URBAN GreenUP

D3.4: Monitoring program to Liverpool

WP 3 , T 3.6

Date of document

31 August 2018 (M15)

Authors: University of Liverpool (UOL), Mersey Forest (CFT), Liverpool City Council (LIV)

URBAN GreenUP

SCC-02-2016-2017

Innovation Action – GRANT AGREEMENT No. 730426

Technical References

Project Acronym	**URBAN GreenUP**
Project Title	New Strategy for Re-Naturing Cities through Nature-Based Solutions – URBAN GreenUP
Project Coordinator	Raúl Sánchez Fundación Cartif rausan@cartif.es
Project Duration	1 June 2017 – 31 May 2022 (60 Months)

Deliverable No.	D3.4
Dissemination Level	PU[1]
Work Package	WP 3 – Liverpool Demonstration
Task	T 3.6 - Development of the monitoring program
Lead beneficiary	9 (UOL)
Contributing beneficiary(ies)	7 (LIV), 8 (CFT)
Due date of deliverable	31 August 2018
Actual submission date	31 August 2018

[1] PU = Public

PP = Restricted to other programme participants (including the Commission Services)

RE = Restricted to a group specified by the consortium (including the Commission Services)

CO = Confidential, only for members of the consortium (including the Commission Services)

Versions

Version	Person	Partner	Date
0	Jenny Hodgson	UOL	27 June 2018
1	Cathy Highfield	UOL	02 July 2018
2	Tom Butlin & Mike Norbury	CFT	9 July 2018
3	Sarah Clement	UOL	22 July 2018
4	Ian Mell	UOL/UOM	1 August 2018
5	Sarah Clement	UOL	1 August 2018
6	Sam Hayes	UOL	2 August 2018
7	Juliet Staples	LIV	6 August 2018
8	Cathy Highfield	UOL	7 August 2018
9	Jenny Hodgson	UOL	10 August 2018
10	Sarah Clement	UOL	12 August 2018
11	Jenny Hodgson & Cathy Highfield	UOL	13 August 2018
12	Sarah Clement & Tom Butlin	UOL & CFT	13 August 2018
13	Sarah Clement	UOL	31 August 2018

Table of Contents

List of Tables

List of Figures

0 Executive Summary

The Urban GreenUP project is a 5-year project combining practical implementation of nature-based solutions (NBS) with social, ecological, and economic research. NBS have been presented as an innovative way to address the many challenges facing urban areas. This project tests whether – and to what extent – NBS can contribute to solving biophysical, social, and economic challenges in urban areas by first undertaking 1 year of baseline research, then implementing targeted NBS interventions, followed by a 2-year post-intervention monitoring period.

This document outlines the monitoring protocols proposed for the City of Liverpool URBAN GreenUP interventions, following Task 3.6: Development of the monitoring programme, and in line with the higher order principles outlined in D5.3: City Diagnosis and Monitoring Procedures (Urban GreenUP 2018). This monitoring protocol focuses on the principles and procedures of the biophysical and social monitoring, as structured by the Eklipse framework (Raymond et al. 2017) and KPIs selected in the City of Liverpool.

For each KPI, the document describes the rationale for measuring the indicator, including associated literature that suggests why it may be important and/or relevant. The monitoring procedures are then outlined in general terms, with respect to the methods and approaches appropriate for each discipline. To allow for these disciplinary differences, the document is divided into two parts, with the first outlining biophysical monitoring procedures and the second part outlining socio-economic monitoring procedures. Each section concludes with a plan for management and sharing of the data generated over the course of the Urban GreenUP project and beyond.

1 Introduction

The Urban GreenUP project is a 5-year project combining practical implementation of nature-based solutions (NBS) with social, ecological, and economic research. NBS have been presented as an innovative way to address the many challenges facing urban areas. This includes both challenges that are primarily biophysical (e.g. climate change, poor air quality, poor water quality and ecosystem degradation), as well as the linked social challenges prevalent in urban areas (declining participation in governance, socio-economic inequalities, and economic development). This project tests whether – and to what extent – NBS can contribute to solving these challenges by first undertaking 1 year of baseline research, then implementing targeted NBS interventions, followed by a 2-year post-intervention monitoring period.

As directed by the European Commission, Liverpool has selected a set of Key Performance Indicators (KPI) based on the Eklipse framework (Raymond et al., 2017) and in collaboration with the other front-runner cities in the Urban GreenUP project: Valladolid and Izmir. The framework was developed out of a project funded by the EC to provide guidance on how cities can evaluate the efficacy of NBS. It aimed to assist stakeholders across the European Union:

1) To develop an impact evaluation framework with a list of criteria for assessing the performance of NBS in dealing with challenges related to climate resilience in urban areas;
2) To prepare an application guide for measuring how NBS projects fare against the identified indicators in delivering multiple environmental, economic and societal benefits;
3) To make recommendations to improve the assessment of the effectiveness of NBS projects, including the identification of knowledge gaps according to the criteria presented in the impact evaluation framework.

To apply the framework the Eklipse expert panel established ten areas in which cities face urgent challenges, and for which NBS can be used as a partial solution:

- Challenge 1: climate mitigation & adaptation;
- Challenge 2: water management;
- Challenge 3: coastal resilience;
- Challenge 4: green space management;
- Challenge 5: air quality;
- Challenge 6: urban regeneration;
- Challenge 7: participatory planning and governance;
- Challenge 8: social justice and social cohesion;
- Challenge 9: public health and well-being; and
- Challenge 10: potential of economic opportunities and green jobs.

These challenges provide a structure for organising evidence for the efficacy of NBS. Eklipse is not a prescriptive framework, and instead outlines the areas that existing research suggests are relevant to NBS, with broad recommendations on potential KPIs. To establish the parameters of the URBAN GreenUP delivery and monitoring protocols, the Liverpool project team have drawn on the Eklipse documents in developing its KPIs. This has led to the development of set of KPIs that:

1) Are relevant to our interventions;

2) Can be robustly and consistently measured; and

3) Aligns with the human and financial resources available for the project.

These criteria are comparable to the areas of concern and subsequent investigation that would be used by any city interested in evaluating the efficiency and effectiveness of their investment in NBS. Based on these criteria, the Liverpool project team have developed a list of KPIs[2] (Table 1) that will be used to develop a baseline and to monitor post-intervention effectiveness or change.

The table below structures the KPIs by the Eklipse challenges. We recognise that the KPIs do not always fit neatly into one category, and that one KPI may be suitable for several challenge areas. These categories are thus used as a guide rather than a concrete means to delineate between urban challenges and indicators for measuring NBS performance. The KPI number has been included in Column 2 for cross-referencing to D5.3 City Diagnosis and Monitoring Procedures (Urban GreenUP 2018).

Table 1. KPIs for Liverpool

Type of Indicator	KPI	Associated NBS
Challenge 1: Climate Change Mitigation and Adaptation		
Environmental (physical)	**Tonnes of carbon stored in vegetation (KPI 1)**	Tree related actions; vertical and horizontal green infrastructure; SUDs and raingardens; Urban Carbon sink
Environmental (physical)	**Heatwave risk (KPI 9)**	Vegetated NBS (horizontal and vertical) for evaporative cooling; Trees NBS for evaporative cooling and the effects of shading
Environmental (physical)	**Projected maximum surface temperature reduction (KPI 13)**	
Economic indicators (benefits)	**Economic value of carbon sequestration by vegetation (KPI 6)**	Tree related actions; vertical and horizontal green infrastructure; SUDs and raingardens; Urban Carbon sink

[2] Note that there are no KPIs for the coastal resilience challenge area, as this are not relevant to the interventions being monitored.

Type of Indicator	KPI	Associated NBS
Environmental (biological)	**Increased opportunity for species movement in response to climate change as a result of NBS***	All GI NBS in each of the three Liverpool sub-demo areas.
Challenge 2: Water Management		
Environmental (physical)	**Run-off coefficient in relation to precipitation quantities (KPI 16)**	Tree related actions; SUDs and raingardens; Urban Carbon sink; horizontal GI
Environmental (chemical)	**Nutrient abatement and abatement of pollutants (KPI 30)**	SUDs and raingardens; Green filter area; smart soils, natural waste water treatment
Economic	**Volume of water removed from water treatment system (KPI 38)**	SUDs and raingardens; tree related GI; horizontal GI, smart soils
Economic	**Volume of water slowed down entering sewer system (KPI 39)**	
Economic	**Economic benefit of reduction of stormwater to be treated in public sewer system (KPI 35)**	Tree related actions; SUDs and raingardens; horizontal GI; smart soils
Challenge 4: Green Space Management		
Social	**Accessibility of urban green spaces for population (KPI 53)**	Vertical & Horizontal Infrastructure; Tree related actions; Amenity green space, cycle and footpaths, and plazas/public spaces with urban greening.
Social	**Assessment of typology, functionality and benefits provided (KPI 109)**	All NBS interventions
Environmental (biological)	**Increase in density and seasonal spread of floral resources for pollinators***	Pollinator verges and spaces; horizontal green interventions; vertical green interventions; SUDs and raingardens
Environmental (biological)	**Increase in plant species richness and functional diversity as a result of NBS***	

Type of Indicator	KPI	Associated NBS
Environmental (biological)	**Increase in Insectivore (e.g. bat) abundance and use of corridors for movement as a result of NBS***	All biophysical NBS (pre-intervention/post-intervention) including floating gardens (up to 10 m from surveyor).
Environmental (biological)	**Pollinator species increase (KPI 77)**	Pollinator verges; pollinator walls vertical; SUDs (Rain garden); Pollinator roofs; SUDs (open water)
Social indicators (benefits)	**Increased connectivity to existing GI (KPI 76)**	All accessible GI NBS in each of the three Liverpool sub-demo areas.
Environmental (chemical)	**Annual mean levels of fine particulate matter (KPI 83)**	Street trees and green walls (or screens)
Environmental (chemical)	**Trends in levels of NOx and SOx (KPI 84)**	Street trees and green walls (or screens), improved highway improvements
Economic	**Value of air quality improvements (KPI 88)**	Tree related actions; Smarts soils as substrate; green filter area, vertical GI
Challenge 6: Urban Regeneration		
Social	**Diversity of NBS (land use and functionality) (KPI 95)**	All technical and non-technical interventions
Economic	**Savings in energy use due to improved GI (KPI 110)**	Vertical GI, Tree related actions, Horizontal GI
Challenge 7: Participatory Planning and Governance		
Social	**Social learning concerning NBS (KPI 113)**	All technical and non-technical interventions
Social	**Perceptions of citizens on urban nature (KPI 115)**	
Social	**Engagement with NBS (sites/projects) (KPI 117)**	

Type of Indicator	KPI	Associated NBS
Challenge 8: Social Justice and Social Cohesion		
Social	**Crime reduction (KPI 123)**	All technical and non-technical interventions
Challenge 9: Public Health and Well-Being		
Social	**Perceptions of health and quality of life***	Green cycle lane; Vertical green interventions; Horizontal green interventions; SUDs
Social	**Increase in walking and cycling in and around areas of interventions (KPI 139)**	
Challenge 10: potential of economic opportunities and green jobs		
Economic	**Changes in mean house prices/rental markets (KPI 142)**	All technical and non-technical interventions
Economic	**Number of jobs created; gross value added (KPI 141)**	
Economic	**Additional business rates (KPI 143)**	
Economic	**Job creation, increased footfall and spend in the areas of interventions (KPI 151)**	

Those KPIs marked with an asterisk (*) do not yet have a KPI reference number.

1.1 ABOUT THIS DOCUMENT

This document outlines the monitoring protocols proposed for the City of Liverpool URBAN GreenUP interventions, following Task 3.6: Development of the monitoring programme, and in line with the higher order principles outlined in D5.3: City Diagnosis and Monitoring Procedures. Key information about the City of Liverpool, the rationale for developing the interventions, and their locations are provided in the diagnosis and baseline reports (Urban GreenUP 2017a, 2017b). These provide an important contextual basis for this monitoring protocol, which focuses only on the principles and procedures of the biophysical and social monitoring.

This document is divided into 2 parts: biophysical monitoring and socio-economic monitoring, reflecting what Bryman (2006) described as multi-strategy research. The rationale for taking a multi-strategy approach follows what Greene *et al.* (1989) described as 'expansion', that is, using multiple research methods to increase the breadth of the research. To organise this multi-strategy and multi-method research we are drawing on the typology created by Leech and Onwuegbuzie (2009) and specifically following a 'partially mixed, concurrent, equal status' design. The biophysical and socio-economic research methods are considered partially mixed because of the distinct research questions they respond to and because mixing is predominantly designed to occur in later stages of analysis. The data are collected generally concurrently through baseline and monitoring phases, and carry equal status in the research design. To communicate this complex design with clarity the two parts of this document are organised differently to align with disciplinary and methodological differences.

2 BIOPHYSICAL MONITORING

The following chapter outlines current plans for environmental and ecological monitoring. It is critical to note that these plans are subject to change, particularly with respect to the number of samples to be collected, sampling locations, and parameters included during each sampling period, based on resources available and final design specifications. It is particularly important to note that funding has only been provided for a full time member of staff to conduct this monitoring for less than one year after the interventions, so the second year of post-intervention sampling will necessarily be more limited than the first to account for this limitation, focusing on those parameters and location where more data is needed.

2.1.1 General Principles of Survey Design and Sampling

Survey Design: Before After Control Impact (BACI)

BACI survey design aims to separate the effects of an intervention (impacts) from those of other spatial and temporal variables. An impact site is where a specified impact from the intervention (NBS) is expected to occur. A control site is selected as a location similar - ideally identical - to the impact site pre-intervention, which is expected not to be affected by the intervention. The control site should be located at a sufficient distance from the paired impact site to minimise the likelihood of observations not being independent. As baseline conditions (e.g. ecological community, windspeed, pollutant levels) of the impact and control sites selected are unlikely to be identical, sampling both impact and control sites pre-intervention as well as post-intervention can identify and account for other variables, providing a more robust survey approach. For most biophysical variables in this monitoring program, we will pair Liverpool NBS sites (impact site) to control sites located within the same demo area, similar to the pre-intervention NBS site. NBS (impact) sites and control sites will be sampled during the year pre-intervention (September 2018-2019) to provide a baseline and post-intervention.

Temporal and Spatial scale

Monitoring design should be at an appropriate temporal and spatial scale to detect change in the indicators selected. For example, considering the metric *observed pollinator-flower visits* as an indicator of change in number of pollinator species using an NBS as foraging habitat post-intervention: sampling should be carried out at both impact and control sites over sufficient time to account for natural population fluctuations. Depending on the environmental parameter selected, a series of control sites may be placed at different radii from the intervention to assess the scale of the impact. For example, additional control sites can be located at increasing intervals from roadside impact and control sites to inform the scale at which an NBS green infrastructure intervention impacts NO_2 levels originating from vehicle emissions.

Causation and inference

Replicated experiment with randomized assignment of the treatment (intervention and control) is not practicable for most studies of environmental impact. In this study the NBS (intervention) site locations are subject to existing constraints including urban infrastructure. BACI is therefore selected as the most robust approach to survey design to evaluate impact of an intervention. Causation of impact by the intervention cannot be established by this method as the influence of non-identified confounding variables cannot be ruled out. Impact from the intervention can be inferred by significant difference in measured values for an environmental parameter between samples from the impact site post-intervention, and samples from pre-intervention impact and control as well as post-intervention control sites. The scale at which the impacts of the intervention are relevant should be stated.

Limitations

Known limitations of the study/monitoring method should be stated so that the reader can interpret the results within the context of these constraints. For example;

- Potentially confounding variables for which the study has been unable to account (such as possible differences in land management between impact and control sites)
- Sub-optimal survey conditions or missing surveys/data
- The assumptions underlying a model used to quantify environmental impact or economic benefit

Sample size and statistical analysis

The power of statistical tests increases with the number of sampling units. Monitoring design should incorporate enough sampling units to generate data with sufficient statistical power to enable the rejection of the null hypothesis of no difference pre- and post-intervention in the environmental parameter selected.

Ecological Survey Principles

Selection of indicator species

Robust empirical evidence should underpin the selection of indicator species to infer an ecosystem function or service, or the presence of a group of species. The size of the sampling areas (study sites) should be appropriate to the ecology of the focal taxon.

Stratification

Stratification starts by partitioning a study area into blocks of similar habitat (which in total represent the population of interest within the study site). For example, identifying each of the floral resources strata within an otherwise urban grey study site. Sampling is then organised within each of the blocks, and an assumption may be made that the results can be extrapolated to the rest of a given block.

Sample replication in ecological survey

As a complete census of a study site for a focal taxon is generally not practicable in ecological survey, a random sampling method should be determined with sufficient samples to be representative of the community sampled. For example, construction of a diversity curve to evaluate at what point diversity index values level off as sample numbers rise, can indicate of level of sampling effort required to represent the diversity of the community sampled. Samples should spaced from each other as much as practicable in order to be independent. Random sampling will be employed where feasible, but some of our surveys take a systematic sample along a transect route, and practical accessibility has also influenced survey locations – for more details see the individual protocols in each section below.

General References

Block *et al.* 2001. Design and Implementation of Monitoring Studies to Evaluate the Success of Ecological Restoration on Wildlife. Restoration Ecology 9

Dytham, C. 2011. Choosing and Using Statistics, 3rd edition. Wiley-Blackwell

MaGurran, A.E. 1988. Ecological Diversity and Its Measurement. University Press, Cambridge

2.1.2 CHALLENGE 1: Climate Mitigation and Adaptation

Total amount of carbon stored in vegetation

Rationale

Vegetation sequesters and stores carbon from the atmosphere, thus helping to mitigate climate change. GI-Val tool 1.7 can be used to estimate the amount of carbon sequestered by trees as they grow, and tool 1.8 can estimate the amount of carbon sequestered as a result of various other land use changes.

Tool 1.7 is based upon the Forestry Commission's Woodland Carbon Code Calculators and Lookup Tables (West, 2018). It distinguishes between broadleaf and coniferous trees, using sycamore/ash/birch of yield class 4 at 2.5m spacing as a proxy for the former and Sitka spruce of yield class 12 at 2.0m spacing as a proxy for the latter, as per the Small Project Carbon Calculator. It also distinguishes between thinned and non-thinned planting, and takes into account the varying levels of sequestration as the trees mature. The total is reduced by 20% to account for the model precision level and by 15% to represent the possibility that the trees are removed within the 50-year modelling period.

Tool 1.8 is based upon De Deyn et al (2010) and Dawson & Smith (2007). It estimates the carbon sequestration resulting from three types of land cover change:

- Land converted from improved grassland or other land use to semi-natural grassland
- Land converted from arable to wetland
- Land converted from grassland to wetland

Method

The areas of each type of new vegetation planted will be entered into GI-Val (Appendix 1)[3].

