Urban Greenspace Amenity[1]

Economic Assessment of Ecosystem Services provided by UK Urban Habitats

Report to the Economics Team of the UK National Ecosystem Assessment

University of East Anglia

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0. Executive Summary

Key ecosystem services provided by urban greenspace in the UK as identified by Davies et al. (2011) are valued using the benefit transfer method. These benefits include recreation, aesthetics, physical and mental health, neighbourhood development, noise regulation and air pollution reduction provided to local residents as a bundled good. A number of additional ecosystem services provided by urban greenspace are covered elsewhere. Sen et al. (2011) value recreational benefits of parks to non-residents via day trips, Mourato et al. (2011) cover domestic gardens, Termansen et al. (2011) considers the benefits of carbon stored by urban ecosystems and Morling (2011) treats biodiversity. Nevertheless, some services like the impact of urban greenspace on the reduction of downstream flooding risks are not covered. The values presented should therefore be treated as lower bound estimates.

Based on a meta-analysis of economic studies valuing urban greenspace in the UK, marginal value functions of proximity to Formal Recreation Sites (FRS: parks, gardens, accessible recreation grounds and accessible woodlands of at least 1ha) and City-Edge Greenspace are estimated. A marginal value function of General Greenspace (natural land cover) is derived from Cheshire and Sheppard (1995). For five UK cities these value functions are combined with detailed geographical information system (GIS) data to calculate the benefit changes implied by the six NEA scenarios (Haines-Young et al., 2010) at the level of full postcodes. Table 1 presents the quantitative representation of the six NEA scenarios for urban areas.

Average per household values are presented for all five cities and the spatial distribution of benefit changes within cities is illustrated using Norwich as an example. The spatial variation of benefit gains and losses within cities is largely driven by location of Formal Recreation Sites and the distribution of income.

To extrapolate benefit changes to urban areas in Great Britain, the median of postcode level per-household values is computed for each Lower Super Output Area (LSOA) in each of the five cities. They are then regressed on variables generally observable at this or a higher level (median household income, population density etc.). The estimated functions are then applied to all LSOAs in Great Britain that are part of a city with a population of 50,000 or more.

Table 1: Changes in key urban parameters implied by NEA scenarios 2010-2060.

Scenario	Change in Urban Area in %	Change in Urban Population in %	Change of FRS Area in %	Change of Informal Greenspace Area in %
Green & Pleasant Land	0.0	21.7	38.9	5.4
Nature@Work	-3.0	13.8	39.0	-4.9
World Market	79.0	52.6	73.0	20.7
National Security	-3.0	17.2	-34.3	4.8
Local Stewardship	-3.0	0.0	4.5	2.8
Go with the Flow	3.0	32.2	36.2	0.0

The extrapolation reveals that households living in major conurbations such as London, Birmingham and Manchester stand to gain or lose the most by the changes in urban ecosystem services specified in the NEA Scenarios. The impacts on households in smaller cities and the fringes of the bigger urban areas are typically less but still can be in the order of a few thousand pounds.

The estimated changes in benefits derived from urban ecosystems measured as discounted capital values are presented in Table 2. They differ substantially between scenarios. Different policy regimes can hence result in both substantial increases (about £9k per urban household in the Nature@Work scenario) or decreases (about £-45k per urban household in the World Market scenario) in urban ecosystem services. The report analyses the effects on these values if alternative discounting regimes. All values presented in this report are based on a fifty year (2010 – 2060) period over which the changes implied by scenarios are spread. These are the values reported in the *Economics* chapter of the NEA. For comparability purposes a sixty year period (2000 – 2060) is used in the *Scenario Valuation* chapter which is achieved by applying a simple conversion factor.
When distributional weights (H.M. Treasury, 2003) are applied to correct for the difference in marginal utilities of consumption at different income levels, the impact of changes in greenspace supply increase by up to thirty percent since less well off households are more

dependent on publicly provided greenspace than more affluent households. The effect is even more pronounced in Scotland where distributional weights double the impact of some scenarios.

Country level summaries are provided.

Table 2: Per household and aggregated benefit changes of scenarios for Great Britain as net present values using HM Treasury (2003, standard) discount rates for all cities with a population of 50,000 or more.

	Green & Pleasant Land	**Nature@Work**	**World Market**	**National Security**	**Local Stewardship**	**Go with the Flow**
Aggregate Benefit Changes in Billion £	66	134	-676	-280	61	-55
Per Household[3] Benefit Changes in £	4,360	8,800	-44,500	-18,500	4,000	-3,650

While the values reported are approximations that are affected by a number of shortcomings in both data availability and methodology, they represent the first systematic attempt to value marginal changes in the UK's urban greenspace for a number of plausible policy scenarios taking spatial heterogeneity into account.

[3] Based on the 15.2 million urban households living in the areas included in the extrapolation.

1. Introduction

The full array of ecosystem services provided by urban greenspace in the UK are discussed in great detail in Chapter 10 by Davies et al. (2011). The aim of the present report is to quantify and value a selected subset of benefits. The focus is on key benefits derived from urban greenspaces that can be meaningfully measured including recreation by residents, aesthetics, physical and mental health, neighbourhood development, noise regulation and air pollution reduction.

The above benefits will be measured as a bundle. It is therefore not possible to disentangle individual value categories. Davies et al. (2011) provide some estimates of individual services. However, to do so for the whole range of benefits measured below, this would require both dose-response functions establishing the relationship between a specific increase in urban greenspace and the service provided (e.g. a specific reduction in air pollution) and valuation studies that monetize the benefit changes of exactly such a change in environmental quality. While this information is available for a small selection of benefits, this is not the case for the full range evaluated below. Furthermore, adding up all those individual values would create the risk of double counting as many services are indeed provided as bundles and disentanglement is difficult even at the stage of provision.

The extent of the analysis is nevertheless restricted by the availability of valuation studies that provide usable monetary measures for the services under concern. To some extent this is due to the inherent difficulty of valuing some of these services. However a further constraint is the lack of relevant studies in this area for the UK in particular. As not all benefit categories can be fully measured, the values presented should be viewed as lower bound estimates.

Some important ecosystem services derived from urban greenspaces are valued in other reports to the National Ecosystem Assessment. The economics report on cultural services (Mourato et al., 2011) covers domestic gardens.[4] Carbon storage is covered by the economics report on enclosed farmland (Termansen et al., 2011) and day visits to urban parks from people living outside the city's boundaries are included in the analysis in the economics report on recreation (Sen et al., 2011). Morling (2011) treats biodiversity.

[4] Note that the greenspace variable they use differs markedly from the one used in this chapter. We focus on three types of urban greenspaces using high resolution, city specific GIS data. The cultural services group uses the label 'greenspace' to summarize all areas covered with vegetation, i.e. most of the rural countryside.

Together this covers many of the ecosystem services provided by urban greenspaces discussed in Davies et al. (2011). Nevertheless there are some exceptions that could not be meaningfully measured within this exercise. Among them is the role of urban greenspaces in water flow regulation and flood prevention as far as they are not reflected by prices of nearby properties.

2. Methodology

Five UK cities, Aberdeen, Bristol, Norwich, Sheffield and Glasgow, are studied in detail with summary statistics for each being provided in Table 3. They are selected on the grounds of including cities of different size, location and for which the necessary data is made available by city councils. In section 5 the values are then extrapolated to other urban areas in Great Britain.

Table 3: Characteristic variables of cities included in the study area.

	Aberdeen	Bristol	Glasgow	Norwich	Sheffield
Population in study area[5]	210,400	402,358	588,470	181,340	473,746
Households in study area[6]	91,616	169,080	272,847	84,576	204,025
Number of formal recreation sites (>1 ha)	77	67	223	33	134
Total area of formal recreation sites (ha)	738	1,318	2,225	401	1,772
Area of Formal Recreation Sites per household (m^2)	80.5	77.9	81.6	47.4	86.8
Informal Greenspace (ha)	1,443	2,174	6,026	3,531	2,866
Informal Greenspace per household (m^2)	157.5	128.6	220.9	417.5	140.5

For each city, a study area is defined as the developed land use area (OS Meridian DLUA) within the 2001 census District Area boundary for each city. Spatially referenced data

[5] Based on Lower Super Output Areas of the postcodes included.
[6] Based on address counts of postcodes included (excluding small businesses).

concerning the distribution of accessible greenspace is supplied by city councils, the UK Forestry Commission and Natural England. This data is used within a Geographical Information System (GIS) to compute a layer of *Formal Recreation Sites* for each city. Formal Recreation Sites (parks) are defined as accessible greenspaces of at least 1 ha in size and include; accessible formal parks (including play parks) and gardens, accessible recreation grounds, accessible woodlands (from the Forestry Commission Woods For People Data Set) and other natural areas covered by the Natural England CROW access layers.

The straight distances to all formal recreation sites from all postcodes in the study areas are calculated where straight distance is defined as that from each geometric postcode centroid to each geometric park centroid using a 3,000m cut off point. City-Edge Greenspace directly adjacent to the boundary of cities is taken into account by computing the straight distance to the city boundary as defined above but ignoring parts of the boundary that border on the developed land use boundary of other cities.

To take account of all other greenspace not included in the Formal Recreation Site layer or the City-Edge Greenspace category the percentage of *General Greenspace* is calculated within $1km^2$ grid squares draped over each of the study areas. General Greenspace was defined as any land designated natural by the OS Mastermap Topographic area layer (scale 1:1250) using a 1m resolution. Formal Recreation Sites and City-Edge Greenspace are taken into account. This is important since the presence of a major park or proximity to the city's edge does affect the marginal value of an extra bit of General Greenspace. The General Greenspace category picks up benefits of green spaces that are not directly distance related and do not depend on accessibility or connectivity. The greenspace included over and above Formal Recreation Sites and City-Edge Greenspace is labelled *Informal Greenspace*. A discussion of different greenspace definitions and classifications and the problems created by the absence of consistent and comprehensive data on UK urban greenspace can be found in Davies et al. (2011).

For all postcodes, the number of households is obtained from the 2010 (February edition) UK National Statistics Postcode Directory.[7] Median gross annual household incomes for each postcode area are taken from the 2008 Experian Mosaic Public Sector data set at the Census Lower Super Output Area.

2.1 Economic Valuation

Our empirical approach uses the meta-analysis method to derive marginal value functions for the types of greenspace identified above. Meta-analysis is a commonly used and robust approach that aims to econometrically estimate a functional relationship between a specified dependent variable and a series of independent variables based on coefficients that have been estimated in existing empirical studies. In our case, the dependent variable we aim to explain is the marginal value of living in proximity to urban greenspace. The explanatory variables include characteristics of the urban greenspace valued in the original studies such as size, characteristics of the sample of each study and of the study area (e.g. median income levels of the area), and methodological characteristics of the studies themselves. The first step of the meta-analysis method is to determine which studies are usable (in that the method used in a particular study is valid, that its results are adequately and openly disclosed, that it is well executed and that it is relevant to the aims of the specific meta-analysis). Once this is accomplished the relevant data sets from the original studies are assembled and any necessary standardization transformations are performed (e.g. to standardize all monetary values into the same base year using a price index transformation). This step is followed by an econometric analysis of the data which yields a meta-analytic function. Finally, this function is used to predict the levels of the dependent variable in question (in our case value of proximity to urban greenspace).

An intense screening of the economics literature produced a set of five studies that value Formal Recreation Sites in UK cities from which 61 marginal valuations of proximity to urban greenspace are extracted. These studies embrace three different valuation methods namely hedonic pricing (two studies giving thirty-seven values), contingent valuation (two studies

[7] Full postcodes were used. A postcode area comprises on average about 20 households (excluding postcodes without residential addresses).

providing six values) and expert interviews (one study yielding eighteen values).[8] The hedonic pricing method uses observed and realised market behavioural data (or so called 'revealed preference' data) to derive a functional relationship between the price of goods and the characteristics of these goods. This function is then used to obtain the value of each of these characteristics. For the case of urban greenspace the main application of the hedonic method is accomplished using data from house sale price coupled with data on the characteristics of these houses. One such set of house characteristics is related to the availability, proximity and the accessibility to a specific quantity and/or quality of urban greenspaces. The estimated hedonic price function is then used to yield estimates of the value (at least to home purchasers and/or tenants) of urban green spaces. This value consists of a bundle of benefits including recreation, aesthetic, and health benefits that cannot easily be decomposed.

Stated preference approaches such as contingent valuation use (as the term suggests) expressed indications of one's possible behavioural choices when presented with a hypothetical market setting. This data is obtained through surveys conducted over the relevant population. Though there is a variety of such methods (e.g. contingent valuation, choice modelling) they all posit to the interviewee some form of trade-off between income and different levels of a private or non-market good. The analyst can then use this information on the types and levels of trade-offs people are willing to undertake in order to derive theoretically consistent measures of value of the change in the quantity or quality of any private or non-market good. Extensive design guidelines exist that in essence aim at minimizing the divergence between the hypothetical trade-offs people state in the survey and the actual behavioural choices they would have opted for if faced with a similar situation in real life. Since the values obtained from these methods are contingent on the hypothetical market setting created by the analysts, in principle these methods can derive separate estimates of any type of benefits associated with green spaces. Yet, this is not always achievable in practice and hence (as in the case of hedonic pricing method) an estimate of a 'bundle' of benefits is obtained. Lastly, expert based methods rely on key stake-holders in a particular market to suggest the appropriate values of a particular good. These values are

[8] The valuation studies included in the meta-analysis are given in a separate section in the list of references.

hence neither derived from market transactions nor asking prices but judgments from qualified surveyors and property agents with long experience in the local property market.

The sixty-one valuations are supplemented with data on the size of and distance to the greenspace analysed in those source studies, income in the study area, population of the city and characteristics of the studies themselves such as the elicitation method used. Table 4 presents summary statistics for the dataset. Note that the dataset includes all relevant UK studies that are deemed to be of sufficient quality and contain the necessary information e.g. on size of the parks valued[9], regardless of whether they find a positive marginal value of proximity to urban greenspace or not. The monetary values reported represent the increase in the value of an urban park if the household moves one meter closer to the centre of the park.

Table 4: Summary statistic of meta-analysis dataset (full description of variables is given in the appendix) used to derive the marginal value functions for Formal Recreation Sites and City-Edge Greenspace.

