Forest Research

Benefits of green infrastructure

Report to Defra and CLG

defra
Department for Environment Food and Rural Affairs

Communities and Local Government

URBAN
REGENERATION &
GREENSPACE
PARTNERSHIP

Promoting sustainable greenspace

Benefits of green infrastructure

Report to Defra and CLG

Contract number WC0807

October 2010

defra
Department for Environment Food and Rural Affairs

Communities and Local Government

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The report should be cited as: Forest Research (2010). *Benefits of green infrastructure*. Report to Defra and CLG. Forest Research, Farnham.

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Executive summary

The content of this report

Urban policy today can be classified as hitting three main targets:

- economic development, including local economic activity, income generation and employment policy;
- social development, including housing and neighbourhood issues, relations within and between communities, and social inclusion;
- environmental issues, concerned with spatial relationships in the city, planning, transport and the urban infrastructure.

From the perspective of green infrastructure, the report examines how these main policy objectives can be supported. It provides a synthesis of the evidence on the benefits of green infrastructure, based on expert evaluation of scientific and other related literature. Each of the main chapters is structured in a similar way: after the introduction, the main part is devoted to the critical review of the evidence, followed by the identification of potentially useful toolkits, knowledge gaps, case studies and a list of key bibliographic references. The following gives a short summary of each of these chapters.

Economic benefits

Placing accurate economic values on green infrastructure or its green space components is far from easy, but is vital to support the case for sustained investment. Although the vast majority of the evidence points to green infrastructure benefiting many vital aspects of social and environmental sustainability, the challenge is in convincing budget holders of the economic value of such 'indirect' impacts. In most cases there is little doubt that returns on green infrastructure investment are high, but without adequate demonstration it is often difficult for investments to be made in line with other initiatives where direct cost-benefit valuation is simpler. A series of case studies where economic valuation has taken place are discussed in order to demonstrate the net economic value of initiatives to create or improve green infrastructure. There is good evidence that green space can make positive impacts on both local and regional economic regeneration, especially for job creation, business start up and inward investment. However, the quality and quantity of this evidence is comparatively poor and further research is needed to improve it.

Social benefits

There are many potential social benefits that good quality, accessible green space and infrastructure can provide, but the most significant of these can be grouped into three broad categories:

1. Improvements in levels of physical activity and health.
2. Promotion of psychological health and mental well-being.
3. Facilitation of social interaction, inclusion and community cohesion.

Benefits of green infrastructure

Associations have been found between access to green space and raised levels of physical activity, which in turn improves individuals' health. There is a strong body of evidence which shows that they can have a beneficial impact on mental well-being and cognitive function. At their best, green spaces can also help facilitate social interaction, integration and the development of community cohesion.

The potential social benefits that green infrastructure can provide are therefore substantial and have been strongly linked to a range of key government priorities. Although direct economic evidence about the provision of these benefits is limited, what little exists suggests that green infrastructure provision and green space initiatives are a cost-effective method of achieving them. The improvement of existing and creation of new green infrastructure should be prioritised, especially in areas of greatest need.

Environmental benefits
Urban green infrastructure can deliver a wide range of environmental benefits, particularly:

- Reduction in air pollution.
- Reduction in flood risk as part of sustainable urban drainage systems.
- Improvement of the perceptions of an urban area as aesthetically pleasing.
- Amelioration of high summer temperatures caused by the urban heat island effect and climate change.

None of these benefits occur in isolation, and well-designed and well-managed green infrastructure can deliver all of them at the same time. However, pressures on land use in urban areas may make it difficult to site green space in the optimum position, which make trade-offs and compromise necessary. These trade-offs should not, however, prevent urban GI from delivering a good subset of the above benefits.

Land regeneration benefits
Previously developed, derelict, underused, neglected (brownfield) land in and around urban centres can provide real opportunities to deliver social, environmental and economic benefits via conversion to green infrastructure. In particular, by delivering improved environmental health, quality of place and subsequently increased land value and regional investment, the conversion of brownfield land to green infrastructure can be very cost-effective. Nevertheless, land regeneration requires both project resources and revenue funds for long-term management and maintenance; these can be substantial.

The regeneration of brownfield land presents a prime opportunity to make the connections between existing green space and facilitate its functioning at a larger scale. Work needs to be done to secure further delivery including: effective sustainability evaluation for land regeneration and green infrastructure creation programmes; an understanding of the impacts of climate change on some contaminated land remediation strategies and associated risks to human and environmental health; a much improved understanding of the relations between people and landscapes, especially in a UK setting; and the use of zonation in green space design in order to drive delivery of quality functional green spaces desirable to local residents.

Hydrological benefits

Alterations to the natural environment can affect the movement of water through the hydrological cycle and alter its composition. By replacing vegetation with more impermeable materials, urban development has had a significant impact on the hydrology, freshwater ecology and terrestrial ecosystems that river systems support. Green infrastructure can provide hydrological benefits in two key areas: flood alleviation and water quality (improvement and protection). Urban and peri-urban trees (in the riparian zone and floodplain) can contribute to flood alleviation by delaying the downstream passage of flood flows, reducing the volume of runoff, and promoting rainfall infiltration into the soil, thereby reducing the rate of runoff. Flood alleviation using trees may be restricted to small-scale flood events; however, this is significant as trees store more water during lower intensity rainfall events over longer time periods than intense events over short periods. Moreover, small storm events are responsible for most of the annual pollutant loading to receiving waters so there is considerable scope for water quality improvements. Green roofs, Sustainable Urban Drainage Systems (SUDS), wetlands and retention/detention basins also offer hydrological benefits through reduced runoff, increased storage and improved water quality. Further studies are required to quantify hydrological benefits and assess the efficacy of individual green infrastructural components and their integrated use.

Ecological benefits

Ecological benefits of urban green infrastructure are largely related to the provision of habitat. Species from the very common to the very rare make use of all types of green infrastructure, from large 'brownfield' sites to tiny patches on roundabouts and road islands. Provision of green infrastructure in urban areas can help meet targets for UKBAP priority habitat ('Open Mosaic Habitat On Previously Developed Land'), broader habitats such as native woodland and UKBAP priority species.

Effective networks of green infrastructure also provide opportunities for species to move, spread and colonise new habitats. Some of this movement and colonisation is of animal species which damage property, cause vehicle collisions or carry disease. Other species which benefit disproportionately from urban green infrastructure are non-native, highly competitive species that threaten native species assemblages. Increased opportunities for movement are considered a key adaptation activity for many species' response to climate change, and resilient ecological networks are advocated to support this. However, while they are based on sound theory and good evidence of the effectiveness for some individual components, the overall value of ecological green networks in climate change adaptation remains to be demonstrated.

1 Introduction

1.1 What is green infrastructure?

Infrastructure is defined as the basic structures and facilities necessary for the efficient functioning of a given geographical area. Although there is no commonly accepted or authoritative definition in the UK, 'green infrastructure' refers to the combined structure, position, connectivity and types of green spaces which together enable delivery of multiple benefits as goods and services. It is important to consider green infrastructure holistically and at landscape as well as individual site scale.

Integration of urban green space with the built environment that surrounds it is crucially important if benefits are to be maximised. Green space, whether connected or not, must be seen as providing facilities or services for the people who live amongst it. Its real potential will only be realised if activities or operations undertaken in or on the green space are supported by the whole local community.

Green infrastructure benefits will be achieved most successfully if green space creation and management are integrated with more traditional land development and built infrastructure planning. An important consideration is the spatial positioning of the component parts of the green infrastructure. Some goods and services depend on a strong connectivity between location and user. Others, such as wildlife habitat, may depend on the interconnectedness of the component parts of the green space 'jigsaw'.

Such sentiments are progressive and in keeping with our increasing understanding of the importance of urban green space. However, moving from the single purpose and single scale to a more complex conceptual model requires a much better comprehension of what green infrastructure can and cannot do. At its most basic, multifunctionality means performing 'more than one' function, yet some who advocate greater amounts of urban green space and green infrastructure seem to suggest that it can be 'all things to all men'. This is clearly impossible – clear choices need to be made about what is required of our green infrastructure and how it is to be managed at a site-based level to give maximum multifunctionality at the community and landscape scales. Nevertheless, consideration of the benefits of a green space away from dedicated single usage (e.g. parks for recreation) allows us to explore in more detail just what green infrastructure is about.

Green infrastructure 'ecosystem services'
'Ecosystem services' are the benefits provided by ecosystems that contribute to making human life possible and worth living; there is a wide range of goods and services that

different land-use sectors, including green infrastructure, can provide. These can be classified as supporting, provisioning, cultural and regulating services. Table 1.1 describes some of the more important ones using the typology created by the Millennium Ecosystem Assessment. Some of the services, such as enhancing the landscape or promoting recreation, are well known, but others such as pollution mitigation are unseen, and for many they go unnoticed.

Table 1.1 Types of green infrastructure (GI) ecosystem service, based on framework from the Millennium Ecosystem Assessment.

Type of ecosystem service	Examples of delivery
Provisioning	
For bio/woodfuel	Timber products (e.g. raw and recycled wood) as fuel for heat and power plants, as domestic firewood
GI for other products	Some types of GI will support informal provision of berries and fungi. Formal types of GI such as allotments can support a wider range of food provision
Regulating	
GI for pollution mitigation	Capture of atmospheric pollutants in tree canopies and consequent reduced exposure for humans, buildings etc. Green cover to stabilise contaminated brownfield land and hinder the pathways between source and receptors
GI for soil protection	Vegetation, especially grass and trees, offers protection from soil erosion and slope failure. Silviculture and arboriculture will reduce exposure to chemicals and pesticides and likelihood of soil compaction compared to agriculture
GI for flood and water protection	Trees especially moderate rainfall events and river and stream hydrographs, delaying and reducing flood events. Because of minimal use of pesticides and fertilisers, woodlands managed under sustainable principles also offer benefits of water quality
GI for carbon sequestration	Vegetation especially trees will capture carbon through photosynthesis, and pass it into below and above ground biomass. Soil carbon likely to be increased under most GI vegetation types
GI for climate (change) mitigation	A tree cover can help dampen the climatic effects experienced in the open, thus protecting soils, animals and humans from extremes of temperature and UV light
Cultural	
GI for social cohesion, personal strength	Green spaces are important for personal enlightenment, and as places or catalysts for social activity and cohesion, especially when people are involved in GI planning and management
GI for amenity/recreation/ health	Green space is open to the public for the enjoyment of outdoor pursuits and recreational activities. Access facilitates exercise and benefits human health and longevity
Supporting	
Soil formation, nutrient cycling, water cycling, oxygen production	Green space is essential for soil formation and other biogeochemical processes essential to life
GI for biodiversity	Green space can provide valuable habitat for a wide range of fauna and flora

One aspect of the use of the term 'green infrastructure' that is less commonly emphasised than it should be is the need for the integration of urban green space with the built environment (e.g. bricks, concrete, tarmacadam) that surrounds it. Green space, whether connected or not, must be seen as providing facilities or services for the people who live within the bricks and mortar and who use the tarmac for transport. In other words, green space isn't an addendum or after thought, or something which isn't the built environment. Its real potential will only be realised if activities or operations undertaken in or on the green space are framed by policies for the whole community that lives there. For example, the value of urban green infrastructure for health-enhancing activities such as running or cycling may be considerably increased if supported (and monitored) by health and medical professional organisations responsible to the community. Some goods and services will have benefits that are much wider than this, for example the downstream benefits of flood alleviation for urban communities by the creation of particular types of green infrastructure upstream of the urban centre. Some benefits may reach national scale, such as helping the nation to meet statutory responsibilities for reduction in greenhouse gas emissions. But in all these examples, green infrastructure benefits will be achieved most successfully if creation and management take place in concert with more traditional land development and built infrastructure planning.

When exploring the benefits of green infrastructure, it is important to take a balanced viewpoint – some aspects of urban green space may negatively impact on the individual or local communities. For example, some regard trees as exacerbating clay soil shrinkage through evapo-transpiration, and thus increasing the risk of building subsidence, although this by no means an established 'fact'. Similarly, while there is good evidence that vegetation, especially trees, can intercept and thus reduce the amount of many forms of atmospheric pollution, it is also true that some types of tree are responsible for emission of volatile organic compounds (VOCs), the precursor of ozone generation. And it is also the case that some goods and services ascribed to green infrastructure (Table 1.1) can be found and met by other means – there is no single agenda that green infrastructure is the only or even the best or most cost-effective 'delivery agent'. Nevertheless, there is now compelling evidence that green infrastructure is in many ways a vastly underused resource, and that increasing the diversity of uses may represent a case of reasonably 'sweating' this existing asset.

Another consequence of moving from point to landscape in considering urban green space is the spatial positioning of the component parts of the green infrastructure. Some goods and services depend on strong connectivity between location and user, for example recreation. Here, it is important that there is suitable access from zones of habitation (or employment) into the green space, and it is increasingly important that accessibility is truly for all, i.e. there is no inadvertent exclusion of parts of the community, for example the disabled or the elderly. However, provided green space is in reasonably close proximity to its recreational users, exactly where it is located isn't usually critical.

In contrast, other goods and services, such as wildlife habitat, may depend on the interconnectedness of the component parts of the green space 'jigsaw'. Here there are serious constraints on where new green space might be located in order to maximise optimal delivery. Indeed, it might be supposed that for some goods and services, such as formal sports fields, benefits may grow arithmetically as the amount of green space provided increases. But for others, such as habitat or sustainable urban drainage, a form of geometric improvement will be attained if interconnectedness is achieved as green space provision increases.

Climate change

The importance of green infrastructure in urban policy matters has risen up the agenda in recent years as a response to climate change and the need to move towards a low carbon economy; for example, in 2009 the Department of Energy and Climate Change published *The UK low carbon transition plan*. Certainly, urban green infrastructure can play its part in supporting carbon capture, for example in building soil carbon reserves over time.

Green infrastructure has an important role in supporting the adaptation of people who live in towns and cities to a changing climate. Depending on location, type and extent, green infrastructure provides shade, cooling and wind interception and an insulation role in the winter. Green infrastructure can also potentially mitigate risks from climate change induced reductions in air and water quality, buffer against disruption to regional ecology, whilst contributing to attainment of sustainable urban drainage and controlling upstream water flows to reduce flood risk. Effectively harnessed, green infrastructure has real potential for 'educating' people about climate change. Green spaces can also be used to promote an appreciation of the impacts of climate change, and lifestyle changes needed to reduce further effects and/or to adapt to them.

Climate change will certainly affect the performance and delivery of green infrastructure in urban areas. At a technical level, choice of vegetation and species, provision of adequate contamination management, soil and form of land management will all need to be factored into the planning of new green infrastructure. A changing climate and need to reduce our carbon footprint also gives an opportunity to reconsider green infrastructure, and the outcomes we will want from it in the years to come. An informed position, based on a synthesis of the evidence for a range of important potential benefits, should allow policy-makers, planners and landowners to make complex decisions about it more effectively.

Community engagement

The previous discussion has identified that green infrastructure is far more than the 'green bits' on the urban map. It is also, in the main, a public resource, ready for use by the 80 per cent of the population who live in towns and cities. Such a latent demand, set against the comparatively small resource that green space still is, requires careful planning in order to maximise its cost effectiveness and its ability to deliver the most desirable goods and services in a sustainable way. It is thus vital that proposed, and existing, green infrastructure is considered in the context of the communities it will serve. There is now considerable evidence that the most successful elements of this infrastructure are those where effort has been made to consult and, more importantly, to engage with these communities. Green space left to 'the authorities' is likely to miss the mark – committed individuals, societies and business enterprises can make all the difference to its success, and can attract additional funding to maintain or improve the facilities, while acting as superintendents or care managers too. Understanding the range of benefits that green space can offer can help identify the parts of the community which might particularly support its management, and exploit its potential.

Methodology
The methods used in this study included a literature review of research exploring the relationships between green infrastructure and economic, social and environmental benefits, and focused on peer-reviewed journals.

Web-based searches focused on the relationship between green infrastructure and:
- Economic benefits
- Social benefits
- Environmental benefits
- Land regeneration benefits
- Hydrological benefits
- Ecological benefits

Studies were identified through a search of online databases including Web of Science, Science Direct, CAB Abstracts, Medline, PsychInfo PubMed.

In addition, reference lists of recent reviews of green infrastructure were examined to identify studies meeting the search criteria.

2 Economic benefits

2.1 Introduction

Placing accurate economic values on green infrastructure or its green space components is far from easy, but is vital to support the case for sustained investment. Although the vast majority of the evidence points to green infrastructure benefiting many vital aspects of social and environmental sustainability, the challenge is in convincing budget holders of the economic value of such ‘indirect’ impacts. In most cases there is little doubt that returns on green infrastructure investment are high, but without adequate demonstration it is often difficult for investments to be made in line with other initiatives where direct cost-benefit valuation is simpler.

This chapter focuses on the economic benefits of green infrastructure, i.e. the impact of green infrastructure on the local economy. In other chapters evidence is presented on the monetary value of the benefits provided by green infrastructure such as the value of increased physical activity.

In addition to the scientific literature, the research uses a series of case studies where economic valuation has taken place in order to demonstrate the net economic value of initiatives to create or improve green infrastructure. The methodology used in this critical review can be found in Appendix 1.

2.2 Critical review

2.2.1 Economic growth and investment

Investments in green space have been shown to improve a region’s image, helping to attract and retain high value industries, new business start-ups, entrepreneurs and workers. This, in turn, increases the scope for levering in private sector investment, reducing unemployment and increasing ‘Gross Value Added’ (GVA) (NENW, 2008: 8).

Although levering in private sector investments is beneficial to a local economy it must be acknowledged that (except for some foreign direct investments) this money is likely to have been displaced from elsewhere and be of no net benefit to the UK economy. In some cases, however, it may be beneficial in reducing regional disparities.

In total nine case studies (Table 2.1) were identified as being potentially relevant to the review of the benefits of green infrastructure on economic growth and investment. These were presented in six studies (CESR, 2004; CLES, 2007; CSI, 2008; EKOS, 1997; Land Use Consultants, 2006; Regeneris, 2009).

Table 2.1 Economic growth and investment.

Project	**Estimated benefits**	**Reference**	**Value or impact study** [a]	**Additionality issues**
Riverside Park Industrial Estate in Middlesbrough. Investment in the green infrastructure of the park, over 1800 new trees planted.	Created a setting for stimulating business growth and investment; attracted new, high profile, occupants and saw occupancy grow from 40% to 78%, and levered over £1 m of private investment; 28 new businesses started up. Over 60 new FTE[b] jobs created.	CLES (2007)	Impact	Only basic comparisons to regional / national trends
Winsford Industrial Estate in Cheshire. Environmental and landscape improvements including new plantings.	88 new FTE jobs created. 13% increase in the number of employees in Winsford Wharton between 2003 and 2005 (compared to 2.9% for England as a whole). Private matched funding of over £290,000 was levered in. Number of businesses increased from 104 to 160 all paying business rates to the local authority.	CLES (2007)	Impact	Only basic comparisons to regional / national trends
Portland Basin Green Business Park, Tameside, Greater Manchester. Landscaping improvements.	Just under £425,000 of public sector funding levered in over £1.8 m of funding from the private sector. 13 new FTE jobs were created and a further 314 jobs safeguarded. As a result of the programme the number of businesses located in the park increased from 120 to 140.	CLES (2007)	Impact	Not considered
The National Forest creation.	Number of local jobs increased (1991-2001) by 4.1%. Jobs created, safeguarded (1995-2001): 213 FTE. By 2001 directly related regeneration programmes resulted in funding of £32.5 m for the area which attracted leverage of £96 m and created over 500 jobs.	CESR (2004)	Impact	Only basic comparisons to regional/national trends

Project	Estimated benefits	Reference	Value or impact study [a]	Additionality issues
Manvers Regeneration scheme by Rotherham Metropolitan Borough Council (MBC) in South Yorkshire.	20 year scheme. Private sector investment in the scheme to date has been estimated at over £350 m; about 9000 jobs have been created.	CSI (2008)	Impact	Not considered
Langthwaite Grange, Wakefield, West Yorkshire. Landscape quality and security improvements at a 57 ha industrial estate. Started 2005.	16 new businesses moving in, bringing over £12 m investment and creating 200 new jobs. Crime has fallen by 70% in 12 months.	CSI (2008)	Impact	Not considered
The Mersey Forest, Merseyside (new tree planting, land reclamation, bringing woodland into management, creating access to green space and recreational facilities, managing and improving habitats, engaging local communities and business support activity for forestry businesses).	Direct increases in economic output in Merseyside: £2.8 m gross GVA from tourism spend, from direct jobs (products from the land), and from improvements in health or £436,000 net additional benefits.	Regeneris (2009)	Both	Well considered
Kennet and Avon canal restoration. Restored historic waterway enhances landscape. The long-term restoration effort has involved £38.9 m since 1997, including a Heritage Lottery Fund donation of £25 m.	Direct and indirect employment created by the project totalled 150-210 FTE jobs between 1997 and 2002. The total number of jobs created and safeguarded by the project is estimated at 1198-1353 FTEs.	Land Use Consultants (2006: 9)	Not clear[c].	Not clear.
Improvements to the local footpath network in Dunkeld and Birnam: establishment cost (£70,000) and annual maintenance cost (£3,000).	Generated between £1.37 m and £3.69 m of income a year to the local economy, directly supporting between 8 and 15 FTE jobs.	EKOS (1997)	Impact	Not clear[c].

[a] See Appendix 1 Methodology, paragraphs 3 and 4.

[b] Full-time equivalent (FTE) jobs.

[c] No detailed information is provided in the publication only a brief project description.

The strongest evidence is presented within the Mersey Forest case study (Regeneris, 2009) as this is the only one to take account of additionality and related issues (double counting, displacement and multiplier effects, sensitivity analysis) following best practice guidelines (Defra, 2007; Eftec, 2010). However, their long-term discounting approach in calculating net present value (NPV) of benefits does not follow the Treasury Green Book advice (HM Treasury, 2003: 98-99)[1]. The study estimates that every £1 invested in the Merseyside Objective One programme will generate over the lifetime of the investment (50 years[2]) £2.30 in increased GVA (Regeneris, 2009: 3, 5), composed of GVA from tourism spend, from forestry (i.e. direct jobs related to products from the land), and from improvements in health. It was assumed that annual value for each of the benefits was calculated at the point where the trees have matured (Regeneris, 2009: 29-30). This assumption may lead to an overestimation for some benefits[3]. The authors applied GIS analysis to the benefits with spatial characteristics (Regeneris, 2009: 30-31) including tourism. However, it is important to say that the study is not primary research but bases its estimates on values available from the existing literature (Regeneris, 2009: 8). Nevertheless, this would appear to be the only study in our view that is reasonably robust with respect to annual benefits values and informative to make their findings acceptable for use in a value transfer approach, given that the possibility/applicability of value transfer itself is decided upon by following best practice guidelines (Eftec, 2010).

The impact of improvements in the local environment on local and regional economy is the main research topic in three case studies: Riverside Park Industrial Estate in Middlesbrough, Winsford Industrial Estate in Cheshire and Portland Basin Green Business Park in Tameside, Greater Manchester (CLES, 2007). None of the three projects deal exclusively with the improvement of green space, however. Other than landscape improvements (mainly planting and clean ups) measures included improving signage, lightning and access, roads and transportation, introduction of energy saving and waste recycling policies, security improvements (CCTV and fencing) and buildings renovations. Inclusion of these significant components of a project made it impossible (given available data) to quantify precisely the benefits that can be attributed to green space improvements alone. All of the projects resulted in the creation of new jobs, new businesses started, private investment levered in, occupancy rates increased and a fall in crime. While these could be expected to have increased local GVA, the extent to which this occurred is not reported.

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[1] In particular, benefits have been discounted at 3.5% p.a. (the standard government social discount rate) for fifty years but assumed to increase in real terms by 2%, in line with the UK trend growth in real income (Regeneris, 2009). First, when discounting over a long term the Green Book suggest a 3% discount rate after first thirty years. Second, a 2% annual real growth is already included in 3.5% p.a. (the standard government social discount rate).

[2] Choice of 50-year time horizon for this forestry project seems an arbitrary one and is not supported by the Treasury Green Book.

[3] For example, the forestry GVA estimate is based upon an average for all types of woodland and so might be expected to over estimate the GVA associated with immature stands at the start of the Mersey Forest tree planting project. Similarly, tourism expenditure associated with visits to recently planted forests might be expected to be significantly lower than the average for country parks.

In terms of additionality, the study (CLES, 2007) used a very crude measure of net additional benefit, applying a basic comparison to regional and national trends to infer and form judgement on additionality of interventions. The basic comparison to regional and/or national trends was performed in relation to employment, earnings and property prices and is not detailed or disaggregated by appropriate sectors or categories. For example, although local employment changes by industry sector were available for Winsford Industrial Estate, Cheshire, only aggregate values are compared (CLES, 2007: 36-37). Sometimes total spend on the project is not presented, for example, for Winsford Industrial Estate (CLES, 2007). This basic additionality treatment was performed only for employment for two case studies: Riverside Park Industrial Estate in Middlesbrough and Winsford Industrial Estate in Cheshire. It yielded over 16% and 13% of net (above local trends) growth in employment correspondingly in Riverside Park and Winsford. It appears that the issues of additionality are not investigated in accordance with best practice guidelines (Scottish Enterprise, 2008), because issues of leakage, displacement (e.g. how much of the higher occupancy rate can be due to displacement of businesses from immediate neighbouring areas), substitution and multiplier effects are not discussed or investigated. Values reported in the study are not suitable for use in a value transfer approach because valuation itself is not up to best practice guidelines (Eftec, 2010, Annex 2). In particular, not all necessary data were collected, and impact assessment was not in accordance with best practice guidelines (described above).

Similar problems occur when considering the social and economic impact of the National Forest (CESR, 2004). Again only a basic comparison to regional and/or national trends was performed to infer and form a judgement on the additionality of interventions. The study reported growing employment rates and growing numbers of businesses with number of businesses registered per 10,000 population above regional and national averages, overall levels of benefit dependence below regional averages, but average earnings still below regional averages. However, due to the length of the project sometimes comparison is infeasible because of data definition changes, for example, age group definitions changed from Census 1991 to Census 2001 (CESR, 2004: 21). Some of headline indicators (e.g. average property price and households without access to a car) only present a snapshot of development and not changes with respect to a baseline. Some data are not robust due to small sample sizes (CESR, 2004:12). Spatial distribution was a key challenge in the collation of the data given that forest boundaries generally do not coincide with ward boundaries that the majority of data sets are based upon (CESR, 2004:14). Given the above data problems values reported in the study are not suitable for use in a value transfer approach.

For two other case studies presented (CSI, 2008: 20, 23): Manvers Regeneration scheme in South Yorkshire and Langthwaite Grange in Wakefield, West Yorkshire, information on projects is reported without any attempt to estimate net additional benefits.

Knowledge gaps

The following knowledge gaps are identified. More primary studies of interventions and investments to improve green space following additionality and impact assessment guidance (Scottish Enterprise, 2008) are needed to build up a database with intervention outcomes of reasonable quality that can be used within a value transfer approach.

Conclusions

Summarising, it could be asserted that there is little direct, strong and reliable evidence of impacts of green space on economic growth and investments. However, there is evidence that investments in green space have a positive impact on such constituent components of economic growth and investments as job creation, new business start up, amount of private investments levered in. This should consequently increase local GVA. There are though a lot of issues regarding the estimates of additionality and magnitude of net benefit of such investments. Currently, only the Mersey Forest study (Regeneris, 2009) is reasonably robust and informative to make their findings on the value of annual benefits acceptable for use in a value transfer approach, but bearing in mind the caveats.

2.2.2 Land and property values, and aesthetics

Developing and improving green space in key locations within urban and semi-urban areas is argued to have significant benefits which are reflected in increasing property and land values. Investment in green space can lead to higher returns for the property sector. Greener areas have a better image and attract more visitors, bringing with them retail and leisure spending and providing job and rental opportunities. This in turn increases land and property values (NENW, 2008: 9).

Higher house prices used in hedonic studies can reveal people’s preferences for green space, and when green space is developed or improved near a location the existing local homeowners may benefit from property price increases. However, a property price increase is not in itself unambiguously a benefit, especially as it may disadvantage prospective buyers. Nonetheless property price increases may benefit local economies in indirect ways, such as by encouraging further property development in an area and increasing local council tax receipts as a result.

Numerous studies have been conducted into the value of trees in urban and suburban settings, such as Thompson *et al*. (1999) and CTLA (2003). The aesthetic value of trees is subjective and difficult to measure; however, research has shown that the trees add 15% to 25% to the total value of property, depending on size, condition, location and species rating (CTLA, 2003). CABE (2005) have shown that properties increase in price by an average of 7% in environments landscaped with trees. According to the North West Development Agency a view of a natural landscape added up to 18% to property in North West England, and residents in peri-urban settings are willing to pay £7,680 per household for views of broadleaved woods, equivalent to £4.2 billion across the UK. Needless to say, development of green space has been used to promote economic activity in an area (Cousins and Land Use Consultants, 2009).

In total nine studies (Table 2.2) were identified as relevant to the review of green infrastructure to land and property values and aesthetics benefits (CABE, 2004; 2005; Dunse *et al.*, 2007; Edwards *et al.*, 2008; Forestry Commission, 2005; Garrod, 2002; GEN Consulting, 2006; GLA Economics, 2003; Regeneris, 2009).

Table 2.2 Land and property values, and aesthetics.

Project	**Estimated benefits**	**Reference**	**Value or impact study**	**Additionality issues**
The Mersey Forest	Net additional monetised benefit due to landscape improvements (visual amenity), views from home: £412,000 p.a. and while travelling: £527,000 p.a.	Regeneris, (2009: 36-37)	Both	Well considered in general, also uses WTP here
Development of Bold Colliery Community Woodland.	Enhanced property values in the surrounding area by *c*. £15 m and helped realise a further £75 m of new development.	Forestry Commission (2005)	Impact	Only basic comparisons to regional / national trends
Glasgow Green (the city's oldest park) Renewal project: £15.5 m investment of public funds (1999-2006).	Stimulated the development of new residential properties (net impact 500-750 new residential properties), enhanced average house prices and the total value of property transactions (net £3 m–£4.5 m), a 47% increase in council tax yield (additional £0.8 m–£2 m). The value of the land increased from a nominal £100,000 per hectare to £300,000.	GEN Consulting (2006)	Impact	Adequate
Ten case studies in CABE (2005) into the impact of park improvements on house prices, though often not clear how much was invested and what is the return.	One study found that, following improvements, houses near parks were on average 8% more expensive than comparable houses further away.	CABE (2004; 2005)	Value	N/A[a] (use hedonic pricing method)
Comparison of 'greenness' across the City of London's 760 wards.	Hedonic pricing approach showed that higher property values (in terms of the average house price) exist in areas with a higher percentage open space: a 1% increase in green spaces (in London) was linked to 0.3% to 0.5% increase in house prices.	GLA Economics (2003)	Value	N/A (use hedonic pricing method)

Project	Estimated benefits	Reference	Value or impact study	Additionality issues
Impact of green space in Aberdeen	Hedonic pricing estimations yielded average premium values for property located near particular type of green space of: 10.1% for city parks, 9.0% for local parks and 2.6% for amenity green spaces.	Dunse *et al.* (2007)	Value	N/A (use hedonic pricing method)
Survey (GB wide) to estimate the value of woodland views from properties and on journeys using stated preference approach.	Respondents' estimated WTP: a woodland view for houses on the urban fringe is £269 per annum per household (2002 prices), and a view of woodland while travelling is £227 per annum per household (2002 prices).	Garrod (2002)	Value	N/A[a] (use WTP)
Valuation of the current social and economic benefits of forestry, forests and woodlands in Scotland.	The economic value of woodland views from homes in Scotland is estimated to be between £5 m and £74 m per year at 2007/08 prices. The value of woodland views on journeys (based on commuting trips only) is about £15.7 m per year at 2007/08 prices.	Edwards *et al.* (2008)	Value	N/A (use WTP)

[a] See Appendix 2 for explanation of terminology.

Landscape benefits are not as well researched as recreational benefits and valuation tends to either be included with recreational benefits or within 'views from residential properties'/'increase in house prices'. Various studies of the landscape value of woodland have shown that people have a strong preference for 'natural-looking' woodland compared to the blanket uniform structure that typifies many commercial plantations (Entec, 1997). This study was confirmed by Garrod and Willis (1992) and, later, Garrod (2002) who found that proximity to/view of broadleaved woodland enhanced property values, whilst conifers (such as sitka spruce, but excluding larch, Scots pine and Corsican pine) significantly reduced property values and that people have a preference for a patchwork of woods and fields in the landscape, rather than 100% forest cover. Furthermore, it was estimated that proximity to at least 20% woodland cover would raise the value of the average house by 7.1%, the presence of a wetland would reduce the value of the average house by 18%, a woodland view would increase the value of the average house by 7.3%, and an urban view would reduce the value of the average house by 5.8%. Clear preferences for forested landscapes compared with the non-forested alternatives were only found for broadleaved woodland in a peri-urban setting. For views from a home, willingness-to-pay (WTP) ranged from between £200 and £500 per household per year depending on model used and the forest configuration, while for views whilst travelling WTP ranged £155 to £330 per household per year. These values excluded recreational benefits, which were estimated separately. Such findings have been reinforced by international research. For example, as observed by Stafford (2006), consumers continue to express a desire for more green space through a market preference for suburban style living, complete with the requisite yard.

A report by Forest Research (2008) uses the aforementioned values from Garrod and Willis (1992) and Garrod (2002) to derive the aesthetic benefits gained by the Scottish population from seeing forests from where they live and during their daily activities, rather than through forest visits. They note this to be an important value, as the view from the window benefits people's health and well-being benefits (Ulrich, 1991). GIS-based viewshed analysis was used to estimate the proportion of residences in Scotland with views of forests and a tentative non-market value for the landscape was derived. Landscape values were calculated to be £37-74 m per year in 2007/08 prices for woodland views from homes in Scotland, which equates to capitalised landscape values of £1,050 m to £2,120 m. The study noted that the estimates should be treated with caution as they are based upon a landscape value for broadleaved woodland and some households will have views of conifers. Taking this into account, a summarised economic value of woodland views was estimated to be between £5 million and £2,000 million per year (2007/08 prices). Views of urban fringe broadleaved woodland on journeys were estimated to be valued at around £448 million at 2007/08 prices, or about £15.7 million per year (the figure was predicted to be a conservative estimate). The research reveals that the aesthetic qualities of woodland in the landscape are a key motivational factor in determining recreational uses of an area, making them a highly valuable resource for local business, but that more research is required to refine these estimates.

It is argued (Regeneris, 2009: 29) that 'land and property values' is not a separate economic benefit of green space. It incorporates and depends on such green space benefits as quality of place (including visual amenity), recreation and leisure and biodiversity benefits. This is why it is also important to consider improvements in aesthetic quality (focusing on visual amenity of green space for this review) and its valuation and impact on land and property prices. Visual amenity of green space can enhance the views from people's homes and/or on journeys to and from work, thereby contributing to a higher quality of life (Regeneris, 2009: 18).

The primary study (Garrod, 2002) of public preferences for visual amenity with respect to woodland views forms a basis for two other valuations (Edwards *et al.*, 2008; Regeneris, 2009). It uses a stated preference approach with a GB-wide survey and choice experiment technique to estimate the value of woodland views from properties and on journeys in terms of individuals' willingness-to-pay (WTP). It represents the most recent primary study of its kind available in UK. The study follows best practice but displays some shortcomings which should be noted. Firstly, the sample sizes are quite small for a GB-wide study: 211 and 205 completed questionnaires correspondingly for woodland views from homes and on journeys (Garrod, 2002: 9). Secondly, socio-economic characteristics were not utilised in WTP estimations (Garrod, 2002:13). As a result robust WTP estimates were obtained for only some types of forest type/landscape configurations, i.e. only for urban fringe broadleaves, omitting coniferous woodlands and landscapes other than peri-urban ones (Garrod, 2002: 20). Finally, it does not report the typical distance between a viewer and woodland. This puts another limitation on the estimated WTP usage because the nature of WTP decay with distance was not explored. Nevertheless, the WTP estimates for peri-urban broadleaves are considered sufficiently robust to be used in other studies, especially for views within approximately 300 metres of a viewer. Naturally the above shortcomings of the primary study apply to secondary studies (Edwards *et al.*, 2008; Regeneris, 2009) making use of the estimated WTP.

Glasgow Green Renewal project study (GEN Consulting, 2006) is an impact study of public investments in green space. It does address issues of additionality and net impact (GEN Consulting, 2006: 20, 27, 21), baseline scenario and displacement. However, it is not always possible to collect comparable data and for some important indicators (change in number of businesses and employees) only 2004 and not 2006 data were available (GEN Consulting, 2006: 23-24) leading to comparisons over different time periods for changes in the area and Glasgow[4]. Despite investments in this once run-down area, house prices in Glasgow have increased faster than at the Green; between 1998 and 2005 prices in Glasgow increased by 111%, compared to 50% for the same period at the Green. Nevertheless, the estimates obtained by the study with respect to property market (increases in council tax generated and house prices and additional residential property transactions) and business developments (increases in the total value of rateable properties and number of businesses and total employment) can be used in a value transfer approach, given that the possibility/applicability of value transfer itself is decided upon by following best practice guidelines (Eftec, 2010).

Expert judgement was used to evaluate the impact of community forest development on property prices (Forestry Commission, 2005). Five beacon locations[5] were used as benchmarks against which property price changes were judged. It was established that once the general property price rises have been stripped out as well as any other differing factors the enhancement value of the housing stock is in the region of £15 million for the existing housing stock and as a result of the scheme new development to the value of £75 million has been realised. No additionality issues were assessed.

[4] While discussing business development no numbers are given on the sample size of interviews with businesses and sometimes anecdotal evidence is used (GEN Consulting, 2006: 25, 27).
[5] A beacon location in this report is a road identified as being typical of that particular locality, and thus containing properties that are typical in age, size, type and degree of modernisation and repair to the locality.

A further three studies applied a hedonic pricing approach[6] to estimate the benefits of urban green space as reflected in property prices. All of the papers followed best practices and their findings are judged as being sufficiently robust (Eftec, 2010: Annex 3) and can be used in a value transfer approach.

The London study (GLA Economics, 2003) applied a hedonic pricing approach to value 'greenness' across the City of London's 760 wards. Open space in each ward was modelled as the percentage of green areas[7] (in km^2) in each ward. Socio-economic variables taken into account included housing density, deprivation, education, crime (domestic burglaries), travel and health accessibility and environmental situation with respect to nitrogen dioxide (NO_2) concentration. Estimations showed that higher property values (in terms of the average house price) exist in areas with a higher percentage open space holding all other factors constant, with a 1% increase in the amount of green space in a ward associated with a 0.3% to 0.5% increase in the average house price in that ward.

Another study presented a series of eight case studies focused on parks of high environmental quality throughout the UK using a hedonic pricing method to estimate the benefits of urban green space (CABE, 2005). Property evaluation involved comparisons between the residential properties immediately overlooking the park and residential properties in a wider area around the park, including those bordering on the park, a street/block or two away from the park and several blocks away from the park. The results showed a positive impact on the property price linked to properties overlooking or being close to a high quality park with a wide range of impact values. For properties 'on' the park the average premium was 11.3% (standard deviation of 9.4%) and for properties within close proximity the average premium was 7.3% (standard deviation of 9.4%)[8]. An earlier study (CABE, 2004) reported that in The Netherlands a view of a park was shown to raise house prices by 8%, and having a park nearby by 6%.

