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Barriers to resident participation in tree-planting initiatives across a metropolitan area

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ABSTRACT

Past research on barriers to the development and implementation of green infrastructure (GI) has examined the experiences of policy makers and community leaders, with a focus on planting or installing GI. However, many of these programs rely on participation from the public — especially residents — who often steward GI over the long-term on both public and private lands. To better understand the barriers experienced by primary stewards of GI, we conducted 93 intercept interviews with residents spanning four neighborhoods in the City of Philadelphia and in four nearby suburban municipalities with active TPIs. Selected neighborhoods and towns included areas with varied canopy cover and economically and racially diverse communities. We found that residents viewed trees as a neighborhood asset, yet they also identified multiple categories of barriers across the tree lifecycle, including physical, maintenance, aesthetic, knowledge, and environmental issues. Our study also reveals the convergence and divergence of barriers experienced across city and suburban neighborhoods based on contextual factors. Our results suggest that barriers to participation in TPIs are multi-dimensional, context-specific, and endure across the lifecycle of GI. Long-term maintenance concerns relate to tree care that is outside the purview of TPIs led by non-profit organizations. Advancing equitable urban forestry that reaches neighborhoods with the greatest need requires recognition and respect of resident and community experiences, needs, and land use priorities, as well as improved institutional collaboration.

1. Introduction

Cities have incorporated green infrastructure (GI) into the built environment to promote an array of environmental and social benefits (Conway et al., 2020). Although there can be varied GI meanings across municipalities (Conway et al., 2020; Grabowski et al., 2022), GI is broadly defined as "vegetation or vegetated spaces that provide multiple ecosystem services" (Conway et al., 2020) and may include trees, rain gardens, green roofs, public parks, urban wetlands, and natural unmanaged spaces (Van Oijstaeijen et al., 2020). Governments, non-governmental organizations, and residents install and steward GI, with a range of motivations, including mitigating the urban heat island effect, absorbing stormwater runoff, promoting biodiversity, beautifying outdoor space, and reducing maintenance burden (Conway et al., 2021; Matthews et al., 2015).

Given this widespread promotion of green infrastructure (GI) initiatives in cities around the world, researchers have documented barriers complicating the development, construction, and maintenance of these green features (Heidari et al., 2023). Recent synthesis articles identified a wide array of barriers, including institutional and governance, socio-cultural, knowledge, technical and biophysical, and funding and market challenges (Deely et al., 2020; Dhakal and Chevalier, 2017; Heidari et al., 2023). Institutional barriers include lack of policy development or ineffective governance and leadership, while

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socio-cultural barriers include perceptions of GI or a reluctance to change current practices and/or participate in a new program. Knowledge barriers revolve around stakeholder awareness and understanding of GI, and the technical and biophysical characteristics that relate to site conditions and suitability for GI, as well as issues connected to construction and design. Finally, funding and market challenges pertain to how GI is financed, with funding issues manifesting differently for different stakeholders depending on existing GI initiatives and municipal policies. For instance, in some programs, residents pay for GI, or receive GI for free, while other landowners (e.g., companies) are compensated for allowing GI to be installed on their property (Deely et al., 2020). Early studies identified financial resources and funding as the most common barrier (Dhakal and Chevalier, 2017), yet more recent studies have found cognitive barriers, such as lack of awareness of GI benefits, experiences with GI burdens, or hesitations to take on maintenance, to be key barriers to participation in GI initiatives (Dhakal and Chevalier, 2017; Riedman et al., 2022).

While much of the GI research has focused on barriers that policy makers and practitioners face in installing or planting GI (Dhakal and Chevalier, 2017; Ordóñez et al., 2019), a growing body of literature has pointed toward the importance of the perspectives and experiences residents who often become the primary stewards of the GI over time on both public and private lands (Conway et al., 2021; Conway et al., 2023; Geron et al., 2023; Gwedla et al., 2024; Watkins et al., 2018). This is especially relevant in the context of urban tree-planting initiatives (TPIs), which have become widespread in United States (US) cities (Eisenman et al., 2021), and often involve community members. Residents are central actors for many TPIs in the US, including as the individuals requesting to plant trees through municipal and non-profit programs, as communicators about TPIs to neighbors, and as advocates for expanding urban canopy (Conway et al., 2021; Geron et al., 2023).

Advancing equitable urban forestry that reaches neighborhoods with the greatest need requires recognition and respect of resident and community experiences and needs for land use priorities in their neighborhood. However, rather than incorporating resident perspectives, urban forest management plans and other planning documents, such as urban tree canopy (UTC) assessments, tend to focus on educating residents about the ecosystem services of trees, including their ecological and economic benefits, to increase participation in TPIs (Breyer and Mohr, 2023; Grant et al., 2022). While most people generally value urban trees (Ordóñez Barona et al., 2022), ecosystem disservices, or the downsides of trees, also shape people's perceptions of and experiences with trees (Roman et al., 2021b). For instance, some residents are concerned about long-term maintenance costs or potential future infrastructure damage (e.g., trees damaging sidewalks, power lines, buildings) (Drew-Smythe et al., 2023; Riedman et al., 2022). In neighborhoods that have been chronically under-resourced, residents may not trust that public trees will be properly cared for due to decades-long disinvestment in municipal arboriculture operations (Carmichael and McDonough, 2018; Riedman et al., 2022). Worries about the negative impacts of large, poorly maintained trees or the potential of newly planted trees to trigger gentrification may result in resistance to new trees (Donovan et al., 2021; Grant, 2023; Wolf-Jacobs et al., 2023). Broadly speaking, some residents may view the problems of urban trees (e.g., property damage, nuisance tree litter) as more impactful than benefits (e.g., shade and cooling).