Variable	No. Obs.	Mean	Median	Std. Dev.	Min	Max
Marginal value of proximity to Formal Recreation Site (£ in 2009 prices per meter), *MValue*	61	150.2	5.3	473.2	-40.7	3,347.6
Size of greenspace (in ha)	61	34.5	18	50.5	0.5	180
Distance (in m)	61	406.1	300	281.0	35	1,500
Green Belt	61	.03	0	.18	0	1
Household **income** (£/year)	61	39,153	29,413	8,119	16,071	48,015
Population of study area	61	471,141	213,800	1,357,238	4,505	7,753,600
No. Obs. in original study	61	4,353	166	10,292	3	32,539
Peer Reviewed	61	.525	1	.506	0	1
Year of Data Collection	61	1992	1984	10.1	1984	2009

[9] Unfortunately this required to exclude a number of high quality studies such as Bateman et al. (2004), Lake et al. (2004) and Powe et al. (1995).

Table 5 presents the regression results for the meta-analysis conducted. The variables are the same as those in Table 4 a full description of which can be found in the appendix. The dependent variable is the marginal value of proximity to urban greenspace in pounds per meter. All regressions presented use a log-log specification to avoid the heteroskedasticity present in a linear model.[10] The log-log specification resulted in the exclusion of the two negative marginal values and hence a sample size of fifty-nine. Regressions (1) and (2) are estimated using OLS on the full sample. Regression (3) is again an OLS regression but including only observations with strictly positive marginal values of proximity to an urban park (MValue+). The reason to focus on this smaller sample is that the absence of a significant impact of distance on marginal value can be due to study design and methodology. For example, none of the studies using contingent valuation finds a significant impact of distance on marginal value with one of them not reporting any results on distance at all. Hence, at least some of these zeros might not be due to the absence of such a relationship but due to study design.

However, just ignoring the zero values bears the risk of over-estimating the impact of the explanatory variables on the marginal value of distance since some of the zero values might be genuine. We therefore use a Heckman selection model that treats all marginal values that are not strictly positive as missing and in two steps estimates both the relationship between study characteristics and the likelihood to observe a strictly positive marginal value and the impact of variables that can drive the real valuations on the marginal value of proximity. Regressions (4) and (5) confirm that the coefficients of the OLS regression (3) are not subject to a selection bias (lambda is not significantly different from zero). Moreover, only one of the variables that could affect the real marginal value is found to have a weakly significant impact on whether the marginal value of proximity to a park is found to be zero or not. Hence, whether a study finds such an effect or not is indeed mainly due to the study's design (here: elicitation method and number of observations).

[10] The Breusch-Pagan / Cook-Weisberg test for heteroskedasticity of regression (3) yields a *p*-value of 0.4716 compared to one of 0.0001 in the linear specification.

Table 5: Regression results of the meta-analysis used to derive the marginal value functions for Formal Recreation Sites and City-Edge Greenspace.

	(1) OLS lnMValue	(2) OLS lnMValue	(3) OLS lnMValue+	(4) Heckman lnMValue+	(5) Heckman lnMValue+
lnDistance	-0.481	-0.662	-0.774**	-0.879**	-0.941***
	(0.292)	(0.123)	(0.049)	(0.018)	(0.008)
lnSize	0.511*	0.439	0.451*	0.520**	0.500**
	(0.091)	(0.128)	(0.092)	(0.040)	(0.032)
lnIncome	-2.517*	-2.976**	-2.393**	-2.873**	-2.945**
	(0.098)	(0.042)	(0.048)	(0.015)	(0.011)
lnPopulation	-0.269	-0.252	-0.562**	-0.524**	-0.554**
	(0.454)	(0.476)	(0.044)	(0.048)	(0.021)
Greenbelt	-1.717				
	(0.344)				
Expert	0.577				
	(0.542)				
PeerReviewed	-0.161				
	(0.850)				
Constant	33.10*	38.88**	38.75***	43.08***	44.53***
	(0.071)	(0.027)	(0.009)	(0.002)	(0.001)
Selection Equation					
lnDistance				0.112	
				(0.684)	
lnSize				0.0678	
				(0.712)	
lnIncome				-1.150	-1.196*
				(0.156)	(0.068)
lnPopulation				0.0623	
				(0.777)	
Expert				2.813*	2.685*
				(0.061)	(0.051)
No.Obs				0.000134**	0.000132**
				(0.025)	(0.016)
PeerReviewed				1.865	1.916
				(0.189)	(0.144)
Constant				8.215	10.27
				(0.404)	(0.131)
mills					
lambda				1.130	1.258
				(0.169)	(0.137)
Observations	59	59	37	61	61
Adjusted R^2	0.043	0.063	0.136	0.0623	
df_r	51	54	32		
F	1.377	1.979	2.416	2.813*	

p-values in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Coefficients are generally robust across specifications. Only the ones for lnDistance and lnPopulation roughly double between (1) and (5). For the key variable lnDistance the difference between (2) and (3) and hence the effect of excluding observations with a zero marginal value of distance has only a minor impact on the coefficient. However, in the case of lnPopulation the reduction in sample size has a substantial effect (compare (2) with (3)). The coefficients of regression (5) are used to specify the marginal value function for proximity to Formal Recreation Sites and City-Edge Greenspace. Distance to park, park size and city income and population are highly significant.

The marginal value functions are monotonically decreasing in distance, income and population and monotonically increasing in the size of the Formal Recreation Site. While the results for distance and size are intuitive those for income and population require some explanation and a note of caution.

The marginal value of proximity is decreasing with income since people with higher income can afford provision and access to substitutes in the form of private gardens and trips to the countryside, respectively. This is reflected in some of the underlying original studies (Dehring and Dunse, 2006; Dunse et al., 2007) that find the prices of flats being more sensitive to the proximity of greenspace than that of detached and non-detached houses. Nevertheless, it is somewhat surprising that this effect appears to dominate the normal good character present for many environmental goods. It has to be noted that only one of the original studies (Andrews, 2009) reports income of participants. The income variable was hence generated by using the description of the study area to retrieve data on Lower Super Output Area (LSOA)-level median household incomes from the Experian Mosaic data set which clearly is less accurate than if income would have been reported in the original studies.

City level population captures any effect correlated with the size of a city including population and park density. The negative effect of population on park valuation might hence be driven by increased crowding of parks in bigger cities.

2.2 The Marginal Value Function for Formal Recreation Sites and City-Edge Greenspace

All studies included in the meta-analysis report one-off payments. Hence, the marginal value functions measure the discounted marginal benefit derived from proximity to a Formal Recreation Site over the planning horizon. Regression (5) in Table 5 identifies the following basic marginal value function for Formal Recreation Sites and City-Edge Greenspace.

MValue(Distance, Size, Income, Population)

$$= \quad e^{44.53} \frac{Size^{0.5}}{Distance^{0.941} \cdot Income^{2.945} \cdot Population^{0.554}} \qquad \text{Eq. 1}$$

This marginal value function is illustrated in Figure 1 (dotted line and right part of the bold line) for a 10 hectare park in a city with a population of 200,000 and a household with an income of £25,000.

To take into account that distance is measured from the centre of a park instead of from its edge, the following adjustment is applied for Formal Recreation Sites.

MValueFRS = MIN[

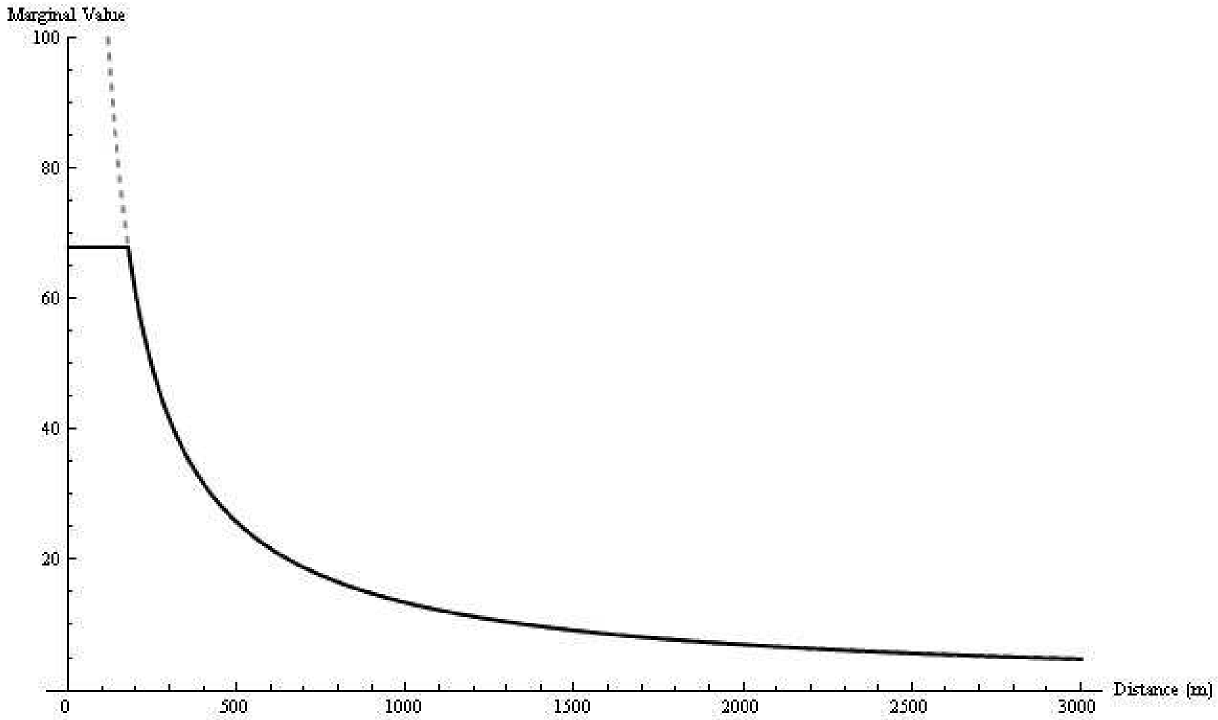
MValue(Distance, Size, Income, Population),

MValue(100(Size/3.14)^0.5, Size, Income, Population)]*

Eq. 2

This adjustment is illustrated by the bold line in Figure 1 and caps the left part of the marginal value function at a distance from the centre of the site that is equivalent to the radius of a circle with the same area as that of the park. This reflects the fact that we cannot distinguish between households living at the edge of a park or a couple of blocks away.

Figure 1: Distance decay function of marginal value for a 10 ha park (population: 200,000; income £25,000).

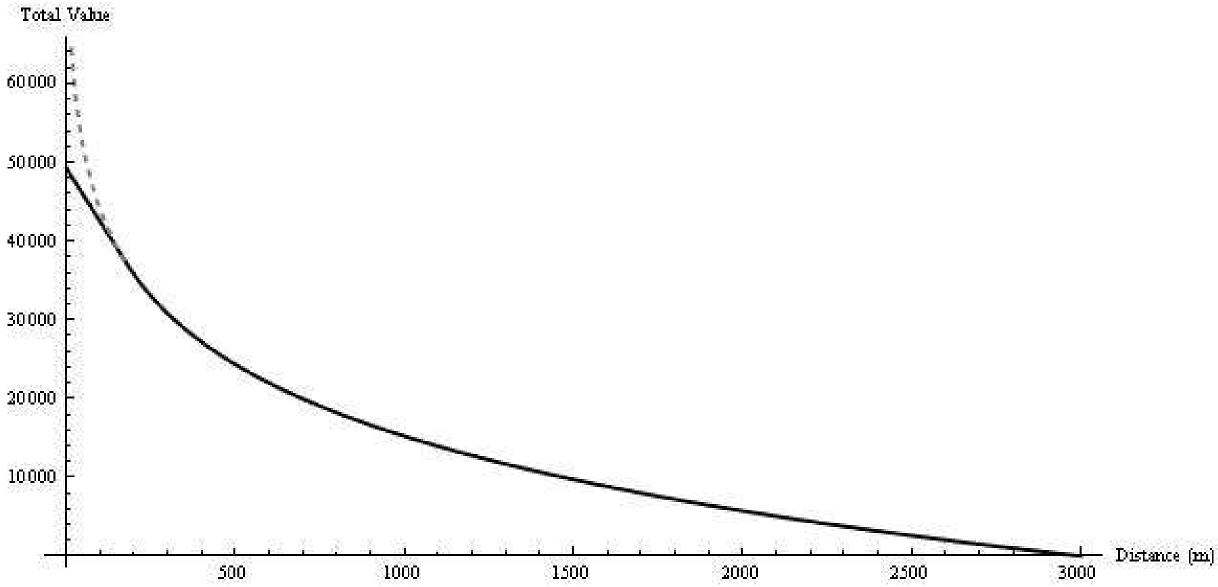


For greenspace at the edge of a city, the adjustment is similar in spirit. However, the crucial difference is that for City-Edge Greenspace we actually measure the distance to the edge and not to the centroid, while the marginal value function is based on centroid based measures. Hence, an unadjusted distance would overestimate the value of City-Edge Greenspace. To correct for this we add the radius of a circle with a 10ha area (178.5m) to distances. The marginal value function used is hence the following

$$MValueEdge = MValue(Distance + 178.5, 10ha, Income, Population) \quad \text{Eq. 3}$$

Adjustments in both equation 2 and 3 make the derived values more conservative and remove a source of high sensitivity. This is especially relevant for Formal Recreation Sites where the distance variable used is rather inaccurate for small distances because it does not measure the distance to the edge of the park which is what really drives most of the actual benefits derived.

Figure 2: Aggregate value generated to a household with a gross income of £25,000 moving closer to a 10ha park starting at a distance of 3,000m (city size: 200,000).



The distance decay functions illustrate the fact that, on average, people living closer to a park typically derive more benefits from its presence than those living further away. This has several reasons. One is that the fraction of people using the site for recreational purposes decreases with distance (Bateman et al, 2006), another is that some of the non recreation ecosystem services such as noise abatement and pollution reduction tend to be greater the closer one lives to the site.

Both for Formal Recreation Sites and City-Edge Greenspace, the change in benefits induced by a policy change is measured by integrating the marginal value function over the interval defined by the policy change. The total value generated to a household moving closer to a Formal Recreation Site (starting at a distance of 3,000m) is given in Figure 2. Again, the bold line presents the actual value function used while the dotted line presents the unadjusted value.

