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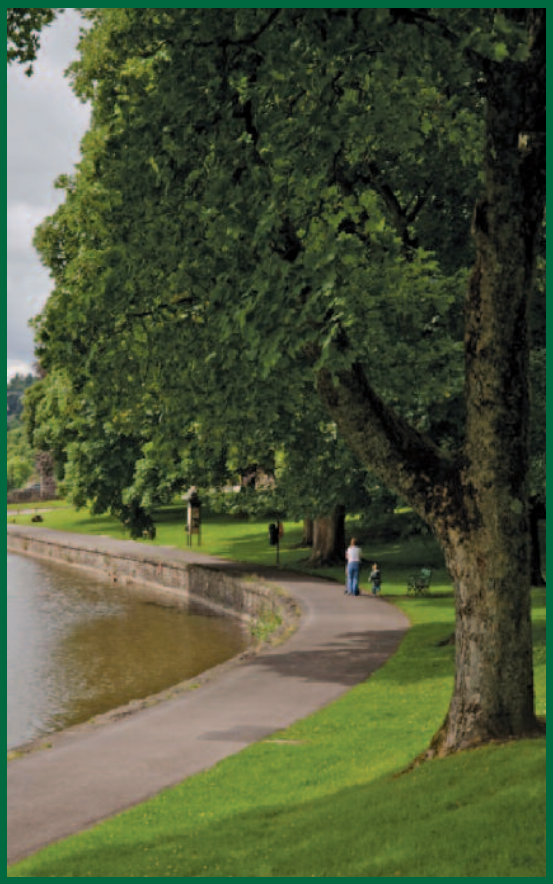
Benefits of green infrastructure

Report by Forest Research



URBAN REGENERATION & GREENSPACE PARTNERSHIP

Promoting sustainable greenspace

Forest Research
The Research agency of the Forestry Commission

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Homes & Communities Agency

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NATURAL ENGLAND

Communities and Local Government

Promoting sustainable greenspace

Benefits of green infrastructure

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October 2010

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What is green infrastructure?

Infrastructure can be 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.

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'.

This report provides a synthesis of the evidence covering the benefits of green infrastructure, based on expert evaluation of scientific and other related literature. Each section gives a concise review of relevant evidence and examples (case studies, research projects and summary points) of how green infrastructure has been applied to maximise benefits in a practical sense. The following are short summaries of each of these sections.

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 (e.g. the UK Low Carbon Transition Plan, 2009). Urban green infrastructure is likely to play an increasingly important role within 'climate proofing' of UK towns and cities. It also directly supports carbon capture, for example in building soil carbon reserves over time. Larger woodlands can support some timber products, and by-products from street tree management can be usefully converted into renewable energy or mulches and composts.

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, it 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; and it can provide a buffer for habitats and species, 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 informing 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, and soil and form of land management will all need to be factored into the planning of new green infrastructure. A changing climate and a need to reduce carbon footprints also provide an opportunity to reconsider green infrastructure, and the outcomes expected 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 land owners to make complex decisions about green infrastructure more effectively.

Health and well-being

Good quality, accessible green space and infrastructure can provide many potential health and well-being benefits. The most significant of these can be grouped into three broad categories: (1) increased life expectancy and reduced health inequality; (2) improvements in levels of physical activity and health; (3) promotion of psychological health and mental well-being. Associations have been found between access to green space and raised levels of physical activity, which in turn improves individuals' health. Green space can also have a beneficial impact on mental well-being and cognitive function. The evidence strongly suggests that, at their best, green spaces can help reduce health inequalities and that both the improvement of existing, and creation of new, green infrastructure should be prioritised, especially in areas of greatest need.

Economic growth and investment

Placing accurate economic values on green infrastructure or its green space components is vital to support the case for sustained investment. Examples of case studies where economic valuation has taken place are outlined 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 local economic regeneration, especially for job creation, business start up, increased land values and inward investment. However, the quality and quantity of this evidence is comparatively poor and further case studies are needed to improve it.

Land regeneration

Previously developed, derelict, underused, neglected (brownfield) land in and around urban centres can deliver social, environmental and economic benefits via conversion to green infrastructure. By delivering improved local environment and quality of place this conversion can be very cost-effective as a result of reduced environmental health risks. Nevertheless, regeneration requires both land regeneration project resources and revenue funds for long-term management and maintenance, and these can be substantial. The evidence highlights the need to improve delivery through effective sustainability evaluation for land regeneration and green infrastructure creation programmes and the impacts of climate change.

Wildlife and habitats

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. Provision of green infrastructure can help meet targets for UK Biodiversity Action Plan (UKBAP) priority habitat ('Open Mosaic Habitats on Previously Developed Land'), broader habitats such as native woodland, and UKBAP priority species. 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.

Stronger communities: social inclusion and community cohesion

Green infrastructure is, in the main, a public resource, available 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 that 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. 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, whilst 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. Green space has potential for enhancing social cohesion; it can bring people together, and can create community cohesion as different social groups engage with each other.

Introduction

Green infrastructure has an important role to play in the adaptation to and mitigation of climate change.

There is a growing body of scientific evidence to show that climate change since the mid-20th century is largely due to human activity. Projections show that major changes to UK climate are likely in the absence of mitigation actions (Defra, 2009). In the UK, climate change is predicted to bring higher average temperatures and increasing incidents of sudden, heavy rain.

Already, UK cities have higher temperatures than rural areas due to the urban heat island effect (CABE, 2010). Twelve per cent of air pollution in urban areas is attributable to this urban heat island effect, due to temperature-dependent formation of pollutants such as volatile organic compounds (VOCs) and ozone (Beckett *et al.*, 1998). In addition, sudden heavy rainfall on built-up areas will be increasingly likely to overwhelm drainage systems, resulting in flooding.

Green infrastructure can provide climate change mitigation and adaptation, as per the UK's National Strategy for Climate and Energy (HM Government, 2009). For example:

- Green infrastructure can help to reduce ambient heat and flooding in urban areas due to the cooling effects of individual trees, and by slowing the rate at which water reaches the ground through infiltration and interception.
- The implementation of sustainable urban drainage systems (SUDS) in the right locations plays a vital role in combating flooding.
- A higher percentage of green cover in urban areas reduces the air temperature.
- Trees and other vegetation remove CO_2 from the air.
- Increasing environmental quality and quality of place encourages more people to travel sustainably through green space linkages.
- Green space linkages enable continued species diversity.

Heat amelioration

Towns and cities are usually a degree or two warmer than surrounding rural areas, as a result of the urban heat island (UHI) effect mentioned in the introduction. The UHI is caused by two main factors: the absorption of direct solar radiation by buildings and other man-made surfaces, and the lack of vegetation in urban areas (Heidt and Neif, 2008). Green infrastructure in urban areas has an important role to play in ameliorating the warming effects of climate change and the UHI. Provision of green infrastructure can reduce higher urban temperatures through evapotranspiration, direct shading and conversion of solar radiation to latent heat (Dimoudi and Nikolopoulou, 2003). The research outlined below shows how green infrastructure can facilitate heat amelioration:

- Potcher *et al.* (2006) have shown that open spaces with a higher number or larger area of trees have been found to have lower temperatures than those with fewer trees. Trees and shrubs provide protection from both heat and UV radiation by direct shading.
- Gill *et al.* (2007) suggested that increasing the current area of green infrastructure in Greater Manchester by 10% (in areas with little or no green cover) could result in a cooling of up to 2.5 °C under the high emissions scenarios based on the UK Climate Impacts Programme (UKCIP02) predictions.
- Beckett *et al.* (1998) found that 12% of air pollution in urban areas is attributable to the urban heat island effect, due to temperature-dependent formation of pollutants such as volatile organic compounds (VOCs) and ozone.
- Parks of at least 3 ha have been shown to be cooler than that of the surrounding urban areas, the temperature in parks of less than 3 ha is more variable, and the quantity of paved surfaces in a park also causes variation in park temperatures (Chang *et al.*, 2007).
- Several studies of parks in Singapore by Yu and Hien (2006) have shown that the temperature outside the park's boundary gradually increases when moving further away from the green area, suggesting that the park has a cooling effect and that this extends beyond the boundary. The largest of the parks (156 ha) showed the strongest relationship between temperature and distance. A study by Shashua-Bar and Hoffman (2000) suggested that the cooling effect of trees could be detected up to 80 m away.

The scale of the challenges

- In future years the warming effects of climate change are likely to increase the intensity of the UHI in our urban areas.
- Increased summer heat in urban areas will increase levels of indoor and outdoor thermal discomfort. Adverse health effects such as sunburn, skin cancer and cataracts are likely to increase (Kovats, 2008).
- The UHI effect will cause a direct increase in the energy costs associated with air conditioning.

Reducing flood risk

Alterations to the natural environment can affect the movement of water through the hydrological cycle and alter its composition. Urban development retains very little of the original vegetation and landscape, replacing it with buildings, roads, gardens and parks (Whitford *et al.*, 2001), and these changes have a significant impact on the hydrology and also on freshwater ecology and the terrestrial ecosystems that river systems support. Green infrastructure provides a means through which to restore natural environmental features to the urban environment and can provide hydrological benefits in two key areas: flood alleviation and water quality.

