways, in the breakdown of waste products, controlling water supplies and helping to regulate climate. They provide space for recreation and contemplation, and play a pivotal role in creating a sense of place that underpins the mental and spiritual well-being of many. Measuring the value of all the benefits we derive from ecosystems has proven hugely challenging, with the consequence that ecosystem services have been consistently undervalued in economic analyses and decision making.

The UK's existing ecosystems are the product of continuous interaction between people and their environment over millennia. These interactions, and their impact, have varied greatly over time and from place to place, and will continue to do so. Change here, as elsewhere, has been particularly marked and rapid in the past half century or so. The country's population has grown significantly, from just over 50 million in 1950 to around 62 million today. Incomes have increased greatly too, and with them the per capita demands for goods and services. Technological developments have had a direct impact on production systems, for example through agricultural intensification and industrialisation of fishing. There have also been many changes in individual and collective behaviour. Globalisation and its primary driving force, international trade and associated mass consumer advertising, have also had a major effect on behaviour and consumption patterns.

Changes in the past 60 years

- **Ecosystems and their services have been directly affected by conversion of natural habitats, pollution of air, land and water, exploitation of terrestrial, marine and freshwater resources, invasive species and climate change.**
- **From the late 1940s onwards, emphasis in the UK was placed on maximising production of goods to meet human needs for food, fibre, timber, energy and water.**
- **While productivity increased, there was an initial decline in the delivery of a range of other ecosystem services, particularly those relating to biodiversity and air, water and soil quality.**

The late 1940s saw the UK enter a phase of national reconstruction, with priorities focused on increasing production and building homes and infrastructure. Much activity in these areas was in direct response to market forces, but government policy and subsidies promoting production and infrastructure development also played an important part. Agricultural production began a period of rapid expansion that continued for several decades. In England the area of land under crops increased by 40% from 1940 to 1980. Thanks to plant breeding, increasing chemical inputs and technological innovations, yields per hectare of most crops also increased – more than threefold in the case of wheat (**Figure 1**). Similar productivity gains have been seen in livestock, with average milk yields doubling between 1960 and 2009. Timber production also rose, almost entirely as an increase in softwood production, which now accounts for over 95% of timber harvest in the UK.

Not all production increased. Most notably, landings of fish and other seafood declined steadily, from 1.0 million tonnes in 1970 to 0.5 million tonnes in 2000 (although this figure has remained roughly constant since then) (**Figure 2**). By the early 1990s, 10% or fewer of the fish stocks in UK waters were sustainably harvested.

The gains in production had impacts on other ecosystems and ecosystem services. Extensive areas of semi-natural vegetation were converted or modified – it is estimated, for example, that 97% of enclosed semi-natural grasslands in England and Wales were lost between 1930 and 1984 through intensification or conversion to arable land. Major increases in fertiliser use, particularly nitrogen and phosphorus, have adversely affected aquatic ecosystems through runoff. The Farmland Bird Index – a measure of the state of biodiversity on agricultural lands – declined by 43% between 1970 and 1998 (**Figure 3**). The push to increase timber production – which dates from the early years of the 20th Century – resulted, particularly in Scotland, in the creation of extensive areas of coniferous plantation at the expense of other habitats. Two-thirds of the UK's current woodland area of around 3

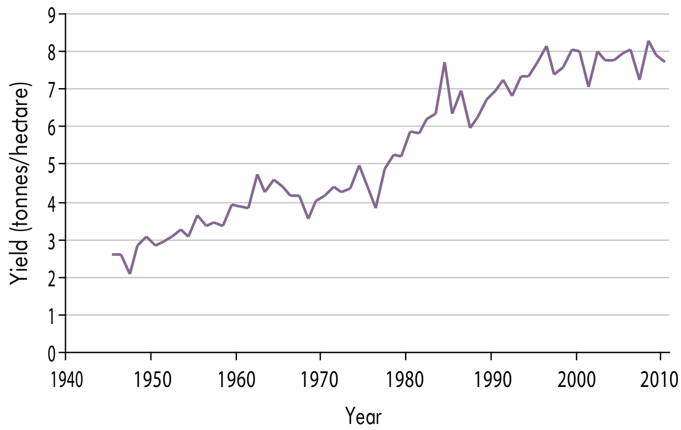


Figure 1 Average yield of wheat in the UK from 1945 to 2010. Source: Defra (2010). © Crown copyright 2010.

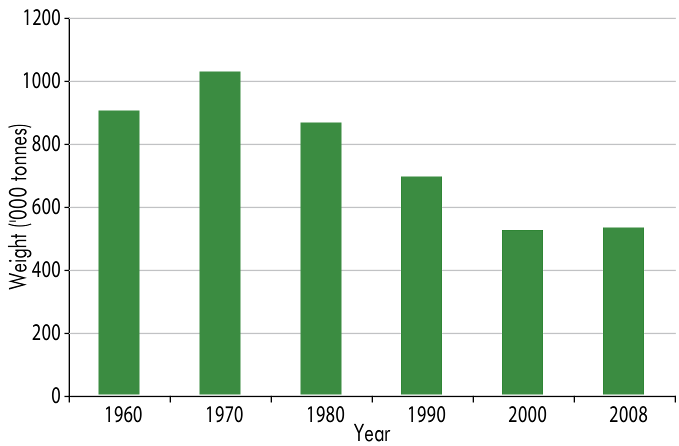


Figure 2 Landings of fish and shellfish into the UK by UK and foreign vessels between 1960 and 2008. Source: MMO (2010).

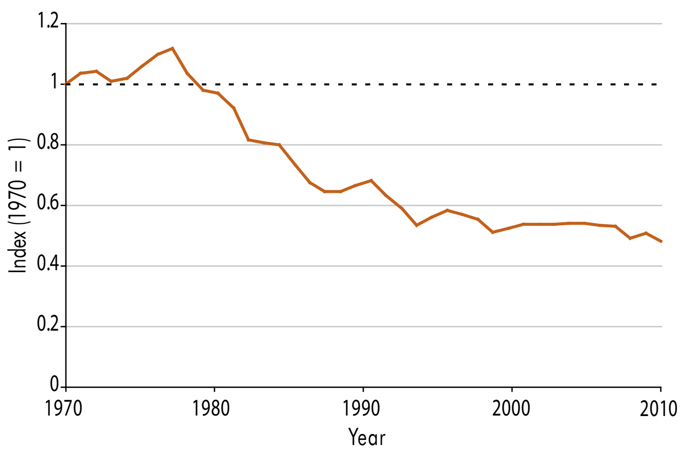


Figure 3 The UK Farmland Bird Index, 1970 to 2009, calculated on data from 19 individual farmland bird species. Source: RSPB, BTO, JNCC, Defra (2010).

million hectares is productive plantation, mostly less than 100 years old and much of it comprising non-native species.

Other sectors, including energy, industry, housing and transport, also had major impacts on ecosystems and the delivery of ecosystem services. For example, through deposition of atmospheric nitrogen and sulphur, loss of habitats through construction, and disruption of flood regimes in river basins and coastal wetlands.

Changes in the urban environment have had a direct impact on the very high proportion of the population living in cities and towns. There has been a marked decline in the condition and accessibility of urban greenspace: around 10,000 playing fields were sold between 1979 and 1997, while allotments are now down to 10% of their peak level, with an estimated total area of around 10,000 hectares, compared with over 100,000 hectares in the late 1940s.

- **Changes in national policy and legislation, latterly often driven by European Union policy, along with technological developments and changing attitudes and behaviour, have led to improvements in some ecosystem services, particularly in the past 10–20 years.**

Attempts to address declines in ecosystem services through legislation and policy reform began relatively early on, notably with the 1949 National Parks and Access to the Countryside Act and the 1956 Clean Air Act, the latter a direct response to the observed impact of air pollution on human health. The 1981 Wildlife and Countryside Act was a landmark in recognising the importance of biodiversity in law, several years before the term itself became common currency. More recently, many of the responses within the UK have been driven by European Union policy directives.

Since the early 1990s, financial support to farmers under the European Union Common Agricultural Policy has been partially decoupled from production to encourage wider stewardship of the countryside. There has been wide uptake of various environmental stewardship schemes – in England these now cover around 6.5 million hectares, a large proportion of eligible agricultural land. Fertiliser application rates have also dropped – in the case of nitrogen in England and Wales from around 150 kilograms per hectare in 1987 to just under 100 kilograms per hectare in 2009. This, along with a large decrease in atmospheric sulphur deposition (down by 90% since the 1970s) and reversal of soil acidification, has contributed to improvements in water quality in both marine and freshwater ecosystems.

Forestry policy has also moved away from a strong focus on production and since the mid-1980s, has increasingly sought to provide a mix of services, including recreation and maintenance of biodiversity, resulting in increased planting of broadleaved tree species and a diversification of plantation forests. The area of broadleaved and mixed woodland in the UK increased by around 7% in just 10 years, between 1998 and 2007.

Fisheries management has started to improve in the last decade or so, with around half (out of a sample of 18) UK finfish stocks now at full reproductive capacity and harvested sustainably (**Figure 4**).

Public attitudes have also changed, with increasing awareness of environmental issues, manifested in a number of different ways. Membership of organisations involved in nature conservation has increased dramatically: in 1944 the National Trust had fewer than 7,000 members; it now has 3.5 million. The Royal Society for the Protection of Birds (RSPB) currently has over 1 million members, compared with just 10,000 in 1960, and the UK's 45 Wildlife Trusts have 800,000 members between them. Active participation in a range of nature-based and outdoor activities has also grown: over half a million people participated in the RSPB's Big Garden Birdwatch in 2010, and there has been a recent upsurge of interest in the home production of fruit and vegetables.

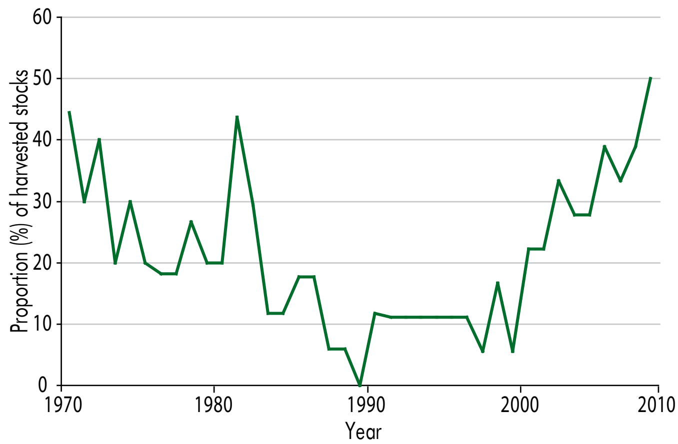


Figure 4 Propotion (%) of harvested finfish stocks around the UK which are at full reproductive capacity and harvested sustainably, 1970 to 2008. Source: Armstrong & Holmes (2010), CEFAS. © Crown copyright 2011.

Present challenges and the future outlook

- **Despite improvements, many ecosystem services are still far below their full potential – often as a consequence of long-term declines in habitat extent or condition, or both – and some continue to deteriorate, with adverse impacts on human well-being.**
- **A growing population and the increasing impacts of climate change mean that the future is likely to bring more challenges.**
- **The UK will remain an active trading nation, with substantial flows of biomass across its borders, generating a substantial ecological 'footprint' overseas while simultaneously being affected by social, economic and ecological changes elsewhere.**

Despite improvements, many ecosystem services continue to decline or have shown little improvement. Expert judgement indicates that, assessed across the broad range of terrestrial and aquatic habitat types, about 30% of services are currently declining and many others are in a reduced or degraded state (Figure 5). The condition of many soils in the UK – absolutely fundamental to continued productivity and support of biodiversity – is considered degraded, mainly because of atmospheric deposition and inappropriate management. Although there is ongoing recovery of soil buffering capacity, thanks to large decreases in sulphur deposition since the 1980s (Figure 6), there is continuing loss of soil carbon in arable systems and little or no decline in elevated levels of contaminants from industry and transport. Pollinators, which provide ecosystem services estimated to be worth hundreds of millions of pounds annually, continue to decline. Marine fish catches remain low compared with historical levels and many issues remain regarding the wider ecological impacts of fisheries. And while interest in, and engagement with, the natural world has grown tremendously in some sectors of society, many among the current generation of young people are spending less and less time outdoors, as a result of the use of new technologies, concerns over child safety and the decrease in urban greenspace.

The need to manage our ecosystems so that we benefit from the full range of ecosystem services is going to become more pressing, not less. The country's population is projected to grow to nearly 72 million by 2033 on current trends, increasing demand for food and other basic services. Moreover, the proportion of single person households has increased dramatically in the past few decades, from 12% in 1961 to nearly 30% today. This trend is likely to continue, leading to pressure to convert more land to housing and increasing per capita demand for water and energy.

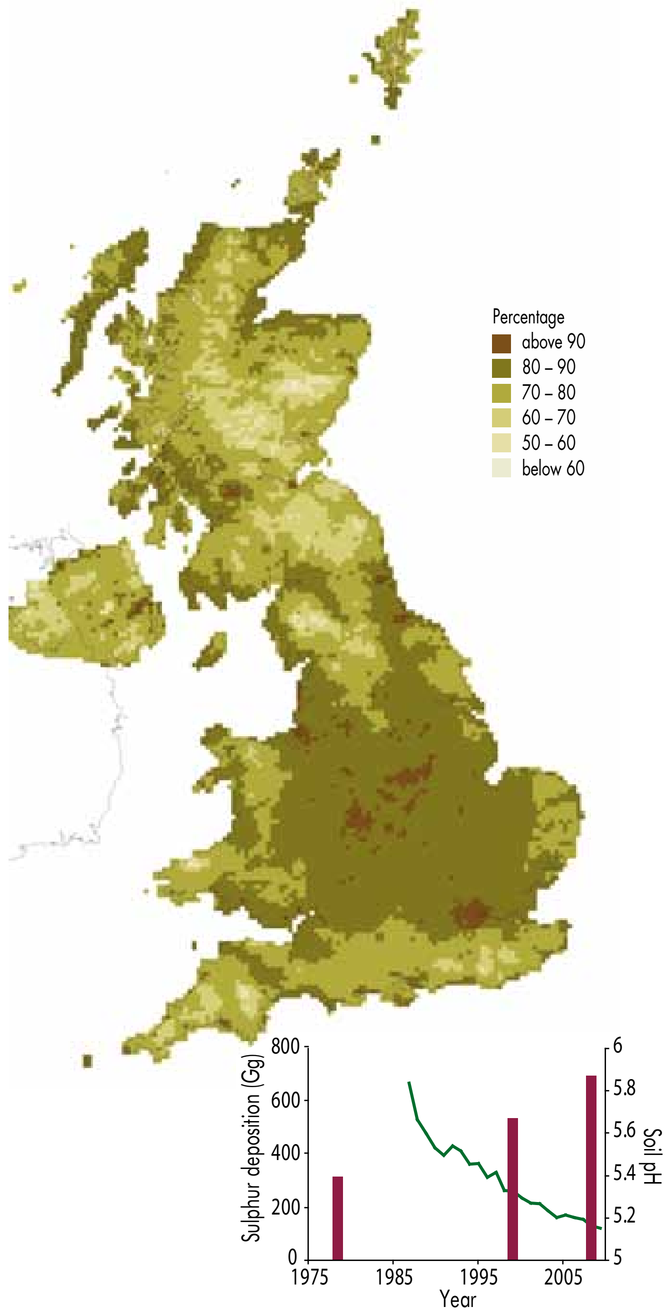


Figure 6 The percentage reduction in the anthropogenic sulphur deposition between 1987 and 2008 mapped over the UK at 5x5 km resolution. Source: map provided by RoTAP (2011); **Inset: The decline in sulphur deposition (Gigagrams, Gg; line) in the UK and the recovery of top soil buffering capacity as indicated by an increase in soil pH (columns).** Source: sulphur deposition data from RoTAP (2011); soil buffering and pH data from Emmett *et al.* (2010).

To date climate change has had a relatively small impact on the UK's biodiversity and ecosystems. However, impacts are predicted to increase over the coming decades, with more severe weather events and changes to rainfall patterns (Figure 7), with implications for agriculture, flood control and many other services, both locally and nationally.

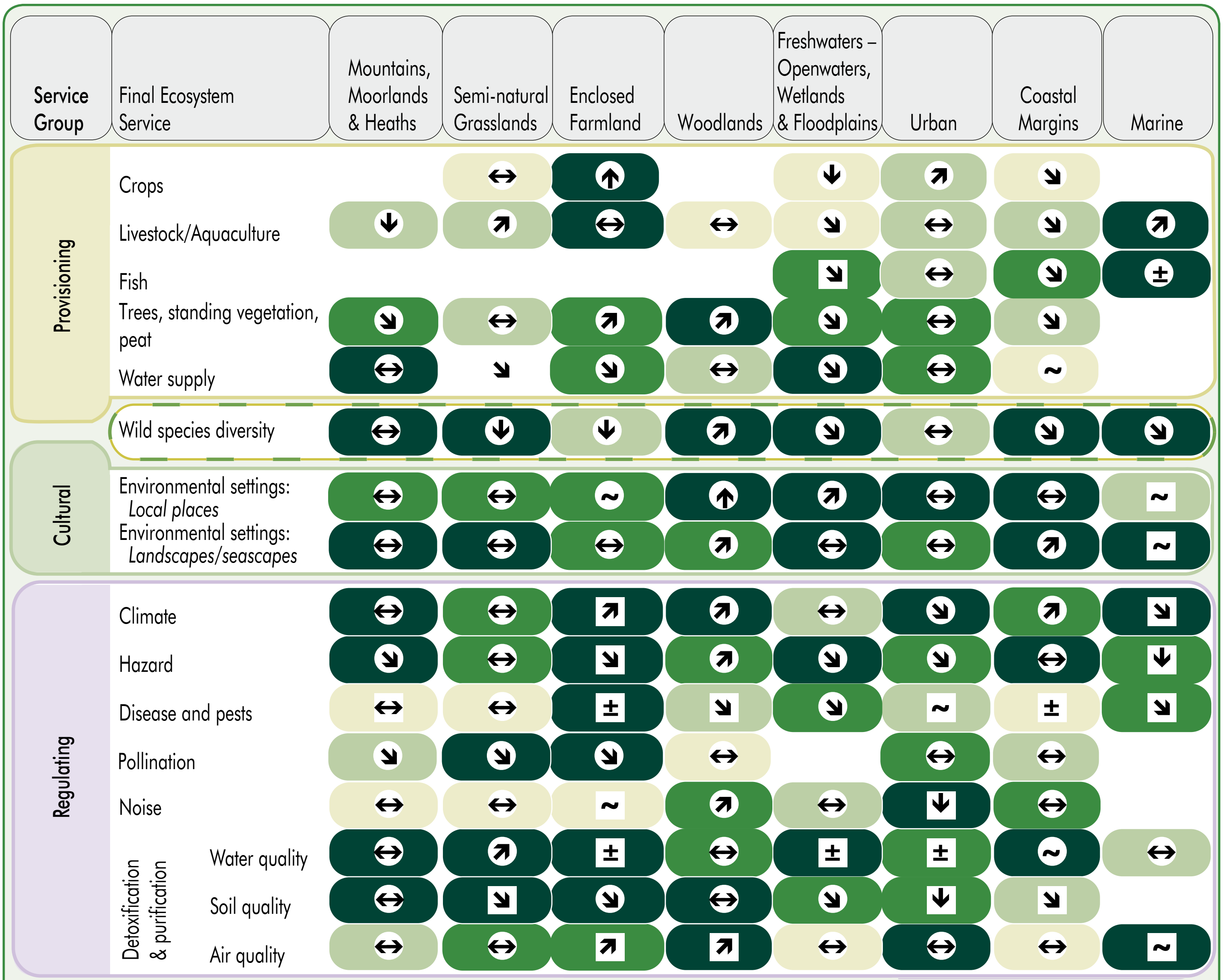


Figure 5 Relative importance of Broad Habitats in delivering ecosystem services and overall direction of change in service flow since 1990. This figure is based on information synthesized from the habitat and ecosystem service chapters of the UK NEA Technical Report (Chapters 5–16), as well as expert opinion. This figure represents a UK-wide overview and will vary nationally, regionally and locally. It will therefore also inevitably include a level of uncertainty; full details can be found in the Technical Report. Arrows in circles represent where there is high evidence for or confidence in the direction of service flow amongst experts; arrows in squares represent where there is less evidence for or confidence in the direction of service flow. Blank cells represent services that are not applicable to a particular Broad Habitat.

Importance of Broad Habitat for delivering the ecosystem service

- High
- Medium – High
- Medium – Low
- Low

Direction of change in the flow of the service

- ↑ Improving
- ↗ Some improvement
- ↔ No net change
- ± Improvement and/or deterioration in different locations
- ↘ Some deterioration
- ↓ Deterioration
- ~ Unknown

Furthermore, like most countries, the UK is an active trading nation, importing and exporting substantial quantities of goods, many of which are the products of ecosystem services. It imports, for example, around 80% of its timber (down from 96% in the 1940s) and 30% of its food requirements. A study conducted in 2008 concluded that, overall, the UK imported around 50 million tonnes of biomass in the form of food, fibre and biofuels, this being roughly 40% of net biomass consumption in the UK and around one-third of biomass flow (the UK exports around 20 million tonnes). Although these proportions may change somewhat in the future, the UK will undoubtedly continue to experience significant flows of biomass across its borders, thereby being affected by social, economic and ecological changes elsewhere and continuing to export a significant environmental 'footprint'.

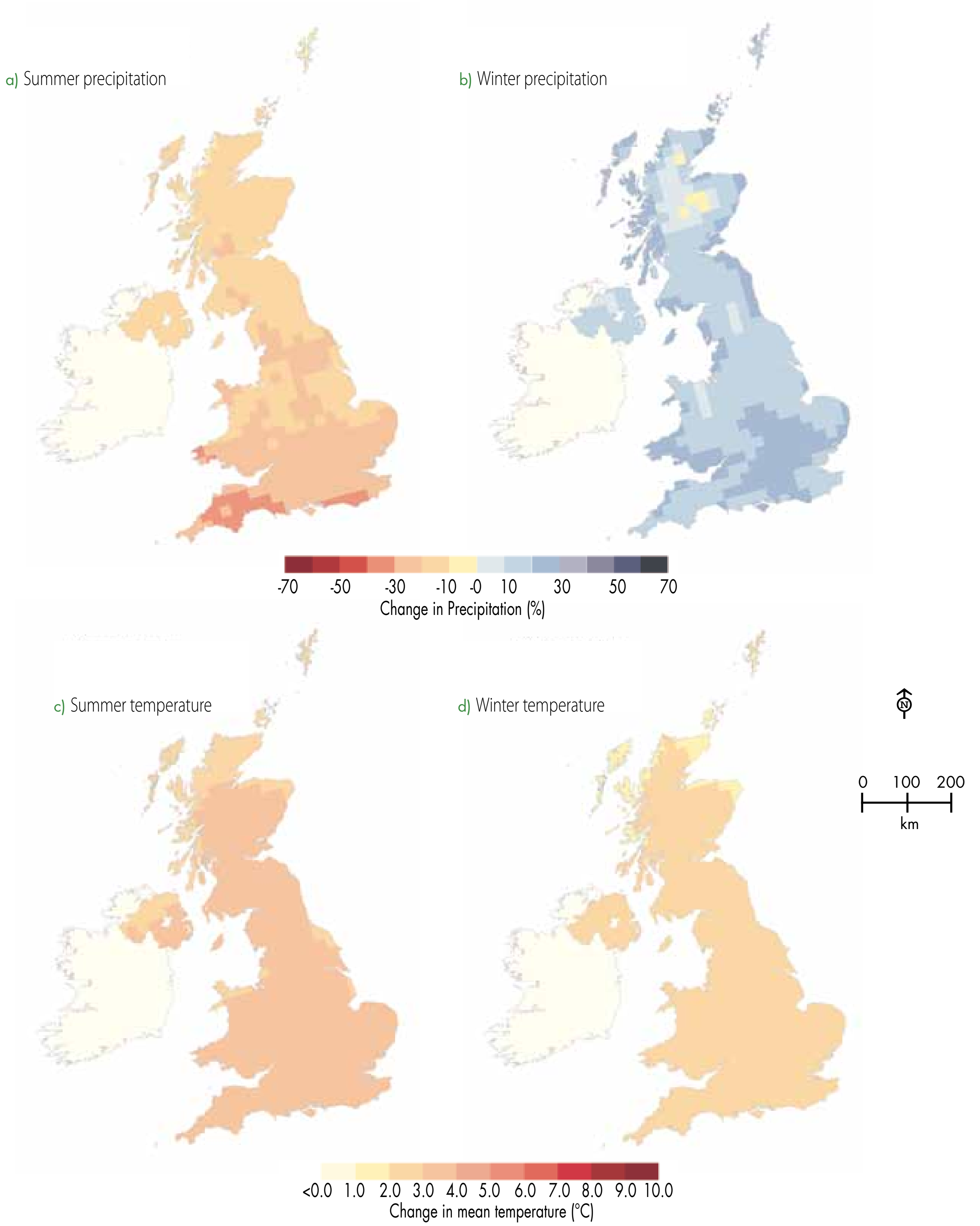


Figure 7 Projected change in precipitation (%) and temperature (°C) patterns for the 2060s (high emissions climate change scenario, 50% probability) in the UK at 25x25 km resolution. a) Summer precipitation; **b)** Winter precipitation; **c)** Summer Temperature; **d)** Winter Temperature. Summer: June, July, August; Winter: December, January, February. Source: adapted from data supplied by UK Climate Projections (UKCP09 2011).

Responding to the challenges

- **Reversing declines in ecosystem services will require the adoption of more resilient ways of managing ecosystems, and a better balance between production and other ecosystem services – one of the major challenges is to increase food production, but with a smaller environmental footprint through sustainable intensification.**
- **Ecosystem services are critically important to our well-being and economic prosperity, but are consistently undervalued in conventional economic analyses and decision making. Contemporary economic and participatory techniques allow us to take into account the monetary and non-monetary values of a wide range of ecosystem services. These techniques need to be adopted in everyday decision-making practice.**
- **Failure to include the valuation of non-market goods in decision making results in a less efficient resource allocation, with negative consequences for social well-being. Recognising the value of ecosystem services would allow the UK to move towards a more sustainable future, in which the benefits of ecosystem services are better realised and more equitably distributed.**
- **Exploring some of the plausible futures open to us shows that there is a huge range of potential outcomes for the state of the nation, its people and its ecosystems in the coming decades. Decisions that we all make now and in the immediate future will have a major impact on these outcomes.**

With a significant proportion of ecosystem services declining or in a reduced or degraded state (see **Figure 5**, p11), and with a challenging future ahead, it is clear that we need to find new, more resilient ways of managing our ecosystems. Because of the long recovery times of many ecosystem services (soils, for example, form at an average rate of just one centimetre per century) actions taken and decisions made now will have consequences far into the future for ecosystems, ecosystem services and human well-being. It is important that these consequences are understood, so that we can make the best possible choices, not just for society now but for future generations.

An important prerequisite for this is a better grasp of the values of the full range of ecosystem services, including cultural values based on ethical, spiritual and aesthetic principles. The values of most ecosystem services are currently omitted from national economic frameworks and local decision making. Failure to include the valuation of non-market goods in decision making results in a less efficient resource allocation. Contemporary economic techniques now allow us to account for most of the market values and some of the non-market values of ecosystem services. In cases where comparisons can be made, the latter often far exceed the former. The collective value of cultural goods linked to ecosystem services will need to be understood using a range of participatory and deliberative techniques requiring the use of both quantitative and qualitative methods in multi-criteria analysis. In addition, the values of many ecosystem services vary from place to place. Integration of the spatial dimension of ecosystem services in local decision making would increase the potential for the true value of these services to be realised.

In order to understand what the future might hold, a range of plausible scenarios has been developed (see **Figure 8**, p14), some of which emphasise environmental awareness and ecological sustainability, while others stress national self-sufficiency or economic growth and the removal of trade barriers. Applying the values derived for ecosystem services to these scenarios shows that a huge range of possible outcomes awaits us. Importantly, allowing decisions to be guided by market prices alone forgoes opportunities for major enhancements in ecosystem services, with negative consequences for social well-being. In contrast, recognising the value of all ecosystem services would allow the UK to move towards a more sustainable future, in which the benefits of ecosystem services are better realised and more equitably distributed.

- **A move to sustainable development will require changes in individual and societal behaviour and adoption of a more integrated approach to ecosystem management.**
- **This will require an appropriate enabling environment of a mix of regulations, technology, financial investment and education, and the involvement of a wide range of different actors, including government, the private sector, voluntary organisations and civil society at large.**
- **We already have enough information to start managing our ecosystems more sustainably and good evidence of the benefits of doing so.**

Green and Pleasant Land

A preservationist attitude arises because the UK can afford to look after its own backyard without diminishing the ever-increasing standards of living.

Nature@Work

The belief that the promotion of ecosystem services through the creation of multifunctional landscapes is essential for maintaining the quality of life in the UK is widely accepted.

Local Stewardship

This is a future where society is more concerned with the immediate surroundings and strives to maintain a sustainable focus on life within that area.

Go with the Flow

This scenario is essentially a projection based on current trends and results in a future UK that is roughly based on today's ideals and targets.

National Security

Under this scenario climate change results in increases in global energy prices forcing many countries to attempt greater self-sufficiency (and efficiency) in many of their core industries.

World Markets

High economic growth with a greater focus on removing barriers to trade is the fundamental characteristic of this scenario.

Figure 8 An overview of the six scenarios developed for the UK NEA. All share the common characteristics of a decline in global resource availability and an ageing UK population. They also include some level of technological innovation, although there are differences in the sectors involved.

Developing such an approach in practice will entail use of an appropriate mix of regulations, technology and financial investment. It will also require us to take a more integrated, rather than the conventional sectoral, approach to the management of ecosystems and their services, which recognises the multi-functional nature of ecosystems and is adaptable enough to operate over a range of spatial and temporal scales. Such an approach should extend beyond the borders of the UK itself to embrace regional and global processes.

It will also be important to recognise that different people have different priorities and needs, which will sometimes conflict. Decision making needs to be open and transparent enough to allow dialogue and collaboration between a wide range of different actors. Mechanisms need to be established to allow negotiation to take place, and trade-offs to be understood and agreed. In particular, ways need to be found to balance ethical, spiritual and aesthetic considerations, which are essentially non-monetarisable, with those based on utility. To participate effectively in decision-making, people will need access to relevant information and a clear understanding of the issues at stake.

While there are still uncertainties, knowledge gaps and controversies in our evidence, we already have sufficient understanding to manage our ecosystems more sustainably and good evidence of the social benefits that would arise from doing so.

The UK National Ecosystem Assessment

The UK National Ecosystem Assessment (UK NEA) is the first analysis of the UK natural environment in terms of the benefits it provides to society and the nation's continuing prosperity. It is based on the processes that link human societies and their well-being with the environment and emphasises the role of ecosystems in providing services that bring improvements in well-being to people.

The UK NEA was carried out between mid-2009 and early 2011 as part of the *Living With Environmental Change* Partnership. It involved over 500 natural scientists, economists, social scientists and other stakeholders from government, academic, NGO and private sector institutions. It was specifically intended to:

1. Produce an independent and peer-reviewed assessment of the state and value of the UK's natural environment and ecosystem services.
2. Identify and understand what has driven change observed in the natural environment and the services it has provided over the last 60 years, and what may drive change in the future.
3. Foster better interdisciplinary cooperation between natural and social scientists to assist in strengthening policy making, to ensure effective management of the environment and ecosystem services in the future.
4. Ensure full stakeholder participation and encourage different stakeholders and communities to interact.
5. Use the key messages from the assessment to raise awareness amongst society of the importance of the natural environment to human well-being and economic prosperity.

The principal output of the UK NEA is a Technical Report of 27 chapters, running to over 1,000 pages in total, of which the present report is a synthesis.

The UK NEA conceptual framework is structured around the processes that link human societies and their wellbeing with the environment. It explores the drivers of change impacting on ecosystems, and the services which flow from them to deliver a range of goods that we value individually and as a society (**Figure 9**).

Like the Millennium Ecosystem Assessment (MA) the UK NEA recognizes four categories of ecosystem service (**Box 1**, p18):

- Supporting Services
- Regulating Services
- Provisioning Services
- Cultural Services

A detailed analysis of each of these is provided in Chapters 13–16 of the Technical Report.

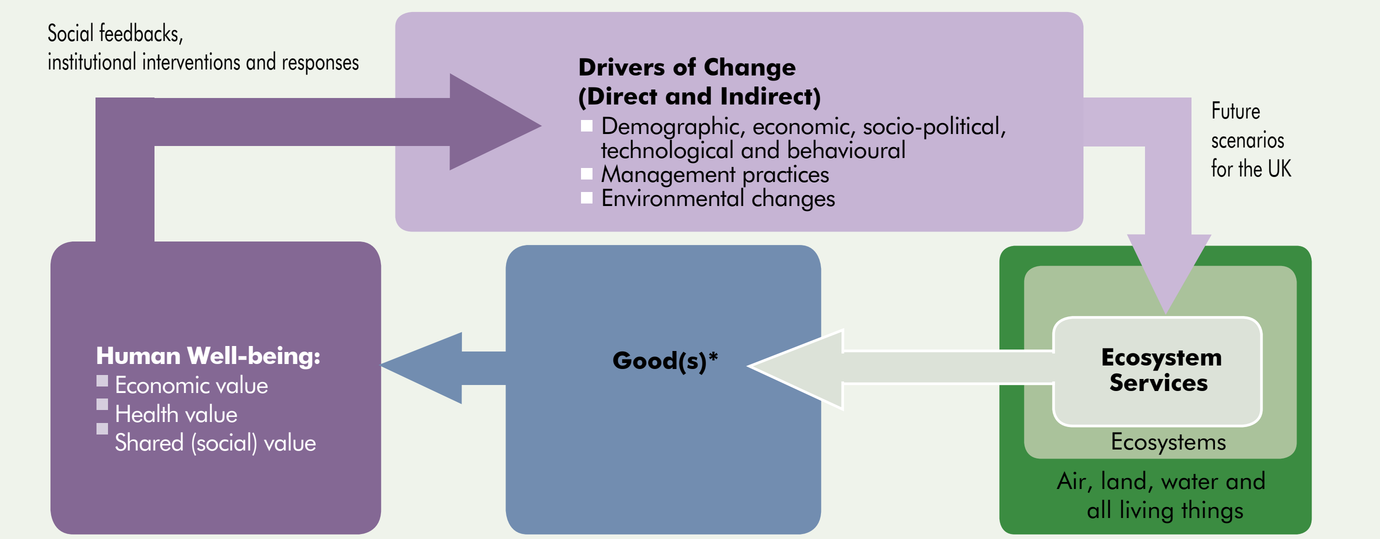


Figure 9 Conceptual Framework for the UK NEA showing the links between ecosystems, ecosystem services, good(s), valuation, human well-being, change processes and scenarios. *Note that the term good(s) includes all use and non-use, material and non-material benefits from ecosystems that have value for people.

However, the UK NEA also incorporates post-MA advances, especially for the economic valuation of ecosystem services and focuses on 'final ecosystem services' developed to avoid the double counting of services which are part of a suite of primary processes, including supporting services (**Figure 10**).

The complex role of biodiversity in the delivery of ecosystem services (**Box 2**, p19) has also been addressed both in an individual chapter of the Technical Report (Chapter 4) and in each of the habitat chapters. Compared to the MA we have taken a slightly different approach to the treatment of biodiversity and explicitly separate out the underpinning natural processes that depend to a greater or lesser degree on biodiversity, from landscapes, seascapes, habitats and wild species. These latter elements of biodiversity are part of our natural heritage and, through the pleasure they bring to many people, form one kind of cultural ecosystem service.

Ecosystems vary widely because of differences in the interaction of biological, chemical and physical factors at anyone location. In practice ecosystems are usually defined by the scope of the function, process or issue being studied. For the purposes of the UK NEA, we use **Broad Habitat** types based on those from the Countryside Survey for classifying ecosystems (**Figure 11** and **Box 3**, p20–21):

- Mountains, Moorlands and Heaths
- Semi-natural Grasslands
- Enclosed Farmland
- Woodlands
- Freshwaters – Openwaters, Wetlands and Floodplains
- Urban
- Coastal Margins
- Marine

Each of these Broad Habitat types is the subject of a separate Chapter (5–12) in the Technical Report.

In order to assess the contribution of ecosystem services and goods to human well-being, the UK NEA has developed an innovative approach to valuing ecosystem services (Chapters 22–24 of the Technical Report) which takes into account the full range of monetary (market and non-market) and non-monetary values of ecosystem service flows to individuals and collectively

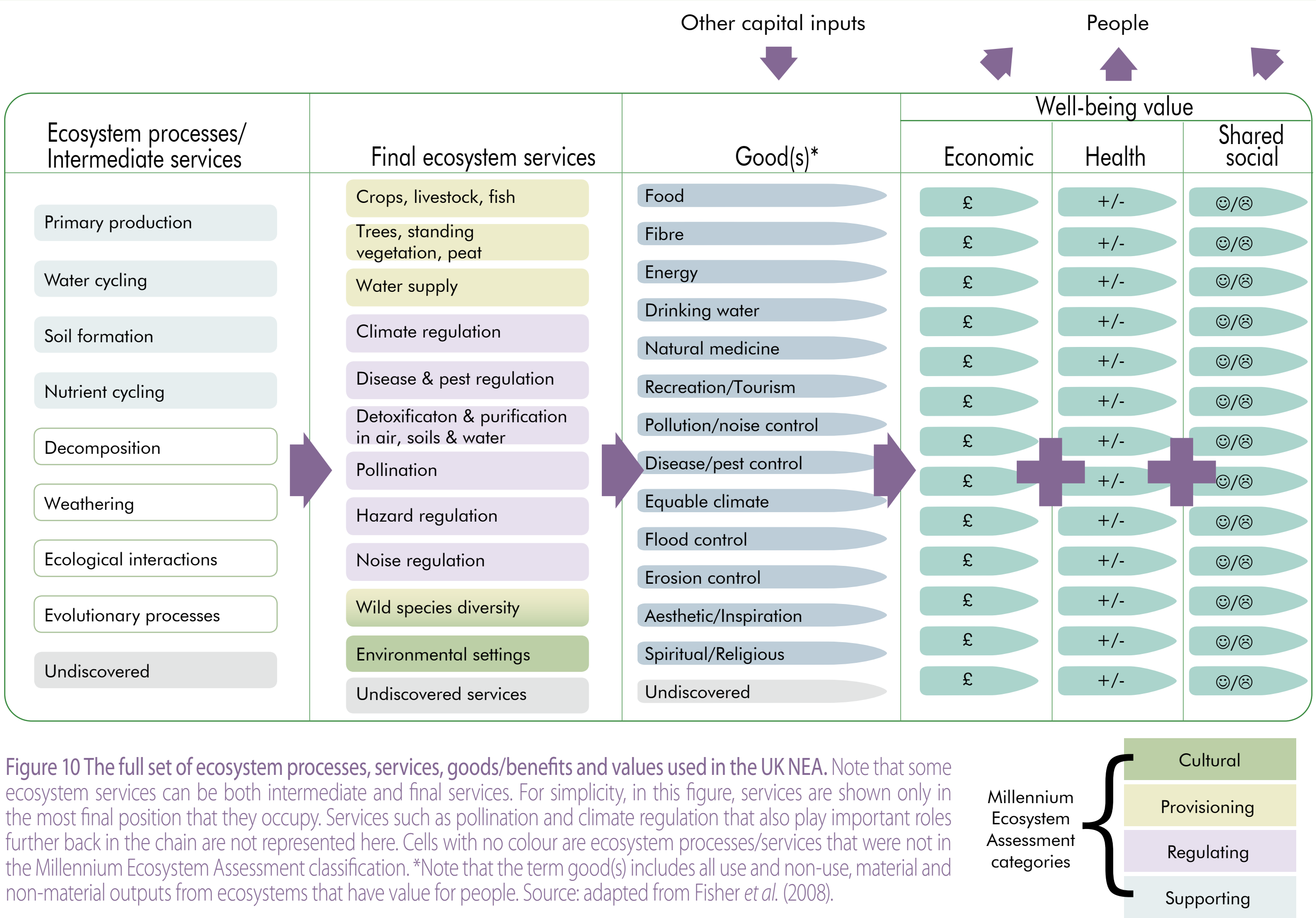


Figure 10 The full set of ecosystem processes, services, goods/benefits and values used in the UK NEA. Note that some ecosystem services can be both intermediate and final services. For simplicity, in this figure, services are shown only in the most final position that they occupy. Services such as pollination and climate regulation that also play important roles further back in the chain are not represented here. Cells with no colour are ecosystem processes/services that were not in the Millennium Ecosystem Assessment classification. *Note that the term good(s) includes all use and non-use, material and non-material outputs from ecosystems that have value for people. Source: adapted from Fisher *et al.* (2008).

to society. Our approach to non-monetary benefits to people from ecosystems was to describe additional well-being measures as health and shared social values.

In examining the drivers of change, the UK NEA has looked in particular at how societal changes have influenced both demand for different services and the ability of ecosystems to deliver them, often by affecting the extent and quality of different habitats. Within this context, the UK NEA has examined in detail the various response options available – that is mechanisms that can lead to changes in behaviour at individual, institutional and societal level that have a potentially positive impact on the delivery of ecosystem services over a range of timescales. Drivers of change are considered in Chapter 3 and response options in Chapter 27 of the Technical Report.

Finally a series of scenarios has been developed to assess what the future might hold, depending on the kinds of choices that are made now and in the immediate future as to how ecosystems are managed and the services they provide are used. (see **Figure 8**, p14). The scenarios are discussed in Chapter 25 and their wider economic implications in Chapter 26 of the Technical Report.

