Environmental Management (2021) 68:566–579
https://doi.org/10.1007/s00267-021-01515-5

Resident Knowledge of and Engagement with Green Infrastructure in Toronto and Philadelphia

Tenley M. Conway[1] · Camilo Ordóñez[1] · Lara A. Roman[2] · Annie Yuan[1] · Hamil Pearsall[3] · Megan Heckert[4] · Stephen Dickinson[3] · Christina Rosan[3]

Received: 2 June 2021 / Accepted: 26 July 2021 / Published online: 12 August 2021

Abstract

Green infrastructure (GI) initiatives, including programs to plant trees and install bioswales, have been adopted by a growing number of local government and non-governmental organizations. While the details of these programs vary, a common characteristic of most Canadian and US GI initiatives is a distributed approach that includes both public and private land. To date, little research has explored residents' knowledge of GI or their engagement with related initiatives even though residents' installation of GI is often key to creating distributed GI networks. In this study, we (1) assess residents' knowledge of the term GI, (2) identify residents' level of engagement with GI initiatives, and (3) examine whether factors like level of concern about local environmental issues can predict GI knowledge or level of engagement with GI initiatives. We explored these objectives through a survey of residents in Toronto (Ontario, Canada) and Philadelphia (Pennsylvania, US). We found that about a quarter of survey respondents in both cities had previously heard the term "green infrastructure". Neither knowledge of GI nor level of engagement with GI initiatives could be predicted by the level of concern about local environmental issues, but residents' interest in using their outdoor space for nature activities (e.g., gardening) predicted GI knowledge in both cities and level of initiative engagement in Philadelphia. Our results suggest the need for widespread education campaigns that clearly define GI so that residents can be participants in policy discussions, link it with their needs, and identify ways to manage GI to create desired benefits.

Keywords Green stormwater infrastructure · Urban forests · Municipal policy · Residential landscapes

Introduction

There are a growing number of initiatives emphasizing the use of green infrastructure (GI) to address a variety of environmental challenges facing urban areas, including programs led by governments, non-governmental organizations (NGOs), and communities. There is, however, considerable variation in how GI is defined (Hansen et al. 2021; Mell and Clements 2019), due to the multiple disciplinary origins of the term (Matsler et al. 2021), which resulted in definitions that differ in focus and scale (Mell 2016). In Canada, GI is often defined as vegetation or vegetated spaces that provide multiple ecosystem services (Conway et al. 2020). In the United States (US), GI is primarily framed as a solution to stormwater management that emphasizes on-site storage and infiltration, increasingly referred to as green stormwater infrastructure (McPhillips and Matsler 2018), albeit with expectations for environmental, social and economic co-benefits (Spahr 2020). GI can also be understood as a communication metaphor: a simple term that captures complex relationships between natural processes and human benefits, used to communicate with non-experts (Escobedo et al. 2019; Keeley et al. 2013).

Supplementary information The online version contains supplementary material available at https://doi.org/10.1007/s00267-021-01515-5.

✉ Tenley M. Conway
tenley.conway@utoronto.ca

[1] Department of Geography, Geomatics and Environment, University of Toronto at Mississauga, Mississauga, ON, Canada

[2] USDA Forest Service, Northern Research Station, Philadelphia Field Station, Philadelphia, PA, USA

[3] Department of Geography and Urban Studies, Temple University, Philadelphia, PA, USA

[4] Department of Geography and Planning, West Chester University, West Chester, PA, USA

A common characteristic of most Canadian and US GI initiatives is a decentralized or distributed approach that combines direct government-led installation of GI with incentives for private property owners to install GI on their own or with assistance (Keeley et al. 2013; Lieberherr and Green 2018). This, in addition to the extent of private land in most cities, means GI initiatives are often dependent on engagement by many actors (Heckert and Rosan 2016), including residents who can install and maintain GI on their property (Drescher and Sinasac 2021; Lieberherr and Green 2018; Nguyen et al. 2017). While individual GI features on residential land (e.g., trees, rain gardens, and rain barrels) are relatively small, these initiatives rely on residential adoption across a city, creating a network of GI (Drescher and Sinasac 2021; Meerow et al. 2020). A critical challenge for management and research is understanding how to develop a distributed system that has public and private components.

Most research to date has focused on the installation, function, and governance of GI in public spaces (Byrne et al. 2015), with limited attention given to the role that private property and residents play (Mason et al. 2019). Recent research has highlighted the small-scale GI features appropriate for residential yards, including trees, rain gardens, and rain barrels (Larson et al. 2015). However, there is a need for further examination of residents as potential managers of GI, including their knowledge about the concept and local GI initiatives, to better understand the potential for widespread adoption of GI and identify barriers to reaching all residents.

Although knowledge of GI is likely not enough to ensure that residents will install GI, studies examining pro-environmental behavior suggest that it is a necessary precondition for such behavior (Kollmuss and Agyeman 2002). Discerning whether residents are aware of the term, and how they define it, will help evaluate whether GI is an effective communication term to encourage installation of GI on residential property. On the other hand, residents may have limited knowledge about the term, but still be knowledgeable about and participate in GI initiatives. For instance, residents may have participated in tree planting, but not considered trees as GI. Thus, a better understanding of residents' engagement with GI initiatives is also needed if urban greening professionals want to scale up existing programs to reach all communities.

Most studies that include residents narrowly focus on one type of GI (e.g., trees or bioswales) and do not explicitly investigate residents' recognition of such features as GI (van Vliet and Hammond 2021). The few studies that have explored residents' knowledge of the term indicate limited knowledge or interpretation of GI as eco-friendly buildings or transportation (DEFRA 2007; Mason et al. 2019), representing a misalignment between residents' understanding and meanings established among professionals and academics. Lack of public knowledge and community engagement are also identified by decision-makers as common barriers to the successful implementation of GI initiatives (Deely et al. 2020; Dhakal and Chevalier 2017; Mathews et al. 2015). If residents do not understand the concept of GI or recognize the benefits GI can produce, they may be less likely to install and maintain GI, given the costs associated with those activities, or to demand or support public policies that support GI distribution.

We investigate residents' knowledge of GI and engagement with GI initiatives focused on private residential property in Toronto (Canada) and Philadelphia (US). The study objectives are (1) assess knowledge of the term and, if familiar, determine how residents define it; (2) identify residents' engagement level with GI initiatives in each city; and (3) examine whether the level of concern about local environmental issues, attitudes toward outdoor space on their property, gardening knowledge and activity level, or demographic measures can predict knowledge of GI and engagement with GI initiatives. We chose Toronto and Philadelphia as case-study cities because both have been identified as GI leaders in their country, with government initiatives to increase GI features on private residential land (often in conjunction with NGOs), as well as active NGO and community-led GI initiatives focused on resident education and engagement. At the same time, the cities have different social and economic characteristics.

Knowledge of GI and Related Initiatives

In general, the public's knowledge of an issue and strategies to address it are relevant in predicting individual behaviors (Casaló et al. 2019; Frick et al. 2004), and are also positively associated with the success of policy implementation (Anderson 2014; Milfont, 2012). A direct causal relationship between knowledge and behavior, often referred to as the knowledge-deficit model (Burgess et al. 1998; Petts and Brooks 2006), has mixed empirical support in studies examining climate change, recycling, and other environmental issues, such that increasing knowledge of an issue does not necessarily change-related behavior (Kollmuss and Agyeman 2002). Instead, knowledge is thought to be one of several factors (e.g., ability to take action, external incentives) that shape behavior, often indirectly by influencing attitudes that, in turn, affect behavior (Casaló et al. 2019; Robelia and Murphy, 2012). Thus, knowledge is recognized as necessary, but not sufficient on its own to trigger pro-environmental behavior, while lack of knowledge or inaccurate knowledge is a barrier to such behavior (Kollmuss and Agyeman 2002).