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; and these alterations can exacerbate the nature and seriousness of flood and drought events by changing volume, velocity and direction of water flow (Defra, 2008).

There are three main ways in which woodland and other vegetation in the urban or peri-urban environment can contribute to flood alleviation:

- By delaying the downstream passage of flood flows.
- By reducing the volume of runoff through interception.
- By promoting rainfall infiltration into the soil.

The following range of studies help to illustrate this important contribution.

- Nisbet *et al.* (2004) 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 raise the flood level within the woodland by up to 270 mm for a 1 in 100 year flood.
- 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.
- Green roofs contribute significant benefits for urban water management, including stormwater management (Mentens *et al.*, 2006).
- Natural England highlighted the use of green belts to act 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.
- Urbanisation has also been shown to affect groundwater temperatures, with urban groundwater values found to be 3.5 °C higher than rural groundwater values (Yalcin and Yeteman, 2009).
- American research has found that a yard tree can intercept 760 gallons (3455 litres) of rainfall in its crown, thereby reducing polluted stormwater runoff and flooding.
- Trees in gardens and yards can provide environmental and economic benefits by retaining pollutants and intercepting rainfall (CUFR, undated).

Improving 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 speed runoff, pollutants and detritus collected from urban surfaces and reduced infiltration of precipitation (Pompeu and Alves, 2005; Stovin *et al.*, 2008; Jacob and Lopez, 2009). Additionally, 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 following studies show how green infrastructure can help improve water quality:

- 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 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.
- 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).
- 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. 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).
- A study by Seters *et al.* (2009) on 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.
- 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).

The scale of the challenges

- The majority of water bodies in the UK currently fail to meet the 'good status' target of the EU Water Framework Directive due to diffuse pollution and other pressures.
- The contamination of water bodies with agricultural pesticides can pose a significant threat to aquatic ecosystems and natural resources (Dabrowski *et al.*, 2002).
- Many countries world-wide rely on forests. One-third of 105 of the largest cities in the world rely on forest protection areas for some or all of their drinking water (Dudley and Stolten, 2003).

Sustainable urban drainage

Sustainable urban drainage systems (SUDS) have been developed to improve urban drainage and reduce the volume of urban runoff. SUDS encourage green space in urban areas by controlling the water at the source through trees and vegetation, green roofs, infiltration trenches and filter drains, swales and basins and ponds and wetlands. Drainage is a continual problem in highly urbanised areas and with space at a premium green roofs especially can be implemented as an alternative measure to reduce rainwater runoff and prevent flooding.

The studies below show how SUDS within green infrastructure can help.

- Gill *et al.* (2007) suggest that increasing green space would reduce runoff by 4.9%, increasing tree cover reduces runoff by 5.7% and that green roofs would have a significant effect in reducing runoff by 11.8–14.1%.
- Duffy *et al.* (2008) produced a cost benefit analysis which supports SUDS and indicates that well-designed and maintained SUDS are more cost effective than traditional drainage solutions, as they cost less to construct and maintain.
- A study by Mentens *et al.* (2006) concluded that the rainfall retention capability of green roofs on a yearly basis may range from 75% for intensive green roofs to 45% for extensive green roofs. The authors also noted that another benefit of green roofs over traditional green space is that they make use of previously unused space and do not limit the demands of people for open space on the ground.
- Green roofs also 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).

Case study: Malmo, Sweden

A new storm water management system has been installed because the former sewage and water management system was outdated and heavy rain would cause flooding, leading to vehicle and property damage. The new system collects runoff from the rooftops and impervious surfaces and channels it through canals, ditches, holding ponds and wetlands before it enters the traditional closed sub-surface storm water system. This helps to slow the volume of water that enters the storm water system and prevent flooding (CABE, 2009).

The scale of the challenges

- The cost to the national economy due to urban flooding is estimated to be £270 million a year in England and Wales (Parliamentary Office of Science and Technology, 2007).
- Environmental damage due to pollutants is estimated to be between £150 million and £250 million a year based on 2004-05 values (Environment Agency, 2007).
- A foresight report suggests that if no action is taken, the cost of urban flooding could rise to between £1-10 billion pounds a year by the 2080s (Parliamentary Office of Science and Technology, 2007).
- Around 15% of rivers and 22% of groundwaters are at risk of failing the EU water framework directive objectives (Environment Agency, 2007).

Improving air quality

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). Trees in urban green space can influence air quality in a number of ways; for example through direct absorption of gaseous pollutants and interception of particles onto leaf surfaces, by lowering air temperatures through transpiration which can reduce the formation of ozone, and through the direct production of oxygen during photosynthesis. Further examples of studies include:

- Nowak (1994) showed that trees in the Chicago area were estimated to remove 6190 tonnes of air pollution per year, which equates to an average improvement in air quality of approximately 0.3%. Further improvement in air quality of 5-10% can be gained from increased tree cover.
- Tiwary *et al.* (2009) showed that trees reduce pollution through the deposition of particulate matter onto leaf surfaces. The structure of large trees and their rough surfaces cause interception of particulate matter of less than 10 microns in diameter (PM_{10}) by disrupting the flow of air, and trees provide a surface area for capture that can be between 2 and 12 times the area of land they cover.
- A study by Broadmeadow and Freer-Smith (1996) found that the proportion of gaseous pollutants such as SO_2, NO_x and ozone that are absorbed by trees depends on species, stomatal conductance, environmental conditions and pollutant concentration in the atmosphere. It was shown that the uptake of SO_2, NO_x and ozone was higher in broadleaved species than conifers.
- Freer-Smith *et al.* (2005) found that conifers capture larger amounts of PM_{10} than broadleaved trees. This is due to the larger total surface area of needles, giving conifers larger filtering capacity than broadleaved trees (Stolt, 1982).
- Research by Jouraeva *et al.* (2002) found that trees can intercept particle-bound PAHs by accumulating particles of less than 2.5 microns ($PM_{2.5}$) on the surface of leaves and bark. Some species of tree, such as those with needles, are more successful at intercepting $PM_{2.5}$ due to high surface area.
- Lovasi *et al.* (2008) found that street trees have been associated with a lower prevalence of asthma in children, even after adjustment for potential confounding factors including socio-economic characteristics, population density and proximity to pollution sources.

The scale of the challenges

- Government estimates suggest that 24 000 people die prematurely in the UK as a result of air pollution (NWDA, 2007).
- Estimates show that admissions to hospital linked to air pollution cost the NHS between £17 million and £60 million a year (Sustainable Development Commission, 2008).
- Air quality in the UK has improved since the 1950s, but remains a problem. For example, the prevalence of asthma is still high and exacerbations of this disease have been linked with poor air quality. An estimated 1.1 million children in the UK have been diagnosed with asthma (Asthma UK, 2007).

Introduction

There has been a growing recognition that green infrastructure can help deliver key benefits for public health and well-being. The Department of Health's plan for improved physical activity 'Be active be healthy – a plan for getting the nation moving' and public mental health framework 'New Horizons: flourishing people, connected communities' and the Marmot report 'Fair society, healthy lives' all acknowledge the role of green space.

This recognition is based on a growing body of evidence which shows that green spaces can, in particular, assist with the delivery of priorities for:

- Increased life expectancy and reduced health inequality.
- Improvements in levels of physical activity and health.
- Psychological health and mental well-being (O'Brien *et al*., 2010).

Key examples of the role played by green spaces include:

- Health inequalities related to income deprivation are lower in populations living in the greenest areas. The effect holds for all-cause mortality, and mortality from circulatory diseases.
- Living closer to parks or recreation/leisure facilities is associated with increased physical activity and reduced levels of obesity.
- There is a clear association between good mental health and physical activity, and access to good quality green space can encourage people to take exercise (Department of Health, 2009).
- Around 83% more individuals engage in social activity in green spaces as opposed to sparsely vegetated/concreted ones, helping community cohesion.
- The benefits of green space are greatest for people from lower socio-economic groups.

Increasing life expectancy and reducing health inequality

The Sustainable Development Commission (2010) has reported that access to green spaces is unequally distributed across socio-economic groups, with poorer social groups having, in general, lower access. It is also considered that green space could have positive influence on health conditions such as obesity, mental health, circulatory disease and asthma, which are significant factors in relation to health inequality. The commission considered that more equal access to green space could be key to reducing health inequalities between socio-economic groups, and provide a preventative and synergistic approach that has social, environmental and economic benefits.

These studies help to demonstrate the positive links between green space and physical and mental health.

- In a study by Mitchell and Popham (2008) the population of England was classified on the basis of income deprivation and exposure to green space, and it was shown that health inequalities related to income deprivation were lower in populations living in the greenest areas. The effect held for all-cause mortality and mortality from circulatory diseases, but no effect was found for causes of death unlikely to be affected by green space, such as lung cancer and intentional self-harm.
- Research by Maas *et al*. (2006) found that the percentage of green space in a person's residential area was positively associated with their perceived general health, and that this relationship was strongest for lower socio-economic groups.
- An analysis by Cohen *et al.* (2007) found that public, urban parks are critical resources for physical activity amongst residents in low-income, minority communities.
- A study by the Mental Health Foundation (2009) found that green space is particularly influential on conditions which are significant contributors to health inequalities, such as obesity, circulatory disease, mental health, chronic stress and asthma.

