UK National Ecosystem Assessment

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Draft synthesis of current status and recent trends

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18 October 2010

This progress report prepared by the co-chairs of the UK NEA provides a draft of the key messages distilled from the chapters of first phase of the UK NEA, which looks at the status and trends of ecosystems across the UK and the services they provide. Although at this stage this has not been fully peer-reviewed, the aim is to give a flavour of the emerging findings documented in detail in individual chapters. Also, we have drafted answers to two of the six questions posed in this first phase of the assessment:

i) What are the drivers causing changes in ecosystems/Broad Habitats in the UK and the services they provide to society?
ii) What are the uncertainties limiting our understanding of ecosystem services?

The final assessment will include the economic analysis of changes in ecosystem services, and a wider evaluation of well-being in-terms of health value and shared (social) value. In addition, we are awaiting the country specific assessments to summarise the contrasts in status and trends in ecosystems and the services they deliver across the UK.

Executive Summary

Conceptual Framework

The conceptual framework for the UK National Ecosystem Assessment (UK NEA), like the Millennium Ecosystem Assessment, is based on linking the drivers of change (direct and indirect) to changes in biodiversity and ecosystem goods and services, and human wellbeing. The conceptual framework can be used to assess how historical, as well as plausible future changes, in drivers affect the main broad habitats (ecosystems) in the UK and their role in providing ecosystem services that benefit people.

Drivers of Change

Direct and indirect drivers including economic growth, demographic changes, advances in science and technology, coupled with changes in both policies and behaviour, have resulted in significant changes in broad habitats throughout the UK since the Second World War (WWII). For example, the widespread conversion of various semi-natural habitats (e.g., grasslands) to arable land between the 1940's and 1990's was partly stimulated by increased demand (due to increased population and wealth) and agricultural production subsidies. Coupled with the increased intensity of agricultural production and use of agro-chemicals, these drivers resulted in a significant increase in food production but with a resultant loss of biodiversity and degradation of some regulating, supporting and cultural services. Activities other than agriculture, such as the increased demand for water, and air and water pollution from the production and use of energy, have also impacted UK habitats and ecosystem services.

Biodiversity

The diversity of life at the genetic, species and ecosystem level, otherwise known as biodiversity, underpins the provisioning of food, fibre and energy, regulates the Earth's climate, air and water quality, provides aesthetic, religious and spiritual value, and underpins key processes such as soil formation and nutrient cycling. Significant biodiversity loss has been documented in the UK over the last 50 years among higher plants, birds and mammals, which all comprise taxonomic groups with adequate data, but data for many other taxonomic groups, including insects (other than for butterflies and moths) as well as microbes and fungi, is poor. This incomplete inventory thwarts a comprehensive assessment of the status and trends of our ecosystems and their capacity to provide for human well-being.

Ecosystem Services

Since WWII increases in **provisioning services**, including crops, livestock, and trees, have been achieved through both using more land and intensification, and enabled the UK to produce more food and timber in the last decade than at any time in the last century. However, the expansion of agriculture, forestry and new settlements demanded by the growing population has come at the expense of some key **supporting services**, especially nutrient cycling, **regulating services**, including soil quality, the control of pest and diseases, and possibly pollination by insects, and **cultural services**, for example changes in landscape.

Provisioning services: Policy, technology and market forces have enabled greater levels of provisioning from resources with well defined property rights, including significant increases in crops, meat and dairy, and trees. However, a failure of policy has allowed provisioning from some wild, unmanaged resources to decline, in particular marine fisheries. The emphasis of policies has changed over the last 60 years. At first serving to incentivise production (e.g. common agricultural policy, forestry), but more recently trying to ameliorate environmental impacts of production (e.g.: agri-environment schemes in agriculture, planning for aquaculture), and to prevent over-exploitation (e.g.: common fisheries policy). Technological developments have enabled major changes in both the systems of production and increased productivity, and these have enabled businesses to meet market demands for cost efficiency.

Regulating Services: Since the late 1950's air quality, and since the 1980's 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 emissions from cars. However, other sources of diffuse atmospheric pollution and inappropriate land management may be causing declines in both pollinating insects and soil quality. The loss of carbon from some soils, 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 Lyme disease and bovine tuberculosis has increased.

Cultural Services: the *non-material benefits* people obtain from ecosystems. Since 1945 government has implemented many 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. There is growing evidence that "green space" in urban areas, as well as, access to the wider countryside, leads to positive child development, and improved physical and mental health outcomes for all. The sense of citizenship and the strength of national and personal identity felt by individuals and communities in different parts of the UK are based, in part, on landscape character and sense of local place.

Supporting Services: Since soil formation is slow at an average of <1 cm 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 due associated with coal-fired electricity generation. Recent reductions in phosphorus available to plants in soils, possibly associated with increased primary production stimulated by increased atmospheric nitrogen deposition and climate warming, could become an issue. 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.

Broad Habitats

Enclosed farmlands are dynamic habitats, managed largely for agricultural production, underpin the UK agri-food sector that contributes over 6% of the UK GDP, producing 73% of indigenous foods, but can also provide many other benefits**.** The levels of agricultural production increased greatly until the 1990s, while many other ecosystem services declined; the increases in total agricultural productivity were halted during the 1990s, while the deterioration in other ecosystem services was reduced, and in some cases, reversed Currently, many interactions between provisioning and other ecosystem services are negative, though 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). There is currently a lack knowledge of how best to optimise agricultural land management for multiple outcomes, how to address the scale dependencies of such optimisations, assess the impact of land management on some services, or the impact of some services on agricultural production.

Woodlands provide an important provisioning service for timber, and are highly valued by people for social and cultural services, and their capacity to sequester carbon. The area of woodland has doubled since WWII to cover 12% of the UK. There are multiple drivers of change in woodland ecosystems, including climate change, pollution, government policy on land use, global trade, and the endogenous dynamics of ageing woodland. Forest policy and woodland management have changed over time, seeking varying combinations of goods and services, upon which the delivery depends on specific characteristics of trees and woodlands and management practices. Diversification of forest structure for biodiversity benefits may improve cultural services, and increases in forest cover may benefit carbon regulation and contribute to flood regulation.

Semi-natural grasslands are a vital part of the UK's cultural landscape, provide habitat for important and rare species and are higher in biodiversity and support greater ecosystem services (e.g., store greater densities of carbon, allow greater water infiltration rates and enhanced storage, which should aid flood prevention, and produce less nitrous oxide and pollution due to the low fertilizer inputs) than agriculturally-improved grasslands and arable land. The area of semi-natural grassland has declined greatly since WWII, 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 semi-natural grassland biodiversity and ecosystem services.

Open waters (rivers and lakes), wetlands and floodplains are integral to all UK landscapes, highly connected to each other and to their catchments, and provide services of major importance to human well-being. Freshwater ecosystems are crucial for the supply of fresh water, regulation of flooding, erosion, sedimentation, and local climates, as well as characteristic and recreationally-important landscapes. They also regulate water quality and support dispersal of chemicals, energy and organisms between habitats. They have substantial cultural value for nature and heritage conservation, recreation, tourism, education and as inspiration for the arts and religion. However, despite the multiple benefits many of these services are poorly valued or completely overlooked, and as a consequence, many have been degraded or lost through wetland drainage, flow modification for flood defences, toxic pollution and acidification, habitat degradation and loss, exploitation and introduction of exotic species.

Mountains, moors and heathlands are highly multi-functional and are important source habitats for about 70% of UK drinking water, hold about 40% of the UK's soil carbon mainly in upland peat soils, and buffer water quality against the effects of diffuse and point source atmospheric pollutants. In addition they are nationally treasured landscapes, providing breathing spaces for people, are important cultural landscapes steeped in history, and are of great importance for biodiversity, with a large part under national and international designation for conservation. Substantial changes to mountains, moors and heathlands, which currently cover about 18% of the UK, took place in the first 30 years after WWII, both in extent and condition and how they have been used by people, but with no further dramatic losses in extent in the last two decades. Greatest losses in extent and quality, primarily due to afforestation, agricultural development, high grazing pressures, airborne pollution and to a lesser extent climatic changes, were reported for bog, upland and lowland heathland.

Coastal margin habitats (sand dunes, machair, saltmarsh, shingle, sea cliffs and lagoons) have declined in extent by about 10% and quality since WWII due to development and coastal squeeze. Coastal margins are important in providing coastal defence, support a wide range of specialist and rare species, and have high biodiversity, which forms part of the foundation for culturally important ecosystem services (living space for coastal communities, as a symbol of identity, a place for rest and relaxation, with a sense of freedom, where people can enjoy scenery, wildlife, sunbathing, walking, birdwatching, boating, swimming, and outdoor sports). Sand dunes and saltmarsh have been lost due to agricultural improvement (including forestry) and land-claim, while rapid coastal development for industry, housing, military activities and tourism has affected all habitats. The quality of these habitats have been impacted by widespread installation of artificial sea-defence structures and increased armouring of soft cliffs reducing sediment supply and natural dynamics, while reductions in traditional forms of management such as grazing and decades of conservation effort have led to more stabilised systems. Sustainable management options for coastal margin habitats, which are holistic and take into account physical and biological processes, spatial scale, drivers of change and cultural elements have potential wide ranging benefits.

Marine ecosystems around the UK provide a wide range of ecosystem services and benefits, including food (fish, shellfish, aquaculture), avoidance of climate stress (carbon and other biogas regulation); energy (wave, tidal, biofuels); genetic resources (e.g.: for aquaculture); industrial inputs (biocatalysts, natural medicines); fertiliser (seaweed); coastal protection including erosion and flood control; waste breakdown & detoxification leading to pollution control, waste removal and waste degradation; disease and pest control; tourism, leisure and recreation opportunities; a focus for engagement with the natural environment; physical and mental health benefits; cultural heritage and learning experiences.

