Chapter 26:
Valuing Changes in Ecosystem Services: Scenario Analyses

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Key Findings

This chapter sets out to illustrate the decision making potential of the ecosystem service approach by valuing certain goods arising from changes in land use in Great Britain under a range of alternative future options. This analysis is extended to include both market and non-market goods and is given, as far as possible, in monetary terms. Where monetary valuation is not deemed reliable, alternative, quantitative assessments are made to permit an analysis of the cost-effectiveness of providing non-monetised goods.

The UK NEA Scenarios team provided six alternative futures, each of which is described in terms of land use, incomes and population in 2060. Furthermore, each scenario was presented with both a high and low climate change variant. Comparisons of the predicted situation in 2060 with a contemporary baseline allow us to identify the changes implied under each scenario. The novel work presented in this chapter applies various modelling techniques to quantify the impacts which these changes are expected to have upon the following five key ecosystem services:

- agricultural food production;
- terrestrial carbon storage and annual greenhouse gas emissions;
- biodiversity (assessed using birds as an indicator species);
- open-access recreation; and
- urban greenspace amenity.

Economic valuation techniques were applied to provide monetary assessments of the changes in the value of all these ecosystem services with the exception of biodiversity. In this latter case assessment was left in purely quantitative terms due to reservations about our ability to generate robust economic values for such effects.

Of these various ecosystem services, only agricultural food production has its value reflected in market-priced goods; remaining services all generate non-market values. Setting aside biodiversity for the moment, analysis of the scenarios revealed that in many cases, increases in market values could only be generated at the expense of those non-market ecosystem services. Furthermore, allowing decision making to be guided by market values alone (as per most contemporary decisions) often resulted in negative overall impacts for society, with total values (market plus non-market) falling substantially from the baseline. There were options which generated win-win increases in both market and non-market values; however, the greatest improvements in overall social well-being were generated by options which sought to treat both market and non-market values in an even-handed manner.

Bringing in the non-monetised measures of biodiversity effects allowed us to examine the costs of adopting options which avoided any such impacts. This provides an alternative perspective to decision making, highlighting options which deliver both increases in social values (assessed across both market and non-market goods) and avoids further pressures upon biodiversity. Interestingly, this shows that individuals may have to forgo attaining the highest possible gains in other values if they wish to avoid any loss of biodiversity.

All of the analyses conducted in this chapter adopt a unified methodology which captures the trade-offs in ecosystem services both across scenarios and across the country. The UK is highly heterogeneous and even under the same scenario, the changes induced in any given ecosystem service can vary from positive to negative depending upon which area of the country is considered. This methodology is highly appropriate for a localism agenda of decision-making systems which place great emphasis upon the distribution of costs and benefits across different areas and social groups.

26.1 Introduction

The purpose of economic analysis is to aid decision making. As discussed in the Economic Analysis chapter, (Chapter 22) decision making seeks to examine the trade-offs implied by each of a set of feasible options, so identifying that option which offers the best net benefits for society. For this reason, economic analysis is less interested in the total value of ecosystem services (not least because, for essential services, total values may be infinite) than in the change in value generated under one state as opposed to another. A key measure, then, will be the change in value arising from a move from a particular baseline to an alternative state. The present chapter assesses moves from a common baseline to each of the states described under the UK National Ecosystem Assessment (UK NEA) Scenarios (Chapter 25). In each case we consider the changes they imply for selected ecosystem services and the value of those changes.

This chapter does not pretend to value the impact of future scenarios upon all ecosystem services. This is, in part, a reflection of the state of available data and knowledge (and as such is an indicator of the need for further research in this area). As discussed at some length in Chapter 22 and supporting documents, economic values (for any good, not just ecosystem services) are contextual. By this we mean that marginal values (the value of a single unit change in a good) vary across space and time. So, for example, the value of a recreational visit may vary according to the location of that visit (e.g. because of the habitat type at that location). Similarly, the value of sequestering a tonne of carbon is likely to alter over time as the state of the climate alters. This information is not available for all of the ecosystem services considered in Chapter 22. Because of this we focus upon a subset of ecosystem service-related goods for which we do have sufficient data to undertake defensible valuations. Obviously, this subset does not represent the totality of values generated in the move from one state to another. Consequently, the valuations reported in the present chapter are necessarily partial and provisional. As a result, these analyses should not be taken as indicating the overall value of ecosystem service changes arising under each scenario.

A further caveat concerns the scenarios themselves. As discussed in Chapter 25, these are not the product of a modelling exercise in which trends are extrapolated and estimates of the future produced. Rather, the scenarios are hypothetical future worlds drawn in major part from a process of interaction with relevant agencies. As such they represent, in some considerable part, a wide spectrum of hypothetical but plausible future states. Another issue is that, as these are pre-generated outcomes, no information was provided on any transition path between the present and the scenario description. Where necessary, we have had to assume linear transition paths between the present and the future scenario. However, in the absence of further information we cannot improve on this assumption. A further caveat concerns the fact that these scenarios concern consumption of domestically produced ecosystem services and deliberately omit direct or indirect imports of such services. In effect, these are omitted from the total, future UK consumption of ecosystem services.

Despite these caveats, the present chapter does, we feel, amply demonstrate one very important and fundamental result: that methods now exist to unite natural sciences with economic assessments so as to estimate the value of changes arising under different states and thereby inform decision analysis. This is, arguably, the most important finding of the UK NEA in terms of its implications for the future. It paves the way for a new approach to decision making in which ecosystem services can be directly incorporated into policy choice. That this incorporation does not require a wholesale rejection of standard approaches to decision analysis, but rather an extension of current approaches, should significantly facilitate the acceptance and uptake of such techniques. In effect, these techniques facilitate an evolution, rather than a revolution, in decision making.

26.1.1 Valuing Scenarios of Ecosystem Service Change: Goods and Scenarios

Our demonstration of this evolution in decision making is executed through a series of highly comparable scenario analyses. These concern a consistent set of ecosystem service goods for which we can generate spatially and temporally sensitive data for each of the states described in Chapter 25. This work was conducted for the UK NEA by the SEER project[1] at the Centre for Social and Economic Research on the Global Environment (CSERGE), University of East Anglia in collaboration with colleagues at the British Trust for Ornithology and the School of Earth and Environment at the University of Leeds.

Five integrated ecosystem service goods are considered, as follows:

- agricultural food production;
- terrestrial carbon storage and annual greenhouse gas emissions;
- biodiversity (assessed using birds as an indicator species);
- open-access recreation; and
- urban greenspace amenity.

In each case, changes are calculated between a baseline[2] and the envisioned state of the UK in 2060 under the six UK NEA Scenarios. Ideally we would use the present day as the baseline; however, data availability prevented this[3] and the physical situation of land use, population and its characteristics in the year 2000 was adopted. However, to adjust somewhat to the present day, all baseline monetary values were adjusted to 2010 levels.

1 The Social and Environmental Economic Research (SEER) into Multi-Objective Land Use Decision Making project is held by the Centre for Social and Economic Research on the Global Environment (CSERGE) at the School of Environmental Sciences, University of East Anglia. SEER is funded by the Economic and Social Research Council (ESRC; Funder Ref: RES-060-25-0063).

2 As discussed subsequently, our analysis of farmland bird biodiversity adopts a somewhat different baseline.

3 While we would have liked to have used a more recent baseline, crucial sources of data such as Land Cover Map 2007 and 2011 Census details were not available at the time of the analysis. Consequently the analysis uses land use information from the CEH Land Cover Map 2000 while population, socioeconomic and demographic data is taken from the UK Census 2001.

- ***Go with the Flow*** essentially follows today's sociopolitical and economic trends and results in a future Britain that is roughly based on today's ideals, with some leaning towards improving the environmental performance and sustainability of the UK. Current ideas being developed in academic circles, government and the media about the way forward for the UK have been adopted. Environmental improvements are still important in the government's vision for a future UK, but the public are less keen on adopting many global or national environmental standards (business and industry even less so). This stand-off continues to dominate, and a lot of environmental progress is hindered. **It is very important to note that this scenario does not conform to that usually used as a baseline in an economic analysis.** The present approach is justified by noting both that it refers to a very long time horizon over which modelling would be problematic and that the scenarios listed here are designed to explore the how different drivers of change might shape the future. Typically, an economic analysis would define a baseline case under which existing trends and expected shifts are modelled to generate an estimate of how the world might look in the absence of particular policy changes. Economists typically refer to these as 'business as usual' or 'do-nothing' baselines. Other scenarios which embody such drivers such as policy change can then be analysed to assess their likely impact. This is not the case here and economists or other decision-makers should not infer that the *Go with the Flow* scenario is a 'do-nothing' baseline. To overcome this problem **we take the situation in 2060 under each scenario** (including *Go with the Flow*) **and compare this with our baseline.**

- ***Green and Pleasant Land*** is a storyline where the conservation of biodiversity and landscape are the dominant driving forces. Whilst it is recognised that biodiversity often provides essential benefits to society, its intrinsic value is accorded a pre-eminence in policy and legislation. A preservationist attitude arises because the UK can afford to look after its own backyard without diminishing standards of living. Tourism and leisure are consequently boosted by this drive and increase their share of overall UK GDP (Gross Domestic Product)—and by the decline in popularity of many of late 20th Century holiday destinations because of climate change (e.g. France, Spain and Italy). The countryside is very much a managed, cultural landscape but the focus is now on trying to maintain, protect and improve the aesthetic appeal. In general, landscape preservation often coincides with biodiversity conservation, although one major source of conflict is between the importance of recognising habitat and ecosystem change and the preservation of landscapes.

- ***Local Stewardship*** has localism as a dominant paradigm, yet is also more environmentally aware and open to international trade than some other scenarios (e.g. *National Security*, see below). Here political power has been devolved and many major issues are decided at a regional or local level (except crucial national aspects like defence); local timber and energy production is encouraged and there is great pride in the numerous local food products. This scenario focuses on optimising resources and consumption is reduced to more sustainable (and healthy) levels—GDP is low but sustainable. The 'tragedy of the commons'[4] would not be recognised in the UK; societal equity fits alongside environmental equity. People travel less and depend more on local resources; more of our food and leisure activities take place in the immediate locale. Technological development occurs in localised areas due to private innovation and a government initiative for developing sustainable technology. The implementation of the sustainable management of resources is a priority and society relies less on technological innovation. Low carbon economies spring up and there is greater use of alternative economies such as LETS (Local Exchange Trading Systems) schemes. Through local specialisation the UK becomes less homogenised—landscapes become more distinct and even local economies vary considerably. Social and environmental regulation has advanced, though, particularly regarding workers' welfare and rights, and environmental protection. Although economic growth is slower compared to other storylines, the economy is more stable.

- Under the ***National Security*** scenario, UK industry is protected from foreign investors and imports. Trade barriers and tariffs are increased to protect jobs and livelihoods in the UK; immigration is also very tightly controlled. Technological development is state-funded and many industries are subsidised by the state (including agriculture). Food, fuel, timber and mineral resources are prioritised over the conservation of biodiversity. Climate change results in increases in global energy prices, forcing many countries to attempt greater self-sufficiency (and efficiency) in many of their core industries. Britain is no exception, and agricultural and other primary industries 'optimise' (rather than intensify) accordingly.

- In the ***Nature@Work*** scenario, the conservation of biodiversity as an end in itself is less of a priority compared to maintaining and enhancing the output of ecosystem services. Adapting to climate change is also a priority, which means that some non-native species are introduced to provide food, energy or shade. A campaign of promoting ecosystem services in multifunctional landscapes as essential to maintaining the quality of life in the UK is now embedded in all walks of society (from primary schooling all the way to large industry). Society accepts that some trade-offs have to be made and as a result, becomes more environmentally aware. Habitat restoration and creation are seen as important components of this campaign, but the explicit

4 This derives from the seminal work of Hardin (1968) who observed that, in the absence of mediating economic incentives or social rules, unfettered access to common property resources could lead to over-exploitation and even destruction of such resources.

conservation of species is sometimes overruled by a 'greater' ecosystem service benefit; this sometimes results in habitat conversion (e.g. Semi-natural Grassland to Woodlands). As well as carbon mitigation, an important focus is the enhancement of societies' resilience to climate change through 'ecosystem-based adaptation'. Modern technology is used where appropriate, though, and even GM biotechnology is adopted if it can be shown to enhance ecosystem service provision. This includes the use of drought-tolerant crops to maintain production and reduce soil erosion. 'Optimal service provision' is key, and many ecosystem services in the landscape are a result of careful examination of the trade-offs through scientific and community review.

- In the ***World Markets*** storyline, unfettered economic growth through the complete liberalisation of trade is the main goal. International trade barriers dissolve, agriculture subsidies disappear and farming, for example, is now industrial and large scale. Consumption in society is high, which results in greater resource use and more imports. There is competition for land and this, coupled with reduced rural and urban planning regulations on housing, agriculture and industry mean that biodiversity is often the loser. Technological development in all industries is mainly privately funded but nevertheless is burgeoning. Food is cheap and plentiful but of low quality. As in land-based food production, food supplies from the seas are equally seen as a resource for exploitation without recourse to any sustainable management. Fish stocks plummet and a few species have been wiped out; most fish is imported from Asia. Desalination plants are built in areas on the east coast to meet water demand for the southern and eastern counties. 'Home-grown' fossil fuel energy production is declining and has been overtaken by imports of gas from abroad and privately funded nuclear industry in the UK. Consequently, coastal areas are built upon to accommodate power plants and gas pipeline stations. Supplies of other ecosystem services increasingly become privatised.

Table 26.1 provides an overview of the UK NEA Scenarios described according to a number of common dimensions. These were used to synthesise a series of GIS-based maps articulating each scenario into a consequent land use allocation. The procedures used to generate these land uses are described in Chapter 25 and are summarised at a Great Britain (GB) scale in **Table 26.2**.

All of these scenarios were further modified according to two different responses to climate change as taken from the simplified UKCIP-09 Low and High Emissions scenarios for 2050–2079, discussed in Chapter 25. In sum then, we assess

Table 26.1 Overview of the UK NEA Scenarios.

Scenario	Knowledge	Legislation	Policies, institutions and governance	Behaviour	Markets and incentives	Technologies and practice
Green and Pleasant Land	Investment in green technologies; less focus on biotechnology.	Strong links to EU and global obligations.	Globally minded government; investment in public services.	Stewardship and responsibility; intrinsic values of nature.		
Nature@Work	Technology industry focused on sustainable resource use.	Strong links to EU and global obligations.	Globally minded government; investment in public services. Commitment to global free trade.	Utilitarian view, recognising the importance of 'nature's services'.	Growth of market delivering economic progress.	Industry drives technological innovation in the context of resource use.
World Markets	Technology largely driven by private profit motive.	Reversal of devolution. Deregulated markets. Few environmental policies.	Shrinking of the welfare state. Strong, centralised national government. Deregulation of environmental protection.	Narrowly utilitarian, failing to recognise values of nature.	Growth of market but greater exposure to global fluctuations.	Industry driving technological innovation for private profit.
National Security	Technology industry focused on sustainable resource use.	Trade barriers and protectionist measures to protect UK interests.	Protectionist policies to protect UK interests.	Society values landscapes and features of nature that characterise 'national identity'.	Protection-led growth, but periods of stagnation and global crises. Markets protected.	
Local Stewardship		Tight controls on immigration. Greater devolution to local governments.	Tax-raising powers devolved to local levels.	Utilitarian view, recognising the importance of 'nature's services'.	Slow but steady economic growth. Incentives for small families.	Technology focuses on self-sufficiency and construction goods.
Go with the Flow	Rapid development of technology through government investment.	Oscillation between pro-EU and more narrowly nationalistic approaches.	Oscillation between pro-EU and more narrowly nationalistic policies. Slow shrinking of public services.	Some leaning towards improved environmental performance but with limited public support.	Growth of market but greater exposure to global fluctuations.	Technology driven by government investment.

Table 26.2 Mean land use coverage and population figures for Great Britain: Year 2000 baseline and UK NEA 2060 Scenarios. Cells are shaded so as to indicate the magnitude of change from the 2000 baseline under each of the UK NEA Scenarios. Unshaded cells indicate that there is no significant change; green cells indicate significant increases over the baseline (with bold text indicating more substantial increases); purple cells indicate significant reductions from the baseline (with bold text indicating more substantial reductions). Scenarios are as follows: GF-H = *Go with the Flow* High emissions; GF-L = *Go with the Flow* Low emissions; GPL-H = *Green and Pleasant Land* High emissions; GPL-L = *Green and Pleasant Land* Low emissions; LS-H = *Local Stewardship* High emissions; LS-L = *Local Stewardship* Low emissions; NS-H = *National Security* High emissions; NS-L = *National Security* Low emissions; N@W-H = *Nature@Work* High emissions; N@W-L = *Nature@Work* Low emissions; WM-H = *World Markets* High emissions; MW-L = *World Markets* Low emissions; LSOA = Census lower super output areas.

UK NEA Broad Habitat	Land cover	Baseline	GF-H	GF-L	GPL-H	GPL-L	LS-H	LS-L	NS-H	NS-L	NW-H	NW-L	WM-H	WM-L
Coastal Margins	% Coast	0.48	0.44	0.47	0.47	0.47	0.44	0.47	0.41	0.44	0.45	0.46	0.42	0.45
Marine	% Freshwater	0.77	1.95	0.90	1.54	1.51	1.82	0.77	1.63	0.77	2.12	1.69	1.62	`0.78
Semi-natural Grassland	% Grasslands	15.9	18.34	17.64	25.3	22.1	21.9	21.5	8.42	8.15	20.20	20.03	13.7	13.28
Mountains, Moorlands & Heaths	% Mountains & Heathlands	13.8	15.04	14.75	14.62	14.82	14.22	14.06	8.16	8.02	16.6	15.6	11.7	11.5
Marine	% Other Marine	7.08	7.12	7.09	7.09	7.09	7.12	7.09	7.09	7.08	7.11	7.11	7.46	7.35
Urban	% Urban	6.72	7.61	8.06	6.74	6.71	6.36	6.50	6.95	6.81	6.61	6.72	14.3	14.57
Woodlands	% Conifer Wood	5.32	4.23	4.23	3.82	3.77	4.77	4.77	18.91	18.2	8.54	8.79	6.18	5.01
	% Broadleaved Wood	6.34	9.76	9.37	11.06	11.94	7.69	6.73	6.40	7.21	10.57	10.57	5.25	5.75
Enclosed Farmland	% Enclosed Farmland	43.5	35.5	37.49	29.25	31.53	36.6	38.06	42.04	43.22	27.75	28.85	39.32	41.2
	LSOA mean population	1,518	1,781	1,781	1,543	1,543	1,524	1,524	1,660	1,660	1,612	1,612	1,831	1,831
	Change in total real income	0	+1.5%	+1.5%	+2%	+2%	+0.5%	+0.5%	+1%	+1%	+3%	+3%	+2%	+2%
	Change in proportion retired	**0**	+20%	+20%	+22%	+22%	+19.5%	+19.5%	+19.5%	+19.5%	+20%	+20%	+21%	+21%

changes to all five of our ecosystem service-related goods under 12 scenarios.

We re-emphasise that the *Go with the Flow* scenario is not a conventional economic 'business as usual' baseline in that it does not attempt to model future trends based upon best available data (on policy and market trends and environmental change forecasts) but is rather a product of the ideologies summarised in the discussion given above. As such, it does not constitute an economically conventional baseline for comparison with other scenarios. Consequently, all economic analyses in this chapter compare the situation envisioned in 2060 under each of the above scenarios with a consistent baseline for the year 2000.[5]

The valuation of changes under each scenario informs decision analysts of the trade-offs across the set of goods under consideration. Such information is clearly an important input to decision making. However, alongside caveats regarding the incomplete set of goods being considered, we also emphasise the point raised in Chapter 22 that, while the valuation of ecosystem service flows is a very important improvement over sole reliance upon market prices, sustainability requires that we also consider the impacts of flow changes upon the levels of stocks of relevant ecosystem services. This is again highlighted as an important area for future research.

26.2 Valuing Scenarios for Agricultural Food Production

26.2.1 Introduction and Methodology

Our agricultural scenario analysis is decomposed into two parts. First, we analyse the variation in agricultural land types and livestock numbers under the baseline and under each scenario. Second, we derive the economic impact on farmers in terms of farm gross margin (FGM), defined as the

5 Land use under the baseline is taken from the CEH Land Cover map 2000, while population data is taken from the UK Census 2001 (on the assumption that any error this slight discrepancy causes will be insignificant).

difference between revenues from agricultural activities and associated variable costs.[6]

The agricultural land and livestock scenarios are derived by applying the CSERGE econometric agricultural land use model (Fezzi & Bateman 2010; Fezzi *et al.* 2010a) to the area of farmland predicted under each of the UK NEA Scenarios. The CSERGE model then determines the specific land use and (where appropriate) livestock numbers which are consistent with the behavioural patterns observed throughout its large cross-sectional and time series database.

As discussed in Chapter 25, each scenario is used to generate maps describing the corresponding land use for all of the UK. Following some harmonisation of scales[7] and categorisations,[8] the CSERGE land use model was applied to the area of each 2 km grid square across GB that was predicted to be farmland under each scenario. Within each of these grid squares the CSERGE model predicts the share of farmland under each agricultural land use type and predicts livestock numbers (dairy cows, beef cows and sheep) where appropriate. As discussed in Chapter 22, these shares are predicted from the estimated effect that policy, prices and the natural environment have upon farm land use and, therefore, differ between the low and high emission scenarios because of the varied impact of climate change. Note, however, that we do not allow for the effect of new technologies such as the possible introduction of new crop varieties or husbandry practices. This is a potentially important caveat and means that the present results should not be over-interpreted.[9]

26.2.2 Agricultural Land Use Under the Baseline and Scenarios

26.2.2.1 Baseline

The baseline for our analysis describes agriculture in GB in the year 2000. The area of each land use and livestock numbers are reported in **Table 26.3**. This shows a highly heterogeneous picture, with the flatter and warmer lowlands of south-east England dominated by arable cultivation and the hilly North West primarily devoted to grazing systems. Wales and Scotland are also characterised by the presence of a high percentage of low-quality agricultural land, which translates into the highest shares of rough grazing in the whole of GB. Livestock rates are strongly related to land use, with dairy stocking rates being higher in the south and west, while sheep numbers are highest in England's northern upland areas and in Scotland.

Table 26.3 Average land use (hectares/2 km grid square) and livestock numbers (head/2 km grid square) in the year 2000 baseline. OSR = oilseed rape; CE = cereals; RC = root crops; OA = other arable; TG = temporary grassland; PG = permanent grassland; RG = rough grazing; D = dairy; B = beef; S = sheep.

Region	OSR	CE	RC	OA	TG	PG	RG	D	B	S
East Midlands	19.0	132.2	1.7	59.9	11.3	53.3	52.1	15.5	69.6	336.3
East of England	21.2	158.5	2.3	73.9	3.7	19.9	46.5	4.9	29.2	124.9
London	2.8	25.5	0.5	4.9	4.0	27.9	46.4	23.3	44.0	162.8
North East	10.0	66.2	0.3	24.7	21.0	64.5	122.7	19.8	105.9	593.2
North West	2.3	34.9	0.4	10.6	21.3	112.8	130.1	49.3	129.9	761.6
South East	11.7	96.8	1.1	26.1	14.9	69.9	52.8	31.4	72.2	296.4
South West	6.4	83.2	1.3	29.5	24.5	124.8	48.1	52.9	121.4	611.9
West Midlands	10.9	85.8	1.4	28.6	23.4	100.7	58.2	45.2	117.0	533.9
Humber	12.6	96.3	1.2	40.7	12.7	56.0	101.7	14.5	80.2	523.6
Scotland	3.5	25.4	0.1	8.0	14.3	36.2	227.6	9.9	53.2	509.6
Wales	0.5	12.6	0.3	5.1	21.8	125.1	150.6	48.9	124.8	903.0
GB	**7.9**	**64.8**	**0.8**	**24.5**	**16.0**	**66.7**	**131.1**	**24.8**	**79.5**	**511.8**

6 As stressed in Chapter 22, while this is a commonly applied approach, it is not a theoretically ideal measure, being only a fair approximation of the net economic value. That said, the trends in relative values provide some useful information regarding the likely changes in agricultural productivity in the four scenarios. Note, however, that in practice it is likely that any increases in FGM are likely to be ultimately capitalised into rents. Therefore it should not be assumed that any such increases will represent long-term gains to farmers.

7 The UK NEA Scenario maps are generated at a 1 km grid square scale. These are rescaled to the 2 km grid square basis used in the CSERGE agricultural land use model.

8 The UK NEA Scenarios team used a somewhat different land categorisation to both the CSERGE model and the Broad Habitats definitions used in previous chapters of the UK NEA. For example, the Enclosed Farmland Broad Habitat was split into further subdivisions such as 'arable' and 'improved grassland' To make this categorisation compatible with the CSERGE model the Scenarios team's categories 'upland', 'improved grassland' and 'arable' were classified as 'agricultural' land, with the 'upland' category taken as indicating rough-grazing land. Similarly the 'improved grassland' category was split into permanent or temporary grassland according to the shares of each land use predicted by the CSERGE model. A similar approach was taken to reallocate the area defined by the Scenarios team as 'arable' into 'cereals', 'oilseed rape', 'root crops' (potatoes and sugar beet) and 'other arable'.

9 The impact of unanticipated technical change upon the valuation of the UK NEA Scenarios is somewhat difficult to assess. The land use changes envisioned by the scenarios are themselves not modelled and hence do not respond to technological change. However, one would expect the absence of new technologies to lead to an underestimate of agricultural performance in the future. This issue could be addressed with further research. A possible approach would be to develop a full econometric model including not only land use allocation and livestock equations, but also profit and yield equations. This, however, requires farm-level data which were not available at the time of the analysis. Another strategy would be to use a hybrid econometric-simulation model as per Antle & Capalbo (2001).