A study of the impact of green space in the city of Aberdeen, Scotland was estimated by hedonic pricing method (Dunse *et al.*, 2007) where 'green space' represented city parks (large parks), local parks and amenity green space. Data for 53,674 observed sales was obtained for 1984–2002 property transactions. Each property had associated geo-codes which allowed for precise GIS location and analysis with respect to green space features. The estimations yielded a positive and significant link between the additional percentage increase in net price and a reduction in distance towards the park for all property and

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[6] See Appendix 2 for explanations.

[7] The identifiable green spaces are the Green Belt, Metropolitan Open Land, Sites of Metropolitan Importance, Sites of Borough Importance and Sites of Local Importance. Green spaces such as urban parks, private gardens and common green spaces around flats are excluded from this study, except in the Green Belt, because of data limitations (GLA Economics, 2003: 3).

[8] Author's calculation from the study data.

park types but with significant variations across types. The location on the park edge was either insignificant or significantly negative for detached and non-detached houses which may have been due to the potential negative externalities that can be attributed to parks. For flats the park edge location was significant and positive, probably because the positive externality of a view and accessibility is valued higher than any negative impacts. Combining the effects of location on the park edge and distance to the park the overall premium for a property located next to a park relative to a similar property 450 metres away is positive across all house types. Calculated average premium values were 10.1% for city parks, 9.0% for local parks and 2.6% for amenity green spaces.

Knowledge gaps

The major knowledge gap in this area is a lack of primary stated preference studies on WTP for green space improvements following best practice guidelines (Eftec, 2010) that can be used subsequently within a value transfer approach. The only GB-wide WTP study (Garrod, 2002) may serve as a basis for planning larger and/or more local studies. Hedonic studies only value aesthetics in as much as it is reflected in revealed market prices and will not account for non-use value while a WTP study can yield the total value and in the case of aesthetics the non-use value component may be significant.

Conclusions

To sum up, a large body of evidence exists that supports the view that investment in improving green space and as consequence aesthetic quality of place (visual amenity) positively impacts on land and property prices. The estimated impacts are necessarily case and location specific and have a wide range. Properties with well-managed green space nearby have increased property values of between 2.6% to 11.3%. In terms of a marginal change a 1% increase in the amount of green space in a vicinity is associated with up to 0.5% increase in the average house price (GLA Economics, 2003). Additionally, increasing the stock of housing increases the value of council tax generated in the area (GEN Consulting, 2006:14).

2.2.3 Economic toolkit

GENECON LLP has been developing a toolbox designed to assist the valuation and case making of green infrastructure investments. The toolbox sets out how different benefits of green infrastructure can be valued:

- In monetary terms, applying economic appraisal tools, where possible.
- Quantitatively: for example, with reference to PSA and other public targets, e.g. jobs, hectares of land, visitors.
- Qualitatively: referencing case studies or important research where there appears to be a link between green infrastructure and societal benefit, but where quantification and/or monetisation is not possible and where other approaches are required to evaluate the benefits.

The toolbox cannot cover all eventualities, but it aims to provide a practical set of tools that can be applied to a wide range of interventions (Genecon, 2010).

Appendix 1 Methodology

The critical review focused on the most recent evidence, i.e. the years 2000-2010. In order to help tease out any differences, evidence was classified according to whether it relates to improvements in the quality of green infrastructure or the extent of green infrastructure, or both. The type(s) of green infrastructure affected and size of area within which values are measured were noted, as were other factors that may affect values such as the initial level of green infrastructure (e.g. as a proportion of the total land area), the duration of the greening initiative, and the mean annual cost.

The robustness of the existing evidence was assessed using expert judgement and critical analysis. Factors such as use of sound statistical techniques, an appropriate sample size, goodness of fit, statistical significance of findings, baseline and additionality methodologies applied, suitability for value transfer, and comparability with findings of similar studies were considered. Statistical and econometric estimates were considered robust if robust statistical techniques were used (e.g. where there is a strong suspicion of heteroskedasticity of errors[9]) and various scenarios or sensitivities were assessed (Eftec, 2010: Annex 3).

Economic valuation (welfare) and economic impact studies were distinguished. The latter investigate the effect of changes in demand, including government expenditure, on indicators such as value added and employment. They are concerned with net impacts and utilise concepts of additionality, deadweight, and leakage, displacement, substitution and multiplier effects (see below and Appendix 2). The former quantify the benefits enjoyed by people as a result of the consumption of goods and services (including environmental services which are not traded in markets) and are based on welfare or well-being concepts, where policy will try to maximise the welfare of a society (SEERAD, 2007).

A major conceptual difference between these two types of studies is the treatment of employment. It is treated as a benefit in the economic impact studies and as a cost in the economic valuation (welfare) studies. When measuring welfare, labour appears as a cost because wages are a payment for the use of the labour resource (SEERAD, 2007). Conversely, in an economic impact assessment any employment is treated as a benefit even if it occurs in a loss-making activity that is actually having a negative economic effect on the aggregate value of output. Economic impact studies are not designed to determine whether or not any of the uses of the resources are economically efficient and welfare enhancing. They only compare differences in impact between using resources in

[9] Random variables have different variances.

different ways. Therefore, cost benefit analysis (CBA) is a better tool for resource allocation decisions while economic impact studies can be of most use in informing policy decisions when they compare the impacts from spending similar amounts of money in different ways (SEERAD, 2007).

The net economic value[10] of creating or improving green space is defined as the net effect of the intervention. For current purposes, this is broadly defined to include both economic values and economic impacts[11]. Closely related to the concept of ‘additionality’, it is measured as the difference between the position if the intervention is implemented, and the reference case (also known as the counterfactual or ‘base case’) position expected to occur in the absence of the initiative. The evaluation process takes account of deadweight, and leakage, displacement, substitution and multiplier effects. Methods used to establish these effects and the baseline reference case were assessed drawing upon Scottish Enterprise guidance (Scottish Enterprise, 2008). Definitions and different elements encompassed by these concepts are presented in Appendix 2.

Double counting issues need to be considered in estimating net economic values. Double counting may occur when benefits from green space intersect and are not completely independent. This can be the case for at least two sets of benefits (Regeneris, 2009: 29):

1. Land and property prices are not independent of quality of place, recreation and leisure and biodiversity, with land and property prices incorporating these other effects, rather than being a separate economic benefit of green space.
2. Health and well-being and labour productivity benefits may also overlap as increases in labour productivity can arise from increased health and well-being.

Where existing evidence is judged sufficiently robust, its potential applicability to other areas using benefit transfer has been assessed drawing upon Government guidance (Eftec, 2010). When assessing the quality of evidence the following questions should be considered (Eftec, 2010: 48, 79):

1. Are the data collection procedures sound?
2. For survey-based economic valuation methods is the sample representative?
3. Does the study follow the best practice?
4. Are the results consistent with the expectations based on the economic theory?
5. Was GIS analysis used for spatially distributed goods?

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[10] Widely accepted measures, especially in economic impact studies, include jobs, income, and Gross Value added.

[11] One can often find similarly broad definitions adopted in the literature, for example, 'Total Monetised Benefit' (Regeneris, 2009:33) that includes together with many clearly defined monetary benefits (e.g. money spent by tourists) valuation on non-traded goods for which society is willing to pay (e.g. biodiversity, Quality of Place (landscape/visual amenity) and recreation).

Information on the following factors should also be collected (Eftec, 2010, Annex 2):

1. Availability of substitutes? Generally the more substitutes there are the less the marginal value for a change is likely to be.
2. Size of the good (e.g. green space) and the scale (direction and size) of change.
3. Price of the good: in the case of non-market goods the associated willingness-to-pay (WTP) or willingness-to-accept (WTA).
4. What controls were used for socio-economic factors (age, gender, income levels, employment, education, number of children) that may affect the outcomes, and how should these be accounted for in using benefit transfer if feasible?
5. Is the evidence applicable to urban, peri-urban or rural settings?

The extent to which spatial factors (e.g. distance decay) were taken into account in any aggregation, and whether sensitivity and/or scenario analysis was performed will also be considered.

Note that two basic variants of value transfer exist: unit value transfer and value function transfer, with some variations within these. The approaches are distinguished by their degree of complexity, data requirements and the perceived reliability of the results.

Unit value transfer can be either an *unadjusted unit value transfer* from single or multiple studies, or an *adjusted unit value transfer*, where value is adjusted to account for the differences between the study and policy goods with respect to factors that may influence economic value. The most common adjustment factor is income.

The *value function transfer* provides more control, allowing a set of factors found to explain variation in economic values for the study good (e.g. WTP, socio-economic characteristics of the affected population, characteristics of the good, the change in its provision and the availability of substitutes) to be controlled for (Eftec, 2010: 51).

A sequential approach was taken to geographical focus. For each type of value the review looked initially at evidence identified in UK studies. Where none had been undertaken or evidence was insufficiently robust, studies in other European countries were reviewed. If no European studies were identified or evidence was insufficiently robust, North American studies were reviewed.

Appendix 2 Terminology

In economic valuation (welfare) studies economic value is often measured by the willingness-to-pay (WTP) for environmental goods or willingness-to-accept (WTA). Total economic value (TEV) is the sum of the WTP of all individuals whose well-being is affected by changes in the quantity (or quality) of an environmental good arising from a particular policy or project. These TEVs are used in cost-benefit analysis (CBA) to compare the potential welfare improvement associated with an investment in different types of green space changes in different areas.

The net economic value of creating or improving green space is defined as the net effect of the intervention. It is closely linked to the concept of additionality and takes account of deadweight, and leakage, displacement, substitution and multiplier effects.

Total Net Additional Local Impact (or Benefit) of an Intervention =
Total Net Local Effects (Case with Intervention) – Total Net Local Effects (Reference Case without Intervention)

where:
Total Net Local Effects = Net Local Effects + Multiplier Effects,
Net Local Direct Effects = Gross Local Direct Effects – Displacement & Substitution
Gross Local Direct Effects = Gross Direct Effects – Leakage
Gross Direct Effects = Deadweight.

Additionality may be related to scale (for example, a greater quantity of business turnover or jobs may be delivered in an area), timing (for example, an activity may happen earlier than would otherwise have been the case) and quality. Scale additionality is the most significant type when it comes to assessing overall economic impact in terms of Gross Value Added (GVA) (Scottish Enterprise, 2008: 3). The time period over which additionality is calculated should be long enough to capture all the important costs and benefits of the intervention.

Deadweight is defined as benefits that would have occurred without the intervention. It is the quantification of outputs, outcomes and impact under the reference case. It is based on assumptions on economic, social and environmental trends or events that are likely over the intervention period (Scottish Enterprise, 2008: 6-7).

Displacement is defined as the proportion of project benefits accounted for by reduced benefits elsewhere in the target area. It happens when due to the intervention the project takes market share or labour, land or capital from other existing businesses within the geographical area, thereby reducing existing local activities. Closely related is the effect of substitution that arises where a business substitutes one activity for a similar one (such as recruiting a jobless person while another employee loses a job) to take advantage of public funds within the project.

Leakage is defined as the proportion of benefits that go to those outside of the intervention's target area or group. That is, benefits occur where not intended.

Multiplier effects are wider economic impacts (on jobs, expenditure or income) associated with additional local income, local supplier purchases or longer-term effects. Two types of multiplier can be identified (Scottish Enterprise, 2008: 12):

- a supply linkage multiplier (sometimes referred to as an indirect multiplier or Type I multiplier) due to purchases made as a result of the intervention and further purchases associated with linked firms along the supply chain;
- an income multiplier (also referred to as a consumption or induced multiplier or Type II multiplier) associated with local expenditure as a result of those who derive incomes from the direct and supply linkage impacts of the intervention.

Methods to value non-market goods associated with visual amenity and green space fall into two categories: revealed preference methods and stated preference methods. In the first category are travel costs and hedonic models that measure only use values, with the value of open space being deduced from the estimated relationship between the value of a property and measures of proximity to open space and other property and neighbourhood characteristics. As they are based upon analysis of actual market data, revealed preference methods are often preferred by economists. In the second category are contingent valuation (CV) and choice experiment (CE) methods that use surveys and direct work with people to elicit their preferences with respect to open space. In principle the latter have the advantage that they can be used to estimate the total value, i.e. both use and non-use values.

Hedonic price models (HPM): the value of the view is separated from the total value of the landscape by the use of control variables to account for other landscape characteristics (for example, woodland's size, shape and species composition), property features and the individual's socio-economic background. In the stated preference approach this separation is achieved by questionnaire design including necessary background and context information.

The majority of studies find a positive impact of nearby green space. In the case of the hedonic approach it is reflected in the higher house prices, while in the case of the stated preference approach it is reflected in a positive WTP.

Hedonic studies usually evaluate open space close to home primarily related to scenic views and other characteristics, while stated preference studies can capture broader, more general perceived benefits from open land preservation, including non-use values not measured in hedonic studies. Stated preference studies can also reveal the particular attributes of open space valued by respondents. Hedonic studies only measure the value of marginal changes in the open space amenity, while the stated preference studies tend to estimate the value of large changes in the amount or provision of the amenity.

In case studies, where small changes and use value linked to property market and recreation are investigated, the hedonic pricing method is most appropriate (conditional on data availability). A good example is valuation of amenity woodland views as seen from property and small changes of woodland cover in the cities and near urban fringes. However, for large-scale changes and/or where non-use or total value is sought the stated preferences methods are most appropriate.

There is no clear link between valuation studies which use revealed preference and stated preference methods and additionality issues of impact assessment studies. First, while impact assessment studies use at least two snap shots of the development, before and after an intervention, revealed and stated preference models are usually cross-sectional studies with a single snapshot. Second, unlike impact assessment studies revealed and stated preference models are concerned with individuals' preferences rather than resource allocations. That is the finding that some individuals are prepared to pay more for living nearer green space has no relation to additionality issues (including deadweight, leakage, displacement, substitution and multiplier effects).

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3 Social benefits

3.1 Introduction

There are many potential social benefits that green space can provide, and the most significant of these can be grouped into three broad categories:

1. Improvements in levels of physical activity and health.
2. Promotion of psychological health and mental well-being.
3. Facilitation of social interaction, inclusion and community cohesion.

Access to safe, local, good quality green space has been shown to encourage higher levels of physical activity, which is beneficial to population health in many respects, and most especially in terms of tackling rising levels of obesity. Increasing levels of physical activity among the population also has mental health benefits but, in addition, evidence suggests that these benefits are actually greater in green spaces as opposed to those proffered by other, less natural settings. The potential of green space for mental health benefits is not just to be found through physical activity however. There is a strong body of evidence which demonstrates the restorative value of green space showing that more passive forms of usage, or even just access to views of green space, can have a beneficial impact on mental well-being and cognitive function. Restorative value can be defined as the potential for green spaces to reduce stress and restore cognitive function and capacity to function with the demands of life (O'Brien *et al*., 2010). Cognitive function is our thinking and thought processes; including our perception, reasoning and remembering (The American Heritage Dictionaries, 2007). Green spaces can also play a role in enhancing mental well-being if they help individuals to experience increased levels of social interaction and integration, which, at their best, they can.

Evidence also suggests that green spaces can offer opportunities for people who may not normally interact to come together, and help develop social ties and community cohesion. This is particularly useful in areas of high deprivation and for groups in society who are more vulnerable to social exclusion, such as older and younger people, ethnic minorities and people with disabilities.

The literature demonstrating the social benefits of green spaces is fast developing as shown by the rising numbers of studies and reviews that have been commissioned in the past five years. Most of the available literature focuses on green space as opposed to green infrastructure. However, many of the insights provided are relevant to planning and developing multifunctional green infrastructure and the social benefits it can provide.

3.2 Critical review

3.2.1 Improving levels of physical activity and health

Introduction

Health is a fundamentally important government concern, especially considering the cost of running the National Health Service (NHS), which in 2008/9 was £96 billion in England and Wales, and is expected to rise to around £110 billion in 2010/11 (NHS Counter Fraud, 2009). Urban areas in particular have various stresses which exacerbate the physical health issues already present in the general population. For example, respiratory disorders and obesity are both negatively affected by aspects of urban and peri-urban life. These include high levels of vehicle emissions, high population densities, poor housing and a lack of good quality green spaces. It is well established that regular exercise, for example walking, can reduce the negative effects of many major health threats such as obesity, type 2 diabetes, coronary heart disease and respiratory disorders.

On the whole, evidence suggests that there is a positive relationship between green space and the general health of the population and studies indicate that better health is linked to green space provision, regardless of the socio-economic status of the people who use it. Evidence also exists that suggests that people who use green spaces on a regular basis are likely to take exercise in them and there is an increasing number of initiatives focused on using green spaces for formal and informal exercise programmes. Green infrastructure can also be used to encourage active travel, with integrated walking and cycling networks which promote cardiovascular health. However, there is also evidence to suggest that the benefits of green space are unevenly distributed throughout society, and certain groups, such as those living in deprived areas, ethnic minorities, the elderly, women and people with disabilities do not experience the same levels of benefits as others, either because they have less access to green space or because they use it less (Weldon *et al*., 2007; Fairburn *et al*., 2005).

General population health and green space

Various epidemiological studies have demonstrated a positive relationship between green space and population health. For example, a study in the UK by Mitchell and Popham (2007) used responses from the 2001 UK census on health, and data from the Generalised Land Use Database, at the lower level super output areas, to calculate a standardized morbidity rate for those areas. The index of multiple deprivation was also utilised to examine differences in area population characteristics that could affect health. The authors concluded that ‘A higher proportion of green space in an area was generally associated with better population health’, although this association varied in relation to the combination of income deprivation and urbanity (Mitchell and Popham, 2007).

This work supports the findings of other recent large-scale studies investigating the strength of the relationship between the amount of green space in an urban area and the general health of the population in Holland (de Vries *et al*., 2003; Maas *et al*., 2006). de Vries *et al*. (2003) studied the relationship between population health and green space through self-reported health data from 17 000 inhabitants, and land-use data. Like Mitchell and Popham (2007), they found that living in a greener area was positively related to self-reported health. Similarly, Maas *et al*. (2006) looked at the relationship between the amount of green space in residents' neighbourhoods and their perceptions of general health. They collected over 250 000 questionnaire responses and calculated the percentage of green space within a 1 km and 3 km radius of people's homes. Their findings showed that general health was perceived to be better in people living in greener areas: 10.2% of residents stated that they felt unhealthy in areas where 90% of the environment surrounding the home was green, whereas 15.5% of residents reported feeling unhealthy in areas where 10% of the nearby environment was green.

However, it should be noted that these three studies relied on self-reported data to evaluate health, perhaps limiting their reliability. Furthermore, in some cases selection bias could have been a problem. For example, while the de Vries *et al*. (2003) study used a large sample (*n*= 10 197), this sample was drawn only from people visiting primary care facilities (Tzoulas *et al*., 2007).

However, the findings of the above studies are corroborated by recent work by Mitchell and Popham (2008) which tested the hypotheses that income-related health inequalities would be lower in populations living in greener areas. In this study, the authors classified the population into groups based on income deprivation and exposure to green space. They also obtained individual mortality records for over 366 000 people to investigate whether the relationship between income deprivation, all-cause mortality, and cause-specific mortality varied depending on exposure to green space. The key finding of this study was that 'the inequality in all-cause and circulatory disease mortality related to income deprivation is lower in populations who live in the greenest areas than in those who have less exposure to green space' (Mitchell and Popham, 2008). However, as in their previous study, this association varied according to the combination of income deprivation and urbanity.

Physical activity and green space

These large-scale population studies are useful in that they show a general positive relationship between green space and population health. However, they fail to explain the means by which green spaces act positively on an individual's health. Other studies investigating this relationship on a smaller scale have highlighted four main mechanisms:

1. Inducing physical activity.

2. Making physical activity particularly beneficial because it has a greater psychological benefit than physical activity in other settings.
3. Ameliorating the stress response – helping people to relax.
4. Encouraging social interaction and inclusion – an important element of well-being.

The first of these mechanisms is discussed below while the psychological, stress relieving and restorative potential of green space is discussed in Section 3.2.2 and the social inclusion potential in Section 3.3.3

As noted in the introduction, it is widely held that regular exercise can reduce the negative effects of many major health threats. A longitudinal study undertaken in Tokyo found a positive relationship between walkable green space availability and the longevity of senior citizens (Takano *et al*., 2002). Green spaces have been shown to independently promote physical activity, thereby enhancing the health profile of users. In a comprehensive review of studies linking parks and recreation and physical activity, Kaczynski and Henderson (2007: 315) found that living closer to parks or recreation/leisure facilities was generally associated with increased physical activity. A Danish study by Nielson and Hansen (2007) examined the relationship between access and use of green space and body mass index (BMI), as well as stress. They found that the further away residents lived from green space the less likely they were to visit it: 'The distance decay is in all cases characterised by a steep decline in use frequency with increasing distance, especially over the first 100-300 m. The effect of distance gradually levels off as distance to green areas increases' (Nielsen and Hanson, 2007: 843). Furthermore, for those individuals under 25 years of age, the further they lived from green space, the more likely they were to be obese.

Cohen *et al*. (2007) studied how parks contribute to physical activity in minority communities. They looked at eight parks in Los Angeles, using direct observation and interviews with park users and residents living in the area. From the interviews, they found that the park was reported to be the most common place interviewees exercised. Significantly, 'Both park use and exercise levels of individuals were predicted by proximity of their residence to the park', suggesting that 'Parks play a critical role in facilitating physical activity in minority communities' (Cohen *et al*., 2007: 509; 513), although it would be useful to know if any other alternative recreation facilities were available in the area. Similarly, a review of literature linking health and green infrastructure, observed that there were a number of epidemiological studies linking proximity of green space and levels of physical activity (Booth *et al*., 2000; Humpel *et al*., 2004; Pikora *et al*., 2003 cited in Tzoulas *et al*., 2007: 170). Furthermore, Brown and Grant (2005: 334) note that evaluations of green gym schemes (a programme run by British Conservation Trust (BTCV) which gives people the opportunity to undertake physical exercise through practical jobs in local green spaces) 'have shown that participants in the initiatives were more likely to continue with exercise than those on more traditional gym-based regimes'.

An American study by Zlot and Schmid (2005) found that communities with more parks showed significantly higher levels of walking and cycling for transportation. This points to the significant role green infrastructure can play in promoting and facilitating active travel. Indeed, the green infrastructure approach is an important element of improving accessibility to green space and encouraging active travel: with its focus on networking and the connectivity of green spaces it can aid movement through landscape.
These positive results are not universal however. Using GIS to measure access to green space, a study in Bristol concluded that 'There was no evidence of clear relationships between recreational activity and access to green spaces' (Hillsdon *et al*., 2006: 1127).

Also worth noting, although green spaces can be conducive to stimulating more regular exercise amongst the population, it must be recognised that many people use them for other activities. For example, in 2006, The Royal Parks Survey in the UK reported a figure of only 11% for park users participating in exercise and informal games, although 11% also reported one of their main reasons for visiting the park was to walk the dog, and 45% reported that one of their reasons was to go for a walk or stroll, both of which can also be considered physical exercise (Synovate, 2007: 29). The reason for visiting the park that gained the highest positive response rate (49%) was to get some peace and quiet. However, even though green spaces are not always used for physical activity, significant social benefits can be born through other uses, which are covered in Sections 3.2.2 and 3.2.3.

Valuation: toolkits and unit cost of benefits/economic valuation data
Valuation toolkits are covered collectively for all social benefits in Section 3.2.4. This section focuses on the economic evidence relating to the physical health benefits of green space.

Lack of physical exercise is estimated to cost the NHS 2–3% of its total budget (Nicholson-Lord, 2003, cited in Brown and Grant, 2005: 334), so around £2-3 billion per annum. Various estimates exist of the costs of obesity and related diseases in England. For example, the Department of Health (cited in CABE, 2009) estimates the cost to the NHS to be £4.2 billion per year, with this figure forecast to more than double by 2050. Another estimate of the cost of obesity and diabetes in England and Wales is shown in Table 3.1.

Table 3.1 Estimated cost of obesity and diabetes in England and Wales (Sustainable Development Commission, 2008).

Health problem	Health and social care	Wider economy	Total
Obesity	£1 billion per annum	£2.3 billion per annum	£3.7 billion
Diabetes	£1.3 billion per annum	Unknown	£1.3 billion

The Department for Culture, Media and Sport has suggested that a 10% increase in adult physical activity would benefit England by £500 million per annum (Natural Economy Northwest, 2008: 20). A report for the Forestry Commission (CJC Consulting *et al*., 2005) entitled *Economic benefits of accessible green space for physical and mental health: scoping study*, estimated that a reduction of 1% in the level of sedentary behaviour in the UK would prevent 1063 deaths per year, although if people over 75 are excluded because they are less likely or able to undertake physical activity then the figure falls to 343 deaths per year. They also estimated that a 1% reduction in sedentary behaviour would reduce morbidity cases by 15 000 per year in the UK (9200, if people over 75 are excluded). The annual value of decreased morbidity and mortality from a 1% reduction in sedentary behaviour in the UK was estimated at £1.44 billion (a mean average of £2,423 per additional active person per year). This figure reduced to £479 million if people over 75 were excluded; 70% of the benefit was related to a reduction in mortality from coronary heart disease.

Furthermore, evidence from evaluations of current green space initiatives linked to health demonstrate that green space initiatives can be a cost effective tool for addressing improvement in the population's physical health. For example, the Mersey Forest is the largest of England's 12 Community Forests and, since its inception in 1994, has been delivering various interventions including land reclamation, creating access to green space, tree planting, engaging local communities and bringing woodland into active management. The Mersey Forest is part-funded through the EU's Merseyside Objective One Programme, with a total Objective One spend of more than £7 million spread over 100 projects. It is estimated that this Objective One funding will generate a gross monetised benefit of £5.5 million annually (in 2009/10 prices) and a net present value of £71 million. As one element of this, the physical exercise benefits provided are estimated to be £122,000 in total (gross), made up of GVA benefits from reduced absenteeism and premature death, and the cost savings to the NHS. Table 3.2 shows the total net additional monetised benefit of the Mersey Forest's Objective One funded investments in terms of health and well-being (Regeneris Consulting, 2009).

Table 3.2 Total net additional monetised benefit of the Mersey Forest's Objective One Programme (Regeneris Consulting, 2009).

Source of benefit	Annual	Net present value
Health and well-being: exercise (GVA)	£20,000	£722,000
Health and well-being: exercise (cost saving)	£13,000	£474,000

Another, perhaps more illuminating example of the specific cost benefits in terms of health in relation to a green space initiative can be seen in the Walking the Way to Health Initiative (WHI) (see case study 'Walking the way to health initiative', physical activity and health). This initiative has helped to create over 500 local health walk schemes in England utilising natural spaces. Its aim is to get more people walking, locally, especially in areas of poor health. Natural England and the Department of Health have joined in partnership to expand the scheme, aiming to increase the number of regular walkers four-fold, with an investment of £11.3 million over three years, beginning in 2009. An estimate of the economic health value and cost effectiveness of the expanded WHI scheme was undertaken (Natural England, 2009) and this suggested that the value over the three-year period would be:

- 2817 Quality Adjusted Life Years (QALY) delivered at a cost of £4008 per QALY.
- Savings to the health service of £81,167,864 (based on life-cost averted).
- A cost benefit-ratio of 1:7.18.

The estimated value of the life-costs averted by establishing universal and equitable access to green space was calculated at a saving of £2.1 billion per annum.

A Social Return on Investment (SROI) study by Greenspace Scotland (O'Neil, 2009) (discussed in further detail in Section 3.2.4) found that for every £1 invested in the Greenlink project in Scotland, there was a social return of £7.63 , which included physical and mental health benefits as well as social interaction, inclusion and community cohesion benefits.

The Forestry Commission economic benefits report mentioned above (CJC Consulting *et al.*, 2005), however, concluded that the net benefit from additional green space provision or programmes to increase physical activity on existing green space would depend on the cost of providing these and the success in changing sedentary behaviour in the long-term. However, considering the cost to the NHS of sedentary lifestyles, and the potential benefits green space and green infrastructure can offer in this respect, it seems justified that more effort is given to providing good quality, easily accessible, well-managed and safe green spaces for communities to use and enjoy, as well as increasing interventions to encourage the active use of green spaces. As Nielson and Hanson (2007: 849) argue, 'a green health perspective in urban planning and park management could have a *strategic* role in future "welfare disease" prevention and health promotion activities'.

Relationships between increased levels of physical activity and health and other benefits of GI

Table 3.3 outlines these relationships.

Table 3.3 GI benefits of: improved levels of physical activity and health.

Benefit	Primary relationship	Secondary relationship
Improved levels of physical activity and health [helps deliver: *Choosing Health: Making healthy choices easier* (Department of Health, 2004); *Health Challenge England – next steps for Choosing Health* (Department of Health, 2006); and *Be Active, Be Healthy: A plan for getting the nation moving* (HM Government, 2009)]	Enhanced mood, stress reduction, more positive self-concept Increased social interaction (especially if physical activity done in groups) Increased levels of active travel Reduced absenteeism in the workplace Increased tourism	Improved mental health and well-being Increased social inclusion and community cohesion Reduced $C0_2$ emissions Higher levels of productivity Stronger local economy with increased employment opportunities

Physical activity in green space is closely linked to mental well-being benefits, as shown in section 3.2. When physical activity in green spaces is undertaken within a group, there is also the potential for social interaction and community cohesion benefits to be achieved. There is also a link between green space/green infrastructure, health, physical activity and climate change mitigation through the potential reduction in CO_2 emissions which could be gained through active travel and the utilisation of green infrastructure as a walking and cycling network. Clearly too, a healthy population is a more productive one since there will be reduced absenteeism in the workplace. Thus, improving individuals' health has important economic benefits. Providing green spaces which facilitate physical exercise can also provide economic benefits in terms of helping to increase tourism.

Identified knowledge gaps

- There is little evidence to show whether the impacts of green space on health vary depending on the type of green space involved.
- No tangible explanation exists of the mechanisms or means through which green space impacts positively on individual's health.
- The particular or unique role or benefit of green space in terms of exercise promotion programmes has not been fully demonstrated, although there are indications that the

attractiveness of green spaces does present increased incentive to continue exercising (Ashley and Bartlett, 2001).

- More multidisciplinary studies which integrate qualitative and quantitative indicators and more longitudinal studies could provide a better understanding of the role of green spaces in the health of urban communities (O'Brien *et al*., 2010).
- In relation to economic evidence, more is needed in terms of evaluation of activity programmes, including costs of the programmes, measures of drop out rates and health outcomes (CJC Consulting *et al*., 2005).
- There is a lack of evidence on the time profile of risks when exercise is continued or discontinued and the relative risks to different age groups (CJC Consulting *et al*., 2005).

3.2.2 Promoting psychological health and mental well-being

Introduction

Although there is no universally agreed definition of mental health, the Department of Health (Department of Health, 2009: 10) assert that 'it is more than the absence or management of mental health problems; it is the foundation for well-being and effective functioning for individuals and their communities'. Mental health problems are increasing: one in six adults have mental health problems at any one time. For half of these people the problem will last for more than a year, and it is estimated that around one in four people will suffer some form of mental illness at some point in their lives (Department of Health, 2009: 8; The Future Vision Coalition, 2009).

Stress can have a substantial impact on physical health but it can also play a significant part in mental well-being and can be a contributing factor in disorders such as anxiety and depression. The World Health Organization predicts that by 2020, depression will be the second largest single cause of ill health (Mind, 2007: 3). A number of studies have found that in urban areas incidences of depression, psychiatric morbidity, alcohol and drug dependence are higher (cited in Cooper *at al*., 2008: 13).

The Department of Health's 2009 *New horizons* consultation document attempted to move towards creating a shared vision on mental health, recognising that it is linked to physical health, higher educational achievement, better employment opportunities, increased social inclusion, reduced criminality and reduced health inequalities (Department of Health, 2009: 9). Furthermore, the economic costs of mental health problems are considerable. According to the Sustainable Development Commission (2008), mental ill health in England costs the country £12 billion per year in terms of health and social care, and £64 billion per year in terms of the wider economy, giving a total cost of £76 billion a year. Improving mental health therefore has major benefits for individuals and for society as a whole.

There is strong evidence to suggest that green spaces have a beneficial impact on mental well-being and cognitive function through both physical access and usage (Whitelaw *et al*., 2008), as well as through access to views (Ulrich, 1984). In particular, green spaces have been shown to provide a restorative environment which helps alleviate stress and mental fatigue. As Croucher *et al*. (2007: 27) assert, while the potential benefits of green space for physical health may be significant, 'it is the restorative effects of green space and contacts with nature where evidence is most compelling'. Similarly, in an extensive review on *Urban health and health inequalities and the role of trees, woods and forests in Britain*, O'Brien *et al.* (2010) found that when attempting to explain the relationship between health and green space, 'there is greater evidence for restorative and social support mechanisms' and 'less consistent evidence for physical activity'. As this implies, green spaces can also have a multifunctional role and help to improve mental well-being by encouraging social activity and interaction; this is covered in Section 3.2.3.

The restorative and stress reducing potential of green space
Section 3.2.1 discussed the evidence that establishes links between physical activity, population health and green space. Morris (2003: 12) cites van den Berg's work which found that physical activity is associated with improvements in four broad areas: enhanced mood, stress reduction, a more positive self-concept, and a higher quality of life. Importantly, however, physical activity in green environments may have greater psychological and physiological benefits than physical activity in other settings (van den Berg *et al*., 2007).

The positive influence of green space is not solely based on promotion or enhancement of physical activity however; passive or less strenuously active contact with green spaces can also be psychologically and physiologically restorative, reducing blood pressure and stress levels (van den Berg *et al*., 2007). A study conducted by Hartig *et al*. (2003) included various controlled field experiments, one of which involved 112 participants who were randomly assigned to a gentle walk in either an urban or a natural setting. This study provided evidence of the positive impact of natural settings on improved attention functioning, emotional gains and lowered blood pressure.

There is also evidence that even the visual presence of green spaces and natural views of elements such as trees and lakes is enough to have a positive effect on stress levels, can promote a reduction in blood pressure and may encourage faster healing in patients following post-surgical intervention. For example, in an American study Kuo (2001) tested the hypothesis that green space improves the capacity of residents in urban public housing to cope with the effects of poverty. The study looked at residents who lived in homes both with and without green spaces nearby. Findings suggested that people living in urban public housing close to vegetation, for example with views of trees, were significantly more effective in managing major life issues and better equipped to cope with stress.

Similarly, Kaplan and Kaplan (1989) found that after attention fatigue, even passive viewing of natural settings could alleviate stress which, in turn, could ultimately present health benefits. In 1984, Ulrich published a study, which has since been much debated, and found that healing occurred faster in patients recovering from gall bladder surgery who had a view of nature as opposed to those without such a view. They also required fewer strong painkilling drugs. In a later experimental study by Ulrich *et al*. (1991), a video of either natural settings or urban settings was shown to participants after they had viewed a stress inducing video. They found that those who viewed the natural settings had a significantly better recovery from stress, indicated by lower blood pressure, skin conductance and muscle tension.

People have a well-developed awareness of the stress reducing benefits of nature. In a large postal survey of residents in nine Swedish towns and cities, Grahn and Stigsdotter (2003) found that, when asked what they would recommend to a friend who was feeling stressed and worried, taking a walk in the forest was ranked highest by most respondents. Statistically significant relationships were found between the use of urban open green spaces and self-reported experiences of stress – regardless of the informant’s age, sex and socio-economic status. The results suggest that the more often a person visits urban open green spaces, the less often he or she will experience stress-related illnesses (Grahn and Stigsdotter, 2003). Similarly, other self-report studies have indicated that people visit certain places to regulate their feelings, especially green spaces which afford them emotional release and restorative experiences (Korpela, 1989; Korpela, 1992; Korpela and Hartig, 1996; Korpela *et al*., 2001). For example, Korpela *et al*. (2001) asked 101 students to name their favourite places; a significant proportion named natural places and reported that they made them forget their worries, aided contemplation and helped make them feel relaxed.

Wilson's ‘biophilia hypothesis’ seeks to explain the calming and mood enhancing effect of certain green spaces in terms of our evolutionary history. The hypothesis includes the claim that, as a consequence of evolution, humans have an innate tendency to focus on life and lifelike processes (Gullone, 2004). The attraction of open green spaces with scattered clumps of trees and areas of open water, which are features of many of our parks and designed parklands, may unconsciously impact the human mind and reduce stress. This is due to the idea that the presence of trees and water provide resources and shelter, and therefore the absence of greenery may have a negative effect and increase stress levels (Grinde and Patel, 2009).

Mental health

The stress reducing effects of green spaces play a prominent role in the management of mental health issues, which are particularly prevalent in urban populations. The work of

Rachel Kaplan and Stephen Kaplan (Kaplan, 1985; Kaplan, 1995; Kaplan and Kaplan, 1989) has been influential in constructing a theory of how natural environments have a restorative effect. Attention Restoration Theory proposes that natural environments provide good opportunities for psychological restoration because of a rare combination of attributes:

1. Being away from daily routines.
2. Aesthetically pleasing stimuli, which promote ‘soft fascination’.
3. A sense of extent – ‘rich enough and coherent enough so that it constitutes a whole other world’.
4. A high degree of compatibility between the environment and the purposes of the person. (Kaplan, 1995: 5).

Direct evidence of the restorative effects of green space and mental health has been found in several studies. Two studies looking at children aged 7-12 found that green space can have a beneficial impact on concentration and on the ability to focus attention. In an American study, Wells (2000) looked at children in urban, low-income households before and after relocation. His findings suggested that children who had the most exposure to green space and nature in their new homes tended to have a greater propensity to direct their attention several months after moving. Similarly, Taylor *et al*. (2001) studied 96 children suffering from attention deficit disorder (ADD) and found that, according to parents’ assessments, they experienced fewer problems if the children had access to green space for play and the ‘greener’ the setting, the less severe were the ADD symptoms.

In the previously cited study by de Vries *et al*. (2003), which used self-reported health data from around 17 000 inhabitants and land use date, it was found that living in a greener area was positively related to self-reported mental health. Looking at mental health and vitality using a postal survey and tested scales for analysis, Guite *et al*.’s (2006) study in Greenwich confirmed an association between the physical environment and mental well-being across a range of areas. ‘Escape facilities’, such as green spaces and community facilities, were highlighted as being amongst the most important independent factors.

Such findings have motivated organisations involved with mental health issues to promote new approaches to treating sufferers. ‘Ecotherapy’ is the name given to the green agenda for mental health whereby people are engaged in green exercise activities as part of their treatment programme. Mind is the leading mental health charity in England and Wales and they have conducted some evaluations of green exercise activities (Mind, 2007). Of particular relevance is a small-scale study evaluating the effects of walking in a group in a country park as opposed to walking in a group in an indoor shopping centre. They found that walking in the different settings provoked different responses in terms of self-esteem and mood, and that walking in nature had a more positive effect. In fact, overall, '90 per cent of people who took part in Mind green exercise activities said that the combination of nature and exercise is most important in determining how they feel' (Mind, 2007: 2). Similarly, a study looking at the effects of horticulture projects on 137 people with severe mental health problems (Sempik *et al*., 2005) found that, through the projects, their mood was enhanced, they were more in touch with their surroundings, appreciating the peaceful setting, and they were able to think more clearly. Furthermore, they found that it gave participants something positive to focus on and encouraged relaxation at the end of the day.