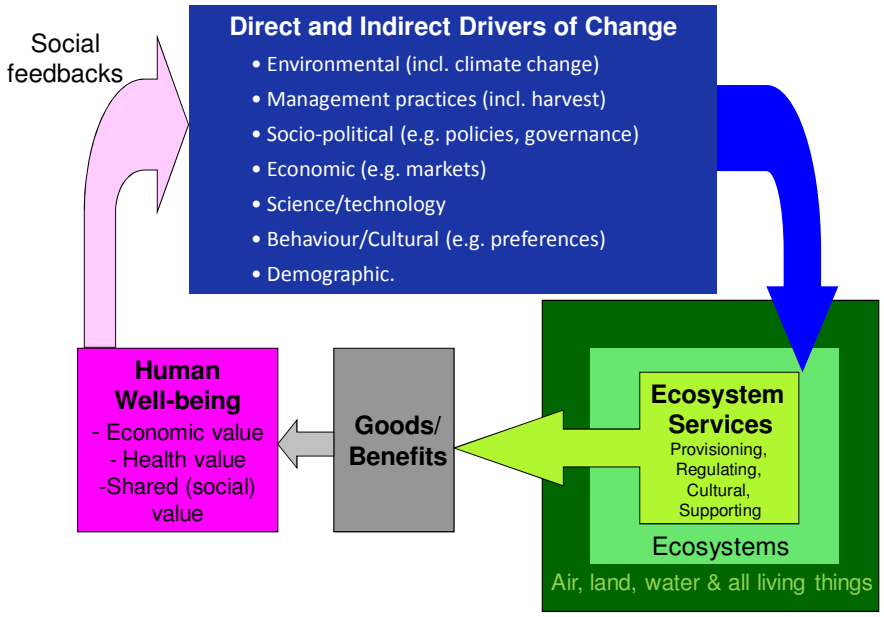
Urban ecosystems, which now cover over 10% of England, 1.9% of Scotland, 2.9% of Northern Ireland and 4.2% of Wales, currently provide very limited provisioning services, though there is a revival in allotments, and tend, in general, to be ineffective in regulating services, with the possible exception that green infrastructure can contribute to urban cooling, providing shade and removal of pollution particles. However, cultural services arising from access to good quality "green" space, through public parks and private gardens, contributes to positive mental health, childhood development and physical health. Sustainable enhancement of the provision of urban ecosystem services requires both active urban planning and conceptual changes to the evaluation of urban greenspace. Ecosystem services can be enhanced through green corridors. However, there are trade-offs and synergies in ecosystem goods and services, e.g., tree cover in urban environments could reduce surface run-off, noise exposure and mid-afternoon peak temperatures, but some tree species emit volatile organic compounds, hence selection of tree species is important. Climate modelling, intelligent building design and planning of greenspace can facilitate urban adaptation to climate change.

Key Messages

Conceptual Framework

The conceptual framework for the UK National Ecosystem Assessment (UK NEA), like the Millennium Ecosystem Assessment, is based on linking the drivers of change (direct and indirect) to changes in biodiversity and ecosystem goods and services, and human well-being (Figure 1).

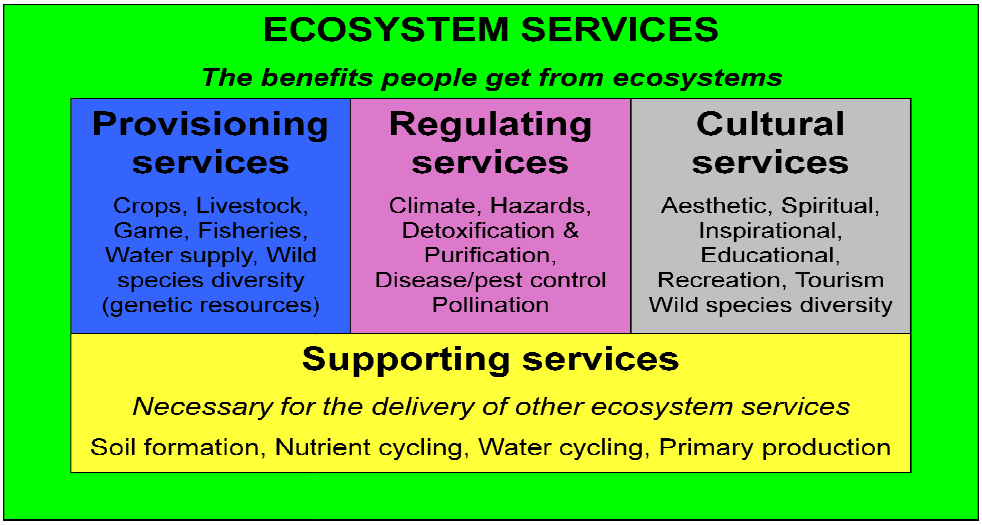
Figure 1: Conceptual Framework



Ecosystems are places where biological, chemical and physical processes come together and where interactions among these components determine the properties of the ecosystem and set limits to the types of functions that could take place. The Broad Habitat types used as the basis for the classification of ecosystems are adopted from the Countryside Survey of the UK.

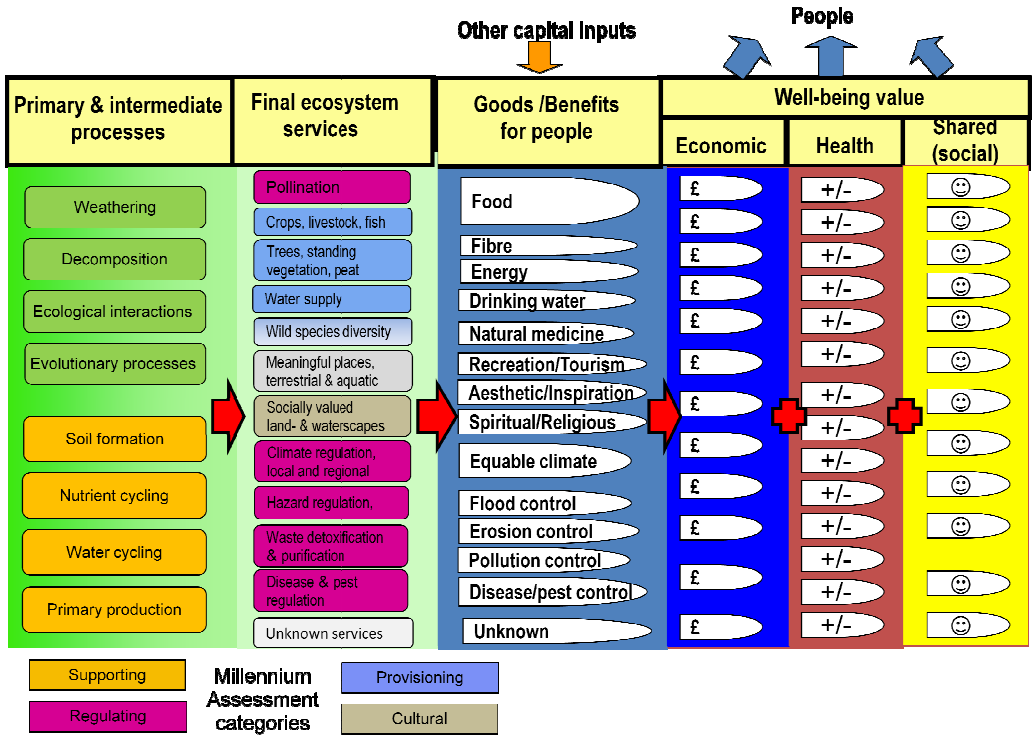
The UK NEA uses the broad definition of ecosystem services – outputs of ecosystems from which people derive benefits - and their classification into Provisioning, Regulating, Cultural and Supporting Services, which has proven to have traction for both science and policy development (Figure 2).

Figure 2: Ecosystem Services



There are a variety of outputs from ecosystems, but while ecosystems function and produce services, people place different values and choices around goods and benefits. The crucial link between services (as outputs of ecosystems), and goods/benefits (that people value and use) is that goods/benefits can be valued, both economically and non-economically, including shared (social) value. The UK NEA differentiates the final ecosystem services that directly deliver goods and benefits to people from the primary and intermediate processes and services upon which these depend to avoid double accounting (Figure 3).

Figure 3: Valuing of Ecosystem Services



The NEA conceptual framework also recognises that the values that people receive from ecosystems may to a greater or lesser degree alter the way that they choose to use and manage the environment. This in turn may lead to further changes in environmental pressures and drivers (the feedback loop in Figure 1).

Finally in the NEA we recognise the intrinsic value of biodiversity – the diversity of life *within species, between species and of ecosystems*, but specifically consider how it may directly contribute to some goods/benefits (see page 8-10).

Drivers of Change

Economic growth, demographic changes, advances in science and technology, coupled with changes in policies and behaviour have resulted in significant changes in habitats throughout the UK since the second world war, although the effects vary across the UK. Many of these changes in habitat and their associated ecosystem services are a result of satisfying the increased demand for food, water, fibre and energy. Historically, the lowlands in south east England and east Scotland have been converted to productive farmland, while the uplands have suffered from atmospheric pollution and high livestock densities. To date climate change has not been a significant driver of ecosystem change.

The increase in food production outstripped increases in the UK population since WWII, however, converting semi-natural habitats (e.g., grasslands) to arable land between the 1940's and 1990's, stimulated by demand and agricultural production subsidies, coupled with the increased intensity of agricultural production and use of agro-chemicals, has resulted in a significant increase in food production but has resulted in the loss of biodiversity and degradation of some regulating, supporting and cultural services:

- The UK population increased by 19% between 1951 and 2008, with a 117% increase in the number of people aged over 85 and over between 1983 and 2008;
- Personal and family wealth has significantly increased since the 1940s resulting in the proportion of average family expenditure on essential items such as food decreasing;
- Over half the land area of the UK is now under productive agriculture –England (75%), Northern Ireland (66%), Wales (about 50%), and Scotland (less than 25%) - the production yields of the main 4 cereals in the UK showed an increase of 80% to 220% from 1945 to 2005;
- Following entry into the Common Agricultural Policy support for productive agriculture led to overproduction of foodstuffs in combination with increased levels of intensive land use - Nitrogen additions to farmland increased by over 300% from 1957 to peak in the 1980's, but decreased significantly by 2007 - from 1990 to 2006 there was a 16% increase in the pesticide treated area of crops
- Commercial UK marine fisheries maximised short term production beyond sustainable levels. Over-exploitation has a significant adverse impact in marine ecosystems, both on target species but also on non-target species through wider ecosystem changes. UK fisheries that are at full reproductive capacity and sustainably harvested have only recently increased from 10% in 1990 to almost 25% by 2007.

