Chapter 2:

Conceptual Framework and Methodology

Coordinating Lead Authors: Georgina M. Mace and Ian Bateman
Lead Authors: Steve Albon, Andrew Balmford, Claire Brown, Andrew Church, Roy Haines-Young, Jules N. Pretty, Kerry Turner, Bhaskar Vira and Jonathan Winn

2.1 Introduction

This chapter introduces a conceptual framework and methodology for the UK National Ecosystem Assessment (UK NEA). It is intended that this will provide a readily understood, logical and consistent approach to enhance coherence across chapters and permit the derivation of clear and generally applicable conclusions. A conceptual framework is a representation of the main components of a system or issue of interest, showing their interrelationships or linkages. It serves to develop a common understanding of which issues should be included in an assessment. It provides a basis for different groups to contribute their analyses of specific issues and linkages, and for these analyses to combine in a logical manner in an overall assessment. The framework should also assist in the identification of data or knowledge gaps–in the context of the UK NEA, these gaps may form a focus for extending the assessment in the future.

The framework described here is based on existing methods, especially those used for the Millennium Ecosystem Assessment (MA) (MA 2005). The MA framework—in particular, its broad definition of ecosystem services and their classification into provisioning, regulating, supporting and cultural services—has proven to have traction for both science and policy development. However, the UK NEA also incorporates post-MA advances, especially for the economic valuation of ecosystem services and procedures developed to avoid the double counting of such services. Therefore, we take particular note of conceptual advances proposed for The Economics of Ecosystems and Biodiversity (TEEB) project (Ring *et al.* 2010; Balmford *et al.* 2011), those used for the review of ecosystem services in Europe (Fitter *et al.* 2010), as well as detailed suggestions for enabling economic valuation of ecosystem services (Fisher & Turner 2008) .

The framework has some additional distinctive elements. Firstly, we recognised at the outset that a major objective of the UK NEA was to incorporate, as far as possible, a systematic and comprehensive valuation of ecosystem services. Therefore, we developed a framework which would yield the type of information which economists need for monetary valuation, but also incorporated flexibility to allow non-monetary valuation of services that cannot be meaningfully assessed in monetary terms. Secondly, we have explicitly identified elements for incorporation into the assessment that are relevant for the UK; hence, the classifications of ecosystems (Broad Habitat types), ecosystem services, change processes and outcomes impinging on human well-being are all significant in the UK context. Thirdly, the methodology clearly recognises the remit of the UK NEA to consider policy-relevant changes occurring over a defined timescale. These are implemented through a series of scenarios and response options involving feasible and decision-pertinent changes in the environment, markets and policy. Finally, we have taken a slightly different approach to the treatment of biodiversity and have separated out the underpinning natural processes that depend to a greater or lesser degree on biodiversity, from landscapes, seascapes, habitats and wild species. These latter elements of biodiversity are part of our natural heritage and, through the pleasure they bring to many people, form one kind of cultural ecosystem service.

2.2 Overall Conceptual Framework

The conceptual framework is based around the processes that link human societies and their well-being with the environment (**Figure 2.1**). Taking the core UK NEA questions as a starting point, the conceptual framework emphasises the role of ecosystems in providing services that bring improvements in well-being to people.

Here, we provide an overview of the conceptual framework illustrated in **Figure 2.1**, with each component being described in more detail later in the chapter. Starting at the bottom right of **Figure 2.1**, we see that the basis for ecosystems (Section 2.3) are the fundamental earth processes on land, and in water and air—processes which involve all living things. The most widely accepted definition of an 'ecosystem' is: "A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit" (MA 2005;). Thus, an ecosystem is a complex where interactions among the biotic (living) and abiotic (non-living) components of that unit determine its properties and set limits to the types of processes that take place there. Ecosystems vary widely in spatial scale and their key processes operate across a range of rates that are overlapping in time and space. In practice, ecosystems are usually defined by the scope of the function, process or problem being studied. For the purposes of the UK NEA, we use the Broad Habitat types from the Countryside Survey as the basis for the classification of ecosystems (Section 2.3).

People are part of ecosystems and, like all other living organisms, affect the processes taking place there, as well as deriving welfare gains from them. Compared to other organisms, people have an enormous influence on ecosystems, both in the UK and elsewhere, as a result of the population numbers and densities, patterns of consumption and use of technology.

The definition of 'ecosystem services' developed by the UK NEA is the outputs of ecosystems from which people derive benefits (MA 2005). In the UK NEA, we distinguish between the 'ecosystem processes and intermediate ecosystem services' (Section 2.4) and the 'final ecosystem services' that directly deliver welfare gains and/or losses to people (Section 2.5). This distinction is important to avoid double counting in the valuation of ecosystem services (Fisher & Turner 2008). Section 2.4 also introduces biodiversity and geodiversity and details the way that these components of the natural environment are related to ecosystems and their services.

There are many outputs from ecosystems, but while ecosystems function and deliver services, people benefit in well-being terms from the outcomes of those services. The

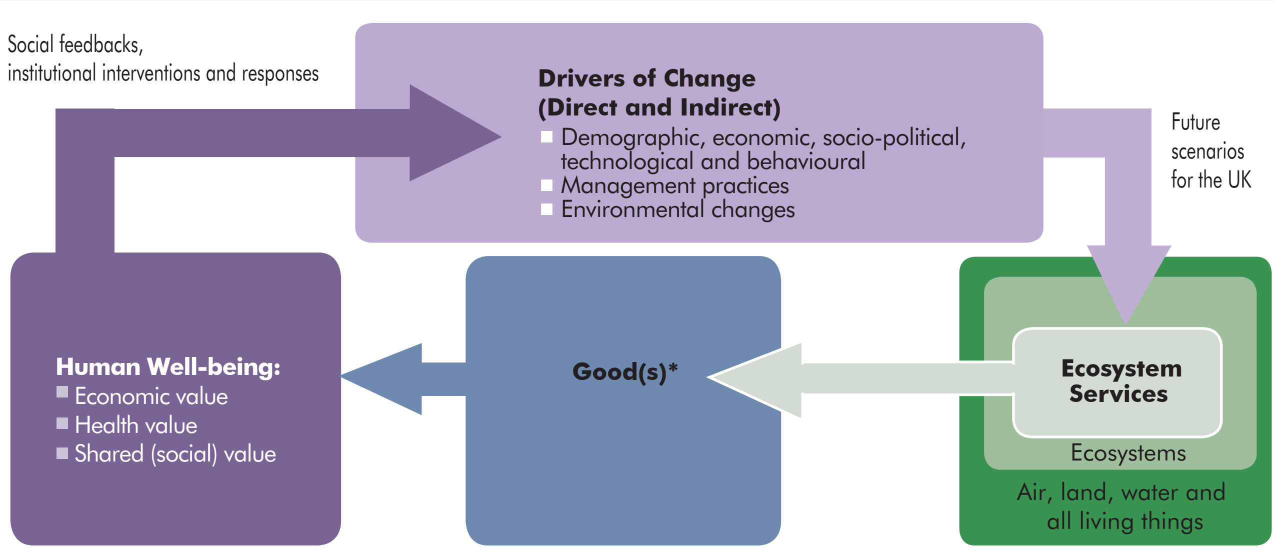


Figure 2.1 Overall Conceptual Framework for the UK NEA showing the links between ecosystems, ecosystem services, good(s), valuation, human well-being, change processes and scenarios. *Note that the term good(s) includes all use and non-use, material and non-material outputs from ecosystems that have value for people.

crucial link between services (as outputs of ecosystems), the outcomes they produce (the 'goods') and the 'values' that these generate for people is explained in Section 2.6. A distinction is also drawn between the overall value of a good and the portion of that value which can be attributed to relevant final ecosystem services. It is clear that the value of a good which can only be produced by applying major inputs of manufactured and/or human capital to some ecosystem service cannot be attributed solely to that service.

While some values can be measured using monetary valuation, certain kinds of benefits to people from ecosystems are not measurable through quantitative economic approaches. Therefore, we define additional well-being measures as health and shared (social) values. The three components of well-being—economic (monetary) value, health value and shared (social) value—are described in Section 2.7. The way that people perceive ecosystems and the extent to which they do or do not obviously provide values affects the choices people make about how to use and manage the environment. These choices may be driven by individuals, communities, societies or governments through a complex series of processes and interactions. However, the ultimate consequences are changes in drivers affecting the environment (Section 2.8).

The UK's ecosystems have changed dramatically over the past 50 years as a result of many direct and indirect drivers, but especially due to land use change to support food production and infrastructure development for the growing population. Over the coming decades, ecosystems will continue to change, transformed by a range of indirect and direct drivers. Increasingly, the many ways that decisions, policies and behaviours influence rates and types of environmental change will be affected by other trends that may be less easy to alter or influence. In particular, there are many ongoing changes in the environment (especially climate change and land use change), while society itself is continually transforming, with different preferences and markets developing, and trends affecting the demographic structure (age structures, household size, urban-rural distributions, etc.) of different areas of the UK. These changes in the UK NEA are incorporated in analyses of scenarios (Section 2.9) and response options (Section 2.10) for potential futures for the UK's ecosystems and ecosystem services.

