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Who participates in green infrastructure initiatives and why? Comparing participants and non-participants in Philadelphia's GI programs

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ABSTRACT

Green infrastructure (GI) refers to trees, rain gardens, rain barrels, and other features that address stormwater management, climate change and other challenges facing many cities. GI is often not equitably distributed across urban landscapes, making its benefits unevenly experienced. Cities have multiple initiatives focused on different types of GI in residential areas, including underserved neighborhoods, although there is potential for GI programs to serve more privileged neighborhoods. The goal of this study was to examine GI program participants and non-participants to better understand who participates in different types of residential GI programs and why. We surveyed residents who had previously participated in Philadelphia's GI programs as well as those who had not, comparing socio-demographics, knowledge-levels, environmental concerns, outdoor space preferences, motivations and barriers. We found that the GI program participants are on average younger, wealthier, more highly educated, and more likely to be White than our sample of residents who have not participated. Participants in tree programs have different socio-demographics and motivations as compared to those who installed green stormwater infrastructure. Future research should examine strategies to reach neighborhoods with different socioeconomic conditions and built environment characteristics, such as offering features appropriate for small properties with limited plantable space.

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Introduction

Green infrastructure (GI) is increasingly emphasized as a nature-based solution for stormwater management, climate change adaptation, and many other critical urban challenges (Matsler et al., 2021; Miller & Montalto, 2019). In the United States (US), GI includes trees and green stormwater infrastructure (GSI), which is vegetated and non-vegetated features (e.g. rain gardens, rain barrels) that contribute to stormwater management through onsite infiltration, evapotranspiration and storage (McPhillips & Matsler, 2018).

Cities often rely on residents to help expand GI, in part because of the extent of privately owned residential property in most urban areas. However, existing GI is often inequitably distributed across a city, with marginalized communities typically containing less GI (Hoover et al., 2021; Nesbitt et al., 2019; Schwarz et al., 2015). Recent research suggests that marginalized residents are also less likely to install new GI (Drescher & Sinasac, 2021; Meerow et al., 2021), which reinforces equity concerns given these residents are often more vulnerable to heat, flooding and other climate risks (Heckert & Rosan, 2016). Costs, lack of knowledge about GI, and renters'

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lack of authority to install GI are frequently cited reasons residents do not install it (Berry, 2018; Conway et al., 2021; Dhakal & Chevalier, 2017; Ureta et al., 2021).

Many city governments and non-profit organizations, often in partnership, have recently developed programs to encourage the installation of GI features on or around residential property, attempting to directly address cost and knowledge barriers. These programs typically provide trees or GSI at reduced or no cost to participating residents (Gao et al., 2016; Nguyen et al., 2017), and may involve training about GI benefits and stewardship for residents and community leaders (Roman et al., 2018).

When examining neighborhood-level characteristics associated with program participation, research suggests that GI programs may also exacerbate existing inequalities. Median household income at the census block level was significantly related to program-supported tree planting in several US cities (Watkins et al., 2016), and high participating neighborhoods often already have more tree canopy (Locke & Grove, 2016). In Chicago, Illinois, neighborhood-level income was positively correlated with participation in that city's rain barrel adoption program (Ando & Freitas, 2011), while in Indiana, very low-income households were the least likely to install a rain barrel through subsidized programs (Gao et al., 2016).

Education, racial identity, and housing tenure – which are often correlated with income – may also play a role in who participates in GI programs. For example, Spahr et al. (2021) found higher education to be positively correlated with support for installing more GSI in one's neighborhood in Philadelphia, Pennsylvania. In a comparison of several US programs, the percent of Black and/or Hispanic residents was negatively associated with tree planting program activity (Watkins et al., 2016). Finally, homeowners participate in GI programs at disproportionately high rates (Perkins et al., 2004), likely because they have the authority to install GI on their property while renters generally do not. Collectively, these findings suggest that residential GI programs are not reaching marginalized communities who are often most in need of GI expansion, although with a few exceptions (e.g. Gao et al., 2016), studies have primarily focused on neighborhood-level relationships based on aggregated socio-demographic profiles (e.g. US Census data).

Other studies have examined the role of cognitive factors like knowledge and environmental concerns related to GI, with inconsistent findings. For example, interest in GI may be related to exposure to information (Derkzen et al., 2017; Everett et al., 2018), although Ordóñez et al. (2021) did not find a relationship between knowledge of GI or gardening and intention to install GI on one's property in Toronto, Canada. Residents' level of concern about localized flooding or heat impacts are often related to installing GI (Coleman et al., 2018; Meerow et al., 2021; Ureta et al., 2021), but not in all cases (Ordóñez et al., 2021). Additionally, previous research found those who installed rain barrels through a subsidized program expressed more positive attitudes towards the environment in general (Gao et al., 2016) or lived in neighborhoods with a higher percentage of the population with 'green' attitudes (Ando & Freitas, 2011).

