UNIVERSITY OF CALIFORNIA

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Hot Climate, Cool Shade:

Community-Based Methods for Urban Forest Equity and Heat Health

A dissertation submitted in partial satisfaction of the requirements for the degree

Doctor of Philosophy in Environment and Sustainability

by

Edith Ben-Horin de Guzman

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ABSTRACT OF THE DISSERTATION

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Professor Elizabeth C. Koslov, Co-Chair

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In a growing number of cities around the world, urban forestry is receiving investment for its social and ecological benefits. As the planet warms, advancing urban forest equity by planting trees in marginalized neighborhoods is acknowledged as a climate health equity strategy to counter heat exposure, which disproportionately burdens under-resourced communities. However, significant barriers exist to growing robust urban forests, and tradeoffs of tree planting are often not considered. In drier climates, complex logistics of watering during a multi-year establishment period pose a challenge because street trees are typically unirrigated and funding for maintenance is generally insufficient, creating an expectation that community members will provide stewardship. This dissertation presents three mixed-methods studies. The first is an empirical investigation of the thermal benefits of trees on residential spaces, contributing insights about time-of-day indoor heat exposure by residents who have limited access to air conditioning. Varied theory-guided community methods are then tested to explore the potential of resident engagement in tree stewardship to advance urban forest equity and reduce heat risk. A second study explores behavior change strategies around resident volunteerism in tree stewardship, testing environmental health and public health interventions and correlating outcomes to the degree of engagement with a community organization. A third study presents an alternative approach which equips frontline community members by providing compensation, training, and a support network as they engage neighbor-to-neighbor around tree stewardship and heat mitigation. These studies serve to elucidate the suite of expectations that the co-production of the urban forest creates, parsing out how reasonable and realistic the assumptions made by these programs are or are not, and evaluating their effectiveness. The potential of tree planting to contribute to green gentrification is also discussed. The dissertation concludes by suggesting that trees are a type of marginal, linear greening that has the benefit of being a nimble, distributed amenity, and which brings a reduced likelihood of unintended consequences compared to more grandiose forms of urban greening – provided it is deeply community-driven. Policy and program implications of the research and possible directions for future research are also provided.

The dissertation of Edith Ben-Horin de Guzman is approved.

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As I sit to write this, I look out my living room window at the latticework of branches of now-mature trees that I convinced my landlady and neighbors to plant in 2009. There's the lime green of the crape myrtle, just leafing out after an unusually long and wet winter. Beyond it, the shiny, olive green willow-like leaves of the African sumac glisten in the sunlight. To its left, the simple elegance of the magnolia, whose slow growth makes it seem as though it was planted long after the sumac, though the two trees became arboreal siblings on my street on the same spring day. The 18 new trees we planted on our block changed its look and feel immediately, a transition that would only magnify as the trees matured.

These trees also changed my neighborhood in other ways. After months of preparation that included permitting, inspections, and working out many details ranging from tree delivery to volunteer management, the planting event finally arrived. On that day, I met several of my neighbors for the first time when they showed up to help. In anticipation of the dozens of volunteers, friends, and neighbors who would visit our block, my landlady, Joan Tremayne, dolled herself up with lipstick — something I had never seen this petite, down-to-earth septuagenarian do in the years I had known her. A few weeks later, she pulled me aside and said enthusiastically, "thank you for helping our building not look like a motel anymore!" Though at first I chuckled at her comment, I soon realized that she was conveying her appreciation for an improvement we had realized together and which made our busy street feel more like home. We had palpably changed our neighborhood — and our community.

That experience made me curious about the potentiality we each have to be agents of change in our own little corner of the world. It also left me wondering whether a seemingly random

constellation of circumstances must come together in order for such change to happen. This dissertation is the result of that curiosity.

The doorway to the transformative experience I had was training as a volunteer community forester at TreePeople, an organization for which I also worked for many years. I'm indebted to the many colleagues, mentors, and friends I made in my time at TreePeople who inspired me to be a change agent in my own corner of the world, and who taught me that Earth Day is every day. There are too many Treeps to name (you know who you are), but one name cannot be omitted: Andy Lipkis, who planted the seed of the organization as a teenager just a couple of years after the first Earth Day was celebrated in 1970 and who altered the life path of many, myself among them.

Every page of this document is built upon countless conversations, site visits, funding proposals, reports, and late-night email exchanges with a community of support without whom my PhD journey would not have been possible. The idea to go back to school some dozen years after I completed my master's degree (after I thought I was all done with school) came from the work I did with my co-founder on the Los Angeles Urban Cooling Collaborative, Dr. Larry Kalkstein. With his enthusiasm and optimism, Larry helped me rediscover my excitement for the work I was leading as Director of Research at TreePeople. To me, it seemed that the caliber of research we conducted with the rest of the Collaborative felt rather worthy of a PhD, and this work ultimately provided the springboard I needed.

I hadn't begun my PhD journey just yet, and already I enjoyed tremendous luck to have the support of David Eisenman and Alan Barreca, two brilliant minds I had the fortune to collaborate with prior to beginning my doctoral studies. When I approached each of them with the idea of applying for this PhD program, they were immediately supportive and agreed to be on my (at the time imaginary) committee. To those two names I added another two to my committee: Liz Koslov

and Erica Wohldmann. I feel very fortunate that my committee's support and their investment in me never wavered throughout my studies. I have benefited tremendously from the generous guidance and critique each member gave me.

David showed me what the daily work of developing and enhancing one's intellect looks like, and that motivation to do the work is easy when you're inspired by it (if a project doesn't spark joy, he taught me, it's okay to say no). He also showed me that it is possible to align knowledge and skill to the service of ameliorating conditions on our planet and to do so across a wide variety of subject areas with depth and expertise.

Alan showed me how quick synapses coupled with deep acumen and an inextinguishable spirit for solving problems can turn a lifelong mathematical neophyte into a scientist who now relies equally on both sides of her brain. He taught me to ask the right question and to say more with less — two lessons worth their weight in gold.

Erica Wohldmann was a mentor and ally who never balked at the many pivots we took in our collaborative research, and who inspired me with her endless insights, caring, and generosity. Her frequent reminders to keep my soul batteries charged showed me that nourishing my inspiration is the best way to come back to a problem with fresh eyes and replenished energy.

Liz Koslov made me feel like I was safe throwing any number of harebrained ideas and half-baked drafts her way, which she would then faithfully and painstakingly review in order to provide masterful, thought-provoking guidance. I'm convinced she employs some kind of sorcery to turn even the most mundane student writing into a respectable, worthwhile end product. She is a benevolent genius, as brilliant as she is kind and supportive.

At various points on this journey, I received encouragement and inspiration from my fellow PhD students in the program, especially those in my cohort. Noam Rosenthal, Tanner Waters, Chase Niesner, Will Krantz, Jess Heckman, and Emma Barnosky: I look forward to seeing you all flourish and to celebrating your achievements long into the future (Paul Stainier and Viraj Sawant — that goes for you too!). Clare Beer, a fellow advisee of Liz Koslov in the UCLA Geography Department whom I have yet to meet in person, was generous with tips and kind with encouragement about the final phases of the dissertating process. I was also the beneficiary of much behind-the-scenes support from staff and faculty at the Institute of the Environment and Sustainability, who went through growing pains with me and the rest of the first cohort in this brand-new PhD program. Thank you Cully Nordby and Harrison Levy, and the rest of the IoES team.

No words can adequately describe how absolutely impossible, completely unachievable, and wholly out of reach this endeavor would have been without the neverending support of my husband, Jolly de Guzman. Like a Jedi master, he knew just what needed to happen at every turn. He was a sounding board when I had a new idea, a navigator when I didn't know where to go, a spotter when I needed someone to catch me — and, just as importantly, he got out of the way when I needed him to. The infinite number of meals he cooked and laundry loads he did kept us both sane. If he ever felt that his sacrifices were not seen or appreciated, he never conveyed it — deliberately making sure not to add to my load.

My family and friends kept my heart full with their love and my spirit lifted with their cheerleading. My parents, Shoshana and Samuel Ben-Horin, reminded me that tenacity comes in many forms and is sometimes only visible in retrospect. I am indebted to them for nourishing my curiosity from a young age and helping me believe that there was no reason I couldn't do any thing I imagined. To my sister and brother-in law, Hilà and Matt, and my nephew and niece, Liam and Sophia: every meal and gathering with you helped punctuate what sometimes felt like an interminable PhD process with moments of joy. To my friends who heard me say "sorry, I can't" for five years — I'm about to cash in on those rainchecks!

And of course, none of this would have come to fruition without the many committed collaborators, participants, funders, and supporters of the work I present in this document.

Chapter 1 didn't come together until Cristina Basurto, in her always big-hearted way, said yes to having me share her story. Cristina's influence is all over each of these chapters, and I feel fortunate that she and I continue to travel in the same orbit almost two decades after we first met. She and her family continue to inspire me.

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PUBLICATIONS

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CHAPTER 1
Introduction: Cities, Climate, and Trees

Cristina Basurto never planned to become the ad hoc leader of an urban forestry movement in Huntington Park, California. She and her family were focused on the daily challenges of raising two autistic children and caring for her aging parents. "The doctors said that Samuel would never speak, and that he would probably be institutionalized by his eighteenth birthday," Cristina told me about nine-year-old Sammy, her eldest. Improving her neighborhood was far from her mind.

Seeking activities that her family could do together, Cristina's friend and colleague Rosa suggested she bring her husband and three kids to volunteer at a tree planting and habitat restoration event in the mountains above Los Angeles, organized by the nonprofit organization TreePeople. Cristina had recently been hired by TreePeople as an administrative assistant doing office work, but her job did not entail going out into the field. On a summer morning in 2005, the Basurtos piled into the family car and drove over an hour from their home in Huntington Park up the winding roads of the Santa Monica Mountains to participate in their first volunteer event.

Cristina did not have high expectations. She figured it was a free activity that she and her husband could do together with the kids and that there was no harm in trying it. But as the day's stewardship activities got underway, Sammy, who was almost entirely nonverbal, became engaged almost immediately. He played with sticks. He studied leaves closely. He helped water young trees. He took in the smells of chipped wood used as a groundcover to help sapling roots hold onto precious moisture.

Cristina recalls that the drive home was a turning point in Sammy's life — and in the trajectory of the Basurto family. Sitting in the rear seat, Sammy started talking, describing his encounters with insects, how the leaves felt, and what smells he had experienced. Cristina and her husband, Ruben, could not believe what they were witnessing. "He and I just started crying," Cristina recalls. Their son seemed to have discovered a pathway to connect with the world.

> "I got to see that here was a child that can understand concepts that I didn't think he had the ability to. I'd been doing speech therapy. I'd been doing behavioral therapy…but just a couple of hours out here in nature, and he's touched like that? 'I guess we're coming back.' That was like the only thing we could say to each other. 'It [took] a long time [to drive to the event], but I guess we're coming back.'"

The Basurtos began to volunteer weekly, eventually logging thousands of volunteer hours at tree planting and care events throughout Los Angeles (LA) County. Along the way, Sammy became more extroverted and communicative. Soon, Cristina began providing a wide variety of support for TreePeople events throughout the LA region — helping with catering, setting up the event spaces, translating whenever Spanish-speaking attendees needed it — with her family always in tow.

Figure 1-1. Cristina and her children at a volunteer event in February 2006. From left to right: Sammy (age 9), Cristina, Andrew (2) and Crystal (7). (Photo credit: Ruben Basurto)

A chance encounter at an event in her neighborhood led Cristina to meet the mayor of Huntington Park, a connection that soon gave her access to decision-makers who would eventually help her broker a long-term tree-planting partnership between TreePeople and the city. In the years that followed, Cristina would succeed in rallying her community of Huntington Park around planting many more trees. She persuaded her boss to let her shift her professional focus to supporting a green vision for her community, ultimately becoming Regional Manager for forestry activities in Huntington Park and surrounding communities. All the while, Cristina's husband and kids came along to volunteer regularly, participating in efforts which mobilized hundreds of community volunteers, including dozens of high school students who interned with Cristina summer after summer. In the years that followed her first volunteer event in 2005, Cristina oversaw planting and care for some 1,600 street trees in Huntington Park with participation from local government offices and support from TreePeople. When mature, these trees are expected to raise Huntington Park's tree canopy cover by a relative 3 to 5% — quite a remarkable transformation for a single resident with a green thumb and an optimistic vision to initiate.

Huntington Park is a low-income, working-class incorporated community in southeast Los Angeles County that is home to 55,000 people living within its 3 square miles. Located on traditional, ancestral, and unceded territory of the Gabrielino/Tongva, Chumash, and Kizh peoples, it is one of the most densely populated cities in the nation's most populous county. More than 97% of people who call Huntington Park home identify as Latino/a, with many recent immigrants, predominantly from Mexico (United States Census Bureau, 2023). It is one of the Gateway Cities, so called because of a strong link to international trade: the region has a heavy manufacturing industry presence and is located along a transportation corridor of major freeways that links to the largest port complex in the country. Consequently, Huntington Park ranks in the highest percentiles for exposure to environmental pollutants (Office of Environmental Health Hazard Assessment, 2020). Access to green space is limited, and tree canopy cover is 11% — about half of the county's average (Los Angeles County Advanced Tree Canopy Viewer, 2023). Heat-related emergency room visits are nearly 50% more likely to occur in Huntington Park than they are in LA County on average (University of California Los Angeles, 2022).

Cristina's random encounter with urban greening and the access she subsequently gained to the levers of power that nonprofit and city agencies afforded her led her to embark on a mission to fundamentally change her neighborhood. Her journey demonstrates how a single individual — propped up by fortuitous linkages to public and private arenas of power — can be an agent for positive change and bring about tangible benefits to the urban landscape and the people who depend on it. But it also raises difficult questions about environmental governance; who should ultimately be responsible for realizing and maintaining public and environmental goods and services; and how resultant outcomes differ if urban greening is initiated and driven by the community versus by government. In a more government-run instance, an urban greening campaign would be funded and administered by a government agency. In contrast with Cristina's initiative, the Massachusetts Greening the Gateway Cities program (unrelated to LA's Gateway Cities region), for example, is a multi-year effort funded and managed by state agency staff who oversee siting, planting, and maintenance (Breger at al., 2019). The program plants thousands of trees in environmental justice neighborhoods of post-industrial cities and is made possible through state funding. It is run by the Massachusetts Department of Conservation and Recreation, in cooperation from municipal agencies and a local nonprofit, and while there are opportunities for community engagement, its greening activities are not reliant on community members for their success.

In Huntington Park, on the other hand, it is unlikely that a significant government-led planting campaign would have occurred without bottom-up initiation and significant commitment to see it through. What if Cristina had not had a transformative experience that she leveraged not only to provide a healthy outlet for her son's development, but also as an avenue to transmute her neighborhood by lining its streets with trees? And if, through some unexpected turn of events, an ambitious urban greening campaign had eventually been initiated and administered by local government instead of by Cristina, would outcomes including tree health and individual and community capacities have differed? The significance of these questions is further elevated when we consider forces that presently influence the spatial, social, and ecological dynamics of cities, including accelerating climate change, the urgency to adapt, and the potential of urban greening to exacerbate gentrification and displacement of low-income communities.

A decades-long shift in the provision of public goods from government to communities and the private sector has served to highlight both the limitations of government in addressing complex social and environmental problems, and the emergence of alternative approaches and mechanisms. These approaches enable individuals and businesses to contribute to the provision of public goods and to solutions in the face of challenges including climate change (Mees et al., 2019). But as governments have adopted entrepreneurial ideologies more suited to competitive markets, the management of public goods and services demands that community members learn how to navigate and negotiate city services — leaving out residents who have less access or lack the time or proficiency to maneuver government programs and policies (Klinenberg, 2015, pp. 139-142; Lowery et al., 1995). In an era when top-down urban governance continues to be fragmented and cities face compounding threats to environmental, social and economic wellbeing, bottom-up approaches requiring new forms of partnership and cooperation between government, residents, and the private sector often emerge to fill the gap, creating new problems along the way.

Among the many areas where this co-production of public goods and services occurs, the management of *urban forests* — defined as a network of all trees and woody plants in an urban area, both on public and private lands (United States Forest Service, N.D.) — demonstrates the tensions and complexities that such alternative governance structures create. Many municipal and nonprofit tree planting programs rely on volunteer engagement of community members as a way of providing *tree stewardship* (or the act of taking on the maintenance and care required to bring a tree to maturity) (de Guzman et al., 2018; Roman et al., 2015). This strategy theoretically enables available funding to be stretched and go toward planting more trees rather than maintaining already-planted trees — arguably a necessity given LA's inability to allocate sufficient funding to urban forest maintenance since the 2008 recession, which has resulted in the city spending less per capita on trees than cities of comparable size, creating an estimated $70-80 million gap to reach robust urban forest management levels (Dudek, 2018).

However, the tradeoffs of this approach are not clear. Proponents of bottom-up or co-managed urban greening point out that community engagement in such civic actions produces both ecological and social benefits (Ostrom, 1990; Krasny & Tidball, 2015). Others criticize the transfer of such responsibilities, pointing out that it represents unreasonable expectations of unpaid labor and exacerbates material inequities, especially for low-income communities where residents must already contend with other burdens and longstanding disinvestment (Pincetl, 2013; Blythe et al., 2018). Indeed, the environmental conditions that residents in Huntington Park and other working-class communities face have long been understood, and top-down attempts to improve those conditions have created a long string of disappointments. As Cristina put it: "We get folks that will come in and say, oh, we have all…these ideas, and [they] get people excited, and [then] nothing comes through."

"This community is overlooked," Cristina told me of her neighborhood. "I grew up with folks always having runny noses, having asthma, having all these issues, and it made me feel like [asking] why. Why in my community?" She began to learn about some of the causes.

> "I didn't understand…until I started doing more of the work…that I was doing with community organizing. That's when I started understanding more because of CBE [Communities for a Better Environment], they had these toxic tours, and I was like, oh my god!"

She also reflected on heat exposure, where in her densely developed, inadequately shaded neighborhood central air conditioning is a luxury: "I learned from my daughter that when it's too hot to sleep at night, I can turn on a fan, soak a shirt in water and put it on to cool my body. After a few hours it dries and I get up to wet it again." "But," she adds, "it's not like that in every community. Other places have shade and air conditioning."

Where does this leave residents of neighborhoods that have long borne the brunt of industrial activities which fuel local, regional — and in LA's case, national and international — economies? In the absence of comprehensive and consistent government services, it can be difficult to imagine how conditions are expected to improve. Often, that burden is absorbed by residents.

"This is where I've decided to settle, and knowing all this I still don't want to move, because then I feel like there is a lot of the community that still needs support and help," Cristina said. "How can I move away to a better place [if] I didn't do anything for my community to make it better? I can't continue to grow unless my community grows with me," she explained.

As governance debates play out in cities around the world, many tree planting programs continue to be designed on the basis of limited or lacking evidence about the impacts and effectiveness of engaging — or in Cristina's case, relying — on community members. Gaps in the provision of services continue to be filled in random, oftentimes inequitable ways, and programs which are typically not evaluated beyond metrics such as number of trees planted leave an array of unanswered questions about how community engagement in tree stewardship impacts community members, their neighborhoods, and the urban forest itself.

This dissertation aims to tackle these questions by interrogating how reliance on the community in urban forest management impacts *urban forest equity*, which for our purposes will be defined both as distributional equity (or how equitably tree cover is distributed among neighborhoods in the same city or region) (Landry & Chakraborty, 2009; Riley & Gardiner, 2020), and as procedural and recognitional equity (Grant et al., 2022; Campbell et al., 2022). Procedural equity refers to creating inclusive opportunities for participation in the array of community-level activities that relate to urban forest management — including community meetings, stewardship actions, and other tree-related activities; recognitional equity considers and makes space for perspectives of disadvantaged groups as they relate to trees, acknowledging the historical and institutional factors that shape them (Grant et al., 2022).

Specifically, this dissertation engages with the topic of urban forest equity through the lens of challenges that a hotter climate creates, including increased heat-health risk and the role trees and their stewardship play in mitigating that risk. I draw on methods from disciplines that include the behavioral sciences, climate science, public health, and urban planning — disciplines that approach urban forest planning and management, environmental governance, climate adaptation, and resilience from varying angles. Interdisciplinary research is inherently fraught with complexities and nuances that arise from differing approaches and methods which emerge from diverse schools of thought and practice. Despite these messy entanglements, it is at the intersections of multiple disciplines that we can begin to investigate and address our era's foremost climate and equity challenges.

1.1 Research context and motivation: Challenges to the urban forest in a hotter climate

Trees provide a variety of benefits including air pollution mitigation, wildlife habitat, and improved mental health (Nowak et al., 2006; Le Roux et al., 2018; Wolf et al., 2020). While tree planting campaigns are often pursued with the promise of multiple benefits, urban forestry has enjoyed increased popularity and investment in many cities in part because trees are considered an effective heat mitigation strategy (Keith et al., 2020). This is important because extreme heat is the leading cause of weather-related deaths in the United States — even before a warming climate is factored in (Karl et al., 2009). Heat disproportionately affects urban low-income communities and people of color, who are more likely to live in urban heat-islands with older housing, limited cooled spaces, and less *urban forest cover* (or UFC, the layer of tree leaves, branches, and stems that provide coverage of the ground when viewed from above) (Jesdale et al., 2013; United States Forest Service, N.D.). Of the dominant built environment strategies for reducing urban heat — which include trees and other types of vegetation, modifications to the urban environment and building materials, and adding inland urban water bodies — trees reduce heat in a wider variety of situations than other strategies, providing cooling through multiple mechanisms of shading, transpiration of heat, and absorption of reflected light heat from other surfaces (O'Malley et al., 2015). By countering urban heat, UFC reduces heat-related illnesses and deaths (Vanos et al., 2012).

If urban forests provide many environmental and health benefits, including heat mitigation, why not just plant more? Answering this question requires weaving a complex fabric of opportunities and challenges, with threads representing a host of realities rooted in urban ecology, political economy, urban planning, and social and environmental equity. The prospect of wide-scale, successful deployment of trees faces significant barriers ranging from invasive pests, to urban development pressures, to entrenched drivers that have led to inequitable distribution of urban forests. In Los Angeles and elsewhere, low-income neighborhoods enjoy a fraction of the UFC that their wealthier counterparts have (Galvin et al., 2019; Schwarz et al., 2015). The lack of certainty about the widespread deployment of trees stems not only from the fact that trees face multiple barriers to thriving in urban environments, but also because planting trees to realize a multitude of benefits is not free from tradeoffs. For instance, when considering the goal of heat mitigation, it is important to understand that trees provide cooling in hot weather but can actually increase the need for wintertime heating (Taha, 2015). Trees also raise indoor humidity, reducing human thermal comfort in humid climates or during humid heat waves (Zhou, et al., 2020). These tradeoffs will be explored further in the subsequent chapters.

Considering the contemporary context of planetary warming, there are two practical, minimum requirements necessary to give urban forests a chance to optimize cooling. First, a holistic, evidence-based approach which considers both the heat mitigation benefits and tradeoffs of trees is needed to inform what species to plant and where to plant. Second, young trees must be provided with a period of establishment care to help them reach maturity to, at a minimum, keep up with the loss of trees that die or are removed. As researcher and practitioner communities continue to make progress toward understanding what and where to plant, providing establishment care remains a monumental challenge and a time- and resource-intensive commitment which necessitates funding that often lacks (Jack-Scott et al., 2013). This barrier is especially pronounced in drier climates, where months-long periods of hot, dry weather require supplemental watering to bring young trees to maturity, when they are able to connect to underground hydrology, be largely self-sustaining, and begin providing maximum benefit.

Within this constellation of challenges lies an additional one: achieving equitable distribution of urban trees is complicated for myriad reasons. These reasons may include a lack of program oversight resulting in haphazard progress, limited funding availability, and physical and ecological constraints (see Figure 1-2), which in environmental justice communities located in more densely built-out parts of the city provide limited plantable sites that do not require pavement removal or other costly site modifications (Danford et al., 2014; Pincetl et al., 2013). This matters because iin many neighborhoods, planting only in available sites is insufficient from an urban forest equity perspective.

Figure 1-2. Tree planting site conditions commonly encountered in Los Angeles. (a) A middle class single-family neighborhood with available planting spaces in both the public parkway and on private yards. (b) A multi-family neighborhood with narrow sidewalks and no parkways. The street is an active walking path to a local elementary school. (c) A commercial street with limited tree-planting options due to narrow sidewalks, overhead utilities, driveways, and lighting/utility/street sign infrastructure. (d) An industrial street with large driveway aprons that limit potential tree planting to the right side of the street, where large trees are not suitable due to power line conflict. (CAPA Strategies, 2021a)

A study that evaluated various tree planting scenarios in Boston found that focusing planting efforts mainly in environmental justice zones resulted in a lower overall canopy increase relative to planting scenarios that prioritized neighborhoods with mixed or higher socioeconomic status, due to site constraints such as narrow sidewalks that cannot accommodate trees and a lack of pervious space suitable for planting (Danford et al., 2014). The study focused only on immediately planting available sites such as vacant tree wells, which represents a less expensive pathway. However, in cities including LA limiting tree planting to presently-available spaces and not expanding efforts to spaces that require removal of impervious surfaces or other site modifications will not result in substantial UFC increase in neighborhoods that could benefit most from additional UFC (CAPA Strategies, 2021b; McPherson et al., 2011). Many of LA's tree planting programs have shifted to prioritizing low-canopy areas while continuing to face physical, social, and funding challenges entrenched in these neighborhoods that are the result of decades of political decision-making. Untangling and addressing these forces to reverse these conditions requires navigating challenges that are embedded in socioeconomics, policy, and the political economy of resource distribution.

Urban forest equity is affected by numerous factors ranging from biophysical conditions to sociocultural processes (Volin et al. 2020; Schwarz et al. 2015; Riley & Gardiner 2020). Biophysical factors include climate zone, precipitation patterns and averages, soil type, and topography, among others, and the Los Angeles region is unusually diverse across all of these categories. In arid and semi-arid regions like Southern California, where summers are typically dry, trees must receive supplemental watering during the multi-year establishment period in order to survive. Indeed, due to these factors the West has both lower UFC and higher levels of UFC inequality compared to other US regions (Volin et al., 2020).

However, urban forest inequity looks different in different cities. While it is generally understood that tree canopy is correlated with socioeconomic variables, that correlation is highly context-specific. Clear relationships often emerge across factors such as minority population, income, education, rentership, imperviousness, and climate zone; but elsewhere those relationships do not correlate (Schwarz et al., 2015; Landry & Chakraborty, 2009; Riley & Gardiner, 2020). For example, in Los Angeles UFC is negatively correlated with percent Black and percent Latino/a but positively correlated with the percent of Asian residents, whereas a population with a higher Asian concentration is negatively correlated with UFC just a few hundred miles north of LA in Sacramento, CA (Schwarz et al., 2015). Contradictions abound, in large part because communities are highly variable, and factors such as the instability of neighborhood demographics and various legacy effects, including redlining, further contribute to these varied associations (Volin et al., 2020; Locke at al., 2021). When looking at income and educational attainment, the picture of inequity becomes clearer in LA: neighborhoods that have lower incomes and where educational attainment levels are low have much lower UFC than their wealthier counterparts (McPherson et al., 2007; Riley & Gardiner, 2020). In cities where overall UFC is relatively high, tree equity tends to be lower, though the strength of that relationship too is variable (Volin et al., 2020).

Considering the long periods required for the establishment of UFC, current conditions may be inherited and serve as reflections of past preferences and processes rather than current forces (Schwarz et al., 2015; Boone et al., 2010; Locke et al., 2021). Many of these forces have led to systemic segregation and have important implications for health (Jesdale et al. 2013). One such historical driver is redlining, a federal government practice of refusing home loans and insurance based on neighborhood safety and desirability rankings tied to race, leading to neighborhoods with high concentrations of minority residents receiving little investment relative to white communities. The practice was in place from the 1930s until the passage of the Fair Housing Act of 1968, yet more than half a century later the legacy patterns of disinvestment are still evident today and they continue to be perpetuated by ongoing discriminatory practices evident in racial gaps in loan denial and mortgage cost (Quillian et al., 2020). A spatial assessment of 108 urban areas in the U.S., including LA, found that in 94% of cases formerly redlined neighborhoods presently have two to three times less tree cover and are on average 2.6°C (4.7°F), and up to 7°C (12.6°F), hotter than their non-redlined counterparts (Hoffman et al., 2020). Another assessment of the impact of redlining on cities, including LA, found that redlined neighborhoods receiving the lowest grade of "D" had an average 23% UFC, while neighborhoods with an "A" grade had an average 43% UFC (Locke et al., 2021). Currently, in many cities trees also lack protection in the face of redevelopment trends, which favor larger homes and higher ratios of hardscape, all while UFC inequity persists between higher- and lower-income neighborhoods (Lee et al., 2017; Pincetl, 2010b). We therefore see that policies and trends compound historical contributors to low UFC.

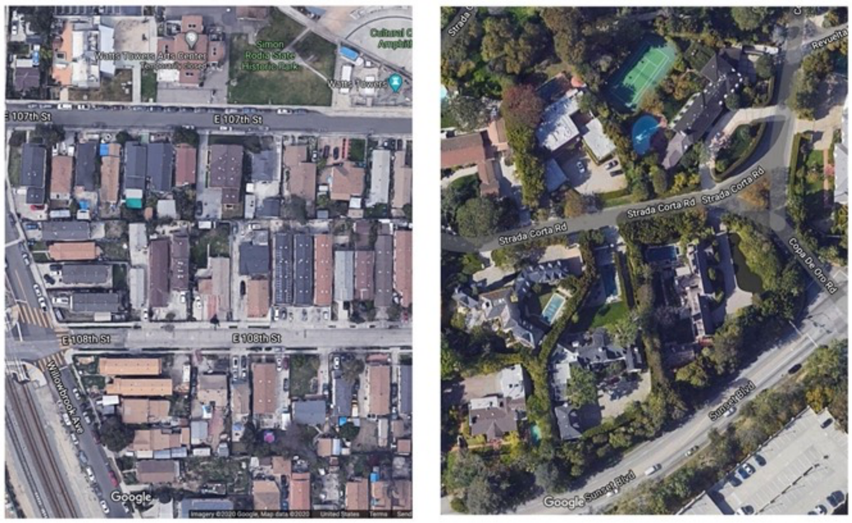

Figure 1-3. Disparities in distribution of tree cover in two Los Angeles neighborhoods. On the left, Watts is a formerly redlined LA City neighborhood graded "D." It has a population that is 60% Latino/a and nearly 40% Black and a median household income of around $25,000/year. The UFC in Watts is 10%. On the right, Bel-Air, which had a mix of "A" and "B" grades, has a UFC of 35% and is 83% white. Median household income is more than $200,000/year. (Galvin et al., 2019; Los Angeles Times 2021a and 2021b) (Image: Google Maps)

How residents think about trees also impacts the distribution of the urban forest. Perceptions are highly variable, and assorted reasons exist for why residents may be unenthusiastic about tree planting. In Detroit, for instance, an evaluation of a nonprofit-led initiative to plant trees in low-income neighborhoods found that one-quarter of residents declined an offer for free tree planting because of a host of negative associations including feeling that residents' values were not adequately considered and a perceived lack of assistance with tree maintenance such as deferred pruning or removal of dead trees (Carmichael & McDonough, 2019). Other concerns may also emerge. Trees can cause problems even as they provide benefits, and in certain cases maintenance costs can exceed the benefits or the willingness and ability of local residents to provide maintenance (Schwarz et al., 2015).

The transfer of watering responsibility from municipalities and tree-planting organizations to residents is another reason why residents may be resistant, and is a factor that raises a host of questions about the political economy of watering and how that affects equity. While watering is not the only tree maintenance activity required in the establishment period of young trees, it is an action that must be done frequently and is a determining factor in the ultimate success or failure of a planting program. Thus, at a pragmatic level, increasing UFC and addressing inequities is a question of resources, where the money comes from to pay for ongoing maintenance, and who should perform that maintenance.

1.2 Whose tree is it anyway? Complexities of urban forest co-production

A broad range of actors — from local users to volunteers to the professional managers — play a role in stewarding resources within shared social and ecological systems, including that of urban forest (Ernstson, 2013). In Los Angeles, the responsibility for planting street trees — trees that are planted in the parkway, the public right-of-way planting strip between the sidewalk and curb — falls on local government and nonprofit organizations. But planting a tree is only the first step, and a tree must be cared for until it becomes established by reaching an underground water source a few years after planting. The tasks of watering and other maintenance activities are logistically complex due to urban tree planting locations often being scattered over large geographic areas rather than concentrated in smaller areas, and because street tree planting sites typically do not have automatic irrigation systems. Delivering water from tree to tree is time-intensive and requires sufficient resources to cover costs including labor, transportation, and watering infrastructure (Jack-Scott et al., 2013; Pincetl et al., 2013). Tree-planting municipalities and organizations operate within limited resources, a reality that exists even in environmentally-progressive California, where the importance of greening is widely recognized and where the Greenhouse Gas Reduction Fund and other state-run funding streams produce revenues in support of local greening programs.

There are various approaches to operating public tree-planting programs, ranging from local government-led to nonprofit-led campaigns, with public-private partnerships falling within that spectrum. Trees require physical labor for planting and post-planting maintenance, and urban forest management requires human agency to play a direct role in the production and distribution of related benefits, services, and potential disservices. How and by whom management is performed, and how resultant costs and benefits are shared and distributed is determined largely by directives made by local government, the policies and mandates that influence those directives, and the constellation of resources that are cobbled together to attempt to support them.

In some cases, philanthropic funds may be present — for instance, Betty Brown Casey provided a $50-million endowment to found Casey Trees in Washington D.C., while celebrity Bette Midler committed $200 million to former New York Mayor Bloomberg to plant one million trees (Popkin, 2018; Danis, 2007). Los Angeles has not been the subject of such philanthropic fortune, and instead continues to face a funding shortage which results in reliance on volunteers and private actors to secure public goods. The City has nevertheless embarked upon ambitious tree-planting efforts on several occasions in recent decades. In advance of the 1984 Olympics, an effort to plant and distribute one million trees was undertaken and was led by volunteers (Lipkis, 1984). In 2007, under the leadership of newly-elected LA Mayor Antonio Villaraigosa, the City launched Million Trees Los Angeles (MTLA), a private-public partnership designed to rely on nonprofit partners to plant trees and help raise the funds necessary to do so (Pincetl et al., 2013; Garrison, 2021). The MTLA initiative had mixed results. It received a fair amount of press attention, but clearly fell short of its million-tree goal, succeeding in planting approximately 400,000 trees (City Plants, personal communication, June 4, 2021). MTLA set out to address tree inequity, but in practice plantings occurred opportunistically where private-public partnerships could be established (Pincetl et al., 2013), and while efforts were made to prioritize under-represented neighborhoods, program records were insufficiently detailed to confirm this outcome (Garrison, 2021). Residents in lower-income communities sometimes declined trees due to perceptions that trees provide spaces for criminals to hide — a perception that has been countered in research and practice (Troy et al., 2012; Kuo and Sullivan, 2001) but which nevertheless created a reluctance to embrace MTLA's efforts in some neighborhoods (Pincetl, 2010b). Additionally, an opt-in process for requesting a tree required a signature, which discouraged residents in communities with many immigrants, multi-family homes, or high rentership (Pincetl, 2010b).

More recently, LA's "Green New Deal" — a 2019 update to the City's original *Sustainable City pLAn* first published in 2015 — calls for increasing tree canopy in disadvantaged communities by 50% in time for the 2028 Olympics coming to Los Angeles (City of Los Angeles, 2019). Considering the urban forest of the City of Los Angeles is composed of approximately 10.8 million trees (McPherson et al., 2011), increasing tree canopy by 50% is a highly ambitious goal that would require significant investment and resources to achieve. To facilitate achieving these and other urban forestry goals, in 2019 the City of LA hired its first-ever City Forest Officer to oversee City-wide coordination in support of these goals (Los Angeles Daily News, 2019), even as the necessary resources to realize the City's tree-planting goals are still far from secured (City Plants, personal communication, March 8, 2021).

Though grants occasionally provide support for paid crews to perform a specified period of maintenance, in general the responsibility for watering trees once planted rests with the homeowner, tenant, or property manager of the adjacent property, even if the tree planting is initiated by governmental and/or nonprofit entities (City Plants, N.D.). Cities in the LA region use one of two methods to transfer watering responsibility to adjacent properties: depending on the jurisdiction, property owners or managers are either given the opportunity to opt in or opt out of having a new tree planted. Opting in requires a signed form before the tree is planted and asks for the resident to commit to watering the tree for a specified period. Opting out means that a tree is planted unless a signed form is received declining the tree, and is generally the approach taken when a planting campaign includes at least some funding for minimal maintenance by crews — for example, watering on a monthly basis (City Plants, personal communication, March 8, 2021). There is little empirical evidence that either the opt in or opt out methods of transferring watering responsibility produce the desired result of healthy trees and residents who are engaged in tree stewardship to help make that happen. In Los Angeles, past tree health assessments evaluating the success of street tree planting campaigns have not systematically differentiated between trees that receive maintenance from a hired crew versus those that do not, but limited, random spot check assessments conducted by the City have found that those that do not receive organized maintenance tend to fare more poorly (City Plants, personal communication, March 8, 2021).

Reliance on residents to provide maintenance of trees in the public right-of-way raises fundamental social contract questions about the unequal burden this may present for communities with limited resources relative to their more affluent counterparts. Placing expectations on residents to serve as tree stewards may represent an undue onus on individuals and households with fewer resources and discretionary time, begging the question of whether communities should take on responsibilities traditionally served by government (Pincetl, 2013). In wealthier communities, residents often hire gardeners to maintain landscaping, and watering a tree in the parkway is not a significant ask; but in more resource-constrained communities, that burden falls on the resident (Pincetl, 2010a).

Expecting community members to serve as tree stewards is a form of volunteer-based programming that can make a greening campaign with limited resources financially and logistically possible, and while this practice raises questions, it is also touted as having the potential to support resilience-building, preparedness, and post-disaster recovery (Dark, 2014). However, this stance, too, is problematic. It presupposes that governance of natural assets in public spaces is at best a multi-layered set of responsibilities shared both by the state and community actors (which in reality may see varying degrees of government support), and at worst, the sole responsibility of community members who must invest their own time and resources if they are to reap the benefits of greener neighborhoods. It is also problematic because claims of the efficacy of responsibility-transfer strategies have rarely been evaluated methodically (I discuss this further in Chapter 3). The social, economic, and environmental costs and benefits of this transfer of responsibilities are not fully understood, which is concerning as Los Angeles and cities around the world make decisions about how to adapt to climate change and how to equip communities to be resilient to extreme events that may overwhelm the capacity of government institutions and infrastructure systems.

At the same time, the impetus for the rise of collective action toward natural resource management is understandable. In some cases, relying on community members offers a way to get things done in the absence of public resources or political will. Small, hyperlocal decisions about what is governed, by whom, and to what end (Bridge & Perreault, 2009) set the stage for much greater tensions around environmental governance. On the one hand, critiques of the neoliberal shift from state-centric government to a patchwork of actors involved in governance loom large (MacLeod & Goodwin, 1999); on the other hand, stories of decentralized, community-based efforts are celebrated as successes (Mehta et al., 2001).

Beyond the problem of placing potentially unreasonable expectations on under-resourced communities, if we conceive of tree stewardship as a neighborhood resilience and preparedness action it is also relevant to consider critics' concerns about inadequate attention paid to social differentiation, or how the same event or stressor can have dramatically different outcomes for different groups (Blythe et al., 2018). Among other risks identified is the unjust shifting of the burden of response onto vulnerable communities, and the shifting power dynamics that occur as a result of the redistribution of costs and benefits and resultant winners or losers (Blythe et al. 2018). Lodging a stronger criticism, Evans and Reid (2013) question the very concept of resilience by asserting that resilience-thinking requires us to abandon the belief that we can live in a secure world with life as a permanent process, and that we must instead subscribe to the perspective that life requires constant adaptation to dangers beyond our control — and beyond the control of communities, even those that are well organized.

Crises of extreme proportions ranging from devastating wildfires to life-altering pandemic disasters highlight an increasing need to find effective avenues for strengthening communities while supporting physical adaptation of neighborhoods. Subscribing to the notion that under-resourced communities should not be burdened with performing their own adaptation and risk-reduction actions can prevent those communities from having opportunities to foster resilience capacity. Comparing two communities affected by the same flooding disaster, O'Brien, Hayward and Berkes (2009) found that perceptions of individual responsibility for protection being skewed toward oneself rather than external actors and perceptions of future risk explained differences in willingness to take individual adaptive actions in the absence of supportive actions from government. Fostering more control, encouraging empowerment, and enhancing the possibility for people to control aspects of their lives can help counter the judgment or categorization of under-resourced community members as victims in need of expert intervention, and instead promote the perspective that members of those communities play active roles in improving health and resilience (Krasny & Tidball, 2015; Rappaport, 1981).