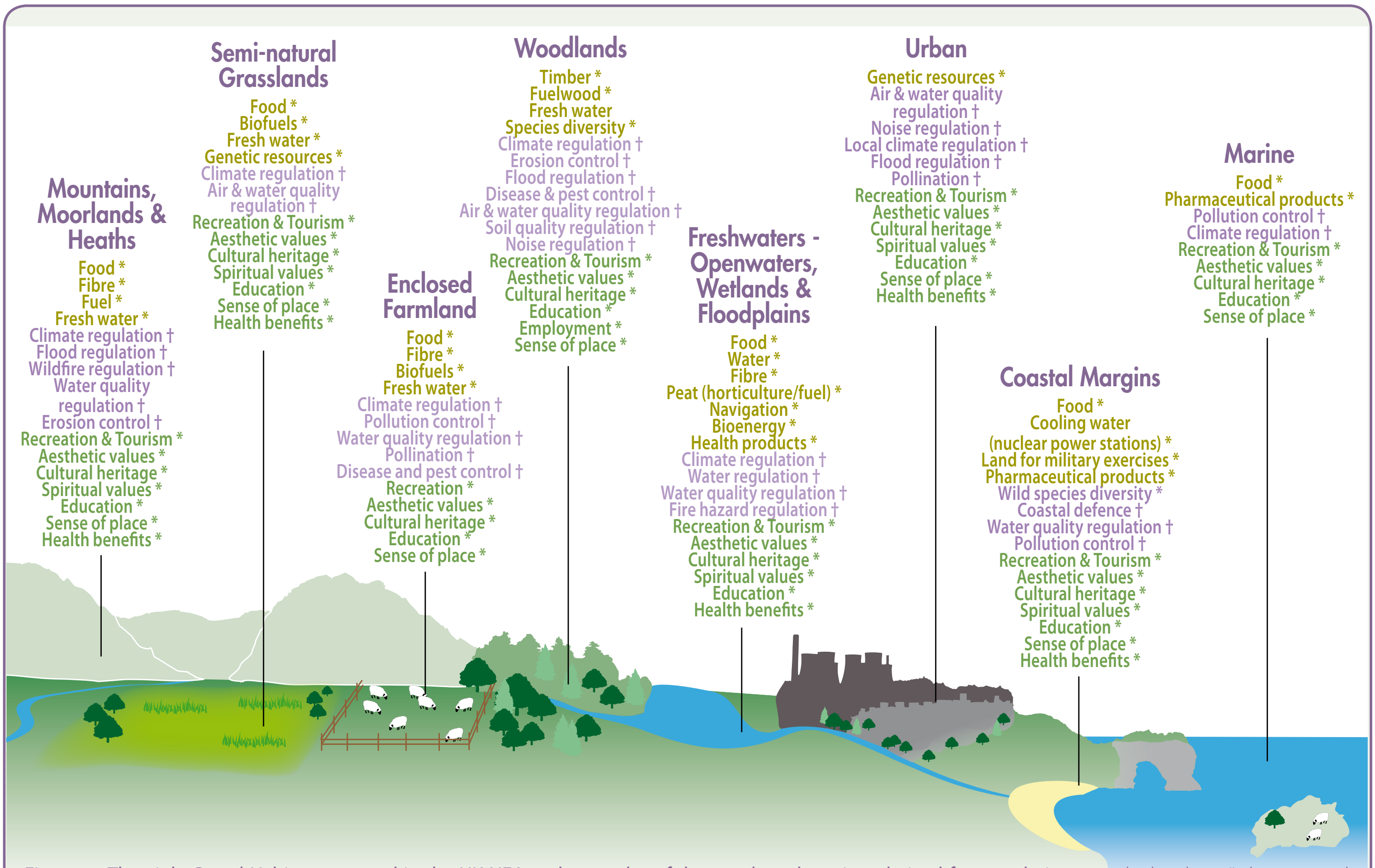
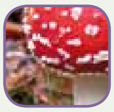


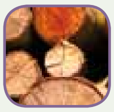
Figure 11 The eight Broad Habitats assessed in the UK NEA and examples of the goods and services derived from each. Items marked with an * denote goods, those with † denote services. Items in yellow are considered to be from provisioning services, purple from regulating and green from cultural. The supporting services, including amongst others primary production and nutrient cycling, are not listed against individual habitats as they are considered necessary for the production of all other ecosystem services. Source: adapted from the Millennium Ecosystem Assessment (MA 2005).

Box 1. The UK's Ecosystem Services

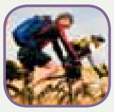


Supporting services provide the basic infrastructure of life. They include primary production, (the capture of energy from the sun to produce complex organic compounds), soil formation and the cycling of water and nutrients in terrestrial and aquatic ecosystems. All other ecosystem services – regulating, provisioning and cultural – ultimately depend on them. Their impacts on human well-being are indirect and mostly long-term in nature: the formation of soils, for example, takes place over decades or centuries. Supporting services are strongly interrelated to each other and generally underpinned by a vast array of physical, chemical and biological interactions. Our current understanding of exactly how such ecological interactions influence ecosystem processes and the delivery of supporting services is limited (TR 13).

Regulating services provided by ecosystems are extremely diverse and include the impacts of pollination and regulation of pests and diseases on provision of ecosystem goods such as food, fuel and fibre. Other regulating services, including climate and hazard regulation, may act as final ecosystem services, or contribute significantly to final ecosystem services, such as the amount and quality of available freshwater. As with supporting services, regulating services are strongly linked to each other and to other kinds of services. Water quality regulation, for example, is determined primarily by catchment processes and is thereby linked to other regulating services such as control of soil and air quality and climate regulation, as well as to supporting services such as nutrient cycling (TR 14).



Provisioning services are manifested in the goods people obtain from ecosystems, such as food and fibre, fuel in the form of peat, wood or non-woody biomass, and water from rivers, lakes and aquifers. Goods may be provided by heavily managed ecosystems, such as agricultural and aquacultural systems and plantation forests, or by natural or semi-natural ones, for example in the form of capture fisheries and harvest of other wild foods. Supplies of ecosystem goods are invariably dependent on many supporting and regulating services. Provisioning services have historically been a major focus of human activity and are thus closely linked to cultural services (TR 15).



Cultural services are derived from environmental settings (places where humans interact with each other and with nature) that give rise to cultural goods and benefits. In addition to their natural features, such settings are imbued with the outcomes of interactions between societies, cultures, technologies and ecosystems over millennia. They comprise an enormous range of so-called 'green' and 'blue' spaces, such as gardens, parks, rivers and lakes, the seashore and the wider countryside, including agricultural landscapes and wilderness areas. Such places provide opportunities for outdoor learning and many kinds of recreation; exposure to them can have benefits including aesthetic satisfaction and improvements in health and fitness and an enhanced sense of spiritual well-being. People's engagement with environmental settings is dynamic: meanings, values and behaviours change over time in response to economic, technological, social, political and cultural drivers; and change can be rapid and far-reaching in its implications (TR 16).

Box 2. The UK's Biodiversity: providing the building blocks for habitats and ecosystems

All ecological processes are the product of interactions between different groups of organisms and are dependent on there being a range of these present. In this sense, biodiversity – the variety and variability of living organisms – ultimately underpins the functioning of all ecosystems and thereby the delivery of all ecosystem services.

Of crucial importance are primary producers – higher plants, algae and some kinds of bacterium – that harness energy (almost always sunlight) to transform carbon dioxide and water into the complex organic compounds that heterotrophic organisms such as humans require for nutrition. Equally vital are decomposing organisms, including fungi and many bacteria that break down potentially noxious waste products into re-usable forms.

On land the great majority of primary producers are higher plants. To function effectively, plant-based ecosystems require a range of associated biodiversity, chiefly in the form of organisms that create and maintain soil structure, function and fertility, but also others such as pollinators and dispersers.

At the species level and from a global perspective, biodiversity in the UK is not particularly diverse. Nevertheless, there is still a wide range of species present – there are around 4,000 beetles, 2,500 butterflies and moths, some 1,500 lichens, 1,500 native higher plants and over 200 breeding bird species.

As well as being of fundamental ecological importance, many of the UK's wild species are of considerable direct economic value, for example through capture fisheries and hunting. Many are also of great cultural significance – birds of all kinds, butterflies, trees such as oak, beech, and birch, mammals such as badgers, otters and seals. Individual responses to each of these, as to nature more generally, vary widely. However, collectively they undoubtedly have a huge hold over the popular imagination.

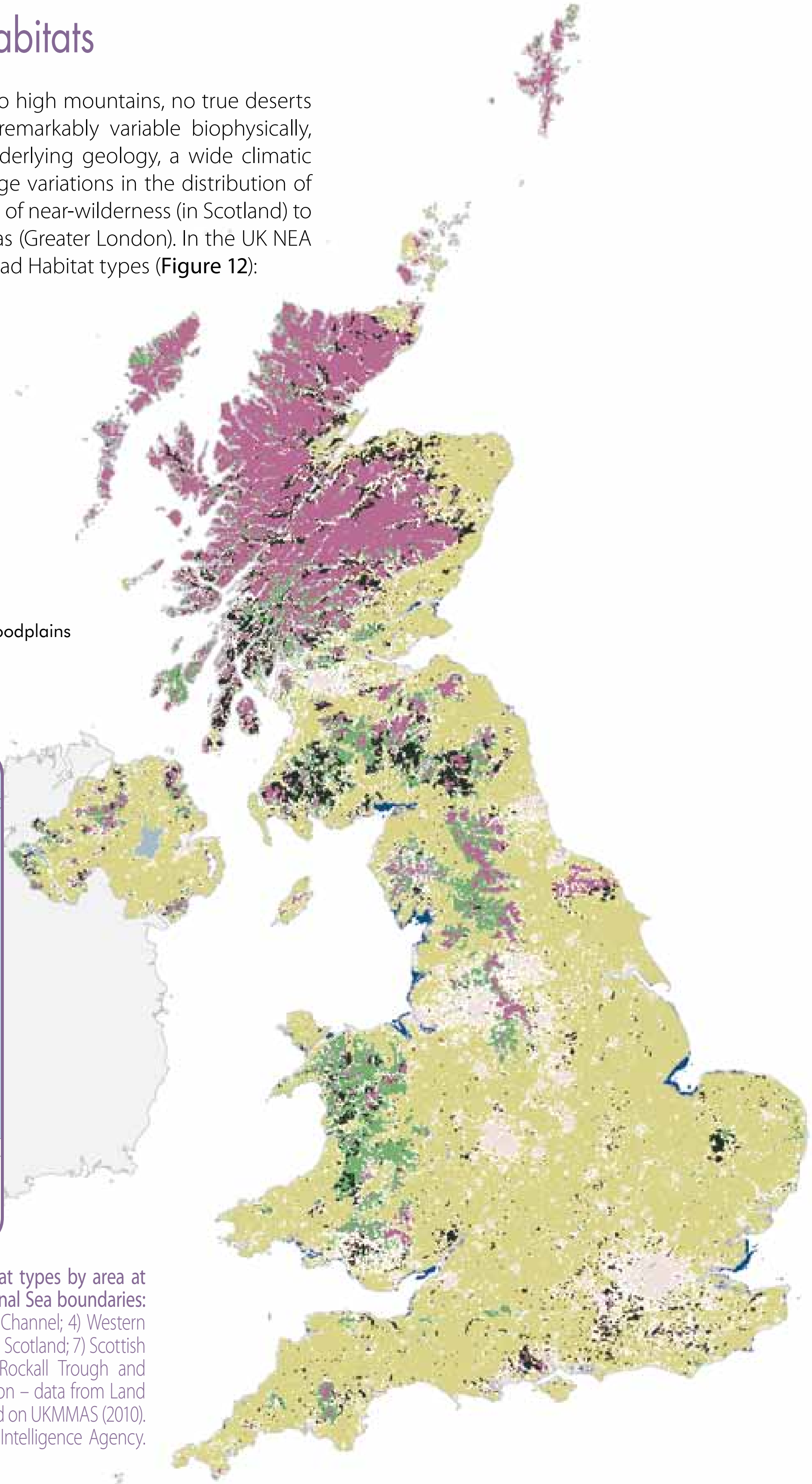
Due to a long and distinguished natural history tradition, some aspects of the UK's biodiversity (birds, butterflies, mammals, many groups of plants) are probably better known than those of any other country. Other groups remain much less well understood, including some that play a major role in the provision of supporting and regulating ecosystem services, such as soil microorganisms and microscopic photosynthesisers that are the basis for food webs.

The UK's biodiversity is in a constant state of flux, with the vast majority of recent changes attributable directly or indirectly to human activities. A number of species have become extinct since the 19th Century while large numbers of non-indigenous species are now established in the wild, as a result of deliberate or accidental introduction. These include over 800 non-native plant species, representing over one-third of the resident flora. Some introduced species, such as the grey squirrel, have had major impacts – generally negative – on native species and ecosystems; some of these impacts have significant economic consequences.

The UK's Biodiversity Indicators, covering groups for which sufficient information is available to discern trends, generally show improving or stable condition over the past decade for those of high conservation priority, although usually at lower population levels than recorded historically. There are still generally declining trends among biodiversity groups in the wider environment (TR 4.5.2).

Box 3. The UK's Broad Habitats

Although lacking in extremes – there are no high mountains, no true deserts and no major rivers – the UK is in fact remarkably variable biophysically, ecologically and socially, with complex underlying geology, a wide climatic range, (from very wet to semi-arid), and large variations in the distribution of the human population, from extensive areas of near-wilderness (in Scotland) to one of the world's largest metropolitan areas (Greater London). In the UK NEA this diversity has been captured in eight Broad Habitat types (**Figure 12**):



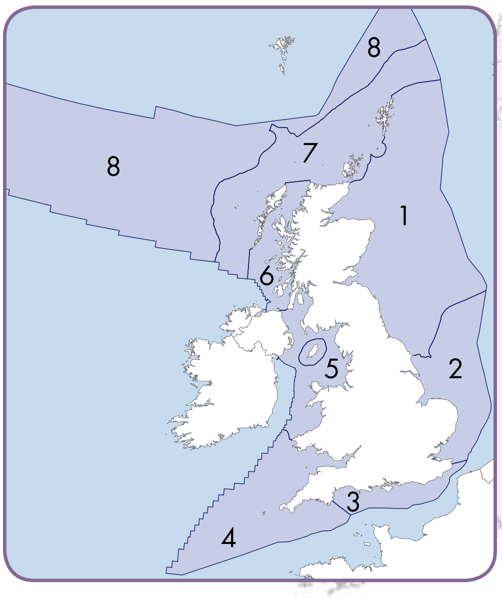


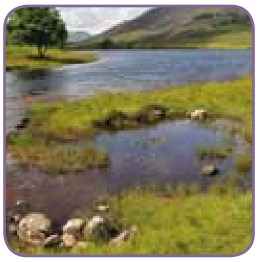
Figure 12 Distribution (%) of the UK NEA Broad Habitat types by area at 1x1 km resolution. Inset: Charting Progress 2, UK Regional Sea boundaries: 1) Northern North Sea; 2) Southern North Sea; 3) Eastern Channel; 4) Western Channel and Celtic Sea; 5) Irish Sea; 6) Minches and Western Scotland; 7) Scottish Continental Shelf; 8) Atlantic North-West Approaches, Rockall Trough and Faeroe/Shetland Channel. Source: Broad Habitat distribution – data from Land Cover Map 2000 (Fuller *et al.* 2002); Regional seas map based on UKMMAS (2010). Coastline: World Vector Shoreline@National – Geospatial Intelligence Agency. Source: NOASS, NGDC.

Mountains, Moorlands and Heaths cover 18% of the UK land area. Lowland heaths are highly fragmented, while mountains and upland moors and heaths provide the largest unfragmented semi-natural habitats in the UK. Mountains, Moorlands and Heaths are the source of around 70% of the UK's drinking water, hold an estimated 40% of UK soil carbon, and include some of the country's most iconic landscapes (TR 5).

Semi-natural Grasslands once covered a large proportion of the UK's land area, largely the result of low-intensity traditional farming. The extent of Semi-natural Grasslands is now extremely reduced, with high-diversity grasslands comprising a mere 2% of UK grassland (≥1% of total land area). Semi-natural Grasslands are highly valued culturally – the South Downs, dominated by chalk downland, receives around 40 million visitor days a year (TR 6).

Enclosed Farmland is the most extensive form of land use in the UK, accounting for around 40% of land area and producing around 70% of the UK's food. Most is managed for cereal, cattle and sheep production. Half the area of Enclosed Farmland is arable land, mostly in eastern England; almost all the rest is nutrient enriched grassland, mostly in wetter, western parts of the UK. As well as playing a crucial role in provisioning services, Enclosed Farmland is also of great cultural significance and is a major determinant of landscape in much of lowland UK (TR 7).

Woodlands include managed plantations as well as ancient, semi-natural woodlands. Woodlands cover 12% of the UK's land area, making the country one of the least wooded in Europe. At least 80% is less than 100 years old and just 5% is classified as ancient woodland. Much planting in the past century has been of coniferous trees (often non-native). Only in England is Woodland dominated by broadleaved species. Much of the Woodland estate is managed as a source of timber, but Woodlands are increasingly valued for their delivery of other ecosystem services, particularly recreation and carbon storage (TR 8).



Freshwaters include Openwaters, Wetlands and Floodplains**.** In the UK there are more than 389,000 kilometres of rivers, 200,000 hectares of permanent lakes and nearly half a million small ponds. There are also estimated to be at least 390,000 hectares of fen, reedbed, lowland raised bog and grazing marsh and nearly 1 million hectares of floodplain. Freshwater habitats are a major source of water for a wide range of uses and are important for recreation, including angling, boating and other water sports, and in hazard (notably flood) regulation (TR 9).

Urban areas in the UK cover just under 7% of land area. They are home to 8 out of 10 people, often living at extremely high population densities. Green space is very limited in extent, and access to it is unequally distributed; it thus assumes disproportionate cultural significance. Urban areas depend very largely on other habitat types for provision of most of their ecosystem services (TR 10).

Coastal Margins, comprising sand dunes, machair, saltmarsh, shingle, sea cliffs and coastal lagoons, cover just 0.6% of the UK's land area. Culturally, Coastal Margins are of immense significance. There are over 250 million visits per year to the UK coast, of which around one-third are to natural habitats. These areas are also important in coastal defences, sediment transport and as nursery grounds for fish (TR 11).

Marine habitats of the UK cover more than three and a half times the land area (see **Figure 12**, p20) They are highly variable, comprising a very wide range of sub-habitats. Inshore Marine habitats are of great cultural importance, offering many opportunities for tourism and recreation. Offshore habitats support fisheries and provide a wide range of other ecosystem services, such as avoidance of climate stress and waste breakdown and detoxification (TR 12).

Key Questions Addressed in the UK National Ecosystem Assessment

1. What are the status and trends of the UK's ecosystems and the services they provide to society?
2. What are the drivers causing changes in the UK's ecosystems and their services?
3. How do ecosystem services affect human well-being, who and where are the beneficiaries, and how does this affect how they are valued and managed?
4. Which vital UK provisioning services are not provided by UK ecosystems?
5. What is the current public understanding of ecosystem services and the benefits they provide?
6. Why should we incorporate the economic values of ecosystem services into decision making?
7. How might ecosystems and their services change in the UK under plausible future scenarios?
8. What are the economic implications of different plausible futures?
9. How can we secure and improve the continued delivery of ecosystem services?
10. How have we advanced our understanding of the influence of ecosystem services on human well-being and what are the knowledge constraints on more informed decision making?

1. What are the status and trends of the UK's ecosystems and the services they provide to society?

Key Findings

- The landscape of the UK has changed markedly during the last 60 years with the expansion of Enclosed Farmlands, Woodlands and Urban areas, and the contraction and fragmentation of Semi-natural Grasslands, upland and lowland Heaths, Freshwater wetlands and Coastal Margin habitats.
- Changes in the extent and condition of habitats has significantly altered the ecosystem services they provide.
- Within Enclosed Farmland, crop and livestock production has increased significantly, but accompanied by a loss of landscape diversity, an increase in soil erosion and reduced soil quality, and a reduction in farmland birds and pollinators, in particular. However, there have been a number of recent improvements, including a reduction in greenhouse gas emissions, due to both reduced fertiliser application and lower livestock numbers, and improved chemical quality of water.
- The expansion of Woodlands has contributed to both improved climate regulation, through greater carbon sequestration, and air quality, while at the same time increased timber supply. More recent changes in forest policy and woodland management have enhanced general amenity value and wild species diversity.
- Expansion of Urban areas has degraded regulating services for climate, hazards, soil and water quality, and noise.
- Fragmentation and deterioration of wetlands, and in particular the separation of rivers from their floodplains, has compromised hazard (flood) regulation and many other ecosystem services.
- Across all habitats apparent reductions in soil quality and continuing declines in the diversity of many wild species, including the variety and abundance of pollinators, is of particular concern.

Changes in the composition of the UK landscape

The landscape of the UK has changed markedly over the last 60 years as some Broad Habitats have expanded, in particular Enclosed Farmland, Woodlands and Urban, while others, including Semi-natural Grasslands, Mountain, Moorlands and Heaths, Freshwater – Openwaters, Wetlands and Floodplains, and Coastal Margins, have both declined in total area and become more fragmented. The initial policy drive for greater food and timber production saw an expansion of farmland (including improved grassland, arable and horticulture), particularly in the lowlands and marginal uplands, along with a twofold increase in forests in the uplands. Until the mid-1980s these changes were at the expense of Semi-natural Grasslands in the lowlands and heaths in the uplands, where each was historically more widespread. In the drier lowlands of the east, the switch was to arable, while in the wetter parts of the west, and also the north, they were reseeded with higher yielding grass varieties. Fen, marsh and coastal wetlands were often drained for agriculture, while seasonally grazed floodplains have been used for new settlements. More recent changes in the UK landscape reflect alternative uses of agricultural land, including the uptake of farm woodland schemes and the expansion of housing associated with the trend for people to move from metropolitan areas to the peri-urban fringes and into smaller settlements in rural districts.

Recent reductions in the intensity of land management for agriculture, as well as the effort in tackling diffuse and point-source pollution from all sources, have probably contributed to slowing the decline in many species used as indicators of trends in ecosystem quality. However, these indicators tend to be based on changes in plants, birds and mammals, taxonomic groups with adequate data. Little is known about microbial diversity in soils and water, which is crucial to sustaining production. This incomplete inventory of biodiversity thwarts a comprehensive assessment of the status and trends of our ecosystems and their capacity to deliver ecosystem services for human well-being. Nevertheless, it is clear that our various habitats each deliver a wide range of different services that are changing in complex ways (see **Figure 5**, p11).

Status and trends in Broad Habitats

Mountains, Moorlands and Heaths: Substantial changes to Mountains, Moorlands and Heaths, which currently cover about 18% of the UK, took place between the 1940s and 1980s, both in extent and condition and how they have been used by people. Greatest losses in extent and quality, primarily due to afforestation, agricultural development, high grazing pressures, airborne pollution, and to a lesser extent climatic change, were reported for bog and both upland and lowland heaths. There have been no further dramatic losses in extent in the last two decades (TR 5.2).

Semi-natural Grasslands: The area of Semi-natural Grassland has declined greatly in the last 60 years, primarily due to agricultural activities, with the biggest losses (about 90%) in the UK lowlands, although the loss in area has slowed substantially over the last decade. Agri-environment schemes are critical to restore and enhance the biodiversity of Semi-natural Grasslands and present opportunities for delivering multiple services whilst requiring relatively low energy inputs (TR 6.2).

Enclosed Farmland: Levels of agricultural production increased greatly until the 1990s, while many other ecosystem services declined, in particular because of the large-scale inputs of nitrogen and phosphorous fertiliser. Total agricultural productivity plateaued in the past decade. While the deterioration in other ecosystem services has reduced, and in some cases reversed, many interactions between provisioning and other ecosystem services are still negative. However, mutually positive interactions can be generated by changes to the land management regime and also by allocating land to different objectives at scales ranging from within-field (biodiversity) to catchment (water quality) (TR 7.2).

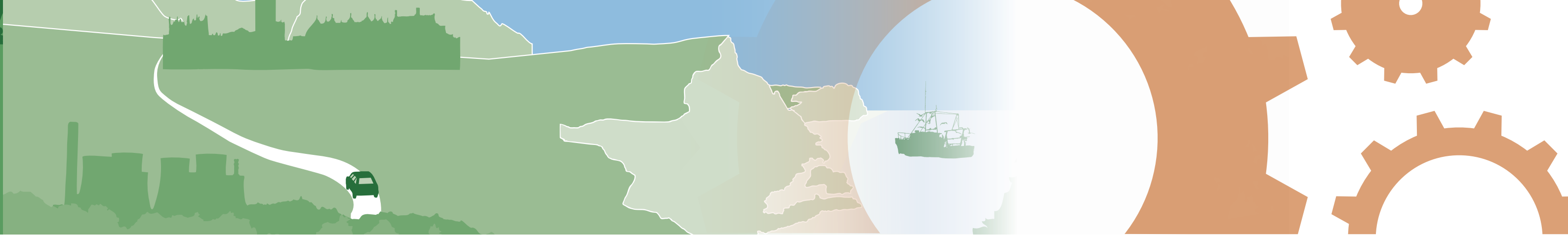
Woodlands: The area of Woodland has doubled since the 1940s to cover 12% of the UK, and as much as 17% of Scotland. In the immediate post-war decades, government policy on land use and global trade drove a rapid expansion of coniferous plantation forest, peaking in Wales in the 1970s and Scotland in the 1980s. However, forest policy and woodland management have changed over time, seeking varying combinations of goods and services. Diversification of forest structure for biodiversity benefits improve cultural services, through better amenity value, while increases in forest cover potentially benefit carbon regulation and can also contribute to flood regulation throughout river catchments (TR 8.2, 8.3).

Freshwaters – Openwaters, Wetlands and Floodplains: After 1945 the loss of wetland habitats and deterioration of water quality, particularly through diffuse pollution, was an issue. However, the chemical quality of rivers and lakes has been progressively improving since the 1980s, although trends are locally variable. Freshwater habitats have substantial cultural value. However, despite the multiple benefits of these habitats, many of their services are poorly valued or completely overlooked. Consequently, many have been degraded or lost through wetland drainage, flow modification for flood defences, toxic pollution and acidification, habitat degradation and loss, exploitation and the introduction of exotic species (TR 9.2, 9.3).

Urban: The area of Urban habitats now cover over 10% of England, but as little as 2% of Scotland, 3% of Northern Ireland and 4% of Wales. An increasing majority of the population resides within Urban areas. Currently they provide very limited provisioning services, though there is a revival in allotments after decades of decline. In general, Urban areas also tend to be ineffective in delivering regulating services, with the possible exception that green infrastructure can contribute to urban cooling, providing shade and removing pollution particles, and help noise abatement. However, cultural services arising from access to good quality greenspace, through public parks and private gardens, contribute to positive mental health, childhood development and physical health (TR 10.3).

Coastal Margins: Coastal Margin habitats have declined in extent, by about 10%, and quality in the last 60 years due to development and coastal squeeze. Sand dune and saltmarsh have been lost due to agricultural improvement and forestry, as well as land-claim, while rapid coastal development for industry, housing, military activities and tourism has affected all habitats. The quality of these habitats has been impacted by widespread installation of artificial sea-defence structures and increased armouring of soft cliffs, which reduces sediment supply and natural dynamics, crucial to contributing to protection elsewhere. Furthermore, reductions in traditional forms of management, such as grazing of levees, have led to the risk of increased erosion and potential flooding (TR 11.2).

Marine: The Marine habitats around the UK deliver a very wide range of ecosystem services and goods of value to society. However, the delivery of many of these provisioning and regulating services in the Marine environment are declining because of heavy



exploitation and sea temperature rise associated with climate change. Wild fisheries are declining, while trawling also has an adverse effect on seabed life, which plays a key role in cycling nutrients crucial to ensuring the productivity of the seas. The breakdown of waste and detoxification of freshwater runoff appears to be keeping pace but is locally problematic in estuaries and coastal waters. Increasing sea temperatures also raise concerns about the potential outbreak of pathogens (TR 12.3).

Trends in delivery of ecosystem services

Over the last 60 years the dramatic increases in provisioning services, including crops, livestock and trees, have been achieved both through using more land and through intensification, such that by 2000 the UK was able to produce more food and timber than at any time during the last century. However, the expansion of agriculture, forestry, and new settlements to meet the needs of the growing population, has come at the expense of non-provisioning services. For example, some key supporting services have been adversely affected, especially nutrient cycling, as well as regulating services, including soil quality, the control of pest and diseases, and pollination by insects. Also, cultural services may have deteriorated: for example, hedgerows have been lost from lowland landscapes.

Provisioning services: Policy, technology and market forces have enabled greater levels of provisioning for goods with market value, including food and timber. Technological developments have enabled major changes in both the systems of production and levels of productivity, and these have enabled businesses to meet market demands for cost efficiency. However, some policy failures have allowed productivity from certain wild, unmanaged resources to decline, in particular marine fisheries. The emphasis of policies has changed over the last 60 years. At first they served to incentivise production (e.g. the Common Agricultural Policy, forestry), but more recently their aims have been towards ameliorating the environmental impacts of production (e.g. agri-environment schemes in agriculture, planning for aquaculture, and the development of a UK Forestry Standard), and preventing overexploitation (e.g. Common Fisheries Policy) (TR 15).

Regulating services: Since the late 1950s, air quality, and since the 1980s, water quality, has improved through legislation, first tackling point source pollution, in particular, emissions from burning fossil fuels and treatment of effluent waste, and more recently diffuse pollution associated with agriculture and emissions from cars (TR 14.7, 14.8). However, other sources of diffuse atmospheric pollution and inappropriate land management are continuing and may be causing declines in both pollinating insects (TR 14.5) and soil quality (TR 14.7). The recent increase in dissolved organic carbon in rivers, which degrades water quality and potentially contributes to increased greenhouse gas emissions, is of particular concern. There have been some significant changes in weed and disease incidence, mainly driven by agricultural intensification, population growth and land/wildlife management. For example, weeds at the base of the arable food web have declined, while the incidence of bovine tuberculosis has increased (TR 14.4).

Cultural services: Since 1945, successive governments have implemented policies to conserve culturally and socially important nature, places and landscapes valued by UK society. In turn, the social, aesthetic and spiritual benefits stimulate recreational activities and tourism, helping maintain rural communities by diversifying their economies, as seen in the last two decades. There is growing evidence that greenspace in urban areas, as well as access to the wider countryside, enhances child development, and improves physical and mental health outcomes for all (TR 16.2). However, recent evidence suggests that the quantity and quality of urban greenspace may be declining. In contrast, membership of civil societies, often based on nature, landscape character and sense of local place, continues to increase (TR 16.2).

Supporting services: Since soil formation is slow, at an average of less than one centimetre soil depth per century, there are concerns about some losses to erosion under intensive agriculture, and in particular the potential loss of organic matter due to more extreme weather events. Over the last 30 years, the pH of surface soils and water has increased, which is related to a decline in sulphate deposition associated with coal-fired electricity generation (TR 13.2). Recent reductions in phosphorus available to plants in soils, possibly associated with increased primary production stimulated by increased atmospheric nitrogen deposition and climate warming, is of increasing concern (TR 13.5). Finally, although there have been few trends in the water cycle, milder winters in the last 30 years have been associated with increasing winter rainfall, and greater flows in rivers in the north and east of the UK (TR 13.5).

2. What are the drivers causing changes in the UK's ecosystems and their services?

Key Findings

- **The primary drivers of change in UK ecosystem services during the past 60 years have been i) conversion and intensification of natural habitats to farmland; ii) exploitation of natural resources, especially marine fish; iii) air and aquatic pollution, especially nitrogen, sulphur and phosphorus; and to a lesser extent iv) climate change, and v) invasive species, including plant pests and animal diseases.**
- **These direct drivers have largely been influenced by an increasing and ageing population, the economic liberalization of trade, increased mechanisation and use of agrochemicals, policy changes and reform and behavioural changes, especially consumption patterns. Collectively, these changes in indirect drivers have placed a greater demand on the services provided by UK ecosystems, and have ultimately influenced the way we manage our natural resources.**
- **The emphasis placed on provisioning services to meet the increased need for food (crops and livestock), and to a lesser extent fibre, water and energy, for an increasing and wealthier population during the last 60 years, has resulted in the unintended degradation of many UK ecosystems and the delivery of many regulating services, supporting services and cultural services.**
- **The Rural Development Programme, in particular the agri-environment schemes of the European Union Common Agricultural Policy, has had some successes, while other European Union environmental directives, such as the Water Framework Directive, have led to significant improvements in ecological status in the past 10–15 years.**
- **Changes in the intensity of land management, as well as a reduction in diffuse and point-source pollution and an expansion of protected areas, are likely to have contributed to slowing the decline of many species, including birds used to monitor trends in ecosystem quality.**
- **Air and water quality have improved significantly over the past 50 years, largely due to direct regulatory interventions, resulting in reduced emissions and improving condition of ecosystems.**

Biodiversity and ecosystem services are affected by both direct and indirect drivers. Direct drivers are those which directly impact on biodiversity and ecosystem services, for example land use conversion, overexploitation of natural resources, pollution, introduction of invasive species and climate change. Indirect drivers are those which influence the direct drivers of change, for example economic and population growth resulting in an increased demand for food, and to a lesser extent fibre, water and energy, as well as policies, such as agricultural subsidies that promote increased agricultural production. Consequently, it is important to understand the relationship between the indirect and direct drivers of change, which have interacted in different ways across the UK. While some lowland natural ecosystems, for example saltmarshes, have been converted to productive farmland, in general, the lowland landscapes have become less diverse as farming has become more intensive, large-scale and specialised. In contrast, the uplands have seen high livestock densities and have been subjected to high levels of pollution deposition. The impacts of agricultural activities have also changed over time in response to policy changes. For example, subsidy support for agricultural production after entry into the European Union Common Agricultural Policy (1973) led to overproduction of foodstuffs, resulting in the conversion of some natural ecosystems, intensification of others, and a loss of biodiversity and the degradation of non-provisioning ecosystem services. Reform of the Common Agricultural Policy in 1992, 1998 and 2003, through the introduction of the Rural Development Programmes, and particularly the agri-environment schemes, has increasingly supported environmental enhancement of farmlands. As a result, biodiversity has benefited and falling livestock numbers have resulted in reduced greenhouse gas emissions.

The primary drivers of change in UK ecosystem services during the past 60 years have been changes in the area and condition of habitats, the overexploitation of terrestrial and marine resources, and air and water pollution, and to a much lesser extent invasive species and climate change. The relative importance of, and trends in, the impacts of direct drivers on UK NEA Broad Habitat extent and condition and the services they provide are depicted in **Figure 13** and **Figure 14** (TR 3.2).

Many of the changes in habitats and their associated ecosystem services result from satisfying the increased demand for the provisioning services of food, and to a lesser extent water, fibre and energy, at the expense of biodiversity and regulating, cultural and supporting services. Since 1945, the production yields of the four main cereals of the UK have shown increases of between 80 and 220%. This increase in food production, in response to an increasing population and the desire for the UK to become more self-sufficient, was achieved through the conversion of semi-natural habitats (e.g. saltmarshes) to arable land, and the adoption of new technologies, for example improvements to farm machinery, fertilisers and pesticides which transformed farming practices and the level of intensification (TR 3.4.1). However, this increase was associated with changes in habitats and major declines in the diversity and numbers of plants, terrestrial invertebrates and vertebrates in agricultural areas, especially higher plants and farmland birds. For example, only 26 out of 710 (4%) Areas and Sites of Special Scientific Interest (ASSI/SSSIs) on Enclosed Farmland habitat are in favourable condition; and the Farmland Bird Index – a measure of the state of biodiversity on agricultural lands – declined by 43% between 1970 and 1998 (**Figure 3**, p8) (TR 3.3.3).

The key indirect drivers of change, which have resulted in significant changes (positive and negative) in habitats and human well-being throughout the UK during the last 60 years, are:

- **Demographic changes:** Between 1951 and 2009, the UK population increased by 18% from 50.3 million to 61.8 million people, with the proportion of older people (>65 years) growing faster than any other age group. Up until 1998, population growth was primarily due to a greater number of births than deaths; however, since 1998, net migration has been the main contributor (66%) to population growth, especially since expansion of the European Union in 2004, which enabled a greater freedom of movement into the UK for non-UK European citizens. Population growth has led to increased urbanisation, placing greater pressure on land

UK NEA Broad Habitat	Habitat Change*	Pollution & Nutrient Enrichment	Overexploitation	Climate Change	Invasive Species
Mountains, Moorlands & Heaths	Very high ↗	Very high →	Moderate ↗	Moderate ↗	Low →
Semi-natural Grasslands	Very high ↘	Very high →	High ↗	Low ↑	Moderate →
Enclosed Farmland	Very high →	Very high ↘	Low →	Low ↗	Moderate ↗
Woodlands	Moderate →	Low →	Very high ↘	Low ↗	Moderate ↗
Freshwaters – Openwaters, Wetlands & Floodplains	Very high →	High ↘	High ↗	Low ↗	Moderate ↗
Urban	Very high →	Very high →	Low ↗	Low ↗	Moderate ↗
Coastal Margins	Moderate ↗	Very high →	Low ↘	High ↑	Moderate ↗
Marine	Moderate ↗	Moderate ↘	Very high ↗	Moderate ↑	Low ↑

Figure 13 Relative importance of, and trends in, the impact of direct drivers on UK NEA Broad Habitat extent and condition. *Cell colour* indicates the impact to date of each driver on extent and condition of Broad Habitats since the 1940s. The *arrows* indicate the current (since the 1990s) and ongoing trend in the impact of the driver on extent and condition of the Broad Habitat. Change in both impacts or trends can be positive or negative. This figure is based on information synthesized from each Broad Habitat chapter of the UK NEA Technical Report (Chapters 5–12) and expert opinion. This figure presents UK-wide impacts and trends, and so may be different from those in specific sub-habitats or regions; however more details can be found in the individual Broad Habitat chapters. *Habitat change can be a result of either land use change or deterioration/improvement in the condition of the habitat.

Driver's impact on extent and condition of Broad Habitats since the 1940s
- Very high
- High
- Moderate
- Low

Driver's current (since 1990) and ongoing trend
- ↘ Decreasing impact
- → Continuing impact
- ↗ Increasing impact
- ↑ Very rapid increase of the impact

Service Group	Final Ecosystem Service	Habitat Change*	Pollution & Nutrient Enrichment	Overexploitation	Climate Change	Invasive Species
Provisioning	Crops	Very high →	High →	Low →	Low ↗	Low →
Provisioning	Livestock	Very high →	High →	Moderate →	Low ↗	Moderate ↗
Provisioning	Wild fish	Very high ↗	Moderate ↘	Very high →	Moderate ↑	Moderate →
Provisioning	Farmed fish (aquaculture)	High →	Moderate →	Moderate ↗	Low ↗	Low ↗
Provisioning	Timber	Very high ↗	High →	Very high ↗	Low ↑	High ↑
Provisioning	Water	Moderate →	Very high ↗	Very high ↗	Low ↑	Low ↗
Provisioning	Peat	Very high →	Low →	High ↘	Low →	Low →
Provisioning	Wild game	High ↗	Moderate →	Moderate ↘	Low ↗	High →
Provisioning	Honey	Low ↗	Low →	Moderate ↗	Low ↑	Moderate ↑
Provisioning	Ornamentals	Moderate ↗	Low →	High ↗	Low ↗	Low →
Provisioning	Genetic resources	High →	Low →	Moderate ↗	Low ↗	Very high →
Provisioning / Cultural	Wild species diversity	Very high ↗	Very high ↘	Very high ↗	Moderate ↑	High ↗
Cultural	Environmental settings	Very high ↗	High →	Moderate →	Low ↗	Moderate ↗
Regulating	Climate	Very high →	High →	High ↘	Moderate ↑	Low →
Regulating	Hazard	Very high →	Low →	High ↗	Moderate ↑	Moderate ↗
Regulating	Disease and pests	Very high →	Moderate →	Moderate ↗	Moderate ↗	High ↗
Regulating	Pollination	Very high →	High →	Low →	Low ↗	Very high ↗
Regulating	Noise	Very high →	Low →	Moderate ↗	Low →	Low →
Regulating	Water quality	High →	Very high ↘	High →	Low ↗	Moderate →
Regulating	Soil quality	Very high →	Very high →	High ↘	Low ↗	Low →
Regulating	Air quality	Very high →	Very high ↘	High →	Moderate ↑	Low →
Supporting	Soil formation	Very high ↗	Very high ↘	High ↗	Low ↑	Low ↗
Supporting	Nutrient cycling	High →	Very high →	Moderate →	Low ↗	Low →
Supporting	Water cycling	Very high →	Low ↗	High ↗	Moderate ↑	Low →
Supporting	Primary production	Very high →	High →	Moderate →	Low ↑	Low →

Figure 14 Relative importance of, and trends in, the impact of direct drivers on UK ecosystem services. *Cell colour* indicates the impact to date of each driver on service delivery since the 1940s. The *arrows* indicate the current (since the 1990s) and ongoing trend in the impact of the driver on service delivery. Change in both impacts or trends can be positive or negative. This figure is based on information synthesized from the biodiversity and ecosystem service chapters of the UK NEA Technical Report (Chapters 4 and 13–16), as well as expert opinion. This figure presents UK-wide impacts and trends, and so may be different from those for specific final ecosystem services; however more details can be found in the biodiversity and ecosystem service chapters. *Habitat change can be a result of either land use change or deterioration/improvement in the condition of the habitat.

Driver's impact on ecosystem service delivery since the 1940s

- Very high
- High
- Moderate
- Low

Driver's current (since 1990) and ongoing trend

- ↘ Decreasing impact
- → Continuing impact
- ↗ Increasing impact
- ↑ Very rapid increase of the impact

conversion for housing, and higher demands on water and energy resources (TR 3.3.1).

- **Economic growth:** Over the past 60 years, the UK economy has grown and transformed from an industrial-based to post-industrial, service-based economy; currently, developments are towards a low-carbon, high technology-based economy. Market forces that affect the environment have altered as wealth has increased and consumption choices have changed. For example, the significant increase in personal and family wealth in the UK since the 1940s has resulted in a decrease in the proportion of average family expenditure on essential items, such as food, leaving money available to spend on luxury items, travel and leisure (TR 3.3.2).

- **Socio-political changes, especially in policies:** As society has become more aware and concerned about environmental change, legislation and regulation, such as the 1956 Clean Air Act which led to a successful reduction in pollution levels, has been developed and implemented to protect human well-being and, consequently, ecosystem health. Between 1962 and 2002 there was a 95% decline in particulate smoke and sulphur dioxide emissions in the UK, while emissions of nitrogen oxide have declined by 60% since 1990. Woodland cover has doubled in the last 60 years: first in response to increased timber production, and then, since the mid-1980s, forestry policy has increasingly prioritised biodiversity and the provision of a wider range of services, including cultural and regulating services. This has resulted in increased planting of broadleaved tree species and a diversification of plantation structures stimulated by grants, favourable economic and tax conditions, and the development of UK Forestry Standard and voluntary certification schemes such as the UK Woodland Assurance Standard. There has been a strong post-1940s tradition of financial support for productive agriculture (e.g. the Common Agricultural Policy) and forestry which has influenced land management practices and land conversion. Over time, these payments supported activities that increased food production from farmlands. More recently, agricultural support schemes have reduced their focus on production and now include support and rewards for positive environmental management and 'environmental stewardship'. For example, the agri-environment schemes provide support for energy crop cultivation and farm diversification. There is also a range of payments that are linked to a system of cross compliance activities that promote traditional and environmentally beneficial management options, such as hedge management, crop rotations and woodland management. Over 8.45 million hectares of farmland in agri-environment schemes, along with set-aside, are likely to have been responsible for the 5.4% increase in enclosed grassland between 1998 and 2007, and for the restoration of some diversity in arable landscapes (TR 3.3.3).

- **Behaviour change:** Consumption choices, combined with societal knowledge and environmental attitudes, can affect market forces and impact on, for example, land or sea management: consumption choices favouring sustainably caught fish can influence fisheries management practices. Changes in environmental attitudes and media attention can also raise public awareness of environmental issues and influence government and private sector decisions. For example, knowledge of the dangers and impacts of acid rain and climate change stimulated the development and implementation of legislation to reduce levels of sulphur dioxide and greenhouse gas emissions (TR 3.3.4).