To date, few studies have compared residents who do and do not participate in opt-in GI programs using household data. Past research has typically been limited to neighborhood-level analyses or data collected only from residents who participated (e.g. Ando & Freitas, 2011; Locke et al., 2015; Locke & Grove, 2016), although a few recent studies have explicitly examined barriers to participation (Carmichael & McDonough, 2018; Riedman et al., 2022). Furthermore, most studies examined only one type of GI program (e.g. yard tree giveaway) rather than the range of GI features offered through different programs, which may be associated with participants who have different characteristics. Finally, while motivations and barriers have begun to be examined, these have not been considered in relation to the programs' priorities.

Our study's goal was to examine GI program participants and non-participants to better understand who participates in different types of residential GI programs and why. We conducted a survey of residents in Philadelphia, Pennsylvania (US), a city that has heavily invested in residential GI initiatives. We surveyed residents who had previously participated in the city's three largest GI programs and compared them to a sample of residents who had not participated to (1) identify differences between program participants and non-participants related to socio-demographic factors, knowledge, and attitudes and (2) determine primary motivations and barriers to participation. A better understanding of who is and is not participating in different types of GI programs, as well as the motivations and barriers associated with participation, will highlight similarities and differences between participants based on the type of GI and provide insight into why some residents are not participating.

Methods

Study area

Philadelphia's racial and economic diversity, as well as its GI programs, make it a compelling location for this study. With a population of 1,584,064 in 2019 (US Census Bureau, 2019), most residents identify as either White or Black (Table 1). Philadelphia also has a substantial low-income population, with a median household income of $45,925 and a poverty rate of 24.3%, making it the poorest large city in the US (Shields, 2020).

Single-family residential properties represent about 78% of all properties in the city, and about half of the zoned land area (City of Philadelphia Zoning Base Districts, 2012). Single-family properties include fully detached, semi-detached, and fully attached homes. Many neighborhoods are dominated by fully attached homes (e.g. rowhouses, Schade, 2008) that lack front yards, while some post-World War II neighborhoods contain a mix of housing types and yard sizes (e.g. semi-detached with modest yards, detached homes with ample yards). The median home value in Philadelphia is $163,000, with a homeownership rate of 53% (US Census Bureau, 2019).

The city has become a national leader in urban GI. In past decades, Philadelphia struggled to meet federal water quality regulatory requirements, resulting in a 2007 EPA directive to reduce water pollution through a GSI approach (Fitzgerald & Laufer, 2017). Like many other cities, Philadelphia's infrastructure and natural areas have also been identified as vulnerable to climate change (City of Philadelphia, 2016). In response to these challenges, municipal leaders adopted policies and plans that promote GI (Hopkins et al., 2018), aiming to improve the health of the city's waterways, and more generally address broad environment and goals through wide-scale implementation of GI (City of Philadelphia, 2009).

Table 1. Selected demographics and knowledge variables for all residents of the City of Philadelphia and survey respondents.

	City of Philadelphia	Non-participants % ($n = 106$)	GI program participants % ($n = 838$)
Gender			
Male	47	39	31
Female	53	61	68
Country of origin			
US	86	90	90
Outside of US	14	10	10
Age			
18–44	41	25	52
45–64	22	45	33
65 and older	14	34	16
Household Income			
Less than $10,000	12	5	2
$10,000 to $24,999	15	16	4
$25,000 to $49,999	24	27	15
$50,000 to $99,999	27	24	36
$100,000 or more	22	28	44
Education			
No high school	14	4	0
High school or GED	33	24	4
Some college, no degree	16	16	8
Associates degree	6	10	5
Bachelor's degree	18	24	35
Graduate degree	13	22	48
Race[a]			
White	41	45	78
Black or African American	42	33	15
American Indian or Alaska Native	0.4	2	2
Native Hawaiian	0	0	0
Asian or Pacific Islander	7	6	5
Latino/a or Hispanic	15	4	5
Other	3	1	2

[a]Respondents could select more than one race.

Collectively, these plans detail the city's commitment to GI, while pointing to the need for GI investment on private residential property (Heckert & Rosan, 2016). To promote GI implementation on private property, the city has incentivized voluntary GI implementation (Mandarano & Meenar, 2017; Nguyen et al., 2017). However, a recent study examining Philadelphia's GSI on private property found it to be unevenly distributed across census tracts based on factors like income, education, and race (Mandarano & Meenar, 2017).

GI programs

We explored participation in the three largest GI programs in Philadelphia that are focused on residential areas: TreePhilly, Tree Tenders and Rain Check. All three programs use an 'opt-in' approach, with GI features given and/or installed at resident's request. Thus, we were able to explore the characteristics of residents who had chosen to participate versus those who had not.

TreePhilly is a community forestry program that is a partnership between the Philadelphia Parks and Recreation (PPR) Department and Fairmount Park Conservancy. This program was launched in 2011 with a focus on yard tree giveaways in response to the Philadelphia Office of Sustainability's *Greenworks Plan* to help Philadelphia residents plant and care for trees (Nguyen et al., 2017; TreePhilly, n.d.). The program aims to increase tree canopy cover to 30% in every neighborhood. Homeowners participate by requesting trees that are picked up at events run by community organizations or delivered directly to their homes, with events focused on neighborhoods that have low canopy cover and score high on an internal environmental justice prioritization. Residents are responsible for planting the tree in their yard, although some assistance is available for those physically unable to plant. To date, TreePhilly has given away more than 25,000 free trees to residents and engaged more than 9000 Philadelphians (TreePhilly, n.d.).

