UPLanD – Journal of Urban Planning, Landscape & environmental Design, 5(2), 39-50 [2020]

UPLanD
Journal of Urban Planning, Landscape & Environmental Design

Research & experimentation
Ricerca e sperimentazione

Green Infrastructure as a climate change mitigation strategy: quantification of environmental & economic benefits for the City of Somerville

Silvia Cioci[a], Matthew J. Eckelman[b], Annalisa Onnis-Hayden[b]

[a]Department of Civil, Constructional and Environmental Engineeering, Sapienza University of Rome, IT
[b]Department of Civil & Environmental Engineering, Northeastern University, Boston, US

Highlights

- Climate change mitigation systems and protection of the territory
- Multifunctional ecological and environmental systems fort the reconnection of the territory and landscape
- Evaluation of environmental and economic benefits and opportunity for social cohesion for the wellness and wellbeing.
- The local scale as an essential element in the process of re-design the cities

Abstract

The growing awareness of the negative impact of human activities on climate has led to adopt territorial adaptation and mitigation policies. Strategies capable of coping with increasingly extreme and sudden negative impacts make their way into the scenario of territorial planning, which focus on choices that create more resilient cities. A suitable strategy for this new approach to territorial planning includes green infrastructure a multifunctional tool designed to mitigate impacts of climate change and to intervene on "urban waste" and dismiss places to re-naturalize and make them more inclusive. The paper examines the innovative scenario of the Inner Core in Boston, Massachusetts, exploring the policies of the city of Somerville, which focus on the implementation of green infrastructure to provide multiple benefits.

Former industrialized area of Somerville, the Inner Belt is one of the settlements most exposed to the climate crisis and particularly weak territorial context from a social, economic, and political point of view. The evidence of a settlement that "ceded to environmental blackmail" in exchange for jobs, required a procedural approach by rethinking the area in a strategic perspective capable of combining the needs of the community with adaptation to change. The Inner Belt was thus reconsidered as a hub (system of places), that is, as an integral part of the new vision of a green infrastructure network for the city of Somerville and an urban area of planning emergency in the re-composition and identity re-appropriation of its widespread and pervasive waterproofed spaces. This choice highlighted the importance of the local scale in the process of redesigning the public space and forgotten places in the evolution of green infrastructure. This study analyzes and quantify the environmental and economic benefits provided by the green infrastructure, demonstrating the effectiveness of the adoption of this multi-functional strategy.

Article history

Received: August 04, 2019
Reviewed: May 15, 2020
Accepted: June 06, 2020
On line: July 03, 2020

Keywords

Green Infrastructure
Sustainability
Best Management Practice
Tools and Techniques
Quantifications

Email: silvia.cioci@uniroma1.it; m.eckelman@northeastern.edu; aonnis@coe.neu.edu

1. Introduction

Climate change, a key challenge of our time, is modifying the policies and practices of spatial planning with the aim of influencing the ability to adapt and recover human and natural systems. Words like "air pollution", "low albedo", "anthropic emissions" are increasingly being accompanied by terminologies such as "resilience", "strategic planning", "re-naturalization". It is scientifically proven, in fact, how greenhouse gas emissions are increasing faster than expected and the negative effects of global warming are emerging sooner than original predicted (Cole & Waller, 2015). The management of the territory and its transformations, the affirmation of the policies of mitigation and adaptation to climate change is the sign of a growing awareness of the negative influence that anthropic activities have on the climate system (IPCC, 2014). A tangible sign of the high level of alarm can be seen in the proceeding of the UE conference held in Paris in December 2015 which highlighted the need for a radical change of course of the landscape planning especially in progressively vulnerable urban areas (Mirzaei & Haghighat, 2010; Solecki & Marcotullio, 2013). There is, therefore, a need, not to be postponed, to develop new methods of interventions aimed at achieving greater efficiency in the management of available resources, the control of land use and biodiversity, the production and maintenance of ecosystem services and the reduction of carbon emissions; this new method will allowed the territory to respond and react to the negative impact of climate change (Baró et al., 2014; Gill, Handley, Ennos, & Pauleit, 2007). The landscape issue, as it is perceived today, is certainly not disconnected from the processes of globalization of environmental, economic, social and cultural dynamics. The passage from the society of places to the society of flows, connected by technologies and the culture of communication, tends to sever the bonds of people with places, to undermine the territorial rooting of social formations and to accelerate the processes of deterritorialization (Gambino, 2003). The new visions that characterize international scenarios, the new paradigms that should guide the conservation of nature, the reticular perspectives that are looming in contemporary cities and territories, call for complex and multifunctional, trans-scalar and multi-sectoral sustainable strategies. One of the strategies for this new multi-functional approach to territorial planning is the concept of green infrastructure (GI). The concept of GI arose in the late 1990s in the Anglo-Saxon countries and the first theoretical and methodological definitions are attributable to the Environmental Protection Agency (EPA) in the United States and the England's Community Forest Network in the United Kingdom (Benedict & Mcmahon, 2002; Benedict & McMahon, 2006; Canzonieri, 2007). The GI initially configured itself as a specialized system of the ecological network for the enhancement of its ecosystem services, subsequently it expanded is functions as an integration tool for territorial planning, with the precise aim of mitigating the negative effects of climate change such us the increase and the intensity of precipitation and urban heat island effect (Acierno, 2012). Emblematic in this sense is the holistic approach to spatial planning in the Boston metropolitan region in Massachusetts. The topography of the Inner Core in Boston was largely modeled by the glaciers that covered the territory during the ice age, thus defining the boundaries between land and riparian areas that intersect touching the different County from Middlesex to Suffolk to reach the Massachusetts Bay. Committed to a strategic approach, the Metropolitan Area Planning Council (MAPC) in collaboration with the Trust for Public Land (TPL), studied the regional reconnection GI to be able to exploit the natural potential present throughout the Inner Core territory. Where the scientific landscape of spatial planning makes way for the concept of "exploiting the capacity of nature to absorb and control impacts" (Malcevschi & Bisogni, 2016), the idea of landscaping proposed for the Boston metropolitan region contemplates the realization of an infrastructure capable of crossing densely populated urban areas with the aim of making them more resilient. The awareness of the need for re-planning of the territory by the municipality of Boston, Cambridge and Somerville has made the concept of urban re-naturalization assume a more dense and complex meaning, leading to investing in the GIs, not only, to achieve sustainable development goals but also to address the inequalities and insecurities of the most disadvantaged communities. The adjective "multifunctional" that accompanies the strategic GI looks, therefore, at a re-stitching system as a tool capable of tackling both environmental problems and environmental justice issues.