- **Advances in science and technology:** Key technological developments either in, or adopted by the UK over the last 60 years have included the increased mechanisation of farming and fishing practises, development of novel agrochemicals, i.e. pesticides and fertilisers, and improved genetics techniques which has led to changes in the choice of crops grown and the breeding of livestock. Some of these changes have had profound effects on UK ecosystems and the services they provide. For example the use of agrochemicals and the development of highly effective drainage systems has enabled large swaths of land to be reclaimed for agriculture, increasing food production but consequently causing a reduction in area of wetland habitats. Catch rates of fish have increased through enhanced netting equipment and sonar technology; however the ability to capture different components of the population, for example juvenile fish in nets with finer mesh sizes, and the destruction of the seabed by new bottom trawling techniques, have led to ecosystem-wide changes in the marine environment. Detection and management of the impacts of technological developments on ecosystems and services is continuously improving with improved information technology and environmental monitoring techniques which has facilitated feedback to policy development aimed at the drivers of such change (TR 3.3.5).

These in turn have caused:

- **Conversion of natural and semi-natural habitats:** Over half the land area of the UK is now under productive agriculture or developed land, which has resulted in the loss of biodiversity and degradation of some regulating, supporting and cultural services. Over 100,000 kilometres of hedgerows were lost between 1984 and 1990. At the end of the 20th Century, the populations of 67% of 333 farmland species (broadleaved plants, butterflies, bumblebees, birds and mammals) were declining due to agricultural practices. For example, woodland and farmland bird populations declined by 14% and 47% respectively (see farmland bird decline in **Figure 3**, p8). In contrast, urban bird populations increased by 11%. Wetlands have been particularly susceptible to drainage and conversion behind flood defences; rivers have been prone to flow modification. Prior to 1980 more than 20% of Mountain, Moorlands and Heath habitats were converted to agriculture, grasslands or forestry, and subjected to high grazing pressures. Coastal Margin habitats have declined in extent and quality during the last 60 years due to development and coastal squeeze, with sand dunes and saltmarsh being lost due to agricultural improvement (including forestry) and land claim, while rapid coastal development for industry, housing and tourism has affected all habitats. High density housing in Urban areas has contributed to dense inner cores and suburbs often devoid of adequate greenspace, tending to limit important social and cultural services and overwhelming local regulating services (TR 3.4.1).

- **Pollution of air, land and water:** Examples include nitrogen from the use of fertilisers and sulphur from the combustion of fossil fuels. Nitrogen additions to farmland increased by over 300% from 1957 and peaked in the 1980s, but decreased significantly by 2007. From 1990 to 2006 there was a 16% increase in the area of crops treated with pesticides. Prior to 1990, rivers and lakes had been particularly susceptible to elevated nutrient loading, often from diffuse agricultural pollutants. Novel pollutants (e.g. endocrine-disrupting substances and nanoparticles) are becoming an emerging concern in most terrestrial ecosystems. Sulphur emissions from industry and power plants peaked in the 1980s, resulting in acidification of soils in many areas, with 54% of semi-natural areas still considered at risk of damage despite major reductions in emissions. Heavy metals emissions from a range of industrial uses and transport are generally not declining (TR 3.4.2).

- **Overexploitation of terrestrial, marine and freshwater resources:** The impacts of overexploitation are most apparent in the marine environment. Unsustainable catch rates and habitat destruction from fishing gear have had a significant adverse impact on marine ecosystems, including both target and non-target species, causing ecosystem-wide changes. Spawning stock biomass of species exploited by UK fleets are estimated to have fallen by 43% since 1982 and catch rates of some species, such as those for haddock and halibut, have declined by more than 99%. However, there have been significant improvements: the proportion of fish stocks assessed around the UK that are being fished sustainably and are at full reproductive capacity has risen from between 5% and 10% in the 1990s to 50% in 2008 (see **Figure 4**, p9). This is likely to be related to changes within the European Union Common Fisheries Policy (TR 3.4.3).

- **Climate change:** To date, climate change has not been a major driver for most ecosystems. For example, there is little evidence of climate-related changes in the composition and structure of UK forest and woodlands. However, it is expected to play a significant role in future change, with some changes already evident: range changes of the more mobile species, such as insects and birds, plus changes in the timing of flowering and fruiting have been observed, which may eventually have an impact on a range of ecosystem services. Climate change has also appeared to have affected river biodiversity; for example, populations of trout and salmon have declined by about 50%–60% in some UK catchments, which has been linked to the 1.5–3°C rise in some river temperatures that has occurred since 1980. Changes in sea temperature are also thought to be impacting on plankton species, the food chain and a range of marine ecosystem services (TR 3.4.4).

- **Invasive species:** Invasive species are typically thought to have detrimental impacts on ecosystems and their services, often acting as vectors for disease, changing biodiversity, disrupting cultural landscapes, reducing the value of land and water for human activities, and causing potential damage to crops, livestock and timber. While the public may enjoy the views of invasive species such as rhododendrons within upland woodlands, they have recently been associated with the spread of *Phytophthora ramorum* into the UK, which has transferred itself to Japanese larch (*Larix kaempferi*), with significant dieback and mortality and hence economic costs. Non-native species recorded in Great Britain number 3,473, with at least 49 viewed as a 'high threat'. England is most affected, with over 2,000 invasive species, 100 of which are considered to have a negative environmental impact (TR 3.4.5).

How do ecosystem services affect human well-being, who and where are the beneficiaries, and how does this affect how they are valued and managed?

3.

Key Findings

- **Society in general benefits from the full range of provisioning, regulating and cultural services. Examples include, i) the increase in the production of crops and livestock has resulted in a wider selection of food at a reduced cost; ii) carbon sequestration by soils and woodlands limits human-induced climate change; and iii) ecosystems influence both physical and mental health, and the quality of life in general.**
- **Changes in ecosystem services have both positive and negative impacts on human well-being. For example, the conversion of saltmarshes and dunes to farmland results in increased agricultural output, but locally leads to loss of habitat for recreation and potential implications for coastal defence against storm surges.**
- **However, the evidence base linking changes in ecosystems to human well-being is incomplete, and tends to be biased towards assessments based on economic value, particularly where there are markets for goods, and may largely ignore less well quantified health values and un-quantified shared social values.**
- **The distribution of beneficiaries of ecosystem services is not evenly spread. For example, carbon sequestration in woodlands benefits society at large, while access to woodlands for recreation and leisure primarily benefits those in close proximity or with transport access, while loss of urban green space has often impacted most severely on lower income households.**
- **The management of ecosystem services tends to be localized, whereas the beneficiaries may be widely distributed. For example, much of the regulation of water quality happens in upland ecosystems, while the beneficiaries are downstream to those ecosystems. This disconnect between the providers and beneficiaries of the service requires regulatory and/or incentive schemes for land and water management.**
- **Where beneficiaries are local to the source of ecosystem services, and are able to influence the ecosystems from which services flow, this will affect the way that these ecosystems are valued and managed. For example farmers working the soil are directly dependent upon good soil quality on site, and should value and manage it accordingly.**
- **Human well-being and quality of life is a function of both satisfying individual needs, including social and health-related aspects, and cultural and wider, collective needs. Thus, there is an emerging view that there are shared values for ecosystem services, conditioned via networks of people and institutions, and elicited through participatory activities, including focus groups, local forums and citizen juries.**

Well-being is a broad term that is generally understood to encompass social and mental, as well as physical, aspects of the human condition (Box 4, p32). In common language it is sometimes referred to in terms of '*health, wealth and happiness*'. The UK NEA conceptual framework identifies three distinct types of well-being value: economic value, health value, and shared social value (described below on p32 and 33). Ideally all three types of well-being value should be considered when evaluating changes in ecosystems, the delivery of services and goods to different individuals and sectors of society, and the likely consequences of different policy interventions (TR 2.7).

However, the evidence base linking changes in ecosystems to human well-being is incomplete, and tends to be biased towards economic value, particularly where there are markets for goods. Although there is growing evidence to show that ecosystems can affect both the physical and mental health of all social groups, and people's quality of life in general, this evidence often relates to non-specific access to the wider landscape and seascapes, or specific use of urban greenspace, particularly for leisure in public parks and private gardens. There is also insufficient information on shared social value, the ethical and aesthetic values that individuals and groups attribute to their interactions with the natural world (TR 2.2–2.4).

Given that the measures of well-being are so diverse, it is becoming increasingly evident that decision makers require a range of deliberative tools with which they can integrate the variety of quantitative and qualitative information about both change in, and the well-being value of, ecosystems. Furthermore, any evaluation has to be undertaken at the appropriate spatial and temporal scales, and therefore ideally will make use of the local

knowledge of stakeholders, as well as relevant scientific information. Both ecosystem services and human well-being are spatially extremely complex across the UK at all scales and therefore interact in ways that can be difficult to discern.

A full understanding of who and where the beneficiaries of ecosystem services are, and how this influences the ways in which ecosystem services are valued and managed, requires more detailed spatial analysis and case studies, and is beyond the immediate remit of the UK NEA. Our attempt to answer the question combines expert opinion with advances made in considering specific types of value, whilst recognising the need for further work.

Measures of well-being value

Economic value: While considerable progress has been made on developing robust economic methods, their application to the valuation of changes in a range of ecosystem services is far from complete because we need: i) an understanding of the change in delivery of the good under consideration (i.e. the change in the number of units or amount being provided) given changes in the environment, policies and societal trends; ii) a robust and reliable estimate of the marginal (i.e. per unit) benefit value; and iii) knowledge of how ii) might alter as i) changes. Although there is historical data for changes in the delivery of provisioning goods and their market values, there is, typically, limited data for changes in goods delivered from regulating and cultural services, and there is even less information about the marginal values, because commonly there are no markets to value them. Hence it has not been possible to formally assess the economic value of changes in ecosystems during the last 60 years for a comprehensive suite of ecosystem services. However, the UK NEA has used the available data and where appropriate, transferred data over time and space to provide aggregate economic value for goods with non-market values. This enabled it to estimate the current annual value of a number of ecosystem goods and services, and explore the consequences of changing land use under a suite of different plausible scenarios in 2060, compared with the 2000 base line (see Question 8) (TR 2.7.1, TR 24).

Box 4 Shared understanding of wellbeing.

"Wellbeing is a positive physical, social and mental state; it is not just the absence of pain, discomfort and incapacity. It requires that basic needs are met, that individuals have a sense of purpose, that they feel able to achieve important personal goals and participate in society. It is enhanced by conditions that include supportive personal relationships, strong and inclusive communities, good health, financial and personal security, rewarding employment, and a healthy and attractive environment. Government's role is to enable people to have a fair access now and in the future to the social, economic and environmental resources needed to achieve wellbeing. An understanding of the effect of policies on the way people experience their lives is important for designing and prioritising them." Source: Defra (2007).

Health value: Ecosystems provide three generic health benefits. First, ecosystems can have direct positive effects on the mental and physical health of individuals. Second, ecosystems have indirect positive effects on human health, including i) facilitating nature-based activity and social engagement (e.g. providing locations for contact with nature, or physical activity), and ii) providing a catalyst for behavioural change, encouraging the adoption of healthier lifestyles (e.g. improving life pathways, activity and behaviour, and encouraging the consumption of wild foods). Third, ecosystems can reduce the incidence of pollution and disease vectors, through a variety of purification and control functions, including local climate regulation, and the scavenging of air pollutants and waterborne pathogens (TR 2.7.2, TR 23, TR 24).

New research undertaken within the UK NEA is helping to reveal detailed patterns of the relationships between subjective well-being and the natural world. In particular, the research captures some of the complexity of the links between environmental settings (i.e. landscapes and waterscapes, and the Broad Habitats within them), and the delivery of certain cultural goods, for example, recreation, and well-being. Instantaneous measures of happiness (mappiness) collected repeatedly from more than 18,000 mobile phone users were analysed in relation to respondents' location and activity. The mappiness results support and add extra information to a separate web survey regarding the link between outdoor pursuits (such as use of domestic gardens and parks) and well-being, and uncover a larger range of potentially happiness-enhancing activities (TR 23, TR 24).

Shared social value: This term refers to ethical concerns and aesthetic judgements as well as the collective benefit derived from ecosystem services. Shared values often have deeper historical roots than some individual consumer desires. As such, they are context-specific; that is, they are the outcomes of local circumstances, of specific times and particular places. Values attributed to nature change over time; they are expressed in different ways among members of all societies; and give rise to different kinds of formal and informal institutions. Academic research in the fields of ethical concerns and aesthetic judgements about nature, place and landscape tends to rely on a wide range of methods, including the production of sophisticated descriptive interpretations, based on reasoned argument, and the weighing of many different sources of quantitative and qualitative evidence. Decision makers require a wider range of evidence-gathering techniques in order to ensure that important shared values are not lost through the application of monetary valuation alone. For these reasons, policy makers require a range of deliberative tools, such as participatory multi-criteria analysis, to integrate quantitative and qualitative information so as to embed the ecosystem approach and the nature of shared values in decision-making (TR 2.7.3, TR 24).

The influence of changes in ecosystems on human well-being

Impacts have been both positive and negative. Many ecosystems have increased delivery of provisioning services (e.g. crops, trees) and contributed to improved human well-being (e.g. plentiful food, timber). However, these increases have come at the expense of other services including supporting (e.g. nutrient cycling), regulating (e.g. soil and water quality, and numbers and diversity of pollinators), and cultural (e.g. number of farmland birds, and landscape integrity). Although many of the non-provisioning indicators have shown declines, the specific impacts of these changes on well-being are not easy to quantify. For example, the impact of loss of pollinators on either crop or wild plant productivity and diversity is unknown, though the total value of pollination services is estimated at £430 million per annum.

The cost society associates with these disbenefits may reflect whether changes are dramatic, rather than subtle. For example, large scale urbanisation of the 'green belt' commonly generates a perception of ecosystem degradation because of loss of cultural services such as aesthetic value, irrespective of any consideration of the fact that the construction of houses and roads covers and compacts soil, preventing good drainage and increasing the risk of flooding, creates heat islands and, where traffic is congested, causes pollution to air, soils and water. Conversely, long-term loss of biodiversity in Semi-natural Grasslands through nitrogen enrichment, or other subtle changes in the landscape, may have little impact on perceptions of ecosystem change, except amongst naturalists. Some

examples of ecosystem changes and their effects emerging from the UK NEA include:

Woodlands: Woodland cover in the UK has expanded from 6% to 12% in the last 60 years. In turn, this has increased carbon sequestration (valued at £680 million/annum), with the benefit of climate regulation for all. This expansion, and a shift in management objectives towards multiple service provision, has brought about increased amenity benefits through recreation, in particular for those with access to woodland close to urban centres. However, poorly located and poorly designed coniferous forest can cause deleterious changes to water quality and losses to open ground biodiversity (TR 8).

Freshwaters – Openwaters, Wetlands and Floodplains: The drainage of wetlands and the separation of rivers from their floodplains, often to facilitate new housing, has led to the loss of multiple services. Of particular concern is the loss of natural flood protection, replaced by what proves now to be inadequate engineered solutions, given an increase in the size and frequency of extreme rainfall events. Overall freshwater quality has improved as a result of controls of industrial pollution and domestic sanitation, and reductions in the use of agricultural fertilisers have reduced the costs of providing potable water, as well as having direct health benefits. However, locally there are still issues with excessive abstraction and diffuse pollution of water bodies. On a more positive note, conservation organisations working with other land managers are striving to reverse the fragmentation of wetlands, re-linking sites to increase local community amenity value and conservation potential (TR 9).

Coastal Margins: Reclamation of saltmarsh, conversion of sand dunes and shingle habitats for agriculture, forestry, and land for housing and primary industry (refineries, power stations) all have positive impacts on some aspects of human well-being, but locally, reclamation leads to loss of habitat for recreation and biodiversity, and causes tensions related to coastal defence, both of which potentially diminish well-being. Although coastal tourism has been declining as a share of the whole UK tourism industry, it is still very strong, and this trend is largely independent of changes in the Coastal Margins themselves. The evidence from subjective well-being studies and direct health studies of the 'blue gym' indicates pronounced well-being arising from people's interaction with our coasts (TR 11).

Urban: The growth of the UK population, combined with a trend for smaller households, has driven up housing demand everywhere. This has led both to an expansion of urban settlement into the countryside and also to an increase in housing density in inner cities. In metropolitan areas, per capita greenspace provision has therefore declined, particularly in the most deprived areas, adversely affecting health by reducing childhood development, mental and physical well-being, for example through less exercise, less community cohesion, and a diminished sense of security, and by causing the loss of a sense of place. In particular, the sale of playing fields and loss of associated wildlife has reduced opportunities for young people to participate in sporting activities and to study nature. This has affected their education, ecological knowledge and understanding of the natural environment and its importance to them, and risks long-term detriment (TR 10).

The distribution of the beneficiaries of current ecosystem services

Some benefits and beneficiaries of ecosystem services are widespread. Other benefits, and costs, are more localised, applying to particular sectors of society or to people in particular localities. The patterns are determined by the ways in which services flow from ecosystems and can be illustrated by examples in provisioning, regulating and cultural services.

Provisioning services: The major beneficiaries of increased agricultural output and the decline in 'real' prices have been the public at large. Successive generations have increased in physical stature, partly as a result of better nutrition, and associated health improvements. However, recently the benefits of cheap food have become confounded by poor dietary/lifestyle choices by increasing numbers of individuals, leading to obesity and other nutrition-related disorders, such as Type 2 diabetes. The economic benefits of agriculture are skewed across the food supply chain. While retailers have increased their profits most over time, processors and manufacturers have intermediate levels of profit, but farmers and producers, in general, have minimal profits, such that many small farm businesses are no longer viable without alternative income streams (TR 23).

Regulating services: While the climate regulation effects of carbon sinks ultimately benefit all of society, ecosystem-based hazard regulation generally provides more localised or directional ('downstream') direct benefits, for example along rivers where exposure to flooding and erosion is reduced by upstream attenuating processes. Specific pests/pathogens determine the main beneficiaries of disease and pest regulation, or those who are impacted negatively. For example, cattle farmers in the south-west and mid-west of England and south and east Wales have been most affected by bovine tuberculosis (TB). All farms are at risk of being affected by introduced pathogens (TR 14).

Pollination services are generated and delivered locally, and so the direct beneficiaries (arable farmers and fruit growers whose productivity depends, at least in part, on pollination services) are also local. Additional beneficiaries include other sectors of the agri-food industry involved in the processing and transport of pollinator-dependent goods, and also retailers and consumers of these goods. The wider public benefit (through cultural services) from the maintenance of diverse wildflower communities in protected areas and other landscapes (TR 14).

Conversely, the major beneficiaries of water quality regulation are located downstream of the ecosystems in which water quality regulation occurs, such as the uplands, agricultural landscapes and the river systems themselves. Therefore, there is a disconnect between the providers and the beneficiaries of water quality regulation. This has led to the use of regulatory or incentive schemes, such agri-environment schemes to improve land and water management for water quality. Utility companies are increasingly involved in land-management intervention aimed at improving the quality of raw water supplies (TR 14).

Cultural services: Increased mobility has allowed many people to travel longer distances to valued landscapes and seascapes for leisure, tourism and recreational purposes. These changes may have altered some peoples' relationships between well-being and environmental settings and cultural goods. For example, the fact that no individual in the UK is more than about 100 kilometres from the sea means that, with today's transport infrastructure, coastal areas are accessible to a great many more people, and more frequently, than in the past. Yet despite this, increasing urbanisation and sedentary lifestyles have disconnected many people, particularly less affluent urban-dwellers, from natural ecosystems. Negative changes in urban green- and bluespaces are, however, being reversed in some places, thereby restoring local opportunities to enjoy outdoor recreation (TR 16).

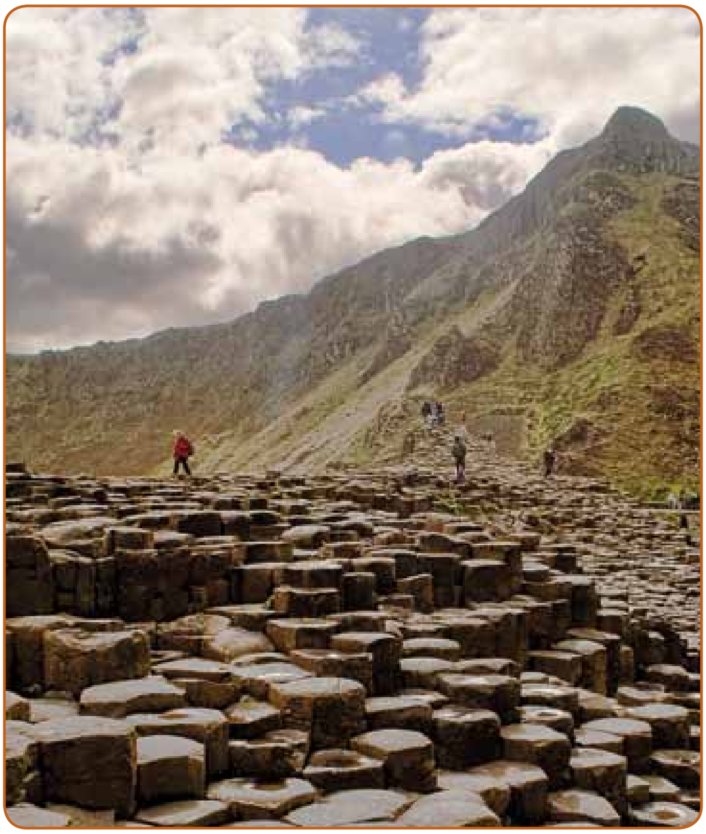
The influence of the location of beneficiaries on the value and management of ecosystem services

There are good examples to illustrate that location, in relation to the source of ecosystem services, influences which services are valued and how strongly, as well as influencing control over ecosystem management and decision making. Where beneficiaries are local to the source of ecosystem services, and are able to influence the ecosystems from which services flow, this will affect the way that these ecosystems are valued and managed. For example, farmers working the soil are directly dependent upon good soil quality on site, and should value this and manage it accordingly.

Where benefits and costs are more widely distributed, the location of beneficiaries may have little influence on the value associated with particular ecosystem services and their management, compared with i) the number of people affected, ii) who bears the costs of remedial action and iii) who has been charged with developing and enforcing alternative management practices. For example, the management of upland soils to improve water quality or for flood risk control will be considered differently if the water is supplying or affecting a large urban area compared to a few rural houses. Likewise, the recreational value of woodland is higher for more accessible woodlands near to centres of population, and this is likely to affect the priority placed on recreation as a woodland management objective (TR 22).

Other examples of how management itself can affect value, and the distribution of beneficiaries, include urban greenspace, where neglected sites become undervalued, regardless of location. Good site management results in the smallest of sites becoming desirable and valued wherever they are located, and people may travel further to enjoy them. Likewise, where local and distant beneficiaries benefit in different ways, local voices and/or more powerful lobbies may have a louder voice. There has been a trend in the past, in examples such as wetland decline or coastal zone management, for ecosystem changes to favour narrow sectoral interests, rather than valuing the wider range of functions and services which benefit a broader range of society.

There is much more to be explored and understood in terms of the ways that different people in different places benefit from ecosystem services. Policy and management decisions that alter ecosystem services will affect the composition and distribution of beneficiaries. Besides trade-offs in the kinds of ecosystem services provided under different management regimes, there will be trade-offs between beneficiaries, in space and in time. Considering these trade-offs is important if overall societal benefits are to be maximised.



4. Which vital UK provisioning services are not provided by UK ecosystems?

Key Findings

- **The UK is not self-sufficient in meeting its food, fibre, water (embedded in products) and energy needs, and consequently depends significantly on non-UK ecosystem services, thus exporting a substantial environmental footprint.**
- **The annual biomass flow from agriculture, forestry and fisheries through the UK economy is 150 million tonnes, based on domestic production of approximately 100 million tonnes, imports of 50 million tonnes and exports of 20 million tonnes. Therefore, approximately one-third of the biomass used by the UK is sourced from overseas.**
- **Approximately 66% of the UK's annual water demand of 102 billion cubic metres is met by overseas sources through embedded (virtual) water, three-quarters of which is due to production of agricultural biomass.**
- **Depending upon future policy choices, the UK dependence on provisioning services from non-UK ecosystems could increase or decrease (see Question 7): for example, a storyline which focuses on national self-sufficiency would reduce our dependence on non-UK ecosystems and their services, whereas one that emphasises local preservation of ecosystems could increase our dependence on non-UK ecosystems and their services.**
- **The UK is dependent upon a wide range of other non-UK ecosystem services, for example climate control, but these have not been analysed in this assessment.**

Economic growth in the UK since 1990 is drawing increasingly on the services of overseas ecosystems to support this growth. In particular, current natural resource consumption patterns in the UK mean that the UK landmass itself cannot provide the entire ecosystem provisioning services required to support the national economy (**Figure 15**). Access to overseas ecosystems services, particularly those provisioning services that supply biomass including food, fibre and bioenergy, is essential (TR 21.3).

Domestic biomass consumption appears to be recession proof and its steady growth within the UK economy over the last 40 years has been primarily related to population size. With domestic biomass production relatively stable, growth in the use of biomass by the UK economy has been supported by a growth in imports from 1980 through to a peak in 2002 (TR 21.5).

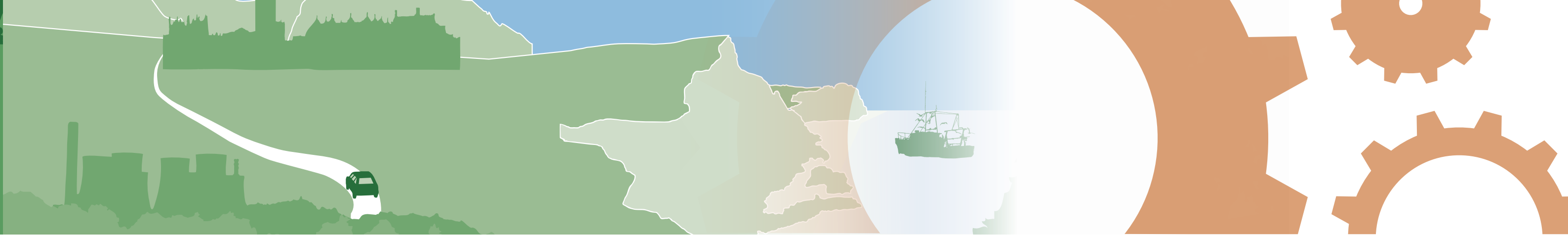
Environmental Accounts prepared by the Office for National Statistics, using Material Flow Analysis (**Box 5**), show an annual biomass flow from agriculture, forestry and fisheries through the UK economy of 150 million tonnes, based on domestic production of approximately 100 million tonnes, imports of 50 million tonnes and exports of 20 million tonnes (TR 21.5).

In 2008 approximately 50 million tonnes of biomass was imported into the UK as food, fibre and biofuel. Provision of food (for human or animal consumption) and forest products (timber, pulp, paper) accounts for 90% of the required overseas land use and the remaining 10% is related to bioenergy crops. Imports from marine systems represent less than 2% by volume. The overseas total land requirement in 2008 was approximately 14 million hectares, compared with a domestic productive area within the UK of approximately 20 million hectares (TR 21.4).

Imported biomass flow appears to have stabilised since 2002 at approximately 50 million tonnes per year. The change in the population/consumption relationship since 2002 primarily appears to represent a decline in timber imports, probably reflecting increased reuse/recycling of timber. However, UK population and economic growth, coupled with implementation of new bioenergy policies, is projected to increase future national demand for biomass, including imports (TR 21.5).

The majority of the overseas biomass utilised by the UK economy in 2008 comes from the European Union and wider Europe, with a land requirement of 8.5 million hectares. The estimated land requirement in South America, North America, Oceania, and the Afrotropics to supply biomass to the UK in 2008 was approximately 2.3 million hectares, 1.3 million hectares, 1.3 million hectares, and 0.3 million hectares respectively (TR 21.7).

Approximately 10 million of the UK's 14 million hectare overseas land use impact can be assigned to four individual biomes. Boreal and Temperate Broadleaf and Mixed Forest biomes are key suppliers, with a land use impact of approximately 3 million hectares each.



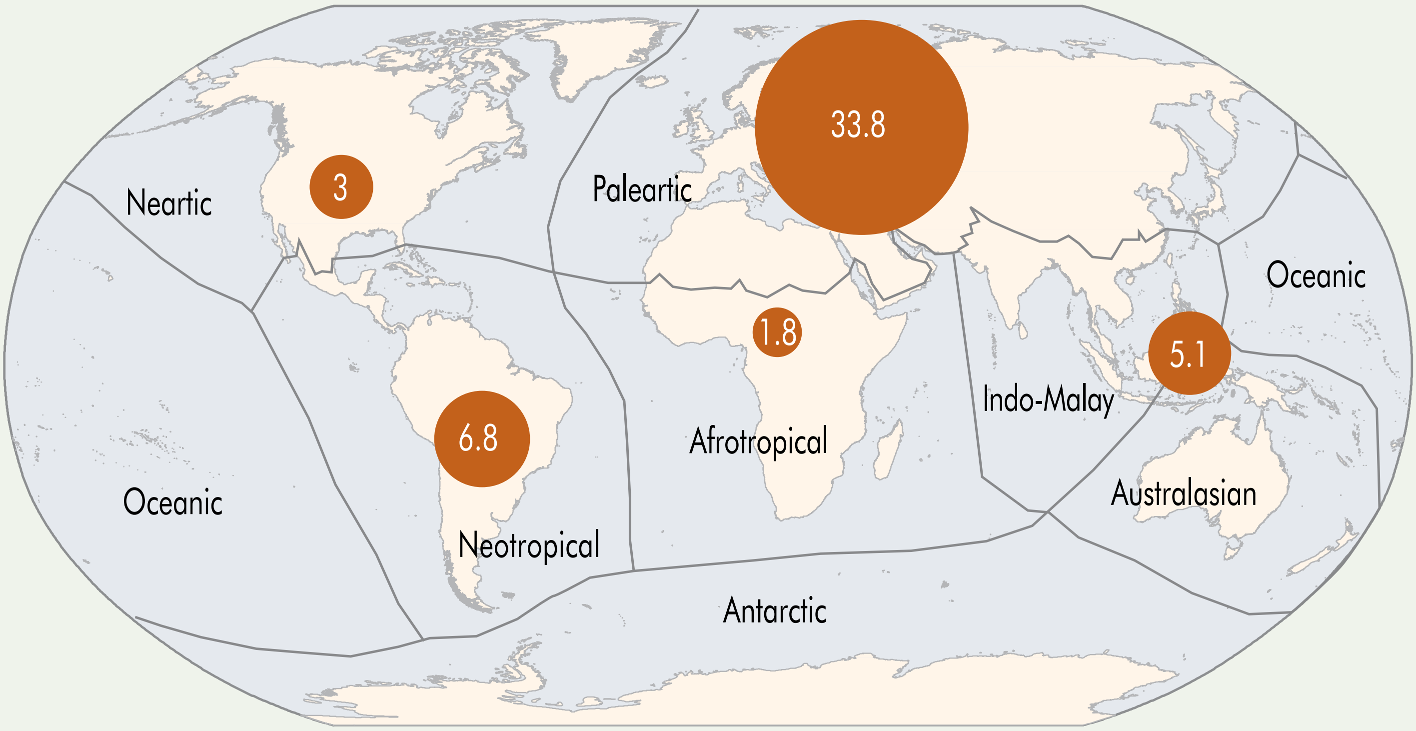


Figure 15 Source of biomass (millions of tonnes) imported into the UK by Biogeographical Realms in 2008. Source: data from HMRC (2008); underlying map based on Olson *et al.* (2004).

Impacts in the Boreal Forest Taiga biome occur primarily through import of timber products, whereas impacts in the Temperate Broadleaf and Mixed Forest biome are due to provision of food chain biomass for human or animal consumption. Outside these areas there is a land use impact of less than 2 million hectares in both the temperate grasslands of North and South America (primarily soya-based products for food chain biomass and biofuels) and tropical moist broadleaved forests of South America and South East Asia (primarily for food chain biomass and timber) (TR 21.4).

Approximately 66% of the UK's annual water demand of 102 billion cubic metres is met by overseas sources through embedded (virtual) water, three-quarters of which is due to production of agricultural biomass (TR 21.2.3).

The capacity to measure biomass use by the UK economy, and combine these measurements with other data to determine the drivers for national biomass consumption, allows an assessment to be made of the effects of these drivers on overseas ecosystems.

Box 5 Material Flow Analysis (MFA).

The use of biomass Material Flow Analysis (MFA) provides a framework for reporting on UK trends in biomass use, measurement of impacts on overseas ecosystems and the basis for domestic and international policy initiatives. The framework allows identification and quantification of the UK's overseas biomass dependencies, including the spatial determination of material sources, and also identifies the nature of potential ecosystem impacts that may arise from use of imported biomass imports, for example land use change, water abstraction, water and soil pollution, and soil degradation. The need for, and potential benefits arising from, domestic policies to minimise the overseas impacts of UK biomass consumption are made explicit. This enables policy identification and development of effective policy responses to possible overseas ecosystem service degradation attributable to the UK's use of imported provisioning services (TR 21.1).

Material Flow Analysis indicators permit identification of key biomass types entering the UK, their market price, volumes and source countries. Changing patterns of supply through time can be monitored and source ecosystems identified. Biomass material flow data, combined with other information, allows an analysis of pressures exerted on overseas ecosystems by UK biomass consumption, including locating where these pressures are occurring. Indicators of biomass flow and use of material flow analysis techniques do not provide a direct measure of the impacts of UK biomass consumption on overseas ecosystems, but identify global ecosystem pressure points arising from this consumption. The actual scale and nature of these impacts will require location-specific analysis (TR 21.1).

Growth in population, changes in national wealth and patterns of biomass use can be translated into a strategic overview of where (in which countries and ecosystems) new pressures will be felt and through what specific mechanisms. Empirical assessment of biomass flows and qualitative assessment of how and where pressures may be exerted does not in itself mean that negative ecosystem impacts are occurring, but serves to identity where and how they may occur. Detailed sustainability analysis on a case-by-case basis will be needed to determine if the pressures within the identified ecosystems are acceptable on social, economic and ecological grounds and are being effectively managed. Such analysis needs to be undertaken to determine the resilience of the ecosystems concerned and the appropriate thresholds below which we can safely continue to exploit specific systems. Given the economic dependence of the UK economy on these overseas ecosystems, it is in the national interest to ensure that we and other countries identify, and operate within these limits (TR 21.3.2).

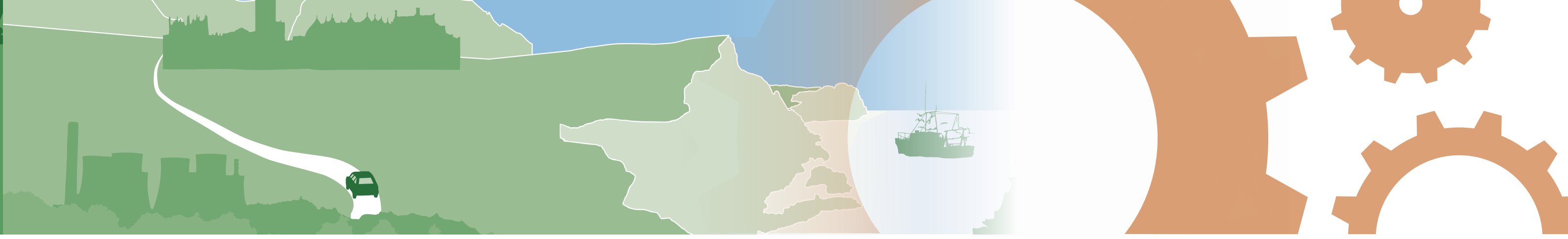
Given that in 2008 almost 90% of domestic biomass consumption involved food chain material for human or animal use and that national food requirement will be a key driver of future UK biomass demand as population continues to grow, if current consumption and waste patterns persist, and domestic production remains stable, food demand will drive import demand for food chain biomass in proportion to population growth. Imports could rise from the current 33 million tonnes to almost 50 million tonnes in 2030, requiring an additional overseas land demand of approximately 5 million hectares. This demand could be mitigated by food waste reduction, increased domestic production, and changes in consumption patterns, which together could effectively compensate for the underlying increased food demand arising from population growth (TR 21.6).

Demand for heat and power production will increase significantly in the coming decades, at a time when the UK is committed to reducing greenhouse gas emissions through adoption of a low carbon economy. In the next decade, as the UK complies with the European Union Renewable Energy Objective, the provisioning of biomass will exceed the UK's domestic capacity before 2020 (TR 21.4.2). As much as 27 million tonnes per year of additional biomass imports may be required to feed this one industry. This biomass for energy demand alone will potentially create an additional 7 million hectares or greater overseas land requirement by 2020, equally divided between boreal forest and temperate grassland systems, after which demand will stabilise if renewable targets remain unaltered. This is a significant increase over the current overseas land use for bioenergy of 1.3 million hectares (TR 21.6).

Projections of historic food consumption patterns, and quantifying the future demand for biomass for heat and power generation, illustrate the significant scope for influencing biomass imports and their associated overseas impacts. Increased domestic biomass production and food waste reduction could make significant contributions to reducing the biomass import demand and the associated land use impact overseas. If biomass import demand is unmitigated by increased domestic production and reduced waste, the overseas land use requirement could almost double by 2030 from the current 14 million hectares to 26 million hectares by 2030, and then continue to increase with population growth. Mitigated through increased domestic production and reduction in waste, this land use requirement could be limited to approximately 20 million hectares and potentially held at this level. Future population growth and increased bioenergy demands beyond this date could be achieved without increased environmental impacts overseas (TR 21.6).

The UK dependence on overseas biomass could increase if the UK takes a preservationalist attitude towards its own landscape, or where free markets determine the source of UK biomass with little regard for environmental issues. Alternatively, UK dependence could decrease if there is a conscious decision to be more self reliant, or be imposed by a need to fall back on its own resources through a lack of access to world markets (TR 21.6.3).

Targeted international policies can be designed to protect the long-term functioning of ecosystems vital to the UK's national interest, such as technical assistance, financial aid and political dialogue. Bilateral actions could be complemented by working through European Union mechanisms and through dialogues with other significant global consumers. These supply-side



policies could be complemented by increased domestic production of biomass and domestic demand-side policies which influence UK consumption, such as more effective use of biomass through reduced waste (TR 21.7).

The UK's domestic and international policies to protect the overseas ecosystems on which the economy depends must be based on data and analytical techniques that can quantify, describe and locate the potential impacts of the UK economy on these systems (**Figure 16**). Established material flow analysis techniques are able to achieve these objectives in respect of the national use of non-UK primary production, as reflected in biomass imports. Using data collected by the Office for National Statistics and HM Revenue and Customs domestic biomass production, consumption, exports and imports can be characterised and measured. A set of indicators based on this biomass data can provide the basis for long-term (40-year) analysis of trends and drivers for biomass use by the UK economy, including the importance of imported material (**Figure 17**). The use of primary productivity (biomass for food, fuel, fibre) from overseas ecosystems therefore represents a significant and quantifiable provisioning service from non-UK ecosystems (TR 21).

This dependence on overseas ecosystems, particularly in respect of this primary productivity, makes the protection of the long-term functionality of these overseas ecosystems an economic imperative for the UK (TR 21.7).

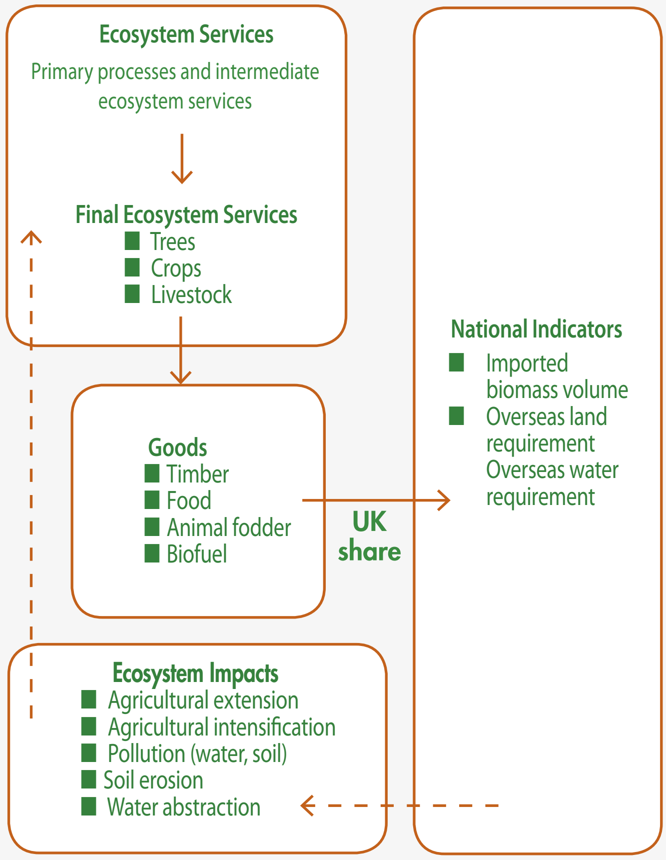


Figure 16 Phases of a quantitative and qualitative assessment of the dependencies and impacts of UK consumption of biomass on overseas ecosystems. Source: adapted from Bateman *et al.* (2010).

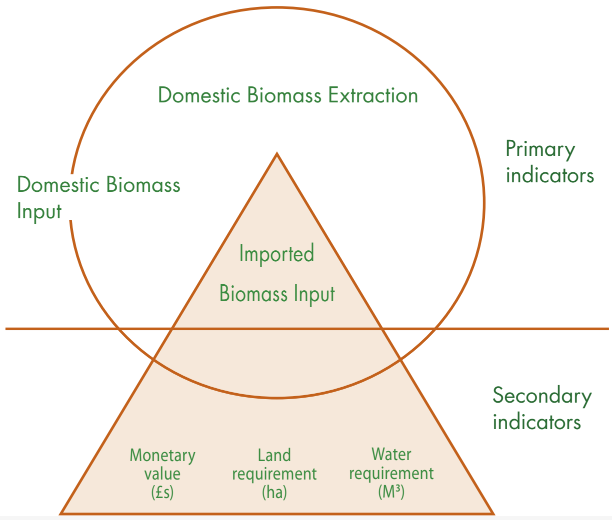


Figure 17 Total biomass available to the UK economy ('Domestic Biomass Input') comprises domestic extraction plus imports. These material flows are directly recorded (as mass) and provide a set of Primary Indicators of UK biomass supply. Secondary Indicators, derived from mass flow data, can be generated including the monetary value of biomass flows and the land or water required for biomass production.

