Engaging the Private Sector in Green Infrastructure Development and Financing:

A Pathway Toward Building Urban Climate Resilience

OCTOBER 2018

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Cover Photo: Aerial view of Lumphini Park, Bangkok, Thailand; Photo by Terence Ong, June 2007.

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Prepared for:
United States Agency for International Development (USAID)
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ACRONYMS

CBA	Cost–benefit analysis
CONANP	Comisión Nacional de Áreas Naturales Protegidas (National Commission of Natural Protected Areas)
EPA	Environmental Protection Agency
GDP	Gross domestic product
GI	Green infrastructure
LCA	Life cycle assessment
MKB	Malmö Municipal Housing Company
NGO	Nongovernmental organization
O&M	Operation and maintenance
PACE	Property Assessed Clean Energy
PES	Payment for ecosystem services
PG	Prince George's (County)
PPP	Public–private partnership
SCCZZ	Swire Coca-Cola Zhengzhou
TIF	Tax Increment Financing
USAID	United States Agency for International Development

EXECUTIVE SUMMARY

PURPOSE AND STRUCTURE OF THIS REPORT

Through case study analyses, this report provides recommendations for steps that city officials and the donor community can take to engage private sector partners in green infrastructure development and financing in developing countries. This report is intended to be a complementary resource to USAID's Green Infrastructure Resource Guide (2017), which provides development practitioners involved in the planning and development of green infrastructure with an in depth understanding of their design and benefits.

This report is divided into the following sections: (1) executive summary; (2) an overview of GI; (3) the types of GI; (4) the cost, benefits and challenges of GI in the development context; (5) mechanisms to promote GI in developing countries' cities, including incentives for private sector investment; (6) recommendations for stakeholders to ensure the success of GI interventions; and (7) additional resources for GI. Four case studies of successful GI that yield both climate resilience and mitigation benefits in urban settings are provided to showcase opportunities for private sector involvement.

OVERVIEW OF GREEN INFRASTRUCTURE

In 2016, 55 percent of the world's population lived in urban areas and cities accounted for 80 percent of global gross domestic product (GDP) (World Bank 2018a). By 2050, it is expected that 66 percent of people globally will live in urban areas, representing an additional 2.5 billion people living in cities (WEF 2016). Of that increase in urban population, it is expected that approximately 90 percent will be in cities in Africa and Asia (UN DESA 2016). This demographic shift will further strain the ability of cities to provide basic services to their residents, including drinking water, treatment of wastewater, and trash removal, particularly in developing countries (Mora et al. 2017). Water resource management is one of the most pressing needs for governments and development organizations to address (Ham and Klimmek 2017), as evidenced by the 2018 drought crisis in Cape Town, South Africa[1]. Extreme weather events that cause intense rains, rising seas and heat waves will compound these problems even more.

Green infrastructure (GI) is defined by USAID as "any engineered intervention that uses vegetation, soils, and natural processes to manage water and create healthier built environments for people and the natural resources that sustain them" (USAID 2017). In cities, GI can be a part of the solution to this set of challenges. GI delivers multiple benefits – stormwater management, reduced heat impacts, increased biodiversity, and improved air and water quality – that work together to improve a city's overall resilience. Water infrastructure investment needs are stark – projections of global financing needs for water infrastructure range from USD 6.7 trillion by 2030 to USD 22.6 trillion by 2050 (OECD 2018).

1 See the JRC Global Drought Observatory's "Drought in Western Cape Province – January 2018" analytic report for more information: http://edo.jrc.ec.europa.eu/documents/news/GDODroughtNews201801_South_Africa.pdf

Significant investment is needed in GI so that cities worldwide can continue to thrive, protect people and their homes, keep businesses running, provide transportation to jobs, and safeguard supply chains. Urban policies and programs that reflect this need and take into account the disproportionate impacts of climate variability on vulnerable populations will ultimately yield more resilient urban areas.

BENEFITS OF GREEN INFRASTRUCTURE

Cities can undertake a number of GI interventions with an array of benefits. This report focuses on some of the most common GI options, including: green roofs, bioswales and bioretention areas, permeable pavements, urban agriculture and native landscaping, wetland/marshland creation or restoration, mangrove restoration and rainwater harvesting. However, as the purpose of this report is to highlight the various policy and financial enabling conditions a city can take to encourage GI investment and build urban resilience, refer to USAID's Green Infrastructure Resource Guide (2017) for an in-depth explanation of GI benefits, some of which are referenced in Table 1.

RECOMMENDATIONS

In many developing country contexts and more broadly, incorporating GI into planning, zoning, regulations and taxation (and ultimately capital expenditure and operations and maintenance (O&M)) is an effective way for a local government to improve climate resilience. The widespread adoption of GI in developing nations requires a holistic approach from local governments, the private sector and donors, mainstreaming GI into planning and regulatory documents, establishing incentives, providing education and outreach, and providing implementation support to government officials and contractors unfamiliar with GI.

Mainstream green infrastructure into planning processes and documents

Investment in GI requires (1) developing a long-term plan that lays out goals and priorities for GI, and (2) mainstreaming GI into planning documents, action plans, investment plans and budgets across the government. Exemplary approaches include:

- ***Develop a long-term GI plan***. Using other planning documents (e.g., infrastructure investment plans, sustainability or "green" plans) as a basis, develop a long-term GI plan that prioritizes infrastructure investment (Garrison and Hobbs 2011). The plan should identify long-term goals for GI; current issues that GI could address (e.g., flooding in particular parts of the city, aging sewerage infrastructure, reducing air pollution); departments/agencies that should be involved in decision making regarding GI and the roles, codes and regulations that need to be updated to incorporate GI; skills and knowledge gaps related to GI that need to be addressed; and funding source(s) for GI projects.
- ***Add GI policy and interventions to department/agency-level policy and action plans.*** In addition to a citywide GI plan, elements of the GI plan will need to flow down to department-level policy and action plans, ensuring specific GI interventions are planned and budgeted for by the implementing departments. Examples of departments that would be included in this action include the departments of Planning and Development, Transportation, Water & Sewerage, Parks and Recreation, and Housing/Buildings.

- *Incorporate GI into infrastructure investment planning.* If a city's infrastructure investment plan is a separate document from standard citywide or department-level action plans (as it often is), GI should be included in the infrastructure plan to ensure sufficient funds are allocated.

- *Establish a monitoring and evaluation system for GI.* Monitoring and evaluation of GI can likely be incorporated into current systems used to monitor infrastructure, but GI needs additional indicators that assess interventions for their climate risk reduction, mitigation benefits and their provision of ecological services more generally. These elements are a critical part of establishing the necessary evidence base for continued GI support.

Update codes to include green infrastructure and enforce new regulations

Updating building codes and regulations related to stormwater runoff and other anticipated benefits is crucial to the success of GI. Without codes in place that mandate some level of stormwater retention on site, for example, or that compel property owners to use GI to manage runoff, often little incentive exists to change practices, particularly if those practices are new or untested locally. Cities in developing countries must also take the lead in applying these new standards to public spaces.

- *Develop and enforce a retention standard for stormwater.* Municipalities should develop regulations that require private property owners to retain a specific amount of precipitation onsite; in other words, if the standard is one inch and a rain event drops one inch or less of precipitation, the property should be able to infiltrate, evapotranspire or capture for reuse all of the precipitation, so that no water enters the storm sewer.

- *Require GI to manage runoff from impervious surfaces.* In addition to capturing precipitation onsite, cities should update land use and zoning regulations to require property owners to use GI as a means of managing runoff from roofs, parking lots or other impervious surfaces.

- *Institute a stormwater management fee.* Much like providing potable water or managing wastewater from homes, managing stormwater represents a significant cost for municipalities, and as such, cities should impose a fee to recoup that cost. The most common system in the United States for calculating the fee is a set rate multiplied by square feet of impervious surface, as this directly correlates with runoff, and tends to be progressive, as larger fees are applied to larger landowners (often commercial buildings). In addition to providing a revenue source to cover the cost of stormwater management and to future GI projects, a stormwater management fee discount (discussed below) offers an incentive to property owners to install GI.

- *Introduce a discharge permit process.* In the United States, the National Pollutant Discharge Elimination System (NPDES) program requires private "point sources" (e.g., industrial operations, construction sites, large agricultural operations) as well as municipalities to apply for and receive a permit to discharge surface water. The overall goal at the federal level is to regulate pollutants, but at the municipal level, municipalities have included GI in the permitting process, requiring commercial operations and large developments to include GI as part of their strategy to reduce runoff and pollutants.

Develop incentives to promote green infrastructure

Incentives provide a counterbalance to regulations, and in addition to stimulating positive change in their own right, they increase public acceptable of regulatory changes. Incentives are particularly important in developing countries with little or no experience with GI, as beginning with incentives and then phasing in regulatory changes can help establish pioneers and a base of knowledge. The US EPA's "Municipal Handbook: Incentive Mechanisms" offers four primary mechanisms in use by municipalities in the United States that could be adopted by cities in developing countries.

- ***Development incentives***. Typically offered to developers during the process of applying for development permits, this incentive can take a number of forms, including expedited permitting, reduced permit fee or an increase in floor area ratio.
- ***Stormwater fee discount.*** This incentive requires that a stormwater management fee is in place and is being collected. It functions by offering a discount on the fee as property owners reduce the volume of runoff. Depending on a municipality's goals, the discount can incentivize various GI interventions, including reducing impervious areas, increasing infiltration, increasing the number of buildings with green roofs or increasing the practice of rainwater harvesting.
- ***Grants***. Municipalities can provide direct funding to property owners or community groups to stimulate GI buy-in and implementation. In the developing world, a grant program may or may not be feasible, but a donor could provide a grant pool to incentivize GI as part of a larger project.
- ***Rebates and financing.*** This incentive requires that participants have the upfront capital necessary to fund the GI intervention directly; they then receive support from the government through low-interest loans, tax credits or reimbursements. In developing countries, rebates would likely be best targeted at businesses, as residents may not have the capital to fund GI improvements without assistance.

Communicate and demonstrate the benefits of green infrastructure

As with any major change in thinking, residents and business need information about GI: what it is, how it looks and works and what benefits it provides. For most cities in developing countries, this means assessments need to be conducted to study the feasibility and potential cost savings to both private firms and residents in the local context; demonstration projects need to be implemented to show in practice how GI works and further build the evidence base; and these results need to be communicated to the public to improve the acceptance of regulatory changes and buy-in for GI.

- ***Build an evidence base***. Municipal governments should conduct a comprehensive economic and environmental analysis to more accurately compare green versus gray infrastructure in the local context (The Nature Conservancy 2013). This could include a CBA of specific interventions during the investment planning phase, comparing lifetime construction and O&M costs of grey infrastructure projects to potential GI alternatives. It could also include an assessment of benefits beyond climate risk reduction that grey infrastructure may not provide (e.g., other ecological services, biodiversity conservation, beautification of the public realm, creation of recreational spaces, increased public safety, etc.).

- ***Demonstrate the benefits of GI through pilot projects.*** Municipalities should partner with donors or establish PPPs to develop and test GI projects. A partnership model can help reduce risk, accelerate implementation and provide experience on developing, implementing and financing GI initiatives. Successful pilot projects can also serve as models for future development, and can help further build the business case for GI.