One example of legislation that has simultaneously protected human health and ecosystems is the Clean Air act of 1956 which led to a successful reduction in pollution levels. From 1962 to 2002 there was a 95% decline in particulate smoke and sulphur dioxide emissions in the UK, while by 2006 nitrogen oxide emissions had shown a 50% decline from levels in 1970.

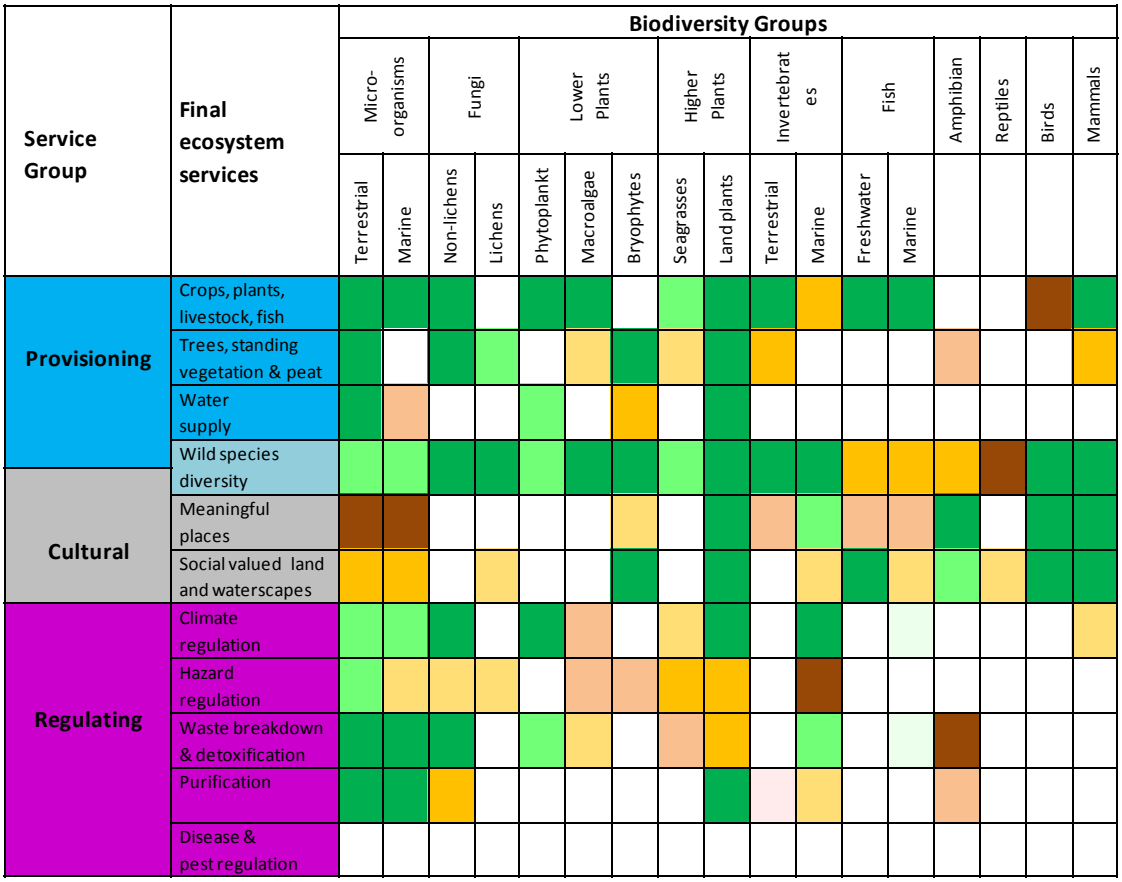
Policies and support mechanisms can support the protection and sustainable use of ecosystems. Woodland cover has doubled since WWII in response to grants and favourable economic and tax conditions, and recent agri-environment schemes have been successful in increasing biodiversity and ecosystem services.

Biodiversity

The diversity of life at the genetic, species and ecosystem level, otherwise known as biodiversity, underpins the provisioning of food, fibre, water and energy, regulating the Earth's climate, air and water quality, providing aesthetic, religious and spiritual value, and underpinning key process such as soil formation and nutrient cycling.

- There are 17 groups of species, which underpin key UK ecosystem services, include micro-organisms (terrestrial and marine), fungi (non-lichens and lichens), lower plants (phytoplankton, macro-algae, bryophytes),higher plants (sea grasses, land plants), invertebrates (terrestrial and marine), fish, (freshwater and marine), amphibians, reptiles, birds and mammals.
- The number of biodiversity groups that play an important role in ecosystem services, varies from service to service, e.g., water quality (3); socially valued landscapes and waterscapes (6); crops, plants, livestock and fish (11); and wild species diversity (all 17). Micro-organisms, fungi and plants play a role in underpinning all provisioning and regulating services. Vertebrate groups play a role in all cultural services, but only play an important role in 25% of the provisioning and regulating services (see Figure 4).

Figure 4: The importance of different biodiversity groups for the delivery of different final ecosystem services.



Importance is colour coded: high (green), medium (amber), low (brown), unimportant on the basis of available evidence (blank). The intensity of each colour is used to illustrate the level of uncertainty in the available evidence, ranging from dark (high levels of agreement across a large body of evidence) to pale (little agreement relating to limited evidence).

- Changes in biodiversity are linked to changes in ecosystem services. Such relationships *are well established* for some biodiversity groups and specific ecosystem services, but overall our quantitative understanding of these relationships is poor.
- A particularly well characterised relationship concerns pollinating insects and pollination services to crop plants. The evidence shows that changes to pollinator abundance and diversity through the loss of natural habitats can adversely affect pollination services in agro-ecosystems. However, although the patterns are clear, the mechanisms involved *are less well understood*.
- One example of where relating changes in biodiversity to changes in ecosystem services can be problematic is that we are currently unable to assess the magnitude of changes in cultural services associated with the well established changes in bird populations, i.e., relating the declining trends in woodland and farmland bird populations, or the increase in urban bird populations to socially valued cultural services.
- There is limited evidence that ecosystem functions are more stable in natural ecosystems with relatively high levels of biodiversity, hence in general terms, the level and stability of ecosystems services tends to improve with increasing biodiversity.

Figure 5: Drivers of biodiversity change for different biodiversity groups in the UK.

Biodiversity Group		**Trend information**	**Drivers of biodiversity change**				
			Land-use change	Climate change	Invasive species	Exploitation (direct and	Pollutants
Micro-organisms	Marine	Patchy					
	Terrestrial	Poor					
Fungi	Non-lichenised	Poor					
	Lichens	Moderate					
Lower Plants	Phytoplankton	Good					
	Macroalgae	Patchy					
	Bryophytes	Moderate					
Higher Plants	Seagrasses	Patchy					
	Land plants	Good					
Invertebrates	Marine	Patchy					
	Terrestrial	Moderate					
Fish	Marine	Moderate					
	Freshwater	Good					
Amphibians		Moderate					
Reptiles		Patchy					
Birds		Good					
Mammals		Moderate					

The colours reflect the the importance of different drivers: high (red) ,moderate (orange), low (green) unimportant on the basis of available evidence (blank)*. The intensity reflects the certainty of the evidence. The trend information available for each biodiversity group was assessed as good (UK-wide data on distribution, abundance and population trends over >20 year time period), moderate (limited data due to spatial or temporal coverage on abundance and population trends), patchy (only localised data available on distribution or trends) or poor (negligible data available on distribution or trends).*

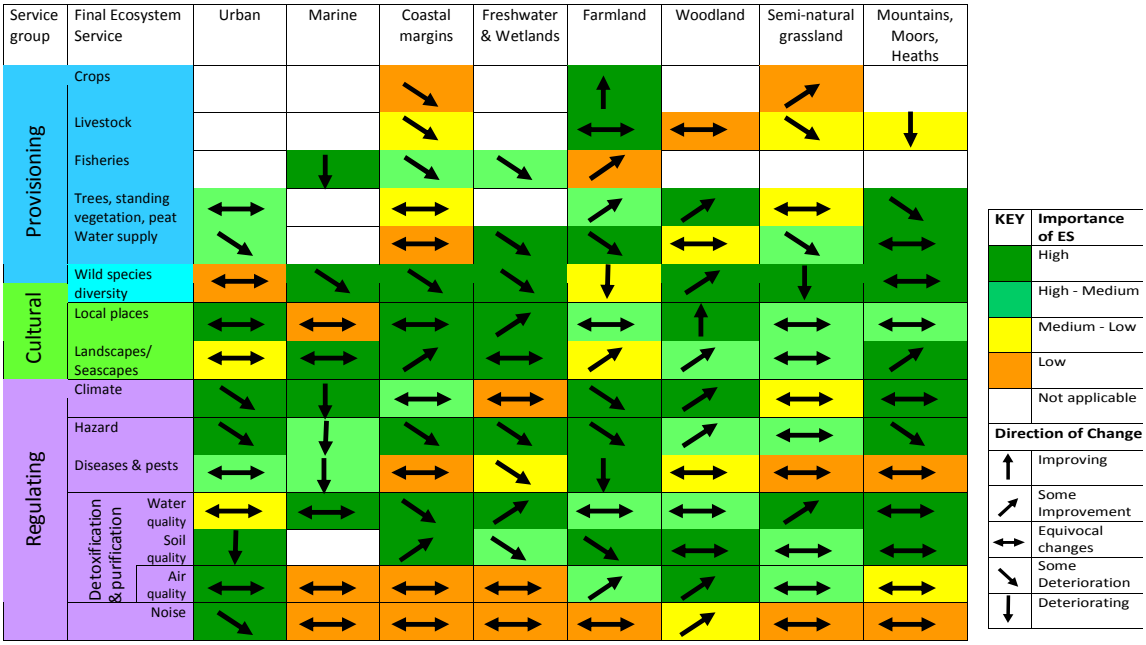
Significant biodiversity loss, primarily due to land-use change and pollution, over the last 50 years has been documented in the UK for biodiversity groups where there is adequate data, but data for a number of biodiversity groups is poor precluding a comprehensive assessment of status and trends (see Figure 5 above). Given the cultural importance of plants, fish, birds and mammals national-scale data on abundance and range exist over several decades, hence their status and trends are *well established*, there is clear evidence of significant biodiversity losses, together with evidence of population increases in certain species groups and limited evidence of population recovery in others:

- Ranges of native land plants have contracted on average since the 1960s across 1142 native species.
- Marine fish populations and communities have changed significantly since the 1960s, with exploited populations declining in abundance and some vulnerable species, such as the Common Skate, becoming regionally extinct. Since the early 1990s there is evidence of population recovery in 10-20% of finfish populations.
- Seabird populations have increased by 28% since 1970, but have decreased (-5%) over the last decade; woodland and farmland bird populations have both declined (-14% and -47% respectively); whereas urban bird populations have increased (11%).
- Among 37 UK mammal species, 40% appear to be increasing, 12% declining, and 16% stable, with the remaining 32% being considered data deficient.
- 67% of 333 farmland species (broad-leaved plants, butterflies, bumble bees, birds and mammals) had declining populations at the end of the 20th Century due to agricultural practices;
- There are very limited data available on several biodiversity groups, such as micro-organisms and fungi, which underpin provisioning and regulating services precluding an assessment of their status and trends.
- For culturally important biodiversity groups, status and trends are well established, but data on associated cultural services are frequently lacking. In contrast, there is quantitative data on changes in provisioning and regulating services, but the status and trend information for associated biodiversity groups is considered poor.

