URBAN GreenUP

D3.1: Report on the diagnosis of Liverpool (Revision)

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1 Executive summary

The following report sets out the ecological and socio-economic diagnosis undertaken for Liverpool. It presents an overview of the city's social, economic and ecological resource base, as well as its current development context. The diagnosis builds on the evidence-base of a comprehensive evaluation of Liverpool's green infrastructure (GI), assessing the current GI network and Nature-Based Solutions (NBS) in the city, and identifies gaps in the network and opportunities to introduce innovative NBS in a way that takes advantage of favourable policy conditions.

In our diagnosis, we have used the terms green infrastructure and Nature-Based Solutions to describe the role that nature can play in helping to address the challenges facing the city. Whilst strictly it can be argued that these are different approaches, at the city level we believe that the terms can be used interchangeably.

The report provides an evidence base for the URBAN GreenUP interventions In Liverpool to test and demonstrate NBS and provide the basis for upscaling the approach in the city, replicating the approach in follower cities and enabling exploitation in markets for NBS across the world.

Our diagnosis of the city has used the Eklipse methodology currently under development as a framework. Key performance indicators (KPIs) have been proposed for the city based on this framework. A number of these indicators have been identified as common across all three lead cities.

To simplify the narrative for the Liverpool, we have identified four themes for the city, linked to the Local Plan Vision for Green Infrastructure[1] and in turn, linked these to the Eklipse Framework Challenges.

Table 1 Diagnosis framework

Liverpool City Council Vision for Green Infrastructure (taken from the Local Plan)	Themes	Eklipse Framework Challenges
To protect and enhance Liverpool's green infrastructure to ensure more attractive and cleaner residential neighbourhoods; sustain and promote biodiversity; mitigate against and adapt to climate change including contributing to	Sustainable City	Urban regeneration, green space management, promotion of economic opportunities and green jobs, participatory planning and governance
	Cool City	Water management, climate adaptation and mitigation

[1] http://liverpool.gov.uk/council/strategies-plans-and-policies/environment-and-planning/plan-making-in-liverpool/current-local-plan-documents/local-plan/

flood risk management; and to provide greater opportunities for sport and recreation and growing food locally to encourage better health and wellbeing.	Healthy city	Air quality, public health and wellbeing, social justice and social cohesion
	Biodiverse city	More, bigger, better managed and well-connected habitats, enhancing ecological networks

The diagnosis for Liverpool has used a wide range of data sources to describe the city, identify key issues to address, suggest types of green infrastructure interventions that might be considered and point to demonstration areas where more, in depth, assessment and specification of interventions can take place.

1.1 The city of Liverpool

Liverpool lies at the heart of the Liverpool City Region, one of two urban conurbations in North West England along with Manchester. The city covers an area of 113 square kilometres and has a population of more than 460,000.

The waterside setting, flanked by several important buildings including the 'Three Graces', gives a unique river approach and a world-renowned frontage. This has been recognised by the inscription in 2004 of much of the city centre and waterfront as a UNESCO World Heritage Site.

The legacy of its historic long-term economic and population decline is that Liverpool suffers from economic and social deprivation and is ranked fourth in the English Indices of Deprivation. The city has the highest level of income deprivation among England's core cities.

Recent economic growth in the city centre, centred on the city's airport and key radial roads has narrowed the GVA performance gap between Liverpool and the rest of the UK. Liverpool has been one of the fastest growing of any of the core cities in England.

1.2 Policy

The ability to deliver NBS is, to some extent, influenced by policy and strategy at national and local level. A wide-ranging review of policy was undertaken as part of this diagnosis. At a national level, there is a supportive policy framework for NBS. Local Policy and Strategy is also supportive of green infrastructure intervention to address a range of issues in the city.

(See Section 8)

1.3 Evidence

Promotion of NBS must be based on good evidence that the intervention can lead to improvements in the issues being tackled. In a similar way to the policy framework, our diagnosis has assessed the evidence base for NBS being able to meet the challenges set out in the Eklipse Framework.

Overall, the evidence base is strong, supportive of NBS in the right circumstances.

(See Section 9)

1.4 Green infrastructure in the city

Green infrastructure accounts for 62% of the total area of Liverpool, increasing to 69% if the large areas of the estuary are included. Large areas (3,779 ha) of the Mersey estuary are within Liverpool's administrative boundary. The river Mersey lies at the heart of all considerations of Liverpool.

The distribution of green infrastructure across the city varies considerably. The north of the city, traditionally the more industrial and more deprived areas, have lower levels of accessible

green infrastructure than the more affluent central and southern areas. The city centre has less than 5% green infrastructure.

1.5 Key issues for the city

Our diagnosis has identified a range of issues for the city. We have identified those issues for which there is robust evidence that NBS can play a role in reducing or removing the impact of an issue. For example:

- Liverpool has seen significant regeneration investment over the past 25 years, with significant EU investment. Liverpool is undergoing a £13bn regeneration-led renaissance with a need to ensure that quality of place is a high priority.
- 14,430 properties are at surface water flood risk from the 1% (1 in 100) event in Liverpool[2]. Of the 33.3km of streams in Liverpool, 29.7km are piped beneath the ground. Many of these culverts (pipes) are over 150 years old and are in poor condition. To combat flood risk, recent EU LIFE IP research has found that Liverpool should be a focal area for low density urban tree planting[3].
- Liverpool has a relatively young population. The 2014-based projections by ONS estimate that Liverpool's total population will increase by 5% by 2027, but the city's over 65 years population was projected to increase by 17%.
- The whole of Liverpool was declared an Air Quality Management Area (AQMA) in May 2008. Currently, Liverpool has exceeded statutory oxides of nitrogen emission targets[4]. Concentrations of sulphur dioxide (SO_2), particles (PM_{10}), ozone (O_3) and other measures remain largely undisclosed[5][6]. High concentrations of these substances and others represent pollution and a risk to health[7].
- The severity of Liverpool's health deprivation is reflected in the life expectancies for its population. Life expectancy for males is 76.2 years, and 80.5 years for females, below the national average. Despite significant regeneration in Liverpool, deprivation remains high.
- There are indications of a growing issue with childhood obesity, as 23.8% of children in Year 6 (8-9-year olds) are classified as obese, worse than the average for England.
- Common mental health problems are estimated to affect a quarter of Liverpool's population at any one time.
- The city has areas of high biodiversity value, with 25 Sites of Nature Conservation Value, four Local Nature Reserves, one Site of Special Scientific Interest, and the

[2] Liverpool City Council (2018) Draft: Local Flood Risk Management Strategy. Unpublished Planning Policy Paper. 1 – 87.
[3] JBA (2017) Merseyside Strategic NFM Targeting Maps: User Guide. The Rivers Trust, Natural Course (EU LIFE IP) and JBA. Unpublished Technical Paper. Skipton:JBA. 1 – 21.
[4] http://liverpool.gov.uk/council/strategies-plans-and-policies/environment-and-planning/air-quality/
[5] http://liverpool.gov.uk/business/environmental-health/air-quality/ ,
[6] http://liverpool.gov.uk/pests-pollution-and-food-hygiene/pollution/air-pollution/
[7] https://uk-air.defra.gov.uk/air-pollution/uk-eu-limits

Mersey estuary, which also has the highest level of designation as it is both a Special Protection Area and a Ramsar site.

A total of 34 NBS issues to consider have been identified across the Eklipse Challenges.

Three demonstration areas in Liverpool have been selected for URBAN GreenUP investment in NBS. These areas will showcase how well planned, evidence based NBS can help to address some of the issues identified in the diagnosis.

A detailed description of each of the three demonstration areas is provided in the URBAN GreenUP document 'Deliverable 3.2.'

2 Introduction

Cities are increasingly turning to nature-based solutions (NBS) to address societal challenges, wherein innovative interventions incorporating or inspired by nature are embedded into urban infrastructure. NBS have been highlighted as a policy priority in Europe, where they are seen as a cost-effective and locally-led way to comprehensively address the social, ecological, and economic impacts of issues that cities face. In particular, as cities around Europe become increasingly subject to climatic changes including shifting rainfall patterns, rising temperatures, more extreme weather events, and altered wind patterns, there is increased focus on how 'natural' solutions can be used to mitigate and adapt to these changes.

The development of green infrastructure plans across the UK has progressed steadily over the past 10 years. Liverpool and the wider north-west region have been at the forefront of this progress, leading the way in developing adaptive, NBS for a diverse range of socio-economic and ecological issues[8].

NBS solutions, according to the European Commission are:

"…solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions."[9]

Within urban areas NBS can be proposed to support the development of economic, social and ecological objectives within a responsive process of environmental management. They aim to promote human and ecological health and well-being and improve the resilience of ecosystems to respond to changing climatic, social and economic influences on urban landscapes. NBS are proposed to address significant issues affecting urban areas including flooding, climate change, health and well-being, social inclusion and economic growth. Eklipse provides a framework to assess these issues consistently across projects and programmes[10].

Due to the pace of development and the growing knowledge of NBS, the Horizon 2020 URBAN GreenUP project is timely. Horizon 2020 aims to deliver the findings of Europe 2020 through a five-year programme of research and investment in environmental innovation. It aims to support the European Union's blueprint for smart, inclusive and sustainable growth. The URBAN GreenUP projects aims to deliver on this vision through a multi-city, internationalised, and forward-looking approach to investment in NBS. Using Liverpool, Valladolid (Spain) and Izmir (Turkey) as front-runner cities, URBAN GreenUP will develop a suite of NBS investment options that can be developed in urban environments around Europe through follower cities (Ludwigsburg, Germany; Mantova, Italy) and three global accelerator cites (Chengdu, China; Medellin, Columbia; Quy Nhon, Vietnam). URBAN GreenUP, and the wider Horizon 2020

[8] Sinnett, Danielle, Nick Smith, and Sarah Burgess, eds. *Handbook on Green Infrastructure: Planning, Design and Implementation*. Edward Elgar Publishing, 2015. (page 124-145)
[9] European Commission. (n.d.) *Nature-based Solutions* [Online]. Brussels: European Commission. Available: https://ec.europa.eu/research/environment/index.cfm?pg=nbs [Accessed 30 July 2017].
[10] Eklipse

programme, are therefore leading the research and development of innovative approaches to urban development placing nature at the centre of this debate to ensure long-term sustainable and adaptive development. This report outlines the key challenges to be addressed in Liverpool over the course of the URBAN GreenUP project.

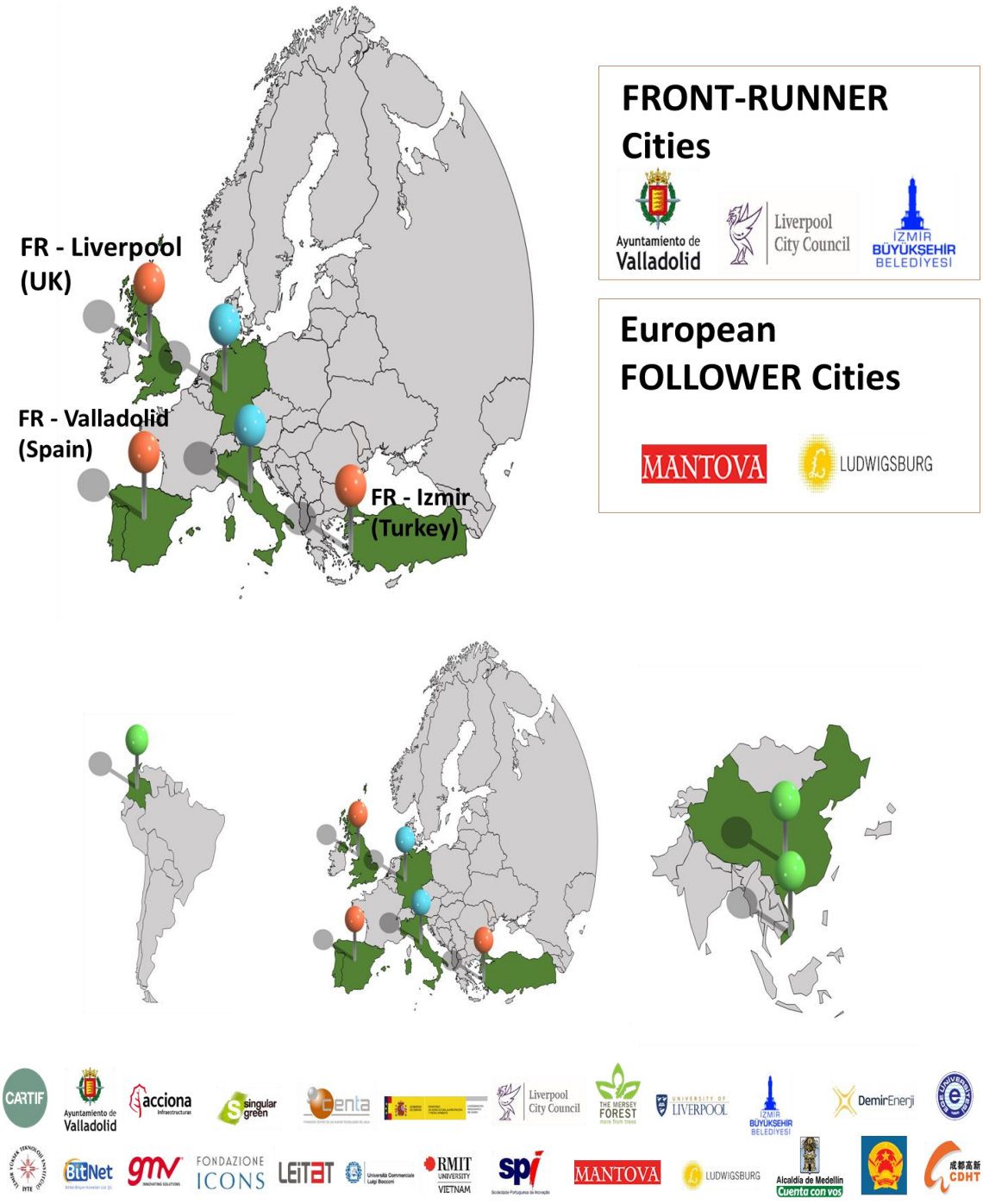

Figure 1 Lead and follower cities

2.1 Liverpool's strategic challenges

Liverpool, as with many major urban areas in the UK and globally, is facing significant challenges in managing its urban form to pursue economic growth agendas, whilst also providing an attractive city for its residents and visitors. Unfortunately, the social, ecological, and economic dimensions of these political mandates are frequently at odds, creating conflicting visions for how urban areas should be being developed and managed. With further densification of urban form, the re-development or conversion of green space into urban land, and a continuing growth spatially of urban footprints we are witnessing an ongoing fragmentation of urban systems. This includes growing problems with the connectivity between people, their places or work, residences and amenities, as well as challenges to the maintenance of supporting, provisioning and regulating ecosystem systems. All of which has a detrimental impact on the ability of urban systems to develop resilience to climatic and socio-economic change.

Liverpool has existing polices (see Section 8) attempting to address employment, health and educational inequality, which have been successful in some areas but not others. One aspect of these programmes which is often overlooked by strategies is how the natural environment can be used to promote greater interactivity with the landscapes around us, encourage investors (and associated jobs) to the city, and make Liverpool an attractive place to live, work and recreate.

Urban GreenUP provides an opportunity to demonstrate to key decision makers and the wider public the value of NBS. The long term monitoring and economic evaluation of NBS in the city provides an Urban Learning Laboratory and a chance to showcase NBS. The work is timely in the UK coming at the early stages of the government's 25 Year Plan for the Environment, which sets out how NBS should be incorporated into plans and strategies amongst other initiatives.

Urban GreenUP also feeds into the established networks such as the Green Infrastructure Forum, allowing dissemination of findings from the work in Liverpool and sharing of information about the wider work with lead and follower cities across the world.

Finally, the aspiration is for Urban GreenUP to help to make a step change in the quantity and quality of green infrastructure that is provided across the city, the wider city region and Mersey Forest.

3 Liverpool diagnosis

The following sections an overview of the current social, economic and ecological status of Liverpool. This provides the basis for our "diagnosis" for the city, leading to suggested NBS to help to overcome the issues that are identified.

Our city diagnosis method does not follow a traditional methodology. Our final choice of NBS sites and interventions is in part driven by:

- The following sections that identify issues in the city
- The central themes of the Urban GreenUP programme
- Opportunities that exist to implement NBS within the timescale of Urban GreenUP
- Availability of match funding, timeliness of opportunities for intervention and political priorities

The Horizon 2020 programme is using the Eklipse Challenge Framework[11], an impact assessment framework, across all of its NBS projects. Eklipse was formulated to guide an assessment of the effectiveness of nature-based solutions projects.

We have used the Eklipse framework as the basis for the Liverpool diagnosis.

The following diagram shows the process that has been used to carry out the city diagnosis.

[11] http://www.eklipse-mechanism.eu/nbs_report

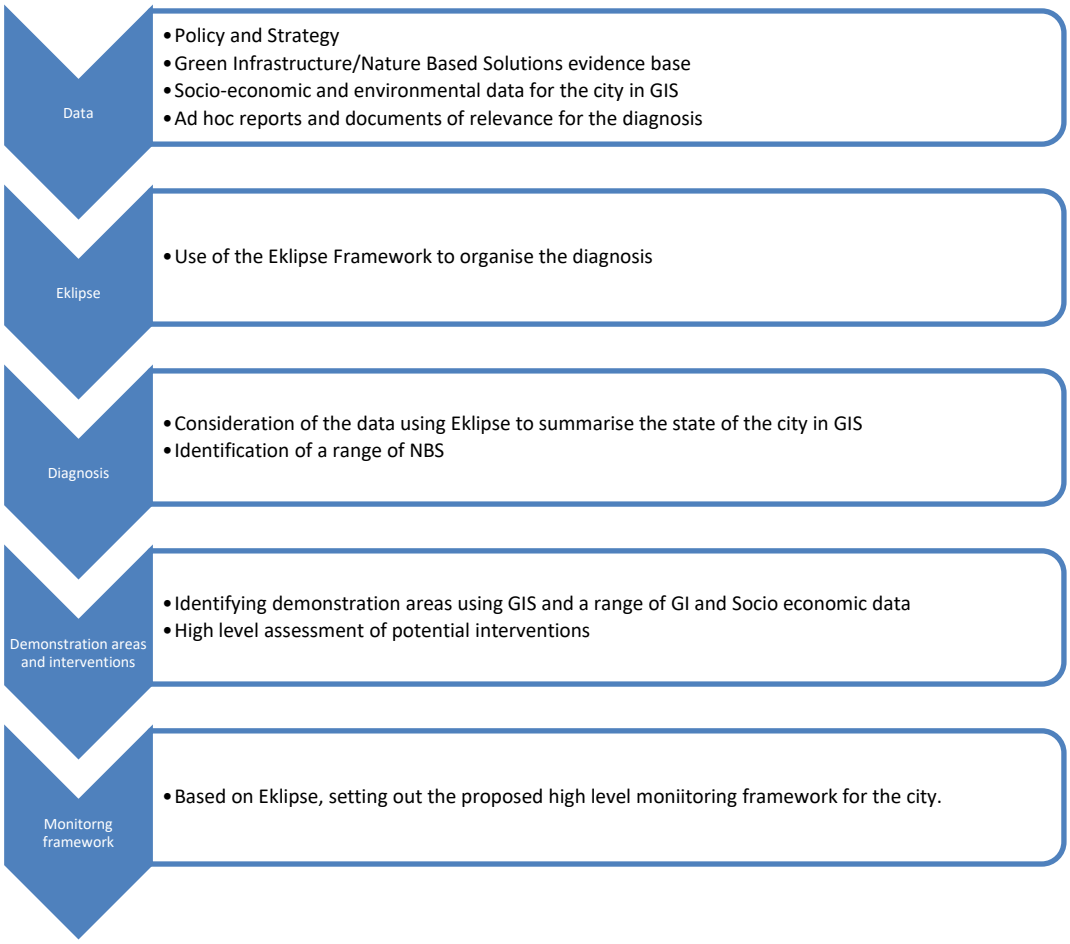

Figure 2 Liverpool diagnosis process overview

3.1 Overall city description

Liverpool lies at the heart of the former county of Merseyside, one of two urban conurbations in North West England along with Manchester. The city covers an area of 113 square kilometres and has a population of over 460,000.

Liverpool is the economic centre of the developing Liverpool City Region. Working alongside neighbouring local authorities, the city's existing powers are set to be expanded both geographically and politically as part of a Combined Authority with new and emerging powers for housing, planning, transport and regeneration and the election of a new regional mayor.

Figure 3 Liverpool, Liverpool City Region and the UK

The City is the primary driver of economic activity within the larger City Region, accounting for 37% of the area's total Gross Valued Added (GVA) in 2014 (the latest year for which data is available)[12]. The city centre is of particularly importance economically, as it is the largest employment-generating area in the city region and serves as its main leisure, cultural, retail and tourism centre. Liverpool also acts as the transport hub and key gateway for the North West, North Wales and North of England. It lies at the western end of the North European Trade Axis, which extends from Ireland to the Humber ports and northern European markets. The key gateways include Liverpool Lime Street rail station and Liverpool John Lennon Airport, while links to the national road network are provided through the M62, M53, M57 and M58.

[12] Liverpool Economic Briefing, January 2016, Liverpool City Council

In the last decade, Liverpool has undergone extensive change, with major investment in the city centre and other locations, particularly south Liverpool, which has included the rapid expansion of Liverpool Airport. There has been increasing investment in residential areas and population loss has stabilised. However, despite these achievements Liverpool still faces a number of challenges. The legacy of its long-term economic and population decline is evident in the economic and social deprivation seen in the city. The scale of this situation is particularly apparent in residential neighbourhoods close to the city centre, especially in northern inner Liverpool where substantial parts of Anfield, Kirkdale and Everton wards fall within the 1% most deprived areas in the country. As the city's economic fortunes have varied, we have seen a corresponding change in the quality of the public open space in Liverpool.

3.2 Liverpool's cultural environment

Liverpool's historic role as a major port and trading centre has resulted in a significant number of physical and environmental assets being located within the city enhancing it with a rich and diverse architectural heritage. The city centre, in particular, is an excellent example of Victorian architecture regionally but also nationally. The waterside setting, flanked by several important buildings including the 'Three Graces', gives a unique river approach and a world-renowned frontage. This has been recognised by the inscription in 2004 of much of the city centre and waterfront as a UNESCO World Heritage Site. In addition, the city has more than 2,700 listed buildings, along with 35 Conservation Areas, 10 registered historic parks (two of which are Grade 1 Listed), and four Scheduled Ancient Monuments. Together, these assets provide Liverpool with a distinctive urban landscape which contributes significantly to the city's identity.

Liverpool is one of the principal centres for leisure, cultural and tourism attractions in the region. In 2011, it was listed fourth favourite UK city in a survey undertaken by readers of a travel magazine, and it was listed as third in the world's best cities to visit in 2014. Tourism-related development in hotels, transport and visitor facilities is a major element of the local economy.

3.3 Historical development of the city

Historically, Liverpool has undergone periods of intense economic growth followed by severe economic retraction and, more recently, steady regeneration of the city's economy and infrastructure. These periods of growth and decline have left a lasting legacy that has shaped not only Liverpool's economy, but also the city's form, its social fabric, and its use of ecological resources. Liverpool's original growth and development into a major city arose as a direct result of the rapid expansion of its role as a port from the 1700s through to the early 20th century.

The city celebrated its octocentenary in 2007.

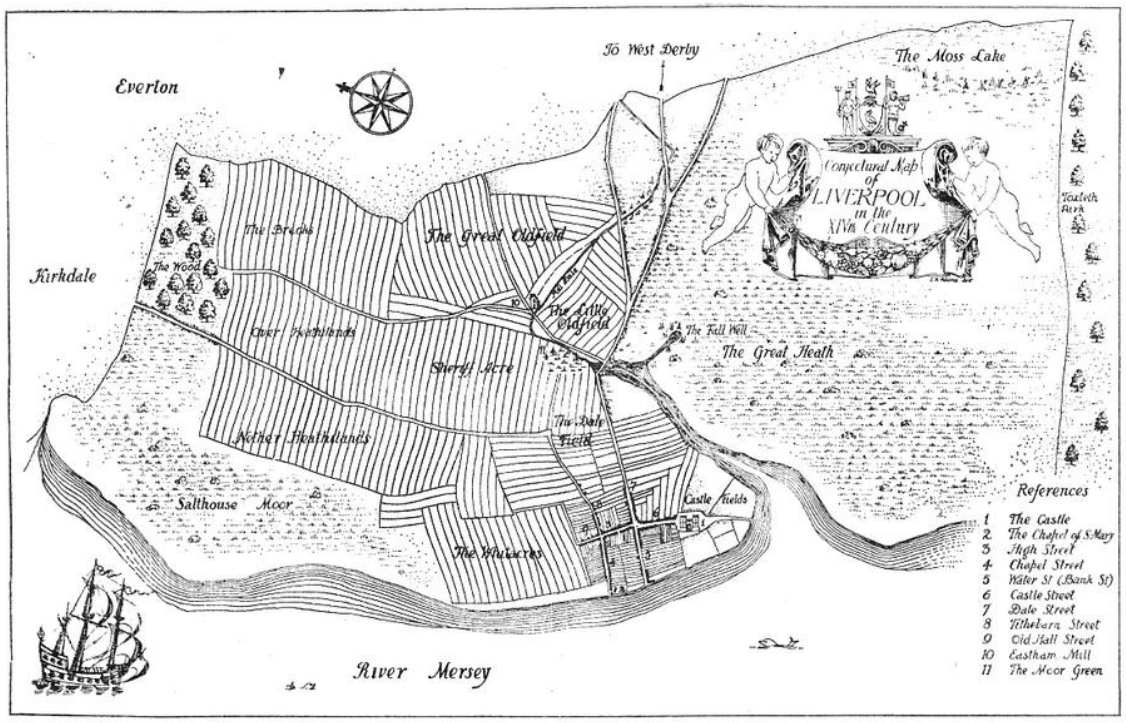

Figure 4 Historical map of Liverpool before development as a major port and city[13]

In the 19th century, new residential neighbourhoods built to accommodate a rapidly growing population attracted to the many port-related jobs and businesses located in a ring around the city centre, dominated in form by tightly packed streets of terraced properties. Many of these remain today. The radial road routes linking these areas with the city centre have continued to provide the focus for shops and community facilities and form many of the city's present-day district and local centres. They have also been the source of growing air pollution as traffic has been concentrated on these roads leading to growing congestion.

During the time of Liverpool's rapid expansion and growth, much of the city's current public open space was laid out, including extensive Victorian parks such as Princes Park, Sefton Park, Stanley Park, and Newsham Park. Many of the city's other planned open spaces, such as garden squares, private parks and gardens and boulevards, still survive and together provide a variety of open space types making a significant contribution to the city's present character. However, it had been observed that as development and growth has continued in the city centre that the proportion of green space, as well as its accessibility, has decreased.

Substantial economic growth in the city centre, centred on the city's airport and key radial roads, from a relatively low base rate, has narrowed the GVA performance gap between Liverpool and the rest of the UK. Liverpool has been one of the fastest growing of any of the core cities in England, albeit from a somewhat lower base level, and made a major contribution to the similarly improved performance of the city region economy.

[13] https://liverpool1207blog.wordpress.com/old-liverpool-maps/

Liverpool's recovery has resulted from significant investment in regeneration over the past 35 years. From 1994-2006, Merseyside, as it was then known, was an Objective 1 region and as such benefited from major levels of investment. In 2000-2006 alone, the amount received exceeded €1bn. During this period, Merseyside had its own Operational Programmes and was responsible for programme management.

In 2007-2013, thanks to growth in its GDP relative to the EU average, Merseyside became a Phasing-In Region; as such it had its own dedicated allocation, though much reduced compared to amounts under Objective 1.

For 2014-2020, Liverpool City Region is a Transition Region, a newly created category of regions whose GDP per head is between 75 and 90% of the EU average.

Liverpool was also European Capital of Culture in 2008. The year is widely considered one of the most successful and is seen by many as a pivotal point in the transformation of Liverpool from decline to growth[14].

More recently, the improving performance of important economic sectors and the strength of key assets have supported growth. In particular:

- Business and professional services, knowledge-based industries, biological sciences and creative industries and development in economically important locations such as the City Centre, waterfront, North Liverpool, Stonebridge Cross, South Liverpool, Central Liverpool, and the Knowledge Quarter. These are key economic areas where business development, innovation and economic growth are the key priorities
- The designation of two Enterprise Zones – Mersey Waters (including Liverpool Waters) and Liverpool City
- A transport system which enables the vast majority of the City to be accessible by a choice of means of transport and which connects it effectively with the wider sub-region
- One of the fastest growing regional airports in the UK – Liverpool John Lennon Airport

Despite the significant achievements over the last decade, the city still faces significant challenges to its development as a sustainable and inclusive city. The legacy of its long-term economic and population decline is that Liverpool suffers from economic and social deprivation and is ranked 4th in the English Indices of Deprivation. This is however an improvement as in in 2004, 2007 and 2010 it was ranked as the most deprived local authority in England. Liverpool also ranks third nationally in respect of health deprivation and disability and is fifth regarding income and employment deprivation. The city has the highest level of income deprivation among England's core cities.

[14] https://www.liverpool.ac.uk/media/livacuk/.../pdf/.../Creating_an_Impact_-_web.pdf

3.4 Historic development of Liverpool's green infrastructure

The historical development of the city described above, has played a major role in determining the distribution and type of green infrastructure in the city. Liverpool's green spaces provide an impressive resource which enables not only the history of urban development in the city to be interpreted but also charts some of the main developments in urban landscape design over the past two centuries. These include:

- 1800–1910: Planned urban spaces: the garden squares, privately funded cemeteries, and the creation of the city's private parks
- 1865–1910: First phase of public parks, landscaped cemeteries and planted boulevards
- 1895–1930: Second phase of public parks; mostly parks developed from private landscaped estates, small inner city landscaped garden sites, also the appearance of allotments
- 1919–1999: Inter-and post-war planned urban spaces and regeneration initiatives: dock basin conversions and coastal reclamation schemes, creation of school and university playing fields
- 1999 to date: Public realm improvements including increasing numbers of city centre trees, green roofs, boulevards, emergence of green infrastructure approach and integration of green and grey infrastructure

The garden squares incorporated into the layout of new housing in the 1800s were the first elements of planned open space developed in the city. The park estates of the 1840s set out to produce an attractive landscape for wealthy landowners, with a range of open space and large forest trees that now provide a mature landscape in areas such as Fulwood and Grassendale. The large public parks in the city were originally planned to provide a belt of green around the city linking its core to residential areas through tree-lined boulevards.

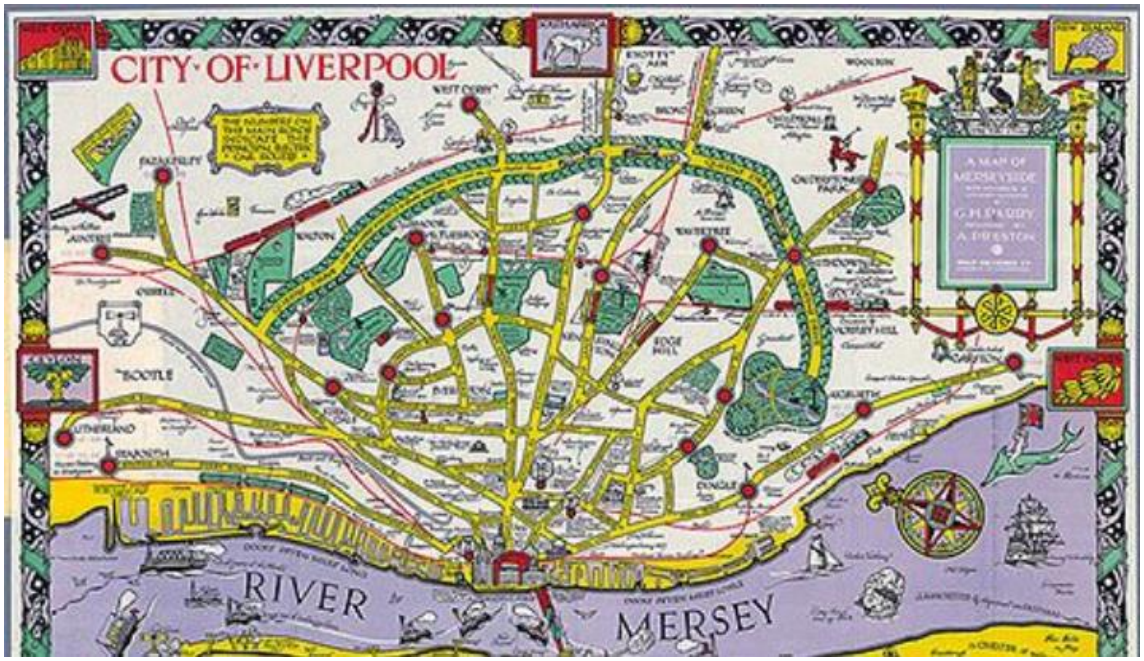

Figure 5 Early layout of the city showing the major parks and the "green" Queens Drive providing a crescent for the city[15]

The parks were originally funded through the sale of plots of housing land on which new housing overlooking the parks would be built, for example Newsham Park. The subsequent gift and acquisition of private estates that were subsequently converted to parks buffered the south of the city and protected it from urban expansion radiating out from the docks and the commercial area of the city. This protective green belt provided the historical basis for the variation seen today in the provision of green space across the city. The wide, tree lined avenues that are a feature of some areas of the city are an artefact of the new transport infrastructure laid out by Brodie, the city's highway engineer in the early 1900s, incorporating large trees along the roads and linking these green spaces to neighbouring areas of housing.

At the start of the twentieth century in the 1920s and 1930s Liverpool was a national leader in the development of garden estates and the remaining high percentage land cover of this type is in part a legacy of that time. Private gardens, along with general amenity space and grassland, account for over 50% of the total green infrastructure in the city. The garden estates were a response to the clearance of slum housing and were based on the model villages such as Port Sunlight.

Over the last 50 years depopulation of the city has led to extensive housing clearance and rebuilding that continues up to the present. Areas of former housing have been grassed over and many infill areas of housing form incidental green spaces, often randomly scattered through the old housing estates. The quality of the landscape in such locations is variable as the management of these sites is less extensive than in formal parks.

[15] https://liverpool1207blog.wordpress.com/old-liverpool-maps/

In 1984, Liverpool hosted a garden festival, part of an effort to regenerate areas of the city that had seen riots as a result of severe economic decline. The National Garden Festivals were part of the cultural regeneration of large areas of derelict land in Britain's industrial districts during the 1980s and early 1990s. Five were held in total - one every two years, each in a different town or city - after the idea was pushed by the Conservative environment secretary Michael Heseltine in 1980. They were based on the German post-war Bundesgartenschau concept for reclaiming large areas of derelict land in cities, and cost from £25-million to £70 million each. The International Liverpool Garden Festival site was a garden festival recognised by the International Association of Horticultural producers (AIPH) and the Bureau International des Expositions (BIE), which was held in Liverpool, England from 2 May to 14 October 1984. The site still remains heavily contaminated in parts but the Government has recently provided £10m of funding for some site remediation and there are now plans being progressed for both housing and parkland.

More recently, there has been a focus on improving the quality of the public realm to support large-scale private investment in areas such as Liverpool One, and public investment through large-scale intervention programmes such as Objective 1. This has led to more urban trees planted within new development – areas such as Chavasse Park in the city centre – and an increasing number of green roofs being created.

3.5 Liverpool and The Mersey Forest

Liverpool City Council is a core partner in The Mersey Forest. Over the past 25 years, the Partnership has planted over 9 million trees across Merseyside and Cheshire.

Liverpool

Liverpool is the most urban local authority within The Mersey Forest and whilst this means that there is less opportunity for the creation of large new woodlands, there is much potential to improve the management of existing woodlands, deliver smaller scale community planting schemes, and extend street tree planting both along the main routes into the city and within local neighbourhoods. This will bring The Mersey Forest to people's doorsteps and thereby help to improve health and wellbeing, tackle issues of health and green space inequality, improve educational attainment, create a city that is more resilient to climate change, and support tourism and the local economy. This will create an attractive setting for people to live, work and invest.

Indicative woodland cover target (%) and policies

Visit merseyforest.org.uk/plan for an interactive version of this map.

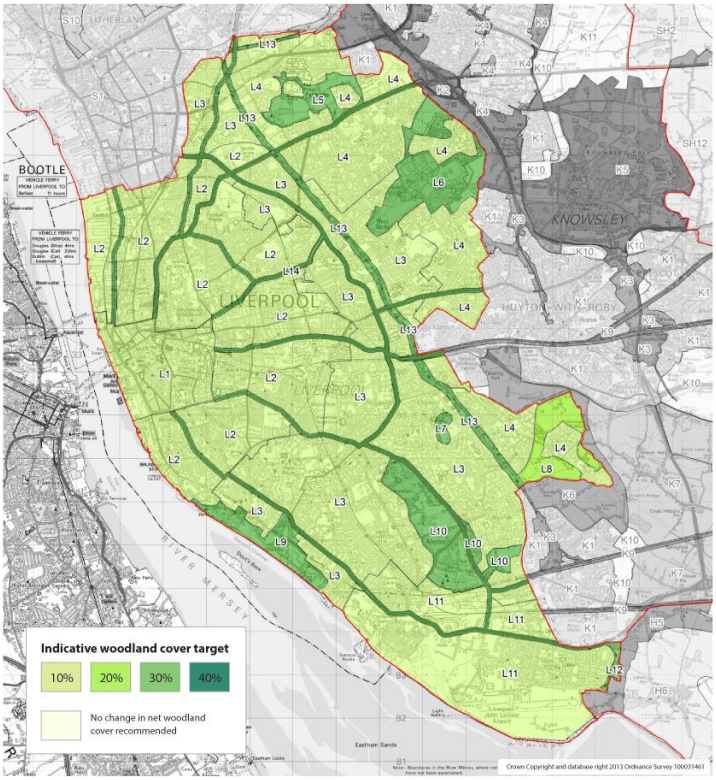

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Figure 6 Mersey Forest strategy map for Liverpool

In Liverpool, more than 90 ha of new woodland have been planted to date. In recent years there has been an increased focus on the planting of urban trees and small-scale woodland areas in schools. These school schemes are often linked to Forest School programmes. The recent Liverpool Green Space Plan advocates a tree for every child and a Forest School for every school in the city.

Community involvement and a focus on addressing issues such as poor health, education improvement, enhancing image and adapting to climate change have been essential elements in the delivery of The Mersey Forest in Liverpool.

3.6 Liverpool's green infrastructure

An assessment of Liverpool's green infrastructure based on typology mapping produced by the Mersey Forest provides the following results:

Table 2 Green infrastructure typology in Liverpool - as a percentage of total land area and as a percentage of the green infrastructure component of land cover in the city

Type	Percentage of total area	Percentage of GI
Agricultural land	1.1%	1.6%
Allotment, community garden or urban farm	0.3%	0.5%
Cemetery, churchyard or burial ground	0.9%	1.2%
Coastal habitat	23.5%	34.0%
Derelict land	0.1%	0.2%
General amenity space	3.8%	5.4%
Grassland, heathland, moorland or scrubland	1.2%	1.8%
Green roof	0.0%	0.0%
Institutional grounds	4.8%	6.9%
Not GI	30.8%	
Orchard	0.0%	0.0%
Outdoor sports facility	2.4%	3.5%
Park or public garden	3.0%	4.4%
Private domestic garden	15.4%	22.3%
Street trees	1.7%	2.4%
Water body	0.7%	1.0%

Water course	5.4%	7.8%
Wetland	0.0%	0.0%
Woodland	4.9%	7.1%

Note that data is provided to 1 decimal place and this means that the very low values for green infrastructure types such as Wetland, Orchard and Green Roofs are shown as 0.0%. In reality, there are small areas of each of these types, but they are very small and do not register at the city scale. They do become more important locally and will show up in the typology data when mapping is carried out at a more local level.

The data certainly indicates that, for example, there are few examples of green roof in the city.

Green infrastructure accounts for 62% of the total area of Liverpool, increasing to 69% if the large areas of the estuary are included. Large areas (3,779 ha) of the Mersey estuary are within Liverpool's administrative boundary and this typology is the largest. The river Mersey lies at the heart of all considerations of Liverpool. This new green infrastructure assessment for the city serves to underline highlight this fact.

On land, private gardens constitute the largest single type of green infrastructure in the city. Private gardens represent a major asset for the city, but one that is not easily influenced by policy.

The distribution of green infrastructure across the city varies considerably. The north of the city, traditionally the more industrial and more deprived areas, have lower levels of green infrastructure that the more affluent central and southern areas.

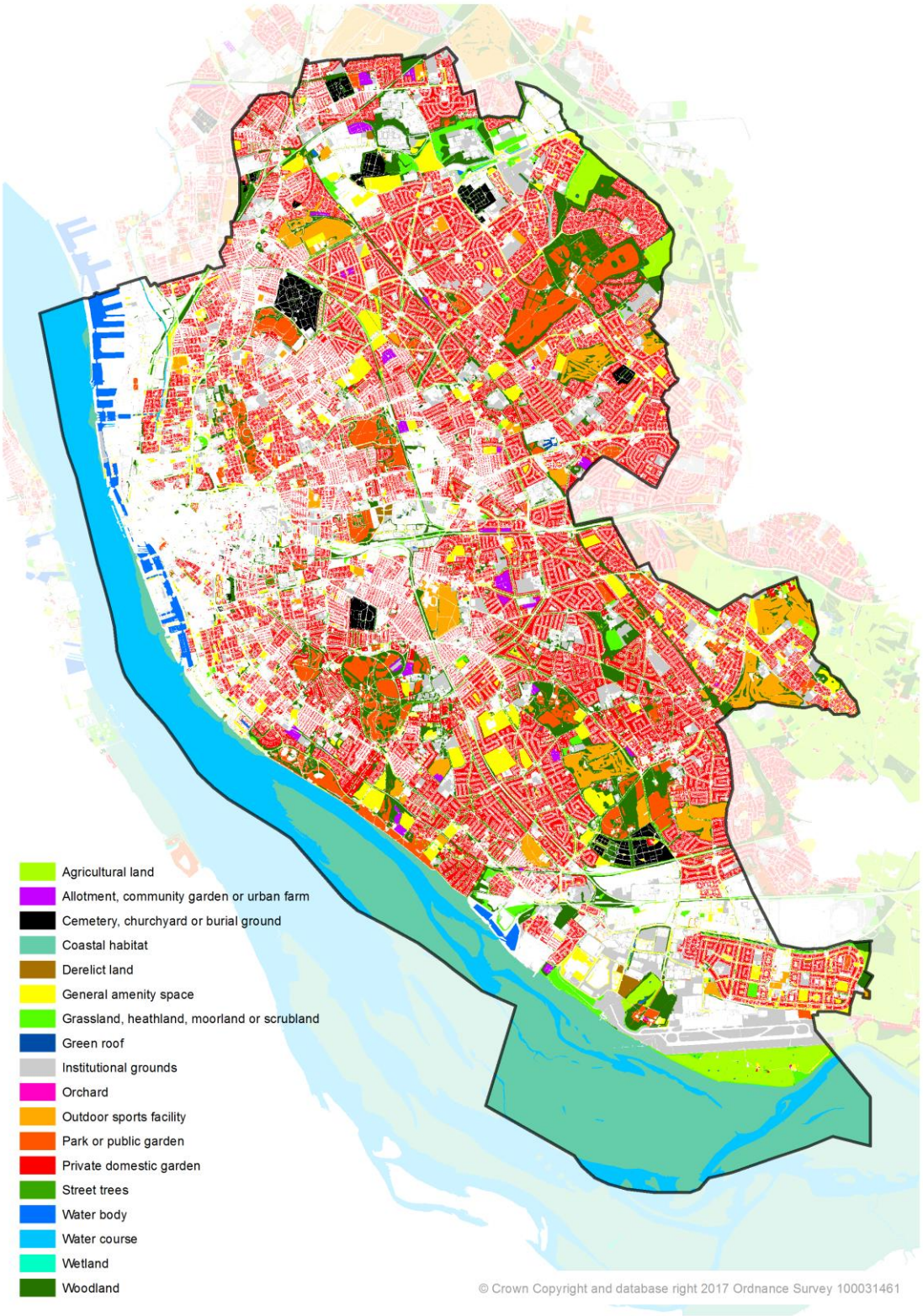


Figure 7 Liverpool's green infrastructure

The importance of private gardens in the city's green infrastructure is seen by comparing a map showing all green infrastructure types and one with the private garden typology removed.

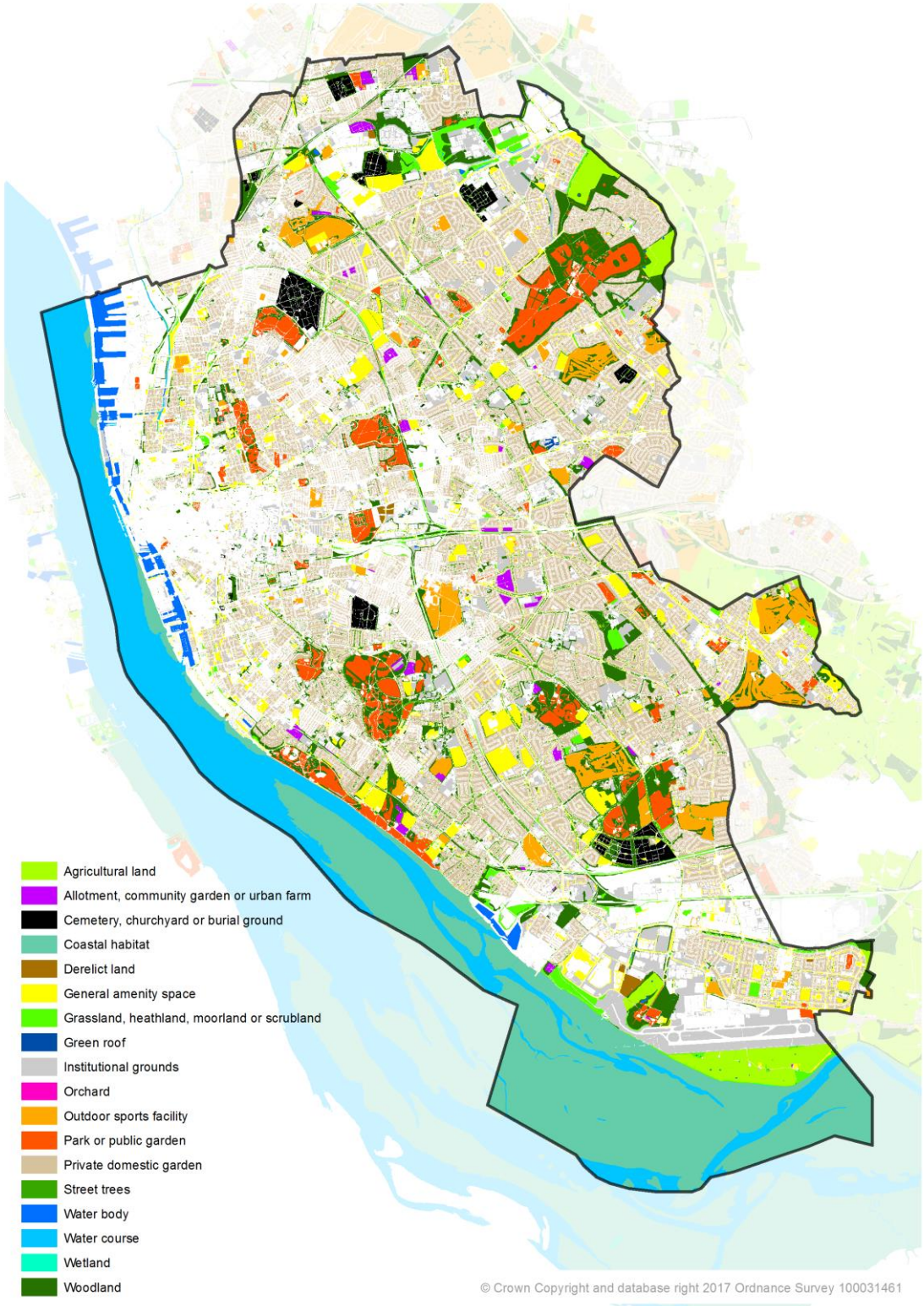


Figure 8 Liverpool green infrastructure

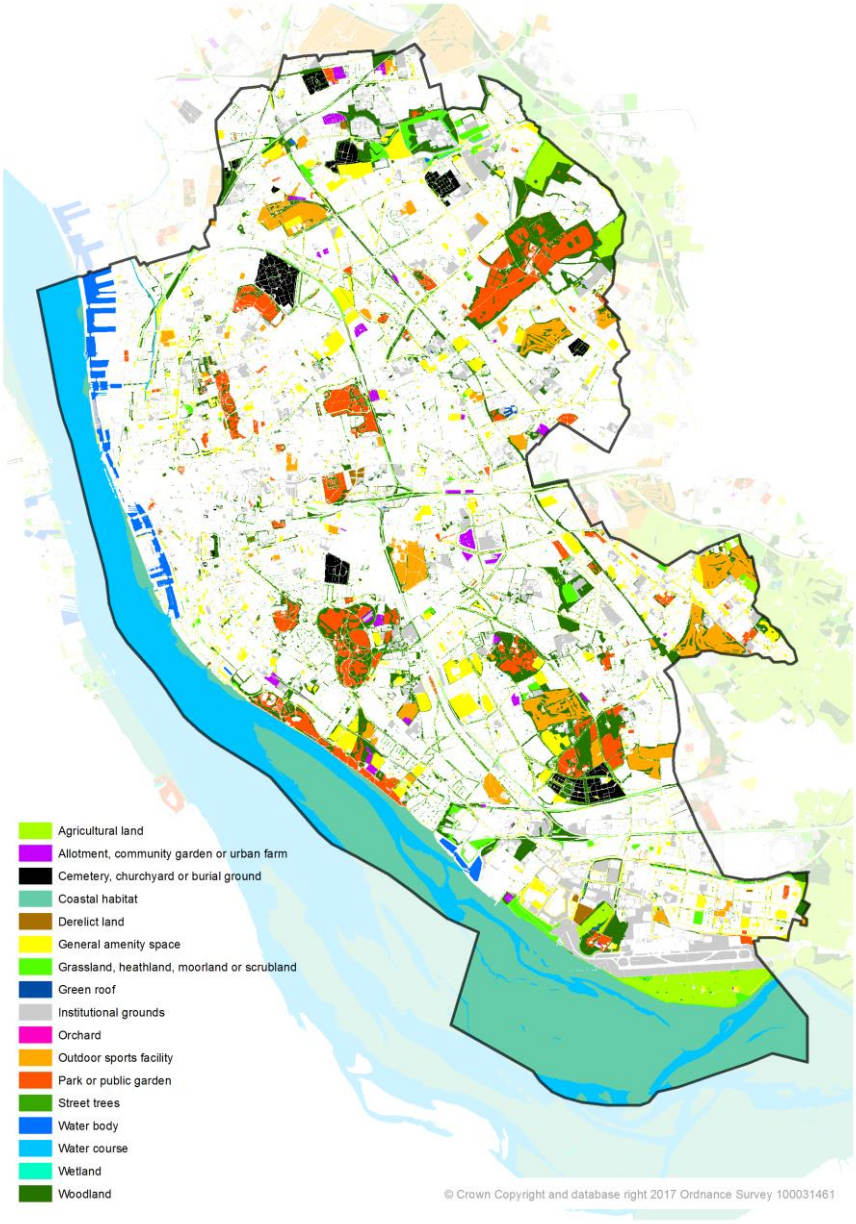


Figure 9 Green infrastructure map without private garden typology

3.7 Liverpool's population

Liverpool has a distinctive demographic profile that makes it an ideal place to invest in innovative solutions. Since 2000 Liverpool has seen its population grow after a period of significant decline, with an increase of over 6% between 2001 and 2011, reflected in part by the recovery in the local economy during that period. Liverpool's population is a young one, reflecting the popularity of the city among students and young professionals: 45.4% of the population are aged between 16-44 years old compared with 23.9% nationally. Over the last ten years (2005-2015), Liverpool's BME (Black and Minority Ethnic) population has increased at a significantly faster rate than seen nationally (110.5% and 77.5% respectively).