- ***Disseminate information about GI.*** A common theme across GI case studies is that community involvement and buy-in are an important factor of success, particularly when GI is being implemented communitywide. Cities should develop gender informed communication campaigns or awareness-building initiatives to foster inclusive public involvement in GI development, articulating the benefits and opportunities of GI, and leveraging potential gender differences in motivations and incentives for men and women. Benefits should also be communicated to businesses, and efforts should be made to create public–private networks to increase communication between city officials and local business leaders. GI projects developed in areas characterized by marginalized populations should be targeted using intensive outreach techniques, including nontechnical language, visual presentations and storytelling.

Provide technical assistance and coordination for green infrastructure implementation

In some developing countries, GI may be a new concept, or it may already be in use, but not used intentionally as GI. City officials, O&M staff, engineers, contractors and others involved in the water and sewerage infrastructure of a city will need technical assistance and training on the design, construction and O&M of GI.

- ***Provide policy support.*** Either through consultants or with donor support, technical assistance should be provided to city officials to review environmental regulations, building codes, environmental impact assessment guidelines and requirements, and other legal and regulatory frameworks to (1) ensure adequate regulations are in place considering issues like stormwater runoff and land use, and (2) look for opportunities to incentivize or require GI elements in planning and design.

- ***Provide capacity building and implementation support.*** Capacity building such as training and knowledge dissemination through workshops, seminars, webinars, professional meetings and other learning activities should be provided to the relevant departments on designing, constructing, maintaining and monitoring GI. While most departments likely have engineers on staff, additional instruction may be required on issues relevant to GI, such as site selection, local hydrology, selection of appropriate GI techniques, and training community members and private land owners on GI maintenance.

- ***Provide training-of-trainers sessions for municipal staff.*** Unlike grey infrastructure, which is typically maintained exclusively by a municipality or a private contractor, GI frequently requires community involvement in maintenance and, occasionally, construction. GI constructed on private land will very likely not be carried out or maintained by municipal staff; therefore, staff will be responsible for disseminating information on GI best practice, and providing training sessions to contractors, businesses and private property owners. Either as a self-funded initiative or with donor support, city officials need to provide training-of-trainers sessions for staff to enable them to effectively develop the community support network necessary to expand and maintain GI interventions.

KEY TERMS

BIORETENTION – a stormwater treatment process for removing pollutants and sediment from stormwater using a system of ponding areas with vegetation, soil, sand gravel and organic material.

BIOSWALE – a vegetated linear depression or trench designed for the collection, conveyance, infiltration and filtration of stormwater runoff.

CONSTRUCTED WETLAND – an engineered wetland that treats and temporarily stores stormwater or other wastewater via the natural processes of wetland vegetation, soils and microbial assemblages.

ECOSYSTEM SERVICES – any positive benefit that wildlife or ecosystems provide to people. The benefits can be direct or indirect and range from small to large.

GREEN INFRASTRUCTURE (GI) – any engineered intervention that uses vegetation, soils and natural processes to manage water and create healthier built environments for people and the natural resources that sustain them. GI can range in scale from small-scale technologies such as rain gardens and green roofs to regional planning strategies targeting conservation or restoration of natural landscapes and watersheds. GI approaches may be interconnected with existing and planned grey infrastructure networks to create sustainable infrastructure that can enhance community resilience to disasters as a result of increased water retention and groundwater recharge, flood mitigation, erosion control, shoreline stabilization, combatting urban heat island effect, improving water quality, conserving energy for buildings.

GREEN ROOFS – or vegetated roofs are roof systems that comprise vegetation along with the supporting growing media (topsoil or lightweight aggregates) that are designed to intercept rainwater.

HEAT ISLAND EFFECT – an environmental condition encountered in cities that have consistently higher temperatures than surrounding areas due to human activities and increased solar radiation absorbed by urban infrastructure.

INFILTRATION/INJECTION WELL – a subsurface infiltration pathway that facilitates using surface water to recharge groundwater reservoirs. The well can use either gravity or mechanical processes.

PERMEABLE PAVEMENT – alternative pavement materials designed to infiltrate stormwater runoff to the subsurface.

RAIN BARREL – a rainwater harvesting container used to collect and store rainwater from rooftops.

RAIN GARDEN – landscape features that are planted with a selection of native and water-tolerant plants and designed to collect and treat runoff.

RECHARGE BASIN – a shallow storage area developed adjacent to rivers or streams intended to encourage surface flows to infiltrate and recharge groundwater reservoirs.

TREESCAPING – the strategic planting of trees or vegetative canopies to increase shading and reduce heat absorption by the built infrastructure.

URBAN AGRICULTURE – activities that involve the cultivation of plants and raising of animals within and around cities and peri-urban areas, including the processing and distribution of food.

URBAN HEAT ISLAND – a metropolitan area that has consistently higher temperatures than surrounding areas due to human activities and increased solar radiation absorbed by urban infrastructure. Urban heat island effects include increased energy consumption for cooling, compromised human health and comfort, and impaired water quality for surface waters.

WATERSHED – the area of land that drains to a common outlet or water body.

XERISCAPING – a landscaping technique that utilizes drought-tolerant species and requires little to no irrigation.

Source: USAID Green Infrastructure Resource Guide (2017)

INTRODUCTION

URBAN CLIMATE RESILIENCE

In 2016, 55 percent of the world's population lived in urban areas (WEF 2016) and cities accounted for 80 percent of global GDP (World Bank 2018a). In virtually every country, cities serve as governmental, financial and education hubs, and in many cases, peri-urban areas serve as industrial hubs. Cities are typically a country's transport and shipping hub, serving as the location for the primary international airport and shipping port, the crossroads of ground transportation, and the main entry and exit point for tourists, raw materials and manufactured goods. In addition to the functions and services provided by cities for the countries in which they are located, cities provide or facilitate a myriad of services for their residents, including housing, employment, access to potable water, electricity, natural gas and sewerage, sanitation, stormwater management, public and mass transit, schools and libraries, health services and hospitals, safety and fire protection, and cultural and recreational attractions.

By 2050, it is expected that 66 percent of people globally will live in urban areas, representing an additional 2.5 billion people living in cities (WEF 2016). Of that increase in urban population, it is expected that approximately 90 percent will be in cities in Africa and Asia (UN DESA 2016), and given that the proportion of women living in urban areas has risen steadily in most parts of the world in recent years, a large percent of that increase is likely to be women (UNFPA 2012). This demographic trend toward higher population densities will further strain the services provided by cities, particularly with respect to fresh water, sanitation and public health (Mora et al. 2017). Extreme weather events that cause intense rains, rising seas and heat waves will compound these problems even more. For example:

- Shifting precipitation patterns can push stormwater management systems past capacity, causing flooding, which in turn can contaminate groundwater, disrupt transport and trade, and spread waterborne diseases.
- Long term drought can stress water services and groundwater supplies, which in turn has a negative effect on sanitation, human health and industries reliant on fresh water.
- Heat waves amplify the urban heat island effect, which in turn causes increased mortality and negatively affects human health, increases energy use and demand, and can stress water systems and power grids on which residents and businesses rely.
- Rising seas can force residents to relocate and can increase a city's vulnerability to storm surges, can compromise infrastructure, can contaminate groundwater and can increase the incidence of vector-borne diseases.

The environmental benefits of healthy ecosystems, in which all components of an ecosystem are intact and properly functioning, are well documented in scientific literature. Freshwater wetlands, for instance, can mitigate flooding, control erosion and filter stormwater. Coastal vegetation can buffer wave action and reduce adverse impacts from storm surge. Urban trees and parklands can sequester carbon dioxide, provide shade that reduces ambient temperatures and filter out airborne pollutants. Ecosystem services can be leveraged as GI to complement or replace traditional grey infrastructure in both urban and rural settings and provide climate resilience and adaptation benefits.

DISPROPORTIONATE IMPACTS ON VULNERABLE POPULATIONS

The draw of urban areas has increased the number of residents who live on the periphery, without access to the benefits and services typically provided in cities. The world's slum population increased over the past 25 years, from 650 million in 1990 to almost 1 billion in 2016. In African cities, which are increasing in population at the highest rate globally, 62 percent of people now live in slum conditions without access to clean water, sanitation and other basic human services (WEF 2016). In addition to slum residents and the urban poor, other vulnerable populations such as women, children, the elderly and the disabled face disproportionate impacts of climate change.

- ***Slum residents and the urban poor.*** An increase in the intensity of storms and frequency of heat waves disproportionately affects the urban poor due to a lack of services (e.g. running water, sewer and sanitation), inadequate housing and less desirable geographic location (e.g., housing in areas prone to flooding). Additionally, it is likely that cases of dengue, cholera and other waterborne diseases will increase with higher flooding rates, further affecting public health infrastructure in slums (Birkmann et al. 2010; WHO 2012).

- ***Children, the elderly and the disabled.*** Due to inadequate water supplies and malnutrition, children in urban slums are at a heightened risk from water-borne disease, which increases during periods of excessive rainfall (Olsson et al 2014). Evidence also suggests that increased temperatures and longer heat waves will cause increased mortality among children and the elderly, particularly within the "urban heat island" of densely populated cities (Munslow and O'Dempsey 2010). Disabled and socially isolated people are least resilient to floods and storms and slow-onset events such as recurrent droughts due to issues related to mobility, income and social networks (Olsson et al 2014).

- ***Women.*** Pregnant and lactating women are among the most vulnerable to health threats exacerbated by climate change, including vector and water-borne diseases, malnutrition and heat related illness such as dehydration and heat stroke. Women (and children) are also 14 times more likely to die than men during natural disasters (UNFPA 2009).

GI interventions must (1) consider the differing impacts on vulnerable populations such as slum dwellers, who often occupy the most degraded and flood-prone land in an urban environment (The Rockefeller Foundation 2013) or children and the elderly, who are the most vulnerable to the impact of climate change, (2) include efforts to develop slum areas and improve infrastructure to provide these areas with basic services.

PROJECT HIGHLIGHT

Volkswagen in Puebla, Mexico

Private Sector-Led, Peri-Urban

Photo credit: Oppla

Volkswagen's production plant in the outskirts of Puebla, Mexico, is its second largest production facility globally, encompassing 740 acres and producing more than 10 million cars in its 50 years of operation (Wolfcale 2014). The production plant is highly automated and relies on groundwater and to a lesser extent rainwater collection to fill cooling towers for machinery; Volkswagen estimates that the plant pumps approximately 900,000 cubic meters (237.7 million gallons) of groundwater annually (VW 2013). The Puebla-Tlaxcala Valley in which the factory resides faces several problems that led the aquifer to be classified as overexploited, including a growing population in Puebla (Mexico's fourth largest city), a growing industrial base, deforestation in the upland portions of the watershed and a reliance on groundwater as the primary source of potable water in the region (Oppla n.d.).

To ensure its production facilities would continue to receive the necessary amount of water while helping to address a root cause of water shortages in Puebla, Volkswagen partnered with the Comisión Nacional de Áreas Naturales Protegidas (CONANP, or National Commission of Natural Protected Areas), Mexico's national park service, to develop a GI solution for the upland watershed in Iztaccíhuatl-Popocatépetl National Park. Over the course of six years, the Izta-Popo project team planted 490,000 Hartweg's pines, a species native to Mexico, and installed 91,000 soakaways and 430 earthen dams to preserve water and help establish the pine trees over an area of 750 hectares (WBCSD 2015).

