10,000 Raingardens: Exploring and using methods for quantifying raingarden benefits

Review of methods

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Foreword

The Hydro Nation Chair (HNC) research and innovation programme was established in 2022 to support the Scottish water sector to go beyond Net Zero by 2040. This ambitious commitment sits alongside action to ensure the climate resilience of Scotland's water system and to contribute to the resilience of Scotland's nature, businesses, communities and places.

Raingardens and other forms of Blue-Green Infrastructure, delivered at scale, have the potential to contribute to all of these priority areas – reducing flood risk (to communities and to water infrastructure) and ameliorating temperature rise, improving water quality through reducing pressure on the combined sewer system and through pollutant capture, providing low carbon (and carbon capturing) alternatives to traditional grey infrastructure, supporting and enhancing biodiversity and creating more attractive and pleasant places. However, to achieve this action at scale, decision making around the use of rain gardens and other blue-green infrastructure needs to be informed by more holistic approaches to both costs and benefits. This is a challenge that the HNC is investigating with Scottish Water and key partners.

The HNC supported the Green Action Trust in undertaking this study to understand the usefulness of existing valuation tools, their strengths and their limitations and the circumstances in which they should or should not be used. This will allow us to better target what is needed to develop and support more holistic decision making and business planning around water management.

The research team from Mott MacDonald and SRUC has, through valuation of a series of Scottish projects, delivered a valuable and informative report that both identifies the best of the current tools and highlights the shortcomings of these tools.

Readers will draw their own insights from the report but among the findings and observations which stood out from a HNC perspective are:

1. The shortcomings across all current tools and the associated research and evidence needs for key classes of benefits.
2. The relative strengths and weaknesses of each tool and their suitability for different stages of project development, realisation and evaluation (different tools having strengths for different stages).
3. Explicit recognition that the combination of benefits being sought, above and beyond surface water management, has an impact on the scale and design of raingardens.

We will be taking all of the learning from this study into the planning of the next phase of HNC work on place-based innovation.

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December 2024

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Executive Summary

Current studies on Sustainable Drainage Systems (SuDS) and Blue-Green Infrastructure, such as raingardens, primarily focus on flood management. However, there is an increasing need to better account for the broader benefits of schemes to both humans and nature. This study aims to identify the most suitable method for quantifying the multiple benefits of SuDS and Blue-Green Infrastructure.

This study is designed for non-economists interested in promoting and quantifying the benefits of SuDS schemes. It is particularly useful for professionals delivering SuDS schemes and environmental studies, community group representatives involved in local projects, or individuals without a technical background who have an interest in blue-green infrastructure. By providing clear and accessible methods for quantifying the multiple benefits of SuDS, this report aims to empower a diverse audience to make informed decisions and effectively advocate for multi-functional SuDS.

Following a literature review, a long-list of ecosystem service assessment methods were screened against criteria, including monetisation of benefits, flexibility of the scale for benefit assessment, level of work, technical complexity, accuracy of results and repeatability.

Based on the assessment, a short-list of three methods was identified:

- **ciriabest**, an online GIS-based tool that supports the screening, qualitative assessment, quantitative assessment, and monetisation of 19 main blue-green infrastructure benefits. This tool provides a comprehensive list of categorised benefits.
- **GI-Val**, an Excel-based tool that supports the identification, qualitative assessment, quantitative assessment, and monetisation of 11 blue-green infrastructure benefit groups. This tool can generate descriptions based on the quantified benefits and is great for qualitative descriptions.
- **Nature-Based Solutions (NBS) Benefits Explorer**, a Web-based tool that helps identify a pathway from nature-based activities to benefits, including identification of numerous benefits, although only 5 benefit categories can be valued. This tool is very user friendly and easy to navigate.

Of the short list, **ciriabest** emerged as the current preferred method for quantifying the benefits of raingardens. It offers flexibility, detailed benefits valuation estimates, GIS integration and an interactive dashboard. It is widely used and recommended by stakeholders for quantifying raingarden benefits. Of the 19 main benefit categories in the tool, 14 can be quantified and monetised, across provisioning, regulating and cultural ecosystem services.

GI-Val's strength lies in its use of both monetary evaluation and qualitative assessments. However, it is a prototype, and the lack of maintenance limits the accuracy of its valuation estimates. At the time of writing, it is unclear whether the tool will be regularly updated and maintained.

The NBS Benefits Explorer tool is best suited for early, pre-feasibility stages for benefit identification. It is, however, less robust in the monetary estimation of benefits and its suitability for small-scale urban raingardens and SuDS projects is unclear.

Ciriabest has been tested by various users across a range of projects, including raingarden retrofit in Leeds, green roofs in Glasgow City Centre and SuDS at Killingworth and Longbenton Basins. Across these examples provided by the tool publishers, ciriabest was used for the evaluation of impacts and developing the business case.

The short-listed tools provide an indicative evaluation of benefits. More extensive benefit evaluations may be needed to meet the requirements of some business cases and funding applications. For example, Enabling a Natural Capital Approach (ENCA) could be used as a framework to develop a bespoke and more detailed benefits evaluation or to replace the valuation studies used in existing tools such as ciriabest.

The next steps for this study include testing the identified preferred option, ciriabest, on five raingarden sites in Scotland to demonstrate the use of the tool with case studies of varying scale and typologies.

The following is recommended when quantifying the wider benefits of raingardens and blue-green infrastructure:

- Using benefits assessment tools at early stages of a project, to have a greater influence in the decision-making process and on the scale of multiple benefits achieved.
- Setting clear objectives at the project inception stage.
- Assessing raingarden investments at an aggregated level, as many of the benefits are only realised when the scale becomes significant.
- Using monetisation outputs where relevant only, noting that in some instances, a qualitative assessment may be more relevant.
- Updating and reviewing the underlying valuation studies that support benefit monetisation tools.
- Leveraging existing tools to limit the development of new tools that may further fragment the industry.

1 Introduction

1.1 Study Overview

Mott MacDonald, in collaboration with SRUC (Scotland's Rural College), were commissioned by Green Action Trust, to explore methods for quantifying Sustainable Drainage Systems (SuDS) and Blue-Green Infrastructure benefits – as part of their '10,000 Raingardens for Scotland' campaign.

The *'10,000 Raingardens for Scotland'* campaign is designed to promote and encourage the use of raingardens as a sustainable and natural way to manage water, particularly in urban areas. The campaign supports pollution reduction and the creation of wildlife friendly and accessible greenspace that provides attractive places for people to visit.

The *'10,000 Raingardens for Scotland'* campaign uses the term 'raingarden' in order to capture the imagination of the public and make an overt connection to the rainwater that such systems manage. The term 'raingarden' has been used broadly and in this study, we are investigating the benefits of all SuDS systems and general Blue-Green Infrastructure at a range of scales.

To date, the benefits of SuDS measures has been predominantly focussed on managing flood risk. If wider benefits are neglected during the planning and design stages, the value of SuDS is not best communicated.

This study aims to address this shortfall, by encouraging decision-makers to investigate and quantify a wide range of benefits of raingardens to both humans and nature, ultimately aiming to promote the delivery of best practice and multifunctional surface water management measures.