Figure 26.1 illustrates the baseline distribution of selected land use types: cereals (the dominant arable crops), temporary grassland (rich grassland used mainly for dairy and beef cows) and rough grazing. The distribution of beef cattle is also shown. Cereals are located in most of the lowland, flatter areas of the country, such as the south and east coast of England and eastern Scotland. Temporary grassland, on the other hand, is concentrated in the wetter south-west of England and in the lowland areas of Scotland and Wales. While rough grazing has some minor presence in all areas, it is concentrated in the uplands of northern England, Scotland and Wales, in which it is the major, if not the only, type of agricultural land use. Beef cattle are abundant in areas where there is either temporary or permanent grassland, but become absent in the more extreme upland areas.

26.2.2.2 Comparing the Baseline with the UK NEA Scenarios

Fezzi *et al.* (2011) present detailed comparisons of the changes in land use from the baseline to each of the UK NEA Scenarios. Given that we have six Scenarios, each with a high and low emissions variant, and that we are primarily interested in the value of changes rather than the land use

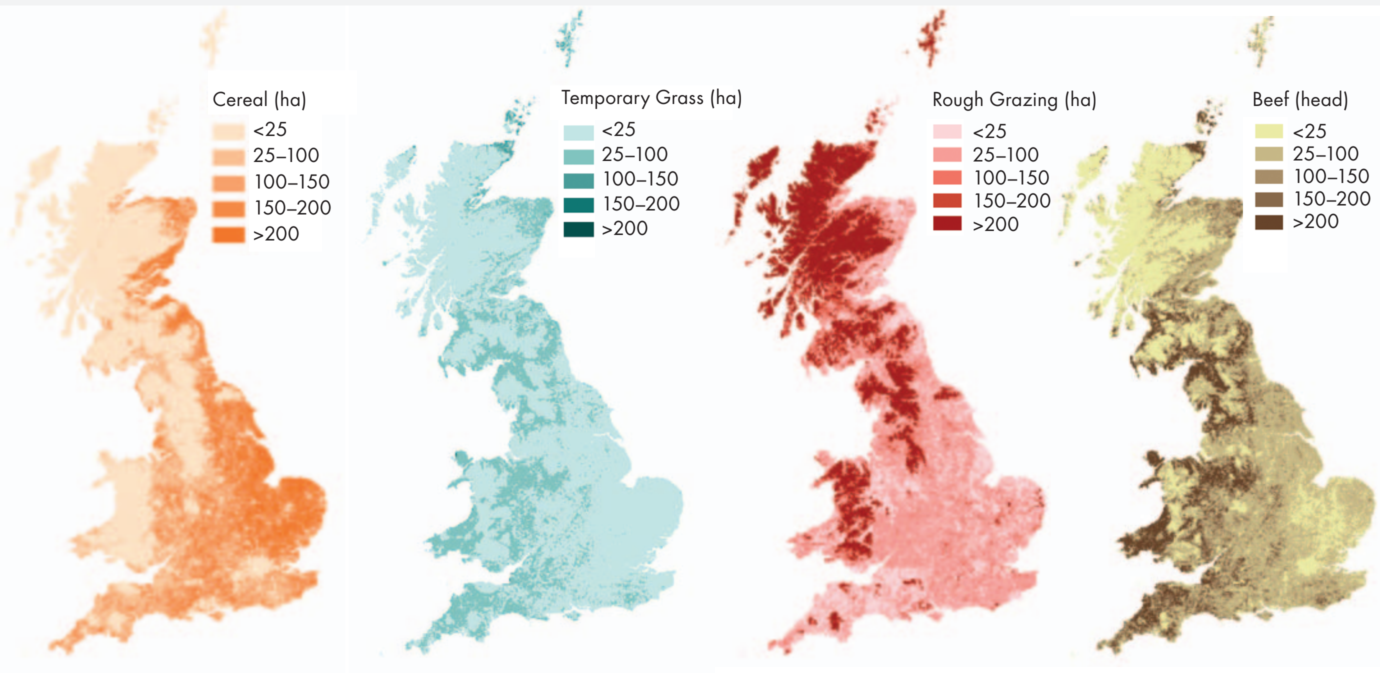


Figure 26.1 Cereals, temporary grassland, rough grazing and beef cows at the year 2000 baseline.

Table 26.4 Average change in amount of land used (hectares/2 km grid square) and livestock numbers (head/2 km grid square) in the *Green and Pleasant Land* High emissions scenario compared to the 2000 baseline. OSR = oilseed rape; CE = cereals; RC = root crops; OA = other arable; TG = temporary grassland; PG = permanent grassland; RG = rough grazing; D = dairy; B = beef; S = sheep.

Region	OSR	CE	RC	OA	TG	PG	RG	D	B	S
East Midlands	-16.4	-87.3	1.1	38.0	6.1	-26.9	53.3	32.2	-66.7	-261.8
East of England	-19.8	-113.2	2.1	49.6	8.8	-16.4	57.4	41.4	-29.0	-124.0
London	-2.8	-25.5	8.6	8.7	11.5	-21.8	19.9	28.6	-43.6	-162.3
North East	-6.1	-26.7	0.8	2.6	-10.1	-18.0	41.7	8.3	-65.9	-95.0
North West	-2.2	-29.4	4.7	12.7	-3.5	-39.8	38.3	3.8	-90.5	-294.5
South East	-11.6	-91.2	4.8	47.3	19.8	-52.4	62.3	34.9	-71.3	-295.7
South West	-6.4	-80.5	11.9	29.8	12.5	-70.2	74.5	19.0	-114.1	-486.5
West Midlands	-10.8	-71.2	2.1	39.3	9.3	-49.7	56.1	23.8	-102.1	-398.8
Humber	-10.1	-53.8	1.1	17.9	-3.0	-20.4	44.2	19.7	-69.3	-205.2
Scotland	-2.3	-10.2	0.6	1.3	-8.2	-6.5	21.4	1.3	-29.3	66.2
Wales	-0.5	-11.6	3.7	2.4	-0.5	-46.6	41.2	-0.2	-94.6	-341.5
GB	**-6.9**	**-46.7**	**3.0**	**18.9**	**1.1**	**-28.8**	**42.6**	**14.5**	**-62.2**	**-171.0**

shifts that precipitate the changes, we do not present all of these analyses here. Instead, we illustrate the comparison process with respect to a single scenario, comparing land use under the baseline with that predicted under the high emissions variant of the *Green and Pleasant Land* scenario.

Comparing the baseline with the high emissions variant of the *Green and Pleasant Land* scenario. The changes in land use and livestock numbers between the baseline in 2000 and the high emissions *Green and Pleasant Land* scenario in 2060 are reported in **Table 26.4**. In the *Green and Pleasant Land* scenario, a high amount of land is converted from intensive land uses to more extensive ones. In particular, cereals and oilseed rape decrease significantly, substituted partly by other arable and temporary grassland. Furthermore, rough grazing increases throughout the country, replacing permanent grassland and arable land. Finally, beef and sheep numbers decrease, while numbers of dairy cows grow as a result of the increase in temporary grassland.

Figure 26.2 presents maps of changes in selected land use types and livestock (cereals, rough grazing and dairy cows) under this scenario change. We observed a significant decrease in cereals in the entire country, a widespread increase in rough grazing and small, positive changes in stocking rates of dairy cows in the lowlands, particularly in the south and East of England.

26.2.3 Valuation of Scenario Changes: Farm Gross Margin Effect

We now move to consider the value of changes in agricultural provisioning services under each scenario. As mentioned in Chapter 22, these are measured as FGM. Two important limitations need to be acknowledged. First, since FGM is defined as the difference between revenues and variable costs, all farm fixed costs (e.g. machinery, buildings, rent, etc.) are not included in the analysis. Secondly, conversion costs are also not included; in other words, all changes in land use and FGM refer to equilibrium conditions, but do not take into account possible costs encountered in order to reach these new equilibriums. Bearing these caveats in mind, FGMs can be used to analyse the trends in overall agricultural productivity in the different scenarios.

We begin by considering the FGM under the 2000 baseline. These are reported in the first column of **Table 26.5** and mapped in **Figure 26.3**. The figure shows that those farms with the highest FGM are located in the lowland and southern areas of the country, while those in upland areas have relatively low FGM levels. This principally reflects the variation in physical environmental conditions across the country.

We can now use the type and amount of each land use estimated under each of the scenarios to generate corresponding FGM values. These are then contrasted with the baseline to estimate the change in value induced under each scenario. We can map the distribution of changes in FGM per hectare for all scenarios under both their low emission (**Figure 26.4**) and high emission (**Figure 26.5**) variants (full details presented in Fezzi *et al.* 2011).

In almost all scenarios the lowland south of the country appears to fare best (possibly with the exception of the low emission variants of the *Green and Pleasant Land* and *Nature@ Work* scenarios), while it is the upland and northern areas which bear the highest losses (partial exceptions being the low emission *World Markets* and *National Security* scenarios). Generally, patterns within scenarios are less marked than those across the different scenarios, although the variability of impacts appears greater in the high emission variants.

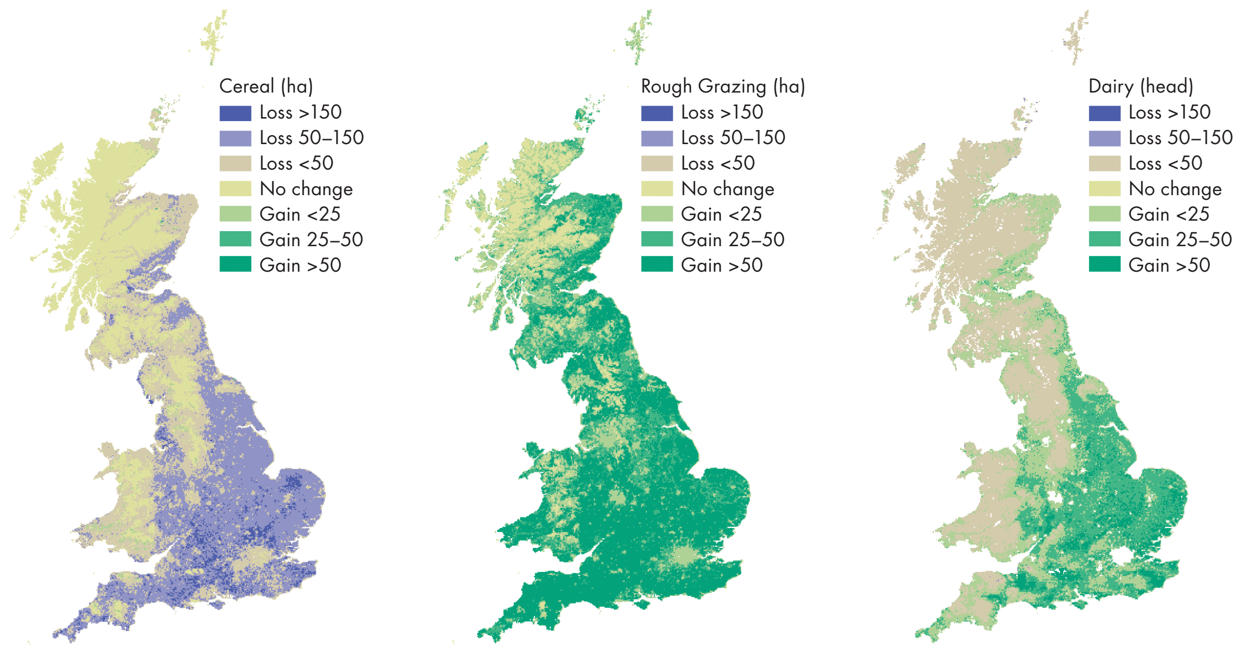


Figure 26.2 Cereals, rough grazing and dairy cows: changes from the 2000 baseline to the *Green and Pleasant Land* High emissions scenario.

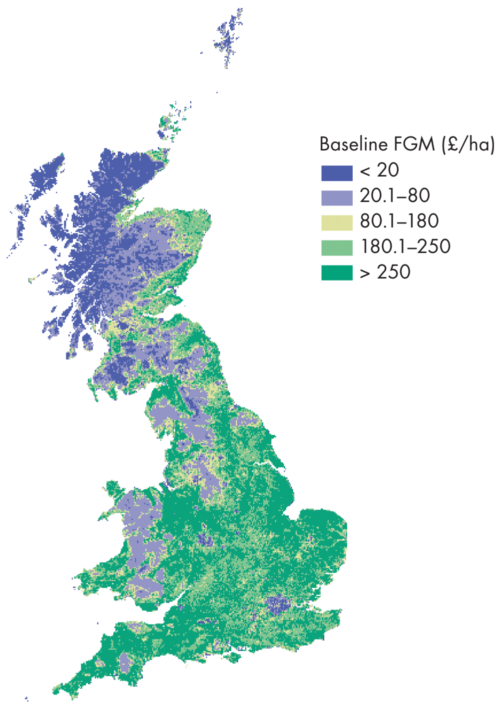


Figure 26.3 Baseline farm gross margin (£/hectare) for the year 2000.

The patterns shown here are in marked contrast to those reported in Chapter 22 during discussion of the impacts of forecast climate change (where the spatial trend was reversed, with the south suffering declines in FGM due to increased droughtiness, and the north and uplands benefiting from higher temperatures and alterations in rainfall patterns). This serves to reinforce the fact that the UK NEA Scenarios are not forecasts but are instead, at least in considerable part, based upon a range of assumptions about the future. The contrasting patterns of land use envisaged by the UK NEA Scenarios show the value implications of future worlds, but do not shed light on the feasibility or paths of policy change required to attain such worlds.

The change in values from the 2000 baseline to each scenario in 2060 is calculated for each 2 km grid square across GB. This spatially explicit approach to valuation allows decision-makers the possibility of targeting policies at those areas which will generate the most efficient use of resources. Grid square values can also be summed to generate national level estimates of the values of changes induced under each scenario, as detailed in **Table 26.6**. Here the upper row details the baseline, which highlights the significant heterogeneity which characterises the present GB farming system (for example, the FGM/ha of the third quartile is more than seven times that of the first quartile).

In **Table 26.6**, the *Go with the Flow* scenarios imply that, at the national level, farm incomes will increase (particularly under high emissions) due to the warmer climate. However, the increase in FGM is not evenly distributed across all farms, and incomes at the lower quartile remain unaffected. Climate change is also incorporated into the other scenarios, but in those worlds the changes in land use and FGM are also influenced by various other social, economic and political drivers which somehow conceal the climate effect as compared to *Go with the Flow*.

Considering other scenarios, achieving higher environmental quality (*Green and Pleasant Land* and *Nature@Work*) would come at some costs to the farming community (overall between 1% and 10% of total FGM for *Green and Pleasant Land* and between 4% and 20% for *Nature@Work*).

Table 26.5 Farm gross margin per hectare (FGM/ha) in the baseline and changes in farm gross margin per hectare (∆ FGM/ha) in the UK NEA Scenarios (high and low emissions). FGM is as follows: cereals = £290/ha, root crops = £2,425/ha, oilseed rape = £310/ha, dairy = £576/head, beef = £69/head, sheep = £9.3/head. Scenarios: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*; LS = *Local Stewardship*. Source: Fezzi *et al.* (2010b).

Region	Base (FGM/ha)	GF (∆ FGM/ha)		GPL (∆ FGM/ha)		NS (∆ FGM/ha)		NW (∆ FGM/ha)		WM (∆ FGM/ha)		LS (∆ FGM/ha)	
		high	low	high	low	high	low	high	low	high	low	high	low
East Midlands	250.2	25.6	10.6	-16.3	-32.3	60.1	35.5	-12.8	-29.6	32.7	10.4	29.0	27.8
East of England	262.3	55.8	35.2	3.4	-17.6	90.6	57.2	18.6	-3.4	49.5	23.9	61.6	59.2
London	157.0	280.9	49.2	174.7	26.4	418.3	83.9	222.5	9.5	232.8	51.0	178.4	104.3
North East	172.5	-8.5	-10.1	-24.4	-26.4	16.6	10.7	-45.7	-45.6	7.1	2.7	-1.4	3.1
North West	183.8	25.0	9.3	-1.8	-17.4	90.3	57.2	-28.7	-41.8	68.8	32.8	11.8	11.6
South East	245.5	94.6	26.9	27.7	-23.3	132.4	48.1	31.9	-36.7	95.9	33.7	69.7	40.3
South West	257.0	136.0	69.0	34.0	-2.0	195.1	122.6	62.5	-19.4	163.9	95.4	89.7	62.3
West Midlands	250.0	25.6	5.1	-15.2	-30.7	61.8	33.2	-26.1	-50.8	37.3	14.8	16.8	17.1
Humber	201.6	12.6	4.7	-19.4	-29.1	43.0	25.7	-22.9	-31.6	27.2	9.3	16.0	15.7
Scotland	77.1	-2.4	-3.8	-7.7	-8.9	9.0	4.9	-20.7	-20.6	8.5	3.8	-2.9	-0.4
Wales	159.7	14.1	-5.5	-11.1	-17.9	79.5	47.1	-29.6	-57.2	66.4	33.5	-6.2	-2.3
GB	**173.1**	**32.8**	**12.2**	**-1.6**	**-16.2**	**66.7**	**37.7**	**-6.1**	**-28.7**	**49.1**	**23.4**	**23.7**	**19.5**

However, here the distributional impact of these losses is progressive, with poorer farmers being relatively unaffected (the first quartile income does not change) while incomes amongst richer farms decline noticeably (note the fall in third quartile incomes).

Encouraging agricultural production under the *National Security* and *World Markets* scenarios will, as one would expect, boost agricultural incomes, increase arable land shares and stocking rates. However, the total amount of agricultural land decreases significantly under these scenarios, depressing aggregate gains. In particular, the scenarios envisage a loss of low-productivity rough grazing and permanent grassland. However, the overall value of agricultural output is expected to increase. While the *World*

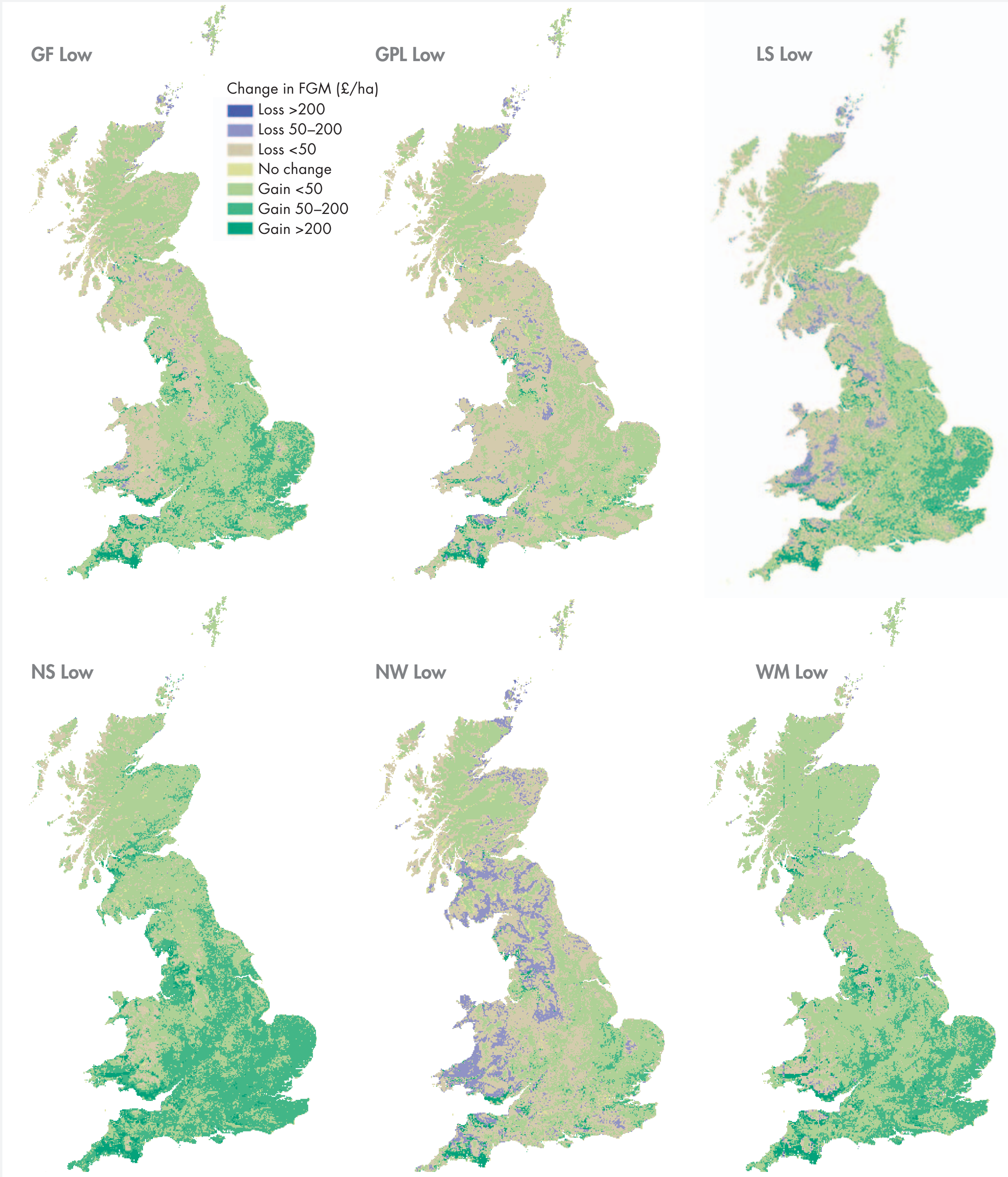


Figure 26.4 Farm gross margin (FGM) per hectare changes from the 2000 baseline to all UK NEA Low emissions scenarios. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship;* NS = *National Security*; NW = *Nature@Work*; WM = *World Markets.*

Markets scenario leads to income increases for all farming groups, incomes for the poorest farms decline under the *National Security* scenario (e.g. first quartile income declines from £34.9/ha under the baseline to £25.3/ha under the *National Security* high emissions scenario). A similar pattern is observed for the *Local Stewardship* scenario where, on average, agricultural incomes increase (both per hectare and at the national level) but low income farms experience a small decline in FGM levels.

Table 26.7 summarises the changes in FGM/ha occurring under each scenario. Interestingly, even those scenarios which deliver the highest agricultural values overall (*National Security*, *World Markets* and *Local Stewardship*) still result in some farms being worse off.

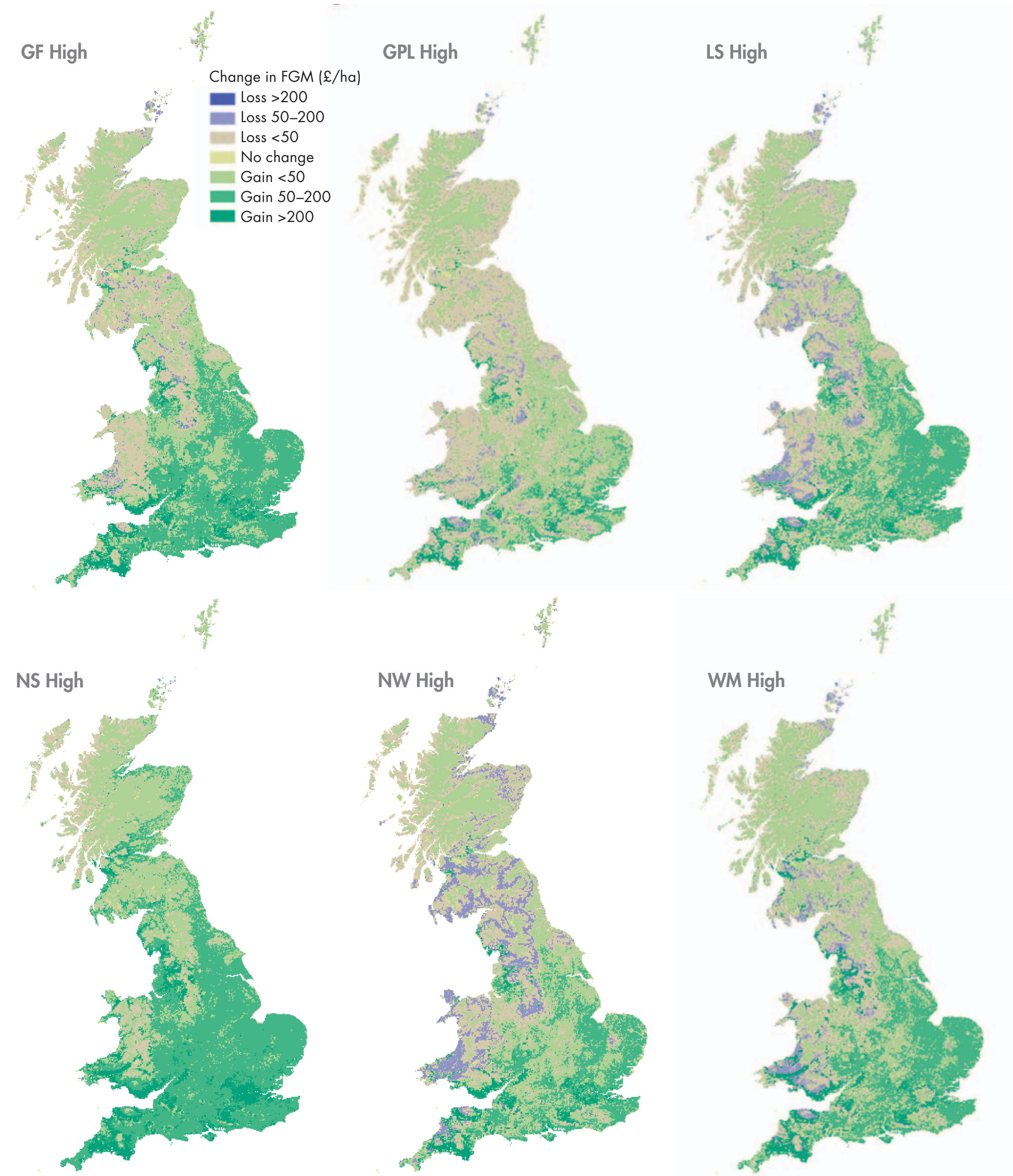


Figure 26.5 Farm gross margin (FGM) per hectare changes from the 2000 baseline to all UK NEA High emissions scenarios. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

Indeed, the first quartile of FGM changes is negative in all but one scenario (*World Markets* high emissions being the exception). Conversely, the third quartile of changes is positive in all scenarios, highlighting that there is a substantial proportion of farms which benefit from all scenarios, even when overall incomes are expected to decrease (e.g. the *Green and Pleasant Land* and *Nature@Work* worlds). As a further illustration, **Table 26.8** reports the percentage changes relative to **Table 26.7**.

