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Cooler and Healthier: Increasing Tree Stewardship and Reducing Heat-Health Risk Using Community-Based Urban Forestry

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Abstract: Heat exposure poses health risks that disproportionately burden disadvantaged communities. Trees protect against heat, but significant barriers exist 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 foster street tree stewardship and individual-level heat mitigation actions in 116 households in Los Angeles County, USA. 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. 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. 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.

Keywords: urban forestry; tree stewardship; climate adaptation; urban cooling; extreme heat; urban sustainability; civic ecology; heat mitigation; environmental psychology

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Citation: de Guzman, E.B.; Wohldmann, E.L.; Eisenman, D.P. Cooler and Healthier: Increasing Tree Stewardship and Reducing Heat-Health Risk Using Community-Based Urban Forestry. *Sustainability* **2023**, *15*, 6716. https://doi.org/10.3390/su15086716

Academic Editors: Richard Hauer, Jess Vogt and Burnell Fischer

Received: 23 March 2023
Revised: 6 April 2023
Accepted: 11 April 2023
Published: 15 April 2023

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1. Introduction

1.1. Trees and Heat Mitigation

Heat exposure is a public health hazard that burdens disadvantaged communities in urban areas disproportionately and threatens the livability and sustainability of cities [1,2]. 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 [3,4]. 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 [5–8].

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 40 °C (72 °F) and summer air temperatures by 0.5–2 °C (0.9–3.6 °F) [8,9]. 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 1–8 °C (2–14 °F) [9,10]. Cooling impacts are well understood, but benefits vary due to factors including climate, season, time of day, surface materials, urban morphology, and tree traits such as crown shape and density of foliage [9,11,12].

1.2. 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 [6,12–14]—cities around the world that seek to advance sustainability are investing in tree planting with the goal of mitigating heat [15]. 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 [16,17]. This barrier is more pronounced in arid and semi-arid regions, where trees must be irrigated during an establishment period [18,19], and tree stewardship during this period is critical to the successful establishment of newly-planted trees that might otherwise die [20]. 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 [17]. 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 [21,22]. 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 [23]. 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 [16], but factors to encourage this expectation of voluntary tree stewardship are often left to chance [24].

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, 8 March 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, 8 March 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, 8 March 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 [25]. 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 [26].

These barriers can be countered with dedicated funding and staffing for tree maintenance [27–29]. Where such funding is unavailable, efforts to support youth internship and volunteer programs have led to high survival rates for newly-planted trees [19,28,30]. Coupling youth outreach to residents with regular watering provided too has been shown to improve tree survival and positive feedback from residents [31].

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 [32,33]. 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 [34,35].

1.3. 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 [35]. 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 the Section 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.

1.4. 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 [36]. 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 [37,38]. and has previously been applied to study homeowner attitudes toward residential trees and to explore methods to encourage street tree stewardship [39,40].

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 [41,42]. SCT posits that the likelihood of a behavior being adopted and maintained is influenced by an individual observing the behavior in others [43]. 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 [44,45]. 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 [46]. 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 [47,48]. Conversely, pro-social behaviors can serve as a precondition or building block toward pro-environmental behaviors [49], 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.

1.5. 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.

1.6. 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 quasi-experimental 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.

2. Materials and Methods

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 TreePeople 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. It 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 [50]. 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 [51].

San Fernando has a tree canopy cover of 19%, on par with the LA County average [52]. The region receives an average of 15 inches (381 mm) of rain annually, most of which falls between October and April [53]. Trees must therefore receive supplemental irrigation during the establishment period, which in the study region ranges between three and five years after planting [21,54]. 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 [55]. 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 [56]. Extreme heat already has measurable effects on human health in San Fernando, highlighting the necessity of heat mitigation strategies to counter worsening impacts.

Table 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 [50]. 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 [50]. 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 [50].

Table 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

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 the Section 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.

2.2. Research Design

2.2.1. 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 Supplementary Materials SM1 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 [40] 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 [50].

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 (see SM 2). 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).

2.2.2. 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 [36]—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 [16,28]. 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 include: 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 [36]. 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 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 [40]. 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). See SM 3 for a selection of the intervention materials.

Table 2. Experimental 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 a quasi-experimental condition (Table 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 quasi-experimental 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), 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. Quasi-experimental 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

2.2.3. 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 h after a rain event.

2.2.4. 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.

2.2.5. 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. Results

3.1. Factors Affecting Tree Stewardship and Tree Health

3.1.1. 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 (residents with higher tree stewardship-related self-efficacy will demonstrate higher tree stewardship).

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).

3.1.2. 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 statistically 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*.