1.2 Study Aims

The main aim of this study is to identify the most suitable and usable method for quantifying the multiple benefits of SuDS and Blue-Green Infrastructure for non-economists. The study can be used to inform the wider approaches to developing business cases for delivering Blue-Green Infrastructure throughout Scotland.

This study aims to:

- Research and develop a database of methods for quantifying the benefits of raingardens
- Review the database of benefit quantification methods against key criteria to identify a short-list of three quantification methods
- Review the short-list in more detail to identify a single preferred method for quantifying the benefits of raingardens
- Apply the preferred method and conduct a benefits assessment on five case study sites

This Stage 2 report focusses on the initial aims and summarises the research undertaken to compile a list of methods which can be used to evaluate the benefits of SuDS and Blue-Green Infrastructure.

2 Methodology Short-Listing

2.1 Discovery of Benefits Assessment Methods

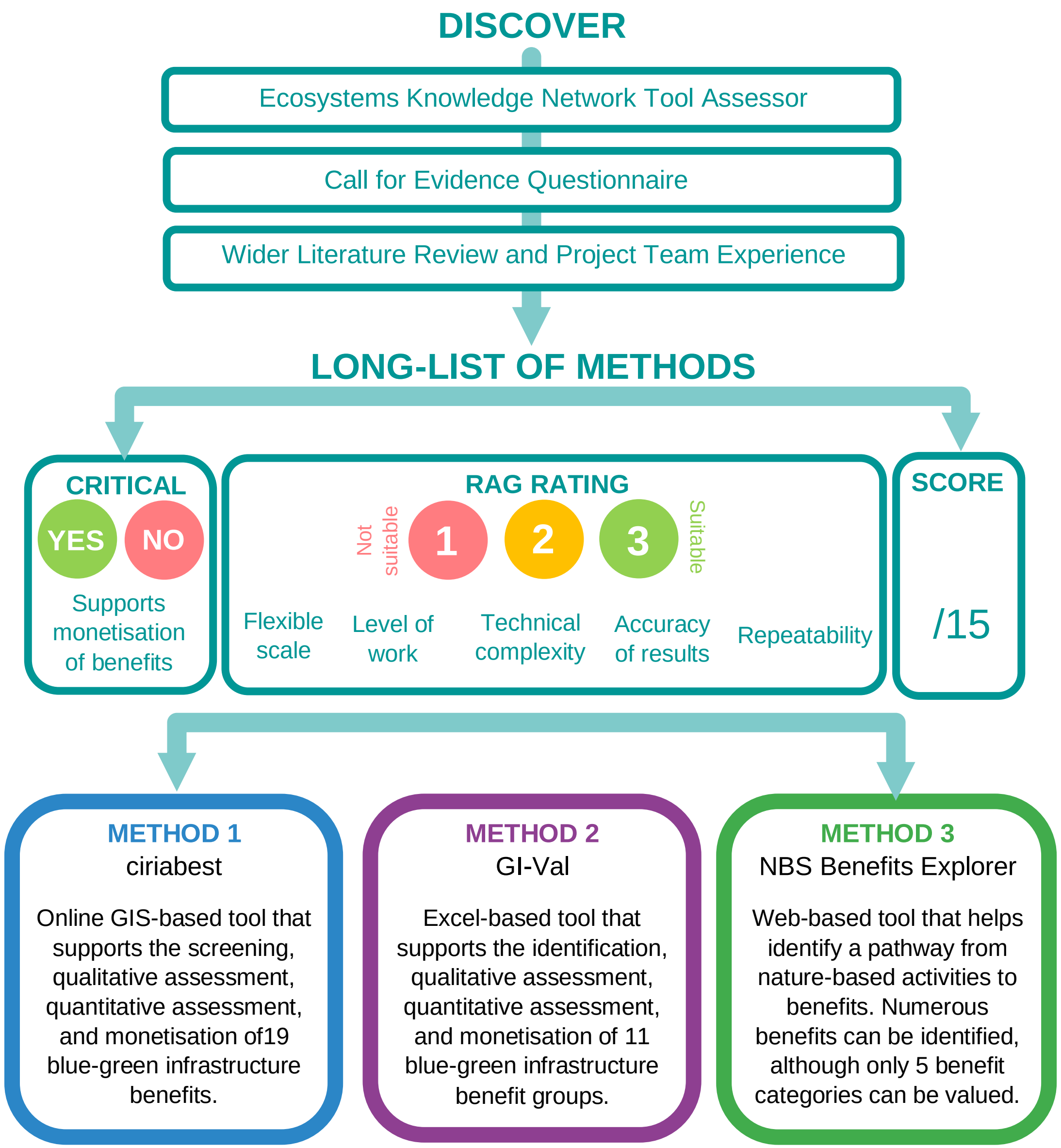
A review of existing available ecosystem services assessment methods was undertaken to identify methodologies suitable for quantifying the wider benefits of raingardens.

To develop the long-list of benefit assessment methods, the *Ecosystems Knowledge Network Tool Assessor* (ESKN) (JNCC, 2024) was used as the central source of information. The information from the *ESKN Tool Assessor* was supplemented by responses from a stakeholder 'call for evidence' questionnaire and by the knowledge and experience of the project team.

2.2 Screening of the Long-List Benefits Assessment Methods

The long-list of methods were reviewed against the criteria discussed in this section. The ability to support the monetisation of benefits was considered critical, due to the influence monetisation has on informing investment decisions. Further criteria was used to determine a RAG ('Red', 'Amber', 'Green') rating and score. The recommended tool should accommodate projects of varying scale, the input requirements should not be onerous, and should have low technical complexity. The tool should also be accurate and repeatable. The full long-list and assessment is presented in Appendix A. The critical criteria and total score were used to screen methods and short-list the following three benefits assessment methods for further assessment.

- ciriabest, (CIRIA, 2023)
- Green Infrastructure Valuation Toolkit (GI-Val), (The Mersey Forest, 2018)
- Nature-Based Solutions Benefits Explorer, (Water Action Hub, 2021)



3 Short-List Review

3.1 Benefit Assessment Process Review

The short-listed methods were reviewed in greater detail to identify a preferred method, most suited to evaluating raingarden benefits. Table 3.1 summarises how each method can be used to support the various stages of a standard benefits assessment process. Best practice aspects of the tools have been **highlighted in bold**.

The tool analysis and comparison against the benefit assessment process identified ciriabest as the preferred tool, by promoting best practice across the benefits assessment process. The tool provides the flexibility in accommodating bespoke external assessments or relying on the integrated benefits valuation estimates. It is understood that the tool will continue to be maintained, via the licence fee, and valuation estimates will be updated as new and best practice supporting studies emerge. Despite the fee, the tool could be good value for money if both the tool and supporting valuation studies are periodically updated. The integration with GIS and interactive dashboard promotes engaging benefits visualisation to inform effective decision-making. The tool also emerged as the most popular and recommended by stakeholders responding to the call for evidence questionnaire. There are many examples of the tool being used to quantify raingarden benefits – as is the focus of this study.

