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Green Infrastructure on Vacant Land: Achieving Social and Environmental Benefits in Legacy Cities

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NEIGHBORHOOD, ENVIRONMENT, AND WATER RESEARCH
COLLABORATIONS FOR GREEN INFRASTRUCTURE
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About NEW-GI

NEW-GI *(Neighborhood, Environment, and Water research collaborations for Green Infrastructure)* contributes to knowledge about green infrastructure in legacy cities by integrating research about water quality, community well-being, governance and ecological design. Involving community, government and academic collaborators, it produces evidence-based guidance for sustainably managing stormwater in ways that enhance landscapes and the lives of residents in Detroit and other legacy cities.

NEW-GI ecological designs link Detroit's vacant property demolition process with new forms of green infrastructure (GI) that aim to manage stormwater as well as increase nearby residents' well-being. This research uses a transdisciplinary design-in-science approach, in which researchers, practitioners and community members work together to contribute knowledge addressing social and ecological objectives. NEW-GI researchers assess the performance of different GI designs and governance approaches. This assessment provides evidence for making decisions about how GI can better achieve objectives.

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Executive Summary

A growing body of research indicates that GI has potential to enhance neighborhood attractiveness, increase property values and improve the health and well-being of area residents.

GREEN INFRASTRUCTURE (GI) is becoming a widespread stormwater management practice. By managing stormwater near where it falls, GI may reduce flooding, manage combined sewer overflows and improve water quality. A growing body of research indicates that GI also has potential to enhance neighborhood attractiveness, increase property values and improve the health and well-being of area residents. This makes GI a particularly promising strategy for addressing some of the social and environmental effects of population loss and infrastructure decay in legacy cities such as Detroit. In these cities, vacant land may create an opportunity for GI to be designed to manage stormwater and also to serve as attractive green spaces for neighborhoods, reducing blight. If properly designed and maintained, GI also has potential to improve nearby residents' health and satisfaction with their neighborhood. Achieving these benefits requires understanding the social dimensions of GI, and designing GI that reflects the needs and preferences of residents.

As a basis for understanding GI and to support decision-making, this White Paper synthesizes relevant scholarly literature related to three key factors affecting GI performance in legacy cities:

1. How governance affects planning and implementation of GI on vacant property: Existing laws, regulations, policies and institutional arrangements typically do not adequately support the construction and maintenance of GI on vacant property. Although GI stakeholders are developing strategies to overcome these impediments, governance reforms may be needed.

- *Fragmented responsibilities impede GI implementation,* but some cities are overcoming this through collaboration between departments and across municipal boundaries.

- *GI development and maintenance may be hindered by limited involvement from stakeholders outside government.* Well-conceived public-private partnerships are important to the effectiveness of GI.

- *Uncertainties about land control slow implementation efforts.* Acquiring vacant properties for GI is often difficult even when land banks or other government entities control the land.

- *Lack of land use policies, plans and monitoring affect implementation of GI.* In reuse of vacant land, plans are needed to target GI development where it will have the greatest social and environmental benefit.

- *Nonprofits, businesses and private land owners may not have the technical expertise to implement GI effectively.* Government entities more often do have access to necessary technical knowledge.

2. How GI in neighborhoods may affect residents: GI has the potential to enhance residents' health and satisfaction with their neighborhood if GI design and maintenance reflects their preferences for neighborhood landscapes.

- *GI landscapes should appear attractive to residents.* Residents want neighborhood landscapes to look neat and well cared-for. GI's design and visible, ongoing maintenance should reflect these preferences.

- *Neighborhood residents may realize immediate social benefits from attractive GI landscapes.* This includes increased satisfaction with their neighborhood and increased interaction with their neighbors.

- *GI design and maintenance may affect perceptions of neighborhood safety, and crime rates.* GI designs that are well-maintained and avoid vegetation that obscures sight lines may promote a sense of safety. Preliminary research also indicates that vacant lot greening may be associated with decreases in certain types of crime.

Aesthetic and social benefits motivate residents to act as stewards of neighborhood GI landscapes.

• *GI landscapes may reduce stress, improving health.* Well-designed and maintained GI landscapes may have restorative effects, reducing chronic stress levels and contributing to the improved mental and physical health of residents in the long-term.

• *GI landscapes may invite physical activity that improves health.* Neighborhood landscapes that appear attractive and safe may enable residents' physical activity.

• *Environmental functions of GI also may impact public health.* Appropriate design and maintenance approaches to GI may alleviate potential health impacts of water pollution, air pollution and elevated urban heat.

3. GI stewardship for long-term success: GI requires ongoing care to provide long-term stormwater management and social benefits. This care should be managed by local government, but nearby residents can act as GI stewards by reporting maintenance issues, advocating for GI and sometimes participating in certain types of maintenance.

• *Aesthetic and social benefits motivate residents to act as stewards of neighborhood GI landscapes.* For stormwater management functions to be sustained over time, GI sites should elicit this stewardship through design and maintenance that reflects residents' preferences and expectations.

• *Community engagement during GI planning enhances resident stewardship.* Residents are more likely to act as stewards for neighborhood landscapes if their capacity for involvement is supported as part of the planning process, and they are involved and their insights absorbed throughout planning.

• *Maintenance is essential for long-term success,* and ensures that GI continues to provide social and environmental benefits over time. Plans and funding for maintenance of GI should be integrated with design and implementation, and local governments should lead the coordination of maintenance activities.

A transdisciplinary design-in-science approach, in which researchers, practitioners and community members work together to apply and expand knowledge, can help to ensure that GI in legacy cities addresses social and ecological objectives. Basing GI design and management decisions on the growing body of relevant scholarly research, as well as assessments of the social and environmental performance of existing GI projects, will help to ensure that GI investments deliver the greatest possible benefits to residents of legacy cities.

Introduction: Potential benefits from green infrastructure in legacy cities

GREEN INFRASTRUCTURE (GI) is a system that uses vegetation, soils and other natural processes to manage and treat stormwater near where it falls rather than removing it from the site through a stormwater or sewer system (US Environmental Protection Agency, 2016e). By reducing the amount of stormwater entering grey infrastructure systems, GI may improve water quality, reduce flooding and combined sewer overflows, and address other environmental and human health hazards. GI also has the potential to enhance neighborhood attractiveness, which may reduce stress and increase physical activity among nearby residents (Coutts & Hahn, 2015; Hufnagel & Rottle, 2014; National Research Council, 2008). This combination of potential benefits makes GI a particularly promising strategy for addressing some of the social and environmental effects of population loss and infrastructure decay that characterize legacy cities (Dunn, 2010; Mitchell & Popham, 2008; Sugiyama et al., 2016). This White Paper summarizes and synthesizes scholarly literature that addresses social and governance characteristics of green infrastructure. Drawing on peer-reviewed studies from ecological design, landscape and urban planning, public administration, law, sociology, and public health, the White Paper aims to support decision-making about GI in legacy cities.[1]

Legacy cities have experienced sustained deindustrialization and population loss in the second half of the 20th century, often shaped by restrictive housing policies and suburban investments that enabled residential segregation (Dewar & Thomas, 2013). Property tax bases have shrunk, the number of ratepayers for municipal services has fallen dramatically, infrastructure has fallen into disrepair, and deteriorated structures and vacant lots have become part of the physical fabric of these cities (Dewar & Thomas, 2013; Morckel, 2015). Deteriorated structures pose hazards to residents, including exposure to toxins as well as animal and waterborne disease through debris, rodents and flooding (Garvin, Branas, Keddem, Sellman, & Cannuscio, 2012; Gulachenski, Ghersi, Lesen, & Blum, 2016). Without adequate maintenance, derelict structures and vacant lots create physical disorder which is associated with decreased neighborhood property values (Whitaker & Fitzpatrick IV, 2013). It may undermine residents' neighborhood social networks and reduce their sense of safety (Johansen, Neal, & Gasteyer, 2015; Kruger, 2008); reduce residents' satisfaction with their neighborhood and with their lives; reduce their self-rated health

[1] This White Paper presents findings from primary research and reviews of primary research published in scholarly, peer-reviewed journals. Articles were identified through keyword searches of online bibliographic databases (Scopus and Google Scholar) and by reviewing the reference lists of included articles. Other sources such as nonprofit and government reports, industry publications and non-peer-reviewed research are used as needed to define concepts, provide case studies, and give context for peer-reviewed research findings.

The stewardship of vacant lots can impact neighborhood environments, resident health and economic development.

WHY USE VACANT PROPERTY FOR GI?

GI can be located in many different neighborhood spaces including established parks, private yards and street right-of-ways. However, several factors make vacant lots well-suited as a location for GI (Nassauer & Raskin, 2014):

- In many neighborhoods in legacy cities, vacant lots are widely available, already owned by land banks or other government agencies and not in demand for development.

- The stewardship of vacant lots can impact neighborhood environments, resident health and economic development. While overgrown or unmaintained vacant lots can have negative social and ecological impacts, well- maintained GI can transform lots into community and environmental assets.

- Vacant land is generally dispersed among houses that continue to be occupied and GI on vacant lots can provide immediate benefits to residents of nearby homes.

- GI can be designed and implemented on single lots or a few adjacent lots, easing land assembly challenges.

- Attractive GI can serve as evidence of care on vacant lots. Research indicates that maintaining vacant lots may encourage the care and maintenance of surrounding occupied properties, improving the overall condition of neighborhood landscapes.

(Grogan-Kaylor et al., 2006; Krekel, Kolbe, & Wüstemann, 2016; Poortinga, Dunstan, & Fone, 2007); and hinder healthy behaviors (Keyes, 2011). These experiences increase stress, and higher stress levels over time are associated with compromised mental and physical health (Barber, Hickson, Kawachi, Subramanian, & Earls, 2015; Boardman, 2004; Brenner, 2012; Casciano & Massey, 2012; Kruger, Reischl, & Gee, 2007; Latkin & Curry, 2003; Ross & Mirowsky, 2001; Schulz et al., 2005; Schulz et al., 2013; Schulz et al., 2008).

Some of these damaging effects may be alleviated by well-designed and properly maintained GI that relieves stormwater pressures on legacy grey infrastructure while functioning as attractive green spaces with the potential to improve

In addition to managing stormwater, GI can be designed as attractive green space that improves nearby residents' health and increases their satisfaction with their neighborhood.

residents' health and increase their satisfaction with their neighborhood (Nassauer & Raskin, 2014). With these improvements GI may counter health disparities in legacy cities (Dunn, 2010; Sugiyama et al., 2016), where low-income communities and communities of color have been disproportionately impacted by disinvestment (Diez & Mair, 2010; Jones, Squires, & Ronzio, 2015; Phelan, Link, & Tehranifar, 2010; Redwood et al., 2010; Schulz, Williams, Israel, & Lempert, 2002). As guidance for proper design and maintenance, this White Paper summarizes evidence for the relationships between specific characteristics of GI and its potential social benefits.