Many of these debates align with those identified in public choice theory, which conceptualizes public participation as a collective action problem, a "social dilemma" situation in which uncoordinated actions of many may not result in optimal outcomes for all. This collective action problem gives rise to shirking or freeriding — a condition where ecosystem services and public health benefits are enjoyed by the public at large but the costs and responsibility are borne by the good will of a few residents — consequently leading to a lack of cooperative participation that impacts the desired outcomes (Rydin & Pennington, 2000; Pincetl et al., 2013). This is problematic for community-based greening programs because their success relies on small, frequent stewardship actions by many rather than bigger actions taken by fewer actors. But important exceptions exist. In local, small-group situations, where participants are more likely to know each other, there is an increased likelihood of monitoring and enforcing social norms — a logic that led to the familiar slogan "think global, act local" (Rydin & Pennington, 2000). Elinor Ostrom's work supports this notion and provides many examples of local communities that have developed the capacity to counter the collective action problem by fostering social networks within which trust and social capital are built (Ostrom, 1990). Ostrom's work highlights the importance of communities engaging in managing resources at a local level, even if desired changes are modest and incremental, as it often is in the context of community-based tree stewardship. This allows for the necessary ingredients to be in place to counter the collective action problem (Rydin & Pennington, 2000). It does not, however, address the potential for causing undue burden and finding avenues to avoid it.

As opposing stances about the role and tradeoffs of community engagement in environmental governance endure, the practical necessities of providing post-planting tree maintenance remain. Establishment care of trees is a prerequisite if tree health and survival are the desired end (Roman et al., 2014). If that care is not provided by paid crews, then it must be provided by other actors in order for the trees to survive and mature. Indeed, tree stewardship by community members is necessary to sustain tree planting programs that may otherwise fail (Moskell & Allred, 2013). Success hinges in large part on whether direct community-based stewardship actions and the social factors that support it, such as level of community activity and social interactions on a neighborhood street, are present (Lu et al., 2010) — which this dissertation will further explore in subsequent chapters. If, however, the end goal is not purely one of tree health and survival — and the inquiry is broadened to include the impacts on a community's ability to address environmental and social inequities that affect it and to adapt to heat and other environmental challenges — then the consequences that tree stewardship has on community members and not just trees demands attention. In the following chapters, I investigate the impact that community engagement in tree stewardship has on individual and community factors, including self-efficacy, social norms, heat mitigation and heat-health risk reduction, and the advancement of urban forest equity.

1.3 Green gentrification: Does advancing urban forest equity create new inequities?

The discourse on urban forest equity is part of a broader field concerned with environmental justice and the inequitable distribution of a host of environmental services and disservices. Traditionally, environmental justice has focused on the disproportionate burden of undesirable or incompatible land uses in disadvantaged communities (Jennings et al., 2012; Chakraborty, 2009; Schwarz et al., 2015). More recently, the focus has shifted to include consideration of access to and distribution of desirable environmental amenities and natural resources as well. Both lenses acknowledge that the physical environment has a critical role in impacting human health and wellbeing (Jennings et al., 2012).

Environmental gentrification, or green gentrification, is the concern that environmental improvements have the potential to displace lower-income residents as neighborhoods become more appealing (Checker, 2011; Wolch et al., 2014). It is clear that any effort to advance environmental justice must include equitable distribution of environmental amenities, yet creating new green spaces can increase housing costs as neighborhoods become healthier and more attractive — creating a "green space paradox" (Wolch et al., 2014).

Though green gentrification applies to a wide array of improvements, much of the literature exploring this phenomenon focuses on park access and the addition of larger-scale civic projects, with less attention paid to the impacts of green cover or tree planting (Wolch, et al. 2014). Does this imply that street tree planting does not carry the same potential risk of gentrification? A relevant aspect to consider is that of scale. The focus on one tree, versus a grove of trees, versus an entire urban forest has considerable scalar ramifications for environmental justice (Heynen, 2003), and in Chapter 4 of this dissertation I demonstrate through the Tree Ambassador / Promotor Forestal community organizing program that small-scale, community-driven improvements can provide the space for communities to organize and may counter gentrification risk presented by larger, more geographically focused, top-down greening efforts that are government-driven.

Still, the fact that higher tree canopy is generally correlated with higher income suggests the concern over green gentrification caused by tree planting campaigns cannot be dismissed, and that the potential for well-intentioned urban greening efforts to have unintended consequences on residents they are aimed at benefiting must be explored (Schwarz et al., 2015; Volin et al., 2020). This has special relevance in the context of the increasing tendency among many governmental, nonprofit, and philanthropic entities to equate investment in urban forest equity as a proxy for advancing social, economic, health and other types of "equities." Interpreting urban forest inequity as a legacy of redlining and other race-based discriminatory practices allows for investment in tree planting to be justified as an act of urban renewal and a way of redressing historical wrongs (Merse et al., 2009; Campbell et al., 2022), but the potential of trading one type of inequity for another must be attended to.

Urban forest equity continues to be understudied relative to access to and equity of distribution of larger and more geographically-concentrated natural and green spaces such as parks. This distinction matters because parks and other green spaces are tangible amenities and a visible expression of how particular land uses are prioritized in a city or neighborhood. A parcel zoned for recreational land use does not, under most circumstances, also serve a commercial or residential use, pinning green space against other priorities. Even when green space is allocated in parcels zoned for other land uses, it is important to note that green space sited on private residential, commercial, institutional or other parcels is nevertheless private space — even if it is made publicly accessible in some form (Garde, 1999; Loukaitou-Sideris, 1993). In contrast, planting trees does not require a certain type of land use to be assigned or reassigned to an urban space. A parcel's land use designation does not change just because a tree is planted there. While tree planting generally represents a less grandiose expression of green space than a new park might, it is a nimble one that can be woven into the urban fabric and fill small, distributed, interstitial voids where opportunities exist.

Nevertheless, more evidence is needed about how tree planting efforts impact affordability and access to housing. This relationship between increased tree cover and housing cost is described by Heynen (2003), who looks at inequitable urban distribution of trees and argues that such patterns can be understood by recognizing the use-value of trees (or the services they provide such as shading and air quality improvement). If this use-value becomes commodified, it becomes part of the political economy that drives housing markets and affordability (Ernstson 2013). Under this view, the urban forest too has the potential of becoming commodified, which in turn can produce and reinforce uneven patterns of distribution. But there may be ways to green neighborhoods and avoid the undesired effects on housing affordability.

1.4 Modest but meaningful: Community-based marginal, linear greening

In an attempt to create an urban greening framework which incorporates the three concerns of sustainability — environmental, economic, and equity concerns — Cousins (2020) proposes the model of "just nature-based solutions" which focuses on "harnessing the power of nature and people to transform the social, political, and economic drivers of socio-spatial inequality and environmental degradation into opportunities to create progressive, cohesive, antiracist, and social-ecologically sustainable communities." Just nature-based solutions are engagements that mobilize communities to use the mixed, sometime chaotic realities present in their neighborhoods as fuel toward change. In our context, as community members engage in neighborhood-level decision-making surrounding tree planting, they are involved in exchanges that carry transformative potential beyond the end goal of planting a tree. In practice, though, it is important to note that the degree to which a community is involved in or drives a planting campaign varies greatly. The opportunities to leverage local energies, assets, and the good will of residents to transform inequities into fuel for neighborhood change, too, vary widely — and nature-based solutions thus cannot always be assumed to be just.

What, then, are possible pathways for addressing the inequitable distribution of environmental amenities while mitigating unintended outcomes? In the wake of the 2008 crash of the housing market, an approach to make neighborhoods "just green enough" emerged in an effort to minimize the threat of green gentrification while simultaneously providing environmental improvements. This approach seeks to bring clean-up and greening efforts that are organized together with working-class populations and industrial land users rather than around new development of the sort exemplified by the "parks, cafes, and riverwalk model" of a green city (Curran & Hamilton, 2012). A neighborhood that is made just green enough is improved sufficiently to remove an environmental hazard or provide environmental and public health protection, while still maintaining industrial or other uses for the purpose of protecting the tenure of working-class residents. By involving existing residents through engagement and activism, this model attempts to challenge the narrative that gentrification is inevitable and the idea that gentrifiers are necessarily resistant toward and incompatible with long-term residents' wants and needs (Curran & Hamilton, 2012). Wolch et al. (2014) borrow the "just green enough" concept and suggest that the adaptive reuse of infrastructure such as streets, underutilized back alleys, rail corridors, or utility corridors could be used to improve public health outcomes via walking and informal play and exercise while providing ecosystem and social benefits.

Building on the concepts of just nature-based solutions and urban renewal that is just green enough, I suggest that promoting small-scale, marginal, linear interventions in a distributed manner can counter gentrification pressures. Deploying interventions at this smaller scale and in a community-driven manner may avoid the pitfalls that Heynen and Ernstson warn about — namely that greening can contribute to gentrification and housing unaffordability. If linear interventions can advance urban forest equity and not contribute to gentrification, a practical implication is that these urban greening applications can then be added to the practitioner and planner toolbox of interventions that are just green enough. In smaller-scale reforestation projects, residents can enjoy the socio-psychological benefits provided by trees that result in a better quality of life (Heynen 2003), even if changes are not grandiose. However, these efforts must be explicitly shaped by community concerns and desires, and refrain from conventional urban design or ecological restoration approaches that impose a top-down vision divorced from community input (Wolch et al., 2014). To be influenced by the community, and an effort must engage community members from the start and be shaped by feedback about the pros and cons of proposed greening, including consideration of whether greening should be prioritized relative to other needs and desires, and if so, where it should occur and how community members will be involved in the design, planning, execution, and maintenance of the project.

The concept of Urban Green Commons (UGC), too, is relevant to our context. UGC refers to physical green spaces in urban settings of diverse land ownership that depend on collective organization and management and which provide opportunities for strengthening socio-ecological relationships (Colding & Barthel, 2013). The UGC concept has been previously applied to contained common spaces such as community gardens or collectively-managed parks. My dissertation considers the potential of expanding that concept linearly to residential parkways — in a manner that is "just green enough" — and in subsequent chapters I explore the potential of a marginal, linear, and distributed greening to provide environmental and public health benefits.

Street trees planted in the public parkway planting strip represent an accessible space that can democratize access to urban nature. Modeled after planting strips in European streets used as spatial and physical separators between the road and pedestrians, parkways are a feature made common in the American streetscape by Frederick Law Olmstead and Calvert Vaux beginning in the mid-nineteenth century (Southworth & Ben-Joseph, 1995). Parkways serve as public right-of-way easements to all users and uses — from pedestrians to utility infrastructure. In American cities and in other parts of the world, including Australia, parkways are generally the legal property of the city and are thus subject to restrictions around how the space can be used and what can be planted, but — in an arrangement that has been the cause of much misunderstanding and disagreement — they are generally the responsibility of adjacent property owners to maintain (Meenachi-Sunderam & Thompson, 2007). Parkways serve as marginal spaces that, in park-poor neighborhoods, may offer the only open space available to residents (Garde, 1999; Loukaitou-Sideris, 1993). Collectively managing these contested spaces as strands in a larger network of green infrastructure offers opportunities to advance equitable access to protective amenities of shading and cooling, and also holds the potential to avoid the risk of green gentrification that accompanies larger civic green spaces such as parks (Wolch et al., 2014). Sites of experimentation which incorporate nature-based solutions have the capacity to create new urban commons and opportunities for new socio-environmental relationships to be fostered (Cousins, 2020), and parkways offer a space that provides such opportunities.

On the other hand, relying on a city's parkways to provide a linear network of open space raises questions about where the responsibility of producing and maintaining such neighborhood assets should lie, and what tradeoffs emerge when a community-based maintenance regime is adopted rather than a government-supported one. In the context of multiple crises — ranging from a lack of affordable housing, to environmental inequities exacerbated by climate change, to the uneven impacts of the COVID-19 pandemic that many marginalized communities are still reeling from — this dissertation places special consideration around what some of the implications are of elevating parkways to the status of an Urban Green Common. I also consider how this approach relates to advancing urban forest equity and environmental justice and whether it serves to address or perpetuate their root causes.

1.5 Tree stewardship toward resilience and adaptation

An additional dimension that relates to these stewardship dynamics, and which also influences social equity outcomes, is resilience. In a sociological context relevant to this dissertation, resilience is "the ability of groups of communities to cope with external stresses and disturbances as a result of social, political, and environmental change" (Adger, 2000). Resilience also applies in a social-ecological context, where it is defined as "the capacity of a social-ecological system to absorb recurrent disturbances" so as to retain essential structures, processes and feedbacks (Adger, 2000). This latter definition supports the perspective that human and natural systems should not be treated as separate, and that humans are a part of the ecosystem (Brand & Jax, 2007). Participating in shared management of green commons — including trees that line neighborhood streets — leads to cognitive resilience building, or the "human perception, memory and reasoning that people acquire from interacting frequently with local ecosystems, shaping peoples' experiences, world views, and values towards local ecosystems and ultimately towards the biosphere" (Colding & Barthel, 2013). Diversity of both ecological and social systems strengthens resilience and adaptive capacity in social-ecological systems (Colding & Barthel, 2013). If the system can self-organize and learn through making use of diversity, the capacity to adapt and be resilient to stressors increases. The process of engagement gives communities the capacity to develop novel and transformative social-ecological relationships that can begin to address the drivers of inequality (Cousins, 2020), as communities burdened with undesirable land uses and limited green space act to reverse and correct those inequities. Resilience building also occurs as shared management of a resource leads to opportunities for urban residents to go through the progressive steps of becoming better informed and more invested, and participating in decision making. Tree planting programs can facilitate this by offering opportunities for residents to make choices about details such as tree species selection, tree placement, and if and how responsibilities for subsequent care will be divided up.

Shared management of green commons, as an expression of practicing civic ecology, aids in the development of social capital where trust is weak and conflict exists, providing opportunities for strengthening social capital where it already exists (Krasny & Tidball, 2015, p. 55). Klinenberg (2018) expands on this notion and includes a broad suite of publicly available spaces — including but not limited to urban green spaces — in his explanation of the "social infrastructure" assets that build more resilient communities. Such assets include spaces ranging from public institutions such as libraries and athletic fields, to spaces such as sidewalks and courtyards. Social infrastructure, he argues, can help neighborhoods flourish by offering repeated opportunities for social interaction that connects alienated individuals and protects vulnerable communities (Klinenberg, 2018, pp. 14-16). In the wake of the historic 1995 Chicago heat wave, Klinenberg notes, social infrastructure played a key role in protecting some communities from heat disaster while other demographically similar communities with comparatively less social infrastructure in place saw disproportionate losses of life.

Adaptation, too, figures into this discourse. An elusive and arguably overused term, the Intergovernmental Panel on Climate Change defines adaptation as "the process of adjustment to actual or expected climate and its effects," which in human systems aims to reduce harm or leverage beneficial opportunities, while in natural systems aims to facilitate adjustment to expected climate and its effects (Noble et al., 2014). Use of adaptation as a term and framework has grown as responses to climate change have shifted from mitigation (or reducing the sources and/or enhancing the sinks of greenhouse gasses) toward adaptation (Intergovernmental Panel on Climate Change, 2014). The concept of adaptation has been criticized for being applied too freely to describe socio-ecological contexts that are manipulated rather than adapted to (Thomsen et al., 2012). In our context, focus on adaptation acknowledges that mitigation is an insufficient response to climate change, and one that pertains to both social and ecological systems. Adaptation is not a method of coping; it must be deliberate and planned.

Social networks, higher levels of trust in the community, and reciprocal support are considered critical to reducing vulnerability, promoting adaptation, and increasing resilience (Bulkeley, 2013). These factors support the capacity for new values and practices to be disseminated and take hold in a group, and this capacity in turn supports the growth of social collectives that work independently of formal government and other higher-level actors (Pelling, 2011). Cousins (2020) articulates a similar vision in which the "activity-space" of nature-based solutions provides sites of power where distribution of risk and opportunity can be addressed. Transformation of social, political, and economic drivers of inequality and of the uneven distribution of environmental amenities occurs through processes of engagement in decision-making about and stewardship of neighborhood-level amenities. The simple act of engaging in tree stewardship exists on a transformation spectrum that can include grander, more disruptive actions to change socioeconomic and political conditions. Change may be expressed via new social contracts or new power dynamics around class, gender, or ethnicity, enabling new pathways toward social justice and sustainable development to emerge by addressing entrenched causes of risk and vulnerability (Pelling et al., 2015). Even as new trees are planted in the neighborhood, the potential to counter green gentrification and build resilience and adaptive capacity emerge as neighbors exercise their decision-making powers and engage in place making, strengthening the social dynamics that support the transformation of communities and the neighborhoods in which they live.

Small, daily acts embody power, and changes around practices such as land management or social ties are important adaptation strategies that by themselves may be perceived as incremental but together express adaptation and resilience at a greater level (Pelling et al., 2015). In our context, the simple act of planting and caring for a tree creates visible, tangible changes to the neighborhood while simultaneously contributing to increases in individual and collective capacities, which in turn can enable other types of transformative actions to occur. As residents learn, enjoy the fruits of their own actions, and experience opportunities to build trust with their neighbors, planting and caring for trees not only grows heat-protective green infrastructure but cultivates greater adaptive capacity and resilience as well.

1.6 Research objectives

The overarching research questions my dissertation tackles are:

1. What is the role of trees in indoor and outdoor urban heat mitigation?
2. What are the impacts of community-based programs as they relate to the advancement of urban forest equity and heat mitigation?

I define programs that are *community-based* as those that rely on the participation of community members (Mehta et al., 2001; Bridge & Perrault, 2009), and *community* as a group of people with diverse characteristics who are linked by social ties, share common perspectives, and engage in joint action in geographical locations or settings (MacQueen et al., 2001).

The following guiding questions help to operationalize the research discussed in the subsequent chapters. Citations refer to a selection of the literature with which these questions engage.

Chapter 2:

1. What impact do trees have on indoor and outdoor temperatures in residential settings? (Wang et al., 2014)
2. Under what conditions are trees beneficial (or not) to modulating extreme heat? (Zhou et al., 2020)

Chapter 3 and Chapter 4:

3. What is the relationship between community-based tree stewardship and advancing urban forest equity (Pincetl, 2010b)?
4. How do processes and outcomes differ in a voluntary resident-based vs. a compensated approach to tree stewardship? (Blythe et al., 2018)
5. What impact does community engagement in tree stewardship have on the health of the urban forest? (Lu et al., 2010; Moskell & Allred, 2013)
6. What impact does community-based tree stewardship have on heat-risk concern and heat-protective actions? (Lindell & Perry, 2011)

7. How does community-based tree stewardship influence self-efficacy and social norms? (Krasny & Tidball, 2015)
8. Can collective management of residential parkway planting strips increase access to green space by promoting its more equitable distribution? (Colding & Barthel, 2013)
9. What is the relationship between parkway greening and green gentrification? (Curran & Hamilton, 2012; Wolch et al., 2014)

Throughout the course of the research that informed these studies, I engaged with a complex and growing community of research and practice that contributes relevant literature and evidence to the discourse on urban heat mitigation strategies, urban forest equity, and the merits and criticisms of varying tree stewardship approaches. The application of this research meant that relevant developments occurred during the course of my dissertation studies, which were incorporated dynamically, sometimes shifting the direction of the original research plan. Taken together, this dissertation leverages a suite of interdisciplinary investigations to contribute new knowledge about the potential of ameliorating social and environmental conditions through the stewardship of urban nature just beyond one's doorstep — and to obtain an understanding of what community members, their neighborhoods, and the urban forest gain or lose as a result.

As with any researcher, I bring my own set of views and experiences to my research. My manner of relating to the world and to other people is naturally curious and compassionate, but I recognize that those ingredients do not equate to a full understanding of those I encounter as a researcher or practitioner — whether they be research subjects/participants, collaborators, funders, students, faculty, or advisors. I recognize that the way I present — a blue-eyed, light-skinned, small-framed individual without a detectable foreign accent — gives me privileges that people in many marginalized groups do not enjoy. I also recognize that the professional positions I have held with organizations involved in the research presented in this dissertation have the potential of influencing power dynamics in different ways, including influencing actions or beliefs of study participants, and persuading collaborators or fellow students of the merit of pursuing a certain course of action. The way I approach my work — with clear ideas of what I want to accomplish and with a degree of unapologetic intentionality and proactivity — also has the potential of influencing power dynamics.

Conducting research in working-class communities that are largely Latino/a and Black, I intentionally try to remain open to growing my understanding of and connection to others. I try to remember that each of us is not immune to the quick and catastrophic changes that could befall our lives at any moment. Having financial stability, living in a good neighborhood, being educated, or coming from a good home does not preclude us from acting to balance inequities prevalent in so many parts of our city, state, country, and world. To the contrary, I believe enjoying those benefits puts us in the position of responsibility to be agents of positive change. I do not take for granted the fact that I am in the fortunate position to affect change for my fellow Angelenos and Californians.

For better or for worse, these views and experiences permeate my perception of the world and impart my relationships with others accordingly. I try my best to acknowledge that my values and experiences influence my research, and to engage in the work with a curiosity to explore others' experiences and be open to gaining an understanding around the perspectives that I lack.

1.7 Dissertation overview

By exploring the merits and criticisms of community-based tree stewardship, this dissertation contributes to a field where vibrant, robust, and often contested debate continues among researchers and practitioners. The subsequent chapters engage with some of the merits broadly claimed by proponents of community-based tree stewardship, including that resident engagement in environmental stewardship:

- Facilitates other pro-environmental, pro-health, or pro-social behaviors at the individual level (Krasny & Tidball, 2015; Rappaport, 1981);

- Facilitates engagement in other aspects of community life, and thus contributes to sociological benefits including stronger community bonds that facilitate other quality of life improvements beyond greening (Cousins, 2020; Ostrom, 1990; Rydin & Pennington, 2000); and
- Results in a healthier, more robust urban forest (Lu et al., 2010; Moskell & Allred, 2013).

I also engage with some of the critiques lodged against resident engagement in environmental stewardship, including that it:

- Places an unjustified burden on under-resourced communities (Blythe et al., 2018; Pincetl, 2010a; Pincetl, 2013); and
- Does not facilitate individual- and community-level improvements in other aspects of home and community life beyond the original action, or worse, that it creates new problems (Dean, 2015).

I explore the potential that community engagement in tree stewardship has for reducing heat risk and advancing urban forest equity, and consider its relationship to fostering self-efficacy and social norms to broader outcomes around resilience and adaptation. This research strives to contribute knowledge in two areas: understanding of the role trees play in urban heat mitigation; and understanding the merits and criticisms of community-based urban tree stewardship. The foundation of the following chapters is engagement with the literature and discourses on environmental governance, the impact of diverse community methods on urban forest equity, the potential of urban forestry in bridging gaps in heat mitigation, and how these dynamic topics interrelate. Building on that foundation, I take a mixed-methods approach to conduct three studies that enable critical and practical involvement with the problems and questions embedded in these topics.

Chapter 2 presents research that provides empirically-derived validation of the impact of trees on thermal conditions in residential spaces. This component contributes to filling a gap in the literature about the role that trees have on residential thermal conditions, particularly indoor conditions. Weather sensors placed in seven homes representing a mix of low- and high-UFC parcels collected continuous half-hourly data over a period of 11 weeks, which were analyzed in order to evaluate the impact of trees on moderating temperatures during heat waves. The study contributes spatially and temporally granular data on how trees influence indoor (bedroom and living room) and outdoor (eave) temperatures in homes in southeast Los Angeles County, yielding insights about time-of-day heat exposure by residents who have limited access to air conditioning.

Chapter 3 and Chapter 4 present two examples of community-based urban forestry efforts that incorporate varying levels of community engagement and input. Chapter 3 discusses a behavior change study that provides limited avenues for community decision-making and an option of opting out of a request for residents to become tree stewards. This chapter presents an experimental behavior change study to investigate resident volunteerism in tree stewardship, which is the fulcrum upon which many tree planting efforts hinge. This research engaged 116 households in the City of San Fernando (northeast LA County) in a longitudinal study to test two intervention conditions against each other and against a control condition — using messaging that is either generic, public health-focused, or environmental health-focused. It also segmented groups by degree of engagement with a tree planting campaign. Pre- and post-survey data and in-situ observations of soil and tree health were used to evaluate intervention effectiveness in advancing tree stewardship, heat-risk concern, and heat-protective actions, and to gauge changes in knowledge, attitudes, and reported behaviors related to these topics.

Chapter 4 explores an alternative approach, whereby greening efforts are driven through community organizing and neighbor-to-neighbor engagement informs if and where planting will take place. I was embedded with a nonprofit-led team that administered a pilot community organizing Tree Ambassador/Promotor Forestal program which hired and trained residents of low-income, low-UFC communities to engage neighbors in awareness-raising about the link between trees and heat, and to plant and maintain new trees on public and private property. This chapter presents an assessment derived using multiple methods including a focus group, longitudinal surveys, and ethnographic observations.

Chapter 4 offers a counterpoint to the assessment of resident volunteerism in Chapter 3, enabling exploration of the impacts of an approach that relies on voluntary engagement and provides limited guidance, versus one that equips frontline community members, provides compensation and a high degree of assistance via training, and offers a support network of project personnel and other tree ambassadors. Together, these chapters aim to elucidate the suite of expectations that such programs reinforce, parse out how reasonable and realistic the assumptions made by these programs are or are not, and evaluate their effectiveness.

I conclude with a summary of the principal findings and theoretical contributions of this research. Chapter 5 discusses policy and program implications of the research. Possible directions for future research are also presented.

This dissertation follows a three-article format. While each chapter contributes to the arc of the dissertation as a whole, Chapters 2 through 4 were written as stand-alone journal articles. As such, there may be some similarities in the context and implications provided in those chapters.

CHAPTER 2
Evaluating the Impact of Trees on Residential Thermal Conditions Using Community Science[1]

2.1 Introduction

As the global climate changes, cities around the world are experiencing unprecedented shifts including heat waves that are increasing in intensity, duration, and frequency (Perkins-Kirkpatrick and Lewis, 2020). In the Los Angeles (LA) region of California, extremely hot days are projected to be up to 10°F (5.5°C) hotter compared to recent historical trends (Hall et al., 2018). New temperature extremes and compound effects from multiple other stressors portend a future when heat mitigation will be ever-more critical. A recent example of these compounding effects occurred when LA hit 121°F (49.5°C) on September 6, 2020 — its highest-yet recorded temperature. This record was set at the height of the COVID-19 pandemic, when air conditioned public spaces were not widely accessible or desirable, and on the same day the Bobcat Fire began. This wildfire would ultimately burn for three months and scorch over 100,000 acres, producing smoke plumes that heavily impacted the LA area and traveled across the continent and beyond, reaching as far as Europe (Wigglesworth and Cosgrove, 2020; Mukherjee et al., 2022).

Extreme heat is the leading cause of weather-related deaths in the United States even before a warming climate is factored in (Karl et al., 2009). Heat disproportionately affects urban low-income communities and people of color, who are more likely to live in urban heat-islands with older housing, limited cooled spaces, and less *urban forest cover* — or UFC, the layer of tree leaves, branches, and stems that provide coverage of the ground when viewed from above (Jesdale et al.,

[1] This chapter has been accepted for publication in the journal *Cities and the Environment*. The forthcoming citation is: de Guzman, E.B. (in press). "Evaluating the impact of trees on residential thermal conditions in Los Angeles using community science. *Cities and the Environment*.

2013; United States Forest Service, n.d.). Of the dominant built environment strategies for reducing urban heat — which include trees and other types of vegetation, modifications to the urban environment and building materials, and adding inland urban water bodies — trees reduce heat in a wider variety of situations than other strategies, providing cooling through multiple mechanisms (O'Malley, et al. 2015). By countering urban heat, UFC reduces heat-related illnesses and deaths (Vanos et al., 2012; Kalkstein et al., 2022).

Cities around the world have adopted tree planting as a heat-mitigation strategy (Keith et al., 2020), but there are significant gaps in knowledge that stand in the way of optimizing the urban cooling potential of trees. One such area is understanding the effects that trees can have on indoor thermal conditions, and specifically on a room-by-room basis at different times of day. This matters because people spend more than 85% of their time indoors (Kleipeis et al., 2001), and when and where indoor activities occur in the home affects heat exposure and risk (Sailor et al., 2015). Understanding nighttime thermal conditions in a bedroom, for example, is critically important because residents are likely to be in that space for an extended period to rest and sleep.

UFC is understood to change local climate conditions, a service provided primarily through the mechanisms of shading and evapotranspiration. But how exactly do trees cool the environment? Shade from trees blocks direct shortwave radiation from heating surfaces beneath the canopy and can reduce surface temperature up to 72°F (40°C) (Rahman et al., 2020) and maximum summer air temperatures by 0.9-3.6°F (0.5-2°C) (McDonald et al., 2016). *Evapotranspiration* — the combined processes of trees transpiring or "breathing" out water vapor, and of water moving from the earth's surfaces to the atmosphere — reduces the amount of heat available to warm the ambient air around a tree, significantly lowering air temperatures relative to spaces shaded by buildings or other built, dry infrastructure (Park et al., 2021). Evapotranspiration can reduce ambient air temperatures some

2-14°F (1-8°C) (Rahman et al., 2020; Rahman et al., 2018), though the impacts on nighttime cooling vary (Ruiz et al., 2017).

At the mesoscale of neighborhoods, higher UFC tends to be significantly correlated with cooler temperature (Hoffman et al., 2020), and cooling benefits of UFC increase as trees mature (Taha, 2015). In LA, city blocks that have more than 30% UFC are about 5°F (2.8°C) cooler than blocks without trees (Pincetl et al., 2013). Tree cover over LA's streets is the most important cause of land surface temperature variations — accounting for some 60% of variation — compared to factors such as topography and distance from the coast, which account for approximately 30% of variation (Pincetl et al., 2013).

On the microscale of parcels or city blocks, trees impact the microclimate via several processes. In addition to providing shade and intercepting solar radiation, trees can modify wind patterns to disperse trapped heat, and as trees transpire, they convert heat energy from sensible heat to latent heat, releasing energy during the phase transition into water vapor (Streiling & Matzarakis, 2003; Steven et al., 1986; Chiang et al., 2018). Cooling at the microscale also impacts energy demand because shade helps air conditioners work more efficiently and reduces building heat gain. Reduced temperature at the microscale also has important implications beyond the microscale. The daily average temperature at which air conditioning use begins in shaded houses is generally higher than in unshaded houses, further avoiding emissions (Akbari et al., 1997; Berry et al., 2013). A tree in Los Angeles avoids the combustion of 40 lbs (18 kg) of carbon annually, exceeding the 10-24 lbs (4.5-11 kgs) it sequesters during the same period (Akbari, 2002), thus reducing additional greenhouse gas emissions.

Tree placement and configuration impact these functions at both the mesoscale and microscale. Tree characteristics such as lower canopy height (closer to ground level where humans dwell), greater canopy size, and density of foliage yield greater cooling benefit (De Abreu-Harbich et al., 2015; Rahman et al., 2020; Kong et al., 2017). De Abreu-Harbich et al. (2015) found that tree-planting configurations of two rows of trees, with minimally five to 10 trees per row, improve thermal conditions — an application that is particularly apt in public right-of-way spaces such as streets and sidewalks. Urban morphology also plays a role, with the cooling benefit of UFC increasing where shade from the built environment is less abundant, such as where street canyon geometry is shallow and broad (Coutts et al., 2016).

Climate type and latitude also influence the impact of UFC on regulating temperature and the relative contribution of each UFC cooling mechanism, as a meta-analysis of the cooling traits of trees by Rahman et al. (2020) found. In hotter and drier climates — including California's semi-arid Mediterranean climate — the magnitude of the shading effect is stronger than it is in high latitude locations because there is greater benefit to intercepting radiation in low and mid latitudes, which receive more intense solar radiation. In wetter climates and those with more evenly distributed precipitation regimes, the magnitude of cooling via evapotranspiration is more significant than it is in drier climates, though shade is still the dominant mechanism regardless of climate or latitude (Rahman et al., 2020).

Despite the cooling benefits of trees, the energy, ecosystem, and health protection services that trees provide are not free from tradeoffs and understanding these tradeoffs can help maximize benefit and reduce risk (Figure 2-1). For instance, when considering the microclimate effects of trees in urban areas, trees can provide cooling through shading of buildings during hot weather but can increase the need for wintertime heating, and can also have a wind shielding effect that reduces mixing and dilution of pollutants that contribute to poor air quality (Taha, 2015). In hot weather, cooling impacts from shade and transpiration peak during summer afternoons, when evaporation levels are at their highest — an important function on hot days (McPherson & Simpson, 2003). However, lower wind speed by trees can produce more conductive heat gain on surfaces in the built environment — a phenomenon that can be beneficial in cool weather but detrimental during hot weather (Huang et al., 1990). While shading and reduction of solar radiation by building-adjacent trees and vegetation reduce temperature, trees can raise humidity outdoors and indoors (Huang, 1987; Akbari, 2002). Increased humidity in dry climates or during dry heat waves can promote improved *thermal comfort* — a subjective condition in which an individual is satisfied with their thermal environment and does not have an impulse to change it (Djongyang et al., 2010) — but it can have the opposite effect in humid climates or during humid heat waves (Zhou et al., 2020). Careful consideration of the placement of trees can help mitigate these tradeoffs. Decision-making tools such as the i-Tree suite of tree planting calculators can reveal building interactions, air temperature impacts, and forecast the effects of land cover changes produced by planting trees, from a single tree to planting campaigns at the neighborhood or city level (i-Tree, n.d.).

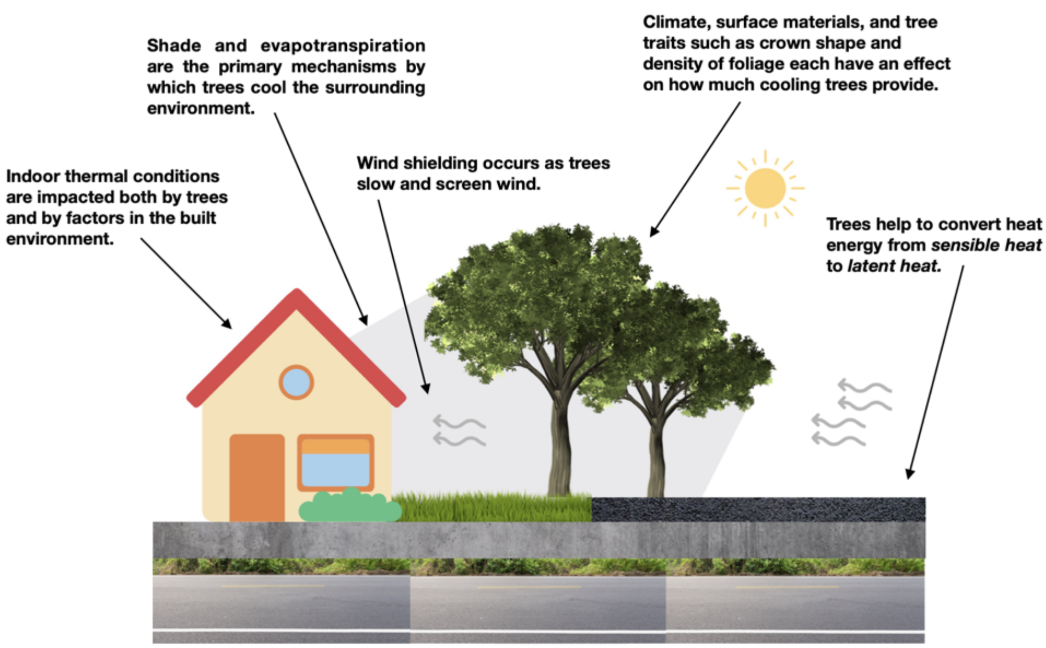

Figure 2-1. Impacts of UFC on thermal conditions at the microscale. The figure shows multiple mechanisms through which trees affect the microclimate.

While exploring these functions holistically can help address these tradeoffs, much of the existing literature explores the benefit of trees solely on outdoor conditions. Studies on the indoor impacts of trees make up a small portion of the literature (Wolf et al., 2020). This is relevant because outdoor conditions may not be a good predictor of indoor conditions, as a multitude of factors in the built environment — such as cavity wall insulation, rate of heat loss or gain of windows, and albedo of roof, pavement, and wall materials — modulate indoor heat exposure (Baniassadi et al., 2018). Fewer still are studies that consider impacts on the microscale rather than the meso or macro scale, those that use empirical observations rather than modeling (Wang et al., 2014), or those that evaluate thermal conditions by room or by time-of-day activity.

This study seeks to contribute to this limited body of knowledge by answering the question: What is the impact of trees on indoor and outdoor residential temperature and thermal conditions? We hypothesized that indoor thermal conditions for residential parcels with trees would be improved on hot days, and that parcels with trees would have lower peak temperatures on hot days compared to residences without trees. Overall, we found that homes with trees experienced *relatively* less warming on hot days than homes without trees, and living rooms (but not bedrooms) in residences with trees had cooler *actual* temperatures during the hottest times of the day. We also found that trees provide relatively less benefit at night, a finding that is consistent with other studies but warrants further investigation for its potential impacts on public health. Our study presents new empirically-derived, spatially and temporally granular data supporting the daytime heat-protective function of trees in an urban environment during hot weather in residential sites, and presents research methods that can serve as a foundation for future studies.

2.2 Difference-in-differences

Conducting empirical research to compare the impact of the presence or absence of trees on thermal conditions of houses is complicated by confounding variables and the likelihood that these two groups of houses differ on other dimensions that might affect temperatures independent of trees, such as building materials, insulation, solar radiation and building orientation. Behavioral factors can also have an influence on thermal conditions. For example, households that live with higher UFC are likely to have greater wealth (Schwarz et al., 2015) and might therefore be more likely to have better-insulated homes. While randomized experiments are one way to control for confounding factors, such studies are costly and difficult to design and execute because such an experiment would ideally plant mature trees that provide benefits immediately. Young trees take time to grow and realize cooling benefits, and households randomized into the treatment group might migrate; as new residents move in, the experiment would be contaminated in non-random ways such as adaptive investments being made — for example, different behaviors than the original tenants, or the addition of a new air conditioning system.

To address these shortcomings, we use a difference-in-differences (DD) approach. DD is a statistical technique that uses observational data to mimic an experimental research design by assigning two groups to either a control or treatment group (Angrist and Pischke, 2008), and is a technique recommended for evaluating the effectiveness of varying strategies for reducing the health impacts of extreme heat (Dwyer et al., 2022). DD enables the evaluation of data by assigning data to either a control or treatment group. The DD approach captures the spirit of differential changes over time across these two groups, where one group is more exposed to a particular treatment (in our case, trees) at a given point in time (Angrist and Pischke, 2008). As shown in Table 2-1, in our study the two groups were *residences with low or no tree canopy cover* (the control group, which we refer to as “non-treehouses”) and *residences with moderate or high canopy cover* (the treatment group, which we refer to as "treehouses"). We calculated the differences in temperatures in each group during hot days ≥90°F (≥32°C) and non-hot days <90°F (<32°C). The model assumed that homes with trees experience a relatively larger cooling effect from trees on hot days and, therefore, have a relatively smaller increase in indoor temperatures on hot days compared to control sites. We did this by calculating the effect of the independent variable (trees) on the dependent variable (temperature) over the study period in the two groups.

Table 2-1. Definitions for terms used in the study. "UFC" refers to the parcel's urban forest cover.

Term	Definition
Treehouse	A participating residence for which the parcel UFC is ≥18%*
Non-treehouse	A participating residence for which the parcel UFC is <18%*
Hot day	A day with a maximum daily temperature ≥ 90°F (32°C)**
Non-hot day	A day with a maximum daily temperature < 90°F (32°C)**

** L.A. County's average UFC is 18%*

*** Temperature recorded at the National Weather Service Los Angeles Downtown/USC weather station*

2.3 Community scientist recruitment

The project scope, which was written before the COVID-19 pandemic — called for interested members of the public living in Los Angeles County to host thermal sensors in their homes and allow study personnel to visit their home to install the sensors and download the data several times during the project period. To accommodate necessary social distancing requirements of the pandemic, we modified the scope. Rather than recruit members of the public at large, we conducted recruitment among frequent and regular volunteers of the LA-based environmental organization TreePeople, which was the prime recipient of the research grant. This modification provided the opportunity for a more hands-on community science approach involving participants in installing sensors, downloading and transmitting data, and troubleshooting sensor issues. This more active level of involvement warranted recruitment of vetted TreePeople volunteers.

Recruitment took place in July and August 2020 with the assistance of TreePeople's community engagement staff, who maintain lists of the organization's approximately 8,800 regular volunteers (L. Rodriguez, personal communication, July 11, 2022). An email explaining the study and the requirements for participation was sent to volunteers who live in two areas: Watts (south central Los Angeles County) and the Gateway Cities (southeast Los Angeles County). These neighborhoods were selected because of their limited resilience to heat waves, measured by low UFC and lower-than-average air conditioning availability (Galvin et al., 2019; Fraser et al., 2017).

Interested individuals were asked to fill out an application. Twenty-nine applications were received and screened, and eight households were ultimately selected, though one of the participating households was ultimately excluded from the study for neglecting to install the sensors. Selection criteria included:

- **Parcel urban forest canopy:** half of selected participants had a UFC lower than the LA County average of 18%, while the other half had moderate or high UFC above the average. UFC was determined by using the Los Angeles Tree Canopy Map Viewer (available at tinyurl.com/treeviewer).
- **Building vintage:** we sought older buildings built prior to the adoption in 1978 of California's Title 24 building energy efficiency standards.
- **Air conditioning access and use:** to minimize the potential of misleading data readings skewed by the use of air conditioning, we sought homes that either had no air conditioning, or homes with window units but no central air conditioning. We asked applicants with window units how often they typically use AC when very hot out (never, rarely, sometimes, always), and we sought participants who reported never, rarely, or sometimes.
- **Geographic location:** we selected sites that were clustered around one heat-vulnerable part of the county to allow for use of one official reference weather station.
- **Tech-savvy participant:** we asked applicants to rate their technological savvy so we could recruit participants who would be able to accurately install the sensors and download and transmit collected data.