Numerous studies confirm that community engagement in local TPIs is critical to successful implementation, and especially for increasing equity and justice in urban forestry (Baptiste et al., 2015; Breger et al., 2019; Breyer and Mohr, 2023; Carmichael and McDonough, 2019; de Guzman et al., 2022; Grant et al., 2023; Grant et al., 2022; Wolf-Jacobs et al., 2023). While US urban forest management plans increasingly reference environmental justice and equity, these plans rarely include a focus on recognitional justice (i.e. the values and perspectives of under-represented and disadvantaged groups) and may only superficially address procedural justice (i.e. avenues for meaningful and fair participation) (Grant et al., 2022). Although a handful of studies have investigated why residents requested trees from non-profit programs or planted trees on their own (e.g.,Kirkpatrick et al., 2012; Locke et al., 2015; Conway 2016), few studies have explored why some residents do not want trees (but see Carmichael and McDonough, 2018; Riedman et al., 2022; Gwendla et al., 2024). Given that TPIs often rely on residents actively choosing to participate and install vegetation on and around their properties, there is need for research on residents' opinions, including their perceptions and lived experiences of benefits and barriers related to trees. Municipal leaders often acknowledge the need for a more intentional focus on specific community needs and priorities regarding planting (Breyer and Mohr, 2023; Grant, 2023; Grant et al., 2022; Wolf-Jacobs et al., 2023). Heidari et al. (2023) call for greater attention to "legitimate frustrations" that may not be addressed through existing programming.

Several recent studies point toward the importance of understanding resident perspectives for addressing barriers to participation in TPI. For instance, in Detroit, MI, residents declined new trees because they felt that their values were not taken into account with regard to tree-planting programs (Carmichael and McDonough, 2019). In Washington DC, residents from a socio-economically disadvantaged non-white neighborhood requested information not just about tree benefits, but about the costs, burdens, and responsibilities associated with tree care (Leets et al., 2022). In Nashville, TN some residents felt that they already had enough trees or were concerned about their maintenance (Morgan and Ries, 2022). In Philadelphia, PA, some community-based tree stewards raised complex socio-political factors as barriers to their stewardship practices, such as whiteness within the urban forestry profession, the underrepresentation of Black, Hispanic and/or Latinx perspectives in tree-related decision-making, and resident concerns of gentrification and subsequent displacement related to increased tree-planting efforts (Grant, 2023). Collectively, these studies point to the knowledge, funding, socio-cultural, and political barriers residents face in urban neighborhoods regarding GI generally and TPI implementation specifically.

The majority of urban forestry research focused on TPIs has examined large cities with relatively larger municipal budgets and institutional structures for urban forest management (Carmichael and McDonough, 2019; Drew-Smythe et al., 2023; Leets et al., 2022; Morgan and Ries, 2022; Young and McPherson, 2013). Yet, other studies have shown that small and mid-sized cities, including suburban municipalities, often have different governance arrangements with fewer resources and staff for tree management than big cities (Gwedla et al., 2024; Hauer and Peterson, 2016; Healy et al., 2023). Further, many previous studies have focused on only one or two low-canopy neighborhoods (Leets et al., 2022; Morgan and Ries, 2022; Riedman et al., 2022) or have conducted a large-scale survey but have aggregated results across a county, city or metropolitan area (Dawes et al., 2018; Drew-Smythe et al., 2023; Locke et al., 2015).

To address the need for more research on resident perceptions of TPIs in diverse urban contexts, we focused on resident perspectives on barriers to TPIs across a metropolitan area. We specifically sought to understand whether particular barriers are context-specific or pervasive across urban-suburban, high-low canopy, and high-low income spectrums. We aimed to understand how barriers emerge at the local scale where TPIs are organized and implemented, as called for by Eisenman et al. (2021), and across varied urban contexts, as called for by Ordóñez et al. (2022). To accomplish this goal, we focused on the metropolitan area of Philadelphia, Pennsylvania (US), which has a long history of TPIs and a reliance on residents to plant and steward their local tree canopy. We conducted intercept interviews with residents spanning four neighborhoods in the City of Philadelphia and in four nearby suburban municipalities with active TPIs. Our study areas included low- and high-canopy neighborhoods, as well as economically and racially diverse neighborhoods, to capture varying perspectives and experiences.

2. Study area

The consolidated City and County of Philadelphia has 1.6 million people, making it the sixth-largest city in the US as of 2020 (US Census Bureau, 2021). The surrounding four suburban Pennsylvania counties (hereafter 'the suburbs') combined have another 2.6 million people (US Census Bureau, 2021). Within these counties, there are many incorporated suburban municipalities that comprise the Philadelphia metropolitan area. Ecologically, the Philadelphia region has mesophytic forests and marshes in riparian areas (Dyer, 2006). Situated in the southeastern corner of Pennsylvania, the city is at the far northern edge of the Köppen-Geiger humid subtropical climate zone (Cfa; Peel et al., 2007). There is year-round precipitation (1120 mm/yr; ((NOAA), 2024), winters are cold with occasional snow, summers are hot and humid, and fall and spring are mild. The coldest month (January) has an average temperature of 0.9 C, while the hottest month (July) has an average temperature of 29.5 C (NOAA, 2024). In this climate, arboriculture professionals consider fall and spring to be the best times to plant trees, with at least weekly watering ((PSU), 2008).

Southeastern Pennsylvania was heavily deforested as Philadelphia became one of the largest cities in the nation, with extensive manufacturing, industrial, and agricultural land use through the 1800 s and early 1900 s. Philadelphia's population declined after the mid-1900 s during post-industrialization, as suburban residential development simultaneously expanded; this urban shrinkage and suburban expansion is common to US post-industrial cities (Adams et al., 1993; Roman et al., 2021a). Over the last few decades, there have been multiple efforts to restore canopy cover in Philadelphia and its suburbs, with a wide variety of governance structures for planting and caring for trees across these places.