2.3 Ecosystems and Broad Habitats

The UK NEA has defined ecosystems based upon recognised 'Broad Habitats' within the UK (Jackson 2000). In the UK and much of Europe, the classification of ecosystems can be considered as significantly overlapping with that of habitats. A definition of a habitat is an ecological or environmental area that is inhabited by a particular animal or plant species. In Europe, Annex I of the EU Habitats Directive lists 231 European natural habitat types including 71 priority types (i.e. habitat types in danger of disappearance and whose natural range mainly falls within the territory of the EU). The Broad Habitats approach is also used in the Countryside Survey—a major source of information on change in the UK's countryside (Carey *et al.* 2008). For reporting purposes, the UK NEA groups these into categories focusing on the interactions of habitats with their physical and social environments (eight types; Chapters 5–12) (**Table 2.1**). The field mapping rules from the Countryside Survey explain how these habitats were identified (Maskell *et al.* 2008).

Table 2.1 Broad Habitat types as defined in the UK NEA.

UK Ecosystem (Broad Habitat)	UK NEA component habitat	UK Biodiversity Action Plan (BAP) priority habitats
Mountains, Moorlands and Heaths	Bracken	• n/a
	Dwarf Shrub Heath	• Lowland heathland • Upland heathland
	Upland Fen, Marsh and Swamp	• Upland flushes, fens and swamps
	Bog	• Blanket bog
	Montane	• Mountain heaths and willow scrub
	Inland Rock	• Inland rock outcrop and scree habitats • Limestone pavements
Semi-natural Grasslands	Neutral Grassland	• Lowland meadows • Upland hay meadows
	Acid Grassland	• Lowland dry acid grassland
	Calcareous Grassland	• Lowland calcareous grassland • Upland calcareous grassland
	Fen, Marsh and Swamp	• Purple moor grass and rush pastures
Enclosed Farmland	Arable and Horticultural	• Arable field margins
	Improved Grassland	• Coastal and floodplain grazing marsh
	Boundary and Linear Features	• Hedgerows
Woodlands	Broadleaved, Mixed and Yew Woodland	• Lowland beech and yew woodland • Lowland mixed deciduous woodland • Upland oakwood • Upland birchwoods • Upland mixed ashwoods • Wet woodland
	Coniferous Woodland	• Native pinewoods
Freshwaters—Openwaters, Wetlands and Floodplains	Standing Open Waters and Canals	• Mesotrophic lakes • Eutrophic standing waters • Oligotrophic and dystrophic lakes • Aquifer fed naturally fluctuating water bodies • Ponds
	Rivers and Streams	• Rivers
	Bog	• Lowland raised bogs
	Fen, Marsh and Swamp	• Lowland fens • Reedbeds
Urban	Built up Areas and Gardens	• Open mosaic habitats on previously developed land (brownfield sites)
Coastal Margins	Sand Dunes	
	Machair	
	Shingle	
	Sea Cliffs	
	Saltmarsh	
	Coastal Lagoons	
Marine	Intertidal Rock	
	Intertidal Sediments	
	Subtidal Rock	
	Shallow Subtidal Sediment	
	Shelf Subtidal Sediment	
	Deep-sea habitats	

2.4 Ecosystem Processes

2.4.1 Physical, Chemical and Biological Processes

Ecosystems are complexes where biotic (living: biological) and abiotic (non-living: chemical and physical) components interact. The interactions between biotic and abiotic components of ecosystems ultimately determine the quantity, quality and reliability of ecosystem services. In **Figure 2.1**, we refer to the fundamental underpinning elements as land, air, water and all living things. Under this heading are the biological, physical and chemical components of the ecosystem and their interactions; these determine the functioning of the ecosystem processes from which ecosystem services result.

As the physical, chemical and biological features and components of ecosystems change, so will the processes that take place there and, consequently, the functions and services that can be delivered. There is much complexity in these interactions, which are not well understood even in relatively simple ecosystems. Importantly, alongside present uncertainties, is the fact that we do not know how these processes and interactions are going to change under complex and global stressors like climate change. It is not the role of the UK NEA to try to disentangle this complexity, which is still an active and growing area of environmental science research, but we do aim to identify particularly significant gaps in knowledge in the chapters dealing with particular habitats or ecosystem services. The implications for the UK NEA and for environmental protection policy are, nonetheless, very important.

The physical and biological underpinning elements of ecosystem processes cannot be ignored since the processes themselves are vulnerable to change (not just the services that we manage ecosystems for) and they have their own characteristic rates and thresholds. In practice, this means that ecosystem responses to environmental change may quite commonly be non-linear, hard to predict and/or irreversible (Carpenter *et al.* 2009). Therefore, as conditions move further away from observed states, say as a result of gradual environmental change, the likelihood of some unexpected shift in the ecosystem and its dynamics will increase. These changes may affect the ecosystem components and have a significant effect on important services (Nicholson *et al.* 2009). For example, increased fertiliser application leading to the eutrophication of rivers and lakes has completely altered ecosystem functions and trophic structures; often, these functions do not recover quickly nor track back on the same trajectory (Scheffer & Carpenter 2003). Another example comes from recent field experiments on the effects of artificially increased levels of atmospheric carbon dioxide on forest production. As expected, primary production increases with carbon dioxide concentrations, but in some of the experiments, a threshold is quickly reached for wood production (Norby *et al.* 2002) and, thereafter, carbon is stored below ground in root systems where it cycles much more quickly back into the atmosphere. The reasons for this are not known (it is likely that some other nutrient, such as nitrogen, becomes limiting (Norby *et al.* 2010)), but the implications for atmospheric carbon capture and storage in forest systems are important. These are just two examples, but illustrate why we emphasise the physical and biological underpinning processes throughout the UK NEA.

Ecosystem processes generally depend on the right combinations of certain biotic and/or abiotic components being present in an ecosystem. However, sometimes what matters for ecosystem functioning is not just the presence of a particular component or its amount, but instead the variety or diversity of types. Biodiversity and geodiversity are terms used to reflect this feature of ecosystems.

2.4.2 Biodiversity

Despite its clear importance to the ecosystem service concept, the term 'biodiversity' is defined in many ways and given various meanings in other ecosystem assessments and other ecosystem services related documents. Previous ecosystem assessments have treated it in a variety of ways including as an underpinning biological process and as an ecosystem service itself. Sometimes biodiversity is equated with ecosystems, sometimes it is equated simply with species richness.

For the UK NEA, we adopt the definition given by the Convention on Biological Diversity (CBD) which is broad and inclusive, and describes biodiversity as the: "variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part. This includes diversity within species, between species and of ecosystems." This definition includes all the different levels of biological diversity and the interactions between them, and emphasises the importance of variability. Using this definition, there are three different ways in which biodiversity is considered in the UK NEA.

Firstly, biodiversity is important for the fundamental ecosystem processes that underpin final ecosystem services. For example, the dynamics of many soil nutrient cycles are determined by the composition of biological communities in the soil (Hector *et al.* 2000; Bradford *et al.* 2002). Resistance to the effects of pests and environmental change is also increased in more diverse biological communities. Interactions between herbivores and plants, and between carnivores and herbivores, have an impact on the vegetation type affecting both biomass and species composition. Therefore, the biological composition of ecosystems, measured as biodiversity, has a key role to play in ecosystem service delivery (Díaz *et al.* 2006). Broadly speaking, biodiversity, measured as variability, probably contributes more to regulating and cultural services, and to the longer-term resilience of ecosystem processes, than to provisioning services, at least over the short-term (Diaz *et al.* 2007). Some diversity effects may be attributable to composition, i.e. the presence of certain key species or the correlation between species richness and functional trait diversity (Hooper *et al.* 2005). The extent to which species richness is important compared to, for example, biomass or structural and trait diversity, is an area of active research (Suding *et al.* 2008). We include consideration of the insurance role of biodiversity: more diversity buffers systems against change (Hooper *et al.* 2005) and offers more options for the future (Yachi & Loreau 1999).

Secondly, biological diversity at the level of genes and species may directly contribute to some goods and their values. For example, the potential value of medicinal plants and the potential for bio-prospecting increases with the number and evolutionary distinctiveness of species. Genetic diversity of wild crop relatives is important for the improvement of crop strains, and the same will be true for biofuel crops and livestock. Therefore, genetic diversity (or surrogates such as wild species richness or phylogenetic diversity) may itself be a final ecosystem service directly contributing to goods. Hence, we include wild species diversity as a final ecosystem service that contributes to both provisioning and cultural services.

Thirdly, many components of biodiversity are valued by people for other reasons. These include the appreciation of wildlife and of scenic places, and their contribution to spiritual, inspirational, educational, religious and recreational experiences. People value places with a diversity of species, especially the more colourful and spectacular animals and plants. Retaining the full complement of UK wild species is important to many people, and a rich and varied wildlife contributes to cultural cohesion and development. Therefore, biodiversity is sometimes also a good in itself and delivers a distinct value.