Tree Tenders, a tree planting and stewardship program of the Pennsylvania Horticulture Society (PHS), began in 1993. Within Philadelphia, Tree Tenders primarily focuses on street trees, with some trees also planted in private yards. Notably, street trees in the city are owned by adjacent property owners, but formally fall under the jurisdiction of PPR; new plantings require both property owner consent and approval of PPR arborists. Tree Tenders has a semi-autonomous structure, with neighborhood volunteer groups recruiting residents to plant street trees (Riedman et al., 2022). For a resident to be eligible to receive a free tree there must be a neighborhood Tree Tenders group with at least three people trained through the Tree Tenders program. PHS staff prioritize neighborhoods with few existing trees, high average temperatures, and/or environmental justice concerns. To date, more than 6000 volunteers have completed the Tree Tenders training and organize their neighbors to plant over 1000 trees each year (PHS, 2022).

The Rain Check program was started by the Philadelphia Water Department in 2012 to help residents manage stormwater as part of the *Green City, Clean Waters* plan (Rain Check, n.d.). Program goals include mitigating water pollution and reducing combined sewer overflows entering Philadelphia's waterways. Since 2014, PHS has managed Rain Check, including delivering workshops and installing GSI, such as rain barrels, rain gardens and downspout planters.[1] While the rain barrels are free, rain gardens and downspout planters are partially subsidized by Rain Check. For example, residents typically pay $100 towards the approximate $1000 cost of a downspout planter (Rain Check, n.d.). To date, more than 6000 Philadelphia residents have participated and/or installed GSI on their properties through Rain Check (Rain Check, n.d.).

GI survey

Two rounds of GI surveys were sent to Philadelphia residents. The first round of surveys was used to generate a random sample of residents who had not participated in one of the three GI programs, while the second round of surveys targeted recent program participants. The survey methods were approved by the researchers' university research ethics boards (University of Toronto Protocol No.: 36051 and Temple University Protocol No. 25155).

To generate a random sample of non-participants, the first-round survey was sent to 2000 households living in single-family homes – residents that likely have outdoor space where GI could be located – using a

spatially stratified random sampling approach weighted by number of single-family homes per zip code. The stratification approach aimed to capture a range of socio-demographic, built, and environmental conditions. The PWD stormwater billing dataset was used to obtain mailing addresses for the non-participants sample (City of Philadelphia, 2018). We only selected addresses for single-family homes where the billing address matched the home address. This approach likely excluded many renters while allowing us to focus on the residents who clearly live at the targeted properties. The second-round survey represents GI program participants, sent to 4596 residents who had participated in at least one of the target programs (TreePhilly, Tree Tenders and Rain Check).

The first round, generating a sample of non-participants, was a mail-based survey disseminated in fall 2018, using a multi-contact approach to promote response rates (Dillman et al., 2014). The potential survey participants first received an invitation postcard informing them about the research project and giving them a link to an online version of the survey. After a week, a survey packet was sent to the residents, which included an informed consent letter, a copy of the survey and a stamped return address envelope. A reminder postcard was mailed after two weeks, followed by an additional survey packet in another two weeks, if no response was received. We asked questions about participation in the three target programs to confirm that the round one survey responses came from residents who were not GI program participants.

The second round of surveys was conducted online in spring 2019 using the GI program participants' email addresses, which were provided by the GI programs. People who had participated in the previous two years were targeted to increase the likelihood that they had not moved to a new home. We included screening questions confirming that the email recipients had participated in at least one of the programs and lived at the same address as when they participated. Participation was considered attending an event or training session and/or receiving a GI feature (tree, rain barrel, rain garden, downspout planter). Similar to the multi-contact approach for round one, the online survey invitation was sent up to three times.

The questions in the two rounds of GI surveys were nearly identical (Supplementary Materials). Both surveys referred to the residents' outdoor space, which was defined as 'all outdoor space around your home on your property – including your yard, porch, driveway, decks and patios, and the sidewalk in front of your house'. This definition was used to include more than just permeable yard space, recognizing that many Philadelphia homes do not have a front yard but do have sidewalk areas where in GI features like downspout planters and street trees can sometimes be placed.

Both surveys also included sections on knowledge, level of concern about local environmental issues GI can address, desired outdoor space uses and characteristics, and household socio-demographics. Knowledge focused on whether respondents had previously heard the term 'green infrastructure' and their self-assessed level of gardening knowledge using a 5-point Likert scale. Local environmental concerns that GI is meant to address (i.e. heat, drought, and flooding impacts; water quality and biodiversity decline) were assessed using a 5-point Likert scale. Specifically, there were 14 statements about environmental concerns that were based on the literature and municipal GI policies, stated in relation to how the issue might impact the resident, their property or neighborhood. Example statements include 'Hot summer temperatures that will stress or kill my lawn and other yard vegetation', and 'Water pollution flowing into local creeks and rivers during a storm.' The survey also asked about the level of agreement with 11 statements related to the desired use of participants' outdoor space (e.g. eating meals, gardening) and 13 statements related to desired characteristics (e.g. be colorful, be mostly lawn). The outdoor space use and characteristic statements, derived from Clayton (2007) and Blaine et al. (2012), capture attitudes related to respondents' private outdoor space that may be associated with interest in adding GI features.