There is considerable variation in canopy cover across Philadelphia and its suburbs. In general, the suburbs have greater canopy cover than Philadelphia, due in large part to these areas having lower density development and associated higher levels of plantable space (Table 1). However, like Philadelphia, many suburban municipalities have older neighborhoods with dense residential and commercial development, including attached housing known as rowhomes and twins, with little or no yard space. Overall, Philadelphia has more high-density development than its surrounding counties, but some of Philadelphia's outlying neighborhoods are pseudo-suburban in character and there is variation in park space, which often include substantial tree cover (Roman et al., 2021a). Some of Philadelphia's neighborhoods have only 3 % canopy cover, while others have greater than 50 % (O'Neil-Dunne, 2019), a range that is similar to other large North American cities such as Baltimore, MD and San Francisco, CA (Locke et al., 2021; Schwarz et al., 2015). Intra-city variation in UTC is shaped by historical legacies as well as local biophysical context (Roman et al., 2018).

Like many other metropolitan areas (Hauer and Peterson, 2016), there is variability in urban forestry governance arrangements across the city and municipalities. Since the late 2000 s, Philadelphia has supported tree planting and residential tree giveaways to address the impacts of climate change, stormwater runoff, and inequities in canopy cover, including programs run by the Philadelphia Water Department and Philadelphia Parks and Recreation (Conway et al., 2023). Additionally, the Pennsylvania Horticultural Society (PHS), a leading urban greening nonprofit, has led the Tree Tenders (TT) program, a tree planting and stewardship program founded in 1993, in response to funding cuts to the municipal parks department (Roman et al., 2021a). The TT program provides trees to property owners, training on tree planting and stewardship techniques, and organizational support for neighborhood volunteer groups. TT groups operate semi-autonomously with extensive support from PHS staff (e.g., strategies to engage and educate neighbors, support with arranging for pavement cuttings for Philadelphia street trees). TT group leaders, who each operate within a defined geographic area, recruit their neighbors to plant and steward trees, with two major volunteer planting events each year in November and April (Riedman et al., 2022). While trees are planted across a variety of sites and land uses, most TT plantings in Philadelphia are in street tree sites adjacent to residential properties. Residents are generally responsible for post-planting tree care, with some TT leaders assisting by reminding residents to water their newly planted trees and by providing guidance and assistance on pruning. The TT program handbook specifically recommends watering trees 57–76 L/week during establishment (depending on precipitation levels), and provides a wide array of other guidance for TT group leaders regarding tree care techniques and community engagement (Kidd (n.d.))

The suburbs are varied in their TPIs. For instance, some towns have formal volunteer Shade Tree Commissions or Tree Committees to support tree planting and stewardship (Fazio, 2015; Harper et al., 2018), while others include tree care as part of municipal departments, such as Public Works or Parks; this variation in municipal urban forestry structure is common in other small to mid-sized towns in the US (Hauer and Peterson, 2016; Healy et al., 2023). The PHS TT program expanded to the suburban municipalities in 2005 and constitutes the primary TPI in some suburban towns, with suburban TT groups planting more in parks and residential lawns compared to city TT groups. Across Philadelphia and its suburbs, the TT program currently plants about 3000 trees per year.

At the time this article was written, a regional urban forestry plan did not exist, although there have been past initiatives focused on increasing tree cover in southeastern PA. Each suburban municipality sets its own planting and/or canopy cover targets. While some have no planting targets, others have detailed master plans with specific goals (e.g. Abington Township, PA seeks to restore canopy cover to 48 % in 20 years). In 2023, the City of Philadelphia's Parks and Recreation department (the municipal agency primarily responsible for trees)

Table 1
Canopy cover and demographic characteristics of city and suburban communities.

	City (C) of Philadelphia				Suburban (S) towns			
Community code	C1	C2	C3	C4	S1	S2	S3	S4
% Canopy cover (2010)	30	46	17	3	54	42	36	31
Total Population	4425	7728	12,522	13,395	58,471	8824	84,891	10,641
Land Area (Sq Km)	0.518	1.807	1.807	0.851	40.152	1.562	20.29	2.187
Poverty	5 %	20 %	11 %	23 %	7 %	22 %	14 %	28 %
Race & ethnicity								
White	90 %	13 %	69 %	61 %	76 %	30 %	46 %	10 %
Black	3 %	75 %	9 %	5 %	11 %	59 %	33 %	87 %
Asian	5 %	4 %	18 %	27 %	4 %	3 %	12 %	1 %
Hispanic	3 %	7 %	4 %	11 %	6 %	5 %	8 %	2 %

Data Sources: Canopy Cover statistics were calculated from the Pennsylvania Statewide High-Resolution Tree Canopy data product released in 2015, based on imagery collected from 2006 to 2010. City of Philadelphia demographic data was calculated from the 2019 5-year ACS Block Group estimates. Suburban town demographic data was extracted from the US Census QuickFacts, 2017–2021 datasets.

released the *Philly Tree Plan*, an urban forest strategic plan focused on equity and environmental justice, following a comprehensive community engagement process (PPR, 2023). Despite different planning processes, one shared factor across the metropolitan area is the reliance on residents to plant and care for trees (Conway et al., 2021). Residential land contains a large portion of current and potential new canopy cover (Nguyen et al., 2017; O'Neil-Dunne, 2019), and subsequently residents play a critical role in planting and maintaining canopy cover across the Philadelphia metropolitan region.

3. Data collection and analysis

We investigated eight communities across the Philadelphia metropolitan region, selecting four neighborhoods in the City of Philadelphia (referred to as 'city neighborhoods' hereafter) and four incorporated suburban townships or boroughs in Delaware and Montgomery Counties (referred to as 'suburban communities' or 'suburban towns' hereafter). All eight communities have active TT groups, so that our research reflects areas where there are ongoing TPIs and subsequently experiences with barriers to participation in these programs. Our selection criteria included 1) variation in canopy cover, 2) racial and economic diversity, and 3) presence of TPIs (Table 1). The high-canopy category included four communities total, with two city neighborhoods and two suburban towns. Thus, one interpretation of the high-canopy neighborhoods is that they are "high" compared to their respective neighboring urban or suburban communities.