The scale of the challenges

- While the health of the UK's population has significantly improved over the past 150 years, huge health inequalities remain (Shaw *et al*., 2005).
- Life expectancy and infant mortality indicators reveal the health gap has even increased in some cases (Department of Health, 2009)
- Life expectancy for males in Kensington and Chelsea was 84 years, while in Greenwich it was 75 in 2005-07. Even greater inequalities are evident, with male life expectancy in Tottenham Green in Haringey being 17 years less than the 88 years in Queen's Gate in Kensington and Chelsea (based on 2002-2006 data; Greater London Authority, 2009).
- The Department of Health's 2009 *New horizons* consultation document recognised that mental health 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).

Improving levels of physical activity and health

Strong associations have been found between access to green space and higher levels of physical activity, which can dramatically improve individuals' health. Green spaces have been shown to independently promote physical activity, thereby enhancing the health profile of the people who use those spaces. For example:

- Living closer to parks or recreation/leisure facilities is generally associated with increased physical activity (Kaczynski and Henderson, 2007).
- The further away residents are from green space the less likely they are to visit it; for those individuals under 25 years of age, the further they lived from green space, the more likely they are to be obese (Nielson and Hansen, 2007).
- Communities with more parks showed significantly higher levels of walking and cycling for transportation (Zlot and Schmid, 2005).
- The Green Gym Scheme run by the British Trust for Conservation Volunteers (BTCV) helps people to take exercise outdoors while participating in activities that improve the environment. Nine out of ten participants with poor mental or physical health show an improvement within seven months (Sustainable Development Commission, 2007). Evaluation of the scheme concluded that the overall physical health of participants improved significantly, with the strongest effect for people with the poorest physical and mental health (BTCV, 2008). Green Gym schemes have also shown that 'participants in the initiatives were more likely to continue with exercise than those on more traditional gym-based regimes' (Brown and Grant, 2005).

It is well established that regular exercise, including walking, can reduce the negative effects of many major health threats such as obesity, type 2 diabetes, coronary heart disease and respiratory disorders. Evidence from 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) and a report for the Forestry Commission suggests that a reduction of 1% in the level of sedentary behaviour in the UK would prevent 1063 deaths per year and avert 15 000 morbidity cases per year by saving £1.44 billion in health care costs (CJC Consulting *et al.*, 2005).

Obesity and diabetes: the scale of the challenges

- Lack of physical exercise is costing the NHS 2–3% of its budget.
- Increasing physical activity through improved access to high quality green spaces could save the NHS £2.1 billion a year (Defra, 2010).
- Obesity costs the UK economy £1 billion per annum in direct health and social care costs and £3 billion per annum in wider impacts.
- Diabetes costs the UK economy £1.3 billion per annum in direct health and social care costs.

Improving psychological health and mental well-being

People have a well-developed awareness of the stress reducing benefits of nature, and green spaces have been shown to provide a restorative environment which helps alleviate stress and mental fatigue. Studies suggest that the evidence on the restorative effects of green spaces, and contact with nature, is more compelling than the evidence on the potential benefits for physical health (Croucher *et al.*, 2007). There is also strong evidence which suggests 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). Furthermore, the restorative benefits of green space generally come at no direct cost to the user whereas other forms of relaxation (such as yoga) or medical treatment usually do. Green spaces can also help improve mental well-being by encouraging social activity and interaction:

- Van den Berg *et al.* (2007) suggest that physical activity in green environments has greater psychological and physiological benefits than physical activity in other settings.
- 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 by Hartig *et al.* (2003) provided evidence of the positive impact of natural settings on improved attention functioning, emotional gains and lowered blood pressure.
- Using a large postal survey of residents in nine Swedish towns and cities, Grahn and Stigsdotter (2003) suggest that the more often a person visits urban open green spaces, the less often he or she will experience stress-related illnesses.

Direct evidence has been found of the restorative effects of green space on mental health. Taylor *et al.* (2001) studied 96 children suffering from attention deficit disorder (ADD) and found that the children experienced fewer problems if they had access to green space for play and the 'greener' the setting, the less severe the ADD symptoms. 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.

Psychological health and mental well-being: the scale of the challenges

- 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).
- 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 *et al.*, 2008: 13).
- The Sustainable Development Commission (2007), estimated that 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.

Ecotherapy

'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, the leading mental health charity in England and Wales, have conducted some evaluations of green exercise activities (Mind, 2007).

Of particular relevance is a small-scale study evaluating the effects of walking or cycling in a group in a country park as opposed to walking or cycling in a group in an urban area. They found that walking and cycling in the different settings provoked different responses in terms of self-esteem and mood and that being near 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).

Introduction

The vast majority of evidence suggests that green infrastructure provides social and environmental benefits, and these in turn can be valued to give a monetary value of benefits provided; for example the value of increased physical activity. In addition to social and environmental benefits green infrastructure can have an impact on the local economy.

The value of good quality accessible green infrastructure to the local economy can be quantified through:

- Inward investment and job creation
- Land and property values
- Local economic regeneration.

In most cases there is little doubt that returns on green infrastructure investment are high. 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).

As the UK leaves the deepest recession since 1930s, economic growth as a result of investment in green infrastructure will help UK companies succeed in international markets and assists overseas companies to bring high quality investment to the UK (ONS, 2010). In addition, investment in green infrastructure helps to meet the requirements of the UK Sustainable Development Strategy 'Securing the future – the UK Government's sustainable development strategy' (Defra, 2005).

Inward investment and job creation

In the UK there are many instances of economic growth and investment as a result of the provision of well-maintained and managed green space:

- Improving the aesthetics of the local landscape increases people's enjoyment of an area, and attracts businesses, which in turn can attract customers, employees and further services (Venn and Niemela, 2004).
- Investments to improve the aesthetic quality of place (including visual amenity) can be reflected in land and property prices. The impacts of green space on local economic regeneration can be indicated by changes in employment (FTE jobs created), new business start ups, GVA, and land and property prices.
- The Mersey Forest study estimated that for every £1 invested in the Merseyside Objective One programme, £2.30 will be generated in increased GVA over the lifetime (50 years) of the investment (Regeneris, 2009:5).
- Landscaping improvements at Riverside Park, Clydebank and Winsford yielded over 16% and 13% respectively of net growth in employment and levered over £1 million of private investment (Scottish Enterprise, 2008).
- The creation of the National Forest increased the number of local jobs by 4.1% and local regeneration using green infrastructure attracted £96 million of investment (CESR, 2004).
- Public sector funding of £425,000 in Portland Basin Green Business Park secured over £1.8 million of private investment due to landscaping improvements (CLES, 2007).
- Due to landscape quality and security improvements at a 57 ha industrial estate at Langthwaite Grange, Wakefield, West Yorkshire, crimes such as vandalism have fallen by 70% in 12 months (CSI, 2008).
- Views of urban fringe broadleaved woodland on journeys were estimated to be valued at around £448 million at 2007–08 prices, or £15.7 million per year (Forest Research, 2008).

Land and property values

Developing and improving green space in key locations within urban and semi-urban areas is argued to have significant benefits by increasing nearby property and land values. Hence, 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 (NENW, 2008:9). Further examples include:

- CTLA (2003) have shown that provision of trees can add 15% to 25% to the total value of properties, depending on size, condition, location and species rating. 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 can add 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 (Cousins and Land Use Consultants, 2009).
- Garrod (2002) also found that proximity to, or the view of, broadleaved woodland enhanced property values; furthermore, it was estimated that proximity to at least 20% woodland cover would raise the value of an average house by 7.1%.
- A primary study (Garrod, 2002) of public preferences for visual amenity with respect to woodland showed that respondents were willing to pay £269 per annum per household for a woodland view from houses on the urban fringe.
- GEN Consulting (2006) found that regeneration using green infrastructure of a run-down area (negative aesthetics and perception) caused house prices to increase by 111% in Glasgow. It was established that once the general property price rises and any other differing factors had been stripped out, the enhancement value of the existing housing stock was in the region of £15 million, and as a result of the scheme new development to the value of £75 million has been realised.
- In a study by CABE (2005) it was found that for properties 'on' a local park the average premium was 11.3% and for properties within close proximity to the park the average premium was 7.3% (standard deviation of 9.4%). 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%.

