CHAPTER TWELVE

The natural capital approach to integrating science, economics and policy into decisions affecting the natural environment

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12.1 The natural capital approach

The term natural capital refers to stocks of assets, provided for free by nature which, either directly or indirectly, deliver well-being for humans. Natural capital stocks in turn deliver flows of services, often called ecosystem services, which produce the benefits upon which humans depend. Natural capital assets include stocks of fresh water, fertile soils, clean air and biodiversity. These stocks may be either renewable (e.g. fish populations) or non-renewable (e.g. oil stocks). Both stock types are vital contributors to economic activity and well-being, but can be driven to exhaustion through human action. Economic activity therefore draws and depends upon natural capital, while also affecting the stock of those assets. This intimate relationship between the environment, economy and human well-being has caught the attention of governments internationally. In this chapter, we set out how governments should incorporate the notion of natural capital into policy- and decision-making. We also consider the means by which changes can be best directed to reflect the underlying science of the environment, the incentives of the economy and the preferences of society.

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12.1.1 Mainstreaming natural capital: the drivers of change

Mainstreaming natural capital involves bringing nature's stock and flows of goods and services into decision-making. A key element of this is to provide decision-makers with an understanding of the factors that drive change in natural capital resource use. While analyses generally examine the advantage of moving from current to alternative resource use, they commonly fail to investigate how the move between these two states is to be effected. For example, it is relatively easy to demonstrate that a move from current intensive agricultural production practices to lower-input systems will deliver improvements in water quality, greenhouse gas emissions, wildlife habitat and greenspace access. These advantages are often rigorously demonstrated without guidance as to how such change should be delivered, leaving the decision-maker facing uncertainty regarding how best to act. Such natural capital analyses alone are of little practical value as they do not acknowledge that land-use change is driven by a wide array of socio-economic/market, policy and environmental forces. Understanding the drivers of change, and the consequences brought about by policy decisions, is one of the major reasons for bringing economists into decision-making.

12.1.2 Natural capital, ecosystem services, goods and values

When making policy decisions regarding the natural environment it is important to understand the linkages between the various forms of natural capital, the ecosystem services they provide and their transformation into valued goods and services (Figure 12.1). In the upper left of Figure 12.1 we have the raw inputs to this system: energy (from the sun) and matter (from the earth). Together these yield stocks of physical natural capital and natural processes. Combining these stocks and processes provides the myriad ecosystem service flows provided by the natural environment. However, as shown in the third column, goods are more typically obtained by combining ecosystem service flows with other human-derived forms of capital, such as labour, machinery and technology. Here the term 'goods' refers to anything which alters human well-being, ranging from tangible products like timber or food to non-tangibles, such as the positive emotions associated with knowing that biodiversity is being conserved. Similarly, while some of these goods are provided through markets and consequently have prices, others are provided outside markets and lack prices. Nonetheless, all are, by definition, of value.

Because natural capital and ecosystem services can be used to generate a wide variety of goods, it is useful to understand whether those resources could be used in better ways. In effect, we need some measure of the value of a set of goods (Figure 12.1). Many of the goods that contribute to human well-being can be assessed in economic values, and changes in these can be analysed in terms of the resultant benefits and costs. However, a few well-being–bearing goods