INSTITUTIONAL ARRANGEMENT

Volkswagen de México partnered with CONANP on this activity, and a 10-person environmental planning team developed and managed the project. The activity also received support from the Secretary of the Environment for Mexico, as one component of overall improvements planned for Iztaccíhuatl-Popocatépetl National Park.

FUNDING DETAILS AND COST

Volkswagen, together with 40 partners from the local component supply industry, provided $500,000 for the initial 300,000 trees along with pits and earthen dams, and $120,000 per year between 2009 and 2013 for the additional 190,000 trees and pits and dams. Volkswagen earmarked $3 million between 2013–2022 for ongoing maintenance to ensure the trees survive and establish (WBCSD 2015; VW 2013).

RESULTS AND BENEFITS

Estimates of the benefits vary, but the 2013 Volkswagen Sustainability Report estimated that due to improved rainwater infiltration, up to 4 million cubic meters per year of additional water are being fed into the region's aquifer, significantly more than the plant consumes each year, increasing the water security of the region and the city. Additional benefits are reduced erosion from the degraded land surrounding the planting, increased carbon sequestration from the planted trees and increased biodiversity in the region.

REPLICABILITY AND CONDITIONS FOR SUCCESS

In the 2013 Volkswagen Sustainability Report, the company acknowledged that "water shortages pose a significant risk to Volkswagen's operations, particularly in light of the Company's plans for new production facilities in Asia, Africa and Central and South America." Based on the success of this project, Volkswagen initiated a similar project in Sierra de Lobos, Guanajuato, Mexico, planting 158,000 trees, and has a number of similar projects in other countries (BAFWAC 2017).

Globally, many cities in developing countries rely on ground and surface water from degraded upland watersheds, and companies are aware of the risk this poses to their operations. For example, in 2016, Coca-Cola had 59 ongoing watershed protection activities, largely focused on watersheds that supply urban areas in developing countries, for a combined replenishment benefit of 221 billion liters annually. As seen from this case, success depends on support from corporate leadership, effective partnerships with the local or national government, and community participation and buy-in.

TYPES OF GREEN INFRASTRUCTURE

In urban environments, water resource management is one of the most pressing needs for governments and development organizations to address (Ham and Klimmek 2017). GI provides a set of possible options that allow cities to adapt to extreme weather events like intense rainfall to long term impacts like droughts by using and restoring natural hydrology to complement existing grey infrastructure that is under ever-increasing pressure.

Also known as Natural Infrastructure, Sustainable Infrastructure, Ecosystem-based Adaptation, Nature Based Solutions or Natural Climate Solutions, GI is defined by USAID as "any engineered intervention that uses vegetation, soils, and natural processes to manage water and create healthier built environments for people and the natural resources that sustain them" (USAID 2017). This definition of GI encompasses a large number of possible activities, including natural solutions such as planting roof gardens, installing bioswales or reforesting degraded land in watersheds that feed into urban areas. GI can also include modifying the design of traditional grey infrastructure to increase its effectiveness and reduce negative impacts on ecosystems and human populations. Semi-natural activities include: installing porous pavements and infiltration shafts to increase groundwater recharge; promoting rainwater-harvesting systems; and designing traditionally grey structures like roadways to better manage water flow. All GI activities are intended to reduce strain on existing infrastructure and ultimately improve community resilience.

The following is a sample of the most common GI options used by governments, donors, and climate practitioners. USAID's Green Infrastructure Resource Guide provides a more comprehensive list of GI options as well as planning and design considerations for incorporating GI inventions into USAID projects. Tab

TYPE	DESCRIPTION	CLIMATE RESILIENCE BENEFITS	CARBON SEQUESTRATION AND AIR QUALITY BENEFITS	WATER MANAGEMENT BENEFITS	EXAMPLE
GREEN ROOFS	Roof systems comprise vegetation along with the supporting growing media (topsoil or lightweight aggregates) that are designed to intercept rainwater. Can be intensive (deeper substrate that can support trees and requires structural support) or extensive (shallow substrate that can be installed on existing roof structures).	• Flood mitigation • Reduced pressure on existing stormwater management infrastructure • Increased resilience to extreme temperatures due to improved thermal insulation • Reduced urban heat island effects • Improved air quality through natural filtration • Improved biodiversity and wildlife habitats	• Improved thermal insulation, reducing energy use needed for heating and cooling • Carbon sequestration from planted materials and substrate • Removal of air pollutants such as ozone, nitrogen dioxide, sulfur dioxide and particulate matter	• Recycling of water for grey water services within the building • Reduced runoff from precipitation • Flood mitigation • Reduced erosion • Reduced pressure on existing stormwater management infrastructure	The Laguna Lake Development Authority (LLDA) partnered with LafargeHolcim Philippines to design and build the LLDA's new headquarters. The building includes: a 208 m^2 green roof planted with native vegetation that increases the building's energy performance and better controls waterflow during storm events; an onsite water treatment facility; and a rainwater harvesting system that can hold 227,125 liters of water (WBCSD 2014).

TYPE	DESCRIPTION	CLIMATE RESILIENCE BENEFITS	CARBON SEQUESTRATION AND AIR QUALITY BENEFITS	WATER MANAGEMENT BENEFITS	EXAMPLE
BIOSWALES	Vegetated linear depression or trench designed for the collection, conveyance, infiltration and filtration of stormwater runoff.	• Increased groundwater infiltration • Reduced heat island effects from grey infrastructure • Flood mitigation • Reduced pressure on existing water management infrastructure • Improved biodiversity and wildlife habitats	• Carbon sequestration from vegetation • Reduced energy needs for managing stormwater (e.g., pumping, treatment) • Removal of air pollutants such as ozone, nitrogen dioxide, sulfur dioxide and particulate matter • Water pollution abatement through filtration of stormwater runoff	• Reduced runoff from precipitation • Increased groundwater infiltration • Flood mitigation • Reduced erosion during storms • Reduced pressure on existing water management infrastructure • Reduced sedimentation of streams and rivers • Water pollution abatement through filtration of stormwater runoff	In Springfield, Ohio, a team investigated the impacts of a bioswale installed in an area adjacent to a major train station. It found that the bioswale successfully and significantly reduced measured levels of lead, cadmium, chromium, diesel fuel, lubricant oils and total suspended solids in stormwater runoff by up to 90 percent when compared to a control area nearby (Cooley & Young 2006).
BIORETENTION AREAS	Stormwater treatment process for removing pollutants and sediment from stormwater using a system of ponding areas with vegetation, soil, sand gravel and organic material.	• Increased groundwater infiltration • Reduced heat island effects from grey infrastructure • Flood mitigation • Reduced pressure on existing water management infrastructure • Improved biodiversity and wildlife habitats	• Carbon sequestration from vegetation • Reduced energy needs for managing stormwater (e.g., pumping, treatment) • Removal of air pollutants such as ozone, nitrogen dioxide, sulfur dioxide and particulate matter • Water pollution abatement through filtration of stormwater runoff	• Reduced runoff from precipitation • Increased groundwater infiltration • Flood mitigation • Reduced erosion during storms • Reduced pressure on existing water management infrastructure • Reduced sedimentation of streams and rivers • Water pollution abatement through filtration of stormwater runoff	In 2005, Miller Brewing Company in partnership with the Milwaukee Metropolitan Sewerage District created a bioretention area designed to capture, slow, and treat runoff from a 37,800-square-foot parking lot. The 375-fot long by 40-foot wide facility was constructed of rock, sand and native grasses, and was measured to be able to control 26,000 gallons of stormwater runoff (CH2M Hill 2007).

TYPE	DESCRIPTION	CLIMATE RESILIENCE BENEFITS	CARBON SEQUESTRATION AND AIR QUALITY BENEFITS	WATER MANAGEMENT BENEFITS	EXAMPLE
PERMEABLE PAVEMENTS	Alternative pavement materials (e.g., pervious concrete, porous asphalt, permeable interlocking concrete pavers) that are designed to infiltrate stormwater runoff to the subsurface.	• Flood mitigation • Increased groundwater infiltration • Reduced pressure on existing water management infrastructure	• Reduced energy needs for managing stormwater (e.g., pumping, treatment) • Water pollution abatement from runoff	• Reduced runoff from precipitation • Increased groundwater infiltration • Reduced pressure on existing water management infrastructure • Water pollution abatement from runoff	In 2009, the US EPA constructed a 0.4-hectare permeable pavement parking lot in Edison, NJ, to measure the infiltrative capacity of three experimental permeable surfaces. Pervious concrete and porous asphalt were found to have approximately twice the infiltration rate of permeable interlocking concrete pavers, but all three types increased groundwater infiltration by more than 10 times that of traditional asphalt. Furthermore, over the course of three years it was found that no maintenance was required for any of the experimental surfaces (Brown & Borst 2014).
URBAN AGRICULTURE	Activities involving the cultivation of plants and raising of animals within and around cities and peri-urban areas, including the processing and distribution of food.	• Reduced heat island effects from paved areas • Increased groundwater infiltration • Flood mitigation • Improved biodiversity and wildlife habitats • Improved livelihoods and food security - increasing adaptive capacity of communities	• Carbon sequestration from planted materials and vegetation • Reduced energy needs for managing stormwater (e.g., pumping, treatment) • Reduced emissions from product transport	• Increased groundwater infiltration • Flood mitigation • Reduced pressure on existing water management infrastructure	The Peru Energy Network (REP), a private company that operates the national power transmission grid, converted degraded land, and leveled landfills and the cleared areas beneath REP's high-tension wires on the southern periphery of Lima into gardens for urban agriculture. Working with local women's groups and the municipal government, REP developed a farmers' market program so community members can sell the produce from the gardens. REP found that the terraces created for agricultural production reduced erosion, downstream sedimentation and maintenance costs for transmission lines. Furthermore, the community reported increased livelihoods and high satisfaction with the project (Ruaf Foundation 2007).