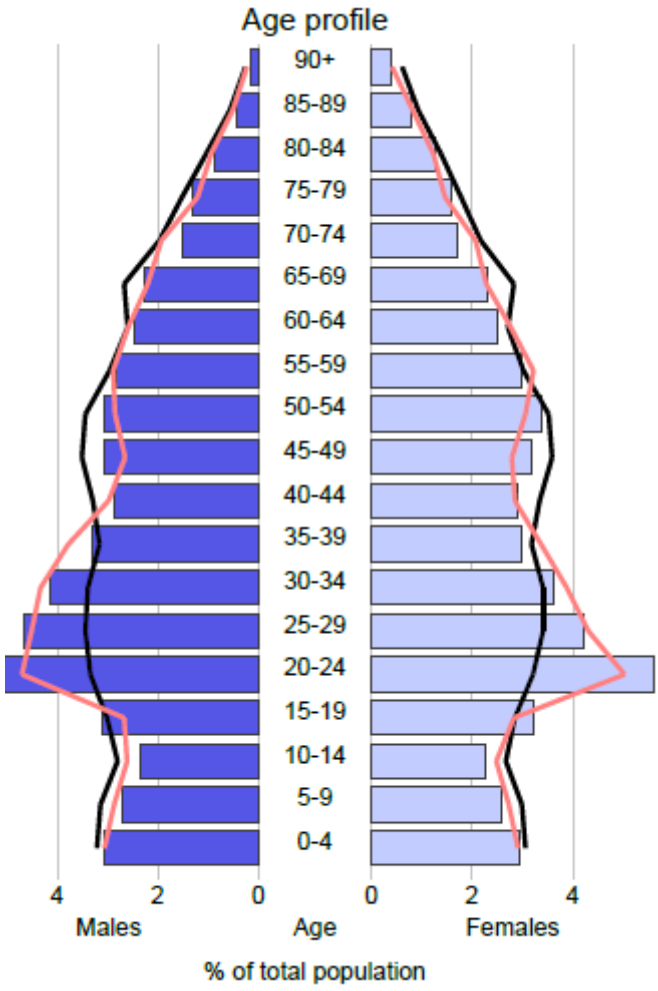


Figure 10 Liverpool population age profile

3.8 City diagnosis based on Eklipse framework

The following sections use the Eklipse framework to organise the diagnosis of the city. Information from a range of sources has been used to provide a synopsis of the current situation in Liverpool.

Underpinning these synopses are the policy assessment and evidence base (Sections 8 and 9). The evidence base helps us to identify which types of NBS may be useful in dealing with the issues raised by each challenge. The policy assessment provides the context within which we will have to deliver interventions through URBAN GreenUP.

To simplify the narrative for the city, we have identified four themes for the city, linked to the Local Plan Vision for Green Infrastructure[16].

Table 3 Diagnosis framework

Liverpool City Council Vision for Green Infrastructure (taken from the Local Plan)	Themes	Eklipse Framework Challenges
To protect and enhance Liverpool's green infrastructure to ensure more attractive and cleaner residential neighbourhoods; sustain and promote biodiversity; mitigate against and adapt to climate change including contributing to flood risk management; and to provide greater opportunities for sport and recreation and growing food locally to encourage better health and wellbeing.	Sustainable City	Urban regeneration, green space management, promotion of economic opportunities and green jobs, participatory planning and governance
	Cool City	Water management, climate adaptation and mitigation
	Healthy city	Air quality, public health and wellbeing, social justice and social cohesion
	Biodiverse city	More, bigger, better managed and well-connected habitats, enhancing ecological networks

[16] http://liverpool.gov.uk/council/strategies-plans-and-policies/environment-and-planning/plan-making-in-liverpool/current-local-plan-documents/local-plan/

3.8.1 Climate change adaptation and mitigation

Challenge 1 Eklipse Framework measures

Climate mitigation & adaptation	Urban Heat Island, Pluvial flooding, species movement, active travel

Urban heat island

Using data from the National Health Service Heat Wave Plan[17], we can map the distribution of communities across the city that have been identified as vulnerable to heatwave. Whilst this data is useful in planning for wider reduction in risks from heatwaves, it does not take into account the impacts of high temperatures on those who work in the most built up parts of the city.

The communities most at risk from heatwave (and potentially Urban Heat Island impacts) are:

- Older age: especially over 75 years old, or those living on their own who are socially isolated, or in a care home
- Chronic and severe illness: including heart conditions, diabetes, respiratory or renal insufficiency, Parkinson's disease or severe mental illness.
- Infants are vulnerable to heat due to immature thermoregulation, smaller body mass and blood volume, high dependency level, dehydration risk in case of diarrhoea
- Homeless people (those who sleep in shelters as well as outdoors) may be at increased risk from heatwaves.
- People with alcohol dependence and drug dependence often have poorer overall health and increased social isolation which can increase their risk of heat stress
- Inability to adapt behaviour to keep cool such as having Alzheimer's, a disability, being bed bound, drug and alcohol dependencies, babies and the very young

High temperatures have a significant impact on health.

"A linear relationship between temperature and weekly mortality was observed in England in summer 2006, with an estimated 75 extra deaths per week for each degree of increase in temperature."[18]

17 www.gov.uk/.../10088-2902328-TSO-Heatwave-Making_the_Case_ACCESSIBLE.pdf
18 Heatwave Plan, above

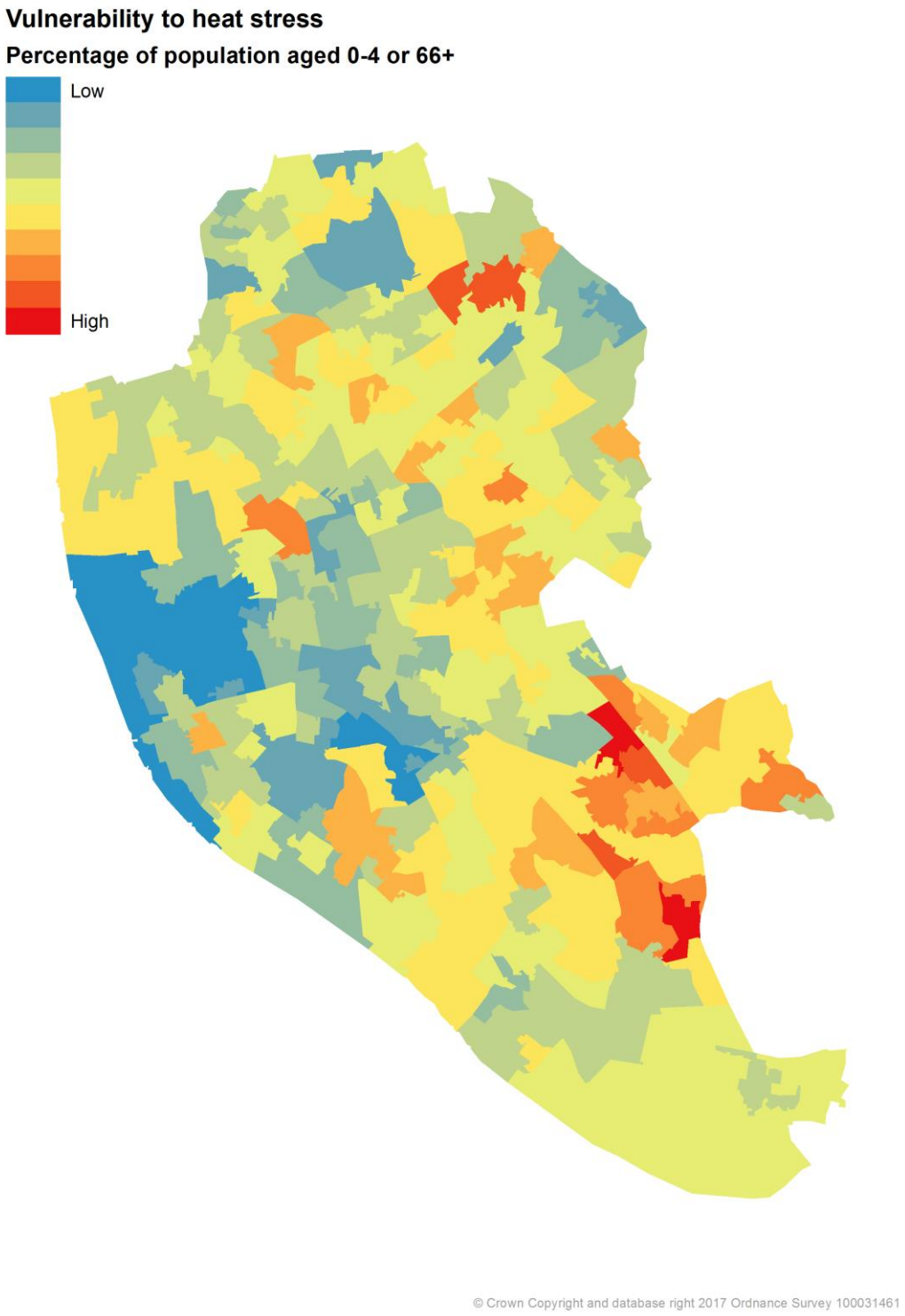


Figure 11 Vulnerability to heat stress, based on NHS Heat Wave Strategy information on vulnerable communities

The pockets of high risk populations are mainly on the periphery of the city.

The Heat Wave Plan identifies the key features leading to Urban Health Island effects:

- Thermal properties of building and road materials, the height and spacing of buildings and air pollution levels. These factors result in more of the sun's energy being captured, absorbed and stored in urban surfaces compared to rural surfaces during the day and a slower loss of this energy at night, thus resulting in comparatively higher air temperatures
- Less evaporation and shading, with the consequent reduction in associated cooling, taking place in the typically drier urban areas as there is less vegetation
- Greater inputs of heat as a result of the high density of energy use in cities – all this energy, for example from buildings and transport, ultimately ends up as heat

The Heat Wave Plan points to the role of NBS in helping to tackle Urban Heat Island as part of long term planning for a city or town in the second bullet point of the list above.

"There is considerable evidence to support the case for well-designed green infrastructure: trees, parks, green roofs, and ponds/lakes can all help to reduce heat retention."

STAR Tools[19] is a model developed through the EU Interreg Programme to assess the role that green infrastructure interventions and in particular an increase in tree canopy cover can play in helping to reduce UHI. (Run for Liverpool)

Climate change projections for the city suggest that there is a likelihood of increased summer temperatures and incidence of heat waves.

Key issues to consider

Use of NBS to

- Reduce risk of heat wave to vulnerable communities
- Use of NBS in city centre to reduce the impacts of UHI and the impacts that this has on health and also on economic activity
- Develop Star Tools as a model to identify benefits of NBS for reducing UHI

Pluvial flooding (also see Section 3.8.2)

Surface water flooding occurs across the city and unlike the river and sea flooding events occurs within the urban areas. Surface water flooding can be exacerbated by sealing permeable surfaces and failing to take local drainage into account in development of urban areas.

The Mersey Forest Team has developed the concept of Urban Catchment Forestry (UCF) in the UK, taking a lead from work that has already taken place and which continues to make progress in the US. UCF is concerned with maximising the use of trees in urban areas due to

[19] http://maps.merseyforest.org.uk/grabs/

the benefits they provide for water management; specifically, surface water management. The adoption of the approach leads to an expansion and enhancement of urban green spaces and can create more functional urban landscape. Whilst the concept is well embedded in the US and the environmental and socio-economic benefits of trees in urban areas are generally accepted in the UK, we lack a clear understanding of the quantifiable benefits that trees can achieve for water management.

This is particularly important with the current prevailing political imperative promoting development which does not necessarily always recognise the social, economic and environmental benefits of green infrastructure and natural flood management measures.

As a result, The Mersey Forest is working with partners to develop a project which will undertake desk based and practical research to develop a convincing business case for increased tree coverage in urban areas based on their role in water management (flood risk management, water resources and water quality). The STAR Tools, described above, also enables assessment of the impacts of changes to green infrastructure on water runoff.

We continue to work closely with colleagues in the US who have developed this approach and they are keen to continue to support our ambition to “catch up” to the stage where they are now.

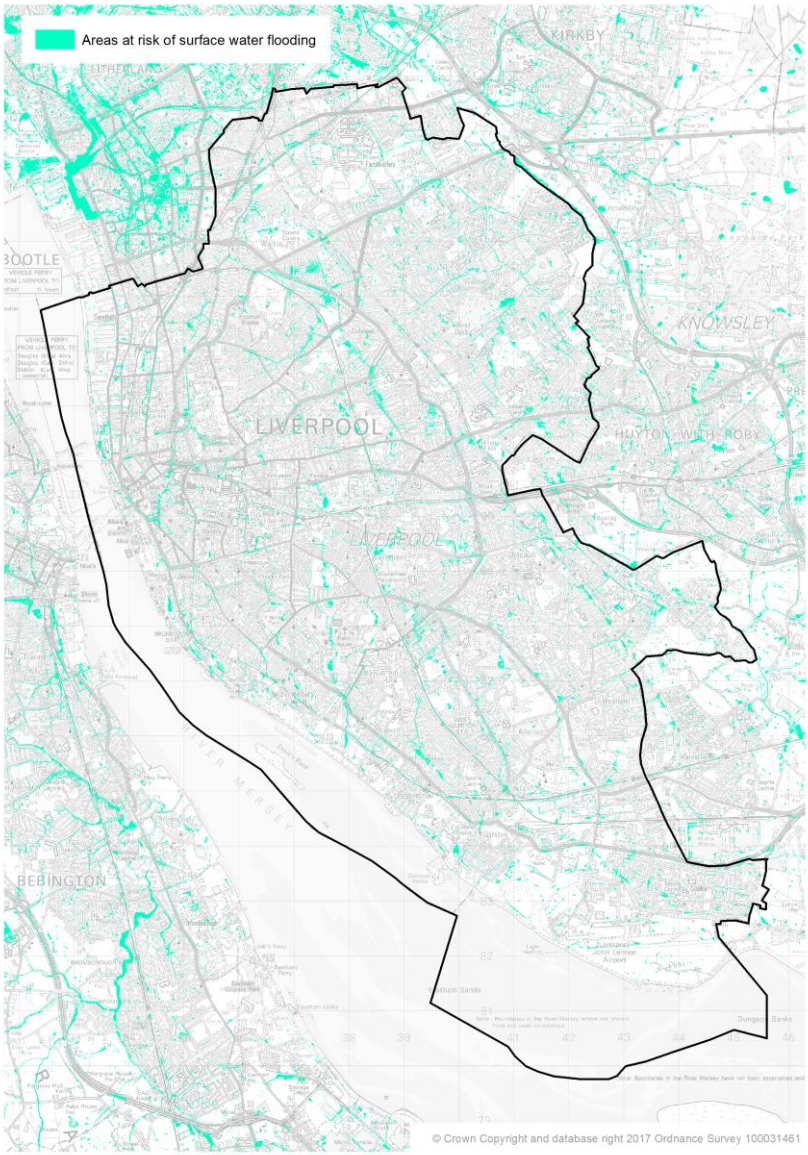


Figure 12 Areas at risk of surface water flooding

Key issues to consider

Use of NBS to

- Reduce impacts of pluvial flooding
- Develop Star Tools as a model to identify benefits of NBS for pluvial flooding
- Assess the benefits of Urban Catchment Forestry as a model for developing a programme of NBS to reduce impacts of rainfall on flood risk.

Species movement

As climate changes, species tend to move northward and/or toward high elevations to stay within their preferred climate envelope.

Networks and corridors of green infrastructure can assist in this movement. However, where there are gaps in the network, movement can be slowed or stopped. This may mean loss of species occurs as the climate changes.

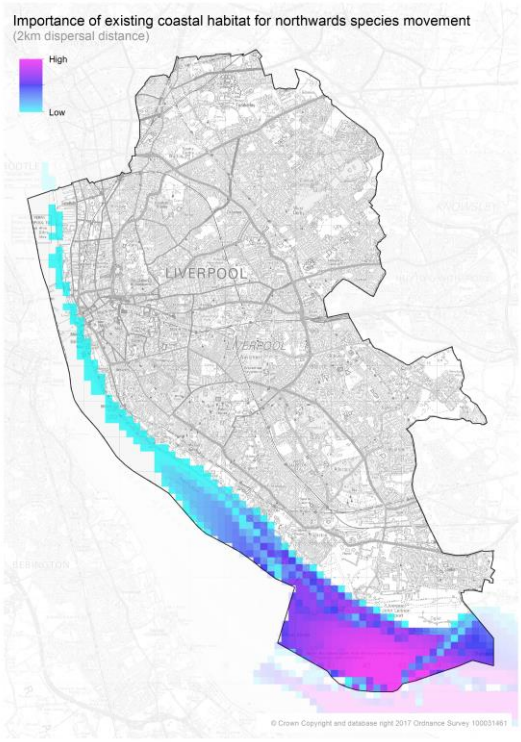
The Condatis[20] programme has been developed by the University of Liverpool. Condatis is a decision support tool to identify the best locations for habitat creation and restoration to enhance existing habitat networks and increase connectivity across landscapes.

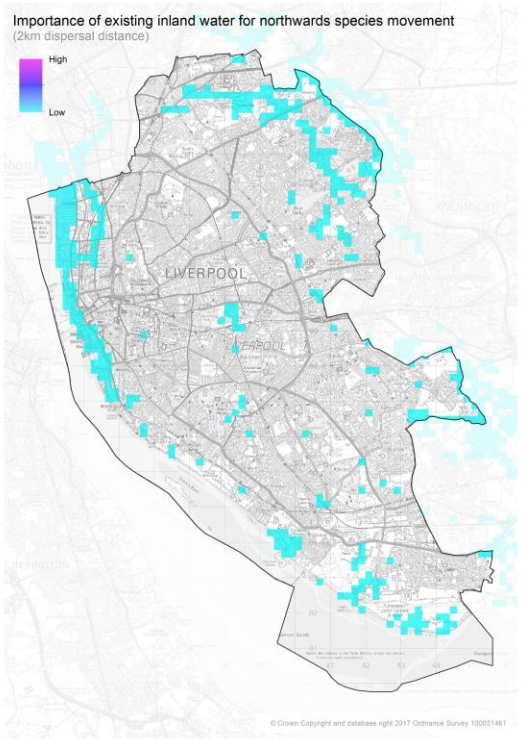
Using the green infrastructure mapping for the city Condatis can be used to identify the key flow pathways for species movement through the city, from south to north.

Six habitat types were used, based on the green infrastructure mapping for the city.

- Coast
- Inland water
- Intensively managed grassland (including gardens)
- Less intensively managed grassland
- Trees and woodland
- Wetland

For each habitat type, species dispersal distances of 1 and 2km were mapped. The following maps show the results for the 2km dispersal distances. The maps show the importance of different areas of each habitat for south to north migration of species.

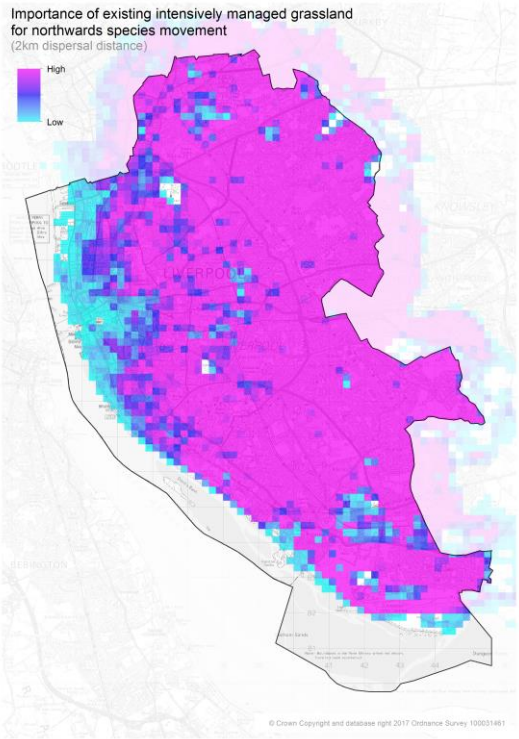


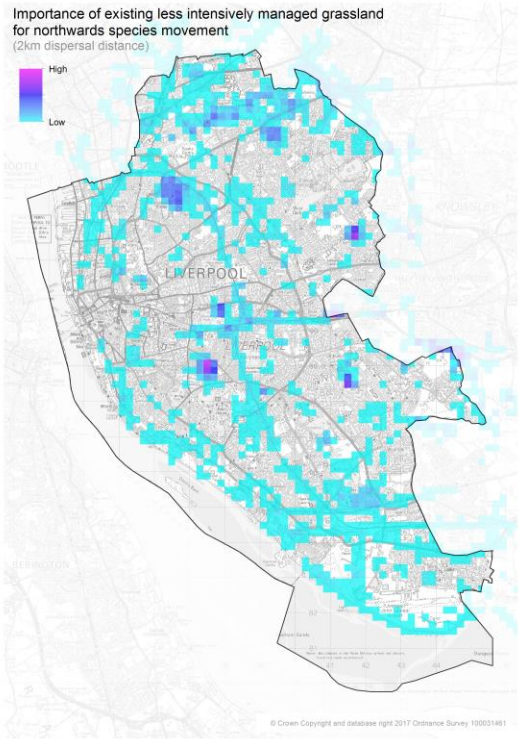


The river Mersey is a major ecological asset for the UK. However, it has limited functionality in for northward migration of species due to the nature of the habitat. Inland water has limited

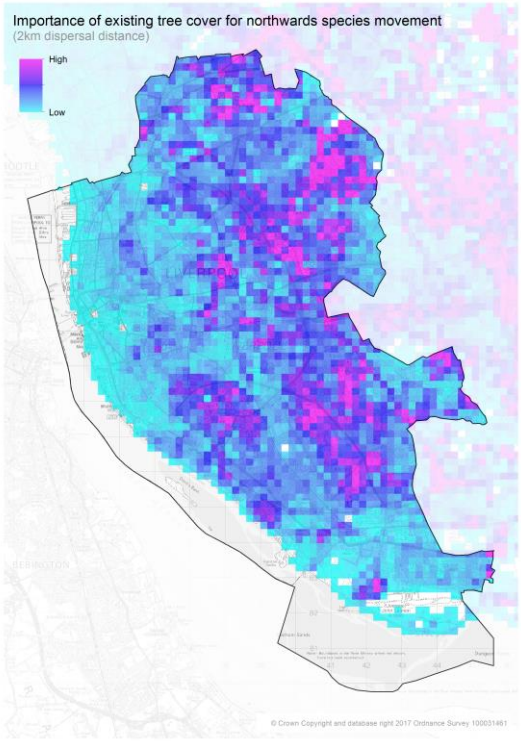
[20] http://wordpress.condatis.org.uk/

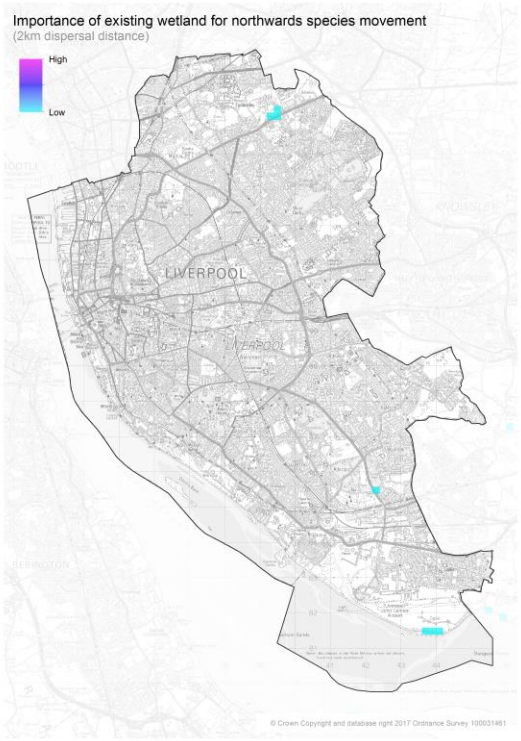
networks of connectivity and low levels of importance of northward species movement. The city has little wetland other than the River – which itself is of international significance.





There is a stark difference between the importance of intensively managed grassland and less intensively managed grassland in terms of northwards species movement. This is related to the abundance of the intensively managed grassland. With large areas of formal parks and private gardens, intensively managed grassland accounts for over 35% of the land area of Liverpool.





There is very little wetland habitat in the city and so the map shows low levels of importance for northward movement of species. Trees and woodland has a broad range of importance, the east of the city has, on the whole, higher levels of importance northward movement of species. The west of Liverpool and in particular the north west and south of the city have lower levels of importance reflecting the lower levels of tree and woodland in these areas.

Key issues to consider

Use of NBS to

- Increase connectivity of habitats
- Target areas with lower levels of green infrastructure
- Promote Lawton principles - more, bigger, better managed and well-connected habitats across the city.

Active travel

Replacing trips normally made by car with increased levels of cycling and walking can help to reduce greenhouse gas emissions. Short car journeys are a key target for active transport. They are frequent, often short journeys that could be walked or cycled.

Liverpool's Green Infrastructure Strategy[21] highlighted the need to develop areas that encouraged walking and cycling, these linked networks of green infrastructure to area of housing and short trip destinations such as schools, health centres, places of work and shops.

[21] http://www.greeninfrastructurenw.co.uk/liverpool/

The key areas for active travel were shown to be in the north west of the city, extending down through the city centre.

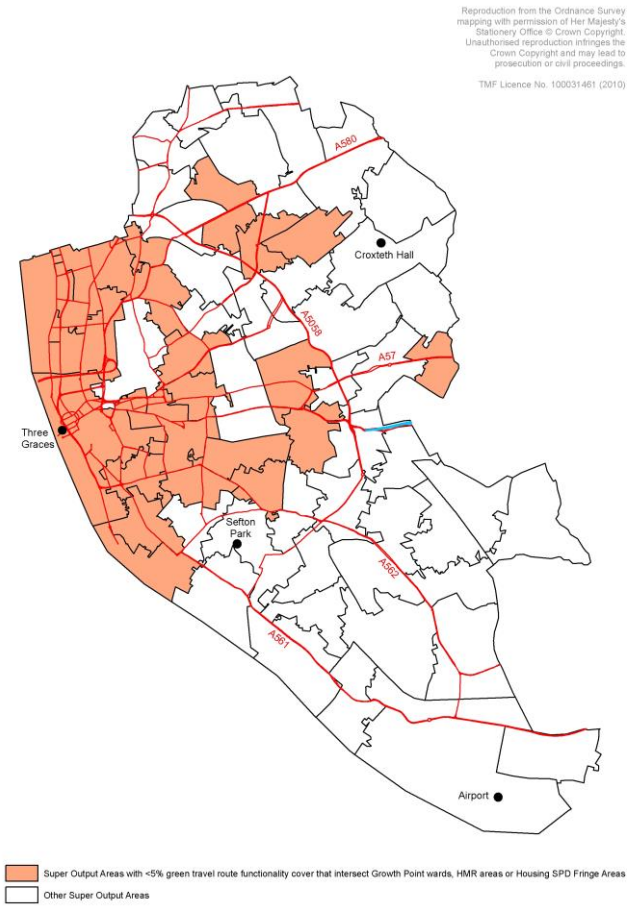


Figure 13 Focus areas for active travel

The opportunities to create "walkable" neighbourhoods are perhaps greatest where there is restructuring through housing regeneration or major redevelopment. Green infrastructure can help to create "walkable" neighbourhoods when it is connected to the wider public realm, other open spaces and pavements, and well managed to provide part of a safe network of routes.

Greening of routes to work, to support active travel, in area of north and south Liverpool (Speke and Everton) and a number of other areas across Merseyside, funded through the Local Sustainable Transport Plan in 2014 resulted in increases in both walking and cycling.

	2015	2013	Change	Number of people	Working population	Additional number of people walking
Everton	60	27.1	33%	10197.026	51%	5200
Speke	45.1	26.3	19%	3816.4	46%	1736
South Sefton	53.6	22.3	31%	17878.873	47%	8367
Kirkby	48	17.6	30%	6124.08	49%	3000
St Helens	30.8	27.1	4%	756.169	51%	386
Birkenhead	46.8	39.9	7%	621	45%	281
Total						18973.

Figure 14 Results of active travel survey 2013-2015

Using the WHO HEAT model[22] to calculate the reduced mortality as a result of changes to activity levels, the health benefits of this increased level of active travel was estimated at £31m over five years.

Increasing active travel also reduces carbon emissions if it replaces travel by car. It is estimated that active travel saves 112,000 grams of CO_2 per person (displaced from single occupancy car to cycle)[23]. Applying these figures to the data from the LSTF programme indicates that the programme reduced CO_2 emissions by approximately 2100 tonnes.

Active travel also has implications for health, promoting more active lifestyles and helping to mitigate climate change risk.

Findings from the Cycle Demonstration Towns[24] have found that for every £1 invested in cycle measures the value of decreased mortality was £2.59.

Data from Strava can be used to identify the use of Liverpool's green infrastructure for cycling.

[22] http://www.heatwalkingcycling.org/index.php?pg=walking&act=introduction
[23] SQW (2007). Valuing the benefits of cycling. http://www.dft.gov.uk/cyclingengland/site/wpcontent/uploads/2008/08/valuing-the-benefits-of-cycling-full.pdf
[24] Department for Transport, Valuing Increased Cycling in the Demonstration Towns, 2009

Figure 15 Active travel heat map - using data from Strava overlaid with accessible greenspace layer

Key issues to consider

Use of NBS to

- Use of NBS to increase active travel
- Links to existing software such as Strava to measure access and identify options for targeting investment in active travel.

Climate resilience

The UK Climate Projections[25] were last issued in 2009 (UKCP09), they are due to be updated in 2018. The storyline for the Northwest, and so in general for Liverpool, told by UKCP09 is similar to that for the UK; warmer wetter winters, hotter drier summers, and more extreme events. In the Northwest, by the 2080s under a high emissions scenario (table 3): in winter, mean temperatures could increase by 1.9-4.8ºC and precipitation could increase by 9-50%; in summer, mean temperatures could increase by 2.5-7.3ºC, with daily maximum temperatures increasing by 2.3-10.1ºC, and precipitation decreasing by 2-51%.

In 2010, "Green Infrastructure, how and where it can help the North West of England mitigate and adapt to climate change" was published as part of the North West Development Agency work on regional climate change resilience[26]. The role that green infrastructure can play in

[25] http://ukclimateprojections.metoffice.gov.uk/
[26] http://www.greeninfrastructurenw.co.uk/climatechange/search_start.php (evidence document written by Dr Susannah Gill with mapping by Tom Butlin)

helping to reduce the risks identified, support the benefits that could be achieved and enable the opportunities was identified in the document. The text in green in Figure 16 indicates the elements of risk, benefit and opportunity that green infrastructure can support.

Risks	Benefits
• Increased heat stress and mortality in urban areas for vulnerable populations, and people in poorly designed, insulated and ventilated buildings • Increased uptake of air conditioning, which uses energy and creates waste heat • Negative health impacts from an increase in ozone pollution episodes in summer (due to hotter, sunnier days with lower wind speeds) • Increased incidence of food poisoning and potential increase in transmissible diseases • Increased water deficit, which will cause stress to vegetation, potentially reducing evapo-transpiration and further increasing temperatures • Greater fire risk in upland areas due to drought and high temperatures • Ecological impacts from shifting patterns of agriculture • Expansion northwards and upwards in the ranges of species (may be limited by habitat fragmentation and urban development, and species' dispersal ability) • Loss of mudflats and salt marshes due to sea level rise and coastal squeeze between sea defences, disrupting internationally significant bird-feeding grounds • Additional stress for remnant semi-natural habitats and loss of niche habitats in uplands • Wetter conditions may result in increased accumulation of carbon in peatlands, however the ability of peat to act as a carbon store may be compromised as a warmer climate may result in increased decomposition • Increased pollution runoff in rural lowlands from saturated winter soils • Water quality decreases as a result of low water levels in summer (increasing pollutant concentrations) and a warmer climate increasing algal blooms • Increased saline intrusion into coastal aquifers as a result of sea level rise • Reduced water availability during prolonged droughts; manufacturing may be particularly affected • Increased flood risk from streams, rivers and sewers • Increased coastal flooding risk from increased wave heights (as a result on increased wind speeds) combined with sea level rise • Greater soil erosion as the intensity of rainfall increases • Pressures on vulnerable landscapes from increased visitors and soil erosion • Inundation of coastal aquifers as sea level rise and hydrology changes • Structural damage to buildings and other infrastructure from storms • Impacts on the historic environment (ancient burial sites, buildings, gardens and parks) from altered rainfall, sunshine and humidity • Changes in timing of seasonal events, such as flowering, bud burst and migration has seen the general trend of earlier spring and summer events. The major impacts of this shift are life cycles of species that have evolved together no longer occurring together.	• Wetter conditions may result in increased accumulation of carbon in peatlands, however the ability of peat to act as a carbon store may be compromised as a warmer climate may result in increased decomposition • Lower heating bills and reduced winter mortality rates • Fewer winter air pollution incidents (typically associated with high concentrations of NO_2, CO and VOCs), due to warmer and windier conditions • Migration of species into the region
	Opportunities
	• New and expanding markets for some sectors, for example, for recreation and tourism • Increase in outdoor-oriented lifestyles as a result of hotter, drier summers; bringing positive commercial, social and health impacts • Increased coastal recreation will provide opportunities for coastal zone regeneration • Agricultural options will broaden out as new crops and varieties become viable

Figure 16 Risks, benefits and opportunities related to climate change in NW England

The study also identified the complimentary nature of green infrastructure interventions for a range of climate change mitigation and adaptation benefits. This highlights the fact that NBS can have multiple benefits. Good planning, design, delivery and management can make use of these multiple benefits, to improve the impact of NBS.

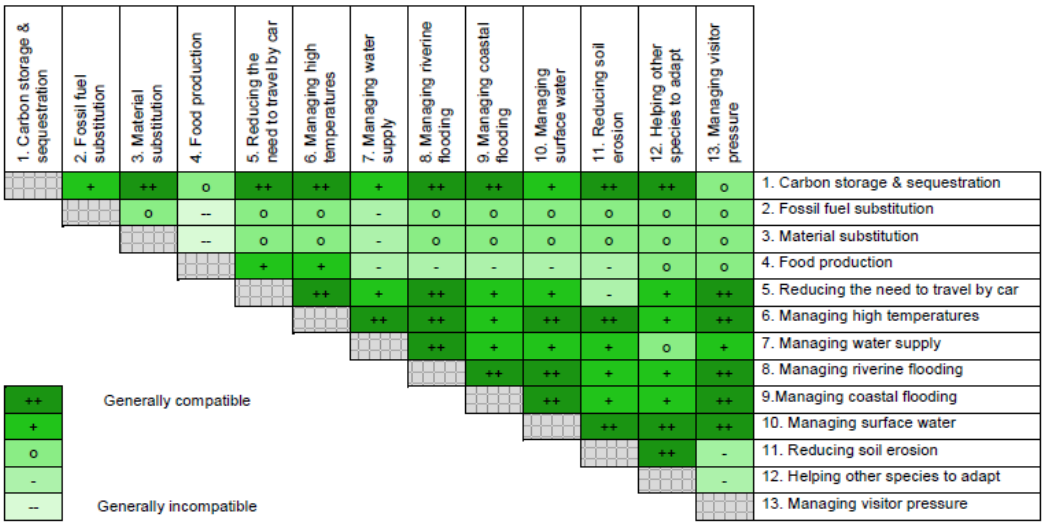


Figure 17 Compatibility of climate change related green infrastructure interventions

The study also looked at sub-regional risks arising from climate change and produced maps showing how the mitigation and adaptation services provided by green infrastructure could be mapped across the city region. To summarise this data, the cumulative number of services that were deemed to help reduce climate change risk were mapped. In addition, five priority services, dealing with reducing urban heat island, reducing flood risk and enabling species movement were also identified and mapped.

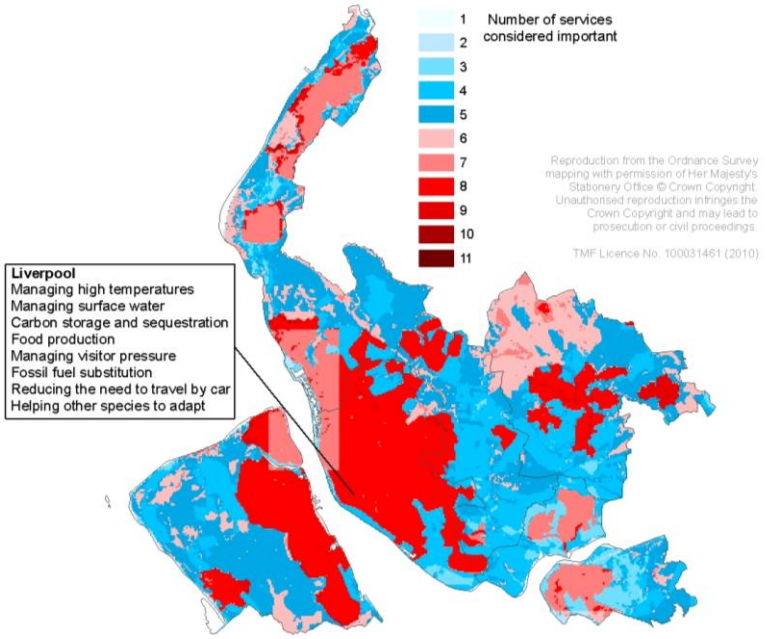


Figure 18 Green infrastructure services that could tackle climate change issues in the Liverpool City Region

The greater the number of services that are deemed to be needed in an area, the greater the opportunity to consider green infrastructure solutions to climate change risks to increase resilience. In the city region context (Figure 18), Liverpool has been identified as having the greatest level of need for the services delivered by green infrastructure to manage climate change risks.

The study also looked at this data on a ward basis. The data for Liverpool is provided below (Figure 19). This shows that the areas around the periphery of the City, and particular the north and south boundary wards are the areas with the greatest need for the services delivered by green infrastructure to manage climate change risks.

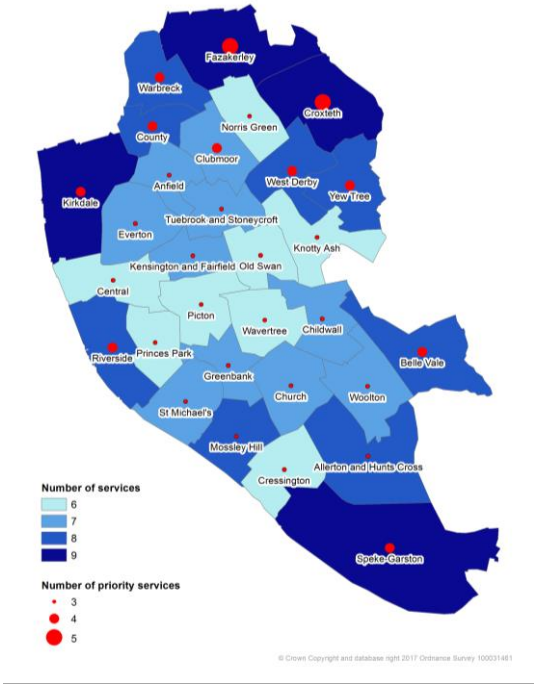


Figure 19 Green infrastructure services that could tackle climate change issues in Liverpool City – information provided by ward

Recognising that cities are subject to a wide range of natural and man-made pressures that have the potential to cause significant disruption, Arup developed the City Resilience Framework and Index with support from the Rockefeller Foundation. These tools provide cities with a comprehensive, accessible, technically robust and globally applicable basis for assessing and measuring resilience at a city scale.

A resilience profile is generated by assessing the Liverpool's current state against 12 goals and 52 indicators. This provides a holistic overview of a city's resilience across four key dimensions:

- People: the health and well-being of everyone living and working in the city.
- Organisation: the systems within the society and economy that enable urban populations to live peacefully and act collectively.
- Place: the quality of physical infrastructure and ecosystems that protect, provide and connect us.

- Knowledge: appropriate leadership and strategy, enabling the city to learn from the past and take timely action.

In 2015, Liverpool was one of five pilot cities selected from across the globe to test the index. The primary activity associated with completing a CRI assessment was the completion of two Questionnaires, each made up of 156 Qualitative and Quantitative 'Prompt' Questions and a range of stakeholders were engaged with the CRI process. A workshop was held in September 2015 was attended by 20 senior stakeholders representing transport, health, utility, education and housing providers, charity, business, police, media. Stakeholders were highly engaged throughout the workshop process and provided a range of valuable feedback and reflections on assessment scores and city resilience performance. From a climate resilience perspective, shocks and stresses identified for Liverpool during the Pilot included extreme weather events – high wind, rainfall, and flash flooding and climate change.

Qualitative results for Liverpool reflect strong overall performance with 'good' outcomes rated across 'health & wellbeing' and 'infrastructure & environment', while more varied performance was identified across 'economy & society' and 'leadership & strategy'. Overall, data availability from the Liverpool Pilot was deemed relatively low compared to the other pilot cities as qualitative data had not been gathered on full city-scale in Liverpool before.

Participation in this pilot enabled Liverpool to establish a baseline understanding of urban resilience, identify strengths and weaknesses, bring together key stakeholders to build a common understanding and encourage cross-sector collaboration regarding priority interventions. All pilot stakeholders and participants expressed interest in viewing the results of the pilot, as a way to identify and improve resilience-building activities for the city. The City Resilience Index is available as an interactive online assessment tool at www.cityresilienceindex.org.

Figure 11: Liverpool Qualitative Resilience Profile

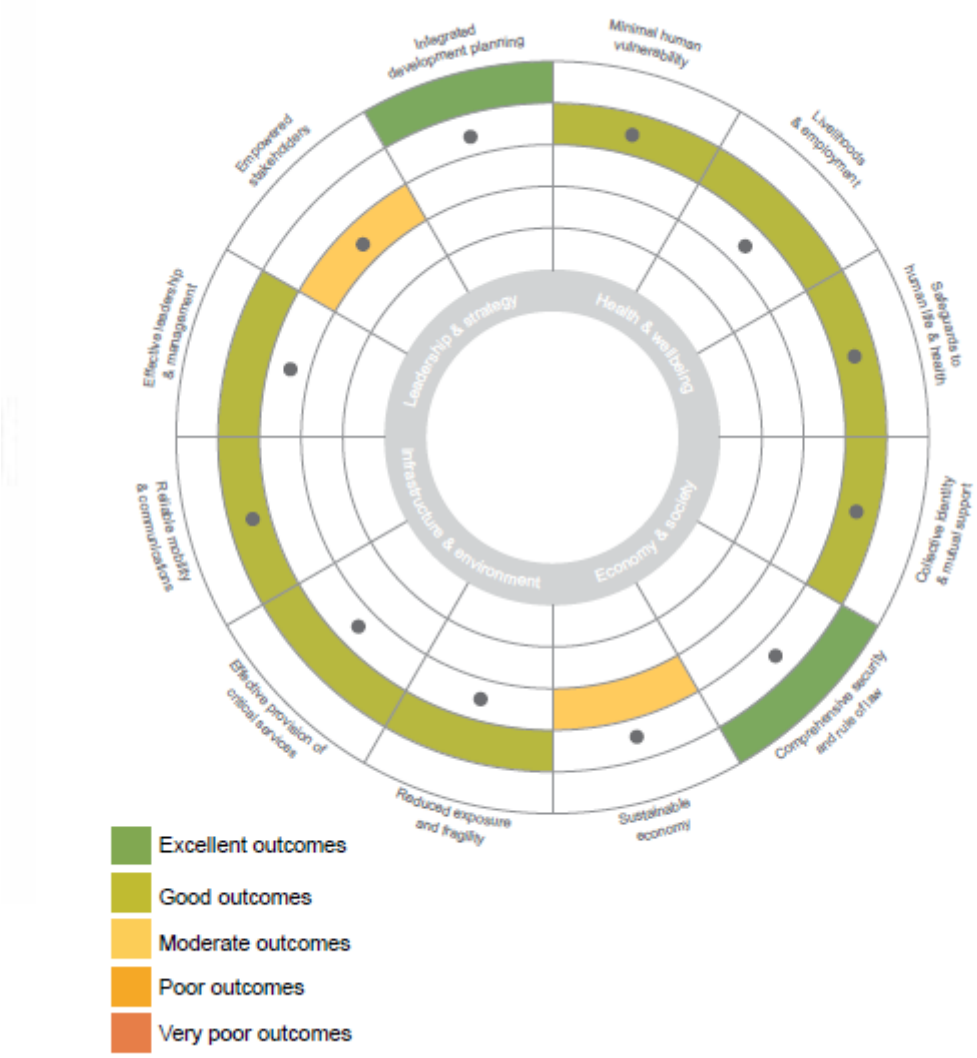


Figure 20 Climate Resilience Indicator for Liverpool

Key issues to consider

Use of NBS to:

- Highlight the range of benefits to climate change resilience that NBS can provide
- Improve climate change resilience
- Improve data availability for the city
- Develop leadership on climate change resilience

3.8.2 Water management

Challenge 2 Eklipse Framework measures

Challenge 2 Water Management	Reduced flood risk, improved water quality

Reducing flood risk

Liverpool is at risk from flooding from multiple sources, including from rivers, namely the Mersey, but also from 10 streams which are mostly culverted. These streams introduce surface water risk when culverts are blocked, exceeded by flood-flows or where overland flow struggles to reach its original channel (Figure 23 Flood risk from rivers and the sea,

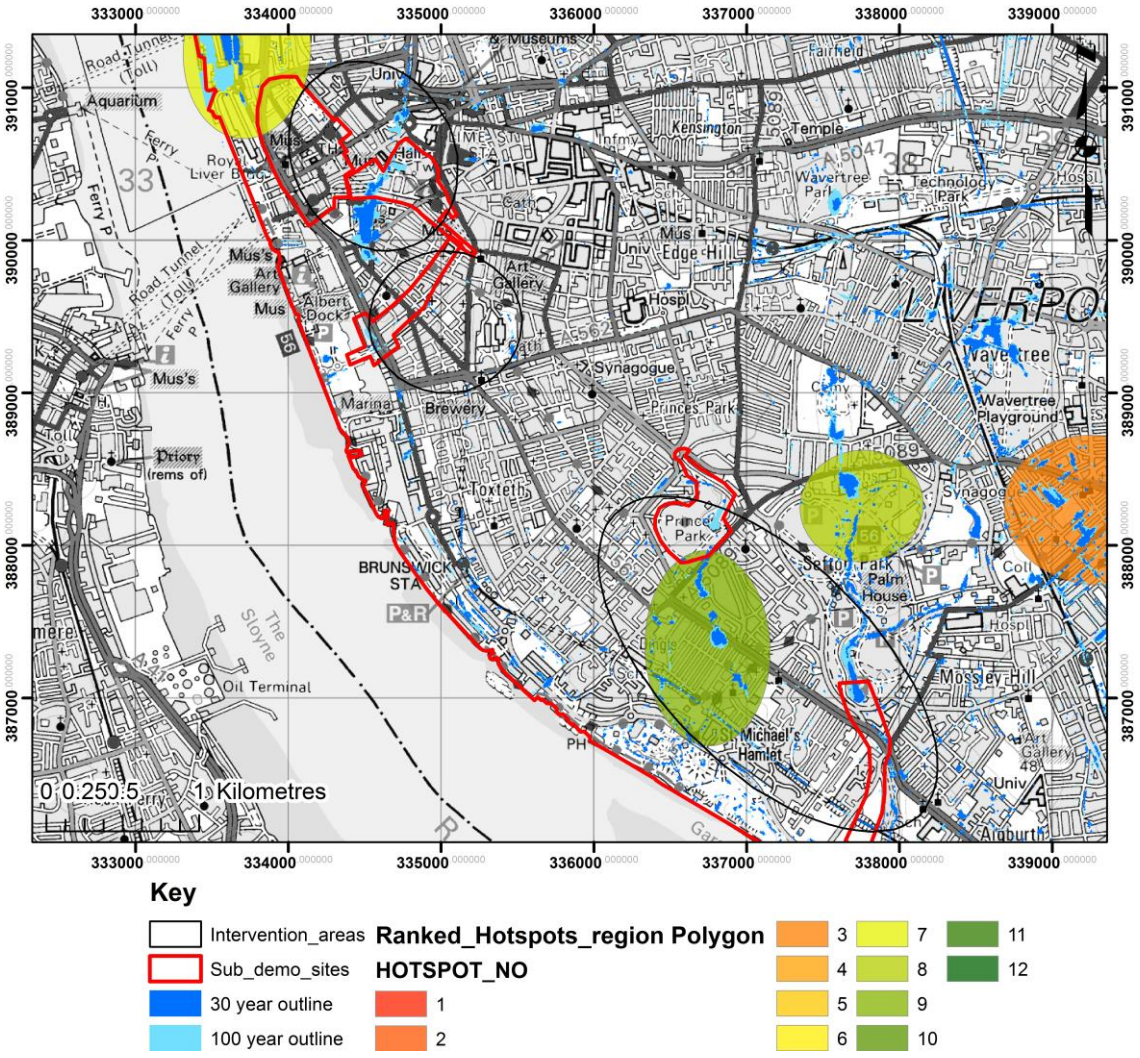


Figure 24 Surface water flood risk (Liverpool City Council and United Utilities data), Figure 25 Fluvial flood risk showing the cumulative number of properties at risk downstream). Most of the world's industrial cities expanded during a time when the earth's climate was relatively stable, and hence, many now inherit a physical infrastructure which in form and layout is unsuited to deal with climate change: introducing people and property into flood risk.