Changes in mean soil moisture as a function of phase and messaging condition are shown in Figure 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, that the environmental health messaging group had the highest soil moisture at all phases of the study.

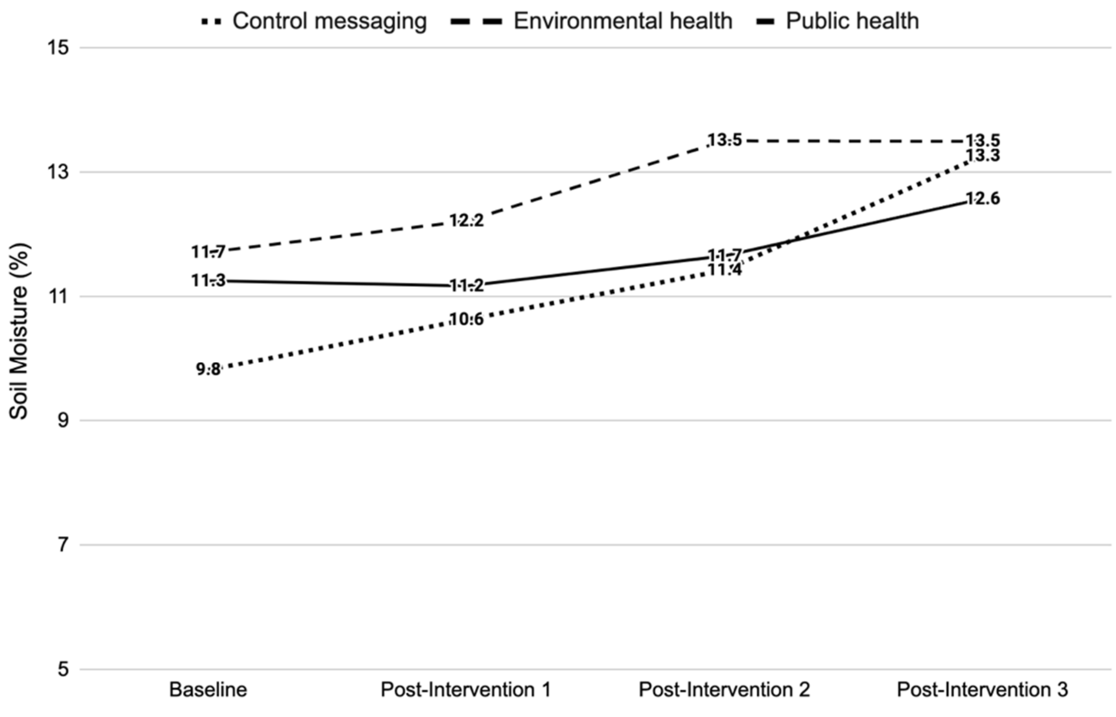

Figure 1. Percentage of soil moisture by phase for each messaging condition ($n = 100$). Mean values are shown for each of the study phases. Baseline values are calculated using three pre-intervention readings. Mean values for the three post-intervention observation rounds included a total of 19 readings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

Although messaging condition had little effect, we found that tree stewardship was correlated with the quasi-experimental variable of 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 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 the start of this study.