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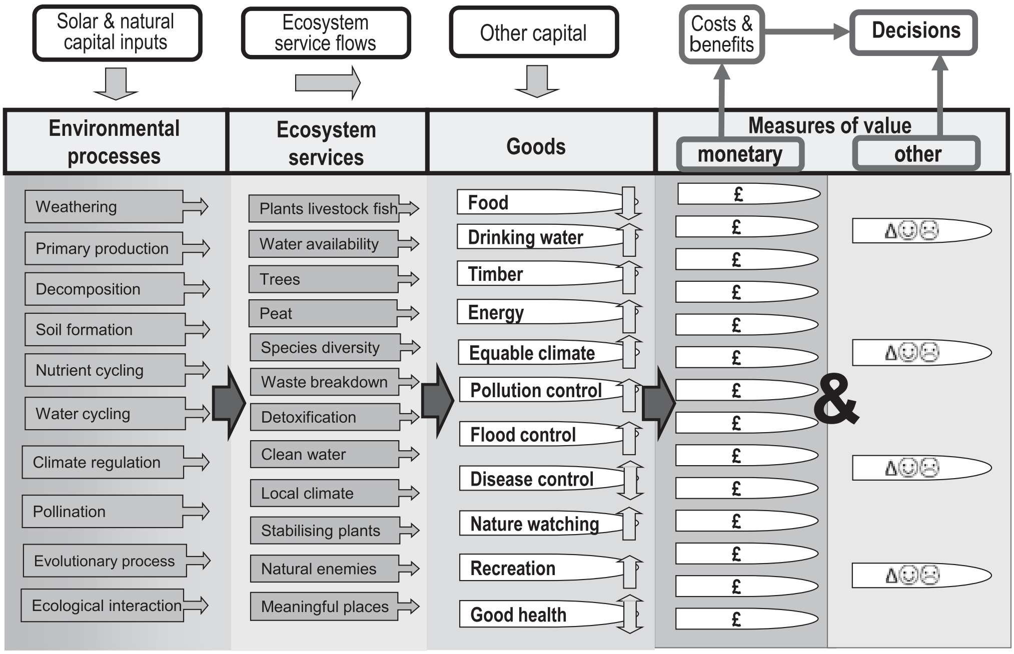

Figure 12.1 Decision-making and the environment: from natural capital to decisions. The yellow arrows illustrate the multiple effects typical of a change in natural capital, in this case those arising from an investment to establish woodland on a currently farmed area. (A black and white version of this figure will appear in some formats. For the colour version, please refer to the plate section.)

cannot be robustly assessed in terms of economic value and therefore other, ideally quantitative, measures have to be incorporated into decisions.

In their raw, unused state, natural capital resources have high usefulness and can be employed to generate a wide range of goods, often simultaneously. However, this means that changes to the use of natural capital often generate multiple consequences. The environment is an interconnected system; changing its use in one way can have multiple effects, many of which might not have been anticipated by the decision-maker who prompted that original change (Figure 12.1). To illustrate, afforestation of farmland will typically reduce the amount of food produced. If the analysis is curtailed there, then an investment to convert farmland to woodland might often appear to yield poor value; timber values are long delayed and may well be less than the food value that can be generated over that period. Such restricted analysis is common, especially if food and timber are the only marketed, and hence priced, goods produced by such a change. However, afforestation can affect the production of a wide range of other goods. A shift from agriculture to

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woodland can often result in an improvement in water quality as forests require much lower inputs of fertiliser than farmland, reducing the run-off of nutrients into waterways, resulting in less-polluted rivers and higher water quality. In very many cases woodlands also reduce emissions of air pollution and store carbon, helping reduce climate change. Similarly, woodlands typically provide much greater recreational benefits than many forms of agriculture. To improve decisions regarding natural capital we need to assess all the major trade-offs arising from a proposed change and ensure that they are valued on a level playing field.

12.1.3 Decisions, trade-offs and valuation

12.1.3.1 Two inescapable facts

The central challenge facing all decision-making can be encapsulated within two inescapable facts.

1. Human wants (including those with the highest possible motivations such as improving society) exceed the resources available to satisfy them all.
2. Because of these resource constraints, every time we decide to do one thing, we in effect decide not to do another; our decisions implicitly place values on each option.

This means that trade-offs are inevitable and valuations are unavoidable, as they are the essence of decision-making. The only real question is whether we leave those trade-offs and valuations implicit and hidden within a decision, or instead make them explicit and open to scrutiny. Economic analyses of environment-related investments are frequently the focus of criticism precisely because they make their valuations clear. However, failing to reveal valuations does not mean that decisions are being made without values. It merely means those values are being determined in an indistinct way, and are often not obvious even to those involved in the decision process.

12.1.3.2 The challenge of decision-making across integrated systems

Low-entropy (i.e. previously unused or raw) natural capital resources have an amazing diversity of potential uses. The more that capital is used the greater its entropy and the less available it becomes for alternative uses. In some cases this is a simple binary choice (e.g. using a soil resource to grow food often means that it cannot be simultaneously used to produce timber). Nevertheless, the relationship is frequently more complex (e.g. using water for intensive food production does not necessarily mean that it is not subsequently available for drinking, but can mean that it has to be treated before consumption). Any decision that ignores this interconnection and its consequences is clearly flawed, whether it understates or overestimates the net effects, or results in decisions that are wholly deleterious for society.