In many instances, flood vulnerability in Liverpool is archetypical of the problems associated with the unintended consequences of mass construction. Historically, the former Pool of Liverpool, the pre-existing dockland, is now Liverpool One, which is now at surface water flood risk, since the dockland was formerly the hinterland of a catchment. Liverpool One sits near the site of the former Fosse Lake and many other Lakes including Moss Lake seem to have now disappeared. 14,430 properties are at surface water flood risk from the 1% event in Liverpool[27]. Of the 33.3km streams in Liverpool, 29.7km are culverted beneath the ground, and many of these culverts are over 150 years old[28]. They containerise the former streams of Liverpool which once flowed in the daylight of open channels. In some areas these culverts are in a poor state of repair, and the re-plumbing of Liverpool has reduced the effectiveness of the original drainage system.

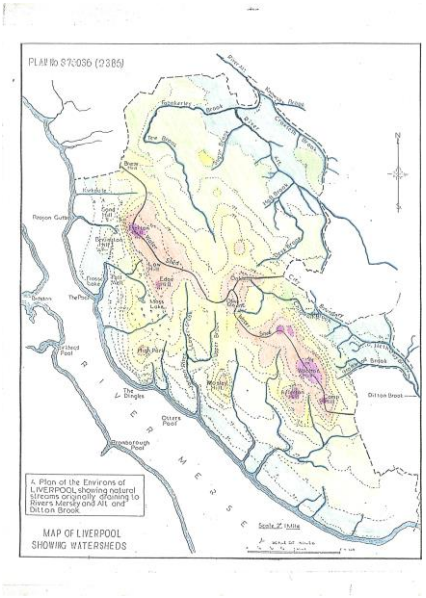


Figure 21 Historic catchments and watercourses of Liverpool (Liverpool City Council)

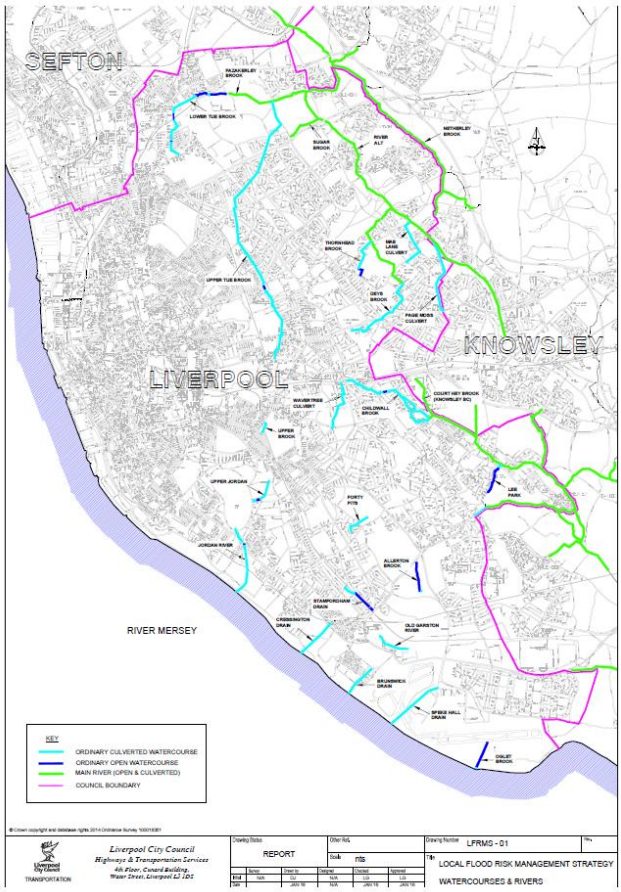
Groundwater possesses a significant flood risk too, most development occurred during times of active abstraction, since the widespread cessation of groundwater pumping, water table rebound has introduced groundwater flood risk. Currently, the Mersey Tunnel and underground railways benefit from costly de-watering, ameliorating groundwater flood risk. Tidally, historic legacy dredging has lowered the channel of the Mersey extending mean high tide water's inland and upstream; 510 properties are at risk from a 1% tidal event such as a storm surge[29].

[27] Liverpool City Council (2018) Draft: Local Flood Risk Management Strategy. Unpublished Planning Policy Paper. 1 – 87.

[28] Liverpool City Council (2018) Draft: Local Flood Risk Management Strategy. Unpublished Planning Policy Paper. 1 – 87.

[29] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/293769/Mersey_Estuary_Catchment_Flood_Management_Plan.pdf

Riparian development contiguous with the Mersey and its tributary brooks, including the Tue Brook, Fazakerley Brook, Sugar Brook and Croxteth Brook has led to 4% (4.57km²) of Liverpool being at fluvial flood risk from the city's watercourses from the 1% and 0.1% events5, 6. Many streams are lost or hidden in undersized pipes, because of culverting during periods of construction boom. Former greenery was literally paved over. Many culverts now form critical infrastructure in terms of managing flood risk and the City Council as Lead Local Flood Authority will develop strategies to address these and other flood risk management matters. In some instances, building in former streambeds, which now exist in underground pipes, has led to some pathways for overland runoff in former depressed channels now covered in hardstanding. Former marshes and ponds, dubbed ghost ponds, may now exist as depressions in the hardened landscape, which collect water at the site where buildings now stand. One of the most recent flood events was July 2010, when 257 properties flooded internally, with an estimated annual probability of 1:20 to 1:50 years[30]. United Utilities have installed 100 property level protection devices on properties, to protect against flood events including sewer flooding[31].



[30]https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/293769/Mersey_Estuary_Catchment_Flood_Management_Plan.pdf

[31] Liverpool City Council (2018) Draft: Local Flood Risk Management Strategy. Unpublished Planning Policy Paper. 1 – 87.

Figure 22 Ordinary Watercourses and Main-Rivers in Liverpool (Liverpool City Council and Environment Agency data)

Holding water in the landscape and planting trees in pits is a vital delivery mechanism available to engineers to help reduce flood risk, which can be dynamically linked to engineering measures to maximise flood risk reduction benefits. The canopies of trees in a hard landscape can intercept the rainfall where it falls; reducing the time it would have otherwise taken for rain to become runoff. Water held in the landscape, and on and in trees, can also lead to cooling locally through latent heat vaporisation. This not only breaks the urban monotony of a previously grey city but can address heat stress, fine pollution particulates and hydro-meteorological feedbacks; such as heat island induced convective storms, which are implicit in monsoon-like events. Green infrastructure interventions have the greatest potential to alleviate surface water flood risk in Liverpool, tidal and main-river sources of flood remain a key natural peril.

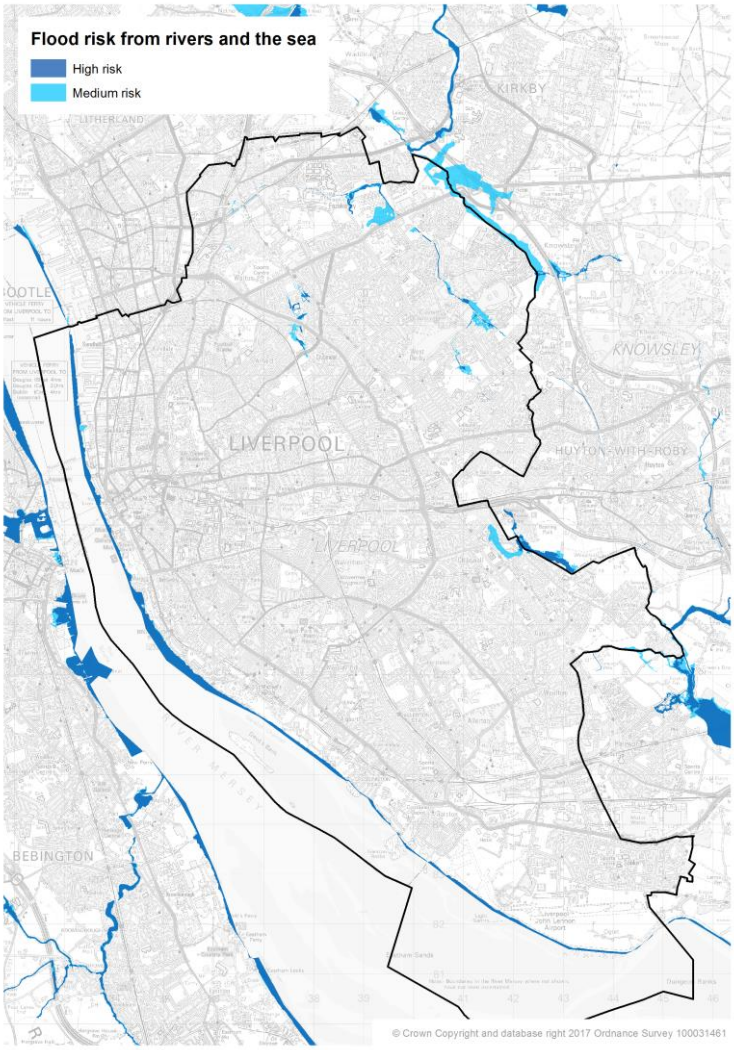


Figure 23 Flood risk from rivers and the sea

These areas of fluvial flood risk are concentrated alongside the main waterways in the north-east of the City, including the River Alt, Tue Brook, Fazakerley Brook, Sugar Brook and Croxteth Brook (Figure 13). Liverpool also has a history of culverting its river as its developed (Figures 15 and 16). These culverts now form critical infrastructure in terms of managing flood risk and the city council as Lead Local Flood Authority will develop strategies to address these and other flood risk management matters. Natural Flood Management using green infrastructure, SUDS or NBS is seen as a delivery mechanism available to engineers to help reduce flood risk.

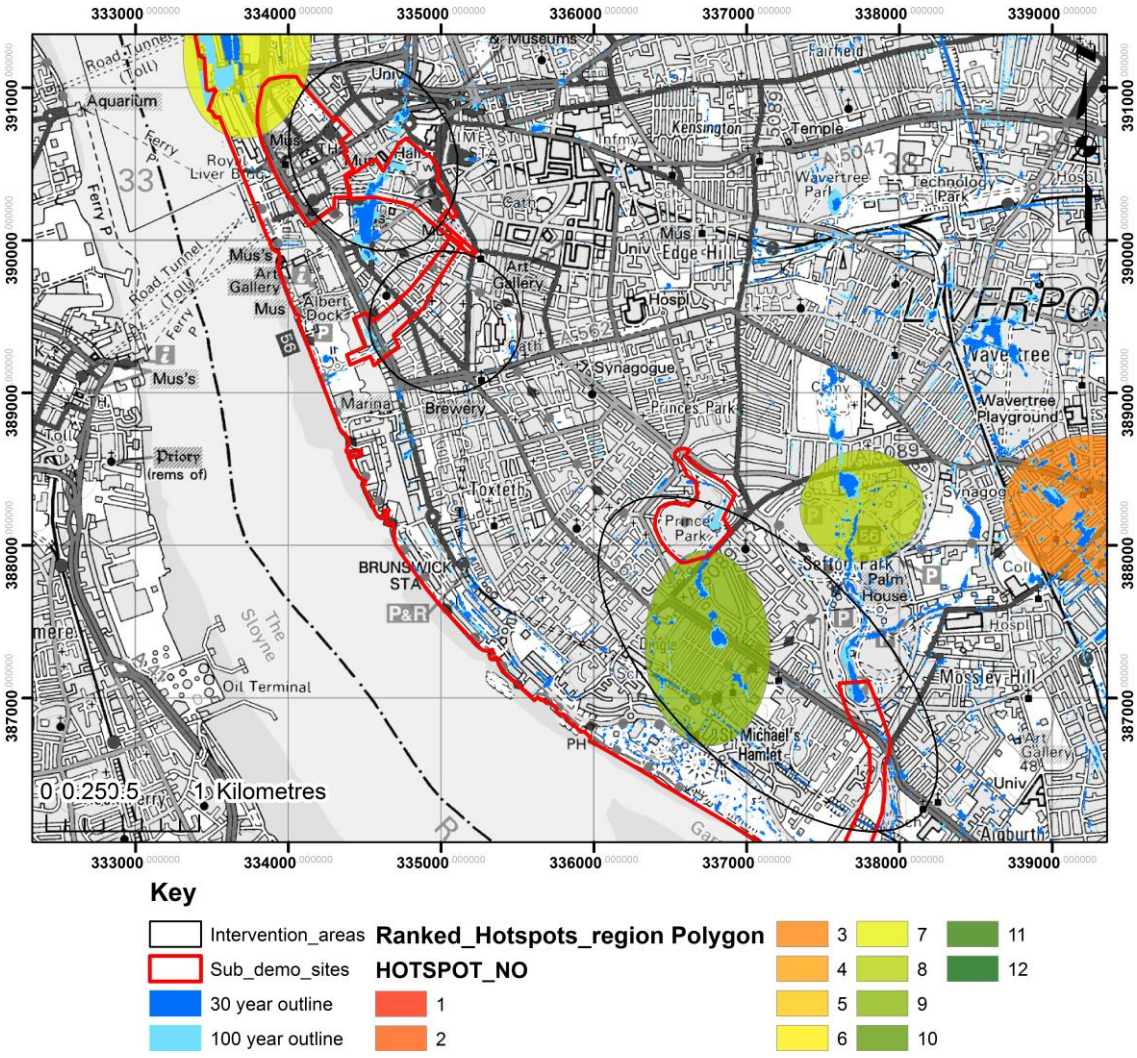


Figure 24 Surface water flood risk (Liverpool City Council and United Utilities data)

Looking at the wider catchment it is possible to identify areas where green infrastructure interventions upstream of communities at risk can reduce flood risk (

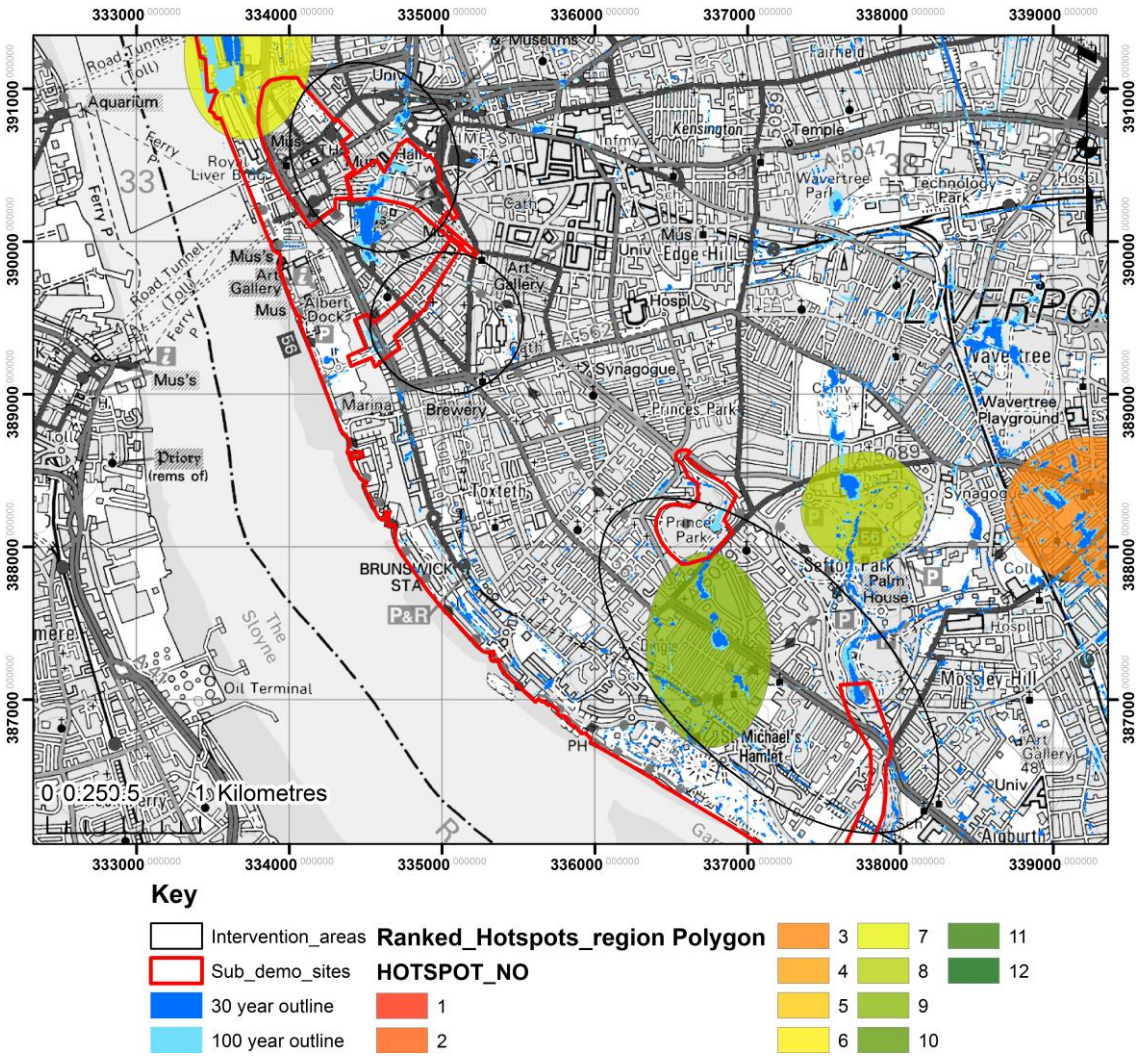


Figure 24 Surface water flood risk (Liverpool City Council and United Utilities data). We can then identify the potential cost savings from the interventions based on the reduced costs of repair and refurbishment of homes that would have been flooded.

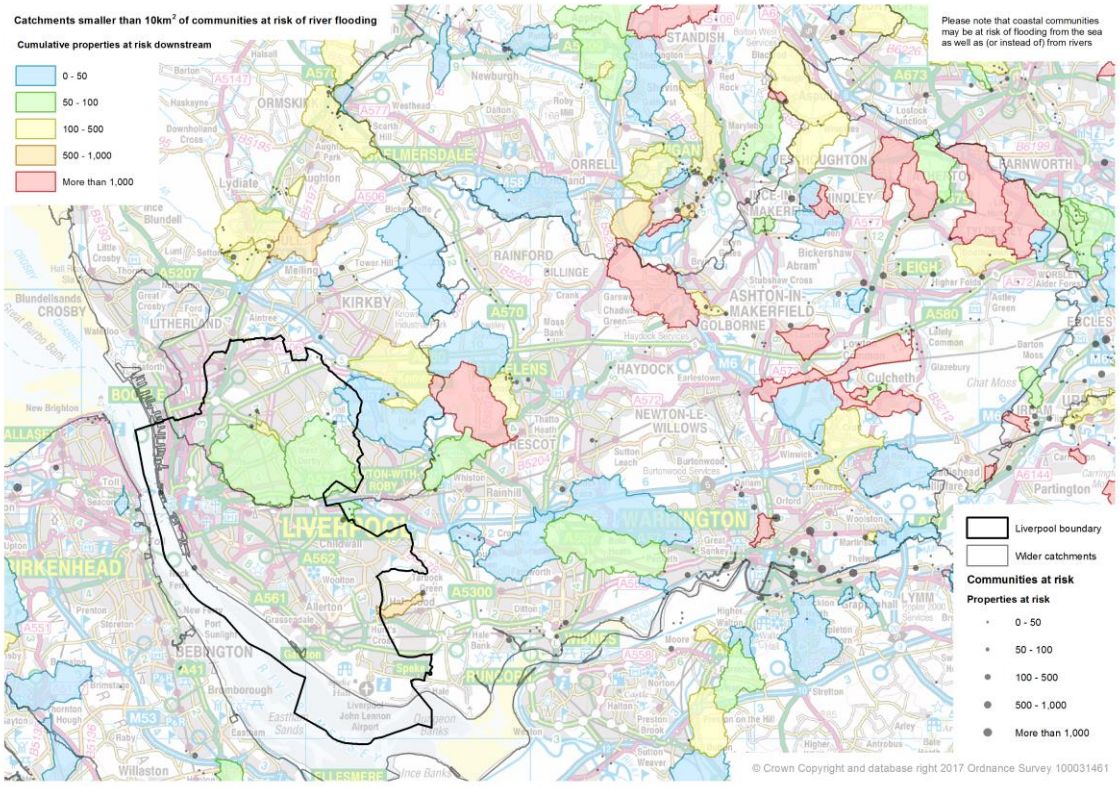


Figure 25 Fluvial flood risk showing the cumulative number of properties at risk downstream

Improving water quality

Urbanisation has a disproportionate negative impact on water quantity and quality[32], both in the enhanced loss of water from the landscape through impervious cover extension, but also through disconnecting rainfall from soil processes such as mineralisation and denitrification. Hardstanding leads to most of the rainfall becoming runoff[33]. Precipitation onto polluted dry deposition (e.g. exhausts and industry) leads to the initial first flush of water off the land being loaded with suspended and dissolved pollutants[34]. A dense cover of drains linked to a pipe network rapidly conveys this enriched, turbid water into streams and rivers – that barely representing a functioning ecosystem[35]. Many watercourses have little resemblance to their original condition prior to the industrial revolution, with canalisation and disconnected from their floodplain, and even daylight, when in pipes[36] - as is the case for most streams are in

[32] Putro, B, Kjeldsen, TR., Hutchins, MG, Miller, J. D., 2016. An empirical investigation of climate and land-use effects on water quantity and quality in two urbanising catchments in the southern United Kingdom. Science of the Total Environment, 548-549, 164-172.
[33] Petts, G., Heathcote, J., Martin, D., (2002) Urban Rivers: Our Inheritance and Future. Dorchester, England: IWA Publishers [on behalf of the Environment Agency].
[34] Mansell.M.G. 2003. Rural and urban hydrology. London: Thomas Telford.
[35] Brown, AG, Tooth, S, Chiverrall, RC, Rose, J, Thomas, DSG, Wainwright, J, Bullard, JE, Thorndycraft, VR, Aalto, R, Downs, P.2013. ESEX Commentary - The Anthropocene: is there a geomorphological case? *Earth Surface Processes and Landforms*, **38**: pp. 431 – 434
[36] Brown, AG, Tooth, S, Chiverrall, RC, Rose, J, Thomas, DSG, Wainwright, J, Bullard, JE, Thorndycraft, VR, Aalto, R, Downs, P.2013. ESEX Commentary - The Anthropocene: is there a geomorphological case?

Liverpool[3738]. This physical disconnection removes vital ecosystem connectivity and mixing between environmental media, for instance soil and water, and water and open air. Processes like photosynthesis and primary production that would have otherwise cycled and reduced nutrient concentrations, and filtered fine sediment through river gravels[39], have largely been removed, and therefore most pollutants will be washed out into the Mersey Estuary, this includes plastics that often end-up in the digestive systems of marine life.[40]

22% of the North Wests waterbodies are at good ecological status[41]. Pollution from towns, cities and transport affects 13% of all waterbodies[42]. Rainwater draining from hardstanding carries pollutants including grit, bacteria, oils and detergents[43]. Mature landscapes like Liverpool's have a contaminated land past too - which can have a legacy effect in the water cycle – introducing pollution ghosts of the land use past in modern day water pollution[44]. Ocherous/ferruginous discharges from mine adits are a widely-recognised example[45]. Historically the water-table was drawn-down by de-watering, and with the pit closures and the cessation of groundwater pumping the water-table has rebounded, introducing oxidised mine water to the surface water environment at discharge points that discolour the water and produce lurid orange acidic flows that can extend for kilometres in length[46].

GI interventions can positively influence the physical properties and impacts of water in the urban environment. Slowing the flow and changing rates in water nutrient cycling are fundamental measures to alleviate flood risk and remediate water quality – both can be addressed simultaneously.

Earth Surface Processes and Landforms, **38**: pp. 431 – 434

[37] Bracken, LJ, Wainwright, J, Ali, GA, Tetzlaff, D, Smith, MW, Reaney, SM, Roy, AG.2013. Concepts of hydrological connectivity: Research approaches, pathways and future agendas. Earth-Science Reviews.119: 17 – 34.

[38] Bracken, LJ, Croke, J .2007. The concept of hydrological connectivity and its contribution to understanding runoff-dominated geomorphic systems. *Hydrological Processes*, **21**: 1749 – 1763.

[39] NORBURY, MICHAEL,THOMAS (2015) The hydrochemistry of the hyporheic zone: Assessing ecotone properties for juvenile freshwater pearl mussel (Margaritifera margaritifera L.) survival in the River Esk, NE England, Durham theses, Durham University. Available at Durham E-Theses Online: http://etheses.dur.ac.uk/11276/

[40] https://www.ceh.ac.uk/news-and-media/blogs/microplastics-UK-freshwater-environments

[41] https://www.gov.uk/government/publications/north-west-river-basin-district-river-basin-management-plan

[42] https://www.gov.uk/government/publications/north-west-river-basin-district-river-basin-management-plan

[43] https://www.gov.uk/government/publications/north-west-river-basin-district-river-basin-management-plan

[44] Harding, J.S., Benfield, E.F., Bolstad, P.V., Helfman, G.S., Jones, E.B.D., (1998) Stream biodiversity: the ghost of land use past. Proceeding of the National Academy of Science (USA) 95, pp. 14843–47

[45] Kelly, M. 1988. Mining and the freshwater environment. London: Elsevier

[46] Kelly, M. 1988. Mining and the freshwater environment. London: Elsevier

In the urban fabric, planting of open areas could increase infiltration of rain into the soil by 67 times, and reduce surface runoff volume by 78%[47]. Urban catchment forests could be used to combat surface water flooding: interception by leaves and stems can reduce the amount of rainfall reaching the ground by as much 45%[48]. Grass and tree pits can slow the flow further, reducing runoff by 99% and 60% respectively, compared with asphalt[49]. Tree pits are observed to accelerate infiltration whilst grasses are effective at slowing sheet overland flow. These alterations to form, pattern and process of water in an environment have consequence on the energy of water and its capacity to entrain pollutants. Interception slows the rate at which dry deposition of surface pollutants (e.g. from exhausts) are washed-off highways by rainfall, whilst the matrix of aggregates in tree pits can filter out fine sediment that could otherwise smother any remaining gravely (riffle) fish spawning beds.

Riparian planting also benefits water quality and keeps rivers cool; percolation through river gravels and deciduous tree roots through 23 metres of substrate can reduce average interstitial nitrate concentration by 73%, whilst reducing water temperature considerably[50]. Though as stated above, around 85% of Liverpool's water courses are culverted.

Incrementally, trees can therefore reduce the rate and volume of overland flow[51], and when it gets to the river cleanse those waters as interstitial flow travels across tree roots and through the biofilm packing the interstices of river gravels[52].

Climate change will introduce significant changes to the UK climate, with greater extremes in wet weather and dry weather[53,54]. In arid zone climates, agroforestry has been monitored to increase groundwater recharge[55] and this will be important measure in climate change resilience in Liverpool. Further groundwater recharge with 'new' could further dilute the concentration of pollutants of 'old' legacy groundwater[56].

[4747] https://www.ceh.ac.uk/news-and-media/blogs/tree-planting-and-reducing-flooding-will-it-work

48 https://www.forestry.gov.uk/fr/infd-6mvecj

49 Armson, D., et al., The effect of street trees and amenity grass on urban surface water runoff in Manchester,
UK. Urban Forestry & Urban Greening (2013), http://dx.doi.org/10.1016/j.ufug.2013.04.00

[50] NORBURY, MICHAEL,THOMAS (2015) The hydrochemistry of the hyporheic zone: Assessing ecotone properties for juvenile freshwater pearl mussel (Margaritifera margaritifera L.) survival in the River Esk, NE England, Durham theses, Durham University. Available at Durham E-Theses Online: http://etheses.dur.ac.uk/11276/

[5151] https://www.ceh.ac.uk/news-and-media/blogs/tree-planting-and-reducing-flooding-will-it-work

[52] NORBURY, MICHAEL,THOMAS (2015) The hydrochemistry of the hyporheic zone: Assessing ecotone properties for juvenile freshwater pearl mussel (Margaritifera margaritifera L.) survival in the River Esk, NE England, Durham theses, Durham University. Available at Durham E-Theses Online: http://etheses.dur.ac.uk/11276/

[53] https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances

[54] Kendon EJ, Roberts NM, Fowler HJ, Roberts MJ, Chan SC, Senior CA. 2014. Heavier summer downpours with climate change revealed by weather forecast resolution model. *Nature Climate Change*. **4:** 570 – 576.

[55] Ilstedt U. et al. 2016. Intermediate tree cover can maximize groundwater recharge in the seasonally dry tropics. Scientific Reports 6, Article number: 21930.

[56] Burt, T.P., Pinay,G., (2005). Linking hydrology and biogeochemisty in complex landscapes. Progress in physical geography, 29, 297-316.

The groundwater of Liverpool is polluted and contaminated by synthetic chemicals[57]. Yet strategically significant boreholes within the city-region require clean groundwater for potable water supply (Figure 17). New trees and woodland may offer an opportunity to partially remediate groundwater quality. High nitrate concentrations in groundwater and rivers can be an indication of nutrient enrichment from sewage, which has been one of the causes of Liverpool's groundwater quality decline[58]. Research in Denmark found that woodland planting reduced groundwater (75-90cm) nitrate concentration by 94% in 12 years[59]. In Iowa, intelligently designed and engineered buffer strips that intercept drainage outfalls can reduce nitrate concentration by over 80%, between adjacent land and the stream[60].

Forestry commission research demonstrates that forestry can lower ammonia, phosphate and suspended sediment concentrations while intercepting FIO (Faecal Indicator Organisms) and reduce Biological Oxygen Demand (BOD) in water bodies[61].

Urban NBS interventions could therefore be used to address diffuse urban pollution, a key objective of the EU Water Framework Directive (2000/60/EC) pursuit to achieve good ecological status, near natural conditions in the water environment by 2017[62].

In the late 1900, blue baby syndrome was associated with methemoglobinemia from ingesting water with high nitrate concentration – resulting in significant public concern[63,64]. Nitrate, as an aqueous fraction of nitrogen, is odourless and colourless in water, and high concentrations led to the EU Nitrates Directive (91/676/EEC), and associated introduction of Nitrate laws in the UK, including zones and the Nitrate Pollution Prevention Regulations 2015[65].

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[57] Whitehead, E., Hiscock, K.M and Dennis, P.F. (1999). Evidence for Sewage Contamination of the Sherwood Sandstone Aquifer Beneath Liverpool, UK. In: J.B. ELLIS, J.B (ed), Impacts of Urban Growth on Surface Water and Groundwater Quality. Pub No.259, IAHS Press Ltd, Wallingford, UK, 179-185.

58 Whitehead, E., Hiscock, K.M and Dennis, P.F. (1999). Evidence for Sewage Contamination of the Sherwood Sandstone Aquifer Beneath Liverpool, UK. In: J.B. ELLIS, J.B (ed), Impacts of Urban Growth on Surface Water and Groundwater Quality. Pub No.259, IAHS Press Ltd, Wallingford, UK, 179-185.

59 Hansen, K., Gundersen, P., Rosenqvist, L., Vesterdal, L. & van der Salm, C. (2004): Theme 2: Nitrate leaching. In Hansen, K. & Vesterdal, L. (eds.) (2004): Guidelines for planning afforestation on previously managed arable land. Forest & Landscape, Hørsholm, 105 pp.

60 Schultz, R.C., Collettil, J.P., Isenhart, T.M., Simpkins, W.W., Mize, C.W. and Thompson, M.L. (1995). Design and placement of a multi-species riparian buffer strip system. Agroforestry Systems, 29(3): 201-226.

61https://www.forestry.gov.uk/pdf/FR_Nisbet_forestry_and_flooding_2015.pdf/$FILE/FR_Nisbet_forestry_and_flooding_2015.pdf

62 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/291522/scho0711btyr-e-e.pdf

63 Buss, S. R., Rivett, M.O., Morgan, P., Bemment, C.D. 2005. Attenuation of nitrate in the sub-surface environment. Science Report SC030155/SR2. Bristol: Environment Agency.

64 Fan, A.M. and Steinberg, V.E., 1996. Health implications if nitrate and nitrite in drinking water: an update on methemoglobinemia occurrence and reproductive and developmental toxicity. Regulatory Toxicology and Pharmacology 23, 35-43.

65 Burt, T.P., Heathwaite, A.L., Trudgill, S.T. eds. (1993) Nitrate: process, patterns and management. Chichester: Wiley.

Importantly, nitrate concentrations are generally much lower in groundwater beneath broadleaved woodland compared to lowland agriculture[66]. The evidence presented above demonstrates the nitrate concentration reduction potential of trees. In order to protect the quantity and quality of groundwater therefore, trees and urban GI present a vital measure in water resource preservation and protection. Trees are form of earth systems engineering that can serve to incrementally return to more natural water conditions[67].

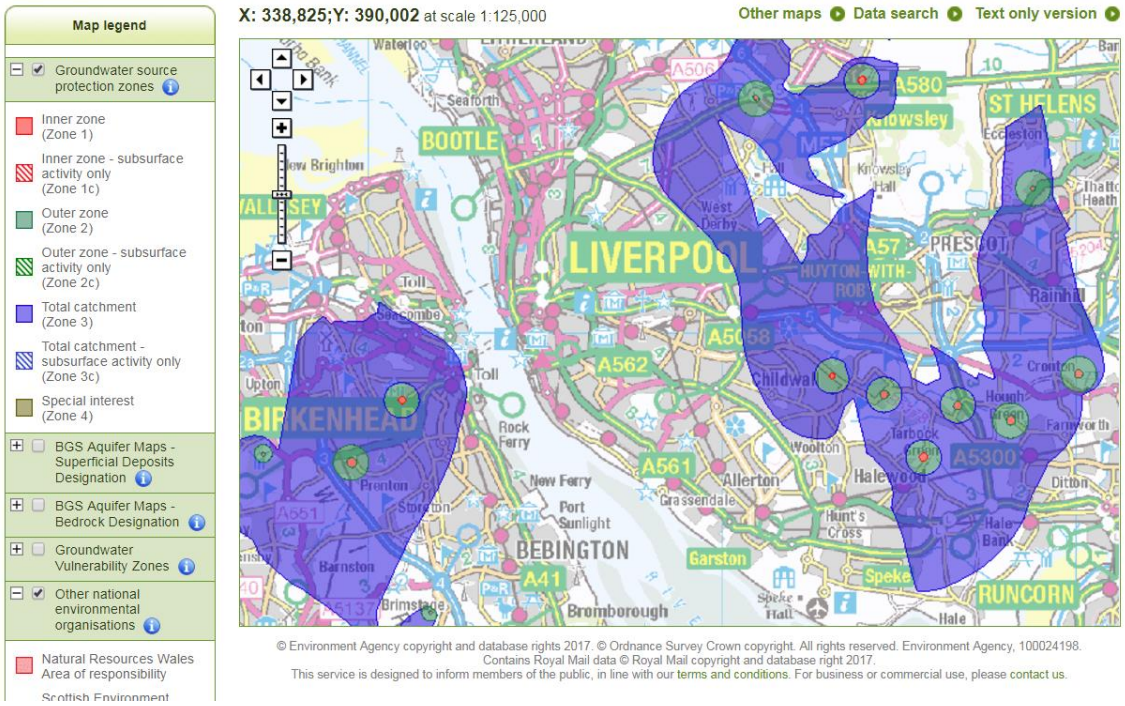


Figure 26 Groundwater Abstraction (Water Withdrawal) Source Protection Zones in Liverpool

Source: Environment Agency

Recent Natural Course research used a 2-dimensional hydraulic model (JFLOW) to model surface water flooding, the model was adapted to include attenuation, tree coverage and other elements[68]. The identified sites were scrutinised by a steering group and excluded from modelling if they were not practical or feasible, the model was then ran[69]. The finding takes forward the Mersey Forest Plan, and demonstrates:

Liverpool should be a focal area for low density urban tree planting. Tree coverage of 10% in Liverpool, the target advocated in the Mersey Forest Plan, is modelled to have a benefit of

66 Lilly, A., Malcolm, A. and Edwards, A.C. (2001). Development of a methodology for the designation of groundwater nitrate vulnerable zones in Scotland. Report prepared for Environmental Protection Unit (Water Unit) Scottish Executive Rural Affairs Department.

67 Allenby. B. 2007. Earth Systems Engineering and Management: A Manifesto. Environmental Science & Technology / December 1, 2007. http://pubs.acs.org/doi/pdf/10.1021/es072657r

68 JBA (2017) Merseyside Strategic NFM Targeting Maps: User Guide. The Rivers Trust, Natural Course (EU LIFE IP) and JBA. Unpublished Technical Paper. Skipton:JBA. 1 – 21.

69 JBA (2017) Merseyside Strategic NFM Targeting Maps: User Guide. The Rivers Trust, Natural Course (EU LIFE IP) and JBA. Unpublished Technical Paper. Skipton:JBA. 1 – 21.

greater than £5M in a 1:100 event in terms of flood damages avoided. This shows the benefit of the existing tree coverage and the value in retaining and enhancing tree coverage through the delivery of street trees and low-density planting initiatives. This flood risk benefit should be judged against concerns about safety and maintenance costs related to existing urban trees. [70]

The use of trees with attenuation to maximise the benefits

Caution should be exercised in evaluating the Natural Course results described above, since the baseline model was out of date, the updated surface water flood model, shows reduced pluvial flood risk compared to the baseline assessment. Compare, for instance, figure 9 (baseline) with 19, which represents the updated flood outlines that were not used in the Natural Course research.

Key issues to consider

Use of NBS to

- Reduce flood risk
- Improve water quality.
- Improve ecological status of water bodies

3.8.3 Green space management

Challenge 3 Eklipse Framework measures

Challenge 3 Green Space Management	Improved perception of green space, alternative delivery models for managing and funding greenspace, improving quality of place and life for older residents

Improved perception of greenspace

There are no known assessments of people's perception of greenspace for Liverpool. Many surveys and studies focus on parks and public open spaces rather than the broader assessment of all greenspaces.

For example, a study on the use and perception of parks in Merseyside and Greater Manchester[71]

- Local parks are enjoyed by a large proportion of community residents. Three quarters of respondents reported using their local park. Just over half (52%) were frequent users, visiting once a week or more in spring/summer months. The percentage of frequent users fell to 41% in autumn/winter months, suggesting that more could be done to encourage park use at this time of year.

[70] JBA (2017) Merseyside Strategic NFM Targeting Maps: User Guide. The Rivers Trust, Natural Course (EU LIFE IP) and JBA. Unpublished Technical Paper. Skipton:JBA. 1 – 21.
[71] www.cph.org.uk/.../use-and-perceptions-of-parks-in-merseyside-and-manchester.pdf

- Use of the park specifically to exercise is high. Sixty percent of park users reported using their local park to exercise, and 53% to let children play. This is an encouraging finding given rising levels of obesity among both adult and child populations in the UK and indicates that parks are being utilised as cheap, accessible areas to engage in exercise.
- Parks are also frequently used to enjoy nature and attend community events (67% and 39% respectively). This suggests that mental health and social benefits are also being derived from park use. Contact with nature is thought to reduce stress and mental fatigue, while community events offer opportunities to meet and socialise with other members of the community.
- Regular exercisers are around twice as likely to be frequent users of the park. It is not possible to determine whether individuals that exercise regularly are more attracted to the park, or whether regular exercise is a result of frequent park use. Regardless, local parks have an important role to play in achieving regular levels of physical activity. Encouragement of frequent park use is therefore likely to be of benefit to exercise levels seen across communities.
- Individuals living in more affluent areas are between one and a half and two times more likely to be frequent users of their local park. With deprived communities likely to derive the most health benefits from free access to green spaces, developing measures to motivate use of local parks in these areas is important. Free opportunities for exercise are particularly valuable in deprived communities where individuals may have less access to resources such as leisure centres or private gyms (e.g. through lack of income or transport). Investments in park quality, safety and infrastructure may show greatest return on investment in these areas.
- Individuals who report feeling safe in the park during daylight hours are between six and seven times more likely to be frequent users of their local park. They are also between six and 13 times more likely to use the park specifically to exercise,

There are examples of smaller scale surveys of perceptions of greenspace.

For example, a survey of 52 (41% of BID registered businesses) businesses in Liverpool city centre in 2015 showed indicated that greenspaces in and around the main commercial and business districts of the city were valued and that there was support for more urban greening[72].

- Over nine in ten businesses consulted (92%) were of the opinion that a green infrastructure would enhance the area.
- Almost seven in ten businesses (69%) stated that the greening of the two Business Improvement Districts would be of benefit to their business.

When asked how the creation of a green infrastructure would be of benefit to their business, the key unprompted reasons given were: nicer environment/nicer place to work in (28%),

72 Liverpool Commercial and Central BID and Mersey Forest Market Research Report, available from The Mersey Forest Team.

increased spend levels (19%), 'holistic' reasons including health and wellbeing, feel good factor, ambience (19%), increased footfall (17%) and brightening up the area (17%).

Alternative delivery models for managing and funding greenspace,

Liverpool's Strategic Green and Open Space Review[73], published in 2016, set out a range of options for the future management and funding of green spaces. Funding of green spaces by the local authority is a non-statutory requirement. As public spending reduces there continues to be pressure to focus spending on the services that the authority has to provide by law.

An example of Liverpool's search for new ways to manage green spaces is the recent tendering Liverpool's only country park. The tender aims to secure new investment, increase activities and visitor numbers and save the council £1m a year in running costs, whilst keeping the park open.

Liverpool is one of many authorities looking at alternative managing and funding models.

For example, at a national level, NESTA have published a number of documents looking at alternative models for greenspace management[74].

In Liverpool City Region, Nature Connected, the Local Nature Partnership, convened work to look at Alternative Delivery Mechanisms for the city region's Parks and Greenspaces[75].

Improving quality of place and life for older residents

Liverpool has a relatively young population. The 2014-based projections by ONS suggests that Liverpool's total population was estimated to increase by 5% by 2027, but the city's over 65+ years population was projected to increase by 17%. Those aged 85-89 years were estimated to increase in number by 13% and those aged 90+ years by 5%. Those aged 75-79 were estimated to increase by 28%, the largest increase in the older person's age categories. Although the demographic trend of an ageing population will be slower in Liverpool than the national average, the older population requiring permanent care and support will likely become increasingly complex[76]

Dementia and poor mental health are likely to be increasing concerns for older people, their families and the agencies that will provide services and care for them. Social care budgets in Liverpool are already under pressure.

Using assets, such as green spaces to maintain or increase levels of physical activity, reduce isolation and stimulate minds can be one element of a city-wide asset based approach to tackling this challenge.

Age	Population	Projected	% change in

[73] http://liverpool.gov.uk/mayor/mayoral-commissions/strategic-green-and-open-spaces-review-board/
[74] http://www.nesta.org.uk/project/rethinking-parks
[75] http://www.natureconnected.org/resource-library/
[76] Liverpool Joint Strategic Needs Assessment, http://liverpool.gov.uk/media/9731/older-person-hna-final.pdf (accessed 17th August 2017)

category	in 2016	population in 2027	population
66-69	22324.573	25345.766	114%
70-74	21882.359	24713.794	113%
75-79	15879.3	20384.027	128%
80-85	13356.884	16706.826	125%
85-90	10421.155	11802.226	113%
90+	9515.182	10031.146	105%

Figure 27 Change in population of older people - 2016-2027

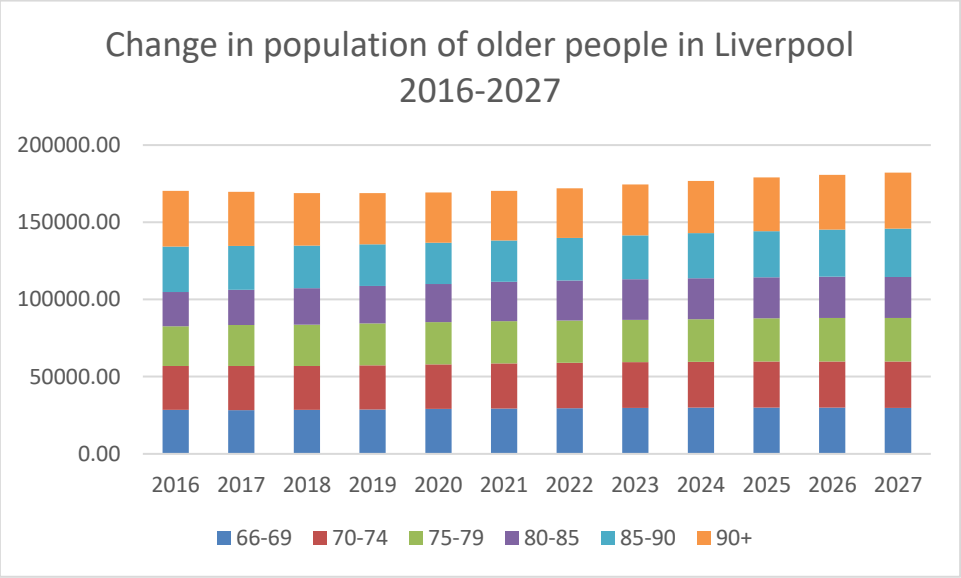


Figure 28 Change in population of older people in Liverpool - 2016-2027

The city faces a complex challenge of adapting to a gradually ageing population, but a city that will still have a relatively young demographic.

Key issues to consider

Use of NBS to

- Help to develop new mechanisms for managing and funding green infrastructure.
- Support the needs of an increased number of older people in our towns and cities
- Increase awareness of the role that natural environment plays in delivering benefits for the individuals and communities.

3.8.4 Air quality

Challenge 4 Eklipse Framework measures

Challenge 4 Air Quality	Reduce air pollution

Reducing air pollution

A recent study (Gibbons *et al,* 2013) estimates that for the UK, in 2010, the costs of poor air quality equated roughly to 5% of GDP. As developed has continued in the UK as a whole, and core cities specifically, we are seeing growing concerns over the quality of air across the nation.

To address this issue the whole of Liverpool was declared an Air Quality Management Area (AQMA) in May 2008. Moreover, between 2005 and 2012 (most recent data available), per capita emissions of carbon dioxide in Liverpool fell from 6.4t to 5.8t per capita. Although the per capita emission figure is lower than the national average, the rate of reducing emissions is slower in Liverpool than across the country. In terms of contribution to total carbon dioxide emissions in the city, industry and commerce account for 41% of emissions, domestic emissions make up 37%, and transport contributes 23%.