Participating households were provided detailed instructions on how and where to install the sensors. Data downloads were requested from the participants every two weeks in order to be able to identify data collection issues such as a unit malfunction or battery problems. The study received an exemption from UCLA's Institutional Review Board, and participants were asked to sign a consent form advising them of the voluntary nature of the project. Participants received a $100 gift card at the conclusion of the project.

Data collection occurred at study sites in Southeast Los Angeles (Table 2-2), at sites located on traditional, ancestral, and unceded territory of the Gabrielino/Tongva, Chumash, and Kizh peoples. Relative to other parts of LA County, this region has some of the highest concentrations of impervious surfaces coupled with low UFC. This is a working-class area that is approximately 70% Latino/a, 7% Black, and 7% Asian, and has an average annual household income ranging between $40,000 for Maywood and Huntington Park to about $60,000 in Downey, which is low for LA County (Los Angeles Times, 2021). The environmental justice mapping tool CalEnviroScreen assigns this area a pollution burden of between the 65th percentile in Downey and the 95th to 100th percentile in Maywood, South Gate, and Huntington Park (Office of Environmental Health Hazard Assessment, 2020).

Table 2-2. Descriptions of study sites, including neighborhood, building vintage, parcel and neighborhood UFC, and housing type.

Study site	Neighborhood	Decade built	Parcel tree cover	Neighborhood tree cover	Housing type
Non-treehouse 1	Central-Alameda	1910s	10%	13%	Duplex
Non-treehouse 2	Bell Gardens	1940s	4%	11%	Single-family home
Non-treehouse 3	Huntington Park	1960s	7%	12%	Single-family home
Non-treehouse 4	South Gate	1940s	9%	13%	Duplex
Treehouse 5	Huntington Park *Tree mix: a mix of mature fruit trees exceeding 20-25' in height*	1960s	23%	12%	Duplex
Treehouse 6	Downey *Tree mix: predominantly mature broadleaf deciduous exceeding 35' in height; mature fruit trees and shrubs*	1940s	72%	16%	Single-family home
Treehouse 7	Maywood *Tree mix: predominantly mature broadleaf deciduous exceeding 35' in height*	1930s	40%	12%	Multi-unit apartment building

2.4 Data collection

Each participating household was given three Kestrel DROP thermal data loggers with instructions for installing the sensors, connecting them to an iOS or Android device via the Kestrel LINK app, and downloading and transmitting the data. Kestrel DROP sensors have been successfully used in other research studies, including a study on the spatial-temporal dynamics of people's interaction with the urban environment (Li et al., 2019); a study that measured above-canopy meteorological profiles using unmanned aerial systems (Prior et al. 2019); and a comparative study of personal temperature exposure assessments (Bailey et al., 2020). Our study used Kestrel DROP D2HS Heat Stress Monitors for indoor installations and Kestrel DROP D3FW Fire Weather Monitors outdoors.

Three devices were installed at each site: in the bedroom, in the living room, and in a shaded location on the exterior of the home, under an eave. Instructions for installation were written based on a literature review of similar studies using weather sensors, and included directions to place the sensor: at a height of 40-50 inches (100-125 cm) above the floor; on an interior wall that is not exterior-facing and does not have a window or door leading out; and away from sources of heat, sources of light, direct sunlight, or heating/cooling vents. Participants were instructed to install outdoor sensors in fully shaded locations. As a precaution, all outdoor sensors were placed in a light-colored upside-down paper cup to shield them in the event of direct sun exposure. Homes considered to have moderate to high UFC were given a fourth data logger to install in the canopy of a tree, but in order to compare sensor location data between the two groups, tree sensor data were ultimately excluded from the analysis.

Thermal readings were collected between September 1 and November 15, 2020, for a total of 76 days of data collection. The study period included occurrences of air masses known to cause higher human mortality under the Spatial Synoptic Classification (SSC). The SSC classifies each day into an air mass type based on air temperature, dew point, cloud cover, and surface air pressure (Sheridan, 2002), and is widely used to analyze the impact of climate on human health (Dixon et al., 2016; Hondula et al., 2014). We focused on the two most deleterious air masses: Moist Tropical Plus (MT+), which is excessively hot and humid, and Dry Tropical (DT), which produces the hottest and driest conditions (Sheridan and Kalkstein 2004). Table 2-3 shows average long-term frequencies of DT and MT+ air masses in LA and occurrences during the study period, recorded at the nearest-available weather station at Los Angeles International Airport (LAX) for which frequency data were available.

Table 2-3. Frequencies of deleterious air masses over a long-term average and for the study period (September-November 2020)* recorded at the LAX weather station. Dry Tropical (DT) produces the hottest and driest conditions, and Moist Tropical Plus (MT+) is excessively hot and humid.

Month	DT Avg. Freq.	DT Study Period	MT+ Avg. Freq.	MT+ Study Period
September	3% (0.9 days)	6.7% (2 days)	1.2% (0.4 days)	- (0 days)
October	6.6% (2 days)	3.2% (1 day)	0.6% (0.2 days)	6.4% (2 days)
November	15.6% (4.7 days)	13.3% (4 days)	0.5% (0.2 days)	- (0 days)

Source: Sheridan SC (2022) Spatial Synoptic Classification, version 3. http://sheridan.geog.kent.edu/ssc3.html

Long-term average frequencies are 1944-2022 and reported monthly rather than daily. Table thus includes entire month of November.

Half-hourly readings were collected by the Kestrel sensors throughout the study, yielding 48 readings per sensor per day. Readings included temperature, relative humidity, heat stress index, and dew point. The total number of half-hourly readings for each site (bedroom, living room, and outdoor) was over 20,000 per sensor. The sensor network was in place in time to capture the hottest day recorded to date in Los Angeles County, which occurred on September 6, 2020.

Daily highs for the study region were obtained from the National Oceanic and Atmospheric Administration's National Centers for Environmental Information. The reference weather station used for the study was the Downtown/USC (KCQT) located just west of the study area.

2.5 Data analyses

We used Stata statistical software (StataCorps, 2019) and applied a difference-in-differences model to compare the change in temperature between hot and non-hot days in treehouses versus non-treehouses. We estimated the following basic model via ordinary-least-squares regression:

$$INDOORit = CLOSEi + \gamma\ HOTt + \beta\ CLOSEit \times HOTt + eit$$

where *INDOORit* represents the temperature of one of two indoor rooms (bedroom or living room) in household *i* on day *t*. *HOT* is an indicator for whether the temperature at the reference weather station was ≥90°F (32°C), *CLOSE* is an indicator for whether the household *i* is a treehouse within the protective reach of UFC, and *e* is an error term. *CLOSEi* captures the average indoor temperature for treehouses on non-hot days, which also accounts for the possible fixed differences in indoor temperature between households that might be spuriously correlated with proximity to trees. The parameter γ captures the change in indoor temperature on non-hot days in non-treehouses that are far from trees. β is the difference-in-differences parameter that captures the difference in indoor temperatures for treehouses versus non-treehouses on hot days.

Behavioral responses might mitigate the effect of the trees and are naturally captured in the parameter β. For example, households without trees might rely on fans or air conditioners more to bring the household temperature down on hot days. Therefore, the model captures the net effect on indoor temperature for the study sites. However, the estimate does not capture the overall societal benefit of trees since the study does not capture energy expenditures, most likely leading to an underestimate of the benefits of trees.

2.6 Results and discussion

The difference-in-differences for bedroom temperatures (Figure 2-2) shows that over the entire study period, the average temperature in bedrooms of treehouses was actually 2.1°F (1.2°C) *higher* on the baseline non-hot days. There are a host of reasons why this could be the case, including building materials and solar radiation as a function of the orientation of the bedroom relative to the rest of the house. This fact alone does not diminish the potential of urban cooling by trees, and it underscores the aptness of the DD research design. More importantly, the data show that on average, bedrooms in treehouses are 5.0°F (2.8°C) warmer on hot days than on non-hot days, and that bedrooms in non-treehouses are 6.1°F (3.4°C) warmer on hot days than on non-hot days. The difference between the two groups of homes being 2.1°F (1.2°C) on non-hot days and shrinking to 1.0°F (0.5°C) on hot days suggests that trees have a 1.1°F (0.6°C) dampening effect in the heat. Without trees, we would expect that treehouses would be warmer and expose residents to even higher temperatures.

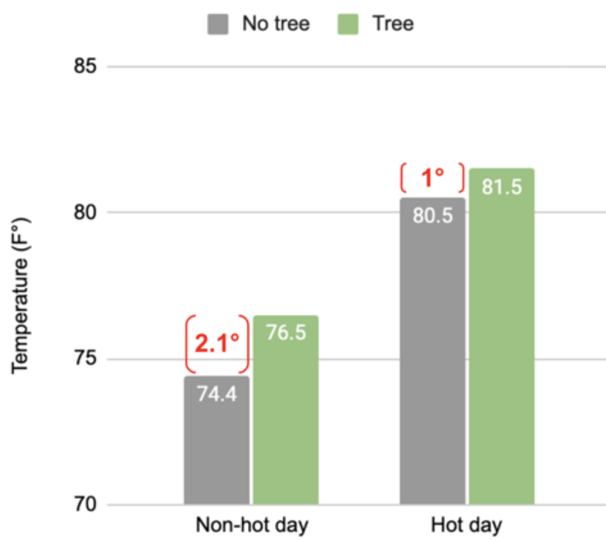

Figure 2-2. Average bedroom temperatures on hot and non-hot days for treehouses and non-treehouses.

When we look at the data by hourly averages throughout the study period, we see that the difference in temperatures between treehouses and non-treehouses is smaller at all times of day on hot days than it is on non-hot days (Figure 2-3), suggesting a temperature attenuation effect by trees on hot days. The fact that the benefits extend to nighttime hours is particularly beneficial to public health, because while occupants are sleeping the body seeks to recuperate after the day's heat exposure. Notably, indoor temperatures peak around 5:00pm, approximately 3 hours after outdoor peak temperatures (Figure 2-7), as heat continues to be retained and conveyed even after outdoor temperatures begin to cool off.

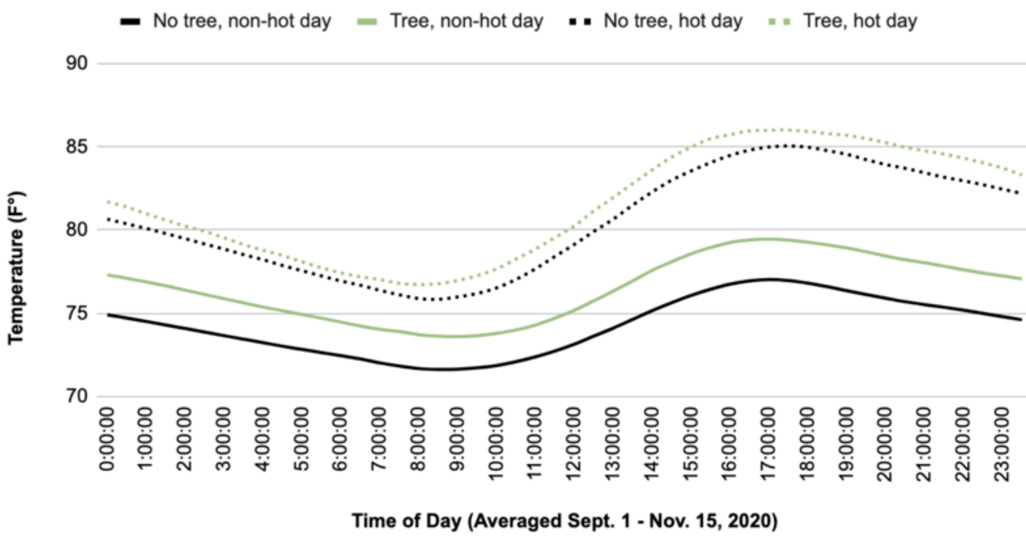

Figure 2-3. Hourly average temperatures for bedrooms on hot and non-hot days for treehouses and non-treehouses.

Figure 2-4 shows that the effects of trees on living room temperatures are similar to those in bedrooms. Living rooms in treehouses are 1.2°F (0.7°C) warmer on non-hot days and 0.2°F (0.1°C) warmer on hot days relative to non-treehouses, implying a DD of approximately 1.0°F (0.5°C). The estimated effect for the living room is similar to the estimate for the bedroom, indicating the benefits of trees are not confined to one area of the house.

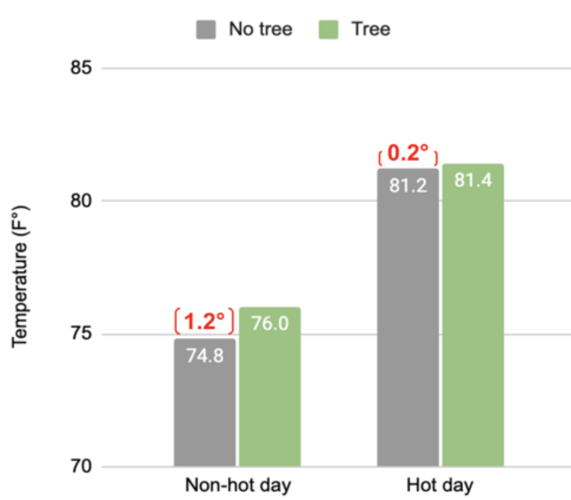

Figure 2-4. Average living room temperatures on hot and non-hot days for treehouses and non-treehouses.

Considering hourly averages (Figure 2-5), we see that temperatures in treehouses increase by a lesser amount on hot days and that actual temperatures in non-treehouses exceed those in treehouses as daily temperature increases between about 11:00am and 6:00pm. This implies that trees have an even larger cooling effect during daytime hours, when temperature is on the rise. This switch is not observed in bedrooms and is likely attributable to factors in the built environment such as building materials, insulation, solar radiation or building orientation.

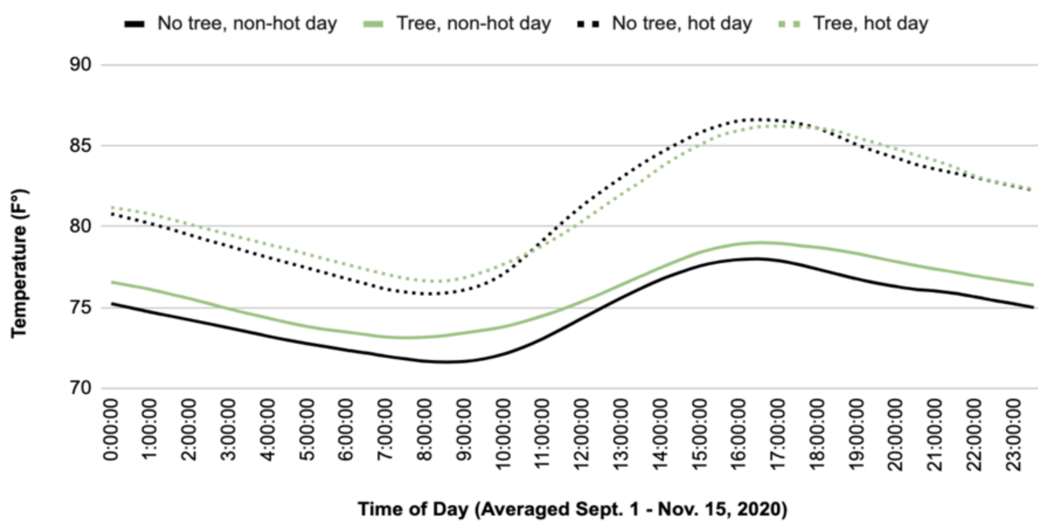

Figure 2-5. Hourly average temperatures for living rooms on hot and non-hot days for treehouses and non-treehouses.

As with the indoor readings, Figure 2-6 shows that average outdoor temperatures recorded over the study period are warmer at treehouses than at non-treehouses. In contrast with indoor temperatures, we see that eave temperatures in treehouses actually rise by a greater amount than eaves in non-treehouses during hot weather. On average, eaves at treehouses are 10.5°F (5.8°C) warmer on hot days than on non-hot days, whereas non-treehouse eaves are 9°F (5°C) warmer on hot days than on non-hot days. The difference between the two groups of homes is 1.1°F (0.6°C) on non-hot days and grows to 2.6°F (1.4°C) on hot days, suggesting that treehouses are actually warming 1.5°F (0.8°C) *more* outdoors on hot days. There are a variety of site-specific reasons that could account for this unexpected phenomenon, and while we cannot conclusively ascribe this differential to any specific factors given the data at hand, we expect that average outdoor temperatures in treehouses would grow even more significantly if trees were absent. This suggests that the findings above, which already support a cooling benefit of trees, might be understated.

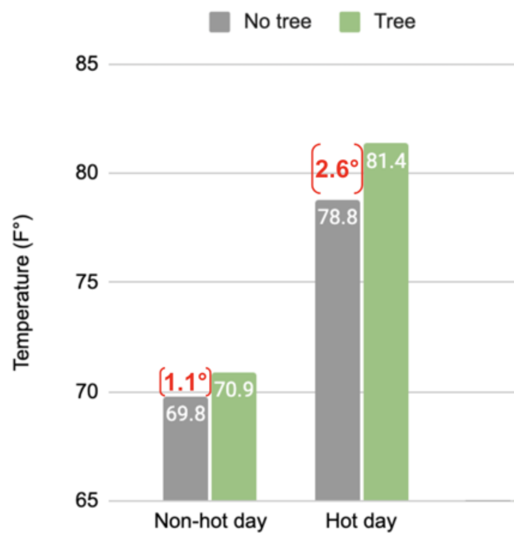

Figure 2-6. Average outdoor temperatures
on hot and non-hot days for treehouses and non-treehouses.

Figure 2-7 illustrates the varying time-of-day effect of trees on outdoor temperatures and indicates that trees have a considerable daytime cooling effect and a lesser effect during the night. Outdoor temperatures are higher on average at treehouses than those observed at non-treehouses during the cooler parts of the day. Importantly, we see that the relationship switches during peak temperature hours (between about 12:00pm and 5:00pm), when outdoor temperatures at treehouses are cooler. This occurs both during hot and non-hot days, though the differential at the coolest part of the day is larger on hot days.

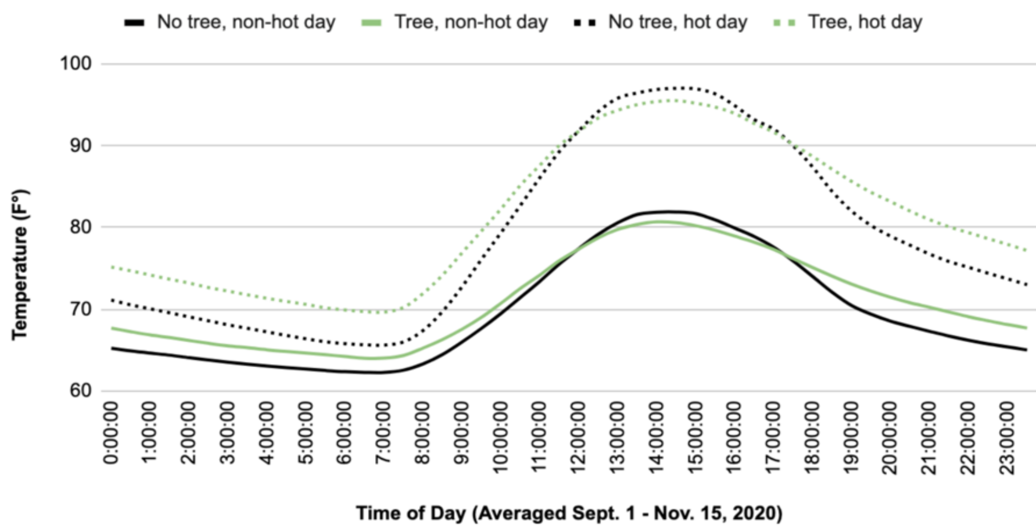

Figure 2-7. Hourly average outdoor temperatures
on hot and non-hot days for treehouses and non-treehouses.

These observations suggest different possibilities: a) trees provide some, albeit relatively less, cooling at night than during the day, or b) trees trap heat and have a warming effect at night. A reduced cooling benefit at night is attributable to the fact that while the mechanism of evapotranspiration operates during nighttime hours, cooling from shade is not actively at play at night, apart from residual thermal benefits accrued during the daytime (McPherson & Simpson, 2003). Relative warming at night may be attributable to factors such as wind shielding (Huang et al., 1990) and longwave radiation emitted from the ground being reflected by the tree back down to the ground due to limited "sky view factor" (Souch & Souch, 1993; Taha et al., 1991). Disentangling these two competing hypotheses is difficult given the small number of study sites, but the first hypothesis seems more likely since the literature suggests the benefits of trees are largest during the hottest part of the day and more tempered during the cooler part of the day (McPherson & Simpson, 2003; Rahman & Ennos, 2016).

Table 2-4. Regression analysis for indoor and outdoor temperatures on hot and non-hot days for treehouses and non-treehouses (robust standard errors in parentheses).

Variable	Bedroom	Living room	Eave
Moderate / High tree cover	2.138	1.237	1.1963
	(.241)	(.197)	(.211)
Hot day >90F	6.129	6.433	9.069
	(.965)	(.946)	(1.152)
Tree x Hot day	-1.111	-1.046	1.351
	(.276)	(-1.046)	(.304)
Constant	74.377	74.759	69.751
	(.650)	(.630)	(.699)
Sample size	25,596	25,326	20,695

Table 2-4 presents the overall study average temperatures in table format and shows the estimates for the dependent variable (temperature), which are identical to those previously shown in Figures 2-2, 2-4, and 2-6. Standard error calculations for the regression analyses are in parentheses. Bedrooms in non-treehouses are 6.1°F (3.4°C) warmer on hot days than non-hot days (*Hot day >90F*). Bedrooms in treehouses are an average 2.1°F (1.2°C) warmer than non-treehouses on non-hot days (*Moderate / High tree cover*), but temperatures in treehouse bedrooms increase by 1.1°F (0.6°C) *less* than they do in non-treehouses (*Tree x Hot day*), once again pointing to indoor temperature modulation impacts of trees. The standard error is 0.28, and the estimates are statistically significant (p = 0.0000). The number of observations varies due to variations in thermal sensor performance over the 76-day study period.

While a DD of 1.1°F (0.6°C) may appear small, we consider these findings to be conservative. This study was intentionally conducted in neighborhoods that have low UFC in order to yield data about the parcel-level function of trees, excluding the influence of neighborhood-level UFC. Even where the parcel had high UFC, as is especially the case with treehouse 6 and 7, we can expect no additional UFC benefit to come from neighborhood-level UFC, because all neighborhoods have less than the LA County average of 18%. The study thus inherently understates the cooling benefit of large-scale planting efforts that are documented in studies such as Kalkstein et al. (2022), Hoffman et al. (2020), and Pincetl et al. (2013). We also note that hourly averages reveal insights about the cooling performance of trees at different times of day and night — details which are not discernible when looking only at the overall study averages.

In addition to contributing new empirical evidence of the benefits of trees on indoor thermal conditions, our study also quantified exposure to extreme heat, which we found to reach dangerous levels in older residences without trees or air conditioning. At various points in the study, each of the homes recorded indoor temperatures that could be harmful to residents with underlying health conditions, and occasionally recorded temperatures that could be dangerous even for healthy individuals. When on September 6, 2020 the LA neighborhood of Woodland Hills reached 121°F (49.5°C), LA County surpassed its previous record high of 119°F (48.3°C) set during California's historic 2006 heat wave (Wigglesworth & Cosgrove, 2020). On that record-breaking day, the daily high for our study's reference weather station at Downtown/USC was 111°F (43.9°C). The hottest of our study sites that day — a residence in Huntington Park with no trees or air conditioning — reached dangerously high temperatures: 110.3°F (43.5°C) outdoors at 2:00pm; 107.4°F (41.9°C) at 4:00pm in the living room; and 99.7°F (37.6°C) at 6:00pm in the bedroom. Such extreme temperatures are risky even for healthy people, and sustained exposure can prove deadly.

Other studies can help us understand the findings and variations we observed in the present study. Kong et al. (2017) used modeling to show that trees planted in higher-density configurations are more effective at cooling not only outdoor but also indoor spaces, and that a dense canopy and large crown are some of the most advantageous characteristics for promoting cooling. Our study included treehouses with varied canopy characteristics and we would thus expect varied findings —

for example, Treehouse 6 has a parcel-level UFC of 72% composed of mix of broadleaf trees, fruit trees, and shrubs of varying canopy density, while Treehouse 5 has a UFC of 23% composed primarily of mature fruit trees which have less dense canopies. A future study could replicate these methods with a larger sample of study sites and include analysis of thermal impacts correlated with canopy characteristics.

Another study relevant in our context, published by Sailor et al. (2021), modeled the impacts on indoor and outdoor conditions by simulating UFC and built environment albedo modifications in single-family homes in Los Angeles. The researchers modeled the combined effects of varying combinations of UFC and albedo on temperature and dew point at 3-hour intervals. Mitigation cases included one focused on increasing albedo more than UFC, another which increased UFC more than albedo, and two cases that tested moderate and high albedo and UFC.

In general, Sailor et al. found that the albedo-dominated case performed better than the UFC-dominated case during daytime hours, while the UFC case performed better at night, likely because higher albedo produces greater effects when solar radiation intensity is high, whereas UFC effects of cooling are influenced both by solar radiation and by ambient temperature and humidity. However, results varied with air mass type. Indoor air temperature reductions were greatest during daytime hours under humid moist tropical+ (MT+) conditions, likely because the mechanisms of shading by trees and of reflecting solar radiation by high-albedo surfaces do not interact with humidity in the way that the mechanism of evapotranspiration does. Indoor temperature responded more favorably to the UFC-dominated case during nighttime hours, regardless of air mass type.

Sailor et al. (2021) provide findings that are useful for discussion for our purposes. The relative performance of albedo- versus UFC-dominated cases points to the impacts that shade and evapotranspiration produce since the potential cooling benefits provided by higher albedo surfaces are achieved by a totally different mechanism — reflecting solar radiation. Sailor et al.'s findings also allow a discussion of how the UFC-dominated case performs at different times of day, both indoor and outdoor. The lower range of their modeled temperature reductions is on par with what we see in the empirical data we collected, but with no empirical data to validate their model, it is not possible to conclude whether their model overstates the results of the tested scenarios. The fact that their UFC-dominated cases tended to perform better at night relative to albedo-dominated cases only tells us how the two interventions performed comparatively, and while this finding seems to conflict with our study finding (that trees provide greater cooling benefit in the daytime), the Sailor et al. study did not include a UFC-only scenario so we cannot draw a direct comparison. Sailor et al. also assumed widespread mitigation via UFC and albedo throughout the city, not at the parcel level — further limiting our ability to draw direct comparisons.

Among the rare studies that use combined field measurements and modeled simulations to investigate both indoor and outdoor thermal conditions is a study by Morakinyo et al. (2016) of two buildings in Nigeria. Using empirical data as well as modeling, the study assessed summer thermal impacts in a building shaded by trees and an unshaded building. The researchers found lower indoor temperatures in the tree-shaded building compared to the unshaded building, but also found that modeled results overestimated the cooling effects by as much as 2.7ºF (1.5ºC) over observed measurements (Morakinyo et al., 2016), highlighting the importance of empirical observations, and suggesting that results of the Sailor et al. study might be overstated. Morakinyo et al. (2013) conducted a study similar to their 2016 study which investigated the effects of trees on indoor and outdoor air temperature and found that shaded buildings had indoor-outdoor temperature differences of no more than 4.3ºF (2.4ºC) for the shaded building, while the unshaded building differences were roughly twice that, peaking at 9.7ºF (5.4ºC). We observed a similar pattern on hot days in our study, though our findings were of a lesser magnitude. Yet even when small, the temperature reductions observed in shaded sites in both our study and the Morakinyo study may be sufficient to improve public health outcomes (Jay et al., 2021; Kalkstein et al., 2022).

Altogether, our study findings point to the benefits of UFC during the daytime but raise important questions about potentially limited nighttime effects. The findings also confirm one of the two original hypotheses (that indoor thermal conditions for residences with trees nearby will be improved on hot days), but did not confirm a second hypothesis (that sites with trees will have lower actual peak temperatures on hot days compared to sites without trees). The difference-in-differences approach shows a *relative* improvement in treehouse temperatures, but not an *absolute* improvement. That is, though treehouse temperatures generally increased by a lesser amount than non-treehouses, actual temperatures were sometimes higher, demonstrating how nuances in the built environment influence the microclimate and thus how heat is experienced differently in the urban environment.

2.7 Limitations

This study has some limitations. The grant that supported this research was written and awarded prior to the COVID-19 pandemic. Recruitment was originally meant to occur through door-to-door canvassing. With agreements in place, the plan was for study team personnel to enter each household to install the data loggers and then visit the homes approximately every two weeks to check on the devices, download collected data, and troubleshoot any issues. This plan was not possible given the realities of social distancing, and our methods changed. Instead, installation instructions were provided to residents who served as community scientists on the study. Study personnel were in frequent communication with residents to obtain photos of sensor installations and data downloads.

Community science, also known as citizen science or participatory monitoring, has gained popularity in recent years because it offers a cost-effective way to collect data across large spatial and temporal scales and brings positive experiences and learning opportunities for volunteers (Aceves-Bueno et al., 2017). In the case of this pandemic-era study, community science made it possible for the research to proceed. However, a community science approach raises questions about accuracy, and in the case of this study, special measures had to be taken to ensure correct sensor placement (confirmed via photos submitted by study participants) and accurate data collection. Candidates interested in participating in the study were screened to ensure they had a thermal sensor-compatible iOS or Android device and were asked how strongly they agree with the statement "I consider myself technologically savvy with the use of mobile applications." Selected participants were provided detailed instructions for installing the devices and downloading the data, and were asked to submit photos of the installed devices. Remote troubleshooting support was available to them from study personnel. These and other measures rely on participants being committed and responsive. In practice, we learned that participants are not all equally committed and communicative. For instance, the community scientist nature of the project led to data downloads occurring sporadically, at times causing a delay in identifying and troubleshooting sensor issues. In another instance, we learned too late that one of the participants failed to install the sensors provided, even after signing an agreement and receiving frequent communications from the study team throughout the course of the study. This led to a sample of seven homes rather than eight.

Another limitation is that a key modeling assumption — that the baseline temperature on non-hot days is not influenced by the tree canopy, or that it is influenced to a lesser degree than on hot days — might be violated because UFC can trap heat in cooler temperatures under certain conditions. Though the magnitude of this warming effect may be small, it would likely lead to overestimating the benefits of trees since it would lead to finding a relatively smaller differential between hot and non-hot days in treatment sites relative to control sites. We attempt to address the magnitude of this bias by considering the mechanics of cooling and warming by trees, and how these are influenced by time of day. Trees provide cooling through the processes of shading and transpiration, both of which are maximized during daylight hours, when temperatures tend to be highest (Rahman & Ennos, 2016). Conversely, trees can have a warming effect at night, as wind is reduced and shielded, preventing dispersion of accumulated heat (Huang et al., 1990). However, the magnitude of daytime cooling is understood to exceed that of nighttime warming, with one study finding that trees provide up to 8.1°F (4.5°C) of daytime cooling while providing only 1.8°F (1°C) of nighttime warming (Taha et al., 1990). We therefore expect any warming effects to have a minimal influence compared to the cooling impacts observed over the course of the study.

Other limitations also exist. Adaptive responses, like use of air conditioning, were not closely accounted for in this study. It is possible that households that lacked cooling from trees may have relied on fans or window air conditioning units more regularly than houses with trees, and it thus possible that the indoor benefit of trees is understated in the analysis. To mitigate this concern, prospective study participants with central AC were excluded because of the relative ease and automation of controlling indoor climate with central systems, and we selected participants who either have no AC or have window or wall units only, which they self-reported to use infrequently. To further address this limitation, a future study could collect daily energy use data or otherwise monitor adaptive responses such as AC use.

Lastly, the small sample size meant that we could not test whether site characteristics, such as housing type, tree type, and tree distance may have impacted cooling by trees. For example, houses where trees are planted on the west-facing wall or in front of windows would be expected to see larger benefits from trees, but with the limited sample size and high variability in built environment characteristics between study sites, aggregating observations into the two study groups (treehouses and non-treehouses) proved to be the most conservative and defensible approach. With these limitations in mind, we offer this as a proof-of-concept study that can serve as the foundation for a larger future study.

2.8 Conclusions

This study contributes new empirically-derived support for the heat-protective function of trees in an urban environment. We found that on average, indoor temperatures in treehouses warm 1.0-1.1°F (0.5-0.6°C) *less* on hot days compared to non-treehouses. These temperature benefits extend to all times of the day, which is critical from a public health perspective, with cooling benefits peaking during daytime hours. Even modest reductions in peak temperatures can translate to improved public health outcomes: UFC and albedo modifications that produce just a 1-2°F (0.5-1.1°C) reduction in peak heat wave temperatures could reduce heat-related deaths 10-20% (Kalkstein et al., 2022).

Such temperature reductions can help improve heat-related public health outcomes and reduce public health costs among heat-vulnerable communities, which is of critical importance as the study also finds that exposure to extreme heat can and does reach dangerously high levels — up to 107.4°F (41.9°C) indoors in older residences without trees or air conditioning. Sustained exposure to such heat is a reality for many residents in LA and other cities who lack access to coping strategies, emphasizing the need for swift action to cool heat-vulnerable communities.

Future research could involve a larger-scale study involving dozens or hundreds of sites segmented by neighborhood and site characteristics. This would enable a deeper exploration of tree and housing type characteristics. Additionally, incorporating household-level energy data for the study period could enable quantification of the impacts of trees on energy demand. Such an analysis could be linked both to in situ sensors, such as the ones used in this study, and remote-sensed temperature data. Further investigation of thermal impacts of different canopy types and of the daytime vs. nighttime effects of trees on thermal conditions are other critical areas that should be explored, especially in the context of how exposure to heat at different times of day and in different rooms of the house impacts public health outcomes.

CHAPTER 3
Increasing Tree Stewardship and Reducing Heat-Health Risk Using Community-Based Urban Forestry[2]

3.1 Introduction

Heat exposure is a public health hazard that burdens disadvantaged communities in urban areas disproportionately and threatens the livability and sustainability of cities (Benz & Burney, 2021; Jesdale et al., 2013). In a warming climate, cases of heat-related illness and death are expected to increase, especially in the absence of measures to mitigate heat and reduce the urban heat-island effect (Li et al., 2020; Chakraborty et al., 2019). While several mitigation strategies exist, planting trees to expand urban forests is broadly acknowledged to provide critical heat-protective infrastructure by lowering both surface and air temperatures (Vanos et al., 2012; Streiling & Matzarakis, 2003; Taha, 2015; McDonald et al., 2016).

Trees provide cooling through two primary mechanisms: shading and evapotranspiration. By intercepting solar radiation, tree shade prevents surfaces from heating, reducing surface temperatures by up to 72°F (40°C) and summer air temperatures by 0.9-3.6°F (0.5-2°C) (McDonald et al., 2016; Rahman et al., 2020). Evapotranspiration is the combined process of trees transpiring water vapor, and the subsequent evaporation of that moisture in the atmosphere. As these processes occur, the amount of heat energy available to warm the ambient air is reduced, lowering temperatures some 2-14°F (1-8°C) (Rahman et al., 2020; Rahman et al., 2018). Cooling impacts are well understood, but benefits vary due to factors including climate, season, time of day, surface

[2] This chapter previously appeared as an article in the journal *Sustainability*. The original citation is: de Guzman, E.B., Wohldmann, E.L., Eisenman, D.P. (2023).“Cooler and Healthier: Increasing Tree Stewardship and Reducing Heat-Health Risk Using Community-Based Urban Forestry. *Sustainability*.

materials, urban morphology, and tree traits such as crown shape and density of foliage (Rahman et al., 2020; Coutts et al., 2016; Huang et al., 1990).

3.1.1 The challenges of providing tree stewardship in urban environments

Despite tradeoffs of trees under certain circumstances — such as further increasing humidity in already humid environments, or wind shielding resulting in increased conductive heat gain, or increased humidity (Streiling & Matzarakis, 2003; Huang et al., 1990; Djongyang et al., 2010; Zhou et al., 2020) — cities around the world that seek to advance sustainability are investing in tree planting with the goal of mitigating heat (Keith et al., 2020). However, significant barriers stand in the way of growing robust urban forests, particularly when post-planting maintenance is not funded and the public is assumed to provide tree care on private property or in public spaces (Moskell & Allred, 2013; Bekesi & Ralston, 2019). This barrier is more pronounced in arid and semi-arid regions, where trees must be irrigated during an establishment period (Levinsson et al., 2017; Jack-Scott et al., 2013), and tree stewardship during this period is critical to the successful establishment of newly-planted trees that might otherwise die (Roman et al., 2014). How and by whom maintenance is provided is a complex question that ultimately determines whether a tree matures to the point of delivering promised sustainability benefits.

Local government and nonprofit organizations are typically responsible for planting trees along streets and in public spaces, but support for necessary maintenance during the establishment period is often limited or non-existent (Bekesi & Ralston, 2019). In Los Angeles (LA) and in many other cities, street tree planting sites located in the parkway — the planting strip between the sidewalk and street curb — are usually not served by automatic irrigation systems, and supplemental hand-watering is seldom provided by the city or the nonprofit group responsible for tree planting (City of Los Angeles Bureau of Street Services, 2015; de Guzman et al., 2022). Instead, the responsibility for watering street trees is generally assumed to rest with the homeowner, tenant, or property manager of the adjacent property, even if the tree planting is initiated by governmental or nonprofit entities (City Plants, n.d.). Many tree planting programs rely on the good will of community members to provide the care needed to sustain planting programs that may otherwise fail (Moskell & Allred, 2013), but factors to encourage this expectation of voluntary tree stewardship are often left to chance (Lu et al., 2010).

Cities may obtain permission to plant and ultimately transfer watering responsibility to adjacent property owners or managers by either giving them the opportunity to opt in or opt out. Opting in requires the resident to sign a form before the tree is planted committing to watering the tree for a specified period — three years in the City of LA (City Plants, personal communication, March 8, 2021). Opting out means a tree is planted unless a signed form is received declining the tree and is the approach generally taken when a planting campaign has funding for maintenance performed by paid crews (City Plants, personal communication, March 8, 2021).

There is little empirical evidence that either the opt in or opt out methods result in healthy trees or residents who become tree stewards. Previous street tree planting assessments have not systematically differentiated between trees that receive maintenance from hired crews versus those that do not. Limited assessments conducted by the City of LA have found that those that do not receive organized maintenance tend to fare more poorly (City Plants, personal communication, March 8, 2021).

Challenges to tree planting and stewardship are common beyond the LA region, and are especially evident in under-resourced neighborhoods with low tree canopy. A study of an urban greening program in a low-canopy Philadelphia neighborhood found that despite widespread recognition of the benefits of trees and green spaces, significant barriers exist which contribute to resistance or a lack of participation from residents (Riedman et al., 2022). These factors include tree care costs and related risks absorbed by the resident, and limited capacity of community organizations to provide maintenance. In Detroit, an evaluation of a nonprofit-led initiative to plant trees in low-income neighborhoods found that one-quarter of residents declined receiving free tree plantings because of a host of negative associations, including a perceived lack of assistance with tree maintenance (Carmichael & McDonough, 2019).

These barriers can be countered with dedicated funding and staffing for tree maintenance (Breger et al., 2019; Roman et al., 2015; Vogt et al., 2015a). Where such funding is unavailable, efforts to support youth internship and volunteer programs have led to high survival rates for newly-planted trees (Jack-Scott et al., 2013; Roman et al., 2015; Boyce, 2010). Coupling youth outreach to residents with regular watering provided too has been shown to improve tree survival and positive feedback from residents (McNamara et al., 2022).

What is less clear is how the success of planting campaigns with limited funding and personnel to provide maintenance can be improved. Research suggests that an effective way to encourage pro-environmental behaviors, such as tree stewardship, is by working at the community level to change social norms — or common behavioral patterns within a group and the beliefs that support conformity to these behaviors (Farrow et al., 2017; Rydin & Pennington, 2000). Social norms serve as determinants of individual behavior, and as such, many programs seeking to change a wide range of individual behaviors aim to do so by influencing social norms first (Nyborg et al., 2016; Van der Linden et al., 2015).

3.1.2 Study motivation and aims

This study used a community-level intervention with the primary aim of shifting social norms around street tree stewardship, and secondarily, to influence heat-risk concern and protective behavior. Trees provide multiple benefits, and we were interested in investigating whether education and engagement around stewardship could yield multiple benefits as well. The exploration of the relationship between tree stewardship and heat-risk concern and protective behaviors is motivated by the fact that people's feeling of detachment from and powerlessness in the face of a warming climate can be countered when local, tangible, solutions-oriented actions are within reach Van der Linden et al., 2015). Tree stewardship is an expression of a solutions-oriented climate adaptation action. In this study, we tested an intervention that explicitly built social norms and reinforced the connections between tree stewardship, a healthier urban forest, and improved heat mitigation.

We aimed to investigate potential pathways to foster street tree stewardship among residents by using evidence-based community engagement strategies in the City of San Fernando (Los Angeles County, CA, USA). We used a behavior change framework to understand community member beliefs, attitudes, knowledge, and behaviors related to tree stewardship, heat risk and protection, and related neighborhood norms. We then used that information to design, implement, and evaluate an intervention designed to improve tree stewardship and heat-risk concern and protective actions. We tested a control intervention against experimental messaging focused on either public health or environmental health ("messaging condition"). We also segmented participants by the degree of prior household engagement with a local tree planting group, related to whether they received a tree, were on a street where trees had been planted, or were not on a planted street ("planting condition"). These conditions are described in detail in Section 3.2.