As a representative case of an action plan that involves the entire metropolitan area of Boston, the paper takes a dive into the plans adopted by the administration of Somerville and try to quantification the environmental and economic benefits that the city will obtain by adopting the green multifunctional system for urban redevelopment.

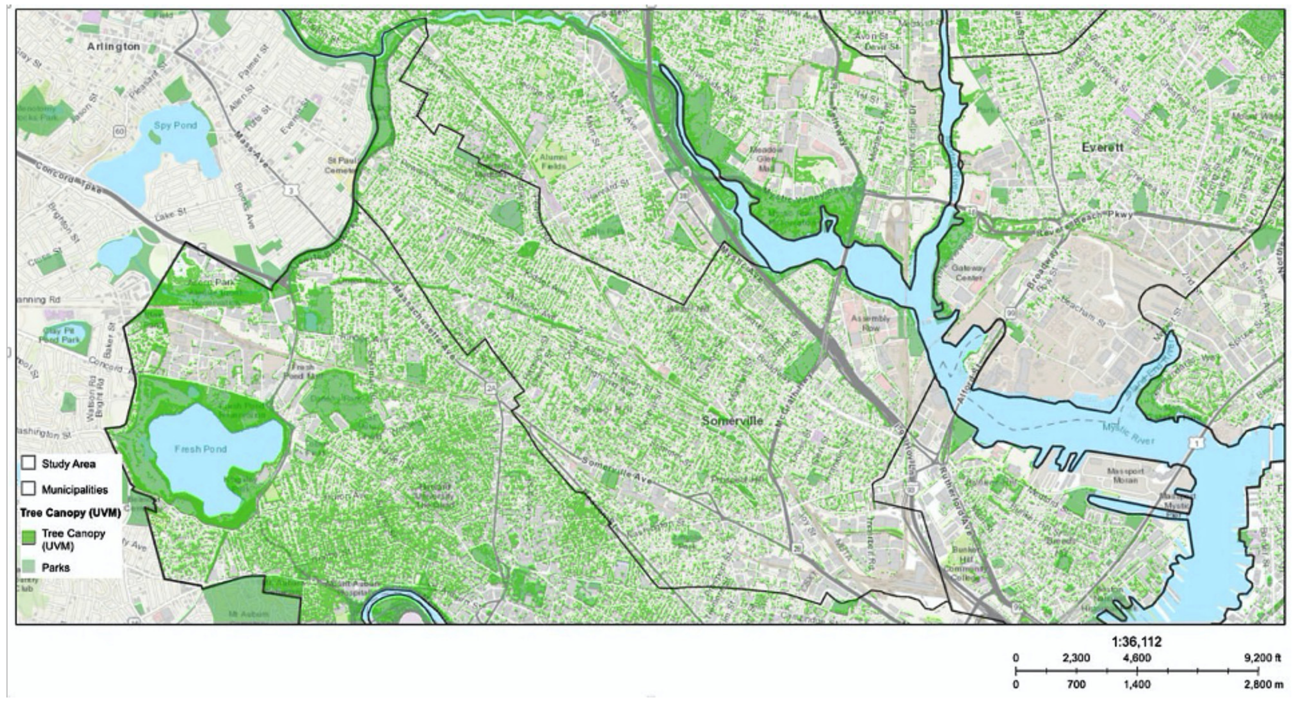

Figure 1: GIS monitoring of tree cover and green spaces in Somerville. *Source: Image created by Silvia Cioci. Data source: MassGIS, the U.S. Census Bureau, NASA, ESRI, data from the cities of Somerville and Cambridge.*

2. The densely city of Somerville

Located in the coastal plain of the northern basin of the Boston metropolitan region, Somerville is bordered to the north by the Mystic River and the communities of Medford, Malden and Everett; west of the Alewife Brook and the city of Arlington, and to the east and south from the cities of Boston and Cambridge. The physical topography is a distinctive feature of Somerville: seven hilly areas have given rise to infrastructural corridors for vehicular transport, while the plains and alluvial swamps have influenced the model of historical and current development of the city. Although Somerville is part of a vast regional network of natural resources and open spaces, such as the cities of Boston and Cambridge, it retains its uniquely urban character that distinguishes it from the peripheral areas that surround it. Because of its proximity to the largest city in the state of Massachusetts and important waterways, Somerville has always been part of the largest regional transport infrastructure: five large rail corridors and three road arteries, cross the city connecting it to Boston and to the northern suburbs (Morris & St. Martin, 2008). Where the geomorphology and the historical planning models have defined the urban fabric of the city, marked by a regular rhythm of 4,000 square lots mostly for residential use, the large infrastructures that cross the south and south-west areas of the city have created barriers that separate neighborhoods from each other, preventing access to open urban and regional green spaces, considerably increasing air pollution and affecting the lives of the communities that live there. The progressive city of Somerville has recognized the need for actions to tackle climate change through solutions that can restore urban ecosystem services and protect natural habitats and landscapes. To help out the city to identify the most appropriate strategies we carried out a GIS monitoring of the urban green heritage (Fig. 1) and of the impervious surface coverage to define the future framework on the increase of temperatures to 2030 (Fig. 2) and on the flood risk to 2070 (Fig. 3).