Temperature data to underpin temperature-based KPIs

Rationale

[3] https://www.merseyforest.org.uk/services/gi-val/

Urban heat island (UHI) effect refers to the increased temperatures of urban areas compared to surrounding rural areas under a range of meteorological conditions. Temperatures of sealed urban surfaces such as roads and pavements can be significantly higher than air temperature due to the higher capacity of construction materials to absorb and retain heat, releasing it during the night. The UHI effect can exacerbate summer heatwave conditions, with a detrimental effect on human health. Vegetation is well known to mitigate the effects of UHI through the process of evaporative cooling; where leaf stomata open at periods of intense heat to release moisture into the air. Trees additionally contribute to reducing temperatures by providing shade, making public space and travelling routes more comfortable for people on summer days when temperatures in urban areas are high. This KPI will focus on human thermal comfort in urban areas on hottest summer days; evaluating the contribution of NBS to reducing the UHI effect.

Monitoring method

Air temperature measurements will be taken once over the summer months (May- September) at multiple fixed points at each NBS study site selected for this type of monitoring and at paired control study sites. Surface temperature measurements may be taken at a subset of these sites, as complementary data and as an accessible communication medium to raise awareness of UHI effects. These temperature readings will usually occur at the same points as biodiversity or air quality monitoring locations (see those sections).

1. Air temperature measurement

Physical air temperature measurements at GI locations and control sites without GI pre- and post-intervention can be obtained using a portable anemometer or standard outdoor thermometer at a standard height, with the sensor shielded from direct sunlight. This is a cheap and simple method suitable for monitoring multiple fixed survey points over time. Temperature measurements at sampling points for each NBS should be taken on the same date and at similar times of day as measurements for its matched control site.

2. Surface temperature

A Thermal imaging camera[4] may be used to capture surface temperatures at GI locations and control sites without GI pre- and post-intervention as a complementary source of data and stakeholder/public education tool. Relative contribution of different urban surfaces to the UHI effect may also be inferred from difference in surface temperatures during hottest summer days. This is a relatively simple method suitable for comparing surface temperatures at multiple fixed survey points over time. Only temperature measurements at sampling points for each NBS be taken on the same date and at similar times of day as measurements for its matched control site will be used as monitoring data.

[4] The RevealPRO handheld thermal imaging camera with 320 x 240 thermal sensor will be used.

3. Reference data: air temperature

- A continuous air temperature data logger will be installed in each of the sub-demo areas to provide background data for air temperature in the shade.
- Air temperature data from the nearest Meteorological Office weather station (Crosby).

Heatwave risk

- Heatwave risk: UK metric (3 days > 25C day and 18C night)

A heatwave is by nature an extreme event with an unpredictable return period. It would be misleading to take observations for a single year or even 3-5 years as representative of the "risk" of heatwaves in a given area. However, given the mechanisms involved it is highly probable that as the mean temperature of an area increases, the amount of time spent above a certain threshold also increases.

We propose to:

1. Determine the relationship between mean daytime air temperature and greenspace coverage within a 50 m radius using our spot samples of air temperature and the three sub-demo continuous loggers (see previous section). (Alternatively we could use the relationship between maximum surface temperature and greenspace coverage which is built into STAR Tools, but we do not know the relationship between average air temperature and maximum surface temperature.)
2. Use the relationship between air temperature increase and increase in total heatwave days which was derived from global circulation models in Perkins-Kirkpatrick & Gibson (2017), at approximately 12 days per degree of warming in Northern Europe. These relationships are found to be remarkably linear all over the world. Note that Perkins-Kirkpatrick & Gibson used a heatwave definition that did not include night-time temperature: that daily T_{max} must exceed the calendar-day 90^{th} percentile of the GCM's control period for at least three consecutive days. However, most heatwave metrics are highly correlated to one another (Perkins & Alexander 2012) and no metric we could use would be very precise given the multiple levels of uncertainty.
3. Map the elevation of heatwave risk (extra expected heatwave days) in the Liverpool demo areas compared to the surrounding countryside using the linear relationships above, and the pre- and post- intervention greenspace maps developed during this project (described in the next section). This makes the assumption that urban heat-island warming has an equivalent effect to global warming of the same magnitude, which may not be true, but we are not aware of any available models that predict the relative severity of a heatwave in urban and rural areas.
4. Calculate the average difference between the pre- and post- intervention maps in days.

Projected maximum surface temperature reduction

The STAR Tools are surface temperature and runoff tools for assessing the potential of green infrastructure in adapting urban areas to climate change. They are freely available at http://maps.merseyforest.org.uk/grabs/. The surface temperature tool can be used to model the maximum surface temperature expected in a neighbourhood, taking into account the evaporative cooling effect of the vegetation. Since the implementation of nature-based solutions will usually result in an increase in vegetation cover, we should be able to see a decrease in the modelled maximum surface temperature under each climate change scenario (including the baseline).

The STAR Tools underlying models were used by The University of Manchester in the ASCCUE project where they were applied to Greater Manchester (Gill, 2006; Gill et al, 2007). They had previously been developed and used in Merseyside (Whitford et al, 2001). As part of the GRaBS project the surface temperature model was also used in Catania, Italy (Cuvato & Ianni, 2011). The surface temperature model was developed from an urban climate model used in Kuala Lumpur, Malaysia (Tso et al, 1991; 1990).

The following maps are an example of how the outputs from the surface temperature tool can be used. In Urban GreenUP, however, the areas of interest will be much smaller, and since the model is not well suited to very small areas, the number of subdivisions will be much smaller as well.

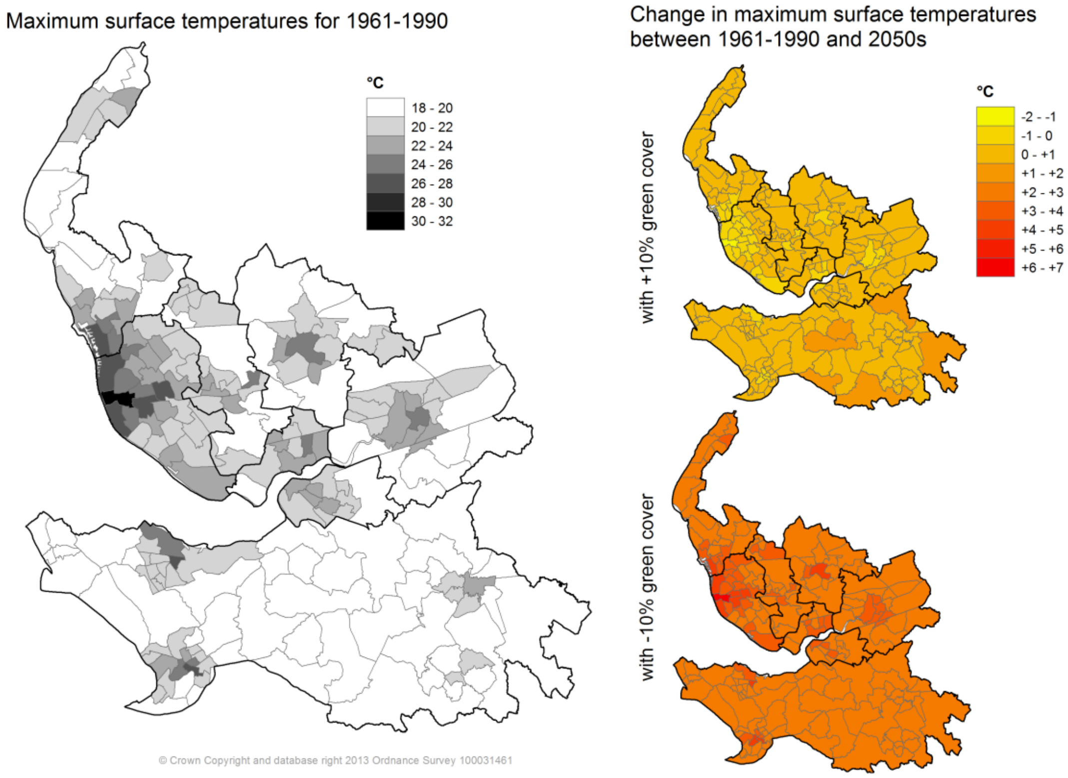


Figure 1: Example of a representation into a map of the KPI-13

Method

The sub-demo areas will be divided into study areas where groups of interventions have been made, and for each study area the pre- and post-intervention land cover will be calculated. The primary inputs for these calculations will be Ordnance Survey's MasterMap[5] and the landscape architects'

[5] https://www.ordnancesurvey.co.uk/business-and-government/products/mastermap-products.html

drawings. The default temperature scenarios and other parameters will be used, as these are appropriate to North West England.

Increased opportunity for species movement in response to climate change

Rationale

Distribution of many species in response to climate change may shift north, or to higher altitudes, to take advantage of newly suitable habitat as temperatures warm and existing habitat becomes unsuitable. The presence of sufficient blocks or corridors of suitable habitat to provide routes along which species can move is therefore key to maintaining populations under changing climate. Modelling habitat resources for movement and dispersal of species under different scenarios is of increasing importance for ecological network assessment and planning. The Condatis software developed by the University of Liverpool (Hodgson *et al.* 2012) is designed to model a multigenerational wave of species movement through a landscape. Using Condatis this KPI will measure whether GI NBS have provided increased opportunity for species movement in response to climate change.

Method

Use of the Condatis model to quantify increased (% change) long-distance range-shift potential for selected taxa as a result of GI interventions.

Baseline habitat input data

Baseline habitat flow maps [Figure 38 **D3.2 Mersey Forest**] show the relative importance of three habitat types, (intensively and less intensively managed grassland and trees) and identify potential bottlenecks for species movement in the three demo areas and wider Liverpool area. Bottleneck view highlights habitat links that currently constrain connectivity (represented by darker coloured lines), which is also where habitat restoration could make a big difference. The baseline habitat flow maps were produced in 2017 using the Condatis model (University of Liverpool) with habitat data (200m rasters) created from OS Mastermap Green infrastructure typology (MasterMap Topography Layer and Greenspace Layer) and tree canopy data from Bluesky's National Tree Map. Polygons classified as intensively managed grassland included land use classifications: general amenity space, green roof, institutional grounds, outdoor sports facility, park or public garden and private domestic garden. Polygons classified as less intensively-managed grassland included land use classifications: grassland, heathland, moorland or scrubland, cemetery, churchyard or burial ground and derelict land. Species dispersal distances were set as 1km and 2km. Source and target locations were selected to represent species movement from south to north through the Liverpool area [Appendix **D3.2** Mersey Forest].

Post-intervention habitat input data

Use existing 2017 Condatis maps referred to above [**D3.2** Mersey Forest] (or updated maps to reflect any update in OS MasterMap Topography/Greenspace Layers/Bluesky National Tree Map) to represent baseline pre-intervention habitat in the demo areas. From project records detailing the extent, location and type of intervention, shapefiles/cells will be created and added to the model to represent the extent and type of new NBS GI habitat post-intervention.

Calculation of % change in long-distance range-shift potential pre- and post-intervention

The Condatis model will be used to test whether the new NBS GI habitat patches have increased the connectivity value of existing habitat networks across the Liverpool area. Calculate the improvement in speed (the overall conductance of the whole landscape) post-intervention. Quantify the impact on flow made by a new habitat cell/cluster of cells (NBS GI) in each demo area by obtaining flow values for each new habitat cell pre- and post-intervention. Express difference in flow speed values as a percentage change value. (Note where there was no habitat pre-intervention the flow will be zero).

Technical specifications

Condatis is a user-friendly, open source program, which is available to anyone. It is released under the GNU General Public Licence version 3 with one additional permitted term: http://download.condatis.org.uk/Condatis_License.html. The Condatis software runs on Windows and Unix-like operating systems such as Mac OS X and Linux. Condatis is written in Python 2.7. Author: David W. Wallis and Jenny A. Hodgson

- Title: Condatis; software to assist with the planning of habitat restoration
- Version: [0.6.0.]
- URL: www.condatis.org.uk

References

Hodgson, J.A., Thomas, C.D., Dytham, C.,Travis, J.M.J. and Cornell, S.J. (2012) The speed of range shifts in fragmented landscapes. PLoS ONE 710

Hodgson, J.A., Wallis, D.W., Krishna, R. & Cornell, S.J. (2016) How to manipulate landscapes to improve the potential for range expansion. *Methods in Ecology and Evolution,* **7,** 1558-1566. http://dx.doi.org/10.1111/2041-210X.12614

Habitat Map data sources

OS Mastermap Topography and Greenspace Layers

https://www.ordnancesurvey.co.uk/business-and-government/products/mastermap-products.html

http://digimap.edina.ac.uk/

Bluesky National Tree Map

https://www.blueskymapshop.com/products/national-tree-map

2.1.3 CHALLENGE 2: Water Management

Run-off coefficient in relation to precipitation quantities

Rationale

The STAR Tools are surface temperature and runoff tools for assessing the potential of green infrastructure in adapting urban areas to climate change. They are freely available at http://maps.merseyforest.org.uk/grabs/. The surface runoff tool can be used to model the volume and percentage of rainfall that will be converted to runoff in a neighbourhood, taking into account the various effects of the vegetation (interception, infiltration and storage). Since the implementation of nature-based solutions will usually result in an increase in vegetation cover, we should be able to see a decrease in the modelled surface water runoff under each precipitation scenario (including the baseline).

The STAR Tools underlying models were used by The University of Manchester in the ASCCUE project where they were applied to Greater Manchester (Gill, 2006; Gill et al, 2007). They had previously been developed and used in Merseyside (Whitford et al, 2001). The surface runoff model is based upon the US Soil Conservation Service approach (Soil Conservation Service, 1972).

Method

Each sub-demo area will be divided into study areas where groups of interventions have been made, and for each study area the pre- and post-intervention land cover will be calculated. The primary inputs for these calculations will be Ordnance Survey's MasterMap[6] and the landscape architects' drawings. The hydrological soil types will be derived from data from the National Soil Resources Institute at Cranfield University[7]. The default precipitation scenarios and other parameters will be used, as these are appropriate to North West England.

Nutrient abatement; abatement of pollutants (nutrient load/heavy metals)

KPI DEFINITION

KPI-30 is principally investigating the change to the chemical properties of water, during and after it has been impacted by Green Infrastructure (GI), in both time and space. Temporally, abatement of the above parameters will be investigated before GI interventions have occurred, once installed, and once the GI has established. Spatially, runoff will be observed before it reaches or is impacted by GI, once it is in the GI medium and once it discharges from the GI measure.

The outlined parameters, in addition to abiotic parameters such as dissolved oxygen (%) and redox (mV), ought to demonstrate the following changes between the baseline and post GI scenario, both spatially and temporally:

i) A reduction in heavy metal concentration

ii) A reduction in nutrient concentration. However, since tree-pits are occurring beneath ground, with low temperatures and in the absence of sunlight, it is possible that nitrate-N (NO_3^-) could increase in concentration, since conditions for nitrification may be suitable, but not for denitrification[8].

---

6 https://www.ordnancesurvey.co.uk/business-and-government/products/mastermap-products.html

7 www.landis.org.uk/data/index.cfm

8 Denitrification occurs with the supply of DOC where nitrogen ions are oxidised, under constant oxygen (O2) loss: nitrate-N (NO3-), nitrite-N (NO2-), nitric oxide (NO) and then dinitrogen gas (N2) (Sprent, 1987; Ranalli and Macalady, 2010). Denitrification is biogeochemically significant since it sinks N into the atmosphere, whereas biota death returns N to the ecosystem (ibid).

The number of samples, sampling locations, and number of samples are subject to change based on the design of the interventions as well as weather conditions, staff time devoted to other KPIs, and other practical considerations.

KPI SCOPE

The following parameters, whilst highly useful in understanding aquatic water quality, will not be monitored under this KPI for reasons of expense, time occupied in the laboratory or the availability of instruments within the University. These parameters are:

i) Biological Oxygen Demand (BOD) (5 day ATU)

ii) Chemical Oxygen Demand (COD), both i and ii above indicate oxygen demand associated with the decomposition of detritus.

iii) Dissolved Organic Carbon (DOC), since the University of Liverpool does not have a TOC (Total Organic Carbon) analyser calibrated to sampling freshwaters.

iv) Polycyclic Aromatic Hydrocarbons (PAHs), from vehicle emissions, The Scottish Environmental Protection Agency reviews of vehicle related metals and PAHs notes:

With literally hundreds of thousands of PAH isomers possible, the logistics make it impossible to monitor all compounds, and only a fraction of the total have even been identified (Harrison, 2001). The US EPA have chosen 16 to represent the family, and these compounds have become the standard suite for environmental studies. The PAH values given here are for total PAH content based on the US EPA 16. [9]

[9] Napier, F., D'Arcy, B., Jefferies, C., (2008) A review of vehicle related metals and polycyclic aromatic hydrocarbons in the UK environment. 10th IWA International Specialized Conference on Diffuse Pollution and Sustainable Basin Management: 18–22 September 2006, Istanbul, Turkey. *Desalinisation*, 226 (1-3), 143 – 150. https://doi.org/10.1016/j.desal.2007.02.104

Table 2. Abiotic properties of water measured by a multi-parameter meter: YSI ProDSS

Abbreviations
RMM = Relative Molecular Mass
RAM = Relative Atomic Mass

Rank	Parameter	Form	Units	Normal Mass Reporting	What is it?/Notes/Comments
BEST MEASURED WITH A PROBE - Table 1					
1	**Dissolved Oxygen**		% Sat or mg L^{-1}		
2	**Redox**		mV		**Redox** (short for reduction–oxidation reaction) (pronunciation: /ˈrɛdɒks/ redoks or /ˈriːdɒks/ reedoks) is a chemical reaction in which the oxidation states of atoms are changed
3	**pH**				
4	**Electrical Conductivity**		µS cm^{-1}		Electrical conductivity (µS/cm), taken as aqueous conductance of electricity through inorganic ionic solution, is affected by anions$^{(-)}$ such as nitrate, phosphate and chloride or, cations$^{(+)}$ such as calcium, sodium and iron (Foster *et al* ., 1982; Eaton *et al.,* 2005). EC is reported in micro Siemens per centimetre (µS/cm), reflecting ion concentration (*ibid*). Distilled pure waters have an EC range of 0.5 – 3 µS/cm. Bio indicator species such as freshwater pearl mussels (*M. margaritifera) have a upper threshold of* 100 µS/cm (Table 2.1., *ibid*), the YSI probe auto-references EC to 25°C since ion activity is influence by temperature
5	**Total Dissolved Solids (TDS)**		mg L^{-1}		
6	**Turbidity**		NTU		This dissolved, colloidal and suspended matter contributes to scaled water opacity (Eaton *et al., 2* 005). Clarity is measured by turbidity (NTU) using light-ray penetration and scatter through a specimen to derive an NTU (Nephelometric Turbidity Units) (*ibid*).
7	**Salinity**		sal.		In the Practical Salinity Scale, practical salinity is defined in terms of the ratio K_{15} of the electrical conductivity of the seawater sample, at a temperature of 15° C and a pressure of one standard atmosphere, to that of a potassium chloride (KCl) solution, in which the mass fraction of KCl is 32.4356 x 10^{-3} at the same temperature and pressure. http://www.salinityremotesensing.ifremer.fr/sea-surface-salinity/definition-and-units
8	**Temperature**		°C		
9	**Total Algae**		RFU		Conventional lab measurement of cyanobacteria is Colony forming units per ml (CFU/mL) or Cells/mL. The YSI units are different, in that they use difference sensor units, Relative Fluorescent Units (RFUs) or µg/L (micrograms per litre) of pigment is the general unit used in automated sampling, which uses known wavelengths of absorption/excitation and emission targeted at cells to determine fluorescence and therefore RFU. RFU is a scaled measurement of the output of the sensor, and is the default output of the sensor, and represents a unit less dependant on the types of algae you have in your sample compared to other units, such as CFU or cells/mL - which require correlation. RFU is the recommended unit, and the one used by USGS and US EPA, and and it will therefore be the unit that will be used for Urban GreenUP, in freshwaters Phycocyanin RHU is the unit under investigation at Sefton Park Lake - Sub Demo C
10	**Total Chlorophyll**		RFU		Chlorophyll is in all algae and has pigmentation and fluorescence, chlorophyll converts sunlight energy through photosynthesis into cellular fixed carbon. Relative Fluorescent Units (RFUs) of Chlorophyll. Total algae and chlorophyll generally correlate with increasing pH and DO% Sat: https://www.glerl.noaa.gov/res/HABs_and_Hypoxia/ . The general rule is the more chlorophyll you have the more algae you have.