TYPE	DESCRIPTION	CLIMATE RESILIENCE BENEFITS	CARBON SEQUESTRATION AND AIR QUALITY BENEFITS	WATER MANAGEMENT BENEFITS	EXAMPLE
NATIVE LANDSCAPING	Landscaping that uses native plants – including trees, shrubs, groundcover and grasses –indigenous to the geographic area being planted. Particularly important in dry or drought-prone areas (see: xeriscaping in key terms).	• Reduced heat island effects from paved areas • Increased groundwater infiltration • Flood mitigation • Reduced water demand for irrigation • Improved biodiversity and wildlife habitats	• Carbon sequestration from planted materials and vegetation • Reduced energy needs for managing stormwater (e.g., pumping, treatment) • Reduced energy needs for irrigation	• Increased groundwater infiltration • Flood mitigation • Reduced pressure on existing water management infrastructure • Reduced water demand for irrigation	Cities have tackled water shortages by incorporating native landscaping into their long-term conservation plans. In Albuquerque, NM, the city runs a xeriscape retrofit incentive program that provides assistance for replacing high water-use landscaping with a more water-efficient plan. In addition to retrofit rebates, properties that meet the native landscaping criteria receive a monthly water bill credit (ABCWA 2018).
URBAN WETLAND CREATION OR RESTORATION	Urban or peri-urban transitional areas between terrestrial and aquatic ecosystems where the water table is usually at or near the surface or the land is covered by shallow water.	• Improved watershed management • Increased groundwater infiltration • Flood mitigation • Reduced heat island effects from paved areas • Reduced pressure on existing water management infrastructure • Improved biodiversity and wildlife habitats	• Carbon sequestration from vegetation (wetlands hold the largest carbon stores and can accumulate up to 40 percent of soil carbon) • Reduced energy needs for managing stormwater (e.g., pumping, treatment) • Removal of air pollutants such as ozone, nitrogen dioxide, sulfur dioxide and particulate matter • Water pollution abatement through filtration of stormwater runoff	• Reduced erosion during storms • Reduced flooding from storm surges • Improved watershed management • Increased groundwater infiltration • Reduced pressure on existing water management infrastructure • Water pollution abatement through filtration of stormwater runoff	Shell Petroleum Company together with the Government of Oman created the world's largest constructed reed-bed wetland as a natural water treatment facility to filter the byproducts of its oil extraction activities. This 360-hectare wetland can effectively treat more than 95,000 cubic meters of produced water per day, approximately 30 percent of the wastewater produced at this facility during oil extraction. As a result, Shell recorded energy savings of 98 percent and canceled plans to construct an additional water treatment facility projected to cost nearly $40 million. The facility now provides a wetland habitat for a wide variety of bird and fish species (The Nature Conservancy 2013).

TYPE	DESCRIPTION	CLIMATE RESILIENCE BENEFITS	CARBON SEQUESTRATION AND AIR QUALITY BENEFITS	WATER MANAGEMENT BENEFITS	EXAMPLE
MANGROVE RESTORATION	Regeneration of mangrove forest ecosystems (primarily in tropical coastal swamps that are flooded at high tide) through replanting or restoring tidal or freshwater hydrology.	• Reduced flooding and damage from storm surges • Coastal erosion protection • Improved biodiversity and wildlife habitats • Improved livelihoods - increasing adaptive capacity of communities	• Carbon sequestration from mangroves • Removal of air pollutants such as ozone, nitrogen dioxide, sulfur dioxide and particulate matter • Water pollution abatement through filtration of stormwater runoff	• Reduced flooding and damage from storm surges • Coastal erosion protection • Water pollution abatement through filtration of stormwater runoff	In Myanmar, many of the natural ecosystem protection that once protected the city of Yangon from flooding was destroyed to create additional agricultural land and accommodate the city's growing population. The degradation of mangrove forests in the deltaic area surrounding Yangon was identified as one of the primary reasons Cyclone Nargis in 2008 was so catastrophic (Rao et al. 2013). In 2010, the Mangrove Ecosystem Rehabilitation Network (MERN), a collection of 17 local NGOs, began replanting mangroves at 15 sites in Pyaopon Township. The mangroves are flourishing, and local communities are breeding fish, prawns and mud crabs in the replanted areas to enhance livelihoods (Myanmar Times 2010).
RAINWATER HARVESTING	Collection and storage of rainwater through a variety of techniques such as cisterns (tanks), check dams, ponds, open wells and groundwater aquifer recharge shafts.	• Increased water security and reduced impact of droughts • Flood mitigation • Increased groundwater infiltration • Reduced pressure on existing water management infrastructure • Improved agricultural yields when linked to irrigation systems • Reduced saltwater intrusion • Reduction of spikes in water prices for individuals and companies	• Reduced energy needs for managing stormwater (e.g., pumping, treatment) • Reduced energy needs for water provision and irrigation	• Reduced runoff from precipitation • Flood mitigation • Increased groundwater infiltration • Reduced pressure on existing water management infrastructure • Reduced water demand from municipal water sources	The Coca-Cola System in Greece in partnership with Global Water Partnership-Mediterranean, municipalities and other local authorities launched "Mission Water," a rainwater harvesting program across 29 Greek islands. The program: installed 57 rainwater harvesting systems and 3 reverse osmosis systems that convert rainwater to potable water; saved about 260,000 liters of water annually; improved the lives of nearly 55,000 island residents; installed a greywater treatment system for irrigation; and trained 210 local technicians in rainwater harvesting, construction and maintenance. This initiative is considered efficient GI at the local level (Coca-Cola Hellenic 2018).

PROJECT HIGHLIGHT

Malmö Municipal Housing Company (Mkb) and the City of Malmö, Sweden

Public–Private Partnership, Urban

Photo Credit: Think Nature

Augustenborg, a neighborhood in Malmö, Sweden, was built in the 1950s as one of the first public housing areas in the city. However, by the 1990s, it faced a number of problems, including dilapidated infrastructure, high unemployment and a declining population. These issues were in part due to seasonal flooding caused by an inadequate stormwater drainage system and an increasing amount of impermeable pavement, which resulted in flooded parking garages, basements, streets and sidewalks, and untreated sewage entering the waterways. In addition to existing flooding issues, projections for Malmö by the Swedish Commission on Climate and Vulnerability determined that a changing climate would likely increase the number of heavy downpours in autumn and winter, with up to 8 days with more than 10 mm of precipitation possible by the 2080s (Kazmierczak and Carter 2010).

From 1998 to 2002, the City of Malmö together with MKB Fastighets AB (MKB) undertook an urban renovation initiative that sought to rejuvenate the neighborhood, rehabilitate buildings, increase energy efficiency and improve waste management. One of its largest undertakings was to address the seasonal flooding issues; this was accomplished through a GI project that replaced stormwater drain pipes with an integrated open stormwater management system consisting of 6 kilometers of open water channels and 10 retention ponds. Rainwater from roofs, roads and parking garages is channeled through a system of trenches, ditches, ponds and wetlands, allowing water to be absorbed as it progresses, so that only surplus or overflow stormwater enters the conventional sewerage system. The city also introduced legislation that all buildings constructed in the neighborhood after 1998 must have green roofs, and approximately 11,100 square meters (120,000 sq. ft) of industrial, public and MKB building roofs were retrofitted with green roofing.

INSTITUTIONAL ARRANGEMENT

MKB owns more than 23,000 apartments and 1,000 commercial buildings, making it Malmö's largest property owner. It is also wholly owned by the City of Malmö, so while it functions as a commercially driven private business, it has a politically appointed board and seeks to provide a public service in addition to being a property owner and manager. The overall project was conceived of and co-managed by MKB and the City of Malmö, and the open drainage system was constructed by MKB together with the Water Department. After construction, MKB and the City of Malmö agreed to a joint management contract for the waste, water and green space systems (City of Malmö 2012).

FUNDING DETAILS AND COST

The overall cost of the renovation was approximately SEK 200 million ($22.5 million). This includes building rehabilitation, energy efficiency upgrades and other work in Augustenborg, in addition to the stormwater management upgrades. Half of the cost was covered by MKB using its funds, and the other half was covered by a mix of public sources, including the City of Malmö, SEK 24 million from the Swedish government's Local Investments Programme for Ecological Conversion and Eco-Cycle Programme, funding from the EU URBAN program, and SEK 10 million from the Swedish Department of the Environment (SEK 4 million) and EU LIFE program (SEK 6 million) to create the 9,000-square meter Botanical Roof Garden (World Habitat 2010).

Currently, management and maintenance are funded jointly by MKB, the water board, and the City of Malmö. MKB MKB incorporates costs into rents, the water board through water tariffs, and the city council through its standard maintenance budget.

RESULTS AND BENEFITS

The effect of the overall rejuvenation effort is that Augustenborg has become a desirable, multicultural neighborhood. The tenancy turnover rate decreased by 50 percent, unemployment fell from 30 percent to the city's average of 6 percent, and the neighborhood is now a global model, with over 15,000 study tour visitors since the project's completion (Rolfsdotter-Jansson and Community 2009). The flood controls have proven effective, with no flooding since the introduction of the stormwater management system, despite a 50-year rainfall event in 2007 that flooded much of the rest of Malmö. The system is estimated to capture 90 percent of rainfall runoff from impermeable surfaces, and the annual runoff volume flowing through the system decreased by 20 percent due to evaporation and absorption from the channels and retention ponds. This improved sewerage system performance citywide, as stormwater flows from the neighborhood into the city's traditional sewerage system are now negligible (ECAP 2014).

PROJECT HIGHLIGHT

REPLICABILITY AND CONDITIONS FOR SUCCESS

Several factors came together in this case to ensure success, including: local champions, significant public engagement during the design phase, collaboration with a private company that is wholly owned by the city, and sufficient funding from a variety of sources. The project was first conceived of by three individuals from the City of Malmö, the Swedish Urban Program and MKB, all of whom were responsible for development in Augustenborg, and they were able to gather a larger group of relevant stakeholders who shared a similar vision of increasing the sustainability of the neighborhood. The public was consulted extensively during the design phase, which helped identify issues in the design as well add in elements the community wanted; the result was significant buy-in for the project. The government-owned structure of MKB was another key factor of success, as its mission was aligned with the city's objectives. However, as a property owner, the rejuvenation of the neighborhood and decrease in turnover rates provided a financial benefit to MKB, and it was able to build maintenance costs into rents. Last, sufficient funding ultimately allowed all elements of this effort to be carried out together as one project, which depended on a private company paying half of the cost, the City of Malmö shouldering one-third of the cost and government grants covering the rest.

COST AND OTHER BENEFITS OF GREEN INFRASTRUCTURE

The construction and maintenance of infrastructure is one of a municipality's largest expenses. It is estimated that about 3.8 percent of global GDP ($3.3 trillion per year) needs to be invested into infrastructure O&M (McKinsey Global Institute 2016). Ensuring that infrastructure can withstand stronger winds and rains, repeated flooding, and extreme heat, adds an additional cost, particularly in developing countries where access to basic infrastructure is often lacking; a report by UNEP (2016) estimated that the cost of making infrastructure in developing countries more climate resilient is between $140–300 billion per year by 2030 and $280–500 billion per year by 2050.

In comparison to grey infrastructure, GI can be a low-cost, low-maintenance and low-carbon emission alternative that allows cities to build resilience and safeguard their social and economic assets (European Commission 2015). GI can be implemented as a new initiative or used to retrofit existing traditional infrastructure. Additionally, the social, economic and environmental benefits of GI can reach far beyond the intervention. The co-benefits often include better sanitation for urban residents, increased access to water resources, reduced damage from flooding, lower morbidity from heat wave events and increased access to public funds that would otherwise be devoted to the repair and maintenance of hard infrastructure (Spatari, Yu, and Monalto 2011). GI has rarely been used in isolation; rather, it has been used as a complementary measure to existing grey infrastructure. An opportunity exists to introduce and scale up GI use in developing country cities, using innovative natural solutions to complement traditional infrastructure technology.

