Is It Worth the Green?

Assessing the Value of Green Stormwater Infrastructure Using Triple Bottom Line Analysis

PIA 2125: City Region Theory and Practice

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Executive Summary

Urbanization and land development alter the landscape and increase impervious surfaces. Parking lots, sidewalks, and other paved areas prevent rainwater infiltration and increase stormwater runoff. This water carries harmful pollutants into nearby waterbodies. One approach to solve this problem is to supplement gray infrastructure with green stormwater infrastructure (GSI). This involves a natural system that manages stormwater, reduces the risk of floods, captures pollution, and improves water quality. Assessing the value of green infrastructure using a Triple Bottom Line Analysis (TBL) measures the benefits in a comprehensive way, from an environmental, economic and social perspective.

Nine Mile Run Watershed Association (NMWRA), a local nonprofit in Pittsburgh, Pennsylvania, aims to effectively communicate GSI benefits to local residents, using a TBL framework during Phase I of their Rosedale Runoff Reduction Project (RRRP). This report explores the TBL procedure and its relevance to the NMRWA. The following sections address the environmental, economic, and social benefits and if TBL is the best way to analyze the benefits for NMRWA.

Environmental impacts are fairly straightforward to analyze; however, it can be difficult to attribute the economic and social benefits solely to the GSI or the surrounding environment. Additionally, the scale of GSI projects greatly impacts the magnitude of the quantitative results from a TBL analysis. Smaller projects yield lower quantities that may not effectively communicate the benefits of these projects. However, it is still critical to communicate environmental, economic, and social benefits that green infrastructure could contribute to a community; a potential that gray infrastructure lacks. This report creates a foundation for future research and the potential to build a tool that quantifies the benefits of green infrastructure.

Introduction

The Problem: Evaluating the Benefits of Green Stormwater Infrastructure

As many communities around the United States strive to increase sustainability and resilience, alternative methods are being explored to solve common urban problems, for instance utilizing green infrastructure to help combat stormwater overflow. Traditional methods of analyzing the effects of GSI, such as a cost benefit analysis, only speak to numerical quantities and doesn't consider all benefits. A TBL framework is a comprehensive approach to assessing the value that GSI presents within a community, taking into consideration three attributes: environmental, economic, and social.

Pittsburgh, Pennsylvania is a community that is struggling with stormwater runoff, which is one of the largest causes of water pollution in urban areas. Water is unable to be absorbed by impervious surfaces (rain falls on roofs, the pavement) and travels through storm sewers carrying trash and pollutants that is discharged into water bodies. Large runoff volumes inundate pipes, leading to sewer overflows, which can cause erosion and flooding in urban streams, causing environmental and infrastructure damage (EPA, 2017).

The Nine Mile Run Watershed Association, a Pittsburgh nonprofit, is involved with reducing the amount of stormwater overflows in their community. To achieve this task, they are implementing GSI for their Rosedale Runoff Reduction Project. NMRWA is looking to assess the benefits of GSI to the community by using the TBL framework.

In order to better communicate the benefits of these projects, the following pages will assess the impacts of green stormwater infrastructure. This paper will discuss the differences between grey and green infrastructure and will define triple bottom line analysis as an approach to measure the benefits of GSI, reviewing environmental, economic, and social impacts.

Background Information

Pittsburgh Practices

Pittsburgh, Pennsylvania implements a combined sewer system, which transports sewage and stormwater by the same pipe. During wet weather, stormwater overflow creates situations where sewage flows untreated into nearby streams and rivers. Combined Sewer Overflows (CSOs) are regulated under a Combined Sewer Overflow Control Policy by the United States Environmental Protection Agency (EPA) (EPA, 2016). Currently, the Allegheny County Sanitary Authority (ALCOSAN), which serves 83 municipalities in the Pittsburgh area, is under a consent decree with the EPA due to the volume of CSOs, which exceeded the federal limit, in the Pittsburgh region. ALCOSAN is currently implementing a plan to address the consent decree using a combination of gray and green infrastructure to reduce CSOs.(Hopey, 2016). The NMRWA is implementing green infrastructure within their own community to reduce sewage overflow to their watershed.

Grey vs Green

Green infrastructure is used to compliment grey infrastructure. Grey infrastructure, commonly referred to as sewer systems (including CSOs), includes the use of ditches, pumps and other engineered resources used by urban areas to manage stormwater runoff (SSA, 2017), running them through pipes, and later moved to a treatment plant before being discharged into water bodies.

The costs of implementing, maintaining, and upgrading grey infrastructure are high, including the necessity of skilled workers and firms that are not necessarily local. Also, there are associated negative externalities not factored into cost benefit analysis (i.e. increased carbon emissions, threats to natural habitats, and overall quality of life).

Whereas grey infrastructure uses cement, steel and other materials, a natural alternative to contribute to water management is green infrastructure (GI). The American Planning Association (2008) defines green infrastructure as an "interconnected network of open spaces and natural areas that naturally manages stormwater, reduces the risk of floods, captures pollution, and improves water quality". Green Stormwater Infrastructures constitutes various strategies that aim to manage storm precipitation, preventing them from going directly to the sewage system (Maimone, M., *et al*. 2011).

GSI, also known as Low Impact Development (LID), intercepts stormwater, managing a portion of it into the ground, into the air, and usually a small portion into the sewer system, recreating the natural water cycle in a dense urban area (Econsult Solutions, 2016), helping decrease runoff pollution between 30 and 90 percent (Wise, S., 2008). It implies the use of a natural system, open space, and also some manufactured solutions (i.e. permeable pavement), in order to manage stormwater runoff in urban areas (Maimone, M., *et al*. 2011). This approach may also include tree planting, green roofs, rain gardens, etc (Wise, S., 2008).

Since green infrastructure relies on a natural system, it reduces and treats stormwater at its source and reduces the amount of rainwater and pollution of effluents into rivers, lakes and bays, and other ecosystem benefits (McEwen B., et al, 2013). GSI implementation can capture stormwater from surfaces, increasing rain infiltration, reducing stormwater runoff, and flooding (MSSD, 2013).