2.4.3 Geodiversity

Geodiversity is a term used less commonly than biodiversity, but is defined similarly as the variety of rocks, minerals, fossils, landforms, sediments and soils in a place. Geodiversity supports the provision of basic raw materials and the foundation upon which ecosystems are based. Preserving geodiversity in the landscape is important for several different reasons. Other than for the provision of raw materials, the amount of geological diversity at a site may not be as important as the geodiversity in a landscape. Therefore, geodiversity, like biodiversity, is a good in itself and underpins some important cultural final ecosystem services. People like and wish to preserve rare and distinctive landforms and geological formations. But geodiversity is not only relevant for cultural services. The type and complement of geological forms affects physical, chemical and biological functions, particularly in freshwater systems, coastal areas and uplands. In addition, the heterogeneity of geological formations within landscapes underpins spatial variation in habitats and biodiversity. Spatial heterogeneity of geological formations and habitats in an area will, therefore, be one determinant of the quality and diversity of the ecosystem services that can be delivered there. Finally, the local spatial heterogeneity of landforms, habitats and biodiversity will increase the potential interactions among them, with positive or negative consequences for ecosystem services.

The UK NEA includes a chapter on biodiversity, but not one on geodiversity. Environmental change has a huge effect on biodiversity, but comparatively little effect on the diversity of rocks, minerals, fossils, landforms, sediments and soils. Their quantities and qualities may be changed through direct and indirect extraction, but direct intervention in ecosystems through changed management practices or polices is unlikely to have major impacts on geodiversity or the ability of the ecosystems involved to deliver services. Most processes influencing geodiversity operate on much longer timescales than those influencing biodiversity, although direct changes by people to landforms can affect local geodiversity. Because biodiversity is more likely to be influenced by changed management and environmental change, with consequences for ecosystem service delivery, it warrants more detailed treatment (Chapter 4); geodiversity is considered in most detail in Chapters 16 and 13.

2.5 Ecosystem Services

'Ecosystem services' are the outputs of ecosystems from which people derive benefits. In the UK NEA, ecosystem services are considered under the broad headings of provisioning, supporting, regulating and cultural services. This classification derives from the MA (2005) and is a useful means for distinguishing broad categories of services. 'Final ecosystem services' directly contribute to the good(s) that are valued by people, and people tend to intervene or manage ecosystems to influence the delivery of final ecosystem services. Intermediate ecosystem services and 'ecosystem processes' underpin the final ecosystem services, but are not directly linked to good(s) (**Figure 2.2**) and are less often the focus for management. In fact, ecosystem processes are often inadvertently affected by management for final ecosystem services, sometimes with deleterious consequences.

The goods that are derived from final ecosystem services have a value, only some of which is derived from ecosystems because of capital inputs (from manufacturing and remanufacturing) that add value. Different goods will have different proportions of value attributable to ecosystems versus human capital inputs.

As discussed further in Section 2.6, this separation between ecosystem processes/intermediate services and final ecosystem services is necessary to avoid double counting when valuing the benefits derived from ecosystems (Fisher & Turner 2008). In **Table 2.2** we show the full list of ecosystem services used in the UK NEA, classified according to both ecosystem service type (provisioning, regulating, cultural and supporting) and whether or not they are final ecosystem services or intermediate services/processes.

It should be noted that provisioning and cultural services are always classed as final ecosystem services; regulating services may be either final services or intermediate services/processes; and supporting services are always intermediate services/processes. The provisioning, regulating, cultural and supporting services classification shown in **Table 2.2** maps on to the MA classification which is already in general use. However, for the UK NEA, we develop the distinction between final ecosystem services and intermediate ecosystem services and/or processes in order to allow the valuation of final ecosystem services.

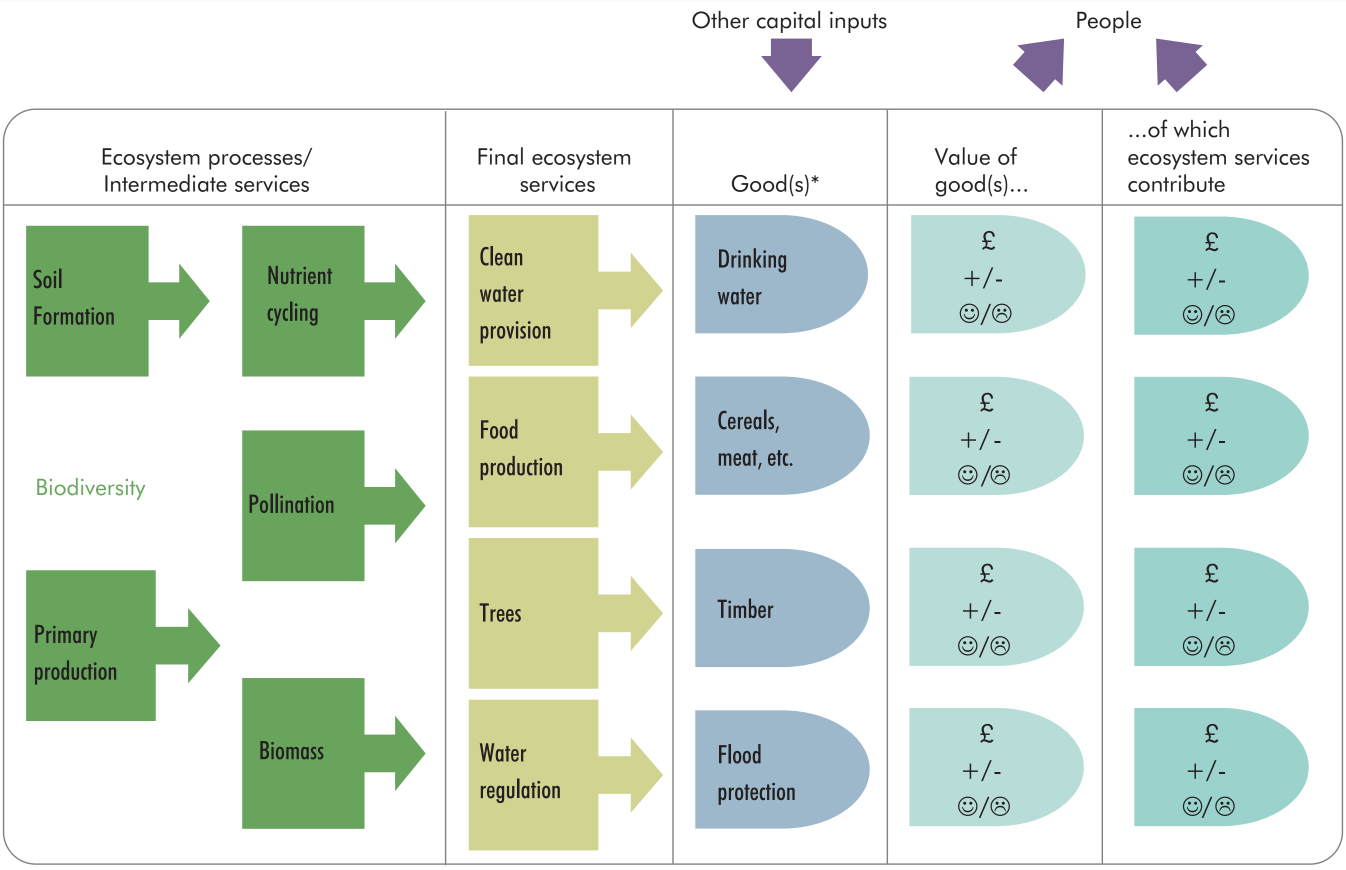


Figure 2.2 Schematic diagram of a small selection of ecosystem processes and services to illustrate how ecosystem processes are linked to final ecosystem services and the goods and values they generate for people. The final ecosystem services are the outcomes from ecosystems that directly lead to good(s) that are valued by people. The full value is not just from the ecosystem, but depends on the addition of inputs from society (other capital inputs) and the value is often context dependent. The final value of the good(s) is, therefore, attributable to both the ecosystem and human inputs. For a fair valuation of ecosystem services, both the separation of final ecosystem services from underpinning processes and the accounting for other capital inputs is necessary. *Note: the term 'good(s)' includes all use and non-use, material and non-material outputs from ecosystems that have value for people. Source: adapted from Fisher *et al.* (2008).

Table 2.2 Ecosystem services in the UK NEA classified according to both ecosystem service type (provisioning, regulating, cultural and supporting) and whether or not they are final ecosystem services or intermediate services and/or processes. For each final ecosystem service an example of the good(s) it delivers is provided in italics.