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Unfortunately, such incomplete analyses are commonplace. Some decision-makers may have preconceived notions of what is important and focus upon those consequences rather than the bigger picture. Often this is because the remit of the decision is constrained. So a government department charged with increasing food security may fail to adequately consider the wider environmental and societal impacts of its actions. A classic example is the EU Common Agricultural Policy (CAP) designed to promote food security. While the CAP has been substantially revised and improved in recent years, its early operation focused almost exclusively on boosting the production of food without consideration of the environmental consequences. Indeed, an argument that one objective supersedes all others is a common hallmark of many poor policy decisions. These poor policies impose unjustified and avoidable costs upon society and natural capital, which always have to be addressed in the long term and are better avoided from the outset. The catalogue of policy reversals that characterise the history of the CAP illustrate the unsustainable nature of policies with limited focus (e.g. subsidies for hedgerow removal being superseded by subsidies for their replacement).

Within the private sector, businesses typically focus upon those consequences of investment decisions that improve profits for its owners and shareholders; this, in turn, can result in a focus upon the output of goods that have market-priced values, often at the expense of other non-market, unpriced goods. In our opinion this is not morally reprehensible as, in many legal contexts, the management of a firm is legally obliged to operate in ways that benefit its owners. However, it means that public regulators need to consider policy frameworks that align the profit incentives of businesses with the interests of wider society, including environmental sustainability.

12.1.3.3 The challenge of decision-making across non-commensurate metrics

If decision-makers are interested in the overall impact that changes will have upon society then appraisals need to be comprehensive and consider all of the impacts of an investment; not only the policy focus (e.g. boosting agricultural production) but also all consequent trade-offs ('externalities' such as water pollution), be they negative or positive. A substantial challenge is that impacts are often measured using an array of different metrics. For instance, flood control is most obviously assessed in terms of risk per household, drinking water quality in mg/litre of pollutants, greenhouse gases in tonnes of carbon equivalent, recreation as the number of visits, and so on. These measures are typically non-commensurate (how many recreational visits should be given up to sequester an additional tonne of a given greenhouse gas?). Given that the overall objective of natural capital investments is to improve sustainable well-being, then the logical approach is to assess the extent to which each trade-off contributes to well-being (either positively or negatively). But what is the best unit with which to assess changes in well-being? Ideally we would want a pure unit of well-being, or, as economists term it, utility. Unfortunately, this does not exist. Therefore, an alternative is to use a unit that people commonly use to express the well-being they obtain from the gain or loss of a good. This, of course, is not a challenge that is confined to natural capital, and throughout history society has solved the problem of how to exchange different goods through the medium of money.

Using money as a unit of well-being for making commensurate the multiple trade-offs associated with natural capital change has important benefits. A commonly claimed advantage is that decision-makers are familiar with money, yet this general assertion hides a more important truth. If investments are being considered by the public sector, then the government needs to ensure that the limited tax funds at its disposal are allocated wisely, in the way that will maximise well-being. Society needs a robust natural capital base and high-quality environment. However, it also needs a health service, education, transport infrastructure, employment, security, etc., all of which draw upon the finite financial resources available to the government.

This is not to claim that money is the perfect common unit with which to express diverse benefits. Conversion problems abound, but these are even more challenging when other units are used. Indeed, it would be more accurate to argue that money is simply the least-worst common unit available. The long-term failure to assess the benefits of investing in the natural environment in monetary terms has coincided with long-term over-use and degradation of natural capital, as it is seen as a net cost yielding little obvious benefit. Certainly the case for increasing spending on the environment is difficult to make when expressed in diverse and unfamiliar units. Given this, it is hardly surprising that public spending on the environment typically represents a tiny fraction of GDP.