Table 26.6 Summary statistics and change (∆) for farm gross margin (FGM) per hectare (ha) in the 2000 baseline and in the various UK NEA 2060 Scenarios (real values, £2010). FGM is as follows: cereals = £290/ha, root crops = £2,425/ha, oilseed rape = £310/ha, dairy = £576/head, beef = £69/head, sheep = £9.3/head. Minimum values are zero throughout. Q1 and Q3 are the first and third quartiles respectively. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*. Source: Fezzi *et al.* (2010b).

Scenario	Mean £/ha	Standard error ±£/ha	Q1 £/ha	Median £/ha	Q3 £/ha	Max £/ha	Total GB £ million p.a.	∆ Total GB £ million p.a.	∆ Total GB £ p.a.
Baseline	173.1	113.3	34.9	223.4	268.6	1,182	3,100	0	
GF High	205.9	184.1	34.8	227.4	301.3	1,980	3,690	590	19.0%
GF Low	185.3	151.5	35.0	214.6	280.5	2,073	3,320	220	7.1%
GPL High	171.5	133.7	34.8	198.0	254.8	1,721	3,070	-30	-1.0%
GPL Low	156.9	114.8	35.1	188.4	236.7	1,777	2,810	-290	-9.4%
LS High	196.8	164.0	33.3	223.8	299.7	2,272	3,530	430	13.9%
LS Low	192.6	145.6	36.7	224.6	297.7	1,697	3,450	350	11.3%
NS High	239.8	218.6	25.3	269.2	340.1	2,202	4,300	1,200	38.7%
NS Low	210.8	186.1	25.8	247.5	311.1	2,221	3,780	680	21.9%
NW High	167.0	159.0	31.5	164.8	253.3	1,697	2,990	-110	-3.5%
NW Low	144.4	120.3	32.0	147.4	227.4	1,871	2,590	-510	-16.5%
WM High	222.2	205.4	38.9	242.3	308.9	6,039	3,980	880	28.4%
WM Low	196.5	169.9	40.5	229.0	284.7	6,047	3,520	420	13.5%

Table 26.7 Summary statistics for change in farm gross margin per hectare (∆FGM/ha) in the 2000 baseline and in the various UK NEA Scenarios. FGM is as follows: cereals = £290/ha, root crops = £2,425/ha, oilseed rape = £310/ha, dairy = £576/head, beef = £69/head, sheep = £9.3/head. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship;* NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*. Q1 and Q3 are the first and third quartiles respectively. Source: Fezzi *et al.* (2010b).

	∆FGM mean (£/ha)	∆FGM median (£/ha)	∆FGM standard error (£/ha)	∆FGM Q1 (£/ha)	∆FGM Q3 (£/ha)
GF High	33	7	124	-7	39
GF Low	12	3	87	-10	19
GPL High	-2	-7	74	-30	6
GPL Low	-16	-19	56	-39	0
LS High	24	7	98	-9	39
LS Low	20	8	72	-5	37
NS High	67	29	155	-4	77
NS Low	38	14	121	-5	48
NW High	-6	-7	112	-45	9
NW Low	-29	-20	74	-63	1
WM High	49	13	148	0	43
WM Low	23	8	112	-2	21

Table 26.8 Summary statistics for change in farm gross margin per hectare (∆FGM/ha) in the 2000 baseline and in the various UK NEA Scenarios. FGM is as follows: cereals = £290/ha, root crops = £2,425/ha, oilseed rape = £310/ha, dairy = £576/head, beef = £69/head, sheep = £9.3/head. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship;* NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*. Q1 and Q3 are the first and third quartiles respectively. Source: Fezzi *et al.* (2010b).

	∆FGM mean (%)	∆FGM median (%)	∆FGM standard error (%)	∆FGM Q1 (%)	∆FGM Q3 (%)
GF High	19	3	109	-21	15
GF Low	7	1	77	-28	7
GPL High	-1	-3	66	-86	2
GPL Low	-9	-8	49	-110	0
LS High	14	3	87	-26	15
LS Low	11	4	64	-14	14
NS High	39	13	137	-10	29
NS Low	22	6	107	-14	18
NW High	-4	-3	99	-128	3
NW Low	-17	-9	65	-180	0
WM High	28	6	131	1	16
WM Low	14	4	99	-5	8

26.3 Terrestrial Carbon Storage and Annual Greenhouse Gas Emissions: A Scenario Analysis[10]

26.3.1 Introduction

This section presents an analysis of the changes in annual greenhouse gas emissions from terrestrial ecosystems resulting from changes in land use and associated land management, as envisaged under the UK NEA Scenarios. We then provide an economic valuation of the changes in climate regulation arising from the comparison of the 2000 baseline with each of the UK NEA Scenarios.

Our assessment of carbon storage and greenhouse gas emissions, while based on the land use patterns defined by the UK NEA Scenarios, draws directly on the CSERGE land use change model (Fezzi & Bateman 2010) as reported in the preceding section. It therefore shares the same methodology and assumptions in determining both detailed agricultural land use and livestock intensities. Both of these are important determinants of greenhouse gas balance. For example, land use influences carbon storage while methane and nitrous oxide emissions from grazing livestock represent important sources of terrestrial greenhouse gases. The limitations imposed by the prior focus upon agricultural land were in part relaxed by incorporating information on changes in Woodland extent over time directly from the UK NEA Scenarios analysis.

26.3.2 Scenario Analyses: Quantifying Changes in UK Terrestrial Greenhouse Gas Emissions

Three major categories of greenhouse gas emissions were considered when estimating changes in annual greenhouse gas emission flows:[11]

i) Direct and indirect emissions from land use and land management. Within this category three sources of emissions were considered: 1) the indirect emissions due to energy use from farmland activities such as tillage, sowing, spraying, harvesting and the production, storage and transport of fertilisers and pesticides. Per hectare estimates of greenhouse gas emissions for typical farming practices were applied to each type of land use in order to map these emissions across the UK.[12] 2) Emissions of nitrous oxide and methane from livestock, including beef cattle, dairy cows and sheep through the production of manure and enteric fermentation.[13] 3) Direct emissions of nitrous oxide emissions from artificial fertilisers applied to agricultural land.

ii) Annual flows of carbon from soils due to land use changes. For example, permanent grassland converted from arable farming will be accumulating soil organic carbon (SOC), while permanent grassland on land that was previously under rough grazing may be losing SOC. For the baseline year (2000) annual flows of SOC were only estimated for organic (peat) soils as there is insufficient data on land use change prior to the baseline to accurately model changes in SOC in non-organic soils. In the analysis of the UK NEA Scenarios, SOC flows due to land use change in both organic and non-organic soils are included in the annual greenhouse gases emission estimates.

iii) Emissions and accumulations of carbon in terrestrial vegetative biomass. Estimates of the predicted annual accumulations of carbon in existing[14] and UK NEA Scenario-predicted future Woodlands were combined with annualised changes in the stock of vegetative biomass on agricultural land. Where the annual accumulation of carbon in terrestrial vegetative biomass under a scenario was lower than in the baseline, this was considered a net emission of greenhouse gases.

For the baseline year (2000) we estimate the annual greenhouse gases emissions from terrestrial ecosystems to be approximately 26 million tonnes of carbon dioxide equivalent ($MtCO_2e$). Land use management represents the dominant source of emissions in the baseline, with this category of emissions itself dominated by emissions from enteric fermentation and the direct release of nitrous oxide from both artificial fertilisers and the application of farmyard manure. The emissions from land use management, and to a lesser extent SOC, were partially counterbalanced by estimated annual accumulations in woodland biomass of approximately 7.6 $MtCO_2e$, with around a further 3 $MtCO_2e$ accumulating annually as SOC in woodland soils.

Figure 26.6 and **Figure 26.7** map the change in terrestrial ecosystem emissions (tonnes of CO_2e/ha/yr) between the baseline (2000) and 2060 under each of the UK NEA Scenarios. Comparison of these figures shows that changes induced by a move from the low to high emission variants yield only modest variation in results. However, changes in greenhouse gas emissions across scenarios are highly significant. Perhaps not surprisingly, both the *Green and Pleasant Land* and *Nature@Work* scenarios generate less

10 This sections draws on Abson *et al.* (2010).

11 Here it should be noted that this does not represent a complete inventory of greenhouse gas emissions. The analysis is limited by the information provided by the scenarios and therefore does not account for emissions from land use practices (for example peat extraction) that cannot be inferred from the scenarios land use data. Moreover, the spatial modelling of greenhouse gas emissions required the use of coefficients that might not fully coincide with those used in other inventories.

12 Estimates of greenhouse gas emissions for forestry practices (such as application of fertilisers and energy use in harvesting) were not included as such data were not available.

13 The scenarios do not provide explicit data on livestock densities. Therefore, livestock densities were calculated using the CSERGE land use model and the land use patterns provided for the scenarios.

14 Estimates of the annual accumulations of carbon in woodland were taken from Thomson *et al.* (2007), based on the assumption that GB woodland planted before 1921 is in carbon balance (ibid). In the absence of spatially explicit data regarding the planting date of GB woodland, it was assumed that the post-1921 (carbon accumulating) woodland is distributed evenly across the total GB woodland extent. Consequently, a single (per hectare) estimate of carbon accumulation in woodland was applied to the baseline data.

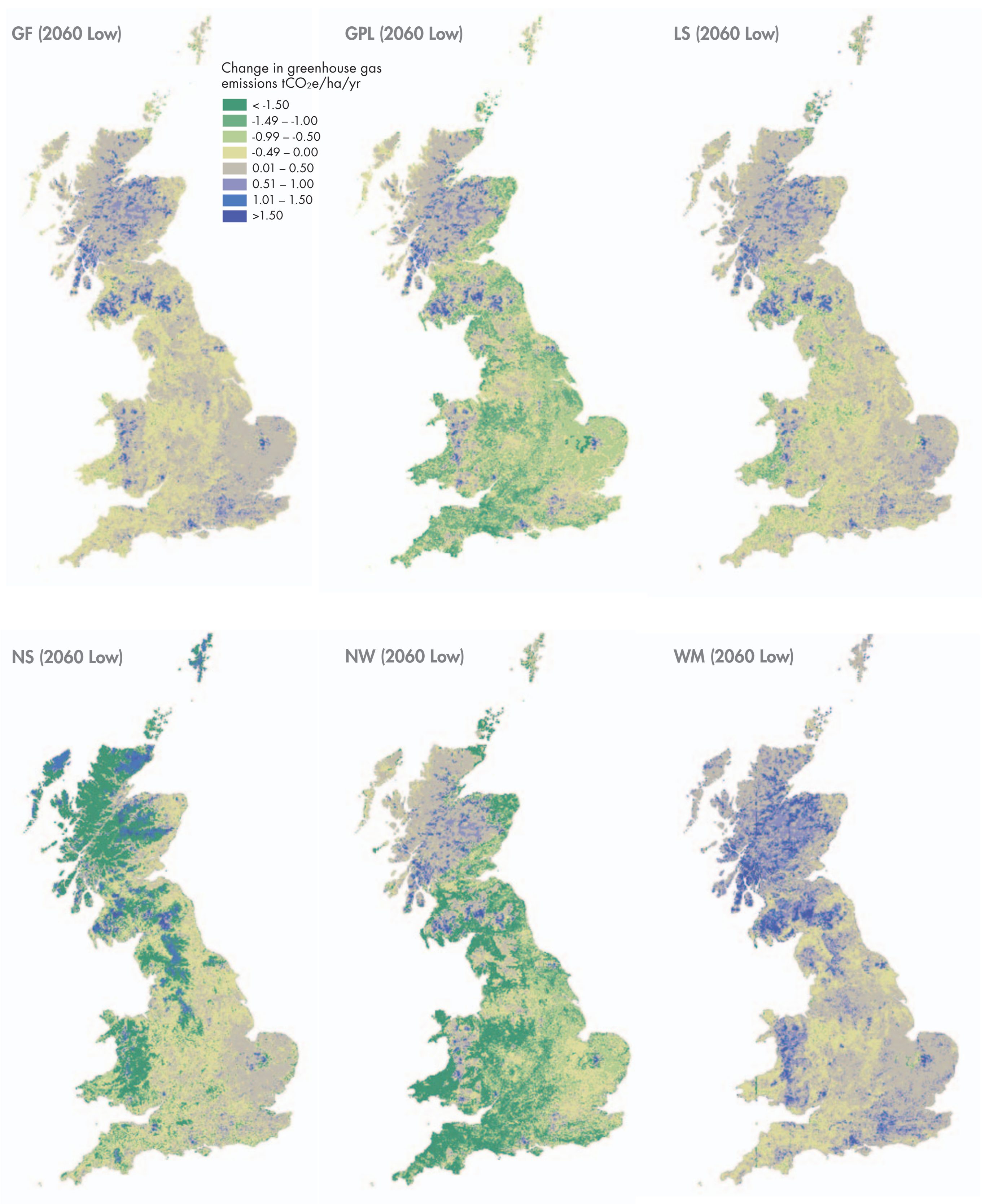


Figure 26.6 Estimated changes (from 2000 baseline) in terrestrial ecosystem carbon dioxide equivalent emissions (tCO_2e) for UK NEA Scenarios under the UKCIP low emissions climate scenario. Mapped changes in greenhouse gas emissions include: emissions from agricultural machinery; enteric fermentation from livestock; nitrous oxide emissions from artificial fertilisers and livestock origin manures; changes in all vegetative agricultural annual stocks; changes in Woodland not currently in carbon balance allowing for transition to balance over time adjusted for planting dates; allowances for estimates of future Woodland planting; changes in soil organic carbon (SOC). Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

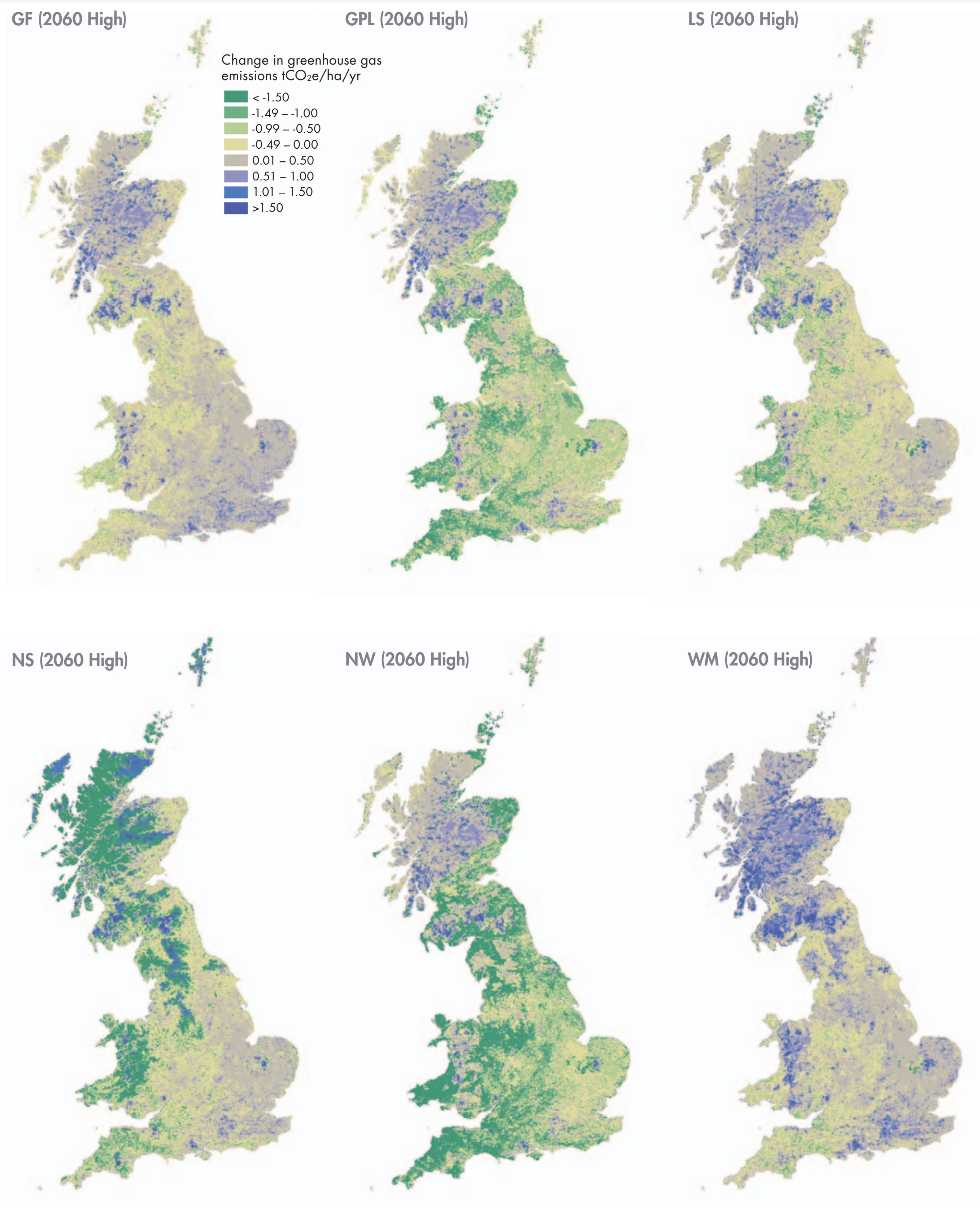


Figure 26.7 Estimated changes (from 2000 baseline) in terrestrial ecosystem carbon dioxide equivalent emissions (tCO_2e) for the UK NEA Scenarios under the UKCIP high emissions climate scenario. Mapped changes in greenhouse gas emissions include: emissions from agricultural machinery; enteric fermentation from livestock; N_2O emissions from artificial fertilisers and livestock manures; changes in all vegetative agricultural annual stocks; changes in Woodland not currently in carbon balance, allowing for transition to balance over time adjusted for planting dates; allowances for estimates of future Woodland planting; changes in soil organic carbon (SOC). Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*. NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

emissions than the baseline. These scenarios show relatively uniform decreases in greenhouse gas emissions in lowland areas, driven by an extensification of agriculture, with conversion of arable land and improved grasslands to semi-natural grasslands and rough grazing. This in turn results in lower stocking densities of beef and sheep and reduced emissions from both enteric fermentation and nitrous oxide emissions from fertilisers than in the baseline case. However, the *Green and Pleasant Land* and *Nature@Work* scenarios show moderate increases in greenhouse gas emissions in upland areas, largely driven by increased livestock densities and a decline in carbon accumulation in afforested and upland areas. The *Local Stewardship* scenarios show similar patterns of greenhouse gas emissions as the *Green and Pleasant Land* scenarios, but with less extensive land use changes and therefore less dramatic changes in emissions. The *National Security* scenarios show significant decreases in emissions (relative to the baseline), but with very different patterns of emissions from *Green and Pleasant Land* and *Nature@Work*. In the *National Security* scenario, a move to boost agricultural output leads to increased emissions in the most productive areas of southern and eastern England, combined with significantly elevated emissions from upland peatlands. This is somewhat counterbalanced by large decreases in emissions in Scotland, northern England and Wales due to increased afforestation in those regions. The *World Markets* and *Go with the Flow* scenarios show generally increased emissions compared to the baseline. However, falls in emissions in some upland areas means that the *Go with the Flow* scenarios overall result in only moderate increases in emissions of around 0.13 tonnes of CO_2e/ha/yr by 2060, compared to 0.46 tonnes of CO_2e/ha/yr by 2060 for the low emissions climate variant of the *World Markets* scenario.

Table 26.9 summarises the national changes in total greenhouse gas emissions under the UK NEA land use scenarios, where positive values represent net increases (from the 2000 baseline) in greenhouse gas emissions. At a national scale, only the *World Markets* and *Go with the Flow* scenarios show consistent increases in annual emissions compared to the baseline. Increases in emissions from the *World Markets* scenarios are driven by reductions in the extent of Woodlands and moderate expansions in arable and dairy production, largely at the expense of Semi-natural Grasslands. Emission increases in the *Go with the Flow* scenarios (of approximately 2.9 $MtCO_2e$/yr for both the *Go with the Flow* climate variants) occur mainly in Scotland and are driven largely by a reduction in carbon accumulation in Woodland. In contrast, Scotland sees significant declines in greenhouse gas emissions under the *National Security* scenario. Decreases in arable farming and the extent of Improved Grassland across lowland England result in significant decreases in emissions (between 8 and 13 $MtCO_2e$/yr) under the *Green and Pleasant Land* and *Nature@Work* scenarios.

Figure 26.8 shows in more detail how the three major sources of terrestrial carbon emissions/accumulations (land management, SOC changes and carbon accumulation/release for vegetative biomass) interact in the six scenarios. Note that only the UKCIP low emissions variants of the scenarios are presented here, as the patterns of emissions are broadly similar to those recorded for the high emissions scenario variants. *World Markets* and *Go with the Flow* are the only scenarios with consistently large increases in emissions relative to the baseline. This arises through declines in the annual accumulation of carbon in vegetative biomass in both these scenarios, exacerbated by additional emissions due to soil disturbance through land use change on peat soils in the *World Markets* scenarios. Nevertheless, as with the other four scenarios, the *World Markets* and *Go with the Flow* scenarios indicate consistent declines in emissions from land use management, driven by aggregate declines in arable farming, improved grassland and livestock numbers. Only the *Green and Pleasant Land* and *Nature@Work* scenarios show increased accumulation in SOC. Further investigation showed that this was due to increases in Woodlands and Semi-natural Grasslands (rough gazing) on non-organic soils. In contrast, aggregate emissions from SOC are predicted to increase in the *National Security* scenario as peat soils are disturbed through tree

Table 26.9 National (GB) analysis of changes (from the 2000 baseline) in total annual greenhouse gas emissions ('000s of tonnes CO_2 equivalent/yr) in 2060 under each UK NEA Scenario (positive values represent increases in annual greenhouse gas emissions). Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

	GF	GPL	LS	NS	NW	WM
	UKCIP low emissions variant					
England	835	-8,355	-518	-4,327	-12,609	2,357
Scotland	1,986	330	1,404	-6,610	-1,791	4,813
Wales	92	-803	-522	-2,185	-2,381	600
GB	2,913	-8,828	364	-13,122	-16,781	7,770
	UKCIP high emissions variant					
England	1,467	-8,020	-2,513	-3,550	-12,219	1,394
Scotland	1,676	189	1,201	-6,728	-2,104	4,360
Wales	-173	-979	-762	-2,126	-2,384	370
GB	2,970	-8,810	-2,073	-12,405	-16,707	6,124

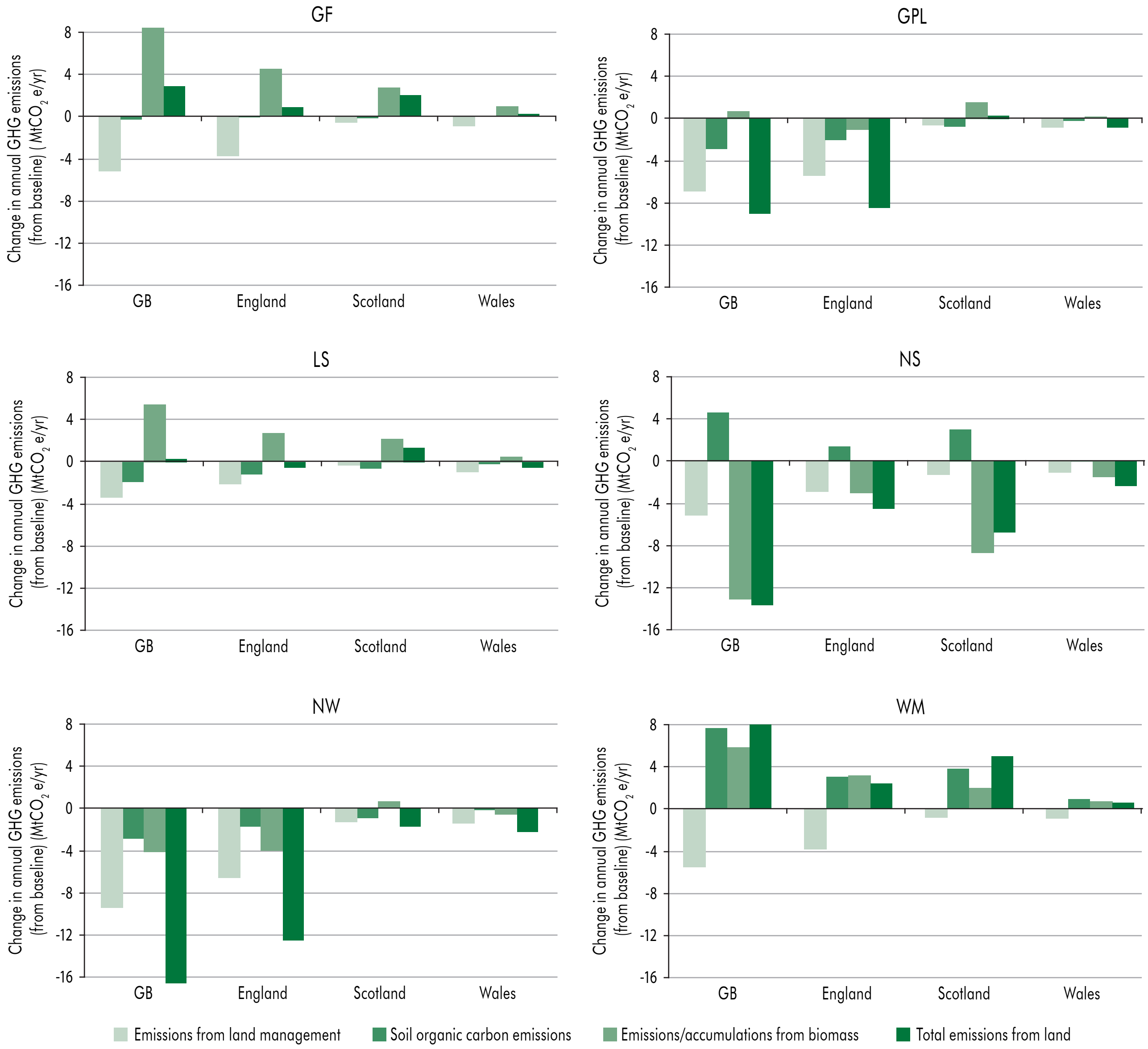


Figure 26.8 National (GB) analyses of changes (from the 2000 baseline) in greenhouse gas (GHG) emissions under each UK NEA Scenario (UKCIP low emissions variants; positive values represent increases in annual GHG emissions). Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

planting and the conversion of Semi-natural Grasslands to arable land uses in Scotland and upland England.