In this article we discuss all study phases, including: subject recruitment; pre-intervention field data collection and survey; intervention development and implementation; post-intervention field data collection and survey; and data analysis. Implementing strategies such as the ones we tested can be done with limited investment, and requires relatively less resources than regularly paying crews to provide maintenance directly or staff to oversee volunteer programs. Where effective approaches are identified, they can be adopted and improved upon to enhance outcomes of urban greening and heat mitigation campaigns with limited resources, supporting related urban sustainability goals.

3.1.3 Theoretical basis

This study is grounded in several theoretical approaches. Community-Based Social Marketing (CBSM) provided the primary framework. CBSM uses methods from the field of social marketing with behavior change strategies drawn from social psychology, environmental psychology, and other behavioral sciences to support adoption of targeted behaviors (McKenzie-Mohr, 2011). CBSM initiatives are delivered at the community level and focus on understanding and reducing barriers to an activity while simultaneously enhancing the benefits related to a behavior. CBSM goes beyond provision of information to address and facilitate changes in behavior (McKenzie-Mohr et al., 2011; Schultz & Tabanico, 2008) and has previously been applied to study homeowner attitudes toward residential trees and to explore methods to encourage street tree stewardship (Dilley & Wolf, 2013; de Guzman et al., 2018).

Social-cognitive theory (SCT) also informed our study. SCT attempts to explain the processes that occur in the space between human cognition and human action, and its application has been influential in programs aimed at promoting pro-health and pro-environmental behaviors (Bandura, 2004; Bandura, 2011). SCT posits that the likelihood of a behavior being adopted and maintained is influenced by an individual observing the behavior in others (Bandura, 2008). Given our study was confined to a geographically-specific community and that the primary behavior of interest occurred outside the home, we expected that residents might observe their neighbor(s) watering street trees at some point during the study.

Our study also drew from a related theory within SCT: self-efficacy theory (SET). SET adds another determinant of behavior to SCT: one's perceived self-efficacy—an individual's belief in their own effectiveness in performing a given task (Bandura, 1995; Gallagher, 2012). In our study, a pre-intervention survey allowed us to first identify a resident's level of self-efficacy around tree stewardship and heat-protective actions. We were then able to track to what extent self-efficacy changed, and how well levels of self-efficacy predicted actual tree stewardship. Together, SCT and SET suggest that individuals who are exposed to others who engage in tree stewardship would be more likely to engage in such behaviors compared with those who are not, and that residents with high perceived self-efficacy would be more likely to engage in tree stewardship.

Our study was also informed by the protective action decision model (PADM), which offers a relevant multistage model developed empirically around people's responses to environmental hazards and disasters. PADM considers how social and environmental cues influence the processing of information by those at risk, and how threat perceptions, protective action perceptions, and stakeholder perceptions inform individual decision-making around imminent or long-term threats Lindell & Perry, 2011). PADM can be applied both to self-reported responses about protective actions such as staying out of the sun during the hottest part of the day, or staying well hydrated on very hot days, and to tree stewardship (a long-term, heat-protective action that increases preparedness by mitigating heat).

The dual goals of investigating an intervention's effect on tree stewardship and heat-risk concern and protective actions allowed us to explore the potential of linking environmental goals of behavior change programming to health-related goals. Engagement in environmental stewardship has been shown to facilitate other pro-environmental, pro-health, or pro-social behaviors at the individual level (Rappaport, 1981; Krasny & Tidball, 2015). Conversely, pro-social behaviors can serve as a precondition or building block toward pro-environmental behaviors (Nolan & Schultz, 2015), reinforcing the feedback loop between these. With this in mind, in this study we examine whether an environmental stewardship program can serve as a portal toward increasing the adoption of heat-protective actions.

3.1.4 Hypotheses

Hypothesis 1 (H1): Residents with higher tree stewardship-related self-efficacy will demonstrate higher tree stewardship.

We tested this hypothesis by correlating tree stewardship-related self-efficacy with tree stewardship behaviors. Self-efficacy was measured through self-reported tree care actions, and tree stewardship behavior was measured through soil moisture.

Hypothesis 2 (H2): The intervention will result in improved self-efficacy and tree stewardship.

We tested this hypothesis by analyzing the correlation each intervention treatment had with the outcomes of self-efficacy and tree stewardship.

Hypothesis 3 (H3): Residents with higher tree stewardship will exhibit higher heat-risk concern and take more protective actions.

We tested whether interventions aimed primarily at influencing tree stewardship could also influence heat variables. We did this by correlating the tree stewardship indicator of soil moisture with heat variables (i.e., concern about heat waves, heat protective measures) and analyzing the effect of each treatment.

3.1.5 Main conclusions

In brief, we found messaging condition did not have a significant impact on tree stewardship actions, which were instead influenced significantly by the variable of planting condition. We also found that residents on a recently planted street demonstrated higher levels of concern about heat, and that higher knowledge about how trees influence health was correlated with how likely a resident was to take protective actions against heat. Renters and homeowners were equally likely to demonstrate tree stewardship, and neither income nor education levels predicted higher stewardship, indicating that an intervention does not need to be tailored around socioeconomic status.

3.2 Materials and methods

3.2.1 Study area and subject recruitment

The study took place in the City of San Fernando, a location that was selected due to an ongoing tree planting campaign jointly administered by nonprofit tree group Tree-People and city government. The planting campaign had a target to plant 950 trees in this community using the opt out method of notifying residents that a tree will be planted in front of their home. With this opt out notification, residents were provided with watering instructions, asked to water the tree, and given the opportunity to decline having the tree planted if they did not commit to watering. Planting was funded through a State of California grant awarded to TreePeople. At the time this study was conducted, approximately 600 of the 950 trees had been planted.

San Fernando is a 6.2 km^2 (2.4 mi^2) incorporated jurisdiction with a population of approximately 23,000 people, located in Los Angeles's northeast San Fernando Valley. Located on traditional, ancestral and unceded territory of the Gabrielino/Tongva, Chumash, and Fernandeño Tataviam people, San Fernando is entirely surrounded by the City of Los Angeles, which has 3.9 million residents, and is within Los Angeles County, which has 10 million residents. San Fernando is a working-class community that is nearly 90% Latino/a, and has an average annual household income of $60,655, roughly on par with the rest of Los Angeles County (United States Census Bureau, 2022b). About half of the city's census tracts fall between the 75th and 85th percentile for pollution burden and related vulnerability on the CalEnviroScreen index (Office of Environmental Health Hazard Assessment, 2020).

San Fernando has a tree canopy cover of 19%, on par with the LA County average (Los Angeles County Tree Canopy Advanced Viewer, n.d.). The region receives an average of 15 inches (381 mm) of rain annually, most of which falls between October and April (Los Angeles Almanac, 2021). Trees must therefore receive supplemental irrigation during the establishment period, which in the study region ranges between three and five years after planting (City of Los Angeles Bureau of Street Services, 2015; Pincetl, 2010b). Based on a field assessment conducted by the research team, most parkway planting strips in the study neighborhood are not served by sprinklers or other automatic irrigation systems.

San Fernando is in an inland valley that experiences approximately 54 days of extreme heat per year, a number that is expected to increase to between 79 and 126 days per year in the coming decades under moderate and business-as-usual climate emissions scenarios, respectively (Sun et al., 2015). This means that residents may experience one-third of the year under extreme heat conditions later this century. Already, residents of San Fernando experience some of the highest rates of excess emergency room visits due to extreme heat — 3.1 excess visits per 100,000 people, compared to only 1.5 for LA County on average (University of California Los Angeles, 2022). Extreme heat already has measurable effects on human health in San Fernando, highlighting the necessity of heat mitigation strategies to counter worsening impacts.

Table 3-1 shows study participant demographics. Approximately 79% of participants in the study reported owning their homes, compared with just 57% of San Fernando residents at large (United States Census Bureau, 2022b). The average household income of participants was in the range of $50,000–$75,000, with 42% earning more than $75,000. This compares with a median household income in San Fernando of $60,655 in 2020 dollars (United States Census Bureau, 2022b). The majority of study participants (73%) reported that they had completed at least some college or had earned a degree from either a trade school or university, including 16% who had completed graduate degrees. This compares with just 65% of San Fernando residents over 25 years old whose highest level of educational attainment is a high school diploma or equivalent (United States Census Bureau, 2022).

The sample was somewhat skewed in terms of homeownership, with more homeowners than renters, and residents had a relatively high income and educational attainment. However, as we discuss in Section 3.3, we found no correlations between homeownership, income, or education and intervention effects. This suggests that renters and homeowners are equally likely to care for trees, and that residents with higher income and education are no more likely to water their tree than those with lower income and education. Home ownership, income, and education were also not correlated with tree care barriers. That is, renters, lower-income residents, and those with relatively less education did not report having more barriers than homeowners or those who earn a high income and/or are highly educated.

Table 3-1. Demographics of study participants.

Characteristic	N	%
	118	100
Gender		
Female	77	68
Male	36	32
Other	1	1
Age		
18-20	-	-
20-29	9	5
30-39	13	7
40-49	28	15
50-59	26	14
60-69	18	10
70+	9	5
Race/ethnicity		
Asian	4	4
Black or African-American	-	-
Hispanic or Latino/a	84	79
White	15	14
Other	4	4
Education		
Kindergarten or less	2	2
Grades 1 through 8	7	6
Some high school	2	2
High school graduate or GED	19	16
Some college	26	22
Trade/technical school or 2-yr degree	19	16
College graduate	22	19
Graduate degree	19	16
Annual household income before taxes		
Less than $12,000	5	5
$12,000 to $25,000	10	10
$25,001-$50,000	18	18
$50,001 to $75,000	23	23
$75,001 to $100,000	22	22
Over $100,000	20	20
Years living in neighborhood		
<2	3	3
2-5	10	9
6-10	22	19
11-15	15	13
>15	46	40
Whole life	20	17
Home ownership		
Own	89	79
Rent	23	21

3.3 Research design

3.3.1 Pre-intervention survey

Recruitment was conducted by mail to 400 households in San Fernando in July 2020. A packet containing a 44-question baseline survey was sent to households, with all correspondence sent in both Spanish and English (see Appendix A for the survey in English). Originally intended to be conducted via door-to-door canvassing, survey data collection was modified due to social distancing during the COVID-19 pandemic. Recruitment was instead conducted exclusively by mail, with all correspondence co-messaged by the nonprofit tree group TreePeople and the City of San Fernando.

The survey packet included: an invitation letter explaining the purpose of the study and providing the option to complete the survey on paper, electronically, or by telephone; a consent form advising them of the voluntary nature of the project and that recipients did not need to respond to any questions they did not wish to answer; a paper survey; $2 cash to incentivize response; an incentive selection card to indicate the preference for a $20 gift card (Amazon, Chipotle, Starbucks, or Target), which respondents would receive upon completion of the survey; and a pre-paid envelope for returning the paper survey.

The survey was informed by a literature review, focus groups, and a prior survey conducted during an earlier study on tree stewardship administered by members of the research team in Huntington Park, a city in LA County located approximately 48 km (30 mi) southeast of San Fernando (see de Guzman et al., 2018 for details about this prior study). Demographically, Huntington Park and San Fernando are comparable in terms of ethnicity, educational attainment, and age distribution, though Huntington Park is somewhat more densely populated and has lower average household income (United States Census Bureau, 2022a).

A follow-up reminder mailing containing a one-page letter in Spanish and English was sent to non-responsive households approximately three weeks after the recruitment packet was sent. Of the 400 packets that were originally sent, 11 were undeliverable and returned to sender. Recruitment yielded 118 fully or partly completed surveys, for a response rate of 30%. Households that responded to the survey received an intervention packet four months after the pre-intervention survey was sent, described in the next section.

Inter-rater reliability measures were to ensure responses from paper surveys were accurate. The survey questions and their variables were re-coded into fewer variable categories (Appendix B). These re-coded variables included: values pertaining to trees; beliefs around tree care; tree care actions; values pertaining to neighborhood; tree care barriers; knowledge about the link between trees and health; locus of responsibility; beliefs about heat; concerns about heat; past experiences with heat impacts on health; perceptions around heat; heat protective measures; access to coping strategies during heat waves; community resilience and social ties; and demographics. Tree care action variables were used to measure self-efficacy. Where necessary, variables were reverse coded so that higher values indicated positive outcomes (e.g., questions about the presence of barriers were reverse coded so that higher values corresponded to fewer barriers).

The study was approved by the California State University Northridge Committee for Protection of Human Subjects and the University of California Los Angeles Office of the Human Research Protection Program under study #20-001140.

3.3.2 Intervention

We used data from the pre-intervention survey to support development of the intervention. Two of the 118 households that responded to the survey were not included in the intervention because they had no tree or landscaping to water in the parkway, making the intervention irrelevant. The sample thus included a total of 116 households.

The goal of any CBSM intervention is to further boost benefits while reducing barriers to encourage the adoption of the targeted behavior (McKenzie-Mohr., 2011) — in our case, tree stewardship as demonstrated through regular watering. We target watering as our primary and most direct indicator of tree stewardship both because it can be objectively measured through soil moisture readings, and because it is a behavior that must be completed frequently and one that can determine the ultimate success or failure of a planting program (Moskell & Allred, 2013; Roman et al., 2015). A secondary goal was to influence heat-risk concern and protective actions.

Several preliminary findings from the pre-intervention survey informed the intervention design. These included:

- Trees are broadly valued for their benefits. High mean values (in parentheses) indicate strong agreement with the following question-statements, on a 7-point scale:
  - "Having more shade will encourage people to be outside more" (6)
  - "Having trees in my neighborhood helps reduce air pollution" (6.4)
  - "Trees are important for human health" (6.6)
- Two particular barriers to tree stewardship were pronounced:
  - "It is the responsibility of the city to care for the trees that line the streets" had a mean of 5.2 out of 7, indicating that most people believe it is not their responsibility to maintain street trees. This suggests that the intervention would need to indicate that the community's help is needed to keep newly planted trees healthy.
  - "I do not want to pay for the water needed to care for a tree" emerged as a moderate barrier—with a reverse-coded mean of 4.9 out of 7, suggesting that the intervention should make clear that, using local water rates, the annual cost for watering a young tree is $5–10.
- Importantly, the statement "I have time to water the tree each week" had a mean of 6.1, indicating that time is not a barrier.
- Tree stewardship is positively correlated with values pertaining to trees ($r = 0.494$, $p < 0.001$), suggesting that an intervention should emphasize the value and benefits of trees.
- Tree stewardship increases as barriers to tree care decline ($r = -0.316$, $p < 0.001$), suggesting that an intervention should strive to reduce barriers, whether they are perceived (e.g., the belief that watering trees is the city's responsibility), physical (e.g., difficulty carrying a 19-L (5-gallon) bucket of water), or structural (e.g., no garden hose available for watering).

- Respondents who report a high concern around heat-health impacts also report higher rates of tree stewardship ($r = 0.218$, $p = 0.025$). That is, residents who indicated that they have high concern about the impacts of heat on themselves and their loved ones had higher rates of tree stewardship, suggesting that an intervention should emphasize the role that trees have on reducing temperatures and that tree stewardship is a way to reduce heat risks.
- There is a weak positive relationship between tree care actions and heat protective actions ($r = 0.176$, *ns*). This suggests that framing tree stewardship as ultimately beneficial to heat protection could be a worthwhile strategy to test, which may be reinforced by the fact that there is a positive correlation between being concerned about health and tree stewardship, and that there is a positive correlation between tree stewardship and knowledge about the link between health and trees ($r = 0.373$, $p < 0.001$).

We used a variety of behavior change strategies that draw from social psychology, environmental psychology, and other behavioral sciences as part of the CBSM toolbox for reducing barriers and boosting benefits. These included: commitments to move residents from intention to action; prompts that serve as a reminder to act at suitable intervals; and educational strategies such as vivid communication using graphics to demonstrate the behavior and reinforce benefits and instructional pieces to explain the behavior (McKenzie-Mohr, 2011). All of these strategies support the establishment or reinforcement of social norms and encourage social diffusion to accelerate adoption of tree stewardship behaviors.

We implemented a community-based intervention that tested three messaging strategies and was offered in Spanish and English. Segmentation occurred across the experimental conditions shown in Table 3-2. Messaging conditions were compared for their effect on the main outcome of fostering street tree stewardship, and on the ancillary outcomes of heat-related indicators. The first condition (control) used materials produced for a pilot study on tree stewardship implemented in Huntington Park (de Guzman et al., 2018). This strategy contained simple instructions about how to water trees correctly. We considered this control condition to be "generic" because it was not informed by neighborhood-specific factors such as attitudes held by the community around trees, and was not specifically designed to appeal to neighborhood values around safety, social ties, or related factors. A second condition ("environmental health messaging") provided instructions and also framed the importance of trees watering within the context of health of the local environment (i.e., how trees impact neighborhood factors such how clean the air is or how hot it gets during a heat wave). A third condition ("public health messaging") provided instructions and framed the importance of tree watering within the context of individual and public health outcomes (i.e., how tree cover can affect rates of asthma or diabetes). Appendix C includes a selection of the intervention materials.

Table 3-2. Segmentation by intervention messaging condition.
Participants (*n* = 116) in each study group received a packet of materials at the start of the intervention which contained items specific to one of three messaging conditions.

	Control	**Public health messaging**	**Environmental health messaging**
Sample size	38	39	39
Condition description	Replicated the pilot study strategy and used an outreach packet consisting of bilingual materials as described below.	Bilingual packet of materials emphasizing link between trees and health from a physical health perspective.	Same packet of materials but instead emphasizing the link between trees environmental health.
Number of intervention touchpoints	1 (all items delivered together)	3 total (primary items delivered at the beginning of the intervention; 2 individual reminders subsequently delivered)	
Instructional item	Refrigerator magnet with tree stewardship instructions, incl. messaging aimed at reducing the perceived barrier that watering a tree is costly and to reinforce that environmental stewardship is consistent with community values	Postcard, designed in a nostalgic mid-century style designed to appeal to neighborhood aesthetics, with tree stewardship instructions messaging to reduce the perceived barrier that watering a tree is expensive and demonstrate the relatively little amount of water a tree needs on average. The postcard was clipped to a heavy duty decorative refrigerator magnet in the same aesthetic.	
Prompt/reminder item	Car air freshener with a reminder to check soil moisture weekly. Many homes in the pilot neighborhood lack private parking and moving a parked car for street cleaning on a weekly basis is common.	1) A decorative 3-inch ceramic pot with a succulent plant. Instructional postcard clipped to pot with a reminder to check the moisture of the tree in the parkway whenever checking if their new plant needed to be watered. 2) Two postcards mailed a few weeks apart reminding residents to water their tree and emphasizing the physical or environmental health benefits of trees.	
Public, durable commitment item	Static-cling sticker, which recipients were asked to display in a sidewalk-facing window, indicating a household's commitment to greening the neighborhood and designed with the intent to appeal to community values and shift norms toward increased environmental stewardship.	A static-cling sticker, which recipients were asked to display in a sidewalk-facing window, using the same shade tree design as the magnet and with the message "San Fernando, we care for trees / Cuidamos nuestros árboles."	

The two conditions framed around environmental health or public health were chosen in order to explore the connection between tree planting and heat mitigation. These messaging strategies were chosen to explore how pro-environmental framing would fare compared with pro-social framing when the topic of study pertains to factors that influence both the environment and society. The two conditions enabled us to compare the relative effect of these two framings and determine whether one of these framings had more resonance with the residents involved in the study.

In addition to segmentation by experimental messaging condition, we also tested an additional condition (Table 3-3). Households were segmented by level of prior participation in a tree planting campaign conducted in the months preceding the intervention, which we refer to as "planting condition." This variable was included because a community organization had been executing a tree planting program in this community, and residents exposed to this organization may have been more knowledgeable about and/or motivated to engage in tree stewardship. Another motivation behind including this condition was that maintenance of the entire urban forest — not just newly planted street trees — relies on engagement of the public. It also enabled us to investigate whether tree stewardship behaviors could influence residents who had little to no prior interaction with the city or tree planting group. While the sample was less evenly distributed among the tree planting conditions (Table 3-3), a post hoc power analysis of the study yielded an effect size of 0.5 for intervention conditions that had as few as 12 subjects. Our study exceeded this threshold despite the fact that more study participants were in the "received a tree" condition.

Table 3-3. Segmentation by tree planting condition. Study participants (*n* = 116) were in one of three conditions related to tree planting in the neighborhood.

	Received a Tree	**On Planted Street**	**New Area**
Sample size	49	36	31
Quasi-experiemental condition	Street tree recently planted in the parkway in front of the home since a TreePeople/City of San Fernando planting campaign began in January 2019.	Homes that are located on a street segment that has been recently planted but in front of which a tree was not planted as part of the recent planting campaign. Homes in this segment have an existing tree or other plant material in the parkway requiring irrigation and care.	On a street with no previous or planned planting campaign, but with a tree or other vegetation in the parkway requiring irrigation and care.
Exposure to tree planting group	High	Medium	Low

3.3.3 Field observations

The intervention was immediately followed by an evaluation of the effectiveness of the program via field observations of soil moisture and other measures detailed below. The observations were collected during field visits held on varying days and times of the week. Field crews collected three categories of data: soil moisture readings using a soil moisture meter; tree health characteristics, including ratings for trunk, branch and leaf health, based on industry standards; and other observed characteristics, including the presence of mulch and weeds, and whether intervention materials were seen on display (i.e., a sticker that residents were asked to display in a visible location as a "public commitment" toward shifting social norms).

If a tree was dead or missing, this was also noted. At the pre-intervention baseline, 18 of the 118 trees originally planted were dead or missing, indicating that at that point in time the planting had a survival rate of 84.5% for trees planted 6-18 months prior. We further culled the study sample once the observations began, removing the 18 trees from the count for a sample of 100 trees. Moisture readings were taken starting October 2020 and ending November 2021, during four distinct study phases: prior to the start of our study (Pre-Intervention); immediately following the first distribution of intervention materials (Post-Intervention 1); immediately following the second distribution of intervention reminders received by subjects in the treatment groups (Post-Intervention 2); and finally, after participants completed the post-intervention survey (Post-Intervention 3). Post-intervention observations included a total of 19 readings per household.

In order to ensure that each reading was representative of the moisture content within the entire parkway, readings were taken at each residence using two separate sensors (DSMM500 Precision Digital Soil Moisture Meters) to probe two different sides of each planting site, 46 cm (18 in) away from the trunk. When the readings differed, an average of the two readings was recorded. Data collection days were scheduled at least 48 hours after a rain event.

3.3.4 Post-intervention survey

In May 2021 participating households received a post-intervention survey, 10 months after the baseline survey and six months following the beginning of the intervention. We requested that the post-intervention survey be completed by the same person who responded to the pre-intervention survey, and in the data analysis phase we used anonymous identifiers (year of birth and gender) to verify that both surveys were completed by the person. If verification was not possible, the survey responses were not included in the analysis. The post-intervention survey was identical to the baseline survey, enabling a longitudinal analysis of changes in self-reported tree behaviors as well as knowledge and attitudes around trees, heat, and other survey domains.

To ensure a high response rate, several reminders were sent. An initially low response rate prompted us to increase the incentive from $20 to $50 per completed survey. Of the original 118 households that responded to the baseline survey, 106 also completed the post-intervention survey, yielding a retention rate of 90%. We could not verify that 20 of the post-intervention surveys were completed by the same person who completed the pre-intervention survey, and we removed these from the longitudinal analyses, for a total sample of 86 paired pre- and post-intervention surveys.

3.3.5 Analysis methods

Study data included survey responses and field observations, as described previously. We used descriptive statistics, including means and proportions when appropriate, to analyze the pre-intervention survey data, and used these as well as results from correlational analyses to guide the intervention. We present a selection of these analyses, as well as soil moisture readings from the pre-intervention phase. We compared post-intervention changes in the Likert scale survey variables using Repeated Measures Analyses of Variance (ANOVA) and correlational analyses. Changes in soil moisture were examined using repeated measures ANOVA.

3.4 Results

3.4.1 Factors affecting tree stewardship and tree health

3.4.1.1 Hypothesis H1: Residents with higher tree stewardship-related self-efficacy will demonstrate higher tree stewardship

As discussed previously, self-efficacy was measured through self-reported tree care actions, and tree stewardship behavior was measured through soil moisture. We found that barriers to tree stewardship were negatively correlated with higher tree stewardship, meaning that residents who reported engaging in tree stewardship also reported fewer barriers to tree care ($r = 0.537$, $p < 0.001$). Self-reported tree care action was significantly correlated to soil moisture levels ($r = 0.229$, $p = 0.035$), indicating that higher self-reported tree stewardship is a fairly good predictor of higher soil moisture. These two findings prove the hypothesis H1.

These measures are important for tree health and survival. Of the 100 trees that were present and alive when the intervention was first administered: 97% were still alive; 71% received a health rating of "4" (good health, no apparent problems); 18% had a health rating of "3" (fair health, with only minor problems); 5% received a "2" (poor, with major problems); and 3% received a "1" (dead or dying, extreme problems).

3.4.1.2 Hypothesis H2: The intervention will result in improved self-efficacy and tree stewardship

Next, we analyzed the correlation each intervention treatment had with the outcomes of self-efficacy and tree stewardship. We performed a repeated measures ANOVA to compare the effect of the three messaging strategies on self-efficacy and found no statis-tically significant difference by messaging condition, $F(2, 82) = 1.6$, *ns*. We conducted the same analysis to compare the effect on tree stewardship, as measured by soil moisture, and found little effect, with no statistically significant difference in soil moisture between the groups, $F(2, 92) = 0.24$, *ns*.

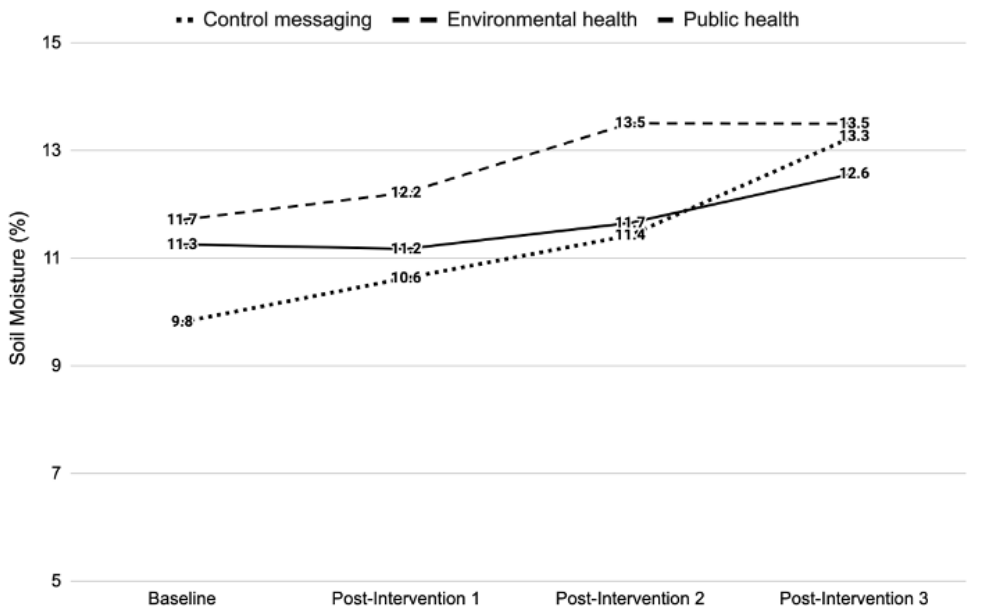

Figure 3-1. Percentage of soil moisture by phase for each messaging condition ($n = 100$). Mean values are shown for each of the study phases. Baseline values are calculated using three pre-intervention readings. Mean values for the three post-intervention observation rounds included a total of 19 readings per site.

Changes in mean soil moisture as a function of phase and messaging condition are shown in Figure 3-1. Soil moisture increased from the baseline through the three subsequent post-intervention phases. Interestingly, the largest and most steady increase was in the control group, which actually surpassed one of the two treatment groups by the end of the study. This group started with the lowest soil moisture and thus required the greatest increase to arrive at a suitable threshold of soil moisture. While we cannot definitively attribute this phenomenon, it is possible that the regular presence of field crews collecting soil moisture was observed by the residents and had an intervention-like effect. Notably, the environmental health messaging group had the highest soil moisture at all phases of the study.

Although messaging condition had little effect, we found that tree stewardship was correlated with planting condition across several outcomes. We found a statistically significant effect when we performed a repeated measures ANOVA to compare the influence of planting condition on soil moisture $F(2, 92) = 10.0$, $p < 0.001$. Changes in mean soil moisture as a function of phase and tree planting condition are shown in Figure 3-2. Moisture readings were highest for residents in the Received a Tree condition, including at baseline, but they were also quite high for those in the On Planted Street condition. These two conditions had the most interaction with the tree planting group. As a matter of fact, pre-intervention moisture readings for residents in both conditions were almost twice as high as those in the New Area condition. Residents in the latter condition likely had no interaction with the tree planting group prior to the start of this study.

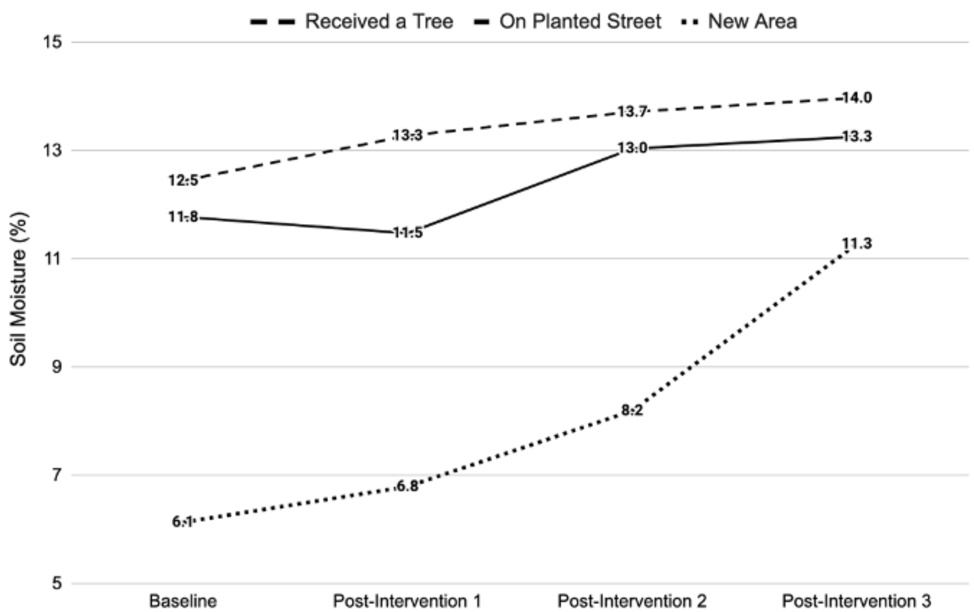

Figure 3-2. Percentage of soil moisture by phase for each tree planting condition ($n = 100$). Mean values are shown for each of the study phases. Baseline values are calculated using three pre-intervention readings. Mean values for the three post-intervention observation rounds included a total of 19 readings per site.

We note that while New Area households had lower soil moisture compared to the other two groups throughout the study period, the increase from single- to double-digit percentages is critical from a tree health perspective. Optimum soil moisture varies, but must be above the wilt point of plants, which is generally considered to be between 10 and 18% (Urban, 2014). The near doubling of average soil moisture from 6.1% to 11.3% is thus meaningful in supporting tree planting outcomes, particularly in the region's semi-arid climate.

A surprising outcome, shown in Table 3-4, was a reduction in the means of self-reported tree care actions post-intervention, both for the messaging and planting conditions. We attribute this unforeseen result to the timing of the pre-intervention survey occurring during the height of summer and the post-intervention survey occurring in the cooler, wetter spring months, when the need to water a tree is less pronounced in the Southern California climate.

Table 3-4. Means for tree stewardship variables for messaging condition and planting condition. Variables are significantly correlated (*r* = 0.229, p = 0.035). The top value shows means over the study period. Pre- and post-intervention means are presented in brackets. The pre-intervention value is averaged over three readings; the post-intervention value is calculated by averaging 16 readings taken over subsequent rounds of observations. Standard errors for the study period mean values are presented in parentheses. The * symbol indicates a statistically significant result.

Variable	Messaging Condition			Planting Condition		
	Control	*Environmental Health*	*Public Health*	*New Area*	*On Planted Street*	*Received a Tree*
Soil moisture (%)	11.8 [10.2, 12.3] (.599)	12.4 [11.4, 12.8] (.573)	11.6 [11.0, 11.9] (.449)	8.1* [5.9, 8.8] (.680)	12.4* [11.8, 12.6] (.623)	13.4* [12.4, 13.7] (.363)
Self-reported tree care actions	6.5 [6.4, 6.6] (.129)	6.0 [6.1, 5.9] (.287)	6.6 [6.8, 6.3] (.127)	6.2* [6.2, 6.2] (.215)	6.0* [6.2, 5.8] (.246)	6.7* [6.9, 6.7] (0.68)

Taken together, these findings only partially confirm the hypothesis H2 (the intervention will result in improved self-efficacy and tree stewardship). Messaging condition had limited effect on self-efficacy and tree stewardship, but planting condition showed a positive correlation to these measures.

3.4.1.3 Additional factors affecting tree stewardship and tree health

We also found that soil moisture correlated positively with observed variables. The first of these was tree health — that is, trees that were assessed to be healthy based on a 4-point evaluation of trunk, branch, and leaf health also had higher soil moisture ($r = 0.205$, $p < 0.001$). This confirms that increases in soil moisture support better tree health. Tree health was also positively correlated with the use of mulch ($r = 0.347$, $p < 0.001$), meaning that households that applied mulch — another indicator of tree stewardship — tended to have healthier trees. However, we found no significant correlation between households that displayed the sticker that study participants were asked to place in a visible location as a public commitment on either tree health ($r = -0.064$, *ns*) or on soil moisture ($r = 0.078$, *ns*). We note that we were only able to verify that stickers were displayed in a publicly visible manner by approximately 10% of households, and we thus consider this result inconclusive.

In addition to using soil moisture data to confirm the effect of planting condition on tree stewardship, we also analyzed survey responses (Table 3-4). Residents in the Received a Tree condition had higher self-reported tree care actions (a mean of 6.7 on a 7-point scale) compared with residents in the On Planted Street and New Area conditions (which reported means of 6 and 6.2, respectively), $F(2, 82) = 3.2$, $p < 0.05$. These results suggest that having a community organization on the ground likely encourages people to take care of their trees by watering them regularly. However, we note that only small changes in self-reported tree care actions occurred during the study for any of the conditions, possibly because agreement with that statement was already high at the beginning of the study.

There was a significant correlation between residents' knowledge of the link between trees and health and whether they reported higher tree care actions ($r = 0.532$, $p < 0.001$). In other words, the more a resident understands the importance of trees to health, the higher their level of tree stewardship. This could be because people who understand the health benefits of trees intentionally remove those barriers or perceive less barriers to tree care, suggesting that increasing awareness about the benefits that trees have on health could be an effective strategy for increasing tree stewardship and reducing barriers.

3.4.2 Factors affecting heat-related variables

3.4.2.1 Hypothesis H3: Residents with higher tree stewardship will exhibit higher heat-risk concern and take more protective actions

We explored correlations between self-reported heat-risk concern and protective actions and tree stewardship (as measured by soil moisture) and found no significant correlation. Heat-risk concern was weakly correlated with tree stewardship ($r = 0.045$, *ns*), while protective actions had a negative correlation with tree stewardship ($r = -0.106$, *ns*).

Perhaps not surprisingly, those with higher heat-risk concern took more protective measures against heat ($r = 0.274$, $p < 0.005$). For example, they were more likely to stay out of the sun during the hottest part of the day, drink plenty of liquids, avoid alcohol, and check in with family and friends on hot days. Although the effects were small, residents were somewhat more likely to report engaging in tree care actions if they expressed higher heat-risk concern ($r = 0.184$, *ns*) and if they took more protective actions ($r = 0.173$, *ns*), suggesting that raising awareness about the impacts that heat can have on health could increase tree care actions. However, given that we did not see a correlation with soil moisture and either heat-risk concern or protective actions, we reject hypothesis H3. We nevertheless present the following results to further explore the relationships that emerged between tree stewardship and heat risk and the effect that the intervention had on these.

3.4.2.2 Additional factors affecting heat-risk outcomes

Residents in the public health condition showed a small increase in heat-risk concern between the pre- and post-intervention surveys, from a mean of 5.3 to 5.4 on a 7-point scale (Table 3-5). Those in the control and environmental health condition did not show an increase. We suspect that survey timing had an influence, as the pre-intervention survey collection occurred during the summer months of what was a particularly hot summer in the Los Angeles region, when the experience of heat was likely salient. The post-intervention went out the following spring, when experiences with heat were likely psychologically distant.

Table 3-5. Heat-risk concern and protective actions taken by messaging condition and planting condition. Heat-risk concern is a Likert-scale measure on a 7-point scale, where 1 = low concern and 7 = high concern. Self-reported heat protective actions are out of 10 possible actions. Standard errors are in parentheses.

Variable	Measure	Messaging Condition			Planting Condition		
		Control	*Environmental Health*	*Public Health*	*New Area*	*On Planted Street*	*Received a Tree*
Heat-risk concern	Study means	5.5	5.7	5.3	5.2	5.5	5.7
	Pre-intervention	5.5 (.334)	5.7 (.302)	5.3 (.329)	5.2 (.360)	5.6 (.326)	5.6 (.302)
	Post-intervention	5.5 (.318)	5.7 (.299)	5.4 (.273)	5.3 (.362)	5.3 (.332)	5.8 (.222)
Protective actions taken	Study means	7.7	7.5	8.2	7.7	7.8	7.8
	Pre-intervention	8.6 (.253)	8.8 (.232)	8.7 (.252)	8.7 (.305)	8.6 (.260)	8.7 (.202)
	Post-intervention	6.8 (.589)	6.2 (.667)	7.6 (.566)	6.8 (.732)	7.0 (.608)	7.0 (.539)

Survey timing may also have influenced the reporting of protective actions taken against heat. Residents in all messaging conditions actually reported fewer protective actions taken post-intervention than they did pre-intervention (Table 3-5), but those in the public health condition had a smaller reduction (a mean reduction of 1.1 out of a possible score of 10 protective actions, compared with a reduction of 1.8 and 2.6 actions for the control and environmental health conditions, respectively). Recalling actions taken during the hotter part of the year required residents to think back several months to the previous summer. The smaller reduction in actions reported in the public health condition indicates that that messaging may have had an influence on keeping a resident's heat-protective actions as more salient despite the more comfortable spring weather, when they completed the post-intervention survey. This is important because Los Angeles's climate has high seasonal variability and is prone to occasional heat waves that increase human mortality even during colder parts of the year (Kalkstein, et al., 2018).

While there was some variation between messaging conditions, there was virtually no numeric variation in protective actions taken between planting conditions, $F(2, 103) = 0.02$, *ns*. Residents in the Received a Tree, On a Planted Street, and New Area conditions reported a mean protective action score (out of 10 possible actions) of 7.8, 7.8, and 7.7, respectively. Planting condition was also not significantly correlated with heat-risk concern, $F(2, 80) = 0.66$, *ns*. There was a moderately high degree of concern about heat risk (between 5 and 6 on a 7-point scale) among most respondents, with residents in the Received a Tree, On a Planted Street, and New Area conditions reporting a mean score of 5.7, 5.47 and 5.21, respectively (Table 3-5).

Heat variables correlated with other tree-related variables. Residents with a higher knowledge of the benefits that trees have on human health were somewhat more likely to report that they had experienced symptoms, such as headaches, dizziness, tiredness or nausea/vomiting, due to heat exposure — indicating a higher awareness of heat-health risk ($r = 0.257$, $p = 0.008$). Knowledge about the benefits that trees have on human health was also correlated with protective actions ($r = 0.290$, $p = 0.002$). Residents with higher knowledge of the benefits trees have on human health also expressed more concern that heat waves are a problem for health than those who were less knowledgeable ($r = 0.424$, $p < 0.001$), and were also more likely to report engaging in tree care actions ($r = 0.532$, $p < 0.001$). This suggests that an intervention aimed at increasing knowledge about the benefits that trees have on human health can boost heat-risk awareness, concern, protective action, and tree care actions.

3.5 Discussion

3.5.1 Significance of study findings

To our knowledge, this is the first published empirical study that looks at the effects of messaging and exposure to a community group on tree stewardship, and the first to consider how a program that seeks to foster tree stewardship can simultaneously foster heat-risk reduction. Our findings suggest the messaging intervention had minimal impact on tree stewardship actions and that outcomes were instead influenced by the variable of planting condition. Having a community organization on the ground appears to increase tree stewardship behaviors, and increasing awareness about the benefits of trees not only increases the likelihood that residents will care for the trees planted in their parkways and yards, but that they will also care for themselves by taking protective actions that reduce health vulnerability to heat waves.

While self-reported tree stewardship behavior changed little during the study, soil moisture readings for all three planting conditions increased. Perhaps surprisingly, the largest increase was among those who live on a street that had not been planted, though we note that they started at a very low pre-intervention average of 6.1% soil moisture and thus had the greatest room for improvement. By the end of the study, moisture levels for residents who lived on a street that had not been planted were still significantly lower than the other groups — with post-intervention averages still lower in this group than the pre-intervention averages for the Received a Tree and the On Planted Street conditions. Taken together, this finding suggests that interaction with a community organization and the establishment or reinforcement of social norms around tree stewardship are helpful for improving outcomes.

