Chapter 10:
Urban

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Key Findings*

The ecosystem goods and services that could potentially be derived from Urban greenspace are substantial. In the past, the importance of these areas for the health and general well-being of society was not appreciated and their potential not realised[2]. It is not just the limited extent and variable quality of greenspaces, but also their spatial distribution, connectivity, functionality and accessibility that currently create barriers to their optimisation.

[2] established but incomplete evidence

Access to Urban greenspace is essential for good mental and physical health, childhood development, social cohesion and other important cultural services[1]. More than 6.8% of the UK's land area is now classified as 'urban', with more than 10% of England, 1.9% of Scotland, 3.6% of Northern Ireland and 4.1% of Wales contributing to this habitat. About 80% of the population resides in these areas, where the amount of mean accessible greenspace is 2 hectares (ha) per 1,000 people in England and 16 ha per 1,000 people in Scotland[2]. Deprived areas systematically fare worse in terms of quantity and quality of greenspace[2].

[1] well established
[2] established but incomplete evidence

During the last three decades of the 20th Century, there was a decline in the condition and accessibility of Urban greenspace in the UK[2]. It is likely that the reduction in funding for public parks, the absence of any statutory parks services, and the sale of playing fields (approximately 10,000 between 1979 and 1997) and allotments (estimated at below 10% of peak levels) have all contributed to this decline. Evidence suggests that there has been some improvement since the work of the Urban Task Force. Local authorities, public bodies and over 4,000 community groups, many with National Lottery funding, have contributed to the refurbishment and renewal of many of these areas.

[2] established but incomplete evidence

Greenspace within urban areas is not systematically monitored. Without such basic data the ecosystem services cannot be quantified[2]. There is no regular collection of data or centrally coordinated Urban greenspace database. Responsibilities are spread across a range of organisations, from different government departments and agencies to charities and private sector organisations, which collect extensive amounts of information but often using inconsistent typology at different temporal and spatial scales.

[2] established but incomplete evidence

Provisioning services are limited and the majority of goods are imported; but there is evidence of changing attitudes towards urban food production[2]. In the early 1940s, gardens (covering 4% of England) and allotments, over half of which were in urban areas, provided 10% of all food production in the UK (1.3 million tonnes). Today, there is increasing interest in domestic production, with 33% of people now saying they grow their own food[2]. Per household, savings exceeding £1,000 per annum have been reported from allotments.

[2] established but incomplete evidence

Many of the supporting and regulating functions that Urban soil could provide have been reduced and restricted[1]. Widespread sealing and degradation have resulted in Urban soil losing function and resilience, and has led to major hazards such as flooding. In London alone, it is currently estimated that 3,200 ha of front gardens have been paved, and, in Leeds, an estimated 75% of the increase in impervious surfaces that has occurred from 1971 to 2004 is attributed to the paving of residential front gardens[2].

[1] well established
[2] established but incomplete evidence

* Each Key Finding has been assigned a level of scientific certainty, based on a 4-box model and complemented, where possible, with a likelihood scale. Superscript numbers indicate the uncertainty term assigned to each finding. Full details of each term and how they were assigned are presented in Appendix 10.1.

Urban air quality has significantly changed over the last 60 years with consequences for clean air that extend far beyond the urban boundary[1]. Improvements in air quality arising from the national decline of sulphur dioxide and black smoke emissions (both have declined by more than 95% in London since 1962) are attributed to good regulation and enforcement, together with cleaner fuels. The growing significance in recent decades of nitrogen oxides, fine particles (PM_{10} and $PM_{2.5}$) and background ozone have largely been driven by changes in energy production and the rise in vehicle ownership.

[1] *well established*

Species respond differently to increasing urbanisation of a landscape and the form of that urbanisation[2]. Overall, the species that tend to disappear with urbanisation include habitat specialists, more area-demanding species (the patch size of greenspace tends to decline with urbanisation) and species typically associated with more complex vegetation structures such as forests. The species that tend to remain or increase in richness are more likely to be habitat generalists, less area-demanding species and edge specialists.

[2] *established but incomplete evidence*

Urban ecosystem services could be significantly enhanced to improve climate mitigation and adaptation. Temperatures in cities are higher than in rural areas with consequences for human well-being and the environment[2]. London's maximum daytime and nocturnal Urban Heat Intensity can reach 8.0°C and 7.0°C respectively[2]. The process of urbanisation and development alters the natural energy balance, mainly due to the loss of cooling from vegetated surfaces when they are replaced by impervious materials used in the construction of buildings and roads.

[2] *established but incomplete evidence*

Trade-offs and synergies in ecosystem goods and services are complex, with scale a major issue in decision-making. As yet, they have not been widely investigated in the Urban environment. For example, increasing vegetation cover in urban areas could reduce surface water runoff, decrease peak temperatures and the temperature-dependent formation of ozone and volatile organic compounds (VOCs)[2]. Conversely, increasing vegetation cover incurs maintenance costs, requires watering, is vulnerable to disease, can produce VOCs and would be expensive in city centres, the place where it would be likely to deliver high levels of ecosystem services and benefits.

[2] *established but incomplete evidence*

Urban greenspace is fundamental to sustaining urban life and, therefore, should be integral to the way in which it is planned and managed[1]. For example, the Thames Gateway Green Grid Network in South East England demonstrates the effectiveness of integrating multifunctional land use, connectivity, and accessibility using an ecosystem services approach early in the planning process. While in Scotland, sustainable drainage systems (SuDS), which can substantially enhance ecosystem goods and services delivery, have already been incorporated into an estimated 80–90% of all new developments.

[1] *well established*

10.1 Introduction

The UK NEA Conceptual Framework (Chapter 2) acknowledges the value of the Urban environment in providing ecosystem services by including Urban as one of its eight Broad Habitats. Assessing Urban habitats in the UK poses a number of challenges since they are not systematically monitored and the wide range of organisations collecting data often use inconsistent typology.

There is no international agreement on the defining characteristics of the Urban habitat (McIntyre *et al.* 2000; OECD 2010), nor are there any scientifically accepted criteria by which to identify urban areas and populations (McGranahan *et al.* 2005). Urbanisation is generally defined by the size or density of the human population and the associated geographic boundaries which often vary in extent and ecological diversity. A variety of landscapes (natural and semi-natural environments) and organisms are found within these boundaries, but humans and the built environment form the dominant features.

While recognising the importance of the built environment, this chapter can only attempt to assess the extent, condition and trends of Urban greenspace using available data. In the UK NEA, the term 'greenspace' refers to, and includes, the following Urban subhabitats (mainly land use types): i) natural and semi-natural greenspace (woodlands, Sites of Special Scientific Interest (SSSIs), urban forestry and scrub); ii) street trees; iii) public parks and formal gardens; iv) domestic gardens; v) green corridors; vi) outdoor sports facilities and recreational areas; vii) amenity greenspace; viii) allotments, community gardens and urban farms; ix) cemeteries, churchyards and burial grounds; x) Previously Developed Land (brownfield); xi) water; and xii) peri-urban areas (the urban fringe between the suburbs and the open countryside) (see Section 10.1.4 for further definitions of the urban subhabitats).

Towns and cities can be considered as urban systems, which are characterised by their history, structure and function (including both biotic and abiotic components), and the cycling and conversion of energy and materials. They also have their own spatial organisation and distinctive patterns of change, which influence species behaviour patterns, population dynamics and the formation of communities (Sukopp 2000).

Furthermore, urbanisation can be considered as a human ecosystem framework with three levels: social, biological and physical (Pickett 2008). The interaction between these three components within the Urban environment can be expressed in terms of interacting spheres: abiotic spheres include the atmosphere, hydrosphere, lithosphere and pedosphere; and biotic spheres include the biosphere of urban plants and animals, plus the socioeconomic world of people, known as the anthroposphere (Marzluff *et al.* 2008). Ecosystem assessments incorporate all of these components.

Unlike other habitats, such as Woodlands (Chapter 8) and Coastal Margins (Chapter 11), which primarily generate and supply ecosystem services, Urban habitats are sites of consumption (McGranahan *et al.* 2005). They draw heavily on other habitats for their basic needs (energy and materials), exporting their wastes and accelerating ecological decline on a local and global scale. Conversely, there are substantial benefits from urbanisation, not least the economies of scale it provides; for example, utilities and other essential services are far more efficient in urban than in rural areas. Here, we focus on the ecosystem services and goods arising within Urban habitats.

10.1.1 Urbanisation

The value of ecosystem goods and services arising from the Urban environment is, to a large extent, related to land use—which is the "functional dimension of land for different human purposes or economic activities" (OECD 2010)—and the extent, location, condition, connectivity and accessibility of that land. Each town or city is unique, with proportional provision of the various land types not always scaling with city size. This chapter identifies the main Urban subhabitats (Section 10.1.4) and highlights the main abiotic and biotic processes (air, water and soil) within towns and cities and the ecosystem services and goods arising from them. We review post-war trends in extent and condition of Urban subhabitats, as well as processes and associated drivers of change. Finally, we consider some of the options for sustainable management that could increase the efficiency and functionality of Urban ecosystems, along with some of the constraints.

10.1.2 The Urban Boundary

The Broad Habitats used by the UK NEA have been mapped using data from the UK Land Cover Map 2000 (LCM 2000) project (Fuller *et al.* 2002). However, the Office of National Statistics (ONS 2005) classifies 'urban' as contiguous areas with 10,000 people, which they define as 'physical settlement areas'. These data appear to reflect more closely the extent of urbanisation than the LCM 2000 data and administrative units such as local authority boundaries—the latter of which often include large expanses of sparsely populated open land (Bibby 2009). For the purposes of this report, we illustrate the distribution of urban areas across the UK (**Figure 10.1**) and the extent of urbanisation by country (**Table 10.1**). Note that **Table 10.1** compares urban areas based on population sizes greater than 10,000 people (and associated boundary conditions) to urban areas classified as 'built up areas' by LCM 2000 and clearly shows the difference in extent between the two approaches. It should be understood that the difference between land use classifications can be immense and should not be underestimated when comparing data; in most examples, it is not possible to compare across datasets due to the different approaches and typologies applied.

The proportion of the population living in urban areas was calculated as 79% in 1951 (House of Commons 1999), rising to circa 90% in 1991 (ONS 1998), based on the definition of an urban area as being at least 20 hectares (ha) in size and having a minimum population of 1,000 people. A change in the definition of 'urban' was introduced in 2004 and raised the minimum population size to more than 10,000 for England (Countryside Agency *et al.* 2004), 4,000 for Scotland, 3,000 for Wales and 4,500 for Northern Ireland.

The change also extended the area definition to 'contiguous areas', thus, based on 2001 census data, the proportion of people living in urban areas of the UK is currently estimated at 80% (ONS 2005) which is equivalent to 44 million people. Urban ecosystem goods and services will differ according to the population size, boundary and location of settlements. Villages and small towns (now defined as 'rural') will benefit from many of the goods and services provided by neighbouring Broad Habitats, but may also be subject to some of the disadvantages of more densely populated areas such as increased air pollution.

10.1.3 Overview of Urban Land Use: History and Classification

Up to and during the First World War (WWI), cities were largely composed of dense, urban cores of industry and poor housing, which began to spread out as an increasingly wealthy population, supported by government, aspired to their own homes. The advent of the car enabled people to travel further, but it was not until after the Second World War (WWII), in the 1950s, that suburban development became the predominant mode of urban growth. The creation of new towns, originally designed to ease congestion in large cities by lowering densities, accelerated this trend by housing the overspill population from slum clearances in particular. The development of better road networks facilitated a shift to travelling by car rather than rail, bus and walking, which reinforced suburbanisation. This process of suburbanisation was accompanied throughout the post-war

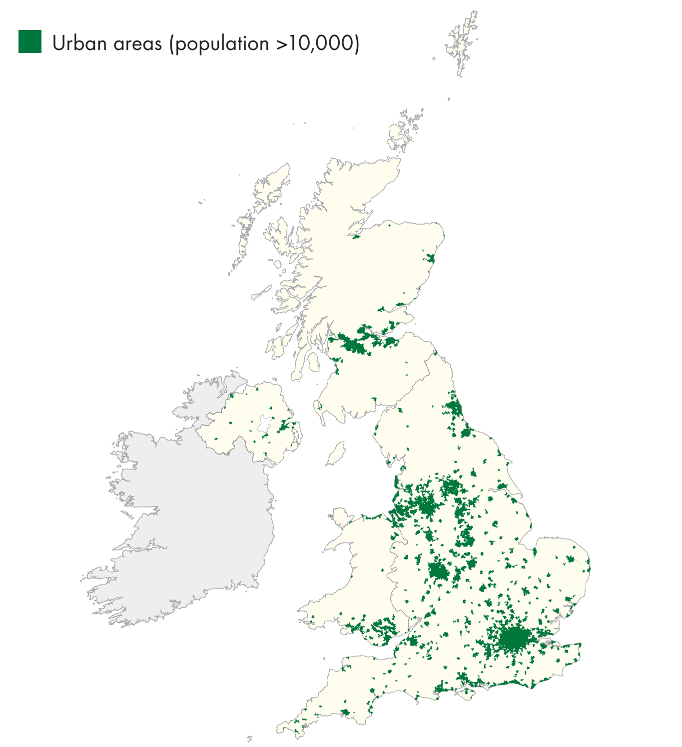


Figure 10.1 UK urban and suburban areas with populations >10,000 people. Source: England, Scotland and Wales data is provided through EDINA UKBORDERS with the support of ESRC and JISC, and uses boundary material which is copyright of the Crown. Northern Ireland population statistics data was provided by Neighbourhood Statistics (NISRA): www.ninis.nisra.gov.uk. Crown copyright material is reproduced with permission of the Controller of HMSO. Northern Ireland spatial data is © Crown copyright and database rights.

Table 10.1 Urban areas: comparison of the extent of urban areas estimated from 'land-use' classification methods with 'population-based' classification methods. Source: data for land-use classification methods derived from the Land Cover Map 2000 (Fuller *et al*. 2002). Data for population-based area estimates for England, Scotland and Wales is provided through EDINA UKBORDERS with the support of ESRC and JISC, and uses boundary material which is copyright of the Crown. Northern Ireland population statistics data was provided by Neighbourhood Statistics (NISRA): www.ninis.nisra.gov.uk. Crown copyright material is reproduced with permission of the Controller of HMSO. Northern Ireland spatial data is © Crown copyright and database rights.

The LCM 2000 maps all built-up areas* ranging from a single building up to a city, based upon 25 m cells (Fuller *et al*. 2002). The urban areas zones map areas with populations >10,000† and their boundaries include a range of land use types. Although each country has developed mapping of the urban-rural typology (identifying areas with populations >10,000 people) the methods used to create the boundaries of the urban areas differ between the countries. In Northern Ireland mapped settlement zones have been delimited by the Planning Service and closely reflect the edges of the built-up areas of towns and cities. Within England and Wales, the urban-rural typology has been based upon mapped census boundaries named Output Areas (OA). The OA boundaries are designed to include a certain number of households and populations within an area, and differ in size between locations. The OAs range in size from very small areas to hundreds of hectares. Within Scotland, the urban-rural typology has been applied to mapped DataZones; each DataZone is based on a group of approximately five OAs. Due to these methods, the accuracy with which these mapped boundaries capture the perceived extent of urban areas differs between countries. The accuracy of boundary capture is highest in Northern Ireland, declines for England and Wales, and is lowest in Scotland. The result of these differences is such that, in Scotland, large areas of farmland or grassland will be present within areas classified as 'urban'.

It is a known limitation of the OA boundaries that they include significant areas where the boundary extends into the marine areas. The calculations presented here have excluded the areas returned for the extent of marine ecosystem within urban areas.

	Extent of Urban areas ('Built-up Areas')*		Extent of Urban areas (>10,000 population)†		Total area of country
	'000 ha	%	'000 ha	%	'000 ha
England	1,384	10.6	1,902	14.6	13,043
Northern Ireland	48	3.4	42	3.0	1,416
Scotland	152	1.9	240	3.0	7,871
Wales	87	4.2	164	7.9	2,081
UK	1,672	6.8	2,348	9.5	24,729

years by a massive restructuring of industry based on the decline of heavy industry and the growth of the services sector (deindustrialisation). By the late 1980s, however, suburbanisation had gradually come to a halt.

In more recent years and, in particular, due to the publication of the Report of the Urban Taskforce (DETR 1999), there has been a focus on urban regeneration within cities, with more than 60% of all new development occurring on Previously Developed Land (PDL, commonly termed 'brownfield'). The process of urban compaction and the designation of the 'Green Belt' in the fight against sprawl, together with housing policies, have increased density quite severely in some parts (DCLG 2010a). New build on all land types in London increased from 47 dwellings per hectare (dph) in 1989 to 121 dph in 2009 (48 dph to 122 dph on PDL). In other regions, increases were more modest, but rises from 23 dph and 21 dph (in 1989) to 43 dph and 34 dph (in 2009) were observed in the North West and East Midlands respectively (26 dph to 49 dph, and 23 dph to 37 dph on PDL (DCLG 2010b)). In addition, during the past decade, many large cities have developed extensive flatted accommodation in inner areas (Bibby 2009), which houses high population densities and provides little greenspace (**Figure 10.2**).

One of the most important distinctions within urban areas relates to spatial variation. The densest urban areas have the least open space, and all open space, including domestic gardens, strongly inversely correlates with density. Generally, there is good provision in the lowest density areas, with less greenspace in intermediate and higher density areas. Recent research has found that wards with fewer than 20 dph have three times as much greenspace as wards in high density areas (CABE 2010). This issue of spatial variation is illustrated using data for Greater London (**Figure 10.3**).

Since the 1947 Town and Country Planning Acts, which were created over 70 years ago and established a universal planning system, there has been very little focus on the extent and condition of greenspace, although this has started to change in recent years.

Using the Broad Habitat criteria applied in other chapters of the UK NEA, Urban areas extend over approximately 6.8% of the UK, covering 1,672,000 ha (Fuller *et al.* 2002). In England, 10.6% of the land (1,384,000 ha) is classified as Urban, which compares with 4.2% of Wales (87,000 ha), 3.4% (48,000 ha) of Northern Ireland and 1.9% (152,000 ha) in Scotland (**Table 10.1**). The UK NEA classification of Urban areas is based on the LCM 2000 (Fuller *et al.* 2002) and is described as '*Built-up Areas and Gardens*' which includes rural development, roads, railways, waste and derelict ground (including vegetated wasteland), gardens and urban trees. Urban greenspace estimates are, however, hugely variable, ranging from 54% in the Generalised Land Use Database (England only[1]), which does not distinguish agricultural land within urban areas from other greenspace, to 14%, according to the National Audit Office (NAO 2006). This compares with an area of just 6.5% of accessible greenspace in a recent, but incomplete, study using a more detailed classification and consistent typologies (CABE 2010).

There is no single source of Urban greenspace data. It is, therefore, difficult to provide good estimates of extent and condition across the UK. To help illustrate this issue, and to explore the variation in extent data and classification of greenspace, we draw on four different data sources:

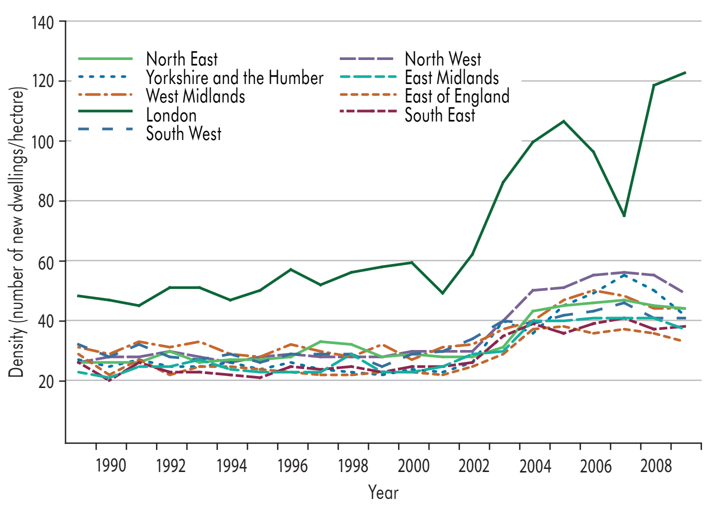


Figure 10.2 Density of new dwellings (per hectare) built on Previously Developed Land in the English regions from 1989 to 2009. Source: data from Land Use Change Statistics and Communities and Local Government Housing Statistics; DCLG (2010b).

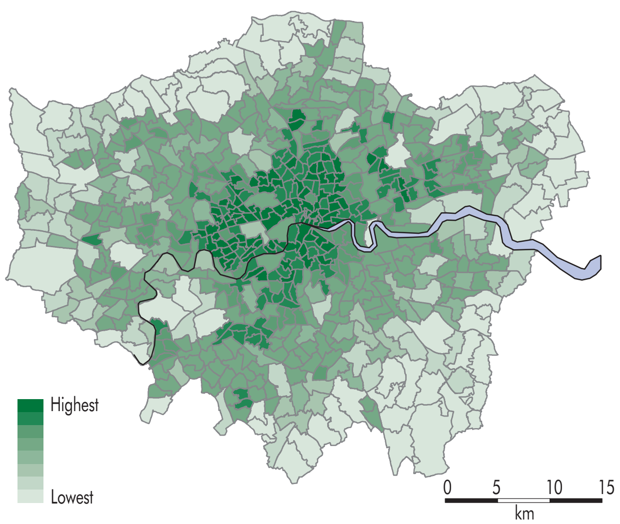


Figure 10.3 Population density in London in 2001. Dark green indicates highest densities and light green indicates lowest densities. Source: based on an analysis by Mike Batty, University College London, using 2001 Census data from the Office of National Statistics (ONS 2002).

1 However, Greenspace Scotland are currently mapping and categorising Scotland's Urban greenspace using aerial photography and have identified different types of greenspace in around two thirds of Scottish authorities. (Greenspace Scotland 2009; Figure 10.4). Plus, in Wales, in 2010, 18 of the 22 local authorities were working on complete assessments of the extent and location of accessible natural greenspace in their Urban areas (Chapter 20).

1. **Inventory of individual greenspaces by the Commission for Architecture and the Built Environment (CABE 2010)**
This inventory includes records for more than 16,000 individual greenspaces, covering 11 categories and using data from numerous sources collected specifically to try to quantify the extent of Urban greenspace (**Table 10.2**). Each record contains an estimate of size and geographic location. Although incomplete, this is the first time that these data have been collated into one database. They provide a useful indication of the extent of the various greenspace subhabitats in England. Calculated *per capita*, mean provision is given as 1.79 ha per 1,000 people, with variation between regions ranging from 2.86 ha per 1,000 people in the South East to 1.24 ha per 1,000 people in London.