If the respondent had acquired a specific GI feature (i.e. tree, rain barrel, rain garden, or downspout planter) through one of the programs they were asked about their motivations. Survey respondents were also asked about reasons for not acquiring GI through the programs (i.e. barriers), although only round two respondents were specifically asked about barriers to GSI installation. Motivation and barrier questions included predefined reasons based on the existing literature and discussions with GI program staff. Survey respondents could choose multiple options.

Data analysis

After receiving survey responses from both round one and round two, incomplete surveys were removed. Respondents from round one who had participated in one of the three target programs were labeled as participants. All respondents from round two of the survey were also considered GI program participants.

Simple descriptive statistics were calculated for relevant survey questions related to program participation, motivations, and barriers. To simplify measures of resident's level of environmental concerns, desired outdoor space activities and desired outdoor space characteristics, a Principal Components Analysis (PCA) with a varimax rotation (Kaiser, 1974; Thurstone, 1947) was completed for each set of statements (Supplementary Materials). All retained components have an eigenvalues greater than 1. These components were then used in further analyses.

We then examined associations with three binary variables, capturing different types of GI program participation: (1) *Participant,* reflecting whether the respondent participated in at least one program event or installation; (2) *Received Tree*, reflecting whether the respondent received one or more trees through TreePhilly or Tree Tenders; and (3) *GSI Install*, reflecting whether the respondent installed a rain barrel, rain garden, and/or downspout planter through Rain Check. Separating the tree recipients from the GSI recipients allowed us to explore differences by type of GI.

Chi-square tests were used to compare differences between the three binary GI participation variables and household socio-demographic measures previously explored in the GI literature (age, household income, education-level, racial identity, and house type), GI knowledge and self-assessed gardening knowledge. Age, income, education, race, house type, and gardening knowledge data from the survey were reduced to binary variables based on natural breaks in the data. This simplified measures to avoid over-prediction, and for race to account for survey respondents having the option to check more than one racial identity. Mann–Whitney Tests were used to compare the GI participation variables with the retained PCA components reflecting level of environmental concern, desired outdoor space uses, and desired outdoor space characteristics. Stepwise binary logistic regression analyses were then completed for each of the three binary participation variables to further explore associations of interest with socio-demographics, knowledge-levels, environmental concerns, and desired outdoor spaces uses and characteristics. Multicollinearity, explored through VIF and binary tests of association with explanatory variables, was not an issue.

Results

Survey responses and GI program participation

In the first round of surveys, 146 surveys out of the 2000 mailed were not successfully delivered. A total of 126 completed surveys were received, representing a response rate of 7.2%. In the second round of surveys, a total of 4596 survey invitations were sent by email, 1109 surveys were started, and 818 completed surveys collected, representing a response rate of 17.8%. Both response rates are relatively low. The first round of surveys was sent during a heat wave when public schools unexpectedly closed for several days. Additionally, a similar survey of a random sample of Philadelphia residents also had a very low response rate (City of Philadelphia, 2017), suggesting relatively low response rates in Philadelphia may be typical.

By separating GI program participants and non-participants from round one surveys and considering all round two survey respondents as program participants, there are 838 respondents who are GI program participants and 106 respondents who are non-participants. Among our GI program participants, 20% attended one or more of the programs' events or workshops but did not acquire GI through any program. Most GI program participants indicated they received GI through one program (57%), 21% through two programs, and 2% of participants received GI through all three programs (Table 2). More respondents acquired trees through TreePhilly than Tree Tenders. Of those who installed GSI, 88% installed a rain barrel, while 25% installed a rain garden or downspout planter. These frequencies reflect the relative size of the three programs.

When comparing our sample of non-participants with the entire population of Philadelphia, our sample has more female and older respondents (Table 1). Additionally, non-GI program participants include fewer very low-income respondents and residents without a high school diploma as compared to the city population.

This may reflect a bias based on who completed the survey or differences between our target survey population (residents of single-family homes) and population-wide characteristics.

Eighty-two percent of non-participants were homeowners, which was expected given the sampling design. Nearly all GI program participants were also homeowners (96%). Of the 30 GI program participants who were renters, 11 participated but did not receive any GI feature, nine received a rain barrel, five received a tree through TreePhilly and six received a tree through Tree Tenders.[2]

For the statements related to the level of environmental concern, three components were retained in the PCA: (1) *Flooding*, including concerns related to neighborhood, street, yard and basement flooding; (2) *Heat & Drought*, with statements about summer heat and drought concerns, primarily in relation to yard vegetation; and (3) *Broad Env*, related to local water quality and biodiversity (See Supplementary Materials). The second PCA analysis evaluating desired outdoor space activities resulted in two components: *Nature & Social* and *Home Extension*. *Nature & Social* includes statements about using outdoor spaces to socialize, as well as gardening and wildlife watching. *Home Extension* reflects a desire to eat meals, read, play, relax, and BBQ in one's outdoor space. The final PCA analysis evaluated desired outdoor space characteristics, retaining three components: (1) *Aesthetics*, including demonstrating care of property and contributing to the value on the property; (2) *Eco Health*, with wanting native plants and no toxic chemicals positively associated and having mostly lawn and no plants negatively associated; (3) *Low Maintain*, including little or no watering or maintenance and a low-cost outdoor space.