2.3 The Value Function for General Greenspace

For the percentage of General Greenspace in a 1km square, a marginal value function is derived based on results from Cheshire and Sheppard (1995)[11]. This takes the form:

[11] Cheshire and Sheppard (1995) provide two estimates of mean marginal values one for Reading (18%, £120) and one for Darlington (8%, £192) where the marginal values have been converted to 2009 prices. Additionally

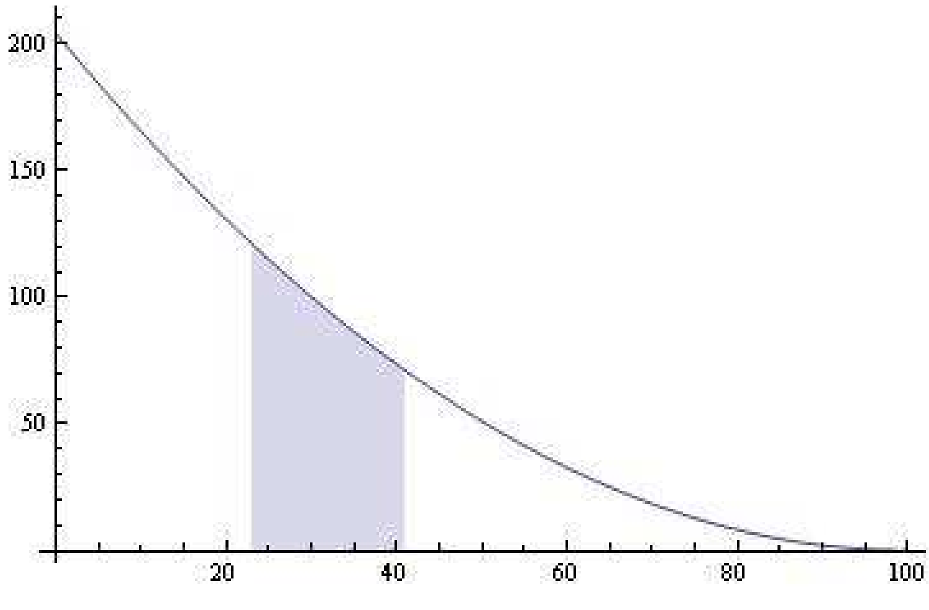
$$MarginalVvalue = 0.02268\ p^2 - 4.53686\ p + 226.843$$

Eq. 4

Where *p* measures the percentage of General Greenspace cover in a $1km^2$ square. The change in benefits caused by a policy affecting the percentage of General Greenspace, *p*, is computed by integrating the above function over the interval given by the current and the proposed percentage of General Greenspace (e.g. the shaded area in Figure 3). The result is a monetary value for the change in discounted benefits induced by a change in the amount of General Greenspace in a household's vicinity. Note that the General Greenspace variable (and the value function derived) is quite different from the 'greenspace' variable used in Mourato et al. (2011). Their greenspace variable includes all 'green' areas in England and effectively captures the countryside and not urban greenspace. The overlap between the two concepts is minimal.

Figure 3 illustrates Eq. 4. The marginal value decreases in the percentage of General Greenspace already available reflecting the standard saturation effect.

Figure 3: Marginal value of % of General Greenspace in a $1km^2$ square



the assumption that the marginal value is zero at 100% has been used. A quadratic function was then fitted through those points using the additional restriction that values are non-negative in the range between 0 and 100%.

The three marginal value functions presented above are combined with detailed GIS data to provide estimates of the gains and losses in urban ecosystem services implied by the six NEA scenarios. The Formal Recreation Sites and City-Edge Greenspace functions measure distinctive physical entities and hence there is no risk of double counting benefits. For the General Greenspace category there is some overlap with both Formal Recreation Sites and City-Edge Greenspace as it includes all natural land cover some of which is also part of the latter two categories. However, double counting is limited for two reasons. Firstly, the type of benefits measured by the General Greenspace function is different from the two distance decay functions. The former measures the value of living in a 'green' neighbourhood as opposed to the proximity to a major greenspace. Secondly, it turns out that the General Greenspace category contributes only a small share of the overall change in benefits (see Table 7). The benefit changes of all three marginal value functions are hence added to obtain the total change in benefits (see Table 7). More details on how the marginal value functions are combined with the GIS data and the changes in provision implied by the six NEA scenarios is given below.

3. Scenarios

The marginal value functions derived above are applied to the six NEA scenarios in order to illustrate how these functions can be used to evaluate different policy proposals. The main purpose is to set out a methodology that allows the application of the functions at the regional or national level.

The six NEA scenarios describe the UK in 2060. Key urban parameters like the area covered by urban settlements, the number of people living in urban areas and the amount of urban greenspace provided are modelled. Table 6 presents the percentage changes for these key variables between 2010 and 2060 for each of the scenarios based on numbers provided by the NEA Scenario group.

The full narrative for each scenario can be found in the NEA scenarios chapter but some brief illustrations are in order. The World Market scenario has the most extreme impact on urban areas. By 2060 the UK experiences dramatic urbanisation both in terms of urban extent and population. An expansion of housing into green belt and parks and gardens results in a loss of green space and built-on surfaces increase substantially. Urban space has diminished considerably as the demand for housing targets every space available. In contrast to that urban extent is reduced in three other scenarios as some housing stock is removed e.g. from areas prone to flooding. In the National Security scenario the dramatic loss in formal recreation sites as they are converted into agricultural land that is less valuable for recreational purposes.

Table 6: Changes in key urban parameters implied by NEA scenarios 2010-2060. Numbers provided by the NEA Scenario team.

Scenario	**Change in Urban Area in %**	**Change in Urban Population in %**	**Change of FRS Area in %**	**Change of Informal Greenspace Area in %**
Green & Pleasant Land	0.0	21.7	38.9	5.4
Nature@Work	-3.0	13.8	39.0	-4.9
World Market	79.0	52.6	73.0	20.7
National Security	-3.0	17.2	-34.3	4.8
Local Stewardship	-3.0	0.0	4.5	2.8
Go with the Flow	3.0	32.2	36.2	0.0

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 all distances (to Formal Recreations 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 Market).[12] This procedure effectively inflates or deflates a city preserving the set of postcodes included but adjusting their relative position.

[12] 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.

The distance between people's home 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 as 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 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's home are decreasing.

The change in urban population is modelled by increasing the population in each postcode by the same percentage to match the new city size. Formal Recreation Sites are expanded or contracted in line with the specifications of each scenario.[13] 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 houses would be located within the new boundaries of a park is limited by the adjustment of the marginal value function described above and illustrated in Figure 1.

The new percentage cover of General Greenspace is calculated by increasing the areas covered by Formal Recreation Sites and by Informal Greenspace in line with the specification of each scenario (see Table 6). The General Greenspace cover is divided by '1 + change in urban area' to take into account the change in the size of the city.

Note that income is held constant. This is done for a number of reasons. The first is that the estimated impact of income on valuation is driven by relative income positions. However, the NEA Scenarios do not quantitatively model the evolution of the income distribution within cities but only report average annual growth rates of GDP until 2060. Secondly, the estimated coefficient is rather large and would likely 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.

[13] This presents a lower bound estimate for any given increase in FRS size. Adding a new park at a different location would generally generate higher benefits than adding the same area to an existing park.

Holding income constant is considered to impose a smaller error than increasing it in line with general GDP growth but keeping relative prices constant.

3.1 Dynamic Aspects

The scenario descriptions (Haines-Young et al., 2010) specify the state of the world in 2060 but do not provide any details about the period in between, i.e. exactly when or at which rate individual changes are assumed to happen. This generates some challenges for the discounting of benefits. This section presents the issues, the approach taken and how to adjust the evaluation of scenarios conditional on the preferred set of assumptions regarding discounting. Note that the issues raised below only affect the per-household and aggregated values for the six scenarios but not the marginal value functions presented above.

Comparing a monetary value of the status quo with that of scenario-endpoints fifty years into the future is not straightforward.[14] Discounting the latter but not the former would obviously induce a substantial bias towards losses. Ideally any marginal change in ecosystem services provided would be valued at the point in time it occurs and discounted appropriately. However, the necessary detail is not available.

The approach taken is the following. Unless stated otherwise all values presented are undiscounted changes in ecosystem services. This is equivalent to assuming that any change in the provision of urban greenspace, population and city size implied by scenarios would occur instantaneously.[15] This obviously results in an overestimation of any benefit change both at the household and at the country level. This can be easily corrected for by assuming that the changes in benefits are spread evenly across the fifty years considered. It is then sufficient to specify the discounting rule in order to compute an adjustment factor that transforms the values presented into the appropriate present values.[16]

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[14] Note that for the Scenario Valuation chapter a period of sixty years (2000 – 2060) is used to make the values comparable with those reported by other groups which due to data availability had to use 2000 as the baseline.

[15] Note, the marginal value function represent discounted values in the sense that they give the present value of any change in benefits at the point in time they occur. The discounting that is the concern of this section is about taking into account that the point in time the change occurs might be in the future.

[16] This procedure assumes that for each individual value change computed (and as the next section describes there are millions of them included in this study) the marginal value function is constant and equal to the average marginal value. This procedure hence underestimates losses and overestimates gains because the real marginal value functions are downward sloping and changes occurring closer to the present are valued higher under any discounting regime.

An obvious candidate discounting rule is the one 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 and at 3% for years 31 to 50. The adjustment factor that transforms the undiscounted benefit changes into present values under this discounting regime is 0.47. This is the discounting rule used for the country maps presented below and abbreviated 'H.M. Treasury – Standard Discounting' in the tables.

However, just applying the above discount rates introduces a degree of inconsistency. They are based on the assumption of a 2% average growth rate of the UK economy. However, four of the six 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 the one used by the Treasury implies differentiated discount rates and hence adjustment factors for each scenario (starting at 0.395 for Nature@Work with up to 0.634 for Local Stewardship). This scenario specific discounting regime is labelled 'H.M. Treasury, scenario specific' in the tables below. Figure 7 illustrates the impact of the consistent scenario specific discounting on the benefit changes induced compared to the standard discounting rule.[17]

Another dynamic aspect is the growth of the urban population. Each NEA scenario specifies by how much the urban population has increased by 2060 (see column three in Table 6). Hence when aggregating per-household values into ones for Great Britain (see Section 5) it matters whether one uses the current size of the urban population or the projected, scenario specific one in 2060. In Section 5 the current population size is used. The values presented can be easily converted using the numbers presented in Table 6.

[17] 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 NEA scenarios the range of adjustment factors spans from 0.51 for Nature@Work to 0.86 for Local stewardship. The fifty year time horizon considered in the NEA arguably involves intergenerational comparisons although not exclusively.

4. Detailed Analysis for Five UK Cities

The change in benefits derived from ecosystem services are simulated for each of the six scenarios. This is done by calculating the change in benefits brought about by the parameter changes given in Table 6 for Formal Recreation Sites, City-Edge Greenspace and General Greenspace for each full postcode in each of the cities. For City-Edge and General Greenspace between 4,248 (Norwich) and 12,548 (Glasgow) individual values are computed for each of the greenspace categories and scenarios. For the change in benefits derived from proximity to Formal Recreation Sites a much larger number of values are computed as the distance decay function Eq. 2 is applied to all sites within a 3km range. As a result in between 45,800 (Norwich) and 360,000 (Glasgow) benefit changes are being calculated per scenario.[18]

Table 7: Per household benefit changes as for all greenspace categories and scenarios for Norwich 2010-2060 (undiscounted).

	Formal Recreation Sites (distance)	**City-Edge Greenspace (distance)**	**General Greenspace (area)**	**Sum**
Green & Pleasant Land	£7,970	n.a.	£389	£8,358
Nature@Work	£18,000	£-2,020	£258	£16,238
World Market	£-71,900	£-10,800	£-780	£-83,480
National Security	£-33,900	£-2,520	£195	£-36,225
Local Stewardship	£7,070	£249	£305	£7,624
Go with the Flow	£-3,980	£-4,880	£192	£-8,668

[18] For Formal Recreation Sites and City-Edge Greenspace the marginal value functions are integrated over the distance variable. The total value in the status quo and under each scenario is computed by taking the difference between the total value at 3,000m and the respective distance. For each scenario the parameters for city population, distance and size are adjusted according to Table 6. The benefit undiscounted change per household for each postcode and scenario is then given by the difference between the scenario and the status quo total values.

For each of the greenspace categories, the postcode level per-household values are multiplied with the number of households living in that particular postcode area and summed across all postcodes of a city. These sums are then divided by the total number of households which yields the per-household values presented in Table 7 for the case of Norwich. Note that the city boundary and hence the distance to City-Edge Greenspace does not change in the Green & Pleasant Land Scenario and hence no value is reported in that category. All benefit changes reported are one-off undiscounted capital values.

Table 8 presents aggregated per-household changes in benefits at the city level for all five cities. The entry for Norwich hence is equal to the last column in Table 7. The per-household values are in the same range across cities with Glasgow being somewhat of an outlier. This might be caused by particularities in its geography including but not restricted to shape and location of parks and the shape of the city itself.

Three scenarios (Green & Pleasant Land, Nature@Work and Local Stewardship) result in an increase in urban ecosystem services as measured in this report with Nature@Work generating the highest benefits. The three other scenarios (World Market, National Security and Go with the Flow) reduce the amount of urban ecosystem services provided in 2060 compared to their current level. Both World Market and National Security impose substantial ecosystem service losses on urban households with World Market having roughly twice the negative impact than National Security and the biggest net impact of all scenarios.