"Neighborhood landscape" refers to all of the outdoor spaces of a neighborhood that can be seen by residents.

DEFINING GREEN INFRASTRUCTURE, GREEN SPACE, NEIGHBORHOOD LANDSCAPES AND GREENING

The terms green infrastructure, greening, green space and neighborhood landscape are used throughout this White Paper. These terms have different but sometimes overlapping meanings.

Green infrastructure (GI) refers to systems that use vegetation, soils and other natural processes to retain, detain, infiltrate or evapotranspire stormwater at its source rather than removing runoff from the site through a municipal stormwater system (US Environmental Protection Agency, 2016e). By this definition, GI may incorporate aspects of greening or green space, but it has a separate and distinct fundamental purpose: to manage stormwater.

In different parts of the world, different terms are used to refer to GI. They include low-impact development (LID), water sensitive urban design (WSUD), integrated urban water management (IUWM), sustainable urban drainage systems (SUDS), source controls and distributed stormwater management (Fletcher et al., 2015; Water Environment Research Foundation, 2009). All these terms refer to the basic concept of using landscapes and natural processes to manage stormwater.

Greening describes efforts to increase the amount or quality of green space in a neighborhood landscape by planting or maintaining trees, shrubs, grass or other vegetation. Vacant lot greening refers to planting and maintaining vegetation or structures (e.g. gardening beds, fences or signs) on vacant lots.

Green space is land that is "partly or completely covered with...vegetation" (US Environmental Protection Agency, 2016f). While commonly-given examples of urban green spaces include parks, community gardens, cemeteries, playgrounds, the term may also refer to residential yards and other vegetated areas. Green space can occur on private or public land.

Neighborhood landscape refers to all of the outdoor spaces of a neighborhood that can be seen by residents. Neighborhood landscapes include streets, buildings, trees, yards, parks and vacant lots. Green spaces and green infrastructure are part of the neighborhood landscape.

GI captures and manages stormwater using landscape features, rather than removing it only through a sewer system. PHOTO: DAVE BRENNER

How governance affects planning and implementation of GI on vacant property

KEY FINDINGS:

- **Fragmented responsibilities impede GI implementation,** but some cities are overcoming this through partnerships between departments and across municipal boundaries.

- **GI development and maintenance may be hindered by limited involvement from stakeholders outside government.** Well-conceived public-private partnerships are important to the effectiveness of GI.

- **Uncertainties about land control slow implementation efforts.** Acquiring vacant properties for GI is often difficult, even when land banks or other government entities control the land.

- **Lack of land use policies, plans and monitoring affect implementation of GI.** In reuse of vacant land, plans are needed to target GI development where it will have the greatest social and environmental benefit.

- **Nonprofits, businesses and private land owners may not have the technical expertise to implement GI effectively.** Government entities more often do have access to necessary technical knowledge.

EMPLOYING GI, particularly on vacant land for which there is little market demand, presents governance challenges. Existing systems of stormwater governance have evolved to support the function of grey infrastructure. Meanwhile, urban land use governance has traditionally focused on managing growth and development; planning and regulatory tools must be adapted to guide the conversion of vacant land in shrinking cities to beneficial uses. Meshing these two types of governance, GI and vacant property, creates particular challenges but also presents synergistic opportunities.

This section draws on the scholarly literature of GI governance, urban watershed management and vacancy to discuss impediments to GI governance in Detroit and in other legacy cities with large amounts of vacant land. Then, it describes strategies for overcoming these impediments as discussed in the literature.

Legacy cities have unique opportunities house demolition and vacant land management with GI development. However, combining these processes can present governance challenges. PHOTO: CHRIS FAUST

WHAT IS GOVERNANCE?

Governance refers to laws and regulations, institutions, political and administrative relationships, and practices and procedures that determine how policies are implemented and how publicly-provided goods and services are managed (Lynn, Heinrich, & Hill, 2001). Governance affecting urban stormwater occurs at a range of scales and includes federal and state-level laws and regulations; the state and local processes through which stormwater infrastructure is designed, funded, built and maintained; planning processes that influence land use across a city; and the codes, regulations, fees and incentives that shape the ways landowners manage stormwater on their properties. These forms of governance can support or hinder the use of GI as a stormwater management strategy.

WHO IS INVOLVED IN GOVERNANCE AFFECTING URBAN STORMWATER MANAGEMENT, AND GI IMPLEMENTATION AND MAINTENANCE?

Government entities (including agencies, legislatures and courts at federal through local levels) along with nonprofit organizations, businesses and individuals play important roles in setting policy for managing stormwater and implementing and maintaining GI. For example, the Philadelphia Water Department (PWD) manages stormwater in compliance with a binding agreement with the US Environmental Protection Agency (EPA). This agreement emphasizes use of GI and the Department has recently begun an initiative to develop GI on vacant lots. To implement GI on vacant lots as well as in streets, schools, parks and private land, the Department works with the City Planning Commission, Philadelphia Redevelopment Authority, the Department of Streets, the Department of Parks and Recreation, the Philadelphia Land Bank and county government agencies. Department officials also engage with residents, businesses, schools and other property owners about where to implement what types of GI (Dhakal & Chevalier, 2016; Heckert & Rosan, 2016; Philadelphia Water Department 2016; Travaline, Montalto, & Hunold, 2015).

FRAGMENTED RESPONSIBILITIES IMPEDE GI IMPLEMENTATION

Within municipalities, multiple agencies are responsible for different functions that affect urban stormwater.

The 1987 amendments to the federal Clean Water Act provide an overarching legislative framework for stormwater management and, with that authority, the Environmental Protection Agency requires state and local governments to meet clean water standards by managing and regulating urban stormwater within their jurisdictions (Revised Federal Water Pollution Control Act of 1987; Ellis, Green, & Revitt, 2010; Government Accountability Office, 2007). However, state enabling acts for local government, political boundaries and the organization of local ∆governments often distribute this regulatory responsibility among numerous entities (Hufnagel & Rottle, 2014). Watersheds or sewersheds can stretch across multiple municipalities, each of which may regulate land use and manage local infrastructure differently. Within municipalities, multiple agencies are responsible for different functions that affect urban stormwater. For example, land use planning, stormwater infrastructure maintenance, vacant house demolition, parks management and street repair may be the responsibility of separate local government departments. Fragmentation of these functions may result in poor coordination of policies that affect GI, limiting government capacity to implement GI and achieve clean water requirements (R. R. Brown, 2005; Chaffin et al., 2016; De Sousa, 2014; Dhakal & Chevalier, 2016; Heckert & Rosan, 2016; Keeley et al., 2013; Scarlett & Boyd, 2015).

In Pennsylvania, the Philadelphia Water Department partners with other City departments and county government agencies to develop GI landscapes.

PHOTO: REBECCA LABOV

GI DEVELOPMENT AND MAINTENANCE MAY BE HINDERED BY LIMITED INVOLVEMENT FROM STAKEHOLDERS OUTSIDE GOVERNMENT

GI differs from grey infrastructure in that it is often a highly visible part of neighborhood landscapes, can provide social benefits beyond stormwater management, and may be located on land that is owned or managed by different types of public and private entities including individual households. As a result, construction or maintenance of GI sometimes relies on public-private partnerships between government, non-profits, community organizations, businesses, individuals who own property, or residents of neighborhoods where GI is located (Heckert & Rosan, 2016; Pincetl, 2010; Vatter & Karll, 2014). Non-governmental entities sometimes can help inform and engage residents and other stakeholder groups, identify potential locations where GI may be needed, and support GI maintenance (Connolly, Svendsen, Fisher, & Campbell, 2013; De Sousa, 2014; Dhakal & Chevalier, 2016; Ellis et al., 2010).

However, unclear responsibilities, insufficient funding and a lack of coordination can limit the efficacy of public-private partnerships (Young, 2011). Leaders of GI efforts in Cleveland and Milwaukee identified a lack of clear responsibility for funding and maintaining GI as a limitation of existing collaborations (Keeley et al., 2013). In another example, the Million Trees tree-planting program in Los Angeles relied on five nonprofits to implement the planting, but did little to guide their efforts or provide information to residents. Although the City Department of Public Works provided trees and an initial plan, nonprofit partners were expected to reach out to residents, identify planting locations and plant the trees. Although city government agreed to reimburse the nonprofits for their work, this did not happen. Nonprofits struggled to engage residents; their efforts were poorly coordinated; and they competed for the same pool of federal, state and foundation grants (Pincetl, 2010; Pincetl, Gillespie, Pataki, Saatchi, & Saphores, 2013).

UNCERTAINTIES ABOUT LAND CONTROL SLOW IMPLEMENTATION EFFORTS

In urban areas where developers are building new projects, water and sewer agencies can require developers to incorporate GI into their projects or to install or pay for mitigation GI sites elsewhere. Where demand for land is weak, vacant land may create opportunities to incorporate GI but no developer to pay for its installation (Keeley et al., 2013). Further, gaining control of vacant land can be difficult even where city and county government are major landowners, because hopes of other forms of redevelopment often hold up the sale of publicly owned land for GI. Projects that require land assembly for larger sites are especially challenging.

For example, a coalition of developers, city agencies and nonprofits have faced difficulties in acquiring vacant lots for large-scale urban agriculture projects in Cleveland, although the city and county land banks control much of the land (Burten, Bell, Carr Development, n.d.; Keeley et al., 2013). City government has no plans for repurposing vacant land for green uses; it allows the real estate market to determine outcomes or community development corporations to develop land use plans. Community development corporations, in turn, do not necessarily approve plans for GI on sites where they believe housing development might be viable (Chaffin et al., 2016; Keeley et al., 2013). In contrast, in Milwaukee, the government release of city-owned land was key to implementing a plan for a greenway in the Menomonee Valley (De Sousa, 2014).

LACK OF LAND USE POLICIES, PLANS AND MONITORING AFFECT IMPLEMENTATION OF GI IN REUSE OF VACANT LAND

A lack of long-term planning is a recurring impediment to sustainable urban water management (R. R. Brown & Farrelly, 2009). In most cities land use policies and comprehensive planning support development but do not provide guidance for widespread GI implementation, particularly on vacant land. In the absence of a shared planning process to direct where and how GI should be implemented, different agencies' and organizations' efforts may be inconsistent, uncoordinated and unsystematic. For example, GI stakeholders in Cleveland cited the lack of a shared plan for designing and locating GI as an impediment to coordinating their efforts (Keeley et al., 2013).