26.3.3 The Value of Terrestrial Climate Regulation

The UK government's official non-traded marginal abatement cost of carbon (MACC) prices (DECC, 2009) are used to value the changes in annual emissions from 2000 to 2060 under each scenario.[15] This means that carbon prices are set at £41.28 per tonne of CO_2e in 2000, and are increasing to £273.50 per tonne of CO_2e in 2060.[16] **Table 26.10** shows the change in the annual costs of greenhouse gas emissions from GB terrestrial ecosystems compared to the baseline year (2000) for each scenario. This represents the difference in value generated by each of the scenarios (in 2060) compared to that under the baseline land use patterns in 2000. This means that positive (negative) values represent an increase (decrease) in costs. Three of the scenarios (*Green and Pleasant Land*, *National Security* and *Nature@Work*), in both their low and high emission

15 Only the Department of Energy and Climate Change (DECC) central estimates of carbon prices are reported here, the upper and lower bound estimates are ± 50% of the central estimate. Here it should be noted that the official DECC carbon price is an estimate of the cost of abating greenhouse gas emissions and not the social cost of the damage caused by greenhouse gas emissions. The analysis uses a simplified approach to carbon valuation compared to that discussed in Chapter 22. Interested readers should consult the accompanying report by Abson *et al.* (2010) for further discussion of carbon pricing issues.
16 All values in 2010 prices.

Table 26.10 Change in the value from baseline year (2000) of annual greenhouse gas emissions from Great Britain terrestrial ecosystems in 2060 under the UK NEA Scenarios (£million/yr). Negative values represent increases in annual costs of greenhouse gas emissions. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

	GF	GPL	NS	NW	LS	WM
	UKCIP low emissions variant					
England	-228	2,285	1,183	3,449	142	-645
Scotland	-543	-90	1,808	490	-384	-1,316
Wales	-25	220	598	651	143	-164
GB	-797	2,414	3,589	4,590	-100	-2,125
	UKCIP high emissions variant					
England	-401	2,193	971	3,342	687	-381
Scotland	-458	-52	1,840	575	-328	-1,192
Wales	47	268	581	652	208	-101
GB	-812	2,410	3,393	4,569	567	-1,675

Table 26.11 National (GB) cumulative present value of the changes in greenhouse gas emissions between the 2000 baseline and 2060 under each UK NEA Scenario (£1,000 million); calculated for various discount rates (negative values represent additional costs relative to the baseline). Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

	Discount rates (%)								
	0.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
Scenario	**UKCIP low emissions variants**								
GF	-13.8	-7.0	-5.6	-4.6	-3.7	-3.0	-2.5	-2.1	-1.7
GPL	41.9	21.2	17.0	13.8	11.2	9.2	7.5	6.2	5.2
LS	-1.7	-0.9	-0.7	-0.6	-0.5	-0.4	-0.3	-0.3	-0.2
NS	62.2	31.5	25.3	20.5	16.7	13.6	11.2	9.3	7.7
NW	79.6	40.3	32.4	26.2	21.3	17.4	14.3	11.9	9.9
WM	-36.9	-18.6	-15.0	-12.1	-9.9	-8.1	-6.6	-5.5	-4.6
	UKCIP high emissions variants								
GF	-14.1	-7.1	-5.7	-4.6	-3.8	-3.1	-2.5	-2.1	-1.7
GPL	41.8	21.1	17.0	13.8	11.2	9.2	7.5	6.2	5.2
LS	9.8	5.0	4.0	3.2	2.6	2.2	1.8	1.5	1.2
NS	58.8	29.8	24.0	19.4	15.8	12.9	10.6	8.8	7.3
NW	79.2	40.1	32.3	26.1	21.2	17.4	14.3	11.8	9.8
WM	-29.0	-14.7	-11.8	-9.6	-7.8	-6.4	-5.2	-4.3	-3.6

UKCIP variants, show significant reductions in annual costs associated with emissions of greenhouse gas compared to the baseline land use configuration. The majority of these savings occur in England for the *Green and Pleasant Land* and *Nature@Work* scenarios, while Scotland generates most benefits under the *National Security* scenario.

If we assume that the changes in projected emissions occur linearly over the period, then we can calculate present values for 2000–2060 (**Table 26.11**) and convert these to annual equivalents[17] (**Table 26.12**).

The analysis shows marked differences between scenarios with the highest benefit attributed to the *Nature@Work* scenario. Only the *World Markets*, *Go with the Flow* and *Local Stewardship* (low UKCIP emissions variant) scenarios show an increase in the greenhouse gas costs associated with terrestrial ecosystems. As expected, an increase in the discount rate reduces the absolute values associated with the service/disservice.

Table 26.12 Cumulative annuity values for Great Britain of the changes in greenhouse gas emissions between the 2000 baseline and 2060 under each UK NEA Scenario (£million); calculated for various discount rates (negative values represent additional costs relative to the baseline). Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

	Discount rates (%)								
	0.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
Scenario	**UKCIP low emissions variants**								
GF	-230	-177	-162	-147	-134	-121	-110	-100	-91
GPL	698	538	490	446	405	368	334	302	275
LS	-29	-22	-20	-18	-17	-15	-14	-12	-11
NS	1,037	800	729	663	602	547	496	450	408
NW	1,326	1,022	932	848	770	699	634	575	522
WM	-614	-473	-432	-393	-357	-324	-294	-266	-242
	UKCIP high emissions variants								
GF	-235	-181	-165	-150	-136	-124	-112	-102	-92
GPL	696	537	489	445	404	367	333	302	274
LS	164	126	115	105	95	86	78	71	64
NS	981	756	689	627	569	517	469	425	386
NW	1,321	1,018	928	844	767	696	631	572	520
WM	-484	-373	-340	-309	-281	-255	-231	-210	-190

17 Present Value, $PV = \sum_{t=0}^{60} P_{CO_2}^t \times E_{CO_2}^t \times (1+r)^{-t}$, where $P_{CO_2}^t$ and $E_{CO_2}^t$ are the carbon price and emissions, respectively, at time *t*, and *r* is the discount rate. $PV = AEQ \times a_{\overline{60}|r}$, where *AEQ* is the equivalent annual value shown in Table 26.11, and $a_{\overline{60}|r} = \frac{1-1/(1+r)^{60}}{r}$
A constant discount rate assumed.

26.4 Biodiversity Impacts: Using Birds as an Indicator Species

As discussed in Chapter 22, while there are a variety of methods available for estimating the use value of biodiversity, to date monetary estimates of its non-use existence value[18] can only be obtained via stated preference (SP) methods.[19] While a number of such studies have been undertaken, critics question whether the values estimated by SP analyses for such a low-experience[20] good as biodiversity are based upon the robust preferences required for admission within cost-benefit analyses. While we do not pass judgement on this matter, we use the present analysis to demonstrate that, even in the absence of monetary estimates of non-use existence values, there are useful inputs which economic analyses can provide to decision-makers. In particular, economists can advise on the cost-effectiveness of different situations by comparing the levels of both biodiversity and other economic values arising in different situations. Each of the UK NEA Scenarios imply a different array of ecosystem services for which robust values can be estimated. These can be contrasted with the consequences of each scenario in terms of levels of biodiversity, and a trade-off can be observed. Suppose that, for argument's sake, we observe one scenario where monetised benefits are high but biodiversity levels are poor, whereas in another state monetised values are lower but biodiversity improves. Decision makers now have the costs of improving biodiversity. We term this a 'cost-effectiveness analysis' (CEA). Clearly this is not as desirable as knowing the monetary value of that biodiversity and entering it within a cost-benefit analysis (CBA); nevertheless, at least the feasible trade-off is now explicit. Furthermore, additional analyses might find win-win situations where both biodiversity and the monetary value of other goods increase. In the present section of this chapter we discuss quantitative assessments of the impacts of each scenario upon biodiversity. In the final section we go on to compare the valuation of all monetised outcomes of each scenario with their impacts upon biodiversity. By comparing across scenarios we see the trade-off between monetary values and biodiversity, thus revealing the cost-effectiveness of providing different levels of biodiversity.

While the other analyses in this chapter provide us with an (albeit partial) economic valuation of the ecosystem-related goods under consideration, we now need to assess some measure of biodiversity in each scenario before we can complete our CEA. This section provides that assessment through two analyses, both of which use birds as indicators of biodiversity. Birds are a highly visible and widely studied feature of UK biodiversity. Furthermore they are high in the food chain and are often considered to be good indicators of wider ecosystem health (e.g. Gregory *et al.* 2005). Birds are more mobile than most other groups, and so will respond to, and reflect, environmental quality at a rather broader scale than mammals or terrestrial insects, for example. This probably makes them better indicators at the landscape scale and less good locally. However, no single animal or plant group, and especially no small set of variables describing that group, can ever provide a comprehensive summary of all aspects of biodiversity and we do not suggest that they do so. Rather, we note the value that birds have as indicators and make use of the important pragmatic benefit that they are better monitored than any other aspect of UK biodiversity. Our first analysis takes a wide view across almost all GB bird species, while the second focuses upon farmland birds as the group that has suffered the most dramatic declines over the past half century and earlier. In both cases, measures of bird success are modelled as a function of land use, because aspects of this have a proven impact upon biodiversity. These models are then used to assess the predicted impact upon these bird measures as a result of the differing land uses envisioned under each of the UK NEA Scenarios.

26.4.1 Breeding Bird Diversity as a Function of Land Cover[21]

26.4.1.1 Methods

The model used for this analysis is overviewed in Chapter 22 and discussed in detail by Hulme & Siriwardena (2010). Essentially, it links GB data collected in and around the year 2000 by the BTO/JNCC/RSPB Breeding Bird Survey (BBS) with land use information provided by the CEH Land Cover Map 2000. After excluding extremely rare species, the composition of the bird community represented by the presence and abundance of all remaining bird species in each survey square was summarised using Simpson's Diversity Index (D), calculated in each year following Equation (1).

$$D = \frac{1}{\sum_{i=1}^{s} P_i^2} \qquad (1)$$

Where S = number of bird species recorded at a focal site in that year, pi = proportion of birds of species i relative to the total number of birds of all species.

18 This refers to the value which individuals may obtain from the pure knowledge that a species or entity continues to exist, quite separately from any use of that species or entity. For further discussion see Chapter 22.

19 Stated preference monetary valuation methods are overviewed in the opening sections of Chapter 22. Methods for the non-monetary assessment of various values are considered in the UK NEA discussion of shared social values (Chapter 24).

20 Non-use values concern goods which the valuing individual typically has no direct experience of (e.g. the preservation of a pristine Antarctica). A further concern is that the individual may lack understanding of that good (e.g. the role of a species within the sustainable functioning of an ecosystem). Low experience and understanding may well affect the values individuals attribute to a good. While this does not necessarily invalidate SP responses (in such circumstances a willingness-to-pay response may indeed reflect underlying preferences) there is evidence to suggest that in such circumstances responses may be more vulnerable to 'framing' effects, i.e. they may be biased by elements of study design and question phrasing which economic theory would see as irrelevant to well formed, stable preferences. For further discussion see Chapter 22 of the UK NEA and the closing chapter of Bateman *et al.* (2002).

21 This section draws from Hulme & Siriwardena (2010).

The mean value of *D* was calculated for each square across all years within the study period in which that square was surveyed and this was modelled alongside the habitat and land-use classes from the CEH Land Cover Map 2000.[22] Models were run with all different combinations of land-cover classes, the relative importance of the classes in predicting diversity was calculated from these results and diversity across the whole of the UK was predicted at the 1 km^2 level using these values. Diversity was then predicted using the same models for each of the UK NEA land-cover scenarios, considering both low and high climate change predictions for land-use change. The difference between these diversity predictions and those for the Land Cover Map 2000 data were then calculated and summary statistics generated for the full set of 12 scenarios.

26.4.1.2 Results

Records for some 3,468 BBS 1 km grid squares across GB were analysed and 96 bird species were included in the diversity calculation. The best model of those that were run contained all land cover classes except for coastal habitats and inland water cover, indicating that all were associated with a variation in bird diversity.

All land cover variables, except for upland habitats, displayed generally positive, but non-linear, influences on bird diversity which levelled off or declined at high percentages of cover. Upland habitats had a negative influence on diversity but this levelled off at high cover. The coastal habitat cover had a negative influence on diversity and inland water cover had a positive influence but these effects were weaker than for the other land cover classes. Overall the largest influence on diversity in the models was geographic region (a control in the analyses), with large differences in diversity between 100 km squares across the UK.

The predicted change in bird diversity between the 2000 baseline and each of the UK NEA Scenarios for both high and low emissions climate change were calculated. **Figure 26.9** illustrates the resulting spatial patterns for each of these scenarios using high emissions assumption.

Considering the various spatial distributions mapped in **Figure 26.9** we can see that, in general, the *Go with the Flow*, *Green and Pleasant Land* and *Nature@Work* scenarios all lead to some modest increase in bird diversity in lowland areas. While this might be as expected for the overtly pro-environmental *Green and Pleasant Land* and *Nature@ Work* scenarios, the increase in diversity under the *Go with the Flow* scenario indicates that this is set against the ongoing commitment across society to biodiversity-friendly management, for example as reflected by the Common Agricultural Policy 'Pillar 2' investment in agri-environment measures, as well as a general leaning towards biodiversity under this scenario. However, all three of these scenarios also reveal a slightly more pronounced decrease in diversity in upland areas as climate change induces increases in relative agricultural intensity within these areas. This trend is broadly reversed for the *Local Stewardship* and *National Security* scenarios and becomes most extreme under the *World Markets* scenario, although here we also see some declines in upland areas. Indeed, across all scenarios, it is the *World Markets* high emissions case which gives both the greatest declines (-0.131) and largest increases (0.040) in predicted bird diversity.

To illustrate what the predicted changes may mean in terms of real changes in the bird community, the diversity for one high-diversity, lowland square in south-east England and one low-diversity, upland square in Scotland was calculated for the year 2000, altering bird numbers slightly to show their effects on the diversity index. The lowland square had 26 species in 2000, including 15 blackbirds, one blackcap, 11 chaffinches, 16 great tits and 37 wood pigeons, giving a diversity index of 9.087. Removing the blackcap resulted in a reduction of 0.123 in the index, removing all eight species with only one individual resulted in a reduction of 0.953, removing one chaffinch reduced the index by 0.043 and redistributing the total number of individuals as if all 26 species had been recorded in equal numbers seen increased the index by 16.913. The upland square had four species, comprising six golden plovers, 24 meadow pipits, one red grouse and two skylarks, giving a diversity index of 1.765. Removing the red grouse reduced the index for the upland square by 0.103, removing one of the golden plovers reduced the index by 0.075, removing one of the meadow pipits reduced the index by 0.0351 and removing 14 meadow pipits reduced the index by 0.795.

Most of the hypothetical changes envisioned in the above illustration lie outside the minimum-to-maximum ranges predicted under any of the scenarios. The patterns of change predicted under each of these scenarios are summarised in **Table 26.13** and all present changes in absolute diversity values that are well below 10%. Thus, all of the changes predicted would represent, in practice, rather minor changes in bird communities, rather than local extinctions or colonisations.

26.4.1.3 Discussion

An uncritical assessment of the results of this analysis would suggest that the average impact of the *Go with the Flow*, *Green and Pleasant Land*, *National Security* and *Nature@Work* scenarios would be a modest increase in bird diversity while only the *Local Stewardship* and *World Markets* scenarios would lead, on average, to reductions in diversity. Such an assessment oversimplifies the messages of the analysis and underplays important caveats spelt out in detail by Hulme & Siriwardena (2010), to which the interested reader is directed (chief amongst these is the issue that simple species diversity does not necessarily reflect the presence or diversity of species of conservation interest). However, as outlined in the introduction to this chapter, our purpose here is not to produce a complete analysis to answer any specific policy question, but rather to demonstrate that techniques now exist to change the approach to policy formulation and decision making. As such, the present analysis provides an

22 Regional variations in bird diversity were controlled for by including the 100 km Ordnance Survey grid square in which each BBS square is located within the analysis. A regional bias in survey effort across the UK towards highly populated areas with a higher number of volunteers was accounted for by weighting regions with lower survey effort more highly.

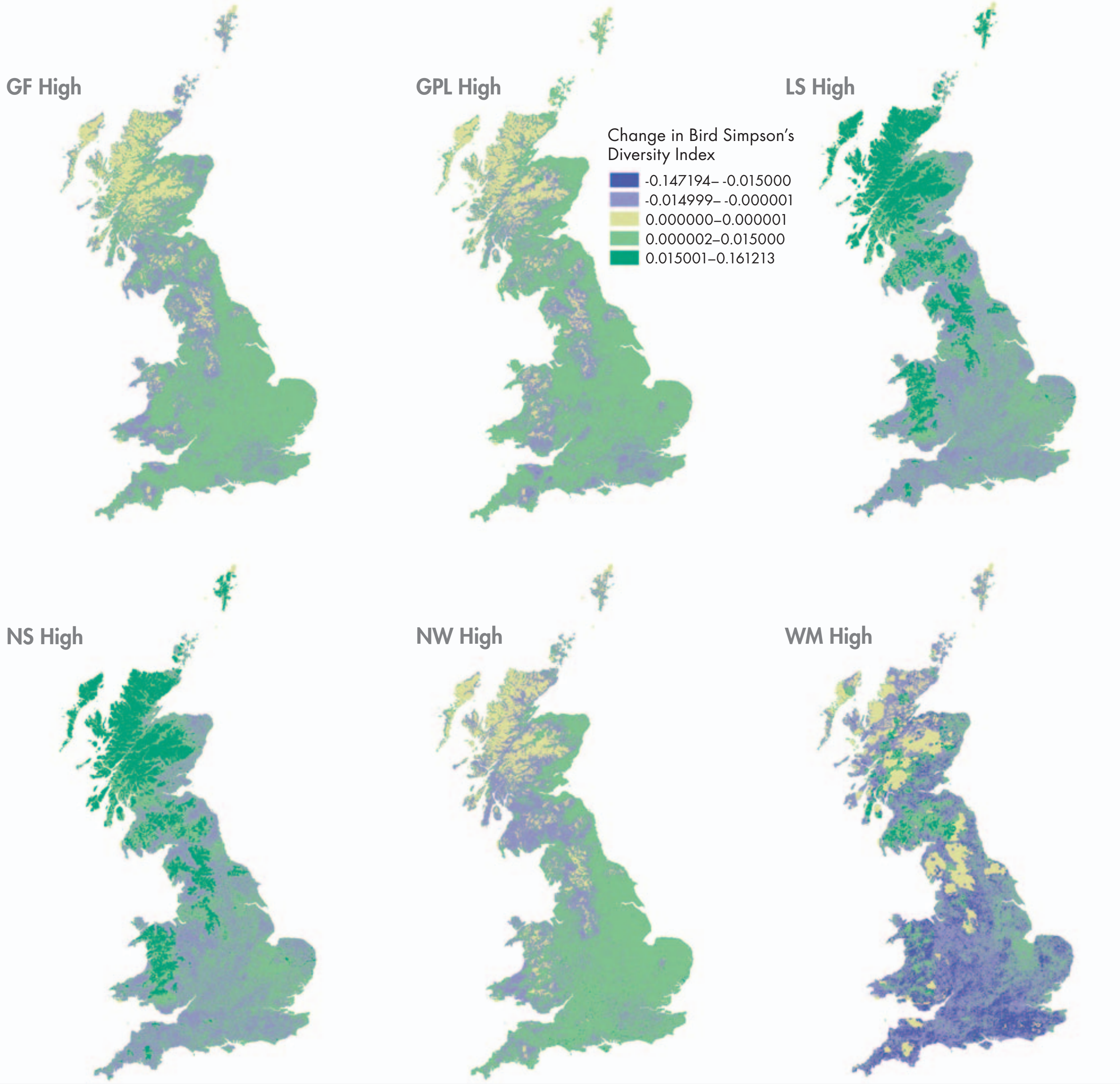


Figure 26.9 Predicted change in Simpson's Diversity Index for British birds arising from a shift from the 2000 baseline to the UK NEA Scenarios under high emission climate change. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

indication of the type of quantitative biodiversity analysis which can be generated to set aside economic benefit valuations within a cost-effectiveness analysis.

26.4.2 Habitat Association Modelling for Farmland Birds[23]

Changes in farming practices have contributed to a 52% decrease in the Farmland Bird Index for England between 1970 and 2009 (Defra 2010). Such bird species are important, not only as indicators of wider biodiversity, but also in their own right.

The model used for this analysis is discussed in Chapter 22 and presented in detail by Dugdale (2010). The analysis considers a single 'guild'[24] of 19, primarily farmland, bird species. Guild richness was measured as the number of these species present in each 10 km grid square in England and Wales, with data being taken from Gibbons *et al.* (1993). Models were developed linking guild richness to data on land use, Woodland and Urban extent. The percentages of each 10 km grid square utilised for cereals, temporary grassland, Coniferous Woodland and Urban use, along with the mean altitude, were found to be highly significant predictors of measures of the number of farmland bird species present. The analysis was adjusted for spatial autocorrelation using geographically weighted regression techniques. The analysis was undertaken for a baseline period (which for data

23 For full details see Dugdale (2010).
24 Defined as a group in terms of the common foods they consume; in this guild primarily seeds and invertebrates.

Table 26.13 Summary of statistics showing the predicted changes in bird diversity from the 2000 baseline to each UK NEA Scenario (Low and High emissions) for 2060. All statistics are summaries across all 235,974 1-km squares in Great Britain for which mapped predictions were available and so represent the average changes across the whole country and the variability in these patterns. Mean standard error <0.00005 in all cases. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*. Q1 and Q3 are the first and third quartiles respectively.

Scenario	Mean	SD	Min	Q1	Median	Q3	Max	Range
GF Low	0.00141	0.00262	-0.00480	0.00000	0.00054	0.00220	0.01689	0.02169
GPL Low	0.00684	0.00570	-0.01561	0.00097	0.00654	0.01172	0.02880	0.04441
LS Low	-0.00080	0.00348	-0.01424	-0.00237	0.00000	0.00116	0.00777	0.02200
NS Low	0.01034	0.01213	-0.00722	0.00093	0.00442	0.01864	0.04681	0.05403
NW Low	0.00557	0.00556	-0.00552	0.00078	0.00432	0.00852	0.03199	0.03751
WM Low	0.00019	0.00465	-0.02124	-0.00211	0.00020	0.00286	0.01085	0.03209
GF High	0.00175	0.00271	-0.00774	0.00000	0.00118	0.00336	0.01526	0.02300
GPL High	0.00467	0.00497	-0.01995	0.00000	0.00372	0.00879	0.02577	0.04572
LS High	-0.00024	0.00369	-0.01541	-0.00203	0.00015	0.00195	0.01057	0.02598
NS High	0.00870	0.01154	-0.01477	0.00022	0.00327	0.01522	0.03838	0.05315
NW High	0.00396	0.00519	-0.00959	0.00000	0.00243	0.00659	0.03032	0.03992
WM High	**-0.00434**	**0.01215**	**-0.12531**	**-0.00735**	**-0.00087**	**0.00139**	**0.02533**	**0.15064**

Table 26.14 Summary statistics for the change in guild richness for 19 species of farmland birds from the baseline to 2060 under each of the UK NEA Scenarios (High and Low emissions). Note: The baseline here is 1988 rather than the year 2000 baseline used for all other analyses in this chapter. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

	GF High	GF Low	GPL High	GPL Low	LS High	LS Low	NS High	NS Low	NW High	NW Low	WM High	WM Low
Mean	-0.42	-0.32	-0.37	-0.27	-0.39	-0.30	-0.84	-0.72	-0.62	-0.54	-0.47	-0.30
Mean (% change)	-2.2	-1.7	-1.9	-1.4	-2.1	-1.6	-4.4	-3.8	-3.3	-2.8	-2.5	-1.6
± Standard deviation	2.35	2.21	2.34	2.21	2.32	2.19	2.30	2.16	2.38	2.25	2.28	2.12
Lower quartile	-1.89	-1.68	-1.85	-1.64	-1.85	-1.65	-2.26	-1.95	-2.10	-1.90	-1.91	-1.63
Median	-0.48	-0.40	-0.47	-0.36	-0.49	-0.38	-0.85	-0.75	-0.73	-0.65	-0.58	-0.41
Upper quartile	0.95	0.94	0.97	0.96	0.95	0.96	0.61	0.61	0.72	0.70	0.87	0.88

availability reasons was fixed at 1988; see Dugdale, 2010) and for all scenarios with changes to 2060 being calculated.

Results of the scenario analysis are summarised in **Table 26.14**. The mean impact of all scenarios is of a reduction in guild richness, although this is generally not large enough to generate a one species change in typical 10 km grid squares. Nevertheless, four scenarios reduce mean guild richness by more than 0.5 (*National Security* High, *National Security* Low, *Nature@Work* High and *Nature@Work* Low) suggesting that, on average, one species fewer would be present under these scenarios.[25] That these scenarios are the most negative for guild richness seems logical, as under *National Security* there are major losses of grasslands and heaths accompanied by large increases in conifer plantations, while under the *Nature@ Work* scenario the area of farmland (obviously important to this guild) decreases markedly. More generally, the lower quartile results suggest that, under almost all scenarios, more than one-quarter of all 10 km grid squares in England and Wales would suffer the loss of two species. However, this is partly offset by a further quarter of grid squares which would, typically, gain one species from this guild.