The GI-Val toolkit's greatest strength is its focus on using both monetary evaluation and qualitative assessments to guide the benefits assessment process. The tool provides a 'Summary of Quantities' table that quantifies the scale of each benefit category in its own terms. For example, carbon sequestered is summarised in kgCO_{2e} sequestered. This helps to more tangibly link benefits back to project or national objectives, rather than solely flattening these complex impacts into monetary terms. The tool is however a prototype and lack of maintenance limits the accuracy of the tool's valuation estimates, which is a limitation that will persist if the tool and studies are not regularly updated with emerging best practice. At the time of writing, it is unclear whether the tool will be regularly updated and maintained.

The Nature-Based Solutions Benefits Explorer tool is best suited for early, pre-feasibility stages for benefit identification by clearly suggesting likely benefits based the proposed activities. Other useful features include flagging relevant UN Sustainable Development Goal targets, which could be used to inform targeted project objectives. The tool is however less robust and clear in the monetary estimation of benefits and it remains unclear whether the tool would be suited to the small scale required for urban raingardens and SuDS projects. It is therefore recommended this tool is not taken forward as the preferred method for raingarden benefit quantification in this study.

The following analysis in Table 3.1 outlines this in more detail.

Table 3.1: Summary of methods against the benefit assessment process

ASSESSMENT STAGE	METHOD 1 ciriabest	METHOD 2 GI-Val	METHOD 3 NBS Benefits Explorer
A Objective setting	The tool itself does not set objectives, but the benefit screening stage of the tool could help to identify benefits that could be targeted via specific and measurable objectives.	The tool itself does not set objectives. Completion of the project data tab could help prompt discussions on likely benefits to inform objectives, but relatively detailed data is required to complete this. Objective setting and benefit identification should be conducted in advance of using the tool. The guidance document does however illustrate likely benefits based on example green infrastructure, that could be targeted via specific and measurable objectives.	The tool itself does not set objectives, but does suggest benefit categories based on the activity selected. **It identifies relevant Sustainable Development Goals that the project could address.** These could be used to inform objectives. **A range of nature-based solutions are suggested based on desired benefits – helping structure conversations about objectives.**
B Benefit identification	**Screening questions help identify 19 main potential project benefits categories for further assessment.** **Supporting guidance flags risk of potential double counting since some of the accounted benefits are not mutually exclusive.**	The guidance document illustrates likely benefits from the 11 categories based on example green infrastructure. **Potential double counting between benefit categories is illustrated.**	The focus of the tool is on early-stage project planning and identifying a clear pathway from activities to 27 benefits across 5 themes. **Benefit categories are suggested based on the nature-based activity selected.**
C Qualitative description	**The benefit screening method and qualitative ranking score helps to qualitatively describe the benefits and indicates the potential significance.** **Guidance recommends which benefit categories should only be assessed qualitatively, unless a local evidence or evaluation study is available.**	**The 'cost benefit assessment' tab allows users to qualitatively describe benefits and highlight why the project will deliver these – emphasising the importance of qualitative narrative in building the return-on-investment case.**	The tool does not have an integrated method for recording qualitative benefits, but the benefit descriptions could be useful in helping to describe and report benefits. **Benefit forecasting graphs indicatively show the change in benefit accrued (scaling from trade-off to low to high)**

Qualitative description continued	The previous Excel-based iteration of the tool used a coarse screening and qualitative assessment to identify benefits for further assessment, although this feature is not included in the updated GIS-based version.		**over three time periods (1-4 years, 5-9 years and 10+ years). It also provides different spatial scales (property, municipal, watershed). This could be useful for SuDS assessments. Some benefits are higher at the property scale.**
D Quantitative assessment	Some benefits provide estimates in natural values such as tonnes of pollutant removed, although the focus on the tool seem to be monetisation. Benefits that cannot be monetised provide indicative scales of impact, such as crime where a scale from 1-5 indicates level of improvement.	**A 'summary of quantities' tab provides a summary table that quantifies the scale of each benefit category in its own terms. For example, carbon sequestered is summarised in $kgCO_{2e}$ sequestered. This helps to more tangibly link benefits back to project or national objectives.**	The tool suggests indicators and methods for quantifying the selected benefits that could be used to support a bespoke quantitative assessment. The tool provides an estimate for the tons of carbon sequestered.
E Benefit monetisation	Of the 19 main benefit categories in the tool, 14 can be quantified and monetised. **The valuation studies used to in the monetisation model are highlighted.** The valuations are based on a variety of sources across a wide time range. It is however unclear how they have been adjusted for inflation. **The updated version has introduced a licence fee to enable maintenance of the tool and updates to account for updated and best practice valuation studies.**	Of the 11 benefit categories in the tool, 10 can be quantified and monetised. **The valuation studies used to in the monetisation model are highlighted.** The tool is a prototype, with some benefit indicators highlighting additional work is required to develop a monetisation tool. The valuations are based on a variety of sources across a wide time range. It is however unclear if and how they have been adjusted for inflation. As the tool is a prototype, it is unclear whether the valuation estimates will be continuously revised.	6 benefit categories can be monetised. **The valuation studies used to in the monetisation model are highlighted.** It is however unclear how the values have been adjusted for inflation and differences between countries (i.e., exchange rates and conversion year used). This would require care for use of the robustness of value estimates in the UK. Valuations are based on various sources, varying in age, across the ecosystem services. For example, the biodiversity valuation model (de Groot, et al., 2012) has since been substantially updated (Brander, et al., 2024).

Benefit monetisation continued	It is unclear how the spatial element of the tool is used to quantify benefits, beyond presenting the benefiting areas and assigning benefits to these areas. Further insight would be required to confirm whether size or geospatial elements such as population and baseline information is or could be used to automatically inform the assessment. **Users can input individual evaluation estimates from external bespoke assessments, as an alternative to using the inbuilt estimates.** **The discount rate can be manually updated from the default *Green Book* values** (HM Treasury, 2022)**. In accordance with *The Green Book,* a separate discount rate can be used for health impacts.**		
F Benefits visualisation	**The assessment is within a spatial, map-based format that allows appraisal areas to be visualised.** **Benefits are also visualised via graphs and summary tables in a dashboard.**	**Benefits are visualised via graphs and summary tables in a dashboard.**	**Benefits are visualised via graphs in a dashboard.** **The benefits forecasting graphs are also a useful visualisation of indicative benefit over time.**
G Sensitivity Testing	**Integrated confidence scoring on valuation assumptions helps communicate uncertainty and highlight sensitivity of the assessment.**	Low, average and high reference valuations are provided for some benefit indicators that could be used to support sensitivity testing with manual adjustments to Excel formulas.	The tool does not have integrated sensitivity testing or provide an indication on the margin of uncertainty in the results.

H Option comparison and selection	The tool allows option comparison relative to a baseline scenario. The previous Excel-based tool included a separate option comparison spreadsheet for up to four options, although this is not directly possible in the updated online version.	The tool allows option comparison relative to a baseline scenario. **The tool also includes a calculator for capital and maintenance costs.**	The tool allows option comparison relative to a baseline scenario.
I Commercial use	Licenses to use ciriabest are available to purchase at the following 2024 rates: - Individual user licence, £600 + VAT per annum - Multiple users' (up to ten employees can access ciriabest simultaneously) licence, £2,500 + VAT per annum	The current prototype is free and open source. The resources are licensed under a Creative Commons Attribution-NonCommercial 3.0 Unported License.	The tool is free and open source.

