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Building soil by building community: How can an interdisciplinary approach better support community needs and urban resilience?

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Given the interrelated problems of climate change, energy and resource scarcity, and the challenge of supporting critical natural systems in cities, urban dwellers may be exceptionally vulnerable to the impacts of climate change. While a number of programs and policies have been developed and implemented to help reduce the environmental and social impacts of climate change on communities, we argue that effective and sustainable programs must not only consider how the changing environment impacts communities, but also how communities interact with and impact the environment. Specifically, drawing on a case study of the needs assessment of the Healthy Soils for Healthy Communities Initiative conducted in Los Angeles (LA) County, CA as a model for a Virtuous Cycle Framework, we attempted to better understand how urban residents interact with land, green spaces, and soil as a means of finding ways to address some of the environmental and health disparities that many urban residents experience, while also exploring ways to improve soil health to support its capacity to provide essential ecosystem services (e.g., carbon sequestration, water filtration, food and biomass production). A unique feature of our approach is that it involved an interdisciplinary and multi-level partnership composed of a well-established environmental organization dedicated to urban forestry, environmental justice, and climate resilience, university faculty researchers who study human behavior and human-nature relationships, government partners, and, most importantly, community members, among others. The first step in understanding how community members interact with their environment involved collecting survey and focus group data from residents of LA County to assess attitudes, beliefs, and behaviors around land and soil. Results were used to explore strategies for deepening community engagement, addressing

knowledge gaps, and shaping policies that would benefit not just people who live/work in LA, but also the soil and other natural systems that rely on soil. This article integrates our previously published survey and focus group findings with new results that pertain specifically to the Virtuous Cycle Framework, and demonstrates how the data are being used to inform our community-based interventions (e.g., policy change, public education and community engagement, and demonstration projects).

KEYWORDS

soil education, community science, community engagement, soil science, urban soil management, climate resilience

Introduction

The Virtuous Cycle was first proposed by Morrison (2015) as a socioecological systems framework for conservation. The framework is centered around an intervention, grounded in a specific place, that aims to improve conservation outcomes. The intervention has beneficial outcomes for nature, and when those benefits are recognized by people, communities reinforce positive conservation outcomes through policies and actions that promote sustained positive change. Thus, the Virtuous Cycle Framework envisions a positive feed-forward loop.

However, we know that community-based environmental interventions, including policies, can have unintended consequences, or are not universally beneficial, recognized, or even desired by communities and, therefore, fail to impact human behavior. For example, if an intervention or policy enacted is not supported by the community in which it is embedded, it is unlikely that the environmental benefits will be fully realized or reinforced by the community, weakening the positive feedback loops that contribute to long-term environmental change. Going further, while community support is essential for long-term change, we believe interventions that are proposed, planned, implemented, and evaluated by the communities in which they are situated–and are supported by community leaders and/or backed by policy–produce even stronger reinforcing positive feedback loops among people and nature, resulting in highly resilient and sustainable socio-ecological systems. In this paper we argue that interventions that are driven by community goals and values not only strengthen the Virtuous Cycle, but also increase the likelihood of being accepted and adopted. We draw on a case study of the needs assessment of the Healthy Soils for Healthy Communities Initiative as a model for a Virtuous Cycle Framework to explore how to protect people and the planet through better soil management practices in Los Angeles (LA) County, California, which is the most populous county in the United States (Chen et al., 2021; Schwarz et al., 2022).

Urban populations continue to increase with well over half of the global population living in urban areas. In the United States, 86% of people lived in urban metro areas in 2020, and LA County currently houses over 10 million people (United States Census Bureau, 2021). Although urbanization, if planned strategically and managed properly, has the potential to reduce poverty and inequality by providing more opportunities for employment, education, and better access to medical facilities, important environmental and social challenges must be addressed as urban populations increase. For example, large urban agglomerations pose significant challenges for natural resources, and can lead to a degradation of the environment and, consequently, human health and well-being (e.g., Khan et al., 2021). Thus, there is an urgent need to protect and enhance environmental quality in highly urbanized settings in order to secure an improved quality of life for the increasing numbers of urban dwellers. Urban systems are socio-ecological in nature, however, and understanding human perspectives on conservation interventions and the resulting outcomes is essential.