5. What is the current public understanding of ecosystem services and the benefits they provide?

Key Findings

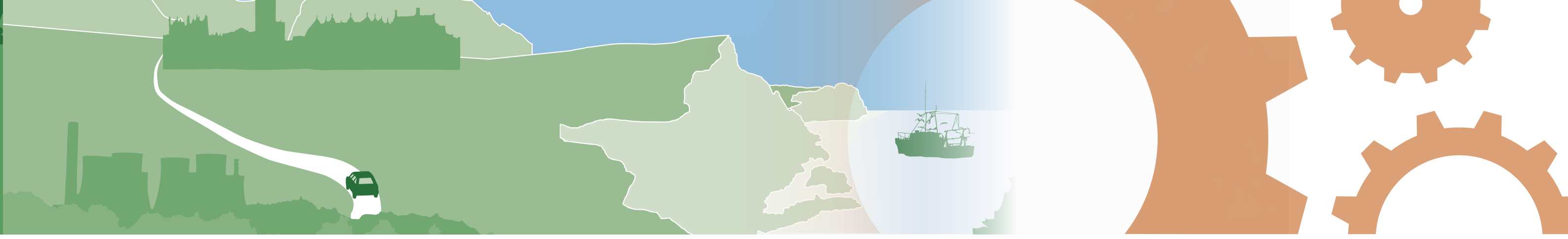
- **A recent survey suggests that in the UK, ecosystem services are not a meaningful framework of interpretation of human-environment relations for the vast majority of people, although the term has gained traction in science and policy. Culturally the concepts which have most meaning are those of nature, place and landscape.**
- **The diverse groups of participants in the study shared a common language and understanding of nature, that is the sky, seas, hills, mountains, forests, woodlands, rivers, streams, lakes, beaches, and countryside, characterised by the presence of many different species of mammals, birds, insects, and fish. They associated nature with greenery, such as leaves, trees, grass, plants and fruit, and fresh air, clean air and cleanliness.**
- **The increasing membership of organisations such as the Royal Society for the Protection of Birds (RSPB), which has increased from 10,000 members in 1960 to over 1 million today, and the UK's 45 Wildlife Trusts with 800,000 members, illustrates an increasing appreciation and awareness of environmental issues.**
- **Even though the public does not relate to the concept of ecosystem services *per se*, they do appreciate the benefits of provisioning services, for example the supply of food and clean water, regulating services such as sequestration of carbon to mitigate climate change, and cultural services, including recreation and urban greenspace.**

A key question is: what is the public understanding of the terms and concepts of ecosystems and ecosystem services? A recent survey suggests that in the UK, *ecosystem services* is not a meaningful framework of interpretation of human-environment relations for the vast majority of people, although it has gained traction in science policy. Culturally, the concepts which have most meaning are those of *nature, place* and *landscape*, for these are the products of cultural communications and practices which, despite the homogenising forces associated with multinational forms of consumer capitalism and communications media, still vary across different regions of the UK.

Evidence to support these assertions comes from two recent studies. Qualitative research by the Central Office for Information (COI) used a stratified socio-demographic sampling strategy to produce eight focus groups who were led through discussions about the ecosystem approach. The study found that the phrase *ecosystem services* 'was a completely unfamiliar term, and proved to be baffling for most due to the lack of awareness of the term *ecosystem*'. *Nature,* on the other hand, meant a lot. The diverse groups of participants in the study shared a common language and understanding of *nature*. They described the components of nature as including the sky, seas, hills, mountains, forests, woodlands, rivers, streams, lakes, beaches, and countryside, characterised by the presence of many different species of animals, birds, insects, and fish. They associated nature with greenery, such as leaves, trees, grass, plants and fruit, and fresh air, clean air and cleanliness. The COI reports that everyone in the study talked about *nature* as 'other' to themselves and not 'man-made' (TR 16.1.2).

In the COI study, the participants iterated ideas of 'naturalness', but also showed understanding of human impacts on the *natural environment*. They recognised a more use-orientated understanding through associations of *natural environment* with farming and gardening, leisure experiences in parks and the countryside, awareness of some of the negative impacts of economic activity on the *natural environment* such as climate change, and the need for nature conservation. Their perceptions illustrate a common-sense knowledge of *nature* and *natural environment* in contemporary UK culture, as people draw on material learned at school. The teenagers in the COI study, for example, remembered the *ecosystem* concept from science lessons, mass media, and the many other forms of local knowledge (TR 16.1.2).

Current cultural attitudes mean that people tend to perceive these physical settings as distinct from the other places humans occupy, such as the interior of the home, workplaces and shopping malls. Humans need places where we can interact with each other and with nature. These physical settings provide spaces that our current culture sees as important, as highlighted in a recent survey where 88% agreed that spending time outdoors was an important part of their life, and 93% agreed that having green spaces near to where they lived was important. Over 80% of households in the UK have access to a garden, a physical setting adjoined to their homes.



The places where we spend much of our everyday lives provide informal local green settings, such as footpaths, bridleways, street trees, and roadside hedgerows, and green settings such as ponds, rivers and lakes, and also contain formal local settings designed for certain activities such as recreation in parks, food growing in allotments or retreat and contemplation in cemeteries. These physical settings can satisfy a number of human needs at any point in time (TR 16.2.1).

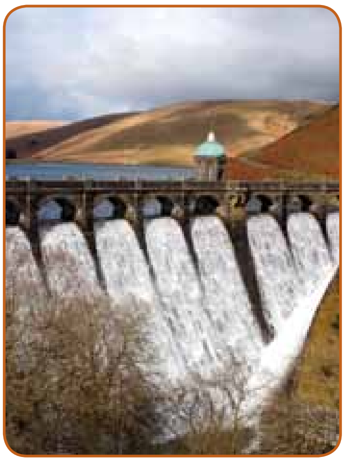
The UK NEA commissioned Lexical Computing to undertake a quantitative study of how more than 100 words and phrases related to *ecosystems* are currently being used in public discourse. The study was carried out using UKWaC, which is a structured set of texts of over 1.5 billion words of UK English in the public domain. In addition, the researchers built three new, large and structured sets of texts with language relating to ecosystems from i) academic websites, ii) government websites, and iii) newspapers, NGO websites and blogs. Software known as Sketch Engine provides an interface which gives measures of the frequency of use of words and the way they co-occur with other words in particular grammatical relationships (TR 16.1.2).

The study found that *ecosystem* is more than twice as frequent in academic texts as in government and public texts, with government much more likely to use the phrase *ecosystem goods and services*. The study finds key adjectives and nouns associated with *ecosystem* are those indicating habitat type (such as *marine, aquatic, forest)*; adjectives which indicate vulnerability (such as *fragile, threatened, endangered, delicate)*; verbs indicating harm done to ecosystems (such as *degrade, disrupt, damage, harm, threaten, upset, suffer*); and verbs referring to the protection and restoration of ecosystems (such as *conserve, preserve, protect*). The word which is used most similarly to *ecosystem* in the UKWaC is *habitat*. Whilst *habitats* and *ecosystems* are likely to be described as *degraded*, *ecosystems* are more likely to be described as *delicate* than *habitats*, which are more often described as *valuable* and *rare,* reflecting the characteristic framing of nature by conservationists (TR 16.1.2).

Even though the public did not relate to the concept of ecosystem services, they do appreciate the benefits that nature provides through provisioning services, such as the production of affordable, safe and nutritious food; regulating services, such as the maintenance of clean air and water, pollination services, and the limitation of climate change; and cultural services, such as meaningful places, recreation and use of urban greenspace (TR 16.1.2).

The increasing membership of organisations such as the National Trust, which has increased from 7,000 members in 1944 to 3.5 million today, the Royal Society for the Protection of Birds (RSPB), which has increased from 10,000 in 1960 to over 1 million today (**Figure 18**), and the UK Wildlife Trusts, which have a total membership of 800,000, illustrates an increasing appreciation and awareness of environmental issues. Active participation in a range of nature-based and outdoor activities has also grown (TR 16.3.4).

A series of recent Forestry Commission surveys found that a majority of people agreed that 'trees are good because they remove carbon dioxide from the atmosphere and store it in wood', 'that woodlands are places to reduce stress and anxiety', and 'that they felt healthier when spending time outdoors in the woodlands' (TR 16.3.2).



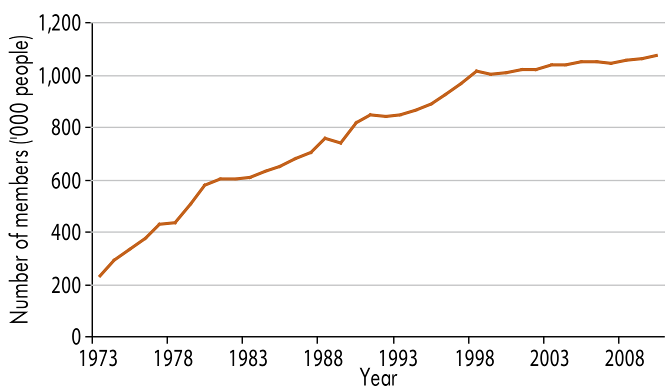


Figure 18 The total number of members of the Royal Society for the Protection of Birds (RSPB) between 1973 and 2010. Source: data provided by RSPB (2011).

6. Why should we incorporate the economic values of ecosystem services into decision making?

Key Findings

- **The economic, human health and social benefits that we derive from ecosystem services are critically important to human well-being and the UK economy, and each should be considered when evaluating the implications of changes in ecosystems and their services. Effective conservation and sustainable use of ecosystems are critical for human well-being and a future thriving and sustainable green economy.**
- **The values of most ecosystem services are currently omitted from national economic frameworks and local decision making. However, a conceptual framework is now available to account for most of their market values and some of their non-market values.**
- **Failure to include the valuation of non-market values in decision making results in a less efficient resource allocation; however, a major challenge is to develop systems to capture the values of non-market ecosystem services to land managers.**
- **The values of some ecosystem services are spatial independent. For example, the value of reduced greenhouse gas emissions or carbon sequestration. While others are highly spatially, including the recreational value of woodlands, which is dependent on its proximity to high population centres.**
- **Integration of the spatial dimensions of ecosystem services within local decision making would increase the potential for the true value of ecosystem services to be recognised.**

Ecosystem services and the other benefits that we derive from the natural world are critically important to both the UK economy and human well-being. Many of the most important ecosystem services provide values which are not reflected in market prices (e.g. clean and regular water supplies, outdoor recreation, climate regulation). However, even if we were to restrict ourselves to those which do directly contribute to the production of market priced goods, it is easy to demonstrate that the services of the natural world underpin billions of pounds of economic activity in the UK. For example, the £6,600 million which UK farmers generate each year could not be produced without the help of ecosystem services such as water purification and regulation, soil fertility processes, and pollination. Clearly, we cannot ascribe all of the value of agriculture to ecosystem services because other inputs such as machinery and farmers' expertise are also vital requirements. Nevertheless, these would be of no avail without those environmental inputs which are typically underestimated in terms of the value they bring to production in this, or other, sectors (TR 22).

But does it matter that ecosystem services are typically ignored and hence given a default value of zero in decision making? Where ecosystem services provide inputs to production then the fact that the producer does not have to pay for them will typically lead to their overuse. This can become a problem if those same resources are now unavailable for other uses, and that problem becomes more acute when those other uses result in large social values which are also zero priced. So, for example, ecosystem services are clearly crucial to the more than 3,000 million outdoor recreational visits which UK residents make each year. Analyses conducted for the UK NEA shows that these visits generate a social value in excess of £10,000 million annually (TR 26.5). Comparison of this value with that for agriculture clearly does not imply that the UK should move away from farming and instead devote all countryside areas to recreation. In recent years farming itself has been adapted to provide multiple outputs, including biodiversity, habitat and landscape amenity which can complement recreation experiences. So the choice is not farming or conservation but what combination of ecosystem services should be provided to yield net social gains. What this example shows is that reliance purely upon signals provided by market prices will not ensure that we are getting the best deal in terms of the wider social values generated (TR 22).

The UK NEA has developed a clear conceptual framework, underpinned by a body of theoretically sound methodologies, in order to account for the social value of ecosystem service flows (i.e. the flow of values which ecosystems deliver to individuals). Economic valuations of these services include both those that have, or are directly related to, market prices and most of those non-market goods and services. In line with standard economic analysis, the methodology developed rejects attempts to estimate the total value of ecosystem services, as many of these services are essential to continued human existence and claimed total values are therefore underestimates of infinity. Real world decisions concern choices between options, with values being assessed in terms of the relative costs and benefits of incremental changes in ecosystem services provision. Importantly, this approach extends, but is consistent with, standard decision analysis principles such as those set down by HM Treasury. As such, it provides a firm basis for use in government policy and decision making, including the forthcoming Natural Environment White Paper for England. Accurate valuation of ecosystem service flows is a vital requirement for delivering efficient use of both market and non-market resources, including those provided by ecosystems and the natural environment (TR 22.2, 26).

Alongside better valuation of both market and non-market goods, the UK NEA conceptual framework also emphasises the need to recognise the spatially explicit nature of ecosystem services and benefits. Thus the recreational value of an area of woodland, for example, varies not only because of the type of trees and wildlife it offers, but also because of its location in relation to where people live (TR 22.2, 26).

To demonstrate why we should incorporate the economic values of ecosystem services into decision making, we use a simple case study which illustrates the combined principles of valuing both market and non-market goods and the incorporation of spatial variation into those valuations. Returning to the land use example discussed above, the UK NEA Economics chapter (Chapter 22) considers the case of rural land use in Wales. **Figure 19** (p44) summarises the main economic values that would arise from a change of land use from farming to multi-purpose woodland, including both the market and non-market values generated and their variation across space. Working from left to right along the maps given, the first illustrates variation in the market value of agricultural output (**Figure 19a**). As can be seen, this varies very markedly across the country, being low along its mountainous central spine and higher in lowland areas. These values would be lost in any area where land was converted out of agriculture and into woodland; therefore these are shown as negative values in the first map. The second map shows the single market value generated by woodland: timber (**Figure 19b**). As these values would be gained under a shift from agriculture to woodland they are shown as positive amounts. However, comparison of the market value of agricultural losses, shown in the first map, with the market value of timber, shown in the second, shows that the former are almost always greater than the latter. Hence, left to the market we observe the current situation, with agriculture dominating almost all of rural Wales and woodland confined to upland areas where land prices are low. The third map brings in our first non-market value; the change in carbon storage arising from a switch towards woodland (**Figure 19c**). This is almost always positive (woodlands store more carbon that farmland) except for some upland areas where tree planting dries out peatlands and can release large quantities of carbon. In the fourth map (**Figure 19d**) we see the change in recreation values, which are again almost always positive (i.e. higher for woodland than agriculture) and now show the influence of population distribution, being greatest around cities and in areas with good road infrastructure. (Note that, unlike other values which are on a per hectare basis, the recreation is valued using one site per 5 km grid (**Figure 19d**); this captures the fact that once a woodland site is established the per hectare recreational value of establishing a second site is not constant but diminishes significantly and to air on the side of caution we take that marginal value as being zero). **Figure 19e** sums together all preceding values (i.e. losses of agricultural production are taken as negatives and gains of woodland goods are taken as positives), both market and non-market, and removes all subsidies (which are transfer payments within society) to obtain the net benefits to society of a move from agriculture to woodland. Here, areas coloured in shades grading from yellow to purple indicate locations where such a move would be impose net losses to society. This includes areas relatively far from major populations in the west of the country (where farming yields high values and new woodlands would not generate substantial recreation benefits) and peatland areas along the central mountain spine where afforestation would result in major carbon emissions due to such wetlands drying out. Green shows locations where a shift to multi-purpose woodland would generate net benefits. As can be seen, these are predominantly around areas of high population in the south-east (around Cardiff) and north-west of the country (the latter reflecting the high populations just over the border in England within Merseyside and Greater Manchester). This pattern stands in stark contrast with that illustrated in the last map (**Figure 19f**), which shows where market forces have consigned forests to be located; away from lowland areas (and hence cities) and in remote uplands where land values are low. Perversely, this includes some peatland areas where forests may contribute to global warming through the drying of peat and emissions of carbon (TR 22.2.4).

The case study shown in **Figure 19** clearly answers our question regarding why we should incorporate the economic and social values of ecosystem services into decision making. If we fail to do so, the allocation of resources will be dictated by the market alone. While markets can efficiently allocate goods whose market prices roughly reflect social values, they fail to provide the socially optimal allocation of unpriced non-market goods, including many ecosystem services. Only by directly addressing this failure will markets be corrected to the point that they can be left to provide the goods and services that society both wants and needs (TR 22.2.4).

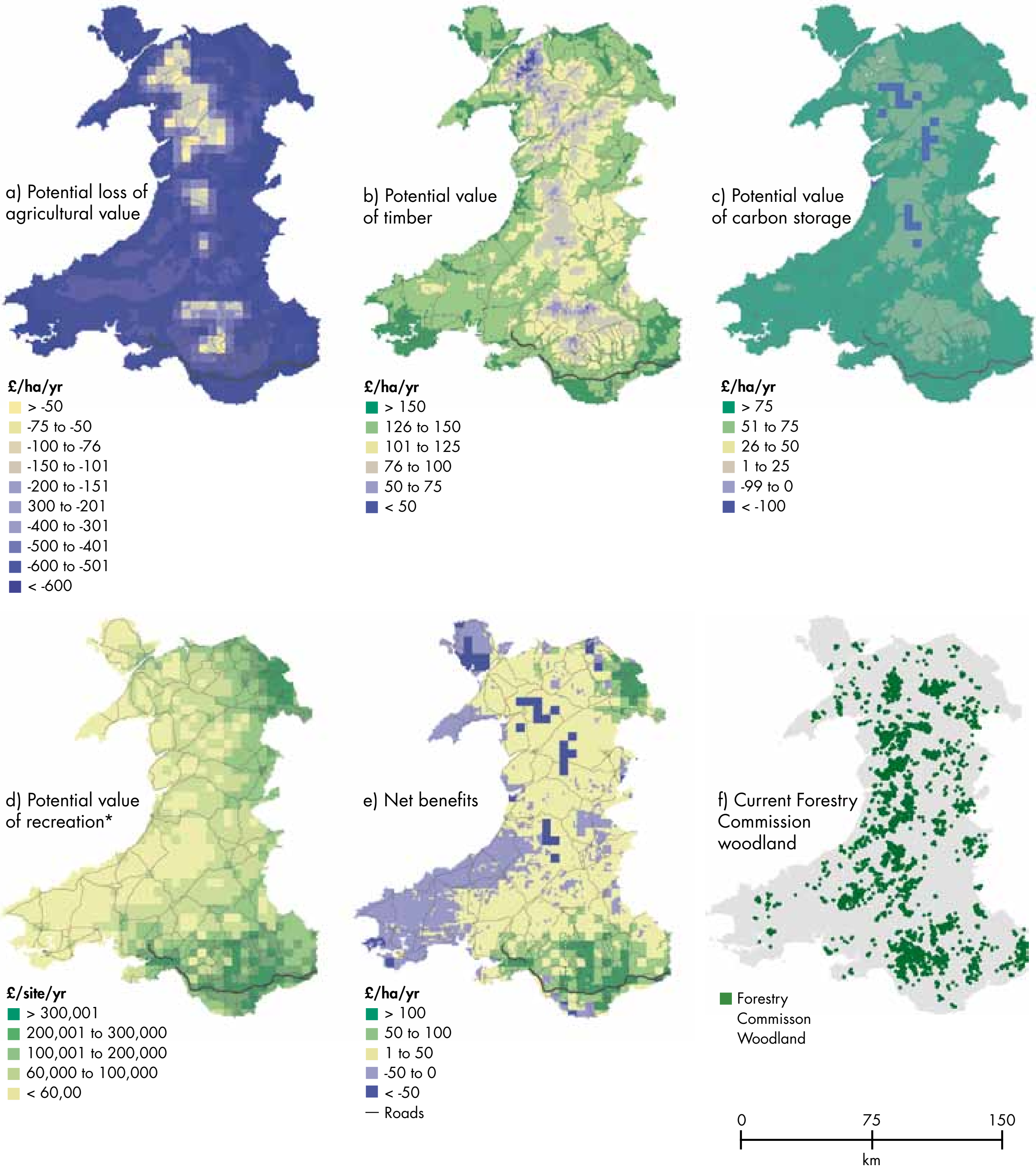


Figure 19 Economic values that would arise from a change of land use from farming to multi-purpose woodland in Wales (£ per year). *Unlike other values which are on a per hectare basis, recreation is valued using one site per 5 km grid; this captures the fact that once a woodland site is established the per hectare recreational value of establishing a second site is not constant but diminishes significantly and to air on the side of caution we take that marginal value as being zero. Source: adapted from Bateman *et al.* (2002), Bateman & Jones (2003) and Bateman (2009) and reproduced with permission from Elsevier © (2009).

How might ecosystems and their services change in the UK under plausible future scenarios?

7.

Key Findings

- **Past and future policy choices can have dramatic impacts on ecosystem services and human well-being.**
- **The UK NEA explored the implications of a range of plausible changes in drivers for ecosystem services, showing that choices made by governments and the private sector in the near-term can lead to vastly different outcomes – some ecologically and economically sustainable, others not.**
- **Six storylines employing very different policy priorities were developed: i) *Green and Pleasant Land*, where a preservationist attitude to UK ecosystems was taken; ii) *Nature@Work* where ecosystem services are promoted through the creation of multifunctional landscapes; iii) *Local Stewardship*, where society strives to be sustainable within its immediate surroundings; iv) *Go with the Flow*, where current trends are assumed to continue, and in which current principles and practices are not radically altered; v) *National Security*, where there is reliance on greater self-sufficiency and efficiencies; and vi) *World Markets*, where the goal is economic growth and the elimination of trade barriers.**
- **Storylines that emphasised environmental awareness and ecological sustainability resulted in significant gains in the output of a broad range of ecosystem services, in contrast to storylines that emphasised national self-sufficiency or economic growth.**
- **Land use change and pollution continue to be major drivers of change for biodiversity and ecosystem services, although by 2060 climate change is also predicted to be a significant driver of ecosystem services and of losses and gains of species throughout the UK.**

Plausible scenarios allow an uncertain future to be explored. The UK NEA employed a wide range of direct and indirect drivers to develop six plausible futures, each assessing the impact of two different climate change scenarios (high and low) taken from UKCIP 09.

Six storylines employing very different policy priorities were developed (**Figure 20**, p46): i) *Green and Pleasant Land*, where a preservationist attitude to UK ecosystems was taken; ii) *Nature@Work* where ecosystem services are promoted through the creation of multifunctional landscapes; iii) *Local Stewardship* where society strives to be sustainable within its immediate surroundings; iv) *Go with the Flow* where current trends are assumed to continue; v) *National Security* where there is reliance on greater self-sufficiency and efficiencies; and vi) *World Markets* where the goal is economic growth and the elimination of trade barriers (TR 25.3).

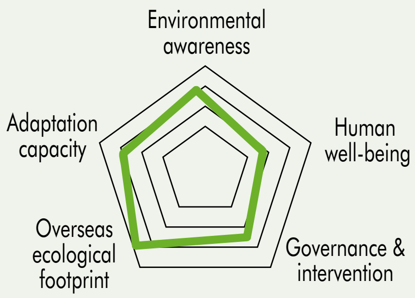
Nature@Work, Green and Pleasant Land, Go with the Flow and *Local Stewardship* embody the greatest environmental awareness and UK ecological sustainability, in contrast to *National Security* and *World Markets* that have very low levels of environmental awareness. *Nature@Work* has the smallest overseas environmental footprint, followed by *Green and Pleasant Land* and *National Security*, then *Go with the Flow*, with *World Markets* having the greatest. *Nature@Work* contributes most to human well-being, followed by *Local Stewardship*, and then *Green and Pleasant Land*, *National Security, World Markets* and *Go with the Flow*. *Nature@Work* also provides the greatest adaptability to future challenges, for example climate change, followed by *Local Stewardship, National Security, Green and Pleasant Land*, and *Go with the Flow*, with *World Markets* being the least adaptable. *National Security* and *Nature@Work* are the most interventionist, followed by *Green and Pleasant Land* and *Go with the Flow*, with *World Markets* and *Local Stewardship* being the least (TR 2.5.3).

Expert judgment and current scientific evidence, where available, was used to link the drivers of change in each storyline to changes in land use and ecosystem services. Area changes were derived for habitats and ecosystem services from quantitative land cover projections for each scenario, thus allowing a broad comparison of overall service output to be made (TR 25.5, 25.6).

A preliminary comparison of ecosystem service outputs was made for each scenario by counting the number of services that appeared to be increasing, stable or declining under the assumptions of each storyline (**Figure 21**, p47). This indicative analysis showed that while current policy approaches, as characterised in *Go with the Flow*, were likely to lead to some improvements in ecosystem service output, the UK can make significant gains where policy takes the approach outlined in three scenarios: *Green and Pleasant Land, Nature@Work* and *Local Stewardship*. In each of these, the majority of services appeared to show increasing trends, compared to the past 20 years, where a more mixed picture has been reported (see **Figure 5**, p11). By

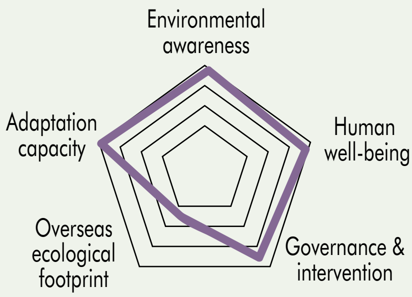
Green and Pleasant Land

A preservationist attitude arises because the UK can afford to look after its own backyard without diminishing the ever-increasing standards of living.



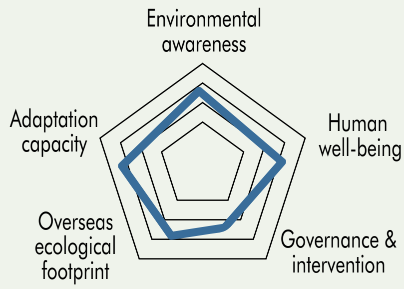
Nature@Work

The belief that the promotion of ecosystem services through the creation of multifunctional landscapes is essential for maintaining the quality of life in the UK is widely accepted.



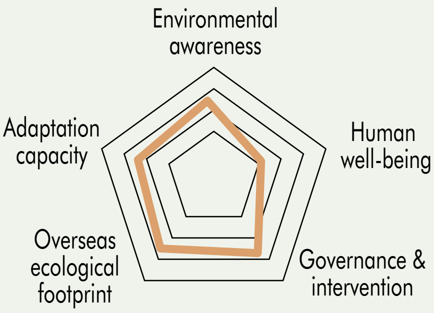
Local Stewardship

This is a future where society is more concerned with the immediate surroundings and strives to maintain a sustainable focus on life within that area.



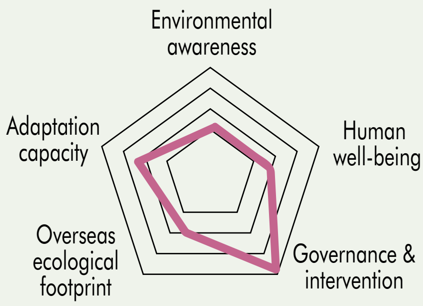
Go with the Flow

This scenario is essentially a projection based on current trends and results in a future UK that is roughly based on today's ideals and targets.



National Security

Under this scenario climate change results in increases in global energy prices forcing many countries to attempt greater self-sufficiency (and efficiency) in many of their core industries.



World Markets

High economic growth with a greater focus on removing barriers to trade is the fundamental characteristic of this scenario.

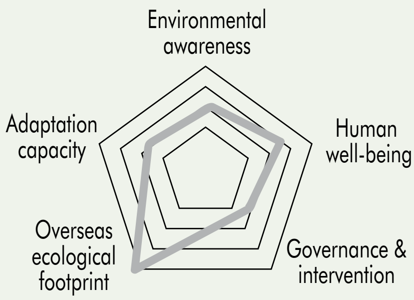
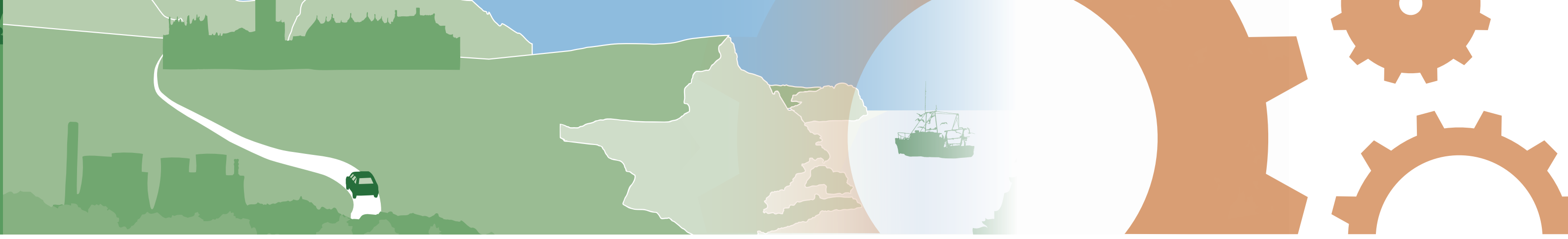


Figure 20 An overview of the six scenarios developed for the UK NEA. All share the common characteristics of a decline in global resource availability and an ageing UK population but five contrasting socio-economic aspects are highlighted. The largest ring in the spider diagram demonstrates the highest level of each aspect. *Environmental awareness* describes the level of appreciation and concern for conservation and sustainability issues in society, for example recycling; *Human well-being* relates to the standards of health provision, education, employment, freedom, human rights and happiness; *Governance and intervention* describes how much the state uses political authority and institutional resources to manage society; *Overseas ecological footprint* is a measure of demand on the earth's resources overseas (resulting from imports of biomass and energy and exports of waste products); *Adaptation capacity* relates to societies' ability and willingness to cope with the impacts if climate change.



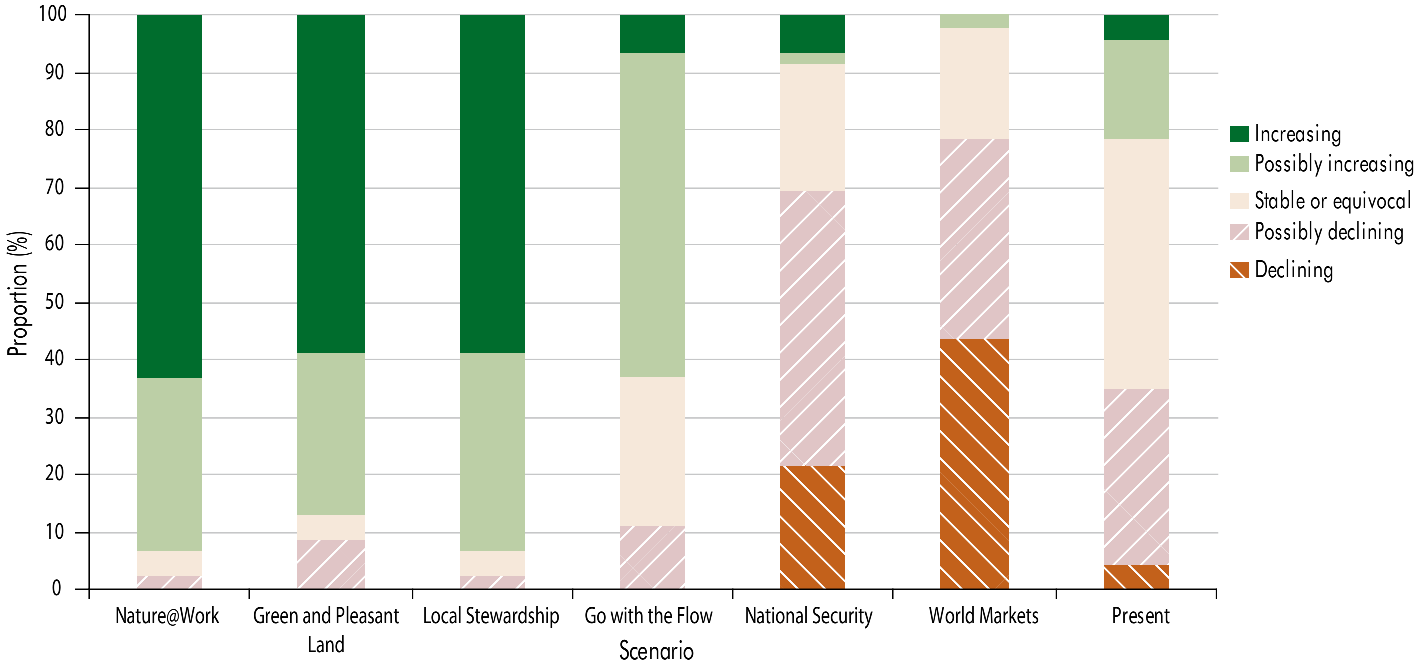


Figure 21 Preliminary comparison of storylines in terms of the projected trends in ecosystem services. Bars show proportion of services in each scenario with increasing (solid bars) or decreasing (hatched bars) trajectories.. Scenarios are ordered from left to right in terms of increasingly unfavourable impacts. A comparison with the present is shown. All services were treated as equally important and the outputs were not weighted according to the contributions made by each UK NEA Broad Habitat or the differences in the effects of the high and low climate change impacts for each scenario.

contrast, *World Markets and National Security* showed significant losses compared to the present and *Go with the Flow* (TR 25.4).

The key elements of a *Nature@Work* scenario that results in a more sustainable world include investment in public services, recognition of the importance of the market in economic growth, commitment to global trade, and strong links to European Union and global obligations. Industry is focused upon technological innovation and sustainable resource use, while public behaviour is driven by a recognition of the importance of nature's services. *Green and Pleasant Land* has many of the characteristics of *Nature@Work,* but takes a less pragmatic view of nature, emphasises more of its intrinsic values and is characterised by a more preservationist perspective. In *Local Stewardship*, immigration is more controlled, power and taxes are devolved to local governments, technology is developed for self-sufficiency, but as with *Nature@Work*, public behaviour is driven by recognising the importance of nature's services (TR 25.4.2).

Go with the Flow appears to be an improvement over current conditions because current policies and interventions start to have a positive effect. However, gains are modest and opportunities to adapt to changing circumstances may be missed. Most significantly, the value of the UK's natural capital is not fully realised. In contrast, *World Markets* and *National Security* appear to show significant losses of natural capital compared to the present situation, *Go with the Flow*, and all the other scenarios (TR 25.4.2).

The *World Markets* storyline is characterised by deregulation of markets and environmental protection, and a society where technological innovation is driven by private profits; in this world the public does not recognise the value of nature. There is competition for land and this, coupled with reduced rural and urban planning regulations on housing, agriculture and industry, mean that biodiversity is often the loser. The *National Security* world is consistent with protectionist policies and trade barriers designed to defend UK interests; here climate change, population growth and competition for resources have resulted in increases in global energy prices, forcing many countries to attempt greater self-sufficiency, including the UK (TR 25.4.2).

A comparison between high and low climate change scenarios for each storyline suggested that the overall differences between them were smaller than those between different storylines, suggesting that future changes in land use have as much impact on ecosystem services as the direct effects of climate change (TR 25.4.2).

The following section describes the implications of different storylines for biodiversity and habitats. It should be noted that many of the findings are implicit in the storylines that underpin the scenarios, which then guided the experts in assessing changes in land use. Comparison between these scenarios is exploratory and provides a rich area for further investigation following publication of the UK NEA.

Biodiversity: Land use change and pollution continue to be the major drivers of change for biodiversity and ecosystem services, although by 2060 climate change will also be a significant driver of loss (and gains) of species throughout the UK. The adverse impacts of climate change on biodiversity are ameliorated through conservation strategies embedded in the *Nature@Work* and *Green and Pleasant Land* worlds. *Green and Pleasant Land* takes a preservationist approach to conserving native flora and fauna and cultural landscapes, whereas *Nature@Work* and *Local Stewardship* take a more dynamic view, where ecosystem services are protected even if the introduction of non-native species is required to maintain them (TR 25.4.2).

Mountains, Moorlands and Heaths: In most scenarios the cover of Mountains, Moorlands and Heaths does not change significantly, except in *National Security*, where an extensive programme of afforestation takes place. In *Nature@Work, Green and Pleasant Land* and *Local Stewardship*, grazing pressures are reduced.

Semi-natural Grasslands: The huge loss of Semi-natural Grasslands in the 20th Century is partially addressed in *Green and Pleasant Land, Nature@Work, Local Stewardship* and *Go with the Flow* through restoration programmes resulting in improved soil carbon and recreational opportunities (TR 25.4.2).

Woodlands: The area of Woodlands increases by 2060 in all scenarios except *World Markets*, reflecting their importance in delivering multiple ecosystem services, including biodiversity, recreation, carbon stocks, flood alleviation, timber and non-timber products. *Nature@Work* places its emphasis on a combination of provisioning services as well as biodiversity and recreation, whereas *Local Stewardship* primarily emphasises local provisioning services of high-yield timber, which can have a negative effect on services such as soil quality, recreation and biodiversity. Woodland cover expands close to major centres of population because of cultural and recreational benefits (TR 25.4.2).

Enclosed Farmlands: Enclosed Farmlands continue to be the dominant land cover in all six scenarios. The factors shaping farm management are demand, which is sensitive to population (*Green and Pleasant Land* and *Local Stewardship* have a population in 2060 of 65 million; *Nature@Work* 67 million; *National Security* 70 million; and *Go with the Flow* and *World Markets,* 75–77 million); global economic forces, which determine the price and ability to import food; technology and management techniques; and societal views on the environment and diet. *Nature@Work* seeks to balance food production for home demand by adopting resource-efficient but high output management, in contrast to *Green and Pleasant Land* and *Local Stewardship,* where provision declines as a low-input agricultural model is adopted to conserve a range of ecosystem services. *Go with the Flow* adopts a middle ground, with increased productivity per unit area and better environmental standards than today. *World Markets* requires large imports, due to high population demands (TR 25.4.2).

Freshwaters – Openwaters, Wetlands and Floodplains: The area of Freshwater systems increases or stays the same in all scenarios but for a range of reasons, thus partially ameliorating the consequences of the major wetland drainage programmes in the 19th and 20th Centuries. In the more environmentally benign scenarios, the restoration of wetlands and riverine habitats has multiple ecosystem benefits including biodiversity, recreation, flood control, erosion control and water quality. In *World Markets*, freshwater expansion occurs due to abandonment of land from lack of investment to adapt to greater flood incidence (TR 25.4.2).

Urban: Greenspace and the management of water in Urban areas are common themes in *Nature@Work, Green and Pleasant Land, Local Stewardship* and *Go with the Flow*, through creating parks, gardens or open spaces (*Green and Pleasant Land* and *Go with the Flow*) or through the creation of green areas with a focus on food production and recreation opportunities through allotments, permaculture gardens and urban farms (*Nature@Work* and *Local Stewardship*). Rivers, lakes and ponds are restored, protected or re-channelled to ensure connectivity for wildlife, improved recreation and flood control. In both *National Security* and *World Markets,* Urban greenspace decreases (TR 25.4.2).

Coastal Margins: There is improved management of Coastal Margins in *Nature@Work, Green and Pleasant Land* and *Local Stewardship,* by adopting a larger ecosystem and land/seascape approach to ecosystem service delivery, taking into account geomorphological processes, alongside biodiversity. *Nature@Work* takes a fluid and dynamic approach to habitat change by allowing habitats to migrate in response to sea-level rise (TR 25.4.2).

Marine: In *Green and Pleasant Land* the Marine habitat is provided with conservation protection and is an increasing source of recreation. *Local Stewardship* adopts a regional management approach and encourages the sustainable fishing of unfashionable fish; *Nature@Work* adopts the most holistic approach to marine management and conservation of ecosystem services. *World Markets* and *National Security* exhibit a trajectory that could be described in terms of the 'tragedy of the commons' in relation to fish stocks, and are the most harmful (TR 25.4.2).

By working with scenarios we can try to understand how sensitive the UK ecosystems are to the various drivers of change, and start to think about how we might intervene if we need to protect or restore them. However, scenarios are only as good as our understandings of the way ecosystem function supports the output of ecosystem services. What the work for the UK NEA Scenarios has shown is that in many cases we lack this knowledge. The challenge highlighted by this work is that we need better data and ecosystem models to fully explore the factors that will shape ecosystem service futures for the UK (TR 25.6).

Question 8 takes the mapped land-use changes from the UK NEA Scenarios and assesses the economic implications of each.

What are the economic implications of different plausible futures?

8.

Key Findings

- **Each of the UK NEA scenarios was assessed in terms of the changes they induce from the present day. Assessments examined five major ecosystem services: i) agricultural food production; ii) net change in greenhouse gases from land use; iii) open-access recreation; iv) urban greenspace amenity; and v) biodiversity (assessed using birds as indicator species). These assessments demonstrate the ability of methods developed for the UK NEA to assess the relative economic implications of different storylines.**
- **Even recognising the limitations of the UK NEA analyses (e.g. not all goods and services are valued) the analyses demonstrate that simple reliance upon market prices is likely to yield an inaccurate assessment of the overall economic value of different scenarios to society.**
- **If market values only are taken into account then storylines that emphasised national self-sufficiency or economic growth resulted in the largest economic gains in the short- to medium-term due to increased agricultural production. Conversely, if all monetised values are taken into account then the storylines that emphasised environmental awareness and ecological sustainability resulted in the largest economic gains to society, much of which is available over the long run.**
- **The assessments revealed significant spatial differences across the UK for each ecosystem service analysed.**
- **The type of analysis provided by the UK NEA is vital if we are to ensure more economically efficient decision making and sustainability.**

Given that the future is always uncertain, the UK NEA explored the implications of a range of plausible changes in ecosystem services so as to assess their impact upon corresponding values. The UK NEA Scenarios are not developed from modelling of ongoing or expected future trends; as such they diverge from standard economic forecasting approaches. Rather, they reflect in part the different philosophies and concerns of different groups. Nonetheless, the UK NEA used these scenarios to demonstrate that the methods developed for conducting economic analyses of ecosystem services are capable of delivering decision-relevant information to policy makers. We have shown that, for a number of key ecosystem service-related goods, methods exist for generating spatially and temporally sensitive valuations which amply demonstrate how values vary across both of those dimensions.

The UK NEA developed six plausible scenarios, each with two different climate scenarios (high and low). Question 7 describes the basic attributes of each of the scenarios: i) *Green and Pleasant Land*; ii) *Nature@Work*; iii) *Local Stewardship*; iv) *Go with the Flow*; v) *National Security*; and vi) *World Markets* (TR 25.3). Expert judgement was used to project how land would be used throughout the UK consistent with each of the storylines, and to predict the consequent changes in ecosystem services. While useful in assessing the likely direction of change in land use and ecosystem services, care must be taken to avoid attributing too much precision to these changes (TR 25.5, 25.6).

Recognising these limitations, the UK NEA then assessed the implications of each scenario in terms of changes in five ecosystem service goods: i) agricultural food production; ii) terrestrial carbon storage and annual greenhouse gas emissions – resulting in net greenhouse gas emissions; iii) open-access recreation; iv) urban greenspace amenity; and v) biodiversity (assessed using birds as indicator species). While this clearly does not represent the totality of ecosystem service changes arising from these alternate scenarios, these are, nevertheless, major value streams which demonstrate the ability of the methods developed to assess and value these options (TR 26.1).

The analyses demonstrate the very substantial changes in value generated when differing levels of ecosystem services are provided. Perhaps most importantly, these analyses underline the vital importance of including valuations of the non-market goods generated by ecosystem services within decisions. The results show that such inclusions radically change the outcome of decision analyses. Indeed, failure to include such values leads to a continuation of errors in resource allocation which arise when decisions are based upon market-priced goods alone. The UK NEA conceptual framework calls for the conventional techniques of economic analysis to be implemented in full rather than in the partial manner in which they are currently applied. The developments demonstrated here call for evolution, not revolution, and are long overdue for more general implementation.