Ecosystem processes/intermediate services		**Final ecosystem services (*example of goods*)**	
Supporting services	• Primary production • Soil formation • Nutrient cycling • Water cycling	**Provisioning services**	• Crops, livestock, fish (*food*) • Trees, standing vegetation, peat (*fibre, energy, carbon sequestration*) • Water supply (*domestic and industrial water*) • Wild species diversity (*bioprospecting, medicinal plants*)
	• Decomposition • Weathering • Climate regulation • Pollination • Disease and pest regulation • Ecological interactions • Evolutionary processes • Wild species diversity	**Cultural services**	• Wild species diversity (*recreation*) • Environmental settings (*recreation, tourism, spiritual/religious*)
		Regulating services	• Climate regulation (*equable climate*) • Pollination • Detoxification and purification in soils, air and water (*pollution control*) • Hazard regulation (*erosion control, flood control*) • Noise regulation (*noise control*) • Disease and pest regulation (*disease and pest control*)

Some services straddle more than one category. Climate regulation, disease and pest regulation, wild species diversity and pollination are both intermediate and final ecosystem services depending on the good(s) being considered. For example, a wider diversity of crop relatives is an intermediate process necessary to sustain the final ecosystem service of crops and livestock that deliver food. Wild species diversity is considered in the biodiversity chapter, but it is a final ecosystem service providing goods related to cultural services, as well as provisioning services as wild species are a source for bio-prospecting, natural medicine and genetic variation for the selection of new agricultural crops and livestock breeds.

2.6 Goods

In moving from the consideration of ecosystems and their services, to the well-being that they bring to people, we adopt (and to some extent adapt) the terminology of economics. Specifically, we consider the concept of 'goods' as being the objects which people value. It is important to note that our use of this term goes well beyond the narrow view of goods simply as physical items bought and sold in markets and, hence, possessing market prices which in some (potentially distorted) form reflect their value. Certainly, market-priced commodities are an important source of values, many of which derive, in part, from ecosystem services (e.g. food). However, the UK NEA concept of goods also includes well-being items which either partly or wholly embody ecosystem services, but have no market price (e.g. open-access outdoor recreation). Furthermore, while the examples listed above involve the direct use of the environment, our concept of goods also includes a range of non-use values associated with those ecosystem services which generate well-being in the absence of any direct use (e.g. the knowledge that remote, yet valued, ecosystems are being preserved in their natural state). Note also that we include within this deliberately broad term 'goods' whose value we do not see any realistic prospect of monetising, such as the spiritual dimensions of the environment. This latter example might well cause some to argue against the implied commodification of the environment they perceive in the term 'goods'. However, we make no such implication. Indeed, the term is merely used as shorthand for 'good things' whose presence yields well-being and whose absence lowers that well-being.

Our definition of goods allows us to separate the source of value from the size of that value (**Figure 2.3**). Often we will term the value of welfare improvements as 'benefits' (and by corollary, the value of welfare losses as 'disbenefits', an admittedly ungainly term, but one which allows us to distinguish between this and the 'costs' of delivering benefits). This leads us to some further distinctions. Firstly, distinguishing between the terms 'good' and 'value' allows us to reflect the fact that the value of many goods is context specific and varies over time and space. This is true of a great variety of goods (e.g. the value of a bottle of cold freshwater is greater on a hot day) and those derived from ecosystem services are certainly no exception. So, for example, the recreational services provided by a woodland can yield a much higher value when located on the edge of a large town (where it offers recreational opportunities to the populace) than when a physically identical forest is situated at the top of a remote mountain. Indeed, shifts in the location of a resource can also alter both the value and range of services provided. Continuing our woodland example, alternative locations can generate additional biodiversity habitat, carbon storage

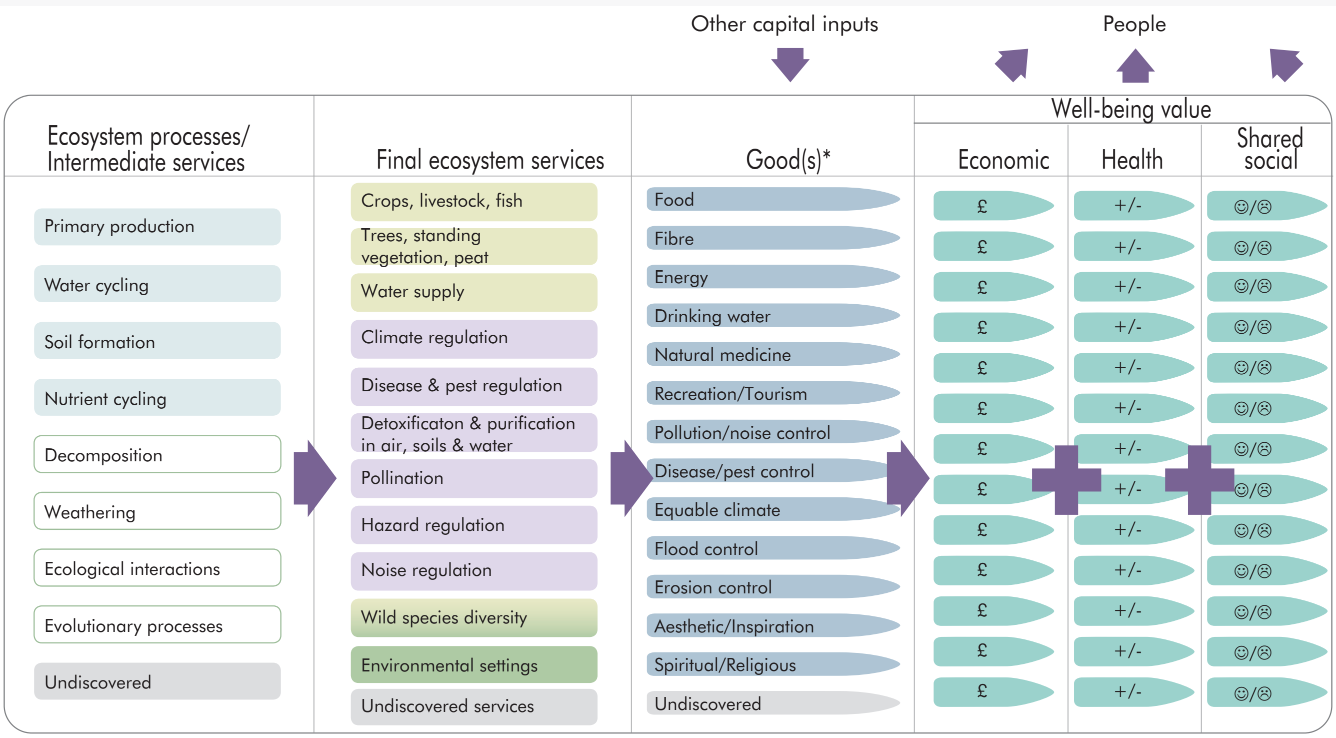


Figure 2.3 The full set of ecosystem processes, services, goods/benefits and values used in the UK NEA. Note that some ecosystem services can be both intermediate and final services. For simplicity, in this figure, services are shown only in the most final position that they occupy. Services such as pollination and climate regulation that also play important roles further back in the chain are not represented here. Cells with no colour are ecosystem processes/services that were not in the Millennium Ecosystem Assessment classification. *Note that the term good(s) includes all use and non-use, material and non-material outputs from ecosystems that have value for people. Source: adapted from Fisher *et al.* (2008).

and visual amenity values. Therefore, much of the analysis contained in the UK NEA is necessarily spatially explicit, while the assessment also stretches both back in time and forward into the future.

A second issue is that, while ecosystem services are vital to the generation of many goods, in many cases we would be in error if we ascribed all of the value of those goods to their corresponding ecosystem services. Many goods can only be generated by applying manufactured capital (e.g. machinery) and human capital (e.g. ingenuity) to ecosystem services (**Figure 2.2**). For example, while nature generates the massive temperate forests of northern latitudes, it is only through the application of human and manufactured capital that we obtain timber. Therefore, it would be incorrect to ascribe all of the value of timber to ecosystem services. Some of that value is due to capital which could be transferred to generate alternative values.

Similarly, we do not consider the value of the subsequent remanufacture of goods. The timber mentioned above might be subjected to further additions of human and manufactured capital to produce furniture. It would clearly be incorrect to add the value of the furniture to that of the timber and ascribe the sum to ecosystem services—such a procedure would massively inflate the value of the latter and undermine the credibility of the assessment. Such an error is analogous to the double counting problem that would arise if we added the value of supporting services to those of final ecosystem services.

There is another type of value which we introduce here, but do not attempt to deal with in this assessment. 'Intrinsic value' refers to the view held by many people that the natural world, and therefore ecosystems, biodiversity and geodiversity, merit conservation regardless of any material benefits or measurable values. This viewpoint is a meta-ethical claim such that the intrinsic value of nature cannot be compared with any other value set. Therefore, it lies outside the UK NEA, but we recognise that this is an important consideration for many people. Intrinsic value should not be confused with the various kinds of extrinsic anthropocentric, but non-market, values such as option, existence and bequest values (**Box 2.1**). They are difficult to estimate, but dominate many people's concerns for the conservation and protection of biodiversity and ecosystems. We do aim to deal with all these kinds of values in the UK NEA.