However, implementing green infrastructure does not replace the use of grey infrastructure. Grey infrastructure has expanded to meet the growing demands of urbanization (SSA, 2017) and is required to guarantee quality drinking water through their treatment plant, and for high volume water treatment in small areas (AWP, 2017). Thus, affecting hydrological processes such as runoff and infiltration using green infrastructure can act as complement or supplement of “grey” (UNEP, 2014) and be an important strategy that can help mitigate urban stormwater impacts (EPA, 2012).

Cities like Philadelphia, New York City, and Milwaukee are using green infrastructure as a complement of grey infrastructure, supplementing its traditional storage and treatment capacity (EPA, 2012).

Green infrastructure is a relatively new concept, there are multiple variables that may affect its effectiveness in the long run (i.e. climate change, extreme weather events), and therefore the predictions of its benefits in the long run is subject to inherent variability and demographic factors (EPA, 2012). However, implementing green stormwater infrastructure brings multiple benefits for the environment, but it also has an economic and social impact, which can improve communities’ welfare in a holistic way, that can be identified, measured and valued, which gray infrastructure does not provide.

Nine Mile Run Watershed Association

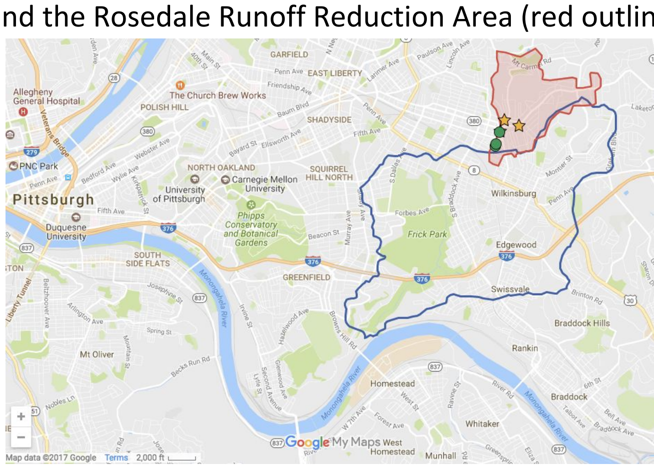
NMRWA is located in Wilkinsburg, Pennsylvania, and is an advocate for the Nine Mile

Run Watershed, a 6.5 square mile urban watershed located in the East End section of Pittsburgh. With community engagement NMRWA uses a variety of urban ecology projects to protect and revitalize the watershed. One project of NMRWA is reducing CSOs to the Nine Mile Run area, the current focus for this project is at an overflow that occurs at a confluence of pipes on Rosedale Street, north of the Port Authority's East Busway Wilkinsburg Station (NMRWA, 2017). Sewage is supposed to flow in the direction of the Allegheny River and to ALCOSAN to be treated, however during wet weather, stormwater mixes with sewage and flows into the culvert of a Nine Mile Run Tributary, which then flows into Nine Mile Run in Frick Park (NMRWA, 2017). To combat this overflow and pollution of Nine Mile Run, NMRWA is working on the RRRP.

Rosedale Runoff Reduction Project - Phase I

The RRRP is a 1.15 square mile area located in Homewood, East Hills, and Penn Hills of Pittsburgh, Pennsylvania, and is a holistic sustainable stormwater project with the mission to remove 25 million gallons of sewage overflow into Nine Mile Run every year.

Map 1: Map of Nine Mile Run Watershed Association Watershed Boundary (blue outline) and the Rosedale Runoff Reduction Area (red outline).



Source: NMRWA, 2016

The RRRP will occur in several stages; Phase I's objective is to reduce the stormwater runoff to Nine Mile Run by 20 to 25 percent by utilizing green stormwater infrastructure. Throughout the RRRP process, NMRWA has engaged the community, partnering with Operation Better Block, East Tri-Borough Neighborhood Association, East Hills Consensus Group, Homewood Children's Village, and Penn Hills Community Development corporations (NMRWA, 2016). Operation Better Blocks' Junior Green Corp, a program for youth to participate in activities that promotes leadership, community, and opportunities to experience green collar jobs, was involved with the clearing of vacant land as part of a large infrastructure project for Phase I (Operations Better Block, 2017 & NMRWA, 2016). The Community Project Advisory Group, consisting of stakeholders, elected officials, residents, community leaders and partners, was established in 2015 to assist NMRWA throughout the RRRP Process (NMRWA, 2016). NMRWA attended many meeting and worked with stakeholders to ensure that the community was engaged and participating during the design, construction, outreach, and monitoring of the RRRP (NMRWA, 2016). Phase I of the RRRP has already started and includes: three large green infrastructure projects, installing 40 storm water management tree pits, 10 rain gardens, and 200 rain barrels through the Rosendale Runoff area (NMRWA, 2016). The three large stormwater infrastructures include: the Oakwood-Batavia Site, Crestwood Early Childhood Center, and the Frankstown Avenue and Wheeler Street Site.

The Oakwood-Batavia Site, completed in the fall of 2016, is located at the intersection of Oakwood Street and Batavia Street in the neighborhood of East Hills. Besides stormwater management this site is also being used as the beginning of beautifying and improving an adjacent vacant lot, which the community is trying to purchase to continue to improve the quality of the land in this neighborhood. This site, built with a total cost of $232,000 for design and construction, is expected to capture annually 700,000 to 17 million gallons, which is approximately 2.8% to 68% of the total stormwater runoff for the RRRP (NMRWA, 2016). The Oakwood-Batavia Site consists of green infrastructure that includes bioswale bumpouts, green gutters, water management tree pits, and an underground storage system (NMRWA, 2016). . Operations Better Block, Junior Green Corp, participated in assisting in cleaning up the vacant lots prior to the construction of the green infrastructure.