Table 8: Benefit changes per household for all cities in the study area and scenarios aggregated over greenspace categories 2010-2060 (undiscounted)

	Aberdeen	**Bristol**	**Glasgow**	**Norwich**	**Sheffield**
Green & Pleasant Land	£7,992	£6,614	£1,078	£8,358	£11,315
Nature@Work	£16,377	£13,781	£1,750	£16,238	£24,229
World Market	£-83,695	£-69,587	£-14,753	£-83,480	£-110,877
National Security	£-34,584	£-28,252	£-4,228	£-36,225	£-47,667
Local Stewardship	£7,442	£6,290	£1,182	£7,624	£10,372
Go with the Flow	£-7,623	£-5,957	£-1,835	£-8,668	£-8,089

Figure 3: Spatial distribution of benefit changes at the household level for Norwich 2010-2060: Nature@Work (undiscounted)

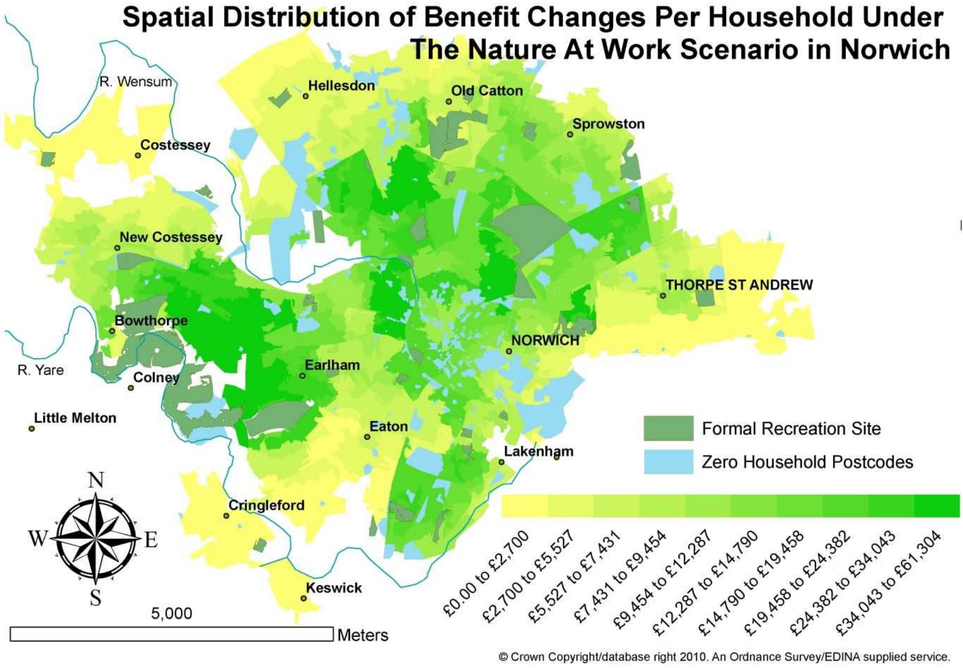
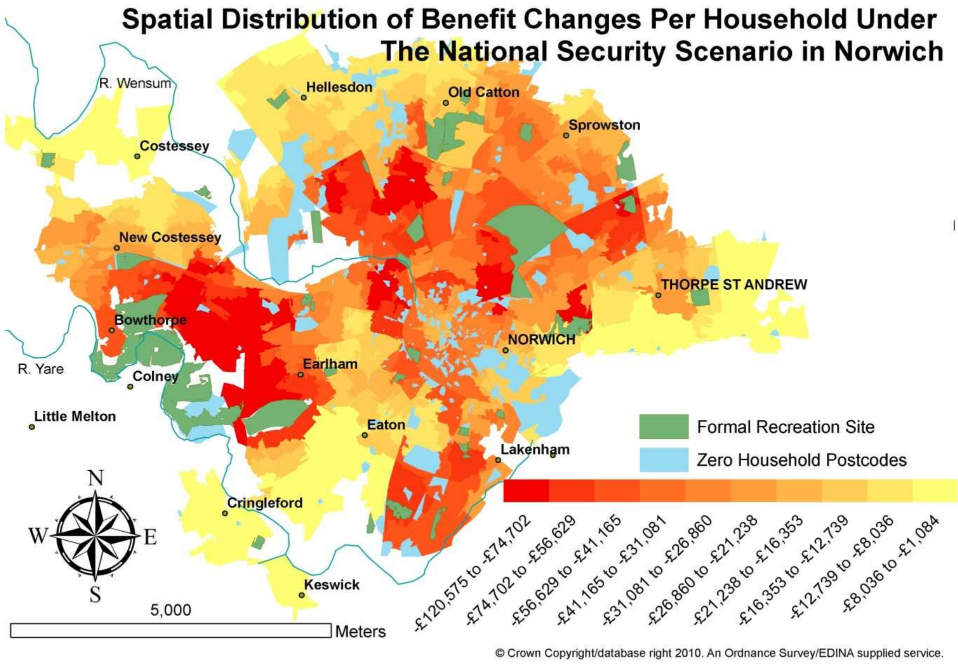


Figure 4: Spatial distribution of benefit changes at the household level for Norwich 2010-2060: National Security (undiscounted)



The spatial distribution of benefit changes at the postcode level is illustrated in Figures 3 and 4 for the Nature@Work and the National Security scenarios, respectively. The spatial distribution of benefit changes is very similar across scenarios with the main difference being their direction and scale. The value added of displaying the remaining four scenarios would therefore be minimal.

The spatial pattern of benefit changes is driven by a number of factors: one being the proximity to Formal Recreation Sites. Households closer to a site are more directly affected by changes in their size. Moreover, the median income of neighbourhoods is reflected in the maps. Since poorer households rely more on publicly and locally provided greenspace for recreational purposes, they suffer or gain more if their provision changes.

5. Extrapolation to Urban Areas in Great Britain

In what follows we restrict our attention to Great Britain as comparable data for Northern Ireland is not available. However, urban areas in Northern Ireland represent only about three percent of total urban area in the UK (Davies et al, 2011, Section 10.1.3). Moreover, we include only cities with a population of 50,000 or more as the methodology used is regarded as less suitable for smaller settlements. The smallest urban area studied in detail is Norwich with a population of roughly 180,000. Extrapolating the values generated to settlements smaller than 50,000 would not seem very plausible. The general reasoning behind this restriction is that for smaller towns urban greenspace plays a lesser role in the provision of many ecosystem services than for larger ones as by their very nature most households live rather close to the non-urban land surrounding the town.

The extrapolation to urban areas in Great Britain is conducted by first computing median per-household benefit changes at the Lower Super Output Area (LSOA) (for English cities) or the datazone (for Scottish cities) level based on the postcode level data generated for the five cities for each scenario. These values are then combined with variables such as total number of households, median gross household income in 2008 and population density obtained at the LSOA/datazone level and the city’s population. Table 9 presents two OLS regressions for each scenario. The first always includes all explanatory variables and the second only those that cannot be rejected as insignificant (at the 1% level) following a stepwise elimination procedure.

Not surprisingly, the natural log of median income is highly significant (*t*-values between 56 and 83) for all scenarios. The obvious reason being that it is one of the variables used to compute the distance related values for Formal Recreation Sites and City-Edge Greenspace (see Eq. 2 and 3). In all regression the coefficient of the income variable is very close to the coefficient used in the respective marginal value functions.

The effect of a city's population has a positive effect on the size of benefit changes although the coefficient of this variable is negative in the marginal value functions Eq. 1 - Eq. 3. The variable CityPopulation hence picks up effects that are correlated with city size but cannot be explicitly controlled for in the above regressions like the number and size of parks and other greenspaces.

Population density is positively correlated with changes in urban ecosystem benefits for all but one scenario. City centres are typically the most densely populated area. They are hence also the ones that are both furthest away from non-urban greenspace and therefore rely most heavily on urban ecosystem services e.g. for recreation. City centres are also usually located in between a number of Formal Recreation Sites and hence a change in their size affects these households more than those living in a city's fringe.
Davies et al. (2011, Section 10.1.3) document an inverse relationship between population density and local greenspace provision. At the same time marginal benefits are typically higher the scarcer the good resulting in a positive relationship between population density and changes in benefits derived from urban ecosystem services. This establishes an alternative rational for the relationship between population density and changes in benefits.

Table 9: Regression of median per household benefit changes at LSOA/Datazone level for all scenarios used to specify the extrapolation functions.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	lnGaP	lnGaP	lnNaW	lnNaW	Ln(-WM)	Ln(-WM)	Ln(-NS)	Ln(-NS)	lnLS	lnLS	Ln(-BAU)	Ln(-BAU)
lnCityPopulation	0.879***	0.704***	0.839***	0.709***	0.751***	0.688***	0.839***	0.728***	0.792***	0.692***	0.721***	0.706***
	(10.12)	(15.00)	(5.20)	(10.97)	(9.80)	(16.69)	(9.92)	(15.99)	(9.94)	(16.15)	(5.95)	(15.35)
lnLSOA-HH	0.251***	0.240***	0.303***	0.295***	0.320***	0.316***	0.257***	0.250***	0.292***	0.286***	0.270***	0.263***
	(5.36)	(5.14)	(4.38)	(4.29)	(7.75)	(7.69)	(5.65)	(5.52)	(6.81)	(6.70)	(4.14)	(4.12)
lnLSOA-Income	-2.998***	-3.000***	-3.130***	-3.131***	-3.020***	-3.020***	-3.211***	-3.212***	-2.987***	-2.988***	-3.229***	-3.225***
	(-72.47)	(-72.44)	(-74.51)	(-74.85)	(-82.92)	(-82.96)	(-79.89)	(-79.91)	(-78.90)	(-78.92)	(-56.55)	(-57.51)
lnLSOA-Pop-Dens	0.108***	0.108***	0.136***	0.136***	0.0968***	0.0969***	0.0845***	0.0846***	0.113***	0.113***	-0.0193	
	(7.32)	(7.32)	(7.07)	(7.05)	(7.49)	(7.49)	(5.92)	(5.93)	(8.38)	(8.39)	(-1.28)	
Glasgow	-0.855***	-0.865***	-0.803***	-0.810***	-0.902***	-0.906***	-0.937***	-0.944***	-0.850***	-0.855***	-1.237***	-1.253***
	(-16.74)	(-16.96)	(-12.02)	(-12.04)	(-20.10)	(-20.25)	(-18.92)	(-19.10)	(-18.21)	(-18.38)	(-21.84)	(-27.09)
Aberdeen	0.236		0.175		0.0843		0.150		0.134		0.0332	
	(2.39)		(0.96)		(0.97)		(1.56)		(1.49)		(0.24)	
Norwich	1.126***	0.933***	0.973***	0.830***	0.958***	0.889***	1.121***	0.998***	1.009***	0.899***	1.166***	1.145***
	(11.06)	(15.00)	(5.54)	(10.58)	(10.67)	(16.22)	(11.31)	(16.50)	(10.81)	(15.78)	(9.02)	(19.97)
Sheffield	0.126*	0.140*	0.169**	0.179**	0.107*	0.112*	0.137*	0.146**	0.124*	0.132*	0.0127	
	(2.77)	(3.11)	(3.44)	(3.87)	(2.69)	(2.85)	(3.12)	(3.35)	(2.99)	(3.22)	(0.30)	
Constant	25.94***	28.36***	28.29***	30.08***	29.70***	30.57***	29.84***	31.38***	26.68***	28.06***	29.37***	29.69***
	(22.48)	(50.93)	(13.12)	(42.70)	(29.19)	(62.53)	(26.58)	(58.13)	(25.23)	(55.19)	(17.69)	(44.07)
Observations	1635	1635	1636	1636	1639	1639	1639	1639	1639	1639	1633	1633
Adjusted R^2	0.782	0.782	0.778	0.778	0.822	0.822	0.810	0.810	0.810	0.809	0.809	0.809
df_r	1626	1627	1627	1628	1630	1631	1630	1631	1630	1631	1624	1627
F	734.8	836.5	798.3	917.8	948.4	1083.8	875.4	999.3	871.8	995.3	654.3	943.0

t statistics in parentheses

* $p < 0.01$, ** $p < 0.001$, *** $p < 0.0001$

Table 10: Per household and aggregated benefit changes of scenarios for all cities with a population of 50,000 or more in Great Britain 2010-2060.

	Green & Pleasant Land	**Nature@Work**	**World Market**	**National Security**	**Local Stewardship**	**Go with the Flow**
Aggregate Values in Billion £						
Undiscounted Value Change	141	284	-1,440	-597	129	-118
Annuity (50 years)	2.81	5.68	-28.8	-11.9	2.59	-2.36
Net Present Value (H.M. Treasury – Standard Discounting)	66	134	-676	-280	61	-55
Annuity (infinite, 3.5%)	2.32	4.67	-23.7	-9.82	2.13	-1.94
Net Present Value (H.M. Treasury - Scenario Specific Discounting)	66	112	-676	-341	82	-61
Annuity (infinite, scenario specific)	2.32	5.05	-23.7	-8.52	1.64	-1.83
Per Household[19] Values in £						
Undiscounted Value Change	9,300	18,700	-94,700	-39,300	8,500	-7,800
Annuity (50 years)	185	374	-1,900	-786	170	-155
Net Present Value (H.M. Treasury – Standard Discounting)	4,360	8,800	-44,500	-18,500	4,000	-3,650
Annuity (infinite, 3.5%)	152	308	-1,560	-647	140	-128
Net Present Value (H.M. Treasury - Scenario Specific Discounting)	4,360	7,400	-44,500	-22,400	5,400	-4,000
Annuity (infinite, scenario specific)	152	333	-1,560	-561	108	-120

[19] Based on the 15.2 million urban households living in the areas included in the extrapolation.

The number of households in a LSOA/datazone is highly significant as are the city dummies for Glasgow and Norwich and the city's population. The goodness of fit is generally high. However, the regressions for Nature@Work and Go with the Flow suffer from heteroskedasticity and hence all *t*-values for those scenarios are computed using robust standard errors.[20]

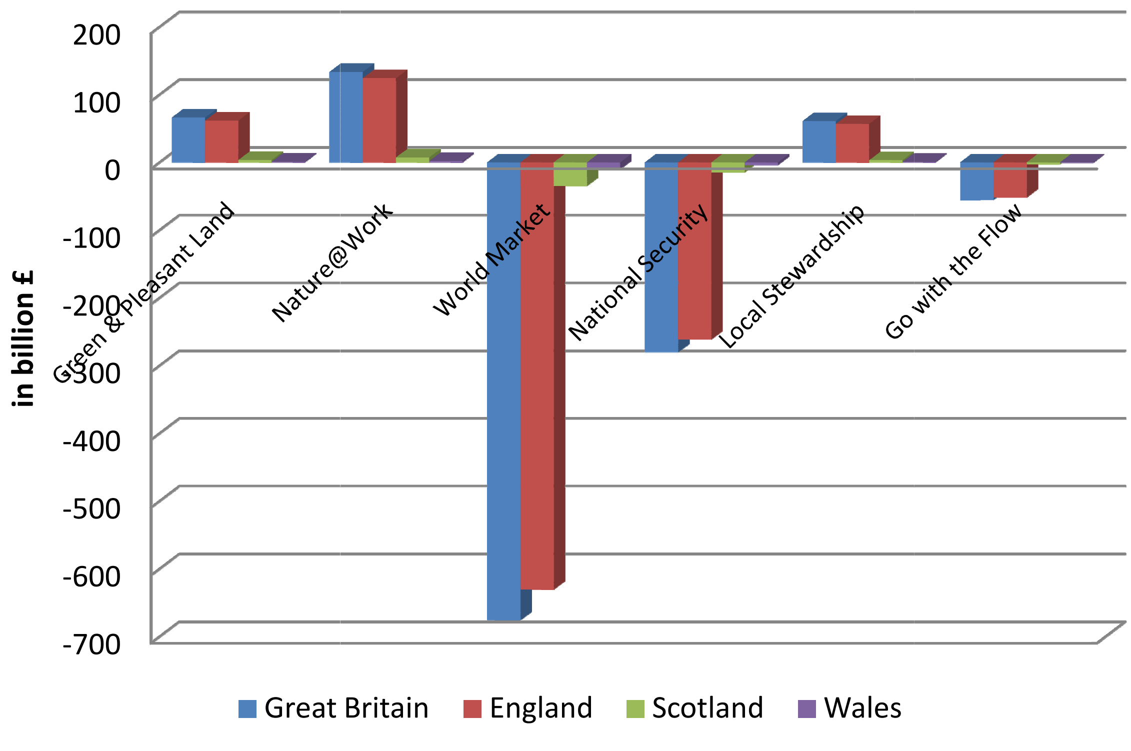
Coefficients of the second regression for each scenario are used to extrapolate the per-household changes in benefits derived from urban ecosystem services for all LSOA/datazones in Great Britain that are part of a city with a population of 50,000 or more.[21] This covers some 25,118 LSOA/datazones and 39.4 million people or about two thirds of the population in Great Britain.[22] For all scenarios a long but very thin tail of outliers was cut by setting the value of the 125 highest (lowest) LSOAs equal to the value predicted for the 126th highest (lowest) LSOA.[23]

Table 10 presents average changes in benefits for urban households in Great Britain and the aggregate value of these changes for entire Great Britain both undiscounted and using both discount regimes presented above. While these numbers should be viewed as rough estimates only, they make clear that the impacts of the scenarios and hence future policy decisions can have substantial impacts on the value of ecosystem services provided in urban areas. In the very extreme case of the World Market scenario the discounted losses amount to roughly half of the UK's GDP in 2009. Country level versions of Table 10 are contained in the appendix (Tables 12-14). The distributions of value estimates at the LSOA-level (not population weighted) are presented in Table 18 in the appendix.