Comparing GI participants and non-participants

When comparing all GI program participants with non-participants, there were differences for several socio-demographic and knowledge variables (Figure 1). GI program participants (*Participant*) were on average significantly younger, wealthier, and more highly educated, and more frequently identified as White and lived in a fully detached home. With the exception of age, the same relationships existed for *Received Tree*. Age, education and fully detached house type were significant for *GSI Install*, although fully detached house type was positively associated with *Participant* and *Received Tree* and negatively associated with *GSI Install.* Previous knowledge of GI was associated with *Participant* and *GSI Install*, while having a moderate or very high knowledge of gardening (4 or 5 on a 5-point scale) is associated with all three participation variables.

Significant associations between the level of local environmental concerns, desired outdoor space activities and desired outdoor space characteristics varied among the three GI participation variables (Table 3). For example, both flooding concerns and low maintenance outdoor spaces were significantly related to *Participant*. Flooding concerns and heat and drought concerns were significantly associated with *Received Tree* but not *GSI Install*, while broader environmental concerns and desire for outdoor space to support a healthy ecosystem were significantly associated with *Participant* and *GSI Install* (Table 3). Wanting to use one's outdoor space for nature and social activities was significantly associated with all three participation variables, although the level of significance was relatively weak.

For the logistic regression with the variable *Participant*, having a Bachelor's degree and living in a fully detached house type were positively associated (Table 4). Significant positive relationships exist for White

Table 2. Program participant's installation rates through the targeted GI programs, with percentages by each program combination.

Number of GI Programs (% of participants)		Specific GI Program(s) (% of participants)	
Zero	20%	None	20%
One	57%	Tree Tender	9%
		TreePhilly	19%
		Rain Check	34%
Two	21%	Tree Tender & TreePhilly	4%
		Rain Check & Tree Tender	3%
		Rain Check & TreePhilly	9%
Three	2%	All three programs	2%