Although often overlooked, the impacts of urbanization on soil contributes to many environmental and social challenges. For instance, the conversion of land from primarily agricultural and forest uses to urbanized landscapes significantly modifies soils via scraping, redistribution, compaction, and management (Pouyat et al., 2020), especially with respect to their ability to store carbon and mitigate the release of greenhouse gasses (Trammell et al., 2018). Urban soils also receive inputs such as irrigation, fertilizers, pesticides, and construction debris that can alter function. In urban environments, the proportion of soil covered by impervious surfaces can be very high, resulting in elevated air temperatures compared to the surrounding rural landscape, an effect commonly known as the urban heat island effect (Arnfield, 2003). Additionally, soils covered by impervious surfaces are "sealed" from water and gas exchanges and lack organic matter inputs (Pouyat et al., 2020).

Changes in climate, including higher temperature and more intense precipitation events, may further impact urban soils and their ability to provide important ecosystem services including climate regulation, stormwater management and filtration, provisioning of habitat for various organisms, and social services

such as pollution mitigation and food security. Soils perform these functions directly, but also support vegetation, including urban forests and food crops. In turn, plant types can drive changes in urban soil characteristics such as nitrogen and carbon accumulation (Setälä et al., 2016; Kotze et al., 2021).

The ecosystem services of soils are vital for reducing the vulnerability of densely populated areas to natural disasters, as well as for improving the health and quality of life of urban residents, especially those living in disadvantaged communities, as they are usually the most vulnerable to climate impacts and frequently have limited adaptive capacity to climate change. For example, those living with poverty or in marginalized communities may be at higher risk for urban heat exposure (Voelkel et al., 2018). In addition, ozone exposure has also been found to be significantly higher in community parks located in disadvantaged communities (with majority Latino use) compared to affluent community parks (Winter et al., 2019), while urban tree canopy, which could mitigate these effects, is positively related to household income (Schwarz et al., 2015). Additionally, many studies have shown that high concentrations of heavy metals are more often found in soils located in low-income areas (e.g., Montaño-López and Biswas, 2021). Moreover, because urban areas are major contributors to air pollution, urban residents, especially vulnerable populations, are often exposed to unhealthy air, an effect that is amplified by the micro-climatological effects of buildings and other infrastructure and the associated decrease in vegetation due to limited soil resources (Lane et al., 2022). Thus, understanding ways to address these disparities and increase resilience in impacted neighborhoods is key. In this article, we argue that public engagement strengthens the Virtuous Cycle Framework and, thus, is an important and necessary part of the equation.

Guided by the Virtuous Cycle Framework, in 2020, through a partnership composed of NGOs, universities, governmental agencies, and community groups, TreePeople, launched the "Healthy Soils for Healthy Communities" initiative (Chen et al., 2021). Our team defined healthy soils as the capacity of soil to function as a living ecosystem that offers a range of services that support and sustain life, and is the foundation for healthy environments that foster robust socio-ecological systems. One of the main goals of this initiative was to conduct a needs assessment of LA County's soils using online surveys, focus groups, and an in-depth understanding of the literature (Chen et al., 2021; Schwarz et al., 2022). Through this assessment, we learned that LA County residents value green space, and actively maintain their green spaces. In addition, LA County residents are accustomed to composting, and the majority regularly use the "green bin" (i.e., the curbside residential yard waste bin) for their green waste, or they allow green waste to compost in some form on their property. However, despite the fact that interest in gardening and composting is high, knowledge about factors that affect soil health was generally low. Furthermore, although most LA residents expressed concern about soil contamination and pollution, very few had ever tested their soils, and those who had, only tested for nutrient deficiencies, not heavy metals or pollutants (Schwarz et al., 2022).