- Green infrastructure can improve the aesthetic quality of an area which in turn can increase inward investment, attract businesses and customers and encourage people to spend more time and money in an area.
- Economic growth as a result of investment in green infrastructure can lead to higher levels of employment and tourism, and to lower levels of crime.
- Having a well-managed green space nearby results in average property premiums from 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 housing stock increases the value of council tax generated in the locality (GEN Consulting, 2006:14)

Local economic regeneration

Economic regeneration means increasing employment, encouraging business growth and investment, and tackling economic disadvantage (Audit Commission, 2005:2). Investment in green infrastructure involves the creation, improvement and development of green space and landscaping. This investment encourages and attracts high value industry, entrepreneurs and skilled workers to a region through the maintenance and creation of high quality, landscape sensitive, environmentally friendly living and working environments, adding GVA to local economies (ECOTEC, 2008). Local economic regeneration is strongly related to benefits of green space such as economic growth and investment, quality of place (including visual amenity), recreation and leisure, and tourism.

Good local economic regeneration is illustrated in the following two examples:

- Developing woodland can enhance property values in the surrounding area, for example in Bold Colliery, St Helens, Lancashire, property values increased by around £15 million and helped realise a further £75 million for new development (Forestry Commission, 2005).
- The Glasgow Green Renewal project stimulated the development of 500-750 new residential properties, enhanced average house prices and the total value of property transactions by net £3 million–£4.5 million, increased yield in council tax by 47% and increased the value of the land from £100,000 to £300,000 per ha (GEN Consulting, 2006).

The scale of the challenges

- Across England there remains an ongoing struggle to find capital funding for investment in green infrastructure and also to find funding for maintaining green spaces to a good standard (NAO, 2006).
- The current economic climate makes it difficult to invest in, let alone maintain, green infrastructure.
- There is an on-going struggle across England to find capital funding to improve green spaces that are run-down and sustainable sources of revenue funding to maintain spaces to a good standard (NAO, 2006).
- Creation of a park from blank canvas could cost in excess of £3.9 million (CABE, 2009).

Introduction

The provision of green infrastructure in urban areas can deliver a wide range of environmental benefits, such as:

- Increased environmental and aesthetic quality
- Regeneration of previously developed land (PDL)
- Improvements in quality of place.

Well-designed and well-managed green infrastructure has the potential to deliver all of these environmental benefits while at the same time enabling the provision of green infrastructure to meet a range of key UK policies. These include the National Air Quality Strategy, the EU water framework directive and the Mayor of London's draft climate change strategy.

- Trees in urban areas improve air quality by removing different types of air pollution, including particulate matter, sulphur dioxide, nitrogen oxide and ozone.
- Children living near street trees have a lower prevalence of asthma.
- Sustainable urban drainage systems help to slow the volume of water that enters the water system and prevent flooding.
- The benefits of attractive urban green space include: increased inward economic investment; increased property values; attraction of tourists; improved area image and improved flow of local money.
- Open spaces with a higher number or larger area of trees lower the ambient temperature in urban areas through shading, evapotranspiration and conversion of solar radiation into latent heat.
- The most deprived populations are more likely to be living in areas of low environmental quality in relation to flood risk, waste management sites, landfill sites, industrial air pollution and distance to parks and woodland (Environment Agency, 2008)

Regeneration of previously developed land

Areas of previously developed land (PDL) are often contaminated from their former uses. The regeneration of PDL to green infrastructure can reduce the human and environmental health risks associated with these areas, and can also help to improve the local environment. Due to the potential risks, English planning law requires that contaminated sites must be remediated prior to redevelopment and remediation must ensure that the site is 'suitable for use'. The use of green space and woodlands has been proposed as a cost-effective remedial strategy for the redevelopment of contaminated PDL. The Government's Sustainable Communities plan of 2003 set a target for 60% of new housing to be constructed on PDL by 2020 (Alker *et al*., 2000; English Partnerships, 2006). Such regeneration when combined with green infrastructure will have the following positive effects:

- Trees have the potential to remove and immobilise contaminants through the processes of phyto-remediation and phyto-stabilisation, and these processes are an inexpensive *in situ* approach to remediation (Hutchings, 2002).
- The establishment of vegetation on contaminated PDL can break the pollutant linkage pathways, for example through prevention of soil erosion which minimises dust production and reduces the risk to humans (Hutchings, 2002).
- Regeneration of PDL provides indirect health benefits linked to use of the green space for exercise, general fitness and improved well-being (Defra, 2004; Mitchell and Popham, 2008; Stubbs, 2008; Kessel *et al*., 2009). The provision of nearby green space also helps to encourage sustainable patterns of travel, such as cycling (Hillsdon, 2008), which can reduce the prevalence of obesity and cardiovascular diseases (Barton, 2009).
- Regeneration of PDL can improve the condition of the soil, vegetation, surface waters (including culverts, sustainable urban drainage systems and ditches) and groundwater. Regenerating PDL to green infrastructure will provide and improve local ecosystem services (Handley, 1996).
- 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 (English Partnerships, 2006). The removal of contamination, waste and derelict buildings through regeneration transforms local areas, increases inward investment and increases local house prices.

The scale of the challenges

- In 2009 there were an estimated 66 000 ha of PDL that posed potential risk to human and environmental health (English Partnerships, 2006).
- The economic costs associated with hospital admissions and premature deaths due to contaminated land were estimated at £85.2 million (Forest Research, 2008).
- Vacant, derelict or abandoned open spaces often become a haunt for anti-social behaviour, and become a blight on the visual landscape (CABE Space, 2005).

Improving quality of place

Green space provision can make a positive contribution to improving 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 provision of high quality, well-maintained green space can have a positive effect on local activities and business, and improve an area's image and the confidence of both local inhabitants and potential investors (Land Use Consultants, 2004).

Swanwick (2009) noted that highly valued green spaces enhance the positive qualities of urban life, offer a variety of opportunities and physical settings and encourage sociability and cultural diversity. However, a report by Land Use Consultants (2004) showed that 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. One example of the potential for green infrastructure to have a positive impact is Ingrebourne Hill Community Woodland (Landscape Institute, 2009).

Ingrebourne Hill Woodland (courtesy: Forestry Commission).

The scale of the challenges

- Deprived neighbourhoods experience more severe problems with graffiti, litter and fly-tipping, and poorly maintained public and open spaces (Hastings *et al.*, 2005).
- Neglected spaces negatively impact on their surrounding areas, contributing to the onset of vandalism, anti-social behaviour, graffiti and littering (CABE Space, 2005).

Increasing environmental quality and aesthetics

The visual appearance and attractiveness of towns and cities has been found to be strongly influenced by the provision of green space (Tibbatts, 2002). The two main components of environmental quality are the 'physical' and 'perceived' quality of the local environment (Khattab, 1993); the concept of local environmental quality is broad and can encompass many elements including environmental pollution and cleanliness, and visual quality and personal security, but green infrastructure can improve the current situation.

Introduction

Urban green infrastructure can have influences on urban biodiversity. Green space can form a functioning ecosystem in its own right for many species, for example rare or protected or those that are invasive and require careful management. Just as importantly, urban green space contributes to wider ecosystem function for species whose persistence is influenced by larger-scale processes. Green infrastructure can influence biodiversity by:

- Increasing habitat area.
- Increasing populations of some protected species.
- Increasing species movement.

The positive impacts that urban green infrastructure can have on air, soil and water quality provide benefits for biodiversity. This influence will 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 importance of green infrastructure for biodiversity is covered in the consultation document on 'Planning for a healthy and sustainable environment' (CLG, 2010).

- Species population size is directly linked to the size of available habitat area.
- A wide range of protected and rare species make use of green infrastructure in urban areas.
- Urban green infrastructure provides 'stepping stones' of habitat and greater permeability of urban areas between habitat patches.
- Some species will be affected by changing climatic conditions and will need to adapt or move north and west to keep track of their 'climate space'. Even species which do not travel far will need to move to a new habitat with a more suitable microclimate.

Increasing habitat area

The habitats provided in urban green infrastructure can be particularly important for a range of species. As the area available for habitation increases, both the population size of individual species and the total species richness of an area increase. The species-area relationship works approximately 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. Good quality green infrastructure can help in a variety of ways:

- Fernández-Juricic and Jokimäki (2001) found that habitat area explained much of the bird species richness of any one patch, and that most 10-35 ha parks will contain all the birds recorded in any urban area of that region.
- In a study by Hardy and Dennis (1999) butterflies were found to be more abundant in urban areas than rural areas if there were more nectar resources.
- Angold *et al.* (2006) 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.
- Green roofs are used by birds and a wide range of invertebrates, including beetles, ants, bugs, flies, bees, spiders and leafhoppers, as well as large numbers of collembolans, which is an important group of invertebrates for soil carbon cycling (Schrader and Bonning, 2006).
- Urban mammal occurrences in gardens have been found to increase with the availability of nearby green infrastructure. Grey squirrels and mice were most frequently reported; it is likely that the most infrequent sightings such as otter and hazel dormouse were from rural gardens (Baker and Harris, 2007).

Increasing populations of some protected species

A wide range of UK Biodiversity Action Plan (UKBAP) priority species make use of urban green infrastructure. Some habitats that are characteristic of urban green infrastructure are of national or international importance. In particular, the new UKBAP habitat 'Open Mosaic Habitat on Previously Developed Land' (OMHOPDL) 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. Green infrastructure can assist in increasing such populations:

- 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 eleven nationally scarce invertebrate species (Jones, 1999).
- Four UKBAP priority species are primarily associated with the OMHOPDL. These are the horehound long-horn moth, the streaked bombardier beetle, the red star-thistle and the oolite downy-back beetle (Gibson, 1998).