Table 1 Summary impacts for the changes from the 2000 baseline to 2060 under each of the UK NEA Scenarios (low climate change scenario) in Great Britain (£million per year). Positive numbers indicate improvements from the baseline (negative numbers indicate worsening situations). The last but one row ranks the Scenarios when only their market values are considered (1= highest value; 6 = lowest values with green values being positive and purple indicating negatives). The final row repeats this ranking when all values (market and non-market) are considered. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*

	GF	GPL	LS	NS	NW	WM
Market agricultural output values *	220	-290	350	680	-510	420
Non-market GHG emissions †	-800	2,410	-100	3,590	4,590	-2,130
Non-market recreation ‡	5,710	6,100	1,540	4,490	24,170	5,040
Non-market urban greenspace ¶	-1,960	2,350	2,160	-9,940	4,730	-24,000
Total monetised values §	**3,170**	**10,570**	**3,950**	**-1,180**	**32,980**	**-20,670**
Rank: Market values only	4	5	3	1	6	2
Rank: All monetary values	4	2	3	5	1	6

* Change in total Great Britain farm gross margin.

† Change from baseline year (2000) in annual costs of greenhouse gas (GHG) emissions from Great Britain terrestrial ecosystems in 2060 under the UK NEA Scenarios (millions £/year); negative values represent increases in annual costs of GHG emissions

‡ Annual value change for all of Great Britain.

¶ Undiscounted annuity value; negative values indicate losses of urban greenspace amenity value.

§ We acknowledge some double counting between urban recreation and urban greenspace amenity value. Further data is needed to correct for this.

Table 1 summarises the changes in value, from a year 2000 baseline, which arise under each of the six UK NEA Scenarios (here we use the low climate change variant for each scenario; Chapter 26 of the Technical Report also shows the changes for a high emission variant).

The results displayed in **Table 1** should not be interpreted as precise data findings, but rather as comparative indicators of approximate outcomes for the different scenarios. A general observation regarding **Table 1** is that the magnitude of value changes within the farm provisioning services is generally lower than those of the other services included. This is immediately important as, in this analysis, it is only agricultural values which are reflected in market prices, all other changes occurring in non-marketed goods. This means that, from the outset, we can see that simple reliance upon market prices is likely to yield an inaccurate assessment of the overall economic value of different scenarios to society. This is clarified in the last two rows of **Table 1,** which ranks the various scenarios from highest value (rank = 1) to lowest (rank = 6) and colour codes these such that positive sums are shaded green and negative sums are shaded purple. The penultimate row only considers market-priced goods, showing that, under such a partial analysis, it is *National Security* and *World Markets* which yield the highest values, while the *Nature@Work* and *Green* and *Pleasant Land* scenarios are ranked last, both with negative market values. However, the final row of the table shows the results when all values, both market and non-market, are considered. Here the ranking is completely reversed, with *Nature@ Work* and *Green and Pleasant Land* scenarios both yielding very substantial net benefits to society, while both *National Security* and *World Markets* are found to actually lower overall social values relative to the baseline (TR 26.7.2).

A major finding of the UK NEA economic analysis of scenarios is that, even accepting that the present illustration is incomplete with other values still to be assessed, allowing market-priced values to dominate to the complete exclusion of non-market values results in less benefits to society overall. It shows that decision making must change if social values are to be optimised and resources used efficiently.

We deliberately did not monetise biodiversity (see both Chapter 22 and Chapter 26 of the Technical Report for discussions of the strategy adopted here).

Turning to consider the various scenarios under analysis, we can see that the contrasting land uses, net greenhouse gas emissions (sequestration minus agricultural emissions), urban extents and other characteristics of these scenarios are reflected in correspondingly different overall valuations. We can summarise these as follows:

- **Go with the Flow:** Overall agricultural incomes rise, as do recreational values. These gains are partially offset by an increase in net greenhouse gas emissions and losses of urban greenspace amenity. Nevertheless, overall well-being increases under this scenario (TR 26.7.2).

- **Green and Pleasant Land:** The reduction in agricultural intensity leads to a decline in farm incomes. However, this pro-environment scenario results in substantial gains in terms of reduced net greenhouse gas emissions, accompanied by an increase in recreation and urban greenspace, and resulting in an overall gain in economic value. So, while from a market perspective *Go with the Flow* outperforms *Green and Pleasant Land*, from a social value perspective *Green and Pleasant Land* dominates *Go with the Flow* (TR 26.7.2).

- **Local Stewardship:** While the *Go with the Flow* and *Green and Pleasant Land* scenarios implied trade-offs between some market and non-market (environmental) values, the *Local Stewardship* scenario appears to offer somewhat of a win-win situation in terms of its monetised benefits. Agricultural incomes, recreation and urban greenspace amenity all improve while the level of greenhouse gas emissions increases only slightly (TR 26.7.2).

- **National Security:** This scenario delivers the greatest gain in market-priced goods as agricultural incomes increase markedly. Recreation increases, while net greenhouse gas emissions fall (due in part to the significant investments in woodland envisioned under this scenario). However, the prioritisation of output and resources results in very substantial falls in urban greenspace values, to the extent that they dominate the other monetary values generated and overall social values are negative (TR 26.7.2).

- **Nature@Work:** The headline promotion of multifunctional landscapes under this scenario results in a decline in agricultural lands and with it, farm income. However, this reduction in agricultural activity fuels the largest improvements in greenhouse gas emissions, recreation and greenspace amenity, resulting in the most substantial net benefits for society of any scenario (TR 26.7.2).

- **World Markets:** The drive for unfettered economic growth leads to substantial market-priced gains in agricultural output value. However, these trigger increases in greenhouse gas emissions and are dwarfed by the losses in urban greenspace value due to substantial losses of such land, exacerbated by substantial increases in population. While the rise in population increases the value of recreation (although, as discussed in Chapter 26 of the Technical Report, this declines per capita), overall this storyline results in the most substantial reduction in net social values of any scenario (TR 26.7.2).

One issue with the above findings, which should be stressed, is that they should not be interpreted as a criticism of the agricultural sector. UK farmers are generally highly efficient producers of food who also generate major ecosystem service values. However, the prices they receive do not reflect the value of social benefits such as recreation or visual amenity which they create. Some move towards payments for ecosystem services (PES) is needed, such as those provided through ongoing reforms of the Common Agricultural Policy, but it seems likely that such moves will have to be substantially extended if society is to optimise the flow of ecosystem services associated with agricultural land.

The methodology developed for the UK NEA permits the analysis of the spatial distribution of all value changes, disaggregated by each value type. To illustrate this, **Figure 22** compares two contrasting scenarios, *Nature@Work* and *World Markets*, in terms of each of the dimensions of change they generate (for further contrast, the high emission variants are selected in both cases). As can be seen under each scenario, individual value streams differ markedly across different areas of the country. The figure also reveals the very adverse impact of the *World Markets* scenario on the biodiversity index in terms of this important non-monetary indicator of social value (TR 26.7.3).

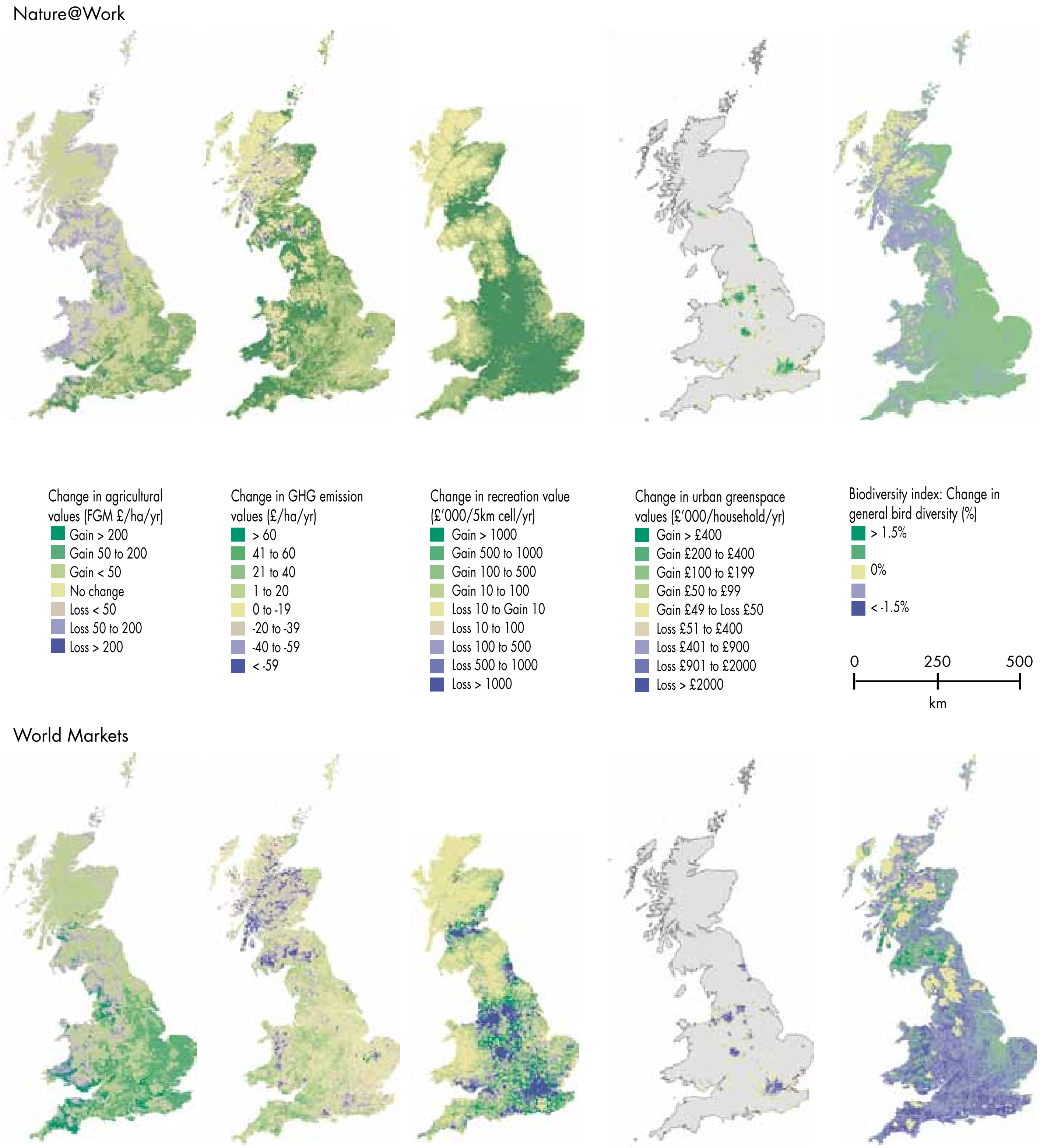


Figure 22 Spatial distribution of changes from the baseline in five ecosystem service related goods (agricultural production (FGM: Farm Gross Margin); greenhouse gas (GHG) emissions; recreation; urban greenspace; biodiversity) under the *Nature@Work* scenario (upper row) and the *World Markets* scenario (lower row) for Great Britain.

How can we secure and improve the continued delivery of ecosystem services?

9.

Key Findings

- **Contemporary society is less sustainable than it could be. Responding to the pressures to provide food, water and energy security, while at the same time conserving biodiversity and adapting to rapid environmental change, will require getting the valuation right, creating functioning markets for ecosystem services, improving the use of our resources and adopting new ways of managing those resources.**
- **No national-, regional- or global-scale environmental issue (e.g. air and water quality) has ever been successfully addressed without an appropriate enabling framework using a mix of regulations, technology, financial incentives and behavioural changes. However, local initiatives have proved invaluable by instigating a range of local conservation activities and improving the delivery of some ecosystem services.**
- **Many of the recent improvements in ecosystem services and biodiversity conservation have happened as a result of effective regulation. These have been driven by various European Union policy directives such as the Rural Development Programme, and in particular by the European Union Common Agricultural Policy's agri-environment schemes, complemented by the Nature Directives and an increase in the area and condition of protected areas.**
- **In future, the management of ecosystem services will need to be resilient and adaptive to societal (e.g. demographic), environmental (e.g. climate change) and land use (e.g. increased use of bio-energy) changes. Therefore the underlying indirect and direct drivers of change must be considered.**
- **The transition to a more sustainable use of ecosystems and their services can be facilitated by taking a more integrated, rather than conventional sectoral, approach to their management, recognising that some difficult trade-offs will have to be made between individual ecosystem services.**
- **Integration can be facilitated by taking a multi-functional approach adaptable enough to recognise the scale of response required, from local to global, and open and transparent enough to facilitate dialogue and collaboration between a wide range of different actors.**
- **Governments, the private sector, voluntary and civil society at large all have key roles to play in the transition to a more sustainable use of ecosystems.**

There are three types of activity that can be used to influence the management of ecosystems: i) generating and sharing knowledge and information (Tier 1: foundational activities); ii) establishing legal, policy and institutional frameworks, and also understanding and influencing social behaviours (Tier 2: enabling activities); and iii) changing markets, incentives, technologies and practices, as well as voluntary actions (Tier 3: instrumental activities) (**Figure 23**) (TR 27.1.1).

How do these responses play out?

Knowledge (foundational): The evidence base supporting our understanding of biodiversity, ecosystems and their services continues to grow, as evidenced by the richness of the UK NEA, and the large underlying literature base. However, there is a need to better understand linkages between biodiversity, ecosystem structure, functions and services. There is also an important need to develop monitoring and reporting frameworks which are better aligned with the ecosystem approach (TR 27.2).

Legislation (enabling): The global and European Union context within which the UK has to frame policy responses is important, and often provides a strong push towards a more integrated and collaborative approach. In the context of environmental policy, external obligations should not necessarily be seen as a constraint. They often enable the adoption of more effective responses, while allowing scope for variation in national models of implementation (TR 27).

Examples of important legislation include the Habitats Directive and the Birds Directive, aimed specifically at the protection and conservation of wild animals, plants and habitats. Legislation from a wide range of sectors can have a positive impact on biodiversity, e.g. the Natural Environment and Rural Communities (NERC) Act 2006, and the Marine Strategy Framework Directive 2008. The agri-environment scheme of the Common Agricultural Policy (CAP) has provided an important source of funding for land managers to better align farming practices with the delivery of benefits to biodiversity, as well as landscape and resource protection in each region (TR 27.1, 27.4).

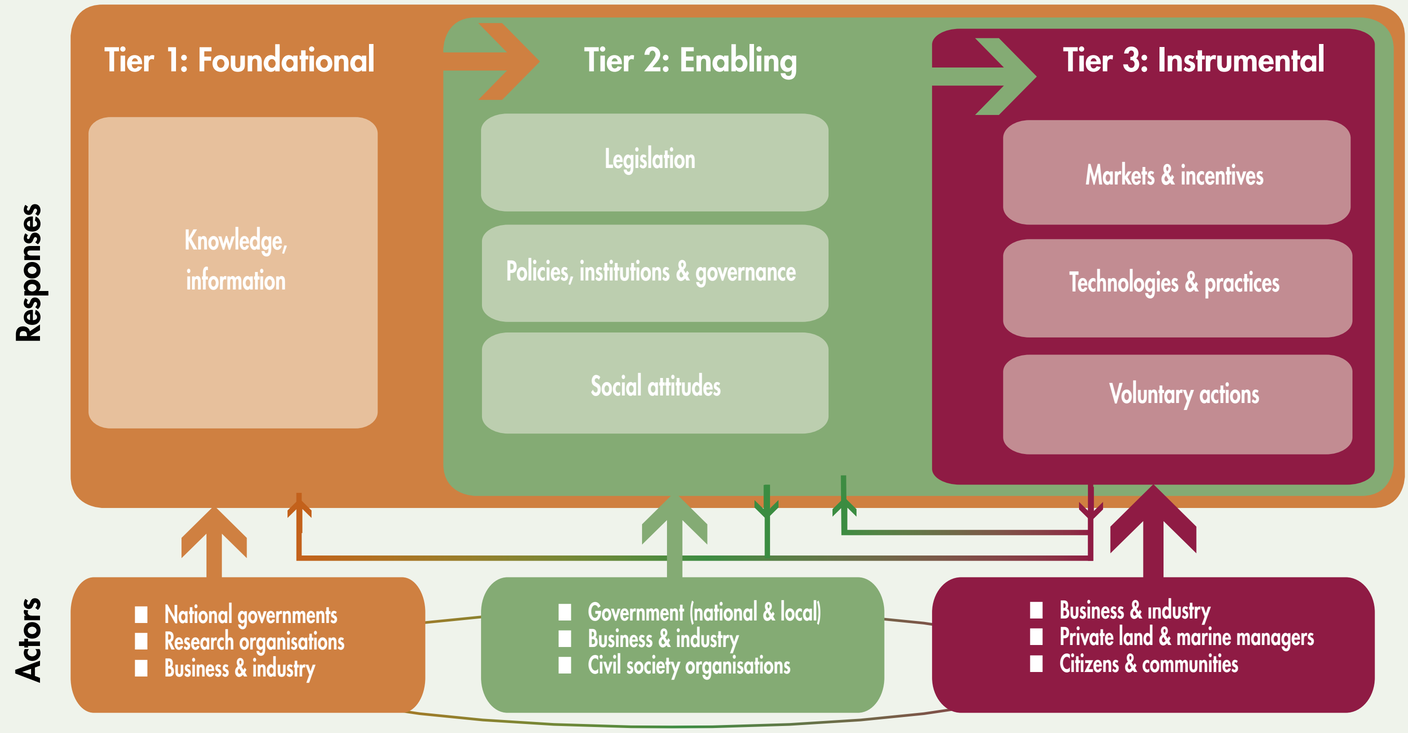


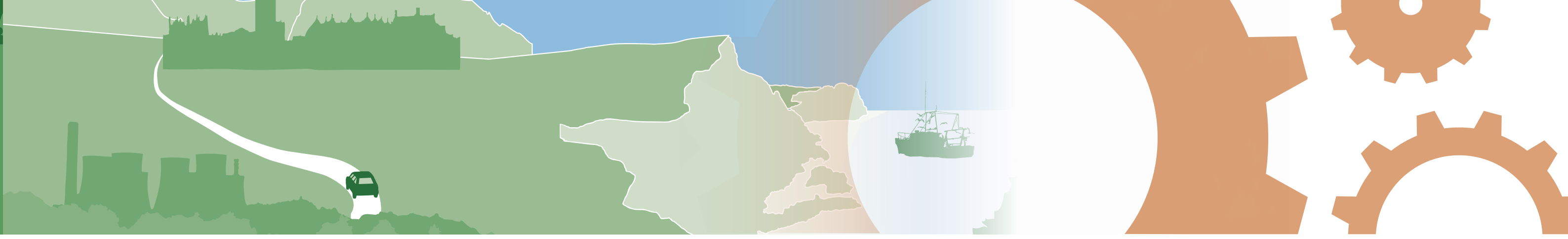
Figure 23 Cascade of responses. Knowledge (at a fundamental or 'Foundational' level) creates the context within which governments enact Legislation, adopt Policies, Institutions and Governance-based interventions, and influence Social Attitudes towards habitats and ecosystem services. These provide the 'Enabling' conditions within which actors undertake specific 'Instrumental' strategies that frequently involve the use of Markets and Incentives for action, the deployment of specific Technologies and Practices, or the adoption of Voluntary Approaches. The figure also shows the role that key actors play in the initiation and implementation of responses at each of these three tiers.

Policies, institution and governance (enabling): The UK Biodiversity Action Plan (UK BAP) led to the development of a framework of BAPs implemented by a broad array of stakeholders, with biodiversity targets expressed at UK and country levels. The UK BAP contains 1,150 species and 65 habitats for which Species Action Plans and Habitat Action Plans have been published. Over 170 Local BAPs have been developed for priority habitats and species through local partnerships and community engagement.(TR 27.1)

Social attitudes (enabling): National biodiversity strategies and policies acknowledge that the engagement of local communities and non-experts in conservation is of great importance. Public understanding of the value of biodiversity has strong implications for the acceptance and adoption of measures. While there has been a positive change in public attitude to the environment, the terms and concepts of biodiversity, ecosystems and their services are not meaningful to the vast majority of people at present. Culturally, the concepts which have most meaning are those of nature, place and landscape (TR 27.2).

Markets and incentives (instrumental): Production subsidies (e.g. CAP Pillar 1) have long been used as an instrument to increase agricultural production, often resulting in the degradation of natural habitats and the loss of non-provisioning ecosystem services. More recently, evidence-based, well targeted CAP agri-environmental schemes, especially the higher level stewardship schemes, have generally led to the maintenance and restoration of existing habitats, with associated benefits to biodiversity. Reform of the CAP could further safeguard biodiversity and promote multifunctional land use by rewarding, for example, the provision and protection of carbon stores, by promoting integrated pest management and by responding to new disease threats linked to climate change. Other market-based schemes that have proved effective include certification schemes such as the UK Woodland Assurance Standard (TR 27.4, 27.5).

Technologies and practices (instrumental): Agricultural production has been greatly increased by the application of technology, for breeding, cultivation, management and protection from pests and diseases. Inevitably, habitats that are highly productive in terms of food are typically uniform and species-poor. However, the wider negative effects of fertilisers, pesticides and livestock manures are now much reduced, due to improved storage, new chemicals and more efficient applications. In addition, biodiversity is being supported by the allocation of non-productive areas at field (promoting pollination and biological pest control), catchment (promoting landscape and water quality) and higher scales, using biodiversity-offsetting mechanisms such as agri-environment schemes. Seabed trawl technologies have significantly damaged marine biodiversity.



However, new, more environmentally friendly technologies and practices are now being developed, such as fishing technology to minimise harm to non-target species and juveniles (TR 27.4, 27.6, 27.7).

Voluntary actions, education and awareness (instrumental): Education, at all ages, is essential for increasing public knowledge and understanding of the importance of conserving biodiversity. Statutory requirements stipulate that the science curriculum must include sustainable development, life processes and living things. The creation of awareness leads to action by civic and voluntary groups, which plays an important role in the conservation of biodiversity.(TR 27).

What does this mean going forward?

Evidence shows that economically, environmentally and socially sustainable management of biodiversity, ecosystems and ecosystem services are facilitated by employing an appropriate mix of approaches. These include legislation and regulations supporting attitudinal changes, underpinning markets and incentives, technological innovation and voluntary compliance. The evidence shows that local initiatives have been invaluable for introducing a range of local conservation activities and improving the delivery of some ecosystem services, but no national-, regional- or global-scale environmental issue (e.g. air and water quality) has ever been successfully addressed without an appropriate enabling framework using a mix of regulations, technology, financial incentives and behavioural changes (TR 27).

Evidence also shows that the sustainable management of biodiversity, ecosystems and ecosystem services will be made easier by using integrated approaches. This involves recognising the scope for a wide range of actors to participate and collaborate, recognising the importance of spatial and temporal scales in formulating appropriate response mechanisms, and using flexible, adaptive management frameworks (TR 27).

Broadly, the trends suggest that responses are becoming more integrated and reflective of ecosystem thinking, which suggests that the overall direction of change is positive. Moreover, in an international context, European Union/UK approaches to ecosystem management reflect more integrated and collaborative modes of intervention. However, considerable challenges remain, and they should not be underestimated (TR 27).

Evidence from the national assessments (England, Northern Ireland, Scotland and Wales) demonstrates some divergence in approach, which provides useful benchmarks for a comparative assessment of policy options. In many ways, the UK context provides a 'controlled experiment' in which policies are differently implemented across the devolved administrations. There is considerable scope for innovation at country level, and for shared learning from these divergent approaches (TR 27).

Integrated approaches: In order to reflect ecosystem thinking when considering policy responses, the evidence suggests that decision makers need to cut across narrow sectoral boundaries. An integrated approach requires the identification of win-win opportunities which conserve and enhance multiple services (e.g. through strategies such as managed realignment), while recognising the importance of potential trade-offs between services. Responses that are initiated within a single sector often impact negatively upon other sectors and services (as well as human well-being), so a multifunctional approach is a key aspect of ecosystem service-based thinking (TR 27.10).

For example, agri-environment schemes provide markets and incentives shaped by European Union law, albeit with variations in implementation in each region of the UK:

- The goal is to secure non-production ecosystem services from the farmed landscape to supplement income farmers make from provisioning services such as crop, livestock and dairy production (TR 27.10).

- Evidence-based, well-targeted agri-environment schemes (the higher level schemes) have been successful in delivering considerable biodiversity improvements, as well as services such as recreation (TR 27.10).

- There is potential to deliver other services that require work across spatial scales and cooperation among farms, for example water (quantity, quality and recharge) and flood control (TR 27.10).

Setting frameworks

Actors: There is considerable evidence that in each sector, action has been undertaken by a range of individuals or groups at every level. This suggests that there is scope for a wide range of actors to participate in the management of ecosystems. Different actors may be best placed to undertake particular types of responses, but it is important to recognise that responses are not the exclusive domain of officials/government, and that effective responses have been led by a range of private/non-governmental and community individuals or groups. Governments are primarily involved in foundational and enabling activities, and the scientific community in foundational activities. The private sector is primarily involved in foundational and instrumental activities, but also enabling activities, especially in terms of shaping social attitudes. Individuals and communities are involved in changing social attitudes and values (enabling) and responding to incentives and undertaking voluntary activities (instrumental) (TR 27.10).

Collaboration between actors: In order to be effective and to deliver lasting improvements to ecosystem services and human well-being, there is a need to recognise the importance of collaboration between actors. While responses may be typically initiated by particular actors, they are rarely implemented in isolation, and usually require cooperation from other actors in order to be successful. For example, collaboration between actors in river basin management (TR 27.3, 27.8):

- Water Framework Directive – legislation (enabling), implemented at local/regional scales.
  - The goal is to reach good ecological status in river basins.
  - The lead stakeholders are competent government authorities in each river basin district (e.g. Environment Agency, Scottish Environment Protection Agency, Northern Ireland Environment Agency).
  - Extensive consultations on the development of River Basin Management Plans have taken place with stakeholders in the agricultural sector, the water industry, planning authorities, businesses, environmental organisations, those involved in fishing and boating, and other water users. This has established a foundation for continued collaboration between stakeholders.

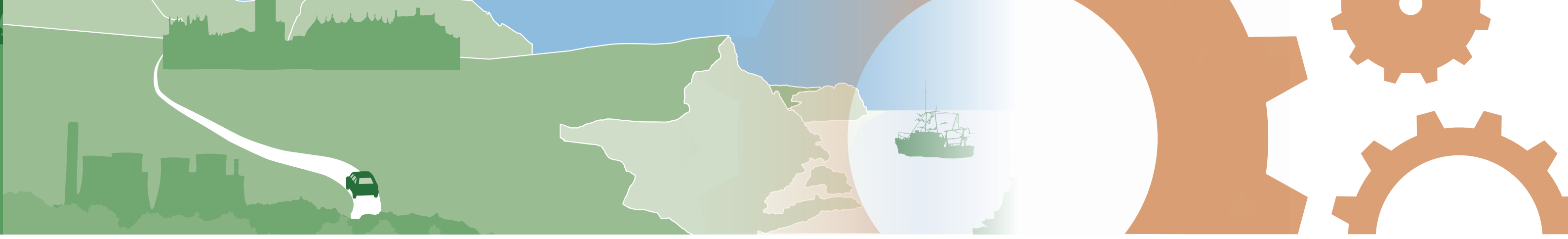
Spatial and temporal scales: Institutional mechanisms that link across spatial scales (from small- to large-scale in terms of area) provide opportunities for stakeholder engagement and greater collaboration between actors, and for the involvement of local groups and non-governmental organisations. Strategic spatial planning of habitats (terrestrial, freshwater and marine) is important for the delivery of ecosystem services. This is happening in some cases, but needs to be better reflected in future responses. One example of thinking across spatial scales is marine planning (TR 27.11):

- Marine and Coastal Access Act – legislation (enabling), under implementation in each region (TR 27.7).
  - The goal is an overarching framework for marine spatial planning, recognising linkages across spatial scales.
  - Key features include consistency at UK level across devolved governments, recognition of competing demands taking an integrated ecosystems approach across scale, and engagement of all stakeholders/actors.
  - Relevant evidence is the enactment of the Belgium Marine Protection Act in 1999, which established a master plan for Belgium's North Sea marine area, making it among the first countries to develop an operational, multi-use marine spatial planning system with effective engagement of relevant stakeholders.

In terms of temporal scale, recognising potential trade-offs between short-term goals and medium/long-term targets may require the adoption of longer planning horizons. One example of thinking across temporal scales is forest schools (TR 27.5):

- Forest schools – influencing long-term social attitudes (enabling) through education in woodland (TR 27.10).
  - The goal is to use woodlands as a learning tool and site for education. There are approximately 140 Forest Schools in the UK.
  - Evidence shows that outdoor learning environments enhance the physical health and mental well-being of participants.
  - There are positive long-term impacts on attitudes to nature and forested landscapes, and greater local involvement in forest stewardship.

Flexible, adaptive management frameworks: Planning responses in the face of uncertainty (such as in the context of climate change) require that more flexible, adaptive management frameworks are implemented, which recognise that mistakes often help to construct more effective future responses. Knowledge frameworks need to support this adaptive approach, and lay/local knowledge needs to be adequately recognised as part of this broader learning environment, especially to encourage greater involvement by a wide range of stakeholders in response strategies.



How have we advanced our understanding of the influence of ecosystem services on human well-being and what are the knowledge constraints on more informed decision making?

10.

Key Findings

- **The UK NEA conceptual framework incorporates a number of recent innovations in ecosystem assessment, including ways of avoiding double counting the economic value of services and goods, the potential to also consider non-monetary values of health value and shared (social) value, and a morphological approach to constructing scenarios of plausible futures.**
- **While there are uncertainties, knowledge gaps and controversies in our evidence base, we have sufficient information to manage our ecosystems, and the flows of services from them, more sustainably.**
- **In order to refine our understanding of the fundamental ecosystem processes underpinning the delivery of ecosystem services we need to both extend our observations and experimental manipulations, and also improve our models of the key mechanisms.**
- **Better holistic ecosystem models offer a potential way forward for understanding some of the uncertainties and highlighting the sensitivities of multiple interacting drivers on ecosystems, the processes within them, and the flow of services and goods.**
- **Currently we are unable to comprehensively quantify the relationships between UK biodiversity and the ecosystem services it supports, in particular, we need to understand better the role of microbial and fungal diversity.**
- **The paucity of information on how both health value and shared (social) value aspects of wellbeing are linked to ecosystem services constrains our understanding of how to account for them in decision-making.**

Evolution of the conceptual framework

The UK NEA built on the Millennium Ecosystem Assessment (MA) in several subtle but important ways, by adapting its conceptual framework to incorporate more recent developments in theory and practice. First, the economic valuation of ecosystem services tried to avoid potential double counting of services. This was done by considering only final ecosystem services, those which directly generate good(s), and not attempting also to value the supporting services, crucial for the delivery of many provisioning, regulating and cultural services. Second, the conceptual framework recognised the need to incorporate non-monetary values of both health and shared social value, in order that these potentially might be considered alongside economic value. Third, rather than considering four plausible futures generated simply from two dichotomous axes (e.g. a scale axis - local to global, and an environmental motivational axis - pro-active to reactive), as used in the MA, the UK NEA used a morphological approach to exploring a range of scenarios. The method involves constructing a matrix where the columns of the matrix are the direct and indirect drivers, while the rows set out different potential states for each driver. Different scenarios can then be constructed by linking cells across the matrix, each strand forming a distinct set of assumptions about how drivers might be associated or causally connected. Fourth, we have taken a slightly different approach to the treatment of biodiversity and explicitly separate out the underpinning natural processes that depend to a greater or lesser degree on biodiversity from landscapes, seascapes, habitats and wild species. These latter elements of biodiversity are part of our natural heritage and, through the pleasure they bring to many people, form one kind of cultural service (TR 2).

The conceptual framework developed in the assessment is made relevant to the UK because it explores the delivery of services and goods from ecosystems based upon a recognised classification of 'Broad Habitats' within the UK. These Broad Habitats are a convenient subdivision of the UK environment, which reflect differences in both ecological processes and management. Also, since many of these Broad Habitats are well-studied and monitored, they tend to be a rich source of information on status and change. However, the assessment also identified uncertainties about some of the fundamental processes driving change, and important gaps in basic information, which potentially limit our understanding of the dynamics of ecosystem service flows and their influence on well-being. Although some of the uncertainties have recently become the focus of new research programmes under the Living With Environmental Change partnership, these limitations in our understanding compromise our ability to make robust decisions to deal with current and future changes (TR 2).

In addressing this question we describe some of the knowledge constraints within the major elements of the conceptual framework and take the opportunity to outline the potential for future research.

Drivers of change

While much is known about the impact of many indirect drivers (e.g. policy and technology) and direct drivers (e.g. use of land, freshwater and marine habitats and pollution) on provisioning services, generally less is known about the consequences for supporting, regulating, and cultural services. However, the state of knowledge of the impact of each driver varies, even for some provisioning services, and our understanding of the interaction of multiple drivers on a specific ecosystem service is much less well known. For example, understanding how multiple drivers acting simultaneously affect nutrient cycles represents a major research challenge for the future. Better holistic ecosystem models, as have been developed for greenhouse gas emissions, offer a potential way forward for understanding the uncertainties and highlighting the sensitivities of individual drivers alone and in concert. Such models could accommodate the spatial variation in magnitude of individual drivers and the strength of their interaction, and therefore inform awareness of the likely variation in ecosystem delivery locally (TR 3).

Biodiversity and ecosystem processes

We are currently unable to comprehensively quantify the relationships between UK biodiversity and the ecosystem services it supports. The difficulty arises partly because of differences in the depth of our knowledge of particular taxonomic groups, in relation to our knowledge of the different ecosystem services those taxonomic groups functionally underpin. For example, although trends in bird abundance are better described than any other taxonomic group, we are unable to assess the consequences of recent declines on changes in cultural services, because data on well-being values are lacking. In contrast, there is very limited data both on the diversity of lower level taxonomic groups, (e.g. microorganisms, fungi, invertebrates), and their functional role in key supporting services, including soil formation, nutrient cycling, and primary production, and on where the changes in their provisioning and regulating services are potentially easily valued. In this case, the paucity of data on trends in these lower taxonomic groups precludes an assessment of the consequence of changes for ecosystem services. This emphasises the need for a set of specific fit-for-purpose indicators, in general, and the need for high-throughput molecular methods for monitoring future trends, in particular (TR 4).

In order to refine our understanding of the fundamental ecosystem processes underpinning the delivery of ecosystem services, we need both to extend our observations and experimental manipulations, and also to improve our models of the key mechanisms. For example, the apparent decadal trends in the loss of soil carbon, so crucial for ecosystem service delivery, are contentious and unlikely to be resolved without better UK-wide information on variation through the soil profile. Also, studies are needed of the dynamics of soil water and the influence of various drivers, such as climate change and land use, on soil water fluxes, and in turn, the consequences for nutrient and carbon cycling. Finally, there is a need to reduce uncertainty, and increase resolution of, hydrological models and their outputs, in order to improve our ability to predict future variability in the water cycle in space and time (TR 4).

Final ecosystem services

Here we describe briefly some illustrative examples of the research opportunities which should help inform sustainable delivery of a range of final ecosystem services.

Regulating services: There is a need for specific spatial and temporal (seasonal and annual) measurement and monitoring of greenhouse gas emissions from land under different management practices (e.g. minimum tillage), as well as under different land uses, in order to refine models of local climate regulation (TR 14.2.5). Other examples include the lack of national or regional monitoring schemes for both pollinators and pollination services and the capacity of different habitats and floral resources to support pollinator communities. The pollination requirements of many crop varieties and wild plants are poorly documented or unknown, and the relationship between pollinators and service delivery is not well understood, making it difficult to predict future changes (TR 14.5.5).

Provisioning services: Given the need to increase the levels of food and fibre produced from our ecosystems, an immediate challenge across agriculture, fisheries and forestry is to increase the resource efficiency of production. Research is needed to develop systems of production that use fewer non-renewable resources, including water, while simultaneously producing lower levels of pollution, per unit of production. At the same time it would be useful to understand which species really are crucial to maintaining the productive ability of an ecosystem, and which are effectively redundant from a production point of view. Such information would ensure that managers of farms, forests and fisheries do not accidentally cause loss of species vital to the functioning of their productive ecosystems. In this situation, it would be important to develop indicators that would alert managers to the risk of intrinsic effects (e.g. over-cultivation of soil which leads to extreme soil erosion) decreasing their productive activities in the future. This would then enable them to alter their management regimes and hopefully ensure the long-term flow of provisioning services from their systems. Finally, there is an opportunity for research to explore the potential benefits of zoning of intensification of agriculture, fisheries and forestry versus management for non-provisioning services at a variety of scales from local to regional (TR 15.13).

Cultural services: Using an ecosystem services framework to understand culture-nature interactions is a relatively new perspective and consequently, many key sources of social, economic and environmental data are not designed to examine key aspects of cultural services and goods. There are knowledge gaps related to data collection and the uneven monitoring of change of different environmental settings. Although national planning guidance also instructs local authorities to audit the use and access to open spaces, the approaches adopted are not consistent. In general, it appears that more needs to be done by lead agencies working with researchers to develop a suite of appropriate indicators and measures, as well as recommend ways to gather the information consistently across the UK (TR 16.4).

Human well-being

Although the conceptual framework identified three categories of well-being value, there was little existing evidence, and insufficient time and resources, to undertake new studies to specifically relate changes in ecosystem services to more than economic value. For health goods there is well-established evidence of the potential of ecosystems to play a role in facilitating exercise and other activities that enhance child development, and improve the mental and physical health of all. However, much of the specific evidence is restricted to urban greenspace, and further research is required to understand the social and physiological processes involved in people acquiring mental and physical health benefits from engagement with nature, local places and landscapes, so that management of our Broad Habitat for health outcomes can be more effective. While it is recognised that, when dealing with non-use values for public goods such as a beautiful landscape, individuals, as citizens, accept the existence of shared values and wish that these should contribute to public policy choices through deliberative participatory methods and the use of multi-criteria studies, the subject is in its infancy (TR 22-24).

The paucity of information on how health and shared (social) value aspects of well-being are linked to ecosystem services constrains our understanding of how to account for them in decision-making and, in particular, consider them alongside economic value.

A Snapshot of the Countries of the UK

England, Northern Ireland, Scotland and Wales account for 53%, 6%, 32% and 8%, respectively, of the area of the UK. There are large differences in their coastlines, and particularly because of the large number of islands in the west and north of the UK, Scotland has a disproportionately long coastline, and with it, about 54% of the inshore (12 nautical miles) marine waters. The populations differ markedly, too, so that population density varies sixfold, from about 66 people per square kilometre in Scotland, to 395 people per square kilometre in England. Variation in human population pressure, coupled with marked differences in climate, geology and topography, strongly influence the percentage of the eight Broad Habitats found in each of the countries (**Table 2** and **Figure 24**). This in turn has consequences for the delivery of different ecosystem services. For example, 55% of England consists of Enclosed Farmland, reflecting the demand for food, and the fact that the south and east are low-lying and dry, favouring arable agriculture, while the higher, wetter, western parts are devoted to livestock farming. In contrast, only about 20% of Scotland comprises Enclosed Farmland, while Northern Ireland and Wales are intermediate, with 44% and 41% respectively. This reflects the lower agricultural potential of higher, wetter and colder land, which favours grazing, much of which is also undertaken on the more common Semi-natural Grasslands as well as Mountains, Moorlands and Heath habitats. Scotland, in particular, is home to the majority of Mountains, Moorlands and Heaths, which cover 44% of its land: more than double the percentage found in Northern Ireland, four times that found in Wales and almost nine times the percentage in England. Collectively, these uplands provide almost 70% of the UK's drinking water from surface water sources.

	UK		England		Northern Ireland		Scotland		Wales	
UK NEA Broad Habitat	Area ('000 ha)	%	Area ('000 ha)	%	Area ('000 ha)	%	Area ('000 ha)	%	Area ('000 ha)	%
Mountains, Moorlands & Heaths	4,603	18.6	693	5.3	234	16.5	3,430	43.6	246	11.8
Semi-natural Grasslands	4,065	16.4	1,878	14.4	243	17.2	1,470	18.7	474	22.8
Enclosed Farmland	10,220	41.3	7,211	55.3	622	43.9	1,536	19.5	851	40.9
Woodlands	2,867	11.6	1,238	9.5	142	10.1	1,207	15.3	280	13.4
Freshwaters- Openwaters, Wetlands & Floodplains	328	1.3	126	1.0	69	4.9	109	1.4	26	1.2
Urban	1,675	6.8	1,384	10.6	48	3.4	152	1.9	87	4.2
Coastal Margins	336	1.4	194	1.5	7	0.5	85	1.1	49	2.3
Marine	16,477	-	5,165	-	566	-	8,470	-	1,570	-
Total Land Area	**24,729**	-	**13,043**	-	**1,416**	-	**7,871**	-	**2,081**	-
Total Land + Marine Area	**41,206**	-	**18,208**	-	**1,982**	-	**16,341**	-	**3,651**	-

Table 2 Estimate of the total area ('000 hectares; ha) and proportion (%) of the eight UK NEA Broad Habitats in the UK and each of its constituent countries. Source: Area of Mountains, Moorlands and Heaths, Semi-natural Grasslands, Enclosed Farmland, Woodlands, Freshwater* habitats and total UK land area derived from the Countryside Survey 2007 (Carey et al. 2008); Urban, Coastal Margins and total land area of each country estimated from the Land Cover Map 2000 project (Fuller *et al.* 2002); Area of Marine habitat estimated by UNEP-WCMC by using spatial analysis to calculate that enclosed by the 12 nautical mile limit around the UK. *Estimates for Freshwater habitats only include Standing Waters and Rivers and Streams.