These tools stand upon the foundation of a library of economic valuation studies. These studies have used approaches, including stated preference (such as willingness to pay studies) or revealed preference (such as travel cost surveys), to interpret goods and services provided by the environment using Pounds, £. However, every project is different. And whilst we believe that these short-listed tools should provide enough coverage of benefits for SuDS projects – on the occasion they do not, there is the option to move to a more bespoke stage. Moreover, the use of different valuation methods across different benefits may limit whether values can be summed into a robust single figure. Using monetary values to compare across alternatives for individual benefits would be defensible.

The Enabling a Natural Capital Approach (ENCA) framework, published by DEFRA is not a tool, but is a framework to undertake more detailed and bespoke economic valuation of environmental improvements.

We haven't shortlisted this framework, because it is not particularly easy to use, and requires some knowledge of ecosystem services and economics. However, we note that this is a robust approach, recommended for use by the Environment Agency's *Flood and Coastal Erosion Risk Management Appraisal Technical Guidance*, and therefore we signpost it here, should a more detailed appraisal be required which cannot be serviced by ciriabest, GI-Val or The Nature-Based Solutions Benefits Explorer tool.

3.2 Ecosystem Services Assessed

The *Millennium Ecosystem Assessment* (Millennium Ecosystem Assessment, 2003) assesses the consequences of ecosystem change for human wellbeing and was a key influence on the early mainstreaming of the ecosystem services agenda. Table 3.2 summarises the ecosystem services presented in the *Millennium Ecosystem Assessment* and how well these are covered by each method. Only benefits that can be monetised by the tool have been included.

Table 3.2: Summary of ecosystem services that can be monetised by the tools

ECOSYSTEM SERVICES			
		SUPPORTING SERVICES	
	PROVISIONING SERVICES	REGULATING SERVICES	CULTURAL SERVICES
METHOD 1 ciriabest	ASSET PERFORMANCE	AIR QUALITY BUILDING TEMPERATURE CARBON REDUCTION FLOODING WATER QUALITY WATER QUANTITY	AMENITY EDUCATION HEALTH NOISE RECREATION TRAFFIC CALMING
	BIODIVERSITY & ECOLOGY		
METHOD 2 GI-Val	LAND MANAGEMENT	CLIMATE CHANGE WATER & FLOOD MANAGEMENT	RECREATION & LEISURE TOURISM PLACE & COMMUNITIES
	HEALTH & WELLBEING	LABOUR PRODUCTIVITY	LAND & PROPERTY VALUES	BIODIVERSITY
METHOD 3 NBS Benefits		WATER QUANTITY WATER QUALITY GREEN HOUSE GASES FLOOD	RECREATION
	BIODIVERSITY		

3.3 Case Studies

A literature review was conducted to identify existing case study examples of where the short-listed tools have been used to quantify benefits of blue-green infrastructure and to understand how applicable the methods are to promoting the delivery of best practice raingardens across Scotland. Unfortunately, no case study examples of using the NBS Benefits Explorer Tool on surface water management schemes were discovered. This case study review section therefore focusses on the ciriabest and GI-Val tools. The updated version of ciriabest is relatively new and no case studies were publicly available. The ciriabest case studies presented are therefore based on the 2019 Excel-based version of CIRIA B£ST.

3.3.1 Ciriabest Case Studies

Roundhay Park Lane Roadside
Raingardens Retrofit

Present
value benefit

Photo source: (Mott MacDonald Bentley, 2022)

CIRIA B£ST was used to compare SuDS with a concrete tank solution to mitigating CSO spills. The tool was used to support the SuDS option, by monetising the following benefits:

Amenity
Flooding
Water Quality
Recreation
Air Quality
Asset Performance

Data source: (Susdrain, 2019)

Glasgow City Centre
Green Roofs, Swales and Wetland

Present
value benefit

Photo source: (MGSDP, 2024)

CIRIA B£ST was used to support the business case for integrating green roofs, swales, permeable paving and wetlands into the city's redevelopment plan, by monetising the following benefits:

Flooding
Recreation
Amenity
Water Quality
Enabling Development
Carbon Sequestration

Data source: (Susdrain, 2019)

Killingworth and Longbenton
SuDS Basins

Present
value benefit

Photo source: (Susdrain, 2018)

CIRIA B£ST was used to evaluate the benefits of SuDS basins and surface water disconnection from the combined network. The following benefits were monetised in the business case:

Flooding
Water Quality
Recreation
Amenity
Education
Biodiversity and Ecology

Data source: (Susdrain, 2019)

3.3.2 GI-Val Case Studies

Stanley Bank SuDS and Woodland and Grassland Management

Photo source: (The Mersey Forest, 2011)

GI-Val was used to evaluate the impact of integrating SuDS basins, woodland and grassland management into a road scheme. The tool was used to monetise the following benefits:

Health and Wellbeing
Biodiversity
Land and Property Values
Flood Alleviation
Tourism
Labour Productivity

Data source: (The Mersey Forest, 2011)

Swindon Triangle SuDS and Landscaping Improvements

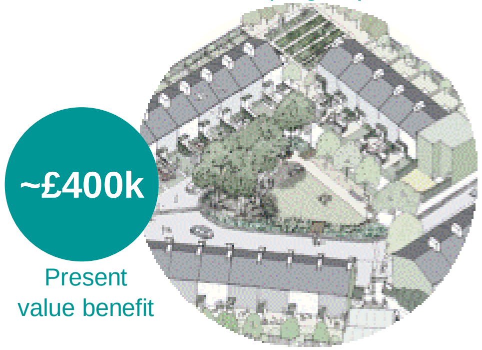


Photo source: (The Horticultural Association, 2011)

GI-Val was used to evaluate the wider returns from excellence in green infrastructure investments, including SuDS. The tool was used to monetise the following benefits:

Property Values
Water Management
Land Products
Recreation
Climate Change

Data source: (The Horticultural Association, 2011)

Stockport Town Centre Green Infrastructure

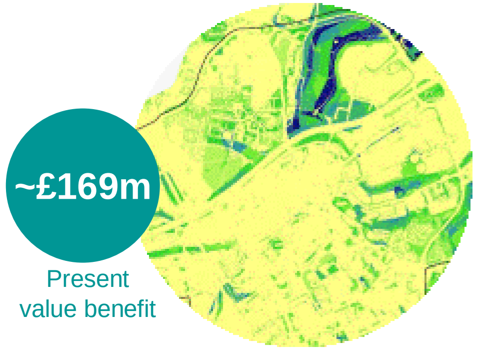


Photo source: (MD2 Consulting, 2015)

GI-Val was used to evaluate the economic value of Stockport's existing green infrastructure to justify further enhancement. The tool was used to monetise the following benefits:

Health and Wellbeing
Land and Property Values
Biodiversity
Water Management
Tourism
Recreation and Leisure

Data source: (MD2 Consulting, 2015)

The case studies demonstrate that both the ciriabest and GI-Val tools can be used to quantify the benefits of blue-green infrastructure at varying scales and that both tools can be used to support the business case for delivering multi-functional raingardens across Scotland. All case studies demonstrated a range of ecosystem services can be monetised by the tools. Despite the applicability of both tools in supporting the 10,000 Raingardens for Scotland Project, the literature review identified no recent examples of the GI-Val tool being used. At the time of writing, it is unclear whether the prototype tool is being further improved and maintained.