Poor air quality is associated most often with the busiest parts of the road transport network, where the key processes of dilution, dispersion and deposition are most inhibited[77]. The risk of air quality standards breach is highest during times of heavy traffic and static air conditions, for instance blocked high pressure and persistent humidity. In 2010, the attributable death due to air pollution (age 25+) was 239 and the associated life-years lost were 2440, making Liverpool rank 6th from the top of the largest cities outside London to live for air quality[78].

Although poor air quality emanates from both domestic and industrial sources the majority of the air pollution, especially in relation to NO_2 and particulate matter in Liverpool is associated with transport sources in particular buses, heavy goods vehicles and taxi fleets. Monitoring reveals that, at times, Liverpool's air exceeds statutory NO_2 emission targets.

Air quality is poorest in the north of the city and around the airport.

There is no airflow model available to the project that can help to inform intervention locations.

[77] http://theconversation.com/do-trees-really-help-clear-the-air-in-our-cities-48202

[78] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/332854/PHE_CRCE_010.pdf

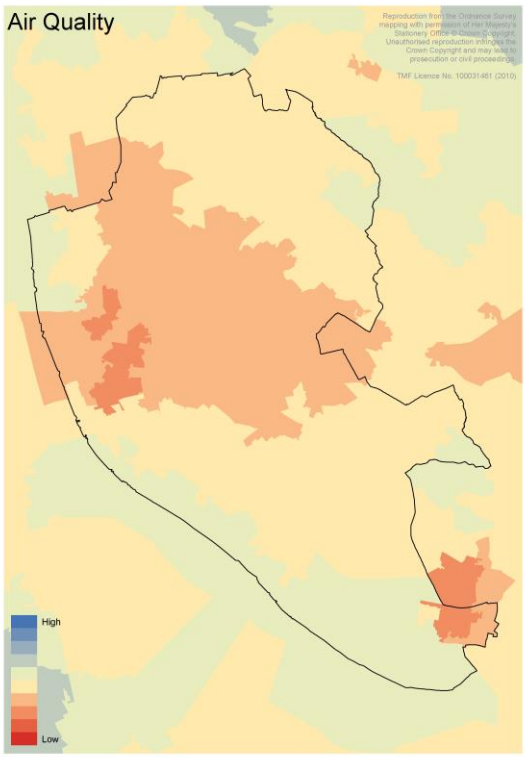


Figure 29 Air quality in Liverpool

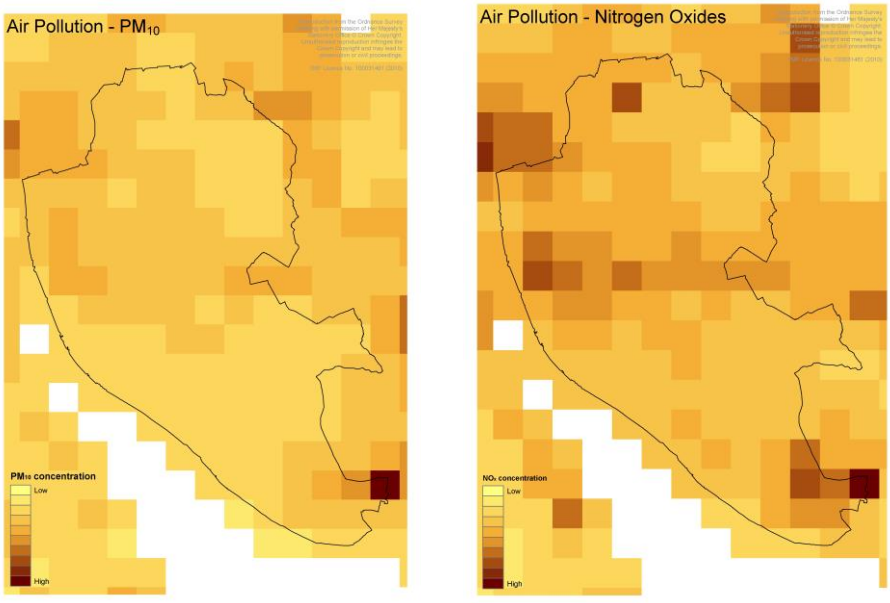


Figure 30 Maps showing levels of PM10 particulate and nitrous oxides in Liverpool

The GI Strategy assessed the where green infrastructure was already playing a role in reducing harmful concentrations of substances such as oxides of nitrogen, and, and also where there were opportunities to add NBS (green infrastructure) to help reduce air pollution[79].

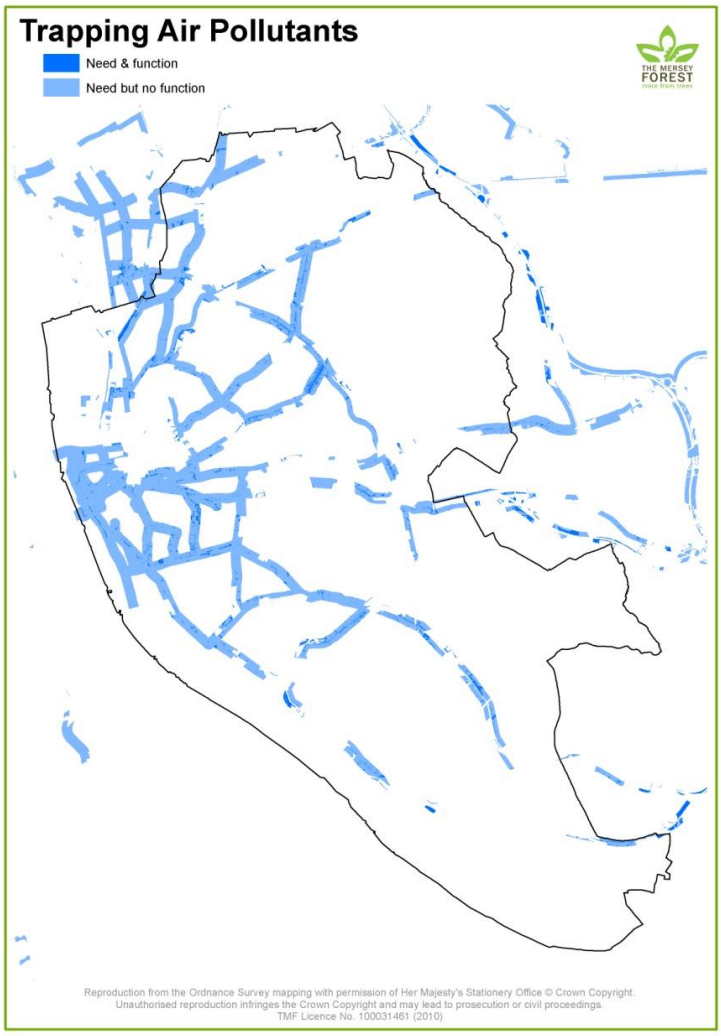


Figure 31 Areas where green infrastructure is or could be reducing air pollution

Key issues to consider

Use of NBS to

- Improve air quality in target areas.
- Maximise the efficacy of GI interventions to disperse, dilute and deposit substances, which at their present concentrations, represents air pollution. Dispersion, dilution and deposition are the main mechanisms to reduce harmful concentrations of particulates, oxides of nitrogen, carbon and sulphur along with other substances.

[79] http://theconversation.com/do-trees-really-help-clear-the-air-in-our-cities-48202

Urban regeneration

Liverpool has seen significant regeneration investment over the past 35 years, with €1bn of EU funding supporting regeneration since 1994.

The city is part of the UK's Core City programme. Along with nine other major cities, Liverpool argues for greater devolution of resources and power to the country's leading cities. Core cities also act regeneration engines for their regional economy.

Regeneration of the city is accelerating. Liverpool is undergoing a £13bn regeneration led renaissance. Large scale regeneration of the Liverpool waterfront, a new creative district and the development of world-leading knowledge sector, supported by Liverpool's Universities, are all underway.

In the next five years Liverpool will deliver of 10,000 new homes, Everton FC's new stadium, a new cruise terminal, a new TV and Film hub, £250m of road infrastructure and 2 million sq. ft. of commercial office space. Liverpool is ideally positioned on Britain's Atlantic-facing coastline it is the gateway to the Northern Powerhouse, a focal point for a city region with a GVA of £30bn per annum.

Regeneration of the city centre and the knowledge and creative districts will continue to attract new residents, businesses and visitors.

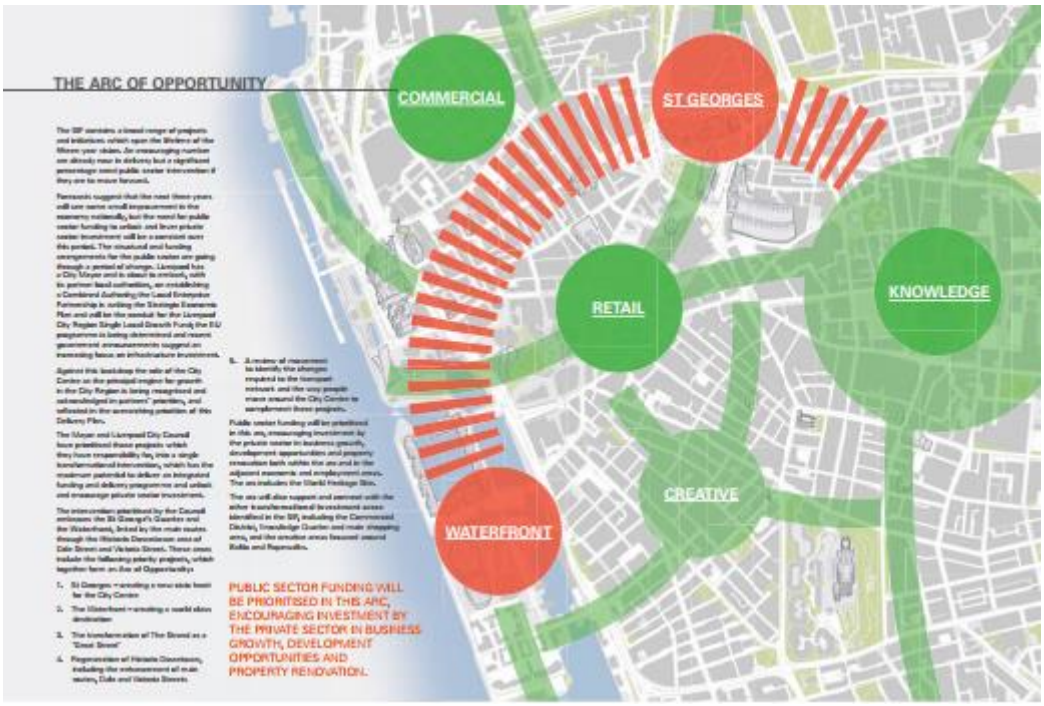


Figure 32 Programme for regeneration in and around Liverpool city centre

Business Improvement Districts have been set up in the commercial and retail areas of the city centre.

A Business Improvement District (BID) is a designated zone in which businesses benefit from a wide range of additional services over and above those funded through the standard commercial rates and council services. Constituted by UK law in 2004, a BID is a powerful, independent voice representing the interests of a varied community of organisations, committed to working together to ensure that the area continues to progress whilst providing the best possible trading and working environment for its occupiers. These extra benefits are aimed at vastly improving the quality of the area for the businesses, visitors and employees within it as well as improving attractiveness to new investors. This can include physical projects such as better lighting and street cleaning as well as the creation of green spaces, crime reduction programmes, events, transport and accessibility improvements, in addition to marketing, networking and inward investment initiatives. Every five years businesses in the designated area vote for the continuation of the BID and if they vote yes, any occupiers within the BID become members for the duration of the next 5-year term. Members within the area pay a levy based on a small percentage of their rates to contribute towards these benefits and improvements.

Liverpool BID Company was formed in 2005 as one of the first in the UK. The Liverpool BID areas cover some of the most iconic locations in Liverpool city centre, from the independent shops of Bold Street, and the thriving restaurant and hotels of Castle Street, to the professional and financial services around Old Hall Street, and retailers on the high street The Bid focusses on four key areas:

- Improving the environment and safety
- Animating and promoting the BID areas
- Improving connectivity
- Providing support to BID businesses

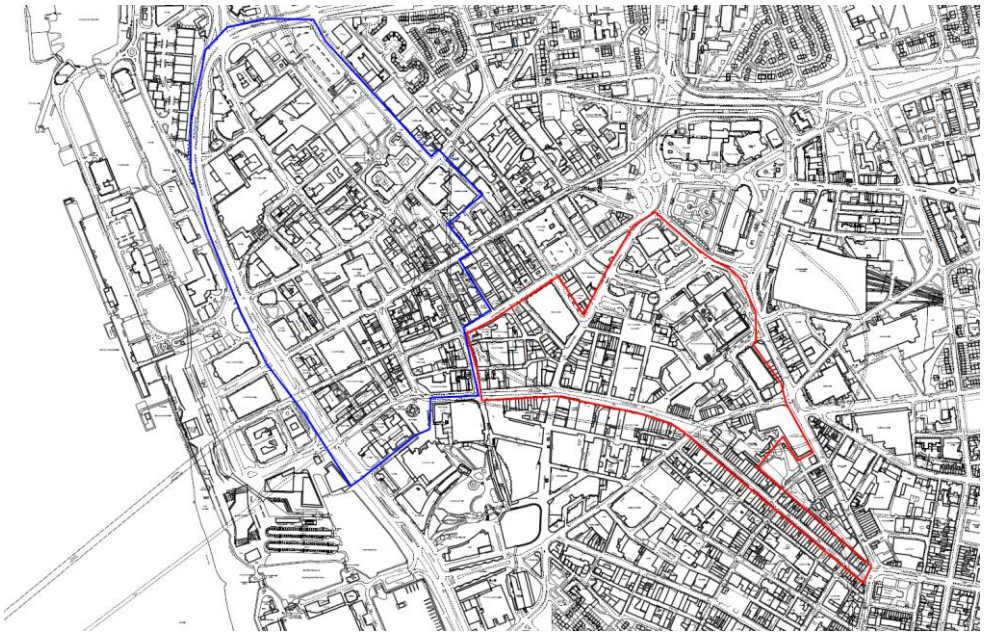


Figure 33 Extent of Liverpool BID areas in central Liverpool

At a wider city level, gateways and main transport routes into Liverpool are important for the image of the city. Attractive, high quality green infrastructure can provide the setting for the city, making a good first impression and improving the attractiveness of the city for investment.

Figure 34 Liverpool strategic gateways and routes

These main routes link to the key strategic investment areas of the city. These are areas where growth and development are anticipated to happen fastest. These are also the areas where air and noise pollution is often highest.

Key issues to consider

Use of NBS to:

- Work closely with businesses to promote understanding of green infrastructure in helping to improve quality of place, tackle issues such as flood risk, air quality and UHI to improve investability and returns from investment.

- Target key gateways, the first impression of the city for many visitors
- Develop GI Val as a toolkit that can support investment in green infrastructure to support regeneration.

3.8.5 Health

Challenge 9 Eklipse Framework measures

Challenge 9 Public Health and Well-being	Increase physical activity, improve wellbeing

Increase physical activity

In Liverpool, the scale of economic deprivation in parts of the city has substantial effects on social factors, including significant health inequalities. Poor living, social, economic and environmental circumstances have impacted adversely on physical health and mental well-being on communities within the city. This has not though been equal with areas of north and south Liverpool showing significant variations from the city average. The severity of Liverpool's health deprivation is reflected in the life expectancies for its population. Life expectancy for males is 76.2 years, and 80.5 years for females. However, whilst there have been improvements, life expectancy is 10.3 years lower for men and 9 years lower for women in the most deprived areas of Liverpool than in the least deprived area of the city.

Liverpool's Physical Activity and Sport Strategy[80] sets the context for programmes and activity to enable 118,000 (30%) more people to sustain a physically active lifestyle in Liverpool through sport and active recreation by 2022.

The Strategy sets out the health benefits of increasing physical activity, including impacts on:

- Diabetes - An active person with diabetes (who walks three hours a week) is 2.5 times less likely to die of heart disease than an inactive resident without diabetes.
- Chronic Obstructive Pulmonary Disorder (COPD) - People with Chronic Obstructive Pulmonary Disorder (COPD) who walk gently 30 minutes a day halve their risk of an emergency hospital admission.
- Coronary Heart Disease (CHD) - 10% of deaths from CHD are due to inactivity. Brisk walking for 180 minutes a week can reduce the risk of heart attack by 22% for men and 33% for women. Physical inactivity is responsible for 146 emergency cardiac admissions in Liverpool and can increase the risk of cardiac mortality by 30%. Hypertension[2] - Physical Activity has a modest reduction of Blood Pressure in patients with hypertension by 3.4/2.4mmHg which is significantly greater than Angiotensin-Converting-Enzyme (ACE) inhibitors[2].

[80] file:///C:/Users/paul/ShareFile/Shared%20Folders/Liverpool%20GI%20Strategy%20data/liverpool-active-city-pas-strategy.pdf (accessed 27th August 2017)

- Depression - The National Institute for Clinical Excellence (NICE) recommends physical activity as an effective treatment for depression particularly when delivered in groups. The City experiences the second highest prevalence of common mental illness in England with over 93,000 people affected. Liverpool also has the highest prevalence of Psychosis amongst the eight core cities in England.
- Cancer - Patients who become active on diagnosis of breast cancer have a 34% reduction in breast cancer deaths and a 24% reduction in breast cancer recurrence. 18% of all deaths from breast cancer are due to inactivity. Liverpool has some of the lowest survival rates amongst the core cities with 78% of female patients surviving breast cancer (compared to the average in England of 84%).
- Dementia - There is strong evidence that patients who are active have a 40% reduced risk in developing dementia.
- Osteoarthritis - Physical activity reduces the risk of developing osteoarthritis and reduces pain with similar efficacy than non-steroidal anti-inflammatory drug

The economic and social benefits are also clearly set out in the Strategy.

There are indications of a growing issue with childhood obesity, as 23.8% of children in Year 6 (8-9-year olds)[81] are classified as obese, worse than the average for England.

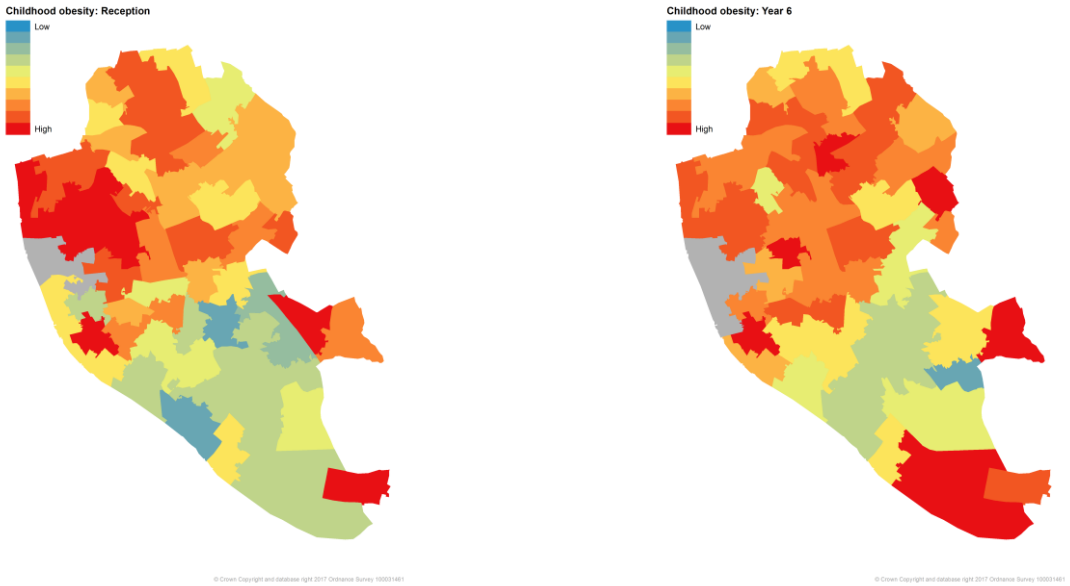


Figure 35 Childhood obesity in Liverpool for children aged 4-5 and 8-9

Childhood obesity is concentrated in the north of the City, where accessible green spaces are fewer. Obesity levels increase from reception through to Year 6. Obesity is closely linked to the most deprived areas of the city.

[81] http://fingertips.phe.org.uk/profile/health-profiles/area-search-results/E08000012?place_name=Liverpool&search_type=parent-area, 2017 data

Obesity in adults follows a similar pattern though the levels are lower than for childhood obesity.

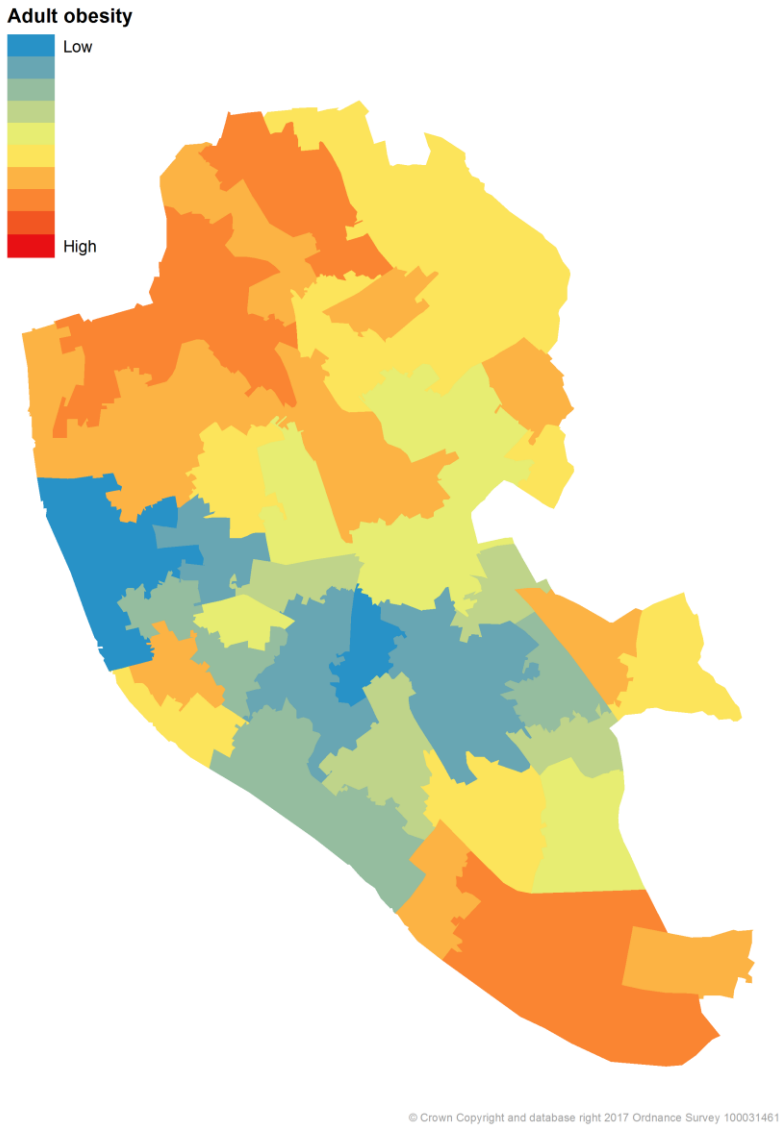


Figure 36 Adult obesity in Liverpool

There is evidence to show that green infrastructure can help to support more active lifestyles and reduce health inequalities. Figure 37 Coronary heart disease in Liverpool, shows the distribution of hospitalised incidence of coronary heart disease across the city. The north and south of the city show the highest prevalence of coronary heart disease.

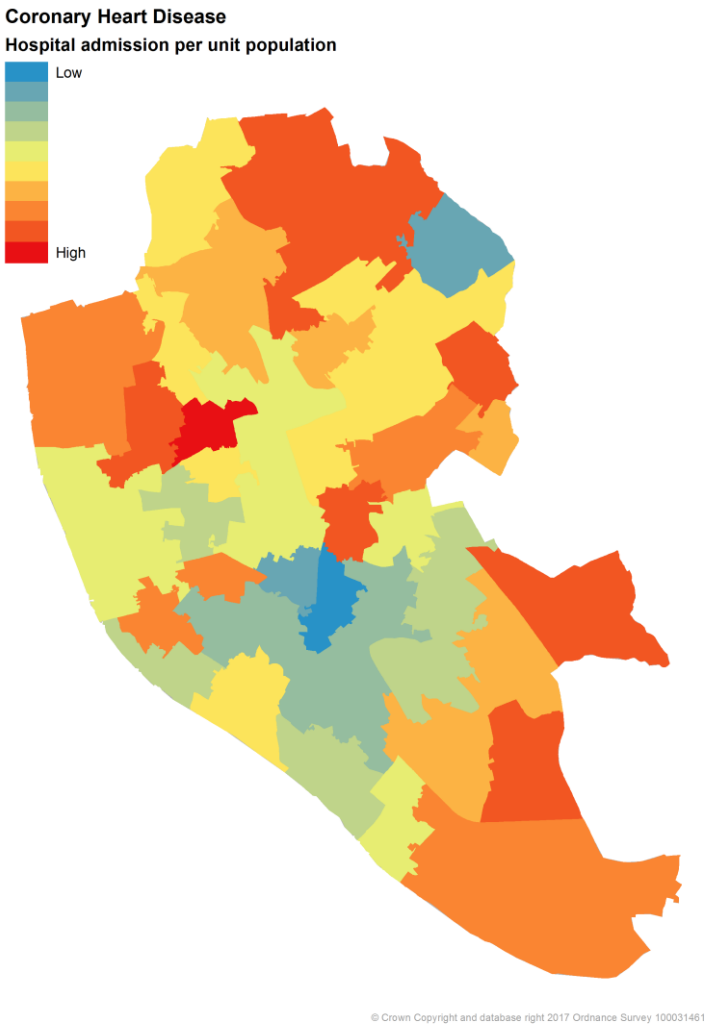


Figure 37 Coronary heart disease in Liverpool

Improve wellbeing

Common mental health problems are estimated to affect a quarter of Liverpool's population at any one time. Estimates produced by the Mental Health Observatory in 2008 suggest Liverpool experiences the second highest prevalence of common mental illness in England, with over 93,000 people affected[82].

A report for the Mental Health Foundation underlines the large overlap between substance misuse and mental health problems, though it points out that mental illness and substance misuse occurring simultaneously affects a smaller proportion of people. The report found that:

[82] JSNA - http://liverpool.gov.uk/media/9738/adultsolderpeoplementalhealth.pdf (accessed 11th August 2017)

- Between a third and half of people with severe mental health problems consume alcohol or other substances to levels that meet criteria for 'problematic use'.
- 51% of alcohol-dependent adults say they have a mental health problem.
- 44% of people using services of Community Mental Health Teams in four urban centres reported problematic drug or alcohol use in the preceding year.

There are clear links between physical activity and mental health.

Many of the datasets for mental health are provided at local authority level. To provide a greater level of detail, an index of risk of poor mental health, based on a range of data and evidence, has been developed by The Mersey Forest Team to identify areas where poor mental health may be of greatest concern within a local authority.

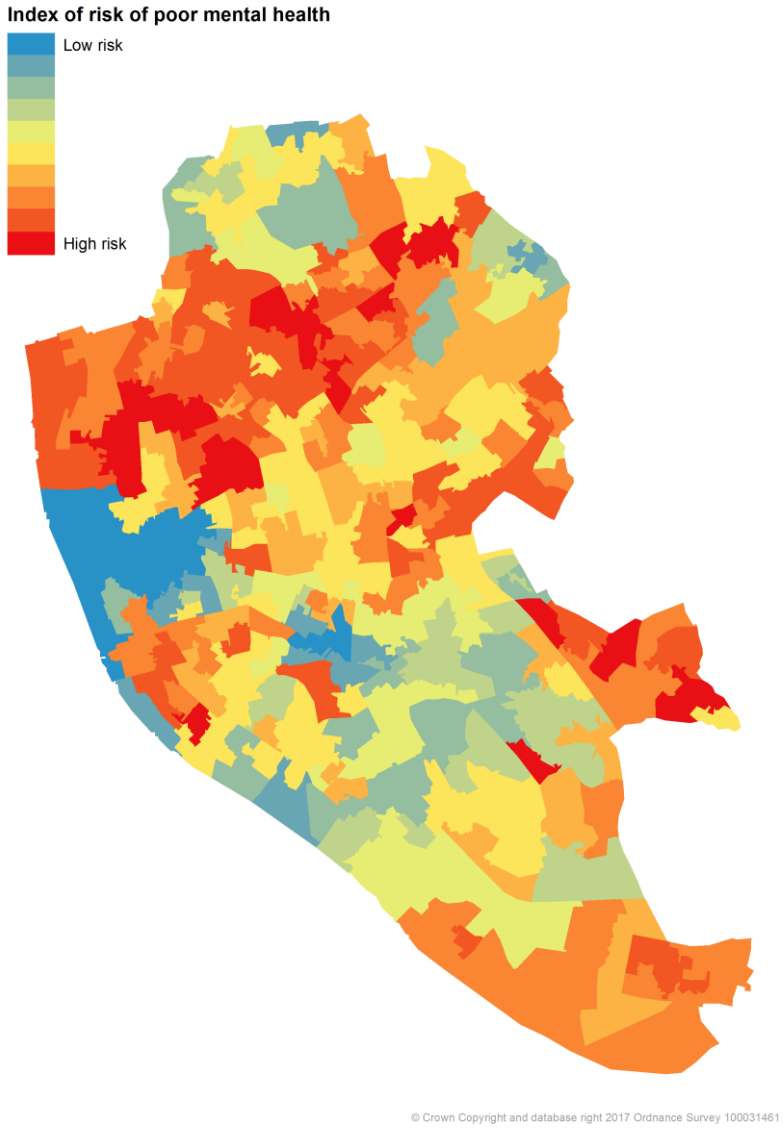


Figure 38 Index of risk of poor mental health for Liverpool

The population of students in Liverpool is high. There is concern about the increasing levels of poor mental health amongst students. A recent National Union of Students (NUS) survey indicates that 20% of students experience mental health problems but, of these, only 36% seek formal advice or support. The problems relate to coursework deadlines (65%), exams (54%), financial difficulties (47%), pressures about "fitting in" (27%) and homesickness (22%). Stress is the most common symptom (80%), with many students also reporting a lack of energy or motivation (70%), anxiety (55%), insomnia (50%) and panic (38%). 14% consider self-harm and 13% report suicidal thoughts.[83]

Provision of local green infrastructure can assist in maintaining a healthy population, by encouraging exercise and ameliorating mental health. Liverpool's JSNA includes the health benefits of green infrastructure[84]. Equally important to provision is the quality of design and safety of accessible green infrastructure, the barriers to choosing healthy lifestyles are not solely about availability but also linked to perception, culture and attitudes. As with many of the key issues for the city it is only through taking action to address all the major factors affecting an issue that will enable a transformation to take place.

The Natural Health Service has been developed by a consortium of organisations, including the Liverpool Universities, to develop products with a strong evidence base that use the natural environment as a location for health programmes that increase physical activity and improve wellbeing[85].

Key issues to consider

Use of NBS to

- Increase physical activity
- Improve wellbeing

3.9 Planning and governance

The city of Liverpool has engaged directly with the management of its physical environment working with partners to ensure that the city's water bodies, parks and open spaces are of high quality. This requires a collaborative approach to evidence-based planning and decision-making that draws on the public, private and third sector involvement. The creation of the city's Local Plan and Local Development Framework highlight this process, as does the development of the city's Green Infrastructure Strategy and Green & Open Space Review. However, to ensure that NBS are developed in the right location and with the most appropriate focus requires a discussion of the planning approaches and governance structures

[83] Brown, Poppy. "The invisible problem? Improving students' mental health." *Higher Education Policy Institute (HEPI)* (2016).
[84] http://liverpool.gov.uk/media/9123/jsna-statement-of-need-update-2014-v2-1.pdf (accessed 17th August 2017)
[85] http://naturalhealthservice.org.uk/wordpress/ (accessed 17th August 2017)

that support such investment, and how this translates into accessibility and multi-functionality of green spaces, while maintaining their quality for the provision of ecosystem services.

3.9.1 Planning

England's planning system is centralised, with the National Planning Policy Framework (NPPF)[86] setting clear expectations for both strategic and local development. The English system is statutory requiring local authorities to develop policies which reflect the existing condition of a city, and to identify where investment in strategic and locally significant development should occur. At a local level, Local Plans are used to frame development and are produced by Local Authorities in consultation with local stakeholders. Local Plans set out both the vision and a framework for the future development of the area, and are based on extensive evidence collection and synthesis addressing needs and opportunities in relation to housing, the economy, community facilities and infrastructure. They also offer a safeguard the environment through the development of policy which assesses adapting to climate change and securing good design in landscape and urban design.

Local Plans cover a local authority area, in the case of URBAN GreenUP the City of Liverpool. At the scale below Local Plans, Neighbourhood Plans can be produced by local communities (with the assistance of local planners and other stakeholders). Unlike Local Plans, Neighbourhood planning is not a legal requirement but right which communities in England can choose to use to help guide develop in their areas. At a more discreet scale Area Action Plans (AAPs) can also be developed by local authorities to provide additional guidance for specific localities/sites.

At the core of the planning system in England is a presumption that sustainable development drives investment. This golden thread of planning policy states that development should be sustainable and support economic growth as a central mandate[87]. This principle should be used to should inform all of the planning procedures described above. Although the NPPF is a more discreet rationalisation of the previous planning legislation (Planning Policy Guidance and Strategies) it does set out concisely the key drivers of development in the UK. The NPPF identifies 12 key principles for planning of which several are relevant to the Urban GreenUP Diagnosis for Liverpool. These include:

- Planning should be genuinely plan-led, empowering local people to shape their surroundings, with succinct local and neighbourhood plans setting out a positive vision for the future of the area. Plans should be kept up-to-date, and be based on joint working and co-operation to address larger than local issues. They should provide a practical framework within which decisions on planning applications can be made with a high degree of predictability and efficiency.
- Support the transition to a low carbon future in a changing climate, taking full account of flood risk and coastal change, and encourage the reuse of existing resources,

86

87 From National Planning Policy Framework - https://www.gov.uk/guidance/national-planning-policy-framework/achieving-sustainable-development

including conversion of existing buildings, and encourage the use of renewable resources (for example, by the development of renewable energy);

- Contribute to conserving and enhancing the natural environment and reducing pollution. Allocations of land for development should prefer land of lesser environmental value, where consistent with other policies in this Framework
- Encourage the effective use of land by reusing land that has been previously developed (brownfield land), provided that it is not of high environmental value
- Promote mixed use developments, and encourage multiple benefits from the use of land in urban and rural areas, recognising that some open land can perform many functions (such as for wildlife, recreation, flood risk mitigation, carbon storage, or food production)
- Actively manage patterns of growth to make the fullest possible use of public transport, walking and cycling, and focus significant development in locations which are or can be made sustainable
- Take account of and support local strategies to improve health, social and cultural wellbeing for all, and deliver sufficient community and cultural facilities and services to meet local needs

A more detailed discussion of the principles embedded within the Local Plan for Liverpool and the NPPF are provided below in the Policy section of this document.

Key issues to consider

Use of NBS to

- Inform development of plans and strategies for the city and city region.

3.9.2 Government

Effective implementation of NBS requires the requisite resources, power and authority. The UK is a highly centralised system, wherein authority rests with the British government, and a significant proportion of financial resources flow from the central government. At the same time, a great deal of responsibility rests with local government, who do not always have commensurate resources, which is a well-known challenge for effective natural resource management[88]. Such challenges have been compounded by austerity and recent cuts to discretionary services, including management of GI.

Great Britain & Northern Ireland (aka UK) is a parliamentary democracy with a constitutional Monarch as Head of State. The principle behind British democracy is that the people elect Members of Parliament (MPs) to the House of Commons in London at a general election, held no more than five years apart. Most MPs belong to a political party, and the party with the largest number of MPs in the House of Commons forms the government.

[88] Lockwood, M., Davidson, J., Curtis, A., Stratford, E. & Griffith, R. 2010. Governance Principles for Natural Resource Management. *Society & Natural Resources,* 23**,** 986-1001.

The main functions of Parliament are:

- to pass laws
- to provide, by voting for taxation, the means of carrying on the work of government
- to scrutinise government policy and administration, including proposals for expenditure and debate the major issues of the day

At a sub-national scale, local authorities are responsible for the provision of an extensive range of public services in a specific area, for example Liverpool. A democratically elected local government represents the views of local communities, voicing local concerns and responding to local needs. Local authorities promote the interests of local communities, including the social, economic, environmental, recreational, cultural, community or general development of an area.

These responsibilities are typically broken down into the following broad categories:

- Housing
- Planning
- Roads
- Development incentives and controls
- Environmental protection including rivers, lakes, air and noise
- Recreation facilities and amenities

While it is councillors, locally elected officials representing smaller areas within a city/location, who decide on local government policy, it is the local government officers who ensure compliance with the legal regulations of management and ensure that the decisions taken by elected officials are actioned, and that local services are delivered correctly

Local government officers are responsible for the practical development of council policies and procedures, and need to ensure that local services are delivered. There is an important distinction between the functions that a local authority legally has to carry out by law (passed by Parliament) and the functions /services that are discretionary.

For example, local authorities have a legal responsibility to provide social care for individuals in need, whilst the provision and management of green spaces/NBS is discretionary. A local authority chooses whether to, and which discretionary services it delivers, and is subject to socio-economic pressures. The provision of green space in Liverpool is subject to an ongoing review due to the impacts of centralised government austerity measures which have limited the funding that the city receives. Consequently, all discretionary services are current under review to evaluate which may be withdrawn.

Liverpool city council's approach to governance of its green spaces is set out in its Green Space Review. Policy on wider green infrastructure is set out in the Local Plan. At a neighbourhood level, there is an increasing amount of community stewardship of green spaces. This is partly driven by funding cuts meaning that there is less capacity in the local authority to manage sites and partly comes from community interest and empowerment.

Local authorities can also choose to work collaboratively within a "Combined Authority". A combined authority (CA) is a legal body set up using national legislation that enables a group of

two or more councils to collaborate and take collective decisions across council boundaries. The creation of a CA means that member councils can be more ambitious in their joint working and can take advantage of powers and resources devolved to them from national government. While established by Parliament, CAs are locally owned and have to be initiated and supported by the councils involved.

Liverpool is part of the Liverpool City Region Combined Authority. Along with five other authorities (Sefton, Knowsley, Wirral, Halton and St.Helens), Liverpool has chosen to work collaboratively on issues related to housing, planning, regeneration and transport.

In May 2017, Liverpool City Region elected its first Metro Mayor, to lead the Combined Authority. The Mayoral Manifesto includes The Metro Mayor's manifesto included a goal for a zero-carbon city region by 2040, protection of green spaces and encouraging young people to become more involved in environmental projects and programmes.

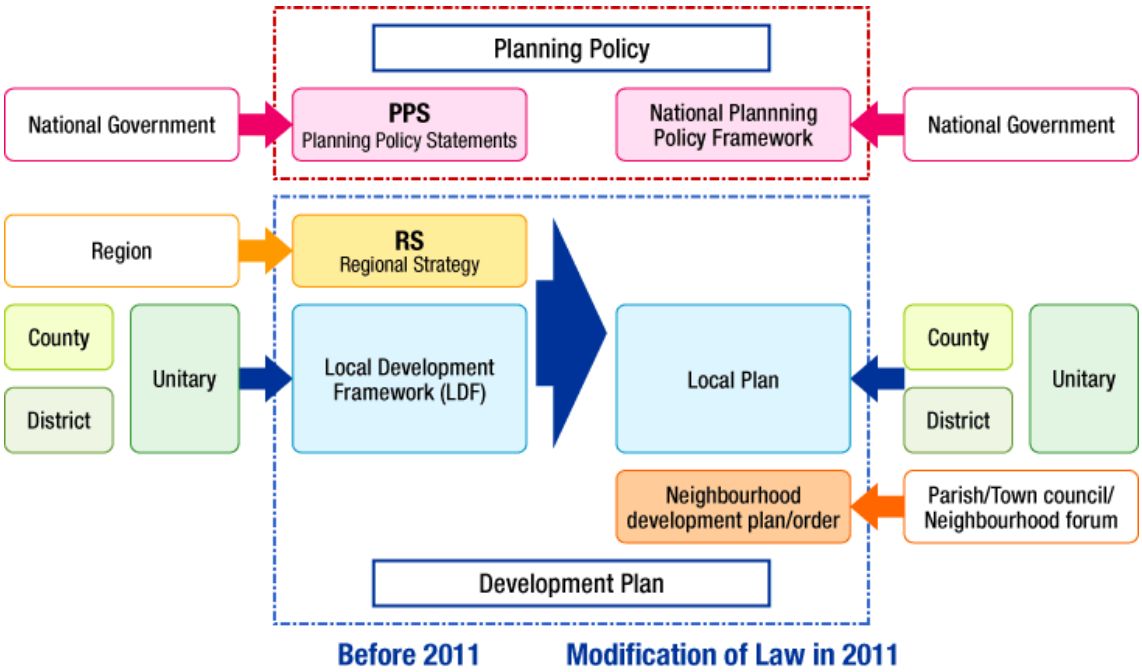


Figure 39 UK Planning System (pre-post-2011 reforms)[89]

Key issues to consider

Use of NBS to

- Influence policy and strategy in the city, city region and nationally
- Highlight opportunities of NBS to the new City Region

89 https://www.mlit.go.jp/kokudokeikaku/international/spw/general/uk/index_e.html

3.10 Social justice and social cohesion

Social justice recognises that society comprises of a diverse set of social groups, with varying requirements, rights and duties that need mutual support, co-operation and acceptance[90]. In green infrastructure planning, most attention has been devoted to environmental justice, which includes the promotion of an equitable process of development and access, elements of distribution, procedure and recognition[91]. Distributional justice relates to the unequal distribution, both social and spatial, of environmental qualities[92]; procedural justice relates to inclusiveness and fairness in processes and in rule enforcement[93]; and recognition-based justice focuses on the acknowledgement of the elderly and typically excluded social groups (e.g. migrants, women, persons with disabilities)[94]. Each of these forms of justice is visible in Liverpool, as NBS and green and open spaces are technically split evenly between the north-south of the city (49%/51% split), yet the quality, access and functionality of these spaces is more diverse.

Support for environmental justice can also promote greater social cohesion in urban areas. For example, supporting processes which enable immigrants to feel comfortable in their living environment supports intercultural understanding[95]. Moreover, where spaces are perceived to be welcoming they attract a greater diversity of users from different ethnic communities and age groups. High quality amenities located within parks and/or green spaces are therefore seen as important elements in promoting social inclusion/cohesion. Social cohesion is also a multi-dimensional concept that takes into account structural and cognitive aspects as described below.

90 Zajda, J. et al. (2007): Introduction: Education and social justice. International Review of Education, 52(1), 9- 22.
91 Rutt, RL. & Gulsrud, NM. (2016) Green justice in the city: A new agenda for urban green space research in Europe. Urban Forestry & Urban Greening, 19, 123-127.
92 Perez, AC, Grafton, B, Mohai, P, Hardin, R, Hintzen, K. & Orvis, S. (2015) evolution of the environmental justice movement: activism, formalization and differentiation. Environmental Research Letters, 10, doi:10.1088/1748-9326/10/10/105002
93 Schlosberg, D (2013) Theorising environmental justice: the expanding sphere of a discourse. Environmental Politics, 22, 37-55.
94 Fraser, N. (2009) Scales of Justice: Reimaging Political Space in a Globalizing World. Columbia University Press, New York.
95 (de Vries et al., 2013; Leikkilä et al., 2013).

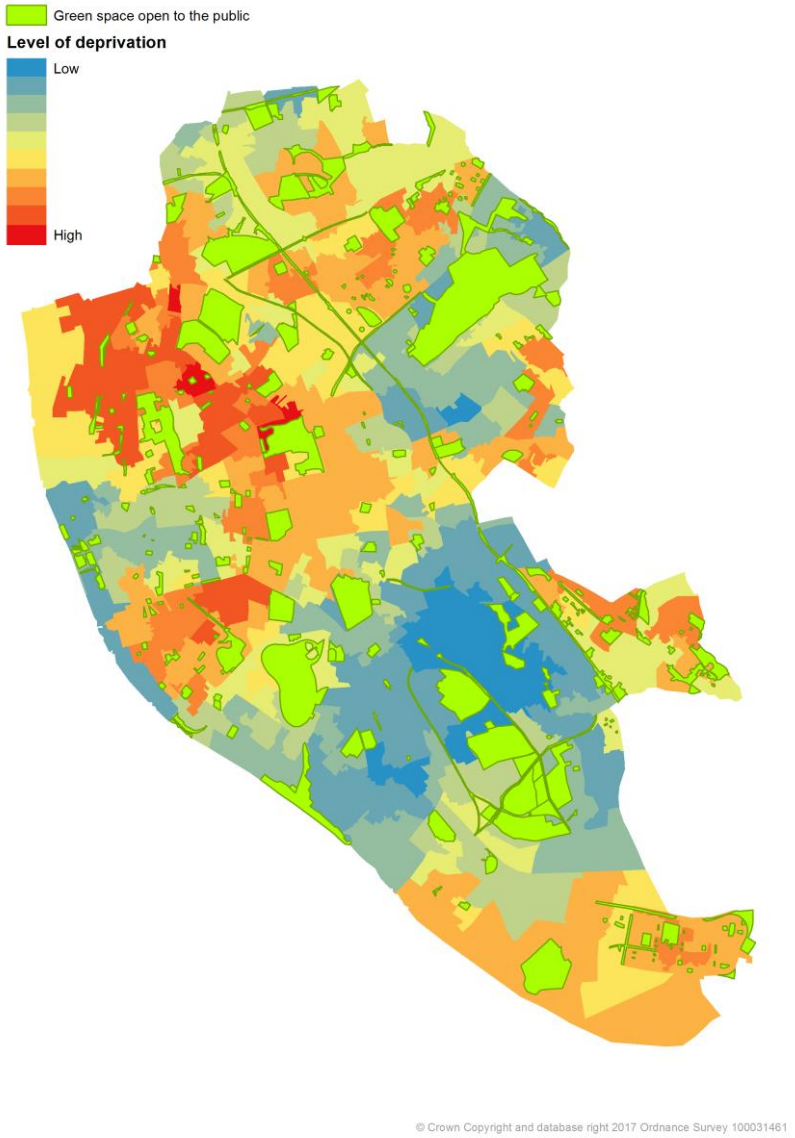


Figure 40 Deprivation and accessible green spaces in Liverpool

Not all members of society engage with green spaces in the same way thus there is a need to evaluate the ways in which parks and open spaces are located, what they offer different groups, and how people are engaged/directed to use the spaces[96]. The scales of a site and its proximity to other amenities, such as homes, have been identified as influencing use. However, there is also a need to reflect upon the structures associated with parks and how they influence use. In Liverpool, we can see more established sites that provide a range of activities and support being used more frequently. Unfortunately, due to funding cuts, environmental programmes are being scaled back. This could lead to an increased dislocation between people and their landscapes, and could be particularly acute in harder to reach

[96] CABE Space (2005) Start with the Park: Creating Sustainable Urban Green Spaces in Areas of Housing Growth and Renewal. CABE Space, London.

communities in north Liverpool[97]. It is therefore important to assess the support people receive to engage with green and open spaces, as well as their location when discussing social inclusion issues[98].

For example, in recent years the city council has lost 58% of Government funding and by 2020 this will reduce to zero Government funding. Local Authorities are now dependent on income from Business rates and council tax and in cities like Liverpool where houses are small with lower council tax and businesses are struggling to trade, the opportunity to raise income through this approach is restricted. Liverpool is also adversely affected as it has a higher level of residents who are not in employment or have long term health conditions. As green space maintenance is not a statutory Local Authority responsibility, priority for funding is being given to statutory services such as children and adults services.

Despite significant regeneration in Liverpool, deprivation remains high. Liverpool is deemed to be the fourth most deprived area in England[99]. Entrenched unemployment, poor health and a range of other factors require coordinated, generational action to enable the most deprived areas and communities to "catch" with the areas of the city that are thriving. Deprivation is highest in the north of the city with lower levels across the middle band of the city. The northern areas have traditionally been the industrial/docks/manufacturing area of the city and have been subject to greatest concerns following the closures of these industries[100].

The areas of highest deprivation tend to have lower levels of accessible green spaces, and there is an ongoing discussion regarding whether the quality of these resources is equitably distributed. Although the north of Liverpool has high quality spaces, Stanley Park, Walton Hall and Croxteth Hall, there are also a higher proportion of incidental spaces and parks/green spaces, which are considered to be of lower socio-environmental quality. The South of the city is perceived in some sections of the city to hold a greater number of sites of greater quality due to the socio-economic make-up and development history of the city. Comparable variability in quality, quantity and access to green spaces exists in the south of Liverpool, however, there tends to be a focus on Sefton and Calderstones Parks as the indicator of high quality[101].

The quality, quantity and types of green infrastructure located in Liverpool is therefore variable and is subject to complex communal and city government interpretations of its value.

[97] Jerome, G. (2017) Defining community-scale Green Infrastructure. Landscape Research, 42, 2, 223-229.
[98] Jerome, Mell & Shaw (2017) Re-defining the characteristics of environmental volunteering: Creating a typology of community-scale green infrastructure. Environmental Research, 158, 399-408
[99] Liverpool City Council (2015) The Index of Multiple Deprivation 2015: A Liverpool Analysis – Main Report. Liverpool City Council, Liverpool.
[100] Morrissey, K (2015) Exploring Spatial Variability in the Relationship between Long Term Limiting Illness and Area Level Deprivation at the City Level Using Geographically Weighted Regression. AIMS Public Health, 2, 3, 426-440
[101] Liverpool City Council (2016) Liverpool Strategic Green & Open Space Review: Final Report. Liverpool City Council, Liverpool.