NONPROFITS, BUSINESSES, PRIVATE LAND OWNERS AND RESIDENTS MAY NOT HAVE THE TECHNICAL EXPERTISE TO IMPLEMENT GI EFFECTIVELY

City officials, stormwater managers, regulators and the public may be less willing to implement GI if they are not familiar with its design and construction or are uninformed about its potential to meet regulatory requirements (Dhakal &

A wide range of stakeholders can contribute to GI development. Here, representatives from City departments, foundations, nonprofit organizations and universities come together to celebrate the opening of a GI garden in Detroit. PHOTO: DAVE BRENNER

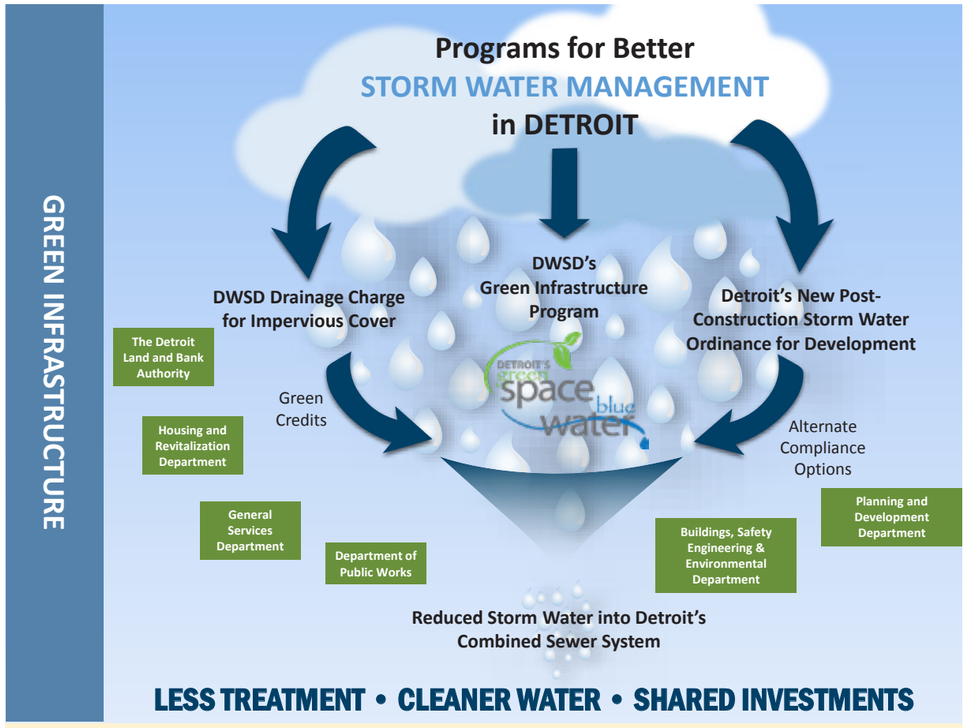
Chevalier, 2016; Hinds & Beezhold, 2014; Shuster & Garmestani, 2015). Municipal planners, engineers and other officials may be more likely to consider GI as useful in achieving stormwater management goals if they perceive it as easy to use and think their agency is committed to implementing it (Carlet, 2015). Where government officials have technical GI knowledge, other issues often interfere with use of GI (R. R. Brown & Farrelly, 2009; Dunn, 2010; Keeley et al., 2013; Olorunkiya, Fassman, & Wilkinson, 2012; Shuster & Garmestani, 2015). Cleveland's stormwater management agency, for instance, had the capacity to engineer GI but lacked experience with non-technical aspects of GI implementation including developing partnerships, conducting outreach and managing property (Chaffin et al., 2016).

On the other hand, lack of technical knowledge can undermine the efforts to install GI by nonprofits, businesses and homeowners. In Cleveland and Milwaukee, practitioners expressed concern that GI developed by small municipalities, community development organizations and private landowners may be less effective because these actors have limited engineering expertise or inadequate access to technical assistance (Keeley et al., 2013).

Acquiring vacant properties for GI is often difficult, even when land banks or other government entities control the land.

STRATEGIES EXIST TO OVERCOME IMPEDIMENTS TO GI ON VACANT LAND

The scholarly literature documents several strategies for overcoming these impediments to GI implementation and maintenance. In particular, partnerships are important to overcoming fragmented responsibilities within city government and bringing a wider variety of capacities and expertise to GI development. Land use planning to guide GI development can coordinate these different partners' efforts to ensure that GI delivers social and environmental benefits across an urban landscape.



Partnerships can overcome barriers of fragmented responsibilities. Stormwater management and GI development in Detroit involves six City departments collaborating on three different programs. DIAGRAM: CAROL HUFNAGEL, TETRA TECH, INC.

Researchers have proposed organizational structures that address fragmentation of responsibilities and lack of routine coordination among government agencies. For instance, Dhakal and Chevalier (2016) draw on the example of neighborhood associations to recommend dividing cities into hydrologic districts based on small watersheds. Each district would have an elected authority responsible for involving private landowners in stormwater management and implementing GI on public property within the its boundary. The city government would set stormwater control goals for each hydrologic district, enforce standards, monitor performance and provide technical assistance. Alternatively, an initial change in governance could establish a stakeholder group of intra-agency and inter-agency jurisdictions to implement GI (Vatter & Karll, 2014). However, these strategies have not been implemented and therefore have not been evaluated. As a result, their success in resolving fragmentation of responsibilities is unknown.

Partnerships between local government entities and nonprofits have been investigated as a way to implement or maintain GI. Nonprofit partners played a role in developing a neighborhood GI pilot project in Cleveland, OH. While the Northeast Ohio Regional Sewer District (NEORSD) brought technical capacity to the project, agency staff lacked familiarity with the neighborhood. A community development nonprofit filled this gap by working with nearby residents to identify vacant parcels that might be candidates for GI. EPA and university researchers monitored the performance of the sites. The Cleveland Botanical Garden drew on relationships with participating organizations and past experience implementing GI to connect and facilitate the work of these different project partners. While this was a one-time undertaking and no new systems or routines resulted from it, researchers recommended fostering institutional networks like the ones in the Cleveland project to work toward "creating political, economic, financial and social space for GI in urban sewersheds" (Chaffin et al., 2016).

Partnerships are important to overcoming fragmented responsibilities within city government and bringing a wider variety of capacities and expertise to GI development.

In a New York City tree-planting initiative, having data on which to base a city-wide plan and a commitment to monitoring were identified as contributing to the program's success. This plan used data from a city-wide tree census to direct new plantings in the city areas with few trees; tracked progress in planting; and monitored the survival of trees (Young, 2011).

Ultimately, however, governance reforms may be needed to institutionalize implementation and maintenance of GI. This would involve reorganizing the distribution of responsibilities among departments and agencies; developing new codes and regulations for planning and managing GI implementation and maintenance and vacant land reuse; and building broad-based technical expertise about GI design and performance.

GI GOVERNANCE SOLUTIONS IN THE PROFESSIONAL PRACTICE LITERATURE

A growing body of literature written for and by practitioners and policymakers addresses strategies for improved GI governance. Most notably, the Water Environment Federation's Green Infrastructure Implementation (Hufnagel & Rottle, 2014) provides strategies for building collaborations with agencies and non-governmental partners; identifying and overcoming existing code and regulatory barriers; and developing regulatory mechanisms to promote GI development including GI design standards and stormwater ordinances. Green Infrastructure Implementation and other publications provide valuable guidance for those developing GI programs.

How GI in neighborhoods may affect residents

KEY FINDINGS:

- **GI landscapes should appear attractive to residents.** Residents want neighborhood landscapes to look neat, orderly and well cared-for. GI design and its visible, ongoing maintenance should reflect these preferences.

- **Neighborhood residents may realize immediate social benefits from attractive GI landscapes.** This includes increased satisfaction with their neighborhood and increased interaction with their neighbors.

- **Design and maintenance of GI may affect perceptions of neighborhood safety, and crime rates.** GI designs that are well-maintained and avoid tall or dense vegetation may promote a sense of safety. Preliminary research also indicates that vacant lot greening and GI may be associated with decreases in certain types of crime.

- **GI landscapes may reduce stress, improving health.** Well-designed and maintained GI landscapes may have restorative effects, reducing chronic stress levels and contributing to improved mental and physical health of residents in the long-term.

- **GI landscapes may invite physical activity that improves health.** Neighborhood landscapes that appear attractive and safe may enable residents' physical activity.

- **Environmental functions of GI also may impact public health.** Appropriate design and maintenance approaches to GI may alleviate potential health impacts of water pollution, air pollution, and elevated urban heat.

GI vegetation may reduce health risks associated with air pollution and extreme heat that are associated with climate change.

TO ANTICIPATE HOW GI MAY AFFECT RESIDENTS, decision-makers can use knowledge about how residents perceive GI, what they prefer about different GI landscapes and features, and which aspects of GI design and maintenance may have neighborhood benefits. GI landscapes that residents perceive as attractive, safe and well-cared for can serve as green spaces that enhance the appeal of neighborhoods and immediately benefit residents (Coutts & Hahn, 2015; Dunn, 2010; Nassauer & Raskin, 2014; Tzoulas et al., 2007). Residents value green spaces in their neighborhoods for relaxation, recreation, social interaction, attachment to their neighborhoods and connection to nature (Balram & Dragićević, 2005; Bertram & Rehdanz, 2015b; Korpela, Ylén, Tyrväinen, & Silvennoinen, 2008; Matsuoka & Kaplan, 2008; Stewart, Liebert, & Larkin, 2004). In general, green space access correlates with increases in overall life satisfaction and decreased likelihood of moving (Comstock et al., 2010; Dassopoulos, Batson, Futrell, & Brents, 2012; Hur & Nasar, 2014; Hur, Nasar, & Chun, 2010; Kimpton, Wickes, & Corcoran, 2014; L. R. Larson, Jennings, & Cloutier, 2016). In neighborhoods characterized by residential vacancy, these benefits may be particularly important for counteracting effects of physical disorder.

As a form of green space, GI also has potential to improve residents' health (Hufnagel & Rottle, 2014; Nassauer & Raskin, 2014; National Research Council, 2008). Measurements of access to green space have been correlated with improvements in self-reported physical and mental health; reductions in stress, cardiovascular disease and respiratory illness; and reductions in overall rates of death from all causes (James, Hart, Banay, & Laden, 2016; Krekel et al., 2016; Lee & Maheswaran, 2011; Maas, Verheij, Groenewegen, De Vries, & Spreeuwenberg, 2006; Mitchell & Popham, 2007; Danielle F Shanahan et al., 2015; M. van den Berg et al., 2015). If designed and maintained accordingly, GI vegetation may reduce health risks associated with air pollution and extreme heat that are associated with climate change (Dunn, 2010). Where GI reduces localized flooding, it also may reduce related residents' exposures to molds and toxins and relieve the emotional and economic stressors of home damage (Dunn, 2010; Gaffield, Goo, Richards, & Jackson, 2003).