Table 3. Nutrient and salt concentration analysed in a laboratory by a SEAL Auto-Analyser 3 HR

1	**Chloride (Cl)**		mg L^{-1}	RMM	Chloride is an emerging urban pollutant as a result of road de-icing (Novotny et al. 2009). The chloride concentration in streams has been directly correlated with the percent of impervious surface area (Kaushal et al. 2005) and the quantity of rock salt purchases (Novotny et al. 2008)
2	**Nitrogen (N)**	Nitrate-N (N-NO_3^-)	mg N L^{-1}	RAM	
3		Nitrite-N (N-NO_2^-)	mg N L-1	RAM	
4	**Phosphorous (P)**	Orthophosphate (PO_4^{3-})	mg P L-1	RAM	
5	**Ammonia (NH_3)**				
6	**Ammonium (NH_4^+)**		mg L^{-1}	RMM	
7	**Fluoride (F)**		mg *x* L^{-1}	RAM	

Table 4. Dissolved aqueous metal concentrations analysed by an ICP-MS (Inductively Coupled Plasma - Mass Spectroscopy)

1	**Zinc (Zn)**		mg L^{-1}	RMM	Research Napier *et al* (2008) has demonstrated a year on year increase in particulate zinc loss into UK waterways.
2	**Copper (Cu)**		mg L^{-1}	RMM	Cars are now major sources of copper, zinc and PAHs to the environment. Zn and Cu are most soluble, and likely to be easily traced in the aquatic environment.
3	**Cadmium (Cd)**		mg L^{-1}	RMM	`
4	**Mercury (Hg)**		mg L^{-1}	RMM	
5	**Lead (Pb)**		mg L^{-1}	RMM	In general decline with unleaded petrol, but with a legacy effect, as with lead paint.
6	**Manganese (Mn)**		mg L^{-1}	RMM	
8	**Potassium (K)**				
9	**Magnesium (Mg)**				
10	**Sulphate (S)**		mg *x* L^{-1}	RAM	
11	**Bromide (Br)**		mg *x* L^{-1}	RAM	
12	**Calcium (Ca)**		mg L^{-1}	RMM	
13	**Sodium (Na)**				

Table 5. Suspended sediment concentration and sedimentary metal concentration

1	**Suspended Sediment Concentration (SSC)**		mg L^{-1}		Best analysed in a sediment laboratory
2	**Carbon Content of Sediment (Loss on Ignition)**		%		Best analysed in a sediment laboratory
3	**Metal concentrations of Sediment**		µg or %		Alaysed using an XRF (X-ray flourescence)

KPI Methods

1) Abiotic sampling (as in table 2)

A YSI multi-parameter (Pro Digital Sampling System) meter will be used to sample all parameters listed in table 1. Further information, including technical specifications and detailing of parameter extrapolation, can be found here: https://www.ysi.com/prodss

2) Near dissolved aqueous nutrient and salt concentration (as in table 3)

All grab samples will be collected in a 100ml sample vial, and immediately refrigerated in a cool-box for transportation to the laboratory. Upon arrival at the laboratory samples will be pulled through a micro-filter with a pore size of 1.5 µm before being loaded into the SEAL AutoAnalyzer 3 HR. Filtration through a 1.5 µm does not mean that the samples loaded represent dissolved aqueous concentration, but near dissolved status, since some suspended/colloidal material will enter the sample. This filtration standard will be used for speed and efficiency, but introduces a non-standardisation to sampling for nutrients and metals (see section 3 on metals). The SEAL auto analyser has an on-line filtration system, which may compensate for the introduction of colloidal matter.

3) Dissolved aqueous metal concentration (as in table 4)

All grab samples will be collected in a 100ml sample vial, and immediately refrigerated in a cool-box for transportation to the laboratory. Upon arrival at the laboratory, 10 ml of the sample was filtered through a 0.2 µm pore size syringe filter; this diameter (⌀) was chosen to strain-out bacteria, and derived dissolved concentrations of metals. In order to acidify the sample, 1ml of ultrapure nitric acid (HNO_3) will then be added to the filtered sample to preserve trace cations, all samples were then frozen, to enable batch processing of samples at the end of each month[10]. C c.1 µl of sample was loaded into the ICP-MS for determination of a full range of metals, including those outlined in table 3, and metals such as arsenic.

The above filtration and acidification procedure is likely to be sufficient. However if samples from the urban environment are highly turbid and fouled, then a 4-acid digestion procedure will be adopted to dissolve most silicate minerals. Where samples are determined to be organic rich and oil contaminated, microwave digestion will be used either separately or in addition to 4-acid digestion. See solution ICP-MS laboratory in the US. Geological Survey guidance: https://crustal.usgs.gov/laboratories/icpms/solution.html

4) Suspended Sediment Concentration – and metal concentration within that sediment (as in table 5)

In-stream waters were sampled for Suspended Sediment Concentrations (SSC) with samples being extracted using a 1000ml bottle. Pre-weighed Whatman grade 934AH glass micro-fibre papers with a pore size of 1.5 µm were installed in the Buchner flask and the sample pulled through using a vacuum pump. The sediment laden filters were oven dried at 103 ± 2 °C for 24hrs, placed in a desiccator to cool, before being reweighed. The difference in filter weight proportional to sample volume was used to calculate SSC in mg L^{-1} (Equation 1.1.).

[10] USGS (2004) National Field Manual for the Collection of Water-Quality Data (NFM). Available at: https://water.usgs.gov/owq/FieldManual/ (Chapter 5). Accessed: July 12th .18

$$SSC = \Sigma M \frac{M}{V}$$ **Equation 1.1**

where SSC is suspended sediment concentration (mg L^{-1}), *m* = mass of sediment less the filter paper weight (mg) and, V = volume of sample water (L).

Having determined the SSC, and therefore the known mass of sample, the sample was placed in a pre-weighed crucible. Before this, the crucible had been in an oven at 105 °C for 24 hours to eliminate any moisture. The sample and crucible were then placed in a muffle furnace at a temperature of 550°C for 4 hours. The samples were subsequently cooled in the desiccator before being reweighed (g) (MAC). The mass of the ash material (g) (Ash_{550}) was then calculated using the equation:

$$Ash_{550} = MAC - MC$$ **Equation 1.2**

From which the organic content (%) is calculated:

$$LOI\%_{550} = \frac{MS - Ash_{550}}{MS} \cdot 100$$ **Equation 1.3**

In order to determine the metal concentration of the sediment, filter papers were loaded into the crucibles of the XRF, then analysed for metal concentration, proportioned against the overall suspended sediment concentration of water.

Volume of water removed from water treatment system

Rationale

Green infrastructure can prevent rainfall from entering the water treatment system by allowing it to soak into the soil or to evaporate back into the air.

Method

See 'Volume of water slowed down entering water treatment system' below

Volume of water slowed down entering water treatment system

KPI DEFINITION

KPI-39 is principally investigating rate change in runoff production at field or plot scale. The parameters under principle investigation are discharge (m^3 sec^{-1}) and flow velocity (m sec^{-1}), which when plotted on a storm-hydrograph, ought to demonstrate the following changes between the baseline and post GI scenario:

iii) An increased lag-time (L), the time of peak rainfall to peak discharge and,

iv) Reduced peak discharge (Q_p)

KPI SCOPE

Evapotranspiration (ET) (mm sec^{-1}) and interception rates will not be directly observed under this KPI, through various processes, both are implicit in reducing inflow rates into sewers. ET represent system losses of groundwater, potentially lowering wetted fringe and water table, that is hypothesised to reduce soil moisture and increase infiltration – a useful GI service if permeable paving is installed (Hankin 2016).

KPI METHOD

I) Source local tipping bucket rainfall data (P), from Liverpool University weather observatory, scale P rates to study site area.

II) Determine inflow and outflow points to a given locality of GI interventions, established from surface water flood mapping (Environment Agency RoSWFM/JFLOW[11]) and overland flow routing model[12]

III) Apportion percentage inflow and outflow to the boundary of the plot or field-scale site under investigation.

IV) At the area of largest or principle inflow and outflow, install a gauging station, with one or more mid-point gauging stations along the overland flow-pathway and proposed GI corridor, to augment boundary observations, creating a longitudinal chain of continuous discharge observation.

V) Conduct continuous discharge monitoring through the baseline and post-intervention scenario to tests the effects of GI on increased lag-time and reduced $Q_{p.}$

APPARATUS

Open Pipe

I) V-notch gauging station weir with stilling well and spot discharge measurement to establish stage-discharge relationship, and therefore continuous discharge, extrapolated from 5 minute water-level (stage).

II) Non-contact flow measurement – Particle Image Velocity [13]and infa-red height sensors to continually monitor height and velocity, over a known cross sectional area. Together these observations can combine to create a continuous discharge data-series.

Closed Pipe

i) Ultrasonic Flow Meters, see example here: http://www.rshydro.co.uk/liquid-pipe-flowmeters/

[11] https://www.gov.uk/government/publications/flood-risk-maps-for-surface-water-how-to-use-the-map

[12] http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/stream-order.htm

[13] http://meetingorganizer.copernicus.org/EGU2015/EGU2015-8582.pdf

2.1.4 CHALLENGE 4: Green Space Management

Increased connectivity to existing GI

Rationale

The extent and spatial arrangement of accessible green space within each sub-demo area may have an important influence on public health and wellbeing; as well as having the potential to increase biodiversity. Vegetated areas provide cooling on hot days through evapo-transpiration; and trees reduce radiant heat by shading, making public space and travelling routes more comfortable for people on days when temperatures in urban areas are high. This KPI will focus on public accessible greenspace, therefore residential gardens will not be considered here.

Method

Typology map data representing areas of GI both before and after NBS GI interventions will be analysed using a Geographic Information System (GIS) to calculate change in each sub-demo area in *a)* the proportion of the sub-demo area represented by GI, *b)* distance between areas of GI, and *c)* the number of street trees

Baseline habitat input data

Baseline GI typology maps [Figure 38, D3.2 Mersey Forest] were produced in 2017 using OS Mastermap Green infrastructure typology (MasterMap Topography Layer and Greenspace Layer) and tree canopy data from Bluesky's National Tree Map. If the Mersey Forest maps are updated to reflect any update in OS MasterMap Topography/Greenspace Layers/Bluesky National Tree Map before interventions start in the demo areas this updated version will be used.

Post-intervention habitat input data

From project delivery records detailing the extent, location and type of each GI intervention, shapefiles will be created and added to the baseline typology map to create a new map layer representing the extent and type of new NBS GI habitat post-intervention.

Calculations

Use of GIS to calculate % change in the following parameters in each sub-demo area following NBS GI interventions:

1. The extent of accessible GI. Calculate the proportion of the sub-demo area occupied by GI (select all GI types in typology layer except residential gardens) pre- and post- GI interventions.
2. The distance between each accessible GI patch and its nearest accessible GI neighbour within the sub-demo area. If *d* is the nearest-neighbour (Euclidean) distance from accessible GI patch *i* to accessible GI patch *j*; calculate the mean nearest-neighbour distance over all patches, both pre- and post-intervention (FRAGSTATS, 2015)
3. The distance to the nearest accessible green infrastructure everywhere (for every raster cell) calculated using a raster nearest neighbour approach
4. the number of street trees

Technical Specifications

Habitat Map data sources

OS Mastermap Topography and Greenspace Layers

https://www.ordnancesurvey.co.uk/business-and-government/products/mastermap-products.html

http://digimap.edina.ac.uk/

Bluesky National Tree Map

https://www.blueskymapshop.com/products/national-tree-map

Spatial Analysis software

QGIS is free, open source software. The current version is QGIS 2.18.16 'Las Palmas' and was released on 19.01.2018. QGIS is available on Windows, MacOS X, Linux and Android. https://www.qgis.org/en/site/forusers/download.html#. QGIS 2.18 user guide is available at https://docs.qgis.org/2.18/en/docs/user_manual/

Calculation of landscape metrics in QGIS

QGIS Landscape Ecology Plugin LecoS http://plugins.qgis.org/plugins/LecoS/ is based on metrics taken from FRAGSTATS for calculation of landscape metrics using raster and vector layers. http://www.umass.edu/landeco/research/fragstats/fragstats.html.

References and sources of further information

Urban GreenUP (2017) D3.2 Baseline Document for Liverpool 2017. Urban Green UP Project Deliverable. Liverpool, UK.

FRAGSTATS, 2015 McGarigal, K. fragstats.help.4.2.pdf

http://www.umass.edu/landeco/research/fragstats/fragstats.html.

LecoS2.0.7 http://plugins.qgis.org/plugins/LecoS/

QGIS Development Team 2013. QGIS Geographic Information System. Open Source Geospatial Foundation. URL http://qgis.osgeo.org

Ecological surveys underlying biodiversity analysis

Phase 1 vegetation

Purpose of survey

- To map and classify the habitats present within the sub-demo areas (plus buffer) pre- and post-intervention.
- To inform site selection for KPI monitoring, including source sites, control sites and other UGI sites.
- To assist in planning transect routes for surveys of focal species so that source, target and control habitats are represented.
- To provide detailed habitat data to measure change in extent and spatial arrangement of habitat suitable for focal species (pollinators and insectivores) pre- and post- NBS GI interventions

- To provide detailed habitat classification for calculation of a range of habitat variables in evaluating the influence of habitat composition within a range of different radii on pollinator species composition and abundance at study sites.

Method proposed

- Field survey of accessible areas of the sub-demo areas plus 100m buffer (April - June)
- Use of aerial (Digimap Aerial) or satellite imagery to confirm whether non-accessible areas are vegetated or non-vegetated/ with mature trees present.
- Create a QGIS spatial database to digitise and present Phase 1 Habitat Map Layers

Protocol

JNCC Handbook for Phase 1 habitat survey A technique for environmental audit (2007). JNCC Phase 1 Habitat guidelines provide appropriate classifications for urban land and habitat features:

- Broadleaved tree (can indicate species on map)
- Coniferous tree ((can indicate species on map)
- Broadleaved woodland - semi-natural
- Broadleaved woodland – plantation
- Coniferous woodland - plantation
- Mixed woodland – semi-natural
- Mixed woodland – plantation
- Scrub
- Parkland and scattered trees
- Marsh/marshy grassland
- Neutral grassland
- Acid grassland
- Calcareous grassland
- Improved grassland
- Semi-improved grassland (species-poor or species-rich)
- Bare ground
- Ephemeral/short perennial vegetation
- Tall ruderal vegetation
- Swamp
- Marginal
- Innundation
- Standing water
- Running water
- Cultivated/disturbed land – arable
- Amenity grassland
- Wall
- Introduced shrub
- Buildings
- Other habitat
- Refuse tip
- Spoil
- Fence

- Dry ditch
- Earth bank
- Hedges

Additional and adapted vegetation classification categories to describe urban planting types

For the purposes of this survey, the semi-improved grassland category above will include urban grassland which has developed in response to anthropogenic influence such as development, land management or disturbance; to include sites re-seeded with wildflower mixes/naturally regenerating abandoned sites/road verges etc (which may be species poor/species rich). Target notes will be used to describe vegetation communities in this category in more detail.

Two additional vegetation classifications are used in this survey for types of ornamental planting which are frequent in city parks and gardens and amenity landscape planting around city developments

- 'Mixed planting' to describe areas of landscaping planting which mainly comprise a mix of introduced shrubs and non-native herbaceous flowering plants
- 'Herbaceous border' to describe managed ornamental borders containing non-native flowering plants

Target notes

Target notes can be used in extended Phase 1 habitat survey to describe site management and vegetation characteristics and to indicate locations for

- plant species lists including the dominant and characteristic species of a vegetation type. A full species list for each habitat is not necessary for Phase 1 habitat classification.
- habitat features which are suitable to support protected/priority/focal species (structural/topographical/suitable for bat roosts -hollow trees/tree cavities/caves)

Pollinators and floral resources

NBS Type

Monitoring focus for this KPI will be NBS sites with herbaceous or shrub vegetation including floral resources, but not including trees; (although some urban trees produce flowers/blossom, it is difficult to survey them in a comparable way to the quadrat method below). The NBS types proposed in this category are:

Sub-demo A (Baltic)

Pollinator verges

Pollinator walls vertical

SUDs (Rain garden)

Sub-demo B (BID)

Pollinator roofs

Pollinator walls vertical

Sub-demo C (Jericho)

Pollinator verges

Pollinator walls vertical

SUDs (open water)

Study sites

A 'study site' will comprise the extent of an area of homogenous herbaceous vegetation selected within a 'patch'. A 'patch' will represent an area of (more or less) continuous greenspace (e.g. park or NBS). A large patch (e.g. park) may contain more than one 'study site'.

Study site selection categories

(i) Pollinator NBS sites with herbaceous vegetation (i.e. not tree interventions); (ii) paired control sites within the same demo area and of a similar size to NBS match site, where no intervention is planned (i.e. similar during the baseline time period, but different afterwards); (iii) a matching number of randomly selected pre-existing UGI sites (with public access) within or close to each demo area; (iv) a matching number of homogenous areas of herbaceous vegetation in large source sites (with public access - parks etc) within or close to each sub-demo area.

Phase 1 Habitat Survey and/or Typology Map created by Mersey Forest in 2017 using OS Mastermap Typology and Greenspace layers will be used to identify suitable source sites/pre-existing UGI sites and control sites.

Number of study sites

Pollinator NBS GI – a total of 9 study sites depending on the spatial arrangement and design of NBS within the demo sites: (each with 2x 1x1m pollinator samples and 6x 1x1m floral resources samples)

For each pollinator NBS study site selected; a control study site, a randomly selected existing UGI study site and a source study site will also be selected.