Key issues to consider

Use of NBS to

- Engage communities and support work to improve areas of greenspace in areas of low provision.

3.11 Economic opportunities and green jobs

In Liverpool in 2016/17 the percentage of economically active 16-64-year-old people was 70%[102]. This compares with a figure of 75% for north-west England and 78% for England as a whole. The activity rate has varied by over the past twelve years as shown in Figure 42 Employment by occupation in Liverpool (2016/17), but currently shows a rise in the number of people employed within the city.

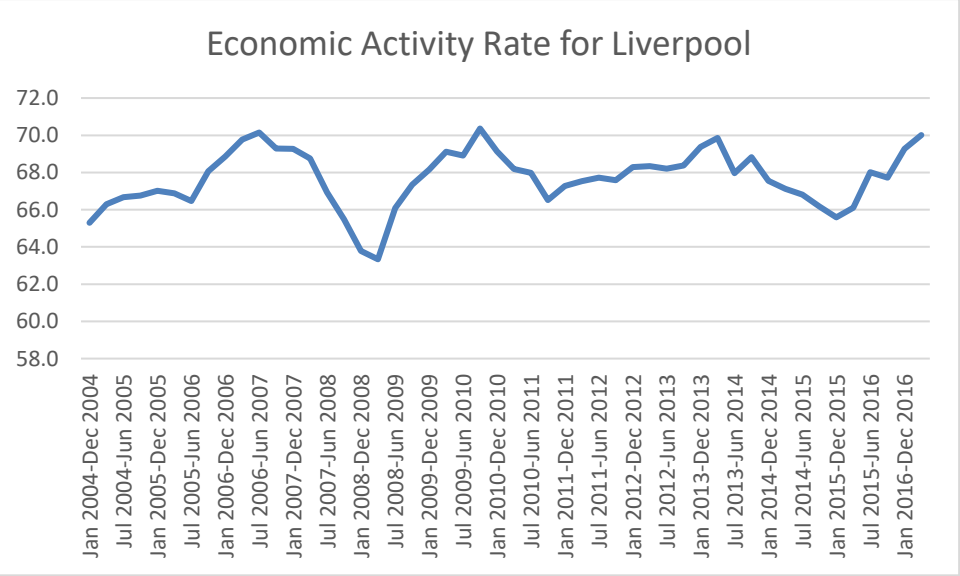


Figure 41 Economic activity rate in Liverpool 2004-2017[103]

[102] Nomis data accessed 17th August 2017.
https://www.nomisweb.co.uk/reports/lmp/la/1946157104/report.aspx?town=liverpool#tabempocc
[103] ONS Crown Copyright Reserved [from Nomis on 17 August 2017]

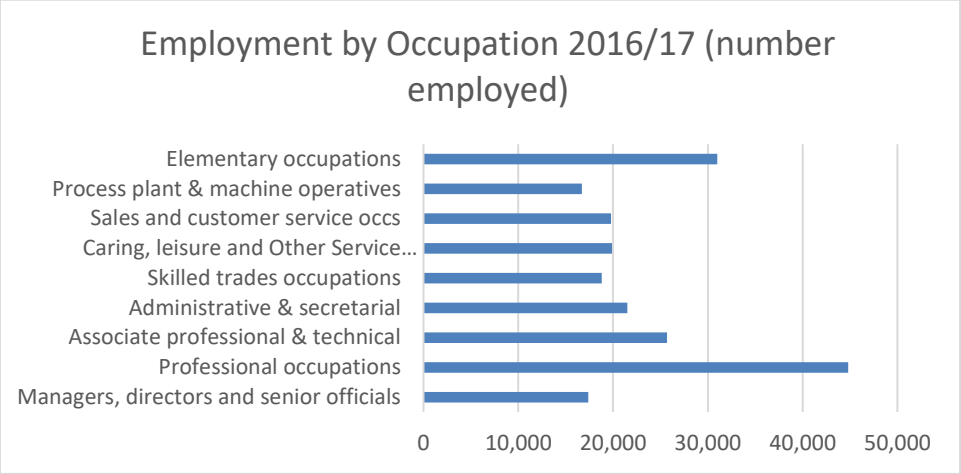


Figure 42 Employment by occupation in Liverpool (2016/17)[104]

The main occupations of the city are professional and elementary followed by associate professional and technical jobs. A proportion of these jobs will centred around environmental or sustainability issues and could be considered "green jobs", but the way in which data is gathered does not allow for disaggregation to identify these jobs[105].

There is no easy way to identify the numbers of jobs associated with green infrastructure planning, delivery, management and usage for Liverpool. Work at the sub regional level by Regeneris[106] attempted to identify both the scale of the green infrastructure sector and estimate the likely increases in 'green' jobs based on increased investment in green infrastructure projects and programmes. Using data from NOMIS, they estimated that there were approximately 8,000 jobs in the city-region related to green infrastructure, generating over £300m of GVA/annum. The report also projected that a proposed programme of £36m in investment, with a focus on skills development and apprenticeships, could create 2000 new jobs in the city-region. In addition to these projections Liverpool's Green Infrastructure Strategy used version 1.0 of the Green Infrastructure Valuation Toolkit to assess the economic value of the existing landscape resource in the city. This identified that the parks, woodlands, gardens, rivers and wetlands collectively provided over £8bn of economic benefits for the city.

Green infrastructure can also play a major role in attracting investment. Surveys have shown that green infrastructure adds value to commercial property. 95% of property developers would be willing to pay at least 3% more to be near open space[107]. Coupled with this, 98% of

[104] ONS Crown Copyright Reserved [from Nomis on 17 August 2017]
[105] Employment by occupation in Liverpool (2016/17) ONS Crown Copyright Reserved [from Nomis on 17 August 2017]
[106] GI and Jobs – Report to The Mersey Forest, available from Mersey Forest Team
[107] Gensler and Urban Land Institute (2011) Open Space: an asset without a champion? Available at: http://www.gensler.com/uploads/documents/Open_Space_03_08_2011.pdf

people believe that trees and green spaces can improve the appearance of a town and have been found to increase land and property prices by 7-18%[108].

How the city uses this analysis to promote the business case for investment in NBS and green infrastructure remains open to discussion. Whilst an economic value of the city's green infrastructure has been recognised in city policy, through the granting of World Heritage Status for its riverfront, and in terms of added-value to housing in some areas of the city, there is no universal approach to valuation. The valuation undertaken for the Green Infrastructure Strategy provides a baseline figure for discussion; however the quantitative analysis supporting this is somewhat abstract to many in the city. We therefore have to carefully review how the economic values of NBS can be communicated to city officials, as well as developers, the business sector and local people.

However, it is imperative that an economic value should be calculated for the city's green infrastructure resource base. When such figures are generated it is easier to 'sell' the benefits of investment in both the city and its landscape, as the economic returns can be illustrated[109,110]. Such discussions can be targeted at construction companies, SMEs and large-scale public sector organisations, as the rate of return is nominally far greater than the cost of investment[111,112].

Key issues to consider

Use of NBS to

- Support new jobs and businesses.
- Develop a green infrastructure sector that can argue for support.
- Attract investment by improving quality of place.

3.11.1 Biodiversity

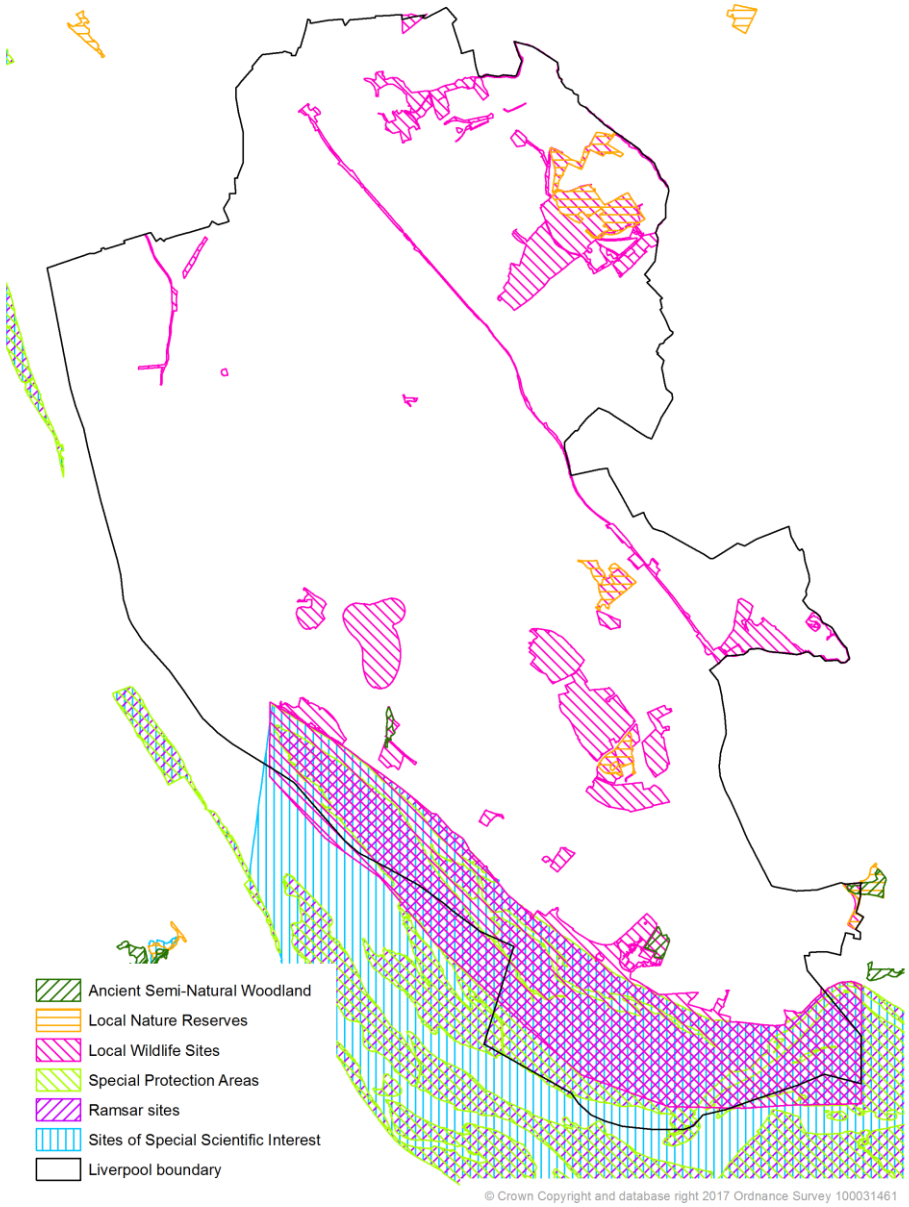
Eklipse Framework

Biodiversity	More, bigger, better managed and well-connected habitats. Enhancing ecological networks.

[108] CLES POLICY ADVICE. 2007. The Contribution of the Local Environment to the Local Economy presented to Groundwork UK.
[109] Mell, IC, Henneberry, J, Hehl-Lange, S. & Keskin, B. (2016) To green or not to green: Establishing the economic value of green infrastructure investments in The Wicker, Sheffield. Urban Forestry & Urban Greening. 18, 257-267. http://doi:10.1016/j.ufug.2016.06.015
[110] Mell, I.C., Henneberry, J., Hehl-Lange, S. & Keskin, B. (2014) Promoting urban greening: Valuing the development of Green Infrastructure investments in the urban core of Manchester, UK. *Urban Forestry & Urban Greening,* 12, 3, 296-306.
111 South Yorkshire Forest Partnership & Sheffield City Council (2012) The VALUE Project – Final Report. South Yorkshire Forest Partnership & Sheffield City Council, Sheffield.
112 Ecotec & Sheffield Hallam University (2013) Green Infrastructure's contribution to economic growth: A Review. Sheffield Hallam University, Sheffield.

More, bigger, better managed and well-connected habitats

A number of studies have been carried out to assess habitats and biodiversity across the city including the 2006 Phase 1 Habitat Survey. The city has areas of high biodiversity value with 25 Sites of Nature Conservation Value, four Local Nature Reserves, one SSSI, and the Mersey Estuary improve which also has the highest level of designation as it is both a Special Protection Area and a Ramsar site. The city has 17.8ha of ASNW, and four veteran trees have been identified, including the famous Allerton Oak in Calderstones Park.



All public bodies are required to consider biodiversity conservation; this is referred to as the "biodiversity duty". The scope for creation of large scale new habitat in Liverpool is limited.

Improvements in land management and ensuring that the large programme of regeneration planned for the city results in biodiversity improvements are key.

The North Merseyside Green Infrastructure Habitat Action Plan[113] was produced in 2008, recognising that the existing Biodiversity Action Plan and Habitat Action Plans were lacking in their application to urban areas. The Habitat Action Plan sets out a number of targets that can form part of the targeting for this Green Infrastructure Strategy.

Enhancing ecological networks

The Ecological Framework for Liverpool[114] sets out many of the key biodiversity issues for the city. The framework should influence the Local Plan and contribute toward the delivery of biodiversity and green infrastructure plans.

The Ecological Framework for Liverpool focuses on:

- Core biodiversity areas – areas that should be buffered where possible to increase habitat area and reduce impacts of surrounding development on the protected areas of the sites.
- Corridors and linkages – areas that can improve the viability of the most important ecological sites, provided that the corridors are well planned and provide an opportunity for species movement through the urban environment. Large areas of green space that are suitable for enhancement to improve the status of the core biodiversity areas are identified.
- Deficiency areas – the framework indicates these as areas of deficiency in the city which affect social wellbeing and ecological functions
- The Liverpool City Region Ecological Framework has used a similar approach to the Liverpool Framework. It also includes some specific target areas based on buffers for:
- Search Areas for Potential Habitat Expansion (SAPHE) – around core biodiversity areas, with the search area varying in size depending on the type of habitat.
- Connectivity Zone – This is a standard 100m buffer around all important biodiversity sites.

[113] http://www.merseysidebiodiversity.org.uk/pdfs/Urban%20GI%20HAP.pdf

[114] http://www.meas.org.uk/projects/lcr-ecological-network.aspx

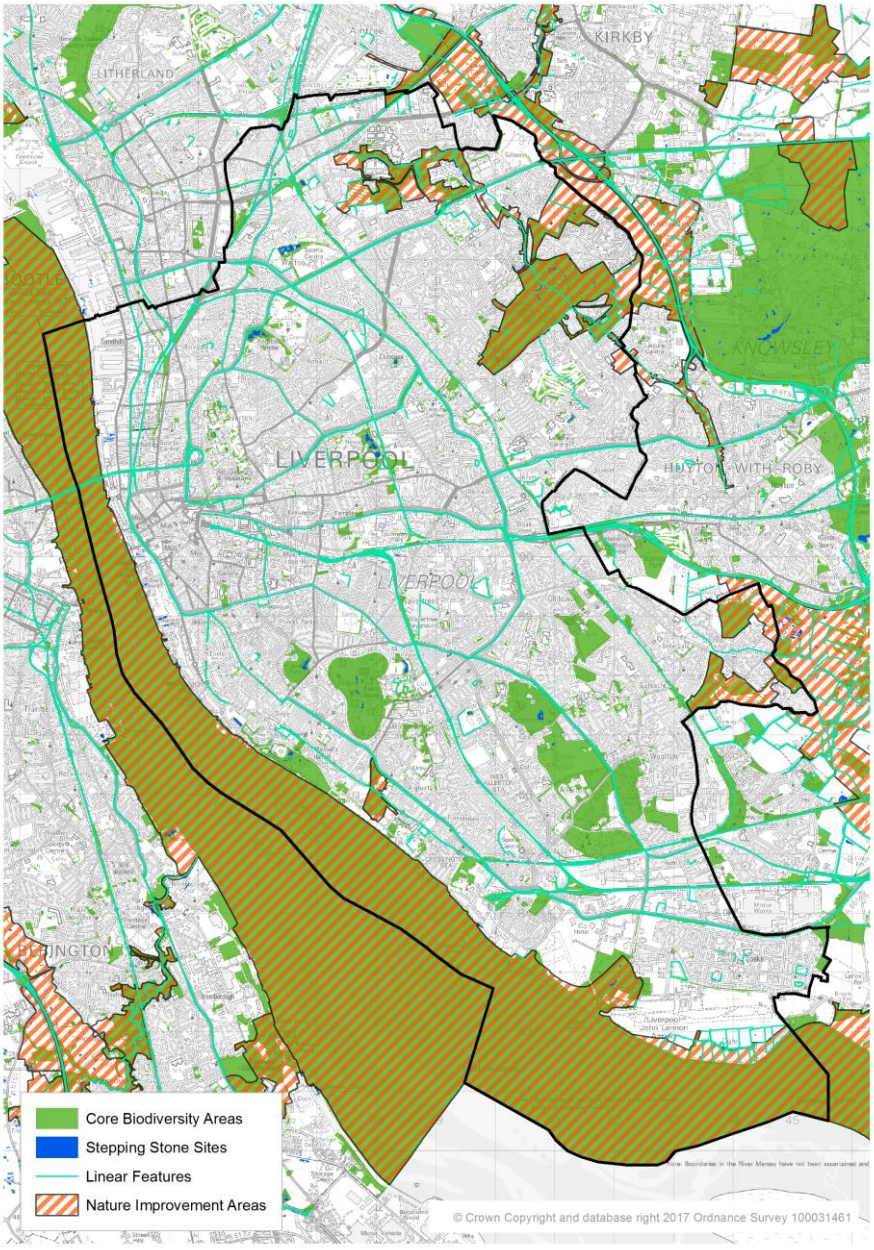


Figure 43 Liverpool Ecological Network

Liverpool has a national reputation for the good management of urban trees. Planting new urban trees is often a challenge, with issues of ownership, long term management, cost and conflict with underground services. However, in our towns and cities they represent one of the main ways of "retro-fitting" green infrastructure into the public realm, and they are multifunctional. Other towns and cities in the UK are starting to recognise the need to increase urban tree numbers, not least because of the positive impacts for climate change adaptation. Liverpool lost over 70,000 elm trees to Dutch Elm Disease in the 1970's, mainly in the north part of the city. These trees have not been replaced and represent a significant historic loss for the green infrastructure of the city.

Biodiversity is in part a measure of the health of a city's green infrastructure resource. A thriving green infrastructure is likely to have a range of sustainably managed habitats that support a wide range of species. Providing connectivity offers opportunities for species movement, habitat expansion and enables south-north movement of species as climate warms.

Assessing a number of factors, Natural England[115] has identified the Merseyside Conurbation, and so Liverpool, as an area of the Northwest where the natural environment has high vulnerability to climate change. Climate change will put additional pressure on both the areas that are designated for nature conservation and the wider biodiversity that exists across the city. Actions to buffer and reduce fragmentation of habitat can help species to adapt and move in response to a changing climate.

Key issues to consider

Use of NBS to

- Increase biodiversity in the city
- Improve connections to neighbouring areas
- Increase awareness of the importance of biodiversity in the city

[115] As part of the NW Climate Change Adaptation Plan: Natural England (2010) An Assessment of the vulnerability of the Natural Environment in the Northwest to climate change at the National Character Area scale

4 Nature Based Solutions – types of green infrastructure interventions

There is a wide range of potential green infrastructure interventions that can help to address the issues that have been identified by the diagnosis for Liverpool. Table 4 Table of green infrastructure/NBS interventions to address city priorities (examples) provides examples of green infrastructure interventions and the type of benefit that well planned, delivered and managed green infrastructure can achieve.

Table 4 Table of green infrastructure/NBS interventions to address city priorities (examples)

	Benefits										
Suggested GI intervention	Economic growth & investment	Land & property values	Labour productivity	Tourism	Products from the land	Health & well-being	Recreation & leisure	Quality of place	biodiversity	Flood alleviation & management	Climate change adaptation & mitigation
Increase tree cover on site	x	x	x	x	x	x	x	x	x	x	x
Select a mixture of native species (to provide food and habitat for wildlife)									x		
Select species to improve air quality						x		x			
Select species to provide shade (e.g. that will have large canopies when mature) and plant in areas where people walk and gather							x				x
Select broadleaf species and plant to provide shade to buildings (e.g. on south facing facades)			x								x
Select species with large canopies to capture rainwater										x	
Select species (e.g. conifers) and plant to provide wind shelter								x			
Select species and plant for aesthetic quality / image and to provide visual screening	x	x		x				x			
Select species to provide fruit and nuts					x			x			
Planted in streets	x	x						x			x
Retain existing mature trees on site		x						x	x		
Planted along streams, rivers and on floodplains										x	

Suggested GI intervention	Benefits										
	Economic growth & investment	Land & property values	Labour productivity	Tourism	Products from the land	Health & well-being	Recreation & leisure	Quality of place	biodiversity	Flood alleviation & management	Climate change adaptation & mitigation
Select and manage species to provide carbon sequestration and storage											x
Plant trees to stabilise slopes and soils vulnerable to erosion									x		
Plant trees as part of a sound barrier		x						x			
Manage trees on site as a timber and/or fuel resource					x						
Install green roofs	x	x	x		x	x	x	x	x	x	x
Designed to capture rainwater			x							x	x
Design green roofs to increase biodiversity (e.g. a using a variety of substrates, differing depths, and selecting species appropriately)			x						x		x
Design green roofs to allow access by people			x			x	x				x
Grow food crops			x		x						x
Install on buildings which are overlooked for aesthetic purposes	x	x	x					x			x
Install green walls	x	x	x		x	x		x	x		x
Plant to provide shade to buildings (e.g. on south facing facades); reducing direct solar gain in summer, use species to allow for solar gain in winter			x			x					x
Plant to increase biodiversity (e.g. species to provide food and habitat)									x		
Grow food crops					x						
Plant to improve aesthetic quality or image	x	x	x					x			
General vegetation-related interventions	x	x	x	x	x	x	x	x	x	x	x
Increase green cover on site										x	x
Design green infrastructure on site to provide a variety of micro-climates for users (e.g. access to sun, shade, wind, shelter)				x		x	x	x			x
Plant vegetation to stabilise slopes and soils vulnerable to erosion									x		

Suggested GI intervention	Benefits										
	Economic growth & investment	Land & property values	Labour productivity	Tourism	Products from the land	Health & well-being	Recreation & leisure	Quality of place	biodiversity	Flood alleviation & management	Climate change adaptation & mitigation
Safeguard wildlife habitats on site, referring to Biodiversity Action Plans									X		
Create new habitats on site, including ponds									X		
Select vegetation to provide food for wildlife e.g. nectar rich plants									X		
Plant a diverse mixture of vegetation, using native species									X		
Install bird and bat boxes									X		
Minimise use of mown lawns on site									X		X
Avoid development in areas of high carbon storage											X
Design the green infrastructure to improve the image of the area, taking into account landscape character	X	X		X				X			
Provide public access to the on-site green infrastructure, including any linear features such as rivers and canals						X	X				
Provide benches on-site, in a variety of microclimates				X		X	X	X			X
Provide recreation facilities on site different age groups						X	X				
Safeguard existing green infrastructure and landforms that act as sound and visual barriers		X						X			
Create new green infrastructure features as part of sound and visual barriers		X						X			
No development on best and most versatile agricultural land					X						
Safeguard any allotments on site					X						
Create allotments on site					X						
Use species that provide food, including fruit and nuts					X						
Compost household and garden waste for use on site					X						
Involve the local community in the design, construction and management of the site								X			

Suggested GI intervention	Benefits										
	Economic growth & investment	Land & property values	Labour productivity	Tourism	Products from the land	Health & well-being	Recreation & leisure	Quality of place	biodiversity	Flood alleviation & management	Climate change adaptation & mitigation
All windows in office developments to have a view over greenery	x		x								
In office developments, provision of accessible outdoor green space for office workers	x		x								
Water-related interventions		x		x		x	x	x	x	x	x
Avoid development in river and coastal flood zones		x								x	
Use river and coastal flood zones as multifunctional green spaces, including combining recreation and biodiversity with flood water storage						x	x	x	x	x	
De-culvert water courses										x	
Re-create natural floodplain vegetation									x	x	
Create or enhance green infrastructure upstream to store flood waters										x	
Use Sustainable Urban Drainage Systems (SUDS) as part of the on-site green infrastructure so there is no increase in runoff post-development and water quality is improved										x	
Use permeable surfacing within the design of any green infrastructure areas										x	
Where soils have a high water infiltration rate, keep surfaces unsealed										x	
Harvest, store and use rainwater on-site to irrigate green infrastructure (so that it provides urban cooling)										x	x
Increase of blue cover and features on site for its role in urban cooling				x		x	x				x
Irrigate green infrastructure on site, preferably from a sustainable source (e.g. greywater or harvested rainwater)										x	x
Linear features and connectivity				x		x	x	x	x		

Suggested GI intervention	Benefits										
	Economic growth & investment	Land & property values	Labour productivity	Tourism	Products from the land	Health & well-being	Recreation & leisure	Quality of place	biodiversity	Flood alleviation & management	Climate change adaptation & mitigation
Use green infrastructure on site to connect up nearby habitats off site									X		
Make linear features such as canals, rivers, railway lines, and road verges friendly to wildlife									X		
Create new wildlife friendly linear features (e.g. hedgerows)									X		
Safeguard existing rights of way on the site						X	X				
Connect public access routes in on-site green infrastructure to existing access routes in the surrounding area (e.g. public rights of way)						X	X				
Provide sign-posting to connect up green infrastructure routes				X		X	X	X			

This information will be used to guide the interventions that are selected for the NBS interventions in the three Liverpool demonstration areas.

5 Calculation indicator for city diagnosis

Based on the diagnosis of Liverpool, the Eklipse framework and the specific interventions that identified as being appropriate for the city, the following table provides an overview of the indicators that are to be used to assess the effectiveness of the URBAN GreenUP interventions in Liverpool.

These will be applied in the demonstration areas.

CHALLENGES	KPI	LIVERPOOL	ESA core KPIs
CHALLENGE 1: Climate mitigation & adaptation	Tonnes of carbon removed or stored per unit area per unit time (Zheng et al., 2013), total amount of carbon (tonnes) stored in vegetation (Davies et al., 2011).	X	1
	Decrease in mean or peak daytime local temperatures (ºC) (Demuzere et al., 2014).	X	1
	use of Star tools to calculate projected maximum surface temperature reduction	X	1
	physical measurement of temperature in the demo sites	X	
	use of GI Val to calculate carbon savings from GI providing shade, shelter, reduction in water treatment etc	X	
CHALLENGE 2: Water Management	Run-off coefficient in relation to precipitation quantities (mm/%) (Armson et al., 2013; Getter et al., 2007; Iacob et al., 2014; Scharf et al., 2012)	X	1
	Absorption capacity of green surfaces, bioretention structures and single trees (Armson et al., 2013; Davis et al., 2009)	x	1
	Temperature reduction in urban areas (°C, % of energy reduction for cooling) (Demuzere et al., 2014).	x	1
	Areas (ha) and population exposed to flooding	x	1

	Water for irrigations purposes (m^3 ha^{-1} $year^{-1}$)	x	1
	Economic benefit of reduction of stormwater to be treated in public sewerage system (€) (Deng et al., 2013; Soares et al., 2011; Xiao and McPherson, 2002)	X	
	volume of water removed from water treatment system	X	1
	volume of water slowed down entering sewer system	X	1
CHALLENGE 4: Green Space Management (including enhancing/conserving urban biodiversity).	Accessibility (measured as distance or time) of urban green spaces for population (Tamosiunas et al., 2014).	x	1
	Weighted recreation opportunities provided by Urban Green Infrastructure (Derkzen et al. 2015)	x	1
	Production of food (ton ha-1 year-1)		1
	sustainability of green areas	X	
	quality of life for elderly people	X	
	Increased connectivity to existing GI	X	1
	Pollinator species increase	X	1
	perceptions of connectivity and mobility	X	
	11.6.2 Annual mean levels of fine particulate matter (e.g. PM2.5 and PM10) in cities (population weighted) concentration recorded	X	1

CHALLENGE 5: Air Quality	ug/m^3		
	Trends in emissions NO_X, SO_X	X	1
	Monetary values: value of air pollution reduction (Manes et al., 2016); total monetary value of urban forests including air quality, run-off mitigation, energy savings, and increase in property values (Soares et al., 2011). use of GIVal to calculate the value of air quality improvements	X	1
	Number of deaths from air, water and soil pollution and contamination (proposed indicator for SDG target 3.9)	x	1
	air quality parameters NO_x, VOC, PM etc	X	1
CHALLENGE 6 Urban Regeneration	Accessibility (Schipperijn et al., 2010): distribution, configuration, and diversity of green space and land use changes (multi-scale; Goddard et al., 2010).		1
	assessment of typology, functionality and benefits provided pre and post interventions	X	
	savings in energy use due to improved GI	X	1
CHALLENGE 7 Participatory Planning and Governance	Perceptions of citizens on urban nature (Buchel and Frantzeskaki, 2015; Colding and Barthel, 2013; Gerstenberg and Hofmann, 2016; Scholte et al., 2015; Vierikko and Niemelä, 2016).	X	1
	citizen participation in the development and delivery of interventions	X	
CHALLENGE 8 Social Justice and	crime reduction through police reports and local authority data	X	

Cohesion	green intelligence awareness	X	
CHALLENGE 9 Health and Wellbeing	measurement of wellbeing of people in the area, employees and visitors	X	
	increase in walking and cycling in and around areas of interventions	X	1
CHALLENGE 10 Potential for Economic Opportunities and Green Jobs	Number of jobs created (Forestry Commission, 2005); gross value added (Forestry Commission, 2005).	x	1
	Change in mean or median land and property prices (Forestry Commission, 2005).	x	
	job creation, increased footfall and spend in the areas of interventions if appropriate	X	
	152	36	28

6 Liverpool's demonstration areas

To demonstrate how NBS can play a role in tackling some of the issues identified in the diagnosis the URBAN GreenUP project will focus investment in NBS on the following three areas in Liverpool.

These are areas exemplify both the issues and opportunities for nature based solutions in cities.

Sub-Demo A - The Baltic Corridor

This has been identified in the Green and Open Space review as an area where there are currently issues of poor connectivity for pedestrians and cyclists between the waterfront and the city centre and where there is a degraded environment. The area is one of the fastest growing locations in the city and as a consequence also hosts potential conflicts between communities engaged in significant economic regeneration activity, new cultural businesses; new student accommodation and an established local residential population including primary school and church. The area has a poor perception of through connectivity linkages into surrounding areas (with the exception at the City Centre link). As a former industrial area the Baltic Triangle has repurposed a significant proportion of its built infrastructure, however, there remains a clear deficiency in the quality and quantity of its green and open space. Street trees will aim to address on-street surface water flooding, offer pollutant capture, increase the habitat and biodiversity provision, to improve the connectivity and multi-functionality of the area. It pretends to evaluate how urban-environmental systems can be developed in post-industrial landscapes to improve biodiversity and social interactions with urban spaces. The network will linkup social spaces (schools/community centres) with homes and businesses to promote greater fluidity of use and functionality of the Baltic area.

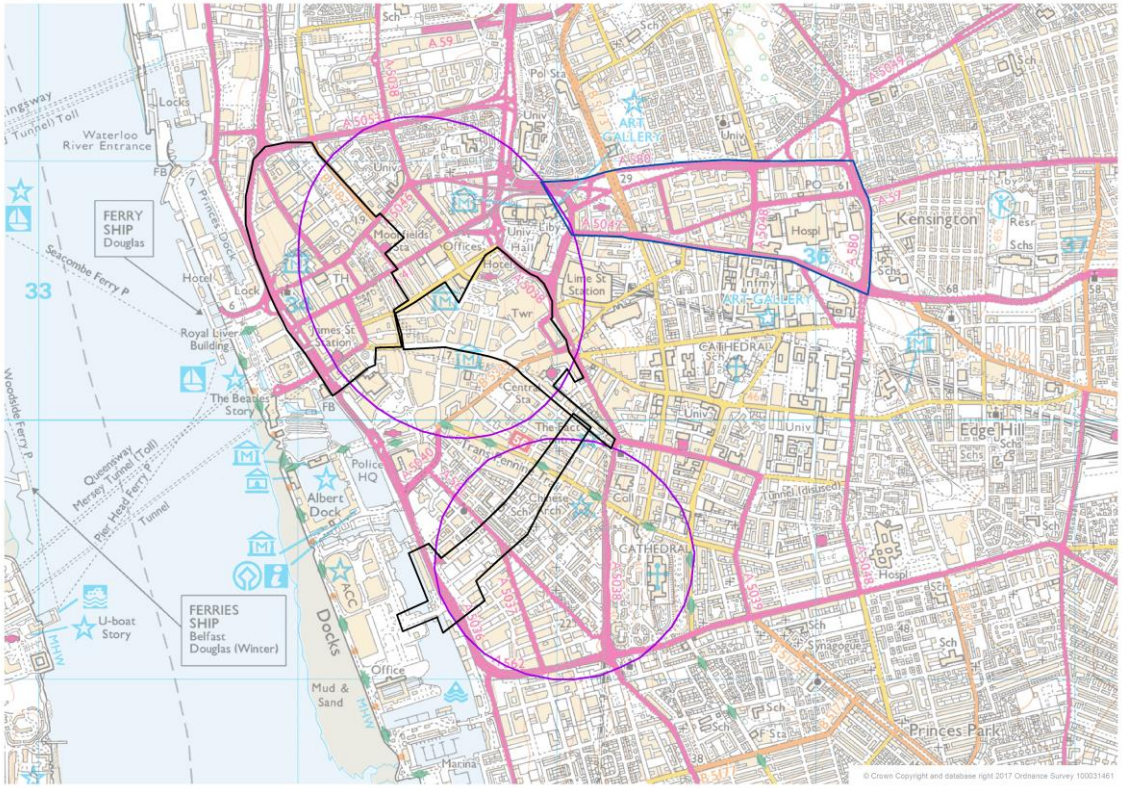


Figure 44 Location of the adjoining interventions at Baltic and Liverpool BIDs

Sub-Demo B - City Centre Retrofit

The central Business Community in Liverpool City Centre is of significant importance to city regeneration. In recent years the local private businesses have come together with Mersey Forest to work as a formal partnership to exchange knowledge and to improve the local city centre environment[116]. The BID represents over 630 small businesses and they have identified the need for improved City Centre GI which they believe will: improve their city centre economic resilience; improve liveability and quality of experience; improve air quality; reduce impacts of climate change and introduce greater biodiversity. The City Centre of Liverpool is one of the worst resourced neighbourhoods of the city for green space. The City Centre is also constrained by its density and the limited availability for green space development. Therefore, although the area is the economic hub of the city it lacks a level of quality and functionality to its environment. The City Centre GI WP will address this deficiency through a series multi-scaled GI. A network of 'vertical gardens' are proposed to provide an ecological and aesthetic corridor running through the area. Working with a selection of stakeholders (and the BID) the vertical gardens will raise environmental awareness of the value of urban greening, and promote a more in-depth understanding on the ecological value GI in compact urban areas. Increasing the awareness of landscape functionality is a key to generating longer-term

[116] http://www.liverpoolbidcompany.com/

engagement with the landscape. To achieve this, series of 'moving/temporary gardens' are proposed for the City Centre of Liverpool.

Sub-Demo C - Jericho Lane SUDS

This suburban site is already perceived as green sites with extensive biodiversity but it has drainage issues and associated pedestrian connectivity issues. Jericho illustrates a site where by a lake over flow and historic local; drainage infrastructure is reaching the end of its life and there is an opportunity to design and trial the creation of a natural solution with waters being opened up in a 'parkland' setting as a SUD project. There are also similar drainage issues nearby in Princes Park and there is an opportunity to create a blue corridor within a green corridor by linking work on water quality and water drainage from Princes Park, through Sefton Park to Otterspool Promenade; and in doing so to also seek to address issues of pedestrian connectivity between these sites. This would be contrasted with both a previously implemented SUD project which has proved very successful and with a similar one that has not been as successful to learn and share lessons. Linking the city-centre to the southern core of the city is Otterspool promenade one of the city's best used linear corridors. However, along its route are several recent housing developments and amenity green spaces/sports pitches, which are of varying quality. To address this, a series of interventions along the transport routes linking into the areas green spaces are proposed. Jericho Lane/Aigburth Road junction road will be improved through increased accessible paving and a redesigned layout to facilitate movement, especially young and older people. Additional urban greening in the form of buffer planting could be used to provide further moderation of the areas emissions. To ensure that the areas water systems are functional a process of de-culverting is proposed to reinstate the areas waterways (by SUDS and innovation monitoring of water management).

Figure 45 Location of demonstration sites in Liverpool (linked to task D3.2)

7 Conclusions

After several decades of economic and population decline Liverpool is now growing strongly and has a growing population.

However, the city still faces a range of challenges based on:

- Financial pressures - Reduced public funding has meant that there is less scope for discretionary spending on non-statutory spending, including on NBS.
- Demographics - Increasing population, larger numbers of older people, increasing burden of ill health.
- Climate change - increased risk of flooding, heatwave, urban heat island, and biodiversity loss.

Our diagnosis of the city has used the Eklipse methodology currently under development as a framework. Key performance indicators (KPIs) have been proposed for the city based on this framework. A number of these indicators have been identified as common across all three lead cities.

The diagnosis for Liverpool has used a wide range of data sources to describe the city, identify key issues to address, suggest types of NBS that might be considered and point to demonstration areas where more, in depth, assessment and specification of interventions can take place. An overview of the process is shown below.

The ability to deliver NBS is, to some extent, influenced by policy and strategy at national and local level. A wide-ranging review of policy was undertaken as part of this diagnosis. At a national level, there is a supportive policy framework for NBS. Local Policy and Strategy is also supportive of green infrastructure intervention to address a range of issues in the city.

(See Section 8)

Promotion of NBS must be based on good evidence that the intervention can lead to improvements in the issues being tackled. In a similar way to the policy framework, our diagnosis has assessed the evidence base for NBS being able to meet the challenges set out in the Eklipse Framework.

Overall, the evidence base is strong, supportive of NBS in the right circumstances.

(See Section 9)

Green infrastructure accounts for 62% of the total area of Liverpool, increasing to 69% if the large areas of the estuary are included. Large areas (3,779 ha) of the Mersey estuary are within Liverpool's administrative boundary. The river Mersey lies at the heart of all considerations of Liverpool.

Based on assessment of a wide range of socio-economic and environmental data, policy and evidence for the city, there are 34 challenges to consider in the development of NBS interventions for Liverpool.

Evidence based NBS interventions in the Baltic, Liverpool BID and Jericho Lane areas of the city will be monitored using the agreed set of KPIs to assess their impact on many of the challenges that have been identified in the diagnosis for Liverpool.

8 Appendix 1 Policy framework

The following is intended provide further depth to the policy framework discussions presented previously to both highlight and set out the key national legislation that is currently supporting planning in Liverpool. It is also used to illustrate how the future introduction of Nature Based Solutions into urban city environments can occur with policy support. This will be debated alongside examples of current policy, strategy and implementation in Liverpool to show how national legislation is being delivered at a local level.

Given the range of environmental legislation in the UK (and across Europe which is relevant to the Horizon 2020 programme), it is necessary to concentrate on the legislation that is directly relevant to the environmental issues being addressed and monitored through the sub demo proposals in Liverpool and include:

1. Climate Change (carbon mitigation and adaptive responses)
2. Water (flood risk and flooding)
3. Biodiversity (conserving and protecting species and habitats)
4. Green Infrastructure (addressing areas of land use; open space; transport and connectivity)
5. Pollution (addressing issues of poor air quality)
6. Health and Wellbeing (including mental health).

Currently, much of the UK's policy and law is driven by the European Union and international agreements. However, on 23 June 2016, 52% the citizens of the UK voted to leave the EU and to withdraw from the European Union; an act that that has since been popularly known as 'Brexit. As part of the process of Brexit, the UK will need to repeal European legislation and all existing EU legislation will need to be copied across into domestic UK law to ensure a smooth transition.

To do this The European Union (Withdrawal) Bill will need to:

- Repeal the European Communities Act 1972. This legislation provides legal authority for EU law to have effect as national law in the UK. This will no longer be the case after Brexit.
- Adopt all current EU laws onto the UK legislative books. This means that laws and regulations made over the past 40 years while the UK was a member of the EU will continue to apply after Brexit.
- Give ministers power to make secondary legislation as technical problems will arise as EU laws are put on the statute book. For instance, many EU laws mention EU institutions in which the UK will no longer participate after Brexit, or mention "EU law" itself, which will not be part of the UK legal system after Brexit. There will not be time for Parliament to scrutinise every change, so the bill will give ministers some powers to make these changes by secondary legislation, which is subject to less scrutiny by MPs.

The impact on such a policy transfer will be felt across government in the UK, and will require local government to review their existing policy to ensure that it complies with any centralised

changes. It will also mean that local government have an opportunity to reflect upon its current policy position, which may lead the promotion of investment in NBS. The following sections outline the key policy areas which may (a) be impacted upon by Brexit and (b) have a relevance to the URBAN GreenUP project.

1. CLIMATE CHANGE

Introduction

Changes in the Earth's climate have been occurring for many years since the Industrial Revolution, and future projections of climate change predict ongoing and significant impacts on economic, social and environmental aspects of our everyday lives. The last set of UK Climate projections (UKCP09) were published in June 2009, since then, and following the Paris Agreement on Climate Change in 2015, Defra (Department of Environmental, Food and Rural Affairs) have engaged with a process of updating the UK's climate projections and it is anticipated that these projections, UKCP18 which are due to be completed in 2018, will build on UKCP09 to provide greater regional data and provide more analysis of potential extremes and impacts of climate change. UKCP09 lists the main climate change projections for the north-west of England as: hotter, drier summers; milder wetter winters; more unpredictable and extreme weather events; and sea level rise.

Key National Legislation and Guidance

The UK is a signatory of the Kyoto Protocol in 2005, which set binding obligations for industrialised countries (including the UK) to reduce emissions of greenhouse gases. To deliver these the UK has implemented several pieces of legislation including:

The UK Climate Change Act (2008) is part of the UK government's plan to reduce greenhouse gas emissions. It established the framework to develop a targeted and economically-credible plan to reduce current and future emissions. The act highlights the UK's commitment to urgent international action and aims to improve carbon management to help the transition towards a low-carbon economy. The key provisions of the Act include:

- a legally binding target of at least an 80% cut in greenhouse gas emissions by 2050 and a reduction in emissions of at least 34% by 2020 (both against 1990 baseline);
- a carbon budgeting system that caps emissions over five-year periods;
- creation of the Committee on Climate Change;
- further measures to reduce emissions, including measures on biofuels;
- a requirement for the Government to report at least every five years on the risks to the UK of climate change, and to publish a programme setting out how these will be addressed.

The Act also introduces powers for the UK government to require public bodies and statutory undertakers to carry out their own risk assessment and make plans to address those risks.

The National Adaptation Programme was created through the Climate Change Act (2008) to assess the risks to the UK from climate change, prepare a strategy to address them and to encourage key organisations to do the same**.** In additional further policy has been created to address the growing concern for the environment and the scarcity of resources has resulted in additional UK legislation in related areas such as the carbon emissions trading system (2005), the renewable energy directive (2009) and the Energy Bill (2010), which includes carbon capture and storage and fairness in energy markets.

Local Strategy, Policy and Implementation

EU Covenant of Mayors is a pan-European co-operation movement involving local and regional authorities. Signatories of the Covenant of Mayors voluntarily commit to increasing energy efficiency and the use of renewable energy sources within their territories and have developed or are developing a Sustainable Energy and Climate Action Plan (SECAP), covering both mitigation and adaptation, within two years following the formal signing. Originally signatories sought to achieve a 20% reduction in carbon emissions by 2020 but a revised Covenant of Mayors now urges authorities to implement or go beyond the EU 2030 targets and seek a 40% reduction in CO_2 (and possibly other greenhouse gases) through improved energy efficiency measures and greater use of renewable energy sources. Signatories also commit to enhancing their resilience to climate change and co-operating with fellow local and regional authorities within the EU and beyond to improve access to secure, sustainable and affordable energy. In line with the revised Covenant of Mayors emission reduction target, Liverpool has recently adopted a revised target for carbon emissions of 40% reduction by 2030. This target has been based on recent success which has seen performance set to exceed both the city reduction targets for 2017/18 and those included in the city's earlier EU Covenant of Mayors targets for 2020.

Liverpool City Climate Change Strategic Framework (2009) and Liverpool Adaptation Framework Report (2009) form the backbone of the City's Climate Change Framework. Together they address climate change impacts and projections and identify a number of priority and supporting actions for a low carbon city. The Adaptation Framework highlights a number of key risks and opportunities for parks and open spaces. Although the Climate Change Strategic Framework and Adaptation Framework were published almost a decade ago, the City Council continues to provide strong leadership to drive the move towards a Low Carbon Liverpool. In recent years the city has:

- Adopted an increased carbon reduction target of 40% CO_2 equivalent emission reduction by 2030
- Worked closely with the University of Liverpool to undertake specific areas of climate research
- Remained the accountable body for the NW Local Authorities Climate Advice Centre (CLASP);

- Successfully bid and delivered £600K of funding for local property flood protection schemes; protecting over vulnerable homes from surface water flooding; undertaking additional landscape design for flooding and biodiversity; created the first flood warden group in the city.

Sustainable Energy Action Plan (SEAP)

The Liverpool City-Region Sustainable Energy Action Plan (SEAP) has been prepared with assistance from the Government's Climate Change Skills Fund (administered by the Climate Change Local authority Support Programme, CLASP). The work has been co-ordinated by Merseyside Environmental Advisory Service (MEAS) with the support of planning consultancy Arup and the participation of the Local Enterprise Partnership and six City Region Councils, Halton, Knowsley, Liverpool, Sefton, St Helens and Wirral. The SEAP sets out provides a vision for the City Region to co-ordinate its energy sector ambitions, advance projects and bring greater resilience to its energy networks. Implementation has the potential to generate significant investment, economic growth and create new jobs, as well as delivering substantial social and environmental benefits.

A number of local projects are currently being delivered and these include housing initiatives that could attract around £100m of investment and benefit up to 120,000 properties. Similarly £41m of spend across the city region has been targeted for sustainable transport (walking and cycling measures) which will be additionally supplemented by a new fleet of electric and hybrid buses. The City Council is seeking to lead the way; having recently introduced its own Energy company (LECCy) to provide affordable energy to those in fuel poverty. The City Council is also moving its fleet of vehicles to alternative fuels and promoting energy from waste, green waste composting and reviewing food waste collections. Working with partners there is also an opportunity for local district heat generation and networks, off shore wind and solar and tidal energy production. New building design and planning for energy efficiency have also seen plans progress for street lighting trials of LED lamps which have an estimated saving of £2.7m over 5 years. Many of these initiatives will help to drive the growth in the low carbon economy and create jobs and grow supply chains. For example, staff directly employed in the offshore wind farm have seen employment opportunities almost triple to 200 staff and almost 3,200 people are employed in construction and manufacturing associated with the £2.2 billion project for the 160 wind turbines.

Woodlands and forests have a key role to play in both mitigating and adapting to future climate change. In 2009, the Forestry Commission published, "Combating Climate Change - a role for UK forests" (also known as the "Read Report"). This report set out the case for forestry as mitigating and adaptive activity that can help to combat projected climate change. As part of the Forestry Commission response to the review the Woodland Carbon Code has been developed. The Code sets out design and management requirements for voluntary UK based projects that aim to sequester carbon through woodland creation. It accounts for:

- carbon sequestration and emissions for new woodland creation, within the woodland boundary;
- woodland created by planting and natural regeneration (where some intervention is necessary to establish woodland);
- carbon sequestration and emissions under various management regimes from frequent clear felling to minimum intervention woodland; and
- emissions outside the woodland boundary as a result of the project going ahead.

Furthermore, DEFRA's Climate Change Action Plan 2010 details their commitment to minimising the damage of climate change, both by reducing emissions and by preparing for a changing climate.

2. WATER AND FLOODING

Introduction

Liverpool's history, growth and general development has created a core city but like many other cities its drainage infrastructure dates from Victorian times and was designed to service a much smaller population (approximately 100,000-150,000). As a result, many of the culverts under the city are more than 150 years old, in poor condition and provide inadequate capacity to meet today's drainage needs. Coupled with many of the earlier open channels, ditches and watercourses having been culverted or backfilled as the city developed leading to a reduced efficiency in the original land drainage system, which collectively in conjunction with the loss of green/open space to development has resulted in Liverpool having the fourth highest surface water flood risk in the UK. Subsequently, surface water flooding is identified as a key risk for the city. There are three types of measures which can be taken to manage flood risk: preventing of risk, preparing for risk, and protecting from risk. NBS interventions can be classified as both helping to prevent risk and protect from risk.

Key National Legislation and Guidance

The **Pitt Review (2007)** on flooding highlighted the potential benefits that a Natural Flood Management Plan can deliver in the UK, and proposed a recommendation to "achieve greater working with natural processes" (WWNP) by planning and water stakeholders. The **EU Floods Directive (2007/60/EC)** wrote this into legislation, requiring the acknowledgement of floodplains as areas for flood retention, as well as calling for the production of flood risk management plans to promote partnerships to deliver natural solutions.