A DEFINITION OF HEALTH

We use the World Health Organization (WHO)'s definition of health as "a state of complete physical, mental and social well-being, and not merely the absence of disease or infirmity" (World Health Organization, 2003). The WHO definition shows that health is affected not just by illness, but also by many other aspects of individual and community life including people's self-reported stressors, happiness and well-being (Cattell, Dines, Gesler, & Curtis, 2008).

GI LANDSCAPES SHOULD APPEAR ATTRACTIVE TO RESIDENTS

To benefit neighborhood residents, GI design and maintenance should reflect knowledge about what they perceive and prefer in neighborhood landscapes. An extensive literature describes what residents prefer about the appearance of residential neighborhood landscapes and urban green spaces, and much of that knowledge can apply to the design of GI. In this White Paper, we focus on specific visible landscape attributes (See (Churchward, Palmer, Nassauer, & Swanwick, 2013; Palmer, 2000) that affect residents' experiences and can become part of GI design or maintenance.

Residential yards are the most extensive type of urban green space. In many neighborhoods, social norms call for yards with mown turf and neat plantings.

Preferences for residential land uses are particularly relevant for GI.

Preferences for residential land uses are particularly relevant for GI because residential land is the largest proportion of urban land area in America and because vacant residential property in legacy cities has inherent advantages for locating land-based GI. Residential yards are the most extensive type of green space in urban settings; these privately owned yards include public easements along street frontages and utility corridors, which are often perceived as private land. More than other types of urban green space, residents may understand yards—particularly front yards that are visible to the public— to reflect social characteristics (Belaire, Westphal, & Minor, 2016; Kelli L Larson, Casagrande, Harlan, & Yabiku, 2009; Uren, Dzidic, & Bishop, 2015; Yu, Prell, Skaggs, & Hubacek, 2015). The appearance of residential property affects how residents are perceived by their neighbors as well as the value of their property (Blaine, Clayton, Robbins, & Grewal, 2012; Nassauer, 2011).

Neighborhood norms affect residents' preferences for the appearance of their own yards and of GI

The appearance of surrounding lots, particularly front yards, strongly influences residents' decisions about their own yards by indicating what types of landscape care are socially acceptable within a neighborhood, and this influence may be stronger than that of residents' individual preferences, environmental values, or cultural norms (Blaine et al., 2012; Carrico, Fraser, & Bazuin, 2012; Clayton, 2007; Harris et al., 2012; K.L. Larson, Cook, Strawhacker, & Hall, 2010; Nassauer, Wang, & Dayrell, 2009; Peterson et al., 2012; Visscher, Nassauer, Brown, Currie, & Parker, 2014). Aligning the design and maintenance of GI and other urban green spaces with neighborhood norms can affect its ongoing social acceptability, and encourage residents to notice it and act as stewards for it (Gobster, Nassauer, Daniel, & Fry, 2007; Gobster & Westphal, 2004; Nassauer, 1997; Tveit, Ode, & Fry, 2006).

Because residents' actions are affected by the landscapes they see nearby, the condition of an individual lot can influence the nearby neighborhood.

Because residents' actions are affected by the landscapes they see nearby, the condition of an individual lot can influence the nearby neighborhood (Grove et al., 2006; Nassauer, 2011; Nassauer et al., 2009; Visscher et al., 2014). Krusky et al. (2015) found that residential properties located near well-maintained produce gardens or greened vacant lots exhibited higher levels of maintenance than those located near unmaintained lots in a high-vacancy neighborhood in Flint, MI. In a separate study, residents reported perceiving improved maintenance of adjacent, occupied homes and yards following the greening of vacant Flint lots (Sadler & Pruett, 2015). Studies found that residential lots with similar gardening styles tended to be clumped together in Ann Arbor, MI, and Guelph, Ontario (M. C. R. Hunter & Brown, 2012). This suggests that evidence of care and maintenance on GI sites can influence how nearby residents care for their own home landscapes.

CHANGING NEIGHBORHOOD NORMS

Where neighborhood norms support neatly mown residential lawns, GI designs that incorporate mown turf and flowery plantings are likely to be more attractive to residents. At the same time, research suggests that, if clusters of residential properties or whole neighborhoods display other styles of greening that also respect residents' preferences, neighborhood norms for the appearance of the landscape can evolve to appreciate new styles. For example, across a block or neighborhood, more trees, shrubs, or flowers and less mown turf might come to be preferred (Kurz & Baudains, 2010; Nassauer et al., 2009; Uren et al., 2015). A study about GI in Cincinnati, OH, underscores the influence of neighborhood norms. Residents were more likely to participate in a program installing rain barrels or bioretention gardens on their property when their neighbors also participated (Green, Shuster, Rhea, Garmestani, & Thurston, 2012).

An orderly landscape often is interpreted as a sign of neighborliness, hard work and pride.

CUES TO CARE IN RESIDENTIAL LANDSCAPES

"Cues to care" connote human intention to care for a place, inhabiting or returning to a place over time. According to Nassauer (2011), "Cues to care vary with culture and landscape context, but may include:

- Neatness and order (no litter, things are put away, no weeds)
- Structures in good repair (e.g., well-painted, unbroken)
- Visible, crisp edges of different patch types (including gardens, cropped fields, ecological restorations, fragments of native ecosystems)
- Fences, especially between properties or between patches with different textures
- Trimmed trees and hedges or plants in straight rows
- Mown turf in at least a portion of the most publicly visible areas of a site
- Colorful flowers
- Bird boxes and lawn ornaments
- Signs that identify those who occupy the property or suggest the ecosystem functions that occur there, especially habitat functions."

To be attractive, neighborhood landscapes must look well-cared-for

Preferences for urban landscapes that appear neat, cared-for and safe are remarkably pervasive. An orderly landscape often is interpreted as a sign of neighborliness, hard work and pride (Nassauer, 1995, 2011). Surveys indicate that homeowners rate cleanliness and landscape beauty as among the most important factors in their residential landscaping decisions (Harris et al., 2012; Kelli L Larson et al., 2009; K. L. Larson, Nelson, et al., 2016).

Nassauer (1988, 1995, 2011) identified landscape attributes that operate as "cues to care" within urban and residential landscapes. Designing and maintaining GI to display some cues to care will enhance its attractiveness to residents. Some cues that are particularly relevant to GI are described in more detail below:

Clear borders: Several studies indicate that people prefer urban landscapes that display clearly defined borders and plants arranged in rows (Nassauer, 1988, 1995, 2011). A survey of residents and landscape planners found that the presence of "culturally shaped" landscape attributes, including artificial flower beds and hedges, was significantly correlated with residents' preferences for and perceived beauty in German non-residential urban landscapes (Hofmann, Westermann, Kowarik, & van der Meer, 2012). University students in Alabama and Georgia preferred residential landscape designs combining tree cover and lawn delineated by a white stone border over designs consisting exclusively of lawn cover or unmaintained woodland (Zheng, Zhang, & Chen, 2011). In a study of community gardens and vacant lots in Columbus, OH, Morckel (2015) found that having plants in rows enhanced gardens' perceived attractiveness.

Clear borders between plantings, such as this concrete curb, connote order.

“Cues to care” connote orderliness and human intention in a landscape. Cues include clear, sharp borders such as hedges (10a); mown turf (10b); colorful plantings (10c) and a clean, well-maintained appearance (10d).


10a


10b


10c


10d

Ongoing maintenance ensures that cues such as clear borders, colorful plantings and mown turf continue to connote neatness and human management over time.

Mown turf: Maintaining green, neat and weed-free turf rated high in surveys of homeowners' priorities for residential landscapes across US cities (Blaine et al., 2012; K. L. Larson, Nelson, et al., 2016). In Minnesota, visibly mown areas were significantly associated with neighbors' perceptions of urban wetland restorations as more attractive, better cared-for and safer (Nassauer, 2004). In a series of studies in Michigan and Minnesota, Nassauer found that, to conform to cultural norms, mown turf should occupy a minimum of 25-50% of the most highly visible areas of the front yard (Nassauer, 1988, 1995; Nassauer et al., 2009).

Colorful plantings: Prominent, colorful plantings can connote care across a range of landscape types and cultural contexts (Nassauer, 1995). Hands and Brown (2002) found that plantings with more diverse color were preferred on former industrial sites in Ontario. In Minnesota urban wetlands, visible flowers, along with mown turf, were preferred by neighbors; residents also perceived wetlands with these characteristics to be safer (Nassauer, 2004). In Karlsruhe, Germany, pedestrians found flower plantings that they described as colorful and well-kept to be more attractive than conventional lawns in urban residential areas (Lindemann-Matthies & Brieger, 2016). In Sapporo, Japan, residents preferred streetscapes consisting of ordered compositions of bright flowers of a low height planted beneath trees, more than tall flowers, bare soil, grass, or a hedge (Todorova, Asakawa, & Aikoh, 2004).

Visible ongoing maintenance: Visible ongoing maintenance affects the attractiveness of all urban green spaces. In neighborhoods that are challenged by physical signs of disorder, (including high-vacancy neighborhoods), maintenance may be especially important (Nassauer & Raskin, 2014). Philadelphia, PA, residents identified poor maintenance, indicated by overgrown vegetation, dilapidated structures and debris, as the distinctive negative feature of nearby vacant lots (Garvin et al., 2012).

Visible maintenance may include watering and mowing turf; weeding, pruning and trimming plantings; removing litter or graffiti; and keeping walks cleared in the winter. Litter, overgrown vegetation and other signs of an inadequate maintenance reduce visitor's preferences for and immediate benefits from urban parks (Arnberger & Eder, 2015; Nordh & Østby, 2013). Maintenance increases the attractiveness of landscapes independently of other design elements. For example, the attractiveness of Columbus, OH, community gardens and vacant lots were significantly predicted by their perceived level of lot maintenance including mowing, even when controlling for other elements of the lot design (Morckel, 2015). Where design gives cues to care, ongoing maintenance ensures that cues such as clear borders, colorful plantings and mown turf continue to connote neatness and human management over time.

Mowing, weeding and other visible, ongoing maintenance demonstrate care and help ensure that a landscape continues to appear attractive over time.