2. **Greenspace Strategies in England**
Local authorities in England are currently required to develop Greenspace Strategies. The typology is not always consistent, and extent is often far lower than estimated by data from the Department of Communities and Local Government who include agricultural land (GLUD 2005) in their classification. However, these data provide an indication of the extent of subhabitats defined by local authorities as public greenspace.

Box 10.1 indicates that Greenspace Strategies for four randomly selected cities classified public greenspace (excluding domestic gardens) as extending over 17–24% of the urban area. The case studies illustrate that land use is highly variable; parks and gardens, natural and semi-natural greenspace, and outdoor sports facilities predominate in these areas.

Greenspace Strategies give an indication of *per capita* greenspace provision across the four chosen cities, but such data are not necessarily indicative of access to greenspace. For example, *per capita* greenspace provision is higher in Newcastle (8.42 ha per 1,000 people) than Coventry (5.68 ha per 1,000 people). Yet the single entity, Newcastle Town Moor, constitutes approximately 20% of total greenspace, and the distribution of the remaining greenspace is much less uniform than within Coventry. So, evenness, location and the implications for access need to be taken into account. Moreover, golf courses and school playing fields are included in the outdoor sports facilities category, but are generally not freely accessible to the public. This is important in an assessment because cultural benefits will largely arise where there is public access.

Local audits asking users for their views on the quality of greenspace in Newcastle and Coventry provide an indication of the variability of greenspace condition between and within greenspace categories. In Newcastle, public parks and cemeteries still open for burials typically achieved the highest quality ratings. Amenity greenspace, outdoor sports facilities and natural and semi-natural greenspace received the lowest scores (Newcastle City Council 2004). In Coventry, the country park and war memorial park achieved high scores, followed by neighbourhood parks. Incidental open spaces (mainly amenity greenspace) achieved the lowest scores (Coventry City Council 2008).

Table 10.2 CABE Space analysis of public Urban greenspace.
Source: CABE (2010).

Greenspace type	Count	Area (ha)	Data
Allotments	997	1,356.8	Allotment sites 2004–2005
Cemeteries	1,643	3,679.1	Burial grounds 2006
Community farms	197	472.8	Community gardens and city farms 2004–2005
Country parks	72	5,765.9	Country parks
Doorstep greens	82	140.3	Doorstep greens
Golf courses	361	5,720.6	Golf courses
Grass pitches	10,243	8,170.4	Sport England/Fields in Trust
Millennium greens	91	164.5	Millennium greens
Nature reserves	663	14,308.0	National nature reserves; local nature reserves
Parks	1,770	52,243.2	Registered parks and gardens 2008; Public parks assessment; Green Flag parks 2006–2007
National Trust	128	14,537	National Trust
All types	**16,247**	**106,549.6**	

3. **Generalised Land Use Database (GLUD) for England based on urban Output Areas covering nine land cover categories (2005)**
According to this database, the extent of greenspace in the urban areas of each English region (54% on average across all regions) far exceeds other land use types (GLUD 2005; **Table 10.3**). However, it should be noted that urban agricultural land is included in the greenspace classification. Domestic gardens account for a further 18% of urban land use, and water accounts for an extra 6.6%; thus, 78.6% of urban areas is designated as natural rather than built. The other land use types are domestic and non-domestic buildings, roads, paths and railways.

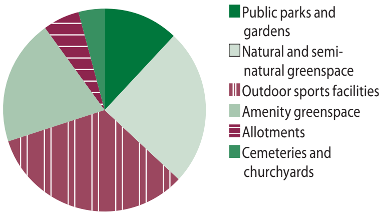
At city level, a comparison of six cities reveals that the relative proportions of various types of space are remarkably similar to each other (**Table 10.4**), with an average of 12% buildings and 11% roads constituting 25% of the area. This can be compared with natural areas where domestic gardens average 21%, water 2% (excluding Liverpool which has a disproportionately high area of water due to the local authority boundary) and general greenspace averages 37% (excluding an unusually high 58% in Newcastle because it includes the Newcastle Town Moor). Even allowing for unclassified land and railways and paths, the total greenspace still exceeds 60% of the land cover in these six cities.

4. **Greenspace Scotland (2009)**
The first analysis of Urban (areas of more than 3,000 people with a 500 m buffer around the settlement area) greenspace extent in Scotland is estimated at 84,870 ha: 30% domestic gardens, 28% natural and semi-natural greenspace, 9% public parks, 15% amenity greenspace,13% sports areas and 5% other (play spaces, allotments, green corridors, burial grounds and civic spaces) (Chapter 19). Spatial variation (**Figure 10.4**)

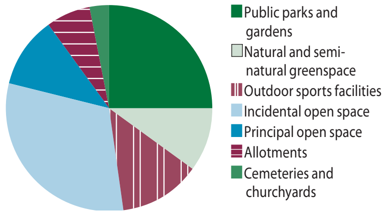
Box 10.1 Analysis of greenspace in four urban areas of England. Source: Coventry City Council (2008); Newcastle City Council (2004); Liverpool City Council (2005); Northampton Borough Council (2006). H Raper, Newcastle City Council, pers. comm.; N Barr, pers. comm.

Greenspace Strategies typically include some form of assessment of both the quantity and quality of greenspace within the city boundaries, as well as including recommendations on how Urban greenspace may be enhanced. In line with Planning Policy Guidance Note 17 (PPG17 2002), city councils have classified their Urban greenspace (see below) using locally derived typologies, hence caution should be exercised when making direct comparisons.

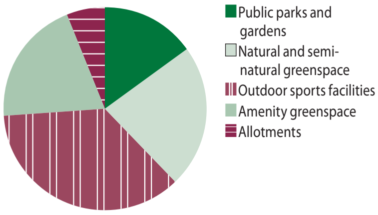
a) Newcastle upon Tyne
Population (2001 census): 259,536
Total area: 11,300 ha
Total area greenspace: 2,185 ha
Per capita provision: 8.42 ha/1,000



c) Coventry
Population (2001 census): 300,848
Total area: 9,864 ha
Total area greenspace: 1,710 ha
Per capita provision: 5.68 ha/1,000



b) Northampton
Population (2001 census): 202,828
Total area: 8,076 ha
Total area greenspace: 1,403 ha
Per capita provision: 6.92 ha/1,000



d) Liverpool
Population (2001 census): 439,473
Total area: 11,184 ha
Total area greenspace: 2,648 ha
Per capita provision: 6.02 ha/1,000

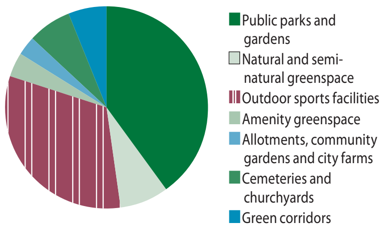


Table 10.3 Generalised Land Use Database (GLUD) for England: proportion of urban land by region. Source: data from GLUD (2005).

Region	Domestic buildings %	Non-domestic buildings %	Roads %	Paths %	Rail %	Domestic gardens %	Greenspace %	Water %	Other land %
East Midlands	4.6	2.6	6.9	0.4	0.4	15.9	62.7	1.7	4.7
East of England	4.7	2.4	6.7	0.5	0.4	16.9	59.1	4.3	5.0
London	9.3	5.0	13.0	0.8	1.1	25.4	34.4	2.9	8.0
North East	5.6	3.0	9.4	0.8	0.8	14.3	57.4	3.2	5.5
North West	5.4	3.1	8.9	0.6	0.6	15.9	50.2	9.8	5.5
South East	5.1	2.3	7.5	0.5	0.4	19.9	55.1	4.4	4.8
South West	5.5	2.7	7.6	0.6	0.4	18.4	55.9	3.8	5.4
West Midlands	6.1	3.7	9.1	0.7	0.5	21.8	50.9	1.2	6.2
Yorkshire and The Humber	5.1	3.0	8.5	0.5	0.7	16.3	58.4	2.0	5.5
England: rural and urban combined (Total)	**1.1**	**0.65**	**2.22**	**0.1**	**0.13**	**4.26**	**87.46**	**2.59**	**1.39**

Table 10.4 Proportion of built to greenspace in Urban environments (based on local authority boundaries). Source: data from GLUD (2005).

City	Buildings (domestic & non-domestic) %	Roads %	Domestic gardens %	Greenspace* %	Water %	Other (paths, railways, unclassified) %
Birmingham	14	12	29	34	1	10
London	13	12	24	38	3	10
Newcastle upon Tyne	9	10	13	58	2	8
Northampton	11	11	21	46	3	8
Coventry	12	11	22	44	1	11
Liverpool	10	11	15	23	32	9

* Farmland is included in Urban greenspace classification.

and accessibility are important factors in the provision of greenspace. Inner city greenspace in central Edinburgh is low (2.66 ha per 1,000 people) compared with the whole of Edinburgh (4.25 ha per 1,000 people) and the urban mean (16 ha per 1,000 people). However, 82% of people in the city centre can access a greenspace within 400 m of their home (**Figure 10.5**). Overall, 50–70% of all Urban greenspace in Scotland is considered accessible.

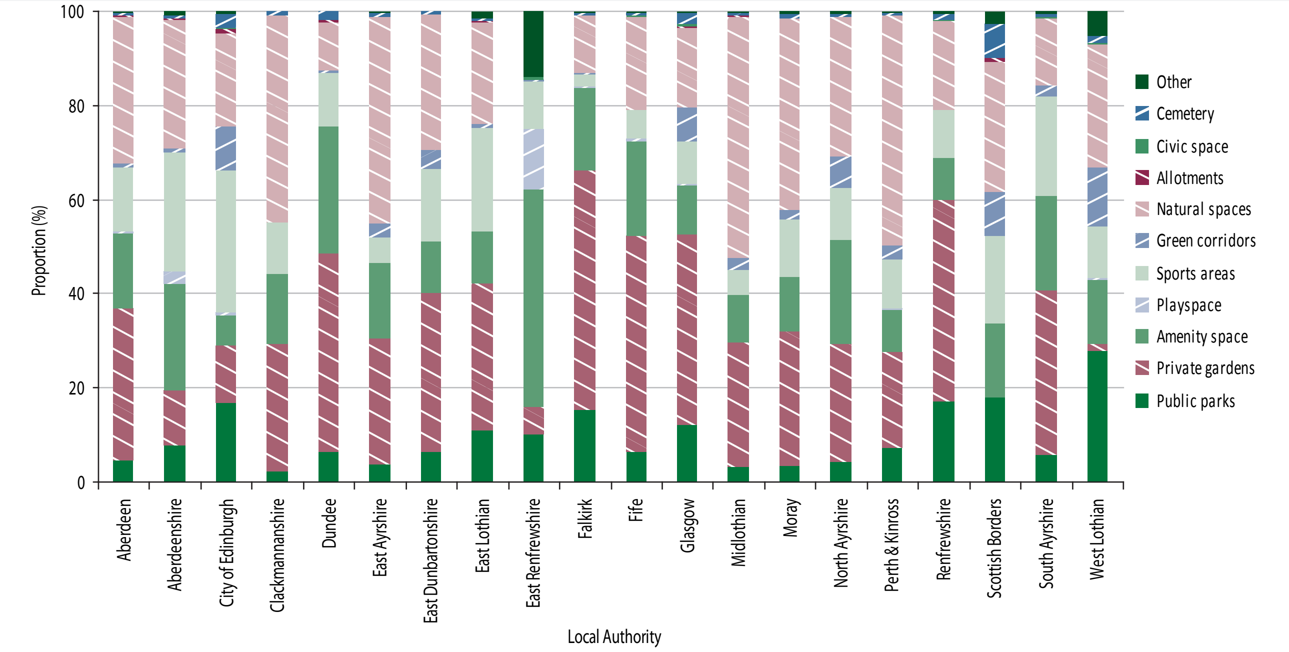


Figure 10.4 Urban greenspace composition within Scotland. The composition of Urban greenspace within 20 reporting local authorities in Scotland has been comprehensively categorised mainly using the Planning Advice Note: PAN 65 Planning and Open Space (PAN 65) typology. This work has shown both the variation in Urban greenspace composition throughout Scotland and the intra-urban heterogeneity of greenspace composition and access (e.g. the dichotomy between central and western Edinburgh's greenspace). Source: reproduced from Greenspace Scotland (2009).

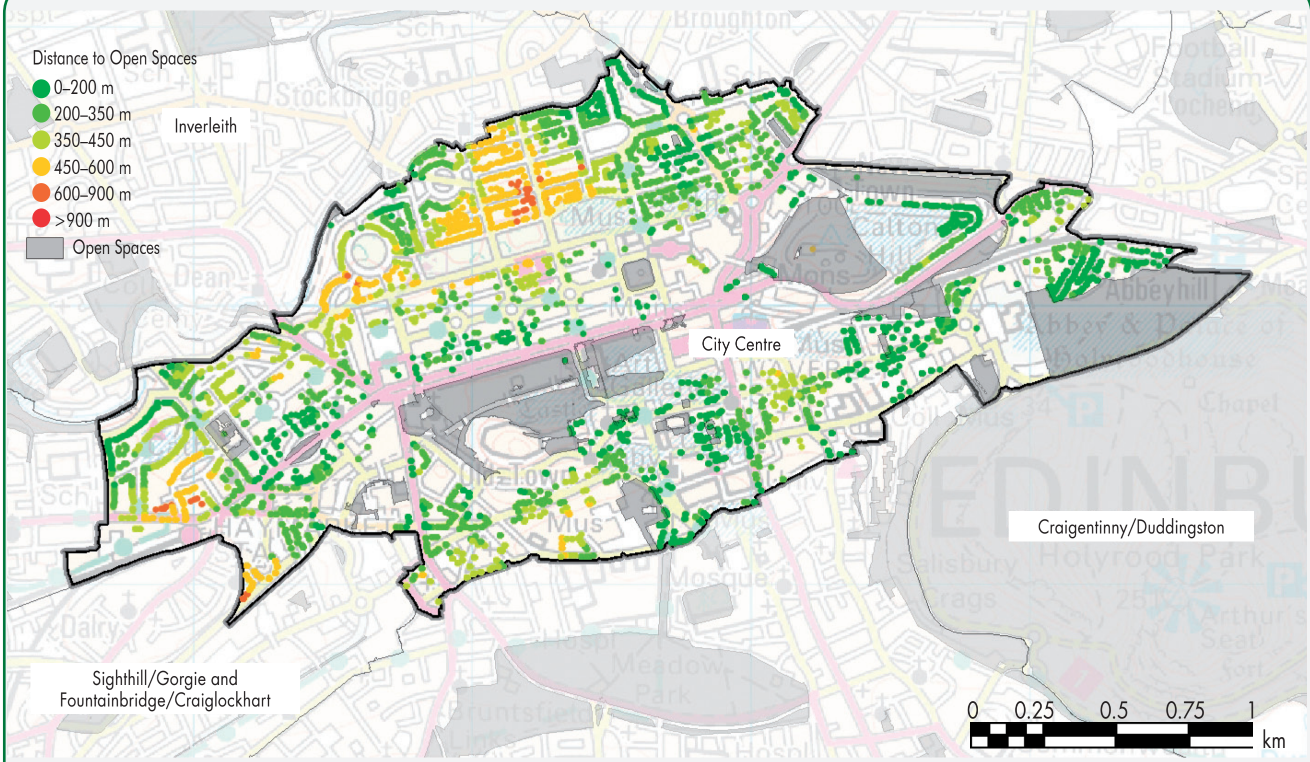


Figure 10.5 Mapping greenspace accessibility in Edinburgh, 2007. The map shows the distance from dwellings to all significant accessible open spaces. Source: reproduced from Greenspace Scotland (2009).

10.1.4 Urban Land Use Classification for the UK NEA

This chapter identifies a range of different Urban land uses, referred to here as Urban subhabitats, that provide ecosystem services (**Table 10.5**). As far as possible, we apply land use typology defined by Planning Policy Guidance Note 17: Planning for Open Space, Sport and Recreation (PPG17 2002), Planning Advice Note: PAN 65 Planning and Open Space (PAN 65 2008) and Planning Policy Statement 8: Open Space, Sport and Outdoor Recreation (PPS8 2004), which categorise open

Table 10.5 Comparison of the Urban subhabitat classification used in the UK NEA (with a focus on provision of ecosystem services) and in local authorities' planning guidance in England and Wales (Planning Policy Guidance Note 17 (PPG17 2002)), in Scotland (Planning Advice Note 65 (PAN 65 2008)) and in Northern Ireland (Planning Policy Statement 8: Open Space, Sport and Outdoor Recreation (PPS8 2004)).

UK NEA Urban subhabitat	What the subhabitat includes	PPG17 (England and Wales)	PAN 65 (Scotland)	PPS8 (Northern Ireland)
Natural and semi-natural greenspace (woodlands, SSSIs, urban forestry, scrub)		**Natural and semi-natural urban greenspaces—**including woodlands, urban forestry, scrub, grasslands (e.g. downlands, commons and meadows), wetlands, open and running water, wastelands and derelict open land, and rock areas (e.g. cliffs, quarries and pits).	**Natural and semi-natural urban greenspaces—** woodland, open semi-natural and open water.	**Natural and semi-natural urban green spaces—**including woodlands, urban forestry, grasslands (e.g. meadows), wetlands, open and running water, and rock areas (e.g. cliffs).
Street trees	Single trees and small areas with scattered trees, often surrounded by paved ground.	*Not listed in PPG17*	*Not listed in PAN 65*	*Not listed in PPS8*
Public parks and formal gardens		**Parks and gardens—**including urban parks, country parks and formal gardens.	**Public parks and gardens**	**Parks and gardens—**including urban parks, country parks, forest parks and formal gardens.
Domestic gardens		*Covered under amenity greenspace.*	**Private gardens or grounds—** private gardens, school grounds and institutional grounds.	*Not listed in PPS8*
Green corridors	Verges and hedges, river and canal banks, cycleways, and rights of way.	Including river and canal banks, cycleways and rights of way.	Green access routes and riparian routes.	Including river and canal banks, amenity footpaths and cycleways.
Outdoor sports facilities and recreational areas	Sports facilities such as golf courses, football pitches, athletics tracks, school and other institutional playing fields, and other outdoor sports facilities (largely grassland).	**Outdoor sports facilities** (with natural or artificial surfaces and either publicly or privately owned)—including tennis courts, bowling greens, sports pitches, golf courses, athletics tracks, school and other institutional playing fields, and other outdoor sports areas. **Provision for children and teenagers—**including play areas, skateboard parks, outdoor basketball hoops, and other more informal areas (e.g. 'hanging out' areas, teenage shelters).	**Playspace for children and teenagers—**playspace. **Sports areas—**playing fields, golf courses, tennis courts, bowling greens and other sports.	**Outdoor sports facilities** (with natural or artificial surfaces and either publicly or privately owned)—including tennis courts, bowling greens, sport pitches, golf courses, athletics tracks, school and other institutional playing fields, and other outdoor sports areas. **Provision for children and teenagers—**including play areas, kickabout areas, skateboard parks and outdoor basketball hoops.
Amenity greenspace	Most commonly, but not exclusively, in housing areas—including informal recreation spaces, greenspaces in and around housing.	Most commonly, but not exclusively, in housing areas—including informal recreation spaces, greenspaces in and around housing, domestic gardens and village greens.	Amenity—residential Amenity—business Amenity—transport	Most commonly, but not exclusively, in housing areas—including informal recreation spaces, communal greenspaces in and around housing, and village greens.
Allotments, community gardens and urban farms	Includes arable farmland and orchards.	**Allotments, community gardens, and city (urban) farms.**	**Allotments and community growing spaces**—allotments and community growing spaces.	**Allotments and community gardens**
Cemeteries, churchyards and burial grounds		**Cemeteries and churchyards**	**Burial grounds—**churchyards and cemeteries.	**Cemeteries and churchyards**
Previously Developed Land (brownfield) but not including domestic gardens	Derelict, contaminated and vacant land.	*Not listed in PPG17*	*Not listed in PAN 65*	*Not listed in PPS8*
Water	Includes natural and artificial e.g. rivers, streams, groundwater, lakes, wetlands, ponds, ditches, canals, reservoirs.	*Covered under natural and semi-natural urban greenspace.*	*Covered under natural and semi-natural urban greenspaces.*	*"Open space is taken to mean all open space of public value, including not just land, but also inland bodies of water such as rivers, canals, lakes and reservoirs which offer important opportunities for sport and outdoor recreation and can also act as a visual amenity" (PPS8 2004)*
Peri-urban		Accessible countryside in urban fringe areas. Green belt.		

space. In order to differentiate between different ecosystem services, it has been necessary to further define some of these definitions; for example, street trees can provide different services from woodlands. It should be noted that the term greenspace is used throughout this chapter to collectively represent the subhabitats, including water.

Ecosystem services arising from the built infrastructure are not quantified, but it is recognised as an important habitat, particularly for birds. It also provides extensive surfaces for vegetation such as roof gardens and window boxes.

10.1.5 Interaction with other UK NEA Broad Habitats

To a greater or lesser extent, all UK NEA Broad Habitats interact with the Urban environment. Enclosed Farmland (Chapter 7), Semi-natural Grassland (Chapter 6) and Woodlands are the most extensive, with the latter constituting a significant part of the peri-urban Green Belt. The lowest interaction occurs with Freshwaters—Openwaters, Wetlands and Floodplains (Chapter 9), which is followed by Coastal Margins (Chapter 11) (LCM 2000). Areas of UK NEA Broad Habitats that are more than 5 km^2 and fall within urban boundaries are illustrated in **Table 10.6**.

Urban populations draw heavily on external resources for provisioning and other ecosystem services. They export considerable solid and liquid waste (largely contained) and release pollution emissions to air, water and land that extend far beyond the urban boundary (Luck *et al.* 2001). The ecological footprint of urban areas is widely recognised. Urban areas also export visitors to other habitats, giving rise to associated transport pressures (pollution and infrastructure). The ecological footprint of the UK is discussed more fully in Chapter 21.