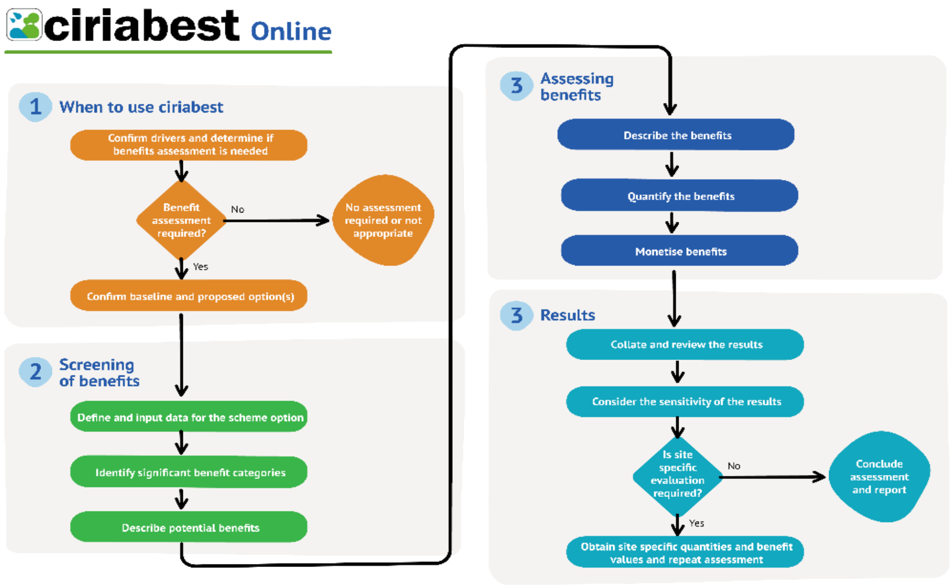
4 Conclusions and Recommendations

4.1 Conclusions

A review of existing available ecosystem services assessment methods identified the following short-list of tools as being most suitable for quantifying the wider benefits of raingardens and blue-green infrastructure:

- ciriabest, (CIRIA, 2023)
- Green Infrastructure Valuation Toolkit (GI-Val), (The Mersey Forest, 2018)
- Nature-Based Solutions Benefits Explorer, (Water Action Hub, 2021)

A detailed review of the short-list identified ciriabest as the current leading tool, by promoting best practice across the benefits assessment process.



Source: ciriabest four-stage approach (CIRIA, 2023)

Ciriabest provides the flexibility in accommodating bespoke external assessments or relying on the integrated benefits valuation estimates. Via the licence fee, it is understood the tool will continue to be maintained and valuation estimates updated as new and best practice supporting studies emerge. The integration with GIS and interactive dashboard promotes engaging benefits visualisation to inform effective decision-making. The tool also emerged as the most popular and recommended by stakeholders responding to the call for evidence questionnaire. As highlighted in the case study review, there are many examples of the tool being used to quantify raingarden benefits.

The GI-Val toolkit's greatest strength is its focus on using both monetary evaluation and qualitative assessments to guide the benefits assessment process. The tool provides a 'Summary of Quantities' table that quantifies the scale of each benefit category in its own terms. For example, carbon sequestered is summarised in $kgCO_{2e}$ sequestered. This helps to more tangibly link benefits back to project or national objectives – rather than solely flattening these complex impacts into monetary terms. The tool is however a prototype and lack of maintenance limits the accuracy of the tool's valuation estimates.

The Nature-Based Solutions Benefits Explorer tool is best suited for early, pre-feasibility stages for benefit identification by clearly suggesting likely benefits based the proposed activities. The tool is however less robust and clear in the monetary estimation of benefits, and it remains unclear whether the tool would be suited to the small scale required for urban raingardens and SuDS projects – as no case study examples were discovered.

To demonstrate the value of using ciriabest to promote raingarden delivery throughout Scotland, the tool will be tested on five case study sites.

4.2 Recommendations

The following recommendations should be considered when quantifying the wider benefits of raingardens and blue-green infrastructure.

4. **Using benefits assessment tools at early stages in the project**
   – The use of tools to identify, describe and quantify wider benefits should be implemented as early in the project stages as possible, to have the greatest influence in the decision-making process and on the scale of multiple benefits achieved.
5. **Setting clear objectives is critical**
   – Effective business cases tell a clear story of what they are trying to achieve. Benefits assessment and identification tools, such as ciriabest, should be used at the project inception stage. The tool should be used to help structure conversations about objectives, identify benefits and beneficiaries and set SMART (Specific, Measurable, Accepted, Realistic, Time-bound) objectives.
6. **Spatial scale of assessment**
   – Although it may be possible to use the tools at a very local individual raingarden scale, guidance on the ciriabest tool notes that many of the benefits will only be realised as the scale becomes significant.
   – Detailed quantitative assessments and monetisation of benefits of individual raingarden features may therefore not be proportionate. Therefore, it is preferable to apply benefit assessment tools to aggregated individual blue-green infrastructure components or schemes as a wider programme work. This practice is more likely to yield distinct and quantifiable benefits.
7. **When to monetise benefits**
   – In some instances, the qualitative assessment of benefits can be more appropriate and powerful in communicating benefit and achieving the objective of removing barriers to raingarden delivery – rather than flattening these complex systems into monetary values.
   – If the scale of blue-green infrastructure proposed is small, qualitative description may be more appropriate for capturing the potential benefit – as the scale may be too small for benefits to be realised and accurately expressed quantitatively.
   – The quantitative assessment makes benefits more commensurable. It could help put benefits on an even playing field to support like-for-like comparisons and decision-making.
   – There is however a recognition that expressing benefits in financial returns on investment, is required to justify investment.
8. **Reliance on valuation studies**
   – The valuation studies that support benefit monetisation tools should be periodically reviewed and updated, as new and improved valuation studies emerge. Appendix B details a review of the valuation studies used in the short-listed tools. It shows where studies are most relevant, considering their date, location and transferability to raingardens.
   – For example, *Enabling a Natural Capital Approach* (ENCA) resources and datasets could be used as a framework to identify up-to-date and improved valuation studies that could be used to review and replace the valuations used in existing tools such as ciriabest.
9. **Caution on the development of additional tools**
   – The literature review stage of the project and research into available benefit assessment methods confirmed there are many existing tools and methods that could be used to quantify benefits of raingardens and blue-green infrastructure.
   – Some responses to the call for evidence questionnaire highlighted concerns over further fragmenting the industry by developing more tools.

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Appendices

A. Database of benefits assessment methods

The database of benefit assessment methods is presented in the Excel document reference number 100119616-MMD-RGN-XX-T-X-001 P01.

A brief summary of the benefit assessment methods is shown in Table A.1.