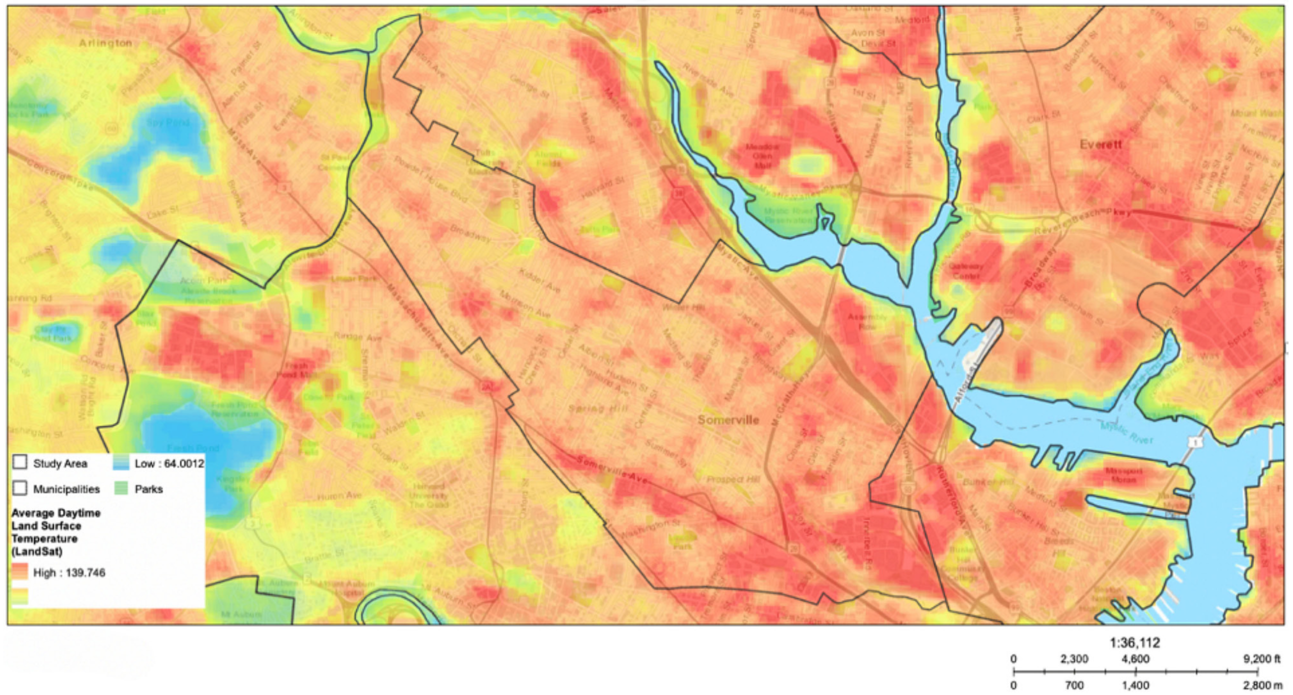

Figure 2: GIS scenario at 2030 of the average daily surface temperatures. *Source: Image created by Silvia Cioci. Data source: MassGIS, the U.S. Census Bureau, NASA, ESRI*

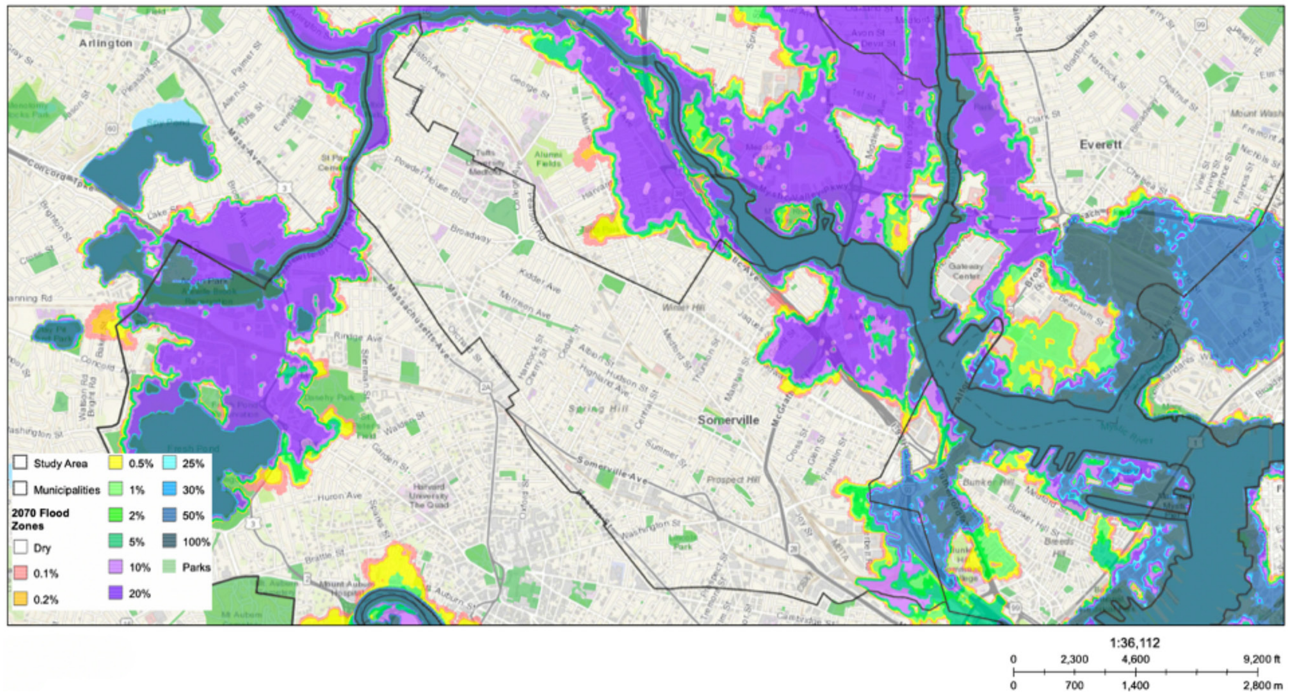

Figure 3: GIS scenario at 2070 of areas at risk of flooding. *Source: Image created by Silvia Cioci. Data source: MassGIS, the U.S. Census Bureau, NASA, ESRI*