The Crestwood Early Childhood Center, the majority is completed, however curb cuts need to be made for runoff to flow into the constructed rain garden, is located at the corner of Bennett Street and Tokey Street in the Pittsburgh Neighborhood of East Hills. The Pittsburgh Public School is located at the bottom of a steep hill where water runoff runs down Tokey Street. This site, built with a total cost of $117, 815 for design and construction, is expected to capture annually 325,000 gallons , which is approximately 1.3 % of the total stormwater runoff for the RRRP (NMRWA, 2016). The Crestwood Early Childhood Center site uses curbcuts to funnel the overflow of Tokey Street into a large stormwater tree pit that is located in front of the school. The tree pit has an underground storage system to capture runoff during large rain events. Not only will the site be used to help control water overflow during rain events, but it is planned on being used as a teaching tool for the students at the Pittsburgh Public School.

The Frankstown Avenue and Wheeler Street Site, which has yet to be built, is located in a neighborhood business district of Pittsburgh. This site, which will cost approximately $170,000 for design and construction, is expected to capture annually 650,000 gallons, which is approximately 2.6% of the total stormwater runoff for the RRRP (NMRWA, 2016). The site is located at the bottom of a steep hill, Wheeler Street, the lot is owned by Lamar Signs and is to be gifted to Operations Better Block for community revitalization. The site will then be maintained by the Junior Green Corps. The site will consist of stormwater tree pits that will direct the overflow to rain gardens with underground storage that surround the existing billboard.

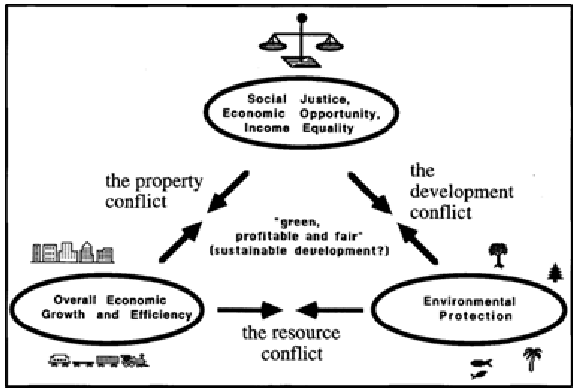
Tree pits are implemented in the large green infrastructure projects and will be located in other locations within the RRRP boundaries, including Rosedale Street and Oakwood Street. Eight residential rain gardens, three in Penn Hills and five in Homewood, and a commercial rain garden, at the Homewood North Family Investment Center, will be installed. In addition to the residential gardens being installed free of cost, a grant from PA Grow Greener to NMRWA allowed 200 rain barrels to go to residents in the Homewood, East Hills, and Penn Hills areas to involve homeowners in the reduction of sewer overflow (NMRWA, 2016).

What is a Triple Bottom Line Analysis?

To understand what a triple bottom line (TBL) analysis is, it is necessary to incorporate the concept of sustainability, which implies the satisfaction of present needs without preventing future generations to satisfy their own (UN, 1987).

These needs can be summarized in three areas that are mutually dependent, but also are in permanent strong conflict: environmental, economic, and social (Campbell, 1996). Considering these three challenging areas and implementing complementary uses in the planning process, contributes to create green, growing, and just cities (Campbell, 1996).

Figure 1: Sustainability Triangle



Source: Campbell (1996)

Economic growth is the measurement commonly used as an approach to determine a society's welfare. However, per capita income is not a complete reliable indicator of well-being, since there are aspects that influence population's welfare that cannot be measured with per capita income. Features like air and water quality, wage distribution, employment rate and poverty, safety, education, and health are characteristics that affect welfare. These factors can be more difficult to identify, measure and value, but that also make an evidence that economic growth is an incomplete assessment of welfare or development.

Thus, triple bottom line analysis is an accounting framework that incorporates economic, environmental and economic areas of performance (Slaper., T. F. and Hall., T. J. 2011). This approach is comprehensive and aims at measuring the main values of an investment more accurately (Hammer, J. and Pivo, G. 2017), including environmental and social benefits, which are usually excluded from traditional analysis that focus only in the economic dimension. Hence, a TBL framework allows to measure sustainability, from these three dimensions of performance (Slaper., T. F. and Hall., T. J. 2011), which are usually called the three P's, as for people, profit and planet. This approach can be used by different businesses, nonprofit organizations, and the government, considering the principles of sustainability, though the outcomes for the three dimensions may differ (Slaper., T. F. and Hall., T. J. 2011).

Is TBL a good approach to measure GSI?

Measuring the values of an investment in a comprehensive and integrated way is important because allows to see the complete portrait of the impacts generated (Slaper., T. F. and Hall., T. J. 2011). Quantifying benefits using a TBL framework may not be as simple as other methodologies can be, since the dimensions do not have the same unit of measure (Slaper., T. F. and Hall., T. J. 2011). However, when implementing green infrastructure, a TBL can be a good approach.

Implementing green infrastructure brings multiple benefits, as mentioned earlier, and quantifying those benefits considering the economic, environmental and social dimension maximize the return in the investment (Tetra Tech, 2013). Moreover, a TBL analysis framework provides a meaningful accounting of the values that contribute to social and environmental dimensions, including nonmarket outcomes (Neukrug, H. 2009). Thus, a TBL framework gathers comprehensively the benefits that can be communicated to the community (Neukrug, H. 2009).

Cities like Philadelphia, New York City, and Milwaukee have implemented GSI for a considerable amount of time, and that has allowed communities to see a more tangible effect of the benefits in the economic, social and environmental area, using a TBL framework. Therefore, taking into consideration the scale and period of implementation is crucial, since benefits are more likely to be measured in the long run.