While marketed goods are often valued with reference to their prices, a range of methods have been developed for valuing non-market goods (Freeman et al., 2014; Champ et al., 2017). These methods can be broadly divided into three categories:

- production function methods, which examine how changes in the environment and ecosystem services affect economic output (e.g. how changes in the climate affect agricultural production; Fezzi & Bateman, 2015);
- revealed preference methods, which infer individuals' preferences and hence values through observing behaviour (e.g. looking at the time/expenditure which visitors spend to reach preferred recreational sites; Herriges & Kling, 2008);
- stated preference methods, which use experiments or surveys to ask respondents to either directly state their willingness to pay for changes,

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or to choose between alternative outcomes with differing costs (e.g. examining choices between different levels of water bill according to the quality of river water they offer; Metcalfe et al., 2012).

Non-market valuation methods are important tools in the estimation of the multiple values that can arise from changes to natural capital. For example, impacts on recreation can be valued by looking at choices made by visitors across sites and relating these to the costs they incur to visit those sites (Herriges & Kling, 2008). If changes in recreational access can be shown to affect visitors' health or life expectancy, then this can be valued by examining people's willingness to pay for changes in health risk (Krupnick et al., 2002). Alternatively, estimates of health costs can be obtained either by looking at impacts on production (Murphy & Topel, 2006), or the avoided costs of illness (Tarricone, 2006). It is worth noting that these are social values, as reflected in individual behaviour, not the values postulated by economic experts.

12.1.3.4 Assessing impacts on biodiversity

While the majority of environmental costs and benefits can be robustly assessed using economic values, the valuation of biodiversity impacts is challenging. Certain aspects of biodiversity value can defensibly be estimated in economic terms (Hanley et al., 2015; Pascual et al., 2017). For example, provided that we have a clear understanding of the relationships between wild species, plant pollination and crop production, the monetisation of changes in output via crop market prices is relatively trivial (Losey & Vaughan, 2006; Melathopoulos et al., 2015; Breeze et al., 2016). Similarly, we can look at the increase in recreation values generated by biodiversity by examining how much further, or how often, people are prepared to travel for experiences such as viewing rare birds or hunting (USNCR, 1999; Kolstoe & Cameron, 2017). Nonetheless, it is also well established that biodiversity generates non-use value (e.g. from the knowledge that wild species continue to exist and will be bequeathed to future generations) (Kotchen & Reiling, 2000; Diafas et al., 2017). The lack of output effects or observable human behaviour in such cases means that production function and revealed preference methods are not applicable. Arguably they may be inferred by examining direct payments for conserving wild species through donations, memberships of conservation groups and legacies (Pearce, 2007; Simpson, 2007; Atkinson et al., 2012). However, such approaches will at best provide poor underestimates of true value (an expectation confirmed by the low values reported by such analyses), well out of synch with other measures of biodiversity conservation concern.

In theory, the non-use values associated with biodiversity can be directly estimated using stated preference methods, such as contingent valuation or choice experiments (Hanley et al., 2003; Christie et al., 2004; Morse-Jones et al.,

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2012). In practice, these exercises face a number of challenges. One problem is that many studies have found the general public to have 'low awareness and poor understanding' of what biodiversity means (Christie et al., 2006, p. 305). Communicating such information to survey respondents is difficult as it can alter preferences and values, making them no longer representative of the social values researchers are seeking to estimate (Samples et al., 1986). Furthermore, studies seeking to estimate conservation values often cannot use scenarios in which the respondents are forced to make payments (unlike water bills as 'payment vehicles' for delivering changes in water quality).

So, how do we ensure that preferences regarding non-monetised values are not ignored? Fortunately, in the case of biodiversity we have plenty of other evidence regarding preferences that we can bring into play. For example, the most recent UK *Public attitudes and behaviours towards the environment* survey (National Statistics, 2009) revealed that 91% of respondents agreed that 'there are many natural places that I may never visit but I am glad they exist', while 85% agreed that 'I do worry about the loss of species of animals and plants in the world'. This provides us with a simple yet effective way of incorporating this preference information into decision analyses, by simply requiring that any potential change to natural capital should avoid the loss of, or enhance, biodiversity. Furthermore, alongside its direct use and non-use value, biodiversity supports a variety of ecosystem service–related benefits, most of which may be too complex and poorly understood to be adequately captured in an assessment (Turner & Daily, 2008; Mace, 2014; Mace et al., 2015; Bolt et al., 2016). A precautionary, standards-based approach should therefore be taken (Bateman et al., 2011a; Harper, 2017). Indeed, legislative support for stricter requirements being placed upon investments is evidenced in the UK Government's 25 Year Environment Plan, which sets out the principle of net environmental gain associated with new development of land (HM Government, 2018). For simplicity, however, we adopt a no-loss constraint in this chapter, confining ourselves to proving the point that biodiversity can be defensibly integrated into a natural capital decision-making approach without having to resort to dubious estimates of the economic value of the non-use benefits it provides.

