COMPENDIUM OF GSI CO-BENEFITS VALUATION RESOURCES

Available Tools that Quantify and Monetize the Value of GSI Projects

GSI Impact Hub
Capturing the Multiple Benefits of Green Infrastructure

The Nature Conservancy

Green Infrastructure Leadership Exchange

One Water Econ

Contents

1 Introduction

Credit: Rick Triana

INTRODUCTION

This compendium summarizes tools that help to quantify and monetize the co-benefits of green stormwater infrastructure and/or those that help identify locations where these benefits are most needed.

Green stormwater infrastructure (GSI) practices include green roofs, rain gardens, permeable pavement, trees, cisterns, and other nature-based approaches that infiltrate, evapotranspire, or reuse stormwater onsite. Often used in combination with gray infrastructure, GSI can serve as an important component of a community's stormwater management portfolio.

In addition to proven effectiveness in meeting stormwater management goals, GSI practices can yield many important co-benefits, including beautifying neighborhoods, improving air quality, reducing respiratory and heat-related illnesses, creating "green-collar" jobs, and more. Stormwater practitioners have expressed a need to better understand and evaluate these "co-benefits" to help make the business case for GSI and ensure the effective provision of multi-benefit projects. Detailed information on specific co-benefits can also help to leverage additional funding and/or financing for GSI projects.

An increasing number of tools are available to support the evaluation, quantification, and valuation of GSI co-benefits; however, navigating these various resources can be a daunting task for stormwater practitioners. Most tools require different inputs, incorporate different quantification/evaluation methods, provide different results, and require varying levels of stormwater management and/or economic expertise. Further, the applicability of available tools varies depending on project phase, data availability, and user objectives.

1.1 Objective and scope of this compendium

To provide a starting point for effective evaluation, this compendium reviews tools and resources that are currently available to help stormwater practitioners assess the co-benefits of GSI. The objective is to help those interested in evaluating co-benefits to navigate the suite of available tools and utilize those that are most useful or relevant to their circumstances and needs (see Figure 1: Which Tool Should I Use? on p. 13).

The compendium includes tools that are available for use by utilities across the U.S., with a focus on those that quantify co-benefits (e.g., in physical units or monetary terms) and/or help practitioners site GSI projects in areas or locations where the provision of these benefits is most needed. It is not intended to serve as an exhaustive review of all existing tools and resources related to co-benefits (e.g., tools developed for specific regions or cities, articles

GSI Impact Hub

This guide is a component of the GSI Impact Hub, a larger project that provides resources and support related to specific GSI co-benefits. Please visit the GSI Impact Hub website to explore additional resources including:

- GSI Impact Calculator, a block-level tool for quantifying and monetizing co-benefits
- Benefit guides related to flood risk reduction, habitat and biodiversity, heat risk reduction, and transportation.

The GSI Impact Hub is a collaboration between The Nature Conservancy, Green Infrastructure Leadership Exchange, One Water Econ, government agencies and technical partners.

evaluating co-benefits in general) nor does it provide detailed guidance on how to use any given tool; where available, links are provided to each tool's webpage.

1.2 Tools reviewed and compendium organization

The tools reviewed as part of this compendium include:

GSI Impact Calculator (p. 18) (TNC, One Water Econ, Radbridge, 2024)

GSI Co-Benefits Valuation Tool (p. 22) (Earth Economics and Green Infrastructure Leadership Exchange, 2018)

Climate Smart Cities (p. 26) (Trust for Public Land, applied in more than 20 cities)

Green Values Stormwater Management Calculator (p. 28) (Center for Neighborhood Technology, 2020)

Green Values Strategy Guide (p. 32) (Center for Neighborhood Technology, 2020)

GSI Triple Bottom Line (TBL) Tool (p. 34) (The Water Research Foundation, 2021)

i-Tree Design and i-Tree Eco (p. 38) (US Forest Service)

Integrated Decision Support Tool (i-DST) (p. 40) (Colorado School of Mines with funding from U.S. EPA, 2020)

Community-Enabled Lifecycle Assessment of Stormwater Infrastructure Costs (CLASIC) (p. 44) (The Water Research Foundation with funding from U.S. EPA, 2021)

Urban InVEST (p.54) (The Natural Capital Project at Stanford University, 2020)

For each tool, the project team reviewed:

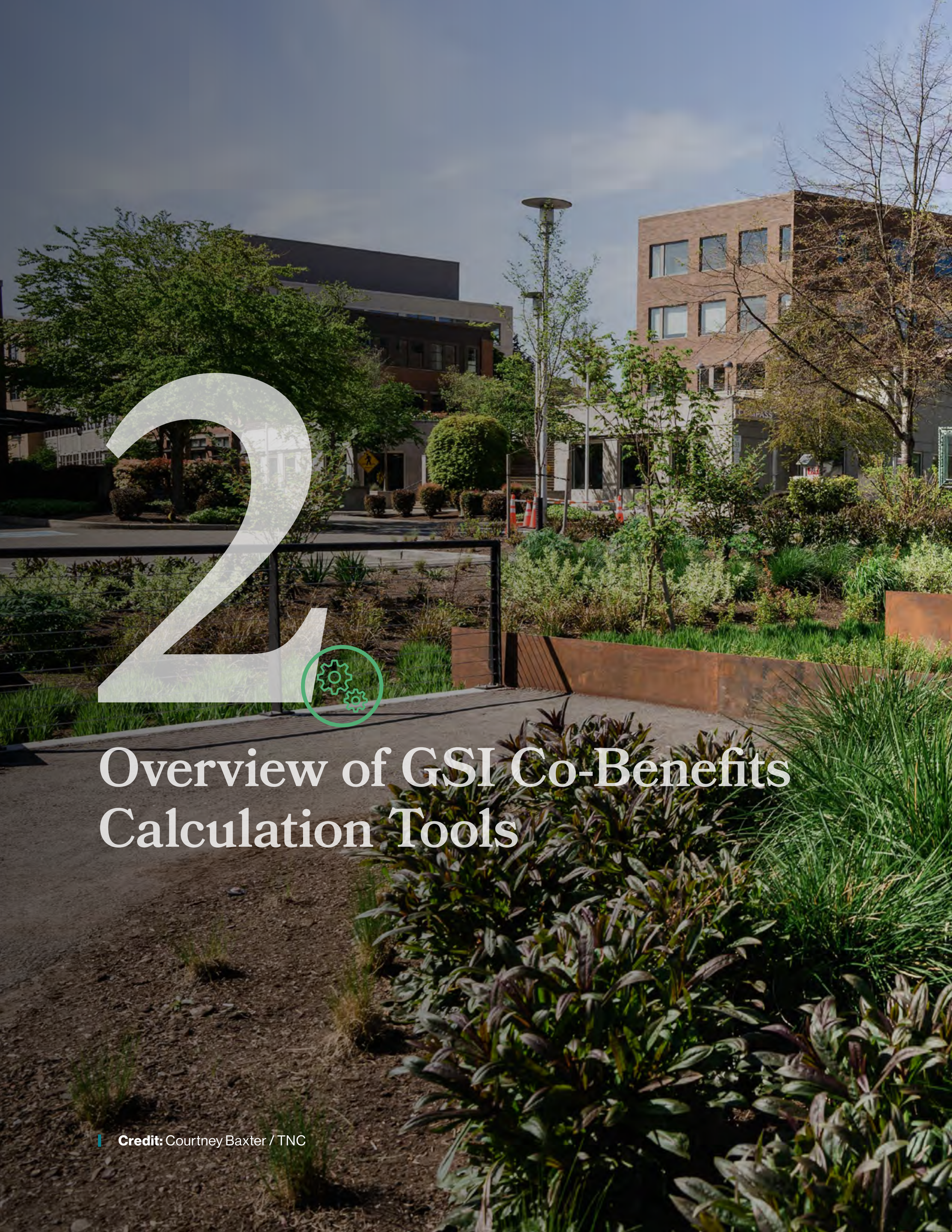
- Stated objectives and purpose
- Basic structure and usability
- Required inputs, including inputs related to GSI practices (e.g., GSI practice type, area, etc.), as well as inputs required for overall benefit calculations
- Co-benefits evaluated, methodology, and associated outputs
- Limitations and/or analysis boundaries
- Case studies that utilize each tool (where applicable)

The following section provides an overview of key findings and themes across tools, including guidance on which tool to use for different purposes. Subsequent sections provide a brief description of each tool, generally organized based on increasing level of complexity - an approximate measure of the amount of time required to become proficient, the technical level of inputs, and the skills required to utilize the tool or understand outputs. The final section identifies key research gaps and areas where existing tools do not meet identified needs and provides a roadmap for further research on GSI co-benefits.

GSI Co-Benefits

Co-benefits are the additional benefits that can be achieved through implementation of GSI and other nature-based solutions, above and beyond water quality and/or volume control benefits. Co-benefits associated with GSI projects and programs can include:

- Urban heat island stress reduction
- Flood risk reduction
- Habitat creation
- Green job creation
- Economic development benefits
- Increased or enhanced recreational opportunities
- Improved air quality and associated public health benefits
- Enhanced neighborhood aesthetics
- Energy savings
- Carbon sequestration



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Overview of GSI Co-Benefits Calculation Tools

Credit: Courtney Baxter / TNC

OVERVIEW OF GSI CO-BENEFITS CALCULATION TOOLS

The tools developed to help practitioners assess, quantify, and/or monetize the co-benefits of GSI vary significantly in required inputs, methodology, and outcomes. The inputs required by users vary by tool objective and level of complexity. For example, the GSI Impact Calculator developed by The Nature Conservancy and One Water Econ requires very few inputs, with key assumptions embedded into the tool based on city and state in which the project is located, and several other basic inputs. This is because it is designed to provide a screening level assessment of the benefits and costs associated with individual GSI projects early in the project planning phase (when data is often limited). The GSI TBL tool developed for the Water Research Foundation requires a more comprehensive set of inputs because it allows users to assess benefits in more detail, specific to a study area or city, and across multiple scales (e.g., project site, neighborhood, citywide assessment). The GSI TBL Tool contains default inputs that vary by region and city but allows for extensive customization.

Table 1 provides an overview of the tools included in the compendium. Table 2 summarizes input requirements and other key characteristics associated with each tool. As shown, the various tools allow users to evaluate co-benefits for a range of stormwater management practices. Trees, bioretention, green roofs, permeable pavement, and rain gardens are featured in most of the tools, while some also include wetlands, wet ponds, detention basins, and conventional (gray) infrastructure solutions (for comparison purposes). Most tools include default design parameters for the various GSI practices (e.g., depth, porosity), which can often be customized by the user.

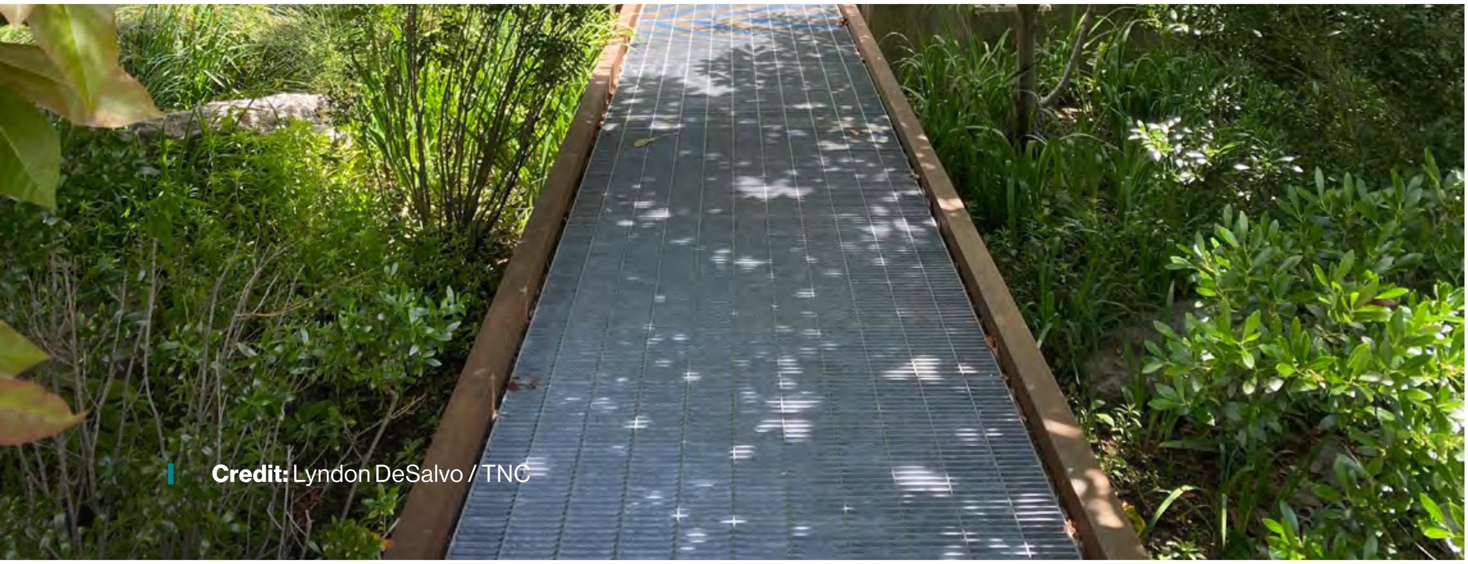
Not all tools provide monetized estimates of benefits and costs. For example, the primary objective of the CLASIC tool is to help users conduct a screening level assessment of lifecycle costs, performance, and co-benefits of alternative stormwater management scenarios. It is a web-based spatial tool that requires users to click on and off different design characteristics, locate projects within a specific study area, and enter pollutant load reduction and stormwater management goals. The tool provides extensive detail related to costs, design, and stormwater management outcomes. Co-benefits are ranked on a relative scale, allowing for direct comparison across scenarios. Users can weigh the importance of different co-benefits, depending on their priorities. Similarly, i-DST provides monetized estimates of the environmental costs (e.g., energy, use pollutant and carbon emissions) of different stormwater management practices. For harder to quantify benefits (e.g., heat stress reduction, property values, recreation), i-DST contains a series of benefit fact sheets that provide a high-level review of literature on co-benefit impacts. Rather than calculating quantified benefit estimates, the Green Values Strategy Guide provides benefit estimates (for some co-benefits) from the literature that users can apply to their own projects.

Table 1. Summary of available GSI co-benefits valuation tools and resources

Tool	Best Use	Things To Know
GSI Impact Calculator (p. 18)	Quantifying and monetizing benefits and costs early in the project planning process	• Designed to assess benefits of GSI at the city block scale • Requires minimal inputs and estimates values for specific locations/cities
Green Infrastructure Co-Benefits Valuation Tool (p. 22)	Rapid screening-level analysis of the costs and benefits for individual GSI projects. Requires few data inputs.	• Rough estimates that rely on state/national level data • Best for site or project-level assessments but can aggregate BMP data to estimate benefits for multiple projects.
Climate Smart Cities (p. 26)	Identify high priority locations for siting GSI projects based on priority co-benefits.	• Designed/customized by TPL for 20 cities (currently). Cities could develop similar/custom tools using GIS data.
Green Values Stormwater Management Calculator (p. 28)	Comparing stormwater management performance, costs, and co-benefits of site-level GSI relative to conventional solutions.	• Contains templates for specific development types. • Requires site-specific inputs or reliance on default values.
Green Values Strategy Guide (p. 32)	Helping municipal officials understand and communicate multiple benefits of GSI.	• Does not provide quantified benefit calculations. • Provides estimates from literature that may be applied to user context. • Reviews wide range of benefits.
GSI TBL Tool (p. 34)	Quantifying and monetizing wide range of benefits and costs of GSI at multiple scales; evaluating life cycle costs and benefits over time.	• Allows for detailed/customized assessment of co-benefits. • Users can rely on default values. • Aligned with and uses cost estimates from CLASIC tool.
i-Tree Design (p. 38)	Siting trees onsite to maximize energy savings, quantifying individual tree benefits.	• Specific to trees and site-level analysis.
i-Tree Eco (p. 38)	Quantifying and monetizing benefits associated with urban forests, extensive forests, and individual trees. Planning for tree/urban forest management.	• Specific to trees. • Includes management information, structure and composition analyses, forecasting, and benefits analyses for small tree inventories to regional scale assessments.
CLASIC (p. 40)	Screening level assessment of lifecycle costs, performance, and co-benefits across multiple user-defined stormwater management scenarios.	• Requires some GSI design expertise. • Provides qualitative assessment of co-benefits, focusing more on life cycle costs and stormwater performance.
i-DST (p. 44)	Comparing hydrologic, water quality, and lifecycle costs and impacts of gray, green and hybrid stormwater control measures (SCMs), optimizing SCMs to meet management objectives at minimum lifecycle cost.	• Contains multiple modules that allow user to assess SCMs at watershed or site scale, compare gray and green solutions, and assess lifecycle costs. • Contains limited number of monetized co-benefits in the form of avoided lifecycle costs.
Urban InVEST (p. 54)	Exploring GSI investment options to improve equity outcomes and/or maximize benefits	• Requires intermediate to advanced GIS skills • Each co-benefit requires separate model run • Outputs are specific to each co-benefit