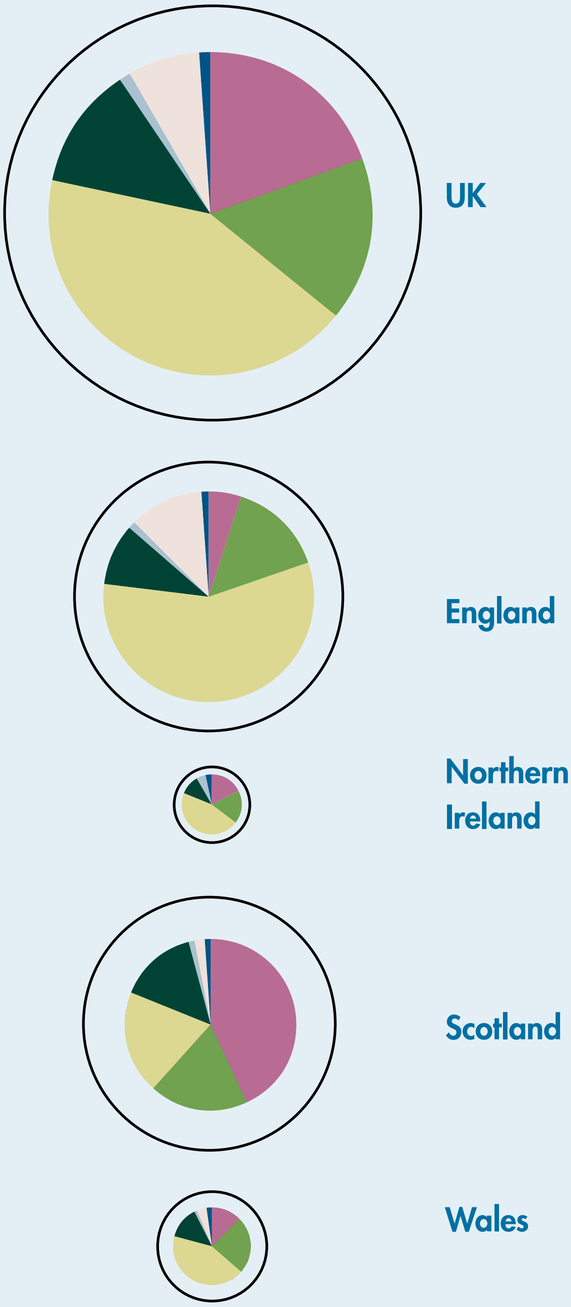


Figure 24 Schematic of the relative proportion of each UK NEA Broad Habitat found in the UK and its constituent countries. The percentage values for each Broad Habitat are shown in Table 2. Colours of segments correspond to Broad Habitat colours in column 1 of Table 2. The size of each country chart is relative to the total area of land and sea (within 12 nautical miles) of the UK. Source: Area of Mountains, Moorlands and Heaths, Semi-natural Grasslands, Enclosed Farmland, Woodlands, Freshwater habitats and total UK land area derived from the Countryside Survey 2007 (Carey *et al.* 2008); Urban, Coastal Margins and total land area of each country estimated from the Land Cover Map 2000 project (Fuller *et al.* 2002); Area of Marine habitat estimated by UNEP-WCMC by using spatial analysis to calculate that enclosed by the 12 nautical mile limit around the UK.

England

England has a population of over 52 million, with over 80% of people living in towns and cities that cover around 11% of the country. These urban areas make the highest demands on, and are the greatest recipients of, ecosystem services, requiring more ecosystem services than they provide (TR 17.2).

The condition of England's Broad Habitats has been declining over the last 50 years as a result of land use change and management, but with some recovery in the last 10 years. This has been accompanied by significant changes to England's biodiversity, with declines in many well-recorded species. Between 2003 and 2006 the overall trends in selected indicator species were positive; however, 26% of species are still depleted or on the UK Biodiversity Action Plan list of priority species and habitats. Sites of Special Scientific Interest (SSSIs) cover 8% of England and while many are not in favourable conservation status, it is likely that their condition is improving (TR 17.3).

About 70% of England is currently farmed, with 55% on Enclosed Farmland and the remainder used for extensive grazing on Semi-natural Grasslands and Heaths. The area of arable Enclosed Farmland increased from the 1940s until the 1990s, but between 1998 and 2007 it decreased by 8.8%, while improved grassland increased by 5.2%. This change is primarily due to alterations in economic and technological drivers and policy (e.g. Common Agricultural Policy reform). Some arable flowering plants have decreased dramatically in number over the last 50 years and are amongst the most threatened flora. In comparison, only 9% of England is wooded, despite cover increasing by 45% since 1945. Initially, mostly conifers were planted, but since the 1980s more broadleaved species have been used. Many woodland species have declined in number due to lack of management, deer grazing, fragmentation and, increasingly, climate change. Woodlands possibly deliver the greatest number of ecosystem services including carbon storage, recreation, timber and a contribution to water regulation (TR 17.4).

The natural cover of Mountains, Moorlands and Heaths has significantly decreased over the last 60 years due to afforestation and conversion to rough and improved grassland in the uplands. It is likely that loss of lowland heathland has been due to the development of towns and roads, afforestation and agricultural improvement, but there were some increases between 1998 and 2007, due to restoration and re-creation. Most Semi-natural Grassland has been lost due to conversion to arable land, although 68% is now protected within SSSIs and 40% designated as Special Areas of Conservation (TR 17.4.1).

Wetlands cover only about 4% of England, but they have disproportionately high biodiversity, including a significant number of internationally important species. As a consequence, 47% of the wetlands are under SSSI protection. Forty-four per

cent of SSSI open waters and 21% of wetland are classified as favourable and 11% and 48% as recovering, respectively. Eutrophication is likely to be the main cause of unfavourable condition in open waters, and overgrazing, burning, pollution and drainage in wetlands (TR 17.4.5).

England holds about 73% of the UK's saltmarsh, and along with sand dunes, this ecosystem has suffered losses due to reclamation, development and erosion. Coastal Margin habitats support a wide range of highly specialised species, and many of these are internationally important for conservation. However, 30% of the coasts are subject to erosion and 46% protected by engineering structures. England's Marine habitats also support a high diversity of species. Overharvesting has adversely affected marine species, and landings of marine fish have declined since 1970 (TR 17.4.7).

Provisioning services are very important to local and national economies and while environmental management is improving, significant impacts on regulating, cultural and supporting services must be addressed. Agricultural expansion and intensification to meet the food demands of a growing urban population have led to habitat loss and degradation, affecting biodiversity and decreasing the supply of some regulating and cultural services (TR 17.5.3).

There has been a decline in many supporting services provided by England's Broad Habitats. Nutrient cycling has been influenced by anthropogenic nitrogen and phosphorus deposition from domestic, agricultural and industrial sources, and soil erosion rates have increased significantly through tillage practices in arable regions. Furthermore, annual losses of carbon due to inappropriate peatland management are likely to exceed the rate of carbon sequestration by peatlands (TR 17.5.1).

The quality of many regulating services is improving; however, various forms of pollution continue to deleteriously impact ecosystems. England is a net source of greenhouse gases, but this trend is diminishing. Pollinating insects are declining, with potentially significant consequences for agricultural production and several habitats. Significant improvements in air quality over recent decades have occurred, but current concentrations and deposition rates often exceed recommended environmental thresholds. While the number of English rivers of good chemical quality is increasing, concentrations of phosphates and nitrates remain problematic (TR 17.5.2).

England's landscape provides highly important cultural ecosystem services, the value of which is often difficult to quantify. Urban and rural greenspaces provide important opportunities for recreation, aesthetic inspiration, community interaction and psychological well-being. Many habitats and landscapes provide important sources of tourist revenues that support rural communities (TR 17.5.4).

Northern Ireland

Northern Ireland is relatively densely populated (about 120 people per square kilometre), with about 65% of the population living in cities and large towns and the rest living in the open countryside or small villages, leading to an overall peri-urban development pattern. Around three-quarters of the land area is used for agriculture, primarily rough and improved grazing. The area, composition and ecosystem services delivered by habitats have changed over time. For example, between 1998 and 2007 improved grassland increased at the expense of both neutral grassland and arable farmland, but there was considerable loss of both improved and neutral grassland to building development, both in the open countryside and adjacent to settlements (TR 18.2.2).

Although there are no National Parks, 7% of Northern Ireland is designated as Areas of Special Scientific Interest (ASSI) and about 42% of the land is involved in agri-environment schemes. While there is generally a lower level of terrestrial species diversity than in Great Britain, the marine biodiversity is rich and supports a substantial fishing industry. A study in 2006 estimated that the natural environment contributed £573 million to the economy (TR 18.6).

Mountains, Moorlands and Heaths cover 17% of the land area, with the majority being upland blanket bog (10%). While the overall area has been relatively stable over the past 20 years, most of the blanket bog has been physically modified, although the majority is still capable of forming peat. Peat is a traditional energy source, is used in horticulture, sequesters carbon and represents a substantial carbon store. Peat soils contain 42% of the soil carbon stock of Northern Ireland and peaty soils account for a further 10%. Uplands are used for low intensity livestock grazing and are of high scenic and recreational value. Water storage in intact peatlands contributes to flood alleviation and water provision (TR 18.5.2).

Enclosed Farmlands, which provide most of the agricultural outputs, cover an estimated 44% of land area, with the vast majority being improved grassland (40%). Agricultural systems have changed markedly over the last century due to intensification, which has led to some loss of habitat and species diversity. While the amount of arable production has decreased over the past century, large amounts of grain are still produced, most of which is used for livestock feed rather than human consumption. Most farmland is used for the production of livestock, and their products for domestic consumption and export. Since the 1950s, many field boundaries with their associated open wet drains, which are important for biodiversity, have been removed, but this trend is declining. Enclosed Farmlands contribute about 23% of Northern Ireland's greenhouse gas emissions (primarily methane and nitrous oxide). Although overall soil degradation is low, many agricultural soils, especially those under intensive grassland, still have elevated

nitrogen and phosphorus levels and are a source of these nutrients in surface waters, despite decreased fertiliser use in recent years. About 10 million tonnes of agricultural waste is generated each year, which is largely disposed of on-farm, with potential pollution implications. There is a strong appreciation of the social value of farming in relation to the agricultural landscape, but both the overall number of farms and the number of people employed on them have decreased in the past 30 years (TR 18.5.4).

Coniferous plantations (predominantly Sitka spruce) cover about 4% of land area, yielding timber used to produce pallets, packaging and fencing, and another 6% is covered by broadleaved woodland, with only 0.04% of Northern Ireland classified as 'ancient' and 0.75% dating back to at least 1830. There has been a large increase in total woodland cover since the 1950s, with the last 10 years responsible for a major increase in broadleaved woodland. Woodlands provide many ecosystem services, including timber production, carbon sequestration, biodiversity and recreational opportunities (TR 18.5, 18.6).

Northern Ireland is notable for its large area of freshwater habitats, especially large lakes. Climatic conditions ensure a good supply of freshwater; however, levels of pollutants and changing patterns of temperature and rainfall are all having impacts on water bodies. Freshwaters – Openwaters, Wetlands and Floodplains, which cover about 5% of land area, provide water, food, recreation and biodiversity benefits as well as detoxifying pollutants and contributing significantly to flood control. Around 98% of drinking water is abstracted from rivers, lakes and reservoirs, so the water quality of rivers and lakes has a direct relationship to the cost of water treatment. Water quality problems are mostly due to diffuse nutrient pollution (agricultural), with fewer than 6% of rivers showing no nutrient enrichment. However, there have been improvements in nitrate and phosphate pollution of rivers since 1994, although there is no evidence yet of any improvement in biological aspects of water quality. Freshwater fisheries have decreased significantly since 2000. Arterial drainage works carried out until the 1990s resulted in Northern Ireland having the highest percentage of modified rivers in the UK, although there has been more recent restoration of riverine habitats and recognition of their role in flood prevention and their importance for biodiversity (TR 18.5.6, 18.6).

Although Coastal Margin habitats (sea cliffs, shingle, sand dunes, saltmarsh, coastal lagoons) cover only 0.5% of land area, they have high biodiversity value, with important seabird populations and invertebrate diversity, and provide major recreation, cultural and tourism benefits. About 75% of the coast is protected, much of it by multiple designations; however, the quality of individual sites is highly variable. Fisheries are important locally, although catches of many finfish have decreased over the past decade and there has been a shift from finfish to shellfish. There is evidence of damage to habitats and deterioration of water quality in coastal areas. The marine environment is valued for its cultural heritage, recreation and tourism and is a vital aspect of energy, nutrient and water cycles, with major roles in carbon balance (TR 18.5.8, 18.5.9, 18.6).

Northern Ireland has a rich cultural and archaeological heritage and a long history of literature, poetry, music and the visual arts where the landscapes have inspired local artists. Tourism is increasingly important and is responsible for about 5% of the economy with scope for expansion, especially in relation to unique and distinctive landscapes. Coarse, game and sea/shore angling are popular contributors to the local economy (TR 18.6.4).

Sustainable management mechanisms have the potential to enhance the delivery of ecosystem services through designations, the planning system and financial incentives for agricultural land management. Land management is strongly influenced by government and European Union policies and financial measures (specifically the Common Agricultural Policy). Land is subject to a complex of 'rights' including turbary, fishing, shooting, mineral and water. The condition of the networks of ASSIs, terrestrial Natura 2000 sites, Special Areas of Conservation and Special Protection Areas varies across habitats. Overall fewer than half of the Natura 2000 sites were in favourable condition, but a number were 'recovering'. 'Wider countryside' and 'landscape-scale' conservation is largely through Areas of Outstanding Natural Beauty. Sites of Local Nature Conservation Importance, Country Parks, Regional Parks and Forest Parks also allow for sustainable management options. The Woodland Grant Scheme encourages the creation of new woodland to increase wood production, improvement of the landscape and woodland biodiversity and the sustainable management of forests and woodlands (TR 18.9).

Scotland

Eighty per cent of Scotland's population live in urban centres, which has led to an increase in the extent of the area of Urban habitat, though Scotland remains the least densely populated nation in the UK (approximately 66 people per square kilometre). The quality of urban environments and of relationships between urban populations and the wider rural and coastal habitats of Scotland is increasingly recognised as being of importance for human well-being. These relationships are also central to understanding the demands placed on Scotland's habitats to supply ecosystem services to urban populations (TR 19.2).

Nearly 15% of Scotland is protected by international designations, and 22% by European Union designations. The two National Parks in Scotland together cover 639,200 hectares, about 8% of the land area. Scotland has 197 priority species and 39 priority habitats of national and international importance under the Biodiversity Action Plan. The latest survey in 2008 showed that 39% of species were stable or increasing, 21% were declining, but trends were

unknown or unclear for 40%. Of the 39 priority habitats, 44% were stable or increasing, 33% were declining, and the status was unclear or unknown for 23% (TR 19.3).

The varied environmental conditions experienced in Scotland contribute to an extremely rich biodiversity (50,400 terrestrial species and 39,200 marine species). Scotland's rivers are global strongholds for Atlantic salmon and freshwater pearl mussel (TR 19.3).

Many of the UK's Mountains, Moorlands and Heaths can be found in Scotland, where this is the most common Broad Habitat, and accounts for 44% of the land. However, the area of mire and bog within this habitat has declined by more than 20% between 1948 and 1988. In contrast, Semi-natural Grasslands are less than 1% of the total grassland area in Scotland. The area of Enclosed Farmland has been in decline, particularly arable, which declined from 1.3 million hectares in the 1940s to 880,000 hectares (11%) in 2000. However, through the use of technology, yields per unit area have increased since the 1940s. In contrast, the area of Woodlands in Scotland has increased from 500,000 hectares in the 1940s to 1.3 million hectares in 2009. This increase is mostly through planting of softwood species native to North America. Scotland has about 70% of the area of freshwater of the UK and 90% by volume. There have been changes in the hydrological regimes of Scottish rivers that reflect variations in rainfall patterns associated with changes in climate since the 1960s. River flow is becoming much more seasonal, with increasing discharge in winter months (TR 19.4).

The length of Scotland's coastline is over 11,800 kilometres and about 13% of the total land area of Scotland consists of islands. The area within 12 nautical miles of Scotland's coast is greater than the total land area of the mainland and islands. The Coastal Margins are under threat from habitat destruction and rising sea levels. The seas around Scotland are potentially among the most biologically productive seas on the planet. The Coastal Margins and sea together support the majority of the global populations of a number of bird species, including the gannet. However, many Marine habitats are of bad and deteriorating status, damage being caused by climate change, human activities including fishing practices, pollution and infrastructure development (TR 19.4).

The functioning of nutrient cycling in Scottish habitats has been altered largely by pollution from nitrogen deposition and the application of fertiliser to arable systems. The pollution is compounded by large loads of pollutants from atmospheric deposition, which occurs due to Scotland's considerable rainfall. In turn, Scottish soils are being damaged. In contrast, water quality is generally good and abundant, with lochs storing almost 35 billion cubic metres of water and soils up to 42 billion cubic metres of water (TR 19.5.1).

The condition of many regulatory services in Scotland has improved in recent years. Of particular note are Scotland's abundant peatlands and organically rich soils. The peatland soils of Scotland are estimated to store 1,620 megatonnes of carbon, thus making Scottish soils an important player in the UK's soil carbon storage (TR 19.5.2).

Provisioning services from Scotland's ecosystems contribute significant quantities and variety of raw materials and thus, economic value to Scotland. Achieving amongst the highest yields globally, crop production has increased since the 1940s, providing 27% of the value of agriculture. Barley and wheat are the most important cereals for Scotland, in terms of total production value but also in terms of total area planted each year. Since the 1940s barley production has increased tenfold to 1.7 million tonnes in 2000 and wheat sixfold to 800,000 tonnes during the same time period. Other important produce includes potatoes, contributing 8% of the value of agriculture and horticulture production, contributing a further 11%. However declines have been seen in fodder crops over the past 70 years, reflecting the availability of alternative winter feed for livestock instead of the traditional turnips and swedes. Livestock contributes over 47% of the value of Scottish agricultural production, with their products contributing a further 16%. The increased value can be attributed to the availability and use of technology. For example, the size of the dairy herd has decreased by more than half in the 1950s to 350,000 head in the 2000s, but in contrast, milk production has remain at over 1 million litres per year. European policy and support have also played a role in livestock production, with sheep numbers, for example, reaching a high of about 10 million in the 1990s and declining to about 7 million in the late 2000s (TR 19.5.3).

Fish production from Marine systems is centrally important, not only to Scotland's economy as a whole, but for coastal communities. However, the catch of wet fish has declined, largely from overfishing, with current landing amounting to 100,000 tonnes per year for demersal fish and 150,000 tonnes per year for pelagic fish. While fishing landings have decreased, the Scottish shellfish fishery has grown to landing 58,000 tonnes per year, contributing 39% of the total value of the marine fish industry. Estuary and freshwater fisheries have also declined since the 1950s, with salmon and migratory trout showing the most marked decline. In contrast aquaculture, with a focus on salmon, trout and shellfish, is growing rapidly (TR 19.5.3).

Other important goods obtained from Scottish Broad Habitats are timber and peat. Softwoods contribute to more than 99% of the wood harvest from Scotland's forests and about 44% of the softwood production in Great Britain is managed by sawmills in Scotland. While the area of peat extraction has fallen over recent years, it has been used historically, and still is being used, for heating, horticultural compost and by the whisky industry (TR 19.5.3).

Scotland's land- and seascapes are distinctive, contribute to the 'Scotland brand' both nationally and internationally, and are valued highly by Scotland's population and visitors. Nature-

based tourism in Scotland, for example, is estimated to provide about £1.4 billion in income with about 39,000 full-time jobs (TR 19.5.4).

There has been considerable change in Scotland's ecosystems and the services they provide over the last 70 years. The delivery of provisioning services has generally increased considerably, especially from agricultural systems. The role of agriculture and forestry in shaping landscapes and ecosystems in Scotland is important because they affect a large proportion (92%) of Scotland's land area. For example, this development of provisioning services, which have a high economic value, has had significant impacts and consequences for biodiversity in Scotland. Habitats have declined in both area and condition, while biodiversity has shown both declines and increases, although the general trend has been of decline (TR 19.7).

The habitats of Scotland provide a diverse and important suite of ecosystem services. The diversity of services and their interdependence on ecosystem condition and management suggests that management for multiple objectives is necessary. Many approaches for achieving multiple objectives exist; the ecosystem approach is one that is gaining in popularity and relevance as it combines a place-based approach with a systematic and integrative approach to environmental management and links communities with decision making. The Scottish Government is actively developing Acts and policies that encourage the enhancement of Scotland's environment while using the many ecosystem services to promote the health and well-being of Scotland's population. The Climate Change (Scotland) 2009 and Marine (Scotland) Act 2010 are recent Acts of importance for developing an integrated approach to the many pressures and demands placed on Scotland's ecosystems from environmental change and human activity (TR 19.9).

Wales

Wales is renowned for its attractive landscapes, with three National Parks and five Areas of Outstanding Natural Beauty covering 24% of the country's land surface (TR 20.3).

There have been significant changes to biodiversity in Wales over the last 70 years. Overall, the total number of priority habitats has increased from 37 in 2002 to 39 in 2005, with 59% of priority habitats declining in 2005, compared with 46% in 2002. The biodiversity of Welsh lakes is exceptional for a small region and closely comparable to that found in England or Scotland. Nine ecologically distinct lake types have been recorded in Wales, out of potentially 11 types found in Britain (TR 20.3).

Currently approximately 60% of upland habitats (Mountains, Moorlands and Heaths) are in unfavourable condition, with blanket bog and heath failing at a high percentage of sites. Direct land management, particularly sheep grazing, in addition to reducing vegetation cover and replacing heaths, woodland and mires with grasslands, also exacerbates the impacts of pollution and climate change. There are indications that climate change may have caused many upland peatlands to be close to the tipping point between carbon sink and carbon source. This is compounded by coniferous plantations on peatland, which cause the soil to dry out, oxidising the peat and releasing carbon dioxide (TR 20.4.1).

The alteration of the composition of lowland Semi-natural Grasslands is one the most rapid and widespread vegetation changes that have taken place over the 20th Century. Approximately 90% of former unimproved and semi-improved swards have been transformed by agricultural management to improved grasslands (TR 20.4.2).

About 41% of Wales is Enclosed Farmland, comprising 3.4% arable/horticultural land and 34% improved grassland. However, it should be noted that Enclosed Farmland varies enormously from one part of Wales to another. For example, there are considerable differences between Pembrokeshire and the Brecon Beacons in terms of hedgerow morphology, nitrogen oxide emissions and recreation. Enclosed Farmland has more or less intrinsic value for many ecosystem services by virtue of how close it is to other habitats. In the Welsh uplands there is a more intimate interaction between Enclosed Farmland and Semi-natural Grasslands and in the lowland between Enclosed Farmland and Freshwaters systems and Woodlands. While there is considerable variation in the delivery of ecosystem services, depending on the location and scale of the Enclosed Farmland in question, Enclosed Farmland has always been, and remains, a vital habitat in terms of food production and its provision of landscape, recreation and other cultural benefits; although it also imposes important disbenefits in terms of emissions of greenhouse gas, diffuse water pollution and losses to biodiversity. Honey bees are the most common pollinator of commercial crops but have shown a 23% decline in Wales between 1985 and 2005, with this trend expected to continue for the present. Livestock production in Wales is dominated by sheep and cattle farming, with Wales contributing 26% of the total sheep in the UK (8.2 million) and 11% of the UK total for cattle (1.1 million) (TR 20.4.3, 20.4.4, 20.4.5).

Provisioning services are heavily supported by subsidy in less favoured areas, which approximates to 80% of the agricultural land area. Agriculture is very severely restricted under waterlogged conditions, and therefore, significant amounts of agricultural land were drained during the 20th Century, in order to shift water off the land surface as quickly as possible, increasing flood risk downstream (TR 20.5).

The area of Woodland has almost tripled since the early 1900s, now covering 13% of the total land area, although this is substantially less than the European Union average of 37%. A

significant amount of the tree resource is outside woodlands, in the form of individual trees (15.3 million live trees) and hedgerows, providing a range of important ecosystem services. Despite their limited extent, semi-natural woodland remains one of the most biodiverse habitats, with a rich association of rare and priority species. Approximately 5% of Woodlands are Sites of Special Scientific Interest. However, just 9% of these are considered to be in favourable condition and 25% are in unfavourable but recovering condition. There is renewed interest in expansion of Woodlands and The Welsh Assembly Government has announced an ambitious programme of creating 100,000 hectares of new woodland over the next 20 years. This initiative would create an additional major sink of 1.6 megatonnes of carbon dioxide equivalents annually by 2040 (TR 20.4.4).

Welsh Freshwater ecosystems are still suffering from an industrial legacy, for example coal mining, but there is evidence of improvement following remediation interventions. Nutrients from diffuse and point sources and other forms of pollution are likely to be responsible for the recent decline in the health of freshwater ecosystems. Biological data suggest significant deterioration of rivers from 'very good' quality to 'good' from around 1995, but the reasons are unclear, but possibly linked with agricultural activity and phosphorus contamination. Nearly all the major river systems are regulated by headwater dams and reservoirs installed for water supply, flood control and energy generation. Despite this in 2009, the Environment Agency estimated that one in six properties (600,000 people in 357,000 properties) in Wales are at risk of flooding. The annual economic risk from flooding to residential and business properties and contents was £200 million a year in 2008 (TR 20.4.5).

Nearly 6% of Wales is classified as Urban, and over the last 40 years activities have taken place to improve the quality of human well-being in the urban environment, including the increase of local nature reserves close to urban centres and further urban tree planting. In 2010, 18 of the 22 local authorities in Wales were working on completing assessments of the extent and location of accessible natural greenspace in their urban areas (TR 20.4.6).

Sand dunes, saltmarsh and sea cliffs are the most extensive Coastal Margin habitats in Wales. Sand dunes are important habitats for a range of regulating services, including coastal erosion protection. Since 1900, though, there have been considerable losses of the sand dune area due to agricultural land claim, forestry, golf courses and development for housing and tourism. A further 23% of the Welsh coastline is eroding and 28% of the coast has some form of artificial sea defence works. In 2007, sea defence services by sand dunes have been calculated to be worth between £53 and £199 million in Wales (TR 20.4.7).

Marine designated sites in Wales total more than 0.5 million hectares. Seven in every 8 hectares of Welsh Natura 2000 sites are in the marine environment, reflecting the high conservation importance of the Marine habitat. However, this habitat exhibits the greatest deterioration, with continued or accelerated decline across 60% of marine, compared to 8% of terrestrial, habitats (TR 20.4.8).

Unlike England, which is a net source of carbon dioxide, Wales is considered to be a net sink, because of land management activities, with large amounts of carbon 'locked up' in its soils and peatlands. In particular, soils represent a significant store of carbon, of which approximately one-third is in the form of peat, despite peat deposits occupying only 3% of the surface area. Soils hold nine times the amount of carbon that is stored in all vegetation (including forestry), with over 80% of this carbon associated with our upland and grassland soils. The strength of the forest carbon sink increased from 1990 to 2004, but may now start to decline as a result of a drop in planting rates in the last 20 years. The total carbon stored in Welsh forests and their soils is equivalent to more than 10 times the annual emissions from industry and services (TR 20.5.2).

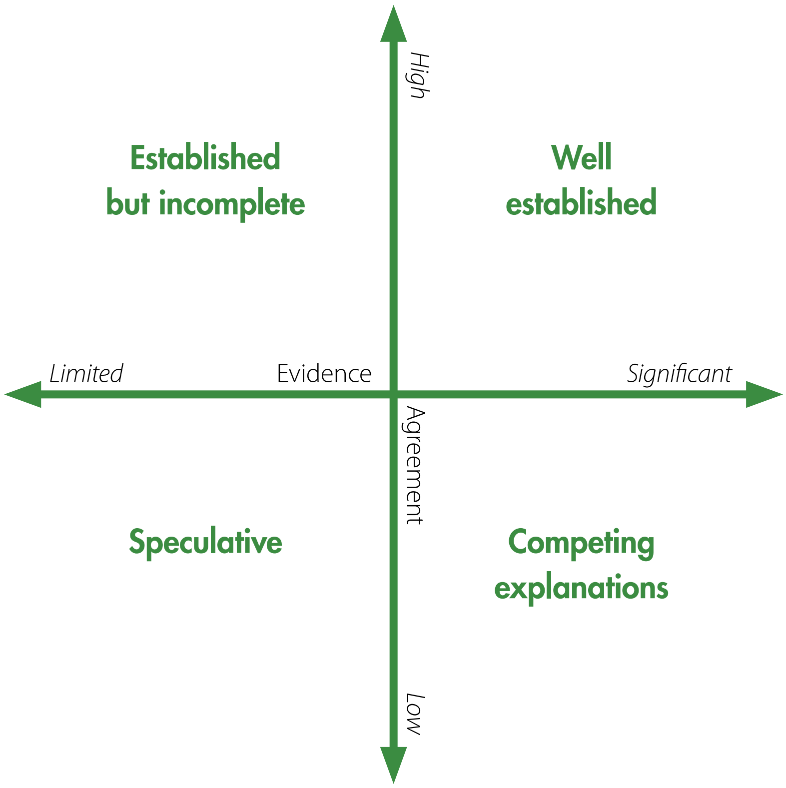
In Wales, 72% of the population have access to Woodlands greater than 20 hectares in extent within 4 kilometres of their homes, and 58 cultural landscape types are listed in the Register of Landscapes of Historic interest in Wales. However, the distinctive character of the Welsh landscape has been and remains under threat, particularly from the planting of conifer forests and intrusive developments related to energy, transport and tourism (TR 20.5.4).

Annex – Key Findings of the Biodiversity, Broad Habitat and Ecosystem Service Chapters

Each chapter of the UK NEA Technical Report begins with a set of Key Findings. Adopting the approach and terminology used by the Intergovernmental Panel on Climate Change (IPCC) and the Millennium Ecosystem Assessment (MA), those chapters that present the existing evidence base (Chapters 3–21) also include an indication of the level of scientific certainty of each finding. The 'uncertainty approach' of the UK NEA consists of a set of uncertainty terms derived from a 4-box model and complemented, where possible, with a likelihood scale (see below). Estimates of certainty are derived from the collective judgement of authors, observational evidence, modelling results and/or theory examined for this assessment.

In this annex, the Key Findings from the Biodiversity (Chapter 4), UK NEA Broad Habitats (Chapters 5–12) and ecosystem services (Chapters 13–16) chapters are presented. Throughout, superscript numbers indicate the estimated level of certainty for a particular key finding:

1. *Well established:* high agreement based on significant evidence
2. *Established but incomplete evidence:* high agreement based on limited evidence
3. *Competing explanations:* low agreement, albeit with significant evidence
4. *Speculative:* low agreement based on limited evidence



a. *Virtually certain:* >99% probability of occurrence
b. *Very likely:* >90% probability
c. *Likely:* >66% probability
d. *About as likely as not:* >33-66% probability
e. *Unlikely:* <33% probability
f. *Very unlikely:* <10% probability
g. *Exceptionally unlikely:* <1% probability

Certainty terms 1 to 4 constitute the 4 box model, while a to g constitute the likelihood scale.

Biodiversity in the Context of Ecosystem Services (Chapter 4)

The term 'biodiversity' describes the diversity of life on Earth. Diversity can occur at a number of levels of biological organisation, from genes, through to individuals, populations, species, communities and entire ecosystems[1].

Biodiversity underpins all ecosystem services. Biodiversity plays a wide range of functional roles in ecosystems and, therefore, in the processes that underpin ecosystem services[1]. Examples range from the roles bacteria and fungi play in nutrient cycles which are fundamental processes in all ecosystems, to particular animal groups, such as birds and mammals, which are culturally important to many people. Ecosystem functions are more stable through time in experimental ecosystems with relatively high levels of biodiversity[2]; and there are comparable effects in natural ecosystems[c]. Taken together, this evidence shows that, in general terms, the level and stability of ecosystem services tend to improve with increasing biodiversity.

Biodiversity plays a wide range of roles in UK ecosystem services. All ten of the ecosystem services that are important in a UK context are underpinned by a range of biodiversity groups. The number of biodiversity groups playing an important role varies between ecosystem services: water quantity (3/17 of biodiversity groups); socially valued landscapes and waterscapes (6/17 groups); crops, plants, livestock and fish (11/17 groups); and wild species diversity (all 17 groups). The role of different biodiversity groups varies between ecosystem services. Microorganisms, fungi and plants play a role in underpinning all provisioning and regulating services; vertebrate groups contribute to all cultural services, but they only play a role in 25% (2/8) of the provisioning and regulating services.

Biodiversity is a key component of multifunctional ecosystems. The importance of managing ecosystems to provide multiple services and associated values (so-called 'multifunctional ecosystems') is becoming increasingly recognised both globally and in the UK. The sensitivity of UK ecosystem services to changes in a range of biodiversity groups implies that achieving this multifunctionality will require management measures to support a wide range of biodiversity groups.

Significant biodiversity loss has been documented in the UK over the last 50 years, but monitoring data for a number of biodiversity groups is poor, precluding an assessment of status and trends. The quality of monitoring data in the UK varies between biodiversity groups. For some biodiversity groups, such as marine plankton, land plants, some invertebrate groups, fish, birds and mammals, national-scale data on abundance and range exist for a timeseries of 10–20 years. These datasets show clear patterns of biodiversity change. The quality of monitoring data across UK biodiversity groups increases in relation to their cultural importance. As a result, there are only limited data available on several biodiversity groups, such as microorganisms and fungi, which underpin provisioning and regulating services, precluding an assessment of their status and trends.

Relating changes in UK biodiversity to changes in ecosystem services can be problematic due to a lack of data on associated values and benefits. Interpreting the impact of even well-established trends in UK biodiversity on associated ecosystem services can be problematic where data on values and benefits are lacking. For example, we lack quantitative data on cultural services, so we are currently unable to assess the magnitude of changes in cultural services associated with well-established changes in bird populations. In contrast, specific, well-established biodiversity trends linked to provisioning and regulating services can have clear implications for service provision. For example, declines in the abundance of commercially important marine and freshwater fish species lead directly to a reduction in the output of provisioning services.

Land use change and pollution have been the major drivers of change across biodiversity groups in the UK. Land use change is considered a significant driver of change across all UK biodiversity groups associated with terrestrial and freshwater ecosystems, and for marine groups affected by activities on land. For example, recent evidence suggests that about 67% of 333 farmland species (broadleaved plants, butterflies, bumblebees, birds and mammals) were threatened by agricultural intensification in the year 2000. Pollution impacts reflect a range of human activities including diffuse pollution from agriculture, point source pollution from urban ecosystems, and air pollution (e.g. acid rain).

There is a cultural divide among biodiversity groups and associated ecosystem services in the UK. On one side of this divide are culturally important biodiversity groups; on the other side are biodiversity groups that underpin provisioning and regulating services. For several culturally important biodiversity groups, status and trends are well-established, but data on associated cultural services are frequently lacking. This makes it difficult to quantify the impact of biodiversity change on cultural services. For provisioning and regulating services, quantitative data on changes in the services themselves are often available, but status and trend information for associated biodiversity groups is considered poor. This makes it difficult to understand the role biodiversity plays in changes in associated provisioning and regulating services. Bridging this cultural divide represents a major research and policy challenge.

Mountains, Moorlands and Heaths Key Findings (Chapter 5)

Mountains, Moorlands and Heaths (MMH) cover about 18% of the UK and comprise the great majority of our near-natural and semi-natural habitats and landscapes. Most occur in Scotland (3.4 million hectares (ha)) where they make up 43% of the land surface area, followed by England (693,000 ha), Wales (246,000 ha) and Northern Ireland (228,000 ha), representing 5%, 12% and 12% of the land surface respectively. While Mountains represent some of our least human-influenced ecosystems, the extent and condition of our Moorlands and Heaths have been shaped by, and continue to be dependent on, a range of human activities.

Substantial changes to the extent, condition and use of MMH habitats have taken place since 1945[1]. The greatest losses in extent have been for Bog, and upland and lowland heathland. Much of the once moss-dominated mountain habitats in Wales and England has been converted to grassland. Such losses have been limited during the last two decades. Nonetheless, there is widespread evidence of long-term reductions in habitat condition, notably: greater peat erosion; loss of structural diversity; decreases in species richness; and the expansion of grasses at the expense of moss and dwarf shrub-dominated communities. The economy in MMH areas has shifted from one based largely on farming to one where tourism and recreation are also important. Grouse and deer management continue in the uplands, although associated management practices, such as burning and predator control, have come under increasing scrutiny. More traditional forms of land management have largely ceased in most lowland heaths, except when carried out for conservation purposes.

The key drivers of change in the extent and quality of MMH habitat since 1945 have been afforestation, agricultural development, changes in grazing pressures, airborne pollution and, to a lesser extent, climatic changes[2]. Almost invariably, MMH habitats have been affected by multiple pressures; a combination of sheep-grazing and nitrogen deposition, for example, may provide the best explanation for the replacement of dwarf shrub and moss communities by grasses. The changes in land use reflect shifts in markets towards the exploitation of provisioning services (i.e. food, timber and energy) at the expense of other services brought by MMH habitats. Economic reasons also explain the abandonment of many lowland heaths. The impacts of these factors have been moderated by cultural pressures and a number of policy mechanisms, such as nature conservation and pollution control schemes, that do recognise the wider values of MMH.

About 70% of the UK's drinking water is sourced from MMH, and these habitats buffer water quality against the effects of atmospheric, diffuse and point source pollutants[2]. The high quality water that drains from upland environments sustains healthy aquatic ecosystems and provides drinking water to the majority of UK water customers. The soils and biota of intact MMH ecosystems can retain a significant proportion of airborne pollutants, thereby reducing pollution runoff into freshwater habitats and the drinking water supply.

About 40% of UK soil carbon is held by MMH, mainly in upland peaty soils. This presents opportunities for short-term reductions in UK carbon dioxide emissions, both through reducing ongoing losses of soil carbon and further sequestration[2]. Any reduction in the volume of peat through its extraction for use as fuel or soil improver, or through the erosion of degrading peat, represents an exacerbation of current carbon dioxide emissions to the atmosphere. Active restoration of Moorland, notably 'degraded' blanket bog, should enhance its capacity for carbon storage and some sequestration.

Mountains, Moorlands and Heaths are nationally treasured landscapes[1] which provide breathing spaces for people[2]. They are particularly cherished for their 'wildness' and as sources of inspiration. Recreation and tourism make significant contributions to their total economic value; their 'non-use' or existence value is also high. The majority of UK National Parks are located within MMH habitat; in England alone, these receive 69.4 million visitor days per year.

Steeped in history, MMH are important cultural landscapes[1]. Moorland and Heath habitats are shaped by society's long-term and continuing use of the land, and underpin livelihoods, as well as creating distinctive cultural identities and a sense of place. Mountain landscapes are often part of iconic imagery that is used to convey a national or regional sense of identity. The relatively low levels of physical disturbance (e .g. ploughing, building) makes them valuable sources of palaeo-environmental and archaeological evidence of past landscapes, management and culture.

Mountains, Moorlands and Heaths are of great importance for biodiversity: large parts have national and international conservation designations[1]. Whereas lowland heaths are highly fragmented, upland MMH habitats form the largest unfragmented semi-natural landscapes of the UK and are a refuge for many species that used to occur throughout the country. Due to a long history of deforestation, grazing and, more recently, grouse moor management in the uplands, UK MMH contain the majority of the world's heather-dominated landscapes. The blanket bogs and oceanic mountain habitats are also of international importance. They provide a home to some of the UK's rarest species, and communities comprise a unique mixture of temperate, alpine and arctic species.

Mountains, Moorlands and Heaths are highly multi-functional, providing different ecosystem services to different people in different places and times[1]. Some of these provide synergistic opportunities such as management for carbon storage, biodiversity and water quality. Others inevitably lead to trade-offs between ecosystem services where the provisioning of different services is mutually exclusive. Given the multi-functional nature of MMH habitats, the continued development of the evidence base must better take into account the (often contradictory and dynamic) objectives of beneficiaries if it is going to inform on sustainable management strategies in the future.

Semi-natural Grasslands Key Findings (Chapter 6)

Semi-natural Grassland has greatly declined in area since the 1945, with losses of around 90% in the UK's lowlands. Currently, only 2% of the UK's grassland area comprises high diversity (Biodiversity Action Plans (BAP) Priority Habitat) Semi-natural Grassland. Two separate studies show a 97% loss of enclosed Semi-natural Grasslands in England and Wales between 1930 and 1984, and an 89% loss of lowland Semi-natural Grassland in Wales between the 1930s and 1990s[1]. Losses continued throughout the 1980s and 1990s[1], with regional English studies indicating declines in specific lowland grassland types ranging from 24% to 62% over various timescales within this period. There are few trend data for Scotland or Northern Ireland, but the scale of loss across the lowlands of these countries is similar to that reported for England and Wales[c]. Changes in upland Acid Grassland since 1945 are poorly documented.

Since 1945, agricultural improvement was the major driver of the loss of Semi-natural Grassland. Technological advances and incentives drove the conversion of high diversity (BAP Priority Habitat) Semi-natural Grasslands to either 'improved grasslands' or arable land. Today, however, agricultural improvement has decreased in importance as a driver as much Semi-natural Grassland is now protected; for example, in England, 68% is within Sites of Special Scientific Interest (SSSIs) and, in Wales, 52% is within National Parks. There is now evidence for a number of other drivers which continue to cause habitat and species loss in Semi-natural Grassland, particularly nitrogen deposition, inadequate management and habitat fragmentation; although their relative effects are poorly quantified, they are widely recognised as the primary drivers[2]. In the uplands, forestry has been, and continues to be, a major cause of the loss of Acid Grassland, although the Scottish Forestry Strategy aims to plant woodland on 270,000 hectares (ha) of 'unimproved grassland'.

The loss in area of Semi-natural Grassland has slowed substantially over the last decade. The Countryside Survey 2007 showed that there was generally no change in area of Acid, Neutral and Calcareous Grasslands in each of the UK countries between 1998 and 2007[1]. However, a few habitats did show some changes in certain countries over that time period; in particular, Acid Grassland increased in extent in the uplands of both Scotland (+9%) and Wales (+7%). The slowed decline is due to the improved protection, restoration and re-creation of grasslands through, for example, agri-environment schemes[c]. Conservation management is important to maintain the quality of Semi-natural Grasslands[1]; for example, only 21% of English non-SSSI Semi-natural Grasslands were found to be in favourable condition, whereas the management of Scottish SSSI lowland grasslands increased the amount of sites in favourable or recovering condition from 45% in the early 2000s to 71% in 2010. The cause of the increase in extent of Acid Grassland is less clear, but may be a continuing impact of overgrazing and degradation of upland heather moorland[d].

Semi-natural Grasslands are a vital part of the UK's cultural landscape and provide associated services. Most are remnants of traditional farming practices and are the product of thousands of years of human interaction with land and nature. Humans highly value Semi-natural Grassland species and landscapes[1] as shown by the conservation designation afforded to many of these habitats in the UK. Semi-natural Grasslands provide habitat for important and rare species[1]. Of the 1,150 species of conservation concern named in the UK Biodiversity Action Plan (UK BAP), lowland Semi-natural Grasslands are home to 206 UK BAP priority species, while upland Semi-natural Grasslands are home to 41. The UK's National Parks are valued for their greenspace, health, recreation, education and cultural opportunities, and all contain significant areas of Semi-natural Grassland[1]. Calcareous Grassland is the major habitat of the new South Downs National Park. A 2003 study showed that there were about 39 million visitor days per annum to the South Downs and these visitors spent £333 million.

Livestock production is low in Semi-natural Grasslands[1], leading to pressures on land use. The annual hay yield for a range of UK lowland Semi-natural Grasslands has been estimated as 2–8 tonnes per hectare (t/ha), which amounts to less than 30% of the dry matter usually obtained in silage over a year from agriculturally improved grassland. The addition of fertilisers increases yearly dry matter yields to about 10–12 t/ha. Upland Acid Grasslands have similarly low yields of about 1.5–5 t/ha, which compares unfavourably to the average of 8 t/ha for reseeded upland grasslands. Digestibility and nutrient content are also lower in forage from Semi-natural Grasslands compared to improved grasslands[1]. It has been suggested, however, that livestock grazing on species-rich pasture produce better quality meat than those on species-poor grassland, having, for example higher concentrations of nutritionally beneficial omega-3 fatty acids[4].