12.1.4 Payment mechanisms: uniting payers and providers of ecosystem services

As part of any investment analysis, consideration needs to be given to who will provide and fund a given natural capital change, with the 'payment mechanism' being an important element of the appraisal process (Table 12.1). The provision of non-market environmental goods is most commonly funded by the public sector, while the private sector provides the goods (e.g. farmers subsidised to provide conservation services). A common challenge for public funding schemes is that subsidies are often allocated as untargeted flat-rate

Table 12.1 *The payer–provider matrix of payment mechanisms for environmental goods*

		Provider (of goods)	
		Private sector	Public sector
Payer (for goods)	Private sector	Payments for ecosystem services; profitable environmental improvements	Corporate social responsibility projects
	Public sector	Payments for ecosystem services; subsidies to businesses	Taxation-funded public provision

payments across all locations, whereas the provision of biodiversity and ecosystem services varies spatially. While such an approach is easy to administer, it is highly inefficient. By combining environmental modelling and economic valuation, interventions can be targeted to where they will yield greater benefits. This ensures that funders, ultimately tax payers, receive better value for money. It also means that the same level of resource generates enhanced environmental outcomes. Further improvements in the efficiency and impact of funding can be delivered through the use of 'natural capital markets' to allocate support payments. By creating competitive market structures (so-called 'reverse auction' markets; Elliott et al., 2015; Fooks et al., 2015) which induce competition between ecosystem service providers, the incentive for private firms to over-charge for their actions is reduced.

Of course, from a public-sector perspective, these mechanisms are further enhanced if the private sector finances these initiatives. Corporate social responsibility investments now represent a substantial source of private-sector funding for environment projects involving major multinational corporates. For example, since 2012 Microsoft's global operations have been completely carbon-neutral (Microsoft Corp., 2017), an initiative recently taken up by Google (Google, 2016; Hölzle, 2016). While such investments clearly represent short-term costs to such companies, the social and reputational benefits generated by environmental improvements may well raise sales, generate price premiums and hence improve profits (e.g. Bateman et al., 2015). Moving more in the direction of conventional profit-bearing activities, many companies invest in

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areas that overtly yield a mix of both private and public benefits. For example, Häagen-Dazs (2017) has invested substantially in approaches to sustain honeybee populations, recognising that they are of considerable non-use value to society, as well as being vital to the ingredients supply chain of the ice cream manufacturer. Combining these activities with competitive Payments for Ecosystem Service markets allow companies to achieve cost reductions or revenue increases at minimum cost, thereby maximising the profitability of such actions (Day et al., 2013; Bateman et al., 2018).

12.1.5 Spatial scaling and targeting

From a pure natural science perspective it can be argued that there is no single perfect scale for decision-making involving an ecological system. This situation is further complicated by intersecting administrative jurisdictions and boundaries defined by the geographical extent of the economic benefits generated by ecosystem services (Bateman et al., 2006). We have to recognise these boundaries, overlaps and conflicts when making decisions to delineate the spatial scale that is most suitable for the investment. As highlighted above, a further spatial issue concerns the degree to which policies are untargeted, effectively ignoring the natural variation in the environment. These challenges have to be acknowledged and incorporated within decision-making systems if we are to achieve the levels of value for money that limited public funding requires. In particular, the tendency towards simplistic administrative methods has to be resisted. What appears to be financially cheap can often be economically very expensive in terms of the high opportunity costs and poor value for money delivered.

