Transitioning from Gray to Green Infrastructure Systems

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Abstract

Water managers have traditionally used pipes, ponds and other gray infrastructures to divert runoff away from buildings, parking areas, and roadways. In contrast, proponents of green infrastructure attempt to manage stormwater near its origin, utilizing natural drainage pathways and best management practices (BMPs). The transition from gray to green infrastructure requires communication between managers from different disciplines. The Gray to Green (G2G) green infrastructure planning tool is designed to facilitate these conversations—showing users how BMPs can work within the urban area to manage stormwater on existing or proposed development sites. This paper details the functions of G2G and concludes with the application of the tool in a case study in Tampa, Florida.

Keywords

BMPs, green infrastructure, urban design, urban planning, urban hydrology

Introduction

Green infrastructure is gaining greater acceptance as a versatile and truly-functional urban stormwater management approach[1]. Results from studies[2,3,4] have shown that urban trees and greenspaces restore the natural hydrological cycle in urban areas, and are an important practice for flood control and water quality management. Green infrastructure provides a multitude of secondary benefits, from increasing property values[5] to decreasing human stress[6]. It also act as a stage for informal environmental education as people spontaneously engage "hands-on" with green infrastructure projects. Education related to green infrastructure can inspire interest and future action to expand green infrastructure in cities[7].

Despite the benefits, green infrastructure adoption has been slow due to lack of knowledge, reluctance to change existing practices or adapt new strategies, cost, and a lack of communication and partnerships[8]. Barriers to implementation of green infrastructure solutions will continue to exist until their effectiveness as Best Management Practices (BMPs) can be modeled and communicated by urban foresters, landscape planners, engineers, and other professionals effectively. There is a need to develop decision support tools to evaluate the performance of BMPs, adapt new strategies, and fill the gap in communication and partnerships among different disciplines.

The Gray to Green (G2G) infrastructure planning tool was developed to assist professionals associated with stormwater management visualize and communicate the importance of green infrastructure in their communities. It is a GIS-based mapping toolset for protecting green infrastructure and siting potential stormwater best management practices (BMPs). It includes a spreadsheet-based scenario analysis tool that uses information generated from the GIS tool to show the potential for green infrastructure and BMPs to capture and treat runoff for an assessed project site.

G2G Toolset Description

The G2G tools are intended to help users create and communicate a plan for green infrastructure implementation that:

- Identifies the natural pathways that contribute water to and drain water away from a site;
- Captures and treats runoff water as close to the source as possible; and
- Restores a more natural/pre-development water balance to the site.

To achieve this, G2G relies on a four-step planning process that involves (Figure 1): 1) mapping existing hydrology and green infrastructure; 2) designing and fitting a development or redevelopment project to the site; 3) selecting appropriate green infrastructure BMPs for the site, and 4) evaluating how well the project and BMPs fit the site.

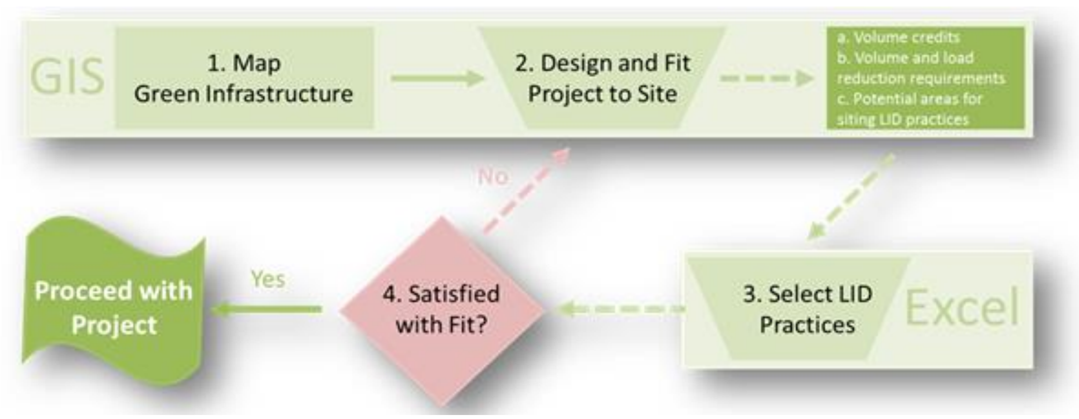


Figure 1: The four-step process facilitated by the Gray to Green (G2G) planning toolset.

The four steps are aggregated into the two main components of G2G:

- ***GIS-based Mapping and Visualization*** tool used to map existing hydrology and green infrastructure, fit a development/redevelopment project to the site, and identify potential areas for siting green infrastructure BMPs, and
- ***BMP Scenario Analysis*** tool that guides users through the process of quantifying volume and pollutant load reduction while exploring the use of different green infrastructure BMPs.