Biodiversity is positively related to many ecosystem services provided by Semi-natural Grasslands. Other than livestock production, many ecosystem services are higher in semi-natural than in agriculturally improved grasslands, and this can be linked partially with the higher plant richness[1]. The Countryside Survey 2007 showed that, within the top 15 cm of soil, Acid Grassland (82.3 t/ha) has the highest carbon stock of any UK NEA Broad Habitat. Although the stock for Neutral Grassland (62.4 t/ha) is lower, it is above that for Improved Grassland and Arable and Horticultural land. Acid and Neutral Grasslands contain 293 teragrams of the UK's carbon store in the top 15 cm of their soil. Semi-natural Grasslands have high invertebrate abundance and diversity, and may provide pollination and pest control services by the spread of insects to agricultural areas[c]. However, declines in bumblebees since the 1960s are linked to declines in key Semi-natural Grassland plants[1].

Semi-natural Grasslands present opportunities for delivering multiple services while requiring relatively low energy inputs. In contrast to Improved Grassland and Arable and Horticultural land, low input Semi-natural Grasslands generally: store greater densities of carbon and produce less nitrous oxide; produce less methane due to their lower stocking densities; allow greater water infiltration rates and enhanced storage (which should aid flood prevention); and experience less pollution because of the low fertiliser input[2]. Nutrient cycling also seems to be more efficient in unimproved grasslands. Enhancement of plant richness within Semi-natural Grasslands can also increase production in the absence of fertilisers[a]; for instance, one experiment showed a 40% difference in hay yield between species-rich and species-poor plots. Therefore, low input, high service-providing Semi-natural Grasslands form an alternative land use to high input agriculture, albeit with lower overall animal production[a].

Agri-environment schemes are critical to maintain and enhance the biodiversity and ecosystem services of Semi-natural Grassland. Maintenance of the biodiversity and cultural value of Semi-natural Grassland requires low intensity management related to traditional farming[1]. Restoration of Semi-natural Grassland from, for example, arable and improved grassland, is well-researched and will be critical to prevent further biodiversity loss through habitat fragmentation, and to improve certain services[1]. Maintenance, recreation and restoration are delivered mostly through the country-based agri-environment schemes. For instance, the Tir Gofal scheme in Wales currently has 35,258 ha of Semi-natural Grassland under maintenance options and 1,985 ha being restored. Such protected and restored Semi-natural Grasslands also have the potential to provide recreation and tourism services (particularly if rare livestock breeds are used), and pollinator and pest control services for adjacent intensive farmland[c].

Enclosed Farmland Key Findings (Chapter 7)

Enclosed Farmland is a vital habitat in the UK in terms of food production and the provision of landscape, recreation and other cultural benefits[1]. However, it also imposes important negative effects on the UK, including greenhouse gas emissions, diffuse water pollution and losses to biodiversity[1]. The challenge for the future will be to enhance the multiple ecosystem services that Enclosed Farmland provides despite a rapidly changing environment.

Enclosed Farmland is managed largely for food production. Changes in this habitat are driven mainly by changes in technologies, markets and policies. Climate change[a] and greater cultivation of bioenergy crops[c] are likely to become important drivers in the future[c]. Arable and Horticultural land occupies an estimated 19% of the UK land area (concentrated in eastern England) and Improved Grassland a further 21% (concentrated in the wetter, western parts of the UK)[1]. The 20th Century saw a trend for specialisation and landscape homogenisation, which was driven by mechanisation, markets and policies, among other factors[1]. Nevertheless, the area of enclosed grassland increased by 5.4% between 1998 and 2007, due to agri-environment and former set-aside schemes, which restored some landscape diversity[1]. The length of hedgerows in Great Britain fell from an estimated 624,000 km in 1984 to 506,000 km by 1990[1]. This loss was caused more by poor management than by outright removal, and was largely stemmed by policy changes[a]. The area of farm woodlands in the UK increased from 280,000 ha to 700,000 ha between 1981 and 2008[1]. Pond numbers and quality have declined, especially in arable areas[a]. Climate change and increasing pressure on water supplies are expected to influence land management in the future through both mitigation and adaptation measures[a], including planting an estimated 350,000 ha of perennial bioenergy crops[c].

Provisioning is the major ecosystem service provided by Enclosed Farmland, underpinning the UK agri-food sector, which contributes more than 6% of UK GDP[1]. Until the 1990s, levels of agricultural production increased greatly, causing an increase in external environmental costs and at the expense of other ecosystem services[1]. The increases in total agricultural productivity slowed during the 1990s, and hence the deterioration in other ecosystem services was reduced[b]. Production has increased since 1945, driven by new technologies and supported by deliberate policy interventions; for example, wheat yields increased from 2.5 tonnes per hectare per year (t/ha/yr) in 1940 and have stabilised at around 8 t/ha/yr since 2000[1]. The value of many UK agricultural products fell in the late 1990s, but recently rose again. Self-sufficiency in production of indigenous foods increased from 30% to 40% in the 1930s, and is now 73%[1].

The contributions of the habitats of Enclosed Farmland to regulating services have often been negative, but are improving[2]. Levels of carbon in Arable and Horticultural soils fell between 1998 and 2007, while stocks under Improved Grassland remained steady at 61 t/ha[2]. The burden placed by agricultural inputs on regulating services through local and exported pollution is declining as nutrients are used more efficiently and livestock numbers fall[b]. For example, absolute values of non-carbon dioxide greenhouse gas emissions from UK agriculture have fallen by 19% since 1990, although they still accounted for 45% of the UK total in 2006[2]. Similarly, over 91% of UK ammonia emissions come from agricultural sources, and were estimated at 0.29 megatonnes (Mt) in 2007, compared to the 1990 estimate of 0.36 Mt[2]. Reductions in fertiliser use are contributing to falls in nitrate levels in rivers[a]. Pollination and biological pest control are provided by many invertebrates of Enclosed Farmland. However, numbers of honey bee colonies in England have declined by 54% since 1985[1]. Little is known of national trends in populations of biological control agents, nor of the relationships between the various organisms providing regulating services and crop yield.

Millions of people enjoy the cultural benefits of Enclosed Farmland landscapes and their associated species[1]. Many Areas of Outstanding Natural Beauty and National Parks contain areas of Enclosed Farmland, and some landscapes are characterised by their patterns of crops, grass, woodlands, linear features and farm buildings[1]. The UK's farmland provides health benefits in terms of both the kind of food produced and opportunities to exercise within it[2]. Many species of plants, birds, invertebrates and mammals are directly associated with farmland cultural services[1], although quantitative data are lacking on their values and benefits. During the 20th Century, agriculture was associated with major declines in the diversity and numbers of plants, terrestrial invertebrates and vertebrates; for example, by 2000, the numbers of specialist farmland birds had fallen to 40% of their 1970 levels, and have they have fallen a further 4% since then[1]. Only 26 out of 710 Areas/Sites of Special Scientific Interest on Enclosed Farmland are in favourable condition[1]. The UK's agricultural sector employs 470,000 people today, which is fewer than 2% of the workforce and half the number employed in 1973[1].

Many interactions between provisioning and other ecosystem services are negative, partly because of releases of nutrients from agriculture as greenhouse gas emissions and diffuse pollution, and partly because of competition between crops and other habitats and taxa[2]. Better management of nutrients at crop, farm and catchment scales will improve regulating services without affecting food production[a]. However, productive agriculture involves removing weeds and pests, and simplifying landscapes, with inevitably negative consequences for biodiversity[1]. Extensive agriculture cannot meet all the UK's food production needs[3], so delivering both food and other ecosystem services requires the management of parcels of land for different purposes, from field to catchment scales[c]. Even then, it is not known whether the demand for ecosystem services can be met. Targeted regulations and guidance are being used to enhance levels of ecosystem services with some success; for example the control of diffuse water pollution[2]. Proposals to increase the area of bioenergy cropping will affect food production unless grown on poor quality farmland[3].

Agriculture in the UK needs to: produce more food and energy; be more efficient in terms of resource utilisation; better provide ecosystem services other than production; and be resilient to climate and other changes[1]. Low-input agriculture provides higher levels of many services per unit area, but cannot meet expected requirements for food production, unless demand for food and energy is also met in other ways[1]. There is scope for increasing the productivity of food production both per unit area and per unit of resource, while the diversification of crop types and using trees or housing to create cooler conditions for livestock will help to manage the risks of climate change[b]. The volatile and complex nature of regulations and markets makes delivery of other ecosystem services difficult[1]. Values for such services are changing rapidly, and it is not clear whether agri-environment schemes are cost-effective mechanisms for delivering all ecosystem services from Enclosed Farmland[c].

New research is needed to discover ways to enhance other ecosystem services while continuing to increase food production[1]. Some of this research should focus on traditional agricultural areas, such as breeding[1]; whereas some may be required in newer areas, such as the manipulation of biogeochemical processes through an improved understanding of soil function[c]. We need more information on how ecosystem services interact if we are to generate optimum farmed landscapes[1]. In particular, we lack information on the contribution of regulating services to food production[1]. In many cases, we only have access to proxy data, for example, declining pollinator numbers rather than the impacts of those declines on food production[1]. This is because the critical experiments are difficult and expensive to conduct at appropriate scales. It may not be possible to meet future demands for all ecosystem services[c]. Public engagement is needed to establish priorities, values and mechanisms for the delivery of ecosystem services from Enclosed Farmland, not least because the full cost of these services may prove far greater than allowed for in current policies and markets[c].

Woodlands Key Findings (Chapter 8)

Since 1945, the area of Woodland has doubled to cover 12% of the UK, but still remains well below the European Union average of 37%[1]. Much of this increase is due to afforestation for timber production, leading to the dominance of coniferous species. These comprise 81% of current Woodland in Scotland, 55% in Wales and 35% in England. Recently, more broadleaved species have been planted, resulting in an increase of 6.9% in the area of Broadleaved Mixed and Yew Woodland in the UK between 1998 and 2007.

There is no primary Woodland in the UK; all remaining Woodland has been influenced by human activities[1]. Nevertheless, the Woodland that remains contains significant biodiversity: a quarter of all UK Biodiversity Action Plan priority species are associated with trees and woods. Trends in the condition of habitats and species vary, but that of woodland Sites of Special Scientific Interest and seven priority native woodland habitats is improving. Short-term trends can be misleading, however [2]. Recent plantations gain native species, albeit with different assemblages from those of semi-natural woods[c].

Many factors, at all scales, effect change in Woodland ecosystems. Key drivers include climate change, pollution, government policy on land use, society, global trade and domestic markets, and the endogenous dynamics of ageing Woodland. Although recent climate change has had little effect on woodland structure and composition, mobile species, such as insects and birds, have shown range changes, and increasing temperatures have led to faster tree growth and altered phenology in some areas[2]. Despite recent reductions in emissions, nitrogen deposition and ozone levels are still above 'critical loads' for habitats such as UK Atlantic Oakwoods. Wild herbivores, particularly deer, have increased in number over the past 30 years to the detriment of woodland habitats[1].

Timber production is an important provisioning service from woodlands. Domestic production has increased from an estimated 4% in the 1940s to 20% of UK consumption of timber, pulp and panel products today[1]. In 2009, 8.5 million green tonnes of softwood was produced in the UK—approximately 60% of annual growth increment—and production is predicted to rise to 11–12 million tonnes in the 2020s. A total of 0.4 million tonnes of hardwood were produced from broadleaves—about 20% of annual growth increment. Non-timber products from woodlands can also be important; for example, game shooting is estimated to contribute £640 million per annum to the UK economy[2].

Woodlands are highly valued by people for social and cultural services[2]; there are approximately 250–300 million day visits to woodlands per year. Woodland includes nearly 5,000 Scheduled Ancient Monuments, plus many areas managed for geological study. The social and environmental benefits of woodlands in Great Britain (GB) were valued in 2002 at more than £1.2 billion per annum (at 2010 prices), with the landscape value of woodland estimated at £185 million (2010), and recreational visits valued at £484 million (2010). However, only 55% of the population has access to woods larger than 20 ha within 4 km of their home.

Carbon sequestration is one of the most important regulating services provided by Woodlands[2]. The total carbon (C) stock in UK forests (including soils) is around 800 megatonnes (Mt) (2,900 Mt of carbon dioxide (CO_2) equivalent), and is estimated to be a further 80 Mt C in timber and wood products. The strength of the UK forest carbon sink increased from 1990 to 2004, but may now start to decline due to a fall off in planting rates in the last 20 years and harvesting of mature trees. At peak growth, coniferous forest can sequester around 24 tonnes of CO_2 per hectare per year (t CO_2/ha/yr), with a net long-term average of around 14 t CO_2/ha/yr. Rates of around 15 t CO_2/ha/yr have been measured in oak forest at peak growth, with a net long-term average likely to be around 7 t CO_2/ha/yr.

The social value of net carbon sequestration by UK Woodlands is currently at least double the market value of wood production per hectare; and the total value of net carbon sequestration by UK Woodlands planted after 1921 increased more than six-fold over the period between 1945 and 2004, falling thereafter[2]. Carbon sequestration currently has the highest annual social value of the Woodland ecosystem services considered; however, as it remains largely a non-market value, there is little incentive for landowners to increase its provision or to maintain existing carbon storage at present.

Forest policy and Woodland management have changed over time as different goods and services have been required[1]. There are both trade-offs and synergies between goods and services produced by Woodlands. The diversification of forest structure for biodiversity benefits may improve cultural services (including aesthetics), while increases in forest cover may benefit carbon regulation and flood regulation. However, maximizing provisioning services through the use of highly productive species and intensive site treatments may have negative effects upon the value of woodland for biodiversity and for cultural services.

A spectrum of techniques within a framework of sustainable forest management can deliver different goods and services[2]. Certification schemes encourage appropriate action. Around half of the UK's Woodlands are certified under independent sustainability assessment schemes. There are multiple spatial (and temporal) scales at which choices can be made, limited evidence for some of the consequences, and a variety of planning frameworks to assist with choices. Achieving coordinated action across multiple ownerships at broad scales is challenging, but has become the target of recent forest policy and research; coordination across land uses to secure integrated landscapes now needs to be pursued.

Freshwaters – Openwaters, Wetlands and Floodplains Key Findings (Chapter 9)

Rivers, lakes, ponds, groundwaters and wetlands provide major services, but their benefits are inadequately identified and valued[1]. This has resulted in habitat losses that are among the fastest in the UK. When managed appropriately, Freshwaters should transport water, matter, energy or organisms within and between terrestrial systems, riparian zones, estuaries and near-coastal waters. They provide: consumptive and non-consumptive uses of water; organisms for food, recreation and conservation; and energy. They can regulate flooding, erosion, sedimentation, local climates and water quality, while facilitating the dilution and disposal of pollutants. They support dispersal through, and resilience in, adjacent ecosystems (for example, though water or nutrient supply), and act as a medium for key biogeochemical cycles. They have large cultural value for recreation, tourism, education, heritage and as inspiration for arts and religion. Costs for people include their role in waterborne diseases and their propensity to flood low-lying infrastructure.

Rivers, lakes and wetlands are present throughout UK landscapes. Historically, they were highly connected to each other and to their catchments, but are now fragmented and disconnected[1]. There are more than >389,000 km of rivers in the UK, almost 6,000 permanent large lakes covering around 200,000 ha and nearly half a million ponds (covering less than 2 ha); but the true extent of the UK's wetlands is less well defined. Distribution is also uneven, with Scotland holding more than 90% of the volume and 70% of the total surface area of Freshwater in the UK – it has over 30,000 open water bodies, as well as some 40% of active raised bog. The llynnau of North and mid-Wales and the tarns of Cumbria form distinctive clusters of natural lake systems on the west coast. In central and southern England, where natural lakes are rare, artificial reservoirs provide important standing water habitats. Natural, small water bodies are also widespread, such as the pingo ponds of the Norfolk and Suffolk Breckland and the smaller Cheshire and Shropshire meres and pools. There are at least 392,000 ha of fen, reedbed, lowland raised bog and grazing marsh, but the true extent is uncertain. Floodplains are the most widespread (963,700 ha) and productive Freshwater systems and are shaped by the natural dynamics of river flows. However, they have been extensively impacted by engineering, including flood embankments and channel modifications, so that over two-fifths (42% by area) of all floodplains in England and Wales (defined by the 100-year flood envelope) have been separated from their rivers.

No completely pristine Freshwater ecosystems remain in the UK; almost all have been impacted by human activity, including drainage, changes in land cover and atmospheric deposition, and most are now managed to a lesser or greater extent[1]. Habitat fragmentation and degradation have reduced their service value[2]. However, while the least damaged are expected to provide the most natural service profile[2], some managed Freshwaters and artificial habitats can be locally important, such as chalk rivers, reservoirs, fenlands, water meadows and ponds[2]. More information is still required about ecosystem services provided by Freshwaters under various levels of management or condition.

There is considerable uncertainty about how ecosystem services are related to ecosystem structure, functioning, habitat type, size, spatial extent and fragmentation[1]. The functions Freshwater ecosystems provide depend on their type, size, condition and position within a catchment[2]. Water connects diverse habitat types along gradients through catchments (with interaction in both directions) via exchanges between the atmosphere, uplands and lowlands, terrestrial and aquatic systems, fresh and saline waters, and between surface and groundwater. We lack precise knowledge of the importance of connectivity, and, in particular, the role of the many small wetlands or water bodies whose number remains poorly estimated and location often unrecorded[1].

Despite the multiple benefits of naturally functioning wetlands and floodplains, many have been degraded, lost or converted (for example, by drainage) to other uses designed to deliver specific services incompatible with their original condition (such as crop production)[1]. Where wetlands are intact, the major reason has been for nature conservation, often due to the important habitat they provide for birds. Wetlands comprise the largest proportion of Sites of Special Scientific Interest (SSSIs), but protection or management for the wide range of other benefits they provide to human well-being is only now beginning to influence policy and decision-making. The past focus on the conservation of species and communities now needs to be complemented with the maintenance of ecosystem functions if services are to be delivered in the future.

To date, our approach in the classification and mapping of different Freshwaters as 'priority habitats' does not necessarily indicate their actual or potential contribution to ecosystem services[2]. We have little idea about the actual areas of different Freshwater habitat required to provide a specified quantity and/or combination of services[2]. Evidence-based tools are becoming increasingly available to enable the assessment of the functioning of wetlands, together with their capacity to deliver ecosystem services[1]. New partnership concepts, such as the Association of Rivers Trusts, and the emergence of innovative implementation strategies, including covenants on land use and rewards for providing ecosystem services that serve the public good, offer considerable scope to recover previously impaired benefits, particularly at the local scale[1].

Rivers are among the UK's most extensively monitored habitats; systematic, long-term data are available from over 25,000 km of the channel network in England, Wales and Scotland. Rivers in urban or intensively farmed areas have significantly lower sanitary quality and elevated nutrients (e.g. nitrate greater than 5 milligrams per litre) than elsewhere. The chemical quality of rivers has been progressively improving since the 1980s, but trends are locally variable[1]. Since 1990, the biological and chemical classification of what were formerly the most polluted rivers in England and Wales has now improved[1], although the quality of some of the best Welsh rivers has recently declined for reasons that are unclear[2]. More widely, nitrate concentrations have increased and phosphorus is still a problem in some locations[1]. Some upland or western regions are still affected by diffuse agricultural pollutants, while biological recovery from acidification lags behind chemical recovery[1]. More than 50% of English and Welsh rivers have been modified physically[1]. The numbers of ponds are now increasing following losses prior to 1980, but, in many, water quality is poor and s declining, possibly due to increasing nutrient concentrations[2]. A similar pattern emerges for lakes, where evidence indicates pressures from water level regulation and catchment developments are compounding water quality issues resulting from excessive nutrient loads[2]. There has been very limited monitoring of lakes and wetlands (with local exceptions including the Lake District and East Anglian fens). Even where monitoring has taken place, it has generally not been oriented towards the assessment of ecosystem services. In Scotland, a change in the monitoring network in 2006 makes a similar overall trend assessment difficult, but up until that time, rivers and canals showed a gradual, continuous improvement[2]. Again, very little monitoring has been directed towards the assessment of ecosystem services.

Freshwater ecosystems appear particularly vulnerable to 'regime' shifts that, once incurred, can lead to large service losses which are difficult to restore[2]. Past adverse effects include acidification, impoundment, flow modification, eutrophication, siltation, habitat degradation, fragmentation, loss and drainage, toxic pollution, over-abstraction and invasion by non-native species[1]. New pollutants (e.g. endocrine disrupting substances, personal care products, nanoparticles, the effects of synthetic biology) are emerging issues for Freshwaters[2]. Urbanisation and climate change are likely to lead to increased water demand and lower resource availability, as well as increased pressure from saline intrusion on freshwater coastal habitats[2]. Climate change has also driven biologically significant water temperature increases of 1.5–3°C in many rivers over the past two decades, although the full effects on river biodiversity are, as yet, unclear[2]. In some catchments, juvenile populations of trout (*Salmo trutta*) and salmon (*S. salar*) have declined by about 50–60%, and there are major declines among other species, such as eels[2]. Invasive species of vegetation, fish, crustaceans and other organisms, including those causing diseases of wildlife, are of growing concern[2].

Throughout human history, the integrity of Freshwater ecosystems has been traded-off against specific management objectives, with little or no understanding of the true costs[2]. Along with wetland drainage, flood defence and the purposeful and accidental use of Freshwaters for waste disposal, such effects have led to degraded ecological quality, loss of asset value and adverse health impacts[2]. The largest potential synergies in the delivery of different Freshwater ecosystem services are likely to arise where surrounding habitats are managed positively to enhance service delivery; indeed, some agri-environment measures now emphasise the importance of protecting the land-water interface[2].

Understanding the linkages between physical, biogeochemical and ecological processes (from genes to ecosystems) that regulate the services of Freshwater systems remains a scientific challenge. Examples include: the role of Freshwaters in element cycles (e.g. carbon, silicon); the importance of microbial processes; the up- and down-scaling effects of modifications to catchments and flow regimes; the identity of critical ecosystem resources that underpin key services; and factors affecting resistance, resilience and critical thresholds to support service delivery. We also lack models predicting how Freshwater ecosystems may be altered by future environmental change and variability.

Only small proportions of wetlands and less than 1% of the UK's entire river length are part of formal protection networks[1]. Sustainable freshwater management will depend on better use of existing legislation, improved casework planning and better decision-support tools capturing ecosystem service delivery[2]. Key needs will include 'slowing-down' water, avoiding adverse runoff quality, and protecting sensitive ecosystem assets[2]. For wetlands, floodplains and catchments ecosystems, there is a need for improved inventory and assessment, including the ecosystem services and benefits they currently, or could potentially, provide[2]. Enhanced stakeholder and community involvement is an important factor in improved Freshwater valuation. Freshwater science is already highly inter-disciplinary, but further development to encompass socioeconomics will bring extra sustainability gains[2].

We need to restore and recreate Freshwater ecosystems in order to maximise and reap the benefits of the ecosystem services they provide[2]. Restoration may provide cost-effective solutions to the enhancement of key services such as flood risk reduction and water quality improvement[2]. There is a growing inventory of practical actions and experience throughout the UK which are improving both the technical knowledge base and our understanding of the operational, policy and governmental actions required to reverse the degradation of our Freshwater ecosystems[2].

Urban Key Findings (Chapter 10)

The ecosystem goods and services that could potentially be derived from Urban greenspace are substantial. In the past, the importance of these areas for the health and general well-being of society was not appreciated and their potential not realised[2]. It is not just the limited extent and variable quality of greenspaces, but also their spatial distribution, connectivity, functionality and accessibility that currently create barriers to their optimisation.

Access to Urban greenspace is essential for good mental and physical health, childhood development, social cohesion and other important cultural services[1]. More than 6.8% of the UK's land area is now classified as 'urban', with more than 10% of England, 1.9% of Scotland, 3.6% of Northern Ireland and 4.1% of Wales contributing to this habitat. Approximately 80% of the population resides in these areas, where the amount of mean accessible greenspace is 2 hectares (ha) per 1,000 people in England and 16 ha per 1,000 people in Scotland[2]. Deprived areas systematically fare worse in terms of quantity and quality of greenspace.

During the last three decades of the 20th Century, there was a decline in the condition and accessibility of Urban greenspace in the UK[2]. It is likely that the reduction in funding for public parks, the absence of any statutory parks services, and the sale of playing fields (approximately 10,000 between 1979 and 1997) and allotments (estimated at below 10% of peak levels) have all contributed to this decline. Evidence suggests that there has been some improvement since the work of the Urban Task Force. Local authorities, public bodies and over 4,000 community groups, many with National Lottery funding, have contributed to the refurbishment and renewal of many of these areas.

Greenspace within urban areas is not systematically monitored. Without such basic data the ecosystem services cannot be quantified[2]. There is no regular collection of data or centrally coordinated Urban greenspace database. Responsibilities are spread across a range of organisations, from different government departments and agencies to charities and private sector organisations, which collect extensive amounts of information but often using inconsistent typology at different temporal and spatial scales.

Provisioning services are limited and the majority of goods are imported; but there is evidence of changing attitudes towards urban food production[2]. In the early 1940s, gardens (covering 4% of England) and allotments, over half of which were in urban areas, provided 10% of all food production in the UK (1.3 million tonnes). Today, there is increasing interest in domestic production, with 33% of people now saying they grow their own food[c]. Per household, savings exceeding £1,000 per annum have been reported from allotments[c].

Many of the supporting and regulating functions that Urban soil could provide have been reduced and restricted[1]. Widespread sealing and degradation have resulted in Urban soil losing function and resilience, and has led to major hazards such as flooding. In London alone, it is currently estimated that 3,200 ha of front gardens have been paved, and, in Leeds, an estimated 75% of the increase in impervious surfaces that has occurred from 1971 to 2004 is attributed to the paving of residential front gardens[2].

Urban air quality has significantly changed over the last 60 years with consequences for clean air that extend far beyond the urban boundary[1]. Improvements in air quality arising from the national decline of sulphur dioxide and black smoke emissions (both have declined by more than 95% in London since 1962) are attributed to good regulation and enforcement, together with cleaner fuels. The growing significance in recent decades of nitrogen oxides, fine particles (PM_{10} and $PM_{2.5}$) and background ozone have largely been driven by changes in energy production and the rise in vehicle ownership.

Species respond differently to increasing urbanisation of a landscape and the form of that urbanisation[2]. Overall, the species that tend to disappear with urbanisation include habitat specialists, more area-demanding species (the patch size of greenspace tends to decline with urbanisation) and species typically associated with more complex vegetation structures such as forests. The species that tend to remain or increase in richness are more likely to be habitat generalists, less area-demanding species and edge specialists.

Urban ecosystem services could be significantly enhanced to improve climate mitigation and adaptation. Temperatures in cities are higher than in rural areas with consequences for human well-being and the environment[2]. London's maximum daytime and nocturnal Urban Heat Intensity can reach 8.0°C and 7.0°C respectively[2]. The process of urbanisation and development alters the natural energy balance, mainly due to the loss of cooling from vegetated surfaces when they are replaced by impervious materials used in construction of buildings and roads.

Trade-offs and synergies in ecosystem goods and services are complex, with scale a major issue in decision-making. As yet, they have not been widely investigated in the urban environment. For example, increasing vegetation cover in urban areas could reduce surface water runoff, decrease peak temperatures and the temperature-dependent formation of ozone and volatile organic compounds (VOCs)[2]. Conversely, increasing vegetation cover incurs maintenance costs, requires watering, is vulnerable to disease, can produce VOCs and would be expensive in city centres, the place where it would be likely to deliver the highest levels of ecosystem services and benefits.

Urban Greenspace is fundamental to sustaining urban life and, therefore, should be integral to the way in which it is planned and managed[1]. For example, the Thames Gateway Green Grid Network in South East England demonstrates the effectiveness of integrating multifunctional land use, connectivity and accessibility using an ecosystem services approach early in the planning process. While in Scotland, sustainable drainage systems (SuDS), which can substantially enhance ecosystem goods and services delivery, have already been incorporated into an estimated 80–90% of all new developments.

Coastal Margins Key Findings (Chapter 11)

The six Coastal Margin habitats (Sand Dunes, Machair, Saltmarsh, Shingle, Sea Cliffs and Coastal Lagoons) make up only 0.6% of the UK's land area, but are far more important to society than their small area might suggest. The total value of the ecosystem services provided by the UK's coast is estimated at £48 billion (adjusted to 2003 values), equivalent to 3.46% of Global National Income (GNI). As an island nation, coastal landscapes are part of our cultural heritage and sense of identity. The Coastal Margins are an interface between land and sea, and directly provide ecosystem services to adjacent terrestrial and marine habitats. The ecosystem services of greatest financial value are tourism and leisure (cultural) and coastal defence (regulating), but the relative importance of these services differs according to location.

Sand Dunes, Saltmarsh and Machair make up the greatest area of Coastal Margin habitats: approximately 70,000 hectare (ha), 45,000 ha and 20,000 ha respectively. However, except for protected areas, basic data on the extent of these habitats is lacking; for some, estimates of their total area vary by up to 50%. Overall, Coastal Margin habitats have declined by an estimated 16% since 1945[2] due to development and coastal squeeze, but this is poorly quantified. All habitats have been affected by coastal development for industry, housing and tourism. Sand Dunes and Saltmarsh have also been affected by agricultural development (including forestry). Although the introduction of greater statutory protection in the 1980s has slowed the rate of loss and fragmentation of many sites, Coastal Margin habitats are still being lost today[2].

Habitat losses due to sea-level rise have been relatively small so far, estimated at 2% over the past 20 years for Sand Dunes and 4.5% for Saltmarsh[2]. However, habitat losses are projected to reach 8% by 2060. Steepening of the intertidal coastal profile on soft coasts has been observed across the UK. Future losses will increase throughout the UK as storm erosion events increase in magnitude and sea-level rise further outstrips isostatic readjustment[2,b]; this issue is of particular concern where coastal squeeze operates, preventing land-ward migration of these habitats in response to sea-level rise.

The quality of Coastal Margin habitats has declined since the 1945[2]. Sediment supply has fallen and natural dynamics have been reduced due to decreased availability of post-glacial sediment, widespread installation of artificial sea-defence structures, and increased armouring of soft cliffs[1]. The proportion of early successional habitats has fallen – by up to 90% in some dune systems – while scrub and grassland have increased. This reduces the Coastal Margins biological and conservation interest, and may indirectly alter ecosystem service provision. It also restricts their capacity to adapt to climate change and sea-level rise. The principal causes of these changes include a decline in traditional forms of management, such as grazing (particularly in the south and east), an increase in nitrogen deposition speeding up plant growth and soil development, and early conservation efforts which often focused on stabilising these naturally dynamic systems.

Cultural ecosystem services provided by the coast are very important to the UK[2], with seaside tourism valued at £17 billion. The public values the coast highly: as living space; as a symbol of identity; for its scenery and wildlife; and for activities like walking, birdwatching, boating and outdoor sports. More than 250 million visits are made to the UK's coast per year, of which, around one-third are to natural habitats. Tourism patterns have changed in recent years, with day trips replacing overnight visits[1]. Overnight trips to the UK's seaside were worth £4.8 billion in 2009, while day visits were worth £3.9 billion in 2002. Moreover, overnight stays at the seaside exceed overnight stays in the rest of the UK's countryside and villages combined. These economic benefits are particularly significant in more remote areas. In Wales, in 2005, seaside tourism accounted for 42% of domestic tourism spend, supporting nearly 100,000 jobs and contributing £5 billion to income; the value of tourism to the Western Isles of Scotland is £49.9 million per year.

Coastal defence is the most important regulating service provided by Coastal Margins[1]. All habitats contribute to coastal defence either directly by dissipating or attenuating wave energy or indirectly through regulating sediment. Sand Dunes and Shingle provide direct protection as a barrier, while Saltmarsh primarily attenuates wave energy. Up to 50% of wave energy is attenuated in the first 10–20 m of vegetated Saltmarsh, reducing the size needed for landward defences; 84% of Essex seawalls rely upon fronting Saltmarsh to maintain defence integrity[1]. Sand Dunes protect residential areas and high quality farmland, particularly in North West England and along the Norfolk Broads, while Shingle protects parts of the south and south-east coasts[2]. The soft coasts provide an estimated £3.1–33.2 billion worth of capital savings in sea-defence costs in England alone.

Carbon sequestration rates are high in Saltmarsh, Sand Dunes and Machair due to rapid soil development or sediment accumulation[2]. Sand Dunes on the west coast of the UK store 0.58 to 0.73 tonnes carbon/hectare/year (t C/ha/yr), while Saltmarsh stores 0.64 to 2.19 t C/ha/yr. However, the net benefit to the UK is small due to the low total area of these habitats. Carbon stocks in Coastal Margin habitats are (conservatively) estimated to be at least 6.8 megatonnes of carbon. Provisioning services generally play a minor role in Coastal Margins, although Saltmarsh-grazed lamb and beef are premium products.

Coastal Margin habitats have high biodiversity and support a wide range of specialist and rare species[1]. This is reflected in the number of coastal sites designated for their biological importance. This diversity is partly dependent on natural dynamics forming a mosaic of habitats of different ages. This biological diversity contributes to the coast's cultural services and directly supports some regulating services; for example, Saltmarsh provides nursery grounds for many fish species including commercially important species such as sea bass (*Dicentrarchus labrax*) and herring (*Clupea harengus*). Coastal Margins provide important habitats for many bird species which provide a focus for nature-oriented visits to the coast[1]; at just four RSPB reserves, for example, such visits are worth £1.2 million. Sand Dunes, Machair, Saltmarsh, Shingle and Sea Cliffs support a wide range of natural pollinators, which, together with ground predators and parasitoids, may provide services of pollination and pest control to adjacent arable fields[4]. This may be of considerable local importance but, at the UK scale, the extent of this service is likely to be small.

The principal conflicts in Coastal Margin habitats occur between services associated with disturbance and those associated with stability. In general, the disturbance resulting from processes such as erosion and sediment transport provide essential dynamics in natural coastal systems. However, pressure for land, fixed human assets, and management requirements to maintain coastal infrastructure, such as ports, mean that this natural dynamism is often deemed unacceptable. Conflicts can also occur between biodiversity interest and use of these habitats for leisure and recreation. Nonetheless, there is potential to identify 'win-win' combinations of services. Synergies are complex and may not occur in the same place or time, for example: sediment transport benefits coastal defence down the coast; pollination benefits other Broad Habitats; property values are greater near the sea; and erosion may cause serious short-term loss, but benefit habitat creation in the longer-term.

Sustainable management of Coastal Margin habitats must be holistic, taking into account physical, chemical and biological processes, spatial and temporal scales, drivers of change, and cultural elements. Most large Coastal Margin sites are designated as Special Areas of Conservation (SACs) under the Habitats Directive, or are Sites of Special Scientific Interest (SSSIs); therefore, the protection and maintenance of the biodiversity, natural processes and geomorphological interest remain primary objectives. However, appropriate management may enhance both biodiversity and other services. Sustainable management options include:

- Allowing Coastal Margin habitats room to migrate inland with rising sea levels in order to mitigate coastal squeeze ('managed realignment'). In Saltmarsh, this has shown additional ecosystem service benefits compared with a 'hold the line' strategy, but the principles can be applied to the other Coastal Margin habitats too.
- Managing sediment supply by allowing erosion to contribute new sediment to the coast, and allowing natural transport processes to proceed where possible.
- Maintaining or encouraging natural formation of early successional habitats where these are threatened or have disappeared.

Implications for policy include:

- The Coastal Margin habitats are of high financial and cultural value to the UK, yet they often fall into the policy no-man's land between marine and terrestrial interests.
- There remain major knowledge gaps for Coastal Margins, including basic data such as extent and trends, particularly in Scotland. This needs to be addressed by unified and strategic data gathering across the UK to detect change in coastal sediments and habitats in order to inform adaptation strategies. Coastal Margins face major threats in the coming decades, particularly from sea-level rise and climate change, as well as pollution and continuing development pressures. These threats are exacerbated by the linear nature of the habitat, with pressures on every edge and very little safe, core habitat, except on the largest sites. Threats from sea level rise will be most acute on coasts with artificial sea defences.
- Coastal Margins need to be managed holistically, maintaining natural dynamics where possible and acknowledging the interdependence with other habitats, including the Marine environment.

Marine Key Findings (Chapter 12)

The diversity of organisms in Marine habitats provide a range of ecosystem services and benefits of significant value to UK society[1]. The benefits include food (fish, shellfish); reduction of climate stress (carbon and other biogas regulation); genetic resources (for aquaculture); blue biotechnology (e.g. biocatalysts, natural medicines); fertiliser (seaweed); coastal protection; waste detoxification and removal and disease and pest control; tourism, leisure and recreation opportunities; a focus for engagement with the natural environment; physical and mental health benefits; and cultural heritage and learning experiences. Energy from waves and tides and biofuels from macro- and microalgae are likely to be provided in the near future. Many of the benefits are accrued directly by coastal dwellers and visitors, but also indirectly by much of the UK's society[1,a].

Changes in sea temperature are likely to be affecting most Marine ecosystem services. These changes are already affecting food production, wildlife populations, such as seabirds, and possibly human health through the increase in optimum environmental conditions for outbreaks of pathogens[c]. Yet at the same time, climate change could bring increased benefits for the marine leisure and recreation industries because of the potential for warmer summers. Some of the effects of increases in sea temperature and those of heavy fisheries exploitation are difficult to distinguish from each other and are likely to have synergistic effects[c].

Climate change is changing species distribution. This is particularly evident in coastal intertidal species, plankton and fish, where long-term data is richest. Comparison of historic (since the 1950s) and present distribution and abundance of over 60 indicator species in the UK has shown some of the fastest changes in the abundance, range and population structures of marine species in the world. These changes have been related to recent, rapid climatic warming. In particular, several southern species of warm water intertidal invertebrates and macroalgae have considerably extended their ranges northwards along the Welsh and Scottish coastlines, and eastwards along the English Channel. Northern cold water species have shown a modest contraction in range and significant declines in abundance at sites close to their southern limits. These species-specific rates of change are driving alterations of community structure and function[1,a].

Human activities that affect the seafloor damage regulating and supporting services. Human activities that have a physical impact on the seafloor (e.g. trawl fishing, building offshore windfarms, aggregate extraction, coastal defences, ports and coastal developments) damage the benthic biota (species which live on the seabed) and their communities, and affect the regulating and supporting services that they provide. Usually the impacts are quite localised, but seabed trawl fishing activity, the most widespread of these activities, has the greatest impact[1,a].

Increasing activity in several economic sectors in the Marine environment is putting extra pressure on all sea shelf, coastal and estuarine habitats[c]. These sectors include marine renewable energy development, expansion in recreation and leisure activities, and port activities. Their impacts vary in spatial extent and importance, but are compounded by climate change. Human contamination of marine waters with a range of hazardous substances has been reduced through reductions in industrial effluent and improvements in sewage treatment infrastructure[1,a]; however, there are now concerns about more recently introduced chemicals, such as nanoparticles and pharmaceuticals, which pass through sewage treatment plants[c].

The quantity of wild fish caught in UK waters is insufficient to meet the UK demand for this food. Landings into UK ports of fish and other seafood declined steadily from 1.2 million tonnes wet weight in 1948 to 0.5 million tonnes in 2000, but have remained steady since then. Since 1945, there has been an increased demand for fish in the human diet leading to the rise of aquaculture, particularly of finfish in Scottish waters and shellfish in English, Welsh and Northern Irish waters. There has also been a 46% increase in the volume of fish imported from overseas between 1998 and 2008[1,a].

The sustainability of food provision from Marine Habitats is threatened by overexploitation of fisheries; fishing is also damaging other Marine ecosystem services. Over the last 50 years, fishing activity has put significant pressure on living resources and habitats. Several fish stocks in the North Sea and Irish Sea are overexploited and are subject to recovery plans. Out of 18 indicator finfish stocks in UK waters, only 50% were considered to have full reproductive capacity and to be harvested sustainably in 2008, but this is an improvement from 10% or less in the early 1990s[1,a].

Water purification and breakdown of waste by ecosystems appears to be keeping pace with inputs in open shelf waters, although localised contamination and some eutrophication problems persist[1,a]. The waste processing and purification services widely provided by Marine habitats generally ensure that food provided by the sea is safe to eat and the water is clean enough to use for recreation, such as swimming, angling, scuba diving, and surfing[c]. In some coastal waters, such as estuaries, local contamination by diffuse pollution (e.g. agricultural fertiliser, urban runoff and synthetic chemicals) still exceeds the capacity of the ecosystem to remediate or assimilate it[c].

The UK's seas are important to people's quality of life but are less well protected than terrestrial environments[a]. The UK population has a strong affinity for the sea and has always derived inspiration from it. More people are using the sea for leisure and recreation, education, research and health benefits. Despite this, protection of the Marine environment falls short of that on land. For example, there are only 81 marine Special Areas of Conservation (SACs) out of a total of 621 designated under the Habitats Directive, and very few marine Sites of Special Scientific Interest (SSSIs). The 2009 Marine and Coastal Access Act signals an increasing awareness of how important Marine Habitats are to UK culture and society and will foster greater biodiversity protection[a].

Marine microbial organisms play a key role in cycling nutrients that are essential for other marine organisms and the services and benefits they provide[a]. Microbial processing of nutrients in the sediment depends on invertebrates disturbing and irrigating the sediment. Without this recycling, most nutrients would be lost from the ecosystem to the seabed as they would sink from the water column and then be buried[a]. In open water, planktonic coccolithophores make a major contribution to the global carbon sink[a]. Climate change may affect internal nutrient cycling by changing nutrient exchange processes between the open waters and the open ocean and altering water stratification, but the likely direction and extent of these changes is still poorly understood[c].

Many organisms create living habitats such as reefs and seagrass meadows. These can provide essential feeding, breeding and nursery space that can be particularly important for commercial fish species. Such habitats play a critical role in species interactions and the regulation of population dynamics, and are a prerequisite for the provision of many goods and services. Fishing at the seabed with trawl nets and dredging fishing gears severely damages living reefs and deep-sea corals, which are very slow-growing and, consequently, take a long time to recover. Boat anchoring, propeller scarring and channel dredging can damage shallow water and intertidal habitats. However, building coastal defences and offshore structures, such as wind turbines, oil platforms and reefs, provides artificial habitats which can have positive impacts, particularly for species usually associated with rocky environments[a].

Marine ecosystem services are strongly interlinked and their delivery can be damaged by fishing. Very similar ecosystem functions and biological activity underpin waste regulation, climate regulation and nutrient cycling. These functions also underpin cultural services, such as leisure and recreation, which depend on clean, functioning seas. Attractive seascapes, inshore fishing boats, and the local food provide, enhance local tourism and cultural services. Yet fishing also affects other components of the ecosystem, damaging food webs and seabed habitats. Hence, the provisioning service of fishing can negatively affect delivery of other services. For instance, seabirds and mammals are important for tourism and recreation, but compete with humans for fish as food or are trapped in fishing nets; this indicates a trade-off between food provision, cultural services and conservation[a].