12.2 Analysis for natural capital decision-making: a national-level case study

12.2.1 Background

The Millennium Ecosystem Assessment (2005) highlighted global ecosystem service degradation and urged action at all governmental levels to address this problem. The first major national level response to this challenge was provided by the UK through its National Ecosystem Assessment (NEA). The NEA sought to assess the consequences of natural capital use and land-use change, and showed that over 30% of the services provided by the UK's natural environment are in decline.

The data provided by the NEA (UK NEA, 2011) formed the basis of the models used in the assessment outlined in this case study (Bateman et al., 2011b, 2013, 2016). A wide range of highly detailed, spatially referenced, environmental data covering all of Great Britain were collected, ranging from soil characteristics (e.g. susceptibility to water logging), climate variables (e.g. temperature, rainfall) and land use (e.g. agricultural output) (Figure 12.2). This was complimented by similar spatially and temporally referenced data on market variables (e.g. prices, costs) and

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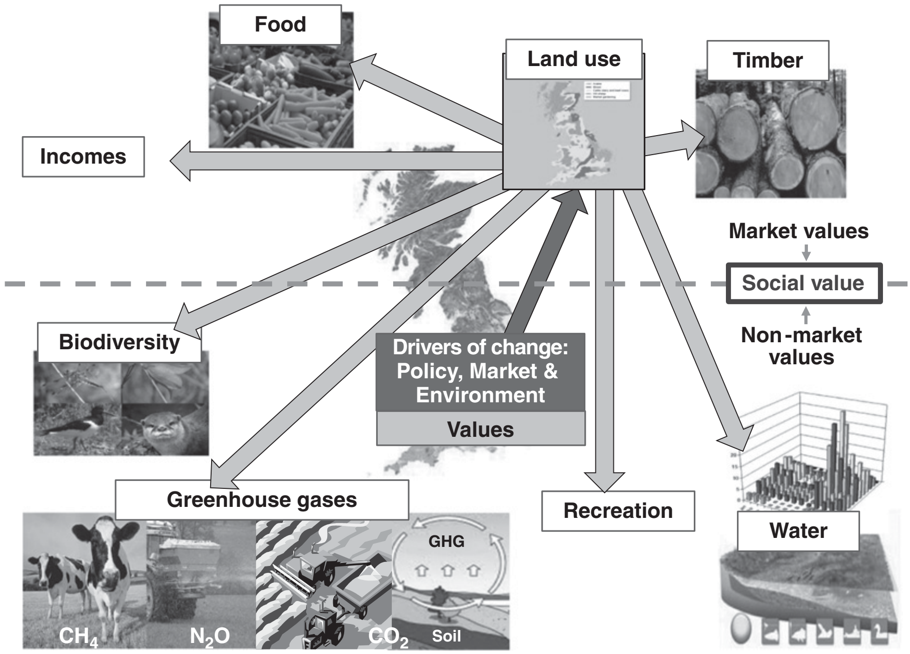

Figure 12.2 The drivers, consequences and values of land-use change, associated with agricultural land use in Great Britain and incorporated within the conceptual framework of the National Ecosystem Assessment (Mace et al., 2011). (A black and white version of this figure will appear in some formats. For the colour version, please refer to the plate section.)

policy (e.g. subsidies, regulations such as land-use constraints). The analysis linked environmental, economic and policy factors to examine both the market and non-market consequences and values generated by land use and changes thereto. The spatial nature of these analyses also demonstrated how future policy can be targeted to most efficiently allocate available resources to maximise their net benefits.

Each analysis began from an econometric model of the environmental, economic and policy drivers of land-use (Fezzi & Bateman, 2011). This model drew upon long-term (~50 year) and high-resolution (2 × 2 km grid square or finer) national-scale data sets. The NEA set out to consider six policy scenarios (UK NEA, 2011; Bateman et al., 2013), each of which integrated both high and low future greenhouse gas (GHG) emission trends (Fezzi et al., 2014). Each predicted land use served as the base data, inputting to a series of interlinked ecosystem service impact and economic valuation models detailing the delivery of food production, emission and sequestration of greenhouse gases (including CO_2, CH_4 and N_2O), expected numbers of open-access recreational visits, levels of urban greenspace amenity and biodiversity metrics (Abson et al., 2014; Bateman et al., 2014; Fezzi et al., 2014; Perino et al., 2014; Sen et al., 2014).

