Title

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Authors

de Guzman, Edith B
Escobedo, Francisco J
O'Leary, Rachel

Publication Date

2022

DOI

10.3389/frsc.2022.944182

Peer reviewed

frontiers | Frontiers in Sustainable Cities

TYPE Original Research
PUBLISHED 03 August 2022
DOI 10.3389/frsc.2022.944182

OPEN ACCESS

EDITED BY
Michele Romolini,
Loyola Marymount University,
United States

REVIEWED BY
Tenley M. Conway,
University of Toronto
Mississauga, Canada
Pallavi Saxena,
University of Delhi, India

*CORRESPONDENCE
Edith B. de Guzman
eb3@ucla.edu

SPECIALTY SECTION
This article was submitted to
Urban Greening,
a section of the journal
Frontiers in Sustainable Cities

RECEIVED 14 May 2022
ACCEPTED 13 July 2022
PUBLISHED 03 August 2022

CITATION
de Guzman EB, Escobedo FJ and O'Leary R (2022) A socio-ecological approach to align tree stewardship programs with public health benefits in marginalized neighborhoods in Los Angeles, USA.
Front. Sustain. Cities 4:944182.
doi: 10.3389/frsc.2022.944182

A socio-ecological approach to align tree stewardship programs with public health benefits in marginalized neighborhoods in Los Angeles, USA

Edith B. de Guzman[1]*, Francisco J. Escobedo[2] and Rachel O'Leary[3]

[1]Institute of the Environment & Sustainability, University of California, Los Angeles, Los Angeles, CA, United States, [2]Pacific Southwest Research Station, United States Department of Agriculture (USDA) Forest Service, Riverside, CA, United States, [3]City Plants, Los Angeles, CA, United States

Extreme heat in the United States is a leading cause of weather-related deaths, disproportionately affecting low-income communities of color who tend to live in substandard housing with limited indoor cooling and fewer trees. Trees in cities have been documented to improve public health in many ways and provide climate regulating ecosystem services via shading, absorbing, and transpiring heat, measurably reducing heat-related illnesses and deaths. Advancing "urban forest equity" by planting trees in marginalized neighborhoods is acknowledged as a climate health equity strategy. But information is lacking about the efficacy of tree planting programs in advancing urban forest equity and public wellbeing. There is a need for frameworks to address the mismatch between policy goals, governance, resources, and community desires on how to green marginalized neighborhoods for public health improvement—especially in water-scarce environments. Prior studies have used environmental management-based approaches to evaluate planting programs, but few have focused on equity and health outcomes. We adapted a theory-based, multi-dimensional socio-ecological systems (SES) framework regularly used in the public health field to evaluate the Tree Ambassador, or *Promotor Forestal,* program in Los Angeles, US. 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 wellbeing by training, supporting, and compensating residents to organize their communities. We use focus groups, surveys, and ethnographic methods to develop our SES model of community-based tree stewardship. The model elucidates how interacting dimensions—from individual to society level—drive urban forest equity and related public health outcomes. We then present an alternative framework, adding temporal and spatial factors to these dimensions. Evaluation results and our SES model highlight drivers aiding or hindering program trainees in organizing communities, including access to properties, perceptions about irrigation responsibilities, and lack of trust in local government. We also find that as trainee experience increases, measures including self- and collective efficacy and trust in their neighbors increase. Findings can inform urban forestry policy, planning, and management actions at the government and non-profit levels that aim to increase tree cover and reduce heat exposure in marginalized communities.

KEYWORDS

urban forest management, urban forest equity, community engagement, tree planting, community-based climate adaptation, collaborative ecosystem management

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 (Chakraborty et al., 2019; Li et al., 2020). Continued warming is projected to increase average temperatures 2.2–2.8°C (4–5°F) by mid-century, and by 2.8–4.4°C (5–8°F) 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 5.5°C (10°F) 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 5–6 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 (Sheridan et al., 2012; Kalkstein et al., 2014). Public health is affected when higher heat 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 tree cover (UTC), 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 2.6°C (4.7°F) and up to 7°C (12.6°F) 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 UTC (Hoffman et al., 2020). During extended heat waves in LA, mortality increases about five-fold 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; Esperon-Rodriguez et al., 2022). Investments to increase UTC 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 (United States Environmental Protection Agency, 2011; Escobedo et al., 2019).