Increasing species movement

Urban green infrastructure creates opportunities for longer-distance movement for some species. This allows species to move around within, and between, urban areas:

- Some UK species benefit particularly from linear features and wildlife underpasses (Eycott *et al*., 2008) and there is evidence that linear 'greenways' increase bird species richness in urban parks (Morimoto and Katoh, 2005).
- Modelling by Rudd *et al*. (2002) suggests that gardens form an important role in urban habitat connectivity.
- Brown and Kodric-Brown (1977) predict that species population in low-quality habitat can be supported or 'rescued' by more productive populations nearby if connectivity is adequate.
- Stream biota diversity can depend more on the adjacency of green space than housing density at wider scales (Urban *et al.*, 2006).
- Use of green infrastructure for sustainable urban drainage systems can improve water quality and thereby improve the diversity of species such as dragonflies and molluscs downstream of the water quality enhancement site (Funk *et al.*, 2009).
- Even small patches have a potential to benefit movement of biodiversity. Well-managed roundabouts and road verges support a wide variety of plants and insects, especially if they are not too intensively mown and are planted with suitable trees (Helden and Leather, 2004).
- Fernandez-Juricic (2000) found that woody streets in Madrid contain a higher number and diversity of birds if they connect directly to an urban park.

The scale of the challenges

- Of the species which use OMHOPDL in the UK as a primary or secondary habitat, three have specific numeric targets currently associated with them (http://www.ukbap-reporting.org.uk/outcomes/nonj.asp).
- 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/).

Introduction

Community engagement during the creation of green infrastructure is vital at all stages in the process in order to ensure its success. The involvement of the local community brings social benefits such as community cohesion and inclusion to local people, and provides residents with a sense of ownership and from this a higher level of satisfaction and positive perception of quality. This helps to conserve the multifunctional use of the green space system, and children, in particular, are able to gain from involvement in green space provision, and can learn about the natural environment and develop skills through play.

- In a report by Forest Research (2008), 98.6% of people agreed that 'woodlands are an important part of our community'. Around 65% of adults reported that the provision of nearby green spaces is important to them (British Market Research Bureau's report to Defra, 2007).

Social interaction, inclusion and cohesion

Green space and social interaction

Green space offers possibilities in terms of increasing social activity, improving community cohesion, developing local attachment and lowering crime levels, particularly in deprived communities (Bell *et al*., 2008; Weldon *et al.*, 2007). The mere presence and local availability of green spaces and natural features have been shown to encourage people to use their outside spaces more and, once outside, these green spaces help to promote positive social interactions. For example:

- Sullivan *et al*. (2004) found that 83% more individuals engaged in social activity in green spaces as opposed to sparsely vegetated/concreted ones.
- A study by Cohen *et al.* (2008) found there was a positive association between neighbourhood features such as parks and the ability of residents to interact positively.
- 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.

Social inclusion and community cohesion

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. Evidence shows that the potential that green space has for enhancing social cohesion is especially pertinent for these groups. Green spaces can bring people together, creating community cohesion as different social groupings engage with each other. For example:

- An epidemiological study by Kim and Kaplan (2004) 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.
- Sullivan (2005; cited in Davies and Deaville, 2008) 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.
- Other studies have considered ethnicity and race in relation to green space. Ravenscroft and Markwell (2000) investigated the relationship between park provision in Reading and social inclusion among urban youths. They found that parks rather than other types of leisure facility are more accessible to youths from ethnic minorities.
- A study undertaken by Gobster (2002) focusing on Warren Park in Chicago, which formed a boundary between very different neighbourhoods, 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.
- Burgess *et al*. (1988) reported 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'.
- Hitchings (2009) reported that urban green spaces have personal and social significance. If these spaces are more widely available, physically improved, and appropriate to practical as well as psychological need then more people could benefit from them. For example, green space could be aligned to fulfill aspects of daily routine, such as lunching, being a thoroughfare, or for conducting a range of social activities.
- A high level of aesthetic quality is a sign of care in the urban environment; this shows care within the community and is likely to lead to community cohesion and increased feelings of safety for residents (Jorgensen *et al*., 2007).

Green infrastructure toolkits covering community engagement

- Social Return on Investment (SROI) framework
- Health Impact Assessment (HIA)
- Towards an excellent service (TAES)
- The Greenflag award scheme
- The Urban Greenspace toolkit

Case studies involving community engagement

- Ingrebourne Hill Community Woodland, Thames Chase, Essex
- Broadhurst Clough, Moston, Manchester
- Creating community forestry in Glan Morfa, Rhyl, North Wales
- Glasgow Green Park: transformation to attractive green space, Glasgow
- Moston Vale, Manchester
- Newlands Green Streets, Merseyside, and Manchester and Salford
- Active England: the woodland projects
- Blarbuie Woodland, Argyll and Bute: evaluating the benefits
- Branching Out: green space and conservation on referral
- Cydcoed: evaluating social and human benefits, Wales
- GOW: Gibson Street, Otago Street and Westbank Quadrant backcourts, Glasgow

Copies of these case studies, and 20 additional case studies written to support this report, can be downloaded via the benefits of green infrastructure knowledge portal (see below).

Case study: lessons learnt

Ambitious designs for Russia Dock Woodland Park and Bow Creek Ecology Park were created by London Docklands Development Corporation (LDDC) on brownfield sites in London. The original designs failed to be sustainable for a number of reasons: the wind pump system at both locations could not maintain the wetlands; the habitat areas were so small that succession became difficult to prevent and habitats merged; there was a lack of long-term funding available to maintain the restoration, a lack of trained staff to run the system and a lack of public consultation. Public consultation which took on the views of the public, ecological experts and maintenance organisations was carried out during a subsequent improvement programme in the area and this ensured that the park design was sustainable (Sellers *et al.*, 2006).

Evidence notes covering community cohesion

For examples of good community engagement in green space provision see the following evidence notes: Economic, Social, Environmental, Land regeneration, Hydrology, Ecology, accessible via the benefits of green infrastructure knowledge portal: where six more evidence notes covering the remaining subsections of this report are also available for download.

Benefits of green infrastructure knowledge portal

A searchable online GI evidence database containing links or access to over 400 source documents is available at: http://www.eforestry.gov.uk/forestdss/webpages/bgi/home.jsp
or contact urgp@forestry.gsi.gov.uk

Green infrastructure: maximising the delivery of multiple benefits

The preceding sections demonstrate how green infrastructure (GI) 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 there, generating the 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 to climate proof towns and cities and their communities, whilst improving people's mental and physical health.

Bringing about such benefits requires strong collaboration between local government, 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. This report identifies the benefits of well-thought out and well-managed GI, however, public and private sector bodies need to give serious consideration to investment in GI.

Climate change

Introduction

Beckett, K.P., Freer-Smith, P.H. and Taylor, G. (1998). Urban woodlands: their role in reducing the effects of particulate pollution. *Environmental Pollution* **99**, 340–360.

CABE and English Heritage, eds (2010). *No trees, no future.* Originally written by the Trees and Design Action Group, 2008. Edited by CABE and English Heritage, 2010.

Defra (2009). *Adapting to climate change.* UK climate projections June 2009. http://www.defra.gov.uk/environment/climate/adaptation/index.htm Accessed 18/03/2010.

HM Government (2009). *The UK low carbon transition plan.* National strategy for climate and energy. http://www.decc.gov.uk/en/content/cms/publications/lc_trans_plan/lc_trans_plan.aspx Accessed 18/03/2010.

Heat amelioration

Beckett, K.P., Freer-Smith, P.H. and Taylor, G. (1998). Urban woodlands: their role in reducing the effects of particulate pollution. *Environmental Pollution* **99**, 347–360.

Chang, C. R., Li, M. H. and Chang, C. (2007). A preliminary study on the local cool-island intensity of Taipei city parks. *Landscape and Urban Planning* **80** (4), 386–395.

Dimoudi, A. and Nikolopoulou, M. (2003). Vegetation in the urban environment: microclimatic analysis and benefits. *Energy and Buildings* **35**, 69–76.

Gill, S.E., Handley, J.F., Ennos, A.R. and Pauleit, S. (2007). Adapting cities for climate change: the role of green infrastructure. *Built Environment* **33** (1), 115–133.

Heidt, V. and Neif, M. (2008). Benefits of urban greenspace for improving urban climate. In: *Economy, planning and management of urban forests: international perspectives,* eds M.E. Carreiro, Y.C. Song and J. Wu. Springer, Heidelberg, New York, 336–345.

Kovats, S., ed. (2008). *Health effects of climate change in the UK 2008: An update of the Department of Health report 2001/2002.* Health Protection Agency.

Potchter, O., Cohen, P. and Britan, A. (2006). Climatic behavior of various urban parks during hot and humid summer in the Mediterranean city of Tel Aviv, Israel. *International Journal of Climatology* **26** (12), 1695–1711.