Ecosystem Services

Habitats (ecosystems) ranging from enclosed farmlands, to natural grasslands, forests, mountains, moors and heaths, rivers and oceans all provide a range of ecosystem services essential to human well-being as shown in Figure 6.

Figure 6: Preliminary analysis of the relative importance (coloured cells) of different habitats, and change over the last 20 years within them (directional arrows), in delivering final ecosystem services across the UK. It will differ at different national, regional and local scales. This representation is subject to revision before the NEA is completed.



Provisioning services

Over the last decade the UK has produced more food per year than at any other time in history. The large increases in the productivity of crops in the last 70 years, for example average UK wheat yields increased from 2.5 t/ha to 8t/ha, were commensurate with the area of cropped land rising from just over 3 million ha of crop land in England in 1940 to 4.2 million ha in 2009. Productivity gains have been made in the livestock sector, too, with average milk yields increasing from 1960 levels of 3500 l/cow/yr to 7000l/cow/yr by 2009, and the average dressed carcass weight for steers increased from 267 kg in 1980 to 316 kg in 2003. However, the numbers of dairy cattle, beef cattle and sheep peaked in 1980, 1999 and 2000 respectively, and have fallen significantly since (e.g., a drop of nearly 50% in dairy cattle and 35% in sheep). While changes in dairying are largely driven by market fluctuations, sheep stocks respond to changes in subsidies.

The provision of food from marine fisheries is lower now than at any time in the last century. Total UK annual landings of marine fish declined from 1.25 million tonnes in 1948 and declined slightly to just over 1 million tonnes in 1970. Since then the total weight of landings has declined steadily to 538,000 in 2008 tonnes. Large declines have been recorded in demersal species, with smaller declines in pelagic species: trends which might have been greater without improved technology accessing new stocks. Landings of shellfish have been constant over the last 60 years. Production from aquaculture has increased over the last 20 years, with most occurring in Scotland where salmon production increased almost 20 fold.

Some game species have shown major declines in numbers, while other have become more abundant and widespread. The numbers of wild caught salmon fell in Scotland after 1970 to a low of < 100,000 fish in 2006 and in England to just 40,000. There were declines in partridges between 1940 and 2009 due to changes in farmland management, but the reasons for declines in red grouse on moors remain unexplained. Deer are now more widespread in the UK, and harvests have not shown any evidence of decline.

Overall provision of timber has increased over the last 40 years, but major increases in softwood harvests mask declines in the harvest of hardwoods. Since 1970 the production of softwoods in the UK has increased steadily, driven by policy and tax incentives, to 8,600,000 cubic metres in 2008, of which 63% came from Scotland. Over the same period the harvest of hardwood declined to less than 400,000 cubic metres. These trends may reflect the fact that softwoods are derived from plantation forests, while most hardwoods are obtained from managed semi-natural woodlands.

The amount of water put into the public water supply in the UK declined between 1990 and 2008 from 20 billion (10^9) litres per day to about 17 billion (10^9) litres per day. The greatest declines occurred in England and Wales, with hardly any declines occurring in Scotland, where losses due to leakage remain significant, and Northern Ireland.

Regulating Services

Climate regulation: **The UK has large amounts of carbon "locked up" in its forests, peatlands and soils (114 Mt C in vegetation; 4562 Mt C in soils) but projected changes in emissions from the land use and forestry sector in the next ten years could switch this from being a net sink of carbon dioxide to a source.** The main drivers of change since 1950 have been intensification of agriculture and land use change, particularly forest planting and urbanisation. Our main knowledge gaps concern the effect of land use management (rather than land use change) on greenhouse gas emissions/removals, particularly for non-CO_2 greenhouse gases.

Hazard regulation: **The capacity to regulate water, nutrient, pollutant and sediment transfer from the land surface continues to be compromised by soil degradation. The ability of the soft landforms of the UK coast to regulate erosion (17% currently eroding) is threatened by sea-level rise, changes in frequency and severity of storms, and low sediment availability**. Assessment of present and future delivery of hazard regulation is limited by knowledge of coast and upland condition; understanding of rates & pathways of recovery from degradation; and, the challenges posed by the need to quantitatively understand the effects of extreme events.

Disease and pest regulation: **Agricultural intensification, population growth and land/wildlife management are currently important drivers of disease and pest spread. Changes in climate are likely to become more important over the next few decades as witnessed recently for vector-borne diseases.** Relatively innocuous weeds at the base of the arable food web have declined due to the more frequent use of broader spectrum herbicides. The inadvertent import of fungal plant pathogens via live plant material is arguably one of the most significant concerns, Detailed longitudinal field studies are required to understand the role of indigenous hosts and vectors in the transmission cycle, in emerging pathogens.

Soil quality: **Soil quality in all UK Broad Habitats has been degraded by human actions over the last 50 years, primarily from atmospheric pollution and some land management practices.** The consequences are reflected in a reduction in the capacity of soils to regulate to buffer, filter and transform chemical substances. Trends indicate that recovery from, and remediation of, both diffuse and point-source pollution is in progress but there remain significant uncertainties over this recovery under changing climatic conditions. Uppermost amongst these are the vulnerability of UK's soil carbon stocks and soil's role in purifying water resources.

Water quality: **Water quality has improved since the 1980s due to controls on point sources and atmospheric pollution, but diffuse pollution from agriculture remains high, and greater incidence of low flows in future could reduce the pollutant dilution service provided by freshwaters.** Upland waters are recovering from acidification, but concurrent increases in dissolved organic carbon concentrations have affected water treatment. Lowland water quality has improved due to better regulation of large point sources since the 1980s, but diffuse agricultural pollution and smaller point sources continue to cause eutrophication, and faecal pollution problems persist in some bathing waters and shellfisheries.

Air quality and noise: **Although there have been significant improvements in UK air quality over recent decades, largely driven by reduced anthropogenic emissions, current concentrations and deposition rates still exceed thresholds for effects on crop and forest production and biodiversity over significant areas of the country.** Ecosystems can have positive effects on air quality, primarily through interception, deposition and removal of pollutants, and negative effects through emissions which directly or indirectly degrade air quality. However, we lack modelling tools to quantify at a national scale the net effects of changes in ecosystem regulation of air quality on the health and ecological impacts of air quality. Noise can have a negative effect on human well-being, but the area of the country characterised by the lack of noise and visual intrusion has decreased significantly, mainly due to increased road traffic.

Pollinators: **Both managed pollinators (honeybees) and wild pollinators (primarily non-managed bees and hoverflies) have severely declined during the last 30 years and this trend is expected to continue.** 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. The value of pollinators to UK agriculture is conservatively estimated to be £440 million p.a. There are multiple drivers of pollinator loss, including loss of semi-natural habitat, pathogens, inappropriate use of agro-chemicals, and climate change.

Trade-offs and synergies between regulating services: **Whilst there are a number of synergies between regulating services (e.g. tree planting to improve air quality, reduce noise, and sequester carbon for climate regulation) there are also a number of trade offs (e.g. reduction in acid deposition has improved soil, water and air quality, but may have released more carbon from upland soils).**

Cultural Services

The experience of cultural ecosystem services through contact with nature in local places and landscapes is valued by a majority of UK residents. 'Local places' are assemblages of man-made structures and natural elements which provide the settings in which everyday experiences with nature give meaning to people's lives. 'Landscapes' are socially constructed through historically and culturally conditioned ways of viewing an area of land and/or sea but not all landscapes are equally valued and partly reflect cultural diversity across the UK.

The cultural benefits from 'local places' and 'landscapes' are those related to inspirational /aesthetic experiences, religious and spiritual sensibilities, and a sense of history and freedom. It is *well established* that there is an enormous range of diverse cultural products which represent aspects of nature, place and landscape in *words* (e.g. nature poetry); *images* (e.g. wildlife documentaries) and *physical objects* (e.g. landscape gardens). Also, 'local places' and 'landscapes' play a positive role in religious practice and faith but more general evidence on their spiritual and religious role is limited and can be *speculative*. *There are competing explanations* as to the ways in which aesthetic experiences of local places and landscapes contribute to enjoyment, inspiration, a sense of history and freedom.

Research shows that being outdoors in 'landscapes' and 'local places' leads to positive physical and mental health outcomes. *Established but incomplete* explanations indicate that, that levels of interaction/engagement with 'green space' have been linked with child development, longevity and decreased risk of mental ill-health, and that vitamin D generated by being outdoors in sunshine plays a role in long-term health. The presence of urban nature is important for improving behaviour and cognitive functioning, reducing levels of aggression and crime, providing an outdoor classroom and aesthetic inspiration, and enhancing exercise.