Table 2. Summary of key co-benefits valuation tool characteristics

Tool	GSI Practices	Input Requirements	Complexity/Time	Tool	Scale	Output Metrics	# of Benefits
GSI Impact Calculator (online calculator)	Rain gardens, bioretention, green roofs, trees, permeable pavement, cisterns, rain barrels, wetlands, wet ponds, bioswales	**GSI**: Practice type, annual rainfall, design storm, management area, % managed via BMPs	Simple (30 min – 1 hr)	**GSI Impact Calculator** (online calculator)	Intended for block-level but can be used for individual projects or larger areas	**Benefits**: Monetized and quantified benefits, NPV across all BMPs. **Costs**: Capital, annual maintenance Net return ($), BCR	10 benefit categories
GSI Co-Benefits Valuation Tool (Excel-based)	Rain gardens/bioswales, bioretention ponds, pervious pavement, wetlands, urban forests, green roofs	**GSI:** Practice type, asset area, drainage area, trees, tree age **Other**: Adjacent structures, state, other default inputs can be customized	Simple (<30 min)	**GSI Co-Benefits Valuation Tool** (Excel-based)	Project/site-level	**Benefits**: Monetized by benefit category, BMP type, and year, NPV across all BMPs. **Costs**: Capital, annual maintenance Net return ($), IRR (%), BCR	9 benefits
Climate Smart Cities (proprietary online mapping tool)	All GSI practices	Spatial tool incorporating multiple data layers (as applicable/available)	Advanced (to develop) Intermediate (to use, 1 – 2 hrs.)	**Climate Smart Cities** (proprietary online mapping tool)	City-wide	Used to prioritize location of GSI projects based on benefit objectives.	5 benefit categories
CNT Green Values Stormwater Management Calculator (online calculator)	Green roof, cisterns, rain barrels, rain garden, planter boxes, trees, bioswales, urban farming/ gardening, raised bed, vegetated filter strip, native vegetation, swales, permeable pavements	**GSI**: Practice type, asset area or number, Design specifications (optional) **Other**: Lot and landscape area, onsite impervious area (by category); other default inputs can be customized	Simple (<30 min)	**CNT Green Values Stormwater Management Calculator** (online calculator)	Specific to site/ development type	**Benefits**: Volume capture and runoff reduction (ft^3), monetized annual and lifecycle benefits ($) **Costs**: Capital, annual maintenance, and lifecycle costs (NPV, $) Marginal benefits compared to conventional approaches	6 benefit categories
CNT Green Values Strategy Guide (PDF guide)	Linear buffer park/trail, stormwater park, planters, parkway bioswale, rain garden, street trees, green roof, permeable pavements, District stormwater	Vary by benefit	Simple (<30 min)	**CNT Green Values Strategy Guide** (PDF guide)	Vary by benefit	N/A	18 benefits
WRF GSI Triple Bottom Line Benefit Cost Tool (Excel-based)	Rain gardens, bioretention, green roofs, trees, permeable pavement, cisterns, rain barrels, wetlands, wet ponds, bioswales	**GSI**: Effective impervious acres managed by practice type, number of trees, cisterns, rain barrels **Other**: Annual rainfall, design storm, study area, population, timeline, climate zone, additional inputs required by benefit category.	Intermediate (2 - 4 hours)	**WRF GSI Triple Bottom Line Benefit Cost Tool** (Excel-based)	Site-level to city-wide	**Benefits**: Quantified/monetized annual and lifecycle benefits ($) **Costs**: Capital, annual, maintenance, lifecycle BCR, NPV ($)	12 benefits
iTree Design (online tool)	Trees and urban forests	Structure, tree species, and years of analysis	Intermediate (1 hour)	**iTree Design** (online tool)	Site level to city-wide	**Benefits**: Monetized benefits per year per tree and overall project	4 benefits
iTree Eco	Trees and urban forests	Structure, tree species, and years of analysis	Advanced (several hours)	**iTree Eco**	City-wide	**Benefits**: Annual monetized estimates by co-benefit	6 benefits
CLASIC (online tool)	Rain garden, sand filter, infiltration trench, detention basin, wet pond, stormwater harvesting, storage vault, permeable pavement, disconnection, green roof	Either modify climate model OR build GSI scenarios based on units of GSI practice in each subunit; inputs vary by BMP type	Intermediate (3-4 hours)	**CLASIC** (online tool)	City-wide, watershed	**Benefits**: score of 0 to 5 for co-benefits by benefit type **Costs**: capital, maintenance, and rehab costs PV costs ($)	16 benefits
i-DST (downloadable software applications/ modules)	Porous pavement, green roof, wetland, bioretention, rain barrel, buffer strip, infiltration trench, vegetated swale, dry pond, wet pond, perforated pipe, cistern	Number of practice units	Advanced (several hours)	**i-DST** (downloadable software applications/ modules)	Watershed	Monetized lifecycle environmental costs of alternative stormwater measures **Costs**: Capital, maintenance, replacement, lifecycle Fact sheets on harder to quantify benefits.	6 environmental cost categories
Urban InVEST (downloadable software application)	Based on changes in land cover/ directly connected impervious area	Spatial data related to urban land use/cover; inputs vary by ecosystem service	Advanced (several hours, requires GIS skills)	**Urban InVEST** (downloadable software application)	Neighborhood, city-wide, watershed	**Ecosystem services/benefits:** physical units and monetized values. Used to prioritize location of GSI projects based on benefit objectives.	9 ecosystem service benefits



For tools that do allow users to quantify and/or monetize co-benefits, a range of metrics and methods are applied, with no standard definition across categories. For example, the GSI Co-Benefits Valuation Tool includes building energy savings as a metric for urban heat stress reduction, while TBL GSI Tool includes reduced mortalities, illnesses, and temperature reductions in this category. The CNT Green Values Strategy Guide provides an overview of estimates from the literature on shaded surface temperature reductions and reductions in peak temperatures (from evaporation) resulting from GSI practices. Table 3 shows the various benefit metrics included in each tool.

A few of the tools are intended or relevant for use in the early planning phases of a project; feedback from utility partners indicates that there is a clear need for co-benefits information in the early stages to help ensure that GSI approaches are not "value-engineered" out of the project and/or that gray infrastructure approaches are not automatically preferred over GSI based on costs alone. The GSI Impact Calculator was developed for this purpose. Both the WRF GI TBL Tool and CLASIC can also be used during the early planning stages but require more detailed inputs and time to navigate.

In addition to making the business case for GSI early on, planners are interested in where GSI installations should be located within a city or watershed to maximize benefits. Some utilities have developed methods or tools to help them prioritize project locations based on specific co-benefits, such as flood and climate change risks, heat stress reduction, pedestrian improvements, and equity considerations, among others. TPL developed the Climate Smart Cities Tool for this purpose in several U.S. cities. However, to our knowledge, there is no comprehensive guidance or publicly available tool that utilities can apply to their specific location to address these questions.

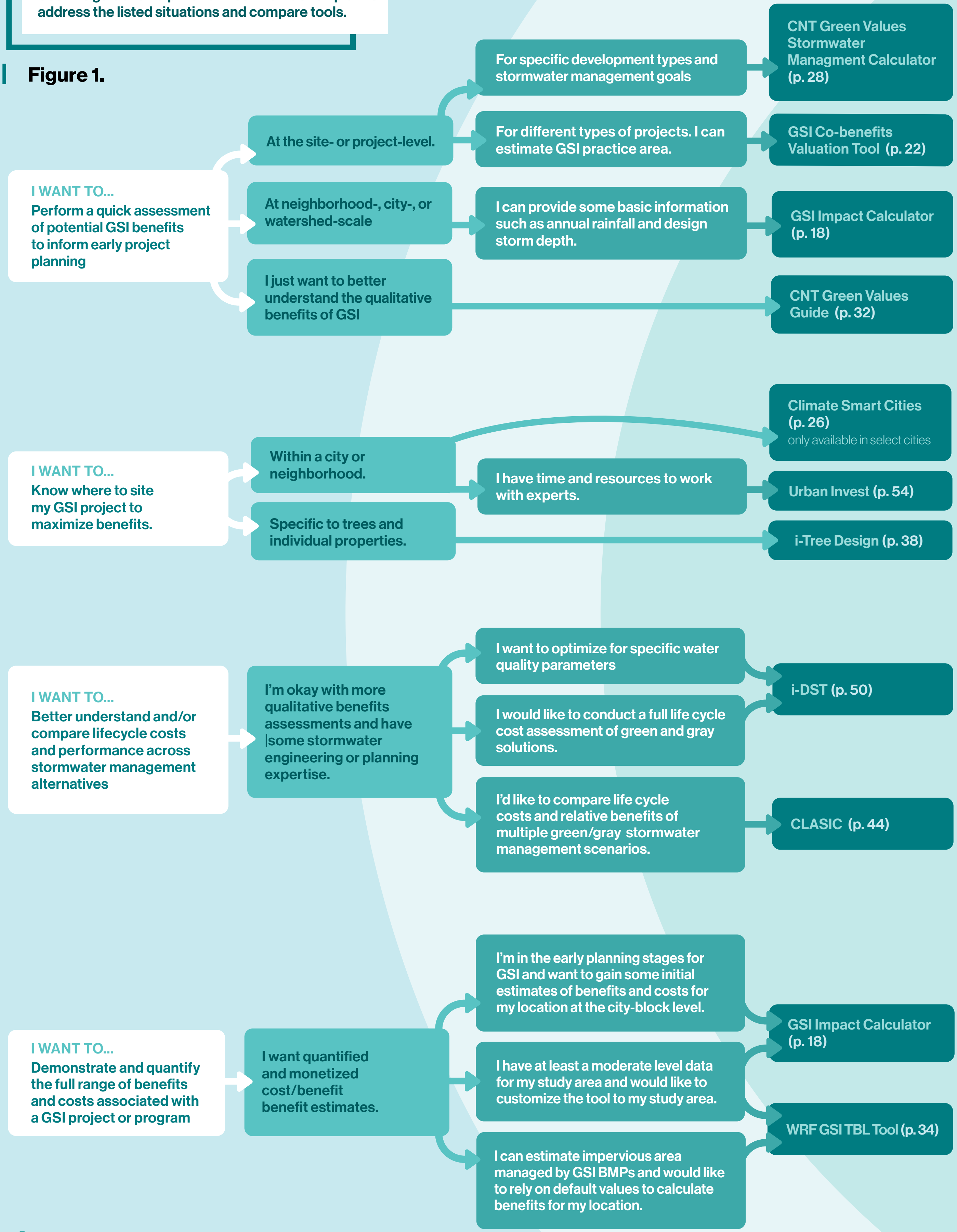
2.1 Matching Tools to Data Availability and Needs: Which Tool Should I Use?

The range of tools available for evaluating GSI co-benefits can be difficult to navigate. In some cases, the tools can require relatively extensive amounts of time and/or resources to work through. The choice of which tool to use depends largely on the user's objective and level of data availability. For example, being able to "make the business case" for trees and other vegetated practices during the early planning phases of a project may only require order of magnitude estimates, while using co-benefits information to allocate costs (e.g., across municipal departments or by funding sources) or justify large-scale investments in GSI may require more detailed or customized benefit and cost assessments. Figure 1 provides an overview of the different tools and situations for which they are best used.

Which Tool Should I Use?

Use this guide to help make "Best-Bet" action plan to address the listed situations and compare tools.

Figure 1.



Learn more about tools in Section 3

Table 3. Summary of key co-benefit tool characteristics

Tool	Benefit metric			
	Energy Savings	**Heat Stress Reduction**	**Carbon Reduction**	**Air Pollution Reduction**
GSI Impact Calculator	Building energy savings. Avoided stormwater pumping/treatment and potable water offsets	Reduced deaths, illnesses, and health care costs	Carbon sequestered Avoided GHG emissions	Value of reduced air pollutants from trees
GSI Co-Benefits Valuation Tool		Building energy cost reduction	Carbon sequestered	Pollutants captured, avoided healthcare costs
Climate Smart Cities		Impervious cover and heat islands (day & night)		
CNT Green Values Stormwater Management Calculator	Building energy savings		Carbon sequestered by trees	Value of reduced air pollutants from trees
CNT Green Values Strategy Guide	Building energy savings	Shaded surface temperature reductions Reductions in peak temperatures from evaporation	Carbon sequestered	Quantity of air pollutants removed by green roofs
WRF GSI Triple Bottom Line Benefit Cost Tool	Building energy savings Avoided energy use for stormwater pumping/ treatment and potable water offsets	Temperature reductions Reduced deaths, illnesses, and health care costs	Carbon sequestered Avoided GHG emissions	Air pollution removal Emission savings from energy use reduction
iTree	Building energy savings from trees		Carbon storage and sequestration Avoided GHG emissions	Air pollution removal Ozone reduction
CLASIC	Building energy savings from green roofs	Percent reduction of UHI estimated based on vegetation and soil	Carbon sequestered	Pollutant removal factors for plants, trees, and green roofs
i-DST		Co-benefits fact sheet (no quantification)		Co-benefits fact sheet (no quantification)
Urban InVEST	Reduced air conditioning needs	Air temp. reduction (C°) Work productivity loss	Carbon stored/ sequestered	

Tool	Benefit metric			
	Public Health	**Water Quality Quality Reduction**	**Neighborhood Beautification (property values)**	**Other**
GSI Impact Calculator	Health benefits from heat stress reduction and avoided emissions	Willingness to pay for water quality improvements Avoided gray infrastructure costs	Property value increases for single family homes	Potable water offsets, groundwater recharge, recreation, green jobs, habitat and biodiversity
GSI Co-Benefits Valuation Tool		Avoided cost of surface water treatment	Average home value * price premium % of BMP	Avoided CSOs, groundwater recharge, educational visitation benefits
Climate Smart Cities	Public health indicators (e.g., diabetes, asthma, obesity)			Flood risk reduction, equity for disadvantaged communities, transportation and safety
CNT Green Values Stormwater Management Calculator		Volume stormwater managed/total runoff captured Avoided water treatment costs	Compensatory value of trees (for property and neighborhood)	Marginal costs of green vs. gray infrastructure Groundwater replenishment
CNT Green Values Strategy Guide	Avoided health care costs	Value of trees for stormwater inception	Estimates for annual property gains (per tree), and % increase in resale value for greened properties	Avoided flood damages, increase in retail sales, recreation, green jobs, improvement in transportation
WRF GSI Triple Bottom Line Benefit Cost Tool		Willingness to pay for water quality improvements Avoided gray infrastructure costs	Property value increases for residential and commercial properties	Value of potable water offsets and groundwater recharge, recreation, green jobs, habitat and biodiversity
iTree				Avoided runoff ($/year and gallons)
CLASIC	Avoided health care costs per ton of pollutants removed	Avoided water treatment	Score based on replacement of impervious area with GSI that include vegetation or wet ponds	Reduced nuisance flooding, avoided CSOs, infiltrated precipitation, green jobs, biodiversity, education
i-DST			Co-benefits fact sheet (no quantification)	Avoided environmental life cycle costs of GSI, neighborhood beautification, biodiversity, recreation
Urban InVEST		Sediment/ nutrients retained	Relative score for visual quality/impact	Avoided stormwater retention costs, pollinator abundance, recreation area

3 Co-Benefit Valuation Tools

Credit: Roberto Gonzalez

GSI IMPACT CALCULATOR

The Nature Conservancy, One Water Econ, Green Infrastructure Leadership Exchange 2024

GSI Impact Calculator: gsiimpacthub.org/calculator

Questions This Tool Answers:

- What are the types and values of the multiple benefits associated with implementing GSI projects across a neighborhood or city-block scale?
- What are the estimated lifecycle costs for a combination of GSI-based BMPs? How does this compare to the cost of traditional (non-GSI) stormwater management?
- For a given project, what are the financial and quantitative benefits of implementing GSI?

Objective/Description: The GSI Impact Calculator provides users with an opportunity to evaluate different GSI scenarios at a scale that embraces multiple BMPs located within a larger project geography, such as a city block or residential subdivision. The Calculator provides monetary and unit values for the co-benefits associated with the overall project, including heat island and flood risk reduction, urban habitat and wildlife enhancement, and economic development including employment creation or uplift. Outputs from the calculator also include estimates of capital and O&M costs, allowing users to compare costs and benefit values.

Applicable scale: City-block or similar scale, allowing assessment and costs for single projects that involve multiple, decentralized BMPs.

Tool structure: Web-based calculator

Level of Complexity: Low

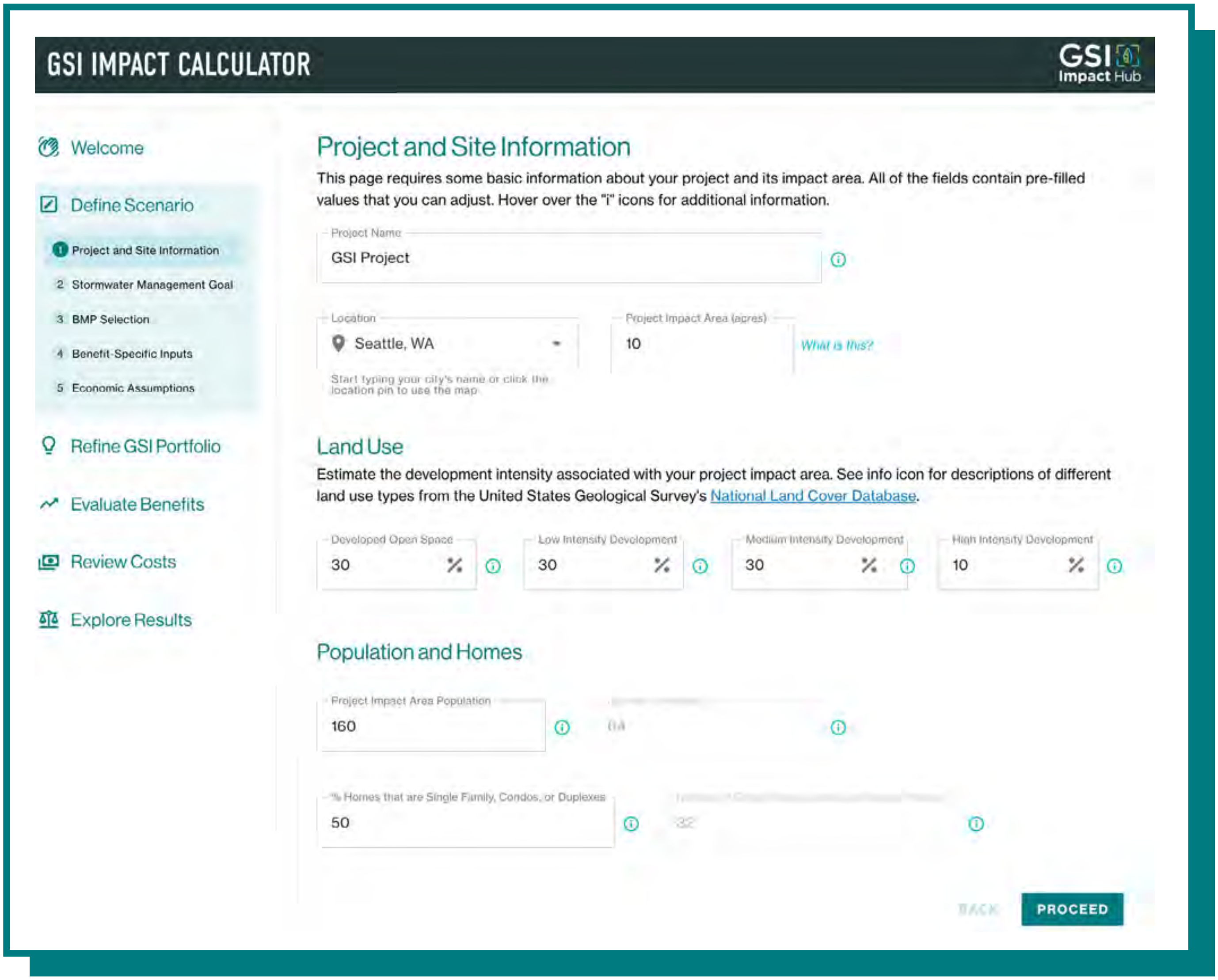
Technical Expertise Required: Using the Calculator requires very little technical expertise, although some knowledge of stormwater management is necessary to enter key inputs such as GSI/BMP area and interpret stormwater benefits.

Audience: Stormwater practitioners, planners, municipal staff, leaders and related stakeholders

Inputs:

- Location (used to calculate average annual rainfall, national averages available by default)
- Volume capacity capture goal (inches of precipitation captured over impervious area, 0.5 inches is default value)
- Lot area, impervious area by land use type (e.g., driveway, roof, parking lot), and landscape area (defaults provided for template sites, but can be customized)
- Type of GSI practices implemented, selected from checklist
- For relevant GSI-BMPs, total area of implementation (e.g., square feet), as well as percentage of total volume managed per BMP type.
- Simple questions specific to benefits, such as combined sewer presence, stormwater use for water supply, incorporation of parks, parklets, or trees, etc.