GIS-based Mapping and Visualization of Green Infrastructures

The first step in the G2G process is to map out the current site hydrology and locate existing green infrastructure elements (e.g., water bodies, wetlands, trees, and forests). The series of maps generated in this step are intended to inform siting decisions when viewing a G2G-generated map of potential green infrastructure sites allowing users to make informed decisions on how the placement of existing and potential roads/structures impact the flow of water within the project boundary. Specifically, G2G helps users generate different layers which provide critical information regarding the hydrologic connectivity of the site. These layers include riparian areas (i.e., wetland areas and waterbodies), trees/forests (i.e., tree covered areas), groundwater recharge zones (i.e., areas where water readily drains into the soil), natural (pre-development) drainage pathways (i.e., surface water flow lines derived from the site's topography), steep slopes (i.e., areas where topography limits infiltration), and pervious areas (i.e., areas within the project area that are/will not be developed).

The GIS tool determines the amount of total area potentially suitable for the placement of 11 green infrastructure BMPs (including green roofs, rainwater harvesting, pervious pavement, bioswales, rain gardens, wetlands, infiltration trenches, infiltration basins, constructed wetlands, etc.), arranged around the source of runoff. Potential areas for BMPs are based on several criteria, including land cover, building footprints, proximity to a runoff source, and slope. The GIS Tool automatically maps and generates an Excel table identifying the total potential areas for siting each LID practice. In addition to providing siting data for decision making, the green infrastructure mapping and visualization enhance the ability of professionals to interact with clients, the public and other stakeholders, and developed educational opportunity[9].

BMP Scenario Analysis

The BMP Scenario Analysis model resides in the spreadsheet-based module of G2G (developed using Microsoft Excel Visual Basic Application). This model uses the outcomes of green infrastructure mapping to estimate stormwater runoff volumes and pollution loads given expected rainfall. Expected rainfall can be user-defined, if known. Alternatively, the values for a range of 24-hour storm events (2-year, 10-year, 25-year, 50-year or 100-year) can be referenced from a series of rainfall isohyetal maps (United States) included with the tool[10]. The stormwater runoff is calculated the SCS Runoff Curve Number method developed by the United States Department of Agriculture[11]. The resulting calculated stormwater volumes are then used to estimate nutrient pollution loads for the site based on published event mean concentration (EMC) values[12,13].

The scenario analysis tool guides users through the process of quantifying volume and pollutant load reduction while exploring the use of different green infrastructure BMPs. This process begins with volume and load reductions at the site structures and continues to the roads/parking lots and surrounding pervious areas.

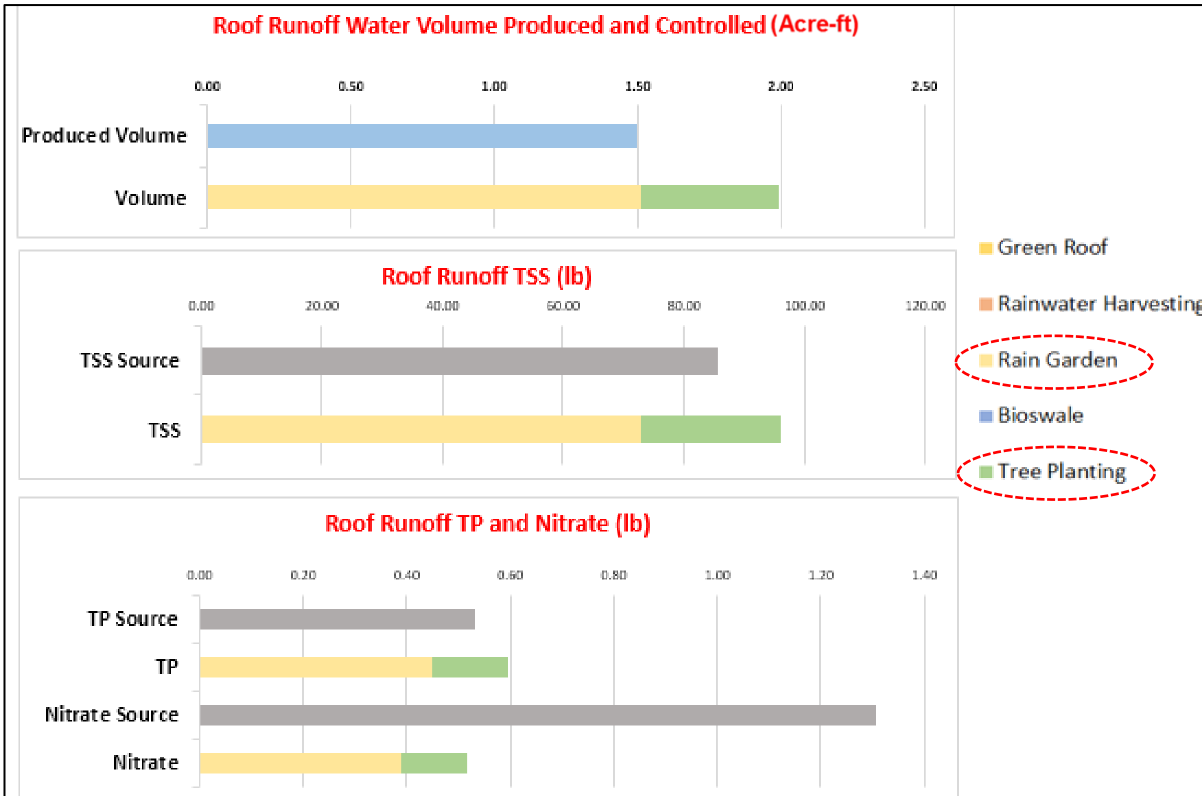
In addition to numeric estimates of runoff volume and load reductions associated with each BMP, the Scenario Analysis model automatically generates bar charts showing the relative reductions of runoff volume, total suspended solids, phosphorus, and nitrate-nitrogen loading for each BMP. It also automatically generates a table showing the ecosystem benefits (qualitative) associated with each of the selected BMPs. These elements are included in the final reporting output, which also includes a green infrastructure map showing the potential areas suitable for siting the selected BMPs and a summary table showing the percent of rainfall captured by the selected BMPs.