Figure 26.10 summarises the overall changes in the expected number of species for England and Wales. All scenarios lead to more grid squares which suffer losses

25 Note that the UK NEA Scenarios team only specify land use change and not changes in the intensity of that land use. If intensity also increases (for example in the *World Markets* scenario) then this might be expected to push impacts towards what is at present the lower quartile of estimates (as discussed subsequently).

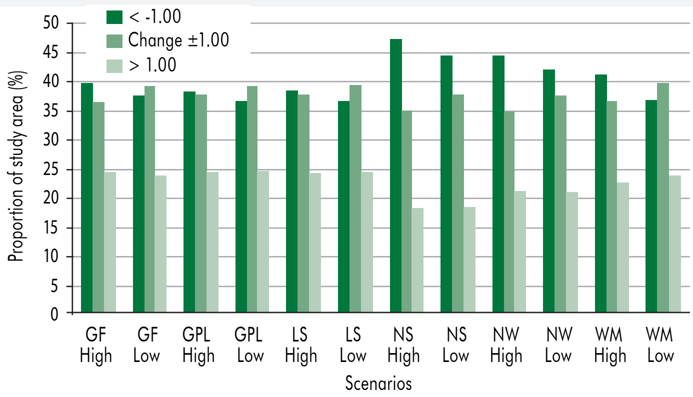


Figure 26.10 The impact of each UK NEA Scenario on predicted guild richness. The proportion (%) of England and Wales that is negatively impacted (predicted loss of more than one species), neutrally impacted (gain or loss of up to one species) or positively impacted (predicted gain of more than one species). Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

in the number of species than squares which enjoy gains. Furthermore, across all scenarios the high emission variant always leads to a reduction in guild richness in a larger proportion of England and Wales than in the case of the respective low emissions scenario.

Five scenarios predicted losses of more than one species in over 40% of England and Wales (*National Security* High and Low, *Nature@Work* High and Low and *World Markets* High). Overall the *National Security* high and low emissions scenarios had a negative or neutral effect over the largest area.

As suggested in **Table 26.14**, there is considerable spatial variation in predicted guild richness across scenarios. These spatial patterns are illustrated in **Figure 26.11** for the low emission scenarios, and **Figure 26.12** for the high emissions scenarios.

Considering **Figure 26.11** and **Figure 26.12**, the general spatial pattern is consistent across all 12 scenarios, with upland areas generally seeing an increase in guild richness and the English Midlands, Welsh borders and Yorkshire

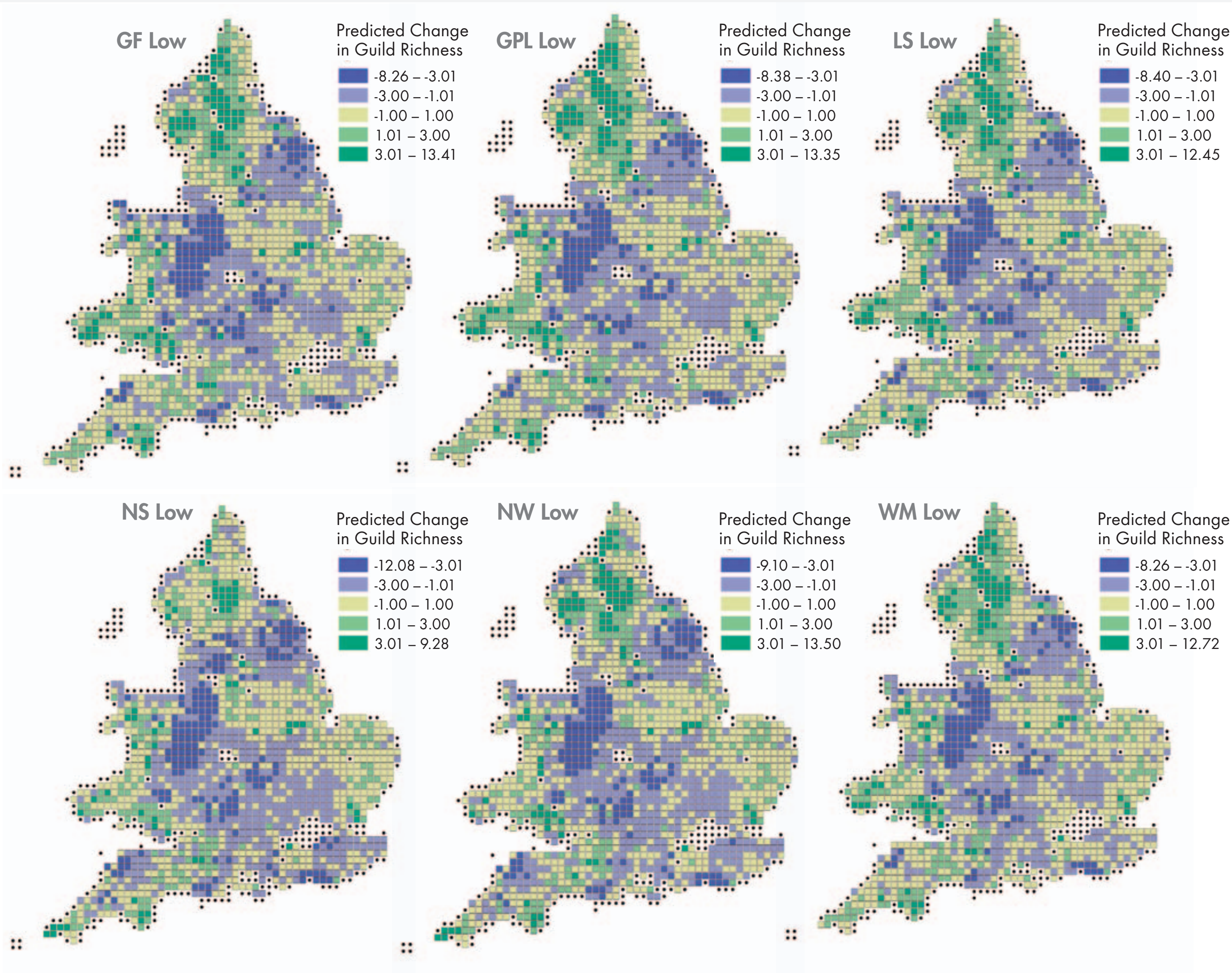


Figure 26.11 Spatial distribution of changes in predicted guild richness between the 1988 baseline and each of the Low emission UK NEA Scenarios for 2060 in England and Wales. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

suffering the most significant reductions. The spatial patterns of predicted change in guild richness between the high and low emissions versions of each scenario were very similar. As might be expected, for any given scenario the high emission variant always leads to greater losses of guild richness than the respective low emission variant.

26.5 Open-access Recreation[26]

26.5.1 Introduction

This section applies the methodology developed in Chapter 22 for predicting the pattern and value of recreational day visits in GB under different scenarios. These predictions are compared with the year 2000 baseline to calculate the changes in recreation values under each scenario.

26.5.2 Methodology

The general methodology is as described in Chapter 22. In essence this involves three linked analyses:

i) A site prediction model (SPM) is used to predict the number and location of recreation sites under each scenario. Here sites are predicted by examining data obtained from the Monitor of the Engagement with the Natural Environment (MENE) which was recently released by Natural England, Department for Environment, Food and Rural Affairs, and the Forestry Commission. These data are used to model the relationship between site location, land use and the proximity to and density of population.

ii) A trip generation function (TGF) is used to predict the number of day visits from any outset location to any specified site as a function of the availability of substitutes around the outset location, the population of that

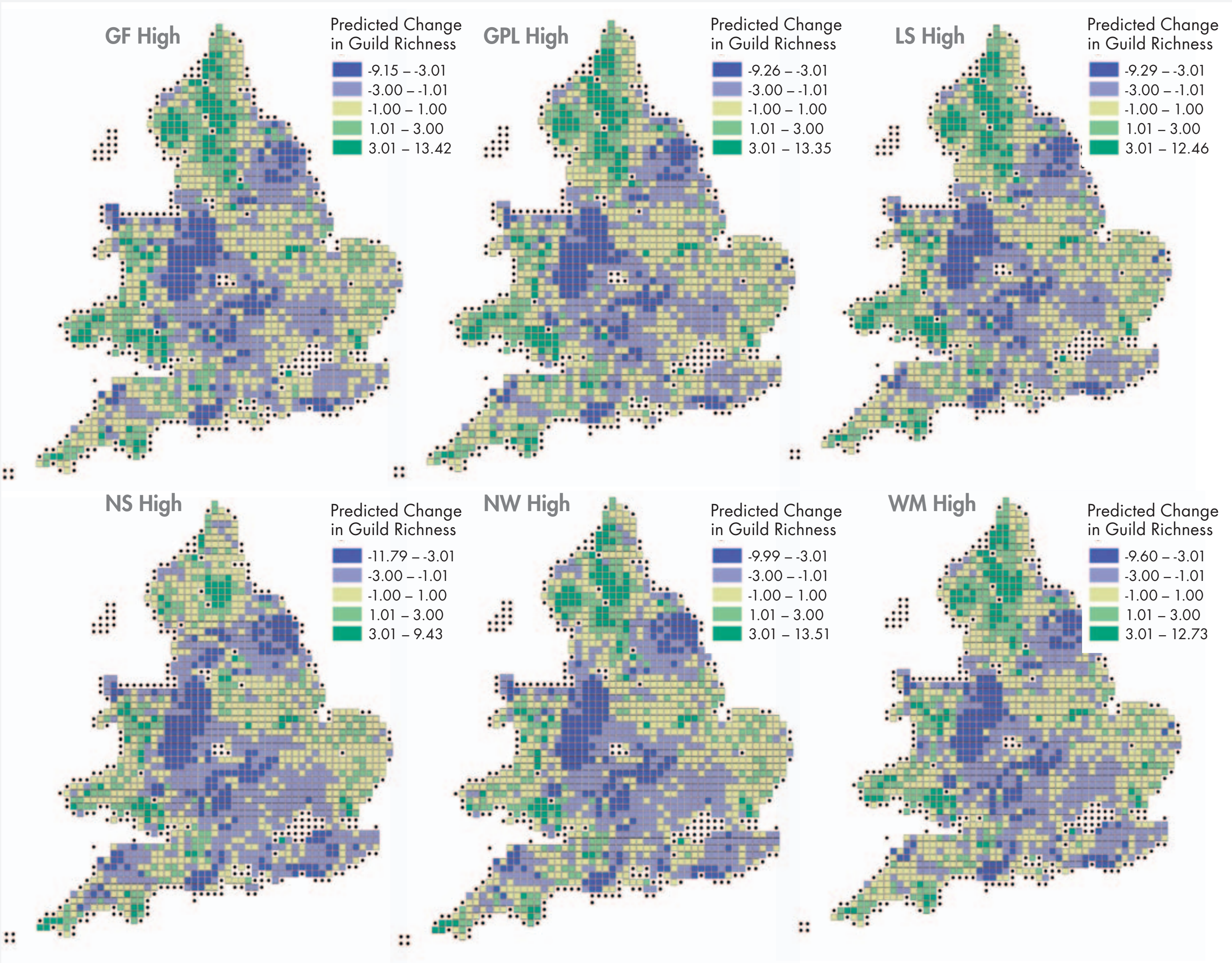


Figure 26.12 Spatial distribution of changes in predicted guild richness between the 1988 baseline and each of the High emission UK NEA Scenarios for 2060 in England and Wales. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

26 For full details see Sen *et al.* (2011).

outset area and their socioeconomic and demographic characteristics, and the physical environmental characteristics of destination sites.

iii) A meta-analysis of estimates of the value of visits is undertaken, taking into account the nature of any visited site.

By combining outputs from the SPM and TGF analyses we can predict both where sites will be and how many day visitors they will attract. By feeding this estimate into the meta-analysis model we obtain an estimate of the value of those visits. Together this linked analysis yields estimates of recreational value which is sensitive to the spatial distribution of populations and their characteristics, and the spatial distribution of recreational sites and their environmental characteristics. This in turn ensures that the methodology is sensitive to the populations and land use changes envisaged under the UK NEA Scenarios.

The detailed methodology is presented in Chapter 22 and those discussions are not repeated here. However, a few adjustments are required in order to extend that approach to the valuation of recreation under the UK NEA Scenarios, as follows:

Census lower super output areas per Census data zone (LOSA/DZ) populations were calculated for 2060 in accordance with the population trends envisaged by the UK NEA Scenarios team (further discussion of these trends is given in Section 26.6.5 which covers Urban greenspace).

Table 26.15 Site probability model (SPM) predicting the number of recreational sites in each 5 km grid square. The model is estimated using a negative binomial model with robust standard errors. Tests on the SPM indicate that the over-dispersion parameter (alpha) is significant, justifying our choice of the negative binomial model. The dependent variable is the number of visited MENE sites in a 5 km cell. Statistical significance indicated by: *p<0.05, **p<0.01, ***p<0.001. Weighted population density variables (weights = 1.0 and 2.0) are only included in the model based on statistical significance. For full definition of variables and discussion of relationships see Chapter 22. Source: Sen *et al.* (2011).

	Coefficients	t-stat
% of coast in cell	0.0210**	2.699
% of freshwater in cell	0.0613***	6.160
% of grasslands in cell	0.00490**	3.220
% of mountains and heath in cell	-0.0169***	-5.267
% of other marine in cell	0.0110***	11.16
% of urban in cell	0.0542***	32.17
% of coniferous forests in cell	-0.00582	-1.358
% of broadleaved forests in cell	0.0267***	10.29
weighted population density (y=1) in cell	0.000000407***	5.407
weighted population density (y=2) in cell	-0.00000460***	-8.695
Constant	-0.811***	-20.40
Log alpha		
Constant	-0.627***	-12.04
Observations	5,526	

The UK NEA Scenarios team employed a 1 km grid resolution to define their maps of the baseline and scenario land use, whereas the SEER team at CSERGE employed a 25 m resolution map in their development of the methods described in Chapter 22. For consistency, the site prediction model (SPM) and trip generation function (TGF) were re-estimated using map information from the UK NEA Scenarios team (including recalculation of the explanatory variables used in those models). These re-estimated models are reported as **Table 26.15** and **Table 26.16**, respectively. Comparison with those reported in Chapter 22 shows that these are similar, with relatively minor changes in parameter values. Accordingly, the reader is referred to those previous models for discussion of the trends reported and the CSERGE team recommend their use for any future application as they are based upon more accurate data. Full details can be found in Sen *et al.* (2011).

26.5.3 Distribution and Value of Recreational Visits Under the Baseline

Our year 2000 baseline data on land use and population distribution and its characteristics was combined with

Table 26.16 Trip generation function (TGF) predicting the number of day visits to a site. The dependent variable is the number of visits from an LSOA/DZ to a site. The above model is estimated using a multilevel Poisson regression model. Statistical significance indicated by: *p<0.05, **p<0.01, ***p<0.001. For full definition of variables and discussion of relationships see Chapter 22. Source: Sen *et al.* (2011).

	Coefficients	t-stat
Travel time from LSOA to site	-0.0628***	-110.6
Coast substitute availability	-0.0233*	-2.151
Urban substitute availability	-0.0219***	-34.75
Freshwater substitute availability	-0.0827***	-6.349
Grasslands substitute availability	-0.0215***	-9.797
Woodland substitute availability	-0.0177***	-8.887
Sea/ocean substitute availability	-0.00198*	-2.164
Mountain substitute availability	0.0120**	2.971
% coast in site	0.0226***	11.12
% urban in site	-0.00222***	-4.617
% freshwater in site	0.0113***	4.812
% grasslands in site	0.00160	1.477
% woodlands in site	0.00364***	3.896
% of sea in site	0.0233***	9.804
% mountain/heath in site	0.0181***	7.980
% non-white ethnicity	-0.00546***	-6.162
% retired	0.00645***	3.661
Median household income	0.0000104***	11.19
Total population of outset area	0.000227***	5.902
Constant	-3.101***	-36.30
lnsig2u		
Constant	-0.912***	-25.47
Observations	4,047,387	

Ordnance Survey information on the road network and data on travel times (Jones *et al.* 2010). This allowed us to generate the range of variables required for our SPM and TGF analyses including: the characteristics of outset locations and potential destination sites, travel times, substitute availability, etc.

Estimation of the SPM provides us with the predicted distribution of sites across GB under the baseline conditions, as illustrated in **Figure 26.13a**. As per expectations, the immediate observation regarding this distribution is that it reflects, at least in some noticeable part, variation in population density across the country. However, there are also noticeable influences from variation in land use type. This is perhaps most clearly seen in areas such as the South West of England and the western coastal areas of Wales where, despite relatively low populations, site probability remains significant. Population pressures become the dominant factors when we consider the baseline predictions of our TGF as illustrated in **Figure 26.13b**. This predicts the number of visitors that there would be to each grid cell on the assumption that it does indeed contain a recreational site. Here the decay in visit rates away from population centres clearly demonstrates the vital importance of placing recreational sites in areas which are readily accessible to large numbers of people. **Figure 26.13c** combines the information given in both of the previous analyses to adjust the TGF predictions for the probability of sites given by the SPM. Note that we have also used this stage to adjust from the sample data given in the central figure to the entire population of GB (Chapter 22 discusses this adjustment). Hence the distribution shows us the estimated total number of visits to each grid cell per annum.

The resulting distribution conforms strongly to prior expectations. Visit numbers reflect the very strong influence of travel time and associated costs. However, the land use and habitat types of each area clearly exert their influence. So, for example, prized landscapes such as large areas of south-west England, the north Norfolk coast, the western coast of Wales and the border areas of Scotland down into the Lakes all exert a pull on visitors which overcomes the fact that they have relatively low resident populations.

The total annual visitor numbers described in **Figure 26.13c** can then be fed into the meta-analysis model to convert visitor numbers into values, taking into account the land use and habitat characteristics of each visited site and their corresponding specific values. **Figure 26.14** maps the resultant values obtained from this analysis. The distribution is similar to, but not identical with, that shown in **Figure 26.13c** due to the different per visit values attached to visits in different habitat types. This is perhaps most noticeable in areas such as the Scottish highlands where, although the number of visits is low relative to the vast numbers around major conurbations, nevertheless the high per visit values attached to such habitats boosts the recreational value of such areas. **Table 26.17** presents a few descriptive statistics regarding the number of visits and their value in the baseline situation.

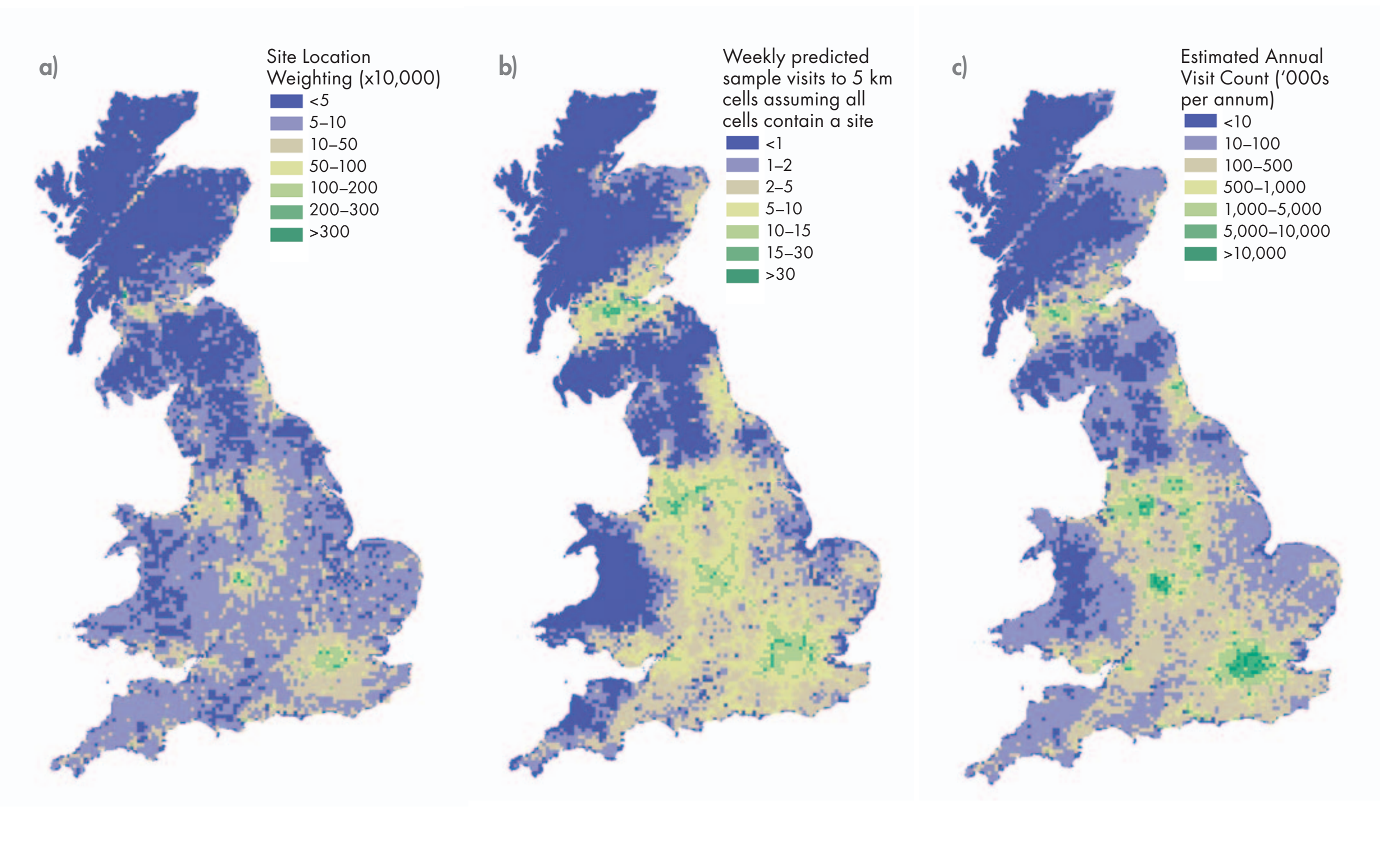


Figure 26.13 The baseline distribution of sites (a); predicted number of day visits (unadjusted for sample size) to sites (b); and the estimated total number of recreational day visits per annum across Great Britain (c); adjusted for sample size).

Table 26.17 Predicted total annual visit numbers and their total value (£'000s) for the 2000 baseline period.

	GB	England	Scotland	Wales
Predicted visits per annum				
Mean (No. per 5 km cell)	394	559	130	94
Median (No. per 5 km cell)	72	133	12	24
Country total (visits)	3,231,000	2,860,000	290,000	81,000
Value of predicted visits per annum				
Mean (£/5 km cell)	1,223	1,732	414	303
Median (£/5 km cell)	241	436	44	79
Country total (£)	10,040,000	8,854,000	926,000	260,000

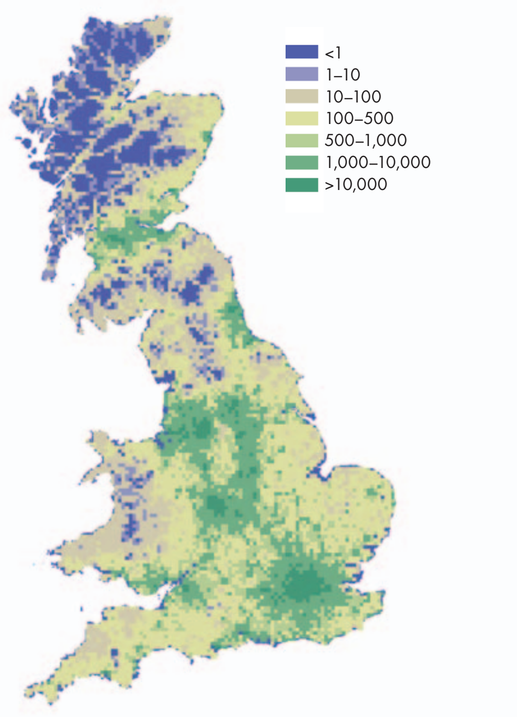


Figure 26.14 Total value of annual predicted visits (£'000s) in the 2000 baseline.

26.5.4 Scenario Analysis

While Chapter 22 discusses the development and estimation of our underlying models in some detail, it does not discuss their use within scenario analyses at any length. Therefore in this section we first describe a single such analysis in some detail. That methodology is then simply repeated to generate results for the remaining scenarios.

Our more detailed discussions concern the estimation of values generated by moving from the baseline situation to that envisaged under the high emissions variant of the *Green and Pleasant Land* scenario.

The UK NEA Scenarios team envision the *Green and Pleasant Land* high emissions scenario as one in which conservation of biodiversity and landscape are the dominant driving forces. There are substantial relative increases in broadleaved woodland, freshwater and grassland habitats and declines in Coniferous Woodland and Enclosed Farmland. Although overall population increase is modest, the proportion who are retired increases more than under any other scenario and incomes also rise substantially. Taken together, these factors would be expected to play out through the SPM and TGF models to increase both the number and value of recreational visits. This is indeed what our analysis reveals, as illustrated in **Figure 26.15** which reworks the format of **Figure 26.13**, although now for the *Green and Pleasant Land* high scenario. The maps are now coloured such that decreases from the baseline are shown in purple and increases are coloured in green. In both cases darker tones indicate more substantial changes from the baseline.

Considering the maps shown in **Figure 26.15**, the immediate observation is the dominance of green tones indicating increases over the baseline. This is least true of the distribution of sites where both upland and high density Urban locations see declines. However, even here there is a noticeable increase in the prevalence of lowland sites, driven in major part by the increases in broadleaved woodland, freshwater and grassland habitats and declines in Coniferous Woodland and Enclosed Farmland in such areas. The contrast between high density Urban locations and areas just outside those centres is particularly noticeable, reflecting an increased availability of urban fringe recreational sites. Increased incomes and an increase in the numbers of retired people enables the population to take advantage of these sites, resulting in a significant increase in predicted day visits. The growth in Urban fringe sites leads to very substantial increases in recreational activity for those who live in highly populated areas, despite a reduction in the availability of recreational sites within the Urban environment. Indeed it is only the more remote areas which do not experience increased recreational visit numbers under the *Green and Pleasant Land* high emissions scenario. These visitor numbers are applied to the meta-analysis model to convert them into values that take account of the new habitat distribution envisioned under the *Green and Pleasant Land* high emissions scenario. **Figure 26.16** maps this distribution of values which again is similar to, but not identical with, that of the number of visitors, the difference being due to the variation in per visit values across habitats.