CONSTRUCTION AND O&M COST REDUCTION BENEFITS

One cost-benefit analysis (CBA) of GI in the United States found that when compared with grey infrastructure, GI initiatives generally had reduced built capital (e.g., equipment, installation) costs, reduced land acquisition costs, reduced external costs (i.e., off-site costs imposed on others), reduced operation costs, and reduced repair, maintenance and replacement costs (American Rivers 2012). In a survey of 479 case study areas in the United States and Canada, more than 44 percent of respondents stated that GI reduced costs and another 31 percent stated that GI solutions cost the same as grey infrastructure (American Rivers 2012). A CBA conducted as part of the storm management plan for the City of Philadelphia found that the benefits of GI for stormwater control ranged from $1.94 billion to $4.45 billion, while grey infrastructure benefits ranged from only $0.06 billion to $0.14 billion over a 40-year period (Stratus Consulting 2009). The City of Philadelphia, through the same plan, converted two square miles to GI, and estimates it has saved the city $340 million (US EPA 2010).

A life cycle assessment (LCA) is a useful exercise to evaluate all costs (e.g., construction, O&M and disposal) of a specific GI intervention, providing a basis for the comparison of different green and grey infrastructure, supporting future economic cases of GI and measuring and reporting the return on investment. An LCA study conducted in India found that while the initial cost of a green building was nearly 8 percent higher than that of a traditional building, the life cycle cost of the green building was 26 percent lower than that of the traditional building over a 20-year period (Kansal and Kadambari 2010). Similarly, increasing evidence suggests that green roofs can extend the period of replacement of a traditional roof (i.e., a 20-year life span for a traditional roof versus 40 years for a green roof).

While initial capitalization costs vary and, in some cases, can be higher than those of grey infrastructure, GI can provide similar levels of environmental or climate risk reduction with lower O&M costs and life cycle cost over time than grey infrastructure. For instance, parking lots constructed with permeable pavement, despite having higher initial capital costs, can have significantly lower maintenance costs compared with traditional asphalt. Restoring and conserving wetlands, floodplains, shorelines and other natural systems can be less costly than building and maintaining concrete and steel structures (The Nature Conservancy 2014). While grey infrastructure depreciates over time, functions provided by well-maintained GI are likely to increase over time.

ENERGY EFFICIENCY BENEFITS

In addition to carbon sequestration, GI can provide energy conservation benefits that grey infrastructure cannot, primarily by adding extra insulation to buildings and providing shade, and reducing the energy needed to manage and treat stormwater. Green roofs increase building energy efficiency by lowering absorption of solar radiation and thermal conductance; on average they are 60°F cooler than black roofs in summer (American Rivers 2012). In practice, this translates to reduced energy consumption and thus lower electric bills. For instance, the city hall building in Chicago, Illinois, has a 1,886-square meter green roof estimated to yield annual building-level energy savings of $3,600 (Clements et al. 2013). The green roof on the Target Center Arena in Minneapolis covers 113,000 square feet and has cut annual energy costs by $300,000. The Center for Sustainable Systems estimated that if commercial developers in the United States installed green roofs on the approximately 40 billion square feet of buildings being constructed between 2003 and 2035, property owners could save $95 billion in avoided heating, cooling and roof replacement costs.

Pumping and treating wastewater are also energy-intensive processes; for municipal governments (in the United States), drinking water and wastewater plants are typically the largest energy consumers, often accounting for 30–40 percent of total energy consumed (US EPA 2018). GI interventions that capture precipitation and manage it locally through natural processes can help reduce the energy needed. For example, green roofs, swales, retention ponds and rainwater harvesting can prevent stormwater from reaching the sewerage system, reducing the amount of water that needs treatment. These methods also assist with recharging local groundwater supplies that could reduce the need to transport water from distant sources. A study by the City of Los Angeles found that increased use of GI throughout Los Angeles County could recharge groundwater supplies, which would save the city from the cost of importing a portion of the city's water. The study estimated the energy savings would be equivalent to the annual usage of approximately 40,000 households, adding up to a savings of more than $23 million annually (Chau 2009).

NONFINANCIAL BENEFITS

GI is most frequently used to improve water resource management, and many interventions have additional co-benefits often not found in traditional grey infrastructure. These can include pollution abatement, reduced erosion, improved biodiversity and carbon sequestration. In addition to mitigating flood damage costs, GI can reduce pollution runoff that flows into rivers, streams and coastal waters, providing a cost-effective strategy to ensure that these waters are safe for fisheries and recreational activities.

GI interventions such as wetlands, mangrove forests and green roofs provide important habitat and enhance biodiversity in urban areas. By conserving and restoring natural landscapes and habitats, GI interventions tend to be popular with the local communities in which they are located, which can be a critical component to raising project funds and building political support. Furthermore, in developing countries GI interventions enhance local organizational and technical capacities to manage natural resources and ecosystem services, as well as improved social capital (e.g., strengthened networks) needed for increasing community resilience and adaptive capacity (UNDP 2015).

GI (such as trees, landscaping and other vegetation) can have a positive effect on real estate market rates and property values by improving the aesthetics of urban areas (Clements et al. 2013). For example, one study demonstrated a property value increase of 2–10 percent for properties with new street tree plantings. Another study conducted in Portland, Oregon, found that the presence of street trees added an average of $8,870 to the sale price of residential properties (CNT and American Rivers 2010).

CHALLENGES OF GREEN INFRASTRUCTURE IMPLEMENTATION

Measuring return on investments and limited awareness about the benefits and effectiveness of GI interventions in urban areas continue to be the biggest challenges facing GI implementation. While the economic analysis of GI is relatively new (thus the lack of historical cost and benefit data), considerable historical cost and benefit data exist on grey infrastructure. This lack of evidence-based knowledge can also increase the perceived risk associated with GI and such projects may have to pass a higher threshold to be considered for implementation (UNDP 2015). This issue can be particularly challenging for private sector stakeholders that are primarily driven by profitability or cost concerns and need to see demonstratable cost savings in addition to any social benefit GI might provide. A global study on GI initiatives also documented a lack of local technical and financial ability to quickly design and implement GI solutions, which increased the cost of GI in some instances (Forest Trends 2016).

Furthermore, legal and regulatory frameworks (e.g., building and health codes) may provide obstacles to introducing GI and incentivize decision makers to stay with technologies they are more familiar with, such as grey infrastructure. GI solutions often require more space than some grey infrastructure. For instance, mangrove restoration might be used for coastal protection in a city, but typically only if there is underdeveloped land that can be used for planting. Additionally, it often takes several years before the living elements of a GI intervention (e.g., trees, grasses) can deliver the full range of benefits, such as carbon sequestration or coastal erosion protection. Lastly, in many developing countries, infrastructure investments are accompanied by corruption risks that can encourage blocking of GI design and implementation, given the real or perceived lower capital cost associated with their construction versus grey infrastructure (Soz Saiman, Kryspin-Watson, and Stanton-Geddes 2016).

PROJECT HIGHLIGHT

Swire Coca-Cola Zhengzhou, Zhengzhou, China

Private–Sector Led, Urban

Photo Credit: Swire

Many urban wetlands in China suffer from issues related to land reclamation, contamination, and insufficient water supply. The Lianhu Wetland in Zhengzhou faced these issues, as it was primarily fed from the municipal water supply, and it was not receiving enough water due to recurring droughts in the region. Prior to the intervention, the northern half of the wetland was primarily dry year-round, and the southern half was stagnant and filled with poor-quality water (Swire Pacific 2016).

The Swire Coca-Cola Zhengzhou (SCCZZ) bottling plant receives all of its water from the municipal water supply, which in turn is drawn from an aquifer. Prior to the intervention, the plant would discharge its waste water to the municipal wastewater treatment plant, after which it would reenter the municipal water supply, but would do nothing to replenish the aquifer. As part of its worldwide effort to replenish 100 percent of the billions of liters of water the company uses each year, SCCZZ partnered with the municipal government of Zhengzhou City to treat its wastewater at the source and redirect the treated wastewater to the wetland, providing a needed benefit to the community and counting toward Coca-Cola's corporate goal.

PROJECT HIGHLIGHT

INSTITUTIONAL ARRANGEMENT

SCCZZ partnered with the municipality of Zhengzhou City on this activity, although the funding for the activity and all of the water comes directly from the SCCZZ plant. To discharge its wastewater, SCCZZ had to demonstrate that its effluent complied with all discharge standards established by the government.

FUNDING DETAILS AND COST

One hundred percent of the cost of this activity was provided by the Coca-Cola Company, which amounted to a one-time cost of $190,000. However, the wetland receives approximately 219 million liters of water per year, equivalent to the annual water usage of 4,760 Zhengzhou residents; this is water the city no longer has to provide to the wetland (LimnoTech 2017).

RESULTS AND BENEFITS

The SCCZZ plant's treated wastewater discharge is metered, and therefore can be accurately measured at 0.6 million liters per day. The plant operates 365 days per year, amounting to 219 million liters of water annually provided to the wetland. As noted above, that is equivalent to the annual average usage of nearly 5,000 residents (LimnoTech 2017). This activity provided multiple benefits to the city, including improving the wetland's water quantity and quality, as well as eliminating the need for the municipality to provide water to the wetland. For the public, rehabilitation of the wetland provided a recreational green space and increased public awareness of the benefits of water reuse and conservation. It also improved biodiversity by providing a wetland habitat. The wetland helps to recharge the aquifer that the city draws from, helping alleviate some of the stress on the water supply. SCCZZ and Coca-Cola benefited in a number of ways, including strengthening the water supply the bottling operation depends on, and helping meet a corporate goal of replenishing 100 percent of its water usage, which globally amounted to 221 billion liters of water in 2016.

REPLICABILITY AND CONDITIONS FOR SUCCESS

Globally, the Coca-Cola Company used 221 billion liters of water in 2016, 99 percent of which came from either the local municipal water system (52 percent of total) or from ground or surface water (47 percent of total) (TCCC 2017). As such, the company has a strong interest in ensuring that the groundwater its operations depend on is replenished, and the municipalities it draws water from are not suffering from water shortages. Coca-Cola has formed numerous partnerships with development organizations – including World Wildlife Fund (WWF), USAID, The Nature Conservancy, Global Water Challenge, UN-HABITAT, and the United Nations Development Programme (UNDP) – and therefore has considerable experience developing and funding urban watershed protection projects and to a more limited extent, GI projects. Many other large beverage companies (e.g., PepsiCo, AB InBev, Heineken, Nestle, SAB Miller) have similar programs. Therefore, replicability of a similar GI project is high, given corporate interest and the urban location of many bottling plants.

MECHANISMS TO PROMOTE GREEN INFRASTRUCTURE

GI activities are funded and incentivized through a variety of financial mechanisms and structures and are implemented by both the private and public sector. In 2015, more than $25 billion was spent by governments, private stakeholders, and banks and other financial institutions on GI solutions, protecting or rehabilitating more than 486 million hectares of land and ecosystems worldwide. These transactions grew an average of nearly 12 percent per year from 2013 to 2015, and 64 percent of this funding flowed through programs that compensate landowners for responsible management of their property. Approximately 95 percent of total GI funding came from governments, but the private sector's role in GI interventions is growing (Forest Trends 2016).

The private and public sectors have similar goals when adopting GI, but have differing incentives. Companies can independently pursue GI interventions for the good of their business, for the good of their communities and to reduce their reliance on public services. Governments implement GI activities not only to increase their resilience and reduce their infrastructure costs, but also to develop the operating environment that encourages the use of GI by the private sector (e.g., regulatory framework, incentives and integrated planning framework) (OECD 2016). The section below covers a number of mechanisms the private and public sectors can use to promote GI.