To generate qualitative data representing people's experiences with and opinions about trees, we conducted intercept interviews with pedestrians in public spaces in each of the eight communities (Flint et al., 2016), broadly similar to other recent research about urban trees (Geron et al., 2023). Our research protocol was reviewed and approved by [redacted to preserve anonymity]. The intercept interviews were conducted from September 2022-February 2023 in public parks (for neighborhoods with high pedestrian traffic) and in libraries (for neighborhoods with low pedestrian traffic). In one suburban town, we conducted intercept interviews during a free festival at a local nature center. Each intercept interview was semi-structured and lasted five to ten minutes and included questions about whether participants had heard of TPIs in their community, what they thought about trees in their neighborhood and what was preventing them or their neighbors from planting a tree (SM 1). The interviews were not recorded, and one or two researchers took detailed notes during each interview (McLean et al., 2007; Nali and Lorenzini, 2009). Participants were asked to self-report demographic data on their age and racial/ethnic identity. In some cases, researchers captured a direct quotation, but in other cases they paraphrased responses. We offered $5 gift cards to participants who completed the intercept interview.

For data analysis, we employed an iterative coding approach following established qualitative research methods, with both deductive (predetermined) and inductive (emergent) codes (Bingham and Witkowsky, 2021). We initially developed a set list of barriers based on a synthesis of ecosystem disservices (Roman et al., 2021b) and conversations with our research team. This process produced an initial barriers list including infrastructure conflicts (e.g., cracked sidewalks), maintenance concerns (e.g., cost to maintain a tree), human health concerns (e.g., pollen), cultural and aesthetic concerns (e.g., blocked view), and environmental concerns (e.g., poor soil). Participants provided a broader set of barriers than our original list, and we developed new codes to reflect the responses provided. Two co-authors coded the interviews separately, then compared the results and reconciled any differences (Church et al., 2019). After completing the coding, we tabulated the codes to report the frequency of barriers across all eight communities and compared frequency by city neighborhoods and suburban towns, as well as high- and low-canopy communities to discern pervasive and context-specific barriers. Our results present counts and frequencies of participants who reported specific barriers, similar to other recent qualitative research about urban trees (e.g., Riedman et al., 2022; Geron et al., 2023).

4. Results

We conducted 93 intercept interviews across the eight study areas, with 47 residents from city neighborhoods and 46 from the suburbs. Out of the 93 interviews, 50 residents lived in high-canopy neighborhoods and 43 lived in low-canopy neighborhoods. Overall, 59 % of residents self-identified as white, 26 % as Black/African American, 5 % as Asian, 2 % as Latin American/Hispanic, and 1 % as other (SM 2). We interviewed residents across a range of ages, from 18 to over 65, with 35 % of residents self-reporting to be between the ages of 35–49, and 23 % over 65 (SM 3). Less than ten percent of residents did not self-report their age or race/ethnicity. Overall, 56 % of residents said they had heard of TPIs across the metropolitan area, with almost equal numbers reporting from city neighborhoods and suburban communities, and 58 % expressed the opinion, "We need more trees."

4.1. Descriptions and frequencies of barriers to planting trees

We identified six major categories of barriers, and multiple subcategories within each of the six major categories (Table 2), described further below.

Physical barriers refer to urban design features that constrain plantable space. Residents discussed the lack of space to plant trees due to having small or no yards and limited or no parks. In densely developed and low-canopy neighborhoods, particularly in city neighborhoods, many residents commented that the sidewalks are too narrow to plant a street tree and still have enough space for pedestrians to pass. Residents from all communities described dense urban development characterized by high-density housing (e.g., rowhomes) or extensive impervious surface cover. One resident commented "there is all cement around where I live". Residents also expressed concern over infrastructure conflicts with overhead wires, pipes, housing foundations and old trees, particularly in suburban communities. A few residents described feeling uncomfortable with tree roots that could intrude on water lines or housing infrastructure, with one resident summarizing: "It's tricky to find space to plant, [you] don't want [a tree] too close to your house and not so deep that it's close to water lines". Finally, several residents living in high-canopy neighborhoods discussed old trees as a physical barrier. They said that diseased and dying trees were difficult to remove and complicated planting replacement trees. In this sense, these old trees and stumps created a physical barrier to planting new trees.

Environmental and site conditions refer to conditions that limit plantings or limit tree growth. Residents described context-specific conditions that were not ideal for trees. One suburban resident explained that the soil in their yard was compacted and required amendments for trees to thrive. Hot weather was also listed as a concern by residents and one reason that their home was not a good place for trees to grow. Another city resident worried that air pollution emitted in their neighborhood was harmful to tree growth. Finally, a few suburban residents said that wildlife posed a threat to trees: "deer will eat new trees and understory".

However, overall, these environmental and site conditions were infrequently mentioned. Only eight residents total commented that the growing conditions in their neighborhoods made it difficult to plant trees.

Maintenance barriers refer to challenges and expenses associated with tree care that caused residents to not plant a tree or maintenance-related issues that led to tree mortality. Maintenance barriers were mentioned by residents in all eight communities, with expense, nuisance, and falling limbs/trees most frequently described (Table 4). Residents discussed the expense of upkeep across the lifecycle of a tree, recognizing that trees can cost residents money for decades. For example, one city resident shared "Free trees are not the true cost- it's 35 plus years of expenses in tree care". They gave examples of expenses such as watering,

Table 2
Definitions of barriers with sample responses, with quotation marks around direct quotations (other sample responses are paraphrased).