Table A.1: Scoring of benefit assessment methods

CRITICAL CRITERIA: YES / NO

RAG RATING CRITERIA: GREEN – Suitable / AMBER / RED – Not suitable

NAME	DATE	COST	Supports monetisation of benefits	Flexibility of method to suit raingarden scales and typologies	Level of work required	Technical complexity	Accuracy of results	Repeatability	SCORE	SHORT-LISTED?
ciriabest	2023	Licence (£600, single user)	YES	3	2	3	3	3	14	YES
Green Infrastructure Valuation Toolkit (GI-Val)	2018 (v1.6)	Open source	YES	3	2	3	3	3	14	YES
Nature-Based Solutions Benefits Explorer Tool	2021	Open source	YES	2	3	3	2	3	13	YES
Enabling a Natural Capital Approach (ENCA)	2021	Open source	YES	3	1	2	3	3	12	NO
Natural Environment Valuation Online tool (NEVO)	2019	Open source	YES	1	3	3	2	3	12	NO
Outdoor Recreation Valuation Tool (ORVal)	2018 (v 2.0)	Open source	YES	1	3	3	2	3	12	NO
Environment and Historic Environment Outcomes Valuation (EHOV-lite Tool)	2023	Open source	YES	2	3	3	1	3	12	NO
Toolkit for Ecosystem Service	2017	Open source	YES	1	3	2	2	3	11	NO

NAME	DATE	COST	Supports monetisation of benefits	Flexibility of method to suit raingarden scales and typologies	Level of work required	Technical complexity	Accuracy of results	Repeatability	SCORE	SHORT-LISTED?
Site-Based Assessment (TESSA)										
Flood and Coastal Erosion Risk Management: A Handbook for Economic Appraisal (Multi Coloured Handbook); FHRC.	2024	Corporate Licence (£2,640) Standard single user (£550 +VAT)	YES	2	1	1	3	3	10	NO
Natural Capital Accounting	2023	Open source	YES	1	2	2	3	2	10	NO
Urban Integrated Valuation of Ecosystem Services and Trade-offs (InVEST)	2024	Open Source	YES	2	1	1	3	3	10	NO
Partnership Funding Supporting Guidance for Outcome Measure 4 (2020) and the Environment Agency's Partnership Funding Calculator.	2020	Open source	YES	2	1	1	2	3	9	NO
Co$ting Nature	2017 (v3)	Open source (non-commercial uses) £1,000 - £8,000	YES	1	2	1	2	3	9	NO

NAME	DATE	COST	Supports monetisation of benefits	Flexibility of method to suit raingarden scales and typologies	Level of work required	Technical complexity	Accuracy of results	Repeatability	SCORE	SHORT-LISTED?
		commercial use								
ARtificial Intelligence for Environment & Sustainability (ARIES)	2024	Open source	YES	2	1	1	2	2	8	NO
Natural Capital Workbook	2017	Open source	NO	3	1	1	1	2	FAILS CRITICAL CRITERIA	NO
Environmental Benefits from Nature (EBN)	2021	Open source	NO	3	2	2	3	3	FAILS CRITICAL CRITERIA	NO
Statutory Biodiversity Calculation Tool	2024	Open source	NO	3	2	1	3	3	FAILS CRITICAL CRITERIA	NO
Natural Capital Planning Tool	2018	Was open source	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed	Not assessed	NO

Source: Mott MacDonald

B. Valuation studies review

This section reviews the valuation studies used in the shortlisted tools (ciriabest, GI-VAL and NBS Explorer). Relevant items for the review, and their assessment, are detailed in Table B.1.

Table B.1: Valuation studies assessment

	Date	Location	Transferability to raingardens
	Less than 5 years old	In the UK.	Low. The study focuses on a habitat/ scale that does not apply to raingardens.
	Between 5 and 10 years old	n/a	Medium. The outputs of the study are transferrable to raingardens to some extent.
	More than 10 years old	Outside the UK	High. The habitat(s) in the study apply to raingardens.

Table B.2 summarises the review of the studies.

Table B.2: Valuation study review

Tool	Environmental service	Intervention (if available)	Study	Date	Location	Transferability to raingardens
Ciriabest	Air quality		Defra (2023) Air Quality: Economic Analysis	2023	UK	High
Ciriabest	Amenity	Creation or improvement of commonly visited park or green space	Fields in Trust (2018) Revaluing Parks and Green Spaces: Measuring their economic and wellbeing value to individuals.	2018	UK	Medium
Ciriabest	Amenity	Street improvements including planting of trees and green verges.	Mell et al (2013) Promoting Urban Greening: Valuing the Development of Green Infrastructure Investments in the Urban Core of Manchester, UK. Urban Forestry & Urban Greening , Volume 12, Issue 3, 2013, Pages 296–306.	2013	UK	High
Ciriabest	Amenity	New or significantly improved ponds	Bastien, N. R. P., S. Arthur and M. J. McLoughlin (2011) Valuing amenity: public perceptions of sustainable drainage systems ponds. Water and Environment Journal, 26:1.	2011	UK	High
Ciriabest	Amenity	General improvements to green/blue open spaces (homes <500m away)	(2022). Enabling a Natural Capital Approach, Defra	2020	UK	High
Ciriabest	Amenity	Commercial properties	Gensler (2011). Open space: an asset without a champion?	2011	Europe	High
Ciriabest	Asset performance		BEIS (2022) Updated energy and emissions projections 2021 - 2040	2022	UK	High
Ciriabest	Biodiversity and ecology		Christie, M., Hyde, A., Cooper, R., Fazey, I., Dennis, P., Warren, J. M., ... & Hanley, N. (2011). Economic Valuation of the Benefits of Ecosystem Services Delivered by the UK Biodiversity Action Plan (Defra Project SFFSD 0702).	2011	UK	Medium
Ciriabest	Building temperature		BEIS (2021) Valuation of greenhouse gas emissions: for policy appraisal and evaluation	2023	UK	High

Tool	Environmental service	Intervention (if available)	Study	Date	Location	Transferability to raingardens
Ciriabest	Carbon reduction and sequestration		BEIS (2021) Valuation of greenhouse gas emissions: for policy appraisal and evaluation	2021	UK	High
Ciriabest	Education	Cost of investing in nature-based school trips	Mourato et al (2010) Economic Analysis of Cultural Services, UK NEA Economic Analysis Report	2010	UK	Low
Ciriabest	Education	Educational visits to nature reserves	n/a		n/a	Low
Ciriabest	Flooding		Environment Agency (2017a) Flood Risk Reduction Benefit Valuation for Natural Flood Management	2017	UK	High
Ciriabest	Health and wellbeing	Emotional health benefit from increased use of local park or green space	Fields in Trust (2018) Revaluing Parks and Green Spaces: Measuring their economic and wellbeing value to individuals.	2018	UK	Medium
Ciriabest	Health and wellbeing	Having a direct view over green space from house/regular place of work (move from no view to having any kind of view)	(2011) UK NEA	2011	UK	High
Ciriabest	Health and wellbeing	Avoided local authority public health costs associated with reduced physical inactivity	(2011) UK NEA	2011	UK	Low
Ciriabest	Noise		Defra (2014). Noise pollution: economic analysis	2014	UK	High
Ciriabest	Recreation	Recreational benefits from constructed or restored wetlands	Hölzinger (2011)	2011	n/a	Low
Ciriabest	Traffic calming		Department for Transport (2020). Reported road casualties Great Britain, annual report: 2020	2020	UK	High