Figure 2. GSI Impact Calculator initial input page.



GSI practices: Green roof, bioretention facilities, cistern, rain garden, rain barrels, trees, bio-swales/biofiltration, permeable paving, constructed wetlands, wet ponds.

Co-Benefits/Tool outputs: Figure 3 shows the co-benefits quantified and/or monetized as outputs from the calculator.

The web-accessible tool also renders outputs in more illustrative charts and graphs (Figure 4). These renderings, and other key output information, are also carried over to a savable/printable two page report that captures essential information about the project and its benefits.

Figure 3. GSI Impact Calculator Benefits Assessed.

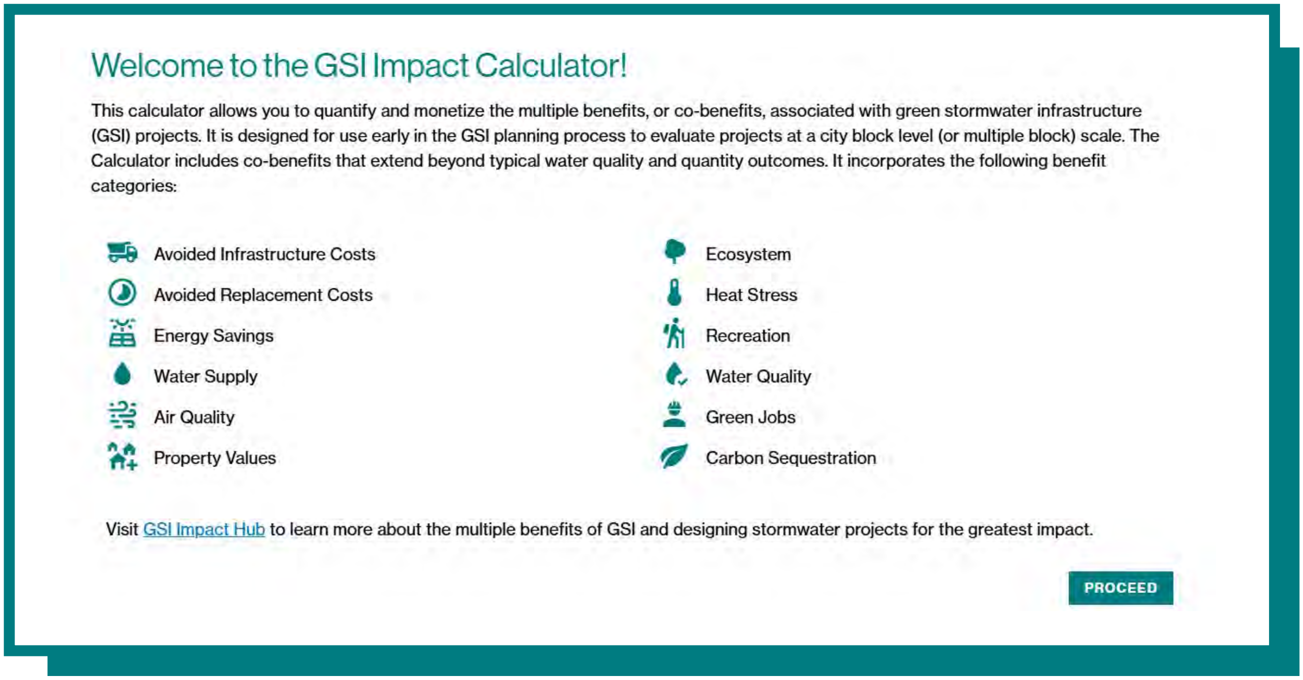


Figure 4. Sample GSI Impact Calculator Output Illustration

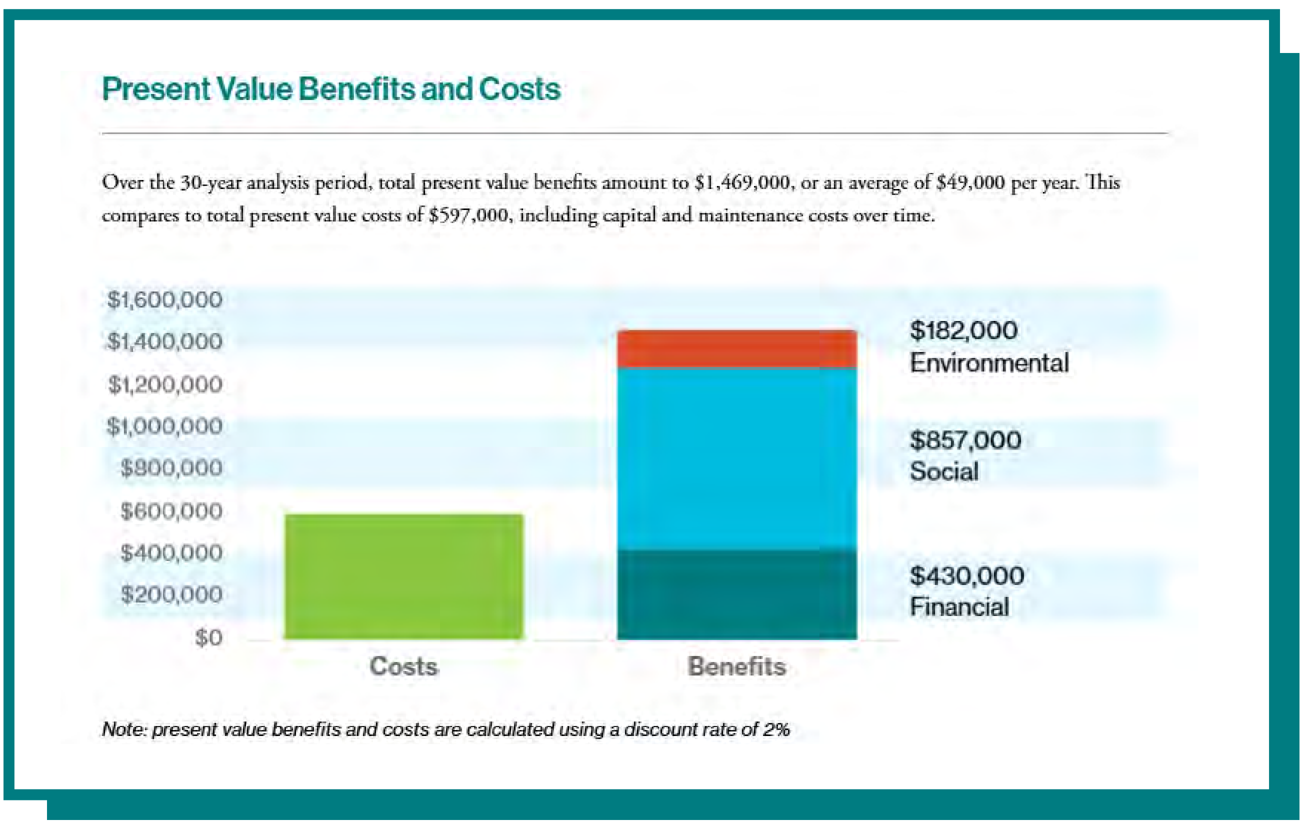
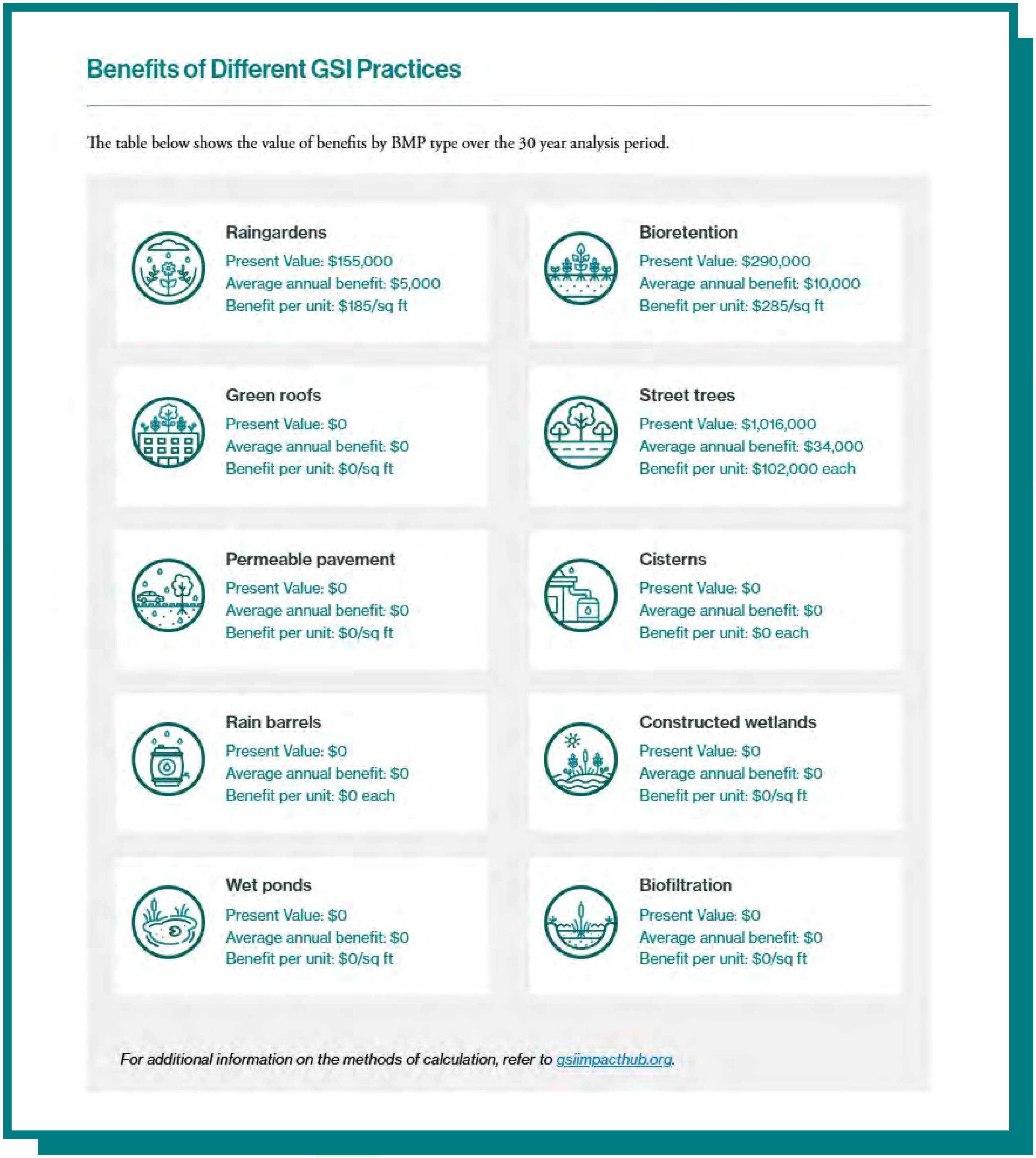


Figure 5. GSI Impact Calculator Select Summary Page



Benefits of Different GSI Practices

The table below shows the value of benefits by BMP type over the 30 year analysis period.

Raingardens
Present Value: $155,000
Average annual benefit: $5,000
Benefit per unit: $185/sq ft

Bioretention
Present Value: $290,000
Average annual benefit: $10,000
Benefit per unit: $285/sq ft

Green roofs
Present Value: $0
Average annual benefit: $0
Benefit per unit: $0/sq ft

Street trees
Present Value: $1,016,000
Average annual benefit: $34,000
Benefit per unit: $102,000 each

Permeable pavement
Present Value: $0
Average annual benefit: $0
Benefit per unit: $0/sq ft

Cisterns
Present Value: $0
Average annual benefit: $0
Benefit per unit: $0 each

Rain barrels
Present Value: $0
Average annual benefit: $0
Benefit per unit: $0 each

Constructed wetlands
Present Value: $0
Average annual benefit: $0
Benefit per unit: $0/sq ft

Wet ponds
Present Value: $0
Average annual benefit: $0
Benefit per unit: $0/sq ft

Biofiltration
Present Value: $0
Average annual benefit: $0
Benefit per unit: $0/sq ft

For additional information on the methods of calculation, refer to gsiimpacthub.org.

GREEN INFRASTRUCTURE CO-BENEFITS VALUATION TOOL

Earth Economics & Green Infrastructure Leadership Exchange (GILE), 2018

giexchange.org/resources

Questions This Tool Answers:

- How can I assess co-benefits with very few data inputs?
- How much will it (roughly) cost to implement a series of GSI practices?
- What is the estimated dollar value of the co-benefits associated with those practices?
- What is the net present value and overall benefit cost ratio of a GSI project?

Objective/Description: Earth Economics, with guidance from members of the Green Infrastructure Leadership Exchange, developed the Green Infrastructure Co-Benefits Valuation tool to support rapid screening-level analysis of the costs and benefits associated with individual GSI projects. This tool allows users to quantify and monetize nine different co-benefits across six GSI practice types with very few data inputs. Intended uses include educating leaders, generating internal discussion about costs/benefits of GSI options, and providing a starting point for a more detailed analysis. The tool is accompanied by comprehensive guidance that provides additional detail on the co-benefits associated with different GSI practices. It provides default regional values and assumptions, but also allows the user to customize inputs when they have more information available.

Applicable scale: Project/site-level; inputs can be aggregated by GSI practice type (which the tool refers to as BMPs) to analyze the benefits of multiple projects.

Project phase: Early planning

Tool structure: Excel-based tool with four main tabs. Guidance is organized by BMP, with each section providing descriptions, calculations, and sources for the ecosystem services associated with that BMP.

Level of Complexity: Low, few inputs required.

Technical Expertise Required: Very little expertise required, although some knowledge of stormwater management necessary to enter key inputs such as GSI asset area and drainage area.

Audience: Planners, local government, public communications

GSI practices included: Raingardens/bioswales, bioretention ponds, pervious pavement, wetlands, urban forests, green roofs

Inputs:

GSI-related Inputs

- GSI practice type
- Area of GSI practice (square feet)
- Drainage area managed (square feet)
- Trees within GSI installation (count)
- Average age of trees (years)

Additional/optional inputs

- Houses adjacent to BMP (count)
- State where GSI project is implemented
- Optional: The tool includes default values/assumptions that vary by region, but users may edit inputs such as:
- Capital and maintenance costs
- Discount rate for calculating present value costs/benefits
- Biophysical factors (weather, CSO, water quality, water retention)
- BMP design elements
- Co-benefit assumptions (e.g., property value increases, educational opportunities, and avoided flood damages)

Co-benefits/tool outputs: Benefits are referred to in the tool/guidance as ecosystem services. Table 4 presents the outputs of the tool, as well as the valuation method for each co-benefit. Figure 6 shows the tool output dashboard.

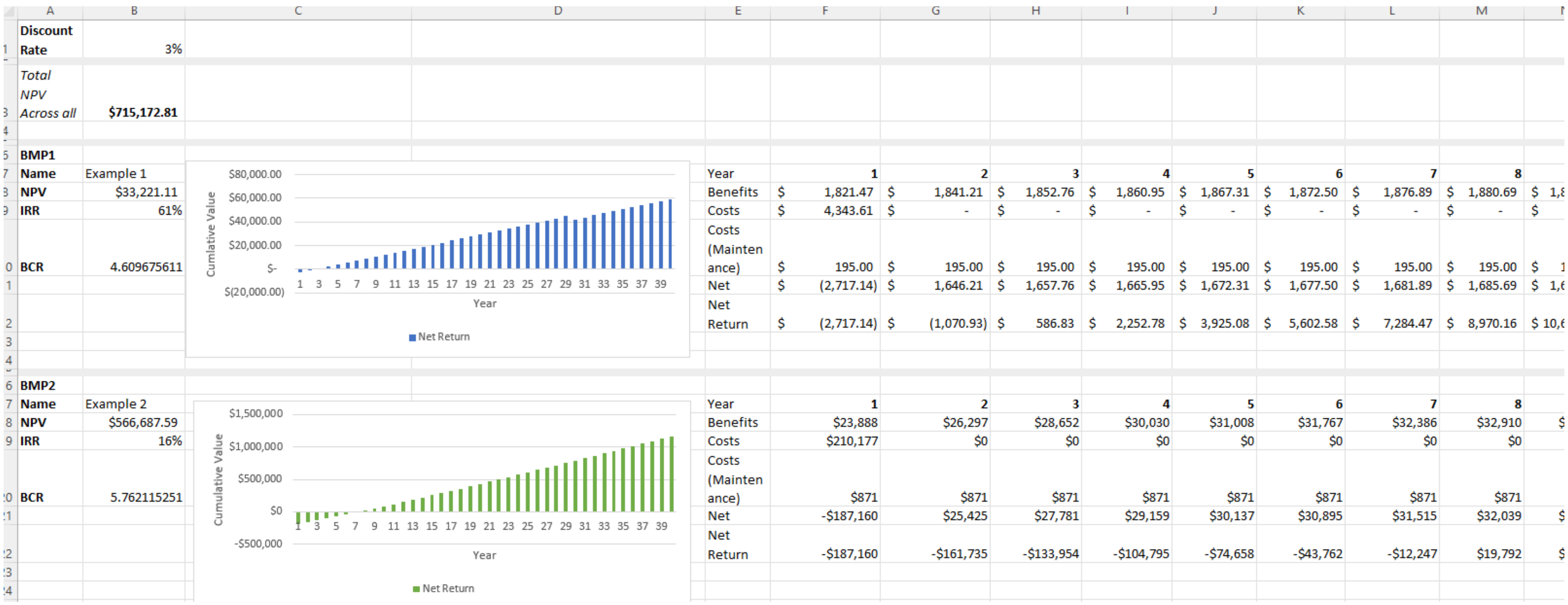
Limitations: Provides a dollar value by GSI practice type but does not provide physical unit outcomes such as gallons of water managed, or tons of carbon sequestered. Detailed outputs are provided by BMP type but not aggregated across multiple BMPs (although this could be easily done by the user). With only a few inputs, simplifying assumptions necessarily reduce the technical precision of this tool compared with others. Tool is not maintained or annually updated.