A large part of Urban and peri-urban greenspace is designated as Green Belt (**Figure 10.6**). The fundamental aim of Green Belt policy is to prevent urban sprawl, and shape patterns of development, by keeping land permanently open. In so doing, Green Belts protect countryside and incidentally help to secure nature conservation interest (Planning Policy Guidance Note 2: Green Belts (PPG2 1995)). Green Belts were first designed to be used in association with growth in large cities and the development of new towns, which were located at some distance from the city, beyond its Green Belt. This was a principle of planning policy in the UK in the mid to late 20th Century, and, in many senses, remnants of that policy still exist today. Current planning policy for England is expressed in Planning Policy Guidance Note 2 as follows (PPG2 1995, amended 2001):

- to check the unrestricted sprawl of large built up areas;
- to prevent neighbouring towns from merging into one another;
- to assist in safeguarding the countryside from encroachment;
- to preserve the setting and special character of historic towns;

Table 10.6 The extent of UK NEA Broad Habitats within Urban areas with a population >10,000. Source: extent of UK NEA Broad Habitats estimated from the Land Cover Map 2000 (Fuller *et al*. 2002). Extent of Urban areas with a population >10,000 for England, Scotland and Wales is provided through EDINA UKBORDERS with the support of ESRC and JISC, and uses boundary material which is copyright of the Crown. Northern Ireland population statistics data was provided by Neighbourhood Statistics (NISRA): www.ninis.nisra.gov.uk. Crown copyright material is reproduced with permission of the Controller of HMSO. Northern Ireland spatial data is © Crown copyright and database rights.

Each country has developed mapping of the urban-rural typology (identifying areas with populations >10,000 people). The methods used to create the boundaries of the urban areas differ between the countries. In Northern Ireland mapped settlement zones have been delimited by the Planning Service and closely reflect the edges of the built up areas of towns and cities. Within England and Wales the urban-rural typology has been based upon mapped census boundaries named Output Areas (OA). The OA boundaries are designed to include a certain number of households and populations within an area, and differ in size between locations. The OAs range in size from very small areas to hundreds of hectares. Within Scotland, the urban-rural typology has been applied to mapped DataZones; each DataZone is based on a group of approx five OAs. The accuracy of boundary capture is highest in Northern Ireland, declines for England and Wales, and is lowest in Scotland. The result of these differences is such that, in Scotland, large areas of farmland or grassland areas will be present within areas classified as 'urban'.

	England		Northern Ireland		Scotland		Wales		UK	
UK NEA Broad Habitat	Area ('000 ha)	% of total Urban area	Area ('000 ha)	% of total Urban area	Area ('000 ha)	% of total Urban area	Area ('000 ha)	% of total Urban area	Area ('000 ha)	% of total Urban area
Mountains, Moorlands & Heaths	34	1.8	3	6.8	19	7.8	14	8.5	69	2.9
Semi-natural Grasslands	189	10	4	10.1	36	15	26	15.9	256	10.9
Enclosed Farmland	582	30.6	11	25.1	73	30.6	47	28.8	713	30.4
Woodlands	164	8.6	1	3.5	28	11.5	22	13.2	215	9.2
Freshwaters – Open water, Wetlands & Floodplains	13	0.7	0	0.5	2	0.9	1	0.5	16	0.7
Urban	826	43.4	21	49.7	76	31.5	41	25.1	963	41
Coastal Margins	42	2.2	0	0.6	1	0.4	9	5.4	52	2.2

	Areal extent of Green Belt ('000 ha)	Areal extent of country ('000 ha)	% Green Belt in country
England	1,983	13,043	15.2
Northern Ireland	336	1,416	23.7
Scotland	143	7,871	1.8
Wales	3	2,081	0.1
UK	2,465	24,729	10.0

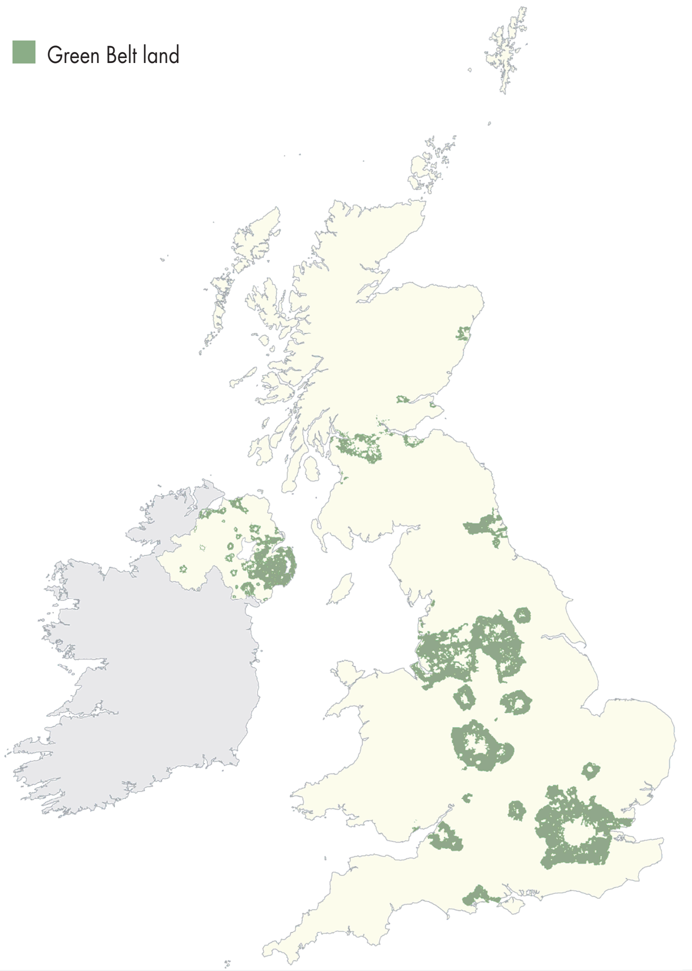


Figure 10.6 Designated Green Belt land in the UK in 2009. Source: data derived from Defra (England), Department of the Environment Northern Ireland (Northern Ireland), Scottish Natural Heritage (Scotland), and Newport Council (Wales). The data for England and Scotland are Copyright Landmark Information Group.

- and to assist with urban regeneration, by encouraging the recycling of derelict and other urban land.

Green Belts have succeeded in preserving openness and areas of countryside around large cities, as well as providing cultural and provisioning services for urban dwellers (Natural England & CPRE 2010; Scottish Government 2004).

10.1.6 Indicators of Change of the Urban Environment and its Potential for Delivering Ecosystem Services

Existing indicators of relevance to ecosystem goods and services can be classified into five broad groups:

1. Urban population size and other social and demographic data (DCLG: ONS).
2. Land use (DCLG: GLUD).
3. Biodiversity (Sustainability Indicators, e.g. urban bird populations; Countryside Survey, see Carey *et al.* 2008; State of the UK's Birds, see Eaton *et al.* 2010).
4. Regulating Services (DCLG: Sustainability Indicators)
5. Cultural Services (DCLG: GLUD; CABE).

Urban ecosystem-specific indicators can be developed from selected, existing indicator scales (1–5), but will need additional indicators to reflect the special nature of the Urban habitat.

Community interest in the state of the environment could be harnessed through a programme of public recording schemes, drawing on expertise developed through projects such as single species sightings (Harlequin Ladybird Survey 2010), ecological surveys (OPAL 2010; Davies *et al.* 2011) and garden bird and wetland surveys (RSPB 2010; WWT 2010). Community participation data from voluntary services, such as 'Friends of Parks', are also relevant (Thornton 2009).

10.2 Trends and Changes in Urban Subhabitats and Associated Abiotic and Biotic Processes

In this section, we present data from a range of sources on the extent, condition and accessibility of the UK NEA Urban subhabitats (identified in **Table 10.5**), from post-war to the present day. Priority is given to national datasets, which are scarce, so additional examples are drawn from various publications based on regional and local studies. Caution is required in data interpretation due to the broad classifications used by some organisations resulting in overlap and duplication. More importantly, the various approaches applied by the different responsible authorities and charities mean that it is not possible to compare data between Urban subhabitats. Trend data are also uncertain due to boundary changes and the differing typologies used.

Each town and city is unique, so it is difficult to make general statements based on this synthesis of published information. Data provided in this report merely give an indication of the extent and condition of greenspaces and physical processes that collectively form the Urban environment; but some trends have emerged that can help to inform the process of assessment and contribute to the valuation of the essential ecosystem goods and services that Urban habitats deliver.

The main drivers of change are identified at the beginning of each subsection. Social and demographic change and economic development are major forces, with policies on planning, housing and transport having the greatest impact on ecosystem services and goods derived from the Urban environment.

Over the past 60 years, there has been a steady increase in the UK's population, of which, a large percentage now lives in urban areas (ONS 2005). Demographic change, commercial growth, new housing and transport needs greatly contribute to the increasing extent of non-permeable surfaces and pollution, associated with which is the loss of regulating and provisioning services and important cultural benefits (Section 10.3). More recently, climate change has become a major driver. Other drivers include market forces, particularly interest in food provision and organic products which are becoming of increasing importance. Recognition of the impact of urbanisation on other habitats nationally and globally, and policies on sustainable development in particular, are stimulating new schemes within urban areas for recycling, local waste management and renewable energy.

10.2.1 Natural and Semi-natural Greenspaces (Woodlands, SSSIs, Urban Forestry and Scrub)

Following a study of landscape character in the 1990s, deterioration in the condition of woodland in Scotland was attributed to neglect (SNH 2004). In England, however, the principle drivers of woodland condition decline (based on data collected from woodlands classified as SSSIs) are inadequate or inappropriate management, and grazing or browsing by deer (Natural England 2008). In comparison, factors contributing to a decline in the condition of Urban SSSIs are more varied due to the broad range of habitats they encompass and include under-grazing, inappropriate scrub control and coastal squeeze (Natural England 2008). In the case of woodland SSSIs in London, in particular, deer do not seem to be causing damage at their current density (taking SSSI condition as a proxy measure); nevertheless, deer populations do appear to be growing in Urban habitats and may well become a problem in the future (S. Lyme, Natural England pers. comm.).

The extent of Urban woodland as a percentage of the total urban area is calculated at 11.3% for the whole of the UK, with 8.7% in England, 13.1% in Wales, 11.5% in Scotland and 3.3% in Northern Ireland (LCM 2000). This is not dissimilar to the 12% coverage of Woodland across the entire UK (Chapter 8). Over 15% of people in Scotland have access to a woodland more than 2 ha in size and within 500 m of their home, and around 55% have access to a woodland more than 20 ha in size within 4 km of their home (Woodland Trust 2004). In England, 50% of the population is estimated to have access to a woodland more than 20 ha in size within 4 km of their home (Defra 2006b); the same is true for Northern Ireland (50%), whereas, in Wales, 70% of the population has equivalent woodland access.

Data to assess trends and condition at UK level have not been located, so Urban woodlands are reviewed using two case studies. The first, from Scotland, documents a decline in broadleaved woodland from the 1940s to 1980s (SNH 2001) mainly due to replacement by conifers. Following a landscape character study in the 1990s, and in recognition of the cultural value of woodlands, a government-funded programme of expansion in, or in close proximity to, urban areas was established and has since proved hugely

Box 10.2 The National Forest. Source: the National Forest Company (2010).

Led by the National Forest Company and involving numerous partners, The National Forest is a initiative that is creating a new Forest for the nation across 200 square miles of the Midlands. Woodland creation is enhancing rural, urban and former coalfield landscapes. Tree planting has been particularly successful in and around the Forest's towns: Burton upon Trent, Swadlincote, Ashby de la Zouch and Coalville. This is achieving multi-purpose benefits including landscape and biodiversity enhancement, creating new places for recreation, carbon sequestration and community involvement. Schemes which the National Forest is initiating include:

- Urban Forest Parks—created at Swadlincote Woodlands (30 ha) and Coalville (15 ha) on former derelict land.
- Woodland 'pocket parks'—in residential neighbourhoods and hospital grounds.
- Sponsored woodland—including the Burton Mail Centenary Woodland and Jaguar Lount Woodland, east of Ashby.
- Urban fringe woodlands—created through farm diversification.
- Development-related and roadside tree planting.
- Community projects—including community orchards, school grounds tree planting, plus the National Forest Company's Plant a Tree, Free Trees for Gardens, and Grow a Tree from Seed schemes.

Around 20,000 people and 40,000 school children are involved in the Forest's creation each year. Key challenges to increasing urban woodland include the availability and cost of land, development 'hope value', avoiding underground services, having an effective catalyst to lead activity, and achieving joined-up working between the public, private and voluntary sectors, landowners and civil society.

Environmental education session at Conkers Discovery Centre, Derbyshire. *Photo courtesy of Christopher Beech/National Forest Company.*

successful (Greenspace Scotland 2010). A basic standard was established of one hectare per 500 people living within five miles of the site. The first planting scheme involved 51 community groups in the development and maintenance of 64 sites covering 22,000 ha. Woodlands were mainly located within the urban belt and averaged 58 ha in size.

The second example is from London. Extent data is taken from a survey in 1993 (GLA 2005b) which estimated that there were seven million trees in London, two thirds of which were located within domestic gardens. Of those remaining, 25% were classified as woodland, making up 8% of London's greenspace. A later survey in 2000 (Forestry Commission 2003) recorded 3.9% (6,204 ha) of London as woodland (up from 3.8% in 1993), with 592 small woodlands less than 2 ha in size and 621 more than 2 ha. Broadleaved woodland dominated with oak as the main species. About 70% of London woodlands were owned by local authorities. Dense woodland (more than 40 trees per hectare) tended to be concentrated on the outskirts of the city, with the exception of a few very important SSSIs.

There are about 600 SSSIs (less than 4% of the total number) within or near urban areas in England, covering about 39,000 ha (Natural England 2009). Trends in Urban SSSI condition from 2003 to 2010 suggest that progress towards the England Biodiversity Strategy objective of increasing the proportion of SSSIs in favourable or recovering condition is being made. The September 2003 baseline assessment reported that 67% of the total area of Urban SSSIs were in a favourable or recovering condition; by March 2009, this had increased to 80%, with figures from March 2010 recorded as 83.6% (Natural England 2009, 2010 unpublished).

The term 'urban forest' was not introduced into the UK until the 1980s and was followed by the country's first city-wide urban forestry project—the Forest of London project. Since then, a number of similar projects and Community Forests in metropolitan areas have been established, which aim to provide a broad range of social, environmental and economic benefits to urban communities. Lately, the health and well-being aspects of these benefits are receiving growing interest (O'Brien *et al*. 2010; see Chapter 23).

More recent initiatives focusing on urban and community forestry include the Black Country Urban Forest in England (BBCWT 2010), the TreeGeneration programme in Wrexham and Flintshire in North East Wales (Forestry Commission 2010), Woodlands in and Around Towns in Scotland (Forestry Commission Scotland 2010), and Northern Ireland's Forest of Belfast partnership (Belfast City Council 2010). One further example is The National Forest in central England (**Box 10.2**), which aims to increase the area of multi-purpose woodland close to towns and cities; it is having very good success in this respect.

10.2.2 Street Trees

Drivers of change in the condition and extent of street trees (not woodlands) are unclear. Tree campaigns that occurred during the 1980s appear to be responsible for the increased plantings at that time, but have not been maintained (DCLG 2008b). Current recognition of the regulatory (particularly climate-based) and cultural services that street trees can provide is generating renewed interest in plantings. Climate change is however also identified as a potential threat to Urban trees through possible increases in pests and diseases (Tubby & Webber 2010).

Data on Urban trees are taken from two surveys carried out in 1992/3 and 2004/5 (DoE 1993; DCLG 2008b). They are distinguished from woodlands, which are covered separately, but some overlap is inevitable. In England, Urban trees are found mainly on private land, with 66% occurring in gardens, schools, churchyards and allotments. A further 20% grow in public parks and open spaces, and 12% are street trees. Town size does not appear to influence tree density (DCLG 2008b). The survey data also provide evidence of temporal trends since 1992, suggesting a regional increase in tree density in South East and South West England, with proportionate increases in street trees in residential areas; there is no obvious explanation for such trends.

Although 70% of Urban street trees surveyed in 2004/5 were in good condition, a comparison with the 1992/3 data suggests that there has been an overall decline in this status; however, there has also been a decrease in the percentage of trees considered poor, dead or dying, so caution is advised when interpreting recent trends in Urban tree condition. It is clear that between 1992 and 2005 there was a relative decline in the quality of trees in town centres, compared to those in surrounding residential areas (DCLG 2008b).

10.2.3 Public Parks and Formal Gardens

Parks and greenspaces are not a statutory service that local authorities are legally obliged to provide. Funding cuts and skills shortages have led to a significant decline in their quality in recent decades (Urban Greenspaces Taskforce 2002). Since the introduction of the Green Flag Awards in England and Wales (1996), and Scotland (2006), and other initiatives to improve parks and the use of greenspace by local communities (NAO 2006; Big Lottery Fund 2008; Heritage Lottery Fund 2008), conditions have improved; however, improvements have not been shared equally (CABE 2010). The main driver of improvements has been recognition of the importance of parks for health and well-being.

The Urban Parks Forum's (UPFOR 2001) Public Park Assessment identified 27,000 parks covering 121,953 ha located in the top 100 deprived areas of the UK, which are predominantly in cities and towns. Of this area, 19,527 ha (16%) were designated as of national historic importance and 19,945 ha (16.3%) as of local historic importance. Of all the parks assessed, 13% were considered to be in poor condition (obvious signs of decay), 69% in fair condition (adequate condition with repairs likely to be made in the near future), and 18% in good condition (thriving and well-managed). A more recent study reported improvements in condition, but observed that more needed to be done (NAO 2006). Deprived areas systematically fare worse in nearly all respects, particular in terms of park quantity, quality and level of use (CABE 2010).

Public parks have been the focus of various studies of Urban biodiversity (Gavareski 1976; Faeth & Kane 1978; Luniak 1981; Sasvári 1984). This continues to be a major theme (Suhonen & Jokimäki 1988; Jokimäki 1999; Morneau *et al.* 1999; Fernández-Juricic 2000, 2001; Fernández-Juricic & Jokimäki 2001; Platt & Lill 2006), motivated principally by the fact that parks typically constitute the largest continuous areas of greenspace in urban areas, so are important contributors to Urban morphology. By definition, they are readily accessible for purposes of data collection, and represent an important point of interaction between people and biodiversity. They have been likened to a series of valuable 'islands' for biodiversity in a less hospitable landscape, leading to suggestions that island biogeography theory may be relevant. Indeed, some of the principal ecological patterns associated with this theory have been found to apply to Urban parks, with species richness commonly increasing with area (Faeth & Kane 1978; Sasvári 1984; Jokimäki 1999; Fernández-Juricic 2000; Fernández-Juricic & Jokimäki 2001) and patterns of species composition being highly nested (Fernández-Juricic & Jokimäki 2001). However, in most urban areas in England, at least, this viewpoint seems inappropriate for a lot of species groups because the landscape matrix in which Urban parks are embedded comprises extensive networks of other kinds of greenspaces (e.g. allotments, cemeteries and domestic gardens).

Some Urban parks have experienced large temporal changes in species composition; this is an important consideration in understanding how biodiversity changes with their structure. For example, from 1947 to 1994, Pelham Bay Park, the second largest park in New York City, lost 25% of the native plant species, while the number of non-native plant species increased by 40% (DeCandido 2004).

10.2.4 Domestic Gardens

The main drivers negatively affecting the extent of domestic gardens include demographic change leading to an increase in housing demand (more flats and smaller gardens, particularly on PDL), and an increase in the paving of front gardens. An additional pressure arises from the introduction into gardens of invasive species. These can take many forms, but include pests and diseases that can have substantial negative effects. This may be compounded by the fact that climate change is predicted to lead to further increases in pests and diseases (Gates 2002; Wilby & Perry 2006). However, the popularity of gardening, particularly horticulture (including exotic species) and food production, together with the need to provide safe play areas, continue to drive the market for homes with gardens.

The extent of both urban and rural domestic gardens in England was reported at just over 4% (564,500 ha) of total land cover (GLUD 2005; **Table 10.3**). Data from other sources (Bibby 2009) suggest that Urban gardens cover an average of 13% of the Urban landscape. Our case studies (GLUD 2005) show the substantial variability of extent by city: Newcastle 13% (1,500 ha), Northampton 21% (1,700 ha), Coventry 22% (2,200 ha) and Liverpool 15% (2,400 ha). Liverpool gardens cover the largest area, but due to the inclusion of water (37%) within the GLUD classification, the percentage of land designated as garden appears proportionately low. London and Birmingham both averaged 25%. In Scotland, 30% of all Urban greenspace is classified as domestic garden. The size of gardens varies with housing type (Smith *et al*. 2005) and is associated with the occurrence and extent of different land cover types within their bounds and the occurrence of different features of relevance to biodiversity (e.g. trees, ponds) (Smith *et al*. 2005). There is limited available information on the condition of domestic gardens because they are not under local authority control.

The importance of these areas in the provision of habitats for the large numbers of species that they can harbour has long been acknowledged (Davis 1978; Owen 1991). Recent studies have shown that the richness and abundance of garden species respond both to characteristics of the gardens themselves (e.g. area, management) and to the nature of the landscape matrix in which they are embedded (e.g. cover by greenspace, housing density and type of housing) (Davis 1978; Smith *et al*. 2006a, 2006b, 2006c). The relative weighting of these two sets of factors tends to be determined, in part, by the dispersal characteristics of the species concerned, with better dispersers being more strongly influenced by the broader context in which individual gardens are placed.

The composition of Urban domestic gardens is poorly understood, but survey data from Sheffield estimated that 14.4% contained ponds, 26% had nest boxes, 29% had compost heaps and 48% had trees more than 3 m tall (Gaston *et al.* 2005). The Garden Bird Watch and Garden Nesting surveys of the British Trust for Ornithology (BTO) are helping to quantify the avian biodiversity of UK gardens (BTO 2010). Although such findings may not be indicative of private gardens throughout the UK, they suggest that this highly heterogeneous Urban subhabitat is likely to provide a wide range of ecosystem-derived goods and benefits that are particularly important for pollination services (Section 10.3). However, gardens also typically comprise a large number of non-native species, some of which may be considered invasive and a potential threat to ecosystem goods and services (Reichard & White 2001).