2.1 GIS monitoring

Distribution and accessibility to open green spaces is often synonymous, in urban areas, with spatial management asymmetries (Ernstson, 2013) which contributes to the inequity in the physical and mental health of different socio-cultural and economic groups (Bird, 2007). The evident feedback obtained from the morphological analysis and corroborated by the GIS monitoring allows us to affirm that the development that took place during the first half of the 20th century led Somerville to adopt territorial subdivision models that today leave the city with a paltry heritage of open spaces: 158 acres (about 64 ha), corresponding to 6% of the total extension of 10.9 km2, represent the urban public spaces assets. The study also showed that 77% of the city is covered by impervious surfaces that include buildings, sidewalks and parking lots in addition to buildings. We focus our attention to the southern neighborhoods of Somerville, where Interstate 93 and State Route 28 trace the boundaries of the Inner Belt and East Somerville districts. These areas are characterized by strong density of roads and limited green spaces witch both contribute to atmospheric pollution, the recurrent danger of flooding and the increase of the surface temperature. The analysis conducted indeed confirmed that these areas of the city have issue managing rainwater, causing flooding particularly in the winter season; moreover we estimated that future temperatures will reach over 103°F (about 39.5°C) during summer, generating an island effect of urban devastation for public health and air quality.

3. The SomerVision Plan: the renaissance of the city of Somerville

The overall view of the urban renewal strategy proposed in the SomerVision Plan is the results of a comprehensive analysis where social inequality and environmental issue are considered together.
The result of the three-year decision-making process, the SomerVision 2010-2040 (Somerville, 2012), plan for the revival of the city of Somerville, identifies more than 584 objectives, values, policies, and actions concerning resilience, the creation of new open spaces, the transformation of areas left to neglect, the construction of new low-cost housing, the creation of new jobs, and the increase in public transport. The willingness and the request of the administration to involve the community in the decision-making choices was supported by a large participation that saw the creation of a steering committee composed of 60 residents, the effort and the will to make Somerville an "An Exceptional Place to Live, Work, Play, and Raise a Family". The biggest obstacle to achieving the goals of the SomerVision Plan, especially as regards the construction of new hectares of open space, is the availability of areas. Where a broad definition of "open space" and a lack of design standards combined to produce unpredictable results through a zoning device dating back to 1925, the Office of Strategic Planning and Community Development (OSPCD) proposed, in 2015, a complete overhaul of the Zoning Overhaul with the aim of initiating the urban de-densification process resulting from the demographic decline of the city. Parallel to SomerVision, the Somerville Climate Forward (CCVA, 2017) is the comprehensive plan that aims to intervene to minimize emissions of greenhouse gases. The set of actions envisaged by the plan adopted by the municipality in 2015, were studied to prepare the territory for the inevitable negative future impacts of climate change and make Somerville a carbon neutral city by 2050.

3.1 The strategical green infrastructure

GIS monitoring identified the densely populated neighborhoods of Union Square, Winter Hill and Davis Square as areas most vulnerable to changing climate, more exposed to the problems of environmental justice and confirmed the choices of the administration to intervene to transform the historically industrial areas of the Assembly Square and Inner Belt where these neighborhoods are located.
Improving the quality of places through the re-naturalization and securing of the most fragile paths and places, become a tool to guarantee healthier lifestyles and give back to the community the right value to those places that, over the centuries, have lost their identity and cultural traditions. Somerville's new urban GI makes use of Best Practices Management (BPM) as strategies that have both the potential to alleviate the negative impacts of climate change and elevate the urban landscape quality of Somerville (EPA, 2017) thus guaranteeing economic and aesthetic advantages (Ernstson,

2013; Escobedo, Kroeger, & Wagner, 2011; Escobedo et al., 2008; Gill et al., 2007; Pataki et al., 2011). Urban re-naturalization practiced such as the use of green roofs, the increased vegetation, the application of permeable pavements, the rain garden and the planter boxes, the recourse of bioretention and infiltration systems, become key player of the new system of networks and spaces of the multifunctional green infrastructure for the city of Somerville (Bendt, Barthel, & Colding, 2013; Hudson County, 2014; Mesimäki, Hauru, & Lehvävirta, 2019; MORPC, 2015) (Fig. 4).

3.2 *The quantification of the environmental and economic benefits*

With the aim of demonstrating effectiveness in the adoption of BPM solution, the study presents an analysis of the monetary benefits deriving from the ecosystem services provided by the GI strategy. The method is defined by a coherent sequence that envisages two phases consisting, respectively, in measuring the environmental benefits provided by each re-naturalization practice and the subsequent assignment of the economic value of these benefits. whenever possible.

Estimates of ecosystem services are based on a standardized data collection and analysis procedure that uses environmental archives applied to the Inner Belt area (Adkins et al., 2015; United States Environmental Protection Agency - Clean Water State Revolving Fund, 2015; US EPA, 2014). Predicting first a redevelopment of a 1ha local area of intervention, the study provided a detailed description of the estimates of four urban ecosystem services: (1) regulation of water flows; (2) energy saving; (3) local removal of atmospheric pollutants; (4) carbon sequestration (Tab 1). In the second phase the identification of the economic values for each benefit disbursed by the different practices was determined based on the environmental resources identified in the previous step and translate into monetary figures depending on the category of reference benefits (Tab 2). The SomerVision Plan that takes into consideration the redevelopment scenario through GI practices in the Inner Belt area of Somerville, foresees the