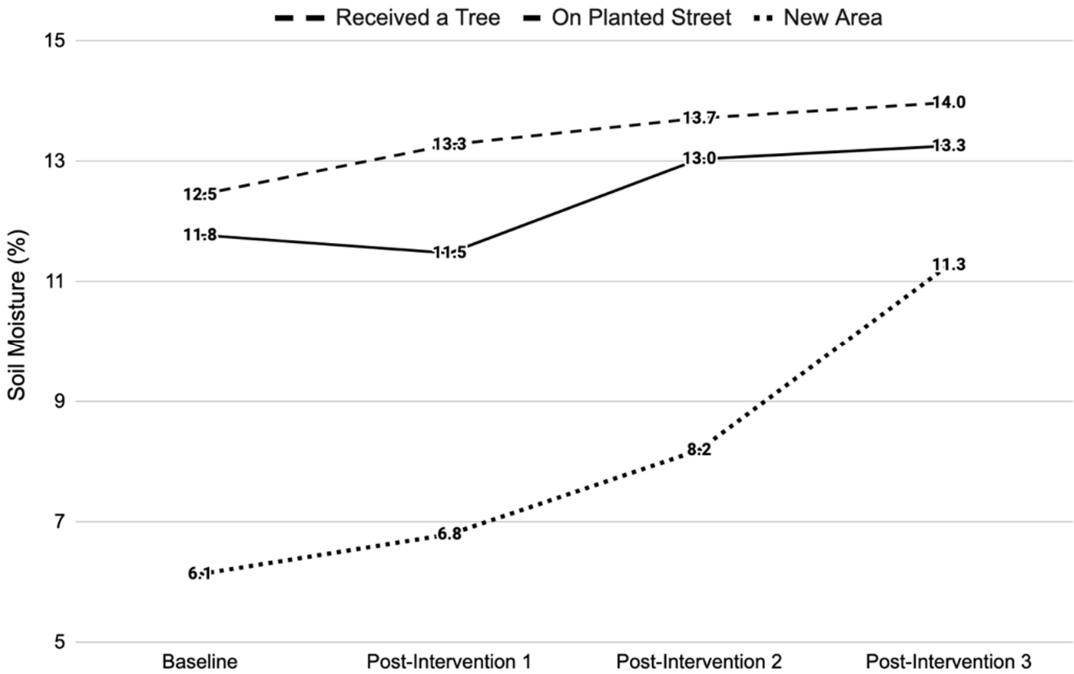

Figure 2. Percentage of soil moisture by phase for each tree planting condition (n = 100). Mean values are shown for each of the study phases. Baseline values are calculated using three pre-intervention readings. Mean values for the three post-intervention observation rounds included a total of 19 readings 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% [57]. 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 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.

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.

Table 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] (0.599)	12.4 [11.4, 12.8] (0.573)	11.6 [11.0, 11.9] (0.449)	8.1 * [5.9, 8.8] (0.680)	12.4 * [11.8, 12.6] (0.623)	13.4 * [12.4, 13.7] (0.363)
Self-reported tree care actions	6.5 [6.4, 6.6] (0.129)	6.0 [6.1, 5.9] (0.287)	6.6 [6.8, 6.3] (0.127)	6.2 * [6.2, 6.2] (0.215)	6.0 * [6.2, 5.8] (0.246)	6.7 * [6.9, 6.7] (0.68)

3.1.3. 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 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.

3.2. Factors Affecting Heat-Related Variables

3.2.1. 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.

3.2.2. 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 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 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 (0.334)	5.7 (0.302)	5.3 (0.329)	5.2 (0.360)	5.6 (0.326)	5.6 (0.302)
	Post-intervention	5.5 (0.318)	5.7 (0.299)	5.4 (0.273)	5.3 (0.362)	5.3 (0.332)	5.8 (0.222)
Protective actions taken	Study means	7.7	7.5	8.2	7.7	7.8	7.8
	Pre-intervention	8.6 (0.253)	8.8 (0.232)	8.7 (0.252)	8.7 (0.305)	8.6 (0.260)	8.7 (0.202)
	Post-intervention	6.8 (0.589)	6.2 (0.667)	7.6 (0.566)	6.8 (0.732)	7.0 (0.608)	7.0 (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 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 [58].

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 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.

4. Discussion

4.1. 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 quasi-experimental 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 the Hawthorne effect, which is the phenomenon of the possible impact that awareness of being studied might have on research participants [59]. 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 [40]. 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 the quasi-experimental 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.

4.2. 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 [4]. 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 [31]. 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 [28,60], 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) [28], 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, 10 March 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 [61]. Another study, in Indianapolis, Indiana, explored how resident-provided watering related to tree outcomes and other collective neighborhood activities [62]. 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.

4.3. 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 [54]. 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.

4.4. 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 for the quasi-experimental 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.

5. 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.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su15086716/s1, SM1: Pre- and post-intervention survey (English version); SM2: Table of re-coded survey variables; SM3:Intervetion Materials.

Author Contributions: Conceptualization, E.B.d.G., E.L.W. and D.P.E.; methodology, E.B.d.G., E.L.W. and D.P.E.; software, E.B.d.G. and E.L.W.; formal analysis, E.L.W.; writing—original draft preparation, E.B.d.G.; writing—review, E.L.W. and D.P.E.; visualization, E.B.d.G.; supervision, E.B.d.G., E.L.W. and D.P.E.; project administration, E.B.d.G.; funding acquisition E.B.d.G., E.L.W. and D.P.E. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the California Department of Forestry and Fire Protection through the Proposition 68 Urban Forestry Education and Research fund, under grant 8GB18418 titled "Cooler and Healthier: Reducing Heat-Health Risk Using Urban Forestry & Stakeholder Engagement."

Institutional Review Board Statement: 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.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The authors agree to make data not already presented in this article available by request.

Acknowledgments: The authors would like to thank other personnel who provided support to this project: Luis Rodriguez and Pam Gibson, TreePeople; Delmy Martir, California State University Northridge; and City of San Fernando staff, with special thanks to Patsy Orozco.

Conflicts of Interest: The authors declare no conflict of interest. The funder had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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