Milwaukee's TBL approach was based on a literature review and relevant studies. Indicators were chosen for each dimension, and for each indicator key methods and assumptions were determined to quantify the benefits. (Tetra Tech, 2013). This approach included report of cumulative benefits using over a 20-year horizon and applied to 600-acre pilot area. In Philadelphia, the approach was similar, though the time path is 40 years and included a sensitive analysis to see effects of slight changes in the outcomes (Tetra Tech, 2013). As for New York City, the Department of Environmental Protection (DEP, 2015) studied the expansion of the current green infrastructure program using a TBL approach, which incorporated literature review, pilot monitoring, life-cycle analyses and development of comparison tools.

The benefits of implementing green stormwater infrastructure are described below by each dimension. Since the Rosedale Runoff Reduction Project is a community based project, the benefits analyzed that are more pertinent for the community are not necessarily the same for big cities that have implemented GI.

Triple Bottom Line Components

Environmental Benefits

Introduction

Environmental benefits is one of the components of a triple bottom line analysis and arguably the easiest of the three to measure. There are direct and indirect benefits captured by hard quantities such as reduced runoff volume, improved air quality, and decreased energy use.

The following section summarizes the environmental benefits of green stormwater infrastructure, discusses methods for measuring the benefits, and looks at a case study done by the New York City Department of Environmental Protection.

What are the environmental benefits of GSI?

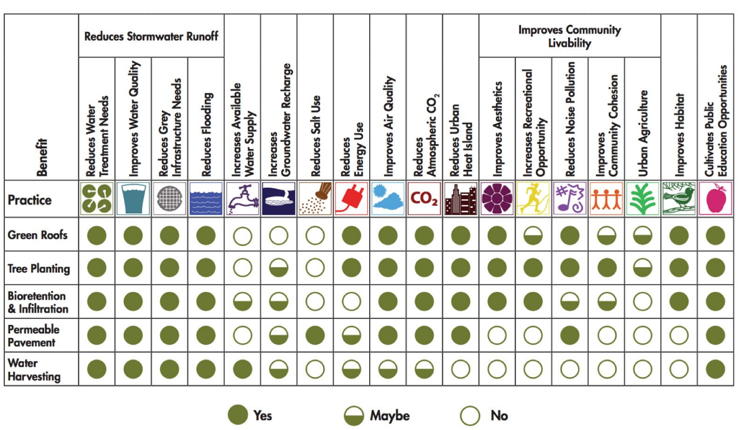
The United States Environmental Protection Agency (EPA) recognizes several benefits from green stormwater infrastructure such as improved water quality, air quality, climate resiliency, habitat and wildlife, and urban livability (EPA 2017). In urban areas, surface runoff carries pollution into nearby streams, lakes, and other bodies of water. Erosion can destroy animal habitats and compromise slope stability. In cities like Pittsburgh, combined sewer systems release untreated sewage into rivers when flow rates exceed the system's capacity. This typically happens during storm events, but can occur in the absence of a storm as well, known as sewer overflows (SO). Rain gardens, bioswales, green roofs, and other green stormwater infrastructure (GSI) mimic natural infiltration processes and capture stormwater runoff before it enters surrounding bodies of water or sewer inlets. As a result, there are fewer combined sewer overflows (CSO). Additionally, capturing stormwater minimizes runoff, and reduces the amount of pollution and sedimentation carried into nearby streams, fostering the growth of native plants and animals. Vegetation provides a habitat for birds and insects, and large scale green infrastructure like urban forests promotes habitat connectivity, allowing animals and wildlife to move throughout an urban area and coexist with people. Green areas are aesthetically pleasing and provide attractive spaces for recreation and activity. GSI reduces urban heat island through the process of evapotranspiration and trees provide shade to help cool the surrounding environment. Plants and trees absorb CO_2 and remove particulate matter from the air. By implementing GSI, natural processes work to clean the air and water while also beautifying the surrounding landscape.

Green infrastructure implementation is part of a larger movement to rethink the way we live and interact with our environment. Cities all over the world are striving for climate resiliency and are looking towards implementing GSI to help achieve this goal.

How do we measure the environmental benefits?

The Center for Neighborhood Technology (CNT 2010) put forth a guide to quantify GI benefits in urban areas. It is difficult to compare the costs and benefits of gray and green infrastructure without accurately quantifying all the benefits associated with GI, including environmental benefits that may be difficult to measure. GI elements included in the guide are green roofs, tree planting, bioretention, permeable pavements, and water harvesting. Benefits include reduced stormwater runoff, decreased energy consumptions, improved air quality, and overall greater resilience to climate change. The chart below shows the type of GI and associated benefits.

Figure 2: Green Infrastructure Benefits and Practices
Source: Center for Neighborhood Technology 2010 pg. 3



Green Roofs

Green roofs contain a medium (typically 2-6 inches deep), vegetation, and some type of waterproofing to prevent leaking into the building. Some green roofs can have irrigation systems or drainage features but most act as natural vegetation, storing water in the growth media that will eventually evaporate away or be transpired by the plants. If the growing media has a depth of 2-6 inches, it is referred to as an extensive green roof. If the media depth is greater than 6 inches, it is an intensive green roof.

During cold months, green roofs help to insulate a building and keep heat from escaping. Green roofs provide more effective insulation than conventional roofs. During warm months, the water retained in the growth media lowers roof temperature and keeps the building cool. Roofs with cooler temperatures affect the surrounding temperature and help to reduce urban heat island effect.

There is a cascade of environmental effects resulting from green roofs –reduced energy consumption decreases electrical use and thereby electricity generation. Electricity generation releases carbon dioxide as a byproduct. Reduced electrical demand, decreases the amount of CO2 released into the atmosphere. Green roofs absorb air pollutants and reducing smog. Smog forms when volatile organic compounds VOCs and nitrogen oxides react. The reaction occurs in warm temperatures, so the cooling effects of green roofs help slow the reaction rate. The vegetation also serves as a sound barrier to minimize noise pollution.

Green roofs possess a number of social benefits including recreational opportunities, urban agriculture opportunities, and educational opportunities. They are aesthetically pleasing and improve community livability.