Farmland food production and urban waste disposal may conflict with the delivery of ecosystem services and benefits in estuarine and coastal waters. Fertiliser use can increase food production, but excess nutrient run off the land into estuarine and coastal waters. These waters also receive significant amounts of other agrochemicals (e.g. pesticides, artificial growth hormones), microorganisms and urban surface waste water, thereby providing a cleansing regulating service for farmlands and urban habitats. However, excessive enrichment of water by nutrients can reduce the flow of oxygen and nutrients to the seabed, with a deleterious effect on the water quality and other organisms. The major pressures occur in the east, south and north-west of England. Here, some estuarine areas are nutrient-enriched and are at risk from, or currently affected by, eutrophication. Nevertheless, UK marine waters as a whole do not suffer from eutrophication[1,a].

The development of Marine Plans and designation of Marine Conservation Zones will incorporate the explicit objectives of sustaining and increasing ecosystem services and managing the use of marine resources sustainably. It is imperative that these plans consider the components of Marine habitats not only in terms of biodiversity and habitats, but also with regards to ecosystem functioning and the provision of ecosystem services and benefits. The use of monetary and non-monetary valuation of ecosystem services will aid the process of considering the impacts and benefits of development on Marine habitats[a].

The characteristics and biodiversity of a large proportion of UK subtidal Marine habitats is still unknown and not mapped; Marine ecosystem services are poorly quantified. We need to understand and measure the links between Marine biodiversity, ecosystem function and provision of ecosystem goods and services, and the effects of human impacts on these links. Although recent national assessments (e.g. Charting Progress 2, State of Scotland's Seas) have gathered a lot of evidence, extensive data gaps remain. Such knowledge would support more effective marine planning and licensing of activity in UK waters for the sustainable use of Marine habitats and the maintenance of clean, healthy, productive and biologically diverse seas[a].

Supporting Services Key Findings (Chapter 13)

Supporting services underpin the delivery of all other ecosystem services. Therefore, understanding their response to key drivers, such as climate change, land use and nutrient enrichment, is vital for the sustainable management of the UK's land and water resource. Supporting services include the ecological status of soil and water, and processes that drive the formation of soils, cycling of nutrients and fixation of carbon by plants. These are all strongly interrelated and, in many cases, underpinned by a vast array of physical, chemical and biological interactions. Our understanding of the ways that these interactions influence supporting services, and of the relative contribution of biological, chemical and physical factors, is generally limited.

The soils of the UK are diverse and relatively young as most of Britain was under ice or peri-glacial conditions until 10–15,000 years ago. Soils form slowly, but can be quickly degraded and lost[1]. Soil formation rates in the UK are 0.04–0.08 mm per year for mineral soils, which is less than 1 cm per century, although there is still a lack of data with which to formulate a truly accurate picture[2]. In actively growing bogs of good habitat status, peat formation is approximately 0.8 mm/yr, which is equivalent to a carbon accumulation rate of 0.5 tonnes carbon/hectare/year (t C/ha/yr). However, the average is probably closer to 0.1 t C/ha/yr given that many peatlands are not of good status[2]. Threats to soil formation include organic matter loss due to climate warming, inundation of coastal soils due to sea-level rise, erosion and compaction caused by intensive agriculture, and soil-sealing due to urbanisation[1]. There are many consequences of loss of soil for supporting, regulating and provisioning services.

The last 50 years have witnessed substantial changes in the nutrient status and pH of waters and soils, with likely consequences for the delivery of both regulating and provisioning services. One of the most dramatic trends in nutrient cycling has been the enrichment of terrestrial and aquatic habitats with nitrogen due to the use of nitrogen fertilisers to increase food production[1]. This has resulted in substantial changes in plant productivity, plant species diversity and composition, and an accelerated rate of nitrogen cycling[1]. Another major change in soils and waters is the recent decrease in acidity of surface soils and acid-sensitive waters due to a substantial decline in sulphate deposition and an increase in rainfall pH since the late 1970s[1].

Recent evidence suggests that there may have been a widespread decline in the availability of phosphorus across terrestrial and aquatic systems over the last decade. Across UK terrestrial systems, extractable phosphorus in soils has apparently declined by an average of 25% between 1998 and 2007[2]. The reasons for this are not understood and require further investigation. There is evidence of decreasing phosphate concentrations in rivers across the UK which is linked to a reduction in the application of phosphorus fertiliser to land[1].

Spatial variation in rainfall and runoff is exceptionally high across the UK and few general trends in precipitation and annual runoff have been identified. However, a change in rainfall seasonality has been observed, with wet winters being more common in the last 30 years[1]. A gradual increase in annual average evaporation loss from 500 mm to 550 mm during the period 1980 to 2005 has been observed[1]. This probably reflects an increase in average temperatures across the UK of around 1.0°C over the last 30–40 years.

There is significant inter- and between-year variation in terrestrial primary production that is driven primarily by weather patterns, such as those which occurred during the summer drought of 2003[1]. There is mounting evidence that climate change will impact on primary production and community composition across all UK habitats, but there is an even greater risk of dramatic changes occurring as a result of extreme weather events[2]. Changes in primary production resulting from climate change will have significant implications for provisioning and regulating services.

In agricultural and forestry systems, improvements in land management have had a major impact on primary production due to nutrient input, technological developments and genetic selection[1]. This is reflected in a ten-fold increase in yields in some agricultural systems over the last century. In semi-natural systems, atmospheric nitrogen deposition has increased primary productivity[2]. In lakes, streams and coastal waters, nutrient inputs of nitrogen and phosphorus from sewage and fertiliser runoff have caused major increases in primary production, in some cases eliminating seasonal patterns and causing undesirable hypoxia[1].

In general, there is much uncertainty about the mechanisms that underpin supporting services, and our knowledge of how these services will be affected by current and future drivers, including climate change, is limited. However, it is clear that the mechanisms that underpin supporting services vary greatly across habitats, and the effects of key drivers, such as climate change, land use and nitrogen deposition, will impact on supporting services differently across UK habitats. Research is urgently needed to develop sustainable options for the management of UK supporting services and the regulating and provisioning services that they underpin.

Regulating Services Key Findings (Chapter 14)

The regulating services provided by ecosystems are extremely diverse. Their status and trends, drivers and consequences of change, effective management, and knowledge gaps differ greatly There are differences even among indicators within individual regulating services, as can be observed, for example, with the various components of water quality including acidity, pollutants and sediment. The services are, therefore, reported independently, although relevant interactions (particularly between air, soil and water quality regulation) are noted.

Ecosystems regulate climate by: i) providing sources or sinks of greenhouse gases (affecting global warming) and sources of aerosols (affecting temperature and cloud formation); and ii) their physical characteristics which can regulate local and regional climate. The UK has large amounts of carbon 'locked up' in its forests, peatlands and soils (114 megatonnes Carbon (Mt C) in vegetation; 9,838 ± 2,463 Mt C in soils)[1]. Projected changes in emissions (under a 'business as usual' scenario) from the land use and forestry sector over the next ten years could switch this sector from being a net sink of carbon dioxide to a source[c]. The effects of a failure in climate regulation services globally would be particularly pronounced in urban areas, and would exacerbate climate stress for large numbers of people. There are a wide range of sustainable management options to improve climate regulation services, which would also benefit other ecosystem services. Our main knowledge gaps concern the effects of land use management (rather than land use change) on greenhouse gas emissions and removals, and the quantification of the climate regulation provided by urban, coastal and marine ecosystems around the UK.

The capacity to regulate water, nutrient, pollutant and sediment transfer from the land surface continues to be compromised by soil degradation[2] and contributes to fluvial flood risk. The ability of the soft landforms of the UK coast to regulate erosion (17% currently eroding) and mitigate flood and storm damage is threatened by sea-level rise, changes in the frequency and severity of storms, and low sediment availability[2]. Assessment of the current and future delivery of hazard regulation is limited by our knowledge of coast and upland condition; our understanding of rates and pathways of recovery from degradation; and the need to quantitatively understand the effects of extreme events.

Ecosystems regulate pests and diseases, but this service is under threat. Agricultural intensification, human population growth, accidental introduction of pest and pathogen organisms and land and wildlife management are currently important drivers of disease and pest incidence. Changes in climate are likely to become more important over the next few decades, as recently witnessed for vector-borne diseases. For example, relatively innocuous weeds at the base of the arable food web have declined due to the more frequent use of broader spectrum herbicides, with likely impacts on wider biodiversity[1]. The inadvertent import of fungal plant pathogens via live plant material is arguably one of the most significant loopholes in terms of biosecurity[d]. Understanding how to better manage ecosystems to control pests and pathogens requires detailed longitudinal field studies to describe host-pest and host-pathogen interactions and to understand how these alter in response to environmental changes.

Both managed pollinators (honey bees) and wild pollinators (primarily non-managed bees and hoverflies) have been in severe decline for the past 30 years and it is very likely that this trend will continue[1]. Twenty percent of the UK cropped area comprises pollinator-dependent crops, and a high proportion of wild flowering plants depend on insect pollination for reproduction. However, the overall extent of pollination limitation in crops and wildflowers has not been quantified in the UK. The value of pollinators to UK agriculture is conservatively estimated to be £430 million per annum. There are multiple drivers of pollinator loss including loss of semi-natural habitat, the introduction of pathogens, inappropriate use of agrochemicals and climate change[2].

Noise, particularly unwanted sound, can have a negative effect on human well-being[1] and certain bird species[2], but can be regulated by ecosystems. Actual spatial measurements of noise are very limited, but national models consistently suggest that noise and visual intrusion has increased[a] as urbanisation, including road traffic, has increased. Ecosystems adjacent to roads (created by tree planting and the use of soil bunds) can reduce some of the effects of road traffic noise[2]. Sounds produced and moderated by ecosystems can also be considered as a cultural service: some natural sounds, such as bird song, are considered positively[2]. However, noise is considered a 'disservice'.

Soil quality is linked to almost all other regulating services (e.g. nutrient cycling, biomass production, water quality, climate regulation, pollination, etc.) through the soil's capacity to buffer, filter and transform. Soil quality in all UK NEA Broad Habitats has been degraded by human actions over the last 50 years[1], primarily by atmospheric pollution and inappropriate management practices[b]. Ecosystems are involved in regulating soil quality at all scales. If soil quality is degraded, then soils' capacity to buffer, filter and transform chemical substances is reduced[2]. The trends[2] indicate that recovery from, and remediation of, both diffuse and point source pollution is in progress[c]. There is insufficient and speculative knowledge regarding the recovery of soils under a changing climate; uppermost among these are the competing explanations for the changes in, and vulnerability of, UK's soil carbon stocks and the role of soil in purifying water resources.

Ecosystems can have positive effects on air quality, primarily through interception, deposition and removal of pollutants. However, if the rate of deposition of pollutants exceeds critical thresholds, there may be adverse effects on a range of other ecosystem services. Emissions to the atmosphere from ecosystems can also directly and indirectly degrade air quality. Although there have been significant improvements in UK air quality over recent decades, current concentrations and deposition rates still exceed thresholds for effects on human health, crop and forest production, and biodiversity over significant areas of the country[1,b]. The national improvements in air quality are primarily due to reduced anthropogenic emissions from the transport and energy sectors[1,b]. In contrast, the main drivers of changes in the ecosystem service of air quality regulation over recent decades are likely to have been those changes in land use and management which influence deposition and emission of pollutants. It is likely that there are local benefits of tree planting for air quality in urban areas and close to point sources of pollution; these benefits have been quantified for individual air pollutants[2]. However, the overall national benefits of ecosystem regulation for air quality, and for its health and ecological impacts, are very uncertain.

Since the 1980s, water quality has improved in the uplands because lower atmospheric pollution levels in these areas enable terrestrial ecosystems to buffer lakes and streams against acidification and nitrate leaching[1]. In the lowlands, water quality improvements have largely been driven by better control of point source pollution, rather than improved ecosystem regulation of diffuse pollutants[1]. Widespread increases in upland dissolved organic carbon concentrations have had negative consequences for water treatment, but appear linked to soil recovery from acidification[3]. The key regulating service of pollutant dilution by water flow is maximised by land management that increases infiltration rates; this also reduces phosphorous, sediment and faecal pollutant losses via overland flow[1]. However, these ecosystem services are likely to be degraded in the future by more extreme droughts and high flows due to climate change.

While there are a number of synergies between regulating services (e.g. tree planting can improve air quality, reduce noise and sequester carbon for climate regulation), there are also a number of trade-offs (e.g. improvements in soil buffering of water quality as a result of decreased acid deposition may cause more carbon to be released from upland soils).

Provisioning Services Key Findings (Chapter 15)

Over the last 60 years, production from owned and managed resources has grown, but production from wild resources has declined. Policy, technology and market forces have all played a role, but policy has had the greatest impact. Its goal has sometimes been to maximise production (e.g. Common Agricultural Policy) and sometimes been to prevent overexploitation (e.g. Common Fisheries Policy). Some policies, such as agri-environment schemes, have aimed to reduce the environmental impacts of production.

It is unlikely that declines in environmental quality have reduced agricultural production levels, but overexploitation has harmed marine fish populations and some game species[1].

Over the last decade, the UK has produced more food per year from crops than at any other time in history. The area of land under crops increased in England from 3 million hectares (ha) in 1940 to 4.2 million ha in 2009, but crop areas declined in other regions of the UK: in Wales, for example, there was a 66% decrease over the same time period. The area of wheat trebled in England between 1940 and 2000, while crops such as oats, flax, turnips and vetches declined. Increases in the cropped area were driven by financial returns to farmers[1], partially derived from the Common Agricultural Policy and partially from the market. The changes were facilitated by technologies such as more effective pesticides, mechanisation, varietal improvement and increased fertiliser use. Large increases in the productivity of all crops occurred between 1940 and 2008, as exemplified by average UK wheat yields which increased from 2.5 tonnes/hectare (t/ha) to 8 t/ha.

Livestock productivity has increased, while animal numbers have fluctuated over time. Average milk yields increased from 3,500 litres/cow/year in 1960 to 7,000 litres/cow/year by 2009, and the average dressed carcass weight for steers increased from 267 kg in 1980 to 316 kg in 2003. These productivity gains have been accomplished through enhanced breeding and improved feeding regimes. Numbers of beef cattle peaked at 1.9 million in 1999, dairy cattle at 3.4 million in 1980 and sheep numbers peaked at 45 million in 2000. Numbers have fallen since these times. In 2009, the UK dairy herd comprised 1.8 million dairy cattle, while the national sheep flock was 33 million in 2008. Sheep numbers have fluctuated according to levels of financial support, while numbers of dairy cattle have been affected by market conditions for milk[1]. There has been a large increase in numbers of broiler chickens, largely due to the changed consumption patterns of UK consumers.

The provision of food from marine fisheries is lower now than at any time in the last century. Landings into UK ports were around 1.2 million tonnes in 1948 and declined slightly to just over 1 million tonnes in 1970. The total weight of landings has declined steadily since that time and, in 2008, landings were only 538,000 tonnes. Large declines have been recorded in demersal species, and smaller declines in pelagic species. Pressure from fishing has reduced the size of fish stocks[1]; the development of new technology for finding and harvesting fish has enabled fishers to maintain higher catch rates and exploit new grounds. Production from aquaculture has increased over the last 20 years, especially in Scotland. In 1988, Scotland produced 18 tonnes of salmon from aquaculture, but by 2008, this had increased seven-fold to 128 tonnes.

Some game species have shown major declines in numbers, while other have become more abundant and widespread. There were declines in the bags of red grouse and partridges between 1940 and 2009, but bags of pheasant increased. Changes in the management of farmland had a major impact on partridge numbers[1]. Deer are now more widespread than during the 1940s, and harvests have not shown any evidence of decline. After 1970, the numbers of wild caught salmon fell in Scotland to a low of less than 100,000 fish in 2006. Yet, in 2007, there was suggestion of an upturn when 91,053 salmon were caught by rod and line, which was the third largest catch by that method since 1952. Catches in England and Wales also declined from 1988, and, in 2006, less than 40,000 fish were caught by all methods. Capture at sea and estuarine netting have been largely responsible for declining numbers of spawning salmon[2].

Overall provision of timber has increased over the last 40 years, but major increases in softwood harvests mask declines in the harvest of hardwoods. The production of softwoods in the UK has increased steadily over the last 40 years. The total harvest of softwood was 8.6 million cubic metres (m^3) in 2008, compared with less than 400,000 m^3 of hardwood. Typically, around 60% of the softwood harvest is derived from Scotland. The increased harvest of softwood reflects the levels of deliberate and extensive planting that began on the national forest estate in the early part of the 20th Century. These were driven by policy needs and, later in the century, were reinforced by financial aid to landowners. The different trends in softwood and hardwood reflect the fact that softwoods are derived from plantation forests, while most hardwoods are derived from managed semi-natural woodlands. The total area of land used for peat extraction fell from 14,980 ha in 1994 to 10,690 ha in 2009. At a Great Britain scale, 1.6 million m^3 of peat were sold in 1999 and 760,000 m^3 in 2008.

The amount of water taken from ecosystems by the public water supply in the UK declined between 1990 and 2009. In 1990, 20 billion litres/day were taken by the public water supply in the UK. By 2008, this had declined to about 17 billion litres/day. The greatest declines occurred in England and Wales, with hardly any declines occurring in Scotland and Northern Ireland. Total levels of abstractions in England and Wales stayed more or less constant between 1995 and 2007. In Scotland, abstractions decreased between 2002–2003 and 2007–2008 by 4.5% to 2,387 mega litres/day in 2007–2008. Leakage was approximately 41% in Scotland in 2007–2008, but only 16% in England and Wales – down from 23% in the late 1990s. Decreased leakage in England and Wales is related to the privatisation of water supply and its associated legislative requirements[c]. Water demand has decreased due to reduced demand from heavy industry[1].

Cultural Services Key Findings (Chapter 16)

Ecosystem cultural services are the *environmental settings* that give rise to the cultural *goods and benefits* that people obtain from ecosystems. Over millennia these environmental settings have been co-produced by the constant interactions between humans and nature. They are inscribed with not only natural features but also the legacies of past and current societies, technologies, and cultures. The continual change in these settings involves a range of complex cultural practices, such as the development of institutions, the application of capital, and human processes involving memories, emotions, the senses, and aesthetic appreciation.

There are many environmental settings where people interact with nature including the domestic garden, informal green and blue spaces, formal green/blue spaces, the nearby and wider countryside and national landscapes. People's engagement with environmental settings is contingent, context specific, fluid and mutable[1,a]. Frameworks of interpretation and social practices associated with the production and uses of environmental settings are dynamic: meanings, values and behaviours change over time in response to economic, technological, social, political and cultural drivers. Change can be rapid and far-reaching in its implications. One particularly noticeable characteristic of UK cultural practice, however, is the depth and breadth of engagement with nature and wildlife[1,c].

Ecosystem cultural services make a significant contribution to achieving people's key needs. In the 21st Century the cultural life of the UK is diverse and dynamic. Yet encounters with the natural world maintain their fascination for very substantial numbers of people, as reflected for example, in the membership of a very wide range of civil society organizations embracing landscape and nature interests, the numbers of people who use urban parks and green-spaces on a daily basis, and the massive popularity of gardening across the UK. Daily contact with nature is part, still, of being human. This is illustrated by the Human-Scale Development Matrix (H-SDM) developed by Manfred Max Neef, which indicates how both existence needs *(being, having, doing, interacting)* and value needs *(subsistence, protection, affection, understanding, participation, creation, leisure, identity and freedom)* can be met through nature[1,a]. Evidence suggests that contemporary consumption practices are not satisfying our human needs adequately. Happiness research in economics, and policy-political initiatives to measure levels of happiness among populations reflects statistical evidence that, although people are far better off in material terms than they have ever been, rates of depression, mental illness, obesity and family breakdown are also increasing[1,b].

The discipline of *ecolinguistics* appeared in the 1990s[2,c]. It brought together research from a number of academic disciplines interested in the ways in which scientific, professional, amateur and popular knowledge about the natural world was constructed; how different media shaped the environmental messages being communicated, and the politicisation of environmental issues associated with the rise of non-governmental organisations and pressure groups from the late 1960s. Whether humankind is regarded as a part of nature or as separate from it continues to be a fault line between different philosophical, moral, ethical and communicative traditions. One distinctive feature of language relating to the environment appears to be that reference to agency is avoided and there is a strong tendency not to identify *who* did *what* when discussing environmental change. This is achieved in a number of ways, such as using the passive rather than active voice or omitting the grammatical subject and using the object instead, for example, *the habitat was destroyed* rather than *the developer destroyed the habitat.* Thus there is frequently a choice of syntax that obscures agency and, thereby, responsibility for negative changes in environmental conditions.

Since 1945 there have been some significant changes in people's interactions with environmental settings. The growth of urban settlements means that more people have a set of local environmental settings with urban characteristics. At the same time, however, increased mobility has allowed more people to travel longer distances nationally and internationally to environmental settings for tourism and recreation purposes[1,b]. In more local environmental settings data limits the interpretations of changes in domestic gardens. Marked changes did occur, however, in certain countryside settings of the UK during the second half of the last century especially those in and around large urban areas, although the characteristics of other environmental settings have remained more static. Declines in numbers and/or the quality of certain local/green blue spaces, such as playing fields, allotments and parks in deprived areas, have occurred over past decades but have been arrested in the last few years[2,c].

Since 1945 a large number of protection schemes instigated by UK and European Union government have been implemented to conserve certain socially and culturally significant environmental settings[1,a]. National Parks, National and Local Nature Reserves, Sites of Special Scientific Interest, Special Protection Areas (SPAs), Ramsar sites, Local Nature Reserves (LNRs) and land owned by bodies such as The National Trust all play a role in managing cultural services in specific landscapes and local places.

A driver of people's changing relationships with environmental settings has been associated with a desire for self-determination, responsibility and security (of self and environment)[1,c]. This has led to a small but increasing number of people making new productive connections to environmental settings. This includes an increasing demand for allotment gardening, increasing membership of community farms, and whilst many people relocate to rural environments for amenity reasons, more people are doing so to run smallholdings or to engage in other forms of 'pro-environmental' lifestyle.

Environmental settings have been one of the most enduringly popular locations for recreation, leisure and tourism[2,c]. They offer generic opportunities to walk, run or cycle; specific opportunities only available in a few habitats, to ski, swim or sail, for example; and unique settings that offer opportunities to achieve specific benefits, related for example to seeing particular fauna and flora, or being able to climb particular crags. Three quarters of the population in England consider local greenspace to be a very important part of the local environment, and 50% visit it at least once a week. Access to environmental settings for recreation, leisure and tourism is highly differentiated, throughout the UK. A number of measures have been implemented to address this, including Natural England's Accessible Natural Greenspace Standard (ANGSt), which provides a set of benchmarks for ensuring access to places near to where people live. Recent legislative changes have contributed to improving access to some settings, with the Countryside and Rights of Way Act 2000 providing access to uplands, downs and commons and the Marine and Coastal Access Act 2009 promising to do the same for access to the coast. Economic studies have highlighted the benefits and monetary value that arise from being able to access environmental settings for recreation, leisure and tourism. Secondary analysis conducted for UK NEA of the English Leisure Visits Survey 2005 estimated that the total recreational value of the 4 billion visits to different habitats generated a value of between £2.2 and £3 billion per annum. A national park designation can raise house prices in proximate locations.

Environmental settings can contribute to a wide range of health goods often by providing places where people can undertake physical activity and interact with nature[2,b]. Levels of interaction/engagement of 'green space' have been linked with longevity and decreased risk of mental ill-health, and that vitamin D obtained from sunshine whilst being in environmental settings plays a role in long-term health. The presence of urban nature has been associated with improved cognitive functioning, aesthetic inspiration and reduced levels of crime and aggression as well providing an outdoor classroom. 'Green exercise', defined as any physical activity taking place in the presence of nature, is predicted to lead to positive health outcomes, as well as promoting ecological knowledge, fostering social bonds and influencing behavioural choices.

Open green space and access to nature is important for children[2,c]. The quality of their environmental exposure is inextricably linked to their wellbeing. Children's relationship with nature is a fundamental part of their development, allowing opportunities for self-discovery and natural environmental experience. The outdoor environment is perceived as a social space which influences their choice of informal play activities and promotes healthy personal development. Nature allows unstructured play, generating a sense of freedom, independence and inner strength which children can draw upon when experiencing future incidents of stress.

Through their differing heritages, every environmental setting is capable of being interpreted as possessing a distinctive sense of place which can contribute to a range of human value needs[2,a]. The intricacies and contingent nature of the relationship between needs, environmental settings and the past creates analytical challenges but is fundamental to understanding heritage goods. There is a very diverse range of heritage goods that are linked to ecosystem services, ranging in scale and ease of identification from perceived national landscapes through territorially demarcated National Trust land to the subtle and personal historical meanings people may attach to some urban commons. Environmental settings also function as a generator of a vast range of *local* identities based around a more local and everyday sense of heritage. Heritage goods, therefore, can be a source of community empowerment as well as potential conflict between different interests and can contribute to a sense of identity, place, freedom and understanding.

The complex emotional and personalised characteristics of heritage goods mean that identifying their value to society is problematic[1,b]. Indeed, a recent survey identified that almost every feature in an environmental setting will connote personal memories and attachments for someone. Despite the highly personal and context-specific nature of heritage, it is widely felt that it should be preserved to be passed on to future generations, as a means of providing both children and adults with an understanding of their history and identity. In addition, several million people across the UK actively support a wide range of civil society organizations dedicated to conserving and enhancing particular landscapes and places, wildlife and habitats through membership fees and, to a lesser extent, volunteering their time.

Environmental settings are valuable surroundings for outdoor learning where engaging with nature can lead to enhanced connectedness to nature and increased ecological knowledge[2,c]. Ecological knowledge has been defined as 'accumulated knowledge about nature' and can be acquired through contact with different natural environments, directly or indirectly. The economic value of ecological knowledge, generated formally in schools and less formally elsewhere, is considered to be substantial . However, there are significant complexities associated with estimating this economic value, with a recent study undertaken as part of UK NEA using an investment in human capital approach to investigate the value of ecological learning experiences of children in the formal educational system. Benefits of this investment in ecological knowledge include a possible boost in lifetime earnings as well as possibly enhanced quality of life through more productive use of leisure opportunities. Whilst this approach may be appropriate for ecological knowledge acquired in school it is difficult to ascribe a gain in knowledge to a specific trip or location. The approach to the latter therefore involved examining travel costs and resource costs in order to estimate investment costs over and above those involved in gaining knowledge in a classroom situation.

Environmental settings play a positive role in religious practice and faith but more general evidence on their spiritual and religious role is limited[4]. Religious and spiritual goods are clearly linked to our existence need for *being*, but the extent to which religious encounters with specific environmental settings are synergistic satisfiers for value needs such as participation and identity resides in the character and qualities of belief. The importance of ecosystems in religious terms had almost certainly increased in the post-war period in Britain, notwithstanding secularisation and the decline of conventional religious observance. There has, apparently, been an increase in the incidence of both pilgrimage and of religious retreats although it is extremely difficult to identify any quantitative measures of this trend. It is extremely hard to pin-point evidence of particular landscapes or ecosystems being conducive to religious experiences. The configuration of Marine and Coastal Habitats which appear to contribute to spiritual/religious experiences at the holy islands of Iona, Lindisfarne and Bardsley have to be seen in the context of other highly popular sites of pilgrimage that are inland and not characterised by dramatic landscape /ecological characteristics, such as Walsingham in North Norfolk.

New evidence gathered as part of the UK NEA indicates that people clearly benefit from a range of environmental settings proximate to their homes and that the presence of certain settings can increase residential house prices[2,c]. A new hedonic price analysis shows that the house market in England reveals substantial amenity value attached to a number of habitats, designations, private gardens and local environmental amenities. In particular, protected areas (National Parks, National Trust land and metropolitan green belt), local environmental settings (domestic gardens, local green spaces, rivers) and several habitats (such as woodland, farmland and freshwater) are a statistically significant factor in explaining higher house prices. A new well-being survey analysis also reveals that respondents who visit non-countryside green spaces such as urban parks at least once a month, and those who spend time in their own gardens at least once a week, have higher life satisfaction than those who do not. Survey respondents who used domestic gardens and local green spaces at least once a month also showed better self-reported health, measured by physical functioning and emotional well-being, compared to those who do not.

There are knowledge gaps related to ecosystem cultural services, specifically in data collection and the uneven monitoring of change in different environmental settings[2,c]. An ecosystem services approach to understanding culture-nature interactions is a relatively new perspective and consequently many key sources of social, economic and environmental data are not designed to examine key aspects of cultural services and goods. Recent initiatives, such as the Countryside Quality Counts analysis and the new Master Map digital inventories, are leading to improvements, but a lot remains to be done, particularly to provide consistent data suitable for economic analyses. Further research is required, particularly longitudinal studies, to understand the social and physiological processes involved in people acquiring mental and physical health benefits from engagement with environmental settings and nature so that management of environmental settings for long term behaviour change can be more effective. Further studies are needed to examine people's exercise habits and understand what proportion of exercise is a direct consequence of the provision of green spaces. A key knowledge gap regarding education and ecological knowledge goods concerns the processes by which adults acquire ecological knowledge, their participation in nature-based educational activities and how knowledge acquisition is influenced by engagement with environmental settings as a form of cultural service. For religious and spiritual goods the knowledge gaps are particularly notable. There is a marked lack of evidence on the numbers of people for whom religious/spiritual experience and wellbeing is related to experiences of nature. We do not know how many people in Britain go on pilgrimage or make retreats or for whom contact with nature is an intrinsic part of their religious/spiritual lives. There is also limited evidence on detailed wildlife viewing figures for species other than birds, benefits of TV and radio programmes about nature, nature-based art markets (paintings, arts and crafts, photography), social cohesion and neighbourhood benefits associated with nature and non-use values of environmental settings at a national scale not already reflected in legacies.

Addressing these knowledge gaps will require the regular and consistent collection of quantitative data at the national scale[1,b]. Many of the gaps, however, require an understanding of the complex ways individuals and groups of people engage with environmental settings, the cultural goods/benefits that may arise and the inequalities associated with cultural goods/benefits. Recent guidance published by Defra emphasises that the cultural goods linked to ecosystem services cannot just be understood in monetary terms but in future their shared and non-monetary value will need to be understood using a range of participatory and deliberative techniques such as multi-criteria analysis that require the use of both quantitative and qualitative methods[3,c].

Acronyms and abbreviations

ASSI	Areas of Special Scientific Interest
BAP	Biodiversity Action Plan
CAP	Common Agricultural Policy
COI	Central Office for Information
GB	Great Britain
GDP	Gross Domestic Product
GHG	Greenhouse Gases
LWEC	Living With Environment Change
MFA	Material Flow Analysis
PM	Particulate Matter
SAC	Special Areas for Conservation
SSSI	Sites of Special Scientific Interest
TB	*Tuberculosis*
UKCIP	UK Climate Impacts Programme
UK NEA	UK National Ecosystem Assessment
UKWaC	UK Web Archiving Consortium
VOC	Volatile Organic Compound

Glossary

Biodiversity: The term biodiversity describes the diversity of life on Earth. Diversity can occur at a number of levels of biological organisation from genes, through individuals, populations, species and communities, to entire ecosystems.

Biomass: The mass of tissues in living organisms in a population, ecosystem, or spatial unit.

Biome: The largest unit of ecological classification that is convenient to recognize below the entire globe. Terrestrial biomes are typically based on dominant vegetation structure (e.g. forest, grassland). Ecosystems within a biome function in a broadly similar way, although they may have very different species composition. For example, all forests share certain properties regarding nutrient cycling, disturbance, and biomass that are different from the properties of grasslands. Marine biomes are typically based on biogeochemical properties. The WWF biome classification is used in the UK NEA.

Conceptual framework: Is a concise summary in words and pictures of the relationships between people and nature including key components of interactions between humans and ecological systems. Conceptual frameworks assist in organising thinking and structuring work when assessing complex ecosystems, social arrangements and human – environment interactions.

Driver: Any natural or human-induced factor that directly or indirectly causes a change in an ecosystem.

Driver, direct: A driver that unequivocally influences ecosystem processes and can therefore be identified and measured to differing degrees of accuracy. (Compare Driver, indirect.)

Driver, indirect: A driver that operates by altering the level or rate of change of one or more direct drivers. (Compare Driver, direct.)

Ecosystem: A dynamic complex of plant, animal, and microorganism communities and their non-living environment interacting as a functional unit.

Environmental settings: Are the locations and places where humans interact with each other and nature that give rise to the cultural goods and benefits that people obtain from ecosystems.

Ecosystem service: The benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on Earth.

Ecosystem resilience: The level of disturbance that an ecosystem can undergo without crossing a threshold to a situation with different structure or outputs. Resilience depends on ecological dynamics as well as the organizational and institutional capacity to understand, manage, and respond to these dynamics.

Final ecosystem services: Are the outcomes from ecosystems that directly lead to good(s) that are valued by people.

Goods: Are all use and non-use, material and non-material outputs from ecosystems that have value for people.

Habitat: Is an ecological or environmental area that is inhabited by a particular animal or plant species. 'Broad Habitats' are used to classify different ecosystems for reporting.

Intermediate ecosystem services: Those whose ecological processes and functions support all life, and, by definition all other services.

Scenario: A plausible and often simplified description of how the future may develop, based on a coherent and internally consistent set of assumptions about key driving forces (e.g. rate of technology change, prices) and relationships. Scenarios are neither predictions nor projections and sometimes may be based on a 'narrative storyline'. Scenarios may include projections but are often based on additional information from other sources.

Shared social values: Refers to the fulfilment, meaning or significance of the collective needs of society in relation to social, health and cultural services.

Responses: Human actions, including policies, strategies, and interventions, to address specific issues, needs, opportunities, or problems. In the context of ecosystem management, responses may be of legal, technical, institutional, economic, and behavioural nature and may operate at various spatial and time scales.

Trade-off: Management choices that intentionally or otherwise change the type, magnitude, and relative mix of services provided

Chapters of the UK NEA

Figure Sources and Copyright

Armstrong, M. & Holmes, I. (2010) An indicator of sustainability for marine fin-fish stocks around the UK: 1990–2008. Centre for Environment, Fisheries and Aquaculture Science (CEFAS). Available at: http://www.cefas.co.uk/media/361785/website%20psa%20sustainability%20indicator%20v2.pdf

Bateman, I.J. (2009) Bringing the real world into economic analyses of land use value: incorporating spatial complexity. *Land Use Policy.* 26S: S30–S42.

Bateman, I.J. *et al.* (2002) Applying geographical information systems (GIS) to environmental and resource economics. *Environmental and Resource Economics.* 22: 219-269.

Bateman, I.J. & Jones, A.P. (2003) Contrasting conventional with multi-level modelling approaches to meta-analysis: an illustration using UK woodland recreation values. *Land Economics.* 79: 235-258.

Bateman, I. *et al.* (2010) Economic analysis for ecosystem service assessments. *Environmental and Resource Economics.* 48: 177-218. DOI 10.1007/s10640-010-9418-x.

Carey, P.D. *et al.* (2008) Countryside Survey: UK results from 2007. NERC/Centre for Ecology & Hydrology, 105pp (CEH Project Number: C03259).

Defra (Department for Environment, Food and Rural Affairs) (2007) Sustainable development indicators in your pocket 2007: An update of the UK Government Strategy indicators. Defra.

Defra (Department for Environment, Food and Rural Affairs) (2010) *Yield* and production time series [online]. Available at: http://www.defra.gov.uk/evidence/statistics/foodfarm/food/cereals/cerealsoilseed.htm

Emmett, B.A., *et al.* (2010) Countryside Survey: Soils Report from 2007. NERC/Centre for Ecology & Hydrology, 192pp. (CS Technical Report No. 9/07, CEH Project Number: C03259).

Fisher, B. *et al.* (2008) Ecosystem services and economic theory: integration for policy-relevant research. *Ecological Applications.* 18: 2050-2067.

Fuller, R.M. *et al.* (2002) The UK Land Cover Map 2000: construction of a parcel-based vector map from satellite images. *Cartographic Journal.* 39:15-25.

HMRC (Her Majesty's Revenue & Customs) (2008) Overseas Trade Statistics data [online] Available at: <https://www.uktradeinfo.com/index.cfm?task=data> [Accessed 15.03.11]

MA (Millennium Ecosystem Assessment) (2005) Living beyond our means: natural assets and human well-being. Statement from the Board. Washington D.C., USA. World Resources Institute.

MMO (Marine Management Organisation) (2010) United Kingdom Sea Fisheries Statistics 2009. Marine Management Organisation. Available at: http://www.mmo.gov.uk

Olson, D.M. *et al.* (2004) Terrestrial Ecoregions of the World: a new map of life on earth. *BioScience.* 51: 933-938. Subsequently modified and extended at UNEP-WCMC (2011).

RoTAP (2011) Review of Transboundary Air Pollution: acidification, eutrophication, ground level ozone and heavy metals in the UK. Report to the Department for Environment, Food and Rural Affairs. Available at http://www.rotap.ceh.ac.uk.

RSPB (Royal Society for the Protection of Birds) (2011) The Royal Society for the Protection of Birds membership numbers. *Pers comms.*

RSPB (Royal Society for the Protection of Birds), BTO (British Trust for Ornithology), JNCC (Joint Nature Conservation Committee), and Defra (Department for Environment, Food and Rural Affairs) (2011) UK Wild Bird Indicator 1970–2009.

UKMMAS (UK Marine Monitoring and Assessment Strategy) (2010) Charting Progress 2. The State of UK Seas. Published by the Department for Environment Food and Rural Affairs on behalf of UKMMAS. 166pp. http://chartingprogress.defra.gov.uk

UKCP09 (2011) UK Climate Change Project. http://ukclimateprojections.defra.gov.uk/. © Crown Copyright 2009. The UK Climate Projections (UKCP09) have been made available by the Department for Environment, Food and Rural Affairs (Defra) and the Department of Climate Change (DECC) under licence from the Met Office, UK Climate Impacts Programme, British Atmospheric Data Centre, Newcastle University, University of East Anglia, Environment Agency, Tyndall Centre and Proudman Oceanographic Laboratory. These organisations give no warranties, express or implied, as to the accuracy of the UKCP09 and do not accept any liability for loss or damage, which may arise from reliance upon the UKCP09 and any use of the UKCP09 is undertaken entirely at the users risk.

Photo Sources and Copyright

P7: Crowded London street by Reinis Traidas[1]. **P7:** Walker in a Sheffield park by Earthwatcher[5] **P9:** Great tit (*Parus major*) feeding in a garden by iJammin[1]. **P13:** Community tree planting at The Bradleys, courtesy of the National Forest Company. **P14:** Otley Wetland Nature Reserve, Yorkshire by T.J. Blackwell[2]. **P17:** Couple walking along abeach at sunset by Midlander1231[2]. **P18:** Fly agaric fungus by Dave W. Clarke[2]. **P18:** Flooded street in Oxfordshire by Dachalan[3]. **P18:** Stack of wood, © Copit, 2011[6]. **P18:** Cyclists, © Maga, 2011[6]. **P19:** Autumn leaves at Allen Banks, Northumberland by Peter Mulligan[1]. **P19:** Small skipper (*Thymelicus sylvestris*) on thistle by Earthwatcher[5]. **P19:** European plaice (*Pleuronectes platessa*), courtesy of Keith Hiscock. **P21:** Cairngorm National Park mountain landscape, Scotland by Peter Mulligan[1]. **P21:** Semi-natural Grassland, South Downs, Hampshire by Alistair Young[1]. **P21:** Hay bales, © Joingate, 2011[6]. **P21:** Veteran oak and beech trees in a mixed lowland woodland, courtesy of FC Picture Library/Isobel Cameron. **P21:** Glen Cannich, Scotland by Peter Mulligan[1]. **P21:** Housing in Plymouth, © Samot, 2011[6]. **P21:** Dorset coast, © Markus Gann, 2011[6]. **P21:** Current swept bed of *Zostera marina*, courtesy of Keith Hiscock (from www.marlin.ac.uk). **P24:** River Elan, Wales, © Martin Fowler, 2011[6]. **P24:** Housing in London, © Pres Panayotov 2011[6]. **P25:** European honeybee (*Apis mellifera),* © Mirek Srb, 2011[6]. **P25:** Deckchairs on a UK beach, © ronfromyork, 2011[6]. **P30:** Rhododendron by Pete Birkinshaw[1]. **P32:** Greenspace in London by Toban Black[2]. **P32:** Group of people rockpooling at Batten Bay, Plymouth, courtesy of MarLIN/MBA. **P33:** Cockermouth in Cumbria during floods in 2009, © Environment Agency/www.petersmith.com. **P35:** Giant's Causeway, Northern Ireland, © Josemaria Toscan, 2011[6]. **P38:** Market stall selling non-UK grown produce by Chris Goldberg[2]. **P39:** Flower market in London by Lois Lindemann[2]. **P41:** Handful of strawberries by Georgina Bright[2]. **P41:** Water overflowing Craig Goch reservoir, Wales © Stephen Aaron Rees, 2011[6]. **P41:** Private garden in London by Cotitoo[2]. **P41:** Children enjoying the outdoors, © Morgan Lane Photography, 2011[6]. **P43:** Walker in the Lake District ©Rick Harrison, 2010[2]. **P50:** Cows in Herefordshire by Serena Epstein[4]. **P50:** A single chestnut tree in Buckinghamshire, © Peter Elvidge, 2011[6]. **P50:** Footpath sign in the Lake District, © Len Green, 2011[6]. **P50:** Public park in London, ©1000 Words, 2011[6]. **P50:** Chaffinch (*Fringilla coelebs*) by Dave Merrett[1]. **P56:** Rope bridge to Carrick-a-Rede island, Northern Ireland by Yi-tao Lee[2]. **P58:** Fungi in a garden in Nottinghamshire by Andy Jakeman[3]. **P58:** Exposed soil in a ploughed field by David Bailey[4]. **P59:** Pegston hills landscape, Hertfordshire, © David Hughes, 2011[6]. **P61:** View of Causey Pike, Cumbria, © Kevin Eaves, 2011[6]. **P62–63:** Giants Causeway World Heritage Site, Northern Ireland by Etrusia UK[4]. **P63–64:** Highlands near Achallader, Scotland by Alastair Knock[4]. **P65-66:** Brecon Beacons, Wales by Trevor Coultart[5].

[1]available under a Creative Commons (CC) Attribution license; [2]available under a CC Attribution-NonCommercial license; [3]available under a CC Attribution-ShareAlike license; [4]available under a CC Attribution-NonCommercial-ShareAlike license; [5]available under a CC Attribution-NonCommercial-NoDerivs license; [6]used under license of Shutterstock.com.

The UK National Ecosystem Assessment (UK NEA), carried out between mid-2009 to early 2011 is the first analysis of the UK natural environment in terms of the benefits it provides to society and continuing prosperity.

Contact details

The UK National Ecosystem Assessment Secretariat is based at United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) in Cambridge.

More information on the UK NEA can be found at **http://uknea.unep-wcmc.org**.

If you have any questions about the UK NEA please email **nea@unep-wcmc.org.**

UNEP-WCMC
219 Huntingdon Road
Cambridge CB3 0DL
United Kingdom
Tel: +44 (0)1223 277314
Fax: +44 (0)1223 277136
Email: info@unep-wcmc.org
Website: www.unep-wcmc.org

ISBN: 978-92-807-3165-1