Barrier Category	Barrier sub-category	Definition	Sample responses
Physical barriers		Urban design features that constrain plantable space	
	Limited Space	Limited plantable space due to houses with no yards, neighborhoods with no parks or open space, narrow sidewalks, and/or dense urban development	*"There are all rowhomes around here with a postage stamp size yard."* *"Width of sidewalks is an issue, if a tree is planted on the sidewalk, it takes up half the sidewalk, and you need enough space to walk by."* *"It's difficult in general because it's a dense urban environment."*
	Infrastructure conflicts	Conflicts, challenges, and limitations created by trees damaging underground pipes, housing foundations, or overhead wires	*"It's tricky to find space to plant - don't want too close to your house and not so deep that it's close to water lines."* *Had to cut down a tree in backyard because the roots were starting to intrude on house/ infrastructure.*
Environmental and Site Conditions		Environmental conditions that limit plantings or limit tree growth	*Deer will eat new trees and understory.* *The soil and weather aren't good for planting.* *Concerns trees won't do well with pollution.*
Maintenance		Difficulties with tree care and maintenance causing residents to opt not to plant a tree, or maintenance-related issues why trees do not survive	
	Expense	Expense of upkeep, including pruning, branch removal and tree and stump removal	*"Free trees are not the true cost- it's 35+ years of expenses in tree care."* *Don't have the resources to purchase a tree.* *Hesitant because of costs of care is increasing.*
	Nuisance	Nuisances created by falling leaves, fruit, and branches. Presence of birds and squirrels	*Leaves falling, makes squirrel problem worse.* *Trees are messy, they drop pollen and flowers.*
	Falling limbs/ trees	Concerns that limbs or trees will fall and damage property	*"I don't know if I want a tree because trees fall, especially with bad weather."*
	Removals	Tree removed for any reason	*People cut down trees because they are concerned about the dangers posed by trees, storms knock them down.*
	Responsibility	Residents concerned about the responsibility associated with caring for a tree (e.g., watering, pruning, removal)	*Neighbors (new) moving in don't have experience with trees and don't understand that they require responsibility for maintaining them.* *Residents need to make sure to sweep up the leaves.*
Knowledge		Limited knowledge about how to request a tree or care for a tree	
	Tree Care	Feel as if they lack the necessary expertise on how to care for a tree or how to plant it properly so it will survive	*"I wouldn't know where to plant a tree." Does not know how to get a tree and if it will survive* *Not sure know which trees will do well in the city.*
	Tree Applications	Interested but do not know who to contact regarding getting a tree	*Not sure know how to get the paperwork to request a tree.*
	Jurisdiction	Unfamiliar with the rules on what can or cannot be planted on the street or sidewalk, zoning laws or how to get necessary permissions to plant a tree	*Concerns that the city would fine resident for planting a tree, the city typically plants trees.*
Aesthetic and landscape preferences		Personal preferences for the use and appearance of the landscape that impact participation in tree-planting initiatives	
	Limited interest	People do not want a tree	*There is a lack of urgency. Trees aren't something that people think about, they have other priorities.* *Nobody cares enough to do it.*
	Enough trees	People think there are already enough trees on their property or in their neighborhood	*There are enough [trees] here.*
	Specific species preferred	People prefer specific trees species due to space constraints, preferences for particular species, or concerns about large trees	*Would like more trees planted, especially native trees.* *Most people want a flowering tree but PHS will only approve a small stature tree.* *Neighbors loved having the trees, but the city planted trees that were too big.*

(*continued on next page*)

Table 2 (*continued*)

Barrier Category	Barrier sub-category	Definition	Sample responses
	Conflict with neighbors	Conflicts about the presence of a tree or the condition of a tree among neighbors	*Had to get a tree cut down because it was dangerous and had to fight with the neighbor to get it down.* *You can't ignore your neighbors when your tree impacts them.*
	Prefer more sun	People prefer to receive more sunlight (e.g., gardening, solar panels)	*"[Trees] provide shade but interfere with my garden."*
	Allergies	People affected by tree pollen-related allergies	*There are a lot of white ash trees planted in Philly, and these trees can cause allergies."*
Institutional		Rules and practices for tree care by municipal agencies, utility companies, and developers	
	Renter	Renters must get permission from their landlords to plant a tree	*Property manager wouldn't like it if resident planted a tree.* *"Not sure I'm allowed to plant a tree here."*
	No jurisdiction	People do not have the authority to plant or get involved in tree stewardship in certain types of places	*Concerned the city would fine resident for planting a tree.* *Not sure about laws regarding trees.*
	City	City does not take care of trees. City lacks sufficient budget and resources to care for trees	*Disease killed the trees on her street 25 years ago and resident had to fight the City to pay for tree removal.* *Not clear what the town will do to maintain trees.*
	Replacement	Trees that have fallen or been removed due to development have not been replaced	*Took down 20 mature trees because of new development, was told there would be no replacement.*

pruning, and tree/stump removal (e.g., hiring a tree care company). Suburban residents provided detailed concerns with tree maintenance, including the expense (e.g. pruning), fears of falling limbs and trees, and tree removal, while city residents emphasized overall "personal responsibility for tree care". Additionally, some residents, particularly in low-canopy communities, described leaves, fruit, and branches that trees drop on the ground as a nuisance. The dropping of leaves and branches can require raking, and fruit droppings could attract unwanted wildlife, including birds and squirrels. A suburban resident described this nuisance as having "too many 'nightmare' trees on my block. A maple that the leaves go everywhere". Others described not wanting leaves or sap to fall on their cars. Residents also expressed concerns over falling branches and trees that could damage property, leading to tree removals due to concerns about trees falling during a storm. Residents from high-canopy areas had particular concerns about large trees, which in few cases prompted residents to pre-emptively remove trees. Finally, residents commented that the responsibility and labor associated with having a tree, including watering, pruning, and removal, presented a barrier. In some cases, residents commented that they did not want to take on this responsibility, while others commented that they did not fully understand what this responsibility would entail, and thus they would be hesitant to take it on.