Credit: Green Infrastructure Leadership Exchange

Table 4. Outputs of Green Infrastructure Co-Benefits Valuation Tool

Output (by BMP type)	Metric/Valuation Method
Estimated water captured by BMP	Liters per year
Annual value of each co-benefit/ecosystem service	Dollars (2018$)
Flood risk reduction	Wetlands - avoided damages ($/per sq. ft.), based on published study Trees - $ per tree value, based on published study
CSO reduction	Avoided CSO storage cost
Stormwater capture for water supply	Market/water rights value of groundwater
Stormwater quality	Avoided cost of conventional surface water treatment
Urban heat island effect	Energy savings for green roofs and trees
Environmental education	Financial cost per student, per hour of education, multiplied by average educational visitations to public green space.
Aesthetic value	Increase in residential property values
Air quality	Green roofs only; avoided health care costs associated with captured pollutants
CO2 sequestration	Social Cost of Carbon ($/ton CO2e sequestered)
Construction and annual maintenance costs	Dollars (2018$)
Annual net benefit and net return	Dollars (2018$)
Net present value (by BMP type and across all BMPs)	Dollars (2018$)
Internal rate of returna	%
Benefit Cost Ratio for lifecycle of a project	Ratio (benefits/costs)

Figure 6. Tool output dashboard, Green Infrastructure Co-Benefits Valuation Tool



Discount Rate	3%
Total NPV Across all	$715,172.81

BMP1

Name	Example 1
NPV	$33,221.11
IRR	61%
BCR	4.609675611

Year	1	2	3	4	5	6	7	8	
Benefits	$ 1,821.47	$ 1,841.21	$ 1,852.76	$ 1,860.95	$ 1,867.31	$ 1,872.50	$ 1,876.89	$ 1,880.69	$ 1,8
Costs	$ 4,343.61	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$
Costs (Maintenance)	$ 195.00	$ 195.00	$ 195.00	$ 195.00	$ 195.00	$ 195.00	$ 195.00	$ 195.00	$ 1
Net	$ (2,717.14)	$ 1,646.21	$ 1,657.76	$ 1,665.95	$ 1,672.31	$ 1,677.50	$ 1,681.89	$ 1,685.69	$ 1,6
Net Return	$ (2,717.14)	$ (1,070.93)	$ 586.83	$ 2,252.78	$ 3,925.08	$ 5,602.58	$ 7,284.47	$ 8,970.16	$ 10,6

BMP2

Name	Example 2
NPV	$566,687.59
IRR	16%
BCR	5.762115251

Year	1	2	3	4	5	6	7	8	
Benefits	$23,888	$26,297	$28,652	$30,030	$31,008	$31,767	$32,386	$32,910	$
Costs	$210,177	$0	$0	$0	$0	$0	$0	$0	
Costs (Maintenance)	$871	$871	$871	$871	$871	$871	$871	$871	
Net	-$187,160	$25,425	$27,781	$29,159	$30,137	$30,895	$31,515	$32,039	$
Net Return	-$187,160	-$161,735	-$133,954	-$104,795	-$74,658	-$43,762	-$12,247	$19,792	$

CLIMATE-SMART CITIES

The Trust for Public Land

tpl.org/how-we-work/climate-smart-cities

Questions This Tool Answers:

- Where are the GSI needs in my city?
- Where should I place GSI in my city or watershed to have the highest impact?
- How do I maximize cooling, transportation, public health, and other high priority co-benefits in my city?

Objective/Description: The Trust for Public Land (TPL) works with cities through the Climate-Smart Cities program to design, fund, and build GSI and parks in vulnerable communities. The Climate Smart Cities tool focuses on transition connection, urban cooling, stormwater management, and protection from future climate challenges. Available in 20 municipalities, the Climate-Smart Cities tool offers a geospatial mapping platform that overlays Geographic Information System (GIS) data on public transit, impervious area, vegetation, hydrologic conditions and flooding, public health rates, socioeconomic indicators, GSI suitability, and other local data. It is designed to help planners and partners identify areas where installing GSI will maximize specific co-benefits across different neighborhoods in their communities.

Applicable scale: Citywide

Project phase: Early planning – used to identify potential project areas.

Tool structure: Web-based mapping tool

Level of Complexity: Low to use, high to develop

Technical Expertise Required: Very little, navigating the tool is relatively simple. Advanced GIS skills necessary to develop.

Audience: City planning, GSI developers

Inputs: Spatial data available will vary by city. Examples include:

- Boundaries of parks, open space, neighborhoods, and schools
- Transit stations, bike stations, historic pedestrian and bike accidents, trails
- Tree canopy and impervious areas
- Basement backup locations (for cities in which this data is available)
- Land and surface temperatures, day and night
- Historic flooding areas, flooding calls and water breaks
- Hydrology of streams, wetlands, and waterbodies
- Hydrologic soil groups ranked by drainage ability
- Socioeconomic characteristics: low-income households, minority populations, renters, populations under 5 years old and over 64 years old
- Rates of public health incidences (diabetes, asthma, obesity, kidney disease, stroke, heart disease, lead)

Co-benefits/tool outputs: Identifies "very high," "high," and "moderate" opportunities related to siting and/or designing GSI within the context of five co-benefit categories:

- **Connect:** areas with limited greening along trails, safe routes to schools, and transit lines for zero-emissions transportation
- **Cool:** heat stress reduction benefits measured through temperatures and impervious area
- **Absorb:** Flood risk reduction & hydrologic factors conducive to improved GI performance; stormwater management, capture, and reuse
- **Public Health:** areas with high rates of obesity, asthma, and other public health indicators
- **Equity:** based on socioeconomic data by Census tract.

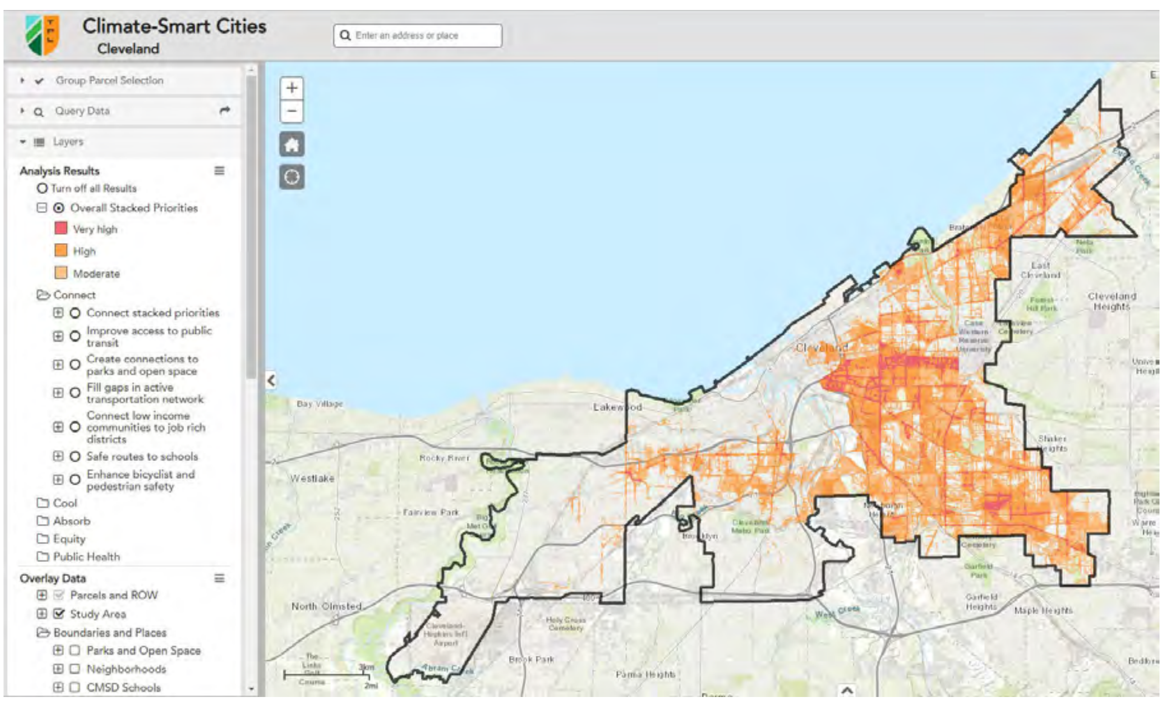
Figure 7 shows an example of the mapping dashboard.

Limitations: This tool has only been developed for 20 cities and is not a publicly available tool that water utility professionals can easily access. Example cities include New Orleans, Cleveland, Los Angeles, Boston, and New York City, among others. Tool does not quantify co-benefits.

Case study: New Orleans

The Climate-Smart Cities program is providing key planning and decision-making support to help New Orleans achieve the goals laid out in the City's climate resilience plan by leveraging the power of green infrastructure for residents most in need. Community partners are using the Climate-Smart Cities GIS planning tool to drive park, open space, and green infrastructure solutions to prepare the city and its most vulnerable populations for a climate-resilient future.

Figure 7. Climate-Smart Cities Tool for Cleveland



Note: Areas highlighted in red, orange, and lighter orange represent very high, high, and moderate opportunities for siting GSI based on co-benefits within five categories: Connect, Cool, Absorb, Public Health, and Equity. Users can prioritize co-benefits within these categories.

GREEN VALUES STORMWATER MANAGEMENT CALCULATOR

Center for Neighborhood Technology, 2020

Stormwater Management Calculator: greenvalues.cnt.org/#calculate

Questions This Tool Answers:

- What are the types and values of the multiple benefits associated with implementing GSI projects across a neighborhood or city-block scale?
- What are the estimated lifecycle costs for a combination of GSI-based BMPs? How does this compare to the cost of traditional (non-GSI) stormwater management?
- For a given project, what are the financial and quantitative benefits of implementing GSI?

Objective/Description: The CNT calculator allows users to compare the performance, costs, and benefits of GSI-based BMPs to traditional stormwater practices. The calculator provides templates for different project sites (e.g., residential, commercial lots, community gardens, urban parks) that include default values for lot size, impermeable area by land use type, and total landscaped area. Users input simple information about the type and size of GSI practices they would like to analyze, and the tool calculates total volume captured, runoff volume managed, hydrologic indicators, costs, and benefits. The calculator allows users to easily switch between GSI practices to determine the combination of BMPs that meets the volume capacity capture goal in a cost-effective way.

Applicable scale: Single property/development type, can be customized to analyze multiple sites or a large area, such as a city or county.

Tool structure: Web-based calculator

Level of Complexity: Low

Technical Expertise Required: Very little, although some knowledge of stormwater management necessary to enter key inputs such as GSI/BMP area and interpret stormwater benefits.

Audience: Stormwater practitioners, planners, developers, property owners

Inputs:

- Location (used to calculate average annual rainfall, national averages available by default)
- Volume capacity capture goal (inches of precipitation captured over impervious area, 0.5 inches is default value)
- Lot area, impervious area by land use type (e.g., driveway, roof, parking lot), and landscape area (defaults provided for template sites, but can be customized, see Figure 8)
- Type and/or number of GSI practices implemented, selected from checklist
- For relevant GSI-BMPs, total area of implementation (e.g., square feet), as well as what the BMP is replacing (e.g., turf, sidewalk area).

GSI practices: Green roof, rain barrel, cistern, drywell, rain garden, planter boxes, foundation/perimeter drain, trees, amended soil, bio-swales, urban farming/gardening, vegetation filter strip, native vegetation, parking lot and roadside swales, permeable paving.

Co-Benefits/Tool outputs: Tables 5 and 6 show the co-benefits and additional outputs from the calculator. Figure 9 shows the results output.

Limitations: The calculator is focused on stormwater capture as the primary benefit and only includes benefits that have a financial effect. Many of the benefits are related to trees. Values do not vary by region. This tool only allows for evaluation of a single property at a time and does not easily compare across different BMP types.

Figure 8. Input page (1 of 2) for commercial site

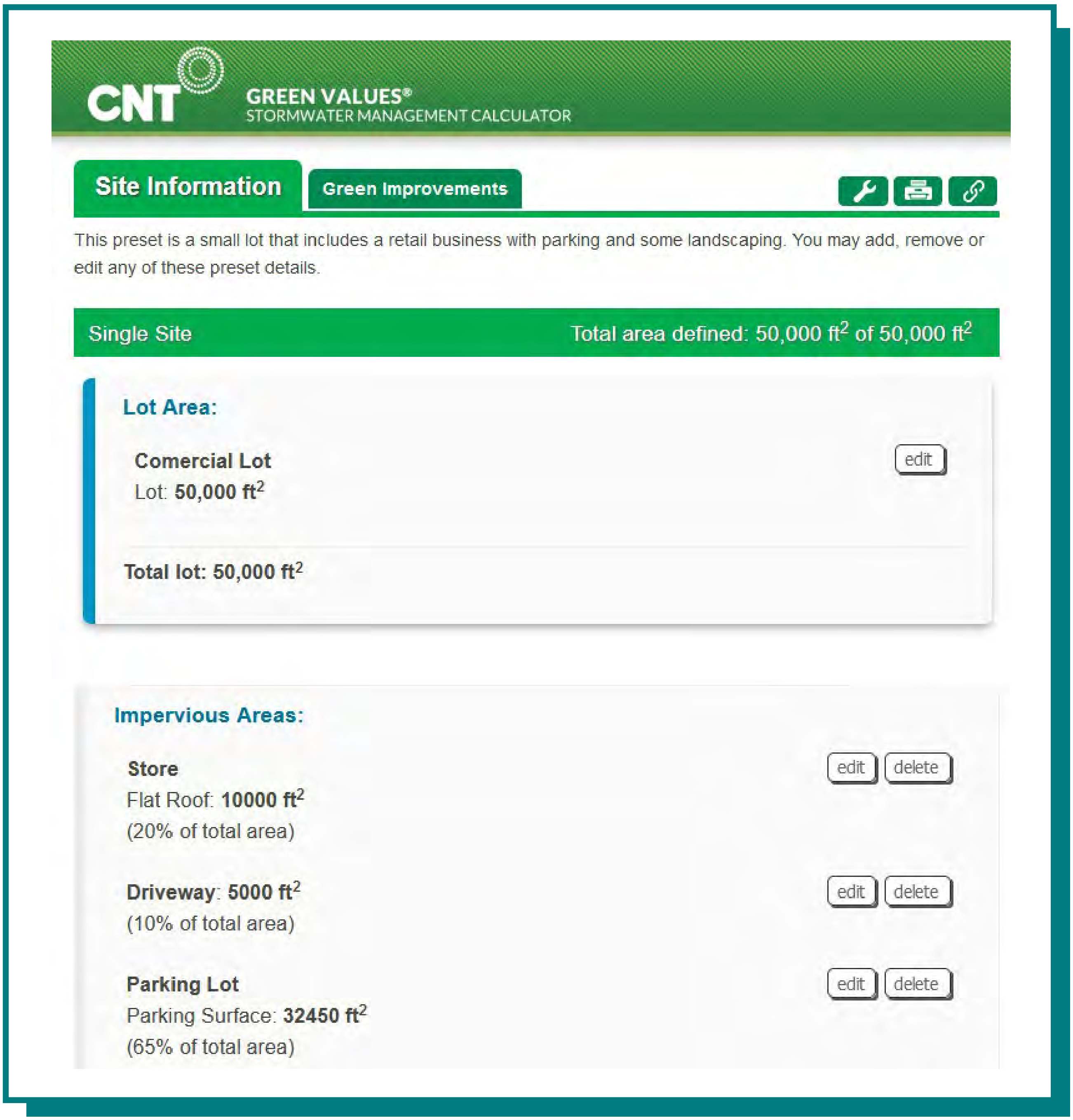


Table 5. Outputs of Green Values Stormwater Management Calculator

Output	Metric
Volume captured	Cubic feet/gallons of capture potential by BMP type Percentage of volume capacity capture goal met
Runoff managed	Inches of runoff and cubic feet/gallons of runoff managed with and without BMPs (for average rain event and annually) Percent difference with and without BMPs
Hydrology (initial abstractions, average cumulative abstractions)	Inches and cubic feet/gallons of rainfall & cumulative abstractions Percent difference with and w/out BMPs Curve number with and w/out BMPs
Costs	Initial/capital costs, annual maintenance, and NPV life cycle (30-year) for GSI-based BMPs, traditional stormwater management, and difference

Table 6. Co-benefits and default values included in the Green Values Stormwater Management Calculator

Benefit	Description	Annual value	Unit
Owner Benefits			
Energy savings (trees)	Trees save energy by providing shade and insulation for buildings	$36	Per tree
Energy savings (green roofs)	Green roofs provide insulation, reducing heating/cooling costs	$18	Per 100 ft^2
Community Benefits			
Reduced pollutants	Trees absorb and redirect air pollution	$0.18	Per tree
CO2 sequestration from trees	Trees sequester CO^2	$0.12	Per tree
Compensatory value of trees[a]	Trees add value to the property of the neighborhood	$275	Per tree
Water treatment cost reduction	Savings from not having to treat runoff volume infiltrated by BMPs	$29.94	Per acre-foot
Groundwater replenishment	Value of replenishing groundwater based on runoff volume infiltrated.	$86.42	Per acre-foot

a. Compensatory values represent compensation to owners for the loss of an individual tree. It can be viewed as the value of the tree as a structural asset.

Figure 9. Benefits output/values from the Green Values Stormwater Management Calculator

Total Cost: $**3,719**

Results: The green infrastructure applied in this scenario increases the area's potential volume capture capacity by **83.6** ft^3 or **106.5**% of the desired goal.

Site Overview | Volume | Runoff | Costs | **Benefits**

Benefits

Financial Benefit	Annual Benefits	Life Cycle Benefits (NPV)
Owner Total	$36.18	$736.24
Reduced Energy Use from Trees	$36	$732.58
Reduced Energy Use from Green Roof	$0.18	$3.66
Community Total	$275.3	$5602.23
Reduced Air Pollutants from Trees	$0.18	$3.68
Carbon Dioxide Sequestration from Trees	$0.12	$2.44
Compensatory Value of Trees	$275	$5596.11
Total	$311.48	$6338.48

Increased Real Estate Value ?

Value From	Existence	Area
Rain Gardens, Swales, Planters, Etc.	2.8%	0%
Trees	5%	0.1%
Total	7.9%	0.1%

GREEN VALUES STRATEGY GUIDE

Center for Neighborhood Technology, 2020

Strategy Guide: cnt.org/publications/green-values-strategy-guide-linking-green-infrastructure-benefits-to-community

Questions This Guide Answers:

- How can we best capture GSI co-benefits in our community?
- Who are the potential partners?
- How have other communities strategically addressed multiple challenges through GSI?

Objective/Description: The Green Values Strategy Guide is an accompanying document to CNT's Green Values Stormwater Management Calculator, intended to provide guidance on the community (non-financial benefits) of GSI. It serves as an update to CNT's 2010 publication: "The Value of Green Infrastructure: A Guide to Recognizing its Economic, Environmental and Social benefits," which has been "used by policy makers, advocates, and organizations across the country to make the case that GSI has a significant and quantifiable value beyond stormwater management" (CNT 2020).

The updated Green Values Strategy Guide highlights the quantifiable ways that GSI provides broad benefits to communities. The guide is divided into four sections (health, economic, climate, and transportation) that describe the benefits associated with different BMPs and provide examples of how communities have achieved multiple benefits through GSI implementation. Overall, the Guide looks at how strategic investments in GSI, when made with an eye towards community equity and affordability, provide broad benefits to all individuals. It offers specific recommendations for "getting started" by identifying key actions for capturing co-benefits within each broad benefit category.