The intervention is likely to have influenced tree stewardship behavior and thus soil moisture, but increases in soil moisture over the course of the study could also be due to the Hawthorne effect, which is the phenomenon of the possible impact that awareness of being studied might have on research participants (McCambridge et al., 2014). One pathway this effect may have occurred is that study staff, who visited the neighborhood with some regularity over a year, may have seen as they visited the parkways in front of the homes, an outcome that is consistent with what we observed during the pilot study in Huntington Park (de Guzman et al., 2018). The surveys may also have served as a reminder to water trees more regularly. That is, the act of completing a survey that asked about tree stewardship behaviors may have had an intervention-like effect and served as a sort of engagement strategy to encourage watering. These two possibilities may explain why soil moisture increases in the New Area condition were greatest, and further bolster the notion that the presence of a community organization in a neighborhood and some form of community engagement — even minimal indirect contact — encourages people to steward trees.

Social cognitive theory (SCT) accurately predicted that the likelihood of tree stewardship behavior being adopted and maintained would be influenced by study subjects observing the behavior in others — in our case, likely both their neighbors and research staff who performed fieldwork of assessing soil moisture and tree health throughout the study year. SCT helps to explain why by the end of the study, households in the New Area condition, which previously had limited interaction with the city or planting group, experience more dramatic soil moisture increases than any other planting condition. SCT somewhat predicted hypothesis H2 (the intervention will result in improved self-efficacy and tree stewardship). Tree stewardship was influenced by planting condition rather than the messaging condition, and thus we cannot conclude that SCT fully predicted the outcome. The related self-efficacy theory predicted hypothesis H1 (residents with higher tree stewardship-related self-efficacy will demonstrate higher tree stewardship). Self-efficacy can be both a pre-existing trait and one that can be developed through effective interventions, and as such, municipal and nonprofit organizations seeking to improve the outcomes of urban greening efforts, but which have limited resources, can focus their activities on providing opportunities for residents to observe tree stewardship behaviors and building related social norms. The protective action decision model proved that risk perceptions informed self-reported protective actions taken during a heat wave and in response to imminent threats. This did not, however, extend to the action of tree stewardship, a long-term preparedness action that mitigates heat.

Findings were not correlated to socioeconomic variables, including income, education, or home ownership status. The lack of correlation between these variables is encouraging given high levels of rentership and variable income and education status in the region. This suggests that effective engagement around tree stewardship and heat mitigation is not predicated on owning a home, having higher wealth, or being highly educated. Instead, it suggests that enhancing tree stewardship and heat protection among residents in the region can be achieved regardless of these socioeconomic variables.

We also saw that increasing knowledge of the link between trees and public health or environmental health increased residents' level of heat-risk knowledge and actions during heat waves. As cities around the world invest in urban forestry for climate adaptation and urban heat mitigation, coupling tree planting and care programming with raising awareness about the risks of heat and how they can be reduced can provide a tangible pathway for residents to engage in actions that promote heat mitigation, sustainability, and climate resilience at the local level.

3.5.2 How the findings compare to other studies

Our methods expanded upon a prior study conducted in Huntington Park, a city in southeast LA County, described in de Guzman et al. 2018. In that study, we sought to address the need for establishment-period care by testing an approach to engage residents to actively care for young street trees planted in front of their homes. Following the Community-Based Social Marketing framework, we used focus groups and a pre-intervention survey to investigate socioeconomic and cultural characteristics to barriers and motivators around tree stewardship, and developed an outreach program strategy according to the findings. The intervention materials created for that study were used in the present study as a control condition, which we designated as such because the materials were originally informed by community-specific factors in Huntington Park, not San Fernando.

In Huntington Park, we pilot-tested and evaluated the program for effectiveness in changing behavior, using two different engagement methods. We compared active, in-person outreach (door-to-door engagement with residents using program materials and offering a live demonstration of tree care actions) against passive outreach (program materials were left at the doorstep and no tree care demonstration was provided). Both methods were compared to baseline conditions. Soil moisture, tree health, and presence of mulch were evaluated over a six-week period after the intervention.

In the prior study, we found that trees at homes in the active outreach group had significantly higher soil moisture, more mulch, and better observed health than trees at homes in the passive outreach group. Mean soil moisture readings in the active group were consistently in the range of 15 to 25%, compared with those in the passive outreach group, which were generally between 10 and 18%. This compares with post-intervention mean soil moisture among San Fernando study participants that did not exceed 14% in any of the messaging or planting conditions. In both the prior and present study, all groups had better outcomes as compared to pre-intervention conditions.

The San Fernando study was conducted during the COVID-19 pandemic, meaning that active, in-person engagement was not a possibility as it was in Huntington Park. This restriction made achieving the desired outcomes more difficult, and we attribute lower soil moisture to this reason. Pandemic-era social distancing reduced or even eliminated in-person interactions, both between the study staff and residents, and likely between residents and their neighbors. Consequently, we saw lower response rates despite significant efforts made to contact and incentivize residents. Even among participants that responded, we saw a lower level of commitment and action than in Huntington Park. This is perhaps not surprising, given that development of social norms — a cornerstone of the behavior change models that informed our strategies — depends on common behavioral patterns being seen, experienced, and reinforced within a group.

McNamara et al. (2022) offers another study that is relevant for discussion. Researchers evaluated a street tree stewardship effort conducted in three LA County unincorporated communities, initiated by the LA County Department of Public Health and Department of Public Works. Local community-based organizations contracted by the County hired at-risk youth from local high schools to conduct door-to-door, bi-lingual (Spanish and English) outreach to residents. Outreach focused on educating residents about tree benefits and tree stewardship, and acquiring permission to plant street trees. Following planting, these workers provided watering using a water truck and hose for up to six months, as funding allowed. Watering responsibility was then transferred to residents. Tree health was assessed, and a resident survey to evaluate previous tree planting and care experience, motivations to participate in stewardship, tree education learning outcomes, and program feedback was conducted post-planting.

McNamara et al. found that tree health was positively correlated with weeks of watering provided by hired workers ($p = 0.01$) but negatively correlated with average monthly rainfall ($p = 0.03$), likely because watering activity was not provided following rain events. Tree health was more strongly predicted by tree species, with species such as *Rhus lancea* (African Sumac) performing very well, and others, such as *Lagerstroemia indica* (Crape myrtle) having poor outcomes. Tree health was somewhat correlated with households that responded to the survey versus those that did not, but this was not statistically significant. Of 11 reasons for participating in the planting program, the top four were benefits that trees provide in: making the neighborhood attractive; being good for the environment; being good for health; and keeping the neighborhood cool. These benefits also ranked highly in our San Fernando study. Residents were also asked about their intent to water their tree. Almost three-fourths responded with the correct frequency (weekly watering) but only about a third reported the correct quantity of 19–38 L (10–15 gallons). Those who responded correctly had somewhat higher tree health scores, but differences between groups were not statistically significant.

In both our study and in McNamara et al. (2022) indicators of tree stewardship, particularly consistent watering, were strongly correlated with tree health. While the McNamara et al. study did not evaluate soil moisture outcomes, we note that the differing stewardship regimes — with residents expected to provide watering immediately after planting in our study, and hired crews providing watering for the initial post-planting period in McNamara et al. — very likely had implications for tree health and program success. This is because regular watering after planting promotes tree survival (Roman et al., 2015; Vogt et al., 2015b), and asking residents to provide that immediate watering does not guarantee that watering will occur. As well, the presence of youth outreach workers in the community providing weekly watering is likely to have been witnessed by residents, enabling the establishment or reinforcement of a social norm around watering. However, in a survey conducted once watering responsibility was transferred, McNamara et al. found only about a third or residents reported the correct watering quantity, pointing to a need to clarify instructions.

Another study that is useful for our discussion is Roman et al. (2015), which evaluated two case studies of street tree planting programs in East Palo Alto, CA and Philadelphia, PA. The study's goal was to identify reasons for these programs' unusually high tree survival rates. Both programs were led by small nonprofit organizations but supported by thousands of hours of volunteer and paid intern labor. Longitudinal data on tree survival and growth and details about planting and tree care practices were used to characterize establishment-period success. The researchers identified a combination of factors that correlated to success, including planting practices, maintenance practices, and program management. Nonprofit-led planting was supported by concerted efforts to recruit youth interns and volunteers to provide maintenance, pairing them with skilled volunteers, such as arborists and landscape architects, who provided training.

East Palo Alto has a fairly similar climate to the Los Angeles region (Philadelphia does not), and like San Fernando, East Palo Alto is a low-to-middle income area. Watering for 568 trees planted in East Palo Alto was either provided by program staff or by automatic drip irrigation approximately every three days during the dry months for the first year, and was subsequently adjusted and provided for up to five years post-planting. In San Fernando, neither automatic irrigation nor staff were available to provide watering, and residents were asked to assume watering responsibility immediately after planting. In East Palo Alto, planting plans were created by a contracted arborist who selected only tree species that would be suitable under current and future climate conditions. In contrast, the trees planted in San Fernando were selected because the species were on a city-approved list and were available at local nurseries, with typically only two species selected by the nonprofit planting manager per neighborhood street (P. Gibson, personal communication, March 10, 2023). The city-approved species list accounts for climate suitability in general terms by including only those species with low or medium watering needs, but the primary characteristics of concern center around avoiding future infrastructure conflict by considering minimum parkway size and tree height at maturity. An arborist-designed planting plan can take into account more nuanced site-specific factors, such as soil type and sun exposure.

Other regions have conducted studies to engage the public in planting and maintaining trees. A study in Ithaca, New York, tested an outreach intervention's impacts on street tree watering behavior and resultant soil moisture and found that reminder postcards had a positive influence, but one which diminished over time (Moskell et al., 2016). Another study, in Indianapolis, Indiana, explored how resident-provided watering related to tree outcomes and other collective neighborhood activities (Mincey & Vogt., 2014). Researchers found that collective (versus individual) watering, signed watering agreements, and monitoring of tree watering all predicted better tree outcomes. Collective watering also predicted other positive social activities, such as neighborhood clean-ups.

3.5.3 Implications of study findings for urban forestry programs and policies

We share the study methods and findings with the intent to help inform future directions for nonprofit and municipal tree planting programs. Our study saw increases in tree stewardship across the board despite the limitations imposed by the COVID-19 pandemic, suggesting that even with limited in-person engagement from a community organization, resident behaviors in support of tree stewardship and heat-health awareness can be fostered. In addition to engaging directly and in the neighborhood, tree planting organizations and municipalities can consider a variety of ways of reinforcing social norms toward tree stewardship.

Programs with limited resources can focus their efforts strategically on demonstrating their presence in the neighborhood. The question we sought to answer in this study was whether a program that is highly tailored to a community (public health or environmental health conditions) yields better results than one that is more generic (control condition, using the pilot study materials). This answer to this question has program implications because developing highly tailored programs requires more resources. A tailored program that performs well may justify spending more time and effort in the community before deploying a program strategy. In contrast, a generic program that performs as well or better provides valuable information for future program development and implementation, as it suggests broadscale implementation can be achieved in a more streamlined, turnkey fashion. We found that generic messaging was equally effective in San Fernando and that highly tailored messaging did not yield better outcomes.

However, we found that the presence of a tree planting group on the ground did influence outcomes. That presence can be expressed in several ways and does not necessarily require significant investment if a program has limited resources. Increasing organizational presence in a neighborhood can be accomplished not only by having staff, volunteers, or other personnel in the community to provide tree care or assess tree health. It can also be accomplished through regular communications — for example, leaving materials on the doorstep; reaching out directly to residents via mail, email, or text; using community posting boards (e.g., NextDoor); inviting residents to answer questions via a poll or survey; or partnering with organizations already operating in the community, such as churches, school groups, or neighborhood councils. However, we note that even with considerable effort, tree stewardship did not increase substantially, begging the question of whether there are other cost-effective methods to ensure newly planted street trees thrive into maturity.

Our study also raises questions about whether the assumptions that many municipal and nonprofit tree planting programs make that residents will take on the responsibility of watering street trees is reasonable, particularly in communities with limited resources. With a concerted effort, we were able to move San Fernando residents to adopt tree stewardship as measured by watering behavior, but soil moisture content did not reach clearly optimal levels, and our research efforts required sustained personnel and financial resources. We note that we differentiate between resource-intensive research activities and the significantly less resource-intensive intervention activities that we were studying. The opt out method used in San Fernando, where a tree is planted unless the resident declines, also likely made uptake of tree stewardship behaviors more difficult among residents who may not have felt they truly had a choice or may have missed the window of opportunity to decline.

Our study also offers policy implications. The present approach to urban greening practiced in many parts of the United States — where funding supports planting but usually not maintenance — creates a gap between the initial investment in planting and the desired return on investment, calling into question the long-term viability of under-resourced urban forestry programs in a warmer, drier climate. Regardless of the possible reasons why changes in tree stewardship outcomes did not improve more substantially, this topic begs the question of whether the arrangement of transferring watering responsibility to the public is sustainable.

As this study and others have shown, this gap can be at least partly addressed through strategically designed engagement programs. However, the assumption that public infrastructure, such as trees planted in the public right-of-way, should be maintained by residents highlights the challenge of placing an unequal burden on communities with limited resources relative to their more affluent counterparts. In wealthier communities, residents often hire gardeners to maintain landscaping, and watering a tree in the parkway is not a significant request; but, in more resource-constrained communities, that burden generally falls on residents (Pincetl, 2010a). Other alternatives must be considered — starting with prioritizing funding and support to hire crews to care for the urban forest, especially during the critical establishment phase for young trees.

Future research could evaluate multiple maintenance regimes and compare outcomes of programs that transfer street tree watering responsibility to residents versus those that mobilize municipal and/or community organization staff and volunteers. Additional research could also investigate the links between tree- and heat-health related outcomes by exploring whether heat programming can be a portal to environmental action — in effect the opposite of what we did. For example, cities with public-facing heat mitigation programs could test the viability of engaging their residents in tree planting and care activities as a heat preparedness and mitigation action.

3.5.4 Limitations

This study had several limitations. The grant that funded this research was written and awarded prior to the COVID-19 pandemic. Data collection was originally intended to occur door-to-door, with study personnel asking survey questions in an interview-like format and then recording the responses in writing. Recruitment occurred via mail instead, and the survey was self-administered via paper copy or electronically. The initial response rate was lower than expected, which we attribute to the more passive recruitment method.

As the survey was self-administered, there was no opportunity to ask for help or clarification from study personnel who would have been available had surveys been collected in person. However, an advantage of self-administration is that a respondent may feel less influence to answer a certain way and may be less subject to social desirability bias or other forms of response bias. Still, given that the pilot study in Huntington Park showed better results for participants who received active rather than passive engagement, we expect that results for the present study would have been more robust if we had been able to engage door-to-door.

Other aspects of research design were also limiting. These included convenience sampling in a particular neighborhood that had already been targeted for tree planting. Starting the study before any trees were planted by the city and community group would have provided more opportunity to assess changes in knowledge, attitudes, beliefs, and values before and after any contact was made with residents.

The uneven distribution of sample groups by tree planting condition, and the timing of surveys and observations, were also less than optimal. Surveys were collected in summer (pre-intervention) and spring (post-intervention), and heat-related questions were likely influenced by this timing, making heat more salient in summer and likely influencing responses during the post-intervention survey, showing the intervention to be less effective than it might have otherwise been. This could have been addressed if data collection had occurred for a longer period (for example, capturing two consecutive summers of data). A longer period of recruitment was necessary due to pandemic-related delays, pushing the project timeline accordingly.

As much as possible, we strove to use quantitative measures, including in assessing tree health. Members of the evaluation team were trained to conduct standardized observations on tree health, but we note that observations may nevertheless have been subject to observer differences. We thus relied on soil moisture as a more objective measure and as a proxy to tree health, even if tree health was ultimately the measure of interest.

Finally, an additional challenge is that the newly planted trees in the study neighborhood were still quite small at the time the research was conducted. Trees had been planted in the months prior to the study and had yet to provide any real benefits of shade. If participants did not perceive or experience significant cooling benefits of the trees, the effect of messaging condition was quite likely limited in influence. A longer-term study to track resident responses to trees that mature to the point of providing noticeable heat mitigation benefits would be better positioned to evaluate the effect of varying message treatments.

3.6 Conclusions

This study investigated the potential of fostering street tree stewardship and individual-level heat mitigation actions using a theory-guided approach. We tested a control intervention against experimental messaging focused on either public health or environmental health, and also segmented participants by the degree of prior household engagement with a local tree planting group. We measured soil moisture, tree health, and survey responses related to both tree stewardship and heat-risk indicators. We found that messaging condition had limited effect on these outcomes, and that level of engagement by the tree planting group was a stronger predictor of tree stewardship. We also found that tree stewardship correlated positively to heat protection measures, suggesting that environmental engagement may be an effective portal to reducing heat risk.

We offer these findings with the intent to provide practical guidance to municipal- and nonprofit-led urban greening campaigns with limited resources. Using creative, cost-effective strategies to increase an organization's presence in the community — even if that presence is not always physically on the ground — can boost urban forestry program outcomes. Finding ways to build and support social norms around tree stewardship can further improve results.

We also offer this study as an example of building a more direct bridge between urban greening and urban cooling programs. In a warming climate, urban forestry efforts are broadly touted as providing cooling services, but much work remains to maximize cooling benefits that trees can provide, and the broader benefits that stewardship programs can provide to urban resilience. We urge researchers and practitioners interested in the heat mitigation potential of trees to design and evaluate programs that link tree and heat-health outcomes so that we can collectively build practical knowledge on how to leverage these two interrelated topics.

CHAPTER 4
A Socio-Ecological Approach to Align Tree Stewardship Programs With Public Health Benefits in Marginalized Neighborhoods[3]

4.1 Introduction

The Los Angeles (LA), California metropolitan region of the United States (US) faces a range of challenges that are induced or exacerbated by extreme climate change events. Of all of the changes anticipated for the region, extreme heat has the potential to impact the largest number of vulnerable populations (Li et al., 2020; Chakraborty et al., 2019). Continued warming is projected to increase average temperatures 4-5°F (2.2-2.8°C) by mid-century, and by 5-8°F (2.8-4.4°C) by the end of the century, with temperature extremes expressed both in the rising number of extreme heat days, and in the hottest days being up to 10°F (5.5°C) hotter than extreme heat days previously experienced (Hall et al., 2018). In addition, due to climate and topographic variability in the LA region, some cities will have 5 to 6 times the number of extreme heat days compared to current levels (Hall et al., 2018). As the planet warms, urban areas are heating up at a faster rate than adjacent rural areas, placing in question the habitability of many cities and highlighting the need for solutions to address heat-related public health impacts (Estrada et al., 2017).

During the hottest summer days in LA, there is an 8% increase in all-cause mortality — deaths from all causes combined — as heat puts extra stress on people with a range of underlying co-morbidity conditions (Kalkstein et al., 2014). In particular, consecutive days of intense heat can have a very harmful impact, with all-cause deaths occasionally increasing by 30% above expected levels (Kalkstein et al., 2014; Sheridan, et al. 2012). Public health is affected when higher heat

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exposure is coupled with limited ways of adapting to heat, particularly in the absence of nighttime relief from the heat, which can increase health risk even more than high daytime temperatures (Dousset et al., 2011).

The burden of extreme heat disproportionately affects vulnerable low-income urban populations and people of color in the US (Jesdale et al., 2013). These communities often live in high-density neighborhoods that have older, substandard housing, less urban forest cover (UFC), and limited access to air conditioning or the ability to pay for it, which create a feedback loop of heating effects. Black Americans are 52% more likely than average to live in areas where a high risk for heat-related health problems exists, while Latino/a communities are 21% more likely to live under such conditions (Jesdale et al., 2013). Residents of neighborhoods that were formerly subject to "redlining" — a Federal practice that determined home lending risk based on racial composition — experience surface temperatures that are on average 4.7°F (2.6°C) and up to 12.6°F (7°C) hotter compared to their non-redlined counterparts in the same city, even more than 50 years after the end of this redlining policy; these higher temperatures are correlated with lower UFC (Hoffman et al., 2020). During extended heat waves in LA, mortality increases about fivefold from the first to the fifth consecutive day; after the fifth day, mortality risk increases 46% in Latino/a communities and 48% in elderly Black communities (Kalkstein et al., 2014).

Despite the growing threat of heat, effective approaches to alleviate urban heat do exist. These include risk mitigation strategies designed to facilitate institutional response during extreme heat events, such as heat alerts, as well as strategies that focus on reducing urban temperatures through measures such as increasing vegetative cover and nature-based solutions, improving building standards, and increasing access to air conditioning (Escobedo et al., 2019; Keith et al., 2020). Air conditioning access is an effective approach for regulating heat and subsequently protecting health, but it is not a sustainable practice in its current form because it generates climate-changing emissions and is often prohibitively costly for low-income households (Barreca et al., 2016). Tree planting is a well-documented heat mitigation strategy that has received increased investment in a growing number of cities around the world (Keith et al., 2020). Investments to increase UFC are understood to provide a range of co-benefits to urban communities such as: reduced urban heat through shading and evapotranspiration; reduced energy demand; carbon sequestration; improved air quality; improved water quality and supply through stormwater runoff management; provision of wildlife habitat; enhanced community cohesion; and improved human health and wellbeing (Escobedo et al., 2019; United States Environmental Protection Agency, 2011). UFC has also been associated with reduced stress (van der Berg et al., 2010; Hartig & Staats, 2006; Roe & Aspinall, 2011).

Trees mitigate heat by regulating climate conditions through shading and evapotranspiration, and these mechanisms can have a significant cooling effect — for example decreasing park air temperatures by up to 11°F (6.1°C) in comparison to surrounding streets (Vanos et al., 2012). Studies modeling projected benefits of UFC in reducing temperatures demonstrate that mature UFC can facilitate exponential cooling for urban areas (Taha, 2015). Cooling at the micro scale also impacts energy demand because tree shade reduces building heat gain and shaded air conditioners work more efficiently (Akbari, 2002; Kendall & McPherson, 2012). Such heat reduction measures result in decreased cases of heat-related illness and death (Kalkstein et al., 2022).

However, the distribution of UFC and its co-benefits is affected by numerous factors ranging from biophysical conditions such as the necessity of supplemental watering in more arid climates, to socio-economic factors such as the potential for gentrification and displacement that neighborhood improvements like greening can potentially exacerbate (Volin et al. 2020; Schwarz et al. 2015; Riley

& Gardiner 2020; Roman et al., 2015; Checker, 2011; Wolch et al., 2014; Dawes et al., 2018; Donovan et al., 2021; Sharifi et al., 2021). Additionally, lower income and formerly redlined communities have greater amounts of impervious surfaces and are more densely developed, signaling increased barriers to community-driven tree planting initiatives, and requiring significantly greater investments and government coordination for capital improvements (CAPA Strategies, 2021a; CAPA Strategies 2021b). Another complicating factor is that planting, maintenance, management, and preservation of UFC is complex. A broad range of actors — from local users to volunteers to professional managers — play a role in stewarding the urban forest (Krasny & Tidball, 2015; Roman et al., 2015). In LA, the responsibility for planting street trees falls on local government and nonprofit organizations, but planting a tree is only the first step. Establishment care during the first three to five years must follow (Levinsson et al., 2017). Perennially underfunded UFC management can also exacerbate already entrenched distrust in historically disinvested neighborhoods and increase barriers to achieving urban forest equity, as tree-planting municipalities and organizations working in disadvantaged areas operate with limited resources (Pincetl, 2010a). This reality exists even in environmentally progressive California, where the importance of greening is widely recognized and where carbon cap-and-trade and other state-administered funding streams produce revenues in support of local greening programs (Bekesi & Ralston, 2010).

In recent years, transdisciplinary frameworks have begun to be used to address the complexities that arise in such socio-ecological systems. For example, applied research in disciplines concerned with the human dimensions of ecology and environmental management are using socio-ecological systems (SESs) frameworks to better understand the dynamics between social and ecological systems and how these can be used to improve understanding of pressing issues associated with sustainability, environmental policies, and climate change (Partelow 2018). Such information and knowledge is necessary for effective climate change responses, as urban actors from community members to policy-makers increasingly find themselves adapting to extreme climate impacts to human communities and ecosystems (Ostrom, 2009). In the present context, environmental management and sustainability-based approaches frameworks traditionally used by urban ecologists, foresters, landscape architects, horticulturists, and planners for evaluating tree planting programs (i.e., Roman et al., 2015; Ko et al., 2015) are often insufficient in addressing human wellbeing outcomes because of their focus on biophysical metrics and objectives (i.e., UFC goals, planting a specified number of trees, or minimizing tree mortality). But urban ecosystems and forests are complex and should also include the socioeconomic, human wellbeing, and public health metrics and objectives such as ecosystem service co-benefits and the social and political dynamics involved in urban greening (Dawes et al., 2018). Such metrics, objectives and dynamics can span scales from individual-level human and tree factors such as human self-efficacy and tree survivorship, to societal and UFC level such as policy and governance formulation and watershed quality. They also span temporal factors, such as who should be responsible for maintaining street trees planted in the public right-of-way space in front of a residence over a tree's life span regardless of changes in government or property ownership and whether that responsibility is understood and acted upon by different stakeholders across time. An approach that also focuses on these social, economic, political, and public health factors across space and time is therefore needed (Escobedo et al., 2019).

Socio-ecological frameworks that include those factors are used by disciplines in the medical science and public health fields (Palafox et al., 2018), and thus warrant further consideration because of their focus on desired outcomes (i.e., improvements to human wellbeing, public health outcomes, and climate equity) as opposed to the planting and caring for trees as an intermediate process of activity to indirectly or subsequently advance urban forest equity and climate equity. This differs from SESs frameworks traditionally used in the previously mentioned environmental management and sustainability fields because those frameworks are concerned with understanding the ecology-society nexus (i.e., governance and natural resource conditions) as opposed to tailoring processes to optimize human wellbeing outcomes (e.g., improved public health and other co-benefits) (Golden & Earp, 2012).

More specifically, in public health disciplines, socio-ecological models are used to elucidate complex dynamics by nesting factors into individual, relationship, institutional, community, and society levels that depict the relational dynamics between them (Golden & Earp, 2012). This approach has been widely used in public health campaigns including in promotion of physical activity, involvement in grandparenting, cancer prevention and control, and violence prevention, and its use is promoted by the Centers for Disease Control and Prevention (Shorey and Ng, 2022; Palafox et al., 2018; CDC, n.d.). SES models often used in public health disciplines could hypothetically be used to capture key determinants that influence tree stewardship and planting programs. Furthermore, informed by a mixed-method approach, the use of such alternative transdisciplinary frameworks could also be used in other environmental management problems to identify evidence-based determinants and to understand the relational dynamics between them and desired outcomes.

In this study, we present such an approach with the aim to apply a socio-ecological framework from the public health field to evaluate a tree stewardship program in the City of Los Angeles, US. The specific objectives are to:

1. Evaluate the effectiveness of a tree stewardship training and community organizing program in advancing urban forest equity and public health.

2. Identify principal barriers and determinants (e.g., policy, infrastructure, social) encountered by trainees in their communities, which hinder or aid the advancement of urban forest equity.
3. Build a socio-ecological framework to understand the spheres of influence (or levels) within which these factors exist and how the dynamics between them interact.

We then use these objectives to discuss how this novel approach and framework can be used to better inform funding, management, planning, policies, and governance of UFC to maximize equity and public health goals.

4.2 Materials and methods

We evaluate a community and volunteer-based tree stewardship initiative — the Tree Ambassador, or *Promotor Forestal,* program — as a case study. This new English/Spanish bilingual community organizing initiative launched in 2021. The program provides 10 months of paid training to residents to mobilize their community to plant and care for trees and increase resilience around heat-health risk in historically disinvested neighborhoods in Los Angeles. The goal of the Tree Ambassador program is to create a trained group of community members that can build connections with and amplify the voices of their communities to achieve urban greening goals. Tree Ambassadors, or *promotores*, attend monthly training sessions with expert instructors and work closely within urban forestry organizations (or "host organizations") in order to gain the tools, knowledge, and connections needed to increase UFC and community resilience in select marginalized neighborhoods. The program was intentionally modeled after the community health workers, or *promotores de salud*, approach (Scott et al., 2018; CDC, 2019), signaling the significance of the application of an SES framework. The community health worker model trains lay people who are trusted members of a community or who have a deep understanding of the community to serve as frontline public health workers (American Public Health Association, 2021). The Tree Ambassador model seeks to mitigate potential for green gentrification (Donovan et al., 2021; Sharifi et al., 2021) by directly compensating and empowering local leaders where they live, work, and play, instead of relying on volunteerism, which often assumes time affluence and excludes residents who work multiple jobs or have family or community responsibilities that preclude regular participation. The first training cohort was composed of 12 Tree Ambassador (TA) trainees who completed the program.

This community-based tree planting partnership is led by City Plants — a nonprofit organization that oversees public-private tree planting partnerships in Los Angeles — together with the City of Los Angeles, state, federal, and international urban and community forestry agencies (the LA Department of Water and Power, the California Department of Forestry and Fire Protection, the USDA Forest Service, and Ecosia), and local tree planting organizations (Climate Resolve, Koreatown Youth & Community Center, and TreePeople). Using surveys, focus groups, and ethnographic data collected through April 2022 with this first training cohort, we first evaluate the program and then use the findings to apply and adapt a socio-ecological model of community-based tree stewardship for improved public health outcomes.

4.2.1 Los Angeles, CA, US and the Tree Ambassador Program case study

Los Angeles, CA is the second-largest city in the US by population, with an ethnically diverse population of 3.9 million people who are 48% Latino/a, 29% white, 12% Asian, and 9% Black; 36% of residents are foreign born (United States Census Bureau, 2021). Median household income was $65,000 in 2020, and 17% of residents live in poverty, with high socio-economic variability between neighborhoods. The City of LA has an area of 468 square miles and an average population density of 8,100 people per square mile (United States Census Bureau, 2021). Located in a Mediterranean climate, LA is both flanked and bisected by mountain ranges, and the region surrounding the city consequently hosts a variety of smaller climate zones ranging from coastal, to high desert, to montane — with varying seasonal temperature and precipitation averages ranging from 125 mm (5 in) to over 750 mm (30 in) (Hall et al., 2018; Los Angeles County Department of Public Works, 2021). The City of LA has one mayor and 15 city councilmembers, each who oversees aspects of city services in one of 15 council districts and is responsible for enacting ordinances that are subject to mayoral approval or veto (City of Los Angeles, 2022).

Our study area and evaluation focused on 9 neighborhoods and 12 Tree Ambassadors representing several City of LA neighborhoods (Table 4-1). Each neighborhood was selected with consideration to factors including income, high concentration of minority residents, and heat vulnerability as determined by heat-related deaths. See Appendix D for details on the socioeconomic and demographic composition of the Tree Ambassadors.

Table 4-1. Tree Ambassador neighborhood characteristics

Tree Ambassador	Neighborhood	% Existing Tree Canopy*	Pollution burden Score**	Heat health action index***
1	Westlake	13%	90	79
2	Pico Union	8%	97	70
3	South LA	10%	89	75
4	South LA	12%	85	77
5	Boyle Heights	13%	87	81
6	Boyle Heights	13%	71	74
7	Canoga Park	26%	68	55
8	Canoga Park	26%	93	64
9	Pacoima, Sylmar	18%	97	61
10	Sunland-Tujunga	26%	67	43
11	Sun Valley	30%	87	54
12	North Hollywood	20%	95	50

*By ZIP code, or numeric average where a neighborhood is made up of multiple ZIP codes, https://www.treepeople.org/los-angeles-county-tree-canopy-map-viewer/.
**Percentile by census tract, with values from 0 to 100 by census tract. Higher values mean higher proportion of disadvantaged individuals per CalEnviroscreen metrics, https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-40.
***Represents heat vulnerability with values from 0 to 100 by census tract. Higher values mean higher heat vulnerability, https://cal-heat.org/explore.

4.2.1.1 An overview of tree planting programs in LA

In 2007, under the leadership of newly-elected Mayor Antonio Villaraigosa, the City of LA launched Million Trees Los Angeles (MTLA), a private-public partnership designed to rely on nonprofit partners to plant trees and help raise the funds necessary to do so (Pincetl et al., 2013). The MTLA initiative had mixed results. It received a fair amount of attention in the media and among LA residents, but clearly fell short of its million-tree goal, succeeding in planting an estimated 400,000 trees (City Plants, personal communication, June 4, 2021). MTLA set out to address tree inequity, but in practice plantings occurred opportunistically where private-public partnerships could be established (Pincetl et al., 2013). Lower-income communities were found to receive relatively fewer trees due to a perception that more UFC provides more spaces for criminals to hide, creating reluctance in some neighborhoods (Pincetl, 2010b). An opt-in process for requesting a tree required a signature, which discouraged residents in communities with many immigrants, multi-family homes, or high rentership (Pincetl, 2010b). In 2014, Mayor Eric Garcetti rebranded MTLA as City Plants, and the organization has since adopted a tree planting and care strategy of "right tree, right place, right reason."

More recently, the City of LA's *Green New Deal*, a 2019 update to the City's *Sustainable City pLAn* first published in 2015, calls for increasing tree canopy in disadvantaged communities by 50% in time for the 2028 Olympics in Los Angeles (City of Los Angeles, 2019). Considering the urban forest of the City of LA is composed of approximately 10.8 million trees (McPherson et al., 2011), increasing tree canopy by 50% is an ambitious goal and will require significant investment and resources. To facilitate achieving these and other urban forestry goals, in 2019 the City of LA hired its first-ever City Forest Officer to oversee citywide coordination in support of these goals (Los Angeles Daily News, 2019).

These developments are critical because in LA, UFC has been documented to have an effect on public health outcomes and environmental benefits. Higher UFC lowers ambient temperature, with LA city blocks that have more than 30% UFC being about 5°F (2.8°C) cooler than blocks without trees (Pincetl et al., 2013). In the city, the percentage of shaded UFC over the city's streets accounts for more than 60% of land surface temperature variations, compared with only 30% of variation being explained by factors such as topography and distance to the coast (Pincetl et al., 2013). Increasing UFC and albedo of roofs and pavements in LA can reduce heat-related mortality by upwards of 25%, especially in low-income communities and communities of color (Kalkstein, et al., 2022). Interventions of higher UFC and albedo also have the potential to delay climate change-induced warming approximately 40-70 years under business-as-usual and moderate mitigation scenarios, respectively (Kalkstein, et al., 2022). Investing in UFC thus has the potential to increase LA's resilience to climatic changes.

4.2.2 Mixed methods approach

Having described the Tree Ambassador program and LA's context in the previous section, we now present how we used a mixed methods approach — commonly used in SESs research — to obtain a comprehensive picture of Tree Ambassadors' experiences and accommodate different avenues for them to provide feedback. Such an approach will allow for results to be analyzed thematically and longitudinally. Results from the multiple methods can also be triangulated to derive richer data, address the goals of the research more comprehensively, and confirm results (Wilson, 2014). Results can then be used to adapt available SES models used in the public health fields, addressing the aims of this study.

4.2.2.1 Focus group

A focus group (*n*=9) was held on November 21, 2021 to provide an opportunity for Tree Ambassadors (TAs hereafter) to have their perspectives heard and inform the structure and content of the program. The focus group was held during the sixth of ten months of training, and was held in an office building in Los Angeles.

All TAs present at the training were invited to voluntarily participate. In total, nine TAs participated. The focus group was held during the last hour of a 3-hour training session and participants received a verbal consent that explained that their participation was voluntary, and that any information gathered during the focus group would be treated as anonymous. Attendees were also advised that anyone not wishing to participate could leave or sit back and listen without participating, and that non-participation would not result in any penalty.

The focus group was facilitated in English by the authors using a script (Appendix E). Simultaneous translation in Spanish was also provided by the authors so that TAs with limited English proficiency could participate in the discussion. The focus group was audio recorded. Three note-takers took live notes and notes were subsequently triangulated. A transcript of the focus group was created using the audio recording and notes taken by three note-takers. The transcript was coded using content analysis, and data were then coded and analyzed thematically. The results were used to develop the following survey instrument using the Total Design Method (Lavrakas, 2008).

4.2.2.2 Survey instrument

A mid-program survey (*n*=11) was conducted electronically using SurveyMonkey following the focus group, between the sixth and seventh training sessions. The survey instrument was provided to the respondents in both Spanish and English language and responses were received between December 6 and 13, 2021. Respondents were first asked to provide anonymous identifiers to allow for an individual's responses to the second survey to be analyzed longitudinally. The survey instrument contained 33 questions (multiple-choice, Likert scale, matrix, and open-ended) to capture the respondent's knowledge, perception, beliefs, and attitudes (Gifford & Sussman, 2012) related to the following themes: content, structure, and pace of the trainings; program materials and support they have received as trainees; and characteristics about the community in which the respondent lives and works.

An end-of-program survey (*n*=8) was conducted at the conclusion of the program with TAs who had previously responded to the first survey. The survey instrument was once again provided in both Spanish and English language; responses were received between March 28 and April 7, 2022. TAs were specifically asked to provide feedback about various aspects of the training program, including whether trainings: were easy to understand; covered material relevant to their communities; prepared TAs to plant and care for trees; were too slow or fast; had an appropriate level and amount of content; and allotted too little or too much time to learning by listening vs. learning by doing.

Data were cleaned and formatted in MS Excel and then analyzed with Student's t-test in R version 4.0.2 (R Core Team, 2020). Specifically, paired sample t-tests were used to check for significant differences between means for the questions asked in both the mid-program and end-of-program surveys. For knowledge-based qualitative questions, word clouds were created to visually display the key answers and their relative frequencies. The word clouds were made online using http://www.wordclouds.com. For qualitative questions that were focused on providing feedback, responses were analyzed in steps. The first step was to look for responses in both mid- and end-of-program surveys that were the same in response content. Then the remaining responses were summarized to facilitate analyses. For the qualitative responses from both surveys, the responses for the end-point survey were sorted by comments that were also provided on the mid-point survey, and those that were new.

4.2.2.3 Ethnographic observations

Ethnographic observations were made during different event types during the program: training sessions, TA meetings with their host organizations, informal weekly TA "hangout" meetings held via Zoom that gave TAs an opportunity to discuss progress and ask question, program team meetings, tree planting events, and tree adoption events organized and supported by TAs between July 2021 and April 2022. The events (n=20) provided a wide variety of settings and conditions for observations through the multiple phases of the program as TAs moved from training to community organizing and holding their own community events. We note that the training program took place during the COVID-19 pandemic, and the initial training sessions were held remotely via Zoom. Some events were thus limited to observations that can be made in digital spaces. Some of the events held remotely included the use of Zoom chats or web-based Audience Response Systems such as Mentimeter (Mohin et al., 2022), resulting in additional collection of opinions and feedback which were considered formative evaluation feedback available for incorporation into the remainder of the program. Prompts used during remotely-held events were presented in Spanish and English, and included: "What would you like to learn as a Tree Ambassador?"; "What are your goals before the end of the program?"; "How have you grown or been challenged during the program?"; and "What specific skills or knowledge have you gained as an Ambassador?" Typically, in-person events yielded more engaged interactions among participants and more opportunities to observe the dynamics at play, resulting in richer notes. In addition to observations, several events included opportunities to speak with the TAs and program staff to ask follow-up questions and obtain additional insights.

4.3 Results

4.3.1 Focus group

The themes that emerged during the focus group are presented in Table 4-2. The primary themes were: 1) that TAs are motivated by a desire to serve as change agents for their communities and the Tree Ambassador Program provides them an avenue to act on that desire; and 2) that TAs face a variety of challenges — some of which are deep-rooted and intractable — as they try to convince members of their communities to engage in tree stewardship. With several months of training remaining in the program and after the focus group, themes that emerged were incorporated into subsequent training materials. Outreach methods and materials that the TAs were given to engage the community were also tailored accordingly. For example, outreach materials were redesigned to include an image of an unshaded street in the neighborhood against a street that is shaded by a canopy of trees, and paper forms were made readily available to decrease the reliance on internet sign-ups. TAs were also provided with information about how to navigate the process of removing concrete or pavement to create tree planting wells where planting spaces are not available, which is a common barrier in historically redlined neighborhoods (CAPA Strategies, 2021a).

Table 4-2. Content analysis of Tree Ambassador focus group in Los Angeles, CA (*n*=9).

Themes	Tree Ambassador comments
Seeing oneself as an agent of positive community change	"I wanted to put in my energy and activism and advocacy through community organizing and talking to people. I wanted to gain more formal community organizing skills."
	"I was actually really skeptical when I first heard about the program. I thought that no one would be interested in my community. But then after thinking about it, I thought, 'Has anyone tried to talk to our community?' Maybe there's a reason they're not interested. Maybe they don't know or they don't think they have the time."
	"I see the benefits of trees in other places and thought that was missing and so wanted to bring that to my own community—this is also an environmental and social justice issue."
	"When I found out about this program I thought it was an additional service that I could be part of to help to uplift the community."
Challenges encountered: Urban greening not a priority for some in the community	"Part of the challenge of getting people to get trees is that there is a long list of priorities that people want to have fixed and trees are not at the top of that list. Even if they are free it's still a responsibility that they need to take, and people are just frustrated. It's harder to push for trees when people feel like there are speed bumps or sidewalks or all these other issues that they feel that the city should take care of."
	"When we ask people in the community, we receive more noes than yeses. When we ask them if they want trees, they'd say, 'No, we just want speed bumps, so that people can walk and run.' They're not interested in trees."
Challenges encountered: Cynicism about local government among community members	"I think another one of the barriers is that the city in general, historically has taken a long time to get things done. Even getting potholes fixed takes forever. That's a big concern with people in the community. Working with the city just takes forever to complete anything or even take initiative, so they just give up just because they don't think it will ever happen."
	"I saw someone describe it as about tree planting guerilla warfare. That would be like them just going out in the street and planting trees in whatever spot people see available. People don't want to work with the city because there is too much red tape."
	" An older disabled person said that the tree had ruined the sidewalk, and he had spent money removing the tree and fixing the sidewalk. They reached out to the city to get it addressed but the city didn't do anything so they weren't willing to take a tree."
	"One of the residents said that she signed up but never got a tree even though neighbors got trees."
Challenges encountered: Spatial and physical barriers	"Apartments, especially those that don't have access to residents directly, where they have a gate…is difficult because we don't have access to the residents."
	"In my neighborhood we don't have many sidewalks."
	"One of the barriers I've heard is that people are interested in getting trees but don't have a car."
Challenges encountered: Internet access and digital literacy	"Outreach materials are mostly email based, and for some people that's not accessible…Even for registration links…this interferes with some people not being able to access it."
	"As soon as we say something about the internet process, they say, 'Oh no we don't want to deal with it.' They don't want to subscribe. They don't want to have to deal with the internet."
	"Older Hispanic communities don't want to deal with the internet."
	"Some people don't know how to navigate the internet, they don't know how to use a computer."