Box 2.1 The different values that people may hold for biodiversity and ecosystems.

There are two different approaches to the valuation of ecosystems and biodiversity - 1) intrinsic/inherent value (see right hand box) and 2) instrumental/extrinsic value (see box below). In the right hand box are some definitions and personal views about 'intrinsic value'. By definition this philosophical position rules out objective valuation. Below is a classification of practical approaches to valuation. In theory, each of the sub-types of value can be estimated and they can be added together for an estimate of the Total Economic Value (TEV) of a system of place. In practice, the methods are best established and available for the use values on the left hand side and become more difficult to define and measure towards the right. It is particularly difficult to estimate non-use values, which are often confused with intrinsic values. Bequest and existence values are often restricted to a subset of species, typically charismatic ones such as large mammals, birds, butterflies and some flowering plants. Note that direct use values are measured by the benefits to individuals, but all other values may be shared (social) values (Section 2.7; **Figure 2.4**).

1) intrinsic/inherent value

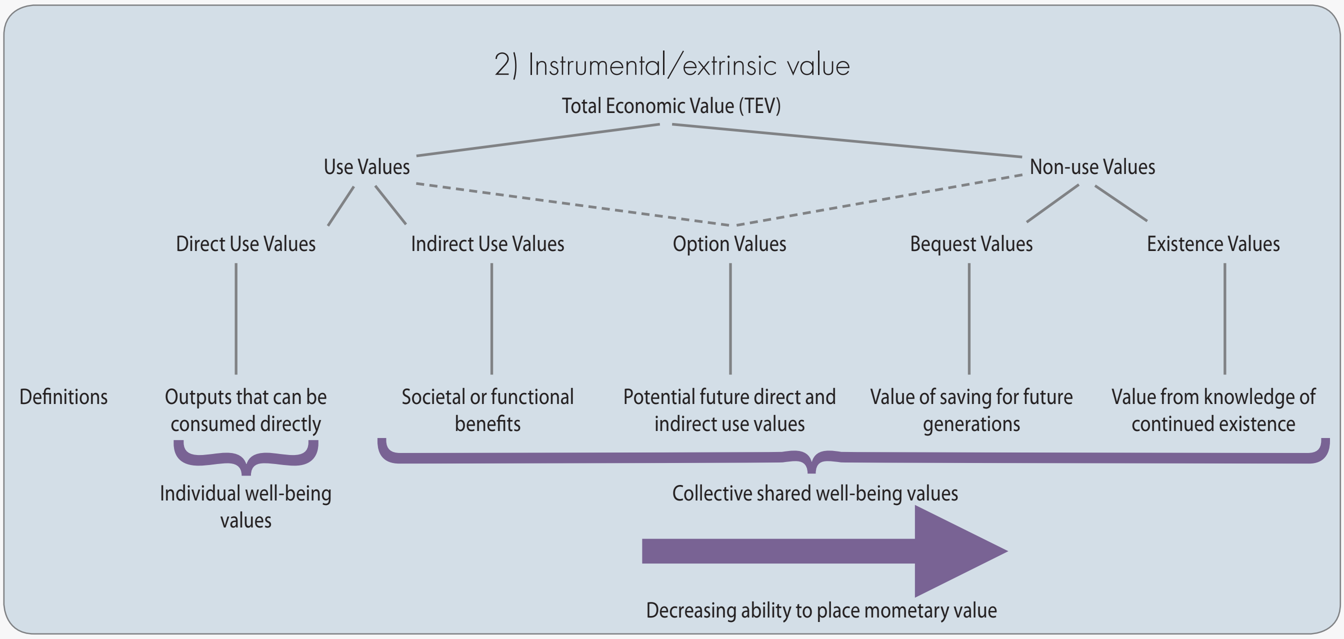
Some views and definitions

"The value of something independent of its value to anyone or anything else"

"Nature has a right to exist without any benefit that we may derive from it"

"The non-humanistic value of communities and species is the simplest of all to state: they should be conserved because they exist and because this existence is itself but the present expression of a continuing historical process of immense antiquity and majesty. Long standing existence in Nature is deemed to carry with it the unimpeachable right to continued existence"

D. Ehrenfeld, Conserving Life on Earth 1972



2.7 Human Well-being

A universal definition of 'well-being' is not available as many sources interpret and define it differently. However, well-being is generally considered in a broader context than simply good health. Defra (2007) has collaborated with other government departments and stakeholders to develop a shared understanding of the meaning of well-being within a policy context (**Box 2.2**). This includes good social relationships, financial and personal security, and a healthy and attractive environment.

Therefore, in considering the benefits from ecosystems, a number of different dimensions of value can be discerned and each may be evaluated in different ways, for example: in monetary terms via economic analysis; in biophysical and geochemical terms via natural science; and in more qualitative terms via sociology, geography, arts and humanities. Each of these value dimensions has validity in its own domain and a goal of the UK NEA is to incorporate all these kinds of values and the benefits they can and do provide.

Environmental philosophers have constructed a generic value typology with four categories: 'anthropocentric instrumental value', which maps closely onto the economic concepts of 'use' and most of 'non-use' values, and 'anthropocentric intrinsic value', a culturally dependent concept which is linked to human stewardship of nature and is represented by 'option' and 'existence' 'values' in **Box 2.1**. The other two value categories—'non-anthropocentric instrumental value' and 'non-anthropocentric intrinsic value'—are less directly relevant to the UK NEA initiative.

Anthropocentric instrumental values are usually assessed via economic analysis techniques in terms of an individual person (or sometimes an aggregated household) and their preferences and motivations. In this regard, the literature on the economic valuation of both market and non-market environmental goods has expanded dramatically in recent years, developing a suite of methods which are now extensively applied (Section 2.7.1). However, even in this domain, there are areas of some contention. For example, non-use existence value derives from individuals who feel a benefit from just knowing that an ecosystem and/or its component parts exists and will continue to exist. The economic valuation literature has yet to reach consensus on whether the value can be reliably measured using survey-based methods (stated preference methods); despite a number of improvements in survey design and testing protocols, debate continues.

In contrast, anthropocentric intrinsic values are more usually viewed in a collectivist way with motivations and preferences which can be assigned to groups and culturally transmitted and assimilated over time as social norms. These cultural values may not be capable of meaningful and full monetary expression; nevertheless, they signal that human well-being and quality of life is a function of both individual wants satisfaction and the fulfilment of a variety of social, health-related and cultural collective needs. These values are shared experiences fostered by, and within, 'groups', often over long periods of time and in connection to specific local places and landscapes. In the UK NEA, these values are assessed within cultural services. **Figure 2.4** introduces a simple typology of valuation as applied in the UK NEA. The typology in **Box 2.1** does not distinguish between the individual versus collective appreciation of value, which is an important component for the social sciences.

We argue that the highlighting of the value of ecosystem service flows provides an important advance over conventional market price-based decision systems. Nevertheless, we recognise the dangers that could result from an over-concentration on the value of ecosystem service flows if this were to lead to the overexploitation of those services threatening system change or collapse. The UK NEA conceptual framework accepts the need to assess and conserve the stocks of natural assets from which services flow, and to maintain the fundamental components and processes which underpin ecosystems. These fundamental processes—labelled 'ecosystem processes/intermediate services' in this framework—are clearly valuable in their own right, and the focus on the flow of assigned ecosystem service values is not meant to deny this. Furthermore, we fully acknowledge the uncertainties that exist regarding the operation of many of these fundamental processes, their contribution to ecosystem services and the existence of thresholds and tipping points regarding their stability. Much of this goes beyond the remit of the present assessment, but is highlighted as a priority area for further research (Nicholson *et al.* 2009).

For reasons discussed subsequently, the UK NEA's valuation of ecosystem services is focused upon feasible incremental changes to those services, rather than some abstract notion of their total value (which is effectively infinite as without such services life could not exist). This is implemented by first assessing the change in values under a 'do-nothing' baseline. For example, looking forward to 2060, we can see that even in the absence of any policy response changes will occur due to drivers such as climate change, population shifts, etc. With this baseline analysed, we can then examine the further changes in value expected under various alternative scenarios for the future incorporating, for instance, proactive policies, societal changes or alternative trends in environment and population (Section 2.8).

Three categories of valuation are implemented in the UK NEA in order to reflect actual or potential well-being. Economic valuation, health benefits and shared (social) values (**Figure 2.4**) are different ways of measuring

Box 2.2 An inclusive statement of 'wellbeing'. Source: Defra (2007).