Applicable scale: Community-wide

Tool structure: Guidance document (downloadable pdf)

Level of Complexity: Low

Technical Expertise Required: None

Audience: Stormwater practitioners, decisionmakers, planners

GSI practices and co-benefits/outputs: Figure 10 shows the GSI practices and co-benefits covered in the Guide. In addition to discussion of each benefit, the guide provides case studies, quantifiable results from existing studies related to each co-benefit, and specific strategies for capturing co-benefits.

Limitations: The guide offering rules of thumb/methodologies for quantifying a few GSI co-benefits; however, the quantification methodology is not consistent across co-benefits, and when available, is not detailed in instructing users. The guide provides many case study examples and literature reviews that while not always translating into quantification methodologies, can be used to help bolster the case for GSI. To use this guide effectively requires reading and additional resources.

Figure 10. GSI practices and co-benefits covered in the Green Values Strategy Guide

GREEN VALUES STRATEGY GUIDE

GREEN INFRASTRUCTURE BENEFITS

GREEN STORMWATER INFRASTRUCTURE

CNT

TABLE 1. COMMUNITY BENEFITS OF GREEN STORMWATER INFRASTRUCTURE

	GREEN STORMWATER INFRASTRUCTURE									
	Linear Buffer Park / Trail	Stormwater Park	Stormwater Planter	Parkway Bioswale	Rain Garden	Street Trees	Green Roof	Permeable Pavement	Permeable Bike Lane	District Stormwater
HEALTH BENEFITS										
Improved Outdoor Air Quality	•••	•	••	•	••	••	•			••
Improved Indoor Environmental Quality	•	•••	••	•	•	•••	•	••	••	•
Reduced Noise Pollution	•••						•••	••	••	••
Reduced Heat Stress	••	•••	•	•	•	••	•			••
Improved Community Cohesion + Mental Health	•	•••	••	•	•	••	•			••
ECONOMIC BENEFITS										
Improved Workforce Development / Job Creation	•••	•••		•		•••	•	•	•	•••
Increased Vacant Land Reactivation	•••	•••			•••					•••
Increased Property Values	••	•••	•	••	•	••	•••			•••
Increased Sales Revenue			••	••	••	••			••	••
Increased Recreational Revenue	•••	•••							•••	
CLIMATE ADAPTATION / RESILIENCE										
Reduced Flooding	•••	•••	••	••	••	•••	••	•••	••	•••
Reduced Urban Heat Island Temperatures	••	•••	•	•	•	•••	•••	•	•	•••
Protected Water Quality (reduced runoff and combined sewer overflows)	•••	•••	••	••	••	•••	••	•••	••	•••
CLIMATE MITIGATION / AVOIDANCE										
Reduced Greenhouse Gases	•••	•••	•••	•••	•••	•••	•••	•	•	•••
Reduced Energy / Fuel Use	••	••				•••	•••			••
TRANSPORTATION BENEFITS										
Reduced On-Street Flooding	••	••	••	••	••	•••	•	•••	•••	•••
Improved Safety	••		•	•					••	••
Increased Opportunities for Active Transportation	•••	•••	••	•••	••				•••	••

••• high benefit •• medium benefit • low benefit

Source: CNT 2020 (Green Values Strategy Guide)

CO-BENEFIT VALUATION TOOLS

GSI TRIPLE BOTTOM LINE (TBL) BENEFIT COST TOOL

Water Research Foundation, 2021

waterrf.org/research/projects/economic-framework-and-tools-quantifying-and-monetizing-triple-bottom-line

Questions This Tool Answers:

- What are the co-benefits of my GSI project or program in quantified and monetary terms?
- How do benefits compare to costs over time?
- How does the value of each co-benefit change over time?

Objective/Description: The GSI Triple Bottom Line (TBL) Tool guides users through a TBL-based benefit cost analysis that accounts for the full range of financial, social, and environmental costs and benefits of a GSI project or program over time. The Tool is organized into benefit modules that incorporate region- and city-specific data for calculating benefits; it allows users to estimate costs, monetized benefits, and physical unit values for 12 GSI co-benefits. The Tool is accompanied by a guidance document that provides data and information for assessing costs and benefits. An additional research-based report documents the key economic principles upon which the Tool is based and provides detailed methods and considerations for assessing GSI co-benefits. While more complex than the tools presented previously, the GSI TBL Tool allows for tailored analyses are more accurate and comprehensive results. The Tool relies on cost data developed for WRF's CLASIC tool. Outputs from CLASIC can be entered directly into the GSI TBL Tool, allowing for a more detailed assessment of co-benefits than CLASIC provides.

Applicable scale: Parcel, neighborhood, watershed, city wide

Tool structure: Excel-based tool

Level of Complexity: Intermediate

Technical Expertise Required: General knowledge of GSI/stormwater management; ability to gather study area data

Audience: Intended for use by stormwater practitioners

Inputs:

- Study area (acres) and population
- Climate zone (selected from map/drop down menu)
- Stormwater management information:
  - o Annual rainfall (inches)
  - o Design storm: percentile and depth (inches)
  - o GSI project/program implementation timeline (years)
  - o For each GSI practice:
  - o Effective impervious area managed (acres) or number of BMPs (see Figure 11)
  - o Optional: GSI design characteristics (where applicable), including depth of practice (inches), porosity (0 to 1), volume capacity (cubic feet), BMP footprint (square feet).
- Analysis period and discount rate (optional, default values provided)
- Capital, maintenance, and replacement costs (optional, default values provided)
- Additional inputs required for individual benefit calculations (default values provided for most)

Figure 11. Example input page, GSI TBL Tool.

GSI Scenario for Evaluation - Manual/CLASIC Data Entry

- Enter GSI Practices from CLASIC, or manually enter practices
- Enter Managed Volume, Area, Number of BMPs

In this worksheet, cells with formulas/calculations are shaded in light gray. These cells can be overwritten to better match local conditions, if desired.
Cells shaded in green require user input. In some cases, green cells contain default values that the user can rely on if local data is not specific. Cells in dark gray should not be changed or do not require inputs.

GSI Practices - Enter Acres Managed or Number of BMPs

GSI Practice (BMP)	CLASIC BMP Name	Effective Impervious Acres Managed (acres)	Number of BMPs	Volume Capacity by BMP type (cft)	Calculated BMP Area (Footprint) (square feet)	Annual Runoff Volume (cft)
Rain gardens	Rain gardens	25	770	88,935	76,967	1,889,869
Bioretention facilities	Infiltration trenches	50	24	177,870	129,454	3,779,738
Green roofs	Green roofs	10	87	35,574	435,600	755,948
Tree planting/street trees	*	1.9	200	7,000	142,139	145,775
Permeable pavement	Permeable pavement		-	-	-	-
Cisterns - rainwater harvesting	Rainwater harvesting	27.62	150	100,267		2,088,068
Rain barrels - rainwater harvesting	Rainwater harvesting	1.15	100	735.3		86,771
Constructed wetland	*		-	-	-	-
Wet ponds	Wet pond		-	-	-	-
Biofiltration/grass or vegetated swale	Grass swale		-	-	-	-
		116		410,382		8,746,168

* CLASIC does not address "Tree planting/street trees" or "constructed wetland"

GSI BMP Design Specifications

GSI Practice (BMP)	Volume of BMP components: Depth (inches)	Ponding Depth (inches)	Porosity (0 to 1)	Volume capacity (cft)	BMP size: Avg. BMP footprint (sq ft.)	Run-on-ratio (Impervious area managed / BMP
Rain gardens	18	6	0.437		100	14.1
Bioretention facilities	24	6	0.437		5,500	16.8
Green roofs	6	0.5	0.35		5,000	1.00
Tree planting/street trees				35		
Permeable pavement	12	0.5	0.437		21,780	2.0
Cisterns - rainwater harvesting				668		
Rain barrels - rainwater harvesting				7.4		
Constructed wetland	24		0.72		21,780	17.6
Wet ponds	36		1		21,780	36.7
Biofiltration/grass or vegetated swale	4		1		10,000	4.0

* CLASIC does not address "Tree planting/street trees" or "constructed wetland"

Annual volume managed

8,746,168	cubic feet/year
65,421,335	gallons/year

Note: Green cells in the upper table represent required inputs. User can overwrite GSI design specifications entered as default values into lower table (green cells). Gray cells represent formulas that can be overwritten.

GSI practices: Rain gardens, bioretention facilities, green roofs, street trees/tree planting, permeable pavement, cisterns and rain barrels, wetlands, wet ponds, biofiltration/vegetated swales

Co-benefits/tool outputs: Tool outputs include net present value and annualized benefits and costs, overall benefit cost ratio, monetized and physical unit values for each co-benefit (Table 7), monetized benefits by TBL category. Figure 12 shows the GSI TBL tool results dashboard.

In addition, cash flows and benefits are presented annually over the analysis period, broken out by each cost and benefit.

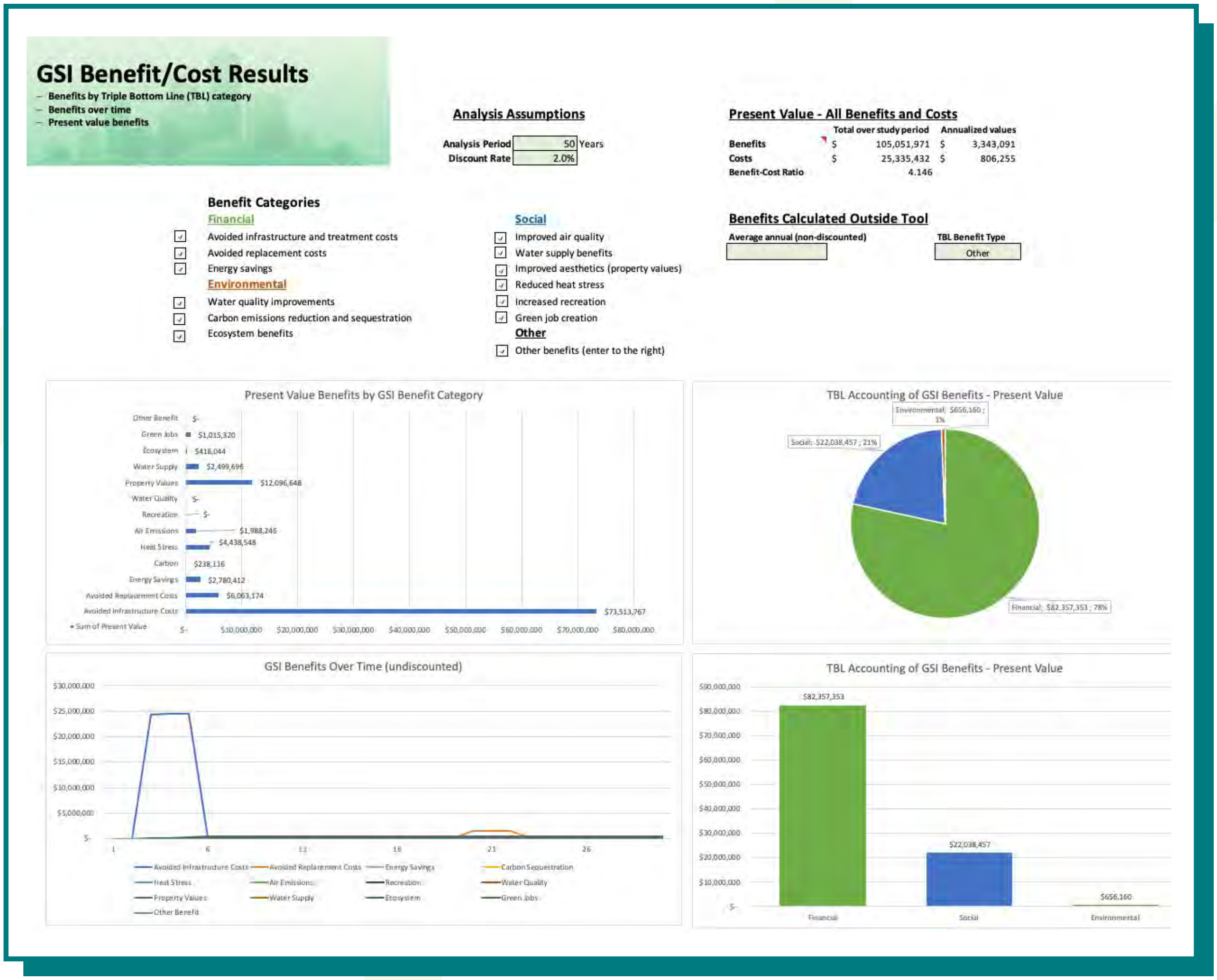
Limitations: The GSI TBL Tool requires a fair amount of information to be known about a GSI project and study area for users to be able to calculate benefits. It does not include less well understood categories such as flood risk reduction or transportation benefits. The Excel-based tool is not updated on an annual basis.

Case study: The report accompanying the GSI TBL tool includes case study applications that assess the benefits and costs of GSI projects in Seattle, WA (Seattle Public Utilities), Cleveland, OH (Northeast Ohio Regional Sewer District), St. Paul, MN, and Lancaster, PA.

Table 7. Benefit metrics/valuation methods for GSI TBL Tool

Benefit Category	Physical Unit Values	Valuation Methods
Avoided infrastructure costs	Volume of runoff managed by GSI (cft)	Avoided cost of gray infrastructure for managing equivalent stormwater volume
Avoided maintenance and replacement costs	N/A	Avoided costs of non-stormwater assets (i.e., traditional roofs and pavement)
Energy savings	Kilowatt hours, therms	Monetary savings from reduced energy use for building heating/cooling, avoided wastewater pumping and treatment, and potable water supply offsets.
Air quality improvements due to reduced energy-related emissions	Metric tons of avoided SO_2, NO_x, and $PM_{2.5}$.	Avoided health care costs.
Air quality improvements due to pollutant uptake from vegetation	Metric tons of SO_2, NO_x, O_3, and $PM_{2.5}$ removed from air	Avoided health care costs.
Water supply - potable water supply offsets	Gallons per year of capture and reuse from rainwater harvesting.	Retail water rates or marginal cost of alternative water supplies.
Water supply - groundwater recharge	Acre-feet.	Water rights values by state or marginal cost of alternative water supplies.
Urban heat stress reduction	Temperature reduction; avoided premature fatalities, hospitalizations, and ER visits.	EPA's value of statistical life estimate and avoided health care costs.
Recreation	Increased recreational visits.	Willingness to pay (WTP) for recreational activities.
Property value increases	Count of impacted properties.	Increase in property values from baseline. Discounted 50% to avoid double counting of benefits.
Green jobs	Construction and maintenance jobs.	Reservation wage or avoided social cost approach.
Water quality improvements	Water quality improvements (1 – 10) based on water quality ladder.	Household WTP for water quality improvements.
Carbon/GHG emission reduction due to reduced energy use	Metric tons of CO_{2e} avoided.	Social Cost of Carbon.
Carbon sequestration	Metric tons of CO_{2e} sequestered.	Social Cost of Carbon.
Terrestrial ecosystem benefits	Acres of increased habitat.	Household WTP for urban habitat.

Figure 12. GSI TBL Tool Results Dashboard



i-TREE

USDA Forest Service, 2022

itreetools.org

Questions This Tool Answers:

- What additional benefits do trees add to a project?
- What is the best place to put trees within a project?
- Where is the best place in a city to plant trees to maximize benefits?

Objective/Description: i-Tree is a software suite that provides urban and rural forestry analysis and benefits assessment tools. The i-Tree tools can help strengthen forest management and advocacy efforts by quantifying forest structure and the environmental benefits that trees provide. Developed by USDA Forest Service and numerous cooperators, i-Tree Tools are desktop and web applications that are freely available to download. The software is peer reviewed and has been used widely to report on the value of individual trees and multiple trees across parcels, neighborhoods, cities, and forests. i-Tree links forest management activities with environmental quality and community livability. This compendium focuses on the following tools for assessing the benefits of individual trees and tree canopy:

- i-Tree Design – estimates current and future benefits of individual trees at parcel-level.
- i-Tree Eco – uses data collected in the field from single trees, complete inventories, or randomly located plots throughout a study area to quantify forest structure, environmental effects, and value of trees to communities. Derives individual tree benefit estimates.
- i-Tree Landscape – spatial tool that incorporates data on tree canopy, land cover, and demographic information to identify priority areas for tree planting for climate and social justice efforts; also values tree canopy benefits.

Additional tools within the i-Tree software suite include:

- MyTree – provides high level benefit estimates for individual trees at a specific site, easiest tool to use.
- i-Tree Canopy – uses aerial imagery to estimate land and tree cover across a selected area and estimates tree canopy benefits.
- i-Tree Species – identifies the most appropriate tree species for planting based on user location and desired benefits.
- i-Tree Planting – estimates the long-term environmental benefits from a tree planting project.

Applicable scale: Parcel for i-Tree design, multiple scales (e.g., neighborhood, Census tract, city, watershed) for i-Tree Eco and Landscape

Tool structure: Dependent on which tool in suite utilized (i-Tree Design and Landscape are web-based, i-Tree Eco requires software download)

Level of Complexity: Low (i-Tree Design and Landscape) to Intermediate (i-Tree Eco).

Technical Expertise Required: Some level of GSI/stormwater management expertise required, as well as some knowledge of economic principles

Audience: Forest managers, planners, GSI designers, property owners (i-Tree design) communicate benefits to public.

Inputs: Inputs vary by tool and depend on the scale of analysis. i-Tree Design inputs are relatively simple; they include: the location/address of property; tree species, diameter, condition, and exposure to light (drop down menus); and number of years to track tree growth and benefits.

i-Tree Eco is a significantly more complex and sophisticated tool, requiring a more extensive data inputs and an investment of time to extract results. Key inputs include:

- Boundaries of study area
- Tree species, diameter, tree height, crown size and crown health
- Location of trees, land use type
- Proportion of plantable space in study area
- Information on nearby buildings (distance and direction from trees)
- Sample stratification (sub-dividing) of study area by land-cover class
- Randomization methodology: how trees are distributed to plots throughout study area

i-Tree Landscape is a map-based tool that allows users to select a study area (various scales available) and view publicly available data related to land use, tree canopy, forest risk, health indicators, and future climate scenarios. Landscape allows users to identify and weight different prioritization criteria (e.g., based on tree cover per capita, minority population density, poverty).

GSI practices: Individual trees, street trees, and urban canopy/forests

Co-Benefits/tool outputs: In general, most i-Tree tools quantify and monetize multiple benefits of trees including: building energy savings, avoided CO2 and pollutant emissions, pollutant uptake/removal, CO2 sequestration/storage, human health impacts associated with air quality improvements, and hydrology effects (avoided run-off, interception, transpiration). In terms of co-benefits, i-Tree Eco also provides tree replacement value, tree bio-emissions, avian habitat suitability, and ultraviolet tree effects (in addition to forest management assessments). The tables and figures below show the outputs and co-benefits valued in the various i-Tree tools.