UTC has also been associated with reduced stress (Hartig and Staats, 2006; Van den Berg et al., 2010; Roe and 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 in comparison to surrounding streets (Vanos et al., 2012). Studies modeling projected benefits of UTC in reducing temperatures demonstrate that mature UTC can facilitate exponential cooling for urban areas (Taha, 2013). 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 and McPherson, 2012). Such heat reduction measures result in decreased cases of heat-related illness and death (Kalkstein et al., 2022).

However, the distribution of UTC 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 (Checker, 2011; Wolch et al., 2014; Roman et al., 2015; Schwarz et al., 2015; Dawes et al., 2018; Riley and Gardiner, 2020; Volin et al., 2020; 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 for Los Angeles Urban Forest Equity Collective, 2021a,b).

Another complicating factor is that planting, maintenance, management, and preservation of UTC is complex. A broad range of actors—from local users to volunteers to professional managers—play a role in stewarding the urban forest (Krasny and Tidball, 2015; Roman et al., 2015). In LA, the responsibility for planting street trees falls on local government and non-profit organizations, but planting a tree is only the first step. Establishment care during the first 3–5 years must follow (Levinsson et al., 2017). Perennially underfunded UTC 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 economically disadvantaged areas operate with limited resources (Pincetl, 2010). 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 and Ralston, 2019).

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., Ko et al., 2015; Roman et al., 2015) are often insufficient in addressing human wellbeing outcomes because of their focus on biophysical metrics and objectives (i.e., UTC 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 UTC 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 stakeholder 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 and 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 and 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 (Palafox et al., 2018; Centers for Disease Control and Prevention, 2019; Shorey and Ng, 2022). SES models often used in public health disciplines could hypothetically be used to capture key drivers 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 UTC to maximize equity and public health goals.

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 UTC 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; Centers for Disease Control Prevention, 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 non-profit 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.

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 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 Supplementary Table 1 for details on the socioeconomic and demographic composition of the Tree Ambassadors.

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 non-profit 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 UTC provides more spaces for criminals to hide, creating reluctance in some neighborhoods (Pincetl, 2010). 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, 2010). 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 ~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, UTC has been documented to have an effect on public health outcomes and environmental benefits. Higher UTC lowers ambient temperature, with LA city blocks that have more than 30% UTC being about 2.8°C (5°F) cooler than blocks without trees (Pincetl et al., 2013). In the city, the percentage of shaded UTC 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 UTC 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 UTC and albedo also have the potential to delay climate change-induced warming ~40–70 years under business-as-usual and moderate mitigation scenarios, respectively (Kalkstein et al., 2022). Investing in UTC thus has the potential to increase LA's resilience to climatic changes.

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.

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 10 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-h 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 (Supplementary Table 2). Simultaneous

TABLE 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.

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).

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 (Data Sheets 1, 2) contained 33 questions (multiple-choice, Likert scale, matrix, and open-ended) to capture the respondent's knowledge, perception, beliefs, and attitudes (Gifford and 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.

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., 2020), 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.

Results

Focus group

The themes that emerged during the focus group are presented in Table 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 for Los Angeles Urban Forest Equity Collective, 2021a).

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 3–7). 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 1, 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 3).

Figures 1, 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 vs. 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.

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 3). As shown in Figure 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 non-profit programming.

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

TABLE 2 Content analysis of Tree Ambassador focus group in Los Angeles CA, US ($N = 9$).

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."

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 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.

The end-point survey asked TAs whether they were able to achieve the program goals (Table 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

TABLE 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%

trees—only 53 of which were street tree applications, making up <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 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.

At the mid-point of the program, Ambassadors most often noted the negative effect trees can have on sidewalks as a problem (Figure 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.

Finally, the TAs were asked several questions about their neighborhood. Figure 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 (Supplementary Table 3) 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.