One particular trend that negatively affects ecosystem services is the increase in paving over front gardens. Aerial photographs from 1971 to 2004 were used to map changes in the impervious cover of a 1.16 km^2 suburban area of Leeds, England. A 13% increase in impervious surfaces was observed over the 33-year study period. Of the increase in impervious surfaces, 75% was due to paving of residential front gardens (Perry & Nawaz 2008). In London, an estimated 3,200 ha of front gardens have been covered in surfacing other than vegetation (i.e. paving, concrete, bricks and gravel)—this represents a loss of a significant percentage of domestic gardens in the area (based on GLUD 2005 data) in order to enable parking (GLA 2005a) and to provide further housing (infilling). This action has resulted in less percolation and increased runoff. Evidence suggests that the paving of front gardens is highest in North East England and Scotland, where 47% and 31% of front gardens are more than three quarters paved respectively (RHS 2006). Policies have been introduced to curb the trend in paving (e.g. Amendment No. 2 of the Town and Country Planning Act 2008) and to stop infilling. Gardens are no longer classified as PDL and housing density caps have been lifted (Barclay 2010).

10.2.5 Green Corridors

One of the major drivers of change for green corridors has been the recent recognition of their importance as transport links and wildlife dispersal aids. This has led to their integration into planning and conservation policy in 2010 through their inclusion in the UK BAP as Open Mosaic Habitats.

Green corridors are generally poorly quantified by local authorities making their extent and condition difficult to assess. There is evidence of increased use of these ribbons of land in terms of recognising their intrinsic wildlife value and their importance as public pathways that join greenspaces across large regions, thus providing valuable cultural benefits to local people and visitors (Wilby & Perry 2006). In Birmingham, the wildlife conservation strategy, published in 1997 (BCC 1997) was explicitly built around the corridor concept. Since then, the management of wildlife in the city has relied heavily on corridors as strategic planning tools. In London, the South East London Green Chain extends over 40 miles linking 300 open spaces across the area (London Borough of Bexley 2009). Green Grids, networks of attractive and accessible greenspaces that can link inner urban areas to rural areas, are also being used more widely in planning to improve accessibility and promote a broad range of benefits through multifunctional land use, as illustrated by the Thames Gateway Green Grid development in South East England (Section 10.5.1).

Hedges are natural features of green corridors that can provide a route for dispersing wildlife; as such, they are recognised for their habitat importance (Defra 2007a). Data on Urban hedge extent were not located although privet (*Ligustrum* spp.) is identified as the mostly widely planted urban hedge species.

10.2.6 Outdoor Sports Facilities, Recreational Areas and Amenity Greenspace

These subhabitats can include a broad range of greenspaces (**Table 10.5**). Amenity greenspace includes play parks and sports facilities but can also be just small patches of ground. Consistent datasets were not identified. Large areas of grassland (more than 5 km^2) are covered under Chapter 6, other grassland areas are covered here under 'playing fields and parks'.

During the 1980s, many playing fields were sold to developers and other land users. But since the importance of these facilities for good childhood development, education, and community cohesion (cultural benefits) was recognised, the decline in these facilities has generally halted. In recent years, funding from local authorities, charities and the Big Lottery Fund has contributed to improvements in outdoor play provision for young people.

Trends in extent and condition are limited, although it is estimated that 10,000 playing fields were sold between 1979 and 1997 (DCMS 2009). A significant proportion of local authority-designated greenspace is classified as outdoor sports facilities (e.g. Coventry 13%, Liverpool 32%, Newcastle upon Tyne 33% and Northampton 33%), but has variable quality and access. A total of 10,243 sports pitches, covering 8,170 ha, were reported in Urban areas (CABE 2010).

Fields in Trust recently commissioned research to assess the provision of outdoor play and recreational facilities in the UK (FIT & NPFA 2008). The report reviews the attainment of The Six Acre Standard (SAS) of accessibility to outdoor sport and play space by 147 local authorities around the UK, but does not provide extent or condition data. Results from the survey indicate that about 70% of local authorities refer to, use or have adopted the SAS in their plans. This means that, in England, playing pitches are provided within 1.2 km of urban dwellings, other outdoor sport facilities within a 20–30 minute drive, and children's playing spaces within 100–1,000 m walking distance from home (FIT & NPFA 2008). These data are compared with the recommendations in the SAS in **Table 10.7**.

Extensive data from Northern Ireland suggests that provision is significantly lower than England, with a median score of 0.06 ha of equipped playing space per 1,000 of the population and 0.48 ha per 1,000 of playing pitches. Insufficient data were received from Scotland and Wales for assessment.

Table 10.7 Comparison between reported provision of space for outdoor sports and play in England and the recommended Six Acre Standard published in 2001. Source: data extracted from FIT & NPFA (2008).

Type of space for outdoor sports and play	Reported median level provision (% response from local authorities)	Six Acre Standard
	ha/1,000 population	
For playing pitches	1.12 (58%)	1.2
For all outdoor sports facilities (including pitches)	1.32 (29%)	1.6
Casual playing spaces/amenity greenspace	0.7 (31%)	0.4–0.5*

*Based on the 1992 children's playing space standard.

10.2.7 Allotments, Community Gardens and Urban Farms

There are numerous views on the main drivers of decline for allotments. Suggested drivers include the emergence of the 'affluent society', which reduced the economic necessity of producing personal food supplies to the extent that allotment gardening became recreational. The sale of allotment space for development is also a key factor. Other influences include the absence of any consistent national campaigns to increase allotment uptake. However, the recent growth of 'green markets' is renewing interest. Factors such as an increased interest in organic food, concerns over reliance on importations, desire for a greater sense of self-sufficiency (33% of people in a recent poll say they now grow their own food; Thornton 2009), concerns over food costs, and general worries about food security are driving the increasing pressure on limited allotment space.

On the eve of WWII, there were 110,000 ha of allotments in England and Wales, made up of 740,000 plots. Urban areas provided approximately 55% of these, albeit generally smaller than rural allotments (Thorpe 1969; Crouch 1997). By the end of the 1940s, there were 1.4 million allotments popularised by the WWII 'Dig for Victory' campaign which encouraged people to grow their own food (Hope & Ellis 2009). During WWII, 10% of all UK-produced food came from allotments, private gardens and plots cultivated by service personnel. In 1941, the Ministry of Agriculture assessed the total annual food production from allotments alone as 1.3 million tonnes. Food production in allotments and city farms is discussed in **Box 10.4** (Section 10.3.1).

Over the past 60 years, the extent of allotments has declined, with only 10% of the post-war acreage remaining in England (Campbell & Campbell 2009) and only 211 plots existing in Scotland (45% of these sites are located in Glasgow, Edinburgh, Dundee and Aberdeen) (SAGS 2007). On an annual basis, the number of people on national allotment waiting lists has varied significantly (Crouch 1997). Today, allotment demand is far higher than allotment supply, especially in inner cities (GLA 2006a; SAGS 2007); a total of 997 plots covering just 1,356.8 ha (compared with an estimated 55,000 ha post-war) were recorded in the CABE Inventory (CABE 2010).

10.2.8 Cemeteries, Churchyards and Burial Grounds

The main driver of change in the extent and condition of cemeteries, churchyards and burial grounds relates to the shift from burials to cremations.

There is no comprehensive list of UK burial grounds, but the Wilson report (2004) estimated that there are 16,000–18,000 Church of England burial grounds in England and nearly 2,000 in Wales (**Table 10.8**).

An extensive survey of burial grounds in England and Wales received a total of 9,747 responses (Ministry of Justice 2007). The average size of local authority burial grounds was just over 3 ha with 46%, 19% and 10% of total area located in 'major urban', 'large urban' and 'other urban' areas respectively (75% of the total grounds). In contrast, Church of England-operated burial grounds averaged just under 0.5 ha with only 15%, 6% and 8% of total area located in 'major urban', 'large urban' and 'other urban' areas respectively[2].

The lack of a centralised record of UK burial grounds makes assessment of temporal trends in their extent and quality difficult. Very few churches built since the Edwardian era have incorporated yards for burial (J. Goodchild, Church of England, pers. comm.). The introduction of cremation in the 1870s, and its gradual rise to overtake burial as the principal mode of disposal by 1968, constrained requirements to expand burial facilities (Rugg 2006).

Table 10.8 Estimated total area usable in England for burials, and predicted future period of operation of local authority and Church of England burial grounds, by district rural/urban classification*† Source: reproduced from Ministry of Justice (2007).

Region	Estimated total area of burial grounds usable for burials (ha)‡	Area occupied by graves		Area occupied by graves more than 100 years old		Area as yet unused		Median predicted period of operation of burial grounds (yrs)¶§	Mean predicted period of operation of burial grounds (yrs)¶§
		Area (ha)	Percentage of total (%)	Area (ha)	Percentage of total (%)	Area (ha)	Percentage of total (%)		
Local authority burial grounds									
Major Urban	1,773	1,469	83	390	22	305	17	25	49
Large Urban	758	624	82	118	16	134	18	19	32
Other Urban	412	315	77	109	27	97	23	20	32
Significant Rural	450	354	79	91	20	97	21	25	42
Rural-50	314	234	74	43	14	80	26	40	50
Rural-80	244	184	75	51	21	60	25	30	40
Church of England burial grounds									
Major Urban	227	208	92	83	36	19	8	20	37
Large Urban	100	89	89	32	32	11	11	20	32
Other Urban	117	94	80	55	47	23	20	20	32
Significant Rural	261	215	82	97	37	46	18	25	37
Rural-50	309	253	82	118	38	57	18	25	40
Rural-80	533	428	80	195	37	105	20	25	55

* Classes are according to the Defra Classifications of Local Authority districts and Unitary Authorities in England. Does not include burial grounds in Wales. See the Defra website (http://archive.defra.gov.uk/evidence/statistics/rural/documents/rural-defn/LAClassifications_technicalguide.pdf) for more information.
† Data in this table exclude those for which a rural/urban classification could not be identified.
‡ For those burial grounds that were able to provide information on area and occupancy, in hectares, as well as a rural/urban classification.
¶ Predicted period of operation is the expected time before unused land available for burials is filled by interments.
§ Median and mean estimates also exclude: those burial grounds already closed to new burials, those open only to burials in existing graves, and those not providing information on predicted period of operation.

2 Urban classifications are from the Defra-recommended method of urban/rural categorisation (Defra 2010b).

Post-war, most of the churchyards that were no longer used for burial were passed to local authorities to manage. Their condition is highly variable; Highgate Cemetery, London, is recognised for its cultural value through its Grade I listing and designation as a site of Metropolitan Importance for Nature Conservation, yet other cemeteries and churchyards are in a state of neglect. Church grounds in general include a wide range of habitats and provide important urban sites for biodiversity (Cooper 2001).

10.2.9 Previously Developed Land (PDL) (Brownfield)[3]

Previously Developed Land is that which is, or was, occupied by a permanent structure, including the curtilage of the developed land and any associated fixed surface infrastructure (Planning Policy Statement 3: Housing (PPS3 2006)); until 2010, PDL included domestic gardens.

Planning policy has driven the redevelopment of brownfield land to curtail urban sprawl, reduce the need to travel by creating compact developments, and to meet the shortfall in new housing identified by the Barker Review (Barker 2004). In combination, these forces led to the once national target for 60% of new housing to be built on PDL (PPG3 2000; PPS3 2006). A recent report (NHPAU 2010) confirms that policies encouraging this brownfield development, coupled with policies to increase housing density from 30 to 50 dph (with a minimum density of 30 dph) (PPS3 2006), have been successful. Critics have argued that such targets have driven extensive development of domestic gardens ('garden-grabbing') with negative consequences for Urban areas (Barclay 2010).

From 1980 to 2000, densities for new homes built on PDL were fairly stable, but over the past decade, they have increased substantially in many regions and are up to 122 dph in London, for example (DCLG 2010b). In general, higher densities are associated with a larger share of flats (Bibby 2009). The extent of PDL is illustrated in **Table 10.9**.

A very recent policy change has led to the following changes to PDL (Barclay 2010):

- Private residential gardens are now excluded from the definition of PDL.
- The national indicative minimum density of 30 dph has ceased.

The general decline in extent of genuine Urban brownfield in England and Scotland over the last 10 years has implications for ecosystem service provision. In particular, the loss of permeable brownfield land and site fragmentation are likely to reduce services such as wild species diversity (Harvey 2000; Eyre *et al.* 2003; Angold *et al.* 2006; Schadek *et al.* 2009), climate regulation and flood regulation within the Urban environment. It should be noted that large areas of brownfield may have some degree of contamination. Some areas within PDL are now being recognised as an important

Table 10.9 Previously Developed Land (PDL)

	England	Scotland	Wales
Classification system	PDL: i) Vacant or derelict; ii) Developed but with potential for redevelopment.	i) Vacant land within urban areas; ii) Derelict land and buildings within all areas (SVDLS 2008).	
Data availability	Lack of comparative data prior to 2002 (DCLG 2006).	Temporal trends analysed since 2002 (SVDLS 2008).	Very limited information on the extent and characterisation.
Current extent	62,130 ha PDL in 2007 (DCLG 2006). An estimated 33,600 ha was vacant or derelict and 28,520 ha are in use but with potential for redevelopment. 47% of vacant and derelict land and buildings is considered urban and 29% is on the urban fringe. 71% of PDL currently in use is urban, with 18% in the urban fringe and only 11% in rural areas (DCLG 2006).	In 2008, 10,832 ha of derelict and urban vacant land were recorded, of which, 2,630 ha (24%) were urban vacant and 8,203 ha were derelict (76%) (SVDLS 2008).	
Temporal trends	Since 2002, the total amount of PDL has declined by approximately 6%. Significantly, increases in PDL currently in use mask far greater declines in vacant land (-18.9%) and derelict land (-5.8%) (DCLG 2007), both of which are more likely to confer ecosystem services, such as flood regulation, due to a greater proportion of permeable land.	In 2002, there were 2,968 ha of urban vacant land. This figure has fluctuated somewhat in the intermediate period; however, by 2008, it had dropped to 2,630 ha (an overall net decrease of 338 ha). This represents a net fall in levels of urban vacant land in Scotland of 11% (SVDLS 2008).	
Spatial trends	Great regional variation. Former industrial regions of the North West and Yorkshire/Humber contain the highest amounts of PDL (17.6% and 14.7% respectively). In contrast, London and the North East contain only 6.3% and 6.5% respectively (DCLG 2006).	The local authority with the highest amount of derelict and urban vacant land was North Lanarkshire, containing 1,397 ha (13% of Scotland total). Glasgow City had the second highest with 1,325 ha (12% of Scotland total), and North Ayrshire was third with 1,276 ha (12%) (SVDLS 2008).	Up to 50% of reclaimed and derelict land is a result of the coal industry, especially in the valleys of South Wales (Environment Agency 2009).

3 Urban/rural classifications are based on the Department of Communities and Local Government urban settlements Ordnance Survey classification (2001).

biodiversity resource and these areas are now being classified as UK BAP priority habitats.

10.2.10 Water

The subhabitat of water separates out natural from artificial water bodies as these can provide different ecosystem services.

Legislation from the EU and associated policies have been the main drivers influencing the aquatic Urban environment and the subsequent goods and benefits derived from it. The EU Water Framework Directive (WFD) requires all water bodies to meet 'good status' or 'good ecological potential' by 2015 (see Chapter 27). Measures are currently being taken to classify and improve all water bodies in Urban locations. In total, 0.8% of the UK is classified as Urban freshwater (LCM 2000), with an average of 6.6% in England (GLUD 2005). The extent of land classified as water within our Urban case study is: Liverpool 31% (5,100 ha), Northampton 2.7% (200 ha), Coventry 0.5% (50 ha) and Newcastle 1.8% (200 ha) (GLUD 2005).

The Scottish Environment Protection Agency carried out an evaluation of the current status of all Scottish water bodies as part of their ongoing implementation of the WFD (2000). Of the 29 wholly Urban water bodies identified, 18 are classified as heavily modified water bodies (**Figure 10.7**). The results of analysis for conventional water quality parameters (dissolved oxygen, pH, temperature and soluble phosphorous) indicated that the quality of Scottish Urban waters is relatively good, with values for only three water bodies falling below a classification of moderate (two are related to soluble phosphorus and one to dissolved oxygen) (**Table 10.10**; **Table 10.11**).

The Environment Agency currently classifies 278 (approximately 34%) of Urban river bodies in England and

Table 10.10 Minimum and maximum total concentrations of metals measured in a selection of Urban stream and river sediments (µg/g dry weight). n = number of samples. Values in green exceed the Canadian Sediment Quality Guidelines (2003) (standard not available for nickel). Source: Scholes *et al.* (2008).

	n	Cadmium	Chromium	Copper	Nickel	Lead	Zinc
Scholes *et al.* (1999)	45	**3.0–10**	3–**169**	17–**178**	22–187	33–**332**	21–**1,035**
Rhoads & Cahill (1999)	41		9–**328**	6–**55**	8–244	10–**225**	29–**528**
Wilson & Clarke (2002)	9			**440.6**	80.9		**407.0**
Filgueiras *et al.* (2004)*	33	0.37–0.41	**78–139**	30.5–**55.9**	32.5–60.7	**43.6–91.1**	
Tejeda *et al.* (2006)	32			9–165		12–**64**	38–**1,467**
Thevenot *et al.* (2007)†		**1.70**	**47**	31		**43**	**140**
Samecka-Cymerman & Kempers (2007)	21	0.20–0.58	4.9–**28.5**	2.1–10.6	7.5–15.2	15–57	6.8–**458**
	24	0.24–**1.72**	17–**85.2**	9.5–43.7	14.5–39.0	17–97	22.9–**174**
Walling *et al.* 2003 ‡	51		8–17	33–92		**689–1,471**	**775–1,850**
	52		21–**181**	**118–198**		**90–237**	**274–580**
	17		**65–313**	**141–235**		**199–343**	**397–907**
Carpentier *et al.* 2002	50¶	<**0.8–6**	4–**78**	<5–**172**	<5–30	<5–**278**	39–**563**

* range of values across 11 sites; † estimated average metal contents over the time period 1995 to 2000 of dredged sediments; ‡ range of values reflect average concentrations at multiple sampling points on 3 different rivers sampled approximately bi-monthly over a 12-month period; rivers located close to metal mines (no longer operational); ¶ number of samples analysed for cadmium = 42 and chromium = 32.

Table 10.11 Concentrations of microbiological parameters recorded in a selection of Urban stream and river waters and sediments. Values in green exceed EU Bathing Water Directive values. MPN = most probable number and CFU = colony forming units. Source: Scholes *et al.* (2008).

	Total coliforms		Faecal coliforms	
	Water	Sediment	Water	Sediment
Torres (1997)	**84,000** MPN/100 ml	280,000 MPN/g	1,800 MPN/100 ml	20,000 MPN/g
Crabill *et al.* (1999)			29–527 CFU/100 ml*	100,000–3,000,000 CFU/100 ml†
Snook & Whitehead (2004)	**710,000** CFU/100 ml		**120,000** CFU/100 ml	
Ellis & Yu (1995)‡	3,000–**3,000,000** MPN/100 ml	22,000 MPN/g	800–**800,000** MPN/100 ml	2,800 MPN/g
Miyabara *et al.* (1992)¶	<2,000–**4,900,000** MPN/100 ml		<2,000–**7,900,000** MPN/100 ml	
He *et al.* (2007)§	8,000–**170,000** MPN/100 ml	50,000–130,000 MPN/g	20–1,300 MPN/100 ml	130–5000 MPN/g
EU Bathing Water Directive**	10,000 CFU/100 ml		2,000 CFU/100 ml	

* range in mean annual values across 8 sites; † range in mean annual values across 4 sites; ‡ geometric mean densities across 4 sites; combined sewer overflows discharging into an Urban stream; ¶ range of values reported across 14 Urban rivers; § average of samples collected across approximately one third of 500 sites; ** value for marine waters.

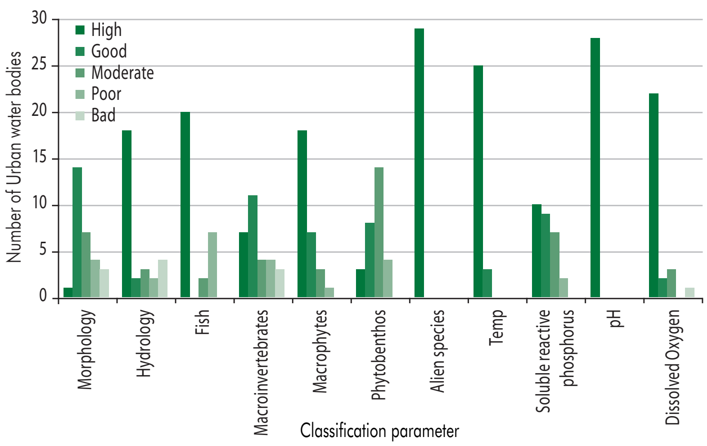


Figure 10.7 Status of Urban surface water in Scotland.
Source: analysis provided by Chris Bromley at the Scottish Environment Protection Agency (2009).

Wales as having an overall status below 'good' and with below 'moderate' status for the parameters: dissolved oxygen, temperature, pH and phosphorus (Jones 2010). Across the UK, there was a general improvement in both the chemical and biological status of rivers and canals between 1990 and 2005. Although the extent to which this trend has occurred in Urban areas in general is difficult to assess, within London the proportion of rivers and canals of 'good' chemical or biological status has more than doubled (ONS 2007).

Urban water bodies are considered by Paul and Meyer (2001) to typically receive polluted inputs from sources that include urban and highway runoff, and cross-connections and overloads from foul to storm sewers (Gasperi *et al.* 2008), resulting in a prevalence of pollution tolerant fauna and flora (Scholes *et al.* 2008). The straightened and modified banks and channels that characterise many Urban streams (Gurnell *et al.* 2007) means that physical habitat variability is low, flow refugia is reduced and a range of other deleterious ecological impacts occur, especially when in association with poor water quality. The water quality of Urban water bodies is also discussed in Chapter 9 and, more generally, in Chapter 14.

Water use can be measured by the amount of water we abstract from natural water resources. The Environment Agency reported little change in the amount of water abstracted (nearly 60,000 megalitres per day) from 2000/01 to 2006/07. In relation to usage *per capita*, between 2002 and 2007, domestic demand varied between 148 and 152 litres per day, indicating that domestic water demand in the UK is fairly stable (Water UK 2008). Policies to reduce water use to 120 litres per day are proposed by the Department for Environment, Food and Rural Affairs as part of its Future Water Strategy (Defra 2008).

10.2.11 Green Belt (Urban Fringe and Peri-urban)

Green Belt land is usually located on the Urban fringe and extends into the countryside, therefore providing accessible greenspace for the urban population who benefit from the additional ecosystem services and goods it provides.

Although the promotion of the reuse of PDL has constrained the demand for housing development elsewhere, this driver has persisted in putting pressure on peri-urban Green Belt (Natural England & CPRE 2010). Since 1989, the annual percentage of new housing built on Green Belt land has fluctuated between 2–4%, stabilising at approximately 2% (DCLG 2010c).