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

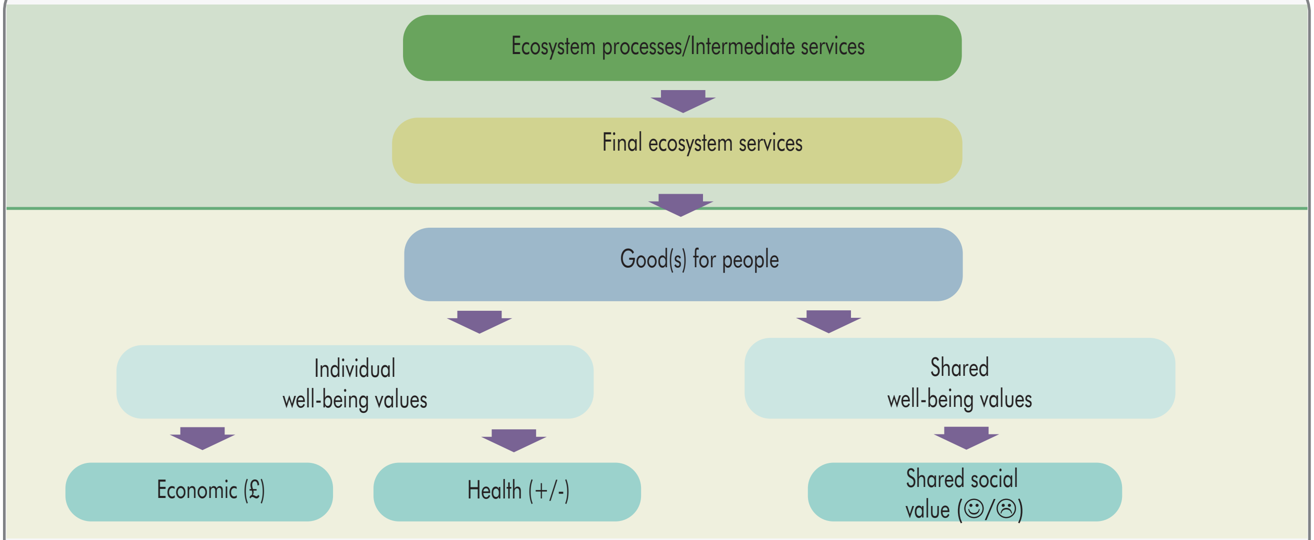


Figure 2.4 Components of value: the ecosystem processes and services which provide goods and benefits to people. These are valued in a variety of ways in terms of both use and non-use values. In the UK NEA, two kinds of individual benefits are recognised (economic and health), as well as shared (social) values that are measured in relative terms.

value and, therefore, overall well-being. Sometimes these categories overlap. For example, health benefits can be expressed in quantitative accounts of the number of persons concerned, qualitative assessments of well-being, or monetary estimates of the benefits or disbenefits concerned.

2.7.1 Economic Value

Economic valuation seeks to determine the monetary value of goods to individuals. Whether these goods are associated with ecosystem services or not, economics attempts to measure value in terms of what people are prepared to give up in order to obtain the goods in question. The most obvious measuring rod (and the one which is most compatible with decision-making) is to examine the amount of money individuals are prepared to pay for a given good: their 'willingness to pay' (WTP).

An immediate problem for valuation is that even goods which are traded in markets may have prices which are distorted by subsidies, non-competitive practices or other imperfections such that they have to be adjusted before we can observe the underlying value of the goods in question. This problem becomes much more complex for the large proportion of environmental goods which are not traded in markets, and so, have no readily observable prices. However, the last thirty years or so has seen the rapid development of numerous methods for estimating monetary values for non-market environmental goods. These are reviewed in the detailed methodology for the economics of the UK NEA (Bateman *et al.* 2011), but, in summary, we can identify several broad categories of economic valuation methods, each being appropriate to different goods and contexts, as follows:

i) Market prices: often not applicable and even then adjustment has to be made for market distortions (e.g. adjusted timber prices).
ii) Production function methods: examining the role of ecosystem services within the production of some goods with an (adjusted) market price (e.g. agricultural crops).
iii) Damage costs avoided and averting behaviour: looks at the benefits of avoiding costs (e.g. avoidance of storm damage caused by improving coastal wetlands).
iv) Revealed preference methods: estimate the value of environmental goods by examining WTP for goods which permit access to those goods (e.g. looking at travel time and costs as a measure of recreation benefits, or the uplift in house prices in quiet areas).
v) Stated preference methods: directly asks individuals to make choices concerning their WTP for environmental goods (e.g. WTP higher water rates for cleaner rivers).

Most of the above methods can, in principle, be used for valuing either the benefits of improvements or the disbenefits of losses.

For reasons set out previously, the economic analysis conducted for the UK NEA focuses exclusively on the value of changes arising under feasible scenarios (Chapter 26). This is achieved by estimating the value of a single unit change in some environmental goods (the marginal WTP or MWTP) and then multiplying this by the size of the change provided under a given scenario. However, care needs to be taken to allow for the possibility of the per unit MWTP changing with the change in provision. For example, the value of storing a tonne of carbon is very unlikely to change if a given area of the UK is used for carbon storage. This is because the likely damage caused by climate change (which drives the true value of carbon storage) will only be slightly reduced by this storage. A very different situation occurs for other environmental goods. For example, the MWTP for creating a 100-acre recreational wood in an urban fringe area might be very substantial. But once it has been created, the MWTP for extending this by a further 100 acres for recreational use only is likely to be significantly lower due to the fact that the additional recreational benefits are lower than for the initial wood. Because of this and other reasons, it is important that economic valuation incorporates spatial and temporal issues into the analysis, thus capturing the vital impact which these issues can have upon values (Balmford *et al.* 2011).

There are some important caveats to the UK NEA economic analysis. Firstly, we make no claims that all environmental goods and their benefits can be monetised; indeed, alternative perspectives on valuation are a distinct feature of the overall assessment. Secondly, the UK NEA economic analysis was a strictly resource- and time-bound exercise, so could not answer all questions. For this reason, a deliberate decision was taken to focus upon the valuation of ecosystem service flows and relatively little attention was given to economic assessments of the resilience and sustainability of natural asset stock levels. This issue is considered in greater detail elsewhere (Bateman *et al.* 2011).

2.7.2 Health Values

The term 'health' is generally taken to incorporate physical health, mental or emotional health, social health, spiritual health, lifestyle and functionality. The World Health Organization's (WHO) definition of health is still the most widely cited and states that: "health is a state of complete physical, mental and social (individual) well-being, and not merely the absence of disease or infirmity" (WHO 1948).

There is growing evidence to show that ecosystems affect not only the immediate health and well-being of individuals, but also their lifelong welfare (Chapter 23). A funnel of life courses within which all lives are shaped can be envisaged. Some people live longer with a better quality of life; others die earlier and often live years with a lower quality of life. On the healthy pathway, people tend to be active, connected to people and society, engage with natural places, and eat healthy foods. Ecosystem services are, therefore, a critical component of healthy pathways. As a result, individuals tend to have better mental health, be members of groups and volunteer more, keep learning, engage regularly with natural habitats and be more resilient to stress (Foresight 2008; Pretty *et al.* 2009). On the unhealthy pathway, people tend to be inactive and sedentary, disconnected from society and social groups, not engage with natural places, and eat energy-dense and unhealthy foods. They also tend to have lower socioeconomic status, be in more stressful jobs, live where active travel to work or school is difficult, have increased likelihood of being mentally ill (16% of the UK's adult population), and be overweight or obese (Foresight 2007).

2.7.3 Shared (Social) Values

Finding ways to capture collective, cultural values in a scientific assessment of the UK's ecosystem services, goods and benefits is challenging. Over the last thirty years, environmental and ecological economists, working closely with natural scientists, have been developing robust, defensible estimates of the monetary value of ecosystem services and the contributions they make to improving human welfare. However, in making a distinction between anthropocentric instrumental and intrinsic values, environmental philosophers argue that societies maintain a range of beliefs about the 'ethical' basis of people's relationships with nature—what constitutes right and proper conduct towards the non-human world—and also make 'aesthetic judgements' about what is beautiful or, significant in terms of landscapes, species and natural processes.

Ethical concerns and aesthetic judgements are always context-specific: contingent outcomes of local circumstances, of specific times and particular places. Values for nature change over time; they are expressed in different ways among members of any given society; and give rise to different kinds of formal and informal institutions. Academic research in the fields of ethical concerns and aesthetic judgements for nature, place and landscape does not conform to the scientific method; the goal is 'hermeneutic', i.e. the production of sophisticated descriptive interpretations based on reasoned argument and the weighing of many different sources of evidence which fall within the domain of humanities disciplines, supported where appropriate with quantitative social scientific evidence such as findings from questionnaire surveys.

Many argue these three dimensions of human-environment relations—utility, ethics, aesthetics—are basic principles guiding human behaviour and, as such, are incommensurable: ethical and aesthetic principles cannot be meaningfully expressed in monetary terms. At the same time, environmental decision-makers do have to make choices which require trade-offs to be made between them. What is important in such cases is that the decision-making process is seen to be reliable, credible and legitimate. To ensure public trust and confidence when reaching difficult decisions which may well override ethical and/or aesthetic values, it is important that decision-makers are able to demonstrate knowledge and understanding of the philosophical and theoretical bases upon which researchers in the humanities and social sciences present evidence of the cultural values individuals and social groups attribute to their interactions with the natural world. For these reasons, it is increasingly recognised that policy makers require a range of deliberative tools, such as participatory multi-criteria analysis, to integrate the range of quantitative and qualitative information into their choices and to embed the ecosystem approach in decision-making (Fish *et al.* 2011).

