HOUSES OF PARLIAMENT
PARLIAMENTARY OFFICE OF SCIENCE & TECHNOLOGY

POSTNOTE

Number 448 November 2013

Urban Green Infrastructure

Urban green infrastructure is a network of green spaces, water and other natural features within urban areas. A green infrastructure approach uses natural processes to deliver multiple functions, such as reducing the risk of flooding and cooling high urban temperatures. This POSTnote summarises research evidence of the effectiveness of green infrastructure, and challenges to its implementation.

Overview

- 80% of people in the UK live in urban areas. Green space has decreased in many cities in recent decades.
- This reduction poses risks to human health and natural systems that may increase with climate change. Urban green infrastructure can help to mitigate these risks.
- Green infrastructure can often provide the same functions as conventional infrastructure, such as water management and flood risk alleviation, with other benefits for health and biodiversity. However, these benefits are not always well quantified.
- Constraints on green infrastructure provision include a lack of understanding of natural systems and their associated benefits, a lack of strategic green infrastructure plans and a lack of co-ordination within local authorities.

Green and Grey Infrastructure

Familiar urban infrastructure such as roads, sewer systems and storm drains is known as 'grey infrastructure'. Such conventional infrastructure often uses engineered solutions typically designed for a single function.

'Green infrastructure', includes parks, playing fields, private gardens, allotments, green roofs and walls, and cemeteries. The term refers to ecological processes rather than colour, so includes sustainable urban drainage systems, wetlands, rivers and canals, which are also sometimes referred to as 'blue' infrastructure. Green spaces in cities are not new, for example urban parks were implemented widely by the Victorians, but ways of incorporating green infrastructure into modern urban design are still being explored.

80% of the UK population lives in urban areas[1] and with an increasing population,[2] many UK urban regions are becoming more densely populated. This is often at the cost of green space,[3,4] loss of which is associated with risks to human health that are greatest in deprived areas. This briefing outlines the evidence for how green infrastructure may help to address these problems, and examines the issues raised by green infrastructure delivery.

Health and Wellbeing Benefits

There is evidence that access to green spaces can provide health benefits, through improved mental wellbeing and levels of physical activity, reduced exposure to pollution and high urban temperatures.[5-7] For example, the NHS is increasing green space on its estates through the NHS Forest Project, which will plant 1.3 million trees by 2015.[8] However, there are many factors that affect human health and wellbeing, of which access to green space is just one. It is usually not practical to conduct experiments to test the effects of green space on health, so researchers often rely on observations. As a result, the evidence is statistically less certain than would be expected for medical treatments.

Mental Health and Wellbeing

The UK Public Health White Paper 2010 notes that green spaces can improve mental health and the quality of community life.[9] Researchers have observed a link between increasing urbanisation and psychosis or depression;[10,11] living closer to urban green spaces is also associated with lower mental distress.[5,12-14] However, such observations may not indicate a causal relationship and could be explained by other factors. For example, socially deprived areas typically have low levels of green space (Box 1). One study aimed to reduce the problem of confounding factors by studying the same 10,000 people over 18 years.

Box 1. Social Equity and Urban Green Infrastructure

Low income areas systematically have fewer and poorer quality green spaces compared with more affluent areas in the same city.[3,15] Investment in green infrastructure has a greater positive effect in economically deprived areas than affluent areas, since economically deprived communities spend more time in their neighbourhoods, and the quality of these green spaces has a larger impact on their health and wellbeing. The use of green infrastructure might also vary between ages, gender, ethnic groups and socio-economic backgrounds,[16] making it is difficult to predict the effect of a green space on the health and wellbeing of a local community. However, there is evidence that successful and well-maintained projects are those that have public support and engagement.

It concluded that living in an area with high levels of green space led to a decrease in mental distress compared with living in areas with little green space, once factors such as age, gender and income have been statistically accounted for. The improvement is equivalent to one third of the increase in the mental health benefits of being married rather than unmarried.[12]

Experimental evidence suggests that spending time in green space, or simply having views of nature, can improve reported mood, self-esteem and concentration, and treat stress and mental health disorders.[17-19] These benefits have been shown to occur over very short exposure periods to green space, for example, five minutes.[20]

This improvement in mental health from exposure to green spaces can be explained by a direct effect on the brain (through reduced stress[21] and improved concentration[17,22]). However, indirect benefits can also come from increased exercise[23] and improved social interactions, though the evidence for these effects is less clear.[24] The UN Millennium Ecosystem Assessment 2005,[25] and the second phase of the UK National Ecosystem Assessment (under review), identify the multiple benefits of nature for mental wellbeing. The magnitude of these benefits is partly dependent on the quality of a green space, so careful design and maintenance is important (see below). The greatest health benefits are seen in the poorest urban areas (Box 1).