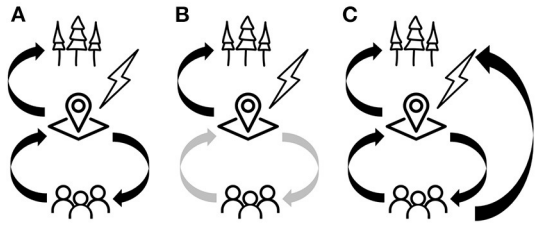

FIGURE 1
(A) Represents the Virtuous Cycle Framework in social-ecological systems (Morrison, 2015). A lightning bolt presents an intervention grounded in a specific location or place. The intervention has direct benefits to nature. When those environmental benefits are realized by people, a reinforcing positive feedback loop is created in which communities perpetuate the cycle through action and behavior that sustains the beneficial environmental outcome. When interventions are not supported by the community in which they are embedded, the reinforcing feedback loop among people and nature can weaken or disappear **(B)**. Alternatively, interventions that are driven by community goals and values **(C)** may promote stronger feedback loops, realized co-benefits, and more resilient socioecological systems.

Another important outcome of the needs assessment related to the process of working with an interdisciplinary and multi-level team. Engaging the community and associated stakeholders in regard to healthy soils was identified as a key to achieving our goals of creating an effective and sustainable strategy for changing attitudes, behavior, and social norms through public engagement. In fact, one primary purpose of the Healthy Soils for Healthy Communities initiative was to create an intentional and meaningful interaction between scientists (i.e., active researchers), the public (i.e., people who operate primarily outside of the practice of science, including the "general public" and highly specialized publics, such as policy makers, business leaders, community leaders, and others with extensive expertise in non-science domains), and practitioners (i.e., those with expertise in soil and soil-related education) to provide opportunities for mutual learning. The process involves raising awareness, providing education, and enabling the community to both advocate for and work toward building healthy soils in the region, which are all important aspects of the positive feedback loops in the Virtuous Cycle Framework (see Figure 1).

Without interventions that are informed and supported by impacted communities, a healthy soils initiative is far less likely to elicit the reinforcing positive feedback loops represented in the Virtuous Cycle Framework. In fact, several lines of research have demonstrated that the deficit model of communication, which presumes the public lacks knowledge, and that scientists need to supply that knowledge, is ineffective (Besley et al.,

TABLE 1 Use of public green spaces (percentage of respondents as a function of home ownership status among residents).

How often do you or members of your household use a public green space…?	Never	Rarely	Sometimes	Frequently	Daily
Home owners	6.8%	18.9%	28.7%	36.0%	9.6%
Renters	5.3%	11.7%	26.4%	44.9%	11.7%

2013). Despite this, "informing the public" and/or "defending science from misinformation" continue to be at the top of scientists' most prioritized communication goals, predictors of valuing outreach, and desires for communication training (Besley et al., 2013; Besley, 2015; Dudo and Besley, 2016). The perceived importance of "informing publics" is so ingrained that its prioritization is generally unaffected by other attitudinal, behavioral, or demographic factors (Dudo and Besley, 2016). Community engagement, often proposed as an alternative to the deficit model, presents an opportunity to identify key interventions and feedback that are likely to sustain a Virtuous Cycle, according to the described framework.

In our project, key interventions were identified by the community, and based on these interventions, our team developed three demonstration projects. The first project was aimed at increasing tree canopy cover and enhancing stormwater mitigation through soil best management practices. The second project involved community-based soil sampling to better understand soil contamination and pollution in disadvantaged communities. The third project established an urban carbon farm to explore the carbon sequestration potential of soils in LA.

Here, we present how the process, results, and interventions contribute to the Virtuous Cycle Framework, as well as the potential that our process has to be applied in different regions in order to achieve more climate-resilient urban communities. We also document some of the lessons gleaned from the process of working with an interdisciplinary and multi-level stakeholder model for community engagement and discuss considerations for moving forward, including outcomes of this project that are currently in process and recommendations for future interventions.

Materials and methods

Study area

LA County, CA, United States covers 4,058 square miles (10,510 sq km), and has a population of approximately 10.04 million people (United States Census Bureau, 2021), making it the most populous county in the nation. County-wide, the average tree canopy cover is 18% (LA County Tree Canopy Advanced Viewer; https://www.treepeople.org/los-angeles-county-tree-canopy-map-viewer/), although tree canopy is greater in wealthy neighborhoods, such as Beverly Hills (35%), than in less wealthy neighborhoods, such as Irwindale (6%) and Compton (11%). Because of the size of LA County, it was divided into eight geographic regions using the California County Department of Public Health service areas (Schwarz et al., 2022).