Tool	Environmental service	Intervention (if available)	Study	Date	Location	Transferability to raingardens
Ciriabest	Water quality		Environment Agency (2013) Water Appraisal Guidance; Assessing Costs and Benefits for River Basin Management Planning	2013	UK	Medium
Ciriabest	Water quantity		Environment Agency (2013) Water Appraisal Guidance; Assessing Costs and Benefits for River Basin Management Planning	2013	UK	Medium
NBS Benefits Explorer	Water quantity	Abatement cost approach	Strong, C., Kuzma, S., Vionnet, S., & Reig, P. (2020). Achieving abundance: Understanding the cost of a sustainable water future. World Resources Institute: Washington, DC, USA.	2020	World	High
NBS Benefits Explorer	Water quality		La Notte, A., Vallecillo Rodriguez, S., Garcia Bendito, E., Grammatikopoulou, I., Czucz, B., Ferrini, S., Grizzetti, B., Rega, C., Herrando, S., Villero, D., Zurbaran Nucci, M. and Maes, J., Ecosystem Services Accounting – Part III - Pilot accounts for habitat and species maintenance, on-site soil retention and water purification, EUR 30856 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-42051-4, doi:10.2760/636621, JRC126566.	2021	Europe	High
NBS Benefits Explorer	GHG		Interagency Working Group on Social Cost of Greenhouse Gases, United States Government (2021). Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990	2021	US	High
NBS Benefits Explorer	Biodiversity		De Groot, R., Brander, L., Van Der Ploeg, S., Costanza, R., Bernard, F., Braat, L., ... & Van Beukering, P. (2012). Global estimates of the value of ecosystems and their services in monetary units. Ecosystem services, 1(1), 50-61.	2012	World	Low

Tool	Environmental service	Intervention (if available)	Study	Date	Location	Transferability to raingardens
NBS Benefits Explorer	Flooding		Vallecillo, S., La Notte, A., Kakoulaki, G., Roberts, N., Kamberaj, J., Dottori, F., ... & Maes, J. (2019). Ecosystem services accounting. Part II-Pilot accounts for crop and timber provision, global climate regulation and flood control. Luxembourg: Publications Office of the European Union.	2019	Europe	Medium
NBS Benefits Explorer	Flooding		Huizinga, J., de Moel, H., & Szewczyk, W. (2017). Global flood depth-damage functions, Methodology and the database with guidelines, Joint Research Centre (JRC).	2017	Europe	High
GI-Val	Social Value of Carbon		BEIS (2023) Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal	2018	UK	High
GI-Val	Willingness to pay for view of community woodland		Northwich Woodlands Consultation (The Murray Consultancy for The Mersey Forest)	2015	Northwich Woodlands	Medium
GI-Val	Cost of life		Department for Transport, Transport Analysis Guidance 3.4.1	2007	UK	High
GI-Val	Biodiversity	WTP value for general green space	Boatman, N., Willis, K., Garrod, G., Powe, N. (2010) Estimating the wildlife and landscape benefits of environmental stewardship	2010	UK	Medium
GI-Val	Biodiversity	Additional WTP for National Nature Reserves and similar	CJC (2004) Cost effectiveness study of approaches for delivery of PSA target relating to SSSIs	2004	UK	Low
GI-Val	Biodiversity	Additional WTP for Woodland/Wetland	Hanley, N., Willis, K., Powe, N., Anderson, M. (2002) Social & environmental benefits of forestry phase 2: valuing the benefits of biodiversity in forests.	2002	UK	Low

Source: Mott MacDonald

Note: n/a indicates where no information was available.

C. Data requirements for evaluation tools

Table C.1: Ciriabest

Benefit Category	Minimum information required	Preferred source of information
Air quality	Size/type of green components in scheme such as the number of trees and green roofs	Local air quality study, national emission/air quality modelling, National Atmospheric Emissions Inventory
Amenity	Number/type of homes/commercial properties and number of people impacted by scheme	Landscape character visual impact assessment, MENE (Monitor of Engagement with the Natural Environment)
Asset performance	Change in flows or energy use due to scheme	Pumped flows, pump run times, energy consumption from hydraulic model, WwTW assessment including chemical and energy usage
Biodiversity and ecology	Change in size/type of green and blue space due to scheme	Biodiversity Action Plan or local habitat surveys
Building temperature	Area of green roof / number of trees	Energy management plan and assessment of building operational performance (e.g. using BREEAM In-Use)
Carbon sequestration	Number and type of trees	Carbon management plan
Crime	Non-expert qualitative estimation of potential impacts from scheme	Assessment of change in crime indices or deprivation levels
Economic growth	Non-expert qualitative estimation of potential impacts from scheme	Assessment of value added, job creation, productivity, investment
Education	Number of children engaged or educational visits/talks	Engagement with schools and other educational institutions
Enabling development	Avoided infrastructure costs	Local development plan, water cycle study or sewerage management plan
Flooding	Number of buildings or people impacted by the scheme	Flood risk modelling assessment
Health	Number of homes and number of people impacted by scheme	Health management plan
Noise	Size/type of green components in scheme such as number of trees	Local noise management study
Recreation	Change in number of visits and type of recreation due to scheme	Open space provision assessments in Local Env Action Plans (LEAPs)
Tourism	Non-expert qualitative estimation of potential impacts from scheme	Assessment of change in visitor numbers

Benefit Category	Minimum information required	Preferred source of information
Traffic calming	Non-expert qualitative estimation of potential impacts from scheme	Assessment of change in vehicle movements, number of traffic accidents
Water quality	Current and projected water quality status and length/area of waterbody impacted	UPM (Urban Pollution Management) modelling or similar, Reason for Failure (RFF) dataset
Water quantity (groundwater recharge)	Volume of water infiltrating to groundwater	Ground water study, water cycle study
Water quantity (rainwater harvesting)	Number of properties, household size, water consumption rates	Water demand / use study
Water quantity (flows in watercourse and waterbody)	Current and projected flows in watercourses and waterbodies and length/area of watercourse or waterbody impacted	Flow modelling assessment, Scheme designs

Source: Table 1-5 from 03 - MWH UK Report.dot (susdrain.org)