Total number of study sites 36

Number of samples

Total number of 1x1m samples per full set (to be repeated every 4 weeks) = 72 pollinator samples and 216 floral resources samples

Size of sampling unit

1x1m quadrats are appropriate to measure floral density, vegetation composition, species richness and diversity in flower-rich grassland or ornamental shrub vegetation and provide a suitable area over which to observe and record flower visits by pollinating insects. In the case of green walls, a 1x1m area will be selected estimated using ground measurements (with the centre of the plot at head height if possible, or if the entire wall is above head height, sampled using binoculars). The position of the plot along the length of the wall will be determined by random number.

Number of samples

An equal number of random samples should be carried out for each study site, although study site size (the area of homogenous herbaceous vegetation) may vary. For each 1x1m pollinator observation sample, 3 1x1m floral resources quadrats should be sampled at random in the study site (to include the quadrat selected for pollinator observation).

Repeated sampling & detectability of focal taxon

Each study site will be sampled once every 4 weeks between May and September (selected as an optimal seasonal time window for recording flowering plants and pollinator foraging activity in the UK) pre-intervention September 2018-2019and post-intervention). Pollinator observations will be carried out between 10 and 4pm, in appropriate weather conditions (see below) for detecting pollinator visits to floral resources.

Location of samples

Sampling locations will be selected at random at every visit on each occasion to ensure observations are independent. To select random location, in advance of the survey a 1m grid produced in QGIS will be overlaid on a map of each study site and random numbers for x and y co-ordinates used to determine location of the required number of pollinator 1x1m quadrats. The co-ordinates generated from the random selection process will be located at the study site using Garmin e-trex GPS (to a 3m accuracy limit of the e-trex device). If there are no open flowers at the point selected at random, then the surveyor should walk to the nearest flower seen and place the quadrat there, recording the distance walked from the random point. The distances can later be used to infer the density of flower-containing squares in the study site. For each pollinator sample, a further 2 floral resources samples will be located; with distance and direction from the previous sample location determined by random numbers. At each sample location count the number of flowers open in a 1x1m quadrat, excluding grass flowers. If the number of flowers exceeds 50, determine a representative area containing 50 flowers and multiply this up to the quadrat area.

Sampling urban 'mosaic' communities

If flowers are extremely rare (the floral element of and urban 'mosaic' community), a slightly different approach will be taken as follows: in a study site comprised mainly of impermeable surfaces, no herbaceous vegetation or only scattered flowering plants (e.g. pre-intervention NBS and control sites) where the total area (m^2) of vegetation supporting floral resources is lower than the area required to support the total number of 1x1m pollinator and floral resources samples required per site; each of the scattered areas of flowering plants will be sampled using 1x1m quadrats, after which additional samples without vegetation - up to the total number of samples required per site - will be recorded as zero floral resources/pollinator-flower visits.

Where a study site is made up of more than one habitat type (for example, public gardens comprising amenity grassland and herbaceous flowering borders), only the sections of habitat providing potential nectar foraging resources for pollinators will be sampled (i.e. in this example, the herbaceous flowering border habitat); using a random stratified sampling approach to determine quadrat locations.

Pollinator samples

At each plot vegetation variables below will be recorded and pollinator visits to flowers within the plot will then be observed for a continuous period of 15 minutes. The observer should stand in a position that does not shade the plot. Close focus binoculars will be used, together with compact close focus camera to aid species ID. Collecting containers/net may be used to aid insect ID if necessary but all pollinators will be released immediately at the study site.

Weather conditions

National Pollinator Monitoring Scheme guidance: pollinator observation count surveys should be carried out when the weather is warm and dry. If the sky is clear (less than half cloud) the minimum temperature for a count is 13°C. If the sky is cloudy (half cloud or more) the minimum temperature for a count is 15°C. (www.ceh.ac.uk/our-science/projects/pollinator-monitoring)

Equipment: Garmin e-trex GPS, compass, lightweight 1x1m quadrat, binoculars, camera, ID guides, temperature logger (portable anemometer)

Variables to be recorded

At each floral resources sampling plot (1x1m) (including pollinator sampling plots)

- Date
- GPS location
- Number of flowers open (nectar source/pollen source), excluding grass flowers
- List of each vascular plant species and optionally estimated abundance (% cover)

At each pollinator sampling plot (1x1m)

- Time
- Temperature
- Beaufort wind scale
- Aspect – if sloped or vertical
- Substrate type
- % plot shaded
- % plot bare ground
- Number of visits by pollinating insects – landing on an open flower: record taxonomic group of each pollinating insect, to species level where possible. Alternatively, higher level pollinator groups can be used: corresponding to family or subfamily: bumblebees, solitary bees, hoverflies, butterflies, moths.
- Photograph of insect or plant species if required for ID.

Limitation

It is possible that the same insect may be recorded more than once if it leaves and returns to the plot during sampling).

Pollinator species increase

Rationale: pollinators as ecological indicators

The presence of pollinating insects such as bees, hoverflies, butterflies and moths visiting flowers is indicative of pollination (ecosystem service). Increased habitat for pollinators in NBS GI may contribute to increased abundance of pollinators in the wider urban area and provide stepping stones or corridors of habitat from a source site such as an urban park to another urban GI site. Flying pollinating insects are an appropriate indicator of pollination and biodiversity in new NBS GI as these taxa are likely to be already present in source sites such as urban parks within normal foraging range of the new NBS. Flying pollinating insects are highly-mobile, and therefore, considered to have the potential to reach the NBS sites within the project monitoring period.

Study site selection and survey method

See **Pollinator and Floral Resources** above

Data analysis

- For each NBS study site compare annual mean abundances (per site, including zeros for quadrats that could not be watched for lack of flowers) and species composition of pollinators recorded pre-intervention with those recorded post-intervention.
- Comparison of annual mean abundances and species composition of pollinators recorded at each NBS study site with those recorded at control sites, existing UGI study sites and source sites both pre- and post-intervention (per site, including zeros for quadrats that could not be watched for lack of flowers).

Optionally, extrapolate any increase seen per site to an overall increase given the area of floral resources created in the demo area.

Increase in density and seasonal spread of floral resources for pollinators

Rationale

Many flowering plants are insect-pollinated, some attracting generalist pollinator species; others having evolved to attract specialist pollinators. An increase in density of floral resources represents an increase in available sources of pollen and nectar which provide energy and food for pollinating insects. Seasonal spread of floral resources is important for sustaining food and energy resources for pollinating insects throughout the flight season. Increased habitat for pollinators in NBS GI may contribute to increased abundance of pollinators (and insectivore species) in the wider urban area and provide stepping stones or corridors of habitat from a source site such as an urban park to another urban GI site.

Site selection and survey method

See **Pollinators and Floral Resources** above

Data analysis

Comparison of number of open flowers (abundance) recorded *a)* during each survey month (May – Sept) and *b)* annually. Seasonal spread can be estimated as the inverse of the variance in flower abundance among months.

- At each NBS and its matched control site both pre and post-intervention

- At each NBS pre-intervention and post-intervention
- At each NBS, control site, existing UGI study site and source site pre-intervention and post-intervention

Increase in plant species richness and functional diversity

Many flowering plants are insect-pollinated, some attracting generalist pollinator species; others having evolved to attract specialist pollinators. It may be inferred that an increase in plant species richness and functional diversity at an NBS site post-intervention will provide new or higher quality potential foraging habitat for pollinating insects, increasing biodiversity. Increased habitat for pollinators in NBS GI may contribute to increased abundance of pollinators (and insectivore species) in the wider urban area and provide stepping stones or corridors of habitat from a source site such as an urban park to another urban GI site.

Site selection and survey method

See **Pollinators and Floral Resources** above

Data analysis

Comparison of flowering plant species recorded annually. Functional diversity can be measured by categorising observed species into ecological types, e.g. by life history or Ellenberg values. Ellenberg Indicator Values (EIV) are ecological indicator values determined according to typical environmental conditions associated with the occurrence of a plant species; originally in a central European context (Ellenberg, 1988), with EIV specific to occurrence of taxa in the UK determined by Hill *et a*l. (1999).

- At each NBS and its matched control site both pre and post-intervention
- At each NBS pre-intervention and post-intervention
- At each NBS, control site, existing UGI study site and source site pre-intervention and post-intervention

Increase in insectivore (e.g. bat) abundance and use of corridors for movement

Bats

Rationale: Use of bat activity survey as an indicator of biodiversity in urban green space

Bats are highly-mobile, insectivorous, flying mammals, and as such have the potential to represent a robust indicator of change in urban biodiversity and habitat connectivity. It may be inferred that the presence of foraging bats indicates the presence of insect prey such as moths (night-flying pollinators). Several bat species are commonly recorded in urban areas. Habitat types associated with bat activity include woodland, waterbodies, linear features (vegetation or water), grassland, suburban gardens and street lights (*Pipistrellus*), although other species are deterred by lighting. Several bat species may travel up to 4km to forage. Depending on species bats emerge from roosts to forage from just before sunset up to an hour after dark. Bat species vary in morphology and diet therefore are likely to target foraging resources in different habitats. A bat transect walk repeated over time using an automated bat detector to record bat echolocation calls can provide data for an index of use of discrete sections of the transect by bats, and of spatial distribution of a taxon.

Bat Transect Survey

Survey Design & NBS types

Transect routes are selected non-randomly to include a range of habitat types forming the focus of the study. However, within the transect (study site) *all* points are sampled, therefore random sampling is not necessary. The transect should be started at different points/reversed on each survey occasion to sample temporal and spatial variation in bat activity (at different time points post-dusk/different points in the survey season/different emergence and activity patterns among species). The transect may lead out of the demo area into an adjacent urban area or source site (to give a wider perspective on connectivity of habitat).

For each demo area transect routes will be selected to incorporate

- All biophysical NBS (pre-intervention/post-intervention) including floating gardens (up to 10 m from surveyor)
- Control habitat (selected as similar to pre-intervention habitat)
- Other urban GI
- Source sites (existing high-quality habitat likely to support bats)

Survey method

Transects are carried out by a surveyor (plus one for safety reasons) carrying an automated bat detector, walking at a constant speed along a pre-determined route. Bat echo-location calls are recorded automatically by the bat detector for subsequent analysis.

Seasonality

April – September inclusive represents optimal bat activity survey time (optimum period June-August)

Weather

Surveys will not be carried out if raining or strong wind. Air Temp should be 10'C or above at sunset (Collins 2016).

Start time

At sunset

Length

1 – 1.5 hours (approx. 3.5- 4km loop or linear transect) per transect, with four selected transects sampling different parts of the city.

Survey Frequency

Each transect survey will be carried out once during each month from May to September.

Equipment

Batlogger M real-time, full spectrum detector: GPS location and time of call and environmental temperature are automatically recorded

Record

- survey duration
- temperature at start and finish of survey
- date
- weather conditions (cloud cover; wind gusting Beaufort scale; rain) at start and finish of survey
- street lighting (for each section of the transect mark as unlit/intermittent lighting/regular street lighting).

Echolocation call analysis

Echolocation call analysis software: BatExplorer Software (Elekon, Switzerland). Download from the BatLogger M website along with guidance/specification documents):. Produces audible recording and sonogram files. Download batlogger echolocation recordings from SD card.

http://www.elekon.ch/en/batlogger/downloads/batexplorer-software/

Data analysis

For each transect: comparison of mean annual number of bat passes (in total and per species, or genus for *Myotis*) recorded for each section of the transect both pre- and post-intervention.

Limitations

Bat activity surveys do not provide a population index, rather an index of use, and provide a snapshot of activity only. Bat activity surveys are not suited to demonstrating absence of bat species (as not a continuous survey method - e.g. static automated detectors).

Bat activity surveys can be used to compare, spatially and temporally, the intensity of activity by bats recorded at different sections of transects through the three demo areas and neighbouring urban areas. Activity surveys can be used to compare the activity of any particular species (or *Myotis* to genus only) between sections of the transect and between different months and years. However, comparisons should not be made between species, as detectability of different species varies (Hundt 2012).

See Adams et al (2012) for different detectors including BatLogger; limits on all detectors range and call detection.

Risk assessment & ethics

Survey to be undertaken after dark in urban area, therefore second person required to accompany surveyor.

Activity surveys using bat detectors in the field will not require a protected species survey licence as bat detectors used correctly do not cause disturbance to bats (Hundt 2012).

References and sources of further information

Adams, A.M., Jantzen, M.K., Hamilton, R.M. and Fenton, M.B. (2012). Do you hear what I hear? Implications of detector selection for acoustic monitoring of bats. Methods in Ecology and Evolution, 3(6): 992-998.

Bat Conservation Trust. (2012). Bat Sound Library.

http://www.bats.org.uk/pages/bat_sound_library.html

Collins J (2016) Bat Surveys for Professional Ecologists; Good Practice Guidelines (3rd Edn) The Bat Conservation Trust, London.

Hundt L (2012) Bat Surveys: Good Practice Guidelines (2nd Edn) Bat Conservation Trust

Middleton et al (2014) Social Calls of the Bats of Britain and Ireland. Pelagic Publishing, Exeter

Russ, J. (2012) British Bat Calls. A guide to species identification. Pelagic Publishing, Exeter

Dragonflies

Dragonfly Transect Survey

Rationale: Use of dragonfly survey as an indicator of biodiversity in urban green space

Dragonflies (*Odonata*) are thermophilous mobile insectivores; attracted to open water habitats with tall marginal emergent vegetation and structural heterogeneity in surrounding habitat. In sub-demo C a dragonfly transect survey is proposed to investigate the ecological impact of:

- wetland SUDs creation (pond with wetland vegetation planting) and enhancement (widening of an existing open water channel)
- wetland habitat enhancement (reedbed creation and habitat management at urban park lakes)

The use of the transect method enables comparison of dragonfly activity between pre- and post-intervention habitat as well as between control and other UGI and source sites habitats represented by different sections of the transect. Several common dragonfly (*Anisoptera*) and damselfly (*Zygoptera*) species are associated with suburban open water habitats.

Survey design

Transect routes are selected non-randomly to include a range of habitat types forming the focus of the study. However, within the transect (study site) *all* points are sampled, therefore random sampling is not necessary. The transect should be started at different points or time of day on each survey occasion to sample temporal and spatial variation in dragonfly activity. The transect route sections will be selected to include:

- Wetland SUDs habitat (NBS) locations
- Control habitats (selected as similar to pre-NBS intervention habitat)
- Other urban GI (green space and blue space)
- Source sites (existing high-quality habitat likely to support dragonflies)

Survey method

Based on the transect method used by the British Dragonfly Monitoring Scheme (https://british-dragonflies.org.uk). Transects are carried out by a surveyor walking at a constant speed along a pre-determined route with fixed point (3 minute) stops at each of several pre-determined locations with a clear view of open water habitat. Fixed points should be at least 10m apart. Transect routes should be between 2-4km long, (walking time 45 mins – 2 hours), including the edges of open water habitats. Transects comprise a 7m wide route (for sections immediately alongside waterbodies the route width represents 1m bankside and 6m outwards from water's edge to include emergent macrophytes) through discrete sections of different habitat, enabling comparison of dragonfly species composition and abundances between habitat types. Routes should be open and sunny (non-shaded). Transect sections will be marked on the survey map.

Survey frequency

Transect to be repeated once every 3-5 weeks determined by the suitability of weather conditions (to a total of 5 transects) between May and September.

Seasonality and weather conditions

Transect surveys to be carried out during May to September between 10.00 am and 4.00 pm on days where weather conditions are suitable for recording dragonflies:

- Transect surveys should be carried out when air temperature is 17˚C or above in the shade (or 15 ˚C or above in the shade on sunny, calm days)
- Windspeed should not exceed 4 on the Beaufort scale
- Cloud cover should be less than 60%
- Transect surveys should not be carried out when it is raining or when temperatures are higher than 30 ˚C

Equipment

Close focusing binoculars should be used to confirm species identification

Record

- Survey duration (start and finish times)
- Temperature at start and finish of survey
- Date
- Weather conditions (cloud cover; wind gusting Beaufort scale; rain) at start and finish of survey
- Dragonfly and damselfly species and number (including newly emerged individuals) observed along **a)** each discrete section of the 7m wide transect and ***b)*** from each stationary observation point (fixed points which will be marked on map)

References & sources of further information

Beaufort scale http://www.crh.noaa.gov/images/iwx/publications/Beaufort_Wind_Chart.pdf

British Dragonfly Society 2009. Dragonfly Monitoring Scheme Manual.

2.1.5 CHALLENGE 5: Air Quality

Annual mean levels of fine particulate matter (e.g. PH2.5 and PM10) in cities

Rationale

Road transport and construction operations are identified as major sources of air pollutants in cities. Airborne particulate matter is associated with harmful effects on human cardiovascular and respiratory health. Particles ≤ 10 microns (PM10), and particularly the finer particles ≤ 2.5 microns (PM2.5) associated with road transport vehicles, are of concern due to their small size; (a micron, or micrometre = one-millionth of a meter: 0.001 millimetre). Green walls (or screens) in urban streets may act as barriers to direct dispersal of pollutants from combustion engine vehicles to pedestrian areas. Particulates may be deposited on the leaf surface of trees or taken up into the leaf surface wax layer, reducing atmospheric particulate concentrations. Monitoring of air quality parameters is complex; involving many potentially interacting variables. Variation in weather conditions; prevailing wind direction and speed; tree species, density, location and structure; and the configuration of built urban infrastructure are among factors which may affect the trajectory and rate of dispersal of particulate pollutants. We aim to compare outdoor air concentrations of PM10 and PM2.5 at child and adult head heights at locations with and without street trees or green walls to evaluate whether these NBS are associated with reduced local concentrations of airborne PM10 and PM2.5.

Method

BACI (Before, After, Control, Impact)

Measure air concentrations of PM2.5 and PM10 at sampling points at a range of radii from NBS street tree/green wall locations both pre- and post-intervention. Compare these data to measurements taken at equivalent locations on equivalent stretches of road without street trees/green wall at a similar time of day on the same dates.

Null hypothesis

There is no difference in concentrations of PM2.5 or PM10 between samples in stretches of road where street trees/green walls are present, and samples taken in stretches of road without street trees/green walls.

Monitoring equipment

A portable photometric sampler designed to measure ambient PM2.5 and PM10 concentrations: for example, the Aeroqual Series 500 Portable PM Monitor. A laser and optical sensor are fitted to the sensor head of the monitor to measure light scattered from particles passing through a laser beam. The scattered light is transformed to electrical signals to provide mass measurements of PM2.5 and PM10. (https://www.aeroqual.com/product/portable-particulate-monitor). Data stored on the device can be downloaded later to a PC using the USB cable and software provided with the monitor.

Measurements

Concentrations of airborne particulate matter are measured by recording PM mass per cubic metre of air.

Unit of measurement

Micrograms (mcg) per cubic metre, µg m–3. (Microgram (µg) One-millionth of a gram; a milligram (mg) = 1000 micrograms).

Calibration

Comparison of the readings from the portable PM monitor against those from the static PM monitoring equipment at the Liverpool local government AQ monitoring station at Speke to inform reliability of measurements (http://www.airqualityengland.co.uk/local-authority/?la_id=183).