The **Flood Risk Regulations 2009** require Lead Local Flood Authorities to identify areas which are at risk of flooding from surface water flooding, groundwater flooding, ordinary watercourse flooding and flooding from canals with significant consequences, and to produce a Preliminary Flood Risk Assessment (PFRA) based on those areas. Whilst, the **Flood and Water Management Act (2010)** introduced legislation to address the threat of flooding and

water scarcity, both of which are predicted to increase with climate change. The act covered the following areas which:

- requires the Environment Agency to create a National Flood and Coastal Erosion Risk Management Strategy, which a number of organisations will have to follow
- requires Lead Local Flood Authorities (LLFA'S) to create local flood risk management strategies
- enables the Environment Agency and local authorities more easily to carry out flood risk management work
- requires the use of sustainable drainage systems in certain new developments.

Local Strategy, Policy and Implementation

Liverpool city Council is the lead Local flood Authority for Liverpool and has to comply with the **Flood and Water Management Act (2010)** to develop strategies to address all flood risk management matters. As the Lead Local Flood Authority Liverpool City Council is responsible for the operational management of flood risk where this is not covered by the Environment Agency, such as relating to local sources including surface water, groundwater and ordinary watercourses. In addition, there are a number of individuals, bodies and agencies involved in flood risk management. These are:

- Environment Agency – Providing a strategic overview for all sources of flood risk and holds responsibility for managing flood risk from main rivers, the sea and large reservoirs.
- Statutory Water and Sewerage Undertaker – United Utilities is responsible for the sewers and drains within Liverpool and they manage flood risk relating to sewers.
- Internal Drainage Board(s) – Providing operational management of ordinary watercourse and maintaining infrastructure in internal drainage districts. (There are no IDB's in Liverpool)
- Riparian – Maintenance of watercourses and flood defences on private land.

Liverpool City Council has prepared a draft **Local Flood Risk Management Strategy**. Consultation has been completed on the draft strategy and Habitat Regulation Assessment and an associated Strategic Environmental Assessment (SEA) is currently being prepared. The Strategy will be published at the end of 2017. A **Preliminary Flood Risk Assessment** was also produced in 2011 and has recently been reviewed and updated in June 2011. This update will be published by the Environment Agency in December 2017. Moreover, a **Strategic Flood Risk Assessment in 2008**, was produced by Liverpool City Council and updated in April 2012. The 2012 Strategic Flood Risk Assessment highlights that Liverpool is covered by three flood alerts from the EA:

- River Alt – River Alt and other watercourses from Huyton to Hightown including Kirkby, Fazakerley, Maghull, Formby, Aughton, Sefton and Lunt.

- River Ditton catchment including areas around Huyton-with-Roby and Widnes - The Ditton catchment includes, Ditton, Logwood Mill, Fox's Bank, Dog Clog, Stewards, and Netherley Brooks and their tributaries. Also including the areas around Huyton, Widnes and Penketh.
- Mersey Estuary from Liverpool to Warrington - The Mersey Estuary area includes both sides of the estuary from Liverpool to Warrington.

The document also identifies the areas in Liverpool which are at risk from different types of flooding. It has already been established that the greatest future flood risk to the city is from surface water flooding partly as a result of aging infrastructure and, in parts, inadequate drainage capacity. Liverpool is addressing this risk through planned investment to upgrade the culverted watercourse network and to replace its brick gully network.

Detailed modelling and the Liverpool Land Drainage Investigation work has aided this process by providing data to help in the assessment of known long-standing flooding issues in the city (hotspots), as well as facilitating the identification and prioritisation of critical maintenance and capital works to reduce future flooding in high risk locations. The identified hotspots will be the subject of future funding bids to the Environment Agency for Flood Defence Grant in Aid funding (FDGiA). The FDGiA funding stream has been utilised well in Liverpool over recent years.

Liverpool City Council has also invested in flood alleviation infrastructure at three key residential areas within Liverpool which were prone to severe flooding and had previously experienced numerous flooding events.

- Thornhead Brook Improvement and Environmental Enhancement Scheme was undertaken at Leyfield Road and involved re-routing a brook through a school grounds to create a meandering watercourse to improve flow and provide self-cleansing properties to reduce flood risk, create new habitat and increase biodiversity.
- Churchdown Park dry swale, the introduction of a dry swale and landscaping to Churchdown Park successfully provided a solution to complement some property level flood protection in Churchdown Road.
- Tuebrook Culvert replacement, the replacement of an existing 160 year old brick and sandstone culvert under West Derby Road addressed the longstanding flooding problem and removed areas which were in poor structural condition and in danger of collapse.

Although the city is subject to surface water and storm water flooding its location on the coast and the Mersey Estuary means the city is covered by the **Environment Agency, Mersey Estuary Catchment Flood Management Plan (2010)**. The CFMP was produced by the Environment Agency and was updated in 2010 and identifies flood risk in the Mersey Estuary catchment and sets out the Environment Agency's plan for sustainable flood risk management over the next 50 to 100 years.

Further policy focussed on water has also been developed in Liverpool to address a range of urban water management issues. These include:

- A **Waterspace Strategy for the Sustainable Development of the Liverpool South Docks** produced by British Waterways (2012) highlighting a 10-year Waterspace strategy for the City Centre docks area.
- **Strategic Waterway Plan (Canal and River Trust, 2013)** - The Northwest Waterway Partnership is currently developing a Strategic Waterway Plan targeting the areas under its remit.
- **Environment Agency - Flood and Coastal Erosion Risk Management Investment Programme 2015 to 2021 (republished 2015)** details how the Environment Agency will manage government investment to reduce flood risk and coastal erosion in England.

The city is also currently developing its **Draft Liverpool Local Plan (September 2016)** which outlines the need to improve and protect water and groundwater quality in the City, covering the canals and River Mersey. The Draft Liverpool Local Plan outlines the actions that LCC is required to prepare and implement a planning strategy that will help to deliver sustainable development by appraising, managing and reducing flood risk. The plan contains a number of policies that are relevant to flooding including recognition of the requirement that sustainable drainage systems (SUDS) should be considered for major developments.

As Lead Local Flood Authority, Liverpool City Council are a statutory consultee for planning applications so ensure that surface water run-off from development is in line with NPPF requirements. Due to underlying geology in the Liverpool area, SuDS are nearly all underground storage in oversized pipes or tanks with the discharge rate being controlled by a flow control device. There are a small number of developments where storage has been provided by ponds creating wetland areas such as the development by Barret Homes on Speke Hall Avenue, this pond is maintained by a management company. Investment in flood risk infrastructure is an ongoing requirement and as a statutory consultee, LCC will ensure that surface water flooding is not increased and future resilience is in built into schemes.

3. BIODIVERSITY

Introduction

Liverpool has several areas of high quality or priority biodiversity of which the estuary is the most important. A large proportion of the estuary, including its banks, is designated as a Site of Special Scientific Interest (SSSI), a Ramsar site, and a Special Protection Area (SPA) due to the vital role played by the intertidal flats and salt marshes in providing feeding and roosting sites for large and internationally important populations of waterfowl.

The city also has 31 Local Wildlife Sites and four Local Nature Reserves. In addition an area of 950.7 hectares in Liverpool has been identified as being of substantive nature conservation interest, which equates to 8.6% of the city's land area and 33% of green and open spaces within the city boundary (Strategic Green and Open Spaces Review, 2016). Others areas across the city have more limited nature conservation value as much of this city's landscape is

fragmented or isolated within the urban setting, although parts are connected to varying degrees by existing green corridors such as the Liverpool Loopline and the Leeds-Liverpool canal.

Key National Legislation and Guidance

A number of national level policies are of relevance to biodiversity management in the city of Liverpool, however, not all are used or as integral as others to the protection of its resource base. These policies include:

- **The National Parks and Access to the Countryside Act 1949** provides power to declare Local Nature Reserves.
- **The Wildlife and Countryside Act 1981** (as amended) is the main piece of legislation relating to nature conservation in Great Britain. This provides detail on a range of protection and offences relating to wild birds, other animals, and plants and other legislation.
- **The UK Biodiversity Action Plan (UK BAP)** was published back in 1994, and was the UK Government's response to the Convention on Biological Diversity (CBD), which the UK signed up to in 1992 in Rio. The UK was the first country to produce a national Biodiversity Action Plan describing the biological resources of the UK and provided detailed plans for conservation of these resources. Action plans for the most threatened species and habitats were set out to aid recovery, and national reports, produced every three-to-five years, showed how the UK BAP was contributing to the UK's progress towards the significant reduction of biodiversity loss called for by the CBD.
- **The Countryside and Rights of Way (CRoW) Act 2000** provides support for access and nature conservation.
- **Natural Environment and Rural Communities Act 2006 (in England and Wales)** imposes a duty to conserve biodiversity and applies to all local authorities and extends beyond just conserving what is already there to carrying out, supporting and requiring actions that may also restore or enhance biodiversity. The Secretary of State is required to publish a list of habitats and species that are of principal importance for the conservation of biodiversity in England**.**

Each of these policies is framed by the **NPPF** which sets out planning policies which local planning authorities should have regard to on biodiversity matters. Within the NPPF a series of protected designations for habitats are included under the Habitats Directive through the Conservation of Habitats and Species Regulations 2010 in England; the Birds Directive, through the Conservation of Habitats and Species Regulations 2010, and the Wildlife and Countryside Act 1981 (as amended). Whilst the NPPS sets out the UK's biodiversity agenda within planning policy this is aided by the **Biodiversity Strategy for England – Biodiversity 2020: A Strategy for England's Wildlife and Ecosystem Services.** This sets out how international and EU commitments on biodiversity are to be implemented. It highlights the importance of the planning system in guiding development to the best locations, encouraging greener design and enhancing natural networks. The UK is also a signatory to the Convention on Biological

Diversity (CBD) and is committed to the new biodiversity goals and targets 'the Aichi Targets' agreed in 2010 and set out in the **Strategic Plan for Biodiversity 2011–2020**. The UK is also committed to developing and using a set of indicators to report on progress towards meeting these international goals and targets.

Planning for biodiversity is also discussed in the the **UK National Ecosystem Assessment, 2011** which demonstrates the strong economic arguments for safeguarding and enhancing ecosystems. The NEA looked at the health and value of the natural environment across the whole of the UK for the first time and proposed six scenarios which described a range of possible futures for our natural environment. The assessment produced a number of key findings around the benefits of ecosystems and their future role and value. **The Natural Environment White Paper – The Natural Choice: Securing the Value of Nature** was also produced with the aim of minimising biodiversity loss by 2020 by supporting healthy functioning ecosystems and establishing coherent ecological networks. The White Paper introduced:

- Local Nature Partnerships – Working closely with LEP and the Health and Wellbeing Boards to contribute to local plan making
- Biodiversity Offsets – Conservation activities designed to deliver biodiversity benefits to compensate biodiversity loss from development.

In addition, the White paper outlined a vision for England' soil resource setting clear targets for sustainable soil management by 2030 for all of England's soils to be managed sustainably. One key driver is to safeguard the ability to provide essential ecosystem services and functions. The Natural Capital Committee has also published four reports setting out a programme of embedding natural capital accounting into government policy. Finally, the **Lawton Report Making Space for Nature** which was informed by the White paper sets out the case for improving the ecological networks of our urban and rural areas. It highlights the ethical case for biodiversity conservation and outlines the value of the natural environment in providing services and benefits critical to the wellbeing of individuals, communities and the economy. Urban green infrastructure is cited as being an effective tool for managing environmental risks such as flooding and heat waves and advocates green spaces being factored into all development.

Local Strategy, Policy and Implementation

At a sub-regional level **Local Nature Partnerships (LNPs) /Nature Connected** have been developed to address local and more strategic biodiversity issues. To achieve this, they are expected to ensure that consideration for the environment is put right at the heart of local decision-making. Local Nature Partnerships originated in a vision set out in the UK government's 2011 'Natural Environment White Paper', which identified the need to take greater account of the value of the environment when strategic decisions are made that affect people and the local economy. The overall purpose of an LNP is to:

- Drive positive change in the local natural environment, taking a strategic view of the challenges and opportunities involved and identifying ways to manage it as a system for the benefit of nature, people and the economy.
- Contribute to achieving the Government's national environmental objectives locally, including the identification of local ecological networks, alongside addressing local priorities.
- Become local champions influencing decision-making relating to the natural environment and its value to social and economic outcomes, in particular, through working closely with local authorities, Local Enterprise Partnerships (LEPs) and Health and Wellbeing Boards.

With a role set in the Environment White Paper, the LNP can provide the "environmental arm" for the local economic and heath strategic partnerships. In Liverpool City Region, the LNP, Nature Connected, has good links to the LEP and Combined Authority and its chair is the Environment advisor to the Metro Mayor.

Biodiversity Action Plans (BAP) have also been developed with the aim of helping local people become more aware of the area's natural environment and the issues facing it. The North Merseyside Biodiversity Action Plan is not a single published document, but alternatively comprises a number of individual Species & Habitat Action Plans (HAP and SAP) and a Business Plan to prioritise work for conservation over the coming years. There are a total of 44 Habitat and Species action plans; each one describing the current status of the habitat or species, issues affecting its wellbeing, conservation objectives & targets and actions to meet them. The **Merseyside BioBank** (http://activenaturalist.org.uk/mbb/) is the Local Environmental Records Centre (LERC), an environmental information service, for North Merseyside. They cover the authority districts of Liverpool, Sefton, Knowsley and St Helens. As a member of the Association of Local Environmental Records Centres (ALERC) and part of the National Biodiversity Network (NBN), they collect and collate information on wildlife within the region, on a not-for-profit basis, and encourage and support the recording of wildlife. The Merseyside BioBank database holds electronic copies of wildlife records provided from a wide range of sources, including; local naturalists, volunteer recorders, local natural history groups, professional consultants and national recording schemes and societies. Records held form an evidence base that underpins conservation, decision making, forward planning and development throughout Merseyside so helping to conserve and protect biodiversity in our rapidly developing region and beyond. Merseyside BioBank provides biodiversity and environmental information to local authorities through Service Level Agreements. Their key functions include:

- Supporting and promoting the North Merseyside Biodiversity Action Plans.
- Promoting Local Sites (Local Wildlife Sites and Local Geological Sites).
- Supporting biological recorders and recording groups through resources and guidance.

- Developing new tools for recorders.
- Training and promoting new recording projects and recording effort.

In terms of ensure that environmental policy is discussed, complied with and developed Liverpool works with the **Merseyside Environmental Advisory Service (MEAS)**[117]. MEAS is a specialist unit which provides environmental advice on planning applications, major projects and planning policy to Merseyside local authorities. MEAS also works in support of the wider environmental agenda in the Liverpool City Region through input to, and management of specific projects and partnerships. MEAS also represents the Liverpool City Region on a number of regional and wider groups including Nature Connected (Local Nature Partnership). By consulting the service appropriately on
planning applications and during the forward planning process, and then acting positively on the advice given, Merseyside local authorities demonstrate compliance with the biodiversity duty within their planning frameworks.

In 2015 the Strategic Green and Open Spaces Review Board commissioned MEAS to undertake a biodiversity assessment of Liverpool and to review data sets and historic habitat reports. The results indicated that species records per hectare were low and under representative of the presence of biodiversity in the city. In many areas no records existed. The report flagged up that the little formal recording or monitoring made it difficult to deliver on conservation obligations or provide protection for fragile sites and species. Previously when Liverpool City Council identified a need for an up to date evidence base for its Local Development Framework in line with national and regional policy, it commissioned the most thorough appraisal of Liverpool's biodiversity ever undertaken. One of the outputs of the Space For Nature project was the Ecological Framework which highlights the ecological function of Liverpool's green infrastructure and contributes to wider green infrastructure objectives central to the Local Development Framework. Recommendations arising from the project will also enable the City Council to contribute to targets in the North Merseyside Biodiversity Action Plan.

4. GREEN INFRASTRUCTURE

Introduction

Green infrastructure includes the provision of parks and gardens, natural and semi-natural green space, amenity green space, provision for children and young people, allotments, cemeteries and churchyards, civic space and green corridors. NBS and green infrastructure both aim to increase the proportion, accessibility and multi-functionality of urban landscapes and within the UK there are a number of policies which support this process.

[117] http://www.meas.org.uk/

Key National Legislation and Guidance

The Localism Act, 2011 was introduced to Parliament in December 2010 with the underlying aim of shifting power from central government to individuals, communities and councils. Provisions in the Bill include:

- A duty to cooperate that requires local authorities and other public bodies to work together on planning matters.
- A requirement for communities to draw up neighbourhood development plans consistent with the Councils local plan and national guidance.
- The ability to use community infrastructure levy funds on maintaining infrastructure, creating new infrastructure.

The Localism Act should be reviewed in conjunction with the NPPF which was designed to consolidate and simplify guidance for the preparation of development plans and assessment of planning applications. In relation to green infrastructure the document encourages local authorities to set out a strategic approach in their local plans to plan positively for the "creation, protection, enhancement and management of networks of biodiversity and green infrastructure." An accompanying appendix encourages a more strategic approach to green infrastructure and a better understanding of the existing green infrastructure network and its functions in their area. Three dimensions are identified for sustainable development:

- an economic role – contributing to building a strong, responsive and competitive economy, identifying and coordinating development requirements, including the provision of infrastructure;
- a social role – supporting strong, vibrant and healthy communities,
- an environmental role – contributing to protecting and enhancing our natural, built and historic environment; and, as part of this, helping to improve biodiversity, use natural resources prudently, minimise waste and pollution.

National level policy is support by guidance from the Royal Town Planning Institute (RTPI), Town & Country Planning Association (TCPA) and Landscape Institute, which provides an evidence base used to deliver the objectives of the NPPF. In addition, the **Fields in Trust Guidance for Outdoor Sport and Play: Beyond the Six Acre Standard (October 2015)** policy framework seeks the protection, provision and improvement of outdoor spaces for sport and play as part of the provision of sustainable communities. Policies are kept under review to ensure that they remain relevant and proportionate. Good planning and design is central to the philosophy and objectives of Fields in Trust and adds value to the overall quality of an area, helping to create a sense of place and space as well as contributing to the health and wellbeing of residents. There is also scope to incorporate the **Safeguarding our Soils: a strategy for England 2009**, document which highlights the areas in which soil will be prioritised and to

focus attention on tackling degradation threats. The vision of this paper is to try and ensure that by 2030, all England's soils will be managed sustainably, that depredation threats are tackled successfully, and that this will improve the quality of England's soils and safeguard their ability to provide essential services for future generations.

Local Strategy, Policy and Implementation

Locally Liverpool has a number of relevant and supporting policies and guidance documents that shape the green and open space provision within the city. These are listed below under the themes of: *Development*, *Green and Open Space* and *Transport and Connectivity*.

Development

Liverpool City Council is currently consulting on its **Liverpool Local Plan 2017,** which is aligned with the NPPF and supported by the **Sustainable Urban Development Strategy**, **Liverpool City Region, 2015** and **Liverpool City Centre Strategic Investment Framework, Liverpool Vision.** The requirement to produce a Local Plan is set out within the NPPF. On the 19th August 2016 Liverpool City Council's Cabinet approved the undertaking of public consultations on the draft Liverpool Local Plan, which is intended to both update and amend the city's existing planning framework, the Unitary Development Plan and will seek to focus on delivering homes in brownfield sites, protecting land and buildings for economic growth and protect Liverpool City's parks for the health and wellbeing of the population. Using the information produced through the Strategic Green & Open Space Review and the forthcoming Open Space Review, as its evidence base the final version of the Local Plan will give direction on the future provision of accessible high quality sustainable provision for green infrastructure and NBS across Liverpool based on population, distribution, planned growth and consultation findings.

The Local Plan is due to be completed in 2017 but in the interim the draft Local Plan contains proposed policies that take on board the Open Space and Green Wedge policies in the existing UDP as well as new policies to address the natural environment. The Emerging Local Plan is also underpinned by an earlier Local Plan Sustainability Appraisal in 2014 which included Strategic Environmental Assessment, Habitat Report Assessment and an Equality Impact Assessment. The Local Plan discussions are supported by the **Liverpool's Sustainable Development Plan** which guides the council's performance framework, corporate strategies and individual service plans, helping to put sustainability at the heart of what Liverpool City Council thinks and does. As sustainability means generating a better quality of life, whilst improving local environmental conditions for local people and future generations for Liverpool City Council this means always challenging the way things are done and providing leadership for the whole community.

Green and Open Spaces

The Liverpool Open Space (Assessment and Standards Report) Study 2017 (in preparation) will form the Open Space policies of the Local Plan will be informed by the Open Space (Assessment and Standards Report) Study which is currently being completed by consultants. This piece of work has been undertaken to update the 2005 Open Space Study and to underpin the development of the Liverpool Local Plan. It will provide an assessment of exiting open space provision, its condition, distribution and quality and overall quality and will provide direction on the future provision of accessible, high quality, sustainable provision for open spaces across Liverpool based on population distribution, planned growth and consultation findings. It will be used, as an evidence base, to meet the government requirement for the Local Plan to be supported by a robust assessment of need for open space, sport and recreation facilities and will provide detail with regard to what provision exists in the City, its condition, distribution and overall quality.

In late 2014 the Mayor of Liverpool commissioned an independent review of the city's green and open spaces – the **Strategic Green and Open Space Review, 2014-2016**. This recognised the value and the many benefits provided by green and open spaces and grappling with the challenge of finding new ways to fund non–essential or discretionary services including the maintenance and investment in green and open spaces, the Mayor challenged the Board to find new and innovative ways to protect Liverpool's parks and secure the long-term future of the city's green spaces. The Strategic Green and Open Space Review Board published an interim report and 31 initial recommendations in December 2015 and a final report with 38 recommendations in October 2016. The most relevant recommendations for URBAN GreenUP included working with stakeholders to seek external green space funding, integrating a network of green corridors into the city's emerging Local Plan together with creating, improving and protecting green and blue spaces. To date a number of the report recommendations have been progressed. The Mayor has made £1m available for new and improved children's outdoor play and local communities have been able to access funding to improve their local green and open spaces. A number of alternative financial models have been explored to help support ongoing green space maintenance and a successful bid was made to the Horizon 2020 programme under the URBAN GreenUP project to highlight the multiple benefits of green spaces and green interventions through the introduction of Nature Based Solutions into urban city areas. This project will trial and monitor a number of different Nature Based Solutions and in turn address issues arising from climate change, surface water flooding and connectivity as well as seeking to positively contribute to improvements in health and wellbeing, enhanced biodiversity and socio-economic improvements.

In 2010 The Mersey Forest produced the **Liverpool Green Infrastructure Strategy, 2010** which was commissioned by Liverpool City Council Planning Service in partnership with Liverpool Primary Care Trust (PCT) to improve public health through the planning of green

infrastructure. The strategy presents a robust evidence base to support decision-making in the Local Development Framework and other strategic plans for the city, as well as to developing a city-wide Green Infrastructure Strategy identifying interventions that can help address environmental and socio-economic needs and capitalise on opportunities. Five priorities have been identified to deliver this vision; a sustainable city; a city providing natural choices for health; a cool city; a green and biodiverse city; and a city where green infrastructure is well-planned. The Liverpool Green Infrastructure Strategy was developed to maximise the benefits that the city can gain from the sustainable management of its natural environment and has been sued as the methodological foundation for the city diagnosis. The strategy remains a useful guide for city planners and has helped to define thinking on the development of the Local Plan. The Green Infrastructure Strategy sets out the direction for the future of NBS in the city and has been instrumental in bidding for and taking a lead partner role in the Horizon 2020 URBAN GreenUP project.

Transport and Connectivity

Under Section 108 of the Transport Act 2000, all transport authorities are required to produce a Local Transport Plan (LTP) in which they set out their objectives and plans for transport development. Typically, they contain policies, strategy and implementation plans which can be reviewed independently of each other. The **A Transport Plan for Growth, Liverpool City Region Combined Authority, 2015 (Local Transport Plan) -** Merseyside1 and Halton2 LTPs were published in 2011 and run to 2024 and 2026 respectively. They provide the statutory framework under which policies and plans are taken forward in each local authority area to guide the future provision of transport. Their publication marked the end of a sustained period of evidence gathering and consultation, which determined where and how transport investment could best be targeted to enable the Liverpool City Region to meet its goals and aspirations.

The Transport Plan for Merseyside is supported by the city's Active Travel Strategy (2011), which focussed on continued improvement and expansion of facilities to encourage cycling and walking, which will have major health benefits, contribute to reducing carbon and increase accessibility to employment and services. Planned schemes including City Centre Connectivity and public realm investment will continue to improve the pedestrian and cycle network. Planned schemes support active travel connections within the City Centre including from the main transport hubs to Liverpool Knowledge Quarter and Waterfront schemes. Liverpool's Cycling Revolution, a cycling strategy for the city was produced by the city council to promote increased investment in pedestrian and cycle networks. However, there are further opportunities to link developments along the Mersey Estuary with public transport hubs. This has the added benefit of providing an alternative to travel by car, combined with health benefits. In terms of the cycling, there are just under 100 kilometres of dedicated cycle infrastructure in Liverpool, comprising a mixture of on-road cycle lanes, designated cycle routes (National Routes 56 and 62) and off-road paths10. In terms of the condition of the

walking and cycling infrastructure 43% of footways failed inspection. This lack of suitable infrastructure is a contributing factor towards diminishing the attractiveness of walking and cycling as a mode of transport throughout the city, in particular for cycling trips as demonstrated in the low levels of cycling as a mode of 'Travel to Work' (i.e. 2% based on Census 2011 statistics). **The draft Liverpool Local Plan 2017 (in preparation)/National Planning Policy Framewor**k will make use of these policies to help shape sustainable transport in the city. As discussed previously the Draft Local Plan dictates that new developments should make provision for cycle parking. Proposals should also demonstrate best practice in design for walkers and cyclists alike, ensuring high quality, accessible town centres and routes into the City Centre. The Draft Local Plan identifies cycling as an increasingly important mode of transport, especially for short trips, in an effort to reduce reliance on the car. Relevant to encouraging individuals to travel via bicycle is the provision of facilities such as conveniently located cycle parking. The city is currently reviewing and planning to expand its citybike cycle scheme into neighbouring boroughs. There are approximately 1,000 bikes available for hire from 140 docking stations across Liverpool and there have been around 300,000 rentals to date, with usage up significantly year on year, and those using the bikes have cycled a total of 1.4 million miles so far. The scheme is currently being reviewed and re-scoped with an intention to extend it into neighbouring boroughs along popular routes.

To ensure that non-vehicular transport grows there is an ongoing programme of structural works being undertaken through the **Rights of Way Improvement Plan for Merseyside, Merseyside Local Transport Plan Partnership (2008)**. There is an extensive network of walking and cycle routes across Merseyside with over 458 kilometres of Public Rights of Way. These routes run through Liverpool and extend out towards Knowsley, Sefton and St Helens, providing a diverse range of routes. The Rights of Way Improvement Plan for Merseyside identified the areas of North Liverpool, Kirkby and Bootle as areas with a fragmented and disjointed cycle network in need of improvement. In addition the following policies can also be used to promote sustainable transport within and across Liverpool:

- Local Cycling and Walking Investment Strategy (national document) and the Local Cycling and Walking Infrastructure Plan. Liverpool have recently submitted and Expression of Interest to the Department for Transport to get support to develop this further
- Local Journeys Strategy (draft)
- Highways Asset Management Plan
- Supplementary Planning Document Ensuring a Choice of Travel. This sets minimum standards for cycle parking dependant on the type and size of development. It also requires an assessment of access for all modes including walking, cycling and public transport.

5. AIR QUALITY

Introduction

Air quality matters as it results in a significant economic and health impact on the city's residents and businesses both in the immediate area of concern and surrounding areas. The scientific understanding of the health effects of everyday health pollution has changed in recent years; population effects of poor air quality are now better understood and causality has been demonstrated. Actions to address the health impacts of air pollution can play a critical role in supporting other local priorities, such as active travel, health inequalities, localism and community engagement, sustainability and growth and regeneration.

Air pollution also damages biodiversity, reduces crop yields and contributes to climate change.

The burden of particulate air pollution in the UK in 2008 was estimated to be equivalent to nearly 29,000 deaths at typical ages and an associated loss of population life of 340,000 life years lost (COMEAP 2010). It is estimated that in the UK air pollution reduces overall life expectancy by seven to eight months, with estimated annual health costs of up to £20 billion.

National Legislation and Guidance

The Environment Act 1995 requires the UK government to prepare a National Air Quality Strategy. The UK National Air Quality Strategy (NAQS) was therefore published in March 1997 setting out policies for the management of ambient air quality. The strategy sets objectives for eight pollutants which may potentially occur in the UK at sulphur dioxide, carbon monoxide, lead, fine particulate matter (PM10), benzene, 1, 3–butadiene and ozone. The Strategy was reviewed and a Review Report and Consultation Document were published by the Department of the Environment, Transport and the Regions in 1999. Following this the City set out its own **Air Quality Strategy (AQS)** in 1997. The objectives within this have been revised and strengthened over recent years, particularly for a number of pollutants with the exception of that for fine particulate matter, which was replaced with the less stringent EU limit value. The objectives for the eight pollutants in the strategy provide the basis of the implementation of Part IV of the Environment Act 1995. The Air Quality Strategy objectives for each pollutant, except ozone, were given statutory status in the Air Quality (England) Regulations, 20003 and Air Quality (England) (Amendment) Regulations 2004. In 2007 the Air Quality Strategy was revised again. This latest strategy does not remove any of the objectives set out in the previous strategy or its addendum, apart from replacing the provisional 2010 objective for PM10 in England, Wales and Northern Ireland with the exposure reduction approach for PM2.5. The UK Government and the Devolved Administrations have now therefore set new national air quality objectives for particulate matter smaller than 2.5µm diameter (PM2.5). **The Air Quality Standards Regulations 2010** set legally binding limits for concentrations in outdoor air of major air pollutants that impact public health such as particulate matter (PM10 and PM2.5) and nitrogen dioxide (NO2). As well as having direct effects, these pollutants can combine in the atmosphere to form ozone, a harmful air pollutant (and potent greenhouse gas) which can be transported great distances by weather systems. Levels of nitrogen dioxide (NO2), emitted

mostly by diesel vehicles, have been above legal limits in almost 90% of urban areas in the UK since 2010. The toxic fumes are estimated to cause 23,500 early deaths a year and the problem was declared a public health emergency by a cross-party committee of MPs in April 2016.

In 2017, in response to court action over missed air quality standards, the government produced its draft document on Improving UK Air Quality. The final document will be published in the latter half of 2017. The Secretary of State for Environment, Food and Rural Affairs has responsibility for meeting the limit values in England and the Department for Environment, Food and Rural Affairs (Defra) co-ordinates assessment and air quality plans for the UK as a whole.

Local Strategy and Policy and Implementation

Liverpool's Air Quality Action Plan presents a series of actions for reducing levels of air pollution in the city in order to comply with UK and European Union health-based air quality standards. The original action plan produced in 2005 that covered two specific areas was updated in 2008 as a result of a worsening air quality across the whole of the city. A number of actions have been taken locally and these include:

- Promotion of low emission transport
- Introduction of voluntary quality bus partnerships
- Installation of Recharging points for ultra-low emission vehicles
- Upgrading of local bus fleet via the Clean Bus Technology Fund
- Improved traffic management
- Introduction of school and work travel plans

Under the Environment Act 1995, Local Authorities are required to undertake regular review and assessments of air quality. In Liverpool the range of pollutants monitored includes NO_2 and also particulate matter PM10s and 2.5s. Monitoring across Liverpool currently shows that the annual mean concentration for nitrogen dioxide across the city exceeds the EU limit value of 40ug/m^3. Source apportionment across Liverpool is calculated by use of the Merseyside Air Emissions Inventory (MAEI). Information is collated and input into the MAEI and from this the main sources of air pollution can be calculated and apportioned. For example over 50% of all nitrogen dioxide and particulate matter is traffic related; the remainder is from industry and domestic use. In direct response to the poor air quality in Liverpool there is now strong political support to improve the city's air quality through a shift away from diesel and petrol based vehicle emissions alongside the future introduction of clean air zones.

6. WELLBEING

Introduction

Sedentary lifestyles and obesity are also some of the most critical health issues of our time and there is much evidence that green and open spaces are an essential element of a healthy human habitat and crucial in enhancing community health and wellbeing (Croucher et al 2008). More specifically green and open spaces have been shown to protect people from harmful exposure such as flooding, air pollution, noise and extremes of temperature (Intelligent Health, 2016, Pugh et al 201, Regional Public Health, 2010, Rao et al, 2014). Similarly accessible and safer urban green spaces have a positive influence on levels of physical activity as long as the space is well maintained and safe to use (Intelligent Health 2016, Bird, 2004, Coombes, Jones and Hillsdon 2010) and green and open spaces offer a site for regular physical activity which can reduce the risk of coronary heart disease, obesity and diabetes (Rydin et al 2012).

National Legislation and Guidance

The **Health and Social Care Act 2012** introduced the first legal duties about health inequalities. It included specific duties for health bodies including the Department of Health, Public Health England, Clinical Commissioning Groups, and NHS England which require the bodies to have due regard to reducing health inequalities between the people of England. The Act also brought in changes for local authorities on public health functions.

- Health and wellbeing boards are a formal committee of the local authority charged with promoting greater integration and partnership between bodies from the NHS, public health and local government. They have a statutory duty, with clinical commissioning groups (CCGs), to produce a joint strategic needs assessment and a joint health and wellbeing strategy for their local population.
- At the local level, the Act gives local authorities the responsibility for improving the health of their local populations. The Act requires directors of public health to publish annual reports that can chart local progress.
- The Government believes that many of the wider determinants of health (for example, housing, economic development, transport) can be more easily impacted by local authorities, who have overall responsibility for improving the local area for their populations. Local authorities are well-placed to take a very broad view of what services will impact positively on the public's health, and combine traditional "public health" activities with other activity locally to maximise benefits.

The **Social Value Act** which was later introduced in 2012 requires public sector commissioners – including local authorities and health sector bodies – to consider economic, social and environmental wellbeing in procurement of services or contracts

More specifically there are a number of key guidelines and frameworks which collectively help to guide delivery of this agenda today. These are listed below.

- The **National Institute for Clinical Excellence (NICE) guideline [NG70] Air pollution: outdoor air quality and health (2017).** This guideline covers road-traffic-related air pollution and its links to ill health. It aims to improve air quality and so prevent a range of health conditions and deaths. It is aimed at: local authority staff working in: planning, local air quality management and public health, including environmental health; staff working in transport and highways authorities; local government elected members; employers; healthcare professionals, people working in the voluntary sector, non-governmental organisations and education and members of the public.
- **The Public Health Outcomes Framework** *'Healthy lives, healthy people: Improving outcomes and supporting transparency'* sets out a vision for public health, desired outcomes and the indicators that will help us understand how well public health is being improved and protected. The framework concentrates on two high-level outcomes to be achieved across the public health system, and groups further indicators into four 'domains' that cover the full spectrum of public health. The outcomes reflect a focus not only on how long people live, but on how well they live at all stages of life. The fraction of annual all-cause adult mortality attributable to anthropogenic (human-made) particulate air pollution (measured as fine particulate matter, PM2.5*) is one of the health protection indicators specified in the report.
- **Air Quality: A briefing for Directors of Public Health (2017)** DEFRA together with Public Health England have published a toolkit which provides details on how local authorities can use the Public Health Outcomes Indicator to specify appropriate mitigation measures to reduce the impact of both short term and long term exposure of air pollution. The guide emphasises the importance of communication and engagement amongst all relevant local stakeholders on air quality issues.
- **Fair Society, Healthy Lives (the Marmot Report), 2010** has been critical to the delivery of public health in England from 2011 and beyond. The Marmot report identifies six policy objectives to help reduce health inequalities, one of which is to '*create and develop healthy and sustainable places and communities'*. A further policy recommendation suggests that improving the availability of good quality open and green spaces across the social gradient alongside improving active travel (for example walking and cycling); the integration of the planning, transport, housing, environmental and health systems can help to reduce health inequalities.
- **Cycling and Walking Investment Strategy (DT 2017)**. Government cycling and walking the natural choices for shorter journeys, or as part of a longer journey.
- **World Health Organisation (2017).** *Urban green space interventions and health*: A review of impacts and effectiveness. (2017). The new findings show that interventions to increase or improve urban green space can deliver positive health, social and environmental outcomes for all population groups, particularly among lower socioeconomic status groups.
- Great Outdoors: How Our Natural Health Service Uses Green Space To Improve Wellbeing. An action report. A Faculty of Public Health report in association with Natural England 2010.

- Faculty of Public Health (2013) Built environment & physical activity. A position statement

Local Strategy and Policy and Implementation

At a local level **The Liverpool Active City Strategy 2014-21** sets out the vision for Liverpool to be the most active city in England by 2021. Physical activity is the city's top priority for prevention, specifically by tackling inactivity. The delivery programme is resourced by Liverpool City Council and Liverpool Clinical Commissioning Group in partnership with strategic stakeholders. Other programmes help to promote activity. For example, **'Fit For Me'** is a social movement which aims to inspire people living and working in Liverpool to be more physically active. The campaign promotes the benefits of physical activity and shares real-life stories of people who have benefitted from becoming active. It provides information and support through the website, social media and activity finder, enabling people to find the right fit for them, from walking through to water sports. In Liverpool this campaign is delivered by NHS Liverpool Clinical Commissioning Group and Liverpool City Council as part of the 'Living Well' programme.

Another example is **'This Girl Can'** which is the city's local activation of the national This Girl Can campaign, developed by Sport England, together with a wide range of partnership organisations. It's a celebration of active women aged 14+ up and down the country who are doing their thing no matter how well they do it, how they look or even how red their face gets. In Liverpool, real life stories of the TGC Champions, key messages and opportunities are shared via the website and social media to inspire local women to be more active.

Locally, Neighbourhood Physical Activity and Sport programmes play a key role and target the least active areas of the City through a range of exercise schemes. Examples of local delivery under the neighbourhood Physical Activity and Sport programmes include:

- Exercise for Health and 4ever Active (enabling adults with a long-term health conditions to access pathways to an active lifestyle through fitness classes, cycling, walking and swimming)
- Mamafit- Exercise and lifestyle scheme for pregnant women and mothers which supports women to be active and healthy during pregnancy and into the early stages of motherhood.
- Capacity building across the third sector with a focus on training and supporting volunteers to enable more people to be more active
- Inclusive Sport programmes coordinated by a range of organisations enabling hundreds of people with a disability the opportunity to be more active and
- Partnership working with Everton in the Community and Liverpool FC Foundation; Liverpool School Sport Partnership and Merseyside Sports Partnership.

The Liverpool Cycling Strategy **"Liverpool Cycling Revolution" 2014-2024** sets out the vision for Liverpool to become the fastest growing cycling City in the UK. In Liverpool the Cycle Hire Scheme provides 160 stations and 100 bikes to hire and there is Walk/Cycle Leader training

supporting over 40 organisations and groups to deliver activity targeting the inactive across the City.

Activity networks are also spread across the city, embedded in the Health System, the workplace and into schools and community organisations and together these networks help to.

- Embed physical activity across the Health System by increasing the awareness of the benefits of physical activity and delivery of brief advice/referrals across Primary and Secondary Care – since April 2016, 63,000 primary care patients have been asked about their physical activity levels, with 50% not meeting guidelines and 90% of these being offered brief advice
- Promote an Active Workplace Programme – 82 organisations have signed up across the public, third and private sector in Liverpool; promoting the benefits of physical activity and encouraging employees to become more active.
- Support the Children and Young People Strategic Plan, which seeks through schools and community organisations to engage children and young people in becoming more active.

References:

Climate Change

UK Climate projections (UKCP09). *https://data.gov.uk/apps/uk-climate-projections-ukcp09*

Kyoto Protocol (2005). http://unfccc.int/kyoto_protocol/background/items/2879.php

The UK Climate Change Act (2008). *https://www.theccc.org.uk/tackling-climate-change/the-climate-change-act/*

The National Adaptation Programme. *https://www.gov.uk/.../adapting-to-climate-change-national-adaptation-programme*

The Carbon Emissions Trading System (2005). https://ec.europa.eu/clima/policies/ets_en

The Renewable Energy Directive (2009). http://ec.europa.eu/energy/en/topics/renewable-energy/renewable-energy-directive

The Energy Bill (2010). *https://www.gov.uk/government/.../energy-bill-2010-to-2011-impact-assessments*

Liverpool City Climate Change Strategic Framework (2009). http://liverpool.gov.uk/council/strategies-plans-and-policies/environment-and-planning/climate-change-strategic-framework/

Liverpool Adaptation Framework Report (2009). http://liverpool.gov.uk/council/strategies-plans-and-policies/environment-and-planning/climate-change-strategic-framework/

EU Covenant of Mayors. *www.covenantofmayors.eu*

Liverpool Sustainable Energy Action Plan (SEAP). *www.meas.org.uk/media/3342/Liverpool-City-Region-SEAP-1st-Edition-130712.pdf*

Forestry Commission (2009). *Combating Climate Change - a role for UK forests.* *https://www.forestry.gov.uk/readreport*

DEFRA (2010). *Climate Change Action Plan.* *www.defra.gov.uk/publications/files/pb13358-climate-change-plan-2010-100324.pdf*

Forestry Commission (2004). *The Woodland Carbon Code*. *https://www.forestry.gov.uk/carboncode*

Water and Flooding

The Pitt Review (2007)
http://webarchive.nationalarchives.gov.uk/20100702215619/http://archive.cabinetoffice.gov.uk/pittreview/thepittreview/final_report.html

The EU Floods Directive (2007/60/EC). http://ec.europa.eu/environment/water/flood_risk/

The Flood Risk Regulations 2009.
http://webarchive.nationalarchives.gov.uk/20140809133216tf_/http://www.legislation.gov.uk/uksi/2009/3042/contents/made

The Flood and Water Management Act (2010). http://www.legislation.gov.uk/ukpga/2010/29/contents

Strategic Flood Risk Assessment (2008).
http://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwjL3L_dvt7VAhUkJsAKHeQ4CGQQFggtMAA&url=http%3A%2F%2Fgeosmartinfo.co.uk%2Fwp-content%2Fuploads%2Fsfra%2FLiverpool-strategicfloodriskassessment.pdf&usg=AFQjCNFVKUT9oql6Y1H4P4wGAG9HPjgnIw

Environment Agency, Mersey Estuary Catchment Flood Management Plan (2010).
https://www.gov.uk/government/publications/mersey-estuary-catchment-flood-management-plan

Draft Liverpool Local Plan (September 2016). http://liverpool.gov.uk/council/strategies-plans-and-policies/environment-and-planning/plan-making-in-liverpool/current-local-plan-documents/local-plan/

A Waterspace Strategy for the Sustainable Development of the Liverpool South Docks, British Waterways (2012).
https://www.engageliverpool.com/.../Liverpool_South_Docks_Waterspace_Strategy_No

Strategic Waterway Plan, Canal and River Trust (2013). *https://canalrivertrust.org.uk/media/library/3903.pdf*

Environment Agency, Flood and Coastal Erosion Risk Management Investment Programme 2015 to 2021 – republished August 2015
https://www.gov.uk/government/publications/programme-of-flood-and-coastal-erosion-risk-management-schemes

Biodiversity

The National Parks and Access to the Countryside Act (1949). *https://uk.practicallaw.thomsonreuters.com/0-508-5372*

The Wildlife and Countryside Act (1981), as amended. http://jncc.defra.gov.uk/page-1377

The UK Biodiversity Action Plan (1994). http://jncc.defra.gov.uk/page-5155

The Countryside and Rights of Way (CRoW) Act (2000). http://jncc.defra.gov.uk/page-1378

Natural Environment and Rural Communities Act (2006). http://jncc.defra.gov.uk/page-5705

The National Planning Policy Framework (2012). *https://www.gov.uk/government/publications/national-planning-policy-framework--2*

Biodiversity Strategy for England – Biodiversity 2020: A Strategy for England's Wildlife and Ecosystem Services, (2011).

https://www.gov.uk/.../biodiversity-2020-a-strategy-for-england-s-wildlife-and-ecosys...

The UK National Ecosystem Assessment (2011). http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx

The Natural Environment White Paper (2011). *The Natural Choice: Securing the Value of Nature* *https://www.gov.uk/government/.../the-natural-choice-securing-the-value-of-nature*

The Lawton Report Making Space for Nature, (2010). *https://www.gov.uk/.../making-space-for-nature-a-review-of-englands-wildlife-sites-p*

The Localism Act (2011) . *https://www.gov.uk/government/publications/localism-act-2011-overview*

Fields in Trust Guidance for Outdoor Sport and Play: Beyond the Six Acre Standard (October 2015) *https://www.theplayingfield.org.uk/fields-in-trust-publishes-new-online-guidance-for-...*

Safeguarding our Soils (2009). *A strategy for England.* *https://www.gov.uk/government/.../safeguarding-our-soils-a-strategy-for-england*

Green Infrastructure – Development

Liverpool Local Plan 2017 (in preparation)/National Planning Policy Framework ; supported by the Sustainable Urban Development Strategy, Liverpool City Region, 2015 and Liverpool City Centre Strategic Investment Framework, Liverpool Vision
http://liverpool.gov.uk/council/strategies-plans-and-policies/environment-and-planning/plan-making-in-liverpool/current-local-plan-documents/local-plan/
https://www.gov.uk/government/publications/national-planning-policy-framework--2

Liverpool's Sustainable Development Plan, (2005). http://liverpool.gov.uk/council/strategies-plans-and-policies/environment-and-planning/sustainable-development-plan/

Green Infrastructure - Greenspace

Greenprint for Growth (year). *www.liverpoolvision.co.uk/news/.../north-liverpool-south-sefton-greenprint-growth/*

Liverpool Open Space (Assessment and Standards Report) Study 2017. *(In preparation*). Liverpool City Council.

Liverpool Strategic Green and Open Spaces Review (2014-2016). www.liverpool.gov.uk/greenandopenspaces

Liverpool Green Infrastructure Strategy (2010). *www.greeninfrastructurenw.co.uk/liverpool*

Green Infrastructure – Transport and Connectivity

A Transport Plan for Growth, Liverpool City Region Combined Authority (2015).
https://www.merseytravel.gov.uk/.../localtransport.../8375%20Plan%20for%20growt..

Active Travel Strategy (2011). *https://www.merseytravel.gov.uk/.../Annexe%2006%20-%20Active%20Travel%20Str...*

Liverpool's Cycling Revolution, A cycling strategy for Liverpool (2014-2026).
http://liverpool.gov.uk/council/strategies-plans-and-policies/roads-and-transport/cycling-strategy/

Liverpool Local Plan 2017 (in preparation)/National Planning Policy Framework (2012).
http://liverpool.gov.uk/council/strategies-plans-and-policies/environment-and-planning/plan-making-in-

liverpool/current-local-plan-documents/local-plan/*https://www.gov.uk/government/publications/national-planning-policy-framework--2*

Rights of Way Improvement Plan for Merseyside, Merseyside Local Transport Plan Partnership, 2008.

Local Cycling and Walking Investment Strategy, (2017) https://www.gov.uk/government/publications/cycling-and-walking-investment-strategy
Local Cycling and Walking Infrastructure Plan

Local Journeys Strategy (draft). Liverpool City Council.

Highways Asset Management Plan. Liverpool City Council

Supplementary Planning Document Ensuring a Choice of Travel (2008).
http://liverpool.gov.uk/council/strategies-plans-and-policies/environment-and-planning/plan-making-in-liverpool/current-local-plan-documents/ensuring-a-choice-of-travel-spd/

Committee on the Medical Effects of Air Pollutants (COMEAP)
https://www.gov.uk/government/groups/committee-on-the-medical-effects-of-air-pollutants-comeap

Croucher et al (2008). *The links between greenspace and health: A critical literature review*. Stirling: Greenspace Scotland.

Bird, W (2016). Intelligent Health Review of evidence of nature and health and plan for Liverpool: A Report, Reading: Intelligent Health. Preventative Medicine, 49, (6) p 50 -505

Pugh et al (2012). *Effectiveness of Green Infrastructure for Improvement of Air Quality in Urban Street Canyons.* Environ. Sci. Technol.,46,7692-7699.

Regional Public Health, (2010). *Healthy Open Spaces: A summary of the impact of open spaces on health and wellbeing.* Regional Public Health Information paper, Lower Hutt: Hutt Valley District Health Board, Greater Wellington Region, New Zealand.

Rao et al (2014*).* *Assessing the relationship among urban trees, nitrogen dioxide and respiratory health.* Environmental Pollution, 194, 96-104.

Bird, W. (2016). *Intelligent Health Review of evidence of nature and health and plan for Liverpool: A report.* Reading: Intelligent Health. Preventative Medicine, 49, (6) pp.50 -505

Bird, W. (2004). Natural Fit: Can Green Space and Biodiversity Increase Levels of Physical Activity?

Coombes, Jones and Hillsdon (2010). *The relationship of physical activity and overweight to objectively measured green space accessibility and use*. Social Science and Medicine 70(6): 816-822

Rydin et al (2012). *Shaping cities for health: complexity and the planning of urban environments in the 21st century*. Lancet 2;379 (9831):2079-108

Air Quality

The Environment Act (1995) http://www.legislation.gov.uk/ukpga/1995/25/contents

The Air Quality Strategy (AQS) 1997, 2000, 2007.
https://www.gov.uk/government/publications/the-air-quality-strategy-for-england-scotland-wales-and-northern-ireland-volume-1

The Air Quality Standards Regulations (2010) https://www.gov.uk/government/publications/2010-to-2015-government-policy-environmental-quality/2010-to-2015-government-policy-environmental-quality

Liverpool's Air Quality Action Plan (2008) updated.
http://liverpool.gov.uk/council/strategies-plans-and-policies/environment-and-planning/air-quality/

Wellbeing

Jenkins et al (2009). *UK Climate Projections*: Briefing Report. Exeter.