[20] The Breusch-Pagan / Cook-Weisberg test for heteroskedasticity for regressions (3) and (4) yields *p*-values of 0.0069 and 0.0097, respectively. For both regression (11) and (12) the *p*-value of the same test is 0.0000.
[21] The areas of LSOA for Wales are not available and have been replaced by the median size of LSOAs/datazones in England and Scotland (329616.9m^2).
[22] The cities for England and Wales are selected using 2001 census data (DCLG, 2008) and for Scotland using mid-2008 population estimates (GROS, 2008). LSOAs and datazones are then selected based on look-up tables by EDINA UKBORDERS that match city codes to output areas. Median household income is extracted from the 2008, Experian Mosaic data set.
[23] This is equal to 0.5% of the 25,118 LSOAs included. The adjustment was one-sided, cutting the upper tail for the three scenarios that yield aggregate gains and cutting the lower tail for the three that generate aggregate losses.

The changes in amenity value provided by urban greenspace under each scenario is driven by a combination of the following 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 etc.) occurring to urban households. An increase in urban population, ceteris paribus, 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. In the World Market scenario for example 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.

Figure 5: Distribution of scenario value changes across countries (aggregate net present value calculated using with standard H.M. Treasury discounting).



Not surprisingly, the majority of aggregate benefit changes for each scenario would occur in England and only small fractions in Scotland and even less in Wales (see Figure 5). This reflects the differences in population sizes in general and urban populations more specifically. But as Figure 6 illustrates, there are marked differences between the three countries even at the household level. This is due to per households effects being highest in large conurbations which are more prevalent in England than in Scotland and Wales.

Figure 6: Distribution of benefit changes per household across countries (net present value calculated using with standard H.M. Treasury discounting)

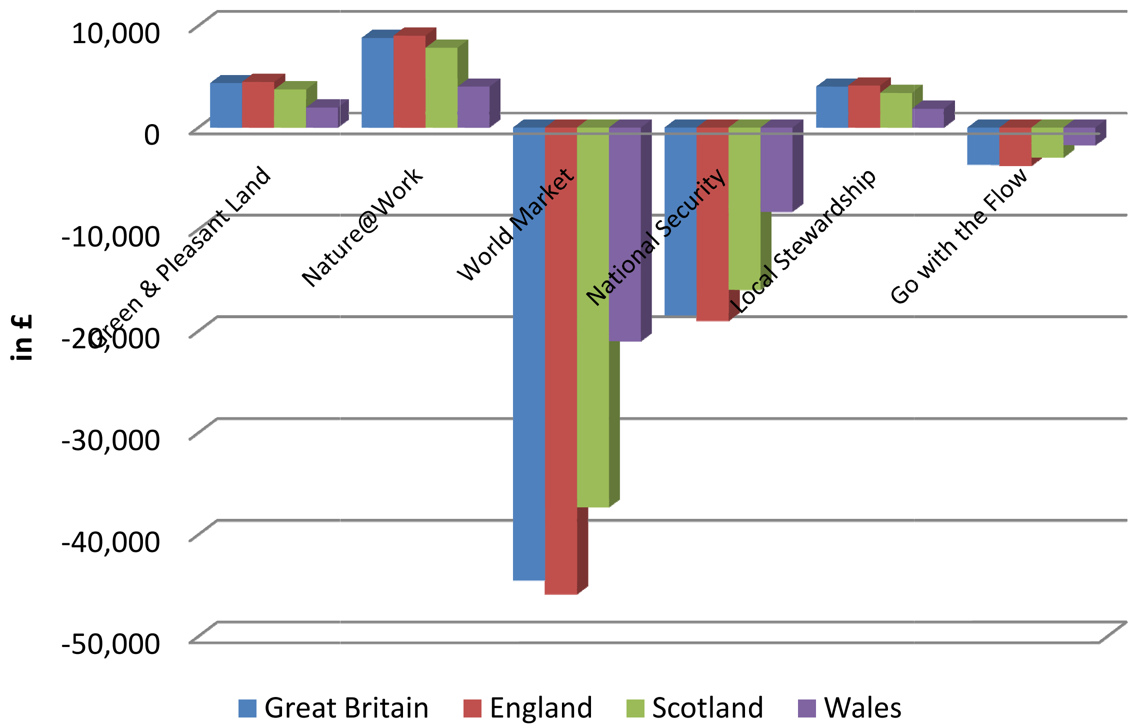
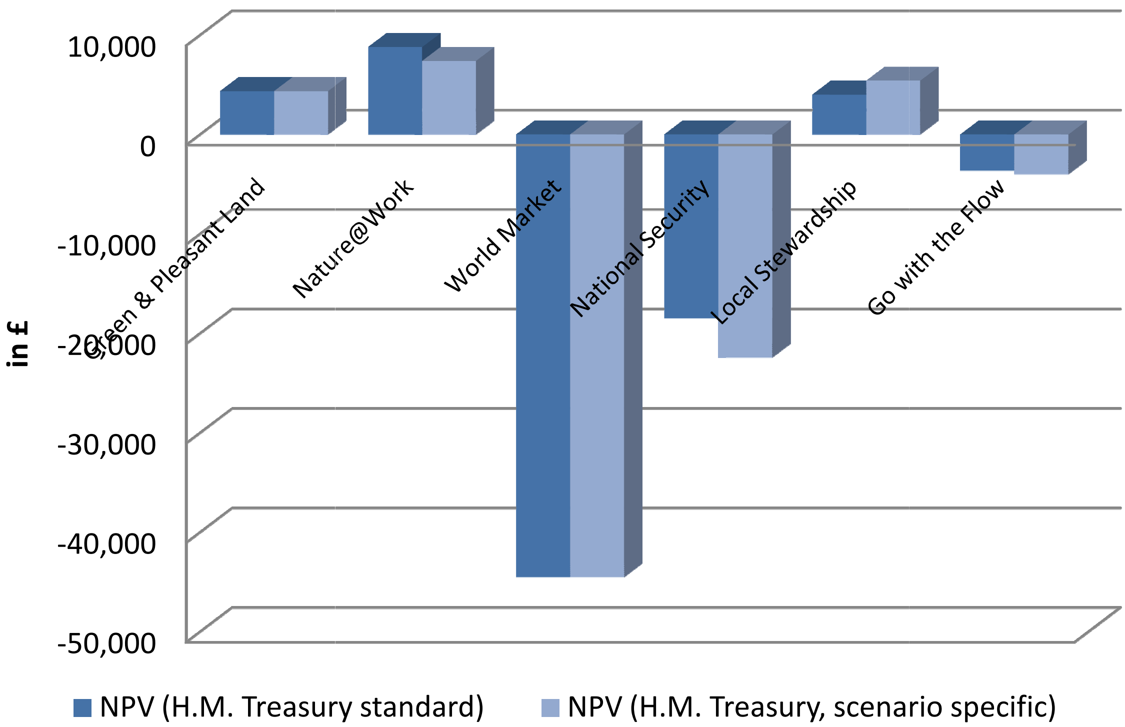


Figure 7 presents the effects of moving from the H.M. Treasury's standard discounting rule to one that takes into account the different growth rates in the respective scenarios and hence is scenario specific. Note that for Green & Pleasant Land and World Market the growth rate is equal to the 2% assumed by H.M. 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 National Security, Local Stewardship and the Go with the Flow scenarios the absolute value of the benefit change increases by up to a third as their growth rates are below the one used by the H.M. Treasury.

Figure 7: Comparing H.M. Treasury standard discounting rule with a scenario specific discounting rule that takes into the account the GDP growth rates assumed in scenarios (net present value per household).



The spatial distribution of gains and losses is presented in Figures 8 and 9 based on the 25,118 LSOA/datazones included in the extrapolation.[24] Figure 8 presents the spatial pattern for the three scenarios (Green and Pleasant Land, Nature@Work and Local Stewardship) that yield net gains while Figure 9 covers the three scenarios (World Market, National Security and Go with the Flow) that generate net losses in terms of urban greenspace amenity. The spatial distribution of costs and benefits is highly correlated across scenarios so that it seems prudent to present them in just two separate maps.[25]

[24] For Aberdeen, Bristol, Glasgow, Norwich and Sheffield the original median values and not the predicted values are used.

[25] The smallest correlation coefficient between the 25,118 values any two scenarios within one of the Figures 8 or 9 is 0.9912. The map of Figure 8 is based on the Green and Pleasant Land and Figure 9 on the World Market scenario.

Figure 8: Spatial distribution of benefit changes under the scenarios which yield net gains for all cities with a population of 50,000 or more in Great Britain (net present value per household using HM Treasury (2003) standard discount rates)

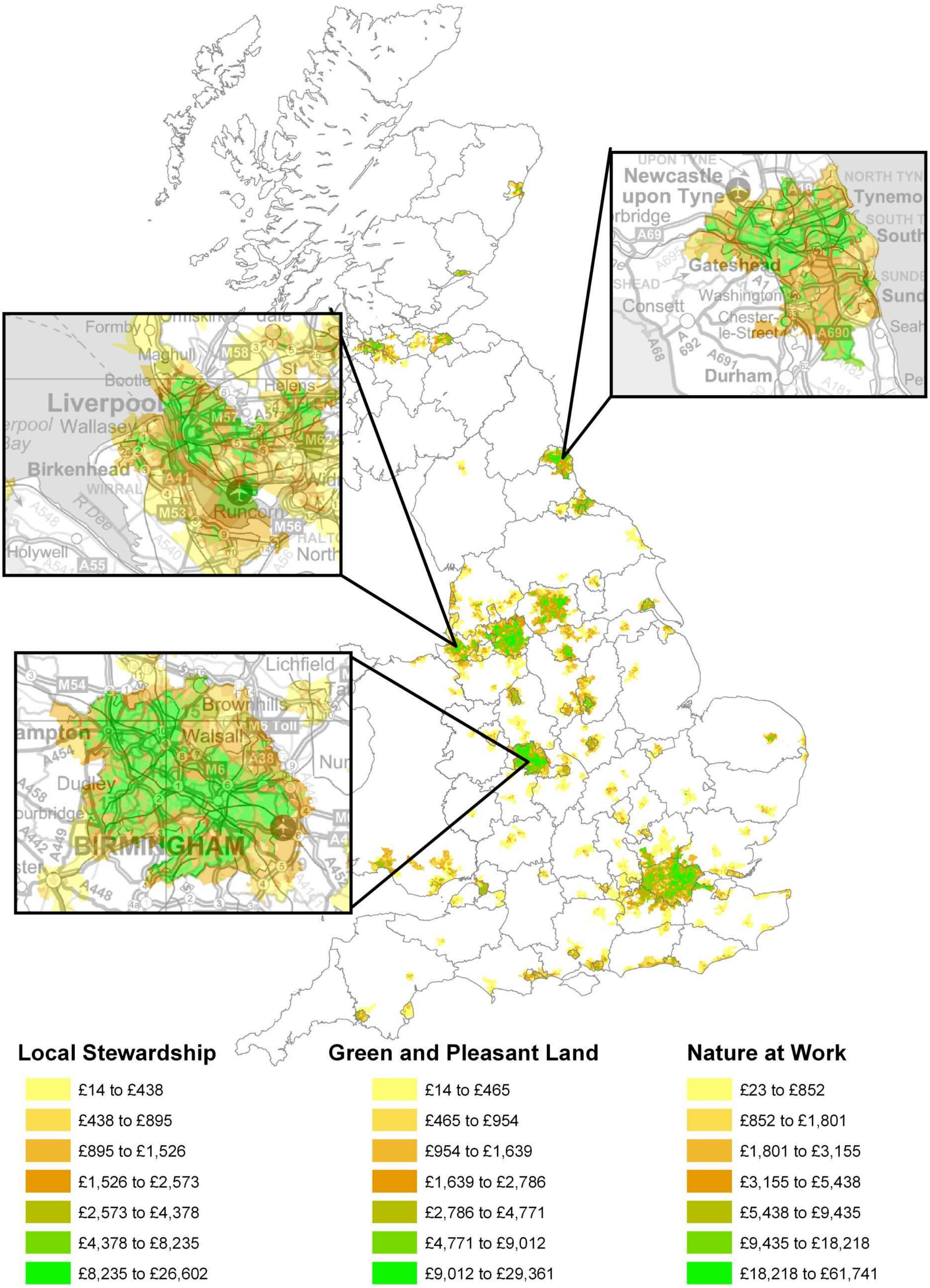
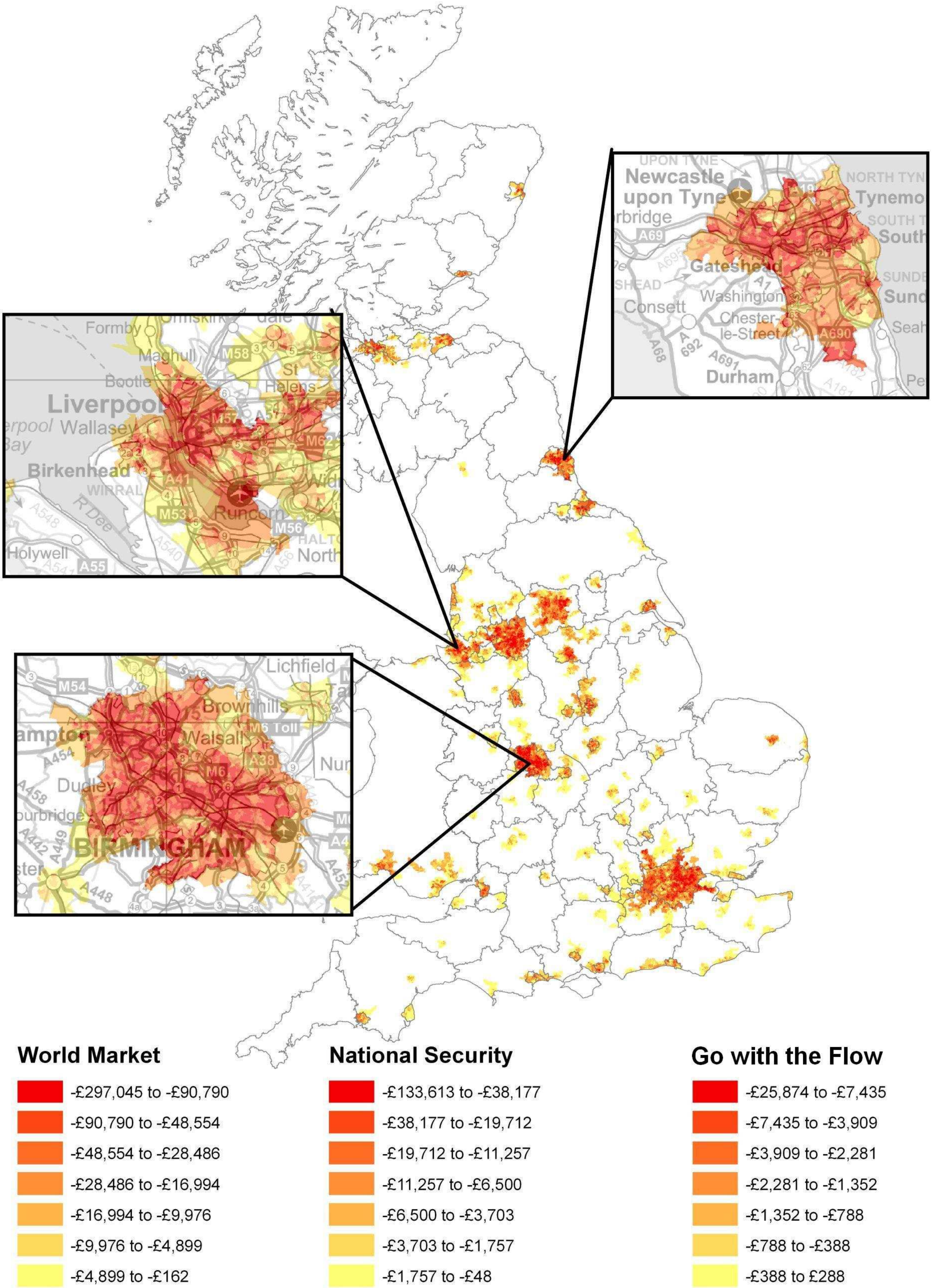