4.3.2 Surveys

Overall, survey findings point to increased TA confidence, knowledge, and care as it pertains to TAs' relationship with trees and with their community, but a corresponding decrease in the TAs' perception of how much other community members care for their neighborhood (Figures 4-3,4-4, 4-5, 4-6 and 4-7). TAs felt moderately or highly prepared to plant and care for trees but indicated that there is room for improving the program in terms of content and format (Figures 4-1 and 4-2).

Another key finding is that despite considerable effort, securing street tree applications, requiring a signed form commitment to water by a tenant or property owner, was very difficult, especially compared with yard tree applications for private property trees (Table 4-3).

Table 4-3. Responses to the question "Were you able to achieve the following program goals?"

Goal	Yes	No
Secure 30 or more street tree applications	17%	83%
Secure 30 or more private property yard tree applications	71%	29%
Host at least one tree adoption	86%	14%
Host at least one tree community volunteer event	43%	57%

Figures 4-1 and 4-2 show that all but three of the means decreased from the mid-program of the program to the program's end; while two items were the same (whether the TAs feel prepared to care for young trees, and how much time was spent listening to presentations versus learning by doing); and only one increased (feel prepared to care for mature trees). However, none of the differences were statistically significant, most likely due to the small sample size. The results suggest that the training in the second half of the program was not as well received and should likely be the focus of any changes for the next year.

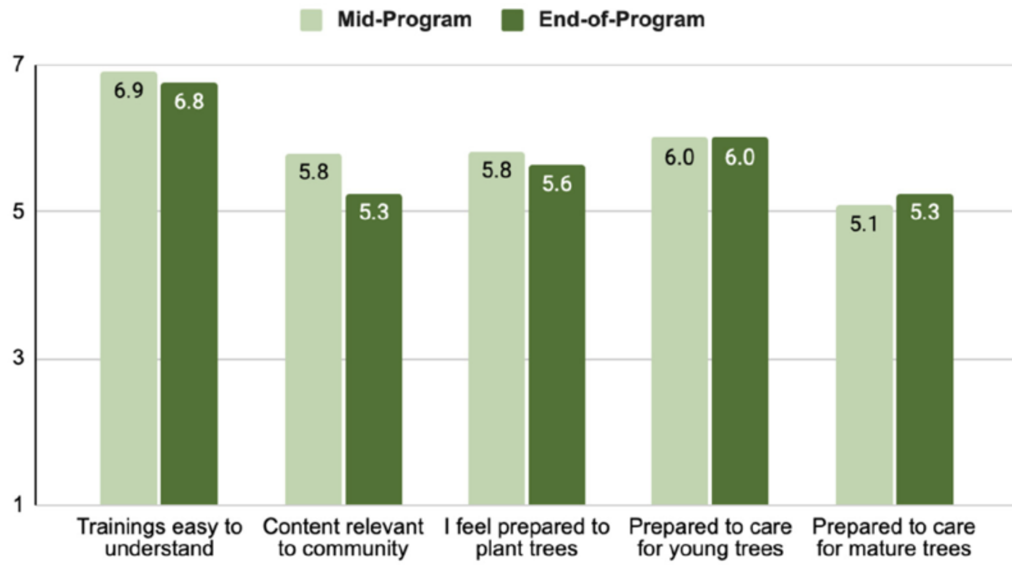


Figure 4-1. Responses regarding the trainings and Tree Ambassador readiness (1=strongly disagree; 7=strongly agree).

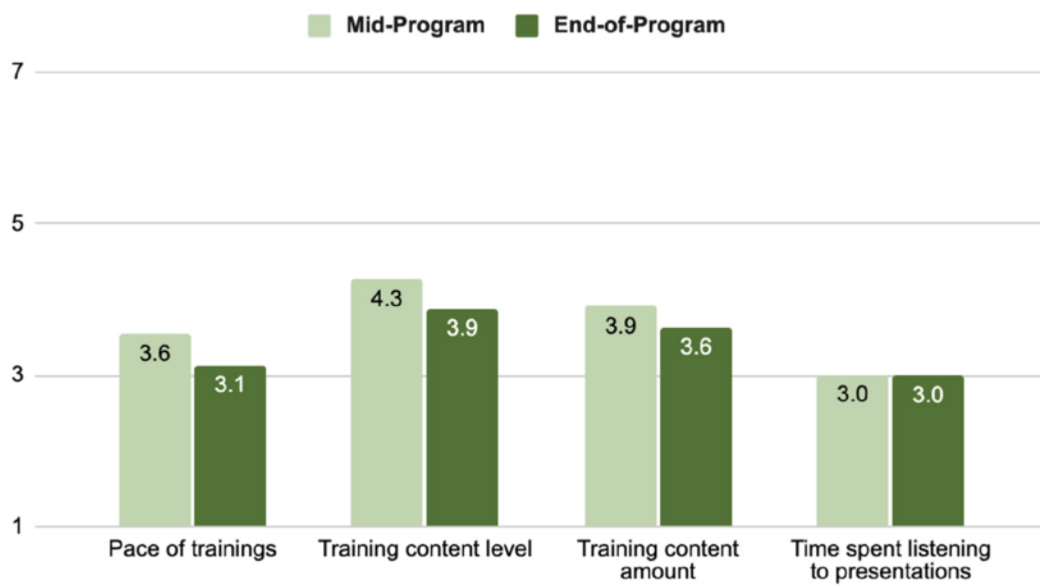


Figure 4-2. Responses regarding the pace and structure of the trainings (1=pace too slow, level too simple, content amount too little, too much time spent listening to presentations; 4=about right; 7=Pace too fast, level too complicated, content amount too much, too much time spent learning by doing).

The TAs responded about skills or knowledge they gained in their time in the Tree Ambassador program that can be used to benefit their community (Figure 4-3). As shown in Figure

4-3, skills related to "community" were the top-mentioned responses. This includes how redlining has impacted communities, advocacy, community organizing, establishing community connections, and community leadership. These skills are transferable to other programs and subject areas. Skills directly relating to trees — how to care for them, when and where to plant them — were the second most mentioned goal. These skills are specific and are of more limited use. Other skills mentioned included communication, relationship building, and connecting small businesses with nonprofit programming.

Figure 4-3. Word cloud exhibiting the skills and knowledge learned by Tree Ambassadors during the program that can benefit the community.

Tree Ambassadors were also asked the following question about their career goals during the end-of-project survey: "Would you like to pursue a career in urban greening or related field? Please share your thoughts. If you are not interested in pursuing a career in this field, do you think this program has prepared you for future careers in other fields? If so, how?"

Six TAs indicated an interest in pursuing a career in urban greening or related fields; one said no but noted "I like having the information on how to help the community"; and one was unclear.

The TAs were then asked to provide feedback on the program materials and their confidence in attaining program goals. Goals for trainees included securing 30 street tree applications with a commitment from adjacent property owners or tenants to water the tree; securing 30 yard tree applications from community members; hosting at least one tree adoption event; and hosting at least one additional community volunteering event such as a tree planting or tree care event. Figure 4-4 shows that scores for all but one question ("The program materials I received help me engage my community meet my community's needs") increased from the mid-point to the end-point. None were statistically significant, most likely due to the small sample size. Their relative scores at the mid-point corresponded fairly well to whether or not TAs ultimately met that goal. Confidence in securing street tree applications was lowest, and this goal was ultimately met by only one TA. Conversely, confidence was highest for private property trees and hosting tree adoptions, and these goals were met by the most TAs. Finally, none of the means were 6 or above, and most were under 5, indicating that there is room to improve the program to better meet the trainees' needs.

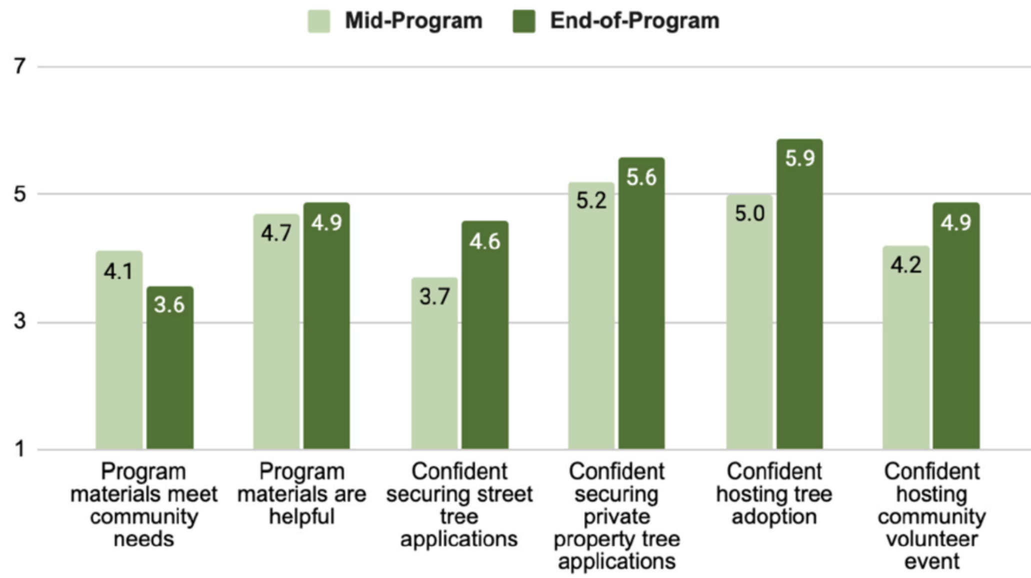


Figure 4-4. Responses regarding program materials and goals at the mid-point and end-point of the training program (1=strongly disagree; 7=strongly agree).

The end-point survey asked TAs whether they were able to achieve the program goals (Table 4-3). Street tree applications — requiring a signed commitment to water form — were the most difficult to secure.

The TAs' self-reports via the survey are in line with the program metrics compiled by the host organizations and City Plants. Altogether, TAs planted or distributed a total of 1,929 trees — only 53 of which were street tree applications, making up less than 3% of the total, despite considerable effort. TAs canvassed an estimated 1,244 residents and held over a dozen events including tabling at places of worship and neighborhood meetings.

The TAs were asked to list both benefits and problems that they believe trees can bring to their neighborhoods. Figure 4-5 compares the mid-point and end-point responses around benefits that trees bring. At both timepoints, the mental and physical health benefits of trees were noted most often. At the mid-point, "biodiversity" was quite prominent, whereas at the end-point “beautification” was similarly prominent. In both surveys, TAs highlighted how trees improve air quality. They also used the words “reducing” and “lowering” often: reducing heat, lowering energy bills and lowering air conditioner use. Shade and biodiversity were each mentioned a few times; and one TA noted at the mid-point they can help avoid summer power outages.

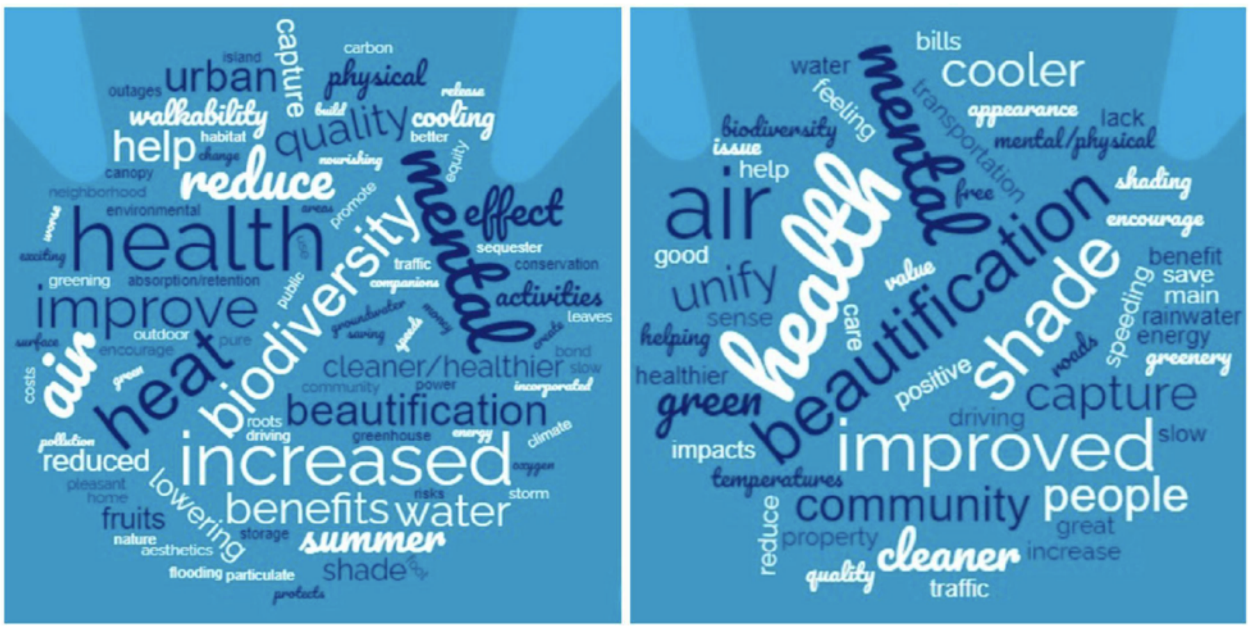


Figure 4-5. Responses to the question “List any benefits that you believe trees can bring to your neighborhood” in (left) mid-program survey and (right) end-of-program survey.

At the mid-point of the program, Ambassadors most often noted the negative effect trees can have on sidewalks as a problem (Figure 4-6). The words “maintenance” and “people” also showed up often, suggesting the problems were not due to the trees themselves but people not wanting the maintenance required of trees. The most prominent theme at the end point was the risk that trees become neglected and not watered. Leaves and branches falling from the trees were mentioned at both points, but not as often as other problems. The word “parkway” – the planting strip between the sidewalk – also appears in comments related to competition with utility poles and limited city resources for providing tree care in this space.

Figure 4-6. Responses to the question "List any problems that you believe trees can bring to your neighborhood" in (left) mid-project survey and (right) end-of-project survey.

Finally, the TAs were asked several questions about their neighborhood. Figure 4-7 shows that responses to all but one of the questions went in a positive direction from mid-point to end-point, although none were statistically significant. TAs reported caring about their community more, knowing more neighbors, and being more comfortable asking neighbors (both neighbors they know and those they do not know) for favors. An explanation could be that the canvassing, tabling, and other activities TAs undertook in their neighborhoods enabled them to interact with and get to know more members of the community. Comments from TAs captured via the ethnographic observations (Appendix F) also support these findings. However, the opposite was reported for other people caring about the neighborhood, as there was a decrease in the mean score. An explanation could be that a high number of refusals and difficulties in getting people to commit to water street trees (which benefit more than just the household) made TAs think that other people in the community did not care about the neighborhood. There was also a slight uptick in the response to the question about whose responsibility it is to prepare for disaster (1=100% mine, 7=100% the government's), though the mean in both time periods indicates that respondents feel responsibility lies somewhere in between.

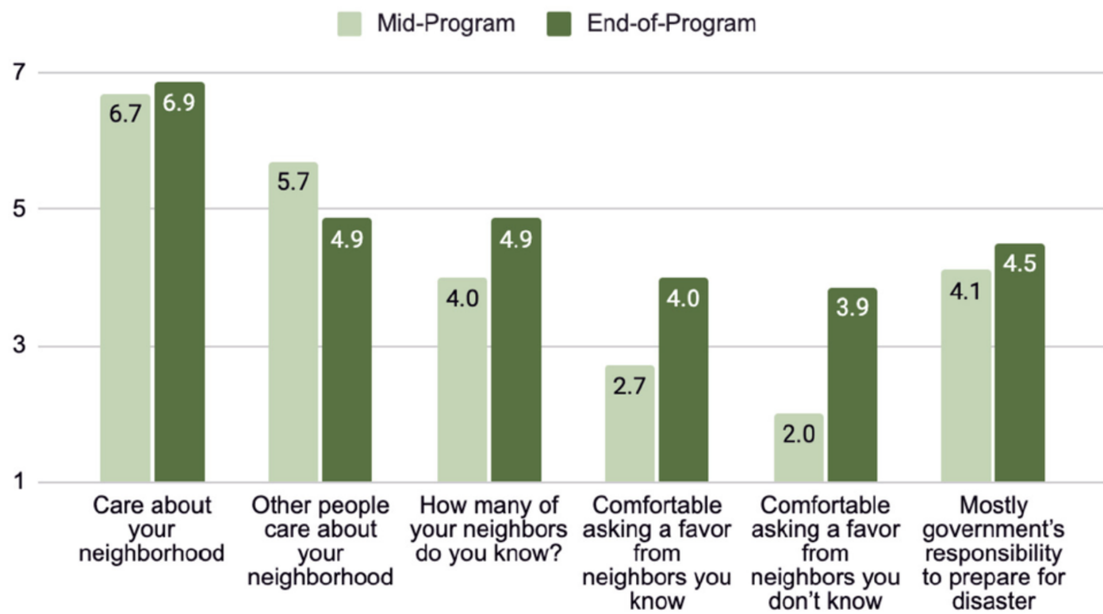


Figure 4-7. Responses to care and stewardship for the neighborhood, asking neighbors for a favor, and the government's role in preparing for a disaster at mid-point and end-point of the program. (1=strongly disagree; 7=strongly agree).

Aside from the responses to open-ended questions that were illustrated in the word clouds in Figures 4-5 and 4-6, additional key insights from TA highlight the conditions and challenges faced in the process of trying to increase UFC in their communities. Here we share a small selection of those insights, which raise issues such as availability of planting spaces, the presence of homeless encampments, awareness of historical injustices, and the challenges of organizing in neighborhoods with high rentership.

Responses to the question "Do you have any comments or recommendations about the materials you have received to help you engage with the community?" included:

"A lot of the material is predicated on availability of space and the assumption that there is a pre-existing community bond within the neighborhood. Although Los Angeles does not have the typical urban spaces that other cities may have, areas with high population of immigrants, low percentage of homeowners/private property, large homeless encampments, and other issues regarding financial, social, and environmental conditions should be taken into consideration in order to create a more intersectional approach."

"I think asking people of the impacted communities if they are aware of the environmental inequities in LA or their community and what impacts might that cause in their community can help gauge how aware a community is about these topics. I think asking them what impact/problems that inequity could create in their communities can bring more awareness and have them thinking about these topics and motivate them more to engage with their community. I never knew about redlining until just recently. Learning about it, I was shocked and angry. But I finally had an answer for why my community wasn't as well resourced as wealthier areas. And why these affected areas continue to remain affected, being stuck in a cycle. I feel like not knowing about redlining, the environmental injustice/inequity in certain communities, etc. made me oblivious or ignorant about the issues they cause. Living in an apartment, I don't even have space for a tree so I wouldn't have even passed by a tree distribution event. I never would've cared as deeply as I do now without knowing these injustices first, because now I can understand the significance of planting a tree."

Responses to the question "Do you have any other comments or recommendations about how to improve the Tree Ambassador program?" included:

"I've felt very supported by my organization but I do wish there was a bit more support from the city. Reaching out to city officials to spread the word and let residents know sounds like a very reasonable thing to ask for. Private property trees are by far the easiest to get forms signed for and that's great, but I think providing tree ambassadors with more resources or knowledge to navigate spaces that don't have as much private property like commercial, industrial, apartment zones, would be very beneficial. These areas tend to lack trees and would greatly benefit from them but it's harder to navigate because of the obstacles (planting on the parkway of an apartment: technically city property but easiest and safest to get permission from property manager- can be tricky)."

"Different areas necessitate different methods. A lot of people who are recently immigrated and/or living in a rented space may view their current residence as a temporary space and therefore be disinvested in larger community needs. Trees are a long term investment, in which the immediate benefits may not be entirely obvious. If a neighborhood is seen as a transitional point, residents may be disinvested in the betterment of the community."

4.3.3 Ethnographic observations

Ethnographic events spanning the 10-month period of the first training cohort — from hiring to training, and graduation — show themes that both complement and augment the findings emerging from the focus group and surveys. Specifically, as TAs gained knowledge, skills, and confidence via the program, this led them to forge new partnerships in their community and organize successful community events such as tree adoption events. Findings are presented in Appendix F. Among the themes that emerged: TAs experienced significant challenges in engaging their communities in urban greening, spanning from cynicism about the City's follow-through and perceptions about the high cost of watering a tree, to the inability to interact with people in person due to factors such as front gates and concerns around potential COVID-19 exposure. Some TAs modified their engagement methods and reported more canvassing success when canvassing focused on inviting neighbors to attend free community tree adoption events rather than on trying to convince them to sign up for a free tree at their doorstep. Findings from the ethnographic events are also incorporated into Appendix G.

4.3.4 Socio-ecological model

The above approach and our findings identified multiple factors that influence community-based tree stewardship. However, the nexus between tree stewardship programs, UFC co-benefits, and public health outcomes is still not clear and warrants exploration. Accordingly, using our findings from Section 4.3.1-4.3.3 we developed a socio-ecological framework to better elucidate the factors associated with tree stewardship encountered by individuals intervening to address urban forest inequity in their neighborhoods. Specifically, we adapted a model frequently used in public health (Palafox et al., 2018; Golden & Earp, 2012) as well as results from our evaluation to better identify factors that relate a tree planting program to positive health outcomes and is shown in Figure 4-8.

We did this by reviewing the themes that collectively emerged from the focus group, surveys, and ethnographic observations. We evaluated the list of factors by first considering whether the presence of a given factor – e.g., high trust in local government, belief that trees cause problems, or availability of planting spaces – should be considered a support or an impediment upon a Tree Ambassador's efforts to foster tree stewardship among community stakeholders. Evaluating each factor through this lens allows for the development of interventions designed to either boost that factor as a benefit or reduce its presence as a barrier (Golden & Earp, 2012). For example, if the belief is prominent that leaf litter from trees is a problem, a Tree Ambassador's outreach can be modified to focus on how species selection (e.g., planting evergreen trees) and can avoid this problem down the line. We then categorized each factor into a level of influence ranging from individual to society level to reveal at what level interventions to address each factor should be focused. For example, individual level interventions should aim to change the knowledge and awareness of the individual, while institutional interventions should aim to create change in social relationships and organizational environments that support those individuals.

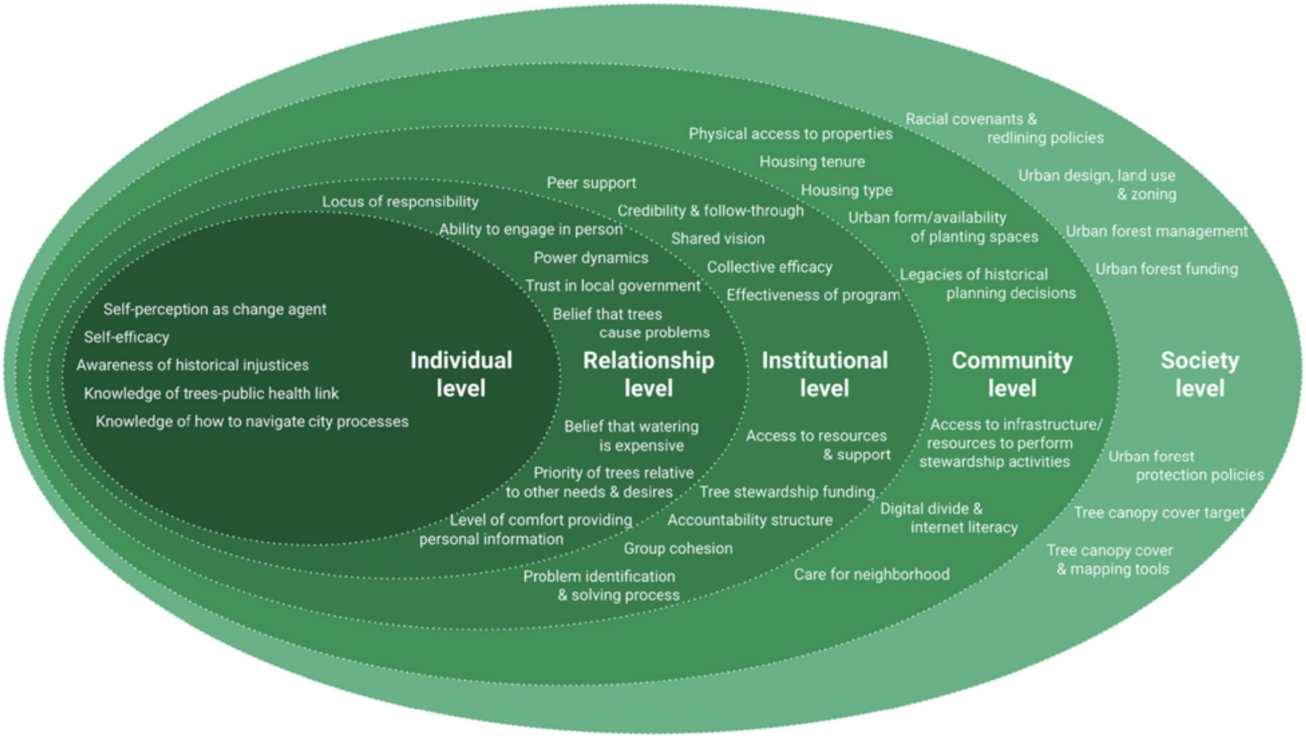


Figure 4-8. Socio-ecological model of community-tree stewardship (nested)

The result is a "Socio-ecological model of community-based tree stewardship" based on our approach and factors (Figure 4-8). Figure 4-8 models the process of participation in urban forest management via tree adoption, committing to watering new trees, and other actions involved in planting and caring for trees. Tree stewardship involves dynamic interactions between individuals and the social and political conditions and contexts that surround them. The model describes factors at each of five different levels — individual, relationship, institutional, community, and society. Community-based tree stewardship is affected by this complex range of influences and nested interactions. The model recognizes that factors can cross between multiple levels, and we thus include nested dotted lines separating each layer of the model. They can also influence tree stewardship in different ways — either aiding or hindering stewardship of trees in support of urban forest equity — based on cumulative and intersectional experiences. We offer additional context and describe these factors in greater detail in Appendix G.

4.3.4.1 Individual level

Individual level factors are those that are present or absent in an individual (in our case a Tree Ambassador) who is actively working to affect tree stewardship in their community. These include drivers related to awareness, knowledge, and self-perception.

4.3.4.2 Relationship level

Relationship level factors are those an individual working to affect tree stewardship may encounter as they attempt to engage with their neighbors or other members in the community. These factors may either aid or hinder their efforts and include drivers such as whether a community member prioritizes trees relative to other needs or desires for their neighborhood, and whether they are comfortable providing personal information.

4.3.4.3 Institutional level

Institutional level factors are those that may be present or absent at the institution that is supporting an individual who is actively working to affect tree stewardship in their community — such as a nonprofit or community organization, or a city agency. Collective drivers such a shared vision, group cohesion, and the belief that the group can produce desired results are among these. Other drivers relate to support, follow-through, and processes to identify and address problems as they arise.

4.3.4.4 Community level

Community level factors are neighborhood characteristics that may aid or hinder an individual's efforts to affect tree stewardship. These include physical attributes such as availability of planting spaces and access to properties to conduct canvassing. These also include indicators, such as whether a home is tenant- or owner-occupied, the level of internet literacy present in the community, and the level of care that a resident believes other community members have for the neighborhood.

4.3.4.5 Society level

Society level factors include elements in the decision-making and information-access realm which occur at a level beyond the community — such as at the municipal, state level, or federal level. These include historical drivers such as redlining, and current drivers such as the presence of robust urban forest management and funding, public tree maintenance, UFC targets, and tree protection policies.

The nested model in Figure 4-8 reveals the primary factors that hinder or aid tree stewardship efforts and the levels at which these occur. We offer an alternative model (Figure 4-9) that takes these factors and levels into account, and adds two additional dimensions: time and space. Temporal and spatial considerations also influence the success of any efforts to advance urban forest equity. Some of the factors used in Figure 4-8 are moved from one of the five levels and placed under either spatial or temporal factors (for example, physical access to properties and housing type are moved from "Community level" to "Spatial factors"). We add several additional factors not captured in the nested model of Figure 4-8, which emerge when considering how spatial and temporal dimensions affect tree stewardship. The additional factors are marked with a * in the figure.

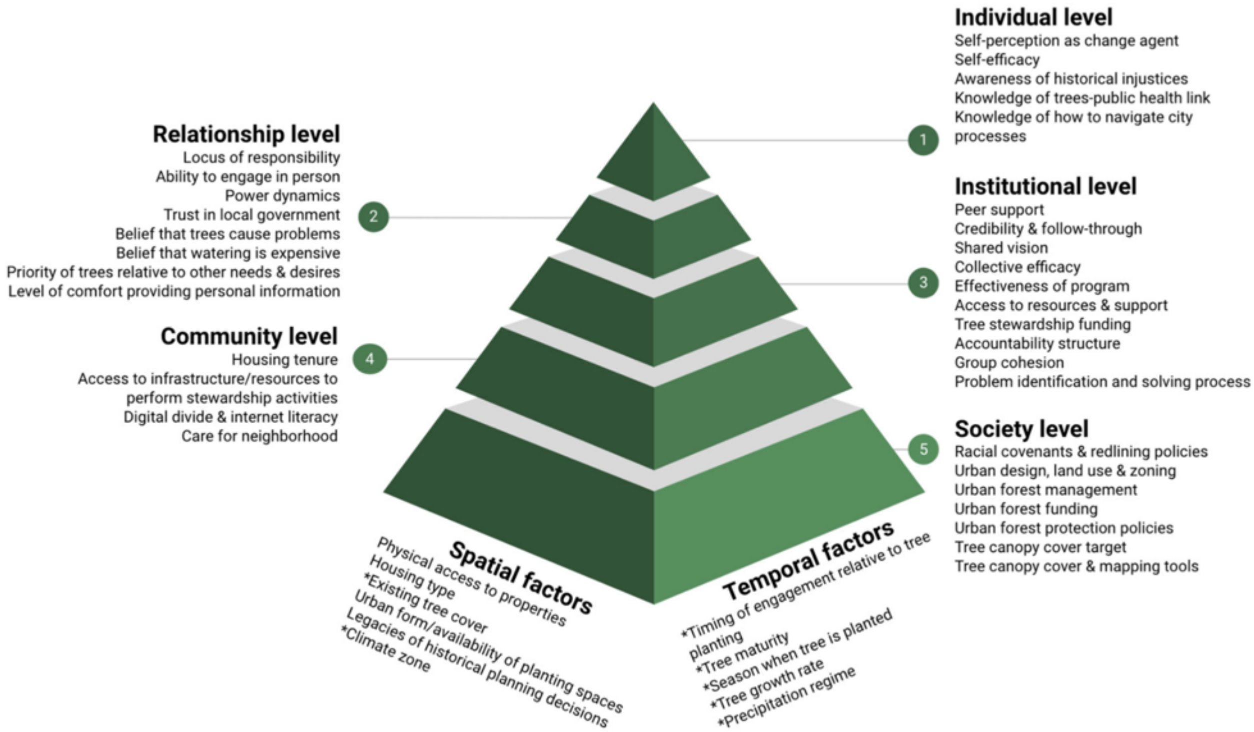


Figure 4-9. Socio-ecological model of community-tree stewardship with spatial and temporal dimensions (pyramidal)

Additional spatial factors include:

Existing tree cover: The existing UFC of a neighborhood can influence the willingness of community members to support additional UFC. Social ties and a sense of community have been shown to be stronger in apartment buildings with more vegetative cover compared to those without (Kuo et al., 1998), and these factors can in turn influence civic engagement in urban greening (Krasny & Tidball, 2015).

Climate zone: In LA's semi-arid Mediterranean climate, summers are warm and dry, and rain is uncommon between late spring and fall, meaning a moisture deficit is likely to occur absent supplemental irrigation (Levinsson et al., 2017).

Additional temporal factors include:

Timing of engagement relative to tree planting: Engaging community members in the act of tree planting rather than after a tree has been planted enables residents to witness the difference of their efforts, boosting self and collective efficacy while reducing barriers to continued engagement (Krasny & Tidball, 2015).

Tree maturity: A young tree planted in LA needs supplemental irrigation and additional care for an establishment period of three to five years, with the frequency of care diminishing as the tree matures (de Guzman et al., 2018).

Season when tree is planted: Planting a tree in the cool, wet season means less supplemental watering is needed in the first months after planting.

Tree growth rate: The species growth rate and the size of the tree at the time of planting influence the length of the establishment period (Watson, 2005).

Precipitation regime: The seasonal distribution of precipitation in a city or region determines how much supplemental irrigation a tree may need during its establishment period.

4.4 Discussion and conclusions

There is increasing recognition of the importance of urban greening to public health in the age of climate change, and approaches are needed that can advance our understanding of the social, ecological, economic, and political mechanisms that either facilitate or hinder urban greening (Donovan et al., 2021; Sharifi et al., 2021). As we have demonstrated, UFC is influenced by socio-cultural and economic processes that shape spatial outcomes, and these are often a combination of both current and historical drivers ranging from available planting spaces and funding, to social stratification (the associations between tree cover and income, race, ethnicity or education) and neighborhood succession (when a previously dominant ethnic, racial, religious, or socioeconomic group leaves a residential area and other groups fill its place) (Danford et al., 2014). These processes give rise to concerns around gentrification and displacement, issues that neighborhood improvements such as greening projects can potentially exacerbate (Checker 2011; Wolch et al., 2014; Dawes et al., 2018; Donovan et al., 2021; Sharifi et al., 2021). Considering the long temporal periods required for the establishment of UFC, current conditions may be inherited and serve as reflections of past preferences and processes rather than current forces (Schwarz et al., 2015; Boone et al., 2010). Whether historical or present-day, many of these forces have led to systemic segregation and have important implications for health (Jesdale et al., 2013). Biophysical factors, including climate, soil type, available planting space, and topography, among others, also impact the success of tree planting programs, and the LA region is unusually diverse across all of these categories. In arid and semi-arid climates, including Southern California's Mediterranean climate, summers are typically hot and dry and trees must receive supplemental watering during the multi-year establishment period in order to survive. While watering is not the only tree maintenance activity required in the establishment period of young trees, it is an action that must be coordinated and done frequently, and it is a determining factor in the ultimate success or failure of a planting program (Roman et al., 2015; Jack-Scott et al., 2013).

In this study, we use a case study that applies and adapts a public-health based framework to better understand the use of tree planting programs as a solution to address extreme heat and subsequent public health benefits in a large semi-arid metropolitan area (Livesley et al., 2016; Santamouris et al., 2017; Kalkstein et al., 2022). We applied a socio-ecological approach used in public health disciplines to address this issue, and we developed our own alternative model to explore spatial and temporal factors as well. We did this by assuming a baseline understanding of the importance of ecological systems in providing ecosystem services and of the role that social systems play in managing natural resources (Escobedo et al., 2019). Our use of an integrated, mixed-methods approach in the City of LA reveals social and political factors and dynamics that influence urban actors engaging in urban greening programs with direct implications for public health.

We find that the Tree Ambassador program effectively provides residents an avenue to act on their desire to serve as change agents for their communities. During the 10-month pilot program ending in April 2022, TAs planted or distributed a total of 1,929 trees and canvassed an estimated 1,244 residents. We also find that TAs face a variety of challenges, some of which are deep-rooted and intractable, as they try to convince members of their communities to engage in tree stewardship. For instance, of the nearly 2,000 trees added to LA's urban forest through their efforts, only 53 were street trees that TAs were able to secure with agreements by nearby property owners or tenants to provide establishment-period watering. Even so, TAs used a variety of creative, community-specific strategies to get trees planted in their communities (Appendix F). TAs feel supported by the program, but there is room to refine the program and further bolster TAs' efforts in its future iterations (Figures 4-1, 4-2 and 4-4).

Our focus group results, survey results, and ethnographic observations reveal that TAs leveraged trees as an avenue for community cohesion and understanding, and tree-centered community events provided an opportunity for TAs to celebrate the vibrancy of their community and highlight social ties and bonds. Whereas power dynamics at the beginning of the training program favored program staff, by the end of the program those dynamics had shifted (Appendix F). Self-efficacy and collective efficacy (people's individual or shared beliefs that they can produce desired results) were evident as TAs supported one another in designing, organizing, and successfully executing community engagement and tree planting and care activities. Through the lens of the socio-ecological framework, the results indicate that the Tree Ambassador program was effective in advancing urban forest equity at the first three levels — individual, relationship, and institutional level — while barriers at the last two levels of community and society remain significant.

Our findings corroborate that in the LA region, trees also lack protection in the face of redevelopment trends, which favor larger homes and higher ratios of hardscape, all while UFC inequity persists between higher- and lower-income neighborhoods (Lee et al., 2017; Pincetl, 2010a). Current policies, funding levels, and trends compound historical contributors to low UFC. Our SES models (Figures 4-8 and 4-9) indicate that there are entrenched drivers that perpetuate these conditions, but also reveal factors that can support advancing urban forest equity at the local level.

We also find that while UFC is correlated with socio-economic variables, that correlation is highly context-specific. Schwarz et al. (2015) and Volin et al. (2020) are among several studies documenting this phenomenon. Where clear relationships emerge across factors such as minority population, income, education, rentership, imperviousness, and climate zone, elsewhere those relationships do not correlate (Schwarz et al., 2015; Landry & Chakraborty, 2009; Riley & Gardiner, 2020). Our study (Table 4-1) adds additional evidence of this. For instance, Tree Ambassador #1 represents a foothill neighborhood that has high UFC (30%) but also has among the highest scores of pollution burden (87th percentile) — a measure that takes into account metrics including poverty, education, and public health indicators.

This is one factor behind the inequitable distribution of UFC in LA, but understanding the context specificity of how UFC and socio-economic variables are related is critical. For example, UFC is positively correlated with the percent of Asian residents in LA but negatively correlated in Sacramento, CA (Schwarz et al., 2015). Contradictions abound in the literature, in large part because communities are highly variable, and factors such as the instability of neighborhood demographics and various legacy effects, including redlining, further contribute to these varied associations (Dawes et al., 2018; Volin et al., 2020). In cities where overall UFC is relatively high, tree equity tends to be lower, though the strength of that relationship too is variable (Volin et al., 2020). In LA, the relationship between UFC and percent Asian is positive, but it is negative and significant for both percent Black and percent Latino/a (Schwarz et al., 2015). When looking at income and educational attainment, the picture of inequity becomes clearer in LA: neighborhoods that are lower income and where educational attainment levels are low have much lower UFC than wealthier neighborhoods (McPherson et al., 2007; Riley & Gardiner, 2020).

More than half a century after the end of redlining, the legacy patterns of disinvestment are still evident today, and they are evident in our findings (Table 4-1, Figures 4-8 and 4-9). A spatial assessment of 108 urban areas in the US, including Los Angeles, found that in addition to being hotter, in 94% of cases formerly redlined neighborhoods presently have two to three times less tree cover than their wealthier, non-redlined counterparts (Hoffman et al., 2020). Our study indicates that raising awareness of these enduring legacies of injustice can be a motivating factor for engaging in their undoing, and that tree stewardship can serve as a tangible act of addressing the causes of injustice.

Despite concerted efforts to raise UFC, achieving equitable distribution of urban trees continues to be difficult for myriad reasons. These may include lack of program oversight resulting in haphazard progress, limited funding availability, and physical and ecological constraints in environmental justice communities that are often located in more densely built-out parts of the city with limited numbers of readily plantable sites such as unplanted planting strip spaces and other sites that do not require pavement removal or other costly site modifications (Danford et al., 2014; Pincetl et al., 2013). A study that evaluated various tree planting scenarios in Boston found that focusing planting efforts mainly in environmental justice zones resulted in a lower overall UFC increase relative to planting scenarios that prioritized neighborhoods with mixed or higher socio-economic status, due in large part to site constraints such as narrow sidewalks that cannot accommodate trees, and a lack of pervious space suitable for planting (Danford et al., 2014). In LA, we found that in addition to physical constraints, distrust in local government, the belief that street tree stewardship is the responsibility of the city, and the belief that watering a tree is expensive, are also significant barriers to tree adoption and care.