DRIVERS OF PRIVATE SECTOR INVESTMENT IN GREEN INFRASTRUCTURE

Private sector investment in GI has typically been driven by three factors: protecting some aspect of operations or the supply chain from risk, reducing the cost of operations or providing a public service for the community as part of a corporate social responsibility initiative.

- ***Response to natural disasters and extreme weather.*** Private sector actors such as real estate developers, foundations, and manufacturing or service delivery companies that face risks to their operations from storm surges and intense rains have installed green roofs and rainwater storage cisterns, provided revegetation along riverbanks and implemented improved stormwater runoff management measures globally (EEA 2017). These GI activities can prove beneficial for companies, ensuring business continuity of their own operations, reducing the risk of damage to their facilities and contributing to the enhanced adaptive capacity of the communities they serve. The beverage industry, for example, has undertaken the largest number of GI activities to date. Brewers and soft drink makers are particularly reliant on clean water supplies and have been pioneers in private sector-led GI interventions (WWF 2016).

- ***Cost reduction.*** Private sector actors have achieved cost savings by implementing GI initiatives. Whether through reductions in cost for inputs such as energy, water consumption or other public services or through protecting their operations and capital investments from the effects of natural disasters, many GI activities reduce costs substantially more than the capital outlay required for their installation and maintenance. For example, in Boston, the first green skyscraper was built to include a water management system incorporating native vegetation that decreased potable water use by more than 60 percent and reduced cooling costs by 15 percent, more than outweighing the additional expense of the GI system (Burgess et al. 2017).

- ***Corporate social responsibility.*** Private sector actors undertake GI activities in an effort to foster good will in the communities in which they operate. These corporate social responsibility activities may likewise be economically logical for their business but are more focused on less quantifiable benefits. In South Africa, for instance, a consortium of private companies including NedBank, Sonae Novobord, and Woolworths partnered with WWF to create the Water Balance Program. As part of this program, the companies pay local community members to clear invasive species from catchments to improve watershed management. In its first three years of operation, more than 1,500 hectares were cleared and 1.7 billion liters of water were conserved (Fourie 2012). This type of activity can improve companies' water security, empower local people and support local livelihoods through employment, and improve companies' reputation in the community.

DRIVERS OF PUBLIC SECTOR INVESTMENT IN GREEN INFRASTRUCTURE

City governments have typically invested in GI for reasons similar to the private sector. A 2010 study conducted by the US Environmental Protection Agency (EPA) that reviewed municipal GI investments in the United States found cities invested in GI for the following reasons: complying with national-level regulations, reducing the cost of O&M, addressing the additional risks associated with natural disasters and extreme weather events, and as part of a strategy to meet larger sustainability goals (US EPA 2010).

- ***Compliance with national-level regulations.*** Cities have used GI to meet national-level targets for stormwater management, pollution control and land use planning. In the United States, federal Clean Water Act requirements, such as the Combined Sewer Overflow (CSO) Control Policy and National Pollutant Discharge Elimination System (NPDES) permit program, set targets for pollutant discharge from storm sewers, and cities have turned to GI as an innovative and lower-cost solution. The City of Philadelphia invested in GI solutions such as rain gardens, infiltration trenches, porous pavements, vegetated swales and green roofs, as well as incentivized GI for property owners as a means of decreasing the amount of runoff that enters the sewerage system (US EPA 2010).

- ***Cost reduction.*** City budgets are rarely sufficient to cover all the services required, let alone invest in new projects, and budgetary limitations will only become more challenging as the urbanization trend continues. Cities have used GI as a cost savings measure, as GI is often cheaper to construct and maintain than grey infrastructure. In Lenexa, Kansas, city officials found that retaining some stormwater onsite with GI cost about 25 percent less than retrofitting grey infrastructure to meet the new EPA standards.

- ***Response to natural disasters and extreme events.*** In many areas, increased intensity of rain events has already caused significant damages due to flooding. GI (e.g., swales, retention areas) can help mitigate flooding by absorbing water and reducing the amount of runoff entering the sewerage system. For example, Chicago, Illinois, faced with frequent flooding in its system of alleys, developed the Green

Alley program, which combines porous pavement with retention trenches, thereby preventing up to 80 percent of precipitation from entering the sewerage system (CDOT 2010).

- ***Meeting larger sustainability goals.*** Many cities already have a green plan or sustainability plan in place that seeks to make the city more environmentally friendly, and GI solutions offer a way to meet those goals across city departments or agencies. For example, planning departments can use GI to promote more efficient land use, transportation departments can use GI in street improvements (e.g., permeable pavement, sidewalk trees and planters, rain garden bump-outs), and parks departments can support GI at a larger scale by connecting greenways and corridors to provide flood protection and habitat in addition to recreation.

MECHANISMS TO INCENTIVIZE GREEN INFRASTRUCTURE

BUILDING CODES	
DESCRIPTION	**EXAMPLE**
A number of city governments have adopted building codes to become more climate resilient and regulate their natural resources more effectively. Well-defined and universally applied codes provide clarity to developers on the types of interventions that are required and ultimately result in lower emissions, greater adaptive potential and improved water resource management across the country.	GREEN BULIDING CODES The Philippines Green Building Code requires all developers to adhere to a number of performance standards including energy efficiency, water efficiency (e.g., stormwater collection, grey water reuse and erosion control), solid waste management, site sustainability and indoor environmental quality (Govt of Philippines 2013).

PROPERTY ASSESSED CLEAN ENERGY (PACE)	
DESCRIPTION	**EXAMPLE**
PACE is a financing mechanism used in the United States wherein a municipality issues revenue bonds to residential, commercial or industrial property owners to finance GI and associated renewable energy installations, energy efficiency retrofits or stormwater retrofits on their properties. PACE borrowers can benefit from new GI installations immediately and repay their debt over time through a set line item on their property tax bill. The PACE assessment is attached to the property rather than a property owner. GI financed through PACE can help reduce greenhouse gas emissions, increase energy efficiency and reduce energy costs of property owners. As PACE is funded through private lending or municipal bonds, it creates no liability to local government funds. For instance, in the United States, over 150,000 residential owners had made $4 billion in energy efficiency and other improvements to their properties through PACE mechanism by 2017 (US Department of Energy 2017).	PACE IN WASHINGTON, D.C. In 2017, the US soccer stadium D.C. United received $25 million in PACE funding from the District government's Department of Energy and Environment to improve water, stormwater and energy efficiency over a 20-year period. Improvements include a green roof, stormwater storage, vegetative management and energy efficiency improvements that can reduce costs by 25 percent and cut CO2 emissions by 830 metric tons per year (DC PACE 2017).

CREDIT ENHANCEMENT	
DESCRIPTION	**EXAMPLE**
Credit enhancement is offered to improve the terms of private financing by reducing financial risk to investors. This mechanism is useful when private stakeholders are interested in GI investment but are hesitant due to perceived risks. City and national governments can extend loans for GI projects to accelerate private sector investment in GI, reducing initial costs. When designed appropriately, this mechanism is a cost-effective measure for the government, reducing public service expenditures by sharing the initial capital costs with the private sector and reducing longer-term O&M costs when compared to grey infrastructure. Similarly, private stakeholders and communities operating stormwater utilities may incentivize the installation of GI practices (e.g., reducing impervious surfaces, retaining stormwater) on private property through stormwater fee discounts and credits to property owners.	**STORMWATER FEE CREDITS** The city of Northampton, Massachusetts, provides stormwater fee credits of up to 50 percent for property owners who install and maintain stormwater best management practices (e.g., stormwater gardens, permeable pavements). The credit for GI expires after three years, and to renew the application property owners need to submit proof of proper GI maintenance (City of Northampton 2015).

PAYMENT FOR ECOSYSTEM SERVICES (PES)	
DESCRIPTION	**EXAMPLE**
Payment for ecosystem services (PES) is a financing mechanism that can support the conservation and expansion of ecosystems and GI implementation. PES is a transaction between economic actors who enhance and conserve ecosystem services, such as farmers or natural resource owners located in upstream areas of a watershed, and direct beneficiaries of the improvements in ecosystem services, such as a water company, government, donor agency or NGO providing services in downstream areas of the watershed. In developing countries, PES is mostly financed by the public sector and donor agencies. Among private sector buyers of PES, the highest amounts recovered are from water utilities and food and beverage companies. The PES mechanism aims to (1) increase efficiency of GI and sustainable management of water and natural resources, agricultural land, biodiversity conservation and carbon sequestration, and (2) enhance capacity building of farmers and natural resource owners (i.e., providing training and technical assistance), promote behavioral change and transformational change (i.e., positive incentives through PES rather than coercion), and increase community resilience and adaptive capacity.	**UGANDA PES** In Uganda, Environmental Trust of Uganda recruited 113 farmers and provided upfront funding to initiate GI activities such as tree planting (i.e., a carbon sequestration service) and terracing, channeling and planting grasslands (i.e., watershed services to reduce runoff). The payment farmers receive is based on the amount of carbon sequestered on their land (e.g., \$2/ton of CO_2), and in the case of water conservation measures, the hectares of land under management (UNDP 2015).

PUBLIC–PRIVATE PARTNERSHIPS (PPPS)	
DESCRIPTION	**EXAMPLE**
The PPP is a long-term contract (e.g., concession agreement) made between a government and a private stakeholder wherein the private stakeholder provides infrastructure or other services traditionally delivered by the public sector. PPPs have long been an option for governments to mobilize capital without taking on debt to design, build and operate public infrastructure facilities by partnering with the private sector, with the added benefit of receiving revenue from the concessionaire over the life of the concession agreement. PPPs delivering environmental services often aggregate a bundle of GI interventions within a public service area to reduce costs to the public sector; they also develop GI subsidy programs to finance the installation and maintenance of GI on private lands, forming partnerships with one or more local public service organizations to conduct lower-cost maintenance while supporting capacity building of private stakeholders. A PPP focused on GI typically would provide revenue to the concessionaire through fees paid by property owners for stormwater and/or wastewater management and/or treatment.	CLEAN WATER PARTNERSHIP To date, examples of PPPs used to fund GI are very limited. One of two operational examples in the United States is in Prince George's County, Maryland, which developed the Clean Water Partnership in 2014 to improve stormwater management using GI. The program aims to retrofit 809 hectares with GI solutions such as bioswales, rain gardens, green roofs, rain barrels and permeable pavements over a 30-year period.

TAX INCREMENT FINANCING (TIF)	
DESCRIPTION	**EXAMPLE**
TIF is a method of financing GI initiatives in a designated area based on the anticipated property tax increase that can be generated by the GI solution's implementation. The revenue generated by TIF is the property tax assessed on the increase in property value following the GI implementation, compared to the baseline property value prior to this GI development. The property value increases can be driven by the GI's effectiveness in mitigating flooding or stormwater runoff, or improving urban aesthetics or environmental health (U.S. PIRG Education Fund 2011). TIF can be a highly valuable option for a local government since it allows for financing GI without raising property tax rates or exceeding municipal debt limits (Georgetown Climate Center 2015).	TIF FOR GREEN ROOFS During the 1984–2014 period, the city of Chicago, Illinois, established nearly 150 TIF districts and leveraged its public investment to attract over $6 billion in private capital investment in TIF districts. Revenue was used to fund the city's Green Roof Improvement Fund, which incentivizes and provides partial reimbursement to commercial buildings that install green roofs to manage stormwater (Georgetown Climate Center 2015).