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12.2.2 Land-use–derived ecosystem services and their economic valuation

The major ecosystem services in the analyses were valued using a mix of market and non-market valuation techniques, with biodiversity set as a no-loss constraint, as follows.

- Food output provided the key, market-valued ecosystem service, determining approximately 75% of land use in the UK, including cropland, grassland, mountain, moor and heathland environments (Bateman et al., 2013).
- GHG sequestration had a non-market value. The quantity of GHG emission/storage associated with land was determined by the use and management of that land (e.g. cattle stocking density of cattle, other major methane producers, machinery emissions), annual flows of soil carbon due and accumulation/emission of carbon dioxide via terrestrial vegetative biomass. GHG values can be obtained through various routes, including estimates of the expected damage of climate change, the cost of abating emissions and the values of carbon traded in emission markets (Abson et al., 2014).
- Open-access recreational visits had a non-market value that varied across environments (e.g. mountains, coasts, forests, urban greenspaces) and location (Sen et al., 2014).
- Urban greenspace had a non-market value reflecting aesthetic, physical and mental health, neighbourhood, noise regulation and air pollution reduction benefits (Perino et al., 2014).
- Wild bird species diversity was used to represent biodiversity, because these species are high in the food chain and are often considered to be good indicators of wider ecosystem health (Gregory et al., 2005). As discussed previously, current estimates of biodiversity values and, in particular, pure non-use existence values are insufficiently robust. Following the reasoning set out above, we imposed a ‘no-loss’ constraint on biodiversity as a consequence of land-use change (Bateman et al., 2013).

12.2.3 Identification of the beneficiaries

The same change can yield very differing consequences to different groups of people. So we considered both the market and non-market net benefits to farmers, foresters, recreationalists, wildlife enthusiasts, etc. This allows the decision-maker to comparatively assess the scenarios and understand which provides the best value for money to society (both nationally and globally). Here, we ignore these distributional issues (but see Bateman et al., 2011b; Perino et al., 2014) and focus upon the overall benefits to society. The major beneficiaries of alternative land-uses included the following.

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- Farmers: the latitude and generally colder climate of the UK means that temperature rises are likely to result in farmers increasing their profits and intensive arable production in areas that are not liable to drought (Fezzi et al., 2014; Fezzi & Bateman, 2015). However, in turn, this will probably negatively impact upon water quality due to nutrient pollution (Fezzi et al., 2015). Lower river water quality will also impact negatively upon freshwater biodiversity and river-related recreational values (Bateman et al., 2016).
- Recreationalists: open-access recreational sites benefit individuals who visit them, with the net benefit declining as distance from an individual's home or outset point grows.
- Urban residents: urban greenspace value is reflected in local property and rental value, with the value generally decaying as distance increases (Day et al., 2007; Andrews et al., 2017). Increasing access to urban greenspace typically generates significant aggregate social benefits. However, the distribution of benefits can be uneven and result in gentrification, which has the potential to push poorer families out to less-advantaged areas. Recently developed techniques such as Equilibrium Sorting Analyses seek to capture this effect and bring it into decision-making (Binner & Day, 2015).
- Biodiversity beneficiaries: improvements in species diversity not only benefit the species being directly or indirectly (e.g. through food chains) conserved, but people who value such improvements through use (e.g. hunter, fisherman, wildlife watchers) or non-use (existence values). Biodiversity also indirectly delivers value through roles in ecosystem functioning and service provision.

12.2.4 Analysing trade-offs across alternative land-use scenarios

For simplicity, we considered the two most extreme policy scenarios in this chapter. The World Markets scenario prioritises economic growth by completely liberalising trade, removing tariffs and trade barriers and ending agricultural subsidies; as a result, farming moved towards large-scale, intensive production methods. By contrast, the Nature@Work scenario priority is to adapt to climate change and enhance ecosystem service provision.