Case Study Application, Tampa, Florida

The G2G green infrastructure planning tool was applied to analyze a sub-basin area that drains towards Frierson Pond in Tampa, FL. The tool was used to evaluate alternatives to expanding an existing stormwater retention pond to relieve acute and chronic flooding in an approximately 12.55 ha (31.01 acres) closed drainage basin with no known outfall (Figure 2). The initially proposed pond expansion, which would require the acquisition and demolition of 12 homes and the closing and demolition of a public road, was expected to increase the flood level of service to something less than a 2-year, 24-hour design storm (approx. 5 inches of rain in 24 hours).

Figure 2: Photos showing the area of flooding in Tampa, Florida.

The BMP scenario analysis tool is used to estimate the amount of runoff that could be captured using different BMPs (the second component of G2G planning toolset). Our analysis of a 2-year, 24-hour storm (12.70 cm/5 inches of rain) with the tool shows that 100% of the roof and parking runoff could be captured using green infrastructure BMPs. Best management practices could also capture 61% of the pervious runoff from the site. The performances of rain gardens and trees for the roof runoff are shown in Figure 3. Unlike the pond expansion, this option would not require the acquisition and demolition of 12 homes or the closing and demolition of a public road.



LID Practice	Volume Controlled	Ecosystem Benefits: Water Management	Energy Usage	Air Quality and Co2	Urban Heat Island	Habitat and Greenspace	Social Benefits
Green Roof	0.00%						
Rainwater Harvest	0.00%						
Rain Garden	100.54%	•	•	•	•	•	•
Bioswale	0.00%						
Tree Planting	32.26%	•	•	•	•	•	•

Figure 3: Estimated pollutant load reductions and other ecosystem benefits from roof runoff for selected BMPs for the 2-year, 24-hour design storm.

As shown in Figure 3, the scenario analysis tool estimated that 100% of the total suspended solids (TSS) and total phosphorous (TP) coming from the roof runoff would be captured with the combination of rain gardens and tree plantings selected. These BMPs were projected to reduce nitrate loads by a little less than 40%. Additionally, the tool automatically generates a table showing the ecosystem benefits (qualitative) associated with each of the selected BMPs. This case study explored how simple visualization can be used to communicate impactful and compelling evidence that green infrastructures provide water quality and quantity, and other ecosystem benefits. The complete G2G toolset, user guide, and training videos can be accessed on the project website at https://gray2green.jimdo.com.

Conclusion

Green infrastructure has the potential to provide stormwater managers with flexible, effective, and benefit-providing solutions for managing storm events. In transitioning from a gray to green infrastructure and a more integrated approach to managing stormwater, professionals need to be able to communicate their specific needs and goals effectively. G2G, as a planning tool (not a design tool), attempts to facilitate this communication—providing users with maps for visualizing the existing hydrology of a site and the potential placement of BMPs. Moreover, users can quickly estimate the impact of these BMPs on controlling stormwater volume and nutrient loads.

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