GREEN BONDS	
DESCRIPTION	**EXAMPLE**
Green bonds are mechanisms by which governments, corporations, state-owned utilities and multilateral development banks can fund GI projects linked to climate resilience or mitigation. This bond enables borrowers to access lower interest rates and incentives such as tax deferrals to help offset some of the uncertainty associated with quantifying and allocating monetary benefits. Green bonds have been one of the fastest growing sectors on the bond market, with nearly $161 billion in green bonds sold globally by 2017. In the United States, green bonds have financed improvement of water-related infrastructure and transport, while globally transport and renewable energy infrastructure have been the most financed sectors (Climate Bonds Initiative 2018). In the developing country context, the East Asia and Pacific region issued the largest amount of green bonds, mostly to finance transport and renewable energy and efficiency. Some limited examples of green bonds for GI implementation and climate adaptation include forest restoration in China, coral reef rehabilitation in Indonesia and sustainable management of forests in Mexico (World Bank 2018b).	**ENVIRONMENTAL IMPACT BOND** In 2016, the Washington DC Water and Sewer Authority issued an Environmental Impact Bond to fund GI development such as permeable pavements and bioretention systems to reduce stormwater runoff. This bond also has a PES component, where investors will receive contingent payments if the project outperforms its stated targets (Environmental Defense Fund 2017).

WATER FUNDS	
DESCRIPTION	**EXAMPLE**
Water funds provide an opportunity for private investors and companies to invest in GI in exchange for the product they receive: clean water. The fund, in turn, pays for watershed protection and water quality restoration activities. Water funds are developed during a five-phase process that includes multistakeholder governance, science-based decision making, strategies and mechanisms to ensure long-term sustainable financing, implementation of water fund activities and communication of the water fund outcomes. The Nature Conservancy launched water funds across Latin America, which led to diversification of private and public funding and more equitable allocation of resources and watershed benefits. Currently, 32 water fund initiatives provide a steady source of funding for the conservation of about 2.8 million hectares of watersheds and secure drinking water for nearly 50 million people (The Nature Conservancy 2018).	**LIMA WATER FUND** Since 2015, Lima's water utility company (SEDAPAL) has implemented a policy of allocating a portion of water tariffs to watershed protection: this means setting aside 1 percent of revenue to invest in GI and 3.5 percent in climate resilience and risk abatement, amounting to around $5 million per year. To capitalize on this policy, USAID launched its Natural Infrastructure for Water Security (NIWS) project in 2017 to provide implementation support to SEDAPAL, and to help manage critical water risks and meet Peru's water demands using GI solutions: wetland and forest conservation, improved grazing and farming practices, and restoring pre-Incan infiltration canals (Thiel 2017).

PROJECT HIGHLIGHT

Corvias Solutions and Prince George's County – Maryland

Public–Private Partnership, Urban

Photo credit: Eric Rogers

Under the federal Clean Water Act of 2010, states were required to address stormwater runoff pollution from impervious areas, which in many areas meant significant infrastructure investments were needed. To help fund these improvements, Maryland passed the Watershed Protection and Restoration Program, which created a Clean Water Act fee that is calculated based on a property's impervious pavement area and collected through annual property taxes. The legislation proved controversial however, and after deliberation, a revised bill was passed that made the fee discretionary but required counties to maintain sufficient levels of revenue to meet their stormwater obligations under the Clean Water Act (EDF 2017).

Prince George's (PG) County is the second most populous county in Maryland. It contains more than 300 streams, as well as portions of the Potomac, Anacostia and Patuxent Rivers, all of which flow into the Chesapeake Bay. Under the Watershed Protection and Restoration Program, PG County is required to retrofit 8,000 acres of uncontrolled impervious surfaces with treatment devices that will filter out pollutants from stormwater by 2025, at an estimated cost of $1.2 billion (Prince George's County 2014).

Faced with a monumental task, PG County entered into a public–private partnership (PPP) agreement with Corvias Solutions to lower costs, increase the efficiency of investments, and bring in the necessary expertise in development and implementation to help guide program management and share risk.

PROJECT HIGHLIGHT

INSTITUTIONAL ARRANGEMENT

PG County entered into the 30-year "Clean Water Partnership" with Corvias, which is a pay-for-performance service delivery model that delegates project selection, design, construction and O&M responsibility to the private partner. Under the agreement, the county provides Corvias with funds to retrofit 2,000 acres over a three-year project period, in which the county provides oversight, and Corvias serves as the program manager, handling procurement of subcontractors to ensure projects are executed in line with the scope, schedule and costs. Under this arrangement Corvias manages a team of subcontractors, including CH2M Hill (general contractors responsible for procurement and construction), Bowman Consulting Group (design engineers responsible for planning and design) and Stormwater Maintenance LCC (responsible for all subsequent O&M). After each project is completed, the Maryland Environmental Service, an independent state agency, inspects and certifies work as completed, and then monitors subsequent O&M work (UNC 2017).

FUNDING DETAILS AND COST

For the first three years of the project, PG County provided $100 million to Corvias to retrofit 2,000 acres of publicly owned impervious surfaces. Simultaneously, the capital projects team of the county's Department of the Environment is retrofitting an additional 2,000 acres that Corvias will also become eligible to maintain for the life of the agreement if performance targets are met during the three-year implementation period (Taylor 2015). The stormwater utility fees collected by the county were used to back debt issuances for the initial installations and will next be used to cover ongoing O&M expenses. For its part, Corvias is permitted to charge a base fee on all project costs including those related to social and economic programs, and an incentive fee based on performance during the implementation period. During the maintenance phase, the county will reimburse Corvias for annual O&M and management expenses, and will include base fees for management and incentive fees for meeting performance goals.

RESULTS AND BENEFITS

Although in many cases private partners in PPPs are responsible for contributing funds to a project or securing private investment, in this case private sector financing was not the primary driver of the partnership. Following the EPA's Community-Based PPP (CBP3) model, the private sector was engaged to meet regulatory requirements in an economically efficient manner, to bring in expertise in GI design, to transfer knowledge to public sector employees, and to provide additional local economic and community benefits. The overall effort is expected to install 46,000 GI elements – including rain gardens, permeable pavement and green roofs – by 2025. The agreement requires that Corvias meet socioeconomic targets as well, with goals for participation of country residents, and goals of 30–40 percent for subcontracting to local small, minority, veteran, disabled and women-owned businesses.

Implementation began in March of 2016; as of May 2018, 68 percent of construction is complete, putting Corvias on track for completing the overall retrofit on time and on budget. Corvias has also subcontracted almost exclusively with local small businesses, providing a significant benefit to the community. Estimates based on construction completed to date show significant pollutant load reductions, including 22,000 lbs. less nitrogen, 2,300 lbs. less phosphorus and 1.3 million lbs. less suspended solids annually (CWP 2018).

REPLICABILITY AND CONDITIONS FOR SUCCESS

The key to the sustainability of this PPP is the Clean Water Act fee, which provides a revenue source to back debt and bond issuance, as well as to pay for ongoing O&M. A similar fee could be introduced by other municipalities to fund stormwater system improvements, but in developing countries this could prove difficult, both politically and logistically, as a fee calculated based on square footage of impermeable pavement requires a survey and database of land and pavement types. For developing countries, a user fee model could be introduced or added on to existing user fees for water, sewage or waste water treatment. O&M PPPs have traditionally focused on sectors where clear fees can be charged, such as water provision or transportation (e.g., toll roads), however this provides an innovative model for GI and stormwater management. At least one other county (Chester, PA) in the United States has since adopted a similar model.

RECOMMENDATIONS

In many developing country contexts and more broadly, incorporating GI into planning, zoning, regulations and taxation (and ultimately capital expenditure and O&M) is an effective way for a local government to improve climate resilience. Cities in high-income nations are leading the way in the development of regulations, building codes, financial incentives and other policies to promote the use of sustainable GI. Many of the underlying principles being used in developed countries can and should be applied to cities in developing countries.

The widespread adoption of GI in developing nations requires a holistic approach from local governments, the private sector and donors, mainstreaming GI into planning and regulatory documents, establishing incentives, providing education and outreach, and providing implementation support to government officials and contractors unfamiliar with GI.

As GI becomes more mainstream in developed countries, there are now hundreds of examples to review and assess. As part of this report, seven case study synthesis and analytic documents were reviewed. From those documents, five common themes emerged, which form the outline of the recommendations below for city officials and the donor community to engage private sector partners in green infrastructure development and financing. Documents reviewed include:

- Green Infrastructure Case Studies: Municipal Policies for Managing Stormwater with Green Infrastructure (US EPA 2010)
- Green Infrastructure Finance – Framework Report (World Bank 2012)
- Green Infrastructure Municipal Handbook (US EPA 2008)
- Incentives for Natural Infrastructure (World Business Council For Sustainable Development 2017)
- Rooftops to Rivers II: Green strategies for controlling stormwater and combined sewer overflows (Natural Resources Defense Council 2011)
- The Case for Green Infrastructure (The Nature Conservancy with private partners 2013)
- Towards a Green Infrastructure Framework for Greater Manchester – Summary Report (The Environment Partnership 2008)

MAINSTREAM GREEN INFRASTRUCTURE INTO PLANNING DOCUMENTS

Investment in GI requires (1) developing a long-term plan that lays out goals and priorities for GI, and (2) mainstreaming GI into planning documents, action plans, investment plans and budgets across the government. Exemplary approaches include:

- **Develop a long-term GI plan.** Using other planning documents (e.g., infrastructure investment plans, sustainability or "green" plans) as a basis, develop a long-term GI plan that prioritizes infrastructure investment (Garrison and Hobbs 2011). The plan should identify long-term goals for GI; current issues that GI could address (e.g., flooding in particular parts of the city, aging sewerage infrastructure, reducing air pollution); departments/agencies that should be involved in decision making regarding GI and the roles, codes and regulations that need to be updated to incorporate GI; skills and knowledge gaps related to GI that need to be addressed; and funding source(s) for GI projects.

- **Add GI policy and interventions to department/agency-level policy and action plans.** In addition to a citywide GI plan, elements of the GI plan will need to flow down to department-level policy and action plans, ensuring specific GI interventions are planned and budgeted for by the implementing departments. Examples of departments that would be included in this action include the departments of Planning and Development, Transportation, Water & Sewerage, Parks and Recreation, and Housing/Buildings.

- **Incorporate GI into infrastructure investment planning.** If a city's infrastructure investment plan is a separate document from standard citywide or department-level action plans (as it often is), GI should be included in the infrastructure plan to ensure sufficient funds are allocated.

- **Establish a monitoring and evaluation system for GI.** Monitoring and evaluation of GI can likely be incorporated into current systems used to monitor infrastructure, but GI needs additional indicators that assess interventions for their climate risk reduction, mitigation benefits and their provision of ecological services more generally. These elements are a critical part of establishing the necessary evidence base for continued GI support.