Research examining specific GI features supports the idea that knowledge is related to attitudes. For example, in Portland, Oregon (US), low knowledge levels about local bioswales' existence and function were associated with less positive attitudes toward these features (Everett et al. 2018). In Rotterdam (Netherlands), when residents were provided information about the climate-change adaptation contribution of specific GI features, they became more supportive of such installations (Derzken et al. 2017). Knowledge about rain barrels and other GI features has also been associated with indicated willingness to install and actual adoption of these features by residents (Baptiste et al. 2015; Gao et al. 2016).

Two types of knowledge have been examined in relation to pro environmental behaviors. The first is objective knowledge, sometimes referred to as factual knowledge, which reflects what facts people know (Casaló et al. 2019). This is frequently assessed by asking people to identify true and false statements about an issue (Glick et al. 2019; St-Laurent et al. 2019). The second is subjective knowledge, which reflects what people perceive they know or self-assessed knowledge level (Casaló et al. 2019). Although people tend to report they have greater knowledge levels than objective knowledge measures indicate, subjective knowledge about a specific environmental issue is often a better predictor of behavior related to that issue (Casaló et al. 2019; Hubbard 2020).

Few studies have examined any aspect of residents' knowledge of GI (Venkataramanan et al. 2020), instead examining practitioner and policy-makers' knowledge. Among these groups, common findings include a belief that the public had limited knowledge of GI (Venkataramanan et al. 2020) and a need for more education to increase public knowledge (Dhakal and Chevalier 2017). One study that explicitly explored residents' knowledge of the term GI in Tennessee (US) found that 63% of the respondents reported no knowledge of the concept, although the majority were interested in learning more (Mason et al. 2019). Greater knowledge of the concept was associated with older respondents and those with higher education levels, along with experience with neighborhood flooding. Derkzen et al. (2017) found that residents of GI-rich neighborhoods were more likely to be aware of the stormwater benefits of GI, while they did not consider sociodemographic influences.

Numerous studies have examined residents' attitudes toward problems and solutions associated with GI (Keeley et al. 2013). In most cases, survey or interview questions have not included the term GI, but rather used close synonyms (e.g., stormwater Best Management Practices; Drescher and Sinasac 2021) or named specific types of GI (e.g., trees or rain gardens; Meerow et al. 2020). This may be because of the lack of clarity about what GI is (Sussams et al. 2015) and concern that study participants may not know the term, or simply reflects an interest in disentangling attitudes associated with specific GI features.

In addition to knowledge of the concept, residents' knowledge and participation in GI initiatives targeting residents are needed. If residents are unaware of such initiatives, then they would not be able to participate, which could preclude the installation and maintenance of GI on their property. We are not aware of any previous research that has considered whether residents have heard about the range of GI initiatives in their area. However, several studies have examined who participates in programs providing specific GI features (Gao et al. 2016; Locke and Grove 2016; Watkins et al. 2016). For tree planting initiatives, sociodemographic factors such as income and education are important predictors of program participation (Locke et al. 2015; Locke and Grove 2016; Watkins et al. 2016), while a study of rain-barrel adoption did not find any association with sociodemographic measures (e.g., Gao et al. 2016).

Improved understandings of residents' knowledge of GI as a concept and engagement with relevant GI initiatives will provide insight into the effectiveness of the term in resident directed communication and opportunities to increase participation in initiatives that support installation and maintenance of GI. We hypothesize that few residents will have even basic knowledge of the term, given the relatively recent (i.e., past 15 years) inclusion of GI in policy discourse and academic literature (Escobedo et al. 2019; Mason et al. 2019). Furthermore, we anticipate that knowledge of GI and greater engagement with GI initiatives will be associated with higher educational attainment, greater concern about local climate and biodiversity-related issues, and residents who want to use their outdoor space for nature-activity purposes (i.e., tending a garden, watching wildlife).

Methods

Study Areas

We conducted a residential survey in the cities of Toronto and Philadelphia to compare knowledge of GI and engagement with GI initiatives in two cities that are GI leaders in their respective countries. Toronto is located in southern Ontario (Canada). The city has a growing population, with 2,731,151 residents in 2016, and a population density of 4334 people/km^2 (Statistics Canada 2016). Of the 1.1 million dwelling units across the city, 44% are on-the-ground single-family homes, the target of this study, as they are most likely to have outdoor space where GI features can be installed. The average sales price of single-family homes in 2019 was 1,251,283 CAD (CMHC 2021). These homes represent a mix of pre-WWII semi-detached or fully

detached houses with limited outdoor space and neighborhoods with larger properties containing newer houses. Toronto has a very diverse population, with 52% identifying as a visible minority (i.e., non-white) and 51% born outside of Canada (Statistics Canada 2016).

Since 2013, the City of Toronto has explicitly referenced GI in a variety of policies and initiatives addressing urban forestry, stormwater management, and street and building design standards. Across the various city documents, GI is primarily defined as vegetation that provides a variety of ecosystem services (City of Toronto 2013), but also sometimes includes broader definitions that incorporate non-living stormwater features (e.g., permeable pavement) and "greening" of gray infrastructure (e.g., bike lanes) (Conway et al. 2020).

The City of Philadelphia is located in southeastern Pennsylvania (US). After decades of decline, the city's population has increased in recent years, with a 2019 population of 1,584,064 (US Census Bureau 2019a). The population density (4502 people/km^2;) is similar to Toronto. Of the almost 700,000 homes in the city, 65% are single-family. With an average sales price of 220,800 USD in 2018–2019 (U.S. Department of Housing and Urban Development 2019), single-family homes are worth significantly less than Toronto even when accounting for currency conversion. These houses are a mixture of pre-WWII rowhouses (i.e., a form of attached housing with narrow frontage), semi-attached twin houses with limited outdoor space in the mid-20th century neighborhoods, and fully detached houses in low-density neighborhoods. The city's residents identify nearly equally as White (41%) and Black (42%) (US Census Bureau 2019a). Fourteen percent of the population were born outside of the US and 12% of households speak Spanish at home, the most common language after English (US Census Bureau 2019b).

In contrast to Toronto, Philadelphia's GI initiatives are primarily focused on stormwater management. In 2009, the Mayor's Office of Sustainability produced *Greenworks Philadelphia*, which includes stormwater goals that forefront GI. That same year the Philadelphia Water Department (PWD) adopted *Green City, Clean Waters* as part of a 2007 EPA consent decree addressing water quality (Hopkins et al. 2018), with a focus on decreasing combined sewer overflows through GI. In these plans, GI includes permeable pavement, rain barrels, rain gardens, and other living and nonliving features that support on-site storage and infiltration of stormwater. Finally, through the 2013 *Parkland and Forest Management Framework*, GI is presented as practices and features, including parks, that contribute to quality of life, with an emphasis on stormwater management and water quality (Philadelphia Parks and Recreation 2013).

Survey Design

A mail-based survey focusing on GI knowledge and the outdoor space on residents' properties was sent to 2000 residents in both Toronto and Philadelphia (Appendix 1). Outdoor space was defined in the survey as: "the space around your home on your property- including your yard, porch, driveway, decks and patios, and the sidewalk in front of your house". The research protocol was approved by the authors' university ethics boards.