It is estimated that 60% of England's population live in towns and cities surrounded by Green Belt. Between 1997 and 2007, land in England designated as Green Belt is estimated to have increased by 33,000 ha, and as of March 2009, stood at 1,983,000 ha, or 15.2% of the land mass (**Figure 10.6**) (DCLG 2009a). In total, there are 14 separate Green Belts in England varying in size from London (Metropolitan) at 486,000 ha to Burton-upon-Trent and Swadlincote at 700 ha. They include 38 towns and cities with populations over 100,000. Most increases in extent since 2007 have been apportioned to improvements in measurement technology, as opposed to changes due to adopted plans (real changes) (DCLG 2009a).

In Scotland, the Green Belt area is estimated to have fallen by 9% between 2007 and 2009 (Greenspace Scotland 2009), and now only covers 143,000 ha, of which, 34,555 ha is classified as Urban. Wales has just introduced its first Green Belt between Cardiff and Newport at 3,000 ha, but the greatest percentage of designated Green Belt by country is found in Northern Ireland which has 23.7% (336,000 ha) cover.

10.2.12 Urban Biodiversity

Recognition of the importance of Urban biodiversity is the likely future driver of policy change and habitat and species monitoring and protection.

A number of studies have explored the relationship between species assemblage structure and Urban greenspaces other than parks and domestic gardens including: allotments (Luniak 1980); brownfield sites (Davis & Glick 1978; Dickman 1987); cemeteries (Lussenhop 1977; Biadun 1994); ponds (Parris 2006); public squares (Zanette *et al.* 2005); remnant habitat patches (Crooks *et al.* 2004); roundabouts and traffic islands (Whitmore *et al.* 2002; Helden & Leather 2004); and woodland/forest patches (Tilghman 1987; Hobbs 1988; Miyashita *et al.* 1998; Park & Lee 2000, Niemelä *et al.* 2002; Magura *et al.* 2004; Lehvävirta *et al.* 2006; Morimoto *et al.* 2006; Platt & Lill 2006; Sadler *et al.* 2006). The predominant themes have been similar to those for Urban parks and domestic gardens, and include the influence of the size of these spaces, of their isolation, and of surrounding land cover and uses. These are important determinants of patterns of biodiversity across Urban habitats, with species richness typically strengthening with an increased size of area, and with the broader coverage of usable habitat. However, these and related ecological patterns may be weakened, if not entirely masked, by variation in the quality of the greenspace and the profound influence upon quality of the form of management that is (or is not) undertaken. Pollution can also contribute to habitat and species change (e.g. the impact of acidification on lichen diversity) (Davies *et al.* 2007).

Threshold effects have been discussed, including levels of urbanisation that are sufficient to cause marked changes in species richness or composition (Paul & Meyer 2001; Riley *et al.* 2005). But given the important influences of species identity and context on observed responses, such thresholds are unlikely to occur on a wide scale. Values for thresholds would have to be established separately, at least for different broad regions.

Some have argued that urbanisation leads to biotic homogenisation, whereby a few widespread and abundant species replace a more diverse assemblage (Brandes 1995; Jokimäki & Kaisanlahti-Jokimäki 2003; Crooks *et al.* 2004; McKinney 2006). While perhaps a useful caricature, this is rather simplistic as Urban species assemblages frequently retain some local character, reflecting the fact that they are drawn, in part, from native regional assemblages, not simply from the species that occur ubiquitously. Similarity of species assemblages in Urban habitats may also be a function of the degree of urbanisation and the sizes of towns and cities, increasing with the number of people and the size of the urban area (Jokimäki & Kaisanlahti-Jokimäki, 2003; McKinney 2006).

10.2.12.1. Biodiversity: species richness and abundance

The categorisation of the findings of individual analyses is not always straightforward, but certain studies (few of which have been conducted in the UK) document a variety of trends in biodiversity.

Trends associated with species richness of major taxonomic groups:

- Declines with increased urbanisation—bees and wasps (McIntyre & Hostetler 2001; Zanette *et al.* 2005); beetles (Niemelä *et al.* 2002; Ishitani *et al.* 2003; Venn *et al.* 2003; Weller & Ganzhorn 2004; Sadler *et al.* 2006); butterflies (Hardy & Dennis 1999); amphibians (Riley *et al.* 2005; Rubbo & Kiesecker 2005); birds (Emlen 1974; Hohtola 1978; Beissinger & Osborne 1982; Jokimäki & Suhonen 1993; Clergeau *et al.* 1998, 2001a, 2001b; Rottenborn 1999; Marzluff 2001; Green & Baker 2003; Melles *et al.* 2003; Donnelly & Marzluff 2006; Sandström *et al.* 2006); mammals (Hourigan *et al.* 2006). This pattern is usually attributed to the loss of suitable habitat and resources as urbanisation increases.
- Peaks at intermediate levels of development—plants (Kowarik 1990; Porter *et al.* 2001; Zerbe *et al.* 2003); butterflies (Blair & Launer 1997); lizards (Germaine & Wakeling 2001); birds (Sewell & Catterall 1998; Blair 2001; Clergeau *et al.* 2001a; Crooks *et al.* 2004; Marzluff, 2001, 2005). This is often associated with a greater number of land use types in intermediate levels of development, disturbance, and the multiple private ownership of land that leads to variation in management (Zerbe *et al.* 2003).
- Increases with increased urbanisation—plants (Kühn *et al.* 2004; Turner *et al.* 2005; Wania *et al.* 2006); butterflies (Hardy & Dennis 1999); birds (Marzluff 2001). Generally, this seems to occur because of the relatively high numbers of invasive alien species in more heavily urbanised areas (Kowarik 1990; Germaine *et al.* 1998; Kent *et al.* 1999; Roy *et al.* 1999; Marzluff 2001; Savard *et al.* 2000; Wittig 2004; Burton *et al.* 2005; Wania *et al.* 2006; Zhao *et al.* 2008). In some cases, numbers of native species have also been shown to be greater (Kühn *et al.* 2004).
- Other or no pattern with increased urbanisation—plants (Roy *et al.* 1999); beetles (Niemelä *et al.* 2002; Magura *et al.* 2004); birds (Jokimäki *et al.* 1996; Sewell & Catterall 1998; Mason 2006).

Trends associated with species abundance of major taxonomic groups:

- Declines with increased urbanisation—bees and wasps (McIntyre & Hostetler 2001; Zanette *et al.* 2005); beetles (Niemelä *et al.* 2002; Ishitani *et al.* 2003; Magura *et al.* 2004); butterflies (Blair & Launer 1997); birds (Marzluff 2001; Sandström *et al.* 2006). This is usually attributed to the loss of suitable habitat with increasing urbanisation.
- Peaks in moderately urbanised areas—beetles (Niemelä *et al.* 2002); lizards (Germaine & Wakeling 2001); birds (Sewell & Catterall 1998; Blair 2001; Marzluff 2001).
- Increases with increased urbanisation—earthworms (Steinberg *et al.* 1997); beetles (Niemelä *et al.* 2002); birds (Emlen 1974; Beissinger & Osborne 1982; Jokimäki *et al.* 1996; Mills *et al.* 1989; Clergeau *et al.* 1998, 2001b; Marzluff 2001; Green & Baker 2003). This pattern is often associated with the abundance of invasive alien species (Mills *et al.* 1989; Clergeau *et al.* 2001b; Niemelä *et al.* 2002).
- No simple pattern with increased urbanisation—beetles (Venn *et al*, 2003); birds (Hohtola 1978; Marzluff 2001; Mason 2006).

There are necessary caveats when drawing conclusions from collations of empirical studies of the relationship between the structure of species assemblages (including species richness and overall abundance) and urbanisation (**Table 10.12**). They explain much of the variation between the patterns documented.

Most studies of changes in biodiversity across rural-urban gradients focus on individual towns and cities and their environs. Others have drawn data from wider regions, encompassing multiple urban centres, often with a focus on how levels of urbanisation contribute to broad geographic patterns (Hostetler & Holling 2000; Kühn *et al.* 2004). This provides much greater generality in the conclusions. However, caution needs to be exercised to avoid confounding effects of other gradients. At broad geographic scales, the number of species in different groups in an area correlates positively with the numbers of people: there is a positive species-human relationship (Luck 2007). In heavily industrialised areas, such relationships seem to persist at quite fine resolutions (10 km; Evans & Gaston 2005). For birds, relationships between species richness and human population density have been shown to be positive up to densities of about 1,000 individuals per km^2, after which they start to decline markedly (Evans & Gaston 2005, Turner *et al.* 2003).

Although there are other possibilities (e.g. coincidence, disturbance, extinction filters, geomorphology; Araújo 2003; Kühn *et al.* 2004), the most generally accepted explanation for this pattern of positive covariance is that species richness and human populations respond positively and independently to levels of environmental energy availability (variously measured in terms of temperature and net primary production). Species numbers often increase with energy

Table 10.12 Methodologies used in Urban biodiversity studies that explain much of the variation between the patterns documented.

Pattern documented	
The range of and position on the rural-urban gradient.	Mazluff *et al.* (2001)
How finely the rural-urban gradient is sampled and its potential for detecting non-linear relationships. There are few studies that sample intensively across the gradient.	
The quality of the rural (e.g. native vegetation, farmland, intensification of agricultural activities) **or less urbanised landscape** with which to compare Urban areas.	
The extent to which sample areas contain heterogeneous land cover or focus on a particular land cover.	Guntenspergen & Levenson (1997) Steinberg *et al.* (1997)
Spatial resolution which is significant because different groups of species may operate, and be managed, across different spatial scales and by different stakeholders (e.g. city councils, developers, individual garden owners).	Hostetler & Holling (2000) Savard *et al.* (2000)
Study plot area which may vary systematically with urbanisation, especially when using habitat patches as the unit of analysis (patch size typically declining with urbanisation), and may be problematic because species richness and abundance may be functions of plot area.	Rosenzweig (1995) Gaston & Matter (2002)
History of urbanisation where the long-term temporal dynamics of the response of species richness, abundance and composition to urbanisation may be marked.	Munyenyembe *et al.* (1989) Morneau *et al.* (1999) Godefroid (2001) Chocholoušková & Pyšek (2003) Pyšek *et al.* (2004) Turner *et al.* (2005)

(the species-energy relationship) at a geographic scale, at least over a wide range of values of energy availability, for a variety of reasons (Evans & Gaston 2005). At broad geographic scales, number and proportions of threatened species tend to increase with the numbers of people in an area (Kerr & Currie 1995; Dobson *et al.* 1997; Kirkland & Ostfeld 1999; McKinney 2001, 2002; Araújo 2003; Chown *et al.* 2003; Luck *et al.* 2004; Vázquez & Gaston 2006).

While urbanisation is a leading cause of species threat in some regions (Czech & Krausman 1997), variable patterns in the number and proportions of threatened species have been reported (Duhme & Pauleit 1998; Zerbe *et al.* 2003; Kühn *et al.* 2004). Presumably, these variations occur because remnant populations have survived the urbanisation process but are at high risk of extinction in their newly developed habitat. In other cases, urbanisation has extirpated these species, and those that remain occur predominantly at lower levels of development.

Due to its high spatio-temporal dynamics, and its transient character, PDL can significantly influence Urban biodiversity (Schadek *et al.* 2009; Angold *et al.* 2006). This land is likely to support higher trophic levels with larger ranges, and high plant and invertebrate diversity has been observed here (Eyre *et al.* 2003; Harvey 2000).

10.2.13 Trends and Changes in Abiotic and Biotic Processes

As described in Section 10.1, the Urban system includes abiotic and biotic processes relating to air, water and soil. This section discusses trends within these processes, covering climate, noise, and air and soil quality. Water is covered in Section 10.2.10 under the Urban subhabitat of water.

10.2.13.1 Climate

Concerns about Urban Heat Intensity (UHI) are driving a range of mitigation and adaptation measures.

Recent temperature increases have most adversely affected urban areas in southern England due to the combination of warmer prevailing conditions and the Urban microclimate (RMetS 2009a). Given the absence of abrupt changes in rainfall over the last few decades, such as those described for temperature, it is not possible to attribute any of the recent UK precipitation trends to anthropogenic warming (Department of Health 2008). However, the 2003 heatwave episode provides an indication of the possible impact to human health from hotter, drier summers (GLA 2010).

Only limited data are available for UK spatial trends on the degree of Urban climate regulation services. The extent of UK Urban 'heat islands' (the warming of the atmosphere and surfaces in towns and cities compared to their rural surroundings) is likely to be synchronous with factors such as city size and percentage and type of greenspace. This dependency has been shown both spatially and temporally for cities such as Atlanta, Georgia, USA (Dixon & Mote 2003), and Singapore (Chow & Roth 2006). In the UK, datasets are less well established, but some urban land use categories, such as storage and manufacturing, are considerably warmer than low density residential areas and farmland (RMetS 2009b). A recent study of the London heat island identified a maximum daytime UHI of 8.9°C in semi-urban (not inner core) areas during partially cloudy periods, while a maximum nocturnal UHI of 8.6°C was found in urban areas during clear sky periods when the wind velocity was below 5 m/s. Among the variables studied, the most critical variable that determines the daytime and nocturnal changes in outdoor air temperature is surface albedo (i.e. the reflectivity of our towns and cities) (Kolokotroni & Giridharan 2008; GLA 2006b).

10.2.13.2 Air quality

Historically, the factors responsible for reductions in acidic atmospheric conditions of the post-war decades were regulation and enforcement, together with cleaner fuels. Anthropogenic alteration of the global nitrogen cycle is now driving change in Urban habitats (Vitousek *et al.* 1997). Reactive nitrogen from transport, industry and heating, as well as nearby intensive agriculture, has led to changes in biodiversity, community structure and the condition of multiple Urban subhabitats, and has also adversely affected human health. The regulatory framework governing air pollution and vehicle standards has been the main driver of change in Urban areas in recent years, offsetting increases in car ownership and distance travelled to an extent. Increasing temperatures and lower levels of nitrogen oxides are contributing to higher background ozone levels.

Changes in atmospheric pollution both within Urban areas and the surrounding countryside have had a profound effect on Urban air quality over the last 60 years. Emissions of black smoke and sulphur dioxide have declined markedly (e.g. in London, annual mean sulphur dioxide and black smoke concentrations have decreased by more than 95% since 1962; AEA 2008), and, more recently, concentrations of lead have also decreased. The dominant source of pollution emissions in Urban environments is now from vehicles (AQEG 2007) and heating. In 2008, 42% of London's nitrogen oxides emissions and 69% of London's PM_{10} (particulate matter of 10µm or less) emissions were attributed to road transport (TfL 2008). This shift from acidic atmospheric conditions to a more eutrophicated environment is clearly illustrated in the change in lichen diversity in London where nitrophytes have replaced acidophytes over a 30-year period (Davies *et al.* 2007; **Box 10.3**). Protective standards for sensitive vegetation do not apply in large conurbations where they are widely exceeded.

Air Quality Management Areas (AQMAs) have to be declared where UK air quality objectives for human health are exceeded (AEA 2009). Despite a substantial decline in nitrogen oxides since the early 1990s, most AQMAs declared for nitrogen dioxide and PM_{10} are located in large conurbations where street canyons inhibit dispersion (Vitousek *et al.* 1997), traffic flow rates are high and traffic speeds are low.

10.2.13.3 Noise

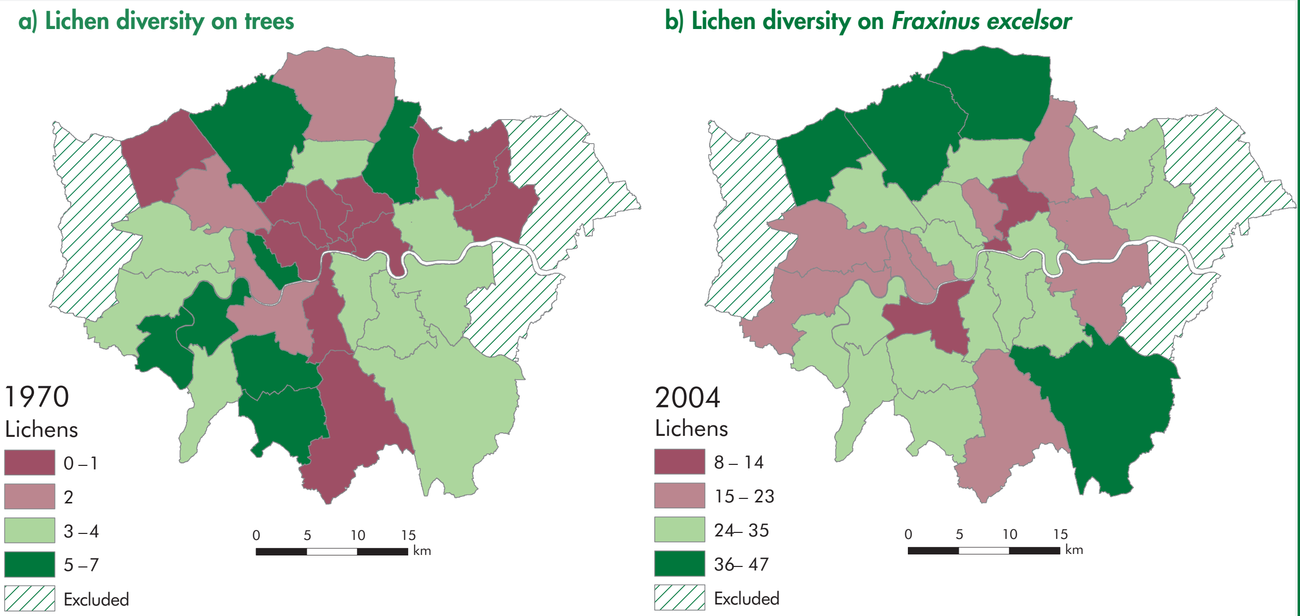
Road traffic is the principal source of noise pollution in the UK (Grimwood 2002). Increases in car ownership and distance travelled (mean has increased from 3,660 miles in 1965 to 6,720 miles in 2001; DfT 2002) are the main drivers that will continue to place increasing pressure on noise regulating ecosystem services. The European Directive on the Assessment and Management of Environmental Noise (END 2002/49) has led to improvements in noise modelling.

Between 1990 and 2000, changes in noise level and exposure in England and Wales were small and trends were subtle, with different indicators showing different changes (Skinner & Grimwood 2002). Average daytime noise levels, measured by L_{Aeq} and L_{A10} indicators, decreased during this period, while average night noise levels, measured by the L_{A90} indicator, increased. For many indicators, over all periods of the day and night, noise levels are significantly higher in Greater London than over the whole of England and Wales (Skinner & Grimwood 2002). Based on current datasets, however, it is not possible to discern the extent to which any trends in Urban noise are the result of altered provision of noise regulation services. Trends in noise regulation are discussed further in Chapter 14.

10.2.13.4. Soil

The importance of soil and the location and extent of permeable surfaces had not been recognised within the planning system until recently. However, recognition in recent years has driven changes that are reflected in Planning Policy Statements PPS3 (Housing; 2006) and PPS7 (Sustainable Development in Rural Areas; 2004), and Planning Policy Guidance 9 (PPG9 Biodiversity and Geological Conservation; 2005). Other drivers of change in

Box 10.3 Trends in lichen diversity in London from 1970 to 2004. Source: Davies *et al.* (2007). Copyright (2007), reproduced with permission from Elsevier.



Between 1970 and 2004, there is strong evidence that the dramatic changes in Urban atmospheric composition had significant consequences for Urban lichen diversity. In 1970, London's lichen flora was found to be highly limited, with just nine epiphytic, mainly acidophytic, species. In contrast, recent surveys indicate that there has been a substantial recovery in lichen diversity across London, with species associated with eutrophication (high nitrogen) now dominant (Davies *et al.* 2007).

soil quality and permeable surfaces include demographic changes and associated housing policy linked to urban regeneration which have driven up housing density in urban areas, reducing garden size. Car ownership has, in part, led to the paving of front gardens, and the use of private and public areas for car standing (with the added benefit of less garden maintenance). Legislation on contaminated land and soil quality should drive new developments in soil remediation and soil quality assessment procedures.

Information about the chemical and physical properties of Urban soil is limited as, historically, these areas have been excluded from soil surveys which focused on rural areas (Fordyce *et al.* 2005). A systematic sampling programme started in the Midlands and has been ongoing since 2005; it confirms that, while the underlying geology is important in determining the elemental composition of Urban soil, the pressures from urbanisation have led to increased levels of pollution (Fordyce *et al.* 2005).

Urban soils are often highly compacted with concomitant structural degradation. Although they retain the ability to support soil flora and fauna, the impacts of anthropogenic activities often mean that many organisms are unable to survive, and opportunities for ecological colonisation can be limited (Wood *et al.* 2005). Basal rates of respiration are commonly elevated in comparison with rural equivalents (Post & Beeby 1996). The implications of the condition of Urban soils in the global carbon cycle (*inter alia*) and on the soils' capacity to sequester atmospheric carbon dioxide remain unclear.

10.3 Ecosystem Goods and Services Provided by the Urban Environment for Human Well-being

In this section, we review the ecosystem services and the subsequent goods and benefits provided by the Urban environment. The definitions of goods, benefits and ecosystem services are described in Chapter 2.

Many of the main goods and benefits available from the Urban environment—which are summarised in **Table 10.13**—arise from cultural services and include good physical and mental health, recreation and community cohesion. Cultural services are particularly important in Urban areas where human population density is higher than it is in all other habitats. The goods and benefits that arise come from the many local and culturally valued landscapes and waterscapes, such as parks and woodlands, playing fields and nature reserves, as well as the many smaller open areas that are found throughout the Urban environment.

Provision of greenspace in towns and cities, while appearing extensive (GLUD 2005), has been shown to vary considerably *per capita.* This uneven distribution reduces provision and the potential benefits for human well-being.

Table 10.13 Main goods and benefits derived from final ecosystem services provided by the Urban environment.