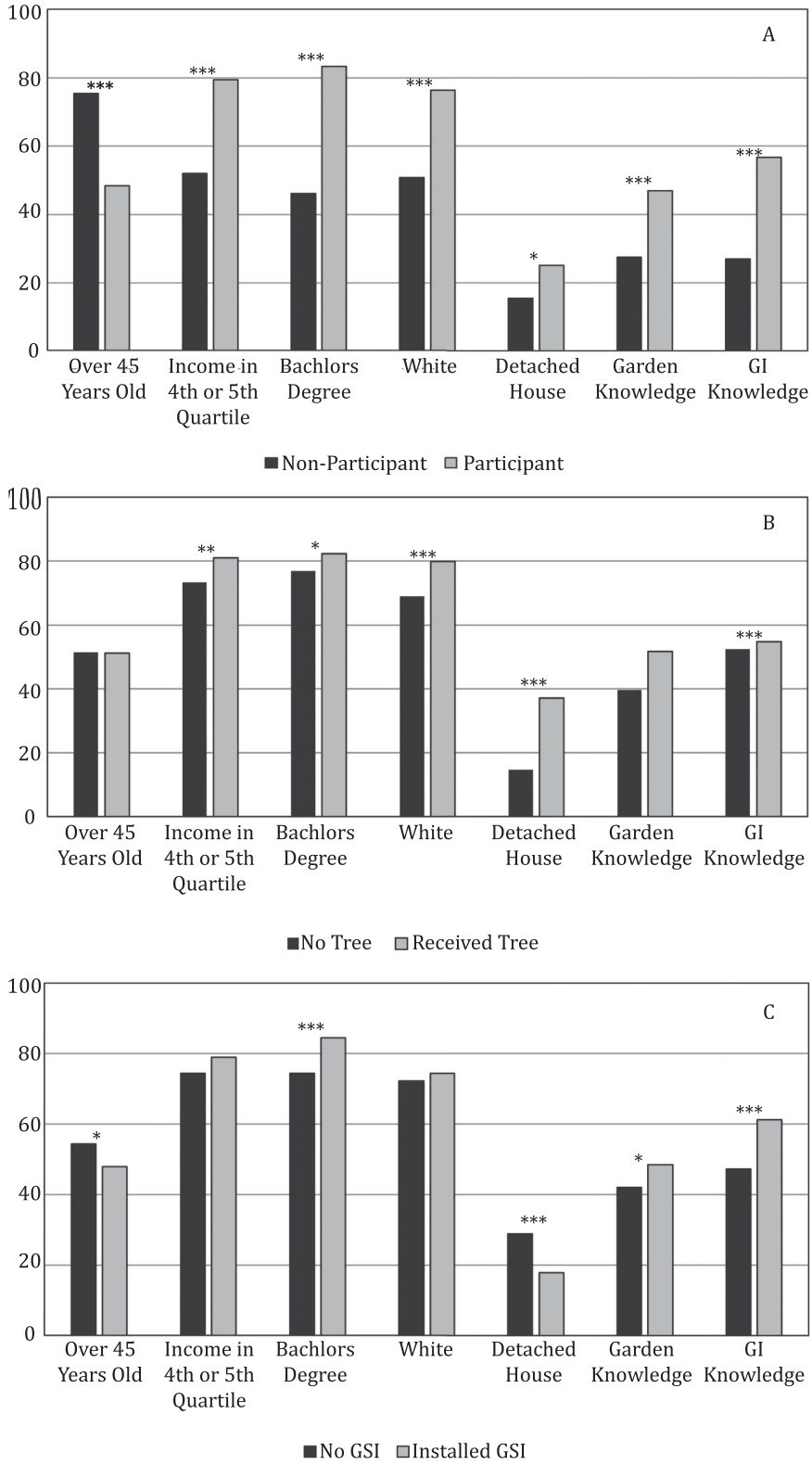

Figure 1. Differences between participants and non-participants' socio-demographics and knowledge. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$ based on chi-square tests.

Table 3. Mann–Whitney test statistic comparing environmental concerns, desired activities in private outdoor space and desired characteristics of private outdoor space across binary GI program participation variables.

	Participant	Received Tree	GSI Install
Env Concern: Flooding	27,855.5***	76,052.5***	
Env Concern: Heat & Drought		87,303.5**	
Env Concern: Broad Env	27,578***		220,357.5***
Outdoor Use: Nature & Social	31,505.5**	91,103.5*	221,974.0**
Outdoor Use: Home Extension	30,734**		90,358.0**
Outdoor Char: Aesthetics			
Outdoor Char: Eco Health	15,396.5***		67,308.0***
Outdoor Char: Low Maintain	28,761.5**	86,482.0**	

***$p < 0.001$.
**$p < 0.01$.
*$p < 0.05$.

and fully detached house with *Received Tree*. Again, the opposite relationship existed between *GSI Install* and fully detached house type, and no other socio-demographic variable was retained. *Participant* was negatively associated with *Flooding* and positively associated with wanting one's outdoor space to contribute to a healthy ecosystem. For *Received Tree*, the negative relationship with *Flooding* was also retained, along with a positive relationship with heat and drought concerns, but no variables reflecting outdoor space desired uses or characteristics. For *GSI Install,* a positive association with a desire for outdoor space to contribute to a healthy ecosystem was retained, but no variables reflecting environmental concerns or outdoor space activities.

Motivations and barriers to participation

The top motivations of survey respondents who received one or more trees through a GI program are 'improve the look of my property' (80%) and 'increase shade' (73%). The least selected answer was 'to help with a wet spot in my yard or reduce flooding caused by storms' (6%) (Figure 2). Alternatively, 'care about the environment' was the most common motivation selected by those who installed either a rain barrel (90%) or rain garden/downspout planter (97%), while 'improve the look of my property' was selected by only 5% of those installing a rain barrel, but 60% of those installing a rain garden/downspout planter. A minority of those who installed GSI were motivated specifically to 'help with a wet spot in their yard or reduce flooding caused by storms' (21% for rain barrel and 33% for rain garden/downspout planters).

Barriers to installing were more varied for all GI features. The most common reason given by those who had not received a tree through a GI program was 'do not have space for more vegetation on my property' (37%) (Figure 3). Additionally, 'other' was selected by 30%, with space often a theme of the written comments. For example, 'I have neighbor's tree shading my yard and it is ruining my garden' and 'would have to break up concrete'. General concerns about having a tree that were not captured by a pre-defined option, like 'too costly to cut down' were also present.

'Other' was the most common reason respondents indicated they did not install GSI (31% rain barrels and 27% rain garden/downspout planter), with a variety of reasons written by those who selected it. Some

Table 4. Logistic regression coefficients for the three GI program participation variables. Only variables retained in at least one model listed. Standard error is given in parentheses.

	Participant	Received tree	GSI install
Bachelor's Degree	1.367 (0.290)***		
White		0.507 (0.184)**	
Fully Detached House	0.880 (0.403)*	1.063 (0.178)***	−0.588 (0.177)**
Env Concern: Flooding	−0.483 (0.148)*	−0.397 (0.79)***	
Env Concern: Heat & Drought		0.274 (0.78)***	
Outdoor Chars: Eco Health	0.987 (0.143)***		0.59 (0.82)***