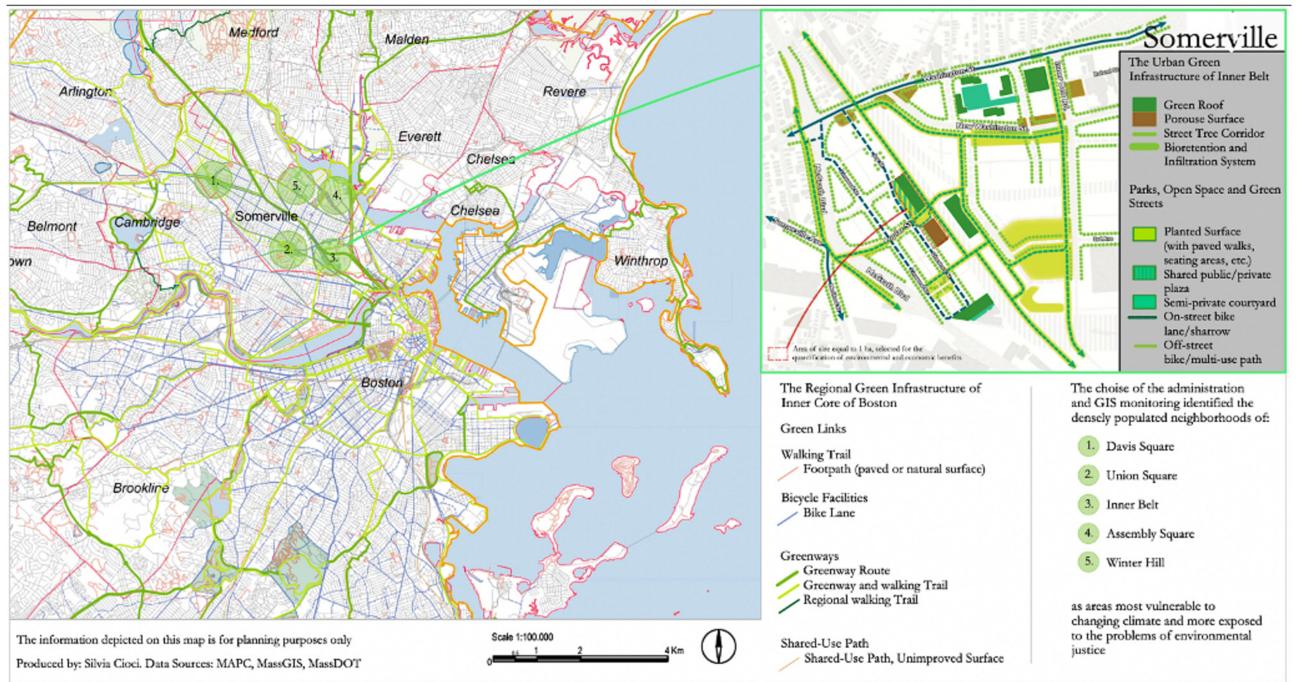

Figure 4: The image shows, on the left, a part of the green reconnection infrastructure foreseen by the Metropolitan Area Planning Council for the Greater Boston area. It identifies the five most vulnerable areas in the city of Somerville and shows, on the right, the strategic redevelopment plan for the Inner Belt area of Somerville. *Source: Image created by Silvia Cioci. Data Sources: MAPC, MassGIS, MassDOT.*

Table 1: Evaluation of the environmental benefits provided by the BPM re-naturalization practices of the urban GI

Step 1. Quantification of environmental benefit																			
		Water			Energy			Air Quality								Climate Change			
		Total (drained) area (ha)	Volume Capacity (m3)	Runoff reduced per year (m3)	Cooling saving (kWh)	Natural gas saving (Btu)	Annual energy saved (kWh)	NO_2 total annual uptake		O_3 total annual uptake		SO_2 total annual uptake		PM_{10} total annual uptake		Annual amount of CO_2 sequestered			
								Low (kg)	High (kg)	Low (kg)	High (kg)	Low (kg)	High (kg)	Low (kg)	High (kg)	Low (kg)	High (kg)	from annual electricity cooling saving	from annual energy saved from reduced water treatment
Green Roof		0.05	106.33	747.6	1,670.0	29,400,000	480.07	0.68	1.08	1.33	2.08	0.52	0.92	0.26	0.30	7.53	7.8		
Tree Planting / Pits		no. 100	0	1101.7	10,010.00	186,805,000	664.3	30.2		9.27		19.7		11.8		2,107.2		5.2 tons	1.6 tons
Porous Pavement		0.08	185.2	4444.6	0	0	198.3	0								1.23	1.28		
Bioretention and Infiltration system	Rain garden	0.034	187.2	2796	0	0	1894.4	0.5	0.8	0.98	1.53	0.38	0.68	0.19	0.22	5.53	5.73		
	Bumpouts	0.006	32.3	815.5	0	0	473.8	0.08	0.14	0.16	0.25	0.06	0.10	0.032	0.04	0.9	0.94		
		Stormwater reduced per year: 112% * 349,803 of 311,961 ft3= -37,842 ft3 remaining Phosphorus pollution reduced: 61% 7.3 of 12.0 lbs annually TSS pollution reduced: 75% 2,150.1 of 2,860.7 lbs annually			Total annual electricity cooling saving: 1,680.00 kWh/ha/year Total annual heating natural gas saving: 216,205 kBtu/ha/year		Total annual energy saved from reduced water treatment (kWh): 3,710.9	Total annual air pollutants removed: 76.1 ÷ 79.1 kg								Total annual Tons of CO_2 sequestration: 2.1 ÷ 2.2			

Data source: Somerville City Hall_* Somerville Geolocalization data: 42°23′15″ N, 71°6′0″ W; Neighborhood type: Dense single family/Apartments/multi-unit. Amount of rainfall per event (inches), [range 0-1]: 1.00; Average annual rainfall (inches): 48. In the selected location, buildings, pavement, and other impervious surfaces lead to 311,961 ft^3 of runoff each year