Ecosystem service	Final ecosystem service	Description of the main goods and benefits from the Urban environment
Provisioning	Crops, plants, livestock, fish,	Food: e.g. vegetables, fruit, meat, milk, honey
		Fibre: e.g. compost
		Ornamental: e.g. flowers
		Genetic resources
	Trees, standing vegetation & peat	Trees: e.g. timber, wood chippings
		Fuel
	Water supply	Drinking water
		Industrial use of water
		Energy
Provisioning/ Cultural	Wild species	Wild food: e.g. berries
		Recreation and tourism
Cultural	Environmental settings	Physical and mental health
		Spiritual and religious
		Heritage: includes cultural heritage, aesthetic and inspirational, security and freedom, neighbourhood development, social and environmental citizenship
		Recreation and tourism
		Education
Regulating	Climate	Avoidance of climate stress
		Carbon sequestration
	Hazard	Erosion protection
		Flood protection
		Avoidance of climate stress
	Purification	Clean air
		Clean water
		Clean soil
	Noise	Noise reduction

Effective delivery of these services is determined by many factors including accessibility and condition. For example, inner cities have the lowest provision, thus the value of goods and benefits should be weighted accordingly. Dense, inner city populations tend to have the least accessible greenspace, with small parks, few domestic gardens or allotments, and associated low biodiversity. In areas of Urban fringe, where the extent of greenspace itself is not an issue, poor condition, caused by neglect and poor maintenance, together with poor accessibility due to safety concerns, can often prevent cultural benefits reaching deprived communities.

Regulating services are essential to the Urban environment. For example, purification provides clean water, air and soil, which contributes to high quality environments that support human well-being (Chapter

14). The Urban environment also supports other regulating services associated with climate, hazards and noise.

To a lesser extent, Urban areas supply provisioning services, such as crops and livestock for food, but these tend to be limited to a smaller number of subhabitats. The provision of trees and standing vegetation is one exception, as it is widely delivered across the subhabitats, and supplies both cultural goods (e.g. recreation and tourism) and regulating goods (e.g. avoidance of climate stress and noise regulation).

Biodiversity can be viewed as underpinning all ecosystem services through its role in supporting fundamental ecosystem processes. Some wild species also directly deliver provisioning services, supplying a range of wild food, such as berries, for example. Moreover, wild species diversity is also considered a cultural service, contributing to the spiritual, aesthetic and cultural value of Urban areas (Chapter 2; Chapter 4). The increasing prevalence of certain mammal species in urban and peri-urban areas, such as badgers and deer, means that more people are aware of, and place value on, the presence of such wildlife (Dandy *et al.* 2009).

10.3.1 Provisioning Services

The limited extent of cultivation and the high proportion of impermeable surfaces in urban areas restrict the production of goods, such as food, flowers, timber and fibre (compost), in the Urban environment. Most essential provisions are produced within other Broad Habitats, so urbanisation almost entirely draws on national and global ecosystems.

Nevertheless, there is some production by community farms, domestic gardeners and allotment holders (**Box 10.4**), with the latter estimated to save up to £1,000 per household per annum through reduced food bills (Hope & Ellis 2009) and seen to gain access to goods that might otherwise be unavailable to them due to high supermarket prices (GLA 2006a). Contrary to widely perceived stereotypes, the goods and benefits provided by allotments are delivered by a wide demographic range of society (NSALG 1993). Honey bees have even been shown to produce more honey in the urban areas of cities such as Birmingham than in the surrounding countryside (Memmott 2010).

Trees in Urban areas provide sources of timber and other byproducts, including charcoal, wood chip and compost, but are particularly important in the provision of other goods arising from regulating services, such as clean air, clean water and erosion protection (Gill *et al.* 2007; NUFU 2005). Species composition and age structure of Urban trees are crucial determinants of ecosystem service provision (NUFU 2005).

Other Urban habitats, such as Urban water bodies, supply drinking and irrigation water (both through abstraction and via recharge of groundwater) and a medium for industrial processes, as well as sites for recreational and spiritual activities (Petts *et al.* 2002).

Very little information exists on genetic resources in Urban greenspace. However, domestic gardens, allotments and some formal gardens are particularly important for horticulture and home-grown produce, and so, it is likely that a considerable amount of genetic diversity exists through generations of breeding plants.

Box 10.4 Urban food production.

Urban food production reached its peak during the Second World War. A sharp decline followed, but interest began to revive in the 1970s as evidence of the impact of pesticides and other pollutants was recognised. Interest in home-grown produce has continued to gain popularity, particularly in more recent years, due to increasing environmental awareness and sustainability issues (Howe & Wheeler 1999), the desire for organic food, and the rising costs of provisions. Produce arises from domestic gardens, allotments (**Figure 1**) and larger facilities such as city farms and orchards.

A recent survey of 124 allotment holders (Perez-Vazquez *et al.* 2005) identified the most common crops as: potatoes, spinach, onions, courgettes, runner beans, leeks, Brussels sprouts, tomatoes and cabbage. The average plot had 16 crop species, although species diversity was highly variable and included maize, squashes, callaloo, scallion and a wide range of herbs and flowers. Produce grown on an allotment cannot be sold, hence the lack of data on its economic value. However, the standard allotment plot in England and Wales is the '10-pole plot' (250 m^2, or one sixteenth of an acre) and the National Society for Allotments and Leisure Gardens estimates that this size of plot, properly husbanded, should feed a family of four for a year (NSALG 1995). Calculations based on current market prices estimate the annual yield value at £1,128.

Figure 1 An allotment in Winshill, Staffordshire. *Photo by Stephen Jones available under a Creative Commons Attribution license.*

In a study of city farms in Leeds and Bradford, annual turnover from food sales was deemed low in absolute and relative terms, with none of the farms exceeding £2,000 in sales per year (excluding animal sales). If animal sales were included, then an approximate peak value of £10,000 worth of animal and vegetable produce was sold annually (Howe & Wheeler 1999), but this represents only a small percentage of a potential estimated revenue of £171,000. Similarly, a farm in Scotland, supported since its beginning by a range of national, district and regional public and private sector funds, and with a turnover of £180,000 a year, generated only 5% of their income from sales of vegetables. Another community farm in Oxford produces vegetables, herbs, soft fruit, top fruit and willow (for basketry), with an estimated 60% of its income coming from statutory bodies and between 15–35% from produce sales (£80 per week) (Garnett 1996).

10.3.2 Regulating Services

The presence of urban heat islands, together with high levels of pollution from transport and commercial and residential heating, mean that the avoidance of climate stress and the ecosystem-derived benefits of clean air, water and soil are extremely pertinent, albeit heavily compromised, in the Urban environment.

10.3.2.1 Air quality

Poor air quality is a major factor influencing health in Urban environments, with the extent of vegetation and open spaces having a large impact on dispersion, deposition and even the formation of certain pollutants (Chapter 23, Section 23.5.1). Epidemiological studies have shown a clear association between human health (including cardiovascular morbidity, decreased lung function, increased hospital admissions and increased mortality) and airborne concentrations of photochemical and particulate pollutants (Kelly 2003). Time-series studies indicating short-term associations between ambient air pollution and mortality are well-established (Stieb *et al.* 2002; Bell *et al.* 2004). Such studies indicate that short-term urban exposure to carbon monoxide, nitrogen dioxide, sulphur dioxide and ozone correlate with varying increases in excess risk of mortality (Stieb *et al.* 2002; Bell *et al.* 2004; Gryparis *et al.* 2004; Defra 2010a). The evidence base linking mortality to long-term exposure to air pollution is increasing (Kelly 2003). In 2005, the estimated cost of the overall health impact from levels of anthropogenic $PM_{2.5}$ (particulate matter of 2.5µm or less) was between £8.6 billion and £20.2 billion (assuming a 6% hazard rate) (Defra 2007c).

Atmospheric processes regulate air pollutant concentrations, including chemistry, atmospheric mixing and deposition. Hydroxyl radical chemistry in the troposphere provides an efficient chemical scavenging mechanism for pollutants. Free radical chain reactions can oxidise pollutants to carbon dioxide and water (Wayne 2000). Pollutants are also dispersed within the atmosphere by diffusion and turbulent mixing.

Pollutants may be removed through dry deposition (where atmospheric elements are settled onto soil, water or plant surfaces) or wet deposition (where constituents are incorporated into precipitation elements, e.g. clouds, rain droplets, aerosols) (Wayne 2000). Within the boundary layer, turbulent mixing brings air parcels into repeated contact with surfaces that enhance deposition. Deposition has the immediate effect of cleansing the atmosphere. Pollutants not deposited within the boundary layer can be incorporated into the free troposphere and transported over potentially large distances with negative national and global consequences. Urbanisation has increased emissions of pollutants, yet resulted in fewer potential sinks for these toxins. Dispersal and formation of pollutants are also influenced by urban heat islands. Overall, these changes have reduced the capacity of the atmosphere to regulate itself.

Greenspaces within the Urban environment can aid the regulation of air quality (biogenic regulation). Vegetation can act as an enhanced deposition sink for gaseous and particulate pollution (Fowler 1989; Freer-Smith *et al.* 1997; Hirano 1996); tree canopies capture particles more effectively than any other vegetation type due to their greater surface roughness (Manning & Feder 1980) which increases turbulent deposition and impaction processes. Within the Urban environment, the interception of particles by vegetation is typically far greater for street trees than for more distant vegetation due to their proximity to high intensities of road traffic (Impens & Delcarte 1979).

Urban trees are said to have reduced atmospheric PM_{10} by 0.4% and 0.72% in Chicago (McPherson *et al.* 1994) and Philadelphia (Nowak *et al.* 1997; Nowak 2006) respectively. More recently, dispersion modelling has predicted potential PM_{10} reduction by increasing tree cover in Glasgow, the West Midlands (McDonald *et al.* 2007) and London (Tiwary *et al.* 2009). Such studies show how Urban trees can contribute to the regulation of air quality (see also Chapter 23).

High rates of transpiration, in addition to shading and pollutant uptake effects, help to reduce localised particulate concentrations by lowering Urban air temperatures. Moll (1996) suggests that up to 12% of air pollution problems in cities are attributable to heat island effects due to the temperature-dependent formation of many pollutants, such as volatile organic compounds (VOCs) and ozone (Nowak *et al.* 1997), and the dynamics of particulate dispersal.

10.3.2.2 Soil quality

There are a variety of both engineered soils and modified natural soils in the Urban environment. Urban soils are moved, mixed, compacted, burned and changed by mineral and chemical additives, and show extreme diversity (Vrscaj *et al.* 2008). The condition, degree of compaction and associated biological activity affects the services they provide (Young & Ritz 2005; Wood *et al.* 2005). Urban soils are often structurally highly degraded, leading to a loss of porosity and a decreased ability to infiltrate and store water; this increases runoff and has consequences for regulating ecosystem services such as flood alleviation, water purification and water storage. In addition, the ability of poor quality soil to support vegetation is reduced (Jim 1998).

10.3.2.3 Water quality

Urban rivers are frequently used as receiving bodies for sewage treatment plant effluents and stormwater discharges. They provide a habitat for a variety of flora and fauna both in-channel and within associated riparian corridors (Petts *et al.* 2002). These riparian corridors are of particular value in Urban areas, providing habitats that can contribute to further regulating services such as pollination, noise regulation and sequestration of carbon. The regulation of water quality is discussed in Chapters 9 and 14.

10.3.2.4 Noise regulation

Aircraft noise alone is estimated to cost the EU £10–40 billion annually, mainly due to impacts on urban areas (Dekkers & van der Straaten 2008); road noise also has major economic costs in urban areas. In terms of its impact on human health, environmental noise has been linked to various non-auditory effects including increased risk of hypertension (Barregard *et al.* 2009; Jarup *et al.* 2008), impaired cognitive development in children (Stansfield & Matheson 2003) and psychological stress (Evans *et al.* 1995, 2001). The negative effects of noise on health and education performance are further discussed in Chapter 14. High noise levels have also been shown to affect bird species adversely (Quinn *et al.* 2006; Habib *et al.* 2007), particularly grassland birds (Forman *et al.* 2002; Green *et al.* 2000). Some species have been shown to modify their signalling behaviour in terms of timing, or increased sound frequency and volume (Slabbekoorn & Ripmeester 2008).

Various Urban subhabitats provide mechanisms for reducing noise pollution. A major factor in the delivery of this service is ground characteristics; for example, soft lawn reduces noise levels by up to 3 dB relative to concrete paving (Bolund & Hunhammar 1999).

10.3.2.5 Climate regulation

Large areas of heat-absorbing surfaces, and high-energy use within city environments, contribute to an increased UHI, which all natural surfaces can help to reduce. Urban water areas level out temperature extremes in summer and winter, strongly influencing Urban microclimates. Vegetation is important as it results in more energy-driving transpiration as opposed to turbulent sensible heat (Grimmond 2009). One large tree can transpire 450 litres of water per day, consuming 1,000 megajoules of heat energy to drive the evaporation process. In this way, city trees can lower summer temperatures (Hough 1989) and, combined with their ability to provide shade and reduce wind speeds, reduce the need for summer air conditioning and winter heating (McPherson *et al.* 1997). A single shade tree in Los Angeles, USA, avoids the combustion of 18 kg of carbon annually, in addition to the 4.5–11 kg it sequesters; therefore, in terms of climate regulation, it is worth 3–5 forest trees (Akbari 2002).

Moisture from soil contributes to climate regulation by facilitating cooling and effective transpiration in vegetation (Wood *et al.* 2005). The role of Urban soils in the global carbon cycle and their capacity to sequester atmospheric carbon dioxide remain largely unclear; however, the flux of carbon to soil in plant residues is highly significant in the carbon cycle (Schlesinger & Andrews 2000). Greenhouse gases are emitted from the soil into the atmosphere, the most significant of which are methane and nitrous oxide. Climate regulation is also discussed in Chapter 14.

10.3.2.6 Hazard regulation (including erosion and flood risk management)

Vegetation roots help to bind and stabilise the soil which, combined with the effect of leaves and branches on reducing the impact of rainstorms, helps to lessen the rate of soil erosion and downstream sedimentation. This physical protection brings significant benefits for highway drainage and wastewater management by restricting sediment loss (Lull & Sopper 1969).

The study of a river catchment in south-east Northumberland estimated the value of existing woodlands for flood alleviation at around £1,200 per ha. This figure is based on savings to the engineering costs of flood risk management (NUFU 2005).

10.3.2.7 Pollination

Pollination potentially has a large impact on regulating the provision of final ecosystem services such as crops (Chapter 14). Gardens play a key role in providing habitats for pollinators, such as solitary and social bees (McFrederick & LeBuhn 2006; Frankie *et al.* 2009), and this is reflected in the subsequent pollination service (Cussans *et al.* 2010). Results of the National Bumblebee Nest Survey 2004 (Osborne *et al.* 2008) indicated that there were much higher densities of bumblebee nests in gardens than in farmland habitats (such as grassland, woodlands, hedgerows and fencelines). And in a single garden in Leicester, 35% of British hoverfly species have been found (Owen *et al.* 1981).

Gardeners are keen to grow long-lasting displays of flowers, so gardens tend to provide a diversity of nectar and pollen resources for flower-visiting insects all year-round (Stelzer *et al.* 2010). They also provide a variety of nesting opportunities for bees. The high density of nests and faster growth rates observed (Goulson *et al.* 2002) are believed to be due to the extent of resources provided and the diversity of habitats afforded by a patchwork of gardens managed in very different ways by different owners (Gaston *et al.* 2007). There is also some evidence that pollination levels of particular plant species are higher in gardens than in arable farmland (Cussans *et al.* 2010), suggesting that the diversity and abundance of bees and other pollinators in suburban habitats provides a strong pollination service compared to agricultural landscapes where pollination can be limiting. In turn, they and the resultant seeds, berries and other fruits are likely to provide important resources for other wildlife (such as small mammals and birds) in Urban areas.

10.3.2.8 Diseases and pests

Diseases and pests affect greenspace in Urban areas and are particularly important during extreme temperatures when vegetation is already under stress, for example from UHI or poor quality soil. Many are invasive species that are unknowingly imported via infected planting stock, and are of particular concern in relation to the extensive planting of newly created areas of greenspace. Prevalence of invasive species is predicted to increase under changing climatic conditions. Steps to reduce the impact of these projected increases have been proposed in relation to trees (Tubby & Webber 2010) and include policies associated with plant health legislation.

10.3.3 Cultural Services

The UK NEA considers the environmental settings provided by the natural environment to be a cultural service that, through people's interactions with it, provides various goods and benefits (Chapter 16). This section explores a range of these goods and benefits in an Urban context.

10.3.3.1 Physical and mental health

The majority of people live in Urban areas where access to greenspace is lower than in any other habitat. Yet an increasing amount of literature supports the view that access to good quality Urban greenspace is essential for physical activity, positive mental well-being and healthy childhood development (Sadler *et al.* 2010). The health benefits of Urban greening are also discussed in Chapter 16 and Chapter 23. Benefits arise from most subhabitats and even the most fragmented green corridors can provide excellent opportunities for physical activity.

Regular physical activity contributes to the prevention and management of over 20 conditions that are major costs to the National Health Service including coronary heart disease, diabetes, obesity and certain types of cancer (Liu *et al.* 2007; Pretty 2004). Epidemiological research has found strong links between health and greenspace in large conurbations (de Vries *et al.* 2003; Maas *et al.* 2006, 2008), with access to walkable greenspace linked to longevity in the elderly (Takano *et al.* 2002; Mitchell & Popham 2008). Living in close proximity to greenspace has been shown to promote physical exercise (Bird 2004). Good quality open spaces encourage people to make short journeys on foot or by bike, and web-based tools, such as Walkit, enable people to avoid areas with poor air quality (Sustrans 2009).

Associations between greenspace and a reduced risk of anxiety and depression are well-documented (Maas *et al.* 2008; Pretty *et al.* 2005; Pretty *et al.* 2004; Grahn & Stigsdotter 2003; Maller *et al.* 2002; Kellert & Wilson 1993; Ulrich *et al.* 1991), with even moderate activity within greenspace improving depression (Natural England 2006). Contact with nature has been shown to promote a better mood (van den Berg *et al.* 2003; Hartig *et al.* 2003) and improve attention (Hartig *et al.* 2003; Ottosson & Grahn 2005). Benefits to cognitive restoration (Kuo 2001; Taylor *et al.* 2002) and self-discipline (Taylor 2009) have also been recorded; these restorative benefits are thought to stem from nature's ability to promote temporary escape and connectedness (Kaplan & Kaplan 1989).

Healthy childhood development is associated with greenspace. Children with access to safe, green areas are more likely to be physically active and less likely to be overweight (Gong 2009; Health Scotland 2008; Wells & Evans 2003). Contact with nature has also been shown to reduce the severity of Attention Deficit Hyperactivity Disorder (ADHD) symptoms in children (Taylor 2009).

Urban rivers have been linked to a variety of mental and physical health benefits, from promoting environmental consciousness and engendering a sense of well-being, to providing increased opportunity for exercise and fresh air (Landrigan *et al.* 2004; Curtis *et al.* 2002; Tapsell *et al* 2001; Environment Agency 2002, 2006; GLA 2004).

Few studies have sought to determine a relationship between the level of biodiversity and human health and well-being in Urban areas (see Chapter 23, Section 23.1.2). One study shows that psychological benefits increase with the species richness of Urban parks (Fuller *et al.* 2007). Botkin and Beveridge (1997) concluded that vegetation is essential for living reasonably within an Urban environment.

10.3.3.2 Heritage

Neighbourhood development and social and environmental citizenship. Good quality greenspace can foster better levels of community cohesion and promote social inclusion (Fredrickson & Anderson 1999). Research has shown that community open space and natural settings enhance social ties and a sense of community in older adults (Kweon *et al.* 1998; Sullivan *et al.* 2004) and can promote social integration within disadvantaged communities (Dines *et al.* 2006). Maas *et al.* (2008) found that having less greenspace in our environment coincided with feelings of loneliness and perceived shortage of social support. Greenspace may also have the potential to reduce health inequalities between the rich and poor (Mitchell & Popham 2008).

Risbeth (in press) found that the experience of first generation migrants in negotiating the Urban landscape was a key aspect in the process of cultural adaptation and social integration, facilitating feelings of belonging. Several studies have found that the social use of parks by minority ethnic groups tends to be in large family or friendship groups (Worpole & Greenhalgh 1995; Burgess *et al.* 1988). This reflects other research, carried out in rural contexts, which shows that many ethnic minority groups, particularly Asians, connect to the landscape via the focus of food and picnics. Limited studies have suggested that greenspace may enhance feelings of social safety in a neighbourhood and help to reduce aggression and crime (Kuo & Sullivan 2001a, 2001b).

Cultural heritage. In the UK, our environments are all heavily infused with the cultural values and histories of human use. Through their differing heritages, every environmental setting is capable of being interpreted as possessing a distinctive sense of place, including Urban areas. However, while certain versions of national or regional identity have developed around Urban areas and spectacular architectural sites and monuments, sense of place appears to be formed around typically rural landscapes (Weiner 2004).

10.3.3.3 Recreation and tourism, and aesthetic and inspirational benefits

In Urban areas, accessible, high quality environments are used by all ages for informal recreation and community events (CABE 2010). Parks provide multiple, concurrent services to the specific areas within which they are located (CABE 2005a). In England, 48% of the population use these spaces at least once a week (Thornton 2009), and, in Scotland, 42% of adults (16+) use them (Scottish Government 2009); 87% of the population said they used their local parks or open spaces regularly (DCLG 2008a). Survey data reveal that 91% of the public believe that parks and open spaces improve quality of life, and 74% believe that parks and open spaces are important to health and mental and physical well-being (CABE 2004). Such sites are considered critical for allowing experiences of Urban wildlife (Defra 2006a). Many of the tourist attractions in cities and towns are built heritage; nevertheless, they are often in historic parks which contribute to their aesthetic value.

10.3.3.4 Spiritual and/or religious benefits

The primary purpose of churchyards and cemeteries is spiritual and religious service provision, space for quiet contemplation, and historic and symbolic value. In 2006, Church of England average weekly attendances were over one million (Church of England 2007), suggesting that churchyards and burial grounds remain a major component of people's regular interaction with nature.

Habitats that contain water are often used for spiritual contemplation as this element is considered peaceful and symbolic. Urban rivers are considered as remnants of nature (Eden *et al.* 2000) offering Urban communities a chance to reconnect with water in both a spiritual and cultural context.

10.3.3.5 Educational benefits

Outdoor play contributes to positive cognitive development (National Heart Forum 2007) and includes wildlife conservation, biodiversity and environmental education (Leather & Quicke 2009). Ecological knowledge is being lost in wealthier countries (Pilgrim *et al.* 2008), and, in the UK, awareness of local wildlife appears to have declined in recent decades (Bebbington 2005; Cheeseman & Key 2007), especially in children where outside play is presently less favoured than other activities (Valentine & McKendrick 1997). Such trends are particularly relevant in minority ethnic groups whose experience of nature occurs predominantly in Urban contexts (Davies *et al.* 2009; Wong 2007). Loss of ecological knowledge is a loss of substantial economic value as it contributes to a wide range of current and future ecosystem goods and services (Pilgrim *et al.* 2008).