The benefit assessment of a single green roof includes four benefit categories –water, energy, air quality, and climate change. Each benefit category requires two steps.

Step 1: Benefit Quantification

Step 2: Benefit Valuation

The benefit quantification includes resource units such as stormwater retained [gal], cooling (electricity) savings [kWh], heating natural gas savings [Btu], off-site water treatment electricity savings [kwH], direct NO2 uptake [lbs NO2], indirect reduction in NO2 emissions [lbs NO2], indirect benefit from electricity and heating natural gas savings [lbs CO2], and direct carbon sequestration benefit [lbs CO2].

The benefit valuation takes the quantities (resource units) developed in step 1 and multiplies them by a price. For example, the unit price of treating 1 gallon of wastewater and stormwater is $0.0000919. This unit price value is the marginal cost of treatment for the Metropolitan Water Reclamation District of Greater Chicago. The Nine Mile Run Watershed Association does not have any green roof projects at the moment, but the the important thing to take away is the method by which is used to calculate the benefits. Again, this includes quantifying the benefit (“Benefit Quantification”) and then evaluating the benefit (“Benefit Valuation”) by multiplying by a cost saving amount.

Tree Planting

Tree planting has multiple benefits. Tree tops can shield the soil and minimize erosion during rainfall events. The leaves intercept raindrops and reduce surface water ponding. Trees recharge aquifers and improve the overall health of the watershed. They provide shade and release water into the air which can minimize urban heat island effects. They also reduce heating needs in cold windy areas by acting as wind barriers. Trees also clean the air by absorbing pollutants such as NO2, SO2, and O3 and reduce carbon dioxide through direct sequestration. Trees provide habitats for animals, promote food foraging, reduce noise pollution, and beautify communities. Trees planted along corridors increase safety by promoting traffic calming. Additionally tree planting can serve as an educational tool for green infrastructure and encourage sustainability.

Following the same process defined for green roofs, the benefit assessment of a single tree falls under four benefit categories (water, energy, air quality, climate change) and for each category, there are two steps.

Step 1: Benefit Quantification

Step 2: Benefit Valuation

The method includes quantifying resource units and then multiplying that by a unit price. The water benefits from tree planting are quantified by gallons of rainfall intercepted. In order to calculate this, tree type and size must be known. Different trees will have different leaf sizes which affect how much rainfall is intercepted and the evapotranspiration rate of the leaves.

Energy benefits from tree planting include reduced heating and cooling needs. Electricity generation for cooling and natural gas for heating translates to [$/kWh] in electrical savings and [$/kBtu] in natural gas savings. Climate zone and tree location relative to the building play an important role in energy savings from tree planting. Trees providing shade and cooling air temperature in already cold areas may increase heating demands. In order to maximize energy savings, trees should be planted opposite to the west facing wall of a building. The next most strategic location is opposite the south facing wall, and then opposite the east facing wall. Tree planting induces energy savings from reduced water treatment. Calculating the volume of water captured and prevented from entering treatment facilities, yields a numerical value of [gallons]. Taking this number and multiplying it by a treatment plant consumption rate [kWh/gallon] will yield the energy savings [kWh]. To avoid double counting, benefit quantification of reduced energy consumption from water treatment does not receive a monetary valuation at this stage. It will be later valued in the air quality and climate change categories. Air quality benefits are defined in terms of lbs of pollutant uptake. The table below illustrates the pollutants removed by tree type and size, as an example.

Figure 3
Source: Center for Neighborhood Technology, 2010

Annual Criteria Pollutant Reductions (uptake and avoided) from 1 tree, 40-year average, Midwest Region

	Small tree: Crabapple (22 ft tall, 21 ft spread)	**Medium tree: Red Oak** (40 ft tall, 27 ft spread)	**Large tree: Hackberry** (47 ft tall, 37 ft spread)
NO_2 Uptake and Avoided	0.39 lbs	0.63 lbs	1.11 lbs
SO_2 Uptake and Avoided	0.23 lbs	0.42 lbs	0.69 lbs
O_3 Uptake	0.15 lbs	0.2 lbs	0.28 lbs
PM-10 Uptake and Avoided	0.17 lbs	0.26 lbs	0.35 lbs

Source: McPherson, E. et al. 2006

Tree planting provides direct and indirect benefits for air quality and climate change. Direct benefits include pollutant uptake and carbon sequestration. Indirect benefits result from reduced power plant emissions.

Another useful resource for quantifying tree benefits is Open Tree Map (OpenTreeMap, 2011). The online tool allows users to enter different tree species, and it calculates annual savings in terms of energy and air quality. Below is an evaluation of the NMRWA Oakwood Batavia Project using the Open Tree Map database. The table shows annual benefits from tree planting. Rain gardens and bioswales were not included in the evaluation.

Table 1: Oakwood Batavia Project Annual Savings from Tree Planting

	QTY	SAVINGS($)
ENERGY CONSERVED	521 KWH/YEAR	$27.00
STORMWATER FILTERED	376 GAL/YEAR	$-
AIR QUALITY IMPROVED	1 LBS/YEAR	$4.00
CARBON DIOXIDE REMOVED	141 LBS/YEAR	$-
CARBON DIOXIDE STORED TO DATE	64 LBS	$-
TOTAL ANNUAL BENEFITS		$31.00

Bioretention and Infiltration Practices

Bioretention, permeable pavements, and water harvesting all work to capture and reduce runoff volume. The volume of runoff retained depends on site characteristics such as maximum ponding time (the rate that the soil can absorb water), temperature, rainfall intensity, and land topography. Information necessary for benefit quantification includes square footage of green infrastructure, depth of area (for bioretention), contributing runoff drainage area, average annual precipitation (inches) and expected percent of retention. The benefit is measured in gallons of runoff reduced annually. NMRWA has several projects that incorporate tree pits and rain gardens. The data intensive method described by the Center for Neighborhood Technology can be used for quantifying long term environmental benefits, and quicker, easier techniques like utilizing an online data source such as Open Tree Map might be beneficial for educational purposes and teaching the public about GSI and the environmental benefits. INTERACTIVE