use of green roofs covering a total surface area of 500 m2, the increase of street trees for a total of 100 new plants, the predisposition of 800 m2 of permeable areas for the new cycle-pedestrian paths and the use of bioretention and infiltration systems such as rain gardens and bumpouts for 400 m2. The results related to the quantification of water flows obtained for
this scenario shows a decrease in the impermeable zone of 21.5% and a consequent capture of 112% of the annual meteoric outflow volume. These data led to the examination of the reduction of pollutants present in freshwater such as phosphorus and suspended solids (TSS) which, through the adopted GI practices, lead to a 61% decrease, corresponding to 7.3 lbs/year (ca. 3.3 kg/year) of a total annual phosphorus of 12.0 lbs (ca. 5.4 kg) and 75% of TSS equal to 2,150.1 lbs/year (ca. 975.3 kg/year) of 2,860.7 lbs/year (ca. 1,297.6 kg/year). The decrease in water pollutants corresponds also to a reduction in the use of energy associated with water treatment of about 3,710.9 kWh; the calculation of energy consumption both in summer and in winter has shown a saving of 11,680.0 kWh/year for cooling and a recovery of 216,205.0 kBtu/year of natural gas for heating, due to ability of GI. In order to quantify the environmental benefits provided by the green strategy adopted in climate change mitigation, the study focused on the calculation of local removal of air pollutants and carbon storage. According to data on air quality indexes (AQI) used by US government agencies, Somerville has experienced an increase in AQI from 50 to 100 in the last twenty years which, in accordance with the US EPA level set to protect public health, classifies air quality in the urban context as moderate.
Where a current AQI of 100 corresponds to an ozone level of 0.070 parts per million (ppm) over an average of 8 hours and a particle level of up to 10 microns in diameter of 35 micrograms per cubic meter over an average of 24 hours, the use of the multifunctional GI would guarantee an annual removal of atmospheric pollutants variable between 76.1 and 79.1 kg (761 ppm ÷ 791 ppm) and a storage of CO2 up to 0, 22 tons. A result of considerable interest, the indirect benefits deriving from the reduction of energy consumption have also highlighted a gain in terms of reduction of CO2 emissions equal to 6.8 tons/year. In addition, a recent study focused on the Urban Heat Island effect (Community Development Department, 2019; Mirzaei & Haghighat, 2010) indicated a reduction of the surface temperature of 1°C for every 10% of reduced impervious surface. According to the results obtained, the adoption of GI practices on 1ha of land in Somerville, would guarantee a lowering of the level of terrestrial thermal energy by about 2.5°C enhancing the health of the residents and ensuring a lower level of pollution of the air. The quantification of the environmental benefits mentioned above shows how BPM solutions distribute ecosystem services in urban areas that need attention, care and protection, allowing a gain not only in environmental but also in economic terms. The data analyzed were, in fact, transformed into a monetary figure verifying the corresponding economic benefits. The use of GI practices would lead to a water treatment reduction corresponding to an annual average of USD 107,870.00, energy saving ethical of USD 12,018.04 and again mean of USD 2,674.8 in terms of carbon storage and air pollutants for a total annual attain of variable benefits between USD 14,973.27 and USD 25,069.03.

4. Discussion

The research highlights how investing in restoration, protection and territorial improvement through GIs is not only advantageous from an ecological and social point of view but also economically profitable. Unfortunately, even if the economic calculations provide useful arguments for environmental improvements, they are not enough to fully acquire, measure or monitor the extent of the benefits related to the restoration of ecosystem services in the cities. In the long-term quantification indeed, it was not calculated 3.5% more than annual benefits provided by the growth of trees and vegetations for the storage of carbon

Table 2: Evaluation of the environmental benefits provided by the BPM re-naturalization practices of the urban GI.

Step 2. Valuation of quantified benefits																			
			Water		Energy			Air Quality								Climate Change			
			Reduced Water Treatment Needs ($/lbs/year)		Annual cooling or on-site electricity savings ($/year)	Annual heating natural gas savings ($/year)	Annaual energy saved from water treatment ($/year)	NO_2 total annual uptake		O_3 total annual uptake		SO_2 total annual uptake		PM_{10} total annual uptake		Annual amount of CO2 sequestered ($/year)		Indirect benefit_Benefit from kWh Saved ($/year)	
			Low	High				Low ($/year)	High ($/year)	Low ($/year)	High ($/year)	Low ($/year)	High ($/year)	Low ($/year)	High ($/year)	Low	High	from annual electricity cooling saving	from annual energy saved from reduced water treatment
Green Roof		Phos.	0	0	376.92	1,214.22	108.4	2.42	3.9	1.21	1.89	11.02	19.5	42.51	49.05	0.067	0.07		
		TSS	0.35	199.20															
Tree Planting / Pits		Phos.	96.00	144.00	2,259.2	7,715.0	149.9	107.8		8.44		417.64		1,929.3		18.96			
		TSS	3.50	4,379.04															
Porous Pavement		Phos.	36.00	54.00	0	0	44.8	0								0.011	0.012	46.8	14.4
		TSS	2.20	1,247.01															
Bioretention and Infiltration system	Rain garden	Phos.	124.00	186.00	0	0	42.7	1.78	2.85	0.89	1.39	8.05	14.42	31.1	35.97	0.049	0.052		
		TSS	5.49	3,163.84															
	Bumpouts	Phos.	36.00	54.00	0	0	106.9	0.28	0.49	0.15	0.23	1.27	2.12	5.23	6.54	0.0081	0.0085		
		TSS	1.60	922.00															
			Total Annual saved: $ 305.14 ÷ 10,349.08		Total annual saved: $ 12,018.04			Total Annual saved: $ 2,569.09 ÷ $ 2,620.61								Total Annual saved: $ 19.09 ÷ $ 19.10		Total Annual saved: $ 61.2	
Total of Benefit giving by Green Infrastructure for 1 year: $ 14,973.27 ÷ 25,069.03																			