Potential participants were limited to residents of on-the-ground homes, which likely have outdoor space where GI could be located. Residents' names and addresses were obtained from a marketing company for Toronto and the PWD stormwater billing dataset for Philadelphia (City of Philadelphia 2018). The 2000 residents targeted in each city were identified through a spatially stratified random sampling approach, weighted by number of on-the-ground residential addresses per postal code/zip code. This sampling design was intended to capture the range of socio-demographic, built, and environmental conditions across both cities. In Philadelphia, the survey materials included an option to request a survey in Spanish. Only one participant requested and completed a Spanish-language version, suggesting that Spanish language households may be under-represented.

We sought to examine residents' self-assessed knowledge of GI through one set of survey questions focused on whether they had previously heard the term "green infrastructure" and, if they had, respondents were asked to identify sources where they had encountered the term and to provide their definition of it. To understand engagement with local GI initiatives, the survey included a list of GI initiatives and related organizations specific to their city (hereafter referred to as initiatives; Table 1) and asked respondents to identify if they had heard of and/or participated in each initiative. The list of initiatives was based on the authors' knowledge of local programs in each city and discussions with local urban greening professionals. We chose to incorporate multiple initiatives in this study to examine the breadth of different ways residents can engage with GI-related initiatives, rather than focus on one type of program. Thus, each city's list is varied in terms of the types, specific goals, and details of the initiatives, but all are opportunities for residents to learn about, engage with, and/or install GI.

Another set of questions, using a 5-point Likert-based agreement scale, assessed respondents' level of concern for environmental issues that GI is meant to address (i.e., heat, drought, and flooding impacts, and biodiversity decline; Table 2). The 14 statements were based on the literature and municipal GI policies in the US and Canada, stated in relation to how the issue might impact the resident or their property. Example statements include "Flooding in my yard or other outdoor spaces on my property during a storm" and "Hot summer temperatures that will stress or kill my lawn

Table 1 Green infrastructure initiatives included in the survey for Toronto and Philadelphia

Toronto			Philadelphia		
Initiative	Heard of but not Participated (% Yes)	Participated (% Yes)	Initiative	Heard of but not Participated (% Yes)	Participated (% Yes)
RAIN Community Solutions	5	<1	PWD Rain Check (aka Rain Barrel Program)	31	7
Depave Paradise	4	0	TreePhilly Yard Tree Giveaway Program	41	12
Local Enhancement and Appreciation of Forests (LEAF)	18	2	Tree Tenders	20	2
Evergreen Brickworks	36	19	Garden Tenders	13	1
Toronto Parks and Trees Foundation	30	4	City Harvest	24	6
Sustainable Neighborhood Action Program (SNAP)	11	1	Philadelphia Flower Show	35	61
Bowery Project	4	<1	University Green City	30	3
Treemobile	4	<1	Philly Tree People	18	4
City of Toronto Free Street Tree Program	35	10	Philadelphia Orchard Project	18	2
City of Toronto Eco-Roof Incentive Program	18	<1	Tookany-Tacony/Frankford Watershed Partnership	21	2
A ‘friends of’ the park group	24	5	Local Arboretum	39	24
A neighborhood greening group	12	1	A “Friends of” Park Group	27	17
A residents or neighborhood association	38	20	A residents or neighborhood association	38	28

Table 2 Survey measures (see details in Appendix 1)

Name	Description	Measure
GI Knowledge	Self-Assessed prior knowledge of the term GI.	Yes/No
GI Initiative	Level of engagement with 13 GI initiatives and programs active at the time of the survey in Toronto and Philadelphia (see Table 1 for the list of initiatives).	1–3 level of knowledge and participation
Env Concern	Level of concern for environmental issues from a list of 14 environmental and ecological changes occurring in the next year, including flooding, extreme heat, and biodiversity reduction.	1–5 level of concern
Gardening Knowledge	Level of self-assessed knowledge about gardening and backyard and outdoor space maintenance.	1–5 level of knowledge
Outdoor Use	Level of agreement with 11 items describing outdoor space uses, including active and passive activities, such as playing or reading, socializing, seeing wildlife, etc.	1–5 level of agreement
Plant	Experience planting vegetation in their outdoor space.	Yes/No
Self-Maintain	Level of self-maintenance in outdoor space, multiple selection of 4 activities in outdoor space that are self-maintained.	Yes/No

and other yard vegetation." The survey also asked about the level of agreement with 11 statements related to interest in use of their outdoor space (e.g., eating meals, gardening). These statements were derived from Clayton (2007) and Blaine et al. (2012), to capture attitudes related to outdoor space that may influence knowledge of GI.

We asked respondents to rate their level of knowledge about gardening and indicate who maintains their outdoor space to reflect the level of experience with yard work. Finally, the survey included basic questions about socio-demographics. For household income, we used five categories corresponding to each city's income quintiles based on the most recently available census data. For racial or ethnic group(s) identity, we included the most common groups identified for each city, plus an "other" option.

The survey was disseminated in Toronto between May and July 2018 and in Philadelphia between September and October of that same year, using a multicontact approach to increase response rates (Dillman et al. 2014). All potential participants were first sent an invitation postcard, alerting them that they would shortly receive the survey in the mail with the option to complete it online. A week later, a survey packet was sent, which included an informed consent letter, a copy of the survey, and a stamped, addressed envelope to return the survey. Two weeks later, a reminder postcard was mailed, followed by a second survey packet in another two weeks, if needed.

Qualitative Analysis of Green Infrastructure Definitions

When respondents indicated that they had previously heard the term GI, they were asked to provide their definition through an open-ended question. We used a descriptive coding approach with a priori categories to classify the definitions provided (Table 3), with multiple codes potentially assigned to respondents' definitions. The categories reflect the three broad definitions of GI that appear in the literature and most commonly in GI policy in the Canada and US (Conway et al. 2020). Three additional categories were also used in the coding: vague, for unclear or very general definitions; other, for definitions that did not fit into one of the other categories; none, when the respondents marked that they had previously heard the term but did not provide a written definition.

Quantitative Analysis of Knowledge with GI and Engagement with GI Initiatives

We also analyzed the data with the aim of quantitatively testing relationships between the level of environmental concern, desired outdoor space use, gardening knowledge, level of self-maintenance of outdoor space, socio-demographics, and two response variables: *GI Knowledge* and *GI Initiatives*. *GI Knowledge* was defined as the self-assessed knowledge of GI (had heard of GI before or not). *GI Initiatives* reflects an index of engagement with the initiatives associated with each city. For each initiative, a value of 1 was assigned if the respondent had not heard of the initiative, a value of 2 was given if they had heard of but not participated in the initiative, and a value of 3 was assigned if the respondents had participated in the initiative. The values for all initiatives were summed to create the index. To address skewness, we standardized the index by applying the formula:

$$\frac{X - X^{min}}{X^{max} - X^{min}} \quad (1)$$

Table 3 Response and possible explanatory variables

Variables	Toronto					Philadelphia				
	Observations	Mean	Standard Error	Min	Max	Observations	Mean	Standard Error	Min	Max
Response variables										
GI Knowledge	585	0.26	0.02	0	1	135	0.24	0.04	0	1
GI Initiative (standardized index)[a]	585	0.42	0.00	0.0	0.8	135	0.49	0.01	0.0	0.8
Demographic variables										
Homeowners (yes)	550	0.91	0.01	0	1	135	0.86	0.03	0	1
Years in location	585	25.87	0.61	0.5	70	135	22.59	1.29	0.5	72
Age	557	63.76	0.55	21	94	135	57.24	1.18	29	86
Gender (female)	553	0.34	0.02	0	1	127	0.56	0.04	0	1
University degree (yes)	558	0.60	0.02	0	1	102	0.53	0.04	0	1
Born in country (yes)	567	0.54	0.02	0	1	130	0.84	0.03	0	1
Years in country (if not born in country)	567	42.08	0.67	3	86	130	30.38	1.24	10	60
Ethnicity white Caucasian (yes)[b]	535	0.73	0.02	0	1	133	0.51	0.04	0	1
Income in 4th or 5th quintile (yes)[c]	481	0.50	0.02	0	1	115	0.46	0.04	0	1
Children in household (yes)	567	0.18	0.02	0	1	130	0.23	0.04	0	1
Scales and components[d]										
Env Concern, Component 1—Flooding	585	2.93	0.05	1.0	5.0	135	2.78	0.10	1.0	5.0
Env Concern, Component 2—Heat / Drought	585	2.31	0.04	1.0	5.0	135	2.44	0.09	1.0	5.0
Env Concern, Component 3—Broad Environment	585	2.13	0.04	1.0	5.0	135	2.13	0.01	1.0	5.0
Garden Knowledge	575	3.22	0.04	1.0	5.0	126	2.81	0.11	1.0	5.0
Outdoor Use, Component 1—HomeExtension	585	4.40	0.03	1.0	5.0	135	4.03	0.10	1.0	5.0
Outdoor Use, Component 2—Utilitarian	585	3.82	0.03	1.0	5.0	135	3.42	0.12	1.0	5.0
Outdoor Use, Component 3—Nature	585	3.95	0.10	1.0	5.0	135	3.41	0.11	1.0	5.0
Plant	585	0.16	0.02	0	1	135	0.15	0.03	0	1
Self Maintain (standardized index)	530	0.75	0.01	0.0	1.0	104	0.57	0.03	0.0	1.0

[a]The unstandardized averages for this variable, based on the sum of raw scores, were as follows (these are also reported in the text): *Toronto:* $N = 585$, Mean = 16.28, SE = 0.15, Max = 32.0, Min = 0.0; *Philadelphia:* $N = 135$, Mean = 19.19, SD = 0.480, Max = 32.0, Min = 0.0. For context, the expected Max and Min for these scores (number of items X maximum/minimum score) were (13 X 3) 392 and (13 X 1) 13, respectively

[b]Respondents could select more than 1 ethnicity

[c]For Toronto respondents, the fourth quintile was 75,000 CAD/year; For Philadelphia respondents, the fourth quintile was 50,000 USD/year

[d]These are defined in Table 2. See explanation for data processing in methods, main text. For explanations of the components of Env Concern and Outdoor Use, see results section

where X is the response item (1–3), X^{min} is the minimum value in the range of responses, and X^{max} is the maximum value in the range of responses.

Potential explanatory variables were prepared from the survey responses in accordance with data preparation procedures that aim to simplify measures and avoid over prediction (Table 4). This included extracting dimensions from the multidimensional rating question level of local environmental concern (*Env Concern*) and desired uses of outdoor space on their property (*Outdoor Use*), using principal component analyses (PCA) with a varimax rotation (Thurstone 1947; Kaiser 1974) based on the "princomp" function in R (v. 4.0.2). We separately analyzed both city datasets, first using the Toronto dataset to extract the dimensions as it represented the largest pool of data, and then confirming the results by doing the same analyses with the Philadelphia data (see details in Appendix 2). We used the average scores of the items that loaded onto a factor or component to create separate-scale dimensions. All these dimensions were used in the analyses as separate variables. The reliability of each factor was calculated using Cronbach's alpha through the "alpha" function in the "psych" package of R (v. 4.0.2).

Self-assessed gardening knowledge (*Garden Knowledge*), prior experience planting in one's outdoor space (*Plant*), and an index of involvement in outdoor space maintenance (*Self Maintain*) were also examined.

Table 4 Classification of GI definitions provided by respondents, by percent of respondents who had previously heard the term

Code	Definition	Toronto (%)	Philadelphia (%)
Living GI	Vegetation or green space that provides ecosystem services or benefits to humans.	71	52
Green Stormwater Infrastructure	Living or non-living features that are associated with infiltration or storage of stormwater management.	30	32
'Green' Gray Infrastructure	Techniques and technologies that address energy efficiency, drinking or waste water system, and transportation systems.	17	6
Vague		9	16
Other		9	10
No Definition Given		2	30

Demographic variables with categorical and ordinal measures were collapsed into single numeric binomial 1/0 scales based on natural breaks in the dataset, as well as the overall demographic profile of the sample (Table 4).

The datasets from each city were analyzed separately. First, we performed normality tests (Kolmogorov–Smirnov, Shapiro–Wilk) to ensure further test adequacy (i.e., parametric vs. non parametric tests). We then performed analysis of proportions (Pearson's X^2 tests) for *GI Knowledge* and means analysis (Welch Two-Sample *t*-test; Mann–Whitney test) for *GI Initiatives* to understand differences in responses among all the binary demographic variables. Second, we used standard multiple regressions (ordinary least squares) to test the associations of interest, with logistic regressions used for the *GI Knowledge* binary response variable. We used the "lm" and "step" functions in R (v. 4.0.2) in the "backward" mode to undertake a stepwise regression to test these relationships. The technique allowed us to improve the models by discarding determinant variables that did not significantly contribute to the models in an iterative manner (Hair et al. 2014). All models were adjusted for demographic variables and none of these variables were removed during the stepwise regression process to keep all the models consistent with each other (Hair et al. 2014).

Results

Survey Response Rate and Overview of Participants

In Toronto, of the 2000 surveys mailed, 91 were not successfully delivered, and 585 were returned with most questions completed. This results in an overall response rate of 31%. The survey sample profile is mostly white (74%), older (65 mean age), male (62%), well-educated (59% university degree), and composed of residents who own their home (91%) (Table 4). Most of the respondents who were born outside Canada (43%) were not recent immigrants (42 median years in country). The income distribution is skewed slightly higher than for the city as a whole, with 50% of Toronto respondents having a household income in the top two quintiles.

In Philadelphia, 146 surveys out of the 2000 mailed were not successfully delivered. A total of 134 completed surveys were returned, resulting in an overall response rate of 7%. This is lower than we would expect given the dissemination approach, and well below the Toronto response rate. However, a similarly disseminated survey of a random sample of city residents conducted by Temple University in partnership with the city also had a low response rate (City of Philadelphia 2017), suggesting that a lower response may not be unusual for Philadelphia. Furthermore, unfortunate timing may have lowered the response rate, with public schools unexpectedly closing for several days due to a heat wave around the time that our first mailing was sent. Philadelphia respondents were mostly identified as white (56%), female (56%), and had a mean age of 57 (Table 4). There is a mix of educational attainment, with just under half of respondents holding a bachelor's degree. Eighty-six percent were homeowners. Like Toronto, the income distribution is skewed slightly higher than Philadelphia as a whole, with 46% in the top two quintiles.

While the survey participants in Toronto and Philadelphia are generally more likely to identify as white, be older and have a higher income than the population of the two cities as a whole, we are unable to assess if they are more representative of residents in single-family homes, as disaggregated demographic data do not exist for this population.