10.3.4 Delivery of Ecosystem Services by the Urban Environment

In recent years, housing density has increased (Bibby 2009), driven by demographic and economic pressure and associated planning, housing and transport policies. Coupled with loss and deterioration of greenspace (e.g. sales of playing fields, poor condition of parks, sale of allotments, reduced tree planting, paving of front gardens, infilling), ecosystem services have been heavily compromised. Where the built environment dominates the landscape, particularly in city centres, it is clear that even the most essential of ecosystem services are ineffective: pollution overwhelms the regulating services, impermeable surfaces make climate and hazard regulation ineffective and affect water quality and water supply, and *per capita* provision of greenspace is at its lowest.

The additional ecosystem services that could potentially be derived from Urban areas appear to be substantial. Their importance to our health and general well-being has not previously been recognised. It is not just the limited extent and variable quality, but also spatial distribution and accessibility, that currently create barriers to optimising existing Urban ecosystem services. Strategic planning and resourcing will be required to take full advantage of opportunities that Urban ecosystems could deliver, but it appears that major advances could be achieved with relatively low investment.

10.3.5 Valuing Urban Greenspace in the UK

Examples of economic analysis of greenspaces are highly variable. In Philadelphia, USA, the park system was valued at $1 billion (Trust for Public Land 2008), while, in England, public parks have been allocated a value as low as £1 (CABE 2009b). An estimate of the value of local trees has been calculated for the Torbay area of Devon, England (**Box 10.5**).

In Chapter 22 of the UK NEA, key ecosystem services provided by Urban greenspace in the UK are valued using the benefit transfer method. These benefits include recreation, aesthetics, physical and mental health, neighbourhood development, noise regulation and air pollution reduction all of which are provided to local residents as a bundled good in relation to the distance of a dwelling from parks and greenspaces. Nevertheless, some important and essential 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.

Box 10.5 i-Tree Eco Project in Torbay, Devon.

Introduction: The UK's pilot i-Tree Eco Project was carried out in order to measure the value of the ecosystem services that Torbay's trees provide. The project applied a system (i-Tree Eco) that has been successfully used in other countries, but which had previously not been applied to the UK.

Project aims: i) Complete a pilot i-Tree Eco Project in the UK, providing a specific UK benchmark allowing the system to be applied elsewhere. ii) To quantify the ecosystem services of Torbay's trees and provide monetary values for these services in order to establish a datum point from which to measure future trends and to demonstrate the value of its trees. iii) To demonstrate the benefits of the Urban forest to communities, businesses and policy makers, thereby promoting an ecosystem services approach.

Methods: The UK pilot was delivered as a partnership between Hi-line (project management and field work), Davey Group (i-Tree Eco developers), Forest Research (UK data handling) and Torbay Council (host area), with assistance from Natural England. In the summer of 2010, information on tree cover, size, species, tree health and ground cover was collected by trained arboriculturalists from 250 random plots stratified by land use across Torbay. Region-specific data on climate, hourly pollution and growth rates were also collated and fed into the model.

Results: Torbay's Urban forest contains 818,000 trees representing an estimated structural asset of £280,000,000. These trees provide the equivalent of £345,811 in ecosystem services annually. An estimated 98,100 tonnes (15.4 t/ha) of carbon (C) is stored in Torbay's trees, with an additional gross sequestration rate of 4279 tC/yr. This equates to £1,474,508 in storage and £64,316 in annual sequestration. Contributions to improving air quality of Torbay total over 50 tonnes of pollutants removed every year which equates to an annual estimated value of £281,495 (Rogers *et al.* 2011).

Full results for the project will be made available in a report to be published in 2011. For more information contact: trees@torbay.gov.uk .

i-Tree is a free peer-reviewed software suite (originally The Urban Forest Effects Model (UFORE)) which has been designed by the United States Forest Service. i-Tree has been used to quantify Urban forest structure, function and values in numerous communities throughout the world. For more information visit www.i-treetools.org

Torbay i-Tree Eco Project: Key Findings
(population: 134,000; area: 6,375 ha)

Ecosystem Service	Value per ha
Carbon Storage (98,100 tonnes)	£240.00
Carbon Sequestration (4,279 tonnes)	£10.09
Annual Pollution Filtration (50 tonnes)	£44.15
Total Annual benefits	**£54.24**

On average, people living closer to a park typically derive more benefits from its presence than those living further away. There are several reasons for this and include the fact that the fraction of people using the site for recreational purposes decreases with distance from the site (Bateman *et al.* 2006); and some of the non-recreation ecosystem services, such as noise abatement and pollution reduction, tend to be greater the closer people live to the site.

Based on the selected data used in the analysis by Perino *et al.* (2010) (which supports Chapter 22 and has been chosen in relation to distance from parks and a limited set of services and goods arising), Chapter 26 presents the changes in Urban ecosystem services implied by the six UK NEA scenarios (Chapter 25) by 2060. Depending on the scenario, urban households stand to gain (about £8,000 per urban household) or lose (about £-40,000 per urban household) substantial amounts.

A number of additional ecosystem services provided by Urban greenspace are covered in Chapter 22, such as recreational day trips and the amenity value and health benefits derived from domestic gardens that are not included in the values presented above.

10.4 Trade-offs and Synergies Among Urban Goods and Ecosystem Services

In this section, we provide some examples of synergies among ecosystem services and consider possible trade-offs. There are many complex issues to consider, particularly for plantings, where ecosystem assessments could aid decision-making. However, before trade-offs are considered, options for multifunctional use should be explored.

10.4.1 Synergies

Urban vegetation is essential to ecosystem service provision. Trees, grasslands and heaths, as well as water bodies, can have a dramatic impact in reducing UHI effects. Increasing tree cover by 25%, for example was estimated to reduce afternoon air temperatures by between 5–10°C (Zipperer *et al.* 1997; ASLA 2011). With up to 12% of air pollution problems in cities attributable to UHI effects (Moll 1996), lower Urban temperature would be indirectly beneficial. Research by Gill *et al.* (2007) suggests that increasing tree cover in Urban areas by 10% could reduce surface water runoff by almost 6%, and increasing greenspace by 10%, could reduce it by almost 5%. Replacement of mature trees with younger trees typically results in considerable reductions in benefits derived from ecosystem services (NUFU 2005). Therefore, multiple benefits would arise from increasing Urban greenspace through schemes such as tree planting programmes, with the synergistic ecosystem services improving the resilience of cities to climate change (GLA 2010).

Well-planned and managed parks, gardens and squares have a positive impact on the value of nearby properties, attracting inward human and capital investment. Increases in property values range between 0–34%, with a typical increase of about 5% (CABE 2005b). They are also used and appreciated more often, and landscape design is critical to ecosystem service interactions and the cultural importance of these greenspaces (CABE 2010).

Synergies between the goods and services provided by aquatic ecosystems have important implications for Urban management. Leaving rivers in a more natural state enhances local flood attenuation and flood storage capacity, while reducing downstream flooding, and is a cost-effective alternative to traditional engineering (Environment Agency 2002). Urban river restoration can provide multiple benefits similar to sustainable drainage systems (Skinner & Bruce-Burgess 2005), as has been shown where concrete channels have been broken down and rivers re-meandered to allow flows to reduce and to provide access to historic floodplains (Defra 2004; Environment Agency 2005, 2006; **Box 10.6**).

New driveways legislation (e.g. in England, Statutory Instrument No. 2362 (2008) requires that permeable paving be used if garden areas are to be paved over to facilitate drainage, reduce flooding and remove pollution from these surfaces, particularly in high frequency, low magnitude events. Planning permission is now required to cover a front garden with an impermeable material (DCLG 2009b). Tree planting schemes can mitigate the effects of soil-sealing, but their adoption has, so far, been patchy and uncoordinated.

Transport policies to encourage walking and cycling, and support low energy technologies, will benefit ecosystem services. Future market penetration of cleaner vehicle technologies, such as hybrid, fully electric and hydrogen fuel cell vehicles, could significantly contribute to improvements in Urban air quality and reduce greenhouse gas emissions and noise (NAIGT 2008; TfL 2008).

The combined ecosystem services, goods and benefits that good quality, accessible public parks can provide are substantial. Programmes to improve their facilities and encourage greater use will help to improve physical and mental health, childhood development, social cohesion, aesthetics and other important cultural benefits. More parks of different sizes and locations will also contribute substantially to regulating services of air quality including dispersion, mixing and deposition, cooling for climate regulation, water drainage and flood protection. Havens for wildlife and provisioning services further contribute to an under-valued resource.

10.4.2 Trade-offs

A significant and obvious trade-off occurs between the extent of the built environment in comparison to greenspace within an Urban area. Options to use built environment as a surface for plantings or to incorporate improved permeable surfaces within the built areas appear extensive.

Here, we provide selected examples to illustrate some of the conflicts that can arise between options to increase ecosystems services. Few studies have been completed to date. Many trade-offs result from complex interactions between biological systems and other components of the

Box 10.6 Sustainable Drainage Systems (SuDS).

The term sustainable drainage systems (SuDS) (also known as stormwater best management practices: BMPs) covers a wide range of systems, such as constructed wetlands, infiltration trenches, swales and porous paving, which approach the issue of stormwater management from a different perspective to that of conventional systems. Rather than piping stormwater away, SuDS aim to manage stormwater as close as possible to its source, reducing runoff volumes and rates. This is achieved in the first instance by infiltrating, but where this is not possible, by collecting, temporarily storing and subsequently discharging stormwater at a controlled rate to the soil, receiving water or sewer system. In addition to managing water volume, SuDS also mitigate water quality through facilitating the occurrence of a complex interaction of biological, chemical and physical processes (e.g. microbial degradation, photolysis and adsorption), offering opportunities to reduce energy costs associated with mechanised water treatment through the provision of localised passive treatment options. Furthermore, SuDS may also provide social amenity, habitat and recreational benefits through the provision of green infrastructure in Urban environments. According to Scottish Planning Policy (SPP 2010) and English legislation (PPS25 2006), the use of SuDS to manage stormwater is required within all new housing developments before it is discharged into the water environment.

The Ardler Regeneration Project in Dundee, Scotland, is an award-winning case study demonstrating the strategic use of SuDS within urban redevelopment. This public, private, community and voluntary organisation partnership drove the regeneration of a 1960s high and medium density housing estate covering a 58 ha site. Prior to its regeneration, Ardler suffered high levels of anti-social behaviour and its population had fallen by 50%. With the key objective of making Ardler a thriving regional centre, the area was completely remodelled over a 10-year period, with work completed in 2008. As an area prone to flooding, the management of surface water was a priority issue and the decision was taken to disconnect surface water from the main trunk sewer. A suite of SuDS was then used throughout the site to retain and treat surface water flows, which were then discharged into the local watercourse. As well as successfully managing surface water runoff, the use of SuDS has additionally provided a network of greenspace including two ponds, a pocket park combined with a detention basin and a football pitch combined with a flood storage zone, all linked by numerous swales. A key factor in the wider success of this regeneration project is recognised to have been the high level of stakeholder collaboration at project inception, with the development of a combined vision to create a sustainable development and community (Scottish Government 2009b; Greenspace Scotland 2007).

Figure 1 SuDS in Ardler Village, Dundee, Scotland. Source: image by kind permission of Alison Duffy, UWTC, University of Abertay Dundee. Based on Google map © 2009 Infoterrra Ltd & Bluesky, © 2009 Europa Technologies, © 2009 Tele Atlas.

Urban environment. Vegetation, for example, can act as an enhanced deposition sink for gaseous and particulate pollution (Fowler 1989; Freer-Smith 1997; Hirano 1996) and provide many other ecosystem services. However, the value of plantings is partly dependent on species composition and quantity, as well as location. Volatile Organic Compounds generated by oaks (most abundant in London), willows and poplars, for example, can contribute to ozone formation and worsen air quality if present in sufficient densities (Donovan *et al.* 2005), in contrast to species with much lower emissions. Similar trade-offs are found in other systems such as green roofs and roof gardens. The goods and benefits arising from a range of new plantings can be highlighted by ecosystem assessments that will help inform decision-making across this very important area, extending ecosystem service provision.

Resources required for the management and maintenance of greenspaces are an important consideration; for example, plantings require water and regular upkeep and have associated cost implications. The resources that are required will be dependent on the design of each scheme. The creation of greenspaces using landscaping close to semi-natural vegetation typically requires less water than more intensive schemes, and is more beneficial for biodiversity, forming a valuable part of a more widely connected ecosystem. Given climate predictions of greater urban drought stress (GLA 2010), good design for a locale may also benefit from incorporating water capture and storage techniques.

There is widespread channelisation and culverting of Urban water bodies to manage floodwaters (Scholes *et al.* 2008). Although it reduces localised flooding, the flood may simply be shifted to a downstream location. Conversely, the direct discharge of stormwater into receiving waters can have a negative effect. Impacts include the erosion of riverbanks and in-stream sediments, and the addition of an associated stormwater pollutant load (e.g. pollutants from vehicles and microbial organisms,) resulting in the prevalence of pollution-tolerant aquatic and riparian species.

A major conflict between air quality and climate change in Urban areas arises from the use of biomass boilers, which reduce greenhouse gas emissions, but increase nitrogen oxides and PM_{10} emissions. Biomass fuel is a key growth area, driven by the recently published Renewable Energy Strategy (DECC 2009) and the UK's binding target to produce 15% of energy from renewable sources by 2020. Conversely, any urban transport policies that restrict the use of diesel vehicles within city centres, as has occurred in Germany, are likely to benefit air quality at the expense of greater carbon dioxide emissions from less fuel-efficient petrol vehicles.

10.5 Options for Sustainable Management

Options for improving ecosystem service delivery through sustainable management are substantial, but require careful evaluation at appropriate scales. For example, regional tree planting schemes, green bridges, green roofs, roof gardens and green corridors can all increase regulating, supporting and cultural services and improve biodiversity, but there are trade-offs to consider, particularly where drivers such as climate change and air pollution are in conflict. In

Box 10.7 Case study of ecosystem service mapping in the Thames Gateway region. Source: THESAURUS project (2006–2008).

The THESAURUS project, supported by the Department for Environment, Food and Rural Affairs Natural Environment Policy Research Programme Phase II (2006 to 2008), sought to assess the types of ecosystem services provided within Kent Thameside (**Figure 1**), an area undergoing extensive urban regeneration, and how best they could be evaluated within current land use planning and decision-making frameworks (Sheate *et al*. 2008). The area is part of the Government's Thames Gateway Growth Area within the Sustainable Communities Plan and already under some considerable environmental constraints in terms of water resource availability, flood risk, air quality, transport and biodiversity. However, there are extensive areas of brownfield land available in North Kent for new development, resulting from historic quarry and cement works activity, and derelict industrial and ports sites, in particular. The Channel Tunnel Rail Link (CTRL) passes through Kent Thameside and the new CTRL station at Ebbsfleet is also located within the area.

Figure 1 Kent Thameside. *Photo courtesy of William Sheate.*

The project focused on the Kent Thameside Green Grid initiative—an important planning concept designed to improve the environmental perception of the Gateway, enhance environmental assets with a network of greenspaces and corridors, recognise the importance of multifunctional greenspaces for community life, and help ensure that greenspaces can also provide important adaptation tools, for example, in relation to helping with flood relief and in improving quality of life. The project explored ecosystem services delivered by the Green Grid at two different scales—sub-regional and local—and related ecosystem services to land use/land cover categories, rather than simply to habitats, since this approach is more appropriate for spatial planning within an Urban context. To connect land use/land cover categories to the ecosystem services they deliver, the open space categories of PPG17 (Planning Policy Guidance 17: Planning for open space, sport and recreation) were used and a network analysis technique applied to understand the relationship between the typology of ecosystem services developed for Kent Thameside (using stakeholder engagement) and the different open space/Green Grid land use/land cover categories for which a range of geographic information system (GIS) datasets already exist. This relationship allowed the ecosystem services delivered by specific land use/land cover categories to be traced, and consequently made the reverse also possible, i.e. to trace back from desired ecosystem services to the various land use/land cover categories that have the potential to deliver those services. Consequently, it was possible to physically map those services using GIS by combining the appropriate existing datasets relating to land use/land cover, e.g. for potential flood regulation services, or visual aesthetic services, etc. (see **Figure 2**).

Network analysis proved to be a useful technique to engage with stakeholders and to understand the relationships between land use/land cover categories and the ecosystem services they provide. GIS was used to represent the land use/land cover types—and thereby ecosystem services—spatially by combining a range of existing datasets. This geographical representation was not without difficulties, including the problems posed by combining different types of datasets of different quality and scale. Any errors or assumptions contained in datasets can be compounded if combined with other datasets; similarly, by combining good quality data with poor quality data it could result in data of unknown quality and unknown limitations. However, it did prove possible to use existing datasets to represent ecosystem services spatially, most usefully at the strategic level; at the local level, the existing datasets are rarely of a resolution sufficiently fine enough to distinguish the heterogeneity of the local

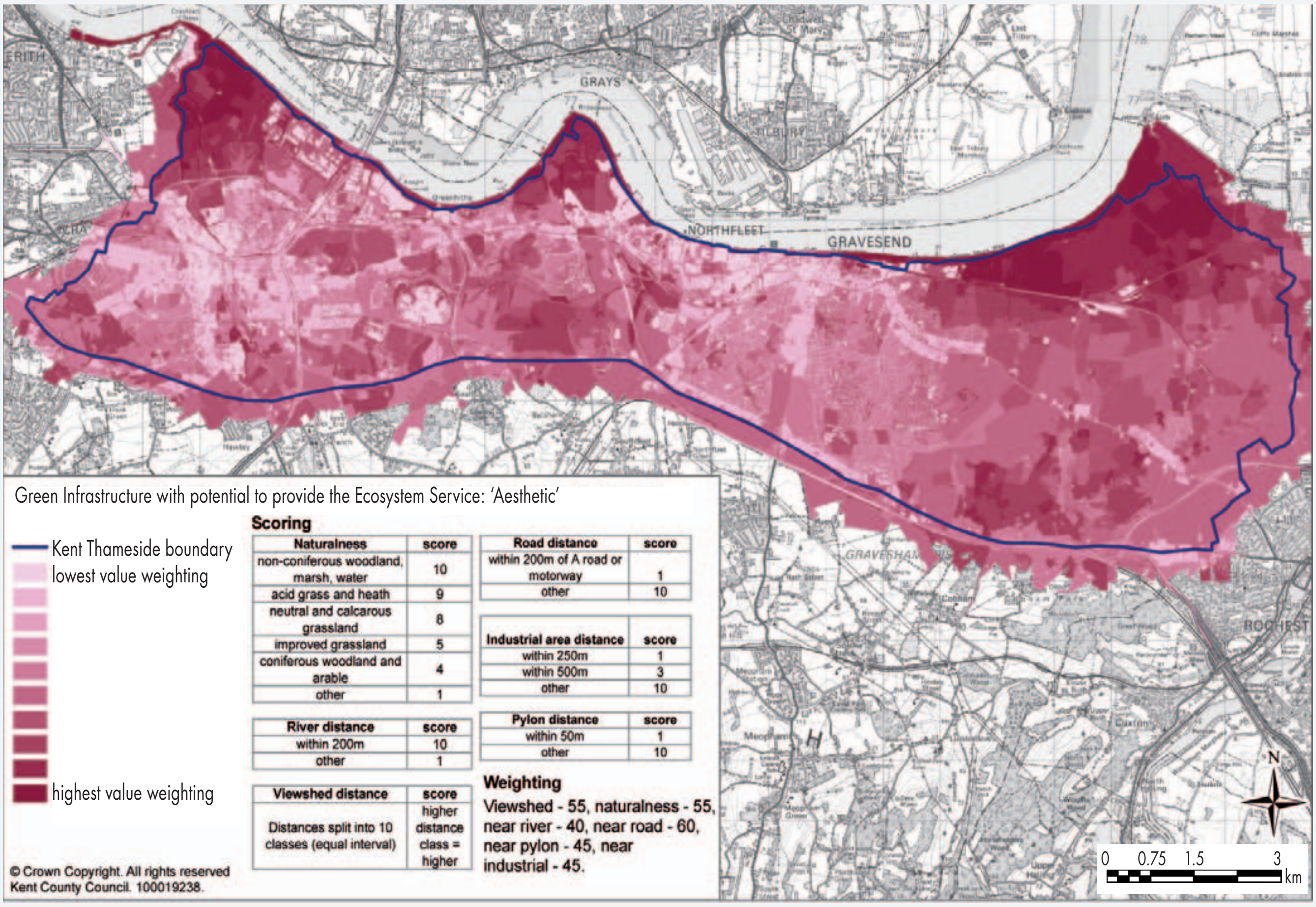


Figure 2 Green infrastructure with potential to provide the Ecosystem Service: 'Aesthetic'. Source: Sheate *et al*. (2008).

environment, although even here, the GIS could be useful in identifying areas with potential for multifunctionality. At the local level, a combination of 'ground-truthing', using aerial photography and site visits, and local public consultation proved to be successful in getting a better understanding of the sorts of ecosystem services delivered by local greenspace. Information gathered in this way was readily translated using network analysis into a typology of local-level ecosystem services by tracing possible management interventions through the interaction pathways back to the associated land cover types. Network analysis proved a useful tool to represent the complexity of an ecosystem and the interactions between its various components.

The ability to map ecosystem services in this way offers real benefits to spatial planning, particularly in promoting multifunctionality, by ensuring that Green Grids (or greenspace generally) help to proactively shape development, planning around what exists and its potential, rather than their delivery simply occurring reactively through development. Ecosystem services also provide a different focus for discussion with stakeholders, with the potential to help reduce the common problem of trade-off between different interests through seeking to deliver multiple services and multiple benefits. Such an approach offers the potential to make baseline data in Sustainability Appraisals and Strategic Environmental Assessments much more relevant to the assessment process by combining datasets in a useful way for planners and decision-making. What GIS and network analysis could not do in this project was quantify the amount of an ecosystem service that was present or desirable, i.e. relate ecosystem services to environmental limits. These shortfalls are not insurmountable and point to the need for more research to develop the tools further.

other cases, ecosystem services can be addressed locally through actions such as: replacing impermeable surfaces with porous materials; encouraging better use of domestic gardens; allocating space for allotments; improving conditions and services in public parks; supporting community engagement and social cohesion; and better greenspace provision for young people.