Table 26.18 presents selected descriptive statistics regarding the change in the number of visits and their value generated by a shift from the baseline situation to the *Green and Pleasant Land* high emissions scenario.

Inspection of **Table 26.18** confirms the message of **Figure 26.16**, that the *Green and Pleasant Land* high emissions scenario delivers a substantial increase in recreation values over the baseline. We now repeat this analysis for each of the scenarios with the resulting distribution of values being mapped in **Figure 26.17** for their low emission variants while **Figure 26.18** repeats this for the high emission scenarios.

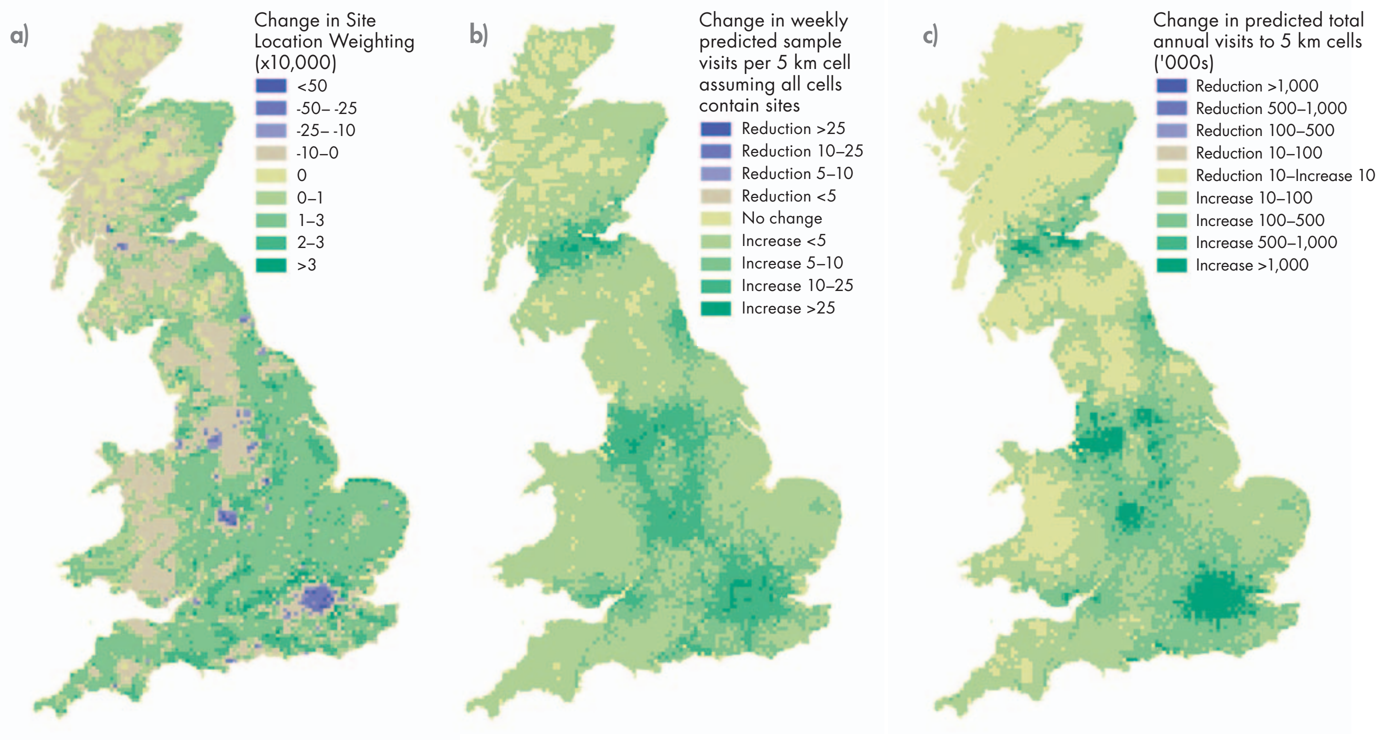


Figure 26.15 Changes induced by a move from the 2000 baseline to the *Green and Pleasant Land* High emissions scenario in terms of the distribution of sites (a); the predicted number of day visits (unadjusted for sample size) to sites (b); and the estimated total number of recreational day visits per annum across Great Britain (c); adjusted for sample size).

In general the maps shown in **Figure 26.17** and **Figure 26.18** are dominated by increases in visit value. The *Nature@ Work* scenario displays the most substantial increases in the value of visits for large areas of GB both at high and low emissions. These gains are followed by those under the *Green and Pleasant Land* scenario, which are a little higher than those under *Go with the Flow*. In both of these scenarios, large increases are seen in and around Urban areas, while more rural areas see smaller increases in the annual value of visits. The *National Security* scenario also shows a similar geographic pattern to *Go with the Flow* and *Green and Pleasant Land*, but with some areas, such as the Scottish Highlands and the Pennines, experiencing a reduction in the predicted annual value of visits. Larger predicted reductions are seen under the *Local Stewardship* scenarios, particularly in the area south and west of London and in the urban centres, although London itself shows a substantial increase in the value of visits. The *World Markets* scenarios probably show the greatest difference both in comparison to the other scenarios and also in the response to high and low emissions. In both high and low scenarios London shows a very large decrease in value of visits with similar decreases in predicted visit value also seen in other urban centres across the country. However, in the low emissions scenario the Urban areas outside of London are expected to experience an increase in the value of visits. In all cases the remote uplands, because of their inaccessibility, remain unvisited and show no change in value.

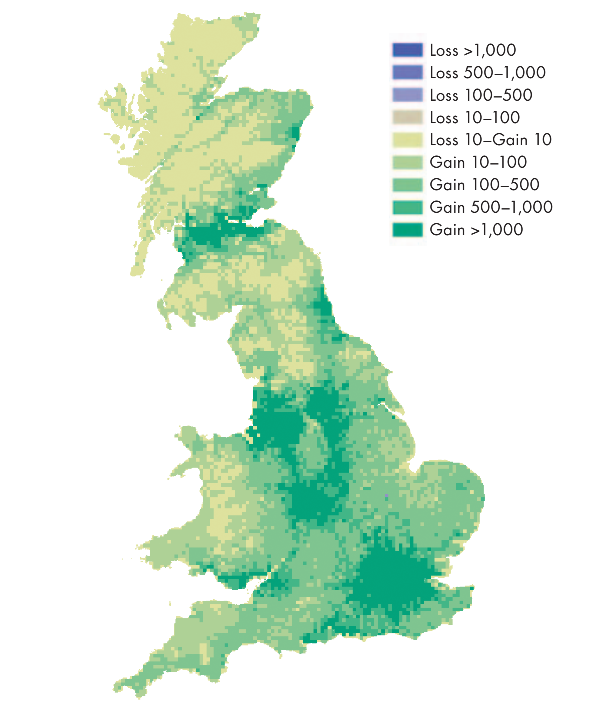


Figure 26.16 Changes in the total value of annual predicted visits (£'000s) under the *Green and Pleasant Land* High emissions scenario.

Table 26.18 Changes in the predicted total annual visit numbers and their total value arising from a move from the 2000 baseline situation to the *Green and Pleasant Land* High emissions scenario. All changes are positive under this scenario analysis. These changes must be added to the baseline figures in Table 26.17 to obtain absolute totals. All numbers are in thousands.

	GB	England	Scotland	Wales
Changes to predicted visits per annum				
Mean (No. per 5 km cell)	199	277	77	54
Median (No. per 5 km cell)	49	85	8	14
Country total (visits)	1,636,000	1,417,000	173,000	46,000
Changes in the value of predicted visits per annum				
Mean (£/5 km cell)	628	871	249	173
Median (£/5 km cell)	163	279	28	47
Country total (£)	5,156,000	4,451,000	556,000	149,000

Table 26.19 summarises the national level changes in value arising between the baseline and each of the scenarios. At this national level all of the scenarios generate increases in the annual value of visits except for the *World Markets* high emissions scenario. In general, we find large gains under the *Nature@Work*, *Green and Pleasant Land* and *Go with the Flow* scenarios and moderate increases for the *Local Stewardship* scenario.

The last row of **Table 26.19** divides the GB level values under the baseline and each scenario by the GB population to obtain per capita values. These adjust the national level results for the increases in population envisioned to occur, at different rates, under all scenarios. While the *Nature@Work* scenario still remains that which yields the highest per capita value, this analysis substantially differentiates the *Green and Pleasant Land* and *Go with the Flow* findings showing that, on a per person basis, the former more than double the value of the latter.

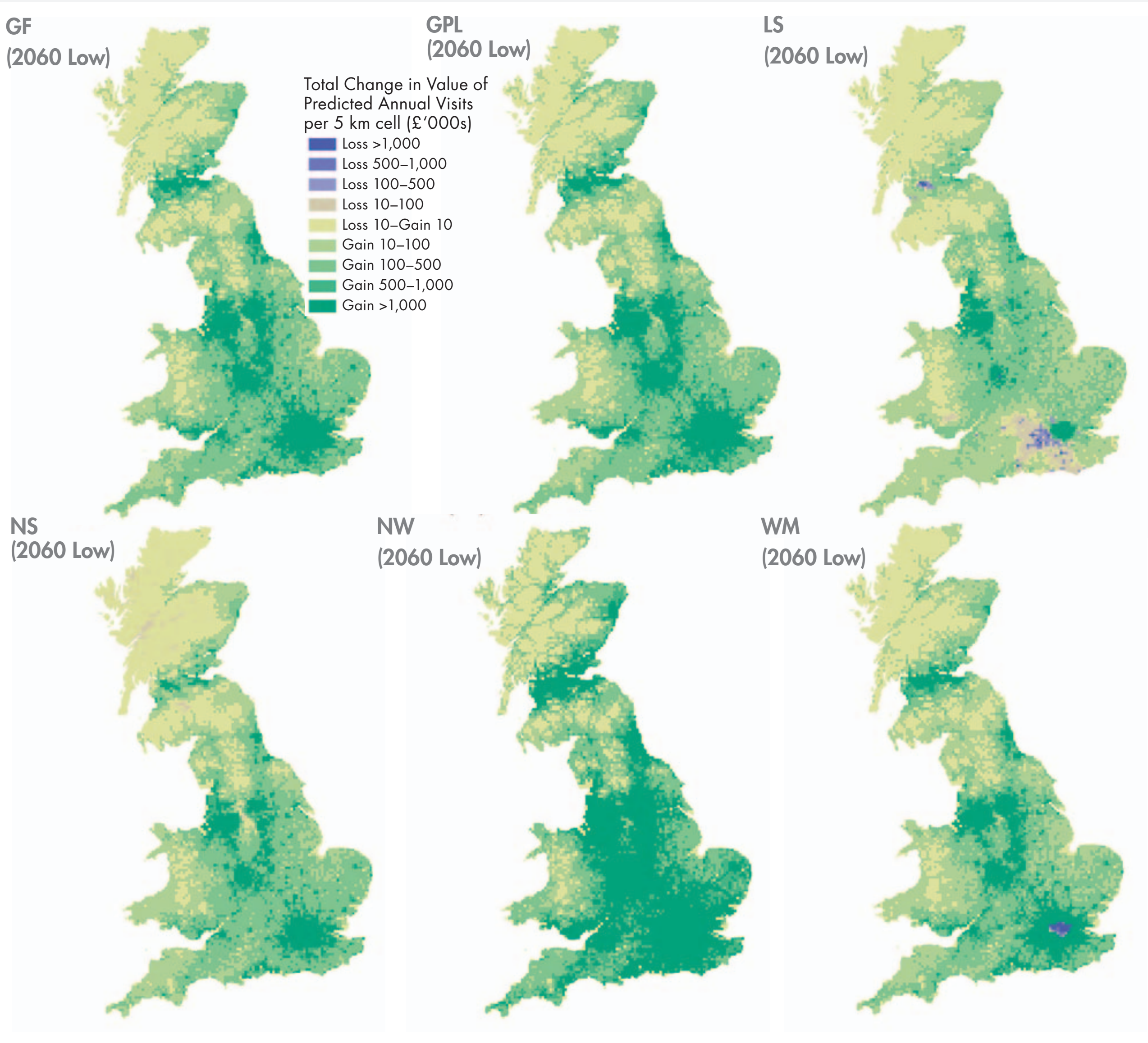


Figure 26.17 Total recreational value changes from the 2000 baseline to all UK NEA Low emissions Scenarios. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

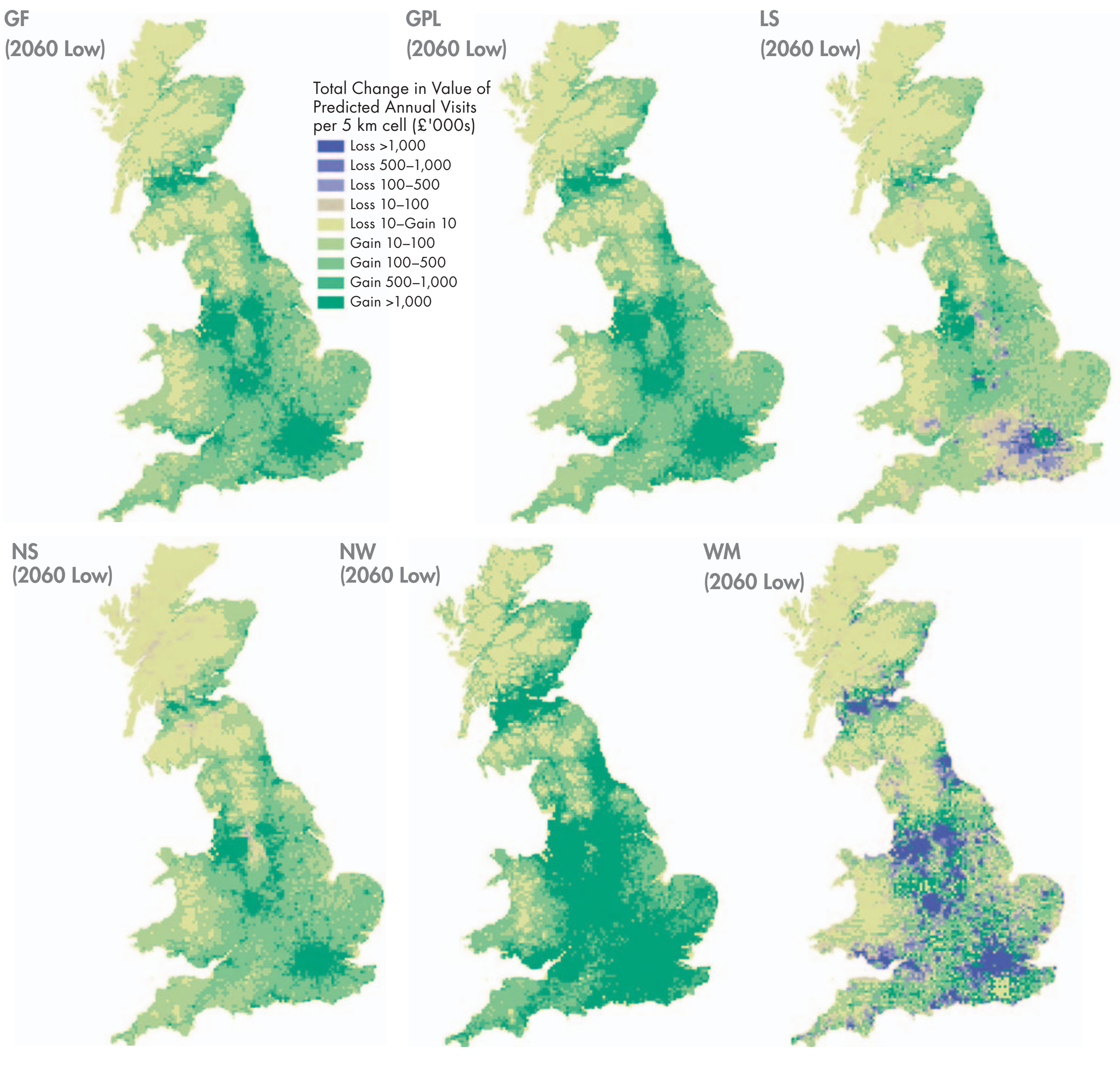


Figure 26.18 Total recreational value changes from the 2000 baseline to all UK NEA High emissions Scenarios. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

Table 26.19 Total (£million) and per capita (£) value of predicted annual visits in the 2000 baseline period and changes in total and per capita value of predicted annual visit under the various UK NEA Scenarios (High and Low emissions). Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

Region	Baseline (£ million)	GF (£ million)		GPL (£ million)		LS (£ million)		NS (£ million)		NW (£ million)		WM (£ million)	
		High	Low	High	Low	High	Low	High	Low	High	Low	High	Low
England	8,854	3,624	5,048	4,451	5,327	898	1,400	3,061	4,125	21,084	21,428	-678	4,398
Scotland	926	370	488	556	602	162	84	189	249	2,262	2,190	-61	517
Wales	260	127	174	149	174	38	52	94	119	568	547	-84	122
GB	10,040	4,121	5,711	5,156	6,103	1,098	1,535	3,344	4,493	23,914	24,165	-823	5,037
GB population (millions)	55.4	62.8	62.8	65.6	65.6	74.5	74.5	67.5	67.5	62.0	62.0	72.4	72.4
GB per capita values (£ p.a.)	181	14	36	61	76	-1	6	17	34	337	341	-57	21

26.6 Urban Greenspace Amenity[27]

26.6.1 Urban Change Scenarios

Key ecosystem services provided by urban greenspace in the UK include recreation, aesthetics, physical and mental health, neighbourhood development, noise regulation and air pollution reduction. As such it is a bundled good[28] and should be valued as such. The benefits derived from domestic gardens are considered in Chapter 22 and are not included in what follows. Our methodology for such valuation is discussed in the Chapter 22, but in summary this undertakes a meta-analysis of prior studies, allowing us to estimate how amenity values decline with increasing distance between households and areas of urban greenspace. Capturing this distance dependence is vital if we are to accurately assess the value of changes in the number, extent and location of urban greenspaces as cities and their populations alter as envisioned in the UK NEA Scenarios.

The six UK NEA Scenarios detail a number of changes to key urban characteristics such as their physical extent, their population and the area of urban greenspace provided. **Table 26.20** presents the percentage changes for these key variables for each of the scenarios based on data provided by the UK NEA Scenarios team.[29] Note that the changes in urban extent shown in **Table 26.20** differ somewhat from those presented in **Table 26.2** of this chapter since the former refers to cities with a population of at least 50,000 while the latter includes all urban areas.

Table 26.20 Changes in urban characteristics from the 2000 baseline to 2060 for each of the UK NEA Scenarios.

Scenario	Change in urban area (%)	Change in urban population (%)	Change in the area of formal recreational space (%)	Change in the area of informal greenspace (%)
Go with the Flow	3.0	32.2	36.2	0.0
Green and Pleasant Land	0.0	21.7	38.9	5.4
Local Stewardship	-3.0	0.0	4.5	2.8
National Security	-3.0	17.2	-34.3	4.8
Nature@Work	-3.0	13.8	39.0	-4.9
World Markets	79.0	52.6	73.0	20.7

The full narrative for each Scenario can be found in Chapter 25, but some brief illustrations are in order. Arguably, the *World Markets* scenario has the most extreme impact on urban areas. Here, by 2060, the UK experiences dramatic urbanisation, both in terms of urban extent and population. Informal greenspace, in particular, fails to keep up with increases in urban extent and population, a situation which, as we show subsequently, leads to losses in urban greenspace values. An expansion of housing into green belt, parks and gardens results in a loss of greenspace and developed areas increase substantially. A further extreme case is given under the *National Security* scenario. Here, although the increase in population is less extreme than under the *World Markets* scenario , now the drive for national self-sufficiency actually leads to a reduction in formal greenspace areas, as parks are used for provisioning purposes. One would expect that this would also yield reductions in the benefits provided by urban greenspace. A less extreme, but still negative, expectation arises with respect to the *Go with the Flow* scenario, where the combined change in overall (formal plus informal) greenspace only just outpaces very substantial growth in a population within a context of little alteration in the overall extent of urban areas. The combined effect of such changes is likely to be a small reduction in greenspace benefits. In contrast, the remaining scenarios (*Green and Pleasant Land, Local Stewardship* and *Nature@ Work*) all envisage increases in combined greenspace which are clearly in excess of population growth. As such, urban greenspace benefits would be expected to increase in all three of these cases.

26.6.2 Methods for Calculating the Implications of Scenarios for Access to Urban Greenspace

The characteristics specified under the UK NEA Scenarios imply alterations in the size of urban areas and the formal and informal greenspace within them.[30] The implicit changes in access to greenspace (and hence distance decay in values) was assessed through GIS analysis of distance and accessibility relationships for the set of UK urban centres (ranging from relatively small cities like Norwich to major conurbations like Glasgow) discussed in Chapter 22. This analysis provided information on the proximity of each household[31] to urban greenspaces, both under the 2000

27 This section is drawn from Perino *et al.* (2011).
28 This means that some overlap with the previous analysis of open-access recreation is acknowledged.
29 With respect to the drivers of urban greenspace values, the UK NEA Scenarios do not differentiate between the high and low emission variants of a given scenario.
30 These changes are implemented by expanding or contracting existing areas of greenspace in line with the specifications of each scenario. This is likely to deliver a lower bound estimate of the value generated by such changes, as gaining or losing an entire park is expected to generate greater changes in value than simply changing an equivalent area of existing parks. The new percentage cover of general greenspace (as defined in Chapter 22) is calculated by increasing the areas covered by formal and informal greenspace as specified in the scenarios and then dividing the general greenspace cover by [1 + decimal percentage change in Urban area] to take account of the overall change in city size.
31 Note that proximity measurements were taken from the centroid of each full postcode, although as these typically contain just 20 households, any error induced by this assumption should be minor. This caveat applies throughout this section. These changes are implemented by the following simple procedures since it is beyond the scope of this project to more accurately simulate urban growth for the five cities. The change in Urban area is represented by multiplying distances to urban parks and other formal recreation sites, and city-edge greenspace by a factor equal to the square root of 1 plus the change in the Urban area (this is 0.98 for *Nature@Work*, *National Security* and *Local Stewardship*, 1.015 for *Go with the Flow* and 1.338 for *World Markets*). The square root is taken to translate a change in area into one in distance. The appropriateness of using a constant factor for all distances follows from the intercept theorems.

baseline and for each of the UK NEA Scenarios. The change in urban population is modelled by increasing the baseline population in each postcode by the growth rate specified under each scenario.[32] The distance between people's homes and the centre of urban greenspaces (>1 hectare) is a major driver of amenity values. Any change in the extent of urban areas will have a direct impact on this because (holding greenspace area constant) homes will be on average either further away (if the city grows) or closer (if the city shrinks) to urban greenspace. Since distances are measured to the centre of a park, a change in the park's size does not affect the distance measure but is captured separately. The marginal impact of an increase in both a park's size and its distance to a household are decreasing.

Although the UK NEA Scenarios include information on overall GDP growth, they do not specify changes in the relative distribution of income and so, for ease of exposition, we hold income constant throughout our analysis.[33] Furthermore, while the UK NEA Scenario descriptions specify the state of the world in 2060, they do not provide details about the intervening period. This does not cause a problem when we report the undiscounted value of changes. However, in order to determine discounted present values we assume that changes occur evenly across the time period and then apply the standard discounting rule specified in the HM Treasury's Green Book (2003, Annex 6, Table 6.1) that discounts any net changes at 3.5% for the first 30 years of a project and at 3% for years 31 to 60. We denote this as the 'HM Treasury–Standard Discounting' approach. However, applying these discount rates introduces a degree of internal inconsistency, as the Treasury bases these on the assumption of a 2% average growth rate of the UK economy. However, four of the six UK NEA Scenarios make different assumptions, with growth rates in the range between 0.5% (*Local Stewardship*) and 3% (*Nature@Work*). Using these growth rates instead of that assumed by the Treasury implies differentiated discount rates. These are calculated and used to define an 'HM Treasury–Scenario Specific Discounting' approach.[34]

26.6.3 Valuing Changes in Urban Greenspace Change

Using these various approaches, Perino *et al.* (2011) calculate values for the changes in urban greenspace envisaged under each scenario for both the set of cities considered and the implied values for the whole of GB[35]; it is these latter, national level values that we focus upon here. In calculating these, value estimates are only made for cities with a population of 50,000 or more, as the methodology used is regarded as less suitable for smaller settlements. This is because urban greenspace is likely to play a lesser role in the provision of many ecosystem services in smaller settlements than it does in larger ones as, by their very nature, most households in smaller towns live relatively close to rural areas. The exclusion of smaller cities explains the difference in urban extent implied by each scenario given in **Table 26.2** and **Table 26.20**.

Our set of sampled cities allows us to calculate the value of changes in urban greenspace under each scenario for more than 1,600 urban areas (defined as LSOA in England and DZ in Scotland). Regression analysis linked these value estimates to a variety of small area characteristics. This analysis identified a number of highly significant ($p<0.0001$) predictors of the change in greenspace value generated by each scenario, including household density and socio-economic characteristics of those households such as their median income levels. Given that the predictors of value can be obtained for all census areas of all cities, the model can be used to extrapolate these value changes across GB. **Table 26.21** presents the resulting valuations of the urban greenspace changes envisioned under each scenario.