UPDATE CODES TO INCLUDE GREEN INFRASTRUCTURE AND ENFORCE NEW REGULATIONS

Updating building codes and regulations related to stormwater runoff and other anticipated benefits is crucial to the success of GI. Without codes in place that mandate some level of stormwater retention on site, for example, or that compel property owners to use GI to manage runoff, often little incentive exists to change practices, particularly if those practices are new or untested locally. Cities in developing countries must also take the lead in applying these new standards to public spaces.

- **Develop and enforce a retention standard for stormwater.** Municipalities should develop regulations that require private property owners to retain a specific amount of precipitation onsite; in other words, if the standard is one inch and a rain event drops one inch or less of precipitation, the property should be able to infiltrate, evapotranspire or capture for reuse all of the precipitation, so that no water enters the storm sewer. Philadelphia's Green City, Clean Waters plan requires all new development to retain the first inch, and provides incentives to property owners to retrofit properties to meet this standard. Pittsburgh enacted a citywide stormwater ordinance that established stormwater volume reduction standards for large properties (thus focusing on commercial properties), including on-site retention of the first inch of rainfall (Garrison and Hobbs 2011).

- **Require GI to manage runoff from impervious surfaces.** In addition to capturing precipitation onsite, cities should update land use and zoning regulations to require property owners to use GI as a means of managing runoff from roofs, parking lots or other impervious surfaces. For example, New York City updated its zoning regulations to require large parking lots to include perimeter and interior landscaping, with the pavement graded to direct water to nonpaved areas. The city of Portland, Oregon, established a regulation requiring all downspouts to be disconnected from the municipal sewerage system. Toronto now requires all new construction with a floor area of 2,000 square meters or larger to install a green roof (Garrison and Hobbs 2011).
- **Institute a stormwater management fee.** Much like providing potable water or managing wastewater from homes, managing stormwater represents a significant cost for municipalities, and as such, cities should impose a fee to recoup that cost. The most common system in the United States for calculating the fee is a set rate multiplied by square feet of impervious surface, as this directly correlates with runoff volume, and tends to be progressive, as larger fees are applied to larger landowners (often commercial buildings). In addition to providing a revenue source to cover the cost of stormwater management and to fund future GI projects, a stormwater management fee discount (discussed below) offers an incentive to property owners to install GI.
- **Introduce a discharge permit process.** In the United States, the National Pollutant Discharge Elimination System (NPDES) program requires private "point sources" (e.g., industrial operations, construction sites, large agricultural operations) as well as municipalities to apply for and receive a permit to discharge surface water. The overall goal at the federal level is to regulate pollutants, but at the municipal level, municipalities have included GI in the permitting process, requiring commercial operations and large developments to include GI as part of their strategy to reduce runoff and pollutants.

DEVELOP INCENTIVES TO PROMOTE GREEN INFRASTRUCTURE

Incentives provide a counterbalance to regulations, and in addition to stimulating positive change in their own right, they increase public acceptable of regulatory changes. Incentives are particularly important in developing countries with little or no experience with GI, as beginning with incentives and then phasing in regulatory changes can help establish pioneers and a base of knowledge. The US EPA's "Municipal Handbook: Incentive Mechanisms" offers four primary mechanisms in use by municipalities in the United States that could be adopted by cities in developing countries.

- **Development incentives.** Typically offered to developers during the process of applying for development permits, this incentive can take a number of forms, including expedited permitting, reduced permit fee or an increase in floor area ratio. For example, Chicago waves permit fees for developments that meet a threshold for GI, and Portland increases a building's allowable area in exchange for the developer installing a green roof. For developing countries this incentive would likely be the easiest to offer, although it would potentially represent a loss of a portion of revenue (Garrison and Hobbs 2011; US EPA 2009).

- **Stormwater fee discount.** This incentive requires that a stormwater management fee is in place and is being collected. It functions by offering a discount on the fee as property owners reduce the volume of runoff. Depending on a municipality's goals, the discount can incentivize various GI interventions, including reducing impervious areas, increasing infiltration, increasing the number of buildings with green roofs or increasing the practice of rainwater harvesting.
- **Grants.** Municipalities can provide direct funding to property owners or community groups to stimulate GI buy-in and implementation. For example, through Washington D.C.'s Community Stormwater Solutions Grants program, the city provided 30 grants totaling $500,000 in 2017 to provide start-up funding for innovative, community-oriented projects aimed at improving water quality. These projects have included implementing GI solutions such as green roofs and forest restoration projects, as well as community outreach and education programs. In the developing world, a grant program may or may not be feasible, but a donor could provide a grant pool to incentivize GI as part of a larger project (DC Department of Energy and Environment 2018).
- **Rebates and financing.** This incentive requires that participants have the upfront capital necessary to fund the GI intervention directly; they then receive support from the government through low-interest loans, tax credits or reimbursements. For example, Philadelphia offers low-interest (1 percent) loans for GI retrofits on nonresidential property to encourage businesses to install GI. In developing countries, rebates would likely be best targeted at businesses, as residents may not have the capital to fund GI improvements without assistance.

COMMUNICATE AND DEMONSTRATE THE BENEFITS OF GREEN INFRASTRUCTURE

As with any major change in thinking, residents and business need information about GI: what it is, how it looks and works and what benefits it provides. For most cities in developing countries, this means assessments need to be conducted to study the feasibility and potential cost savings in the local context; demonstration projects need to be implemented to show in practice how GI works and further build the evidence base; and these results need to be communicated to the public to improve the acceptance of regulatory changes and buy-in for GI.

- **Build an evidence base.** Municipal governments should conduct a comprehensive economic and environmental analysis to more accurately compare green versus gray infrastructure in the local context (The Nature Conservancy 2013). This could include a CBA of specific interventions during the investment planning phase, comparing lifetime construction and O&M costs of grey infrastructure projects to potential GI alternatives. It could also include an assessment of benefits beyond climate risk reduction that grey infrastructure may not provide (e.g., other ecological services, biodiversity conservation, beautification of the public realm, creation of recreational spaces, increased public safety, etc.).

- **Demonstrate the benefits of GI through pilot projects.** Municipalities should partner with donors or establish PPPs to develop and test GI projects. A partnership model can help reduce risk, accelerate implementation and provide experience on developing, implementing and financing GI initiatives. Successful pilot projects can also serve as models for future development, and can help further build the business case for GI. Milwaukee, for example, partnered with the Miller Brewing Company to pilot a GI project at the company's main parking lot, which provided important experience to city officials (CH2M Hill 2007).

- **Disseminate information about GI.** A common theme across GI case studies is that community involvement and buy-in are an important factor of success, particularly when GI is being implemented communitywide. Cities should develop gender informed communication campaigns or awareness-building initiatives to foster inclusive public involvement in GI development, articulating the benefits and opportunities of GI, and leveraging potential gender differences in motivations and incentives for men and women. Benefits should also be communicated to businesses, and efforts should be made to create public–private networks to increase communication between city officials and local business leaders. GI projects developed in areas characterized by marginalized populations should be targeted using intensive outreach techniques, including nontechnical language, visual presentations and storytelling.

PROVIDE TECHNICAL ASSISTANCE AND COORDINATION FOR GREEN INFRASTRUCTURE IMPLEMENTATION

In some developing countries, GI may be a new concept, or it may already be in use, but not used intentionally as GI. City officials, O&M staff, engineers, contractors and others involved in the water and sewerage infrastructure of a city will need technical assistance and training on the design, construction and O&M of GI.

- **Provide policy support.** Either through consultants or with donor support, technical assistance should be provided to city officials to review environmental regulations, building codes, environmental impact assessment guidelines and requirements, and other legal and regulatory frameworks to (1) ensure adequate regulations are in place considering issues like stormwater runoff and land use, and (2) look for opportunities to incentivize or require GI elements in planning and design.

- **Provide capacity building and implementation support.** Capacity building such as training and knowledge dissemination through workshops, seminars, webinars, professional meetings and other learning activities should be provided to the relevant departments on designing, constructing, maintaining and monitoring GI. While most departments likely have engineers on staff, additional instruction may be required on issues relevant to GI, such as site selection, local hydrology, selection of appropriate GI techniques, and training community members and private land owners on GI maintenance.

- **Provide training-of-trainers sessions for municipal staff.** Unlike grey infrastructure, which is typically maintained exclusively by a municipality or a private contractor, GI frequently requires community involvement in maintenance and, occasionally, construction. GI constructed on private land will very likely not be carried out or maintained by municipal staff; therefore, staff will be responsible for disseminating information on GI best practice, and providing training sessions to contractors, businesses and private property owners. Either as a self-funded initiative or with donor support, city officials need to provide training-of-trainers sessions for staff to enable them to effectively develop the community support network necessary to expand and maintain GI interventions.

ADDITIONAL RESOUCES

GUIDEBOOKS AND TECHNICAL RESOURCES

Banking on green: A look at how green infrastructure can save municipalities money and provide economic benefits community-wide (American Rivers 2012)

Financing urban adaptation to climate change (European Environment Agency 2017)

Good practice guides (C40)

Green ecosystem-based management approaches for water-related infrastructure projects (UNEP 2014)

Green Infrastructure: An essential foundation for sustainable urban futures in Africa. Evaluation of the potential of urban ecosystem services (CLUVA 2013)

Green infrastructure resource guide (USAID 2017)

Green infrastructure toolkit (Georgetown Climate Center 2015)

Harvesting the value of water: stormwater, green infrastructure, and real estate (Urban Land Institute 2017)

Incentives for natural infrastructure (WBCSD 2017)

Natural and nature based flood management: A green guide (WWF 2016)

Natural infrastructure in the nexus (IUCN 2015)

Natural infrastructure - investing in forested landscapes for source water protection in the United States (WRI 2013)

Progress report on approaches to mobilising institutional investment for green infrastructure (OECD 2016)

Reducing climate risks with natural infrastructure (The Nature Conservancy 2014)

Supporting the implementation of green infrastructure (European Commission 2016)

The benefits of green infrastructure for heat mitigation and emissions reductions in cities (The Trust for Public Land 2016)

The Green edge: How commercial property investment in green infrastructure creates value (Natural Resources Defense Council 2013)

The New business imperative: Valuing natural capital (Corporate EcoForum 2012)

The role of green infrastructure solutions in urban flood risk management (World Bank 2016)

The value of green infrastructure: A guide to recognizing its economic, environmental and social benefits (Center for Neighborhood Technology and American Rivers 2010)

Unlocking private finance in sustainable infrastructure unlocking private capital to finance sustainable infrastructure (Environmental Defense Fund 2017)

Vulnerable natural infrastructure in urban coastal zones - Problem statement and key messages (The Rockefeller Foundation 2013)

CASE STUDY DOCUMENTS

Adaptation to climate change using green and blue infrastructure - A database of case studies (University of Manchester 2010)

Finance options and instruments for ecosystem-based adaptation overview and compilation of ten examples (GIZ 2018)

Green infrastructure case studies (The Nature Conservancy 2013)

Green infrastructure case studies: Municipal policies for managing stormwater with green infrastructure (US EPA 2010)

CASE STUDY DATABASES

Case study library (Natural Infrastructure for Business)

Catalogue of case studies (Natural Water Retention Measures)

Envision verified projects (Institute for Sustainable Infrastructure)

Green infrastructure resource library (Town and Country Planning Association)

Nature-based solutions case studies (Oopla)

Private sector initiatives database (UNFCCC)

Stormwater case studies by state (American Society of Landscape Architects)

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