Limitations: This tool only looks at the benefit of trees, so it is limited in scope to provide design information for any project that incorporates other BMPs. The suite of tools offers many possibilities for analyzing tree benefits and may be time consuming to navigate and determine which tool is best suited for a project with a given scope. Some tools, such as i-Tree Design, are relatively simple to utilize for small projects, while i-Tree Eco requires more time to learn the software.

Case study: Many reports are generated using i-Tree software, cataloged on the i-Tree website. For example, i-Tree Eco software was used to evaluate the stormwater benefits of Atlanta's urban forests, which helped the local water agency to justify preserving existing forested land and track the benefits of new acquisitions.

Figure 13. Input page (above) and output summary page (below), i-Tree Design

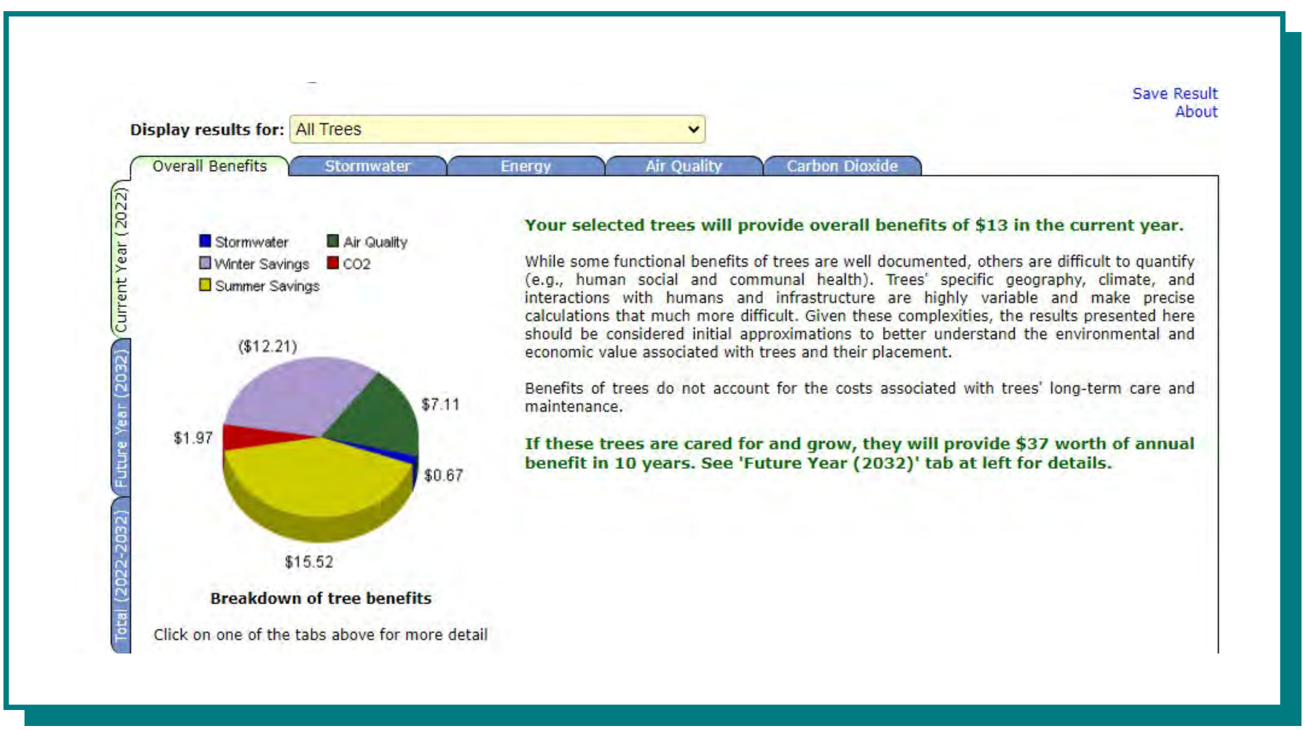


Table 8. Outputs and co-benefits valued, i-Tree Design

Output	Metric:
Tree placement areas for maximum energy savings	Colored GIS diagram (see Figure 10)
Energy savings	Kwh of electricity and therms of fuel conserved; dollar value of savings
Air quality improvements from avoided emissions and pollutant uptake from trees	Pounds of avoided emissions and removed pollutants; dollar value
Carbon emissions avoided and stored/sequestered	Pounds of avoided CO2 emissions and stored CO2 equivalent; dollar value
Stormwater: rainfall interception and avoided runoff	Gallons of rainfall intercepted and avoided stormwater runoff; dollar value
Total benefit	Current, future, and total to date value

Credit: Rick Triana

Figure 14. Sample outputs, i-Tree Eco

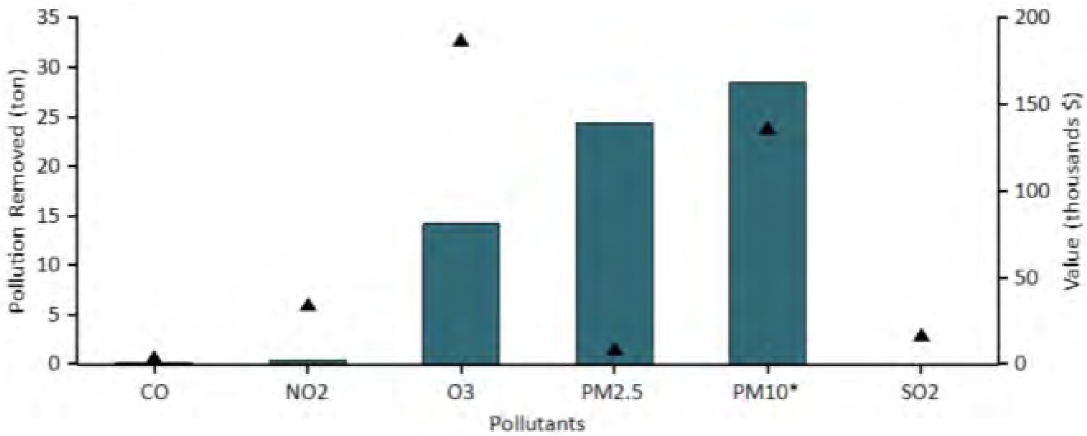


Figure 7. Annual pollution removal (points) and value (bars) by urban trees and shrubs, Adrian

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the Adrian urban forest was conducted during 2012. Data from 200 field plots located throughout Adrian were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

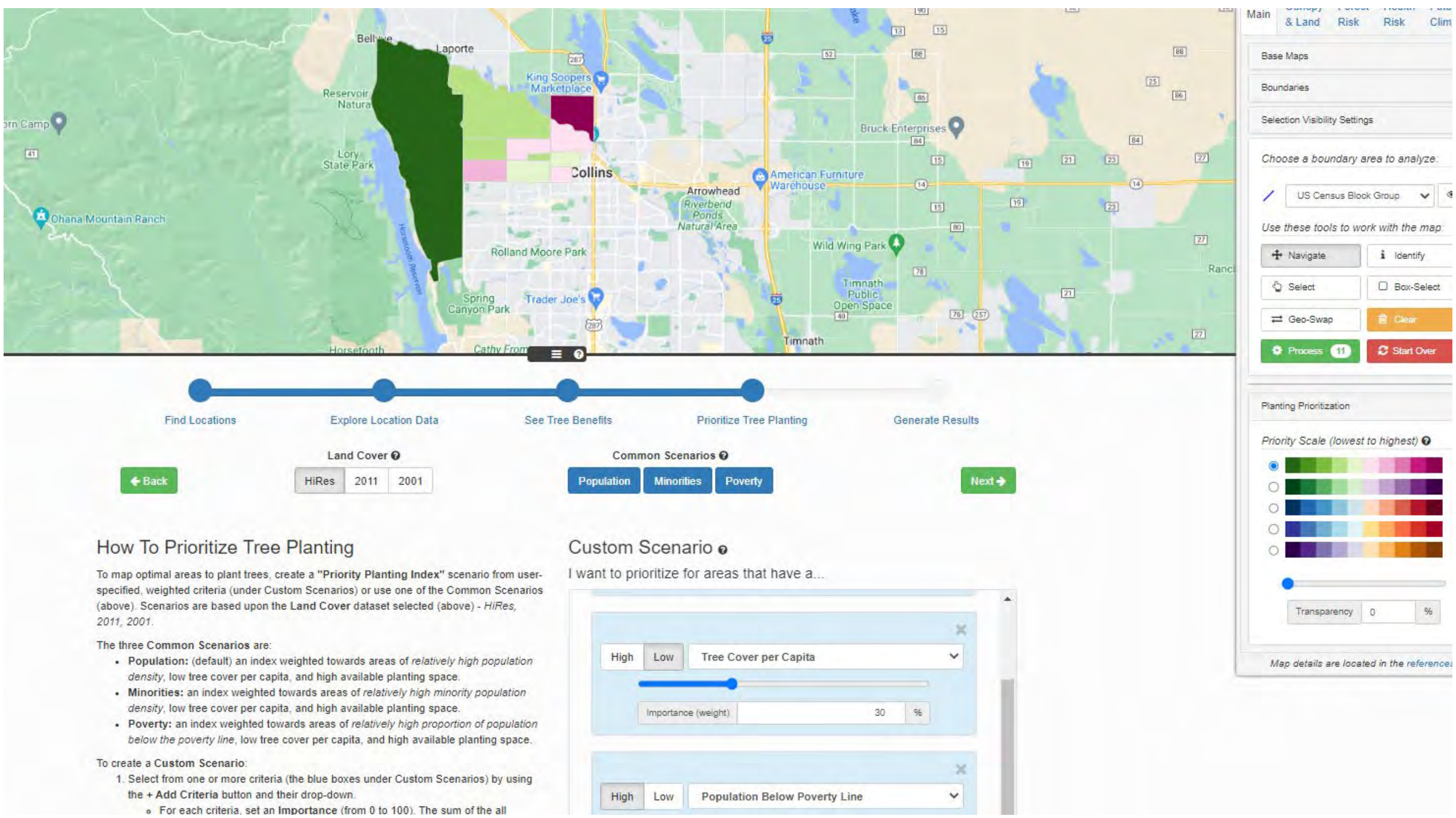
- Number of trees: 287,600
- Tree Cover: 22.2 %
- Most common species of trees: Sugar maple, American elm, Green ash
- Percentage of trees less than 6" (15.2 cm) diameter: 59.5%
- Pollution Removal: 66.83 tons/year ($386 thousand/year)
- Carbon Storage: 55.42 thousand tons ($3.95 million)
- Carbon Sequestration: 1.761 thousand tons ($125 thousand/year)
- Oxygen Production: 1.683 thousand tons/year
- Avoided Runoff: 2.834 million cubic feet/year ($189 thousand/year)
- Building energy savings: $-70,500/year
- Carbon Avoided: -193.1 tons/year ($-13800/year)
- Replacement values: $167 million

Table 3. Annual energy savings due to trees near residential buildings, Adrian

	Heating	*Cooling*	*Total*
MBTU[a]	-13,535	N/A	-13,535
MWH[b]	-114	856	742
Carbon Avoided (tons)	-385	192	-193

[a]MBTU - one million British Thermal Units
[b]MWH - megawatt-hour

Figure 15. i-Tree Landscape mapping tool (prioritization input page)



Community-enabled Lifecycle Analysis of Stormwater Infrastructure Costs (CLASIC)

Water Research Foundation, 2020

waterrf.org/CLASIC

Questions This Tool Answers:

- What are the lifecycle costs and water quality benefits of green, gray, and hybrid stormwater management options?
- How do lifecycle costs and (qualitative) benefits compare between the baseline and alternatives? Across different alternatives?

Objective/Description: CLASIC is a screening tool that utilizes a lifecycle cost framework to support analysis of green, gray, and hybrid (green + gray) infrastructure practices. Users can create scenarios of stormwater control measures (via functional unit analysis) to assess lifecycle costs, performance, and co-benefits associated with those scenarios. CLASIC enables consideration of co-benefits from GSI through Multiple Criteria Decision Analysis (MCDA). CLASIC is not intended for optimization of design. The stated objective of this tool is to provide a robust, peer-reviewed and end-user informed life cycle cost framework model for stormwater infrastructure alternatives that can accommodate regional and scale variations to support integrated planning across a municipality. CLASIC is hosted on a web platform interfaced with GIS and national databases to upload relevant regional data at a community level and incorporates methodology for simulating climate scenarios and land use projections.

Applicable scale: City- or watershed-scale, with flexibility to analyze subunits (based on Census block groups or Census tracts) or to draw or input GIS layers for a specific study area

Tool structure: Web-based spatial software

Level of Complexity: Intermediate

Technical Expertise Required: Knowledge of GSI/Stormwater management infrastructure necessary to specify infrastructure characteristics and develop baseline and alternative infrastructure scenarios. However, default values are provided.

Audience: Stormwater practitioners, planners

Inputs: Users draw project boundary onto a GIS map and select the units of measurement (Census block groups, Census tracts, or hand drawn boundaries). Users then select local climate data drawn from stations chosen from a drop-down menu. The tool allows users to review and modify default parameters regarding water quality, infiltration, and costs among others. Then the user builds baseline and alternative scenarios, including information about size, features, integration, and maintenance of stormwater infrastructure technologies. CLASIC also allows users to select a climate model or edit anticipated precipitation and evaporation changes manually.

For co-benefits analysis, users rate the importance of co-benefits so the model can provide output for comparing economic, social, and environmental performance across scenarios. Finally, the user can enter targets for water quality, hydrologic or cost caps to meet local required or desired conditions. Figure 16 provides a snapshot of the CLASIC scenario-building page.

GSI practices: CLASIC includes evaluation of a range of stormwater infrastructure practices; the tool evaluates costs and performance across small, medium, and large units of each practice type:

- Rain garden
- Sand filter
- Infiltration Trench
- Detention basin
- Wet pond
- Stormwater harvesting
- Storage vault
- Permeable pavement
- Disconnection
- Green roof

Co-Benefits/tool outputs: CLASIC evaluates lifecycle costs, performance, and co-benefits across multiple stormwater infrastructure scenarios. Detailed hydrologic, water quality, and life cycle cost data are provided, as shown in Table 10.

Table 9. Outputs of CLASIC

Output	Metric:
Total volume captured	Cubic feet
Life cycle costs (construction, maintenance, and rehabilitation)	Dollars
Change in volume, runoff, infiltration and evaporation	Percent change from baseline scenario
Change in contaminant load (TSS, N, P, FIB)	Percent change from baseline scenario, annual average dollars per pound removed
Co-benefit overall score: economic, social, environmental	Score of 0 – 5 for each indicator, weighted based on user importance rating for individual co-benefits

As noted the last row of Table 10, co-benefits are assessed qualitatively, and scored based on user “importance” (ratings of 0-5).