Online surveys

We disseminated four separate online surveys (in both English and Spanish) to residents, educators, policymakers, and soils-related professionals across LA County (Chen et al., 2021; Schwarz et al., 2022). However, this article focuses on new analyses conducted using variables not previously analyzed or reported. Specifically, an ANOVA was conducted to determine whether home ownership predicted use of public green spaces. In addition, a correlational analysis was conducted to examine the relationship between frequency of self-reported use of public green spaces and concern about the soil quality in those spaces. Further, correlational analyses were conducted to examine the factors that are associated with the likelihood of soil testing. These analyses center around the Virtuous Cycle Framework and, most critically, how community feedback about soil-related concerns fed into the interventions we developed through the demonstration projects.

Results

We found that residents who rent their homes are significantly more likely to use public green spaces than those who own, $F_{(2,1037)} = 5.97$, $p = 0.003$ (see Table 1).

Further, there was a significant positive correlation between use of public green spaces and concern for the soil in those green spaces, $r(1040) = 0.17$, $p < 0.001$, with residents who use public green spaces being more concerned about the soil quality than those who do not.

One of the key strategies for improving soil health in urban areas involves soil testing. However, Schwarz et al. (2022) described two findings that we believed might be correlated. Specifically, Schwarz et al. (2022) found that very few residents had conducted soil testing. In addition, the authors found that concern for soil contamination and pollution was high. In the present study, we conducted a correlational analysis to test whether concern about soil contamination and pollution was associated with soil testing, but did not find a significant

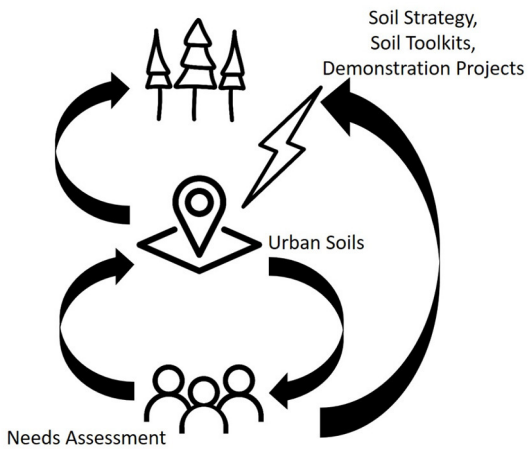

FIGURE 2
The community needs assessment informed several outcomes of this project, including policy-related work, the Los Angeles Urban Soil Toolkit, and Demonstration Projects, each of which are described in more detail below. Through these activities a positive feedback loop that promotes healthy soil was created. This figure represents graphically how the activities included in this project contributed to the Virtuous Cycle Framework.

relationship. That is, concern about soil contamination and pollution was not correlated with soil testing. What was correlated with the likelihood of soil testing, however, was knowledge about factors that contribute to soil health including soil pH, bulk density, permeability, chemistry, and biodiversity, $r(1042) = 0.26$, $p < 0.001$. In addition, knowledge about how to compost was significantly correlated with soil testing, $r(1042) = 0.24$, $p < 0.001$. Thus, the more knowledgeable residents reported being about these topics, the more likely they were to conduct soil testing.

Discussion

There are a number of ways that results from this needs assessment can be used to inform and impact policies and/or practices to improve community resilience, public education and community engagement, as well as to demonstrate potential solutions that address the identified needs, all of which contribute to the Virtual Cycle Framework (see Figure 2). Here, we describe some of the specific outcomes that this project has already produced, including the Healthy Soils Strategy for the City of Los Angeles and the Soil Toolkit. In addition, we discuss how the results were used to create demonstration projects, which included opportunities to interact with and learn about healthy soil, and to actively contribute to potential solutions (e.g., through community-based soil sampling and testing). We would like to note that while our needs assessment was the first of its kind for urban soils, other examples of urban soil programs do exist in other cities, most notably the Urban Soil Initiative (USI) in New York City (https://urbansoils.org). In fact, a partnership between the LA Healthy Soils Initiative and the USI to create and hold joint workshops and other community programming was another outcome of this study.