Shashua-Bar, L. and Hoffman, M.E. (2000). Vegetation as a climatic component in the design of an urban street: an empirical model for predicting the cooling effect of urban green areas with trees. *Energy and Buildings* **31** (3), 221–235.

Yu, C. and Hien, W.N. (2006). Thermal benefits of city parks. *Energy and Buildings* **38**, 105–120.

Reducing flood risk

Campaign to Protect Rural England (CPRE) and Natural England (2010). *Green belts: a greener future.* London.

Center for Urban Forest Research (CUFR) (undated). *Benefits of the urban forest.* Fact Sheet No. 1.

Defra (2008). *Future water, the Government's water strategy for England.* Department for Environment, Food and Rural Affairs, London.

Mentens, J., Raes, D. and Hermy, M. (2006). Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century? *Lands Urban Plan* **77**, 217–226.

Nisbet, T.R., Orr, H. and Broadmeadow, S. (2004). *A guide to using woodland for sediment control.* Forest Research, Farnham.

Whitford, V., Ennos, A.R. and Handley, J.F. (2001). 'City form and natural processes' – indicators for the ecological performance of urban areas and their application to Merseyside, UK. *Landscape and Urban Planning* **57**, 91–103.

Yalcin, Y. and Yetemen, O. (2009). Local warming of groundwaters caused by the urban heat island effect in Istanbul, Turkey. *Hydrogeology Journal* **17**, 1247–1255.

Improving water quality

Center for Urban Forest Research (CUFR) (2002). *Control stormwater runoff with trees.* Fact Sheet No. 4.

Dabrowski, J.M., Peall, S.K.C., Reinecke, A.J., Liess, M. and Schulz, R. (2002). Runoff related pesticide input into the Lourens River, South Africa: basic data for exposure assessment and risk mitigation at the catchment scale. *Water, Air and Soil Pollution* **135**, 265–283.

Dudley, N. and Stolten, S. (2003). *Running pure: the importance of forest protected areas to drinking water.* A research report for the World Bank/WWF Alliance for Forest Conservation and Sustainable Use.

Gambrell, P.R. (1994). Trace and toxic metals in wetlands: a review. *Journal of Environmental Quality* **23**, 883–891.

Gilliam, J.W. (1994). Riparian wetlands and water quality. *Journal of Environmental Quality* **23**, 896–900.

Jacob, J.S. and Lopez, R. (2009). Is denser greener? An evaluation of higher density development and an urban stormwater-quality best management practice. *Journal of the American Water Resources Association (JAWRA)* **45** (3), 687–701.

Jeffries R., Darby, S.E. and Sear, D. A. (2003). The influence of vegetation and organic debris on flood-plain sediment dynamics: case study of a low-order stream in the New Forest, England. *Geomorphology* **51**, 61–80.

Lowrance, R., Todd, R., Fail, J., Hendrickson, O., Leonard, R. and Asmussen, L. (1984). Riparian forests as nutrient filters in agricultural watersheds. *BioScience* **34**, 374–377.

Lowrance, R., Altier, L.S., Newbold, J.D., Schnabel, R.R., Groffman, P.M., Denver, J.M., Correll, D.L., Gilliam, J.W., Robinson, J.L., Brinsfield, R.B., Staver, K.W., Lucas, W. and Todd, A.H. (1997). Water quality functions of riparian forest buffers in Chesapeake Bay watersheds. *Environmental Management* **21** (5), 687–712.

Nisbet, T.R., Orr, H. and Broadmeadow, S. (2004). *A guide to using woodland for sediment control.* Forest Research, Farnham.

Pompeu, P.S. and Alves, C.B.M. (2005). The effects of urbanization on biodiversity and water quality in the Rio das Velhas Basin, Brazil. *American Fisheries Society Symposium* **47**, 11–22.

Seters, T. van, Rocha, L., Smith, D. and Macmillan, G. (2009). Evaluation of green roofs for runoff retention, runoff quality, and leachability. *Water Quality Research Journal of Canada* **44** (1), 33–47.

Stovin, V.R., Jorgensen, A. and Clayden, A. (2008). Street trees and stormwater management. *The Arboricultural Journal* **30**, 1–4.

Vellidis, G., Lowrance, R., Gay, P. and Wauchope, R.D. (2002). Herbicide transport in a restored riparian forest buffer system. *Transactions of the ASAE* **45**, 89–97.

Sustainable urban drainage systems

CABE (2009). New storm water management system in Ekostaden Augustenborg, Malmö. http://www.cabe.org.uk/case-studies/ekostaden-augustenborg

Carter, T. and Butler, C.M. (2008). Ecological impacts of replacing traditional roofs with green roofs in two urban areas. *Cities and the Environment* **1**, Issue 2, Article 9.

Duffy, A., Jefferies, C., Waddell, G., Shanks, G., Blackwood, D. and Watkins, A. (2008). A cost comparison of traditional drainage and SUDS in Scotland. *Water Science and Technology* **57** (9), 1451–1459.

Environment Agency (2007). Response to Royal Commission on Environmental Pollution consultation 'Urban Environment'. Accessed: 15 February 2010.

Gill, S.E., Handley, J.F., Ennos, A.R. and Pauleit, S. (2007). Adapting cities for climate change: the role of the green infrastructure. *Built Environment* **33**, 115–133.

Mentens, J., Raes, D. and Hermy, M. (2006). Green roofs as a tool for solving the rainwater runoff problems in the urbanized 21st century? *Landscape and Urban Planning* **77**, 217–226.

Parliamentary Office of Science and Technology (2007). *Urban flooding.* Postnote number 289. POST, London.

Improving air quality

Asthma UK (2007). *Annual report: review 2007/08.* http://www.asthma.org

Broadmeadow, M.S.J. and Freer-Smith, P.H. (1996). *The improvement of urban air quality by trees.* Arboriculture Research and Information Note. AAIS, Farnham.

Freer-Smith, P.H., Beckett, K.P. and Taylor, G. (2005). Deposition velocities to *Sorbus aria, Acer campestre, Populus deltoides* x trichocarpa 'Beaupre', Pinus nigra and x *Cupressocyparis leylandii* for coarse, fine and ultra-fine particles in the urban environment. *Environmental Pollution* **133**, 157–167.

Jouraeva, V.A., Johnson, D.L. Hassett, J.P. and Nowak, D.L. (2002). Differences in accumulation of PAHs and metals on leaves of *Tilia* x *euchlora* and *Pyrus calleryana. Environmental Pollution* **120**, 331–338.

Lovasi, G.S., Quinn, J.W., Neckerman, K.M., Perzanowski, M.S., Rundle, A. (2008). Children living in areas with more street trees have lower prevalence of asthma. *Journal of Epidemiology and Community health* **62**, 647–649.

Nowak, D.J. (1994). *Air pollution removal by Chicago's urban forest, Chicago's Urban Forest Ecosystem.* Results of the Chicago Urban Forest Climate Project, United States Department of Agriculture.

NWDA (2007). *Economic value of urban design.* Amion Consulting.

Stolt, E. (1982). *Vegetationens formaga att minska expositionen for bilavgaser (The ability of vegetation in decreasing exposure to car fumes).* Goteborgs Universitet pa uppdrag av Goteborgs Halsovardsavdelning (quoted from Svensson and Eliasson 1997, in Swedish).

Svensson, M. and Eliasson, I. (1997). *Gronstrukturens betydelse for stadens ventilation (The importance of green areas for the ventilation of the city).* Naturvardsverkets rapport 4779, Stockholm (in Swedish).

Sustainable Development Commission (2008). *Health, place and nature – how outdoor environments influence health and well-being: a knowledge base.*

Tiwary, A., Sinnett, D., Peachey, C.J., Chalabi, Z., Vardoulakis, S., Fletcher, T., Leonardi, G., Grundy, C., Azapagic, A. and Hutchings, T.R. (2009). An integrated tool to assess the role of new planting in PM10 capture and the human health benefits: a case study in London. *Environmental Pollution* **157**, 2645–2653.

Health and well-being

Introduction

O'Brien, L., Williams, K. and Stewart, A. (2010). *Urban health and health inequalities and the role of urban forestry in Britain: a review.* Forest Research, Farnham.

Department of Health (2009). *Tackling health inequalities: 10 years on – a review of developments in tackling health inequalities in England over the last 10 years.* Department of Health, London.

Increasing life expectancy and reduced health inequality

Cohen, D. A., Mckenzie, T. L., Sehgal, A., Williamson, S., Golinelli, D. and Lurie, N. (2007). Contribution of public parks to physical activity. *American Journal of Public Health* **97** (3), 509–514.

Department of Health (2009). *Tackling health inequalities: 10 years on – a review of developments in tackling health inequalities in England over the last 10 years.* Department of Health, London.

Greater London Authority (2009). The London health inequalities strategy (draft for public consideration).

Maas, J., Verheij, R. A., Groenewegen, P. P., de Vries, S. and Spreeuwenberg, P. (2006). Green space, urbanity and health: how strong is the relation? *Journal of Epidemiology and Community Health* **60** (7), 587–592.