Table 26.21 presents estimates of the average changes in urban greenspace values under each scenario at national and household level. Undiscounted, standard and scenario-specific discounted values are reported, each being accompanied with its annuity equivalent. Note that in contrast to values reported in Perino *et al.* (2011) and Chapter 22, where a baseline of 2010 is used, the values in this and all other tables and figures are adjusted to reflect the common baseline of 2000. This does not affect the undiscounted value change reported in these tables but somewhat reduces all entries in subsequent rows. While these values should be regarded only as approximations, nonetheless they underline the very substantial changes in urban greenspace values which can arise across these scenarios. While more extreme scenarios such as *World Markets* lead to very substantial losses in urban greenspace values, even moderate scenarios show that feasible changes to urban greenspace can generate significant changes in values. We can see that in the *Go with the Flow* scenario, urban greenspace values decline by nearly £2 billion per

32 However, postcode centroids, i.e. the location of houses, are not changed over and above the inflation factor. The bias introduced by the artefact that some additional houses in postcode areas very close to existing parks, might be allocated to areas within the new boundaries of a park. This bias is limited by the adjustment of the marginal value function for such short distances as described in Chapter 22.

33 This is also a somewhat risk averse modelling strategy, as the estimated income effect is likely to dominate the aggregate change in benefits derived from ecosystem services across scenarios. This would be problematic to the extent that relative prices of all goods including substitutes for urban greenspace, e.g. private gardens and recreational trips, are held constant. Both, however, are expected to increase more in those scenarios that increase the scarcity of recreational greenspace in general. Holding income constant is considered to impose a smaller error than increasing it in line with general GDP growth but keeping relative prices constant.

34 This approach is discussed in further detail by Perino *et al*. (2011), who also discuss and present alternative approaches to dealing with the projected changes in population. Note that Stern (2006) deviated from the HM Treasury's guidelines on the grounds that the environmental good valued (climate change) involves intergenerational comparisons of benefit changes and hence should be guided by the moral principle of treating all generations equally. In terms of discounting, this implied a reduction of the 'pure rate of time preference' from the 1.5% used in HM Treasury (2003) to 0.1%. Stern (2006) also used a more cautious growth rate of 1.3%. This resulted in a discount rate of 1.4% (or an adjustment factor of 0.72 in the present case). Again, to be consistent with the growth rates in UK NEA Scenarios, the range of adjustment factors spans from 0.456 for *Nature@Work* to 0.865 for *Local Stewardship*. The 60-year time horizon considered in the UK NEA arguably involves intergenerational comparisons, although not exclusively.

35 Comparable data for Northern Ireland is not available. However, Urban areas in Northern Ireland represent only about 3% of total Urban area in the UK (Chapter 10, Section 10.1.2).

Table 26.21 Per household and aggregated benefit changes of UK NEA Scenarios for Great Britain. Note that per household values are based on the 15.2 million households living in the urban areas included in the extrapolation.

	Go with the Flow	Green and Pleasant Land	Local Stewardship	National Security	Nature@ Work	World Markets
	Aggregate values (£ billion)					
Undiscounted value change	-118	141	129	-597	284	-1,440
Annuity (60 years)	-1.96	2.35	2.16	-9.94	4.73	-24.0
Net Present Value (HM Treasury–Standard Discounting)	-49	59	54	-250	119	-603
Annuity (infinite, 3.5%)	-1.73	2.06	1.90	-8.75	4.17	-21.1
Net Present Value (HM Treasury–Scenario Specific Discounting)	-55	59	76	-311	98	-603
Annuity (infinite, scenario specific)	-1.65	2.06	1.53	-7.79	4.41	-21.1
	Per household values (£)					
Undiscounted value change	-7,800	9,300	8,500	-39,300	18,700	-94,700
Annuity (60 years)	-129	154	142	-655	312	-1,580
Net Present Value (HM Treasury–Standard Discounting)	-3,253	3,880	3,570	-16,500	7,840	-39,700
Annuity (infinite, 3.5%)	-114	136	125	-576	274	-1,390
Net Present Value (HM Treasury–Scenario Specific Discounting)	-3,600	3,880	5,030	-20,500	6,450	-39,700
Annuity (infinite, scenario specific)	-109	136	101	-513	290	-1,390

annum, while pro-environmental scenarios such as *Green and Pleasant Land* lead to value gains of over £2.3 billion annually, and that this is more than doubled under the *Nature@Work* scenario. These are major sums which would be likely to alter resource allocations if included within decision-making systems.

The changes in amenity value provided by urban greenspace under each scenario are driven by a combination of factors. A change in the size of a city changes the average distance to nearby greenspace and hence the amount of benefits (e.g. recreation, cleaner air, aesthetics) occurring to urban households. An increase in urban population, other things being equal, decreases per household benefits as parks get increasingly crowded. A change in the amount and type of urban greenspace provided is the last of the main factors. Each scenario is characterised by a specific combination and usually they point in different directions. For example, in the *World Markets* scenario the fact that greenspaces are both further away from people's homes and are more crowded dominates the (absolute but not relative) increase in provision.

Analysis of the geographic distribution of these value changes shows that, not surprisingly, they generally follow the distribution of population, being largest in England and smallest in Wales, as illustrated in **Figure 26.19**. However, **Figure 26.20** shows that, even after adjusting for this by considering values at the household level, there are still marked differences between the three countries. This is due to household level effects being highest in the largest conurbations, which are more prevalent in England than in Scotland and Wales.

Figure 26.21 presents the effects of moving from the HM Treasury's–Standard Discounting rule to one that takes into account the different growth rates in the respective scenarios and hence is scenario-specific. Note that for the *Green and Pleasant Land* and *World Markets* scenarios the growth rate is equal to the 2% assumed by HM Treasury (2003) and hence there is no difference between the two discounting regimes. For *Nature@Work* the net present value is reduced by about 16%. For the *National Security*, *Local Stewardship* and *Go with the Flow* scenarios the

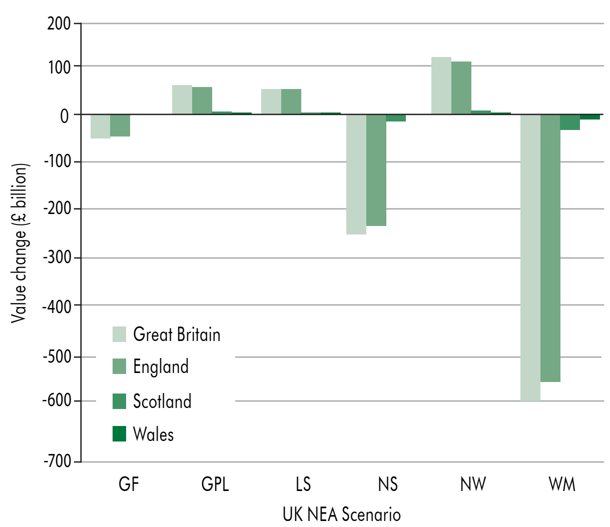


Figure 26.19 Distribution of UK NEA Scenario value changes across countries. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

absolute value of the benefit change increases by up to one-third as their growth rates are below the one used by HM Treasury.

The spatial distribution of gains and losses is presented in **Figure 26.22** and **Figure 26.23**. The former figure presents the spatial pattern for the three scenarios (*Green and Pleasant Land*, *Nature@Work* and *Local Stewardship*) that yield net gains, and differences between these can be assessed with reference to the different scales given at the bottom of this figure. Similarly, **Figure 26.23** illustrates those three scenarios (*World Markets*, *National Security* and *Go with the Flow*) that generate net losses in terms of urban greenspace amenity.

The distribution of value changes under the scenarios differs substantially in the scale and direction of changes. Generally speaking, value changes are greatest in the centres of large Urban areas such as London, Birmingham and Manchester, with smaller cities being less affected. This supports our earlier decision to focus on cities with populations of 50,000 and above, but also suggests that any error induced through the omission of smaller towns might be relatively minor. Note that all values presented in **Figure 26.22** and **Figure 26.23** are per household changes in benefits. Hence, the weight of large Urban areas for the final outcome is even more pronounced than apparent from the maps, as they are home to more people.

26.6.4 Distributionally Weighted Values for Urban Greenspace Change

The aim of a cost-benefit analysis is to test whether a particular policy or project improves social welfare. Strictly speaking, summing up the monetary values of benefit changes across individuals only allows us to draw conclusions about changes in social welfare if the marginal utility of consumption is equal across all individuals. There is strong empirical evidence suggesting that the marginal utility of consumption decreases with income (i.e. the utility of £1 gained by a poor person is greater than if that amount were received by a rich person).[36] To adjust for this factor we follow HM Treasury (2003, Annex 5) and apply distributional weights to the benefits and costs of urban greenspace change. This procedure assumes that the elasticity of marginal utility with respect to consumption is one. This implies that someone with twice the median income receives a weight of one half compared to someone with median income. The distributional weight for each LSOA is calculated by dividing the median UK household income by the median household income in the LSOA or DZ using data provided by Experian (2010).[37]

Figure 26.24 and **Table 26.22** illustrate the impact of distributional weights on the net present value per urban household of each scenario. The benefit changes increase by up to about 30% if distributional weights are applied. This indicates that any reduction (increase) in the amount of urban greenspace would disproportionally hurt (benefit) the poor.

As **Figure 26.25** demonstrates, the impact of applying distributional weights is particularly pronounced for Scotland, where the impact of scenarios almost doubles as a result of the generally lower urban incomes relative to other areas of Great Britain.

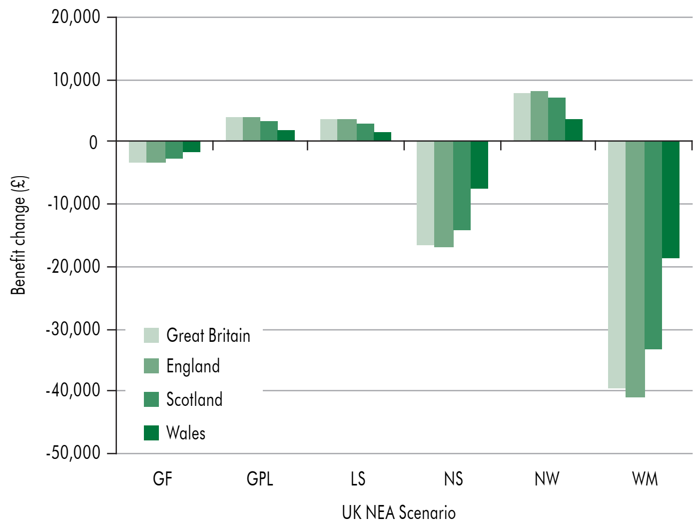


Figure 26.20 Distribution of benefit changes per household across countries. Aggregate net present value calculated using with HM Treasury–Standard Discounting. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

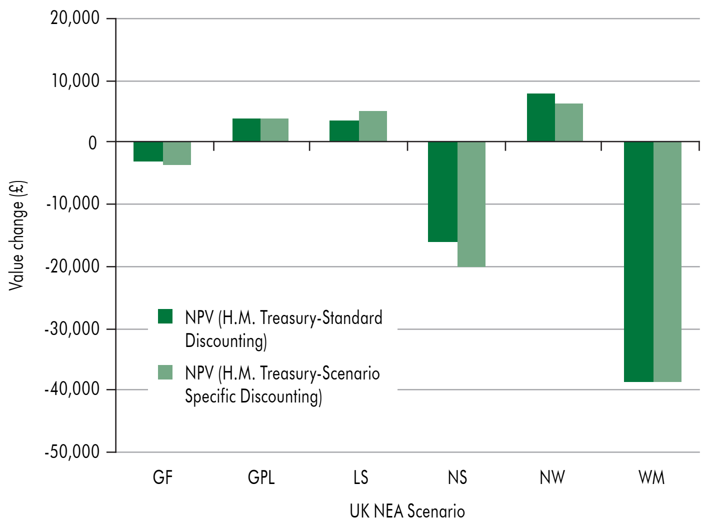


Figure 26.21 Comparing the HM Treasury–Standard Discounting rule with a scenario-specific discounting rule. NPV = Net Present Value. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

36 Note that the sensitivity of the social discount rate to the rate of economic growth discussed above rests on the same concept.
37 The Experian Mosaic database contains median household incomes and the number of households for all LSOAs. Ordering all LSOAs with respect to income and computing the cumulative number of households allows us to obtain an estimate of the median household annual income for the UK, which in 2008 was £25,275.

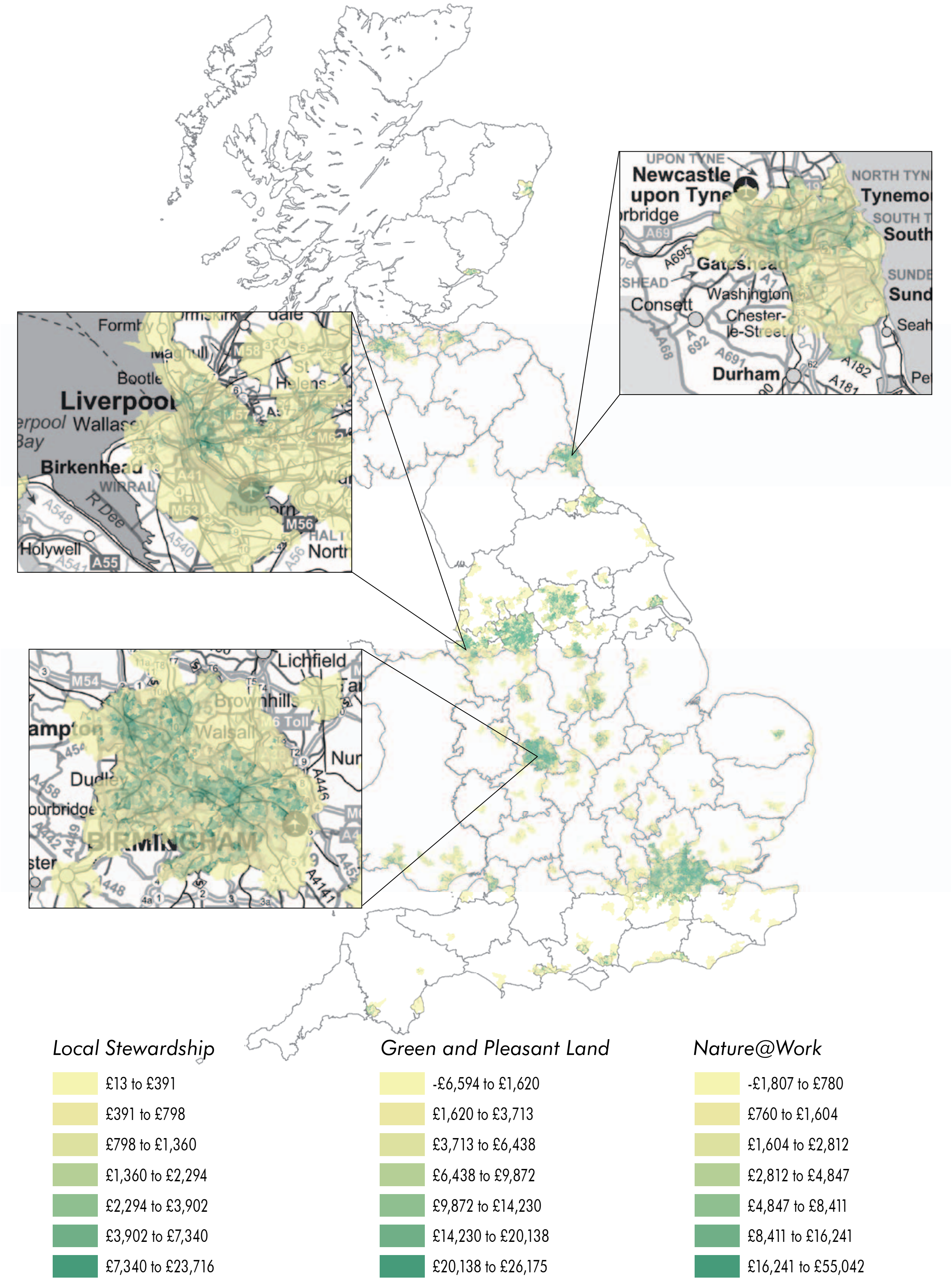
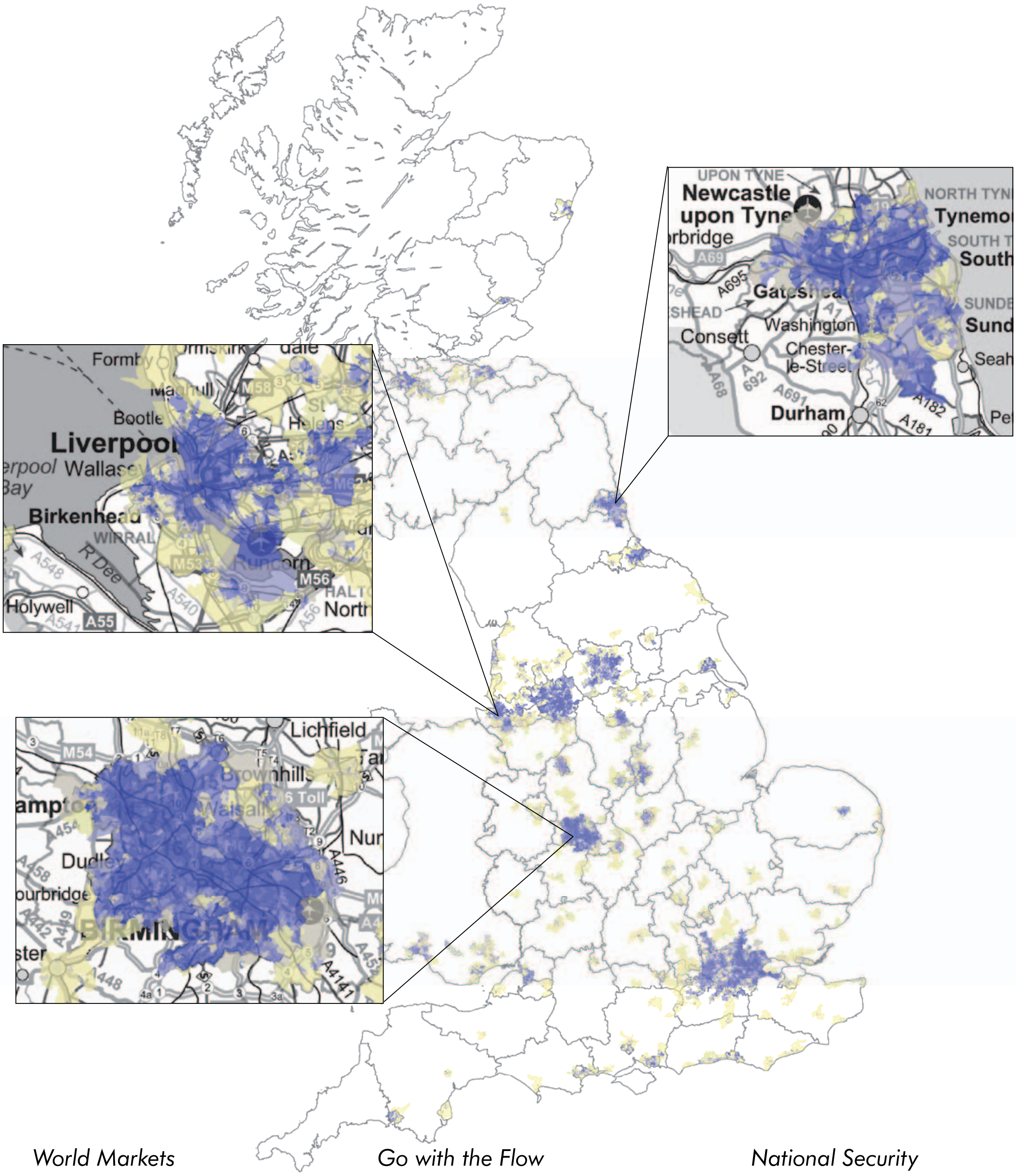


Figure 26.22 Spatial distribution of benefit changes under those UK NEA Scenarios which yield net gains for Great Britain. £/household; net present value assessed using HM Treasury–Standard Discounting rates 2003.



World Markets

- -£264,813 to -£80,911
- -£80,911 to -£43,286
- -£43,286 to -£25,396
- -£25,396 to -£15,145
- -£15,145 to -£8,890
- -£8,890 to -£4,363
- -£4,363 to -£145

Go with the Flow

- -£23,067 to -£6,629
- -£6,629 to -£3,486
- -£3,486 to -£2,034
- -£2,034 to -£1,206
- -£1,206 to -£703
- -£703 to -£346
- -£346 to £257

National Security

- -£119,115 to -£34,012
- -£34,012 to -£17,573
- -£17,573 to -£10,036
- -£10,036 to -£5,795
- -£5,795 to -£3,301
- -£3,301 to -£1,567
- -£1,567 to -£43

Figure 26.23 Spatial distribution of benefit changes under those scenarios which yield net losses for Great Britain. £/household; net present value assessed using HM Treasury–Standard Discounting rates 2003.

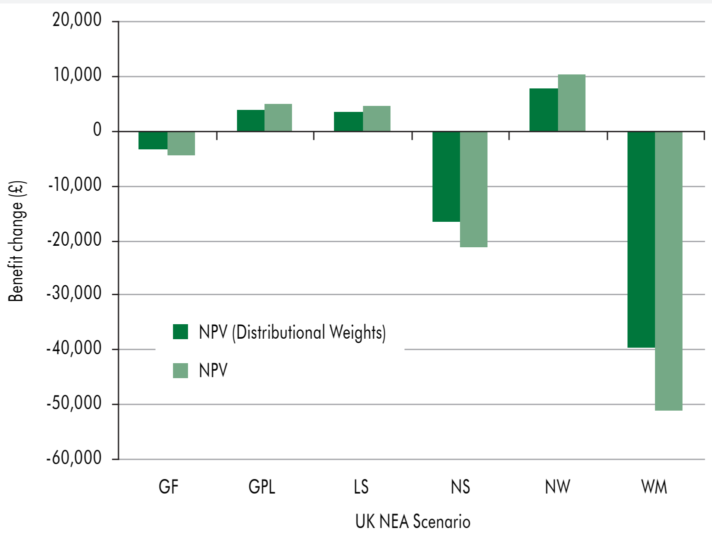


Figure 26.24 The effect of applying distributional weights on per household benefit changes across Great Britain. Net present value (NPV) per household calculated using with HM Treasury–Standard Discounting. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@ Work*; WM = *World Markets*.

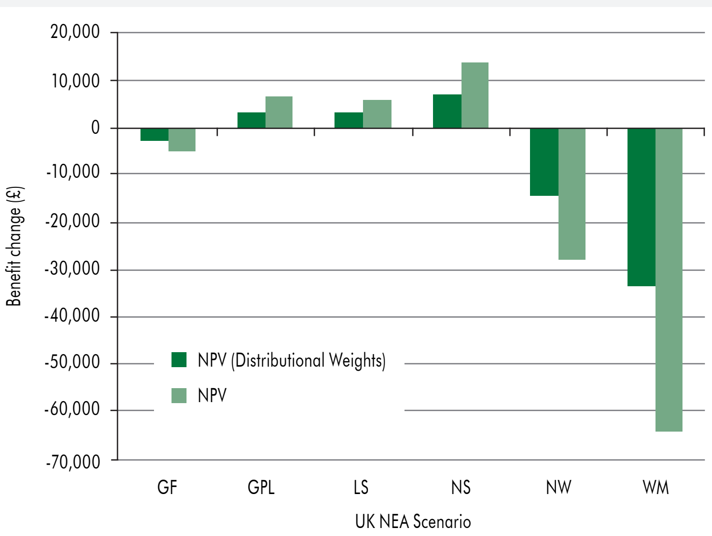


Figure 26.25 The effect of applying distributional weights on per household benefit changes in Scotland. Net present value (NPV) per household calculated using with HM Treasury–Standard Discounting. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@ Work*; WM = *World Markets*.

26.6.5 The Value of Urban Greenspace Change: Conclusions

While Perino *et al.* (2011) note a number of caveats and assumptions underlying their analysis, nevertheless their work provides an initial systematic attempt to estimate values for urban greenspace across GB. While under constant pressure due to the increasing demand for housing and commercial development, urban greenspace generates substantial benefits to local communities. This analysis shows that changes in the provision of urban greenspace can create, or destroy, billions of pounds worth of benefits to local residents.

26.7 Conclusions

26.7.1 Overview

The analysis presented in this chapter has considered five ecosystem service goods, as follows:

- agricultural food production;
- terrestrial carbon storage and annual greenhouse gas emissions;
- biodiversity (assessed using birds as an indicator species);
- open-access recreation; and
- urban greenspace amenity.

For each of these goods we have examined the changes in provision between a baseline[38] set as the situation in 2000 and the envisioned state of the UK in 2060 under the UK NEA Scenarios, which are as follows:

- *Go with the Flow*;
- *Green and Pleasant Land*;
- *Local Stewardship*;
- *National Security*;
- *Nature@Work*;
- *World Markets*.

With the exception of biodiversity, all of the goods are valued in monetary terms. As discussed in Chapter 22, while the use values of biodiversity are readily amenable to monetary valuation, its non-use existence value is the subject of some controversy. While some argue that monetary values can be robustly estimated, others question this. While we do not comment upon the veracity of these competing arguments, in the present analysis of scenarios we have adopted non-monetary, objective indicators such as the number of species becoming locally extinct in an area. These can then be compared against the monetary costs and benefits of each scenario, and most particularly those such as agricultural output, which has a direct impact upon bird diversity, so that we can undertake an analysis of the trade-offs between monetary and non-monetary measures occurring under each scenario. Admittedly this does not provide that clear guidance to decision making that a full cost-benefit analysis (CBA) would. However, CBA is just an informational input to the decision-making process, it is not the decision per se. Therefore we feel justified that our approach is consistent with an extension of existing decision analysis techniques.

38 As discussed, our farmland bird analysis adopts a somewhat earlier baseline. As this would lead our analysis to yield an upper bound prediction of impacts (as all changes are on average negative), this means that ours is a risk averse assessment and hence is considered acceptable for the present purposes.

Table 26.22 Per household and aggregated benefit changes of UK NEA Scenarios for Great Britain using distributional weights. Per household values are based on the 15.2 million households living in the urban areas included in the extrapolation.