Figure 16. CLASIC Scenario builder input page and CLASIC Tool Steps

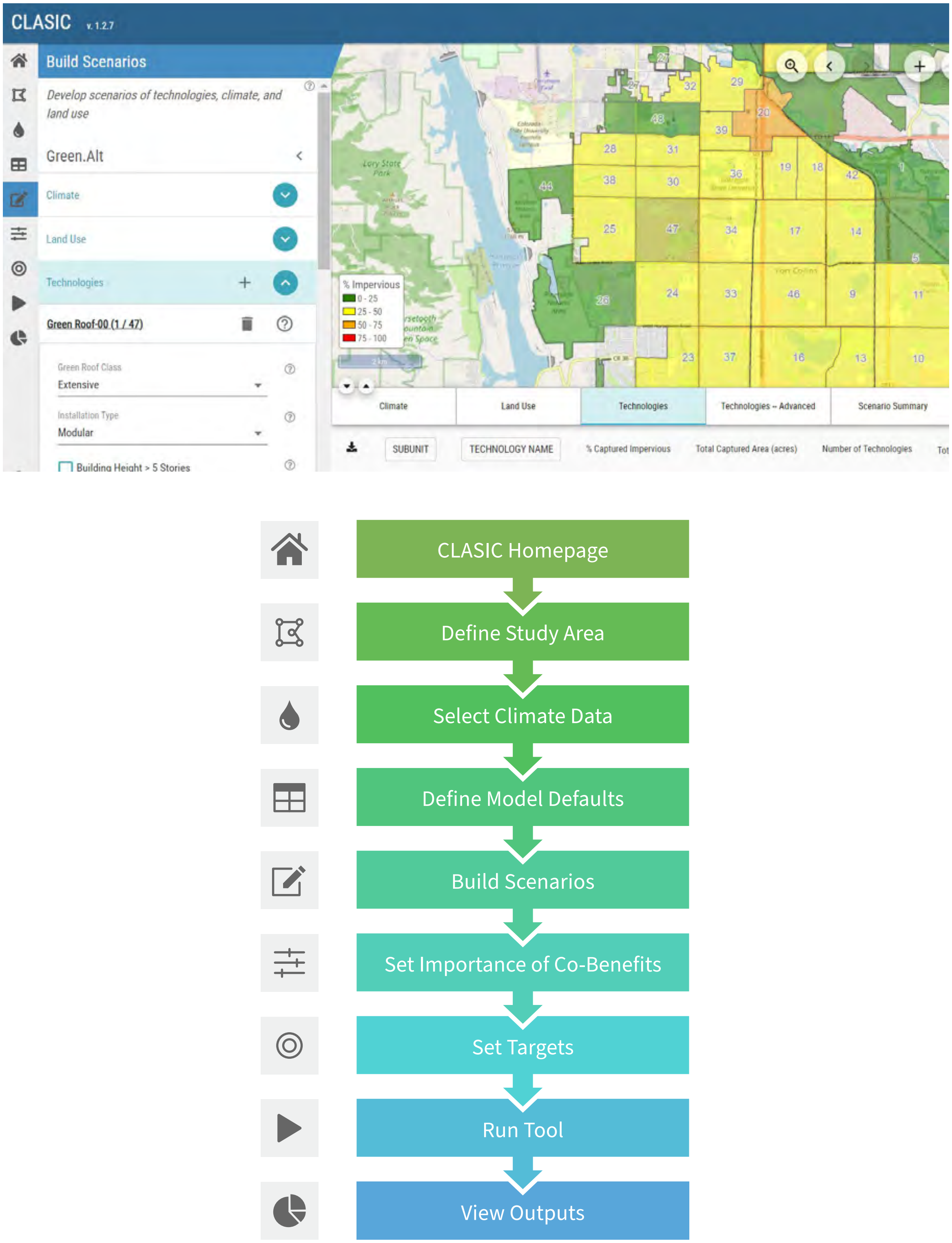


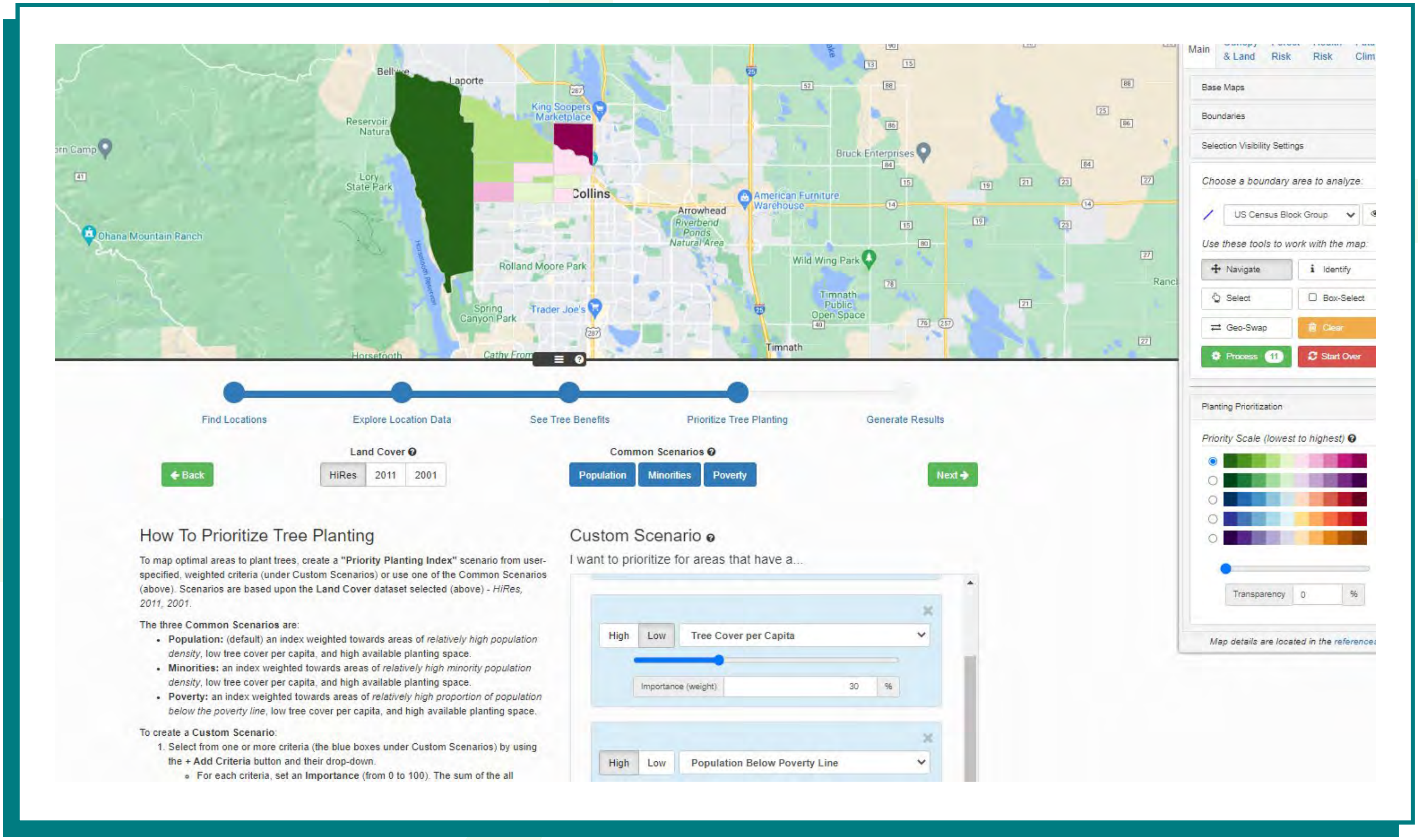
Table 10. Co-benefits included within each indicator category in CLASIC

Economic	Social	Environmental
• Property values • Costs from illness • Avoided CSO costs • Potential impacts from nuisance flooding • Building energy efficiency • Avoided water treatment • Employment opportunities	• Air quality health impacts • Mental health • Thermal comfort • Increased supply from stormwater harvesting • Public awareness of stormwater and water systems • Potential avoided social strain from nuisance flooding	• Ecosystem services • Groundwater flow increase • Carbon sequestration

Limitations: While intuitive to use, the CLASIC model requires a higher level of detail for the inputs necessary to run simulations, particularly for stormwater practice design parameters. However, users do have the option of relying on default values. CLASIC does not provide monetized or quantified values for co-benefits achieved; it is intended to provide a relative comparison across user-defined scenarios.

Case study: CLASIC offers case study applications of the tool in documentation on their website. For example, CLASIC is applied to a small community of Harvey, North Dakota to compare construction of small diffuse wet ponds to one large wet pond to determine which option provides the best value and most water quality benefits to the City. Ten other case studies include Oxford, MS, Dubuque, IA, Kirkland, WA, Carmel, IN, San Diego, CA, Philadelphia, PA and Fort Collins, CO.

Figure 17. CLASIC co-benefits output dashboard, GSI and baseline scenarios



Credit: Jason Whalen / Fauna Creative

INTEGRATED DECISION SUPPORT TOOL (i-DST)

Colorado School of Mines, 2020; EPA-funded project

idst.mines.edu

Questions This Tool Answers:

- How can I optimize the implementation of stormwater control measures (SCMs) within my watershed or at a specific site to meet specific water quality/quantity goals?
- What are the water quality and hydrologic benefits of alternative SCM scenarios? What are the relative (qualitative) co-benefits?
- What are the lifecycle costs and monetized environmental impacts of green and gray solutions?

Objective/Description: i-DST is a suite of decision support tools for planners implementing gray, green and hybrid stormwater control measures (SCMs). The tool allows users to analyze various aspects of SCM implementation. It includes:

- Hydrologic and water quality treatment/outcomes for selected gray and green SCMs
- Automatic optimization of number and type of SCMs to meet management objectives at minimum life cycle cost (through integration with EPA's SUSTAIN model)
- Life cycle cost and life cycle assessments of SCMs
- Gray infrastructure energy use and costs avoided by using distributed SCMs to manage stormwater in combined systems
- Qualitative assessment of co-benefits provided by the SCMs

The i-DST tool contains watershed scale, site scale, life cycle cost and life cycle environmental impact assessment modules for green and gray solutions. The different modules allow users to match the tool's functionality to their specific project goals. While stormwater management performance and costs are a primary focus of the watershed and site scale modules, the life cycle cost and assessment (LCA) components allow users to compare the whole-life environmental costs/impacts of alternative stormwater management strategies. The watershed and site scale modules also include a qualitative assessment of the co-benefits associated with SCM scenarios. Finally, i-DST includes supplemental co-benefit factsheets for several "harder to quantify" benefits, specifically related to the vegetated components of GSI.

Applicable scale: Site, Watershed

Tool structure: Downloadable software platform/modules; life cycle costs and assessment module can also be accessed as a stand-alone Excel workbook.

Level of Complexity: Advanced (overall tool), Intermediate (life cycle assessment module)

Technical Expertise Required: Relative to other tools in this compendium, stormwater engineering/hydrologic expertise is required to properly run the watershed and site scale modules. Less expertise is required for the stand-alone LCA module.

Audience: Stormwater engineers/managers

Inputs: The watershed and site scale modules contain significant SCM design, cost, and performance data. Users can tailor this information to local design standards but may also rely on default values. Required inputs include information related to the study area and individual BMPs selected for analysis (e.g., drainage area, number of units, predevelopment land use type), as well as optimization parameters, as applicable. For the LCA (stand-alone) module, inputs are relatively minimal, although user can change default design/cost parameters embedded in tool. Required LCA inputs include:

- Location and timing of implementation
- Construction and system information (internal or subcontracted labor, rented or owned equipment, combined vs. separate system)
- Inflation or discount rate (default values provided)
- BMP type and "count" (default parameters include a size per unit for each practice, which can be changed by users)

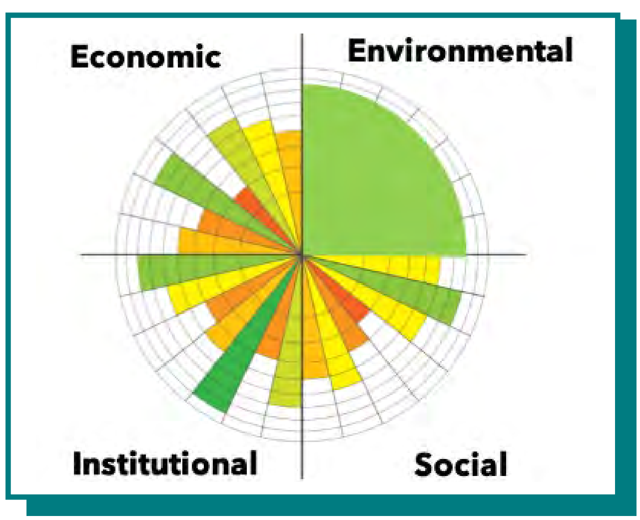
GSI practices: Porous pavement, green roof, constructed wetlands, bioretention, rain barrel, buffer strip, infiltration trench, vegetated swale, dry pond, wet pond, perforated pipe, cistern. Also includes traditional gray practices such as storage tanks, retention/detention structures, underground gravel beds, and wastewater treatment plants.

Co-Benefits/Tool outputs: LCA Tool provides lifecycle financial costs and quantified and monetized environmental costs for a range of green and gray infrastructure options, providing significant detail by SCM and project phase (i.e., design, construction, O&M, end of life). Comparing alternative stormwater management strategies allows users to understand the marginal benefit (i.e., avoided gray infrastructure costs) associated with green solutions. Environmental impacts (and associated units) calculated in the LCA tool include: ozone depletion (kg CFC-11 eq); global warming (kg CO_2 eq); acidification (kg SO_2 eq); eutrophication (kg N eq); smog (kg O_3 eq); respiratory effects (kg PM 2.5 eq); carcinogenics (CTUh); non carcinogenics (CTUh); ecotoxicity (CTUe); and fossil fuel depletion (MJ). Figure 19 shows the results dashboard for the LCA tool.

In addition, while still under development at the time of this writing, the i-DST will include a user-friendly dashboard that synthesizes output from all tool modules. The dashboard will provide a simple, but informative comparison of SCM scenarios generated by the optimization engine, as well as detailed information on life cycle costs, hydrologic and water quality performance, and a qualitative assessment of co-benefits for individual SCM scenarios (Figure 18).

Users can also access a series of factsheets on the following co-benefits: human health and social well-being, air quality, biodiversity, property values, recreational opportunities, neighborhood beautification, neighborhood cooling. The factsheets provide a summary of the state of literature, identify key design considerations, and aim to help decision makers consider trade-offs of each benefit.

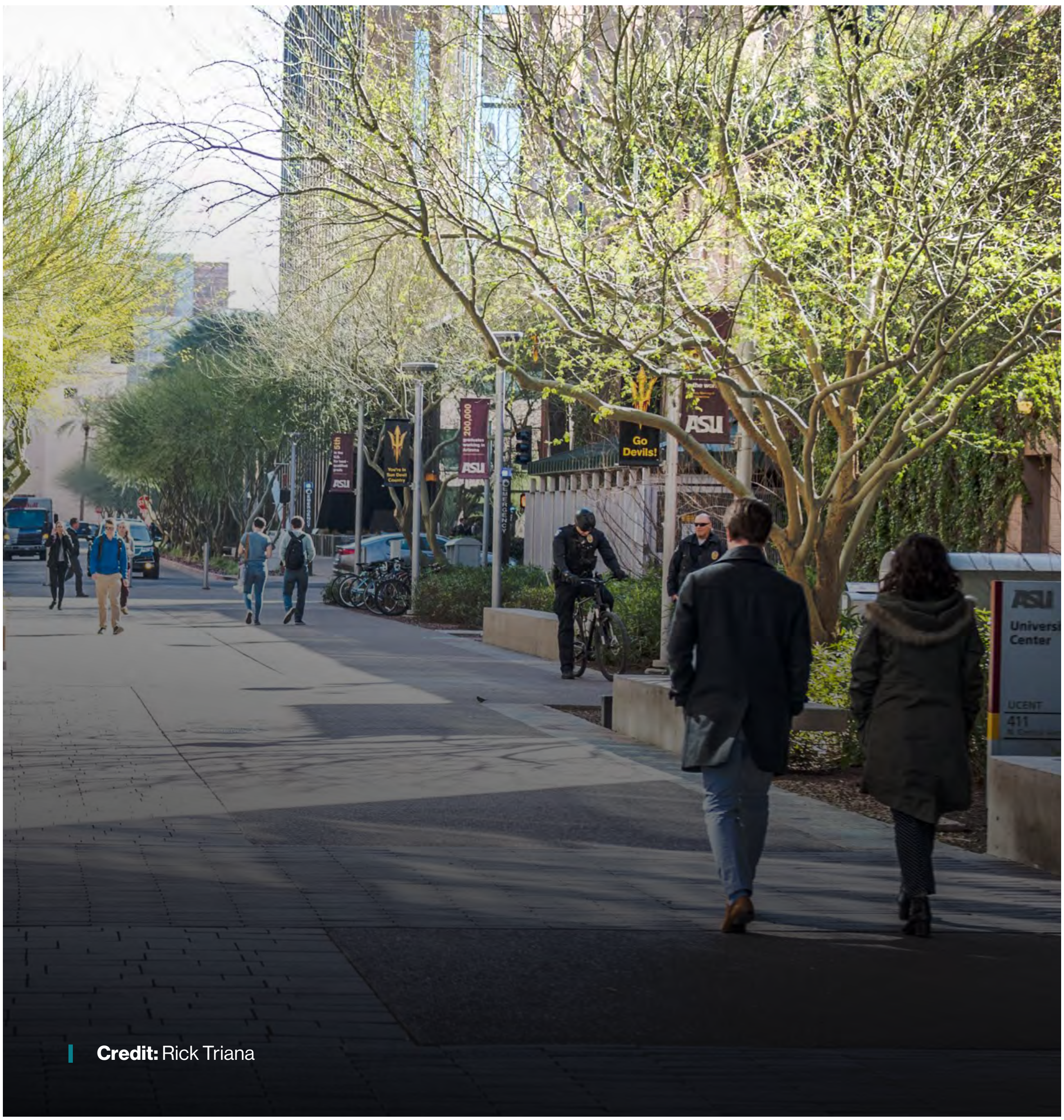
Figure 18. i-DST co-benefits output for SCM scenarios



Source: CSM i-DST

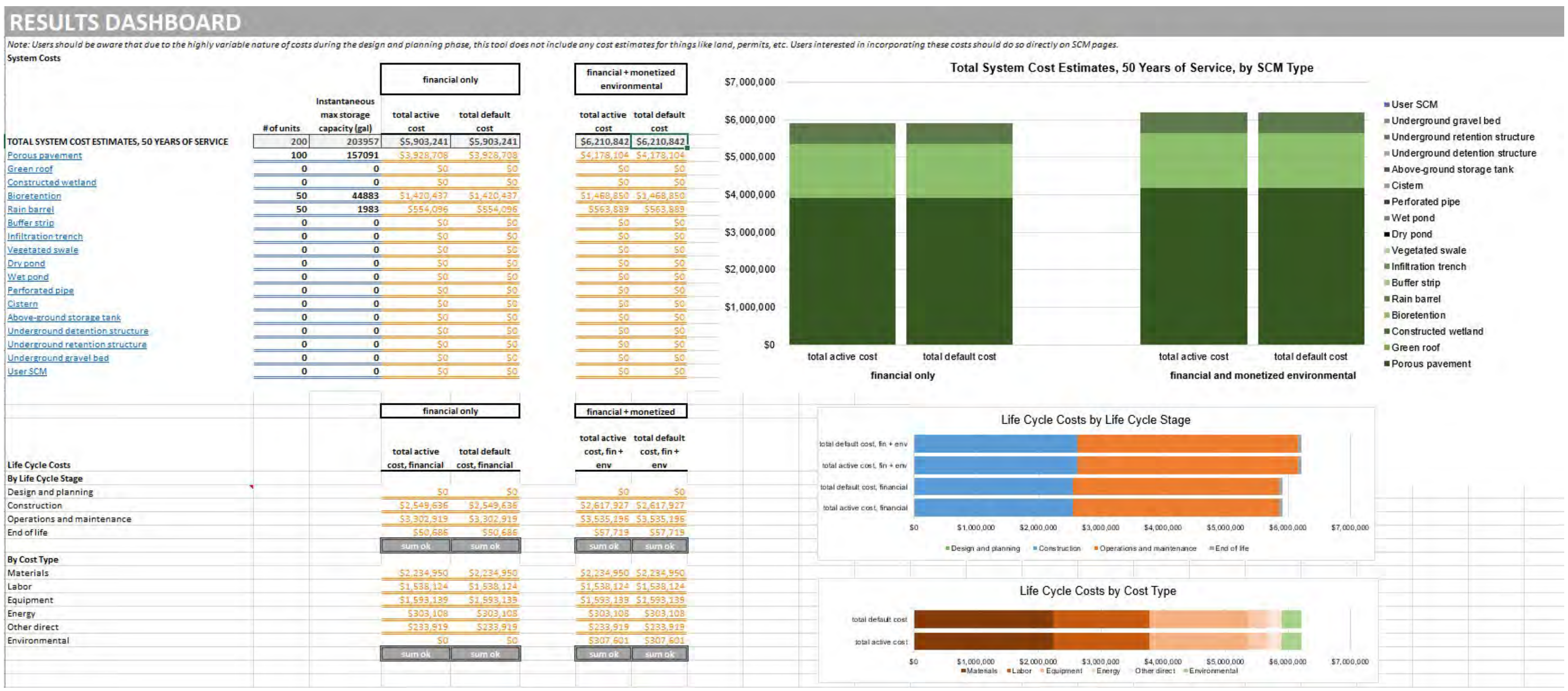
Limitations: The i-DST requires a higher level of expertise to use compared to many of the other tools. In addition, it provides a mostly qualitative assessment of key co-benefits. At the same time, the LCA component provides monetized environmental impacts of green and gray infrastructure scenarios that are not offered by other tools in such a comprehensive way. At the time of this writing, the i-DST was still under development; the final iteration may be a bit different than what is described herein.

Case study: Publications of articles written about the application of i-DST software can be found on the i-DST website. One example applies i-DST to compare the performance of green and grey stormwater control measures in Denver, CO. The resulting analysis demonstrated a mix of green and grey was optimal, given community input and associated benefits and tradeoffs.