Natural settings found in 'local places' and 'landscapes' provide important destinations for tourism and leisure trips but access to the countryside is uneven. Legislative changes in the last decade have contributed to improving access to some landscapes. However, parts of England dominated by intensive lowland farming continue to offer relatively limited accessibility to outdoor environment. In 2007, in Scotland, 44% of the adult population made at least one visit per week to the outdoors for leisure purposes. In England in 2005, approximately 66% of day visits were to inland towns/cities which often included trips through a range of landscapes.

Since 1945 a large number of protection schemes instigated by UK and EU government have been implemented to conserve certain socially and culturally significant landscapes. 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 (for Scotland) all play a role in conserving and protecting specific landscapes and local places. However, new settlements and the expansion of existing settlements have been important drivers of change in landscapes in southern and central England. There is evidence to indicate that many people's satisfaction with ecosystem cultural services has declined over this period, especially with respect to local places.

The sense of citizenship and the strength of national and personal identity felt by individuals and communities in different parts of the UK are based, in part, on landscape character and sense of local place. *It is well established* that 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.

Supporting Services

There is a diverse range of soils within the UK landscape, resulting from almost infinite variation in the soil-forming factors of parent material, climate, biota, relief and time. In general, our soils are relatively youthful due to the presence of ice sheets and peri-glacial conditions that only retreated from most of Britain 10-15,000 years ago, Data on rates of soil formation are few and vary greatly, but typically they lay in the range 0.04-0.08 mm yr−1.

Significant 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. Although soils form slowly, they can be degraded quickly and lost, with significant consequences for all other supporting services and also the regulating and provisioning services that they underpin. Loss of soil carbon and the feedbacks to climate forcing, sufficient high quality soils for provisioning crops and protection of water quality are the most significant.

The last 50 years have witnessed substantial changes in the nitrogen status and pH of soils and waters, with likely consequences for the delivery of both regulating and provisioning services. The nitrogen enrichment of UK Broad Habitats through atmospheric deposition has caused substantial changes in plant species diversity and composition in many UK habitats, though the consequences for soil nitrogen cycling are unclear. Also, the pH of surface soils and water and is almost certainly related to a substantial decline in sulphate deposition and increase in rainfall pH since the late 1970's, which previously damaged vegetation.

There has been a widespread decline in the amount of soil phosphorus available to plants across UK Broad Habitats between 1998 and 2007, by on average 25%. Also, there is evidence of recent decreases of phosphate concentrations in rivers and lakes, although it is unclear whether this is linked to the decline in soil phosphorus. However, recent declines in the use of phosphorus fertiliser on managed land and greater primary production due to enhanced nitrogen deposition, and hence uptake of phosphorus, may have played a role.

There have been few general trends in the water cycle, but climate warming in the last 30 years is likely to have driven a gradual increase in annual average evaporation loss, while rainfall seasonality has increased due to wetter winters. There is also some evidence of increases in runoff for a number of northern and western rivers reflecting increased winter rainfall,

Primary production is the process underpinning all food and fibre production and contributes to climate regulation through capture and storage of carbon. High primary production is associated with managed systems in areas with optimum climate for plant growth. It is likely that climate change will increase primary production in many areas, but with greater risk of dramatic changes expected as a result of extreme weather events, such a the reduction during the summer drought of 2003. There is a speculative role for biodiversity aboveground and belowground affecting the resistance and resilience of primary production to single or multiple stresses.

Broad Habitats

Enclosed farmland

Enclosed farmlands are dynamic habitats, managed largely for agricultural production, underpin the UK agri-food sector that contributes over 6% of UK GDP, producing 73% of indigenous foods, but can also provide many other benefits. Enclosed farmlands are primarily managed for cereal, cattle and sheep production. Arable land occupies an estimated 19% of UK land area, concentrated in eastern England, and improved grassland a further 21% in the wetter parts of western parts of the UK. Wheat yields per ha have increased by over a factor of 3 between 1940 and 2008 approaching 8t/ha. Livestock numbers have decreased by over 25% to 38 million between 1990 and 2007/2009, with an associated decrease in methane emissions of nearly 20%. Self sufficiency in food production has increased from around 30-40% in the 1930s to around 70% in the 2000s. There has been a medium-term trend towards specialization and landscape homogenization due to mechanization, use of inorganic fertilizers, economies of scale and market forces in combination with EU agricultural policies. During the late 1980s there was a significant loss (about 20%) of hedgerows due to poor management.

Currently, many interactions between provisioning and other ecosystem services are negative, though 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 to catchment and above. Agri-environmental schemes, which now cover 8.45 million ha, and set-aside policies are thought to be responsible for the 5.4% increase in enclosed grassland between 1998 and 2007, restoring some diversity in arable landscapes. Low input agriculture tends to provide higher levels of many services per unit area than high intensity agriculture which tends to consistently result in negative impacts on non-provisioning ecosystem services. Interactions between enclosed farmland and other habitats result largely from: co-management with upland grazing areas on the same farms; transport of pollutants between them in air and water; the high value placed on landscape matrices in terms of landscape quality; and impacts on habitat change beyond the UK through trade of food and, increasingly, bio-energy.

The levels of agricultural production increased greatly until the 1990s, while many other ecosystem services declined; the increases in total agricultural productivity were halted during the 1990s, while the deterioration in other ecosystem services was reduced and, in some cases, reversed. Current self-sufficiency in food production is around 70 % of temperate goods in the 2000s, UK agriculture accounted for 45 per cent of all non-CO_2 GHG emissions in 2006; absolute values fell by 19 % since 1990 largely as a result of declining livestock numbers. Levels of carbon in arable and horticultural soils fell between 1998 and 2007, while stocks under improved grassland remained steady. Birds influence many services, including cultural services in farmland, although quantitative data are lacking on the values and benefit they provide. The farmland bird index declined by 43% between 1970 and 1998, and by a further 4% between 1998 and 2008. During the 20th century, agriculture was associated with major declines in diversity and numbers of plants, terrestrial invertebrates and vertebrates. Only 26 out of 710 ASSIs and SSSIs on enclosed farmland are in favourable condition.

We currently lack knowledge of how best to optimise agricultural land management for multiple outcomes, how to address the scale dependencies of such optimisations, assess the impact of land management on some services, or the impact of some services on agricultural production. Sustainable land management at regional scales will be difficult to deliver without influencing decision making through the creation of new patterns of knowledge generation and exchange, market mechanisms, incentives and regulation. Increasing production without reducing other ecosystem services will be extremely challenging if the prices of energy and carbon rise and the availability of phosphorus fertilizers decreases.

Woodlands

The area of woodland has doubled since WWII to cover 12% of the UK (17% in Scotland, 14% in Wales, 9% in England, and 6% in N. Ireland), but still remains well below the EU average of 37%. While there is no primary woodland in the UK, restoration in cover has resulted from afforestation (e.g. of marginal grazing land in the uplands) and re-growth of existing woodland from wartime felling, so that 80% of woodland is younger than 100 years of age. The initial driver for expansion was timber production (a provisioning service) and this underpins the dominance of conifer species which comprise 81% of current woodland in Scotland, 55% in Wales, and 35% in England However, since the mid-1980s, forestry policy has increasingly sought a basket of services (including biodiversity, cultural and regulating), resulting in increased planting of broadleaved tree species (an increase of 6.9% in the area of broadleaved woodland in the UK between 1998 and 2007) and a diversification of plantation structures. About one quarter of priority species listed under the UK Biodiversity Action Plan are associated with trees and woods, and recent reports suggest that that the condition and area of 7 priority habitats are improving. Species monitoring suggests a tendency for decline in some native woodland specialist species in particular groups (e.g. some woodland birds and mammals such as red squirrel) yet some other woodland dwelling species in the same groups are increasing; there are multiple possible causative factors including migration routes, woodland structure, competition and disease.

There are multiple drivers of change in woodland ecosystems, including climate change, pollution, government policy on land use, global trade, and the endogenous dynamics of ageing woodland. There is little evidence of climate-related changes in the composition and structure in UK forest and woodlands but evidence of range change of more mobile species such as insects and birds. There are indications that warmer summer temperatures have increased tree growth and altered phenology in some areas, and milder winters may have led to increased outbreaks of pest species and pathogens. Despite recent reductions in pollutant emissions, N deposition and ozone levels are still above 'critical 'loads' for habitats such as UK Atlantic oak woodlands with sensitive ground flora and epiphytic lichens. Woodland ageing has led to increased shading and loss of structural diversity and is likely to have contributed to the decline of some woodland birds.

Woodlands are important in providing provisioning service (timber), highly valued by people for social and cultural services, and the capacity to sequester carbon. A total of 8.4 million green tonnes of softwood (about 60% of annual increment) was produced in the UK in 2008, and a total of 0.4 million tonnes of hardwood (about 20% of annual increment) were produced from broadleaves. The gross value added in forestry and primary wood processing increased to £2.05 billion in 2007, complemented by a number of non-timber products, e.g., game shooting (about £640 million per annum) and wild harvesting of fungi, berries, etc. Trees and woods form an important component of our most treasured landscapes, greatly enhancing their aesthetic appeal. The social (e.g., landscape and recreational visits) and environmental benefits of woodlands in GB were valued at more than £1 billion in 2002. The total carbon stock in UK forests (including their soils) is approximately 790 MtC. The strength of the UK forest carbon sink increased from 1990 to 2004, but may now start to decline as a result of the fall off in planting rates in the last 20 years, however, there is renewed policy interest in forest expansion in England, Scotland and Wales. New woodland, if located and managed with care, can also contribute to removal of pollutants, absorption of noise, soil protection, flood regulation and maintenance of water quality.

Forest policy and woodland management have changed over time, seeking varying combinations of goods and services, upon which the delivery depends on specific characteristics of trees and woodlands (e.g., growth rate and species composition) and management practices. Diversification of forest structure for biodiversity benefits may improve cultural services, and increases in forest cover may benefit carbon regulation and contribute to flood regulation. However, maximising the 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/aesthetic values. A spectrum of techniques within a framework of sustainable forest management can deliver different baskets of goods and services, and certification schemes exist to encourage appropriate action.