Study sites

a) stretches of road where street tree/green wall interventions are proposed (intervention study sites) selected at random from qualifying intervention locations (random stratified sampling); and

b) a matching number of locations along equivalent stretches of road (road of similar width and with comparable building heights to intervention site) where street tree/green wall interventions are not proposed (control study sites). Control sites should be sufficient distance away from street tree/green wall intervention sites for the observations made to be considered independent from the effects of street trees/green walls.

Number of study sites

The number of study sites has yet to be determined but will include NBS in each of the three sub-demo areas

Number of samples

At each study site and control site, depending on the width between road and street buildings, a sample will be taken at fixed locations: ***a)*** at the roadside, ***b)*** 3-5m from the road (where street trees/green walls have been installed the NBS should be situated between this sampling point and the road) ***c)*** 6-10m from the road; with additional measurements at intervals at greater distances from the road for study sites where urban infrastructure constraints allow. This range of sampling point distances from proposed NBS reflects the scale at which measurable impacts are predicted relative to the size of street tree/green wall interventions proposed for Liverpool.

Sampling method

Both intervention and matched control study sites should be sampled on the same occasion during each round of samples (i.e. an intervention site and matched control should be sampled on the same date and at as close a time of day as possible). At each sampling point two readings should be taken: at heights estimated to represent ***a)*** child and ***b)*** adult head heights.

Data analysis

Data to be downloaded to PC from Aeroqual PM monitor using bundled software and exported to Excel. Calculation of annual mean levels of PM10 and PM2.5 at each sampling location. Comparison of annual mean values for NBS intervention and control sample locations at each study site.

References

AQEG (2005) Particulate Matter in the UK: Summary. Defra, London.

Dover JW. 2015. Green Infrastructure: incorporating plants and enhancing biodiversity in buildings and urban environments. Routledge

Hitchens et al. 2000 Concentration of submicrometre particles from vehicle emissions near a major road. Atmospheric Environment 34

Janhäll, S. 2015. Review on urban vegetation and particle air pollution – deposition and dispersion. Atmospheric Environment, 105, pp.130-137.

Jin, S., Guo, J., Wheeler, S., Kan, L. and Shenguan, C. 2014. Evaluation of impacts of trees on PM2.5 dispersion in urban streets. Atmospheric Environment 99 277-287

Trends in levels of NOx, SOx

RATIONALE

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. The impacts are higher on the most vulnerable, including lifelong impact on children.

The predominant source of NO_x in Britain is road transport and it is thought that half of emissions in Europe originate from this source; certainly the highest concentrations of NO_2 are generally found close to busy roads in urban areas In keeping with other local authorities across England and Wales, Liverpool and the wider city region is close to failing to meet the European Union (EU) air quality standard for Nitrogen Dioxide (NO_2) which is measured as an annual mean of 40µg/m^3. High levels of NO_2 have a health impact on the local population; in particular those suffering from existing heart related conditions, asthma and Chronic Obstructive Pulmonary Disease. Whilst air pollution from NO_2 cannot be said to be the single direct causal effect upon hospital emissions, it does contribute. NO_2 pollution levels within the Liverpool City region follow a similar pattern with the majority of NO_x emissions being road transport related. Commercial, industrial and domestic sources also make a small contribution to background.

The main source of SO_2 is fossil fuel combustion and SO_x emissions in the UK have decreased substantially since 1992, due to reductions in the use of coal, gas and oil, and also to reductions in the sulphur content of fuel oils and DERV (diesel fuel used for road vehicles). The decrease in emissions over time is the continuation of an on-going trend partly due to the decline of the UK's heavy industry. Although the city has made great strides in reducing levels of sulphur dioxide over recent years it remains an important atmospheric pollutant.

The aim is to compare outdoor air concentrations of NO_x and SO_x according to the established practices currently operated by Liverpool City Council to ensure that data remains comparable to our historical citywide baseline. It is intended to mount the diffusion tubes on street furniture owned by the city council such as lamp posts or other street furniture at a monitoring height of roughly 3m or 10 feet. The height of the diffusion tube placement is a little higher than adult head height but is necessary in a public place to reduce unauthorised removal of tubes and disruption to the experiment. The diffusion tubes will remain in situ for a month and then be removed and replaced. Usually two people are required to remove and replace tubes and a litter picker can be used to retrieve and replace tubes. Retrieved diffusion tubes will be sent away for analysis. At present the analysis is carried out for existing city air quality diffusion tubes by a laboratory (Gradko) who use an analytical method of 20% TEA in water. It is proposed that diffusion tube analysis for the URBAN GreenUP project will also be carried out by the same laboratory to provide consistency in comparability of data collected historically and elsewhere across the city.

METHOD

BACI (BEFORE, AFTER, CONTROL, IMPACT)

Measure air concentrations of NO_x and SO_x at identified sampling points close to planned nature-based interventions and highway improvement schemes both pre- and post-intervention. Compare this data for differences and also compare this data to historical city wide data and trends.

NULL HYPOTHESIS

There is no difference in concentrations of NO_x and SO_x between sampling locations with or without nature based or highway interventions.

MONITORING EQUIPMENT

Diffusion tubes designed to measure dissolved gaseous emissions of NO_x and SO_x will be used throughout the study. Diffusion tubes are a type of passive sampler; that is, they absorb the pollutant to be monitored directly from the surrounding air and need no power supply. Passive samplers are easy to use and relatively inexpensive, so they can be deployed in large numbers over a wide area, giving good spatial coverage. This has made them a popular choice for Local Authorities, who often use diffusive samplers to complement more expensive automatic monitoring techniques, or at locations where it would not be feasible to install an automatic monitor.

It should be noted that diffusion tubes have two limitations. Firstly, they are an *indicative* monitoring technique. Whilst ideal for screening surveys, or for identifying locations where NO_2 concentrations are highest, they do not provide the same level of accuracy as automatic monitoring techniques. Secondly, as the exposure period is typically several weeks, the results cannot be compared with air quality standards and objectives based on shorter averaging periods such as hourly means. Diffusion tube samplers operate on the principle of molecular diffusion, with molecules of a gas diffusing from a region of high concentration (open end of the sampler) to a region of low concentration (absorbent end of the sampler). Their use is recognised by DEFRA.

MEASUREMENTS

Concentrations of NO_x and SO_x (units) will be provided following laboratory analysis.

CALIBRATION

Comparison of the readings from the diffusion tubes for NO_x and SO_x can be compared against those from the static monitoring equipment at the Liverpool local government AQ monitoring station at Speke to inform reliability of measurements (http://www.airqualityengland.co.uk/local-authority/?la_id=183). Analysis at the same laboratory, using the same techniques for the city's existing diffusion tubes will help to ensure consistency and comparability between historical and citywide air quality data.

STUDY SITES

- ***a)*** At suitable locations tbc in the Baltic corridor.
- ***b)*** At suitable locations tbc in the Business Improvement District in the city centre
- ***c)*** At suitable locations tbc in the Jericho Lane/Otterspool corridor.

Control sampling will be considered for some key sites according to the available budget. There are 88 diffusion tubes across the city at 86 locations, which are prepared and analysed by Gradko (2017).

NUMBER OF STUDY SITES

There are 3 sub demo areas but the number of individual study sites within each of the sub demo areas has yet to be determined and will be guided by the final position of the Nature Based Solutions.

NUMBER OF SAMPLES

It is estimated that the budget could potentially allow for something in the region of up to 100 diffusion tubes; spread across the 3 demo areas, 2 different air quality parameters over a 3 year period. The location and nature of the various NBS interventions will however dictate the final positioning and type of diffusion tube and they will not necessarily be spread equally between the demo areas or the different air quality parameters being recorded. An option exists to consider some limited replication at key sites and to utilise any current data from existing diffusion tube sampling at appropriate locations. Budget costs dedicated to other essential monitoring equipment will determine the final number of diffusion tube sampling locations that can be supported throughout the duration of the project. A key limitation will be that staff are needed to collect the diffusion tubes on a monthly basis, so final sampling numbers will be determined by a combination of considerations based on collecting robust data within the available budget and time allocations.

SAMPLING METHOD

Both intervention and the control study site should be sampled on the same occasion. Each fixed sampling location at a study site should be sampled every month for a year pre-intervention (September 2018 to August 2019), and for two years following intervention (spring 2020 to spring 2022).

DATA ANALYSIS

Lab analysis will be carried out by a third party to enable calculation of NO_x and SO_x at each location. Data can be compared with available historical data across the city. Data will be supplied to UOL by the lab (contemporary) or by LIV (historical) for calculation of averages over time and differences between control and intervention locations.

REFERENCES

AEA (2008) Diffusion Tubes for Ambient NO2 Monitoring: Practical Guidance for Laboratories and Users. Produced on behalf of Defra. *ED48673043,* AEA/ENV/R/2504 – Issue 1a.

APSE (Association Public Service Excellence) (2017) Briefing 17-34 September 2017. Air quality plan for nitrogen dioxide (NO2) in UK (2017)

DEFRA (2017) Air Quality Plan for tackling roadside nitrogen dioxide concentrations in Liverpool Urban Area (UK0006) July 2017. 2017 Zone plans. Document UK0006.

Gradko (2017) Nitrogen Dioxide Diffusion Tubes. Shop. [Online] URL: http://www.gradko.com/store/environmental-store/no2-tube-analysis.shtml.

Horan, Melody Louise (2016/17). An Investigation Into How Urban Trees Impact Air Quality Within Central and South Liverpool. Dissertation submitted as partial fulfilment for the degree of M.Sc. in Environmental Science, School of Environmental Sciences. University of Liverpool.

2.2 Biophysical Data Management

Biophysical Data Management

1. Metadata file

Excel spreadsheet created and maintained by UOL. All project survey data files listed with data source, description, location in project data folder structure, ownership, date created or downloaded, date/date range of validity of data, and terms of use/citation.

2. Data Sources

2.1 GIS

2.1.1 Baseline data: aerial, satellite and OS map layers

2.1.2 Shapefiles from Mersey Forest and LCC consultants

2.1.2 Shapefiles created by UOL including

- Phase 1 habitat survey
- Transect survey routes
- Pollinator and floral resources survey sites
- Environmental surveys sample locations

2.2 Ecological Surveys

- Habitat and species data from field surveys, collected by UOL. Hand-written field data from species survey will be inputted to an excel spreadsheet as soon as possible after the survey. Hand-written Phase 1 habitat classification field survey data has been digitised in QGIS.
- Bat echolocation sonogram files will be downloaded from the automated bat detector SD card following each survey; checked and stored in labelled folder (for later analysis using Bat Explorer software)

2.3 Environmental Sensor Data

Files to be downloaded, checked, labelled and stored as soon as possible after the survey.

- Continuous static temperature loggers (1 per demo) – download data via USB at required intervals (according to storage capacity of sensor).
- Portable thermal imaging camera data – thermal images downloaded to PC via USB
- Portable PM monitor – data downloaded to PC via USB.
- Portable Water sampling meter – data downloaded to PC via USB.

- **2.4 Lab Results: Analysis of Environmental Field Data**
    - Water samples: suspended sediment/nutrients; heavy metal concentrations. Data files to be downloaded, checked, labelled and stored as soon as possible after receiving results of analysis from lab. Specify compatible file format (excel, csv files etc.).
    - Diffusion tubes: Data files to be downloaded, checked, labelled and stored as soon as possible after receiving results of analysis from lab. Specify compatible file format (excel, csv files etc.).

2.5 Data Storage

- Data to be stored on a UOL networked drive.

2.6 Data format, processing and analysis

- Data to be inputted to excel (csv files) in a consistent standard format suitable for analysis in R. Data processing and analysis should be undertaken in R. R scripts for all data processing operations should be archived so that they are repeatable and easy to update.
- QGIS will be used for processing and analysis of habitat survey data and landscape metrics (see individual protocols)

For reference & further information

British Ecological Society, 2017. A guide to data management in ecology and evolution. www.britishecologicalsociety.org/publications/guides-to

R Core Team (2017). R: A language and environment for statistical computing. R

Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

QGIS is free, open source software. The current version is QGIS 2.18.16 'Las Palmas' and was released on 19.01.2018. QGIS is available on Windows, MacOS X, Linux and Android. https://www.qgis.org/en/site/forusers/download.html#. QGIS 2.18 user guide is available at https://docs.qgis.org/2.18/en/docs/user_manual/

3 SOCIOECONOMIC MONITORING

To ensure that the project generates a comprehensive understanding of the value of NBS investments the biophysical analysis will be supported through a mixed-method approach to socio-economic monitoring. The scope of this process is formative in nature, as many of the issues being debated do not lend themselves to be monitored via quantitative metrics. Thus, the following section highlights how a range of interactive and consultative practices will be adopted to enable the project to evaluate the value of NBS to local communities and businesses in Liverpool. This will focus on developing a more detailed, and locally nuanced, appreciation of how NBS influence the individual and communal interactions and behaviour with local environment. It will also outline how the economic uplift associated with NBS and/or landscape enhancement can be captured.

Both the social-cultural and economic benefits that NBS can deliver viewed by the Liverpool project team and the wider URBAN GreenUP project as helping to build the business case for investment in urban nature. The evidence generated will be used in conjunction with the information generated from the biophysical analysis to highlight the local and city-scale benefits that the NBS implemented in the project have on the liveability and prosperity of the City of Liverpool.

3.1 Case Study Approach

The case study method provides the broad structure to this research. The case study method is a form of empirical inquiry that allows the researcher to investigate a contemporary phenomenon in depth whilst incorporating important contextual conditions (Yin, 2009). The purpose of case study research is to tell a story. More specifically, it is the researcher's task to construct, interpret, and communicate a narrative that captures the complexity of a case and its specific socio-political context (Simons, 2009). Case studies can be used to shed light on situations where there are multiple outcomes and variables (Yin, 2009), which describes most studies of institutions. They are particularly useful for studying SESs, in that they can contribute to theory building and an understanding of the complex relationships between social and ecological systems (Poteete et al., 2010). The case study method is valuable approach to investigate 'how' and 'why' research questions and for exploration, evaluation, and investigation of social complexity (Yin, 2009). These characteristics mean the method requires relatively few assumptions about the cases in question, and researchers are encouraged to adopt an open-ended approach to investigation. The methodology enables examination of the fine-grained details of cases, allowing researchers to untangle complex relationships and discriminate between conceptually important factors. These attributes make case studies useful in the areas of conceptual refinement and theory development and testing, as well as enhancing data quality and construct and internal validity (Poteete et al., 2010).

One of the main challenges of investigating the socio-economic impacts of environmental interventions is selection of methods that provide both a detailed understanding of the social and economic systems of interest, whilst also allowing the researchers to investigate causality. The tacit nature of social and economic phenomena is a particularly important consideration, as it can be difficult to separate impacts from NBS from other contextual factors (e.g. social pressures, political reforms, wider economic forces) (Young et al., 2006). Most social scientists thus adopt a portfolio or mixed methods approach, as no single method can address all of the challenges of studying social phenomena in the 'real world'. Use of multiple methods and data sources is common in social science research and is also a central feature of the case study method, which will be employed in this study. This process of triangulation provides greater validity and minimises the impact of bias by examining data collected from different methods and sources (Denzin and Lincoln, 1994; Neuman, 1994; Yin, 2009).

Survey instruments will be pre-tested to ensure they are sufficiently clear, consistently interpreted, and provides sufficient context for respondents. Pre-testing the questionnaire will be done using an individually-based, expert review and informal interview approach (Presser et al. 2004).

3.2 Social Indicators

Many of the indicators will be measured primarily via social surveys in the form of questionnaires administered in person and online, group discussions with participants at URBAN GreenUP focussed events, and interviews with key local/community leaders. Residents, businesses, decision makers, and other key stakeholders will be asked a series of questions focussing on the socio-cultural and ecological benefits of NBS, which will be the same during the baseline-monitoring period (ex-ante) and after the interventions to measure initial perceptions and changes post-intervention (ex-post). The rationale for this is to generate an added validity to the data, as the project team will be able to assess the influence or impact of the NBS interventions on the perceptions and use of the landscape in the three demo areas of the city. Where required to assist in data analysis and improve data quality, post survey interviews will be used to explore specific issues in more detail or to understand the cognition influencing survey response (Groves et al. 2011).

The draft questionnaire has not been included in this document, as it needs to be pre-tested and submitted for ethics review via the University of Liverpool Human Research Ethics Committee. Pre-testing will also be used to determine if the questionnaire is best divided into multiple instruments. It is thus subject to change to ensure it is a robust measure of the KPIs and manageable for respondents.

3.2.1 CHALLENGE 1: Climate Mitigation and Adaptation

Economic value of carbon sequestration by vegetation

This KPI will be modelled using GI-Val to calculate the projected economic value of carbon stored in vegetation as a result of NBS over 25 years. The input data will be primarily project delivery records.

Rationale

Vegetation sequesters and stores carbon from the atmosphere, thus helping to mitigate climate change. GI-Val tool 1.7 can be used to estimate the amount of carbon sequestered by trees as they grow, and tool 1.8 can estimate the amount of carbon sequestered as a result of various other land use changes. For more information, see 'Total amount of carbon stored in vegetation' (above).

The monetary value of the benefits to society of carbon sequestration can be estimated. The UK Government Department for Business, Energy & Industrial Strategy regularly publishes such estimates (Department for Business, Energy & Industrial Strategy, 2018). These are used by GI-Val to relate a monetary value to its sequestration estimate, discounted over time as appropriate.

Method

The areas of each type of new vegetation planted will be entered into GI-Val[14]. The discounting period will be adjusted to 25 years.

3.2.2 CHALLENGE 2: Water Management

Economic benefit of reduction of storm water treated in public sewerage system

Rationale

Through allowing stormwater to soak into the soil, and storing it in ponds, tanks, wetlands etc, green infrastructure can reduce the amount entering the sewerage system. This results in an economic benefit to the water company in terms of reduced cost of treatment, and to society in terms of reduced carbon emissions. The value of these benefits can be estimated by GI-Val tool 2.1.

The value of the benefit to the water company is estimated in terms of energy savings. The average industry energy use per litre of wastewater is combined with the commercial electricity price (Department of Energy & Climate Change, 2013) to give an estimate of the monetary value of those energy savings.

The value of the reduced carbon emissions is estimated by multiplying the reduction in energy use by the carbon emission factor of grid electricity (Department for Business, Energy & Industrial Strategy, 2015).

Method

Runoff volume results from 'Volume of water slowed down entering water treatment system' (above) will be entered into GI-Val tool 2.1.

[14] https://www.merseyforest.org.uk/services/gi-val/

3.2.3 CHALLENGE 4: Green Space Management

Distribution of public green space – total surface or per capita

Rationale

More public green space in closer proximity to people's homes can result in higher levels of many benefits being provided, notably recreation and benefits arising from being able to see the green space, such as improved mental health. The amount of public green space in a study area can be calculated, and compared with the area's population, using a geographic information system and suitable spatial data.