Mental Health Foundation (2009). *Mental health, resilience and inequalities.*

Mitchell, R. and Popham, F. (2008). Effect of exposure to natural environment on health inequalities: an observational population study. *The Lancet* **372**, 655–1660.

Shaw, M., Smith, G.D. and Dorling, D. (2005). Health inequalities and New Labour: how promises compare with real progress. *British Medical Journal* **330**, 1016–1021.

Sustainable Development Commission (2010). *Sustainable development: the key to tackling health inequalities.* Sustainable Development Commission, London.

Improving levels of physical activity and health

Brown, C. and Grant, M. (2005). Biodiversity and human health: what role for nature in healthy urban planning? *Built Environment* **31** (4), 326–338.

BTCV (2008). *BTCV green gym national evaluation report: summary of findings 2008.*

CJC Consulting with Willis, K. and Osman, L. (2005). Economic benefits of accessible green spaces for physical and mental health: scoping study.

Defra (2010). *Defra's climate change plan.* Department for Environment, Food and Rural affairs, London.

Kaczynski, A. and Henderson, K. (2007). Environmental correlates of physical activity: a review of evidence about parks and recreation. *Leisure Sciences* **29** (4), 315–354.

Natural Economy Northwest (2008). *The economic benefits of green infrastructure: the public and business case for investing in green infrastructure and a review of the underpinning evidence.*

Nielson, T. S. and Hanson, K. B. (2007). Do green areas affect health? Results from a Danish survey on the use of green areas and health indicators. *Health and Place* **13** (4), 839–850.

Sustainable Development Commission (2007). *Healthy futures. The natural environment, health and well-being.* http://ukmaburbanforum.co.uk/docunents/other/hf6.pdf

Zlot, A. I. and Schmid, T. L. (2005). Relationships among community characteristics and walking and bicycling for transportation or recreation. *American Journal of Health Promotion* **19** (4), 314–317.

Improving psychological health and mental well-being

Cooper, R., Boyko, C. and Codinhoto, R. (2008). Mental capital and well-being: making the most of ourselves in the 21st century. State-of-Science Review: SR-DR2. *The effect of the physical environment on mental wellbeing.* Government Office for Science, London.

Croucher, K., Myers, L. and Bretherton, J. (2007). *The links between greenspace and health: a critical literature review.* Greenspace Scotland, Stirling.

Department of Health (2009). *Tackling health inequalities: 10 years on – a review of developments in tackling health inequalities in England over the last 10 years.* Department of Health, London.

Hartig, T., Evans, G. W., Jamner, L. D., Davis, D. S. and Gärling, T. (2003). Tracking restoration in natural and urban field settings. *Journal of Environmental Psychology* **23**, 109–123.

Grahn, P. and Stigsdotter, U. A. (2003). Landscape planning and stress. *Urban Forestry and Urban Greening* **2** (1), 1–18.

Guite, H. F,. Clark, C. and Ackrill, G. (2006). The impact of the physical and urban environment on mental well-being. *Public Health* **120** (12), 1117–1126.

Mind (2007). *Ecotherapy: the green agenda for mental health.* Mind week report, May 2007. Mind, London.

Sustainable Development Commission (2007). *Healthy futures. The natural environment, health and well-being.* http://ukmaburbanforum.co.uk/docunents/other/hf6.pdf

Taylor, A. F., Kuo, F. and Sullivan, W. C. (2001). Coping with ADD: the surprising connection to green play setting. *Environment and Behaviour* **33** (1), 54–77.

The Future Vision Coalition (2009). *A future vision for mental health.* The Future Vision Coalition, London.

Ulrich, R.S. (1984). View through a window may influence recovery from surgery. *Science* **224**, 420–421.

van den Berg, A. E., Hartig, T. and Staats, H. (2007). Preference for nature in urbanized societies: stress, restoration, and the pursuit of sustainability. *Journal of Social Issues* **63** (1), 79–96.

Whitelaw, S., Swift, J., Goodwin, A. and Clark, D. (2008). *Physical activity and mental health: the role of physical activity in promoting mental well-being and preventing mental health problems.* NHS Scotland, Edinburgh.

Economic growth and investment

Introduction

Defra (2005). Sustainable Development Strategy 'Securing the future – the UK Government's sustainable development strategy. Defra, UK. Available from http://www.defra.gov.uk/sustainable/government/publications/uk-strategy/documents/SecFut_complete.pdf *Sustainable development in government.*

NENW (2008). *The economic value of green infrastructure.* Natural Economy Northwest (NENW). Available at: http://www.naturaleconomynorthwest.co.uk/resources+reports.php

Office for National Statistics (ONS) (2010). Labour market unemployment. http://www.statistics.gov.uk/cci/nugget.asp?id=12 Accessed on 16/03/2010

Inward investment and job creation

CESR (2004). *Much more than trees 2: measuring the social and economic impact of The National Forest.* Staffordshire University Centre for Economic and Social Regeneration (CESR).

CLES (2007). *The contribution of the local environment to the local economy.* Research report. April 2007. CLES Policy Advice for Groundwork UK. Available at: http://www.cles.org.uk/information/102156/pp13_lele/

CSI (2008). *Creating a setting for investment (CSI).* Project Report. Available at: http://www.environment-investment.com/images/downloads/final_report.pdf

Forest Research (2008). *A valuation of the economic and social contribution of forestry for people in Scotland.* Final report for Forestry Commission Scotland. Forest Research, Farnham.

Regeneris Consulting (2009). *The economic contribution of the Mersey Forest's objective one-funded investments.* Regeneris Consulting. Available at: http://www.merseyforest.org.uk/pages/displayDocuments.asp?iDocumentID=246

Scottish Enterprise (2008). *Additionality and economic impact assessment guidance note.* Scottish Enterprise, Glasgow. Available at: http://www.scottish-enterprise.com/evaluations-impact.htm

Venn, S.J., Niemela, J.K. (2004). Ecology in a multidisciplinary study of urban green space: the URGE project. *Boreal Environment Research* **9**, 479–489.

Land and property values

CABE (2004). *The value of public space.* Commission for Architecture and the Built Environment, London. Available at: http://www.cabe.org.uk/publications/the-value-of-public-space

CABE (2005). *Does money grow on trees?* Commission for Architecture and the Built Environment, London. Available at: http://www.cabe.org.uk/publications/does-money-grow-on-trees

Cousins, P. and Land Use Consultants (2009). *Economic contribution of green networks: current evidence and action.* North West Development Agency.

CTLA (2003). *Summary of tree valuation based on CTLA approach.* Council of Tree and Landscape Appraisers.

Garrod, G.D. (2002). *Social and environmental benefits of forestry phase 2: landscape benefits.* Report to the Forestry Commission. Centre for Research in Environmental Appraisal and Management, University of Newcastle upon Tyne.

GEN Consulting (2006). *Glasgow Green renewal benefits analysis.* A report to Glasgow City Council. November 2006.

GLA Economics (2003). *Working paper 3: valuing greenness: is there a segmented preference for housing attributes in London?* Greater London Authority, London. Available at: www.london.gov.uk/mayor/economic_unit/docs/valuing_greenness_paper.pdf

NENW (2008). *The economic value of green infrastructure.* Natural Economy Northwest (NENW). Available at: http://www.naturaleconomynorthwest.co.uk/resources+reports.php

Local economic regeneration

Audit Commission (2005). *Economic regeneration – performance indicators.* Audit Commission, London. Available at: http://www.local-pi-library.gov.uk/economicregeneration.html

CABE (2009). *Grey to green: how we shift funding and skills to green our cities.* CABE, London. http://www.cabe.org.uk/publications/grey-to-green

ECOTEC (2008). *The economic benefits of green infrastructure: the public and business case for investing in green infrastructure and a review of the underpinning evidence.* Report for Natural Economy Northwest (NENW). April 2008. Available at: http://www.naturaleconomynorthwest.co.uk/resources+reports.php

Forestry Commission (2005). *Bold Colliery community woodland: district valuer's report on property values.* Forestry Commission, England.

GEN Consulting (2006). *Glasgow Green renewal benefits analysis.* A report to Glasgow City Council. November 2006.

National Audit Office (NAO) (2006). *Enhancing urban green space.* Report by the comptroller and auditor general. HC 935, Session 2005-2006. National Audit Office, London.

Land regeneration

Introduction

Environment Agency (2008). Working towards a better quality of life: Environmental justice in South Yorkshire: summary report.

Regeneration of previously developed land

Alker, S., Joy, V., Roberts, O. and Smith, N. (2000). The definition of brownfield. *Journal of Environmental Planning and Management* **43**, 49–69.

Barton, H. (2009). Land use planning and health and well-being. *Land Use Policy,* S115–S123.

CABE Space (2005). *Start with the park. Creating sustainable urban green spaces in areas of housing growth and renewal.* CABE, London.

Defra (2004). *Creating sustainable communities: greening the gateway.* Defra, London.

English Partnerships (2006). *The brownfield guide. A practitioner's guide to land reuse in England.* The National Regeneration Agency.