Knowledge barriers refer to residents' limited knowledge about how to request or care for a tree. Knowledge of tree care was one of the most frequent barriers described among residents in all neighborhoods. For instance, residents commented that they lacked the expertise on how to plant and care for a tree. One suburban resident shared, "there aren't many resources for learning how to plant and care for trees". In other cases, residents reported that they were interested in planting a tree, but did not know who to contact to request a tree or what the paperwork would entail. Many suburban residents expressed the aforementioned knowledge gap about requesting trees, including people living in high-canopy communities. Finally, some city residents in low-canopy neighborhoods said that they were unfamiliar with the rules about where trees could be planted (particularly for street trees) or how to request permission to plant a tree. A few respondents described concerns over legality of personally planting a tree or if zoning ordinances would allow new trees. "The rules could be more transparent," said one suburban resident.

Aesthetic and landscape preferences refer to personal preferences for the use and appearance of the landscape (including yards) that impacted participation in TPIs or what types of trees residents would plant. In some cases, residents commented that there was limited interest in planting because people have other priorities. For example, a suburban resident shared "most people aren't thinking about trees, they lack knowledge about trees and might prefer to plant things like herbs". In other places, residents said that there were enough trees on their property and neighborhood, thus no new trees are needed. Some residents indicated that they would like to plant only specific species, often small-stature or flowering trees. These residents often expressed concerns about large shade trees becoming too big and/or falling and damaging property. Residents reported having incidents with neighbors about trees, connecting maintenance concerns with landscape priorities that sustain neighborly relationships. Residents seeking to avoid conflict with their neighbors over trees were hesitant to plant new trees. Additionally, some residents commented that they preferred having a yard with open space and sunlight for flowers, vegetable gardens and play areas for children. For example, one suburban resident liked shade trees on their block but did not plant in their yard because "they interfere with my garden". One resident expressed concern over allergies from tree pollen.

Institutional barriers refer to the rules and practices for tree planting and care by municipal agencies, utility companies and developers. In city neighborhoods, institutional barriers were often described by renters, who were required to receive permission from their landlords to plant trees. Other residents commented that they felt that they had no jurisdiction to plant or get involved in tree stewardship in certain types of places, such as apartment buildings, condominium complexes or in public parks. For example, one city resident shared that they did not know if they would be allowed to plant at their apartment and assumed that someone else was in charge of landscaping. In Philadelphia neighborhoods, some residents expressed concern that they would be fined by the City for planting. Finally, several Philadelphia residents said that the City did not have enough resources to adequately care for trees. Multiple city residents commented that the City does not take care of trees (Table 4); this concern with municipal management was the most frequently cited barrier among Philadelphia residents in this category. A handful of suburban residents also expressed similar dissatisfaction with municipal tree care. Residents of Philadelphia neighborhoods observed that fallen or removed trees were not being replaced. One city resident described the removal of twenty mature trees due to development and expressed frustration that there was not an effort to replace them. A city resident from a different neighborhood commented that their street was lined with "wonderful old trees" but that these trees were dying and

needed to be replaced. Both suburban and city residents commented that trees were not replaced after they were removed for development, and residents from high-canopy neighborhoods felt that a lack of replacement trees created a barrier for increasing tree canopy.

In order of frequency of mentions by our interview participants, the aforementioned major barrier categories were: maintenance (51 %), knowledge (42 %), institutional (38 %), land use and aesthetic preferences (27 %), and environmental and site conditions (9 %) (Table 3). Overall, the most frequently cited subcategories were housing density/cement and a lack of knowledge about tree care (Table 4). Suburban residents emphasized housing density, cost of maintenance, concerns about falling limbs/trees, and (limited) knowledge of tree care and tree applications. Suburban residents also focused on landscape and aesthetic preferences related to specific species or land use preferences. These barriers were also discussed by residents in high-canopy neighborhoods, in addition to concerns over the presence of older trees and a lack of effort by institutions (e.g., municipal agencies) to replace them. City residents emphasized housing density and a lack of knowledge of tree care, but also raised concerns about how the City cares for trees. In low-canopy neighborhoods, many residents described tree nuisances, along with housing density and a lack of knowledge regarding tree care.

5. Discussion and Conclusion

In this study, we aimed to address two gaps in research on barriers to TPIs. First, we examined barriers from the perspective of residents, as opposed to municipalities or TPI leaders. While municipalities and community organizations often initiate and lead TPIs, residents are critical stewards of local canopy and essential actors in request-based planting programs (Conway et al., 2021; Eisenman et al., 2021; Geron et al., 2023; Watkins et al., 2018). A large portion of plantable space is on private land (Nguyen et al., 2017), and residents also care for trees on public land in many US cities as a response to limited municipal resources for tree care (Watkins et al., 2018). Recognition and respect of resident experiences, needs, and land use priorities is central to equitable and just urban forestry (Campbell et al., 2022), and our study provides insight into public perceptions of trees. Second, we conducted comparative research across different urban contexts within a metropolitan area to understand how pervasive or context-specific barriers are in different places. Few studies have examined geographic variation in barriers (but see: Baptiste et al., 2015; Hauer and Peterson, 2016; Kloster et al., 2021), and these studies have focused on a single neighborhood or an entire metropolitan area. Given the decentralized nature of TPIs, improved understandings of hyperlocal barriers experiences are critical to implementing successful programs that address community concerns.