Figure 9: Spatial distribution of benefit changes under the scenarios which yield net losses for all cities with a population of 50,000 or more in Great Britain (net present value per household using HM Treasury (2003) standard discount rates)



The scenarios differ substantially in the scale and direction of changes, but generally speaking both positive and negative impacts are highest in the centres of large urban areas such as London, Birmingham, Manchester, etc. Smaller cities are less affected. This confirms the approach to focus on cities with populations of 50,000. Hence besides being questionable on methodological grounds it would not make too much of a difference if we had included smaller towns in our analysis. Note that all values presented in Figures 8 and 9 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.

5.1 Distributional Weights

The aim of a cost-benefit analysis is to test whether a particular policy or project improves social welfare. Summing up the monetary values of benefit changes across individuals only allows drawing 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 is decreasing with income. Note that the sensitivity of the social discount rate to the rate of economic growth discussed above rests on the same concept.

We hence follow H.M. Treasury (2003, Annex 5) and apply distributional weights to correct for the fact that an additional pound to someone rich is worth less than an additional pound to someone poor. The elasticity of marginal utility with respect to consumption is assumed to be 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.

The median income of households on the UK is calculated using the same data source used elsewhere in this report (Experian Mosaic, 2008) which contains median gross household incomes and the number of household for all LSOAs. By ordering all LSOAs with respect to income and computing the cumulative number of households allows obtaining the median household income for the UK in 2008. It is £25,275

Figure 10: The effect of applying distributional weights on per household benefit changes across Great Britain (net present value per household calculated using with standard H.M. Treasury discounting)

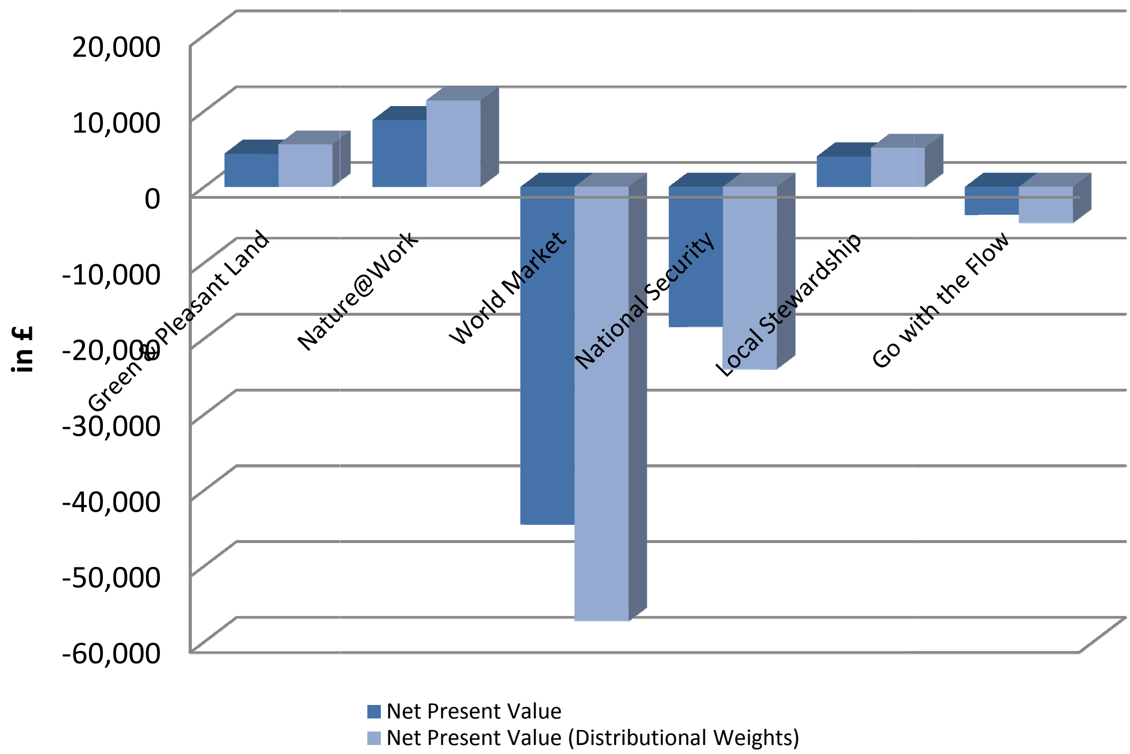
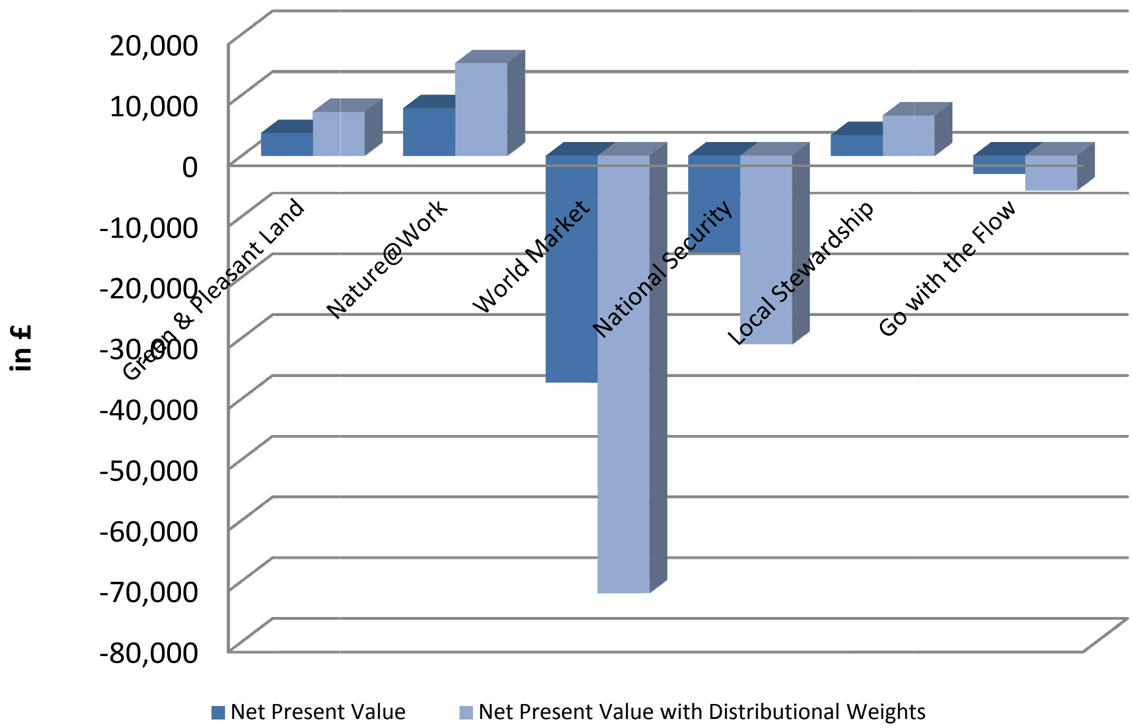


Figure 10 and Table 11 illustrate the impact of distributional weights on the net present value per urban household of each scenario. The benefit changes increase by up to about thirty percent if distributional weights are applied. This indicates that any reduction (increase) in the amount of urban greenspace would disproportionally hurt (benefit) the poor. As Figure 11 demonstrates this is particularly pronounced for Scotland where the impact of scenarios almost doubles if distributional weights are used. This is due to lower incomes in Scotland. Country level versions of Table 11 are contained in the appendix (Tables 15-17). The distributions of value estimates with distributional weights at the LSOA-level (not population weighted) are presented in Table 19 in the appendix.

Figure 11: The effect of applying distributional weights on per household benefit changes in Scotland (net present value per household calculated using with standard H.M. Treasury discounting)



6. Caveats

While, to the best of our knowledge, this report provides the first systematic attempt to value the UK's urban ecosystem services, it still is subject to a number of caveats. The results should hence be treated with an appropriate degree of caution. In addition to the ones discussed above there are caveats of a more general nature to which we turn now.

A first important limitation or the values contained in this report is that a number of benefits people derive from ecosystem services could not or only partially be considered. For example the benefit of living in a 'green' city as opposed to living near to a park (Formal Recreation Site) or in a 'green' neighbourhood (General Greenspace) cannot be captured by the methods applied in this report. This omission results in an underestimation of the true marginal value of urban ecosystem services.

Table 11: Benefit changes of scenarios for all cities with a population of 50,000 or more in Great Britain using distributional weights.

	Green & Pleasant Land	Nature@Work	World Market	National Security	Local Stewardship	Go with the Flow
Aggregate Values in Billion £ (using distributional weights)						
Undiscounted Value Change	180	368	-1,850	-776	166	-154
Annuity (50 years)	3.61	7.37	-37.0	-15.5	3.32	-3.07
Net Present Value (H.M. Treasury – Standard Discounting)	85	173	-870	-365	78	-72
Annuity (infinite, 3.5%)	2.97	6.06	-30.4	-12.8	2.73	-2.53
Net Present Value (H.M. Treasury - Scenario Specific Discounting)	85	146	-870	-443	105	-79
Annuity (infinite, scenario specific)	2.97	6.55	-30.4	-11.1	2.10	-2.38
Per Household[26] Values in £						
Undiscounted Value Change	11,900	24,300	-122,000	-51,100	10,900	-10,100
Annuity (50 years)	238	485	-2,440	-1,020	219	-203
Net Present Value (H.M. Treasury – Standard Discounting)	5,590	11,400	-57,300	-24,000	5,140	-4,760
Annuity (infinite, 3.5%)	196	399	-2,010	-841	180	-167
Net Present Value (H.M. Treasury - Scenario Specific Discounting)	5,590	9,580	-57,300	-29,200	6,930	-5,240
Annuity (infinite, scenario specific)	196	431	-2,010	-730	139	-157

[26] Based on the 15.2 million urban households living in the areas included in the extrapolation.

Secondly, the value functions used are only as good as the original studies they are based on. While the studies included meet certain quality standards, they still differ in quality and are limited in scope.

Thirdly, there is a fundamental problem in that the elicitation methods of the original studies do not allow us to separate the different value categories generated by urban greenspaces. This becomes an issue when transferring values from the original study site to other sites as the composition of services might differ between the two. Although the set of original studies comprises a quite representative sample of UK urban green spaces, the inability to condition on greenspace characteristics (apart from size) is a potentially serious drawback. Only more extensive, sophisticated and standardised original studies could potentially provide enough detail to allow for such a disaggregation of benefit categories (Kirchhoff et al., 1997; Bergstrom and Taylor, 2006; Troy and Wilson, 2006; Eigenbrod et al., 2010).

Fourthly, as stated in the natural science chapter on the urban broad habitat (Davies et al., 2010, Section 10.1.3), standardised data indicating quality or other features of urban greenspaces is not generally available. Combined with more refined valuation results such additional detail of the GIS data would greatly enhance the reliability of the benefit transfer method.

Last not least, some of the scenarios and especially the World Market scenario, imply radical changes in urban extend, population and greenspace provision. The feasibility to credibly model widespread urbanisation as part of this exercise is limited. Especially the values derived for the World Market scenario should hence be treated with caution and taken as indicative only.