Method

The following data will be used:

- Existing public green space: Liverpool City Council Open Space Survey 2012
- New public green space: landscape architects' drawings
- Population: OpenPopGrid (Murdock et al, 2015)

For the purposes of this KPI, the sub-demo areas will be divided at Census Output Area boundaries (Office for National Statistics, 2011), and the area of public green space per capita calculated for each resulting sub-division.

Accessibility of urban green spaces for population

Accessibility is viewed as a key variable in the promotion and use of green spaces in urban areas, as travel times of over 5-10 minutes can be seen to significantly limit use. Accessibility is not though simply a measure of spatial proximity, i.e. distance or time to a site, it also reflects on the ways in which people or groups can access a site. Thus, reflects needs to be made on the mode of travel people use to engage green and open spaces, what barriers are visible (or invisible) supporting or precluding people from accessing sites, and how this translates into use. It is therefore crucial to assess how people access NBS alongside the any estimation of the actual proportion of a landscape that can be considered as nature or green space. Through such an evaluation the City of Liverpool can assess its decision-making in terms of where it places green space and how people can access them to gain the most benefits.

The accessibility of green spaces will be measured via social survey examining the types of spaces they utilise (i.e. city/neighbourhood parks, playing fields or amenity green space), how often they use these spaces (i.e. daily, 2-3 times a week, weekly), their primary mode of access/transport (i.e. walking, bicycle, public transport, or car) and the time taken to travel to these sites (<5 mins, 5-10 mins, 10-20 mins, over 20 mins[15]). Each of these questions will provide qualitative data that will illustrate average distances, mode of travel and frequency of use. These questions will be discussed alongside any perceived barriers to use that participants identify within the survey. This will provide scope for participants to reflect on how they access sites and whether issues of distance, types of

[15] These timings and associated distances will be derived from the Accessible Green Space Standards (ANGSt), which outlines a time-distance-size of a site relationship, and has been successfully applied in the UK since the late 1990s.

travel, safety and time taken to reach of a location influence individual or communal use of green space or NBS. Both sets of data will be used to map (using participant postcode data) the routes, locations, and barriers to use for local/city green spaces to assess the accessibility of URBAN GreenUP NBS interventions.

3.2.4 CHALLENGE 5: Air Quality

Value of air quality improvements (using GI-Val)

GI-Val is The Mersey Forest's green infrastructure valuation toolkit (Appendix 1). The current prototype is free and open source, and can be downloaded from http://www.merseyforest.org.uk/services/gi-val/. It takes the form of a spreadsheet calculator and a user manual. One of the tools, Tool 4.6, can estimate the impact of nature-based solutions on various air pollutants, in tonnes per year, and from those quantities it can estimate the avoided costs of other air pollution control measures. It uses a benefit transfer method, based upon the Chicago Urban Forest Climate Study by the USDA Forest Service (Nowak et al, 1994).

'Annual mean levels of fine particulate matter' (above) will result in some measured air pollutant concentrations. Ideally, these would be used as a starting point to calculate the monetary value of any improvement. However, seeing as there is no obvious way to convert concentrations (in μg/m^3) into masses absorbed over time (in tonnes per year), it will not be possible to simply plug the measured concentrations into tool 4.6 in its current form. The ability to use the measured concentrations depends, therefore, on the exact form of the tool resulting from the planned improvements/replacement. If it is not possible to create a tool that can accept them, the tool will have to be used to model the impact of the interventions on air pollution for the purposes of this KPI.

4.6 Avoided cost of air pollution control measures							*This tool uses currency exchange rates. To update these, right-click the table at the bottom of this sheet and click refresh.*
What type of location is the project in?	*Sub-urban*	*Select*					
What is the existing land use type?	*Vacant*	*Select*					
Input existing area of tree cover (ha)	0	*Ha OR*	~~Number of trees~~	~~0~~			*Tool uses Ha as default, using values entered in the Project Data sheet.*
Proposed increased tree cover (ha)	36.00391967	*Ha OR*	~~Number of trees~~	~~0~~			*If using Number of Trees, reduce C22 and C23 to Zero.*
CURRENT LAND COVER - POLLUTANT REMOVAL	**Tonnes/ha/yr**	**Tonnes/tree/yr**	**Gross removal (tonnes/yr)**	**Cost savings**			
Carbon Monoxide removed (tonnes / year)	0.0008	3.6E-05	0.00	£0.00			*Auto calculation cells*
Sulphur Dioxideremoved (tonnes / year)	0.0028	1.3E-04	0.00	£0.00			*Auto calculation cells*
Nitrogen Dioxide removed (tonnes / year)	0.0025	1.1E-04	0.00	£0.00			*Auto calculation cells*
PM10 particulates removed (tonnes / year)	0.0063	2.9E-04	0.00	£0.00			*Auto calculation cells*
Ozone removed (tonnes / year)	0.0071	3.2E-04	0.00	£0.00			*Auto calculation cells*
PROPOSED NEW ADDITIONAL LAND COVER - POLLUTANT REMOVAL				**Cost savings**	**Net impact of scheme on pollutants removal (tonnes/yr)**		
Carbon Monoxide removed (tonnes / year)	0.0008	3.6E-05	0.03	£36.49	*CO t/yr*	0.03	*Auto calculation cells*
Sulphur Dioxide removed (tonnes / year)	0.0028	1.3E-04	0.10	£226.84	*SO2 t/yr*	0.10	*Auto calculation cells*
Nitrogen Dioxide removed (tonnes / year)	0.0025	1.1E-04	0.09	£546.89	*NO2 t/yr*	0.09	*Auto calculation cells*
PM10 particulates removed (tonnes / year)	0.0063	2.9E-04	0.23	£408.37	*PM10 t/yr*	0.23	*Auto calculation cells*
Ozone removed (tonnes / year)	0.0071	3.2E-04	0.26	£172.47	*O3 t/yr*	0.26	*Auto calculation cells*
Tool 4.6 output	**33,770**	*£ NPV Discounting over 50 yrs already built in the worksheet below*					

Figure 2: Example of GI-Val toolkit

METHOD

The location type (urban) and the pre- and post-intervention tree canopy cover will be entered into GI-Val. In the case of Liverpool demo the tree canopy cover will be measured using the colour infrared imagery and height data available under the Aerial Photography for Great Britain agreement[16] and the landscape architects' drawings.

If the GI-Val tool is substantially changed, as planned, the method will also change to accommodate these revisions, which will be documented.

3.2.5 CHALLENGE 6: Urban Regeneration

Accessibility: distribution, configuration, and diversity of green space

Establishing the accessibility of a NBS requires an understanding of the distribution, configuration and diversity of a resource in both a technical, i.e. land use classifications and a socio-cultural, i.e. access routes and frequency of use, sense. By investigating both the URBAN GreenUP project will be able to propose whether the types of NBS found in the demo site locations has an impact on the use and perception of value of individuals, local communities and businesses, and will help Liverpool City Council to identify areas of NBS need.

To assess accessibility two measured methods of GIS analysis will be used. One is based on calculation of the shortest distance (linear distance) between access of the population to the NBS (line type), and the NBS location centroid. The results obtained shall be in distance (m) and time (min). This KPI will be calculated using GIS. The other measure method to be used is based also on GIS analysis of distance of NBS site but in this case to homes, schools, and businesses. Land use cover will also add to the analysis in GIS to show what each area is comprised of in terms of different types of NBS and their diversity. Data will be collected and analysed by the Mersey Forest with assistance from Liverpool City Council and the University of Liverpool.

In addition the social survey will be used to examine whether, and if so how, participants understand accessibility in terms of the distribution, configuration and diversity of green space located in each demo site (which may subsequently be compared to a wider city understanding of these issues).

Two rounds of social surveys will be conducted. One prior to the NBS being implemented in each of the three demo-areas and a second round following implementation, at least one year after completion, to provide an data to support and ex-ante and ex-post analysis of the interventions.

Participants will be selected using a convenience sampling technique on-site in each of the demo areas. This will sample users of each area to assess their perceptions of recreational and cultural value. Additional online surveys will be conducted with participants drawn from Liverpool City Council and Mersey Forest contacts of individuals and communities who have engaged with community or environmental activities and will include people have signed up to hear about the

[16] https://www.apgb.co.uk/

URBAN GreenUP project. The specifics of this process and the selection of participants will be debated further within the project team.

Savings in energy use (kWh) due to improved GI

Rationale

Improved green infrastructure results in energy savings through a variety of mechanisms. These include:

- Reducing the need to heat buildings by insulating them against the cold
- Reducing the need to cool buildings by insulating them against the heat
- Reducing the volume of stormwater entering the sewer system, thus reducing energy consumption in sewage processing

The energy savings resulting from these three mechanisms are estimated by GI-Val[17] tools 1.1, 1.5 and 2.1 respectively.

Method

The following input values will be entered into GI-Val:

- Tool 1.1: number of additional residential buildings with large trees within 10m, based upon landscape architects' drawings and Ordnance Survey's AddressBase[18], which can be used to determine whether a building is residential
- Tool 1.5: net additional area of green roof (m^2), based upon landscape architects' drawings
- Tool 2.1: pre- and post-intervention land cover percentages for areas where groups of interventions have been made, based upon Ordnance Survey's MasterMap[19] and the landscape architects' drawings

Assessment of typology, functionality and benefits provided and Diversity of NBS

Green infrastructure takes many different forms, and performs many different functions that result in benefits for people. Each of these dimensions can be analysed to show where different types of green infrastructure or NBS can be found (a typology map), where each function is performed, and where each benefit is felt. Merit can be found in assessing this process in both a technical and non-technical manner to examine the ecosystem services associated with investments in NBS, and the ways in which individuals, communities and local business may attribute value and/or function to the landscape of Liverpool.

[17] https://www.merseyforest.org.uk/gi-val/

[18] https://www.ordnancesurvey.co.uk/business-and-government/products/addressbase.html

[19] https://www.ordnancesurvey.co.uk/business-and-government/products/mastermap-products.html

To assess functionality, the project will utilise a mixed-method approach, using GIS and quantitative analysis of land use data and a social survey to assess individual/communal understandings of functionality.

The first technique to be used will be a Mersey Forest-developed green infrastructure mapping method. It is described, with various audiences in mind, in the following documents.

- The value of mapping green infrastructure (RICS, 2011)
- An ecosystem services mapping method for use in green infrastructure planning (The Mersey Forest, 2015)
- Liverpool City Region and Warrington Green Infrastructure Technical Document (The Mersey Forest, 2014) (Appendix 1)

The method makes use of a wide variety of input data, including Ordnance Survey's MasterMap[20] and local authority open space data, to map green infrastructure typology, function and benefit. In this case it will be applied both pre- and post-intervention.

The first step involves mapping where different types of green infrastructure can be found within the study area. The result (a typology map) classifies all land and open water in the area as either not green infrastructure or one of a list of 18 green infrastructure types.

The second step uses the typology map together with other datasets to identify where each of 35 functions are performed by the green infrastructure.

Finally, maps showing where each of eleven benefits is felt are produced by relating the functions to those benefits and calculating the sums of the relevant function maps.

A social survey will be used to generate data regarding the perceptions of functionality and benefits of investment in NBS. Using a blend of qualitative and quantitative questions the survey will examine whether specific elements of a site or the whole area influence functionality, and how this changes between different user groups. The survey will work with the GIS analysis to identify the land uses of each site, and use to develop a set of questions regarding the potential functionality of specific types of NBS, the facilities found in each location, and whether participants perceive functionality to be related to a physical spaces, its amenities or both.

The survey will be structured to focus on the ways in which different groups of users interpret and interact with NBS and green spaces. This will be supported through a series of quantitative questions, using Likert or comparable opinion scales, to assess how specific elements influence understandings of particular activities and functionality.

Two rounds of social surveys will be conducted. One prior to the NBS being implemented in each of the three demo-areas and a second round following implementation, at least one year after completion, to provide an data to support and ex-ante and ex-post analysis of the interventions.

Participants will be selected using a convenience sampling technique on-site in each of the demo areas. This will sample users of each area to assess their perceptions of values and benefits of the

[20] https://www.ordnancesurvey.co.uk/business-and-government/products/mastermap-products.html

interventions. Additional online surveys will be conducted with participants drawn from Liverpool City Council and Mersey Forest contacts of individuals and communities who have engaged with community or environmental activities and will include people have signed up to hear about the URBAN GreenUP project. The specifics of this process and the selection of participants will be debated further within the project team.

3.2.6 CHALLENGE 7: Participatory Planning and Governance

Perceptions of citizens on urban nature and green spaces quality

As with our understanding of accessibility it is important to establish how the public, as individuals and as communities, perceive the quality of green space. Where NBS and other green spaces are viewed as being of high quality in terms of their composition, amenity value or maintenance, there is a corresponding association with use and longer-term engagement. Likewise, where green spaces are viewed as being untidy, unkempt, and lacking in care there is a lower level of engagement from the public. To ensure that the most appropriate forms of investment in NBS and its subsequent management are adopted it is therefore important assess what people value within Liverpool's green spaces, and what extent the investment in NBS will promote positive perceptions of the landscape.

However, urban landscapes and the perception of their functionality is a complex issue with no two communities of interest viewing, interacting or valuing the same NBS in the same way. Consequently, a more nuanced approach to understanding of citizen perceptions is needed that goes beyond simply reviewing whether people like or dislike a site. This requires an assessment of issues such as proximity, accessibility, the provision of amenities for different user groups, the allocation of spaces to undertake varied activities, and the ways in which a space is managed (or perceived to be managed). When reviewed in their totality each of these issues aids out understanding of the intersection of aesthetic, interaction, and functionality.

This is of significant importance in Liverpool due to the historical variability in value attached to the city's green and open spaces. Due to changing level of funding, anti-social behaviour, and demographic structure of the city, its parks and green spaces have seen major changes in their management since the 1980's. As a result, members of the public perceive the value of the city's parks from both a temporal perspective to assess former quality and examine this against the current form, function and management. With the programme of investment in NBS this process will be examined within the URBAN GreenUP programme to investigate whether landscape enhancements can promote a more positive set of interpretations of the city's environment.

To investigate the perceptions of quality in the city's NBS interventions a social survey will be used with participants to examine issues of quality, quantity, accessibility and functionality. The survey will ask individuals, communities and key stakeholders to rate the landscapes around the NBS prior to investment in terms of their use/function, accessibility, and aesthetic quality. This will provide a baseline position of how local people view the environmental resource base in the city. It will also allow the project to make links between personal, perceptual and more abstract notions of "quality" and map these onto specific locations via spatial/geographically specific questions. In addition, the survey will work with Likert scale to support a line of questioning asking what specific features participants find useful or a hindrance to use/quality. These questions will focus on the contextual understanding of the landscape and its utility to individuals and communities.

Further rounds of surveying will be undertaken to assess the quality of the landscape post-intervention in NBS. The same line of questioning will be conducted but an additional series of questions focussing on the added-value or change in potentially quality associated with the NBS will be included. These subsequent surveys will be assessed alongside the pre-intervention surveys to investigate whether specific NBS are linked with changing assessments of quality.

Participants will be generated from Liverpool City Council and Mersey Forest contact lists, as well as through engagement on-site in the demo areas. Moreover, an online survey will be developed to support the creation of a baseline position on landscape quality. There is also potential scope within the project to undertake a targeted survey of residences/businesses proximate to the investment sites. Using a 100-200m buffer (to ensure local understanding/perceptions of the site are captured) this process could be used to develop a more discreet understanding of the current and potential value of the landscape in terms of its quality, functionality and management at a local/site level.

Social learning concerning NBS

Social learning has long been established as essential to policy change, and thus is essential to mainstreaming NBS. To monitor social learning, it is essential to examine how policies and processes have actually changed. Such changes can encompass adoption of new interventions, techniques, policy, and processes in response to past experience and new information (Hall, 1993). Semi-structured interviews, participant observation, and content analysis will all be used as part of baseline monitoring and throughout the project to understand how decision makers, policy makers and practitioners are incorporating new knowledge about NBS into their processes, discussions, and documents. This KPI will focus on a particular form of social learning known as policy learning. In both baseline and post-intervention monitoring, monitoring for this KPI will include structured content analysis on key policy documents relevant to the study area will be undertaken, using a range of techniques including word-frequency counting, key-word-in-context listings, concordances, classification of words into content categories, content category counts, and retrievals based on content categories and co-occurrences (Druckman 2005; Weber 1990).

In addition, using purposive, non-probability sampling, baseline and post-intervention monitoring will include interviews key individuals involved in making relevant policies and making decisions with respect to green infrastructure and NBS in the City of Liverpool, with data being collected until saturation (Minichiello et al. 2008). Sometimes these adjustments will require small, incremental changes, and sometimes they will require radical shifts in approach, and it may also require time for changes to be made on paper, so interviews will allow access to the most up-to-date thinking and information. To ensure consistency in data collection, an interview guide based on the key theoretical elements of policy learning (Suškevičs et al. 2017; Dovers and Hussey 2013) will be used to analyse baseline knowledge of NBS, examine current processes and implementation of policy, and identify adjustments to processes and policies. At the same time, participant observation will be used to analyse decision-making in real-time and evaluate how it evolves over the course of four years. Two levels of policy learning will be assessed: 1) how policy problems are constructed and how solving the problem should be approached (i.e. scope of policy and its goals), and 2) instrumental learning, where lessons about policy design and knowledge about when a particular policy instrument is appropriate or viable (May 1992).

Data from all methods will be analysed using standard qualitative data analysis software (e.g. Nvivo), using a combination of deduction and induction, using a priori codes from theory (Creswell 2013), followed by a second level of analysis where emergent themes were identified from coding patterns in the data (Miles and Huberman 1994). A selection of interviews will also be blindly coded by another researcher to check intercoder reliability is at least 85%.

Engagement with NBS (sites/projects)

The importance and significance of public access to environmental information and participation in environmental decision-making are enshrined in the Aarhus Convention, adopted in 1998 in the Danish City of Århus (United Nations Economic Commission for Europe, 1998). In England the National Planning Policy Framework also emphasises the importance of community engagement to achieving well-design places and public involvement in planning and decision-making (Ministry of Housing, Communities and Local Government, 2018). Moreover, academic sources highlight the benefits for environmental management of understanding the relationships between the views of different stakeholders, including the public (Baur et al. 2016). The monitoring of engagement with NBS in Liverpool is therefore of vital importance.

Fundamental to the monitoring of this KPI is the ability to monitor engagement at multiple stages of development and delivery of NBS. This KPI will therefore be monitored across the various public engagement activities and periods of the project using multiple data collection methods.

Participant observation and record keeping of engagement events and consultation activities will be conducted; this will include the collection of demographic information on the individuals and organisations involved for use as descriptive statistics during analysis. Participant observation allows for the collection of data in a naturalistic setting whereby the researcher observes and participates in the common and uncommon activities of the subject group (Musante and DeWalt, 2010) – in this case by attending, observing and participating in the public engagement activities.