Similar to recent studies in other US and Australian cities, our study suggests that—in general—people appreciate the benefits of trees, but have concerns about tree management, maintenance, and responsibility (Grant, 2023; Kendal et al., 2022; Leets et al., 2022). Our study uncovered similar types of barriers as recent reviews on GI barriers (Deely et al., 2020; Heidari et al., 2023), and we expanded on that past work by defining distinct categories and subcategories of barriers for residents (Table 4). The broad convergence with barrier types identified in Deely et al. (2020) and Heidari et al. (2023) is important to highlight given that their reviews included a wide array of professionals (e.g., staff at municipal departments, policymakers, community organization personnel), and were not focused on resident perceptions. Thus, our results suggest that many residents are acutely aware of common barriers to tree planting and care and that there may be parallel experiences with barriers among residents and professional stakeholders. At the same time, the emphasis placed on particular barriers (e.g., knowledge) in different geographic contexts indicates important nuances for residents as key actors in urban forestry, a finding that reinforces recent work on TPI in mid-size towns (Geron et al., 2023; Healy et al., 2023). Our results suggest that there is need to better understand how barriers have multiple dimensions that are shaped by local context. For instance, lack of knowledge about how to care for trees was discussed in each community, but city residents tended to raise questions about where

Table 3
Frequency of overall barriers based on percent of people who referred to each barrier category.

	City (n=47)	Suburban (n=46)	High Canopy (n=50)	Low Canopy (n=43)	Total (n=93)
	%	%	%	%	%
Physical barriers	57	67	56	70	62
Environmental and Site Conditions	9	9	8	9	9
Maintenance	45	57	52	49	51
Knowledge	43	41	46	37	42
Land use and aesthetic preferences	17	37	28	26	27
Institutional	53	22	44	30	38

Table 4
Frequency of barriers subcategories based on percent of people who referred to each subcategory.

	Percentage of Codes by Participant subcategory				
	City (n=47)	Suburban (n=46)	High Canopy (n=50)	Low Canopy (n=43)	Total (n=93)
	%	%	%	%	%
Physical barriers					
Lack of Space					
No Yards	11	13	10	14	12
No parks or open space	4	13	8	9	8
Narrow sidewalks	17	4	6	16	11
Housing density/ cement	21	26	18	30	23
Infrastructure conflicts					
Wires	4	2	4	2	3
Pipes	6	11	10	7	9
Housing foundations	2	11	6	7	6
Old trees	11	15	14	12	13
Environmental and Site Conditions					
Environmental and Site Conditions	9	9	12	5	9
Maintenance					
Expense	15	22	22	14	18
Nuisance	17	20	12	26	18
Falling limbs/trees	13	24	20	16	18
Removals	2	15	10	7	9
Responsibility	15	11	10	16	13
Land use and aesthetic preferences					
Limited interest	4	13	6	12	9
Enough trees	6	7	10	2	6
Specific species preferred	4	9	8	5	6
Conflict with neighbors	2	9	6	5	5
Prefer more sun	0	7	0	7	3
Allergies	0	2	0	2	1
Institutional					
Renter	15	0	8	7	8
No jurisdiction	17	9	14	12	13
City	21	7	14	14	14
Replacement	17	11	18	9	14
Knowledge					
Tree Care	28	22	26	23	25
Tree applications	11	22	16	14	15
Jurisdiction	11	7	4	14	9

they were allowed to plant a tree, while suburban residents commented that they did not know how to apply for a tree. Understanding this context specificity has important implications for how to overcome barriers in neighborhoods with the greatest need (Matsler et al., 2023). Our results also reinforce the importance of local leadership in TPIs and community engagement to address barriers to TPI in different places (Grant, 2023; Kendal et al., 2022; Morgan and Ries, 2022; Mullenbach et al., 2022).

Our study highlights connections among different barriers over the tree lifecycle. Crucially, some of the concerns raised by residents (e.g., disservices related to old trees, municipal institutional processes) relate to aspects of public and private tree management that are outside the purview of TPIs run by non-profit organizations, like the TT program, which is focused on community organizing for tree planting and young tree stewardship. Nonetheless, residents' concerns about the whole tree lifecycle seem to have ramifications on people's willingness to plant new trees. Notably, to address such concerns, the *Philly Tree Plan* includes specific objectives to improve coordination among institutions and stakeholder groups (PPR, 2023). Residents' concerns about challenges manifesting over tree lifecycles, and their concerns about maintenance and rules around planting, point to policy barriers identified in past GI research (Deely et al., 2020; Heidari et al., 2023).

Our finding that physical barriers comprise a top barrier for residents across the metropolitan area is relatively unique among GI barriers research that has emphasized funding, cognitive barriers, and institutional and governance barriers (de Guzman et al., 2022; Deely et al., 2020; Dhakal and Chevalier, 2017). However, a study in eight towns across Eastern Cape, South Africa also found that limited space is a key barrier to planting trees on public and residential land (Gwedla et al., 2024), suggesting that this may be a common barrier in municipalities globally. Further, we find that physical barriers serve as a through-line for other categories of barriers, and physical barriers relate to the temporal dimension over the lifecycle of a tree. Physical barriers were often raised by residents in low- and high-canopy communities; in other words, physical barriers were not exclusive to low-canopy, high-density areas where such concerns might be expected. However, resident explanations of specific physical barriers varied across localities. Residents from densely built neighborhoods described narrow sidewalks, while residents from lower density neighborhoods expressed concern over infrastructure conflicts. These concerns about physical barriers were connected to fears of falling limbs and property damage as trees mature, including the potential for future neighbor conflicts. Fears around physical barriers related to knowledge barriers, as residents commented that they did not know how to care for a tree and were not sure if trees planted today would damage built structures in the future. In city neighborhoods, concerns about falling limbs were also linked to institutional barriers, related to inadequate municipal maintenance of dying or hazardous trees on public property, leading to property damage for residents, a finding that has been described in Detroit, MI and Los Angeles, CA (Carmichael and McDonough, 2019; de Guzman et al., 2022).