Nearby trees and grass visible from apartment buildings have also been shown to enhance residents' effectiveness in facing their major life issues and to lessen intra-family aggression by reducing mental fatigue. Douglas (2005: 10) asserts that 'Trees play an important social role in easing tensions and improving psychological health. People feel better living around trees' and 'thus living in areas with trees helps to reduce anger and violence and improve the ability to concentrate and work effectively'. Looking at 98 apartment buildings in an inner-city neighbourhood in Chicago and using data from crime reports, Kuo and Sullivan (2001) found that the greener the surroundings of a building, the lower the levels of both property and violent crime reported. The relationship of vegetation to lowered crime levels held after the number of apartments per building, building height, vacancy rate, and number of occupied units per building were accounted for. However, this evidence is tempered by some epidemiological studies which have shown that badly or unmanaged green space can cause fears around personal safety and crime (Tzoulas, 2007: 171).

As was the case in Section 3.2.1 (on population health, physical activity and green space), the majority of studies on restorative value and mental health that promote the potential of green space are based on self-reported data using questionnaires, which could be seen to limit their value. Their reliability can be questioned and a possibility of selection bias remains. However, while in the minority, other studies that use objective measurements (such as blood pressure monitoring to assess stress reduction) do exist and it is clear that the findings of these studies confirm the self-reported data. Tzoulas *et al*., 2007) also point out that causal relationships between the components of urban green spaces and health are not easy to establish. Even those studies with the best controls for socio-economic factors cannot compensate for the array of personal, temporal and cultural factors that also affect human health.

Valuation: toolkits and unit cost of benefits/economic valuation data

As previously stated, valuation toolkits is covered collectively for all social benefits in Section 3.2.4. In terms of economic evidence regarding the mental and psychological health and well-being benefits of green space, there is a distinct short-fall. Other than the previously mentioned figures (Section 3.2.1) on the cost of mental health problems to the NHS and from the Greenlink SROI study, there is little accessible, existent or concrete economic valuation data on green space and mental health and well-being.

Relationships between the promotion of psychological health and mental well-being

These relationships are outlined in Table 3.4.

Table 3.4 GI benefits of: promotion of psychological health and mental well-being.

Benefit	Primary relationship	Secondary relationship
Promotion of psychological health and mental well-being [helps deliver: *Choosing Health: Making healthy choices easier* (Department of Health, 2004); *Health Challenge England – next steps for Choosing Health* (Department of Health, 2006); *Be Active, Be Healthy: A plan for getting the nation moving* (HM Government, 2009a)]; and *New Horizons: towards a shared vision for mental health – consultation* (HM Government, 2009b)	Increased social interaction (especially if physical activity done in groups) Reduced absenteeism in the workplace	Increased social inclusion Higher levels of productivity

When initiatives utilising green space for mental health benefits are undertaken in groups, often there are also benefits in terms of social interaction between participants which can further enhance mental well-being and help reduce feelings of social exclusion. Clearly too, as mentioned previously, a healthy population is a more productive one since there will be reduced absenteeism in the workplace. Thus, improving individuals' health has important economic benefits.

Identified knowledge gaps

- There is a gap in evidence in terms of the economic value of green space for psychological benefits resulting from both physical activity and passive or less-active use (CJC Consulting *et al*., 2005).

- To aid our understanding of the value of green space in relation to mental health, large-scale surveys are needed which look at green space accessibility and use in relation to health outcome measures such as Health Related Quality of Life (HRQOL) (CJC Consulting *et al*., 2005).
- There is little evidence to show whether different types of green space have different impacts on mental health and on different kinds of people (Croucher *et al*., 2007).
- While there is strong evidence that green spaces have a positive effect on recovery from stress and attention fatigue, little is known about the impact of exposure to green spaces over the long-term (Croucher *et al*., 2007).

3.2.3 Facilitation of social interaction, inclusion and community cohesion

Introduction

The potential social and community benefits of green space are substantial and are closely linked to the health and well-being benefits of green space and quality of life. Access to, exposure to, and engagement with green space can play a significant role in community well-being. It can help bring people together, engaging individuals from different social groupings who may not normally interact and it can provide a venue for community events. Well-managed festivals and other events can have a very positive effect on the urban environment, drawing the community together and bringing financial, social and environmental benefits (Wooley *et al*., 2004). Green space offers possibilities in terms of increasing social activity, fostering social capital, improving community cohesion, developing local attachment and lowering crime levels, particularly in deprived communities (Bell *et al*., 2008; Weldon *et al*., 2007). Certain groups in society are particularly vulnerable to social exclusion, including people with disabilities, ethnic minorities, young people, older people, and those at an economic disadvantage, and for these groups, the potential that green space has for enhancing social cohesion is especially pertinent.

Green space and social interaction

Physical and mental health initiatives utilising green space have been shown to have additional social well-being benefits. A study by Surridge *et al*. (2004, cited in Davies and Deaville, 2008: 9-10) used 'adventure therapy' with a group of nine people with severe mental health problems. They found that participants changed dramatically when introduced to nature: 'instead of having poor motivation, lacking interest in their surroundings and being generally non-communicative, they began to care for each other, [and] asked after each other's welfare, which created a "tremendous camaraderie"…nature had not only benefited mood but acted as a catalyst for improved interaction with people, therefore increasing social wellbeing'. This study may have only focused on a very small number of individuals but its findings are collaborated elsewhere. For example, Sempik *et al*.'s (2005) study, examining the effects of horticulture projects on 137 people with severe mental health problems, found that alongside other mental and physical benefits, participants' social inclusion was improved and their social well-being enhanced through increased social interaction and through working in teams with others. In addition, Dawson *et al*. (2006) undertook a national evaluation of the Walking the Way to Health Initiative (WHI) which involved surveying 750 people. They found that for many participants the walks were not just about providing physical activity; equally important was the increased opportunity for social interaction and contact.

A study by Carter and Pycroft (2010) looked at Offenders and Nature schemes run by the Forestry Commission in partnership with prison and probation services across England. These schemes allow individuals who have been sentenced via the criminal courts to undertake work in green spaces to gain experience and skills in forest and conservation management. However, this study also illuminates the fact that beyond experience, skills and in some cases formal qualifications, participants have also benefited in terms of their confidence, and outlook on life, with work in green spaces acting as 'a catalyst of personal change, motivation and strength':

> Participants often observe that they…begin to feel more positive about themselves, about their abilities and contribution and more confident about work; this affects their morale, general work ethic and views for their future. The positive change about how participants feel about themselves, work and people/society around them can be highly significant in triggering or persevering with other changes.

However, the specific linkages between green spaces and these social benefits remain unclear.

Thus formal interventions using green space can enhance social well-being, whether or not this is their specific focus. However, the mere presence and local availability of green spaces and natural features has been demonstrated to encourage people to use outside spaces more, and once outside, green spaces have been shown to promote positive social interactions. Coley *et al*. (1997) investigated the availability of nature and how this influences the use of outdoor public space in two public housing developments in Chicago. They found that the presence of trees plays a strong role in attracting people to use outdoor open space. These spaces then offer opportunities for social interaction. In a different study, members of the same research team (Sullivan *et al*., 2004) found that 83% more individuals engaged in social activity in green spaces as opposed to those with low levels of vegetation. A study by Cohen *et al*. (2008) found there was a positive association between neighbourhood features such as parks and 'collective efficacy' or the ability of residents to interact positively.

Social inclusion and community cohesion

The opportunities for social interaction which green spaces offer have wider ramifications beyond individual social well-being through social contact; social interaction also helps to build social ties and community cohesion. For example, an epidemiological study by Kim and Kaplan (2004, cited in Tzoulas *et al*. 2007: 170-1) suggested that open spaces and natural features play an important role in the attachment of people to the area they live in and the local community, and have an effect on their interactions with other residents. Sullivan (2005, cited in Davies and Deaville, 2008: 12) undertook a study looking at strength of community, domestic violence and crime on a housing estate. Social ties were found to be stronger the greener the neighbourhood, overall reported domestic violence levels were lower in greener areas, and crime levels were significantly lower in residencies near natural spaces. The author suggested that green space may encourage social interaction which in turn increases social ties and decreases aggression. Such impacts are more likely to be the case if the quality of the green space is high and carefully designed projects are initiated.

Some societal groups suffer from social exclusion more than others. Of particular concern are groups such as the elderly, young people, ethnic minorities, people with disabilities and those of a lower socio-economic standing. Good quality green spaces can bring people together, creating community cohesion as people from different social groupings engage with each other. A Chicago-based study (Kweon *et al*., 1998) looked at older adults in deprived areas, living in public housing, and found that access and exposure to green space is related to social integration, which is an important factor in well-being. At the other end of the age spectrum, in a Swiss study, Seeland *et al*. (2009) examined the role of green space in social inclusion of youths from different cultures. They concluded that public urban green spaces played a positive and significant role for children and young people in making friends across cultures, which can be considered a prerequisite for social inclusion. Green space is also beneficial in terms of childhood development, allowing children to be creative and interact with one another and with adults, which ultimately assists them in being socially integrated in society in later life. A study (Taylor *et al*., 1998) of inner city children in Chicago found that there were significantly higher levels of creative play when the children played in the green spaces around their apartment blocks rather than in the barren areas. Children playing in the green spaces also had more opportunity to be with adults, a factor that can aid the development of interpersonal skills.

Other studies have considered ethnicity and race in relation to green space. For example, Ravenscroft and Markwell (2000) investigated the relationship between park provision in Reading, Berkshire (UK) and social inclusion among urban youths. They found that parks are more accessible to youths from ethnic minorities than other types of leisure facility, although they concede that this accessibility is highly localised and therefore the benefits offered by accessible parks may not be experienced equally by all groups in society. They admit that their study is 'no more than a…pilot study' and tentatively suggest that the provision of parks and playgrounds may provide recreational areas for children and youths currently under-represented in the use of other facilities such as leisure centres and that these spaces could cater for more than one ethnic group. Bell *et al*. (2008: 34) cite a study undertaken by Gobster (2002) focusing on Warren Park in Chicago, which formed a boundary between very different neighbourhoods. The study compared the proportion of park users from different social groups to the proportion of their populations in the surrounding areas of the park, estimating use levels and types of use, and investigating the kinds of interactions taking place between individuals from different ethnic or racial groups. The author concluded that it was a successful space in terms of serving the diverse neighbourhoods around it and thus provided evidence that parks and green spaces do not (or do not have to) form barriers between different communities.

Valuation: toolkits and unit cost of benefits/economic valuation data
Valuation toolkits are covered in Section 3.2.4. There are no tangible data on the costs/economic value of green space or green space interventions in respect of community cohesion and social inclusion specifically. There is the evidence from the previously mentioned Greenlink SROI study, which includes this valuation element of social benefit, and this will be discussed in Section 3.2.4. There is also some economic evidence linking increased community cohesion to reduced levels of crime.

The Department for Communities and Local Government (DCLG, 2009) published *The economic case for cohesion* in 2009. Table 3.5 is taken from this study and shows the estimated potential cost savings for different types of crime from an increase in community cohesion.

Table 3.5 Estimated potential cost savings in England and Wales from increase in community cohesion (DCLG, 2009: 7).

Crime type	Average cost 2007/08 (£)	Decrease in crime as sense of community increases by one unit	Adjusted crime level 2007/08	Reduction in crime level from one unit increase in sense of community	Potential cost savings (£)
Violent crime	11,520	2.7%	1 360 000	36 601	422,000,000
Burglary in a dwelling	3,617	3%	610 000	18 425	67,000,000
Theft of a vehicle	4,580	4%	130 000	5 384	25,000,000
Theft from a vehicle	950	2%	890 000	17 837	17,000,000
Total					530,000,000

Note: figures may not sum due to rounding.

However, as the report points out, these are just estimates and are dependent on the assumptions underlying them. There is a large degree of uncertainty regarding the scale or strength of relationship between cohesion and crime, thus the study also undertook a sensitivity analysis to look at cost savings when adjusted for assumptions. This is outlined in Table 3.6.

Table 3.6 Estimated potential cost savings in England and Wales after adjusting the assumptions on marginal impact of community cohesion on crime levels (DCLG, 2009: 8).

	Low estimate			Mid-estimate[a]		High estimate	
Crime type	**Decrease in crime**	**Decrease in crime levels**	**Cost potential saving (£)**	**Decrease in crime level**	**Potential cost saving (£)**	**Decrease in crime level**	**Potential cost saving (£)**
Violent crime	1%	13 566	156,000,000	25 079	289,000,000	36 601	422,000,000
Burglary in a dwelling	1%	6 142	22,000,000	12 283	44,000,000	18 425	67,000,000
Theft of a vehicle	1%	1 346	6,000,000	3 365	15,000,000	5 384	25,000,000
Theft from a vehicle	1%	8 919	8,000,000	13 378	13,000,000	17 837	17,000,000
Total			193,000,000		361,000,000		530,000,000

[a] Mid-estimate is calculated as the mid-point between the original estimate and the low estimate.
Note: figures may not sum due to rounding.

Even after adjustments, however, the report points out that there are many caveats to these estimates, including issues around the direction of causality between crime and cohesion, issues around the fact that the estimates are based on 20 wards at a single point in time and may not be representative of the country as a whole, and issues around the use of potentially out of date multipliers (DCLG, 2009: 9).

Relationships between facilitation of social interaction, integration and community cohesion and other benefits of GI

Table 3.7 outlines these relationships.

Table 3.7 GI benefits of: facilitation of social interaction, inclusion and community cohesion.

Benefit	Primary relationship	Secondary relationship
Facilitation of social interaction, inclusion and community cohesion [helps deliver: *Strong and Prosperous Communities* (DCLG, 2006); *Public Service Agreement 21: Build more cohesive, empowered and active communities* (HM Government, 2007); and *Communities in control: Real people, real power* (DCLG, 2008)]	Improved social networks	Enhanced mental well-being
	Reductions in levels of crime and anti-social behaviour	Increased feelings of safety and economic savings including costs as a consequence of crime and in response to crime.
	Increased community resilience to change.	Communities better equipped to undertake necessary adaptations, for example in relation to climate change

As already described, there are strong links between social interaction and inclusion and mental well-being. Communities which are better integrated and have stronger social ties are also less likely to suffer anti-social behaviour and crime. Furthermore, communities that are more cohesive are likely to be more resilient to change. Somewhat tentatively, this could be seen to contribute to many of the other benefits associated with green space such as climate change, as communities may be better equipped to deal with the adaptations necessary.

Identified knowledge gaps

- There is little economic evidence of the value of community and social benefits of green space, as it is difficult to attach monetary values to such benefits.
- Bell *et al*. (2008) observe that the number of studies which look specifically at the use of green space by different ethnic groups is very small.
- There are also few studies that look specifically at green space use in terms of gender, ageing and disability, all of which receive limited attention. This is especially true in terms of UK-based studies.
- More also needs to be known about the links between green space, social inclusion and deprivation.
- Bell *et al*. (2008) suggest that further study should be done to distinguish between the positive social experiences that green spaces can offer and the positive health benefits.

3.2.4 Valuation toolkits

The most significant and useful valuation toolkit available in relation to the social benefits of green infrastructure and green space is the Social Return on Investment (SROI) framework. This is a relatively new framework for measuring and communicating a broad concept of value, incorporating social, environmental and economic costs and benefits. The framework concentrates on change and measures outcomes using monetary values to represent them. SROI is based around stakeholders and puts financial values on the impacts identified as important by stakeholders that do not have market values. This means that social benefits and values, which are often excluded from markets and economic analyses, can be considered in the same terms, i.e. monetary terms, so that they can be more easily incorporated into resource allocation decisions.

Nevertheless, SROI is about value, as opposed to money; monetary figures are simply used because they are a widely accepted way of conveying value. However, while the SROI framework is very useful in many ways, it does come with a caveat: some outcomes cannot easily be assigned a monetary value and as such must be given proxy values which can lead to inconsistencies in approach and questionable validity. Over time this may improve as more standardised and accepted proxies are developed and adopted.

SROIs can either be done retrospectively as an evaluation of outcomes that have already taken place, or as a forecast predicting the social value that will be created. In simple terms, SROI involves:

1. **Establishing scope and identifying key stakeholders.** It is important to have clear boundaries about what your SROI analysis will cover, who will be involved in the process and how.
2. **Mapping outcomes.** Through engaging with your stakeholders you will develop an impact map, or theory of change, which shows the relationship between inputs, outputs and outcomes.
3. **Evidencing outcomes and giving them a value.** This stage involves finding data to show whether outcomes have happened and then valuing them.
4. **Establishing impact.** Having collected evidence on outcomes and monetised them, those aspects of change that would have happened anyway or are a result of other factors are eliminated from consideration.
5. **Calculating the SROI.** This stage involves adding up all the benefits, subtracting any negatives and comparing the result to the investment. This is also where the sensitivity of the results can be tested.

6. **Reporting, using and embedding.** Easily forgotten, this vital last step involves sharing findings with stakeholders and responding to them, embedding good outcome processes and verification of the report (Nicholls *et al*., 2009: 9-10).

The Cabinet Office of the Third Sector has produced *A guide to social return on investment* (Nicholls *et al*., 2009). An example of a completed SROI on a green space project is the *Social return on investment (SROI) analysis of the greenlink*, a partnership project managed by the Central Scotland Forest Trust (O'Neill, 2009). This was a pilot project by Greenspace Scotland to undertake a limited scope evaluative SROI study before a further, more extensive, SROI research project was undertaken. Greenlink is a 7 km bicycle path which links Motherwell town centre and Strathclyde Country Park. The SROI focused on one aspect of the Greenlink project – conservation volunteering – and found that for every £1 invested, there was a social return of £7.63, which includes social benefits in terms of physical and mental health, social interaction, inclusion and community cohesion, although these are not broken down in to individual values in the report.

Another useful instrument in green space planning and projects is a Health Impact Assessment (HIA). HIAs have been defined by the international Gothenburg consensus as 'A combination of procedures, methods and tools by which a policy, program or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population' (Greenspace Scotland, 2008: 37). A HIA is not an economic valuation tool but it can be used to systematically identify the positive and negative health and well-being impacts of proposed plans, policies or projects on individuals and communities. HIAs can be used to look at individuals' physical and mental health as well as their general well-being, and at community well-being.

Greenspace Scotland (2008) has developed a guide to the HIA of green space which looks at how to assess the health and equity effects of green space initiatives. It also provides advice on how to maximise the positive impacts and minimise the negative impacts of such projects. The Countryside Council for Wales has also come up with a tool for estimating, quantifying and communicating the contribution of their activities to health and well-being in Wales (Davies and Deaville, 2008). Also relevant is the newly launched *Health outcomes framework* (Greenspace Scotland *et al*., 2010) which is a resource aimed at practitioners in Scotland to help them make the links between activities and outcomes. It incorporates different tools which can be utilised to: improve planning and delivery; maximise benefits; demonstrate a clear rationale for how green space is delivering on local and/or national policy.

National indicators can also be used by local authorities to assess the general satisfaction of residents of an area, including perceptions of anti-social behaviour and participation in recreation in urban green spaces (Communities and Local Government, 2008).

Green infrastructure health check
The Government's adviser on urban design, CABE, is calling on urban local authorities to assess the health of their green infrastructure. Launched as part of CABE's 'Grey to Green' campaign, the GI health check is an online tool for urban councils in England to find out how well they are prioritising their green spaces. The 10 GI health check questions ask councils to assess the priority given to green spaces and the staff and resources to manage them. Local authorities will receive feedback that rates their performance, helping them to identify where they need to make improvements, as well as inviting them to participate in CABE's GI pilots, to be launched later this year (Cabe, 2009).

3.2.5 Practical considerations – barriers to green space use

The Royal Commission on Environmental Pollution (2007) argues that, 'Justification of equal access to urban nature can be based on issues of environmental justice, i.e. the right of all urban inhabitants to have access to urban nature because its benefits are critical to their well-being'. Therefore, access is a key factor to consider in relation to green space and social benefits, especially since there is evidence to suggest that those who live closest to green space use it more regularly (Giles-Corti *et al*., 2005; Kaczynski and Henderson, 2007; Neuvonen *et al*., 2007). Indeed, the Royal Commission on Environmental Pollution (2007) maintain that 'in many cases people will only travel short distances to green space, which is particularly true of the distances that children (especially unaccompanied) travel'. This is important since there is a strong relationship between frequent childhood visits to green spaces and being prepared to visit such spaces alone as an adult (Ward Thompson *et al*., 2008).

However, proximity to green space alone cannot explain levels of usage. Accessibility is also another major factor to consider when planning improvements in the use of green space and refers to whether that space is easy to access (i.e. has good, affordable, public transport links, good access points away from busy roads) and the quality of the green space on offer. Croucher *et al*. (2007: 14) suggest that 'green space is most valuable as a resource for physical activity when used by high volumes of people; therefore, spaces need to be accessible, of sufficient size, and connected to residential areas'. The National Institute for Health and Clinical Excellence (NICE, 2008) have produced guidelines on physical activity and the environment and they recommend that designers, managers and planners need to ensure that public open spaces and paths must be reachable on foot, by bicycle or other forms of active transport, as well as by public transport. Indeed, the green infrastructure approach is an important element of tackling accessibility since it is a networking approach, concerned with the connectivity of green spaces, which can aid movement through landscape.

The facilities available within green spaces also impact upon usage. For example, green spaces with a variety of attractive attributes such as landscaped features, ponds, trees and lakes can encourage higher levels of walking (Giles-Corti *et al*., 2005). Croucher *et al*. (2007) proposed that green spaces needed to facilitate diverse uses since single-use spaces, such as sports fields, do not encourage undedicated use. Improving access to and the accessibility of green space is therefore not just about creating new areas of green space, it is also about improving existing ones (Royal Commission on Environmental Pollution, 2007). Where one green space site cannot accommodate all users or serve a full range of purposes, the green infrastructure approach can prove vital because it can enhance the wider spread of green space provision in an area as a whole (Urban Green Spaces Task Force, 2002).

The Urban Green Spaces Task Force (2002: 18) reported that there are six main social barriers to the use of green space:

1. Lack of or poor condition of facilities, especially seats, toilets and play opportunities for children.
2. The incidence of anti-social behaviour. The potential for conflict between children and adults is often cited, but there are increasing concerns over the presence of drug and alcohol users, undesirable characters and ‘stranger danger’.
3. Concerns about dogs and dog mess.
4. Safety and other ‘psychological’ issues including feelings of fear and vulnerability based on real experiences and perceived concerns. This applies not only to people’s own personal fears, but also especially to fears for their children.
5. Environmental quality issues such as litter, graffiti and vandalism.
6. Loss of variety and too much ‘old hat’, especially for young people for whom Victorian parks do not always represent an exciting or attractive environment.

All these barriers need to be tackled head-on and be given the consideration they deserve by planners, designers and managers of green spaces. The Royal Commission on Environmental Pollution (2007) suggests that one strategy for overcoming safety issues (which are of particular concern for women) is to improve sightlines and lighting and reduce ‘hiding and entrapment spots’, for example by reducing shrub layers. However, they also note that improving safety comes with a caveat: CABE Space has argued that if local authorities continue with their approach whereby safety is considered paramount, our public spaces will become boring. What is required in many places is a balance, whereby elements of natural wilderness are retained but where, for example, ground viability is increased. However, to meet diverse needs, variety in design is also required (Royal Commission on Environmental Pollution, 2007). One study in Sheffield examined public attitudes towards urban naturalistic landscapes in contrast to more formal designs of urban green spaces (Ozguner and Kendle, 2006). This study found that formal spaces such as botanic gardens were regarded as safer and more peaceful whilst urban woodland offered a greater sense of naturalness, freedom and opportunities for social contact. At the end of the day, 'Designing a park or green space must begin by recognizing what makes it a special place and what people want of it' (Urban Green Spaces Task Force, 2002: 54).

Evidence exists that in some areas there is inequitable access to green space and very often there is inequitable usage of green space in relation to socio-economic status (Weldon *et al*., 2007: 2). For example, in a Scottish study investigating environmental justice it was found that the percentage of the urban population living within 600 metres of woodland greater than 2 hectares in size was lowest in the most deprived areas of society (Fairburn *et al*., 2005: 93). A Sport England (Moore, 2003) survey of green space use found that those groups in society from higher socio-economic backgrounds used urban parks, country parks, heath-land and gardens more frequently than those in lower groups. For example, nearly three-quarters of adults from social classes A and B reported that they had visited a park in the past 12 months, whereas only half of those in social groups D and E had. One of the reasons for this could be that while deprived areas may have green spaces in their local proximity, local facilities which could be used for healthy activities are often in a worse state in less affluent areas (Coen and Ross, 2006). A study by Crawford *et al*. (2008) in Melbourne, Australia found that public open spaces in lower socio-economic areas were likely to have less use-promoting amenities and features such as lighting, signage and paths, than such spaces in the most affluent neighbourhoods.

Various American studies have looked at park usage by different ethnic groups in society (Gobster, 2002; Lee and Scott, 2001; Tinsley *et al*., 2002) and found that Caucasians used parks more frequently than other ethnic groups. They also found that elderly females from ethnic minority groups with low income and low educational achievement are the lowest users of parks, with young, white, educated males the highest. The Sport England (Moore, 2003) survey also concluded that ethnic minorities 'have relatively low participation rates [in public park usage] as do those adults with a disability.' Similarly, a report on the use of Britain's urban parks found that 'elderly people, ethnic minorities, women and people with disabilities were under-represented as users of parks' (Fairburn *et al*., 2005: 90). This suggests that it is important to understand the motivations and barriers to green space use among different groups in society, since the design of public green infrastructure for social integration must take into account the needs of different groups, including consideration of age, gender, disability, ethnicity and deprivation.

Weldon *et al*. (2007) observed that other barriers to accessing green space include: lack of knowledge, motivation and physical fitness; feeling unwelcome; and conflicts of use. Indeed, as Jones *et al*. (2008: 4) assert:

> The presence and quality of a resource does not guarantee access and usage; and individual's lifestyle, their stage in the life-course and associated preferences and values…[are also] important. What is more, an individual's level of integration may also influence their perception of whether a park [or other green space] is an accessible, safe and available option for them and/or their family.

Consideration of these factors is especially pertinent for those developing and implementing projects or initiatives to promote use of green space for health, well-being and social benefits. One part of a strategy to address this and improve the use of green spaces could be the utilisation of peer group images and media campaigns which concentrate on people's needs and activities that they can envisage themselves doing (Weldon *et al*., 2007). Led and supported activities run by organisations or volunteers can be an effective means of engaging with hard to reach groups who may lack confidence in accessing green infrastructure or may feel unsafe when accessing these spaces alone.

With the range of barriers, interests and uses raised above, there is potential for tension or conflict between, or marginalisation of, different users or potential users of green space. Therefore, as Weldon *et al*. (2007) assert, community engagement and engagement with hard to reach groups (such as ethnic minorities, those with disabilities, the elderly, youth and women) is a vital component of the planning and implementation processes for green infrastructure. In addition, they propose that a capacity building approach, whereby local people take greater 'ownership' of green spaces can help improve the state and use of green space, especially amongst young people. Indeed, if green spaces are located within residential areas, are made accessible and promote social interaction they will encourage public use. This in turn can have the effect of stimulating local stewardship which can help with the maintenance of a site. Furthermore, the Royal Commission on Environmental Pollution (2007) suggests that fears and concerns over safety can be reduced if local residents are involved in site management.

It should also be noted, as observed by Morris (2003), that the potential scale of health benefits that can be provided through green space will take time to achieve and success will hinge largely upon policies and interventions which encourage people 'to feel a sense of pride about green open spaces, to increase community interest in planning and developing new woodland sites and to foster greater use of new access opportunities'. As Morris also observes, there is a need for greater integration and partnership between environmental and countryside agencies, local government, health organisations, land-use planners and others. Moreover, most existing urban green spaces in the UK are managed by local authorities. In recent years, in many authorities there has been a fragmentation of responsibility for parks and green spaces (Urban Green Spaces Task Force, 2002). A more joined-up approach is needed within local authorities to ensure that existing green space quality is improved or, even at a minimum, maintained.

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4 Environmental benefits

4.1 Introduction

The range of environmental benefits that can be delivered by urban green infrastructure (GI) can include:

- Reduction in air pollution.
- Reduction in flood risk as part of sustainable urban drainage systems.
- Improvement of the perceptions of an urban area as aesthetically pleasing.
- Amelioration of high summer temperatures caused by the urban heat island effect and climate change.

The main point to note about this diverse range of benefits is that none of them occur in isolation; and that a well-sited, planned and managed area of GI can potentially deliver all of them at the same time. However, given the constraints and intense pressures on land use that are usually found in urban areas, it will often be necessary to compromise by favouring certain benefits over others, as dictated by the objectives of a particular green space.

Although it may be difficult to find areas of GI that are capable of delivering all of the benefits listed above to their full potential, most areas will deliver a subset of them to varying degrees (and also of their associated economic, social and biodiversity benefits). As greater understanding is gained of how these benefits function individually and in concert, it should become possible to design and manage urban GI for the maximum possible benefit to society.

The sections that follow give an overview of the state of knowledge about the main environmental benefits of GI.

4.2 Critical review

4.2.1 Improving air quality using green infrastructure

Introduction

Air pollution is a major environmental problem in most cities across the world (Nowak, 1994). Major pollutants in urban areas are carbon monoxide (CO), nitrogen oxides (NO_x), ozone (O_3), volatile organic compounds (VOCs), sulphur dioxides (SO_2) and particulate matter (Nowak, 1994). The sources of these pollutants are primarily vehicle emissions, power production, industry and aviation. Trees and woodlands can absorb significant quantities of gaseous pollutants such as SO_2, NO_x and ozone from the atmosphere. The proportion of these pollutants that are absorbed depends on a number of factors, including tree species, stomatal conductance, environmental conditions and pollutant concentration in the atmosphere (Broadmeadow and Freer-Smith,1996). Abdollahi *et al*. (1996) conducted a laboratory study to compare the ability of 12 plant species to absorb ozone, and found that the species varied in their ability but all absorbed ozone to some extent. Uptake of SO_2, NO_2 and ozone pollutant gases has been found to be higher in broadleaved species than conifers, due to higher stomatal conductance. However, evergreen conifers are also effective as they can take up pollutants all year round and throughout the night due to their open stomata, and they also have a higher leaf surface area (Broadmeadow and Freer-Smith, 1996).

Trees can also have a beneficial effect on polycyclic aromatic hydrocarbons (PAHs). If PAHs are bound to harmful particles of less than 2.5 microns in diameter ($PM_{2.5}$) they are harmful to human health as they are deposited directly into the alveoli of the lungs. Trees can reduce the quantity of particle-bound PAHs that are airborne by accumulating $PM_{2.5}$ on the surface of leaves and bark (Joureava *et al*., 2002). Also, the deposition of PAHs on soil beneath trees can lead to the degradation of particles by bacteria in the rhizosphere (Spriggs *et al*., 2005).

There are marked species differences in the ability of trees to capture pollutant particles. Freer-Smith *et al*. (2005) found that conifers capture larger amounts of particulate matter of less than 10 microns in diameter (PM_{10}) than broadleaved trees. Due to the larger total surface area of needles, coniferous trees have a greater filtering capacity than trees with deciduous leaves (Stolt, 1982). Particulate matter within urban environments contains a range of metals, and these can be deposited onto vegetation as particles or within rain or fog droplets: referred to as dry, wet or occult deposition respectively (Peachey *et al*., 2009). Therefore there is great importance attached to improving air quality in the UK due to the health costs that are currently incurred. The establishment of a mix of tree species in urban areas has been proposed as a cost-effective measure to reduce the different types of air pollution, as trees and vegetation serve as effective sinks for the absorption and interception of pollutants in the atmosphere (Tiwary *et al*., 2009).

Urban vegetation can influence air quality in a number of ways. As we have seen, air quality can be directly altered by trees through the absorption of gaseous pollutants and interception of particles at leaf surfaces, and also through the production of oxygen during photosynthesis. Trees can also indirectly alter air quality in a number of ways. Trees can reduce building energy use by reducing conductive heat loss and by shading buildings, and this reduction in the use of energy helps to reduce pollution emissions from power stations. Trees can also lower air temperatures through transpiration and this can reduce the formation of ozone in urban areas. Goode (2006) has demonstrated that green roofs also help to reduce air and noise pollution in heavily built up areas where tree planting is impractical. Therefore the role of vegetation in mitigating the effects of air pollution has been highlighted as one of the potential benefits of urban green space (Tiwary *et al*., 2009). However, trees can also emit VOCs, and the rate of emission is known to be dependent on different tree species, temperature and light. In a study by Fulton *et al*. (1998) it was found that the VOC emission rate from black spruce was dependent on temperature, and an increase in the temperature of boreal forests would lead to an increase in the amount of VOCs released into the atmosphere. As a result of the increased emission of VOCs, trees can also increase the formation of ozone due to the interaction of VOCs with NO_x in the troposphere (AEA Technology, 2002).

Although air quality in the UK has improved since the 1950s, it remains a problem due to the prevalence of asthma and the number of hospital emissions and premature deaths caused by the effects of air pollution. In Great Britain in 1995-96 air pollution was estimated to have contributed to 24 000 premature deaths in vulnerable people (Sustainable Development Commission, 2008). In order to improve air quality in urban areas a number of strategies have been established in order to comply with the EU Air Quality Directive. The National Air Quality Strategy (Defra, 2007) set up a framework for improving air pollution and has established limit values and objectives for key air pollutants, and has defined requirements for monitoring progress against these targets (see Table 4.1). When these objectives cannot be met the local authority must declare an 'Air Quality Management Area' (AQMA) and introduce an action plan which may include congestion charges and traffic management in order to abate the problem. As a result of this policy 127 local authorities have declared one or more AQMAs, mostly in urban areas and resulting from traffic emissions of NO_2, greenhouse gas emissions and PM_{10}.

National Indicators (NI) for local government specifically relate to air quality and include one that is related to the reduction in NO_x and primary PM_{10} emissions from the local authority's estate and operations (NI 194). There are also two indicators that relate to CO_2 emissions: the reduction in CO_2 from Local Authority operations (NI 185) and reduction in CO_2 emissions per capita in the LA area (NI 186). The Forestry Commission has proposed the planting of new trees across the UK as a cost-effective measure to reduce air pollution and atmospheric greenhouse gas concentrations and to increase carbon sequestration in order to combat climate change. This proposal involves the replanting of 4% of the land cover in the UK in order to achieve abatement in greenhouse gas emissions of 10% by 2050 (Read *et al*., 2009).

Table 4.1 Air quality objectives in the UK (Defra, 2007).

Pollutant	Air quality objective		Date to be achieved by
	Concentration	Measured as	
Benzene All authorities	16.25 µg m^{-3}	Running annual mean	31.12.2003
England and Wales	5.00 µg m^{-3}	Annual mean	31.12.2010
Scotland and N.Ireland	3.25 µg m^{-3}	Running annual mean	31.12.2010
1,3-Butadiene	2.25 µg m^{-3}	Running annual mean	31.12.2003
Carbon monoxide England, Wales, Northern Ireland	10.0 mg m^{-3}	Maximum daily running 8 hr mean	31.12.2003
Scotland only	10.0 µg m^{-3}	Running 8hr mean	31.12.2003
Lead	0.5 µg m^{-3} 0.25 µg m^{-3}	Annual mean	31.12.2004 31.12.2008
Nitrogen dioxide	200 µg m^{-3} 18 times yr^{-1} 40 µg m^{-3}	1 hr mean Annual mean	31.12.2005 31.12.2005
Particles (PM_{10}) All authorities	50 µg m^{-3} 35 times yr^{-1} 40 µg m^{-3}	24 hr mean Annual mean	31.12.2004 31.12.2004
Scotland	50 µg m^{-3} 7 times yr^{-1} 18 µg m^{-3}	24 hr mean Annual mean	31.12.2010 31.12.2010
Sulphur dioxide	350 µg m^{-3} 125 µg m^{-3} 266 µg m^{-3}	1 hr mean 24 hr mean 15 min mean	31.12.2004 31.12.2004 31.12.2005

The use of green infrastructure to improve air quality provides a number of other benefits to humans in urban areas. The main benefit from a reduction in air pollution is the improvement in health, which leads to fewer incidences of respiratory diseases and a reduction in hospital emissions as a result. An estimated 1.1 million children are diagnosed with asthma in the UK, and according to research by Lovasi *et al*. (2008) street trees have been associated with a lower prevalence of childhood asthma (Asthma, UK, 2010). There are economic benefits as a result of the improvement in health, due to fewer hospital admissions and fewer premature deaths brought forward by PM_{10} pollution. An estimated 24 000 people die prematurely in the UK as a result of air pollution (NWDA, 2007) and admissions to hospital linked to air pollution cost the NHS between £17 and 60 million a year (Sustainable Development Commission, 2008).

Education in the use of green infrastructure to improve air quality can also affect people's behaviour, which, in turn, will have a significant impact on air quality and health. For example, encouraging people to travel through green space rather than walking along the side of roads, would result in greater benefits in terms of human exposure. However, this will depend on a number of other factors, including the perception of crime, ease of access and the attractiveness of the site. Alternatively, street trees can be used to provide localised improvements in air quality along busy roads or pathways. Bernatzky (1983) found that up to 70% of air pollution can be filtered out using street trees. The most significant impacts are likely to be during peak traffic densities when vehicular emissions are greatest. These are also likely to be the time periods of greatest exposure to air pollution, for example when people are out of their houses or places of work and travelling to work or school. Also, the most significant reductions in PM_{10} concentrations were estimated to be within the green spaces themselves, which suggests that in order for the full effects to be realised, the green spaces should be networked to provide transport corridors for use by local residents. The establishment of such green transport networks for humans if done sensitively will also allow for movement of wildlife (see Section 7.2.1). Twelve per cent of air pollution in urban areas is attributable to the urban heat island effect, due to temperature-dependent formation of pollutants such as VOCs and O_3, and therefore the planting of street trees to reduce air temperature in urban areas can also have a significant effect (Beckett *et al*., 1998). See Section 4.2.3 on the use of urban green space for heat amelioration.

The planting of street trees to improve air quality has also helped to improve community cohesion, and provide psychological benefits (Tzoulas *et al*., 2007; Bell *et al*., 2008). Therefore the benefits to humans as a result of improved air quality are related to an improvement in quality of life through the access to green space. Biodiversity can also benefit from the use of green space to improve air quality.

Evidence

A recent case study covering a 10 km x 10 km area of the East London Green Grid (ELGG) showed the potential for green space to reduce PM_{10} pollution. PM_{10} is an issue in urban areas due to links between human exposure and adverse health impacts (Tiwary *et al*., 2009). Several measures have been introduced in an attempt to reduce PM_{10} emissions, including the tightening of vehicle emissions and road pricing initiatives in the centre of London. However, tree establishment has been proposed to further reduce PM_{10} emissions through the deposition of particles onto leaf surfaces. The structure of large trees and their rough surfaces cause interception of particles by disrupting the flow of air, and provide a surface area for PM_{10} capture that can be between 2 and 12 times the area of land that they cover. Differences between tree species play an important role in estimating PM_{10} capture, and deposition models such as Urban Forests Effects model (UFORE) are available to assess the potential for particulate matter interception by trees.