Policy change: LA City healthy soil strategy

The Healthy Soils for Healthy Communities Initiative has informed and guided the City of LA's work on healthy soils. In 2021, the City of Los Angeles published the Healthy Soils Strategy for the City of Los Angeles (https://lacitysan.org/san/sandocview?docname=cnt067543). This strategy document was prepared by the LA Sanitation and Environment (LASAN) Healthy Soils Team and the Healthy Soils Advisory Panel (HSAP) composed of academics, researchers, local nonprofits, and experts in soil health. The HSAP provided significant guidance on the effort and contributed extensively to the strategy document, ensuring that the document was comprehensive and had buy-in from experts and relevant community representatives. The document details relevant urban soil topics and provides strategies and supporting actions that LASAN, City departments, community groups, and residents can take to conserve and properly manage healthy soils. Each chapter of this strategy document has a specific focus, for example, about the ecosystem services that soil provides, the importance of composting, ways to test for and report contamination and pollution, and opportunities to benefit from and learn more about soil. Each chapter also includes strategies and supporting actions that can be taken to achieve healthy soils goals. The variety of actions proposed encourage involvement at all levels within the community. Some of the actions represent interventions in soil health, for example, incorporating compost into compacted soils. Other actions, such as facilitating community-based soil testing, are interventions that help explicitly identify who might benefit from a specific intervention and thus strengthen information feedback to the community. Several project team members serve on the HSAP. In this way, we can ensure that future policy work is guided by community needs and research and, in turn, increase the adoption and implementation of new strategies by community members. In this way, this project contributes to the positive feedback loop in the Virtuous Cycle Framework.

Public education and community engagement: Los Angeles urban soil toolkits

As part of the needs assessment, we developed the Los Angeles Urban Soil Toolkit (in English and Spanish), which

was meant to serve as a beginner's guide to improving and sustaining the health of LA's urban soil. The objective was to incorporate what was learned from our community engagement efforts and, thereby, transfer science into practice, as well as to provide technical support for communities to actualize what they expressed wanting. The toolkit was intended to be a useful source for information and resources about soil health, including how soils impacts our environment. It is currently being used as an educational resource for TreePeople's public education and community engagement activities, and there are plans to develop two additional soil toolkits that can be used by educators and community leaders, which the needs assessment suggested were the groups that expressed the strongest interest in learning more about soils. We anticipate that education about soils will not only promote soil testing, but will also increase community awareness of the feedback loops stemming from soil interventions. These toolkits can be targeted to help residents recognize when they are seeing the effects of the soil interventions, which serves to elicit a positive feedback loop that contributes to the Virtuous Cycle. A similar project not related to our initiative is one involving the Windy City Harvest Model (Chicago Botanic Garden, 2021), which used a hands-on tool kit for public gardens to connect people to soil and plants (https://www.usbg.gov/urbanagriculturetoolkit). Their toolkit provides an array of information from building effective partnerships, to farm design and operations, to fundraising.

Demonstration projects

To address the identified needs, we developed an overall framework for the continuation of this initiative, which proposes to establish an overall strategy for a Los Angeles Urban Soil Collaborative. The strategy will be developed through community, government, NGOs, academia, and private sector participation. One of the demonstration projects involved community-based soil sampling, which aimed to deliver a powerful tool to help communities, researchers, and policymakers chart the potential for soil restoration or improvement. Soil sampling within and by the community is the first step in generating neighborhood-specific information on the spatial distribution of soil-related hazards, and optimizing remediation efforts through the targeted use of best management practices. This intervention helps explicitly define who will benefit from soil management interventions, a critical characteristic of the Virtuous Cycle. It can also support more climate-resilient futures by empowering communities who have suffered a disproportionate burden of toxic exposure with the tools and information necessary to promote healthier urban ecosystems.