Semi-natural grasslands

The area of semi-natural grassland has declined greatly since WWII, 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**. Today only 2% of semi-natural grasslands comprise high biological diversity. 97% loss of enclosed semi-natural grasslands occurred in England and Wales between 1930 and 1984, and an 89% loss of lowland semi-natural grassland in Wales between the 1930s and 1990s. Losses continued through the 1980s and 1990s, but with no significant change between 1998 and 2007. The slowed decline is *likely* due to improved protection and re-creation of grasslands, for example through agri-environment schemes. However, inadequate management continues to cause declines in the quality of semi-natural grasslands, e.g., in 2005 only 21% of English and 31% of Scottish semi-natural grasslands were in favourable conditions. There are few trend data for Scotland or N. Ireland, but the scale of loss across the lowlands of these countries is *likely* to be similar to that reported for England and Wales. Technological advances and Government incentives drove the conversion of high diversity semi-natural grasslands to either 'improved grasslands' or arable land. Agricultural improvement has decreased in importance as a driver as much semi-natural grassland is now protected within Sites of Special Scientific Interest (68% in England) and within National Parks (52% in Wales). Other drivers continue to cause habitat and species loss: particularly nitrogen deposition, inadequate management and habitat fragmentation.

Semi-natural grasslands are a vital part of the UK's cultural landscape, provide habitat for important and rare species and are higher in biodiversity than agriculturally-improved grasslands (higher plant richness): agri-environment schemes are critical to restore and enhance semi-natural grassland biodiversity and services. Of the 1150 species of conservation concern named in the UK Biodiversity Action Plan, lowland semi-natural grasslands are home to 206 UKBAP species, while upland grassland Priority Habitats are home to 41. The UK National Parks, which are valued for recreation, green spaces, education, etc, all contain significant areas of semi-natural grassland. Semi-natural grasslands have high invertebrate abundance and diversity and may provide pollination and pest control services by spread of insects to agricultural areas, although the evidence for this effect is *limited*. However, declines in bumblebees since the 1960s show a *well established* link with declines in key semi-natural grassland plants. In general low input semi-natural grasslands deliver multiple services, e.g., store greater densities of carbon than improved grasslands and arable land, allow greater water infiltration rates and enhanced storage which should aid flood prevention, and produce less nitrous oxide and pollution due to the low fertilizer inputs. Productivity of semi-natural grasslands increases with enhanced plant richness in the absence of fertilizers. However, productivity in UK semi-natural grassland lowland systems without fertilizers is significantly lower than in agriculturally-improved grasslands, e.g., hay yield is typically 2-8 t per ha, which is less than 30%. Fertilizers can increase yield to 10-12 t per ha. Maintenance of the biodiversity and cultural value of semi-natural grasslands requires low intensity management related to traditional farming.

Open waters, wetlands and floodplains

Rivers (160,00 km), lakes (6000) and wetlands are widespread in all UK landscapes, highly connected to each other and to their catchments, and provide services of major importance. However, systematic understanding of how freshwater services depend on ecological quality and processes, and biological composition is extremely weak, and their benefits are generally only poorly valued and many have been degraded or lost or converted to other uses. When managed appropriately, freshwaters **provide** for consumptive and non-consumptive uses of water; organisms for food, recreation and conservation; and energy. They **regulate** flooding, erosion, sedimentation, local climates and water quality, while facilitating the dilution and disposal of pollutants. They **support** dispersal of substances, energy and organisms as well as providing ecosystem resistance or resilience internally and in adjacent systems (for example though water supply). They have large **cultural** value for recreation, tourism, education and as inspiration for the arts and religion. Despite the multiple benefits of naturally functioning wetlands and floodplains, many have been lost or converted to other uses that emphasise a small number of services.

Freshwater habitat quality, which varies spatially and temporally, has been inadvertently traded-off against wider landscape management. Rivers in urban or intensively agricultural regions generally have significantly lower sanitary quality than other regions within the UK, elevated nutrients and physical modifications (over 50% of English and Welsh rivers), while upland or western regions are still affected by diffuse agricultural pollutants. Since 1990, in England and Wales, 7000km of rivers are biologically improved and 12000 km chemically improved. However, nitrate concentrations have increased in almost 4000km, while biological quality has declined in about 2500km of the best hill-rivers concentrated in Wales and the Welsh borders for reasons that are unclear. Along with wetland drainage, flood defence and the purposeful and accidental use of freshwaters for waste disposal, such effects led in the past to degraded ecological quality, loss of asset value and adverse health impacts. Freshwaters appear particularly vulnerable to catastrophic regime changes, and past adverse effects include acidification, impoundment, flow modification, eutrophication, habitat degradation, fragmentation, loss and drainage, toxic pollution, exploitation and exotic species. Novel pollutants (e.g. endocrine disrupting substances), nano-particles, and the effects of synthetic biology are emerging issues, while freshwaters in general will be highly sensitive to future land-use, climate, flood-risk management and increased water demand. Climate change affects on river biodiversity, e.g., declines in populations of trout and salmon by about 50-60%, are emerging in some catchments as some UK river temperatures have warmed by 1.5–3^{o}C since 1980. With only small proportions of wetlands and less than 1% of the UK river length part of formal protection networks, sustainable freshwater management will depend upon better use of existing legislation, improved planning, and improved instruments to optimise land and water management.

Mountains, Moors and Heathlands

Substantial changes to mountains, moors and heathlands, which currently cover about 18% of the UK, took place in the first 30 years after WWII, both in extent and condition and how they have been used by people, but with no further dramatic losses in the extent in the last two decades. Greatest losses in extent and quality, primarily due to agricultural development, high grazing pressures, afforestation, airborne pollution and to a lesser extent climatic changes, were reported for bog, upland and lowland heathland, whilst much of the previously moss dominated montane habitat in Wales and England was converted into grassland prior to 1990. Recently the direct and underlying drivers of change have been moderated in terms of their impacts by a number of policy mechanisms and cultural pressures. However, there is widespread evidence for long-term reductions in ecological status, notably increased levels of peat erosion, general decrease in species richness and expansion of grasses at the expense of moss and dwarf shrub-dominated communities.

Mountains, moors and heathlands are highly multi-functional:

- important source habitats for about 70% of UK drinking water and also hold about 40% of soil carbon mainly in upland peat soils. In addition, these ecosystems buffer water quality against effects of atmospheric, diffuse and point source pollutants, and present opportunities for short-term reduction of UK CO_2 emissions especially through active restoration of moorland, notably by enhancing their capacity for carbon sequestration;
- nationally treasured landscapes, providing breathing spaces for people living in and around them, are important cultural landscapes steeped in history, and are of great importance for biodiversity, with a large part under national and international designation for conservation. The landscapes are often part of iconic imagery that is used to convey national or regional sense of identity, with recreation and tourism values being important components of the total economic value of these ecosystems, whilst their 'non-use' or existence value is also high. The prevalence of peat and organic soils make them a valuable source of palaeo-environmental and archaeological evidence of past landscapes, management and culture. The blanket bogs and oceanic mountain habitats are of international importance and home to some of the UK's rarest species and communities. They comprise a unique mixture of temperate, alpine and arctic species.

Coastal Margins

Coastal margin habitats (sand dunes, machair, saltmarsh, shingle, sea cliffs and lagoons), which have declined in extent by about 10% and quality since WWII due to development and coastal squeeze, are more important to society than their small area would suggest, directly providing ecosystem services to the terrestrial and the marine habitats on either side and to a broad cross-section of the UK population willing to travel to experience the coast. Sand dunes and saltmarsh have been lost due to agricultural improvement (including forestry) and land-claim, while rapid coastal development for industry, housing, military activities and tourism has affected all habitats. The rate of loss has slowed since the 1980s due to greater statutory protection of many sites, but losses continue. These quality of these habitats have been impacted by widespread installation of artificial sea-defence structures and increased armouring of soft cliffs reducing sediment supply and natural dynamics, while reductions in traditional forms of management such as grazing and decades of conservation effort have led to over-stabilised systems. In general, the disturbance resulting from natural processes such as erosion and sediment transport by the sea and wind provide the essential dynamics in a healthy system, provided there is space to accommodate it. Atmospheric nitrogen deposition, which has doubled since 1945, together with increased temperatures, may be accelerating plant growth and altered soil processes. All of these factors have combined to reduce the proportion of early successional habitats, increase the proportion of later successional habitats, and reduce their biological and conservation interest, and may indirectly alter ecosystem service provision, and their capacity to adapt to climate change and sea level rise.

Coastal margins are important in providing coastal defense, and have high biodiversity, which forms part of the foundation for culturally important ecosystem services. Up to 50% of wave energy is dissipated in the first 10-20m of vegetated saltmarsh, reducing the required size of landward defences. Dunes and shingle protect residential areas and high quality farmland. Saltmarsh, sand dunes and uncultivated machair, regulate climate through carbon sequestration due to rapid soil development or sediment accumulation.

- Coastal margins are highly valued by the public, as living space for coastal communities, as a symbol of identity, a place for rest and relaxation, with a sense of freedom, where people can enjoy scenery and wildlife and specific activities including sunbathing, walking, birdwatching, boating, swimming, and specialist outdoor sports. There are nearly 250 million visits per year to the UK coast.
- Coastal margin habitats support a wide range of specialist and rare species, partly dependent on natural dynamics creating temporal and structural change forming a mosaic of habitats of different ages. Coastal margins provide important habitat for many bird species, provide 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. Saltmarshes provides nursery grounds for many fish species including commercially important species.

Sustainable management options of coastal margin habitats, which are holistic and take into account physical and biological processes, spatial scale, drivers of change and cultural elements have benefits, and may include:

- Allowing coastal margin habitats room to migrate inland with rising sea-levels to mitigate coastal squeeze;
- Managing sediment supply by allowing erosion of soft cliffs to create new sediment, and allowing natural transport processes to proceed where possible; and
- Management to maintain or facilitate early successional habitats where these are threatened or have disappeared.

Marine

UK seas provides a wide range of ecosystem services and benefits, including food (fish, shellfish, aquaculture), avoidance of climate stress (carbon and other biogas regulation); energy (wind, wave, tidal, and biofuels); genetic resources (for aquaculture); industrial inputs (biocatalysts, natural medicines); fertiliser (seaweed); coastal protection including erosion and flood control; waste breakdown & detoxification leading to pollution control, waste removal and waste degradation; disease and pest control; tourism, leisure and recreation opportunities; a focus for engagement with the natural environment; physical and mental health benefits; cultural heritage and learning experiences.