The ELGG study used an integrated modelling approach using air dispersion (ADMS-Urban) and particulate interception (UFORE) to predict the PM_{10} concentrations both before and after green space establishment. Different planting scenarios were used to estimate PM_{10} interception by trees in the ELGG, based on the premise that trees have a greater capacity for PM_{10} than grassland and conifers have a greater capacity than broadleaves. The most realistic scenario comprising 75% grassland, 20% sycamore and 5% Douglas fir was estimated to remove 90.41 tonnes (t) of PM_{10} per year, and this demonstrated the potential for tree planting to have a positive effect on air quality (Tiwary *et al*., 2009).

A study in the Chicago region of the USA was carried out in order to determine air pollution removal of CO, NO_2, O_3, SO_2 and PM_{10} through dry deposition to trees. Analyses of tree canopy, pollution concentrations and total pollutant flux were carried out across the study area of Chicago, Cook and Du Page counties. The average pollutant removal for the entire study area was determined and the pollutant removal was then estimated using future scenarios of various additional percentages of tree cover. The study showed that trees in the Chicago area were estimated to remove 6190 t of pollution per year, which equates to an average improvement in air quality of approximately 0.3%. Further air quality improvement of 5-10% can be gained from increased tree cover. The monthly removal rates for each pollutant were found to vary, but rates were similar in all counties and removal occurred mostly in the in-leaf season during daylight hours. Large individual trees have the greatest estimated pollution removal due to their relatively large leaf surface area, and therefore as air pollution interception increases with leaf area it is higher for trees than for bushes or grassland (Nowak, 1994; Givoni, 1991).

Valuation: toolkits and unit cost of benefits / economic valuation data

Table 4.2 lists examples of tools that can be used to measure the air pollutant uptake by trees.

Table 4.2 Tools for measuring pollutant uptake by trees.

LAQM (Local Air Quality Management)	Helps local authorities assess their local emissions, including industrial emissions and vehicle emissions.
Emissions factor toolkit for vehicle emissions	Allows the user to calculate vehicle emissions for multiple road links based on vehicle composition, traffic speeds and road type. The toolkit produces link by link source allocation covering vehicle exhaust emissions, including brake and tyre wear contributions for PM_{10} and $PM_{2.5}$.
Exempt model	Used to assess the effects of certain types of developments, for example a new out-of-town shopping complex, where many cars may make their journey with cold engines. The models give results as excess emissions (units of mass per metre driven) for up to 10 kilometres from the vehicles. Further work is required independently of the model to calculate concentrations.
UFORE (Urban Forest Effects Model)	Computer model that calculates the structure, environmental effects and value of urban forests. The tool uses air dispersion and particulate interception models to predict the PM_{10} concentrations both before and after green space establishment. An inventory is conducted and trees are measured for their economic value in absorption of air pollution, and this can be used to educate people on the economic value of urban woodland. The model will enable those involved in green space establishment to select species for maximum PM_{10} removal, target tree establishment to those areas posing the greatest risk to the population and monitor the success of such schemes.
ADMS-Urban	Used to assess current and future air quality with respect to the air quality standards such as the EU Air Quality Directive, UK NAQS. It is used to model the impact of major developments such as airport expansion and traffic management schemes. DEFRA (UK Department for the Environment) has contracted CERC to use ADMS-Urban to model air pollutants in a number of urban areas in the UK, including London.
CiTTyCAT (Cambridge Tropospheric Trajectory model of Chemistry and Transport)	Used to investigate ozone production and transport based on factors such as temperature, humidity, pressure and surface pressure.
CITYgreen	Analyses the ecological and economic benefits of tree canopy and other green space, in order to calculate the economic/cost benefits for the services provided by the trees and other green space in a specific area. The air pollution model was developed by the US Forest Service and calculates the pollutant removal capacity of tree canopy. The results of the model show how much of five air pollutants the tree canopy is removing from the atmosphere. The greater the tree canopy, the more air pollution is removed. CITYgreen reports the annual quantity of pollutants removed and the dollar value associated with these services.
TRIM:FaTE	A multi-media fate and transport model that includes logarithms for pollutant deposition. The output concentrations from TRIM.FaTE can also be used as inputs to a human ingestion exposure model, such as TRIM.Expo-ingestion, to estimate human exposures.
Lacors Air quality toolkit	Aimed at councillors and environmental protection officers and provides practical examples of how councils can address the problem of poor air quality. Many councils have already set up innovative schemes or strategies to reduce air pollution levels. For example, London Borough of Greenwich has imposed levies on developers to finance air quality management schemes during urban planning and Manchester City Council has started to issue fixed penalty notices to drivers who refuse to switch off their engines whilst stationary.

Table 4.3 Economic valuation of air quality improvements.

Effect	**Form of measurement to which the valuations apply**	**Monetary value**
Pollution absorption (Nowak 1994)	Cost per metric tonne of pollutant removed 5575 metric tonnes of pollutant	\$540/t O_3 \$1014/t CO \$1441/t PM_{10} \$1801/t SO_2 \$4683/t NO_2 \$9.2 million
Reduce PM_{10} (Mindell and Joffe, 2004)	To target level 20µg m^{-3}	Reduction in 8-20 deaths
Health benefits from woodlands (Powe and Willis, 2002)	Reduced hospital admissions (4-6 people) and fewer premature deaths (5-7 people)	£9,000,000
Reduce PM_{10} (Yang *et al.*, 2005)	1261.4 t pollutants removed	Reduction in 772t/yr PM_{10}
Tree planting (McDonald *et al.*, 2007)	Increase tree cover 25% in West Midlands	Pollution reduction 19%
Health benefit (Lovasi *et al.*, 2008)	Street trees (tree km^{-1})	29% reduction in childhood asthma
Pollution absorption (Nowak, 1994)	1821 metric tons	\$9.5 million
Value of trees (Nowak *et al.*, 2006)	163 500 tons carbon storage 3870 carbon uptake 169 tons air pollution uptake	\$3 million \$71,500/yr \$850,000
Trees, US (Nowak *et al.*, 2006)	711 000 metric tons pollution uptake yr^{-1}	\$3.8 billion
New York city street trees (Peper *et al.*, 2007)	\$1 spent on tree care	\$5.80 benefits
Energy savings (Peper *et al.*, 2007)	Electricity, 45 609 MWh, shading and climate Natural gas 16 306 516 therms	\$6.9 million \$20.8 million Total \$27.8 million
Net CO_2 reductions (Peper *et al.*, 2007)	Sequestration 56 060 tonnes Emissions 68 687 tonnes	\$754,947 or \$1.29 per tree
Pollutant removal PM_{10} interception O_3 interception NO_2 use reduction Interception of rain Aesthetics/property values (Peper *et al.*, 2007)	1.72 lb per tree 63 tons yr^{-1} 129.1 tonnes yr^{-1} 193 tonnes 890.6 gallons yr^{-1} 1432 gallons yr^{-1} per tree Total annual benefits (New York city)	Net \$5.27 million \$9.02 per tree \$1 million \$1.2 million \$1.8 million \$35.6 million \$61 per tree \$52.5 million yr^{-1} \$90 yr^{-1} per tree \$121.9 million \$209 per tree
Cost of hospital admissions - air pollution (Powe and Willis, 2002)	Acute mortality Chronic mortality Respiratory conditions Cardiovascular	£15,000 £29,000 £1,400-2,500 £1,500-1,700
Value of trees, UK (Powe and Willis, 2002)	617 790 060 kg PM_{10} 1 199 840 337 kg SO_2 Net benefit	£304,513 - £11,213,276

Effect	Form of measurement to which the valuations apply	Monetary value
Health costs per annum (Tiwary *et al*., 2005)	PM_{10} pollution	£9.1-£21.4 billion
Mersey Forest (Regeneris Consulting, 2009)	Air pollution absorption yr^{-1} NPV (50 years) Per hectare Carbon sequestration, 3 tonnes per hectare Total	£116,000 £2,717,000 £557 £6.67-£59 per tonne £16,000
Forest of Marston Vale	Pollution amelioration	£29 ha yr^{-1}
Reduction in $PM_{2.5}$	Health cost benefits	$32 million
Carbon emissions	Reduction in CO_2	£100 per tonne
NO_x emission credits (Clark *et al*., 2005)	£3375 per tonne	$0.11 m^{-2}

Relationships between improved air quality and other benefits of GI

The benefits of improved air quality are linked to other benefits of GI, as shown in Table 4.4.

Table 4.4 Benefits of green infrastructure for improved air quality.

Benefit	Primary relationship	Secondary relationship
Improved health	Fewer respiratory diseases (and asthma)	Fewer hospital admissions Shorter recovery time Reduction in premature deaths
Increased physical activity	Reduced obesity and cardiovascular diseases	Sustainable patterns of travel

Identified knowledge gaps

- Research is needed on the extent to which policies for large-scale tree planting within the UK and elsewhere within Europe would influence air quality in high temperature summer pollution episodes. Wider impacts of land-use change upon both air quality and global pollutants also need to be considered (AQEG, 2007).
- Comprehensive research is needed on the effect of green space on pollution, air quality, shelter, noise, energy consumption and flood mitigation, perhaps tied into a wide-ranging cost benefit analysis.
- Further economic evidence on the cost benefits of green space on air quality improvement in the UK is required; more information is available for the US than the UK.
- Further research is needed on how climate change, increased greenhouse gas emissions and extremes in temperature will impact on both the resilience of green infrastructure and its benefit to air quality.

4.2.2. Green infrastructure and sustainable drainage systems

Introduction

There are many hydrological functions of green infrastructure. These include conveyance, infiltration and natural drainage, interception, pollutant removal from soil and water, coastal storm protection, surface flow reduction through surface roughness (e.g. vegetative barriers), water capture with no reuse potential and, finally, water storage with the potential for reuse (Bartens, 2009). GI thereby impacts on both water quantity (see Section 6.2.1) and quality (see Section 6.2.2).

Major reviews, produced mainly as a consequence of various flood events and their catastrophic consequences, predict that climatic changes have significantly increased the risk of surface water flooding. The Pitt Review: *Learning lessons from the 2007 floods* highlighted the need and implementation of sustainable urban drainage systems (SUDS) in areas where the need is greatest (Pitt, 2008). *Making space for water* (Defra, 2005) also raised concerns over flooding in urban areas due to inadequacies in drainage systems. During the 2000 floods, failing urban drainage systems caused over 40% of all flooding, much of it polluted.

Unless steps are taken to manage flood risk, new development could increase the costs of river and coastal flooding by an average of £54.6 million a year, which is a 74% increase in the potential flood damages within the growth areas themselves (Environment Agency, 2007).

England is unique in the fact that no one body is responsible for managing surface water runoff, with responsibility divided between local authorities, housing providers, the Environment Agency, water companies and householders. This has brought about many difficulties including pinning responsibility to one particular body and causing communication breakdowns in various projects (Bartens, 2009). In Scotland, the Scottish Environmental Protection Agency (SEPA) has introduced policy changes where all new developments must have drainage best management practices (BMP) which include flow attenuation and water quality improvements. The findings of a major survey into the use of sustainable drainage are summarised in a SNIFFER report: 'SUDS in Scotland - the Scottish SUDS database'(Jefferies, 2004). The survey highlighted that the use of SUDS has become standard practice in Scotland, with over 700 sites being listed and nearly 4000 systems having been implemented.

The trends towards achieving SUDS not only improves the urban environment through blue-green space creation, it also offers some future protection in the face of both continued urbanisation and climate change and should be recognised as a valuable adaptation to change (Semadeni-Davies, 2007).

SUDS techniques

SUDS can comprise of one or more structures to manage surface water runoff. A combination of techniques using the 'management train principle' helps alleviate the pressures on a drainage system. These will often incorporate traditional underground drainage systems. Some SUDS techniques involve vegetation and water storage (ponds) encouraging green space in urban areas whilst other techniques are engineered solutions below ground level. The SUDS involving green space include controlling the water at source through transpiration in trees and vegetation, green roofs, infiltration trenches and filter drains, swales and basins, and ponds and wetlands.

Green space provision will need to be considered alongside increased storage (Gill *et al*., 2007) thus utilising sustainable drainage techniques. An extensive review for the Environment Agency looked at published material on the performance of various SUDS components, breaking down literature and case studies by each component (Pratt, 2001).

Functions

The primary functions of trees, vegetation and soils are to aid in water interception, storage and infiltration while increasing evapotranspiration potential. Not all sites have the potential for open green spaces and trees, especially in highly urbanised areas where soil conditions restrict the amount of urban canopy cover (Day and Dickinson, 2008). A study in California, USA in Sacramento's urban forest concluded that floods usually occur during and after major storm events after canopy storage has been exceeded and although trees reduce runoff they are not effective at flood control (Xiao *et al*., 1998). In contrast, tree planting on floodplains upstream of urban areas can significantly reduce flood risk (see Chapter 6).

Drainage therefore is a continual problem in highly urbanised areas and with space at a premium green roofs can be implemented as an alternative measure to reduce rainwater runoff. Green roofs increase interception, storm water storage, evaporation and transpiration, and work well for small storm events (Carter and Butler, 2008). A literature review on green roofs concluded that rainfall retention capability on a yearly basis may range from 75% for intensive green roofs to 45% for extensive green roofs. Intensive green roofs have a substrate depth of over 150 mm whereas extensive green roofs have a substrate depth of less than 150 mm; the substrate layer retains water and anchors the plants. The magnitude of the retention depends on substrate depths, climatic conditions and amount of precipitation (Mentens *et al*., 2006). A benefit of green roofs over traditional green space is that they make use of previously unused space and do not limit the demands of the people for open space on the ground (Mentens *et al*., 2006). Flat green roofs are considered the most practical for implementation, followed by commercial and industrial areas targeted for retrofit installations which are known to contain large, flat-roofed buildings (Carter and Jackson, 2007).

For other green spaces soil type is important; for example sandy soils have lower runoff coefficients than slower infiltrating soils such as clays. The soil type and the urban land use type were factors taken into account in study by Gill *et al*. (2007) which used a surface runoff model for Greater Manchester. The model looked at a scenario in 2080 predicting that there will be higher precipitation of which a greater percentage will be surface runoff. They suggested that increasing green cover by 10% would reduce run-off by 4.9% and that increasing tree cover by the same amount would reduce runoff by 5.7%, and this is due to increased interception, storage and infiltration of rainwater. Although this deals with a scenario of increased precipitation the future surface runoff will not fall below their current baseline levels. By 2080 surface runoff is predicted to be 65% higher in high density residential areas. The study also suggests that green roofs would have a significant effect in reducing runoff. For example, in a 28 mm event, runoff can be reduced by between 11.8 and 14.1% (Gill *et al*., 2007).

Methods and tools for quantifying and valuing green space within SUDS

CITYgreen is GIS software developed in the US as an extension to ESRI's ArcGIS. The CITYgreen toolkit calculates the volume of runoff coming from the land cover, based on a 2 year, 24-hour rain event. More impervious surfaces generate higher levels of runoff, while more natural areas decrease the amount of runoff. This can be a modelling tool for planning and zoning. CITYgreen reports the runoff volume and economic value (in US dollars) associated with removing any excess storm water resulting from changes in land cover, such as constructing a retention or detention pond. A review investigating the applications and the economic benefits of CITYgreen concluded that it can only be applied in the US due to underlying models being based upon US environmental data. However, CITYgreen has excellent potential for use in the UK but will currently not provide accurate results when used in other countries, unless local data are used to populate the models (Kingston *et al*., 2009).

Also developed in the US, the HYDRUS 1D, 2D and 3D computer programmes provide a Microsoft Windows-based modelling environment for the analysis of water flow and solute transport in variably saturated porous media. Weather data from any location can be input into the model to determine runoff for any depth modular-block green roof using a similar soil media type (Hilten *et al*., 2008). The models have been in the marketplace for two years and although a useful tool, the complex package requires skill and understanding in modelling and setting of the exact parameters a user requires. HYDRUS can accurately predict runoff especially for small rain events. At larger rainfall quantities, HYDRUS appears to over predict. Storm data collected as part of a green roof study in Athens, Georgia, USA were used to validate HYDRUS-simulated runoff.
i-Tree Hydro is a stand alone application but comes under the umbrella of i-Tree which is a tool for assessing and managing community forests. It was developed by USDA Forest Service in 2006. i-Tree Hydro is in the final stages of development and is due to be released in 2010. This package simulates the effects of changes in tree and impervious

cover characteristics within a watershed river catchment on stream flow and water quality. It is designed specifically to handle urban vegetation effects so that urban forest managers and urban planners can quantify the impacts of changes in tree and impervious cover on local hydrology to aid in management and planning decisions. Model results can be used to improve urban forest management and urban planning and design in order to help improve water quality and reduce the risk of flooding. This package holds good promise for application in the UK, but is likely to require UK-specific data for climate, tree species and local geography.

i-Tree Vue is a utility still in development which uses land cover data maps and compiles data on a specific area with regards to percentage impervious cover and percentage tree canopy. This could be a useful tool in the future to assess land use in urban areas which will address flooding issues and determine the best places to site urban drainage.

Unit cost of benefits / economic valuation data

The economic impact to the national economy due to urban flooding is estimated as £270 million a year in England and Wales, where 80 000 homes are at risk (Parliamentary office of Science and Technology Postnote, 2007). A foresight report suggests that if no action is taken the cost of urban flooding could rise to between £1 billion and £10 billion a year (Evans *et al*., 2004).

Around 15% of rivers and 22% of groundwaters are at risk of not achieving the water framework directive objectives as a result of urban diffuse pollution such as runoff from contaminated land, poor drainage and accidental spills. Estimates of the cost of environmental damage due to pollutants is between £150 million and £250 million per year based on 2004/05 values (Environment Agency, 2007).

Reductions in flood risk and increases in property prices next to SUDS sites are examples of measurable economic benefits. Other benefits include recreational and ecological value and improvements to receiving surface water quality (CIRIA, 2003).

Cost analyses are supportive of creating SUDS, showing that well-designed and maintained SUDS are more cost effective to construct, and cost less to maintain than traditional drainage solutions which are unable to meet the environmental requirements of current legislation (Duffy *et al*., 2008).

HR Wallingford produced a report for a DTI-funded project on *The whole life costing for sustainable drainage*, which included reports on the social and ecological impacts and the operation and maintenance of sustainable drainage systems (HR Wallingford, 2009).

In Germany 43% of cities offer financial incentives for roof greening. About 30 of the largest cities (including Berlin, Frankfurt, Karlsruhe, Kassel and Stuttgart) give direct financial support to roof greening, ranging from 25 to 100% of the installation costs.

Seventeen per cent of German cities offer reduced sewage disposal charges for developments with green roofs (Goode, 2006).

Relationships between improved SUDS and other benefits of GI

Green roofs have the potential to provide ecological services in urban areas and can be used as a multifunctional land cover in urban areas (Carter and Butler, 2008). A wide variety of insects were found on the Ford Motor Company's green roof which is dominated by *Sedum* (Coffman and Davis, 2005). As a green roof cover *Sedum* provides habitat opportunities for macroinvertebrates (Carter and Butler, 2008). Two SUDS units integrated into the design of a new urban extension at Upton, Northampton, UK demonstrated that aquatic fauna had colonised the new site and that over a two-year period the SUDS had operated as backwater habitats for aquatic and wetland species dispersed from the River Nene Valley (Jackson and Boutle, 2008)

Green roofs as well as many green components of SUDS help to lower urban air temperatures and combat the heat island effect. Energy savings can be made with green roofs when incorporated into a life cycle cost as well as improving air quality in densely populated areas (Carter and Keeler, 2008; see Section 4.2.1). The installation of green roofs on residential buildings would provide healthier, aesthetically pleasing communal green space found in typically greenless urban areas.

Using Stockholm as an example, lawns and parks, urban forest, cultivated land and wetland all contribute to drainage but they also contribute to noise reduction, air filtering, microclimate regulation and recreational and cultural values. Wetland also seems to be a valuable ecosystem type since it contributes to all services (Bolund and Hunhammar, 1999).

Table 4.5 Benefits of green infrastructure for SUDS.

Benefit	Primary relationship	Secondary relationship
Flood alleviation	Reduced flood risk	Reduced cost to the government Reduction in insurance claims Affordable flood insurance Reassure the public Promotes natural groundwater recharge Reduction in psychological distress following flooding Enhance the environment Increase in property prices
Pollution control (Water Framework Directive; Environment Agency, 2007)	Reduce pollutant discharge to water bodies Acts as a buffer for any pollution incidents	Reduction in pollution clean up costs Reduction in health risks Achieve water framework directive objectives through improved water quality
Water storage through detention ponds/ basins and wetlands.	Increased water resources	Mitigate water shortages due to demand through increase housing and climate change Promotes natural groundwater and aquifer recharge

Identified knowledge gaps

- The Read report saw the interactions between interception of precipitation by trees, urban tree effects on soil infiltration and sustainable drainage as a research priority need (Read *et al*., 2009).
- Models integrating green roofs, green areas, storage reservoirs etc. on various time scales are clearly needed if runoff is to be predicted more efficiently (Mentens *et al*., 2006).
- Monitoring the biodiversity of SUDS may provide a way forward towards devising a method to assess ecological status and integrity and the ecological services of SUDS (Jackson and Boutle, 2008).
- At a local authority level there can be a distinct lack of knowledge of sustainable surface water management techniques, which should be addressed with the appropriate training and guidance.
- Further knowledge needs to be compiled on the economic benefits of different types and structures of SUDS, to inform planners and developers on the environmentally and economically best system for their cities. This needs to be backed up by clear policy and guidance documents from central and local government on the responsibilities, liabilities and maintenance of SUDS.

4.2.3 Green infrastructure and the urban heat island

Introduction

In urban areas, the warming effects of climate change will be combined with those of the urban heat island (UHI). Towns and cities are usually a degree or two warmer than surrounding rural areas, as a result of this UHI effect. The UHI is caused by two main factors:

- Buildings and other man-made surfaces are warmed by direct solar radiation. Heat absorbed during the day is released into the atmosphere at night time, causing a general warming of urban air.
- Loss of vegetation in urban areas reduces the amount of cooling by evapotranspiration (Heidt and Neif, 2008).

As well as heat from the sun, human activities also contribute to the UHI. This can range from relatively small but significant amounts of heat generated by the metabolic processes of large urban populations to the larger effects of vehicles and industry and loss of heat from buildings. Although air conditioning can make buildings more comfortable for people, it also produces significant amounts of waste heat that contribute to the UHI (Smith and Levermore, 2008). The warming effects of climate change are likely to increase the intensity of the UHI in urban areas.

Green infrastructure in urban areas has an important role to play in ameliorating the warming effects of climate change and the UHI. A detailed modelling study carried out by Gill *et al*. (2007) in Greater Manchester suggested that increasing the current area of green infrastructure by 10% in areas with little or no green cover would result in a cooling of the surface temperature by up to 2.5 ^{o}C under the high emissions scenarios based on the UK Climate Impacts Programme (UKCIP02) predictions.

Some effects of summer heat in urban areas

The increased levels of heat predicted under various climate change scenarios for the UK are likely to affect urban built infrastructure and populations in a number of ways:

- Levels of thermal discomfort will increase, in both outdoor areas and within buildings.
- Adverse health effects such as sunburn, skin cancer and cataracts are likely to increase (Kovats, 2008).
- Higher summer temperatures may cause direct damage to building materials, or promote organisms that cause damage, such as some timber pests (Gill *et al*., 2004).
- Direct energy costs associated with air conditioning will increase.

Cooling effects of green infrastructure

Green infrastructure can reduce the impacts of higher temperatures in several ways:

- Trees and shrubs provide protection from both heat and UV radiation by direct shading, both of buildings and outdoor spaces.
- Evapotranspiration reduces the temperature in the area around vegetation by converting solar radiation to latent heat.
- Lower temperatures caused by both evapotranspiration and direct shading lead to a reduction in the amount of heat absorbed (and therefore emitted) by low albedo man-made urban surfaces (Dimoudi and Nikolopoulou, 2003).

Evidence for the cooling effect of trees and vegetation

The Centre for Evidence Based Conservation at Bangor University in North Wales has carried out a review of the effectiveness of urban green areas in reducing human exposure to ground level ozone concentrations, UV exposure and the UHI effect (Bowler, 2010). It does this in part by examining the evidence for the cooling effects of individual trees, groups of trees and larger areas of vegetation such as parks. A draft of this review has been posted for consultation on the website of Collaboration for Environmental Evidence (http://environmentalevidence.org/Documents/Draftreview41.pdf). The review notes that most of the studies looked at were observational, and were not statistically analysed. It also notes that more work is needed to clarify the effects of variables that may have a significant effect on the outcome of some of the studies. However, the review does give a good indication of what are thought to be the main mechanisms by which vegetation cools an urban area.

Although most of the papers could only be reviewed qualitatively, a subset (looking at the cooling effects of urban parks) was suitable for quantitative meta-analysis. The meta-analysis found significant variation in the effect sizes of the presence of a park, but when further statistical techniques to compensate for the variation were applied to the data, the parks showed a significant cooling effect.

Using a qualitative review Bowler found 23 studies comparing the temperature in a park (or other green area) with urban areas either:

1. Adjacent to the green area (15 studies).
2. Not immediately adjacent to the green area under investigation, but within the same urban area (8 studies).

Most of these studies suggest that parks are cooler on average than the urban areas they were compared with. The studies also investigated the effect of variables such as green area size, season, vegetation type and urban factors. The effects of these variables are summarised below and presented in Table 4.6.

Green space area

Four international studies examined the effect of green space area compared with their estimated cooling effects. The studies measured a number of parks (ranging from 3 to 61), taking replicate measurements over a period of several months by day and night.

The studies indicate that larger parks are likely to be cooler than smaller parks, or that the cooling effect of larger parks is greater. The most extensive study covering 61 parks (Chang *et al*., 2007) showed that parks of at least 3 ha were usually cooler than the surrounding urban areas by an average of 0.81°C at noon in summer (Chang *et al*., 2007). The temperature in parks of less than 3 ha was more variable.

Distance from park

A study of two large parks in Singapore (Yu and Hien, 2006) monitored temperatures both inside and up to 500 m from the park boundary within the surrounding urban areas. The authors found that temperatures outside the park's boundary gradually increased as they moved further away from the green area, suggesting that the cooling effect of the park extended beyond its boundary. A second study of three parks found a similar effect at night. The largest of the three parks (156 ha) showed the strongest relationship between temperature and distance.

Vegetation type

Two studies compared the cooling effect of parks with the number and/or area of trees within them, and both linked higher numbers or larger areas of trees with lower temperatures.

Potchter *et al*. (2006) looked at three similar sized parks in Tel Aviv, Israel. Park A (mainly grass) had little or no tree cover, while parks B and C were 65% and 95% shaded (by medium and large trees) respectively. Parks B and C were cooler than the surrounding built up areas (park C by 2.5°C in June 2002, and park B by 2.3°C). It should be noted that the cooling effect of park C was apparent despite the trees being heavily pruned in 2001, and that a previous study by the same authors (Potchter *et al*., 1999) recorded a cooling effect of around 3-4°C from measurements taken in 1997, 1998 and 1999. The results for park A (which was irrigated during the measurement period) were more complex. Sometimes it showed a cooling effect (a maximum of 0.8°C on day one), while at other times it was actually slightly warmer (by 0.6°C) than surrounding built-up areas in the morning, becoming cooler (by 1.0°C) in the afternoon.

Chang *et al*. (2007), in the Taipei city parks study, also showed that the cooling was not simply an effect of shading, as temperature measurements were also taken in unshaded areas of the parks.

Other factors

The previously mentioned studies looked at the cooling effect of a green site compared with a non-green site. However, three studies looked at the effect of varying percentages of green cover over a wide urban area. Zahoor (1993) looked at the area within a 2 mile radius of three weather stations in the Los Angeles area, quantifying the percentage cover of vegetation within each area. He found that the area with the lowest percentage of tree cover (47%) was 3°F warmer on average than the area with highest percentage cover (55%). All three studies found that temperatures were on average lower in the areas with higher percentages of green cover, although Simpson *et al*. (1994) acknowledged that other factors in the areas monitored may be affecting temperature differences, such as the amount of vegetation within the immediate vicinity of the temperature monitoring point.

Effects of individual trees

The evidence for the effects of individual or small groups of trees on air temperature seems to be slightly contradictory. Although it is apparent that the temperature beneath the canopies of individual trees is usually lower than that of the surrounding air, the mechanism by which this happens seems to be unclear. Some studies (Souch and Souch, 1993; Shashua-Bar and Hoffman, 2000; Golden *et al*., 2007; Huang *et al*., 2008) suggest that the main cause of cooling is direct shading (the cooling effect was not apparent during the night), and that different tree species vary in their ability to reduce local temperatures, possibly due to factors such as tree size and canopy characteristics. Another study (Souch and Souch, 1993) of 44 different species concluded that factors such as leaf area index, diameter and height do not seem to affect the amount by which a tree reduces local air temperature. A third study found that the amount of visible shade provided by trees explained variations in temperatures between measurement points. The same study also suggested the cooling effect of trees could be detected up to 80 m away.

The effect of individual trees compared to several trees also seems to be slightly unclear. One replicated study found little difference in cooling effects between individual or small groups (3-4 trees) of sugar maples (*Acer saccharum*; Souch and Souch, 1993). Another study by Streiling and Matzarakis, (2003) found a marginally higher cooling effect from small groups as opposed to single trees. However, the second study only compared one site of each, taking measurements on only one day.

Shashua-Bar and Hoffman (2000) also noted the importance of background temperatures when looking at cooling effects. In the study of sugar maples, higher temperatures were found under individual trees in a paved street environment than under trees in grassy environments. Where trees are found in street canyons, the position of the tree within the canyon affects the amount of cooling provided. Golden *et al*. (2007) found that trees on a pavement with a high exposure to sunlight due to the orientation of the street canyon provided surface temperature cooling of around 5.5°C, whereas trees that were less exposed to direct sunlight provided a cooling effect of around 10.2°C on a similar paved surface.

Table 4.6 Summary of effects of urban green space on temperature, based on Bowler (2010).

Factors investigated	Number of studies	Main effects
Green area size	4	• Larger parks likely to be cooler than smaller parks (or cooling effect of larger parks is greater) • Parks of at least 3 ha usually cooler than the surrounding urban areas by an average 0.81K at noon in the summer (Chang *et al.*, 2007) • Temperature in parks of less than 3 ha more variable
Distance from park	3	• Cooling effect of park extends beyond boundary (temperatures outside park boundaries rise gradually as distance from green area increases) • Second study of three parks found similar effect at night • Largest of the three parks (156 ha) showed the strongest relationship between temperature and distance
Vegetation type	2	• Higher numbers or larger areas of trees within a park lead to lower temperatures • Cooling not simply an effect of shading, as temperature measurements were also taken in unshaded areas of park
Percentage of green cover in a wider urban area	3	• Temperatures lower on average in areas with higher percentage green cover[a]
Individual trees	9[b]	• Temperature beneath canopies of individual trees usually lower than that of the surrounding air • Some studies suggest that main cause of cooling is direct shading, and that different tree species vary in their ability to reduce local temperatures (possibly due to factors such as tree size and canopy characteristics) • A study of 44 species concluded that factors such as leaf area index, diameter and height do not seem to affect the amount by which a tree reduces local air temperature • One study found that amount of visible shade provided by trees explained variations in temperatures between measurement points, and that cooling effect of trees could be detected up to 80 m away. • One study found little difference in cooling effects between individual or small groups (3-4 trees) of sugar maples (*Acer saccharum*) • Sugar maple study also found higher temperatures under individual trees in paved street than under trees in grassy environments • One study found marginally higher cooling effect from small groups as opposed to single trees • Where trees are found in street canyons, the orientation of the canyon affects the amount of cooling provided by the tree

[a] Other factors in areas monitored may be affecting temperature differences, such as amount of vegetation within immediate vicinity of temperature monitoring point.
[b] In some studies the evidence available is of a slightly contradictory nature.

Status and trends of GI management for heat amelioration

The Climate Change Act (2008) introduces a statutory requirement for certain organisations (see the Defra website at www.defra.gov.uk/environment/climate/documents/rp-list.pdf for a full list of these organisations) to assess the risk from climate change and develop plans for adaptation to reduce these risks.

The main requirements for managing the use of GI as a means of combating urban heat are:

- Quantifying the effects that differing amounts of vegetation have on the local thermal environment.
- Determining which areas of large urban environments are most at risk from the effects of higher average levels of heat.
- Determining the current extent of local GI and the opportunities for its better management or expansion.

Methods and tools for assessing the risk of climate change and quantifying the effect of adaptation measures in urban areas are being developed by two research projects:

- SCORCHIO is a consortium research project run by Manchester University's Centre for Urban and Regional Ecology. One of the main aims of this project is to develop tools that can quantify risk from the combined effects of the UHI and climate change, and show how best to target adaptation strategies over a large urban area (Smith and Lindley, 2008); SCORCHIO is scheduled to run until early 2010, after which time more information on the proposed GIS tool may become available. Further details can be found on the project website at www.sed.manchester.ac.uk/research/cure/research/scorchio.
- LUCID is another consortium project lead by University College London, looking at developing more localised tools for quantifying the effects of building structure and form, climate, energy use and effects on human health. Further details can be found on the project website at www.lucid-project.org.uk.

The Greater London Authority is currently working with the SCORCHIO and LUCID project teams to incorporate these principles into the final Mayor's Adaptation Strategy for London (Greater London Authority, 2010a).

Forest Research has recently started a project looking at urban trees and climate change. Parts of the project will focus on:

- Assessing and mapping the resilience of existing and planned tree stock.
- Establishing provenance trials with a range of species.
- Investigating links between a species' potential for heat moderation and protection from UV radiation and its age, position, management and the physical structure.
- Presenting results with respect to people's thermal comfort, morbidity and mortality risks, as well as energy savings.

It is hoped the project will deliver:

- Best Practice Guidance on risks of climate change to urban trees and shade provision.
- An expanded Right Place Right Tree database.
- A GIS system for quantifying temperature differences and UV exposure using different tree species.

The effects of vegetation on urban climate have been looked at in a number of climate models. These models are usually used to characterise urban surfaces as part of a larger mesoscale meteorological model. The overall usefulness and accuracy of these models is the subject of a study by Grimmond *et al*. (2009).

One of the local scale climate models included in this study is ENVImet, developed as part of the KLIMES project at the University of Mainz, Germany (Bruse and Fleer, 1998). The ENVImet software can be freely downloaded (www.envi-met.com), and is capable of predicting the effects of differing amounts of vegetation on different climate scenarios for a given urban area. However, modelling with ENVImet can be time consuming and ideally needs large amounts of processing power. ENVImet can also be used in conjunction with BOTworld software to look at the effects of its modelled climate scenarios on human thermal comfort (Huttner *et al*., 2009; Bruse, 2009).

Valuation

There are no specific valuation toolkits to describe the value of GI as a means of ameliorating the effects of UHI and climate change. Certain American systems can be used to calculate a dollar value for ecosystem functions (such as the reduction in the amount of energy needed for air conditioning when trees are planted near to buildings). The two main systems used for valuing such ecosystem services are:

- i-Tree. This system uses two main models to give a range of ecosystem service values: UFORE, or the Urban Forest Effects Model; and STRATUM, the Street Tree Resource Analysis Tool for Urban forest Managers. This method has been adapted for use in other countries, but needs local climate and tree species data.
- CITYgreen. A GIS based system used to calculate the economic benefits of urban forests; this programme needs detailed land use data to be effective. A recent study carried out by Manchester University on behalf of Natural Economy Northwest detailed a number of key points that would need to be addressed before this software could be used effectively in the UK (Kingston *et al*., undated). Since both CITYgreen and i-Tree use the same models for calculating ecosystem service values, it may be possible that some of the criticisms directed at CITYgreen by this report may also apply to i-Tree.

Relationships between heat amelioration and other benefits of GI

Table 4.7 shows the relationships between urban heat amelioration and other benefits of green infrastructure.

Table 4.7 Benefits of urban heat amelioration using GI.

Benefit	Primary relationship	Secondary relationship
Reduction of average summer temperatures using green infrastructure	Health benefits	• Reduction in high temperature related mortality • Reduced incidence of sunburn, skin cancer and cataracts
	Climate change mitigation	• Reduced cooling costs for building with appropriate shade trees around them, leading to lower power station CO_2 emissions • Carbon sequestration
	Social benefits	• Improved outdoor and indoor thermal comfort

Identified knowledge gaps

- The Bowler review noted that more detailed, statistically valid experimentation is necessary to get a better picture of the mechanisms by which vegetation cools the surrounding environment.
- The incorporation of urban parameters (including vegetation) into predictive weather models needs to be improved for the UK. A review of these models is currently under way (Grimmond *et al.*, 2009), and the SCORCHIO and LUCID projects may also address this issue.
- More work is needed on methods for valuing certain ecosystem services, including the cooling effects of urban GI.
- There is a lack of standardised land cover and land-use information for urban areas in the UK. Some private companies now provide this type of information, but it can be prohibitively expensive.
- More information is needed on suitable species for use in climate change adapted GI, such as heat and drought tolerance, resistance to frost damage and other physiological characteristics.
- The Read (2009) report on forestry and climate change notes that most local authorities do not have basic inventory data for their urban trees and woodland. The report goes on to suggest that this information gap should be looked at urgently, and that any data collected could be added to the Forestry Commission's National Inventory of Woodland and Trees.
- Right tree, right place principles should be followed for all green infrastructure (Greater London Authority, 2010b).

4.2.4 Environmental and aesthetic quality

Introduction
According to Green Infrastructure North West (undated) the value of GI includes *inter alia* providing a setting for:

- improved regional image and a local sense of place
- landscape character and local distinctiveness
- social inclusion, education, training, health and well-being
- safeguarding and enhancing natural and historic assets.

Inherent in the delivery of these benefits is 'quality', specifically the quality of the place; and a key component to the quality of a place is its environmental quality. See Chapter 5, Section 5.2.2 for a broader discussion of quality of place.

Khattab (1993) notes that environmental quality has two main components: (1) physical environment and (2) perceived environment. The Bartlett Report (CLG, 2007) develops this idea, noting that the concept of local environmental quality is broad; it can encompass tangible elements such as cleanliness and personal security and less tangible concerns such as visual quality and environmental pollution. Walker *et al*. (2003) in their research to improve the understanding of the relationship between environmental quality and social deprivation defined environmental quality relative to three domains: flooding, integrated pollution control sites and air quality. Thus, in respect to GI, environmental quality can be thought of in terms of:

- the environmental quality of a GI component, including such measures as cleanliness at a park or woodland;
- the impact of the GI on the quality of the wider physical environment, including such measures as pollution levels and flooding.

The literature reviewed in this section includes publications on site-based assessments of GI quality (encompassing physical and perceived quality measures) and provides a discussion on aesthetics and landscapes. The benefits GI has with respect to its impact on the quality of the physical environment is described in sections elsewhere in this report: 4.2.1 Improving air quality; 4.2.2 Sustainable drainage systems; 6.2.2 Flood alleviation; and 6.2.3 Water quality.