Dimensions of Environmental Concern and Outdoor Use

The PCA of both the *Env Concern* and the *Outdoor Use* variables yielded a three-component solution that explained 71.4% and 64.1% of the total variance, respectively (see details in Appendix 2). The relatively large number of components in this study suggests that there were separate views about the level of concerns for issues that GI is meant

Table 5 Where respondents have encountered the term 'green infrastructure', as a percent of participants who had previously heard the term

	Toronto (%)	Philadelphia (%)
Online or print media	71	64
An environmental organization	37	48
City or other government source(s)	43	36
Television or radio	50	27
Friends, family	17	24
Neighbors	4	12
Other	15	3

to address and respondent's interest in use of their outdoor space. Specifically, issues related to flooding, heat or drought, and broader environmental concerns fall on different components (Table 4). For interest in use of outdoor space, there are separate components for passive recreational activities that could also be also carried out inside the house, such as reading and socializing (i.e., extension of home), practical activities, such as having a place for pets (i.e., utilitarian), and nature-related activities, such as for gardening (i.e., nature activity).

GI Knowledge and Definitions

We found limited basic knowledge of GI in both cities, with only 26% of Toronto survey respondents and 27% in Philadelphia indicating that they had heard the term before. Online or print media sources were the most common ways to encounter the term in both cities (Table 5). Governmental and environmental organizations, the groups typically leading GI initiatives, are the next most common sources, while few participants had heard the term through informal social channels (e.g., friends).

In Toronto, 71% of the respondents who had previously heard the term defined GI in a way that was coded as a living GI definition (Table 3). Far-fewer respondents provided a definition aligned with stormwater or "greening" gray infrastructure conceptualizations, although some definitions were coded as both living GI and stormwater GI. A living GI definition was provided by a slight majority of Philadelphia respondents (52%), followed by definitions coded as stormwater GI (32%). In Philadelphia, definitions were more likely to be coded as both living GI and stormwater GI than in Toronto, while far fewer Philadelphia respondents described "greening" gray infrastructure. In both cities, all vague definitions referred to the environment or sustainability in nonspecific ways. For example, one respondent wrote "good for the environment" and another wrote "infrastructure with sustainability as a priority". In Philadelphia, a much a larger percentage of respondents who indicated they had previously heard the term did not provide a definition (30%).

Based on our regression analysis, no sociodemographic variables could predict *GI Knowledge* in Toronto. In contrast, we determined that university degree was a strong (coefficient > 0.5) predictor of *GI Knowledge* in Philadelphia, but this was the only sociodemographic predictor in that city (Table 6). The level of concern people had for environmental issues could not predict *GI Knowledge* in either city (Table 7). However, the nature activity dimension of outdoor use (Table 7) and experience planting vegetation were important predictors of *GI Knowledge* in Toronto, but only the nature activity dimension of outdoor use was a predictor in Philadelphia, controlling for demographic variables (basic proportional and mean patterns are included in Appendix 3).

Engagement with GI Initiatives

The mean value for the unstandardized *GI Initiatives* index was 16.28 ± 0.15 in Toronto, and 19.19 ± 0.48 in Philadelphia, out of an empirical maximum possible score of 39. The relatively low values reflect the fact that respondents had not participated or even heard of most initiatives (Table 1). Overall, Toronto had fewer respondents who had heard of the individual initiatives as compared with Philadelphia, although both survey groups have very low levels of participation for the majority of initiatives.

In addition, based on our regression analyses, we determined that university degree, born in country (Canada), and having been in the country for more than 20 years if not born in country (>20 years in country) were weak (coefficient < 0.5) but significant predictors of *GI Initiatives* in Toronto (Table 6), but only the last two variables (i.e., born in country and >20 years in country) were predictors in Philadelphia (Table 6). Like *GI Knowledge*, the level of concern people had for environmental issues could not predict *GI Initiatives* (Table 8). Meanwhile, experience-planting vegetation and gardening knowledge were weak (coefficient < 0.5) but significant predictors of *GI Initiatives* in Toronto (Table 8). Similarly, experience planting vegetation was a weak (coefficient < 0.5) but significant predictor of *GI Initiatives* in Philadelphia, as was the nature activity dimension of outdoor use, controlling for demographic variables (Table 8) (basic proportional and mean patterns are included in Appendix 3).

Discussion

Most survey participants in Toronto and Philadelphia had neither previously heard of GI nor the majority of the initiatives in their respective city. These findings align with

Table 6 Association between all demographic variables and response variables (*GI Knowledge* and *GI Initiative*) using survey data collected in Toronto and Philadelphia

Variable	Toronto		Philadelphia	
	Coefficient (Standard Error)		Coefficient (Standard Error)	
	GI knowledge[a]	GI initiative	GI knowledge[a]	GI initiative
University degree	0.22 (0.22)	0.016 (0.008)*	1.33 (0.54)*	0.025 (0.026)
Born in country	0.51 (0.39)	0.047 (0.015)**	0.44 (1.18)	0.23 (0.05)***
>20 years in country	0.15 (0.39)	0.030 (0.014)*	0.59 (1.39)	0.19 (0.06)**

Model adjusted for homeowners, years in location, age, gender, white ethnicity, income in or above fourth quintile (75 K CAD in Toronto; 50 K USD in Philadelphia), and children in household (see Table 4); only unstandardized comparable regression coefficients included

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

[a]Binomial (logit) model

other studies that suggest residents have little to no knowledge about the concept and lack awareness about the initiatives focused on GI in public spaces (Everett et al. 2018; Mason et al. 2019). The similarly low GI knowledge-level between the two cities was somewhat surprising, given the different population characteristics and that the City of Philadelphia and its partner organizations have a longer history of using the term, and use a more consistent stormwater-focused definition.

The definitions provided by the respondents in Toronto reflect the variety of definitions that have been adopted across city policies, with a living GI definition most commonly appearing in policy discourse, but green stormwater infrastructure and "greening" gray infrastructure definitions also present in Toronto policy and programming (Conway et al. 2020). In Philadelphia, the varied definitions provided by survey respondents are at odds with the city and NGO partners' primary focus on green stormwater infrastructure, suggesting a communication gap. Moreover, the fact that a high percentage of respondents said they had previously heard the term but did not provide a definition or gave a vague definition, suggests a rather low working knowledge of the term among residents.

These findings indicate that GI is not an effective communication term for use with residents in these cities, in part due to its varied usage (Parker and Baro 2019; Sussams et al. 2015). Matsler et al. (2021) document the three different understandings of GI in their review of the academic and gray literatures: greenspace planning, urban ecology, and water/stormwater management. The first two categories capture ideas aligned with our living green infrastructure category, while their third is parallel to our green stormwater infrastructure definition. Interestingly, our "greening" gray infrastructure definition was not captured in their review, suggesting a further area of disconnect between some respondents and discourse among experts.

It is unclear if low knowledge levels reflect the absence of the term in communications directed toward residents, residents overlooking the term when they encounter it, or ignoring or not receiving the communications more generally. In any case, the prevalence of the term within urban environmental policy discourse raises concerns that most residents do not have the basic knowledge needed to contribute to such discussions or advocate for GI programs. Thus, not only does the term GI fall short of its potential to provide a forum for citizen engagement (Green et al. 2012), but over-reliance on the GI term as professional jargon creates a barrier to residents looking to shape policy addressing stormwater, climate change, and other local environmental issues. Increasing residents' knowledge of the concept is particularly challenging because of the many definitions in use by researchers and practitioners, and there is minimal interest in advancing a universally applied definition (Matsler et al. 2021). Thus, explicit communication about the definition and goals of GI being used in specific policy discussions or initiatives is needed to avoid excluding residents or facilitating misunderstandings (Matsler et al. 2021; da Silva and Wheeler 2017).