Developing a defensible conceptual approach to the definition of final cultural ecosystem services, and the assessment of specific goods and benefits arising from them, has been one of the goals of the UK NEA. What narratives of change in cultural services might fit UK conditions and contexts is an open question. We have sought a framework which reflects our understanding of culture not as determining individuals' values, beliefs and norms, but rather as a process of co-production through the enormous range of social communications and social practices which enfold nature, places and landscapes in everyday life. What is needed is a contribution to the overall conceptual framework that allows humanities and social science disciplines to make their contribution to the UK NEA in such a way as to strengthen the integration of scientific, economic, cultural and socio-political evidence.

We consider cultural services in an economic model, through the benefits they provide in recreation, health and residential property values, but our approach goes beyond these economic values to explore other sorts of value provided by these cultural services (Chapter 16; Chapter 24). The Human-Scale Development Matrix (Max-Neef 1989, 1992) allows analysts to systematically explore how different kinds of 'goods' (material objects, abstract ideas, emotional experiences, social practices, physical settings, living things, etc.) are able to satisfy one or more fundamental human need. It also has potential as a deliberative tool for participatory engagement in ecosystem assessment (Cruz *et al.* 2009). Chapter 16 adapts the Human-Scale Development Index to provide a systematic framework for addressing these issues.

Table 2.3 The changing UK environment: drivers of change assessed in the UK NEA.

Direct Drivers of Change	Indirect Drivers of Change
Habitat change (particularly conversion of natural habitat through changes in land use and use of the marine environment)	Demographic changes
Pollution of air, land and water	Economic growth
Overexploitation of terrestrial, marine and freshwater resources	Socio-political changes, especially in policies
Climate change	Cultural and behavioural changes
Introduction of non-native invasive species	Advances in science and technology

2.8 The Changing UK Environment

The UK's environment has always undergone change. In placing current (and potential future) changes of ecosystems and ecosystem services in context, drivers of positive or negative change can be considered as either direct drivers or indirect drivers. Direct drivers are usually associated with physical changes that can be monitored over time, such as the effects of the overexploitation of fisheries on the status of fish species and the marine environment. Indirect drivers can change the rate of one or more direct drivers at the same time. For example, socioeconomic changes affecting demographic structure and market forces may simultaneously directly affect land use and energy in many different ways. Socioeconomic changes through history have impacted on the extent and state of ecosystems and the services they provide. These changes can be traced though trends in land use, external inputs (such as pollution or fertiliser input to land) and demographics, among others. A further example of socio-political change is the introduction of policies that have impacted on the UK's environment through early reactive protective legislation, such as the Clean Air Act which led to reduced particulate air pollution, and the Water Framework Directive which takes an integrated approach to water use, pollution and quality. Chapter 3 sets out the different drivers of change impacting on the UK's ecosystems and the services they provide (**Table 2.3**).

2.9 Scenarios

Scenarios are an essential part of ecosystem assessments. They provide a bridge between the understanding of the current state and past trends in ecosystem services and the likely policy or management responses that might be appropriate given a range of plausible futures. In the context of the UK NEA, the aim has been to use them to explore how UK ecosystems and their services might change in the future, and to identify what the possible effects might be in terms of human well-being and who might be affected most.

As a sub-global assessment conducted within the MA framework, the latter has been seen as providing a model and guide for the UK NEA. In the MA, the method of scenario construction was presented as essentially deliberative, involving dialogue between the researchers and user communities to define objectives, to determine the scope of the exercise and to identify the particular issues that the scenarios would be used to explore (Carpenter et al. 2005). The same broad approach has been used for the UK NEA, within which, scenarios have been viewed as devices that can be used to represent alternative ways that land cover and ecosystems may change under different conditions or assumptions about the future (Carpenter *et al.* 2006).

The work started from the premise that scenario-building is not about trying to predict the future, but rather about identifying a range of possible futures that might unfold under contrasting, but 'plausible', (Chapter 25) assumptions. Thus, they allow a comparison of goods and their values that will be available under different plausible futures, and complete the cycle for the assessment used in the UK NEA. They also provide an opportunity to encourage thinking about how future policy may affect ecosystem services. To this end, storylines should not only be plausible and consistent, but should challenge too.

The UK NEA methodology explicitly recognises the need to consider policy-relevant changes occurring over a defined timescale of about 50 years. Given the time-bound nature of the exercise, interactions with stakeholders were prioritised over the development of detailed timelines, and the scenarios were considered in terms of final outcomes only. Nevertheless, the storylines do offer a description of a set of feasible and decision-pertinent changes in the environment, markets, society and policy. The changes anticipated under each scenario are calculated from a consistent baseline and reflect the best estimates of changes in these various drivers in the absence of any policy response. The timeline considered extends to 2060.

From the outset, the development of the UK NEA scenarios was an inherently inclusive and iterative process involving experts and stakeholders, guided by periodic external feedback and internal review. The engagement with people outside the scenarios team was necessary to not only fill in knowledge gaps, but also to ensure that the process remained transparent and flexible. The UK NEA Scenarios team set out to build on what had already been achieved in this area, and so, reviewed and used aspects from a range of existing scenarios in the grey and academic literatures. By asking the UK NEA stakeholders to provide the Scenarios team with focal questions about future ecosystem change, we were able to identify the key issues they wished to consider.

The six storylines developed as a result of the scenario-building process are summarised below. They present a range of socio-political futures that result in considerable diversity in outcomes for ecosystem services and habitats for land and sea. For each scenario, the impacts of high and low climate change effects were considered. This analysis was based on the projections from the outputs of UKCIP.

- *Green and Pleasant Land* is a future where high economic growth has focused on the service, economic and secondary industries, and most primary industry has declined considerably. Consequently, production and housing pressures in rural UK decline, making way for a programme of 'beautifying' the countryside (with many positive benefits for biodiversity).
- *Nature@Work* is a version of today, but with a very strong emphasis on maintaining ecosystem services through all sectors in the UK. It is inherently about trade-offs between ecosystem services, but sustainability forms the backbone in all walks of life.
- *World Market* is a vision of unfettered economic growth and trade. Trade barriers disappear, imports increase and the UK abandons the EU. Environmentalism is given little merit and the countryside becomes more industrialised and developed as a result.
- *National Security* shares many aspects with World Market, but is different in one key area: it is heavily focused on self-sufficiency and economic protectionism.
- *Local Stewardship* presents a slower pace of life and a determined move towards a low-impact, low resource-use society.
- *Go with the Flow* offers a vision of how the UK will evolve if we continue with current socioeconomic and environmental policies.

The qualitative descriptions of plausible changes in ecosystem services and their associated goods and benefits under each storyline represent the basic output from the scenarios exercise. A novel aspect of the work that takes scenario-building further, however, has been the use of Bayesian Belief Networks to create spatially explicit representations of each of the possible futures for land-based ecosystems (Chapter 25).

It has been argued that to be effective scenarios must not be seen as having "lives of their own, divorced from the processes that generated them…" (O'Neill *et al.* 2008). Instead, their real value comes from the way they can be used to help us understand and reflect upon our current understandings and beliefs, and think more broadly about the problems that may confront us. Thus, the scenarios developed as part of the UK NEA must not be viewed as ends in themselves; they should be used as part of the debate about what the UK NEA is telling us about the state we are in and where current trends might lead us. Having constructed the UK NEA scenarios, these materials have also been used as part of the UK NEA workstream dealing with 'responses', which is reported in Chapter 27.

2.10 Response Options

In the light of findings from the assessment of ecosystem services, and informed by the scenarios work that identifies broad policy changes which might influence their future status and trends, the UK NEA also includes an assessment of alternative, policy-relevant response options (Chapter 27). These are considered in a structure that differentiates among relevant sectors, types of interventions and actors.

The different sectors prescribe the general area of policy within which options may be relevant: biodiversity; agriculture; fisheries; forestry; water; recreation and tourism; planning, transport and energy; and integrated, including marine. For each one of these sectors, interventions are considered across seven categories: knowledge; legislation; policy and institutions; social/behavioural responses; markets/incentives; technologies; and voluntary initiatives. For each sector and intervention type, there are also alternative actors: governments; local authorities; the private sector; non-governmental organisations; civil society organisations; and individuals and communities.

The majority of the assessment is undertaken by sector; the response options available to the full range of actors within each sector is assessed according to response type (e.g. legislation and behaviour). The impacts of these responses on habitats, their ecosystem services and, ultimately, human health and well-being is then assessed, often with the use of examples and case studies. A section on Integrated Responses addresses approaches that go beyond sectoral divides, and explores how responses relating to ecosystem services interact with other social and economic objectives.