Definition of the environmental quality of GI
An explicit definition of environmental quality was not found during the review of literature to prepare this report. However, an understanding of environmental quality is implicit in the literature, in measurement programmes and award schemes. For example, Dunnett *et al.* (2002) refer to environmental quality as including issues such as litter, graffiti and vandalism; the Bartlett Report (CLG, 2007) describes local environmental quality with respect to 'clean and tidy, accessible, attractive, comfortable, inclusive, vital and viable, functional, distinctive, safe and secure, robust, green and

unpolluted, fulfilling (see Appendix 3, Table 1); and the RCEP report (2007) on 'The urban environment' described local environmental pollution in the context of 'nuisance', specifically noise/noise pollution, light pollution, litter and graffiti. In each case, these reports describe environmental quality in terms of the list of parameters considered. Thus, the environmental quality of GI may encompass any constituent part or combination of: aesthetic quality (including cleanliness and maintenance), perception (including fulfilling function/purpose, safety and security) and pollution.

Environmental quality should not be confused with the term environmental equity (also known as environmental justice), which is concerned with the distribution of environmental quality. More specifically, environmental equity is concerned with how environmental bads (such as pollution) and goods (such as access to GI) are distributed across society and with the equity of environmental management decision-making. Environmental equity is concerned with the distribution of the environmental quality of GI across society, rather than definition or measurement of the environmental quality of GI *per se*. Similarly, environmental quality should not be confused with environmental equality, which is concerned with the unequal distributions of GI and GI quality across society. Like environmental equity, environmental equality is concerned more with national geographic distribution and how this maps to demography, than with the definition or measurement of the environmental quality of GI. Whereas the environmental quality of GI may be recorded, for example, through the award of a Green Flag (see below), environmental equity and equality are concerned with the distribution of Green Flag Awards and whether these map equitably and equally, irrespective of social deprivation.

Measurement of the environmental quality of GI

A number of monitoring programmes that encapsulate a range of these domains are active across the UK:

1. The Green Flag Award is the national quality standard for parks and green spaces. Green Flag is a voluntary scheme which recognises the perceived quality of individual sites, rather than the quality of service of regional/local green space delivery. There are over 1000 Green Flag Award parks (Green Flag Award, 2009). The eight criteria of the Green Flag Award scheme are: a welcoming place; healthy, safe and secure; clean and well maintained; conservation and heritage; community involvement; marketing; management; sustainability.
2. GreenSTAT (developed by GreenSpace) assesses user satisfaction with parks and green spaces and (in a limited way) parks services. Originally funded by the Heritage Lottery Fund to obtain comparable visitor surveys, GreenSTAT uses a questionnaire that is sufficiently generic to apply nationally, and was based upon a review of around 60 forms previously used by local authorities. GreenSTAT is a subscription-based on-line database, analysis, benchmarking and networking system for assessing user satisfaction with management and maintenance of parks and green spaces. The

questionnaire can be used face-to-face, or via postal and telephone surveys. GIS functionality and postcode mapping will be added in the future. A report for the London Parks Benchmarking Project Steering Group (TRL, 2007) stated that GreenSTAT is currently used by 85 local authorities with approximately 25 000 park-specific responses to date plus 2500 for the service questionnaire.

3. GPMS (Greenspace Performance Management System) is a survey developed by the private consultancy KMC in response to a perceived demand from local authorities to assess park use. The survey uses two questionnaires (adult and junior – where adults are asked to pass this on to children in the household). Respondents complete the questionnaire based on the specific park they use most frequently. Questionnaires are sent to around 10% of the adult population within a local authority and surveys are sent out at the same time each year. A report for the London Parks Benchmarking Project Steering Group (TRL, 2007) stated that KMC GPMS Survey currently has 20 users. It has been used by 30 local authorities and 12 housing associations and 600 000 surveys have been distributed with 90 000 responses (15% response rate; information to 2007).
4. The Index of Multiple Deprivation (IMD) is a measure of multiple deprivation at Super Output Area level. The IMD has seven domains: crime; education, skills and training; employment; health and disability; barriers to housing and services; income; and living environment. The living environment domain contains measures for the ‘indoors’ living environment (specifically social and private housing in poor condition; and houses without central heating) and the ‘outdoors’ living environment (specifically air quality and road traffic accidents involving injury to pedestrians and cyclists). As such it is not an environmental quality measure applicable to GI.
5. Keep Britain Tidy (formerly known as ENCAMS) is an environmental charity that provides an independent survey of local environmental issues. The survey uses 32 indicators covering 10 aspects of environmental quality assessed on a 4-point scale (including litter, dog fouling, detritus, weeds, fly-tipping, fly posting, graffiti, physical appearance: collectively referred to as ‘cleanliness’). Surveys provide information on ‘cleanliness’ in each local council area in England: on the street, in parks, in town centres and other public places. Keep Britain Tidy data are used as a basis for BV199.
6. The Best Value Performance Indicator 199 (BV199) provides a recognised methodology for assessing standards of maintenance and cleanliness (www.leq-bvpi.com). BV199 forms the basis of SD65, described below.
7. The national Sustainability Development Indicator 65 (SD65) reports ‘local environmental quality’ based on the Keep Britain Tidy data. Related SD indicators include numbers 60: Environmental equality (populations living in areas with, in relative terms, the least favourable environmental conditions); 61: Air quality and health (annual levels of particles and ozone, and days when air pollution is moderate or higher); 66: Satisfaction in local area (percentage of households satisfied with the quality of the places in which they live (a) overall, (b) in deprived areas).

One difficulty in defining environmental quality as constituent parts is that public space users find it difficult to see the local environment as component parts, because they do not think in that way (CLG, 2007). Instead, they take a holistic view and equate environmental quality directly to broad socio-physical constructs, such as community and place. Furthermore, levels of acceptability are dictated by public expectations, and these can differ with context. In some affluent areas, a lack of complaints can signify levels of satisfaction, whilst for many communities levels may not be satisfactory but, at the same time, may not be so unacceptable that they are driven to complain (CLG, 2007).

Within its report to Communities and Local Government, the Bartlett report records a hierarchy of local environmental qualities (CLG, 2007). The research demonstrated that there was not a single quality that respondents regarded as unimportant, but that each quality contributed to a good environmental quality in a complex and mutually reinforcing way. Nevertheless the following qualities were regarded as particularly significant: 'safe and secure', 'clean and tidy' and 'fulfilling', and it was clear that lower order concerns were not unimportant, simply lower priority. There was also an impression that some qualities related to the initial design of a green space and were therefore fixed (not open to influence); 'aesthetic quality' and 'distinctiveness' fell into this category. Although it was recognised that such aspects contributed strongly to the sense of space, and that although residents either liked them or not, they did not feel able to change them, therefore such concerns were generally given lower priority.

Aesthetic quality

An important aspect of environmental quality of an area is the aesthetic quality. The visual appearance and attractiveness of towns and cities is strongly influenced by the provision of green space (Tibbatts, 2002). Venn and Niemela (2004) noted that green space provides diverse benefits for cities and their inhabitants as they provide venues for recreation, places to experience nature, and they improve the quality of the urban environment. As urban areas become increasingly developed there is the need to ameliorate unmanaged green space in order to maintain urban biodiversity and contribute aesthetically to the town's or city's image (Venn and Niemela, 2004). Parks and green space are important components of urban regeneration and neighbourhood renewal schemes and can influence decisions in locating businesses and new homes (Tibbatts, 2002). Companies are attracted to locations that offer well-designed, well-managed public places and these in turn attract customers, employees and services. In town centres, a pleasant and well-maintained environment increases the number of people visiting retail areas, otherwise known as 'footfall' (CABE, 2005). Improving a local landscape increases people's enjoyment of an area (Venn and Niemela, 2004). Some urban green spaces are too small to be of significant recreational value, yet can provide aesthetic value to housing developments (Countryside Agency, 2005).

There are a number of factors that determine the placement of trees and thus their aesthetic contribution to the urban area, including environmental conditions, soil characteristics and maintenance requirements (Wu *et al*., 2008). Arnold (1980) advises the use of rows and symmetrical units in urban design and grouping trees in a variety of settings in order to provide the greatest aesthetic effects. Non-native species can be valued for cultural and aesthetic reasons, however new planting schemes must be appropriate and prevent the unnecessary spread of invasive non-native species (Doncaster County Council, 2007).

Areas of well-maintained, attractive green space are sought after in urban areas. According to research by The Countryside Agency (2005) the highest rated aspirations of residents are for local provision of amenity green space that is clean and litter free and have:

- clearly marked footpaths
- well-kept grass
- adequate lighting, and
- level surfaces and good drainage.

A well-managed green space site should have landscaping in the right places in order to provide a spacious outlook and to enhance the appearance of the local environment (Countryside Agency, 2005). The benefits of an aesthetically pleasing attractive urban landscape environment include: increased inward economic investment; increased property values; attraction of tourists; improved area image; more people spending more time in the area and improved flow of local money (Cousins and Land Use Consultants, 2009). Also, a high level of aesthetic quality is a sign of care in the urban environment, which shows care within the community. This is likely to lead to community cohesion and increased feelings of safety for residents (Jorgensen *et al.*, 2007) and a sense of community from which all the other defining elements of good environmental quality emanate (CLG, 2007).

Fairburn and Smith (2008), in their report on environmental justice in South Yorkshire, argued that the most deprived populations were more likely to be living in areas of low environmental quality, measured relative to flood risk, waste management sites, landfill sites, industrial air pollution and air quality, and proximity to local nature reserves and woodland. Individual households were classified using the Index of Multiple Deprivation. The project outputs allowed South Yorkshire to be mapped for environmental inequalities at the most detailed level possible. As a result of mapping it was possible to target locations for area-based interventions. Key concluding remarks of the study included calls for new policies to address inequalities in the distribution of environmental quality, including changes in regulations and procedures for siting facilities. The study remarked that such changes would need to be addressed through the planning system, possibly through the use of regional spatial strategies. The study noted that deprived communities were more likely to be situated on a floodplain, though the evidence base was weak for this particular part of the study.

Status and trends in environmental quality

There is a lack of co-ordination over GI data holding in the UK. For example, CABE Space (2009) note that no single shared national information resource exists on green assets, their function, quantity, location, ownership or quality. Three government departments – Communities and Local Government (CLG), Department for Culture Media and Sport (DCMS) and Department for Environment, Food and Rural Affairs (Defra) – collect data on a wide variety of green spaces and their characteristics, yet these are not co-ordinated to record information in a consistent way. Furthermore, quality assessments of green spaces (including KMC, Greenstat by Greenspace, Greenflag) are inconsistently applied across green space; KMC and Greenstat also require subscription membership. This lack of co-ordinated information limits any ability to plan or manage green infrastructure strategically and has forced regional approaches, such as the 'public benefit recording system' (www.pbrs.org.uk/) used in the northwest of England. PBRS is used in the selection of derelict sites for regeneration and during the development of green infrastructure to ensure strategic planning that provides economic, social and environmental benefits.

An example of an England-wide dataset on green spaces is MAGIC (http://www.magic.gov.uk/), which was the first web-based interactive map service to bring together environmental information from across government. However 'MAGIC' is still predominantly rural.

CABE Space (2009) commissioned research to accurately establish the current state of urban green space in England, the extent to which people living in urban derived areas experience a poorer quality of environment, and the potential benefits and significance of addressing this. The research suggests a new way of valuing our parks which takes better account of the financial value they bring to society. The project builds upon previous research that has demonstrated that many people in urban areas do not have good access to green space and that this is particularly true of people in deprived areas (NAO, 2006).

Scale of change required to deliver environmental quality

There is some evidence that poorer communities suffer from the poorest quality of environments. Deprived neighbourhoods experience more severe problems regarding graffiti, litter and fly-tipping and poorly managed and maintained public and open spaces (Hastings *et al*., 2005). In turn, neglected spaces negatively impact on their surrounding areas contributing to the onset of vandalism, anti-social behaviour and graffiti and littering (CABE Space, 2005). Under the Sustainable Communities Plan (ODPM, 2003) government policy has sought to improve neighbourhood liveability by making them cleaner, safer and greener, and giving them a quality of 'place'. The plan also aimed to address environmental inequalities, i.e. the disparity in quality between different locations.   The literature review has demonstrated that to increase environmental quality there needs to be a measurable increase in cleanliness, which is linked to a number of anti-social characteristics: fly-tipping, littering, allowing dogs to foul footpaths. The scale of change is more than an increase in resources to local authorities to tackle/clean-up uncleanliness, it seems to require a grass-roots level shift in attitudes and perceptions of places. In the words of the Bartlett report (CLG, 2007) 'a sense of community [is] critical to achieving local environmental quality'; if sense of community is strong, everything else falls into place. To support these findings, a greater understanding of how to develop 'sense of community' and how to raise perceptions of the 'quality of place' is needed.

Forestry Commission England is actively seeking to address the imbalance of green space accessibility in the UK, by increasing the availability of accessible woodland to priority populations from 62% to 66% between 2008 and 2012 (Forestry Commission England, 2008). This would increase accessibility to over 750 000 people from the total priority area population of 19.2 million. The strategy is commendable in the sense that: 1) it targets delivery at 'priority populations', 2) it required a baseline of accessible woodland to be established in order to target delivery; and, 3) it makes an important contribution to wider targets of green space accessibility and supports Natural England's accessible natural green space standards. A baseline of accessible 'green space' is still required across England to target GI delivery more broadly.

The Greenflag award scheme has been implemented to benchmark and reward green space in the UK (NAO, 2006). Under Public Service Agreement 8, a target has been set that 60% of local authorities nationally, and 60 per cent of Neighbourhood Renewal Fund areas, should have at least one park or green space of Green Flag Award standard by 2008. According to the NAO (2008), this target is likely to be met, as 56% of local authorities nationally and 71% in NRF areas had at least one green flag award park or green space. However, in order to meet this target with certainty, the total number of green spaces that are potentially eligible needs to be better quantified. There remains a major gap in the information that is publicly available about England's green spaces, despite numerous calls for a single co-ordinated national database on green space location, numbers, quantity, ownership, function, type and quality (e.g. Dunnett *et al*., 2002; CABE Space, 2005; NAO, 2006).

Methods and tools for quantifying and valuing environmental and aesthetic quality

Table 4.8 shows toolkits that are used to assess the value of green space assets.

Table 4.8 Valuation toolkits for trees, green spaces and green space assets.

Name	Region	Detail
Confirm	New Zealand, Australia, UK.	An infrastructure management software system that enables the management of: roads and other highway infrastructure; property; parks; trees; refuse collection and waste management; and streetlights. Has an asset management module that can log what and where an asset is, and any work that has been completed on it. It can calculate the asset value using any formula required, such as historic cost, replacement value. Used extensively for highways asset management planning. No UK customers have purchased the asset valuation module for parks and green spaces.
Staysafe	UK	Software derivative of Playsafe: playground asset management and inspection software. Can calculate the capital value of each item held on the asset inventory. Used to identify and report faults and specify how caused. Used to generate work schedules for the park service providers.
EzyTreev	UK	A tree management system that records the condition and full history of a tree including enquiries and work undertaken. Information linked to digitised map. Can be used to generate valuations using a simplified version of CAVAT.
Yardstick	New Zealand, Australia	An annual survey which local authorities subscribe to and participate in. Information collected includes: levels of service; finance; best practice; asset management; and policy and planning. Information used to review service levels and financial performance; assist in policy development, promote park standards, identify best practice.
Towards an excellent service (TAES)	England	A diagnostic tool for green space management organisations to accurately define performance against a model of best management practice. TAES improves user satisfaction, staff satisfaction, efficiency of delivery for user needs. TAES covers: standards of service, use of resources, policy and strategy, leadership, performance management and learning, people management, partnership working and community engagement.
The Helliwell system	Adopted by the Tree Council in 1974	System for visual amenity valuations of trees and woodlands. Valuation of trees based on: – a tree's size, location, suitability, life expectancy, shape and proximity to other trees – woodland size, position, viewing population, proximity to other woodland, structure, compatibility. Overall score equates to a monetary value derived from the cost of purchasing extra large trees, linked to the retail price index.
Capital asset value for amenity trees (CAVAT)	England	System for managing publicly owned trees; accounts for value of trees as public assets. Developed by London Tree Officers' Association (LTOA) to value trees in relation to insurance claims for tree-root damage. Derived from the USA's Council of Tree and Landscape Appraisers 'trunk formula'. Trees are assessed on four variables: – basic value/size (based on trunk area, nursery prices and planting costs) – functional value/functional status – adjusted value/individual factors (location, amenity value and appropriateness) – full value/life expectancy.

Despite their integral role in creating and sustaining pleasant places, green spaces remain invisible assets on local authority registers (CABE Space, 2009). CABE Space (2009) proposed a new way of valuing parks that takes better account of the financial value they bring to society. The valuation approach proposed a dual measure:

- Tangible value: financial cost of replacing the park from scratch, including all the facilities and infrastructure (unit: £)
- Intangible value: defined as the annualised park user number (unit: number of visits)

There is little information to quantify the economic impacts of improved aesthetics directly; and there is a risk of double-counting, because a large part of these impacts will be through recreation and tourism (Defra, 2007a). Economists use 'choice' experiments to determine individuals' preferences for the attributes of an area of green space. This is achieved through a questionnaire framework where respondents are asked to make choices on attributes based on their preferences and different levels of those attributes. If one of these attributes is price, then the respondents' willingness to pay for the other attributes can often be inferred and distinction can then be made on the aesthetic value of a landscape (GLA, 2003). A weakness in such an approach is that value may be greater than the sum of the parts, and the approach does little to give insight into the 'combined value' of more than one improvement. Table 4.9 shows the economic value of improved environmental and aesthetic quality in monetary terms.

Table 4.9 Economic valuation of improved environmental quality and aesthetics.

Economic valuation	**Monetary value**
Increase in house price arising from a regeneration	£4.2 billion, UK (Cousins and Land Use Consultants, 2009)
Glasgow: benefits arising from green improvements	Benefit: 15% increase in business, £1m investment over 8 years Benefit: 50% increase in house prices, increase land value, increase council tax, increase £4.7m over 8 years (Cousins and Land Use Consultants, 2009)
Sustainable communities documentation	£22bn investment required to improve housing and communities including over £5bn to regenerate deprived areas. £201m to improve local environment – parks and public spaces (ODPM, 2003)
CABE publication	£41m investment for redesign purposes (CABE, 2005)

Relationships between improved environmental and aesthetic quality and other benefits of GI

Table 4.10 shows the relationships between improved environmental and aesthetic quality and other benefits of GI.

Table 4.10 GI benefits of improved environmental quality.

Benefit	Primary relationship	Secondary relationship
Improved aesthetic quality [helps deliver: Sustainable Communities (ODPM, 2003), National Strategy for neighbourhood renewal (ODPM, 2001)]	More attractive environment provides increased appeal to potential users Increased in value of surrounding land	Increased health of users arising from more frequent use Elevation in house prices and potentially an influx of new business
Reduced litter and fly-tipping [helps deliver: Living Places (ODPM, 2002) and Strong and Prosperous Communities (CLG, 2006)]	Safer environment for users Safer environment for wildlife inhabiting the site	Increased user numbers / frequency of use and range of uses
Reduced levels of dog-waste [helps deliver: cleaner, safer, greener 'Living Places' (ODPM, 2002)]	Increased appeal to users and potential users Decreased risk of *Toxocara canis** infection to GI users (*the dog roundworm which can lead to blindness in children)	Increased levels of use Reduction in reported cases of and treatment for Toxocara canis/ improved child health
Improved air quality [helps deliver: The Air Quality Strategy (Defra, 2007b)]	Improved physical health of users and local residents	Reduction in treatments for ill-health
Improved water quality [helps deliver EA: Water Framework directive)]	Improved aquatic biodiversity	Improved associated land biodiversity Increased in site use for the purpose of wildlife watching
Improved soil quality / reduction in land contamination [helps deliver: National Brownfield Strategy (English Partnerships, 2006)]	Reduced risk of contact between contamination and receptors Improved vegetation growth Safer environment leads to increased use	Increased biodiversity value of site Increased health and well-being of users
GI benefits of improved aesthetic quality		
Improved image/landscape [helps deliver: Sustainable Communities (ODPM, 2003), National Strategy for neighbourhood renewal (ODPM, 2001)]	Improved quality of place/ cleanliness	Increased business investment in the area Higher house prices - further housing development
Increased sense of pride of place [helps deliver: Sustainable Communities (ODPM, 2003)]	Improved feelings of safety/ improved perception	Increased usage of GI
Reclaimed brownfield land [helps deliver: National Brownfield Strategy (English Partnerships, 2006)]	Land no longer derelict Land no longer vacant	Reduced crime and vandalism Reduced anti-social behaviour Reduced fly-tipping
Reduced stress and other psychosocial factors	Increased health	People active for longer periods of time

Identified knowledge gaps

The literature review revealed the following knowledge gaps.

- Accepted definitions (working understanding) of broad concepts such as environmental quality and quality of place, from which measurements of quality can be defined and monitored.
- The relationship between physical (e.g. asset) or perceived value, quality and use is complex and not fully understood. The relationship may differ for constituent components of GI.
- Understanding of the term 'value': users and non-users of GI may place different values on the constituent components of GI. Similarly, people may value GI differently according to their own background, cultural perceptions, experiences or extent of GI available to them. Understanding how people value GI will help elucidate the extent of benefit afforded by it.
- The true value of maintaining constituent components of GI is not known. This is due to the lack of comprehensive data on expenditure spent on GI and differing organisational accounting strategies, e.g. local authorities.
- Lack of understanding of the relationship between capital and revenue expenditure and ensuing quality of the GI, plus the lack of provision within capital awards for the on-going revenue requirements to maintain value.
- The information necessary to compile green space asset inventories is available, but is yet to be done in a way that fully represents the value of GI.
- Walker *et al*. (2003) noted that, whilst there has been a general recognition that deprived communities are likely to experience disproportionate levels of pollution and other forms of environmental degradation, the evidence-base for policy development has been, and is still, lacking. Their findings arise strongly from a literature review focusing on eight environmental issues that found a limited research base in the UK, with only work on air quality, industrial emissions and wastes providing more than two studies.
- Studies on environmental quality and equity are limited by the quality and resolution of source datasets, the spatial scale of analysis and the complexity of real-world environmental variables. Greater consistency in spatial datasets is required.
- Economic valuation data for provision of green space for increasing aesthetic quality in the UK is absent.
- Objectives to increase aesthetic quality across the UK have not been set.
- The literature makes it clear that the quality of GI is important to people's perception and use of GI. The literature does not make a clear distinction between the value of different types of green space for amenity, or for environmental improvements.
- Woolley (2003) illustrated that water, vegetation and places to hide are elements which are important for child's play; green spaces are useful in providing each of these. There is a need to examine further the influence of GI design on the needs of different types of children, including those with special needs, noting the role of environmental quality in providing quality design.

- A proxy measurement of the environmental quality of green spaces may be expenditure on maintenance/upkeep. NAO (2006) noted that there was no direct correlation between the number of Greenflags awarded to a district and residents reported satisfaction with their green spaces. Research is required into the differences between quality awards based on professional judgement and canvassed local views.
- A review of local environmental quality indicators and methodologies is needed, along with a review of the institutional structure of those organisations responsible for applying and reporting the indicators. The knowledge will help homogenise data collection, comparison and, potentially, formulation of a standard measures for environmental quality.
- The Bartlett report (CLG, 2007) noted that levels of 'acceptability' for local environmental quality are dictated by public expectations, which differ with context, as well as by levels of resource and consultation. It is unclear what 'acceptable' levels are, and how these can 'acceptably' change between different types of green space and different communities.

Appendix 3

Table 1 Positive local environmental qualities (after CLG, 2007).

Qualities	Description	Issues/elements
Clean and tidy	Well cared for	Clear of litter, fly tipping, fly posting, abandoned cars, bad smells, detritus and grime; adequate waste collection facilities; provision for dogs
Accessible	Easy to get to and move around	Ease of movement, walkability; barrier free pavements; accessible by foot, bike, and public transport at all times; good quality parking; continuity of space; lack of congestion
Attractive	Visually pleasing	Aesthetic quality; visually stimulating; uncluttered; well-maintained paving, street furniture, landscaping, grass/verges, front gardens; clear of vandalism and graffiti; use of public art; co-ordinated street furniture
Comfortable	Comfortable to spend time in	Free of heavy traffic, rail/aircraft noise, intrusive industry; provision of street furniture, incidental sitting surfaces, public toilets, shelter; legible; clear signage; space enclosure
Inclusive	Welcoming to all, free, open and tolerant	Access and equity for all by gender, age, race, disability; encouraging engagement in public life; activities for young people; unrestricted
Vital and viable	Well used and thriving	Absence of vacant/derelict sites, vacant/boarded up buildings; encouraging a diversity of uses, meeting places, animation; availability of play facilities; fostering interaction with space
Functional	Functions without conflict	Houses compatible uses, activities, vehicle/pedestrian relationships; provides ease of maintenance, servicing; absence of street parking nuisance
Distinctive	A positive, identifiable character	Sense of place and character; positive ambience; stimulating sound, touch and smell; reinforcing existing character/history; authentic; individual
Safe and secure	Feels and is safe and secure	Reduced vehicle speeds, pedestrian, cyclist safety; low street crime, anti-social behaviour; well lit and surveilled, availability of authority figures; perception of security
Robust	Stands up to the pressures of everyday use	High quality public realm, not repeatedly dug up; resilient street furniture, paving materials, boundaries, soft landscaping, street furniture; well-maintained buildings; adaptable, versatile space
Green and unpolluted	Healthy and natural	Better parks and open space; greening buildings and spaces; biodiversity; unpolluted water, air and soil; access to nature; absence of vehicle emissions
Fulfilling	A sense of ownership and belonging	Giving people a stake (individually or collectively); fostering pride, citizenship and neighbourliness; allowing personal freedom; opportunities for self-sufficiency

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5 Land regeneration

5.1 Introduction

The prospect of regenerating previously developed land to green infrastructure provides a wealth of opportunities. Vacant, derelict or abandoned spaces often become not only an eye-sore and a haunt for anti-social behaviour, but also a blight on the visual landscape and in the landscape of people's minds. Regeneration brings a new lease of life that impacts on local communities, as well as the environment and, in many cases, regional image too. In addition to the immediate benefit of a safer environment through the removal of contamination, waste and derelict buildings, regeneration transforms the aesthetic appeal, lending a new quality to the place. This, in turn, entices new users and a wider range of activities are enjoyed on site. Self-policing emanates as anti-social behaviour is deterred through increased user levels which, in turn, provide a growing sense of safety and security. New audiences welcome the safer site and its use diversifies further. Users and neighbours start to benefit from an improved quality of life as they use the site for physical exercise, or simply enjoy the connection with 'nature' or the way it has improved the landscape. Looking beyond the purely social impacts of land regeneration, the planting of trees, grasses and wildflowers and the creation of new habitats and, possibly, water features, lends support to the local wildlife and, if well planned, the biodiversity value of the site grows.

The regeneration of brownfield land to GI represents a prime opportunity to reverse the socio-economic legacy of industrial decline whilst ameliorating human and environmental health risks and offering environmental improvements through provision of quality open spaces and connected natural habitats. Yet there are challenges, including protecting and enhancing the inherent biodiversity value of a site prior to regeneration, securing revenue funding to maintain site quality, and ensuring that the regeneration delivers a GI desirable by the local community.

This chapter reviews the literature evidence for the benefits and wider impacts of land regeneration to GI. Three themes are followed: 'regeneration of previously developed land', 'quality of place, a sense of place', and 'economic benefits of GI creation', to provide a compelling case for land regeneration and the establishment of new GI, and to highlight where existing knowledge may be strengthened.

5.2 Critical review

5.2.1 Regeneration of previously developed land

Introduction to regeneration of previously developed land
English Partnerships, the national regeneration agency that is now part of the Homes and Communities Agency (HCA, 2010), defines 'previously developed land' (PDL) as: 'land which is or was occupied by permanent structures (excluding agricultural or forestry buildings) and associated fixed surface infrastructure'. The definition is often used interchangeably with the term 'brownfield land'. However, brownfield land may also refer to land and buildings that have redevelopment potential but have a physical or regulatory constraint to development. The term 'derelict, underused or neglected land' (or DUN-land) refers to former industrial sites, quarries, old railways, disused reservoirs and tips and is defined as 'land so damaged by industrial or other development that it is incapable of beneficial use without treatment'. For the purposes of this report, we use the term 'brownfield land' as a generic term which refers to all types of PDL and DUN-land (English Partnerships, 2006).

In 2007, there were an estimated 300 000 hectares of brownfield land in the UK, which present severe human and environmental risks through contamination (Dixon *et al*., 2007). This figure includes the *c*. 31 000 ha of land that are regarded as derelict, and *c*. 22 500 ha of land that is in use and considered to have redevelopment potential. The regeneration of brownfield land to GI represents a prime opportunity to ameliorate human and environmental health risks.

Contamination: an opportunity or potential constraint to GI establishment?
By virtue of its former use, brownfield land has the potential to be contaminated. Contaminated land is defined by Defra as 'any land which appears to be in such a condition, by reason of substances on, in or under the land, that: (a) significant harm is being caused or there is a significant possibility of such harm being caused; or (b) pollution of controlled waters is being, or is likely to be caused'. Contaminated land therefore poses a potential hazard to human health, threatens the environment and can limit development in urban areas. A risk-based approach has been adopted by Defra under Part IIA of the Environmental Protection Act 1995 to deal with contaminated land, whereby each pollutant linkage must be identified and the potential risk of harm to receptors quantified. The risk of harm is dependent on the 'source-pathway-receptor' pollutant linkage and a site is designated as contaminated if there is a significant risk of harm arising through the presence of all three elements (Alker *et al*., 2000). The constituent components of the pollutant linkage are defined as:

- A source is a substance or contaminant that is in, on or under the land and has the potential to cause harm, or cause pollution to controlled waters.

- A pathway is the route or means by which a receptor is exposed to, or affected by, a contaminant.
- A receptor is something that is adversely affected by the contaminant, for example humans, ecosystems or a water body.

Where this is a risk to human and environmental health, English planning law requires that the site must be remediated prior to re-use. Remediation must ensure the site is 'suitable for use', and the level of remediation is, therefore, dependent on the proposed new land use. Suitability for use requires representative site exposure data which undergo preliminary screening on the basis of contaminant concentrations compared to assessment criteria. If such a screening reveals contaminant concentrations higher than screening values then a full risk assessment based on the 'source-receptor-pathway' model is warranted. Models such as Contaminated Land Exposure Assessment (CLEA) are used to assess the human health risks of the site. The risks are determined based on average daily exposure (ADE) and health criteria values (HCV) which represent the concentration of contaminant that will pose a risk to humans. The environmental risks to controlled waters are determined using environmental quality standards (EQS) and ecological risks are determined against soil screening values, combined with ecotoxicological testing usually using 'indicator' species as proxies to specific species receptor groups. UK health policies advocate the remediation of brownfield land to green space in order to reduce negative human health inequalities (Thomson *et al*., 2006).

Alker *et al*. (2000) describe many good reasons to regenerate brownfield land and these include improving environmental quality (see also Section 5.2.2 Quality of place, and Section 4.2.4 Environmental and aesthetic quality) and environmental health. O'Riordan (2000) provides a compelling theoretical case for improving land conditions, demonstrating that improved environmental health helps prevent disease. Creating GI on a brownfield site can deliver significant environmental health benefits in both a preventative capacity and as a treatment to on-site pollution. The benefits can arise by limiting wind erosion of contaminated soils, reducing excess release of salts, physical/chemical or biological degradation of contaminants through the regeneration process, as well as reduced overland flow of water and improved infiltration. Benefits can include improving the condition of the soil, vegetation, surface waters (including culverts, sustainable urban drainage systems and ditches) and groundwater. Regenerating brownfield sites to GI will provide and improve local ecosystem services, yet provisions for ongoing maintenance are required to prevent secondary dereliction even after the vegetation has established (Handley, 1996; Perry, 2000). Under some circumstances, regenerated brownfield sites may offer the only opportunity to connect natural habitats.

Furthermore, increased public access to green space arising from the regeneration of brownfield land can provide the many indirect health benefits described in Section 3.2.1.

Integrated remediation and green space creation

Exposure pathways between receptors and sources of contaminants may include ingestion of soil, consumption of contaminated food and water, inhalation of dust and vapours, leaching of contaminants to controlled surface and groundwater, and skin contact with contaminated materials. The use of green space and woodlands to restore contaminated land has been proposed as a cost-effective remedial strategy for the redevelopment of contaminated land (Hutchings, 2002). An integrated approach to contaminant remediation and soil formation can be adopted for most situations, whereby plants are provided with their nutritional and structural requirements whilst contaminants are stabilised into forms which present no risk of leaching to surface or groundwater (Lynch and Moffat, 2005). Such stabilisation can also be used to significantly limit the uptake of contaminants by the vegetation itself, and so negate the risks of food-chain transfer. In the case of certain organic contaminants, soil conditions can be optimised to promote microbial breakdown of the contaminants in a process termed 'bioremediation' (Lynch and Moffat, 2005). The establishment of vegetation on contaminated sites can also break the pollutant linkage pathways by providing a physical barrier to the soil surface and in the subsequent prevention of soil erosion which minimises dust production (de Munck *et al*., 2008). The probable success and, therefore, the selection of a remediation strategy depends on the site characteristics, the contaminants present, the stakeholder opinions and the timescale. All of these factors are site specific (Doick and Hutchings, 2007; English Partnerships, 2006).

Wider benefits

Regenerating brownfield sites can bring significant benefit to biodiversity and Ling (2000) called for reclamation projects to recognise the importance of maximising a site's potential for diversity. Berger (2008) noted that without an evaluation of the natural resource, it is hard to design restoration works that improve ecological integrity and health. However, some brownfield sites already have a significant biodiversity value (Harrison and Davies, 2002; Morrison, 2007). When considering a parcel of land for regeneration, it is therefore important to consider the biodiversity that has already colonised the site. A range of protected species including many priority species of the UK Biodiversity Action Plan (UKBAP) are found on brownfield sites (see Chapter 7 Ecological benefits). Some of these species are specialists of the extreme conditions (e.g. of soil pH or metal concentration) that occur on some post-industrial sites. In addition, some brownfield habitats themselves are protected. There may be legal or policy requirements to protect such species and habitats (e.g. the Wildlife and Countryside Act). Even sites which do not have any protected habitats or species can still contain considerable biodiversity (Angold *et al*., 2006). Generally, the diversity of species on a site reflects both the habitat quality and diversity – having a range of habitats will usually ensure a greater number of species. To maintain that diversity after land regeneration requires careful planning of what habitats the site should contain after regeneration and how they will be created (PP9; ODPM: 2006).

Regenerating brownfield sites to GI offers the opportunity to provide a carbon sink whilst effectively breaking pollutant linkages. At Markham Vale, a former mining site with areas of elevated heavy metal and dioxin contamination, GI was created through the planting of willow species in a technique known as phyto-stabilisation. In addition to bringing stability to eroding mining waste tips (Edwards *et al*., 2005), the site has been transformed into a biomass plantation. The tree planting mitigated the pollutant linkage between the elevated contamination levels and acidity from the coal spoil and environmental receptors, such as the watercourse.

Case studies

An example of conversion of brownfield to GI is in the regeneration of the site of a former paper mill. Elevated levels of arsenic were remediated using acidic soil washing. A secondary impact of this treatment was degradation of the soil structure and reduced pH. Composts and paper sludges were subsequently used as soil amendments which helped to facilitate the growth of *Populus alba* (white poplar) and *Salix alba* (white willow) (Berger, 2008).

At Silksworth Colliery in Sunderland, pollution from acid drainage was brought to a halt following the regeneration of the site to create a town park. The site was responsible for extensive local contamination including contamination to air and water. Site regeneration work was completed in 1976 and made a significant contribution to the regeneration of the city (Cass, 2003).

The regeneration of many of England's deep and open cast coalfields occurred during the 1990s and earlier 2000s, bringing restoration to the landscape and opening up derelict land for new social benefit. For example, the South Yorkshire Coalfields Restoration project started in 2001. By the end of 2005, over 400 ha of brownfield land had been successfully restored with a mixture of woodland, grassland, bird-scrapes and water habitats (see http://www.forestry.gov.uk/landregeneration). In addition to the greening, the objectives of the project were to encourage community engagement, conservation management, social enterprise and commercial timber production. This project was funded by the regional development agency 'Yorkshire Forward', however in some instances the regeneration was funded through secondary mining. At Edlington Colliery high pressured water-jet washing of mining spoils enabled separation of coal residues. The new sites are co-jointly managed by the Forestry Commission and Doncaster Metropolitan Borough Council to deliver maximum community benefit.

The 'Riverside' in Liverpool was the site of a former 100 ha petrochemical works, docks and landfill site; issues at the site included heavy metal contamination and uncontrolled waste tipping. A large scale reclamation programme was undertaken from 1980 to 1986. Reclamation involved planting 250 000 trees and shrubs, amongst other works, which helped improve the environment along 3 km of the Mersey River. The site regeneration replaced severe dereliction with an attractive landscape (Cass, 2003).

Initial regeneration schemes do not always work out as planned and require subsequent re-restoration to deliver the benefits of GI (Sellers *et al.*, 2006). For example, Russia dock in Southwark, London. Developed as dockland in the 1600s, the site closed in 1969 as ships too large for the dock became popular. The site was developed as a green space in the 1980s by the London Docklands Development Agency. The restoration retained historical and cultural significance such as the old wharf edges, but then declined for many years following its opening due to a complicated maintenance regime (Sellers *et al.*, 2006). In 2003, Southwark Borough Council implemented a simpler 'sustainable' management plan following a £350,000 re-restoration. It is now a 20 ha linear green space, with planted woodland, areas of amenity grassland and water features. The site is punctuated by pathways that connect adjoining areas of housing and is well used by the local community.

The clean-up of the former chemical and dye works in Silvertown, near the London Thames Barrier, transformed the site into a formal park. The park is the centre piece in a sub-regional regeneration scheme and architectural masterpiece reminiscent of great French parks like Parc Citroën Cévennes in Paris (Holden, 2001). Thames Barrier Park has traditional uses; it is a place to walk, and to enjoy horticultural displays, impressive views of the Thames Barrier and refreshments in the visitor centre/café, yet it is also a wildlife haven with six different kinds of bumblebee identified in surveys, including rare varieties. The site is flanked by new housing and is a growing visitor destination for local residents and international tourists alike.

Belfield Community Woodland is one of eight developments in the North West created by the Forestry Commission as part of the Newlands scheme. The £1.75 million woodland project has given a new lease of life to 26 ha of underused land to the east of Rochdale town, sandwiched between the River Roch and the Rochdale canal. The previously fragmented sites form a green corridor between residential areas to the town centre. Improvements to the environmental quality include draining areas to make them more useable and a visible reduction in 'visual' pollution along the banks of the river, bringing existing woodlands into long-term management, planting trees on road corridors, improving pathways and fencing and restoring fishing lodges. The site is now cleaner and the transformation has increased people's sense of pride in the area.