NYC DEP Pilot Monitoring Program

The NYC Pilot Monitoring Program (NYCDEP 2012) measures the effectiveness of tree pits, blue roofs, green roofs, detention ponds, porous pavements, and bioretention facilities. Measuring devices record runoff rates, runoff volumes, water quality, and soil quality. Starting in 2010, over 30 projects were monitored. The results from the pilot projects indicate that the GI types have been effective in stormwater management, especially for storms with 1 inch or less of rainfall. Results also revealed deficiencies and areas of concern. Curb cutouts without depressions allowed up to 30% of runoff to bypass. Plants species need to be resilient in order to survive extreme weather conditions. For the Pittsburgh area, plants should be able to endure the winter. Those with longer roots function more efficiently. Maintenance requirements include removal of trash and debris at inlets, and regular weeding.

The NYC DEP also developed a scaled-up version of their pilot monitoring program to evaluate GI benefits on a neighborhood level, referred to as Neighborhood Demonstration Area Projects (NYCDEP 2012). Combined sewer tributary areas included Hutchinson River (Bronx), Newton Creek (Brooklyn), and Jamaica Bay (Brooklyn). Bioswales, greenstreets, and GSI were constructed in the three neighborhoods. Wet weather flow was monitored and recorded before and after GSI implementation. The design goal was to manage the first inch of rainfall over 10 percent of the impervious surfaces for the three study areas. Results indicated that the design goal was met and GSI managed the first inch of rainfall for over 14 percent of the impervious surfaces for all 3 study areas. Additionally, GSI reduced runoff volume entering the combined sewer system by at least 20 percent. The results of the study are summarised below.

Hutchinson River Demonstration Project

GI Constructed: 22 bioswales

Tributary Area: 24 Acres

Design & Construction Costs: $545,000

Jamaica Bay Demonstration Project

GI Constructed: 29 bioswales, 2 stormwater greenstreets, and 2 permeable pavement retrofits at NYCHA's Seth Low Houses

Tributary Area: 23 Acres

Design & Construction Costs: $1.3 million

Newtown Creek Demonstration Project

GI Constructed: 19 bioswales, and 3 biortention areas and 1 subsurface retention system at NYCHA's Hope Gardens Houses

Tributary Area: 20 Acres

Design & Construction Costs: $1.4 million

Source: NYCDEP 2012
URL:http://www.nyc.gov/html/dep/html/stormwater/neighborhood_demonstration_area_projects.shtml
http://greenvalues.cnt.org/calculator/calculator.php

NMRWA can refer to the quantification methods described by the Center for Neighborhood Technology and to monitoring techniques implemented by the NYCDEP to their projects. It could be beneficial for NMRWA to take before and after measurements to further communicate the changes and benefits that resulted from GSI projects.

Economic Benefits

Introduction

Economic impacts are easier to identify, measure and value in bigger investment decisions, building projects or programs that aim to increase the supply or demand, having a direct effect on GDP, labor market and taxes (Slaper., T. F. and Hall., T. J. 2011). However, the provision of environmental services provides economic benefits that are more difficult to identify, measure and usually are more tangible in the long run.

Cities that have implemented green infrastructure have been able to assess its economic impact and quantify its benefits after a few years of implementation using a triple bottom line framework. For example, during its first five years, the "Green City, Clean Waters" program, which consist in the implementation of GSI throughout the City of Philadelphia, has proved that green infrastructure provides multiple economic benefits, including increase of property values, job creation and increase in tax revenue, with a contribution of $1 million annually in local taxes (SBN, 2016).

Thus, it was estimated that the overall increase of a property value that is proximate to a GSI feature is 10.3% (SBN, 2016). Further, studies in Philadelphia also showed that runoff management by using green infrastructure can contribute to reduce property stormwater bills in about 80% (SBN, 2016). In terms of job creation, there is current support of 430 local jobs from green stormwater infrastructure, which helps decrease unemployment rate and reduce poverty, since there is an opportunity to hire unskilled laborers for landscaping and restoration jobs (Sustainable Business Network, 2016). Finally, The situation of New York City is quite similar. Green infrastructure implementation contributes to generation of jobs (operation or maintenance) for local workers who otherwise would have been unemployed and underemployed. Also, it reduces stormwater treatment needs, which contributes to lower maintenance and energy costs saving (CCAP, 2011).

In Milwaukee, the analysis of GSI benefits was based on literature review, considering long run impacts (20-year horizon) and applied to a 600-acre pilot area. Job creation, infrastructure and pumping cost reduction, and increase of property values are the main indicators for economic benefits identified (MSSD, 2013).

Impact on job creation is considered due to the permanent maintenance needed for GSI, which does not necessarily require skilled labor, creating employment opportunities for unqualified people who seek employment, contributing also to a reduction in social services costs.

The increase of property value in Milwaukee is based on aesthetic and drainage improvement, and recreational opportunities driven by the green areas. Also, there is a decrease on maintenance and energy costs of properties, since green infrastructure provides shade, cooling areas and also helps block winter winds.

Considering the three cases of cities implementing and identifying the economic benefits of green infrastructure, it is possible to get an idea of the commonly considered benefits for the Rosedale Runoff Reduction Project and its community. However, it is necessary to acknowledge the scale and economic components of the neighborhood where this project is being implemented, in order to assess the impacts that are relevant for the residents.

As explained earlier in this report, this project encourages community engagement, considering the Homewood, Penn Hills and East Hills communities. One of the neighborhoods that have been crucially involved in the implementation of GSI is Homewood, which is also part of Phase I in the RRRP. NMRWA has already participated in two community cluster meetings, which has helped to understand the community expectations and needs.

Economic profile in Homewood

In 2011, the University Center for Social and Urban Research (UCSUR) collaborated with the Homewood Children's Village State and summarized the demographic and economic characteristics of the neighborhood, presenting a variety of challenges including suburbanization, increase of vacant lots and tax delinquency, population loss, and a decreasing house market, , among others.