National Institute for Clinical Excellence (NICE) guideline [NG70] Air pollution: outdoor air quality and health (2017). https://www.nice.org.uk/guidance/ng70

Air Quality: A briefing for Directors of Public Health (2017). http://www.fph.org.uk/policy_reports

Fair Society, Healthy Lives (the Marmot Report), 2010

Cycling and Walking Investment Strategy (2017). https://www.gov.uk/government/publications/cycling-and-walking-investment-strategy

World Health Organisation (2017). Urban green space interventions and health: A review of impacts and effectiveness. Full report.
http://www.euro.who.int/en/health-topics/environment-and-health/urban-health/publications/2017/urban-green-space-interventions-and-health-a-review-of-impacts-and-effectiveness.-full-report-2017

Great Outdoors: How Our Natural Health Service Uses Green Space To Improve Wellbeing (2010).
http://www.euro.who.int/en/health-topics/environment-and-health/urban-health/publications/2017/urban-green-space-interventions-and-health-a-review-of-impacts-and-effectiveness.-full-report-2017

9 Appendix 2 Evidence

The EU commissioned Eklipse framework sets out ten key city challenges (Fig. 1) which drive the use of Nature-Based Solutions (NBS) in urban areas. These ten challenges focus on the understanding and interaction of environmental resources with economic development and socio-cultural well-being to promote more livable, sustainable and prosperous cities. To fully realize the links between these ten challenges and the ways in which innovative NBS can be used to deliver them individually, and as a collective whole, there is a need to provide a robust evidence base on their function, value and deliverability within the landscape and urban planning context appropriate for Liverpool. The following sections present that evidence base.

Fig 1. City Challenges based on EU Eklipse methodology

In conjunction with Fig. 1 it is also important to set the parameters of what we consider a sustainable and liveable city to be. This needs to include reflections on ecological and human health, as well as the ways in which climate and the approach to economic development influence spatial form of NBS within it. Table 1 outlines the characteristics that are used for the Liverpool frontrunner city to contextualize its use of NBS. The following sections provide a

robust evidence base supporting the use of each of the 'city' types proposed in Table 1 illustrating economic, social and ecological evidence explaining how green infrastructure and NBS can benefit landscape and urban development.

Table 1 Working characteristics of sustainable city approaches

Sustainable City	Urban Regeneration, green space management, promotion of economic opportunities and green jobs, participatory planning and governance
Cool City	Coastal resilience, water management, climate adaptation and mitigation
Healthy City	Air quality, public health and wellbeing, social justice and social cohesion, access to nature
Biodiverse City	Ecological networks, sustainable water management, pollinators, connected biodiverse habitats, scaled investment in green space
Economically Viable City	Commercial, educational and industrial options for growth, connected via several modal options, attractive and livable premises, attractive living environment, inviting location, multi-functional urban form to meet various needs

9.1 Sustainable City

The creation of a *sustainable city* is a key goal of the Liverpool Green Infrastructure Plan[118,119] and the developing Liverpool Local Plan[120]. The city views its coastal location with excellent transport and logistical links as key assets to promote economic development, whilst the innovation and social capital of the city's businesses and communities is driving the city forward. Liverpool's landscape is therefore the final piece of the sustainability puzzle, as it provides climatic, ecological and human-environmental affordances which make the city livable.

The city's network of Victorian Parks form a green wheel[121] that crosses the city, the River Mersey and the city's canal system provide key habitats and the growing understanding of visible and interactive nature within and across the city are ensuring that people live within walking distance of a multi-functional green space. Consequently, Liverpool's environment is not only able to attract businesses and tourists but also to provide a high-quality environment for people to live and work.

However, to ensure that green infrastructure and NBS are embedded within development and management objectives within the city there is an ongoing need to align our understanding of

[118] The Mersey Forest (2010) Liverpool Green Infrastructure Strategy. Risley Moss, Mersey Forest.
[119] The Mersey Forest (2017) Green Infrastructure Action Plan Background: Liverpool City Central and Commercial Business Improvement District. Risley Moss, Mersey Forest.
[120] Liverpool City Council (2016) The Draft Liverpool City Local Plan, September 2016). Liverpool, Liverpool City Council.
[121] Liverpool City Council (2016) Strategic Green & Open Spaces Review, Final Report. Liverpool, Liverpool City Council.

connectivity, access to nature and promoting multi-functionality with a set of quantifiable characteristics that promote social and economic development.

9.1.1 Green environment for retail

Green infrastructure can play a role in creating a pleasant environment in city centres, which increases footfall and revenue in retail areas. Shoppers claim that they will spend 9% to 12% more for goods and services in central business districts having high quality tree canopy[122]. Shoppers indicate that they will travel greater distance and a longer time to visit a district having high quality trees, and spend more time there once they arrive.[123]

9.1.2 Attracting and retaining skilled and productive workforce

Quality of life is becoming an increasingly important consideration in modern business location decisions, in particular in the high-tech and knowledge industries, and cities with attractive parks and natural surroundings are more likely to attract knowledge workers[124]. In particular for small businesses and individuals on high salaries, the quality of life becomes more important than remuneration (potentially 40% of decisions can be based on quality of life indicators)[125]. Greener settings not only attract but also help to retain workers: businesses located next to green spaces in Glasgow recorded improved staff morale and staff retention rates due to the attractiveness of the location[126]. Green infrastructure also improves productivity: office workers who enjoyed a natural view out of the window reported fewer physical ailments and greater job satisfaction compared to those workers without a view[127]. Even the presence of office plants may increase the speed of completing tasks, lower levels of stress and improve attention[128].

9.1.3 Attracting investment and increasing employment

The presence of high quality green infrastructure can improve the 'investability' of an area and its

122 Wolf, K.L. 2010. Community Economics - A Literature Review. In: Green Cities: Good Health (www.greenhealth.washington.edu). College of the Environment, University of Washington
123 Wolf, K.L. (2005) Business District Streetscapes, Trees, and Consumer Response. Journal of Forestry. 103, 8, pp. 396- 400.
124 Crompton JL (2007) Competitiveness: Parks and Open Space as Factors Shaping a Location's Success in Attracting Companies, Labor Supplies, and Retirees in de Brun C (Ed.) The economic benefits of land conservation. The Trust for Public Land, pp.48-54.
125 Shapiro, J.M. (2006) Smart Cities: Quality of Life, Productivity, and the Growth Effects of Human Capital. The Review of Economics & Statistics, 88, 2, pp. 324-335.
126 Gen Consulting (2006) Glasgow Green Renewal Benefits Analysis. A report to Glasgow City Council. Gen Consulting, Glasgow.
127 Kaplan R (1993) The role of nature in the context of the workplace. Landscape and Urban Planning 26: 193-201.
128 Lohr VI, Pearson-Mimms CH & Goodwin GK (1996) Interior plants may improve worker productivity and reduce stress in a windowless environment. Journal of Environmental Horticulture 14: 97-100.

competitiveness as a business location[129,130]. A survey of real estate developers and consultants across Europe found that 95% of respondents believe that open space adds value to commercial property, and they would be willing to pay at least 3% more to be in close proximity to open space[131]. Research focusing on the construction sector in the UK illustrates a comparable willingness by investors to include green infrastructure in their development due to the added rental/sales returns they generate[132.] An example of returned investment in green infrastructure can be seen in Riverside Park Industrial Estate in Middlesbrough, where extensive planting of trees helped to create a setting for stimulating business growth, which attracted new, high profile, occupants; increased occupancy from 40% to 78%; levered over £1m of private investment; and saw 28 new businesses and more than 60 new jobs created[133]. Landscaping improvements in Portland Basin, Tameside and Winsford, Cheshire yielded respectively over 16% and 13% of net growth in employment[134]. Furthermore, green infrastructure could help to make towns more attractive for investment, and increase the profitability of businesses by increasing staff productivity. A number of studies have demonstrated this latter effect[135], which operates through improved health, stress alleviation, and attracting and retaining motivated people.

9.1.4 Higher property prices in greener areas

Many studies have looked at the impact of green infrastrucrture on property value in urban areas. All have found that green infrastructure increases value[136]. In North West England, a view of a natural landscape added up to 18% to property value, and residents in peri-urban settings are willing to pay £7,680 per household for views of broadleaved woods[137]. The development of a community woodland on the former Bold Colliery site in St Helens have enhanced existing property values in the surrounding area by £15 million[138]. Research in central Manchester highlighted willingness to pay higher local taxes that could contribute over £4 million per annum when extrapolated to the city scale[139]. In Aberdeen, properties next to a park can attract a premium of 0.4%-19% compared to a property located 450m away from a

[129] BE Group (2014) Green Infrastructure - Added Value - http://www.merseyforest.org.uk/BE_group_green_infrastructure.pdf
[130] CABE (2004) The Value of Public Open Spaces. Commission for Architecture and the Built Environment, London.
[131] Gensler and Urban Land Institute (2011) Open Space: an asset without a champion? Available at: http://www.gensler.com/uploads/documents/Open_Space_03_08_2011.pdf
[132] Payne, S. & Baker, A. (2015) Implementing green infrastructure through residential development in the UK. In: Sinnett, D., Smith, N., & Burgess, S. (Eds) (2015) Handbook on Green Infrastructure: Planning, design and implementation. Pp. 375-394. Cheltenham, Edward Elgar Publishing.
[133] CLES POLICY ADVICE. 2007. The Contribution of the Local Environment to the Local Economy presented to Groundwork UK.
[134] BE Group (2014) Green Infrastructure-Added Value- http://www.merseyforest.org.uk/BE_group_green_infrastructure.pdf
[135] Other issues include the effectiveness and economic impact of worksite interventions to promote physical activity and healthy diet. World Health Organisation, 2008; Windows and Offices: A Study of Office Worker Performance and the Indoor Environment, California Energy Commission, 2003
[136] Davies, H., Doick, K., Handley, P., O'Brien, L., and Wilson, J. (2017). Delivery of ecosystem services by urban forests Forestry Commission Research Report Forestry Commission, Edinburgh. i–iv + 1–28pp.
[137] Cousins and Land Use Consultants (2009). Economic contribution of green networks: current evidence and action. North West Development Agency, Manchester.
[138] Forestry Commission (no date) Bold Colliery Community Woodland. District Valuer's report on Property Values. Forestry Commission
[139] Mell, IC., Henneberry, J, Hehl_Lange, S. & Keskin, B. (2013) Promoting urban greening: Valuing the development of green infrastructure investments in the urban core of Manchester, UK. Urban Forestry & Urban Greening. 12, 3, pp. 296-306.

park[140]. Trees have been reported to add between 4% and 25% to the total value of property, depending on their size, condition, location and species[141,142]. Another study found that high quality green infrastructure can boost property values by up to 20%[143]. Overall, green areas are vital to the UKs economic competitiveness:

A view of a park was shown to raise house prices by 8 per cent, and having a park nearby by 6 per cent[144]. This compares with a view of an apartment block, which can reduce the price by 7 per cent[145]

The Chartered Association of Building Engineers (2004) as citing Luttik (2000)

This is likely due to the multiple benefits that trees provide: they make an area more visually attractive, but also reduce air pollution and provide a variety of microclimates that can make an area more comfortable (especially shade in summer). Our understanding of the existing housing stock, local amenities, and development trends all need to be accounted for before assessing the added-value of investment in NBS and green infrastructure to generate valid results[146].

9.1.5 High quality gateways to the city

The visual amenity of green space can create attractive gateways to the city, which is often a key first impression for investors. Pleasant journeys to and from work also contribute to a higher quality of life of residents and reduced stress levels[147,148]. Commercial developments

[140] Dunse N, White M & Dehring C (2007) Urban parks, open space and residential property values. RICS Research Paper Series. RICS, London.
[141] 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.
[142] CTLA (2003) Summary of tree valuation based on CTLA approach. Council of Tree and Landscape Appraisers.
143 BE Group (2014) Green Infrastructure – Added Value. Available at: http://www.merseyforest.org.uk/BE_group_green_infrastructure.pdf
144 CABE (2004) The Value of Public Space: How high quality parks and public spaces create economic, social and environmental value: http://webarchive.nationalarchives.gov.uk/20110118095356/http:/www.cabe.org.uk/files/the-value-of-public-space.pdf
145 Luttik, J. (2000) 'The value of trees, water and open spaces as reflected by house prices in the Netherlands'. Landscape and Urban Planning, Vol. 48, pp161-167.
146 Mell, IC., Henneberry, J., Hehl-Lange, S. & Keskin, B. (2016) To green or not to green: Establishing the economic value of green infrastructure investments in The Wicker, Sheffield. Urban Forestry & Urban Greening, 18, pp. 257-267.
147 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.
148 Antonson, H., Mårdh, S., Wiklund, M. & Blomqvist, G. (2009) Effect of surrounding landscape on driving behaviour: A driving simulator study. Journal of Environmental Psychology, 29, 4, pp. 493-502.

alongside major roads leading to the city that contain trees are generally preferred to both developments without trees and undeveloped agricultural land without trees[149].

9.1.6 Cost-benefit of green vs. grey infrastructure

Evidence from the UE, North America and increasingly Asia the added-value that green infrastructure can deliver to urban landscapes. This can be in the form of increased house prices, reduced health costs, improved resilience to climate change or the promotion social interactions150. Where investment in green infrastructure occurs it, generally, is cheaper to implement, cheaper to maintain and provides a greater number of affordances for uses that more traditional grey/built infrastructure[151]. Moreover, the ongoing costs of maintaining green space is significantly lower than comparable engineered investments, especially in terms of water/flood management[152]. However, engineers and developers remain reluctant to transfer their focus onto green infrastructure because the evidence is less grounded and more contemporary. There is a significant body of research though that identifies using cost-benefit analysis the returns that can be generated by investment in green infrastructure[153]

9.1.7 Reducing flood risk

Investing in green infrastructure to manage pluvial and fluvial resources is central to mainlining the functionality of our cities. Working with Environment Agency, water utilities companies and Local Authorities urban greening can be used to developed innovative sustainable drainage systems that work at the local, city and regional scale. This includes the use and creation of water bodies of flood event sinks and locations for supplying water to urban areas[154]. Green infrastructure can also be used to develop targeted woodland planting where it can “Slow the Flow” and act as seasonal biodiversity hubs as seen in the Chicago Wilderness project[155]. The development of Urban Catchment Forestry approaches can maximise the value of urban trees for flood risk reduction and are increasingly being scoped to address flooding in

149 Crompton JL (2007) Competitiveness: Parks and Open Space as Factors Shaping a Location’s Success in Attracting Companies, Labor Supplies, and Retirees in de Brun C (Ed.) The economic benefits of land conservation. The Trust for Public Land, pp.48-54.
150 James et al. (2009) Towards an integrated understanding of green space in the European built environment. Urban Forestry & Urban Greening. 8, 2, pp. 65-75.
151 South Yorkshire Forest Partnership & Sheffield City Council (2012) The VALUE Project: The Final Report. Sheffield, South Yorkshire Forest Partnership & Sheffield City Council.
152 Naumann, S,. Davis, M., Kaphengst, T., Pieterse, M. & Rayment, M. (2011) Design, implementation and cost elements of Green Infrastructure projects. Final report to the European Commission, DG Environment, Contract no. 070307/2010/577182/ETU/F.1. Ecologic institute and GHK Consulting
153 New York City Environmental Protection (2010) NYC Green Infrastructure Plan: A Sustainable Strategy for Clean Waterways. New York, New York City Environmental Protection.
154 Benedict, MA. & McMahon, ET. (2006) Green Infrastructure: Linking Landscapes and Communities. Washington DC, Island Press.
155 Mell, IC. (2016) Global Green Infrastructure: Lessons for successful policy-making, investment and management. Abingdon, Routledge.

coastal and terrestrial areas such as Liverpool[156]. Moreover, following extensive flooding in Cumbria, JBA consulting and Lancaster University undertook dynamic modelling of the Eden, Kent and Derwent catchments and found:

The combined effects of enhanced wet canopy evaporation, infiltration and surface roughness associated with the addition of deciduous trees to key locations in the landscape produced significant reductions to flood peaks even for an event as extreme as Desmond [157]

9.1.8 Managing runoff

Green infrastructure intercepts, infiltrates, stores and evaporates rainwater, thereby reducing the rate and peak volume of water entering drains and limiting the risk of them being overwhelmed during extreme rainfall. Peri-urban and even rural woodlands (in the riparian zone and floodplain) can contribute to flood alleviation in urban areas by delaying the downstream passage of flood flows[158].

Green infrastructure can play a part in reducing flood risk, especially in dealing with the increased risk likely to be caused by climate change. Trees can play a role in intercepting rain, channelling rainwater into the soil and also "slowing" the flow of water in an area; reducing surges on sewer systems[159]. Trees with larger canopies are most effective at intercepting water[160,161]. Individual tree canopies can intercept as much as 79% of a 20mm, 24-hour rainfall event under optimum, full leaf conditions[162] A single young tree planted in a small pit over an impermeable asphalt surface can reduce runoff by around 60%, even during the winter when it is not in leaf[163]. Tree roots can increase infiltration rates in compacted soils by 63%, and in severely compacted soils by 153%[164]. Increasing tree cover by 10% in built-up town centres can

[156] The Mersey Forest (nd) http://www.merseyforest.org.uk/our-work/urban-catchment-forestry/
[157] Hankin et al (2016) The Rivers Trust Life-IP Natural Course Project: Strategic Investigation of Natural Flood Management in Cumbria. http://naturalcourse.co.uk/uploads/2017/04/2016s4667-Rivers-Trust-Life-IP-NFM-Opportunities-Technical-Report-v8.0.pdf
[158] Forest Research (2010) The case for trees in development and the urban environment. Britsol, Forestry Commission
[159] Davies, H., Doick, K., Handley, P., O'Brien, L., and Wilson, J. (2017). Delivery of ecosystem services by urban forests Forestry Commission Research Report Forestry Commission, Edinburgh. i–iv + 1–28pp.
160 Nisbet, T. (2005) Water Use by trees. Forestry Commission Information Note, Forestry Commission, Edinburgh
[161] Inkiläinen, E.N.M., McHale, M.R., Blank, G.B., James, A.L. & Nikinmaa, E. (2013) The role of the residential urban forest in regulating throughfall: A case study in Raleigh, North Carolina, USA. Urban Forestry & Urban Greening, 119, 91-103.
[162] Xiao and McPherson (2003). Rainfall interception by Santa Monica's municipal urban forest. Urban Ecosystems, 6: 291–302.
[163] Armson et al (2013). The effect of street trees and amenity grass on urban surface water runoff in Manchester, UK. Urban Forestry Urban Greening, 12: 282–286.
[164] Bartens et al (2008). Can urban tree roots improve infiltration through compacted subsoils for stormwater management? Journal of Environmental Quality, 37 (6): 2048-2057.

reduce runoff from an 18mm rainfall event by 8%[165]. Urban runoff is a source of urban diffuse pollution, containing pollutants such as metals and chemicals from road transport, faecal matter from animal fouling, and sediment[166]. Trees in biofiltration systems resulted in significant reductions of soluble nitrogen and phosphorus in storm water, compared to unplanted controls; reducing nitrate plus nitrite (NO-2) by 2-78% and reactive phosphorus by 70-96% (PO43-), depending on the soil profile167. Suggesting capabilities to filter faecal pollution and dry nutrient deposition from exhausts and industry, biofilm and heterotrophic process may reduce nutrient concertation too. 168. The annual storm water benefit of an urban tree is $34 (equivalent to £26) from a sample of 17 US cities169, with cities including Chicago and Philadelphia gaining significant benefits from investment in urban green infrastructure170,171. A hectare of grassland and broadleaved woodland in the UK can also help evaporation of 3.4 and 4.0 million litres of water respectively[172]. Modelling conducted on Manchester shows that adding 10% of green space can reduce runoff by 5-6%[173]. Several of these options can be scaled up from the site, i.e. an individual buildings or streets to become wider neighbourhood initiatives and provide important management strategies, especially in locations with variable rainfall or climates.

9.1.9 Reducing the risk of river and coastal flooding

The risk of flooding from rivers and the sea can be reduced by a series of measures, for rivers they can be restored in channel or through their connected floodplain, through leaky barriers and through offline attenuation areas. In coastal margins, salt marshes, mudflats, sand dunes and beeches can be managed to reduce flood risk, for instance beaches can be nourished through sand-scaping. River restoration measures create space for water, allowing water to spill out of banks and sometimes into palaeo or relict river channels, leaky dams attenuate peak flows and levels, forcing water onto the floodplain before it would otherwise travel downstream. Saltmarshes and mudflats dissipate waves and tidal surges, beech nourishment advances the foreshores, offering some natural protection.

[165] Gil, S.l (2006). Climate change and urban greenspace. PhD thesis, University of Manchester.
[166] Defra (2012). Tackling water pollution from the urban environment: Consultation on a strategy to address diffuse water pollution from the built environment.
[167] Denman et al (2012). The use of trees in urban stormwater management. Trees, people and the built environment. Proceedings of the Urban Trees Research Conference. 104-112.
[168] Denman et al (2012). The use of trees in urban stormwater management. Trees, people and the built environment. Proceedings of the Urban Trees Research Conference. 104-112.
[169] Averaging data from 17 US cities presented on p11 of: US EPA (2013). Stormwater to Street Trees – Engineering urban forests for stormwater management.
[170] Chicago Wilderness (nd) http://www.chicagowilderness.org/index.php
[171] Philadelphia Water Department (2011) Green City, Clean Waters: The City of Philadelphia's Program for Combined Sewer Overflow Control. Philadelphia, Philadelphia Water Department.
[172] Hölzinger O (2011) The Value of Green Infrastructure in Birmingham and the Black Country. The Total Economic Value of Ecosystem Services provided by the Urban Green Infrastructure. The Wildlife Trust for Birmingham and the Black Country.
[173] See Gill et al. (2007)

Trees increase the capacity of the soil to absorb water. A modelling study in Somerset showed that planting woodland along a 2.2 km grassland reach of the River Cary could reduce water velocity by 50%, increase the temporary water retention by 71% and delay the downstream progression of the flood peak by 140 minutes[174]. Restoring riparian forest cover over 20-40% of one catchment area reduced flood peak magnitude by up to 19%, whilst engineered log jams to hold back flow increases or decreases peak flows by 6%[175]. Salt marshes also help to dissipate wave energy before it reaches the shore, and it has been estimated that an 80m-wide zone of inter-tidal habitat fronting sea walls can save £4,600 per metre in sea defence costs.[176]

9.1.10 Maintaining sustainable water supplies

Water Sensitive Urban Design can also help to increase groundwater recharge through porous paving systems and detention ponds allowing water to reach, de-compact and infiltrate the soil[177]. The maintenance of water supply of an appropriate quality and quantity is important in providing a reliable service for homes and businesses. Sustainable drainage and the intervention of green infrastructure in and on homes, businesses and on municipal infrastructure will provide options to intercept, retain and release of rainfall and runoff in a controlled manner[178]. Natural water retention measures have been observed to increase groundwater table considerably, suggesting that Runoff Attenuation Features (RAFs) and trees together can recharge groundwater supplies[179,180].

NFM also aids municipal water planners and utilities companies to manage flow through a greater awareness of the added-capacity that natural systems can provide in support of engineered solutions[181]

[174] Thomas H & Nisbet TR (2006) An assessment of the impact of floodplain woodland on flood flows. Water and Environment Journal 21: 114-126

[175] DIXON, S.J., SEAR, D.A., ODONI, N.A., SYKES, T. AND LANE, S., 2016. The effects of river restoration on catchment scale flood risk and flood hydrology. Earth Surface Processes and Landforms, 41 (7), 997-1008.

[176] Collins T, Empson B, Leafe R & Lowe J (1997) Sustainable flood defence and habitat conservation in estuaries - a strategic framework. . In Proceedings of the 32nd MAFF Conference of River and Coastal Engineers. University of Loughborough, July 2-4, 1997

[177] Carter T & Butler C (2008) Ecological impacts of replacing traditional roofs with green roofs in two urban areas. Cities and the Environment 1: 9-17.

[178] Williamson, K. (2003) Growing with Green Infrastructure. Doylestown, Heritage Conservancy.

[179] Hut, R, Ertsen, M, Joeman, N, Vergeer, N, Winsemius, H, Van de Giesen, N. 2008. Effects of sand storage dams on groundwater levels with examples from Kenya. *Physics and Chem-istry of the Earth*. ***33:*** 56 – 66

[180] Mack, TJ., Chornack, MP, Vining, KC, Amer, SA, FahimZaheer, M, Meldin, JH. 2014. Water Resources Activities of the U.S. Geological Survey in Afghanistan From 2004 Through 2014. United States Geological Survey. Fact Sheet 2014–3068; USGS Afghanistan Project Product No. 265. Available at: https://pubs.usgs.gov/fs/2014/3068/pdf/fs2014-3068.pdf (Accessed: 12th February 2017).

[181] Falkenmark, M. & Rockström, J. (2006) The New Blue and Green Water Paradigm: Breaking New Ground for Water Resources Planning and Management. Journal of Water Resources Planning and Management, 132, 2, pp. 129-132.

9.2 Healthy City

Cities the provide opportunities for its population to engage with its landscape are considered to be healthier and more sustainable[182]. Whilst a one-size fits all solution is unviable in most cities there is scope to characterize what a healthy city should be and what green infrastructure and NBS provision can do to assist in this process[183].

9.2.1 Better mental health

The cost of stress to the UK economy stood at £6.8bn in 2014, with ACAS figures reporting that mental ill-health (including stress, depression and anxiety) caused 91 million lost working days each year, with sickness absence costing £8.4 billion each year, £15.1 billion loss in reduced productivity, and £2.4 billion in the cost of replacing lost staff184. The World Health Organisation forecasts depression to be the second greatest health concern globally by 2020. Contact with nature in green space has been shown to reduces stress and improves attention185, whilst unsatisfactory access to green space had been found to be related to mental ill-health by a study in Greenwich, London186. Research investigating residents in a Swedish town found that the more often a person visits urban open green spaces, the less often they will experience stress related illnesses187. Playing in green spaces and living in greener areas has also been shown to have a beneficial impacts on the levels of concentration and the ability to focus attention of children[188,189,] thereby improving their performance at school. Lower levels of stress associated with the use of green space enable people do cope better with major life issues, such as the effects of poverty in low-income areas of Chicago[190]. There is also an evidence for synergistic physical and mental health improvements related to contact with nature discussed through the notion of interaction and 'environmental

[182] Tzoulas et al. (2007) Promoting ecosystem and human health in urban areas using Green Infrastructure: A literature review. Landscape and Urban Planning, 81, 3, 167-178.
[183] Kabisch et al. (2016) Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action. Ecology and Society, 21, 2, 39.
[184] Zehndorfer, E., Mackintosh, C. & Darko, N. (2016) Outdoor recreation as a potential lever for health improvement: A review of the health benefits, barriers and opportunities for the sector: Evaluation Report. Manchester, Manchester Metropolitan University.
[185] Kaplan R & Kaplan S (1989) The experience of nature: A psychological perspective, Cambridge University Press.
186 Guite HF, Clark C & Ackrill G (2006) The impact of the physical and urban environment on mental well-being. Public Health 120, 1117-1126.
[187]Grahn P & Stigdotter UA (2003) Landscape planning and stress. Urban Forestry and Urban Greening 2: 1-18.
[188] Taylor AF, Kuo FE & Sullivan WC (2001) Coping with ADD: The surprising connection to greenplay settings. Environment and Behavior 33: 54-77.
[189] Wells NM (2000) At home with nature: effects of "greenness" on children's cognitive functioning. Environment and Behavior: 32: 775-795.
[190] Kuo F E (2001) Coping with poverty: impacts of environment and attention in the inner city. Environment and Behaviour 33, 5–34.

affordances'[191]. For example, patients recovering from a surgical procedure were found to heal much quicker and require less painkillers if they had a view of nature out of their window compared to those without such a view[192].

9.2.2 Mental health of young people

There is a growing evidence base to support the proposal that contact with nature increases resilience against stress, anxiety and irritability, along with other factors that may cause young people to develop mental health disorders[193] (see Maller et al., 2008 for a synthesis of relevant evidence[194]). However, limited information on how specific elements of nature deliver health outcomes restricts its use for enhancing population health (Shanahan et al 2014). As a consequence mental health disorders have become a major issue in modern society as their prevalence was significantly underestimated historically (1). Mental disorders in young people, in particular, have grown in significance and with up to 20% of young people suffering at any one time, both in Europe and worldwide (3, 4). Common disorders found in populations of young people include anxiety, depression and behavioural disorders (Mental health stats, 6); with these issues increasing consistently over the last few decades (7). Young people suffer from mental health disorders usually due to a combination of biological, psychological and social factors, which can range from genetic tendencies and illnesses to academic failure, destructive lifestyles and bullying (7). Human disconnection with nature is related to poorer health195. The influence of chronic stress on depression appears definitive[196],[197], with research suggesting that depressive symptoms intensify during periods of persistent stress[198]. Chronic stress may also be a precursor to anxiety disorders (Bernstein, 2015), which is supported by prevalence rates[199]. Chronic stress can also worsen disease progression across a number of non-communicable conditions according to the World Health Organisation (WHO). The degree of comorbidity between chronic stress, anxiety and depression is extremely high[200]

[191] Louv, R. (2005) Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder. Chapel Hill, Algonquin Books
[192] Ulrich RS (1984) View through a window may influence recovery from surgery. Science 224: 420-421.
[193] Pretty et al. (20106) the mental and physical health outcomes of green exercise. International Journal of Environmental Health Research, 15, 5, pp. 319-337.
[194] Maller et al., (2008) Healthy Parks, healthy people: The health benefits of contact with nature in a park context – a review of relevant literature. Melbourne, School of Health and Social Development, Faculty of Health, Medicine, Nursing and Behavioural Sciences, Deakin University.
[195] Louv, R. (2005) Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder. Chapel Hill, Algonquin Books
[196] van Praag (2004) Can stress cause depression? Progress in Neuro-Psychopharmacology and Biological Psychiatry
[197] Marin et al. (2011) Chronic stress, cognitive functioning and mental health. Neurobiology of Learning and Memory, 96, 4, 583-595.
[198] Fred et al. (2015) The differential influence of life stress on individual symptoms of depression. Acta Psychiatrica Scandinavica, 131, 6, pp. 465-471.
[199] Arborelius, Owens, Plotsky & Nemeroff (1999) The role of corticotropin-releasing factor in depression and anxiety disorders. Jounral of Endochrinology, 160, pp. 1-12.
[200] Bondi et al. (2008) Chronic Unpredictable Stress Induces a Cognitive Deficit and Anxiety-Like Behavior in Rats that is Prevented by Chronic Antidepressant Drug Treatment. Neuropsychopharmacology, 33,

and this association is strengthened by chronic environmental stressors. Those living in deprived areas are exposed to a higher risk of depression compared to those living in more affluent regions[201,202]. Contact with nature through the medium of green space encourages psychological well-being[203] and can lessen the negative impact of a stressful life[204]. Moreover, research[205] has explored how stress can be reduced through access to nature, where results indicated a significant relationship between the quantity of green space within the local environment, self-reported stress and cortisol levels. It was concluded that providing green space in deprived communities may enhance well-being[206]. Adding to this, the more individual visits green space, the less they will report stress[207]. Furthermore, if individuals have access to green space locally within their neighbourhood, the advantageous effects are enhanced. The distance between areas of residence and green zones is equally important in predicting levels of stress[208].

9.2.3 Forest school and health

A range of Forest School outcomes have been identified, including positive learning dispositions, strengthened self-esteem and enriched children's practices in the early years209. Forest School provides opportunities for children to develop confidence and self-esteem through their experiences. For example, adults using the Forest School approach in schools and early year settings have reported that quiet children aged 5 to 11 years had an increased ability to express themselves and had improved confidence[210]. Further research[211] conducted in the UK evaluated children attending Forest School sessions using observations conducted by

320-331.

[201] Silver, E., Mulvey, EP. & Swanson, JW. (2002) Neighborhood structural characteristics and mental disorder: Faris and Dunham revisited. Social Science & Medicine, 55, 8, pp. 1457-1470

[202] Matheson et al. (2006) Urban Neighborhoods, chronic stress, gender and depression. Social Science & Medicone, 63, 10, pp. 2604-2616.

[203] Pretty et al. (2007) Green exercise in the UK countryside: Effects on health and psychological well-being, and implications for policy and planning. Journal of Environmental Planning & Management, 50, 2, 211-231.

[204] van den Berg, Maas, Verheij & Groenewegen (2010) Green space as a buffer between stressful life events and health. Social Science & Medicine, 70, 8, pp. 1203-1210.

[205] Ward-Thompson et al. (2012) More green space is linked to less stress in deprived communities: Evidence from salivary cortisol patterns. Landscape and Urban Planning, 105, 3, pp. 221-229.

[206] Roe et al. (2013) Green Space and Stress: Evidence from Cortisol Measures in Deprived Urban Communities. International Journal of Environmental Research and Public Health, 10, 9, pp. 4086-4103.

[207] Grahn, P. & Stigsdotter, U.A., 2003. Landscape architecture and stress. Urban Forestry and Urban Greening 2 (1), 1–18.

[208] Nielsen, T. & Hansen, K., 2007. Do green areas affect health? Results from a Danish survey on the use of green areas and health indicators. Health Place 13, 839–850.

[209] O'Brien, L. (2009) Leaning ourdoors: the Forest School approach. Education 3-13: International Journal of Primary, Elementary and Early Years Eudcation, 27, 1, pp. 45-60.

[210] O'Brien, L. (2009) Leaning ourdoors: the Forest School approach. Education 3-13: International Journal of Primary, Elementary and Early Years Eudcation, 27, 1, pp. 45-60.

[211] O'Brien, L. & Murray, R. (2007) Forest School and its impacts on young children: Case studies in Britain. Landscape and Urban Planning, 6, 4, pp. 249-265.

the Forest School leaders over an 8-month period. The observations indicated that children's self-esteem and confidence increased. Notably, positive changes in children's language and communication skills, improvements in physical motor skills and a greater knowledge, care for and understanding of the environment were observed during the Forest School program[212]. Research has also been conducted with primary school-aged children to explore their thoughts, perceptions, and experiences of Forest School. Overwhelmingly, children typically report positive experiences and that Forest School is enjoyable and fun to do[213,214]. Broad Futures and Norfolk County Council reported that teachers viewed Forest School as a 'child-led approach [that] build confidence, encourages creativity and promotes independence which are essential skills for learning and for life' (p.11).

The restorative effects of Forest School for children and young people have also been investigated. Changes to positive participation were demonstrated during Forest School sessions by higher levels of verbal communication with peers reported by teachers[215], whilst increases in social interactions, self-esteem and concentration have been noted in children with special educational needs and shy children[216]. One study reported that Forest School provided an optimal learning environment, whereby children's wellbeing and involvement levels were very high during Forest School sessions, subsequently supporting children's learning as well as their wider developmental needs[217]. The results of this study were particularly pertinent for those children who had low school academic achievement levels. Roe and Aspinall[218] found that teenagers classified as having 'good' and 'bad' behaviour by the schools benefitted from Forest School sessions, with those in the 'bad' behaviour group including those with ADHD, those at risk of exclusion or those exhibiting withdrawn behaviour, experiencing optimal benefits in particular. Forest School could, therefore, facilitate the management of challenging behaviours, and/or positively influence health and wellbeing. The Mersey Forest and the Physical Activity Exchange at Liverpool John Moores University are

[212] O'Brien, L. & Murray, R. (2007) Forest School and its impacts on young children: Case studies in Britain. Landscape and Urban Planning, 6, 4, pp. 249-265.
[213] Ridges, ND., Knowles, ZR. & Sayers, J. (2012) Encouraging play in the natural environment: a child-focused case study of Forest School. Children's Geographies, 10,1, pp. 49-65.
[214] Broad Futures & Norfolk County Council (2007) Forest School Using a Forest School experience as a stimulus for speaking and listening, with a focus on raising achievement in boys writing using ICT. Norwich, Broad Futures & Norfolk County Council.
[215] Swarbrick, Eastwood, & Tutton (2004) Self-esteem and successful interaction as part of the forest school project. SfL: Support for Learning, 19, 3, 142-146.
[216] Slade, M., Lowery, C. & Bland, K. (2013) Evaluating the impact of Forest Schools: a collaboration between a university and a primary school. SfL: Support for Learning, 28, 2, pp. 66-72.
[217] Kenny, R. (2010) Involve, Enjoy, Achieve: Forest School and the Early Years Foundation Stage – An Exploratory Case Study. Bath: Bath Spa University.
[218] Roe, J. & Aspinall, P. (2011) The restorative outcomes of forest school and conventional school in young people with good and poor behavior. Urban Forestry & Urban Greening, 10, 3, 205-212.

collaborating on a Forest School study investigating whether Forest School sessions increase physical activity in children, supporting improved mental health and wellbeing[219].

In addition to the role that physical activity can play in promoting physical and mental health there is a growing discussion of how 'mindful contact' with nature as part of Forest School could also facilitate better health and well-being. To tackle chronic stress, mindfulness-based interventions (MBIs) aim to focus an individual on their moment-by-moment experience[220]. As a result, they can effectively manage and respond to mental processes which trigger emotional anguish and maladaptive behaviour[221]. Furthermore, the stress-reduction techniques taught through mindfulness meditation can be utilised to help prevent relapse of major depressive disorders[222]. For the psychological advantages of green space to be enhanced, a connection with nature should be encouraged. Studies conducted by the University of Oregon[223] established that those who displayed more mindfulness traits also demonstrated a greater connection with nature, which, in turn, implemented a shift towards psychological well-being. This view has been extended to explain that a well-established relationship with nature can enhance psychological and emotional health in ways that cannot be elicited by alternative means[224]. Mindfulness therefore allows an enhanced sensory experience when present in nature, one which strengthens the connection to it. This mindfulness and nature connection positively correlates with psychological well-being[225]. Being connected with nature comforts the constantly thinking mind, calming its restlessness and easing concerns and allows the mind to be still and quiet is taught through MBIs, encouraging people to be mindful within nature can allow people to find peace within themselves[226]. Therefore, nature relatedness could provide a path to reduce chronic stress[227].

[219] Austin, C., Z. Knowles, and J. Sayers. 2013. "Investigating the Effectiveness of Forest School Sessions on Children's Physical Activity Levels." The Mersey Forest in Partnership with the Physical Activity Exchange at Liverpool John Moores University.
[220] Kabat-Zinn, J. (1990). Full catastrophe living: Using the wisdom of your body and mind to face stress, pain and illness. New York, Delacorte.
[221] Bishop, S. R., Lau, M., Shapiro, S. L., Carlson, L., & Anderson, N. D. (2004). Mindfulness: A proposed operational definition. Clinical Psychology: Science and Practice, 11, 230–241.
[222] Teasdale, JD., Segal, Z. & Williams, JMG. (1995) How does cognitive therapy prevent depressive relapse and why should attentional control (mindfulness) training help? Behaviour Research & Theory, 33, 1, pp. 25-39.
[223] Wolsko, C. & Lindberg, K. (2013) Experiencing Connection With Nature: The Matrix of Psychological Well-Being, Mindfulness, and Outdoor Recreation. Ecopsychology, 5, 2, 80-91.
[224] Brymer, E., Cuddihy, TF. & Sharma-Brymer, V. (2012) The Role of Nature-Based Experience in the Development and Maintenance of Well-Being. Asia-Pacific Journal of Health, Sport and Physical Education, 1, 2, pp. 21-27.
[225] Howell et al. (2011) Nature connectedness: Associations with well-being and mindfulness. Personality and Individual Differences, 51, 2, 166-171.
[226] Coleman, M. (2010) Awake in the Wild: Mindfulness in Nature as a Path to Self-Discovery. Maui, Inner Ocean Publishing, Inc.
[227] Zelenski, J. M., & Nisbet, E. K. (2014). Happiness and feeling connected: The distinct role of nature relatedness. Environment and Behavior, 46, 3–23

9.2.4 Social well-being

Social interaction between residents of all ages in the same area develop mainly through outdoor contacts and green and open spaces such as parks and gardens attracts people to use these spaces[228]. For example, CABE Space[229] discussed the collectivism of parks for South Asian and Afro-Caribbean communities in the UK, whilst neighbourhoods with open spaces in Chicago, reported that 83% more individuals engaged in social activity in green spaces than in barren spaces.[230] Furthermore, older people and families with young children are more likely to engage with other people in parks and green spaces compared to other places[231]. The use of green spaces can positively influence the quantity and strength of social relationships of diverse groups, including older adults[232], teenagers from different ethnic backgrounds[233], and female residents of social housing[234].

9.2.5 Space for exercise

A study in the UK235 found that a higher proportion of green space in an area was generally associated with better population health. Living closer to parks has thus been shown to be linked to increased physical activity236,237, such as walking and cycling238. Whilst the majority of the exercise in parks tends to be gentle (over 56% of park users in London simply walk or stroll)239, it still has a positive impact on people's health. A study in Tokyo shows that presence of walkable green space increases the longevity of the elderly240. In England, people

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[228] Coley RL, Kuo FE & Sullivan, WC (1997) Where does community grow? The social context created by nature in public housing. Environment and Behavior 29: 468-494.
[229] CABE Space (2005) Start with the park: Creating sustainable urban green spaces in areas of housing growth and renewal. London, CABE Space.
[230] Sullivan WC, Kuo FE & DePooter SF (2004) The fruit of urban nature. Vital neighbourhood spaces. Environment and Behavior 36: 678-700.
[231] Bedimo-Rung, AL., Mowen, AJ. & Cohen, DA. (2005) The significance of parks to physical activity and public health: A conceptual model. American Journal of Preventative Medicine, 28, 2, 159-168.
[232] Kweon B-S, Sullivan WC & Wiley AR (1998) Green common spaces and the social integration of inner-city older adults. Environment and Behavior 30: 832-858.
[233] Seeland K, Duebendorfer S & Hansmann R (2008) Making friends in Zurich's urban forests and parks: The role of public green space for social inclusion of youths from different cultures. Forest Policy Economics 11: 10-17.
[234] Kuo FE, Sullivan WC, Coley RL & Brunson L (1998) Fertile ground for community: Inner-city neighbourhood common spaces. Americal Journal of Community Psychology 26: 823-851.
[235] Mitchell R & Popham F (2007) Green space, urbanity and health: relationships in England. Journal of Epidemiology and Community Health 61: 681-683.
[236] Kaczynski A & Henderson KA (2007) Environmental correlates of physical activity: A review of evidence about parks and recreation. Leisure Sciences 29: 315-354.
237 Coombes E, Jones A & Hillsdon M (2010) The Relationship Of Physical Activity And Overweight To Objectively Measured Green Space Accessibility And Use. Social Science And Medicine 70: 816-822.
238 Zlot, AI. & Schmid, TL. (Relationships Among Community Characteristics And Walking And Bicycling For Transportation Or Recreation. American Journal Of Health Promotion 19: 314-7.
239 *Synovate (2009) The Royal Parks in-park research report 2009 – All parks combined. The Royal Parks, London.*
240 Takano, T., Nakamura, K. & Watanabe, M. (2002) Urban Residential Environments And Senior Citizens' Longevity In Megacity Areas: The Importance Of Walkable Green Spaces. Journal of

who live furthest from public parks are 27% more likely to be overweight or obese, and children able to play in natural green space gain 2.5 kg less per year than children who do not have such opportunities241. There is also evidence suggesting that people are more likely to walk or cycle if streets are lined with trees242. In The Mersey Forest, the "Green Streets" programme led to a 6% increase in cycling to work from local residents[243]. Moreover, The Woodland Trust Woodland Standard suggests people should have access to a woodland of at least 2 ha within walking distance (500 m) from their home, and a woodland of at least 20 ha within 4 km of their home[244] The urban deprived and Black, Asian and Minority Ethnic groups are more likely to access urban rather than rural nature compared to other population groups[245].

9.2.6 Space to grow food

Participation in food growing projects offers a growing opportunity to increase physical activity and increase consumption of fresh fruit and vegetables. Urban allotments in the UK, USA and Italy have seen extensive uptake from local communities, and particularly from older people who have benefited from the physical exercise and social interactions[246],[247]. Moreover, psychological benefits are possible, due to contact with nature, increased serotonin through sunlight exposure, sense of achievement, and enhanced social networks.[248]

9.2.7 Improving air quality

In 2012 the Woodland Trust published an extensive evidence-based review related to urban air quality[249]. Trees are very effective at removing pollutants which are harmful to human health from the atmosphere, as they absorb gases including as ozone, nitrogen dioxide, sulfur dioxide,

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Epidemiology and Community Health 56: 913-918.

241 Natural England (2009) Green Space Access, Green Space Use, physical activity and overweight: a research summary.

242 Neilsen. A.B. and Hansen, R.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), 839-50

243 The Mersey Forest (nd) http://www.merseyforest.org.uk/our-work/green-streets/

244 Woodland Trust (nd). Position Statement: Access to woodland. https://www.woodlandtrust.org.uk/mediafile/100034294/access-position-statement-1013.pdf

245 Evison, S., Friel, J., Burt J. & Preston, S. (2013) Kaleidoscope: Improving support for Black, Asian and Minority Ethnic communities to access services from the natural environment and heritage sectors. Natural England Commissioned Reports, Number 127.Peterboroguh, Natural England.

246 Mell, IC. (2016) Global Green Infrastructure: Lessons for successful policy-making, investment and management. Abingdon, Routledge.

247 Schmelzkopf, K. (2002) Incommersurability, land use, and the right to space: community gardens in New York City. Urban Geography, 23, 4, 323-343.

248 Leake JR, Adam-Bradford A & Rigby JE (2009) Health benefits of 'grow your own' food in urban areas: implications for contaminated land risk assessment and risk management? Environmental Health 8 (Suppl 1): S6.

249 The Woodland Trust (2012) Urban Air Quality: Discussion Paper. Grantham, The Woodland Trust

and help to deposit pollutant particles smaller than 10 microns in diameter (PM10)[250]. Up to 70% of air pollution in cities can be filtered out by investments in street trees[251]. For example, doubling the number of trees in the West Midlands would reduce excess deaths due to particulate pollution by up to 140 per year[252]; just 5% of green space including trees within a 10 x 10 km^2 of East London could significantly reduce particulate pollution with an estimated effect of two deaths and two hospital emissions avoided per year[253]. Furthermore, the positioning of trees, with consideration of local air flows including along arterial roads within cities significantly affects the removal of pollutants from the atmosphere. In terms of health benefits areas with street trees have been found to reduce the incidence of childhood asthma[254]. As well as filtering pollution from the atmosphere, trees also produce Volatile Organic Compounds (VOCs), which in certain conditions can cause increases in ozone pollution. The Urban Tree Air Quality Score attempts to balance the pollution removal and VOC emission effects of different tree species[255]. Trees in closer proximity to a pollution source will be more effective at mitigating it, thus locating trees between areas of high pollution such as roads and vulnerable areas such as playgrounds, schools, hospitals and residential areas should be prioritised[256]

9.2.8 Reducing noise

The effectiveness of vegetation in reflecting and absorbing noise depends on the density, height, length and width of planting[257]. Dense shrubs combined with trees are the most effective; up to 10 decibels/20 metres width can be achieved[258]. In less dense settings, every 33m width of forest can achieve 7 decibel noise reduction[259] . Visibility and width of a tree belt are more important for reducing noise than height and length (which become insignificant

[250] Nowak DJ (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.
[251] Bernatzky A (1983) The effects of trees on the urban climate. In: Trees in the 21st century. Academic Publishers, Berkhamsted, 59–76. Based on the first International Arboricultural Conference.
[252] Centre for Ecology and Hydrology (nd) Trees and sustainable urban air quality. CEH, Lancaster. Available at: http://www.es.lancs.ac.uk/people/cnh/docs/UrbanTrees.htm
[253] Tiwary A, Sinnett D, Peachey C, Chalabi Z, Vardoulakis S, Fletcher T, Leonardi G, Grundy C, Azapagic A & Hutchings TR (2009) An integrated tool to assess the role of new planting in PM_{10} capture and the human health benefits: A case study in London. Environmental Pollution 157: 2645-2653.
[254] Lovasi et al (2008) Children living in areas with more street trees have lower prevalence of asthma. Journal of Epidemiology & Community Health, 62, pp. 647-649.
[255] Donovan et al (2005) Development and Application of an Urban Tree Air Quality Score for Photochemical Pollution Episodes Using the Birmingham, United Kingdom, Area as a Case Study. Environmental Science & Technology, 39, 17, pp. 6730-6738.
[256] Escobedo et al. (2011) Urban forests and pollution mitigation: Analyzing ecosystem services and disservices. Environmental Pollution, 8-9, 2078-2087.
[257] Bolund, P. & Hunhammer, S. (1999) Ecosystem services in urban areas. Ecological Economics, 29, 2, 293-301.
[258] Fang C-F & Ling D-L (2003) Investigation of the noise reduction provided by tree belts. Landscape and urban Planning 63: 187-195.
[259] Coder RD (1996) Identified Benefits of Community Trees and Forests, University of Georgia Cooperative Extension Service - Forest Resources Publication FOR96-39.

above 4 m and 50 m respectively)[260] Densely planted tree belts and deep woodlands have greater relative noise attenuation than sparsely planted trees or shallow woodlands[261].