At Moston Vale in Manchester, an area ranked in the top 5% on the index of multiple deprivation, £1.7 billion has been used to regenerate and re-landscape a former landfill site to improve the visual aspect of the site. The area had a rich industrial heritage during the early 1800s, used as a bleach works, dye works and number of paper mills. Moston Brook, which flows through the area, was so polluted it was known locally as Black Brook. The vale suffered indiscriminate tipping and was covered over to become an area of low grade, unattractive and neglected green space. Until the regeneration, fly tipping was an issue, and burned-out cars added to the overall state of neglect. The regeneration programme bought in 350 000 tonnes of soil to re-landscape the site and support planting of trees and the creation of wildflower meadows. The regeneration makes up part of the Newlands Project, one of the largest green regeneration schemes in the UK. In a recent survey, 94% of respondents agreed that the regeneration had improved the look of the area (Cousins and Land Use Consultants, 2009).

The Glasgow Green renewal project aimed to restore Glasgow Green to high environmental quality and improve negative perceptions of the area. Regeneration involved both the green space and its infrastructure and improved safety and lighting. The regeneration scheme increased house prices in the area by 50% and business in the area by 15% (Cousins and Land Use Consultants, 2009).

In Merseyside, the £1 million regeneration of Mesnes Park enabled re-landscaping and provision of recreational areas, woodland and wildflower meadows. Previously not formally open to the public, the site now attracts 180 000 people per year. Since the regeneration 530 new homes have been built and the park has played a part in attracting the investment for this development (CABE Space, 2005).

Scale of change required to deliver regeneration objectives

The Sustainable Communities plan of 2003 set a target for 60% of new housing to be constructed on brownfield land or through conversion of existing buildings, by 2020 (Alker *et al*., 2000; English Partnerships, 2006). In 2009, 72% of new development was being built on previously used land, exceeding the minimum density required (Barclay, 2009). However, in 2008 there were still an estimated 63 750 ha of previously developed land that was unused or available for redevelopment, an area approaching half the size of Greater London, and this is an increase of 2.6% since 2007 (Homes and Communities, 2010).

Many brownfield sites across the UK consist of low-demand and abandoned housing. Redevelopment provides an opportunity to improve and increase the supply of new, energy-efficient housing. Constraints to such development include:

- a lack of basic infrastructure and transport links
- difficulties in obtaining bank or institutional funding
- the costs of remediation and preparation of brownfield land
- potential physical problems of the site associated with previous use (English Partnerships, 2006).

Planning guidance for sustainable communities recognises the need to improve the built and natural environment in and around urban areas and rural settlements, including the provision of good quality open space (PPS 1; ODPM, 2005). Allied to Natural England’s access to natural green spaces standard (ANGSt) and the Woodland Trust’s woodland access standards (WAS), it is clear that there is strong support for access to good quality GI. (For these standards, see TCPA, 2008.)

The Land Trust (formerly the Land Restoration Trust; LRT, 2009) notes that there is still significantly more potential to regenerate brownfield land to GI in order to provide areas for redevelopment and to further reduce the human and environmental risks posed by brownfield sites. By 2005, the Land trust had restored 1500 ha of brownfield land and placed it under active management as public green space (LRT, 2009). Many elements of GI are in place, but its value lies in being networked. New skills are required to connect the different elements such as street trees, parks, gardens, woodlands, so that they work together as a functioning system (CABE, 2009). The regeneration of brownfield land presents a prime opportunity to make these connections.

Contaminated land policy

Until 1991, the derelict land grant was the main driver for regenerating derelict sites in the UK (Ling, 2000). The DETR Circular 02/2000 on Contaminated Land (DETR, 2000) explains the objectives in relation to contaminated land, one of which is to identify and remove unacceptable risks to human health and the environment. Planning Policy Statement 23 (PPS23) explains that 'opportunities should be taken wherever possible to use the development process to assist and encourage the remediation of land already affected by contamination'. PPS23 lists potential environmental benefits that may arise as a result of developing polluted land, such as the restoration of former habitats, enhancement or creation of habitats and remediation of past contamination.

Parks and green spaces are recognised as integral to the urban environment (ODPM, 2005; CABE Space, 2005) and best practice principles for green space creation on brownfield land have been advocated by, for example, CIRIA, the Forestry Commission and research consortia like SUBR:IM (Dixon *et al*., 2006; Forest Research, 2006). An underlying policy aim for promoting brownfield redevelopment is the environmental improvement of the sites themselves, as stated in Planning Policy Statement 3 (PPS3; DETR, 2000). PPS3 is overarched by PPS1, which set outs the requirements for planning policies on the delivery of sustainable housing. Supporting these objectives, an urban renaissance White Paper, published in 2000, proposes measures to provide incentives to regenerate brownfield land including accelerated tax credit to cover the costs of remediating the land, reduced landfill tax for soil and stones, tax relief for renovation of derelict or underused space, and a range of tax reductions for conversion of residential properties into flats or communal homes (English Partnerships, 2006). Redevelopment of brownfield sites to green space can be complex and may involve some risk to developers; however, planning guidelines such as the PPS3 suggest that local authorities should propose strategies for bringing previously developed land into use and, as such, work to support developers in delivering brownfield regeneration that is in line with local government objectives. Government policy has been captured in DETR's publication *Our towns and cities: the future – delivering an urban renaissance* in 2000 and subsequently the Sustainable Communities Plan which aimed to give priority to development of brownfield sites in order to ensure protection of the green belt (Communities and Local Government, 2003).

Legislation

The Environment Agency (2009) have championed calls for increased brownfield regeneration sustainability, by ensuring that environmental improvements form an integral part of the regeneration, and that the redevelopment should minimise effects on the wider environment through efficient resource use. Guidance as well as academic literature is still very open on how to assess the sustainability of brownfield regeneration to GI.

The reuse of brownfield sites as open space may be the only suitable solution for some brownfield sites which are situated in areas of high flood risk (Environment Agency, 2009). The Agency has called for revisions to PPG3 and PPG25 to require the application of the sequential flood risk test when the redevelopment of brownfield sites within flood risk areas is proposed (Environment Agency, 2009). It is argued that such revisions will help to ensure that development type matches the risk of flood. Funding brownfield regeneration for uses such as open space can offer long-term management solutions (including remediation) for land with contamination problems and help remediate sites where economic incentive for redevelopment or decontamination is low.

Funding

Funding restoration can be an issue and land is more likely to be restored if it is part of a larger programme (Dixon *et al*., 2007). In addition to the regeneration monies, funding is required for ongoing maintenance to ensure that the environmental benefits to air, land and water continue into the long-term, once the GI is created. At the Millennium Coastal Park, Llanelli in Wales, regeneration turned 520 ha of derelict industrial land into an environmental asset (Holmes, 2003). The park consisted of smaller sites which were contaminated with a range of heavy metals as a result of its industrial past, including coal and tin mining, copper smelting and iron making. The Millennium Coastal Park is an example of how creating GI on brownfield sites can lead to increased partnership working to deliver environmental improvements. The regeneration work has been described as transforming the site into a wildlife haven (Holmes, 2003).

Valuation tools and unit cost of benefit (economic valuation data)

The regeneration of contaminated land to green space can contribute to the local economy due to the increased aesthetics of an area which, subsequently, increases land values and can promote further investment in the area. At Bold Moss, the former Bold Colliery site near St Helens in Merseyside, derelict industrial land has been transformed into community woodland and nearly 600 new homes have been built. A report by the District Valuer found property values in the area had risen by £15 million as a direct result, and new developments worth £75 million had been attracted. Five beacon locations were identified in order to demonstrate this economic data and although there was considerable growth in the residential market in the UK between 1985 and 2004, generally across the St Helens area the growth trends have been much lower than has been found nationally. However, in locations closest to the Bold Colliery site, growth was higher than national trends (Forestry Commission, 2005).

The Capital Modernisation Fund (CMF) woodland programme developed 1500 ha of community woodland, approximately 40% of which was on brownfield land. In a recent review, this programme was demonstrated as value for money because average regeneration costs of £10,000 per ha revealed public benefits from woodland worth an estimated £4,000 per ha annually, plus the programme led to £460,000 worth of further funding (Forestry Commission, 2003).

Indirect economic benefits of brownfield land regeneration to green space are associated with reduced healthcare costs. The economic value of health benefits as a result of remediation arise from fewer hospital admissions and fewer premature deaths. The annual healthcare costs that were avoided by the Cycoed programme between 2001 and 2008 were calculated to be £815,000 (Forest Research, 2008). The calculation was based upon improved health due to the reduction in coronary heart disease, colon cancer and stroke. Additionally, the economic benefit associated with the number of lives saved was estimated at £85.2 million. Further economic health benefits from the development of green infrastructure can be found in Section 3.1.2. Table 5.1 presents the scale of economic input into a selection of regeneration programmes in the UK.

Table 5.1 Regeneration of brownfield land funding.

Programme	**Monetary input value to regeneration of brownfield land**
NWDA	£3.8 million (73 ha of woodland)
Regional Development Agencies	£350 million in 2002–03 £500 million in 2003–04
Coalfields programme	£800 million
Newlands	£59 million (435 ha of new woodland – phase 1: 2003-2009)
CMF (Capital Modernisation Fund)	£9.4 million (1000 ha of woodland)
Thames Gateway	£6 million £5.8 million (147 ha woodland)
‘Wasteland to woodland’ programme Groundwork	£4000/ha/pa BENEFIT
Forest Enterprise	£3 million (4000 ha)

Toolkits that support land regeneration to GI

- The Contaminated Land Exposure Assessment (CLEA) is the methodology for estimating the risks to people from contaminants in soil on a given site. It determines acceptable levels for contamination in soil below which the risks are considered minimal, under Part IIA of the Environmental Protection Act 1990.
- Examples of monitoring strategies that can be used for or in support of the assessment of urban regeneration include the Redevelopment Assessment Framework (RAF; Pediaditi *et al*., 2006), 'Prove it!' (NEF, 2000) and 'Methuselah: A Monitoring and evaluation strategy for green space' (Forest Research, 2009).
- Risk-based corrective action (RBCA) toolkit is a generic term for corrective action strategies that categorise sites according to risk, and move all remedial sites towards completion using the appropriate levels of action (Environment Agency, 2003a).
- Risc Human is a Windows-based computer tool that can be used to estimate human exposure to contaminants in soil, groundwater and sediment, and is a method for deriving site-specific human health assessment criteria for contaminants in soil (Environment Agency, 2003b).

Relationships between land regeneration to GI and other benefits of GI

The relationships between land regeneration and other benefits of GI are summarised in Table 5.2.

Table 5.2 The relationships between land regeneration to GI and other benefits of GI.

Benefit	Primary relationship	Secondary relationship
Reclaimed brownfield land [helps deliver: National Brownfield Strategy (English Partnerships, 2006)]	Increased aesthetics Improved cleanliness	Quality of place Increased sense of pride of place
Land no longer derelict Land no longer vacant [helps deliver: National Brownfield Strategy (English Partnerships, 2006) and Sustainable Communities (ODPM, 2003)]	Reduced anti-social behaviour Reduced fly-tipping	Improved feelings of safety Reduced site management charges
Land bought into active management [helps deliver: Sustainable Communities strategy (ODPM, 2003)]	Improves quality of place	Improved quality of life
Contamination reduction [helps deliver: Contaminated Land (England) Regulations 2000 – compilation and maintenance of a register of contamination land]	Reduced risk to human health Reduced risk to environmental receptors	Increased use
Preservation of soil resource/ improved quality of soil [helps deliver: Safeguarding our soils (DEFRA, 2009)]	New habitats	Improved biodiversity
Access to GI [helps deliver: Access to Natural Greenspace Standard (ANGSt) developed by English Nature and used in PPG17]	Increased social use Increased use for exercising	Increased community cohesion Increased health
Create new habitats [helps deliver: UK's Biodiversity Action Plan commitments]	Increased habitat cover	Promoted/increased biodiversity Increased opportunities for wildlife watching

Identified knowledge gaps

- There is little evidence of the impact of national urban regeneration investment on socio-economic or health outcomes. Where impacts have been assessed, these are often small and positive but adverse impacts have also occurred. Impact data from future evaluations are required to inform healthy public policy; in the meantime work to exploit and synthesise 'best available' data is required (Thomson *et al.*, 2006).
- The identification of successes and shortfalls in green space establishment projects is paramount for assessing whether projects have met their primary objectives. There is the need for quantitative and qualitative toolkits to evaluate the impacts associated with regeneration projects. Conclusions with respect to project and site sustainability must be drawn (Pediaditi *et al*., 2006), yet it is not clear how this can or should be achieved. This knowledge gap is meritable for land regeneration to new hard-end uses as well as to soft-end uses such as GI.
- Treatment of contaminated soils using stabilisation/solidification techniques is proven to manage pollutant linkages. However, there is limited research or published case studies into long-term performance of stabilisation/solidification materials where the technique has been used on sites for GI (CL:AIRE, 2005). Research is needed to clarify long-term trends and potential impacts of climate change on performance.

5.2.2 Quality of place, a sense of place

Introduction to quality of place

Quality of place is defined as the physical characteristics of a community that affect the quality of life and life chances of people living and working in it (Cabinet Office Strategy Unit, 2009). The core elements to quality of place are:

> 'the range and mix of homes, services and amenities in a community; the design and maintenance of buildings and spaces; the treatment and use made of historic buildings and places; the provision of green space and green infrastructure.'

Provision alone does not guarantee quality of place; compounding factors include GI type, quantity and quality, as poor quality green space can negatively affect local activities and business, undermining an area's image and the confidence of both local inhabitants and potential investors (Land Use Consultants, 2004). Another layer of complexity comes from personal and cultural preferences to GI and green spaces *per se.*

This review looks at the evidence that green space and GI provision has made a positive contribution to quality of place especially that made through land regeneration.

Evidence

Manor Estate, Sheffield

In a recent report, CABE (undated) case studied tackling neighbourhood-scale multiple deprivation through multifunctional GI at Manor Estate, Sheffield. In 1996, the *Guardian* newspaper reported that the Manor Estate in Sheffield, home to some 20 000 people, was the 'worst estate in Britain', but not for a lack of provision of open green space. Six hundred hectares of mixed open space were neglected, purposeless and viewed as a liability. In 1999, two organisations partnered to take a fresh look at the open space through the eyes of residents and secured £2 million from the single regeneration budget and developer contributions. The project is widely regarded as a monumental success because of its wide range of positive social and economic impacts that all contribute to a new sense of place. Its delivery to quality of place includes cleaner safer green spaces and landscape-scale changes including sustainable urban drainage, naturalistic playgrounds and green waste processing. However, a more radical and sustainable change was needed for a lasting impact, including evolving the Green Estate programme into a social enterprise. Green Estate Ltd is now a £1.8 million turnover business, employing 38 people, and guardian of the Manor Estate GI vision. Yet, the company's business relies on offering services to other areas further afield and bringing the benefit back to the area. The case study highlights the ongoing financial constraints of delivering and maintaining quality GI and, without central funding, the need for more innovative business opportunities to improve other green spaces beyond Manor Estate.

Street trees improve quality of place

Street level quality of place improvements have been reported by Newlands working in association with their local Community Forests (Pathways, 2009). 'Newlands', a Northwest Regional Development Agency funded programme, is reclaiming large areas of brownfield land across England's Northwest and transforming it into thriving community woodlands (http://www.newlandsproject.co.uk). Newlands initiated a Green Streets project (see Green Streets case study) aimed at improving the standard of living in urban areas with high levels of poverty and deprivation and enhancing green infrastructure by planting 600 street trees across 10 locations in Merseyside, Manchester and Salford. Respondents to a project evaluation questionnaire included comments such as 'it's made the area prettier and more welcoming' and 'it's just nicer… I'm not scared as much' demonstrate personal appreciation of changes to quality of place. The £300,000 project received £533,135 in match funding, from the European Union and local authorities. Average unit all inclusive costs to plant a tree were: Salford £2,075, Manchester £1,607; Mersey £902 (overall normalised mean: *c.*£1,290). Key implications in costs were:

- Variations in specification per street
- Quantity of work required to plant trees
- Variation in tree protection
- Compliance with local authority specifications and processes
- Level and timing of securing match funding.

The Mayor's Street Tree Programme has targeted 40 priority areas around London to plant an additional 10 000 trees over the Mayor's four-year term. The trees (average unit cost approximately £420) are being planted in some of the most disadvantaged areas of the capital, those which already have very few trees. Local residents have responded very positively to the planted trees when asked; comments included 'they're great', 'we need more of them' and 'they really improve the streets around here'. However, community involvement increases the unit cost of street tree planting considerably and therefore because most of the planting is handled via local authority term contractors in London, as opposed to charities or Non-Governmental Organisations (NGOs), the unit cost is much lower than elsewhere (Forestry Commission, 2010).

Cydcoed, Wales

Cydcoed was a £16 million programme that gave 100% grants from an EU Objective 1 programme to 163 community groups across West Wales and the Valleys region. The programme was primarily aimed at the most deprived (as classified in the Wales Index of Multiple Deprivation) and communities where the population has no access to community green space for relaxation and exercise. The core objectives of Cydcoed were to use community forestry to deliver a wide range of long-term social, economic and environmental benefits, through improved quality of places.

An evaluation of the Cydcoed programme (Forest Research, 2008) highlighted many of the ways that new community woodlands contributed to quality of place. Table 5.3 summarises project outputs (physical attributes) that helped to deliver the improved quality of place. Access to woodland is an important component of delivering quality of place. Table 5.4 demonstrates that 98.6% of the sample questioned agreed that 'woodlands are an important part of our community'. This figure is much higher than the 65% of adult respondents reporting that it is very important to have green spaces nearby, as quoted in a British Market Research Bureau's report to Defra in 2007. This result suggests that an active green space initiative may be a compounding factor in people's appreciation of green space, raising their awareness or attributed value. Such a supposition was also reported in a publication investigating the contribution of trees, woods and forests to quality of life, produced for the Forestry Commission. Adult respondents who used woodlands ascribed more benefits derived from woodlands than non-users (Forest Research, 2009). Similarly, Scott (2002) reported that people's relationship with a landscape can affect their perception (e.g. farmer vs tourist).

Table 5.3 Physical quality of place attributes delivered through Cydcoed.

Facility provided / improved	**Average improvement**	**Total improvement**
Creation of new footpath or track	420 m per project	68 460 m
Improvement of existing footpath or track	200 m per project	32 600 m
Creation of new mountain bike or cycle track		30 047 m
Improvement of existing mountain bike or cycle track		7812
Number of new access points	2 per project	326
Number of improved access points	2 per project	326

Table 5.4 Social benefits of woodlands, summary of Cydcoed evaluation respondents.

Statement	**Score (% of respondents)**				
	Strongly disagree	**Disagree**	**Neither agree not disagree**	**Agree**	**Strongly agree**
I find visiting the woodlands helps myself and others to learn about nature (*n*=147)	**0.0**	**2.0**	**14.3**	**38.8**	**44.9**
The project has given me a better understanding of our local environment (*n*=133)	**0.0**	**2.3**	**19.5**	**44.4**	**33.8**
Woodlands are an important part of our community (*n*=146)	**0.0**	**0.0**	**1.4**	**28.1**	**70.5**

Green spaces for city workers

The personal social significance of urban green spaces such as sitting lunching alone or outdoor socialising could 'shutdown' due to a decline in the social triggers that otherwise stop busy workers from staying indoors, according to Hitchings (2009). Working with a single cohort of city lawyers in London, Hitchings investigated reproduction of behavioural norms and subsequent limited degrees of reflection. Key points of highlight from the research include:

- When office workers are not provided with windows, studies suggest they often hang up pictures of natural scenes (Heerwagen and Orians, 1986).
- Workers can easily become indifferent to changes in outdoor local conditions that otherwise encourage them to spend time outside; and younger respondents were more likely than older counterparts to hanker after a fuller relationship with outdoor conditions and nature when at work.
- It is worth considering the wider routines and behaviours exhibited in green spaces; much more than just benches and litter, green spaces should be aligned to opportunities for getting things done – thoroughfares, engaging in a variety of social activities.
- Respondents did not like to assume that colleagues could cope with the physical experience of being outdoors in green environments, though individually they could easily do so.

Key implications of the research were:

- If spaces are more widely available, and physically improved, appropriate to practical as well as psychological need, then more people could benefit from them more of the time.
- GI is widely known to combat the urban heat island effect; however, this research highlights the opportunity to save on office climate control costs by increasing the variability of indoor temperatures in line with seasonal outdoor change. Shifts in cultural norms may be required, e.g. related to dress codes, though this was welcomed by respondents in this research.
- Other cultural shifts that could be challenged include how individuals view society's perspective on GI and green space use.

In reviewing the literature, Swanwick (2009) notes that the most highly valued spaces are those which enhance the positive qualities or urban life, offer a variety of opportunities and physical settings, and encourage sociability and cultural diversity. Furthermore, Burgess *et al*. (1988) report that unofficial green areas are extremely important for local people and that 'the most valued open areas are often the intimate and familiar ones which play a part in people's daily lives, rather than the distant parks and outstanding landscapes far from home'. Dunnett *et al*. (2002) suggest that people can describe their aspiration for ideal, improved green space, which can be gathered under three themes: overall design, specific measures to meet people's needs, the nature of management.

Burgess *et al.* (1988) and Dunnett *et al.* (2002), as well as the more contemporary research findings of Hitchings (2009) and Swanwick (2009), highlight the paucity of understanding in the disciplines of urban green space and landscape design and, complementarily, the building and green space management professions.

Delivering a quality of place

In its document *Sustainable communities: building for the future*, it is stated that 'sustainable communities are places where people want to live and will continue to want to live', adding also 'one of the key requirements of sustainable communities is 'a sense of place' (ODPM, 2003). In *Living places: greener, safer, cleaner* the then Deputy Prime Minister John Prescott argued 'successful, thriving and prosperous communities are characterised by streets, parks and open spaces that are clean, safe and attractive – areas that local people are proud of and want to spend time in' (ODPM, 2002), i.e. they have a quality of place. The core elements to quality of place have been defined (Cabinet Office Strategy Unit, 2009): the distinguishing marks are quality and distinctiveness. Since the appointment of the Urban Green Spaces Taskforce and their reports of 2002, a greater understanding of green space provision, quality and use, has been sought in order to deliver quality places.

In their publication, *Start with the* park, CABE Space (2005) observed that much of the GI is already around us, but that there is a need to make the most of what green space already exists, to raise quality. Throughout the study they demonstrate that good quality GI requires a multifunctionality that comes from a hierarchy (or a mosaic) of green spaces delivered at the regional and sub-regional level (integrated through the planning system) and maintained at high quality at individual green spaces. Effective cross-sector working (i.e. the environment, housing, highways, transport, health and education sectors), in support of GI delivery, is strengthened by integrated plans, ideally in a geographic information system (GIS), to guide regional delivery. The number of local authorities reporting to have a green space strategy in 2000 was 53%, rising to 69% in 2006 (NAO, 2006).

Examples of integrated regional delivery frameworks in England include:

- Creating sustainable communities: Greening the Gateway. A green space strategy for Thames Gateway (Defra, 2007). (http://www.communities.gov.uk/archived/publications/thamesgateway/creatingsustainablecommunities2)
- East London Green Grid Framework London Plan (Consolidated with alterations since 2004). Supplementary Planning Guidance. London, Mayor of London (GLA, 2003).
- Planning Sustainable Communities - A Green Infrastructure Guide for Milton Keynes and the South Midlands.
- A Green Infrastructure Plan for the Weaver Valley: Interim Report (The Mersey Forest, 2008).

Related support documents include:

- The Essential Role of Green Infrastructure: Eco-towns Green Infrastructure Worksheet. Advice to Promoters and Planners (September 2008).
- Green infrastructure Planning Guide version 1.1 (North West Green Infrastructure think tank, 2008).

A repository of GI documents is available from Green Infrastructure North West (http://www.greeninfrastructurenw.co.uk/html/index.php)

Quality of GI is as important as provision for the full range of benefits to be achieved (CABE Space, 2005). The components of 'the ideal green space' are often quoted to be: vegetation, water, play opportunities facilities/comforts (seats, toilets, shelters), good access, sports, events, refreshments (at a good price), environmental quality (including litter bins, lighting and anti-vandalism measures) and specific defining features (may be a maze or a sculpture) (NAO, 2006). By the same notions, the factors that deter green space use include: lack of or poor quality facilities/comforts, anti-social behaviour, concerns over dogs and dog mess, safety (real or perceived issues), environmental quality issues and lack of variety. Thus, GI quality is defined physically (for example, in terms of environmental quality) as well as qualitatively (for example, in terms of perception). See Section 4.2.4 for a detailed discussion of environmental quality with respect to GI. The *Strong and prosperous communities – the Local Government White Paper* puts emphasis on improving outcomes for local people and places; central to this is capturing local people's views, experiences and perceptions – including in respect of green and open spaces. The mechanism for capturing this data is a range of national indicators measured through The Place Survey.

Results from the *Place Survey 2008* (CLG, 2009) show that in 2008, 80% of the population were reported to be satisfied with their local area as a place to live. A constituent component of this indicator shows that 69% of the population were very or fairly satisfied with their parks and open spaces (aggregate figure for England; CLG, 2009). The real value of the *Place Survey*, however, is not in the national averages, but in interpretation of the indicators in their local context. The Place Survey represents an important shift to localism for delivering Governments' priorities, i.e. local delivery assessed locally.

An example of a survey specific to one green space typology is the UK-wide public opinion of forestry survey. Survey results for 2009 (Forestry Commission, 2009) state that, of 1685 English respondents, 77% had visited a woodland or forest in the past few years, a significantly higher proportion than in 2005 (65%) and, of those respondents who had not visited, 31% gave their main reason for not visiting as 'too busy/not enough time'. However, the survey again presents a simplistic overview of people's satisfaction with (woodland) green spaces, as respondents answers will not be explicitly linked to one green space. Highlighting the importance of local assessment, the Forestry

Commissions 'Contribution of trees, woods and forests to quality of life' research programme reported that, whilst around 25% of the population living within a 4 km radius of two community woodlands had heard of the woodland, only about 10% had visited. Non-use was associated with a number of barriers (including too busy/not interested; see survey report (Forestry Commission, 2009) for details) and reflected similar findings for non-use of urban green spaces and parks (Dunnett *et al*., 2002). Given that around 70% of visits would recommend the site to others (indicating a satisfaction with the site), further research is required into the use and non-use of all green spaces; this would include analysis of whether those who don't visit certain types of green space such as community woodland do visit other types such as parks or linear green routes, and how many would visit given incentive, e.g. an event.

Scale of change required to deliver quality GI

To quantify the required scale of change two elements are required: current provision and target provision. In addition, the physical provision requires a qualification, and this requires understanding of definitions and measurement of GI quality.

There is a major gap in the information that is publicly available about England's green spaces, despite numerous calls for a single co-ordinated national information resource (or database) recording the locations, number, quantity, ownership, function, type and quality of green spaces (e.g. Dunnett *et al*., 2002; CABE Space, 2005; NAO, 2006). Access to and amalgamation of a variety of databases holding GI information is constrained by inconsistencies in definitions, meta-data storage and intellectual property. CABE Space has resurrected calls for this need through their 2009 campaign Grey-to-green (CABE, 2009), noting that a GIS spatial dataset is required. Any future resource should be capable of displaying regional GI frameworks in the GIS or hold a textual linkage (e.g. repository of national and regional GI documentation).

The Green Flag Award is the national standard for parks and green spaces in England and Wales (NAO, 2006). It is a discretionary award scheme that began in 1996 as a means of recognising and rewarding the best green spaces, encouraging an increase in standards, and establishing a benchmark of excellence. The scheme recognises the diversity and distinctive qualities of green spaces, and commends management approaches that have effectively involved local people (DTLR, 2002). The Green Flag Award target is for 60% of local authority areas nationally, and 60% of local authority areas in receipt of Neighbourhood Renewal Funding to have achieved at least one Green Flag Award by 2008. There are now over 1000 Green Flag Award parks (www.keepbritaintidy.org/greenflag, 2010). However, the Green Flag is not consistently applied across England and Wales and there is no positive correlation between the number of Green Flags within a ward and resident satisfaction with local parks and open spaces (NAO, 2006); this relationship is also being assessed in CABE Space's 'Green and pleasant' research project. Irrespective of the result of CABE Space's investigation, the correlation will have limited value as Green Flags are not appropriate to all green spaces (for example, the Green Pennant Award was launched in 2002 to cover green spaces managed by voluntary and community groups) and research is required to determine if 'quality badges' are the best ways to drive an increase in green space quality. Applying fit-for-purpose principles could lead to the development of a satisfactory grading system across the green space typology (e.g. based on a described functionality, an accepted GI typology, and linked to a regional GI delivery framework in order to assess quality according to appropriateness). Research to verify such an approach is required; it could justify a shift away from targets for accolade awards that some fear are causing a diversion of funds to priority sites and, subsequently, an increased divide between high quality sites and those in need of improvements. Across England there remains an ongoing struggle to find capital funding to improve green spaces that are rundown and sustainable sources of revenue funding to maintain spaces to a good standard.

Valuation: unit cost of benefits/economic valuation data

An attempt to value city parks has been published by CABE Space (2009). The report case studies Highbury Fields in Islington, London, and Sefton Park in Liverpool and values the sites in the region of £53 million and £105 million, respectively. As grand totals, the figures translate poorly to other parks of a similar size or heritage because of site specific attributes such as the swimming pool (Highbury), the palm house (Sefton), or the number of mature trees. Re-worked figures for Highbury Fields, presented in Table 5.5, suggest that the creation of such a park from blank canvas would cost in excess of £3.9 million. Inventories and bill of quantities for the two case studies supplied in the report's appendices may guide future work to determine the cost of delivering and maintaining green spaces, as well as their value. These figures are complimented by previously unpublished values presented in Table 5.6 from the Forestry Commission on the establishment and maintenance of new community woodland.

Table 5.5 Valuation of a 12 ha inner-city public park[a].

Valuation summary	£
Land value	1
Hard landscape	2,145,767
Play equipment	700,000
Soft landscape (exc. mature trees)	1,131,123
Sub-total:	***3,976,891***
Building	95,818
Swimming pool	3,416,304
Trees	44,960,886
Topsoil	411,934
Sub-total	***48,884,942***
Total	**52,861,833**

[a] Figures re-worked from CABE Space (2009) to provide a guideline figure to create the park on a blank canvas (excluding buildings and mature trees). Top soil has been excluded from 'creation' cost as this would feasibly be imported as soil-forming material (Forest Research, 2006) or created on site, especially in the case of brownfield regeneration.

Table 5.6 Unpublished Forestry Commission and Thames Chase values for establishing and maintaining new community woodland[a].

Item	**Cost (per ha)**
Forestry Commission staff costs	£850 per annum
Consultations (e.g. professional stakeholders)	£466
Surveys	£466
Recreation Infrastructure (Paths, car parks, art, benches interpretation etc)	£5,300
Tree planting (inc fencing, individual tree protection, orchard planting etc) (gross not net area planted)	£3,700
Other habitat establishment (inc ground prep, wildflower meadows, pond creation, vegetation management	£3,000
Community engagement	£600
Estate Works (such as litter picking, general maintenance)	£870
Site integration (physical links and strategies)	£1,650
Total (total project cost excluding land purchase)	£**18,600**
Continued revenue costs	£700 - £1,200

[a] Figures are averages, based on a number of 2 and 3 year delivery projects and as such they are a 'rough guide'.

An examination by PricewaterhouseCoopers (CABE Space, 2009) of budget books for four English local authorities to establish current expenditure relative to total expenditure is presented in Table 5.7. Key findings from this report include:

- Revenue and capital spend on roads (a component of grey infrastructure) for the city council was 24 times its green expenditure.

- Green expenditure is a more significant share of expenditure at district level, though this probably reflects the much smaller range of expenditure considered.
- A large proportion of the GI spends relates to cemeteries: 27% of the county council spend related to burial grounds; 18% rural council GI spend related to cemeteries.
- Based on these figures, a 0.5% shift in investment from grey to green would equate to a 141% increase in local authority green expenditure.

Table 5.7 Comparison of 'green' and total expenditure in area categories for four English local authorities.

Budget	**'Green' expenditure**		**Total expenditure**	
			£	**%**
Large town/city	£14 per head pa	£18 million	£3,932 million	0.5%
Borough	£16 per head pa	£1 million	£23 million	4.3%
County	£2.50 per head pa	£3.5 million	£2,789 million	0.1%
Rural district	£9 per head pa	£1.5 million	£37.5 million	4.0%

Relationships between quality of place and other benefits of GI

The relationships between quality of place and other benefits of GI are given in Table 5.8.

Table 5.8 Relationships between quality of place and other benefits of GI.

Benefit	**Primary relationship**	**Secondary relationship**
Environmental quality improved (cleanliness, maintenance, aesthetic value) [helps deliver: Sustainable Communities and Place Making (cleaner, safer, greener)	Promote quality of life	Increased demand to live in locality
Appeal to visitors and potential users increased [helps deliver: Sustainable Communities and Place Making (cleaner, safer, greener)	Increased use for physical health improvement activities, and for relaxing and contemplation	Increased safety and perception of safety

Identified knowledge gaps

- Much of the academic literature on people and landscape is from the USA and other countries outside the UK, yet there is evidence that attitudes and perceptions are place-specific. UK-based evidence is required.
- The personal and social influences that result in greater use of urban green spaces are poorly described. Such knowledge is required for translation into site design as well as urban design planning.
- Variety within sites (zonation) or a variety of sites within a locality in encouraging use of green spaces are important to people's quality of experience. The necessary quantities, qualities and configuration of GI that contributes to regular use by all segments of society, with changing socio-demographic characteristics, is not known.
- A comprehensive analysis is needed of public funds spent on green infrastructure in comparison to grey and blue infrastructure
- Non-use of green space can be a lifestyle choice (i.e. personal preference). The question remains over whether those who do not visit certain types of green space, such as community woodland, would visit other green spaces such as parks or linear green routes; and how many would visit given the incentive (such as an event).
- There is a reasonable amount of literature available on parks, championed by CABE Space. This literature is very meaningful, as well as highlighting significant knowledge gaps. Critically, much of the research conducted for parks should be conducted for others in the green space typology. There is very little information available related to:
  - delivering brownfield regeneration to any green space – unit costs across the range of hard and soft infrastructure that may be designed in to a green space;
  - management and maintenance of other types of green space, other than parks.

Where this is available, it has not been collated. Future work to gather such data will be hampered by a lack of consistency in record keeping.

5.2.3 Regional and local economic regeneration

Regional and local economic regeneration is an important government activity. Economic regeneration means increasing employment, encouraging business growth and investment, and tackling economic disadvantage (Audit Commission, 2005: 2). Working with local authorities, and local government involved in regeneration and performance management, a set of economic regeneration performance indicators was developed (Audit Commission, 2005: 13-19). The indicators have been grouped into eight themes covering the main areas of interest in local economic development activity. A shorter version (focusing on economic aspects) is presented in the Table 5.9. The methodology used in this critical review can be found in Chapter 2, Appendix 1.

Table 5.9 Economic regeneration performance indicators.

Theme	**Performance indicator**
Employment	The percentage of people of working age in employment Proportion of the working age population who are claiming Job Seekers Allowance (JSA) The percentage of local jobs in each sector Annual change in number of local jobs
Earnings and skills	Median annual earnings for all in full-time employment Percentages of population of working age qualified to various NVQ levels
Economic vitality	Gross Value Added (GVA) and its growth per head of local population The number of VAT registrations in the area per 10 000 economically active population Median property price Median earnings of full time employees (1) Previously developed land that is unused or may be available for redevelopment and (2) derelict land as a percentage of the local authority land area
Demography and deprivation	Percentage of people living in the local authority area categorised by gender, age bands and ethnicity Population density Children under 16 living in low-income households The percentage of population of working age who are claiming key benefits
Town centres and tourism	Visits (measured by pedestrian footfall) to the town centre (survey) Prime retail rent per square metre Day visitors per annum and their average spend (1) Bed nights per annum and (2) room occupancy
Workforce development and employability	The percentage of employees and self-employed that have received job-related training in the last 13 weeks
Investment	Total number of (1) new investments and 'inward investment' enquiries and (2) re-investments made in the area Jobs created and/or safeguarded (and cost per job) to which the authority's promotional and support activity has made a significant contribution Brownfield land reclaimed as a percentage of all land made available for industrial, commercial and leisure purposes

Business and social enterprise support	Number of new business start-ups supported in the local area per 1,000 VAT registered businesses. Their survival rate (i.e. after two years). Number of persons employed by businesses occupying managed workspace provided by (or funded by) the local authority Number of business enquiries for advice and information received in the financial year per 10,000 economically active population Jobs created in the last financial year by social enterprises that have received substantive support from the local authority

Source: Audit Commission (2005: 13-19).

The list of indicators above suggests that regional and local economic regeneration is not an entirely separate green space benefit, but a compound one. In particular, it depends upon such benefits of green space as economic growth and investment, quality of place (including visual amenity), recreation and leisure, and tourism.

Investment in green infrastructure (creation, improvement and development of green space and landscaping) is thought to encourage and attract high value industry, entrepreneurs and skilled workers to a locality and region through the maintenance and creation of high quality, landscape sensitive, environmentally friendly living and working environments, adding GVA to local economies (ECOTEC, 2008: 23). Similarly, investments to improve the aesthetic quality of place (including visual amenity) can be reflected in land and property prices. Therefore, the various indicators measuring the impacts of green space on regional and local economic regeneration include changes in employment (jobs created), new business start ups, GVA, and land and property prices.

In total 13 studies (some with several case studies) were identified as relevant to the 'regional and local economic regeneration' topic (CABE, 2004; 2005; CESR, 2004; CLES, 2007; CSI, 2008; Dunse *et al.*, 2007; EKOS, 1997; Forestry Commission, 2005; Garrod, 2002; GEN Consulting, 2006; GLA Economics, 2003; Land Use Consultants, 2006; Regeneris, 2009). These are presented in Table 5.11. See Chapter 2, Appendix 2 for explanation of terminology.

Since individual studies have been reviewed already in earlier sections (Section 2.2.1 Economic growth and investment and Section 2.2.2 Land and property values and aesthetics), the focus here is on summarising green space projects' outcomes across different regeneration themes (Table 5.10).

On employment (including earnings and skills) five studies reported the creation of new jobs after the intervention. However, lack of information on projects' expenditures breakdown and complex interactions among various project activities preclude direct comparisons. Only the Glasgow Green Renewal project (GEN Consulting, 2006: 17) reported a detailed breakdown of new jobs by demographic and social characteristics. There is also evidence that green space projects can be associated with a reduction in the number of Job Seekers Allowance (JSA) and incapacity and sickness related benefits claimants (CLES, 2007: 27-28), and can raise the skills level (CLES, 2007: 44).

Table 5.10 Regional and local economic regeneration.