	Go with the Flow	*Green and Pleasant Land*	*Local Stewardship*	*National Security*	*Nature@ Work*	*World Markets*
	Aggregate values in £billion (using distributional weights)					
Undiscounted value change	-154	180	166	-776	368	-1,850
Annuity (60 years)	-2.56	3.01	2.77	-12.9	6.14	-30.8
Net Present Value (HM Treasury – Standard Discounting)	-64	76	70	-325	154	-775
Annuity (infinite, 3.5%)	-2.25	2.65	2.43	-11.4	5.40	-27.1
Net Present Value (HM Treasury - Scenario Specific Discounting)	-72	76	98	-405	127	-775
Annuity (infinite, scenario specific)	-2.15	2.65	1.96	-10.1	5.72	-27.1
	Per household values in £ (using distributional weights)					
Undiscounted value change	-10,100	11,900	10,900	-51,100	24,300	-122,000
Annuity (60 years)	-169	198	182	-852	404	-2,030
Net Present Value (HM Treasury – Standard Discounting)	-4,240	4,980	4,580	-21,400	10,200	-51,100
Annuity (infinite, 3.5%)	-149	174	160	-750	356	-1,790
Net Present Value (HM Treasury – Scenario Specific Discounting)	-4,720	4,980	6,450	-26,700	8,370	-51,100
Annuity (infinite, scenario specific)	-142	174	129	-667	377	-1,790

26.7.2 Synthesis of Scenario Values

With the analysis of scenario impacts on individual ecosystems services complete, we can begin to synthesise results together. Great care has to be exercised in the interpretation of such findings. Most obviously, while this analysis goes beyond the normal decision remit of purely market values, it only considers a small subset of ecosystem service-related goods. Many market and non-market values are omitted here and so the analysis is necessarily partial and incomplete. Similarly, we are not considering the extent to which different scenarios impinge upon international trade and the effective import of ecosystem services (e.g. water embodied in agricultural imports) and resultant export of an ecological footprint. While these are important caveats, they do not undermine the fundamental objective of this analysis, which is to demonstrate that methods for the integrated valuation of highly varied goods have now been developed. However, there is an obvious danger of a simplistic acceptance of the following results as representing the value of all changes induced under any scenario. This would be highly erroneous and must be resisted. Nevertheless, what this demonstration does illustrate is that methods exists which address many of the key challenges to the incorporation of ecosystem services and the wider values of the natural environment within practical decision making. Furthermore, even this partial analysis amply shows that such incorporation can radically alter the apparent value of a given scenario or policy option. As such, these techniques point to a superior basis for future decision making.

Table 26.23 summarises comparable results from the various analyses reported in this chapter. It is important to recall that all of the values and impacts recorded here relate to changes rather than totals. So, for example, the agricultural values reported are simply for the change in value relative to the baseline. Total values could readily be computed by adding these to the baseline value. However, while we acknowledge that total values can be of some political use, such as underlining the importance of environmental resources as opposed to, say, the contribution of the health sector to well-being, the same example serves to show that no policy maker would ever wish to take a decision which placed either total value in jeopardy.[39] Instead it is the change in value induced by policy or other drivers which should be the focus of decision analysis allowing an informed choice between options.

Examining the monetary values reported in **Table 26.23** reveals a number of interesting findings. A general observation is that the magnitude of value changes within the farm provisioning services is generally lower than those of other monetised goods. This is immediately important, as it is only agricultural values which are reflected in market prices. This means that, from the outset, we can see that simple reliance upon market values is likely to yield an inaccurate assessment of the overall economic value of the different scenarios to society. In simple terms, analyses such as those provided by the UK NEA are vital if we are to ensure efficient decision making and an optimal allocation of resources.

39 It is also worth noting that for methodological reasons, the accuracy of total values is considerably smaller than that of value changes. While small deviations from the status quo can be reliably valued, a comparison of the status quo to an extreme and highly hypothetical state of the world where no ecosystem services are provided is on much shakier grounds.

Turning to consider the various scenarios under analysis we can see that the contrasting land uses, pollutions, urban extents and other characteristics of these scenarios are reflected in correspondingly different overall valuations. We can summarise these as follows:[40]

- ***Go with the Flow***: Here, overall agricultural incomes rise (although our geographical analysis shows that this is driven by gains in the south and lowlands offsetting losses in the north and uplands). As expected, these gains are largest under high climate change, reflecting the increased productivity arising from higher temperatures. (This reflects our analysis in Chapter 22; indeed, impacts on national farm incomes are always more positive under the high emissions variant of each scenario). These gains are added to by increases in recreational values, especially in areas where there are high urban population levels. Furthermore, there are generally positive trends in general bird diversity and farmland birds, which have declined significantly over the past half century, remain at present levels. However, the increase in agricultural production envisioned under this scenario results in a substantial increase in carbon emissions. There is also a marked reduction in the amenity value of urban greenspace, which results from a combination of two effects. First, the expansion of Urban areas increases the average distance to the nearest urban greenspace. Second, substantial urban population growth exacerbates both crowding in greenspaces and population density in general. The provision of additional formal recreation sites under this scenario is insufficient to compensate for this, leaving urban households with an average annual loss in the order of £129/annum.

Table 26.23 Summary impacts for the change from the 2000 baseline to 2060 under each of the UK NEA Scenarios for Great Britain (High and Low Emissions). All values given in £ million per annum. Scenarios are as follows: GF = *Go with the Flow*; GPL = *Green and Pleasant Land*; LS = *Local Stewardship*; NS = *National Security*; NW = *Nature@Work*; WM = *World Markets*.

	GF High	GF Low	GPL High	GPL Low	LS High	LS Low	NS High	NS Low	NW High	NW Low	WM High	WM Low
	£millions p.a. (real values, £2010)											
Market agricultural output values*	590	220	-30	-290	430	350	1,200	680	-110	-510	880	420
Non-market greenhouse gas emissions†	-810	-800	2,410	2,410	570	-100	3,400	3,590	4,570	4,590	-1,680	-2,130
Non-market recreation‡	4,120	5,710	5,160	6,100	1,100	1,540	3,340	4,490	23,910	24,170	-820	5,040
Non-market urban greenspace¶	-1,960	-1,960	2,350	2,350	2,160	2,160	-9,940	-9,940	4,730	4,730	-24,000	-24,000
Total monetised values§	1,940	3,170	9,890	10,570	4,260	3,950	-2,000	-1,180	33,100	32,980	-25,620	-20,670
	Non-monetised impacts**											
Change in farmland bird species‡‡	0	0	0	0	0	0	-1	-1	-1	-1	0	0
Bird diversity (all species)††	++	++	++	++	-	-	++	+++	++	++	- -	+
Rank: Market values only	4	8	9	11	5	7	1	3	10	12	2	6
Rank: All monetary values	8	7	4	3	5	6	10	9	1	2	12	11
Rank: positive monetary values & number farmland bird losses	6	5	2	1	3	4						
Rank: positive monetary values & biodiversity gains	4	3	2	1								

* Change in total GB farm gross margin.
† Change from baseline year (2000) in annual costs of greenhouse gas (greenhouse gas) emissions from GB terrestrial ecosystems in 2060 under the UK NEA Scenarios (millions £/yr); negative values represent increases in annual costs of greenhouse gas emissions.
‡ Annual value change for all of GB.
¶ Annuity value; negative values indicate losses of urban greenspace amenity value.
§ We acknowledge some double counting between urban recreation and urban greenspace amenity values. Further data is needed to correct for this.
** Note that some commentators prefer to use monetised values for biodiversity. See discussion in Chapter 22.
†† Based on relative diversity scores for all species.
‡‡ Expected impact on the mean number of species in the seeds and invertebrates guild (including many farmland bird species) present in each 10 km square in England and Wales from 1988 to 2060 (rounded to the nearest whole number)—the 2000 baseline has 19 species in this guild (Dugdale 2010).

40 All of the assessments of monetary values presented in Table 26.23 are indifferent to the allocation of gains and losses across society. However, as discussed previously, this need not be the case. Indeed, policy makers have an explicit remit to consider distributional issues. Generally, the economist would argue that these should not be dealt with through the manipulation of values for any given good, preferring instead that these issues are dealt with directly through explicit redistribution policies such as progressive taxation (Just *et al.* 1987). While our instinct (as, in the main, economists) is to agree with the mainstream view, some would argue that the allocation of non-market environmental benefits can itself be used as a tool of redistribution and indeed this is allowed for in the Treasury Green Book which supplies a methodology for redistribution weighting of benefits.

Taking these various and opposing effects together, this scenario implies a modest overall net benefit. Two caveats are important, though. First, as mentioned, we are only considering a subset of market and non-market values here. While this seems preferable to the standard pure focus upon market values alone, it is still a partial and provisional analysis and should not be interpreted as implying that overall such a scenario improves welfare. Secondly, as emphasised at the start of this chapter, the *Go with the Flow* scenario does not conform to a standard economic 'do-nothing' baseline. Therefore it should not be interpreted as implying that an absence of any policy response will somehow lead to a beneficial outcome for society.

- ***Green and Pleasant Land***: The reduction in agricultural intensity envisioned under this scenario leads to a decline in farm incomes (driven by losses in northern and upland areas which are only partly offset by gains in the southern lowlands), although this becomes relatively small when mitigated by a more rapidly warming climate. However, this pro-environment scenario results in substantial benefits in terms of reduced emissions. The scenario also generates very high gains in recreational value (second only to the *Nature@Work* scenario). Urban greenspace amenity improves as the average distance to urban parks remains constant but their size increases substantially and urban population growth and hence crowding is less than in the *Go with the Flow* scenario. Given that *Green and Pleasant Land* replicates the impact on birdlife exhibited by the *Go with the Flow* scenario, it is clear that, from a social value perspective, *Green and Pleasant Land* dominates *Go with the Flow*. Again, this result underlines the vital importance of analyses such as the UK NEA; if we were to restrict our analysis solely to market prices then the loss in agricultural values would reverse this outcome and reject a scenario which clearly benefits society as a whole.

- ***Local Stewardship***: While the *Go with the Flow* and *Green and Pleasant Land* scenarios implied trade-offs between market and non-market (environmental) values, the *Local Stewardship* scenario appears to offer a win-win situation in terms of its monetised benefits. Agricultural incomes, recreation values and urban greenspace amenity all improve. Benefits derived from urban greenspace increase by about £142 per urban household per year as the urban population remains constant and provision of urban greenspace improves. However, returning to consider agricultural impacts, increases in farm incomes are confined to lowland areas, while upland regions exhibit falling incomes. Elsewhere, impacts upon greenhouse gas emissions are somewhat equivocal and themselves depend upon the rate of climate change. The *Local Stewardship* scenario also results in our first decline in overall bird diversity, although noticeably, this does not extend to our high-concern farmland species. Contrasting this scenario with, say, *Green and Pleasant Land*, gives us an analysis of the costs of avoiding that former decline. The analysis cannot provide a cost-benefit assessment of whether or not those costs represent a suitable trade-off for the improvement in general bird diversity they would deliver, as we do not have robust non-use biodiversity values. However, if we contrast, say, the low emission *Local Stewardship* value (£3,950 million/annum), which does impose some decline in biodiversity, with the low emissions *Go with the Flow* value (£3,170 million/annum), which maintains biodiversity, we can see that the opportunity cost of avoiding that biodiversity loss is roughly £780 million per annum.

- ***National Security***: This scenario delivers the greatest gain in market-priced goods as agricultural incomes increase markedly. Net greenhouse gas emissions fall, due, in part, to the envisioned investment in Woodland, which in turn contributes to the modest increase in recreational values. However, the prioritisation of provisioning output results in very substantial falls in urban greenspace values to the extent that they dominate the other monetary values generated. The decline in urban greenspace values is driven by a marked loss in urban formal recreation sites, accompanied by a substantial increase in the urban population. Our biodiversity indicators extend trends seen from the middle of the last century, i.e. overall measures of general bird diversity improve, but our priority farmland bird indicators record the first localised species loss. Clearly, a decision rule which precluded options that result in such extinctions would reject such a scenario.

- ***Nature@Work***: The headline prioritisation of multifunctional landscapes results in a marked decline in agricultural lands and with it, farm income. While this does generate strong improvements in our general biodiversity indicator, it actually results in a fall in our priority farmland bird indicator. Impacts upon greenhouse gas show the greatest reduction in emissions (compared to the baseline) of any of the scenarios. Moreover, the emphasis given to multifunctional landscapes results in by far the largest gains in both recreational values and urban greenspace amenity. The latter is driven by a substantial expansion in the provision of formal recreation sites, with only a moderate increase in urban population. These gains mean that, in monetary terms, the sum of market and non-market values is far larger in this than in any other scenario. In short, if society is prepared to accept the local loss of some farmland bird species, then this is by far the scenario yielding the highest net benefits. However, that caveat highlights the problem of dealing with a non-use value for biodiversity which, we argue, cannot be robustly established. In the end this is a problem which decision-makers would have to tackle.

- ***World Markets***: The drive for unfettered economic growth envisioned under this scenario leads to substantial market-priced gains in agricultural output value. Where these are most extreme (under the high emission variant) they lead to the only losses of recreational value generated by any scenario, although these are slightly less than the increase in agricultural output values. However, these values are dwarfed by the losses in urban greenspace value and the rise in greenhouse gas emissions, both of which are larger than under any other scenario. In terms of urban growth, the *World Markets* scenario models an extreme case. The urban population increases by more than half, and the increase in urban greenspace is not sufficient to compensate for the fact that households live on average much further away from parks that are now more crowded. However, while *World Markets* clearly has

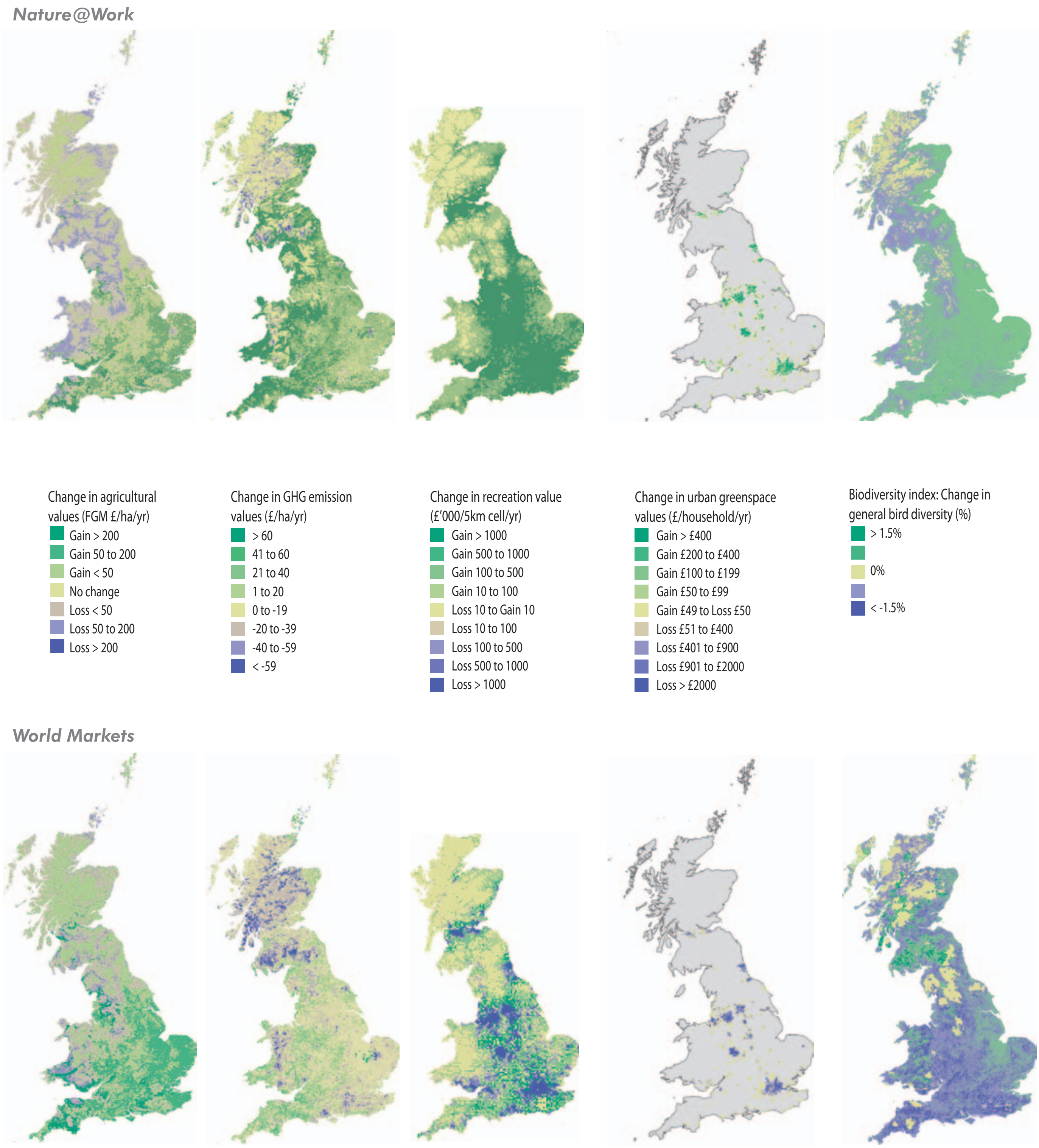


Figure 26.26 Spatial distribution of the changes induced by moving from the year 2000 baseline in five ecosystem service related goods (agricultural production (FGM: Farm Gross Margin); greenhouse gas (GHG) emissions; recreation; urban greenspace; biodiversity) under the *Nature@Work* scenario (upper row) and the *World Markets* scenario (lower row) for Great Britain.

a strongly negative effect on urban greenspace amenity, the actual monetary value derived should be treated with some caution as the scenario requires extrapolation well beyond the range of observable data. Clearly, the lunge for market values here generates outcomes which are undesirable in terms of overall social welfare. Furthermore, while the prioritisation of agriculture means that changes in farmland birds are not significant, the high emissions variant of *World Markets* generates the largest reduction in our general biodiversity indicator. In summary, this scenario does not offer an efficient allocation of resources for British society.

Considering all of the scenarios together underlines the vital importance of extending conventional decision analysis techniques to incorporate the generally non-market values generated by ecosystem services. The last four rows of **Table 26.23** underscore this message. The first of these ranks the UK NEA Scenarios solely according to the market value goods they generate: here represented by agricultural produce. We can see that most of the scenarios generate improvements in agricultural values (as indicated by the green shading of cells), particularly under their high climate change variants, with the *National Security* and *World Markets* scenarios providing the highest value, while the *Nature@Work* and *Green and Pleasant Land* scenarios produce, respectively, the greatest and second greatest losses of all scenarios. The following row extends our analysis to include all monetised values, irrespective of whether they are generated in markets or not. Here the ranking of scenarios changes dramatically, with the *Nature@Work* scenario moving from being the worst to now being the best option in terms of social value and the *Green and Pleasant Land* scenario coming second. In a similar manner, the *National Security* and *World Markets* scenarios, which were ranked as best in terms of market values alone, now appear to yield the two worst outcomes in terms of their overall social value. This is a major message of the UK NEA: omission of non-market values can result in socially sub-optimal situations, or even outcomes which actually reduce overall social welfare.

The final two rows of the table progressively exclude scenarios purely on the basis of their outcomes in terms of biodiversity. The penultimate row ranks outcomes only for those scenarios which both generate net social benefits and which avoid any further losses to our priority farmland bird diversity measure. This leads to the rejection of the *Nature@Work* scenario, because its reduction in agricultural area results in localised losses of some farmland bird species. However, the opportunity costs of rejecting this scenario (which actually improves other biodiversity measures) are substantial, amounting to a loss of net social benefits of over £20,000 million/annum or two-thirds of the net value of the *Nature@Work* scenario. The final row of **Table 26.23** further restricts the analysis to only those scenarios which actually deliver biodiversity gains; although in this application the optimal scenario does not alter.

26.7.3 Spatial Patterns of Change

Our analysis has demonstrated that market and non-market values and non-monetary assessments vary substantially across both scenarios and locations. We end our analysis by demonstrating the versatility of the methodology developed in capturing this variation. In **Figure 26.26** we compare two contrasting scenarios, *Nature@Work* high emissions and *World Markets* high emissions, in terms of each of the dimensions of change they generate. As can be seen, even when a scenario generates net benefits at a national scale, there are still winners and losers across different areas. The methodology developed provides decision-makers with the quantitative information required to incorporate this variation within the policy process. Long term, we feel that this constitutes one of the major contributions of this work. While we recognise that the analyses presented here are far from complete, nevertheless we contend that they constitute an agenda for future development in improving the incorporation of real world environmental complexity within economic assessments and decision-making analyses.

References

Abson, D.J., Termansen, M., Pascual, U., Fezzi, C., Bateman, I.J. & Aslam, U. (2010) Valuing regulating services (climate regulation) from UK terrestrial ecosystems. Report to the Economics Team of the UK National Ecosystem Assessment, School of Earth and Environment, University of Leeds, Department of Land Economy, University of Cambridge, and Centre for Social and Economic Research on the Global Environment (CSERGE), University of East Anglia. [online] Available at: <http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx> [Accessed 18.03.11].

Antle, J. & Capalbo, S. (2001) Econometric-process models for integrated assessment of agricultural production systems. *American Journal of Agricultural Economics*, **83**, 389–401.

Bateman, I.J., Carson, R.T., Day, B., Hanemann, W.M., Hanley, N., Hett, T., Jones-Lee, M., Loomes, G., Mourato, S., Özdemiroglu, E., Pearce, D.W., Sugden, R. & Swanson, J. (2002) Economic Valuation with Stated Preference Techniques: A Manual. Edward Elgar Publishing, Cheltenham.

DECC (Department of Energy and Climate Change) (2009) Carbon valuation in UK policy appraisal: a revised approach. Departmant of Energy and Climate Change, London.

Defra (Department for Environment, Food and Rural Affairs) (2010) Wild populations: farmland birds in England 2009. Statistical release, Department for Environment, Food and Rural Affairs. [online] Available at: < http://www.defra.gov.uk/statistics/environment/biodiversity/england-biodiversity-indicators/> [Accessed 23.03.11].

Dugdale, S. (2010) Habitat Association Modelling for Farmland Birds, Report to the Economics Team of the UK National Ecosystem Assessment. CSERGE, University of East Anglia, Norwich. Experian (2010) Mosaic UK 2009/2008. [online] Available at: <http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx> [Accessed 23.03.11].

Fezzi, C. & Bateman, I.J. (2010) Structural Agricultural Land Use Modelling for Spatial Agro-Environmental Policy Analysis. Centre for Social and Economic Research on the Global Environment (CSERGE), School of Environmental Sciences, University of East Anglia, Norwich.

Fezzi, C., Bateman, I.J., Askew, T., Munday, P. Pascual, U., Sen, A. & Coombes, E. (2010a) Enclosed Farmland 1: Provisioning services, Report to the Economics Team of the UK National Ecosystem Assessment. Centre for Social and Economic Research on the Global Environment (CSERGE), School of Environmental Sciences, University of East Anglia, Norwich. [online] Available at: <http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx> [Accessed 18.03.11].

Fezzi, C., Hutchins, M., Rigby, D., Bateman, I.J., Posen, P. & Deflandre-Vlandas, A. (2010b) Integrated assessment of Water Framework Directive nitrate reduction measures. *Agricultural Economics*, **41**, 123–134.

Fezzi, C., Crowe, A., Abson, D., Bateman, I.J. & Haines-Young, R. (2011) Agricultural food production scenarios. Report to the UK National Ecosystem Assessment. Centre for Social and Economic Research on the Global Environment (CSERGE), School of Environmental Sciences, University of East Anglia, Norwich. [online] Available at: <http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx> [Accessed 23.03.11].

Gibbons, D.W., Reid, J.B. & Chapman, R.A. (1993) The New atlas of breeding birds in Britain and Ireland: 1988-1991. T. & A.D. Poyser, London.

Gregory, R.D., van Strien, A., Voríšek, P., Meyling, A.W.G., Noble, D.G., Foppen, R.P.B. & Gibbons, D.W. (2005) Developing indicators for European birds. *Philosophical Transactions of Royal Society B*, **360**, 269–288.

Hardin, G. (1968) The tragedy of the commons. *Science*, **162**, 1243–1248.

HM Treasury (2003) The Green Book: Appraisal and Evaluation in Central Government. HMSO, London.

Hulme, M. & Siriwardena, G. (2010) Breeding bird diversity as a function of land cover. Report to the Economics Team of the UK National Ecosystem Assessment, British Trust for Ornithology, Thetford. [online] Available at: <http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx> [Accessed 23.03.11].

Jones, A.P., Wright, J., Bateman, I.J. & Schaafsma, M. (2010) Estimating arrival numbers for informal recreation: A geographical approach and case study of British woodlands. *Sustainability*, **2**(2), 684–701. DOI:10.3390/su2020684.

Just, R.E., Hueth, D.L. & Schmitz, A. (1982) Applied Welfare Economics and Public Policy. Prentice Hall, Englewood Cliffs, New Jersey.

Perino, G., Andrews, B., Kontoleon, A. & Bateman, I.J. (2011) Urban Greenspace Amenity: Economic Assessment of Ecosystem Services provided by UK Urban Habitats. Report to the UK National Ecosystem Assessment, University of East Anglia, Norwich. [online] Available at: <http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx> [Accessed 23.03.11].

Sen, A., Darnell, A., Crowe, A., Bateman, I.J. & Munday, P. (2011) Economic Assessment of the Value of Open-Access Recreation in UK Ecosystems: A Scenario Analysis. Report to the UK National Ecosystem Assessment, Centre for Social and Economic Research on the Global Environment (CSERGE), School of Environmental Sciences, University of East Anglia, Norwich. [online] Available at: <http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx> [Accessed 23.03.11].

Stern, N. (2006). Stern Review on The Economics of Climate Change: Executive Summary. HM Treasury, London.

Thomson, A.M., Mobbs, D.C. & Milne, R. (2007) Annual inventory estimates for the UK. Inventory and projections of UK emissions by sources and removals by sinks due to land use, land use change and forestry (eds A.M. Thomson & M. Van Oijen). Centre for Ecology and Hydrology/Defra, London.