As shown in Figures 4-3 and 4-6, tree care, maintenance and watering are also persistent factors at the society level that impact a Tree Ambassador's ability to organize their communities around tree planting and stewardship. In a city that is nearly 500 square miles, such management actions pose significant logistical challenges due to urban tree planting locations often being scattered over large geographic areas rather than concentrated in smaller areas, coupled with the fact that many planting sites are not served by automatic irrigation systems (City of LA Bureau of Street Services, 2015). In particular, LA's model of shared maintenance responsibilities for street trees presents additional complexities, and delivering water from tree to tree is time-intensive and requires sufficient resources to cover costs including labor, transportation, and watering infrastructure (Jack-Scott et al., 2013; Pincetl et al., 2013). Additionally, despite increasingly widespread acknowledgement that trees are critical city infrastructure, the City of Los Angeles has struggled to allocate sufficient funding to urban forest maintenance in line with industry standard best management practices since the recession that began in 2008, spending less per capita on trees than cities of comparable size, with an estimated $70-80 million needed to bring LA up to robust urban forest management levels (Dudek, 2018). Due to inadequate funding, the city's public tree management approach across various departments has been limited to emergency response rather than proactive enhancement, preservation, and care, and nonprofit organizations must often fill in the gap for city services that are deferred or wholly unavailable (City of LA Bureau of Street Services, 2015). Of the many barriers TAs encountered in their community organizing, the "opt-in" method of requiring residents to water street trees was consistently raised, and yet an alternative vision to transfer watering responsibility to the city seems unattainable due to funding levels that are chronically insufficient.

The complexity of factors related to tree stewardship programs lead to various approaches to operating public tree-planting programs, ranging from local government-led to nonprofit-led campaigns, with public-private partnerships falling within that spectrum. Whether performed by a paid workforce or volunteer residents, urban forest management demonstrates how human agency plays a direct role in the production and distribution of the services, potential disservices and benefits of urban ecosystems, including benefits to public health. How and by whom management is performed, and how resultant costs and benefits are shared and distributed is determined largely by directives made by local government and the constellation of resources that are cobbled together to try to support them. In some cases, philanthropic funds may be present — for instance, heiress Betty Brown Casey provided a $50 million endowment to found Casey Trees in Washington D.C., while celebrity Bette Midler committed $200 million to former New York Mayor Bloomberg to plant one million trees (Popkin, 2018; Danis, 2007). Los Angeles has not experienced such philanthropic fortune but the City has nevertheless embarked upon ambitious tree-planting efforts on several occasions in recent decades. In advance of the 1984 Olympics, an effort to plant and distribute one million trees was undertaken, led by volunteers. More recently, the launch of Million Trees LA in 2007 signaled a renewed commitment to elevating urban greening. Despite falling short of its goal and drawing criticism regarding its methods (Pincetl, 2010b; Pincetl et al., 2013), in 2014 the program underwent a transformation, rebranding itself as City Plants and aligning its approach with the tree planting ethos "right tree, right place, right reason." In its current iteration, City Plants oversees an array of urban forest programs and funding streams that serve as a critical force in greening LA, with a focus on equitable access to trees. This equity focus drove the pilot of the Tree Ambassador program, which has received funding to continue future rounds of hiring and training. The focus on equity also drives additional programs, including City Plants' convening of the Los Angeles Urban Forest Equity Collective, a collaborative of government, nonprofit, community, and academic entities working to actively grow, protect, and prioritize and urban forest that is accessible, inclusive, deeply valued, community-driven, adequately funded, and enduring for all Angelenos (CAPA Strategies, 2021a; CAPA Strategies 2021b).

We capture the constellation of factors impacting tree stewardship in Figures 4-8 and 4-9 with the intent to provide a framework to inform future UFC management activities and urban forest equity programming in Los Angeles. The nested framework (Figure 4-8) can be used to understand not only the relevant drivers that facilitate or hinder tree stewardship, but also to shed light on how the city and its nonprofit partners can intervene in boosting factors that support increased UFC and reduce those that hinder it. The pyramidal framework (Figure 4-9) offers an alternative way of conceptualizing these drivers, and adds the additional considerations of how time and space impact tree stewardship. It is our hope that these frameworks are useful to decision makers, nonprofit leaders, as well as individual residents; that factors will be added or removed to tailor the models to local needs; and that they will be improved upon in LA and beyond.

Our study does have some limitations. First, our sample size was low due to the exploratory nature of this new program. Thus, long-term follow up is needed not only of TA knowledge and neighborhood governance metrics, but if indeed increased UFC in the neighborhoods has measurably improved human thermal comfort and public health metrics such as morbidity and even mortality. Second, because this initial stage of the program focused primarily on tree planting in readily available sites, such as vacant street tree wells or private lots with front or back yards, we did not explore other planting options available to neighborhoods with multi-residential housing units or the use of concrete or asphalt removal to create tree planting sites. Though this method of creating tree planting sites via removal of impervious surfaces or other site modifications represents a more expensive pathway, in cities including LA, limiting tree planting initiatives to presently-available spaces and not expanding efforts to spaces that require removal of impervious surfaces or other site modifications can hinder substantial UFC increase in impervious surface dominated neighborhoods that stand to benefit the most from additional trees (CAPA Strategies, 2021a; McPherson et al., 2011). Similarly, we did not explore in detail the attitudes and perceptions of respondents to trees and UFC as well as the economic and funding limitations of TAs, property owners, renters, and other stakeholders and how this affects tree stewardship and public health outcomes (Dawes et al, 2018).

With growing recognition of the drivers behind urban forest inequity, many of LA's tree planting programs have shifted to prioritizing low-canopy areas while continuing to face the realities of physical, social, and funding challenges entrenched in these neighborhoods. Untangling and addressing these forces is an intractable task strongly bound to socio-economics, policy, and the political economy of resource distribution. Additionally, prioritizing locations and identifying site modifications needed for large stature trees is critical, as larger trees maximize public health benefits for the same amount of establishment care resource investment. The emphasis on the number of trees planted may be less important than the size of the trees planted, given the greater shade that larger trees are able to provide, particularly when it comes to protecting frontline communities from the public health risks of urban heat. In heavily concretized, densely populated neighborhoods like

Westlake, where current site conditions cannot easily accommodate trees on private property or in the public right-of-way, Tree Ambassadors would need to address significant society level barriers in order to significantly move the needle on increasing UFC and addressing urban forest equity in their communities. At the individual or relationship level, this can be a monumental task (for example, leading to decision points such as trading a parking space for a tree well). This reality indicates that policy makers and society level stakeholders have considerable control over advancing urban forest equity, and that individual or community level programs will only go so far without significant society-level intervention.

Through our application of the SES framework, and in our analysis of the results, we conclude that interaction between all spheres of influence, across space and time, from the individual level to the society level, is required to advance urban forest equity in support of public health, and a singularly top-down or bottom-up approach is inadequate. The approach and SES model developed in this study used an equity-focused lens and accounted for the nexus between public health and urban forestry and its related fields. In a similar manner to the increased acknowledgment seen in recent years of the role that contact with nature plays in promoting mental health, we suggest that urban greening programs can be better aligned with optimizing climate adaptation, heat reduction, and the provision of public health benefits. Further, we suggest that increased coordination between urban ecology and public health disciplines can serve as a tangible expression of the interdisciplinarity necessary to navigate the intractable challenges of a climate-changed era, particularly in marginalized communities, not only in LA but in other cities across the globe as well.

CHAPTER 5
Conclusion: Toward Urban Forest Equity for Heat Mitigation

The research presented in this dissertation was motivated by contemporary circumstances. Planetary warming is accelerating, disproportionately impacting cities and calling for urgent adaptations to protect communities who are least positioned to cope. Simultaneously, tensions and opportunities around advancing social and environmental equity are playing out in communities around the world. Within this context, the preceding chapters engaged with discourses around urban forest equity, the role of urban trees in heat mitigation, environmental governance, and how these dynamic topics interrelate. The research was propelled by two overarching research questions. First, what is the role of trees in indoor and outdoor urban heat mitigation? Second, what are the impacts of community-based programs as they relate to the advancement of urban forest equity and heat mitigation?

5.1 Summary of findings

This dissertation presented novel research on the role that trees play in the modulation of urban temperatures in residential settings (Chapter 2), and then investigated the effects of two approaches to grow and manage urban forests (Chapters 3 and 4). One approach directly engaged residents to provide voluntary tree stewardship, while the other compensated and trained community members in frontline communities to serve as intermediaries to educate and engage their neighbors about heat-health risk and how trees can help.

Chapter 2 investigated the impact that trees have on indoor residential spaces, where urban dwellers spend most of their time. I engaged community scientists to collect data and create a thermal sensor network that contributed continuous readings for indoor and outdoor temperatures between September and November 2020, at the height of the COVID-19 pandemic. I mimicked an experimental research design using a difference-in-differences (DD) approach where "treehouses" with moderate to high tree cover and "non-treehouses" with low or no tree cover were compared on hot days (>90°F or 32°C) and non-hot days (<90°F or 32°C). I found that on hot days indoor temperatures in treehouses warm -1.1°F (0.6°C) compared to in non-treehouses, but that trees provide relatively less benefit at night. I also found that exposure to extreme heat reaches dangerous levels in older residences without trees or air conditioning. Los Angeles (LA) County experienced its highest-yet recorded temperature of 121°F (49.5°C) on September 6, 2020. On that day a participating non-treehouse reached an indoor temperature of 107.4°F (41.9°C), hotter than it was outside at the time of the reading. Sustained exposure to such temperatures is a reality for many residents of Los Angeles and other cities who lack access to cooling strategies, underscoring the need for swift action to cool heat-vulnerable communities.

Chapter 3 presented an approach to address significant barriers to growing robust urban forests. In drier climates, complex logistics of watering during a multi-year establishment period pose a challenge because street trees are typically unirrigated and funding for maintenance is generally unavailable. This study tested the impacts of varying theory-guided community engagement approaches on beliefs, attitudes, knowledge, and behaviors related to fostering street tree stewardship and individual-level heat mitigation actions in 116 households in Los Angeles County. I tested a control intervention against experimental messaging focused on either public health or environmental health, and also segmented participants by the degree of prior household engagement with a local tree planting group. Outcomes measured were soil moisture, tree health, and survey responses indicating benefits and barriers related to tree stewardship. Results indicate that intervention messages had limited effect on these outcomes, and that level of engagement by the tree planting group was a stronger predictor of tree stewardship. I also found that tree stewardship correlated positively to heat protection measures, suggesting that environmental engagement may be an effective portal to reducing heat risk.

Chapter 4 investigated an approach to advancing urban forest equity as a climate health equity strategy, acknowledging a lack of information about the efficacy of tree planting programs in advancing urban forest equity and public wellbeing as a starting point. To address the mismatch between policy goals, governance, resources, and community desires on how to green marginalized neighborhoods for public health improvement — especially in LA's water-scarce environment — I adapted a theory-based, multi-dimensional socio-ecological systems (SES) framework regularly used in the public health field to evaluate the City of Los Angeles's Tree Ambassador / Promotor Forestal program. The program is modeled after the community health worker model, where frontline health workers are trusted community members. It aims to address urban forest equity and public wellbeing by training, supporting, and compensating residents to organize their communities. I conducted focus groups, surveys, and ethnographic observations and used the collected data to develop an SES model of community-based tree stewardship. The resultant SES model (Figure 4-8) elucidates how interacting dimensions — from individual to society level — drive urban forest equity and related public health outcomes. I then present an alternative framework (Figure 4-9), adding temporal and spatial factors to these dimensions. Results highlight factors which aid or hinder program trainees in organizing communities, including access to properties, perceptions about irrigation responsibilities, and lack of trust in local government. I also found that as trainee experience increased, measures including self-efficacy and collective efficacy and trust in neighbors also increased.

5.2 Contributions to the literature and recommendations for integration into programs and policy

Tree planting is a heat mitigation approach that is receiving investment in a growing number of cities around the world, but there are significant knowledge gaps about the cooling potential of trees in the urban context, and perhaps even more pronounced gaps in our understanding about how and by whom urban trees should be maintained when post-planting investment and resources lack to realize promised urban cooling and other benefits. There are also lingering questions about the impacts of advancing equitable distribution of environmental amenities such as trees, and whether this contributes to a "green space paradox" that has the potential to displace low-income communities as neighborhoods become healthier and more attractive (Wolch et al., 2014). This dissertation makes theoretical and practical contributions to these topics.

To begin with, understanding how trees impact thermal environments, especially indoor residential spaces where people spend much of their time, provides insights about the benefits and tradeoffs of relying on urban forestry as a climate adaptation strategy. Empirical research to compare the impact of the presence or absence of trees on thermal conditions on urban sites is complicated by a multitude of variables that might affect temperatures independent of trees, which cannot easily be controlled for — such as building materials, insulation, solar radiation, and building orientation. Behavioral factors, too, can have an influence on thermal conditions. Using a difference-in-differences method enabled comparison of homes with moderate to high tree cover against those with low or no tree cover, circumventing potential confounders present in the high heterogeneity of the urban environment, and providing an indication of the thermal impact of trees in low-canopy neighborhoods while laying the foundation for future research.

Chapter 2 contributes new empirical evidence of the benefits of trees on indoor thermal conditions; points to limitations and tradeoffs of relying on trees to mitigate urban heat (i.e., trees are less effective at cooling at night and during humid heat waves); and quantifies exposure to extreme heat, which reaches levels dangerous to human health in older residences without trees or air conditioning. Overall, during the 3-month study period indoor temperatures in treehouses warmed by -1.1°F (-0.6°C) compared to non-treehouses on hot days. Temperature benefits extended to all times of the day, with cooling differentials peaking during daytime hours. Even modest reductions in peak temperatures, such as those found in this study, can translate to improved public health outcomes: urban forest cover and albedo modifications that produce just a 1-2°F (0.5-1.1°C) reduction in peak heat wave temperatures have the potential to reduce heat-related deaths 10-20% (Kalkstein et al. 2022).

Importantly, the study showed a relative improvement in treehouse temperatures, but it did not always show an absolute improvement. That is, though temperatures at shaded houses generally increased by a lesser amount than houses without trees, actual temperatures were sometimes higher, demonstrating how nuances in the built environment influence the microclimate and thus how heat is experienced differently in the urban environment. This effect, heightened by LA's urban form and climate variability, is aptly referred to not as the urban heat *island* but as the urban *archipelago* (Taha, 2017; Taha et al., 2018). Trees should indeed be considered an effective urban cooling strategy, but there are important distinctions that should be considered, ranging from tree placement to species selection.

This dissertation then picks up from this point and explores pathways for growing and maintaining heat-protective tree canopy in heat-vulnerable, under-resourced neighborhoods where government support for the urban forest is limited. To do this, I first explored whether a resident-engagement tree stewardship program that is highly tailored to a community yields better results than one that is more generic, discussed in Chapter 3. The answer to this question has program implications because developing highly tailored programs requires more resources. A tailored program that performs well may justify allocating more resources in the community before deploying a program strategy. In contrast, a generic program that performs well suggests broadscale implementation can be achieved in a more streamlined and less resource-intensive fashion.

The present research showed that generic messaging was equally effective in the study site of San Fernando, CA and that highly tailored messaging did not yield better outcomes. In either case, messaging should still be written in a way that is suitable to the audience and considers cultural and linguistic sensitivity. Despite more tailored messaging having minimal impact, findings showed that the presence of a tree planting group on the ground did influence outcomes — even in the face of limitations imposed by the COVID-19 pandemic which prevented in-person engagement. Presence in the neighborhood can be demonstrated and reinforced in several ways that do not always necessitate significant investment, and this dissertation presented several possibilities — ranging from inviting residents to answer questions via a poll or survey, to partnering with trusted organizations already operating in the community, such as churches, school groups, or neighborhood councils. This research suggests that programs with limited resources should focus their efforts strategically on demonstrating their presence in the neighborhood in order to shift social norms toward tree stewardship.

Policy implications also emerge from this research. The approach to urban greening currently practiced in many parts of the United States — where funding supports planting but typically not maintenance — creates a gap between the initial investment in planting and the desired return on investment, calling into question the long-term viability of under-resourced urban forestry programs in a warmer, drier climate. Though this gap can be at least partly addressed through strategically designed engagement programs, the assumption that public infrastructure such as street trees should be maintained by residents highlights the challenge of placing this burden on communities, especially those with limited resources. Other alternatives must be considered that prioritize funding support to hire crews to care for the urban forest, especially during the critical initial establishment phase for young trees. Policies are necessary which elevate the status of urban forests and other types of green infrastructure to the funding and maintenance levels that more traditional "gray" infrastructure such as bridges and roads typically enjoy.

As a counterpoint to voluntary, resident-focused tree stewardship, in Chapter 4 I evaluated the effectiveness of the Tree Ambassador / Promotor Forestal tree stewardship training and community organizing program in advancing urban forest equity and climate health equity. This evaluation enabled identification of principal barriers and determinants (e.g., policy, infrastructure, social) encountered by trainees in their communities which may either aid or hinder achievement of program goals. Urban forest equity is influenced by socio-cultural and economic processes that shape spatial outcomes, and these are often a combination of both current and historical drivers which in turn influence available planting spaces and funding. I applied a multi-dimensional socio-ecological framework regularly used in the public health field to examine the spheres of influence within which these aiding or hindering factors exist and how the dynamics between them interact (Figures 4-8 and 4-9). Using this integrated, mixed-methods approach, the social and political factors which influence urban actors engaging in urban greening programs emerge, and intervention points at which to positively shift conditions are identified.

Findings indicated that the Tree Ambassador program was effective in advancing urban forest equity at the first three levels — individual, relationship, and institutional levels — while barriers at the last two levels — community and society — remain significant. In particular, LA's model of shared maintenance responsibilities for street trees presents significant complexities. Of the many barriers program trainees encountered in their community organizing, the City of LA's "opt-in" method of requiring residents to assume watering responsibility to maintain street trees in the first years after planting was a consistent barrier to the efforts of Tree Ambassadors, and yet an alternative vision to have the city absorb watering responsibility seems unattainable due to funding that is chronically insufficient. Adding to these complexities is the reality that inadequate protections for existing trees also threaten the advancement of urban forest equity. Existing trees lack protection in the face of redevelopment trends which favor larger homes and higher ratios of hardscape, further perpetuating urban forest inequities between higher- and lower-income neighborhoods (Lee et al., 2017; Pincetl, 2010a).

In densely-developed neighborhoods where current site conditions cannot easily accommodate trees on private property or in the public right-of-way, prioritizing locations and identifying site modifications needed for large-stature trees is critical. Larger trees maximize public health benefits for the same amount of establishment care resource investment and offer disproportionately more ecosystem services than their smaller counterparts. Considering the greater shade that larger trees are able to provide, the emphasis on the number of trees planted may thus be less important than the size of the trees planted. But larger trees need more space to grow, and the very neighborhoods that stand to gain the most from added shade often require considerable physical modifications in order to create such spaces.

Unraveling and tackling this multitude of factors is a complex task that is deeply woven into socio-economics, policy, and the political economy of resource distribution. Intervening at this level necessitates decision-makers at the policy level to dedicate planning resources to untangle barriers present in the urban space. At the individual or relationship levels of the socio-ecological framework, this can be an unreasonable task (for example, requiring a community member to navigate bureaucratic processes for non-traditional requests such as trading a parking space for a tree well). This reality indicates that policymakers and other decision-making stakeholders have considerable control over advancing urban forest equity, and that individual or community level programs will have limited success without interventions at the society level.

However, due to insufficient allocations of funding for urban forest maintenance, public tree management is often limited to emergency response rather than proactive enhancement, preservation, and care — with nonprofit organizations often filling in the gap for city services that are deferred or wholly unavailable (City of LA Bureau of Street Services, 2015). Significant policy interventions resulting in changed budgetary priorities favoring the urban forest are needed. Such interventions could take the form of bonds or special tax assessments, which have previously been successfully implemented to support water management in the City of Los Angeles through Proposition O in 2004 and in Los Angeles County through Measure W in 2018 (City of Los Angeles, n.d.; Los Angeles County, n.d.). Other cities have taken different approaches to support tree maintenance, including: capital improvements plans to support public tree management and maintenance (adopted in Charlottesville, Virginia); special taxing districts, which designate certain streets or neighborhoods where property owners allow the city to provide a public improvement or special service through an assessment not based on property value (adopted in Modesto, California); and street tree assessments, which are charged to property owners to support public tree planting and maintenance (adopted in Toledo and Cincinnati, Ohio) (City of Holyoke, 2021).

The Los Angeles Urban Forest Equity Collective (UFEC) is a group of more than 20 governmental, academic, nonprofit and community representatives which I co-founded in 2020 with City Plants executive director Rachel O'Leary to tackle barriers to greening high-need urban neighborhoods in Los Angeles. The group has already made significant contributions to urban forest equity discourse and practice and continues to develop novel decision-making tools and frameworks that can be adapted by nonprofit and government tree-planting programs. Among these contributions is a three-tiered system which categorizes planting opportunities based on the effort and investment associated, with higher tiers representing more effort, time, and investment (CAPA Strategies, 2021a). Tier 1 represents readily plantable spaces requiring no modification, such as empty tree wells or yards. Tier 2 planting requires some site modification which is possible to accomplish within current local government standards (e.g., concrete cuts to create a parkway tree well). Tier 3 sites are those requiring significant site modifications in locations where tree canopy increase would otherwise not be achievable (e.g., curb extensions). This approach seeks to codify a new terminology and practice in support of scalable solutions to the systemic problems that cause and perpetuate urban forest inequity. The tiered system allows for a spatial evaluation of how planting only readily available sites around the city would position different neighborhoods relative to greening goals such as the City of LA's *Green New Deal* goal of increasing tree canopy in under-represented neighborhoods by 50% by the 2028 Olympics. UFEC's preliminary analysis shows that focusing only on Tier 1 locations would be insufficient in most LA City council districts, and that investment in Tier 2 and 3 greening would be necessary (CAPA Strategies, 2021a). UFEC is expected to conclude a major project phase in the coming months which will contribute new practical tools and strategies to grow new canopy and protect existing trees in (and with) low-canopy, heat-vulnerable communities.

This dissertation was also concerned with the potential of urban forestry efforts to cause environmental or green gentrification, which can emerge when environmental improvements contribute to displacement of lower-income residents as neighborhoods become more appealing (Checker, 2011; Wolch et al., 2014). Tree planting differs from the typical array of improvements that are considered to contribute to green gentrification in a few ways. First, green gentrification is generally concerned with park access and the addition of larger-scale civic projects. The focus on one tree, a grove of trees, or an entire urban forest has scalar implications for gentrification (Wolch, et al. 2014; Heynen, 2003). This dissertation suggests that small-scale improvements such as those presented in the research may not pose the same gentrification risk presented by larger, more geographically focused greening efforts. Tree planting is a way to make neighborhoods "just green enough" by improving them sufficiently to provide environmental and public health protection, while still maintaining other uses that can protect the tenure of existing residents. This is because parks and other dedicated green spaces require a suitable land-use designation that generally precludes other land uses from occupying the same space concurrently. Planting trees, on the other hand, can be incorporated into any land use. While tree planting generally represents a less grandiose expression of green space, it is a nimble one that can be woven into the urban fabric and fill small, distributed, interstitial spaces where opportunities exist. As a versatile feature, trees allow for adaptive use of infrastructure such as streets, alleys, or utility corridors into an amenity that supports walking, informal play, and exercise and provides social and ecosystem benefits.

Promoting small-scale, marginal, linear interventions in a distributed manner rather than larger green spaces can reduce gentrification pressures. If linear interventions can advance urban forest equity and not contribute to gentrification, a practical implication is that these urban greening applications can then be added to the practitioner and planner toolbox of interventions that are "just green enough." In smaller-scale reforestation projects, residents can enjoy the socio-psychological benefits provided by trees that result in a better quality of life (Heynen 2003), even if changes are not grandiose.

Scale and the nimbleness of trees to be included in any land use are two factors that can reduce the potential of tree planting to cause green gentrification, but the degree of community engagement matters. Urban forestry efforts that involve or are driven by the community reduce the potential for gentrification, and are an example of "just nature-based solutions" that engage and mobilize communities to address the drivers of a variety of inequities (Cousins, 2020). As Chapters 3 and 4 show, the degree to which a community is involved in or drives a planting campaign varies greatly.

"Just green enough" efforts must be explicitly shaped by community concerns and desires, and refrain from conventional urban design or ecological restoration approaches that impose a top-down vision divorced from community input (Wolch et al., 2014). An endeavor that is influenced by the community is one that engages community members from the start and is shaped by feedback about the pros and cons of proposed greening, including consideration of whether greening should be prioritized relative to other needs and desires, and if so, where it should occur and how community members will be involved in the design, planning, execution, and maintenance of the project.

Chapters 3 and 4 demonstrate differing degrees of community influence. Chapter 3 illustrates community involvement that was only marginally driven by community input. Chapter 4, on the other hand, presents an alternative model in which trained frontline community members receive compensation to serve as ambassadors engaging their neighbors. By engaging in conversations about neighborhood priorities and exploring the variety of opinions and desires that community members hold around tree planting and other community priorities, Tree Ambassadors help to realize marginal, linear greening in a deeply community-driven manner.

Merging these concepts, I suggest there is potential for a marginal, linear, and distributed approach to greening which provides environmental and public health benefits and minimizes the likelihood that advancement of urban forest equity will produce other social inequities. I build on the concept of Urban Green Commons, physical green spaces in urban settings of diverse land ownership that depend on collective organization and management, and which provide opportunities for strengthening socio-ecological relationships (Colding & Barthel, 2013). This idea has been previously applied to contained common spaces such as community gardens or collectively-managed parks, and this dissertation suggests expanding that concept linearly to residential parkways. Parkways serve as marginal, linear spaces that, in the absence of dedicated green spaces, may offer an alternative to otherwise unavailable open space in the neighborhood. Collectively managing these contested spaces as strands in a larger network of green infrastructure offers opportunities to democratize access to protective amenities of shading and cooling and holds the potential to avoid the risk of green gentrification that accompanies larger civic green spaces. Sites of experimentation which incorporate nature-based solutions — including the modest parkway — have the potential to create new urban green commons and opportunities for new socio-environmental relationships to be fostered (Cousins, 2020).

5.3 Future research directions

Future research related to evaluating the thermal impacts of trees on urban spaces could involve larger-scale studies of sites segmented by neighborhood and site characteristics. In the research presented in Chapter 2, this would enable a deeper exploration of tree and housing type characteristics. Additionally, incorporating household-level energy data for the study period could enable quantification of the impacts of trees on energy demand. Such an analysis could be linked both to in situ sensors, such as the ones used in this study, and remote-sensed temperature data. Further investigation of thermal impacts of different canopy types and of the daytime vs. nighttime effects of trees on thermal conditions are other critical areas that could be explored, especially in the context of how exposure to heat at different times of day and in different rooms of the house impacts public health outcomes. Additional research on the potential of nighttime warming impacts by trees is also needed.

The body of knowledge related to tree stewardship that is shared between governmental, nonprofit and community actors would benefit from more evidence about how tree planting and stewardship impacts affordability and access to housing. Additional research to study the economic impacts and long-term viability of using an "urban green commons" approach of marginal, linear greening would be an important contribution to the field. A potential area for future research would be to explore the relationship between urban forest inequity, increased tree cover, and housing cost — and specifically to investigate these through the use-value of trees, or the services they provide such as shading and air quality improvement (Heynen 2003). If this use-value becomes commodified, it becomes part of the political economy that drives housing markets and affordability (Ernstson 2013). Under this view, the urban forest too could have the potential of becoming commodified, which in turn could produce and reinforce uneven patterns of distribution. Marginal, linear planting that is "just green enough" may avoid the undesired effects on housing affordability, but given the many factors that influence housing cost, an economic study of how marginal, linear greening impacts housing costs relative to other factors warrants investigation (Garde, 1999; Cousins, 2020; Wolch et al., 2014).

Other prospective research could evaluate multiple maintenance regimes and compare outcomes of programs that transfer street tree watering responsibility to residents versus those that mobilize municipal and/or nonprofit staff and volunteers. Additional research could also investigate the links between tree- and heat-health related outcomes by exploring whether heat programming can be a portal to environmental action, rather than exploring whether engagement in environmental stewardship can link to engagement around heat mitigation — as this dissertation presented in Chapter 3. For example, cities with public-facing heat mitigation programs could test the viability of engaging their residents in tree planting and care activities as a heat preparedness and mitigation action.

As the climate continues to change, the future of research and practice that leverages urban forest equity toward heat mitigation holds great potential. By integrating scientific research, innovative community engagement strategies, and forward-thinking policies, Los Angeles and cities around the country and the world can forge a path toward home-grown adaptation and resilience. Embracing the critical roles that urban forests play — as well as the complexities of urban forest co-production and management — offers us the opportunity to collectively strive to realize cooler, greener, more inclusive neighborhoods where the social and ecological benefits of trees are equitably distributed and accessible.

Appendix A: Survey instrument (English)

ID Number: ___________

Date: ______________

Time: ______________

Are you at least 18 years old? If not, would you please deliver this envelope to someone in your household who is at least 18 years old? Surveys must be completed by someone who is 18 or older. □ **I am 18 or older**

1. What is the current temperature outside? If you are unable to check, please give it your best guess: ___________

These first questions are about your general attitude and values.

2. Using a scale from 1 to 7, where 1 means not at all important and 7 means extremely important, please tell me, how important is it… (Mark "X")

	Not at all Important 1	2	3	4	5	6	Extremely Important 7
for you to have a tree in your front yard?							
for your neighborhood to have trees up and down the streets?							
for your neighbors to have trees in their front yards?							
to have well-maintained streets and sidewalks for people in your neighborhood?							

We are asking residents about two ways to take care of these young trees: watering and weeding. Typically, a young tree needs 15 gallons of water per week. Weeds need to be pulled from around the base of young trees to make sure their roots have room to grow. There are plans to plant 200 trees in the City of San Fernando within the next few months. The trees will be planted along the parkways – the planting strip between the sidewalk and the curb – in front of houses. You or some of your neighbors might already have a young tree in the parkway area. A young tree needs 15 gallons of water per week. This is equal to three 5-gallon buckets, or using a hose and letting the water run for about two minutes. Weekly weeding around the base of the tree is needed to give the root system the space it needs to grow.

3. Using a scale from 1 to 7, where 1 means strongly disagree and 7 means strongly agree, how much you agree or disagree with each of the following statements. (Mark "X")

	Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7
Having more trees in the neighborhood will increase property values.							
I do not want to pay for the water needed to care for a tree.							
A tree in my front yard will keep my yard cooler.							
During drought trees need extra care in order to live.							
Having more shade in the neighborhood will encourage people to be outdoors more.							
Trees are beautiful to look at.							
I like having a tree in my front yard.							
It is the responsibility of the city to care for the trees that line the streets.							
Having a tree in every yard is good for my neighborhood.							

	Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7
A tree in my front yard will keep my home cooler.							
Having trees in my neighborhood helps reduce air pollution.							
Trees are important for human health.							
I would rather have a tree than a $5 monthly discount on my power bill.							

These next questions are about your attitude and abilities.

4. Using the scale below, how much you agree or disagree with each of the following statements?

	Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7
I am physically able to weed around the tree.							
Taking care of the tree will make my yard look nice.							
I have time to water the tree each week.							
I like to take care of plants and trees.							
Taking care of the tree will make my street look nice.							
I have time to weed around the tree each week.							
Watering is important for the health of the tree.							
Carrying a 5-gallon bucket of water would be difficult for me.							
I have what I need to weed around the tree.							
I want my neighbors to water their trees.							
I see my neighbors taking care of their trees.							
I water my tree.							

Now we would like to ask you some questions about your yard.

5. Do you have any flowers, fruit trees, grass or other plants in your yard that you take care of by watering?

□ Yes □ No Skip To: 10

6. Who is typically responsible for watering the flowers, fruit trees, grass or other plants in your yard?

□ Me □ Service/Gardener □ Spouse/Partner □ Other (Specify): ______________________

7. Who is typically responsible for weeding the flowers, fruit trees, grass or other plants in your yard?

□ Me □ Service/Gardener □ Spouse/Partner □ Other: ______________________

8. Which method do you use most often to water your grass or plants?

- A manual sprinkler attached to a hose
- An automatic sprinkler system that is not programmed, but is turned on and off manually
- A sprinkler system that is programmed to turn on and off automatically
- A hose
- A bucket
- Other: ____

9. **Do you use mulch, compost or wood chips around your flowers, fruit trees, grass or other plants?**
□ Yes □ No □ Don't know

10. **Do you have a water spigot in your front or backyard?**
□ Yes □ No □ Don't know If NO or DON'T KNOW, Skip To: 13

11. **Do you have a hose to attach to the spigot in your front or backyard?**
□ Yes □ No □ Don't know If NO or DON'T KNOW, Skip To: 13

12. **Is the hose long enough to reach the parkway, the area next to the street?**
□ Yes □ No □ Don't know

13. **If I told you that the City of San Fernando has very little funding for taking care of trees in the parkway area in front of people's homes, how likely would you be to water this tree *if the city* asked you to do so?**
□ Very unlikely □ Somewhat unlikely □ Somewhat likely □ Very likely □ Don't know

14. **If I told you that the City of San Fernando has very little funding for taking care of trees in the parkway area in front of people's homes, how likely would you be to water this tree *if a community group* asked you to do so?**
□ Very unlikely □ Somewhat unlikely □ Somewhat likely □ Very likely □ Don't know

15. **Using the scale below, how much leisure time do you spend in your front yard?**

□ 1	□ 2	□ 3	□ 4	□ 5	□ 6	□ 7
None at all						A lot

The next few questions have to do with air conditioning and your experience of hot weather in your neighborhood.

16. **Do you have a functioning air conditioning unit in your home? Check all that apply.**
- ▢ YES, I have central air (forced air that comes out of the wall, ceiling ducts or floor ducts) Skip To: 18
- ▢ YES, I have an individual unit(s) installed in a window or wall Skip To: 18
- ▢ NO

17. **Why do you not have a functioning air conditioning unit in your home? Check all that apply.**
- ▢ I can't afford AC Skip To: 20
- ▢ I don't need AC Skip To: 20
- ▢ I don't like AC Skip To: 20
- ▢ Building wiring is not equipped to support AC Skip To: 20

18. **When it's really hot outside, how often do you use AC?** □ Never □ Rarely □ Sometimes □ Always Skip To: 22

19. **Why do you limit your air conditioning use when it's really hot out? Check all that apply.**
- ▢ I don't like AC
- ▢ I do not mind the heat
- ▢ I want to conserve energy
- ▢ I am concerned about my electricity bill
- ▢ I go somewhere else to get cool rather than stay at home
- ▢ Other: ______________________________

20. **When you are at home during the day, what, if any, actions do you take to cool down when it's really hot out? Check all that apply.**
- ▢ I stay home because the heat doesn't bother me
- ▢ I stay home even though I feel hot
- ▢ I visit a community center, library or other free public space
- ▢ I visit the mall, stores, or other places of business
- ▢ I go to the movies
- ▢ I go to someone else's home
- ▢ Other: ______________________________

21. When you stay home even though you feel hot, why? Please answer this question considering normal circumstances when "Stay at Home" orders are not in place. Check all that apply.

- ☐ I never stay home when I feel really hot
- ☐ I prefer to stay home
- ☐ I don't think heat is dangers
- ☐ I don't feel safe leaving home
- ☐ My health makes it hard to leave home
- ☐ I don't know where to go
- ☐ I don't want to leave a family member or other person I live with
- ☐ I don't want to leave a pet(s)
- ☐ I don't have transportation
- ☐ I don't like spending time with strangers
- ☐ Other: ____

22. Using the scale below, how much do you agree or disagree with each of the following statements? (Mark "X")

	Strongly Disagree 1	2	3	4	5	6	Strongly Agree 7
I believe heat waves have become *hotter* in the past few years.							
I believe heat waves have become *longer* in the past few years.							
I believe heat waves have become *more frequent* in the past few years.							
I am concerned that heat waves are bad for *my health*.							
I am concerned that heat waves are bad for *the health of people I care about*.							
I am concerned that heat waves are bad for *the health of animals*.							

23. Have you or someone who lives in your home experienced any of the following problems on really hot days? (Mark "X")

	YES	NO	I DON'T KNOW
Dehydration			
Discomfort			
Headaches			
Dizziness			
Nausea/Vomiting			
Confusion			
Tiredness			

24. On really hot days, do you try to do any of the following? (Mark "X")

	YES	NO
Stay out of the sun in the hottest part of the day		
Stay in the shade		
Apply sunscreen		
Avoid intense physical activity (heavy exercising or sports)		
Drink plenty of liquids		
Avoid alcohol		
Check in on friends or family who are sensitive to heat such as those who are ill, elderly, or babies		
Open windows at night		
Close curtain of windows that receive the afternoon sun		
Use an electric fan		

25. How hot outside does it feel to you today?

☐ Not at all ☐ A little ☐ Moderately hot ☐ Very hot

The following questions have to do with your community.

26. In thinking about the COVID-19 pandemic, have you or your family, friends, or other members of your circle supported each other? We have listed several ways communities support one another. (Mark "X" for all that apply.)

	I have done this	Someone from my community has done this	I believe someone from my community would be willing to do this
Deliver groceries/food			
Provide transportation			
Help with childcare			
Check on members of my community			
Provide basic first aid			
Offer emotional support			

27. How many of the people you refer to in the last question (your family, friends, and members of your circle) live in your neighborhood?

□ None □ Very few □ Some □ Most □ All

28. Using a scale from 1 to 7, where 1 means not at all and 7 means very much, how much do you care about your neighborhood?

□ 1 Not at all □ 2 □ 3 □ 4 □ 5 □ 6 □ 7 Very much

29. Using that same scale, how much do you believe other people in your neighborhood care about your neighborhood?

□ 1 Not at all □ 2 □ 3 □ 4 □ 5 □ 6 □ 7 Very much

30. How long have you lived in this neighborhood?

□ Less than 2 years □ 2-5 years □ 6-10 years □ 11-15 years □ More than 15 years □ My whole life

31. Using a scale from 1 to 7, where 1 means none of them and 7 means all of them, how many of your neighbors do you know?

□ 1 None of them □ 2 □ 3 □ 4 □ 5 □ 6 □ 7 All of them

Skip To: 33 If "1, None of them"

32. Using that same scale, of those neighbors, how many of them do you feel comfortable asking for a favor?

□ 1 None of them □ 2 □ 3 □ 4 □ 5 □ 6 □ 7 All of them

33. Using that same scale, how many of your neighbors who you don't know would you be comfortable asking for a favor?

□ 1 None of them □ 2 □ 3 □ 4 □ 5 □ 6 □ 7 All of them

34. Some people think it's mainly the government's responsibility to help communities prepare for a disaster or an emergency. Other people think that it's everyone's responsibility. Using a scale of 1 to 7, do you think it is mostly the government's responsibility or mostly your own responsibility? Please mark one number on the scale below.

□ 1 100% mine □ 2 □ 3 □ 4 Equal □ 5 □ 6 □ 7 100% government

We are almost finished. These last questions are used for classification purposes only. Again, all of your answers are strictly confidential, and you can skip questions you would prefer not to answer.

35. Do you own or rent your home? □ OWN □ RENT

36. Including yourself, how many people live in your household?______________ IF 1: Skip To: 39

37. How many of those are children under 18? _______________

38. How many of those are adults over 65?_________________

39. In what year were you born? _______________

40. What is the highest level of school you have completed or the highest degree you have received?

- NEVER ATTENDED SCHOOL OR ONLY ATTENDED KINDERGARTEN
- GRADES 1 THROUGH 8 (ELEMENTARY ONLY)
- GRADES 9 THROUGH 11 (SOME HIGH SCHOOL)
- GRADE 12 (HIGH SCHOOL GRADUATE)
- GED
- SOME COLLEGE
- TRADE or TECHNICAL SCHOOL (INCLUDES 2-YEAR DEGREE)
- COLLEGE GRADUATE (4-YEAR DEGREE)
- GRADUATE COLLEGE DEGREE (POST GRADUATE DEGREE)

41. We don't need to know exactly, but just roughly, what is your annual household income from all sources before taxes?

□ Less than $12,000 □ From $12,000 to $25,000 □ From $25,000 to $50,000
□ From $50,000 to $75,000 □ From $75,000 to $100,000 □ Over $100,000

42. How do you identify? Check that all that apply.

□ White □ Hispanic/Latino/a □ Black or African-American □ Asian □ Other

43. What is your gender?

□ Male □ Female □ Other

44. Please choose one of the following options for your $20 gift card.

□ Amazon.com □ Target □ Chipotle □ Starbucks □ I do not want a gift card

Please write your name and address on the card included in your envelope and return it with this completed survey and your signed consent form. If you completed the survey online, you do not need to return anything.

Thank you very much for your time and participation. We will be mailing you another survey in a few months and will offer you a second $20 gift card if you choose to complete it. We would be grateful for your participation in the future. If you would be willing to answer the second survey online, please enter your email address and we will send it to you electronically in a few months.