- Ecosystem breakdown of waste and purification of water appears to be keeping pace with inputs in open shelf waters although localised contamination and some eutrophication problems persist. In some coastal waters, such as estuaries, local contamination by diffuse organic and inorganic pollution (e.g. sewage effluent, agricultural fertiliser run-off) still exceeds the capacity of the ecosystem to remediate.

- Provision of wild fish as food in UK waters is now insufficient to meet demand. Since WWII there has been an increased demand for fish in the diet, leading to the rise of aquaculture, particularly finfish in Scottish waters and shellfish in English, Welsh and Northern Irish waters, and the importation of growing quantities of fish from overseas.
- The sustainability of food provision from marine ecosystems is under threat from the overexploitation of fisheries; fishing impacts are also damaging biodiversity and other marine ecosystem services. Fishing activity has increased over the last 50 years to the extent that the pressure on living resources and habitats is significant, resulting in several fish stocks in the North Sea and in the Irish Sea being outside the biological limits set for exploitation.
- By-catch of dolphins and harbour porpoises are a significant pressure from some types of fishing methods although harbour porpoise by-catch rates have been declining as gillnet fishing effort has reduced. By-catch as a result of commercial fishing also affects seabirds.
  Human activities that have a physical impact on the seafloor adversely affect the benthic biota (species which live on the sea bed) and communities that live there. Sea-bed trawl fishing activity has the greatest impact as it results in direct mortality of benthic organisms.
- Changes in sea temperature are impacting on plankton species and possibly on other marine ecosystem services. The effects of changes in sea temperature and heavy fisheries exploitation are difficult to distinguish from each other but they are *likely* to have synergistic effects. Changes are already evident in the distribution of plankton species. Such changes are *likely* to be affecting specifically food production, wildlife such as seabird colonies, and possibly human health through enhancement of pathogens.

Urban

Over 10% of England is now classified as urban, 1.9% of Scotland, 2.9% of N. Ireland, and 4.2% of Wales, with the majority of the population (about 90%) residing in these areas, up from about 79% in the 1950s. High density housing has contributed to dense inner cores and suburbs often devoid of adequate greenspace tending to limit important social and cultural services and overwhelming regulating services. The condition of urban greenspace declined during the last three decades of the 20th Century in England, likely due to a reduction in funding for public parks, the absence of any statutory parks services and the sale of playing fields, undermining the provision of substantial ecosystem services, although this trend is now reversing.

Urban areas' ecosystems currently provide very limited provisioning services, though there is a revival in allotments, and tend, in general, to be ineffective in regulating services, with the possible exception that green infrastructure can contribute to urban cooling, providing shade and removal of pollution particles. However, cultural services arising from access to good quality "green" space, through public parks and private gardens, contributes to positive mental health, childhood development and physical health.

- During WWII allotments once provided 10% of all food production in the UK and over half were located in urban areas. After decades of decline, allotments now cover just 10% of post war extent. Demand in recent years is increasing with interest in organic products and self-sufficiency driving household food production.
- Urban air quality has significantly changed over the last 60 years. There has been a decline in sulphur dioxide and black smoke emissions (greater than 95% decline since 1962 in London), but a growing significance of nitrogen oxides and fine particles (e.g., $PM_{10\ and}$ $PM_{2.5}$), largely driven by changes in energy production and the rise in vehicle ownership.
- Supporting and regulating services that could be provided by soils are severely restricted in urban areas because planning systems largely treat soils as platforms upon which to build. This results in a loss of porosity from widespread sealing, compaction and structural deterioration, a loss of function and resilience, with consequences for increased run-off and decreased ability to support vegetation.
- Sustainable enhancement of the provision of urban ecosystem services requires both active urban planning policies and conceptual changes to the evaluation of urban greenspace. Ecosystem services can be enhanced through green corridors, which can address the fragmentation of greenspace, thus helping to maximise multi-functional land-use and accessibility. However, there are trade-offs and synergies in ecosystem goods and services, e.g., tree cover in urban environments could reduce surface run-off, noise exposure and mid-afternoon peak temperatures (thus reducing the formation of ozone and volatile organic compounds), but some tree species emit volatile organic compounds, hence selection of tree species is important. Unfortunately the extent, condition and use of urban greenspace are not systematically monitored posing difficulties for effective management and valuation of ecosystem services.
- Climate modelling, intelligent building design and planning of greenspace can facilitate urban adaptation to climate change. Policy developments such as greenspace and tree planting schemes can enhance the broader appreciation of the ecosystem services that can be provided.
- Public parks, natural and semi-natural green space, amenity green space and playing fields extend over about 14% of urban areas while domestic gardens cover about 4% of all land in England and are largely located in towns and cities likely covering 12 to 25% of urban open space. Many social and cultural benefits, including community cohesion, neighbourhood development and environmental citizenship arise from the many meaningful places in urban areas.

Key Questions

Here we have drafted responses to two of the six questions identified at the outset (May 09) of the UK NEA

2 What are the drivers causing changes in ecosystems/Broad Habitats in the UK and the services they provide to society?

Biodiversity and ecosystem services are affected by both direct and indirect drivers. Direct drivers are those which directly impact on biodiversity and ecosystems, e.g., land-use conversion, overexploitation, introduction of invasive species, pollution and climate change. Indirect drivers are those which influence the direct drivers of change, e.g., economic and population growth resulting in an increased demand for food, fibre, water and energy, and 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 combined in different ways across the UK, e.g., the lowlands, especially in south east England have seen widespread conversion of natural ecosystems to productive farmland, whereas the uplands have seen high livestock densities and been subjected to high levels of pollution deposition. Also the impacts of agricultural activities have changed over time in response to policy changes, e.g., EU agricultural production subsidies stimulated increased agricultural production resulting in the conversion of natural ecosystems and a loss of biodiversity and the degradation of non-provisioning ecosystem services. With reform of the Common Agricultural Policy and the introduction of Pillar 2, which rewards environmental sustainability, biodiversity is being restored and ecosystems are becoming more sustainable.

Many of the changes in habitat and their associated ecosystem services are a result of satisfying the increased demand for the provisioning services of food, water, fibre and energy at the expense of biodiversity and regulating, cultural and supporting services. The increase in food production (the production yields of the main 4 cereals in the UK showed an increase of 80% to 220% from 1945 to 2005) outstripped increases in the UK population since World War II by converting semi-natural habitats (e.g., grasslands) to arable land and intensifying production between the 1940's and 1990's. However, this increase in food production was associated with major declines in diversity and numbers of plants, terrestrial invertebrates and vertebrates. Only 26 out of 710 ASSIs and SSSIs on enclosed farmland are in favourable condition.

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

- ***Economic growth:*** personal and family wealth has significantly increased since the 1940s resulting in a decrease in the proportion of average family expenditure on essential items such as food;
- ***Demographic changes:*** the UK population increased by 19% between 1951 and 2008, with more single and older people; until 1999 the main driver of population growth was the excess of births over deaths, but since 1999 the main contributor was net migration, especially since expansion of the EU in 2004;
- ***Advances in science and technology*** mechanization of farming practices and drainage technologies; use of agro-chemicals, e.g., fertilizers, and pesticides; crop and livestock breeding and species selection; mechanization of fishing practices and sonar technology; energy production and use.
- ***Socio-political, especially changes in policies***: Entry into the Common Agricultural Policy support for productive agriculture led to overproduction of foodstuffs in combination with increased levels of intensive land use; the agri-environmental schemes of Pillar 2 of the CAP, which now cover 8.45 million ha, along with set-aside policies are thought to be responsible for the 5.4% increase in enclosed grassland between 1998 and 2007, restoring some diversity in arable landscapes; the 1956 Clean Air Act, which led to a successful reduction in pollution levels in urban and rural environments, has simultaneously protected human health and ecosystems (from 1962 to 2002 there was a 95% decline in particulate smoke and sulphur dioxide emissions in the UK, while by 2006 nitrogen oxide emissions

had shown a 50% decline from levels in 1970); woodland cover has doubled since WWII first in response to increased timber production, and since the mid-1980s, forestry policy has increasingly sought a basket of services (including biodiversity, cultural and regulating), resulting in increased planting of broadleaved tree species and a diversification of plantation structures stimulated by grants and favourable economic and tax conditions;

- ***Behaviour change*** e.g., consumption patterns, e.g., fresh fruits all year round and changing diets; environmental attitudes; vehicle ownership.

These in turn have caused:

- ***Conversion of 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. 67% of 333 farmland species (broad-leaved plants, butterflies, bumble bees, birds and mammals) had declining populations at the end of the 20th Century due to agricultural practices, e.g., woodland and farmland bird populations declined 14% and 47% respectively, in contrast to urban bird populations, which have increased 11%. Wetlands have been particularly susceptible to drainage and conversion for flood defence and rivers to flow modification, while prior to 1980 some mountains, moors and heathlands were converted to agriculture, grasslands or afforested, and subjected to high grazing pressures. Coastal margin habitats (sand dunes, machair, saltmarsh, shingle, sea cliffs and lagoons) have declined in extent and quality since WWII due to development and coastal squeeze, with sand dunes and saltmarshes being lost due to agricultural improvement (including forestry) and land-claim, while rapid coastal development for industry, housing, military activities 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 regulating services.**
- ***Over-exploitation,*** especially overfishing in the marine environment - commercial UK marine fisheries maximised short term production beyond sustainable levels. This over-exploitation has a significant adverse impact in marine ecosystems, both on target species but also on non-target species through wider ecosystem changes. Marine fish populations and communities have changed significantly since the 1960s, with exploited populations declining in abundance and some vulnerable species, such as the Common Skate, becoming regionally extinct. Since the early 1990s there is evidence of population recovery in 10-20% of finfish populations**.** UK fisheries that are now at full reproductive capacity and sustainably harvested have recently increased from 10% in 1990 to almost 25% by 2007.
- ***Pollution of air, land and water,*** especially nitrogen from the use of fertilizers and sulphur from the combustion of fossil fuels. - Nitrogen additions to farmland increased by over 300% from 1957 to peak in the 1980's, but decreased significantly by 2007 - from 1990 to 2006 there was a 16% increase in the pesticide treated area of crops. Prior to 1990, rivers and lakes had been particularly susceptible to elevated nutrient loading, often from diffuse agricultural pollutants, with novel pollutants (e.g. endocrine disrupting substances and nano-particles) becoming an emerging concern.
- ***Climate change*** to date has not been a major driver for most ecosystems. For example, there is little evidence of climate-related changes in the composition and structure in UK forest and woodlands, although some evidence of range change of more mobile species such as insects and birds. In contrast, climate change has appeared to have affected river biodiversity, e.g., declines in populations of trout and salmon by about 50-60% in some catchments as some UK river temperatures have warmed by 1.5–3^{o}C since 1980, and changes in sea temperature are impacting on plankton species and possibly on other marine ecosystem services.