GI AS VISIBLE LANDSCAPE CARE IN HIGH-VACANCY NEIGHBORHOODS

Disorder may characterize some landscapes in high-vacancy neighborhoods, despite residents' preferences or shared norms for care and neatness (Nassauer and Raskin, 2014; Larsen and Harlan, 2006). Sampson and Raudenbush (1999) describe physical disorder as "the deterioration of urban landscapes," including graffiti, dumping, deteriorating structures and overgrown lots (Sampson & Raudenbush, 1999). Qualitative studies in Flint, MI, and Philadelphia, PA, suggest that poorly-maintained vacant lots can result in health and safety concerns that overshadow residents' positive feelings about other aspects of their neighborhoods. The studies find that residents address these concerns by creating a neater neighborhood landscape through maintenance and greening activities, but that their efforts may be limited by a lack of resources (Garvin et al., 2012; Johansen et al., 2015). If designed and maintained to exhibit cues to care, GI can transform vacant lots into attractive sites that support residents' experience of a desirable neighborhood landscape. However, GI that appears messy, poorly-maintained or unsafe may become a source of physical disorder (Bastien, Arthur, & McLoughlin, 2012; Everett, Lamond, Morzillo, Matsler, & Chan, 2016).

Naturalness can look messy and unsafe in cities

The specific attributes that people value in a landscape are influenced by its environmental and social context, and the activities they expect to occur there (Dinnie, Brown, & Morris, 2013; A. J. Hunter & Luck, 2015; Rupprecht & Byrne, 2014). Importantly, people's preferences for urban landscapes are tied to the appearance of maintenance and other visible signs of human intentions for the landscape (Bertram & Rehdanz, 2015a; Jansson, Fors, Lindgren, & Wiström, 2013; Rink & Arndt, 2016). Residents perceive features of physical and social neighborhood environments differently than outside observers (Sampson & Raudenbush, 1999; Schulz et al., 2008). In cities, landscapes that look natural sometimes are perceived as messy or dangerous (Gobster et al., 2007). For example, while park users in the post-industrial city of Sheffield, UK, valued perceived naturalness in large urban green spaces for providing connection to nature, a sense of freedom and benefits to wildlife, they considered more obviously designed park landscapes that showed clear signs of human intention to be "safer, more peaceful, more calming and a better place to relieve stress" (Grahn & Stigsdotter, 2010; Özgüner & Kendle, 2006).

Natural or unmanaged green spaces can appear dangerous or messy in urban neighborhood landscapes.

URBAN RESIDENTS MAY PREFER NATURE IN THE CONTEXT OF LANDSCAPES THAT LOOK TENDED

Urban residents often perceive and value an experience of nature in their home yards and gardens (Blaine et al., 2012; Dahmus & Nelson, 2014), but studies indicate that they generally prefer nature in their yards to have a tended look, including: turf, bird feeders, flowers and trees (Belaire et al., 2016; Clayton, 2007; Nassauer, 1995; Visscher, Nassauer, & Marshall, 2016).

NEIGHBORHOOD RESIDENTS MAY REALIZE IMMEDIATE SOCIAL AND HEALTH BENEFITS FROM ATTRACTIVE GI LANDSCAPES

Aligning GI designs with residents' landscape preferences and desires for their neighborhood may also increase social and health benefits. Neighborhood landscapes that are perceived as connoting order, care and human presence may increase residents' satisfaction with their neighborhood, particularly in areas with property vacancy (Nassauer & Raskin, 2014). Studies from Flint, MI, and Columbus, OH, indicate that unmaintained structures, overgrown shrubs or trees, dumping and empty lots are associated with lower neighborhood satisfaction (Grogan-Kaylor et al., 2006; Kruger, 2008), and when residents perceived improvements in the upkeep of buildings, yards and public areas their overall satisfaction with their neighborhood increased (Hur & Nasar, 2014; Hur et al., 2010). Neighborhood satisfaction has been linked to higher overall life satisfaction, improved mental health and a lower likelihood of moving (Dassopoulos et al., 2012).

Neighborhood landscapes that are perceived as connoting order, care and human presence may increase residents' satisfaction with their neighborhood.

Certain features of neighborhood landscapes also may influence social interactions among residents, with implications for physical and mental health (Project for Public Spaces, 2016). Access to green space may create opportunities for social interaction and several aspects of the appearance of a neighborhood including disorder, aesthetics, property upkeep and perceptions of safety can further hinder or support these interactions (Wood et al., 2008). In high-vacancy neighborhoods litter and physical disorder, decaying buildings, unmaintained vegetation and fear of crime discourage neighborhood social interactions (Sadler & Pruett, 2015).

By providing green space and improving the condition of vacant lots, GI can encourage social interactions on or nearby sites sometimes leading residents to develop stronger networks with their neighbors or passersby. Social networks are vital to health. Residents' relationships and the social support they receive from their neighbors act as a resource that allows them to better cope with the stressors associated with poverty and with living in disinvested neighborhoods; this reduces negative impacts on their health (Ivey et al., 2015; Karb, Elliott, Dowd, & Morenoff, 2012; Mair, Roux, & Morenoff, 2010; Schulz et al., 2006).

NEIGHBORHOOD ENVIRONMENTS AND SOCIAL DETERMINANTS OF HEALTH

The concept of *social determinants of health* is a commonly accepted framework to understand how the characteristics of a place can affect health. Healthy People 2020, a longstanding federal initiative to set "science-based, 10-year national [health] objectives," defines social determinants of health as "conditions in the environments in which people are born, live, learn, work, play, worship and age that affect a wide range of health, functioning and quality-of-life outcomes and risks," and recognizes that "Resources that enhance quality of life can have a significant influence on population health outcomes" (Office of Disease Prevention and Health Promotion, 2014).

Social determinants of health within a neighborhood can be a part of the *physical environment*, which includes neighborhood landscapes and infrastructure; and the *social environment*, which includes networks of individuals, organizations and institutions. The social and physical environments can interact to shape each other and to affect residents' health (Schulz & Northridge, 2004; Yen & Syme, 1999). Although landscapes are a part of the physical environment, their extent and condition can influence how residents interact with each other and feel about their neighborhood. In turn, residents often act to manage or change neighborhood landscapes in order to better fit their own values, needs and desired uses (Conway, 2016; Gobster et al., 2007).

Research in Chicago and Baltimore suggests that trees and vegetation along streets and in public spaces can provide attractive settings that encourage residents to linger and interact with one another (Dinnie et al., 2013; Holtan, Dieterlen, & Sullivan, 2015; Kemperman & Timmermans, 2014; Kuo, Bacaicoa, & Sullivan, 1998; Sullivan, Kuo, & Depooter, 2004). Park maintenance was associated with social interaction among visitors in Manchester, UK (Kaźmierczak, 2013). However, some research does indicate that cursory social interactions in green spaces may be too short to result in lasting social ties or supportive networks (Peters, Elands, & Buijs, 2010). Maas, Van Dillen, Verheij, and Groenewegen (2009) found that residents of neighborhoods with more green space reported being less lonely and feeling healthier, despite having no more social interaction than those living in less green areas—an effect that the researchers attributed to green space strengthening the residents' sense of community.

The degree of upkeep and care visible in neighborhood green spaces can influence residents' broader sense of safety in their neighborhood.

Vacant lot greening in particular may increase residents' trust in their neighbors by promoting landscape characteristics that communicate maintenance, care and attention and adherence to neighborhood norms for landscape care (Wilkerson, Carlson, Yen, & Michael, 2012) Residents who participated in a greening program in Flint, MI, reported perceiving increased interactions between neighbors after nearby vacant lots were cleaned and mowed (Sadler & Pruett, 2015).

In Flint, there were increased interactions among neighbors after vacant lots were cleaned.

GI DESIGN AND MAINTENANCE MAY AFFECT PERCEPTIONS OF NEIGHBORHOOD SAFETY, AND CRIME RATES

As a type of green space, GI may change neighborhood landscapes in ways that affect residents' perceptions of neighborhood safety (their self-reported sense of security in their neighborhood) and observed crime rates (the occurrence of crimes reportable to law enforcement such as violent or drug offenses, arson and burglary). This has implications for physical and mental health. Spaces that feel unsafe may act as stressors and hinder health (Casciano & Massey, 2012; Lorenc et al., 2012), and those that feel safe may enable social interactions and healthy behaviors such as increased levels of physical activity (Tappe, 2013; Voorhees et al., 2010).

Visible landscape care affects perceived neighborhood safety

The degree of upkeep and care visible in neighborhood green spaces can influence residents' broader sense of safety in their neighborhood (Austin, Furr, & Spine, 2002; Wood et al., 2008). One UK-based study found that residents who lived in neighborhoods with naturalistic street plantings perceived the landscape as more wild, uncared-for and less safe compared to residents living in neighborhoods with more formally designed plantings (A. Jorgensen, Hitchmough, & Dunnett, 2007). Regular maintenance has also been linked to greater perceived safety of green spaces in low-income neighborhoods of Glasgow, Scotland (Thompson, Roe, & Aspinall, 2013).

In high-vacancy neighborhoods, poorly maintained vacant lots and green spaces combine with other cues such as litter and vandalism to reduce residents' sense of safety (Baba & Austin, 1989; Johansen et al., 2015; M. C. Kondo, South, & Branas, 2015; Kruger, 2008; Lorenc et al., 2012; Ross & Mirowsky, 2001; Sreetheran & van den Bosch, 2014), an effect that can be reduced through greening and maintenance. Flint, MI, residents reported that overgrown lots and abandoned buildings increased their fear of crime and saw creating cues to care on vacant lots by mowing, trimming trees and shrubs, and removing litter as an effective strategy for addressing this fear (Sadler & Pruett, 2015).

Vegetation characteristics affect perceived neighborhood safety

Height, density and upkeep of vegetation shapes residents' sense of safety around neighborhood green spaces (Kemperman & Timmermans, 2014; Li, Zhang, & Li, 2015). Vegetation that creates enclosed areas (e.g. green spaces bordered by dense understory vegetation), reduces visibility, or blocks paths of movement is perceived as less safe, perhaps because these vegetation characteristics may obstruct views of potential threats (Jansson et al., 2013; Maas, Spreeuwenberg, et al., 2009; Stamps, 2005a, 2005b). Clumps of trees and shrubs can also contribute to perceptions of danger if they appear to create hiding places (L. J. Jorgensen, Ellis, & Ruddell, 2013) (Yang, Li, Elder, & Wang, 2013). In contrast, open arrangements of trees with clear views at eye level beneath the canopy, vegetation that

Green spaces with low-growing plantings and unobstructed views near paths are perceived as safer than those with vegetation that blocks views or creates enclosed spaces.
PHOTO: DAVE BRENNER

is low enough not to obstruct views of other people, and unobstructed views near paths contribute to higher levels of perceived safety (Herzog & Kutzli, 2002; A. Jorgensen, Hitchmough, & Calvert, 2002; Nasar, Fisher, & Grannis, 1993; Rink & Arndt, 2016; Thompson et al., 2013). GI designs should avoid blocking sight lines or creating enclosed areas with tall or dense vegetation, both of which may appear unsafe. More generally, clean, well-maintained green spaces can contribute to residents' overall sense of safety in their neighborhood.