Aside from the responses to open-ended questions that were illustrated in the word clouds in Figures 5, 6, additional key insights from TA highlight the conditions and challenges faced in the process of trying to increase UTC 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

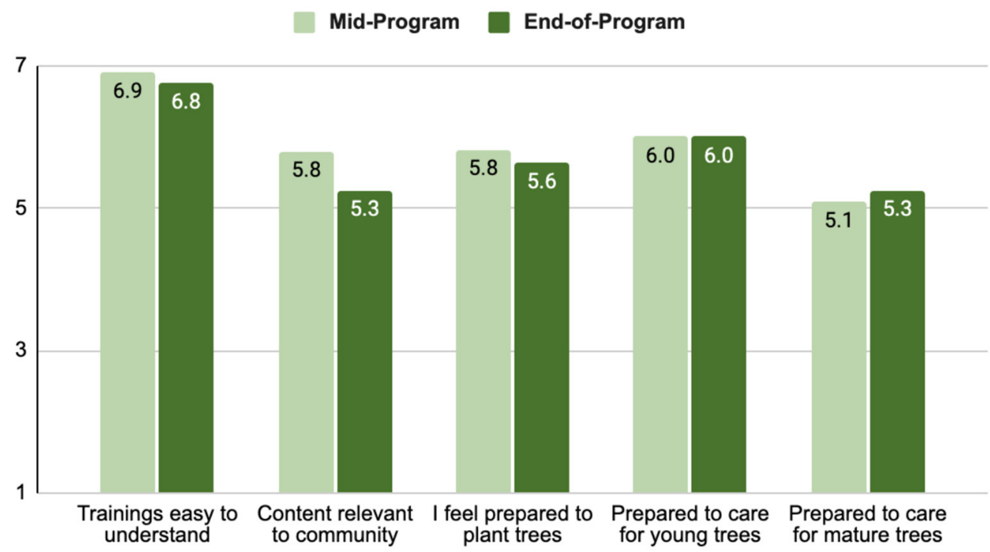

FIGURE 1
Responses regarding the trainings and Tree Ambassador readiness (1 = strongly disagree; 7 = strongly agree).

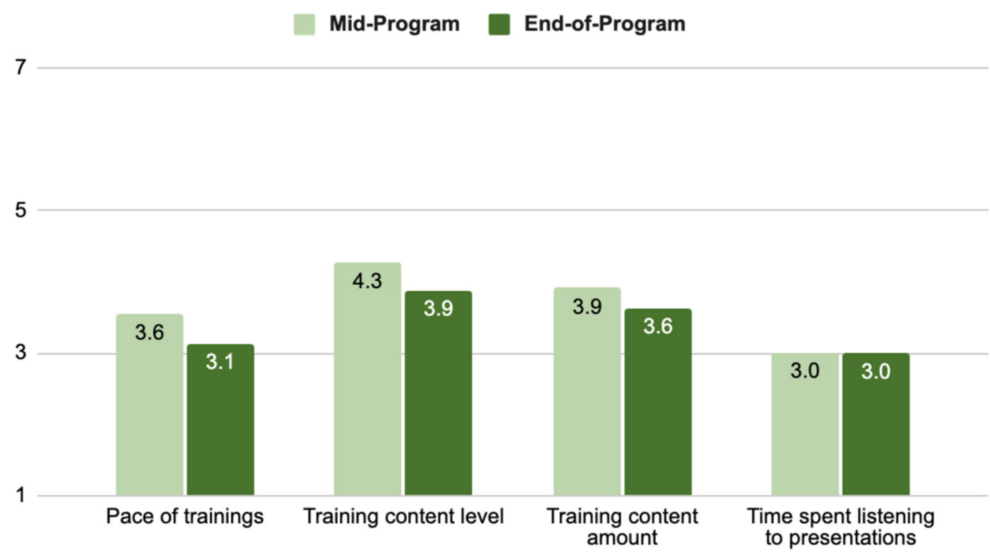

FIGURE 2
Responses regarding the pace and structure of the trainings (1 = pace too slow, level too simple, content amount too little, too much time spent listening to presentations; 4 = about right; 7 = Pace too fast, level too complicated, content amount too much, too much time spent learning by doing).

> 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

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

> 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."

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 Supplementary Table 3. 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 Supplementary Table 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, UTC co-benefits, and public health outcomes is still not clear and warrants exploration. Accordingly, using our findings from Sections Focus group, Surveys, and Ethnographic observations 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 (Golden and Earp, 2012; Palafox et al., 2018) 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 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 and 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.