Between 2000 and 2010, Homewood experienced a population loss of 30.6%, this added to a low sales price for existing residential homes, which on average was $9,600 in 2009 has contributed to an economically depressed neighborhood where the vacant lots increases with the pass of the years, worsening the housing market as one of the lowest within the City of Pittsburgh, with few incentive for investment.

Moreover, between 2010 and 2015 there was a decrease of house unit in over 40% (ACS). The implementation of GSI in this area can be an important asset that can bring economic benefits and boost the general well-being for homeowners and residents of Homewood and close neighborhoods.

Economic Impact Identification and Measurement

Having reviewed, analyzed and studied the economic benefits of implementing green infrastructure in other places, and taking into consideration the characteristic of the

Homewood neighborhood, the potential economic benefits derived from implementing a Green Stormwater Infrastructure through the Rosedale Runoff Reduction Project are the following:

Increase in Property Value

As described earlier, Homewood is a neighborhood that has experienced a decrease in their property values, due to suburbanization, increase of vacant lots, and population loss. Also, owners in Homewood have paid more taxes than the real value of their houses, due to their value decrease. For example, the average home buyer in 2009 paid an average of $664 more in property taxes (UCSUR, 2011).

The Commission for Architecture & the Built Environment (CABE) argues that property values increase near green spaces, and houses that are closer to parks have, on average, 8% higher prices than similar properties further away (CABE, 2008). Moreover, there is also a positive impact of implementing green infrastructure far from a park or school, since green features are being implemented in an area or neighborhood that otherwise would not have much green (SBN, 2016).

Cities have proved that residential houses value has increased after implementing GSI, contributing to homeowners and the housing market. For instance, GSI projects can be found in several neighborhoods throughout Philadelphia, most of them in relatively low-income neighborhoods, and these benefits are perceived by a broad range of household income levels (SBN, 2016).

Positive features added to places there is an increase in the demand for that place as a residential location therefore an increase in its value (SBN, 2016). Hence, the implementation of

GSI can help break this tendency and increase property values, bringing benefits for homeowners and the neighborhood in general.

Indirect support for local businesses

Combined Sewage Overflow (CSO) usually brings disruption and flooding, and requires maintenance that can limit access to businesses due to the traffic delay created, increasing travel time for residents, employees and commercial travelers. This could imply a temporary decline in the number of customer and visitors in local businesses areas (EPA ,2013) and potential business losses, which could be avoiding with the implementation of green infrastructure.

Maintenance and Energy Cost Savings

Saving money in amenities cost and bills is another economic benefit that comes from the implementation of GSI, due to the shade and cooling effects of trees, which reduce the energy needed to cool or heat buildings (Howard. M, 2009). This can be a important benefit for the community, since the average per capita income in the Homewood was $13,076 in 2015, and nearly a 27% of the total household's income is less than $10,000 (ACS).

Jobs and Productivity

Studies have shown that the implementation of green infrastructure increases job opportunities for local unskilled workers, increasing residents' income, although the scale of the RRRP is small and cannot be compared to a city level. However, there is an indirect effect related to productivity. Productivity levels tend to increase when workers are near green areas, which can be positive for local business owners' performance and other social benefits.

All these economic benefits are usually more tangible in the long term, comparing prior and after data or using econometric models. Also, despite there is not a perfect causation relation, it is important to recognize the positive impacts that the implementation of green infrastructure contributes to.

Social Benefits

Introduction

The economic and social aspects of the triple bottom line analysis often overlap. An increase of jobs and housing property values within a community also have positive impacts to the social well-being of a neighborhood. Although social benefits and costs can be hard to quantify, they are important facets to consider when conducting an analysis. Studies use both qualitative and quantitative approaches to analyze the social benefits of GSI. Many of the case studies sampled were larger scale projects and the social benefits focused on aesthetics and recreation improvement. It will be challenging to directly link any positive impacts or net social benefits to the successful implementation of the project rather than exogenous factors. Isolating the effects of the project to prove causation or correlation in this area remains a challenge for all green infrastructure projects, including the RRRP. In addition, most research has been conducted on the impacts of green space, which can be linked to green stormwater infrastructure, but not directly applied. In this analysis we focus on both qualitative and quantitative analysis to assess the RRRP for the NMRWA, and focus on metrics that would be applicable to smaller scale projects.

Community Involvement / Community Aesthetics

One of the most vital aspects of ensuring a positive social benefit to a community is to involve the residents in the entire planning process to ensure diversity in ideas and that important aspects to the neighborhood are not overlooked. By focusing on the community's goals and feedback, there is less adversity when the plan is being implemented and will give the community a sense of responsibility to become involved with the upkeep and resolution of the issue (Briand, 1999).

NMRWA has been engaged locally since the beginning of the RRRP by partnering with organizations within the community. Although community involvement is difficult to quantify, including participation in the evaluation of the project is valuable information that indicates inclusion that green infrastructure promotes. With creating partnerships with Operation Better Block, East Tri-Borough Neighborhood Association, East Hills Consensus Group, Homewood Children's Village, and Penn Hills Community Development corporations and establishing the Community Project Advisory Groups, NMRWA has already facilitated an environment that encourages community participation and engagement for the RRRP (NMRWA, 2016). NMRWA also encouraged community youth to become engaged by involving Operation Better Blocks' Junior Green Corp into the clearing of one of the large infrastructure projects and plans on the the infrastructure implemented at the Crestwood Early Childhood Center to be utilized as a teaching tool for students. Placing a dollar cost on these benefits and other positive externalities continues to be a challenge for social science, however, by communicating these factors to stakeholders, investors, and the community, a more comprehensive assessment of the benefits of GSI can be realized.