Design and maintenance of green space may affect neighborhood crime

Certain types of green space may be associated with reduced crime and violence (Bogar & Beyer, 2016; Kuo & Sullivan, 2001; Wolfe & Mennis, 2012). While research into the specific attributes of these types is limited (M. C. Kondo, South, et al., 2015), maintaining open sightlines at street level and a clean, cared-for appearance is associated with crime deterrence, particularly in neighborhoods with large areas of unmaintained trees and vegetation (Deng, 2015; Donovan & Prestemon, 2012; Troy, Grove, & O'Neil-Dunne, 2012; Troy, Nunery, & Grove, 2016).

Vacant lot greening, in particular, may deter certain types of crime. In Philadelphia, PA, greening vacant lots by removing debris, planting grasses and trees, installing low fences, and performing regular maintenance was associated with nearby reductions in gun assaults, vandalism and criminal mischief (Branas et al., 2011), and in overall gun crimes (Garvin, Cannuscio, & Branas, 2013). These findings are corroborated to some extent by research that found significant reductions in felony assaults, robberies and burglaries around greened vacant lots in Youngstown, OH (M. Kondo, Hohl, Han, & Branas, 2015). Researchers attributed these findings to the possibility that greening cleans up overgrown lots where people hide or where they hide weapons. Although narcotics-related crimes and burglaries declined significantly near Philadelphia GI sites that were not on vacant lots, reductions in violent crimes were not statistically significant (M. C. Kondo, Low, Henning, & Branas, 2015). Ultimately, more research is needed before concluding that GI on vacant lots affects crime.

Green spaces can provide places for residents to relax and recover from stressful events.

GI LANDSCAPES MAY REDUCE STRESS, IMPROVING HEALTH

Attractive neighborhood green spaces may provide restorative environments in which residents can recover from stressful life events or from mental fatigue.

Neighborhood green space, such as GI, may also improve residents' health by reducing chronic stress. Neighborhood environments can both serve as sources of stress and provide opportunities for residents to reduce or recover from stress (Mezuk et al., 2013). Residents in neighborhoods experiencing disinvestment and high levels of property vacancy are often exposed to high levels of crime, poor access to neighborhood amenities and concentrated poverty. The experience of living in this environment contributes to high levels of chronic stress (Casciano & Massey, 2012; Gary, Stark, & LaVeist, 2007; Lorenc et al., 2012; Schulz et al., 2008). Effects from exposure to repeated stressors can accumulate over time, resulting in changes that are measurable by biological markers (Cohen et al., 2012; Jackson, Knight, & Rafferty, 2010) and are associated with harm to mental and physical health (Barber et al., 2015; Brenner, 2012; Kruger et al., 2007; Latkin & Curry, 2003; Merkin et al., 2008; Ross & Mirowsky, 2009; Schulz et al., 2005; Schulz et al., 2013).

There are many theories about how neighborhood green space affects stress and health, although understanding is incomplete about how specific green space attributes such as safety and maintenance shape this influence (Gidlow, Randall, Gillman, Smith, & Jones, 2016; Sugiyama et al., 2016). The percentage of green space in residents' living environments, green space quality, streetscape greenery and vacant lot greening have all been associated with reductions in both self-reported stress and biological makers of stress, particularly among residents of deprived and disinvested neighborhoods (Roe et al., 2013; South, Kondo, Cheney, & Branas, 2015; Thompson et al., 2012; Van Dillen, de Vries, Groenewegen, & Spreeuwenberg, 2012). De Vries, van Dillen, Groenewegen, and Spreeuwenberg (2013) suggest that streetscape greenery's health benefits can be explained through reductions in chronic stress; and others report that nearby green space can reduce stress's negative impacts on health (de Vries et al., 2013; A. E. van den Berg, Maas, Verheij, & Groenewegen, 2010). Attractive neighborhood green spaces may provide restorative environments in which residents can recover from stressful life events or from mental fatigue (Hansmann, Hug, & Seeland, 2007; Hartig, Evans, Jamner, Davis, & Gärling, 2003; Kaplan, 1995; Ulrich et al., 1991; A. E. Van den Berg, Jorgensen, & Wilson, 2014). Neighborhood green space may also reduce chronic stress by enhancing neighborhood social networks, trust, and attachment (Sugiyama, Leslie, Giles-Corti, & Owen, 2008; Thompson, Aspinall, Roe, Robertson, & Miller, 2016), which can help residents cope with the stressors, reducing negative impacts on their health (Ivey et al., 2015; Karb et al., 2012; Mair et al., 2010; Schulz et al., 2008).

GREEN SPACE: HOW MUCH, HOW FAR AND WHAT KIND DO WE NEED TO PROMOTE HEALTH?

The amount and attributes of green space affect its influence on health (Ekkel & de Vries, 2017). Researchers have generally focused on two dimensions: proximity, or the distance residents live from a green space, and the density of green space within a given area.

Studies included in this White Paper define proximity in three main ways:

- The length of a straight line from the home to a green space (e.g. Krekel et al, 2016).

- The distance from the home to a green space travelling along streets, sidewalks or paths (e.g. Sugiyama et al, 2010).

- Self-reported distance, in which researchers ask residents to estimate how far they live from a green space (e.g. Akpinar et al 2016). Perceptions of distance can also influence behavior, and researchers have found that these estimates may differ from measured distances (Peschardt, Schipperijn, & Stigsdotter, 2012; Wang, Brown, & Liu, 2015).

Studies also use distance to define neighborhood scales in which green spaces or landscape conditions may impact health. Research indicates that green spaces generally influence the upkeep of nearby lots within 54 to 110 yards (M. C. R. Hunter & Brown, 2012; Kruger, 2008; Krusky et al., 2015). Greening vacant lots is associated with reductions in certain types of crime within distances ranging from 220 to 440 yards, and residents' satisfaction with their neighborhoods is most strongly influenced by the condition of neighborhood landscapes on the block on which they live or within 440 yards of their home (Branas et al., 2011; Hipp, 2010; M. Kondo, Hohl, et al., 2015; Krekel et al., 2016).

Density refers to the amount of green space within an area and provides a way to look at the combined impacts of multiple green spaces. Studies included in this review used density to measure the total amount of green space in the area around residents' homes, defining that area using different Euclidean distances or political boundaries such as census tracts (e.g. M. C. R. Hunter & Brown, 2012; Maas, Van Dillen, et al., 2009; A. E. van den Berg et al., 2010).

Quality may have as much if not more impact on human health as the quantity of or distance to green spaces (Akpinar, 2016; Francis, Wood, Knuiman, & Giles-Corti, 2012; Sugiyama, Francis, Middleton, Owen, & Giles-Corti, 2010; Wolch, Byrne, & Newell, 2014). One Dutch study found that the quality of neighborhood streetscape greenery (assessed based on accessibility, maintenance, naturalness, colorfulness, cleanliness and safety) was associated with greater improvements in residents' perceived general health and number of health complaints than the quantity of greenery (Van Dillen et al., 2012). Other studies have failed to establish clear relationships between vegetation complexity or species richness and health (D. F. Shanahan et al., 2016; Danielle F Shanahan et al., 2015). However, comparatively few studies consider the quality of green spaces in assessing health impacts, and measures of both density and distance can fail to take quality into account (M. van den Berg et al., 2015). For example, large amounts of vegetative cover in a landscape can be associated with highly-maintained suburban development or with unmaintained vacant lots (Cook, Hall, & Larson, 2012).

Ultimately, there is no standardized approach for measuring how the attributes of green space influence its health-related effects, and caution must be taken in comparing different studies' findings or applying these findings to GI and greening on vacant lots. Further research is needed in order to understand how green spaces can be designed across a neighborhood landscape in order to have the greatest benefits for residents; how this depends on factors such as neighborhood context, green space attributes and the dimension of health being measured; and what implications this may have for GI.

Quality may have as much if not more impact on human health as the quantity of or distance to green spaces.

GI LANDSCAPES MAY CREATE OPPORTUNITIES FOR PHYSICAL ACTIVITY THAT IMPROVES HEALTH

Properly designed and maintained, GI may support health by providing green spaces and cultivating neighborhood landscapes that enable residents to be physically active (Hartig, Mitchell, De Vries, & Frumkin, 2014; Project for Public Spaces, 2016). Proximity to green spaces, the amount of green space nearby and measures of green space quality (primarily clean, ordered and maintained appearances) have all been linked to physical activity, active commuting and outdoor play, particularly for children and the elderly (Akpinar, 2016; Giles-Corti & Donovan, 2003; Gong, Gallacher, Palmer, & Fone, 2014; Sugiyama et al., 2010; Sugiyama et al., 2008; Tappe, 2013; Voorhees et al., 2010). However, other studies find no significant associations between the amount of green space in a neighborhood and physical activity (Ord, Mitchell, & Pearce, 2013). According to a 2011 literature review, 66% of studies found evidence of a positive relationship between green space access (measured varyingly as distance to the nearest green space, the amount of green space within a certain area, measures of green space quality, or using combined approaches) and physical activity, and that evidence was unambiguous in 40% of studies (Lachowycz & Jones, 2011). Different characteristics of urban green space may have different impacts on physical activity. For example, in Chicago, IL, neighborhood park area was associated with residents' physical activity levels, but the distance residents lived from parks and the total area in a neighborhood covered by vegetation were not (Fan, Das, & Chen, 2011).

Neighborhood landscapes that appear safe, clean and well cared-for may also enable physical activity (Hartig et al., 2014). Studies in multiple US cities have found associations between perceived crime levels and children walking to school or spending time playing outside (Tappe, 2013; Voorhees et al., 2010), and research from Chicago, IL indicates that fear of crime may decrease women's likelihood of walking (Craig, Brownson, Cragg, & Dunn, 2002; Evenson et al., 2012). Other studies have failed to find associations between perceived safety and physical activity (Bracy et al., 2014). A study in low and medium-income Detroit neighborhoods found that signs of disorder reduced physical activity levels among the elderly and non-Hispanic whites (Kwarteng, Schulz, Mentz, Zenk, & Opperman, 2014).

Visual appearance may be particularly important if GI is to influence physical activity levels. One Portland, OR, study found that in-street bioretention installations with distinctive, multi-level plantings increased resident's perceptions of a block's walkability, but installations with only grass and trees did not (Adkins, Dill, Luhr, & Neal, 2012).