Primarily in suburban towns, but also in some city neighborhoods, perceptions of limited plantable space also related to land use and aesthetic preferences. Residents from suburban neighborhoods described planting a tree as a decision that represented a tradeoff for other uses of their outdoor space, such as flower gardens, solar panels, or open lawns for children to play. The importance of aesthetic motivations for tree planting has been identified previously (Conway et al., 2023; Locke et al., 2015), and our study shows that preferences for other outdoor amenities may create a barrier to planting trees. City residents echoed this sentiment, both for their private outdoor space if they had one, but also in neighborhood parks. They recognized that space was a premium, and that the space used by a tree could be in conflict with space used for sports or other activities. Many residents wanted to have more trees in their neighborhood, but were hesitant to give up some other land use (e.g., parking, recreational field, flower garden). While physical barriers are multifaceted, urban designers, landscape architects, and stormwater engineers have achieved ways of adding pockets of trees and other vegetation in highly dense areas of Philadelphia (Roman et al., 2017), and there is tremendous potential for additional urban greenspace in cities (e.g., parking areas) (Croeser et al., 2022), yet knowledge about such strategies and programs can still be limited among the general public (Conway et al., 2021; Conway et al., 2023). Notably, PHS is well-poised to communicate with residents in the Philadelphia region about options and tradeoffs across different land uses and different kinds of vegetation (e.g., trees, rain gardens, flower gardens, food gardens) due to their varied areas of programming and avenues of public outreach (PHS, 2022).

Maintenance barriers were described by over half of the residents, and these findings reinforce recent studies conducted in Nashville, TN, Washington DC, Detroit, MI, and Los Angeles, CA (Carmichael and McDonough, 2019; de Guzman et al., 2022; Leets et al., 2022; Morgan and Ries, 2022). While multiple TPIs have sought to reduce the barrier to planting a tree by offering residents free trees and/or assistance with planting, many programs in the US rely on residents to take on the responsibility of tree care for the following years or even decades, including in public spaces like sidewalks as well as private yards (Geron et al., 2023; Ko et al., 2016). Post-planting maintenance is a small component of most TPI funding in the US (Eisenman et al., 2021). In our study, residents took seriously the responsibility they would assume if they were to plant a tree, recognizing the need for ongoing maintenance and associated time, money, and physical labor, and that without their ongoing stewardship, the tree will not thrive. As such, residents see this 'ask' for maintenance across the lifecycle as a barrier to accepting a free tree. For trees under public jurisdiction, such as street and park trees, some municipalities and TPIs have attempted to overcome these barriers by stepping up proactive management of older trees, paying work crews for young tree care, and having municipalities more fully assume responsibility for street tree maintenance (Breger et al., 2019; Fracassa, 2018; PPR, 2023). Notably, in recognition of the need to support maintenance during young tree establishment, the PHS TT program has recently invested in a new staff position to support post-planting tree care, focusing on low-canopy and under-resourced neighborhoods.

Finally, our study contributes to understanding knowledge as a barrier by presenting multiple dimensions of knowledge. Previous research has suggested that lived experiences with GI (Baptiste et al., 2015) and interest in using outdoor space for nature activities (Conway et al., 2021) is associated with greater awareness of the term "green infrastructure" and higher participation in GI programs. Awareness of local initiatives is another important facet of knowledge pertaining to program implementation (Conway et al., 2021), in that residents generally participate in a program if they know that the program exists. The three subcategories of knowledge barriers identified in our study were how to apply for a tree, uncertainty about whether residents were allowed to plant in different places, and lack of knowledge surrounding tree care. Even in our eight communities with active TPIs, 42 % of residents mentioned knowledge as a barrier. For instance, one participant mentioned a general lack of resources about tree planting and care, despite the existence of extensive resources of this sort from PHS and other organizations in the city and state (e.g., in-person and online trainings, TT handbook). This finding reinforces recent calls for greater outreach and education that goes beyond educating residents about the benefits of trees (Heidari et al., 2023). The PHS TT program already seeks to enhance community leader knowledge through their trainings, which address tree care techniques and advocacy strategies while also promoting the importance of local neighborhood engagement. More research is needed regarding the effectiveness of communication, outreach, and engagement strategies about TPIs for the general public, including how such strategies impact multiple dimensions of knowledge and resident participation, and what communication messages and modalities are most effective in different urban and suburban contexts (Hand and Doick, 2019; Hand et al., 2019).

Our study extends previous research by highlighting the importance of co-stewardship among TPIs and residents over the lifecycle of the tree (Geron et al., 2023; Ko et al., 2016). TPIs focus on planting trees, yet our study showed that residents take a long-term approach to tree care and anticipate barriers that may emerge well after trees are planted (e.g., expense of tree maintenance, preventing infrastructure and neighbor conflicts). Our qualitative investigation with mixed deductive and inductive coding expanded the array of barriers to TPIs (and GI more broadly) from previous literature by identifying major categories and subcategories and the contextual factors underlying those barriers in different places (Table 2), as well as multi-dimensional barriers that can be further tested and explored through future research, including through structured surveys. Future studies would benefit from larger, representative samples to be able to make stronger inferences about variation in residents' opinions across neighborhoods and sociodemographic groups, and the factors that influence residents' opinions and their willingness to plant trees (Ordóñez Barona et al., 2021). Given that our study was limited to one post-industrial metropolitan area in the northeastern US, we see need for comparative research across different regions and countries, where there are different TPI processes, local urban forest governance, and cultural norms (Eisenman et al., 2021; Gwedla et al., 2022; Ordóñez et al., 2019).

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CRediT authorship contribution statement

Hamil Pearsall: Conceptualization, Methodology, Formal analysis, Writing – original draft. **Elizabeth Riedman:** Conceptualization, Methodology, Formal analysis, Writing – original draft. **Lara A. Roman:** Conceptualization, Methodology, Writing – original draft. **Amber Grant:** Conceptualization, Methodology, Writing – review & editing. **Asha-Lé Davis:** Conceptualization, Methodology, Writing – review & editing. **Dana Dentice:** Conceptualization, Methodology, Writing – review & editing. **Tim Ifill:** Conceptualization, Methodology, Writing – Writing – review & editing. **Mindy Maslin:** Conceptualization, Methodology, Writing – review & editing. **Jehane Samaha:** Conceptualization, Methodology, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2024.128326.

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