Project	Estimated benefits		
	Employment (FTE)	**Economic, Business, Investment**	**Other**
Riverside Park Industrial Estate in Middlesbrough. Investment in the Green Infrastructure of the park, over 1800 new trees planted. (CLES, 2007)	Over 60 new FTE jobs created. From 2003 to 2006 over the course of the improvements works numbers of job centre plus claimants decreased from 140 to 125; the number of incapacity and sickness related benefits claimants fell from 340 to 280.	Created a setting for stimulating business growth and investment, attracted new, high profile, occupants and saw occupancy grow from 40% to 78%, and levered over £1 m of private investment. 28 new businesses started up.	
Winsford Industrial Estate in Cheshire. Environmental and landscape improvements including new plantings. (CLES, 2007)	88 new FTE jobs created. 13% increase in the number of employees in Winsford Wharton between 2003 and 2005 (compared to 2.9% for England as a whole).	Private matched funding of over £290,000 was levered in. Number of businesses increased from 104 to 160 all paying business rates to the local authority.	Significant crime reduction (vandalism rate halved).
Portland Basin Green Business Park, Tameside, Greater Manchester. Landscaping improvements. (CLES, 2007)	13 permanent jobs were created and a further 314 jobs safeguarded. Programme facilitated the gaining of 87 formal qualifications and the undertaking of 598 training weeks.	Just under £425,000 of public sector funding levered in over £1.8 m of funding from the private sector. As a result of the programme the number of businesses located in the park increased from 120 to 140	
The National Forest creation. (CESR, 2004)	Number of local jobs increased (1991-2001) by 4.1%. Jobs created, safeguarded (1995-2001): 213 FTE. Earnings growth at 5.6% has not kept pace with the regional averages of 11-12% over the period (1999-2002). Female earnings growth was around 2% slower, whilst male growth was some 7% slower.	By 2001 directly related regeneration programmes resulted in funding of £32.5 m for the area which attracted leverage of £96 m and created over 500 jobs (CESR, 2004: 43).	
Manvers Regeneration scheme by Rotherham Metropolitan Borough Council (MBC) in South Yorkshire. (CSI, 2008)	Over 20 years. About 9000 jobs have been created.	Over 20 years. Private sector investment in the scheme to date has been estimated at over £350 m.	
Langthwaite Grange, Wakefield, West Yorkshire. Landscape quality and security improvements at a 57 hectare industrial estate. Started 2005. (CSI, 2008)	Created 200 new jobs.	16 new businesses moving in, bringing over £12 m investment.	Crime has fallen by 70% in 12 months.

Project	Estimated benefits		
	Employment (FTE)	**Economic, Business, Investment**	**Other**
Development of Bold Colliery Community Woodland (Forestry Commission, 2005).		Enhanced property values in the surrounding area by c. £15 m and helped realise a further £75 m of new development.	
Glasgow Green (the city's oldest park) Renewal project: £15.5 m investment of public funds (1999-2006). (GEN Consulting, 2006)	4 FTE, 165 - 245 construction job years associated with residential property development, including: 10 jobs for women; 5 for people under the age of 25; 41 jobs for people from Social Inclusion Partnership (SIP) areas.	Stimulated the development of new residential properties (net impact 500-750 new residential properties), enhanced average house prices and the total value of property transactions (net £3 m–£4.5 m), a 47% increase in council tax yield (additional £0.8 m–£2 m). The value of the land increased from a nominal £100,000 per hectare to £300,000.	Net visitor spend to the Green from 1998 to 2006 is between £14.9 and £22.4 m.
Ten case studies into the impact of park improvements on house prices, though often not clear how much was invested and what is the return (CABE, 2004; 2005).		A study found that, following improvements, houses near parks were, on average, 8% more expensive than comparable houses further away.	
Comparison of 'greenness' across the City of London's 760 wards. (GLA Economics, 2003)		Hedonic pricing approach showed that higher property values (in terms of the average house price) exist in areas with a higher percentage open space: a 1% increase in green spaces (in London) was linked to 0.3% to 0.5% increase in house prices.	
Impact of green space in Aberdeen (Dunse *et al.*, 2007).		Hedonic pricing estimations yielded average premium values for property located near particular type of green space of: 10.1% for city parks, 9.0% for local parks and 2.6% for amenity green spaces.	

Project	Estimated benefits		
	Employment (FTE)	**Economic, Business, Investment**	**Other**
Survey (GB wide) to estimate the value of woodland views from properties and on journeys using stated preference approach. (Garrod, 2002)			Respondents' estimated WTP: a woodland view for houses on the urban fringe is £269 per annum per household (2002 prices), and a view of woodland while travelling is £227 per annum per household (2002 prices).
The Mersey Forest, Merseyside (new tree planting, land reclamation, bringing woodland into management, creating access to green space and recreational facilities, managing and improving habitats, engaging local communities and business support activity for forestry businesses). (Regeneris, 2009)		Direct increases in economic output in Merseyside: £2.8 m gross GVA from tourism spend, from direct jobs (Products from the Land), and from improvements in health or £436,000 net additional benefits.	Net additional monetised benefit due to landscape improvements (visual amenity), views from home: £412,000 p.a. and while travelling: £527,000 p.a. (Regeneris, 2009: 36-37)
Kennet and Avon canal restoration. Restored historic waterway enhances landscape. The long-term restoration effort has involved £38.9 m since 1997, including a Heritage Lottery Fund donation of £25 m (Land Use Consultants, 2006: 9).	Direct and indirect employment created by the project totalled 150-210 FTE jobs between 1997 and 2002. The total number of jobs created and safeguarded by the project is estimated at 1198–1353 FTEs.		Visitor numbers increased by 15% between 1995 and 2001. The net economic impact of the programme was estimated at £82 m to 2003. This included £29 m of direct expenditure on restoration and an additional £53 m of further investment in tourism, leisure and commercial development.

Project	Estimated benefits		
	Employment (FTE)	**Economic, Business, Investment**	**Other**
Improvements to the local footpath network in Dunkeld and Birnam: establishment cost (£70,000) and annual maintenance cost (£3,000) (EKOS, 1997).	Generated between £1.37 m and £3.69 m of income a year to the local economy, directly supporting between 8 and 15 FTE jobs.		Helped reduce the seasonality of tourism employment; contingent evaluation techniques assigned a value of £170,000–£242,000 to the network across the population as a whole (visitors and residents).

Table 5.11 provides rough estimates of the cost of different projects per FTE job created or safeguarded, based upon the information given in the reviewed publications[12]. We distinguish public and total (i.e. including private sector) investments required per FTE created, or safeguarded. The diversity of the projects is reflected in the range of public expenditure costs from £6,000 to £3.9m per FTE job created with a median value of £46,000. [13] Median value of public expenditure costs per FTE created or safeguarded is £20,000.[14]

[12] Only rough estimates are possible given that the information drawn from these publications may be incomplete.
[13] £3.9m per FTE job created probably over-estimates the cost due to exclusion of the additional 165 - 245 construction job years created (GEN Consulting, 2006: 20). Assuming 50 job years as equivalent to one FTE, for example, would imply 3 to 5 further FTEs created and, roughly halving the estimate.
[14] This is in line, for example, with the estimates from the Regional Selective Assistance (RSA) Scheme for Scotland for 2000-2004, which range between £13,273 and £34,419 on the actual amount of assistance paid. Available at: http://www.scotland.gov.uk/Publications/2008/03/20102544/1 (accessed 15 March 2010). The RSA was a prominent feature of regional policy in Great Britain for more than 30 years, 1972-2004.

Table 5.11 Cost of FTE creation.

Project	**Portland Basin Green Business Park, Tameside**	**Riverside Park Industrial Estate in Middlesbrough**[a]		**The National Forest**[b]	**Langthwaite Grange, Wakefield, West Yorkshire**	**Glasgow Green Renewal**[c]	**Kennet and Avon canal restoration**[d]	**Improvements to the local footpath network in Dunkeld and Birnam**[e]
Source	CLES (2007: 43-44)	CLES (2007: 28		CESR (2004: 49-50	CSI (2008: 23)	GEN Consulting (2006: 5, 17)	Land Use Consultants (2006: 9)	EKOS(1997)
Public investments (£000s)	424	500	3,575	21,000	1,200	15,494	38,900	125
Total investments (£000s)	1,820	1,000	15,000	21,000	13,200	15,494	38,900	125
FTE Jobs created[f]	13	60	60	181	200	4	180	12
FTE Jobs safeguarded	314	No data	No data	32	No data	No data	1,096	No data
Public expenditure per FTE created (£000s)	33	8	60	116	6	3,873	N/A	10
Total investment per FTE created (£000s)	140	17	250	116	66	3,873	N/A	10
Public expenditure per FTE created or safeguarded (£000s)	1	8	60	99	6	3,873	30	10
Total investment per FTE created or safeguarded (£000s £)	6	17	250	99	66	3,873	30	10

[a] The first column only includes business grants. The second column includes all public and private investments, including the *Evening Gazette* move to the Industrial Park which brought a further £14 million of investment to the area (CLES, 2007: 27). An additional 4,605 jobs in a wider Middlehaven area were created (CLES, 2007: 49).
[b] No data reported on private sector investments. The data on the National Forest includes the following information (NFC, 2007: 24):

- Between 1995 and 2006 around £115 million was invested in Forest–related projects and regeneration programmes in the area.
- NFC invested £24 million through the National Forest Tender Scheme, land acquisition and project grants.
- Partner organisations invested a further £36.5 million in Forest-related projects, including the £18.6 million Conkers Discovery Centre.
- The area also secured £54.4 million for coalfield, urban and rural regeneration programmes delivering wide ranging community benefits.

[c] No data reported on private sector investments.
[d] No separate data is provided for jobs created and safeguarded for Kennet and Avon canal. Jobs created are given as a range 150 – 210 of which we used a midpoint estimate of 180. Also jobs created and safeguarded are given as a range 1,198 – 1,353 of which we used a midpoint estimate of 1,276. For presentation in the table we assume that number of safeguarded jobs is 1,096 = 1,276 – 180.
[e] Jobs created are given as a range 8 – 15 of which we used a midpoint estimate of 12. Costs are establishment cost (£70,000) and annual maintenance cost (£3,000). Annual maintenance cost was converted to present value of £55,000 assuming 30 years and 3.5% rate per annum.

[f] In the case of the Glasgow Green Renewal project, an additional 165-245 construction job years were created (GEN Consulting, 2006: 20).

Various demographic and deprivation theme changes in the project area are reported in some studies (CESR, 2004; CLES, 2007) but without before and after comparisons. Difficulties include a mismatch between geographic boundaries of a project and local reporting area and definition changes over the lifetime of a project. Some studies report significant crime reduction in the project locality (CLES, 2007: 35; CSI, 2008: 23).

On economic vitality, investment and business and social enterprise support, there is evidence of increases in business occupancy rates, business start ups, property prices, and private sector investments levered in (see Table 5.11 for details). However, due to large differences between projects and level of reporting[15], comparisons are difficult but a summary table of private sector investments levered is presented in Table 5.12. It shows the range of values for the ratio of private to public investments from 2 to 10 with a median value of about 4.2, i.e. for every £1 of public investments projects levered in there are £4.2 of private sector investments[16].

Table 5.12 Private investments levered in.

Project	Source	Public (£000s)	Private (£000s)	Leverage ratio (private / public)
Portland Basin Green Business Park, Tameside	CLES (2007:44)	424	1,820	4.3
Riverside Park Industrial Estate in Middlesbrough[a]	CLES (2007: 25-26)	500	1,000	2.0
Langthwaite Grange, Wakefield, West Yorkshire	CSI (2008: 23)	1,200	12,000	10.0

[a] If data on investments other than business grants are included the leverage ratio changes to 4.2.

Since this chapter is based other sections (2.2.1 Economic investment and growth and 2.2.2 Land and property values, and aesthetics) the corresponding knowledge gaps and conclusions apply.

[15] This is not unexpected since recommendations on economic regeneration performance indicators was published only in 2005 (Audit Commission, 2005).

[16] Although there was no precise data were reported on the amount of private sector investments levered in the Glasgow Green Renewal project, Glasgow City Council apparently levered in an amount of external funding twice the original public investment (GEN Consulting, 2006: 5).

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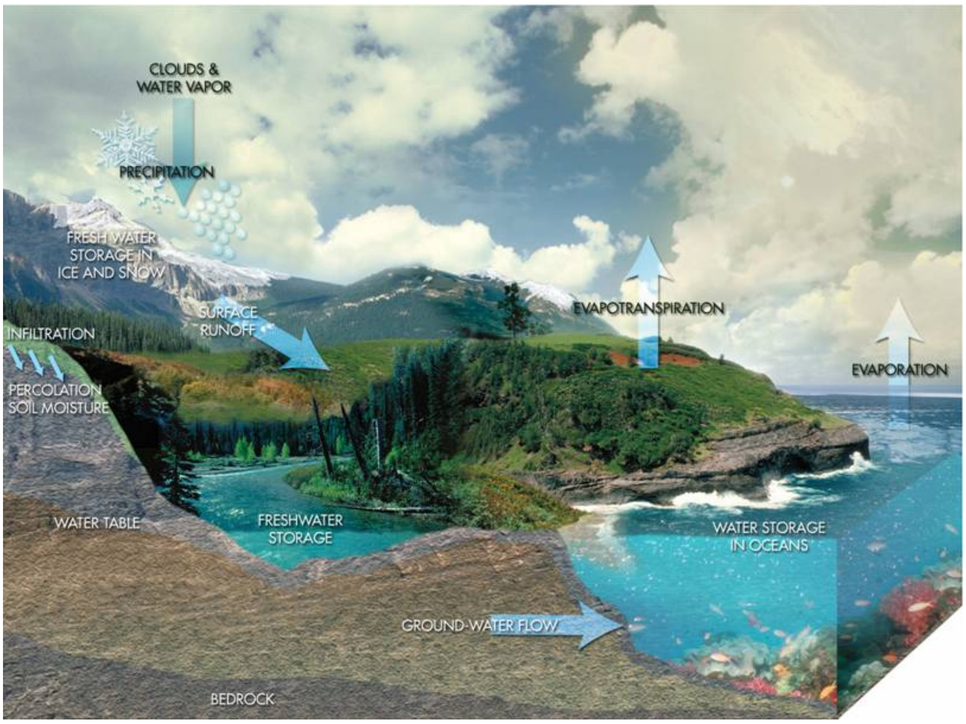
6 Hydrological benefits

6.1 Introduction

Alterations to the natural environment can affect the movement of water through the hydrological cycle (Figure 6.1) and alter its composition. Changes and effects vary in type and extent and may occur naturally or due to anthropogenic activities such as farming, forestry and urbanisation, all of which can adversely affect both the quantity and quality of water flowing through a catchment. Urban development retains very little of the original vegetation and landscape, replacing it with buildings, roads, gardens and parks (Whitford *et al*., 2001): changes that have a significant impact, not only on the hydrology but also the freshwater ecology and the terrestrial ecosystems that river systems support.

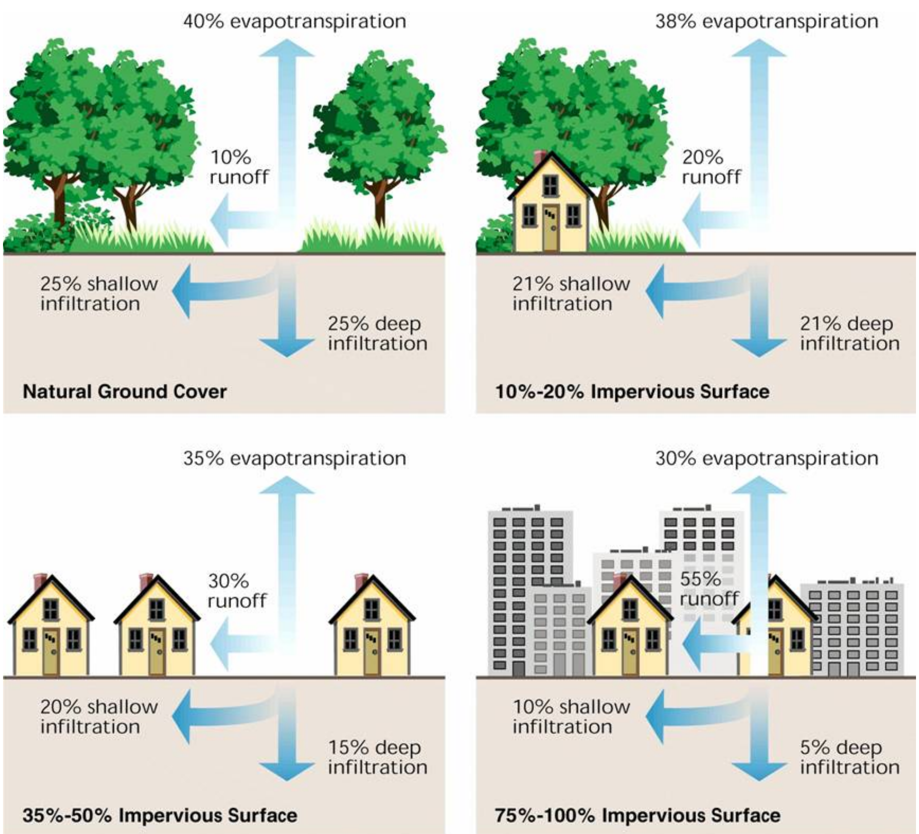
Figure 6.1 The hydrologic cycle, showing how water circulates over, under, and above the Earth's surface (image courtesy NASA).



Removal of natural vegetation reduces foliar interception of precipitation, whilst the use of impermeable materials in urban construction decreases ground infiltration of precipitation, giving an overall reduction in evapotranspiration (Figure 6.2). Reduced ground infiltration also increases speed of runoff and this, combined with artificial drainage networks (sewers and stormwater drains), increases the risk of flooding (Mansell, 2003). Surface water runoff can also transfer pollutants, collected on urban surfaces, to water bodies (Stovin, 2008). Urbanisation has also been shown to affect groundwater temperatures with these temperatures found to be 3.5°C warmer than rural groundwater (Yalcin and Yeteman, 2009). In addition to hydrological processes, urbanisation can affect climate, the carbon cycle and biodiversity (Chapman, 2003; Gill *et al*., 2007; Oke, 1995; Whitford *et al*., 2001), all of which are inextricably linked to the hydrological cycle. Therefore management systems that benefit hydrology can also provide wider benefits in terms of biodiversity and climate regulation.

Green infrastructure (GI) provides a means through which to restore natural environmental features to the urban environment, thereby re-establishing many environmental processes, including those related to the hydrological cycle. GI can provide hydrological benefits in two key areas: flood alleviation and water quality (both improvement and protection). In order to maximise hydrological benefits GI should extend from the urban centres to the peri-urban environment and greenbelts. This chapter reviews the hydrological benefits of GI in terms of flood alleviation and water quality and identifies areas that need to be investigated for the full potential to be realised.

Figure 6.2 Relationship between impervious cover and surface runoff. Increased impervious cover increases the risk of flooding and water quality degradation; as little as 10% impervious cover in a watershed can result in stream degradation (image from FISRWG, 1998).



6.2 Critical review

6.2.1 Impact of urbanisation on the hydrological cycle

Cycling of water through the environment is described by the hydrological cycle. This continuous movement of water through the environment is essential for the sustenance of all life forms, primarily through the provision of clean utilisable water. Moreover, water plays a key role in the provision of a climate that can support life and is central to the process of photosynthesis (Jackson and Jackson, 1996). Alterations to the natural environment affect the movement of water through the cycle and also its composition, which can then have significant environmental impacts on freshwater ecology, for example. Human activities that alter the environment and impact on hydrological processes include forestry, farming and urbanisation. The impacts of these activities are not always harmful and may even be beneficial; for example, agricultural practices such as terracing and multi-cropping can preserve natural storage by reducing the speed of runoff (Mansell, 2003), and well-managed forests retain many characteristics of the natural environment and can contribute to the preservation of the freshwater environment and associated ecosystems. Urbanisation alters the natural land cover through the removal of vegetation and by covering over soil with more impermeable materials used in the building of roads, buildings, driveways, parks and gardens. Removal of natural vegetation reduces foliar interception of precipitation, whilst the use of impermeable materials in urban construction decreases ground infiltration; the two combined lead to reduced evapotranspiration. Reduced ground infiltration also increases the speed of runoff, reducing the lag time between the precipitation peak and discharge peak (Mansell, 2003), which subsequently increases the risk of flooding. Moreover, altering the flow patterns of water flowing through the catchment can fracture hydrological and ecological connectivity, which can then have an impact on the freshwater ecology which relies on high quality flowing water for its survival.

6.2.2 Hydrological benefits of GI: flood alleviation

A number of serious flood events in recent years have focused attention on flood prevention and mitigation. Urban development and engineered flood defences have profoundly changed the natural shape of river beds, banks and shores of estuaries; such changes can lead to erosion and increased sediment delivery, and can alter the habitats available for aquatic plants and animals. These alterations can also exacerbate or reduce the nature and seriousness of flood and drought events by changing volume, velocity and direction of flow (Defra, 2008). There are also serious implications for human health

(Reacher *et al*., 2004; Tunstall *et al*., 2006). The importance of flood management has been recognised by the introduction of the European Directive on the Assessment and Management of Flood Risks (2007/60/EC), also known as The Floods Directive, which is designed to help Member States prevent and limit floods and their damaging effects on human health, the environment, infrastructure and property. Further legislation transposes The Floods Directive into UK law and the management strategies or plans that follow from these acts recognise the need for whole-catchment approaches to flood management, using multiple, integrated flood management measures (Defra, 2005; 2008; Forestry Commission, 2006; 2009). These include more natural, sustainable methods of flood control such as sustainable urban drainage systems (SUDS), wetland restoration and woodland planting in the floodplain and riparian zone; all of which may be components of the urban and peri-urban GI. There are three main ways that woodland and other vegetation in the urban or peri-urban environment can contribute to flood alleviation:

- By delaying the downstream passage of flood flows – vegetation, particularly trees in the floodplain can delay flows, promote out-of-bank flows and increase flood storage, resulting in a lower but longer duration event (Thomas and Nisbet, 2006). This is mainly due to the hydraulic roughness of vegetation (Table 6.1).

- By reducing the volume of runoff – plants intercept precipitation and use water during transpiration, thereby reducing the volume of water flowing through a catchment (Nisbet, 2005).

- By promoting rainfall infiltration into the soil and reducing the rate of runoff – the root systems of plants and associated fauna give rise to increased porosity allowing greater movement of water into the subsurface than non-vegetated land.

Table 6.1 Hydraulic roughness values (Manning's coefficient) of floodplains[a].

Channel	Hydraulic roughness (Manning's n)
Pasture (no scrub) – short grass (long grass)	0.030 (0.035)
Mature field crops	0.040
Scattered scrub, heavy weeds	0.050
Medium to dense scrub in winter (summer)	0.070 (0.100)
Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.100
As above but with flood stage reaching branches	0.120
Dense willows, straight, summer	0.150

[a] Calculated roughness coefficients (Manning's *n*) represent the resistance of vegetation to flood flows in open channels and flood plains (USGS, 1989; ODOT, 1995); the greater Manning's *n*, the higher the potential to impede water.

Government strategy for flood risk management in England and Wales has proposed integrated urban drainage management in high-risk urban areas (Defra, 2008). Spatially, GI should not be restricted to urban centres but should extend to the peri-urban environment so that flooding and water quality benefits can be realised before water reaches urban centres. A report by the Campaign for the Protection of Rural England and Natural England highlights the use of green belts to acts as buffers to protect urban areas from flooding and pollution (CPRE and Natural England, 2009). These buffer areas may consist of wetlands, and floodplain and riparian woodland. The wider benefits of woodland creation and management are discussed in *A strategy for England's trees, woods and forests* (Defra, 2007). This includes a policy to seek 'a landscape-scale approach to tree planting, woodland creation and management, which takes account of the interaction between trees, woodlands and other land uses, and delivers the wider ecosystem services which strategically placed woodland can provide' (Defra, 2007). For example, at Trent River Park in Greater Nottingham, the use of a green corridor of parkland and open space provides flood defence as well as being a location for outdoor leisure and sporting activities and provides an area for aquatic and riparian nature conservation (Environment, Food and Rural Affairs Committee, 2008).

Forests and woodland have long been associated with an ability to slow down runoff and reduce downstream flooding (McCulloch and Robinson, 1993). Trees in gardens and yards can provide environmental and economic benefits by retaining pollutants and intercepting rainfall (CUFR, undated). American research has found that a yard tree can intercept 760 gallons (2877 litres) of rainfall in its crown, thereby reducing polluted stormwater runoff and flooding (McPherson *et al*., 1999a; 1999b). Trees store more water during lower intensity rainfall events over longer time periods than during intense events over short periods.

The ability of forest and woodland soils to reduce overland flow by receiving and storing more rainfall could have a significant impact on flooding; this 'sponge effect' also applies to SUDS (see Chapter 4, Section 4.2.2). For example, studies at PontBren in Wales found that infiltration rates were up to 60 times higher within young native woodland shelterbelts compared to grazed pasture, and so water storage was increased (Bird *et al*., 2003; Wheater *et al*., 2008); results that are supported by Eldridge and Freudenberger (2005). The improvement of the water storage capacity of the soils in the PontBren catchment demonstrates how upstream land-use decisions by farming communities have downstream consequences for rural and urban communities (see PontBren farmers case study). Recent modelling studies, however, present conflicting results on the effects of woodland on flood flows with some predicting a considerable reduction in peak flows (Jackson *et al*., 2008), whilst others suggest a relatively small effect on flood flows (Park and Cluckie, 2006). The contrasting results may be because these studies do not address the impact of woodland planting on the low infiltration rates of soils damaged by agricultural activities, where the benefit of woodland could be expected to be greatest (Nisbet *et al*., in press). Some of the variation in model results are also due to differences in selected parameter values, especially the size of Manning's *n*. More measurements are required to refine this parameter for different woodland types and structures. Alternatively, more sensitive models are required that use drag force and friction, rather than a single Manning's *n* value to represent the effect of vegetation on river flows (Nisbet *et al*., in press).

Modelling studies on the impact of floodplain and riparian woodland by Thomas and Nisbet (2006) showed that the increased hydraulic roughness associated with planting native floodplain woodland along a 2.2 km grassland reach of the River Cary in Somerset could reduce water velocity by 50%, and could raise the flood level within the woodland by up to 270 mm for a 1 in 100 year flood. Temporary flood water storage increased by 71% and the downstream progression of the flood peak was delayed by 140 minutes. These results were considered significant for reducing downstream flood risk by potentially desynchronising flood flows and providing more time for issuing flood warnings. A second modelling study at Ripon in North Yorkshire predicted that planting floodplain woodland at four sites in the River Laver catchment totalling 40 ha in area (<1% of catchment) could delay the progression of a 1 in 100 year flood by around one hour. This had the potential to reduce the flood peak at Ripon by 1-2% by desynchronising the flood contribution from the adjacent tributary, the River Skell. A much greater reduction was expected with a larger planting area (Nisbet and Thomas, 2008).

Riparian woodland acts in a similar way to floodplain woodland but on a different scale. In addition to the hydraulic roughness associated with bankside and adjacent trees in the riparian zone, the presence of large woody debris (LWD) dams within the stream channel act to delay flood flows, promote out-of-bank flows and increase flood storage. Anderson *et al*. (2006) showed that riparian vegetation reduces wave velocity, which would be expected to lengthen catchment response times and, consequently, decrease peak discharge. However, to be effective at a larger catchment scale would require extended reaches of riparian woodland and associated LWD dams along tributary streams. There is also a risk of LWD dams causing flood damage and acting as a barrier to migrating fish, factors which need to be considered when their suitability is being assessed.

Despite the positive evidence from modelling in support of floodplain and riparian woodland having the potential to reduce extreme flood peaks, there is little or no field data to back up the model predictions and flume results. This is primarily due to a lack of field studies, highlighting the need for suitable scale, long-term field experiments.

Green roofs and their contribution to achieving sustainable urban drainage systems

Green roofs - roofs covered in a growth medium or soil with plants growing on them - may contribute significant benefits for urban water management, including stormwater management (Mentens *et al*., 2006), and wider sustainable development goals. Bates *et al*. (2009) looked at the potential to create green roofs to compensate for the loss of brownfield habitats (brown roofs) and simultaneously contribute to stormwater management. Initial indications are that brown roofs provide ecological and hydrological benefits, however the locally sourced waste aggregates have low water retention and do not store as much water as off-the-shelf growth media used in 'traditional' green roofs; the ability to attenuate flood events, therefore, is limited. However, they concluded that there are still potential benefits for downstream regulation of streamflows due to retardation and reduction of drainage flows from low intensity storms.

Gill *et al*. (2007) used a hydrological model to investigate the effects of climate change on urban hydrology. They found that increased future runoff, due to increased precipitation (28 mm event), could be reduced by up to 4.9% if green cover was increased by 10% in residential areas, and that increasing tree cover by the same amount would result in a 5.7% reduction in runoff. However, the authors note that this would only result in a 1.9% reduction in residential areas of the Greater Manchester conurbation. The use of green roofs was found to reduce runoff by 17.0-19.9% and 11.8-14.1% for 18 mm and 28 mm rainfall events, respectively (Gill *et al*., 2007).

These results are comparable to an Australian modelling study exploring Water Sensitive Urban Design (WSUD), which found that vegetated roof treatment reduced annual stormwater by 19% (Mitchell *et al*., 2007). Van Seters *et al*. (2009) evaluated the quantity and quality of runoff from an extensive green roof on a multi-storey building in Toronto. Continuous precipitation and runoff data collected over 18 months outside of the winter period indicated that the green roof discharged 63% less runoff than a neighbouring conventional modified bitumen roof. Runoff volumes from the green roof averaged 42% less than the conventional roof in April and November, and between 70 and 93% less during the summer months.

Whitford *et al*. (2001) used a storm runoff indicator to model the effects of urbanisation on hydrology. They found that the runoff indicator was closely related to the percentage of green space, particularly trees. In order to moderate surface water runoff volume increased green space provision should be considered in conjunction with other strategies such as increased storage, in SUDS or retention/detention ponds for example (Gill *et al*., 2007; Grimmond, 2007). SUDS use a variety of techniques to control surface water runoff, and subsequent pollution and flooding, from urban catchments including green roofs, soakaways, swales, infiltration trenches and balancing ponds (Stovin *et al*., 2008). Bioretention basins are landscaped depressions or shallow basins used to slow and treat on-site stormwater runoff. Stormwater is directed to the basin and then percolates through the system where it is treated by a number of physical, chemical and biological processes. The slowed, cleaned water is allowed to infiltrate native soils or is directed to nearby stormwater drains or receiving waters. Hatt *et al*. (2008) assessed the potential for retention basins to remove pollutants from stormwater. They found that loads of sediment and heavy metals were effectively retained. A study in Australia found that bioretention basins can increase biodiversity (Kazemi *et al*., 2009). An overview of the GI benefits to SUDS is given in Chapter 4, Section 4.2.2.

6.2.3 Hydrological benefits of GI: water quality

The provision of high quality water is essential for the health and survival of all forms of life. The quality of water flowing through an urban catchment can be severely impacted due to high runoff speed and reduced infiltration of precipitation; pollutants and detritus collected from urban surfaces can lead to contamination of receiving water bodies, and impact on the aquatic ecology (Pompeu and Alves, 2005; Stovin *et al*., 2008; Jacob and Lopez, 2009). Moreover, many urban areas have combined sewerage and stormwater collection systems from which overflows, due to high rainfall events, adversely affect water quality (Stovin *et al*., 2008). The EU Water Framework Directive provides a common framework for addressing all pressures on the water environment and has set an objective that water bodies should be restored to 'Good Status' by 2015. The majority of water bodies in the UK currently fail to meet this target status due to diffuse pollution and other pressures. There are a number of techniques, most of which are mentioned above, which can provide water quality benefits in urban environments. These include SUDS (see also Chapter 4, Section 4.2.2), green roofs, infiltration/detention ponds, wetlands and trees in the urban and peri-urban area. Ideally strategies should be integrated and targeted to provide the optimum combination of environmental, social and economic benefits.

SUDS can be used in control of pollution and for sediment retention (Heal *et al*., 2006; Napier *et al*., 2009), and green roofs also provide pollutant retention potential. A study evaluating the quality of runoff from an extensive green roof on a multi-storey building found that most chemical variables in green roof runoff were lower than from the conventional roof (van Seters *et al*., 2009). However, they found that total phosphorus concentrations in runoff were significantly higher than the conventional roof and regularly exceeded the Ontario receiving water objective of 0.03 mg l^{-1}, probably due to leaching from the growth media. The results highlight the need to manage green roofs carefully to minimise leaching of nutrients and other contaminants while maintaining their ability to support plant growth.

The use of trees in urban and peri-urban areas can provide significant water quality benefits. Stovin *et al*. (2008) note that urban trees provide all of the functions associated with SUDS, including the storage and interception of rainfall at source, filtration of pollutants in the canopy, and infiltration at the root zone, along with amenity and ecological benefits. The Center for Urban Forest Research (CUFR) in the USA suggests that urban forests are likely to provide more benefits through water quality protection than flood control (CUFR, 2002). The potential benefits of unmanaged and well-managed woodlands to water quality have been formally recognised by local government in Great Britain (Defra, 2007; WAG, 2008; Scottish Government, 2009) and country forestry strategies reflect the potential of woodland to deliver WFD objectives, including highlighting opportunities for woodland to reduce the impact of diffuse pollution from agriculture and urban activities (alongside flood management). These benefits have also shaped European policy, with a specific Resolution on Forests and Water adopted by the Fifth ministerial conference for the protection of forestry in europe (MCPFE, 2007). This recommends action across Europe to better co-ordinate policies on forests and water, and to incorporate an economic valuation of water-related forest services.

Many countries world-wide rely on ‘Protection Forests’ to preserve the quality of drinking water supplies, alleviate flooding, and to guard against erosion, landslides and the loss of soil. A recent study by the World Bank and World Wildlife Fund (WWF) of 105 of the largest cities in the world found that one-third relied on forest protection areas for some or all of their drinking water (Dudley and Stolten, 2003). The benefits of protection forests and sustainable forest management for water quality are increasingly recognised as a key ecosystem service, and woodland is being created to safeguard the water environment. While there may be water trade-offs in terms of the potential for forests to reduce water yield, these are usually more than compensated for by the water quality and other ecosystem services provided by forests, for carbon, landscape, biodiversity and recreation, for example (Nisbet *et al*., in press).

Tree canopies reduce soil erosion by diminishing the impact of raindrops on barren surfaces and by improving soil strength and stability through encouraging the build-up of soil organic matter and the action of tree roots (CUFR, 2002; Nisbet *et al*., 2004). Trees also store more water during lower intensity rainfall events over longer time periods than during intense events over short periods, which is important because small storm events are responsible for most of the annual pollutant loading to receiving waters (CUFR, 2002). Floodplain and riparian woodland can reduce diffuse pollution, primarily by enhancing siltation and sediment retention (Jeffries *et al*., 2003), nutrient (phosphate and nitrate) removal (Gilliam, 1994) and fixing heavy metals (Gambrell, 1994). Other benefits are carbon sequestration, wood fuel and timber, and improved landscape. Efforts to reduce sediment and pollutant loads, including the use of staging during construction and establishing vegetative buffers along streams and roads would also reduce the stresses on stream biota (Nelson *et al*., 2009). Moreover, the action of riparian and floodplain woodland in encouraging out-of-bank flows and slowing down flood flows promotes sediment deposition and retention, reducing downstream siltation.

The contamination of water bodies with agricultural pesticides can pose a significant threat to aquatic ecosystems and natural resources (e.g. Dabrowski *et al*., 2002). Riparian woodland buffer areas can also provide effective protection for streams and groundwaters from pesticide applications on adjacent land. Lowrance *et al*. (1984) found riparian woodland to be particularly efficient at both intercepting aerial drift of pesticides and trapping pesticides bound to sediment in runoff. Furthermore, pesticide residues may be removed from drainage waters through a number of natural processes within woodland soils, including by tree uptake (Lowrance *et al*., 1984). Both a mature, managed woodland (50 m wide) and a newly restored woodland (38 m wide) achieved almost complete pesticide reduction (Lowrance *et al*., 1997; Vellidis *et al*., 2002). However, few publications have quantified pesticide load reductions by riparian woodland buffers and there have been no studies in the UK. Further work is required to evaluate the role of these controlling factors in order to improve guidance on the best design and management for pollution control.

6.2.4 Valuation: toolkits and unit cost of benefits/economic valuation data

- South East Water Management Climate Change Adaptation Planning Toolkit (LUC, 2005): focuses on three key areas of climate change adaptation for 'water-related' impacts, and how these measures can be delivered through the planning system. The toolkit covers climate change adaptation responses to address:
  - Flood risk.
  - Water resources and water supply issues.
  - Water quality issues (to the extent to which adaptation options to address flood risk and water resource issues have dual benefits for water quality e.g. certain types of Sustainable Drainage Systems (SUDS)).
  - Water related impacts on built structures (such as increased weathering of facades).

- A toolkit for the evaluation of land parcels for green space planning (Kramer and Dorfman, undated). The toolkit provides information on five categories: water quality, farmland protection, economic impact, wildlife protection and cultural protection.
- Toolkits for Greener Practices (Minnesota Pollution Control Agency, undated). Low/No Discharge Stormwater Management Strategies aiming to reduce quantity of storm water runoff from the site or improve the quality of site runoff before it discharges to storm sewers that deliver runoff to area lakes and rivers and before it percolates into groundwater. Use of on-site water infiltration or retention as a means of improving the quality of surface water runoff. Design of new storm water systems to prevent discharge of unmanaged storm water into jurisdictional wetlands, sole-source

aquifers, trout streams or other sensitive areas. Inclusion of wetlands, grassed swales [depressions and ditches], natural vegetation, properly designed extended detention ponds, bioretention and infiltration devices are all effective in reducing runoff volumes from and increasing infiltration at the site. Bioretention practices are designed to mimic naturally vegetated areas, controlling water flow and quality through infiltration and evapotranspiration. Rainwater and rooftop gardens are included among the alternative techniques. Collection systems can be designed for storm water reuse as irrigation water.

- Accessible Natural Greenspace model (CCW, 2004). A practical guide to help identify sites that people need in order to benefit from contact with nature; open water and wetlands are criteria considered.
- Table 6.2 gives a synopsis of the approach for five hydrological schemes and a summary of the cost benefit analysis (CBA) of water-related services.

Table 6.2 Cost benefit analysis (CBA) of water-related services.

Scheme[a]	Approach	CBA[b]
Catskill Watershed Protection Programme, New York (Bureau of Water Supply, 2006; USEPA, 2006)	Integrated water resource management to protect high quality drinking water supply (from phosphorus and microbial pathogens) and preserve natural catchment filtration, rather than constructing and maintaining expensive new water treatment facilities.	Total of ~ €1.35 billion ($1.5 billion) invested since 1991, equivalent to €3,257 ha^{-1} (catchment area = 1600 sq. miles).
City of Aalborg, Denmark - Drastrup Pilot Project (Aalborg Municipality and European Commission, 2002; Loubier, 2002; Water4all, 2005)	Protection of groundwater resource from diffuse pollution (nitrate and pesticides) and provision of recreational facilities close to the city. Converted 900 ha of intensive agriculture into 500 ha of forest (natural broadleaved woodland) and 400 ha of pasture.	Actual costs: €14,000 – 21,000 ha^{-1} to purchase land, and €3000 – 6000 ha^{-1} for cultivation and woodland planting. Drinking water benefit = cost saved estimated at a minimum value of €489 ha^{-1} yr^{-1} (€440,000 per year) for water treatment (cost of NO_3 removal estimated at €0.2 m^3 for > 50 mg l^{-1} NO_3).
Thülsfelde in Lower Saxony, Germany (Water4all, 2005)	Afforestation to achieve good water quality by excluding further application of liquid manure and pesticides to the soil, thereby protecting local groundwater resource from diffuse pollution (from rising nitrate and pesticide concentrations).	Local tax: 5 cents m^{-3} (water penny) used to finance preventative groundwater protection.