References

Balmford, A., Fisher, B., Green, R.E., Naidoo, R., Strassburg, B., Turner, R.K. & Rodrigues, A. (2011) Bringing Ecosystem Services into the Real World: An Operational Framework for Assessing the Economic Consequences of Losing Wild Nature. *Environmental and Resource Economics,* **48**, 161–175.

Bateman, I., Mace, G., Fezzi, C., Atkinson, G. & Turner, K. (2011) Economic Analysis for Ecosystem Service Assessments. *Environmental and Resource Economics,* **48**, 177–218.

Bradford, M.A., Jones, T.H., Bardgett, R.D., Black, H.I.J., Boag, B., Bonkowski, M., Cook, R., Eggers, T., Gange, A.C., Grayston, S.J., Kandeler, E., McCaig, A.E., Newington, J.E., Prosser, J.I., Setälä, H., Staddon, P.L., Tordoff, G.M., Tshcherko, D. & Lawton, J.H. (2002) Impacts of soil faunal community composition on model grassland ecosystems. *Science,* **298**, 615–618.

Carey, P. D., Wallis, S., Chamberlain, P. M., Cooper, A., Emmett, B. A., Maskell, L. C., McCann, T., Murphy, J., Norton, L. R., Reynolds, B., Scott, W. A., Simpson, I. C., Smart, S. M. & Ullyett, J. M. (2008) Countryside Survey: UK Results from 2007. NERC/Centre for Ecology and Hydrology, Wallingford, UK.

Carpenter, S.R., Pingali, P.L., Bennett, E.M. & Zurek, M.B. (eds) (2005) Ecosystems and Human Well-Being: Scenarios. Island Press, Washington D.C.

Carpenter, S.R., Bennett, E.M. & Peterson, G.D. (2006) Scenarios for ecosystem services: An overview. *Ecology and Society*, **11**, 29.

Carpenter, S.R., Mooney, H.A., Agard, J., Capistrano, D., DeFries, R.S., Díaz, S., Dietz, T., Duraiappah, A.K., Oteng-Yeboah, A., Pereira, H.M., Perrings, C., Reid, W.V., Sarukhan, J., Scholes, R.J. & Whyte, A. (2009) Science for managing ecosystem services: Beyond the Millennium Ecosystem Assessment. *Proceedings of the National Academy of Sciences of the United States of America,* **106**, 1305–1312.

Cruz, I., Stahel, A. & Max-Neef, M. (2009) Towards a systematic development approach: building on the Human-Scale Development paradigm. *Ecological Economics*, **68**, 2021–2030.

Defra (Department for Environment, Food and Rural Affairs) (2007) Well-being: International policy interventions. Department for Environment, Food and Rural Affairs, London.

Díaz, S., Fargione, J., Chapin, F.S. III & Tilman, D. (2006) Biodiversity loss threatens human well-being. *PLoS Biology*, **4**, 1300–1305.

Díaz, S., Lavorel, S., de Bello, F., Quetier, F., Grigulis, K. & Robson, M. (2007) Incorporating plant functional diversity effects in ecosystem service assessments. *Proceedings of the National Academy of Sciences of the United States of America*, **104**, 20684–20689.

Fish, R., Burgess, J., Chilvers, J., Footitt, A., Haines-Young, R., Russel, D., Turner, K. & Winter, D.M. (2011) Participatory and Deliberative Techniques for Embedding an Ecosystems Approach into Decision Making. Full Technical Report. (NR0124). Department for Environment, Food and Rural Affairs, London.

Fisher, B. & Turner, R.K. (2008) Ecosystem services: classification for valuation. *Biological Conservation,* **141**, 1167–1169.

Fisher, B., Turner, K., Zylstra, M., Brouwer, R., de Groot, R., Farber, S., Ferraro, P., Green, R., Hadley, D., Harlow, J., Jefferiss, P., Kirkby, C., Morling, P., Mowatt, S., Naidoo, R., Paavola, J., Strassburg, B., Yu, D., and Balmford, A. (2008). Ecosystem services and economic theory: Integration for policy-relevant research. *Ecological Applications* **18**, 2050-2067.

Fitter, A., Elmqvist, T., Haines-Young, R., Potschin, M., Rinaldo, A., Setala, H., Stoll-Kleemann, S., Zobel, M. & Murlis, J. (2010) An Assessment of Ecosystem services and biodiversity in Europe. *Issues in Environmental Science and Technology,* **30**, 1–28

Foresight (2007) Tackling Obesities: Future Choices. Government Office of Science, London.

Foresight (2008) Mental health – Future challenge. Government Office of Science, London.

Jackson, D.L. (2000) Guidance on the Interpretation of the Biodiversity Broad Habitat Classification (Terrestrial and Freshwater Types): Definitions and the Relationship with other Habitat Classifications. JNCC Report Series 307. Joint Nature Conservation Committee, Peterborough, UK.

Hector, A., Beale, A.J., Minns, A., Otway, S.J. & Lawton, J.H. (2000) Consequences of the reduction of plant diversity for litter decomposition: effects through litter quality and microenvironment. *Oikos,* **90**, 357–371.

Hooper, D.U., Chapin, F.S. III, Ewel, J.J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J.H., Lodge, D.M., Loreau, M., Naeem, S., Schmid, B., Setälä, H., Symstad, A.J., Vandermeer, J. & Wardle, D.A. (2005) Effects of biodiversity on ecosystem functioning: A consensus of current knowledge. *Ecological Monographs,* **75**, 3–35.

MA (Millennium Ecosystem Assessment) (2005) Ecosystems and Human Well-being: Synthesis. Island Press, Washington D.C.

Maskell, L.C., Norton, L.R., Smart, S. M., Carey, P.D., Murphy, J., Chamberlain, P.M., Wood, C.M., Bunce, R.G.H. & Barr, C. J. (2008) Countryside Survey. Field Mapping Handbook. NERC/ Centre for Ecology and Hydrology, Wallingford, UK.

Max-Neef, M. (1989) Human scale development: an option for the future. *Development Dialogue*, **1**, 5–81.

Max-Neef, M. (1992) Development and human needs. Real life Economics (eds P. Ekins & M. Max-Neef), pp. 197–214. Routledge, London.

Nicholson, E., Mace, G.M., Armsworth, P.R., Atkinson, G., Buckle, S., Clements, T., Ewers, R.M., Fa, J.E., Gardner, T.A., Gibbons, J., Grenyer, R., Metcalfe, R., Mourato, S., Muûls, M., Osborn, D., Reuman, D.C., Watson, C. & Miller-Gulland, E.J. (2009) Priority research areas for ecosystem services in a changing world. *Journal of Applied Ecology,* **46**, 1139–1144.

Norby, R.J., Hanson, P.J., O'Neil, E.G., Tschaplinski, T.J., Weltzin, J.E., Hansen, R.A., Cheng, W., Wullschleger, S.D., Gunderson, C.A., Edwards, N.T. & Johnson, D.W. (2002) Net primary productivity of a CO_2 enriched deciduous forest and the impliactions for carbon storage. *Ecological Applications*, **12**, 1261–1266.

Norby, R.J., Warren, J.M., Iversen, C.M., Medlyn, B.E. & McMurtrie, R.E. (2010) CO_2 enhancement of forest productivity constrained by limited nitrogen availability. *Proceedings of the National Academy of Sciences,* **107**, 19368–19373.

O'Neill, B., Pulver, S., VanDeveer, S. & Garb, Y. (2008) Where next with global environmental scenarios? *Environmental Research Letters*, **3**, 1–4.

Pretty, J., Angus, C., Bain, M., Barton, J., Gladwell, V., Hine, R., Pilgrim, S., Sandercock, G. & Sellens, M. (2009) Nature, Childhood, Health and Life Pathways. iCES Occasional Paper 2009–2. University of Essex, Colchester.

Ring, I., Hansjurgens, B., Elmqvist, T., Wittmer, H. & Sukhdev, P. (2010) Challenges in framing the economics of ecosystems and biodiversity: the TEEB initiative. C*urrent Opinion in Environmental Sustainability,* **2**, 15–26.

Scheffer, M. & Carpenter, S.R. (2003) Catastrophic regime shifts in ecosystems: linking theory to observation. *Trends in Ecology & Evolution,* **18**, 648–656.

Suding, K.N., Lavorel, S., Chapin, F.S. III, Cornelissen, J.H.C., Díaz, S., Garnier, E., Goldberg, D., Hooper, D.U., Jackson, S.T. & Navas, M.L. (2008) Scaling environmental change through the community-level: a trait-based response-and-effect framework for plants. *Global Change Biology,* **14**, 1125–1140.

WHO (World Health Organization) (1948) WHO definition of Health. Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York, 19–22 June, 1946; signed on 22 July 1946 by the representatives of 61 States (Official Records of the World Health Organization, no. 2, p. 100) and entered into force on 7 April 1948.

Yachi, S. & Loreau, M. (1999) Biodiversity and ecosystem productivity in a fluctuating environment: The insurance hypothesis. *Proceedings of the National Academy of Sciences of the United States of America*, **96**, 1463–1468.