To assist with determining the social benefit the RRRP has created for community improvement, a survey could be conducted within the neighborhood where the project was implemented asking the residents to comment on their evaluation of the green infrastructure and if they felt that the project was an improvement to their community. Questions could be catered to metrics that the organization is trying to quantify, for example if the resident felt safer in their community, had the resident increased the number of walks they took in the community, or had they felt a stronger sense of pride since the infrastructure was built. This could also be an opportunity to inquire as to how the residents felt about involving the local organizations in the process, like the Junior Green Corp for the Oakwood-Batavia Site.

Although surveys can be a helpful tool to assess residents' opinions within a community, they can be difficult to properly structure, and residents can suffer from survey fatigue. However, utilizing community partnerships to assist in conducting the survey, may generate a better response from residents.

Mental Health / Mental Fatigue

Studies show that residents living in greener areas experience less mental fatigue and less aggression than those that lived in more barren areas (Kuo & Sullivan, 2001a). Determining if the increased green space in an area has attributed to local mental health is a challenging metric to measure. Many individuals are cautious about sharing personal medical information about themselves and obtaining spatial data for the areas would be challenging and also may not accurately represent any changes that had occurred. In addition to conducting a survey with questions catered to measure perceived community improvements, questions related to changes in the residents stress level, if they have increased the amount of time they have spent outdoors, and how they feel when they pass by the green space would all be indirect ways to measure improvements in mental health. Experiencing nature can help reduce mental fatigue, which may also contribute to reducing violence and aggression (Kuo & Sullivan, 2001a).

Crime

There have been a number of studies conducted on the benefits of greenspace effects on public safety in urban areas. In a case study performed in Philadelphia, Pennsylvania, well maintained vegetation lowered significantly the incidence of assault, robbery, and burglary, but not theft (Wolfe & Memphis, 2012) and another study indicated that housing with greener surroundings had fewer crimes reported than those that were more barren (Kuo & Sullivan, 2001b). There is also evidence to support that neighborhood green space can reduce urban-dwelling youth aggression (Younan, D, et al. 2016)

Although there are methods to determine if a reduction in crime has occurred in a neighborhood, this attribute would be difficult to positively attribute to the green infrastructure being implemented and not to other factors that have occurred within the community. However, including information from studies that have indicated positive results in crime reduction to green space could be an alternative to provide the information to the community.

The Western Pennsylvania Regional Data Center (WPRDC) managed by The University Center for Social and Urban Research (UCSUR), provides GIS data for crime within Allegheny County. Data prior to the green infrastructure installation could be collected, analyzed, and compared to data that was collected after the infrastructure was installed to determine if any reduction in crime occurred. Data for youth crimes would have to be acquired from a private source, because demographic youth data is removed from the crime statistics data available on the WRPDC website.

The WPRDC data could also be used to compare Tax liens or Permit, Licenses, and Inspection (PLI) violations that have been issued by the city before and after the green infrastructure was built. As residents become more involved in the neighborhood and feel a sense of pride in their community, property aesthetics and care are likely to improve to reflect these changes. This also contributes to increase property values in the area.

Flooding

A consulting company for Fort Wayne, Indiana created a triple bottom line analysis scorecard that has a total of 22 metrics designed to evaluate the environmental, economic, and social aspects of green infrastructure design. Each metric has a score from 0 to 5 and is then weighted based on the priorities of the city, however each category, social, economic, and environmental are weighted equally (Hutton, n.d.). The Fort Wayne assessment was city wide, so many of the social indicators, eight in total, are not applicable to RRRP because of the scale difference between the two projects. The factors from Fort Wayne that are the most applicable to RRRP social analysis are; basement flooding reduction, street flooding reduction, and benefits of the streetscape improvements.

Residential basement flooding can cause financial issues and stress for residents. Many homeowners use basements as storage and flooding can cause damage to items being stored, and to the walls and floors of the basement. This can create financial issues for the homeowners to replace the damaged items and installing safeguards to attempt to prevent the flooding in the future. Inadequate clean-up or drying of saturated items may lead to mold, which can create even larger financial issues and health problems. Flooding may also lead to psychological stress relating to the financial issues, destroyed mementos, and the apprehension of another basement flood event occurring.

The Fort Wayne analysis quantifies basement flooding by assigning a number value (0 through 5) as to how many individuals who reported flooding prior to a major precipitation event no longer experienced flooding after the green infrastructure was installed.

For the NMRWA, this metric could be applied by conducting a survey prior to the installation of a project within the drainage area that the green infrastructure is to effect. A number system (score) can be assigned to the specific ranges according to how the organization would evaluate success. After the infrastructure is implemented another survey can collect data as to how many homes had no basement flooding after a similar sized wet weather event. This number can be compared with the metrics created and assigned a score to evaluate the success of the installation for this metric. For the RRRP Project, two of the large projects would be unable to conduct a before survey, because the work has either been completed or is almost finished. However, a post survey could be conducted to ask residents within the drainage area if they have noticed any changes in the frequency of the flooding since the date the infrastructure was installed.

Social benefits are challenging to quantify, however including language in a template that indicates the potential positive effects that green infrastructure has on a community could be a useful method in displaying the strengths of implementing green infrastructure, which grey infrastructure lacks when it is the solo infrastructure build to combat sewer overflow.

Conclusion

Environmental degradation as a result of development patterns has caused cities to start thinking sustainably. Stormwater infrastructure is one area that can benefit from green design. By supplementing existing grey infrastructure, GSI helps improve water quality, reduces runoff volume, and creates an aesthetically pleasing space for the community to enjoy. As more green design is implemented, the challenge is capturing and communicating the benefits to local residents, funding agencies, and the general public. One approach to quantifying these benefits is a TBL framework. However, it is difficult to quantify social and economic benefits. While environmental quantities can be measured and translated into monetary benefits, social and economic impacts don't have the same luxury. It's difficult to monetize personal utility and positive externalities resulting from GSI. We hope this report has provided the basis for the development of an analytical tool that can effectively communicate all the benefits of GSI to a community, quantitative and qualitative.

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