Table C.2: GI-VAL

Input	Before	After		Relevance
Project area	n.a.	0	*ha*	*Linked to tool 1.4* (reduced temperature)
Total area of greenspace	0	0	*ha*	*Linked to tools 1.4*(reduced temperature), *2.1(energy and carbon savings from sewage management), 4.7(?) and willingness to pay for biodiversity)*
New green space created by the project	n.a.	0	*ha*	*Linked to tools 2.1 (energy and carbon savings from sewage management), 4.7 (?), 5.1 (residential value uplift)*
Pre-existing area of greenspace enhanced by the project	n.a.	0	*ha*	*Linked to tool 5.1 (residential value uplift)*
	Before	**After**		
Tree cover	0	0	*ha*	*Linked to tools 1.7 (carbon sequestered by trees), 2.1 (energy and carbon savings from sewage management) and 4.6* (reduced air pollution)
Total area of green roofs	0	0	*sq.m*	*Linked to tool 1.5* (reduced building energy consumption from cooling)
including: area of intensive green roofs	0	0	*sq.m*	*Tool 2.1 (energy and carbon savings from sewage management)*
area of semi-intensive green roofs	0	0	*sq.m*	*Tool 2.1 (energy and carbon savings from sewage management)*
area of extensive green roofs	0	0	*sq.m*	*Tool 2.1 (energy and carbon savings from sewage management)*
Current land use				*Context only*
Project context eg inner city, urban or rural area (or a mix of all)?				*Context only*
Land ownership?				*Context only*
What is the level of deprivation in the area? Refer to IMD data				*Context. Can contribute to business case.*
Is there currently a lack of green space in the area? Refer to local open space audit results and associated open space standards. Refer to national benchmarks such as ANGsT standards. How will this project help?				*Context. Can contribute to business case.*

Input	**Before**	**After**		**Relevance**
Does the site have heritage value? What features are being enhanced/protected/promoted through the project?				*Context. Can contribute to business case.*
	Before	**After**		
Cycle routes	0	0	*km*	*Linked to tool 4.2b (reduced mortality from increased cycling)*
Current cycle routes upgraded	n.a.	0	*km*	*Linked to tool 4.2b (reduced mortality from increased cycling)*
Footpaths	0	0	*km*	*Linked to tool 4.2a (reduced mortality from increased walking)*
Footpaths upgraded	n.a.	0	*km*	*Linked to tool 4.2a (reduced mortality from increased cycling)*
Is the land publicly accessible?				*Context only*
Is the site currently well connected or remote?				*Context only*
Will the project improve green travel options?				*Context. Can contribute to business case.*
Assessment of transport impact conducted?				*Context. Can contribute to business case.*
Links to existing networks				*Context. Can contribute to business case.*
Before	**<300m**	**<1200m**		
Number of households within 300m and 1200m				*Linked to tools 3.1 (willingness to pay for a view of urban green space), 4.2a (reduced mortality from increased walking) and 4.2b (reduced mortality from increased cycling)*
Number of businesses within 300m and 1200m				*Context. Can contribute to business case.*
Number of residents within 300m and 1200m				*Linked to tools 4.2a (reduced mortality from increased walking) and 4.2b (reduced mortality from increased cycling)*
After	**<300m**	**<1200m**	**<450m**	
Number of households within 300m, 1200m and 450m				*Linked to tool 4.2a (reduced mortality from increased walking), 4.2b (reduced mortality from increased cycling), 5.1 (residential value uplift)*

Input	Before	After		Relevance
				and 10.1 (willingness to pay for biodiversity enhancement)
Number of businesses within 300m and 1200m				*Context. Can contribute to business case.*
Number of residents within 300m and 1200m				*Linked to tools 4.2a (reduced mortality from increased walking) and 4.2b (reduced mortality from increased cycling)*
Other beneficiaries ?				*Context only*
	Before	**After**		
Number of community groups involved	0	0		*Context. Can contribute to business case.*
Total number of users per year	0	0		*Context. Can contribute to business case.*
Of which number of visits from local visitors (recreation)	0	0		*Linked to tool 9.1* (recreation use by local population)
Of which number of visits from tourist visitors (tourism)	0	0		*Linked to tool 8.1* (tourism expenditure)
Estimate of working population	0	0		*Linked to tool 7.3* (savings from reduced short-term absenteeism from work)
Is the site liable to flooding? What is the level of flood risk?				*Context only*
	Before	**After**		
Number of residential properties at flood risk	0	0		*Context. Can contribute to business case*
Number of commercial, business, industrial premises at flood risk	0	0		*Context. Can contribute to business case.*
Amount of SUDS storage	0	0	*m3*	*Context. Can contribute to business case.*
Length of watercourse	0	n.a.	*km*	*Context only*
Length of watercourse improved/restored	n.a.	0	*km*	*Context. Can contribute to business case.*
Is the area serviced by a combined sewer system? If 'Yes' please enter 1	0			*Linked to tool 2.1 (energy and carbon savings from sewage management),*
	Before	**After**		

Input	Before	After		Relevance
Area designated for nature and wildlife conservation (local designation)	0	0	*Ha*	*Linked to Tool 10.1 (willingness to pay for biodiversity enhancement)*
Area designated for nature and wildlife conservation (national designation)	0	0	*Ha*	*Linked to Tool 10.1 (willingness to pay for biodiversity enhancement)*
Area of woodland w/biodiversity value not captured above (ie: not protected through local or national designation)	0	0	*Ha*	*Linked to Tool 10.1 (willingness to pay for biodiversity enhancement)*
Area of wetland w/biodiversity value not captured above (ie: not protected through local or national designation)	0	0	*Ha*	*Linked to Tool 10.1 (willingness to pay for biodiversity enhancement)*
	Before	**After**		
Number of construction jobs created as a result of scheme delivery	n.a.	0		*Context. Can contribute to business case.*
Number of jobs created/safeguarded for management/maintenance of site	n.a.	0		*Linked to tool 11.2 (employment supported by land management)*
Average residential property price in the area (Before)	£0	n.a.	*£*	*Linked to 5.1 (residential value uplift)*

Source: GI-Val_Calculator_v1.6.xlsx (live.com)

Table C.3: NBS Benefit Explorer: project valuations

Input	Option
Country	• United Kingdom
Habitat	• Agriculture • Estuaries • Forests • Grasslands • Lakes • Mangroves • Rivers and floodplains • Urban • Wetlands
Size of the project	Size by Ha
Water Quantity	
How much water quantity does/could your project bring?	Size by m3/yr
What challenge does you project address?	• Access to drinking water • Access to sanitation • Water scarcity in the project region • External water risk of my operations
Water Quality	
Habitat-intervention	• Forest – restoration • Agriculture – management • Grasslands – management • Rivers and floodplains – management • Wetlands – restoration
How much water quality does/could your project bring?	Size by m3/yr
GHG	
Climate type	• Temperate • Boreal

Input	**Option**
Ecological zone	• Temperate continental • Temperate mountain • Temperate oceanic
Area baseline and after intervention	Size by Ha
Cost of carbon	• US EPA • 1.5C Dietz et. al. • World Bank • Custom value
Biodiversity (not applicable to all habitats)	
Type of forests	• Forests – tropical • Forests – temperate and boreal • Forests – others
Recreation (not applicable to all habitats)	
Does your project concern urban forests	• Forests • Wetland • Not applicable
What type of wetland is your project targeting?	• Inland marshes • Intertidal mudflats • Peatbogs • Salt marshes
Flood	
Before the project	• Flood Extent (m2) • Flood depth (m) • Flood return period (years) • Residential (% total area) • Commercial (% total area) • Industrial (% total area) • Transport infrastructure (% total area)

Input	Option
	• Roads & Railroad tracks (% total area) • Agriculture (% total area) • Natural land (% total area)
After the project	• Flood Extent (m2) • Flood depth (m) • Flood return period (years)

Source: NBS Benefits Explorer

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