Credit: Rick Triana

Figure 19. i-DST LCA/LCC output



System Costs

	# of units	Instantaneous max storage capacity (gal)	financial only: total active cost	financial only: total default cost	financial + monetized environmental: total active cost	financial + monetized environmental: total default cost
TOTAL SYSTEM COST ESTIMATES, 50 YEARS OF SERVICE	200	203957	$5,903,241	$5,903,241	$6,210,842	$6,210,842
Porous pavement	100	157091	$3,928,708	$3,928,708	$4,178,104	$4,178,104
Green roof	0	0	$0	$0	$0	$0
Constructed wetland	0	0	$0	$0	$0	$0
Bioretention	50	44883	$1,420,437	$1,420,437	$1,468,850	$1,468,850
Rain barrel	50	1983	$554,096	$554,096	$563,889	$563,889
Buffer strip	0	0	$0	$0	$0	$0
Infiltration trench	0	0	$0	$0	$0	$0
Vegetated swale	0	0	$0	$0	$0	$0
Dry pond	0	0	$0	$0	$0	$0
Wet pond	0	0	$0	$0	$0	$0
Perforated pipe	0	0	$0	$0	$0	$0
Cistern	0	0	$0	$0	$0	$0
Above-ground storage tank	0	0	$0	$0	$0	$0
Underground detention structure	0	0	$0	$0	$0	$0
Underground retention structure	0	0	$0	$0	$0	$0
Underground gravel bed	0	0	$0	$0	$0	$0
User SCM	0	0	$0	$0	$0	$0

Life Cycle Costs	financial only: total active cost, financial	financial only: total default cost, financial	financial + monetized: total active cost, fin + env	financial + monetized: total default cost, fin + env
By Life Cycle Stage				
Design and planning	$0	$0	$0	$0
Construction	$2,549,636	$2,549,636	$2,617,927	$2,617,927
Operations and maintenance	$3,302,919	$3,302,919	$3,535,196	$3,535,196
End of life	$50,686	$50,686	$57,719	$57,719
	sum ok	sum ok	sum ok	sum ok
By Cost Type				
Materials	$2,234,950	$2,234,950	$2,234,950	$2,234,950
Labor	$1,538,124	$1,538,124	$1,538,124	$1,538,124
Equipment	$1,593,139	$1,593,139	$1,593,139	$1,593,139
Energy	$303,108	$303,108	$303,108	$303,108
Other direct	$233,919	$233,919	$233,919	$233,919
Environmental	$0	$0	$307,601	$307,601
	sum ok	sum ok	sum ok	sum ok

URBAN INVEST

Natural Capital Project (NatCap) at Stanford University, 2020

naturalcapitalproject.stanford.edu/software/urban-invest

Questions This Tool Answers:

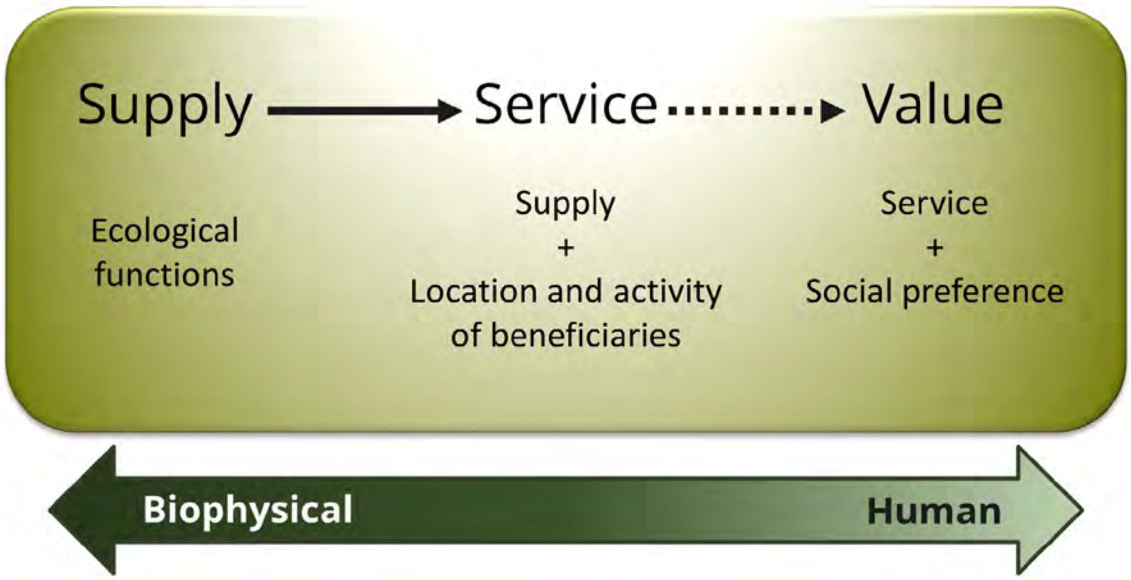
- How much benefit can natural infrastructure provide in an urban setting?
- What is the return on investment in natural infrastructure?
- Where would investment in natural infrastructure provide the greatest benefit?
- What is the provision of ecosystem services to different neighborhoods?
- Who benefits from investment in natural infrastructure?
- Can investment in natural infrastructure reduce inequality?

Objective/Description: i-The Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) tool is a free data and modeling platform that values and maps ecosystem services (or co-benefits) associated with natural capital/infrastructure. It provides information about how changes in ecosystems are likely to lead to changes in the flows of benefits to people, allowing for the evaluation of tradeoffs across alternative natural resource management scenarios. Each ecosystem service incorporated into the software is its own model, requiring separate inputs and employing different valuation methods. As shown to the right, InVEST uses a simple framework delineating "supply, service, and value" to link ecological functions to benefits to communities (Figure 20).

Urban InVEST is a relatively new component of the larger suite of InVEST tools. Urban InVEST features spatially explicit biophysical and socio-economic models that enable users to quantify and map the impacts of incorporating nature into urban design, showing the benefits and costs to communities by socioeconomic status and vulnerability. The software incorporates a suite of models that measure different ecosystem services/co-benefits. Urban InVEST is more applicable for evaluating the co-benefits associated with GSI. Because it is a spatial model, Urban InVEST allows users to explore where to best focus investments in natural infrastructure to improve equity outcomes and/or to maximize benefits.

As of the publication of this compendium, Urban InVEST is in early stages of application, with a recent paper published applying the software to three case study cities including in Shenzhen, China, Minneapolis/St. Paul, MN, and Paris, France. Current Urban InVEST models include urban cooling, urban stormwater retention, and urban flood risk mitigation. However, the developers note that several of the models included in the original InVEST suite are applicable to urban systems, including pollination, climate change mitigation (carbon storage and sequestration), scenic quality, coastal hazard protection, habitat quality, and recreation. Future iterations of the Urban InVEST software will include additional models that quantify and map access to green space, mental health and physical activity, urban biodiversity, noise attenuation, and air pollution mitigation.

Figure 20. InVEST ecosystem service supply chain: Links ecological function to ecosystem services to benefits to people/communities



Applicable scale: Project site, city-wide, watershed, or regional

Tool structure: Free, open-source software models downloaded to desktop. All models (including the Urban InVEST models) are accessed via the "InVEST Workbench" user interface. InVEST requires GIS software to view results (e.g., QGIs or ArcGIS).

Level of Complexity: Advanced

Technical Expertise Required: Intermediate to advanced GIS skills are required to complete InVEST analysis; additional technical knowledge of each ecosystem service is helpful to understand and properly format the inputs required for different models.

Audience: Decision makers (government, non-profit, corporate) who manage land and water for multiple users.

Inputs: Vary by ecosystem service model but typically include a set of biophysical indicators, key assumptions/parameters related to the ecosystem service being evaluated, and a series of spatial files (e.g., GIS raster files) related to land use/land cover, area of interest, and other relevant data. For example, the Urban Stormwater Retention model requires:

- GIS/spatial files of land use/land cover, soil hydrologic groups, areas of interest, and average annual precipitation
- Biophysical table with event mean concentrations (EMCs) for different pollutants by land use/cover type and stormwater runoff coefficients for each land use/cover and soil type (csv file)
- Optional: replacement cost in dollars per cubic meters

GSI practices: Models seem to be based primarily on evaluating changes in land use/land cover, including (for stormwater retention) changes in directly connected impervious area.

Co-Benefits/Tool outputs: Each model provides different outputs. Table 11 shows the supply (i.e., physical unit values) and value metrics provided by each InVEST model applicable to urban settings (including those developed specifically for Urban InVEST in bold). Outputs are also provided as GIS files (TIF or shapefiles). For example, the urban stormwater retention model shows avoided pollutant loads in different areas based on different management scenarios. Figure 21 shows avoided nitrogen concentration pollution runoff in a suburb of Saint Paul, MN for the example project in the InVEST Workbench.

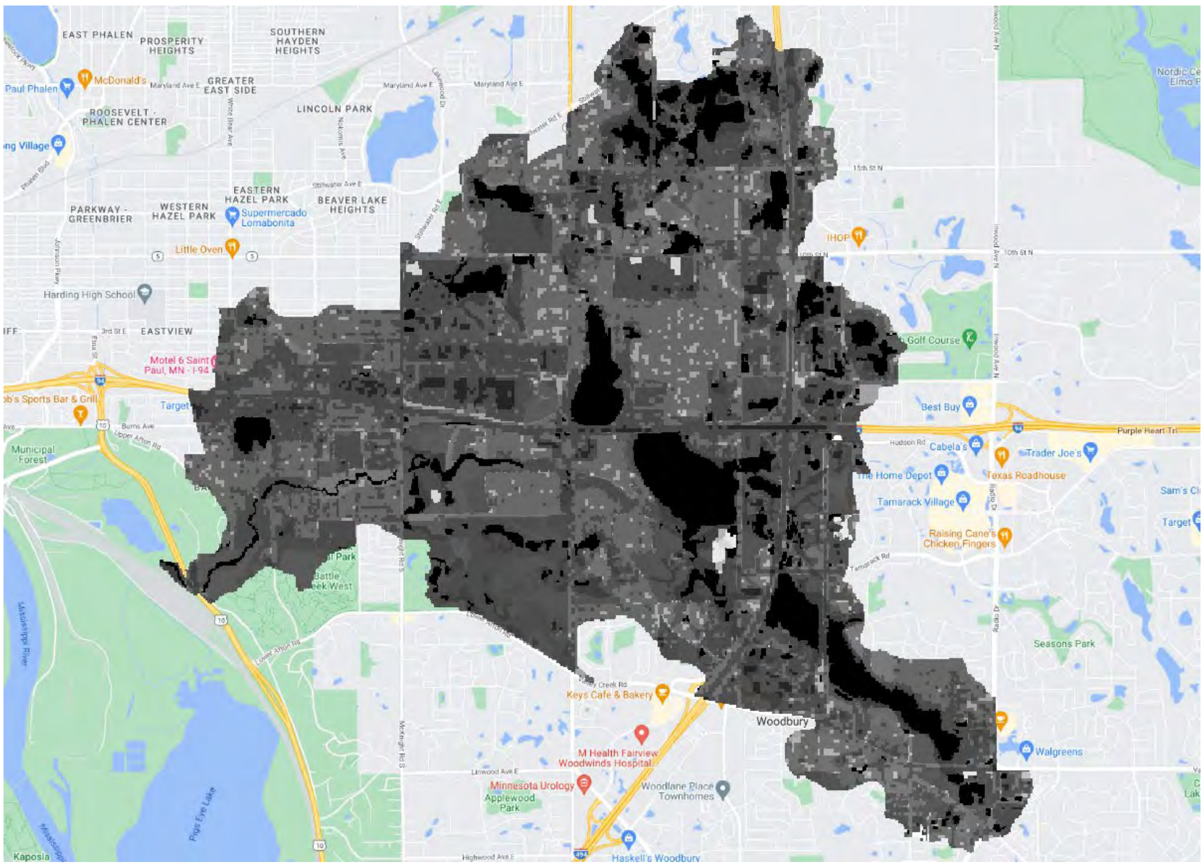
Limitations: The software is technically complex and requires a good deal of time to use competently. Additionally, each ecosystem service model (co-benefit) requires different inputs and must be run separately. The inputs necessary to evaluate co-benefits, including key assumptions and spatial data, are relatively extensive compared to other tools, putting a higher burden of data collection on the user.

Case Study: Projects utilizing InVEST software can be found on the InVEST webpage. The Urban Stormwater Retention InVEST model, Recreation InVEST model and the Blue Carbon model were applied to a study of sea-level rise adaptation strategies in the San Francisco Bay Area. The report explored impacts of different development and management strategies on urban flooding, and outlined nature-based adaptation strategies that are feasible along different stretches of shoreline.

Table 11. Metrics provided by each InVEST model, applicable to urban setting

Model Name (Service)[a]	Supply Metric	Value Metric
Urban cooling (Local heat mitigation)	Air temperature reduction (degree Celsius)	Work productivity loss (%) Energy (kWh) and cost ($) savings
Urban flood risk mitigation (Natural hazard protection)	Extreme weather runoff volume retained (m^3)	Potential avoided damage ($)
Urban stormwater runoff retention (Water flow regulation)	Annual stormwater runoff retained (mm/yr) Avoided nutrient load (kg/yr)	Avoided cost of stormwater retention ($)
Carbon sequestration & storage (Global climate regulation)	Carbon stored and sequestered (Mg) on land and in coastal areas (blue carbon)	Economic value of carbon sequestered ($)
Coastal vulnerability reduction (Natural hazard protection)	Vulnerability index based on biophysical and social factors	None
Nature-based recreationb (Recreation and tourism)	Accessible recreation areas (m2)	Number of photo-user-day (proxy for visitation intensity) Urban green space deficit and surplus (relative to demand)
Scenic quality provision (Landscape aesthetic)	Visible natural areas	Visual impact (number of points) and visual quality indices (binned into classes)
Crop pollination & honeybee forage (Pollination)	Pollinator habitat quality	Crop yield attributable to pollinators Pollinator abundance as a proxy for biodiversity
Sediment/Nutrient retention (Erosion/ Nutrient regulation)	Sediment/nutrient retained (ton/yr)	Sediment/nutrient retained (ton/yr)

Figure 21. Avoided nitrogen pollution in water runoff for sample project in St. Paul, MN. Areas of lighter gray indicate higher avoided pollutant load.



4

EPA Resources and Tools

Credit: Tyler Jones

EPA RESOURCES AND TOOLS

The US Environmental Protection Agency (EPA) has published significant resources related to the co-benefits of GSI. Some of these resources provide high level planning information and tools, while others can be used to value specific co-benefits.

Green Infrastructure Wizard (GIWiz)

https://cfpub.epa.gov/wizards/giwiz/

GIWiz provides access to a repository of EPA-sourced green infrastructure tools and resources that are designed to support community planning. The tools and resources available through GIWiz will help you analyze problems, understand management options, calculate design parameters, analyze costs and benefits, evaluate tradeoffs, engage stakeholders, and/or develop education and outreach campaigns.

GIWiz offers a list of links to research, methodology, webcasts, models, assessments, and case studies related to green infrastructure. The results shown are tailored to the user's inputs.

Avoided Emissions and Generation Tool (AVERT)

https://www.epa.gov/avert

Updated: December 2021

AVERT is a free tool that allows users to evaluate emissions displaced at fossil-fueled power plants by green energy or energy saving technologies. For green infrastructure that reduces energy required for heating and cooling buildings, such as green roofs and trees, AVERT can be used to quantify the carbon emission reduction benefits. Users enter the region as well as the amount by which energy generation will be reduced and AVERT shows the emissions reduction for seven types of pollutants. The data behind this tool is incorporated into the WRF TBL BCA Tool.

Credit: Green Infrastructure Leadership Exchange

Credit: Lesley Bertolotti

Environmental Benefits Mapping and Analysis Program (BenMAP)

https://www.epa.gov/benmap

Updated: May 2021

BenMAP is an open-source software that estimates the health impacts and economic value of changes in air quality. The value is calculated using cost of illness and willingness to pay metrics, summarizing the value of avoided hospital admissions by the reduction in cases of illness associated with poor air quality. With the BenMAP software, users can create maps showing ambient pollution levels, compare benefits associated with different programs, estimate economic values of health impacts, and characterize the benefit distribution among population subgroups. This software is relatively complex, and users would benefit from exposure to GIS software platforms prior to use.

CO-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA)

https://www.epa.gov/cobra

COBRA is a screening model that converts emission reductions into changes in air quality and estimates effects on human health. The model then compares the economic value of health benefits compared with program costs. COBRA is more sophisticated in that it supports design and selection of program options that maximize desirable air quality benefits. This tool is intended to support exploration of state, regional and national policy options that promote large-scale health benefits. Like BenMAP, the software is GIS based and relatively complex.

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Additional Resources and Tools

Credit: Matthew McDaniel

ADDITIONAL RESOURCES AND TOOLS

Green Infrastructure Federal Collaborative

Multiple Federal Agencies, 2021

https://www.epa.gov/green-infrastructure/green-infrastructure-federal-collaborative

The EPA Green Infrastructure Federal Collaborative is a cooperative effort across multiple Federal agencies that work to align knowledge and resources to build capacity for GI implementation. Eleven total agencies constitute the collaborative, including the Army Corps of Engineers, Department of Agriculture, Housing and Urban Development, Department of the Interior, and the Environmental Protection Agency. The public platform promotes knowledge and resources for GI through collaborative webcasts and links to helpful publications. Of note is a series on Water Sector GSI, which includes a presentation on Federal funding opportunities from representative agencies.

Green Infrastructure And Health Guide

Green Infrastructure Leadership Exchange, 2018

http://willamettepartnership.org/wp-content/uploads/2018/07/Green-Infrastructure_final_7_12_18_sm.pdf

This guide provides principles and best practices on how to use green infrastructure to promote health equity. It provides structures for identifying community health needs, making a business case for health intervention, engaging community input on health outcomes, siting and design questions when considering health, and evaluating health benefits of green infrastructure once implemented. The guide is very user friendly, with step by step instructions for methodologies as well as templates for promotional materials.

Equity Guide for Green Stormwater Infrastructure Practitioners

GreenPrint Partners and Green Infrastructure Leadership Exchange, 2022

https://giexchange.org/wp-content/uploads/2024/08/Equity-Guide-for-GSI-Practitioners_March-2022.pdf

The Equity Guide for Green Stormwater Infrastructure Practitioners (the Guide) is a comprehensive guide to advancing and measuring equity within public sector stormwater management organizations' GSI policies, programs, and projects. It offers an action and evaluation roadmap that defines: 1) the industry's shared long-term equity goals, 2) best practices that will move the needle, and 3) sample metrics that help track progress toward those goals over time. It also offers a variety of tools to support practitioners in customizing community-informed Equity Work Plans and Evaluation Plans to local contexts.

TAP into Resilience Toolkit

Water Now Alliance

https://tapin.waternow.org/start-implementing/#toolkit

Objective/Description: The Tap into Resilience Toolkit is designed for water leaders to navigate the financial components of implementing sustainable infrastructure in their communities. An interactive customizable platform provides guidance on tax, accounting, legal and financial questions as well as implementation techniques for scaling and investing in green infrastructure.

The Toolkit is organized into six sections: a 10-part localized infrastructure decision making framework, frontline communities module, financing options, localized water infrastructure implementation strategies, toolkit quick reference library, and an "Ask an Expert" resource.

Credit: Courtney Baxter/TNC

GSI Impact Hub

Capturing the Multiple Benefits of Green Infrastructure

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Citation: Sheridan, C., Clements, J., Odefey, J., DeSalvo, L., Ulrich, J. (2025). *Compendium of GSI Co-benefits Valuation Resources: Available Tools that Quantify and Monetize the Value of GSI Projects.* The Nature Conservancy. www.GSIImpactHub.org

For more information visit: **gsiimpacthub.org**

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