***$p < 0.001$.
**$p < 0.01$.
*$p < 0.05$.

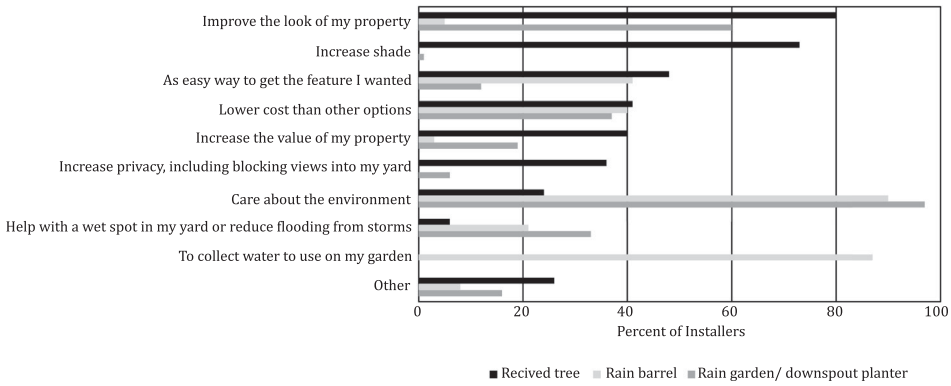

Figure 2. Motivations identified by those who received or installed the feature through a GI program. Number of respondents for each feature varies based on participation level. Percentages are based on the number of people who received or installed the specific feature, with respondents allowed to select more than one reason.

comments indicated they were interested but had not taken action. For example, 'I'm still considering which of the stormwater management tools to take advantage of at my property' and 'the water dept said that my drainpipe was not the correct shape for the rain barrel'. Other comments reflected specific concerns or situations, for example 'barrel would be stolen or vandalism' and 'I have to pay to move my downspout to make it work'. Additionally, 21% indicated they did not install rain gardens and downspout planters due to costs; this is much higher than for the free GI features, reflecting the cost associated with the rain gardens and downspout planters.

Discussion

By comparing recent participants of Philadelphia's GI programs with non-participating residents, we were able to identify differences based on socio-demographics, environmental concerns and desired uses and characteristics of residents' outdoor space. Residents who have higher income, Bachelor's degrees, identify as White, and live in detached houses are disproportionately participating in GI programs based on our survey samples, and specifically acquiring trees through such programs, echoing what others have found in the literature (Ando & Freitas, 2011; Gao et al., 2016; Locke & Grove, 2016; Watkins et al., 2016). These findings indicate that creating free or subsidized residential GI programs is not sufficient to ensure representative participation across socio-demographic groups.

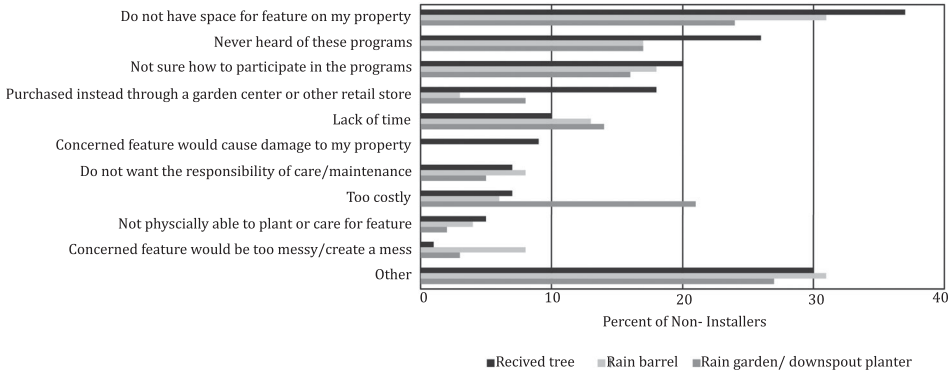

Figure 3. Barriers identified by those who did not receive or install the feature through a GI program. Number of respondents for each feature varies based on participation level. Percentages are based on the number of people who did not receive or install the specific feature, with respondents allowed to select more than one reason.

The different relationship between housing type and our three participation variables provides some insight into the socio-demographic findings. Specifically, the positive relationship between *Received Tree* and living in a fully detached house is likely reflective of the larger yard space of this housing type, as opposed to fully attached rowhouses. In Philadelphia, rowhouses often lackfront yards, making street trees a primary tree planting option, yet narrow sidewalks and other physical constraints limit plantable street tree space (Riedman et al., 2022). Thus, physical space availability may be contributing to the socio-demographic association, particularly related to income, given that larger properties often have higher values. The need for sufficient physical space to plant a tree represents an underlying cause of current uneven distributions (Pham et al., 2013). Creative urban design approaches, however, can often create room for trees in highly built-up urban areas, including dense cities like Philadelphia (Roman et al., 2017).

Physical space availability appears to be less of a concern for GSI in Philadelphia, given the negative relationship between *GSI Install* and fully detached houses among our respondents. Residential property owners with limited outdoor space may seek out the types of small-scale GSI offered by the Rain Check program. While still a barrier, fewer survey respondents indicated that lack of space was a challenge when installing GSI than receiving a tree. These results highlight the importance of addressing physical space limitations in GI programs, which might include offering varying types of GI suitable in different built form (Cvejić et al., 2015).

Notably, we found that financial costs were a concern for some residents, including installation costs for subsidized GSI features, as well as retrofitting required to make GSI and/or tree installation physically feasible. Additionally, Riedman et al. (2022) found that worries around future financial costs from tree damage and limited plantable space can also limit participation in free tree planting initiatives.

Our analysis found mixed associations with the flooding, heat, and drought concerns that property-level GI could help address. Greater concern about heat and drought impacts by respondents was positively related to acquiring a tree, although the inverse relationship was seen for flooding concerns and no significant association was identified for GSI installation. However, these associations are based on level of concern after GI has been installed, so they may not reflect concerns residents had prior to taking action.