The result is a "Socio-ecological model of community-based tree stewardship" based on our approach and factors (Figure 8). Figure 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

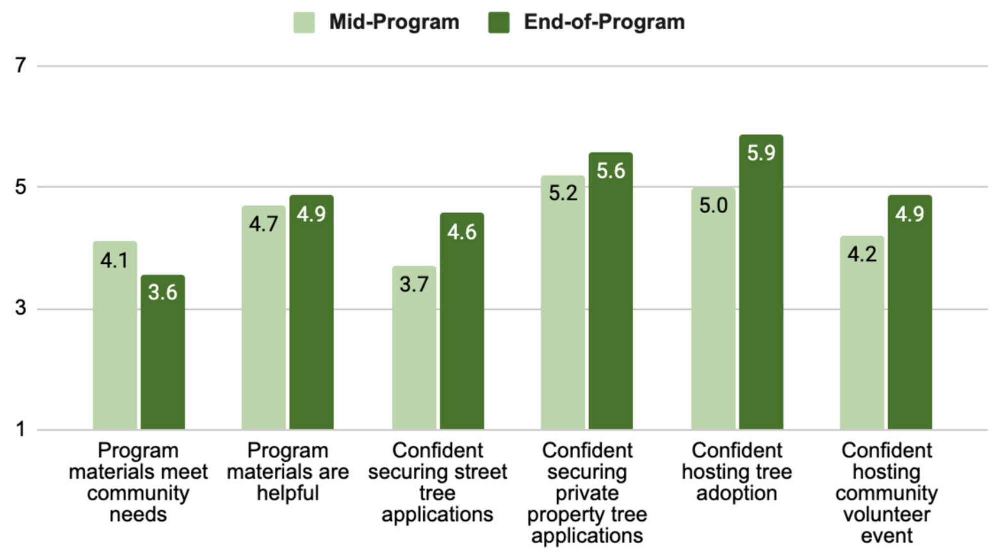

FIGURE 4
Responses regarding program materials and goals at the mid-point and end-point of the training program (1 = strongly disagree; 7 = strongly agree).

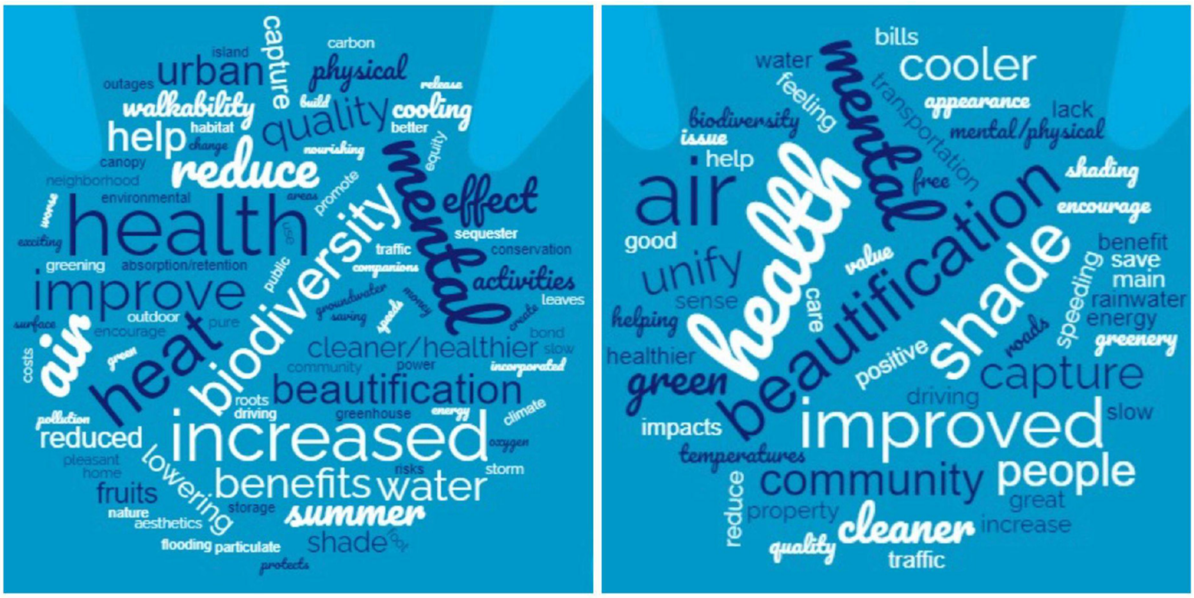

FIGURE 5
Responses to the question "List any benefits that you believe trees can bring to your neighborhood" in (left) mid-program survey and (right) end-of-program survey.