Physical Activity

There is less evidence for improvements in physical health than for mental health, because access to green space does not guarantee that local people will exercise more. The statistical evidence is weak, but some researchers have suggested that levels of physical activity increase with proximity to green areas.[26-32] Where people do exercise in green space, it leads to lower anger, fatigue and depression than the same exercise in urban areas.[18,19,31] Some studies also indicate that for mental illness, such as depression, exercise can produce similar improvements in mental wellbeing as conventional medication.[27,32] Regular physical activity reduces the risk of coronary heart disease, obesity and diabetes.[28] This might include gardening, conservation work through 'green gyms', or walking to work.

Environmental Benefits

Water Management

Flooding in urban areas is estimated to cost a minimum of £270 million per year in England and Wales.[26,27,29] A high coverage of impermeable surfaces in urban areas prevents surface water from soaking into the ground, increasing the risk of flooding and pollution from heavy rainfall (POSTnote 289). Two thirds of the homes affected in the floods of 2007 were flooded as a result of surface water.[33]

Sustainable Drainage Systems (SuDS) are designed to mimic natural drainage and filter and retain rainfall where it lands to prevent 'grey' drainage systems from becoming overwhelmed during storm events (POSTnote 289). SuDS – including green roofs, permeable paving, swales and rain gardens – provide an example of the problems and challenges of green infrastructure (Box 2).

SuDS are often used to retrofit existing infrastructure including transport routes, in the form of rain gardens and street tree pits that receive surface water run-off. For example, rain gardens are now being implemented on highways in a number of London boroughs. However, while SuDS can provide drainage solutions for single sites, a more effective approach is to integrate the water cycle with the built environment at an earlier stage through planning and urban design. An example of this would be Water Sensitive Urban Design (POSTnote 419).

Reduced Air Pollution

Air pollution tends to be highest in deprived urban areas.[34] Exposure to high air pollution can cause and exacerbate respiratory problems, heart disease and cancer (POSTnote 272). Green infrastructure can reduce exposure in two ways:

- Trees and vegetation can reduce air pollution directly by trapping and removing fine particulate matter[35] and indirectly by reducing air temperatures. The strength of the effect depends on multiple factors, such as the weather, the pollution concentration, and the type and quality of vegetation.[36]
- Urban transport infrastructure often results in the funnelling of pedestrians along major roads, where the concentration of air pollution is highest.[37] Green corridors across cities can reduce pedestrian exposure to pollution by providing alternative routes.

Box 2. Implementing Sustainable Drainage Systems

- Planning: The impact of a new development or project on the flow of water through a catchment requires hydrological modelling. Maps of flooding hazards derived from such models are required in England and Wales by December 2013 under the Floods Directive 2007. These maps can inform local planning, such that SuDS are prioritised in areas of high flood risk. This approach is used by Lambeth Council in London, using flood risk maps produced by Drain London Forum and the Greater London Authority.
- Standards: SuDS are required on new developments in England and Wales under the Flood and Water Management Act 2010, although national standards remain under development by Defra. It is intended that SuDS Approval Bodies within local authorities will assess the quality of SuDS against these standards, once they are published. Some have suggested that a similar system of guidance and approval bodies could be adopted for all green infrastructures in urban areas.
- Maintenance of SuDS is no longer the sole remit of local authorities. The Water Bill 2013 proposes to allow companies that provide sewerage services to construct and maintain SuDS to reduce the risk of sewerage systems being overwhelmed during high rainfall.

Cooling Urban Heat Islands

Urban areas often experience elevated temperatures compared with the surrounding countryside, because of extensive heat absorbing surfaces, such as concrete and tarmac, concentrated heat production and impeded air flow.[38] For example, the centre of London is on average 5°C warmer than surrounding rural areas.[39] Heat waves during the summer pose significant health risks to urban populations either directly from the heat[28,40] or from increased air pollution. During the 2003 heat wave, a temperature difference between urban and rural areas of up to 10°C was recorded for London[41] and estimates suggest that 40% of the 600 excess deaths (the number of actual deaths minus the number of expected deaths) in London were due to the urban heat island effect.[42] Climate change projections suggest that by 2050 such summer temperatures will be common. Green infrastructure can lower air temperatures through the evaporation of water from vegetation[31,43] and shading[44] (Box 3). These benefits are recognised in the Heatwave Plan for England 2013 that recommends the use of green infrastructure around hospitals and care homes.[45]