GI may reduce street and basement flooding, which can put residents at risk of increased stress, water-borne disease and mold exposure.
PHOTO: CHRIS FAUST

ENVIRONMENTAL FUNCTIONS OF GI ALSO MAY IMPACT PUBLIC HEALTH

By alleviating combined sewage overflows and residential flooding, GI may reduce water-borne disease transmission and exposure to mold and stress associated with neighborhood or basement flooding (Dunn, 2010; Gaffield et al., 2003; Lennon, Scott, & O'Neill, 2014). Sanitary sewage overflows can contaminate downstream drinking water sources with fecal matter, potentially including bacteria (e.g., Escherichia coli, legionella), viruses (e.g., hepatitis A), parasites (e.g., cryptosporidiosis) and fungi which may lead to illness (Jagai et al., 2015; Jalliffier-Verne et al., 2016). Flooding in basements can contribute to mold growth, which can exacerbate respiratory illness including asthma and create environments that are inviting to certain bacteria or airborne chemicals. Further, the stress of flood events (including economic costs, fear of exposures, loss of work time, or displacement) can undermine mental health (Fernandez et al., 2015; Greene, Paranjothy, & Palmer, 2015).

Where more trees serve the stormwater management purposes of GI, GI landscapes may contribute to reducing health risks associated with air pollution and urban heat island effects (Dunn, 2010; Hartig et al., 2014). Patches of trees may mitigate some health effects of air pollution (e.g., particulate matter, ozone, carbon) (US Environmental Protection Agency, 2016b); however, much research is needed to understand mechanisms by which this effect occurs. Shading from trees can also ameliorate high temperatures (Davis, Jung, Pijanowski, & Minor, 2016; Jenerette, Harlan, Stefanov, & Martin, 2011; Norton et al., 2015). This may be particularly beneficial in highly populated areas and places where climate change projections call for increased intensity, duration and frequency of high temperatures (including parts of the Midwest), making increased heat-related illness or mortality and greater need for costly and energy-consuming air conditioning likely.

If designed well, GI may help to reduce impacts of increased precipitation on stormwater infrastructure, thus reducing financial and health consequences of climate change.

POTENTIAL HEALTH BENEFITS OF GI IN THE CONTEXT OF CLIMATE CHANGE

Across the Upper Midwest, extreme precipitation events have become more intense and more frequent over the second half of the 20th century. Between 1951 and 2015, total annual precipitation in Michigan increased by 4.5%, or 1.4 inches, with regional variation across the state. According to the Michigan Climate and Health Profile, "most of Michigan is projected to experience increases of 3-6% in annual mean precipitation, with slightly less in the southernmost part of the state" (Cameron, Ferguson, Walker, Briley, & Brown, 2015).

On August 11, 2014, Metro Detroit experienced record breaking rainfall —more than six inches in four hours. As a result, severe flooding occurred. The Southeast Michigan Flood Recovery Group estimated repairs to infrastructure and household damages to cost $144,477,558. The Michigan Department of Community Health quickly warned residents that mold could begin growing within a flooded home within two days and urged quick cleanup to prevent health issues. Following this event, nearly 75,000 households applied for assistance from the Federal Emergency Management Agency of which approximately 75% had no homeowner's or renter's insurance, and of which 14% had a senior (65 years or older) and 44% had a child (less than 18 years old) in the household (Southeast Michigan Flood Recovery Group, 2015).

With increased frequency and intensity of precipitation events and related flooding, climatologists and epidemiologists project health effects including increased incidence of mosquito and water-borne diseases, carbon monoxide poisoning, and respiratory illness and allergies; as well as increased stress and poor mental health. If designed well, GI may help to reduce impacts of increased precipitation on stormwater infrastructure, thus reducing financial and health consequences of climate change.

GI stewardship for long-term success

KEY FINDINGS:

- **Aesthetic and social benefits motivate residents to act as stewards of neighborhood GI landscapes.** For stormwater management functions to be sustained over time, GI sites' design and maintenance must reflect residents' preferences and expectations.

- **Community engagement during GI planning enhances resident stewardship.** Residents are more likely to act as stewards for neighborhood landscapes if their capacity for involvement is supported as part of the planning process, and they are involved and their insights absorbed throughout planning.

- **Maintenance is essential for long-term success and ensures that GI continues to provide social and environmental benefits over time.** Plans and funding for maintenance of GI should be integrated with design and implementation, and local governments should lead the coordination of maintenance activities.

THE APPEARANCE AND FUNCTIONALITY of GI changes over time – with maintenance, plant growth, and accumulation of debris, sediment and pollutants—and GI requires care to continue to provide benefits. Local government, non-government partners and nearby residents affect how and when this care is provided. Government departments must ensure that GI landscapes are maintained for stormwater management and as attractive green spaces. However, residents may notice and appreciate whether and how GI is functioning to manage stormwater, report any issues to appropriate agencies, care for their home landscapes in ways that enhance stormwater management, and sometimes they may want to be stewards of neighborhood GI.

FORMS OF GI STEWARDSHIP

Stewardship depends on residents noticing and appreciating GI as a positive part of the neighborhood landscape, and acting to sustain its appearance and function. It can include reporting maintenance issues, keeping streets free of leaves and garbage, discouraging activities in the GI site that might compact surface soils, reporting dumping, or even participating in weeding or other simple maintenance of GI sites. For example, Portland, OR, engages volunteer "Green Street Stewards" to weed, water and clear debris from street-side GI sites (Hufnagel & Rottle, 2014).

AESTHETICS AND SOCIAL BENEFITS MOTIVATE RESIDENTS TO ACT AS STEWARDS OF NEIGHBORHOOD GI LANDSCAPES

Residents' primary motivations for installing rain gardens in their yards were to improve personal spaces and neighborhood aesthetics.

Research indicates that residents generally care for urban landscapes in order to achieve the appearance they want for their neighborhood and to improve their community. If a neighborhood landscape does not match the appearance they desire, they may act to change it (Gobster et al., 2007). They may be more willing to install GI on private land and act as stewards for GI in public spaces if it enhances neighborhood appearance or amenities, rather than only providing less visible environmental benefits (Andersson et al., 2014; Asah & Blahna, 2013). For example, a Portland, OR, study found residents were more willing to act as stewards for GI on public lands if they thought their neighborhood lacked green space (Shandas, 2015). Syracuse, NY, residents' primary motivations for installing rain gardens in their yards were to improve personal spaces and neighborhood aesthetics, and Ontario residents chose tree species based on aesthetic characteristics rather than ecosystem services (Baptiste, Foley, & Smardon, 2015; Conway, 2016).

Because aesthetics and social benefits are more important than environmental benefits in motivating resident stewardship, GI designs need to align stormwater management functions with an external appearance that reflect residents' preferences and expectations (Nassauer, 1997, 2004). When GI does not reflect residents' desires, they may take action to change it in ways that compromise stormwater management. Two examples from Cleveland, OH, illustrate this possibility. There, residents perceived bioretention gardens that were designed with low-maintenance, tall-growing vegetation as overgrown and unkempt, and city crews ultimately had to mow the sites in response to these concerns. Another bioretention garden was repeatedly trampled, destroying plantings. Neighbors explained that "this vacant parcel served as an informal community sport field for youth of the neighborhood" (Chaffin et al., 2016).

Although residents initially may not be aware of GI's stormwater management functions, clear signs of care and stewardship imply that GI has value and can elicit curiosity about these functions (Nassauer, 2011). This awareness can elicit further stewardship. Studies indicate that, in addition to aesthetic and social benefits, residents' knowledge of flood prevention and water quality benefits shape their perceptions of GI, and they report being more willing to install or maintain GI if they are aware of these stormwater management functions (Baptiste, 2014; Baptiste et al., 2015; Everett et al., 2016). However, these studies do not establish whether willingness leads to actual stewardship actions.

RESIDENT STEWARDSHIP OF VACANT PROPERTIES

Residents' stewardship can be particularly important for vacant properties, and they may mow, green or develop new uses for vacant land (Dewar & Linn, 2015; Foo, Martin, Wool, & Polsky, 2013; Kinder, 2016; Langegger, 2013; Nassauer & Opdam, 2008). This stewardship can serve as a way for residents organize to develop and realize visions for their neighborhood landscape, build social ties and improve neighborhood safety (Foo et al., 2013; Sadler & Pruett, 2015). However, these efforts are often limited by a lack of resources, and residents may believe that government agencies should take primarily responsible for caring for vacant lots (Garvin et al., 2012). According to Foo, Martin, Polsky, Wool, and Ziemer (2015), maintenance can be thought of as a social contract between residents and government: while residents will contribute to the care of neighborhood landscapes, they expect government agencies to play a leading and visible role. When residents feel that city government is failing to do its part to maintain neighborhood landscapes, they may reduce their own efforts.

COMMUNITY ENGAGEMENT DURING GI PLANNING ENHANCES RESIDENT STEWARDSHIP

Community engagement during the planning process can help ensure that residents' preferences, values and desired uses are reflected in GI designs, enhancing social benefits.

Community engagement during the planning process can be important to successfully implementing and maintaining GI on vacant land (H. L. Brown, Bos, Walsh, Fletcher, & RossRakesh, 2016; Keeley et al., 2013). It can help ensure that residents' preferences, values and desired uses are reflected in GI designs, enhancing social benefits (Project for Public Spaces, 2016; Trayers et al., 2006). Further, residents may be more likely to act as stewards for neighborhood landscapes when they feel that landscape changes meet neighborhood needs and they have some control over change (Foo et al., 2015). For example, Seattle, WA, and Portland, OR, have ongoing, city-wide GI and stormwater education programs including community forums, site tours and K-12 education programs to build awareness of GI and sustainable stormwater management (Dhakal & Chevalier, 2016).

Community engagement helps to ensure that GI designs reflect residents' desires and can encourage stewardship of GI sites. PHOTO: DAVE BRENNER

Community engagement also can build shared understandings about land use priorities and GI's potential benefits to the neighborhood.

GI design processes that do not engage nearby residents or do not reflect their input may face distrust, limited public support and an unwillingness to contribute to stewardship (R. A. Brown & Hunt III, 2009; Ellis et al., 2010; Keeley et al., 2013; Pincetl, 2010; Travaline et al., 2015). In a Philadelphia neighborhood, limited knowledge about the benefits of GI, concerns that GI would compete with affordable housing and fears that the neighborhood was being "experimented on" contributed to nearby residents' opposition to GI (Travaline et al., 2015).

Community engagement also can build shared understandings about land use priorities and GI's potential benefits to the neighborhood (Travaline et al., 2015). This may be particularly important when developing GI in areas with vacant lots because residents may use or manage vacant land as gardens, private green spaces, or shared public spaces (Dewar & Linn, 2015; Foo et al., 2013; Kinder, 2016; Langegger, 2013).