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

FIGURE 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.

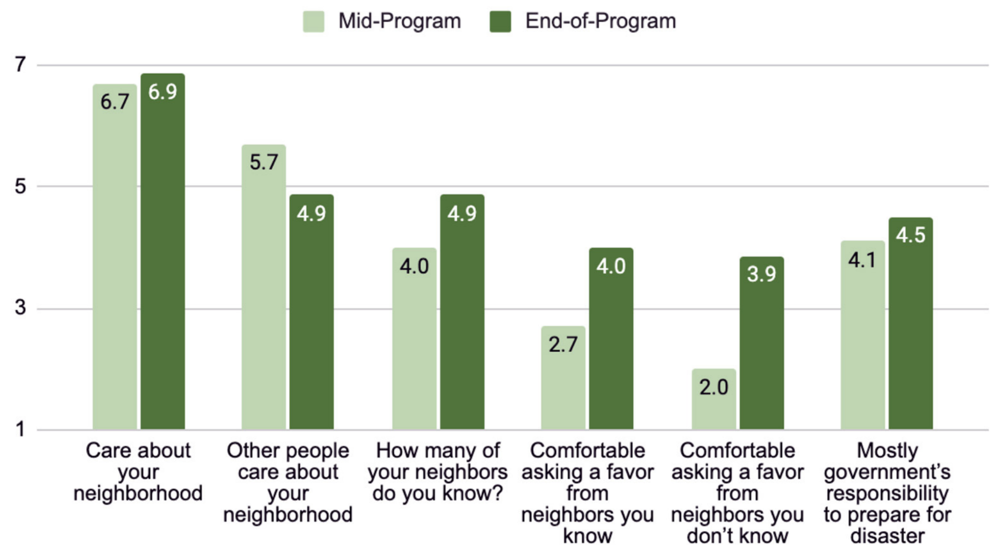

FIGURE 7
Responses to care and stewardship for the neighborhood, asking neighbors for a favor, and the government's role in preparing for a disaster at mid-point and end-point of the program (1 = strongly disagree; 7 = strongly agree).

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 detail in Supplementary Table 4.