Scheme[a]	Approach	CBA[b]
Slea Catchment Study, E. England, UK (Lovett *et al*., 2006; Water4all 2005)	Assessing land-use scenarios to improve groundwater quality (reduce nitrate concentration).	Cost of land use change estimated at €1.96 million (£1.33 million) per year, equivalent to 0.068 cents (0.046p) per litre of water (based on an output of 8 Ml/d) or 12 cents (8p) per person per day (based on average per person use of 180 l/d) or approximately €44 (£30) per person per year.
Social and Environmental Benefits of Forests in Great Britain (Willis *et al*., 2003)	The impact of forests and woodland on water supply, recreation, landscape, biodiversity, carbon sequestration and pollution.	Cost of 19 cents to €1.80 (3p to £1.24) per m^3 where water is lost to abstraction for potable uses; for most areas the cost is zero.

a For further details of the schemes, see Hydrology Case Studies.

b Evaluations have been converted to euros to facilitate comparison (the original currency evaluations are given in parentheses).

Knowledge gaps

Knowledge gaps indicate the following requirements:

- To establish case studies to evaluate the effectiveness of different green space measures for water protection, including street trees, riparian buffer areas, floodplain woodland, infiltration basins, SUDS and green roofs.
- To assess the practicability and effectiveness of integrating the different techniques through detailed integrated assessments.
- To investigate and quantify the effects of trees and vegetation on interception, infiltration, and run-off.
- To evaluate the effect of management (tree type, green roof vegetation type) and strategic planning on the efficacy of measures for diffuse pollution control and flood alleviation.
- To characterise the water use of a greater range of plants and assess suitability based on local climate.
- To investigate the negative impacts of GI on water resources (e.g. increased water use).
- To find ways to identify key locations for green space establishment in order to realise flood management and water quality benefits.

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Hydrological benefits

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7 Ecological benefits

7.1 Introduction

Nature has long been thought of as the ‘opposite’ of urban developments created by humans, with the UK divided into ‘town’ and ‘countryside’. In recent years this perceived distinction has become less apparent. Developments can and should incorporate elements suitable for wildlife; in addition to birds and plants, mammals, insects, fungi and fish can all benefit from well-designed green infrastructure. Green infrastructure in built-up areas is potentially a more hospitable environment for flora and fauna than intensively farmed agricultural land in rural areas. This chapter examines the evidence behind current guidance for creating green infrastructure that benefits biodiversity.

The strategy for the protection of species and habitats in the UK is the Biodiversity Action Plan (UKBAP, 2007), which was the UK government’s response to the 1992 Convention on Biological Diversity (CBD, the ‘Rio’ convention). The objectives of the convention are 'the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits'. Biological diversity, now often shortened to biodiversity, was defined as 'the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. For biodiversity to persist, the constituent species require functioning ecosystems.

Green infrastructure (GI) can act as a functioning ecosystem in its own right for many different species, and can be utilised to achieve BAP targets. Some of those species will be rare or protected; some will be invasive and require careful management. Just as important, urban green infrastructure contributes to wider ecosystem function for species whose persistence is influenced by larger-scale processes. This influence may be mediated by the flow of air or water between components of the wider landscape, or the use of green space elements for resources or movement. The provision of GI has a role in providing wildlife corridors in order to overcome habitat fragmentation and to ensure that populations of key species do not become isolated or die out due to inbreeding.

7.2 Critical review

7.2.1 Benefits and potential costs of urban GI for biodiversity

Increased habitat area

The species-area relationship is a central tenet of ecology. As the area available increases, both the population size of individual species and the total species richness of an area increase. The species-area relationship works almost as well for urban parks and other isolated urban green space patches (Colding, 2007). Part of the species-area relationship is due to larger areas tending to have a greater diversity in habitats. This is not just habitats in the broad sense as perceived by people, but also the small microhabitats such as different types of fallen log in a woodland area. Fernández-Juricic and Jokimäki (2001) reviewed bird-based case studies across Europe, finding that habitat area did indeed explain much of the bird species richness of any one patch. They found that most of 10-35 ha parks will contain all the birds recorded in any urban area of that region. Species might have to move between various areas to reach the different resources they need, and the provision of street trees can provide alternative nesting sites and links between parks (Colding, 2007).

The habitats provided in urban green infrastructure can be particularly important for a range of species for different reasons. An important hypothesis is that of the Safe-habitat – that species with a high tolerance of humans and human environments will be more abundant in urban areas if their predators have lower tolerance. However, urban habitats have other dangers such as cats and the perceived threat of dogs and humans, leading finches to respond to urban habitats as more dangerous. Species of open habitats such as heathland may be particularly easily disturbed by people. For example, ground nesting birds can be severely affected by dog walkers (Mallord et al., 2007). Such habitats may require buffers of additional green infrastructure if development occurs around them. In the Thames Basin, a levy on all new development provides funding for Suitable Alternative Natural Greenspace (SANGS) to provide an alternative for recreation.

For other species, urban habitats provide important resources. Butterflies, for example, can be more abundant in urban areas than rural areas if there are more nectar resources (Figure 7.1; Hardy and Dennis, 1999). It is difficult to tell from this study whether such urban nectar resource patches are also useful for breeding as the authors' conclusion comes from long-term butterfly monitoring data which only records butterfly presence. Overall, urban woodlands contain over half of the species in peri-urban woodlands, and the authors of this statistic (Croci *et al.*, 2008) suggest that improved management of urban woodlands could increase this number.

Figure 7.1 An orange-tip butterfly feeding on herb-robert, a common urban wildflower.

Most studies of biodiversity in GI elements focus on a particular taxonomic group or habitat – Gibson (1998) on invertebrates in brownfield, the BUGS project on gardens or various projects on urban woodlands (Croci *et al.*, 2008). Key evidence of the benefit of urban green infrastructure comes from the 'Biodiversity in Urban Habitat Patches' project of NERC's Urgent research programme. This collaborative project recorded a range of taxonomic groups across different types of urban green space, including railway embankments, parks and derelict land. The range of species recorded from any one particular site reflected patch size, particularly for plants, and habitat quality, particularly for carabid beetles (Angold *et al.*, 2006). GLOBENET (Niemela and Kotze, 1999) was a research programme that used a standard survey protocol to assess carabid (ground beetle) diversity in woodland patches in city centre, suburban and rural sites in eight cities around the world. City centre woodlands contain many carabid species, which tend to be flighted beetles of open habitats, whereas suburban ones contain flightless beetles of enclosed habitats.

Even small patches have a potential to benefit biodiversity. Well-managed roundabouts and road verges support a wide variety of plants and insects, especially if they are not too intensively mown, not sprayed with herbicides, and have suitable trees planted on them. Evidence for roundabouts comes from Hemiptera ('true bugs') in Bracknell, Berkshire (Helden and Leather, 2004) whereas evidence for road verges comes from a much wider range of invertebrates sampled in Durban, South Africa (Whitmore *et al.*, 2002) and butterflies and moths sampled in Finland (Saarinen *et al.*, 2005).
A survey of 3980 people in the UK (largely readers of *Gardeners' World* magazine or members of the Mammal Society) found that urban mammal occurrences in gardens

increase with the availability of nearby green infrastructure. Grey squirrel and mice were most frequently reported by respondents; it is likely that the most infrequent sightings such as otter and hazel dormouse were from rural gardens (Baker and Harris, 2007). Private gardens are of great importance for biodiversity in urban areas, as they contain a diverse range of habitats. For example, ponds will attract amphibians, and tall grasses can attract invertebrates such as the stag beetle and the holly blue butterfly. The analysis of aerial photographs has found that private gardens comprise 20% of Greater London, and these collectively constitute a potentially huge nature reserve (UKBAP, 2007).

Much wider evidence is available for the benefits of green roofs, reviewed in narrative fashion by Oberndorfer *et al.* (2007). Animals such as birds and a wide range of invertebrates, including beetles, ants, bugs, flies, bees, spiders and leafhoppers, use green roofs, as well as large numbers of collembolans, which are an important group of invertebrates for soils carbon cycling (Schrader and Bonning, 2006). Plant species from local stress-tolerant communities (especially mosses and species of the genus *Sedum*) make the best candidates for cover. Slightly deeper substrates support a wider range of plant species but provide greater opportunities for unwanted species such as weeds with roots that may damage the roof. Much of the research in the review comes from Germany (which has a broadly comparable climate to the UK) and applies to unshaded roof sections; the authors note this limitation which is a consequence of the history of green roof research. Wider benefits of green roofs to sustainable urban drainage are reviewed in Chapter 4, Section 4.2.2.

All types of green infrastructure have ecological value; for example retention of shrubbery and dead wood at allotments can be used to encourage hedgehogs, and older well-established allotments are of the greatest value to biodiversity with up to 30% higher species diversity than an urban park (Cambridgeshire BAP, 2000). Largely undisturbed habitats in churchyards and cemeteries can support rare plants and lichens on gravestones, and also provide basking sites for reptiles (Wheater, 1999).

Some habitats that are characteristic of urban green infrastructure are of national or international importance. In particular, the new UK Biodiversity Action Plan Priority Habitat 'Open Mosaic Habitat on Previously Developed Land' is concentrated in urban and peri-urban areas. It is an important habitat for many rare or threatened invertebrates, plants and birds due largely to the unique soil conditions. More information about protected species is given in Section 7.2.2.

Increased populations of some protected species

Four UKBAP priority species are primarily associated with the priority habitat 'Open Mosaic Habitat on Previously Developed Land' (OMHOPDL). These are *Nemophora fasciella*, the horehound long-horn moth, *Brachinus sclopeta*, the streaked bombardier beetle, *Centaurea calcitrapa*, the red star-thistle and *Ophonus stictus*, the oolite downy-back beetle. Table 7.1 shows all UKBAP Priority Species associated with OMHOPDL as a secondary or tertiary habitat.

Figure 7.2 Stag beetle, a protected European species associated with urban habitats.

A much wider range of UKBAP Priority Species makes use of urban green infrastructure. Limited space means examples only are given here. Black redstarts are almost exclusively urban in the UK, living in built spaces especially in London and the West Midlands. Most reptile and protected amphibian sites are large areas on the urban fringe – a viable population needs a lot of space. Heathland areas are particularly good, although adders, for example, have also been found on allotment gardens. Great crested newts are European protected species named in the 1994 Habitats Regulations, as well as UKBAP priority species. All bats are protected in the Habitats Regulations (making it an offence to intentionally or accidentally kill, injure or disturb them or destroy their habitat). Pipistrelles are the bat species most often found in urban habitats and most bat species will use loft spaces or stone structures such as bridges for roosting. The other well-known European protected species associated with urban habitats is the stag beetle, *Lucanus cervus* (Figure 7.2). Gibson (1998) lists the following UKBAP priority invertebrate species as being recorded in 'artificial' habitats: the bumblebees *Bombus ruderatus* and *B. subterraneus*, aculeate Hymenoptera *Cerceris quadricincta*, *C. quinquefasciata* and *Osmia parietina*, the beetles *Harpalus froelichi*, *H. obscurus*, *Mycetophagus quadriguttatus* and *Psylliodes sophiae*, and four moths: the toadflax brocade *Calophasia lunula*, the striped lychnis *Cucullia lychnitis*, the Brighton wainscot *Oria musculosa* and the four-spotted *Tyta luctuosa*.

Gibson (1998) estimated from national invertebrate recording schemes that 12-15 % of rare or scarce UK invertebrate species had been recorded on brownfield sites and that number was expected to rise with additional recording effort. A limited survey of invertebrates on walls of the urban River Wandle and Deptford Creek revealed one nationally rare and 11 nationally scarce invertebrate species (Jones, 1999).

Table 7.1 UKBAP Priority Species which use Open and Mosaic Habitat on Previously Developed Land as primary (main) or secondary (additionally used) habitat. Adapted from http://www.ukbap.org.uk/Signposting.aspx and http://www.ukbap-reporting.org.uk/outcomes/nonj.asp.

Species name	Common name	Primary or secondary	UKBAP national target
Nemophora fasciella	Horehound long-hornmoth	Primary	No target set
Brachinus sclopeta	Streaked bombardier beetle	Primary	No target set
Centaurea calcitrapa	Red star-thistle	Primary	No target set
Ophonus stictus	Oolite downy-back beetle	Primary	No target set
Adonis annua	Pheasants-eye	Secondary	No target set
Lophozia capitata	Large-celled flapwort	Secondary	No target set
Thlaspi perfoliatum	Cotswold pennycress	Secondary	Maintain 16 extant populations; Establish one metapopulation
Triturus cristatus	Great crested newt	Secondary	Increase range; increase occupied ponds by 20% to 120 000; increase high-quality ponds by 20% to 72 000
Ajuga chamaepitys	Ground-pine	Secondary	No target set
Galeopsis angustifolia	Red hemp-nettle	Secondary	Maintain current range; increase suitable habitat

Increased habitat and opportunities for spread of invasive, non-native species

Urban green infrastructure is particularly prone to invasion by highly competitive plants, many of which threaten native plant species or reduce the overall biodiversity of a patch of habitat. Well-known examples are Japanese knotweed (*Fallopia japonica*) and Himalayan balsam (*Impatiens glandulifera*) but native weedy species can also cause problems. In contrast, some people may say that the spread of the non-native *Buddleia davidii*, also known as the butterfly bush, has been a benefit to biodiversity because it is a widely used nectar resource. Eleven species of Lepidoptera caterpillars are known to feed on buddleia leaves or flowers (Owen and Whiteway, 1980).

The relationship between neophytes (plants colonising Britain since 1500) and urban environments has been confirmed by comparing national botanical recording data to the Land Cover Map 2000 (Botham *et al.*, 2009). Archaeophytes, non-native species that colonised Britain before 1500, were not associated with urban habitats but may have been linked to arable fallow land.

There is conflicting evidence, which has not yet been synthesised, as to whether invasive plant species use road verge habitat for movement as well as habitat (e.g. Kalwij *et al.*, 2008; Sullivan *et al.*, 2009).

Negative consequences of increased wildlife

Increased urban green infrastructure can aid the incursion of a range of native wildlife into our towns and cities. Baker and Harris (2007) list the following negative consequences of urban wildlife globally:

- Disease transmission
- Structural damage
- Damage to food crops and ornamental vegetation
- Attacks on humans or pets
- Vehicle collision
- Defecation
- Rubbish bin disturbance
- Digging

They suggest that in the UK, the consequences of urban wildlife are not very severe (Figure 7.3), although their questionnaire that confirmed their hypothesis (that people largely view urban wildlife positively) suffers bias, having been answered largely by readers of *Gardeners' World* magazine and members of the Mammal Society.

Figure 7.3 Most urban wildlife is at worst annoying: a pregnant grey squirrel raids a bird feeder for peanuts.

Large mammals are however undoubtedly taking advantage of urban and suburban green space. The Deer Initiative has been running a wildlife-vehicle collision project since 2003. They estimate that in England, 33% of deer collisions, 28% of badger collisions and 70% of fox collisions are in urban areas (Langbein, 2008). Anecdotally, these are likely to occur near green infrastructure where resources such as food and cover are located. The peri-urban deer project which investigated the relationship between deer and people in towns in the 'central belt' of Scotland found that concern for the welfare of peri-urban deer (whose populations are not managed) is greater than negative experiences of deer by residents (Dandy *et al.*, 2009). However, evidence from other countries suggests that there is potential for large mammals to reach such numbers as to 'change status' from wildlife resource to pest (DeStefano and DeGraaf, 2003).

Birds also make use of urban green infrastructure and may become pests through the spread of disease and through increased collisions (McDonald, 2001). Canada geese gather in great numbers on reservoirs and lawns near UK airports, risking collisions with aircraft (Baxter and Robinson, 2007). There may be a role for good planning to avoid such problems but at the moment a review of guidance suggests it is conflicting and often ill-advised (Blackwell *et al.*, 2009).

The impact of green infrastructure on the spread of pathogens is a developing science and should be the focus of further review.

Positive benefits beyond the GI elements

Urban green infrastructure elements have influences on urban biodiversity beyond their boundaries. The positive impacts that urban GI can have on air, soil and water quality has been covered elsewhere in this review, and other species as well as humans gain the benefits. Reducing the levels of toxic compounds affecting a population may improve survival and reproductive rates and permit recolonisation of areas where species had previously been extirpated.

The amount of impermeable (concrete and tarmac) surfaces in a watershed have been shown to affect reproductive rates of fathead minnows in the USA (Weber and Bannerman, 2004) and the results may be applicable to UK freshwater fishes. Restoration of the Lobau floodplain in the city of Vienna, Austria, including water quality enhancement, has improved the diversity of dragonflies and molluscs downstream of the water quality enhancement site, though not for fishes which may show a lag in their response or require greater connectivity to other populations (Funk *et al.*, 2009). Stream biota diversity can depend more on the adjacency of green space than housing density at wider scales (Urban *et al.*, 2006).

Creating longer-distance movement opportunities for certain species

Two systematic reviews, with quantitative meta-analyses (thought to be the most robust method of interrogating a range of evidence: Higgins and Green, 2008) have found clear indications that urban habitats, with their strong dissimilarity to semi-natural habitats in terms of microclimate, structure and resources, are less permeable to species movement (Prugh *et al.*, 2009; Eycott *et al.*, 2008). There is a broad range of evidence (not yet subjected to meta-analysis) that UK species benefit particularly from linear features and wildlife underpasses. Studies have identified species such as hares, toads and polecats move extensively along linear features such as hedgerows and ditches (Eycott *et al.*, 2008).

Specific evidence of the benefits of linear elements of urban green infrastructure has not been synthesised. There is evidence from Tokyo that linear ‘greenways’ increase bird species richness in urban parks (Morimoto and Katoh, 2005). Modelling suggests that gardens form an important role in urban habitat connectivity (Rudd *et al.*, 2002).

The benefits of green infrastructure can be resource-based, for example Hardy and Dennis (1999) suggest that small urban green space patches are useful for providing nectar resource for vagrant butterflies. Woody streets in Madrid contain a higher number and diversity of birds if they connect directly to an urban park (Fernandez-Juricic, 2000). Ecological theory predicts that populations in low-quality habitat can be supported or ‘rescued’ by more productive populations nearby if connectivity is adequate (Brown and Kodric-Brown, 1977).

Helping biodiversity adapt to changing climate

Researchers modelling the movement of the climatic conditions to which species are adapted have suggested a species may need to move north and west to keep track of their 'climate space'. Even species which do not move far may need to move to a new habitat with a more suitable microclimate (Davies *et al.*, 2006). This move is likely to occur over several generations, and urban green infrastructure may provide 'stepping stones' of habitat and greater permeability of urban areas between habitat patches.

The BRANCH project (Biodiversity Requires Adaptation in Northwest Europe under a Changing climate) modelled species, habitats and networks over time under different climate scenarios. BRANCH found that climate-resilient habitat networks are not yet in place, and recommended that policies and planning systems needed overhauling to take climate adaptation into account. BRANCH also recommended that larger sites worked better than smaller or isolated sites when species were under climate stress (BRANCH Partnership, 2007).

Mitchell *et al.* (2007) published a Defra-commissioned report on adapting to climate change in England and suggested the easiest way to help biodiversity move and survive in urban areas is changing the management of close-mown amenity grass and encouraging wildlife-friendly gardening. Adopting a ‘light touch’ approach helps to improve biodiversity and can significantly reduce the maintenance costs associated with green infrastructure, as this can reduce costs of herbicides, pesticides, fertiliser and labour (Natural Economy Northwest, undated). Functional connections are seen as key to surviving climate change for the wildlife of England.

Climate change and habitat fragmentation have been described as a ‘deadly anthropogenic cocktail’ (Travis, 2003). Some of the impacts of urbanisation (elevated temperatures and increased surface runoff) reflect the changes predicted for wider areas by some climate models (Wilby and Perry, 2006). Freshwater species face particular pressure from the combination of climate change and urban impacts on habitat, which can both serve to elevate temperatures, affect flows through impacts of runoff on hydrological regimes and affect biological and chemical water quality (further reviewed in Chapter 6, Section 6.2.3). Green 'buffer zones' along rivers can be used to mitigate all of the above impacts, thereby improving habitat quality for fish and invertebrate species (Wilby and Perry, 2006). The ameliorating impacts of green infrastructure on temperature, reviewed in Chapter 4, Section 4.2.3, should take some of the immediate temperature pressure off thermally-sensitive species.

Hulme (2005) concludes that there is scope for ecological management to help mitigate climate change impacts, based on the range of evidence he reviewed: mathematical modelling, long-term population studies, 'natural experiments' and natural environmental gradients. The key action is to reduce those environmental management practices which exacerbate effects of climate change.

Conservation targets

There are no published national targets for the UKBAP Priority Habitat: Open Mosaic Habitat on Previously Developed Land (OMHOPDL). Of the ten species which use OMHOPDL as a primary or secondary habitat, three have specific numeric targets currently associated with them (Table 7.1).

Urban habitat creation could help meet other habitat targets. For example, the overall native woodland habitat creation target in the UK Biodiversity Action Plan is 134 500 ha by 2015 (http://www.ukbap-reporting.org.uk/). The target for reedbeds is 3000 ha by 2020 and lowland heathland 6800 ha by 2015. The use of reedbeds in an urban GI network also allows 'multifunctionality' as these can also be used as part of a sustainable urban drainage scheme (see Section 4.2.2).

Individual UKBAP priority species, for example those mentioned in Table 7.1, may have specific targets associated with them, for example different local authorities have different BAPs. Such targets should be identified on a site-by-site or species-by-species basis as there are too many to summarise here.

7.2.2 Biodiversity strategies and policies

The UK biodiversity strategy sets six priorities for shared effort across the countries (UK Biodiversity Partnership, 2007: 6). These are strategic aims. Those involved in the planning, creation and maintenance of urban green infrastructure are in a good position to contribute directly to the first three:

- 'protecting the best sites for wildlife' (by identifying high quality existing urban green infrastructure)
- 'targeting action on priority species and habitats' (by being familiar with where these exist or have the potential to exist within the urban landscape)
- 'embedding proper consideration of biodiversity and ecosystem services in all relevant sectors of policy and decision-making'.

Separate biodiversity strategies exist for each country within the UK, as outlined in the box below.

Biodiversity strategies for the countries

The England biodiversity strategy, working with the Grain of Nature (pp 53 – 59), sets out a plan for urban biodiversity in conjunction with separate plans for agriculture, for forestry and for coasts and seas.

- Integration of biodiversity into policies and programmes for sustainable urban communities.
- Planning policies and development decisions that recognise the need to conserve and enhance biodiversity.
- The planning and implementation of large-scale strategic and infrastructure projects that take full account of the needs of protected areas and species and wider biodiversity.
- Encouragement to local authorities and developers to see the potential of biodiversity as an enhancement to developments.
- Incorporation of more biodiversity elements into green buildings.
- Urban parks and green spaces managed with biodiversity as a core principle.
- Further understanding of biodiversity in gardens and parks and encouragement of gardening practices in urban areas that enhance wildlife.
- Recognition of the opportunities of Local Nature Reserves.
- Promotion of a standardised approach to the identification of local wildlife sites.

The Northern Ireland biodiversity strategy (2002) sets out actions according to the department of government which will be responsible for that action: DOE (Department of the Environment) carries those actions most closely related to UGI:

- '…the protection and restoration of habitats and species…
- '…the Planning Service will have regard to biodiversity conservation when exercising its responsibilities'
- '…improved protection and management for Areas of Special Scientific Interest'

The Scottish strategy 'Scotland's Biodiversity: It's in Your Hands' (2002) lists five strategic priorities, of which two are relevant here:

- Species and Habitats: To halt the loss of biodiversity and continue to reverse previous losses through targeted action for species and habitats.
- Landscapes and Ecosystems: To restore and enhance biodiversity in all our urban, rural and marine environments through better planning, design and practice.

Under Species and Habitats, there are eleven actions of which the most relevant are:

1. Deliver the actions and outcomes identified in the UK species and habitat action plans relevant to Scotland.
5. Develop at local level further actions for biodiversity conservation and enhancement that take full account of climatic, economic and land-use change.
8. Manage existing and develop new local nature reserves and wildlife sites to protect and where appropriate enhance conservation interests.
11. Minimise the detrimental impacts of non-native invasive species.

Under Landscapes and Ecosystems, there are nine actions of which the most relevant are:

2. Provide incentives to create and link habitats and conserve/create important underpinning landscape features in all open spaces.
3. Co-ordinate policies and actions relating to forestry, farming, transport and infrastructure, and urban spatial planning to maximise habitat linkage and minimise further fragmentation.
4. Enhance biodiversity in all transport corridors, and public and private green space through public and private sector initiatives.
5. Develop guidance in relation to maximising biodiversity in all open spaces, and in relation to landscape and ecosystem level planning and management by responsible authorities.

The Wales Environment Strategy (2006) includes biodiversity, and the five priorities for action it sets out (on page 40) are:

- Addressing damaging management practices.
- Ensuring that [Wales's] policies and programmes relating to land-use planning, agriculture, forestry and fisheries have a strong focus on delivering environmental benefits.
- Finding ways to deliver connectivity and environmental improvement at landscape scale, particularly in relation to biodiversity.
- Maintaining landscape character.
- Developing our understanding of biodiversity, landscapes and seascapes, the pressures on them and the most effective way of delivering improvement.

Each of these strategies (UK and country level) explicitly acknowledges that urban areas are part of and contribute to overall biodiversity. Urban green infrastructure, as shown earlier in this chapter, contributes habitat area, including habitats suitable for protected species. Urban GI also contributes greatly to connectivity. With sensitivity, urban GI can also help maintain landscape character, by bringing a sense of the regional landscape into urban areas. For example, managers of urban GI can and most probably already do help meet the first Welsh priority.

The Planning Policy Statement: 'Planning for a natural and healthy environment' (DCLG, 2010) states that biodiversity should be included at all planning levels, based on an understanding of designated sites. Critically, the policy states that local authorities should only permit planning applications that are likely to cause harm to the interests of biodiversity if they are satisfied that there is nowhere else to put the development that would cause less harm (which is different to saying it should not go ahead). The importance of open space for biodiversity is also briefly mentioned in Planning Policy Guidance 17: Planning for open space, sport and recreation (ODPM, 2002).

Habitat networks feature in a range of biodiversity strategies, for example:

- 'Climate change is now our greatest challenge and the plan has actions...these include the creation of habitat networks': *A strategy for England's trees, woods and forests* (Defra, 2007a).

- 'Such networks should be protected from development, and, where possible, strengthened by or integrated within it' (ODPM, 2002).

Current guidance

What does the current biodiversity guidance say? Guidance has been issued by a range of statutory bodies as well as other associations and agencies.

The Town and Country Planning Association (TCPA) produced a biodiversity document as part of their By Design series, making suggestions for planning at the regional, local and unit scales. At the regional ('masterplanning') scale the guidance is based around planning an ecologically functional green infrastructure network from the outset (TCPA, 2004: 18). The TCPA then divide the networks into constituent elements such as large patches on the urban fringe, parks, greenway linkages, street trees and doorstep green space. They encourage:

- Integrating existing and new elements into large scale planning.
- Revising park management to include structurally diverse vegetation.
- Using the distinct flora of the area as a 'pattern book'.
- Managing linear features to minimise disturbance and consider woodland or wetland linkages.
- Planting native species wherever the situation makes them an appropriate choice.
- Using higher plot ratios (more people per m^2 of plot) if the aim is to increase opportunities for a continuous mosaic of doorstep habitats.
- Requiring developers to creatively incorporate habitats into buildings and communal spaces, e.g. through green roofs, climbing plants, and artificial bat and bird nest sites.

All of the above recommendations fit well with the benefits of green infrastructure to biodiversity outlined in the previous sections of this chapter.

CABE Space (the section of the Commission for Architecture and the Built Environment that deals with outdoor spaces and green infrastructure) have issued guidance on encouraging biodiversity in urban parks through contracted groundwork/horticultural services (CABE Space, 2006). Specific recommendations for different types of feature in different kinds of habitats are laid out (CABE Space, 2006: 47-53) and the whole document contains case studies on contract management. They recommend that 'maintenance contractors and client officers need … to look anew at the vegetation they manage as habitats for biodiversity' (see Figure 7.4).

Figure 7.4 Short grass and 'lollipop trees' are appropriate for a formal setting but may have little benefit for biodiversity.

Defra has issued biodiversity guidance for businesses (Cowley and Vivian, 2007), individual and community action (Defra, 2007b), local authorities (Defra, 2007c) and for other public bodies (Defra, 2007d). Defra guidance on meeting the duty of biodiversity conservation for public bodies and local authorities is divided by the areas of operation that each need to consider: policies and strategies; planning and development; management of land and buildings; education and awareness. The public body guidance is necessarily broad due to the range of public bodies from large landowners such as the Forestry Commission to small office-based agencies. The section on managing urban green infrastructure in both publications recommends reducing the area of close-mown grass, planting native species, leaving deadwood and creating a mosaic of habitats wherever possible (public bodies guidance: Defra, 2007d: 36; local authority guidance, Defra, 2007c: 30). This fits in with the ecological benefits reviewed earlier in this chapter. The guidance for businesses is differently arranged: establishing a baseline, creating a plan, and measuring performance. It contains much more basic 'how' guidance, though none of it is related specifically to urban green infrastructure.

Specific guidance on habitat management for birds can be found in the British Trust for Ornithology's brochure *Managing habitat for birds and other wildlife in urban green spaces* (Gough, 2005). The management advice given in this leaflet is based on the London Bird Project, a major survey of urban birds carried out by the British Trust for Ornithology between 2002 and 2004. The survey recorded 90 species of birds from 301 sites in London. The leaflet contains management advice for:

- grassy areas
- trees
- feeding
- bushes
- climbers
- buildings
- nest boxes
- sports areas, playgrounds and flowerbeds

A mosaic of vegetation types with good seed and nectar resources should provide habitats for all kind of species (Figure 7.5).

Figure 7.5 An abandoned colliery site five years after reclamation began.

7.2.3 Valuation: toolkits and unit cost of benefits/economic valuation data

The Urban Green space toolkit issued by the Wildlife Trusts is a 'how to' document aimed at groups trying to create and improve local green space (Calvert *et al.*, 2007). It contains information in colour-coded sections on objectives and evaluation, creating community groups, partnership working, land management and dealing with problems, and funding. It contains 'snippets' of case studies clearly referred back to sources.

It is important to monitor progress whether a toolkit is used or not; indicators of effectiveness are covered by Whitford *et al.* (2001) who settle on two indicators: total area, and a diversity indicator based on the Shannon diversity index but using percentage cover of five broad vegetation classes.

Identified knowledge gaps

The past five years have seen a rise in the number of publications on urban ecology. Many of the references cited in this chapter are from 2008 or 2009, not through deliberate selection of new work but through availability.

By far the greatest remaining gap in our knowledge of the ecological benefits of urban green infrastructure is that general patterns of the benefit of increased permeability cannot be extrapolated to predict individual species' behavioural responses to specific changes in landscapes. Few before/after comparisons are available to guide habitat creation or restoration aimed at increasing species movement (Eycott *et al.*, 2008). There is a balance between in-patch and between-patch influences on the number of emigrants a patch will produce (Bowler and Benton, 2005).

In a similar manner, general patterns of response to climate change cannot necessarily be extrapolated between species. This problem is compounded by the remaining uncertainty in climate models' specific predictions for particular locations, timescales and climate variables such as precipitation (IPCC, 2007).

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8 Knowledge gaps and suggestions

A number of knowledge gaps have been identified in the process of completing this review. These have led to suggestions that should be utilised to maximise the benefits provided by well-designed and well-managed green infrastructure:

- Development and overarching management of a common research strategy for green infrastructure across public and private organisations through support for initiatives such as the Urban Regeneration and Greenspace Partnership (URGP)

- Engender widespread engagement and ownership through involvement of health and education professionals and policy advisors, commercial property agents and developers, insurance industry representatives, utilities companies, green space and tree specialists, planners, economists, ecologists and climate experts

- Support for continued update of the evidence notes, benefits of green infrastructure knowledge portal, and case studies developed under this review.

Economic:

- More primary studies of interventions and investments to establish, maintain and improve green space are needed to build up a database with intervention outcomes of reasonable quality that can be used within a value transfer approach. These should follow additionality and impact assessment best practice guidance (Scottish Enterprise, 2008)

- Research to reverse the lack of primary studies on WTP for green space improvements in aesthetic, land and property values should employed and follow best practice guidelines (Eftec, 2010) that can be used subsequently within a value transfer approach.

Social:

Physical activity and health

- Longitudinal studies to determine whether the impacts of green space on health vary depending on the type of green space involved; and the mechanisms or means through which green space impacts positively on individuals' health. These should be multidisciplinary and involve health, economic, planning and green space professionals. In relation to activity programmes, further demonstration of the particular or unique roles and benefits of green space with economic evaluation are needed to include cost-benefit in terms of drop out rates and health outcomes.

Psychological and mental health and well-being

- An evaluation of the economic value of green space (and type) for psychological benefits (to different groups of users) resulting from both physical activity and passive or less-active use; and the value of green space in relation to mental health. Large-scale surveys are needed which look at green space accessibility and use in relation to health outcome measures such as Health Related Quality of Life (HRQOL). Longitudinal studies on the impacts of green spaces have on recovery from stress and attention fatigue, and the impact of exposure to green spaces over the long-term.

Social interaction, inclusion and community cohesion

- UK studies that specifically examine green space use in terms of ethnicity, gender, ageing and disability and links between green space, social inclusion and deprivation. Further research to distinguish between the positive social experiences that green spaces can offer and positive health benefits.

Climate change and the environment:

- Research and economic appraisal on the extent to which current policies for large-scale tree planting within the United Kingdom, and its regions, would influence air quality in high temperature summer pollution episodes, shelter, heat amelioration, noise, water quality, energy consumption and flood mitigation. Wider impacts of land-use change on such 'ecosystem services' should be specifically considered. Further research on how climate change, increased greenhouse gas emissions, social pressures, flood and drought events, and extremes in temperature will impact on both the resilience of green infrastructure and its benefits

- Research and demonstration on the interactions between interception of precipitation by trees, urban tree effects on soil infiltration and sustainable urban drainage, involving models integrating green roofs, green areas, storage reservoirs etc. This should incorporate various time scales to predict infiltration and run-off more efficiently whilst potentially supporting development of methods to assess ecological status and integrity of a range of SUDS

- More detailed, statistically valid experimentation is necessary to improve understanding of the mechanisms by which vegetation cools the surrounding environment. The incorporation of urban parameters (including vegetation) into predictive weather models needs to be improved for the UK. A review of these models is currently under way, and the SCORCHIO and LUCID projects may also address this issue. Research to place an economic value of such services with potential to compare to other types (non-GI) of intervention

- Production of standardised formats and guidance on 'core' data requirements for land cover and land-use information for determining heat amelioration and flood alleviation within the UK. This should be developed and targeted at the private and public sectors, especially local authorities. Consistent collection, formatting, processing and storage of data would allow utilisation at local, regional and national scales; rather than attempting to collect and manage data purely at the national scale which could become costly, cumbersome and detached from regional and local priorities

- Expansion of the Right Tree, Right Place database to include other vegetation types and information on heat and drought tolerance, resistance to frost damage and other physiological characteristics. This would enable resilience testing for current and planned GI projects

- Standardised recording of basic inventory data for urban trees, woodland and wider green infrastructure. Such data should be gathered and stored locally, but should be collated regionally and nationally and could utilise existing inventory databases e.g. Forestry Commission National Inventory of Woodland and Trees

- Development of accepted definitions (working understanding) of concepts such as environmental quality, quality of place, from which measurements of quality and benefit can be gauged

- A compilation of green space asset inventories with associated case studies used for demonstration

- Studies on the influence of design on environmental quality and equity

- Development of a 'core' set of local environmental quality indicators with supporting methodologies and case studies.

Land regeneration:

- Development of quantitative and qualitative toolkits to evaluate the impacts associated with regeneration projects. Conclusions with respect to project and site sustainability must be drawn yet it is not clear how this can or should be achieved. This knowledge gap is meritable for land regeneration to new hard-end uses as well as to soft-end uses such as GI

- Assessment of social needs within a community against the variety of sites within the locality. The necessary quantities, qualities and configuration of GI that contributes to regular use by all segments of society, with changing socio-demographic characteristics, is not known

- Improved engagement techniques to target management and encourage use and ownership of green infrastructure and unravel barriers to use.

Ecological:

- Studies to determine general patterns of the benefit of increased permeability to provide a means of extrapolating and predicting individual species' behavioural responses to specific changes in landscapes. Inclusion of before/after comparisons to guide habitat creation or restoration aimed at increasing species movement and between in-patch and between-patch influences

- Research to determine general patterns of ecological response to climate change of habitats and species.

9 Conclusions

Green infrastructure: maximising the delivery of multiple benefits

The preceding chapters demonstrate how green infrastructure can deliver a diverse range of individual benefits. It must be stressed that, for an individual green space, its relative positioning within a built-up area and its connectivity with other areas are of paramount importance to ensure that the combined benefits of green infrastructure are maximised. With care given to planning, management and community involvement at the landscape, community and individual site levels, the benefits of green space can become additive and even synergistic, far outreaching the sum of benefits from each individual site.

- At the site scale a green space which is primarily designed and managed to encourage wildlife can engender individuals from the community to come together for the first time, educate children and adults alike on natural history and issues such as climate change, act as a haven to rare and threatened species, and even reduce the flood risk to local homes and businesses. Also the visual and environmental quality of an area can be greatly improved, making people want to live and work within an area, engendering creation of local jobs and increasing property values.

- At the landscape scale each individual site can bring benefits which when added together can reduce the risks of extreme temperatures and flood, and improve water and air quality far beyond the green space boundaries. When sites are connected their value intensifies further giving benefits such as sustainable transport opportunities through walking and cycling ways and promoting populations of fauna and flora to thrive.

- Such connectivity stretches beyond local authority and urban versus rural boundaries. A perfect example is how establishment of floodplain and riparian forestry planted in a rural river catchment, upstream of a built up area, can significantly reduce flood risk by slowing the flow of water generated from sustained or intense rainfall events.

- When combined, these benefits can make a considerable contribution to adaptation and mitigation against climate change, helping climate proof our towns and cities and their communities, whilst improving people's mental and physical health.

Bringing about such benefits requires strong collaboration between local governments, scientific experts, NGOs, planners and site managers alike, and most importantly with the local community. With community involvement the benefits are maximised as sites are respected and become 'owned' by communities, vandalism and crime is reduced, and management costs are minimised. Without community support and 'buy-in' the risk of failure increases and the beneficial value is moderated.

Creating and managing green infrastructure in this way comes at long-term financial and managerial costs. Although, as this report identifies, the value that well-thought out and well-managed green infrastructure can bring should promote serious consideration for investment from across public sector bodies and the private sector alike.