7. Conclusion

Urban greenspace, while under constant pressure due to the increasing demand for housing and commercial development, generate substantial benefits to local communities. Quantifying these benefits at a national scale is the aim of this report. Combining benefit transfer and detailed GIS data on a number of UK cities, per household changes in benefits are identified and extrapolated for England, Wales and Scotland for the six NEA scenarios.

This analysis shows that changes in the provision of urban greenspace can create – or destroy – billions of pounds worth of benefits to local residents.

The report presents a methodology to estimate the spatial distribution of gains and losses arising from well specified policy changes. It therefore provides an important tool for the impact analysis of policies bringing about changes in the amount, location and accessibility of urban greenspace.

References

Andrews, Barnaby (2009) An investigation into the effects of distance and environmental attitudes on preferences for new parks in Norwich, unpublished MRes dissertation, University of East Anglia, Norwich

Bateman, Ian J., Brett Day, Stavros Georgiou and Iain Lake (2006) The aggregation of environmental benefit values: Welfare measures, distance decay and total WTP, *Ecological Economics* 60, 450-460.

Bateman, Ian J., Brett Day and Ian Lake (2004) The valuation of transport-related noise in Birmingham, Technical Report to the DfT, 209 pages

Bergstrom, John C. And Laura O. Taylor (2006) Using meta-analysis for benefit transfer: Theory and practice, *Ecological Economics* 60, 351-360.

Cheshire, Paul and Stephen Sheppard (1995) On the price of land and the value of amenities, *Economica* 62, 247-67

Davies, L., M. Batty, H. Beck, H. Brett, K.J. Gaston, J.A. Harris, L. Kwiatkowski, J. Sadler, L. Scholes, W.R.Sheate, R. Wade, P. Burgess, N. Cooper, H.I. McKay, R. Metcalfe and J. Winn (2011), Urban Broad Habitat, UK National Ecosystem Assessment, Chapter 10

Day, B., Bateman, I.J. and Lake, I. (2007) Beyond implicit prices: recovering theoretically consistent and transferable values for noise avoidance from a hedonic property price model, *Environmental and Resource Economics*, 37(1): 211-232, DOI 10.1007/s10640-007-9121-8

DCLG (2008) Urban Settlement 2001: England and Wales, Department of Communities and Local Government, http://www.communities.gov.uk/publications/planningandbuilding/urbansettlement2001 (accessed: 14/11/2010)

Dehring, Carolyn and Neil Dunse (2006) Housing density and the effect of proximity to public open space in Abderdeen, Scotland, *Real Estate Economics* 34(4), 553-566

Dunse, Neil, Michael White and Carolyn Dehring (2007) Urban parks, open space and residential property values, *RICS Research paper series* 7(8) 40 pages

Eigenbrod, Felix, Paul R. Armsworth, Barbara J. Anderson, Andreas Heinemeyer, Simon Gillings, David B. Roy, Chris D. Thomas and Kevin J. Gaston (2010) Error propagation associated with benefit transfer-based mapping of ecosystem services, *Biological Conservation*, forthcoming

Experian, Mosaic UK 2009/2008 [Shapefile geospatial data] http://www.experian.co.uk/business-strategies/mosaic-uk-2009.html Accessed August, 2010

Forestry Commission, Woodland Trust and the Environment and Heritage Service (Northern Ireland) Woods For People - Version 4, Coverage: GB, Updated November 2007. From Forestry Commission CGIS, Victoria Terrace, Aberystwyth.

General Register Office for Scotland, 2001 Census: Digitised Boundary Data (Scotland) [computer file]. ESRC/JISC Census Programme, Census Geography Data Unit (UKBORDERS), EDINA (University of Edinburgh).

GROS (2008) Table 2: Mid-2008 Population Estimates - Localities in order of size, General Register Office for Scotland, http://www.gro-scotland.gov.uk/files2/stats/population-estimates/08mye-localities-table2.pdf (accessed 14/11/2010)

Haines-Young, R.; Paterson, J. and M. Potschin (2010): UK NEA Scenarios: Narratives. Draft Version 1.1, 13.09.2010. CEM Working Paper No 7

Handley, John, Stephan Pauleit, Paul Slinn, Alan Barber, Mark Baker, Carys Jones and Sarah Lindley (2003) Accessible Natural Green Space Standards in Towns and Cities: A Review and Toolkit for their Implementation, English Nature Research Reports Number 526, Peterborough

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

Lake, Ian R., Andrew A. Lovett, Ian J. Bateman and Brett Day (2000) Using GIS and large-scale digital data to implement hedonic pricing studies, *International Journal of Geographical Information Science* 14(6), 521-541

Kirchhoff, Stefanie, Bonnie G. Colby and Jeffrey T. LaFrance (1997) Evaluating the Performance of Benefit Transfer: An Empirical Inquiry, *Journal of Environmental Economics and Management* 33, 75-93.

Morling, P., Comerford, E., Beaumont, N., Bolt, K., van Soest, d. and Vause, J. (2011) Economic Assessment of Biodiversity Ecosystem Services, Report to the Economics Team of the UK National Ecosystem Assessment, RSPB, Sandy, Bedfordshire.

Mourato, S., Atkinson, G., Collins, M., Gibbons, S., MacKerron, G. and Resende, G. (2011) Economic Assessment of Ecosystem Related UK Cultural Services, Report to the

Economics Team of the UK National Ecosystem Assessment, London School of Economics.

Natural England, CRoW Act 2000 – Access Layer [ESRI Shape file]. http://www.gis.naturalengland.org.uk/pubs/gis/GIS_register.asp Accessed: August 2010

Natural England, CRoW Act 2000 – S16 Dedicated Land [ESRI Shape file]. http://www.gis.naturalengland.org.uk/pubs/gis/GIS_register.asp Accessed: August 2010

Natural England, CRoW Act 2000 – S15 Land [ESRI Shape file]. http://www.gis.naturalengland.org.uk/pubs/gis/GIS_register.asp Accessed: August 2010

Office for National Statistics, National Statistics Postcode Directory (NSPD) 2010 February Version [computer file]. ESRC Census Programme, Census Dissemination Unit, Mimas (University of Manchester)/Census Geography Data Unit (UKBORDERS), EDINA (University of Edinburgh)

Office for National Statistics, 2001 Census: Digitised Boundary Data (England and Wales) [computer file]. ESRC/JISC Census Programme, Census Geography Data Unit (UKBORDERS)

OS MasterMap Topography Layer [GML geospatial data], Coverage: Aberdeen, Bristol, Norwich, Glasgow and Sheffield, Updated June 2010, Ordnance Survey, GB. Using: EDINA Digimap Ordnance Survey Service, <http://edina.ac.uk/digimap>, Downloaded: August 2010

OS Meridian 2 (DLUA) [Shapefile geospatial data], Scale 1:50,000, Coverage: UK, Updated April 2010, Ordnance Survey, GB. Using EDINA Digimap Ordnance Survey Service, <http://edina.ac.uk/digimap>, Downloaded: August 2010

OS Code Point with Polygons [Shapefile geospatial data], Coverage: Aberdeen, Bristol, Norwich, Glasgow and Sheffield, Updated March 2010, Ordnance Survey, GB. Using: EDINA Digimap Ordnance Survey Service, <http://edina.ac.uk/digimap>, Downloaded: August 2010

Powe, N. A., G.D. Garrod and K.G. Willis (1995) Valuation of urban amenities using an hedonic price model, *Journal of Property Research* 12(2), 137-147

Sen, A., Darnell, A., Munday, P., Crowe. A. and Bateman, I.J. (2011) Economic Assessment of the Recreational Value of UK Ecosystems, Report to the Economics Team of the UK National Ecosystem Assessment, University of East Anglia.

Termansen, M., Abson, D.J., Pascual, U. and Aslam, U. (2011) Enclosed Farmland 3: Climate regulation, Report to the Economics Team of the UK National Ecosystem Assessment, University of Leeds.

Troy, Austin and Matthew A. Wilson (2006) Mapping ecosystem services: Practical challenges and opportunities in linking GIS and value transfer, *Ecological Economics* 60, 435-449

Studies used in meta-analysis for Formal Recreation Sites and City-Edge Greenspace:

Andrews, Barnaby (2009) An investigation into the effects of distance and environmental attitudes on preferences for new parks in Norwich, unpublished MRes dissertation, University of East Anglia, Norwich

CabeSpace (2005) Does money grow on trees? CABE, London, 87pages

Dehring, Carolyn and Neil Dunse (2006) Housing density and the effect of proximity to public open space in Abderdeen, Scotland, *Real Estate Economics* 34(4), 553-566

Dunse, Neil, Michael White and Carolyn Dehring (2007) Urban parks, open space and residential property values, *RICS Research paper series* 7(8) 40 pages

Hanley, Nick and Jacqui Knight (1992) Valuing the environment: recent UK experience and an application to Green Belt Land, *Journal of Environmental Planning and Management* 35(2), 145-160

Appendix:

Variables used in meta-analysis

Variable	Description
Marginal value of proximity to FRS (£ in 2009 prices per meter)	Marginal value of proximity elicited for the greenspace, i.e. the additional value of moving one meter closer to the Formal Recreation Site. For hedonic pricing method those are implicit prices, for the expert method it is an educated guess of an implicit price and for the contingent valuation studies it is either willingness-to-pay for the creation of a new park or willingness-to-pay to preserve an existing one.
Size of greenspace (in ha)	Size of the greenspace valued in original study.
Distance (in m)	Distance between the greenspace valued and the place of residence of the person/household carrying this value.
Greenbelt	Dummy variable: 1 if the greenspace is part of Green Belt land 0 otherwise.
Income (GBP)	Income of the study area based on averages over median annual before tax household incomes at the Lower Super Output Areas of the 2001 census (using the 2009, Experian Mosaic data set).
Population	Population of the city where the original study was undertaken (using 2009 ONS estimates).
CVM	Dummy variable: 1 if original study uses the contingent valuation method, 0 otherwise.
Expert Method	Dummy variable: 1if original study uses the expert method, 0 otherwise.
Hedonic	Dummy variable: 1if original study uses the hedonic pricing method, 0 otherwise. Not reported as each original study used only one of the three methods.
Peer Reviewed	Dummy variable: 1if original study was published in a peer-reviewed journal, 0 otherwise.
Year of Data Collection	Year the data of the original study was collected.

GIS Methodology

This section describes the process of generating the spatial variables needed for the above value functions. Two main types of spatial variables were required, the distance to Formal Recreation Sites (FRS) and the edge of the urban area, and the % cover of natural land cover types within one square kilometre grid squares. The ArcGIS 9.2 software suite was used to create these spatial measures. A range of data sources were used and these can be seen in the table at the end of this section.

The sequence of data creation:

1) Define Study area
2) Define formal recreational sites (FRS's)
3) Measure Distances to FRS's
4) Measure Distance to Urban Edge
5) Define natural land cover areas
6) Calculate % natural land cover areas
7) Extract Socio-Demographic variables.

Define Study area

In order to create the Formal Recreation Site layer it was first necessary to define a study area for the city under consideration. The OS Meridian Developed Land Use Area (DLUA) polygons were used alongside the 2001 English Census District boundaries (for Scotland the 2001 Council Areas were used) to define study areas. All DLUA's that intersect the District boundary in question were selected and a shape file created from these. Any small towns and villages were removed so that only large urban areas within the district remained. For areas such as Bristol and Sheffield which merge into neighbouring urban areas such as Rotherham (so that they form one continuous DLUA) it was necessary to create a mask layer polygon using a symmetrical difference function on the district polygon and DLUA. This negative image was then used to erase the connecting urban areas. Finally any donut polygons must be removed from within the study areas.

Define Formal Recreation Sites (FRS)

The FRS's were defined as accessible formal parks, gardens (including play parks and playgrounds), accessible recreation grounds and accessible woodlands with an area of one hectare or more that intersected the study area as defined in the previous step. These were primarily extracted from data sets compiled and supplied by city councils as part of their respective green space audits, with the exception of Norwich where Formal Recreation Sites were extracted from the OS Mastermap Topographic area dataset based on maps found on the Norwich City Council website. This data was supplemented with data from the Forestry Commission (Woods For People Data Set) describing the distribution of open access woodlands and data sets from Natural England regarding the distribution of open access greenspaces (CROW S15 S16 and Access Layer). This rather narrow definition of Formal Recreation Sites was used in an attempt to maintain consistency between the various different council data sets, which due to differences in the scope of their greenspace audits represented varying levels of detail.

The FRS layer was created by extracting formal parks and gardens (including play parks and play areas) and accessible recreation grounds (remove school grounds) from the council data that intersect the study area. Checks were made on recreation grounds and play parks to ensure that they represented natural surfaces. Accessible woodlands (from the Forestry Commission Woods for People data, or just all woodlands for Scottish cities) and CROW S15 and CROW open access spaces that intersect the study area are also extracted. These are merged into one layer and the polygons are aggregate to avoid each greenspace having multiple polygons. An aggregation threshold of 50 metres was used for the aggregation however for cities traversed by many rivers such as Aberdeen it was necessary to reduce this threshold to 10m to avoid aggregating greenspaces across rivers. Areas are recalculated for the aggregated polygons and any below one hectare are removed. Finally centroids are calculated for each of the Formal Recreation Sites.

Measure Distances to Formal Recreation Sites

The calculation of distances to the FRS's was done using Hawths Tools distance between points tool using the study area postcode centroids as the source layer and the FRS centroids as the target source layer. An NxN distance matrix was calculated producing an output in which the distance to every FRS is calculated for every postcode. The output from this was then trimmed to remove any distances over 3,000 metres and the FRS's area was joined back on to the output table.

Measure Distance to Edge of Urban Area

The distance of each postcode to the edge of the urban area under consideration was calculated by converting the study area boundary into a series of points. Hawths Tools line to points tool was used to create points at 10 metre intervals along the study boundary. Again Hawths Tools distance between points tool was used with the study boundary points loaded as the target layer and the study area postcode centroids as the source layer, this time the nearest neighbour option was used thus creating the distance from each postcode to the nearest urban exit point. This data was then trimmed to remove any distances above 3,000 metres.

Define natural land cover areas

To take account for the benefits provided by other greenspaces not included as FRS's a layer was created that represents all other natural surfaces in the study area. The OS Mastermap topographic area layer was used to extract all polygons which have a Make attribute "natural" for the study area. In order to avoid double counting of the FRS's these areas were removed from the layer of natural land cover polygons. These "natural" surfaces were converted into a raster grid (with a one metre resolution) and reclassified so that all natural areas are assigned a value of one and all other areas are given a value of 0.