Akbari, 2002; Anderson, Lambrinos, & Schroll, 2010; Anthoff & Tol, 2013; Bashar, Gungor, Karthikeyan, & Barak, 2018; Boukili et al., 2017; Brantley, Hagler, J. Deshmukh, & Baldauf, 2014; Cherrier, Klein, Link, Pillich, & Yonzan, 2016; Damodaram et al., 2010; De la Sota, Ruffato-Ferreira, Ruiz-García, & Alvarez, 2019; Ernstson, 2013; Escobedo et al., 2011; Escobedo & Nowak, 2009; Farrugia, Hudson, & McCulloch, 2013; Foster, Lowe, & Winkelman, 2011; Gallet, 2012; Getter & Rowe, 2006; Getter, Rowe, & Andresen, 2007; Gill et al., 2007; Gillett, Allen, & Williams, 2003; Gómez-Baggethun & Ruiz-Pérez, 2011; Hope, 2008; Hubacek & Kronenberg, 2013; Jenkins et al., 2014, 2014; Jim & Chen, 2009; Jo & McPherson, 1995; Liu & Li, 2012; McPherson, Simpson, Xiao, & Wu, 2011; McPherson et al., 2017; Nordman, Isely, Isely, & Denning, 2018; Nowak, Greenfield, Hoehn, & Lapoint, 2013; Padró-Martínez et al., 2012; Raffinetti, Siletti, & Vernizzi, 2015; Rao et al., 2016; Ricke, Drouet, Caldeira, & Tavoni, 2018; US EPA, 2014; Vos, Maiheu, Vankerkom, & Janssen, 2013 and atmospheric pollutants (Jim and Chen, 2008; Jingqiu Chen et al., 2019; Gallet, 2012). This data, linked to the growth and the right maintenance of the green heritage, would lead to an increase in the environmental and economic profit that is difficult to quantify year by year (Hedenås et al., 2011). It is believed, however, that the information reported may be essential in the decision-making processes aimed at protecting, safeguarding, managing and regenerating the territory which takes into consideration the use of appropriate strategies to guarantee the mitigation of climate change and the quality of the life for the communities. Furthermore, since many benefits produced by ecosystem services cannot be adequately assessed by monetary metrics, increasing attention is being paid to the benefits provided by GIs such as health, aesthetics and education (Gómez-Baggethun et al., 2013; Hubacek & Kronenberg, 2013; Sullivan & Kuo, 1996). Many of these non-monetary benefits have been empirically defined and measured in cities around the world (Douglas, 2012) demonstrating, for example, that access to green space is related to longevity (Takano, Nakamura, & Watanabe, 2002) to recovery from surgical interventions (Ulrich, 1984) and to mental well-being linked to stress reduction (Maas et al., 2006).

5. Conclusion

The study will lead to reflection on the potential that the GIs can offer. The action envisaged by the administration of Somerville is one of the multiple strategies for bringing nature back to the city and represents an example of how it is possible to enhance undeveloped spaces, typical of peri-urban and extra-urban areas but also of urban voids, placing, at the same time, "a limit to the fragmentation of natural habitats and contributing to the protection and preservation of biodiversity" (ISPRA, 2017). The GI is here interpreted as a plant network of reconnection between waste and waste areas that increasingly interacts with traditional public spaces into the building fabrics and becomes a topic of significant interest in the project of the contemporary and innovative city. Central to the ecological conversion of urban areas, Somerville's planning strategy turns out to be a valid tool that can "stimulate a paradigm shift in urban metabolism based on the recycling of resources and on a social and identity re-appropriation of common goods" (Gasparrini, 2017) at the same time mitigating the negative effects of climate change. The study also shows that precisely because of climate change, green's ability to provide ecosystem services capable of mitigating risks will play an essential role also for the reduction of new physical stresses (Elmqvist et al., 2015).
The use of GI as strategies to add resiliency to the territories are often still limited to single local initiatives, differently, the comprehensive and long-term plan adopted by the city of Somerville appears to be an important tool for adaptation to climate change and urban redevelopment. With this regeneration strategy, Somerville is striving to achieve goals capable of guaranteeing its intelligent, inclusive and resilient growth, becoming one of the cities symbolizing a desire for change.

References

Acierno, A. (2012). Il Piano per l'Infrastruttura Verde di Londra e la gestione della Olympic Park Legacy. *TRIA : Territorio Della Ricerca Su Insediamenti e Ambiente*, (9), 155–166. doi: 10.6092/2281-4574/1342

Adkins, J., Allen, T., Cary-Kothera, L., Cofer-Shabica, N., Harper, D., Tanimoto, J., Scott, L. (2015). *A Guide to Assessing Green Infrastructure Costs and Benefits for Flood Reduction Acknowledgments The project team consisted of*. Retrieved from: www.coast.noaa.gov

Baró, F., Chaparro, L., Gómez-Baggethun, E., Langemeyer, J., Nowak, D. J., & Terradas, J. (2014). Contribution of ecosystem services to air quality and climate change mitigation policies: The case of urban forests in Barcelona, Spain. *Ambio*, *43*(4), 466–479. doi: 10.1007/s13280-014-0507-x

Bendt, P., Barthel, S., & Colding, J. (2013). Civic greening and environmental learning in public-access community gardens in Berlin. *Landscape and Urban Planning*, *109*(1), 18–30. doi: 10.1016/j.landurbplan.2012.10.003

Benedict, M. A., & McMahon, E. T. (2006). Green Infrastructure. *Strategic Green Infrastructure Planning*, 1–289. doi: 10.5822/978-1-61091-693-6_1

Benedict, M. E., & McMahon, J. D. (2002). Green Infrastructure: Smart Conservation for the 21st Century Infrastructure-the substructure or underlying foundation…on which the continuance and growth of a community or state depends. *Renewable Resources Journal2*, *20*(3).

Canzonieri, C. (2007). M.E. Benedict and E.T. McMahon, Green Infrastructure: Linking Landscapes and Communities. *Landscape Ecology*, *22*(5), 797–798. doi: 10.1007/s10980-006-9045-7

CCVA. (2017). *Somerville Climate Forward*.

Chen, Jim and. (2008). Ecosystem services and monetary values of urban forests in China. *Cities*, *9*, 21.

Chen, Jingqiu, Liu, Y., Gitau, M. W., Engel, B. A., Flanagan, D. C., & Harbor, J. M. (2019). Evaluation of the effectiveness of green infrastructure on hydrology and water quality in a combined sewer overflow community. *Science of the Total Environment*, *665*, 69–79. doi: 10.1016/j.scitotenv.2019.01.416

Cole, S., & Waller, D. (2015). NASA releases detailed global climate change projections. *Nasa*.

Community Development Department, C. (2019). *CCPR Alewife - Appendix B - GI analysis and UHI modeling - Cambridge Massachusetts*.