The low knowledge level of GI is not a concern in and of itself if residents are engaged with GI initiatives. However, our survey found that many respondents had never even heard of the initiatives. Given that greater knowledge of GI features is associated with more positive attitudes and associated actions (Baptiste et al. 2015; Derkzen et al. 2017; Everett et al. 2018), low levels of engagement with GI programs suggest that municipal governments and NGOs are missing opportunities to provide information about GI, including highlighting the ways GI can meet residents' needs, which may positively influence attitudes and associated behavior. Toronto and Philadelphia will struggle to meet the full potential of a city-wide network of GI without additional community-informed outreach and education campaigns.

In our study, self-assessed gardening knowledge and the desire to have private outdoor space for nature activities, such as watching wildlife and growing food, were related to knowledge of GI and engagement with GI initiatives. This suggests that residents may be receptive to initiatives that

Table 7 Results of the Binomial (logit) model for associations between selected survey variables and *GI Knowledge* for Toronto and Philadelphia

Variable	Toronto		Philadelphia	
	Coefficient (Standard Error)	95% Confidence Interval of coefficient	Coefficient (Standard Error)	95% Confidence Interval of coefficient
Outdoor Use, Component 3 – Nature	0.38 (0.73)**	[0.13, 0.63]	0.62 (0.23)**	[0.19, 1.11]
Plant	0.66 (0.25)**	[0.17, 1.14]	−0.34 (0.65)	[−1.69, 0.88]

Model adjusted for homeowners, years in location, age, gender, university degree, born in country, years in country, white ethnicity, income in or above fourth quintile (75 K CAD in Toronto; 50 K USD in Philadelphia), and children in household (see Table 4); only unstandardized comparable regression coefficients included

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

support existing interests and activities. Based on Mason et al. (2019), we anticipated that residents who expressed greater concern for environmental issues would be more familiar with GI or more engaged with GI initiatives, but this was not the case, indicating that GI may not be recognized as a solution to concerns about localized flooding, heat, and drought, or that residents may not view GI initiatives as providing property-level solutions that address their concerns.

Previous research has highlighted that residents may not understand their role in implementing stormwater GI, in particular, viewing it as a municipal responsibility (Keeley et al. 2013). Residents are, however, more motivated to install specific GI features when there is a recognized individual benefit (Brown et al. 2016; Gao et al. 2016). These findings suggest that outreach efforts should link environmental issues impacting specific residents and their properties or neighborhoods with GI initiatives that can provide solutions as a way to reach additional residents who are not interested in gardening. A survey in coastal South Carolina that began with a short video about the benefits of green stormwater infrastructure found that most residents expressed an interest in installing GI (Ureta et al. 2021), suggesting that targeted knowledge about GI benefits can support increased residential installations.

As expected, we found that university education was a predictor of *GI Knowledge* (in Toronto) and *GI Initiatives* (in Philadelphia), and residents who identify as white, were older, had obtained a higher-level of education and had a higher household income were associated with being familiar with GI and more engaged with initiatives. Few studies have previously examined GI knowledge in relation to individual demographics (Venkatarmanan et al. 2020), although Mason et al. (2019) also found a positive association between education and familiarity with GI. Other studies examining urban greening have found that racial/ethno-cultural identity, income and education are correlated with participation in tree-planting programs (Locke et al. 2015; Locke and Grove 2016; Watkins et al. 2016). These findings are similar to our results, particularly in Toronto, suggesting that there is a need for both wide-spread knowledge sharing about GI and related initiatives, but also efforts to ensure information and supports are reaching diverse communities.

Being born in the country, in this case Canada or the US, was a stronger predictor in both cities of *GI Knowledge* and *GI Initiative*. These findings may reflect language barriers, cultural preferences, or challenges accessing initiatives and information. Participants who have been in the country for more than 20 years were more similar in knowledge and engagement-level to those born in Canada/US, possibly reflecting increasing access

Table 8 Results of multilinear regression model for associations between selected survey variables and *GI Initiative* for Toronto and Philadelphia

Variable	Toronto		Philadelphia	
	Coefficient (Standard Error)	95% Confidence Interval of coefficient	Coefficient (Standard Error)	95% Confidence Interval of coefficient
Outdoor Use, Component 3 – Nature	0.005 (0.005)	[−0.004, 0.014]	0.029 (0.011)**	[0.007, 0.051]
Garden Knowledge	0.010 (0.004)**	[0.003, 0.017]	0.002 (0.10)	[−0.019, 0.022]
Plant	0.037 (0.009)***	[0.015, 0.052]	0.082 (0.031)**	[0.021, 0.14]

Model adjusted for homeowners, years in location, age, gender, university degree, born in country, years in country, white ethnicity, income in or above fourth quintile (75 K CAD in Toronto; 50 K USD in Philadelphia), and children in household (see Table 2); only unstandardized comparable regression coefficients included

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

to information and initiatives over time, or differences between recent and older immigrants' language, ethnocultural identities, immigration pathways, and cultural barriers that influence access to GI opportunities. While we did not assess the interaction between demographic identities (e.g., combined effect of being born in country and ethnicity), this is an important avenue for future investigation to untangle the role of demographics in GI knowledge and engagement.

This study is unique with the comparison of residents' knowledge and engagement with GI between two cities in different countries. Toronto and Philadelphia are located in countries with many broad social and political similarities, as well as have similar population density, prevalence of single-family neighborhoods, and recognition as GI leaders in their countries. At the same time, they differ in terms of housing costs, local histories, and governmental definitions of GI. Yet, the results were very similar between the cities, suggesting that low levels of GI knowledge exist in different contexts even when the city is relatively focused on GI. Additionally, some initiatives we included in the GI Initiative index are very similar (e.g., tree-planting programs in both cities), while others are quite different (e.g., the Philadelphia Flower Show, a major regional horticultural event; Toronto's Evergreen Brick Works, a large-scale community environmental center and demonstration hub for adaptive flood design), yet we also found comparably low levels of engagement. Collectively, these findings point to broader challenges of incorporating residents and their properties into city-wide efforts to create an equitably distributed network of GI.

While our results indicate limited knowledge of GI and engagement with GI initiatives among the survey respondents, these responses may not be representative of the cities. This is a particular concern for Philadelphia, with the very low response rate that may reflect a response bias. While we purposefully chose to examine knowledge of GI, the low knowledge-levels we document may not translate into limited knowledge about specific GI features and their potential benefits. Rather, we focus on the term to better understand whether it is effectively serving as a communication term with residents.

Conclusions

GI is prevalent in urban environmental discourse among policymakers and practitioners, yet few residents in the case-study cities are familiar with the term, and those that are familiar have varied understanding of its meaning. This is a significant challenge because residents are key GI actors, with GI on numerous private properties needed for successful creation of city-wide GI networks. The low knowledge level suggests that most residents do not have the basic knowledge needed to install and maintain GI explicitly with the purpose of supporting their city's GI goals nor participate in policy discussions. Moreover, our results highlight that residents are not aware of GI initiatives, and there is no relationship between the level of concerns for local environmental issues like heat waves or flooding and engagement with the GI initiatives intended to provide solutions to those concerns. The limited knowledge of GI and engagement with varied GI initiatives highlights the need for widespread-community-informed, -driven and -led education campaigns that clearly define GI, so residents can be participants in policy discussions, link it with their own concerns, and have the information needed to identify ways to manage GI to create benefits for themselves and their community.

Acknowledgements Funding was provided by a grant from the Social Sciences and Humanities Research Council (SSHRC) of Canada. The Pennsylvania Horticulture Society provided administrative support for the Philadelphia survey. Thank you to Janet McKay, Glen Abrams, Zachary Popkin, Erica Smith, Jeanne Waldowski, and Tiffany Ledesma for providing feedback on earlier versions of the survey. The findings and conclusions in this publication are those of the authors and should not be construed to represent any official USDA or US Government determination or policy.