10.5.1 Planning for Multiple Benefits

Issues relating to scale are crucial to inform sustainable management and multifunctional land use; therefore, each development should be considered accordingly. Two case studies illustrate how multifunctional land use can be applied in new developments to maximise ecosystem goods and service provision. One is a recent case study in the Thames Gateway area of South East England (Sheate *et al.* 2008; THESAURUS Project 2008; **Box 10.7**) and the second is from Stoke-on-Trent (**Box 10.8**). They show how ecosystem services can be evaluated within current land use planning frameworks to inform strategic decision-making and encourage a broad range of land uses.

10.5.2 Increasing Surface Permeability, Planting and Creation of Additional Greenspace

Options exist to increase the permeability of a range of surfaces, especially roads, which constitute a significant part of the built environment (12% in London). By limiting the use of non-permeable surfaces and changing the type of building materials, ecosystem services associated with Urban climate, such as temperature and flood regulation, could be substantially increased (GLA 2010; Smith & Levermore 2008).

Allotments, community gardens and outdoor markets are being established on the paved, previously unproductive, surfaces of Urban areas. For example, the Urban Garden Project in Middlesborough has turned unused land, such as roundabouts, into 'makeshift' allotments (One North East 2007). Better use of disused areas, vacant (uncontaminated) PDL, reservoir banks, disused railway lines and urban roofs and walls for gardens, horticulture (**Box 10.9**), and many other community initiatives is already occurring, contributing to enhanced cultural and provisioning services (Pretty 2002, 2004; Mulholland 2008).

Although not classified as an ecosystem, the built environment provides havens for birds and other organisms, offers extensive space for vegetation (**Box 10.9**) for wildlife, horticulture and food production, as well as opportunities for leisure and recreation, and should be considered as a potential area for substantially enhancing Urban ecosystem services.

Increased tree planting and the creation of additional greenspace offer potential for flood storage (GLA 2010) and reduced UHI effects (Smith & Levermore 2008). Such active policies create more open space (pollution dispersion), shade (cooling), new opportunities for recreation and healthy lifestyles, and improved aesthetic value which contributes to cultural services (Trees in Cities 2010). Protecting existing areas and designating new ones that can provide these services are important, and approaches such as Natural England's Sustainable Alternative Natural Greenspace (SANGs) which was successfully used in relation to the Thames Basin Heaths Special Protection Area (SPA) provides a useful example of such mechanisms.

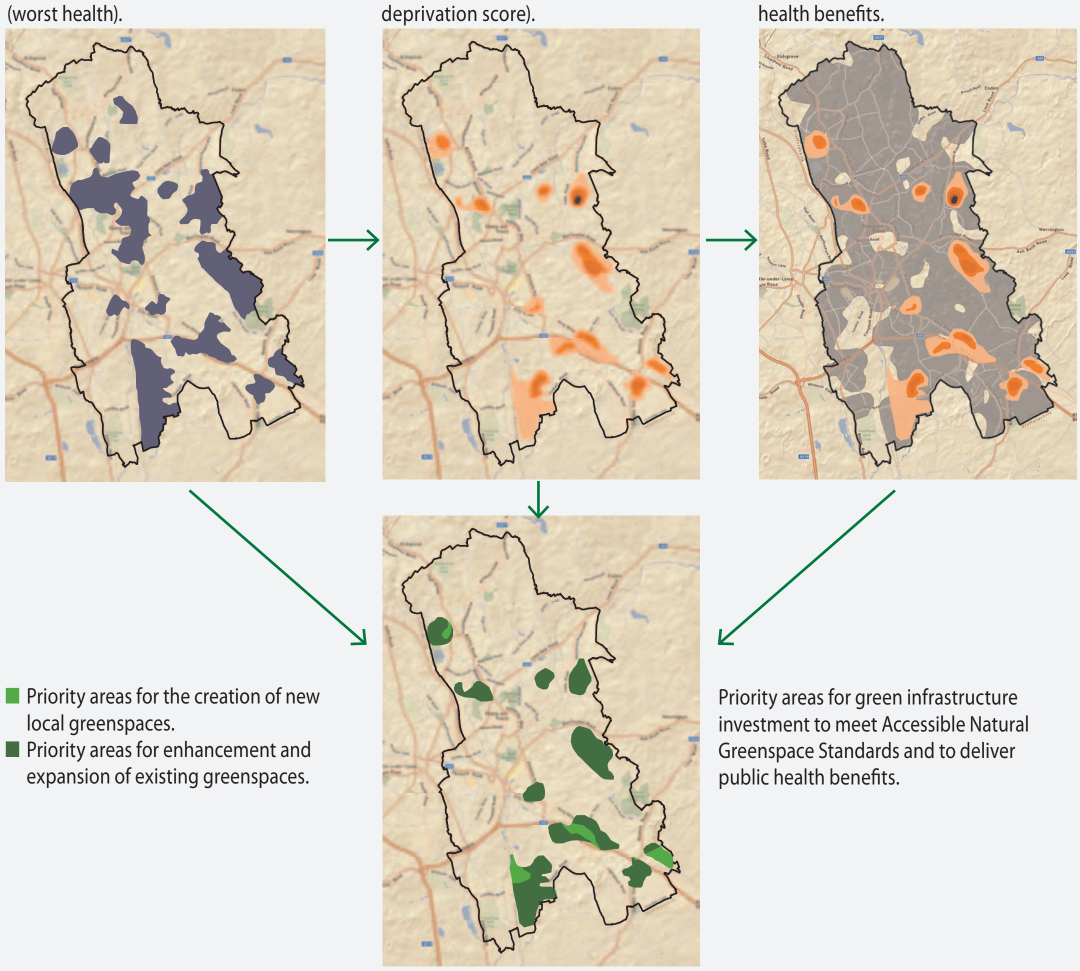
10.5.3 Mapping and Assessments

Accurate mapping of the Urban environment is crucial if planning is to be used more effectively for ecosystem service delivery. Scottish Natural Heritage has recently analysed aerial photographs to identify different types of greenspace in two thirds of Scottish authorities; this has been digitally mapped for planning purposes. It has enabled the understanding and planning of natural habitat networks, facilitated the creation of positive and appropriate recreation provision, and taken account of natural heritage in inner cities (Greenspace Scotland 2009; CABE 2009a). There are opportunities to plan open space provision around that already in existence, with potential for multifunctional provision rather than *ad hoc* designation of areas of open space as a side effect of development.

Incorporating elements, such as lakes and ponds, street trees, small woodlands and green bridges, into new developments can significantly improve the economic value of developments (TDAG 2008) and the interconnection between Urban habitats (Sheate *et al.* 2008). However, it is essential to understand and map ecosystem service provision at different scales for such spatial planning to be most effective.

Urban ecosystem assessments supported by funded maintenance and management schemes would aid ecosystem service delivery. A national strategy on Urban tree management, for example, could address deterioration in tree condition in inner cities, protect ancient and mature trees, recommend appropriate tree species for new

Box 10.8 Case study of planning for multiple benefits from Stoke-on-Trent. Source: based on WMRA (2007).



By mapping the current distribution of green infrastructure within an Urban environment, along with factors such as population density and indicators of deprivation, the creation and enhancement of greenspaces can be highly strategic.

The example for Stoke-on-Trent illustrates how population density, greenspace accessibility and public health can be incorporated using GIS mapping techniques to inform planning and policy implementation within the Urban area.

plantings, review water and maintenance costs, and support new planting schemes.

There is increasing interest in the feasibility of adopting alternative Urban drainage management techniques. Interest has intensified since the analysis of the 2007 floods, which clearly indicated the pressures on sewage and drainage networks (Water UK 2008).

10.5.4 Conceptual Changes to Influence Management

Interaction with Urban greenspace varies between different social and cultural groups (CABE 2010; Harrison *et al.* 1987; Harrison *et al.* 1995). Recognition of this and the perceived risks different genders and ethnicities associate with Urban subhabitats (Burgess 1998) would allow management practitioners to increase the utilisation of Urban greenspace and its ecosystem services, particularly in relation to cultural benefits to society (CABE 2010).

Funding for public parks and Urban greenspace was significantly reduced between 1979 and 2000 (Urban Greenspaces Taskforce 2002). Many services have not recovered from this under-investment. Local authorities prefer not to assume responsibility for new open spaces unless they come with investment to pay for their long-term maintenance. A potential research question is whether developers, seeking to minimise payments to the local authority, landscape as simply as possible, using lawn as the cheapest option. Such behaviour by developers may be misconceived, however, as there is evidence to suggest that changing to a less intensive management regime, with the aim of creating a more biodiverse and naturalistic landscape, can be cheaper and help to engage the local community with the natural environment (CABE 2006).

The creation and maintenance of good quality greenspace in cities is a major challenge for society and requires innovative leadership, philanthropy, fiscal and other

Box 10.9 Roof gardens as an option for sustainable ecosystem management in Urban areas.

Green roofs are a potential way to create synergistic environmental benefits in dense urban areas (Living Roofs 2010). They have been demonstrated to make buildings more thermally efficient, prolong the life of the roof, ameliorate extremes of temperature and humidity, moderate surface water runoff (Gill *et al.* 2007), and help to reduce air and noise pollution.

Green roofs are generally classified as extensive, semi-intensive or intensive. Semi-intensive and intensive green roofs are typically more biodiverse (**Figure 1**), with deeper substrate and higher capital costs. The type of green roof construction will determine the extent of goods and services it provides (Living Roofs 2010).

Green roofs can also reduce the energy required to air condition buildings and, therefore, affect associated greenhouse gas and air quality pollutant emissions. However, there may also be associated trade-offs with green roofs due to large amounts of water being required to sustain them (Grimmond 2009).

Jubilee Park (**Figure 2**) and Cannon Street roof gardens have both been built on the roofs of London Underground and railway stations, and are examples of how impermeable areas of inner cities can be managed for ecosystem services within the constraints of limited land availability (GLA 2008).

Figure 1 The biodiverse green roof of the Transport for London building on Broadway. *Photo courtesy of Green Roof Consultancy Ltd.*

Figure 2 Jubilee Park in Canary Wharf, London. *Photo courtesy of livingroofs.org.*

incentives. Ecosystem services assessment can be used to inform decisions about new and existing developments.

In recent years, tools have been developed to calculate access to public greenspace (Greenspace Scotland 2009; ANGSt 2003; CCW 2006), building on the early work of the Playing Fields Trust and the SAS (FIT 2009). These tools could be applied more widely to encourage and support investment in public areas. New schemes to protect and champion public greenspace are also important. Fields in Trust, for example, has recently launched the Queen Elizabeth II Fields Challenge which, in celebration of the 2012 Diamond Jubilee, gives communities an opportunity to vote for a playing field in the local area to be protected permanently by the scheme (Queen Elizabeth II Fields Challenge 2010).

10.6 Future Research and Monitoring Gaps

Major knowledge gaps remain in terms of Urban land use, extent, condition, location and accessibility.

Many of the processes that determine the quality of Urban water, air and soil remain poorly understood, and degradation continues. While new technology has driven improvements in spatial mapping and process modelling, this review clearly identifies some fundamental problems for Urban ecosystem assessments:

- Typology is inconsistent and confusing.
- Various organisations, local, regional and national authorities, government agencies, charities and other bodies collect substantial datasets, but they are often at different temporal and spatial scales and it is not always possible to extract urban-specific information. There is no single body to collate and interpret Urban greenspace data.
- Monitoring is very limited (only one survey of national public parks in three decades) and collaboration between organisations is unclear.

The Urban habitat needs to be recognised as a unique ecosystem and monitored accordingly.

Progress has been made recently with local authority Greenspace Strategies, an important driver in the mapping of Urban greenspace. There is still a need for a consistent framework for data collection in such strategies, which currently preclude any comparative studies across Urban subhabitats and by country because clear, consistent guidance is not provided nor always compatible with other systems. Local authority greenspace provision is an important aspect of ecosystem services and should not be considered in isolation from other public and private land use, such as domestic gardens, or from air, water and soil processes and biodiversity; these systems are complementary. Urban areas have underperformed in recent decades in relation to the potential ecosystem services, goods and benefits that could be provided. There appears, however, to be significant opportunity for major improvement.

The Urban habitat in the UK has not previously been looked at in terms of ecosystem services, therefore, many knowledge gaps exist in relation to this concept; some of these are detailed below.

10.6.1 Monitoring, Data Collection Methods and Mapping

The lack of systematic monitoring is limiting the present understanding of the Urban environment and its potential for ecosystem service delivery. There is no single inventory in the UK for data on Urban landscape morphology and character, and no harmonisation between existing data sources. Some information is simply not collated or collected; for example, social landlords are responsible for the open spaces of nearly 4 million households, yet such spaces are invisible in national data collection (CABE 2009a). Planning Policy Guidance Note 17 states that local authorities must carry out audits of existing open spaces, taking into account use and access to these areas (PPG17 2002). However, no standardised method of data collection is available, hindering comparability between areas, and the information is not yet collated on a national scale. The Commission for Architecture and the Built Environment (CABE) has assembled a useful, but incomplete, single inventory of public greenspace for English urban authorities by combining data from a wide range of existing data sources (CABE 2010). CABE's research highlights the wide range of organisations involved, and the overlaps, inconsistencies and patchiness of such data (Sadler *et al.* 2010). Sources of information on rural areas are better (MAGIC 2009), probably because they exhibit far less spatial heterogeneity and are, therefore, easier to map.

Natural England has been collating digital map datasets of urban and rural accessible greenspace since 2006. Collation is based on the categories described in PPG17. They have identified 32 datasets and collated 70% of them. Resources are required to review and evaluate the different approaches to, and responsibilities for, Urban greenspace mapping.

The term 'green infrastructure' has been introduced in recent literature to replace greenspace and other similar typologies used to describe the semi-natural environment, as well as terms proposed for assessing connectivity, multifunctionality and ecosystem services. Green infrastructure includes greenspaces and other natural elements, such as rivers and lakes, which are interspersed between, and connect, villages, towns and cities. Individually, these elements are classified as green infrastructure 'assets' and the roles that these play are termed green infrastructure 'functions' (Land Institute 2009). Developing common terminology for use in Urban ecosystem assessment is critical and the green infrastructure system (along with many others) requires urgent review in the broader context in order to establish a consensus among the relevant authorities on the most appropriate way forward.

10.6.2 Developing Datasets to Inform Regulating Services

10.6.2.1 Air and climate

There is a shortage of meteorological stations within most Urban environments, so data on the extent of UHI is limited, although an ongoing national study is attempting to improve the situation (RMetS 2009b). The development of such a dataset would permit greater interpretation of how Urban ecosystems contribute to localised climate regulation, and how the spatial distribution and species composition of Urban vegetation influences cooling effects. Such measurements would contribute to model validation and improve climate predictions and air quality modelling.

Increasing episodes of tropospheric ozone are anticipated due to reductions in nitrogen oxides and the higher temperatures and humidity thought to be associated with elevated atmospheric carbon dioxide (Jacobson 2008). Drought conditions and high temperatures can affect vegetation, shutting down plant stomata and reducing the uptake of ozone, thus enhancing ozone persistence and concentration (ApSimon *et al.* 2009). Such ozone episodes are likely to affect both human health and sensitive vegetation. However, expected reductions in nitrogen dioxide have not been uniform across Urban areas and emission reductions remain challenging.

By 2050, winter river flows are predicted to increase by 10–15% in response to climate change. However, in the late summer and early autumn, flows could fall by over 50%, and by as much as 80% in some catchments. Overall, this could mean a drop in annual river flows of up to 15%, creating huge challenges for water supply. Indications are that climate change may reduce the recharge of aquifers and lower groundwater levels. Climate change may also increase water temperatures and the prevalence of invasive alien species, which will influence aquatic plants and animals. These effects need to be evaluated.

10.6.2.2 Water

A common typology for water services has been developed under the WFD. Action to ensure that the typology is appropriately adopted within the UK will be necessary.

10.6.2.3 Soil

There is a need to find out what soil resources there are in Urban areas, their condition and how they fit into a wider planning context. It is possible to produce spatially explicit (map-based) planning decision support models to assess proposals for new development (with appropriate investment in model development and data acquisition), but it will require the systematic collection and maintenance of high resolution, spatial environmental asset data (Hindmarch *et al.* 2006).

Assessing soil quality is a complex issue. New methods are under development to help prioritise areas where further investigation is necessary, with the potential to complement existing monitoring programmes and to assist in the development and implementation of current and future soil protection legislation (Bone *et al.* 2010; OPAL 2010). Management options that could benefit Urban soil quality are outlined in Chapter 14.

The Environment Agency calculates that around 325,000 sites (300,000 ha) have had some current or previous use that has caused contamination (Environment Agency 2009). Although many PDL sites are important providers of ecosystem services, there remains a currently unquantified risk that may have localised consequences for human health and well-being.

The planning system does not fully recognise the ecosystem services provided by soil. While steps have been taken to address this issue in recent years, more could be done to reduce the widespread sealing and degradation, and subsequent loss of function and resilience, of soil. Raising awareness and providing training for planners on ecosystem services could help address these issues.

10.6.2.4 Noise

While the spatial modelling of noise has increased, actual measurements of noise appear limited. As shown by the UK National Noise Incidence Study of 2000/01 (Skinner & Grimwood 2002), it is useful to be able to compare perceptions of noise with actual measurements.

10.6.3 Understanding the Importance of Urban Biodiversity

Research is required to further the understanding of the importance of Urban biodiversity in general, and the relationship between biodiversity and well-being in particular. It is also important to monetise these benefits as some projects have done (Natural Economy 2010). Most studies of species richness and abundance in Urban areas have been conducted outside the UK. There is a need to investigate trends in Urban areas through case studies, for example, digitising post-war aerial photographs in order to map changes in garden structure and diversity, paving, etc.

10.6.4 Increasing Knowledge Transfer on Ecosystem Services Between Academics and Other Urban Practitioners (e.g. Planners)

There is scope to increase links between academic research groups and delivery organisations in Urban areas to inform parameters for greenspace management and design. A successful example of such collaboration is the Living Roofs project where PhD/MSc research has contributed to design recommendations for biodiverse roofs that support species of conservation concern while providing cooling, water attenuation and, in some cases, amenity (Living Roofs 2010).

10.6.5 Linking Ecosystem Services to Human Well-being

The rise of well-being theory has created an assertion that the best measure of social utility as the basic objective of social policy is creating happiness. The use of subjective well-being as an economic valuation tool, as opposed to revealed and stated preferences, is a technique in its infancy, but it may help evaluate the benefit of ecosystem services to human well-being (Dolan & Metcalfe 2008; Levinson 2009; Luechinger 2009; Chapter 23).

Research programmes in the UK that develop new approaches to Urban development and management, given the pressures of climate change and other drivers, are extensive (e.g. SCORCHIO 2010; LUCID 2010; SUE 2010), but are not reviewed here. It is also recognised that there are numerous examples emerging nationally and internationally of innovation in urban design that reflect the importance of ecological and economic health in Urban planning and their importance to human well-being (WWF 2010).

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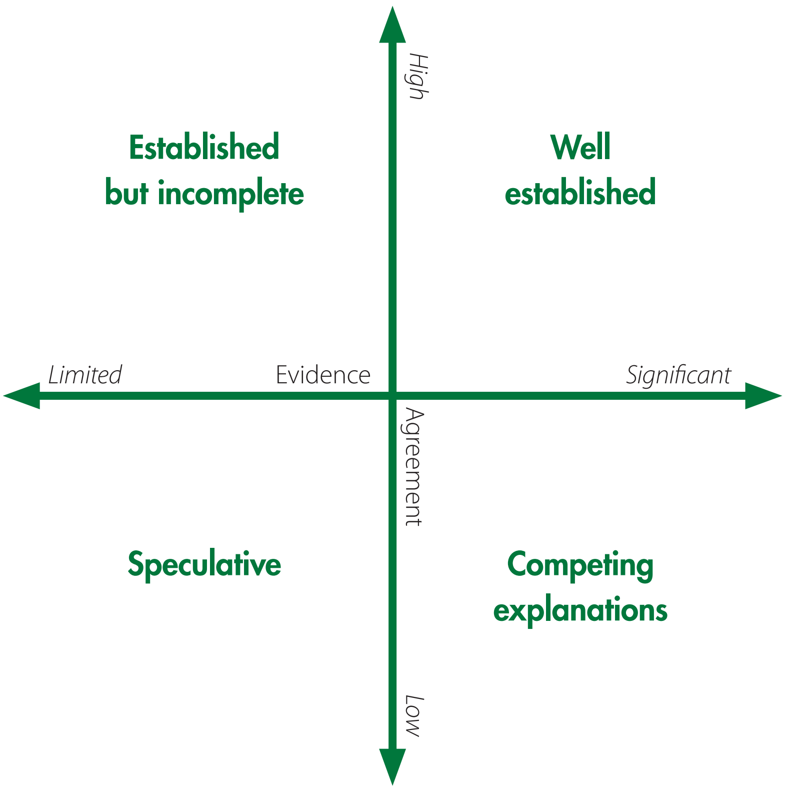
Appendix 10.1 Approach Used to Assign Certainty Terms to Chapter Key Findings

This chapter began with a set of Key Findings. Adopting the approach and terminology used by the Intergovernmental Panel on Climate Change (IPCC) and the Millennium Assessment (MA), these Key Findings also include an indication of the level of scientific certainty. The 'uncertainty approach' of the UK NEA consists of a set of qualitative uncertainty terms derived from a 4-box model and complemented, where possible, with a likelihood scale (see below). Estimates of certainty are derived from the collective judgement of authors, observational evidence, modelling results and/or theory examined for this assessment.

Throughout the Key Findings presented at the start of this chapter, superscript numbers and letters indicate the estimated level of certainty for a particular key finding:

1.	*Well established:*	high agreement based on significant evidence
2.	*Established but incomplete evidence:*	high agreement based on limited evidence
3.	*Competing explanations:*	low agreement, albeit with significant evidence
4.	*Speculative:*	low agreement based on limited evidence



a.	*Virtually certain:*	>99% probability of occurrence
b.	*Very likely:*	>90% probability
c.	*Likely:*	>66% probability
d.	*About as likely as not:*	>33–66% probability
e.	*Unlikely:*	<33% probability
f.	*Very unlikely:*	<10% probability
g.	*Exceptionally unlikely:*	<1% probability

Certainty terms 1 to 4 constitute the 4-box model, while *a* to *g* constitute the likelihood scale.