Content analysis of engagement materials will also be conducted. As with other KPIs where content analysis will be used, a range of techniques will be used including word-frequency counting, key-word-in-context listings, concordances, classification of words into content categories, content category counts, and retrievals based on content categories and co-occurrences (Druckman 2005; Weber 1990).

To complement the above data collection methods and provide a richer source of data on how citizens and community groups engaged with NBS, qualitative semi-structured interviews will be conducted with targeted participants. Interviews can be used to attempt to understand the world from the subject’s perspective, to understand their experiences and their interpretations of them (Kvale, 1996; Mann, 2016) and so can aid in the monitoring of this KPI to further our understanding of how citizens engaged, their motivations and their experiences of engagement in NBS. Purposive and non-probability sampling will be used to select interview participants. Interview participants will be selected based on organisation or participant 'type' to ensure a range of interviewees – for example, community organisation representatives, individual citizens and interest groups.

As with other qualitative data collected, data for this KPI will be analysed using the qualitative data analysis tool, Nvivo. A combination of deductive and inductive coding will be employed, using a priori codes from theory (Creswell 2013), followed by a second level of analysis where emergent themes are identified from coding patterns in the data (Miles and Huberman 1994). As elsewhere, a second researcher will blindly code a selection of interviews to check intercoder reliability is at least 85%.

3.2.7 CHALLENGE 8: Social Justice and Social Cohesion

Crime reduction

Within the research literature there is a wealth of evidence, which highlights the links between the management of green and open spaces, their use by local and city communities and the control of anti-social and criminal behaviour. Moreover, within Liverpool and more widely in cities with changing demographic profiles there is a growing realisation that people use parks and NBS in different ways, and that their potential isolation from observation or community interaction could lead to anti-social behaviour being undertaken in parks. However, where parks are perceived to be well managed, extensively used, and subject to local stewardship (either formal or informal) the likelihood of criminal activity occurring decreases. In addition, through the provision of clear sights lines, lighting and a visible management presence the perceptions or fear of crime can be lowered.

The development of parks and green spaces that are perceived to be safe was a major issue in Liverpool throughout the 1980s when a lack of investment in some sites led to them being perceived as being unsafe or exclusionary. However, over the course of the last twenty years the city has worked with communities, external funders such as the Heritage Lottery Fund, and the police to redevelop a number of parks to make them more attractive and safer.

To assess the potential of NBS in aiding crime prevention and/or control the URBAN GreenUP project will use two techniques to assess the current state of anti-social or criminal activity in the demo areas and the potential for NBS to make a difference in the perceptions of local people and users to those spaces.

The first stage of this process will be to collate data from the police regarding incidences of anti-social behaviour and/or criminal activity in/around the demo sites. This will be mapped using GIS to show the spatial distribution and the frequency of events. A 100-metre buffer located around the investment sites will be placed on the analysis to limit the spatial spread of data and to ensure that the incidences are localised to the green space or NBS. Second, Liverpool City Council will provide data on reported disturbances and anti-social behaviour reported by their employees at the demo sites and by the public to the council's Neighbourhood Team, employees and local officials and reported via the official City Council channels which have been logged, recorded and actioned via the council's CONFIRM system.

This will be mapped along with the police data on GIS to show the locations and frequency of criminal activity at each of the demo sites.

The spatial and frequency data will be supported via a line of questioning in the social survey asking participants about their perceptions in/around the demo sites. This will reflect on their experiences and perceptions of safety and anti-social activity and how this influences their use of the areas green spaces/NBS. Such a line of questioning will be undertaken in the pre-implementation phase and after the NBS have been delivered to assess whether participants perceive there to be any differences in specific issues regarding criminal activity or the wider impact of the NBS on use and perceived safety.

3.2.8 CHALLENGE 9: Public Health and Well-being

Perceptions of health and quality of life

A social survey of local residents will be conducted to understand perceptions of general, physical, and mental health, as well as general, individual, and communal well-being. This will be measured primarily via questionnaires administered in person and online. Residents will be asked a series of questions, which will be the same during the baseline monitoring period and after the interventions to measure initial perceptions and changes post-intervention. Perceptions of general, physical, and mental health and well-being will be measured on 5-point Likert scales and analysed statistically in standard software (Excel and SPSS). The survey will also will examine perceptions of urban nature and its impacts on the health and well-being of respondents more generally and specifically in their neighbourhoods linked to the NBS interventions. If appropriate, perceptions of quality and social values will also be analysed alongside other survey data using cluster analysis to identify variation within the population. Using a stratified probability sampling technique, the researchers will aim for a minimum of a 95% confidence interval and a sample that is representative of the broader target populations that live near the interventions and those who use the sites.

Increase in walking and cycling in and around areas of interventions

This is a social indicator, which links to human health and well-being, as walking and cycling in nature has been shown to improve both physical health and psychological well-being. NBS, and specifically green infrastructure, interventions, is thought to increase street attractiveness, which leads to increased engagement with active transport (Adkins, 2012; Tzoulas et al. 2007). In addition, walking and cycling have been shown to improve the level of social interactions and community cohesion. This is especially relevant to young families and older people who may be less mobile or lack private transport options. Increased opportunities to engage in walking or cycling have also been seen to be indictors of a liveable city, as they citizens with various options to engage with the landscape.

The KPI measures how NBS interventions can increase the opportunities for engagement of citizens specifically related to walking and cycling inside the interventions and in close proximity to NBS.

In Liverpool, this KPI will be measured qualitatively through direct observation and as an item in social survey questionnaire. This will focus on the perceptions of provision of cycling and walking infrastructure locally (and specifically in/around the NBS), how people access these opportunities and how investment in NBS can promote engagement with walking and cycling.

Participants will be selected using a convenience sampling technique on-site in each of the demo areas. Additional online surveys may also be conducted with participants drawn from Liverpool City Council and Mersey Forest contacts of individuals and communities who have engaged with cycling, walking or community activities and will include people have signed up to hear about the URBAN GreenUP project.

3.2.9 CHALLENGE 10: Potential of economic opportunities and green jobs

Number of jobs created; gross value added and increased footfall and spend in the areas of interventions

Change in number of jobs located in areas in NBS investment and the reporting of any changes in income/composition of company post-investment will be measured via questionnaires administered in person and online. Businesses in the local catchment areas of the interventions will be asked a series of questions, which will be the same during the baseline monitoring period and after the interventions to measure initial perceptions and changes post-intervention. Data will be collected on both perceptions (using 5-point Likert scales) of footfall and self-reported increases in jobs, will be collected directly from businesses to determine if there is a statistical difference between dwell time and sales pre- and post-intervention for businesses in the immediate vicinity. Given the relatively small number of businesses, the researchers will aim for a census or at least of minimum of a 95% confidence interval and a sample that is representative of the business communities that operate near the interventions. This perception and self-reported economic data will be checked against footfall data collected during the baseline monitoring period and after the interventions are implemented as a means of triangulation, if budgets allow for the purchase of this monitoring equipment.

Changes in mean house prices/rental markets

Rental and market prices for homes and retail/commercial spaces can be seen as a good barometer of economic prosperity. A wealth of data exists illustrating the association between high quality green space and NBS and increased real estate values. Research suggests that prices can increase by up to 20% of home or retail spaces overlook or are located near to high quality green and open spaces. It has also been reported that an improved physical environment in terms of aesthetic quality is used by businesses when deciding to locate to an area. Thus, with interventions in NBS there is a potential for improved economic development activities to be situated in each of the demo sites. Such data would also allow Liverpool City Council to think more strategically about how they align their economic development targets with their understanding of how, where and NBS could be implemented in the future.

The change in house/rental prices in NBS intervention areas will be measured primarily using secondary analysis of property market data (assessments n Zoopla or similar). A full database of property market value will be collected prior to the interventions, and then monitored for a period of 2 years afterward, then analysed to determine if significant change in property values near the interventions has occurred. This will focus on changes in average rental or sale prices for apartments and houses within a 100-metre radius of the NBS interventions, a standard measure of used in such studies. This data will also be complemented by GI-Val calculations.

An important consideration in monitoring this KPI over the life of this project will be wider economic changes in the City of Liverpool, the UK (e.g. Brexit), the EU and beyond. For this reason, it will be important to analyse housing prices against relevant benchmarks, to see how values have changed in relative – and not just absolute – terms.

Increased returns of business rates with NBS

Change in revenue from businesses in the NBS intervention areas, as self-reported via questionnaires administered in business owners and representatives in person and online. Businesses in the local catchment areas of the interventions will be asked a series of questions, which will be the same during the baseline monitoring period and after the interventions to measure initial perceptions and changes post-intervention. Data will be collected on both their perceptions of the influence on NBS and other environmental interventions using 5-point Likert scales and economic data from businesses on increases in business rates collected by the council (related to the quality of the environment and its desirability as a location for retail/business). This data will be analysed in standard software (Excel and SPSS), to determine if there is a statistical difference between dwell time and sales pre- and post-intervention for businesses in the immediate vicinity. Given the relatively small number of businesses, the researchers will aim for a census or at least of minimum of a 95% confidence interval and a sample that is representative of the business communities that operate near the interventions. Where appropriate, survey data will be complemented with targeted in-depth interviews to help understand the other factors influencing business rate returns.

3.3 Socioeconomic Data Management

Assessment of existing data

This research will make use of several existing datasets (e.g. spatial data, crime statistics, property price data, economic data, census data). Open data published by government departments on data.gov.uk will be used. Spatial data will be obtained from open repositories, especially the Natural England Open Data Geoportal and the Spatial Data Catalogue (environment.data.gov.uk). None of this data will contain identifiable information about individuals, but secondary data analysis will nonetheless be included in the ethics application to be submitted to the relevant University of Liverpool ethics committee.

Information on new data

With respect to the socio-economic monitoring, there will be several new data sets created for use in the project, including: 1) qualitative data from multiple sources, 2) geospatial data and scenario mapping process, and 3) social survey data.

Ultimately, the project will produce a transferable process for developing, implementing, and monitoring NBS. Not only will all the aforementioned data be published publicly, but also access to this data will be organised and presented as part of the data platform developed in WP5.

Qualitative data

Qualitative methods generate a large volume of text-based data. The researchers will follow the UK Data Service's best practice guidelines and recommendations (Corti et al. 2014) to document and annotate qualitative data, and data will be exported from NVivo as RTF files to provide an archive of coding data, following the UK Data Service's guidelines for annotating and archiving qualitative data. To reduce the risk of re-identification, the interview transcripts will not be provided in their entirety, and instead the data will be organised by themes prior to archiving.

Participatory planning and engagement exercises (e.g. public events, community consultation, workshops) will occur over the course of the project. To encourage deliberation and dialogue, activities will not be recorded verbatim, but rather the key points and themes from the activities will be summarised in Microsoft Word and sent to all participants, where feasible, as a record of the workshop. This information will not include personal identifiers, and archived in RTF format. Background documents and workbooks provided to participants will also be archived in RTF format.

Geospatial data

Geospatial data will be converted to one of the ESRI Shapefile formats, while the images will be in the form of standard or geo-referenced TIFF. All of these formats are consistent with those recommended by the UK Data Service.

Social Survey data

Survey data will be analysed in Microsoft Excel and SPSS, and the raw data will be exported CSV format for archiving.

Quality assurance of data

Quality assurance of data is integral to ensure the overall quality and reliability of the monitoring of KPIs in Urban GreenUP. The UK Data Service advice and guidance on quality assurance of data will be followed to maintain high quality data, this includes measures taken during data collection, data entry, and data checking (UK Data Service, 2018). Fundamental to quality assurance of data is the need to develop, ahead of data collection, a protocol for data collection, entry, handling and checking procedures (UK Data Service, 2018).

Protocol: Dr Clement will be responsible for ensuring quality control, and she will develop an overarching protocol for the project that will be checked by experts prior to data collection. A case study protocol as described by Yin (2009) that outlines the full procedures for quality assurance of data to be used by all researchers on the project. The protocol will also include economic data and the geospatial data following ISO/TC 211.

Systematic data collection: The data will be collected using the KPIs as an overarching framework, with subcategories from the literature providing a consistent structure for data collection throughout the project. This ensures that the same categories of data are collected at each point in time to enable consistent data collection and comparison across them. Qualitative data will be transcribed semi-verbatim and then analysed using NVivo. Eklipse outlines the literature underpinning the KPI framework, helping to guide a deductive approach to data analysis and being clear about the conceptual framework improves reliability of data (Miles et al. 2013; Neuman 2013). The interviews will use purposive sampling to select interview participants based on the conceptual underpinnings of the KPIs and to reach the spectrum of individuals engaged in NBS design and delivery in the city, with data being collected until saturation (Minichiello et al. 2008). A selection of interviews will also be blindly coded by another researcher to check intercoder reliability is at least 85%.

Triangulation: The research also uses a mixed methods approach to provide a means of triangulation, along with several different means of accessing data (Neuman 2013; Yin 2009). It is possible that some interviews, workshops, survey responses, and other activities will contain inaccurate or misleading information provided by participants, as well as subjective opinions that cannot be verified, but quality control will be undertaken to ensure the transcripts themselves are an accurate record of the data collected.

As a group Dr Sarah Clement, Dr Ian Mell, Dr Sam Hayes and the Postgraduate Researcher will provide investigator or researcher triangulation where appropriate. Investigator triangulation provides the opportunity for multiple researchers to gather and interpret data during the course of a research project to enhance the confidence in and reliability of results (Bryman, 2003). This will be utilised as part of the relevant research methods, including: semi-structured interviews, workshops and public engagement activities, participant observation, content analysis and coding of qualitative data.

To clean the data from the questionnaires administered throughout the project, the entered data will be spot-checked against the raw data, along with logic checks based on the findings during the research.

Quality assurance for geospatial data will refer to the ISO/TC 211 standards, and use both automatic rules for checking the data and spot checking, using a data reviewer extension to facilitate the process.

Backup and security of data

Data and metadata will be stored securely in the University of Liverpool's Active DataStore, which is a centralised, secure, and supported data storage facility set up to store digital research data throughout the lifespan of a project. The Active DataStore is backed up daily and keeps two independent copies of the research data which is physically held in separate data centres and then backed up to a create a third copy in a third location. Storage is free for up to 1TB of data, which will not be exceeded for this project. Backup and security protocols will follow those set out in University of Liverpool's Research Data management policy. Methods of back-up, security procedures, and version control of data will be included in the case study protocol.

Although not sensitive data, personal data will need to be processed as a part of this research, especially before the transcripts are edited to remove identifiers. Access to transcripts and audio files will be password protected and limited to the four researchers directly employed on the project. Clear version numbers and dates will be recorded as part of the file name while the project is active, and the final versions will be archived. When working in the field, the PI will ensure any laptop conforms to the University of Liverpool Code of Practice for use of Data on Laptops and Mobile Devices, and data will still be able to be stored on the secure Active DataStore server.

Management and curation of data

Data will be recorded using consistent, agreed upon formats for each category of data to minimise any further preparation prior to archiving with the Social Data Service, UK Data Archive and the Liverpool Data Catalogue. These will be agreed upon at the beginning of each research stage and recorded in the case study protocol.

Transmission will follow recommended protocols of each repository, such as encryption procedures recommended by the UK Data Archive. For this project, we plan to provide a transferable method of scenario planning and deliberative mapping, and will be publishing our materials and methods. To ensure the description, annotation, formatting, and contextual information are accessible and practically useful, we will have discussions with end users as part of the project.

Difficulties in data sharing and measures to overcome these

The main issue associated with data sharing is balancing the benefit of sharing the data with any potential risks to participants. While the subject matter of this research is not highly sensitive, it will be important for participants to feel they can speak freely about their work and offer imaginative solutions without feeling constrained by potential disclosures. These issues have been addressed in the data processing described above and outlined in the ethical considerations section of Je-S. In particular, the data will not be shared verbatim to encourage open deliberation and dialogue in the method. This is because full anonymisation (as defined by the Information Commissioner's Office Code of Practice) will be impossible for many participants, given the relatively small population of experts and stakeholders actively engaging in these topics. To reduce the risk of identification without compromising the integrity of the data, the researchers will de-identify transcripts according to UK Data Service guidelines, removing direct and indirect identifiers of participants. The ethical considerations associated with this will be outlined in the ethical review process, and include the need to appropriately inform participants up front and provide participants with an opportunity to review de-identified thematic data that will be archived to review the risk.

Consent, anonymisation and strategies to enable further re-use of data

Data sharing procedures will be summarised in the information sheet for participants, and consent obtained through consent forms that include specific line items on data sharing. The challenges of anonymisation will also be discussed, as well as the measures put in place to protect anonymity. All information will be reviewed and approved by the UoL Ethics Committee through Human Research ethics review and approval processes.

4 References

Adams, A.M., Jantzen, M.K., Hamilton, R.M. and Fenton, M.B. (2012). Do you hear what I hear? Implications of detector selection for acoustic monitoring of bats. Methods in Ecology and Evolution, 3(6): 992-998.

AEA (2008) Diffusion Tubes for Ambient NO2 Monitoring: Practical Guidance for Laboratories and Users. Produced on behalf of Defra. *ED48673043,* AEA/ENV/R/2504 – Issue 1a.

AQEG (2005) Particulate Matter in the UK: Summary. London: DEFRA.

APSE (Association Public Service Excellence) (2017) Briefing 17-34 September 2017. Air quality plan for nitrogen dioxide (NO2) in UK (2017)

Bat Conservation Trust. (2012). Bat Sound Library. [online] URL: http://www.bats.org.uk/pages/bat_sound_library.html.

Baur, J.W.R., Tynon, J.F., Ries, P. & Rosenberger, R.S. (2016). Public attitudes about urban forest ecosystem services management: A case study in Oregon cities. Urban Forestry & Urban Greening, 17, 42-53.

Beaufort scale. (n.d.) http://www.crh.noaa.gov/images/iwx/publications/Beaufort_Wind_Chart.pdf

Block *et al.* 2001. Design and Implementation of Monitoring Studies to Evaluate the Success of Ecological Restoration on Wildlife. Restoration Ecology 9.

Bluesky National Tree Map. [online] URL: https://www.blueskymapshop.com/products/national-tree-map

British Dragonfly Society. (2009). Dragonfly Monitoring Scheme Manual. Peterborough: British Dragonfly Society.

Bryman, A. (2003). Triangulation. In: Encyclopedia of Social Science Research Methods. Thousand Oaks, CA: Sage.

Bryman, A. (2006). Integrating quantitative and qualitative research: how is it done? Qualitative Research, 6, 97-113.

Collins J (2016) Bat Surveys for Professional Ecologists; Good Practice Guidelines (3rd Edn) The Bat Conservation Trust, London.

Corti, L., Van den Eynden, V., Bishop, L. and Woollard, M., 2014. *Managing and sharing research data: a guide to good practice*. Sage.

Creswell, J. W. 2013. *Qualitative inquiry and research design: choosing among five approaches,* Thousand Oaks, SAGE Publications.

Cuvato, E. and Ianni, I. (2011). Urban planning strategies for climate adaptation assessment: the case study of Catania metropolitan area. Presentation to EcoCities and University of Catania workship, 7th April 2011, Catania, Sicily.