Box 3. Green Infrastructure for Cooling Urban Heat Islands

Well designed green roofs and walls can contribute effectively to the thermal insulation of buildings,[55] reducing the need for air conditioning. Green spaces and water bodies also lower air temperatures and are on average one degree cooler than the surrounding urban areas.[31] Heat dispersion around a city depends on a number of factors, including weather, street layout, and the surface material of buildings. Determining the cooling effect of green infrastructure at the urban scale therefore requires modelling. In Manchester, the SCORCHIO project predicted that an increase in the area of green space of 10% would reduce the maximum surface temperature by 2.2°C compared no change in green space. This cooling increases to between 2.4°C and 2.5°C under low and high UKCIP02 climate scenarios.[56] Similar results have been found by modelling projects conducted in Birmingham (BUCCANEER project)[57] and London (LUCID project).[39]

Challenges to Delivery

Green Infrastructure in the UK

The extent and type of green space in all Scottish urban settlements was mapped in 2011 by Greenspace Scotland.[46] An equivalent resource is not yet available across England, Wales or Northern Ireland, and data availability varies between local authorities. Natural England, Ordinance Survey and others are discussing developing a mapping solution for England.

Green Infrastructure Policy

In May 2013, the European Commission released a Green Infrastructure Strategy[47] which recognises the significant contribution of green infrastructure to growth (Box 4), jobs, health and social welfare, climate change, disaster mitigation, and agricultural and environmental policy. The strategy promotes green infrastructure across rural and urban areas within existing legal, policy and financial frameworks. In the UK, the Natural Environment White Paper 2011 for England[48] committed to supporting the development of green infrastructure, and led to the creation of the Green Infrastructure Partnership (GIP), co-ordinated by Defra and DCLG. The GIP aids knowledge exchange between over 300 partner organisations. From 1 April 2014 Government facilitation of the GIP will end, but Defra hopes that it will continue into the future.

Planning and Design

Local authorities such as Birmingham,[49] London,[50] Manchester,[51] Plymouth[52] and Worcestershire[53] have developed green infrastructure strategies. However, the uptake of green infrastructure in local planning is variable. The National Planning Policy Framework 2012 (NPPF 2012) suggests that all local authorities set out a strategic approach to the creation, protection, enhancement and management of green infrastructure networks.[54] It also requires that Local Planning Authorities take into consideration the needs for open space, recreation and sport, based on an assessment of needs and opportunities (previously the PPG17 assessment). However, with the exception of SuDS, new green infrastructure is not required by national legislation. The Landscape Institute recommends that to prevent implementation being restricted to a few local authorities, green infrastructure is made a core requirement in relevant local authority documents, such as Local Plans.[58]

Green Infrastructure Networks

While careful design and maintenance can improve individual sites, many of the benefits of green infrastructure such as flood alleviation, improved air quality and improved connectivity for organisms[59,60] derive from interaction between multiple green spaces. To maximise these cumulative benefits, the network itself would need to be well planned. This may entail the provision of new green spaces, as in the case of Coventry City,[61] or the strategic improvement of existing sites, as in the case of the All London Green Grid.[62] Networks can be planned by engaging with experts during the early stages of development. Only a few local authorities have green infrastructure strategies that include spatial plans of additional sites, such as Birmingham.[49]

Site-Level Design

Design recommendations for individual green infrastructure projects are difficult to form, as they are necessarily site specific and existing projects are rarely monitored after implementation. However, some general principles can be applied. For example, increasing plant species diversity, or increasing the range of vegetation by planting trees and shrubs rather than grass alone, can significantly increase other forms of biodiversity.[63,64]

Planning for Climate Change

There is good evidence that green infrastructure can aid climate change adaption and mitigation in urban centres. Under a warming climate, extreme weather events are expected to become more severe and frequent.[65] Infrastructure built today will need to resist these predicted changes in climate in the following decades, although this is not always considered in Local Plans. The NPPF 2012, the UK Climate Change Risk Assessment 2012 and the subsequent National Adaptation Programme 2013 all recognise the role of urban green infrastructure in climate change adaptation. This is reflected in the London Climate-Change Adaptation Strategy, which aims to increase green

Box 4. Economic Benefits of Green Infrastructure

Natural England has argued that green infrastructure can provide a competitive advantage to urban centres at a local scale[66,67] through:

- **Inward investment**. Attractive areas encourage the movement of employers to an area, and increase the value of local property. The Glasgow Green Renewal Project led to a 47% increase in council tax receipts.
- **Visitor spending**. Attractive areas with green infrastructure attract more visitors, increasing spending with local businesses.
- **Environmental cost-saving**. Green infrastructure can be a cost-effective alternative to grey infrastructure. In New York, a mixture of green and grey infrastructure was predicted to provide the same benefits for water quality as grey infrastructure alone, but at a saving of $1.5 billion.[68]
- **Health improvement**. Where the provision of green infrastructure has a positive effect on the physical and mental health of local communities, it may reduce NHS spending and improve workforce productivity (see health and wellbeing benefits). Researchers have not quantified the economic benefit of these effects robustly.
- **Job creation**. Green infrastructure can create jobs directly through activities involved with construction, maintenance or management, and indirectly through increased visitor spending. The Commission for Architecture and the Built Environment estimated that 5% of all jobs in England are in the green space sector.