While considering market goods alone and ignoring non-market impacts captures only a single dimension of impact, the World Markets scenario indicated values which are frequently given primacy in policy decisions. This scenario saw agricultural value increase £1.03 billion per annum because of a shift towards more intensive production (Table 12.2). Conversely, the Nature@Work scenario led to agricultural values declining by £0.13 billion per annum as farmland was converted to urban-fringe and recreational greenspace. So, if we restricted our analysis to market-priced goods alone, then the

Table 12.2 *Policy scenario effects on ecosystem service values in Great Britain (£ millions per annum), adapted from Bateman et al. (2014). All values are given in real (inflation-adjusted) 2010 values. Positive values indicate net gains, negative values show net losses. The two scenarios use high GHG emissions*

Scenario	Market agricultural output values	Non-market GHG emissions	Non-market recreation	Non-market urban greenspace	Total mon-etised values	Biodiversity
World Markets	1030	−440	−1180	−18,400	−18,990	–
Nature@Work	−130	230	13,060	4760	17,920	+

World Markets scenario almost always appeared justified. This conclusion was unaffected by varying the degree of climate change across our analysis (Bateman et al., 2011a, p. 1268).

However, when we extended our assessment to consider the impacts of land-use change upon non-market goods, we find that the Nature@Work scenario consistently yielded preferable outcomes (Table 12.2). GHG emission values in the World Markets scenario were negative in nearly all areas. In contrast, under the Nature@Work scenario, most areas saw benefits in terms of increased carbon storage; the exceptions were upland areas dominated by fragile peatlands which were vulnerable to both agricultural intensification in the World Markets scenario and increasing forestry in the Nature@Work scenario. The World Markets scenario saw losses in visitor values in almost all areas across the country, while the Nature@Work scenario led to recreational benefits over the large majority of the country. Similar results were seen for urban greenspace values. Our biodiversity metric clearly shows that the World Markets scenario resulted in major declines across large swathes of the country. In comparison, the Nature@Work scenario generated improvements across the lowlands (and, therefore, much of the UK), although the picture in the uplands was more mixed, with insignificant or weakly negative effects. This suggests that an optimal solution would combine elements of multiple policies.

In summary, the World Markets scenario increased the production of marketed agricultural output at the cost of significant declines in all other ecosystem services, which strongly outweighed the value of agricultural gains. It therefore lowered overall social value very substantially. In contrast, the Nature@Work scenario reversed this pattern, causing a relatively modest reduction in agricultural production in return for very substantial increases in all other non-market ecosystem service–related goods, and a correspondingly major increase in overall social value. This disparity was

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further reinforced when we considered the non-monetised biodiversity measures. If we applied our constraint that any decision that would lower biodiversity in an area is ruled ineligible then, at a national level, the World Markets scenario was unacceptable. A spatially targeted optimisation approach could avoid biodiversity losses in local areas and further enhance decision-making.

12.2.5 Policy implications

The UK Government responded quickly and positively to the challenge of the National Ecosystem Assessment, adopting an overarching policy goal to be 'the first generation to leave the natural environment in a better state than it inherited' (HM Government, 2011, 2018; House of Commons, 2012). As part of this ambition, the UK has invested in research seeking to develop a 'natural capital approach' to decision-making, which explicitly recognises the dependence of economic value and well-being on the natural capital stocks provided by the environment and the ecosystem service flows which those assets provide. To help guide this process, the 2011 Natural Environment White Paper (HM Government, 2011) set up the world's first independent Natural Capital Committee (NCC) to advise on the restoration and improvement of natural capital as a means of sustaining and enhancing economic growth in the UK (Defra, 2012; NCC, 2013). Importantly, while it has a close relationship with the UK's environmental department, the NCC actually reports to the country's finance ministry. Indeed, the UK's Chief Finance Minister, the Chancellor of the Exchequer, chairs the Economic Affairs Committee (EAC, 2017), which the NCC formally advises (NCC, 2017a).

The NCC has reported extensively on methods to 'mainstream' natural capital considerations into both policy and business decision-making (NCC, 2017a, 2017b). Furthermore, it has also provided extensive advice on the valuation, accounting and financing of natural capital enhancement (NCC, 2017a, 2017c). Additionally, the NCC proposed and advised on a 25-year plan for the natural environment, focusing upon the need to ensure sustainable flows of ecosystem services from the UK's natural capital (NCC, 2015, 2017d), a recommendation which was then adopted by all of the major UK political parties and government (HM Government, 2018). This places the natural capital approach at the heart of decision- and policy-making over both the short and long term.

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