3 What are the uncertainties limiting our understanding of ecosystem services?

INTRODUCTION

The regular monitoring of many aspects of the state of the environment through the activities of statutory environment agencies and conservation bodies, as well as periodic assessments such as Countryside Survey, means that in the UK we have a suite of measures, or indicators, of trends in ecosystem services, many of which are summarised in this assessment. This rich source of data, coupled with detailed research on biogeochemical, ecological and hydrological processes, and the development of mechanistic models has helped to identify some of the key drivers of changes in ecosystem services in both time and space. However, the assessment also identified uncertainties about some of these relationships, and important gaps in basic information, which potentially limit our understanding of the dynamics of ecosystem services and thus, compromise our ability to make robust predictions about changes likely under plausible future scenarios.

UNCERTAINTIES ABOUT THE ROLE OF BIODIVERSITY IN ECOSYSTEM SERVICES

In general, the evidence linking biodiversity and ecosystem services implies that changes in biodiversity should be accompanied by concomitant changes in ecosystem services. However, we are currently unable to comprehensively quantify the relationships between UK biodiversity and the ecosystem services it supports. The difficulty arises partly because of asymmetries 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 that any other taxonomic group we are unable to assess the consequences of recent declines on changes in cultural services, because data on values and benefits are lacking. In contrast, there are very limited data on other biodiversity groups, such as micro-organisms and fungi, which underpin provisioning and regulating services, and where the changes in services are potentially easily valued. In this case, the paucity of data on trends in these taxonomic groups precludes an assessment of the consequence of changes for ecosystem services.

Not only is more effort required to describe diversity at lower taxonomic levels but also one of the biggest challenges is to increase our understanding of the role that soil biodiversity plays in key supporting services, including soil formation, nutrient cycling, and primary production. Furthermore, the speculative role for biodiversity below-ground interacting with biodiversity aboveground to influence the resistance and resilience of primary production to single or multiple stresses, is worthy of wider exploration.

UNCERTAINTIES ABOUT SUPPORTING SERVICES

Soil formation

The consequences of changes in land use for soil and geodiversity (and hence habitats and species) of increased pressures on the land bank, driven by changing policy and demands, as well as climate change, are poorly understood. The depth of soil and its spatial variation is difficult to measure, but such an assessment of soil C stocks to depth is of fundamental importance in determining the natural capital stock of our soil resource, and the soil organic C and nutrients required to support ecosystem services and the links to human well being.

Nutrient cycling

Understanding how multiple drivers acting simultaneously affect nutrient cycles represents a major research challenge for the future. Little is known about the mechanisms involved in the retention of anthropogenic N in soils, although it is evident that microbes can act as a major sink for N, and that they can regulate the transfer of N to soil organic matter, plants and aquatic habitats. Our understanding of P cycling is also relatively limited, especially with regards to how plants and microbes interact to access soil P, and how both N and P cycling are coupled. As a result we have little understanding of the reasons for the widespread decline in soil P.

Water cycling

There is a need to elaborate the seasonal flow paths between groundwater, soil water and river channels within catchments, especially at times when critical flows are exceeded. Future studies are needed to better understand 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 C cycling. 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.

Primary production

There is a need for studies which explore the consequences of real scenarios of non-random changes in plant species diversity and composition on primary production and other related ecosystem services across UK habitats. The consequences of reductions in soil biodiversity for primary production and the services that it underpins are poorly understood. Predictive models of Net Ecosystem Exchange (NEE) need to accommodate biotic factors such as grazing in order to accurately simulate the dynamics of carbon dioxide fluxes in UK terrestrial ecosystems. There is a need for experiments which simultaneously vary two or more change drivers to determine their influence on primary production and other ecosystem services across a range of UK habitats.

UNCERTAINTIES ABOUT REGULATING SERVICES

Climate regulation

There is a need for specific spatial and temporal (seasonal and annual) measurement and monitoring of GHG emissions from land under different management practices (e.g. minimum tillage), as well as under different land uses. Mountain/moorland/heathland habitats, in addition to their existing carbon stores, can either be sources or sinks of carbon dioxide and methane depending on location, management, prevailing climate and season. Information on GHG fluxes from deep peats is at present too patchy to make consistent, robust calculations at the UK scale. There is a need for improved modelling of long-term future scenarios and integration of emissions models with socio-economic models to explore potential trade-offs in strategic policies.

Hazard regulation

Coasts & Flooding: A systematic assessment of the drivers of past and present changes to coastal landforms and habitats is crucial to better inform decision-makers about the nature of future impacts.

River Flooding: A rigorous estimate of the possible increase in flood hazard is therefore a crucial task for planning future climate adaptation strategies, and our understanding of this change in risk is currently poorly understood.

Disease/Pest regulation

Recent problems with managing pathogens in the UK and Europe have arisen where the role of indigenous hosts, pathogens and vectors in the transmission cycle has not been fully explored, and even where it has been, we may lack information on their distribution in the UK. There is incomplete knowledge of important natural enemies, such as insect pathogens. The utility of practices such as conservation biological control could have significant positive impacts on pathogen and arthropod natural enemies and requires continuing investigation.

More comprehensive studies of the management of weeds and other arable pests are needed. The impacts of the increased use of herbicide (e.g. glyphosate) and other changes of this nature, on the yield and economy of crops, on weed flora and food webs, on the overall profile of pesticides in water and on the carbon footprint of arable cropping are poorly understood.

Pollination

We lack 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, and levels of pollination limitation, of many crop varieties and wild plants are poorly documented, or unknown, and the relationship between pollinators and service delivery is not well

understood. The combined lack of knowledge about pollinator-habitat relationships and drivers of pollinator shifts make it difficult to predict future changes.

Noise regulation
Whilst the spatial modelling of noise has increased, in particular for urban areas, actual measurements of noise seem very limited, in general, and especially in rural areas.

Air quality
We lack the modelling tools to provide an integrated assessment for all the major pollutants at a national scale, and hence an overall assessment of the value of air quality regulation. Also, there is a need for more knowledge about the impacts of air quality on human health, crop and forest production, carbon sequestration and ecosystem integrity.

Specific knowledge gaps that need to be addressed include: i)The deposition velocity of particulate matter to vegetation in relation to the particle size distribution, ii) Improved, spatially and temporally disaggregated, emission inventories and parameterisations for VOC from vegetation need to be developed.

Soil quality
Although various soil quality indicators have been identified for regulating services, data is still limited on optimal ranges, thresholds or trigger values for soil quality in individual Broad Habitats. This information will be required by land managers or other stakeholders to plan and assess the effectiveness of current or future management options to improve soil quality. A major challenge for protecting soil quality will be to disentangle the relative importance of direct and indirect drivers, as well as the nature of their interactions, in particular, management practices, atmospheric pollution and climate change.

Water quality
There is a need for a better distribution of monitoring sites to include coverage of smaller catchments and headwaters of large catchments. Everywhere improved measurements of sediment, phosphorus and microbial pollutant transport during extreme events should be a priority.

There is a need to improve understanding of the capacity of terrestrial ecosystems to buffer water quality, including nutrient retention, control of DOC, and micro-contaminants (e.g.: endocrine disrupting compounds and synthetic nano-particles). How these mechanisms are impacted by climate change is incompletely understood.

UNCERTAINTIES ABOUT PROVISIONING SERVICES

The key knowledge gaps relate to two fundamental relationships between a) Production and ecosystem function, and b) Society and production.

Production and Ecosystem Function

1) *Biodiversity:* What levels of biodiversity are essential to enable continued agricultural production? The flip side of this question is 'What level of redundancy exists in agri-ecosystems? Are all taxa necessary to enable continued production, or can production be maintained/enhanced if there is a reduction in the species richness in some taxa.
2) *Multifunctionality:* Is the philosophy of multifunctionality and integrated conservation / production the best way to enhance production and protect biodiversity? Or would a more segregated approach be better.
3) *Climate Change:* How can we redesign agri-ecosystems in order to reduce emissions of greenhouse gases (GHGs) from ruminants and soils? How can we redesign agri-ecosystems in order to increase sequestration of carbon into forest and agri-ecosystems?

Society and Production

1) How do the public trade-off food supply, prices of food and biodiversity in the UK countryside?
2) How do the public trade-off energy supply from renewable sources, food supply and biodiversity?
3) At what geographical scale is production publicly acceptable? Is there a real desire for 'very local' food even if this is shown to be environmentally sub-optimal? Can the public accept some level of formal zoning of land use?

UNCERTAINTIES ABOUT CULTURAL SERVICES

Although contact with the natural world is part of the bedrock of our society, there are justifiable concerns that the ecosystem service concept may lack cultural resonance. This has important implications for raising awareness of the wider benefits of sustainable management of natural resources.

More research is needed into understanding, specifically, losses in aesthetic value, not only in terms of visual and scenic value but also aesthetic qualities experienced through the other senses. Also, research in environmental and landscape aesthetics has tended to focus on landscapes. New directions for understanding the benefits of aesthetics and inspiration ought to include aesthetics and wildlife and the aesthetic qualities of marine, coastal and water environments.

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 for whom contact with nature is an intrinsic part of their religious/spiritual lives. There is a need to take a more sophisticated approach to spirituality and space, and apply it empirically, and relate it to different types of ecosystems.

For more information and updates please see http://uknea.unep-wcmc.org/.