Email: ____

Appendix B: Re-coded survey variables

SM2: Table of re-coded survey variables

Variable	Survey question
Values pertaining to trees	How important is it for you to have a tree in your front yard?
	How important is it for you that your neighborhood have trees up and down the streets?
	How important is it for you that your neighbors have trees in their front yards?
	Having more trees in the neighborhood will increase property values.
	I do not want to pay for the water needed to care for a tree.
	Trees are beautiful to look at.
	I like having a tree in my front yard.
	Having a tree in every yard is good for my neighborhood.
	I would rather have a tree than a $5 monthly discount on my power bill.
	Taking care of the tree will make my yard look nice.
	I like to take care of plants and trees.
	Taking care of the tree will make my street look nice.
	I want my neighbors to water their trees.
Beliefs around tree care	During drought trees need extra care in order to live.
	Watering is important for the health of the tree.
Tree care actions	I water my tree.
	Do you use mulch, compost or wood chips around your flowers, fruit trees, grass or other plants?
Values pertaining to neighborhood	How important is it for you to have well-maintained streets and sidewalks for people in your neighborhood?
	Having more shade in the neighborhood will encourage people to be outdoors more.
	How much do you care about your neighborhood?
	How much do you believe other people in your neighborhood care about your neighborhood?
Tree care barriers	It is the responsibility of the city to care for the trees that line the streets.
	I am physically able to weed around the tree.
	I have time to water the tree each week.
	I have time to weed around the tree each week.
	Carrying a 5-gallon bucket of water would be difficult for me.
	I have what I need to weed around the tree.
	Do you have a water spigot in your front or backyard?
	Do you have a hose to attach to the spigot in your yard?
	Is the hose long enough to reach to the parkway, the area next to the street?
Knowledge about the link between trees and health	A tree in my front yard will keep my yard cooler.
	A tree in my front yard will keep my home cooler.
	Having trees in my neighborhood helps reduce air pollution.
	Trees are important for human health.
Locus of responsibility	If I told you that the City of San Fernando has very little funding for taking care of trees in the parkway area in front of people's homes, how likely would you be to water this tree if the city asked you to do so? ...if a community group asked you to do so?
	Some people think it's mainly the government's responsibility to help communities prepare for a disaster or an emergency. Other people think that it's everyone's responsibility. Co you think it is mostly the government's responsibility or mostly your own responsibility?
Beliefs about heat	I believe heat waves have become hotter in the past few years.
	I believe heat waves have become longer in the past few years.
	I believe heat waves have become more frequent in the past few years.
Concerns about heat	I am concerned that heat waves are bad for my health.
	I am concerned that heat waves are bad for the health of people I care about.
	I am concerned that heat waves are bad for the health of animals.
Past experience with heat impacts on health	Have you (or someone who lives in your home) experienced any of the following problems on really hot days? Dehydration; Headaches; Dizziness; Nausea/Vomiting; Confusion; Tiredness.
Perceptions around heat	How hot outside does it feel to you today?
Heat protective measures	When it's really hot outside, how often did you use AC?
	When you are at home during the day, what, if any, actions do you take to cool down when it's really hot out?
	On really hot days, do you take any of the following actions? Stay out of the sun in the hottest part of the day; Stay in the shade; Apply sunscreen; Avoid intense physical activity (heavy exercising or sports); Drink plenty of liquids; Avoid alcohol; Check in on friends or family who are sensitive to heat such as those who are ill, elderly, or babies; Open windows at night; Close curtain of windows that receive the afternoon sun; Use an electric fan.
Access to coping strategies during heat waves	Do you have a functioning air conditioning unit in your home?
Community resilience and social ties	In thinking about the COVID-19 pandemic, have you or your family, friends, or other members of your circle supported each other? Deliver groceries/food; Provide transportation; Help with childcare; Check on members of my community; Provide basic first aid; Offer emotional support
	How many of your neighbors do you know?
	How many of them do you feel comfortable asking for a favor?
	How many of your neighbors who you don't know would you be comfortable asking for a favor?
	How many of the people you refer to in the last question (your family, friends, and members of your circle) live in your neighborhood?
Demographics	Do you own or rent your home?
	Including yourself, how many people live in your household?
	How long have you lived in this neighborhood?
	How many of those are children under 18?
	How many of those are adults over 65?
	In what year were you born?
	What is the highest level of school you have completed or the highest degree you received?
	What is your annual household income from all sources before taxes?
	How do you identify? (Race and ethnicity)
	What is your gender?

Appendix C: Intervention materials

Sample of materials used in treatment condition
(Instructional postcard, refrigerator magnet clip, commitment sticker)

Don't forget: water your tree!

- **Once a week:** Check the soil around the tree. Dig your finger in the soil—is it dry? If it is...
- Your tree needs water to soak down into its roots, so give it a good soaking of 15 gallons of water.
- That's like 15 milk jugs or 3 big paint buckets.
- If using a hose, set a timer and leave it on for 2-5 minutes, depending on the strength of the flow.
- Did you know? It only costs about $5 a year to water your tree!

No lo olvides: ¡riega su árbol!

- **Una vez a la semana**: Chequear la tierra alrededor del su árbol. Mete su dedo en la tierra— está seca? Si lo es...
- Su árbol necesita agua hasta las raices, asi que dale 15 gallones de agua. Esto es 3 botes grandes, como botes de pintura.
- Si estas usando una manguera, deje que corre de 2-5 minutos, dependiendo del flujo.
- Usted sabia? Solo cuesta como $5 al año para regar su árbol!

x 15

x3

TreePeople

SAN FERNANDO

Treatment condition
(Prompt/reminder postcard #2, attached to potted succulent plant)

Help us make San Fernando even healthier and more beautiful!

When you water your new plant each week, don't forget to also water the trees and plants in the parkway (the area between the sidewalk and the street) in front of your home.

It's going to take all of us! The City and TreePeople have plans to plant more trees in San Fernando. We need your help to keep them alive!

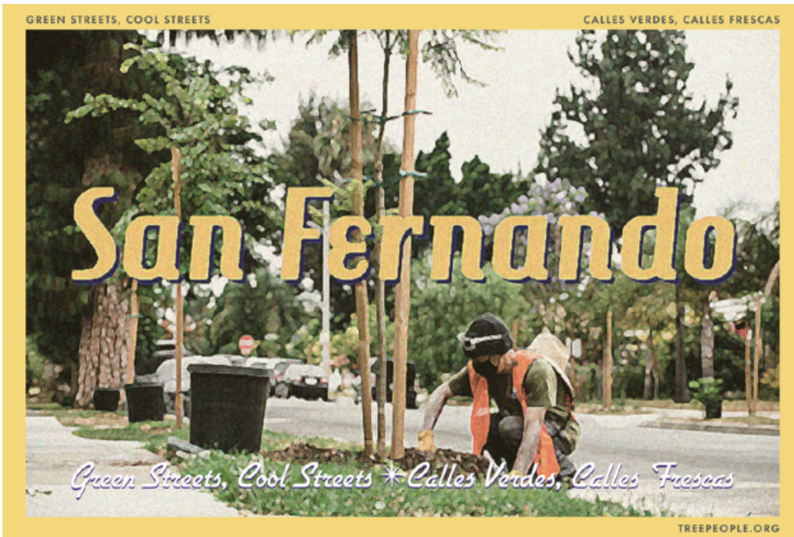
Ayúdanos a hacer que San Fernando sea más saludable y más bello!

Cuando usted riega su planta cada semana, no se le olvide regar su árbol y plantas enfrente de su casa.

¡Nos va a llevar a todos! La ciudad y TreePeople tienen planes para sembrar más árboles en San Fernando. ¡Necesitamos su ayuda para mantenerlos vivos!

TreePeople   THE CITY OF SAN FERNANDO

Treatment condition
(Prompt/reminder postcard #3a - public health messaging (top) and #3b environmental health messaging (bottom) - same front image on both)



When your tree is healthy, you are healthy!

Trees reduce rates of asthma, obesity, and diabetes. Watering your tree today means lower medical bills tomorrow.

Cuando su árbol está sano, ¡usted está sano!

Los árboles reducen los casos de asma, obesidad y diabetes. Regar su árbol hoy significa menores facturas médicas mañana.

TreePeople THE CITY OF SAN FERNANDO

When your tree is healthy, your neighborhood is healthy!

Trees reduce the temperature on your streets and in your home, clean the air, and capture the rain. Watering your tree today means lower energy bills tomorrow.

Cuando su árbol está sano, ¡su vecindario está sano!

Los árboles reducen la temperatura en sus calles y en su hogar, limpian el aire y capturan la lluvia. Regar su árbol hoy significa menores facturas de energía mañana.

TreePeople THE CITY OF SAN FERNANDO

Appendix D: Socioeconomic and demographic composition of Tree Ambassadors

Category	Tree Ambassador Responses
Number of years living in the neighborhood	Eight TAs have lived in their neighborhood their entire lives, and only two TAs have lived in their neighborhood less than a decade
Race/ethnicity	Nine identified as Hispanic or Latino, and one as multi-racial (Latino, Native American and white)
Gender	Five identified as female, three as male, and one as non-binary
Annual household income	One reported below $12,000, three reported a range of $12,000-25,000, two reported a range of $25,000-50,000, and one each reported $50,000-75,000 and over $100,000 per year
Highest level of educational attainment	One high school graduate, three who have completed some college, two college graduates, and three with graduate degrees
Housing tenure	Seven rent their homes and three own
Housing type	Six live in a multi-family building and five live in a single-family home

Appendix E:
Tree Ambassador Mid-Program Assessment Focus Group Questions

Opening Question: Please share with us your name, which organization you are working with (KYCC, Climate Resolve, or TreePeople?) and something you love to do in your free time.

Transition Question: Think back to when you first heard about the Tree Ambassador program. What was your first impression?

Transition Question: Think back to when you decided to apply for this program. What motivated you to become a Tree Ambassador?

Transition Question: Think back to your interview for this program. How was the Tree Ambassador program described to you during your interview?

Key Question 1: Tell me about the process of planting trees in your community. What steps does it take?
Follow up: How many of you have taken that step in your community?
Probing Question: Did anyone encounter any issues in taking that step?
Probing Question: Did anyone else have a similar experience?
Follow up: Are there any other steps you need to take?
Probing Question: Did anyone encounter any issues in taking that step?
Probing Question: Did anyone else have a similar experience?

Key Question 2: (if it didn't already come up) Tell me about the process of securing commitment to water forms for planting street trees. Has anyone experienced any challenges?
Probing Question: Did anyone else have a similar experience?
Follow up: Has anyone had an experience where you were successful in getting commitment to water forms? What worked well?
Probing Question: Did anyone else have a similar experience?
Follow up: What about getting your neighbors to be interested in yard trees for their homes. Has anyone experienced any challenges?
Probing Question: Did anyone else have a similar experience?
Follow up: What has worked well?
Probing Question: Did anyone else have a similar experience?

Key Question 3: Tell me about other ways that you have used to engage people in your local community, other than those we have already discussed.
Follow up: Did anyone else use this approach?
Follow up: How did it go?
Follow up: Which of these strategies did you learn from the Tree Ambassador trainings?
Follow up: How has your hosting organization supported you in this process?
Follow up: Do you feel that you need more support in the future?

Key Question 4: Tell me about your experience of heat waves in your community. How do you cope during hot days?
Probing Question: Has anyone else had a similar experience?
Follow up: How do trees connect to this issue of heat?

Key Question 5: Are there any other issues, concerns, questions, or comments that anyone would like to share?

Ending Question: We will follow up with a survey in a couple of weeks where you will be able to give anonymous feedback about the training materials and content. But for now, what advice would you give to the people creating and presenting the training materials?
Follow up: Does anyone else have any advice for the people creating and presenting the training materials?

Appendix F:
Content analysis of Tree Ambassador program ethnographic observations

Themes	Event	Select observations and comments from Tree Ambassadors
Challenges in the community - Reasons/resistance against trees	In-person training on tree planting and young tree care, held on a street in Boyle Heights in September 2021 in celebration of Latino Heritage Month	In conversation with a resident that is watching the street tree planting activity from his yard. Speaking Spanish, the man says that he likes trees and had more on his property before. *"Not much shade now because I had to remove them after they died and that cost a lot to remove….we don't have much trees because I'm afraid to plant the wrong tree...afraid of root damage and foundation damage."* He points to two Chinese elm trees planted in the parkway of his next-door neighbor's house. They are heavily and poorly pruned. He explains that his neighbor says that if you maintain the top (canopy) of the tree small, then the roots won't grow and cause damage.
	A training on the theme of Careers in Urban Forestry held via Zoom in February 2022	TAs were asked "Has this program helped you become a better steward for your community?" One TA responded" *"I never realized exactly how much history and politics and any other kind of socio-econnomic, socio-political indications there are in something that we just kind of take for granted -- like trees. Trees are such natural monuments, I would say, and a lot of people don't really think much beyond their presence of the existing trees that they've already seen"*
	A TA-led distribution event at Emerson Unitarian Church in Canoga Park in March 2022	A TA tells me that *"when people hear that the city is interested in trees, we are greeted with negative senses about the city."* The TA is joined by another TA and they expand on this by sharing some of the resistance they've gotten: •Registration is difficult •Problem trees are removed and not replaced with new plantings like they're supposed to, even after the community asks repeatedly •Trees lift sidewalks •The city refuses to trim on time
Challenges in the community - COVID	Weekly Zoom "hangout" session in January 2022 -- the first that is being held after a mid-program assessment revealed the need for time together in between the monthly trainings	The first issue brought up after everyone has been welcomed comes from a TA who is concerned with COVID-19 infections spiking once more. The TA remarks that people are nervous about being near each other, and is unsure about how manage those interactions. *"There are some people who are opposed to us going up their house, and with COVID there is an added layer of fear. What do you recommend us doing?"* The topic is discussed as a group and City Plants staff says they are struggling to answer the same question themselves. They conclude that it's up to one's own level of comfort, so long as public health guidelines are being followed, and that flyering rather than engaging in-person may be best for the time being.
Challenges in the community - daily work of greening communities	In-person training on tree planting and young tree care, held on a street in Boyle Heights in September 2021 in celebration of Latino Heritage Month	The street where the event takes places is narrow. Two cars going in opposite directions cannot pass unless one tucks into a parking space or driveway to let the other one pass. All TAs and some program staff are circled around to watch a tree planting demonstration and engage in questions and answers. The instructor asks "*what conflicts and issues do we have to look out for?*" and a TA responds *"powerlines, utilities."* Then a man driving Tesla interrupts. There is a flat-bed truck stopped in the street and he cannot get around. The man in the Tesla says *"This is a public street! I've been working for 12 hours!"* One of the crew says *"this is a public service we are offering, please just wait a moment and we will move the truck"* but by now everyone's attention is on the altercation and the training has halted. The truck is moved and the man drives off. A few comments are made about the man being in a fancy car and being entitled even if he is in this neighborhood.

	Weekly TA meeting held via Zoom with host nonprofit organization in February 2022	Debriefing about a TA-led tree care event in Sunland the weekend prior, one TA remarks: *"We didn't have all the tools we needed, and parking lot was far to go back and forth for water, and it was very loud."* They then continue, " *"Maybe I should have just planned for the worst. We needed more leading volunteers, as well as hands-on volunteers, mulch, watering."*
	Weekly Zoom "hangout" session in March 2022	In response to the question "What do you feel you're going to take from the TA program now that it's over?" *"The behind the scenes…how to do a tree adoption or tree event…what it takes to make that happen"*
Power dynamics - Demographics and hierarchies	A training on the theme of Careers in Urban Forestry held via Zoom in February 2022	TAs were asked "How can you leverage this program in your future or current career paths?" One TA responded: *"I also like to work with people, and it seems like most entry level jobs in urban forestry are more technical. I learned about inventory/data collection job, which is an entry level position but very much solo work. They pay is low because we are not certified arborists"* A TA with limited English proficiency asks in Spanish if one has to be an English speaker in order to take the certification exam.
	A training on the theme of Careers in Urban Forestry held via Zoom in February 2022	TAs were asked "How have you grown or been challenged during the program?" Responses typed into the Zoom chat included: "communicating with community" "working with difficult characters in my community" "learning how greening and inequity are connected"
	Weekly Zoom "hangout" session in March 2022	I ask whether anyone has had a change in their relationship with or perception of the local government bureaucratic process. One of the TAs responds that they tried unsuccessfully to get pavement removed from around some existing trees in the neighborhood, adding that: *"trees have been here before people and the government is way behind... trees are the last thing that gets taken care of"*
	A TA-led distribution event at Emerson Unitarian Church in Canoga Park in March 2022	Toward the end of the training program, a TA tells me *"My understanding of the role of the city changed."*
Power dynamics - Capacity and follow-through	In-person, hands-on training on mature tree care held at Whitsett Sports Complex in North Hollywood in January 2022	The instructor, an envionmental educator from one of the host organizations, narrates a demonstration and then asks "is everyone up for some pruning?" She then walks everyone over to the staging area to get tools — new gloves, pruners, loppers, saws. She starts removing stakes and says "anybody else want to join? Let's do it!" TAs grab tools and position themselves next to trees that need maintence, strewn around the park. I walk around from tree to tree and see that TAs are all deeply engaged in tree care in groups of 3s and 4s. Thoughout the morning some TAs proceed to do work on their own. They appear confident and self-sufficient -- the first time they all get to model and demonstrate their skills together.
	Weekly Zoom "hangout" session in January 2022	A TA shares that they have been working with the host organization to organize tree distributions in different neighborhoods — North Hollywood, Sun Valley, and nearby communities — but they find insufficient time to make neighborhood connections and organize a tree event in the neighborhood closest to the TA's home. A City Plants staffer asks, is this something we can support you with? The TA responds *"Oh, that would be great"* and the staffer responds that if their host organization cannot support the TA in the remaining time in the program, City Plants has other ways to make that happen. *"It's totally doable in the next couple of months or so."*

	Weekly TA meeting held via Zoom with host nonprofit organization in February 2022	Debriefing about a TA-led tree care event in Sunland the weekend prior, a TA remarks: "I'll be blunt, none of the other Tree Ambassadors showed up from the other organizations, just us four from TreePeople. The rest was volunteers from the neighborhood."
Power dynamics - Self and group efficacy	A training on the theme of Careers in Urban Forestry held via Zoom in February 2022	TAs were asked "Has this program helped you become a better steward for your community?" One TA responded that: *"I've tried to work with community leaders and just different people in the community to try to find ways to help rehabilitate the community, and I know that trees play just such an big part of that. It was important for me to plant trees in my community and get more people involved in caring for their neighborhood more."*
	A TA-led tree adoption event held at the Latinx With Plants parking lot in Boyle Heights in March 2022	A mother and son are ordering a tree that will be dropped off to them later. The son (approx. 20 years-old) fills out the form. Next after the mother and son are two girls I saw earlier playing an emergency preparedness game set up along the line to raise awareness about heat as people wait . They also fill out a form to receive a tree. At the tree ordering/pick-up table, people are asked about what direction the tree will be planted and how far from the building, since the funding comes from the local utility. TAs at the table help people fill out the form, speaking both English and Spanish depending on the resident.
	Weekly Zoom "hangout" session in March 2022	A TA shared that the program afforded them a chance to learn who is responsible for what in the city, and how they can affect change through grant writing: *"I got to see how we might be able to go through it and get grants or working with the council office."*
	Weekly Zoom "hangout" session in March 2022	In response to the question ""What do you feel you're going to take from the TA program now that it's over?" *"the knowledge and the trainings… the back end of what goes on with events and how they turn out"*
Tensions - Pomp and circumstance vs. the daily work of greening communities	In-person training on tree planting and young tree care, held on a street in Boyle Heights in September 2021 in celebration of Latino Heritage Month	The event is remarkably well attended, with well over 100 people there. The program includes speaking by an LA City commissioner, the City Forest Officer, a representative from the Bureau of Street Services, and staff from City Plants. There is a film crew from Outside Magazine and there are mariachi musicians playing before and after the speaking portions of the program. All of this activity brings residents out of their homes and creates opportunities for community celebration, but the grandiose and ceremonial atmosphere is in contrast with the daily work of urban greening.
	A TA-led tree adoption event held at the Latinx With Plants parking lot in Boyle Heights in March 2022	A film crew from the NBC Today show is at the event. They are here to film footage for an Earth Day weekend story. Their presence adds to the excitement around this busy event, but probably also adds a fair amount of distraction. The crew has several staff, cameras, tripods, sound gear, a correspondent, etc. This reminds me of the first in-person event the training cohort attended in September 2021, also in Boyle Heights. There were camera crews from Outside Magazine, elected officials speaking, musicians to celebrate the day.
Vibrancy of marginalized neighborhoods (density, family/community dynamics)	In-person training on tree planting and young tree care, held on a street in Boyle Heights in September 2021 in celebration of Latino Heritage Month	The street is packed. There are people on sidewalks, cars parked in all available spaces. More people come out of their houses. The street is narrow. Some parkways have been planted by residents with plants and trees, lots of tropicals and cactus. The community imprint is obvious. There is a festive atmosphere and the event hasn't even officially started yet. A mariachi band starts to play and their instruments are blaring — there are five musicians, all dressed in matching mariachi charro suits — black suits with metal

		ornamentation up the leg and on the arms. A neighbor with a small dog across the street starts to sing along to one of the mariachi songs, inserting an emphatic "hey!" everytime the song gets to that point.
	A TA-led distribution event at Emerson Unitarian Church in Canoga Park in March 2022	There are about a dozen people lingering, chatting, talking to the folks at the tables and to each other. They span all ages -- they are young, middle-aged and elderly. Many of them look white, but throughout the event there are many Latinos that visit (sometimes making up half of the attendees).
	A TA-led distribution event at Emerson Unitarian Church in Canoga Park in March 2022	The line to adopt a tree moves very slowly but people are patient. An elderly Latina with a hat stands quietly on the street corner near the line, her young tree sticking out of a Southern California Gas Company paper bag. She is waiting for someone to pick her up.
Trees as an avenue for community cohesion and understanding	In-person training on tree planting and young tree care, held on a street in Boyle Heights in September 2021 in celebration of Latino Heritage Month	The event is a street tree planting and a fruit and shade tree adoption taking place on several blocks of Judson Street. Just before the official start of the event at 9:00am, the neighborhood really starts coming to life. Residents and families come out of their homes and watch from elevated porches. One of the porches has 4 or 5 kittens. Another has dogs. The family immediately opposite all the action comes out — a mother, father, and 12 or 13 year old daughter, it seems. They are all smiling and nodding as the father films the music on his phone. Then he picks up their small dog and holds it while the family continues to watch. Other families and residents are looking on curiously.
	Weekly Zoom "hangout" session in February 2022	Debriefing about a hands-on training session on mature tree care, which take place in-person the prior weekend at the Whitsett Sports Complex in LA's North Hollywood neighborhood. The site receives heavy use on weekends, hosting many soccer games and hundreds of kids and their families. A TA reflects that they had multiple interactions with park users who were curious about the tree care activities. The TA reflects that they were able to talk about what they had just learned to community members, which helps reinforce the training.
	A TA-led distribution event at Emerson Unitarian Church in Canoga Park in March 2022	One of the TAs tells me, "The most rewarding part is the people, and numbers don't accurately reflect our work. It's more about events, the conversations we have." Soon after, a resident comes up to the table to talk to the TA. She just got a commitment to water form signed on behalf of a beauty salon proprietor.
	Weekly Zoom "hangout" session in March 2022	In response to the question "What do you feel you're going to take from the TA program now that it's over?" "*it's a big question...more appreciation of trees…the benefits they give, but also how to care for them…and how to sympathize with other people and that there's not enough funding for people who care about trees" "just driving down the road and seeing that trees need care…just more awareness"*
	A TA-led tree adoption event held at the Latinx With Plants parking lot in Boyle Heights in March 2022	I arrive around 10:40am to do some observations and am pleasantly surprised to see that there is a line of about 30 people wrapping around the building waiting to get a tree. People are waiting in pairs mostly — friends, siblings, a mother and her son, others. People started arriving around 9am, an hour before the event started. This happened at the Canoga Park event as well.
Cohesion among TAs / TA program team	In-person training on overcoming barriers in urban forestry, held at an office building in LA's Koreatown neighborhood in November 2021	Program staff start with an icebreaker and everyone is asked to stand up. A staffer reads a list of tree facts and everyone is asked to raise their arms. If the fact is a benefit, lean right. If negative, everyone is asked to lean left with their arms. There is some chuckling and giggling as the group gets going, which brings people out of the quiet, passive vibe of previous trainings. Some facts are confusing (e.g., tree liability) which prompts people to look at each other in some confusion and serves to further lighten the mood as people engage with one another.

	In-person training on native plants and ecology held at Eaton Canyon Nature Center in December 2021	It's a sunny, crisp day. The temperature is in the upper 50s and the sky is blue. Visibility toward the mountains is great and the group is gathered under a large coast live oak tree that appears to be several hundred years old. The instructor is a Native American ecologist and educator. The group spends the morning listening a broad suite of topics about historical, cultural and ecological aspects of Southern Califonia's environment. The lecturer brings a variety of natural and cultural items to show, and TAs and program staff Nick are captivated. I am mesmerized, and many others are as well. All pay attention, looking up at the lecturer and then referring to the handout of slides. Some take notes on the handout or in notebooks.
	In-person, hands-on training on mature tree care held at Whitsett Sports Complex in North Hollywood in January 2022	During a hands-on lecture in the field about mature tree care, the instructor (an educator from one of the host organizations) transitions to the topic of topping and points to a page in the chapter — STOP, DON'T TOP! She shows an evocative photo with topped trees on one side of the street and healthy trees on the other side. The contrast is staggering. One of the TAs asks "does it shock the tree when you top it?" and the instructor says yes, "trees don't need an annual haircut." Her co-instructor says "they don't need a haircut at all! They just get pruned because people want them to." Everyone giggles and more TAs ask questions. The TAs appear much more comfotable with each other than they have in past trainings.
Creative solutions - Self and group efficacy	Weekly Zoom "hangout" session in January 2022	A TA shares that they have been doing flyering door-to-door, with business cards attached, but hasn't had any response yet. The group, which includes 3 TAs and 4 program staff, discuss what methods they've tried or would like to try to improve success in engaging community members. Methods shared include targeted social media ads, posting on neighborhood sites such as patch.com or nextdoor.com. The TA who brought up the topic initially shares that they flea markets and spaces like the Melrose Trading Post could work for staging a tree distribution, because people are already going there to get large items and often have trucks. Another TA shares that they have had success using Facebook, Nextdoor and canvassing. The local neighborhood council has been useful, they print TA events in the newsletter and that goes to the older community who reads it. A City Plants staffer asks the TAs if they've had any success engaging stable in the community that can help them spread the word and do the work. A TA says they engaged a business owner who *"knows everything about the community."* He and his wife actively clean up their street. He signed a commitment to water form. The TA is giddy telling us how every time they engage they and up talking for 45 minutes about different things in the community.
	A TA-led distribution event at Emerson Unitarian Church in Canoga Park in March 2022	Some people in line hold fliers to the event. They appear to have come after receiving a flier via canvassing in the days prior, or at the farmers' market down the street, where two of the TAs went flyering earlier in the morning. They also advertised the event online — via City Plants website, the councilmember's website, on Instagram and Facebook, and via the local Business Improvement District and Neighborhood Council. They reached about 50 homes via canvassing, leaving fliers when no one was home. The TAs tell me that as they did more door-to-door canvassing they learned that people are more receptive to being invited to an event such as this, rather than to being asked to sign a tree adoption form or commitment to water form at their door. The TAs subsequently changed their outreach methods.

Appendix G:
Socio-ecological factors that influence tree stewardship

1.1 Individual Level

Individual level factors are those that are present or absent in an individual (in our case a Tree Ambassador) who is actively working to affect tree stewardship in their community.

Self-perception as change agent: A common belief among all TAs is a belief that their engagement in the neighborhood can and does create positive change — a belief that was reinforced through the program.

> *"I was actually really skeptical when I first heard about the program. I thought that no one would be interested in my community. But then after thinking about it, I thought, 'Has anyone tried to talk to our community?' Maybe there's a reason they're not interested. Maybe they don't know or they don't think they have the time." -(Focus group participant responding to what motivated them to become a Tree Ambassador).*

Self-efficacy: An individual's belief in their own effectiveness in performing a given task (Bandura, 1995). Self-efficacy allows individuals to visualize success scenarios, in turn providing guidance in support of outcomes (Bandura, 1993). As TAs moved through the training and held their own tree planting, adoption, and care events in the community and saw the positive outcomes of their efforts, many showed greater confidence and a desire to hold more events, as seen in survey findings in Figure 4.

Awareness of historical injustices: Several TAs remarked that learning about historical policy decisions such as racial covenants and redlining in their neighborhoods was a motivating factor because they understood the forces that they were working to dismantle. In some cases, TAs incorporated this information into talking points and outreach materials, and reported success in engaging community members based on this information.

> *"I think asking people of the impacted communities if they are aware of the environmental inequities in LA or their community and what impacts might that cause in their community can help gauge how aware a community is about these topics. I think asking them what impact/problems that inequity could create in their communities can bring more awareness and have them thinking about these topics and motivate them more to engage with their community. I never knew about redlining until just recently. Learning about it, I was shocked and angry. But I finally had an answer for why my community wasn't as well resourced as wealthier areas. And why these affected areas continue to remain affected, being stuck in a cycle. I feel like not knowing about redlining, the environmental injustice/inequity in certain communities, etc. made me oblivious or ignorant about the issues they cause. Living in an apartment, I don't even have space for a tree so I wouldn't have even passed by a tree distribution event. I never would've cared as deeply as I do now without knowing these injustices first, because now I can understand the significance of planting a tree." -(Survey respondent comment about program materials received for engaging the community).*

Knowledge of the trees-public health link: The neighborhoods that TAs worked are impacted by a host of pollution burdens and environmental injustices. As TAs gained knowledge during the program about the benefits that trees can have on public health — ranging from heat mitigation to air quality improvement as seen in Figure 5— they incorporated this information into their outreach strategies. In this context, the act of planting or caring for a tree can be a way to restore health and address an aspect of environmental injustice.

Knowledge of how to navigate city processes: Increasing tree canopy by planting, distributing, and caring for trees involves steps that require engaging with bureaucratic processes such as permitting, securing funding, selecting species from the municipality's approved lists, and obtaining permission from tenants or property owners. TAs learned how to navigate these steps as they went through the program.

> *"Find an actual spot to plant the tree"*
> *"Find someone who's willing to care for it."*
> *"Get educated on the steps to start the planting process."*
> *"I look for neighborhood councils that are already kind of doing similar work, and they would need volunteers to water trees that are not close to people's houses."*
> *-(Focus group participants' responses to the prompt "Tell me about the process of planting trees in your community. What steps does it take?").*

1.2 Relationship Level

Relationship level factors are those an individual working to affect tree stewardship may encounter as they attempt to engage with their neighbors or other members in the community. These factors may either aid or hinder their efforts. Below we list each factor individually.

Locus of responsibility: The belief that outcomes of our actions depend primarily on what we do (internal responsibility orientation) versus on events beyond our control (external responsibility orientation) (Gerrig & Zimbardo, 2002). In attempts to get community members to commit to watering street trees planted in the planting strip in front of their homes, a commonly encountered belief is that street trees are the responsibility of the city or another entity, not the community's responsibility (de Guzman et al., 2018).

Ability to engage in person: TAs encountered numerous barriers to engaging one-on-one while canvassing, and reported less success when leaving outreach materials at the doorstep versus when engaging community members in person. Barriers included physical access due to gates; people not being home or not opening their doors; and restrictions due to the COVID-19 pandemic, either as TAs elected not to engage in-person during the Omicron variant surge in the winter of 2022, or as residents declined to engage due to concerns over safety and social distancing.

> *"A lot of the outreach that we're doing is during the waves of COVID increases. It was just kind of like trying to find a balance, you know, where it doesn't feel like we're putting people at risk and we're going out there and they're like 'what are you doing in front of my house?'" -(TA quote captured during ethnographic observation of tree distribution event)*

Power dynamics: Some TAs started out as timid and uncertain about how to affect change, and gradually became more assertive and decisive about what activities to lead in their neighborhoods and how to execute them. These TAs demonstrated shifts in power dynamics during the course of the program, both in relation to program staff, and in relation to how they dealt with points of contact at the partner organizations in the community with which they collaborated to bring tree stewardship events.

> *"The trainings have helped me gain confidence and knowledge regarding the work I'm doing in my community." -(Survey respondent comment in response to the question "What do you like most about the trainings so far?")*

Trust in local government: A major theme that TAs heard from community members repeatedly is distrust of the city, with complaints including the city's inability to provide services like traffic improvements, taking too long to get things done, and imposing bureaucratic red tape that makes progress difficult. Additionally, lack of trust that trees would be adequately maintained once planted, and confusion surrounding whether it was the city or individual's responsibility to maintain the trees long term (via the shared maintenance responsibilities of "opt in" or "opt out" methods of street tree planting in LA) posed significant challenges for Tree Ambassadors organizing in their own communities.

> *"I think another one of the barriers is that the city in general, historically, has taken a long time to get things done. Even getting potholes fixed takes forever. That's a big concern with people in the community. Working with the city just takes forever to complete anything or even take initiative, so they just give up just because they don't think it will ever happen." -(Focus group participant's comment about what challenges they encounter when organizing their community).*

> *"When people hear that the city is interested in trees, we are greeted with negative senses about the city." - (TA quote at tree distribution event)*

Belief that trees cause problems: Another recurring theme encountered in the community is that trees cause problems. Among the problems cited: they create litter, their roots cause pavement or foundation damage, and they block views (Figure 6).

Belief that watering is expensive: Yet another reason frequently cited by people who declined a tree was the belief that the cost of water for irrigating a tree would be substantial (de Guzman et al., 2018).

Priority of trees relative to other needs & desires: Many community members conveyed to TAs that there are other priorities more important in their neighborhoods, such as speed bumps to slow down traffic and addressing the homelessness crisis.

> *"It's harder to push for trees when people feel like there are speed bumps or sidewalks or all these other issues that they feel that the city should take care of." -(Focus group participant's comment about what challenges they encounter when organizing their community).*

> *"A lot of people who are recently immigrated and/or living in a rented space may view their current residence as a temporary space and therefore be disinvested in larger community needs. Trees are a long term investment, in which the immediate benefits may not be entirely obvious. If a neighborhood is seen as a transitional point, residents may be disinvested in the betterment of the community."-(Survey respondent comment in response to the question "Do you have any comments or recommendations about how to improve the Tree Ambassador program?")*

Level of comfort providing personal information: Signing up to adopt a yard tree for the home or committing to water a street tree requires providing personal information such as name and address. TAs encountered individuals who were uncomfortable providing this information when canvassing, and reported more success when inviting community members to attend events such as free tree distributions hosted in public spaces in the neighborhood.

> *"They didn't want to sign a form, they felt a lot of mistrust with forms and me seeing their address, or even with the form itself, like there are scammers all over the neighborhood unfortunately... And so that was kind of like the main concern, almost everyone who comes to the door is an older person, or it's a younger person who then says 'My elder is the person that handles the business of the house.' It was just trying to gain the elders' trust, so in order to bypass building that trust if there was no way of building that trust, is to show up at an event like this. So anyone who didn't sign a form came over here and lined up or came over here and just picked up some compost" -(TA quote captured during ethnographic observation of tree and compost distribution event).*

1.3 Institutional Level

Institutional level factors are those that may be present or absent at the institution that is supporting an individual who is actively working to affect tree stewardship in their community — such as a nonprofit or community organization, or a city agency.

Peer support: TAs were paired up with a "buddy" in or near their neighborhood that was also going through the program. This meant each TA had the opportunity to rely on and support another trainee. This enabled them to gain more confidence in conducting activities such as canvassing and tabling, and also provided opportunities to learn from each other.

Credibility & follow-through: At regular check-ins with their host organizations or other program staff, TAs raised issues that they were experiencing, such as the need to have more community-relevant outreach materials or needing information about how to get concrete cuts for new tree wells. These needs provided a chance for program staff to follow through and provide needed support. In rare instances that this did not happen, some TAs sought other solutions.

Shared vision: The training program included quantitative and qualitative goals that served as goal posts during the course of the program. In addition, TAs worked with their host organizations to set shared goals for TAs paired up in a buddy system to achieve.

> *"Trainings remind me of the shared mission."-(Survey respondent comment to the question "What do you like most about the trainings so far?")*

Collective efficacy: People's shared beliefs that they can collectively produce desired results. When actions that facilitate self-efficacy (see Individual Level) are shared with other members of the community, the sense of collective efficacy is increased. It is produced through social interactions and helps influence what actions community members elect to take on and how much effort they will exert (Bandura, 1982).

Effectiveness of program: Clarity of program goals and objectives, pathways to achieve them, and methods to track progress are determining factors of how effective a tree stewardship training program is.

Access to resources & support: Various needs for resources emerged as TAs learned the multiple, sometimes complicated steps to increasing UTC in their neighborhood. These included the need for more community-relevant outreach materials and information about how to remove concrete for tree wells.

Tree stewardship funding: The TA program is quite novel for the LA area because it offers paid training and support to people from the community to lead tree stewardship activities rather than rely solely on the good will of volunteers from the community.

Accountability structure: Some TAs indicated that they struggled with the self-directed parts of the program and needed more structure in between planning and check-in meetings with their host organization or other members of the program team.

Group cohesion: A reflection shared by virtually all TAs was that the opportunities to build camaraderie with other TAs were deeply valued for the connection and motivation they created. Most also expressed a desire to have more opportunities to build group cohesion.

Problem identification and solving process: TAs encountered varying challenges, such as how to accommodate community members who want a tree but do not have transportation or other means to bring adopted trees home. In such cases, having a system to discuss identified issues and find a solution increased the TAs ability to be effective.

1.4 Community Level

Community level factors are neighborhood characteristics that may aid or hinder an individual's efforts to affect tree stewardship.

Physical access to properties: Inability to access front doors during canvassing hinders community engagement efforts. Canvassers are generally not advised to enter gates to single-family homes or security gates to multi-family buildings.

> *"Apartments, especially those that don't have access to residents directly, where they have a gate...is difficult because we don't have access to the residents." -(Focus group participant's comment about challenges encountered in the community).*

Housing tenure: Tenants often do not have the freedom to decide to plant a tree without asking the property owner, limiting a tenant's ability to commit to water a tree on or in front of the property. Lower-income communities often have lower rates of owner-occupancy.

> *"It's because that's how this neighborhood was meant. It was meant like, you stay here and your rent and you work and that's all you do. You know, almost like a company town, like that's how it was at first. Not a community." -(TA quote captured during ethnographic observation of tree distribution event)*

Housing type: Owners or managers of multi-family residential buildings are often not on site or hard to reach, making it difficult to engage on the topic of tree planting and care. Residents of single-family homes are generally easier to engage.

> *"I tended to hit more, like, single family homes than apartment buildings, just because I feel like in my experience apartments are more difficult." -(TA quote captured during ethnographic observation of tree distribution event)*

Urban form/availability of planting spaces: There is significant variability in the amount of readily plantable space in different neighborhoods. Where spaces are harder to come by, increasing tree canopy may necessitate costly modifications to the site (CAPA Strategies, 2021a).

> *"In my neighborhood we don't have many sidewalks."-(Focus group participant's comment about challenges encountered in the community).*

Legacies of historical planning decisions: The legacies of zoning decisions result in some neighborhoods hosting a greater concentration of land uses (i.e., industrial) that are less compatible with urban greening due to large proportions of impervious surfaces (CAPA Strategies, 2021b).

Access to infrastructure/resources to perform stewardship activities: Engaging a community member in tree stewardship is easiest when their perceived or actual barriers to the action of caring for a tree — such as access to a water spigot with a hose long enough to reach the tree — are low (de Guzman, et al. 2018).

Digital divide & internet literacy: An increased reliance on online forms for yard tree adoptions or commitments to water street trees means alternative methods should be available in communities where there is limited internet access or internet literacy.

> *"As soon as we say something about the internet process, they say, 'Oh no we don't want to deal with it.' They don't want to subscribe. They don't want to have to deal with the internet."*
> *"Some people don't know how to navigate the internet, they don't know how to use a computer." -(Focus group participants' comments about challenges encountered while organizing their community).*

Care for neighborhood: The level of concern that a community member believes their neighbors have for the neighborhood can influence their involvement in greening activities.

> *"...some people are trying to solve their problems in the easiest manner possible, in a way they can solve it or doesn't cost them. I can't believe the lack of awareness, the lack of love for nature. That's what really shocks me." -(Focus group participant comment about challenges encountered while organizing their community).*

1.5 Society Level

Society level factors include elements in the decision-making and information-access realm, and which occur at a level beyond the community — such as at the municipal, state level, or federal level.

Racial covenants & redlining policies: Neighborhoods that were formerly redlined as "undesirable" under the federal practice of using race-based grades to determine where insurers and banks would provide their services still have less tree cover and experience hotter temperatures relative to wealthier neighborhoods (Hoffman et al., 2020).

Urban design, land use & zoning: As cities update their land use and zoning plans, there are opportunities to elevate minimum canopy cover requirements and protections for trees for new developments and/or tree protection zones during construction.

Urban forest management: An urban forest management plan (UFMP) establishes a shared vision for a city's urban forest, helps a city understand current conditions, and allows decision makers to identify proactive pathways for realizing a thriving urban forest that maximizes public health benefits for its residents.

Urban forest funding: Urban forestry funding mechanisms and levels have a significant impact on a city's ability to proactively plan for and prioritize the preservation, maintenance, enhancement, and protection of UTC. For example, funding determines who is responsible for watering newly established trees, which directly impacts individual and community level stewardship of a city's urban forest.

Urban forest protection policies: Establishing strong tree protection policies and equipping city agencies with sufficient staffing for enforcement of those policies can support preservation of mature trees currently providing public health benefits that would otherwise take years to replace, as newly planted trees take years to mature. Urban forest protection policies impact a city's annual canopy loss.

Tree canopy cover target: With an agreed-upon citywide UTC, city agencies, nonprofits, and residents can collaborate to achieve a common goal and enact a tree planting prioritization plan over a designated period.

Tree canopy cover & mapping tools: Publicly-available GIS data to understand UTC distribution and opportunities for new planting enables a broad suite of stakeholders to engage in urban forest management. Tree inventories and forestry management systems aid policymakers in understanding the age, species, and distribution diversity of an urban forest and allows for analysis and future planning.

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