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

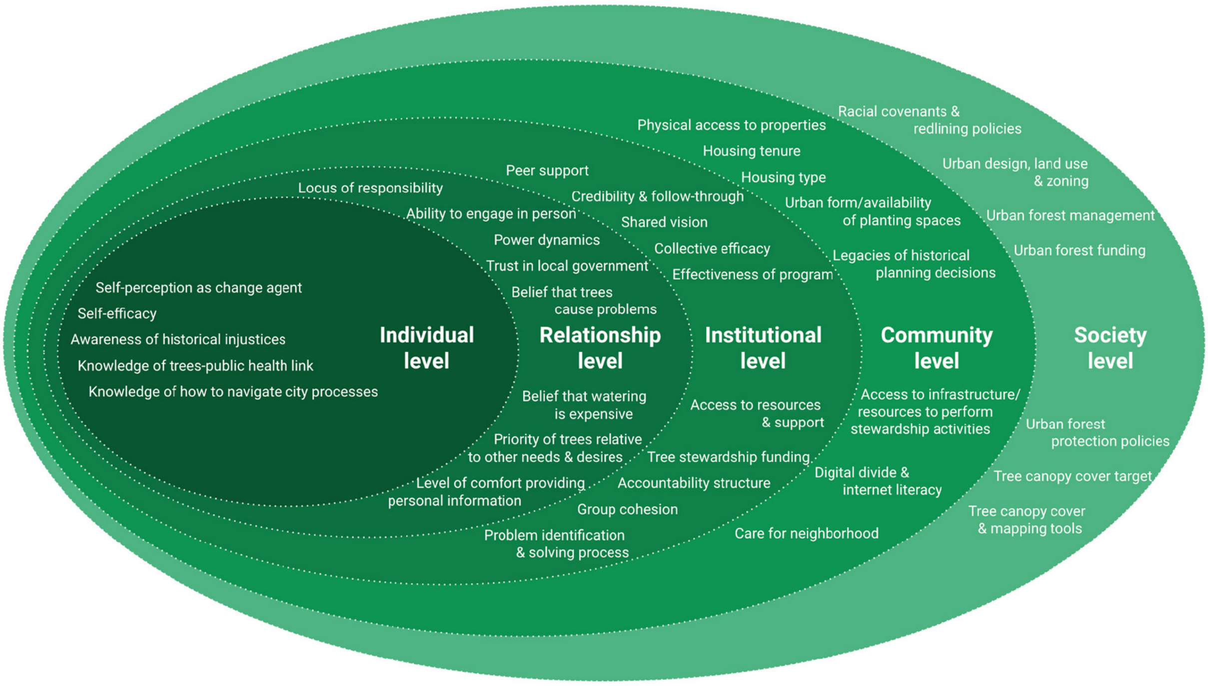

FIGURE 8
Socio-ecological model of community-tree stewardship (nested).

community. These include drivers related to awareness, knowledge, and self-perception.

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.

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 non-profit 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.

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.

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, UTC targets, and tree protection policies.

The nested model in Figure 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 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

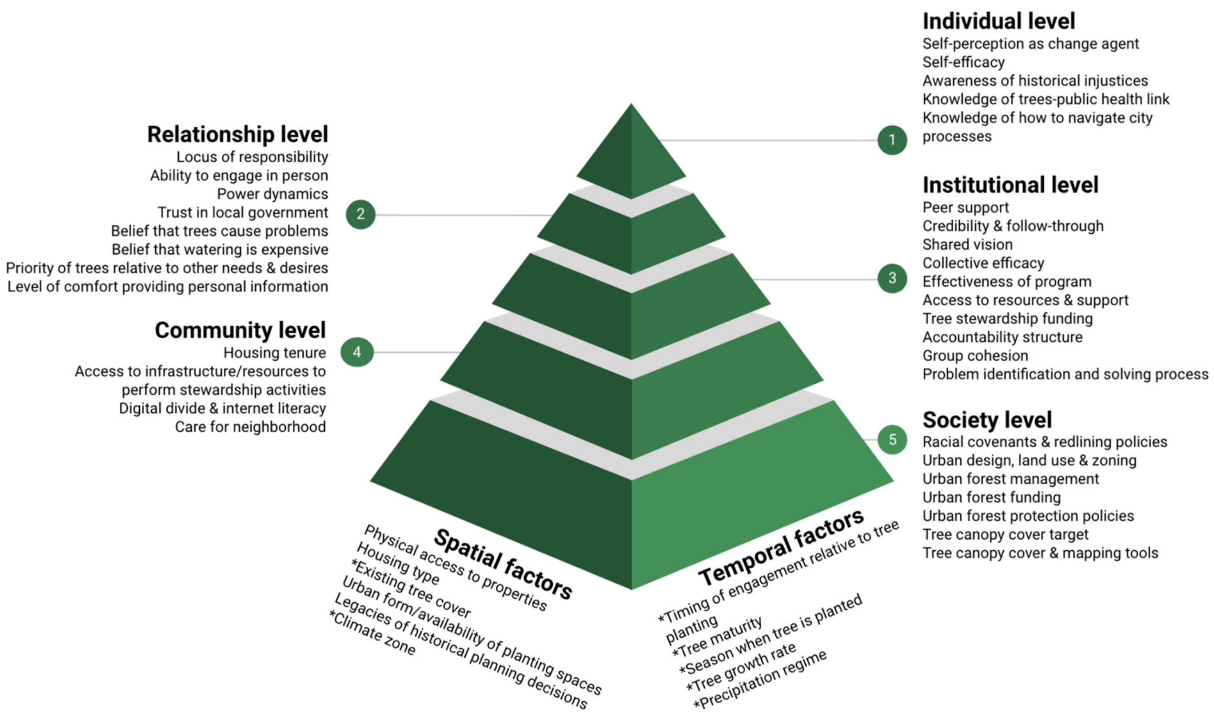

FIGURE 9
Socio-ecological model of community-tree stewardship with spatial and temporal dimensions (pyramidal).

to advance urban forest equity. Some of the factors used in Figure 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 8, which emerge when considering how spatial and temporal dimensions affect tree stewardship. The additional factors are marked with a * in the figure.

Additional spatial factors include:

Existing tree cover: The existing UTC of a neighborhood can influence the willingness of community members to support additional UTC. 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 and 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 and Tidball, 2015).

Tree maturity: A young tree planted in LA needs supplemental irrigation and additional care for an establishment period of 3–5 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.