Closing the loop: Recommendations for future interventions

One of the key strategies for improving soil health in urban areas involves soil testing. However, our survey results suggested that only a proportion of LA residents have tested their soil. As stated previously, the most common testing examined only pH and NPK. However, it is well-known that harmful levels of lead and arsenic can be found across parts of Los Angeles due to the operations of Exide Technologies, a former battery recycling plant in Vernon, CA that was responsible for widespread soil contamination. While respondents were keenly aware of the potential for harmful levels of contaminants, they found it challenging to identify ways in which they might engage in this part of the cycle. In fact, the survey results suggested residents were very concerned about soil contamination, and the results of the focus groups aligned with the survey results. That is, community members expressed a high level of concern about the potential that their neighborhoods may have been contaminated by heavy metals (Schwarz et al., 2022). Additionally, based on the results from focus groups, there was a strong desire and consensus around future work needing to effectively engage and center communities, working to build trust and address past harm. Without the community engagement efforts and, more specifically, the online surveys and focus groups, we would not have identified the community's desire for access to soil testing that was not controlled by either the private sector or government–institutions in which the community lacks trust.

One way for cities like LA to establish trust and encourage residential soil testing could be to follow the lead of, for example, the New York City Urban Soils Institute. More specifically, this organization offers individual soil testing packages for home and community gardeners, as well as more specialized soil and site assessments from their own soil specialists or member academic soil scientists (https://urbansoils.org/soil-assistance). They offer low-cost tests that measure nutrients, physical properties, and trace, as well as free consultation for collecting and processing samples.

Other ways to improve soil health include education about factors that influence soil health, and strategies for improving soil health (e.g., composting). Schwarz et al. (2022) found that only about 8% LA residents reported being highly knowledgeable about factors that influence soil health (e.g., soil pH, permeability, composition), and only 15% reported being highly knowledgeable about composting. New analyses reported here suggest knowledge on these topics may be an important predictor of soil testing, as these factors were significantly correlated. Specifically, we found that people who are highly knowledgeable about one or both of these topics are also more likely to have their soil tested than those who are not

knowledgeable. Future research could explore this relationship more systematically.

Taken together these results suggest public education and engagement around soil health and composting could be one way to increase soil health. Further, residents' concern for soil contamination in public green spaces could be addressed by (1) conducting widespread soil testing with community involvement, and (2) posting signage or providing other similar forms of indirect education that identify the links between interventions and wellbeing.

While a sustained healthy soil engagement and education effort that raises awareness is necessary to achieve long-lasting change, several key actions must be taken to gain community and stakeholder support–engage residents directly in the virtuous cycle–and encourage behavior and mindset change. First, developing a public-private partnership is essential. This project was successful because of its focus on maintaining a true collaboration between nonprofit organizations and the City of Los Angeles. Specifically, TreePeople, LA Compost, and Kiss the Ground–all LA-based non-profits, worked together to inform the original research questions, distribute the online surveys and recruit participants for the focus groups. In addition, they have continued to collaborate on demonstration projects, for example, developing an urban carbon farm situated at a public park that is being used for additional research, public education, community engagement, and as the site for one of the demonstration projects. Furthermore, this collaboration was composed of a multi-disciplinary team including nonprofits, scientists, and government agencies. TreePeople conducted the needs assessment report as part of the community engagement process while building strong partnerships with soil scientists. This diverse effort allowed for a more effective and well-rounded project and deepened the community connections that are essential to create and sustain a Virtuous Cycle.

Conclusion

A comprehensive community engagement approach allows interventions in urban natural systems to support a Virtuous Cycle that increases the likelihood of long-term sustainable improvements in environmental outcomes. Such a community-based approach with an interdisciplinary team can help identify key areas where initiatives can be tailored to support either feedback or interventions that will strengthen the Virtuous Cycle. Without this information, feedback information may not be directed to appropriate sectors of the community or may be misinterpreted, weakening the sustainability of such initiatives. Many urban residents are uniquely vulnerable to climate-related health and other impacts. Targeted interventions based on the Virtuous Cycle Framework may increase the likelihood of success in mitigating these impacts.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by the UCLA and CSUN Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

Author contributions

EW, YC, KS, RP, and SD designed the study. EW conducted analyses and interpretation of the online survey. EW, YC, KS, and SD wrote the manuscript with substantial contributions from RP, MG, and MB. All authors contributed to the article and approved the submitted version.

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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.

Publisher's note

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