Funding Funding was provided by a grant from the Social Sciences and Humanities Research Council (SSHRC) of Canada.

Compliance with Ethical Standards

Conflict of Interest The authors declare no competing interests.

Ethical Approval The ethics protocol guiding the survey used in this study was approved by the University of Toronto (No. 36051) and Temple University (No. 25155) Ethic Review Boards.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

References

Anderson, JE (2014) *Public Policymaking*, 8th Edition. Cengage Learning

Baptiste AK, Foley C, Smardon R (2015) Understanding urban neighborhood differences in willingness to implement green infrastructure measures: a case study of Syracuse, NY. Landsc Urban Plan 136:1–12. https://doi.org/10.1016/j.landurbplan.2014.11.012

Blaine TW, Clayton S, Robbins P, Grewal PS (2012) Homeowner attitudes and practice towards residential landscape management in Ohio, USA. Environ Manag 50:257–271. https://doi.org/10.1007/s00267-012-9874-x

Brown HL, Bos DG, Walsh CJ, Fletcher TD, RossRakesh S (2016) More than money: how multiple factors influence householder participation in at-source stormwater management. Journal of Environmental Planning and Management **59**(1):79–97. https://doi.org/10.1080/09640568.2014.984017

Burgess J, Harrison C, Filius P (1998) Environmental communication and the cultural politics of environmental citizenship. Environ Plan A 30:1445–1460. https://doi.org/10.1068/a301445

Byrne JA, Lob AY, Jianjun Y (2015) Residents' understanding of the role of green infrastructure for climate change adaptation in Hangzhou, China. Landsc Urban Plan 138:132–143. https://doi.org/10.1016/j.landurbplan.2015.02.013

Casaló LV, Escarioa J-J, Rodriguez-Sanchez C (2019) Analyzing differences between different types of pro-environmental behaviors: do attitude intensity and type of knowledge matter? Resour Conserv Recycling 149:56–64. https://doi.org/10.1016/j.resconrec.2019.05.024

City of Philadelphia (2018) PWD Stormwater Billing Parcels. https://www.opendataphilly.org/dataset/pwd-stormwater-billing-parcels. Accessed 10 Aug 2018

City of Toronto (2013) Sustaining and expanding the urban forest: toronto's strategic forest management plan. City of Toronto, Parks, Forestry, and Recreation, Urban Forestry, Toronto, Ontario

Clayton S (2007) Domesticated nature: Motivations for gardening and perceptions of environmental impact. J Environ Psychol 27:215–224. https://doi.org/10.1016/j.jenvp.2007.06.001

CMHC (2021) Toronto — Historical Average, Median and Price Percentiles for Absorbed Homeowner and Condominium Units https://www03.cmhc-schl.gc.ca/hmip-pimh/en/TableMapChart/Table?TableId=1.9.1.3&GeographyId=2270&GeographyTypeId=3&DisplayAs=Table&GeograghyName=Toronto Accessed 20 May 2021

Conway TM, Khan A, Esak N (2020) An analysis of green infrastructure in municipal policy: divergent meaning and terminology in the Greater Toronto Area. Land Use Policy 99:104864. https://doi.org/10.1016/j.landusepol.2020.104864

da Silva JMC, Wheeler E (2017) Ecosystems as infrastructure. Perspectives in Ecology and Conservation 15(1):32–35. https://doi.org/10.1016/j.pecon.2016.11.005

Deely J, Hynes S, Barquín J, Burgess D, Finne G, Silió A, Alevarez-Martínez JM, Bailly D, Ballé-Béganton J (2020) Barrier identification framework for the implementation of blue and green infrastructures. Land Use Policy 99:105108. https://doi.org/10.1016/j.landusepol.2020.105108

DEFRA (2007) Public understanding of the concepts and language around ecosystem services and the natural environment (DEFRA Project code: NR0115). http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=15310#RelatedDocuments2007. Accessed 04 May 2021

Derkzen ML, van Teeffelen AJA, Verburg PH (2017) Green infrastructure for urban climate adaptation: How do residents' views on climate impacts and green infrastructure shape adaptation preferences? Landsc Urban Plan 157:106–130. https://doi.org/10.1016/j.landurbplan.2016.05.027

Dhakal KP, Chevalier LR (2017) Managing urban stormwater for urban sustainability: barriers and policy solutions for green infrastructure application. J Environ Manag 203:171–181. https://doi.org/10.1016/j.jenvman.2017.07.065

Dillman DA, Smyth JD, Christian LM (2014) Internet, phone, mail, and mixed-mode surveys: the tailored design method, 4th Edition. Wiley, Hoboken, NJ

Drescher M, Sinasac S (2021) Social-psychological determinants of the implementation of green infrastructure for residential stormwater management. Environ Manag 67:308–322. https://doi.org/10.1007/s00267-020-01393-3

Escobedo FJ, Giannico V, Jim CY, Sanesi G, Lafortezza R (2019) Urban forests, ecosystem services, green infrastructure and nature-based solutions: Nexus or evolving metaphors? Urban Forestry Urban Green 37:3–12. https://doi.org/10.1016/j.ufug.2018.02.011

Everett G, Lamond JE, Morzillo AT, Matsler AM, Chan FKS (2018) Delivering Green Streets: An exploration of changing perceptions and behaviours over time around bioswales in Portland, Oregon. J Flood Rick Manag 11:S973–S985. https://doi.org/10.1111/jfr3.12225

Frick J, Florian Kaiser G, Wilson M (2004) Environmental knowledge and conservation behavior: exploring prevalence and structure in a representative sample. Personality and Individual Differences 37(8):1597–1613. https://doi.org/10.1016/j.paid.2004.02.015

Gao Y, Babin N, Turner AJ, Hoffa CR, Peel S, Prokopy LS (2016) Understanding urban-suburban adoption and maintenance of rain barrels. Landsc Urban Plan 153:99–110. https://doi.org/10.1016/j.landurbplan.2016.04.005

Glick DM, Goldfarb JL, Heiger-Bernays W, Kriner DL (2019) Public knowledge, contaminant concerns, and support for recycled Water in the United States. Resour, Conserv Recycling 150:104419. https://doi.org/10.1016/j.resconrec.2019.104419

Green OO, Shuster WD, Rhea LK, Garmestani AS, Thurston HW (2012) Identification and Induction of Human Social and Cultural Capitals through an Experimental Approach to Stormwater Management. Sustainability 4(8):1669–1682. https://doi.org/10.3390/su4081669

Hair JJ, Black WC, Babin BJ, Anderson RE (2014) Multivariate data analysis, 7th Ed. Pearson Education, Upper Saddle River, N.J

Hansen R, van Lierop M, Rolf, W, Gantar D, Erjavec IS, Rall, EL, Pauleit S (2021) Using green infrastructure to stimulate discourse with and for planning practice: experiences with fuzzy concepts from a pan-European, a national and a local perspective. Socio-Ecol Pract Res https://doi.org/10.1007/s42532-021-00087-2

Heckert M, Rosan CD (2016) Developing a green infrastructure equity index to promote equity planning. Urban Forestry Urban Green 19:263–270. https://doi.org/10.1016/j.ufug.2015.12.011

Hopkins KG, Grimm NB, York AM (2018) Influence of governance structure on green stormwater infrastructure investment. Environmental Science & Policy 84:124-133. https://doi.org/10.1016/j.envsci.2018.03.008