Dawson, J.J.C., Smith, P. 2007. Carbon losses from soil and its consequences for land-use management. Science of the Total Environment, 382, 165-190.

De Deyn, G.B., Shiel, R.S., Ostle, N.J., McNamara, N.P., Oakley, S., Young, I., Freeman, C., Fenner, N., Quirk, H., Bardgett, R.D. 2010. Additional carbon sequestration benefits of grassland diversity restoration. Journal of Applied Ecology. doi: 10.1111/j.1365-2664.2010.01925.x.

DEFRA (2017) Air Quality Plan for tackling roadside nitrogen dioxide concentrations in Liverpool Urban Area (UK0006) July 2017. 2017 Zone plans. Document UK0006.

Denzin, N. K. & Lincolnx, Y. S. (eds.) 1994. *Handbook of qualitative research* Thousand Oaks: Sage Publications.

Department for Business, Energy & Industrial Strategy. (2015). Government emission conversion factors for greenhouse gas company reporting. https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting

Department for Business, Energy & Industrial Strategy. (2018). Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal. https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

Department of Energy & Climate Change. (2013). Quarterly energy prices. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/267320/qep_december_2013.pdf

Dover JW. (2015). Green Infrastructure: incorporating plants and enhancing biodiversity in buildings and urban environments. London: Routledge.

Dovers, S. & Hussey, K. 2013. *Environment and sustainability: a policy handbook,* Annandale: Federation Press.

Druckman, D. 2005. Doing research. *Methods of inquiry for conflict analysis.* Thousand Oaks: Sage Publications.

Dytham, C. (2011). Choosing and Using Statistics, 3rd edition. Wiley-Blackwell

Ellenberg, H. 1988. Vegetation ecology of Central Europe, 4 edition. Cambridge: Cambridge University Press.

FRAGSTATS. (2015). McGarigal, K. fragstats.help.4.2.pdf

http://www.umass.edu/landeco/research/fragstats/fragstats.html.

Gradko (2017) Nitrogen Dioxide Diffusion Tubes. Shop. [Online] URL: http://www.gradko.com/store/environmental-store/no2-tube-analysis.shtml.

Greene, J.C., Caracelli, V.J. and Graham, W.F. (1989). 'Toward a Conceptual Framework for Mixed-method Evaluation Designs', Educational Evaluation and Policy Analysis. 11(3), 255–74.

Gill, S.E. (2006). Climate change and urban greenspace. PhD thesis, University of Manchester. http://www.ginw.co.uk/resources/Susannah_PhD_Thesis_full_final.pdf (see chapters 5 and 6 in particular).

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.

Groves, R.M., Fowler Jr, F.J., Couper, M.P., Lepkowski, J.M., Singer, E. and Tourangeau, R., (2011). *Survey methodology* (2nd ed). Hoboken: John Wiley & Sons.

Hankin B, Craigen I, Chappell NA et al. (2016) Strategic Investigation of Natural Flood Management in Cumbria. Jeremy Benn Associates, Skipton, UK. [online] URL: http://naturalcourse.co.uk/uploads/2017/04/2016s4667-Rivers-Trust-Life-IP-NFM-Opportunities-Technical-Report-v8.0.pdf

Hill MO, Mountford JO, Roy DB, Bunce RGH (1999) Ellenberg's indicator values for British plants. *ECOFACT Volume 2 Technical Annex.* Institute of Terrestrial Ecology, Huntingdon. http://nora.nerc.ac.uk/6411/1/ECOFACT2a.pdf

Hitchins, J., Morawska, L., Wolff, R. and Gilbert, D. (2000). Concentration of submicrometre particles from vehicle emissions near a major road. Atmospheric Environment 34(1): 51-59.

Hodgson, J.A., Thomas, C.D., Dytham, C.,Travis, J.M.J. and Cornell, S.J. (2012) The speed of range shifts in fragmented landscapes. PLoS ONE 710.

Hodgson, J.A., Wallis, D.W., Krishna, R. & Cornell, S.J. (2016) How to manipulate landscapes to improve the potential for range expansion. *Methods in Ecology and Evolution,* **7,** 1558-1566. http://dx.doi.org/10.1111/2041-210X.12614.

Horan, Melody Louise (2016/17). An Investigation Into How Urban Trees Impact Air Quality Within Central and South Liverpool. Dissertation submitted as partial fulfilment for the degree of M.Sc. in Environmental Science, School of Environmental Sciences. University of Liverpool.

Hundt L (2012) Bat Surveys: Good Practice Guidelines (2nd Ed) London: Bat Conservation Trust.

Janhäll, S. (2015). Review on urban vegetation and particle air pollution – deposition and dispersion. Atmospheric Environment, 105: 130-137.

Jin, S., Guo, J., Wheeler, S., Kan, L. and Shenguan, C. (2014). Evaluation of impacts of trees on PM2.5 dispersion in urban streets. Atmospheric Environment 99 277-287

Kvale, S. (1996). Interviews: an introduction to qualitative research interviewing. London: Sage.

LecoS (Landscape Ecology Statistics) v2.0.7 QGIS. URL: http://plugins.qgis.org/plugins/LecoS/

Leech, N.L. & Onwuegbuzie, A. J. (2009). A typology of mixed methods research designs. Quality & Quantity, 43, 265-275.

MaGurran, A.E. (1988). Ecological Diversity and Its Measurement. Cambridge: University Press.

Mann, S. (2016). The research interview: reflective practice and reflexivity in research processes, Houndmills, Basingstoke, Hampshire UK, Palgrave Macmillan.

Middleton et al (2014) Social Calls of the Bats of Britain and Ireland. Exeter: Pelagic Publishing.

Minichiello, V., Aroni, R. and Hays, T., 2008. *In-depth interviewing: Principles, techniques, analysis*. Canberra: Pearson Education Australia.

Ministry of Housing, Communities and Local Government, (2018). National Planning Policy Framework. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/728643/Revised_NPPF_2018.pdf

Murdock, A.P., Harfoot, A.J.P., Martin, D., Cockings, S. and Hill, C. (2015) OpenPopGrid: an open gridded population dataset for England and Wales. GeoData, University of Southampton. http://openpopgrid.geodata.soton.ac.uk/

Musante, K. and DeWalt, B.R. (2010). Participant Observation: A Guide for Fieldworkers, Blue Ridge Summit, US: AltaMira Press.

Neuman, W. L. (1994). *Social research methods: qualitative and quantitative approaches,* Boston: Allyn and Bacon.

Nowak, McPherson and Rowntree. (1994). Chicago's urban forest ecosystem: results of the Chicago urban forest climate project. Chicago: USDA.

Office for National Statistics. (2011). Census geography: an overview of the various geographies used in the production of statistics collected via the UK census. https://www.ons.gov.uk/methodology/geography/ukgeographies/censusgeography

OS Mastermap Topography and Greenspace Layers. [online] URL:

https://www.ordnancesurvey.co.uk/business-and-government/products/mastermap-products.html

and http://digimap.edina.ac.uk/

Perkins, S.E., Alexander, L.V., 2012. On the Measurement of Heat Waves. Journal of Climate 26, 4500-4517.

Perkins-Kirkpatrick, S.E., Gibson, P.B., 2017. Changes in regional heatwave characteristics as a function of increasing global temperature. Sci Rep-Uk 7, 12256.

Poteete, A. R., Janssen, M. & Ostrom, E. 2010. *Working together: collective action, the commons, and multiple methods in practice,* Princeton, N.J: Princeton University Press.

Presser, S., Couper, M.P., Lessler, J.T., Martin, E., Martin, J., Rothgeb, J.M. and Singer, E., 2004. Methods for testing and evaluating survey questions. *Public opinion quarterly*, *68*(1), pp.109-130.

QGIS Development Team 2013. QGIS Geographic Information System. Open Source Geospatial Foundation. URL http://qgis.osgeo.org

Raymond, C.M., Berry, P., Breil, M., Nita, M.R., Kabisch, N., de Bel, M., Enzi, V., Frantzeskaki, N., Geneletti, D., Cardinaletti, M., Lovinger, L., Basnou, C., Monteiro, A., Robrecht, H., Sgrigna, G., Muhari, L., Calfapietra, C. (2017). An Impact Evaluation Framework to Support Planning and Evaluation of Nature-based Solutions Projects. Report Prepared by the EKLIPSE Expert Working Group on Nature-based Solutions to Promote Climate Resilience in Urban Areas. Centre for Ecology & Hydrology, Wallingford.

Ranalli, A.J., Macalady, D.L. (2010). Review paper – The importance of the riparian zone and in-stream processes in nitrate attenuation in undisturbed and agricultural watersheds – A review of the scientific literature. Journal of Hydrology. 389: 406 – 415.

RICS (2011). The value of mapping green infrastructure. https://www.merseyforest.org.uk/files/The_Value_of_Mapping_Green_Infrastructure_pdf.pdf

Russ, J. (2012) British Bat Calls. A guide to species identification. Exeter: Pelagic Publishing.

Simons, H. (2009). *Case study research in practice.* Thousand Oaks: Sage Publications.

Soil Conservation Service (1972). Soil Conservation Service National Engineering Handbook - Section 4: Hydrology. Washington, DC: United States Department of Agriculture, Soil Conservation Service.

Sprent, J.I., (1987) The ecology of the nitrogen cycle. Cambridge: Cambridge University Press.

Suškevičs, M., Hahn, T., Rodela, R., Macura, B. & Pahl-Wostl, C. 2017. Learning for social-ecological change: a qualitative review of outcomes across empirical literature in natural resource management. *Journal of Environmental Planning and Management*, 1-28.

The Mersey Forest (2013). Liverpool City Region and Warrington Green Infrastructure Framework: Technical Document. https://www.merseyforest.org.uk/Technical_document.pdf

The Mersey Forest (2015). An ecosystem services mapping method for use in green infrastructure planning. https://www.merseyforest.org.uk/files/Ecosystem_services_mapping_method_paper.pdf

Tso, C.P., Chan, B.K. and Hashim, M.A. (1990). An improvement to the basic energy balance model for urban thermal analysis. Energy and Buildings, 14 (2), 143-152.

Tso, C.P., Chan, B.K. and Hashim, M.A. (1991). Analytical solutions to the near-neutral atmospheric surface energy balance with and without heat storage for urban climatological studies. Journal of Applied Meteorology, 30 (4), 413-424.

United Nations Economic Commission for Europe (1998). 'Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters': https://www.unece.org/fileadmin/DAM/env/pp/documents/cep43e.pdf

UK Data Service (2018). Quality Assurance. University of Essex, University of Manchester and Jisc. https://www.ukdataservice.ac.uk/manage-data/format/quality

Urban GreenUP (2018). D5.3 City Diagnosis and Monitoring Procedures. Urban Green UP Project Deliverable.

Urban GreenUP (2017a). D3.1: Report on the Diagnosis of Liverpool. Urban Green UP Project Deliverable.

Urban GreenUP (2017b). D3.2 Baseline Document for Liverpool. Urban Green UP Project Deliverable.

Weber, R. 1990. Basic Content Analysis. Thousand Oaks, USA: SAGE Publications.

West, V. (2018). WCC Carbon Lookup Tables and Small Project Carbon Calculator Version 2.0. https://www.forestry.gov.uk/forestry/infd-8jue9t

Whitford, V. Ennos, A.R. and Handley, J.F. (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 (2), 91-103.

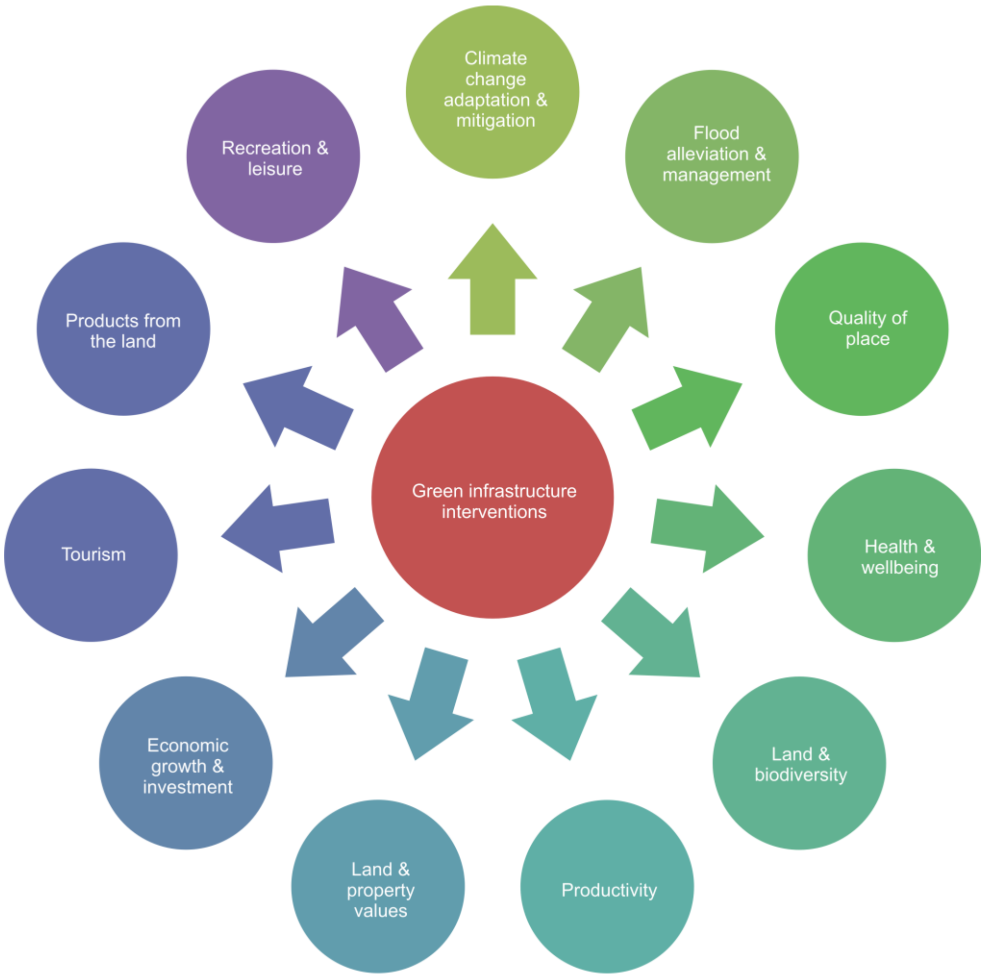
YIN, R. K. 2009. *Case study research: Design and methods,* Thousand Oaks, Sage publications, Inc.

YOUNG, O. R. 2006. Vertical interplay among scale-dependent environmental and resource regimes. Ecology and Society, 11(1): 27 [online] URL: https://www.ecologyandsociety.org/vol11/iss1/art27/main.html

5 Appendix 1: GI-Val Summary

GI-Val is The Mersey Forest's green infrastructure valuation toolkit. The current prototype is free and open source, and can be downloaded from www.merseyforest.org.uk/gi-val.

The toolkit provides a set of calculator tools, to help assess an existing green asset or proposed green investment. They are organised under eleven key benefits of green infrastructure:

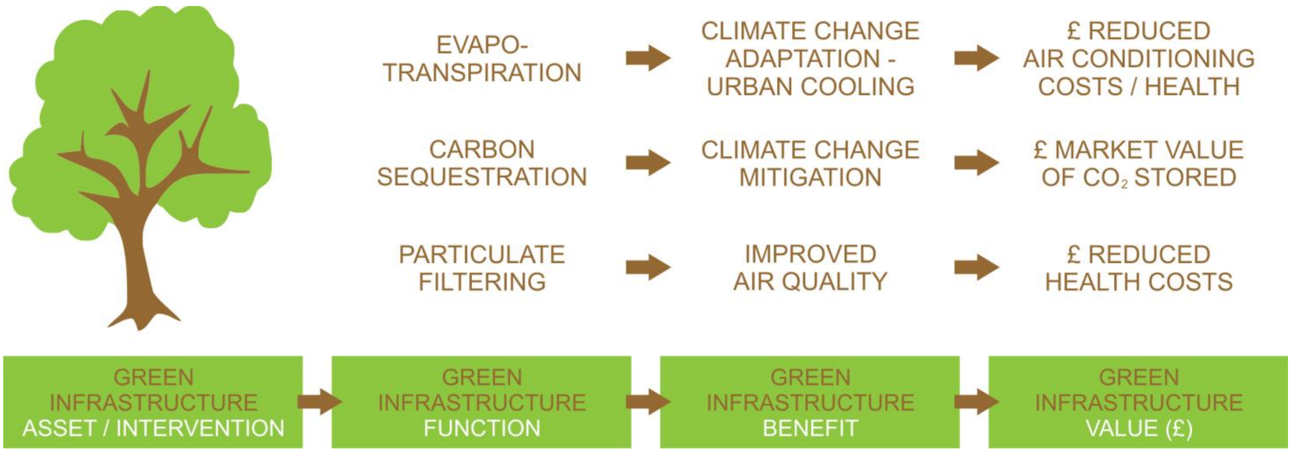


The toolkit looks at how the range of green infrastructure benefits derived from an asset or investment can be shown:

- **in monetary terms** – applying economic valuation techniques where possible
- **quantitatively** – for example with reference to jobs, hectares of land, visitors
- **qualitatively** – referencing case studies or important research where there appears to be a link between green infrastructure and economic, social or environmental benefit but where the scientific basis for quantification and/or monetisation is not yet sufficiently robust.

The toolkit uses standard valuation techniques to assess the potential benefits provided by green infrastructure within a defined project area. These benefits are assessed in terms of the functions that the green infrastructure may perform, support or encourage, depending upon the type of project.

For example, the diagram below shows how an urban tree planting scheme can result in improved air quality, carbon sequestration and reduced health costs, thereby illustrating green infrastructure function, benefit and potential monetisation.



Once data is entered into the toolkit, it generates financial values for many of the green infrastructure benefits. The toolkit identifies the marginal benefit, the additional value of the green infrastructure, and also tries to ensure that there is no ‘double counting’ of value.

BENEFITS	BENEFIT MONETISATION		
Benefits groups	GVA value	Land and property value	Other economic value
1 Climate Change Adaptation & Mitigation	£2.4k	n.a.	£13.6k
2 Water management & Flood Alleviation	£517k	n.a.	n.a.
3 Place & communities	n.a.	n.a.	n.a.
4 Health & Well-being	£48.9k	n.a.	£5.8m
5 Land & Property Values	n.a.	£13.9m	n.a.
6 Investment	n.a.	n.a.	n.a.
7 Labour Productivity	£335k	n.a.	n.a.
8 Tourism	£527k	n.a.	n.a.
9 Recreation & leisure	n.a.	n.a.	£11.2m
10 Biodiversity	n.a.	n.a.	£7.4k
11 Land management	£178k	n.a.	n.a.
TOTAL ECONOMIC VALUE OF BENEFITS	£1.6m	£13.9m	£11.2m
	These three figures should not be added together, as they represent different kinds of value		

The value of reduced mortality from walking/cycling has not been included in the other economic value total because of the risk of double counting