Douglas, I. (2012). Urban ecology and urban ecosystems: Understanding the links to human health and well-being. *Current Opinion in Environmental Sustainability*. doi: 10.1016/j.cosust.2012.07.005

Elmqvist, T., Setälä, H., Handel, S. N., van der Ploeg, S., Aronson, J., Blignaut, J. N., … de Groot, R. (2015). Benefits of restoring ecosystem services in urban areas. *Current Opinion in Environmental Sustainability*. doi: 10.1016/j.cosust.2015.05.001

EPA, U. (2017). Best Practices for Green Infrastructure O&M. Retrieved July 26, 2019, from: https://www.epa.gov/green-infrastructure/best-practices-green-infrastructure-om

Ernstson, H. (2013). The social production of ecosystem services: A framework for studying environmental justice and ecological complexity in urbanized landscapes. *Landscape and Urban Planning*, *109*(1), 7–17. doi: 10.1016/j.landurbplan.2012.10.005

Escobedo, F. J., Kroeger, T., & Wagner, J. E. (2011). Urban forests and pollution mitigation: Analyzing ecosystem services and disservices. *Environmental Pollution*. doi: 10.1016/j.envpol.2011.01.010

Escobedo, F. J., Wagner, J. E., Nowak, D. J., De la Maza, C. L., Rodriguez, M., & Crane, D. E. (2008). Analyzing the cost effectiveness of Santiago, Chile's policy of using urban forests to improve air quality. *Journal of Environmental Management*, *86*(1), 148–157. doi: 10.1016/j.jenvman.2006.11.029

Gallet, D. (2012). The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits. *Proceedings of the Water Environment Federation*, *2011*(17), 924–928. doi: 10.2175/193864711802639741

Gambino, R. (2003). Progetto e conservazione del paesaggio. *Ri-Vista - Ricerche Per La Progettazione Del Paesaggio*, *1*, 1–15. doi: 10.13128/RV-17542

Gasparrini, C. (2017). *Biennale dello Spazio Pubblico 2017 Workshop organizzato dall'INU Introduzione le IInfrastrutture verdi e blu nel progetto della città contemporanea*.

Gill, S. E., Handley, J. F., Ennos, A. R., & Pauleit, S. (2007). Adapting cities for climate change: The role of the green infrastructure. *Built Environment*, *33*(1), 115–133. doi: 10.2148/benv.33.1.115

Gómez-Baggethun, E., Gren, Å., Barton, D. N., Langemeyer, J., McPhearson, T., O'farrell, P., Kremer, P. (2013). Urban ecosystem services. In *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: A Global Assessment* (pp. 175–251). Cham, CH: Springer. doi: 10.1007/978-94-007-7088-1_11

Hedenås, H., Olsson, H., Jonasson, C., Bergstedt, J., Dahlberg, U., & Callaghan, T. V. (2011, September). Changes in tree growth, biomass and vegetation over a 13-year period in the Swedish sub-Arctic. *Ambio*. doi: 10.1007/s13280-011-0173-1

Hubacek, K., & Kronenberg, J. (2013). Synthesizing different perspectives on the value of urban ecosystem services. *Landscape and Urban Planning*, *109*(1), 1–6. doi: 10.1016/j.landurbplan.2012.10.010

Hudson County, N. J. (2014). *Low Impact Development/ Green Infrastructure / Best Management Practice For Sustainable Stormwater Management Hudson County Planning Board*.

IPCC. (2014). *Summary for Policymakers, In: Climate Change 2014, Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. doi: 10.1017/CBO9781107415324

Malcevschi, S., & Bisogni, G. L. (2016). Green Infrastructures and ecological reconstruction in urban and peri-urban areas. *TECHNE*, *11*, 33–39. doi: 10.13128/Techne-18398

Mesimäki, M., Hauru, K., & Lehvävirta, S. (2019). Do small green roofs have the possibility to offer recreational and experiential benefits in a dense urban area? A case study in Helsinki, Finland. *Urban Forestry and Urban Greening*, *40*, 114–124. doi: 10.1016/j.ufug.2018.10.005

Mirzaei, P. A., & Haghighat, F. (2010). Approaches to study Urban Heat Island - Abilities and limitations. *Building and Environment*. doi: 10.1016/j.buildenv.2010.04.001

MORPC, M. O. R. P. C. (2015). *Green Infrastructure Best Management Practices Bioswales Creek Restoration Green Roofs Open Space Permeable Pavements Planter Boxes Rain Gardens Retention Ponds Street Trees Underground Storage*.

Morris, D., & St. Martin, D. (2008). *Somerville, Massachusetts : a brief history*. History Press.

Pataki, D. E., Carreiro, M. M., Cherrier, J., Grulke, N. E., Jennings, V., Pincetl, S., … Zipperer, W. C. (2011). Coupling biogeochemical cycles in urban environments: Ecosystem services, green solutions, and misconceptions. In *Frontiers in Ecology and the Environment* (Vol. 9, pp. 27–36). doi: 10.1890/090220

Solecki, W., & Marcotullio, P. J. (2013). Climate change and urban biodiversity vulnerability. In *Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: A Global Assessment* (pp. 485–504). doi: 10.1007/978-94-007-7088-1_25

Somerville, C. (2012). *SomerVision Plan*. Sullivan, W. C., & Kuo, F. E. (1996). *Do trees strengthen urban communities, reduce domestic violence? / written by W.C. Sullivan & F.E. Kuo*. Evanston Ill.: Northeastern Area State and Private Forestry Urban Forestry Center for the Midwestern States.

Takano, T., Nakamura, K., & Watanabe, M. (2002). Urban residential environments and senior citizens' longevity in megacity areas: The importance of walkable green spaces. *Journal of Epidemiology and Community Health*, *56*(12), 913–918. doi: 10.1136/jech.56.12.913

Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science*, *224*(4647), 420–421. doi: 10.1126/science.6143402

United States Environmental Protection Agency - Clean Water State Revolving Fund. (2015). Financing Green Infrastructure: A Best Practices Guide for the Clean Water State

US EPA. (2014). The Economic Benefits of Green Infrastructure A Case Study of Lancaster, PA About the Green Infrastructure Technical Assistance Program. Retrieved from: http://water.epa.gov/infrastructure/greeninfrastructure/gi_support.cfm.