A major recreation resource

Over 40% of people in England visit parks at least once a week, and only 7% never use parks[262]; 87% of the population use their local parks or open spaces regularly[263]. Urban parks in England are estimated to receive 2.6 billion visits a year[264], making parks the most frequently used public service[265].The majority of the public believe that parks and open spaces improve their quality of life (90%) and that they are important to physical and mental well-being (74%)[266]. This is illustrated by activities in parks: the main reasons for visiting the Royal Parks in London are 'for a walk or stroll' (54%), 'for fresh air' (33%) and 'peace and quiet' (25%), the average visit taking 72 minutes[267]. In a survey in Amsterdam, nearly three-quarters of the respondents went to parks to relax and 54% to listen and observe nature[268]. Sport is an important activity: for example, Leicester's urban green spaces were found to support 1,985 team games a year involving 54,249 men and 1,136 women[269]. However, people over 65, the disabled, black and ethnic minorities (BME groups), women and 12-19 year-olds use parks less frequently[270]. Whilst less than 10% of people in the UK do not visit parks for fear of their personal safety[271],[272] research in Leicester shows that this disproportionately affects the above groups[273].

[260] Fang, C-F. & Ling, D-L. (2003) Investigation of the noise reduction provided by tree belts. Landscape and Urban Planning, 63, 4, pp. 187-195.
[261] Huddart, L. (1990). *The use of vegetation for traffic noise screening*. Crowthorne, Berkshire: U. K. Transport and Road Research Laboratory Research Report, p 238.
[262] CABE Space (2010) Urban green nation: Building the evidence basis. London, CABE Space
[263] DCLG (2008) Place Survey: England. London, DCLG.
[264] DTLR (2002) Improving urban parks, play areas and green spaces. London, Department for Transport, Local Government and Regions.
[265] CABE Space (2010) Urban green nation: Building the evidence basis. London, CABE Space
[266] CABE Space (2004) Public Attitudes to Architecture and Public Space: Transforming neighbourhoods. London, CABE Space
[267] Synovate (2009) The Royal Parks in-park research report 2009 – All parks combined. The Royal Parks, London.
[268] Chiesura A (2004) The role of urban parks for the sustainable city. Landscape and Urban Planning 68: 129-138
[269] DTLR (2002) Improving Urban Parks, Play Areas and Green Space. London, DTLR.
[270] Urban Green Spaces Task Force (2002) Green Spaces. Better Places: Final Report of the Urban Task Force. London, DTLR.
[271] CABE Space (2005) Decent parks? Decent Behaviour? Commission for Architecture and the Built Environment, London.
[272] Burgess, J., Harrison, C. & 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, 6, pp. 455-473.
[273] Madge C (1997) Public parks and the geography of fear. Tijdschrift voor economische en socialegeografie, 88: 237-250.

9.2.9 Proximity of green space

The majority of visits to green spaces are made on foot[274,275], with the majority of visits being made to spaces that are less than five minutes-walk[276,277]. However, in a large proportion of UK cities, only a small proportion of people live within this distance: this was the case in Sheffield (36.5% of people lived close to parks)[278] and Leicester (10.3% close to a green space over 2 ha).[279] Moreover, the distribution of green space is unequal. The most affluent 20% of wards in England have five times the amount of parks or general green space than the most deprived 10% of wards, and areas which are more than 98% white have 6 times as many parks as wards which are 40% non-white.[280]

9.2.10 Quality of green space

Surveys suggest that the following make for a good quality green space: vegetation and water, play opportunities, seating, toilets and shelters, good access, sport, and events[281], which give a sense of community, and allow for relaxation, escapism and contact with nature[282]. The main issues negatively affecting the use of green spaces are lack or poor condition of facilities; other users, including undesirable characters; concerns about dogs/dog mess; safety; litter, graffiti and vandalism.[283,284,285]

9.3 Cool City

As the urban form of our urban areas leads to increased changes in their climate planners, landscape architects and environmental specialists have becoming increasingly focused on adapting and mitigating our cities to climate change[286,287]. The global projections for climate

[274] Forestry Commission (2010) Forestry statistics 2010. Forest Commission, Edinburgh.
[275] Pauleit S, Slinn P, Handley J & Lindley S (2003) Promoting the natural greenstructure of towns and cities: English Nature's Accessible Natural Greenspace Standards Model. Built Environment 29: 157-170.
[276] Ravenscroft N & Markwell S (2000) Ethnicity and the integration and exclusion of young people through urban park and recreation provision. Managing Leisure 5: 135-150.
[277] Coles R & Bussey S (2000) Urban forest landscapes in the UK - progressing the social agenda. Landscape and Urban Planning 52: 181-188.
[278] Barbosa O, Tratalos JA, Armsworth PR, Davies RG, Fuller RA, Johnson P & Gaston KJ (2007) Who benefits from access to green space? Landscape and Urban Planning 83: 187-195.
[279] Comber A, Brundsdon C & Green E (2008) Using a GIS-based network analysis to determine urban greenspace accessibility for different ethnic and religious groups. Landscape and Urban Planning 86: 103-114.
[280] CABE Space (2010) Urban green nation: Building the evidence basis. London, CABE Space
[281] DTLR (2002) Improving urban parks, play areas and green spaces. London, Department for Transport, Local Government and Regions.
[282] CABE Space (2005) Parks and squares: who cares? London, CABE Space.
[283] DTLR (2002) Improving urban parks, play areas and green spaces. London, Department for Transport, Local Government and Regions.
[284] ENCAMS (2006) A guide to improving your local environment. ENCAMS, Wigan.
[285] CABE Space (2005) Start with the park: Creating sustainable urban green spaces in areas of housing growth and renewal. London, CABE Space.
[286] Jim, C., Lo, A. & Byrne, J. (2015) Charting the green and climate-adaptive city. Landscape and Urban

change identify drier summers, with more heatwaves likely, and an increased risk of flooding in both summer and winter. They also illustrate changes in air quality and quality of life. All of which green infrastructure and NBS have been proposed to address[288],[289]

9.3.1 Mitigation

Mitigation activities use green infrastructure and NBS to limit the magnitude or rate of long-term change in landscape and urban climate change, and include the following:

9.3.2 Carbon storage and sequestration

UK woodlands currently hold as much carbon as the UK emits in one year of fossil fuel burning; however, an enhanced woodland creation programme involving planting 23,200 hectares could deliver abatement of approximately 15 megatonnes of CO_2 per year by the 2050s[290] (10% of projected emissions at that time)[291]. Better management of woodland for fuel and timber can also reduce carbon emissions. Wood fuel is carbon neutral and timber can replace fossil fuel based products, such as building materials[292].

Around 36.6 billion tonnes of potential CO_2 are stored in UK soils. Grassland and arable soils provide the largest storage (due to their overall size)[293]. However, peatlands contain the highest concentrations of carbon and degraded peatlands release 2.8-5.8 million tonnes of carbon a year, making peat restoration a priority[294]. Saltmarshes are also important for carbon storage and sequestration, and returning 26 km^2 of coastal land to intertidal area in Humber Estuary could result in storing about 800 tonnes of organic carbon and 40 tonnes of non-

Planning, 138, 51-53.

[287] Hansen, R. & Pauleit, S. (2014) From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for urban areas. Ambio, 43, 3, pp. 516-529.

[288] Eggermont et al. (2015) Nature-based Solutions: New Influence for Environmental Management and Research in Europe. GAIA - Ecological Perspectives for Science and Society, 24, 4, 243-248.

[289] European Commission (2015) Towards an EU Research and Innovation policy agenda for Nature-Based Solutions & Re-Naturing Cities. Final Report of the Horizon 2020 Expert Group on 'Nature-Based Solutions and Re-Naturing Cities'. Brussels, European Commission.

[290] Read DJ, Freer-Smith PH, Morison JIL, Hanley N, West CC & Snowdon P (2009) Combating climate change - a role for UK forests. An assessment of the potential of the UK's trees and woodlands to mitigate and adapt to climate change. TSO, Edinburgh.

[291] Broadmeadow M & Mathews R (2003) Forests, Carbon and Climate Change: the UK Contribution. Forestry Comission, Edinburgh.

[292] Broadmeadow M & Mathews R (2003) Forests, Carbon and Climate Change: the UK Contribution. Forestry Comission, Edinburgh

[293] Bradley RI., R.I., Milne, R., Bell, J., Lilly, A., Jordan, C &. Higgins, A. (2005) A soil carbon and land use database for the United Kingdom. Soil Use and Management 21,: 363-369.

[294] Thompson, D. (2008) Carbon Management by Land and Marine Managers. Natural England, Peterborough.

organic carbon[295]. Across the UK woodlands currently provide a balance neutralizing as much carbon as the UK emits in one year from fossil fuel burning; however, an enhanced woodland creation programme involving planting 23,200 hectares could deliver abatement of approximately 15 mega tonnes of CO_2 per year by the 2050s[296], 10% of projected emissions at that time[297]. Better management of woodland for fuel and timber would also reduce carbon emissions: wood fuel is carbon neutral and timber can replace fossil fuel based products, such as building materials[298].

9.3.3 Natural cooling and insulation

A study on wind sheltering by trees of a two storey office building in Scotland predicted a reduction of 400 kg/floor area on CO_2 emissions compared to the use of natural gas was used for the heating). [299]

9.3.4 Reduced car travel

The Green Street programme in The Mersey Forest resulted in an 6% increase in walking and cycling along tree lined routes[300]. A further study in Maastricht (Belgium) highlighted that the more parks people had within their neighbourhood, the more their commuted by bicycle[301]. In the UK, from a survey of 5844 respondents, 78% agreed with the statement 'Improved traffic free footpaths and cycle routes would encourage me to walk or cycle'[302].Green infrastructure can be used to facilitate non-vehicular transport by providing alternative routes and infrastructure that links areas together and promotes a safer environment for people of all ages to cycle[303].

[295] Downing JA,, J.A., Cole JJ,, J.J., Middelburg JJ,, J.J., Striegl RG,, R.G., Duarte CM,, C.M., Kortelainen, P,., Prairie YT &, Y.T. and Laube KA, K.A. (2008) Sediment organic carbon burial in agriculturally eutrophic impoundments over the last century. Global Biogeochemical Cycles 22, GB1018.
[296] Read DJ,, D.J., Freer-Smith PH,, P.H., Morison JIL,, J.I.L., Hanley, N,., West CC &, C.C. and Snowdon, P. (2009) Combating climate change - a role for UK forests. An assessment of the potential of the UK's trees and woodlands to mitigate and adapt to climate change. TSO, Edinburgh.
[297] Broadmeadow, M. and Mathews, R. (2003) Forests, Carbon and Climate Change: the UK Contribution. Forestry Commission, Edinburgh.
[298] Broadmeadow, M. and Mathews, R. (2003) Forests, Carbon and Climate Change: the UK Contribution. Forestry Commission, Edinburgh.
[299] Wang F, Hunt T, Liu Y, Li W & Bell S (no date) Reducing Space Heating in Office Buildings Through Shelter Trees. Available at: http://www.cibse.org/pdfs/8cwang.pdf.
[300] Mersey Forest (nd) http://www.merseyforest.org.uk/our-work/green-streets/
[301] Wendel-Vos W, Schuit AJ, De Niet R, Boshuizen HC, Saris W & Kromhout D (2004) Factors of physical environment associated with walking and bicycling. Medicine and Science in Sports and Exercise 36: 727-730.
[302] GreenSpace (2010) GreenSTAT visitor survey system.
[303] Austin, G. (2014) Green Infrastructure for Landscape Planning: Integrating Human and Natural Systems. Abingdon, Routledge.

9.3.5 Adaptation

Adaptation techniques are complementary to mitigation activities and are used to reduce the social and ecological systems vulnerability of a resource base to changing climatic variation and global warming[304,305]. Green infrastructure and NBS can be used to adapt the ways in which we manage cities and the practices undertaken to ensure that socio-economic and environmental resources become resilient to the stresses placed on them by changing demographic, ecological, economic and infrastructure needs. A suite of NBS and green infrastructure adaptation options are available to landscape and urban mangers including:

9.3.6 Cooling the city

Green infrastructure can significantly lower the temperatures in urban areas, thereby reducing the health risks to vulnerable people such as the elderly[306]. Grassed surfaces in tree shade can be 15-20°C cooler than tarmac exposed to sun, and the air temperature in tree shade can be 5-7°C lower than in the sun.[307] Urban parks with dense vegetation are on average 1°C cooler than built up areas during the day[308]. Green infrastructure and NBS therefore have the potential to help urban areas cope with increased temperatures, by providing evaporative cooling and shading. Trees with large mature canopies are especially important for their shade provision[309]. In addition surface temperature has been shown to vary with levels of green infrastructure cover[310]. Figure 2 below illustrates the relationship between green infrastructure cover and maximum surface temperature, using both current climate data and climate change projections. Surface temperature, rather than air temperature, is used here as a proxy for the temperature that people sense in a particular area, and so how comfortable they feel. Within Figure 2 we can identify that as green infrastructure increases, the maximum surface temperature reduces, providing a mechanism for planners and urban designers to take some control of the impacts of projected climate change on the comfort of the city for residents and

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[304] Kabisch et al. (2016) Nature-based solutions to climate change mitigation and adaptation in urban areas: perspectives on indicators, knowledge gaps, barriers, and opportunities for action. Ecology and Society, 21, 2, pp. 39.

[305] Norton et al. (2015) Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. Landsacpe and Urban Planning, 134, pp. 127-138.

[306] Oven et al. (2012) Climate change and health and social care: Defining future hazard, vulnerability and risk for infrastructure systems supporting older people's health care in England. Applied Geography, 33, pp. 16-24.

[307] Ennos R (2011) Quantifying the cooling and anti-flooding benefits of green infrastructure. Available at: http://www.sed.manchester.ac.uk/architecture/research/ecocities/news/documents/UoM_Roland_Ennos.pdf

[308] Bowler DE, Buyung-Ali L, Knight TM & Pullin AS (2010) Urban greening to cool towns and cities: A systematic review of the empirical evidence. Landscape and Urban Planning 97: 147-155.

[309] Amrson, D., Stringer, P. & Enoos, AR. (2012) The effect of tree shade and grass on surface and globe temperatures in an urban area. Urban Forestry & Urban Greening, 11, 3, pp. 245-255.

310 Gill, S. (2006). Climate change and urban green space. PhD thesis completed as part of the ASCCUE project, University of Manchester. Available at: http://www.ginw.co.uk/resources/Susannah_PhD_Thesis_full_final.pdf

visitors. If temperature is to be maintained at a comfortable level, the area of green infrastructure will need to be increased.

Therefore by increasing the amount of green infrastructure in a given location a level of moderation of increasing temperatures with climate change could be achieved. For example, the evaporative cover of Liverpool Knowledge Quarter is approximately 30%, thus, to maintain surface temperatures at levels similar to present day hot periods green infrastructure must be increased by 10%.

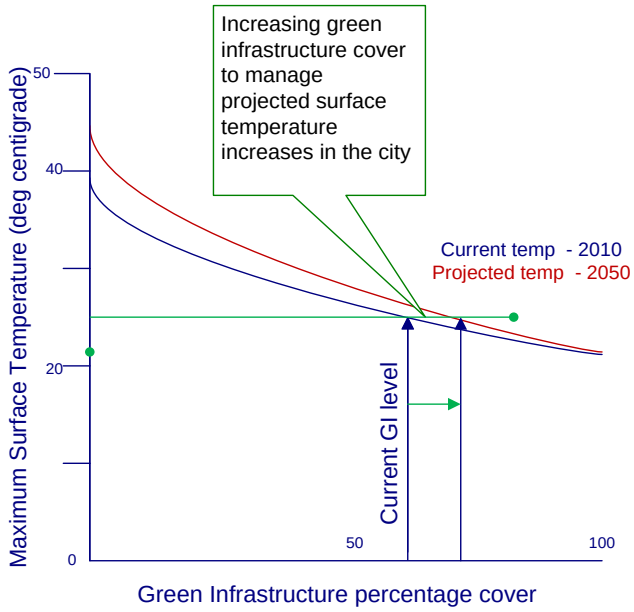


Figure 46 Relationship between green infrastructure and maximum surface temperature

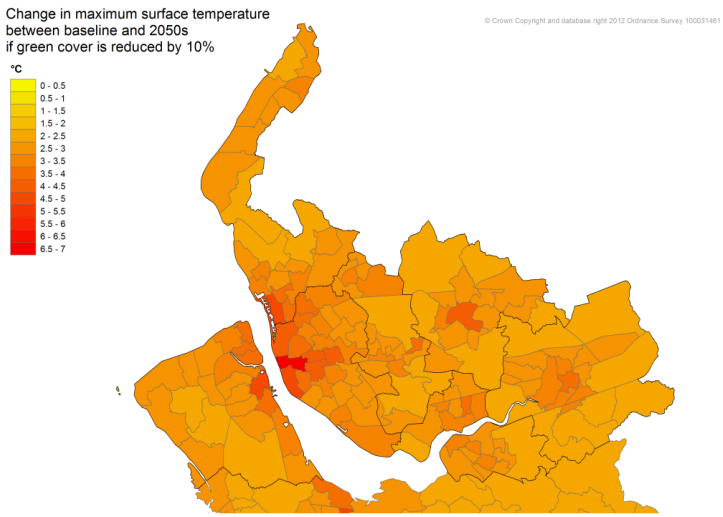


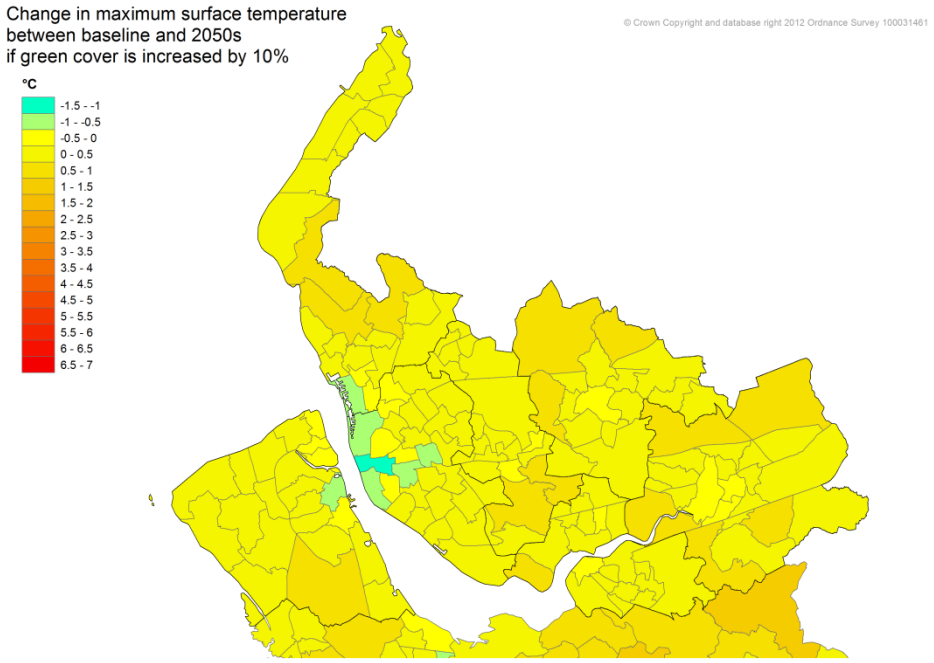
Fig. 3. Change in maximum surface temperature with 10% decrease in green space coverage

In support of Gill's research the GRaBS (Green & Blue Space adaptation for urban areas and eco towns) Interreg Project[311] developed an online assessment tool (STARS tool) that can be used to evaluate future maximum surface temperatures based on this model and the assessment of current green infrastructure. Star Tools[312] has been used to calculate temperature values for the city region and Warrington based on UK Climate Change projections. The STAR tool have been used to illustrate the impact of increasing or decreasing green cover on maximum surface temperature across Mersey Forest area (see Fig. 3 and 4 below).

Decreasing green cover by 10% increases Maximum Surface Temperature across all areas, but the increase is particularly significant in urban areas. This is important for day and night time comfort and is linked to incidence of overhearing and potentially heat wave induced deaths as seen in 2003 and 2006. In contrast increasing cover by 10% keeps temperatures close to the current levels.

Fig 4. Change in maximum surface temperature with 10% increase in green space

[311] See Krauuse, A. (2011) GRaBS Expert Paper 6 the green space factor and the green points system. London, Town and Country Planning Association. http://nextcity.nl/wp-content/uploads/2017/01/1701256-Malmoe-Tools-c-Annika-Kruuse.pdf
[312] Mersey Forest (nd) http://maps.merseyforest.org.uk/grabs/



Within this assessment grassed surfaces in tree shade can be 15-20°C cooler than tarmac exposed to sun, and the air temperature in tree shade can be 5-7°C lower than in the sun[313]. Urban parks with dense vegetation are on average 1°Ccooler than built up areas during the day[314]. Whilst research in Manchester suggests that a 10% increase of green space in densely built-up areas would reduce the urban heat island effect by 2.2-2.5% and would help to maintain the current temperatures at the end of the 21st century[315]. Using green infrastructure to manage high temperatures helps to reduce heat stress and mortality, particularly in vulnerable communities[316]. It also ensures that cities continue to be comfortable places to live, work, visit and invest in the future[317]. It should be noted that green infrastructure responses which help to manage high temperatures, can also help mitigate climate change by reducing energy use for cooling buildings[318].

[313] Ennos, R. (2011) Quantifying the cooling and anti-flooding benefits of green infrastructure. Available at: http://www.sed.manchester.ac.uk/architecture/research/ecocities/news/documents/UoM_Roland_Ennos.pdf

[314] Bowler DE,, D.E., Buyung-Ali, L,., Knight TM, T.M. and Pullin AS, A.S. (2010) Urban greening to cool towns and cities: A systematic review of the empirical evidence. Landscape and Urban Planning 97: 147-155.

[315] Gill SE,, S.E., Handley JF,, J.F., Ennos AR &, A.R. and Pauleit, S. (2007) Adapting cities for climate change: the role of the green infrastructure. Built Environment 33: 115-133.

[316] Lafortezza, Carrus, Sanesi & Davies (2009) Benefits and well-being perceived by people visiting green spaces in periods of heat stress. Urban Forestry & Urban Greening, 8, 2, pp. 97-108.

[317] Norton et al. (2015) Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. Landscape and Urban Planning, 134, 127-138.

[318] Mell, IC. (2016) Global Green Infrastructure: Lessons for successful policy-making, investment and management. Abingdon, Routlegde.

Urban areas can also display an 'urban heat island' effect, where they are warmer than the surrounding countryside[319]. It is here where green infrastructure can make the biggest impact in terms of helping manage high temperatures, and is critical where vulnerable people live, where green infrastructure levels are currently lowest, and in areas where people congregate [320].

By the 2080s, it is predicted that a heat wave similar to that experienced in England in 2003 will happen every year. The NHS Heat Wave Action Plan[321] sets out long term planning to increase green infrastructure as a key action to help to reduce the impacts of heat waves. It identifies the factors which make people more vulnerable to increased temperatures as:

Older age: especially women over 75 years old, or those living on their own who are socially isolated, or in a care home.

Chronic and severe illness: including heart conditions, diabetes, respiratory or renal insufficiency, Parkinson's disease or severe mental illness. Medications that potentially affect renal function, the body's ability to sweat, thermoregulation or electrolyte balance can make this group more vulnerable to the effects of heat.

Inability to adapt behaviour to keep cool: having Alzheimer's, a disability, being bed bound too much alcohol, babies and the very young.

Environmental factors and overexposure: living in urban areas and south facing top floor flats, being homeless, activities or jobs that are in hot places or outdoors and include high levels of physical exertion.

9.3.7 Natural cooling and insulation

Green roofs act as effective insulators[322], reducing the requirement for both heating and air-conditioning. A study on wind sheltering by trees of a two storey office building in Scotland predicted a reduction of 400 kg/floor area on CO2 emissions (if natural gas was used for the heating) 323. Moreover, research in the UK suggests that approximately 50% of buildings could

[319] Center for Clean Air Policy (2011) The value of green infrastructure for urban climate adaptation. Washington, DC. Center for Clean Air Policy.
[320] Dunn, AD. (2010) Siting Green Infrastructure: Legal and Policy Solutions to Alleviate Urban Poverty and Promote Healthy Communities. Boston College Environmental Affairs Law Review, 27, 41-66.
321 NHS England (2015) Heatwave plan for England: Protecting health and reducing harm from severe heat and heatwaves. London, NHS England.
[322] Kumar, R &. and Kaushik SC, S.C. (2005) Performance evaluation of green roof and shading for thermal protection of buildings. Building and Environment 40, 1505-1511.
[323] Wang, F,., Hunt, T,., Liu, Y,., Li, W &. and Bell, S. (no date) Reducing Space Heating in Office Buildings

be suitable for the retrofitting of a green roof, which would have significant impacts of energy efficiency, as well as urban heat island324. Given the variability of green roof performance in warmer climates the UK is well suited to the water and heat stresses which can be minimized through green roof implementation (Especially when compared to warmer European countries)325.

9.3.8 Managing runoff

Green infrastructure intercepts, infiltrates, stores and evaporates rainwater, thereby reducing the rate and volume of water entering drains and limiting the risk of them being overwhelmed during extreme rainfall[326]. Runoff can be reduced by 60% by trees over hard surfaces and by nearly 100% by grassland[327]. Moreover, a hectare of grassland and broadleaved woodland in the UK can evaporate, respectively, 3.4 and 4.0 million litres of water[328]. Modelling conducted on Manchester shows that adding 10% of green space can reduce runoff by 5-6%, and adding green roofs to all buildings in densely built-up areas could reduce runoff by 17.0-19.9%[329]. In addition the Forestry Commission and the Environment Agency published research[330] looking at how woodland can help to achieve Water Framework Directive objectives, including reducing runoff and soil erosion and flood alleviation. The study reported that there was significant scope for using woodland to help reduce flood risk, and in particular floodplain and riparian woodlands were identified as valuable for attenuating flooding in downstream towns and cities.

Through Shelter Trees. Available at: http://www.cibse.org/pdfs/8cwang.pdfhttp://www.cibse.org/pdfs/8cwang.pdf.

[324] Castleton et al. (2010) Green roofs; building energy savings and the potential for retrofit. Energy and Buildings, 42, 10, pp. 1582-1591.

[325] Ascione et al. (2013) Green roofs in European climates. Are effective solutions for the energy savings in air-conditioning? Applied Energy, 104, pp. 845-859.

[326] Natural England and Landuse Consultants (2009) Green Infrastructure Guidance. Peterborough, Natural England.

[327] See Ennos (2011) Ennos, R. (2011) Quantifying the cooling and anti-flooding benefits of green infrastructure. Available at: http://www.sed.manchester.ac.uk/architecture/research/ecocities/news/documents/UoM_Roland_Ennos.pdf

[328] Hölzinger, O. (2011) The Value of Green Infrastructure in Birmingham and the Black Country. The Total Economic Value of Ecosystem Services provided by the Urban Green Infrastructure. The Wildlife Trust for Birmingham and the Black Country.

[329] See Gill et al. (2007) 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.

[330] Nisbet, T., Silgram, M., Shah, N., Morrow, K., and Broadmeadow, S. (2011) Woodland for Water: Woodland measures for meeting Water Framework Directive objectives. *Forest Research Monograph*, 4, Forest Research, Surrey

9.3.9 Reducing the risk of river and coastal flooding

Trees increase the capacity of the soil to absorb water; a study in Wales found that infiltration rates were up to 60 times higher within native woodland compared to grazed pasture[331]. Planting shelterbelts across the lower parts of grazed grassland sites could also reduce peak flows by 13-48%[332]. A modelling study in Somerset showed that planting woodland along a 2.2 km grassland reach of the River Cary could reduce water velocity by 50%, increase temporary water retention by 71%, and delay the downstream progression of the flood peak by up to 140 minutes.[333] Furthermore, Salt marshes dissipate the wave energy before it reaches the shore: it has been estimated that an 80m wide zone of inter-tidal habitat fronting sea walls can save £4,600 per metre in sea defence costs.[334]

9.3.10 Maintaining sustainable water supplies

Sustainable Urban Drainage Systems can also help to increase aquifer recharge through porous paving systems and detention ponds allowing water to reach the soil[335]. The maintenance of water supply of an appropriate quality and quantity it important in providing a reliable service for homes and businesses. Sustainable drainage and the intervention of green infrastructure in homes, businesses and on municipal infrastructure will provide options to the interception, retention and release of rainfall in a controlled manner[336]. It also aids municipal water planners and utilities companies to manage flow through a greater awareness of the added-capacity that natural systems can provide in support of engineered solutions[337]

9.3.11 Helping other species to adapt

As the climate changes, the range of species may shift northwards and upwards to higher altitudes as they seek new 'climate spaces'. A number of factors will limit their ability to do this, including their own dispersal ability and the nature of the landscape through which they are moving (i.e. the fragmentation of existing habitats and the permeability of the landscape

[331] Bird, S.B., Emmett, B.A., Sinclair, F.L., Stevens, P.A., Reynolds, A., Nicholson, S. &. and Jones, T. (2003) PONTBREN: Effects of tree planting on agricultural soils and their functions. Centre for Ecology and Hydrology, Bangor, Gwynedd.
[332] Jackson et al. (2008) The impact of upland land management on flooding: insights from a multiscale experimental and modelling programme. Journal of Flood Risk Management 1: 71-80.
[333] Thomas, H. and Nisbet TR, T.R. (2006) An assessment of the impact of floodplain woodland on flood flows. Water and Environment Journal 21: 114-126
[334] Collins, T., Empson, B., Leafe, R &. and Lowe, J. (1997) Sustainable flood defence and habitat conservation in estuaries - a strategic framework. In Proceedings of the 32nd MAFF Conference of River and Coastal Engineers. University of Loughborough, July 2-4, 1997
[335] Carter, T &. and Butler, C. (2008) Ecological impacts of replacing traditional roofs with green roofs in two urban areas. Cities and the Environment 1: 9-17.
[336] Williamson, K. (2003) Growing with Green Infrastructure. Doylestown, Heritage Conservancy.
[337] Falkenmark, M. & Rockström, J. (2006) The New Blue and Green Water Paradigm: Breaking New Ground for Water Resources Planning and Management. Journal of Water Resources Planning and Management, 132, 2, pp. 129-132.

between habitats)[338]. The management of linear features and corridors (e.g. river corridors, and road, railway and canal verges) for species movement may become increasingly important. Features oriented north-south may aid species movement, whereas east-west features could act as barriers unless appropriately designed[339]. Providing further evidence of these issues a Natural England study assessed and mapped the vulnerability of the Northwest's natural environment to climate change according to character areas. It found that protected landscapes are often the most resilient, whilst areas of highest risk correspond with built up areas and act as a barrier to movement of species through the Northwest[340]. The natural areas of Liverpool City Region and Warrington are identified as having high vulnerability to climate change[341]. Green infrastructure and NBS can help other species to adapt to climate change as it provides existing habitats. In addition, action should be taken in areas deemed to be vulnerable to climate change; this could be by creating new habitat to connect fragmented areas, or by increasing the wider landscape permeability through, for example, the planting of appropriate species and management of linear corridors[342].

9.4 Biodiverse City

Moving towards a more biodiverse and ecological city requires us to think about how we value and make best use of our Natural Capital to measure our progress toward being the first generation in the UK's history to actually manage and improve the quality of the natural landscape and not degrade or damage its provisioning, servicing, supporting and cultural services.

Urban landscapes provide key habitats for a range of flora and fauna both within cities and across their urban/rural boundaries[343]. A number of factors influence the value of green infrastructure for biodiversity including the area of habitat available, the type and diversity of green spaces, and proximity to other sites[344]. A study of four urban areas on Merseyside

[338] MONARCH (Modelling Natural Resource Responses to Climate Change) was a seven year phased programme to assess impacts of projected climate change on wildlife in Britain and Ireland. www.ukcip.org.uk/images/stories/Pub_pdfs/Monarch_summary.pdf http://www.ukcip.org.uk/wordpress/wp-content/PDFs/Monarch1_summary.pdf

[339] Gilchrist A (2011) Climate change, species range expansion and the institutional response. Unpublished PhD thesis, University of Manchester.

340 Natural England (2010). An Assessment of the vulnerability of the Natural Environment in the Northwest to climate change at the National Character Area scale. See http://www.naturalengland.org.uk/regions/north_west/ourwork/climatechangeproject.aspx

[341] The Mersey Forest (2010) Liverpool Green Infrastructure Strategy. Risley Moss, Mersey Forest.

[342] Ahern, J. (2011) Urban landscape sustainability and resilience: the promise and challenges of integrating ecology with urban planning and design. Landsacpe Ecology, 28, 9, 1203-1212.

[343] Countryside Agency & Groundwork (2005) The Countryside in and around towns: A vision for connecting town and county in the pursuit of sustainable development. Weatherby, Countryside Agency.

[344] Beneduct, MA. & McMahon, E. (2006) Green Infrastructure: Linking Landscapes and Communities. Washington, DC. Island Press.

revealed that the greatest influence on their ecology was the proportion of green space, particularly trees[345]. Sites where many species most commonly occur include city parks, cemeteries, rail tracks and previously developed land[346]. Sufficient levels of green space of relevant ecological quality in urban landscapes may even allow the presence of specialist forest or endangered species[347,348]. Furthermore, a survey of 15 parks in highly urbanised Flanders (Belgium) revealed that they contained 30% of wild plant species, 50% of breeding birds, 40% of butterflies, and 60% of the amphibians occurring in Flanders[349]. A range of evidence therefore suggests that, generally, the larger the parks or other habitat patches, the higher the species richness[350]. However, parks that are between 10-35ha in size are likely to contain every species that can be recorded in any urban area of a given region[351]. The diversity of land use types and adjacent green space in urban areas in the UK has been found to be crucial for supporting richness of bird[352] and butterfly species[353].

9.4.1 Connectivity of habitats

Wildlife corridors are important in helping to overcome habitat fragmentation and to ensure that species can reach the different resources they need, and that populations of species do not become isolated or die out due to inbreeding[354]. Also, as the climate changes, the range of species may shift northwards and upwards to higher altitudes as they seek new "climate spaces". Their ability to do this is affected by the fragmentation of existing habitats and the permeability of the landscape between habitats[355]. A study of butterflies migration in the North West of England suggests that features oriented north-south (such as grass verges along major roads) may aid species movement, whereas east-west features could act as barriers

[345] Whitford V, Ennos AR & Handley JF (2001) 'City form and natural process' – indicators for the ecological performance of urban areas and their application to Merseyside, UK. Landscape and Urban Planning 57: 91-103.
[346] Kendle T & FORBES S (1997) Urban nature conservation. E&FN Spon, London.
[347] Park C-R & Lee WS (2000) Relationship between species composition and area in breeding birds of urban woods in Seoul, Korea. Landscape and Urban Planning 51: 29-36.
[348] Alvey AA (2006) Promoting and preserving biodiversity in the urban forest. Urban Forestry and Urban Greening 5: 195-201.
[349] Cprnelis J & Hermy M (2004) Biodiversity relationships in urban and suburban parks in Flanders. Landscape and Urban Planning 69: 385–401.
350 Davies L, Kwiatkowski L, Gaston KJ, Beck H, Brett H, Batty M, Scholes L, Wade R, Sheate WR, Sadler J, Perino G, Andrews B, Kontoleon A, Bateman I & Harris JA (2011) Urban In: The UK National Ecosystem Assessment Technical Report. UK National Ecosystem Assessment, UNEP-WCMC, Cambridge
351 Fernández-Juricic E & 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.
352 Young CH & JARVIS PJ (2001) Assessing the structural heterogeneity of urban areas: An example from the Black Country (UK). Urban Ecosystems 5: 49-69.
353 Hardy PB & Dennis RLH (1999) The impact of urban development on butterflies within a city region. Biodiversity and Conservation 8: 1261-1279.
354 O'Brien E (2006) Habitat fragmentation due to transport infrastructure: Practical considerations. Environmental Pollution 10: 191-204.
355 Niemelä, J. (2014) Ecology of urban green spaces: The way forward in answering major research questions. Landsacpe and Urban Planning, 125, 298-303.

unless appropriately designed[356]. To help biodiversity move and survive in urban areas, change in the management of close-mown amenity grass and encouraging wildlife friendly gardening are needed[357]. Ecological networks can therefore be designed into cities across the UK to ensure that links, hubs and nodes are accessible and available to species. For instance in Birmingham, the management of wildlife in the city has relied heavily on corridors as strategic planning tools since development of the wildlife conservation strategy in 1997 explicitly built around the corridor concept[358]. In London, the South East London Green Chain extends over 40 miles linking 300 open spaces, combining nature conservation and other benefits[359].

9.4.2 Gardens as an important biodiversity resource

Gardens cover around a quarter of the major urban areas in the UK[360], and 16.2% of Liverpool is covered by gardens[361]. In London, out of the estimated 7 million trees, two thirds are located within domestic gardens[362]. The variation of management practices of gardens creates a diverse land mosaic, which supports higher number of species (plants, butterflies, birds, lizards) than more urbanized areas or managed countryside [363,364,365.] The biodiversity in gardens is also supported by the popularity of bird feeding and wildlife gardening practices: survey data from Sheffield estimated that 14.4% contained ponds, 26% had nest boxes, 29% had compost heaps and 48% had trees more than 3 m tall [366],[367]. By creating adjacent gardens

356 Gilchrist A (2011) Climate change, species range expansion and the institutional response. Unpublished PhD thesis, University of Manchester.
357 Mitchell R J, Morecroft MD, Acreman M, Crick HQP, Frost M, Harley M, Maclean IDM, Mountford O, Piper J, Pontier H, Rehfisch MM, Ross LC, Smithers RJ, Stott A, Walmsley CA, Watts O & Wilson E (2007) England Biodiversity Strategy - towards adaptation to climate change. Department for Food, Environment and the Rural Affairs.
358 Birmingham City Council (1997), Nature Conservation Strategy for Birmingham. Birmingham, Birmingham City Council.
359 London Assembly (2011) South East London Green Chain Plus Area Framework - All London Green Grid. London, Greater London Authority.
360 Loram A, Tratalos J, Warren PH & Gaston KJ (2007) Urban domestic gardens (X): the extent & structure of the resource in five cities. Landscape Ecology 22: 601–615.
361 The Mersey Forest (2010) Liverpool Green Infrastructure Strategy. Risley Moss, The Mersey Forest.
362 Smith, C., Dawson, D., Archer, J., Davies, M., Frith, M., Hughes, E. and Massini, P., 2011. *From green to grey; observed changes in garden vegetation structure in London, 1998-2008*, London, London Wildlife Trust, Greenspace Information for Greater London, and Greater London Authority.
363 Blair RB & Launer AE (1997) Butterfly diversity and human land use: Species assemblages along urban gradient. Biological Conservation 80: 113-125.
364 Sandstrom UG, Angelstam P & Mikusinski G (2006) Ecological diversity of birds in relation to the structure of urban green space. Landscape and Urban Planning 77: 39-53.
365 Smith, C., Dawson, D., Archer, J., Davies, M., Frith, M., Hughes, E. and Massini, P., 2011. *From green to grey; observed changes in garden vegetation structure in London, 1998-2008*, London, London Wildlife Trust, Greenspace Information for Greater London, and Greater London Authority.
366 Gaston KJ, Warren PH, Thompson K & Smith RM (2005) Urban domestic gardens (IV): the extent of the resource and its associated features. Biodiversity and Conservation 14: 3327–3349.
367 Gaston KJ, Fuller RA, Loram A, MacDonald C, Power S & Dempsey N (2007) Urban domestic gardens (XI): Variation in urban wildlife gardening in the UK. Biodiversity and Conservation 16: 3227–3238.

in residential areas the largest semi-natural areas in cities can be formed [368], which can act as dispersal corridors for various species[369],[370] and individual gardens can be 'stepping stones' allowing dispersal to other sites, e.g. for insects with limited ability of flight. However, the area of gardens in cities is shrinking as a result of infill and paving: 13% of gardens were lost in a residential area of Leeds over the last 33 years[371] and 5% of vegetated areas got developed in Merseyside between 1975 and 2000[372].

[368] Rudd H, Vala J & Schaefer V (2002) Importance of backyard habitat in a comprehensive biodiversity conservation strategy: a connectivity analysis of urban green space. Restoration Ecology 10: 368-375.
[369] Szacki J, Glowacka I, Liro A & Matuszkiewicz A (1994) The role of connectivity in the urban landscape: Some results of research. Memorabilia Zoologica 49, 49-56.
[370] Bolger DT, Scott TA & Rottenberry JT (2001) Use of corridor-like landscape structures by bird and small mammal species. Biological Conservation 102: 213-224.
[371] Perry T & Nawaz R (2008) An investigation into the extent and impacts of hard surfacing of domestic gardens in an area of Leeds, United Kingdom, Landscape and Urban Planning 86: 1–13.
[372] Pauleit S, Ennos R & Golding Y (2005) Modelling the environmental impacts of urban land use and land cover change – a study in Merseyside, UK. Landscape and Urban Planning 71, 295–310.

10 Appendix 3 Mapping methods

Air quality, NOx, PM10, PM25

National Air Quality Archive estimated background air pollution maps (2010)

Population living near main roads

Main roads: Ordnance Survey Integrated Transport Network motorways and A roads

Population: OpenPopGrid

The population within a 100m buffer of main roads was compared with the total population of each Lower Layer Super Output Area

Vulnerability to heat stress

Percentage of population aged 0-4 or 66+ in 2011 at Lower Layer Super Output Area level (Office for National Statistics)

Communities at risk smaller catchments

Communities at risk: provided by the Environment Agency for Greater Manchester, Merseyside and Cheshire; for the rest of the area, a method similar to the Environment Agency's was applied: a 30m buffer of addresses (from Ordnance Survey's AddressBase) within Flood Zone 2

The number of properties at risk is the number of addresses (from Ordnance Survey's AddressBase) within Flood Zone 2 and within the community at risk, for all communities at risk including those provided by the Environment Agency

Digital terrain model: Ordnance Survey Terrain 5

Catchments were calculated using ArcGIS hydrology tools:

The Fill tool was used to remove any sinks from the digital terrain model

The Flow Direction tool was used to generate a flow direction raster from the result

The Flow Accumulation tool was used to generate a flow accumulation raster

The Arc Hydro Stream Definition tool was used to generate a stream definition raster

The Arc Hydro Stream Segmentation tool was used to generate a stream link raster

The Arc Hydro Catchment Grid Delineation tool was used to generate a catchment raster

The Arc Hydro Catchment Polygon Processing tool was used to convert the catchment raster to vector

The Arc Hydro Drainage Line Processing tool was used to generate drainage lines

The Arc Hydro Adjoint Catchment Processing tool was used to generate adjoint catchments

The Arc Hydro Batch Watershed Delineation tool was used to calculate the catchments of the communities at risk centroids

The catchments of the communities at risk were filtered to show only those smaller than 10km^2 and larger than 10ha

Surface water flooding

Environment Agency Updated Flood Map for Surface Water (1 in 100)

Flood risk from rivers and the sea

Environment Agency Flood Zones 2 and 3

Deprivation and green space open to the public

Department for Communities and Local Government Indices of Multiple Deprivation 2015

Liverpool City Council Open Space Survey 2012

Adult obesity

Prevalence of obesity in adults 2003-5 at Middle Layer Super Output Area level (The NHS Information Centre)

Childhood obesity

Prevalence of obesity in children at Reception and Year 6, 2012/13 to 2014/15, at Middle Layer Super Output Area level (Public Health England)

(Note that some values are missing for confidentiality reasons)

Coronary Heart Disease

Hospital admissions for Coronary Heart Disease per unit population 2007-8 at Middle Layer Super Output Area level (Office for National Statistics)

Index of risk of poor mental health

As suggested by Moscone et al (2006)[373], the following regressors were used to calculate the index. All are taken from Census 2011 statistics except for the last, which are Office for National Statistics model-based estimates for 2007-8. The index is simply the sum of the percentages at Lower Layer Super Output Area level.

- Percentage of population aged 0-15
- Percentage of population aged 65+
- Percentage of females in the population
- Percentage of population living alone
- Percentage of population with no qualifications
- Percentage of population with a long-term health problem or disability
- Percentage of households in poverty (below 60% of median income)

Respiratory diseases

Deaths from respiratory diseases per unit population 2006-10 at Middle Layer Super Output Area level (Public Health England)

Potential Strategic Investment Areas

Appropriate strategic investment areas identified by the Liverpool City Region Strategic Economic Plan

Green infrastructure typology

1. The latest version of Ordnance Survey's MasterMap Topography Layer was downloaded
2. Polygon features intersecting a 1km buffer of the Liverpool City Council boundary were extracted
3. Features where DescGroup like 'Landform%' were deleted, as these overlap other features
4. The result was unioned with Ordnance Survey's MasterMap Greenspace Layer
5. Features were classified according to MasterMap Greenspace attributes as follows (in the order given, only classifying at each step features not previously classified)

Attribute	Value	Type
priForm	Beach Or Foreshore	Coastal habitat

[373] Moscone, F, Knapp, M and Tosetti, E, Mental Health Expenditure in England: A Spatial Panel Approach (2006). Available at SSRN: https://ssrn.com/abstract=898474 or http://dx.doi.org/10.2139/ssrn.898474

priForm	Manmade Surface	Not GI
priForm	Woodland	Woodland
priFunc	Allotments Or Community Growing Spaces	Allotment, community garden or urban farm
priFunc	Amenity - Transport	General amenity space
priFunc	Bowling Green	Outdoor sports facility
priFunc	Cemetery	Cemetery, churchyard or burial ground
priFunc	Golf Course	Outdoor sports facility
priFunc	Institutional Grounds	Institutional grounds
priFunc	Other Sports Facility	Outdoor sports facility
priFunc	Play Space	Park or public garden
priFunc	Playing Field	General amenity space
priFunc	Private Garden	Private domestic garden
priFunc	Public Park Or Garden	Park or public garden
priFunc	Religious Grounds	Institutional grounds
priFunc	School Grounds	Institutional grounds
priFunc	Tennis Court	Outdoor sports facility

6. Features were classified according to MasterMap Topography attributes as follows (overwriting previous classifications)

Attribute	**Value**	**Type**
Make	Manmade	Not GI
DescTerm	Orchard	Orchard
DescTerm	Marsh%	Wetland

7. Features were classified as per matching features in the previous green infrastructure mapping (only classifying features not previously classified)

8. Features were classified according to MasterMap Greenspace attributes as follows (in the order given, only classifying at each step features not previously classified)

Attribute	**Value**	**Type**
priForm	Inland Water	Water body
priForm	Open Semi-Natural	Grassland, heathland, moorland or scrubland
priFunc	Camping Or Caravan Park	Institutional grounds
priFunc	Land Use Changing	Institutional grounds
priFunc	Amenity – Residential Or Business	Institutional grounds

9. Features were classified according to MasterMap Topography attributes as follows (in the order given, only classifying at each step features not previously classified)

Attribute	**Value**	**Type**
DescTerm	%Trees% and not %Scattered%	Woodland
DescTerm	Foreshore	Coastal habitat
DescTerm	Scrub	Grassland, heathland, moorland or scrubland
DescTerm	Multi Surface	Private domestic garden
DescGroup	Inland Water%	Water body
DescGroup	Rail%	Grassland, heathland, moorland or scrubland
DescGroup	Roadside%	General amenity space
DescGroup	Tidal Water	Water course
DescGroup	Unclassified	Not GI
DescGroup	Road Or Track%	Not GI
DescGroup	Natural Environment	Grassland, heathland, moorland or scrubland

10. Remaining features larger than 1,000m^2 were classified by visual comparison with aerial photography
11. Remaining feature were classified as institutional grounds
12. Features with more than 50% tree canopy cover (according to Bluesky's National Tree Map) were classified as woodland where they met the following conditions (overwriting previous classifications)
    - Area > 1,000m^2
    - DescGroup not like Road Or Track%
    - DescGroup not like Building%
    - DescGroup not Inland Water
    - DescGroup not like Roadside%
    - Type not Private domestic garden
13. Features classified as street trees were reclassified as general amenity space
14. The result was updated with tree crowns (from Bluesky's National Tree Map) with their centroids within a metre of roads and roadside – these were classified as street trees
15. Some incorrectly classified features were fixed by visual comparison with aerial photography and Ordnance Survey background mapping

Importance of existing habitat for northwards species movement

Condatis flow maps using the following parameters:

Habitat: 200m rasters of:

- Tree canopy cover
- Inland water
- Wetland
- Coastal habitat
- Intensively-managed grassland
- Less intensively-managed grassland

These were based upon the green infrastructure typology mapping, with the exception of tree canopy cover, which was based upon Bluesky's National Tree Map

General amenity space, green roof, institutional grounds, outdoor sports facility, park or public garden and private domestic garden were counted as intensively-managed grassland

Grassland, heathland, moorland or scrubland, cemetery, churchyard or burial ground and derelict land were counted as less intensively-managed grassland

Source/target: assigned to simulate south-north movement through Liverpool, taking into account the extent of the input data

Dispersal distances: 1km and 2km

Bottlenecks in northward movement of species

Condatis bottlenecks maps using the same parameters as above