Discussion and conclusion

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've demonstrated, UTC 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 UTC, current conditions may be inherited and serve as reflections of past preferences and processes rather than current forces (Boone et al., 2010; Schwarz et al., 2015). 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 (Jack-Scott et al., 2013; Roman et al., 2015).

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 (Supplementary Table 3). TAs feel supported by the program, but there is room to refine the program and further bolster TAs' efforts in its future iterations (Figures 1, 2, 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 (Supplementary Table 3). 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 UTC inequity persists between higher- and lower-income neighborhoods (Pincetl, 2010; Lee et al., 2017). Current policies, funding levels, and trends compound historical contributors to low UTC. Our SES models (Figures 8, 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 UTC 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 (Landry and Chakraborty, 2009; Schwarz et al., 2015; Riley and Gardiner, 2020). Our study (Table 1) adds additional evidence of this. For instance, Tree Ambassador #1 represents a foothill neighborhood that has high UTC (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 driver behind the inequitable distribution of UTC in LA, but understanding the context specificity of how UTC and socio-economic variables are related is critical. For example, UTC 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 complex, 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 UTC 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 UTC 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 UTC than wealthier neighborhoods (McPherson et al., 2007; Riley and 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 1, Figures 8, 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 UTC, 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 (Pincetl et al., 2013; Danford et al., 2014). 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 UTC 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 3, 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 1,295 square kilometers, 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 Los Angeles 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 acknowledgment 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 for City Plants, 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 non-profit organizations must often fill in the gap for city services that are deferred or wholly unavailable (City of Los Angeles 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 non-profit-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 Washington Post, 2001; 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 (Lipkis, 1984). 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, 2010; 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, non-profit, 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 for Los Angeles Urban Forest Equity Collective, 2021a,b).

We capture the constellation of factors impacting tree stewardship in Figures 8, 9 with the intent to provide a framework to inform future UTC management activities and urban forest equity programming in Los Angeles. The nested framework (Figure 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 non-profit partners can intervene in boosting factors that support increased UTC and reduce those that hinder it. The pyramidal framework (Figure 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, non-profit 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 UTC 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 UTC increase in impervious surface dominated neighborhoods that stand to benefit the most from additional trees (McPherson et al., 2011; CAPA Strategies for Los Angeles Urban Forest Equity Collective, 2021a). Similarly, we did not explore in detail the attitudes and perceptions of respondents to trees and UTC 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 highly impervious, 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 UTC 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 transdisciplinarity 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.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary materials, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by UCLA Office of the Human Research Protection Program. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

EdG: project conceptualization, methodology, investigation, data collection, editing, supervision of original manuscript, and project administration. EdG and FE: data analysis. FE: translation. EdG and RO'L: SES framework development and funding acquisition. EdG, RO'L, and FE: writing and editing of original manuscript. All authors contributed to the article and approved the submitted version.

Funding

This project was made possible with support from U.S. Forest Service, Region 5's Urban and Community Forestry Program, the Los Angeles Center for Urban Natural Resources Sustainability, and the UC Center for Climate, Health and Equity.

Acknowledgments

The authors thank Alyssa Thomas and Macy Dreizler with the U.S. Forest Service Pacific Southwest Research Station for their work analyzing the survey and geospatial data. The Tree Ambassador Program was made possible via support by the Los Angeles Department of Water and Power, the California Department of Forestry and Fire Protection, the U.S. Forest Service, and Ecosia, through City Plants, the Los Angeles Conservation Corps, and Koreatown Youth and Community Center, and was administered with participation from Climate Resolve and TreePeople. The authors also wish to thank Dr. Liz Koslov and Dr. David Eisenman at UCLA.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsc.2022.944182/full#supplementary-material

SUPPLEMENTARY TABLE 1
Socioeconomic and demographic composition of Tree Ambassadors who anonymously responded to demographic questions in the survey.

SUPPLEMENTARY TABLE 2
Tree Ambassador mid-program assessment focus group script.

SUPPLEMENTARY TABLE 3
Content analysis of Tree Ambassador Program ethnographic observations.

SUPPLEMENTARY TABLE 4
Socio-ecological model of factors that influence tree stewardship.

DATA SHEET 1
Survey instrument (Spanish).

DATA SHEET 2
Survey instrument (English).

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