Hubbard ML (2020) The role of knowledge in water resource management: an assessment of the Oregon general public. The Social Science Journal 1–18. https://doi.org/10.1080/03623319.2020.1782635
Kaiser HF (1974) An index of factorial simplicity. Psychometrika 39 (1):31–36. https://doi.org/10.1007/BF02291575
Keeley M, Koburger A, Dolowitz DP, Medearis D, Nickel D, Shuster W (2013) Perspectives on the use of green infrastructure for stormwater management in Cleveland and Milwaukee. Environ Manag 51:1093–1108. https://doi.org/10.1007/s00267-013-0032-x
Kollmuss A, Agyeman J (2002) Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? Environ Educ Res 8(3):239–260. https://doi.org/10.1080/13504620220145401
Larson KL, Nelson KC, Samples SR, Hall SJ, Bettez N, Cavender-Bares J, Groffman PM, Grove JB, Heffernan SE, Hobbie J, Learned JL, Morse C, Neill LA, Ogden J, O'Neil-Dunne M, Pataki DE, Polsky C, Roy Chowdhury R, Steele M, Trammell TLE (2015) Ecosystem services in managing residential landscapes: priorities, value dimensions, and cross-regional patterns. Urban Ecosyst 19:95–113. https://doi.org/10.1007/s11252-015-0477-1
Lieberherr E, Green OO (2018) Infrastructure through citizen stormwater management: policy instruments, participation and engagement. Sustainability 10(6):2099. https://doi.org/10.3390/su10062099
Locke DH, Grove JM (2016) Doing the hard work where it's easiest? Examining the relationships between urban greening programs and social and ecological characteristics. Appl Spat Anal 9:77–96. https://doi.org/10.1007/s12061-014-9131-1
Locke DH, Roman LA, Murphy-Dunning C (2015) Why Opt-in to a planting program? long-term residents value street tree aesthetics. Arboriculture & Urban Forestry 41(6):324–333
Mason LR, Ellis KN, Hathaway JM (2019) Urban flooding, social equity, and "backyard" green infrastructure: an area for multidisciplinary practice. J Community Pract 27(3-4):334–350. https://doi.org/10.1080/10705422.2019.1655125
Matsler AM, Meerow S, Mell IC, Pavao-Zuckerman MA (2021) A 'green' chameleon: exploring the many disciplinary definitions, goals, and forms of "green infrastructure". Landsc Urban Plan 214:104145
Matthews T, Lo AY, Byrne JA (2015) Reconceptualizing green infrastructure for climate change adaptation: Barriers to adoption and drivers for uptake by spatial planners. Landsc Urban Plan 138:155–163. https://doi.org/10.1016/j.landurbplan.2015.02.010
McPhillips LE, Matsler AM (2018) Temporal evolution of green stormwater infrastrtcure strategies in three US cities. Front Built Environ 4:26. https://doi.org/10.3389/fbuil.2018.00026
Meerow S, Helmricj AM, Andreade R, Larson KL (2020) How do heat and flood risk drive residential green infrastructure implementation in Phoenix, Arizona? Urban Ecosyst. https://doi.org/10.1007/s11252-020-01088-x
Mell I (2016) Global green infrastructure: lessons for successful policy-making, investment and management. Routledge, Abingdon, UK
Mell I, Clement S (2019) Progressing green infrastructure planning: understanding its scalar, temporal, geo-spatial and disciplinary evolution. Impact Assess Proj Appraisal 38:449–463. https://doi.org/10.1080/14615517.2019.1617517
Milfont TL (2012) The interplay between knowledge, perceived efficacy, and concern about global warming and climate change: a one-year longitudinal study. Risk Anal 32(6):1003–1020. https://doi.org/10.1111/j.1539-6924.2012.01800.x
Nguyen VD, Roman LA, Locke DH, Mincey SK, Sanders JR, Fichman ES, Duran-Mitchell M, Tobing SL (2017) Branching out to residential lands: missions and strategies of five tree distribution programs in the U.S. Urban Forestry Urban Green 22:24–35. https://doi.org/10.1016/j.ufug.2017.01.007
Parker J, de Baro MEZ (2019) Green infrastructure in the urban environment: a systematic quantitative review. Sustainability 11 (11):3182. https://doi.org/10.3390/su11113182
Petts J, Brooks C (2006) Expert conceptualisations of the role of lay knowledge in environmental decisionmaking: challenges for deliberative democracy. Environ Plan A 38:1045–1059. https://doi.org/10.1068/a37373
Philadelphia Parks and Recreation (2013) Parkland and Forest Management Framework. City of Philadelphia. https://www.phila.gov/media/20171220162100/Parkland-Forest-Management.pdf Last Accessed 04 May 2021
Robelia B, Murphy T (2012) What do people know about key environmental issues? a review of environmental knowledge surveys. Environ Educ Res 18(3):299–321. https://doi.org/10.1080/13504622.2011.618288
Spahr K (2020) Contextualizing and communicating the ancillary benefits of green stormwater infrastructure. Colorado School of Mines, Golden, CO
St-Laurent GP, Hagerman S, Findlater KM, Kozak R (2019) Public trust and knowledge in the context of emerging climate-adaptive forestry policies. J Environ Manag 242(2019):474–486. https://doi.org/10.1016/j.jenvman.2019.04.065
Statistics Canada (2016) Census Profile, 2016 Census. Ontario and Canada [Country], Toronto, City [Census subdivision], https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/Page.cfm?Lang=E&Geo1=CSD&Code1=3520005&Geo2=PR&Data=Count&B1=All
Sussams LW, Sheate WR, Eales RP (2015) Green infrastructure as a climate change adaptation policy intervention: muddying the waters or clearing a path to a more secure future? J Environ Manag 147:184–193. https://doi.org/10.1016/j.jenvman.2014.09.003
Thurstone LL (1947) Multiple factor analysis. University of Chicago Press, Chicago, IL, USA
Ureta J, Motallebi M, Scaroni AE, Lovelace S, Ureta JC (2021) Understanding the public's behavior in adopting green stormwater infrastructure. Sustainable Cities and Society 69:102815–10. https://doi.org/10.1016/j.scs.2021.102815
US Census Bureau (2019a) QuickFacts. Philadelphia city, Pennsylvania. https://www.census.gov/quickfacts/philadelphiacitypennsylvania. Last Accessed 5 May 2021
US Census Bureau (2019b) American Community Survey. Table S1602. https://data.census.gov/cedsci/table?q=United%20States&t=Language%20Spoken%20at%20Home&g=0500000US42101&tid=ACSST1Y2019.S1602&hidePreview=true. Last Accessed 5 May 2021
U.S. Department of housing and urban development (2019) comprehensive housing market analysis: Philadelphia, Pennsylvania. https://www.huduser.gov/portal/publications/pdf/PhiladelphiaPA-CHMA-19.pdf Last Accessed 20 May 2021
van Vliet K, Hammond C (2021) Residents' perceptions of green infrastructure in the contemporary residential context: a study of Kingswood, Kingston-upon-Hull, England. J Environ Plan Manag 64(1):145–163. https://doi.org/10.1080/09640568.2020.1756757
Venkatarmanan V, Lopez D, McCuskey DJ, Kiefus D, McDonald RI, Miller WM, Packman AI, Young SL (2020) Knowledge, attitudes, intension, and behavior related to green infrastructure for flood management: a systematic literature review. Sci Total Environ 720:137606. https://doi.org/10.1016/j.scitotenv.2020.137606
Watkins SK, Mincey S, Vogt J, Sweeney SP (2016) Is planting equitable? An examination of the spatial distribution of nonprofit urban tree-planting programs by canopy cover, income, race, and ethnicity. Environ Behav https://doi.org/10.1177/0013916516636423