To better understand if residents view GI as a way of addressing localized flooding or heat and drought impacts, we can look to findings related to motivations: the second most common motivation for those receiving a tree was to increase shade, suggesting that many residents recognize that cooling service, while few were motivated by trees' ability to reduce localized flooding.

On the other hand, respondents who were GSI installers were primarily motivated by demonstrating care for the environment, and there were significant associations with broad environmental concerns and an interest in having their outdoor space support a healthy ecosystem. Addressing wet spots or reducing flood potential were far less frequently identified motivations. This suggests that installing GSI may be viewed as environmentally friendly, but is not widely understood as a solution to localized flooding concerns (Meerow et al., 2021). Additionally, many who installed rain barrels also valued the ability to use the collected water on their garden, findings similar to Gao et al. (2016). Thus, the different motivations between those who received a tree and installed GSI in our survey likely also reflect the function and appearance of these features, with Meenar et al. (2022) identifying rain barrels' appearance as a barrier to installation, in contrast to the aesthetic appeal of trees.

The varied motivations also reflect differences in the design and messaging of the programs themselves. Residential participants in the Rain Check program are required to attend a workshop explaining the goals of that program. Their website mentions three benefits of installing GSI – aesthetics, using captured water for gardening, and contributing to less pollution in local waterways – but does not highlight reducing localized flooding (Rain Check, n.d.), which mirrors our GSI installers' motivations.

Communication about benefits for the tree-focused programs are less centralized, often flowing through neighborhood leaders. Those who aquire a tree through TreePhilly receive a short demonstration on planting techniques and a brochure about tree care. Neighborhood organizations and leaders often assist with recruiting tree recipients, and may use varied messaging. For Tree Tenders, communication with tree recipients was primarily managed by neighborhood leaders who are required to attend at least eight hours of training, but tree recipients are not. While the leader training highlights a variety of environmental, health, social and

economic benefits (personal communication, PHS staff, May 20, 2022), some neighborhood leaders may prioritize cultural services and social benefits when discussing the program with neighbors (Riedman et al., 2022). Our survey respondents who received a tree were most frequently motivated by the aesthetic contribution to their property, which aligns with previous findings (Conway, 2016; Locke et al., 2015; Morgan & Ries, 2022). Future research could explore if communication strategies emphasizing different benefits**,** including benefits related to flood risks and cooling, impact residents' knowledge, perceptions and actions.

Finally, we found that prior knowledge of the term 'green infrastructure' was significantly associated with *Participant* and *GSI Install*, and gardening knowledge was associated with all three. This suggests that those who lack basic horticultural knowledge may be less interested in GI. While knowledge of pro-environmental behavior is not enough to guarantee actions are taken, lack of knowledge can be a barrier (Kollmuss & Agyeman, 2002). GI requires on-going maintenance, and residents with greater knowledge of gardening may be more aware of the maintenance requirements so more comfortable taking them on (Riedman et al., 2022). The connection with gardening is particularly relevant as two of these programs are run by PHS, which has numerous horticultural and gardening programs and an overall vision to support 'gardening for the greater good' (PHS, 2019).

Limitations of this study are primarily related to the low response rate, and associated uncertainty about whether the non-participants sample is representative of all residents who could participate in the GI programs. We chose to focus primarily on homeowners who live in single-family houses, as renters and dwellers of multifamily units often cannot participate in the GI programs without the permission of the property owner. Low participation by renters was supported by a high rate of homeownership among the GI program participant sample. Given the documented challenges of including renters in residential GI programs (Morgan & Ries, 2022; Perkins et al., 2004) future research should explore ways to incorporate renters and multifamily housing into GI programs, which in turn may support more equitable participation across socio-demographic groups.

Additionally, we did not have addresses or other geographic location data for the program participants, so could not explore spatial patterns, including whether residents in the neighborhoods the GI programs want to target were participating at higher rates. Our socioeconomic and demographic differences and the indication of space and cost as barriers to participation raises concerns about the extent to which the programs address or exacerbate existing GI inequalities. Because our survey focused primarily on motivations and barriers to participation without explicitly looking at the location of participants, we are unable to answer those questions here. Future research can further explore the relative effectiveness of different programmatic strategies to promote equitable participation and address existing inequalities.

Our research demonstrates that GI program participants differ from non-participating residents by sociodemographics, knowledge, attitudes, and housing type, although who participants in programs also varies by type of GI offered. The GI programs in Philadelphia have different physical space requirements and costs, as well as different priorities associated with GI. Based on these findings, we recommend that future research examine steps GI programs could take to increase participation, including the effects of emphasizing varied benefits; identifying specific types of GI that work best in different neighborhood typologies, including areas with very limited physical space; the effects of subsidized versus free GI, as well as approaches to address costs associated with installation and maintenance; and strategies that can encourage an interest in gardening.

Notes

1. Small metal planters (approximate footprint of 0.75 sq. m) designed to filter and absorb stormwater flowing from a roof downspout. For more information: https://www.pwdraincheck.org/en/stormwater-tools/metal-downspout-planters.
2. Three renters received GI from more than one program.

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