Calculate the Percentage of Natural Land Cover Areas

A one square kilometre grid was created over the study area using the Hawths Tools create vector grid command and any squares that did not intersect the study area were removed. Using these grid squares and the natural raster layer a mean is calculated for the raster values contained in each grid square using the ArcGIS Zonal statistics tool, when multiplied by 100 this mean gives the percentage of land in that grid square that is a natural surface. Every postcode was assigned the mean for the square that its centroid was contained in and these values were exported to the main spreadsheet.

Extract Socio-Demographic variables

Each postcode centroid in the study area was assigned the average household income value for the 2001 Census Lower Super Output Area that it is within (using the 2009, Experian Mosaic data set). These income values for every postcode were added to the spreadsheet. To obtain address counts the study area postcodes were uploaded to the Geoconvert website and address counts for each were extracted from the 2010 NSPD (February version) extracted and added to the final spreadsheet.

Sources of GIS and other data

Data Used	Data source and Declarations
OS Meridian DLUA	http://edina.ac.uk/digimap/ © Crown Copyright/database right 2010. An Ordnance Survey/EDINA supplied service
OS Mastermap Topographic Area and ITN Layer.	http://edina.ac.uk/digimap/ © Crown Copyright/database right 2010. An Ordnance Survey/EDINA supplied service
2001 Census England Districts	http://edina.ac.uk/ukborders/ "This work is based on data provided through EDINA UKBORDERS with the support of the ESRC and JISC and uses boundary material which is copyright of the Crown."
2001 Scottish Council Areas	http://edina.ac.uk/ukborders/ "This work is based on data provided through EDINA UKBORDERS with the support of the ESRC and JISC and uses boundary material which is copyright of the Crown and the Post Office."
OS Code-Point Polygons (Postcode Polygons)	http://edina.ac.uk/digimap/ © Crown Copyright/database right 2010. An Ordnance Survey/EDINA supplied service
Experian Mosaic Public Sector	http://cdu.mimas.ac.uk/experian/index.htm
National Statistics Postcode Directory (NSPD) 2010 February Version	http://geoconvert.mimas.ac.uk/
Forestry Commission Woods For People	We have a special license with the Forestry Commission for this one. © Crown copyright and database right 2010. All rights reserved. Ordnance Survey licence no 100025498.
Councils Green Space Audit Data (Various)	Supplied by the respective city councils.
CROW Act 2000 - Access Layer Crow Act 2000 - S15 Layer CROW Act 2000 – S16 Layer	http://www.gis.naturalengland.org.uk/pubs/gis/gis_register.asp © Crown Copyright and database right 2010. Ordnance Survey licence number 100022021 Terms of Use: http://www.naturalengland.org.uk/Images/DataTerms_tcm6-7878.pdf

OS 1:50,000 Scale Colour Raster (used for background maps)	http://edina.ac.uk/digimap/ © Crown Copyright/database right 2010. An Ordnance Survey/EDINA supplied service
National Statistics Postcode Database (NSPD) 2010 February edition.	Accessed through geoconvert: http://geoconvert.mimas.ac.uk/

Table 12: Per household and aggregated benefit changes of scenarios for all cities with a population of 50,000 or more in England.

	Green & Pleasant Land	**Nature@Work**	**World Market**	**National Security**	**Local Stewardship**	**Go with the Flow**
Aggregate Values in Billion £						
Undiscounted Value Change	131	264	-1,340	-556	121	-110
Annuity (50 years)	2.62	5.29	-26.8	-11.1	2.41	-2.20
Net Present Value (H.M. Treasury – Standard Discounting)	62	124	-631	-261	57	-52
Annuity (infinite, 3.5%)	2.16	4.35	-22.1	-9.15	1.98	-1.81
Net Present Value (H.M. Treasury - Scenario Specific Discounting)	62	104	-631	-318	76	-57
Annuity (infinite, scenario specific)	2.16	4.70	-22.1	-7.94	1.53	-1.71
Per Household[27] Values in £						
Undiscounted Value Change	9,540	19,200	-97,600	-40,500	8,770	-8,010
Annuity (50 years)	191	384	-1,950	-809	175	-160
Net Present Value (H.M. Treasury – Standard Discounting)	4,490	9,030	-45,900	-19,000	4,120	-3,760
Annuity (infinite, 3.5%)	157	316	-1,610	-665	144	-132
Net Present Value (H.M. Treasury - Scenario Specific Discounting)	4,490	7,600	-45,900	-23,100	5,560	-4,100
Annuity (infinite, scenario specific)	157	342	-1,610	-577	111	-124

[27] Based on the 15.2 million urban households living in the areas included in the extrapolation.

Table 13: Per household and aggregated benefit changes of scenarios for all cities with a population of 50,000 or more in Wales

	Green & Pleasant Land	**Nature@Work**	**World Market**	**National Security**	**Local Stewardship**	**Go with the Flow**
Aggregate Values in Billion £						
Undiscounted Value Change	2.06	4.22	-22.1	-8.70	1.95	-1.83
Annuity (50 years)	0.041	0.084	-0.442	-0.174	0.039	-0.037
Net Present Value (H.M. Treasury – Standard Discounting)	0.969	1.98	-10.4	-4.09	0.915	-0.860
Annuity (infinite, 3.5%)	0.034	0.069	-0.363	-0.143	0.032	-0.030
Net Present Value (H.M. Treasury - Scenario Specific Discounting)	0.969	1.67	-10.4	-4.97	1.23	-0.946
Annuity (infinite, scenario specific)	0.034	0.075	-0.363	-0.124	0.025	-0.028
Per Household[28] Values in £						
Undiscounted Value Change	4,170	8,550	-44,700	-17,600	3,940	-3,700
Annuity (50 years)	83	171	-894	-352	79	-74
Net Present Value (H.M. Treasury – Standard Discounting)	1,970	4,010	-21,000	-8,280	1,850	-1,740
Annuity (infinite, 3.5%)	69	141	-735	-290	65	-61
Net Present Value (H.M. Treasury - Scenario Specific Discounting)	1,970	3,380	-21,000	-10,100	2,500	-1,920
Annuity (infinite, scenario specific)	69	152	-735	-251	50	-57

[28] Based on the 15.2 million urban households living in the areas included in the extrapolation.

Table 14: Per household and aggregated benefit changes of scenarios for all cities with a population of 50,000 or more in Scotland.

	Green & Pleasant Land	Nature@Work	World Market	National Security	Local Stewardship	Go with the Flow
Aggregate Values in Billion £						
Undiscounted Value Change	7.43	15.6	-74.2	-31.7	6.79	-5.87
Annuity (50 years)	0.15	0.31	-1.48	-0.63	0.14	-0.12
Net Present Value (H.M. Treasury – Standard Discounting)	3.49	7.32	-34.9	-14.9	3.19	-2.76
Annuity (infinite, 3.5%)	0.12	0.26	-1.22	-0.52	0.11	-0.10
Net Present Value (H.M. Treasury - Scenario Specific Discounting)	3.49	6.15	-34.9	-18.12	4.31	-3.03
Annuity (infinite, scenario specific)	0.12	0.28	-1.22	-0.45	0.09	-0.09
Per Household[29] Values in £						
Undiscounted Value Change	7,950	16,700	-79,400	-33,900	7,270	-6,280
Annuity (50 years)	159	333	-1,590	-679	145	-126
Net Present Value (H.M. Treasury – Standard Discounting)	3,760	7,830	-37,300	-16,000	3,410	-2,950
Annuity (infinite, 3.5%)	131	274	-1,310	-558	120	-103
Net Present Value (H.M. Treasury - Scenario Specific Discounting)	3,760	6,580	-37,300	-19,400	4,610	-3,250
Annuity (infinite, scenario specific)	131	296	-1,310	-485	92	-97

[29] Based on the 15.2 million urban households living in the areas included in the extrapolation.

Table 15: Benefit changes of scenarios for all cities with a population of 50,000 or more in England using distributional weights.

	Green & Pleasant Land	**Nature@Work**	**World Market**	**National Security**	**Local Stewardship**	**Go with the Flow**
Aggregate Values in Billion £ (using distributional weights)						
Undiscounted Value Change	163	331	-1,670	-701	150	-140
Annuity (50 years)	3.26	6.63	-33.5	-14.0	3.00	-2.79
Net Present Value (H.M. Treasury – Standard Discounting)	77	156	-786	-329	70	-66
Annuity (infinite, 3.5%)	2.68	5.45	-27.5	-11.5	2.46	-2.30
Net Present Value (H.M. Treasury - Scenario Specific Discounting)	77	131	-786	-400	95	-72
Annuity (infinite, scenario specific)	2.68	5.89	-27.5	-10.0	1.90	-2.16
Per Household[30] Values in £						
Undiscounted Value Change	11,800	24,100	-122,000	-51,000	10,900	-10,100
Annuity (50 years)	237	482	-2,430	-1,020	218	-203
Net Present Value (H.M. Treasury – Standard Discounting)	5,570	11,300	-57,200	-24,000	5,120	-4,770
Annuity (infinite, 3.5%)	195	396	-2,000	-838	179	-167
Net Present Value (H.M. Treasury - Scenario Specific Discounting)	5,570	9,520	-57,200	-29,100	6,910	-5,250
Annuity (infinite, scenario specific)	195	428	-2,000	-727	138	-157

[30] Based on the 15.2 million urban households living in the areas included in the extrapolation.

Table 16: Benefit changes of scenarios for all cities with a population of 50,000 or more in Wales using distributional weights.

	Green & Pleasant Land	**Nature@Work**	**World Market**	**National Security**	**Local Stewardship**	**Go with the Flow**
Aggregate Values in Billion £ (using distributional weights)						
Undiscounted Value Change	3.23	6.68	-34.6	-13.8	3.04	-2.91
Annuity (50 years)	0.065	0.134	-0.692	-0.277	0.061	-0.058
Net Present Value (H.M. Treasury – Standard Discounting)	1.52	3.14	-16.3	-6.51	1.43	-1.37
Annuity (infinite, 3.5%)	0.053	0.110	-0.569	-0.228	0.050	-0.048
Net Present Value (H.M. Treasury - Scenario Specific Discounting)	1.52	2.64	-16.3	-7.91	1.93	-1.50
Annuity (infinite, scenario specific)	0.053	0.119	-0.569	-0.198	0.039	-0.045
Per Household[31] Values in £						
Undiscounted Value Change	6,540	13,500	-70,000	-28,000	6,160	-5,880
Annuity (50 years)	131	270	-1,400	-560	123	-118
Net Present Value (H.M. Treasury – Standard Discounting)	3,080	6,350	-32,900	-13,200	2,900	-2,760
Annuity (infinite, 3.5%)	108	222	-1,150	-461	101	-97
Net Present Value (H.M. Treasury - Scenario Specific Discounting)	3,080	5,340	-32,900	-16,000	3,910	-3,040
Annuity (infinite, scenario specific)	108	240	-1,150	-400	78	-91

[31] Based on the 15.2 million urban households living in the areas included in the extrapolation.

Table 17: Benefit changes of scenarios for all cities with a population of 50,000 or more in Scotland using distributional weights.

	Green & Pleasant Land	Nature@Work	World Market	National Security	Local Stewardship	Go with the Flow
Aggregate Values in Billion £ (using distributional weights)						
Undiscounted Value Change	14.4	30.3	-143	-61.7	13.1	-11.3
Annuity (50 years)	0.29	0.61	-2.86	-1.23	0.26	-0.23
Net Present Value (H.M. Treasury – Standard Discounting)	6.76	14.3	-67.3	-29.0	6.17	-5.31
Annuity (infinite, 3.5%)	0.24	0.50	-2.35	-1.02	0.22	-0.19
Net Present Value (H.M. Treasury - Scenario Specific Discounting)	6.76	12.0	-67.3	-35.3	8.32	-5.84
Annuity (infinite, scenario specific)	0.24	0.54	-2.35	-0.88	0.17	-0.18
Per Household[32] Values in £						
Undiscounted Value Change	15,400	32,400	-153,000	-66,100	14,000	-12,100
Annuity (50 years)	308	649	-3,060	-1,320	281	-242
Net Present Value (H.M. Treasury – Standard Discounting)	7,230	15,200	-72,000	-31,000	6,600	-5,680
Annuity (infinite, 3.5%)	253	534	-2,520	-1,090	231	-199
Net Present Value (H.M. Treasury - Scenario Specific Discounting)	7,230	12,800	-72,000	-37,700	8,900	-6,250
Annuity (infinite, scenario specific)	253	576	-2,520	-943	178	-187

[32] Based on the 15.2 million urban households living in the areas included in the extrapolation.

Table 18: Per-household benefit changes of scenarios at the lower super output area level (2001 census) in cities with a population of at least 50,000 in Great Britain as net present values (in £) using HM Treasury (2003, standard) discount rates. Values are not population weighted.

	Green & Pleasant Land	**Nature@Work**	**World Market**	**National Security**	**Local Stewardship**	**Go with the Flow**
Mean	4,250	8,570	-43,400	-18,000	3,900	-3,550
Median	2,140	4,160	-22,100	-8,600	1,990	-1,770
Stand. Dev.	5,290	11,000	53,500	23,500	4,820	4,510
Min	-7,400	-2,000	-297,000	-134,00	14	-25,900
1st quart.	816	1,540	-55,800	-22,800	765	-4,510
3rd quart.	5,500	10,900	-8,570	-3,160	5,050	-677
Max	29,400	61,700	-163	-48	26,600	288

Table 19: Per-household benefit changes of scenarios at the lower super output area level (2001 census) in cities with a population of at least 50,000 in Great Britain as net present values (in £) using HM Treasury (2003, standard) discount rates. Values are not population weighted. Distributional weights are applied.

	Green & Pleasant Land	**Nature@Work**	**World Market**	**National Security**	**Local Stewardship**	**Go with the Flow**
Mean	5,550	11,300	-56,600	-23,900	5,090	-4,700
Median	2,180	4,230	-22,600	-8,740	2,030	-1,810
Stand. Dev.	8,540	18,000	86,600	38,300	7,780	7,410
Min	-13,400	-3,680	-1,100,000	-19	5	-95,900
1st quart.	722	1,350	-66,500	-27,200	677	-5,430
3rd quart.	6,510	13,000	-7,540	-2,790	5,970	-593
Max	109,000	229,000	-63	-495,000	98,600	159