MAINTENANCE IS ESSENTIAL FOR LONG-TERM SUCCESS

Regular, ongoing maintenance is crucial to ensuring GI's social and environmental benefits in the long-term. As GI ages, it changes in both appearance and function (Lenhart & Ill, 2011). Maintenance to sustain GI's stormwater management functions can include regularly cleaning catch basins, intakes and bioretention cells of litter, debris and sediment, as well as replacing the top layers of bioretention media if it becomes clogged with fine sediment (R. A. Brown & Hunt, 2012; Hufnagel & Rottle, 2014).

Maintenance is also essential for sustaining resident stewardship and the cared-for, attractive appearance that underlies many of GI landscapes' social and health benefits. Concerns about inadequate maintenance sometimes undermine community support for GI (Baptiste, 2014; Travaline et al., 2015). Portland, OR residents most often identified accumulated litter and messiness as disadvantages of in-street bioswales, with messiness seen as a result of infrequent or poor maintenance (Everett et al., 2016). Similarly, Edinburgh, Scotland, residents cited negative aesthetic impacts of litter as a disadvantage of nearby bioretention ponds (Bastien et al., 2012). Maintenance needed to sustain GI's appearance includes watering plants until they are established, mowing turf, weeding, pruning, removing and replacing dead plants, and cleaning up litter or dumping.

Agencies should plan for and fund regular maintenance in order to sustain GI's social and environmental benefits over time.

GI is most often successful when government agencies take the lead in funding and conducting maintenance.

GI is most often successful when government agencies take the lead in funding and conducting maintenance. Local governments and nonprofits often hope to engage residents and neighborhood groups in GI maintenance. However, residents may believe that government should be responsible for maintenance and, particularly in lower income neighborhoods, residents are rarely able to maintain GI without tools, training, compensation and organizational support from government agencies or nonprofit organizations (Moskell & Allred, 2013; Young, 2011). A review of urban tree planting programs in Palo Alto, CA, and Philadelphia, PA, found that while volunteers were important to maintaining newly-planted trees, they depended on nonprofits with paid staff to organize their efforts, provided technical expertise, and obtain and manage funding (Roman et al., 2015). Similarly, in Flint, MI, the Genesee County Land Bank's Clean & Green program for vacant lots provides administrative support, equipment and stipends for volunteer groups, which are based out of existing community organizations (Sadler & Pruett, 2015). In contrast, a Los Angeles, CA, street tree planting initiative relied entirely on residents to maintain trees and assume watering costs. This contributed to negative public perceptions of the program and to the death of trees due to inadequate care (Pincetl, 2010).

Residents often lack the tools, training or resources to conduct GI maintenance. This Detroit Water and Sewerage Department maintains this bioretention garden in a residential neighborhood. PHOTO: DAVE BRENNER

Conclusion: Lessons for GI in legacy cities

GI IS A PROMISING APPROACH for managing stormwater in legacy cities. The scientific literature indicates that, with appropriate design and maintenance, GI can also help to improve neighborhood landscapes and residents' health in ways that are particularly relevant to neighborhoods challenged by vacancies. Implications for GI in Detroit and other legacy cities include:

GOVERNANCE OF GI IN LEGACY CITIES

- Effective GI in legacy cities, especially involving vacant land, requires capacity to coordinate different functions of local government including: stormwater management, public works planning and maintenance, urban planning, construction permitting, parks planning and maintenance, sales of publicly owned land, and public health.

- Involvement of neighbors from the start of GI planning is important. Considering residents' preferences for neighborhood landscapes helps to ensure that GI sites will be valued and provide social benefits. Residents are more likely to act as stewards of GI when they appreciate its appearance and value its social benefits.

- Non-profit partners can be instrumental in supporting collaborative efforts by government agencies and neighborhood residents.

- For different stakeholders to work together successfully, GI governance needs to be collaborative and coordinated.

EFFECTS OF GI ON NEIGHBORHOOD RESIDENTS

- GI design and maintenance can result in neighborhood landscapes that appear better cared for, more attractive and safer. Vegetation that obstructs sight lines or looks weedy or messy undermines the appearance of neighborhoods in legacy cities.

- GI design and maintenance should respect residents' norms for the appearance of their neighborhoods and the desirability of new forms of green space nearby.

- GI design and maintenance may contribute to residents' health by promoting greater social interaction and physical activity, reducing stress, increasing neighborhood safety, and reducing residential flooding and other environmental hazards.

- The ways in which GI may contribute to health are particularly relevant to neighborhoods with high levels of property vacancy. Locating well-designed and maintained GI in these neighborhoods may help counter health disparities linked to vacancy and disinvestment.

EFFECTS OF GOVERNANCE AND NEIGHBORHOOD RESIDENTS ON GI

• Because stormwater movement, plant growth, and land use and landscape change affect GI function, ongoing maintenance is essential to its effectiveness. To provide for public health and safety, local government should ensure regular maintenance over the long-term.

• Residents should not be expected to maintain GI sites. However, they should be supported in acting as stewards by noticing changes in GI sites and nearby stormwater flows and by participating in vegetation maintenance, depending on their interests and resources.

• Residents should be supported in reporting issues of GI maintenance to appropriate, responsive agencies.

This White Paper synthesizes peer-reviewed scholarly literature from several disciplines relating to GI. This literature is rapidly growing, and the NEW-GI project will issue an updated White Paper for decision-makers in 2018. It also will issue additional technical advisory reports as our own research with our Detroit collaborators produces new knowledge. NEW-GI moves this research forward with the goal of sustainably managing stormwater in ways that make Detroit neighborhoods attractive, healthy places to live.

SOME RESEARCH NEEDS

GI planning and implementation now underway in Detroit and other legacy cities present important opportunities for research to address topics where existing knowledge is not yet adequate. Some of these topics include:

• Identifying long-term strategies for effectively coordinating stormwater governance - particularly employing vacant land - among agencies, NGOs and residents.

• Understanding how and at what scale complex urban watershed stormwater systems can effectively reduce localized flooding, and mitigate pollution and downstream ecological impacts.

• Understanding how and at what scale aspects of GI design and maintenance can most effectively contribute to the quality of neighborhood landscapes and human health.

• Informing and planning for long-term maintenance of environmental and social functions of GI.

Appendix A: Glossary

Chronic stress: stress that persists or is repeated over an extended period of time. Chronic stress can harm physical and mental health (American Psychological Association, 2017; National Institute of Mental Health Office of Sicence Policy).

Combined Sewage Overflows (CSOs): common in older cities, combined sewage systems use a single set of pipes to carry both stormwater and sewage to a sewage treatment plant. Combined sewage overflows occur when large volumes of rain or snowmelt overwhelm the capacity of the treatment plant and an untreated mixture of stormwater and sewage is discharged directly into water bodies (US Environmental Protection Agency, 2016a).

Green infrastructure: systems that use vegetation, soils and other natural processes to retain, detain, infiltrate or evapotranspirate stormwater at its source rather than removing it from the site through grey infrastructure (US Environmental Protection Agency, 2016e).

Green infrastructure landscapes: the elements of green infrastructure that can be seen by residents and passersby, including landform, turf, flowers, shrubs, and trees.

Greening: efforts to increase the amount or quality of green space in a neighborhood landscape by planting or maintaining trees, shrubs, grass or other vegetation. Vacant lot greening refers to planting and maintaining vegetation or structures (e.g. gardening beds, fences or signs) on vacant lots.

Green space: land that is "partly or completely covered with...vegetation" (US Environmental Protection Agency, 2016f). While commonly-given examples of urban green spaces include parks, community gardens, cemeteries, playgrounds, the term also may refer to residential yards and other vegetated spaces. Green space can occur on private or public land.

Governance: laws and regulations; institutions; political and administrative relationships; and practices and procedures that determine how policies are implemented and publicly-provided goods and services are managed (Lynn et al., 2001).

Grey infrastructure: constructed systems that are "designed to move urban stormwater away from the built environment and includes curbs, gutters, drains, piping and collection systems." Grey infrastructure collects "stormwater from impervious surfaces, such as roadways, parking lots and rooftops, into a series of piping" and ultimately into a water body (US Environmental Protection Agency, 2016g).

Health disparities: differences in human health that are "closely linked with social or economic disadvantage" (Centers for Disease Control and Prevention, 2014). Epidemiological evidence consistently indicates that "some groups have a better chance for health and longevity than others, with the economically disadvantaged and racial and ethnic minorities fairing less well in these regards" (Pearlin, Schieman, Fazio, & Meersman, 2005).

Landscape care: people's efforts to protect or maintain aspects of a landscape, particularly its noticeable and visible characteristics. Types of care may include planting and maintaining vegetation, cleaning and maintaining structures and weeding and mowing (Nassauer, 2011).

Landscape stewardship: "a particular type of [landscape] care, invoking broad scales of time or space and connoting care of something that ultimately belongs to others rather than only to oneself" (Nassauer, 2011).

Legacy cities: cities, primarily in the Midwest and Northeastern US, which experienced sustained deindustrialization and population loss over the course of the second half of the 20th century. These changes have transformed many neighborhoods into landscapes dominated by unoccupied structures and vacant lots (Dewar & Thomas, 2013; Morckel, 2015).

Neighborhood landscapes: all of the outdoor spaces of a neighborhood that can be seen by residents. Neighborhood landscapes include streets, buildings, trees, yards, parks and vacant lots.

Neighborhood satisfaction: residents' subjective evaluation of "how well the local area meets their personal needs and desires" (Adams, 1992; Grogan-Kaylor et al., 2006).

Physical disorder: "the deterioration of urban landscapes," including graffiti, dumping, litter, deteriorating structures and overgrown lots. Physical disorder can occur both in public spaces and on visible but privately-owed spaces, and can shape how neighborhoods are perceived by both residents and outsiders (Sampson & Raudenbush, 1999).

Social determinants of health: the "conditions in the environments in which people are born, live, learn, work, play, worship and age that affect a wide range of health, functioning and quality-of-life outcomes and risks." Social determinates of health can include "resources that enhance quality of life," improving health (Office of Disease Prevention and Health Promotion, 2014).

Social environment: the human and social dimensions of the places in which people live, work and play. Social environments can include peoples' relationships, their patterns of interaction, the organizations to which they belong and the institutions with which they interact (Schulz & Northridge, 2004; Yen & Syme, 1999).

Stormwater: rain and snowmelt that flows "over the land or impervious services, such as paved streets, parking lots and building rooftops" (US Environmental Protection Agency, 2016c).

Vacant lots: lots that do not contain any buildings and are not being put to some other productive use, such as parks, gardens or GI. Vacant lots may have never been built on, or may once have held a building that was demolished or burned (US Environmental Protection Agency, 2016d).

Appendix B: References

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