Many of these local benefits may be generated by the displacement of wealth from one area to another. The extent to which green infrastructure creates additional economic growth at the national scale is not possible to estimate with the available evidence.

space in central London to provide a cooling effect.[69]

Access to expertise

Good design depends on an understanding of natural processes. Over recent decades the capacity of local authorities to plan green infrastructure has been reduced through the loss of experts, such as hydrologists and ecologists. Worcestershire County Council has pooled its experts at the county level, to provide an ecological consultancy service for districts and cities.[70]

Standards

National standards exist only for a small subset of green infrastructures such as the national Green Roof Organisation Code, and draft Defra standards for SuDS (Box 3). As such, approaches to green infrastructure implementation by local authorities can vary significantly.[71] Codes of building excellence, such as BREEAM, and points systems, such as the Green Space Factor,[72] can be used by local authorities to set minimum standards for green infrastructure in new developments. Many local authorities are following the northwest European approaches to implementing green infrastructure, for example, Sutton in London and Southampton City Council. In the absence of national standards, available guidance documents include:

- Good Practice Guidance for Green Infrastructure and Biodiversity by the Town and Country Planning Association and Wildlife Trusts
- Green Infrastructure Guidance by Natural England
- GRaBS (Green and Blue Space Adaptation for Urban Areas) Climate Adaptation Action Plan Guidance
- Delivering Biodiversity Benefits through Green Infrastructure by CIRIA (the Construction Industry Research and Information Association)
- UK Rain Garden Guide. Depressions that collect rainwater from impervious surfaces, known as Rain Gardens, reduce the risk of flooding and water pollution by allowing water to soak into the ground.[73]

However, much advice remains general since data on the effectiveness of green infrastructure projects are limited.

Maintenance

Maintenance of green infrastructure is essential to maximise its benefits. For example, while well-maintained green spaces can improve mental health, overgrown vegetation can have a negative impact by increasing the fear of crime,[74-76] although these overgrown spaces may be better for biodiversity.[77] Some infrastructure such as green roofs, walls and rain gardens require minimal maintenance once installed. For other types of infrastructure, such as green spaces, the cost of maintenance can be higher – through mowing, weeding and watering. These costs often fall to local authorities, and have been the focus of budget cuts in recent years. Green Infrastructure includes a wide range of infrastructure types, so generalisations regarding the cost of implementation and maintenance are difficult to make. Maintenance may increase long-term jobs in the local community (Box 4), but alternative sources of funding are required to cover these costs (Box 5). Design that is sensitive to maintenance costs can improve the sustainability of a project by minimising this budget.

Box 5. Sources of Funding for Green Infrastructure

Installation or maintenance may be funded from a number of sources.

Installation

- **EU funding through the Structural and Cohesion Policy and its European Regional Development Fund (ERDF) or LIFE+ programme**. Both enable green infrastructure projects by providing funding to support ecological coherence or connectivity. Most projects are rural, but some urban projects have been funded.[78]
- **Match funding**. Community groups that provide funds (or volunteer time) to a program can apply for a similar value again from the Government. For example, The Big Tree Plant has attracted around £7m in match-funding so far.
- **Utilities subsidy**. For buildings with green roofs, United Utilities in Manchester allow a 50% discount of the surface water drainage charges for that portion of the property.

Maintenance

- **Section 106 agreements** negotiated with developers by local authorities. These generally last for five years before costs fall back to the local authority, and relate only to on-site measures.
- **The Community Infrastructure Levy** (Planning Act 2008) is a local development tax toward the upkeep of all types of community infrastructure. One example is the Portbury Wharf nature reserve in Bristol, funded by a new residential development nearby.[79]
- **Other hypothecated taxes** used to fund local infrastructure, for example business rates. This approach has been implemented in Business Improvement Developments (BIDs).[80]
- **Voluntary maintenance by local communities** to maintain green spaces on a volunteer basis. Some councils, such as Islington Council in London, transfer a proportion of maintenance funds to the community for this service.
- **Existing maintenance funds** for highways and buildings. These are often very large sources of funding that some have suggested could be redirected to green infrastructure.

Endnotes

For references, please see:
http://www.parliament.uk/documents/POST/postpn448_Urban-Green-Infrastructurereferences.pdf

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology. POST is grateful to Rebecca Wilebore for researching this briefing, to NERC for funding her parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact the co-author, Dr Jonathan Wentworth.