Forest Research (2008). *A valuation of the economic and social contribution of forestry for people in Scotland.* Final report for Forestry Commission Scotland. Forest Research, Farnham.

Handley, J. F. (1996). *The post-industrial landscape: a groundwork status report.*

Hillsdon, M., Jones, A. and Coombes, E. (2009). *Green space access, green space use, physical activity and overweight: a research summary.* Natural England.

Hutchings, T. (2002). *The opportunities for woodland on contaminated land.* Information Note 44. Forestry Commission, Edinburgh.

Kessel, A., Green, J., Pinder, R., Wilkinson, P., Grundy, C. and Lachowycz, K. (2008). Multidisciplinary research in public health: a case study of research on access to green space. *Public Health* **123**, 32–38.

Mitchell, R. and Popham, F. (2008). Effect of exposure to natural environment on health inequalities: an observational population study. *The Lancet* **372**, 655–1660.

Stubbs, M. (2008). Natural green space and planning policy: devising a model for its delivery in regional spatial strategies. *Landscape Research* **113** (1), 119–139.

Improving quality of place

Cabinet Office Strategy Unit (2009). *Quality of place: improving the planning and design of the built environment. An analysis of issues and opportunities.* Cabinet Office, London.

CABE Space (2005). *Start with the park. Creating sustainable urban green spaces in areas of housing growth and renewal.* CABE, London.

Hastings, A., Flint, J., McKenzie, C. and Mills, C. (2005). *Cleaning up neighbourhoods: environmental problems and service provision in deprived areas.* Joseph Rowntree Foundation, York.

Khattab, O. (1993). Environmental quality assessment: an attempt to evaluate government housing projects. FDRUM, 4, 36–41.

Land Use Consultants (2004). *Making the links: greenspace and quality of life.* Land Use Consultants.

Landscape Institute (2009). *Green infrastructure: connected and multifunctional landscapes.* Landscape Institute position statement.

Swanwick, C. (2009). Society's attitudes to and preferences for land and landscape. *Land Use Policy* **26**, S62–S75.

Tibbatts, D. (2002). *The benefits of parks and greenspace.* The Urban Parks Forum.

Wildlife and habitats

Introduction

CLG (Department for Communities and Local Government) (2009). *Place survey 2008, England: local government statistical release.* CLG, London.

Increasing habitat area

Angold, P.G., Sadler, J.P., Hill, M.O., Pullin, A., Rushton, S., Austin, K., Small, E., Wood, B., Wadsworth, R., Sanderson, R. and Thompson, K. (2006). Biodiversity in urban habitat patches. *Science of the Total Environment* **360** (1-3), 196–204.

Baker, P.J. and Harris, S. (2007). Urban mammals: what does the future hold? An analysis of the factors affecting patterns of use of residential gardens in Great Britain. *Mammal Review* **37** (4), 297–315.

Colding, J. (2007). 'Ecological land-use complementation' for building resilience in urban ecosystems. *Landscape and Urban Planning* **81**, 46–55.

Fernández-Juricic, E. and Jokimäki, J. (2001). A habitat island approach to conserving birds in urban landscapes: case studies from southern and northern Europe. *Biodiversity and Conservation* **10**, 2023–2043.

Hardy, P.B. and Dennis, R.L.H. (1999). The impact of urban development on butterflies within a city region. *Biodiversity and Conservation* **8** (9), 1261–1279.

Schrader, S. and Boning, M. (2006). Soil formation on green roofs and its contribution to urban biodiversity with emphasis on Collembolans. *Pedobiologia* **50** (4), 347–56.

Increasing populations of some protected species (BAP)

Gibson, C.W.D. (1998). *Brownfield: red data. The values artificial habitats have for uncommon invertebrates.* ENRR 273. English Nature, Peterborough.

Jones, R.A. (1999). Entomological surveys of vertical river flood defence walls in urban London - Brownfield corridors: problems, practicalities and some promising results. *British Journal of Entomology and Natural History* **12** (4), 193–213.

Increasing species movement

Brown, J. and Kodric-Brown, A. (1977). Turnover rates in insular biogeography: effects of immigration on extinction. *Ecology* **58**, 445–449.

Eycott, A., Watts, K., Brandt, G., Buyung-Ali, L., Bowler, D., Stewart, G. and Pullin, A. (2008). *Which landscape features affect species movement? A systematic review in the context of climate change.* Forest Research report for Defra. Forest Research, Farnham.

Fernández-Juricic, E. (2000). Avifaunal use of wooded streets in an urban landscape. *Conservation Biology* **14** (2), 513–521.

Funk, A., Reckendorfer, W., Kucera-Hirzinger, V., Raab, R. and Schiemer, F. (2009). Aquatic diversity in a former floodplain: remediation in an urban context. *Ecological Engineering* **35** (10), 1476–1484.

Helden, A.J. and Leather, S.R. (2004). Biodiversity on urban roundabouts - Hemiptera, management and the species-area relationship. *Basic and Applied Ecology* **5**, 367-377.

Morimoto, T. and Katoh, K. (2005). The effect of greenways connecting urban parks on avifauna in the winter period (in Japanese, English summary). *Journal of the Japanese Institute of Landscape Architecture* **68** (5), 589–592.

Rudd, H., Vala, J. and Schaefer, V. (2002). Importance of backyard habitat in a comprehensive biodiversity conservation strategy: a connectivity analysis of urban green spaces. *Restoration Ecology* **10** (2), 368–375.

Urban, M.C., Skelly, D.K., Burchsted, D., Price, W. and Lowry, S. (2006). Stream communities across a rural-urban landscape gradient. *Diversity and Distributions* **12** (4), 337–350.

Stronger communities

Introduction

British Market Research Bureau (2007). *Attitudes and behaviours in relation to the environment.* Defra, London.

Forest Research (2008). *A valuation of the economic and social contribution of forestry for people in Scotland.* Final report for Forestry Commission Scotland. Forest Research, Farnham.

Social interaction, inclusion and cohesion

Bell, S., Hamilton, V., Montarzino, A., Rothnie, H., Travlou, P. and Alves, S. (2008). *Greenspace and quality of life: a critical literature review.* Greenspace Scotland, Stirling.

Burgess, M., Harrison, C.M. and Limb, M. (1988). People, parks and the urban green: a study of popular meanings and values for open spaces in the city. *Urban Studies* **25**, 455–473.

Cohen, D. A., Inagami, S. and Finch, B. (2008). The built environment and collective efficacy. *Health & Place* **14**, 198–208.

Davies, P. and Deaville, J. (2008). *Natural heritage: a pathway to health.* Countryside Council for Wales.

Dawson, J., Boller, I., Foster, C. and Hillsdon, M. (2006). *National evaluation of health walk schemes.* Department of Health, London.

Gobster, P. H. (2002). Managing urban parks for a racially and ethnically diverse clientele. *Leisure Sciences* **24**, 143–159.

Hitchings, R. (2009). *Indoor office workers and outdoor nature: a research report.* UCL Department of Geography, London.

Jorgensen, A., Hitchmough, J. and Dunnett, N. (2007). Woodland as a setting for housing – appreciation and fear and the contribution to residential satisfaction and place identity in Warrington New Town, UK. *Landscape and Urban Planning* **79**, 273–287.

Kim, J. and Kaplan, R. (2004). Physical and psychological factors in sense of community: new urbanist Kentlands and nearby Orchard Village. *Environment and Behavior* **36** (3), 313–340.

Ravenscroft, N. and Markwell, S. (2000). Ethnicity and the integration and exclusion of young people through urban park recreation provision. *Managing Leisure* **5**, 135–150.

Sellers, G., Hutchings, T.R. and Moffat, A. J. (2006). Learning from experience: creating sustainable urban greenspaces from brownfield sites. In: *Brownfields III: Prevention, assessment, rehabilitation and development of brownfield sites.* WIT Press, Southampton.

Sullivan, W. C., Kuo, F. E. and DePooter, S. F. (2004). The fruit of urban nature: vital neighbourhood spaces. *Environment and Behavior* **36** (5), 678–700.

Weldon, S. and Bailey, C. in collaboration with O'Brien, L. (2007). *New pathways to health and well-being: summary of research to understand and overcome barriers to accessing woodland.* Forestry Commission, Scotland.

Benefits of green infrastructure

This report provides a synthesis of the evidence on the multiple benefits of green infrastructure, based on expert evaluation of scientific and other related literature.

The evidence is designed to support decision making and highlight cost-effective opportunities to achieve local through to national goals for the provision of sustainable green infrastructure.

The Urban Regeneration and Greenspace Partnership (URGP) is a new partnership which aims to:

- Promote impacts and outcomes of green infrastructure.
- Support sustainable planning, establishment and management practices.
- Disseminate best practice guidance.
- Develop a common research strategy across stakeholders.
- Create a URGP national database and a network of research, monitoring and evaluation sites.
- Build a collaborative research programme to determine the ecosystem services which green infrastructure provides including climate amelioration, air and water quality, sustainable urban drainage, social inclusion, education, health and wellbeing, and biodiversity.

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